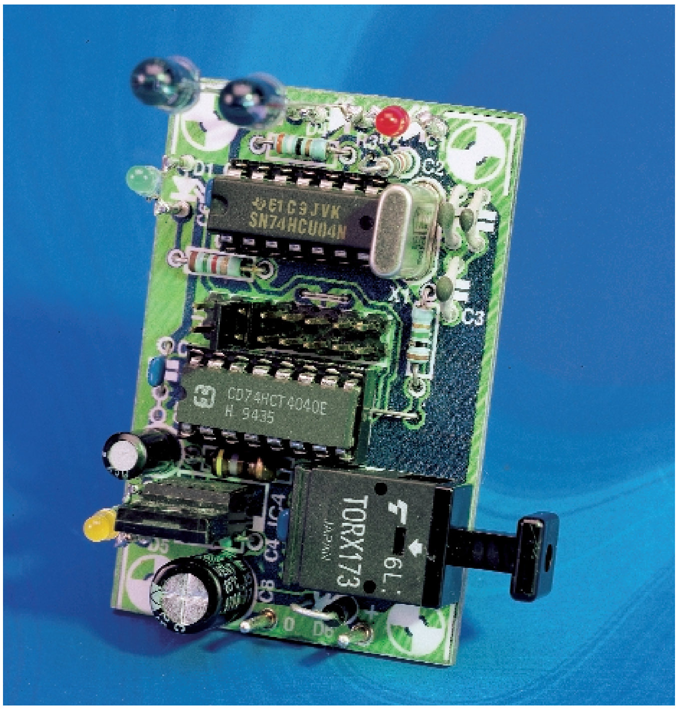
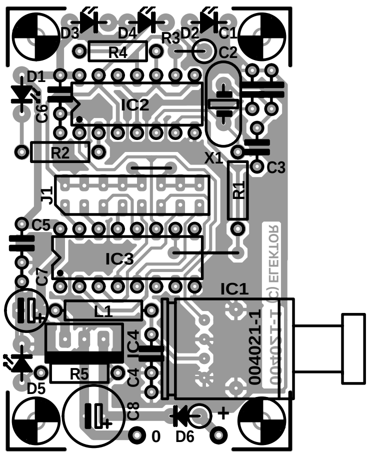
001 Transmitter for Fibre-Optic IR Extender

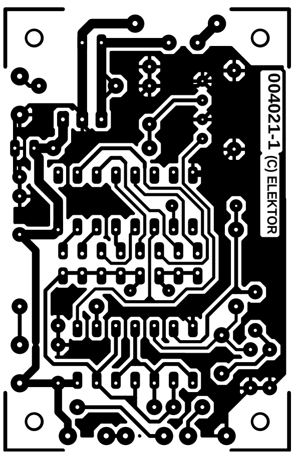
T. Giesberts

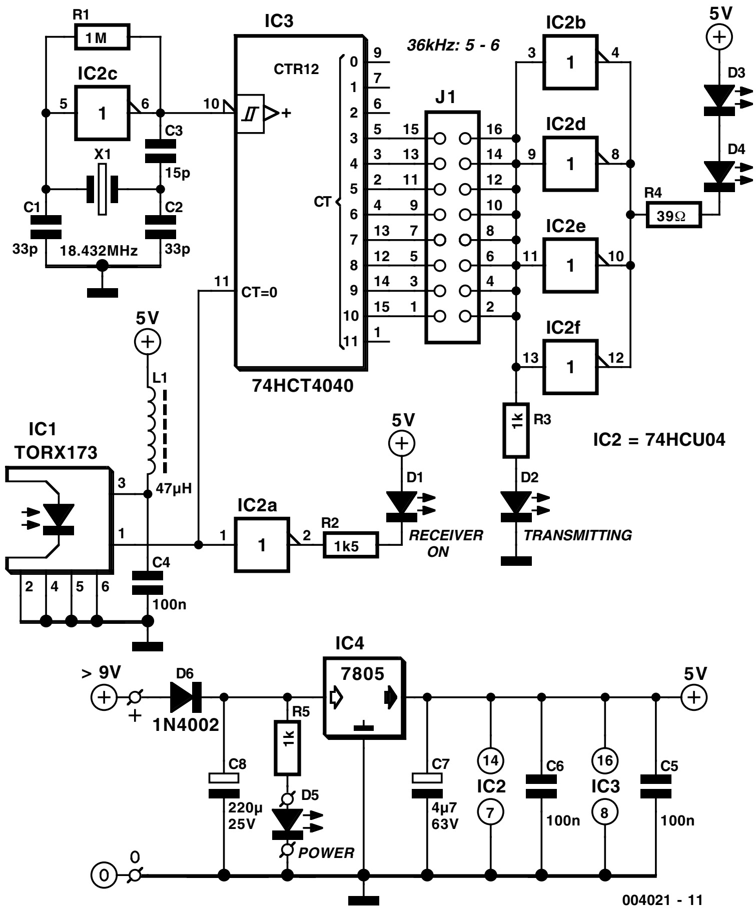
This circuit restores the original modulation of the signal received from the remote-control unit, which was demodulated by the receiver unit at the other end of the extender (see 'Receiver for fibre-optic IR extender').

If no signal is received, the Toslink transmitter in the receiver is active, so a High level is present at the output of the Toslink receiver in this circuit. Buffer IC2a then indicates via LED D1 that the receiver unit is active. The received data are re-modulated using counter IC3, which is a 74HCT4040 since the Toslink module has a TTL output. In the idle state, IC3 is held continuously reset by IC1. The oscillator built around IC2c runs free. When the output of the Toslink receiver goes Low, the counter is allowed to count and a carrier frequency is generated. This frequency is determined by the oscillator frequency and the selected division factor. Here, as with the receiver, we assume the use of RC5 coding, so a combination has been chosen that yields exactly 36 kHz. The oscillator frequency is divided by 2^9 on pin 12 of the counter, and 18.432 MHz ÷ 2^9 = 36 kHz. The circuit board layout has a double row of contacts to allow various division factors to be selected, in order to make the circuit universal. You can thus select a suitable combination for other standards, possibly along with using a different crystal frequency. The selected output is connected to four inverters wired in parallel, which together deliver the









drive current for the IR LEDs D3 and D4 (around 50 mA). A signal from the counter is also indicate that data are being transmitted, via LED D2. This has essentially the opposite function of LED D1, which goes out when D2 is blinking.

In the oscillator, capacitor C3 is used instead of the usual resistor to compensate for the delay in IC2c. As a rule, this capacitor is needed above 6 MHz. It should have the same value as C_{load} of the crystal, or in other words 0.5C1 (where C1 = C2). At lower frequencies, a 1kΩ to 2kΩ2 resistor can be used in place of C3.

A yellow LED is used for the power-on indicator D5. The current through this LED is somewhat higher than that of the other LEDs. If you use a red high-efficiency LED instead, R5 can be increased to around 3kΩ3.

The circuit draws approximately 41 mA in the idle state when the receiver is on. If the receiver is switched off, the transmitter emits light continuously, and the current consumption rises to around 67 mA.

The PCB shown here is unfortunately not available ready-made through the Publishers' Readers Services.

(004021-1)

COMPONENTS LIST

Resistors:
R1 = 1MΩ
R2 = 1kΩ5
R3,R5 = 1kΩ
R4 = 39 Ω

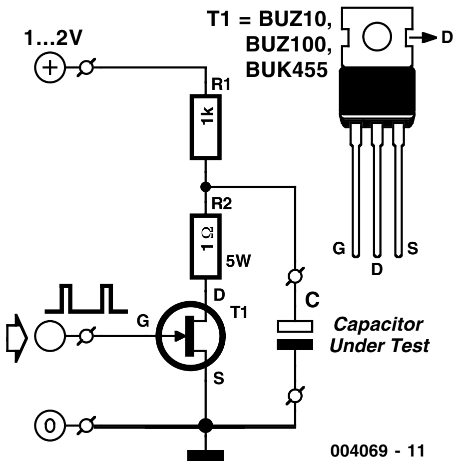
Capacitors:
C1,C2 = 33pF
C3 = 15pF
C4,C5,C6 = 100nF ceramic
C7 = 4µF7 63V radial
C8 = 220µF 25V radial

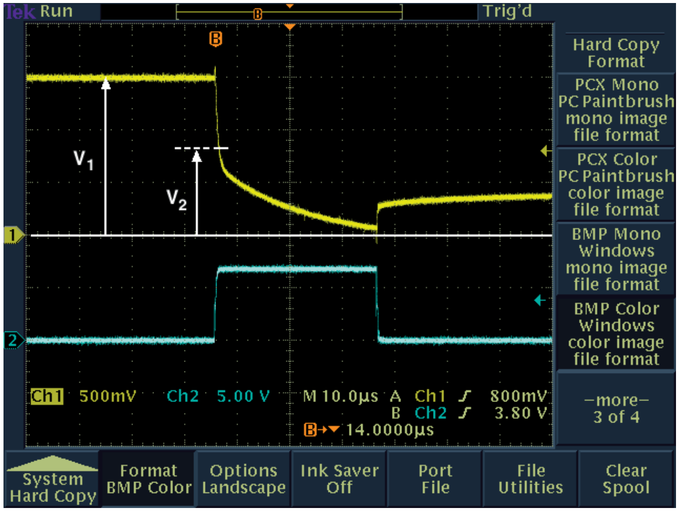
Inductors:
L1 = 47µH

Semiconductors:
D1 = high-efficiency LED, green
D2 = high-efficiency LED, red
D3,D4 = LD271
D5 = high-efficiency LED, yellow
D6 = 1N4002
IC1 = TORX173 (Toshiba)
IC2 = 74HCU04
IC3 = 74HCT4040
IC4 = 7805

Miscellaneous:
J1 = 16-way double contact row, plus jumper
X1 = 18.432MHz quartz crystal

002 ESR Measurements





K. Walraven

In a switch-mode power supply, the quality of the output voltage depends strongly on the quality of the electrolytic capacitors that are used. Here the effective series resistance (ESR), which is the internal 'ohmic' impedance of the capacitor, is one of the most important factors, since large currents are involved. It is rather difficult to *exactly* measure the ESR, but if you only want a quick idea, or you want to compare different families of capacitors, the illustrated simple measurement setup is very suitable.

The capacitor under test is charged via the 1-kΩ resistor (R1) until its voltage is the same as the applied supply voltage. You can then calculate the ESR using the formula (U1/U2) – 1 (see trace 1 of the oscillogram). This formula is very simple, since we have chosen a value of 1 Ω for R2. The values of the supply voltage and R1 are not critical, since the measurement is relative (as shown by the formula). The capacitor is discharged via a 1-Ω resistor and a power FET. You would expect the discharge to occur according to the well-known exponential formula, but as you can see from the oscillogram, the voltage first drops quickly, after which the expected exponential curve appears. This fast initial drop is due to the ESR of the capacitor, which produces a voltage drop equal to the product of the resistance and the discharge current. The greater the voltage drop, the poorer the capacitor.

If the initial voltage drop is approximately equal to half of the charge voltage, as in this case, then we can deduce that the ESR is approximately equal to the discharge resistance of 1 Ω. This is actually a relatively good value for a small, inexpensive 10-µF electrolytic capacitor. As a general rule, you can assume that the ESR decreases proportionally as the capacitance increases, and that it also decreases slightly as the voltage on the capacitor increases.

You can drive the FET directly from a pulse waveform generator, if it can deliver a short positive pulse to the gate with an amplitude of at least 6 V (see trace 2). The repetition interval must be 100 to 1000 times as long as the width of the positive pulse, since the capacitor will otherwise not have enough time to recharge. In most cases, you will only be able to obtain a stable image on the oscilloscope if it has a storage function. Almost any type of FET can be used, as long as the total discharge resistance (the sum of R2 and R_{ds} of the FET) is as close as possible to 1 Ω.

(004069-1)

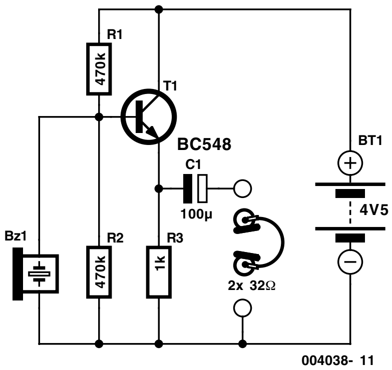
003 Electronic Stethoscope

B. Kainka

In order to listen to your heartbeat you would normally use a listening tube or stethoscope. This circuit uses a piezo sounder from a musical greetings card or melody generator, as a microphone. This transducer has an output signal in the order of 100 mV and its low frequency response is governed by the input impedance of the amplifier. For this reason we have chosen to use an emitter follower transistor amplifier. This has a high input impedance and ensures that the transducer will have a very low frequency response. At the output you just need to connect a set of low impedance headphones to be able to listen to your heartbeat.

Replacing the emitter follower with a Darlington transistor configuration will further increase the input impedance of the amplifier.

(004038)



004 Heatsink Calculations

K. Walraven

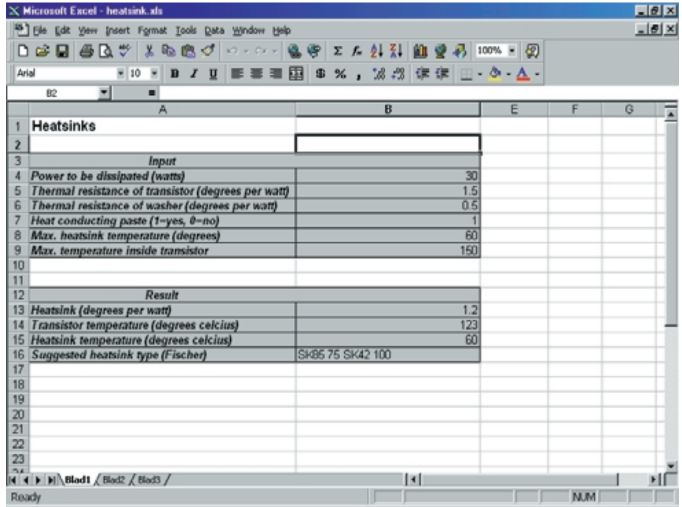
Making heatsink calculations has always been a bit of a nuisance. This sample spreadsheet makes life easier. Its main advantage is that you can see at a glance which heatsink you need and how hot it will become.

First you have to enter a certain amount of data. Reasonable default values are already present, so you can simply keep what is already present for anything that you don't know.

Let's have a look at the various fields. You start with the power that the transistor must handle, in watts. You can calculate this by multiplying the voltage across the transistor by the current through the transistor. Next comes the thermal resistance. This differs for each type of transistor and package, so you will have to look it up on the manufacturer's data sheet under R_{thjc} (junction to case). A 7805 in a TO220 package, for example, has a value of 4, while a 2N3055 in a T03 package has a value of 1.5. A modern component, such as the Siemens BUZ100 in a TO220 package, has the unbelievably low value of only 0.6!

After this, you need to know the thermal resistance value for the insulator (if one is used). If no insulator is used, enter a zero. A few typical values are: flexible plastic: 0.4; aluminium oxide (hard, white, 1 to 2 mm thick): 0.3; mica: 0.4. In addition, it makes a difference whether or not heat-conducting paste is used. Here you can only select between yes (1) and no (0). The spreadsheet will then automatically fill in either 0.1 or 0.5, respectively.

Next, enter the desired maximum temperature. For example, the internal temperature of the transistor may not be allowed to be higher than 125, 150 or 175 degrees. You can find this value on the data sheet of the component in question (maximum junction temperature). If you don't know the value, 150 degrees is usually the maximum allowed value (175 is only for the most recent components), and 125 is a safer value that is always acceptable.



However, you may want to avoid having the heatsink become too hot. According to safety regulations, any heatsink that is exposed to touch must not be hotter than 60 degrees. A heatsink that becomes hotter than this must be protected against being touched. If you don't care about this, you can enter a higher value here.

The program now displays a result consisting of four values. The first is the required heatsink specification in degrees per watt. This represents the larger of the two heatsinks required to maintain the maximum transistor temperature and to remain below the maximum heatsink temperature. In addition, you will see the internal temperature of the transistor, the temperature of the heatsink and a suggestion for a suitable heatsink (type and length), such as 'SK85, 75 mm'. Several different suggestions may be displayed in a row, as in the illustration. This is only a very limited suggestion, but it does give you a quick impression. Furthermore, you are always dependent on what your dealer has in stock, and he can work with the calculated value of degrees per watt. You will see that it's fun to play around with various input values, and this will give you insight into the relationship between the heatsink and the temperature of the transistor.

The spreadsheet is available from the Download section of the *Elektor Electronics* website at
http://www.elektor-electronics.co.uk

If you want to modify the program, you will first have to disable the protection and make the invisible columns visible. We (and other readers) would enjoy hearing about any improvements you make.

(004084-1)

005 Precision Electroscope

P. Lay

This circuit can precisely measure electrostatic charge. The charge to be measured is stored on C1 (a high quality MKT capacitor with a value of 1-2 μF). The voltage (U) across the capacitor (C1) is related to its charge (Q) by the equation $U = Q/C1$. Operational amplifier IC2 buffers this very high impedance source. An input lead is connected to one side of capacitor C1 and terminated with a test probe. The other side is connected with an earth lead and to a convenient earth point. IC3 amplifies the low voltage level at the output of IC2 and drives the moving coil meter M1 (±100 μA to ±1 mA centre zero). Switch S2 allows selection between two measurement ranges. With S2 closed the amplification factor is 5 and when open the amplification factor is 10. The internal impedance of P1 is 2.2 kΩ. Alternatively a digital multimeter can be used in place of P1, in this case resistor R7 (2-20 KΩ) can be omitted. Low Current LED D2 indicates that the electroscope is on.

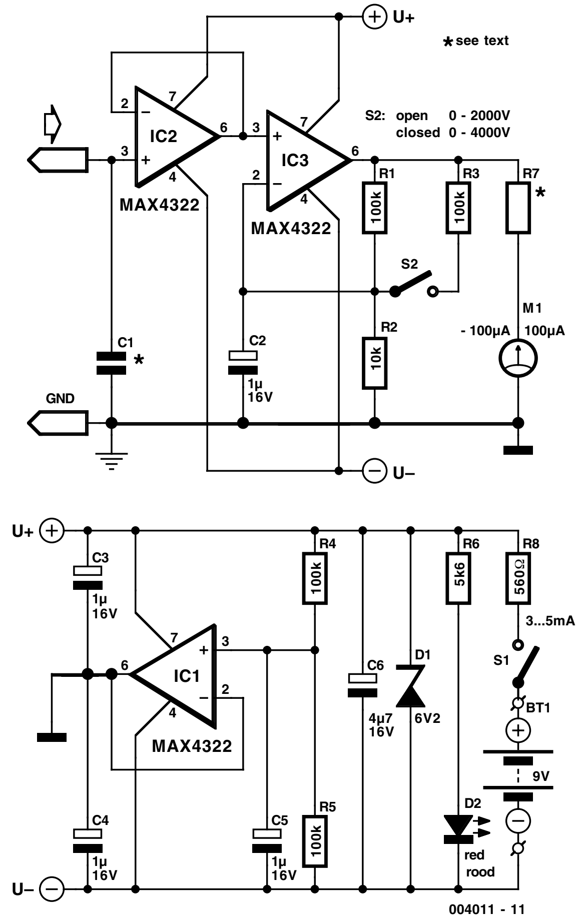
The operational amplifiers used here are MAX4322 from Maxim. The common mode input voltage for these devices can go to the supply rails; likewise the outputs will drive from rail to rail. The maximum supply voltage is 6.2 V, hence the need for zener diode D1 to limit the supply voltage. A full data sheet can be obtained from *www.maxim-ic.com*.

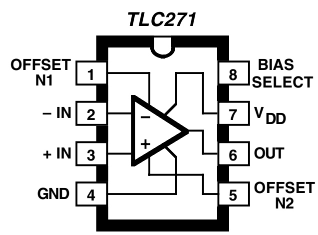
The operational amplifier IC1 produces a symmetrical supply with a centre rail (earth) from the 9-V battery. The supply current for the electroscope is in the order of 5 mA, most of which is used by the zener diode D1. Alternatively, the operational amplifiers can be replaced by a type that can operate at a higher supply voltage. For example IC2 and IC3 can be replaced by a single (dual op-amp) TLC272 (see the DIL outline for this device to assign the new pins). IC1 can be replaced by a TLC271 (pin 8 should in this case be connected to earth and pins 1 & 5 left unconnected). The maximum supply voltage for these IC's is 16 V so zener diode D1 can be omitted which will bring the supply current down to 3 mA.

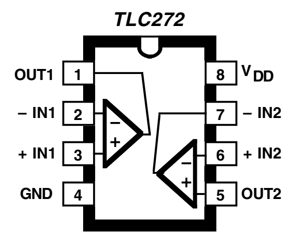
Operation of the precision electroscope is simple:

1. Switch on S1, LED D2 lights.
2. The test probe is touched to the earth lead to discharge capacitor C1 before a measurement is made. Alternatively a small push button switch can be wired in parallel to C1 to discharge it.
3. The test probe is now touched onto the charged part.
4. The meter will show any charge, its polarity and its value.
5. After use, turn off to save the batteries.

(004011)







006 Adapter for SB Live! Player 1024

T. Giesberts

In the December 1999 issue, we published a design for a digital extension for the Sound Blaster Live! Value Player (circuit board #990079-1). This sound card has a 12-pin Audio Extension connector. The successor to this card is the Live! Player 1024, which has a 40-pin connector that includes the same inputs and outputs (plus others), but in different positions. To allow the extension to be used with the new sound card as well, we have developed an adapter card that makes the connections easy. The necessary signals from the 40-pin connector are passed through to a 14-pin connector whose pin assignments match those of the extension card. The accompanying table describes the available inputs and outputs on

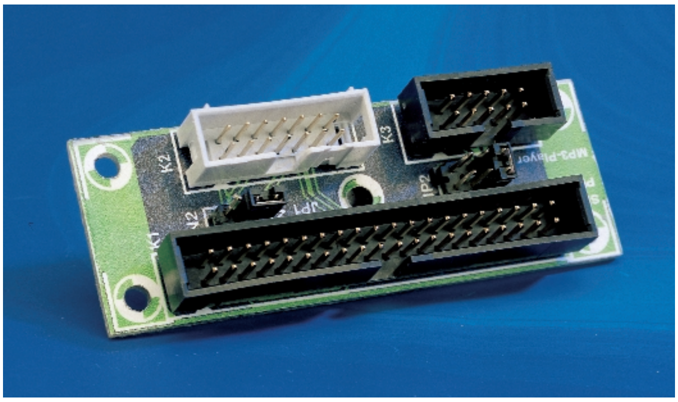
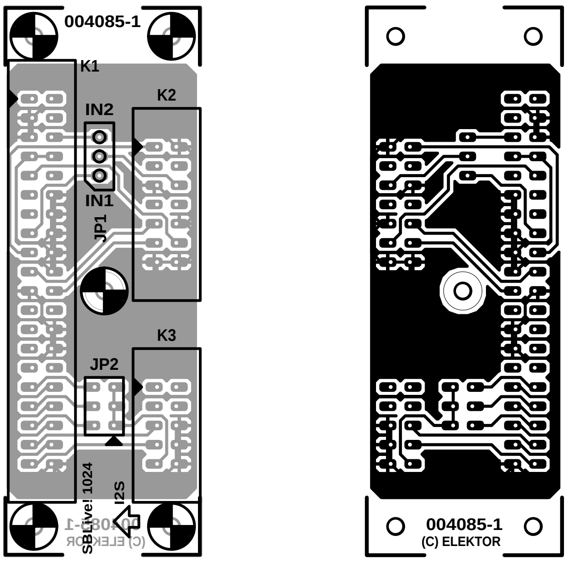
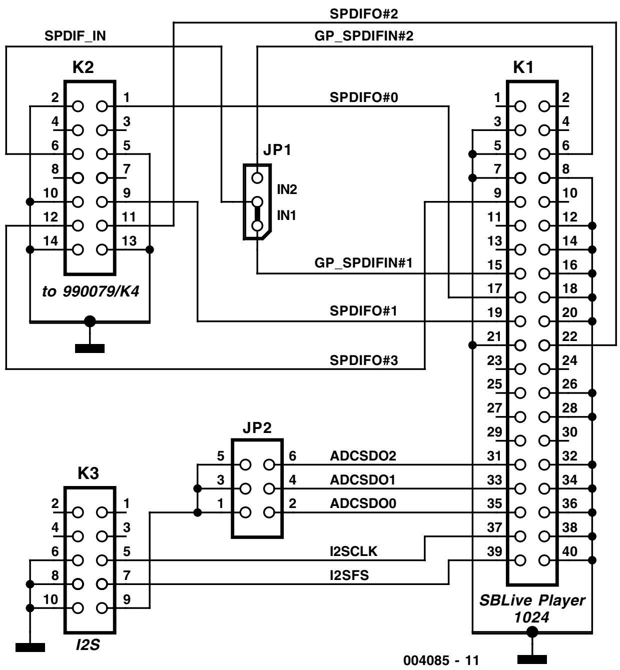


Table 1.
AUD_EXT connector pin assignments for the SB Live! Player 1024.

Pin	Name	Description
1	VCC	Supply+5 V
2	VCC	Supply+5 V
3	GND	Earth
4	AC97CLK	Clock output 4.5 MHz
5	GND	Earth
6	GP_SPDIFIN#2	S/PDIF input 2
7	GND	Earth
8	GND	Earth
9	SPDIFO#3	S/PDIF output 3
10	GPO1	Output 1 (general purpose)
11	GPO2	Output 2 (general purpose)
12	GND	Earth
13	GPO0	Output 0 (general purpose)
14	GND	Earth
15	GP_SPDIFIN#1	S/PDIF input 1
16	GND	Earth
17	SPDIFO#0	S/PDIF output 0
18	GND	Earth
19	SPDIFO#1	S/PDIF output 1
20	GND	Earth
21	GND	Earth
22	SPDIFO#2	SPDIF output 2
23	GPI0	Digital general-purpose input 0 (reserved)
24	GPI1	Digital general-purpose input 1 (reserved)
25	OUTMIDI	MIDI output
26	GND	Earth
27	INMIDI	MIDI input
28	GND	Earth
29	KEY	
30	KEY	
31	ADCSDO2	I2S input 2 for audio data
32	GND	Earth
33	ADCSDO1	I2S input 1 for audio data
34	GND	Earth
35	ADCSDO0	I2S input 0 for audio data
36	GND	Earth
37	I2SCLK	Serial bit clock for I2S
38	GND	Earth
39	I2SFS	Frame sync
40	GND	Earth





COMPONENTS LIST

Miscellaneous:
JP1 = 3-way SIL header with jumper
JP2 = 2x3- way SIL header with jumper
K1 = 40-pin boxheader
K2 = 14- pin boxheader
K3 = 10- pin boxheader

the 40 pins (see also the help menu of the software for the new sound card). The 40-pin connector has two inputs, one of which can be selected using JP1. Apparently, only the first of these inputs is supported in the SB Live!Ware 3.0 software.

With regard to the four outputs, output 0 provides the S/PDIF signal for normal two-channel information. The other outputs also provide signals when (for example) AC3-encoded DVDs (5.1-channel Dolby Digital) are played back, if this is supported by the hardware/software player. In this case, output 1 provides a non-decoded data stream. As an extra feature, the I^2S inputs can also be connected through to the ten-pin connector K3, but it appears that this is not supported by Live!Ware 3.0 for the 1024 card. JP2 can be used to select which of the three data inputs is connected to K3, but we have not been able to determine what if any benefit this may provide.

(004085-1)

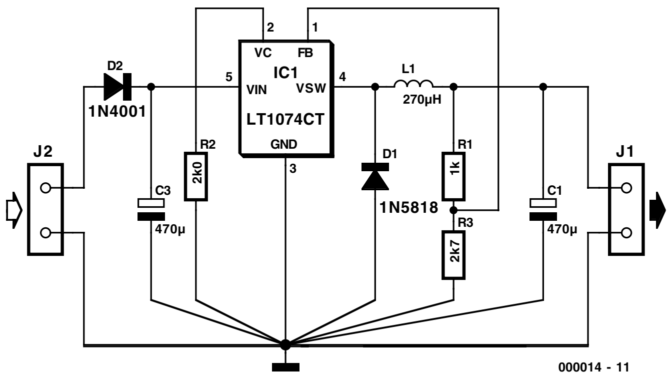
007 3-volts Car Adapter

A. Grace

This circuit is based on a standard LT1074CT switching regulator IC. For sure, *Application Note AN35* published by Linear Technology describes the design far more elegantly than the author could in this short article. Interested readers are therefore strongly advised to get a copy of AN35.

The schematic shows the LT1074CT used as a positive step-down or 'buck' converter. The 'switcher' is used to convert a +12-volt car battery voltage down to +3 volts for use with the personal hi-fi's and handheld games for the author's two boisterous children on long car journeys. Note at under ten years of age, children will rarely be hi-fi aficionado's and are generally not concerned with any noise generated by the 'switcher 'circuit.

The circuit is connected to the car +12-V system via the cigarette lighter socket — is advisable to use a fused version of the cigarette lighter plug. The +12-V arrives on the board via screw- terminal block J2. Diode D2 provides a reverse voltage protection, while C3 decouples the input to the switcher IC. The LT1074CT briskly switches the supply voltage on and off in response to the signal applied to its F/B input, to the extent that the average output voltage is at the required level. The values of potential divider resistors R1-R3 have been chosen to attenuate the output voltage so that there is 2.5 V at the F/B pin. The difference between the attenuated output voltage and the internal 2.5-V reference is used to control the modulation effect of the switcher. Components R2 and C2 provide frequency stabilisation for the feedback loop. Inductor L1 along with the LT1074CT form the main switching components, while C1 provides decoupling for the output load. The 3-V output voltage is taken from screw terminal J1.



With this circuit built, boxed up and installed in your car, you can look forward to possibly your first 'quiet' long car journey.

(000014-1)

008 Noise-Driven Sound Generator

G. Kleine

The sound generator shown here uses its built-in loudspeaker as a microphone when it is in the standby state. As soon as it detects a noise that exceeds an adjustable threshold level, it becomes active. This small, clever circuit can be used as an alarm generator that reacts to noises. You can also use it to help you locate an object in response to a loud sound, such as clapping your hands or whistling loudly.

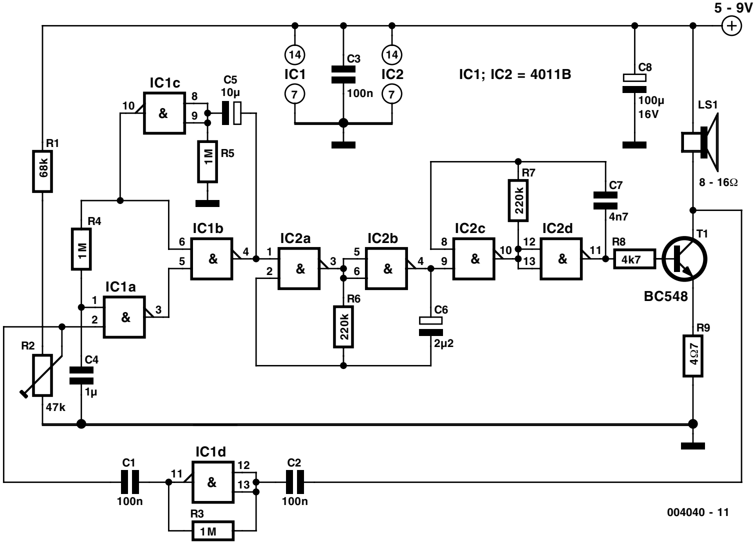
The gate at the bottom of the schematic diagram acts as a linear low-frequency amplifier, due to the negative feedback resistor R3. It receives its input signal from loudspeaker LS1, which acts as a microphone when T1 is cut off. The amplified output signal from this gate passes via C1 to a second 4011 gate, which triggers a monostable formed by the two gates located before and after C5 and R5. The DC threshold level is applied to pin 2 of IC1 via R2. This DC voltage is superimposed on the signal from C1. Retriggering of the monostable is prevented by the combination of R4, C4 and the first gate, in addition to which the sound generator (IC2) prevents the loudspeaker from acting as a microphone once it has been activated.

A High output signal from pin 4 of the monostable enables a pair of astable multivibrators in IC2. The first of these is a low-frequency generator, which modulates the audio-frequency tone produced by the second multivibrator. The result is a 'siren' sound. Finally, T1 is driven via R8 to push the loudspeaker quite hard. The loudspeaker current is limited a little bit by R9.

The duration of the alarm signal is determined by the monostable time constant of R5 and C5. A Low level on pin 4 of IC1 blocks the sound generator. After the time delay determined by R4 and C4 has expired, the loudspeaker once again acts as a microphone.

The circuit can be powered by a 5 V to 9 V battery.

(004040-1)

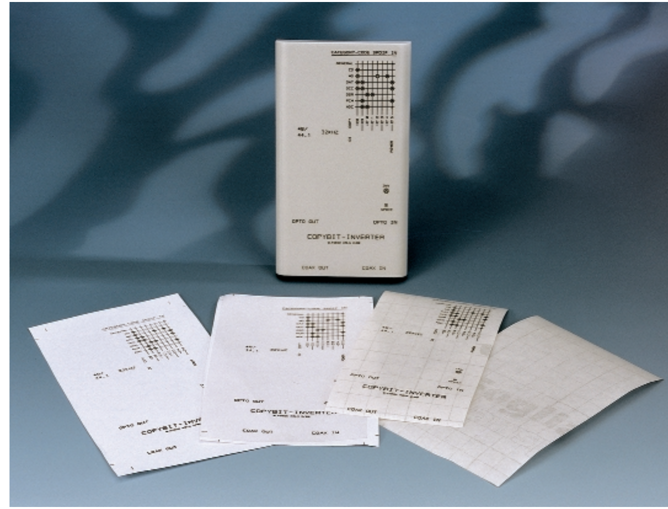


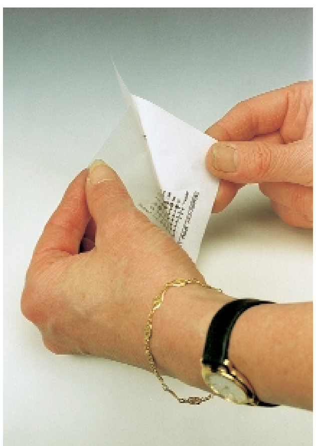
009 DIY Front Panel Foils

Using an inkjet printer and self- adhesive foil

W. Foede

It is fairly easy to produce professionally looking, permanent front panel foils ('decals') for use on electronic equipment if you have a PC available along with an inkjet printer (Hewlett-Packard DeskJet or similar). Plus, of course, matt transparent sheet of the self-adhesive type as used, for instance, to protect book covers. This type of foil may be found in stationery shops or even the odd building market. One foil brand the author has used successfully goes by the name of Foglia Transparent. The production sequence is basically as follows:





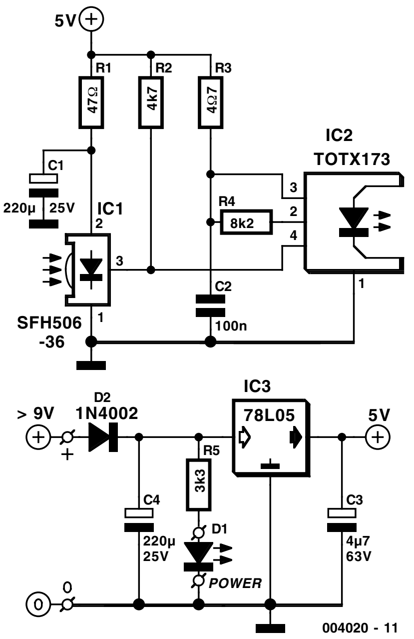
1. The decal is designed at true size (1:1 or 100%) with a graphics program or a word processor, and then printed in black and white on a sheet of white paper (do not use the colour ink cartridge). Allow the ink to dry. Cut the foil as required, then pull the adhesive sheet from the paper carrier sheet. Keep the carrier paper handy, it will be used in the next phase.

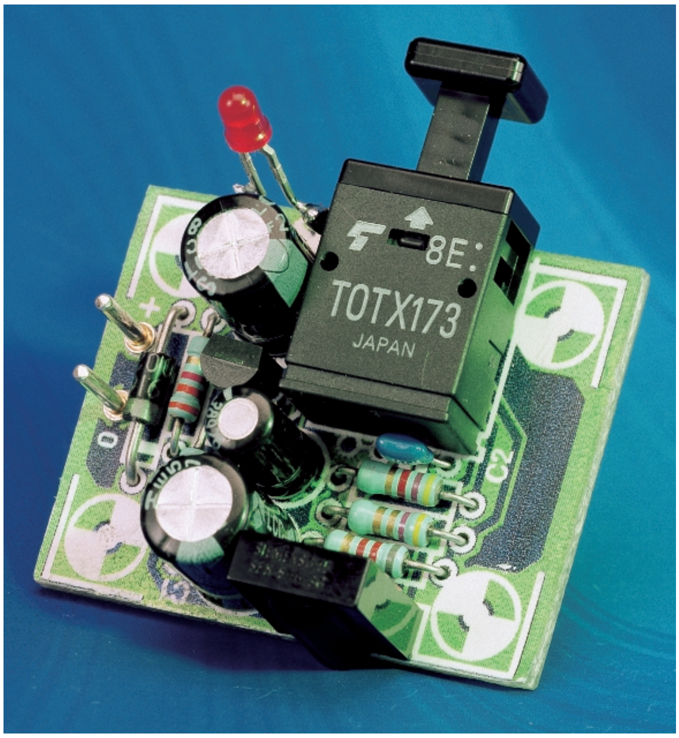
2. Once the ink has dried, the transparent foil is placed on top of the decal. The foil is lightly pressed and then slowly pulled off the paper again (see photograph). Because the adhesive absorbs the ink to a certain extent, the mirror image of the decal artwork is transferred to the adhesive side of the foil.

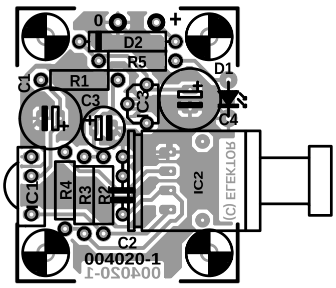
3. For further processing, first secure the foil on the carrier paper again. Next, cut the decal to the exact size as required by the equipment front panel. Finally, pull off the carrier sheet again and apply the transparent foil on to the metal or plastic surface.

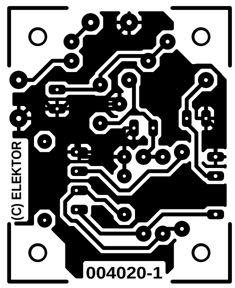
(005090-1)

010 Receiver for Fibre-Optic IR Extender









T. Giesberts

There are various types of remote-control extenders. Many of them use an electrical or electromagnetic link to carry the signal from one room to the next. Here we use a fibre-optic cable. The advantage of this is that the thin fibre-optic cable is easier to hide than a 75-Ω coaxial cable, for example. An optical link also does not generate any additional radiation or broadcast interference signals to the surroundings. We use Toslink modules for connecting the receiver to the transmitter. This is not the cheapest solution, but it does keep everything compact. You can use a few metres of inexpensive plastic fibre-optic cable, instead of standard optical cable for interconnecting digital audio equipment. The circuit has been tested using ten metres of inexpensive plastic fibre-optic cable between the receiver and the transmitter (which is described elsewhere in this issue).

The circuit is simplicity itself. A standard IR receiver/demodulator (IC1, an SFH506) directly drives the Toslink transmitter IC2. We have used the RC5 frequency of 36 kHz, but other standards and frequencies could also be used. Both ICs are well decoupled, in order to keep the interference to the receiver as low as possible. Since the Toslink transmitter draws a fairly large current (around 20 mA), a small mains adapter should be used as the power source.

There is a small printed circuit board layout for this circuit, which includes a standard 5-V supply with reverse polarity protection (D2). LED D1 is the power-on indicator. The supply voltage may lie between 9 and 30 V. In the absence of an IR signal, the output of IC1 is always High, and the LED in IC2 is always on. This makes it easy for the transmitter unit to detect whether the receiver unit is switched on.

The PCB shown here is unfortunately not available ready-made through the Publishers' Readers Services.

(004020-1)

COMPONENTS LIST

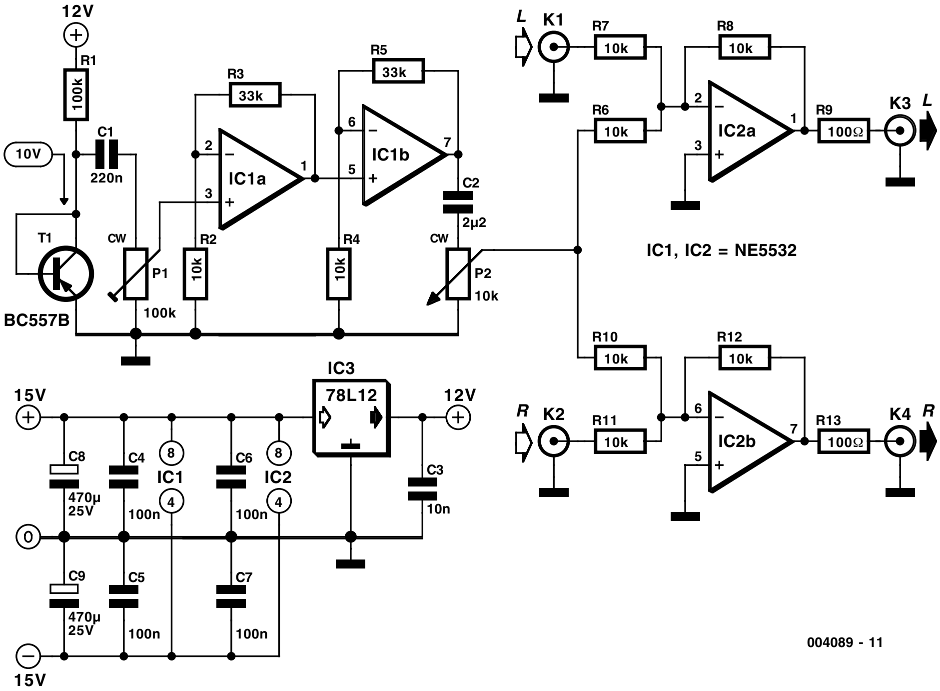
Resistors:
R1 = 47Ω
R2 = 4kΩ7
R3 = 4Ω7
R4 = 8kΩ2
R5 = 3kΩ3

Capacitors:
C1,C4 = 220µF 25V radial
C2 = 100nF ceramic
C3 = 4µF7 63V radial

Semiconductors:
D1 = high-efficiency LED
D2 = 1N4002
IC1 = SFH506-36 (Siemens)
IC2 = TOTX173 (Toshiba)
IC3 = 78L05

011 Noise Injector

T. Giesberts



This circuit is primarily intended to be used by persons who want to experiment with audio. For example, you can determine whether your own audible threshold for noise is different with and without music, or whether a particular CD sounds better with a little bit of noise. However, since this circuit produces white noise, it can also be used for test measurements, such as comparing the sounds of different loudspeakers, measuring filter characteristics and so on.

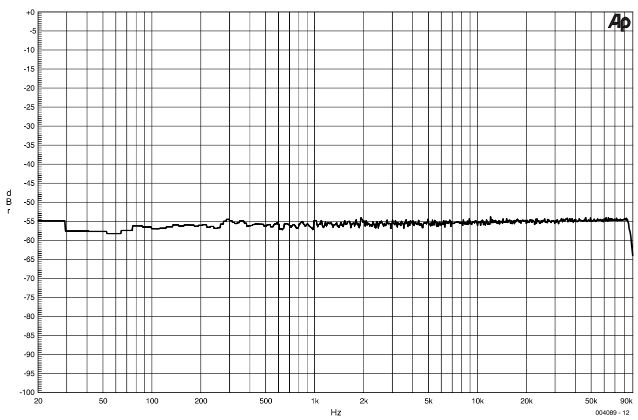
The measured characteristics, as shown in **Figure 2**, show a nearly flat amplitude distribution (averaged over 64 measurements). The effective value of the noise signal at the output is around 100 mV maximum (with both potentiometers set to maximum), measured over the frequency range of 22 Hz to 22 kHz.

The noise is generated by reverse-biasing the base-emitter junction of a PNP transistor (BC557B) so that it zeners. In our prototype, the voltage across T1 was approximately 10 V. P1 is used to set the level of the generated noise so that it is just audible, following which the output level can be adjusted using the logarithmic potentiometer P2. For making measurements, P1 can also be simply set to its maximum position. The noise is amplified by two opamp stages. Depending on the transistor manufacturer, or the type of transistor if you use a different type, the level of the generated noise can vary significantly. Using two amplification stages in series provides more options and considerably more bandwidth, and you can implement various filter characteristics around IC1a and IC1b according to your own taste. The gain of the two stages has been kept equal to ensure the maximum possible bandwidth. The amplified signal is then passed to a simple summing amplifier (IC2). We have used a stereo arrangement, in which both channels receive the same noise signal. If you want to expand on the design, you can provide each channel with its own noise generator. In this case, you will have to use a dual potentiometer for P2.

The well-known NE5532 is used for the amplifiers, but any other good dual opamp would also be satisfactory. The opamps are fed from a standard, symmetrical ±15-V supply. In order to suppress possible positive feedback via the power supply, and to reduce the effects of power supply noise (since the opamps are non-inverting), the supply for the noise diode circuit (R1 and T1) is separately stabilised by IC3 (7812) and extra filtering for the ±15-V supply is provided by C8 and C9. IC3 must be located as close as possible to R1, T1 and IC1. The coupling capacitors C1 and C2 are necessary to prevent the DC component of the noise signal from appearing at the outputs.

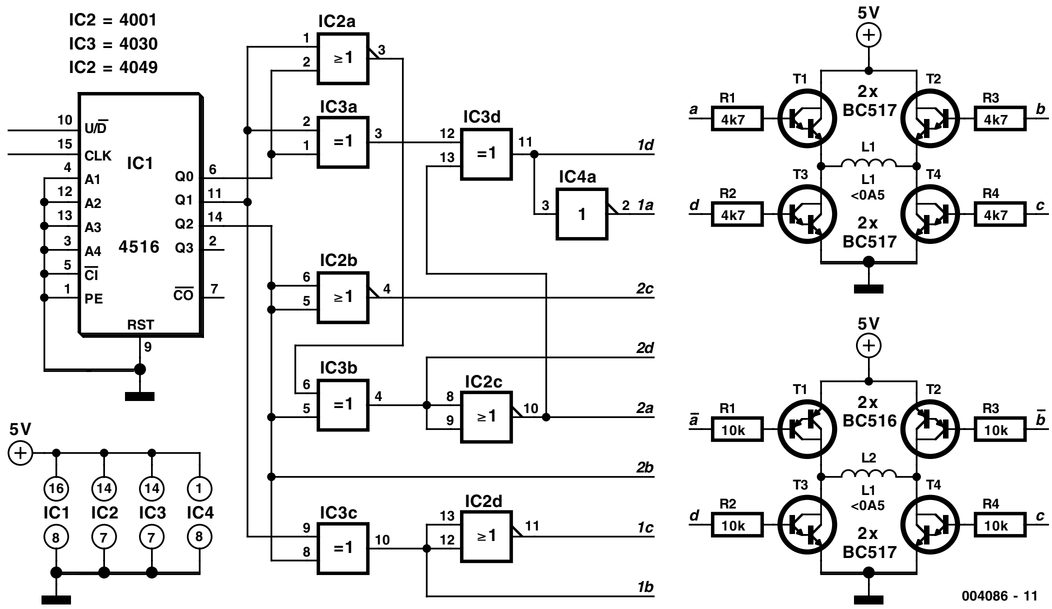
The table lists some measured characteristics of the circuit, for a bandwidth B of 22 Hz to 22 kHz and a reference level of 2 V_{eff}.

(004089-1)



THD + N (1 kHz, P2 min.)	< 0.0005 %
Noise level (P2 min.)	– 107 dB
Noise level (P1 min. / P2 max.)	– 88 dB
Noise level (P1 max. / P2 max.)	– 25 dB (112 mV_{eff})
Noise level (P1 max. / P2 max. / B > 500 kHz)	– 10.5 dB
Gain (K1/K3, K2/K4)	– 1 x
Current consumption	21 mA

012 Bipolar Stepper Motor Control



K. Walraven (text) and
R.T.J.M. van der Heijden (design)

The subject of stepper motors is clearly very popular, with many reader responses to every published article. A design for a unipolar controller appeared in the May 1999 issue, and now we present a bipolar version. First, we want to explain how such a controller works and what's involved. A bipolar motor has two windings, and thus four leads. Each winding can carry a positive current, a negative current or no current. This is indicated in **Table 1** by a '+', a '–' or a blank.

A binary counter (IC1) receives clock pulses, in response to which it counts up or down (corresponding to the motor turning to the left or the right). The counter increments on the positive edge of the pulse applied to the clock input if the up/dwn input is at the supply level, and it decrements if the up/dwn input is at earth level. The state of the counter is decoded to produce the conditions listed in **Table 2**.

Since it must be possible to reverse the direction of the current in the winding, each winding must be wired into a bridge circuit. This means that four transistors must be driven for each winding. Only diagonally opposed transistors may be switched on at any given time, since otherwise short circuits would occur.

At first glance, **Table 2** appears incorrect, since there seem to always be four active intervals. However, you should consider that a current flows only when a and c are both active.

The proper signals are generated by the logic circuitry, and each winding can be driven by a bridge circuit consisting of four BC517 transistors. Two bridge circuits are needed, one for each winding. The disadvantage of this arrangement is that there is a large voltage drop across the upper transistors in particular (which are Darlingtons in this case). This means that there is not much voltage left for the winding, especially with a 5-V supply. It is thus better to use a different type of bridge circuit, with PNP transistors in the upper arms. This of course means that the drive signals for the upper transistors must be reversed. We thus need an inverted signal in place of 1a. Fortunately, this is available in the form of 1d. The same situation applies to 1b (1c), 2a (2d) and 2b (2c). In this case, IC4 is not necessary.

Stepper motors are often made to work with 12 V. The logic ICs can handle voltages up to 15 to 18 V, so that using a supply voltage of 12 V or a bit higher will not cause any problems. With a supply voltage at this level, the losses in the bridge circuits are also not as significant. However, you should increase the resistor values (to 22 kΩ, for example). You should preferably use the same power supply for the motor and the controller logic. This is because all branches of the bridge circuit will conduct at the same time in the absence of control signals, which yields short-circuits.

(004086-1)

Table 1. Driving the windings.

Phase 2	1	2	3	4	5	6	7	8
Winding 1	+	+		–	–	–		+
Winding 2		+	+	+		–	–	–

Table 2. Decoded counter states.

Phase	1	2	3	4	5	6	7	8
1a	+	+	+					+
1b			+	+	+	+		
1c	+	+					+	+
1d				+	+	+	+	
2a		+	+	+	+			
2b					+	+	+	+
2c	+	+	+	+				
2d	+					+	+	+

013 Compact Switching Step-Down Converter

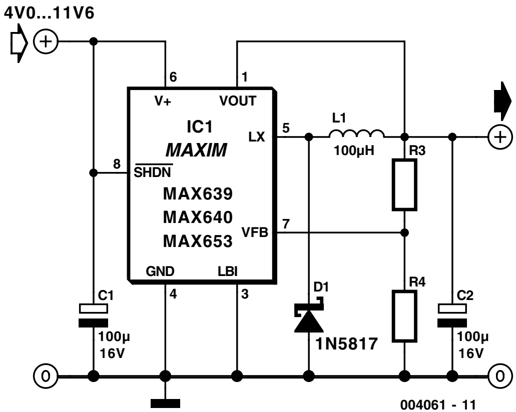
H. Steeman

Switch-mode power supplies are used in electronic circuits to increase (step up) or reduce (step down) voltage levels in the most efficient manner possible. Compared to linear voltage regulators, switch-mode supplies convert relatively little energy into heat. Their efficiency is thus high. This is a major advantage with compact power supplies in particular, since it sometimes makes forced-air cooling unnecessary.

Building a switch-mode supply is considerably easier if you use components that have been specially developed for this application. One example of such an integrated step-down converter is the Maxim MAX639. This is designed for a fixed output voltage of +5 V, with an input voltage ranging between +5.5 and +11.5 V. Although this IC is primarily designed for a fixed output voltage, the output voltage can be tailored using a simple feedback network. With the given component values, resistors R3 and R4 determine the output voltage, with

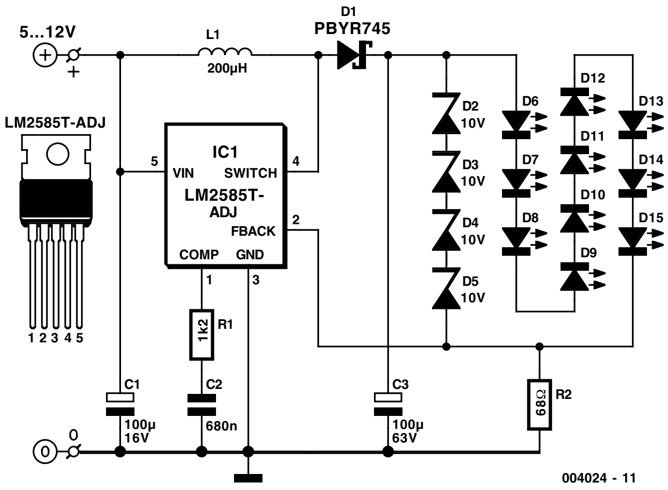
$$R3 = R4\,[(V_{out} / 1.28) - 1]$$

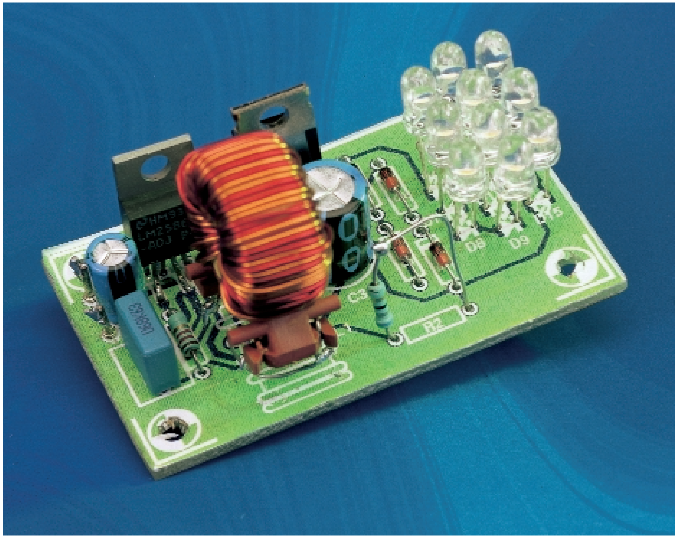
The value of R4 may lie between 10 kΩ and 10 MΩ, but a value of 100 kΩ is a good choice for most applications. The maximum output current is 100 mA. If desired, a different type of Schottky diode with similar specifications can be used in place of D1 (a 1N5817). Inductor L1 must be suitable for a maximum current of 500 mA.



(004061-1)

014 White LED Lamp





K. Walraven

Nowadays you can buy white LEDs, which emit quite a bit of light. They are so bright that you shouldn't look directly at them. They are still expensive, but that is bound to change.
You can make a very good solid-state pocket torch using a few of these white LEDs. The simplest approach is naturally to use a separate series resistor for each LED, which has an operating voltage of around 3.5 V at 20 mA. Depending on the value of the supply voltage, quite a bit of power will be lost in the resistors.
The converter shown here generates a voltage that is high enough to allow ten LEDs to be connected in series. In addition, this converter supplies a constant current instead of a constant voltage. A resistor in series with the LEDs produces a voltage drop that depends on the current through the LEDs. This voltage is compared inside the IC to a 1.25-V reference value, and the current is held constant at 18.4 mA (1.25 V ÷ 68 Ω).
The IC used here is one of a series of National Semiconductor 'simple switchers'. The value of the inductor is not critical; it can vary by plus or minus 50 percent. The black Newport coil, 220 μH at 3.5 A (1422435), is a good choice. Almost any type of Schottky diode can also be used, as long as it can handle at least 1 A at 50 V. The zener diodes are not actually necessary,

but they are added to protect the IC. If the LED chain is opened during experiments, the voltage can rise to a value that the IC will not appreciate.

The PCB shown here is unfortunately not available ready-made through the Publishers' Readers Services.

(004024-1)

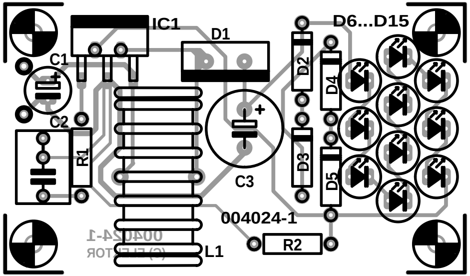
COMPONENTS LIST

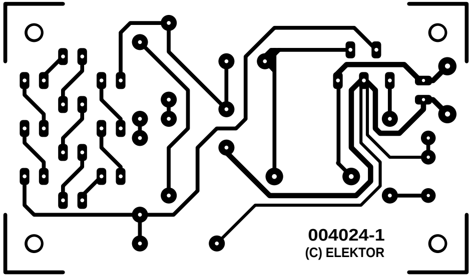
Resistors:
R1 = 1kΩ2
R2 = 68Ω

Capacitors:
C1 = 100µF 16V radial
C2 = 680nF
C3 = 100µF 63V radial

Inductors:
L1 = 200µH 1A

Semiconductors:
D1 = Schottky diode type PBYR745 or equivalent
D2-D5 = zener diode 10V, 0.4W
D6-D15 = white LED
IC1 = LM2585T-ADJ (National Semiconductor)





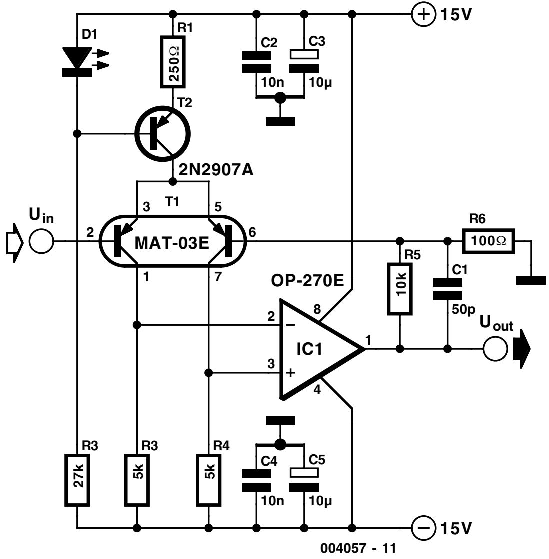
015 Low-Noise Microphone Amplifier

H. Steeman

The signal from a microphone is two weak for a standard line input. This low-noise DC-coupled microphone amplifier provides a solution for anyone who wants to connect a microphone to his or her hi-fi installation. As can be seen from the schematic diagram, a good circuit does not have to be complex. A differential amplifier is built around T1 (MAT-03E), which is a low-noise dual transistor. The combination of T2 and LED D1 forms a constant-current source for the input stage. A low-noise opamp (OP-270E) amplifies the difference signal that appears at the collectors of the dual transistor. The result is an analogue signal at line level. The bandwidth of the amplifier ranges from 1 Hz to 20 kHz. Within the audio range (20 Hz to 20 kHz), the distortion is less than 0.005 percent. Since only half of the OP-270E is used, the remaining opamp could be used in the output stage of a stereo version.

The amplifier can be powered from a stabilised, symmetrical supply with a voltage between ±12 V and ±15 V. Such supply voltages are already present in many amplifiers.

(004057-1)



016 Power-On Sequencer

A. Grace

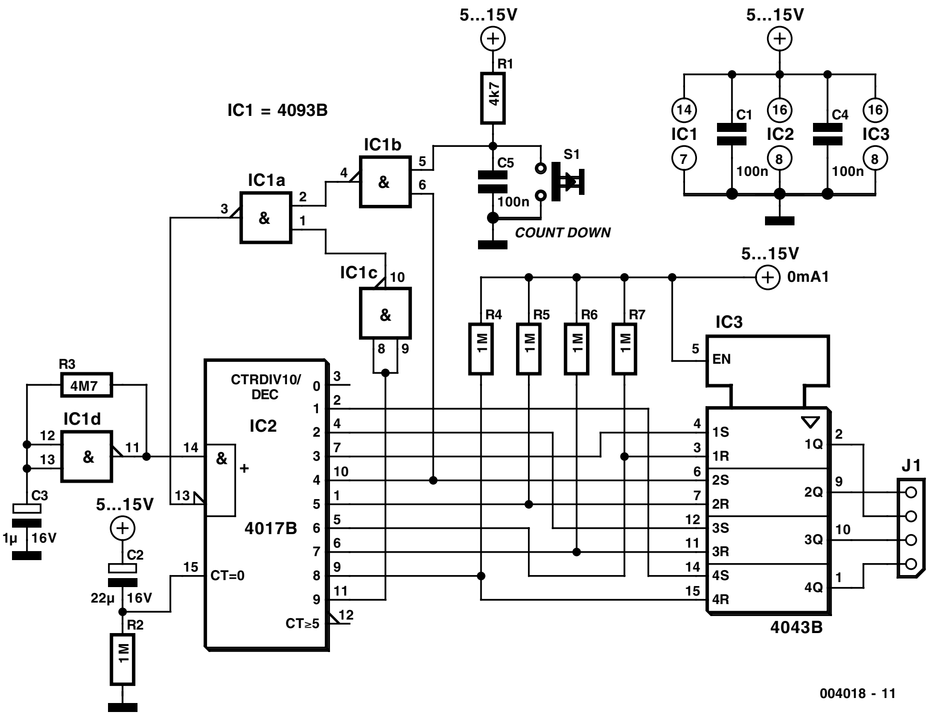
This circuit was developed to turn on power supplies in sequence, and then turn them off again in the reverse sequence. This can be helpful for experimenting with equipment and circuits whose power has to be applied and removed in a particular order (like the PC/EPROM-Programmer combination used by Elektor's Software Service Department; *Ed.*)

The heart of the circuit is the venerable 4017 CMOS decade counter. Outputs Q1 to Q4 are used to set latches in the order 1-2-3-4, at which point the count is suspended. Pressing switch S1 allows the counting to continue. Counter outputs Q5 to Q8 are used to reset the latches in the reverse order, i.e., 4-3-2-1. The last output, Q9, is used to halt the counter.

When power is applied, C2 and R2 initially keep the counter reset. When the power supply voltage is stable, the reset signal will go low and the 4017 will begin to count the 1-Hz clock signal supplied by an oscillator consisting of IC1d, R3 and C3. The outputs of the 4017 are actuated in sequence with each rising edge of the clock pulse — but as the next clock pulse comes along the previous output is de-activated. The latches in the quad RS-latch type 4043 enable the outputs to stay active. IC2 stops counting at Q4 due to IC1b which removes the clock enable signal on pin 13 via IC1a. To enable the 4017 to continue counting and hence turn off the outputs, S1 has to be closed, thus restoring the clock enable on pin 13. Counter outputs Q5 to Q8 are connected to the reset inputs of the latches, so as IC2 increments, the latches are reset in the opposite sequence.

The count is finally halted at Q9 by IC1c, which again removes the clock enable signal. Weak pull-up resistors (R4-R7) are used on the latch 'reset' inputs to prevent undefined start conditions.

(004018-1)



017 ±5-V Voltage Converter

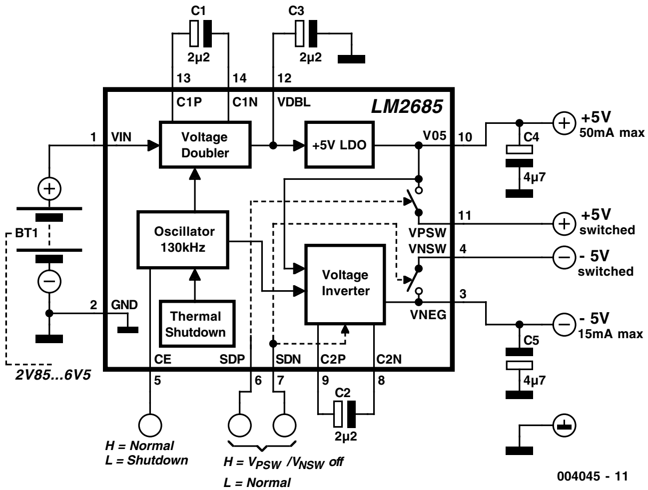
G. Kleine

A symmetrical ±5 V power supply is often needed for small, battery-operated operational amplifier projects and analogue circuits. An IC that can easily be used for this purpose is the National Semiconductor LM 2685. It contains a switched-capacitor voltage doubler followed by a 5-V regulator. A voltage inverter integrated into the same IC, which also uses the switched-capacitor technique, runs from this output voltage. The external circuitry is limited to two pump capacitors and three electrolytic storage capacitors.

The IC can work with an input voltage between +2.85 V and +6.5 V, which makes it well suited for battery-operated equipment. The input voltage is first applied to a voltage doubler operating at 130 kHz. The external capacitor for this is connected to pins 13 and 14. The output voltage of this doubler is filtered by capacitor C3, which is connected to pin 12. If the input voltage lies between +5.4 and +6.5 V, the voltage doubler switches off and passes the input voltage directly through to the following +5-V low-dropout regulator, which can deliver up to 50 mA. C4 is used as the output filter capacitor.

All that is necessary to generate the –5-V output voltage is to invert the +5-V voltage. This is done by a clocked power-MOS circuit that first charges capacitor C2, which is connected between pins 8 and 9, and then reverses its polarity. This chopped voltage must be filtered by C5 at the output. The unregulated –5 V output can supply up to 15 mA.

The LM 2865 voltage converter IC also has a chip-enable input (CE) and two control inputs, SDP (shut down positive) and SDN (shut down negative). If CE is set Low, the entire IC is switched off (shut down), and its current consumption drops to typically 6 μA. The CE input can thus be used to switch the connected circuit on or off, without having to disconnect the battery.



The SDP and SDN inputs can be used to switch the V_{PSW} and V_{NSW} outputs, respectively. These two pins are connected to the voltage outputs via two low-resistance CMOS switches. This allows the negative output to be separately switched off, whereby the voltage inverter is also switched off. Switching off with SDP not only opens the output switch but also stops the oscillator. There is thus no longer any input voltage for the –5 V inverter, so the –5 V output also drops out. The SDP and SDN inputs are set Low (< 0.8 V) for normal operation and High (>2.4 V) for switching off the associated voltage(s).

The positive output of the LM 2865 is short-circuit proof. However, a short circuit between the positive and negative outputs must always be avoided. The IC is protected against thermal destruction by an overtemperature monitor. It switches off automatically at a chip temperature of around 150 °C.

The full type number of the IC is LM 2685MTC. It comes in a TSSOP14 SMD package. National Semiconductor can be found on the Internet under *www.national.com*.

(004045-1)

018 JAL for the PIC84

W. van Ooijen

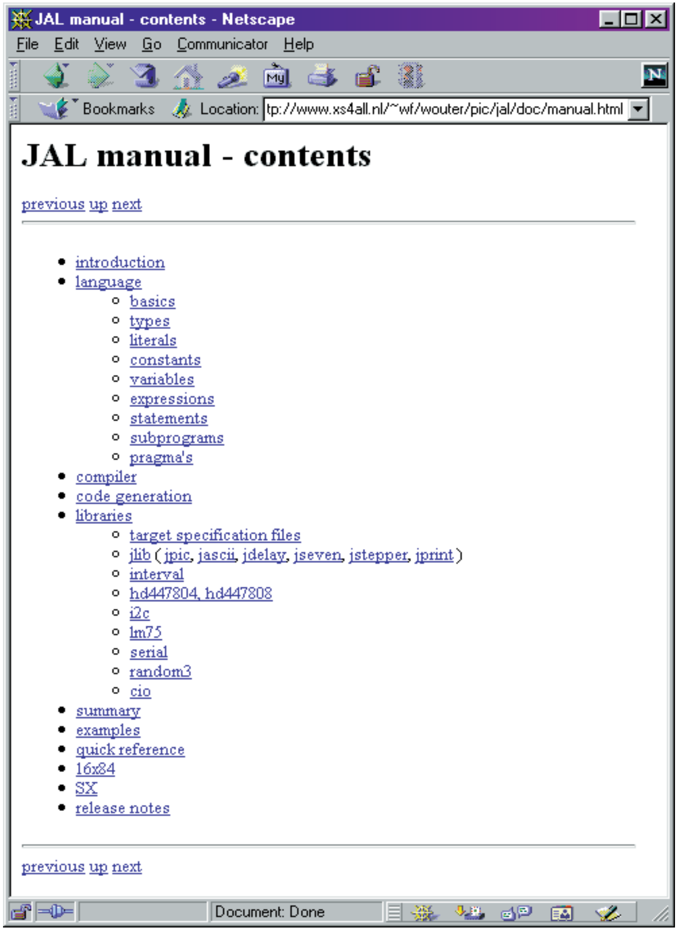
JAL stands for 'Just Another Language', and it is a programming language similar to Pascal for the PIC 16C84, PIC 16F84, Scenix SX18 and Scenix SX28. The author is not a fan of C. He found it easier to write his own programming language, which meets his needs and preferences, and which in addition better matches the features (or lack thereof) of the microprocessors in question. You can read more about this language in the summary and examples in the on-line manual. There is also a FAQ section. Anyone who does not have experience working with a compiler for the PIC family will find good advice under '16x84 assignments'. You can find all of this, as well as compilers for DOS, Windows and Linux (all gratis), at the Internet site *www.xs4all.nl/~wf/wouter/pic/jal/*.

A small sample program that causes a LED to blink gives an impression of the language:

```
[1] — flash a LED on pin A0
[2] include 16f84_10
[3] include jlib
[4] pin_a0_direction = output
[5] forever loop
[6] pin_a0 = on
[7] delay_1s
[8] pin_a0 = off
[9] delay_1s
[10] end loop
```

The line numbers are not necessary; they have only been added for reference. In addition, there are a number of libraries available with routines such as pic I/O, delays, i2c, asych, random, hd44780 (LC display), I/O extensions, math and so on.

(004096-1)

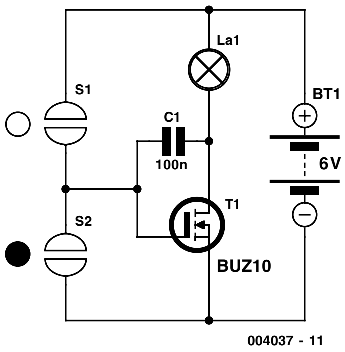


019 Simple Touch Pad Dimmer

B. Kainka

Using a Power-FET it is possible to build a very simple touch dimmer for low voltage lamps. Two drawing pins are used here as the touch contacts. The electrical resistance of your skin is in the order of 100 kΩ to 1 MΩ. The circuit operates as an integrator with a capacitor in its negative feedback path. This configuration gives a relatively linear control characteristic. Once you have selected a brightness level, it will be maintained for hours if you use a low leakage (foil) capacitor. Another feature of this circuit is that the harder you press on the contacts, the quicker the lamp brightness changes.

(004037)



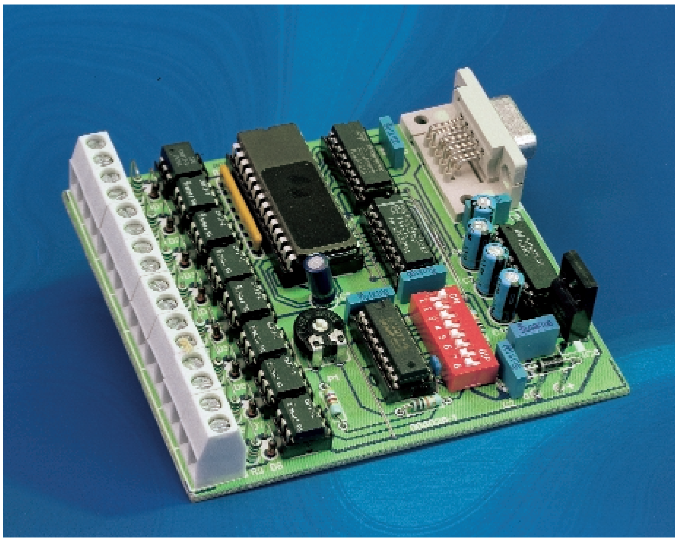
020 8 Channel D/I Card for RS232

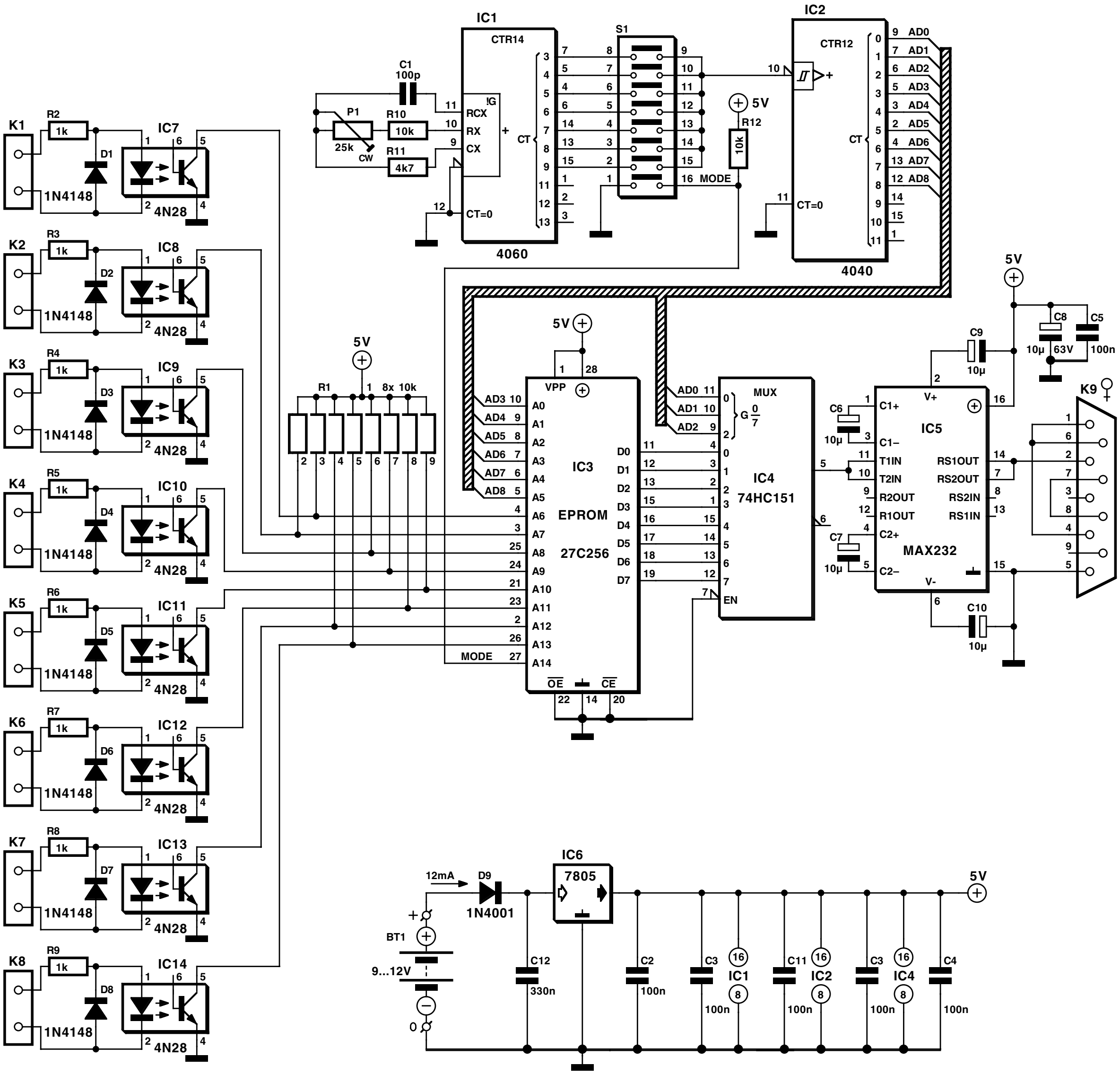
G. Vastianos

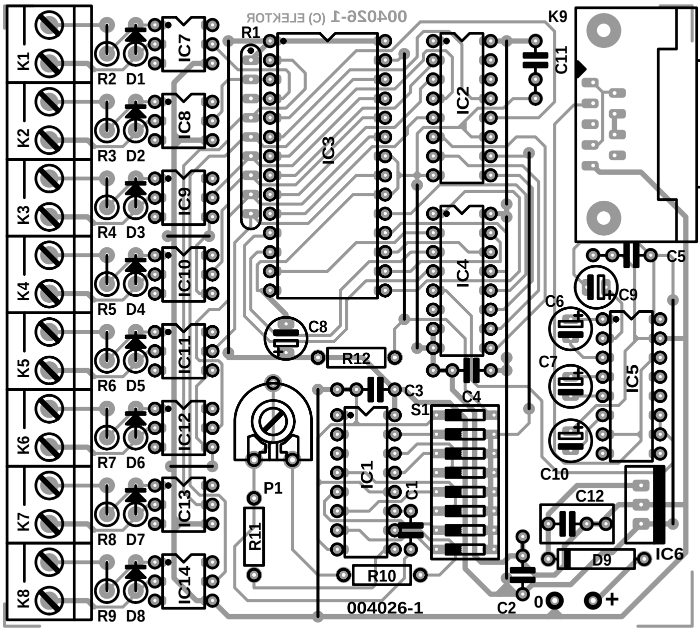
The author is a student at the Electronics Department, Technological Educational Institute of Piraeus, Greece.

This project is a card with eight optically isolated TTL-compatible inputs for external connection to the serial port, which communicates through the RS-232 protocol. On this card you will look in vain for a UART or microcontroller chip because the design is based on a 27C256 EPROM.

Each digital input is connected to an optocoupler (IC7-IC14) through a resistor (R2-R9), and drives it with a current of 5 mA when the input voltage is 5 Vdc. A diode (D1-D8) is connected in parallel with each optocoupler input to protect against the ill effects of reversed signal polarity. The collectors of the internal optocoupler transistors drive EPROM address lines A6 to A13. The logic states of A6 to A13 are inverted (because the optocouplers work as inverters) and for this reason a second inversion is performed in software (EPROM) to cancel the total inver-







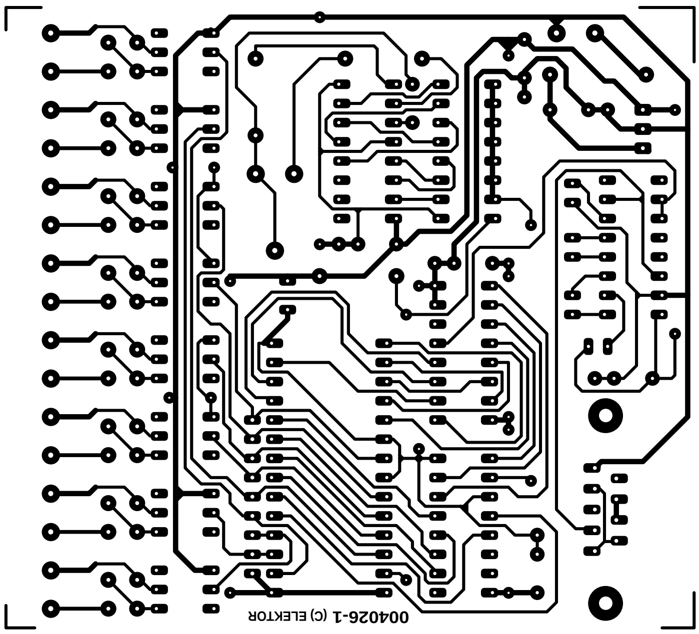


Table 1. ASCII Codes & bit values

CHAR	ASCII	D7	D6	D5	D4	D3	D2	D1	D0
CR	13	0	0	0	0	1	1	0	1
LF	10	0	0	0	0	1	0	1	0
'C'	67	0	1	0	0	0	0	1	1
'H'	72	0	1	0	0	1	0	0	0
'0'	48	0	0	1	1	0	0	0	0
'1'	49	0	0	1	1	0	0	0	1
'2'	50	0	0	1	1	0	0	1	0
'3'	51	0	0	1	1	0	0	1	1
'4'	52	0	0	1	1	0	1	0	0
'5'	53	0	0	1	1	0	1	0	1
'6'	54	0	0	1	1	0	1	1	0
'7'	55	0	0	1	1	0	1	1	1
':'	58	0	0	1	1	1	0	1	0
SP	32	0	0	1	0	0	0	0	0
SYNC	255	1	1	1	1	1	1	1	1

COMPONENTS LIST

Resistors:
R1 = 10kΩ 8-way SIL array
R2-R9 = 1kΩ
R10,R12 = 10kΩ
R11 = 4kΩ7
P1 = 25kΩ preset H

Capacitors:
C1 = 100pF
C2-C5,C11 = 100nF
C6-C10 = 10 μF radial
C12 = 330nF

Semiconductors:
D1-D8 = 1N4148
D9 = 1N4001
IC1 = 4060
IC2 = 4040
IC3 = 27C256 (see text for programming)
IC4 = 74HC151
IC5 = MAX232
IC6 = 7805
IC7-IC14 = 4N28 of CNY17-2

Miscellaneous:
K1-K8 = 2-way PCB terminal block, raster 5mm
K9 = 9-way sub-D socket (female), PCB mount
S1 = 8-way DIP switch

sion effect. In this way the 8 inputs become TTL compatible.

IC1, a CD4060, with the help of C1, P1, R11 and R10, forms a bitrate generator for 150, 300, 600, 1200, 2400, 4800 or 9600 bps. Preset P1 needs to be adjusted to the desired baudrate — an accuracy of 1-2% is required! The bitrate is selected using DIP switch S1. The CD4040 works as a 9-bit binary counter. The three LS bits of the counter outputs (AD0, AD1, AD2) drive the selection inputs of multiplexer IC4 (74HC151). The other counter bits (AD3-AD8) drive the LS address bits of the EPROM (A0-A5). The highest EPROM address line, A14, is connected to one of the DIP switches in S1 which defines the data transmission mode (TTY or BIN).
With the above connections counter IC2 sweeps a range of 512 bits (64 bytes) of the total of 256 kBits (32 Kbytes) contained in the EPROM.

The number of 512-bit blocks (packets) equals the number of different combinations of CH0 to CH7 and MODE, and can be calculated from the following formula :

$$\begin{aligned} \text{Memory}_{\text{size}} &= 512 \text{ packets} * 512 \text{ bits/packet} \\ &= 256 \text{ Kbits} = 32 \text{ Kbytes} \end{aligned}$$

The data encoding unit consisting of IC1- IC4 transmits 512-bits packets (coming from the multiplexer output). The data in the transmitted packet depends directly on the logic states of lines CH0 to CH7 and MODE.
The power supply includes a 7805 regulator so that the card will not need a separate regulated power supply. Circuit IC5 (a MAX232) works as an RS232 Driver/Receiver, converting the multiplexer' s output data from TTL to RS232 compatible.

With the EPROM programmed with the right data, the circuit will produce messages (packets), through the RS-232 protocol, that will inform us for the logic states of the card's inputs. The transmission used by this card is 8 **data bits, 1 stop bit and no parity.** Assuming an 'A' is **to** be sent**,** and that your PC runs a terminal simulation program receiving (via the RXD pin of its serial port) the following 10 bits '0100000101', then it will print on its screen the character 'A'.

This card transmits the logic states of its inputs in one of two modes, TTY (teletype) or BIN (binary).

In **TTY Mode**, the card transmits the following message to the computer:

```
<SYNC>,<SYNC>,<CR>,<LF>,'CH0:X',<SP>,'CH1:X',
<SP>,'CH2:X',<SP>,'CH3:X',<SP>,
'CH4:X',<SP>,'CH5:X',<SP>,'CH6:X',<SP>,'CH7:X'
```

Where <SYNC> is the character with ASCII code 255, used to synchronize the computer. Reception of this character (from the computer) causes a space to appear on the screen. <CR> and <LF> are 'carriage return' and 'line feed' with ASCII codes 13 and 10 respectively, and <SP> is the 'space' character with ASCII code 32. Reception of this character (from the computer) causes a space to appear on the screen. Finally, X is the logic state of each input, which will cause a '1' or a '0' to appear on the screen.

In **BIN Mode,** the card transmits the following message to the computer:

```
<SYNC>,<SYNC>,<DATA BYTE>
```

Where <SYNC> is as above and <DATA BYTE> is the character with an ASCII code equal to the numerical value of the byte built from the logic states of the inputs (with the MS Bit representing CH7, and LS Bit, CH0).

These two modes are used in different cases. In cases where we want just to see the logic states of the input we just set the card in TTY mode and we use a terminal program as Telix, Procomm Plus, Hyper Terminal etc. In cases where we want to do some data logging or to compose a data acquisition & control system with other DAQ & control cards then we just set the card in BIN mode (because the decoding of the data is easier done by dedicated software).

The characters, their ASCII codes and their bit values, as used in the two modes are shown in **Table 1**. The bitstreams that must be transmitted for each character appear in **Table 2**.

The contents of the EPROM are created by a program (EPROMFMP.BAS) developed in Quick Basic, which is available from the author's website. The program first makes a temporary file that contains all data to be written in the EPROM in bit format (08DICARD.TMP). Next, it converts this file into byte format (08DICARD.BIN) and deletes the temporary file. Finally, it runs an external program (BIN2HEX.EXE) and adapts the file from Binary to IntelHex format (08DICARD.HEX). To program your own EPROM, you may use 08DICARD.BIN or 08DICARD.HEX file.

Finally, the mode and bit rate selection on S1 is shown in **Table 3**. The PCB designed for this project is unfortunately not available ready-made through the Publishers' Readers Services.

All software you will need to complete this project may be downloaded free of charge from the author's website at
http://members.xoom.com/robofreak/download/08dicard.htm
Also, for other projects developed by Mr. Vastianos, visit this address:
http://members.xoom.com/robofreak/

(004026-1)

Table 2. Character composition

CHAR	START BIT	D0	D1	D2	D3	D4	D5	D6	D7	STOP BIT
CR	0	1	0	1	1	0	0	0	0	1
LF	0	0	1	0	1	0	0	0	0	1
'C'	0	1	1	0	0	0	0	1	0	1
'H'	0	0	0	0	1	0	0	1	0	1
'0'	0	0	0	0	0	1	1	0	0	1
'1'	0	1	0	0	0	1	1	0	0	1
'2'	0	0	1	0	0	1	1	0	0	1
'3'	0	1	1	0	0	1	1	0	0	1
'4'	0	0	0	1	0	1	1	0	0	1
'5'	0	1	0	1	0	1	1	0	0	1
'6'	0	0	1	1	0	1	1	0	0	1
'7'	0	1	1	1	0	1	1	0	0	1
':'	0	0	1	0	1	1	1	0	0	1
SP	0	0	0	0	0	0	1	0	0	1
SYNC	0	1	1	1	1	1	1	1	1	1

Table 3. DIP switch settings

			SW	1				USAGE
#1	#2	#3	#4	#5	#6	#7	#8	MODE
OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	"150, 8, 1, N : BIN"
OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	"300, 8, 1, N : BIN"
OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	"600, 8, 1, N : BIN"
OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	"1200, 8, 1, N : BIN"
OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	"2400, 8, 1, N : BIN"
OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF	"4800, 8, 1, N : BIN"
OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	"9600, 8, 1, N : BIN"
ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	"150, 8, 1, N : TTY"
ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	"300, 8, 1, N : TTY"
ON	OFF	OFF	ON	OFF	OFF	OFF	OFF	"600, 8, 1, N : TTY"
ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	"1200, 8, 1, N : TTY"
ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	"2400, 8, 1, N : TTY"
ON	OFF	OFF	OFF	OFF	OFF	ON	OFF	"4800, 8, 1, N : TTY"
ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	"9600, 8, 1, N : TTY"

021 PC 12-V Adapter

T. Giesberts

This circuit can replace small mains adapters in the vicinity of the computer. This is particularly handy for devices that need a 12-V supply, such as active PC loudspeakers. The necessary 12-V supply voltage is taken directly from the PC power supply. In order to protect the PC supply against possible short circuits, and especially to prevent the PC from being crashed, a current limiting circuit is connected in series with the 12-V supply. This regulator consists of only four resistors, two transistors and HF decoupling.

The circuit works very simply. MOSFET T2 is normally driven fully on via R4, so that the 12-V potential from the PC power supply appears at the output. The current through R1 produces a voltage drop, which at a certain current level will cause T1 to start to conduct. This in turn 'pinches off' T2 somewhat, so that less output current is supplied. In order to minimise the voltage drop across R1, a bias voltage is applied to the base-emitter junction of T1 via R2 and R3. The current limiting value can thus be easily set by adjusting the value of R2. With the given component values, the maximum output current is more than 2.5 A (see **Table 1**). The circuit itself draws at least 1 mA, which rises to over 3 mA with a short circuit (excluding the load current). An IRF9540 is used for the P-channel MOSFET T2, due to its low $R_{DS(0n)}$ of 0.15 Ω (typical). Any desired type of power MOSFET can be used, as long as it can handle the maximum dissipation of 30 W.

For your convenience, we have also made a circuit board layout for the regulator. The outputs are a row of three adapter plugs. Everything fits behind the punchout for a 25-pin sub-D connector, which is present in nearly every PC. The mounting holes of the circuit board have the same separation as the mounting holes for a 25-pin sub-D connector. The board can easily be fixed in place using two small angle brackets.

The dissipation of FET T2 can easily be quite significant – around 30 W in case of a short circuit! This means that a heat sink must be used for T2. In theory, a heat sink with a thermal coefficient of around 2 K/W is needed for a continuous short circuit, but in practice you can manage with a thick piece of aluminium angle stock (3 to 4 mm thick) fixed to the PC enclosure. Don't forget that T2 must be well insulated electrically, since its case is connected to the drain and thus to 12 V!

The PCB shown here is not available ready-made through the Publishers Readers Services.

(004017-1)

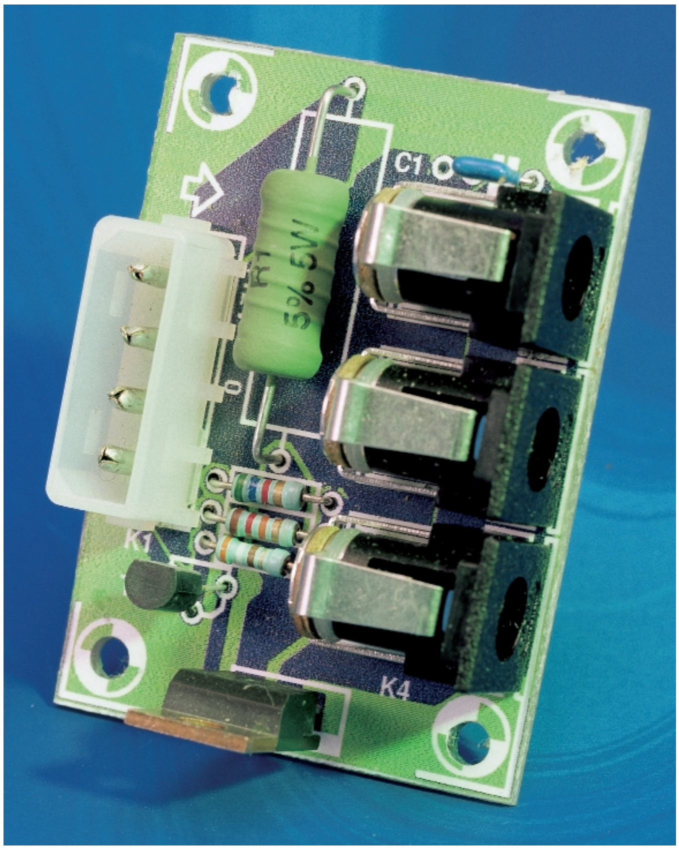
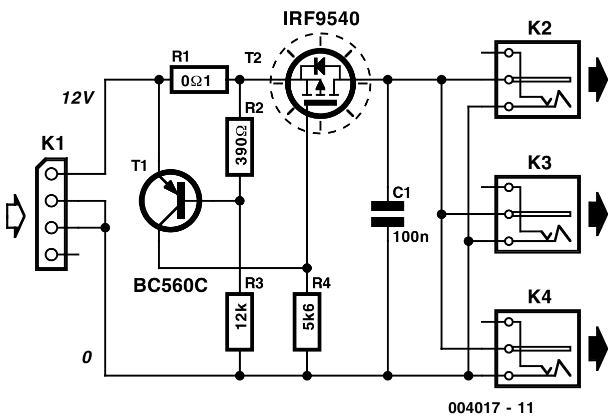


Table 1. Output voltage vs output current

Output load (W)	Voltage (V)	Current (A)
open	12	0
22	11.8	0.54
6.8	11.4	1.68
4.7	11.0	2.34
3.3	8.6	2.6
2.2	5.7	2.6
0	0	2.6



COMPONENTS LIST

Resistors:
R1 = 0Ω1 5W
R2 = 390 Ω
R3 = 12kΩ
R4 = 5kΩ6

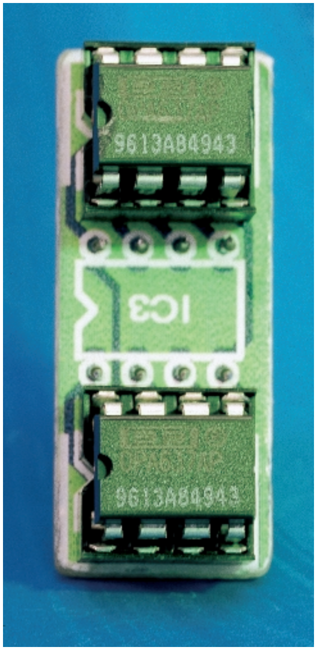
Capacitors:
C1 = 100nF ceramic

Semiconductors:
T1 = BC560C
T2 = IRF9540 (see text)

Miscellaneous:
K1 = 4-way PC-supply plug, PCB mount (Farnell)
K2,K3,K4 = mains adaptor plug, PCB mount

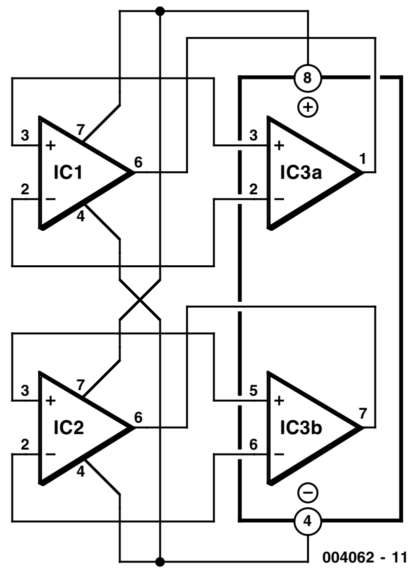
022 2 × single = 1 × dual

T. Giesberts



There are many more types of single opamps available than dual or quad versions. Not only can it sometimes be interesting to replace a dual opamp by two equivalent single opamps, it also allows the use of two completely different types of opamp, depending on the application. One example is the combination of the DAC and output filter of a CD player. A dual opamp is sometimes used here, although a fast linear amplifier is needed for the current-to-voltage converter, while a good low-noise opamp is more suitable for the output filter.

It's fairly easy to replace a dual opamp if you use one of the accompanying printed circuit boards. The schematic shows the connections between the two single opamps and the pin locations of the dual package. First solder eight short pieces of wire to the circuit board in the dual package location. After you have fitted the single opamps (with sockets if desired), solder these wires in place of the dual opamp. Pay careful attention to the orientation. Two layout versions are shown here. The larger one has better channel separation but takes up more space, while the other one is a lot more compact. With the larger board, the leads will probably have to be reasonably long, depending on the height of the surrounding components. This slightly increases the likelihood of interference. A third version is possible, using two small, separate printed circuit boards, with the ICs mounted back-to-back. In this case, however, the power supply leads would have to be connected between the two boards using wire bridges.



The PCB shown here is unfortunately not available ready-made through the Publishers' Readers Services.

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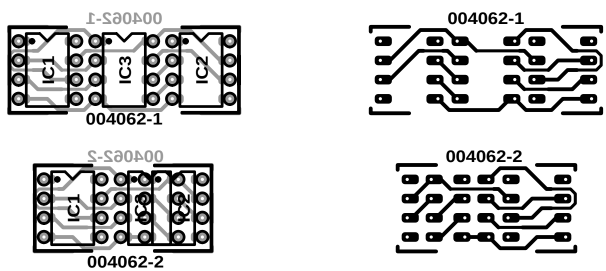
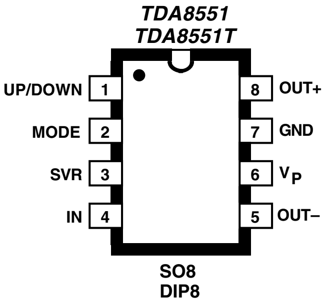


023 AF Amplifier with Up/Down Volume Setting



G. Kleine

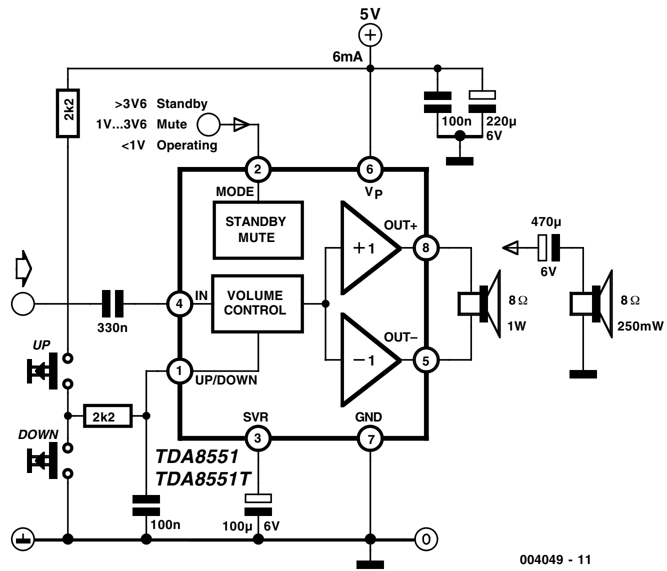
The Philips Semiconductors TDA8551 is a small audio amplifier with an integrated volume control. When operated from +5 V, it delivers a nominal output power of more than one watt into 8 ohms. It can also be used over a supply voltage range of +2.7 to +5.5 V, with correspondingly reduced output power. The output volume can be adjusted from –60 dB to +20 dB in 64 steps, using a set of up and down pushbuttons. The shared UP/DOWN input for the up and down switches has three states. If it is 'floating', which means that both of the switches are open, the volume remains unchanged. A pulse to earth decreases the volume by 1.25 dB, while a positive pulse increases the volume by 1.25 dB. When the power is switched on, the internal counter takes on the –20 dB setting.

An additional input (MODE) allows the amplifier to be switched from the operating state to the mute or standby state. If this input is held at the earth level, the amplifier is operational. If +5 V is applied to this pin, the TDA8551 enters the Standby mode, in which the current consumption drops from the typical operational level of 6 mA to less than 10 μA. Finally, the MODE input can be used as a mute input by applying a voltage of 1 t0 3.6 V to this input. This voltage can be provided by a connection to the SCR pin, which lies at half of the operating voltage and to which a filter capacitor is connected.

The loudspeaker is connected in a floating configuration between the two outputs of the bridge amplifier in the TDA8551. This provides the desired output power level, in spite of the low supply voltage. For headphone applications, which do not need as much output power, you can connect the headphone between earth and one of the outputs, via an electrolytic coupling capacitor. You can make a stereo headphone amplifier in this way, using two TDS8551 ICs.

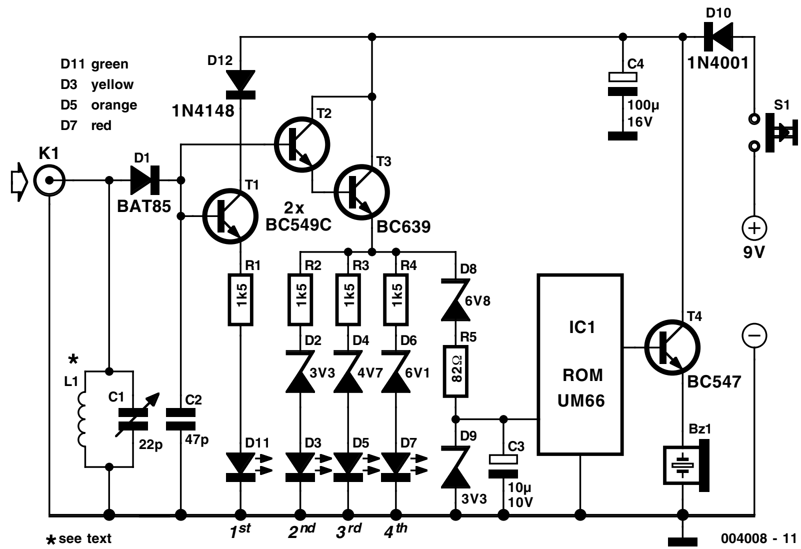
The TDA8551 is housed in a DIP8 package. The SMD version is the TDA8551T, in an SO8 package. The datasheet can be obtained from *www.semiconductors.philips.com*.

(004049-1)



024 Simple RF Detector for 2 m

N.S. Harisankar VU3NSH



This simple circuit helps you sniff out RF radiation leaking from your transmitter, improper joints, a broken cable or equipment with poor RF shielding. The tester is designed for the 2-m amateur radio band (144-146 MHz in Europe).

The instrument has a 4-step LED readout and an audible alarm for high radiation voltages. The RF signal is picked up by an antenna and made to resonate by C1-L1. After rectifying by diode D1, the signal is fed to a two-transistor high-gain Darlington amplifier, T2-T3. Assuming that a 10-inch telescopic antenna is used, the RF level scale set up for the LEDs is as follows:

LED	approx. RF e.m.f.
D1	>1 V
D3	>2 V
D5	>3 V
D7	>4 V
All	>7 V

When all LEDs light, the (optional) UM66 sound/melody generator chip (IC1) is also actuated and supplies an audible alarm. By changing the values of zener diodes D2, D4, D6 and D8, the step size and span of the instrument may be changed as required. For operation in other ham or PMR bands, simply change the resonant network C1-L1.

As an example, a 5-watt handheld transceiver fitted with a half-wave telescopic antenna (G = 3.5 dBd), will produce an ERP (effective radiated power) of almost 10 watts and an e.m.f. of more than 8 volts close to your head.

Inductor L1 consists of 2.5 turns of 20 SWG (approx. 1 mm dia) enamelled copper wire. The inside diameter is about 7 mm and no core is used. The associated trimmer capacitor C1 is tuned for the highest number of LEDs to light at a relatively low fieldstrength put up by a 2-m transceiver transmitting at 145 MHz.

The tester is powered by a 9-V battery and draws about 15 mA when all LEDs are on. It should be enclosed in a metal case.

(004008-1)

025 Max. Temp. Detector for Fan controller

T. Giesberts

The fan controller circuit for the Titan 2000 and other AF heavy-duty power amplifiers, published in the May 1999 issue, has an output that sets a voltage if the fan controller reaches the end of its range. Since the controller responds to temperature, this signal is seen by the amplifier protection circuitry as an overtemperature indication. The disadvantage of this output is that the maximum voltage for the fans is not constant, but depends on the load (number of fans, defective fans) and the mains voltage. This variation is caused by the fact that the supply voltage for the output stage is taken directly from the filtered transformer voltage. If the fans should fail, for example, the maximum temperature limit would lie at a considerably higher level than the desired value. The accompanying circuit, which compares the magnitude of the fan voltage to a fixed reference value, has been developed to allow the maximum temperature to be reliably detected. This circuit is tailored for 12-V fans.

The reference voltage is generated by the 'micropower voltage reference' D1 and the FET T1, which is wired as a current source. These components are powered directly from the applied fan voltage. The current source is set up to deliver approximately 50 µA. D1 can work with as little as 10 µA.

The supply voltage for the IC is decoupled by R10, C3 and C4, with D4 providing overvoltage protection. A maximum supply voltage of 16 V is specified for the TLC271. This opamp works with a supply voltage as low as 3 V and can handle a common-mode voltage up to approximately 1.5 V less than the positive supply voltage. Accordingly, 1.2 V has been chosen for the reference voltage. The fan voltage is reduced to the level of the reference voltage by the voltage divider R2–R3–P1. The limits now lie at 11.2 V and 16.7 V. If you find these values too high, you can reduce R2 to 100 kΩ, which will shift the limits to 9.5 V and 14.2 V.

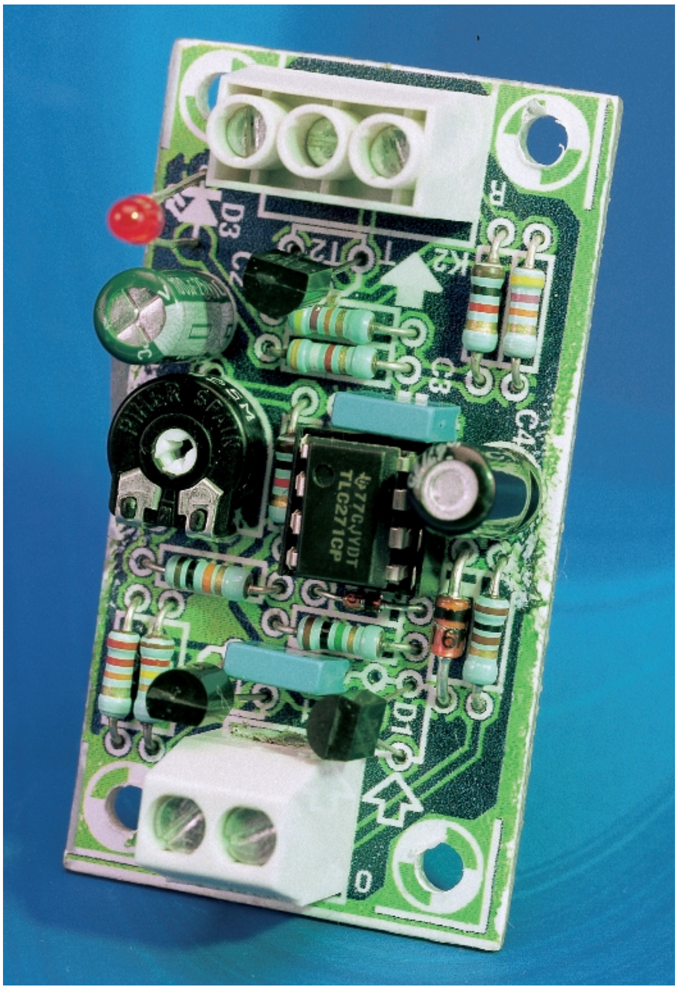
The output of the voltage divider is well decoupled by C2. A relatively large time constant was selected here to prevent the circuit from reacting too quickly, and to hold the output active for a bit longer after the comparator switches states. A small amount of hysteresis (around 1 mV) is added by R4 and R5, to prevent instability when the comparator switches. D2 ensures that the magnitude of the hysteresis is independent of the supply voltage.

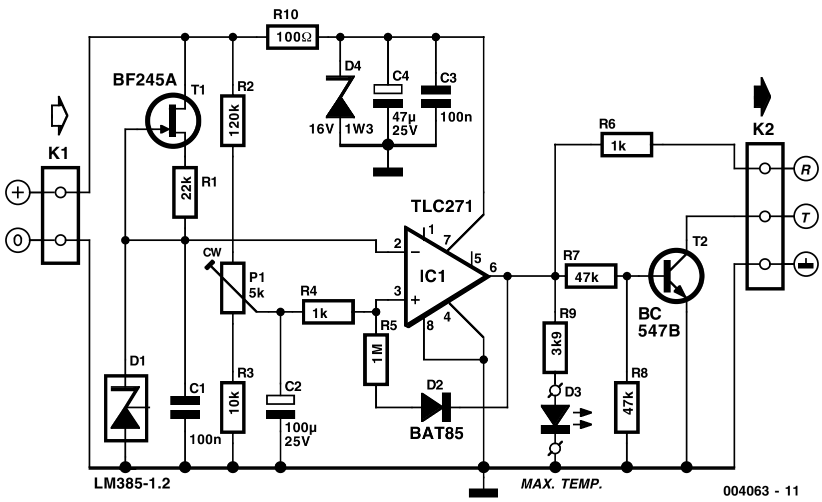
Two outputs have been provided to make the circuit more versatile. Output 'R' is intended to directly drive the LED of an optocoupler. In addition, transistor T2 is switched on by the output of the opamp via R7 and R8, so that a relay can be actuated or a protection circuit triggered using the 'T' output. The high-efficiency LED D3 indicates that IC1 has switched. It can be used as a new 'maximum' temperature' indicator when this circuit is added to the fan controller of the May 1999 issue.

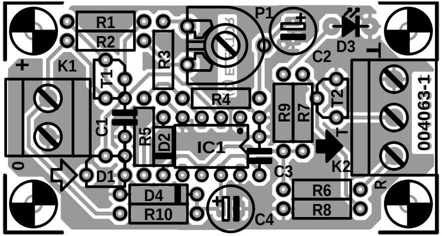
The circuit draws only 0.25 mA when the LED is out, and the measured no-load current consumption (with a 12.5-V supply voltage) is 2.7 mA when the LED is on.

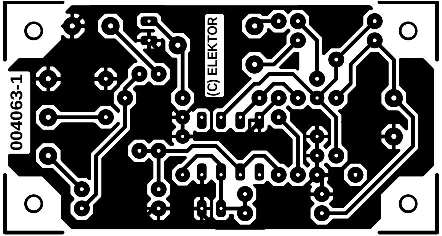
The PCB shown here is unfortunately not available ready-made through the Publishers' Readers Services.

(004063-1)









COMPONENTS LIST

Resistors:
R1 = 22kΩ
R2 = 120kΩ
R3 = 10kΩ
R4,R6 = 1kΩ
R5 = 1MΩ
R7,R8 = 47kΩ
R9 = 3kΩ9
R10 = 100Ω
P1 = 5kΩ preset

Capacitors:
C1,C3 = 100nF
C2 = 100µF 25V radial
C4 = 47µF 25V radial

Semiconductors:
D1 = LM385-1.2
D2 = BAT85
D3 = high-efficiency-LED
D4 = zener diode 16V/1W3
T1 = BF245A
T2 = BC547B
IC1 = TLC271CP

Miscellaneous:
K1 = 2-way PCB terminal block, raster 5mm
K2 = 3- way PCB terminal block, raster 5mm

026 Two-Position Dimmer

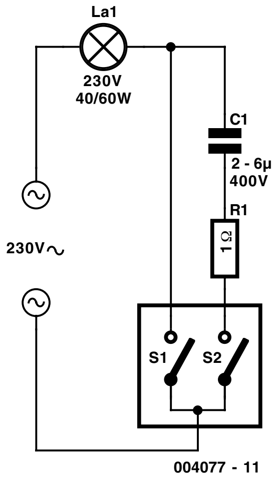
G. Baars

This super-simple dimmer consists of only two components, and it can easily be built into a mains switch. If you do this, don't forget to first switch off the associated branch circuit in the fuse box, since the mains voltage is always dangerous!

The circuit does not need much explanation. When S1 is closed, the lamp works at full strength, and the position of S2 does not matter. When S1 is open and S2 is closed, the capacitor causes a voltage drop, so the lamp is dimmed. The power dissipation of the capacitor is practically zero, so the circuit does not generate any heat. The resistor prevents sparking when S2 is closed while S1 is already closed. The value of the capacitor can be matched to the power of the lamp to be dimmed; it should be between 2 and 6 μF.

Be sure to use a class X2 capacitor. Also, don't forget that this circuit works only with resistive (non-inductive) loads. Unpredictable things can happen with an inductive load!

(004077-1)



027 10 to 1000 MHz Oscillator

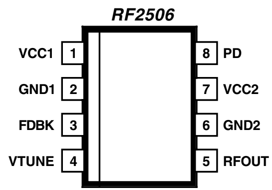
G. Kleine

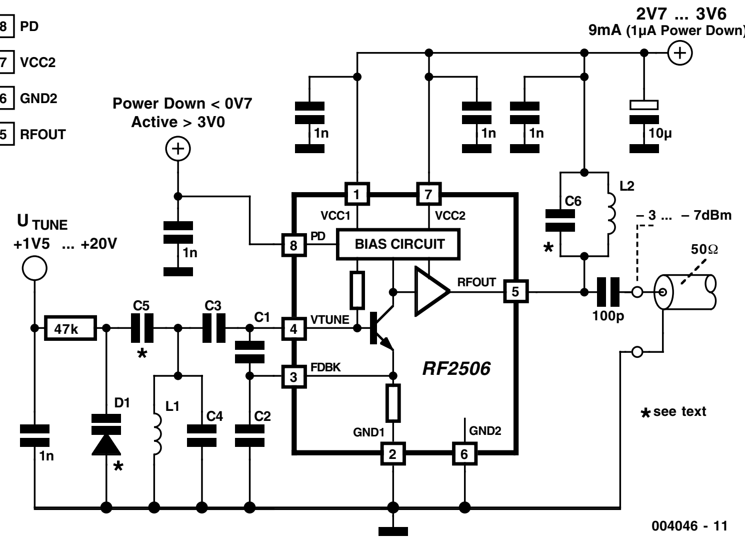
Nowadays, it is no longer necessary to use discrete components to build oscillators. Instead, many manufacturers provide ready-made voltage-controlled oscillator (VCO) ICs that need only a few frequency-determining external components. One example is the RF Micro Devices RF2506. This IC operates with a supply voltage between 2.7 and 3.6 V (3.3 V nominal) and provides a low-noise oscillator transistor with integrated DC bias setting. In addition, it has an isolating buffer amplifier that strongly reduces the effects of load variations (load pulling) on the oscillator. If a voltage less than 0.7 V is applied to the power-down input (pin 8), the oscillator is shut down and the current consumption drops from 9 mA to less than 1 μA. The VCO is enabled when the voltage on pin 8 is at least +3.0 V.

Connecting the feedback capacitors C1 and C2 to pins 3 (FDBK) and 4 (VTUNE) transforms the internal transistor into a Colpitts oscillator. A resonator is also needed; here this consists of C4 and L1, and it is coupled via C3. Keep the Q factor of the coil as high as possible (by using an air-core coil, for example), to ensure a low level of phase noise. Since most applications require a tuneable oscillator, the varicap diode D1 (BBY40, BBY51, BB804 etc) can be used to adjust the resonant frequency. The tuning voltage U_{Tune} is applied via a high resistance. The value of the tuning voltage naturally depends on the desired frequency range and the variable-capacitance

diode (D1) that is used. The table shows a number of suggestions for selecting the frequency-determining components.
If the frequency range is narrow, a parallel-resonant circuit should be connected between the output pin and $+V_{CC}$, to form the collector load for the output transistor. This can be built using the same components as the oscillator resonator. With a broadband VCO, use a HF choke instead, with a value of a few microhenries to a few nanohenries, depending on the frequency band. In this case C6 is not needed. The output level of this circuit is –3 dBm with an LC load and –7 dBm with a choke load.
The table that accompanies the schematic diagram provides rough indications of component values for various frequencies. It is intended to provide a starting point for experimentation.
The coupling between the variable-capacitance diode and C5 determines the tuning range of the VCO. The manufacturer maintains an Internet site at *www.rfmd.com*, where you can find more information about this interesting oscillator IC.

(004046-1)



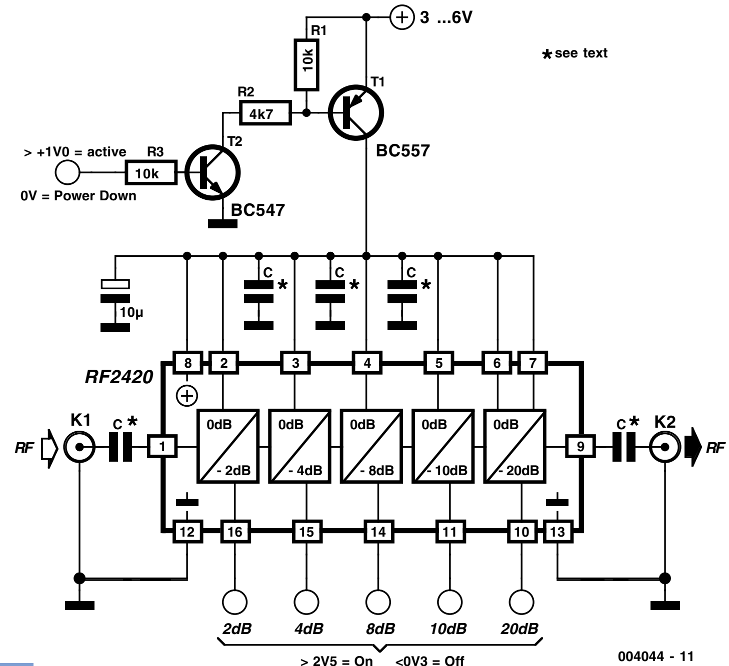


f in MHz	C1 in pF	C2 in pF	C3 in pF	C4, C6 in pF	L1, L2 in nH
50	47	47	1000	15	140
100	18	18	10	10	64
250	6.8	12	6.8	8.2	30
400	3.3	5.6	3.9	1.8	40

028 0 - 44 dB RF attenuator

G. Kleine

Anyone who has to reduce the amplitudes of RF signals in a controlled manner needs an attenuator. Linearly adjustable attenuation networks using special PIN diodes are available for this, but they require quite intricate control circuitry.



A simpler solution is to use an integrated attenuator that can be switched in steps. The RF 2420 is an IC built using gallium-arsenide (GaAs) technology, which works in the frequency range between 1 MHz and 950 MHz. It can thus be used as an attenuator for cable television signals, for example. The attenuation can be set between 0 and 44 dB in 2-dB steps. An insertion loss of 4 dB must also be taken into account. This base attenuation can be measured in the 0-dB setting, and it forms the reference point for switchable attenuation networks that provide 2, 4, 8, 10 and 20 dB of attenuation. These are all controlled by a set of 5 TTL inputs. The control signals must have Low levels below 0.3 V and High levels of at least +2.5 V. The RF 2420 works with a supply voltage between +3 V and +6 V, with a typical current consumption of 4 mA. A power-down mode, in which the current consumption drops to 0.8 mA, can be activated by removing power from the bussed V_{DD}- pins.

f	C
≥ 1 MHz	10 nF
≥ 10 MHz	1 nF
≥ 100 MHz	100 pF

The sample circuit diagram for the RF 2420 shows that the only external components that are needed are decoupling capacitors. The coupling capacitors at the input and output determine the lower operating frequency limit. The table lists possible capacitor values. The input and output are matched to 50-ohm operation, but they can also be used with 75-ohm cables with a small increase in reflections.

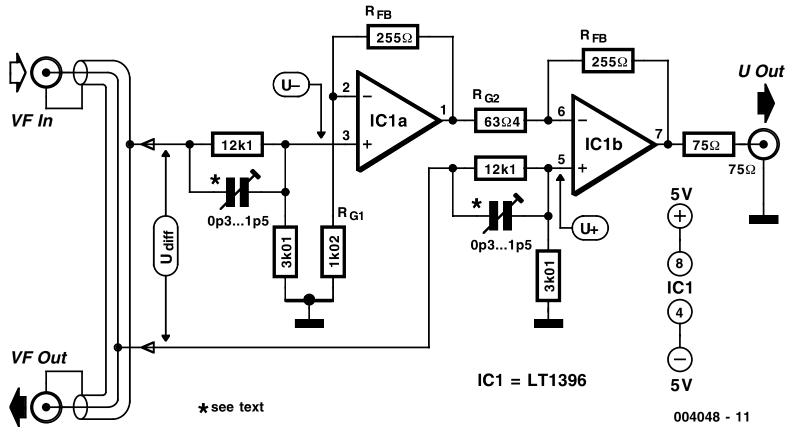
The RF 2420 is available in a 16-pin SOP-16 SMD package. Its data sheet can be found at *www.rfmd.com*.

(004044-1)

029 Video-Out Coupling

G. Kleine

If you want to connect a video signal to several destinations, you need a distribution amplifier to match the 75-ohm video cable. A distribution amplifier terminates the incoming cable in 75 ohms and provides several outputs, each with 75-ohm output impedance. Since this is usually achieved by putting a 75-ohm series resistor in the output lead of each video opamp (current-feedback amplifier), the opamps must be set up for a gain of 2 in order to achieve an insertion gain of 1 (0 dB). The disadvantage of this arrangement is that if the amplifier or its power supply fails, no signal is available at any of the outputs.



$$V_{OUT} = {}^{1}/_{2}\cdot G \cdot (V_{+}\text{-}K) = {}^{1}/_{10}\cdot G\cdot V_{DIFF}$$
$$R_{G1} = (G+3)$$
$$R_{G2} = R_{FB}/(G+3)$$

This can be remedied by using a high input impedance amplifier, which can be tapped into a video line without having to have its own 75-ohm termination resistor. In order to eliminate hum interference and voltage differences between the cable screen and the circuit earth, the circuit exploits the common-mode rejection of the opamp. This can be optimised with resistor R_{G1}. With the indicated LT1396 video opamp, more than 40 dB of common-mode rejection can be achieved. The signal bandwidth of the circuit can be optimised using the trimpots. It reaches to more than 10 MHz, which is quite acceptable for video signals.

Thanks to the high-impedance connection to the video line, the video signal is not affected when the power for the coupled amplifier is switched off. You can learn more about the LT1396 from its data sheet at *http://www.linear-tech.com*.

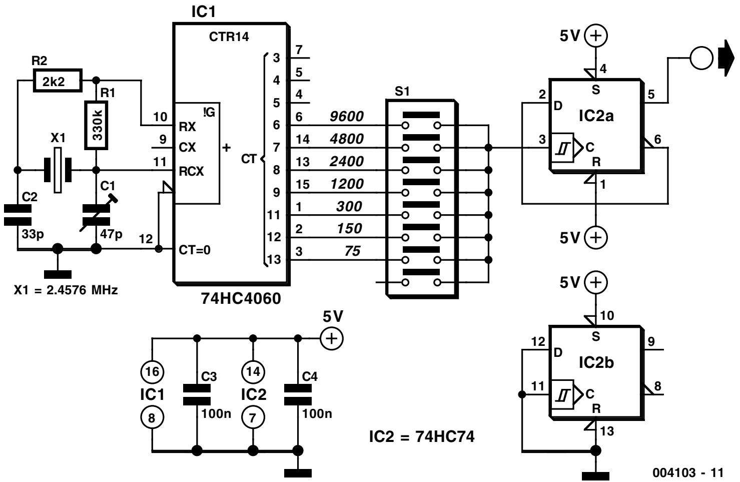
(0040048-1)

030 Baud Rate Generator

K. Walraven

Elsewhere in this issue, an *RC* oscillator is used as a baud rate generator. If you can calibrate the frequency of such a circuit sufficiently accurately (within a few percent) using a frequency meter, it will work very well. However, it may well drift a bit after some time, and then.... Consequently, here we present a small crystal-controlled oscillator.

If you start with a crystal frequency of 2.45765 MHz and divide it by multiples of 2, you can very nicely obtain the



well-known baud rates of 9600, 4800, 2400, 600, 300, 150 and 75. If you look closely at this series, you will see that 1200 baud is missing, since divider in the 4060 has no Q10 output! If you do not need 1200 baud, this is not a problem. However, seeing that 1200 baud is used in practice more often than 600 baud, we have put a divide-by-two stage in the circuit after the 4060, in the form of a 74HC74 flip-flop. This yields a similar series of baud rates, in which 600 baud is missing. The trimmer is for the calibration purists; a 33 pF capacitor will usually provide sufficient accuracy.

The current consumption of this circuit is very low (around 1 mA), thanks to the use of CMOS components.

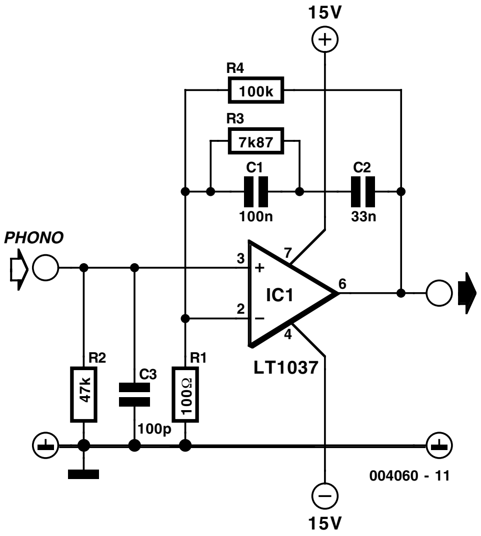
(004103-1)

031 Simple MD Cartridge Preamplifier

H. Steeman

Phonographs are gradually becoming a rarity. Most of them have had to yield to more advanced systems, such as CD players and recorders or (portable) MiniDisc player/recorders. This trend is recognised by manufacturers of audio installations, which means that the traditional phono input is missing on increasingly more systems. Hi-fi enthusiasts who want make digital versions of their existing collections of phonograph records on a CD or MD, discover that it is no longer possible to connect a phonograph to the system. However, with a limited amount of circuitry, it is possible to adapt the line input of a modern amplifier or recorder so that it can handle the low-level signals generated by the magnetodynamic cartridge of a phonograph. Of course, the circuit has to provide the well-known RIAA correction that must be used with these cartridges. The preamplifier shown here performs the job using only one opamp, four resistors and four capacitors. For a stereo version, you will naturally need two of everything. Any stabilised power supply that can deliver ±15 V can be used as a power source.

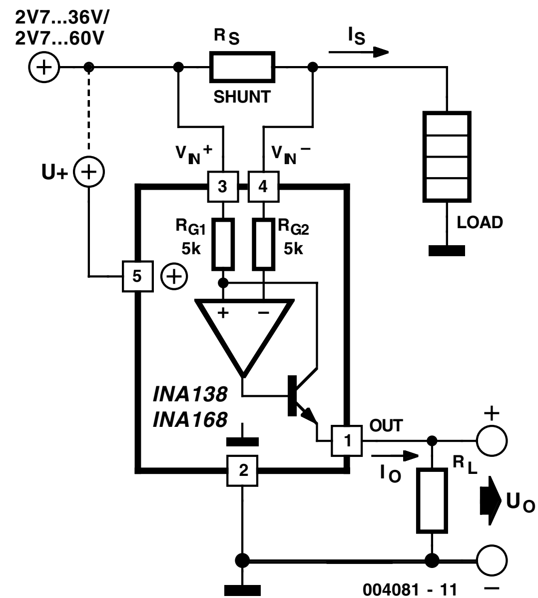
(004060-1)



032 High-Side Current Measurements

K. Walraven
(from a Burr-Brown application note)

It's always a bit difficult to measure the current in the positive lead of a power supply, such as a battery charger. Fortunately, special ICs have been developed for this purpose in the last few years, such as the Burr-Brown INA138 and INA168.
These ICs have special internal circuitry that allows their inputs to be connected directly to either end of a shunt resistor in the lead where the current is to be measured. The shunt is simply a low-value resistor, across which a voltage drop is measured whenever a current flows. This voltage is converted into an output current I_o by the IC. This current can be used directly, or it can be converted into a voltage by means of a load resistor R_L. In the latter case, the 'floating' measurement voltage across the shunt is converted into a voltage with respect to earth, which is easy to use.
The value of R_L determines the gain. A value of 5 kΩ gives 1×, 10 kΩ gives 2×, 15 kΩ gives 3× and so on. It all works as follows. Just like any opamp, this IC tries to maintain the same potential on its *internal* plus and minus inputs. The minus input is connected to the left-hand end of the shunt resistor via a 5-kΩ resistor. When a current flows through the shunt,



this voltage is thus lower than the voltage on the plus side. However, the voltage on the plus input can be reduced by allowing a small supplementary current to flow through T1. The IC thus allows T1 to conduct just enough to achieve the necessary lower voltage on the plus input. The current that is needed for this is equal to V_{shunt} / 5 kΩ. This transistor current leaves the IC via the output to which R_L is connected. If the value of R_L is 5 kΩ, the resulting voltage is exactly the same as V_{shunt}.
The IC is available in two versions. The INA138 can handle voltages between 2.7 and 36 V, while the INA168 can work up to 60 V. The supply voltage on pin 5 may lie anywhere between these limits, regardless of the voltage on the inputs. This means that even with a supply voltage of only 5 V, you can make measurements with up to 60 V on the inputs! However, in most cases it is simplest to connect pin 5 directly to the voltage on pin 3. Bear in mind that the value of the supply voltage determines the maximum value of the output voltage. Also, don't forget the internal base-emitter junction voltage of T1 (0.7 V), and the voltage drop across the shunt also has to be subtracted.

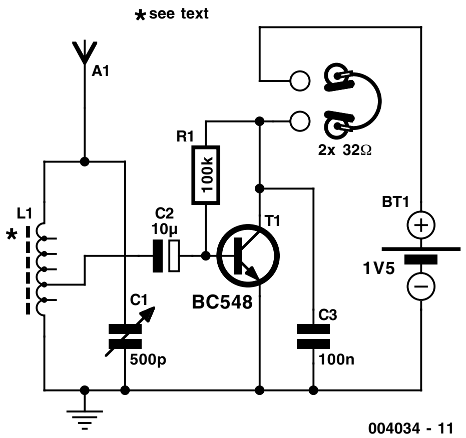
(004081-1)

033 One Transistor Radio

B. Kainka

Here is a simple circuit for a one transistor Audion type radio powered by a 1.5 V battery. It employs a set of standard low-impedance headphones with the headphone socket wired so that the two sides are connected in series thus giving an impedance of 64 Ω. The supply to the circuit also passes through the headphones so that unplugging the headphones turns off the supply. Using an Audion configuration means that the single transistor performs both demodulation and amplification of the signal. The sensitivity of this receiver is such that a 2 m length of wire is all that is needed as an antenna. The tap on the antenna coil is at 1/5th of the total winding on the ferrite rod. For details of the antenna coil see the article *Diode Radio for Low Impedance Headphones.* This circuit is suitable for reception of all AM transmissions from longwave through to shortwave.

(004034)



034 Stepper Motor Generator

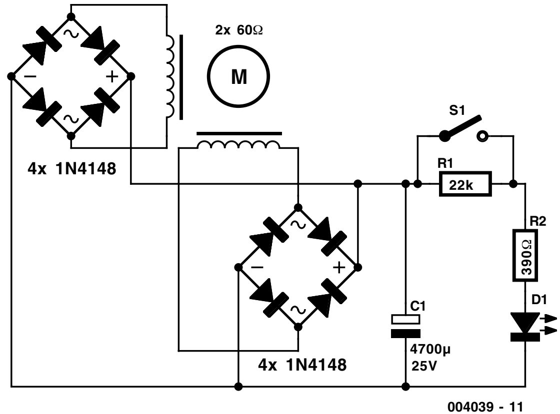
B. Kainka

Any stepper motor can be used as a generator. In contrast to other generators, a stepper motor produces a large induced voltage even at low rotational speeds. The type used here, with a DC resistance of 2×60 Ω per winding, can generate more than 20 V when turned by hand, without any gearing. The circuit diagram for a 'hand-cranked torch' shows how you can use a stepper motor as a generator.

A supplementary circuit stores the energy. Two bridge rectifiers, each made up of four 1N4148 diodes, charge the 4700-μF capacitor. The super-bright (white) LED is driven either via a 390-Ω resistor (Power Light), or via 22 kΩ in series with 390 Ω. In the latter case, the LED is not as bright, but it stays on longer.

You must restrain yourself when cranking the dynamo, since in the 'bright' setting it is possible to exceed the rated LED current of 20 mA, while in the 'long' setting it is possible to exceed the rated capacitor voltage of 25 V. If necessary, adjust the value of the LED series resistor.

The lamp is bright enough for reading in complete darkness. The stepper motor generator is thus ideal for spies, thieves and children who want to read under the bedcovers. You could also keep it handy in your hobby room, in case of a short circuit.



(004039-1)

From the workshop of the author:
http://home.t-online/home/B.Kainka

035 Video Correction for Pinnacle Studio MP10

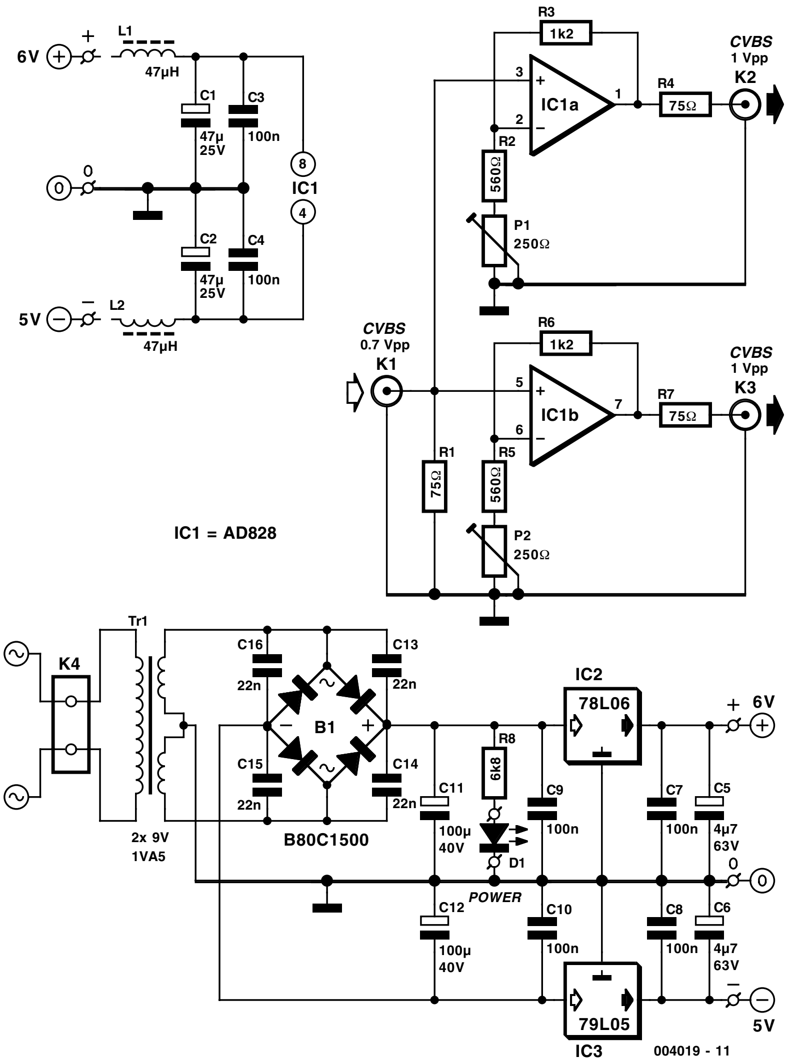
T. Giesberts

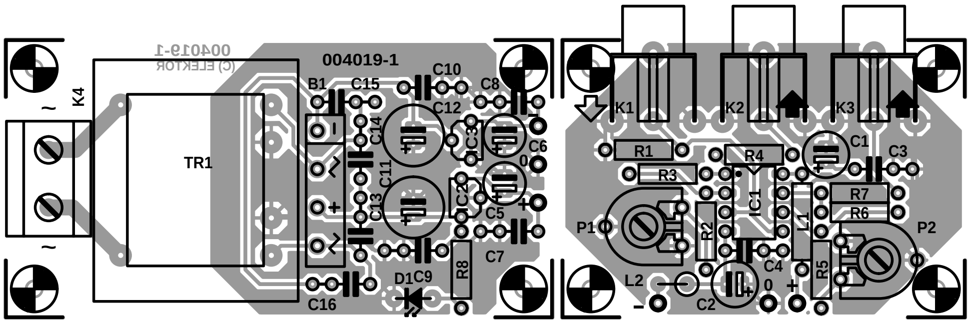
The Pinnacle Studio MP10 is an external real-time MPEG1 codec that includes composite video input and output. The output provides only 0.7 V, which is too low for most video equipment. Many video inputs are standardised for 1-V signals. The low output level of the MP10 can easily be corrected. The correction circuit, with its own small power supply, can also be used for many other applications.

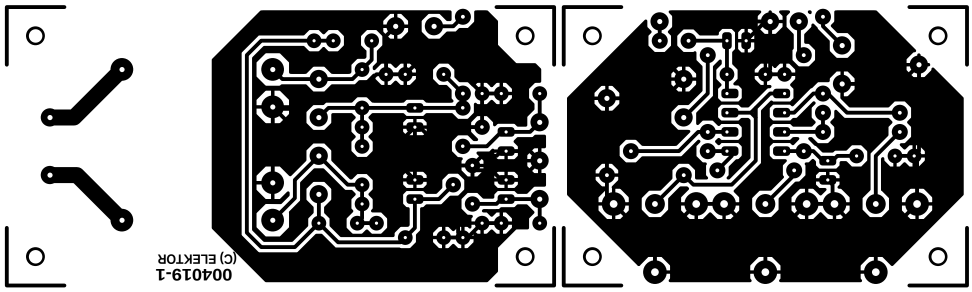
An Analog Devices AD828 dual low-power video opamp is used for the amplifier. Both opamps are connected to the output of the MP10, so two separate devices can be connected to the outputs of the correction circuit. The amplifier IC combines high bandwidth and a large slew rate with a relatively low no-load current consumption. The input and outputs of the circuit have the standard 75 Ω impedance. This means that the gain of the amplifiers must be a bit less than 3 (2 ÷ 0.7 = 2.86). Two trimpots (P1 and P2) allow the output levels to be set to the standard value, and compensate for various component tolerances. The inputs and outputs are DC-coupled, since certain video inputs need a signal with a DC offset to maintain the proper black level. With VHF/UHF modulators or video capture cards for PCs, the synchronisation may otherwise be unstable with bright pictures, since the sync pulses are weakened by the asymmetric supply voltage and the equipment in question evidently does not have clamp circuitry. According to the data sheet, the no-load bandwidth of the IC is 85 MHz at a gain of 2 with a ± 5 V supply. With a 75-Ω load (150 Ω in total), the measured bandwidth is roughly 45 MHz (1 V_{pp} across 75 Ω). The supply voltages for the IC are well decoupled by L1, L2, and C1 through C4.

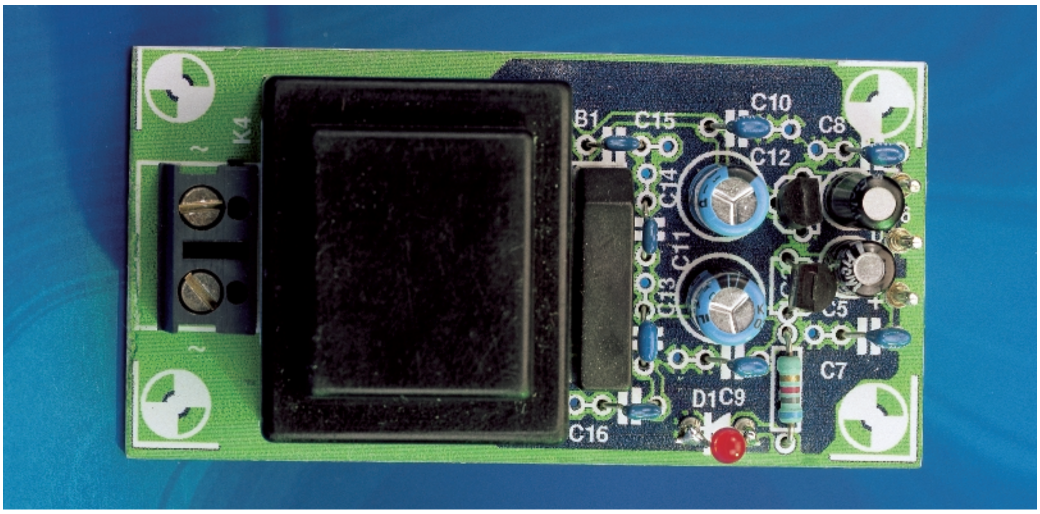
To minimise power dissipation, the supply voltages are limited to +6 V and –5 V. The positive voltage is larger, since we assume that the signal is usually positive and that consequently more headroom is needed on the positive side. The power supply is a standard design, with generous RF decoupling. The 78L06 and 79L05 voltage regulators can adequately handle the low current demand. LED D1 is the required mains power indicator, which must be externally visible when the circuit is built into an enclosure.

The printed circuit board layout uses standard components and has been made as compact as possible. IC1 was mounted in a standard IC









COMPONENTS LIST

Resistors:
R1,R4,R7 = 75Ω
R2,R5 = 560Ω
R3,R6 = 1kΩ2
R8 = 6kΩ8
P1,P2 = 250Ω preset

Capacitors:
C1,C2 = 47μF 25V radial
C3,C4,C7-C10 = 100nF ceramic
C5,C6 = 4μF7 63V radial
C11,C12 = 100μF 40V radial
C13-C16 = 22nF ceramic

Inductors:
L1,L2 = 47μH

Semiconductors:
D1 = high-efficiency LED
B1 = B80C1500 (80V piv, 1.5A peak) rectangular case
IC1 = AD828AN (Analog Devices) (Farnell)
IC2 = 78L06
IC3 = 79L05

Miscellaneous:
K1,K2,K3 = cinch sockets, PCB mount (e.g., Monacor/Monarch type T-709G)
K4 = 2-way PCB terminal block, raster 7.5 mm
Tr1 = mains transformer, PCB mount, secondary 2x9 V/1.5 VA (e.g. Monacor/Monarch type VTR-1209)

socket for the measurements, but it would be better to solder it directly to the board. The layout of the power supply and amplifier portion has been keep modest, so that you should not have any trouble finding a small enclosure to hold everything.
The no-load current of the IC is around 13 mA with no input signal. With both outputs loaded and driven, the current rises to around 16 mA.
The PCB shown here is unfortunately not available ready-made through the Publishers' Readers Services.

(004019-1)

036 Series/Parallel Equivalent Circuits in Excel

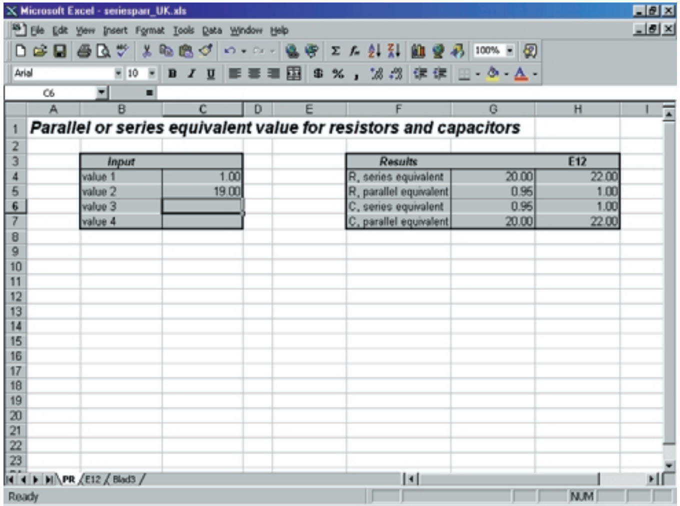
K. Walraven

We all complain occasionally about Microsoft, but the advantage of their monopoly position is that everyone has the same programs. As a result, in spite of everything there is at least a sort of standardisation. The program described here runs under Excel and calculates the serial and parallel values of resistors and capacitors.

You can enter up to four values in the input section, and the output section displays the both the calculated value and the result rounded to the nearest value in the E12 series. Enter the values with all necessary zeros, thus '3400' instead of '3k4' and '4000000' instead of '4 M'. If you want to leave a cell empty, don't type a zero, since the program won't like this (due to divide-by-zero problems). Instead, type any arbitrary value and then delete it. You can also use decimal values, with a period as a separator. You don't have to enter commas to separate the thousands; Excel will generate them automatically.

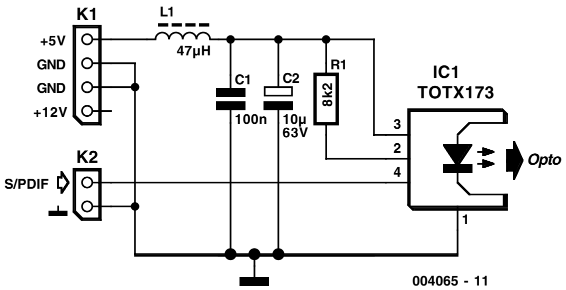
The formulas behind this program are not especially complex. A series circuit simply involves summing the values, and a parallel circuit is calculated by adding up the 1/Rx values and then computing the inverse value of the sum.

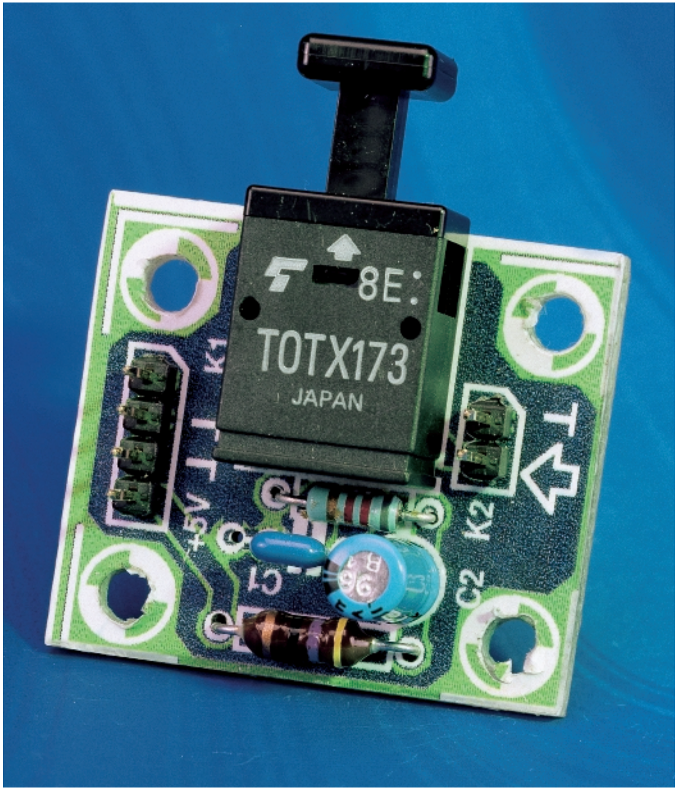
You might enjoy having a look at the program and modifying it to suit your own taste. First unlock the worksheet via Tools → Protection → Unprotect Sheet. Now you can change anything that you want. For a brief description of the routine that computes the E12 value, see the article 'E12 in Excel' elsewhere in this issue. You can find the spreadsheet on the *Elektor Electronics* website, *http://www.elektor-electronics.co.uk*.



(004071-1)

037 Optical S/PDIF Output





T. Giesberts

This little circuit is intended to be used to provide external access to an unused digital output of a CD or DVD drive in a PC. It provides an electrically isolated interface. In addition, this circuit is also handy for connecting a (portable) MD recorder, since these devices usually only have optical digital inputs.

The circuit is a standard application for the Toshiba Toslink transmitter module. On account of the large amount of interference present in the PC environment, extra decoupling for the transmitter module is provided by L1, C1 and C2. A small PC power connector can be attached to the pin header K1 (pay careful attention to the orientation; +5 V is red). The cable for the S/PDIF output of the CD or DVD player can be connected to K2. Make sure that the signal and earth leads are correctly connected. A suitable screened cable is often provided with a player that has an S/PDIF output. Otherwise, you can make your own single-lead screened cable, with a two-pole connector for a pin header at each end.

Most drives provide a standard logic level at the digital audio output, and this signal can be connected directly to the input of the Toslink transmitter without any modifications. The circuit draws approximately 13 mA.

There is only on additional remark. It seems that certain CD and DVD drives provide a signal at the S/PDIF output only when a CD is actually being played (there is not even a S/PDIF clock present if no disc is being played). This means that a recorder will miss a small part of the signal when an audio CD starts playing, since the PLL of the clock extraction circuit must re-lock to the clock signal.

The PCB shown here is unfortunately not available ready-made through the Publishers' Readers Services.

(004065-1)

COMPONENTS LIST

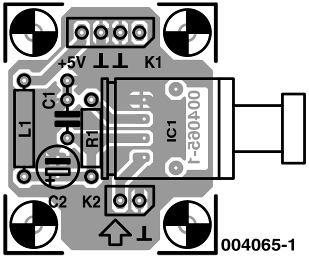
Resistor:
R1 = 8kΩ2

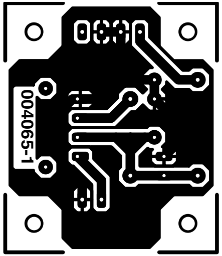
Capacitors:
C1 = 100nF ceramic
C2 = 10µF 63V radial

Inductor:
L1 = 47µH

Semiconductor:
IC1 = TOTX173 (Toshiba) (Eurodis)

Miscellaneous:
K1 = 4-pin SIL-header
K2 = 2-pin SIL-header





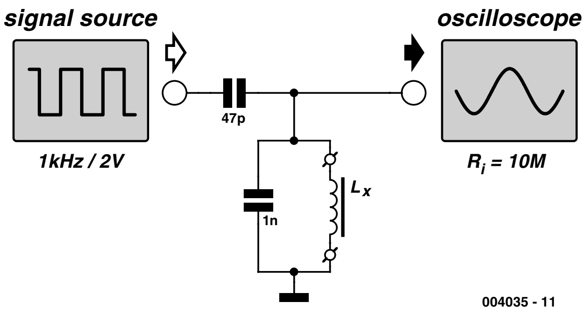
038 Measuring Inductors

B. Kainka

Often you find yourself in the position of needing to wind your own coil for a project, or maybe you come across an unmarked coil in the junkbox. How can you best find out its inductance? An oscilloscope is all you need. Construct a resonant circuit using the coil and a capacitor and connect it to a square wave generator (often part of the oscilloscope itself) Adjust the generator until you find the resonant frequency *f.* When *C* is known (1000 pF) the inductance *L* may be calculated from:

$$L = 1 / (4\pi^2 \cdot f^2 \cdot C)$$

If you are also interested how good the coil is i.e. what is its quality factor or Q, you can use the oscilloscope again. If the level of the damped oscillation drops to 0.37 (= 1/*e*) of the maximum after about 30 periods, then the Q factor of the coil is about 30.



The Q factor should be measured at the intended operating frequency of the coil and with its intended capacitor. The coupling capacitor should by comparison be a much smaller value.

(004035)

039 Simple mV Source

A. Grace

This design can be used to simulate millivolt (mV) sensor signals for industrial control systems.

Most of the new sensors used to day include some form of 'intelligence' at the measurement head, that is, the point at which the sensor comes into contact with what it is to measure. At this point, the sensor signal is conditioned/digitized and fed into a microcontroller that transmits a digital representation of the sensor value to the remote control system. However, there are still a number of 'elderly' control systems still in the field that have the intelligence remote from the sensor head. These systems rely on field wiring to convey the measured signal back to the control system.

During commissioning of these types of plant, it is useful to simulate the sensor signal to ensure amongst other things, that the sensor signal gets back to the correct terminals on the control system as they invariably pass through various junction boxes on the way. It can also be used to ensure that the control system operates correctly in response to the sensor signal.

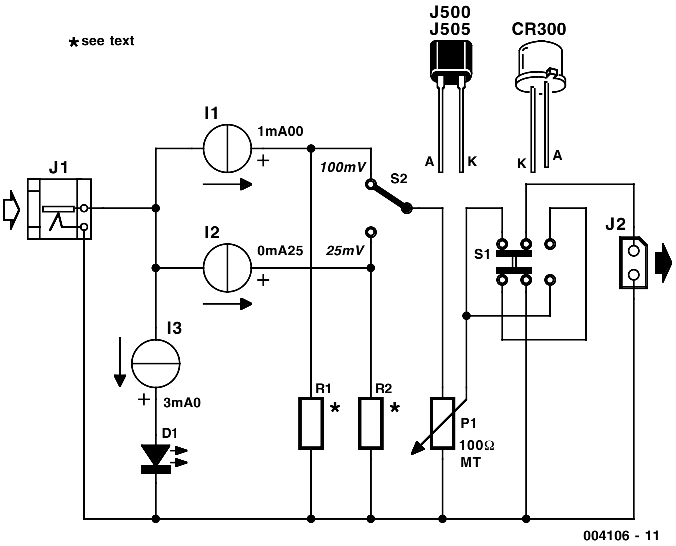
The design shown here has been used by the author to 'bench test' a control system prior to being installed. Please note that the design is only suitable for simple simulation and is not accurate enough for calibration purposes.

Power from a 'plugtop' PSU (when bench testing) or a battery is fed to three current sources (diodes). Of these, I1 generates a 1.00 mA current signal, which when switched across the 100-Ω pot creates a 100-mV signal. Likewise, I2 generates a 0.25-mA signal which generates 25 mV across the pot. Current source I3 develops 3.0 mA and is used to illuminate the LED to give a power indication. The selected current source is switched via S2 to the 10-turn pot. Switch S1 is used to cleverly swap the polarity of the output signal. If the Type MTA206PA DPDT switch from Knitter is used, you get a centre-off position which actually shorts out the output signals (S1 pins 2 and 5) together, ensuring a zero output signal.

The current sources, despite being pretty expensive, are not very accurate — they have 10% tolerance! (hence the unsuitability for calibration use). If the output is too high, the tolerance can be 'trimmed' by fitting a bleed resistor (R1, R2) as shown in the diagram. The current sources are manufactured by Vishay/Siliconix and stocked by Farnell.

The circuit draws a current of about 4.25 mA.

(004106-1)



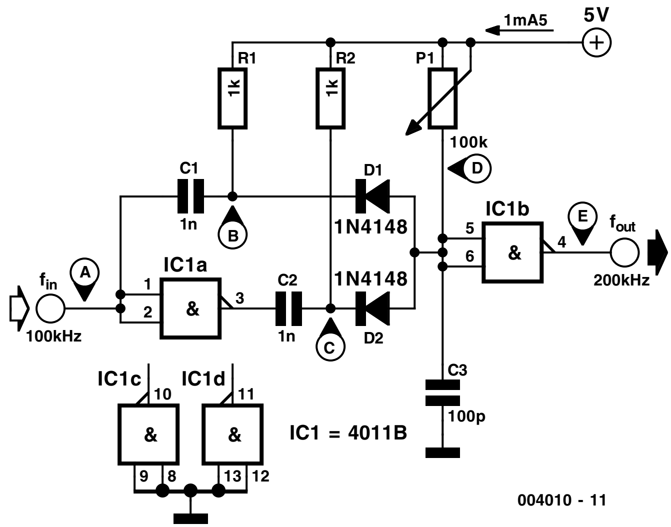
040 Simple Frequency Doubler

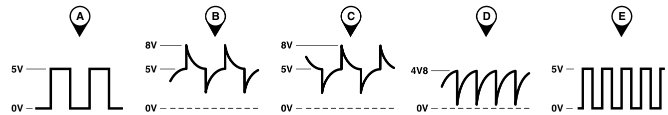
K. Kraus

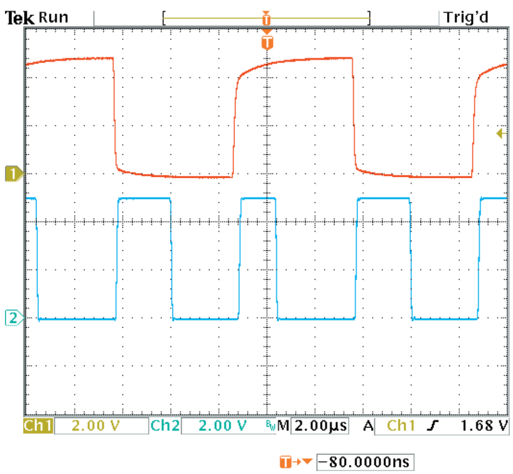
Using just a few discrete components and two inverters, it is possible to build a simple TTL square wave frequency doubler for signals up to about 100 kHz. The input signal is applied to the differentiating circuit R1-C1. This converts the rising edge of the square wave into a positive pulse and the falling edge into a negative pulse. The inverter IC1a (you could use a NAND or NOR gate with the inputs tied together) inverts the input square wave and applies it to the differentiating circuit R2-C2. This differentiator performs the same function as R1-C1 i.e., producing positive pulses on rising edges and negative pulses on falling edges but in opposite phase to the output of R1/C1. The two diodes only pass the negative parts of the two signals, so at the anodes we get a series of negative pulses at a frequency of twice the input signal.

The output consists of a capacitor, which is charged up through preset R3. Each negative pulse stops the charging process and quickly discharges the capacitor. The resultant sawtooth waveform is applied to the input to IC1b (actually, the slopes of the waveform are not linear but exponential). The final inverter converts this signal back into a square wave but with twice the frequency of the input signal. The on/off ratio of the output square wave can be adjusted by preset R3, which will alter the time constant of R3-C3.

The current consumption of the frequency doubler is approximately 1.5 mA at 5 V. The low value of R1 means that the design has a low input impedance and the input current to IC1 is greater than the suggested maximum in the data sheet for this type of IC. It is therefore important that the supply voltage is not increased above +5 V.



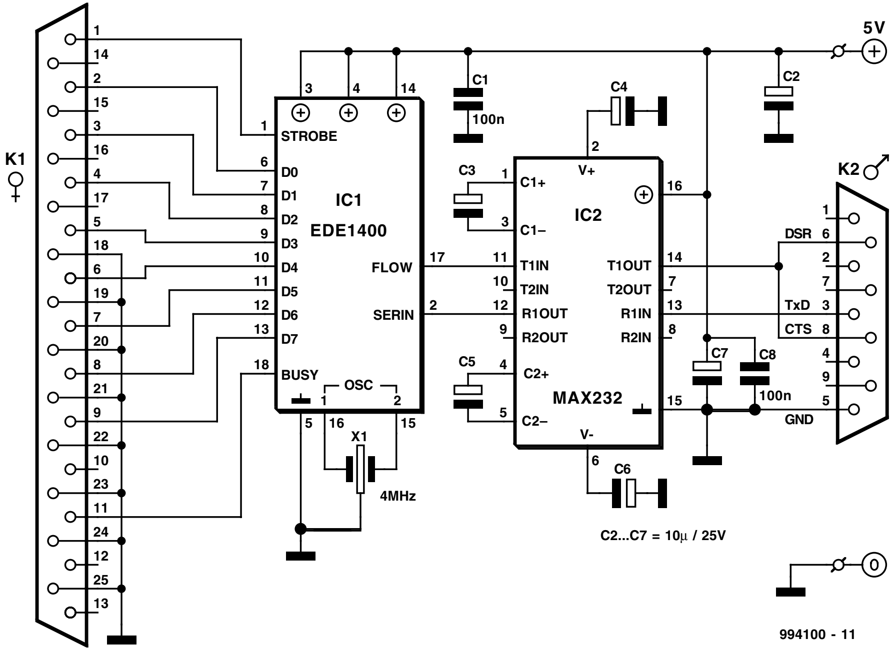




(004010)

041 Serial-to-Parallel Converter

L. Lemmens



This converter may help if just the serial port on a personal computer is free, whereas the printer needs a parallel (Centronics) port. It converts a serial 2400 baud signal into a parallel signal.

The TxD line, pin 3, CTS line, pin 8 and the DSR line, pin 6, of the serial port are used — see diagram. The CTS and DSR signals enable handshaking to be implemented.

Since the computer needs real RS232 levels, an adaptation from TTL to RS232 is provided in the converter by a MAX232. This is an integrated level converter that transforms the single +5 V supply into a symmetrical ±12 V one.

The serial-to-parallel conversion is effected by IC1. This is essentially a programmed PIC controller that produces a Centronics compatible signal from a 2400 baud serial signal (eight data bits, no parity, one stop bit). The IC also generates the requisite control signals. If there is a delay on the Centronics port, the RS232 bitstream from the computer may be stopped via the Flow signal (pin 17). This ensures that no data is lost.

The controller needs a 4 MHz ceramic resonator, X1.

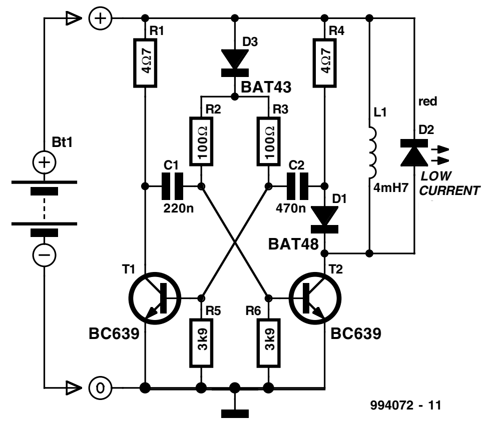
(994100-1)

042 Battery Discharger

J. Friker

The battery discharger published in the June 1998 issue of this magazine may be improved by adding a Schottky diode (D_3). This ensures that a NiCd cell is discharged not to 0.6–0.7 V, but to just under 1 V as recommended by the manufacturers. An additional effect is then that light-emitting diode D_2 flashes when the battery connected to the terminals is flat.

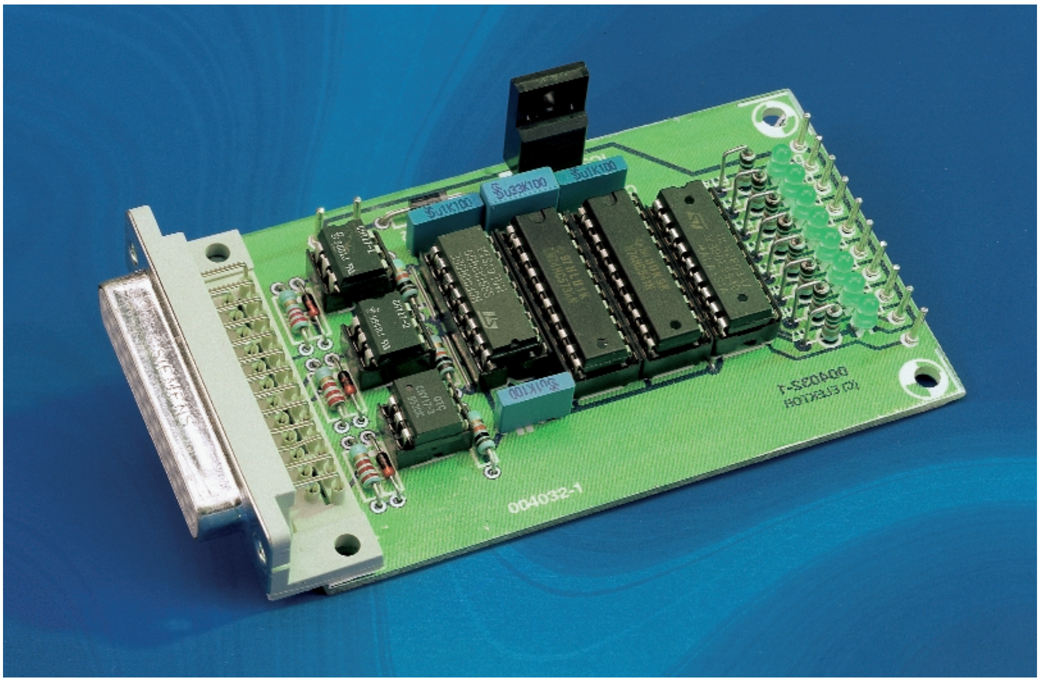
The circuit in the diagram is based on an astable multivibrator operating at a frequency of about 25 kHz. When transistor T_2 conducts, a current flows through inductor L_1, whereupon energy is stored in the resulting electromagnetic field. When T_2 is cut off, the field collapses, whereupon a counter-emf is produced at a level that exceeds the forward voltage (about 1.6 V) of D_2. A current then flows through the diode so that this lights. Diode D_1 prevents the current flowing through R_4 and C_2. This process is halted only when the battery voltage no longer provides a sufficient base potential for the transistors. In the original circuit, this happened at about 0.65 V. The addition of the forward bias of D_3 (about 0.3 V), the final discharge voltage of the battery is raised to 0.9–1.0 V. Additional resistors R_5 and R_6 ensure that sufficient current flows through D_3. When the battery is discharged to the recommended level, it must be removed from the discharger since, in contrast to the original circuit, a small current continues to flow through D_3, $R_{2-R}3$, and $R_{5-R}6$ until the battery is totally discharged



The flashing of D_2 when the battery is nearing recommended discharge is caused by the increasing internal resistance of the battery lowering the terminal voltage to below the threshold level. If no current flows, the internal resistance is of no consequence since the terminal voltage rises to the threshold voltage by taking some energy from the battery. When the discharge is complete to the recommended level, the LED goes out. It should therefore be noted that the battery is discharged sufficiently when the LED begins to flash. [994072]

043 8 Channel D/O Card for RS232

G. Vastianos



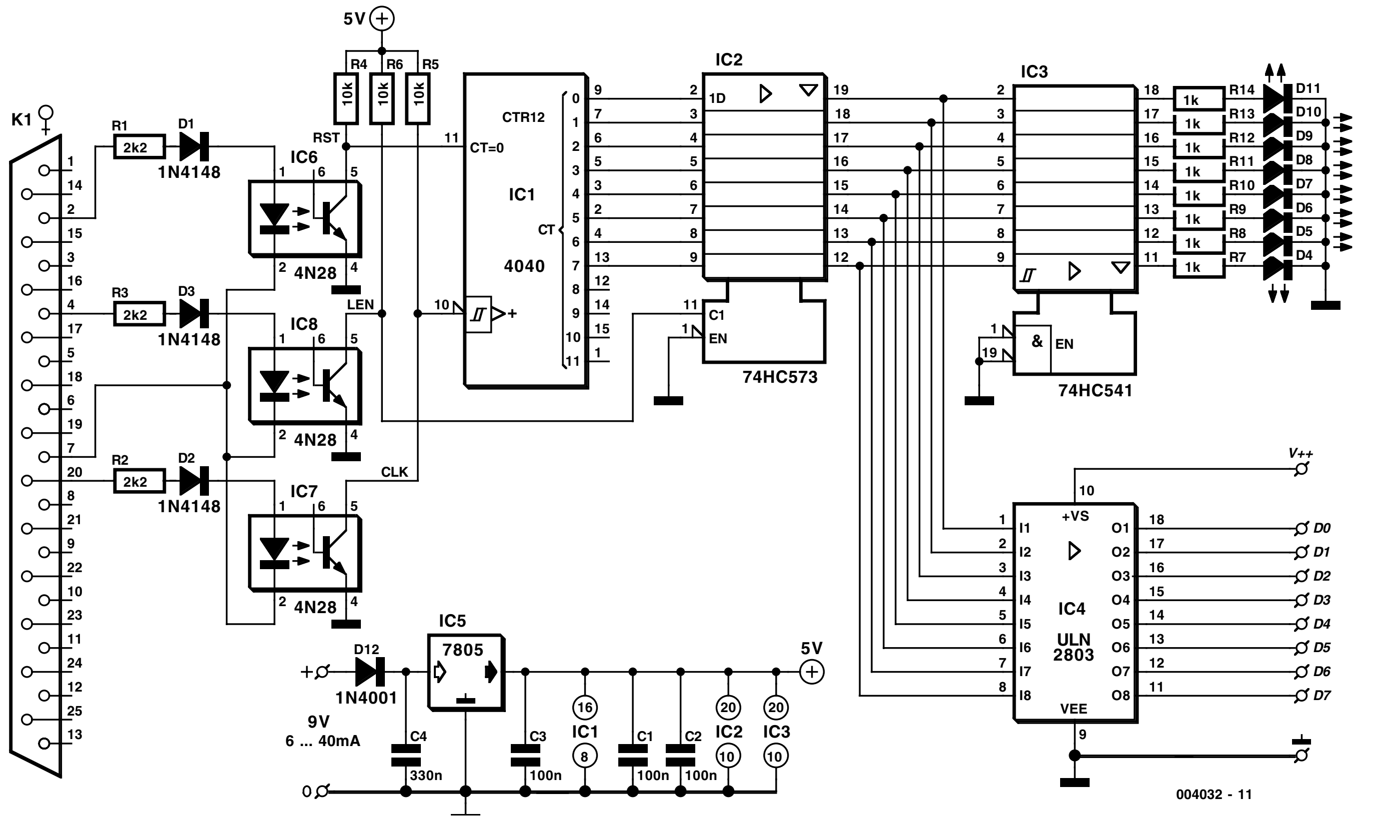
The author is a Student at the Electronics Department, Technological Educational Institute of Piraeus, Greece.

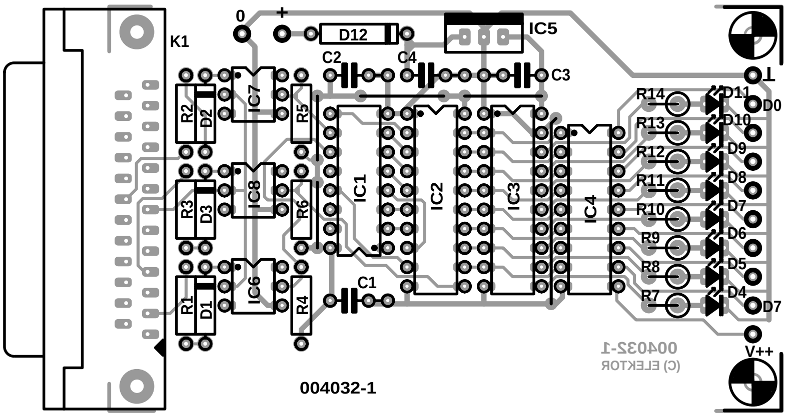
This article describes a card with 8 open-collector digital outputs for external connection to a PC serial port. The design of this card is based on direct accessing of the PC's UART registers to adapt the communication from serial to parallel.

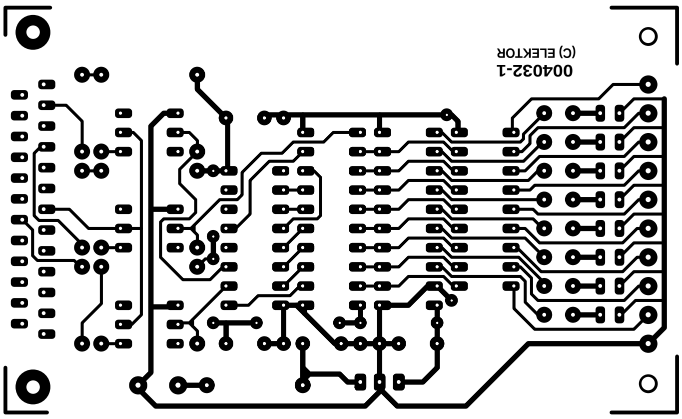
A computer may have one to four serial ports (COM1 to COM4) where each port occupies eight locations on its memory map as shown in **Table 1**.

The basic lines that a UART uses in serial communication for transmission and reception, are TXD and RXD. Also a group of extra lines (DCD, DSR, RTS, CTS, DTR, RI) is used to establish different types of serial communication. Some of these extra lines work as inputs and others as outputs, but each of them (except RXD) may be controlled through a bit in the UART register as shown in **Table 2**. The voltage levels on a serial port (RS232 levels) are officially –12V for logic 1 and +12 V for logic 0.

The computer's serial port is connected to the card through the connector K1. The three available outputs of the serial port (TXD, DTR, RTS) are applied to R1-D1, R2-D2, R3-D3 to ensure







COMPONENTS LIST

Resistors:
R1,R2,R3 = 2kΩ2
R4,R5,R6 = 10kΩ
R7-R14 = 1kΩ

Capacitors:
C1,C2,C3 = 100nF
C4 = 330nF

Semiconductors:
D1,D2,D3 = 1N4148
D4-D11 = LED, high efficiency
D12 = 1N4001
IC1 = 4040
IC2 = 74HC573
IC3 = 74HC541
IC4 = ULN2803
IC5 = 7805
IC6,IC7,IC8 = 4N28 or CNY17-2

Miscellaneous:
K1 = 25-way sub-D socket (female), PCB mount
12 solder pins

Table 1. PC COM port addresses

Register Name	COM1	COM2	COM3	COM3
Transmit/Receive Buffer	3F8h	2F8h	3E8h	2E8h
Interrupt Enable Register	3F9h	2F9h	3E9h	2E9h
Interrupt Identification Register	3FAh	2FAh	3EAh	2EAh
Line Control Register	3FBh	2FBh	3EBh	2EBh
Modem Control Register	3FCh	2FCh	3ECh	2ECh
Line Status Register	3FDh	2FDh	3EDh	2EDh
Modem Status Register	3FEh	2FEh	3EEh	2EEh
Scratch Pad Register	3FFh	2FFh	3EFh	2EFh

safe driving of the optocouplers IC6, IC7 and IC8. So when a serial port output line is at +12 V, the internal transistor of the relevant optocoupler works is driven to saturation. Conversely, when this line is at –12V, the same transistor will be cut off. The logic equations between the TXD, DTR, RTS and the RST, CLK, LEN lines are the following : RST_{TTL} = NOT TXD_{RS232} ; CLK_{TTL} = NOT DTR_{RS232}; LEN_{TTL} = NOT RTS_{RS232}.

The RST and CLK lines drive 12-bit binary counter IC1 of which only 8 bits are used. The eight least significant outputs of the binary counter are applied to latch IC2, together with the LEN line.

The normal operating sequence is as follows. First an RST pulse is generated to reset the counter. Next, we produce the number of the CLK pulses needed to get the desired logic states on all counter outputs. Finally, we produce a LEN pulse to hold the logic states at the outputs of the latch.

Buffer IC3 (74HC541) drives LEDs D4-D11, which give a visual representation of the output logic states. Another buffer, IC4, this time a ULN2803A, is the actual output stage of the card. The eight open collector outputs of the ULN2803 are available as solder pins at the card edge. Note that the ULN2803 has open-collector outputs. Each of these is capable of switching up to 50 V, while the total load current on all outputs should not exceed 500 mA.

The card has its own voltage regulator and may be powered by any mains adapter rated at 9-15 V.

The software for the communication with the card has been developed in Turbo Pascal. The communication routine is called CARD08DO. Calling this routine (from any program written in Turbo Pascal) should comply with the following syntax:

```
CARD08DO (COMADDRESS,
VALUE, DELTIME)
```

Where
`COMADDRESS:` Word type variable, must contain

Table 2. UART bit locations

Pin Name	25pin Connector	9pin Connector	COM1	COM2	COM3	COM3	Bit	I/O
TXD	#2	#3	3FBh	2FBh	3EBh	2EBh	6	O
DTR	#20	#4	3FCh	2FCh	3ECh	2ECh	0	O
RTS	#4	#7	3FCh	2FCh	3ECh	2ECh	1	O
CTS	#5	#8	3FEh	2FEh	3EEh	2EEh	4	I
DSR	#6	#6	3FEh	2FEh	3EEh	2EEh	5	I
RI	#22	#9	3FEh	2FEh	3EEh	2EEh	6	I
DCD	#8	#1	3FEh	2FEh	3EEh	2EEh	7	I

(before calling) the base address of the serial port. Acceptable values of this variable are $3F8 (for COM1), $2F8 (for COM2), $3E8 (for COM3), $2E8 (for COM4).
VALUE: Byte type variable, must contain (before calling) the arithmetic value of the 8 channels group. The 8 logic states of the 8 channels make a Byte with LS Bit Ch0 and MS Bit Ch7. Acceptable values of this variable are 0 to 255.
`DELTIME:` Byte type variable, must contain (before calling) the value of 'delay time'. Acceptable values of this variable are 0 (for a slow 8086 computer at 8 MHz) to 4 (for a fast Pentium computer running at 266 MHz).

The source code of the communication routine (CARD08DO.SUB) and a demonstration program (08DOCARD.PAS), with an executable version of the demonstration program (08DOCARD.EXE) may be downloaded from the author's website at

http://members.xoom.com/robofreak/download/08docard.htm

The PCB shown here is unfortunately not available ready-made through the Publishers' Readers Services.

(004032-1)

044 Infra-Red Light Barrier

Pradeep G.

This is a short-range light barrier for use as an intruder alarm in doorposts, etc. The 555 in the transmitter (**Figure 1**) oscillates at about 4.5 kHz, supplying pulses with a duty cycle of about 13% to keep power consumption within reason. Just about any infra-red LED (also called IRED) may be used. Suggested, commonly available types are the LD271 and SFH485. The exact pulse frequency is adjusted with preset P1. The LEDs are pulsed at a peak current of about 100 mA, determined by the 47 Ω series resistor.

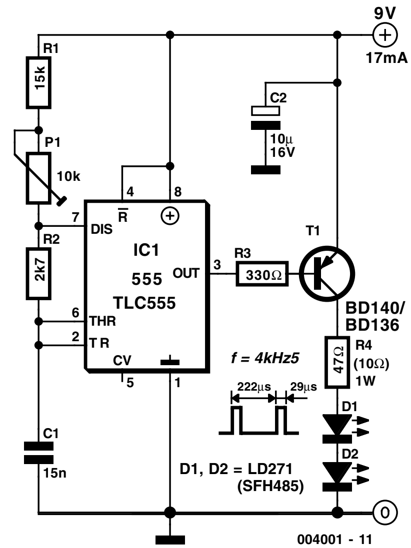
In the receiver (**Figure 2**), the maximum sensitivity of photodiode D2 should occur at the wavelength of the IREDs used in the transmitter. You should be okay if you use an SFH205F, BPW34 or BP104. Note that the photodiode is connected reverse-biased! So, if you measure about 0.45 V across this device, it is almost certainly fitted the wrong way around. The received pulses are first amplified by T1 and T2. Next comes a PLL (phase lock loop) built with the reverenced NE567 (or LM567). The PLL chip pulls its output, pin 8, Low when it is locked onto the 4.5 kHz ‘tone’ received from the transmitter. When the (normally invisible) light beam is interrupted (for example, by someone walking into the room), the received signal disappears and IC1 will pull its output pin High. This enables oscillator IC2 in the receiver, and an audible alarm is produced.

The two-transistor amplifier in the receiver is purposely overdriven to some extent to ensure that the duty cycle of the output pulses is roughly 50%. If the transmitter is too far away from the receiver, overdriving will no longer be guaranteed, hence IC1 will not be enabled by an alarm condition. If you want to get the most out of the circuit in respect of distance covered, start by modifying the value of R2 until the amplifier output signal again has a duty cycle of about 50%.

The circuit is simple to adjust. Switch on the receiver, the buzzer should sound. Then switch on the transmitter. Point the transmitter LEDs to the receiver input. Use a relatively small distance, say, 30 cm. Adjust P1 on the transmitter until the buzzer is silenced. Switch the receiver off and on again a few times to make sure it locks onto the transmitter carrier under all circumstances. If necessary, re-adjust P1, slowly increasing the distance between the transmitter and the receiver.

(004001-1)

1



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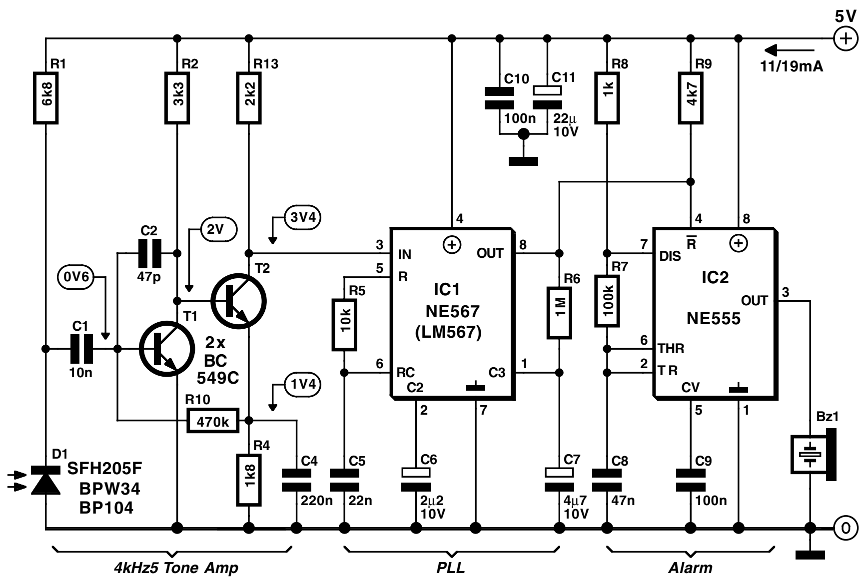
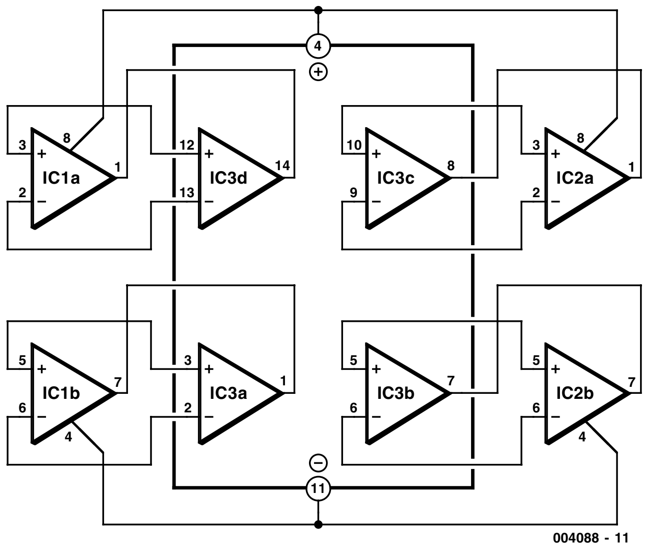
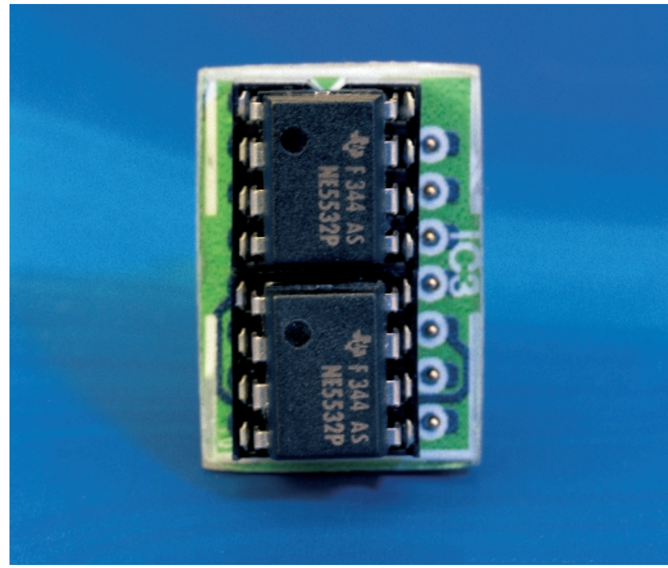
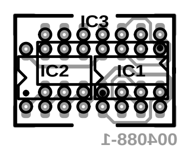
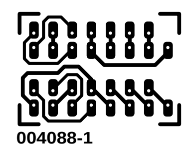


045 2 × Dual = 1 × Quad









T. Giesberts

This is a sort of sequel to the article '2 × single = 1 × dual'. In this case, two dual opamps are combined to make one new quad opamp. This allows many possible variations, and again it allows two completely different types of dual-opamps to be used.

It is very easy to replace a quad opamp if you use the printed circuit board shown here. The schematic diagram shows the interconnections between the two dual opamps and the pin locations of the quad opamp. The two dual opamps are soldered on top of the board, and two 7-pin contact strips are soldered to the bottom side. These can then be plugged into the socket of the original quad opamp.

When selecting the opamps, carefully check their pinouts, as well as that of the quad opamp to be replaced. Nowadays, most types have 'standard' pinouts, but there are a few exotic types that do not conform to the standard.

The PCB shown here is unfortunately not available ready-made through the Publishers' Readers Services.

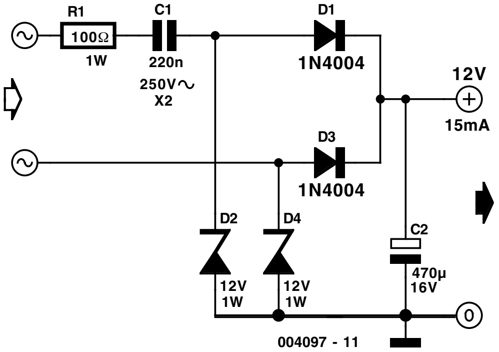
(004088-1)

046 Mains Powered!

K. Walraven

Many circuits can be powered directly from the mains with the aid of a series capacitor (C1). The disadvantage of this approach is that usually only one half cycle of the mains waveform can be used to produce a DC voltage. An obvious solution is to use a bridge rectifier to perform full-wave rectification, which increases the amount of current that can be supplied and allows the filter capacitor to be smaller. The accompanying circuit in fact does this, but in a clever manner that uses fewer components. Here we take advantage of the fact that a Zener diode is also a normal diode that conducts current in the forward direction. During one half wave, the current flows via D1 through the load and back via D4, while during the other half wave it flows via D3 and D2.

Bear in mind that with this circuit (and with the bridge rectifier version), the zero voltage reference of the DC voltage is not directly connected to the neutral line of the 230-V circuit. This means that it is usually not possible to use this sort of supply to drive a triac, which normally needs such a connection. However, circuits that employ relays can benefit from full-wave rectification.



The value of the supply voltage depends on the specifications of the Zener diodes that are used, which can be freely chosen. C2 must be able to handle at least this voltage. The amount of current that can be delivered depends on the capacitance of C1. With the given value of 220 nF, the current is approximately 15 mA.

A final warning: this sort of circuit is directly connected to mains voltage, which can be lethal. You must never come in contact with this circuit! It is essential to house this circuit safely in a suitable enclosure (see the 'Safety Guidelines' page that appears occasionally in *Elektor Electronics*).

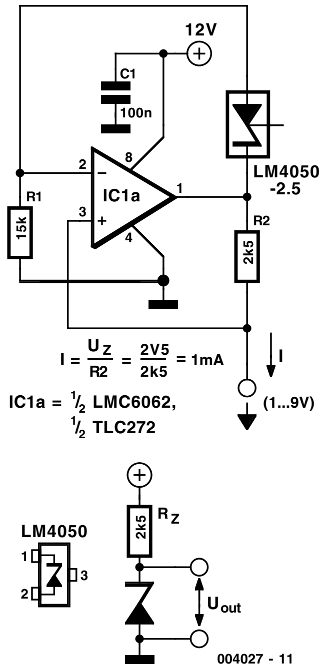
(004097-1)

047 Voltage Reference for Battery Powered Circuits

The LM4050 from National Semiconductor is a high precision micropower shunt voltage reference in a sub-miniature, surface-mount, three pin, SOT-23 package. The unit operates in the industrial temperature range of –40°C to +85°C. The design eliminates the need for an external stabilising capacitor and is at the same time stable when operated into any capacitive load. The unit is available in several different, fixed reverse breakdown voltages from 2.500 V, 4.096 V, 5.000 V, 8.192 V to 10.000 V. The minimum operating current ranges from 60 μA for the LM4050-2.5 to 100 μA for the LM4050-10.0 this, along with its tiny outline, makes it ideal for use in battery powered applications. The LM4050 is available in three different grades of accuracy of **0.1%, 0.2% and 0.5%,** all have a low temperature coefficient of less than 50 ppm/°C.

During the manufacturing process, the use of fuse and zener-zap reverse breakdown voltage trimming ensure that the premium (or A grade) components have an accuracy of better than ± **0,1%** at 25°C. Stable reverse breakdown accuracy over a wide range of temperatures and operating currents is achieved by bandgap reference temperature drift curvature correction and a low dynamic impedance. Altogether this is a versatile component with an impressive specification.
The full data sheet is available from the web site: *www.national.com*

(004027)

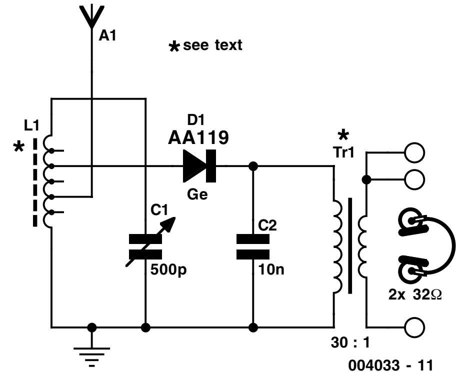


048 Diode Radio for Low Impedance Headphones

B. Kainka

If you ever look at construction notes for building old detector type radios the type of headphones specified always have an impedance of 2 × 2000 Ω. Nowadays the most commonly available headphones have an impedance of 2 × 32 Ω, this relatively low value makes them unsuitable for such a design. However, with a bit of crafty transformation these headphones can be used in just such a design. To adapt them, you will need a transformer taken from a mains adapter unit, the type that has a switchable output voltage (3/4.5/6/9/12 V) without the rectifying diodes and capacitor. Using the different taps of this type of transformer it is possible to optimise the impedance match.

For the diode radio (any germanium diode is suitable in this design) the key to success is correct impedance matching so that none of the received signal energy is lost. The antenna coil on the 10 mm diameter by 100 mm long ferrite rod is made up of 60 turns with a tap point at every 10 turns; this is suitable for medium wave reception. If a long external aerial is



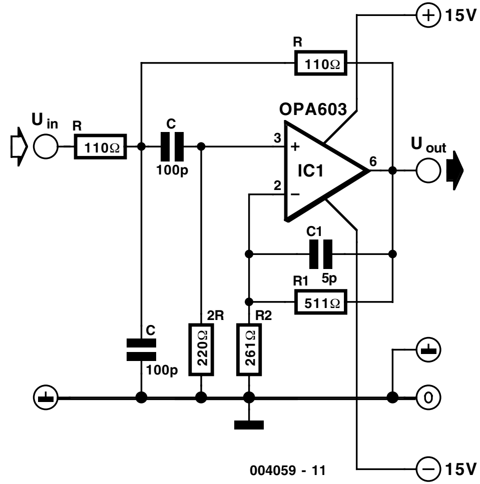
used it should be connected to a lower tap point to reduce its damping effect on the circuit. You can experiment with all the available tapping points to find the best reception. With such a simple radio design, the external aerial will have a big influence on its performance. Tip: If your house has metal guttering and rain water pipes, it will be possible to use these as an aerial, as long as they are not directly connected to earth. Those who live in the vicinity of a broadcast transmitter may be able to connect a loudspeaker directly to the output or if the volume is too low, why not try connecting the active speaker system from your PC?

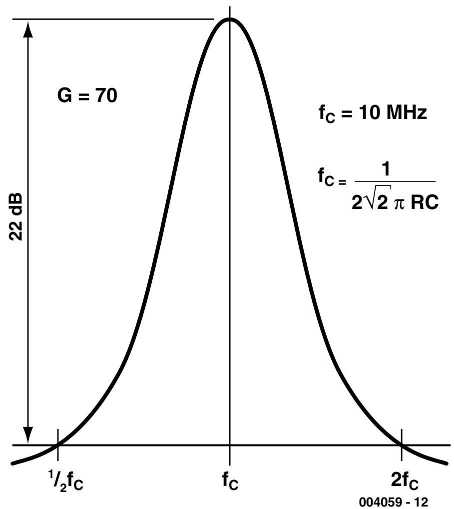
(004033)

049 Single-Opamp 10-MHz Bandpass Filter

H. Steeman

A bandpass filter is usually used to pass frequencies within a certain frequency range. If a high-performance opamp is used, such a filter can also be used at relatively high frequencies. As shown in the schematic diagram, here we have chosen an OPA603, which is a fast current-feedback opamp with a 100 MHz bandwidth for gain values between 1 and 10 (0 to 20 dB). If the circuit only has to handle a narrow range of frequencies, as in this case, the gain can be increased. With a current-feedback opamp, just as with an ordinary opamp, the negative feedback between the output and the inverting input determines the gain. In addition, the impedance of the feedback network determines the open-loop gain and the frequency response. With the component values shown in the schematic diagram, signals outside the passband are attenuated by 22 dB. The centre frequency of the filter is 10 MHz. As indicated by the printed formula, the centre frequency can easily be altered. However, keep in mind that 10 MHz is roughly the maximum frequency at which this circuit can be used. The circuit can be powered by a supply voltage of ±15 V.





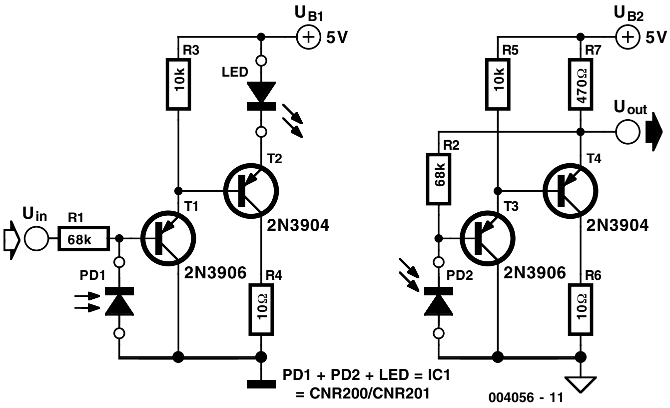
(004059-1)

050 Analogue Optical Coupler

H. Steeman

It is sometimes necessary to make an electrically isolated connection in a circuit. An optocoupler is usually the key component in such a situation. In most optocouplers, a single light-emitting diode (transmitter) and a single photodiode (receiver) are optically coupled inside the package. This solution is satisfactory for transferring digital levels (such as the control signals for a thyristor), since only two logical states (LED on or LED off) have to be transferred. An exact (analogue) coupling is thus not necessary.

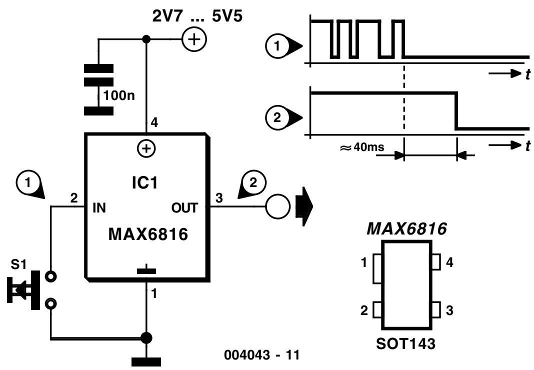
If an analogue voltage must be transferred, then it is important that the voltages at the input and the output closely track each other. To make this possible, the transmitter and receiver must employ comparable components that are incorporated into an analogue circuit. The type CNR200 and CNR201 opto-

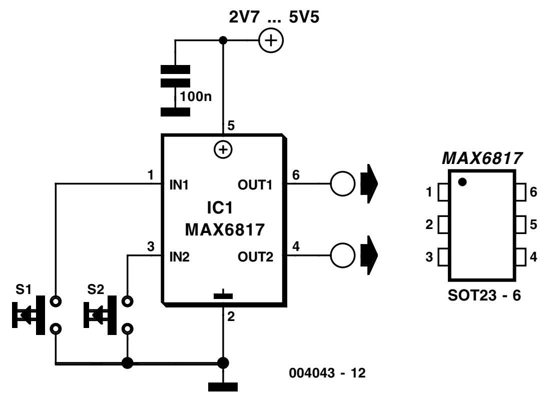


couplers that are available from Agilent (formerly Hewlett-Packard) contain all the essential components for such a function. There are two photodiodes and one LED in a single package, with an optical coupling between the LED and one of the photodiodes. The schematic diagram shows how the transmitter LED is optically coupled to the photodiode in the receiver. The remaining photodiode is incorporated into the transmitter and ensures that the characteristic of the transmitter amplifier is the same as that of the receiver. Assuming a supply voltage of 5 V, analogue voltages in the range of 0 to 3 V can be readily transferred. The isolation voltage between the input and output of this optocoupler is 1000 V. The value that can be achieved in practice depends on the printed circuit board layout.

(004056-1)

051 Single-Chip Switch Debouncer





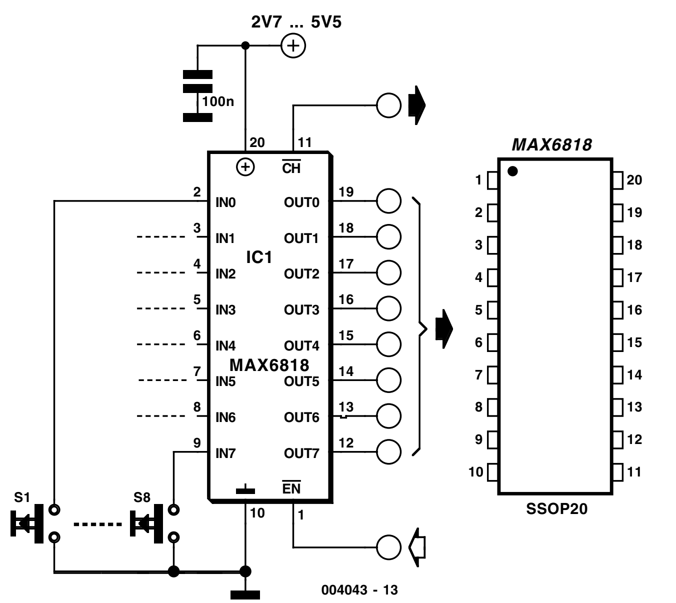
G. Kleine

Contact bounce is an age-old problem with all types of push-button switches and keypads that are connected to digital components. The measures that are used to deal with the repeated closing of the contacts when the switch is first activated include *RC* networks, flip-flop circuits and software routines. Now there is a single IC that takes over this task and delivers clean digital pulses to the following circuitry.

The MAX 6816, MAX 6817 and MAX 6818 ICs are well-protected pushbutton switch debouncers with one, two and eight inputs, respectively. The wiring for these ICs is simple, as shown in **Figure 1**. No external components are needed. The switches connected to the inputs need only make contact to earth. Internal pull-up resistors are provided. These ICs work with supply voltages between 2.7 V and 5.5 V, with a current consumption of less than 20 μA. The inputs can handle (fault) voltages up to ±25 V and electrostatic discharges up to ±15 kV.

Each MAX 681x IC works with an internal oscillator that clocks a counter. The counter is always reset whenever the input level changes within 40 ms. Only after the level applied to the input remains stable for longer than 40 ms will the counter increment to its final count and enable the output signal. This sort of debouncing is used for both closing and opening the switch.

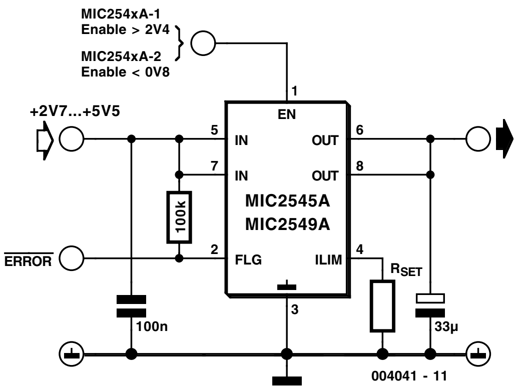
The MAX 6818 can be connected directly to a data bus, since it has an enable input (/EN) that switches the outputs to a high-impedance (tri-state) condition when a High level is applied. There is also a Change output (/CH), which indicates a change of state of one of the pressed keys. The /CH output can be directly connected to the interrupt input of a microprocessor system. The pinout of the MAX 6818 corresponds to that of the well-known 74xx573 latch, so it can be directly substituted for the latter IC.

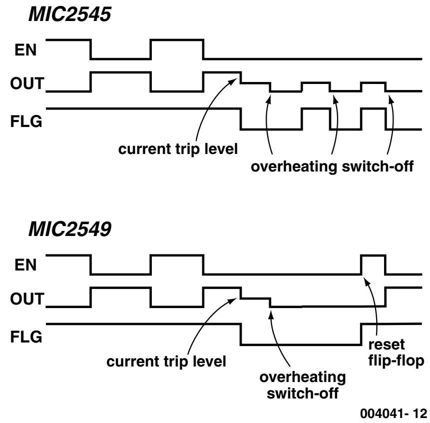


The MAX 6816 comes in a tiny SOT-143-SMD package, while the MAX 6817 comes in a 6-pin SOT23 SMD package and the MAX 6818 in a SSOP20 package. Data sheets for these debouncer ICs can be obtained via the Internet from *www.maxim-ic.com*.

(004043-1)

052 Switch ICs with Adjustable Current Limiting





G. Kleine

Transistors are often used for switching power supply voltages. MOSFETs are most often used, since they have low 'on' resistances, and they are also available for large currents. What a discrete transistor or MOSFET lacks are protective functions, such as current limiting and overtemperature protection.

The MIC2545A from Micrel can provide a solution to this problem. This MOSFET switch has programmable current limiting, as well as undervoltage and overtemperature cutouts. It works with input voltages between +2.7 V and +5.5 V. With a typical 'on' resistance of only 35 mΩ, this IC can switch up to 2.5 A in a DIP8, SO8 or TSSOP14 package. It also includes a soft-start circuit, which limits the switch-on current for the first two milliseconds. An integrated charge pump generates the gate voltage needed for switching the MOSFET.

The current limiting level can easily be set by an external resistor between the ILIM pin and earth. The resistance value can be calculated using the following simple formula:

$R_{set} = 230 / I_{lim}$

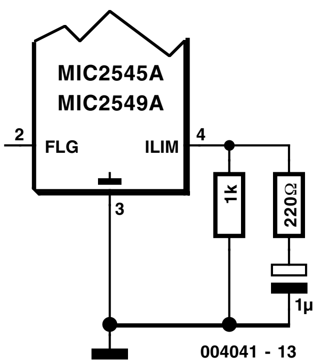
where the current I_{lim} is in ampères and the resistance R_{set} is in ohms. For a maximum current between 0.5 and 2.5 A, the resistance thus lies between 460 Ω and 92 Ω. In case of a short circuit, the current is limited to around $1.6 I_{lim}$.

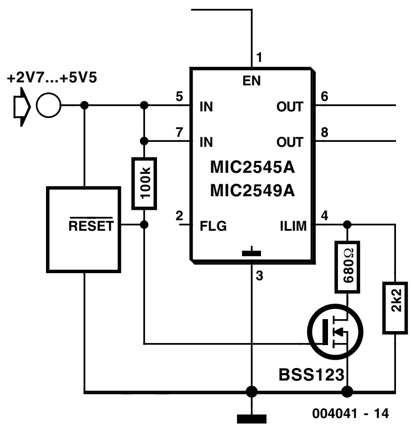
The MIC2454A is controlled via an Enable input. In order to satisfy all possible applications, it is available in two versions. The MIC2454A-1 switches on the MOSFET when the Enable input is High (V_{in} > 2.4 V), while the MIC2454A-2 version switches on the MOSFET when the Enable input is Low (V_{in} < 0.8 V). The IC typically draws 90 µA when the switch is enabled, but it draws less than 1 µA in the switched-off state. This means that it can also be used for switching on battery-operated equipment. The low operating current consumption of the MIC2545A makes a mechanical battery switch unnecessary.

The operating state of this high-side switch is indicated by an open-gate flag output. An error condition (overcurrent, undervoltage or overtemperature) in signalled by a low resistance at this output, so that an external pull-up resistor is pulled to earth.

The MIC2545A switches on again after an overtemperature cutout as soon as the chip temperature has dropped sufficiently. However, in some cases it may be desirable to save the overtemperature state and prevent the output from automatically being switched on again after an overtemperature excursion. In such cases, the derivative type MIC2549A can be used. It contains a flip-flop, which must be reset by deactivating the Enable signal before the switch can be re-enabled. The MIC2549A is also available in two versions, namely the MIC2549-1 with active high Enable and the MIC2549-2 with active low Enable.

The overtemperature cutout is triggered at a chip temperature of approximately 130 °C. The switch can be re-enabled after the temperature drops below 120 °C.





The MIC2545A has an interesting feature that allows the switch-on current for a following assembly to be increased. If a series RC combination is connected in parallel with R_{set}, the effective resistance connected to the ILIM pin is reduced for a short time immediately after switch-on. During the charging time for the capacitor (corresponding to the time constant of the RC combination, $t = RC$), the two resistors are connected in parallel, and the current limit value is thus increased. Once the capacitor is charged, only the normal resistor is effective. An additional interesting possibility is to switch the current limiting level to a different value by means of a transistor, which can for example be driven by a reset IC or a supply voltage monitoring IC. This allows the switch-on current to be limited to a lower level. As long as the input voltage is not high enough, the current limiting level is switched to a low value, since $\overline{\text{RESET}}$ is Low and the FET is cut off, so that only one of the two resistors is effective. As soon as the input voltage is OK, the $\overline{\text{RESET}}$ signal goes High and switches on the FET. Both resistors are now connected in parallel, and the current limiting level lies at a higher value. You can obtain more information at *www.micrel.com*.

$R_{SET} = 230\ V/I_{LIM}$

$0.5\ A \le I_{LIM} \le 2.5\ A$

$I_{LIM}\,|_{t<RC} = 230\ V / (1\ k\Omega\,||\,220\ \Omega) \approx 1.3\ A$

$I_{LIM}\,|_{t>RC} = 230\ V / 1\ k\Omega \approx 0.23\ A$

$RC = 220\ \Omega \cdot 1\ \mu F = 220\ \mu s$

$I_{LIM} = 230\ V / 2.2\ k\Omega \approx 100\ mA$

$I_{LIM} = 230\ V / (680\ \Omega\,||\,2.2\ k\Omega) \approx 440\ mA$

(004041-1)

053 Opto-Isolated RS232 Interface

A. Grace

This design is for a simple half-duplex optically isolated interface that converts a 20 mA current loop (connected to J2) into an RS232 signal (on J1) which can be monitored by, say, a laptop PC. In the author's case, the system operates at 1200 baud. The signal to be monitored should be a fully digital on-off communications signal, rather than the usual 4/20 mA (industrial) analogue transmission standard.

The overall action of the interface is of double inversion. The current in the comms signal is normally present when no data is being sent, and the current is switched off to represent data. Consequently the transistor in the opto-isolator is normally switched on, giving a low at the input to IC1c. This is inverted to give a high (+12 V) on the RS232 input, which is the default condition for no data.

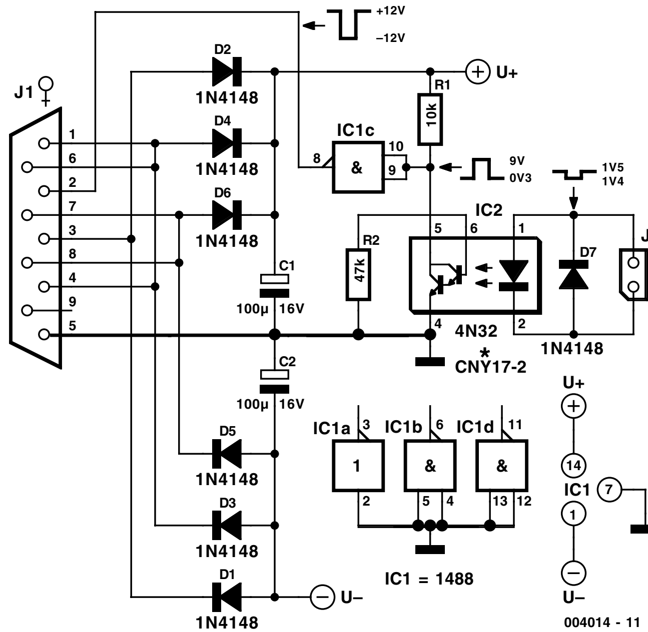
The interface itself is powered by the serial (RS232) port used to monitor the comms signal. This is achieved by stealing power from unused RS232 signal lines. The standard RS232 connector is a 9-way male 'D' type whose connections are shown in the table.

The positive and negative supply rails for IC1 are set up by rectifying the unused RS232 potentials via diodes D1 through D6, with C1 and C2 acting as reservoir capacitors.

Opto-isolator devices normally switch on reasonably fast but are relatively slow to switch off. Resistor R2 speeds up turn-off time. Diode D7 has been included to protect the opto-isolator against excessive reverse voltages — these may occur when the interface is accidentally wired back to front.

If voltage drive is used instead of 0/20 mA pure current drive, a current limiting resistor is required at the opto-isolator input. This resistor will typically be between 330 Ω and 1 kΩ, and the LED current should always be kept well below 50 mA to prevent damage to the opto-isolator.

Pin no.	Signal	In/Out
1	DCD	In
2	RxD	In
3	TxD	Out
4	DTR	Out
5	Common	
6	DSR	In
7	RTS	Out
8	CTS	In
9	RI	In

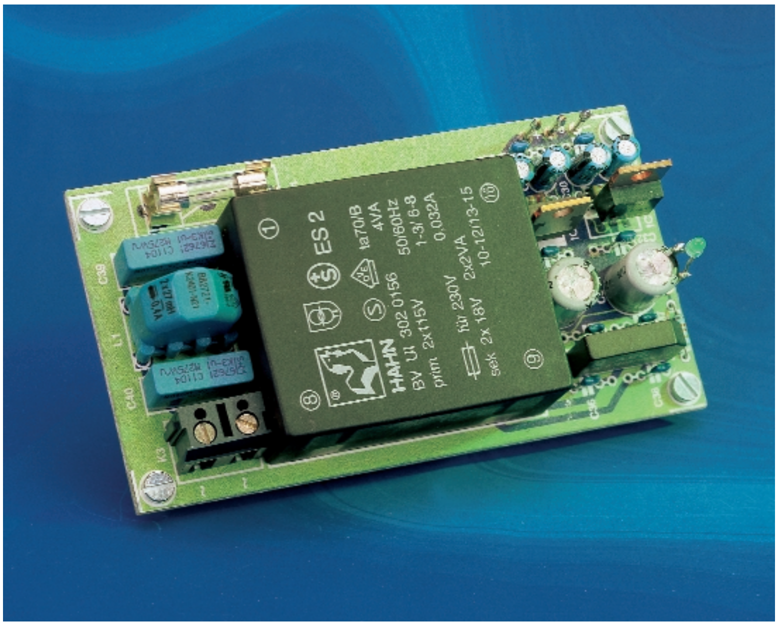


The circuit may be modified for compatibility with 4/20 mA industrial current-loop systems by carefully matching the value of R2 to the opto-isolator used. In general, the lower the value, the less sensitive the interface will become. Almost any opto-isolator device may be used provided its transfer is close to 100% (or '1' — check datasheets). Good results were obtained with, among others, the Siemens CNY17-2. This device boasting a breakdown voltage specification of 5,300 V, it is Class-2 compliant provided the distance between the pins is greater than 6 mm. This however will require some bending. For Class-1 safety requirements, the normal pin distance governed by an 8-way DIL socket is adequate.

(004014-1)

054 Universal Symmetric Power Supply

T. Giesberts



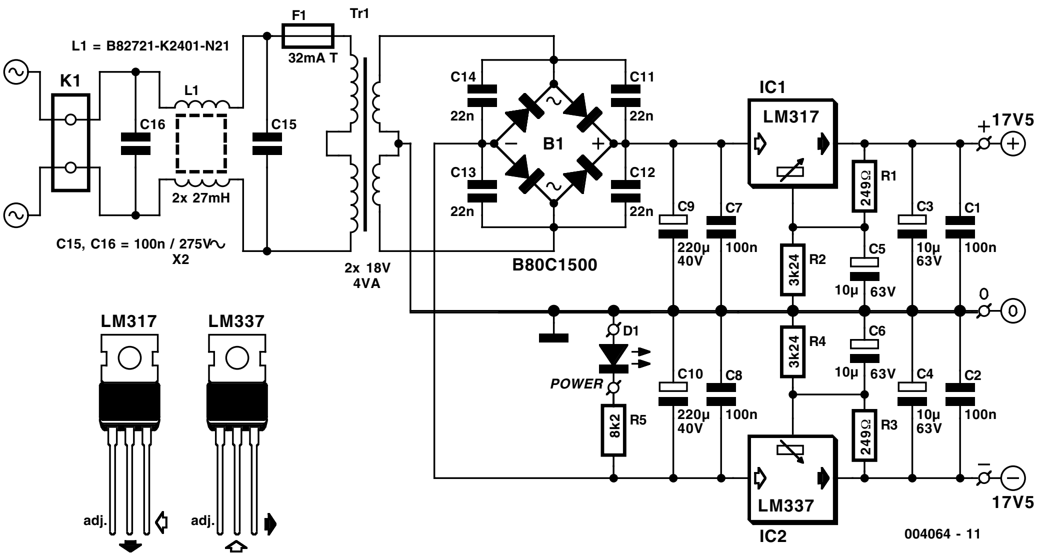
This power supply has been specially designed for the 20th-order filter described elsewhere in this issue, but it can also be used for a legion of other opamp circuits. The supply voltage is set to ±17.5 V, in light of the maximum output level of the filter. This benefits the signal to noise ratio. The specified absolute maximum supply voltage for most opamps is ±18 V, and we have intentionally kept a bit below this limit.

The transformer is one of a series made by Hahn (model UI 30), so the circuit can be easily adapted for higher power levels by using a different transformer. All transformers in this series have the same footprint (53 × 44 mm), with only the height changing according to the power capacity. The series consists of 3, 4, 6, 10 and 16-VA models, which are respectively 16.3, 18.3, 21.8, 27.7 and 37.6 mm high. There are two secondary windings, with standard voltages of 2 × 6, 2 × 9, 2 × 12, 2 × 15 and 2 × 18 V. We chose a 4 VA transformer with 2 × 18 V secondaries for this application. Certain models are also available from other manufactures, but the locations of the secondary connections are different. The circuit board layout can accommodate two different types.

The circuit is based on the well-known LM317 and LM337 voltage regulators. Since the output voltages are set by voltage dividers, any voltage between 1.25 V and 40 V is possible. In case you don't already know, the formula for the positive output voltage (LM317) is

$$V_{out} = 1.25 \cdot (1 + R2/R1) + I_{adj} \cdot R2$$

The same formula applies to the negative regulator, using R3



COMPONENTS LIST

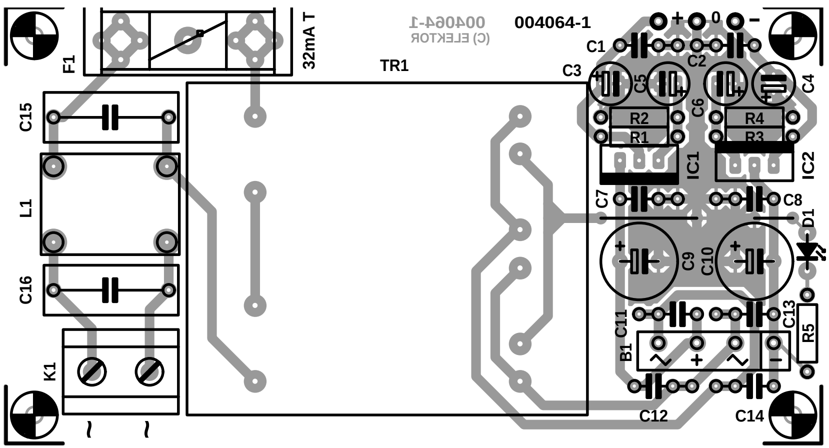
Resistors:
R1,R3 = 249Ω 1%
R2,R4 = 3kΩ24 1%
R5 = 8kΩ2

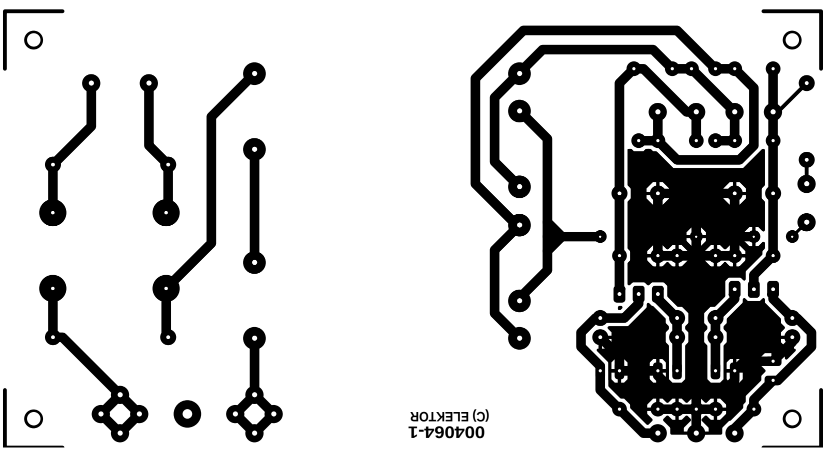
Capacitors:
C1,C2,C7,C8 = 100nF ceramic
C3...C6 = 10µF 63V radial
C9,C10 = 220µF 40V radial
C11-C14 = 22nF ceramic
C15,C16 = 100nF 275V_{AC} class X2

Inductors:
L1 = 2x27 mH (e.g., Siemens type B82721-K2401-N21) (Electrovalue)

Semiconductors:
D1 = high-efficiency LED
IC1 = LM317T (TO220 case)
IC2 = LM337T (TO220 case)

Miscellaneous:
K1 = 2-way PCB terminal block, raster 7.5mm
B1 = B80C1500, rectangular case (80V piv, 1.5A peak)
F1 = fuse, 32mA slow, with PCB mount holder and cap
Tr1 = mains transformer, PCB mount, secondary 2x18 V/4VA (e.g., Hahn type BV UI 302 0156)
PCB, order code **004064-1**





and R4 instead. Capacitors C5 and C6 increase the ripple suppression to 80 dB. Depending on the application and the output power, it may be necessary to use heat sinks for the regulator ICs.

The power supply has a simple mains filter to suppress common-mode interference. This is primarily needed if the supply is used to power sensitive circuits. The coil is a Siemens type that has been used in many other *Elektor Electronics* projects. D1 acts as a mains voltage indicator. The indicated value of the fuse, both in the diagram and on the circuit board, is 32 mA (slow). This value will have to be modified for higher power levels (as will the label on the circuit board!). With lower output voltages and larger output currents, the filter capacitors C9 and C10 must be made larger. The working voltage can then be reduced, so the physical dimensions will probably remain the same.

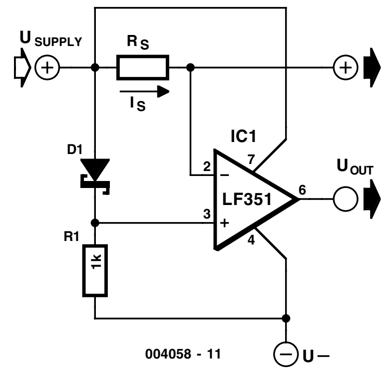
The PCB shown here is available ready-made through the Publishers' Readers Services.

(004064-1)

055 Sensitive Overload Sensor

H. Steeman

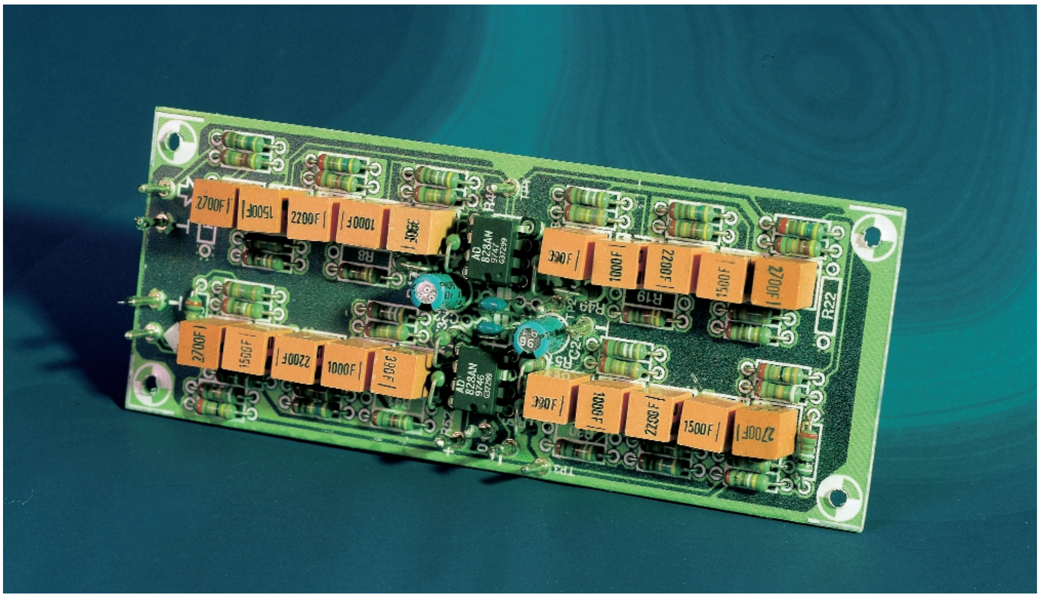
The best way to measure the current in a circuit is to place a sense resistor in the current path. The higher the resistance, the more exact the measurement will be. However, the drawback of a high resistance is that it affects the operation of the circuit in which the measurement is being made. If an active sort of sensor is used, the sense resistance can be kept small. The circuit diagram shows how a sensitive overload indicator can be built using a simple opamp (such as an LF351) and a sense resistor in the current path. A voltage difference is generated between the plus and minus inputs of the opamp with the help of a diode. Usually, the voltage drop across D1 (a Schottky diode) will be 0.2 to 0.3 V. This value can be influenced somewhat by R1, which affects the amount of current that flows through the diode. The larger the value of R1, the smaller the voltage drop across the diode. The inverting input of the opamp is connected to the positive supply voltage following the sense resistor R_S. Consequently, the voltage level at the output of the opamp will be equal to the negative supply voltage, for example –5 V. As the current that flows through the sense resistor R_S increases, the voltage on the inverting input of the opamp decreases. As soon as the voltage drop across R_S (= $I_S \times R_S$) becomes slightly greater than the voltage drop across D1, the output of the opamp will switch to the positive supply voltage level. An indicator lamp or relay can be connected to the opamp output. The maximum supply voltage for the opamp is ±15 V, so the circuit can readily be used to monitor symmetric power supplies with voltages between 5 and 15 V.



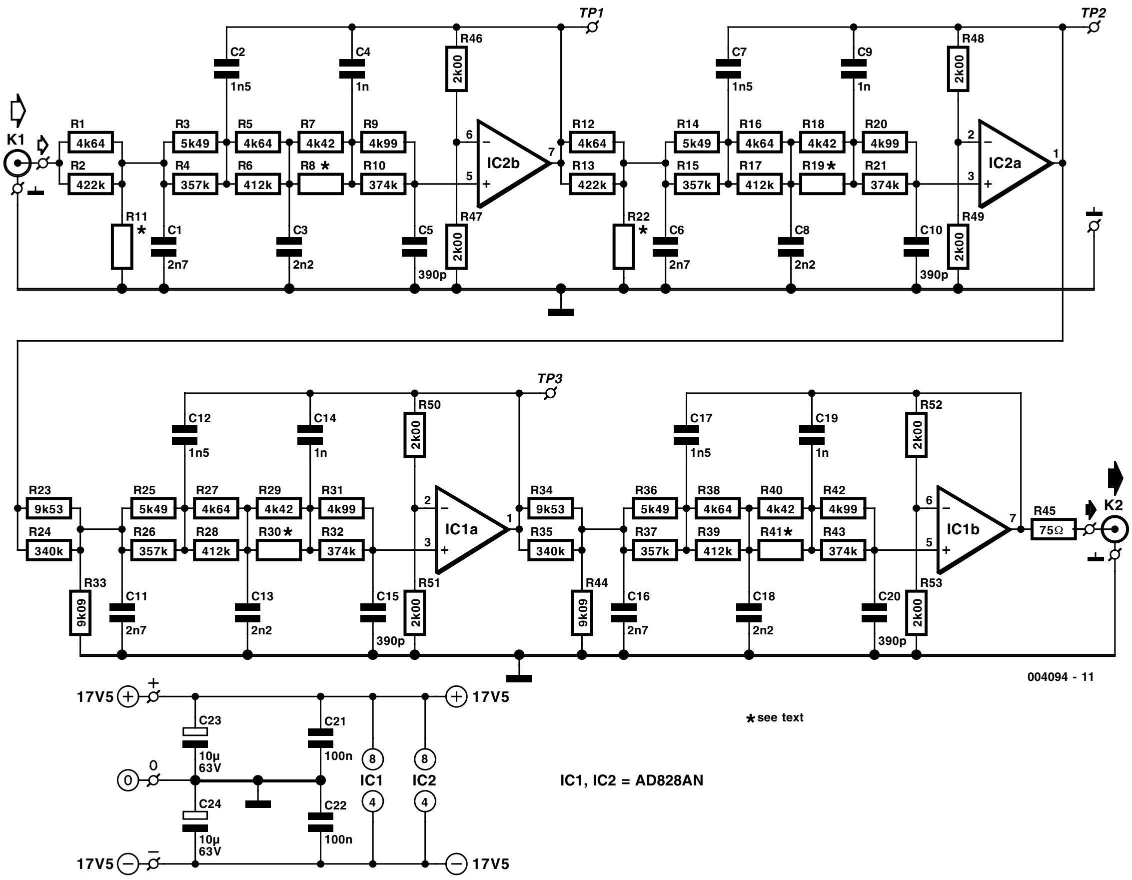
(004058-1)

056 20th-Order Measurement Filter

T. Giesberts



This circuit is based on the configuration of a fifth-order Butterworth filter using only one opamp (see p 116 of the 1995 Summer Circuits issue). Here we achieve a 20th-order filter by connecting four fifth-order sections in series. The first three sections are tapped off at TP1, TP2 and TP3. As you will see, the transfer characteristic is not a pure 20th-order Butterworth, but it does have the steepness of such a filter. The desired bandwidth for the whole filter is achieved by adjusting the turnover point of each section to a higher value. The –3 dB bandwidth of the total filter is theoretically set to 22 kHz, which means that a value of 26 kHz must be used for each section. The measured total bandwidth of the prototype is 20.9 kHz. In this regard, we have to point out that all components must be selected with a tolerance of less than 0.1 percent, since it is otherwise pointless to try to copy the circuit. Excessive tolerances in the component values will degrade the characteristics of the filter. There are 12 components per section that must be selected within this tolerance (with each parallel network counting as one component)! Even with selected components, the practical implementation will always vary a bit from the theoretical behaviour (with a somewhat lower turnover point, for example).



The filter calculations employ exact E12 values for the capacitors, which produces rather ‘strange’ values for the resistors. It is necessary to connect resistors with E96 values in parallel to achieve the necessary resistance values. **Table 1** summarises the resistor values.

The choice of opamp is even more critical than the precision of the components. The opamps must have a very large bandwidth and low distortion in the audio band, and they must be able to supply enough current. This last factor comes from the fact that the dimensions of the filter components represent a compromise between the amount of noise generated by the impedance of the filter network itself, the load on the opamp due to the negative feedback and the load of any following network. In practice, a video amplifier must be used to avoid affecting the filter characteristics. The chosen opamp, an Analog Devices AD828AN, does not however have the desired distortion specifications. It is only possible to achieve better specifications by using a discrete amplifier specially designed for this application. With such an amplifier, it is possible to significantly reduce the impedance of the filter network and increase the maximum current, in order to improve the specifications.

This circuit was originally intended to be used to measure codecs, for example. Their specifications are often given only for the audio band, for which a steep measurement filter is used. The mixer products with the sampling frequency, which lie outside the audio band, are often not attenuated by any more than 50 to 70 dB by digital filtering.

In order to produce a 5th-order filter using the illustrated arrangement, each section must have a gain of 2. In order to prevent the amplification of the overall filter from becoming to large, extra attenuators have been added to the last two sections. We chose 2 V_{eff} as the maximum allowable signal level. The attenuators form the first resistances of the filter sections, which means that the parallel impedance of R23, R24 and R33 is equal to that of R1 and R2. The printed circuit board layout allows such networks to be used for all four sections (with positions R11 and R22 open). If the measured values of R7, R18, R29 and R40 match the desired theoretical value (which falls within the tolerance range of a 1% 4k42-Ω resistor), no parallel resistors are necessary in these positions. Make sure that the signal source has DC coupling. It is recommended to use a very good audio opamp in series with the input, to provide a well-defined input impedance.

The brief specifications of the filter are as follows:

supply voltage	±17.5 V
bandwidth (–3 dB)	20.9 kHz
suppression (40 kHz, 2 V_{eff} in)	78 dB
THD+N (1 kHz, 1 V_{eff} in)	0.005 %
THD+N (1 kHz, 2 V_{eff} in)	0.009 %
S/N (2 V_{eff} in)	94 dB
gain (10 kΩ load)	7.75
output impedance	75 Ω
current consumption	28 mA

Figure 3 shows the measured characteristics of each of the cumulative sections. The ultimate suppression is around 94 dB before the signal disappears below the noise level. The gain of the first section is naturally 6 dB lower.

(004094-1)

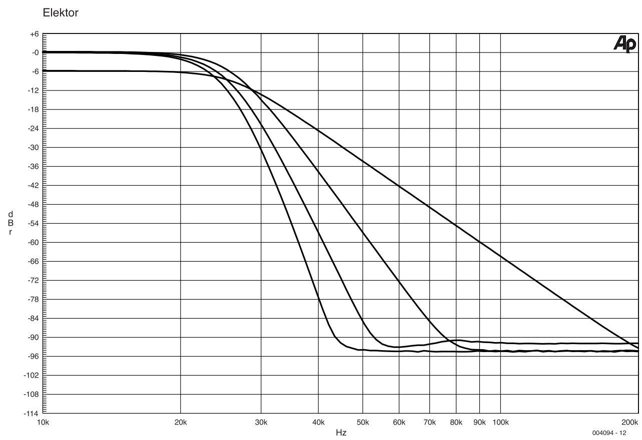
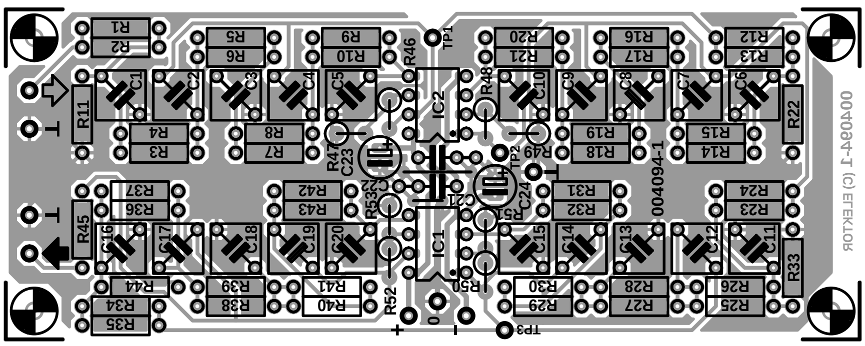
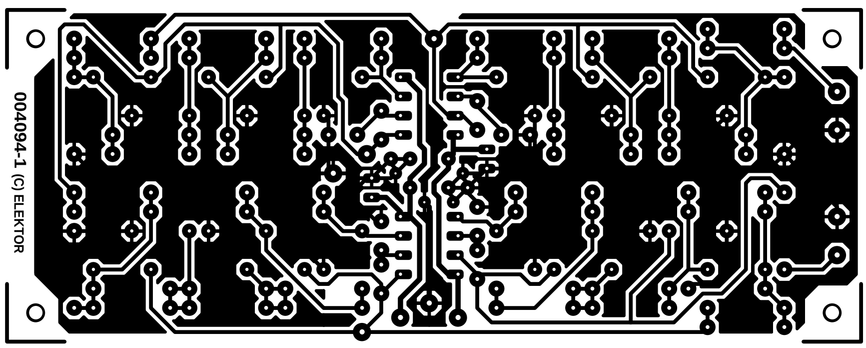


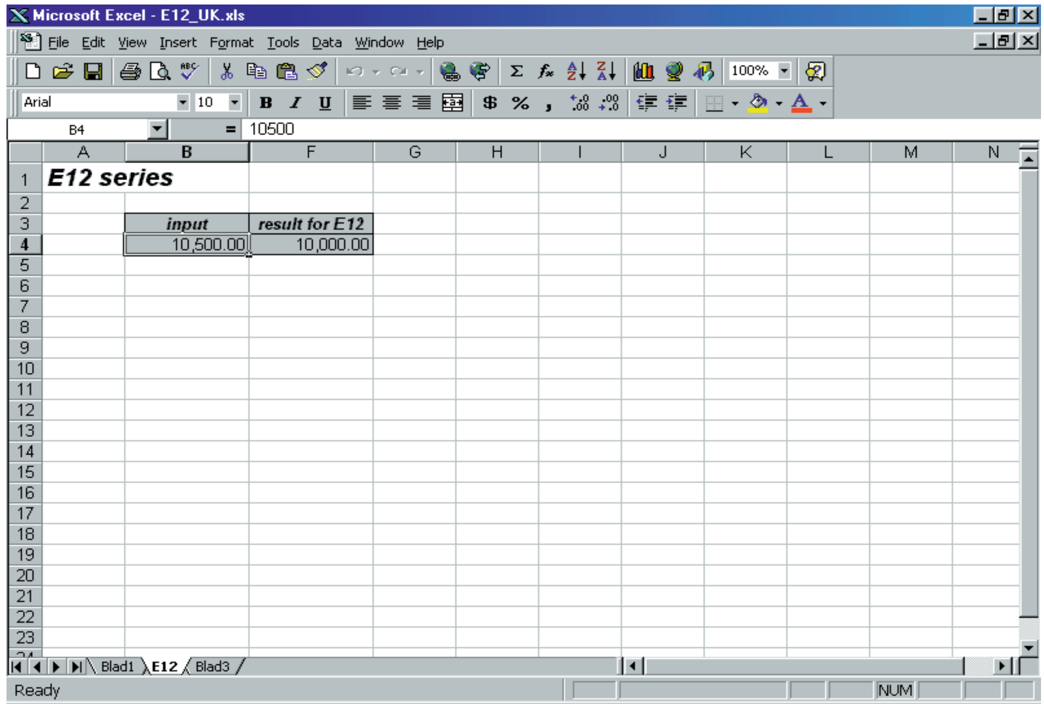
Table 1			
Resistors (A = 2 x)		**Parallel**	**Theoretical**
R1, R12	= 4k64		
R2, R13	= 422 k	4k5895	(4k58974)
R3, R14, R25, R36	= 5k49		
R4, R15, R26, R37	= 357 k	5k4069	(5k40684)
R5, R16, R27, R38	= 4k64		
R6, R17, R28, R39	= 412 k	4k5883	(4k58787)
R7, R18, R29, R40	= 4k42		
R8, R19, R30, R41	= (5M62)	4k4200	(4k41649)
R9, R20, R31, R42	= 4k99		
R10, R21, R32, R43	= 374 k	4k9243	(4k92361)
R11, R22	= open		
Alternative values:			
R7, R18, R29, R40	= 4k53		
R8, R19, R30, R41	= 178 k	4k4176	(4k41649)
Extra 6 dB attenuation:			
R23, R34	= 9k53		
R24, R35	= 340 k		
R33, R44	= 9k09	4k5896	(4k58974)





057 E12 Series in Excel

K. Walraven



You can do all sorts of neat things with Excel, such as computing the nearest E12 value. Select the cell under 'Input' and enter the value that you want to have rounded off. Type the value with all necessary zeros, thus '6800' instead of '6k8' and '1200000' instead of '1M2'. The nearest E12 value will appear in the cell just to the right. It's handy to permanently install this program on your computer, so that it's always available when you need it.

The program also works with values less than 1 Ω; all you have to do is to enter a leading period as a separator. The result will be displayed to two decimal places, but Excel naturally works internally with more decimal places. If you want to see them, select the cell and click on 'Increase Decimal'. Since the worksheet is protected, you will first have to delete the protection via Tools → Protection → Unprotect Sheet.

Maybe you have another nice application that might interest other readers, or you may just want to modify the worksheet. After you have deleted the protection, you can start to work. First make the hidden columns visible by selecting columns B and F and then selecting Format → Column → Unhide. The logarithm of the entered value is taken to determine the power of ten that it contains, and the entered value is then divided by this number to yield a value between 1 and 10. Next, this value is looked up in a normalised E12 table. The result is then multiplied by the power of ten, to produce a value with the proper number of zeros. Of course, we could have just made a big E12 table containing all possible values, but that is not such an elegant solution.

(004072-1)

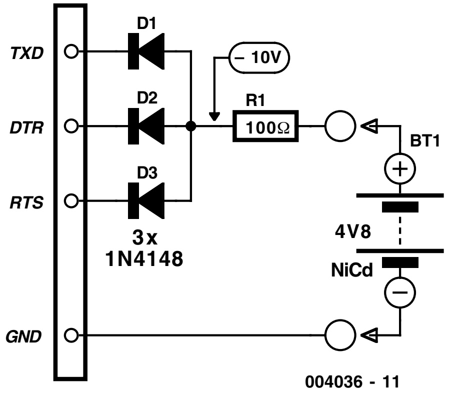
058 PC Battery Charger

B. Kainka

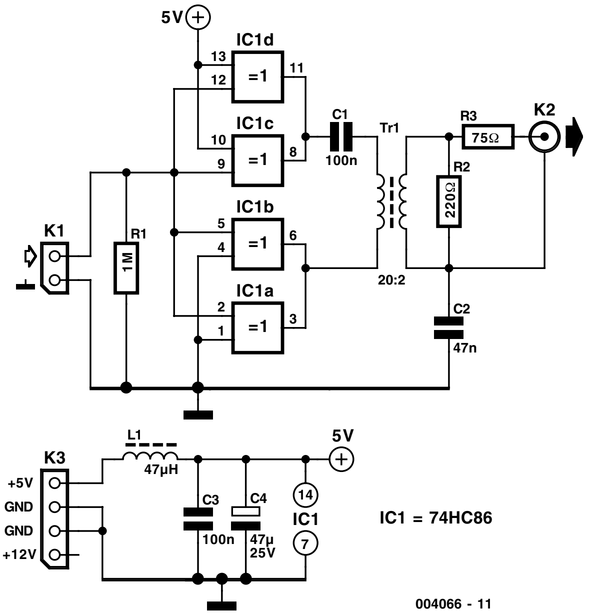
Some workbenches can't help ending up looking like a rats nest of cables and equipment, so its always an advantage if a piece of mains equipment can be removed from somewhere to free up an extra mains socket. Here we are using the ubiquitous PC as a battery charger. An unused serial interface port can supply enough current to charge (or trickle charge) low-capacity Nickel Cadmium (NiCd) batteries. You could for example, use the batteries in a radio and charge them during use.

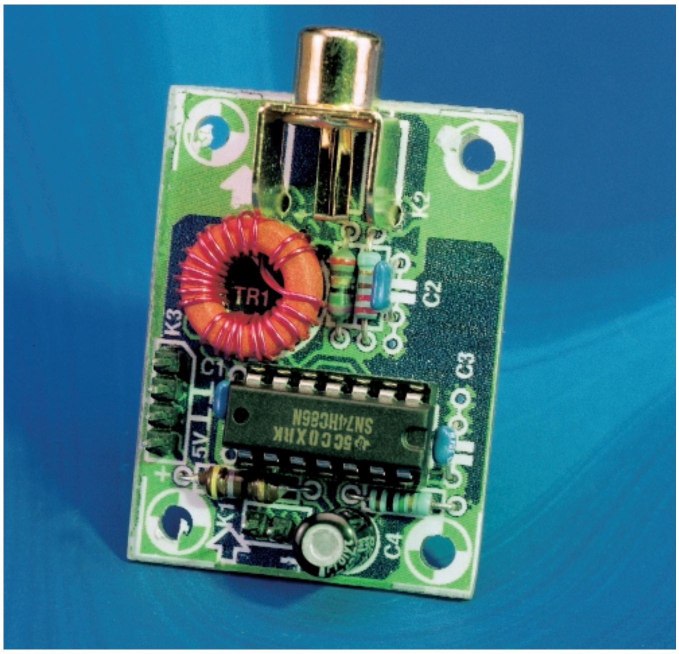
The three serial port connections TxD, DTR, and RTS, when not in use, are at –10 V and can supply a current of around 10 to 20 mA (they are short-circuit protected). The circuit shown supplies a charging current of approximately 30 mA. If it is necessary to alter the polarity of the charging circuit then it is a simple job to reverse the diodes and using software, switch the port signals +10 V. Those interested could also write a software routine to automatically recharge the batteries.

(004036)



059 Coaxial S/PDIF Output





T. Giesberts

This circuit is an alternative to the optical S/PDIF output described elsewhere in this issue. The quality of the connection provided by this link is usually better than that of an optical link (less jitter). In order to avoid earth loops, a small output transformer is normally used for digital audio signals. The construction of such a transformer has been described several times in *Elektor Electronics*. It is based on a Philips toroidal core, with 20 turns on the primary and 2 turns on the secondary, both using 0.5-mm varnished copper wire. An output signal of 0.5 V_{pp} across 75 Ω must be delivered, which means that 10 V_{pp} is necessary on the primary. This signal is provided by a quad EXOR gate (74HC86). A clean symmetrical buffer stage is created by wiring two EXORs as inverters (IC1c and IC1d) and letting the other two work without inversion (IC1a and IC1b). Using EXOR gates makes the delay times of the two buffers the same, and using two gates in parallel on each side allows more current to be delivered. R1 ensures that the gates have a defined level if there is no connection to the signal source, In the absence of an S/PDIF signal, C1 prevents a short-circuit current from flowing. R2 damps any overshoots (which mainly occur if there is no load). C2 provides an HF earth connection for the screen of the interconnecting cable. The power supply is well decoupled by L1, C3 and C4. The current consumption with a signal and load is around 4 mA, but with no S/PDIF signal it drops to zero.

The PCB shown here is unfortunately not available ready-made through the Publishers' Readers Services.

(004066-1)

COMPONENTS LIST

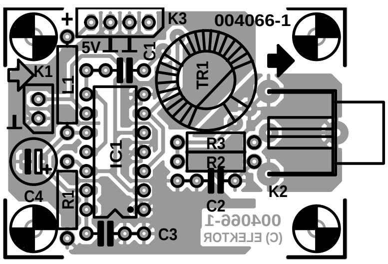
Resistors:
R1 = 1MΩ
R2 = 220Ω
R3 = 75Ω

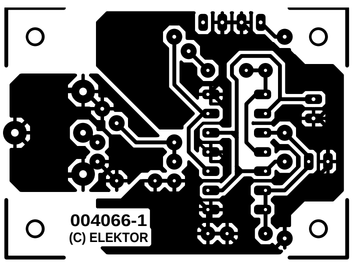
Capacitors:
C1,C3 = 100nF ceramic
C2 = 47nF ceramic
C4 = 47µF 25V radial

Inductor:
L1 = 47µH

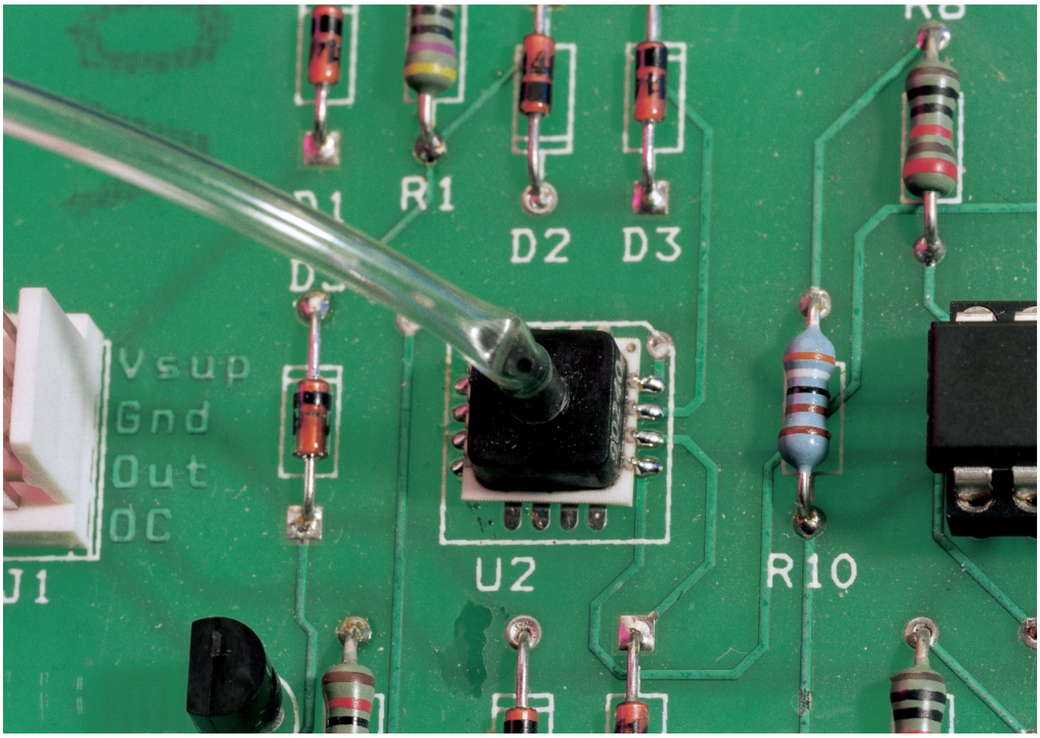
Semiconductor:
IC1 = 74HC86

Miscellaneous:
K1 = 2-pin SIL header
K2 = cinch socket, PCB mount (e.g., Monacor/Monarch T-709G)
K3 = 4-pin SIL header
Tr1 = ferrite ring core Philips type TN13/7,5/5-3E25. Primary 20 turns, secondary 2 turns





060 Pressure Switch



J. Schuurmans

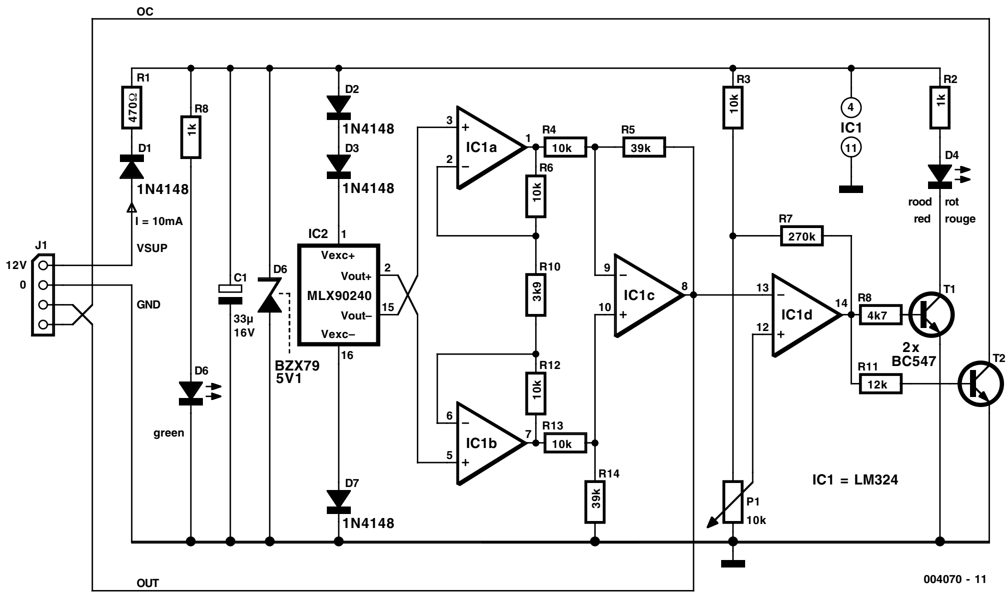
A simple pressure switch with a range of 50 to 350 mbar can be made using a pressure sensor. If you can accept somewhat reduced linearity, the sensor can even be used up to 500 mbar. As shown in the schematic diagram, the circuit contains very few components other than the sensor. D1, R1, C1 and D5 form a simple voltage stabiliser that holds the supply voltage for the sensor and opamps at 5 V. The three diodes in series with the sensor provide temperature compensation (more on this later). The differential output signal from the sensor is amplified 30× by an instrumentation amplifier composed of opamps IC1a, IC1b and IC1c. The amplification factor can be adjusted if necessary by modifying the value of R10. The amplified output signal is compared to the voltage on the wiper of P1. If the voltage that results from the pressure being measured is less than the value set by P1, the output of comparator IC1d is High and LED D4 is on. An external load can be switched via the open-collector output of T2.

We used a Melexis MLX90240 sensor (*www.melexis.com*), but unless you work in the automotive industry, you won't be able to obtain this sensor. An Exar sensor (such as the SM5310-005-G-P; see *www.exar.com*) or a Motorola type can be used instead. If necessary, the circuit can be modified as described below.

Start with the sensor sensitivity specification from the data sheet (approximately 60 mV/bar/volt in our case). Since the supply voltage of the sensor is 5 V minus 3 diode drops, or around 3 V, the net sensitivity is thus 180 mV/bar. The range of the sensor is 0 to 350 mbar, so the maximum output voltage is 63 mV. The following amplifier has a gain of approximately 30, so the output signal ranges between 0 and 1.89 V. This voltage is compared to the voltage on the wiper of P1, which can be varied between 0 and 2.5 V. If the sensitivity differs from the nominal value, the amplification can be adjusted as necessary using R10.

Finally, a remark on the temperature compensation. The sensor used here has a temperature coefficient of 2100 ppm/degree. Other types of sensor will have somewhat different values (consult the data sheet). The supply voltage should thus increase by 2100 ppm of 3 V for every degree, which is 6.3 mV per degree. The voltage across a silicon diode drops approximately 2 mV per degree, so the supply voltage of the sensor increases as the temperature increases. This compensates for its decreased sensitivity. With the indicated sensor, three diodes in series are needed to just about fully compensate for its temperature coefficient. Two diodes are sufficient for the previously mentioned Exar sensor.

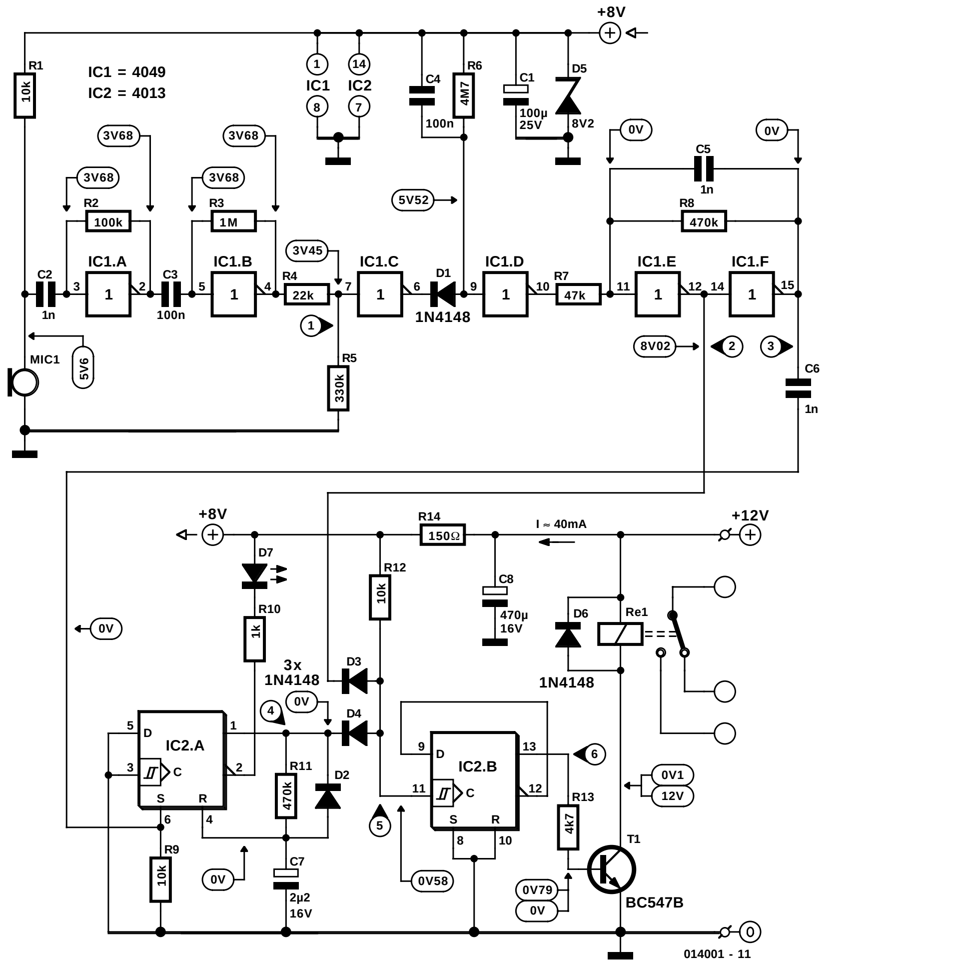
(004070-1)



Clap Activated Switch

001

B. Trepak



This circuit has been designed to respond only to two hand claps which occur in (relatively) quick succession, and to ignore one hand clap or even continuous clapping, as well as most other sounds which normally have a lower frequency contents than a hand clap. Even so, the system is not foolproof but is should be adequate for simple domestic applications such as switching lights on and off.

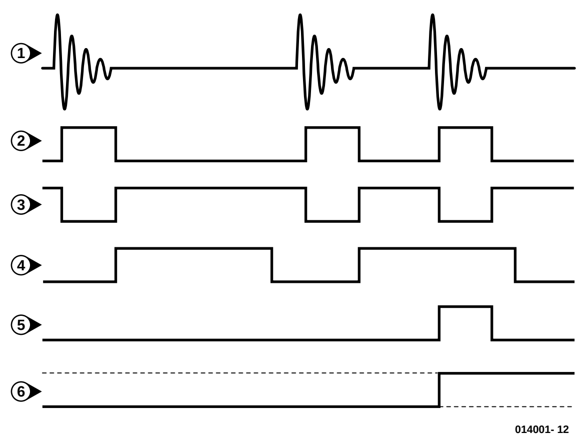
The circuit diagram and the accompanying timing diagram will be discussed briefly to explain the basic operation of the circuit.

The sound picked up by the electret microphone is first amplified to a level suitable for further processing. This is done with two inverters from a 4049 IC, which is normally listed as a 'hex inverter' package. By connecting high value feedback resistors between the input and output of each inverter, and coupling the inverters with a capacitor (C3), a primitive but otherwise perfectly adequate analogue amplifier is created. The value of capacitor C2 at the amplifier input is such that only higher frequency sounds are amplified. The amplifier output signal is 'squared' before being used to charge C4 via D1. The final two inverters from the 4049 package, IC1e and IC1f, are configured to act as a Schmitt trigger. The first inverter of this pair produces a negative pulse each time a sound of sufficient amplitude is picked up by the microphone. The duration of this pulse is determined by that of the sound and the values of C4-R6 which are chosen to ensure that the output will only go high when the sound ceases. The final inverter produces a corresponding positive pulse.

The rising edge of the Schmitt trigger output signal is differentiated by C6-R9 producing a positive going pulse when the sound ceases. This triggers monostable IC2a built around one half of a 4013 dual D flip-flop. If a second pulse appears on D3 after the first one has ceased, while the output of the monostable is still high, the clock input of toggle flip-flop IC2b will go high causing the Q output to go high and T1 to be turned on. Consequently relay Re1 is energized and the load is switched on and will remain on until a valid clap command is received (toggle function).

LED D1 is connected to the $\overline{Q}$ output of IC2a and will indicate the time slot available for the two successive claps.

The circuit is best powered from a mains adaptor set to achieve about 12 V DC output voltage when loaded with 40 mA plus the relay coil current.



The microphone is an electret (a.k.a. 'condenser') type with an internal amplifier which is normally supplied without any leads. The pad connected to the microphone encapsulation is usually the negative terminal.

When the relay is used to switch mains-powered loads, electrical safety precautions should be observed, including compliance with the relay contact ratings specified by the manufacturer and a minimum contact distance of 6 mm between all contacts and wires carrying the mains voltage. The coil resistance of the relay should not be lower than about 400 Ω to prevent overloading of T1 and the supply voltage dropping when the relay comes on. Only the make contact of the relay is used.

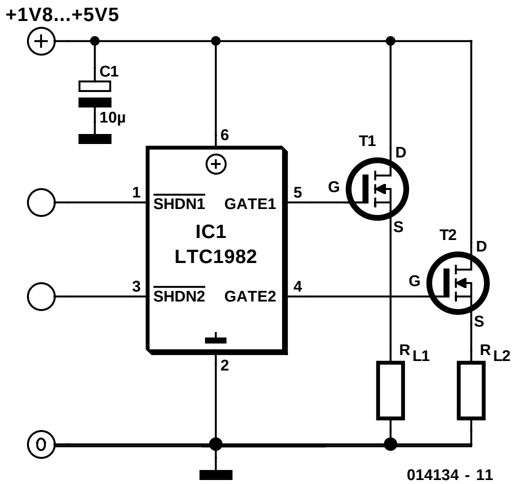
(000167-1)

Dual High Side Switch Controller 002

One of the most frequent uses of n-channel MOSFET's is as a voltage controlled switch. To ensure that the MOSFET delivers the full supply voltage to the load it is necessary for the gate voltage to be a few volts above the supply voltage level. This can be a problem if no other suitable higher voltage sources are available for use elsewhere in the circuit.

The LTC 1982 dual high-side switch controller from Linear Technology (www.linear-tech.com) solves this problem by incorporating a voltage tripler circuit in the gate driver stage. The gate voltage is limited to +7.5 V which is 2.0 V above the IC's maximum operating voltage. It can directly drive the gate of logic-level MOSFET with a V_{GS}(th) from 1.0 V to 2.0 V. A suitable n-channel logic level MOSFET would be the BSP 295. This device can switch up to 1.5 A and is available in an SOT 233 SMD package.

(014134-1)



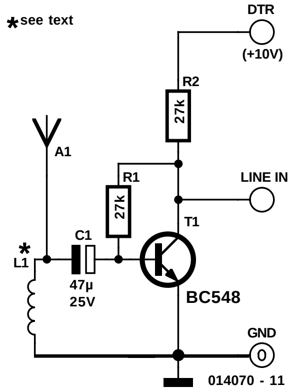
Very Wideband PC Radio

003

B. Kainka

PC radios are certainly nothing unusual. However, unless you are prepared to spend a lot of cash you can't buy a wideband PC radio that receives short-wave signals — if you want one that will not break the bank, you will have to build it yourself. There's no need for a battery or power supply, since power can be drawn directly from the PC serial interface. The audio signal is fed into the PC sound card. The circuit diagram in **Figure 1** shows this simple audion receiver. The transistor in the common-emitter circuit demodulates AM signals, thanks to its exponential characteristic curve. Since the base–emitter junction is already biased, RF potentials of a few millivolts are sufficient to achieve demodulation. For this reason, the audion circuit is significantly more sensitive than a simple diode detector.

1

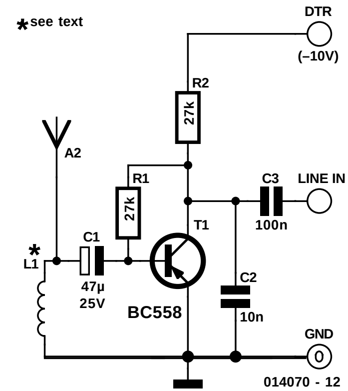


So where is the tuning capacitor? It's not needed, since the receiver has an extremely wide bandwidth and (simultaneously!) receives all strong signals ranging from the 49-m band to the 19-m band. The coil is wound in two layers with 15 turns on a pencil. This yields an inductance of around 2 µH. The resonant circuit capacitance of around 100 pF is composed of the base capacitance of the transistor and the aerial capacitance. This places the resonant frequency at around 11 MHz. The low input impedance of the transistor damps the resonant circuit to the point that its Q factor is 1, so the bandwidth is also around 11 MHz. The receiver thus picks up everything between 6 MHz and 17 MHz. This complete elimination of the usual selection leads to surprising results.

Less is more. For communications technicians, this means: less selectivity = more bandwidth = more information. Indeed, here you dive into a sea of waves and tones. The special propagation conditions for short-wave signals cause first one signal and then another signal to predominate. You hear messages in several languages at the same time, music ranging from classical to pop and folk songs from distant countries. Without the bother of the usual dial spinning, you can roam at your leisure through the entire short-wave region.

The supply voltage for the radio must be first switched on by using a program (HyperTerminal is adequate) to switch the DTR lead of the serial interface from –10 V to +10 V. If you want to avoid this trouble, you can use a PNP transistor. The alternative circuit diagram shown in **Figure 2** shows

2



some additional improvements. The coupling capacitor prevents the dc component from reaching the input of the sound card, and residual HF components are shorted out by the parallel capacitor. With these modifications, the radio is also quite suitable for direct connection to a stereo system, final amplifier or active speaker. In such cases, you can do without the PC and use a battery (1.5 to 12 V) instead.

A downpipe from the eavestrough can be used as an aerial if it is insulated at its lower end (where it connects to the sewer system) by a rubber ring or concrete. If you are not so fortunate as to have access to such an arrangement, you will have to rig a wire aerial (at least 5 m long).

(014070-1)

Li-Ion Protection Circuit 004

Linear Technology application

When a lithium-ion battery is discharged below the minimum recommended cell voltage its life expectancy is dramatically reduced. The circuit described here can avoid this by disconnecting the load from the battery when the cell voltage reaches a set level.

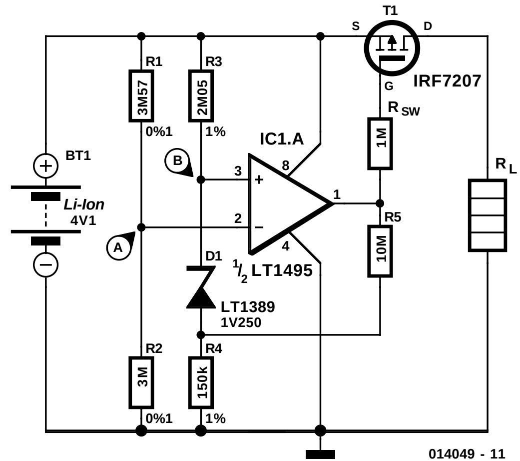
The voltage at junction A may be set to 3 V, for example, by selecting the correct ratio of R1 and R2. When the battery voltage drops below the minimum value, the voltage at junction A will be smaller than that at junction B. The latter voltage is equal to:

$$V_B = 1.25\ \text{V} + I\,R4 = 1.37\ \text{V}$$

where:

$$I = (V_{min.} - 1.25\ \text{V}) / (R3 + R4) = 800\ \text{nA}$$

($V_{min.}$ = minimum value)



At this point the output of opamp LT1495 will go high, causing SW1 (a P-channel logic level MOSFET) to block and break the connection between the battery and the load.

Because the battery voltage will rise when the load is disconnected, a certain amount of hysteresis is created by the addition of R5. This prevents the circuit from oscillating around the switching point. The value of R5 shown here provides 92 mV of hysteresis. So the battery voltage has to rise to 3.092 V before the load is reconnected to the battery. An increase or decrease of the hysteresis is possible by reducing or increasing the value of R5, respectively. The required hysteresis depends in the internal impedance of the battery and the magnitude of the load current.

The switching point defined by the values of R1-R2 is quite critical with a circuit such as this. If the switching point is too high, then the available capacity of the battery is not fully utilised. Conversely, if the switching point is too low, the battery will be discharged too far with all the harmful consequences that may entail. Using the values shown here and including the tolerances of the parts, the switching point is between 2.988 V and 3.012 V. In practice it may be easier to select slightly lower values for R1 or R2 and connect a multi-turn trimpot in series with it. This makes an accurate adjustment of the switching point possible and has the additional advantage that R1 and R2 may be ordinary 1%-tolerance types.

Finally, before using the protection circuit it is advisable to first connect it to a power supply instead of a battery and carefully verify the operation of all its features!

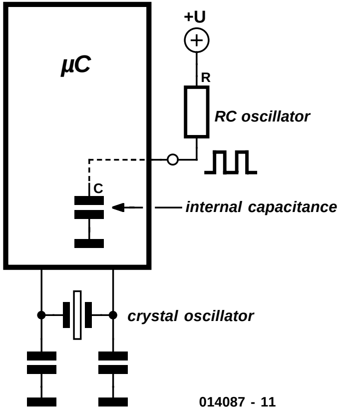
(014049-1)

Low-Cost Temperature Measurement with a Microcontroller

005

It frequently happens that you have an application in which you want to measure the temperature of a circuit or the outside world. This can be easily achieved using additional components in the form of ICs, or by using a RC network and a software routine. However, if all the I/O port pins are already in use, it's hard to know what to do. A circuit trick can provide a solution to this dilemma.

As a rule, modern microcontrollers have RC oscillators with (relatively large) temperature coefficients. Since instructions are processed at the speed of the RC clock, the execution time of a software loop varies with the chip temperature. If your program includes a loop that increments a counter, you will obtain a count that is different for each different chip temperature, and a specific temperature can be assigned to each counter value. Of course, it is necessary to have a highly stable time reference, which may be provided by the 50-Hz mains frequency (for example) or a second (crystal) oscillator network connected to the microcontroller. Such a second oscillator circuit is used with low-power microcontrollers to operate them at very low clock rates, such as 32 kHz, in order to save power. The RC oscillator is then only put into play as needed to meet the demands placed on the software.



(014087-1)

BITBUS Monitor

006

A. Grace

Intel's BITBUS is an extensive protocol for the low cost networking of distributed control systems. Primarily intended for use in factory automation, BITBUS networks use one master and up to 250 slaves. The full specification may be found in Document no. 280645-001 © Intel Corporation.

The BITBUS specification has a pre-defined connector designation based on the standard 9 way 'D' connector. The pin-out is summarized in the **Table**.

The **circuit diagram** shows the design of a simple differential BITBUS transmission detector. The original design was used to monitor the presence of BITBUS data between two pieces of control equipment.

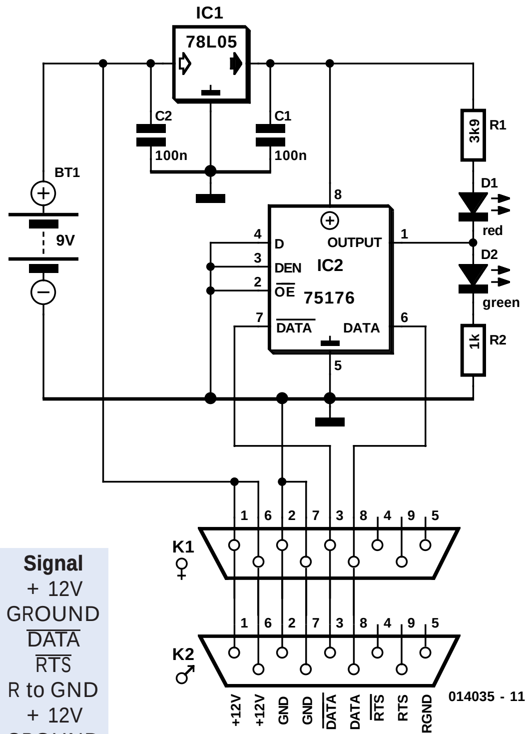
The BITBUS specification allows for two types of transmission, synchronous and self-clocked.

Synchronous transmission is used for high speed (0.5 to 2 Mbits/sec) data links over a short distance (30 metres). The data is transmitted using data and $\overline{\text{DATA}}$, and clocked by using RTS and $\overline{\text{RTS}}$.

Self-clocked mode permits data to be transmitted, all be it much slower, over greater distances — 375 Kbits/sec over 300 metres or 62.5 Kbits/sec over 1200 metres. Self-clocked mode combines serial data and the clock onto a single signal data and /data wire pair.

BITBUS data is detected using IC2, a 74176 RS485 transceiver. In this instance it is used in the receiver mode only. The DATA and $\overline{\text{DATA}}$ signal lines are wired to pins 8 and 3 of the connectors respectively. The receiver output, on pin 1, toggles when there is data present on the BITBUS network. This is represented by the two LEDs flashing on and off. The red LED represents a High, the green LED, a Low.

If the network utilises the full capability of the BITBUS system, the BITBUS Monitor can be powered from the +12 V supply line, which is a available on pin 1 and pin 6 of the BITBUS connector. The +12 V is stepped down via IC1, a +5 V low-current regulator. Use of the BITBUS Monitor could not be simpler. Plug the Monitor into the network and the LEDs will flash if there is data present. If there is no data on the network only one LED will light. (014035-1)

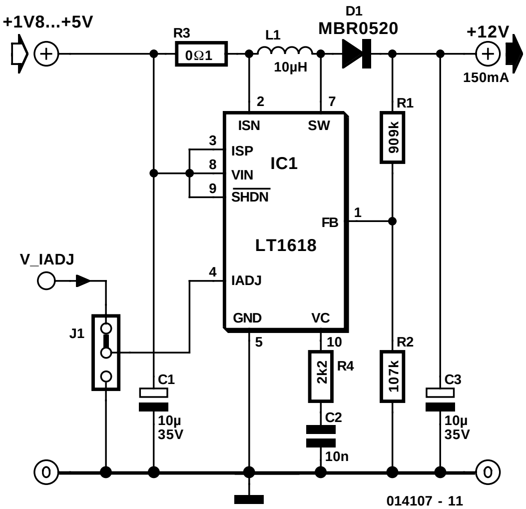


Pin no.	Signal
1	+ 12V
2	GROUND
3	$\overline{\text{DATA}}$
4	$\overline{\text{RTS}}$
5	R to GND
6	+ 12V
7	GROUND
8	DATA
9	RTS

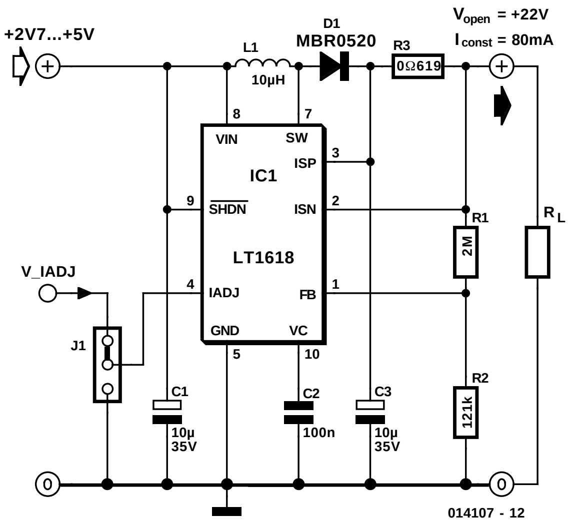
Step-up Switching Regulator with Integrated Current Limit

007

1



2



In the form of the LT1618, Linear Technology (www.linear-tech.com) has made available a step-up switching regulator with a current limit mechanism. This makes it easy to protect an otherwise not short-circuit-proof switching regulator: the input voltage is always connected to the output via an inductor and a diode. We can limit the current at the input (**Figure 1**), which limits the current drawn by the entire circuit; alternatively, with the circuit of **Figure 2**, the output current can be limited. This enables the design of constant current sources at voltages higher than the input voltage. In the circuit shown the nominal output voltage of the step-up switching regulator will be around 22 V.

The output voltage can be calculated using the formula

$$V_{out} = 1.263\ \text{V}\ (1 + R1/R2)$$

The output current can be set via R3 as follows:

$$I_{max} = V_{sense} / R3$$

where $V_{sense} = 50$ mV

The I_{ADJ} input can be set to a voltage between 0 V and +1.58 V resulting in a linear reduction of the limit current. The sense voltage of 50 mV across R3 for maximum current is reduced as follows:

$$V_{sense} = 0.04\ (1.263\ \text{V} - 0.8\ V_{IADJ})$$

Hence, for a fixed value of R3, the V_{IADJ} input allows the current limit to be adjusted.

Note that in the first circuit the sense resistor R3 is fitted between the input electrolytic capacitor and the inductor. If R3 is fitted before the capacitor, the inductor current cannot be properly controlled.

The LT1618 operates on input voltages between +1.6 V and +18 V. Its output voltage must lie between V_{in} and +35 V. With a switching current of 1 A through pin SW to ground, an output current of around 100 mA can be expected. The switching frequency of the IC is about 1.4 MHz, and the device is available in a 10-pin compact MSOP package.

(014107-1)

Ammeter

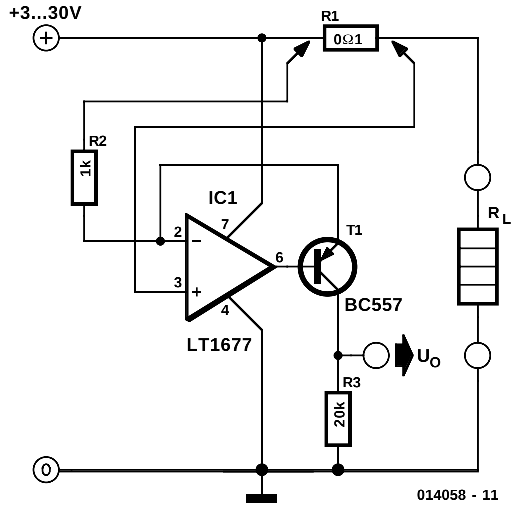
008

Linear Technology application — www.linear-tech.com

From the feedback from our readers we have learned that the measurement of currents in the positive lead of a power supply is often fraught with practical difficulties. The circuit shown here will in many cases be a welcome aid. The design is not really new, but it is very useful.

The required shunt or current measuring resistor R1 is connected in series with the load. The voltage drop across this resistor is proportional to the current through the load. As usual, the opamp will strive to minimise the potential difference between its inverting- and non-inverting inputs. As a consequence, a compensating current will flow from the emitter of T1 to the inverting input of IC1 with the value U_{R1}/R2. The same current flows through R3 as well, of course, resulting in a voltage of U_{R1}·R3/R2; at the values shown this is 2 V per ampère. This voltage can be displayed with a moving coil instrument or other appropriate indicator.

An important remark: as can be seen, the inverting input of the opamp is effectively connected to the power supply. This requires an opamp with an input common-mode range that includes at least the positive supply rail. Also, the output has to be able to swing (close) to the power supply voltage, otherwise T1 will not turn off sufficiently. This requires a very good 'rail-to-rail' opamp. The LT1677 that is used here is cut out for this purpose and has, among other things, the following characteristics:



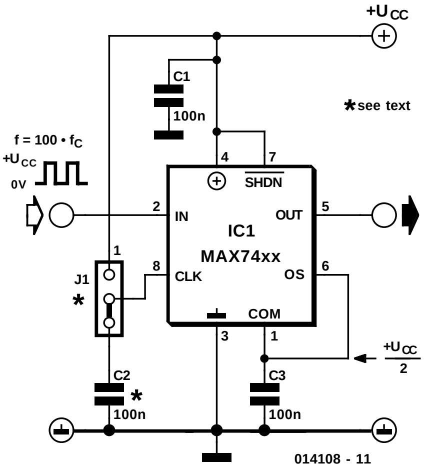
– rail-to-rail input and output;
– extremely low noise (3.2 nV/√Hz at 1 kHz);
– gain/bandwidth 7.2 MHz;
– offset 60 µV;
– power supply range 3 to 30 V.

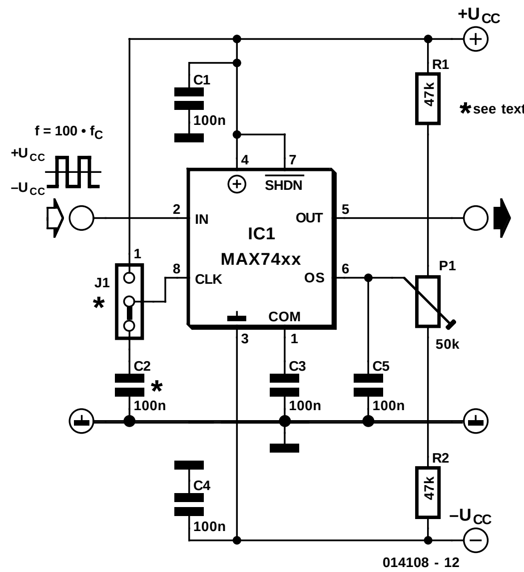
These particular characteristics make the LT1677 eminently suitable for the processing of small signals.

(014058-1)

Switched-Capacitor Fifth-Order 1 Hz to 45 kHz Low-Pass Filter

009





Low-pass LC-filters in the audio frequency range require huge ferrite-cored inductors. Active filters are also tricky to construct because of the tight tolerance required of the resistors and capacitors. Switched capacitor (SC) technology, however, allows small audio frequency low-pass filters with adjustable corner frequency to be constructed simply. The switching clock frequency used is 100 times higher than the desired corner frequency, so that any residual switching-frequency component at the output can be removed easily using an RC or LC low-pass combination.

Maxim (www.maxim-ic.com) has recently released eight new SC filter ICs with a current consumption of only 3 mA. Four different filter characteristics are available, and there are both 3 V and 5 V versions of the devices. The corner frequency can be continuously adjusted from 1 Hz to 45 kHz by suitable choice of clock frequency. **Table 1** gives an overview of the components and their chief characteristics.

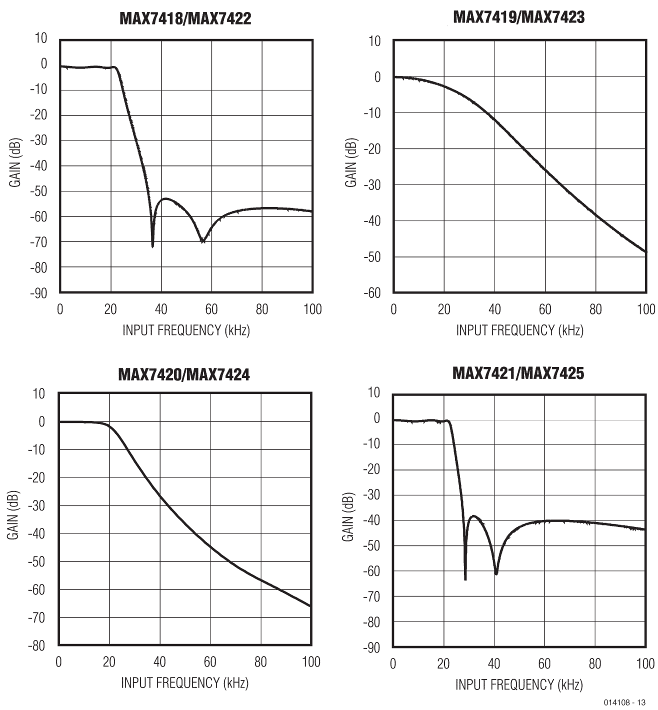
Figure 1 shows the frequency responses obtained with a clock frequency of 2.2 MHz, nominally giving a 22 kHz low-pass filter.

A second interesting possibility is stand-alone use without an external clock. A capacitor is connected to the CLK pin, which sets the frequency of a built-in oscillator circuit. This option is only suitable where the exact corner frequency is not important, since otherwise the capacitor must be adjusted to tune the corner frequency. The frequency of the internal oscillator also suffers from a slight drift with temperature.

The MAX74xx circuit can be powered either from a single 3 V or 5 V supply (according to the device) or from a symmetrical ±1.5 V (respectively ±2.5 V) supply. When using an external clock, note that a square wave with a duty cycle of 50 % ± 10 % is required, with a frequency 100 times the desired filter corner frequency and an amplitude appropriate for the supply voltage (see **Figure 2**).

The output DC offset can be calculated as follows:

$$V_{out} = (V_{in} - V_{com}) + V_{os}$$



where Vcom is half the supply voltage (or 0 V when using a symmetrical supply). Vos is the offset compensation voltage, if any, fed into the OS pin. If the offset voltage need not be set, OS can be connected directly to COM. The formula thus tells us that if a single supply is used, a DC component equal to half the supply voltage is required. A reasonably low-impedance drive is required for the device, whereas the output should be connected to an impedance of at least 10 kΩ.

In stand-alone mode with a capacitor C connected to the CLK pin, the filter corner frequency depends on the capacitance as follows:

$$f_c = 0.01\ f_{osc} = 0.01\ k\Omega\ /\ C$$

Here C is in pF and f is in kHz. The appropriate value of k is given in **Table 2**.

(014108-1)

Table 1.

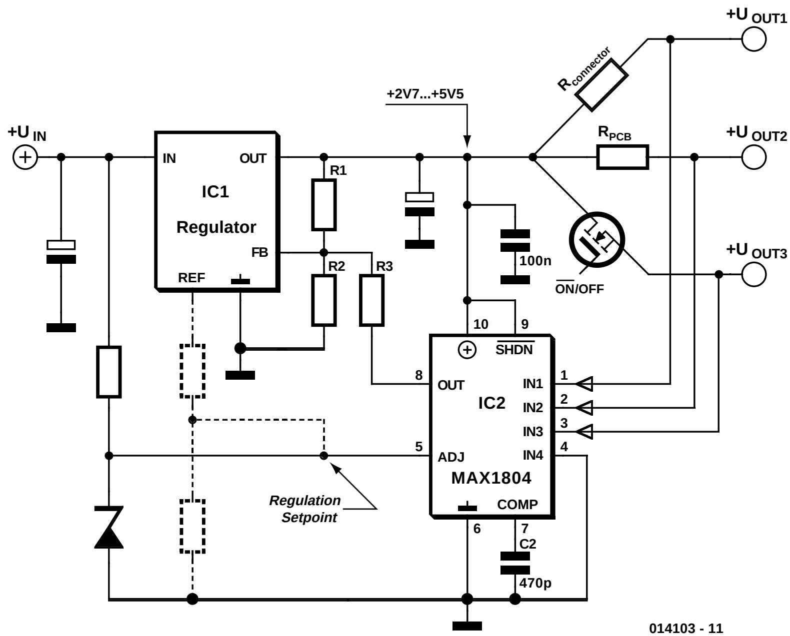
+3 V supply	+5 V supply	Filter frequency response	Characteristics
MAX 7422	MAX 7418	Elliptic filter, r = 1,6	53 dB stopband rejection
MAX 7423	MAX 7419	Bessel filter	linear phase
MAX 7424	MAX 7420	Butterworth filter	maximally flat passband
MAX 7425	MAX 7421	Elliptic filter, r = 1,25	37 dB stopband rejection

r = corner frequency / stopband lower frequency, i.e. steepness of cutoff in transition band

Table 2.

+3 V supply	+5 V supply	k
MAX 7422	MAX 7418	$k = 87 * 10^3$
MAX 7425	MAX 7421	$k = 87 * 10^3$
MAX 7423	MAX 7419	$k = 110 * 10^3$
MAX 7424	MAX 7420	$k = 110 * 10^3$

Voltage Regulator Assistant 010



Everyone will be familiar with the problem of voltage drop across wires, connectors or filtering components such as inductors, which force the voltage at the regulator output to be set higher than the circuit operating voltage. If the current drawn falls then the operating voltage rises above its nominal value; when the current rises, the voltage falls.

Assistance here comes in the form of the four-input MAX1804 *Feedback Integrator*, a novel product from Maxim (www.maxim-ic.com). The device can be connected to your favourite voltage regulator and will intervene in its feedback loop if any of its four inputs is fed with too low a voltage. The MAX1804 manages the fine control of the regulator output voltage by increasing it until the lowest voltage of those sensed is made correct. Unused inputs to the MAX1804 are automatically disabled if the voltage present is below 90 % of the nominal value. The MAX1804 will therefore not intervene in the feedback loop if the voltage drop is too great. The device is designed for supply voltages between +2.7 V and +5.5 V. It is supplied directly from the output of the controlled regulator.

The OUT connection of the MAX1804 is connected to the feedback pin of the regulator via R3, which has a rather higher value than R1 or R2. The OUT pin draws as much current as necessary to ground to force the regulator to raise its output voltage to bring the lowest of the MAX1804 inputs to four times the voltage on the ADJ pin. The voltage on ADJ can be provided by a reference voltage generated by the regulator, or, if this is not available, by an external voltage reference or Zener diode. The available control range can be set via R3: in the limit, R3 is effectively in parallel with R2.

The COMP pin is used for compensating the regulation loop. The manufacturer recommends a compensation capacitor of 470 pF.

The shutdown pin ($\overline{SHDN}$) forces all four inputs and the output into a high-impedance state, so that the MAX1804 can no longer affect the regulator.

(014103-1)

Random Flashing LED

011

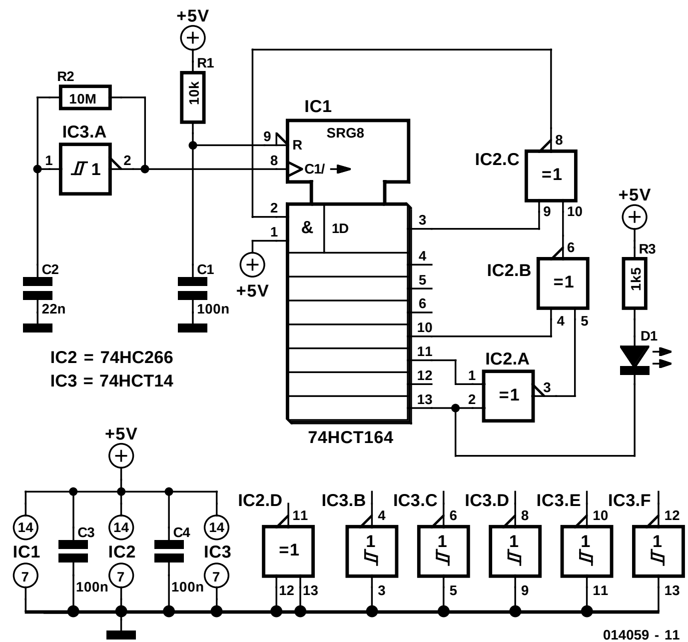
In recent years, the chapter 'flashing lights' in its many incarnations, has already received plenty of attention in *Elektor Electronics*. Therefore, a newly presented flasher circuit has to have at least one special characteristic in order to be considered for publication.

The version described here is therefore definitely not an 'ordinary' flasher. Unlike most other circuits, the on/off rhythm of this circuit is not regular, but random. The circuit will undoubtedly find applications in various games, while it may also be very appropriate as a 'pseudo-alarm-indicator' to deter potential burglars.

Obviously, a random flasher will require a little more circuitry than a standard version. As is shown in the schematic, Schmitt-trigger IC3a is used to build a conventional oscillator, which runs at a relatively low frequency. This signal is used to clock a shift register IC. By feeding back the various outputs of the shift register through three inverting XOR gates (IC2a/b/c), the level changes at the output QH of the shift register will exhibit a quasi-random characteristic. This voltage is applied to a high-efficiency LED (D1), which completes the flasher.

The circuit has been designed for a power supply voltage of 5 V. The current consumption is about 8 mA when the LED is on.

(014059-1)



Fan Control IC with Over-temperature Output

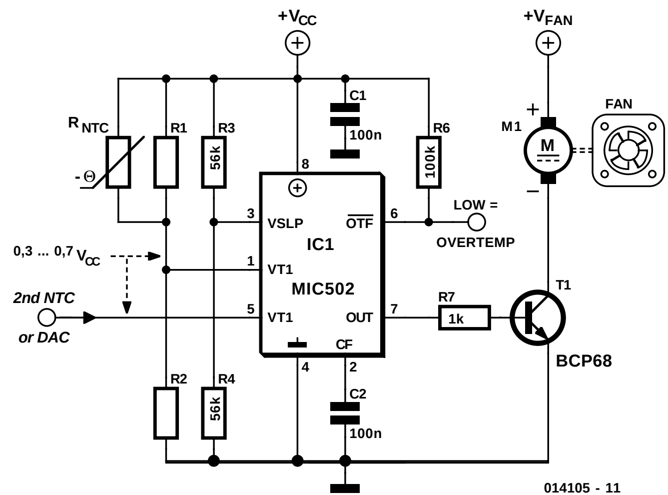
012

A simple proportional fan controller can be built using the MIC502 from Micrel (www.micrel.com). With this IC the speed of the fan runs slowly at low temperatures, reducing noise and wear. Any fan can be controlled using the pulse width modulated output signal via a driver transistor. Using PWM control has the advantage that the fan can be run much slower than using variable DC control. Up to two NTC thermistors can be connected. The second control voltage can alternatively be derived from a DAC output from a processor system, for example. The MIC502 operates from a supply between 4.5 V and 13.2 V (V_{CC}). Since drive is via a transistor, the actual fan voltage can be higher than the supply voltage: you can drive a 12 V fan from a 5 V controller.

Control is independent of supply voltage, since the device only uses the ratio of the voltages at inputs VT1 and VT2 (so-called 'ratiometric' operation). A voltage of 0.3 V_{CC} gives rise to an output duty cycle of 0 %, stopping the fan.

0.7 V_{cc} at input VT1 and/or VT2 produces an output duty cycle of 100 %, making the fan run at full speed. Whichever of the two inputs VT1 and VT2 has the higher voltage (corresponding to the higher temperature) takes priority.

The VSLP input can be used to set the voltage below which the fan is switched off (*sleep mode*): both inputs VT1 and VT2 must be below this voltage. The fan starts again if either input VT1 or VT2 rises above VSLP + 0.12 V_{cc}. If sleep mode is not required, the VSLP input should be tied to ground. A capacitor is connected to the CF pin to set the basic frequency of the PWM signal: a value of 100 nF is recommended, giving a frequency of about 30 Hz. At power up or at exit from sleep mode an integrated start-up timer causes the fan motor to receive full voltage for a time 64/f (around 2 s at 30 Hz), ensuring a reliable start.

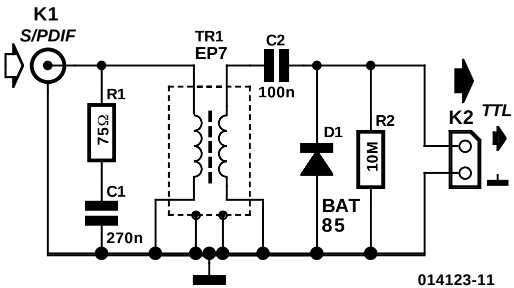


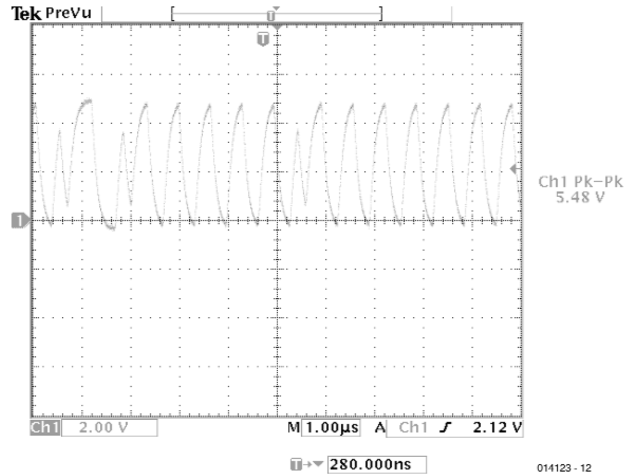
Finally an open-collector over-temperature output $\overline{\text{OTF}}$ (‘over-temperature failure’) is provided that can be pulled up to the desired logic level with an external resistor. $\overline{\text{OTF}}$ switches low when one of the two inputs VT1 or VT2 rises above 0.75 V_{cc}.

(014105-1)

S/PDIF-to-TTL-Converter

013





The idea for this circuit came from the question whether there was a simple method for connecting a digital audio output to the TTL input of, for example, a sound card. A typical S/PDIF signal has a level of 0.5 V_{pp} at 75 Ω. This level is of course much too low to drive an input that works at TTL levels. The simplest way to obtain the correct voltage is to use a small transformer to step up the voltage. The input impedance of the circuit should be 75 Ω in order to keep distortion of the signal as low as possible.

The transformer we've used has an EP7 core with an accompanying former, since it is very small; the outer dimension are only 10.7 mm by 8.5 mm. A core material of T38 was chosen (available from Farnell), which gives the transformer an A_L of 5200 nH. Since the windings (copper is diamagnetic) form a large part of the transformer, we find that in practise the A_L-value is a lot lower (30 to 40 % less).

The primary winding consists of 15 turns of 0.2 mm diameter enamelled copper wire. This is wound in one layer from a pin at the corner to a pin at the other corner. The secondary winding consists of 150 turns of 0.1 mm diameter enamelled copper wire and is wound similarly between two corner pins. Be very careful with the coil former whilst joining the halves of the core with the metal clip: it is very easily broken. The clip also shields the transformer. The coil former can be fixed in place during the winding using a 3.5 mm drill-bit and a piece of paper.

In order to keep the input impedance linear and constant within an as wide as possible bandwidth, the 75 Ω terminating resistor has a 270 nF capacitor connected in series. At the secondary is a clamping circuit (C2 and Schottky diode D1), which gives the correct DC offset to the AC signal. The screenshot of the oscilloscope shows the output signal. This was taken at a sampling frequency of 48 kHz. It is clear that this is the limit at which this circuit can be used, at 96 kHz the logic ‘1’ level will become too small.

A second possible method would be to have a potential divider between 5 V and earth, set to be exactly in the middle of the two logic levels. An AC-coupled S/PDIF signal ($1\ V_{pp}$ open circuit) should be large enough to be accepted at the logic input. A third method could be a combination of the previous two. With a winding ratio of 1:5 the quality of the signal (especially the bandwidth) will be much better and could give a better performance when used with the potential divider.

The aim was to keep this circuit completely passive, avoiding the need for an external power supply. This has in fact been achieved, albeit with a limited performance. No doubt a different core material and a larger core should give better results. The converter still has plenty of scope for home experimentation!

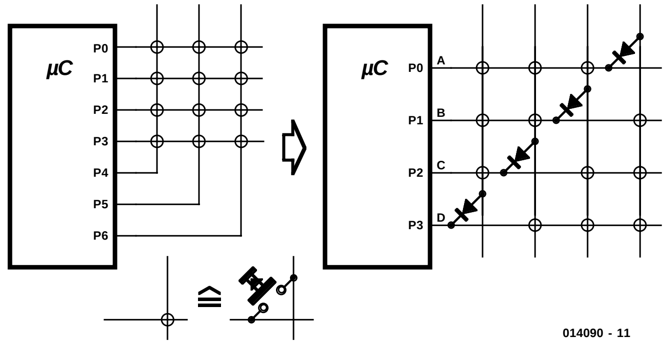
(014123)

Key Scanning with a Small Number of Connections

014

If a large number of keys have to be scanned, the individual keys are not normally connected directly to the microcontroller. Instead, a matrix arrangement is used. This allows the number of port pins to be reduced to seven for twelve keys, for example. The software scans the rows and columns and thus determines which key is pressed. However, sometimes only a small microcontroller with just a few port pins is available, so even this economical matrix method cannot be used.

Using a trick, the same problem can be solved using only four port pins. This requires the use of four extra diodes and the possibility of individually configuring the pins as either inputs or outputs via software. Four column lines (1-4) are arranged in a matrix with the four row lines (A-D) that are connected to the microcontroller, with each row line connected to a column line by a diode (1N4148). The software can recognise a pressed a key by applying a voltage to each row in turn while observing the states of the remaining port pins, which are configured as inputs. Thanks to the diodes, a voltage will be detected on only one of the inputs, depending on which key is pressed, and the software can assign the appropriate action to this event.



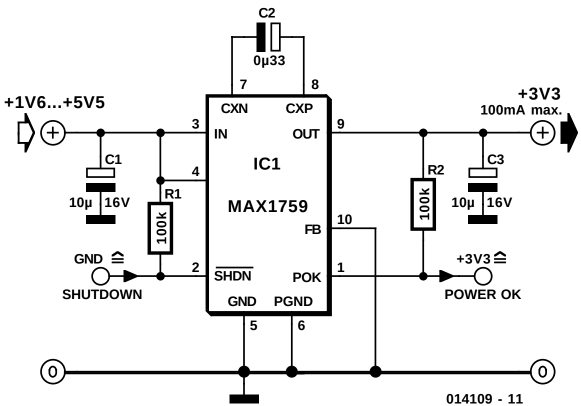
(014090-1)

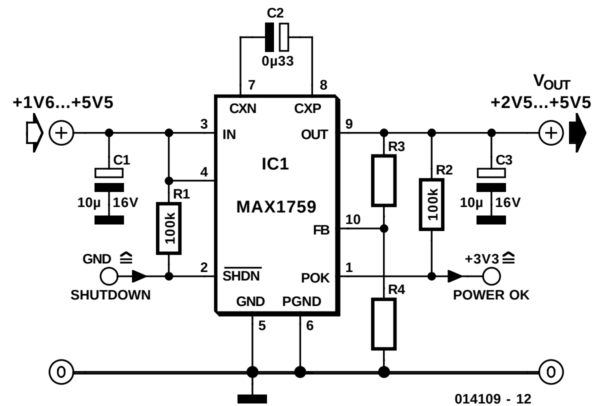
Step-Up/Step-Down Switching Regulator

015

If you wish to convert a range of possible input voltages into an output voltage that lies somewhere in the middle of that range, a regulator that can automatically switch between step-up and step-down modes is required. Such a device is the MAX1759 from Maxim (www.maxim-ic.com), which can take in an input voltage between +1.6 V and +5.5 V and generate an output between +2.5 V and +5.5 V. It is based around a switched capacitor (C2).

A further special feature of the MAX1759 is the automatic detection of the potential divider R3/R4. This allows it to





produce an externally settable output voltage between +2.5 V and +5.5 V, as given by the following formula:

$V_{OUT} = 1.235\ V\ (1 + R3/R4)$

The resistors should be chosen with values of the order of 100 kΩ.

If the feedback input FB is tied to ground, the MAX1759 switches over to an internal voltage reference giving a fixed output voltage of 3.3 V.

The open-drain 'power OK' output POK goes low when the regulator control loop is not stabilised, and is pulled high when the output voltage is stable and at the desired value.

(014109-1)

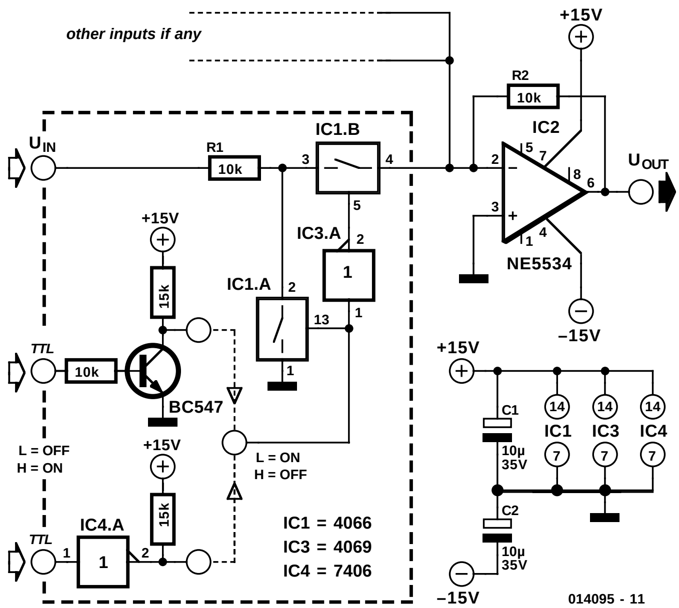
Switching Amplifier for Analogue Signals

016

H. Prince

If analogue signals have to be switched, a bilateral switch such as the 4066 is often utilised. Because this IC can be powered from single-ended supply only, all the associated components are usually connected to the same asymmetrical supply (typically 8 V). The disadvantage of this is that the opamp runs on only half the power supply voltage, with the corresponding reduction in output voltage. The result is, among other things, a reduced signal to noise ratio.

The circuit described here solves this problem. The design is based on the fact that the current in the bilateral switch (IC1) at zero volts can flow in both directions. We will have to take precautions to make sure that the input voltage at the switch is not allowed to become negative. This is taken care of by using one of the switches in IC1 to short the input to ground at the right time.



The operation is as follows: When the switch input is 'high', IC1a is closed and IC1b is open so that no signal arrives that the inverting input. IC1a shorts the signal to ground. When the switch input goes 'low', IC1a is opened and IC1b is closed and the audio signal is amplified by the opamp.

In order to make the switching levels TTL-compatible, a small buffer stage can be added to each input, consisting of a BC547, for example, or a 7406, as is shown in the schematic. If need be, multiple inputs can be connected to the virtual earth node resulting in a mixing circuit. The circuit inside the box has to be duplicated to achieve this.

The gain is easily calculated using the standard formula: $U_{out} = -(U_{in} \cdot R2)/R1$. The input impedance of each individual input is about 10 kΩ. Take note: the circuit inverts!

It speaks for itself that any spare ports and switches can be used for additional inputs.

(014095-1)

Fairy Lights

017

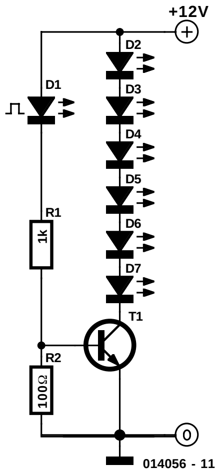
M. Schreiner

This simple and cheap circuit is not just for Christmas! There are just two resistors, a small-signal transistor such as a BC547, one ‘flashing’ LED and a string of ‘normal’ LEDs. The flashing LED works as an oscillator and switches the transistor on and off; and the transistor switches all the other LEDs. An (unregulated) 12 V mains supply can be used for power.

No current-limiting resistor is required in the LED chain, because the forward voltages of the LEDs in the chain add up to the supply voltage. If red LEDs are used, with a voltage drop of 1.65 V, then 12 V will supply seven; alternatively, use six yellow (2.1 V each) or five green (2.7 V). You can of course always mix the colours.

Variation:
Alongside the NPN transistor add a PNP transistor with its emitter connected to +12 V, with another string of LEDs connected down to ground. The two strings will flash alternately.

(014056-1)

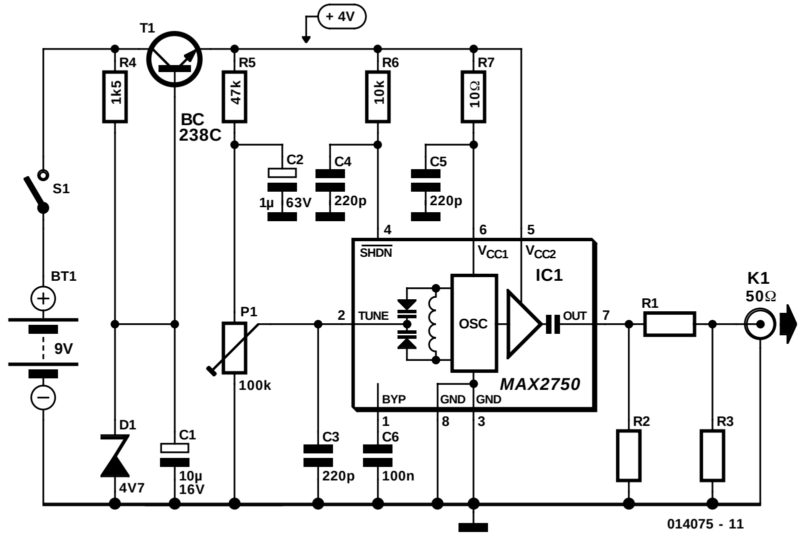


2.5-GHz Signal Source

018

More and more communications systems are operating in the 2.4-GHz ISM (Industrial, Scientific and Medical) band, including Bluetooth, various WLAN (Wireless Local Area Network) and Home-RF systems. A simple test oscillator for the frequency band between 2.4 GHz and 2.5 GHz can prove useful in testing receivers.

Such an oscillator is available from Maxim (www.maxim-ic.com) as a single IC. The MAX2750 covers the frequency range between 2,4 GHz and 2.5 GHz using in internal LC network that can be tuned using a varactor diode that is also built into the IC. An output buffer delivers a level of –3 dBm into 50 Ω. This component is housed in an 8-pin µMAX package.



The circuit is powered from a 9-V battery. The BC238C transistor stabilises the battery voltage at around 4 V. Although the MAX2750 can work with supply voltages between +2.7 V and +5.5 V, the frequency stability of the free-running oscillator is better with a stabilised supply voltage. All connections to the IC are decoupled using 220pF capacitors, which must be located as close as possible to the IC pins. The tuning voltage at pin 2, TUNE, may lie between +0.4 V and +2.4 V, which provides a tuning range between 2.4 GHz and 2.5 GHz. If it is desired to switch off the oscillator, this can be done by connecting the Shutdown input ($\overline{\text{SHDN}}$) to earth potential. When the IC is shut down, its current consumption drops to around 1 µA. Here the shutdown input is connected to the Vcc potential by a pull-up resistor, so that the oscillator runs.

The –3 dB output level can be reduced using the indicated pi attenuator. A number of resistance values for this attenuator are shown in the table.

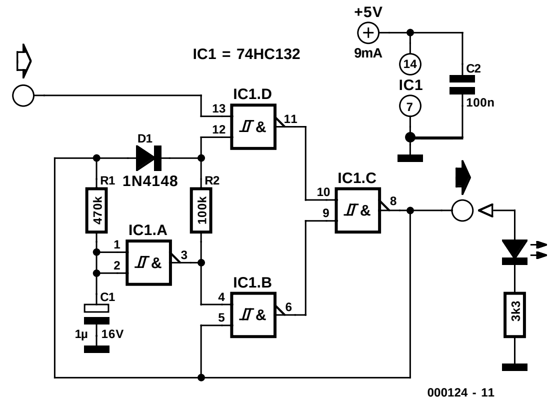
(014075-1)

Output level	Attenuation	R1	R2, R3
– 3 dBm	0 dB	0 Ω	–
– 5 dBm	2 dB	10 Ω	470 Ω
– 10 dBm	7 dB	47 Ω	130 Ω
– 15 dBm	12 dB	100 Ω	82.5 Ω
– 23 dBm	20 dB	243 Ω	61.9 Ω

Pulse Edge Visualiser

019

F. Rimatzki



A digital signal must have a certain duration before it can be monitored using an LED. Short pulses cause the LED to flash for an interval that is too short to be registered by our ‘slow’ eyes. The small supplementary circuit described here, which consists of only four two-input NAND gates in the form of a 74HC(T)132, two resistors, a diode and a capacitor, lengthens a short pulse enough that it can be clearly recognised using an LED.

The output level at pin 8 prepares the circuit for the subsequent pulse edge. If a logic ‘1’ is present at the output, C1 will be fully charged and the output of gate 1a will be Low. The output of IC1b and pin 9 of IC1c will thus be High. The High level on pin 8, which is applied to the input of IC1d via D1, ‘overrides’ the Low level on pin 3 that is applied via R2, so a High level is also present at pin 12 of IC1d. The whole arrangement is stable only as long as the input signal is also High.

If on the other hand a Low level is present at the output, the capacitor will be discharged and the output of IC1a will thus be High. This means that pin 9 and pin 12 are also High (D1 is now blocking). This state is also stable, but only as long as the input signal remains Low.

The situation changes as soon as the signal level at the input changes. When a positive or negative pulse edge appears at the input, the level at either pin 9 or pin 12 (respectively) goes Low momentarily while the level at the other pin remains unchanged. As a result, the output level changes in the same direction as the input signal. A new, immediately following level change has no effect, since it can reach the output only if pin 9 and pin 12 are simultaneously High. This is true only after the expiry of a prescribed interval determined by the values of R1 and C1 (in this case, several hundred milliseconds). During this ‘dead time’, a change in the input level has no effect at all on the output!

The circuit is so compact and simple that it can be used for applications such as debouncing pushbutton switches or digital signals. For such purposes, it can simply be inserted in the signal path.

It can also be easily fitted into the housing of a logic tester, and if a high-efficiency LED is used, it can make even short pulses visible.

By the way, the current consumption of the circuit (around 9 mA average) is least when the input level is Low, since in this case only the gate input current and diode leakage current flow through R2. In the opposite case, a much higher current flows via pin 8, D1 and R2 to pin 3. This behaviour can easily be reversed by simply swapping D1 and R2.

Even more power savings can be realised by replacing D1 and R2 with a true OR gate. With this modification, the circuit can be left permanently connected to a power source and no on/off switch is necessary.

The pulse edge visualiser should be powered from the circuit being tested, if only because of the values of the logic levels. Pay attention to the switching speed (HC or HCT) and the thresholds of the ICs used.

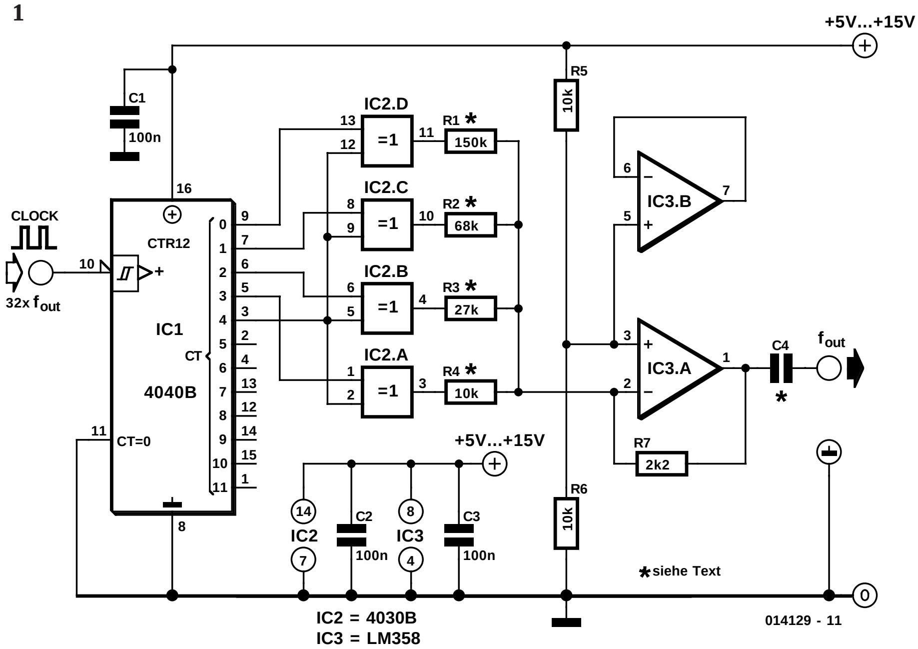
(000124-1)

Wideband Waveform Generator 020

This circuit is designed to provide a wideband digital sine wave signal source. Its main feature is that because it synthesises the signal in 32 steps, no low-pass filter is required to suppress the odd harmonics.

A well-known method for synthesising a sine wave under control of an input frequency is to apply a low-pass filter to a square wave of the same frequency. Along with the fundamental, this includes odd harmonics. After filtering out these parts of the signal we are left with a clean sine wave at the desired frequency. Unfortunately, the corner frequency of the low-pass filter limits the usable range of frequencies.

1



The solution presented here in **Figure 1** avoids low-pass filtering by using more voltage levels than just ‘high’ and ‘low’. Here there are 16 voltage levels which follow one after the other in a series of 32 samples. Outputs Q0-Q3 of counter IC1 control the voltage steps. Q4 inverts the polarity of the output in the second half of the period. This does not completely remove the odd harmonics — the signal still has steps in it — but they are severely attenuated.

Resistors R1-R4 together provide operational amplifier IC3 with 16 voltage levels. R5 and R6 hold the non-inverting input of IC3 (pin 3) at half the supply voltage. The operational amplifier therefore operates as an inverting amplifier with R7 as the feedback resistor. To obtain as symmetrical a signal as possible, a potentiometer is recommended for fine adjustment of this path.

This fine adjustment was be made before measuring the distortion: a THD+N figure of less than 10 % (over a bandwidth of 22 kHz) and less than 13 % (over a bandwidth of 500 kHz) was obtained with an input frequency of 32 kHz and an output frequency, therefore, of 1 kHz. The measured output signal is shown in **Figure 2**.

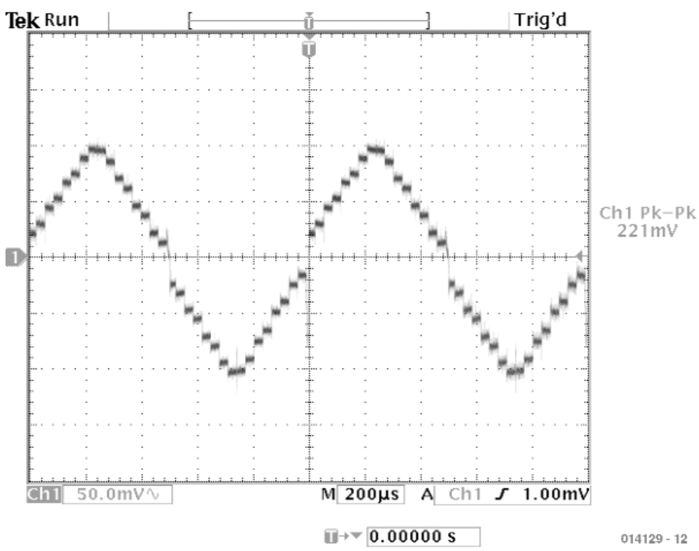
The shape of the output waveform (in this case a sine wave) is determined by the ratios between resistors R1 to R4. This allows plenty of scope for experiment! The clock frequency at the input to the counter should always be 32 times the desired output frequency.

The output of the operational amplifier has a DC offset of half the supply voltage. If this causes a problem in the circuit being driven, a coupling capacitor C4 must be fitted: the lower the operating frequency and the lower the load impedance, the greater the required value of capacitor.

The circuit operates from a supply of between +5 V and +15 V, and this determines the amplitude required of the input clock signal to drive counter IC1. The amplitude of the output signal can be set with resistor R7 and is independent of the output waveform. The current consumption of the waveform generator is about 3 mA.

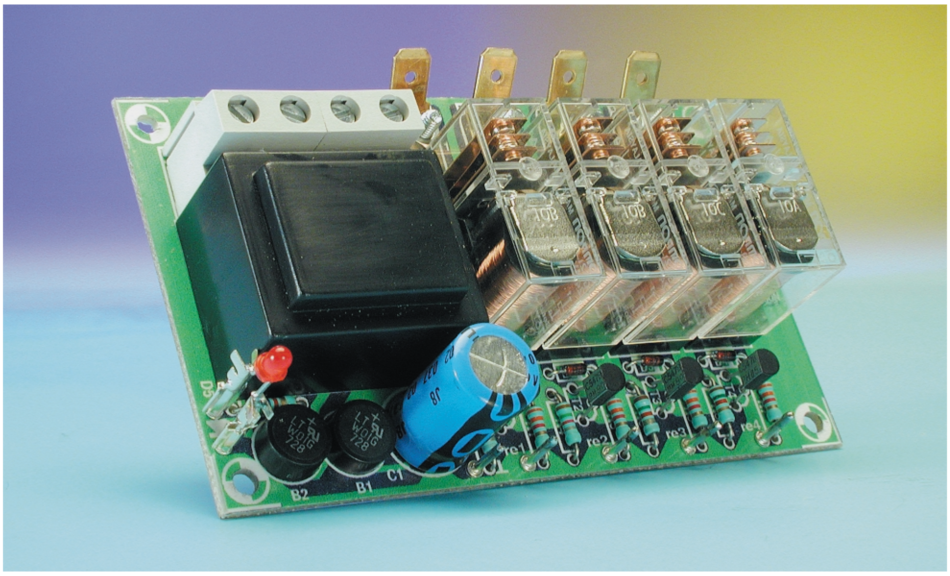
(014129-1)

2



Switchbox for Loudspeakers/Amplifiers

021



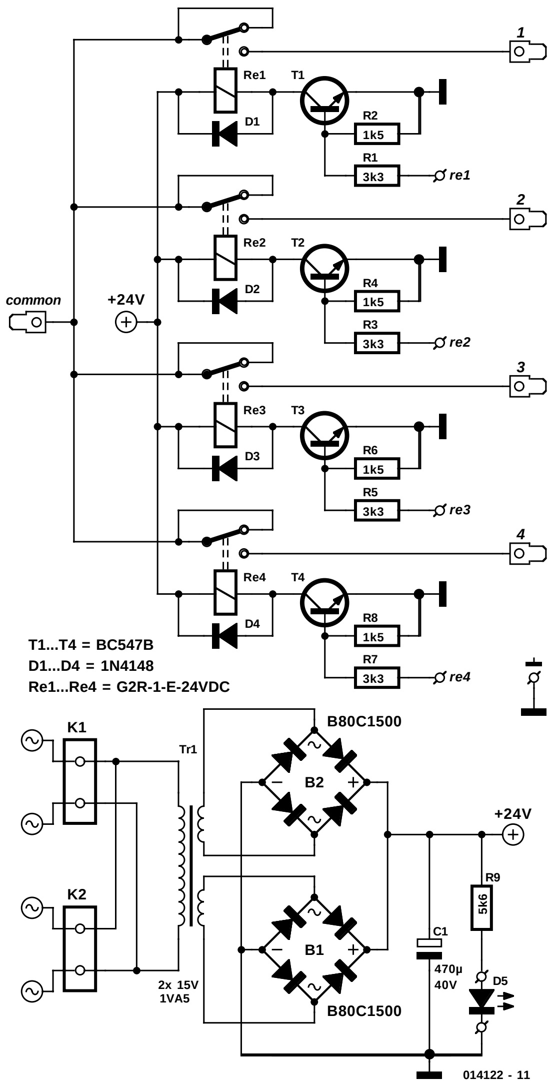
Anyone who has ever taken part in a listening test with various loudspeaker systems and amplifiers knows that the differences are often very subtle and difficult to judge. To make a good comparison it is absolutely necessary that changes from one combination to another can be made quickly. The adjacent circuit will be a welcome aid in these cases. It is specifically intended to switch between four amplifiers or loudspeakers. Also, when using the ‘Simple Remote Control’ described elsewhere in this issue it is not even necessary to leave your listening position.

The circuit consists of four relays, each with its own switching transistor and power supply. The connections for the loudspeakers/amplifiers are deliberately made with robust connectors, in order to deal with large currents and minimise the influence on the quality. The relays that have been selected are rated 16 A and each contact has two pins. The voltage dividers have been chosen such that the transistors will start to conduct at a voltage of around 2 V.

The power supply is provided by a 1.5 VA transformer, which is actually capable of delivering more power than is required by the relays used (not even 0.6 VA). We make welcome use of the fact that the open-circuit voltage of short-circuit proof transformers is significantly higher than the rated voltage. With one relay energised, the power supply voltage is around 23 to 24 V, and that is more than may be expected from a 15 V winding.

A striking detail is that two bridge rectifiers have been used for the power supply. The reason is that with short-circuit proof transformers of this kind, the two secondary windings are usually not equal to a degree that permits direct parallel connection. Providing each winding with its own rectifier does make this possible. This way, current cannot flow from one winding to another and unnecessary losses are avoided. An additional advantage is that a transformer with a single secondary winding may also be used, in this case the current will flow through one bridge rectifier through the load to the other rectifier.

The ripple voltage on the power supply amounts to less than 350 mV_{pp}. The mains connection on the printed circuit board has been duplicated. This allows for an easy loop-through mains voltage when multiple PCBs are used. LED D5 is the power supply indicator.



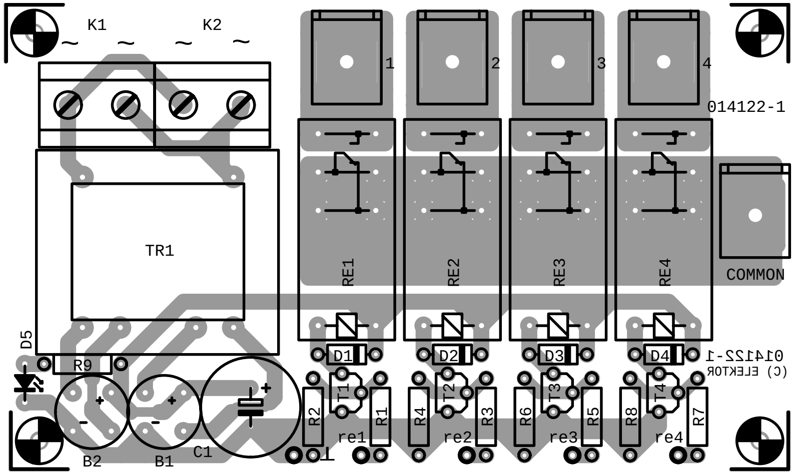
COMPONENTS LIST

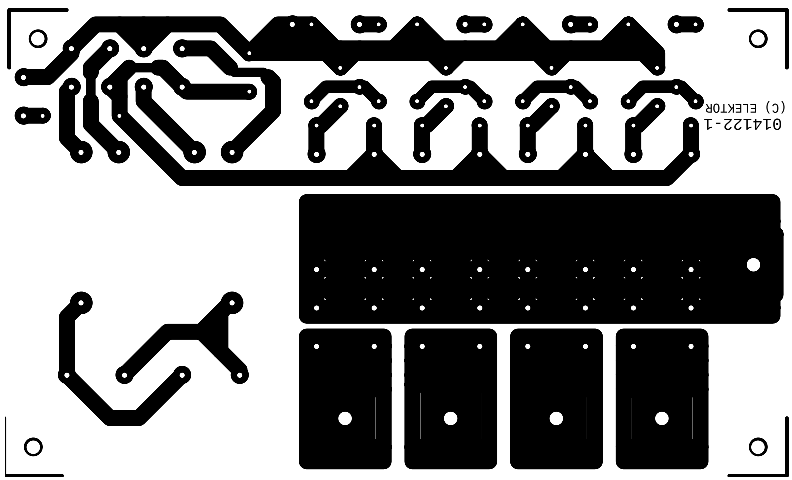
Resistors:
R1,R3,R5,R7 = 3kΩ3
R2,R4,R6,R8 = 1kΩ5
R9 = 5kΩ6

Capacitors:
C1 = 470µF 40V radial

Semiconductors:
B1,B2 = B80C1500, round case (80V piv, 1.5A peak)
D1-D4 = 1N4148
D5 = LED, high-efficiency
T1-T4 = BC547B

Miscellaneous:
Re1-Re4 = G2R-1-E-24VDC Omron (Conrad Electronics)
K1,K2 = 2-way PCB terminal block, lead pitch 7.5mm
Tr1 = 2 x 15 V/1VA5, e.g. Hahn type BV EI 302 2028
5 off spade terminal, screw mounting (3mm screw)





Considering that the circuit comprises a small number of parts, it is unlikely that the construction, with the aid of the PCB design shown here, should present any difficulties.

(014122-1)

Baudrate Divider Calculator for AVR Micros

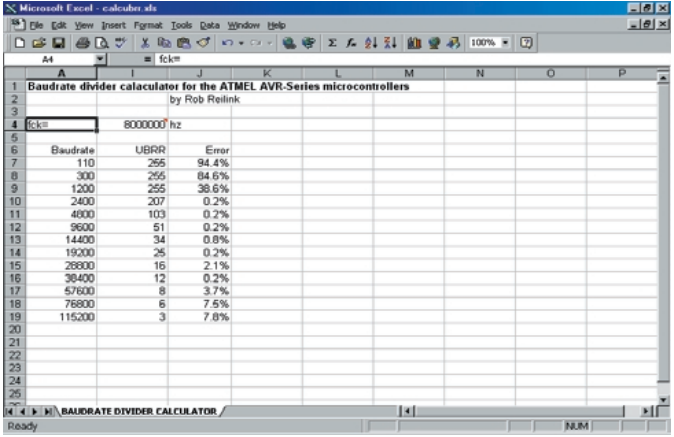
022

R. Reilink

An Excel spreadsheet is an extremely useful tool when you need to calculate a value to be loaded in the UBRR register of an Atmel AVR microcontroller. As most AVR programmers will know, these values depend on the crystal frequency used because they are derived from it. Without such a spreadsheet, such calculations are tedious.

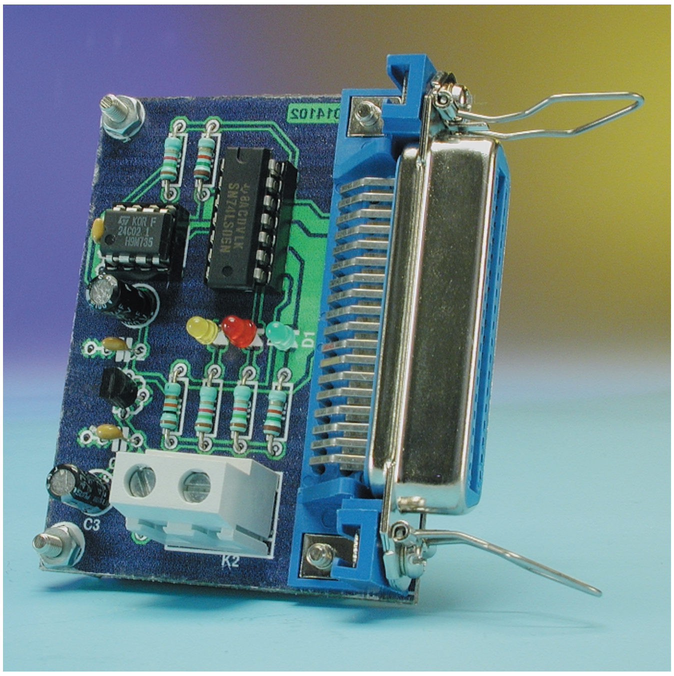
A Microsoft Excel spreadsheet called **calcubrr.xls** was developed for this purpose. It may be downloaded as file number **000167-11** from the Free Downloads section on the *Elektor Electronics* website, www.elektor-electronics.co.uk. Look under July/August 2001 items.

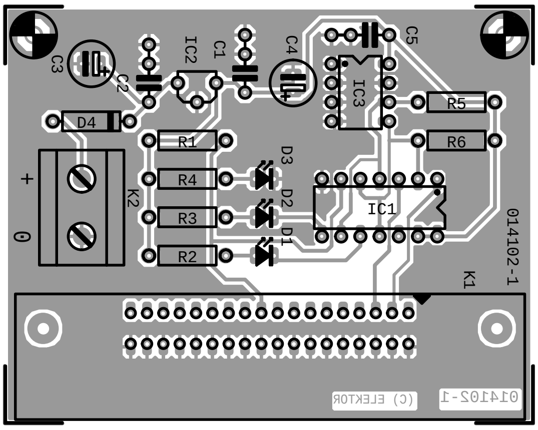
(000167-11)

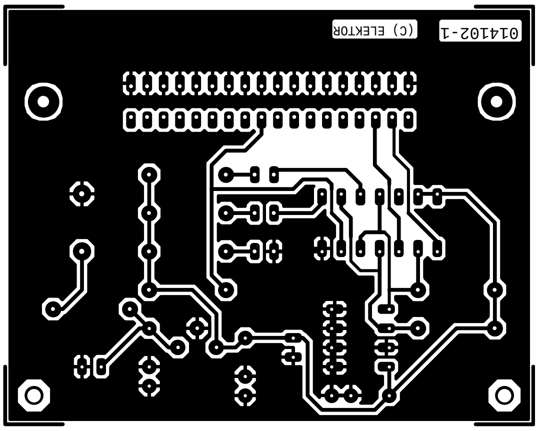


Simple EEPROM Programmer

023







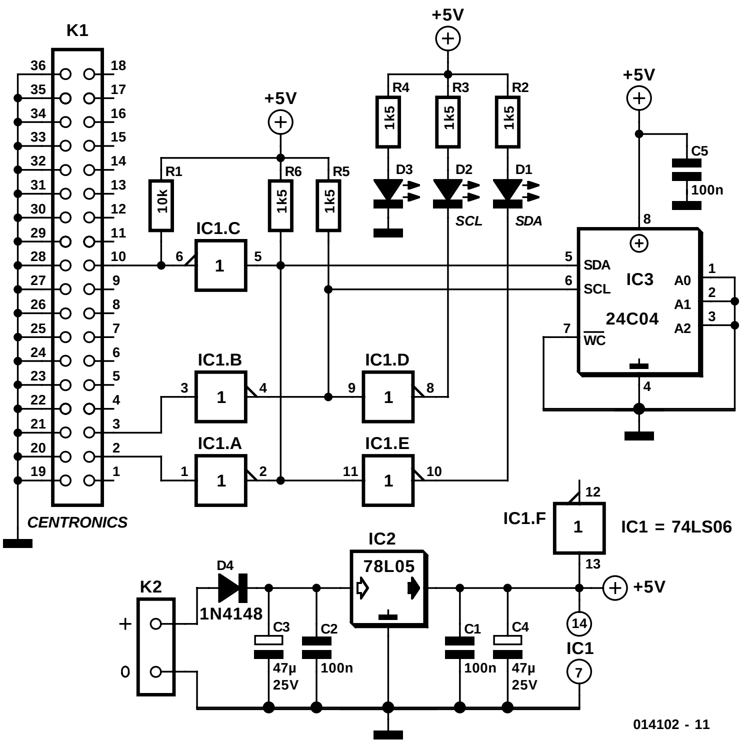
R. Weber

An extremely popular programmer for the PIC16C84 micro-controller has already appeared in *Elektor Electronics* (Summer Circuits, 1998): that design used the parallel interface and the popular PIP-02 shareware from Silicon Studio, together with a special driver written by Dave Tait. PIP-02 is capable of programming not just PICs but also EEPROMs equipped with an I²C interface.

This works with essentially the same hardware as we presented then, and the circuit in **Figure 1** shows how the device to be programmed can be connected. The connection for the special programming voltage has gone, since the EEPROM does not require it.

What remains is a hex inverter with open-collector outputs (type 74LS06), which buffers the serial clock SCL before taking it to the appropriate EEPROM pin. The serial data line is, in contrast to the clock signal, bidirectional. For this reason two separate buffers are required, IC1B for signals from PC to EEPROM and IC1C for the reverse path.

Since a PCB is hardly worthwhile for just a couple of ICs and a connector, we have added a little extra: two spare inverters from the 74LS06 are connected to the two bus lines and drive LEDs, which allow the programming process to be monitored. A third LED is connected to the supply to verify operation. And



COMPONENTS LIST

Resistors:
R1 = 10kΩ
R2-R6 = 1kΩ5

Capacitors:
C1,C2,C5 = 100nF
C3 = 47µF 25V
C4 = 4µF7 25V

Semiconductors:
D1 = LED, green, low current
D2 = LED, red, low current
D3 = LED, yellow, low current
D4 = 1N4148
IC1 = 74LS06
IC2 = 78L05
IC3 = 8-way IC socket

Miscellaneous:
K1 = Centronics connector, angled pins, PCB mount
K2 = 2-way PCB terminal block, lead pitch 7.5mm

finally, IC2 and the capacitors provide a regulated power supply on the PCB so that an ordinary (9 V) mains adaptor can be connected to K2 to power the programmer. Nothing can go wrong if the supply is connected backwards: D4 protects the hardware (and the PC) from damage.
The PIP-02 software, along with the **`dtait.exe`** driver, is available on the Internet from Dave Tait's very informative website www.thepicarchive.cwc.net/dtpa/links.html and of course it is all free. Although the link to Silicon Studio is broken, the software (along with much else) is archived on Dave's site.

(014102-1)

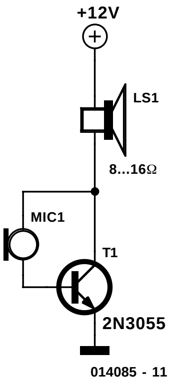
Three-component Oscillator

024

P. Lay

At first glance, this circuit appears to be just a primitive microphone amplifier. Why then is the title of this article 'Three-component Oscillator'? The answer is very simple: the microphone is not intended to pick up speech; instead, it is placed so close to the loudspeaker that massive positive feedback occurs. Here we intentionally exploit an effect that is assiduously avoided in public-address systems — the positive feedback results in a terribly loud whistle. The loudspeaker is connected directly to the 12-V supply voltage and the power transistor, so it must be able to handle a power of at least 1.5 W, and it should have an impedance of 8 to 16 Ω. An outstanding candidate can be cannibalised from an old television set or discarded speaker box. The microphone should be a carbon-powder type from an old-fashioned telephone handset. If you place a switch in series with the power supply, this sound generator can also be used as an effective doorbell or siren. Surprisingly enough, the circuit can also be used as a simple microphone amplifier — hardly hi-fi, of course, but still usable.

(014085-1)

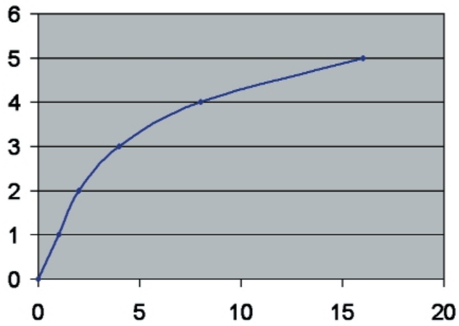


Graphs in Excel

025

Drawing nice-looking graphs requires both feeling and skill. In the past, this was taught at school using grid paper, but these days anyone can grab a computer and even a steady hand is no longer a requirement. But which program lends itself best for the drawing of graphs? The familiar Microsoft Excel, which is installed on practically any computer nowadays works quite well: simply enter a table of numbers, choose the desired type of graph and voilà, a beautiful graph, which can be pasted into a document or printed!

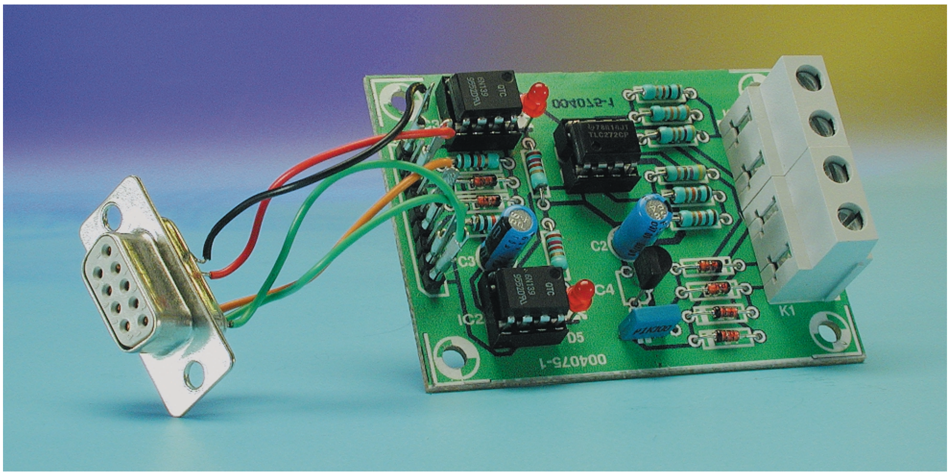
On certain occasions however, you will be disappointed. This is because Excel assumes that all the intervals are equal, and this is not the case with many measurements. Selecting the 'scatter' type of graph can solve this problem; this version of the graph is able to deal with irregular intervals, as is illustrated by the accompanying picture.



(000168-1)

Opentherm Monitor

026



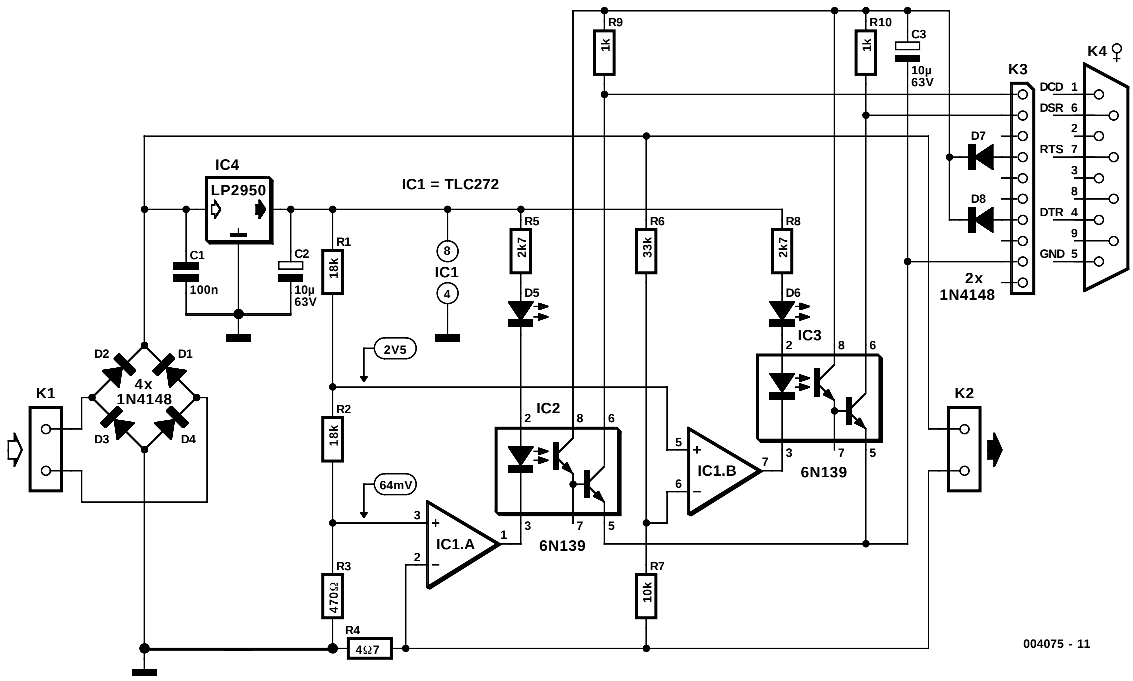
If you say that the term ‘Opentherm’ is unfamiliar to you, then this will not surprise us the least. Opentherm is a protocol, which can control central heating boilers and hot water systems digitally. ‘Open’ indicates that it is not specific to a single brand. Anyone can, in principle, make use of this protocol, provided you are prepared to hand over several thousand pounds for ‘membership’ and are prepared to keep the information secret (talk about ‘open’…). As a consequence we unfortunately do not know a great deal about it, but we do have a few technically interesting pieces of information we would like to share with you.

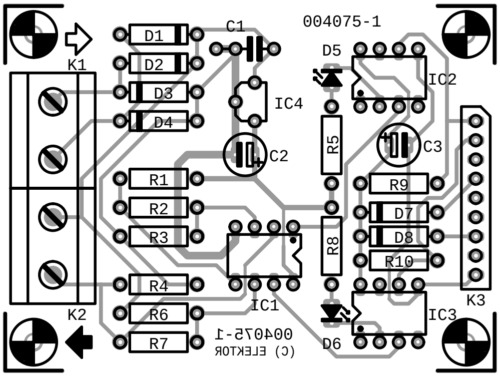
The connection between the master device (usually the room thermostat) and the slave (typically the central heating boiler) consists of two wires, which permits the use of existing cabling. Via this cable the boiler powers the thermostat with DC. In order to prevent wiring errors, the thermostat is fitted with a bridge rectifier, allowing the conductors (positive and negative) to be reversed. The installer cannot make any mistakes here.

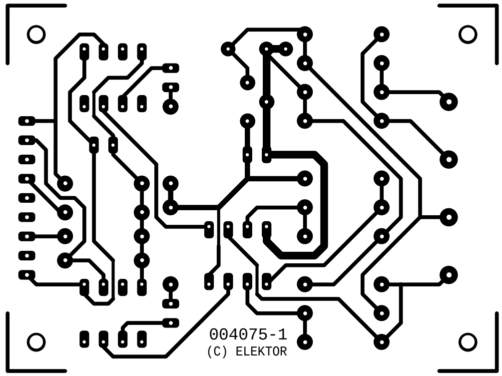
The master places on this connection a digital signal. Every second, 32-bits are transmitted in Manchester-code and after about 0.2 seconds the slave responds with the return message. Every bit lasts 1 ms, and a message consists of:

1	Start bit (logical zero)
1	Parity bit
3	Message type
4	Spare
8	Data ID
16	Data
1	Stop bit (logic zero)

From the electrical perspective, an interesting solution has been selected. The boiler sources **current**, a logic Low is a current between 5 and 9 mA, a logic High a current between 17 and 23 mA. This way the thermostat is always powered. In the opposite direction, the thermostat signals







COMPONENTS LIST

Resistors:
R1,R2 = 18kΩ
R3 = 470Ω
R4 = 4Ω7
R5,R8 = 2kΩ7
R6 = 33kΩ (30kΩ)
R7 = 10kΩ
R9,R10 = 1kΩ

Capacitors:
C1 = 100nF
C2,C3 = 10µF 63V radial

Semiconductors:
D1-D4,D7,D8 = 1N4148
D5,D6 = LED, high-efficiency
IC1 = TLC272 CP
IC2,IC3 = 6N139
IC4 = LP2950 CZ 5.0

Miscellaneous:
K1,K2 = 2-way PCB terminal block, lead pitch 7.5mm
K4 = 9-way sub-D socket (female)

by pulling down the open circuit boiler **voltage** of 24 V to a voltage less than 9 V (logic Low) or between 15 and 18 V for a logic High. So, at the risk of over-emphasising: the boiler provides information by modulating the current, and the thermostat by changing the voltage. All this can easily be observed on an oscilloscope.

In order to follow the activities, we have designed a circuit that does not unduly influence the operation, although it causes an unavoidably small voltage drop of course. The boiler is connected to K1; the polarity is of no consequence because the connector is followed by a bridge rectifier (D1-D4). The thermostat is connected to K2. R4 and IC1a look if the current corresponds with a logic ‘Low’ or a ‘High’ and signal this, electrically isolated, to the DCD of the serial input of your computer. The voltage of the connection is monitored by R6, R7 and IC1b and copied to DSR. An oscilloscope connected to these points easily shows you the messages going back and forth. It is likely that the current channel shows both messages. When the voltage on the wires changes, there is also an inevitable change in current because the thermostat is a capacitive load.

The circuit is powered from the RTS and DSR handshaking lines. They have to be made logic Low first, of course. Naturally, it is also possible to connect a power supply of around 10 to 12 V **behind** the diodes.

Those who are keen can write a program to read the serial inputs and decode the Manchester-code to data. Certain information, such as room and boiler temperature can easily be found.

Unfortunately we do not have any more information and neither do we have a program. Every now and then there is something to be found in the Internet, so it may be sensible to keep an eye this.

(004075-1)

VHF Test Transmitter

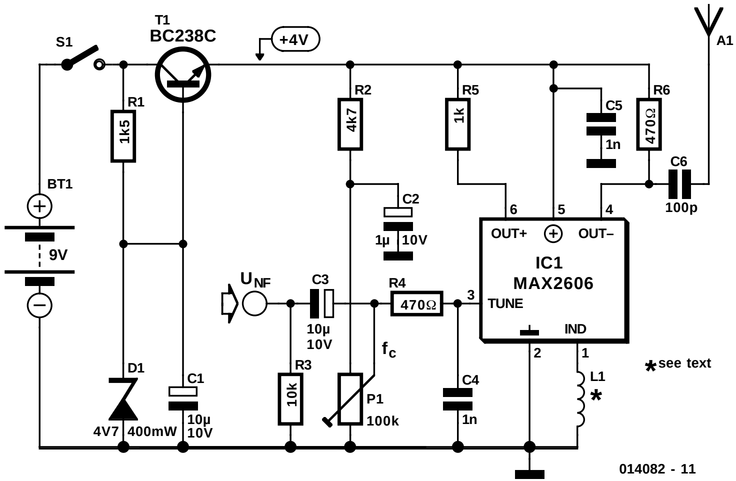
027

If you want to be independent of the local radio stations for testing VHF receivers, you need a frequency-modulated oscillator that covers the range of 89.5 to 108 MHz — but building such an oscillator using discrete components is not that easy. Maxim now has available a series of five integrated oscillator building blocks in the MAX260x series (see the May 2001 issue of *Elektor Electronics*), which cover the frequency range between 45 and 650 MHz. The only other thing you need is a suitable external coil, dimensioned for the midrange frequency.

The MAX2606 covers the VHF band, although the frequency can only be varied by approximately ±3 MHz around the midrange frequency set by the coil L. The inductance values shown in the table can serve as starting points for further experimenting.

The SMD coils of the Stettner 5503 series are suitable for such oscillators. In Germany, they are available from Bürklin (www.buerklin.de), with values between 12 nH and 1200 nH. You can thus directly put together any desired value using two suitable coils. If you want to wind your own coils, try using 8 to 14 turns of 0.5-mm diameter silver-plated copper wire on a 5-mm mandrel. You can make fine adjustments to the inductance of the coil by slightly spreading or compressing the coil.

The circuit draws power from a 9-V battery. The BC238C stabilises the voltage to approximately 4 V. Although the MAX2606 can work with a supply voltage between +2.7 V and +5.5 V, a stabilised voltage improves the frequency stability of the free-running oscillator. The supply voltage connection Vcc (pin 5) and the TUNE voltage (pin 3) must be decoupled by 1-nF capacitors located as close as possible to the IC pins. The tuning voltage TUNE on pin 3 may lie between +0.4 V and +2.4 V. A symmetric output is provided by the OUT+ and OUT– pins. In the simplest case, the output can be used in a single-ended configuration. Pull-up resistors are connected to each of the outputs for this purpose. You can use a capacitor to tap off the radio signal from either one of these resistors. Several milliwatts of power are available. At the audio input, a signal amplitude of 10 to 20 mV is enough to generate the standard VHF frequency deviation of ±40 kHz.



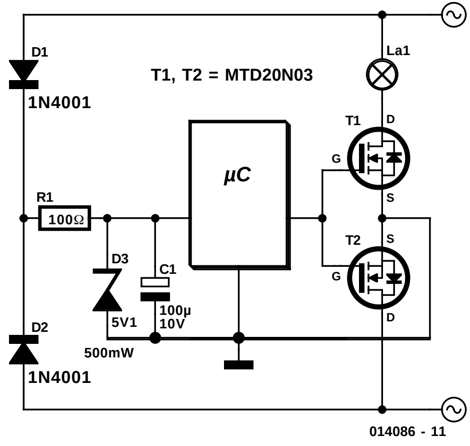
f (MHz)	89–95	93–99	97–103	100–106	103–109
L (nH)	500	470	420	390	350

(014082-1)

AC Controller using MOSFETs 028

Particularly with low voltages, triacs are usually used as control elements for ac voltages. The disadvantage, as so often is the case, is in the power dissipated in the control element, which is quite evident for currents greater than 1 ampère. In such cases, it is essential to use a heatsink for the triac. If you want to control the brightness of a halogen lamp using such an arrangement, for example, the voltage drop across the triac also results in a significant reduction in the maximum brightness of the lamp.

This disadvantage can be avoided by using two MOSFETs for the control element, in place of a triac. The trick here is to connect the two MOSFETs in series with opposite polarity, with the gates connected in parallel to the control circuit. The junction of the two gate leads represents the virtual ground of the circuit, which forms the reference for all other potentials. Modern MOSFETs, such as the 20N03 from On Semiconductor (www.on-semi.com) with an $R_{DS(ON)}$ of 0.035 Ω, can be used in this circuit for controlling a 50-W halogen lamp without any supplementary heatsink. The loss in brightness is negligible, since the voltage drop is only (0.035 Ω × 4.2 A) = 0.147 V. Of course, you do not necessarily have to use the 20N03; in principle, any n-channel



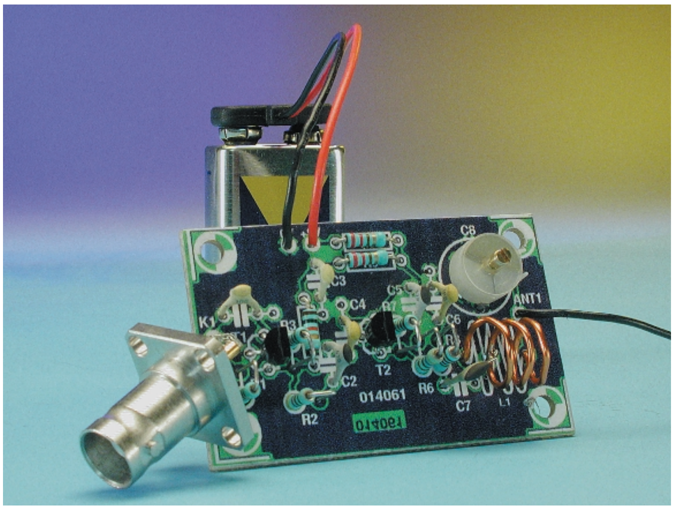
MOSFET with a low gate voltage (preferably a 'logic FET') can be used.

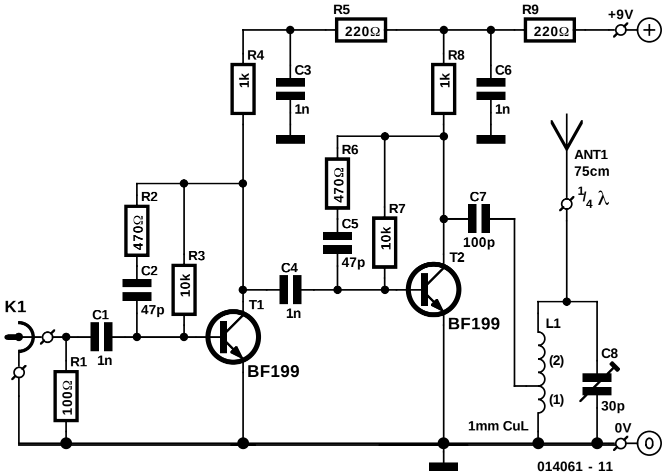
Another benefit of this circuit is its 'zero-power' gate drive, in contrast to triacs, which require drive currents of 10 mA or more. This means that any microcontroller, TTL gate or 555 timer IC can be used as the controller.

(014086-1)

Booster for Cable Radio

029





With the aid of this circuit it is possible to listen, using a portable VHF FM radio, to listen to stations that transmit only your local cable network. Both from its properties and its design this ‘cable booster’ appears similar to an antenna amplifier, because this is a two-stage amplifier with two common RF transistors type BF199. Only this time, the input is connected to the cable connection instead of an antenna while the output does not contain a coaxial connection but a tuned circuit that acts as impedance matching for a 1/4λ-antenna. If the circuit is tuned correctly (using trimmer C8), the amplified cable signal is radiated by the vertical antenna and can be easily received by a portable receiver up to three metres away.

It is always possible to build the circuit on a piece of prototyping board, but because an RF-circuit is usually a little more critical it will probably work a lot better if you make use of the PCB layout shown here. During the design, the essential connections have been kept short and the ground plane has been made as large as possible. Capacitor C7 is best directly connected to the tap on L1, as can be seen in the photo. The (air-cored) coil consists of three turns of 1-mm enamelled copper wire (ECW) wound around a pencil (diameter about 8 mm).

During the construction make sure that you keep the connecting wires from the coax connector K1 to the PCB as short as possible. This prevents the circuit from picking up signals from the air and possibly showing an undesirable tendency to oscillate. The PCB must be fitted in a metal enclosure.

The power supply of the cable booster can either be a 9 V battery or a small, regulated mains power supply. The current consumption amounts to about 2.5 mA.

(014061-1)

COMPONENTS LIST

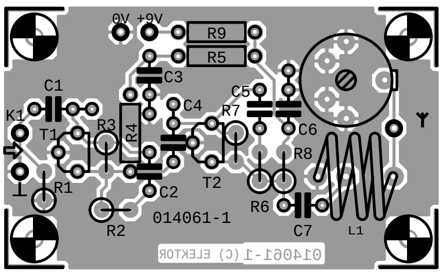
Resistors:
R1 = 100Ω
R2,R6 = 470Ω
R3,R7 = 10kΩ
R4,R8 = 1kΩ
R5,R9 = 220Ω

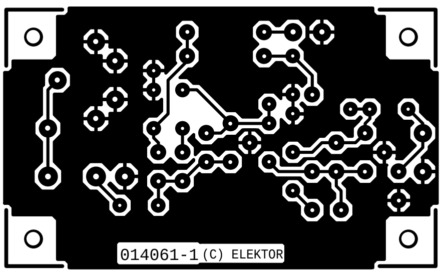
Capacitors:
C1,C3,C4,C6 = 1nF
C2,C5 = 47pF
C7 = 100pF
C8 = 30pF trimmer capacitor

Inductors:
L1 = 3 turns 1mm dia. ECW, internal dia. 8mm, tap at 1 turn

Semiconductors:
T1,T2 = BF199

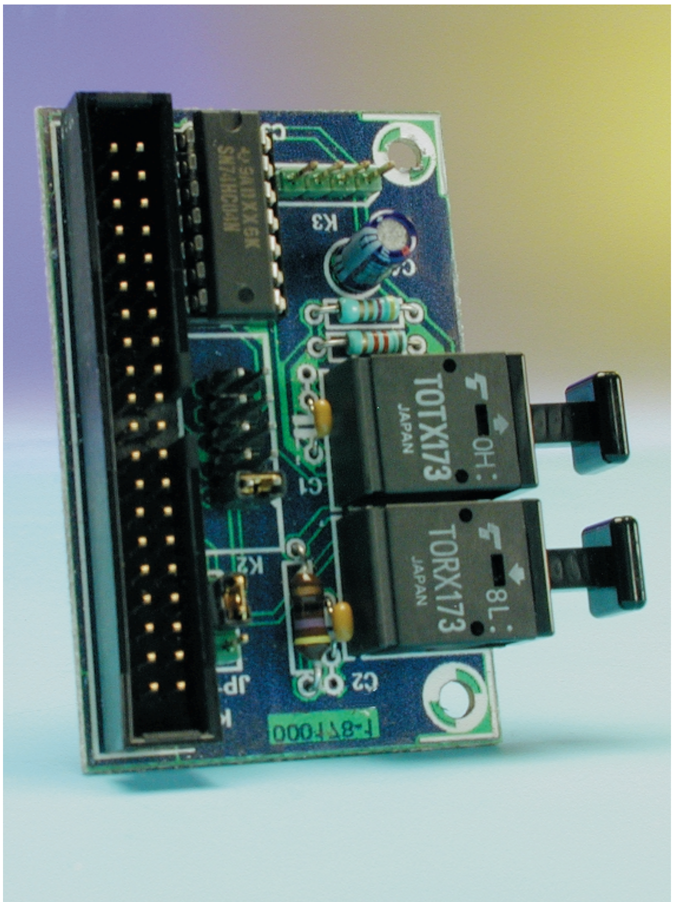
Miscellaneous:
K1 = coax socket, chassis mounting
ANT1 = telescopic or whip antenna, length approx. 75cm
9V battery with holder and wires
Diecast enclosure

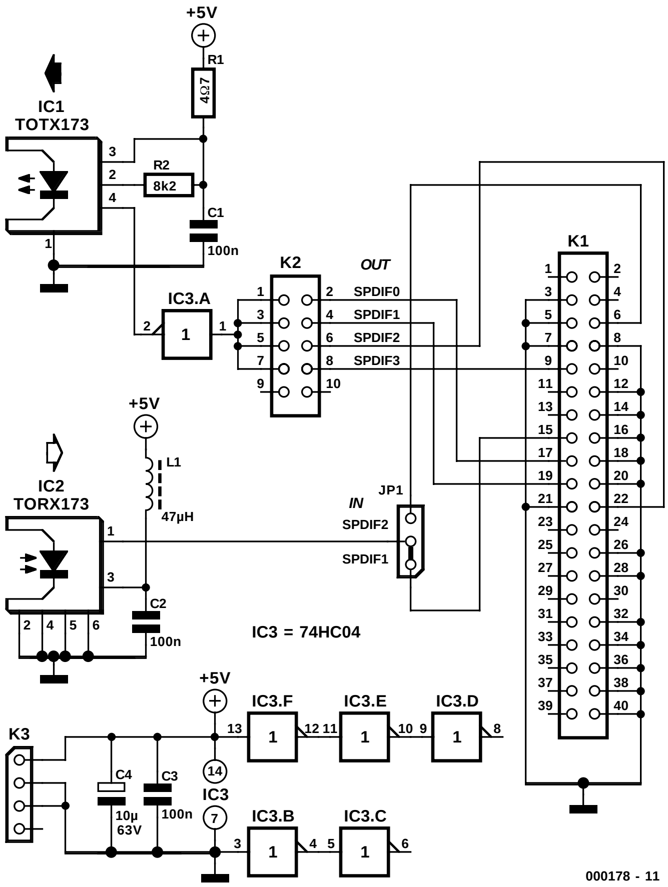




Simple Adapter for SB Live! Player 1024

030

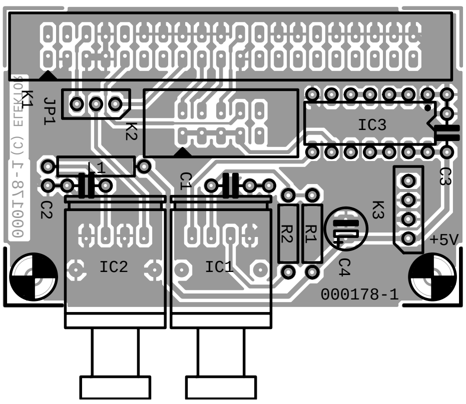


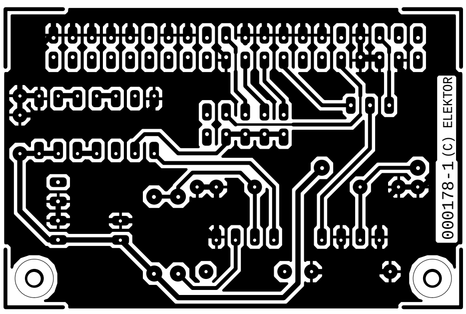


F. Brandt

The 2000 Summer Circuits Collection contained an adapter that made it possible to connect the digital extension (PCB **990079-1**) from December 1999 in the correct manner with the 'Sound Blaster Live! 1024'. This digital extension, fitted with both coaxial as well as optical inputs and outputs, was originally designed for the 12-pin expansion connector (Audio-Extension-connector) on the 'Sound Blaster Live! Player (Value)'. The 1024 model has a 40-pin connector.

This circuit combines the two in a simplified fashion. There is now only one optical input and one optical output. Using jumper K2 you can select one of the four outputs. Similarly, JP1 lets you select one of the two inputs. It appears that Live!Ware 3.0 supports only the first input. For those who are interested, the pin assignment details of the expansion connector can be found in the help menu, or with the aforementioned circuit description ('Adapter for SB Live! Player 1024') in the 2000 Summer Circuits Collec-





tion. To make the connection to a Home-MD recorder a Toslink-to-Toslink-cable is required. To link to a portable MD recorder a Toslink-to-miniplug is necessary.

This simplified adapter has been specifically designed for use with MD recorders, because these are usually fitted with optical inputs and outputs only. The construction of the circuit with the aid of the PCB design shown here should be a piece of cake. The power supply for the circuit is obtained from a small PC power supply connector, which is connected to 4-way pin header K3. Pay careful attention to the polarity when attaching the connector; the red wire is the +5 V connection!

(000178-1

COMPONENTS LIST

Resistors:
R1 = 4Ω7
R2 = 8kΩ2

Capacitors:
C1,C2,C3 = 100nF ceramic
C4 = 10µF 63V radial

Inductor:
L1 = 47µH

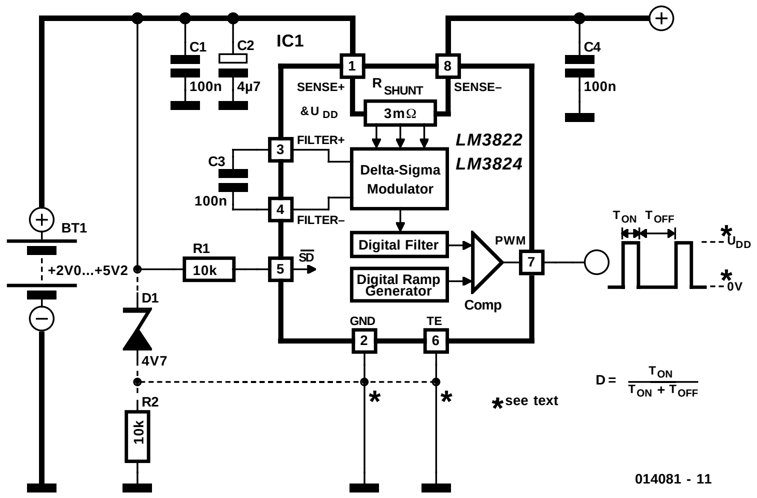
Semiconductors:
IC1 = TOTX173
IC2 = TORX173
IC3 = 74HC04

Miscellaneous:
JP1 = 3-way pinheader with jumper
K1 = 40-way boxheader
K2 = 10-way double row pinheader with jumper
K3 = 4-way pinheader

LM 3822/24 Current Meter

031

ICs for measuring currents usually employ external sense resistors with values of a few tens of milliohms. Not only are such resistors difficult to obtain, the circuit board layout can have a disturbing effect on the accuracy of the measurement. This problem is eliminated by the LM3822 and LM3824 ICs from National Semiconductor (www.national.com), which have built-in sense resistors with a value of only 3 mW. A delta-sigma modulator converts the measured value into a digital value. A digital filter takes the average value of the current every 50 ms (LM 3822) or every 6 ms (LM 3824). A pulse-width modulated signal (PWM) that is proportional to the current level is generated by comparing this to a digital ramp signal. According to the manufacturer, the LM3822/24 provide the highest measurement accuracy of any currently available high-side current measurement IC. In the case of the LM3824, the accuracy is ±2%.



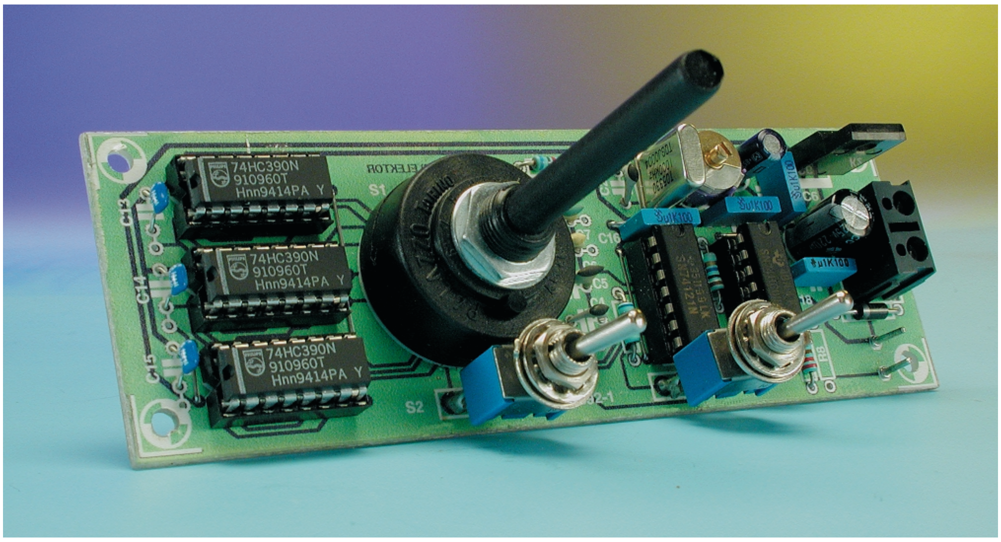
Type	Measurement range	Error	Sampling interval	PWM resolution
LM3822-1.0	–1.0...+1.0 A	±2 %	50 ms	0.1 %
LM3822-2.0	–2.0...+2.0 A	±2 %	50 ms	0.1 %
LM3824-1.0	–1.0...+1.0 A	±3 %	6 ms	0.8 %
LM3824-2.0	–2.0...+2.0 A	±3 %	6 ms	0.8 %

On the output side, the LM3822/24 deliver a pulse-width modulated signal (PWM) whose duty cycle D indicates the measured value of the current, including its sign. If the current is equal to zero, D is exactly 50 %. Positive currents yield duty cycle values ranging from 50 % to 95.5 %, and negative currents yield duty cycle values ranging from 50 % to 4.5 %. A value of 95.5 % thus corresponds to +1 A (or +2 A), while a value of 4.5 % corresponds to –1 A (or –2 A). The current is considered to be positive when it flows from SENSE to SENSE–.

The LM3822/24 ICs work with a supply voltage between 2.0 V and 5.5 V and have an internal current consumption of less than 150 µA. For operation at voltages greater than 5.5 V, the Zener diode shown in dashed outline in the schematic diagram can be use with a 10-kΩ series resistor. The Zener diode limits the operating voltage across the LM3822/24 to a safe 4.7 V. Note however that in this case, the output signal is not longer referenced to ground, but swings between the supply voltage level and 4.7 V below this level. A level converter is thus needed for signal processing. The GND and Test (TE) pins should be connected to the zener diode.

(014081-1)

Economical Timebase Calibrator 032

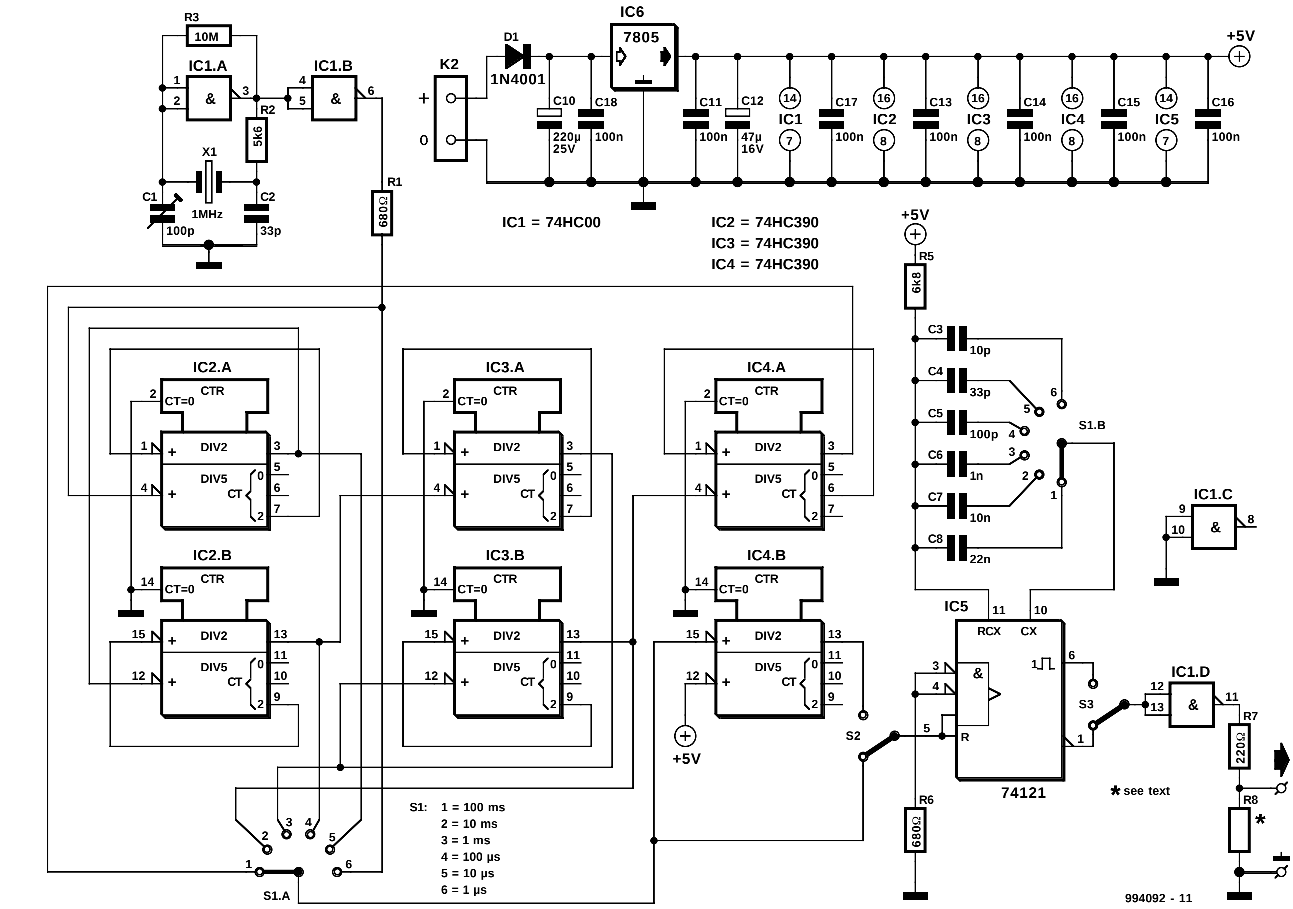


F. Hueber

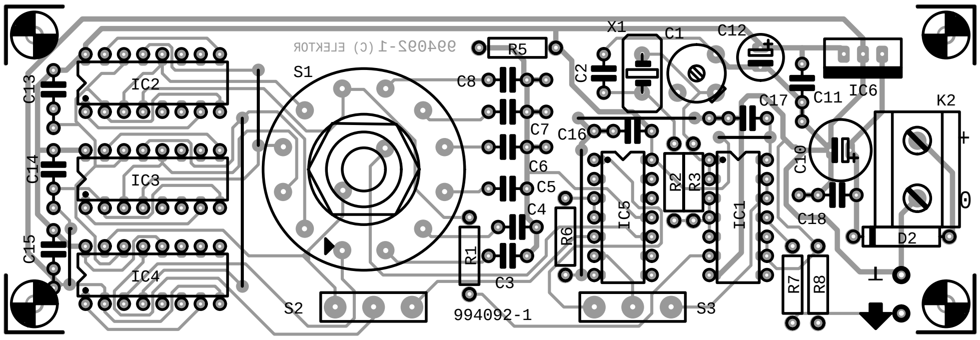
An external timebase calibrator is a useful accessory for any oscilloscope it provides precise, visible time markers on the scopes horizontal sweep. Basically the circuit is a pulse generator with accurate time intervals between pulses i.e. the pulse repetition frequency. If the pulse width is made relatively small compared to the repetition rate and the pulse edges are steep then the output signal will look like a series of illuminated dots. These can be conveniently used to measure time periods on the screen just as you use the graduation marks on a ruler to measure length.

The circuit diagram shown in **Figure 1** uses five commonly available ICs (excluding the power supply). A 1 MHz crystal provides an accurate time base for the oscillator circuit built around IC1A. Resistor R3 governs the switching threshold while trimmer C1 alters the loading on the crystal and allows its frequency to be

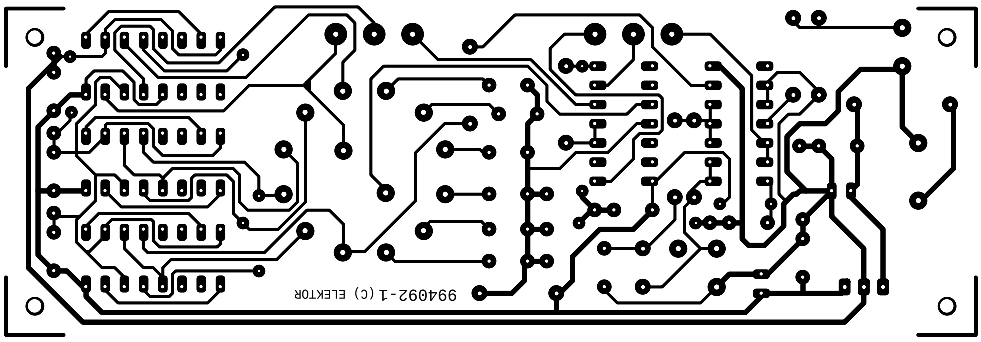
1



‘pulled‘ slightly which is necessary when calibrating the circuit. IC1B buffers the oscillator from the rest of the circuitry and R1 cleans up the square wave output by reducing any overshoot on the clock edges. The output signal is connected to five cascaded decade counters type 74HC390 (IC2 to IC4A) each counter divides its input frequency by 10. Switch S1A selects one of the frequencies or time intervals from 1 MHz (1 µS) to 10 Hz (100 ms) to route it to a pulse generator formed by IC5. The second half of counter IC4 is used to provide a divide-by-two function, this can be bypassed by switch S2. In total this gives 12 possible pulse repetition rates from 1 µS to 200 ms.



2



The output timing pulse is generated by IC5. This is a standard TTL monostable type 74121. Standard TTL devices can be interfaced directly with HC devices without any problem. The output pulse width of the monostable is a function of the resistor/capacitor value at pins 10 and 11. As the repetition rate is changed by switching the counter outputs with S1A so the second half of the switch (S1B) also switches different R-C components to the monostable. This ensures that the marker pulses shown on the oscilloscope screen will be the correct width for each selected range. The output stage of a standard TTL IC does not drive symmetrically so IC1D is used as a buffer to give a better output performance. Switch S3 allows the polarity of the output pulse to be switched and resistor R7 provides short circuit protection for the output buffer. Unfortunately in combination with the capacitance of the output lead, this resistor also forms a low pass filter that has the effect of rounding off the sharp edges of the output signal. Socket K2 is used for connection of an external 9 V mains unit to power the circuit and IC6 regulates this to 5 V for use on board. Current consumption is only a few milliamps so a heatsink is unnecessary.

Fitting the PCB into a case is greatly simplified by mounting the single-sided PCB directly to the back of the front panel switches.

Mounting the components on the board is begun by first soldering the six wires bridges and the smaller components to the board. It’s worth taking a little care here to ensure that the polarised capacitors and diode are correctly fitted. This design will produce RF interference so it is advisable to fit the unit inside a metal case or at least a screened plastic case, the screen or case should be connected to the power supply ground.

To test the circuit, first check that 5 V is available from the power supply. Next, connect a frequency counter to resistor R1 and adjust trimmer C1 until 1.000 MHz is achieved. If there is insufficient adjustment in C1 then try a different value for C2. If you do not have access to a frequency counter then just set the trimmer to mid-position or replace it with a 56 pF fixed capacitor.

The output of the calibrator can be connected to the scope input channel via a short length of 50-Ω coax cable. An output series resistor (R8) is used to dampen ringing on the output pulses introduced by the cable capacitance. R8 can be fitted directly to the output BNC socket and its value will be in the range of 220 Ω to 470 Ω.

The best output pulses will be produced by hooking the tip of a 10x scope probe directly on the output pin of the

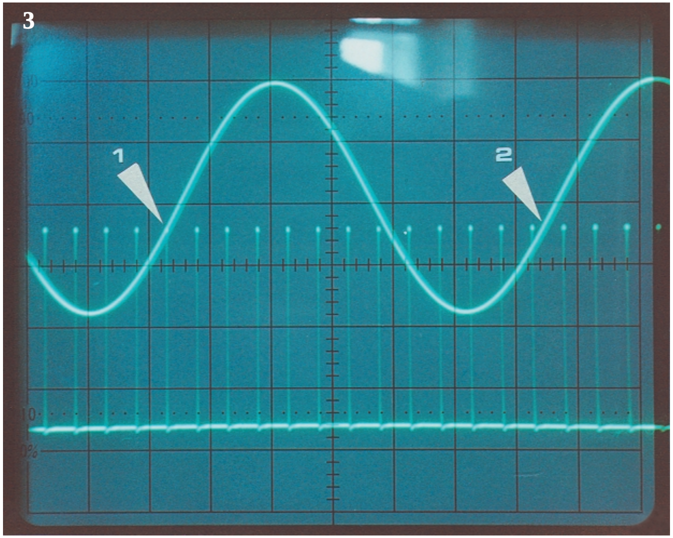
COMPONENTS LIST

Resistors:
R1,R6 = 680Ω
R2 = 5kΩ6
R3 = 10MΩ
R5 = 6kΩ8
R7 = 220Ω
R8 = *

Capacitors:
C1 = 100pF trimmer
C2,C4 = 33pF
C3 = 10 pF
C5 = 100pF
C6 = 1nF
C7 = 10nF
C8 = 22nF
C10 = 220µF 25V radial
C11,C13-C18 = 100nF
C12 = 47µF 16V radial

Semiconductors:
D1 = 1N4001
IC1 = 74HC00
IC2,IC3,IC4 = 74HC390
IC5 = 74121
IC6 = 7805

Miscellaneous:
S1 = rotary switch, 2 poles, 6 contacts
X1 = 1MHz quartz crystal
S2,S3 = toggle switch,1-change-over contact
K2 = 2-way PCB terminal block, lead pitch 5mm



BNC connector, most scope probes will be able to manage this without any problem. A useful addition to the front panel next to the BNC output would be a solder/test point connected to the circuit earth. This provides a convenient parking spot for the scope probe earth clip.

To check the horizontal timebase of an oscilloscope first make sure that and variable time base controls are set to the ‘calibrate‘ position then select a sweep speed so that each output pulse corresponds to one square of the screen graticule. Use the horizontal position adjustment to place the pulses exactly under the graticule lines Check carefully that the pulses occur exactly at each graticule line intersection across the full width of the screen. This will not always be the case with budget priced oscilloscopes!

If you have a two-channel scope it is also possible to use the calibrator to perform quick and easy frequency measurements so that in many cases you will not need a frequency counter at all. First of all connect the signal to be measured to channel A of the scope input and the calibrator output to channel-B input. Adjust the scope timebase generator so that one whole period of the unknown frequency is displayed on the screen. With the scope trigger mode set to ’alternating’ adjust the vertical positions of the channels until they are superimposed and the edge of one of the pulses coincides exactly with a point on the channel A waveform (see (1) in **Figure 3**). Now to find the frequency just count the number of pulses that occur until the channel-A waveform has completed one complete period (2). In the screen shot shown here there are 12.3 intervals of 1.0 µs therefore the frequency is given by

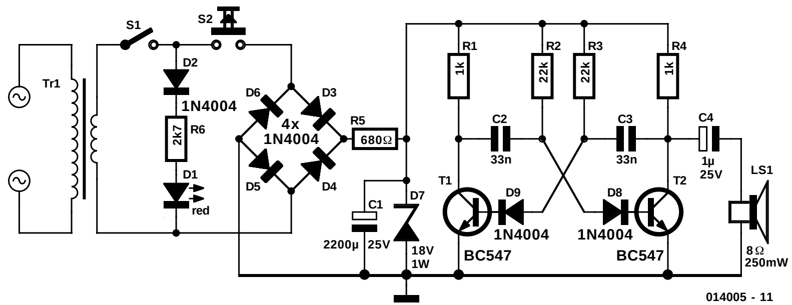
$$f = 1/\ 12.3\times10^{-6}\ \text{s} = 81.3008\ \text{kHz}.$$

These are only two applications of this versatile circuit, no doubt you will find many more.

(994092-1)

EMD-immune Electronic Doorbell 033

P. Lay



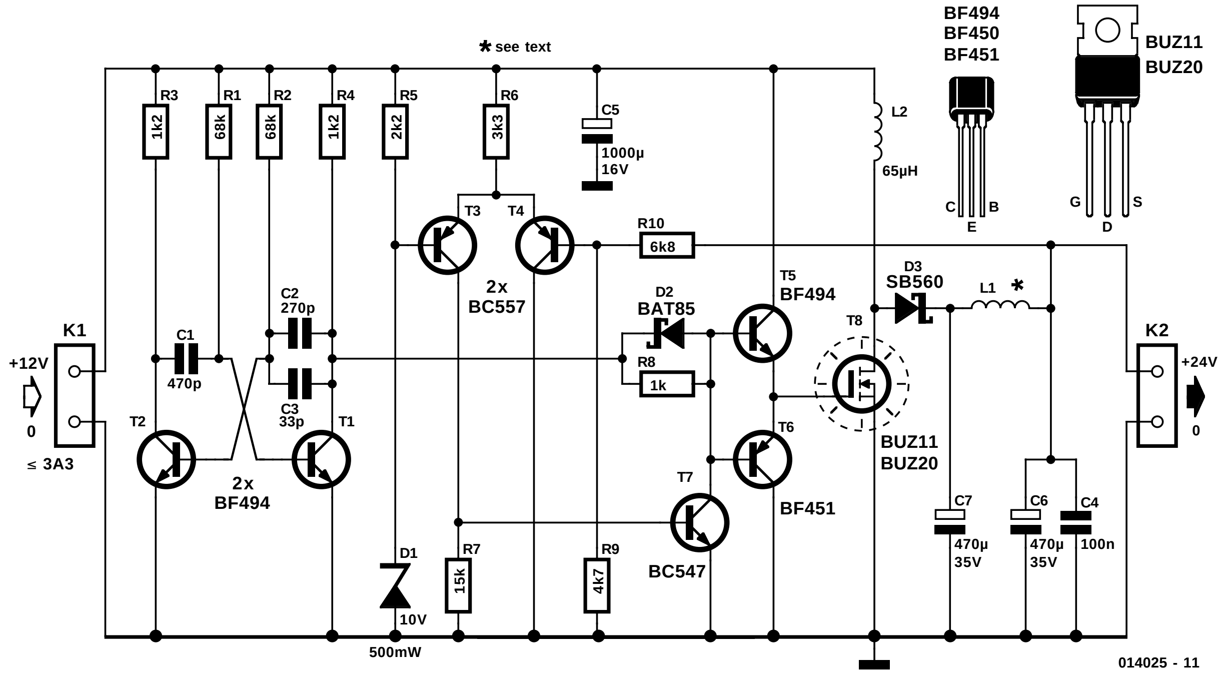
Whenever an antediluvian electric doorbell is used in an apartment building, the rain of sparks that is generated when the Wagnerian hammer pounds against the 'sounding body' infests the bell network with interference pulses. These can significantly disturb electronic doorbells, or even cause them to give up the ghost. If you cannot convince your neighbour to convert to something more modern, or at least to build in a noise suppression network, you can use the electronic doorbell described here, since it is immune to EMD.

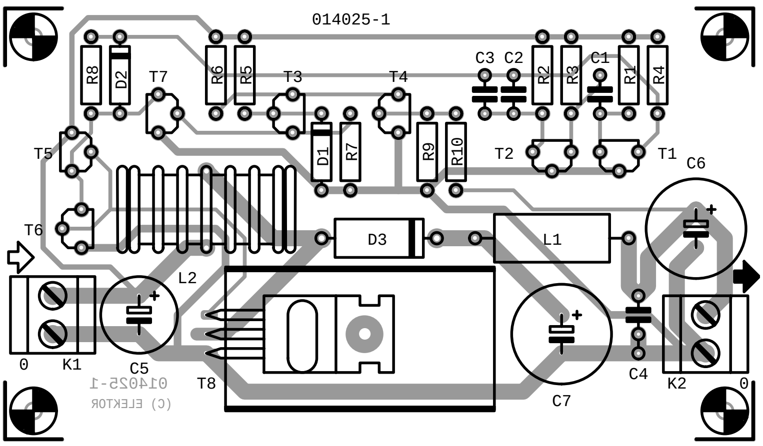
This circuit is based on a simple multivibrator stage to which a loudspeaker is connected. Capacitor C4 provides dc isolation between the multivibrator and the loudspeaker (8 Ω, 0.25 W). The frequency is determined by the RC networks R2/C2 and R3/C3; it lies at around 0.7 RC = 2 kHz. The multivibrator stage receives its supply voltage from the bell transformer. For this purpose, the ac voltage must be rectified by D3-D6, and Zener diode D7 prevents the voltage from rising above approximately 18 V. EMD immunity is provided by the lowpass network R5/C1. The bell can also be silenced using switch S2. In this case, the only thing that happens when someone presses on the bell button is that D1 lights up.

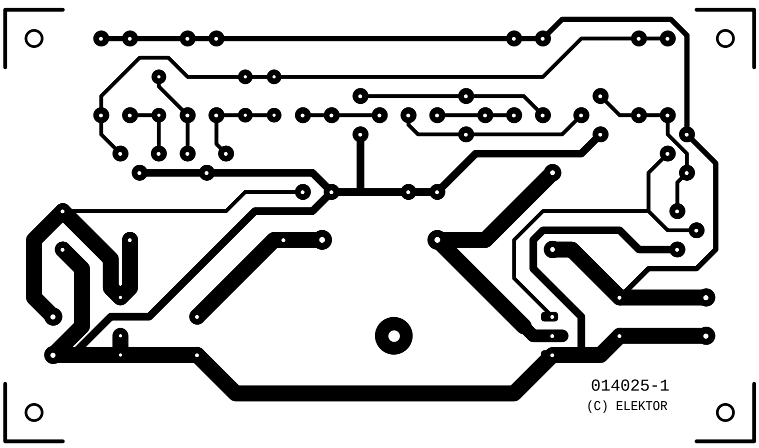
(014005-1)

12V-to-24V Converter

034







G. Baars

This DC-to-DC converter delivers a maximum power of about 36 watts at an efficiency of 90%. Apart from a modern FET and a Schottky diode, this circuit is comprised entirely of familiar and inexpensive parts. In spite of this, the specifications are excellent:

– Efficiency:	approx 90%
– Ripple voltage:	max. 10 mV
– Output current:	max. 1.5 A
– Switching frequency:	40 kHz
– Input voltage:	12 V
– Output voltage:	24 V regulated

The switching element is a fast power FET (T8). This FET has a relatively high input capacitance and is switched on and off by a push/pull stage consisting of two RF transistors (T5/T6). Schottky-diode D2 increases turn-off speed even further, which is crucial here because we are aiming to obtain the highest possible efficiency.

The switching signal is provided by a simple multivibrator, which is also made from two RF-transistors (T1/T2). Difference amplifier T3/T4 has been added to obtain a regulated output voltage of 24 V.

L2 is an off the shelf 5 A suppressor choke with a self-inductance of 65 µH. L1 is part of the output filter, the purpose of which is to eliminate RF noise. This is an air-cored coil, which you can easily make yourself by winding 25 turns of 0.5 mm dia. enamelled copper wire around a 10 mm diameter drill. Because of the high efficiency, the dissipation of T8 remains smaller than about 3.6 W so a modest heatsink of about 10 K/W will suffice. It is advisable that the 12 V input supply includes a fast fuse, rated about 3.5 A.

Considering that the duty cycle has a substantial effect on the efficiency, a second capacitor (C3) has been added in parallel with C2. The optimum setting can be determined by varying this additional capacitor.

The remaining components are not at all critical. Any 5 A suppressor choke will work for L2, any 5 A Schottky-diode for D3 and just about any power MOSFET for T8 (BUZ10, BUZ20, BUZ100).

(014025-1)

COMPONENTS LIST

Resistors:
R1,R2 = 68kΩ
R3,R4 = 1kΩ2
R5 = 2kΩ2
R6 = 3kΩ3
R7 = 15kΩ
R8 = 1kΩ
R9 = 4Ωk7
R10 = 6kΩ8

Capacitors:
C1 = 470pF
C2 = 270pF
C3 = 33pF
C4 = 100nF
C5 = 1000µF 16V radial
C6,C7 = 470µF 35V radial

Inductors:
L1 = 25 turns 0.5 dia. ECW, 10 mm dia., no core
L2 = 65 µH/5 A suppressor coil (ring core)

Semiconductors:
D1 = zener diode 10V 500mW
D2 = BAT85
D3 = SB650 (PBYR745)
T1,T2,T5 = BF494
T3,T4 = BC557
T6 = BF450 (BF451)
T7 = BC547
T8 = BUZ11 (BUZ20)

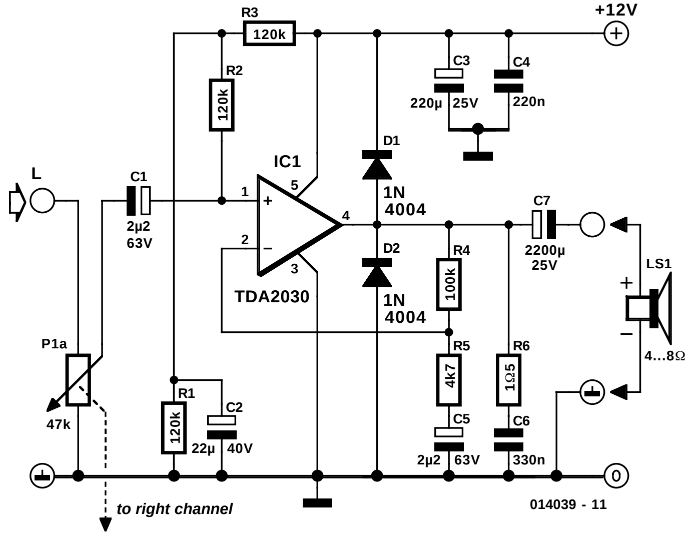
Miscellaneous:
K1,K2 = PCB terminal block, lead pitch 5mm
Heatsink, e.g., Fischer ICK35SA (Dau Components)
PCB, order code **014025-1**

Active PC Loudspeaker

035

P. Lay

With the well-known TDA2030V integrated power amplifier in the Pentawatt package, it is easy to 'activate' a PC loudspeaker or upgrade the quality of an inexpensive active loudspeaker. The TDA2030 combines ease of use with low levels of harmonic and crossover distortion, and it is also incorporates short circuit and thermal overload protection.



No creative brilliance is needed to arrive at the circuit shown in **Figure 1**, which is practically the same as the standard application circuit for single-supply operation as shown in the device data sheet from its manufacturer, ST Microelectronics:

http://us.st.com/stonline/books/pdf/docs/1458.pdf .

The two resistors R1 and R3 set the operating point of the amplifier, and the non-inverting input is biased via R2. The audio signal reaches the power opamp via C1. The gain is determined by the ratio of R5 to R4. Capacitor C5, like C1, affects the lower roll-off frequency. The two diodes protect the IC against positive and negative spikes in the output signal. The RC network C6/R6 ensures stable operation of the amplifier in the high frequency range. The load is connected via the output electrolytic capacitor C7. In the data sheet, you can see which parameters change if you 'play around' with the values of the resistors and capacitors.

Any individual speaker with an impedance of 4 to 8 Ω or a multi-way loudspeaker can be connected to the output. The maximum achievable power is 6 to 12 W, so a heat sink with a thermal resistance of 8.3 K/W to 4.2 K/W is mandatory.

(014039-1)

Secret Lock

036

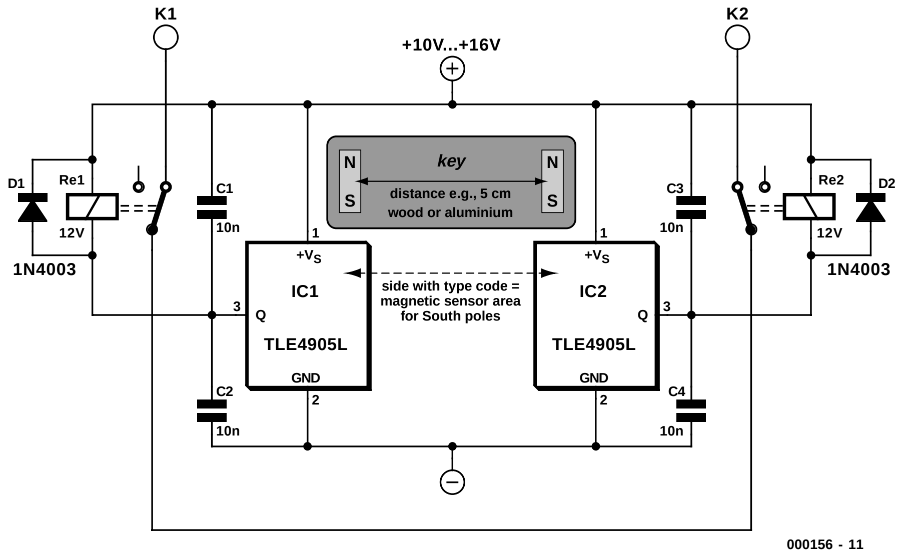
W. Zeiller

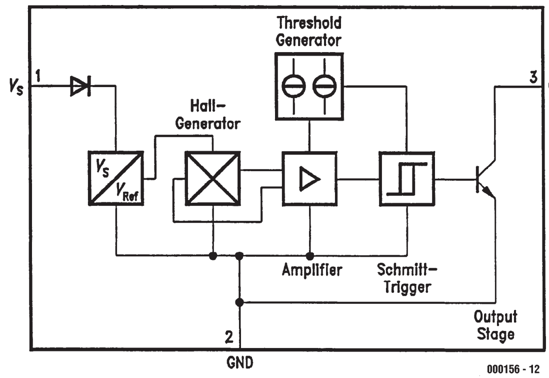
This secret lock, unlike a conventional code lock, gives away no hints to the unwanted visitor as to its existence: there are no buttons, switches or keypads. No code sequence need be learnt: you simply need an inconspicuous key.

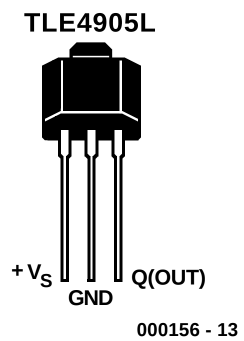
The idea is based on two magnetically-operated switches which, when operated simultaneously, cause two relays to close. These in turn could actuate an electric door latch or start a garage door motor. This would not be particularly noteworthy (and rather easy to defeat) if simple reed switches were used, since they do not depend on the polarity of the magnetic field: they react equally to the north or the south pole of a magnet. Instead we use Hall effect ICs, which only react to south poles.

In this way the would-be intruder, carrying just a powerful permanent magnet in his pocket, is frustrated in his nefarious deeds: horseshoe and bar magnets do not have two south poles. And if that is not secure enough, you can always add further Hall effect ICs and relays: just like a lock with more levers.

The sensor used in the circuit shown in **Figure 1** is smaller than a transistor, and yet contains rather more: a unipolar sensing surface for the magnetic field, Hall generator and threshold generator, amplifier, Schmitt trigger and output transistor. With a field stronger than 20 millitesla the open-collector output transistor is turned on. The series-connected contacts of the 12 V miniature relays then complete the circuit via connection L. Relays with a coil current of 50 mA or less should be used in order not to overload the ICs.







The Hall effect ICs are fitted or glued at least 5 cm apart behind a sheet of glass, plastic or aluminium (perhaps the letterbox or doorbell), at most 4 mm thick, with the component marking towards the key. In no circumstances should iron or steel be used as these screen the sensors from the magnetic field. The sensors can either be wired to directly or fitted on a piece of perforated board. The position of the sensors should be suitably marked on the outside.

The simplest way to make a key is from a piece of square section wood in which two small holes are bored for two cylindrical magnets (as used with reed switches). The two magnets should be glued in the same way round, which can easily be tested by checking that the poles repel. Alternatively, of course, the magnets can be fixed in a flat plastic box using hot-melt glue. Remember that only one side of the key will open the lock.

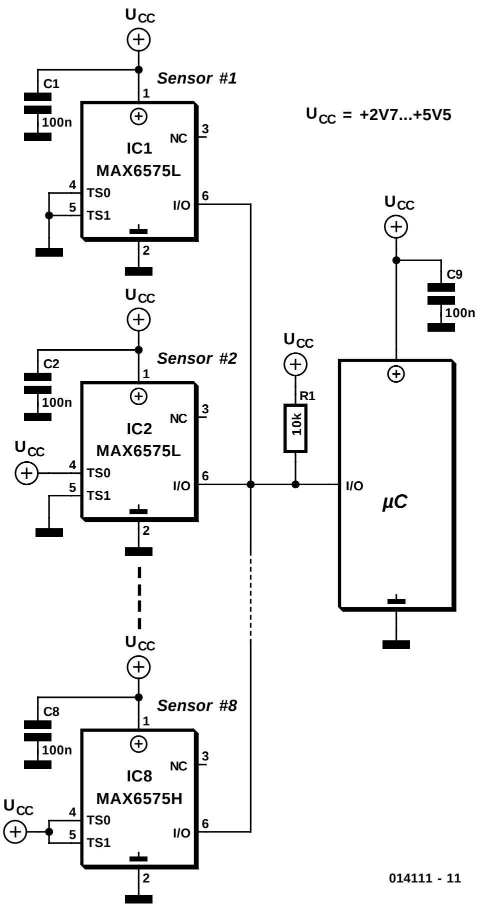
The secret lock can be safely used outside as long as it is fitted in a suitable watertight enclosure. It can save money compared to the services of a locksmith, and it will resist even the professional burglar. The lock is vandal-proof, operates independent of temperature, requires no battery in the key, can be cheaply extended and provided with any number of keys. The Hall effect ICs (Conrad Electronics order code 147508) are inexpensive. The operating voltage depends on the relays chosen, and should lie between 6 V and 24 V. The standby current for two ICs is about 7 mA at 12 V.

(000156-1)

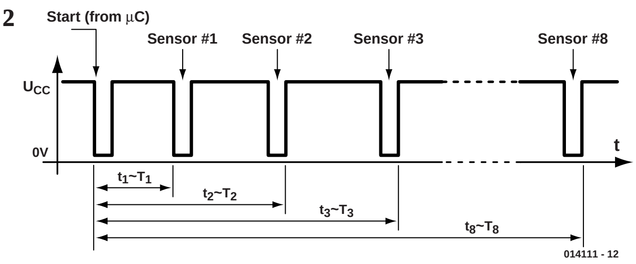
Temperature Sensor with Single-wire Digital Interface

037

1



2



A temperature measurement system with up to eight distributed temperature sensors can be realised using only a single signalling lead. This objective is supported by the Maxim MAX6575 temperature sensor (www.maxim-ic.com), which can be used to measure temperatures between –40 °C und +125 °C. It is housed in a small SMD transistor package (SOT23). As shown in **Figure 1**, all the ICs are connected to the signalling line via their open-drain input/output pins. Resistor R1 pulls the voltage on the signalling line to Vcc. The microcontroller can initiate a measurement cycle by placing a Low pulse on the signalling line for an interval of 2.5 µs to 1 ms. The MAX6575 ICs recognise this pulse, and each one starts a timer whose period is proportional to the temperature T*n* of sensor *n* (in degrees Kelvin). One of four different timer coefficients can be selected for each MAX6575 using the TS0 and TS1 inputs. The timing is illustrated in **Figure 2**.

In order to allow eight different sensor positions to be used, the MAX6575 comes in two versions: the H version and the L version. The table shows the configurable timer coefficients in microseconds per Kelvin for the two versions. As can be seen, overlaps in the pulse durations can occur in case of large differences between the temperatures of the individual sensors (e.g. sensor *n* at +125 °C, sensor *n*+1 at –40 °C). To the extent that such an unlikely situation can arise, it may be necessary to omit one of the timer regions, which would mean that the maximum number of sensors connected to a single line would be reduced to seven or six.

The temperature of sensor *n* in Kelvin is given by

$$Tn = tn / Mn$$

where
T*n* = temperature of sensor *n* in Kelvin;
t*n* = time between the Start pulse and the pulse from sensor *n*:
M*n* = temperature factor of sensor *n* in µs/K

The temperature can be converted to degrees Celsius using the formula

$$Tn\ (\text{in °C}) = Tn\ (\text{in K}) - 273.15\ \text{K}$$

A new measurement requires the microcontroller to first generate a Reset pulse, which is a Low pulse with a duration of at least 4.6 ms so that it can be reliably distinguished from the Start pulse. The maximum allowable length of the Reset pulse is 16 ms. The MAX6575 also allows a new measurement to be made without a Reset pulse if the elapsed time since the previous Start pulse is more than 520 ms.

(014111-1)

TS1	TS0	MAX6575L	*tn* for –40°C to +125°C
GND	GND	5 µs/K	1.16 ms to 2.0 ms
GND	VDD	20 µs/K	4.66 ms to 8.0 ms
VDD	GND	40 µs/K	9.32 ms to 16.0 ms
VDD	VDD	80 µs/K	18.64 ms to 32 ms
TS1	**TS0**	**MAX6575H**	***tn* for –40°C to +125°C**
GND	GND	160 µs/K	37.28 ms to 64 ms
GND	VDD	320 µs/K	74.56 ms to 128 ms
VDD	GND	480 µs/K	111.84 ms to 192 ms
VDD	VDD	640 µs/K	149.12 ms to 256 ms

Wire Tracer (Transmitter)

038

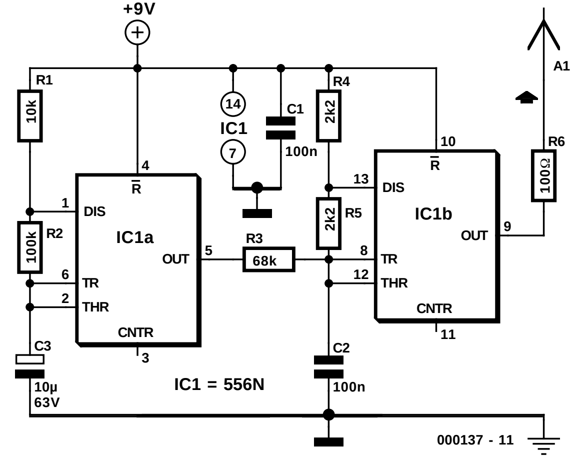
E. de Leeuw

The circuit depicted here forms one half of a device that will prove extremely handy when tracing the path of electrical wiring in a building or to locate a break in a wire. The system is based on similar equipment that is used by technicians in telephone exchanges.

The operation is straightforward. You require a generator that delivers an easily recognisable signal which, using a short antenna, is inductively coupled to a simple, but high gain, receiver.

To create a useful transmitter it would suffice to build a simple generator based on a 555. But as the adjacent diagram shows, a 556 was selected instead. The second timer (IC1a) is used to modulate the tone produced by IC1b. The output frequency alternates between about 2100 Hz and 2200 Hz. This is a very distinctive test signal that is easily distinguished from any other signals that may be present. Resistor R6 is connected to a piece of wire, about ten centimetres long, that functions as the antenna. The ground connection (junction C2-C3) is connected to ground.

When the antenna is connected directly to a cable, it is possible to determine at the other end of the cable, with the aid of the receiver, which conductor is which (don't do this with live conductors!).



The schematic for the matching receiver may be found elsewhere in this issue.

(000137-1)

Wire Tracer (Receiver)

039

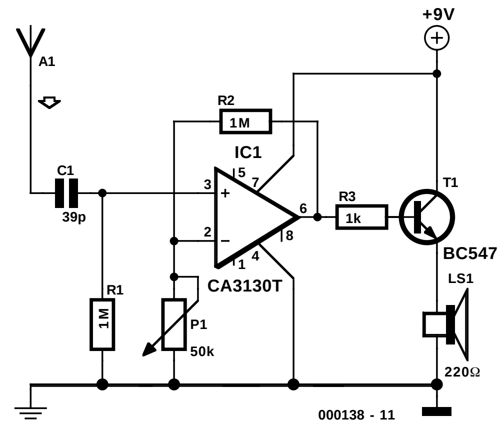
E. de Leeuw

The circuit depicted is the receiver device of a transmitter/receiver combination that will prove extremely handy when tracing the path of electrical wiring in a building or to locate a break in a wire.

The corresponding transmitter may be found elsewhere in this issue. The transmitter produces a distinctive tone which alternates between 2100 Hz and 2200 Hz.

The matching receiver for the wire tracer is possibly even simpler than the transmitter, as is shown by the schematic. It consists of no more than a short wire antenna (a piece of wire, 10 cm long is adequate), a high-pass filter (C1-R1), an amplifier stage (IC1), an output stage (T1) and a loudspeaker. The prototype used a high impedance loudspeaker from a telephone handset, and this worked remarkably well.

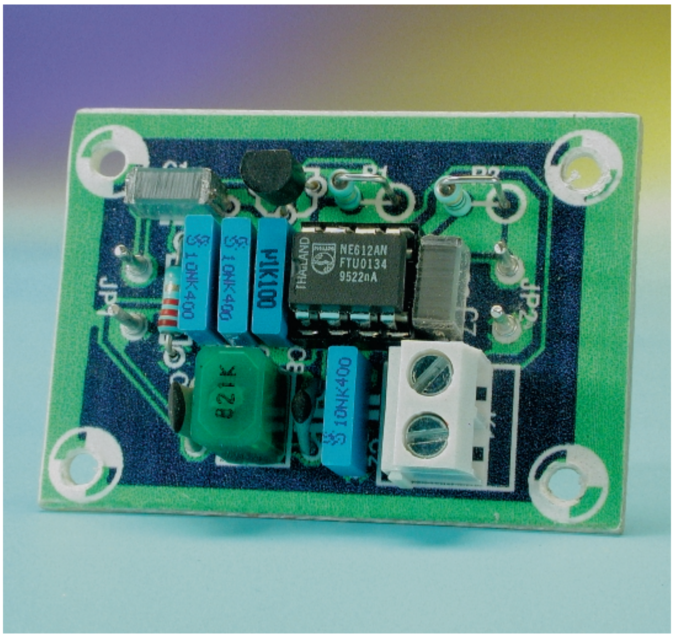
The purpose of P1 is to adjust the amplification. At the highest amplification, the wire energised by the transmitter can be traced from several tens of centimetres away. A

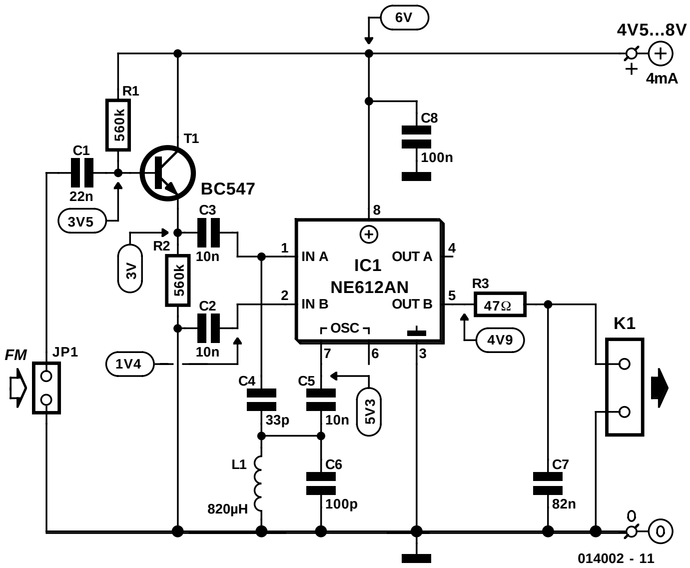


direct electrical connection is therefore not required. However, it is important that you hold the ground connection (earth) in your hand.

(000138-1)

Alignment-free FM Detector 040





G.Baars

This 455-kHz quadrature detector for narrow-band FM signals boasts two important advantages: it is pleasantly simple and it does not require any alignment.

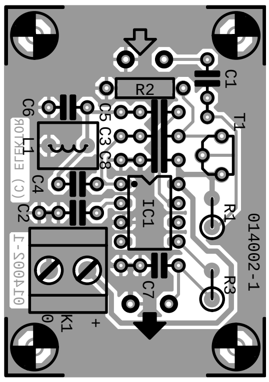
The heart of the circuit is formed by the well-known NE612 IC, which is a double-balanced mixer cum oscillator in an 8-pin DIL package.

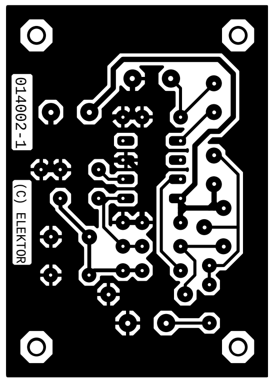
The signal is first buffered by T1 and then fed to the input of the NE612. At the same time, a small portion of the signal is passed to the mixer via a low-value capacitor (C4). The operation of the circuit is such that when the input frequency matches the resonant frequency of the parallel L-C network, the signal on pin 7 has a phase lead of 90 degrees with respect to the signal on pin 2. The phase angle increases when the input frequency rises and decreases when the input frequency drops. Since the signals on pins 2 and 7 are multiplied together, the average output level is maximum when the signals are in phase and zero when they are anti-phase. This is the operating point of the detector. Consequently, an input signal with a varying frequency produces an output signal with a varying level. The operating range of the detector is inversely proportional to the *Q* factor of the parallel resonant network.

This circuit works best with an input signal level of 0.5–2 V_{pp}. Since it is linear over a very wide range (420–500 kHz), it does not need alignment, and normal tolerance variations in the values of the inductance and capacitance in the resonant circuit have little effect. The output level varies by approximately 1 V over the working range, so the detection sensitivity is around 13 mV/kHz. This is adequate for most narrow-band FM applications with an intermediate frequency of 455 kHz.

The supply voltage may lie between 4.5 and 8 V. The current consumption is limited to approximately 2.5 mA. Using the small printed circuit board shown here, you should have no difficulty assembling this FM detector in less than half an hour.

(014002-1)





COMPONENTS LIST

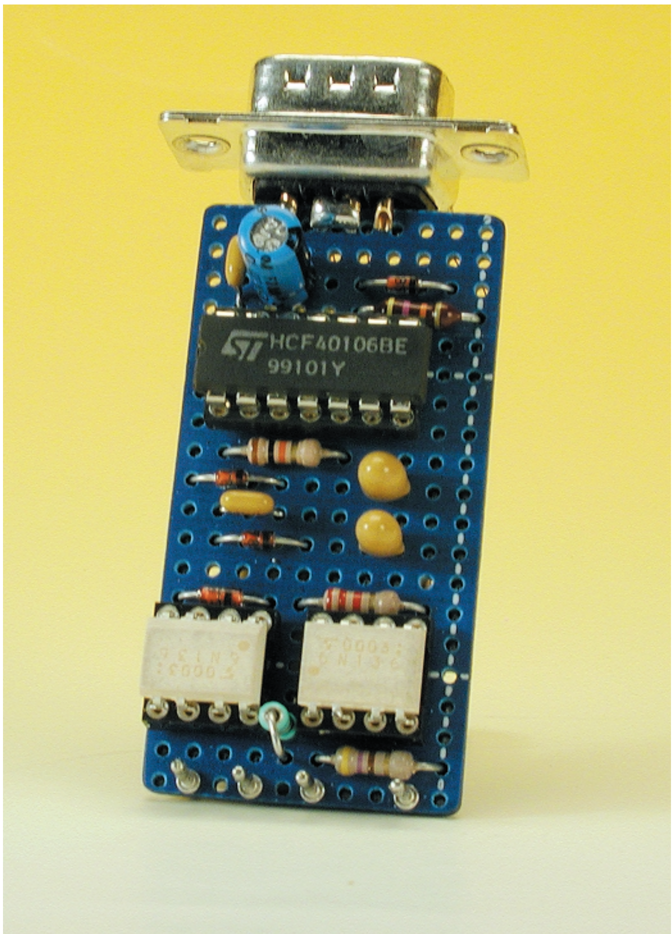
Resistors:
R1,R2 = 560kΩ
R3 = 47Ω

Capacitors:
C1 = 22nF
C2,C3,C5 = 10nF
C4 = 33pF
C6 = 100pF
C7 = 82nF
C8 = 100nF

Inductors:
L1 = 820µH

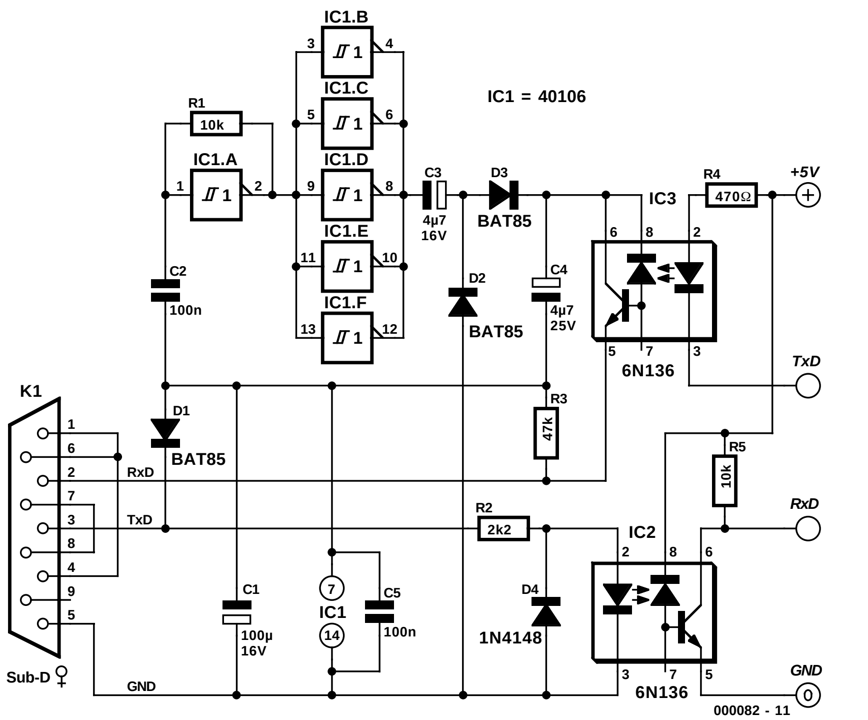
Semiconductors:
T1 = BC547
IC1 = NE612AN

Electrically Isolated RS232 Adapter 041



A. Schiefen

This circuit represents an interface converter between the UART pins of a microcontroller (with TTL levels) and a 'standardised' RS232 port with symmetric ±15-V levels. In contrast to the commonly used IC solutions such as the MAX232, it also provides electrical isolation between the two sides of the converter. This interface converter inverts the signals, so the usual inverters on the microcontroller side can (and must!) be omitted.
In most cases, the data lines RxD and TxD are all we need for communications with microcontroller systems. Fortunately, handshake signals are very seldom exchanged. The related RS232 leads are thus interconnected in such a manner that communications can take place without any problems.
All that is needed for the electrical isolation of a signal is an optocoupler. If the data flow from an external device to the microcontroller, the solution is easy. Since the RxD input of the microcontroller works with a +5-V level, all that we need is an optocoupler (IC2) whose LED is directly driven by the TxD output of the external device via resistor R2. This resistor also limits the current through D4 when TxD is inactive and thus has a negative level (usually around –9 V). During data transmission, the level of the pulses changes to around +9 V. The collector of IC2 is connected directly to the RxD input of the microcontroller. Resistor R5 is needed if microcontroller RxD input does not have an internal pull-up resistor. In any case, the microcontroller side of IC2 thus works with TTL levels.
If we now want to send data from the microcontroller to the external device, the microcontroller level (+5 V) must be converted into an RS232 level of at least +6 to +7 V. To achieve this, the negative voltage present at the RS232 TxD output is tapped off by D1 and buffered by C1, which acts as a storage capacitor. IC1 is a CMOS 40106 IC containing six inverting Schmitt triggers.
One of these Schmitt triggers (IC1a) is wired with C2 and R1 as an oscillator. It generates a frequency of around 1.5 kHz. This signal is fed to the other five Schmitt triggers, which are connected in parallel and act as a driver. They provide the necessary output current. When the output is Low, C3 charges to the supply voltage level via D2 (less the voltage drop across the diode). When the output changes to High, the voltage on C3 rises and adds to the voltage already present; D2 blocks and C4 is charged via D3 to nearly twice the



supply voltage. A voltage of around +9 V is thus available from C4, which is connected to the collector of optocoupler IC3. In principle, the voltage level at an RS232 interface should be +12 V to +15 V, but PCs can generally work with significantly lower voltages. Notebook computers in particular sometimes have a voltage of only +8 V.

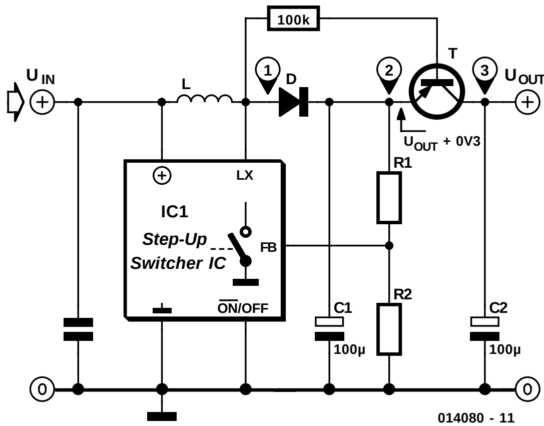
The emitter of IC3 leads to the RxD input of the RS232 port and is held at around –9 V by R3. When the microcontroller transmits data, the pulses from the TxD output of the microcontroller arrive at the LED of optocoupler IC3. The transistor of IC3 switched on and applies the positive voltage to the RxD input of the external device.

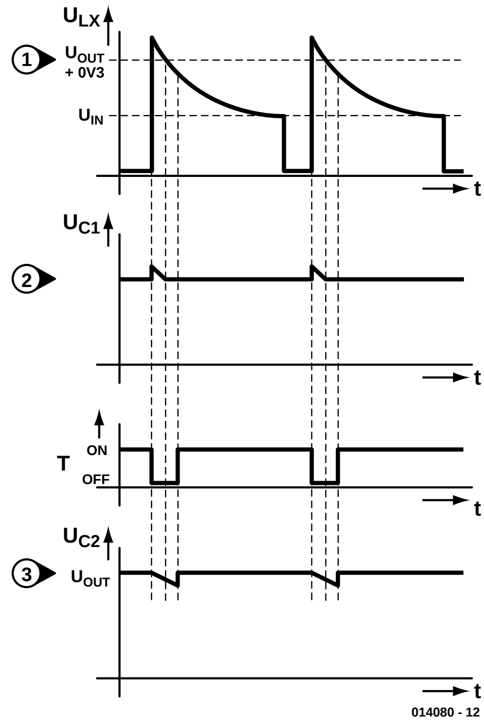
Normal diodes (1N4148) can also be used in place of the Schottky diodes, although the generated voltages will be somewhat lower. The 6N136 optocoupler is a high-speed type; normal optocouplers are not suitable. The circuit can theoretically transmit data at up to 57,600 baud, but in practice microcontroller circuits only use 9600 baud. These data transmission rates have been successfully used with both older-model and more recent notebook computers.

(000082-1)

Output Cutoff for Step-Up Switching Regulator

042





$$V_{out} + 0{,}3V = V_{ref} \cdot \left(1 + \frac{R1}{R2}\right)$$

Nowadays, there is a whole series of switching regulator ICs that work according to the step-up principle and thus convert the input voltage to a higher output voltage. This takes place using coil L, which is periodically switched to ground via the LX connection of the IC. This causes a magnetic field to build up in the coil L, and this field stores energy. When the step-up regulator IC switches off, the collapsing magnetic field in L forces the current to continue to flow. Now, however, the current must flow through diode D to the output capacitor and the external load connected to Vout. In this way, a voltage is generated that is greater than the input voltage. Resistors R1 and R2 form a voltage divider that is used to set the value of the output voltage, according to the formula shown. The value of V_{ref} is usually around 1.2 V.

One problem with the step-up regulator is that if the IC is inactive, there is always a current path from the input to the output via coil L and diode D. This means that the output voltage is not zero, but instead Vin. This problem can be eliminated with the aid of a simple transistor and a series base resistor. The pnp transistor, in this case a BCP69, is placed in series with the output circuit and periodically passes the dc output voltage of the switching regulator to output capacitor C2. The base of transistor T is connected via the series resistor R to the switch pin LX of the step-up regulator IC.

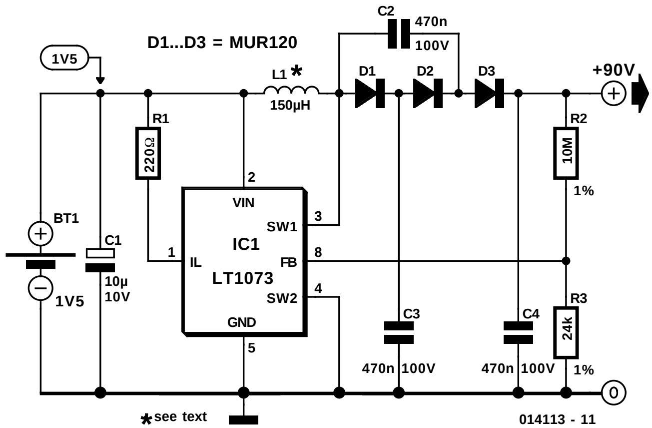
The voltage waveforms are shown in the diagram. Pin LX is periodically switched to ground. As soon as the switch goes open, a voltage pulse that adds to the input voltage appears at LX. Diode D conducts briefly and passes this voltage on to C1, which charges up to a voltage, determined by the voltage divider R1/R2, that is 0.3 V higher than the output voltage. The small charging peaks shown in curve 2 are not drawn to scale. If V_{LX} is more than 0.7 V lower than V_{C1}, transistor T conducts and passes the voltage across C1 on to C2. The small voltage sags shown in curve 3 are also not drawn to scale, for the sake of clarity. If the step-up regulator IC is disabled, the voltage across C1 will be only as high as the input voltage. This voltage is also present at LX, so there is not enough base bias voltage to switch on the transistor, and it is cut off.

(014080-1)

High Voltage Converter: 90 V from 1.5 V

043

The circuit shows one way of obtaining a voltage of 90 V from a 1.5 V battery supply. The LT1073 switching regulator from Linear Technology (www.linear-tech.com) operates in boost mode and can work with an input voltage as low as 1.0 V. The switching transistor, which is hidden behind connections SW1 and SW2, briefly takes one end of choke L1 to ground. A magnetic field builds up in the choke, which collapses when the transistor stops conducting: this produces a current in diode D1 which charges C3. The diode cascade comprising D1, D2, D3, C2, C3 and C4 multiplies the output voltage of the regulator by four, the pumping of C2 causing the voltage developed across C4 via C3, D2 and D3 to rise. Finally, the regulator control loop is closed via the potential divider (10 MΩ and 24 kΩ). These resistors should be 1 % tolerance metal film types. With the given component values, fast diodes with a reverse voltage of 200 V (for example type MUR120 from On Semiconductor www.onsemi.com) and a choke such as the Coilcraft DO1608C-154 (www.coilcraft.com) an output voltage of 90 V will be obtained. The output of the circuit can deliver a few milliamps of current.



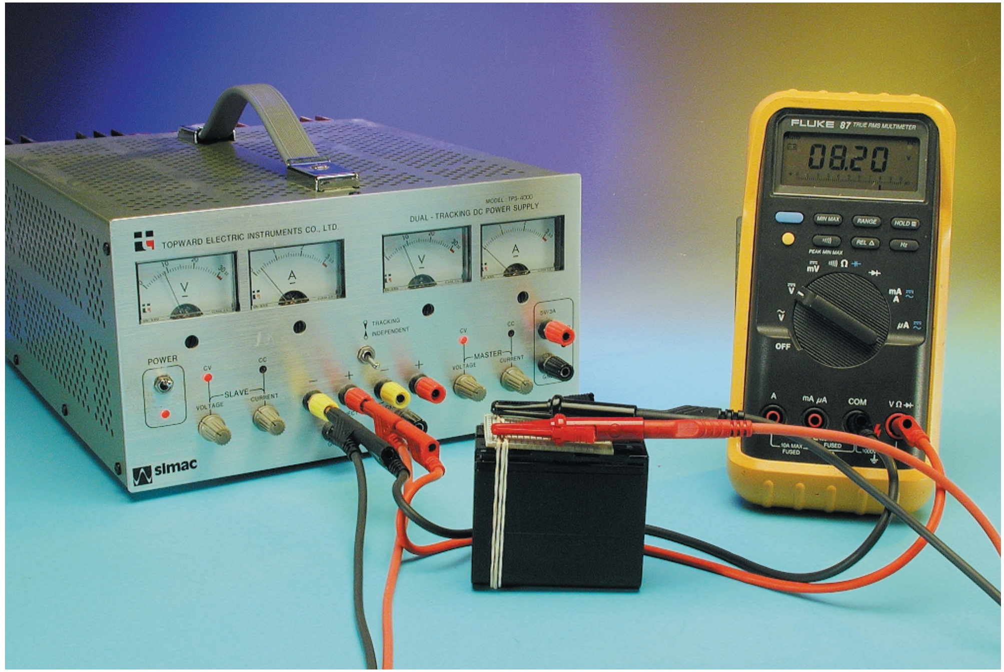
(014113-1)

Lithium-Ion Charger II

044

In the December issue we'll describe a fancy Li-Ion charger based on a specially designed IC and boasting many bells and whistles. However, it can also be done in a much simpler way, provided you are prepared to work carefully. The latter is particularly important, because we will point out again that charging Li-ion batteries with a voltage that is too high can cause explosions! In this respect Li-ion batteries are not the least comparable with the much less critical NiCd- or NiMH-types.

Li-ion batteries may, just like lead-acid batteries, be charged with a constant voltage. The charging voltage for a 3.6 V cell is 4.1 V **maximum**, and for 3.7 V cells this is 4.2 V. Higher voltages are **not permissible**; lower voltages are, but every 0.1 V results in a reduction of capacity of about 7%. As a consequence, great precision is required and it is therefore highly recommended to measure the output voltage with an accurate (less than 1% error) digital voltmeter. A good stabilised lab power supply is in principle perfectly suited as a Li-Ion charger. Adjust it to 4.1 V (or 8.2 V if you are charging two cells in series) and also adjust the current limiting to an appropriate value, 1 *C* for example (where *C* is the capacity, e.g.,. 1 A for a 1 Ah battery). A too low value



is preferred over one that is too high; when the value is a little low it will simply take a little longer to fully charge the battery, but it makes no difference otherwise. Li-Ion batteries are not suitable for high currents, so limiting the value to 1C is a safe maximum.

You can now connect the battery. If the battery is discharged, the power supply will deliver the maximum adjusted current at a voltage less than 4.1 V. As the battery is charging, the voltage will rise. Once the value of 4.1 V is reached, the voltage will cease to rise and the current will begin to fall. When the current is less that 0.2 of the adjusted value, the battery can be considered charged. It is not a disaster if the battery is connected for longer; overcharging is not possible provided the voltage is less than 4.1 V per cell.

Keep children, cleaning housewives, pets and other possible disturbances away to avoid an inadvertent change of the voltage knob. It may not be a silly idea to provide the adjustment knob of the power supply with some method of mechanical locking.

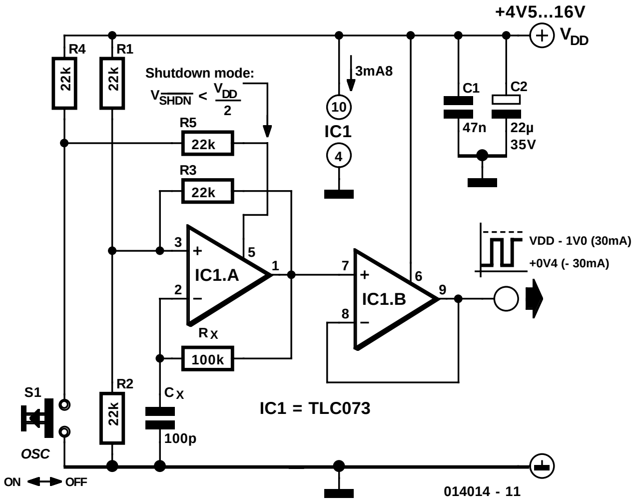
Note. Although they can hardly be called new, Li-Ion batteries are still difficult to obtain as spare parts. It may be a useful hint to also look at replacement batteries for camcorders and laptops as in these applications Li-Ion batteries are very common.

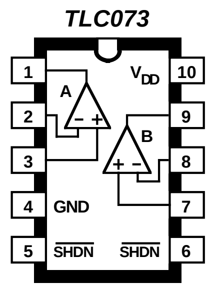
(014133-1)

Squarewave Oscillator Using TLC073

045

K. Thiesler





The new range of low-noise, high-speed and low-distortion BiMOS op-amps from Texas Instruments, type TLC070 to TLC075, is intended for use in instrumentation, audio and automotive applications. This oscillator is an ideal example of its application: a stable, highly accurate squarewave at frequencies up to 60 kHz can be produced with an output current of ±30 mA.

The TLC073, a dual op-amp with shutdown function, is used here. IC1a is configured as a standard squarewave generator, IC1b as a driver. The frequency of oscillation depends on Cx and Rx and is calculated (for frequencies up to 20 kHz) as follows:

$$f = \frac{1}{\frac{1}{7000} \times \sqrt[3]{Rx \times Cx} + \sqrt{2} \times Rx \times Cx}$$

where Rx is measured in Ohms and Cx in Farads.

The table shows preferred values that give various frequencies. Note that the frequency variation is largely determined by the capacitor, since Rx must always be significantly larger than feedback resistor R3. The effect of supply voltage, at –130 dB, is negligibly small, and the temperature coefficient of frequency is very low: only 1.5 %. At frequencies above 20 kHz the oscillator remains stable, but increasingly non-linear.

The mark-space ratio of the signal can be adjusted in the range 10% to 90% by changing the ratio of resistors R1 to R2. If the two resistors are equal, the output is symmetrical. The output of the driver swings between +0.3 V (low) and 1 V below the supply voltage (high).

The oscillator is switched on and off via the shutdown input of IC1a. The output of the opamp goes to high impedance and the current consumption drops to 35 nA.

The oscillator can of course be built using the common or garden TL071 (U_b = 7 V, U_{out} = 1.2/6.2 V, I_{out} = 1.75 mA, f_{max} = 50 kHz). As can be seen, the output drive capability is rather lower.

(014014-1)

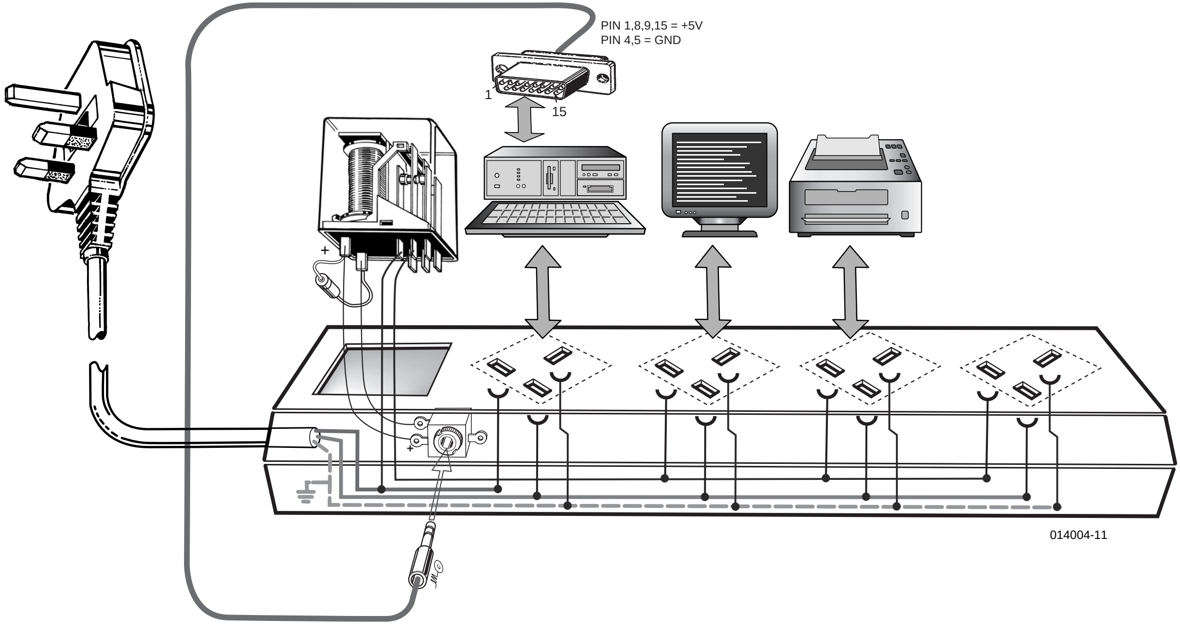
BiMOS opamp family TLC07x

The new family of BiMOS opamps types TLC070 to TLC075 replaces the older TL070 family of BiFET amplifiers. The new components incorporate some significant advances:

– Very low noise (7 nV/√Hz)
– Low harmonic and non-harmonic distortion (0.002 %) at A = 1
– Bandwidth 10 MHz, slew rate 16 V/µs
– Input quiescent current only 1.5 pA
– Offset voltage 60 µV
– Output current ±50 mA
– Supply voltage rejection –130 dB
– Quiescent current consumption 1.9 mA per opamp
– Symmetric (±2.25 to 8 V) or single supply voltage (+4.5 to16 V)
– Shutdown function for each opamp (TLC070, TLC073 and TLC075 only)
– Single, dual and quad opamps available in DIP, SO and TSSOP packages

f	60 kHz	10 kHz	6 kHz	3 kHz	400 Hz	50 Hz
Cx	100 pF	680 pF	1 nF	1 nF	10 nF	68 nF
Rx	100 kΩ	100 kΩ	100 kΩ	220 kΩ	180 kΩ	220 kΩ

Computer Off = Monitor Off 046



P. van Geens

Older PCs had, despite their slowness and other shortcomings, in comparison with their modern descendants at least one important advantage: they almost universally were fitted with a switched mains output socket for the monitor. The main power switch on the PC controlled this socket, therefore: computer off = monitor off!

Modern PCs make use of a ‘soft’ power switch, which puts the power supply in standby mode only; as a consequence the switched mains output on the back of the power supply is usually omitted. Progress therefore, compels the user once again, to separately switch off the monitor by hand. Naturally, this is often forgotten.

Fortunately, there is an easy way to do something about this. It so happens that when the PC is switched on, a potential of +5 V is present at the game port. Therefore, it is enough to simply tie a relay to this signal, which then switches the monitor (and printer, etc.). This uncomplicated relay circuit restores an old convention: computer off = monitor off!

(014004-1)

Piezo Amp

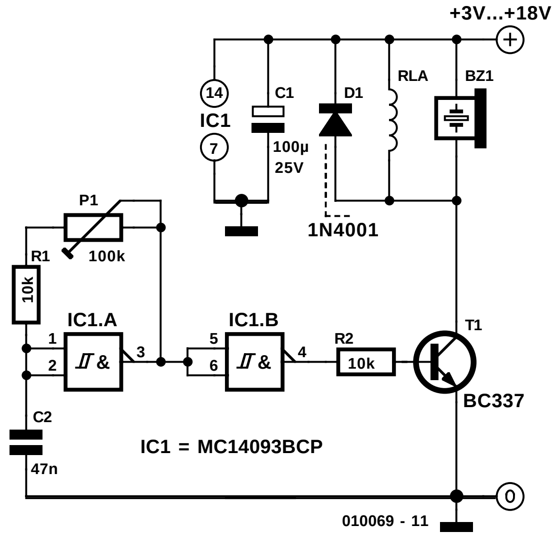
047

Rev. T. Scarborough

This circuit takes advantage of back-e.m.f. (electromotive force) to amplify the voltage across a piezo sounder. Ordinarily, IC1 would only achieve a gentle beep. However, the addition of a very high inductance choke of a few Henry — in this case the coil of a miniature reed relay is used — achieves a penetrating screech, and represents an easy method of obtaining considerably more volume in such a circuit.

The usual protective diode (D1) may be included across the choke, at the expense of a little volume. In practice, it was found that no harm was done by omitting D1. The operating voltage of the relay is immaterial, as long as it is not less than the supply voltage. Preset P1 should be adjusted to find the piezo sounder's resonant frequency. A higher supply voltage means greater volume — as long as T1's ratings are not exceeded.

(010069-1)



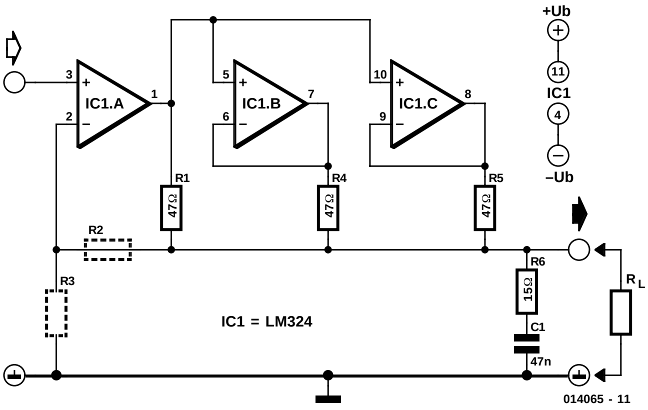
Parallel Opamps

048

National Semiconductor application note

Some applications notes are real evergreens. This one originally dates from 1979(!) but has lost nothing of its relevance and is always very interesting when you're looking for something like this.

Opamps can only deliver a limited current; typically only about 10 mA max. When more current is required, several opamps can be connected in parallel. But this usually doesn't work very well because opamps are never 100% equal. In practice they will fight each other and only get warm, which was not the intention of course.



In the adjacent application note, IC1a is the boss and is supported by IC1b and IC1c or as many stages as you require. IC1a delivers, via R1, current to the load R_L. The 'helper-opamps' are connected to the voltage drop across R1. This way they will all deliver an identical current, because the resistors R4 and R5 have all the same values. Make sure that the whole thing does not oscillate — the addition of an RC-network R5-C1 across the load can work wonders.

The circuit can be used with symmetrical or single-ended power supplies. In the latter case you will have to connect the negative lead of the power supply to 0 V.

IC1a may also be configured as an amplifier. In this case you will have to add the dotted resistors. To obtain unity gain, omit R3 and use a wire link for R2.

(014065-1)

Dual Switching Regulator

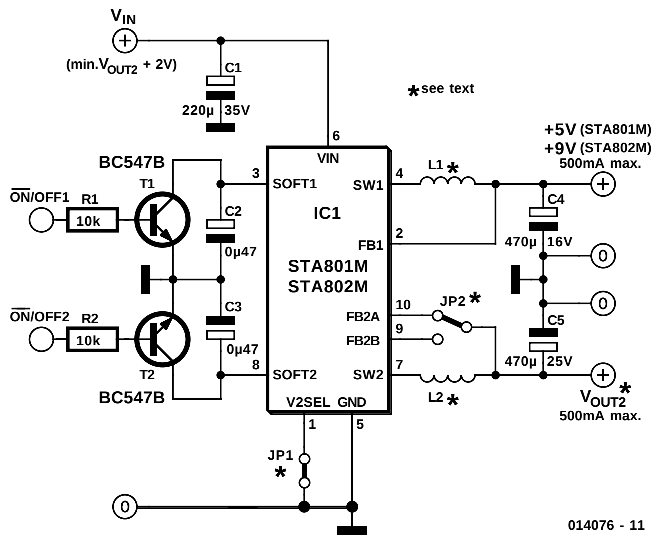
049

There are presently many switching regulator ICs. However, the STA801 and STA802 provide two switching regulators in a single package, each capable of supplying a maximum current of 0.5 A. Each device in the Allegro Microsystems STA800 series (www.allegromicro.com) contains a first step-down switcher with an output voltage of +5 V (STA801M) or +9 V (STA802M) and a second switcher that can be jumper-programmed for an output voltage of +9 V, +11.5 V, +12 V or +15 V. Jumpers 1 and 2 in the schematic diagram must be installed according to the table to achieve the desired output voltage.

The input voltage must be at least 2 V greater than the output voltage. The storage inductors L1 and L2 have values of 100 µH for a +5-V output and 150 µH for output voltages between 9 V and 15 V. Capacitors C1 and C2 are Softstart electrolytics, which cause the output voltages to ramp up gradually. Each of the converters can be disabled via transistors T1 and T2 respectively (High = shutdown).

The STA800 components described here may be obtained from Spoerle distributors, see www.spoerle.com. Suitable inductors can be found in the Coilcraft DO3316 series, for example (www.coilcraft.com).

(014076-1)



Jp1	Jp2	STA 801M	STA 802M	required Vin
open	Pin 9	9,0 V	9,1 V	> 11 V
open	Pin 10	11.5 V	11.7 V	> 14 V
closed	Pin 9	12.1 V	12.1 V	> 14 V
closed	Pin 10	15.5 V	15.7 V	> 18 V

Transistor Tester

050

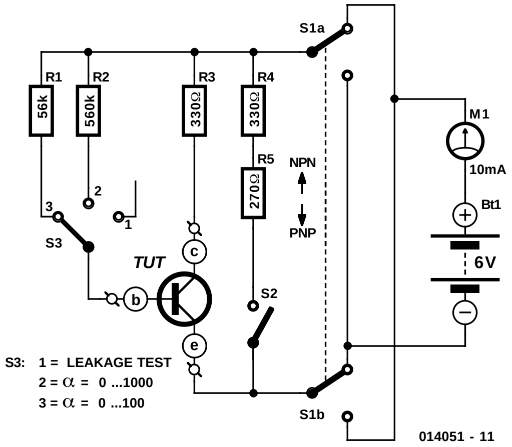
H. Kemp

This tester is intended to quickly check whether a transistor is functional or not and possibly also select two or more transistors with (approximately) equal gains. This is about the simplest conceivable test circuit, so don't expect super accuracy. The circuit has been designed only to quickly carry out a brief check, when there is no time or equipment to carry out a thorough test.

The operation is simple: in the position 'battery test' (S2 closed), the 10 mA moving coil meter M1 in series with a 600 Ω resistor (R4 + R5) is connected to a 6 V battery. A current of 10 mA will flow, resulting in full-scale deflection of the meter.

When a transistor is being tested (S2 open, S3 in position 2 or 3) a current will flow through the base-emitter junction of the transistor under test, the value of which can be computed by dividing the voltage across R1 or R2 by its resistance. With S3 in position 2 this will be (6 V – 0.6 V)/560 kΩ = approx. 10 µA. If the transistor has a gain of 1000 it will cause a collector current (and therefore a meter current) of 10 mA, causing full-scale deflection of the moving coil instrument. Therefore, the value indicated by the meter, when S3 is in position 2, has to be multiplied by a factor of 100 to obtain the gain of the transistor. In position 3 the base resistor is 10 times lower (R1 = 56 kΩ), so in this case the reading has to be multiplied by 10 to obtain the gain.

It will be clear that position 2 of S3 is intended for high gains of up to 1000 and position 3 for gains of 0 to 100. The purpose of S1 is to reverse the polarity: the upper position drawn is for NPN transistors, the bottom for PNP types. If you have no moving coil instrument available, it is of course also possible to replace M1 with a digital meter.



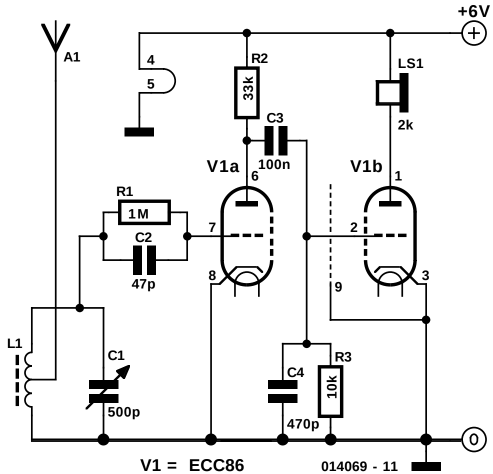
(014051-1)

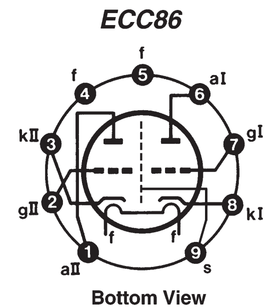
ECC86 Valve Radio

051

B. Kainka

Actually, the age of valves is already past — but valves just refuse to go away! There's many a valve radio still in use, and there are many valves lying in the 'junk box' waiting to be rediscovered. If only we could do without the high voltages! However, there is a valve that can manage with only 6 V — the ECC86. At the beginning of the 1960s, the electronics industry was faced with a problem. The transistor had just been born, so it was finally possible to build car radios without vibrators and large transformers. However, the cut-off frequencies were still too low to allow usable VHF mixer stages to be built using transistors. This meant that a valve had to be used in a transistor circuit. This valve was the ECC86, which was intended to be used for short wave input stages and self-oscillating mixer stages in car receivers powered directly from the car battery. According to the data sheet, an anode voltage of 6.3 V or 12 V may be used. The heater voltage is always 6.3 V. We owe the ECC86 low-voltage valve to this unique bottleneck in the history of electronics technology.





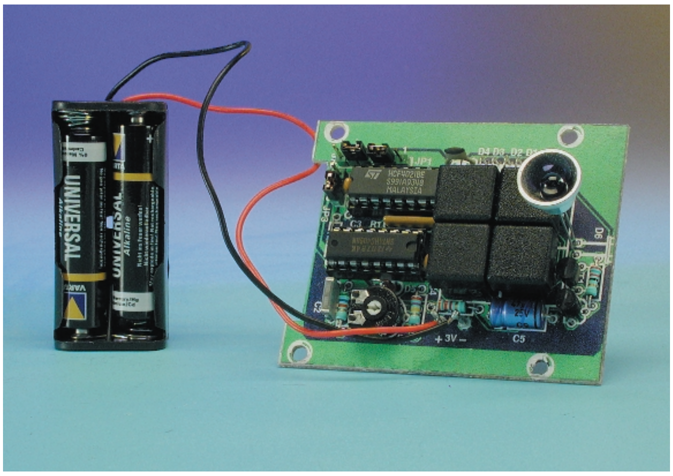
Our circuit is a nearly classical valve audion for the medium-wave range. Power is supplied by a 6-V lead-acid gel battery. The circuit is nearly the same as that of a two-stage amplifier. The first stage provides the demodulation and preamplification. The second stage is the audio output amplifier, which directly drives a headphone with an impedance of 2 kΩ. A 500-pF capacitor between the two stages ensures that RF signals will not be further amplified. Otherwise the valve might easily recall its original intended use and start oscillating in the short-wave range. A ferrite rod with a diameter of 10 mm and a length of 100 mm, with a winding of 50 turns of enamelled copper wire, serves as the aerial.

The radio has a good sound and can receive local signals. In the evening, with a sufficiently long external aerial, it can receive numerous MW stations. It feels just like being back in the good old days.

(014069-1)

Simple IR Transmitter

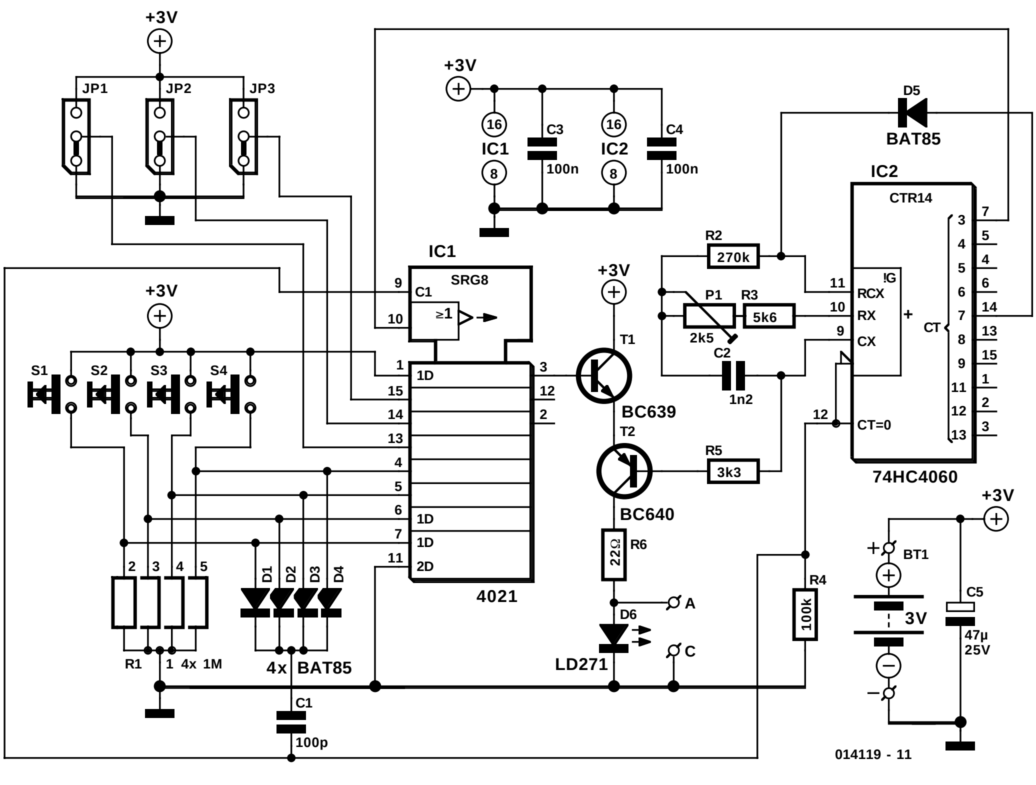
052

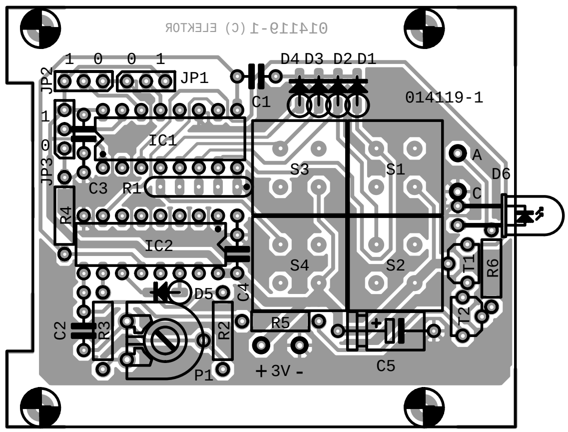


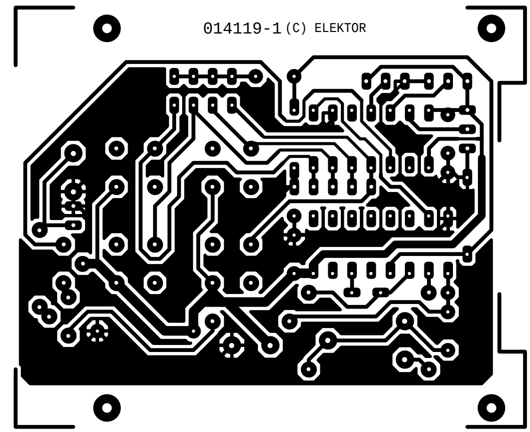
This circuit uses just two standard logic ICs which, with the accompanying receiver, forms a four-channel remote control and has been designed for use with the 'Audio/Video Switch' and the 'Switchbox for Loudspeakers' (shown elsewhere in this issue, as is the IR Rreceiver).

Each pushbutton is connected to an input of a shift register (4021), which is clocked by a binary counter/oscillator (74HC4060). A cycle is started via one of the diodes connected to each pushbutton and a differentiator-network (C1/R4), creating a short pulse that is fed to the shift register and counter/oscillator. The parallel-load input at the shift register then becomes momentarily active, causing the shift register to latch the data at the parallel inputs. At the same time, since the pulse is very narrow, one of the four pushbutton inputs will be high (in spite of any longer pulses that may be caused by switch bounce). The pulse also goes to the reset input of the 4060 and starts the oscillator.

The oscillator around P1/R2/R3/C2 is set to about 36 kHz because IR receiver modules are widely available for this frequency. Pin 7 is the Q3-output of the 4060 and clocks the shift register. The data at the parallel input is now output in a serial format at QH (pin 3). When QH is high the emitter of T2 is made high via T1, and a pulsed current at 36 kHz will flow through LED D6 via R5 and T2. Pin 1 (MSB) of the 4021 is permanently high and is clocked first to the output. This bit functions as the start-bit for the receiver. Since the receiver clocks the data on the rising edge, the start-bit has a length of only 8 cycles at 36 kHz. The rest of the data is modulated at 16 cycles per bit. Output Q7 (pin 14) of the 4060 is connected to the oscillator via a diode, which causes the oscillator to stop after 8 clock cycles of the Q3 output (pin 7) and the circuit becomes idle. The relevant code is therefore sent only once for every button press. A new code will only be transmitted when a pushbutton is pressed again. The only current drawn now are various leakage currents and the current through D5/R2/P1/R3 which is about 10 µA. So even without an on/off switch the







COMPONENTS LIST

Resistors:

R1 = 4-way SIL array 1MΩ
R2 = 270kΩ
R3 = 5kΩ6
R4 = 100kΩ
R5 = 3kΩ3
R6 = 22Ω
P1 = 2kΩ5 preset H

Capacitors:

C1 = 100pF
C2 = 1nF2, MKT
C3,C4 = 100nF ceramic
C5 = 47µF 25V axial (lead pitch 12.7 mm)

Semiconductors:

D1-D5 = BAT85
D6 = LD271
T1 = BC639
T2 = BC640
IC1 = 4021
IC2 = 74HC4060

Miscellaneous:

JP1,JP2,JP3 = 3-way pinheader with jumper
S1-S4 = pushbutton, 1 make contact, PCB mount,e.g., D6-Q-BK-SWITCH + D6Q-BK-CAP (ITT/Schadow)
BT1 = 2 x mini penlite battery (AAA) with holder
Enclosure, e.g., Conrad Electronics #52 28 64-24 (dim. 101x60x26 mm)

batteries should last for years (assuming a capacity of 750 mAh for AAA cells).

P1 has been added to compensate for the various component tolerances and to tune the transmitter and receiver to each other. JP1, JP2 and JP3 are a bonus and can be used for addressing purposes or for a possible expansion with more pushbuttons. At the receiver side these bits are made available on three outputs. The PCB has been designed to fit inside a plastic box with an integral battery compartment (see parts list). If required, the PCB can be made a bit smaller by cutting off the blank areas (where the mounting holes are). That makes it possible to use a smaller enclosure, especially if a 3 V lithium cell is used for the supply.

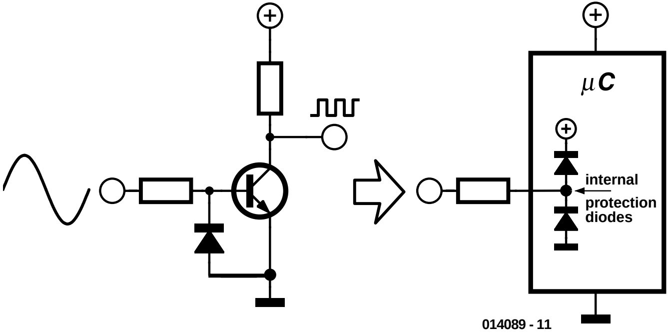
(014119-1)

Zero-Crossing Detector for Microcontrollers

053

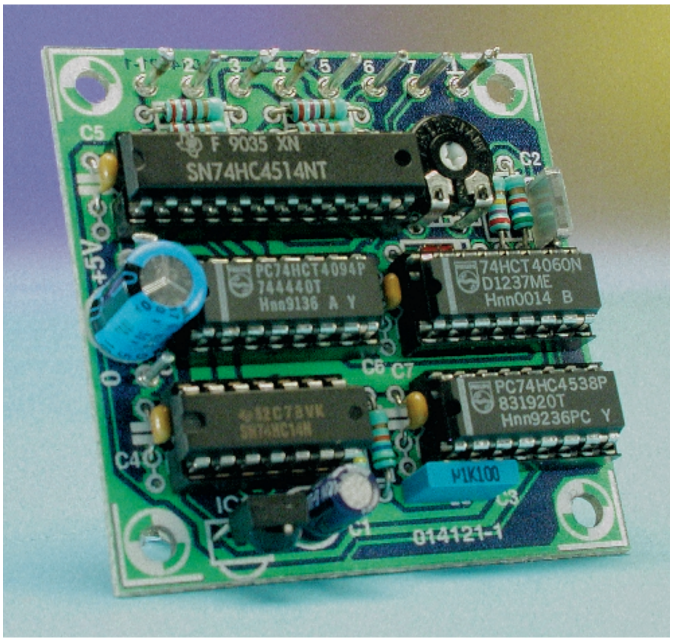
In lighting controllers and clock circuits that need the mains frequency as a parameter for evaluations carried out within a microcontroller, you will often find a transistor stage to convert the mains voltage (reduced by the transformer) into a 50-Hz squarewave signal that is suitable for input to the microcontroller. Generally speaking, this stage is unnecessary with modern microcontrollers if the port input is wired as a Schmitt trigger. The only additional component that is needed is a resistor to limit the port current to a safe value, as specified by the data sheet. The Schmitt trigger ensures reliable edge detection by the software.

(014089-1)



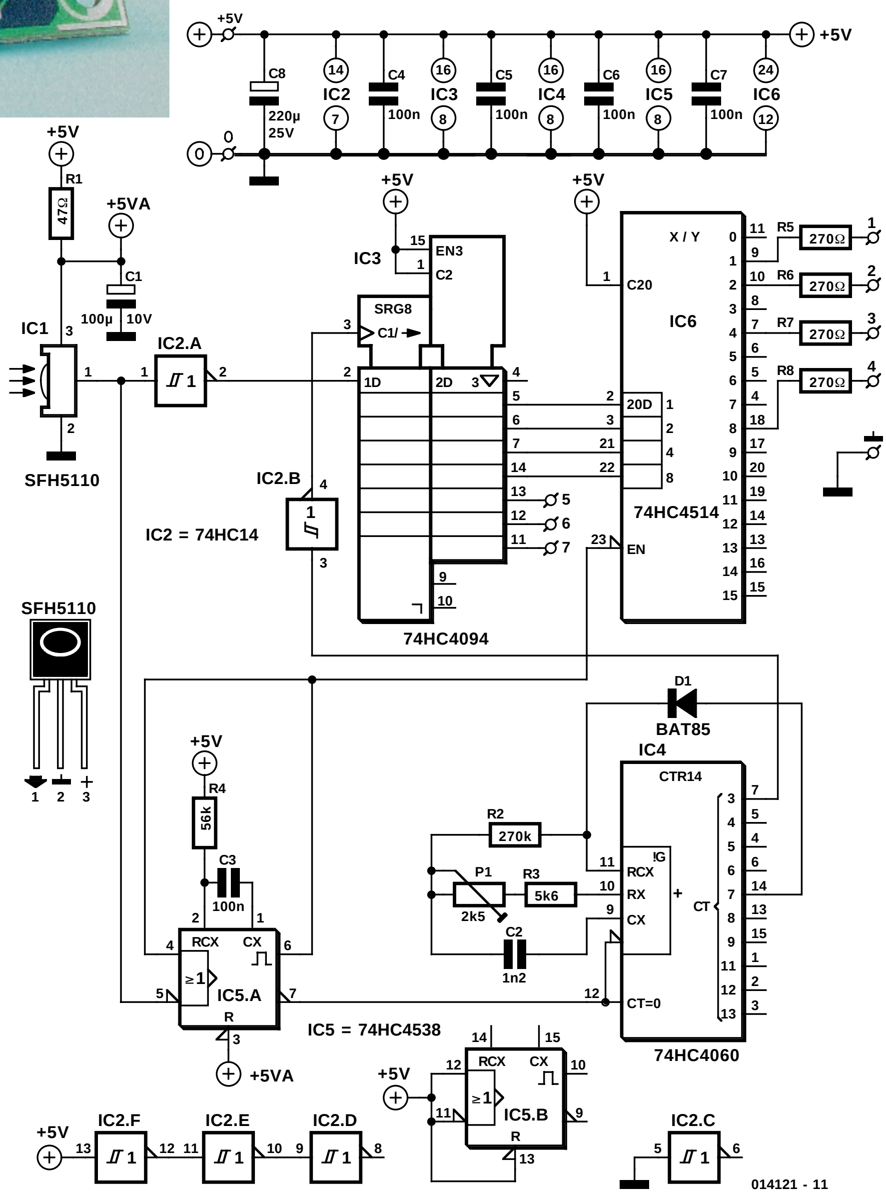
Simple IR Receiver

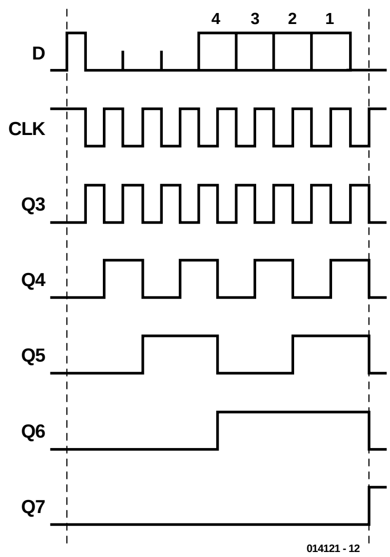
054



This circuit has been designed to complement the 'Simple IR Transmitter' and to decode its transmitted signals. The similarity to the transmitter can be clearly seen: the received data is decoded by a shift register (74HC4094), which again is clocked by a counter/oscillator (74HC4060). The receiver is started by the first edge from the IR-receiver module, which triggers monostable IC5a. The output of the module is active-Low, so the negative trigger input is used. The monostable used is a 74HC4538, which is re-triggerable. By connecting the Q-output to the positive trigger input, IC5 is prevented from being triggered whilst it has an active output.

When IC5a is active, the $\overline{Q}$ output clears the reset input of IC4, thereby enabling it. The oscillator is again tuned to 36 kHz, making the clock from Q3 of the 4060 to the shift register run almost synchronously with the clock of the transmitter. By tying the strobe and output-enable of IC3 to logic '1', the internal latch becomes transparent and its outputs are always enabled. The received pulses are inverted by IC2, as otherwise outputs 5/6/7 would be active low. At first sight outputs 1/2/3/4 could have been simply connected to the other outputs. Instead, these four outputs are fed to a 4-to-16 demultiplexer, making sure that there can



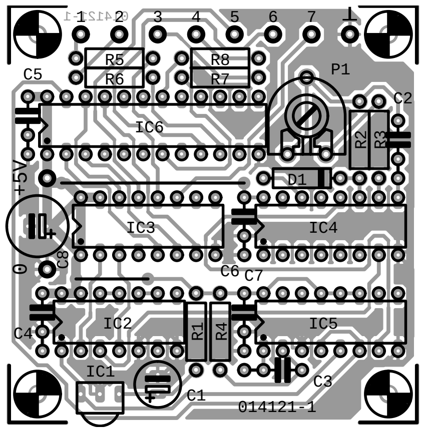


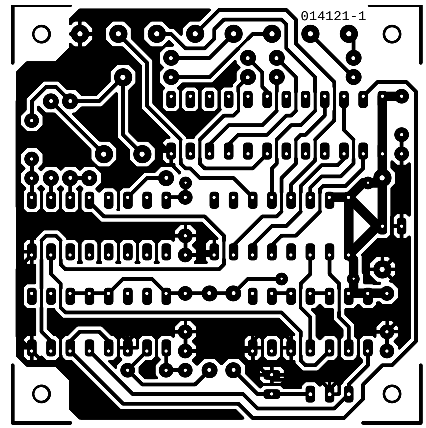
never be more than one active output. In case of the 'Switchbox for Loudspeakers', when several amplifiers are connected to a loudspeaker, there can never be a short circuit, or conversely, an overload of the amplifier. For this reason the 'inhibit' is also connected to the output of IC5a, stopping any transient pulses from appearing at the outputs during the clocking in of the data and giving time for the relay contacts to release before another relay is activated (break-before-make).

The pulse-width of monostable IC5a is slightly longer than that required to deal with the data (3.9 ms). Depending on the relays used, it may be advisable to increase this time a little (by increasing the value of R4). This time has to be greater than the difference between the operate and release times. Normally the release time is less than the operate time, but better safe than sorry. Signal Q3 from IC4 is inverted by IC2b, causing the data to be clocked halfway through the period that a bit is active. The four outputs of the demultiplexer are therefore suitable for the 'Switchbox for Loudspeakers' or the 'Audio/Video-Switch', which can also be found in this issue.

In standby mode this circuit has a current drain of only 3 mA. The resistors in series with the outputs are there for protection against an overload or short circuit. When the receiver is used to drive the 'Audio/Video-Switch', The output voltage drops to 4.2 V when three boards are driven in parallel, which is still sufficient to activate the relays. When more boards are driven in parallel, for example six are required for 5.1 surround, then the values of R5-R8 should be at least halved.

(014121-1)





COMPONENTS LIST

Resistors:
R1 = 47Ω
R2 = 270kΩ
R3 = 5kΩ6
R4 = 56kΩ
R5-R8 = 270Ω

Capacitors:
C1 = 100µF 10V radial
C2 = 1nF2
C3-C7 = 100nF ceramic
C8 = 220µF 25V radial

Semiconductors:
D1 = BAT85
IC1 = SFH5110 (IS1U60, TSOP1836)
IC2 = 74HC14
IC3 = 74HC4094
IC4 = 74HC4060
IC5 = 74HC4538
IC6 = 74HC4514

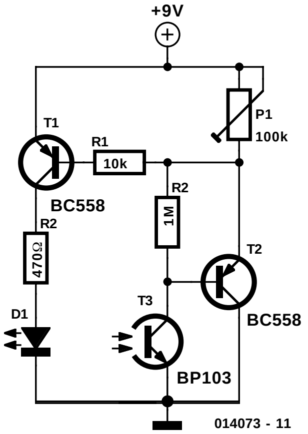
Simple Remote Control Tester 055

F. Jensen

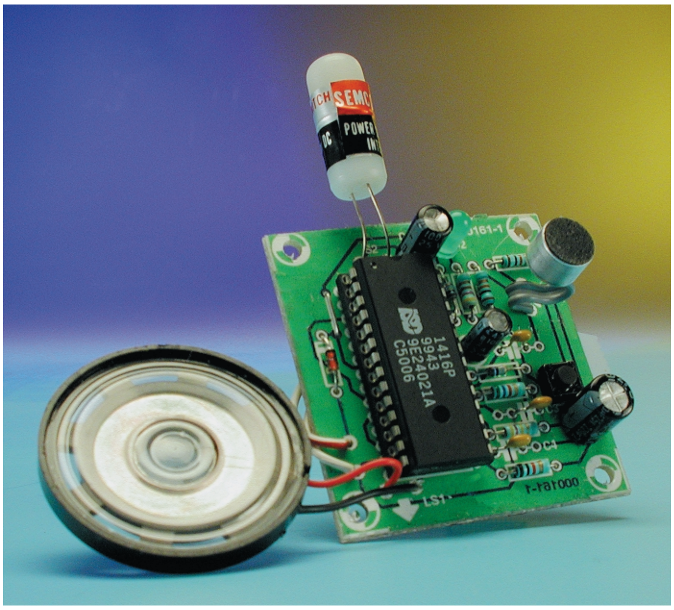
Nearly always when a remote control doesn't work, the underlying problem is elementary: the unit does not emit light. The cause may be dry solder joints, defective LEDs etc., but also a flat battery (perhaps due to stuck key).

The human eye is unable to perceive infra-red light. By contrast, an ordinary photo transistor like the BP103 has no problems working in the infrared spectrum, so in the circuit here it simply biases the BC558 which, in turn, makes LED D1 flash in sympathy with the telegram from the remote control. The preset in the circuit determines the sensitivity.

(014073-1)



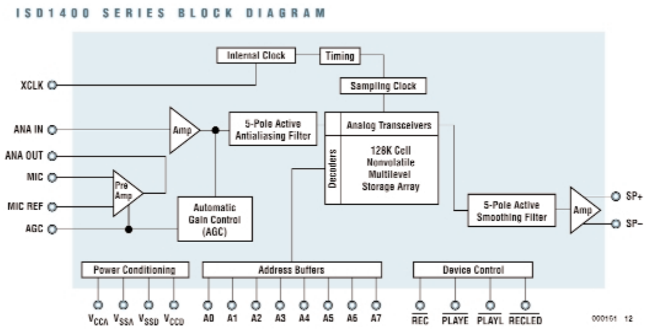
Integrated Voice Memory 056



Features of the ISD1416

- High quality recording and playback
- 16 s recording time
- Edge- or level-sensitive playback control, allowing push button operation
- Automatic power down
- Power down current consumption about 1 µA
- Non-volatile memory
- Memory retention: typically 100 years
- Typical life: 100,000 record cycles
- On-chip clock generation
- Operating voltage: 4.5 V to 6.5 V

1

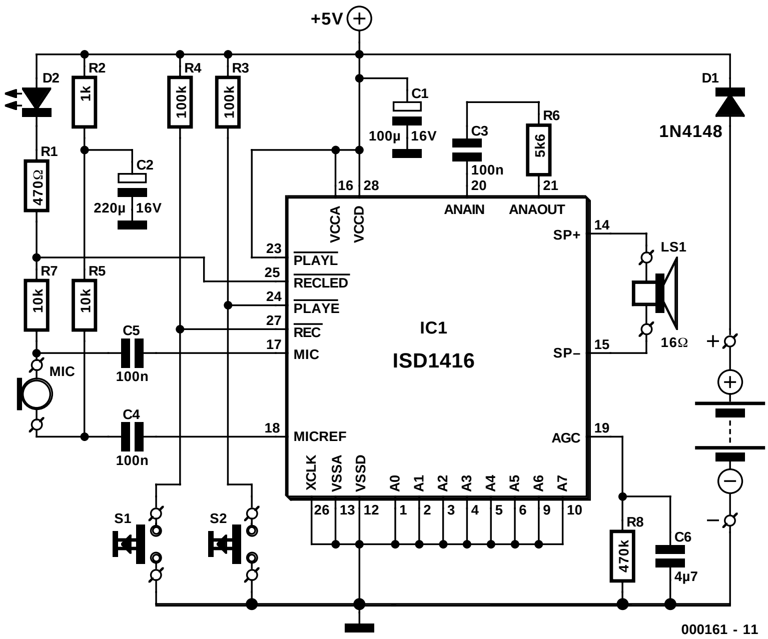


There are lots of exciting applications for a voice memory. The circuit presented here has been installed in the author's toilet in order to advise potential users of the facilities to do so sitting down rather than standing! A mercury tilt switch detects when the seat is lifted and activates the (remotely connected) voice memory: the admonitory text can be chosen at the whim of the householder.

At the heart of the circuit is a voice memory device from ISD (Integrated Storage Devices, now part of Winbond), which is also used in various answering machines and clocks made by Braun. The data sheet is in three parts (...1400_1.pdf, 1400_2.pdf, 1400_3.pdf) and can be downloaded from the Winbond website at

http://www.winbond-usa.com/products/isd_products/chipcorder/datasheets/1400/1400_1.pdf

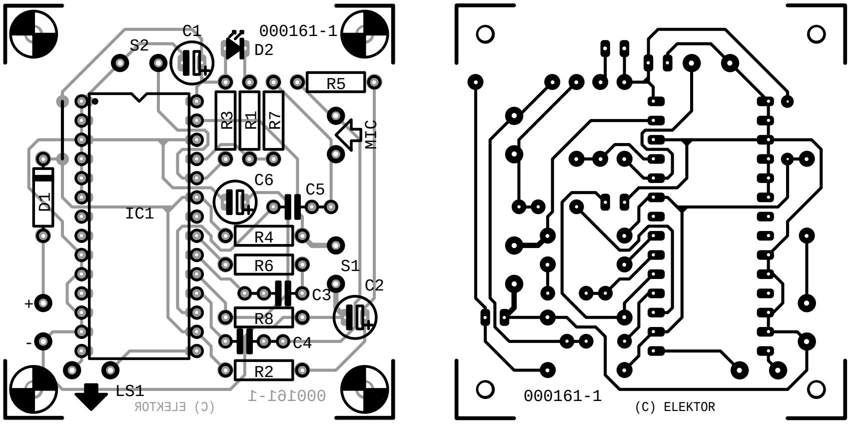
2



The block diagram in **Figure 1** shows that the ISD1416 contains all the electronics required to record and play back speech or music. Even a practically independent microphone preamplifier with differential inputs is provided. An automatic gain control (AGC) prevents the circuit from being overdriven. The time constant of the AGC circuit is set by R8 and C6. The amplified microphone signal is filtered externally by C3 and R6 and then passes through a line-level amplifier and five-pole anti-aliasing filter before being sampled at 8 kHz. The timing of the A/D converter is governed here by an internal clock: an external clock can also be used.

The samples are stored in a 128 k non-volatile EEPROM array, which makes for a maximum recording time of 16 s. Winbond offers voice memories with recording times

3



COMPONENTS LIST

Resistors:
R1 = 470Ω
R2 = 100kΩ
R3,R4 = 100kΩ
R5,R7 = 10kΩ
R6 = 5kΩ6
R8 = 470kΩ

Capacitors:
C1 = 100µF 16V radial
C2 = 220µF 16V radial
C3,C4,C5 = 100nF
C6 = 4µF7 16V radial

Semiconductors:
D1 = 1N4148
D2 = LED, high efficiency
IC1 = ISD1416 (Conrad Electronics #164984)

Miscellaneous:
S1 = pushbutton with make contact
S2 = pushbutton with make contact or tilt switch (Conrad Electronics #700444) or photodiode (BPW34)
Mi1 = electret (condenser) microphone (Conrad Electronics #302155)
PC1,PC2 = solder pin
LS1 = loudspeaker 16Ω

of up to 2 minutes. It is interesting to note that the samples are not stored digitally, but in quasi-analogue form with one of 256 different levels in each memory cell. This gives a considerably higher storage density than is possible with conventional digital storage technology, as well as guaranteeing a high quality recording.

The EEPROM array need not be written all in one go: several messages can be recorded and played back independently. Inputs A0-A7 are used to configure the device and to address the memory.

The IC has four control connections: an edge-sensitive and a level-sensitive playback input, a record input and an output which is pulled low during recording. This output activates the microphone and lights a LED. An active five-pole smoothing filter is used during playback, connected to an output amplifier with symmetrical outputs. As can be seen from a glance at the circuit of **Figure 2**, a 16 Ω loudspeaker can be connected directly to these outputs. The quality of this loudspeaker is largely responsible for the final quality of playback. The external circuitry required for the ISD1416 is minimal. The electret microphone is connected symmetrically via two coupling capacitors and only activated in recording mode, when the RECLED connection is low. Only then does the LED light.

The record input is connected to a push button, while the playback input can be connected to a (tilt-) switch, a push button or a photodiode. The edge-sensitive playback input is used, and so once under way, playback will not stop. The photodiode (type BPW34) can be fitted in parallel with or instead of a switch or push button. It could be fitted at the middle of a target: when a laser pointer is fired at the sensor, the marksman is greeted with applause or adulation. The applications are endless.

The small circuit can be constructed on the printed circuit board shown in **Figure 3** (not available from Readers' Services). The layout and component mounting plan can be obtained from the downloads area of the *Elektor Electronics* website under ref**. 000161-1**. The circuit is also sufficiently simple that construction on perforated board (Veroboard) is perfectly possible.

Current consumption during playback is around 25 mA. After playback the IC goes into a power down mode, in which the circuit draws only 90 µA. The two lithium cells (type CR2032) used as the power supply should therefore last for a long time.

(000161-1)

Alternating Blinker

057

K. Lorenz

The circuit represents a general-purpose astable multivibrator that alternatively energises two heavy loads via a relay (in this case, the loads are 12-V incandescent lamps).

In contrast to an ‘analogue’ flip-flop, here it is not necessary to use power transistors with heatsinks. This alternating blinker can thus be built at a lower cost, more easily and more compactly.

In the idle state, capacitor C1 is charged via R1 and at the same time discharged via R2 and P1. Here P1 must be adjusted such that sufficient current is available to switch on transistor T1. This should occur when the voltage on the capacitor is around 1.2 V, if a BC517 is used. As a consequence, the relay pulls in.

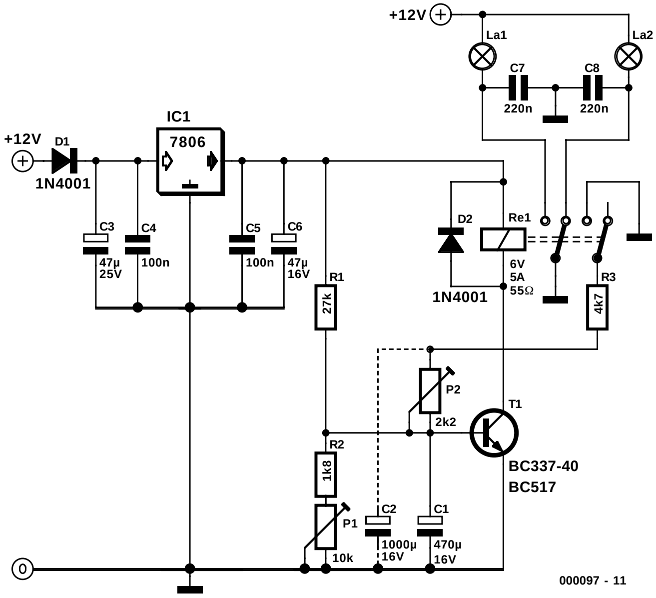
This causes R3 and P2 to be connected in parallel with R2 and P1. P2 must be adjusted such that there is not enough current left to provide the base current for T1. This causes the voltage on C1 to drop, and a short time later the transistor is cut off. The relay then drops out, and the cycle starts over again.

Operating power can be supplied by an unregulated 12-V mains adapter (for example). The current consumption essentially depends on the two loads, since the alternating blinker circuit only draws the rated current of the relay.

Each load is connected directly to the supply voltage, while the blinker circuit receives a stabilised supply voltage via the fixed voltage regulator IC1. Diode D1 protects the circuit against an incorrectly polarised input voltage.

To set up the circuit, first turn P1 to minimum and P2 to maximum resistance. Now turn up P1 slowly (!) until the relay pulls in. Repeat the same process with P2 until the relay again drops out. Using this basic procedure, you can select both the blinking rate and the desired on/off ratio.

The author used a BC337-40 for T1. If this is difficult to obtain, a BC517 (Darlington) can also be used. The proper operation of the circuit also depends on the type of relay



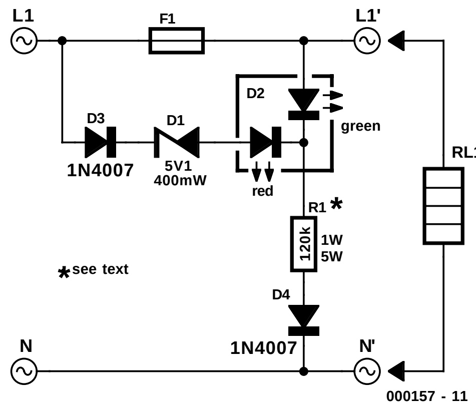
used. In one prototype model, the relay pulled in OK and energised R3 and P2, but it refused to do anything further. If your construction exhibits similar behaviour (and you are dependent on a particular type of relay), it may help to include capacitor C2 in the circuit (as shown in dashed outline) in order to slightly delay the effect of switching in P2 and R3.

(000097-1)

Fuse Failure Indicator

058

S. Lenke



This circuit indicates when a device is functioning or when its fuse has blown. It is a development of the Mains/Fuse Failure Indicator published in *Elektor Electronics* July/August 1995. It is smaller and cheaper than the previous design, even though it works on any mains supply voltage. A single bi-colour LED (D2) with separate anode connections indicates **operating** (green) or **fuse failure** (red). Resistor R1 limits the current through the LED to around 2 mA: the LED is thus reasonably bright. If higher brightness is desired, the resistor value can be reduced.

The zener diode prevents the red and green LEDs from lighting simultaneously in normal operation. With the fuse intact, the LEDs are effectively in parallel, but the greater voltage drop in the red LED's arm of the circuit means that only the green LED lights. General-purpose diodes D3 and D4 prevent damage to the LEDs in the negative half-cycle of the AC supply. If the circuit is used on a DC supply, the diodes can be removed.

If the circuit is used to monitor the fuse on mains-operated equipment, it is vital to note that the components are not isolated from the mains and the voltages present on them can be lethal: do not touch!

(000157-1)

Pump Protector

059

C. van Lint

This circuit has been developed to limit the running time of a sump pump, since the pump can be damaged if it runs too long when the sump is dry. The circuit detects how long the pump has been switched on, and if this time exceeds a previously set limit (30 minutes in this case), the supply voltage to the pump is interrupted.

The protector circuit is connected in series with the pump's mains supply cable. The 230-V input is on the left-hand side of the schematic diagram, and the output is on the right. The schematic diagram consists of three main elements: the power supply, the timing circuit and the in-use detector.

The supply voltage is taken from the mains connection to the pump via transformer Tr1. Since voltage stabilisation is not necessary, the power supply can be limited to the standard combination of a transformer, a bridge rectifier and a smoothing capacitor. LED D5 acts as an on/off indicator.

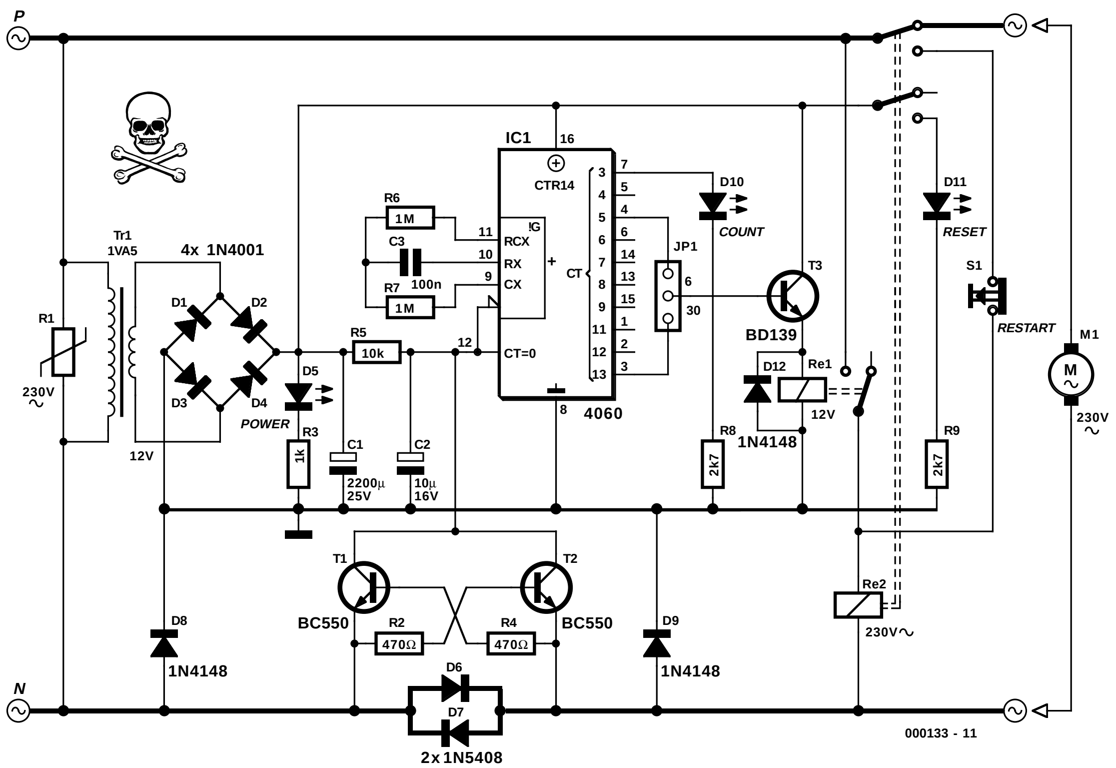
A 4060 (IC1) is used for the timing function. LED D10 (Count) blinks as long as power is supplied to the load. Output Q14 of IC1 goes High after 30 minutes. Alternatively, the Test jumper position can be used to select output Q6. This output interrupts the power to the pump after 6 seconds for testing purposes.

Two diodes connected anti-parallel (D6–D7) are placed in series with one of the supply leads to detect whether the pump is running. When the pump switches on, the voltage drop across these diodes is sufficient to cause T1 and T2 to conduct. These transistors pull down the Reset input of IC1, so the timing circuit starts to count. Diodes D8 and D9 provide a return path to ground from the Reset pin; a direct connection at this point would short out the detection diodes, which is not what we want! These diodes cause the Reset level to lie at around 0.8 V. Capacitor C2 suppresses the crossover spikes from the ac signal, which could otherwise cause the circuit to malfunction.

If the pump is still running when the time interval has expired, T3 energises the 12-V relay Re1, which in turn drives a 220-V relay with two changeover contacts. One of these contacts interrupts the supply voltage to the pump, while the other one is used to activate the Reset LED (D11). The pump can be started again by pressing the Restart button.

We can conclude with some practical remarks. First, a Eurocard relay relay may be used for Re1, and second, the Reset pushbutton switch must naturally be a normally-closed 230-V type. Finally, since the entire circuit is connected to the mains network, full consideration must be given to electrical safety in its construction, and a well-insulated enclosure is mandatory.

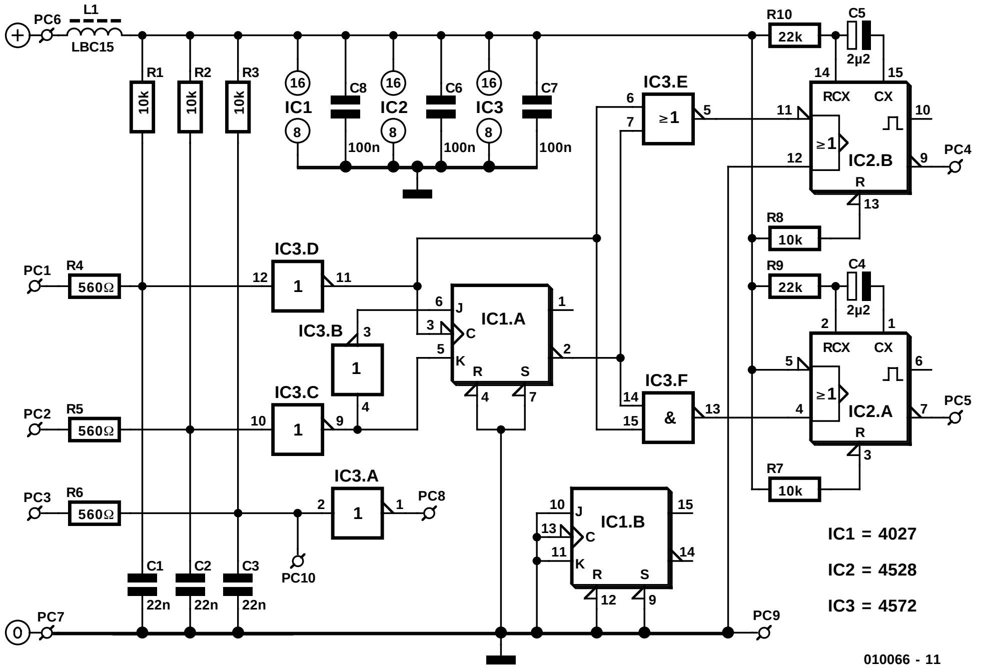
(000133-1)



Rotary Encoder for Digital Volume Control

060

A. Ziegler



The digital volume control published in *Elektor Electronics* October 1997 can be used either with an RC5 remote control or with two pushbuttons (louder/softer). If for whatever reason you cannot do without the feeling of turning a real potentiometer, then with a little effort it is possible to add a shaft encoder to provide rotational control. The outputs of the circuit presented here can simply be connected in place of the two pushbuttons.

The shaft encoder produces two trains of pulses at PC1 and PC2, with a different relative phase depending on the direction of rotation. A complete revolution produces 15 pulses. In order to drive the two pushbutton inputs correctly, not only the number of pulses, but also the direction information (clockwise = louder, anticlockwise = softer) must be taken account of.

First of all the pulses must be debounced using R4/C2 and R5/C2: the shaft encoder is after all just a mechanical rotary switch. R1...R3 are pull-up resistors. The JK flip-flop, connected as a D-type flip-flop, determines the direction of rotation. The clock input is connected to PC1 via inverter IC3.D, while the other output of the encoder drives the K input of the flip-flop via inverter IC3.C. IC3.B provides an inverted form of this signal at the J input to the flip-flop. When a pulse arrives at the clock input the flip-flop is set or cleared according to the direction of rotation.

The 4572 contains a variety of gates: three inverters, a NAND (IC3.F) and a NOR (IC3.E). These are used the produce pulses from the static signals. At one input to the two gates is the clock signal PC1, while at the other input we have the output of the flip-flop. The NAND gate passes the pulses to its output only when the second input is high; likewise, the NOR gate only propagates pulses when the second input is low. Thus only one of the gates can ever be propagating pulses at a time.

The signals thus generated have the disadvantage that in the quiescent state, when the encoder is not being turned, they can equally well be either high or low. A low level, however, will drive the volume control continuously, so winding the volume up to the maximum or down to the minimum. This is clearly not desirable: to rectify the situation we use a monostable to deliver a brief negative-going pulse. The pulse width is determined by R9-C4 and R10-C5.

The inverting input to monostable IC2.B is connected to the NOR gate, and the non-inverting input to logic one. For monostable IC2A the NAND gate is connected to the non-inverting input, and the inverting input is tied low. The Reset inputs (pin 3/pin 13) must be tied high. On a positive-going clock edge monostable IC2B produces a low-going pulse, and if the input stays high, no further pulses are produced. IC2A behaves in a similar way.

The outputs of the two monostables can be connected directly to the pushbutton inputs of the digital volume control. The supply voltage is +5 V, which is obtained from the potentiometer circuit via inductor L1 to avoid interference: you may find that the inductor can be dispensed with. The current consumption of the circuit is just 1 mA.

Now to the pushbutton function of the shaft encoder. The relevant connection is wired to PC3, buffered, and then not used. The pulse at PC8 could be used to switch another circuit (with a +5 V supply) on or off. Alternatively the signal at PC10 can be used to drive the digital volume control directly by connecting PC10 and PC5. Here, an extra resistor (4.7 kΩ) is required to protect the monostable's output, between the IC and PC5/10. Then, if the encoder is pressed, the audio signal will become gradually softer, providing a kind of mute function. Or alternately, connect PC10 with PC4 instead of PC5: then rather than softer, the audio signal will become louder.

(010066-1)

Literature:

Infra-red controlled noiseless volume control, Elektor Electronics October 1997 54

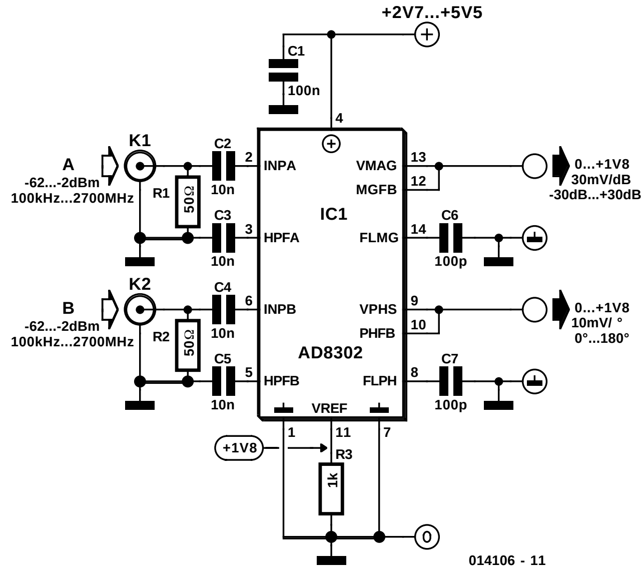
Gain and Phase Meter

A simple way of measuring the amplitude and phase difference between two high-frequency signals is provided by the AD8302 from Analog Devices (www.analog.com).

The two input signals A and B are terminated with 50 Ω and fed to the internal logarithmic demodulators. Taking the difference of the outputs leads to a voltage which represents the amplitude difference in decibels (dB); by multiplying the internal signals an output voltage proportional to the phase difference between A and B is produced.

The circuit produces a voltage at output VMAG ('magnitude') between 0 V and +1.8 V. 0 V represents –30 dB while +1.8 V represents +30 dB, each 30 mV step thus representing one decibel. The amplitude of input B is taken as the reference. The phase output also varies between 0 V and +1.8 V, each 10 mV step representing one degree of phase difference. The outputs can drive up to 15 mA, and so the load impedance must be at least 120 Ω.

The AD8302 can be used, for example, as a level meter by applying a signal with a known amplitude to input B. The input level range runs from –62 dBm to –2 dBm. Error in the device is typically less than 0.5 dB in amplitude and 1 degree in phase. The device operates from a supply voltage between 2.7 V and 5.5 V. If modulation is present on the input signals, the modulation envelope will appear on the outputs.



The IC has a bandwidth of 30 MHz, which can be reduced by fitting a capacitor between pins 8 and 14. Pin 11 is a +1.8 V reference voltage output which can be used when further processing the outputs of the device.

(014106-1)

Graphical Compiler for the MCS-51 Microcontroller 062

J. C. Bracker

In both hobby and semi-professional electronics the use of microcontrollers is becoming more and more popular. This is mainly down to the Internet, where anyone can discuss their problems and experiences with microcontrollers, and application and programming software is as a rule freely downloadable.

Whereas in the past programming had to be done in hard-to-read machine code or assembler, these days high-level languages such as Pascal, C, Basic and a host of others are used. Spend a little time searching, and you will find a wide range of possibilities available on the Internet (or in the advertisements in *Elektor Electronics*!).

The GraphCom package described here belongs to the so-called fifth generation of programming languages. The term ‘programming language’ is not really the correct one here: it is more of a graphical compiler. Together with a graphical editor (in this case the freeware version of the Eagle schematic editor, downloadable from www.cad-soft.com) it is possible to use GraphCom to draw a block diagram of the desired system, just as when programming PLCs with the ‘C-Control-Software’ package available from Conrad Electronics. The schematic is converted into a netlist using the Export command in the editor. From this data GraphCom produces an assembler listing, which can then be converted into a HEX file using for example the Elektor EASM51 assembler.

The program comes with a library of functions which are used by GraphCom and converted into meaningful MCS-51 instructions. The GraphCom environment is a fully ‘open system’. The functions can be extended at will by the user and tailored for a particular microcontroller. It is worth noting that GraphCom (in contrast to some other graphical compilers) is very frugal in its use of the microcontroller’s resources, and so it is possible to write complex programs even for simple Atmel microcontrollers such as the 89C2051.

The package includes a terminal program which can be used to set parameters and observe the outputs of functional blocks in the target system. GraphCom is available in English and German versions, occupies about 4 MB (or only 350 MB as a ZIP file), and runs under Windows 95, Windows NT or Linux. A DOS version is also available. The program is shareware and can be downloaded from www.bracker-automation.de.

(014018-1)

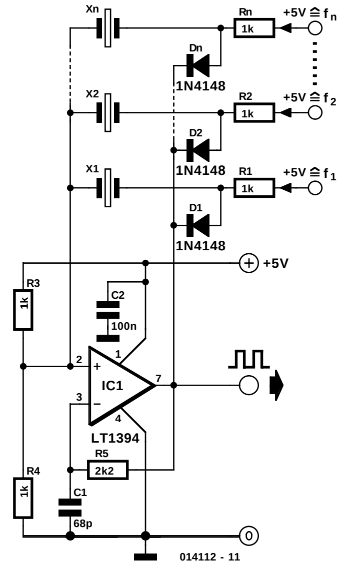
Switchable Crystal Oscillator

063

The circuit shows a switchable crystal oscillator which can generate any one of a number of set frequencies. Using the high-speed LT1394 comparator from Linear Technology (www.linear-tech.com) it is possible to build a crystal oscillator by putting the crystal in the negative feedback path, while an RC network in the positive feedback path provides the required phase lag.

Switching between the crystals is simply achieved using diodes (type 1N4148). The diode corresponding to the crystal to be selected is forward biased via its 1 kΩ series resistor, while all the other inputs to the circuit must remain at ground potential. Any crystals suitable for fundamental frequency operation in the range 1 MHz to 15 MHz can be used. Use of a comparator guarantees that the output signal is a squarewave.

(014112-1)



Pulse Selector

064

B. Schädler

The circuit presented here can be useful in triggering, test and measurement applications. It converts a rising edge into a square pulse whose length is equal to the period of an input pulse train.

In the quiescent state, flip-flop IC1B is clear, holding flip-flop IC1A set.

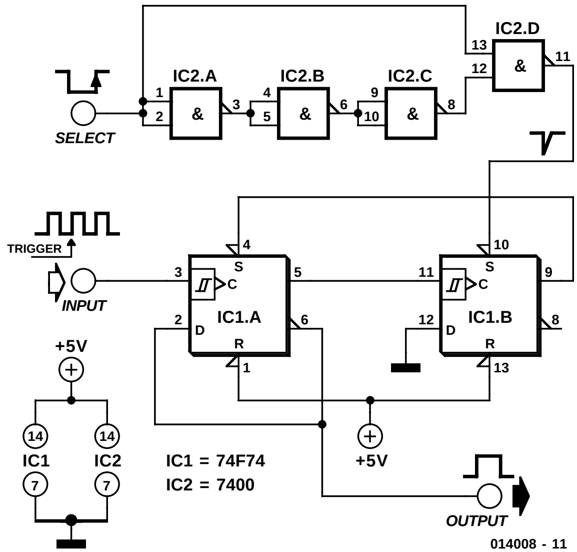
A TTL-level rising edge at the SELECT input causes a brief spike to appear at the output of gate IC2D. The spike is only a few nanoseconds long, and depends on the propagation delay through NAND gates IC2A, IC2B and IC2C, which are connected as inverters.

The spike sets flip-flop IC1B. Its output (pin 9) goes high, releasing the set input on flip-flop IC1A. This state is stable and persists after the trailing edge of the spike, IC1A remaining set.

However, the inverting output of IC1A is connected to its D input, and so the next positive edge arriving at the trigger input ('INPUT') clears it. The inverting output goes high and the non-inverting output goes low. On the next rising edge of INPUT IC1A is set again. The inverting output, connected to OUTPUT, goes low again, and the non-inverting output goes high. This rising edge on its clock in turn clears IC1B, since its D input is tied to ground. With IC1B cleared, IC1A is again held in the set state, and this situation will persist, independently of TRIGGER pulses, until the next SELECT edge arrives.

The result is that the output is high for one period of the input following the spike. The circuit works equally well with CMOS gates, although it should be observed that the spike must be short compared to the period of the input.

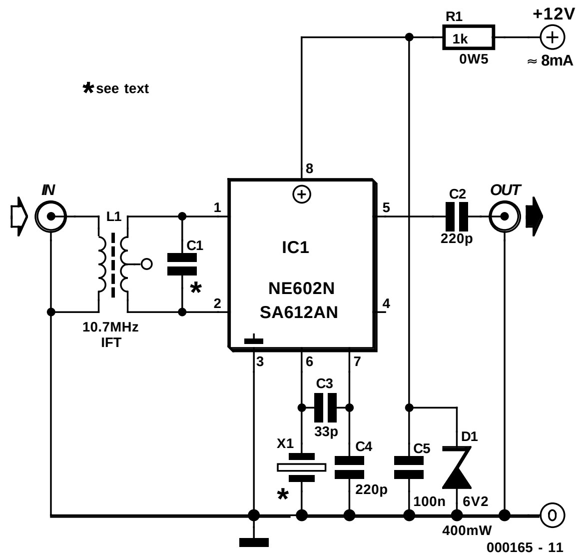
(014008-1)



SW Converter for AM Radio

065

P. Laughton, VK2XAN



Apart from chucking it in the bin, what can you do with old AM car radio or clock radio in your junkbox? How about turning it into a crystal controlled, stable, short wave radio receiver, for a minimum investment in time and money? Read on.

The heart of the circuit shown here is an IC which goes by the name NE602, NE612 or SA612. It is a double balanced mixer that includes an oscillator that can be crystal-controlled, free running or even driven externally from a PLL, etc. It was originally designed for mobile telephones and is probably available in junked car phones from the tip.

The NE602/612 contains a differential input amplifier (called a Gilbert Cell), an oscillator/buffer, a temperature compensated bias network and a power regulator. Typical frequency response is in excess of 500 MHz for the input and 100 MHz for the oscillator. Supply current is 2.4 mA and the absolute maximum supply voltage is 9 V. Input and output impedances are approx. 1.5 kΩ.

As you can see from the circuit diagram, the input from the aerial is passed through a 10.7 MHz IF (intermediate frequency) transformer. This gives isolation from the aerial and reduces the effect of strong local AM radio breakthrough. The transformer can be salvaged from a dead FM radio or stereo or even the FM section of an old clock radio. (The AM section is what we want to use anyway so ratting a bit from the FM section saves cost).

A number of 10.7 MHz IF coils from Toko and other far-Eastern manufacturers may be used, including the 94AES30465N and 94ANS30466N, but obtaining these as new parts may be more costly than a complete radio rescued from the tip. There is usually a small capacitor under the IFT coil, between the pins. If so, remove it by crushing it with a pair of pliers and ripping out the remains. The capacitor is not needed as we add an external one according to the band wanted.

The input signal is fed into the balanced input of the IC. The crystal is connected to pin 6. It oscillates at its fundamental frequency and is mixed with the input signal giving a number of outputs.

The mixer output signal appears on pins 4 and 5. Here, only pin 5 is used for the output. By the way, the inputs and outputs are internally biased with pull-up resistors, so there is no need to tie the unused pins to ground or power. The 220 pF capacitor gives isolation to any DC into the AM radio aerial input. Note also that the same circuit can be used to extend the range of an existing short wave radio receiver in exactly the same manner. The AM radio is used as a tuneable intermediate frequency amplifier, with a tuning range of about 1.6 MHz.

You can try different values for C1 to get resonance at the NE602 input: 150 pF for up to 5 MHz, 47 pF for up to 8 MHz, and no capacitor for up to 10 MHz. In practice however 33 pF should do for all ranges.

Almost any crystal can be used. The author tried many types from FT-243 WW2 surplus ones to 27 MHz, 3rd overtone CB crystals. Every crystal tried worked. TV sub-carrier crystals work well, as do large oven types. Several crystals can be connected through a switch, giving a convenient way of switching bands. Keep the leads to the switch as short as possible though to prevent radiation of the crystal oscillator.

There are many ways to build the circuit. You could make it into an external metal box that can be connected to several radio's, depending on your location. For instance, if you are a traveller, make it in a small box with an internal 9-volt battery, and leave enough wire on the output to wrap a few dozen turns around the clock radio in your Hotel room. This will give you your short-wave reception on the go.

It is also possible to build the converter right into the car radio. Any sort of construction method can be used, from a small piece of perforated board that I used, to a more elaborate printed circuit board and even just lash all the small components underneath the IC socket. A small switch may be used to change from AM to short-wave.

Connect the circuit to the car radio with screened cable to prevent or lessen the effect of strong station breakthrough. To couple the output of the converter to a radio without an external AM aerial input, wind several turns of wire around the internal ferrite rod aerial. As suggested before, winding a dozen or so turns around the plastic radio case will also couple the converter to the radio. This will work at the expense of increased AM signal breakthrough.

Connect the positive power lead to the switch on the radio so that it switches the converter on and off as well.

The short-wave aerial can be 2 to 3 meters of wire strung around the room, but better results will be obtained with a outdoor aerial. The test aerial was about 100 meters long and 10 meters high.

At night there is a lot of activity on the short waves after dark. Find a weak station around 1 MHz on the AM dial and adjust the core of the IFT for minimum volume from the broadcast station. That's the only adjustment.

SSB signals can be heard, but as no beat frequency oscillator is fitted, you hear the "duck talk" of the signal.

The 10 kHz bandwidth of the radio means that on the ham bands, signals do overlap, but it also makes the broadcast stations sound better as most of them do broadcast with reasonable quality audio. Digital tuned AM radios are usually not suitable for the circuit as presented, because the tuning steps are 9 or 10 kHz apart and we want much smaller steps. The old manually tuned types of car radio are what you want.

The idea of the circuit is not to get too complicated, but to just enjoy listening on a simple, stable, cheap, short wave receiver. Experiment and enjoy!

(000165-1)

SDCC (Small Device C Compiler) 066

The subject of this Summer Special article is a valuable tip, rather than a circuit. For some time now, a free C compiler for microprocessors has been available via the Internet. This compiler, which is called SDCC, can be found at the Sourceforge site (http://www.sourceforge.net). It runs under Linux and Windows (in a DOS window).
There are distinct advantages to programming in C. For example, it is possible to reuse frequently used functions by packaging them in 'routines', which can be easily incorporated into new software projects. Furthermore, C has come to be a standard language that is intensively used in the professional world. This also means that many C functions can be found on the Internet, and you can directly use these functions in your own programs.
Another advantage of C is that you can write programs that are nearly independent of the processor used to run them. This means that, for example, you can try out a routine on the PC before using it in an embedded processor. This

drastically shortens the development time, and in addition, in many cases you do not need to have a special debugger for the target processor.
SDCC can generate machine code for all processors in the MCS-51 series. There is also work in progress to provide support for the following processors: Z80, Gameboy-Z80, AVR, DS390 and PIC. In short, SDCC is an ideal complier for anyone who works with microprocessors and would like to program in C without having to dig deep into his or her purse.

(010063-1)

Video Line Driver

067

This circuit is a video line driver specifically intended for use with a single-ended power supply. As a matter of fact, the synchronised outputs of a line driver for composite-video signals go negative with respect to ground. In order to be able to process these negative signals in a circuit powered from a single-ended supply, it is necessary to AC-couple the input of the opamp as well as

COMPONENTS LIST

Resistors:

R1,R7 = 75Ω
R2...R4 = 4kΩ7
R5,R6 = 1kΩ

Capacitors:

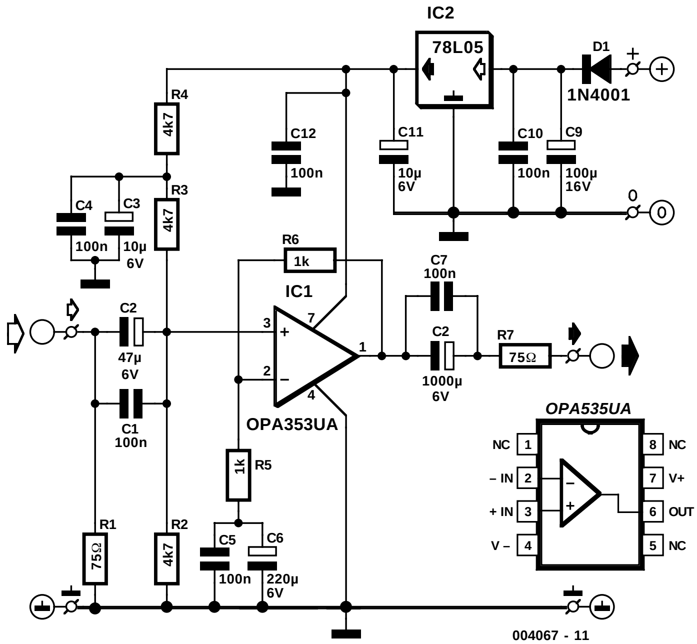
C1,C4,C5,C7C10,C12 = 100nF
C2 = 47µF 16V radial
C3,C11 = 10µF 6 V radial
C6 = 220µF 6 V radial
C8 = 1000 µF 6V radial
C9 = 100µF 16V radial

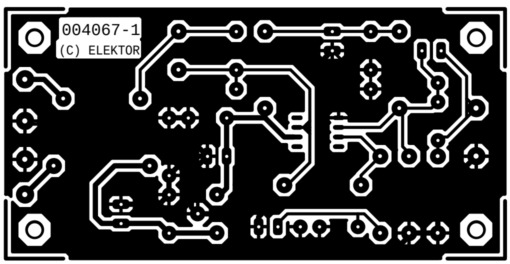
Semiconductors:

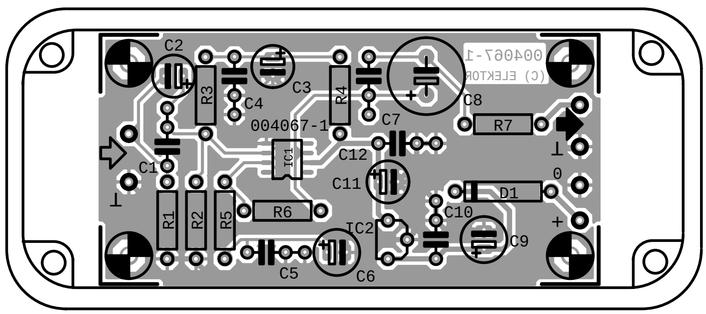
D1 = 1N4001
IC1 = OPA353UA
IC2 = 78L05

Miscellaneous:

PC1-PC6 = PCB solder pin
Case, e.g., Hammond type 1590A







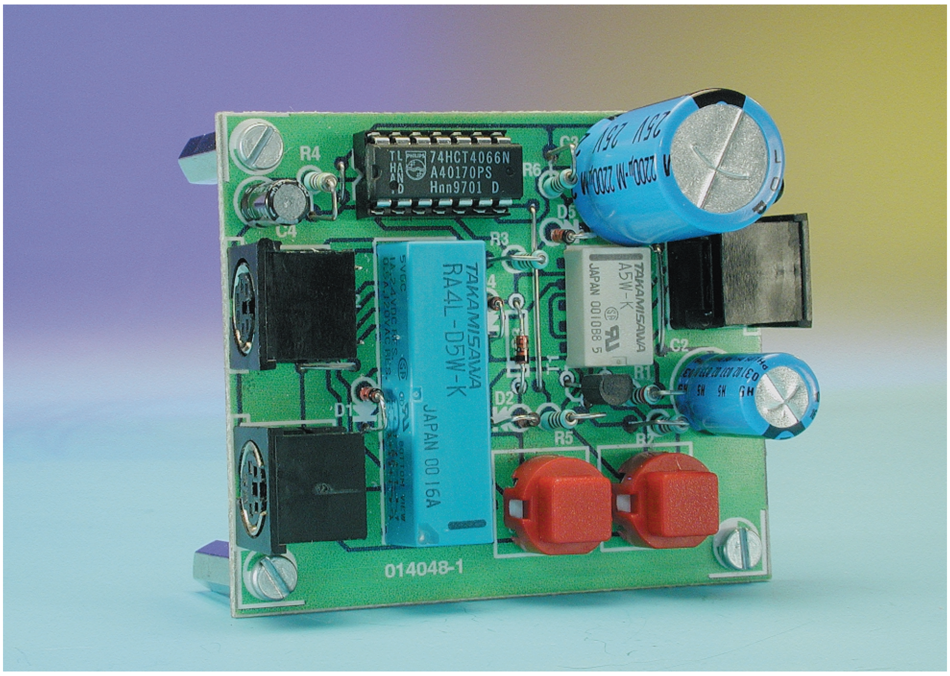
level-shift the signal in the positive direction.

The input is terminated into a 75 Ω resistor (R1). From here, the signal passes through AC-coupling capacitor C2 and is applied to potential divider R2-R3, which provides the necessary DC-offset. The shift into the positive direction amounts to +1.7 V, with the values shown in the schematic. To avoid any misunderstandings we should add that this value is fairly critical. Deviating from the values shown can lead to distortion in the complementary input stage of the opamp that has been used here, and this of course, has to be avoided.

Because we provided the circuit with its own voltage regulator circuit (IC2), just about any mains adapter will suffice for the power supply. The current consumption is less than 20 mA. The construction of the line driver using the accompanying printed circuit board layout is no more than a simple, routine job.

(004067-1)

Keyboard/Mouse Switch Unit 068



H. Kraus

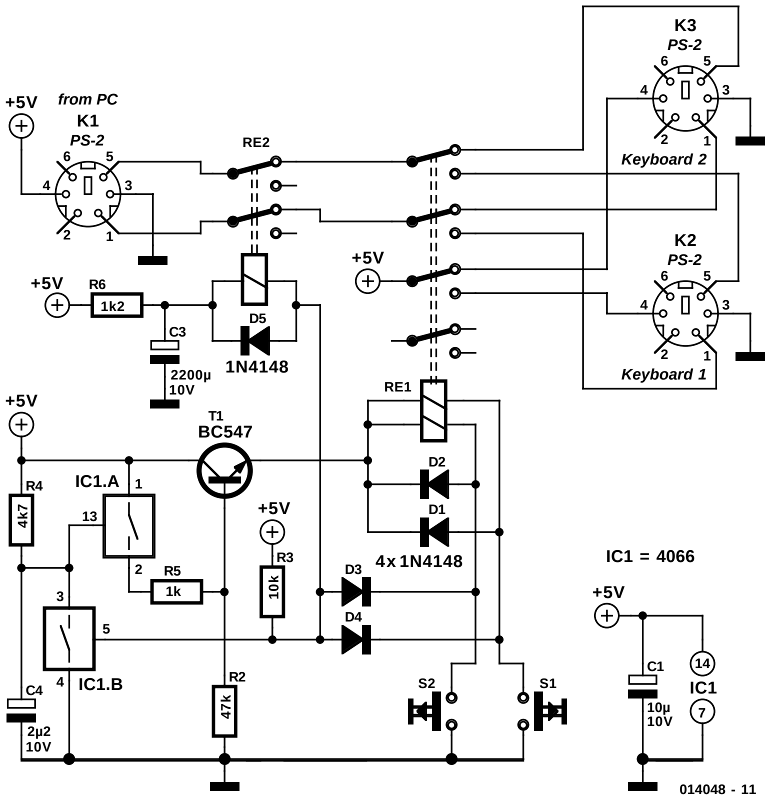
Unplugging or re-connecting equipment to the serial COM or PS2 connector always gives problems if the PC is running. Even if you only need to swap a mouse or changeover from a graphics keyboard to a standard keyboard. The chances are that the connected equipment will not communicate with the PC, it will always be necessary to re-boot. If you are really unlucky you may have damaged the PC or the peripheral device.

In order to switch equipment successfully it is necessary to follow a sequence. The clock and data lines need to be disconnected from the device before the power line is removed. And likewise the power line must be connected first to the new device before the clock and data lines are re-connected. This sequence is also used by the USB connector but achieved rather more simply by using different length pins in the connector.

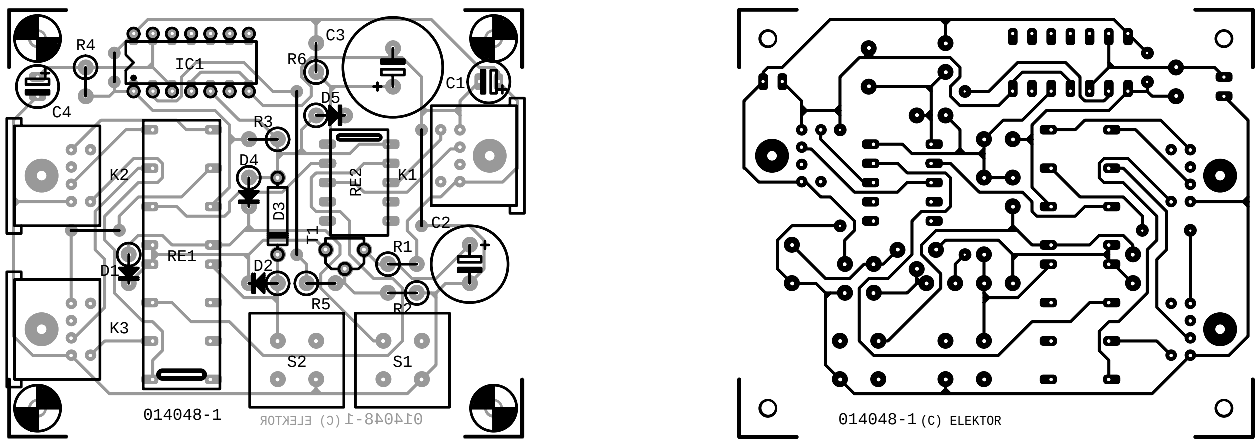
The circuit shown here in **Figure 1** performs the switching sequence electronically. The clock and data lines from the PC are connected via the N.C. contacts of relay RE2 through the bistable relay RE1 to connector K3. Pressing pushbutton S1 will activate relay RE2 thereby disconnecting the data and clock lines also while S1 is held down the semiconductor switch IC1B will be opened, allowing the voltage on C4 to charge up through R4. After approximately 0.2 s the voltage level on C4 will be high enough to switch on IC1A, this in turn will switch on T1 energising one of the coils of the bistable relay RE1 and routing the clock, data and power to connector K2. When S1 is released relay RE2 will switch the data and clock lines through to the PC via connector K1. It should be noted that the pushbutton must be pressed for about 0.5 s otherwise the circuit will not operate correctly. Switching back over to connector K3 is achieved similarly by pressing S2.

The current required to switch the relays is relatively large for the serial interface to cope with so the energy

1



2



COMPONENTS LIST

Resistors:
R1 = 2kΩ2
R2 = 47kΩ
R3 = 10kΩ
R4 = 4kΩ7
R5 = 1kΩ
R6 = 1kΩ2

Capacitors:
C1 = 10µF 10V radial
C2 = 1000µF 10V radial
C3 = 2200µF 10V radial
C4 = 2µF2 10V radial

Semiconductors:
D1-D5 = 1N4148
T1 = BC547
IC1 = 4066 or 74HCT4066

Miscellaneous:
RE1 = bistable relay 4 c/o contacts (Takamisawa, Conrad Electronics #502936)
RE2 = monostable relay 2 c/o contacts (Takamisawa, Conrad Electronics #504700)
K1,K2,K3 = 6-way Mini-DIN socket (pins at 240°, PCB mount
S1,S2 = pushbutton (ITT D6-R)

necessary is stored in two relatively large capacitors (C2 and C3) and these are charged through resistors R1 and R6 respectively. The disadvantage is that the circuit needs approximately 0.5 minute between switchovers to ensure these capacitors have sufficient charge. The current consumption of the entire circuit however is reduced to just a few milliamps.

The PCB layout and component placement is shown in **Figure 2** and is also available from the *Elektor Electronics* website. The PCB is designed to accept PS2 style connectors but if you are using an older PC that needs 9 pin sub D connectors then these will need to be connected to the PCB via flying leads. In this case the mouse driver software configures pin 9 as the clock, pin 1 as the data, pin 8 (CTS) as the voltage supply pin and pin 5 as earth.

(014048-1)

LED–LDR Blinker

069

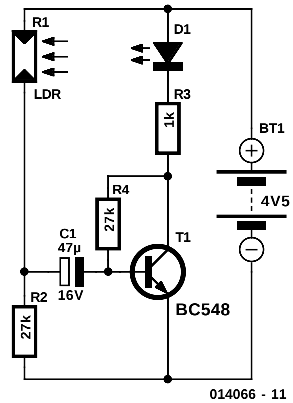
B. Kainka

It normally takes two transistors to build a blinker circuit (in order to make positive feedback possible). However, you can also use a photoresistor (LDR) that is illuminated by an LED. The feedback takes place here by means of light rays.

The circuit is easy to understand. When light falls on the LDR, the current increases. The capacitor then charges, and this increases the base current. This causes the transistor to switch the LED fully on. The stable 'on' state switches to the 'off' state as soon as the capacitor is fully charged. The LED is then completely off, the base voltage goes negative and the transistor is cut off. The circuit cannot switch back to the 'on' state until the capacitor has been discharged via the base resistor.

The circuit naturally reacts to external light sources as well. You will have to test it in different light environments to see whether it will work. In any case, it will not work in full sunlight. With an ultrabright LED and a very low-resistance LDR, it might be possible to build a blinker without using a transistor. The combination of the LED and the LDR would have to provide the gain that is needed to produce oscillations.

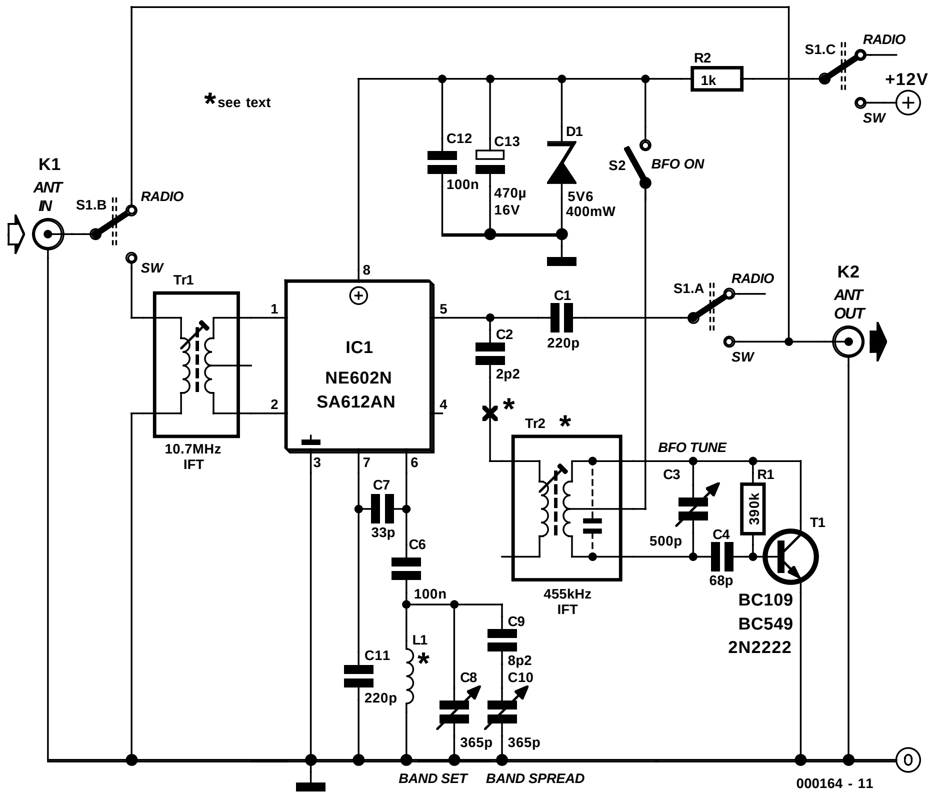
(014066-1)



SW Converter for Digital AM Car Radio

070

P. Laughton, VK2XAN



This circuit is purposely presented with many loose ends (not literally, of course) to stimulate experimenting with RF circuitry at a small outlay.

Looking at the circuit diagram you may recognize a modified version of the SW Converter for AM Radios described elsewhere in this issue. The modifications were necessary to make the circuit compatible with a digital rather than analogue AM car radio. The main difference between digital AM radios and their all-analogue predecessors is that tuning is in 9 kHz (sometimes 4.5 kHz steps) in compliance with the international frequency allocation for the band. Obviously, that particular step size, desirable as it may be on MW, is a stumbling block if you want to use a digital AM receiver in combination with a frequency step-up converter for SW, where chaos reigns and there is no fixed step size.

The first attempt was to make the crystal oscillator variable by about 5 kHz each way. Unfortunately, despite serious efforts, the crystal could not be pulled more than 1 or 2 kHz so another solution had to be found.
After studying the NE/SA602/612 datasheet, it was found that a variable LC based oscillator was the best alternative. The circuit worked after winding a resonant LC circuit and adding a 0.1 µF series capacitor to block the DC component on pin 6 of the NE602 (612). When the tuning was found to be a bit sharp with the original capacitor, a simple bandspread (or fine tuning) feature was added by shunting the LC resonant circuit with a lightly loaded 365 pF tuning capacitor (C10) which, like the main tuning counterpart, C8, was ratted from an old transistor radio.

The tuning coil, L1, consists of 8 to 10 turns of 0.6-0.8mm dia. enamelled copper wire (ECW) on a 6-8 mm dia. former without a core. With this coil, frequency coverage will be from about 4 MHz to 12 MHz or so.

Details on Tr1 may be found in the referring article. Note that no tuning capacitor is used on the secondary — the input stray capacitance of the NE602 (612) does the trick.

A BFO (beat frequency oscillator) was added to enable SSB (single sideband) signals to be received. The BFO built around T1 is simple, has a heap of output and is stable enough to hold an SSB signal for a few minutes without adjustment. The BFO frequency is tuned with C3. Tr2 is a ready-made 455 kHz IF transformer whose internal capacitor was first crushed and then removed with pliers. When S2 is closed the BFO output signal is simply superimposed on the NE602 (612) IF output to the MW radio.

The converter should be built into a metal box for shielding. If you find that the BFO gives too much output, disconnect it as suggested in the circuit diagram and let stray coupling do the work.

Sensitivity, even on a 1-metre length of car radio aerial, is quite amazing. Bearing in mind that most of the major international SW broadcasting stations like Radio NHK Japan, Moscow, BBC etc.) generate enough power to make sure that you will hear them, it is still quite exciting to hear such signals for the first time on your car radio.

(000164-1)

Keypad Encoder IC with Serial Output

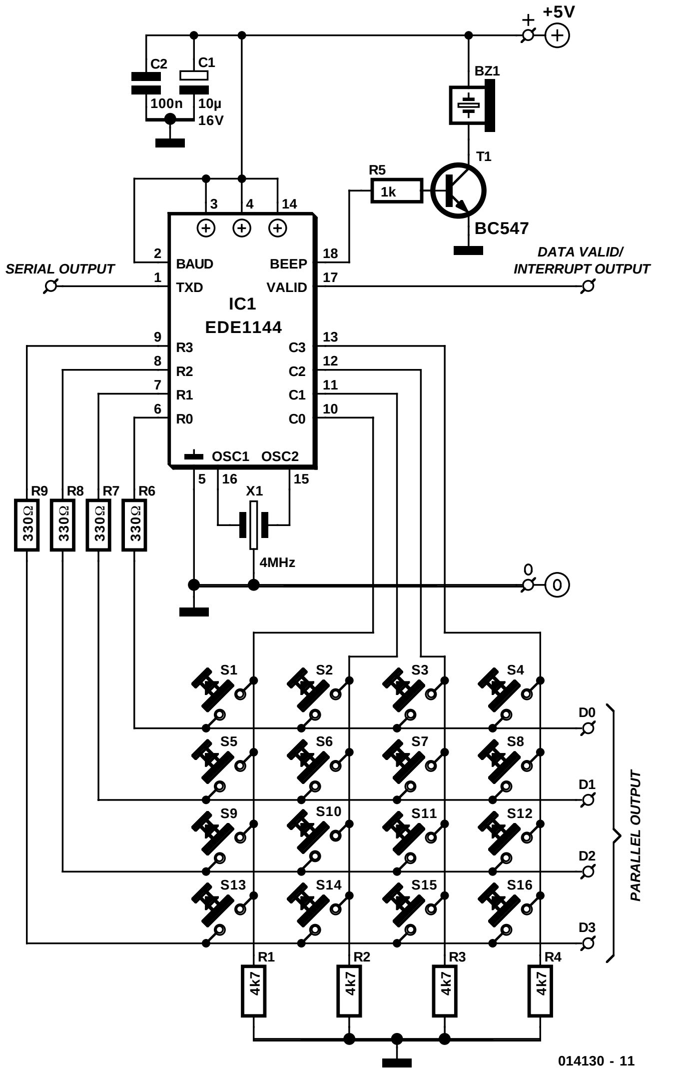
071

Source: E•Lab Digital Engineering Inc.

The EDE1144 Keypad Encoder IC from E•Lab Digital Engineering (www.elabinc.com) is designed to interface a matrix-type 4 row × 4 column (16-key or less) keypad to a microcontroller or other host processor. A 1-wire serial or 4-wire parallel interface returns the keypress data and can be used in conjunction with a 'data valid' signal for polled or interrupt-driven applications. The EDE1144 provides enhanced keypad features such as contact debouncing and key auto-repeat in an easy-to-use package that will lower software overhead in the host microcontroller and reduce the I/O pin requirements from eight to one, frequently resulting in the use of a less costly host microcontroller in your design.

In addition, the EDE1144 is electrically quiet. Many keypad encoders continually scan the keypad, radiating EMI noise from the wires leading to the keypad (resulting in trouble during emissions testing & final product certification & approval). The EDE1144 reduces this problem by monitoring the keypad with unchanging signals, and then scanning only once each time a keypress is detected.

The **schematic** shows the standard application circuit with the EDE1144 residing between the keypad and host microcontroller/ processor. The host microcontroller receives keypress data via either the four parallel data outputs (D0-D3, Pins 6-9) or the Serial Data Output (Pin 1). The Data Valid signal (Pin 17) is activated upon keypress (and upon each key repeat cycle if key is held). The Data Valid signal is activated prior to transmission of the serial data to allow polled (software-UART) style host serial systems such as the BASIC Stamp™ or a microcontroller without a hardware UART to enter the serial receive routine and receive the keypress data without needing to continually wait for the start bit. Note that the data outputs to the host microcontroller reside on the row output pins (Pins 6-9), therefore parallel-output data should only be read while the Data Valid (Pin 17) signal is active (Low). Upon power-up, the four data output pins will be high, and will remain high except when a key is pressed.



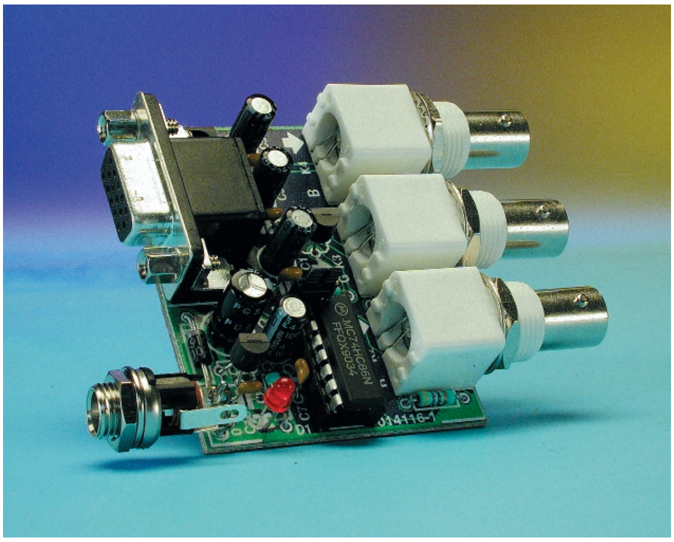
The **table** illustrates the data values returned by the serial and parallel outputs of the EDE144 upon each keypress. Note that the serial values are increased (by hexadecimal 30 ($30) for 0-9 and hex $37 for 10-15) to correspond to the ASCII equivalent (0-9, A-F) of the BCD (binary-coded decimal) value on the parallel outputs.

(014130-1)

Key	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
RS232:	$30 ('0')	$31 ('1')	$32 ('2')	$33 ('3')	$34 ('4')	$35 ('5')	$36 ('6')	$37 ('7')
D3-D0:	0000	0001	0010	0011	0100	0101	0110	0111
Key	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
RS232:	$38 ('8')	$39 ('9')	$41 ('A')	$42 ('B')	$43 ('C')	$44 ('D')	$45 ('E')	$46 ('8')
D3-D0:	1000	1001	1010	1011	1100	1101	1110	1111

VGA-to-BNC Adapter

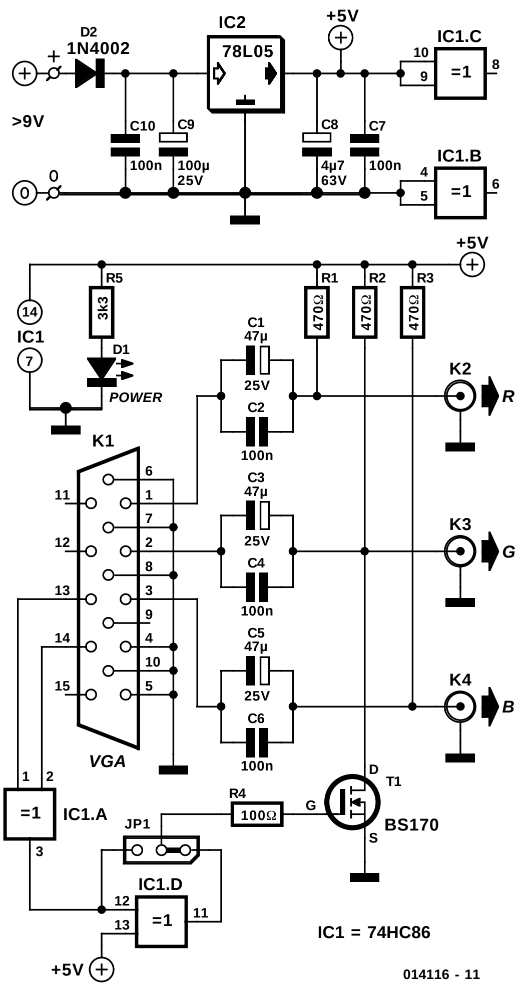
072

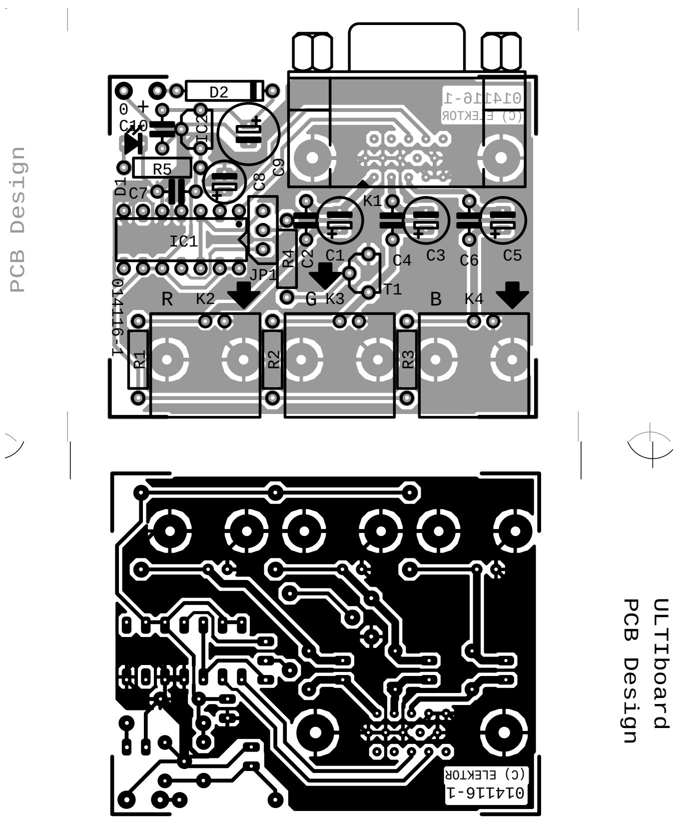


There are monitors which only have three BNC inputs and which use composite synchronisation (‘sync on green’). This circuit has been designed with these types of monitor in mind. As can be seen, the circuit has been kept very simple, but it still gives a reasonable performance.

The principle of operation is very straightforward. The RGB signals from the VGA connector are fed to three BNC connectors via AC-coupling capacitors. These have been added to stop any direct current from entering the VGA card. A pull-up resistor on the green output provides a DC offset, while a transistor (a BS170 MOSFET) can switch this output to ground. It is possible to get synchronisation problems when the display is extremely bright, with a maximum green component. In this case the value of R2 should be reduced a little, but this has the side effect that the brightness noticeably decreases and the load on the graphics card increases. To keep the colour balance the same, the resistors for the other two colours (R1 en R3) have to be changed to the same value as R2.

An EXOR gate from IC1 (74HC86) combines the separate V-sync and H-sync signals into a composite sync signal. Since the sync in DOS-modes is often inverted compared to the modes commonly used by Windows, the output of IC1a is inverted by IC1b. JP1 can then by used to select the correct operating mode. This jumper can be replaced by a small two-way switch, if required. This switch should be mounted directly onto the PCB, as any connecting wires will cause a lot of interference.





The PCB has been kept as compact as possible, so the circuit can be mounted in a small metal (earthed!) enclosure. With a monitor connected the current consumption will be in the region of 30 mA. A 78L05 voltage regulator provides a stable 5 V, making it possible to use any type of mains adapter, as long as it supplies at least 9 V. Diode D2 provides protection against a reverse polarity. LED D1 indicates when the supply is present. The circuit should be powered up before connecting it to an active VGA output, as otherwise the sync signals will feed the circuit via the internal protection diodes of IC1, which can be noticed by a dimly lit LED. This is something best avoided.

(014116-1)

COMPONENTS LIST

Resistors:

R1,R2,R3 = 470Ω
R4 = 100Ω
R5 = 3kΩ3

Capacitors:

C1,C3,C5 = 47µF 25V radial
C2,C4,C6,C7,C10 = 100nF ceramic
C8 = 4µF7 63V radial
C9 = 100µF 25V radial

Semiconductors:

D1 = LED, high-efficiency
D2 = 1N4002
T1 = BS170
IC1 = 74HC86
IC2 = 78L05

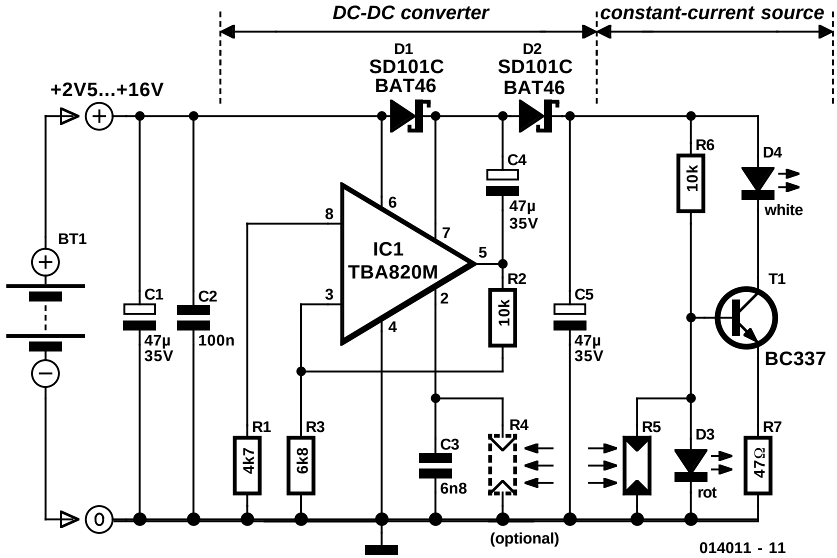
Miscellaneous:

JP1 = 3-way pinheader with jumper
K1 = 15-way VGA socket (female), PCB mount (angled pins)
K2,K3,K4 = BNC socket (female), PCB mount, 75 Ω

Battery Juicer

073

W. Zeiller



More and more electronic devices are portable and run off batteries. It is no surprise, then, that so many flat batteries find their way into the bin — and often far too early. When a set of batteries can no longer run some device — for example, a flashgun - the cells are not necessarily completely discharged. If you put an apparently unserviceable AA-size cell into a radio-controlled clock with an LCD display it will run for months if not years.

Of course not every partially discharged cell can be put in a clock. The circuit presented here lets you squeeze the last Watt-second out of your batteries, providing a bright 'night light' — for free!

The circuit features a TBA820M, a cheap audio power amplifier capable of operating from a very low supply voltage. Here it is connected as an astable multivibrator running at a frequency of around 13 kHz. Together with the two diodes and electrolytic capacitor this forms a DC-DC converter which can almost double the voltage from between four and eight series-connected AA-, C- or D-size cells, or from a PP3-style battery.

The DC-DC converter is followed by a constant current source which drives the LED. This protects the expensive white LED: the voltages obtained from old batteries can vary considerably. With the use of the DC-DC converter and 20 mA constant current source a much greater range of usable input voltages is achieved, particularly helpful at the lower end of the range when old batteries are used. With the constant current source on its own the white LED would not be adequately bright when run from low voltages.

An additional feature is the 'automatic eye'. The LDR detects when the normal room lighting is switched on or when the room is lit by sunlight: its resistance decreases. This reduces the U_{BE} of the transistor below 0.7 V, the BC337 turns off and deactivates the LED. This prolongs further the life of the old batteries. A further LDR across capacitor C reduces the quiescent current of the circuit to just 4 mA (at 4 V). Light from the white LED must of course not fall on the LDR, or the current saving function will not work.

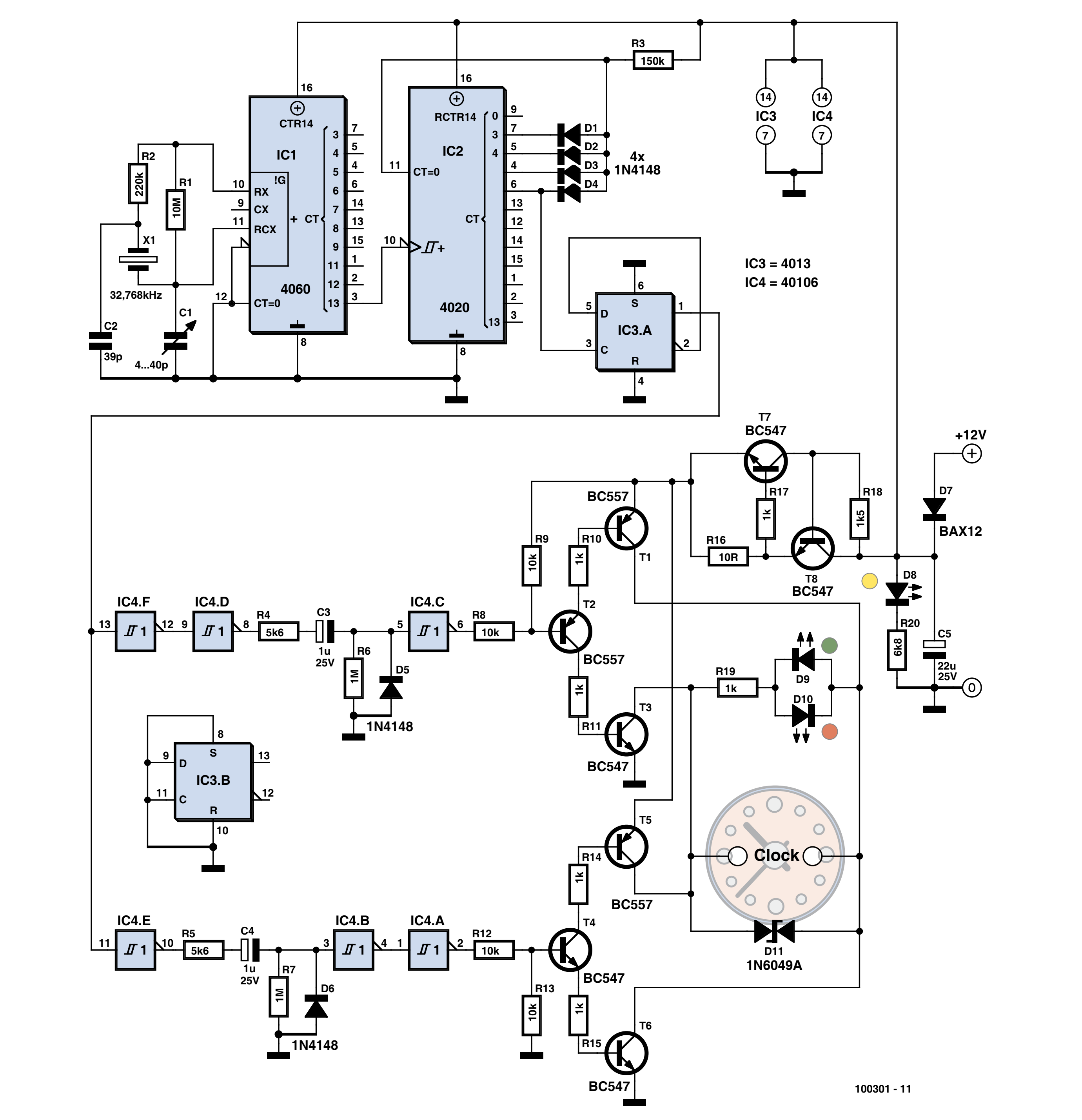
(014011-1)

Clock Pulse Generator

Ed Flier (The Netherlands)

For many years the author has been approached by people who have managed to lay hands on an ‘antique’ electric clock and need an alternating polarity pulse driver. This is immediately followed by the question whether an affordable circuit for this is available. The design described here has been working very nicely for years in three of the author’s clocks. To keep the circuit simple and thus inexpensive, the author dispensed with automatic adjustment for summer and winter time.

A 32.768 kHz oscillator is built around IC1. X1 is a crystal of the type that can be found in almost every digital watch, especially the cheaper ones. The frequency can be adjusted with trimmer C1 if necessary.
The clock signal is divided by IC1 and IC2 to obtain a signal on CT=6 (pin 6) of IC2 with a frequency of one pulse per minute. IC3.A is wired as a divide-by-2 circuit to maintain a constant signal during each 1-minute period. IC4.E and IC4.F buffer this signal, and IC4.D inverts the output of IC4.F.
When CT=6 of IC2 goes high, IC3.A receives a clock pulse and its Q output goes High. IC4.F and IC4.D then charge C3 via R6 (1 MΩ), and the output of IC4.C remains low for approxi-



mately 1 second. This drives T2 into conduction, and with it T1 and T3. The resulting current through the clock coil causes the green LED to light up. When CT=6 of IC2 goes high again after 1 minute, IC3.A receives a new clock pulse and its Q output goes Low. Now C4 is charged by IC4.E via R7 and the output of IC4.B is low for approximately 1 second, so the output of IC4.A is logic High. This drives T4 into conduction, and with it T5 and T6. The resulting current through the clock coil causes the red LED to light up. In this way the clock is driven by pulses with alternating polarity.

Diode D7 protects the circuit against reverse-polarity connection of the supply voltage. Diode D8 is lit constantly when the supply voltage is present. Transistors T7 and T8 provide current limiting if a short circuit occurs in the clock mechanism. The peak pulse current can be increased by reducing the value of R16 (minimum value 2.2 Ω). Diode D11 is a dual suppressor diode that clips any voltage spikes that may occur. This diode is fairly expensive, so it was omitted in the circuits actually built. This has not led to any problems up to now, but it may be advisable with heavy-duty clocks or multi-pulse clocks.

Note: this circuit is only suitable for pulse-driven clocks that operate at 12 V. The circuit must be modified for models that operate at 24, 48 or 60 V. As these models are less common, or in many cases can be converted to 12 V operation, this option is not described here.

(100301-I)

Simple RF Noise Source

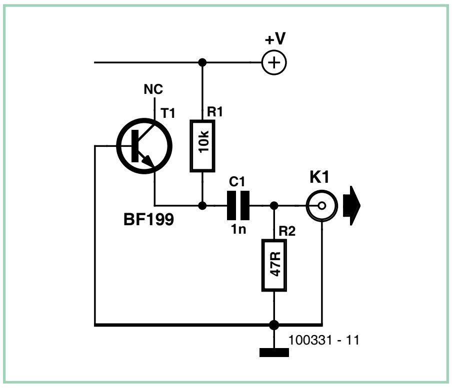
By Fred Brand (Netherlands)

A noise generator with a wideband output signal is always handy to have around when you're adjusting receivers and other types of HF equipment.

The noise generator circuit described here uses the base–emitter junction of a transistor (in this case a BF199) operating under reverse bias. As a result, it acts as a Zener diode and generates a wideband noise signal. The noise signal passes through a 1-nF capacitor to the output connector (female BNC), which means that its low-frequency components do not appear at the output. The 47-Ω resistor gives the noise generator an output impedance of nearly 50 Ω.

You can easily fit the entire noise generator in a small metal enclosure equipped with a BNC connector. The supply voltage is not critical; anything in the range of 8 to 15 V will do.

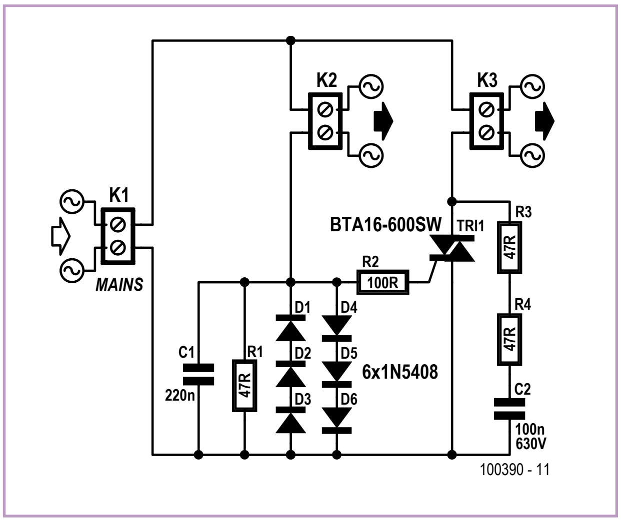
(100331-I)



Intelligent AC Power Bar

Ton Giesberts (Elektor Labs)

This circuit is a modified version of the circuit found at [1]. The purpose of the circuit is to ensure that AC power is not supplied to devices connected to K3 unless the device connected to K2 is drawing sufficient power.



Six power diodes connected in series with the load plugged into to K2 generate a voltage drop of approximately 2 V if the load is switched on. This voltage drives a triac, which in turn supplies power to the load plugged into K3.

Capacitor C1 reduces the sensitivity of the circuit to spikes. To avoid premature switching due to power drawn by an AC line filter, stand-by operation or the like, R1 can be used to raise the threshold level. It will be approximately 10 watts with a 47 Ω resistor, but this is strongly dependent on the characteristics of the triac and the waveform of the load current. If the current is not sinusoidal or R1 is too small, the triac will trigger later and may not be able to supply sufficient power to K3, in which case the circuit will act as a sort of dimmer.

Be careful when modifying the value of R1. Remember that the entire circuit is at AC line potential. Unplug everything before working on the circuit.

The combination of C2, R3 and R4 forms a snubber network that suppresses switching spikes, such as are produced by inductive loads.

We selected an ST triac that can handle more current than the TIC225 used in the original circuit, but which still has a reasonably low trigger current. The BTA16-600SW is rated for 16 A continuous or 160 A peak. Here the suffix 'SW' is especially significant. This is what is called a 'logic level' triac, with a maximum trigger current requirement of only 10 mA, symmetric

in quadrants I and III. This is not true of the TIC225. If the trigger sensitivity is not the same in both quadrants and the trigger conditions are marginal, the triac may trigger in only one quadrant. This results in rectification, which most equipment cannot handle. At minimum this will cause fuses to blow.
The resistance of the snubber network consists of two resistors connected in series (R3 and R4). Standard resistors are often not suitable for use at AC grid voltages. Over the longer term, spikes can also cause resistor failure, which leads to triac failure.

Pay attention to the maximum load current. The triac can handle around 1 A without cooling, but at this level it is actually too hot already. Fit a small heat sink if the current through the triac will be more than 0.5 A. The maximum allowable triac junction temperature is 125 °C, but in practice it's better to work on the basis of 70 °C, since high temperatures shorten the life of semiconductor devices.
The circuit is very compact and can probably be built into the power distribution bar.

(100390-I)

[1] www.electronicsweekly.com/blogs/gadget-freak/2008/09/flavio-plugs-into-smart-extens.html

Crystal Tester

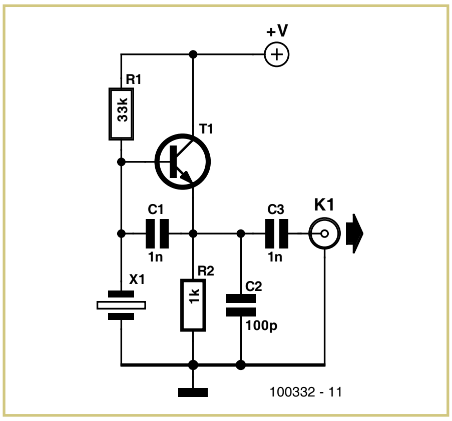
Fred Brand (The Netherlands)

This crystal tester is very straightforward. Fitting a crystal or switching on the supply voltage generates a 'start pulse' resulting from the fact that the crystal briefly pulls the voltage on the base of T1 low. This directly affects the operating point of the transistor via feedback capacitor C1, with the result that the transistor starts oscillating.

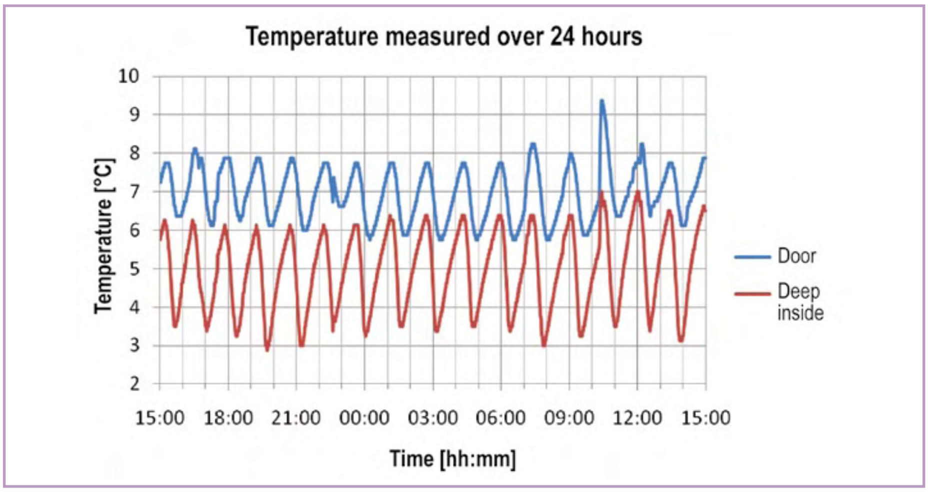
Resistor R2 limits the maximum operating current of the transistor. A 100-pF capacitor (C2) is connected in parallel with R2 for decoupling, and capacitor C3 is used to prevent the DC voltage on the emitter from appearing at the output.
An AC signal will therefore be present at the output if the crystal is OK. You can put together your own indicator circuit to make this visible, such as an HF probe connected to a meter or a transistor with an LED.

Another tip: if you connect two LEDs in reverse parallel in series with the ground lead of the crystal, they will both light up when the crystal oscillates.

(100332-I)



Temperature Logger for the Fridge



Fons Janssen (The Netherlands)

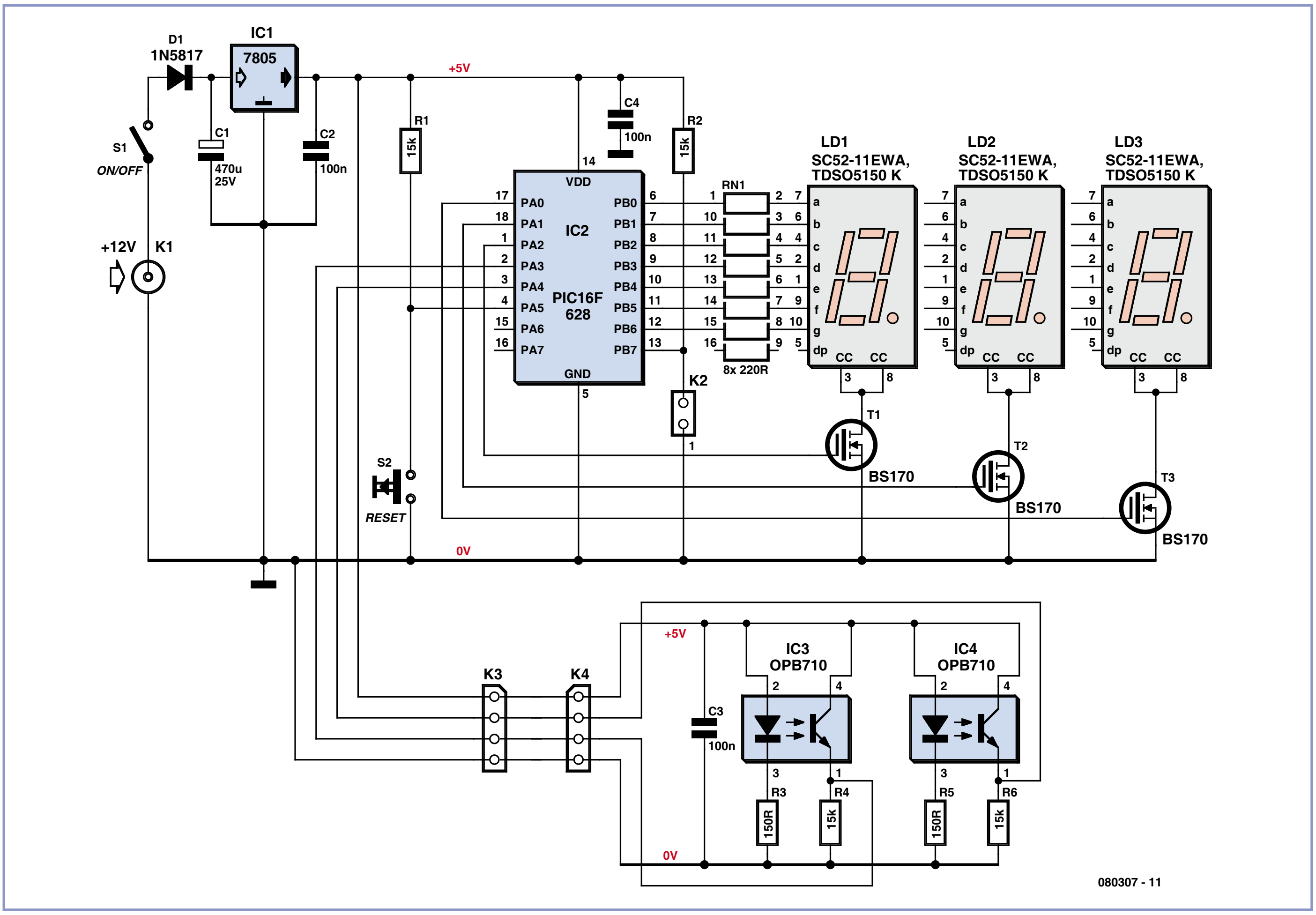
Most National Health Departments and Councils seem to agree that the recommended fridge temperature should be between 2 °C and 7 °C (35 °F to 44 °F). The lower the temperature, the slower the growth of bacteria and the longer perishable foods will keep fresh. You can check the temperature with an ordinary thermometer, but that only tells you what the temperature is at that particular time. But what happens to the temperature during the whole day?

To get a good idea of the temperature over a period of time the DS1921Z made by Maxim comes in very handy. It is an autonomous temperature logger in an iButton package [1]. This is a strong metal button the size of about four small coins put on top of one another. The DS1921Z has an internal temperature sensor (range: –5 °C to +26 °C, accuracy: ±1 °C), 4 Kbit memory, a real-time clock and a battery, which lasts between 2 and 10 years, depending on the log frequency. The iButton can log temperatures at a rate between once per minute up to once every 255 minutes. The memory has room for 2048 values, which means it's possible to store a measurement every minute for a full day (24×60=1440). The (free) 1-Wire viewer software makes it a piece of cake to configure the iButton and to read the results after the measurements are complete. Apart from the iButton you also need a USB dongle (the DS9490 made by Maxim) to connect the iButton to the PC.

In the graph you can see the result of the measurements during a 24-hour period, where one iButton was placed in the door and another at the back of the bottom shelf. It is clear that there is a temperature variation of about 2 to 3 °C in both places as a result of the thermostat in the fridge. According to the advice of the Health Department the door wouldn't really be cold enough to store perishable items in this case, whereas it would be safe to store them at the back of the bottom shelf.

(091091)

Daggerboard Position Detector



Hermann Sprenger (Germany)

In sailing regattas it's handy to have a daggerboard that can be raised and lowered vertically. As the winding handle or positioning motor needs to rotate the spindle of the lifting device some 100 to 150 times throughout its full range it would be extremely handy to have a quick idea of its current position. An electronic count of the number of revolutions would be ideal. Thank goodness most sailors now have a 12-V supply available!

To get this to work you need to apply white and black markings to the spindle, each covering half of the circumference. Next, mask off two electric eye devices (reflected light sensors) next to one another (approximately 10 mm apart). For secure detection both sensors should be positioned not more than 5 mm from the paint markings.

The markings to be read by the sensor should be displaced laterally, so that the direction of rotation can be recognized in addition to the number of revolutions counted.

At the heart of our circuit is a PIC16F628 from Microchip, which as usual can be bought ready programmed from Elektor or you can do this bit yourself by downloading free firmware (for details of both see [1]).

At pins 1 of the two reflected light sensors IC3 and IC4 we need to 'see' more than 2.0 V from the white segment and less than 0.8 V from the black mark (with an operating voltage between 4.5 and 5.5 V). The two signals detected are taken to plug connector along with the operating voltage and ground. It's convenient if you also provide a connector from the microcontroller as well, so that the sensor and the controller board can be linked by a test lead.

The multiplexing of the three seven-segment displays is programmed at a rate of 100 Hz. Acceptable values for the revolution count are between 0 and 140. If the count exceeds or falls below these limits, then the counter is not incremented. The RESET key S2 sets the counter back to zero. Jumper K2 enables you to reverse the direction of counting. The count is retained if the operating voltage is removed and is loaded again when next powered up.

The source code can also be downloaded from the website mentioned above, making it possible (for instance) to define alternative counter limit values (the maximum value is defined in the line #define max 140). For compiling the code you can use the CC5X compiler, of which there is a free version (www.bknd.com/cc5x).

(080307)

[1] www.elektor.com/080307

Ground-free DVM Module Supply from 5 V

Heinz Kutzer (Germany)

The majority of hand-held digital volt meters use an LCD screen and are powered from a nine volt battery. Inside is most probably an ICL7106 chip (or something compatible). This takes care of measuring the input and driving the LCD. This IC is very popular and can be found in other laboratory and homebrew equipment where it offers a simple solution for both measuring current/voltage and driving the display. So far so good, there is however one feature of this device which needs careful consideration. The power supply to the chip (both the positive and negative connection) must not have any direct connection to either of the two measuring input terminals. It requires floating supplies. This is not a problem for battery powered equipment but needs more thought when the ICL7106 is fitted into AC line powered equipment.

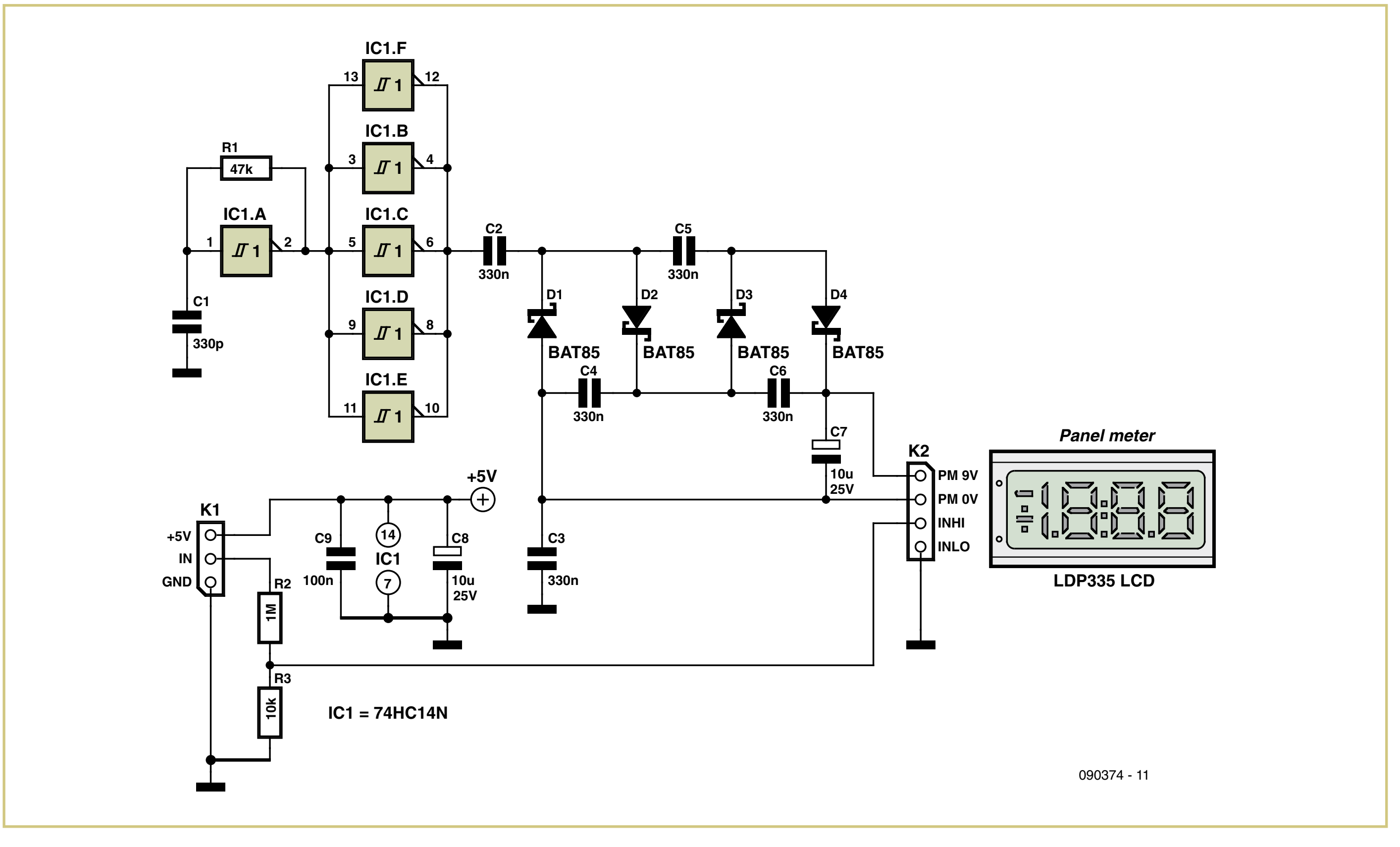
The simplest, most expensive solution is to use two independent power supplies in the equipment. A battery could also be used as an isolated supply but in an AC powered device it would seem a bit out of place and inconvenient.

In this case the term 'floating supplies' means that it is possible to have two separate DC levels. This level of isolation can be achieved with capacitors to separate the two DC supplies. Back in 2003 we published a circuit in the July/August edition of Elektor (circuit number 75) which used a NE555 IC. Unfortunately this design required a supply voltage upwards of 10 V. If the DVM module is fitted to equipment which only uses a 5 V supply (as is often the case) the circuit will not be of much use. The author has solved the problem by modifying the original circuit, using a hex Schmitt trigger inverter type 74HC14N instead of the NE555. One of the inverters generates a square wave of about 75 KHz. The remaining five inverters are wired in parallel to provide more output drive current for the voltage multiplier stage.

DC isolation is provided by capacitors C2 and C3. A classic voltage multiplier configuration is made up of capacitors and diodes. The circuit generates an output of around 8.5 V at a load current of 1 mA. This is sufficient to power the DVM chip. The 5 V supply for the circuit must be stabilized.

The values of the input voltage divider resistors R2 and R3 are independent of the chip's power supply and must be selected according to the desired measurement range.

(090374)

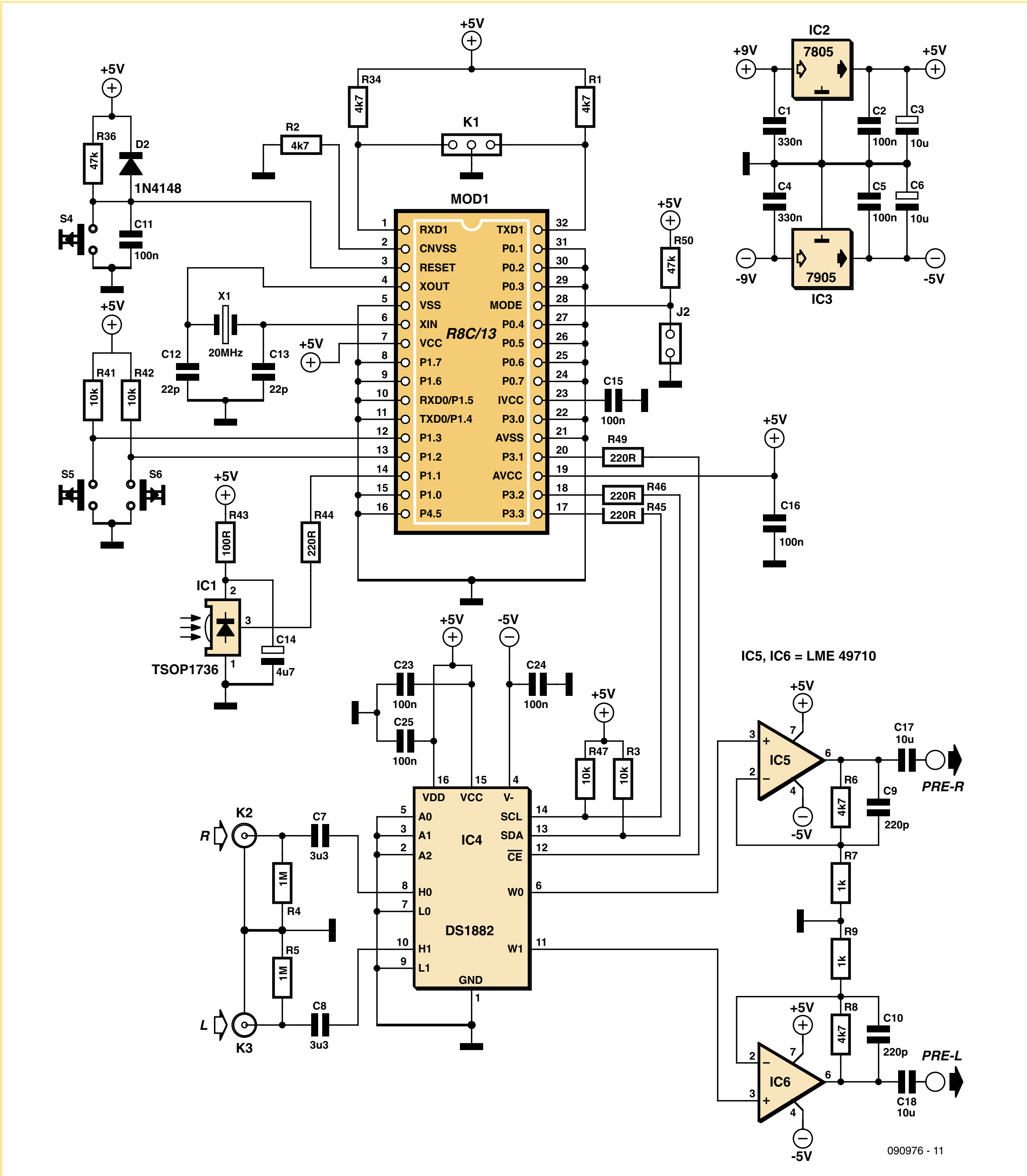


Remote-controlled Preamp with Digital Pot

Michael Hoelzl (Germany)

This circuit is a simple but high-quality preamplifier using a DS1882 digital potentiometer, a device specially designed for audio applications. The potentiometer is controlled over an I²C interface by an R8C/13 microcontroller. The main features of the design are its remote control and lack of moving parts.

The circuit is controlled by two buttons (volume up and volume down) and an infrared receiver connected to the microcontroller. The software in the microcontroller, written in C, is designed to interpret RC5 codes and supports the following commands:



- volume up;
- volume down;
- mute.

Other commands could of course be added. The audio signal arrives via phono sockets and is taken to the digital potentiometer via coupling capacitors. The potentiometers are configured as voltage dividers with an overall resistance of 45 kΩ. The wiper position is adjusted over the I^{2}C interface.

At the output of the potentiometers there are two operational amplifiers in non-inverting configuration to buffer the high-impedance attenuated signal. They provide a gain of 5.7. The capacitors in the feedback network are dimensioned to provide a signal bandwidth of around 150 kHz with unloaded output.

The value of the output coupling capacitors depends on the input impedance R_{in} of the following power amplifier stage. As a rule of thumb a value of $C=1/(100R_{in})$ is suitable, and so the value of 10 µF shown in the circuit diagram is easily large enough in most cases.

In some situations it is useful to connect the outputs to ground via high-value resistors to provide a definite DC level.

The ±5 V supply voltages for the opamps and the DS1882 are decoupled using 100 nF capacitors. The lower-cost NE5532 opamp can be used instead of the specified device without noticeable signal degradation. All unused pins on the microcontroller are taken to ground.

As has already been described in detail in Elektor [1], the R8C includes a serial debugging interface and boot code that allows a program to be downloaded into its flash ROM. The serial connections are brought out at K1. To connect to a PC an RS232-to-TTL level adaptor (typically incorporating a MAX232) is required; to connect via a USB port, use a USB-TTL cable [2]. TxD from the PC should be connected to RXD1 on the R8C, and RxD on the PC should be connected to TxD1 on the R8C. J2 must be fitted for programming, taking pin 28 (MODE) on the R8C to ground. Then apply power to the circuit (for a power-on reset) or press reset button S4. The program FlashSTA can be used for programming: the web pages accompanying this article [3] have this software available for free download, along with the firmware for the microcontroller.

One possibility for expansion would be to add an input selection switch, which could be implemented using an analog switch IC. The IC could also be controlled over the existing I^{2}C bus.

The structure of the RC5 remote control code has been described previously in *Elektor*: see the free 'RC5 Code' download at [4]. The protocol specifies a five-bit address for the type of device to be controlled remotely (such as a television or VCR). In the author's set-up the preamplifier was controlled using the remote control from a Hauppauge TV card, and so the firmware was configured to use the address reserved for TVs ('00000'). If a different remote control is to be used, the address in the firmware must be modified accordingly. The address appears in the file 'preamp.h' as '#define IR_DEV_ADDRESS 341', where the value 341 is the Manchester-coded form of the address '00000'. The coding procedure is relatively straightforward: with the address written in binary, convert each zero into '01' and each one into '10'. For the address '00000' this results in '0101010101'. For convenience the commands and addresses are converted into decimal, in this case giving 341.

A timer module in the R8C is used for clocking out the RC5 signal, and the whole process is kicked off using an interrupt.

It is worth noting that the infrared sensor does not work reliably if placed near to fluorescent or low-energy light bulbs, as these emit a considerable amount of light in the infrared part of the spectrum.

(090976)

[1] www.elektor.com/050179-2

[2] www.elektor.com/080213

[3] www.elektor.com/090976

[4] www.elektor.com/071149

Car Alarm Sound Booster

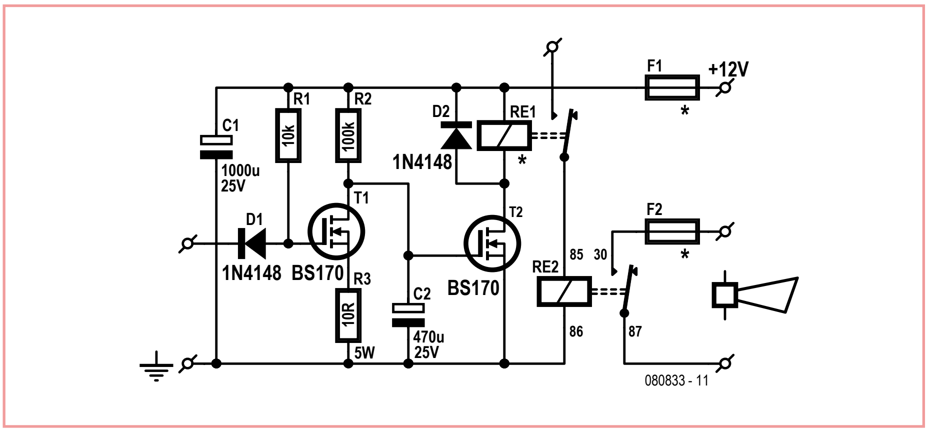
Hagay Ben-Elie (Israel)

For car alarms, emphasis should be put on hearing the audible alert and identifying it as belonging to your 'wheels'. Unfortunately, modern car alarm systems seem to have more or less the same alarm sound — especially if they are from the same brand. Also, to comply with legal noise restrictions, the alarm sound is not always loud enough to be heard if the car is parked down the road.

The circuit shown here is designed to help boost the alarm sound by also activating the car's horn(s) when the alarm goes off.

Internally the car alarm system often provides a signal that activates the (optional) engine immobilizer and/or volume (ultrasound) sensors. This signal usually goes Low upon system triggering and high again when the alarm system is deactivated.

The alarm activation signal is fed to the circuit through D1. When in idle state, T1's gate is High and consequently the FET conducts,



keeping power FET T2 firmly switched off. When the system gets an active low signal, T1 switches off allowing timing capacitor C2 to charge via R2. About 15 seconds later, when the voltage across C2 is high enough, T2 starts to conduct and relay RE1 is energized. This, in turn, provides the required path for the 'lights flashing' signal to energize RE2 and feed battery power to the car's horn(s).

When the alarm system is turned off the activation signal returns to High. T1 starts to conduct and rapidly discharges C2 via R3. T2 is then cut off and RE1 is de-energized. Diode D2 suppresses back EMF from RE1.

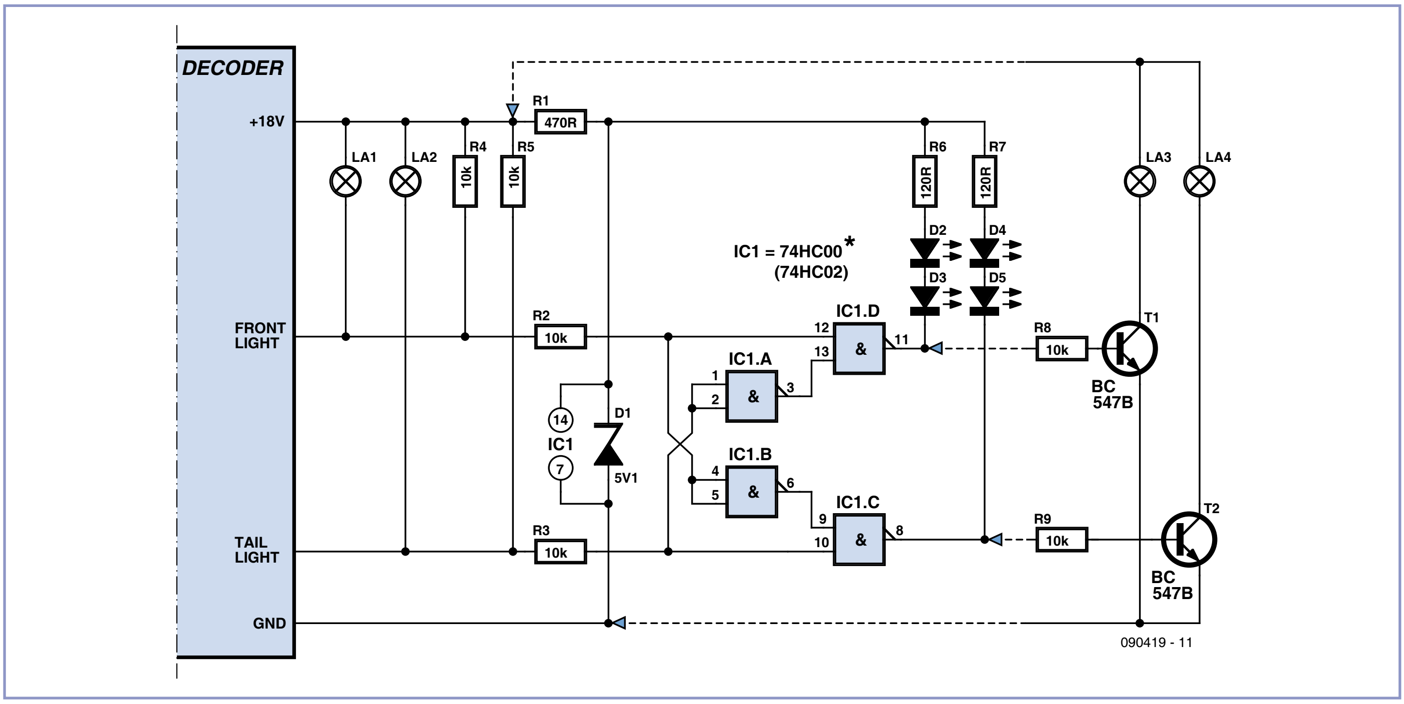
The circuit draws less than 2 mA when idling. When activated the circuit's current consumption is virtually that of the RE1 coil.
RE1 is any simple SPST or SPDT relay, capable of switching about 0.5 A (at 12 V). The coil rating is for 12 VDC and a current requirement as low as you can find. Fuse F1 should be a slow blow type and rated about twice RE1's coil current.

The BS170 in position T2 can sink a continuous current of about 0.5 A. However, a value of 1.2 A pulsed is specified by Fairchild for their devices. To keep the FET's d-s current due to C2 discharging within safe limits, R2 may be increased, C2 decreased and R3 increased, all proportionally. A factor of 2 will keep the FET out of harm's way with maybe a slight change in the 15-second delay and the sensitivity of the circuit.
C1 is used as a smoothing capacitor and F2 should be rated in accordance with the horn(s) maximum current draw.

(080833)

Caution. The installation and use of this circuit may be subject to legal restrictions in your country, state or area.

Shunting Lights for DCC Locomotives

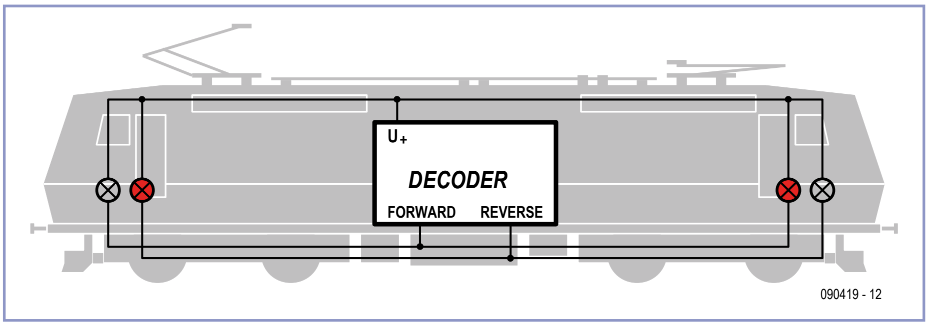


Dr Stefan Krauss (Germany)

Digital decoders in model locomotives usually have two outputs for lighting functions. One switches the front lights for forward travel, and the other for reverse travel. If the locomotive has red rear lights, they are also connected to the two outputs.

Many digital decoders include function mapping capability, which allows the switch functions to be assigned as desired. For example, with function mapping you can control the lighting not only for normal running, but also for shunting yard operations with the lights lit at both ends of the locomotive.

However, in case of model locomotives fitted with rear marker lights it is necessary to switch off the red lights for shunting operation. This can be done by connected the rear lights to their own, suitably programmed decoder outputs. Unfortunately, decoder outputs are a scarce commodity that we would rather use for other tasks, such as switchable cab lighting.



The remedy here is a simple circuit that causes the red rear lights to be disabled when both light outputs are active (on).
The circuit is inserted in the leads to the two sets of rear lights, and it essentially consists of a bit of logic circuitry formed from the four NAND gates of a 74HC00, which drive the LEDs directly. Series resistors R6 and R7 as well as R1 are dimensioned for a current of somewhat more than 10 mA. Pull-up resistors R4 and R5 can be omitted if incandescent lamps are used for the rear lights, as indicated here. However, they are necessary when LEDs are used. The combination of Zener diode D1 and resistor R1 provides a 5-V supply voltage for the logic IC.

An alternative circuit with transistors T1 and T2 for driving incandescent lamps used as rear lights is also shown here. As the transistor stages act as inverters, with this version of the circuit a 74HC02 (quad NOR) must be used for IC1 instead of a 74HC00 (quad NAND). The value of R1 can also be increased to 2.2 kΩ to reduce the power dissipation. Connect the front and rear (tail) marker lights as follows:

Locomotive front marker lights: D2 and D3 (LED version) or LA4 (incandescent lamp version).

Locomotive tail marker lights: D4 and D5 (LED version) or LA3 (incandescent lamp version).

The circuit can easily be built on a small piece of prototyping board and fitted in the locomotive. If you're an old hand with a soldering iron, we suggest using an SMD device for IC1 and making the connections with short pieces of enamelled copper wire; the entire assembly can then be packaged in a length of heat-shrink tubing.

(090419-I)

Line Input for Zoom H2

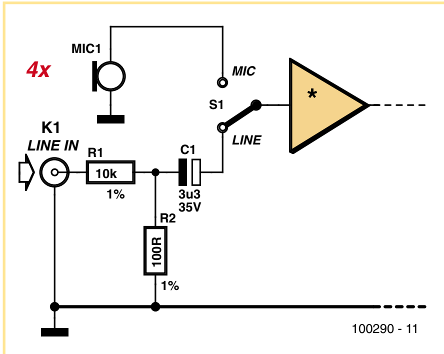
Berto Aussems (The Netherlands)

The Zoom H2 is a popular portable audio recorder. This recorder can record four tracks simultaneously, but unfortunately this only applies to the signals from the four built-in microphones.

The modification described here also lets you record four signals at line level. For this we add four phono sockets to the recorder, where the signals are attenuated by 40 dB via a resistor network. The capacitor blocks the supply voltage for the electret microphones, which would otherwise appear at the line inputs, which is obviously not desirable. Two switches are used to select either the line input or microphone as the source. A short YouTube movie [1] shows all the steps required to modify the H2.

(100290)

[1] www.youtube.com/watch?v=N1vJq13ukrk

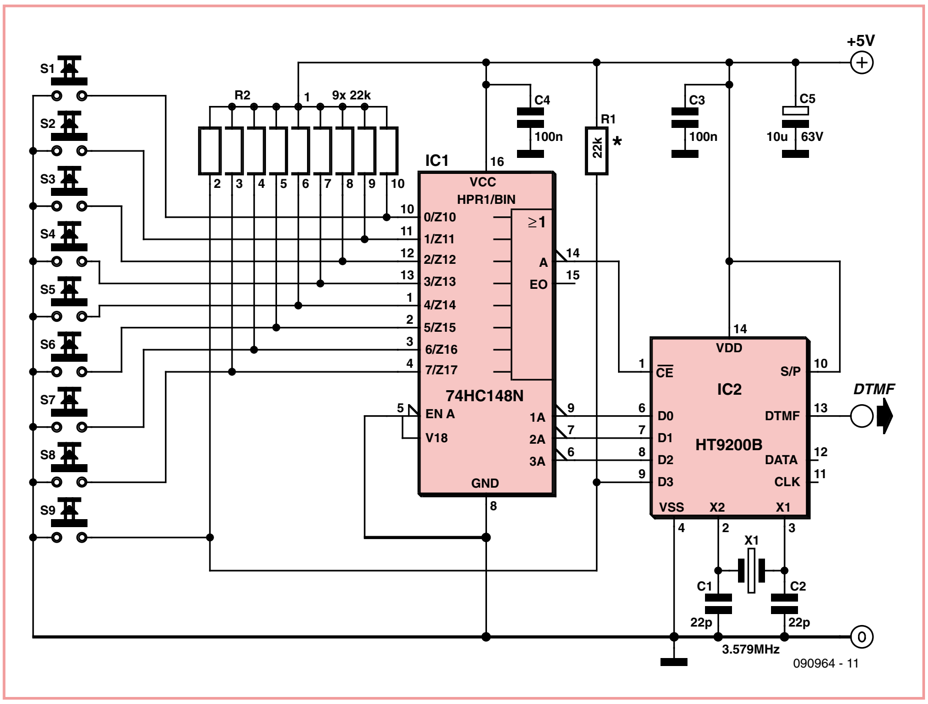


8-channel DTMF Link: Encoder

Angelo La Spina (Italy)

Generated millions of times every day by our telephone keypads, the eight DTMF frequencies were chosen so that the harmonics and intermodulation do not generate significant in-band signal levels. The signal is encoded as a pair of sine waves, ensuring that no frequency is a multiple of the other and the sum and difference between two frequencies does not match any single tone — and that's why DTMF sounds so ugly!

The DTMF encoder circuit shown here is based on the HT9200B tone generator device produced by Holtek and distributed by Futurlec (www.futurlec.com) among others. The encoder is complemented by a decoder elsewhere in this publication. The HT2900B is supplied as a nice old fashioned 14-pin device. It can be instructed by a microcontroller to generate 16 dual tones and (in serial mode only) 8 single tones from the DTMF pin output. Its 8-pin 'younger brother' the HT9200A provides a serial mode only whereas the HT9200B contains a selectable serial/parallel mode interface for various applications such as security systems, home automation, remote control through telephone lines, communication systems, etc.



A 74HC148 8-to-3 priority encoder is used to convert the 'keypad' information from S1–S8 into 3-bit tone selection words the HT9200B wants to see at its input. The ninth switch, S9, is connected to input D3 on the encoder chip. Pressing one of the switches S1–S8 generates a complementary 3-bit binary word at outputs A0, A1, A2 of IC1. IC2 then generates the dual tones accordingly to these binary codes.

Pressing S1–S8 generates the dual tones for DTMF digits C, B, A, #, *, 0, 9 and 8. By press-

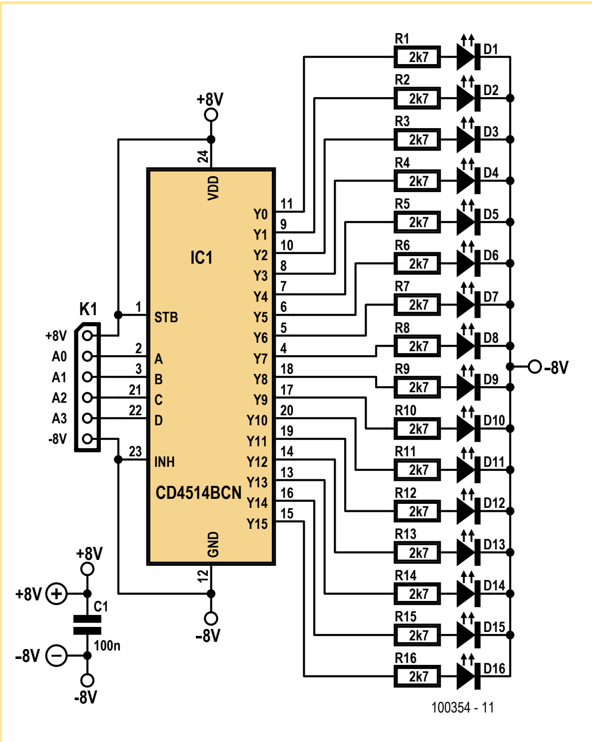
ing and holding down S9 the DTMF digits 7, 6, 5, 4, 3, 2, 1 and D are generated.
To generate the eight single frequencies accurately a 3.58 MHz crystal quartz is connected to pin 2 and 3 of IC2. Pin 13 of the HT9200B supplies a DTMF signal of about 150 mV at a 5 KΩ load.
Pull-up resistor array R2 may be omitted if you substitute the 74HC148 with a 74LS148. R1 must be present in that case, otherwise it can be omitted.
The circuit consumes about 2 mA from a regulated 5 V supply. It should be easy to build on a small piece of prototyping board.

(090964)

Indicator for Dynamic Limiter

Ton Giesberts (Elektor Labs)

The indicator described here is specifically designed for adjusting the dynamic limiter described elsewhere in this edition and checking whether the maximum level of the reference voltage (P1) needs to be modified. Here we use a 4-to-16 decoder IC (type 4514) to monitor the state of the four-bit up/down counter in the limiter circuit. This IC can be powered from the ±8 V supply voltages of the limiter. The limiter board has a 6-way connector (K5) that provides access to the four counter outputs and the supply voltages. Connector K1 of the indicator circuit can be connected to K5 on the limiter board.
One output of the 4514 goes high for each unique 4-bit combination on its inputs, while the other outputs remain logic Low. A separate current-limiting resistor is connected in series with each LED. It was not possible to use a common cathode resistor here because most LEDs have a maximum reverse blocking voltage of only 5 V, while the supply voltage here (16 V) is a good deal higher.



The 16 LEDs arranged in a row provide a ‘fluid’ indication of the control process. You can enhance the display by using different colors for the first and last LEDs, such as red for D1 (maximum gain) and green for D16 (minimum gain), with yellow for the rest of the LEDs. While observing signals from various sources (TV set, DVD, media player, etc.), you can easily use the 16 LEDS to monitor the behavior of the limiter and adjust the setting of potentiometer P1 in the limiter circuit. It must be set such that D16 only lights up at the maximum signal level. If this is not possible and D16 remains lit a good deal of the time regardless of the position of P1, it will be necessary to increase the value of P1. Of course, it is also possible to adjust P1 so the strongest signal source extends slightly above the control range of the limiter.

This circuit can easily be assembled on a small piece of prototyping board. The current consumption is around 4 mA.

(100354-I)

8-channel DTMF Link: Decoder

Angelo La Spina (Italy)

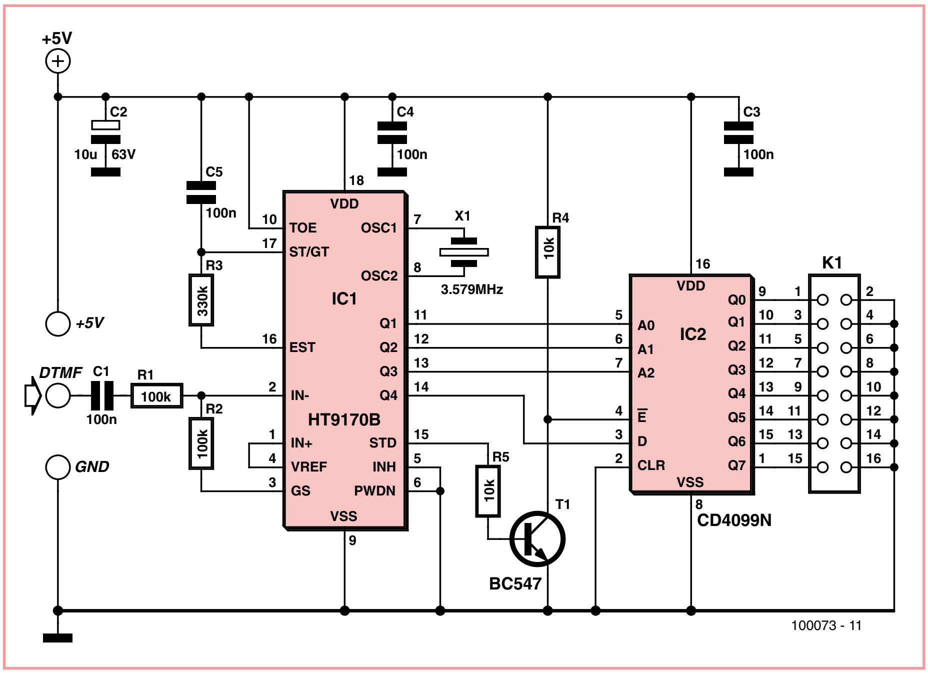
In the decoder designed for the DTMF Link project a Holtek HT9170B does the main job. The natural counterpart of the HT9200B used in the associated encoder (described elsewhere in this publication), the HT9170B is a Dual Tone Multi Frequency (DTMF) receiver with an integrated digital decoder and band-split filter functions. Then IC uses digital counting techniques by means of a 3.58 MHz crystal to detect and decode all the 16 DTMF tone pairs into 4-bit words. Highly accurate switched capacitor filters are employed to divide DTMF signals into low and high group signals. A built-in dial tone rejection circuit is provided to eliminate the need for prefiltering. The HT9170B is pin to pin equivalent to the famous (and dearer) MT8870 from Mitel. Both DTMF decoder chips can be ordered from Futulec (www.futurlec.com).
The table shows the correspondence between the frequency pairs and the 4-bits words obtained from the decoder output.

In the circuit, a CD4099 acts as an 8-bit addressable latch. Data is held on the D input, and the address of the latch into which the data is to be entered is held on the A0, A1, and A2 inputs. When the Enable input is taken Low, the data is copied through to the addressed output. The data is stored when the Enable input transitions from logic Low to High. All unaddressed latches will remain unaffected. With Enable logic High, the device is deselected, and all latches remain in their previous state, unaffected by changes on the data or address inputs. To eliminate the possibility of entering erroneous data into the latches, Enable should be held High (i.e. inactive) while the address lines are changing.
When the DTMF decoder receives a valid tone pair, its STD output goes High; otherwise it remains Low. Since the Enable input of latch IC2 needs a negative-going pulse for ‘strobing’ an output, the logic condition has to be reversed by means of transistor T1.
The state of the individual Q0–Q7 outputs (brought out to pins on K1) represents the

active/inactive active state of pushbuttons S1–S9. Only one of the Q0–Q7 outputs switches its logical state. Actually the correspondence is in reverse order, i.e. by pressing S1 on the encoder output Q7 will be affected, S2 will affect Q6, S3, Q5 and so on until S8 which will control the Q0 output.
The output signals on K1 have CMOS swing and the maximum output sink/source current specification of the CD4099 must be observed — the specification will differ between manufacturers so find that datasheet in case of doubt. As examples that will work safely in most cases, low-current LEDs with commoned cathodes may be connected up to K1 via 2.2 kΩ resistors. The same value for the LEDs in type TIL199 optocouplers, while 470 Ω is recommended for a MOC3020M. Whatever you connect up to K1, make sure the CD4099 outputs are not overloaded.
Like the encoder, the decoder can be built on prototyping board, but feel free to design your own PCB.

The encoder/decoder combination may communicate either via a 2-wire line (of considerable length), wirelessly using an approved audio transmitter and a receiver, or over AC powerlines using suitable interfaces.

(100073)



	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697 Hz	0001	0010	0011	1101
770 Hz	0100	0101	0110	1110
852 Hz	0111	1000	1001	1111
941 Hz	1011	1010	1100	0000

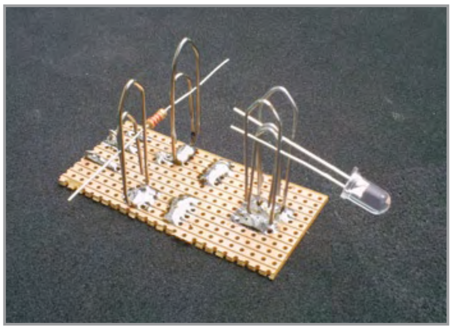
Rapid Test and Measurement

Leo Szumylowycz (Germany)

Pictures are worth a thousand words, so this will be the shortest ever article for an electronics magazine. Recently our overweight cat decided to dive-bomb my carefully sorted tray of LEDs. The result was a thousand or more LEDs of 40 different varieties all mixed up together! The photo shows my quick and dirty test setup, which you can use with a variable power supply with digital current and voltage displays.

The paper clips are the standard size, nickel plated (not plastic!). You can solder banana plugs or other connectors to the little test board's test leads. A nice refinement would be small rubber feet to avoid problems on a conductive work bench surface.

(090969)



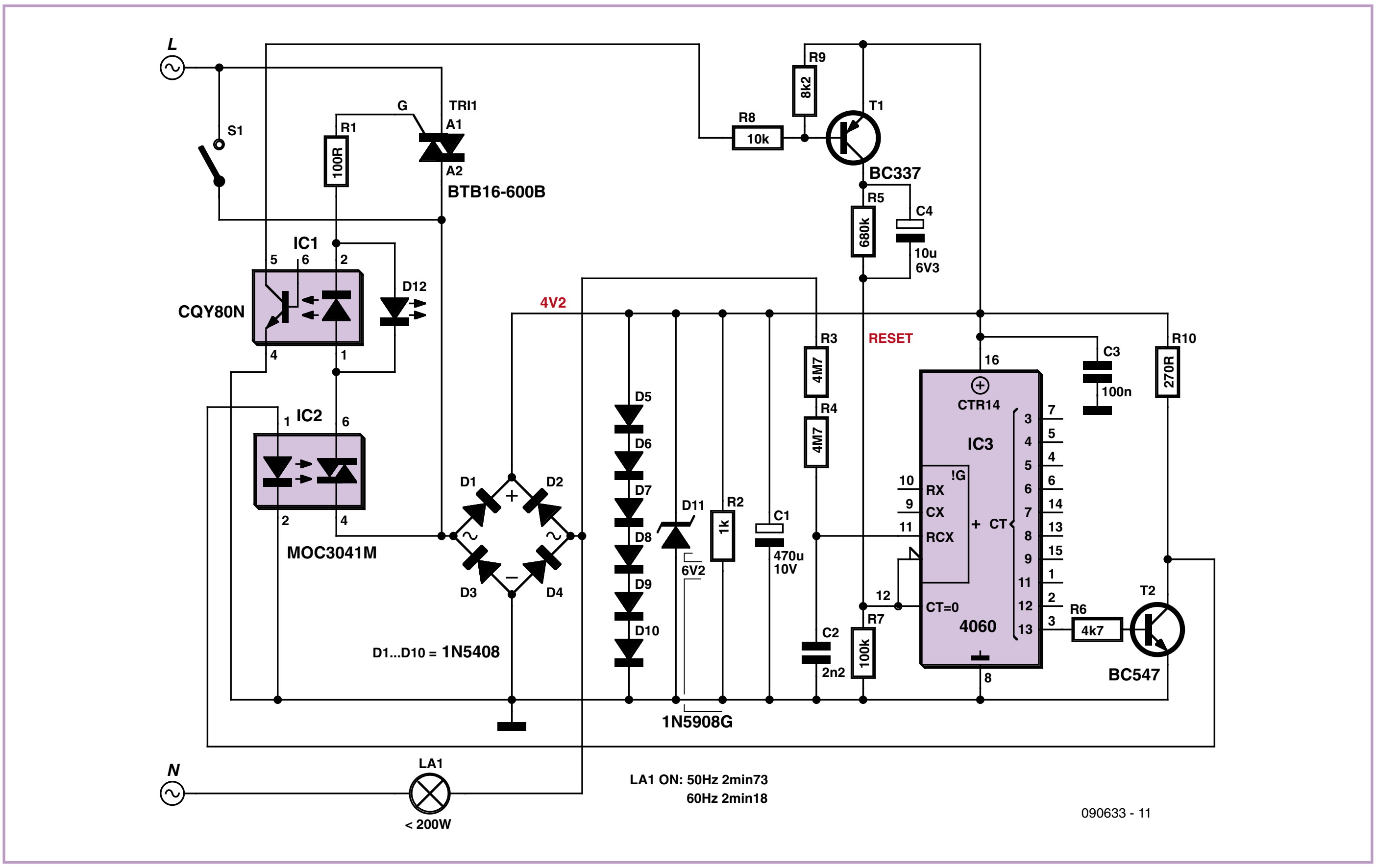
Outdoor Lighting Controller

Harald Schad (Germany)

When you step out of your brightly-lit house into the darkness, it takes a while for your vision to adjust. A solution to this problem is this outdoor light with automatic switch-off. As a bonus, it will also make it a little bit easier to find the keyhole when returning late at night.

Often no AC neutral connection is available at the point where the switch-off timer is to be installed, which makes many circuit arrangements impractical. However, the circuit here is designed to work in this situation. The design eschews bulky components such as transformers and the whole unit can be built into a flush-mounted fitting. The circuit also features low quiescent current consumption.

The circuit is started by closing switch (or pushbutton) S1. The lamp then immediately receives power via the bridge rectifier. The drop across diodes D5 to D10 is 4.2 V, which provides the power supply for the delay circuit itself, built around the CD4060 binary



counter.

When the switch is opened the lighting supply current continues to flow through Tri1. The NPN optocoupler in the triac drive circuit detects when the triac is active, with antiparallel LED D1 keeping the drive symmetrical. The NPN phototransistor inside the coupler creates a reset pulse via T1, driving pin 12 of the counter. This means that the full time period will run even if the circuit is retriggered.

The CD4060 counts at the AC grid frequency. Pin 3 goes high after 2^{13} clocks, which corresponds to about 2.5 minutes. If this is not long enough, a further CD4060 counter can be cascaded. T2 then turns on and shorts the internal LED of opto-triac IC2; this causes Tri1 to be deprived of its trigger current and the light goes out. The circuit remains without power until next triggered.

The circuit is only suitable for use with resistive loads. With the components shown (in particular in the bridge rectifier and D5 to D10) the maximum total power of the connected bulb(s) is 200 watts. As is well known, the filament of the bulb is most likely to fail at the moment power is applied. There is little risk to Tri1 at this point as it is bridged by the switch. The most likely consequence of overload is that one or more of diodes D5 to D10 will fail. In the prototype no fuse was used, as it would not in any case have been easy to change. However, that is not necessarily recommended practice!

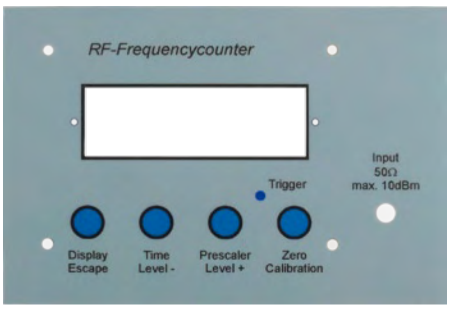
Caution. Circuits at AC live potential should only be constructed by suitably experienced persons and all relevant safety precautions and applicable regulations must be observed during construction and installation.

(090633)

Front Panels the Mouse Mat Way

Kai Riedel (Germany)

Putting professional-looking legends on front panels is a problem for many electronics fans. Transparent plastic films ought to work but the high-gloss surface of most of the types available in shops make them unsuitable for our purposes. Ideally we want something with a textured finish on the top (front) surface, in order to avoid undesirable glints and reflections. In professional circles a popular choice is the 'Autotex InkJet' film produced by MacDermid [1] and if you click on the Where To Buy link there's a contact form that will put you in touch with a distributor. People looking for only small quantities will find the price rather high, however.



A more attractive alternative is mouse mat film, as used in the Folex DIY mouse mat kit. [2]). Using this special film (lightly textured on one side, A4 format) you can print your design with an inkjet printer to achieve excellent front panel overlays quite rapidly. To produce the end product the author uses the following process:

- Design the layout of the front panel in a graphics program (e.g. CorelDraw).

- Print the mirror image of this design onto the reverse side of the special film.
- Leave ink to dry 24 hours and spray the rear side with a light grey undercoat (universal primer in aerosol cans from DIY shops).
- When the paint is completely dry apply double-sided adhesive tape to the reverse side of the film. Conrad Electronics [3] order code 529478-62 is ideal.
- Create cut-outs and holes for displays, switches and operating controls with a craft knife and hollow punches (achieved commercially with plotter or laser cutters).
- Fix film to front panel.

This method can also be used for making professional-looking front panel lettering on industrial prototypes.

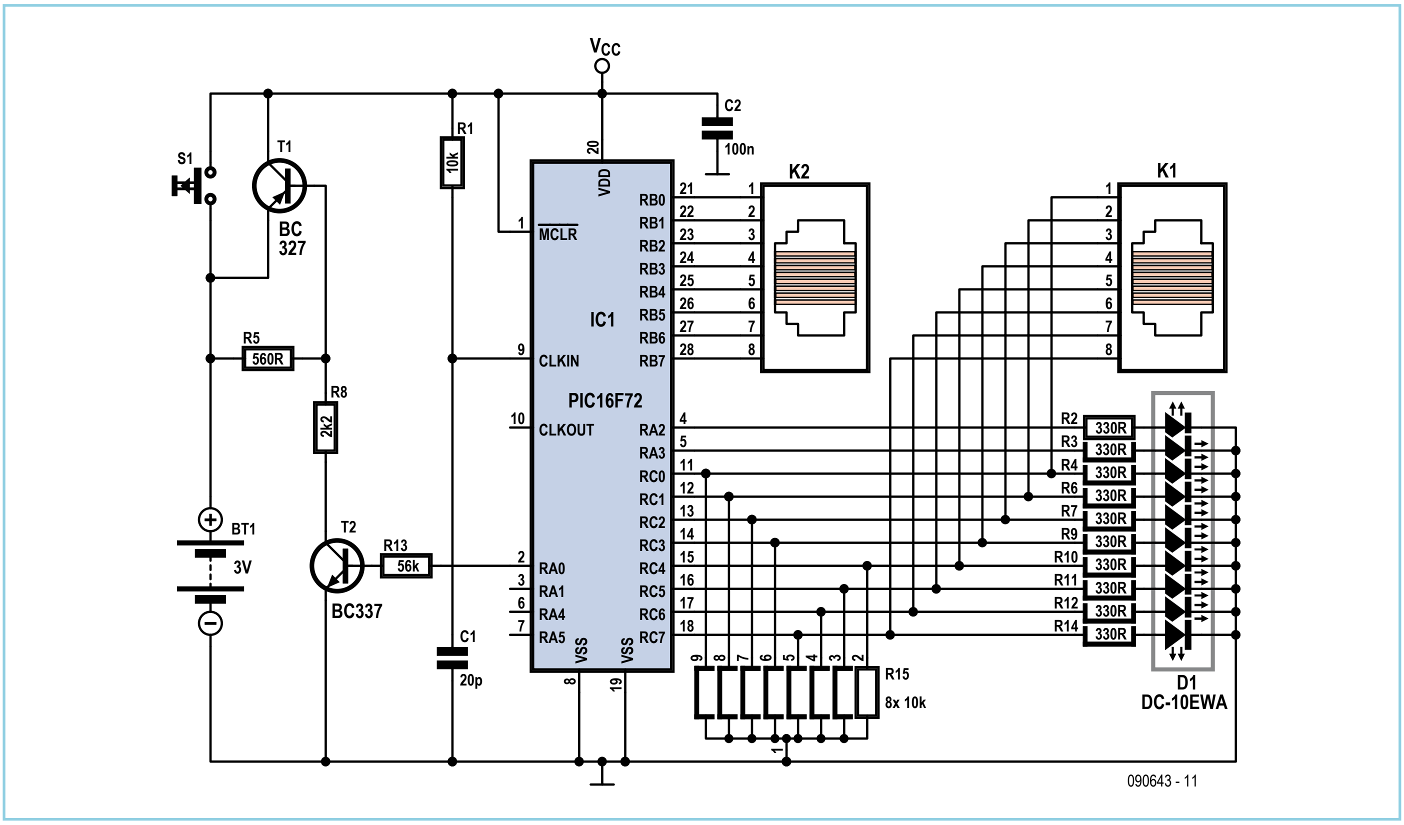
(090426)

[1] www.macdermidautotype.com/autotype.nsf/webfamilieseurope/AUTOTEX

[2] www.amazon.co.uk/ and enter “Folex mouse mat kit”

[3] www.conrad-uk.com

PIC RJ-45 Cable Tester



Pascal Coulbeaux (France)

This RJ-45 cable tester automatically checks cable continuity and tests the connection configuration. Each of the eight connections is checked independently and short-circuits are detected.

The circuit can be built using either a PIC16C62B or a PIC16F72. This microcontroller was chosen, as it has 22 input/output pins. Each RJ-45 socket uses eight input/output pins, i.e. 16 in all, plus two I/Os are used for two LEDs.

The tester described is built using the PIC16C62B, which can work with a supply voltage of 3 V, justifying the use of a power unit with two batteries. Unfortunately, this microcontroller can only be programmed once. It is possible to use the PIC16F72, which is reprogrammable and pin-compatible, but you’ll need to use a three-battery power unit to achieve a voltage of 4.5 V.

The clock circuit is formed by R1/C1, a cheap solution, since we don’t need an accurate clock frequency.

The circuit is started using push-button ??BP, the power is maintained and controlled by transistors T3 and T2. It stops automatically, after a delay generated using Timer0. When Timer0 overflows, an interrupt is produced which leads to pin RA0 going low, and in this way transistor TQ2 turns off, followed by T3.

The LED bargraph allows us to follow the testing of each connection. The first LED (pin 1), controlled by RA2, lights if the cable is good. The second LED (pin 2), controlled by RA3, lights if the cable has a wiring or continuity fault. Both LEDs light if the cable has a short-circuit. The other eight LEDs show how the cable is connected. If the cable is all right, we see a left>right chaser; but if the cable is crossed over, we get a back-and-forth chaser — just like Kitt in the cult TV series ‘Knightrider’.

The software in assembler code is available on [1].

(090643-I)

www.elektor.com/090643

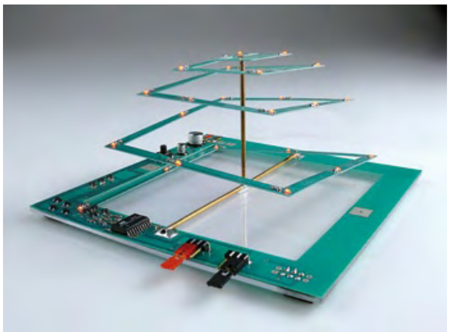
3D LED Pyramid

Lothar Goede (Germany)

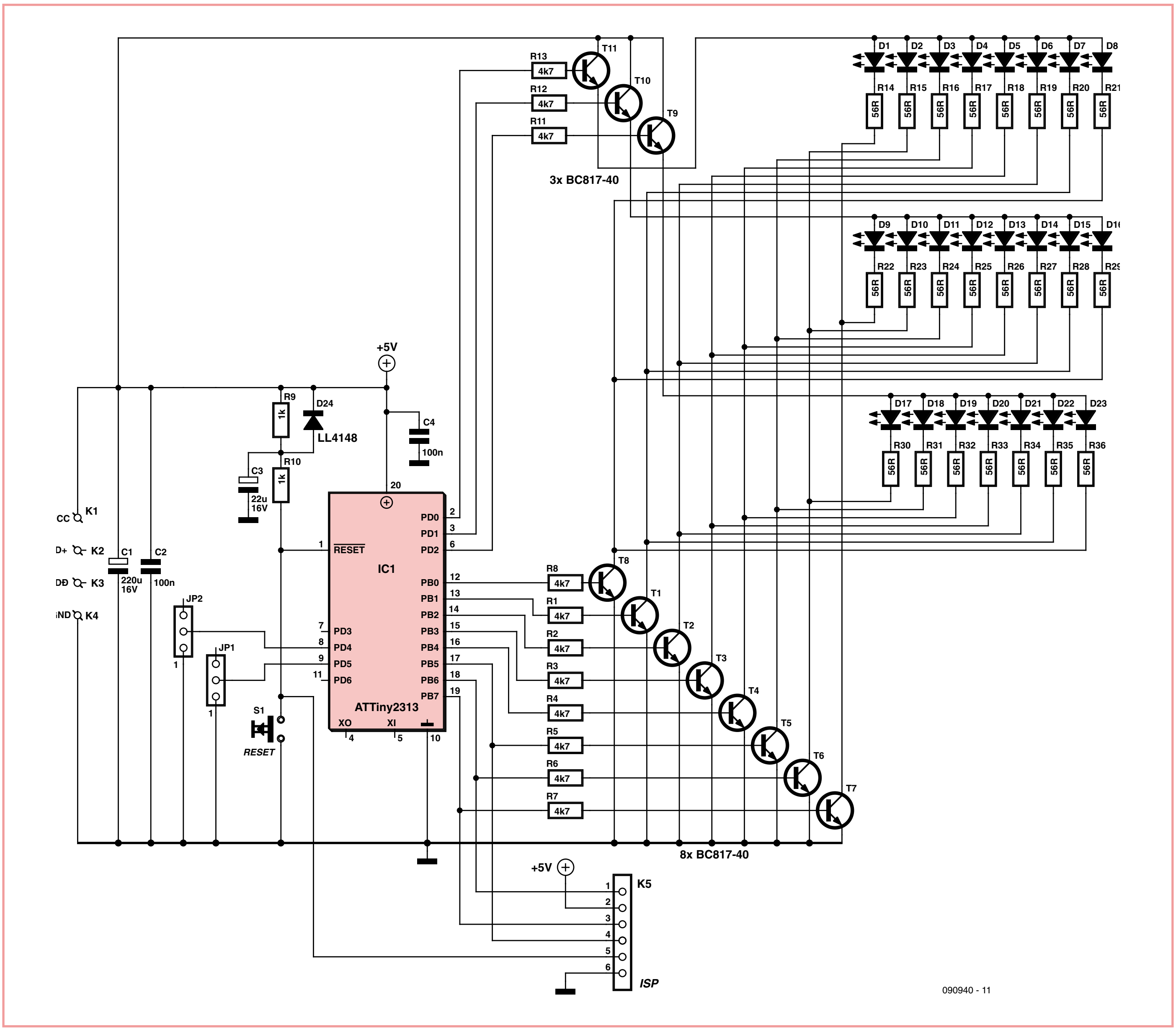
The author 'just wanted to do a bit of microcontroller programming'. However, the project rapidly grew into this impressive and visually attractive pyramid. The circuit consists essentially of a specially-sawn printed circuit board, 23 LEDs and a microcontroller. Despite the fact that the microcontroller is a rather modest Atmel ATtiny2313, the author nevertheless has found room in the 2 KB flash memory for 16 different light sequences.

The 23 LEDs are divided into three groups. The lower and middle sections consist of eight LEDs, while the upper section has just seven. The microcontroller has only 20 pins, and so it is not feasible to provide a direct individual drive for each LED. The multiplexing approach adopted uses just eleven output port pins. Buffer transistors are used to increase the current drive capability of each output.

The software was written in assembler and can, as usual, be downloaded from the Elektor web pages accompanying this article [1] as either source code or as a hex file. The printed circuit board layout files are also available from the same place, as well as a link allowing purchase of ready-made boards and preprogrammed microcontrollers.



Populating the printed circuit board is straightforward: there are some surface-mount components to be soldered, but space is not tight. For best results, it is best to choose LEDs with the widest possible viewing angle so that the pyramid looks its best even when seen from the side. The author used type



LO L296 orange LEDs from Osram, which have a viewing angle of 160 °. A six-way connector is provided to allow in-system programming (ISP) of the microcontroller. The configuration fuses are set to enable use of the internal 4 MHz clock source, which is divided down to 0.5 MHz by an internal divider. If the fuses are not correctly programmed the light sequences will run too quickly, too slowly, or even not at all!

When everything is working, take an 11 cm length and a 5.5 cm length of 1.5 mm² solid copper wire and solder one end of the shorter piece to the middle of the longer piece to make a 'T' shape. Pull the printed circuit board spiral apart so that the T-shaped wire assembly fits underneath, and then solder it to the two pads as shown in the photograph. Fine-bore brass tubing can also be used instead of solid copper wire.

As well as the ISP connector a USB interface is provided, whose job is solely to provide a 5 V supply. An external 5 V mains adaptor would do the job equally well. Two jumpers affect the behavior of the light pyramid: JP1 determines whether the sixteen sequences follow one another in strict order or at random; and JP2 determines whether the light patterns are displayed or whether all LEDs will be continuously lit. S1 is a reset button, which will come in handy if you wish to experiment with modifying the software.

(090940)

[1] www.elektor.com/090940

Cheap Bicycle Alarm

Gerard Seuren (The Netherlands)

The author wanted a very cheap and simple alarm for some of his possessions, such as his electrically assisted bicycle.

This alarm is based on a cheap window alarm, which has a time-switch added to it with a 1-minute time-out. The output pulse of the 555 replaces the reed switch in the window alarm. The 555 is triggered by a sensor mounted near the front wheel, in combination with a magnet that is mounted on the spokes. This sensor and the magnet were taken from a cheap bicycle computer.

The front wheel of the bicycle is kept unlocked, so that the reed switch closes momentarily when the wheel turns. This triggers the 555, which in turn activates the window alarm. The circuit around the 555 takes very little current and can be powered by the batteries in the window alarm. There is just enough room left inside the enclosure of the window alarm to mount the time-switch inside it.

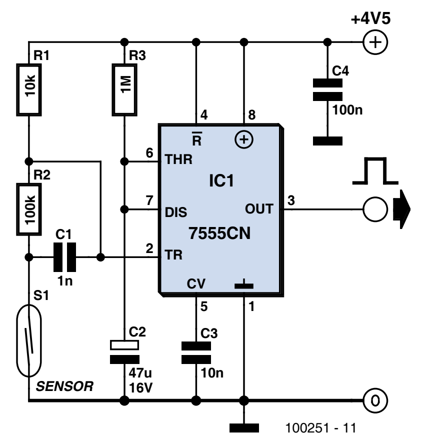
The result is a very cheap, compact device, with only a single cable going to the reed switch on the front wheel.

And the noise this thing produces is just unbelievable! After about one minute the noise stops and the alarm goes back into standby mode. The bicycle alarm should be mounted in an inconspicuous place, such as underneath the saddle, inside a (large) front light, in the battery compartment, etc.

Hopefully the alarm scares any potential thief away, or at least it makes other members of the public aware that something isn't quite right.

(100251)

Caution. The installation and use of this circuit may be subject to legal restrictions in your country, state or area.

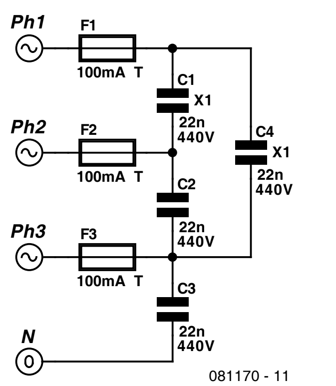


Phase Coupler for PLC or X10 Network

Christian Tavernier (France)

As long as the AC power grid does not carry too much interference, power line carrier communications (PLC) works very well in homes with single-phase AC. Unfortunately, this is not the case with a 3-phase installation. If the transmitter and receiver find themselves on different phases, they cannot communicate. The only coupling between the phases is actually at the supply company's transformers, and as the high-frequency signals used for the powerline carrier cannot travel beyond the user's electricity meter, they never reach the coupling point and so no coupling takes place. In this event, it is necessary to use a coupler fitted before the meter*.

Such a coupler is very easy to build; the circuit involves just four capacitors which form a high-frequency bridge between the phases.



Construction is perfectly simple, but for safety reasons it is vital to use Class X1 capacitors designed for use on 440 VAC grids (e.g. Farnell # 1166428). In theory, the fuses are not strictly essential, but they do offer additional protection in the event of a capacitor's failing.

The PCB [1] fits into a case designed for use on DIN rail, which lets you install the circuit into any modern distribution box. The case to use is a 2-module wide Boss type BE350/605T (Farnell # 1171699).

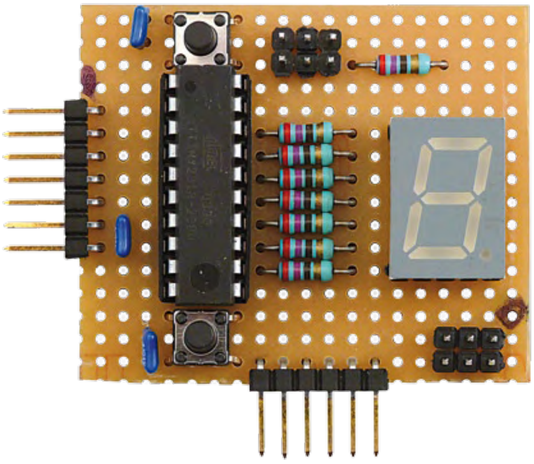
Take the usual precautions when connecting up to the AC grid — after being sure to turn off the main switch, of course! The circuit will work right away. The only problem that may arise is where the AC powerline carrier transmitter is connected to phase 3 in the circuit. Capacitor C3 then has an adverse effect on the high-frequency signals generated by the transmitter, as it will tend to short them out. In this situation, the simplest solution is to disconnect the coupler's neutral terminal connection, which removes this capacitor from the circuit.

(081170-I)

* The installation of this circuit is restricted to qualified electrical engineers. The circuit may not work in all countries or areas.

[1] www.elektor.com/081170

Digital Thumbwheel Switch



Per Stegelmann (Denmark)

Thumbwheel switches are remarkably expensive and always playing hard to get. Here's a cheaper, digital equivalent with the ability to remember the value it was set to. It is programmable to different modes such as inverted or non-inverted BCD code output, programmable READ pin active level, and the choice of hexadecimal or decimal BCD count.

The main elements in the circuit are an ATtiny2313 microcontroller with built-in RC oscillator, a 7-segment LED display (you choose the size and color!) and two small pushbuttons. All functionality of the circuit is within the firmware of the microcontroller.

The project source code files may be downloaded free from [1]. Examining the code you'll discover the following functionality based on jumper settings.

JP1 = on: READ input PD4 responds to active High. JP1 = low: READ input PD4 responds to active Low. When the thumbwheel value is read, the UP/DOWN switches are effectively disabled.

JP2 = on: inverted BCD code. JP2 = off: standard BCD code.

JP3 = on: hexadecimal count (0-F) with auto rollover. JP3 = off: decimal count (0-9) with auto rollover.

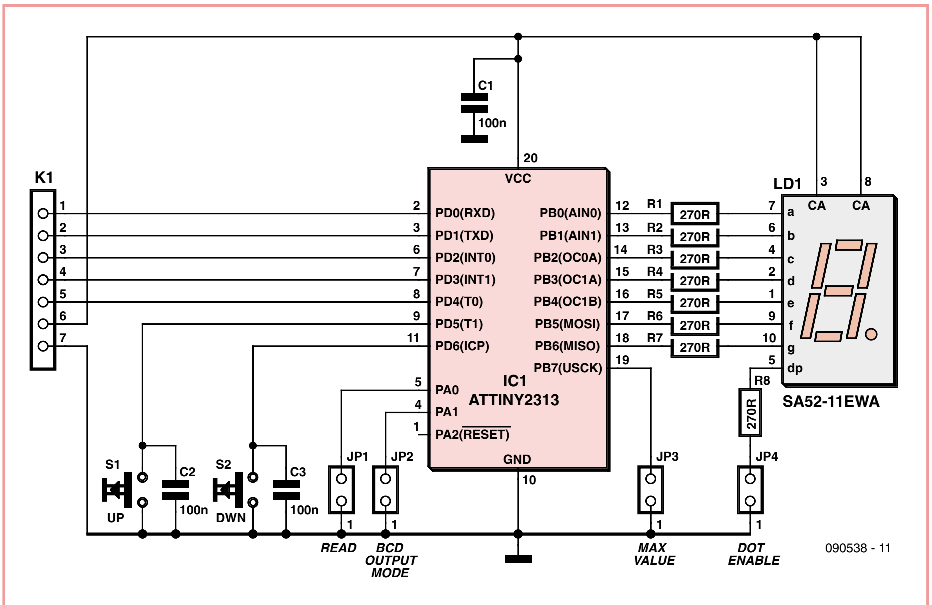
JP4 = on: decimal point ON. JP4 = off: decimal point OFF.

When the thumbwheel switch value hasn't changed for about 10 seconds, the current value is stored into the microcontroller's internal EEPROM to be recovered at power-up. The BCD output pins are then changed to inputs and tri-stated when the READ input (PD4) is not active. This allows multiple outputs of a number of these 'ersatz' circuits to be connected to the same 4 bit 'bus'. By multiplexing (using a 1-of-16 MUX IC) one 'switch' can be selected at a time to read its value. In this way up to 16 switch circuits can be read by the same 8-bit microcontroller bus to minimise I/O count.

When the EEPROM value is higher than the counter's maximum it will return to zero. This is to avoid problems when a value of 15 is loaded from EEPROM and the counter maximum is 9 (decimal mode).

(090538)

[1] www.elektor.com/090538



Deep Discharge Protection for 12 V Batteries

Jürgen Stannieder (Germany)

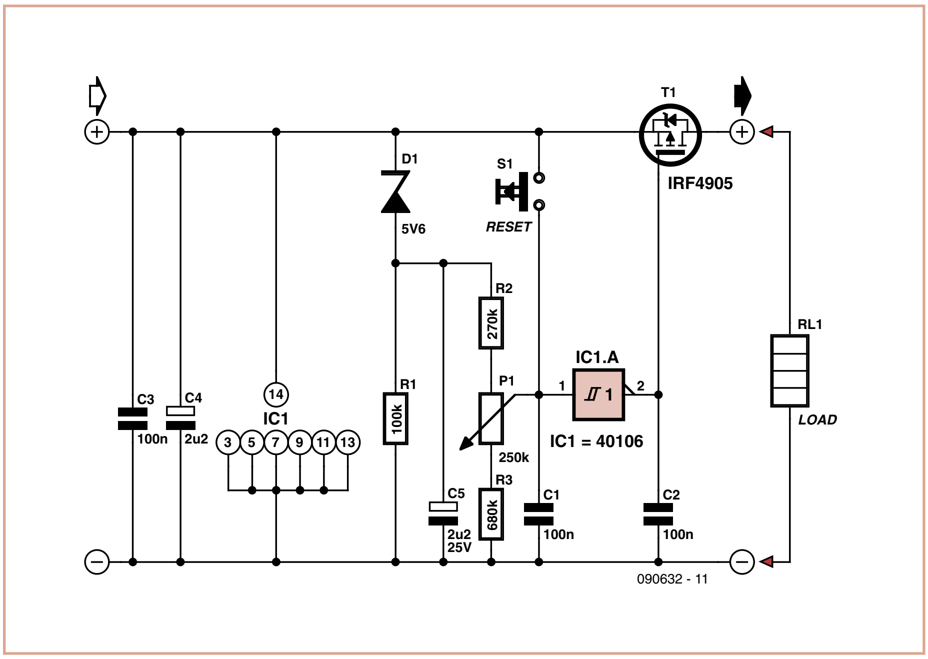
For load currents up to 4 A the author has used a bistable relay to disconnect the load on a 12 V battery to avoid deep-discharge. How can we provide the same function at higher levels of load current?

The solution here is to use a P-channel HEXFET power MOSFET as a semiconductor relay to disconnect the load. The very low $R_{DS(ON)}$ of these devices is not much greater than a relay's contact resistance. The device used here is the IRF4905 from International Rectifier [1]. The IRF4905 has an $R_{DS(ON)}$ of 0.02 Ω and can handle an $I_{D(MAX)}$ of 74 A. It is used in the circuit to pass a current of up to 20 A and disconnect the load when the battery voltage falls below a preset threshold. On a practical note make sure that all interconnect cables

between the battery and load has sufficient cross-sectional area to handle the expected load current. The transistor must be mounted on a suitable heat sink in order to dissipate the power (approximately 4.5 W at 15 A) developed in the transistor.
The current consumed by the circuit itself is in the order of 0.5 mA which is really insignificant in comparison to the battery's inherent self-discharge rate.
P1 adjusts the falling voltage level trigger point for the circuit to disconnect the load. The load remains disconnected even when the battery voltage has risen again after recharging. Pushbutton S1 is used to switch T1 back on and reconnect the load.
Ensure that any unused inputs of the 40106 hex Schmitt inverter chip are tied to ground.

(090632)

[1] www.irf.com/product-info/datasheets/data/irf4905.pdf



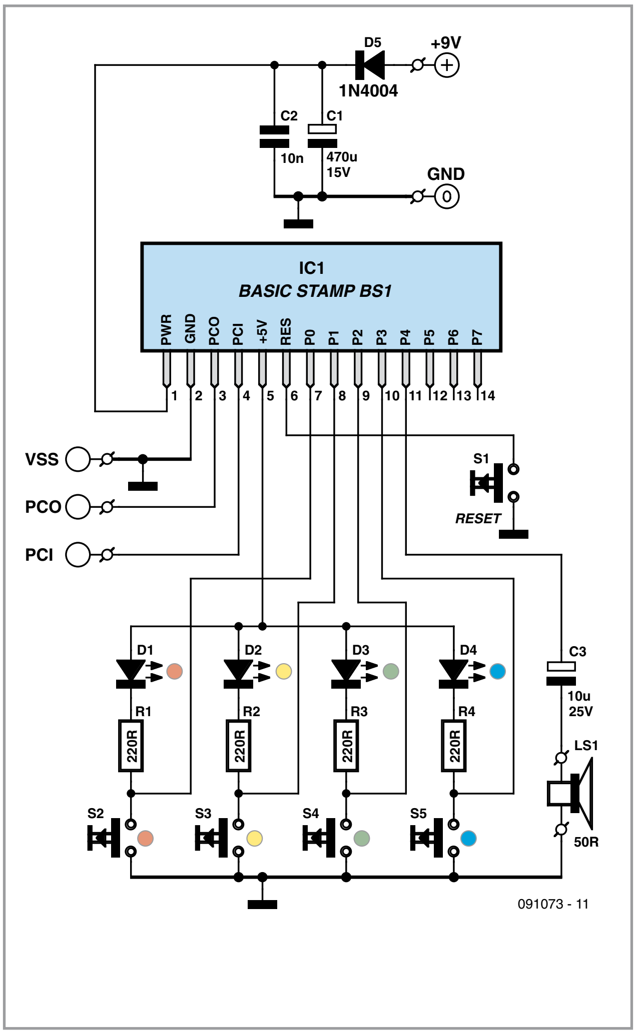
Play 'Simon'

Christian Tavernier (France)

The electronic game Simon comes in the form of a large, round console with four red, green, blue, and yellow illuminated buttons. These buttons light up in a random order with longer and longer sequences, accompanied by musical notes. The object of the game is to reproduce these sequences precisely by pressing the buttons in the same order and the same number of times as they lit up. So apart from the entertainment value, this game also stimulates visual and aural memory.

You can use an 'old' Basic Stamp I to build your own 'Simon' game. It has enough input/outputs lines to drive the LEDs and read the buttons needed by the game. To simplify construction in practice, the illuminated buttons are reproduced here by associating a button and an LED of the same color connected to the same port.

The circuit is very simple, thanks to the Basic Stamp I, and above all the fact that its ports, P0–P3 in this instance, can operate as inputs, where they are used to read the buttons, and as outputs, where they are



used to directly drive the LEDs. Line P4 is used as a output only to drive the loudspeaker that reproduces the musical notes that accompany the lighting of the LEDs.

The power supply uses a voltage between 7 and 15 V, which can come from a 9 V battery, for example, since the circuit goes into standby automatically when not used.

For the loudspeaker, make sure you choose a miniature 50 Ω type. And as for buttons S1–S5, if you want to use our PCB design, you'll need to use the square D6 type from ITT. These types also have colored lenses that are particularly useful here. On the subject of the PCB, do note that the LEDs and buttons can equally well be fitted on the component or track side, in order to make it easier to fit the circuit into a case.

You can organize the layout of the LED and button colors however you like. However, it is important to wire each output (P0–P3) with an LED and a button of the same color, so as to respect the logic of the game.
The program to be loaded into the Basic Stamp is available for free download from the Elektor

website [1] as well as from the author's own website [2].

The circuit has an automatic power-on reset, and you can force a reset at any time by pressing S1. Following a reset, the LEDs light up in turn to encourage you to play. If you don't put in an appearance by pressing any button, other than S1, or course, after a few seconds the game goes into stand-by; all the LEDs go out and the consumption drops to just a few tens of µA.

To start the game up again, all you have to do is perform a reset using S1, or press any other button for at least 2 s. The game lights the first LED and plays the corresponding musical note. You must then press, within the next second or so, the button of the same color. Simon then lights two LEDs in succession (this may be the same one twice!) and generates the two corresponding musical notes.

You in turn then have to press the two corresponding buttons in the same order. The game then continues with a sequence that gets longer each time, up to the point where you make a mistake reproducing it. Simon makes a groaning noise to indicate the slightest error, ending the current round and starting another.
Have fun!

(091073-I)

[1] www.elektor.com/091073

[2] www.tavernier-c.com

Adjustable Low-voltage Power Supply

Vladimir Mitrovic (Croatia)

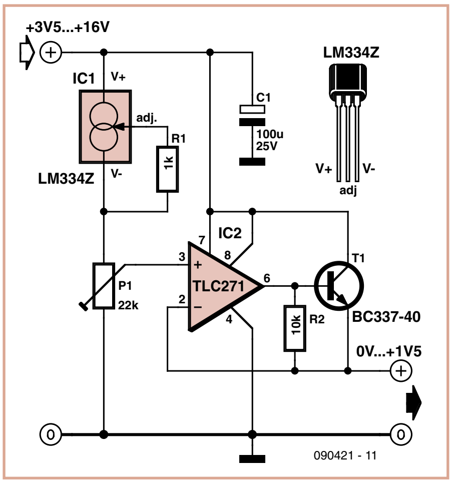
If you want to check the behavior of an electronic circuit at low voltages, an adjustable power supply as shown here may be helpful. Powered from a 3 to 16 volts source (DC for sure), it will provide a stable output voltage in the 0 to 1.5 V range.

Multiturn trimpot P1 allows the output voltage to be adjusted with good precision. The BC337-400 output transistor raises the output current to about 200 mA bearing in mind that the minimum supply voltage is 3.5 V. The transistor's dissipation should be taken into account, and a more powerful type used if necessary.

T1 may be omitted and R2 replaced with a wire link if you are happy with 3 mA at 3 volts out, 10 mA at 6 V or 20-30 mA at 10-16 V.

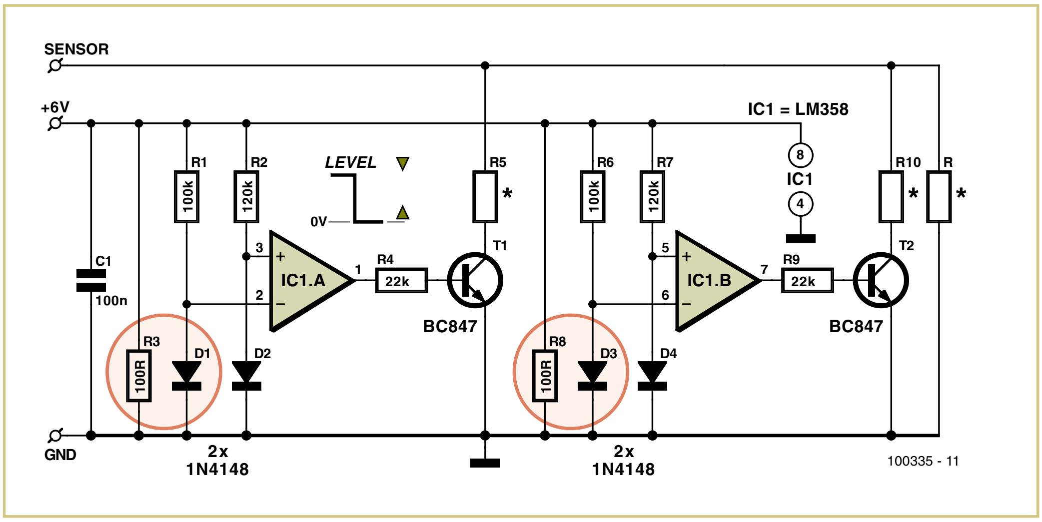
These values represent the maximum output current of the TLC271 op amp. Without T1, the minimum supply voltage is 3.0 V.

(090421)



Petrol/Diesel Level Sensor

Paul de Ruijter (The Netherlands)



This sensor is particularly suitable for use in small spaces, such as the petrol tank of a motorbike. It has the advantage of not having any moving parts, unlike a conventional sensor with a float and float arm that make it difficult to fit in a tank.
The sensor circuit is made from standard, inexpensive components and can be put together for little money.

The operating principle is based on measuring the forward voltages of two identical diodes (check this first by measuring them). The forward voltage of a diode decreases with increasing junction temperature. If a resistor is placed close to one of the two diodes, it will be heated slightly if it extends above the surface of the petrol. For best results, the other diode (used for reference) should be located at the same level. If the diodes are covered by the petrol in the tank, the heating resistor will not have any effect because it will be cooled by the petrol. An opamp compares the voltage across the two diodes, with a slightly smaller current passing through the reference diode. When the petrol level drops, the output of the opamp goes high and the output transistor switches on. This causes a sense resistor to be connected in parallel with the sensor output. Several sensor circuits can be used together, each with its own switched sense resistor connected in parallel with the output, and the resulting output signal can be used to drive a meter or the like.

Using this approach, the author built a petrol tank 'sensor strip' tank consisting of five PCBs, each fitted with two sensor circuits. With this sensor strip installed at an angle in the tank, a resolution of approximately 1.5 litre per sensor is possible. Many tanks have an electrical fitting near the bottom for connection to a lamp on the instrument panel that indicates the reserve level. The sensor strip can be used in its place.

You will have to experiment a bit with the values of the sense resistors, but do not use values lower than around 100 Ω. It is also important to fit the diodes and heater resistor in a little tube with a small opening at the bottom so that splashing petrol does not cool the heater resistor, since this would result in false readings.

The circuit should be powered from a regulated supply voltage of 5 to 6 V to prevent the heating resistors from becoming too hot.

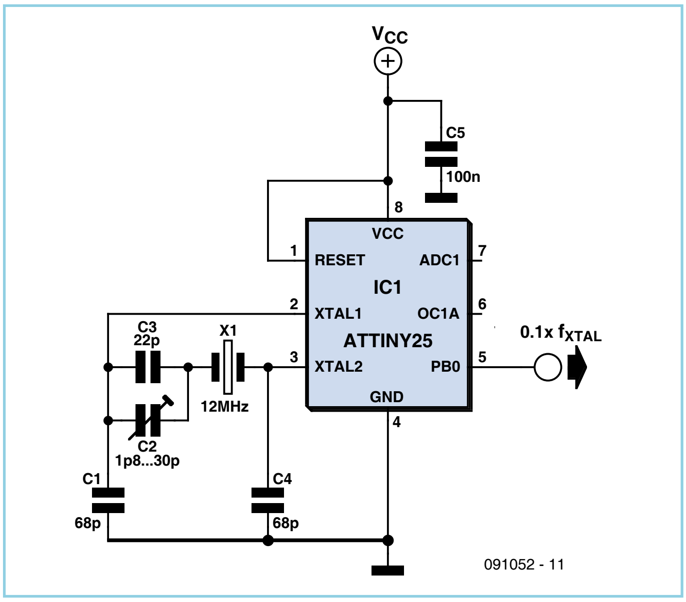
After testing everything to be sure that it works properly, it's a good idea to coat the circuit board with epoxy glue to provide better protection against the petrol.

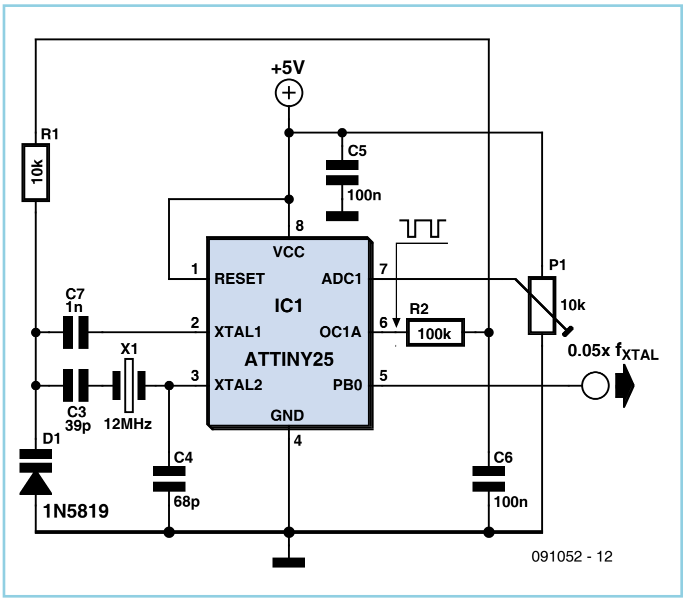
Tip: you can use the well-known LM3914 to build a LED display with ten LEDs, which can serve as a level indicator. Several examples of suitable circuits can be found in back issues of Elektor.

Note: this sensor circuit is not suitable for use in conductive liquids.

(100335-I)

Crystal Pulling





Rainer Reusch (Germany)

In microcontroller circuits quartz crystals provide the highest accuracy for keeping everything on frequency. With frequency and time measurement (and for commissioning master clocks) fine adjustment of crystal oscillators may also be necessary, so we will now investigate in detail how crystal frequencies can be 'pulled'. Although we have taken the ATtiny25 AVR microcontroller from Atmel as our example, the methods indicated can in fact be applied to just about all microcontrollers.

The oscillator in a microcontroller consists of an inverter that is timed externally by just a quartz crystal and two capacitors (Pierce oscillator). The value of the capacitance is matched accurately to the selected crystal, in order that any deviation from the nominal frequency is contained to the minimum possible (see controller data sheet). Crystals can display some tolerance, however, and to compensate for this effect we have to increase the two (parallel) capacitances significantly to drag down the frequency. To make this adjustment possible a trimmer capacitor is fitted in series with the crystal. We select the two parallel capacitors (C1 and C4) so as to be large enough to make the oscillator operate below its nominal frequency at maximum series capacity (C2 and C3). Adjusting the trimmer capacitor (C2) then allows us to pull the crystal upwards.

Carrying out this adjustment in a practical manner calls for a frequency counter of course. In this case its test probe must not be connected to the inverter input of the oscillator (XTAL1)! The capacity of the test probe would alter the frequency and in fact this effect can even be detected at the oscillator output (XTAL2), even if not so pronouncedly. The best solution is to load the microcontroller (or expand the firmware correspondingly) with a program that produces a squarewave signal on one port.

The following little program in C needs only five steps for one cycle in the main loop. Therefore a signal appears at port PB0 with a frequency that is one tenth of the crystal frequency.

```
#include <avr/io.h>
```

```
int main(void)
{
  DDRB|=(1<<PB0);
  for(;;) PORTB^=(1<<PB0);
  return 0;
}
```

But why set the frequency manually when the microcontroller can do this equally well? The relevant preset parameters can be retained in an EEPROM for example. To simplify the circuitry we do this by varying the parallel capacitance at the oscillator input (even though this is less effective than altering the series capacity). Capacitor C1 is replaced by a varactor diode, which means we now require a control voltage for this diode in order to set the capacitance and hence the crystal frequency. The controller is programmed so that at its PWM output we get a squarewave signal with an adjustable pulse width (the AVR can do this without having to execute a line of the program). An R-C element (R2 and C6) smooths the pulses into a DC voltage that is fed to the diode via R1. In our circuit the varactor diode used is a 1N5819 Schottky rectifier diode, which functions impeccably! That said, the supply voltage must remain at 5 volts to ensure an adequate adjustment range. If you are happy to rely on manual adjustment alone the circuit will also work off 3.3 volts.

In this second circuit the fixed series capacitor C3 pushes the crystal frequency upwards. The programmable capacitor D1 pulls the frequency downwards, together with the second parallel capacitor C4. The sole task of capacitor C7 is to isolate the DC control voltage from the oscillator input. For this reason the control voltage level should be significantly higher than the supply voltage!

In our (experimental) circuit we need some 'user input' in order to tell the controller which control voltage to produce (as before the actual calibration is carried out manually). For this we simply hook up a trimpot to an A/D converter input. The digitized potentiometer setting is transferred direct into the register that determines the pulse width of the PWM signal.

Once more we measure the crystal frequency on port PB0, although this time the firmware no longer outputs a tenth of the crystal frequency. Using a couple of NOP commands the frequency relationship is trimmed to one twentieth. In the example illustrated we would therefore expect to see 600 kHz at this output.
The values for the capacitors surrounding the oscillator depend primarily on the actual crystal selected (the values in the photos should be taken as generic standard values). Some 'suck it and see' fiddling around will also be hard to avoid when selecting the varactor diode.

All source code and hex files of the microcontroller programs can be downloaded free from a dedicated Elektor web page [1] or the author's project pages [2].

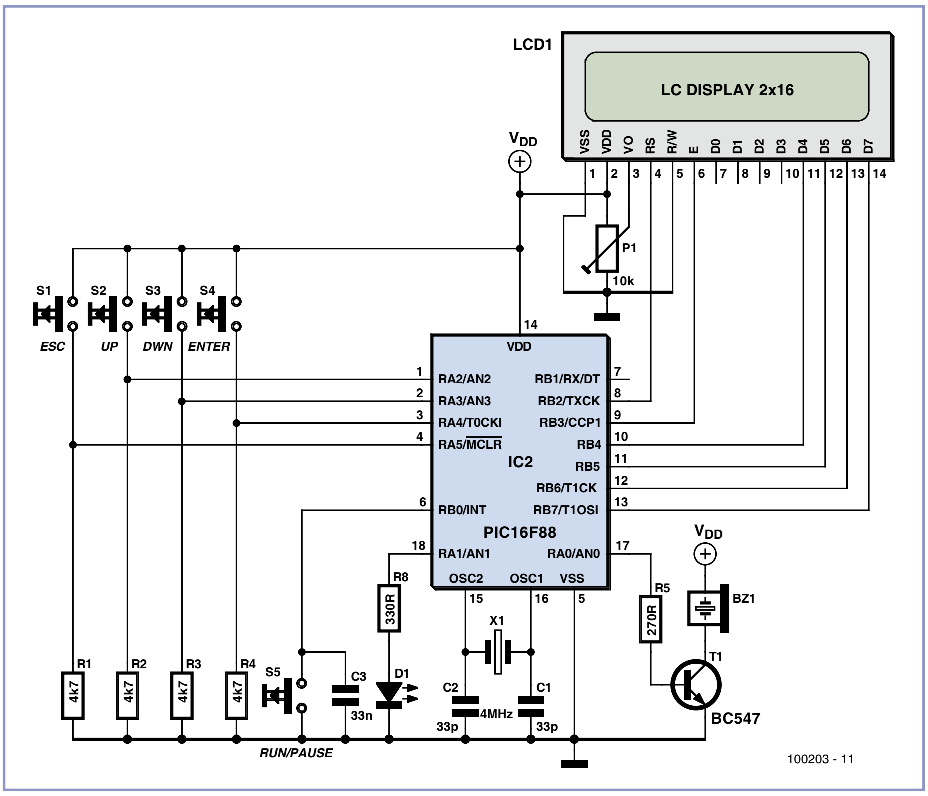
(091052)

[1] www.elektor.com/091052

[2] http://elektor.reworld.eu

Whistler: Electronic Trainer/Coach

Noël Demissy (France)



This device makes it possible to generate beeps at chosen regular time intervals for timing track race training. Each time interval is indicated by a beep, and the end of a performance test is indicated by a double beep. Two types of test are allowed:

Tests 1–4 offer a certain number of cycles, each comprising two periods, a running period followed by a rest period. For example, test 1 offers six cycles comprising a 15 s running period followed by a 15 s rest period.

The first three tests have preset values, while test 4 is fully adjustable.
Test 5 lets you determine Maximum Aerobic Speed (MAS) by making the athlete run in

2 min blocks at increasing speeds. Lengths are run between markers that are either 20 m or 25 m apart, according to choice. You can choose the initial speed and maximum speed values for the test. After 2 min, the speed increases by 1 km/h. In a constant two minute period, the number of lengths run in a shorter time increases. The MAS represents the highest speed the athlete reaches without letting up.

The circuit is very simple and just consists of a microcontroller, five buttons, a 2-line × 16-character display, an LED, and a sounder. A quartz crystal is required in order to obtain a sufficiently accurate timebase.

At power on, the system is stopped. Pressing the Run/Pause button turns the system on and the LED lights. Pressing the same button again puts the system into Pause mode. A training session can be restarted without losing the current values. On the other hand, a final stop (by pressing Escape) resets the values for the training underway.

The software (BASIC source and HEX file), the pre-programmed microcontroller, and the detailed, copiously-illustrated manual (in French only!) are available from [1].

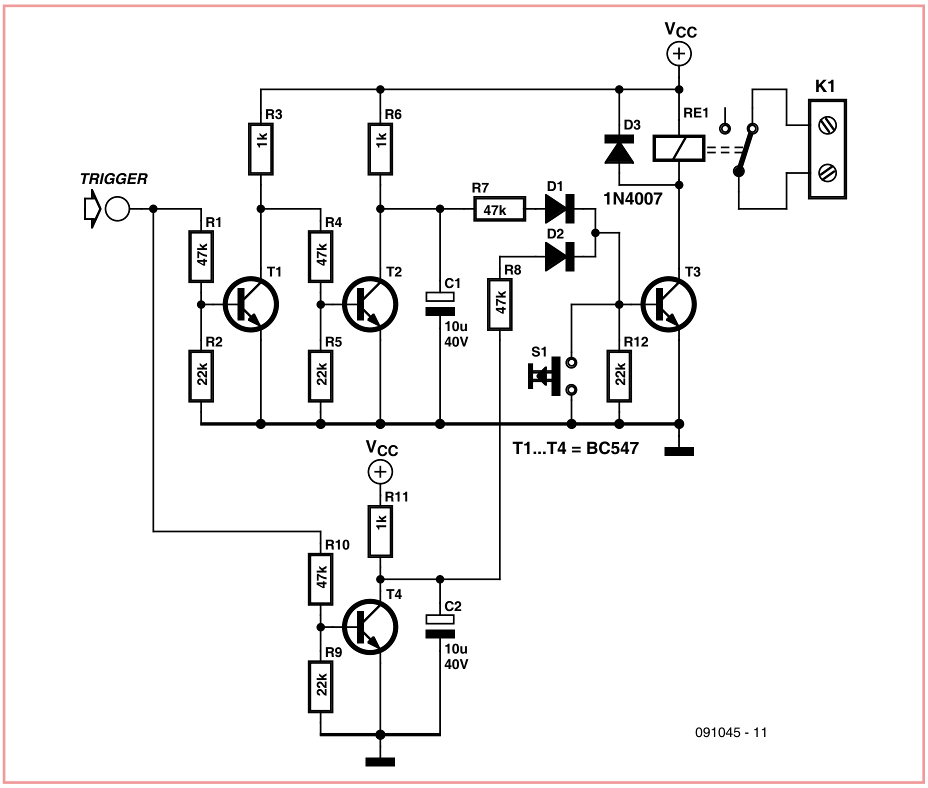
(100203-I)

Internet links

[1] www.elektor.com/100203

Emergency Stop

Jacob Gestman Geradts (France)



The big fear of every developer of a microcontroller or computer-driven control system is that the computer or controller could crash while it is in the middle of controlling something and that the output signal will remain on 'full throttle'. In this scenario motors could continue to spin faster and faster or a heating element could become red hot, without the system taking any corrective action. In reality, any control system needs some sort of emergency stop, which will turn everything off the moment something goes wrong.

Microcontrollers or computers will usually have a spare TTL output, which can be used for this purpose. By adding a few lines of code to the program, this additional output can be made to toggle high and low periodically. This can save a lot of trouble and damage. Should the computer or controller crash, then the toggle signal on this output will stop as well. The circuit then, does little more than check whether this toggling (TTL-) signal is still present. The computer or controller will be turned off as soon as this control signal is missing.

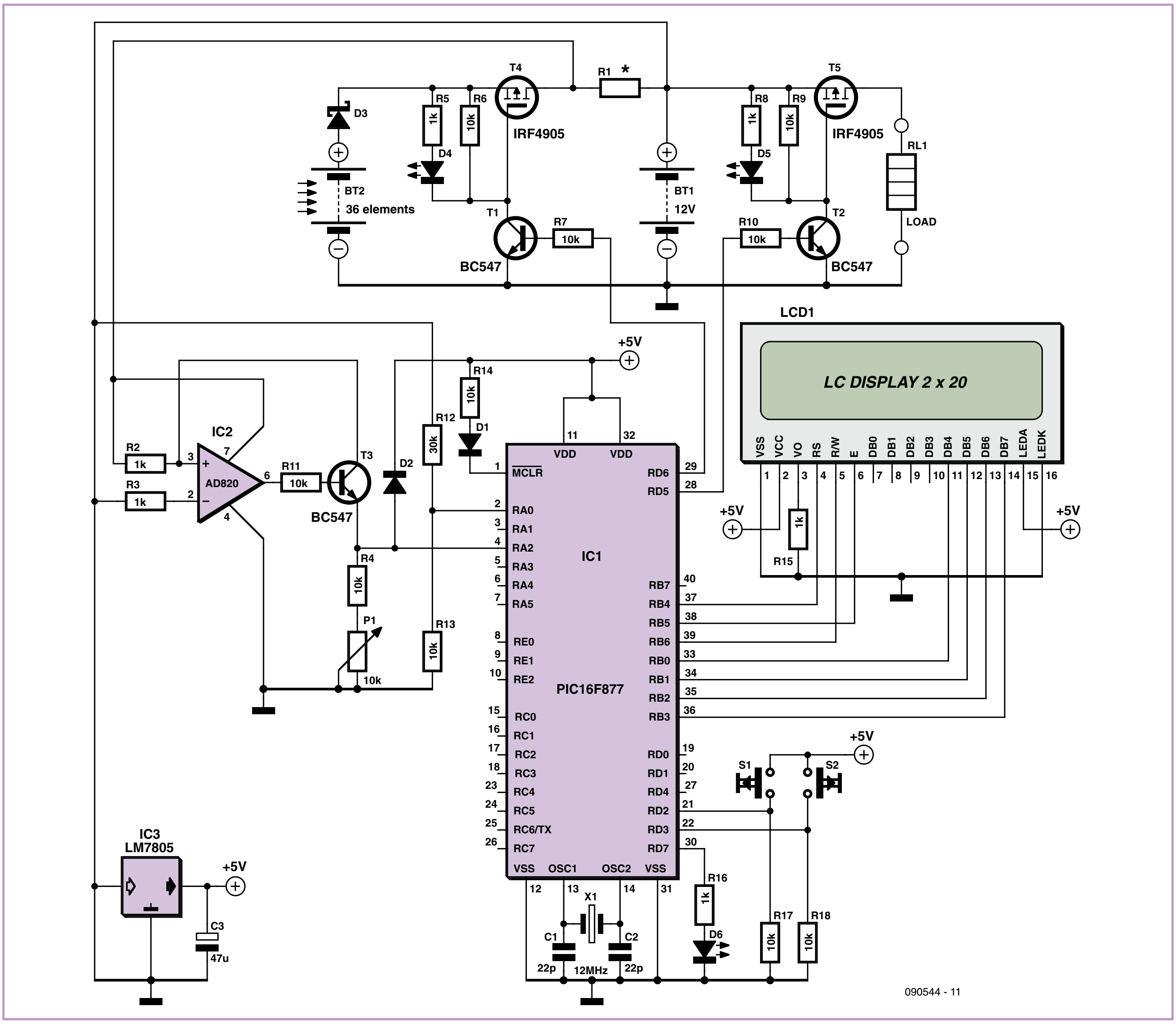
The heart of the circuit is formed by transistors T2 and T4, which follow the control signal. The accompanying capacitors C1 and C2 are charged via resistors R6 and R11. During a logic High signal, T4 will conduct and discharge 'its' capacitor (C2). Since T2 is preceded by an inverter circuit built around T1, T2 will discharge its capacitor when the control signal is 'low'.

Provided that the control signal changes often enough between high and low, both capacitors will remain nearly completely discharged and nothing else happens. If the control signal now hangs at the high level, then the capacitor connected to T2 will no longer be discharged and the capacitor voltage will increase quickly. On the other hand, the voltage across the capacitor connected to T4 will increase quickly if the control signal is stuck at the 'low' level. Via the dual diode circuit, which acts as an OR gate, T3 will be activated as soon as the voltage across one of the two capacitors builds up sufficiently. The relay that is controlled by T3, has to have a normally closed contact. The moment that the control signal stops changing, the control system will be permanently turned off via the normally-closed contact. To turn the system back on, pushbutton S1 needs to be pressed until the control signal reappears at the input of the circuit.

The circuit will operate over a wide range of power supply voltages, including 5, 9 and 12 Volts. The component values are not critical and the value of the capacitors depends on the frequency of the control signal. The time constant with a value of 10 µF amounts to 10 ms, so that the capacitors will have to be discharged at least one hundred times per second to prevent the emergency stop from operating. With higher values of capacitance the capacitors can be discharged at a proportionally slower rate. A 1N4007 can be used for the free-wheeling diode across the relay. The two diodes for the OR gate can be practically any type of signal diode. The circuit will also work with other types of transistors that have comparable specifications.

(091045-I)

Solar Cell Battery Charger/Monitor



Matthijs Hajer (The Netherlands)

During the past year the author has built a standalone solar panel system, which included the construction of the panels themselves. Such a system stores the generated energy in a battery. This is in contrast to an AC power connected system where the excess energy generated is fed back into the national electricity grid.

A battery charger/monitor was designed in order to charge the battery correctly, protect it from deep discharges and to monitor its performance. Specifications for the solar panels: 150 watts maximum at 14.5 volts. With all the losses (glass, temperature, cables, etc.) taken into consideration, the measured current from the combined panels was about 7.5 A during sunny weather (the peak values stated by the manufacturer are rarely reached in practice).

This isn't a fast charger. This charger is intended to be used with solar panels and the like (wind and water energy), where the maximum charging current is much less than 0.1 of the battery capacity C.

The circuit is built around a PIC 16F877 microcontroller. The battery voltage is measured via input RA0 with the help of a 1:3 resistive divider. To measure the current, a 'high-side' reading is taken via R1 (with a value of about 0.03 Ω, using a number of resistors connected in parallel). IC2 amplifies the measured voltage across R1 and buffers it with T3. The resulting 350 mV/A signal is fed to input RA2 of the PIC. The opamp used for the current measurement needs to have a good rail-to-rail performance and a low input offset. The gain here is (R4+P1)/(R2) and the voltage across the resistor (R4+P1) is directly proportional to the measured current. The offset at the output, which is created by the opamp itself, is measured as soon as the 'info screen' is closed (pressing S1 or S2) and used as a 'null-offset' for the current measurement. D2 protects the PIC against too large a voltage at the input.

From the measured current and battery voltage the energy input and the capacity are calculated. This information is shown on the 4x16 LCD display.

FET T4 connects the solar panels to the battery to charge it and removes the connection once the battery is fully charged. FET T5 connects the load to the battery when the voltage is high enough and disconnects it when the battery voltage becomes too low. The Schottky diode prevents the battery from slowly discharging into the solar panel when it is dark. T1 and T2 are required to drive the FETs, which work at the battery voltage, with the 5 V outputs of the PIC. LED D4 and D5 indicate when the corresponding FET is turned on.

The Schottky diode, the current resistor and the FETs have to be provided with small heatsinks.

The code for the PIC is written in C and compiled using the HI-TECH C Pro (Lite mode) compiler included with MPLAB. The code uses very little memory and isn't very time-critical. The only thing you have to make sure of is that the firmware runs at a rate of about 10 times per second in order to obtain an accurate value for the capacity measurement [Ah].

Following a reset, the PIC loads the capacity values [Ah] & [mAh] from its EEPROM and an 'info screen' appears next. This shows the firmware version, the voltages at which the load is turned on and off, and the voltage at which the charger stops charging. When either of S1 or S2 is pressed, the PIC takes 10 measurements in order to determine the offset of the current measurement stage (IC2). The average is taken of these 10 measurements and that value is then used to correct all subsequent current measurements.

When S1 is pressed, the main program is started, where the battery voltage determines whether the load is turned on or off. When S2 is pressed, the load is immediately connected until the battery voltage drops below 11.5 V.

The main program is called 10 times per second; the LCD is refreshed at a rate of 2 Hz. In the main program the A/D converters are read first, after which the values for V, I, P and C are calculated. The results determine whether the charger and load are turned on. When the main screen is displayed, only S1 has a function: When this switch is pressed, the capacity [Ah] & [mAh] is stored in the EEPROM and the info screen is shown.

The watchdog function of the PIC has been enabled in this project. This way the PIC will be reset if the software crashes. In this case the info screen will appear again, and the charger and load are turned off, which is a safe state. In this way the battery is protected against over-charging or a complete discharge due to a crashed PIC micro. When programming the PIC you have to remember to set the configuration bits for the watchdog timer. At the start of the C code they are also set.

The limits for charging the battery were taken from the datasheet from Yuasa. This type of maintenance-free gel lead-acid battery is perfectly suitable for a small solar energy system. If you use a different type of battery you may have to adjust the voltages in the code somewhat. The values used here are:

14.5 V: Gassing voltage
13.6 V: Float voltage (small charging current)
12.7 V: No load, 100% charged voltage (no charging current)
11.5 V: 50% empty with small load ($I < 0.01\ C$)

The charger turns on as soon as the battery voltage drops below 13.6 V. Should the voltage rise above 14.5 V during the charging, the charger will be turned off. Because the battery will be about 80% charged (according to the datasheet), the voltage will drop below 13.6 V again. When this happens, the charger will turn on again after 10 seconds and the battery voltage will rise. This process will repeat itself, but the 'charger-off' period will become longer the more the battery is charged. Overnight, a fully charged battery will slowly drop to 12.7 V.

Every 5 seconds the PIC transmits a text string via pin RC6/TX (2400 baud, 8n1), which shows the current state. This string could for example be sent to a web server or data-logger. An example string:

K_+12055|mV_+00826|mA_+00694|Ah_+00685|mAh–

The structure is as follows:

<Length>_<value>|<unit>_<value>|<unit>_<value>|<unit>>_<value>|<unit><CRC>

<Length> = length of the string incl. CRC (+ offset of 32 to stay within ASCII range)
_ = separator
<value> = field-value
| = separator
<unit> = units of the value
<CRC> = sum of the previous characters mod 256.

The source and hex code files for this project are available free from the Elektor website as archive file # 090544-11.zip. A programmed controlled is available under product number 090544-41.

(090544)

DIY Front Panels

Henk van Zwam (The Netherlands)

This issue includes an article on a handy DIY front panel design program called Galva. Once your design is ready, the next question is how to convert it into a real front panel. One option for this is described here.

There is material available that you can print using your own printer. It is called waterslide transfer paper or waterslide decal paper, and it is the same as the decal material well known to many builders of model aeroplanes. You loosen the decals from the base material in water and then place them on the model aeroplane.

The material looks the same as photo paper, and it is available in two types: one for laser printers (including color printers), and the other for inkjet printers. Transparent sheets and sheets with a background color are available in both types. The letter color is determined by the printer. A lot of information on this material, including demo videos, is available at a website we came across while researching this article [1].

It's just as easy to use as simply printing a normal sheet of paper. If you use a laser printer (color or monochrome), the toner is melted into the material and is therefore well bonded. If you use an inkjet printer, you need to fix the ink to the material after printing. Spray cans with a special fixing agent are available for this purpose.

Now let's examine the process of applying the material to the front panel. After degreasing the aluminium front panel, coat it with several layers of matt grey undercoating for car paint (applied with a spray can). Cut the lettering segments out of the printed sheet and immerse them in water, one at a time. After half a minute or so, depending on the water temperature, you can take the transfer out of the water and feel whether it slides around on the paper. If it does, you can place the transfer where it belongs on the panel. Using tweezers, hold the transfer in the proper place and wipe it carefully with a cotton bud to squeeze out the water underneath the transfer. After the front panel is finished and well dried, it's a good idea to use apply several thin coats of matt varnish to the surface of the panel (use a spray can for this). Let the front panel dry for half an hour after each coat before applying the next one.

Tips:

1. Use demineralized water if you have hard tap water.

2. Do not use dish detergent to break the surface tension of the water, since it causes soap spots.

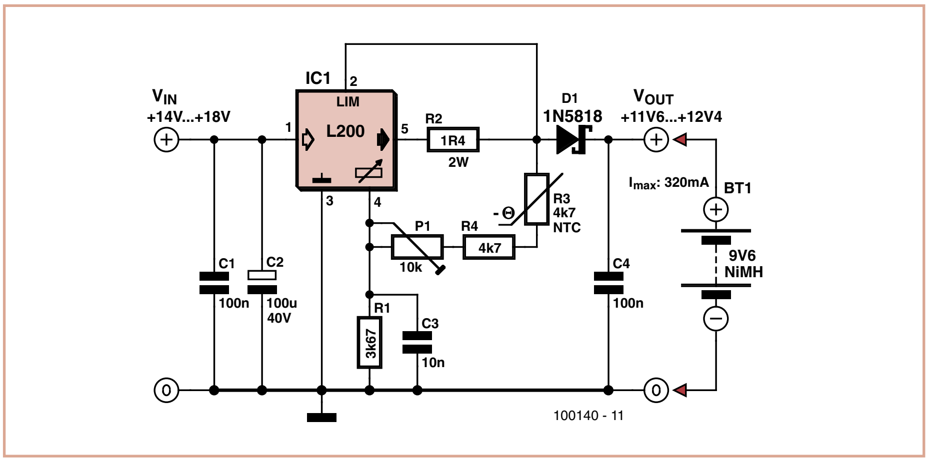
If you google "waterslide transfer" or "waterslide decal paper", you will find a lot of information and locations where you can buy it. Some suppliers even sell transfer paper by the sheet, so it's worth looking.

(100387-I)

[1] www.papilio.com/laser%20water%20slide%20decal%20paper%20original%20pas.html

L200 Charger Circuit

Wolfgang Driehaus (Germany)



This circuit came about as the result of an urgent need for a NiMH battery charger. No suitable dedicated IC being immediately to hand, the author pressed an L200 regulator and a 4.7 kΩ NTC thermistor into service. Those components were enough to form the basis of a charger with a cut-off condition based on cell temperature rise rather than relying on the more common negative delta-V detection.

The circuit uses the L200 with the thermistor in the feedback loop. When 'cold' the output voltage of the regulator is about 1.55 V per cell; when 'warm', at a cell temperature of about 35 °C to 40 °C, the output voltage is about 1.45 V per cell and the thermistor has a resistance of about 3.3 kΩ. This temperature sensing is enough to prevent the cells from being overcharged. P1 adjusts the charging voltage, and R2 limits the charge current to 320 mA. The IC is fitted with a small 20 K/W heatsink as it dissipates around 1.2 watts in use.

The charger circuit can be connected permanently to the battery pack. Charging starts when a 'plugtop' adaptor is connected to the input of the charger. The unregulated 12 V supply used by the author delivered an open-circuit voltage of 18 V, dropping to 14 V under load. Even though the charge voltage is reduced when charging is complete, the cells should not be left permanently on charge.

The author uses the circuit to charge the battery in a torch. After three years and some 150 charge cycles the cells are showing no signs of losing any capacity.

(100140)

AM Receiver with Quadrature Mixer

Gert Baars (The Netherlands)

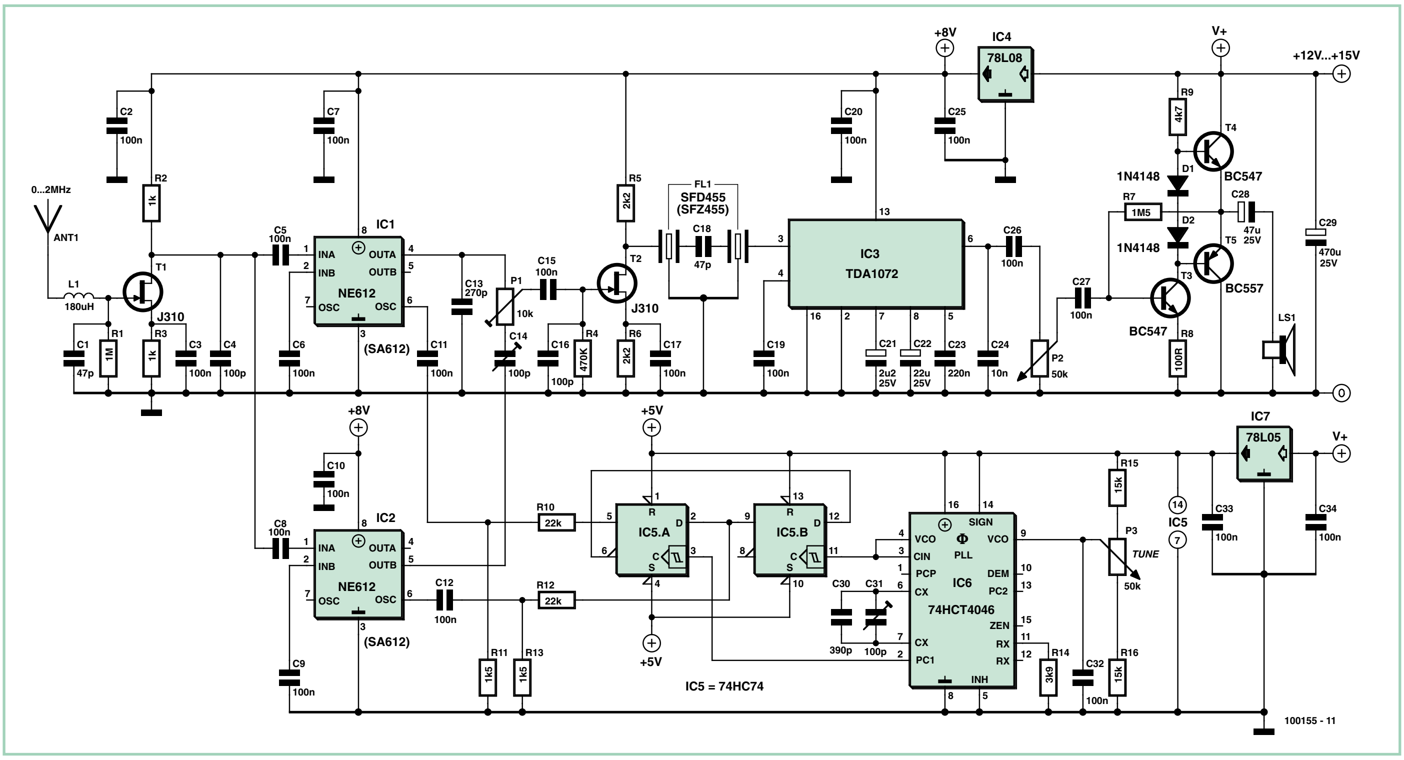
This circuit is for a superheterodyne receiver where the image frequency is suppressed without the use of an input filter. Instead, it uses two NE(SA)612 type mixer ICs that each work 90° out of phase. With a quadrature front-end, the image frequency is rejected and the noise associated with it disappears. In theory, this increases the sensitivity of the receiver by 6 dB.

The phase shift of the local oscillator (LO) is provided by two D-type flipflops configured as a ring counter. The outputs of the flipflops always change in the same order. The result is a frequency that is half that of the oscillator, but with a 90° phase shift between them. These signals are normally called 'Q' (quadrature) and 'I' (in phase).

Phase shifting of the output is provided by two simple RC networks. For the Q mixer the phase shift is set to –45° using a capacitor; for the I mixer it is set to +45° using trimmer (C14). The total phase difference is therefore 90°. The signals are added very simply, using a preset (P1). In this configuration the input frequency is equal to $f_o - f_{if}$ and the image frequency $f_i = f_o + f_{if}$, where the latter is suppressed.

With a low IF, such as used in Software Defined Radio, the phase shifting following the mixers has to cover a relatively wide band, because the IF frequency is low compared to the IF bandwidth. This is much easier to achieve using software rather than a complex phase shifting RC network. With this AM receiver the IF bandwidth is small compared to the centre IF frequency of 455 kHz and the maximum phase error is almost negligible even when a simple RC network is used.

We've used a standard IC for the demodulation: the TDA1072. To drive a loudspeaker



we've added a simple amplifier stage using a pair of transistors (BC547 and BC557) along with a potentiometer (P2) for the volume control.

When setting up the receiver the lowest frequency of the VCO can be configured such that DC can be received. This can be done by ear because the noise disappears and a 50 Hz hum becomes audible. Setting up the phase shifting can be done with the help of a station that's on the same frequency as the image frequency.

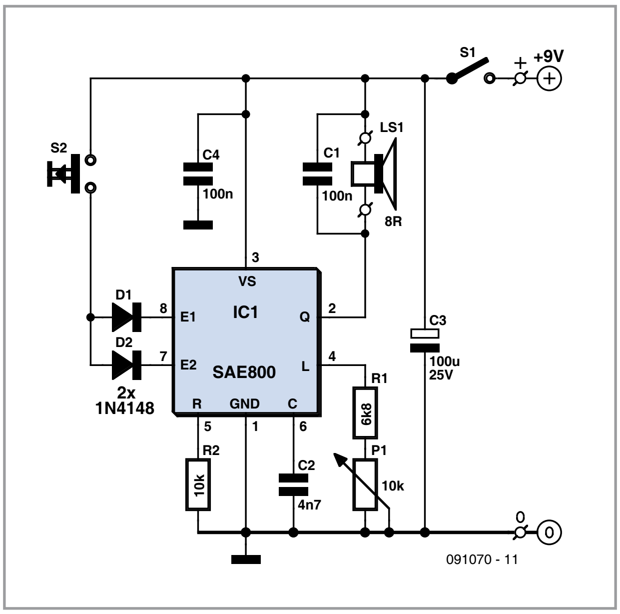
It could happen that the fixed phase shift at the output of the Q mixer isn't exactly –45°, but could be –43°, for example. If you now adjust the trimmer such that the phase shift becomes +47,° the difference becomes 90° again. This is a matter of making small adjustments to the preset and trimmer alternately, while the suppression becomes progressively better until the station is no longer audible due to the image rejection.

(100155)

Musical Horn for ATBs

Christian Tavernier (France)

If you are both an all-terrain biker and handy with a soldering iron, then we suggest you build this musical horn which, apart from the fact of having a much pleasanter sound than a simple bell, will usually make passers-by turn to you with a broad smile, so surprised will they be to hear these few notes coming from an ATB or mountain-bike.



To achieve this, we have repurposed the SAE800 integrated circuit, which is theoretically designed for doorbells or musical chimes for houses. It takes only a very few external components and can run off any voltage between 2.8 and 18 V. So even with a seriously flat battery, it will go on working — though admittedly at the expense of sound volume. This is relatively high and can be adjusted, to a certain extent, by potentiometer P1.

Switch S1 is only vital if you want to make the battery last as long as possible. When the circuit is not activated, i.e. when push-button S2 is not pressed, it goes automatically into standby-by mode, when it consumes only a measly 1 µA or so.

IC1 produces three different sounds, depending on whether E1 or E2, or both together, are activated. This is what we've decided to do here using diodes D1 and D2, as this lets us obtain the most attractive sound, consisting of three notes at 440 Hz, 550 Hz, and 660 Hz, partly overlapping and of decreasing amplitude for around 7 s. Of course, there's nothing to prevent you choosing a different option by fitting only D1 or D2 and leaving the unused input floating.

The project doesn't present any specific difficulties, but it will need to be fitted into a watertight plastic case, to protect it from rain. For the same reason, it would be wise to choose a loudspeaker with a Mylar (plastic) cone, because the traditional fibre cone doesn't get on very well with humidity. Switch S1, if used, and push-button S2 will also need to be chosen to be relatively resistant to humidity. The types available with a small rubber 'boot' are ideal.

(091070-I)

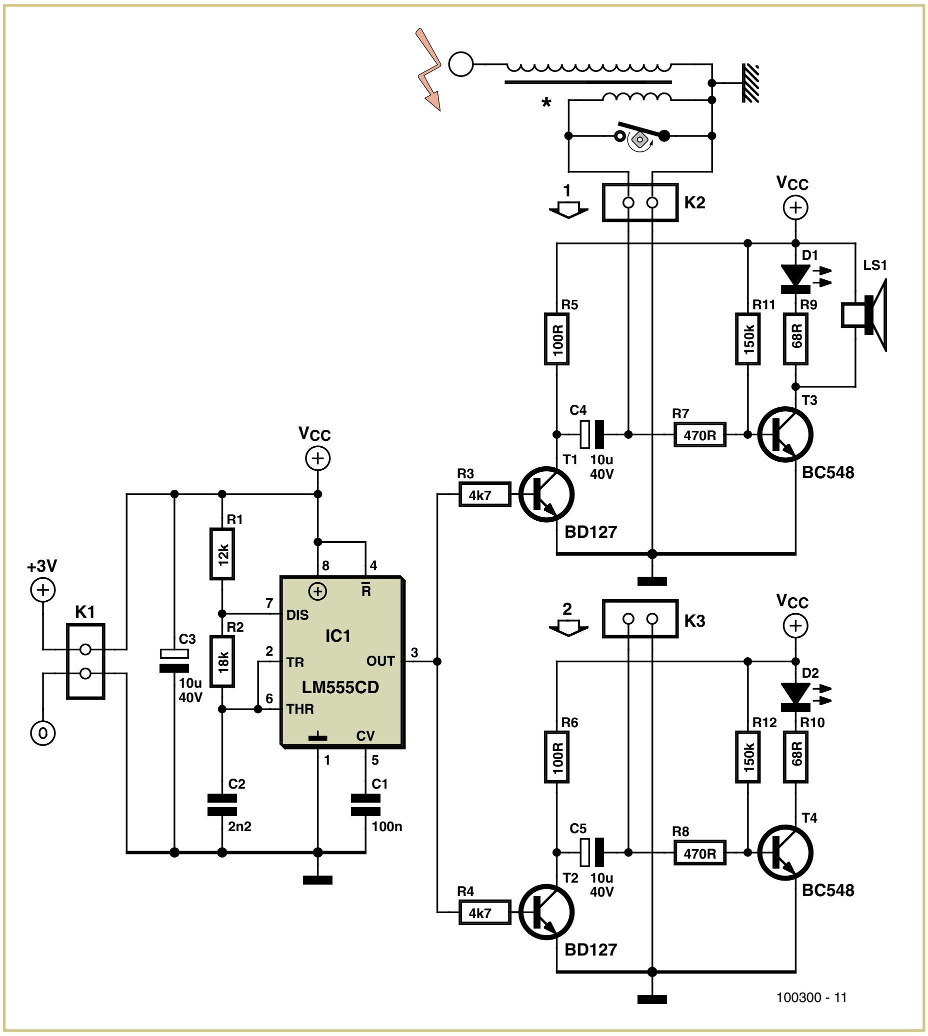
Caution. The installation and use of this circuit may be subject to legal restrictions in your country, state or area.

Ignition Timer

Philip Muylaert (B)

This circuit is a tester for flywheel-based ignition systems in small aeroplane engines. Basically the same ignition coils are also seen in other small combustion engines used in/on mopeds and lawn mowers — in brief, engines without a battery.

The part to be tested comprises a primary coil in parallel with the contact breaker. The timing of this contact breaker has to be adjusted correctly. Since the coil's primary has a very low resistance it is difficult to determine whether the contact breaker is open or closed. However, you can determine that reliably with this circuit, using an LED and a beeper. The circuit is implemented twice because aviation engines (Cessna, Piper and similar) always have two ignitions in parallel to increase reliability. For two-cylinder engines, well the purpose is obvious.



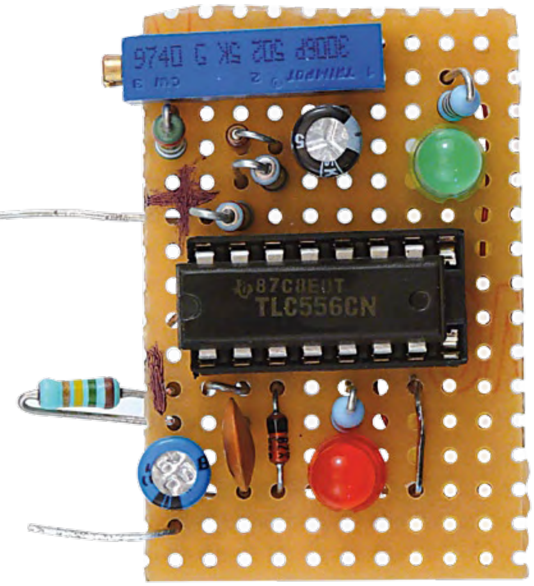
The circuit consists of a 555 and a few transistors. The 555 supplies a square wave of about 3000 Hz. This signal goes to power transistors T1 and T2; these can supply quite a bit of power and are robust enough to withstand the voltage transients from the big coils. The test connection (K2 and K3 respectively) are connected in parallel with the contact breaker to be tested, which itself is in parallel with the ignition coil. The frequency of 3000 Hz is either short circuited by the contact breaker or — if the points are open — is amplified somewhat by the resonance of the coil itself. This allows you to reliably detect the difference between a closed and open contact breaker, despite the low resistance of the coil, which is in parallel with it. When the contact breaker is open the amplified pulses will turn on T3 and T4 respectively, so that the relevant LEDs turn on and the buzzer will sound.
The components are not critical, but do use a sensitive type for the piezo buzzer. The power supply is 3 V (2 times AA or AAA batteries).

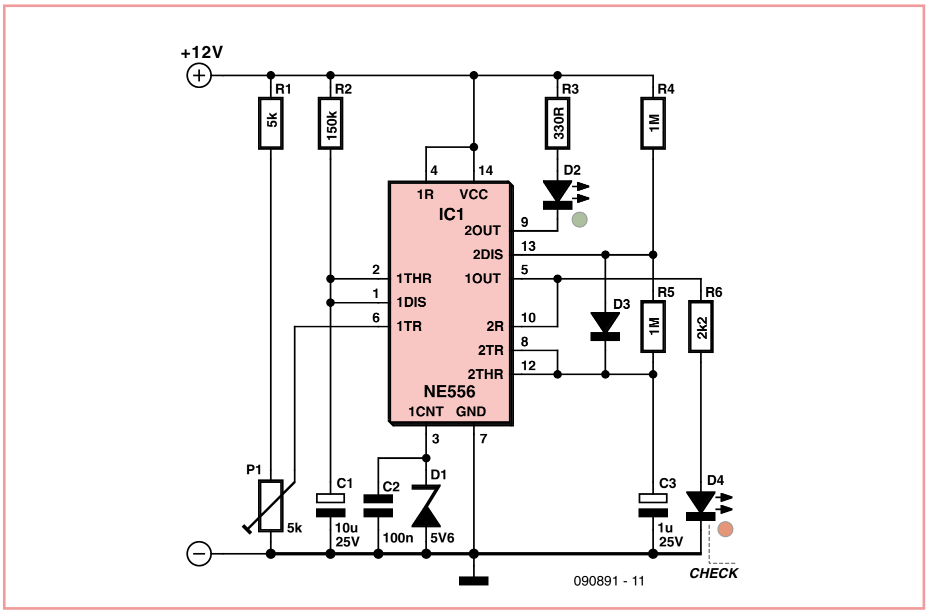
(100300-I)

Voltage Monitor

Jürgen Okroy (Germany)

This voltage monitor circuit is based on an Elektor design with a 555 timer IC in the book *302 Circuits*, which uses two LEDs (red and green) to indicate whether the voltage is within range (bad or good). However, in practice this circuit has some shortcomings because the change in the indicated color when the voltage drops below the threshold often goes unnoticed.
The circuit described here is designed to mon-





itor a 12-V supply voltage (such as voltage of the electrical system in a car) and signals an undervoltage situation with a blinking green LED, which is more likely to be noticed. The small red LED also lights up in case of undervoltage to provide confirmation.

The 556 IC used here contains two 555 timers. One of them detects the switching threshold, and the other provides the blinking function.

The threshold voltage for the undervoltage warning can be set to the desired value with potentiometer P1.

The current consumption of the circuit depends on the type of LED used. If a low-current LED is used as the blinking indicator, the value of the series resistor (here 330 ohms) must be increased significantly.

(090891-I)

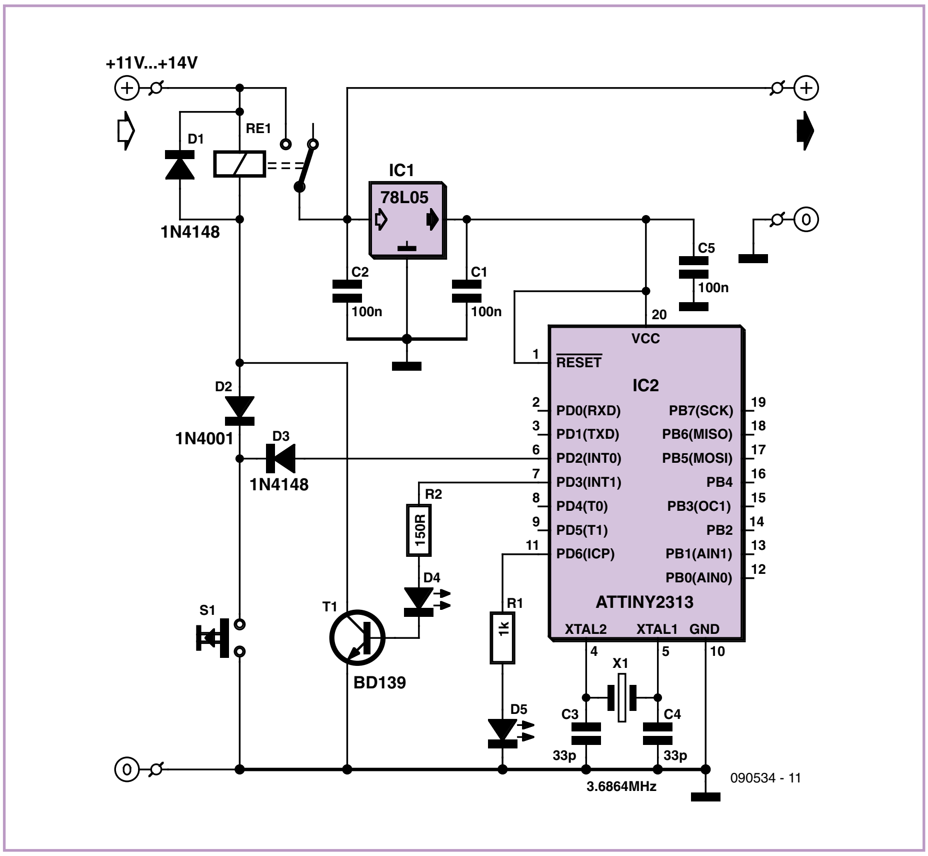
Universal Timer with Zero Standby Current

Jürgen Stannieder (Germany)

This design came about when the author wanted better control of his 12 V solar-charged garden lighting installation. It is however a versatile circuit which can also be used to switch other types of equipment. Pressing pushbutton T1 energizes the relay K1 connecting the supply to the circuit, powering the 78L05 and generating a 5 V supply for the ATtiny2313 microcontroller. The output PD3 (pin 7) will now be switched High by the microcontroller to turn on the transistor and hold in the relay, keeping the lighting on for a pre-programmed length of time defined in firmware. A press of the same button can either turn off the lights or extend the lighting period.

Pushbutton T1 is connected via D3 to input PD2 (pin 6). A press of T1 (a minimum of three seconds after timer start) will stop the timer, turn the lights off and disconnect the circuit from the power supply.

The on-time can also be extended: one minute before the timing period ends the LED on PD6 (pin 11) will light up, warning that the switched equipment (the garden lighting in



the author’s case) will shortly be turned off. Pressing button T1 (start/stop) now restarts the counter and extends the on time for a further period. As before the timer can be terminated at any other time by a press of T1.

The timing periods can be easily changed by altering the values defined in the source code (download from [1]) for the ATtiny2313 and recompiling the program.

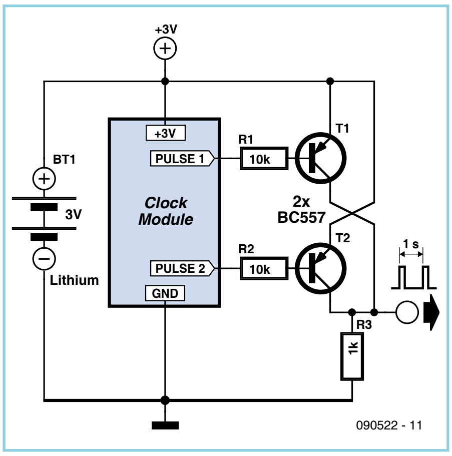
Diode D3 prevents current flowing through the relay and into the I/O pin of the microcontroller when the circuit is in its off state. Without D3 the circuit would be continuously switched on.

In its off-state the circuit (including the 78L05 voltage regulator) is disconnected from the supply giving a total standby current of zero!

(090534)

[1] www.elektor.com/090534

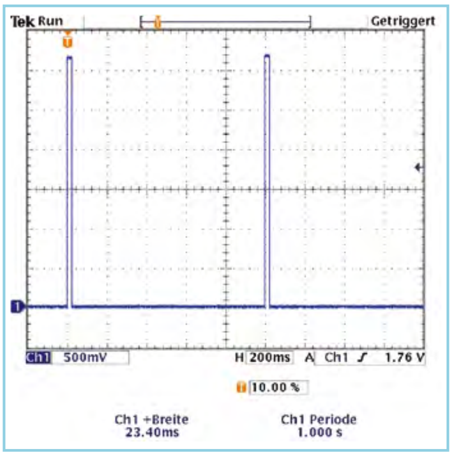
Quartz Clock Timebase



Claus Torstrick (Germany)

Many electronic projects call for a timebase generator, accurate to a second or so. One way of producing this is with a microcontroller, quartz crystal and some software. But a far cheaper and simpler approach is to recycle an old analog quartz clock. After investigating a number of clocks the author discovered that they all use the same drive method: a tiny solenoid coil is pulsed by a current that reverses direction once a second. In the module illustrated this coil is connected between pins Pulse1 and Pulse2. Most of the time both pins are ‘high’ at supply voltage but every second the clock electronics pull first one and then the other of the pins down to ground for about 25 ms.

We need just five additional components to complete the circuit (see diagram). When either of the pulse pins is at ground potential, the corresponding PNP transistor conducts. Once a second a narrow pulse is produced, which is ideal for our own digital circuitry. The author himself uses one of these clock modules as timebase for a data logger with excellent results. Although the clock originally



used a 1.5 V supply, this new arrangement works fine with a 3-V lithium battery. After three months using the same battery there have been no problems whatsoever.

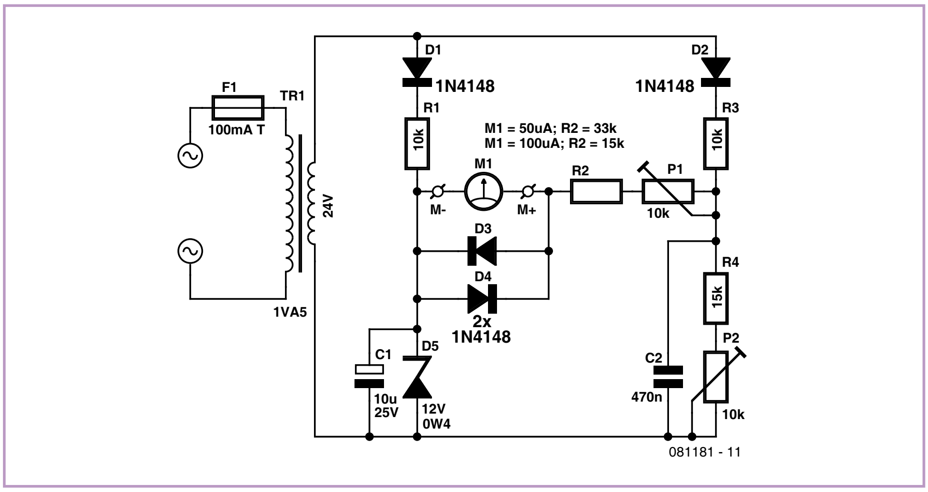
(090522)

Powerline Voltmeter

Christian Tavernier (France)

Here’s a rather special voltmeter that will let you measure the AC grid voltage and also see very accurately how it fluctuates around its nominal value. The voltmeter has a measuring range of around 35 V that you can center around the nominal voltage from the grid.

The circuit uses a bridge supplied at low voltage to make it easier to implement. The voltage available at TR1 secondary, which reflects the mains voltage multiplied by the transformer ratio (fixed and constant), is rectified by D1, filtered by C1, and stabilized at 12 V by D5. This same voltage is also rectified by D2, but this time is not stabilized and is only slightly filtered by C2 so that the circuit remains responsive. Given the value of R3, R4, and P2, the voltage at the junction of R3 and R4 can be adjusted to 12 V when the



mains is at its nominal value. Any increase or decrease in it will then vary the voltage at this point and change the reading of meter M1 accordingly.

There’s no need to use a centre-zero meter, thanks to the adjustment available via P1 and P2. All you have to do is decide that when the needle is at the center of its travel, this cor-

responds to 115 V. In this way, you'll have a margin in both directions for indicating any increase or reduction. The circuit diagram gives you a choice between two types of widely-available meter, but by modifying R2, and possibly R3 and R4, it can be adapted to use practically any reasonably sensitive meter.
It's not difficult to adjust this circuit, but you do need to have access to a variable transformer (variac). As these aren't particularly common, contact your local technical college, for example, where you should be able to borrow one just long enough for your adjustments. Remember, most variacs are auto-transformers, i.e. they do not afford electrical isolation. To adjust, set P1 to mid travel and adjust the variac to 115 V. Now adjust P2 so that the meter reads 0. Then turn the variac up to 130 V and set P1 so the meter reads full scale. Do watch out, though, as the simplicity of the circuit means there is some interaction between the two adjustments, so you'll need to work by successive approximation to achieve the best compromise — but it'll still only take you a few minutes.

All that is left for you to do is to graduate the meter scale from, say, 100 to 130 V, and you'll have a magnificent expanded-scale voltmeter that will let you follow the slightest variation in the AC powerline voltage.

(081181-I)

[1] www.elektor.com/081181

Simple LED Constant Current Source

Rainer Schuster (Germany)

Chip manufacturers are always coming up with ever more sophisticated constant current driver chips for LEDs. We have included this design for those of you who prefer a more cheap and cheerful solution.

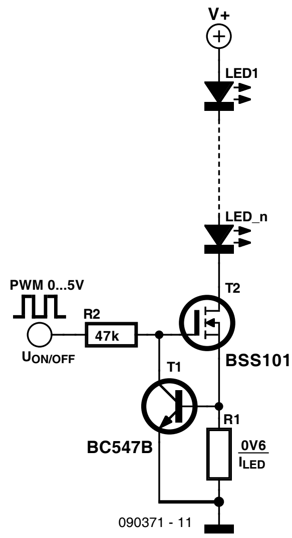
Current through the LEDs produces a voltage drop across resistor R1. As the current rises to a level to produce a voltage drop of 0.6 V across R1 it will cause T2 to start conducting and shunt the gate voltage of T1 to ground. This produces a constant current I = 0.6 V/R1 through the LEDs.

The control input allows the LEDs to be switched on by applying a voltage in the range of 5 V up to around 12 V and switched off by applying a voltage of 0 V. When this input is driven by a pulsewidth modulated signal it gives the possibility to change the LED brightness.

The supply voltage for all the series connected LEDs can be as high as practical providing the maximum drain-source rating of T2 is not exceeded. The choice of T2 and any necessary heat sink will depend on the power dissipated in this device. This can be calculated from:

(Supply voltage minus the voltage drop across the LEDs) × I_{LED}

(090371)

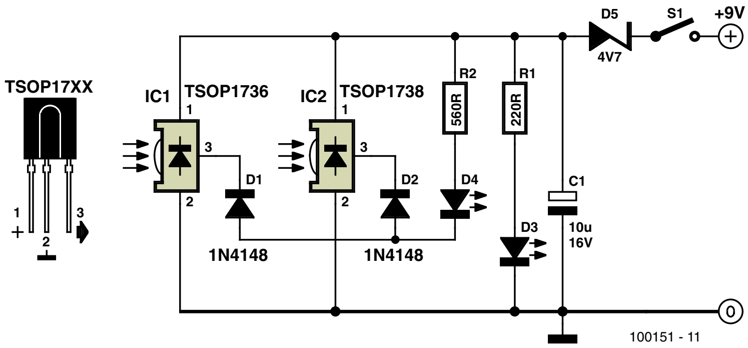


Universal IR Remote Control Tester

Leo Szumylowycz (Germany)

This tester consists of two integrated remote control receivers whose outputs drive an LED to indicate when a suitable infrared signal is received. To cover all current infrared remote controls, one receiver (the TSOP1736) has maximum sensitivity to carriers at 36 kHz, the other (the TSOP1738) to carriers at 38 kHz.

The outputs of the two ICs are connected to indicator LED D4 via D1, D2 and R2. If the output of either of the two ICs goes low the LED will light, and the diodes isolate the outputs of the ICs from one another.



The other LED (D3) indicates when power is applied. The LEDs are white with a minimum output of 20,000 mcd at 20 mA, which means that even at 5 mA (the maximum output current of the receiver ICs) the indicator LED will light reasonably brightly. In his prototype the author used 5 mm LEDs with an output of typ-

ically 55,000 mcd at 20 mA.
The Zener diode reduces the supply voltage for the receiver ICs to about 4.3 V. In fact, they will operate reliably down to about 3.2 V. The circuit is powered from a 9 V PP3-style (IEC: 6LR22) battery, and will function until the battery voltage falls to about 7 V.

(100151)

Tiny Timer

Wilfried Wätzig (Germany)

Developing a lighting control unit recently, the author found that available analog or mechanical timers were not sufficiently accurate or convenient. Without further ado he developed a timer switch driven by a small AVR controller of the type ATtiny2313.

The device presented here can switch a load on and off with 1-second accuracy for a period ranging from one second to 99:59:59 hours. By using a very compact LCD display (the HMC16223 with dimensions of just 52 mm x 20 mm) it was possible to construct the prototype inside a standard wall outlet box.
The ATtiny2313 is timed using a 4.9152 MHz crystal to produce an internal timebase of exactly 1 second. The LCD is driven in 4-bit mode. Data input is by press buttons, making use of the pull-up resistors built into this little controller. The miniature transformer (9 V, 1.5 W) provides electrical isolation between the AC grid and the operating voltage for controller and LCD.

For small switching loads (below 200 W) the power relay can be replaced by an all-electronic solid state relay (e.g. Sharp S202 S02).

AC powerline voltage circuits are not for beginners and it's vital to observe the relevant safety guidelines at all times!

You are recommended to divide the circuit between two separate boards: LCD, microcontroller and press buttons on one and transformer, rectifier and switching relay on the other.

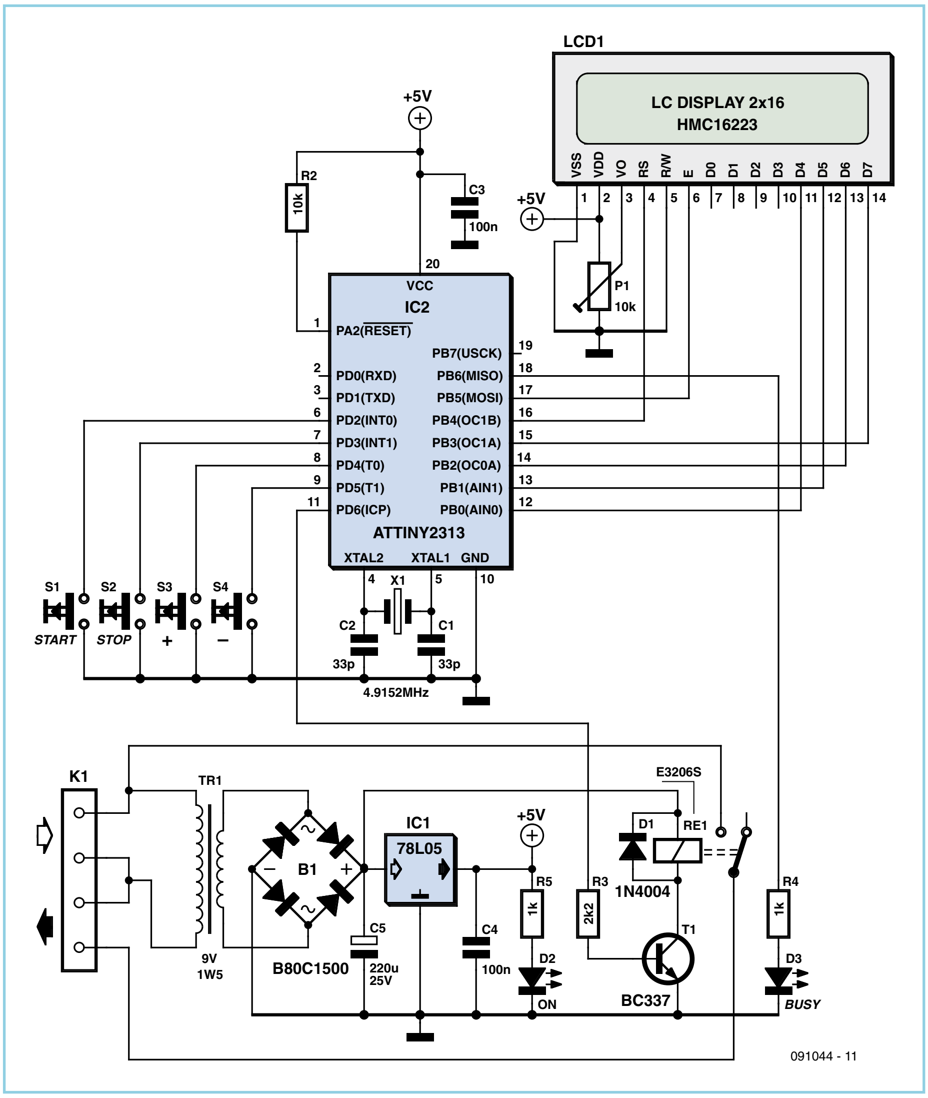
Here's how you use the timer switch:
When the timer is running the preset time period and time remaining are displayed on the readout:

PRESET 1:10:08
COUNT 0:09:59

An alternative format can be selected if you wish:

PRESET 1h 10m 8s
COUNT 0h 9m59s

The four function buttons are used as follows:



START: Start timer for the preset period
STOP: Stop timer, select menu for setting values and options
PLUS: Increment the selected value by 1
MINUS: Decrement the selected value by 1

The following values can be set:

Menu 1:	SET HOURS 00
Menu 2:	SET MINUTES 00
Menu 3:	SET SECONDS 00
Menu 4:	SET DISPMODE 0

Push buttons PLUS und MINUS alter the selected value and pressing them both simultaneously resets the value to zero.

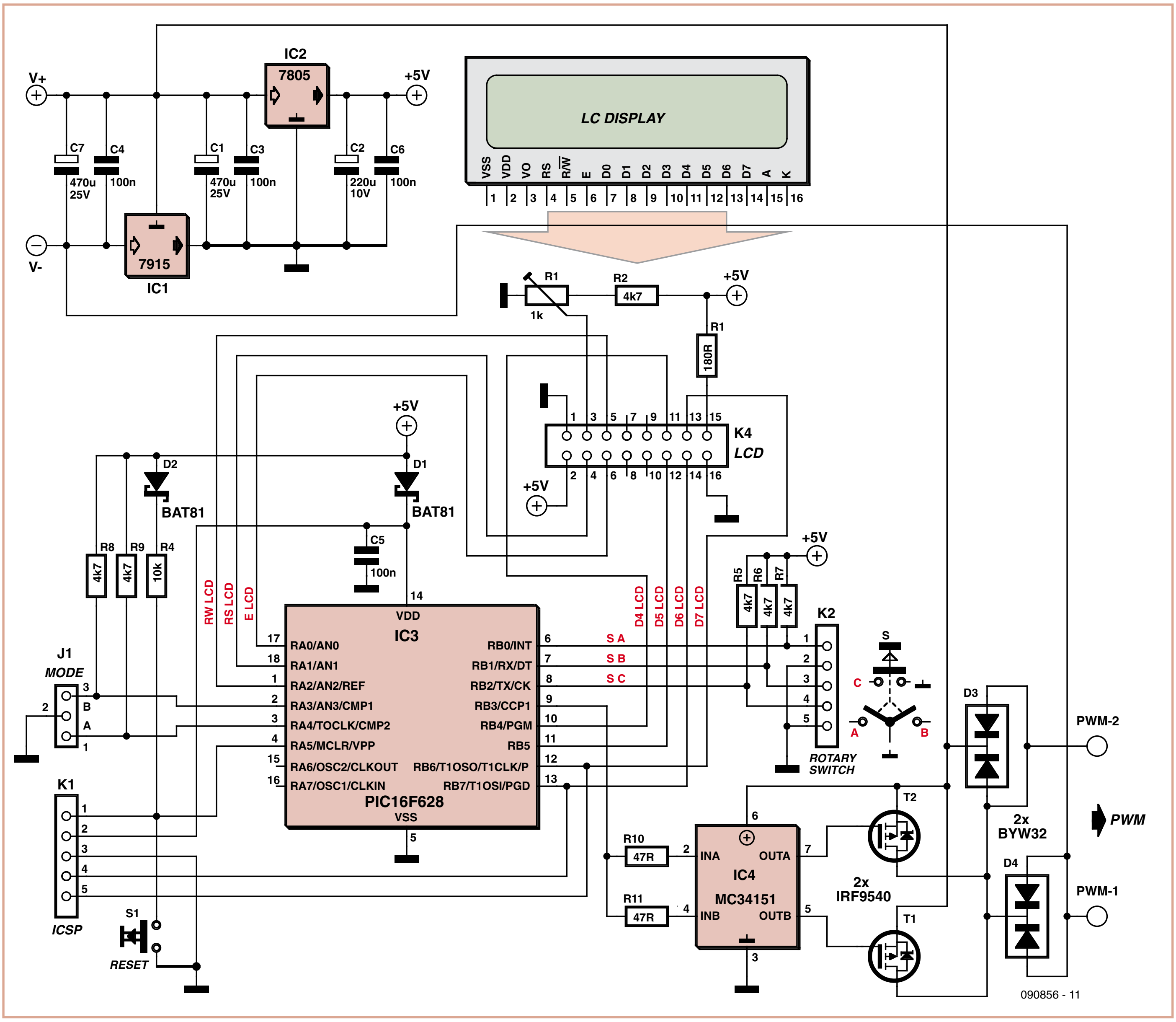
A programmed controller is available from the Elektor shop under order code 091044-41 (www.elektor.com/091044). If you enjoy doing the programming yourself, the fuses of the ATtiny2313 should be set as follows:

EXT. byte: 0xFF - (brown out det. off, no CKDIV8)
HIGH byte: 0xDF - (ext. crystal > 3 MHz)
LOW byte: 0xFD - (64ms start up)

As usual the hex and source code can be downloaded free from the Elektor website (www.elektor.com/091044).

(091044)

Universal PWM Driver



Herbert Musser (Austria) and Alexander Ziemek (Germany)

PWM drivers are used in analyzing, testing, installing and powering all kinds of electronic and electrical devices. We have published a few designs in Elektor over the years: here we present a 'de luxe' version suitable for a very wide range of applications. As usual the software for the project (source code and hex file) can be downloaded for free from the accompanying pages on the Elektor website [1], and ready-programmed microcontrollers are also available. Additionally, the authors' Eagle design files for the printed circuit board are available for download.

The main user control, used for adjusting almost all the settings, is an Alps incremental rotary encoder. This is accompanied by a mode switch used to select the operating mode from among 'off', 'PWM' and 'full power': a three-position center-off switch is suitable. The two controls are connected via headers (K2 and J1). The current settings of the circuit are shown on a standard LCD panel with two rows of sixteen characters, which is connected to the PCB via a standard connector.

At the heart of the circuit is a PIC16F628 microcontroller (a PIC16F628A may also be used). An output stage consisting of two power FETs wired in parallel, along with heavy-duty flyback diodes, allows the circuit to drive DC motors at up to 30 V and rated currents of up to 10 A directly and comfortably. The circuitry is capable of working at even higher currents, but then careful attention must be paid to the cross-sectional area of the conductors: tin the current-carrying circuit board tracks, or add wires in parallel with them.

The motor drive application was foremost in the authors' minds when designing the circuit. A useful feature in this application is the 'boost function', which helps DC motors to start up reliably. The output is switched on at full power for the configured boost time, regardless of the PWM duty cycle setting in force.

For reasons of safety, when the circuit is powered up the output will remain off until the mode switch is set to 'off' and then to one of the 'on' settings. This means, for example, that a connected motor will not suddenly start up when the electricity supply is restored after a power cut.

In normal operation the display shows the current PWM frequency and the duty cycle (as a percentage). The duty cycle can be adjusted using the incremental encoder.

The basic settings can be configured in the set-up menu. This menu is reached by setting the mode switch to 'off' and pressing in the incremental encoder for a few seconds.

The menu includes the following options:
Boost: on / off
Boost time: 1 second / 2 seconds / 5 seconds
PWM frequency: 1 kHz / 2 kHz / 5 kHz
PWM step: 1 % / 2 % / 5 % / 10 %

Choosing 'exit' leaves the set-up menu.

The 'PWM step' parameter determines the amount by which the duty cycle increases or decreases in PWM mode for each step of the rotary encoder.

The settings are stored in the EEPROM of the PIC16F628 and so are not lost when power is removed.

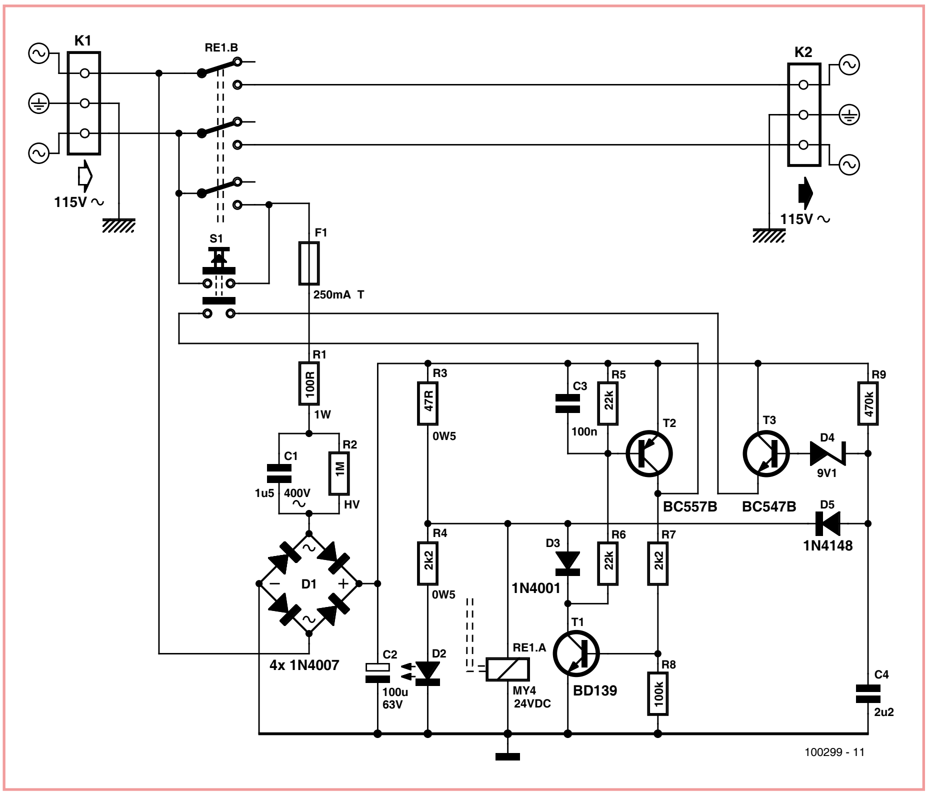
The authors' prototype of this circuit has given sterling service, outputting a clean and stable drive waveform even at a frequency of 5 kHz.

(090856)

[1] www.elektor.com/090856

Economical On/Off Power Switch

Joost Waegebaert (Belgium)



Many appliances these days are switched on and off with the simple push of a 'soft' on/off button. In the 'off' position the appliance is merely in the sleep state and continues to use a small amount of energy — and that is just 'not done' nowadays. This circuit not only retains the feature of switching on and off with one simple pushbutton but also reduces the power consumption in the off-state to zero.
When pushbutton S1 is pressed, the circuit receives its power supply voltage via the capacitive voltage divider containing C1. The rectified voltage across C2 energises the relay RE1.B via R3. LED D2 lights up. One set of the relay contacts is connected in parallel with S1, so that the relay will continue to be energized when S1 is released. The remainder of the circuit has no effect during turn on. C3 ensures that T2 blocks and capacitor C4 is not charged yet. Both conditions ensure that T1 does not have any base current and is therefore off. The relay can now close and the AC powerline voltage across K1 is switched through to K2.
After power on, C4 will charge slowly. After about 0.25 sec the voltage is high enough to turn T3 on via zener diode D4. There is now a voltage at the emitter of T3. If S1 is now pressed then T1 will receive base current via T3 and the second contact of S1. T1 conducts and shorts the voltage across RE1.B, which de-energizes the relay. At the same time T2 ensures that the circuit latches: T1 provides base current, via R6, for T2. This will conduct and provide base current for T1 via R7. So T1 will continue to conduct, even after S1 is released. C2 is discharged via R3. In this way the power supply voltage for latch T1-T2 will eventually disappear, so it will unlatch. Timing capacitor C4 is also discharged, via D5, so that the circuit is now ready for the next start.
The entire circuit is completely disconnected from the mains, the current consumption is literally zero!
The value of capacitor C1 mainly depends on the relay that is used. As an example we are using an Omron MY4-24VDC [1]. The relay is a 24V-type which is happy with a coil current of 40 mA and has contacts that allow for a load of up to 5 A. At 24 V across the relay there is a current of about 10 mA through LED D2. The total current when switching on is therefore about 50 mA. The value of capacitor C1 is roughly determined as follows:

$X_{C1} = U_{C1}/I_{C1}$ = (115 V – 24 V)/50 mA = 1.8 kΩ
C1 = $1/2\pi f X_{C1}$ = 1 / (2 x 3.14 x 50 x 4120) = 1.47 uF (1.5 uF)

It is absolutely essential that this capacitor be suitable for operation at AC grid voltages and is preferably a Class X2 type, for example one from the MKP 336 2 X2 series made by Vishay [2]. The capacitor actually limits the total current that can flow through the circuit. When T1 conducts, C1 limits the current through T1 to about 50 mA. The magnitude of this current also gives an indication of the apparent power that the circuit draws:

$P_S = U \times I$ = 115 V x 50 mA = 5.75 VA.

The actual real power of the circuit is smaller than this value, since the cos φ of the circuit is certainly smaller than 1.
Resistor R2 discharges capacitor C1 after switching off. This also has to be a type rated

for 115 VAC (for example the MBE/SMA 0414 series [3]). Switch S1 too needs to be appropriate for AC powerline operation. It is possible to replace R2 with two 'ordinary' resistors of 470 kΩ in series. Resistor R1 limits the switch-on current through S1 when capacitor C1 is discharged.

(100299-I)

[1] www.ia.omron.com/data_pdf/data_sheet/my_dsheet_gwj111-e1-03.pdf

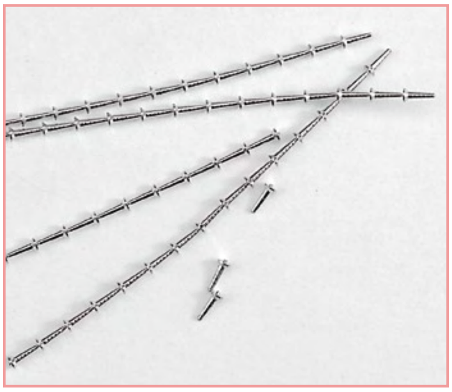
[2] www.vishay.com/docs/28120/mkp3362.pdf

[3] www.vishay.com/docs/28767/28767.pdf

Fast Reliable Vias

Kai Riedel (Germany)

There are several techniques for providing lab-grade contacts from one track side to the other on DIY printed circuit boards. They range from thin wire or solder pins through pressed-in hollow rivets (e.g. from Bungard) and through-contact sleeves (e.g. from ELV) to through-contact rivets (e.g. LPKF 'EasyContac'). These 'vias' can also be produced using electrical techniques or with solder paste. All these methods tend to be time consuming and prone to failure. Some of them also require special tools or employ expensive components.



1

The author prefers the more wallet-friendly track pins made by Harwin in various sizes. Track pins type T1559F46 [1] are available from Farnell for instance (order code 1143874) at a moderate price for a pack of 500). You just drill a hole of 0.8-mm diameter and then insert the pin. Harwin supplies a special insertion tool (Farnell order code 145248, horribly expensive; data sheet at [2]).

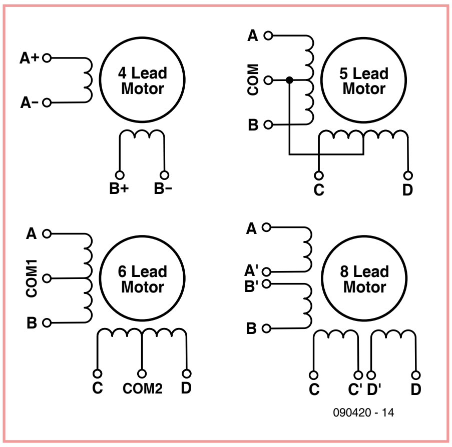
You can also insert these pins without special tools (but not as reliably). A soldering iron with a wide tip will do! Pins heated in this way can be inserted into the PCB with light pressure and then soldered on both sides. The tight fit of the pin in the hole means it will not fall out during or after the insertion and soldering processes, unlike when using pieces of thin wire. Making via connections in this way is quick and easy.

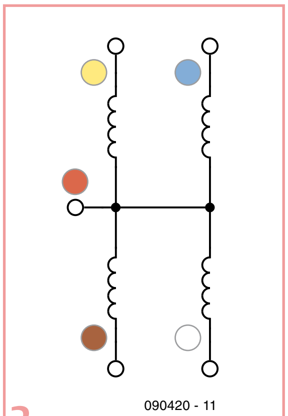
(090425)

[1] www.harwin.com/search/T1559F46?ProductSearch=True

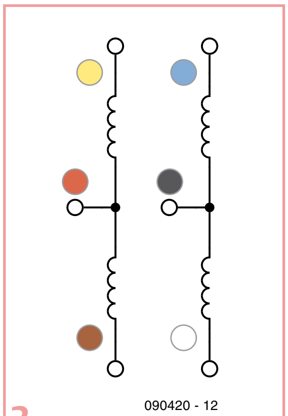
[2] www.harwin.com/include/downloads/tis/ IS-06.PDF

Identifying Stepper Motors

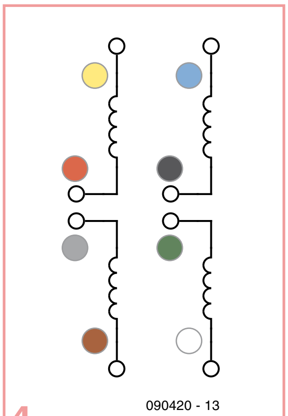




2



3



4

W.G. Jansen (The Netherlands)

There are many different types of stepper motor. Because there is no documentation available for stepper motors that have been removed from old equipment you have to carry out some measurements to identify the different wires.

We only need three things for this: an ohmmeter, an AC voltmeter and a transformer with an output voltage between 2 and 6 V. The majority of stepper motors have either two or four stator coils, which are presented to the outside world via 4, 5, 6 or 8 different colored wires, see **Figure 1**.

For a motor with **4 wires** we have to find two wires that have a resistance between them. We then write down the value of the resistance and the color of the wires. In this way, you can distinguish between the two stator coils and we know that this is a bipolar motor.

For a motor with **5 wires** (unipolar) it is more difficult to identify the four individual coils. You start with the measurement of the resistance between all the differently colored wires and make a note of them in a list (see the example in **Figure 2**). Next, find all pairs of wires that have the lowest resistance between them and call those Rx …Ω. The resistance values of the other combinations aren't important.

Measurements: yellow/red = Rx …Ω
blue/red = Rx …Ω
white/red = Rx …Ω
brown/red = Rx …Ω

From this example it appears that the red wire is the common one (COM). Two pairs of coils make up the A-B phase and the C-D phase. To find out which ones belong together we connect a small AC voltage to one of the coils, if need be via a series resistor to limit the current. In this example we chose yellow/red. Now use the AC voltmeter to measure the voltage across the remaining coils. The coil where we measure the largest voltage will be the one that forms one phase in conjunction with the yellow/red coil. It's not important whether we call this the A-B phase or C-D phase.

For a motor with **6 wires** (both bipolar as well as unipolar devices) it is straightforward to identify the individual coils. Again, we measure the resistance between all colored wires and put them in a list.

Measurements: yellow/red = Rx …Ω
red/brown = Rx …Ω
blue/black = Rx …Ω
black/white = Rx …Ω
yellow/brown = 2Rx …Ω
blue/white = 2Rx …Ω

We find a low resistance value (Rx …Ω) four times and a higher resistance (2Rx …Ω) twice. There is no connection between the two phases (see **Figure 3**). From this it can be seen that yellow/red/brown is one phase with red as common, and blue/black/white is the second phase with black as common. For bipolar use the 2Rx connections are used and the common wire is left unconnected.

For a motor with **8 wires** (both bipolar as well as unipolar devices) it is quite difficult to determine the correct order of the four coils in the two phases. As for the other motors, we start with the resistance measurements and put them in a list, which will make clear what the individual coils are (see **Figure 4**). In order to connect the coils in pairs and in the correct phase, the winding direction of each coil has to be determined. To do this, connect the transformer to one of the coils and measure the voltage across the other coils with the AC voltmeter. The coil that shows the largest voltage will be the one that forms one phase in conjunction with the coil connected to the transformer. To find out if the coils are connected in phase, the coils are connected in series and the transformer is connected across one coil. First measure the voltage across the powered coil and then across both coils in series.

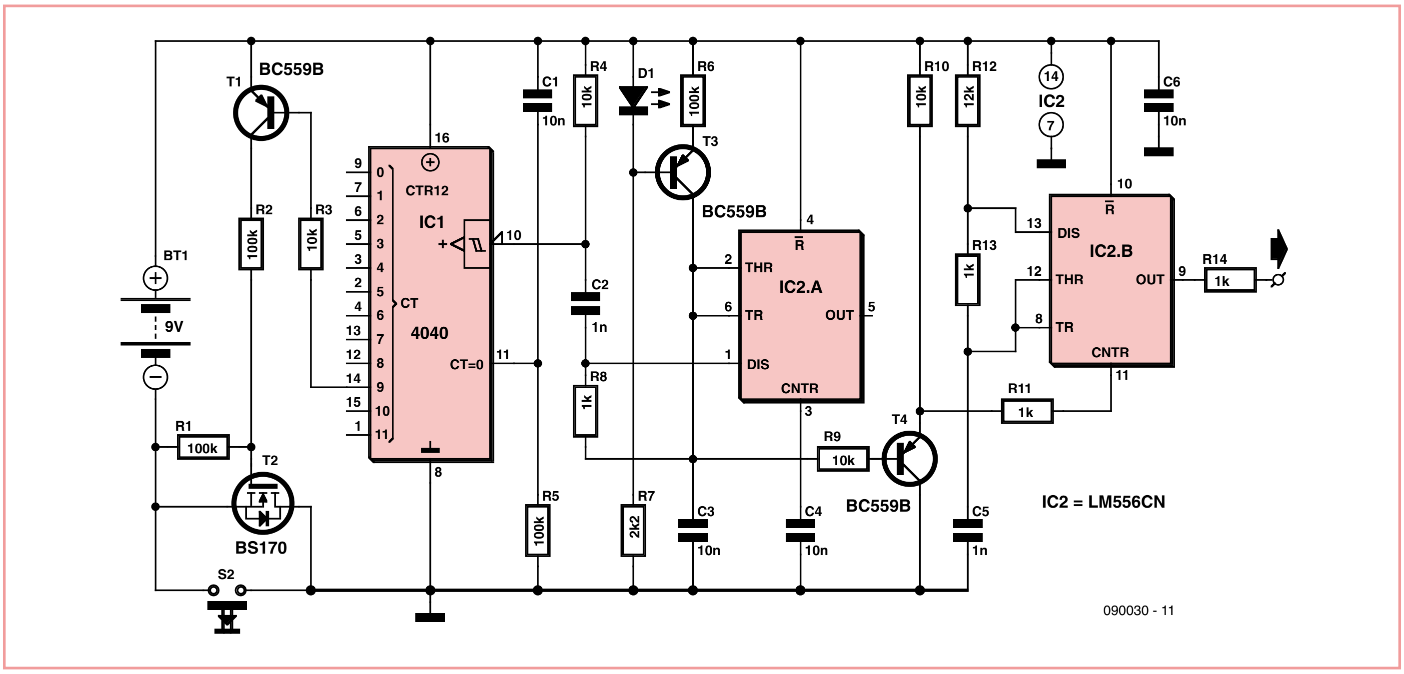
There are two possible outcomes: The voltage across the series connection is about twice that across the single coil, or it's almost zero. The correct series connection is the one where the voltage is highest. For bipolar use you should connect the two coils for each phase in series or parallel, since that results in the maximum torque from the motor.

(090420)

Literature

'Stepper Motors Uncovered',
Elektor November & December 2003.

Zapper for Electrotherapy



Jac Hettema (The Netherlands)

A zapper is a device that is often used in alternative medicine. This device is a so-called electronic bioresonance pulse generator, which generates a square wave at a particular frequency. This signal is applied to the human body via hand or wrist electrodes, causing a minute current to flow through the body. This is claimed to kill bacteria, viruses and other parasites in the body, and to boost the immune system.

After reading the relevant parts in the handbook for self-health by Dr. Hulda Clark and looking at the signal generated by such a device, the author designed a cheap DIY version of such a zapper.

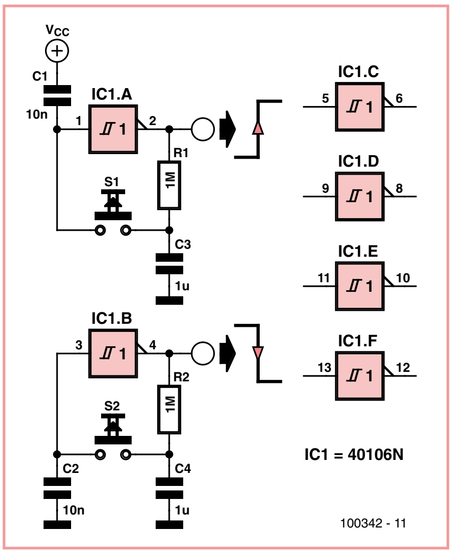
This design is significantly cheaper than the commercially available devices. As far as its effectiveness is concerned, there are various claims and counter-claims put forward, all for what it's worth. At least with this design you can try it for yourself at little cost, in any case a lot less than if you decided to buy a ready-made zapper.

This zapper outputs a square wave signal at the supply voltage of 9 V in series with a resistor of 1 kΩ. This means that the maximum output current can never exceed 9 mA (when short-circuited), which keeps it safe to use. The frequency varies between about 28 kHz and 75 kHz. C3 is charged up via a constant current source so that the change in frequency is fairly linear. The LED used in the constant current circuit doubles as the 'on' indicator for the device. After about eight minutes the zapper turns itself off, since output Q9 (pin 14) of IC2 then goes high. This stops the base current in T1, which turns off the supply voltage to the circuit via T2.

The ground and output connection (R14) of the circuit are connected to the body via two hand or wrist electrodes (in the simplest case these could be two pieces of bare wire). For safety reasons the circuit should only be powered from a 9 V battery.

Caution. Circuit not approved for medical use.

(090030)



Six-way Switch

Kees van het Hoff (The Netherlands)

The 40106 is a versatile CMOS IC containing six Schmitt trigger inverters. It can be used to implement a set of alternating-action switches with hardware contact bounce suppression.

Aside from one gate of the IC, all you need for each switch is a pushbutton, a resistor and two capacitors. It works as follows. The 1 µF capacitor at the output is charged or discharged via a 1 MΩ resistor, depending on the output level of the inverter.

Pressing the button causes the input level of the gate to change, which in turn causes the output level to toggle. The 10 nF capacitor determines the output state after the supply voltage is switched on. You can connect it to the supply voltage rail or the ground rail as required. If you hold the button pressed, the output signal will be a square wave with a frequency determined by the RC time constant, which is approximately 1 second.

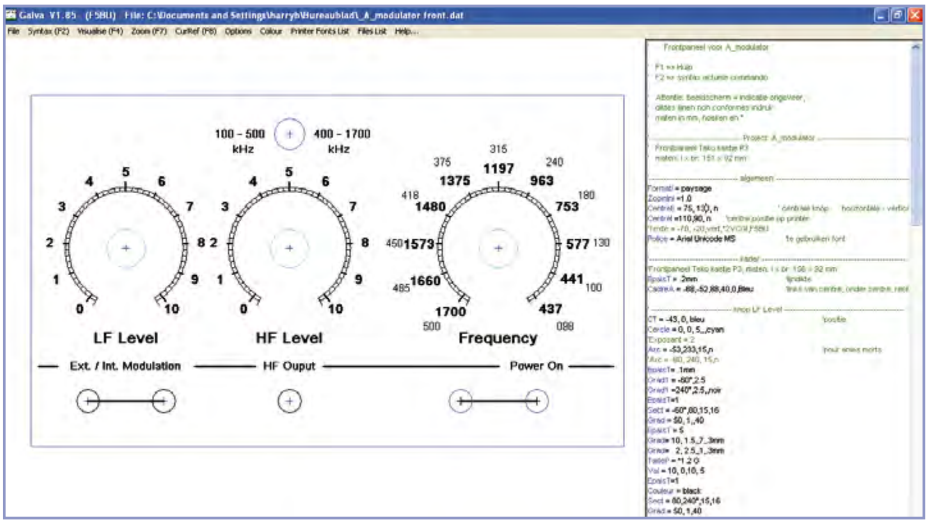
You may experiment with the component values if you wish.

(100342-I)

Front Panel Design Program

Henk van Zwam (The Netherlands)

Everybody who builds their own equipment will come across this problem at some stage: How can I create the layout for a decent front panel? Plain text can be positioned in the right place using a word processor, but scales for potentiometers, rotary switches and variable capacitors are a different matter.



For several years there has been a great program that can solve these problems: Galva (version 1.85). It is freeware and originates from France, but also offers an English language user interface. It also has an extensive help section. The design can be printed on any printer, using paper or a transparency, depending on the printer used.

The program is really a type of programming environment: The user writes a number of commands with parameters that result in the drawing when the F4 key is pressed. The program has two windows: a graphical window for the drawing and a text window where the commands are typed in. It doesn't have the usual graphical interface that we expect with most drawing programs. However, it doesn't take long to learn how to use this program because you know the reasons for issuing a specific command. Logos (signs) etc can be imported and all fonts and symbols present in Windows can be used. It almost goes without saying that colors can be used.

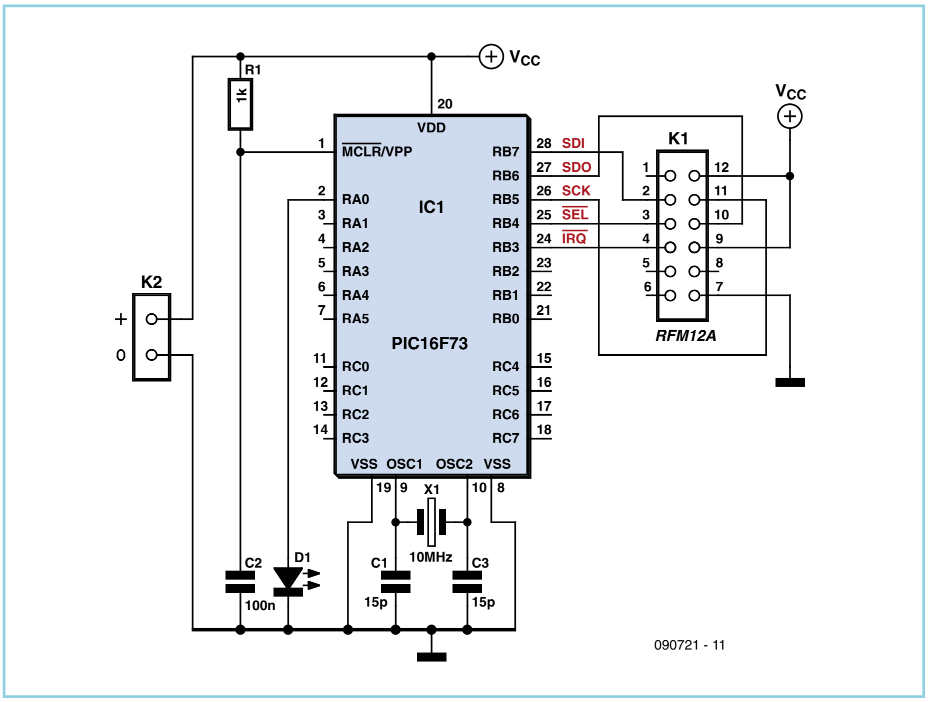
The results are amazing: scale division lines can be positioned to within a fraction of a degree, positioning of components can be done to a tenth of a millimeter. The learning curve is quite short because you can study the included examples and use them as the basis for your own designs. You can quickly see what the possibilities are when you change some of the parameters in the examples. The program is suitable for use in a large number of projects to create scales and front panels, but it can also be used to create millimeter paper, logarithmic paper, nomograms, logarithmic tables and such like.

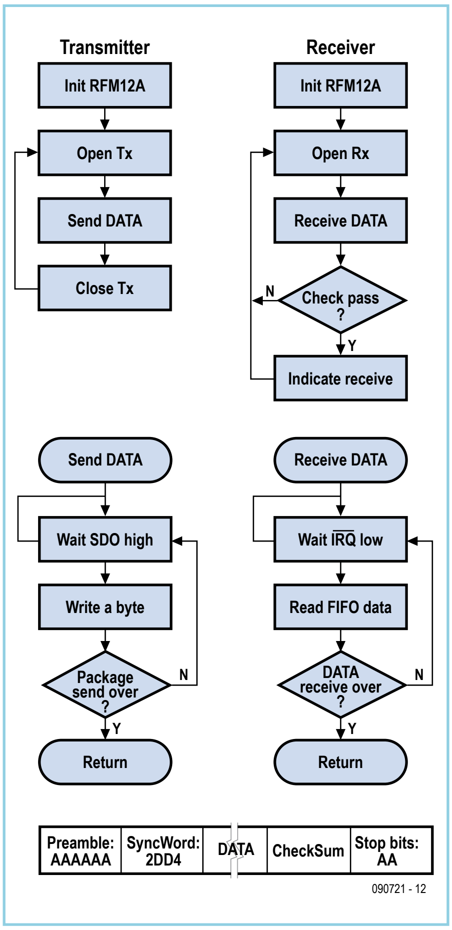
Galva can be downloaded from the (French) website at [1]. You'll find the program in the 'Electronique' section.

(100287)

[1] www.radioamateur.org/download/

PIC/C or VHDL/FPGA for RFM12 TX/RX





By Bojan Jovanovic and Milun Jevtic (Serbia)

The use of the low-cost RFM12 868 MHz (US: 915 MHz) ISM (licence-free) radio module with microcontrollers like the ATmega and the R8C13 is straightforward once you've read some relevant Elektor publications [1],[2],[3].

Here, the use of the RFM12-434-D DIP type transceiver module for 434 MHz (US: 315 MHz) [4] is proposed instead of the RFM12-868-S, which is an SMD type. Of course, the antenna length has to be changed to 17 cm to suit the lower frequency.

The authors used a PIC16F73 to control the RFM12 transceiver module. The firmware for the micro was written in C using an EasyPIC4 development board and mikro C PRO for PIC, both from Mikroelektronika. As a quasi parallel activity, software was developed in VHDL for the FPGA Cyclone II family. For this, the Altera DE2 board and QuartusII software were used.
The communication protocol governing the transmitter and receiver algorithms for the C-coded PIC16F73 are shown here. The supply voltage and logic '1' voltage are both + 5 V.

In the PIC application, the serial SPI communication interface is realized in software. Data rate and frequency deviation are 4.8 kbps and ±90 kHz respectively. During data transmission, the microcontroller monitors the SDO pin to check whether the Tx register is ready (SDO high) or not to receive the next byte. This byte is transferred serially, MSB first. When receiving data, the receiver generates an interrupt request by pulling the nIRQ pin low when the FIFO register has received data. These data bits are transferred serially, again MSB first, to the microcontroller.

Slightly different algorithms and communication protocols were applied for the CycloneII FPGA to make it talk to the RFM12 transceiver module. In this case the supply voltage and logic '1' voltage are both defined as +3.3 V.
All source code files and executables developed by the authors for both 'branches' of the project (i.e. C/PIC or VHDL/FPGA) are available free of charge from the Elektor website [5].
The RFM12-868-S is available through the Elektor Shop as item # 071125-71.

(090721)

[1] ATM18 on the Air, Elektor January 2009, www.elektor.com/080852.

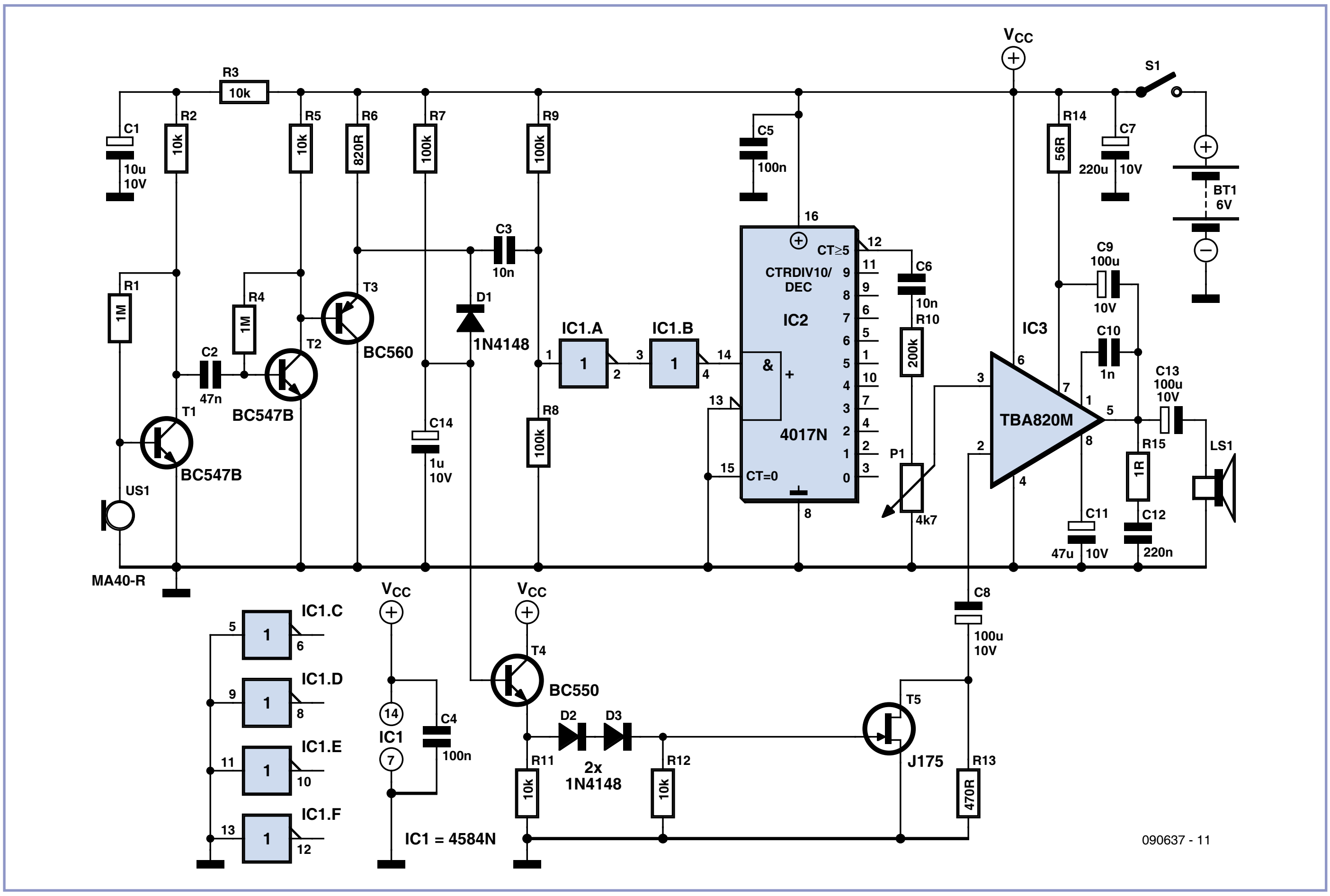
[2] Radio for Microcontrollers, Elektor January 2009, www.elektor.com/071125.

[3] USB Radio Terminal, Elektor July & August 2009, www.elektor.com/090372.

[4] www.hoperf.com

[5] www.elektor.com/090721

Bat Receiver



Guy Boniface and
Jean Rowenczyn (France)

Here's a novel way of listening to bats over the Summer. Put the receiver — powered by four AA (R6) cells — on a window-ledge, for example, preferably aiming the ultrasonic detector towards an outdoor light or some trees. Run out a few metres of cable so as to install the small loudspeaker inside the house. Wait for nightfall and, if there are bats around, you'll hear a sound like bursts of crackling from the loudspeaker. Do note that bats won't fly about under some weather condition (rain, strong winds, etc.)

The detector receives the ultrasonic signals, which are amplified by T1, T2, and T3, then sent to IC1 which is wired as a threshold detector. It converts the analog signal into digital pulses which it sends to IC2, which divides the signal by ten so as to make it audible to the human ear. The gain of the LF amplifier IC3 is adjusted automatically by transistor T4 and T5 depending on the amplification of the signal by T3, filtered by R7 and C14. The impedance between IC3 pin 2 and ground is what determines the amplifier gain.

The 40 kHz ultrasonic receiver used (MA40-R or SQ40-R) is available from Conrad Electronics (# 182281-62) or Farnell (# 213226).

(090637-I)

Flashing Lights for Planes and Helicopters

Jean-Louis Roche (France)

There are two sorts of lights on aircraft: red or white flashing lights, which are called 'anti-collision lights', and steady lights, red on the tip of the left wing, green on the tip of the right wing, and white at the tail, called 'position lights', which enable an observer to see if the aircraft is approaching or going away. On the tip of each wing, in addition to the steady lights, there may also be flashing white strobe lights. The position light simulator given here takes a few liberties with the real position lights, making them flash (it's more fun!) and using a little trick to simulate the strobe effect.

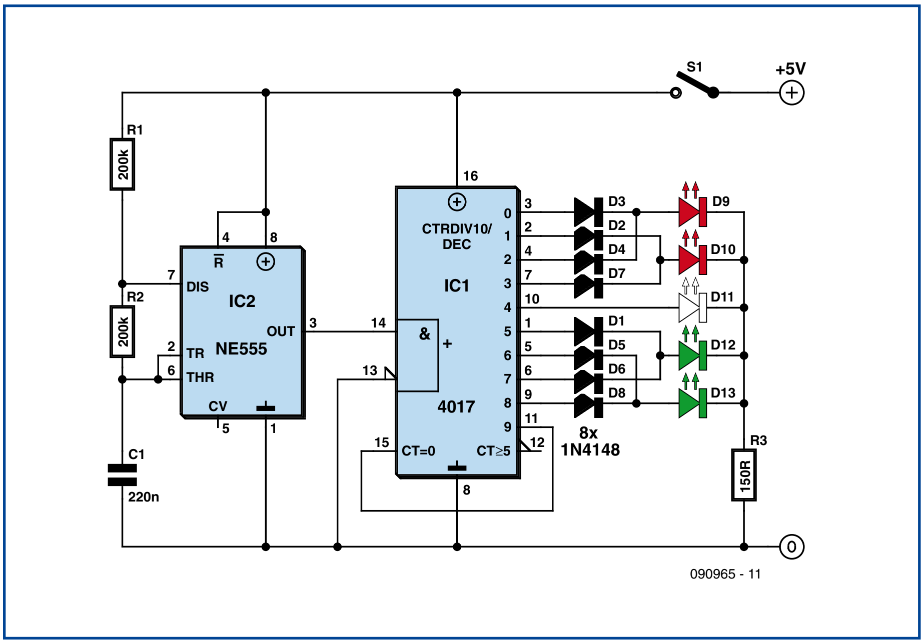
The well-known NE555 is found in its SMD version for the timebase, combined with a 4017 decade counter with ten decoded outputs, also in SMD version. Normally, each output is used independently. In this circuit, two outputs are coupled with a one-output gap: Q0 and Q2 (front left, red LED), Q1 and Q3 (rear left, red LED), Q5 and Q7 (front right, green LED), Q6 and Q8 (rear right, green LED). To avoid the low output's shorting the High output, a diode is used in series with each output.

In this way, we get 'double flashing' of each LED, giving the strobe effect.
Output Q4 is used for the tail of the plane (white LED) or helicopter (red LED) with a single flash, without the strobe effect. Output Q9 is used for the reset.
Only one LED is lit at any given moment, so the consumption is kept low so as not to reduce battery life in flight. The 150 Ω resistor limits the supply voltage/current to each LED.
The circuit's power rail (4.5 V) can be taken from an unused output on the model's decoder. A sub-miniature switch could be fitted if necessary, but since a plane or helicopter is required to have its lights on at all times...

(090965-I)

Internet links

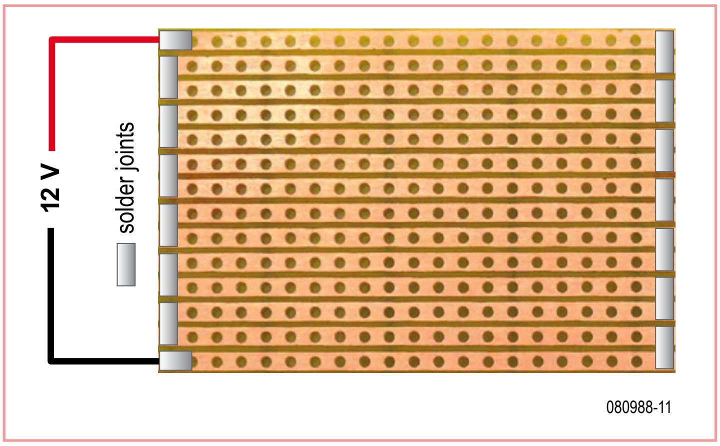
[1] www.elektor.com/090965



Breadboard as Hotplate

Klaus Berthholdt (Germany)

A standard 60 mm x 100 mm piece of prototyping strip board (breadboard) can very simply be used as a 12 V warming plate. All that's necessary is to connect the copper tracks in series. At 12 V the board will pass around 4 A giving a power dissipation of almost 50 watts. Power can be supplied by a standard car battery or 12 V battery charger. The temperature on the epoxy side of the board can reach around 100 °C!



The simplest method to make the plate is first to solder all the tracks together at both ends of the tracks. Now take a small hobby drill like a Dremel fitted with a cutting or grinding wheel and use it to cut through alternate soldered ends so that all the strips are connected in series. The two connections to the plate are made at the end of the strips as shown in the picture.
A 15 cm length of track at 20 °C has a resistance of around 70 mΩ. With the hotplate connected to 12 V a current of around 4 A was measured indicating a total resistance of 3 Ω i.e. approximately 83 mΩ per strip. The average temperature of the copper strips was measured at 65 °C.

Make sure that the connecting wire to the hotplate is of sufficiently heavy gauge to handle the expected current. Any wiring to a car battery should also include an in-line fuse, a short-circuit can be hazardous.
As well as making a good hotplate the strips can also be used to make a precise low impedance voltage divider network.

(080988)

Water Alarm

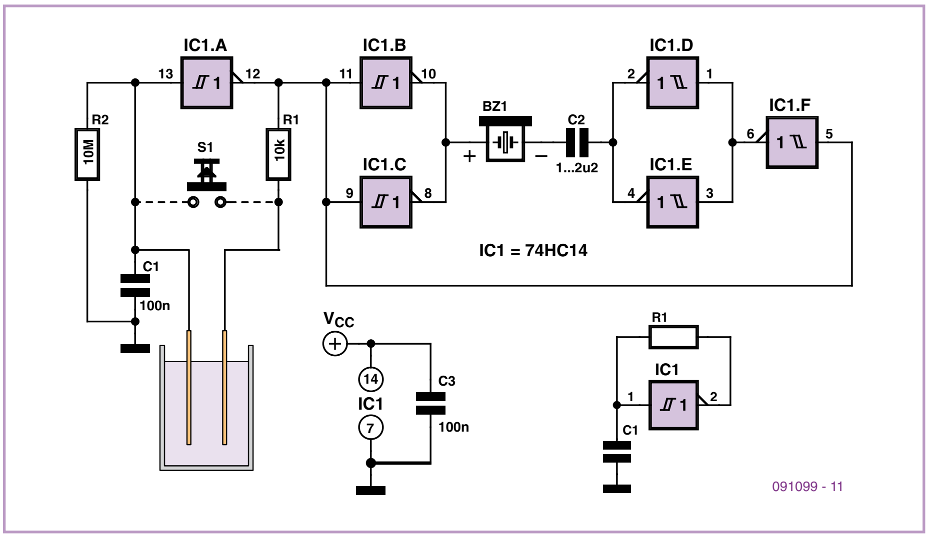
Roland Heimann (Germany)

The LM1830 fluid detector IC from National Semiconductor is designed to be able to detect the presence of fluids using a probe. This chip requires a relatively high supply voltage and is not the most frugal power consumer. It is also quite specialized so unless you are buying in bulk the one-off price is not cheap.

An alternative circuit shown here uses a standard CMOS IC type 74HC14. It has the advantage of operating with a 3 V supply and consumes less than 1 µA when the alarm is not sounding, this makes it ideal for use with batteries.
The 74HC14 has six inverters with hysteresis on their input switching thresholds. A capacitor (C1) and a feedback resistor (R1) is all that's necessary to make an inverter into a square wave signal generator.

In the water alarm circuit the feedback resistor consists of R1 and the water sensor in series. R1 prevents any possibility of short-circuit between the inverter's input and output. Resistor R2 defines the inverter's input signal level when the sensor is not in water. Any open-circuit (floating) input can cause the inverter to oscillate and draw more current. The remaining inverters in the package (IC1.B to IC1.F) drive the piezo buzzer to produce an alarm signal. Capacitor C2 ensures that no DC current flows when the circuit is in monitoring mode (with the alarm silent) this helps reduce the supply current.
A micro-switch can also be substituted for the water sensor to make the circuit a more general purpose alarm generator.

(091099)

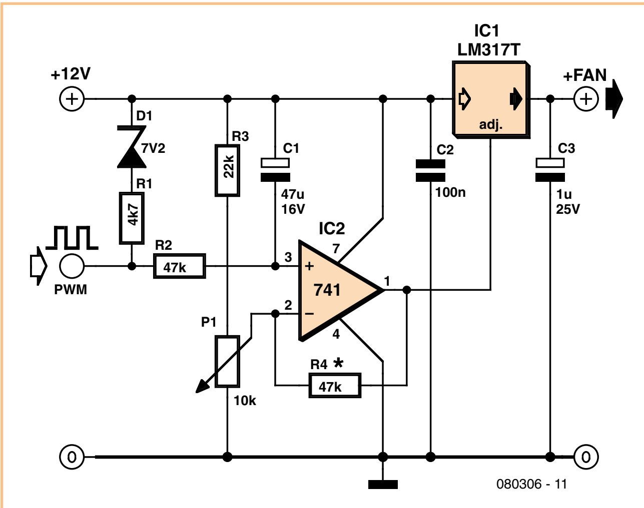


3-Pin Fan in 4-Pin Socket

Joachim Berg (Germany)

The most recent PC motherboards provide four pin connectors for cooling fans especially for the CPU fan. The older three pin fans are controlled by varying their DC voltage. The fourth pin on the newer connectors supplies a PWM signal to control fan speed. A three pin fan can be plugged into the four pin connector but with its fixed 12 V supply it runs at full speed all the time the PC is switched on. This is not an ideal situation if only for the noise levels.
During a recent motherboard upgrade the author was reluctant to replace his existing copper-finned CPU cooler which still had plenty of life left in it. An electronic solution was the only way ahead. A circuit was needed to convert the PWM signals from the fourth connector pin into a variable DC supply for the three pin fan. The PWM signal originates from an open collector output which can only be pulled up to a maximum of 5.5 V. For this reason R1 is connected in series with a zener diode to limit the pull up voltage to 4.8 V. The PWM signal is integrated by the network formed by R2 and C1. The resulting signal is amplified by an opamp (almost any type that can work at 12 V will do here). The opamp output signal controls an adjustable voltage regulator which supplies sufficient current even for the most powerful fan.
P1 adjusts the fan's minimum rotational speed (with a cold CPU). Capacitor C1 is connected to V_{CC} so that when the PC switches on it transfers almost the full 12 V to the opamp input to run the fan at full speed momentarily. This ensures the fan gets a small kick to get it going from rest. The regulation sensitivity can be adjusted by changing the value of R4. Incidentally the plug from an old floppy disk drive power connector can be used (after a little trimming) to connect to the 4-pin motherboard fan plug.

(080306)



Cell Phone TX Demo

Jonathan Hare (UK)

This is a very simple and cheap device that demonstrates cell phones generate RF energy (i.e. radio waves) strong enough to light an LED.

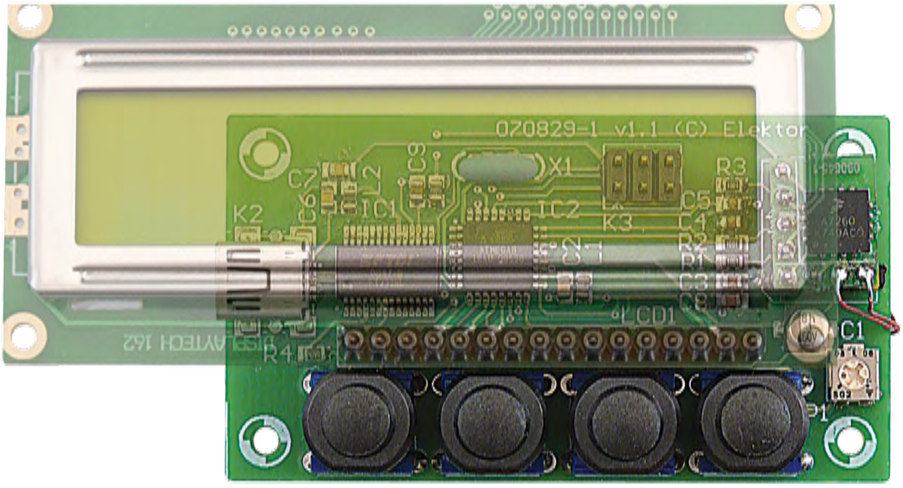
We have a 30 cm (7.5 cm per side) full-wavelength loop antenna (a 'Quad' to radio amateurs) connected to a germanium diode and a hyper-bright LED. The loop can be made of copper wire, thin sheet metal or a track on a PCB. The diodes need to be wired correctly.

A germanium diode is preferable as the LED probably has too great a self-capacitance to perform at the very high frequencies generated by the phone (approx. 800/900 MHz or 1800 MHz) but will work well with the DC(-ish) pulses from the germanium diode (which has a small capacitance as well as low forward drop). In the junkbox or granddad's electronics drawer, look for fossils like the OA91, OA95, OA79 or AA119. The common or garden silicon 1N914 or 1N4148 will also work

USB Tilt Sensor

Wilfried Waetzig (Germany)

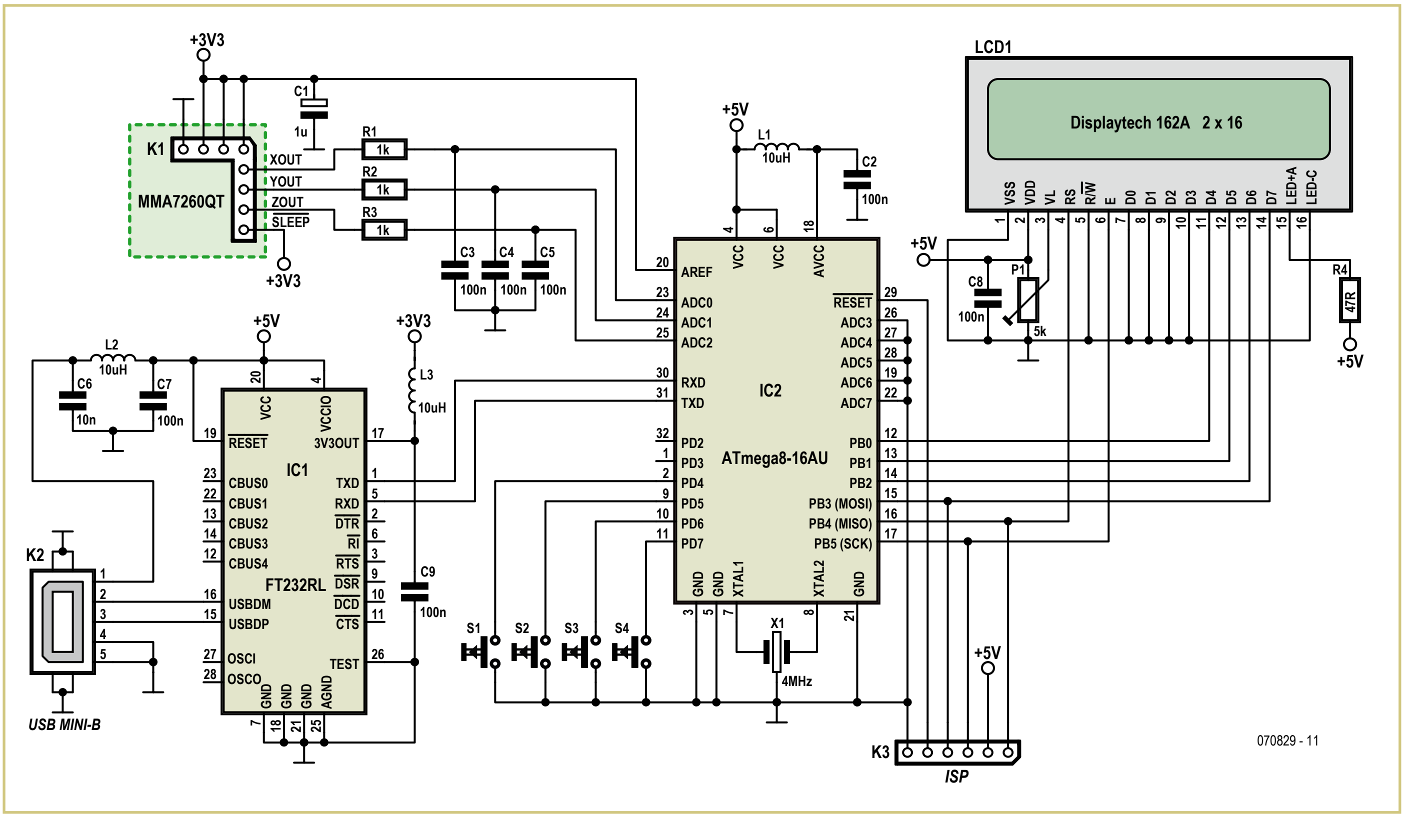
A tilt sensor is a very versatile device: for example, it can be used as a (game) controller or as an alarm sensor to protect valuables. The circuit described here uses the same sensor as we used in our two-axis accelerometer project [1]. The Freescale MMA7260Q can measure accelerations along three spatial axes, producing three proportional analogue output voltages [2]. The sensitivity of the device is adjustable in four steps. For the purposes of this project we use the 800 mV/*g* setting, giving a full-scale range of –1.5 *g* to +1.5 *g* on each of the three axes. The IC comes in a tricky-to-solder QFN package, and so to make life easier we have made available a small carrier board with the device already mounted ('MMA7260 on carrier board', order code 090645-91: see [3]).



The carrier board is simply plugged into the main board via two 4-way pinheaders. If the main board is now tilted about its main horizontal axis (or about the perpendicular horizontal axis), the sensor will record an acceleration in the X (respectively Y) direction equal to some fraction of 1 *g*, the acceleration due to the earth's gravity. From this value we can determine the tilt angle. In practice the sensor is not tilted about just one of its axes, and this is where the Z-axis acceleration measurement comes into play: we can use this value to help determine the deviation from vertical of the axis perpendicular to the main board. In general we can use the three acceleration values to compute a tilt angle in the X and Y directions, assuming that it is held steady and not subjected to any translational accelerations.

Based on the author's suggestions, Elektor lab trainee Jerry Jacobs designed a compact printed circuit board, which can be ordered via the Elektor website [3]. As usual, a pre-programmed microcontroller is also available, or, if you prefer, you can download the software as a hex file or as source code and program it yourself.

The circuit is relatively simple. The central component is an ATmega8-16 microcontroller, which drives an LCD panel via port B and which is controlled by pushbuttons connected to port D. The analog signals from the acceleration sensor are connected to the analog inputs ADC0 to ADC2.
Practically all the passive components are concerned with decoupling and smooth-



ing, with the aim of making the analog measurements as accurate as possible. Particular attention is paid to smoothing the analog supply to the microcontroller (AV_{CC}).

Power is provided over a USB connection, which also provides a means to transfer the measured angular values to a PC or other host. The well-known FT232RL device is used as a UART-to-USB bridge. The 3.3 V power supply for the sensor, which also forms the reference voltage for the ADC, is provided by the FT232RL, which obviates the need for a separate 3.3 V regulator.

Now we turn to the mathematics involved, which are essential to understanding the software. The ADC resolution is 10 bits and so the analogue voltages at ADC0, ADC1, ADC2 are converted to digital values as follows:

val = U*1024/V_{ref},

where V_{ref}=3.3 V. A value of $V = V_{ref}/2$ = 1.65 V corresponds, according to the device datasheet, to an acceleration of 0 *g*; V = 2.45 V corresponds to +1 *g* and 0.85 V to –1 *g*. For tilt angle measurements these are the maximum and minimum values that should be encountered, corresponding to inclinations of +90 ° and –90 °. Call the corresponding ADC conversion results (760 and 264, obtained from the formula above) ADCmax and ADCmin.

In practice the system must be calibrated before making measurements, which in this case means determining the values of ADCmin and ADCmax for each of the three axes. Each axis is calibrated separately, by holding the board vertical in all possible orientations: it is easiest to hold it against a solid vertical surface. At the end of the process we have determined all the ADCkmax and ADCkmin values (where *k*=0 for the X axis, 1 for the Y axis and 2 for the Z axis).

Button S4 then starts the measurement process. The readings are smoothed by averaging 16 consecutive conversion results, which helps to reduce the effect of small vibrations.

Given the current averaged readings for ADCkvalue (where *k* runs from 0 to 2) the software calculates:

(X/Y/Z)gval = (ADCkvalue – ADCkmid) / ADCkdif

where ADCkmid = (ADCkmax + ADCkmin)/2 and ADCkdif = (ADCkmax – ADCkmin)/2.

Xgval, Ygval and Zgval are then the measure accelerations (as a fraction of 1 *g*) along each axis. Freescale Application Note AN3461 [4] describes a method for deriving the values xangle, yangle and zangle:

tan (xangle) = Xgval / sqrt (Ygval^2 + Zgval^2)

tan (yangle) = Ygval / sqrt (Xgval^2 + Zgval^2)

tan (zangle) = sqrt (Xgval^2 + Ygval^2) / Zgval

Here xangle is the pitch (the angle the X axis of the acceleration sensor makes with the horizontal, positive for a clockwise tilt viewed from in front of the board), yangle is the roll (the angle the Y axis of the acceleration sensor makes with the horizontal, positive when the board is tilted towards you) and zangle is the overall tilt (the angle the Z axis of the acceleration sensor makes with the vertical, positive for any tilt). When the board is horizontal, all angles are zero.

The web page accompanying this article [3] links to a free extra document for download covering initialization, calibration and more. There is also a brief description of the communication protocol used with the PC, and details of fuse bit settings in the microcontroller. The web page also includes the parts list and software downloads, and links for ordering the microcontroller and circuit board.

(070829)

[1] www.elektor.com/060297

[2] www.freescale.com/files/sensors/doc/data_sheet/MMA7260QT.pdf

[3] www.elektor.com/070829

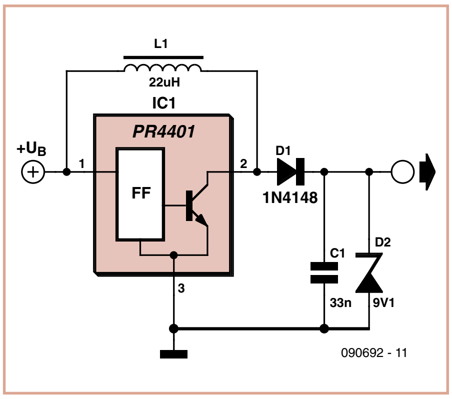
[4] http://cache.freescale.com/files/sensors/doc/app_note/AN3461.pdf

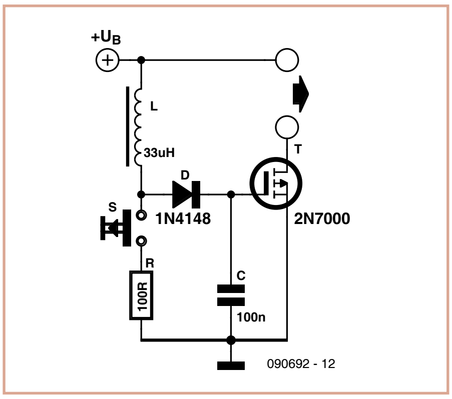
Virtual 9 V Battery

Jakob Trefz (Germany)

PP3-size 9 V batteries (IEC: 6LR22) have a considerably poorer price/energy ratio than 1.5 V AA (IEC: LR6) cells. This makes it all the more unfortunate when you accidentally leave a device switched on!

The author uses a number of such devices and so started looking for a solution to this problem. His first thought was to use a DC/DC converter to allow the use of 1.5 V cells in 9 V equipment. A perfect device for this application is the Prema PR4401 LED driver.
The IC is small, with just three connections, and the required external circuitry consists of just a coil, a diode and a smoothing capacitor. The device can convert input voltages of between 0.9 V and 1.9 V to 9 V with acceptable efficiency. The maximum load is around 3 mA.





However, this is only half the story. Even when there is no load at the output the IC still draws current, and so the battery will eventually run flat even if the equipment is switched off. This means that some kind of automatic shutdown circuit is needed. How can we make a timer that runs on less than 1 volt and which consumes only a negligible current? The answer was found in the form of a MOSFET with a very low on resistance and a threshold voltage of just over 3 volts. This voltage is still more than twice the terminal voltage of an AA cell, however; we need to generate a sufficiently high voltage (greater than 3 V) briefly and store it on a capacitor. The capacitor will discharge very slowly into the gate of the MOSFET to which it is connected, which will then cause the connected device to be powered for a few minutes before being turned off.

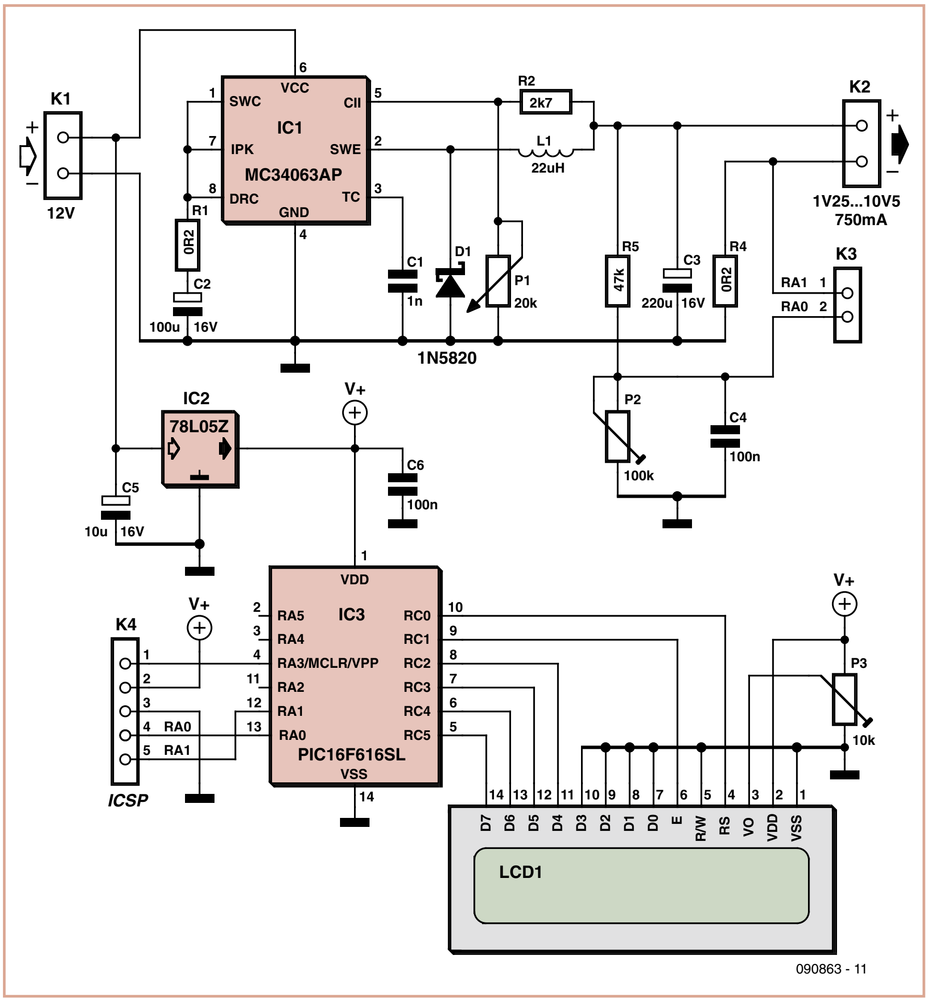
The self-inductance of coil L is used to generate the higher voltage. When switch S is briefly closed a current flows in the coil. We need to check that the maximum gate voltage of the MOSFET (20 V) will not be exceeded: from the maximum input voltage (approximately 1.6 V), the current that briefly flows through R (approximately 1.5 mA) and the inductance of L we can calculate how much energy can be stored in the coil. When S is opened C is charged via D, and we can then work out the resulting voltage across C. With the component values given, this comes to about 5 V. The author's prototype gave a power-on period of 15 to 20 minutes.

(090692)

Bench PSU for PC

Ludovic Voltz (France)

Given that every PC has a powerful, well-regulated PSU that supplies, among other things, a 12 V rail, why not make use of it to produce a PSU variable from 1.25 to 10 V? Well, that's just what we're proposing to do here. This power supply can also be used as an addition to a conventional bench supply in order to simulate an analog voltage, if the bench supply has only one output.



The conversion part is entrusted to the cheap and very popular MC34063 DC-DC converter, arranged as a step-down. Using a switching solution makes it possible to limit losses due to the Joule effect. The MC34063 is associated with a microcontroller, aided by an LCD display (1×16 characters) which lets you display the output voltage along with the current being supplied by the PSU (connect K3 to pins 4 an5 of K4). Under ideal conditions, 700 mA may be drawn, but don't worry, the IC includes a current limiter which will come into action as soon as you go over the limit.

Program the microcontroller using the software available from [1] and adjust P2 to make the displayed output voltage correspond with the actual value. Note that certain single-line 16-character displays behave like a display with two lines of eight characters. The download contains two HEX files for dealing with both eventualities.

Once the PSU has been assembled, you will be able to house it in one of your computer's spare slots for a 5¼-inch floppy disk drive.

One last little detail: to allow more accurate setting of the output voltage, you can include a second 1 kΩ potentiometer in series with P1.

(090863-I)

[1] www.elektor.com/090863

Green/Red Multiflasher

Ken Barry (UK)

This circuit can be made to produce interesting and attractive light effects using just a cluster of red LEDs and one of green LEDs. One effect is first alternating between red and green, and then lighting red and green together. With the exception of the triple LED devices (Rapid Electronics # 56-0205 for green, # 56-0200 for red) all parts are cheap and easy to find, possibly even in your junkbox.

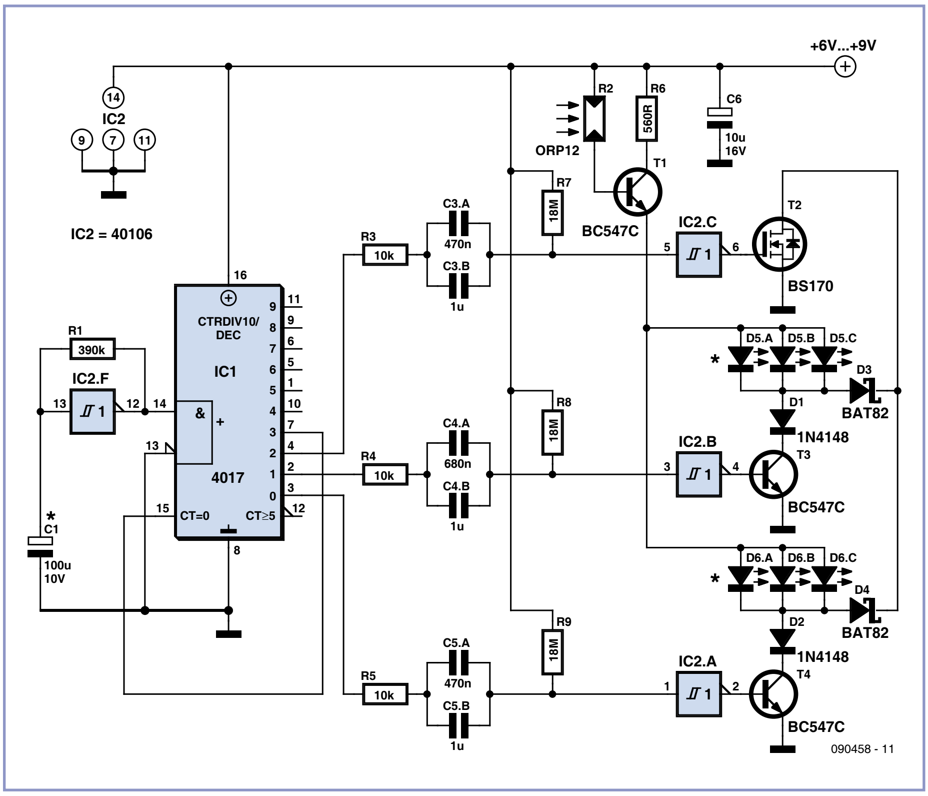
The values of networks R3/C3, R4/C4 and R5/C5 govern the length of the flashes. Using the indicated values, these are about 18 seconds with a 0.5 second interval.

Because the colors used do not have equal luminous intensity (expressed in millicandelas) D1 and D2 are silicon diodes and D3 and D4, germanium, with Schottky devices (BAT82) as an alterative because they also exhibit a low forward drop of about 0.3 V. As germanium devices, look for the OA91, OA85 or AA119. If D1 and D2 are omitted, Green and Red are brighter by themselves than when on simultaneously.

MOSFET T2 switches both LED devices on simultaneously arranging for roughly equal luminous output.

The display has an integrated LDR that causes the LEDs brightness to adapt automatically to darkness and bright light conditions.

The circuit has lots of openings for experimentation and adaptation, for example, the flash rate is determined by the value of C1, while the link between the counter's R (reset) input and O3 output determines if a space is inserted after the last flash, or not. Colourful and lively effects may also be obtained by using tri-color LEDs with a common anode.



The power consumption of the circuit depends largely on the LEDs used. With the Rapid LED types shown, about 70 mA may be expected at a 6 volts supply voltage.

(090458)

Electret Mic Booster

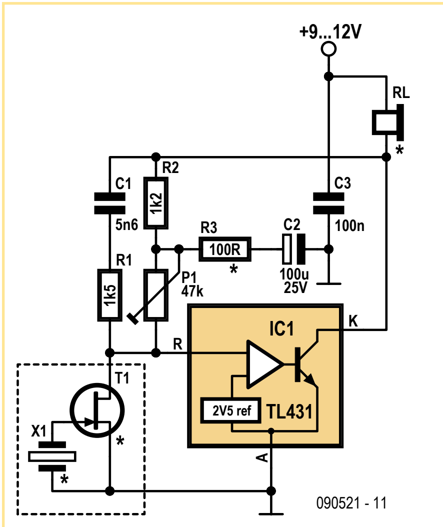
Ian Field (UK)

Anyone who's spent much time searching the web for interesting circuits is likely to have found at least one TL431 based audio amplifier, the circuit being based on the principle that any comparator can be used in linear mode if it's rolled off with enough negative feedback. Although the TL431 is often referred to as a programmable or adjustable zener, it is in fact a comparator with it's own 2.5 V reference all neatly wrapped up in a TO92 package.

The problem with the TL431 amplifiers to be found on the web is that they simply roll it back with large nfb and leave it at that, which results in very low gain, to make matters worse some such circuits make a bit of a hash of biasing the control input.

The circuit presented here takes care of the low gain by adding an AC shunt to the feedback path and using an electret mic for the input — the 2.5 V set on the control input at stable operating condition suits an electret mic perfectly. The first prototype had a 35 ohms loudspeaker as a load (R_L), this gave good results although the TL431 ran a bit warm with a V_{cc} of 12 V. An old 130 ohm telephone earpiece is likely to present a less stressful load. AC shunt C2 (100 µF) has to be a quality component in terms of its ESR specification — don't just use a scruffy capacitor lying about as you may experience RF sensitivity. It was necessary to add a series resistor (R3; about 100 ohms) or in extreme cases an inductor (L1; 100 – 220 µH). Components C1 & R1 are entirely optional to selectively feed some un-shunted feedback to reduce noise; 1.5 kΩ & 5.6 nF are as good a place as any to start off with.

Initial set-up depends on the current drawn by the electret mic and the value for R_L — anywhere between 200 and 2,000 ohms is good. R2 allows the TL431 cathode to swing despite the AC shunt, 1.2 kΩ was found to be satisfactory, P1 can be a 47 kΩ trimpot and is used to set the voltage drop on R_L. In the case of moving-coil speakers a compromise between voltage swing and pre-biasing the cone should be sought, with a resistive load adjust for 0.5 V_{cc}, once the operating point is determined P1 can be measured and replaced by an equivalent fixed resistor.



The circuit has a couple of handy features, firstly it works very well on the end of a twisted-pair — the output can be tapped off at the wiper if R_L is a pot at the power supply end, secondly by salvaging the JFET from an old electret mic (some common types of JFET will work but not quite as well), just about any piezo electric element can be used as the transducer. Brass disc sounders give a good output (handy as vibration sensors if glued to a structure); even the quartz discs from clock crystals give some output, a phono crystal cartridge gives a high output and the piezo-ceramic pellet from a flintless cigarette lighter gives a huge output… the range of possible applications is awesome!

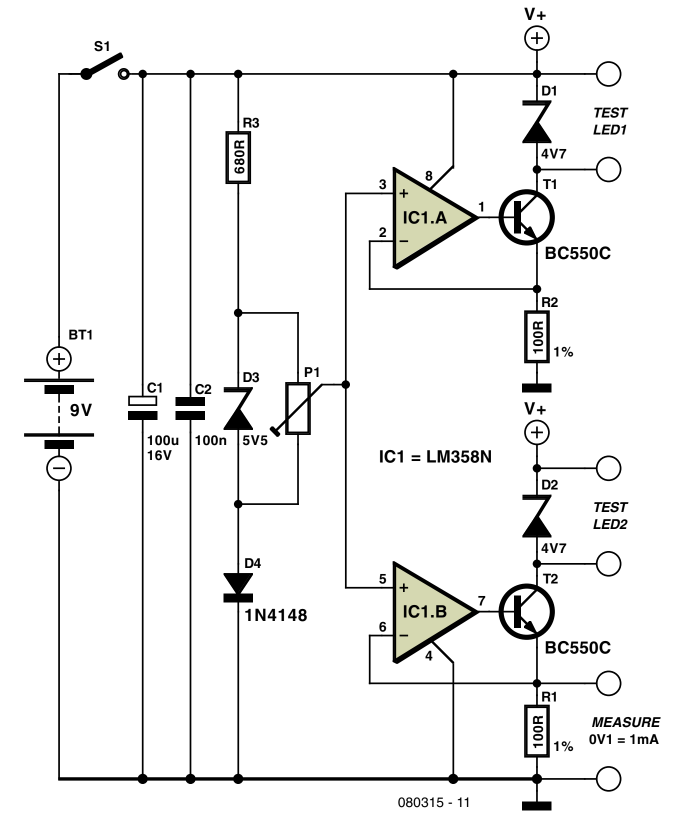
A surprising application is the ability to test the microphonic sensitivity of ordinary capacitors! Disc ceramic types don't need to be tapped very hard to produce an output but rolled metallized foil types produce some output too.

(090521)

LED Tester

Herbert Musser (Austria)

In some circumstances it may be necessary to select LEDs with closely matched characteristics. This design makes the job a whole lot easier. It uses two tracking current sources to allow the comparison of the two LEDs under test. LED current is adjustable by potentiometer P1 giving a range from 1 to 50 mA. Zener diodes D1 and D2 ensure that the voltage across the LEDs cannot rise above 4.7 V. This prevents the LEDs from being destroyed if they are accidentally connected to the tester the wrong way round.



Each of the two opamps together with a transistor builds a voltage controlled current source (more accurately a current sink). Each of the 100 Ω emitter resistors act as a current sense, the voltage developed across them is proportional to the LED current. A voltage of 100 mV per mA of LED current can be measured across the emitter resistor using either a DVM or panel meter. This allows precise control and display of the LED current.

Current through both LEDs track together with very good accuracy and makes it a simple job to identify matching LEDs.

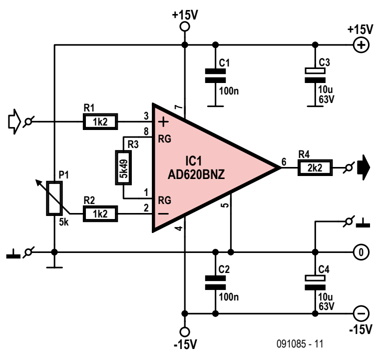
(080315)

Voltage Difference Magnifier

Egbert Wolters (The Netherlands)

This circuit was designed for monitoring the charge- and discharge process of a 6-V lead-acid battery. This process takes place between 6.2 V and 6.8 V. The author used a measuring instrument that has several measuring ranges (0–1 V, 0–10 V, etc.). The 10 V range, however, is too coarse for this measurement. A better measurement result could be obtained if 6 V were subtracted from the measured voltage. The measuring range would then be from 6 to 7 V.

A single opamp such as the LF351 suffered from mutual dependency of the measured and offset voltages and was therefore not suitable. The AD620 from Analog Devices, however, has been especially designed for this type of application and works well. In this opamp each of the input signals has its own opamp, so that they do not interfere with each other.



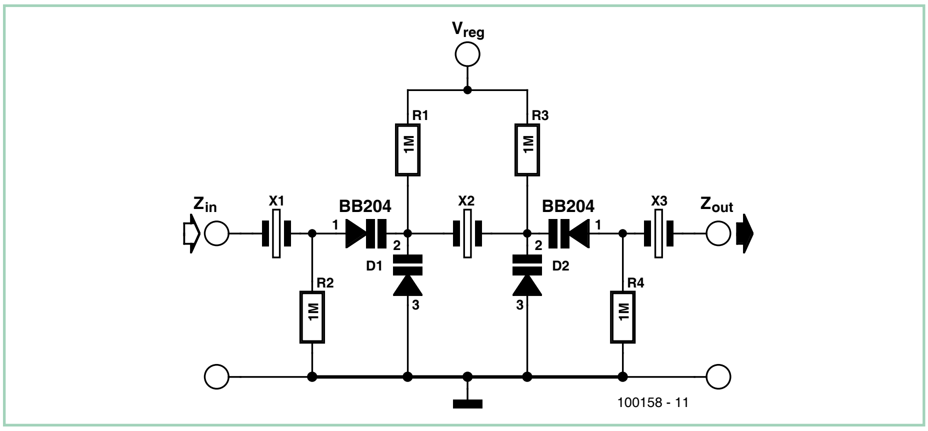
The schematic is simple. The offset voltage can be set accurately with a 10-turn potentiometer. The resistor of 5.49 kΩ (1%) can be connected or removed from the circuit with a jumper; without the resistor the gain

is one, with resistor the difference voltage will be amplified 10 times (9.998 times, to be more accurate).
The AD620 draws slightly more than 1 mA (idle current is 1.3 mA max.), so that battery power is also an option. The IC can be used with power supply voltages ranging from ±2.3 V to ±18 V. Small button cells could even be considered when doing only brief measurements. The maximum differential voltage is 25 V, something that you will have to take into account, particularly if you are going to measure an unknown voltage.

The greatest DC accuracy is obtained with the version of opamp shown in the circuit. There is also a cheaper version, the AD620ANZ (the Z stands for lead-free). For a good application note about the AD620 we can recommend the document that describes the evaluation board made by Analog Devices (EVAL-INAMP-62RZ_82RZ_82_RMZ.pdf at [1]), in addition to the data sheet, of course.

(091085-I)

Variable Crystal Filter



U_r (V)	bandwidth (kHz)		
	−3 dB	−20 dB	−40 dB
0	2	6.2	17.9
0.5	2.7	7.0	20.6
1	3.2	7.7	22.0
2	4.0	8.5	24.4
4	4.6	9.6	29.9
8	5.5	10.7	33.2
16	6.4	12.1	38.5
30	7.3	13.6	40.2
Measured at $Z_{in} = Z_{out} = 330\ \Omega$			

Gert Baars (The Netherlands)

Crystal filters are often used for IF filters in receivers, where the bandwidth of this filter largely determines the selectivity of the receiver. The unique feature of the filter described here is that the bandwidth has been made adjustable.
The configuration is a so-called ladder filter with three crystals of the same frequency. Because the crystals should actually be identical, we recommend that you buy three from the same production batch, which is generally the case of you order/buy them all at the same time.
Varicap diodes are usually specified from U_r= 0.5 V. The measuring result for 0 V is shown nevertheless. With a range in U_r = 0 to 12 V, the bandwidth is adjustable from 2 to 6 kHz, which is suitable for the range of CW/SSB to standard AM.

The ripple of the filter is determined by the input and output impedances Z_{in} and Z_{out}.

With smaller values of Z_{in} and Z_{out} the ripple will increase, but the roll-off will be steeper. A compromise is $Z_{in} = Z_{out} = 330\ \Omega$ resulting in a ripple of <3 dB. It is expected that the characteristics at other IFs such as 10.7 or 9 MHz will be much the same.

(100158-I)

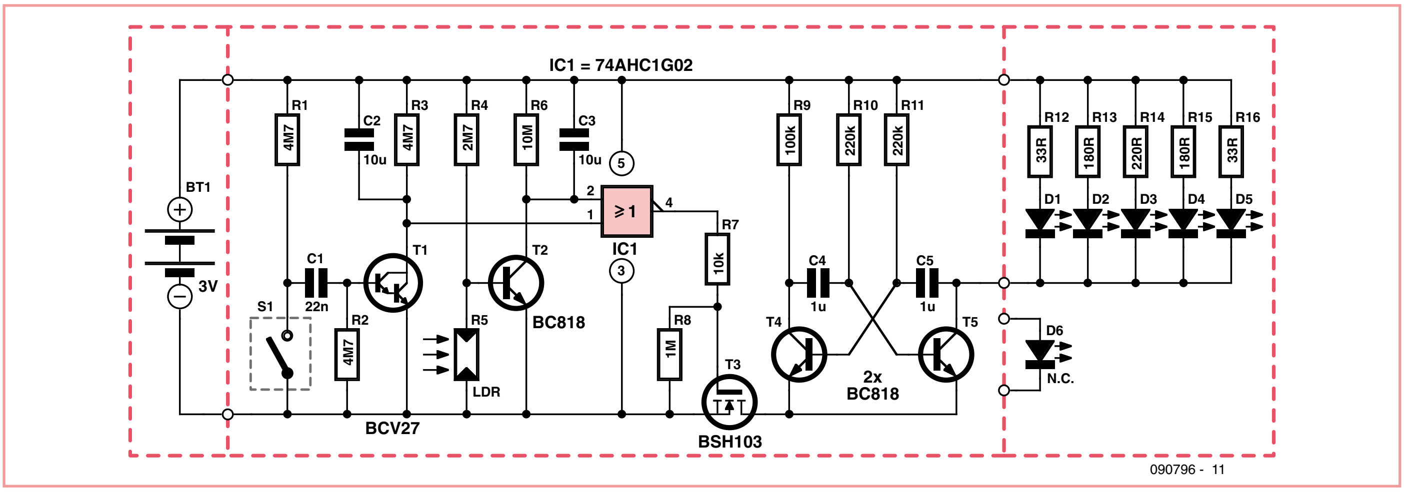
Automatic Rear Bicycle Light

Ludwig Libertin (Austria)

This is a design for a rear bicycle light that automatically switches on and off according to ambient lighting conditions. The red LEDs flash with a 50 % duty cycle to save energy; you can modify the circuit to light the LEDs continuously if local laws require it. The circuit can of course also be used as a safety light by pedestrians.

The author bought a commercially-available rear bicycle light and replaced the printed circuit board inside with his own design: the circuit is shown here. Space was rather tight, and so surface-mount devices were used in the construction of the prototype. Leaded devices would of course work just as well, and the 10 µF SMD film capacitors can be replaced by electrolytics.
The five high brightness red LEDs shown to the right of the circuit diagram were already present in the original unit, on their own circuit board along with their series resistors. This part of the unit was re-used. This explains the variation in value of the series resistors, which can be changed according to the brightness desired and the characteristics of the LEDs used. The original light also included a green LED (D6), which we do not use in this design.
The circuit has two sensors: a vibration switch (S1) in a TO18-like package (for example, RS Components order code 455-3671) and an LDR (R5, a standard type with a resistance when illuminated of around 250 Ω and a dark resistance of at least 10 MΩ). When the bicycle is moved the vibration switch will open and close its contact, generating pulses at the base of Darlington T1 via C1, causing it to turn on. C2 is thus charged and the input to gate IC1.A (pin 1) goes Low. If it is sufficiently dark the voltage produced by the voltage divider formed by R4 and LDR R5 will be greater than 0.6 V, causing transistor T2 to conduct and C3 to charge. When C3 is charged a Low level will appear at the second input (pin 2) to gate IC1.A.

If both inputs are at logic zero the output of



the NOR gate will go high, causing FET T3 to conduct. As a result power is supplied to the astable multivibrator comprising R9, R10, R11, C4, C5, T4 and T5, and the LEDs will flash at 5 Hz. They will continue to flash for as long as pulses continue to be supplied by the vibration sensor S1 and as long as it remains sufficiently dark.

If the vibration sensor stops providing pulses (because the bicycle is stationary) C2 will no longer be charged and will gradually discharge over a period of 25 seconds or so through parallel resistor R3. The output of the gate will go low and T3 will block; hence after the expiry of the 25 second delay the LEDs will go out.
If the bicycle is moving and S1 is delivering pulses, but the LDR is illuminated (perhaps by passing cars or by street lighting) the LEDs will continue to operate for about 70 seconds, with C3 keeping its input to the gate low.

The circuit is designed to run on 3 V (two AAA cells). The quiescent current consumption is less than 2 µA and the batteries should last for over 300 hours of operation.

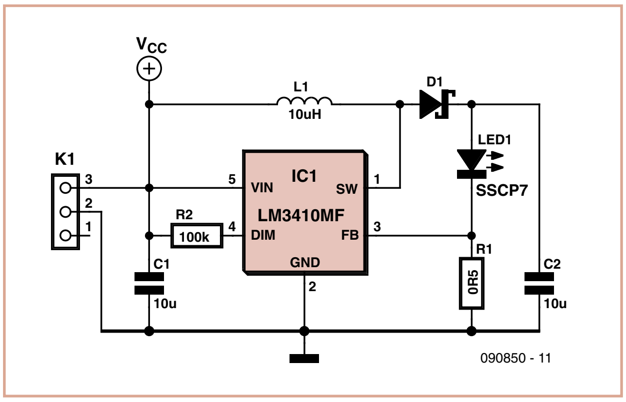
In practice the vibration sensor was found to be so sensitive that it delivers pulses even when the cyclist is waiting at a traffic light, and so the LEDs continue to flash. The LEDs only go out when the bicycle is perfectly still.
The ambient light threshold can be set by adjusting R4 to suit the characteristics of the LDR.

To modify the circuit so that the light is steady rather than flashing, remove T4, T5, C4, C5, R9, R10 and R11 and connect the cathodes of LEDs D1 to D5 directly to the drain of FET T3.

(090796)

The LM3410 LED Driver

Steffen Graf (Germany)



The LM3410 IC is a constant current LED driver useful in either boost converter or SEPIC design applications. A SEPIC (Single Ended Primary Inductance Converter) design allows the power supply's output voltage to be set above, below or equal to its input voltage. In this application the chip is configured as a boost-converter (i.e. the output voltage is greater than the input voltage).
The LM3410 is available in two fixed-frequency variants. Using either the 525 kHz or 1.6 MHz clock version it is possible to build a very compact LED driver. The output stage can supply up to 2.8 A, allowing several high-power LEDs to be driven from a rechargeable Lithium cell or several 1.5 V batteries. The chip also features a dimmer input giving simple PWM brightness control.
Output current is defined by an external shunt resistor. To keep losses low the LM3410 uses an internal voltage reference of just 190 mV. Power dissipation in the shunt resistor is therefore low. Using the desired value of LED current the value and power dissipation of the shunt resistor is given by:

R_Shunt = 0.19 V/I_LED
P_Shunt = 0.19 V*I_LED

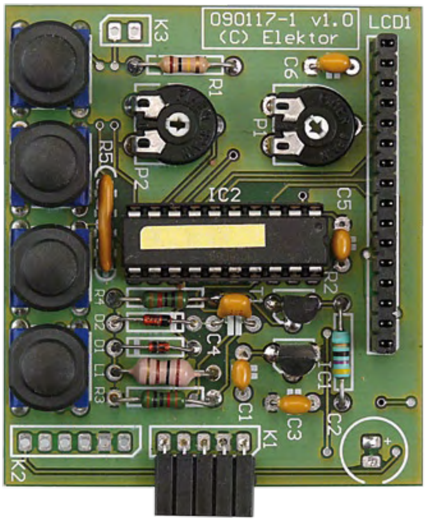
A 10 µH coil (L1) will be sufficient for most applications providing it has a suitable saturation current rating. The Input and output capacitors should be 10 µF ceramic types with a low value of ESR. Many distributors including Farnell stock these components. The Diode should be a Schottky type (as in all switching regulators). The author has developed a PCB for this design; the corresponding Eagle files can be freely downloaded from www.elektor.com/090850. In summary the most important features of the LM3410 are:

- Integrated 2.8 A MOSFET driver.
- Input voltage range from 2.7 V to 5.5 V.
- Capability to drive up to six series connected LEDs (maximum output 24 V).
- Up to 88 % efficiency.
- Available is 525 kHz and 1.6 MHz versions.
- Allows both boost and SEPIC designs.
- Available in 5 pin SOT23 or 6 pin LLP outline.

(090850)

Sailor's Battery Meter

Anders Gustafsson (Finland)



On a sailboat, the condition of the battery is a major concern for obvious reasons. On the author's boat, a 120 Ah lead-acid battery is charged from a 25 watts solar panel. The battery monitor described here was designed to give peace of mind. It consists of two sub circuits: a sensor and a control/readout.

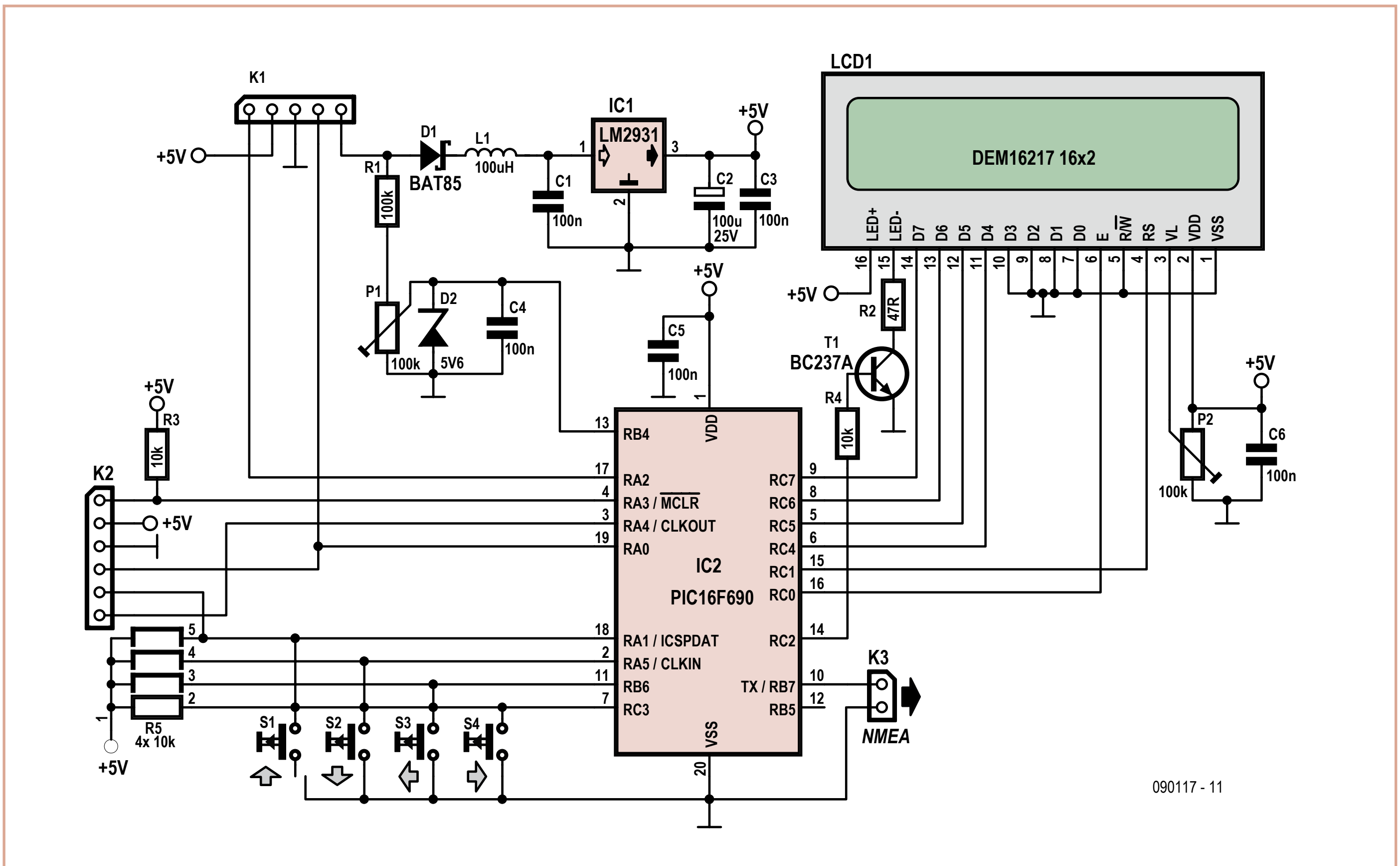
Lead-acid batteries are subject to self-discharge, usually expressed as a percentage of the total capacity per month, at 25 °C. A figure of 5% for a 100 Ah battery means that you will have 95% left after one month at 25 °C. Self-discharge is temperature-dependent, doubling for every 10 °C above 25 °C and halving for every 10°C below 25 °C. This is incidentally why batteries last longer if stored cold (but not freezing).

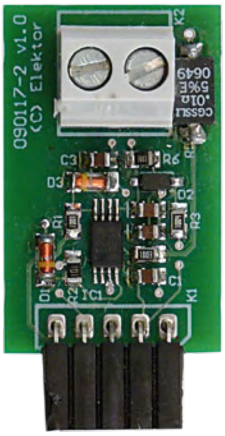
To accurately monitor a battery you need to measure the current into the battery and out of the battery. You also need to monitor temperature to be able to calculate self-discharge accurately. To make things more difficult, neither a photovoltaic panel, nor a fridge compressor represent constant sources or loads, instead they vary with time. Another problem is that you need to accurately measure currents as low as tens of mA up to tens of ampères in our case and do so with reasonable accuracy over time.

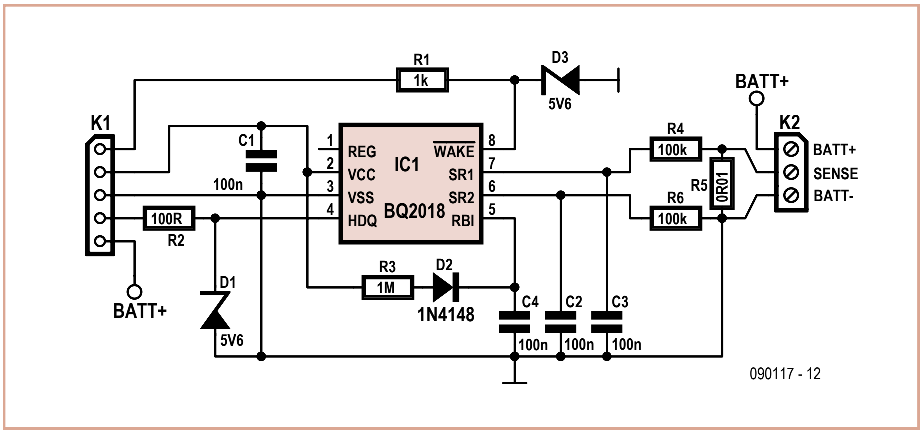
The process to measure charge is called coulomb-counting and is basically an integration of current over time. Having measured the current, usually with a small shunt, the result is integrated to form a value representing the charge. To do this, you can either sample the current and integrate numerically, or you can feed the current (or voltage) into a current (or voltage) to frequency converter and count the resulting pulses. Both methods have their advantages and disadvantages The pulse-counting approach eliminates the quantisation error from the measurement, leading to better accuracy over time. This was the approach chosen for this project.

Here the BQ2018 from Benchmarq (now incorporated into TI) is used as a charge counter. The BQ2018 is a tiny chip originally designed to be embedded into a battery pack. It is completely self-contained, needs only a handful of discrete components and communicates with the outside world through a serial link.

The BQ2018 and associated components can be mounted on a small PCB and located close to the battery in order for the built-in thermometer to read the battery temperature.







The same PCB contains shunt resistor R5 (Welwyn, 0.01 Ω, 1 W, SMD, 20 ppm/K). Since the maximum input to the BQ2018 is 200 mV this gives a full-scale of 20 A. A maximum of 200 A or 400 A might be appropriate for larger vessels, in which case you will use a lower value shunt. Metal-film resistors are recommended for R4 and R6 to keep noise and thermal drift to a minimum. R4, R5 and R6 should be connected in 'Kelvin' arrangement with heavy duty wires on the R5 terminals.
The sensor board communicates with, and is powered by, the control/display board via connector K1.

The control/display with its PIC16F690, LCD display and pushbuttons can poll the BQ2018 at a leisurely pace of once every 30s, allowing plenty of time for the PIC to calculate and display average current. Since the counters in the BQ2018 are 'only' 16-bits, care must be taken to read and zero them before they have a chance to roll over. In our case this happens every 6 hours, but the design has circuitry so that you can put the PIC to sleep and let the BQ2018 wake it when current rises above a predefined value. To implement that in software is left as an exercise for the reader.
Serial data from the BQ2018 is according to a protocol called 'hdq' defined as 'single-wire, open-drain interface asynchronous return-to-one referenced to Vss'. While it is possible to use the UART in the PIC16F690 to read this, you need additional components to make it work and besides, the UART is needed for the NMEA output. The problem is solved by the software using 'bit-bang' communication routines to talk to the BQ2018. Basically the PIC sends a command and immediately changes the output pin to input to receive data — this has to happen quickly as the first data bit may begin as soon as the command R/W bit time ends.
If you define NMEA in the source file the monitor will output NMEA data in the form:

```
;        $IIXDR,U,vvvvvv*CS
;        $IIXDR,A,aaaaaa*CS
;        $IIXDR,G,hhhhhh*CS
```

That's, volts, amps and charge. If you additionally define IDEBUG then it will instead dump out data for logging:

```
; ctc;ccr;dtc;dcr;ctc0;ccr0;dtc0;d
  cr0;charge;amps;volts
```

This is great for debugging and troubleshooting. The source code file for the project is available free from the Elektor website [1]. The same applies for the PCB artwork. Readers without access to a suitable programmer may obtain a ready-programmed PIC16F690 device from Elektor under order # 090117-41.

To connect the sensor, you remove the negative terminal from the battery, connect the negative pole of the battery to the + terminal on the sensor and connect the cable that used to go to the negative battery terminal to the – terminal on the sensor. Connect a wire from + on the battery to BATT+ on the sensor board and connect the headers K1 and K2 through a 5-wire cable.
To calibrate offset, short the shunt and hold down the Up key, whilst powering on. The unit will enter calibration mode and show a running counter on the display. After approximately one hour, the unit will show the measured offset and store it in EEPROM. Next, to calibrate voltage, measure the battery voltage with a DVM and adjust P1 for the same voltage on the display.

To set the unit according to your battery parameters, press → (Right) until you reach 'Maintenance', then press ↓ (Down). This will take you to a menu where you navigate with the Right and Left keys; Down on a value lets you adjust that value with the Left and Right keys. Down accepts and Up aborts without saving.

The left and right keys scroll through a series of display modes where the default of zero is probably the most interesting. Please see the source code for an explanation of the rest.
Finally, the author runs a dedicated website on the battery monitor at [2]. Software updates will be posted there.

(090117)

[1] www.elektor.com/090117

[2] www.dalton.ax/battmeter

Timer for Battery-Powered Tools

Piet Germing (The Netherlands)

Most hobbyists will have some tools that are battery-powered, such as a drill, screwdriver or power scissors. Unfortunately (and especially with cheaper devices) the batteries often seem to be empty when you need to use such a tool. This is usually caused by the self-discharge of the batteries. However, it's not a good idea to continually keep the batteries on charge because the cheap chargers would ruin the batteries in the long term due to their constant charging current. On top of that, it is wasteful of energy.
A simple method for charging cheap battery-powered tools in an environmentally friendly

and battery friendly way is to limit the charging period. The charging current from a simple charger is such that an empty battery-pack can be charged in about 5 hours ('fast' charger) to 15 hours (normal charger). Assuming a charging efficiency of 70% it means that the charging current is between 0.35 to 0.1 times the battery capacity in Ah. To compensate for the self-discharge of a fully charged battery of a maximum of 5% the charger has to operate at a duty-cycle of 1% and 3% respectively. In other words, charge the battery for a quarter of an hour or three-quarters of an hour per day using the original charger. In this calculation we haven't taken account of the discharging of batteries due to the actual usage of the tools.

The practical solution is very simple: use a 24-hour time switch, which can be picked up for a few dollars from a DIY store. The time-slots in the mechanical versions are usually for quarter-hour periods. When pins are used to select the period the minimum time is often half an hour. When you add a 4-way AC power adapter you can charge multiple devices at the same time.

It is recommended to keep the charging periods as short as possible and to spread them out through the whole day, so that if the battery becomes over-charged it won't have enough time to heat up too much internally, which is the most common cause of damage. With this method it won't do any harm if you add one or two extra quarter-hour periods in the day, so that partially discharged batteries can be fully charged again.

(100263)

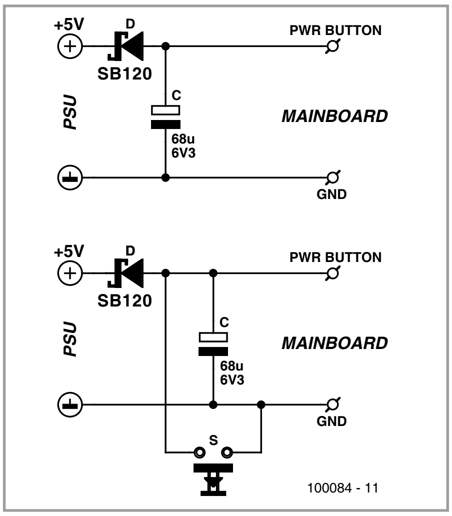
'Always on' for PCs

Dr Rolf Freitag (Germany)

Many enthusiasts will be using their PCs as data loggers, controllers or as web servers. In these cases it is important that the machine is kept powered up for as great a fraction of the time as possible, even if there has been a power cut or if the power button is inadvertently pressed by another member of the household. Today's operating systems offer a range of automation options and it is perfectly possible to arrange things so that the computer starts itself up automatically.

The 'always on' circuit shown here automatically restarts an ATX PC in the above situations. There are just two components: a Schottky diode connecting the power button pin on the motherboard to the +5 V line on the power supply, and a capacitor from the power button pin to ground. The capacitor is a 68 µF tantalum type rated at 6.3 V, and the diode is a type SB 120, rated at 20 V and 1 A. The total component cost is in the sub-one-beer range!

The most convenient arrangement is to mount the circuit directly on a 4-way Molex disk drive power plug, insulating the capacitor and diode using heatshrink tubing. The assembly can then be plugged into a spare socket on the power supply.



The operation of the circuit is straightforward. When the +5 V supply fails (i.e., when the computer is turned off), the power button pin on the motherboard is pulled low via the Schottky diode. This instructs the motherboard to power up again. As long as the +5 V supply is present, the diode blocks and the power button pin remains at high impedance, floating typically at around 3.3 V. The capacitor serves to filter out spikes and brief dropouts.

In its simpler version the circuit replaces the power button on the case, and the computer can now only be switched on and off at the AC power outlet.

The author has tested the circuit on modern SuperMicro X8SAX and X8DTH-6F motherboards as well as on an older Tyan Tiger MPX. He found that the capacitor value should be reduced in some cases: the SuperMicro motherboards have a high internal pull-up resistance which only charges the capacitor rather slowly.

Note that some PC keyboards have a 'Sleep' button which puts the computer into a low-power mode. In this case the circuit will not work, and you should either use a keyboard without such a button or disable sleep modes from within the operating system.

In its more advanced version the existing power button is retained in parallel with the circuit (see circuit diagram). The power button then causes a 'graceful shutdown' whereby the operating system can bring the computer to a halt in an orderly manner.

(100084)

Car Radio Booster

Christian Tavernier (France)

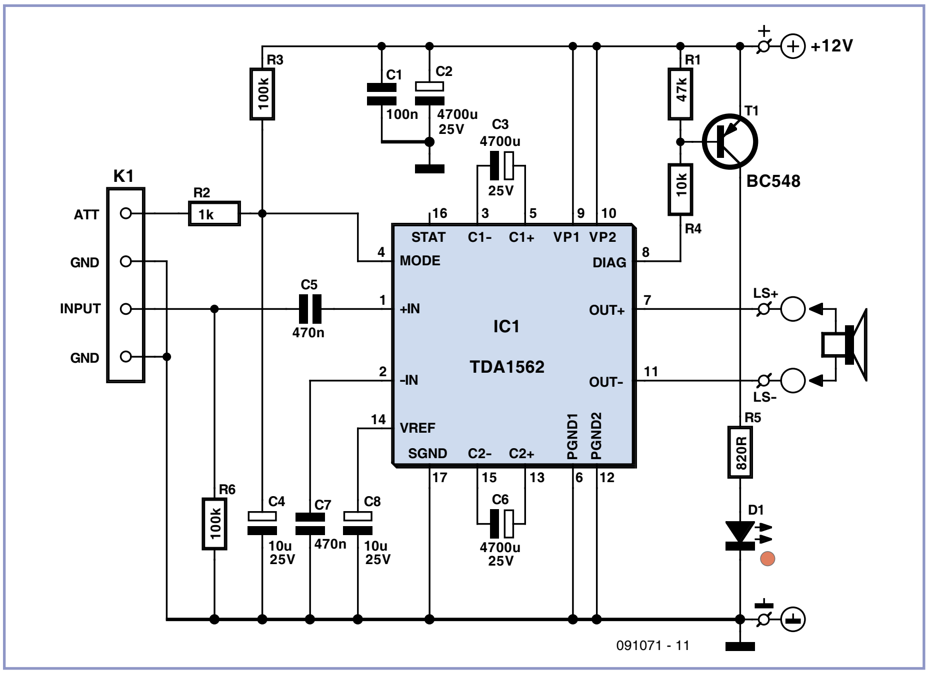
One solution for increasing the power of an amplifier running on a low-voltage supply, like a car radio powered from at best 14 V, is to use a 'bridge' configuration, i.e. to connect the loudspeakers between the outputs of two identical amplifiers whose inputs receive the same signals, but in opposite phases. This doubles the apparent voltage applied to the loudspeaker, which in theory quadruples the maximum power available. In practice, because of the various losses in the power transistors, we can only triple it. The peak-to-peak voltage applied to the loudspeakers in the car radio example is 28 V, less the losses in the power transistors, i.e. around 24 V. So we have an rms voltage of around 8.5 V (24 V / 2√2), which gives an rms power — the only one we hear — of 18 watts (8.5 V² / 4 Ω).

The booster described here does noticeably better, as it can deliver up to 55 watts rms into 4 Ω with distortion of less than 0.5 % — and it's capable of 70 watts rms if you can put up with 10 % distortion. To achieve this, it does not break the laws of physics, but it does use a very original system for boosting the supply voltage, using integrated power switches and high-value electrolytic capacitors.

It uses just a single IC per channel, a TDA1562Q from NXP which handles both the power amplification in class H and the voltage boosting. Since our circuit is intended to be fitted 'behind' a car radio, it has no volume control and its high-impedance input allows it to be connected to either the radio's loudspeaker output, or, preferably, to the line output that some car radios have these days.

Capacitors C3 and C6 are used for the voltage boosting mentioned above. Via the TDA1562Q's integrated electronic power switches, these are alternately charged up to the circuit's supply voltage, then put in series with the supply, thereby doubling it to supply the power output stages. Given the very high currents drawn by such a process when C3 and C6 are being suddenly charged, the supply voltage needs to be very heavily decoupled so as to ensure that it doesn't collapse momentarily when C3 and C6 are connected across it. This is the role of C2.

Transistor T1 drives a 'diagnostic' LED from information provided on IC1 pin 8. This LED, off in normal operation, flashes when the IC detects output distortion (in fact clipping, i.e. distortion of 10% or more) and lights steadily when the IC detects a short-circuited output, in the absence of an output load, or when its thermal protection comes into operation.
The ATT input can be left floating if you don't need it. This is a mute control that puts the circuit into stand-by when grounded. No output signal is produced and the consumption is reduced to a minimum.



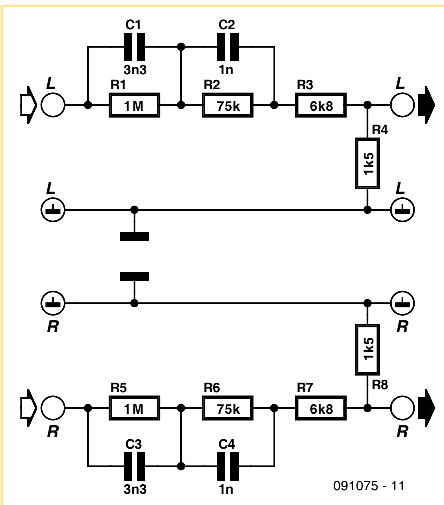
The PCB [1] carries all of the components and two of them will need to be built for a stereo application. Given the heavy currents involved, the wiring for the supply and the connections to the loudspeakers will need conductors with a minimum cross sectional area (c.s.a.) of 2.5 mm².

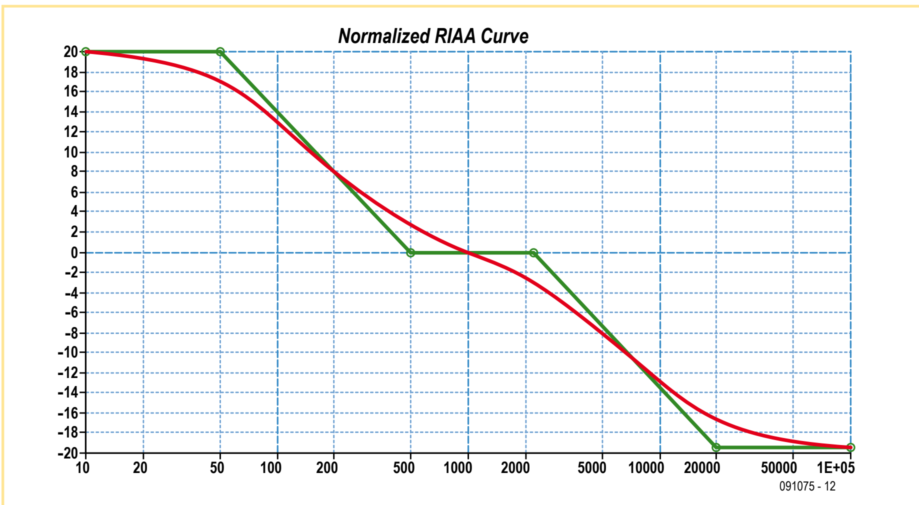
Obviously, the TDA1562Q must be bolted to a heatsink, the efficiency of which will govern the maximum possible time it can work at full power.

(091071-I)

[1] www.elektor.com/091071

Reverse RIAA Adaptor





Christian Tavernier (France)

If you're short of inputs on your amplifier, but it has an input for a magnetic pickup with RIAA correction, this very simple project will let you convert this into a high-level linear input, making it compatible with the outputs from all current audio sources. It won't have quite such perfect quality as a real line input, for two reasons.

Firstly, our circuit is bound to introduce a slight reduction in the signal-to-noise ratio (SNR), as it attenuates a high-level signal and then amplifies it back up again. Secondly, minor linearity 'hiccups' are inevitable, as the correction it produces is not precisely the reverse of the RIAA correction applied by the preamplifier — but it is still perfectly acceptable, especially if it is only for playing MP3 signals!

Our circuit diagram is extremely simple, as it's just a simple passive filter whose components have been calculated to reproduce the inverse RIAA curve to that in the preamplifier, i.e. the same as that used when cutting discs. It's perfectly simple to build, but to avoid degrading the signal-to-noise ratio too much, we recommend using metal film resistors, which are less noisy than their carbon counterparts.

What's more, since the preamplifier magnetic pick-up input applies a great deal of bass amplification, because of the RIAA equalization, the circuit is extremely sensitive to induced interference, especially from AC power lines, and so it will need to be very well screened. We built it 'in the air' and fitted it into a salvaged metal tube (a medicine container) which acts as both case and screen.

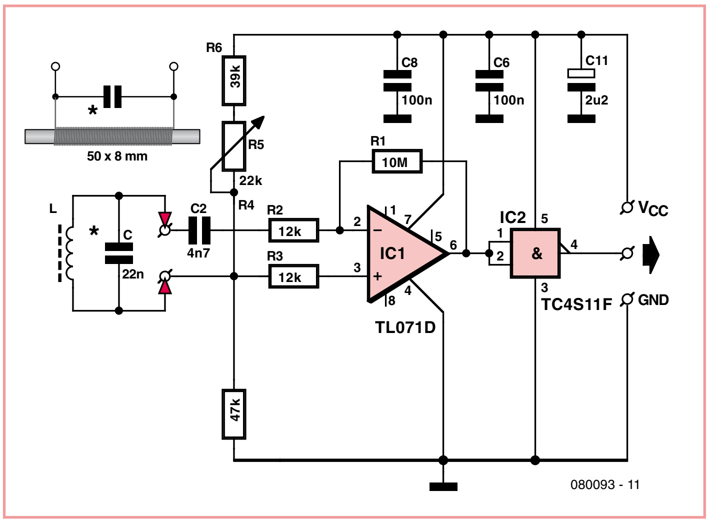
Given the components used, and although it does of course depend somewhat on the sensitivity of the magnetic pick-up input of the amplifier with which it is used, signals with an amplitude of 200–600 mV_{rms} can be applied to this circuit without fear of overloading the preamplifier.

(091075-I)

Pulse Receiver

Siegfried Borst (Germany)

The compact circuit presented here is perfect for receiving the signals from pulsed fixed-frequency transmitters. Chest straps from several well-known brands (Polar, Huger, Kettler, Crane, Outbreaker, ...) transmit a short signal burst with a frequency of 5.3 kHz. These signals can be received and used in your own projects, as the author shows on his website [1].



The circuit uses a ferrite rod with 1000 turns of 0.2 mm enameled copper wire and a (tuning) capacitor to receive the signals. The value of the capacitor (22 nF) has been selected for use at a frequency of about 5.3 kHz, but this can of course be adapted for use at different frequencies. The received signals are amplified by opamp (IC1), after which a NAND gate (IC2) turns them into a nice waveform with straight edges. For the supply you can use any DC voltage source in the range of 9 to 18 V. There is a board layout available [2], which can be ordered via ThePCBShop [3].

(080093)

Web links

[1] http://peterborst.gmxhome.de/sigiborst

[2] http://www.elektor.com/080093

[3] www.thepcbshop.com

AC Power Indicator

Jacob Gestman Geradts (France)

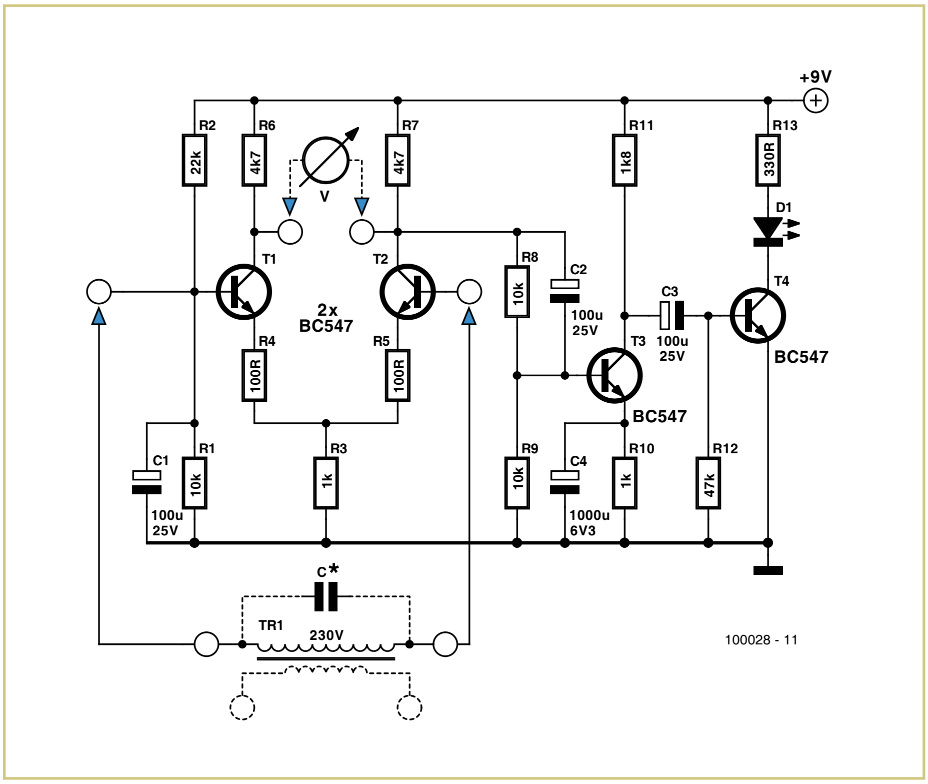
The AC powerline indicator presented here has a complete galvanic isolation from the grid. The indicator is an LED that lights up when a current flows, although the current can be measured more accurately with an AC voltmeter set to its mV range. The detector is a transformer taken from an old cell phone charger. The value of the secondary isn't important because we only make use of the primary winding only (normally 115 V in the US). The (extension) cable through which the current has to be detected should have an as short as possible section of its outer insulation removed. The wires should then be moved apart. The blue wire should be placed on top of the transformer and the brown wire underneath, or the other way round. The brown and blue isolation shouldn't be removed, so there is no danger of the AC line voltage becoming exposed. If there is a green/yellow wire as well, this can be placed on either side of the transformer. The brown and blue wires should be in parallel with the windings on the transformer. The secondary winding(s) should be left open circuit so that they don't attenuate the measured signal.

In our prototype we found that an alternating 60 Hz voltage of about 2 mV was induced when a 30 watt soldering iron was connected to the extension lead. With higher-powered devices the measured voltage rises proportionally. Since it is unlikely that the iron core of the transformer will ever become saturated, the relationship between the measured voltage and the current flow should be fairly linear.

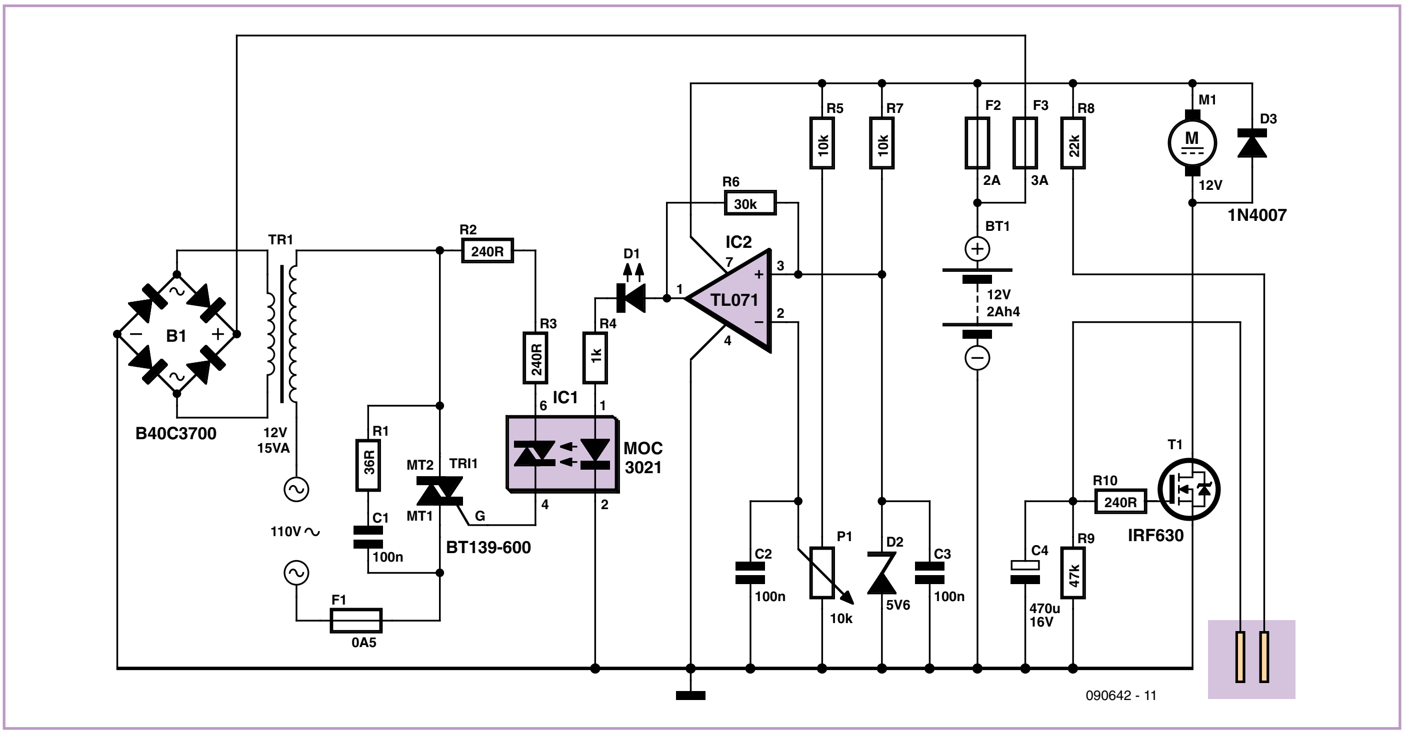
The transformer output signal is amplified by a differential amplifier built around T1 and T2. If you wish, you can connect an AC voltmeter across the collectors of T1 and T2 to get an indication of the size of the current. The rest of the circuit takes care of lighting up the LED when a current flows through the (extension) cable. The measured signal is amplified again by T3 and then T4 is used to drive the LED with a 60 Hz square wave. A 9 V battery is suitable for the power supply.

When a capacitor is connected in parallel with the primary winding of the transformer it can make the circuit less sensitive to frequencies other than 60 Hz. Ideally, the circuit should resonate at exactly 60 Hz. This will make the circuit most sensitive. The capacitor should be chosen such that the measured signal across the collectors of T1 and T2 is at a maximum for a certain current flow. However, the capacitor isn't vital and the circuit still works well when just the transformer is used. When a low-current type is used for the LED, R13 can be increased to 1.2 kΩ (≈ 5 mA max. for D1).

(100028)



12-volt Cellar Drain Pump



Gustave Bolkaerts (Belgium)

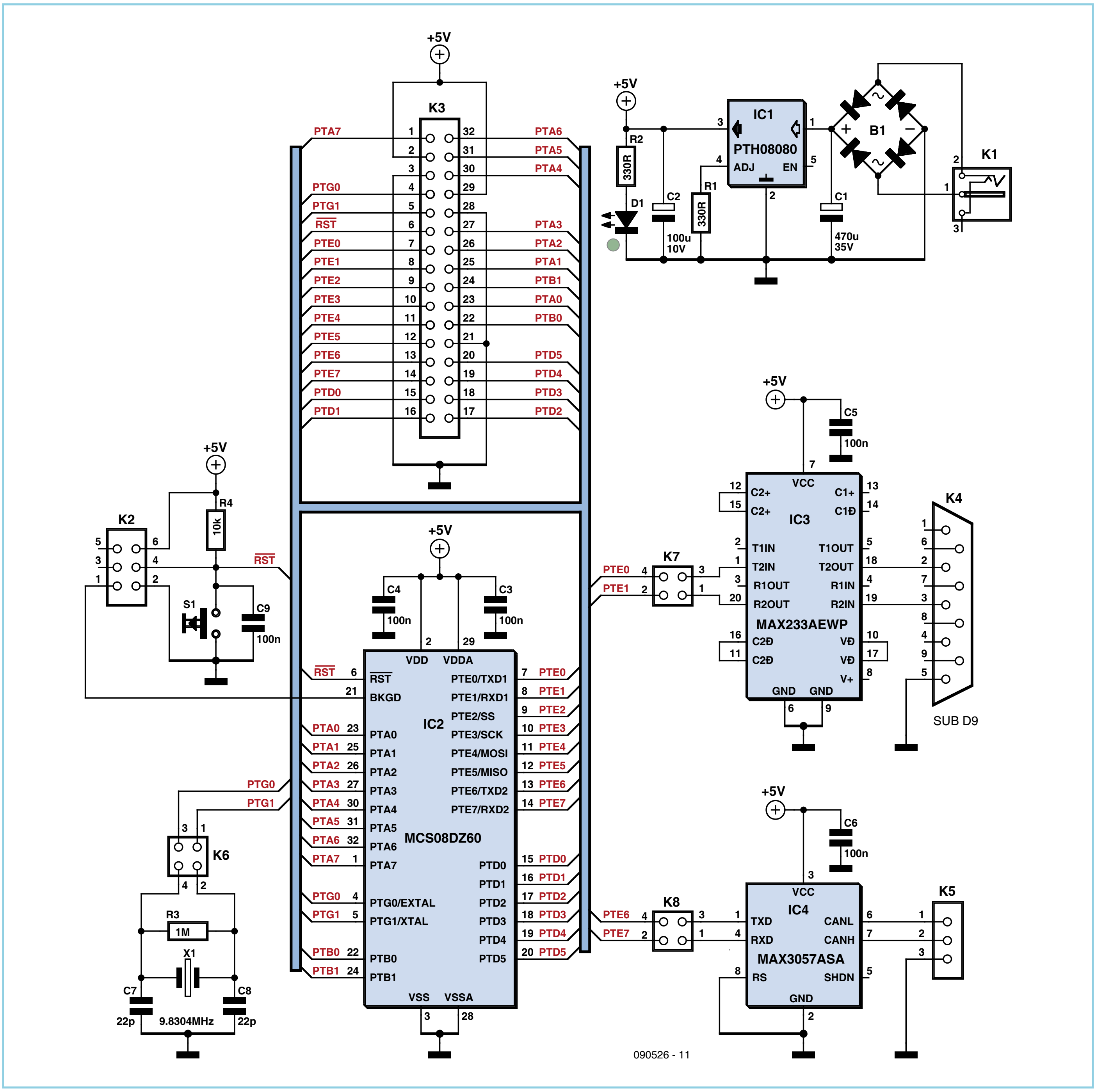
This circuit lets you control a pump, to keep the level of water in a cellar below a certain threshold, for example. Power is supplied to the pump by a battery that is recharged automatically when the AC powerline voltage is present.
If the water level rises, the electrodes touch the liquid and a current begins to flow. The transistor then conducts and the pump runs. The pump stops when the water level has dropped sufficiently for the electrodes to no longer be in contact with it — but not straight away, as the voltage on the transistor gate is maintained for a few seconds

more by the 470 µF capacitor. This makes it possible to ensure the electrodes are completely clear of the water.
The battery is constantly tested by the comparator circuit around the TL071 IC. Its output drives the gate of the triac in the transformer primary circuit via the opto-isolator.
The transformer secondary charges the battery via the rectifier, using as little power as possible, and in this way keeps the battery at 13.2 V.

Note. Some component values may need modifying to suit operation on 115 VAC power.

(090642-I)

MCS08DZ60 Evaluation Board



Joël Guittet (France)

This development board around a 68HCS08DZ60 microcontroller from Freescale aims initially to be a platform for experimenting with the CAN bus. So it's equipped with a CAN driver and the bus is available on a 3-way connector. The board also carries an RS-232 driver. Hence the microcontroller's SCI1 port is available on a standard 9-pin female D connector.

The CAN driver and the RS-232 driver can be disconnected from the microcontroller via jumpers.

The 5 V power supply (with LED indicator) is based around IC1. This is a switching module from Texas Instruments, but can be replaced without modifying the PCB by a conventional 7805 (in this case, there is no need for R1, which should not be fitted).

The clock circuit can be disconnected from the microcontroller via two jumpers, as the microcontroller is actually capable of running on an internal clock.
Connector K2 enables the microcontroller to be programmed, while K3 gives access to all its pins (except for BKGD, which is only used for programming) for a piggy-back module, for example.

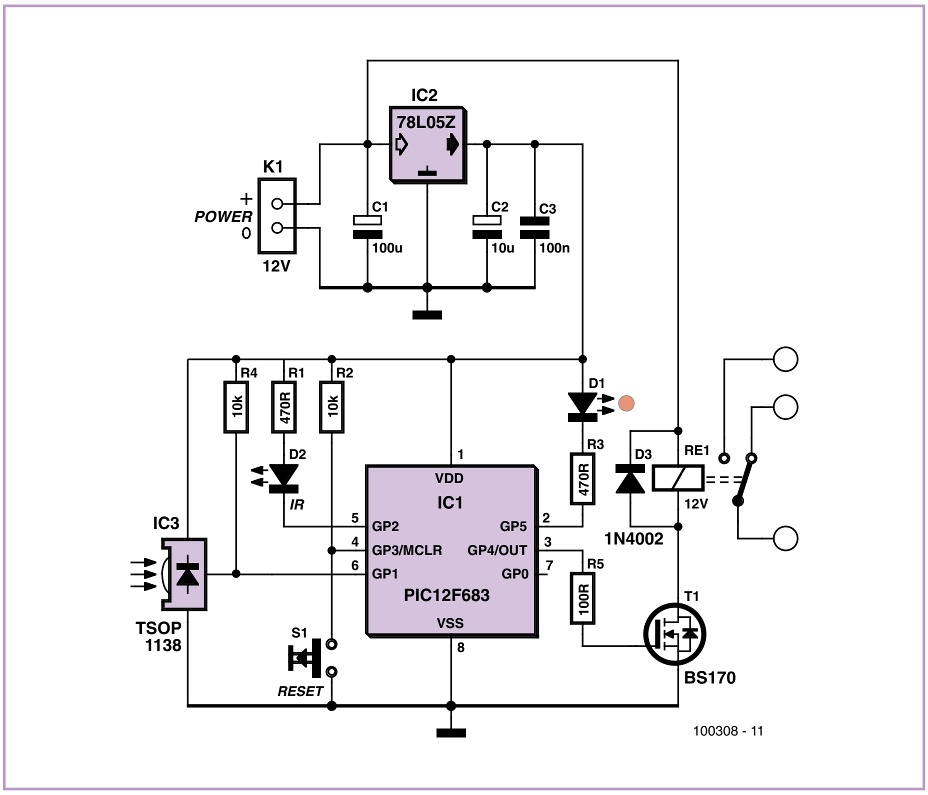
The tools needed for programming are the 'CodeWarrior For Microcontrollers' software available for free download from the Freescale website and a 68HCS08 programmer. Here, there are several possible solutions, like the Multilink programmer from PEMicro or the OSBDM [2,3].

Some programming examples, along with lots of other information about Freescale microcontrollers, are available from the author's website [4].

The PCB design is available from [1]. The PCB gives you an opportunity to have a go at a double-sided board, as there are not many tracks on the back of the board and none of the holes need to be through-plated.

(090526-I)

Animal-friendly Mousetrap



Kees Reedijk (The Netherlands)

This mousetrap is built around a PIC12F683 and uses an infrared transmissive optical sensor that is modulated at a frequency of 38 kHz, so that it isn't affected by the ambient light. The modulation is carried out by the PIC, which generates a 38 kHz signal at port GP2, which is connected to the IR LED. The IR receiver is a type that is usually found for use with remote controls. It reacts only to 38 kHz signals. It reports the presence of an IR signal to the PIC via port GP1. When the IR lightbeam is broken the PIC turns of the relay via port GP4 and FET T1, which causes the door of the mousetrap to close.
The transmissive optical sensor is housed inside a small wooden box. A small amount of food is placed inside this box. When a mouse walks through the light beam on its way to the food it causes the door to shut behind it and an LED starts flashing. The door is normally kept open by the coil of a relay that has been taken apart. When the coil is no longer powered the tin door is pushed shut by means of a spring. A piece of glass or transparent plastic should be put on top of the box, so that the mouse doesn't have to enter a dark space.
When a mouse has been caught it can be let free again somewhere outside, some distance away from the house.
The reset button has to be pressed to ready the trap for its next victim. The author has managed to catch a few dozen mice with this device.
The program is written in PICBASIC Pro and can be freely downloaded from the Elektor website, it is found in archive file # 100308-11.zip.

(100308)

Tiny Pulser

Wilfried Waetzig (Germany)

The author repeatedly needed several different digital signals for testing his circuits, and a simple function generator did not provide a satisfactory solution. He quickly developed a design for a pulse generator with three outputs, as described here, which can generate a variety of pulse trains with adjustable frequency.

The heart of the circuit is an ATtiny13. This compact AVR microcontroller has five external I/O pins, of which three (PB0, PB1 and PB2) are used for the pulse outputs and two (PB3 and PB4) are used as inputs for the A/D converter. Switches Select 1 to Select 3 and the R/2R network (R5, R6, R7, R8, R13 and R14) are used to set a voltage on PB4 that selects the pulse mode (0–7) in the software. The pulse rate is controlled by the voltage on PB3, which can be adjusted with potentiometer R11 to cover the range from 290 Hz to approximately 8 kHz.

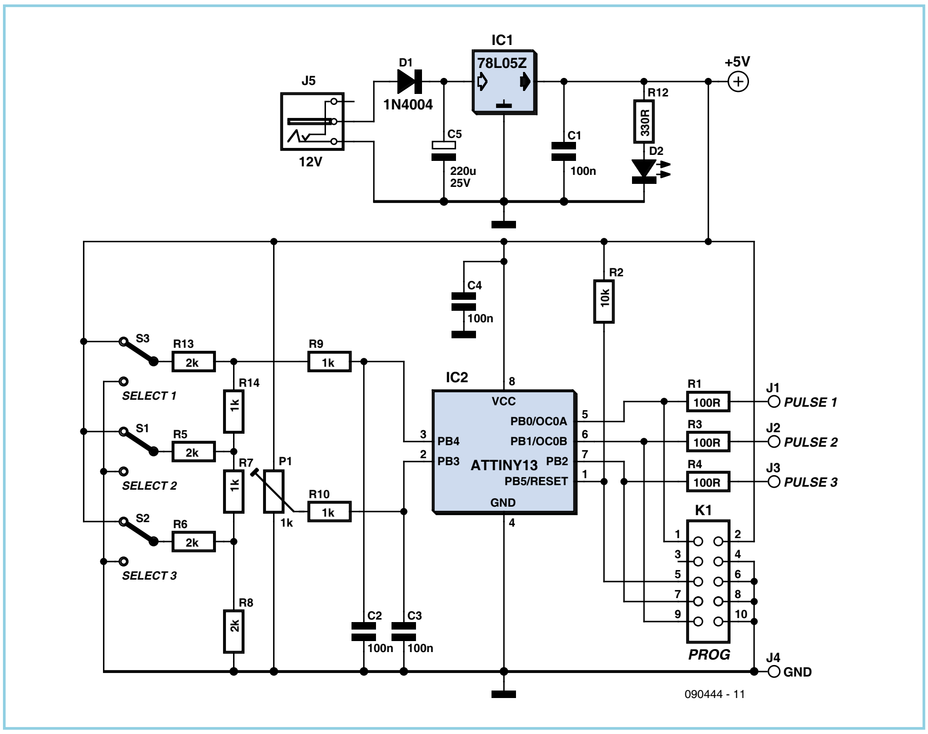
The timing diagrams illustrate the pulse sequences generated in modes 0 to 6:

Modes 1 & 2: non-overlapping pulses with adjustable frequency (normal or inverted)
Modes 2 & 3: fully overlapping pulses with adjustable frequency (normal or inverted)
Modes 4 & 5: partially overlapping pulses with adjustable frequency (normal or inverted)
Mode 6: three-bit binary counter with adjustable frequency

Mode 7 is a special mode in which PWM signals at a frequency of 2300 Hz are output on the PB0 and PB1 pins. PB1 provides a PWM signal that periodically ramps up from 0 to 100% (0–255) and back down again, with a repetition rate of approximately 0.5 Hz. The PWM signal on PB0 can be controlled via the ADC3 input. The pulses from Timer0 are output on PB2. We have more to say about Timer0 further on.

The firmware for the Tiny Pulser was written in assembly language using Atmel AVR Studio 4. Fast execution is especially important here because the output pulses are generated by software in the Timer0 interrupt routine. The pulse sequence is generated using a cyclic counter with a range of 0 to 7, and the values of the three output signals are stored in an array indexed by mode (0 to 7) and cycle state. Each time an interrupt occurs, the appropriate values are read from the PULSE[MODE, CYCLE] array and fed to the outputs.

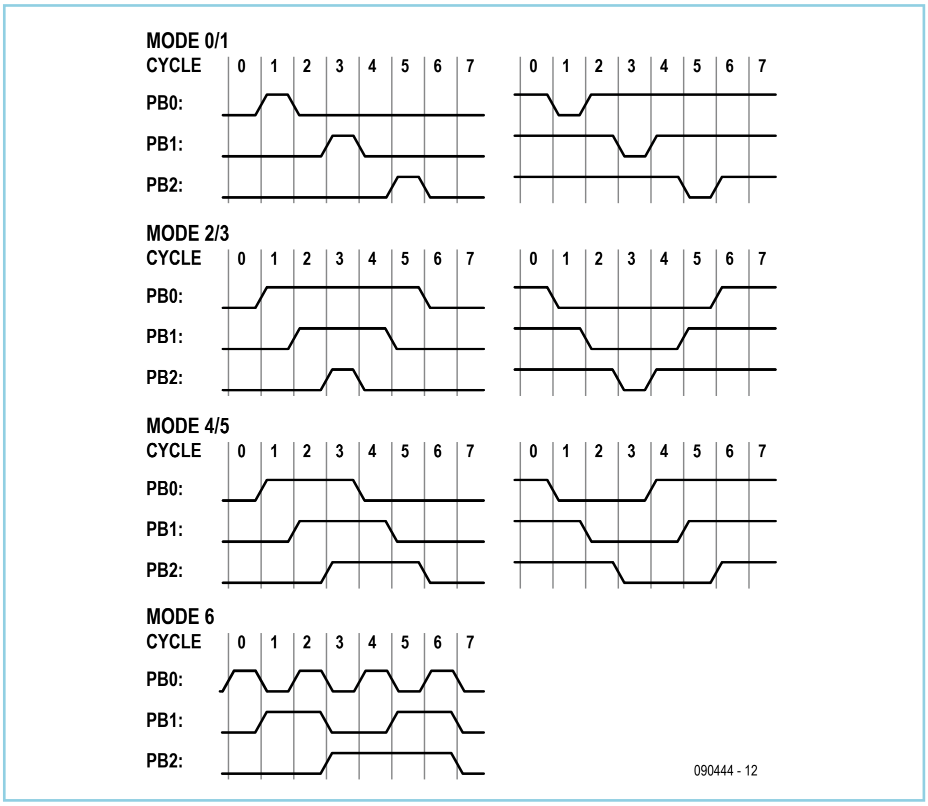
The ATtiny13 microcontroller is clocked by its internal RC oscillator at 4.8 MHz, and the fuse bits must be configured accordingly:



Fuses: CKSEL = 0,1 → 4.8 MHz
CKDIV8 = 0 → no divide by 8
SUT = 1,0 → slow rising power

The source code and a hex file can be downloaded from the Elektor website (www.elektor.com/090444), along with a ReadMe file with information about programming. If you don't want to program the microcontroller yourself, you can order a pre-programmed device from the Elektor Shop at www.elektor.com/090444 (order number 090444-41).

(090444-I)



MicroMinimal Thermometer

Vladimir Mitrovic (Croatia)

The thermometer shown here is “micro” not only because it is built around the ATtiny13 microcontroller, but also because it can be built as a miniature device when built from SMD components.

The temperature is measured by a DS18S20 high precision 1-Wire® digital thermometer from Maxim. The program inside the ATtiny13A microcontroller initiates a single temperature conversion, waits until the conversion has finished, then reads and displays the result. the temperature can be read by counting red and green blinks from a two-color LED. For example, 2 red and 3 green blinks will be produced if the temperature is 23°C. Blinks are easily readable because each blink lasts approximately 135 ms and is followed by a 400 ms pause.

The same LED pair is used to display other events, too:

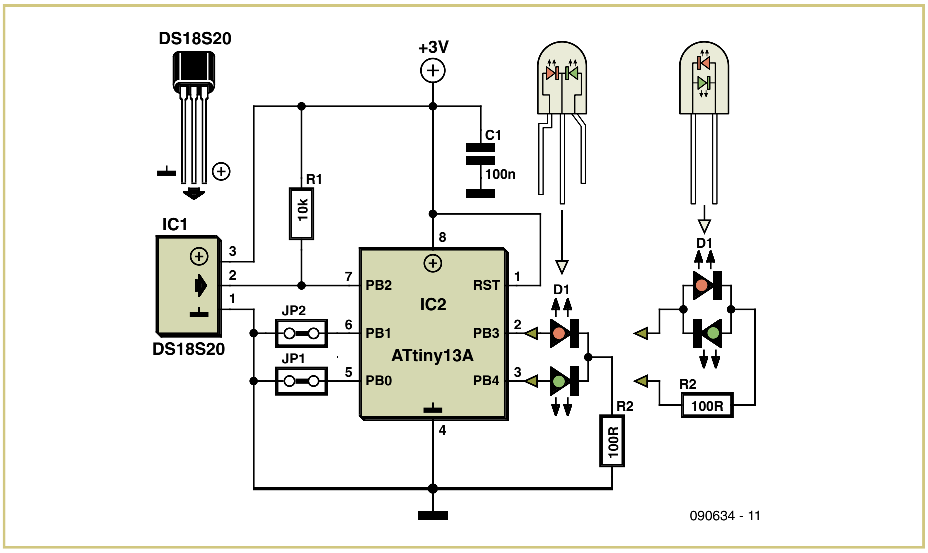
1. When the temperature is negative (centigrade value), an R-G-R-G sequence with no intermediate pauses stands for the “–” sign (red and green blinks are clearly visible);
2. 0°C is displayed as a 1 second long sequence of short red and green blinks (red and green light blend together);
3. A communication error is displayed as a 1-second long red light.

As indicated in the circuit diagram, two different two-color (red + green) LED types may be used: 3-terminal (with common cathode) or 2-terminal (with red and green LEDs in anti-parallel connection). The ATtiny program is the same for both versions. Since LEDs consume most of the power, choose an appropriate value for R2 to suit your own needs. A 100 Ω resistor results in an 8 mA current flow through the LED that’s switched on.

During the display period the LEDs are on at a 25% duty cycle, with 1 second conversion periods between two display sequences to reduce the average LED consumption to roughly 1.5 mA. This may be considerably lowered if two separate red and green low-current LEDs are used for display. But even with 20-mA LEDs, the circuit may be powered by a small 3 V Lithium cell for a good period.

Although in theory the instrument can measure temperatures between –55°C and +125°C, in practice it seems prudent to stay within the –15°C to +50°C range.

The DS1820 can be detached from the rest of the circuit for as far as the 1-wire protocol allows; a 3-m (10 ft.) connecting cable was tested and everything worked well. If the sensor is properly insulated, you can measure the temperature of water or other non-aggressive liquids. But the most common use of the proposed circuit is to build a small and simple thermometer with low power consumption, which will be at hand and functional whenever you need it.




```
Do
   Config Clockdiv = 8                          'Set clock=1.2MHz
   1wreset                                      'Start 1-Wire
   communication
   1wwrite &HCC                                 'Skip ROM
   1wwrite &H44                                 'Convert T
   Config Clockdiv = 64                         'Set clock=150kHz
   Counter0 = 109                               'Wait 1s
   Gosub Wait
   Config Clockdiv = 8                          'Set clock=1.2MHz
   Gosub Read_t                                 'Read T
   Config Clockdiv = 64                         'Set clock=150kHz
   Gosub Disp_t                                 'Display T
   Portb.1 = 1                                  'Prepare to read JP2
   (Powerdown)
   Counter0 = 255                               'Wait 7ms
   Gosub Wait
   If Pinb.1 = 0 Then Exit Do                   'JP2 closed?
   Exit&Powerdown!
   Portb.1 = 0
Loop

Portb.0 = 0
Portb.1 = 0
Powerdown

End
```

With JP1 closed the readout is in ‘modulo 5’ mode: each blink of the red LED now equals 5, while the green blinks are still unity. Thus 4 red and 3 green blinks will occur if the temperature is 23°C.

If JP2 is closed, the microcontroller goes into power-down mode if the temperature is measured and displayed for the first time. This option consumes minimum power. To repeat the measurement, switch off the thermometer, wait for 1 to 2 seconds and switch it on again.

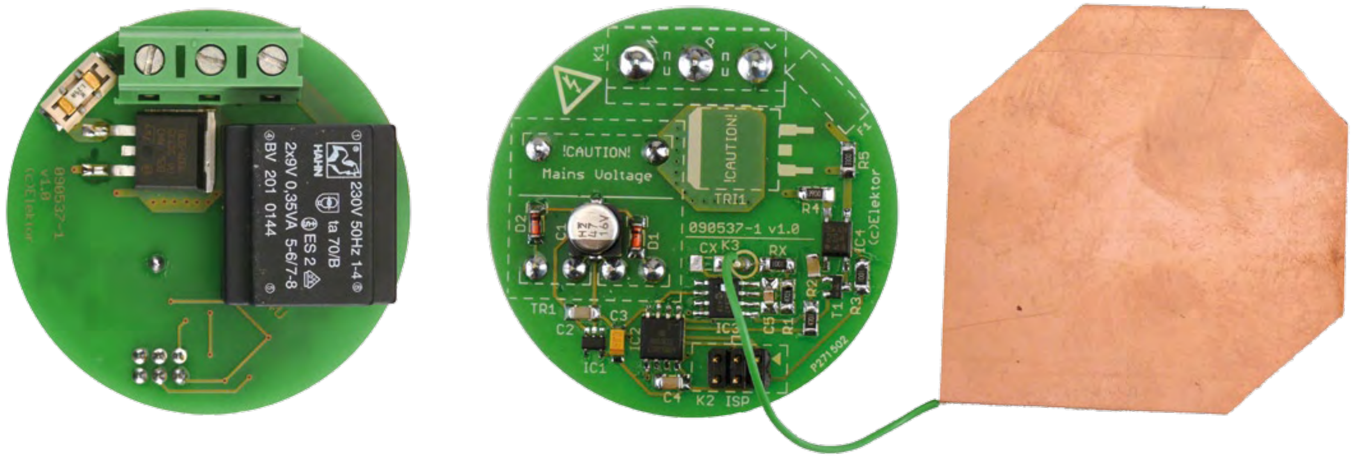
The program developed for the project is called ‘EE_micro_T.bas’ and was written in BascomAVR for compiling and turning into object code. A small extract is shown here. The complete program is a free download [1]. Those without access to an ATtiny13A programmer or BascomAVR may buy their ready-programmed IC through the same web page.

Readers preferring Fahrenheit temperature readout should modify the BascomAVR program accordingly.

(090634)

[1] www.elektor.com/090634

Waterproof Bathroom Switch



Ludovic Mézière (France)

The object of this circuit is turn the domestic lighting on and off in complete safety in a room with very high humidity. A detector, flush-mounted into the wall, detects the magnetic field variations caused by the proximity of a hand and controls an AC power switching system. Hence lighting control is achieved through the wall covering, with no exposed electrical equipment.

Operation is based around a specialized IC (IC3): the QT113A from Quantum (bought out a few months ago by Atmel). This IC generates a pulsed magnetic field while a capacitive measuring system detects the variations. Any variation in the magnetic field results in toggling of its output. A series of filters avoids errors, and detection has to be confirmed three times before the processor will toggle the output, which avoids unwanted triggering. IC3 has a self-calibration feature that enables it to adapt itself to variations in external conditions. The pulsed operation limits RF emissions as well as consumption.

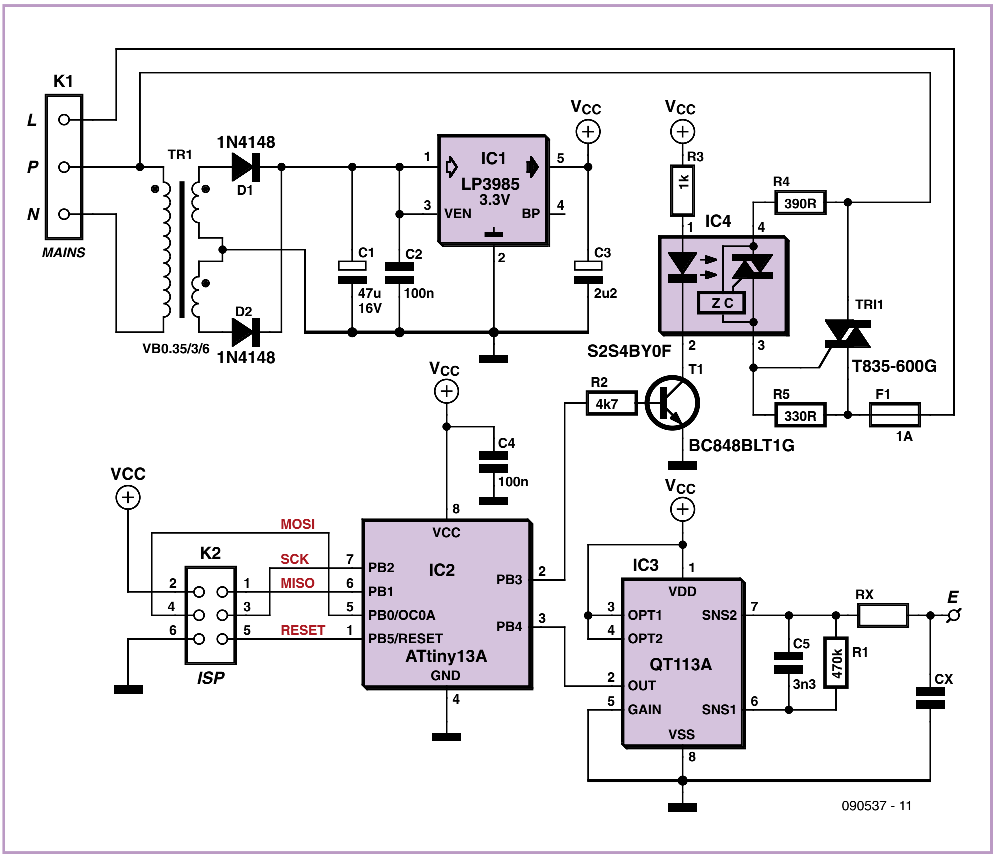
The electrode is formed from a piece of copper-clad PCB board of around 5 × 5 cm, which has had the photosensitive film removed to allow a wire to be soldered on for connecting it to the electronics board. The electrode must be kept a few centimeters away from the electronics board, otherwise it won't work; this prevents you from being able to use a double-sided PCB with one side carrying SMD components and the other side acting as the electrode. The value of capacitor C1 will determine the sensitivity of the detector, and its value will need to be adjusted depending on the environment and the sensitivity required.

IC3's output provides an oscillating signal that enables it to prove it is working, which means we have to use a small controller which will register the information provided by the detector and handle the load switching via an opto-triac and a triac. A standard ISP connector is available for programming the microcontroller. A miniature transformer makes it possible to include a small 5 V PSU on the board and isolate the circuit from the AC powerline. Isolation between the output and the AC is ensured by an opto-triac, but it's important to remember that one part of the circuit is connected to live AC voltage.

All the components are SMD types, but are still easy enough to solder using a conventional iron. The PCB can be fitted into an electrical back-box (e.g. Legrand Batibox) in the bathroom, for example, behind a tile. All you have to do to turn the light on or off is touch this tile with your finger.

(090537-I)

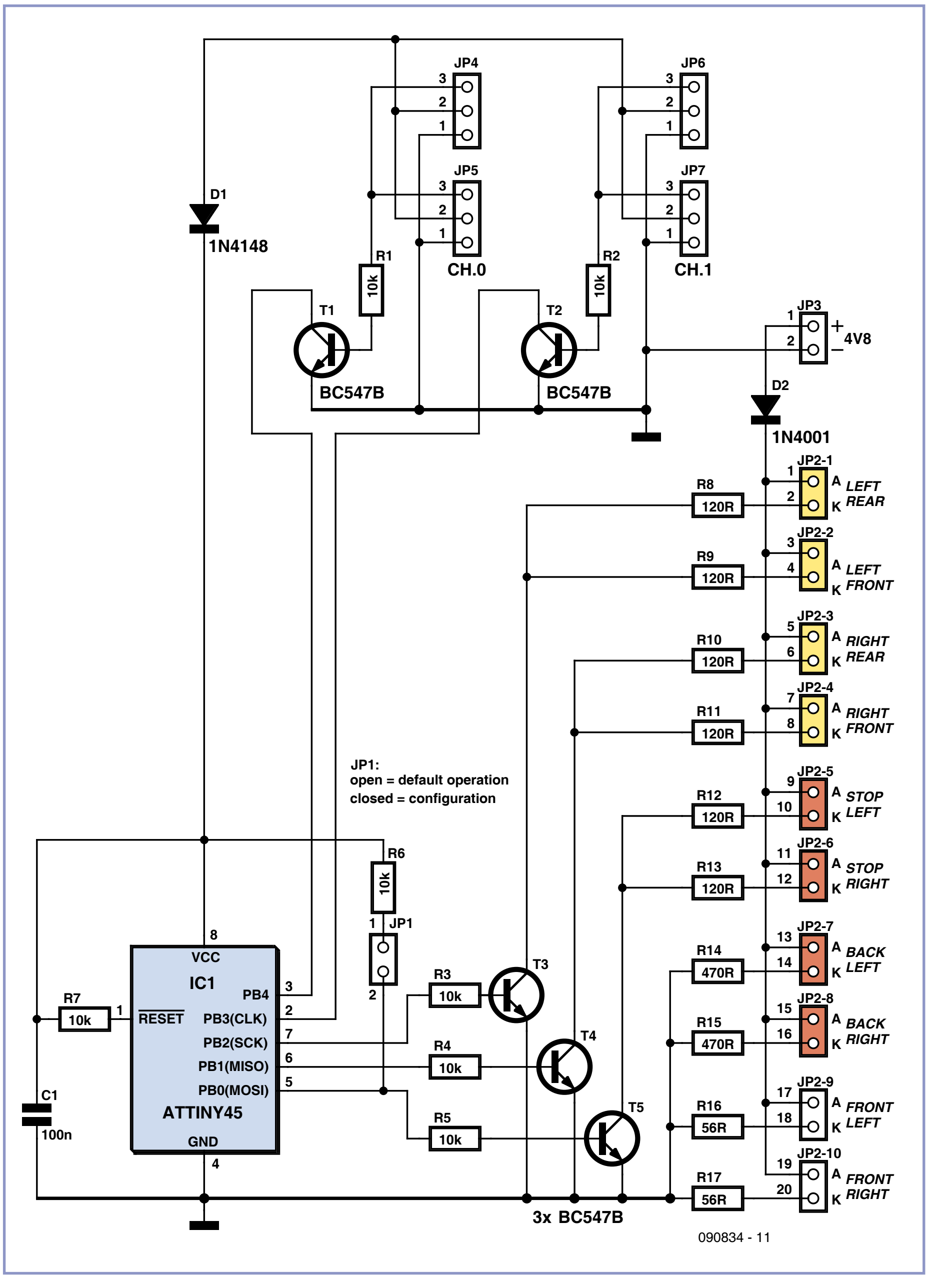
[1] www.elektor.com/090537



Lights Control for Model Cars

Manfred Stratmann (Germany)

The author gave his partner a radio-controlled (RC) model car as a gift. She found it a lot of fun, but thought that adding realistic lights would be a definite improvement. So the author went back to his shed, plugged in his soldering iron, and set to work equipping the car with realistic indicators, headlights, tail lights and brake lights.



The basic idea was to tap into the signal from the radio control receiver and, with a bit of help from a microcontroller, simulate indicators using flashing yellow LEDs and brake lights using red LEDs. Further red LEDs are used for the tail lights, and white LEDs for the headlights. Connectors JP4 and JP5 (channel 0) are wired in parallel, as are JP6 and JP7 (channel 1), allowing the circuit to be inserted into the servo control cables for the steering and drive motor respectively. The ATtiny45 microcontroller takes power from the radio receiver via diode D1. T1 and T2 buffer the servo signals to protect IC1's inputs from damage.

IC1 analyzes the PWM servo signals and generates suitable outputs to switch the LEDs via the driver transistors. T3 drives the two left indicators (yellow), T4 the two right indicators, and T5 the brake LEDs (red). The red tail lights (JP2-8 and JP2-8) and the white headlights (JP2-9 and JP2-10) are lit continuously. The brake lights are driven with a full 20 mA, so that they are noticeably brighter than the tail lights, which only receive 5 mA. If you wish to combine the functions of tail light and brake light, saving two red LEDs, simply connect pin 10 of JP2 to pin 14 and pin 12 to pin 16. Then connect the two combined brake/tail LEDs either at JP2-5 and JP2-6 or at JP2-7 and JP2-8.

JP3 is provided to allow the use of a separate lighting supply. This can either be connected to an additional four-cell battery pack or to the main supply for the drive motor. The values given for resistors R8 to R17 are suitable for use with a 4.8 V supply. JP2 can take the form of a 2x10 header.

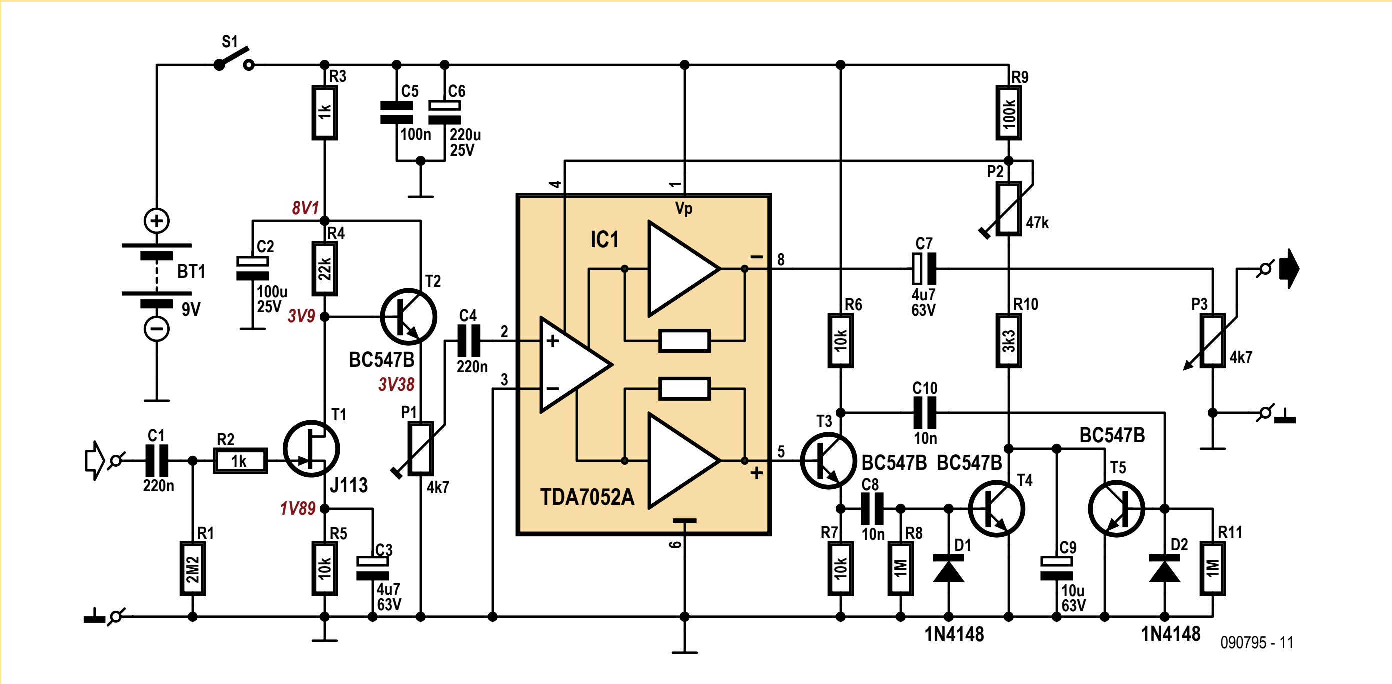
As usual the software is available as a free download from the Elektor web pages accompanying this article [1], and ready-programmed microcontrollers are also available. The microcontroller must be taught what servo signals correspond to left and right turns, and to full throttle and full braking. First connect the finished circuit to the radio control electronics in the car, making sure everything is switched off. Fit jumper JP1 to enable configuration mode, switch on the radio control transmitter, set all proportional controls to their centre positions, and then switch on the receiver. The indicator LEDs should first flash on both sides. Then the car will indicate left for 3 s: during this time quickly turn the steering on the radio control transmitter fully to the left and the throttle to full reverse (maximum braking).

Hold the controls in this position until the car starts to indicate right. Then set the controls to their opposite extremes and hold them there until both sides flash again. Now, if the car has an internal combustion engine (and so cannot go in reverse), keep the throttle control on full; if the car has an electric motor, set the throttle to full reverse. Hold this position while both sides are flashing. Configuration is now complete and JP1 can be removed. If you make a mistake during the configuration process, start again from the beginning.

(090834)

[1] www.elektor.com/090834

No-CA3080 Guitar Compressor



Ian Field (UK)

The TDA7052A is a readily available amplifier chip (Farnell # 526198) that has a DC controlled volume input. Here, the IC is used as the variable gain amplifier in a guitar compressor, so the effect can be accomplished without the hard to obtain CA3080 operational transconductance amplifier (OTA). Note that the suffix-less TDA7052 does not have DC volume control.

The TDA7052A has a relatively low input sensitivity and also a relatively low input impedance, so common source JFET amplifier T1 provides some pre-gain while emitter follower T2 provides low impedance drive for IC1's input. Advantage is taken of IC1's dual outputs to keep the diode pump and output loads apart, although distortion from this probably wouldn't happen as IC1 has very low output impedance (about 0.2 ohms). The output on pin 8 is fed via DC blocking cap C7 to the level pot P3.The output on pin 5 drives phase splitter T3 whose outputs drive T4 and T5 on alternate half cycles. Both of these transistors in parallel discharge C9 which effectively holds the control voltage for pin 4 of IC1.

The input stage has a number of design aspects worthy of mentioning. The JFET stage will clip if the I_{dss} is too high. For T1, a 2N3819 can be got away with if selected for I_{dss} less than 5 mA otherwise the input amplifier won't work. This may not be possible with all brands of 2N3819. The J113 shown here is spec'ed at 2 mA min. and no upper limit given on the data sheet.

Source resistor R5 may be determined empirically by temporary insertion of a trimpot to set the drain to 0.5 V_{BATT}, obviously centring the drain operating point optimizes the headroom for output swing. With lower values of drain resistor it may be possible to use unsorted examples of the 3819.

It is made abundantly clear in the TDA7052A appnote and data sheet that good supply decoupling is important, hence it is recommended that C6 be a good quality electrolytic. C5 is specified as 0.1 µF in accordance with data sheet advice, although if a miniature 0.22 µF that will fit in the available space is ready to hand — every little helps. C5 should be fitted as close as possible to the IC1 supply pins.

It is assumed that anyone who gets as far as building a board for a guitar pedal will know how to wire a bypass stomp switch, however there are some notes that concern the placement of the pots. Ideally only one pole of the two pole changeover stomp switch is needed, to switch the output jack between the compressed output and an additional pot on the pre-gain buffer.

It is likely that P1 (pre-gain) would be useful as a front panel control, and this is a good place to connect the bypass stomp switch. The best option is to use 2x 10 kΩ pot in parallel instead of P1 on its own, one wiper feeding IC1 pin 2 (pre-gain), the other feeding the stomp switch bypass (bypass gain). P2 (sustain) varies how much effect the voltage on C9 affects the voltage on IC1 pin 4 and therefore controls the range of gain control.

The circuit is supplied by the usual PP3 9 V battery, a slide switch can be wired in series with the positive lead from the battery clip if preferred, but it is common practice in the FX industry to use stereo jack sockets with the tip of the plug carrying the signal as normal, the ring contact of the jack socket is shorted to ground when a mono plug is inserted. Provided skeleton style jack sockets are mounted in a metal case, inserting a mono plug connects the ring contact to the case. In this way if the battery negative lead is connected to the ring contact of one socket and the PCB negative lead is connected to the ring contact of the other jack socket, removing either jack plug will break the circuit between the battery negative and PCB negative.

The circuit from C1 to P1 is useful in it's own right as a 'clean boost' pedal, within reason the input impedance can be pretty much as high as you want to make it, and emitter follower T2 gives it a very low output impedance capable of driving long cables without losing the high notes and also overdriving the input stage of valve amplifiers (not so worth while with transistor amps!). However, depending on the JFET choice and biasing it is just possible that a good quality guitar with *ditto* pickups might overload the input stage to a degree.

(090795)

Mini Sixties Plus

Joseph Kreutz (Germany)

This circuit is inspired by an amplifier published in the '60s that produced 8 watts a channel into 8 Ω and was based on AD161 and AD162 germanium (not 'geranium') power transistors. These at last made it possible to build complementary-symmetry power stages with performance similar to that obtained with the standard at the time: a class AB 'push-pull' using with two EL84 (6BQ5) pentodes. Modest as it is, the power of the 'Mini Sixties' is still more than enough to drive high-quality speakers and provide comfortable listening for a signal from a computer or MP3 player. It goes without saying that for a stereo project, you'll need to build two channels.

The input signal is applied to the base of T1, which is biased via the divider formed by R1, R2, and R3, decoupled by C2. T1's emitter receives the negative feedback signal tapped off the output by R6. As T1's collector current is determined by the difference between the input and negative feedback signals, this transistor forms an error amplifier.

Series network R5 and R6 determines the voltage gain of the 'Mini Sixties' in the audio band. In the configuration shown here, the gain is 11 (1+R6/R5). Selecting a value of 22 Ω for R5 (and 470 µF for C3) enables you to increase the gain to 22 if this proves necessary. The values for R5 and C3 have been chosen to obtain a low-frequency cut-off of about 15 Hz.

The amplifier's voltage gain stage is formed by transistor T2, with resistor R12 as its load. The latter is connected to the loudspeaker output and not to the supply rail, in such a way that the voltage across it virtually doesn't vary at all: this is the 'bootstrap' effect. The current through it then stays constant and is enough to drive the power transistor, even when the output voltage nears its maximum. The disadvantage is that this current also passes through the load, resulting in a small DC voltage across the terminals of the load (26 mV @ 33 mA).

Resistor R13 avoids T2 finding itself open collector when there is no load connected to the amplifier, in such a way that the quiescent voltage at the junction of R8||R9 and R10||R11 maintains its value which is half the supply voltage. Emitter resistor R7 linearizes the voltage gain stage and capacitor C4 establishes the dominant pole, which ensures the stability of the amplifier.

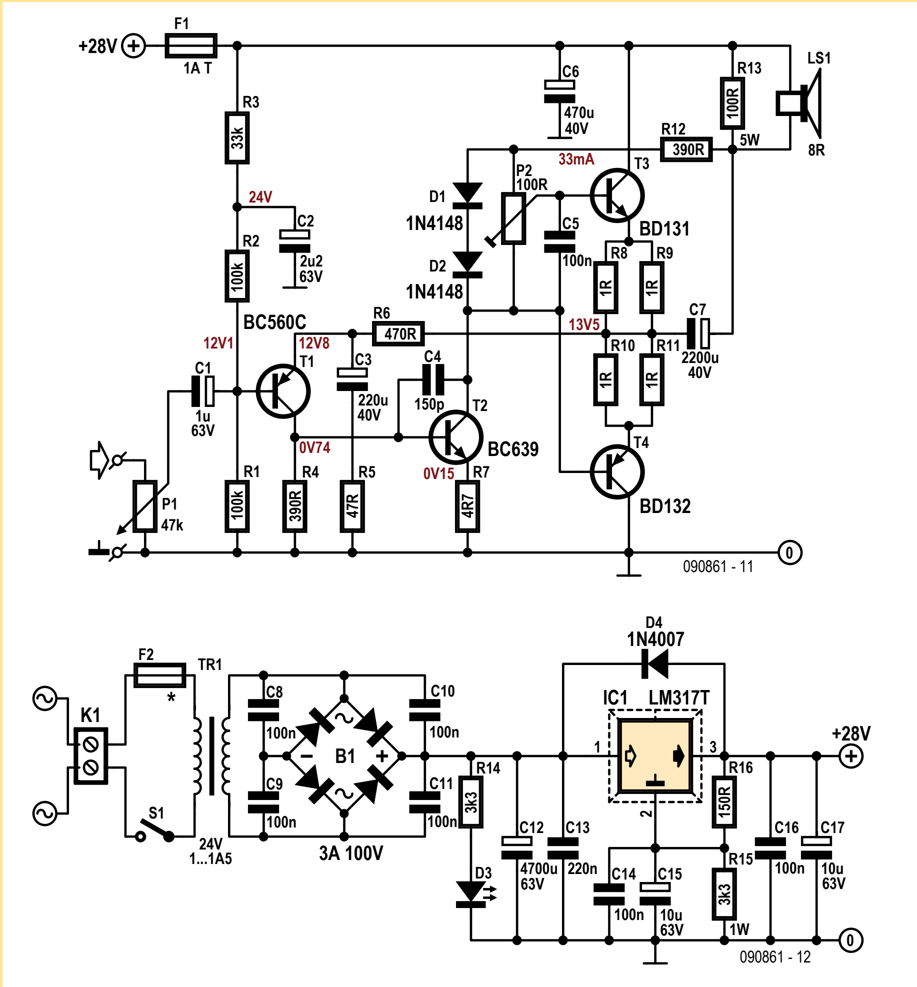
The power stage is formed by T3 and T4 wired as a very classic complementary-symmetry 'push-pull' stage. Diode D1 and D2 stabilize the power stage quiescent current, which will need to be set to 20 mA by adjusting preset P2. A multi-turn type is highly recommended for P2. The quiescent current is measured using a voltmeter between the emitters of T3 and T4: the voltage measured in mV corresponds to the current in mA. If necessary, the quiescent current setting may need to be tweaked once the amplifier has reached its normal operating temperature.

The power transistor will need to be fitted to a heatsink with a thermal resistance of less than 4 °C/W, using insulating spacers and heatsink compound. It will also be necessary to make sure that D1 and D2 are in good thermal contact with T3 and T4.

The amplifier does not use a symmetrical power supply, which is why the load is connected via capacitor C7. Since the amplifier is not protected against short-circuits on the load, a 1 A slo-blow fuse lets us limit the damage in the event of a problem. The 28 V power supply is taken care of by an LM317 regulator, whose current limiter offers an additional degree of protection. The regulator will also need to be mounted on a heatsink with a thermal resistance of less than 2 °C/W. Where applicable, you may also need to provide insulation. The supply transformer TR1 must be capable of supplying 24 V @ 1–1.5 A. The fuse F2 should have the value recommended by the transformer manufacturer.

The voltages and currents shown on the circuit were measured on our prototype. We measured the distortion as 0.14 % (1 kHz, 1 W) — not all that bad for an experimental project using just four transistors.

(090861-I)



Specifications:

Sensitivity: 820 mV (9.1 W)

Gain: 10.4

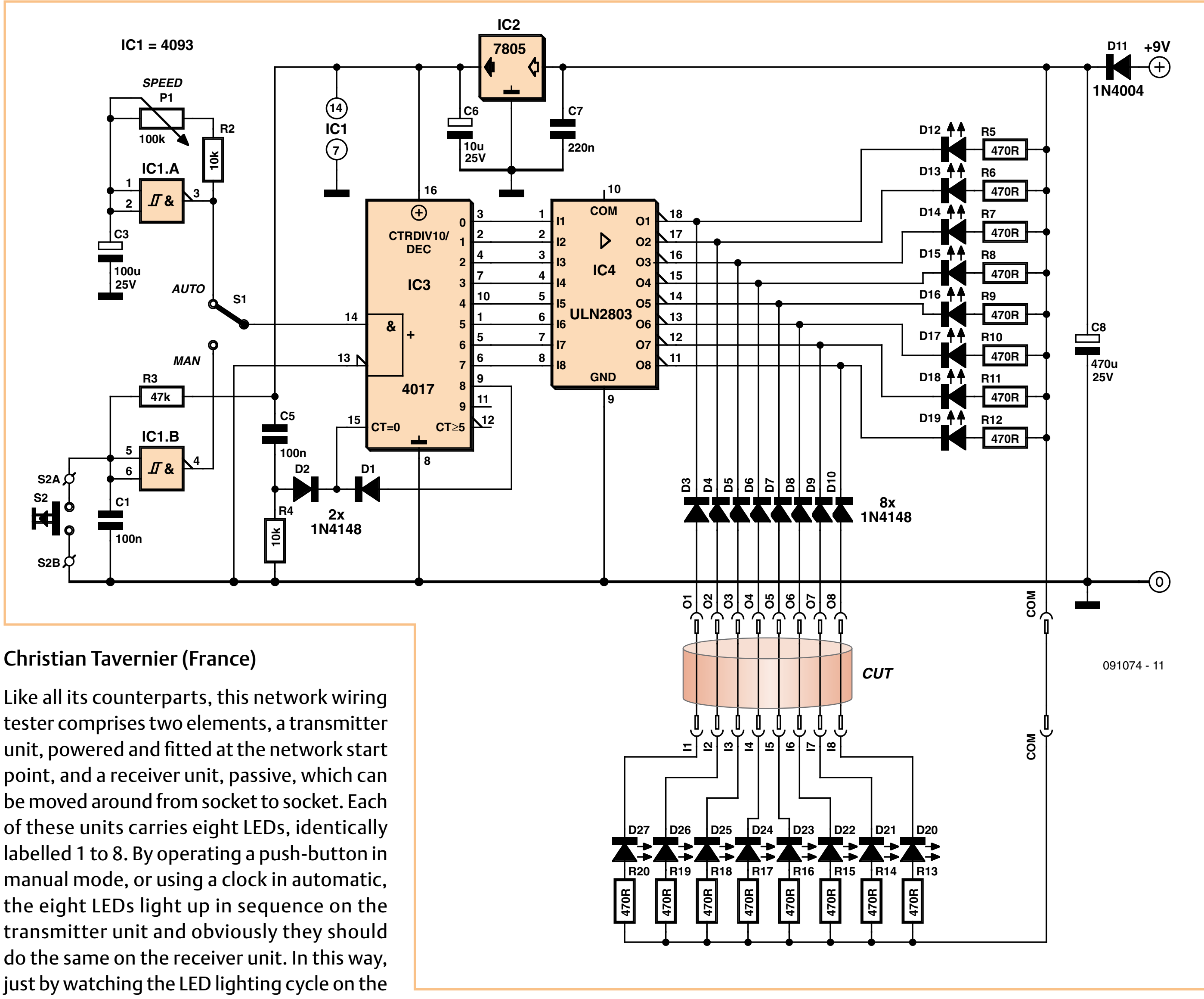
Max. power: 9.1 W (THD = 1 %)

Frequency response: 21 Hz - 1 MHz (1 W)
21 Hz - 400 kHz (8 W)

THD+N: 0,.4 % (1 kHz, 1 W, BW = 80 kHz)

S/N: 78 dB (BW = 22 kHz lin.)
86 dBA

Network Wiring Tester



Christian Tavernier (France)

Like all its counterparts, this network wiring tester comprises two elements, a transmitter unit, powered and fitted at the network start point, and a receiver unit, passive, which can be moved around from socket to socket. Each of these units carries eight LEDs, identically labelled 1 to 8. By operating a push-button in manual mode, or using a clock in automatic, the eight LEDs light up in sequence on the transmitter unit and obviously they should do the same on the receiver unit. In this way, just by watching the LED lighting cycle on the receiver unit, you can immediately spot any crossed wires, as well as any open circuits (the relevant LED never lights up) or shorts (two or more LEDs light at the same time).

The transmitter unit circuit is simple. The Schmitt-input NAND gate IC1.A is wired as a multivibrator, whose speed can be adjusted using P1, while IC1.B is wired as a simple debounce circuit for button S2, used in manual mode. Switch S1 lets you apply the output of one or the other of these to the input of IC3, a decade counter IC, which here we force to count up to eight by connecting its Q8 output back to its reset input. Its outputs are not capable of driving LEDs, especially over wiring that be 'dangerous' for them (a short, for example), so a ULN2803 is used to drive the outputs. This integrated network of eight Darlington transistors, each capable of switching up to 500 mA, drives the eight LEDs fitted to the transmitter unit (D12–D19) and feeds its signals to the socket comprising contacts O1–O8, to which the wiring to be tested must be connected. At the other end of the cable, via the socket comprising contacts I1–I8, is the receiver unit which contains just eight LEDs (D20–D27) and their current limiting resistors. For the latter to work, there obviously needs to be a common connection between transmitter and receiver. In the case of screened network wiring, the screen can be used for this purpose. Another solution consists of using the earth wire of the electrical installation to fulfil the same function. But if neither of these solutions is feasible, then you'll have to resign yourself to running a flying lead for this purpose.

The transmitter unit power supply is obtained from a 'plugtop' adapter supplying around 9 V at around 10 mA or so. The supply to IC1 and IC3 is regulated at 5 V, even though it's not strictly necessary. For occasional short use, a 9 V battery could be used.

If the project is intended solely for testing network wiring, O1–O8 and I1–I8 will be in the form of RJ45 sockets and COM will be connected to their screening contact. Take care to stick to the same numbering for the LEDs on the transmitter and receiver units, and if the project is going to be used in automatic mode, that the LEDs are in the correct order.

(091074-I)

Glass Blower

Merlin Blencowe (UK)

Most guitar pedals obtain a high input impedance simply by using a large resistor at the input of the first opamp, but this generates a good deal of noise due to the input bias current. The Glass Blower avoids this by using a smaller resistance (R2) which is bootstrapped by C2 to an effective value of tens of megohms. The total input impedance of the circuit is then set mainly by R1, which does not carry any DC bias current.

Because most guitar pedals use a 9 V supply as standard, their output swing is limited to about 6 V_{pp} with ordinary opamps, and this is barely enough to cause clipping in the first stage of a tube amp. The Glass Blower doubles these figures without requiring a greater supply voltage, and so can produce 'early Jesus & Mary Chain' i.e. **very** high levels of additional tube overdrive. This is achieved by driving T1 and T2 with the output signal, which forces pins 4 and 7 of IC2 to follow the audio signal, effectively bootstrapping the power rails. With a rail-to-rail opamp for IC2, an output of 16 V_{pp} (!) can be obtained with an ordinary 9 V battery. The voltage **across** the opamp remains constant, however, so there are no worries about damaging the opamp even with supply voltages up to 30 V. To avoid instability at high gain and input levels, individual opamps should be used, not dual opamps.

R7 sets the maximum gain to

1 + R6 / R7

or 22 (27 dB) using the component values shown. For use with humbucker pickups a value of about 1 kΩ for R7 may be more appropriate, to avoid clipping at maximum settings. Switch S1 is an ordinary, latching footswitch (e.g., Maplin # N84AR).

The power supply is of the conventional type used in guitar pedals. Either a 9 V PP3 battery or mains power adapter can be used, and the pedal is only switched on when a mono guitar plug is inserted into the **stereo** input jack.

The author's prototype was built in a 116 × 64 × 30 mm aluminium enclosure (suggest Maplin LH71N and Rapid 303540, or Maplin GU62S and Rapid 303539 for the more experienced constructor!)

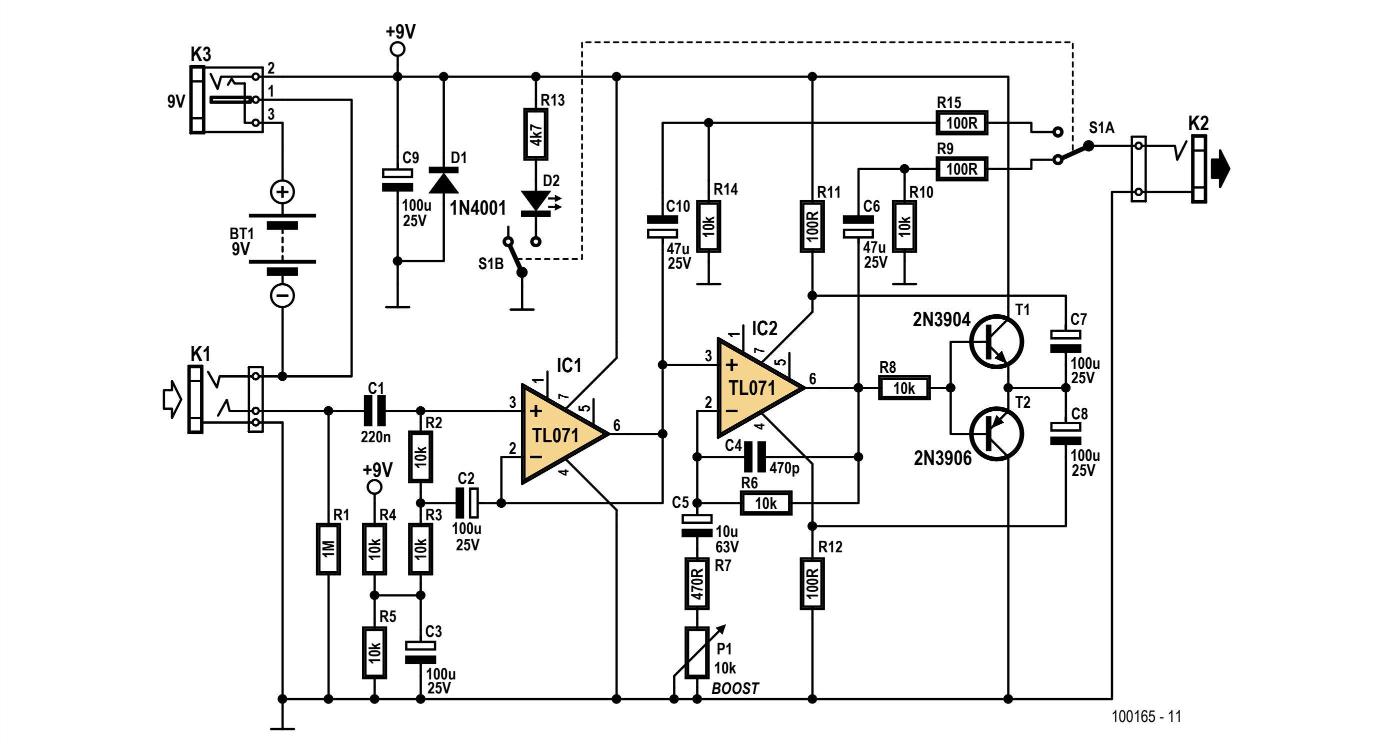
The 2.1 mm DC socket must be an insulated type since the centre pin is grounded (e.g., Rapid 200980, Farnell 1137744, Maplin FT96E). The input / output jack sockets (6.35 mm) should ideally be of the insulated type, but non-insulated ones will do (e.g., Maplin HF92A or HF93B).

For guitar pedals it is inconvenient to have all the sockets / controls on a single circuit board they are panel mounted and wired to the PCB by hand.

The author's design for a PCB and the associated wiring diagram may be downloaded from [1]. Compared to the schematic shown here, small differences exist in respect of component reference numbers.

(100165)

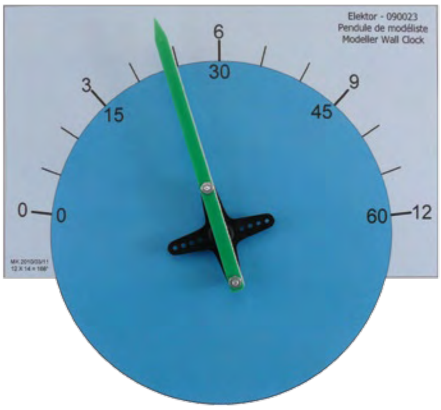
[1] www.elektor.com/100165



Modeler’s Clock

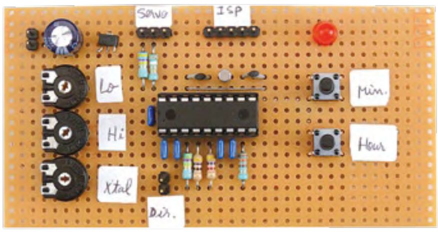
Michel Kuenemann (France)

The special feature of this analog wall clock is that it uses a standard model servo to tell the time. The display principle is the same as for an ordinary wall clock, but with two important differences. A standard model servo is unable to cover a travel of 360°, so we’ll need to adapt the clock face to this situation. What’s more, it’s not possible to show the hours and minutes at the same time using just a single servo – so the clock will show the hours during the first part of each minute, and then the minutes for the rest of the current minute.



The circuit is arranged around a PIC18LF1320 microcontroller with a 32.768 kHz clock crystal to generate the ‘seconds’. The controller core and the peripherals are clocked by the internal RC oscillator running at 8 MHz Test point TP1 delivers one pulse per second.

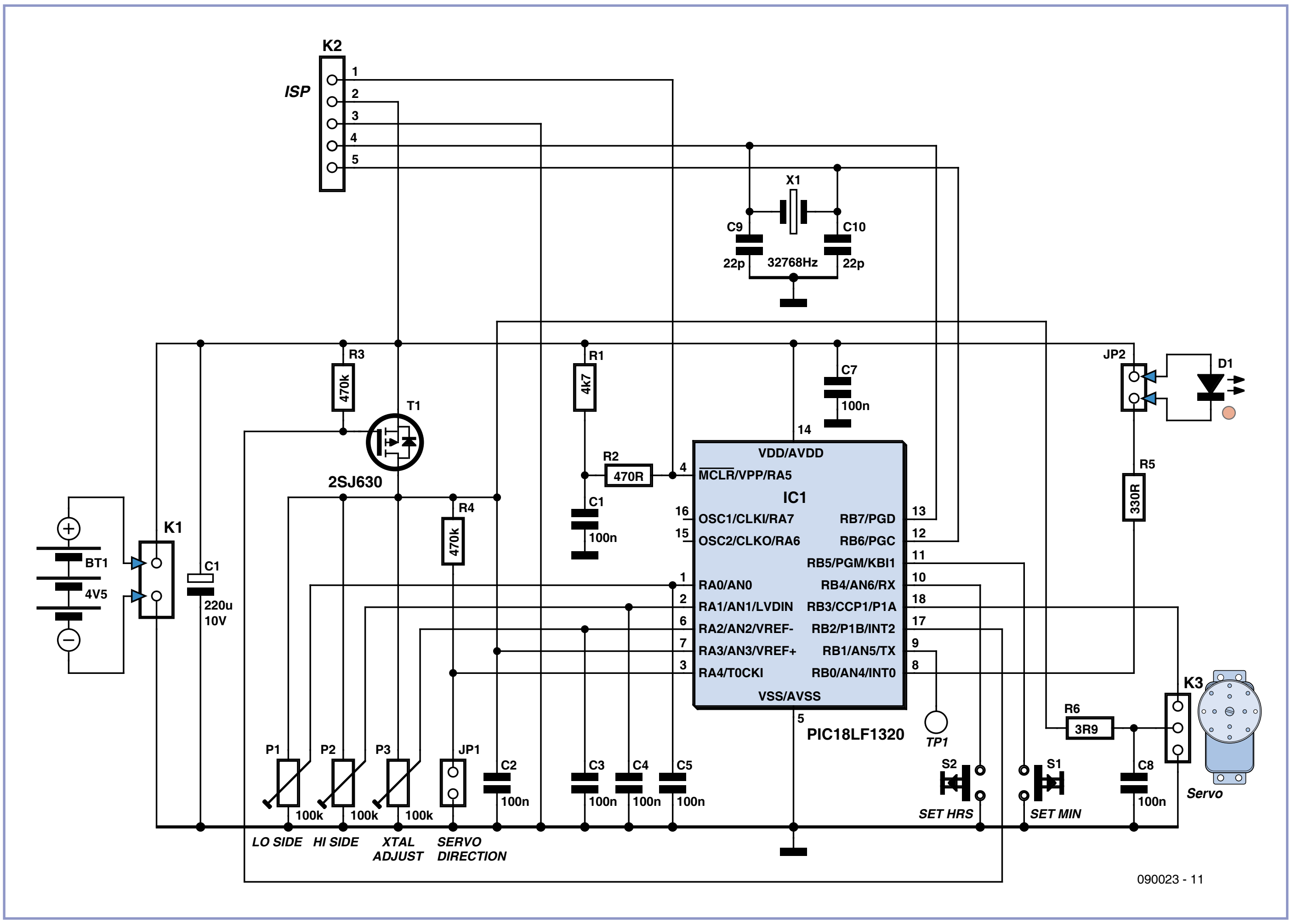
Two push-buttons are used to adjust the time, one for setting the minutes and the other for setting the hours. These buttons are also used to select the mechanical adjustment mode for the clock, as we shall see later.



The LED connected to the microcontroller flashes once per second while the servo is indicating the hours, but is out while the minutes are being displayed. The hand indicates the minutes during the first 50 seconds of each minute and shows the hours during the remaining 10 s.

Two potentiometers allow us to adapt the clock’s operation to the mechanical travel of the servo used. A third potentiometer is used to compensate for any drift in the clock crystal. This adjustment makes it possible to compensate for an error of ±100 ppm, corresponding to a drift of over 4 mins per month.

Jumper JP1 is to be fitted if the servo turns anti-clockwise while the clock is being set. Transistor T1 is used to turn off the servo power between two movements. Even when it’s not rotating, a standard servo consumes around 15 mA or so, which is too much for a battery-powered clock.



The circuit is powered by three 1.5 V cells. Depending on the size of the servo used, it may be better to replace the batteries by a small plugtop adaptor supplying 5 V. You can also use three NiMH rechargeable cells, well known to model enthusiasts. The microcontroller's 'brown out' facility, set at 2.7 V, will avoid deep discharging the batteries by maintaining the microcontroller in reset if the threshold is reached.

This little circuit can easily be built on 0.1 inch-pitch perforated board. The potentiometers should be wired in such a way that they are at maximum voltage at the clockwise end. Do not fit jumper JP1 and set the three potentiometers to mid travel.

Connect up the servo and the supply. The servo goes briefly to neutral (mid travel) then turns anticlockwise to the 0 o'c position. If the servo turns the other way (towards 12 o'c), fit jumper JP1 and reboot the microcontroller. That should sort everything out.
Now it's time to make the face for the clock. You will be able to draw inspiration from the "universal" face available to download [1]. This 120° face can in principle be used with any type of servo that has a travel between 120° and 180°. To adjust the servo travel, proceed as follows.

Set the clock running while pressing one of the setting buttons and wait for the servo to turn in the direction of 0 o'c. Adjust P1 so that the hand is on the 0 o'c mark on the face. Now press one of the buttons to set the servo to the other end of its travel, and adjust P2 so that the hand is on the 12 o'c mark on the face. Repeat this operation until the adjustment is perfect at both ends. Turn the clock off, then back on again, and check that the hand moves to exactly opposite the 0 o'c mark.
Setting the time is easy. Press the 'set hours' button one or more times to set the hours. Keeping the button pressed makes the hours advance fast. Setting the minutes is done in the same way, only pressing the 'set minutes' button.

If after about a fortnight you notice the clock is gaining or losing time, adjust potentiometer P3. If the clock loses, turn P3 slightly clockwise; if the clock gains, turn P3 slightly the other way. After an adjustment, you must wait at least 12 days before touching the adjustment again. The adjustment lets you compensate for several minutes a month, so you'll need to adjust P3 very carefully. What's more, it's important to note that P3 does not affect the frequency supplied by test point TP1.

(090023-I)

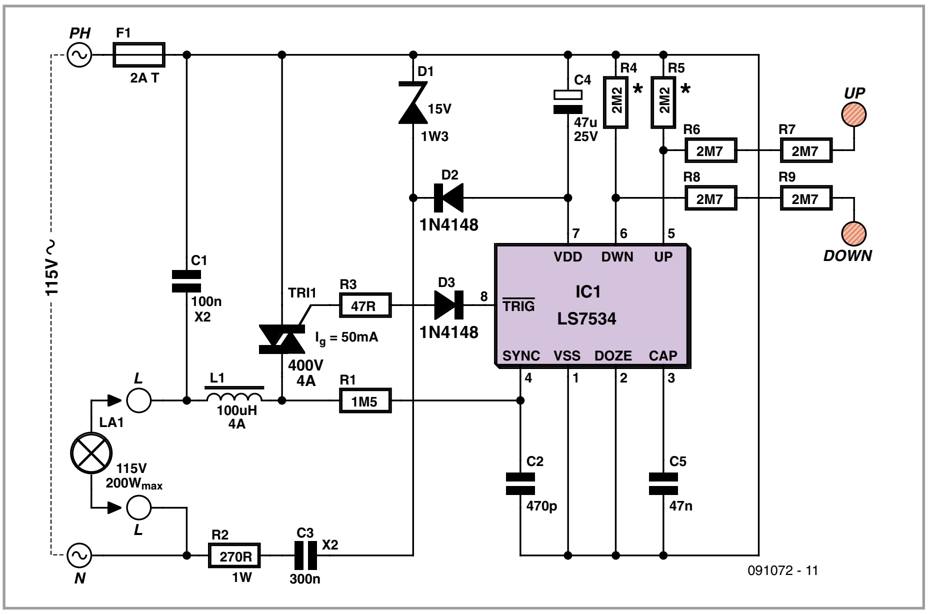
[1] www.elektor.com/090023

Touch-controlled Dimmer

Christian Tavernier (France)

Here's a dimmer that, besides being touch-controlled, also has a setting memory that enables it, for example, to turn the lighting on at the level you had set last time it was turned off. The project uses a specialized IC, an LS7534 from LSI Computer Systems, available from Farnell, among others. This IC is powered directly from the domestic AC powerline, which is dropped using capacitor C3 in order to avoid any thermal dissipation.

The power switching element is a triac, turned on at the zero crossing of the mains via the synchronization information conveyed to the LS7534 via R1 and C2, and turned off after a larger or smaller part of the sinewave so as to be able to adjust the brightness to the required level.



The touch pads are connected to the UP and DOWN inputs via two high-value series resistors, which for safety reasons must not be either reduced in value or replaced by a single resistor of equivalent value. Note here that the values of pull-up resistors R4 and R5 can be adjusted between 1 MΩ and 4.7 MΩ in order to adjust the sensitivity of the touch control.

Choke L1 is a conventional toroidal type intended to reduce the interference radiated when the triac turns off, in conjunction with capacitor C1. For safety reasons, it is vital that the latter, along with C3, should be class X2 types, intended for direct mains operation.
The triac can be any 400 V, 2–4 A type. You just need to take care to pick a type that is fairly sensitive, with a trigger current of no more than 50 mA, otherwise the LS7534 won't be able to trigger it properly. Although on the circuit diagram we have shown the maximum lamp power as 200 watts, it's possible to go above that, but in this case the triac will need to be fitted with a heatsink, which

will make the project bulkier.

If the project is not built in to an electrical wall box, you must be sure to choose an insulating case, since in the absence of a transformer, the whole of the circuit is at AC line potential and any accidental contact with it could be fatal.

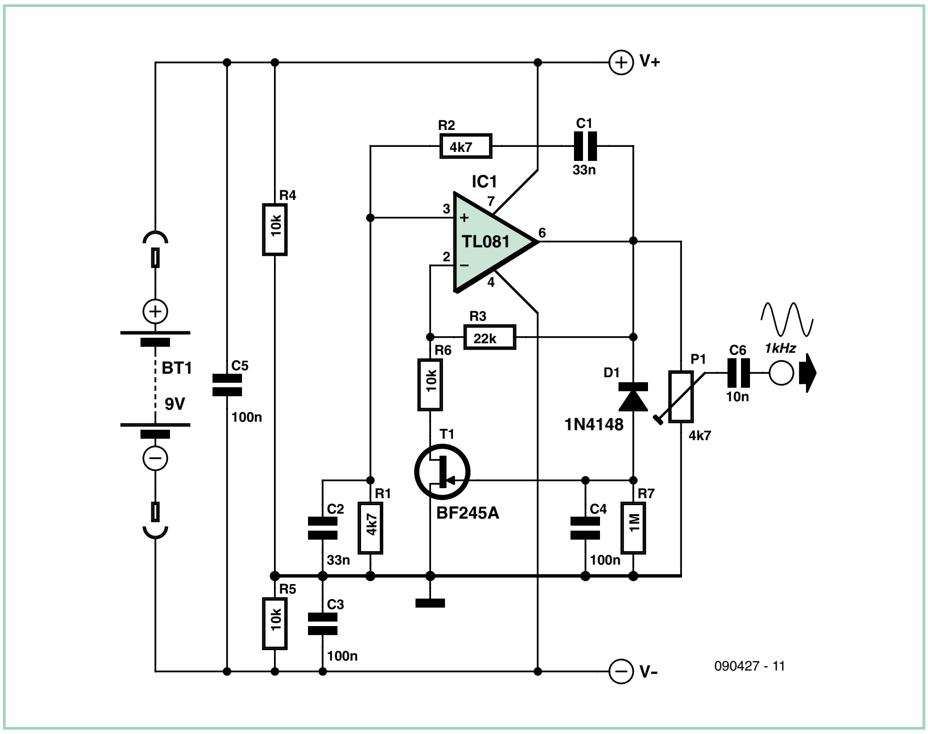
Using the dimmer is very easy, but requires you to make the distinction between long or short contact with the touch pads. When the light is off, a short touch (typically 34–325 ms, according to the data sheet) on UP makes the lamp light gradually up to the maximum value reached last time it was turned off. When the light is on, a short touch on DOWN makes the lamp slowly go out.

A long touch on UP (typically longer than 334 ms) gradually increases the brightness up to maximum, beyond which it has no further effect. A long touch on DOWN reduces this same brightness down to minimum.

(091072-I)

Vest Pocket VHF FM Test Generator

Kai Riedel (Germany)



After licensing restrictions were relaxed in many countries for VHF FM band transmitters with 50 nW transmit power, several small, inexpensive FM transmitter modules appeared on the market. In the author's view, such a module forms a good basis for a small FM-band test generator. This only requires a sine-wave modulation signal, which can come from an existing audio generator. If you don't have a suitable audio generator available, you can build the Wien bridge oscillator described here.

FET T1 provides amplitude stabilization in order to keep the distortion low. The generated signal is fed to the transmitter module via a 3.5-mm stereo headset socket, which mates with the usual 3.5-mm stereo plug of the FM transmitter (the left and right terminals of the socket are wired together). Adjust the output level of the audio oscillator with potentiometer P1 to avoid overdriving the transmitter.

In the transmitter module used by the author, the HF stage is built around a Rohm BH1418FV IC. You can easily find the data sheet for this IC with a Google search, and it can help you identify the RF output on the transmitter circuit board. You can then use a length of coax cable to tap off the FM signal and feed it to the antenna connector of the receiver under test. Here you must pay attention to the maximum rated input level of the receiver and impedance matching, and if necessary you should use an attenuator at the receiver input. You can use an oscilloscope to track the signal in the receiver and analyze the receiver output signal.

(090427-I)

Astrolamp

Martin Dümig (Germany)

It takes up to an hour for our eyes to fully adapt to the dark and achieve maximum light sensitivity with the iris fully open. Astronomers use red light to avoid interfering with this adaptation process. A lamp for stargazing should also have several other features. Some of the features of the lamp described here are:

- Red light for observation
- Dimmable
- Easy operation (including with gloves if necessary)
- White light for erecting and dismantling the telescope
- Reliable protection against operator errors (no accidental white light)
- Existing lamps can be remodeled

The lamp is controlled by a single button and responds to button presses as follows:

- With the lamp off, pressing the button for less than 5 seconds switches on the red light
- With the lamp off, pressing the button

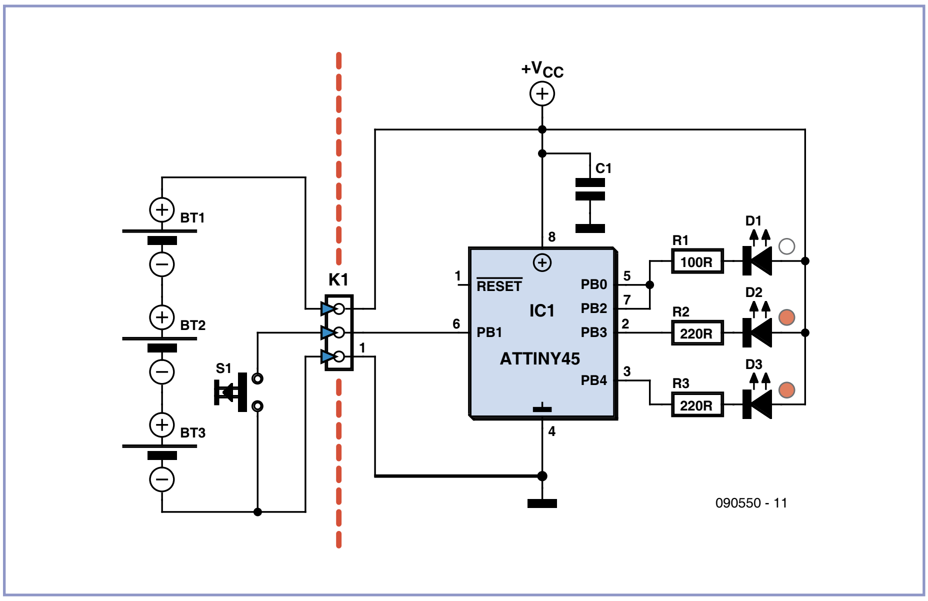
for more than 5 seconds switches on the white light

- With the red light on, pressing the button for less than 1 second switches off the lamp
- With the red light on, pressing the button for more than 1 second alternately brightens or dims the lamp
- With the white light on, pressing the button switches off the lamp
-

The lamp also remembers the red light setting.

The starting point for the remodelled lamp is an inexpensive headlamp from a DIY outlet, which has seven white LEDs and a splash-proof button. The lamp has a battery module that holds three AAA cells (4.5 V), with two spring contacts that press against contact surfaces on the built-in PCB. This board holds the control button for lamp. Three wires lead from this board to another PCB with the LEDS and the LED driver IC. They are: ground (GND), +4.5 V (VCC), and Button (contact closure to ground).

In the remodelling process, the original PCB with the LEDs and LED driver was replaced by a PCB with the author's circuitry. The original portion of the lamp circuit (battery holder and button) appears at the left in the schematic diagram. The new LED board is fitted with an ATtiny45 microcontroller and three LEDs with series resistors, consisting of two diffuse red LEDs and a white LED. The latter LED can be salvaged from the original LED board (maximum LED current around 50 mA). As the microcontroller's rated output current is only 20 mA per pin, the white LED is connected to two pins. Buffer capacitor C1 may be omitted if space is tight.



The firmware (including the source code in assembly language) may be downloaded from the web page for this project [1], where you may also order a pre-programmed ATtiny45 microcontroller. If you wish to program the microcontroller yourself, you can select various ATtiny microcontrollers or the AT90S2343 (the type originally used by the author) in the software. The firmware occupies only a small part of the microcontroller's program memory, so there's plenty of room for extensions.

The values of resistors R1 to R3 can be adjusted to match the forward voltages of the LEDs actually used. The voltage drop across the microcontroller is practically negligible.

The remodelled lamp is switched off exclusively by the microcontroller, which according to the data sheet draws less than 1 µA in sleep mode, nearly the same as the self-discharge rate of the batteries. The microcontroller is awakened by pulling PB2 to ground (when the button is pressed).

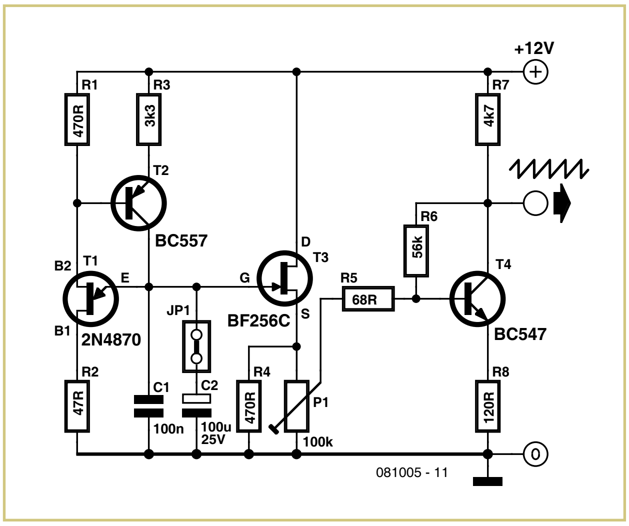
(090550-I)

[1] www.elektor.com/090550

Sweep your Function Generator

Holger Bruns (Germany)

Function generators built around the XR2206 have always had an excellent price/performance ratio, and the IC although 'obsolescent' is still available. If your generator does not have built-in sweep ('wobbulator') capability, a small external circuit is all you need. You can fit the circuit in place of the frequency adjustment potentiometer if you don't already have a sweep input.



The circuit is a classic sawtooth oscillator based on a unijunction transistor (UJT), which switches when its base voltage reaches the trigger level. This allows the capacitor connected to the base to discharge rapidly. To obtain a linear charging characteristic and thus a linear sawtooth ramp, the capacitor is charged by a constant current source built around a BC557. The output signal is buffered by a FET (BF256C) to minimize the load on the oscillator.

The output stage built around the BC547 provides the interface to the XR2206 function generator, with trimpot P1 serving to adjust the sweep amplitude.

To make it easier to see the signal on an oscilloscope during alignment, it's a good idea to remove jumper JP1 near capacitor C2 in order to increase the sawtooth frequency. Fit the jumper again after completing the alignment. With the 100 µF electrolytic capacitor (C2) back in the circuit, the sweep frequency will be significantly lower. If necessary, you can use a different value to obtain a different sweep rate. You can probably find all the necessary components in your parts bin, but if not, the UJT is still available (for little money from RS Components), and the FET can be replaced by most other small-signal N-channel JFETs. For the UJT, you can also use a 2N2646 or a 2N2647. If you also want to put together an XR2206 function generator, check reference [1] for free instructions for assembling a tried and tested Elektor circuit.

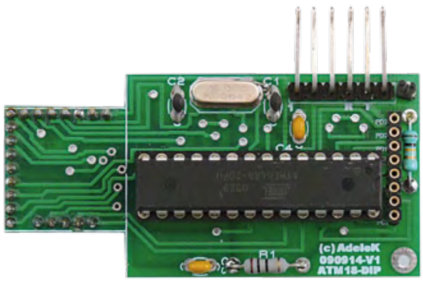
(081005-I)

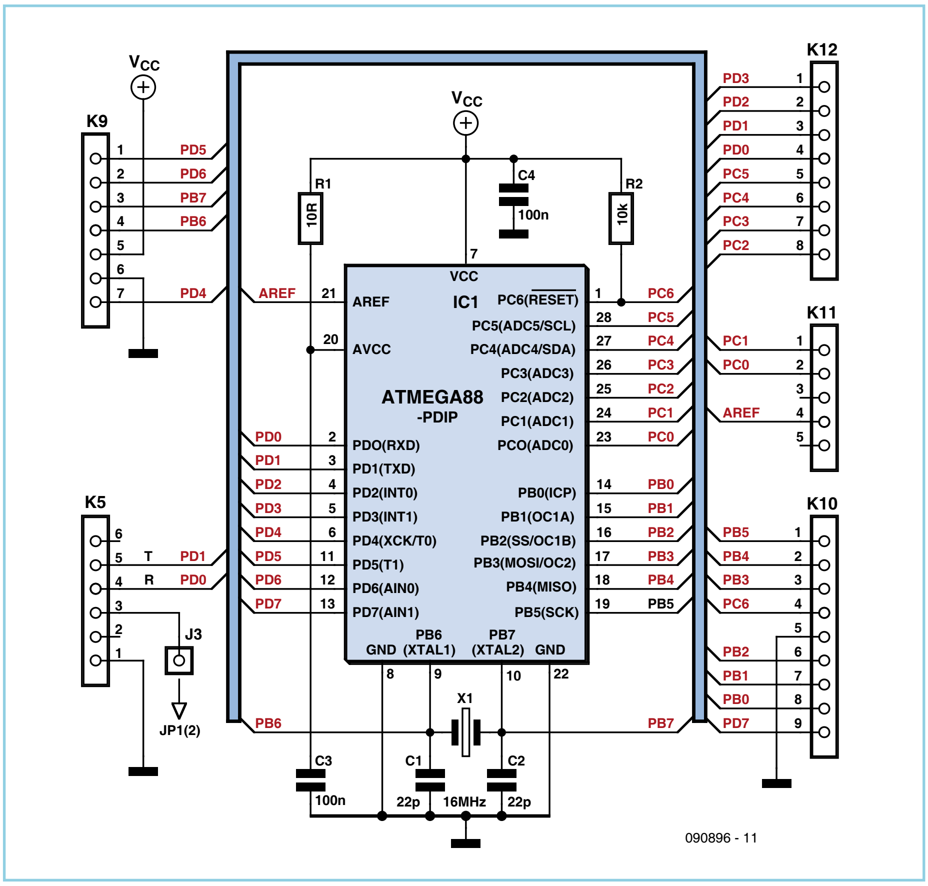
[1] www.elektor.com/060312

ATM18-DIP

Grégory Ester (France)

Even though you can't actually damage the microcontroller in the ATM18 project by the configuration of its fuse bits, setting them wrongly can however disable it. There are actually several different ways of cutting off





the branch you're sitting comfortably on. Thus it is possible to accidentally change, for example, the programmer access mode or the clock source. In both the aforementioned cases, bringing your microcontroller back to life can take some time and may even need equipment you don't have to hand.

Rather than replacing the whole controller board # 071035-91, how about just removing the ATmega88? This substitution operation will only cost you an ATmega88-20PU DIP 28 at just a couple of dollars, which compares favorably with the price of the complete board sold by Elektor.

We should point out that the DIP version offers a 6-channel ADC, as against eight for the TQFP version. Apart from this subtle difference, the ATM18-DIP board is similar to its smaller sister in virtually every respect. Virtually, since we must note the following niceties all the same:

– connector K12 is moved to the top;

– if you opt for powering via the USB port, you'll need to connect the USB/RS-232 (TTL) cable to the ATM18-DIP PCB in the same way as you did for the piggy-back board PCB. Then, if you want to use USB powering, connect a wire from J3 (ATM18-DIP) to pin 2 of JP1 (piggy-back board PCB).

So the ATM18-DIP will be used in the development stages, while once the system has been finalized and debugged, it'll be preferable to use the TQFP version, which takes up less space.

The parts list and PCB artwork for this project may be found at [1]. 'ATM18' is a project series featured in Elektor, starting April 2008.

(090896-I)

1] www.elektor.com/090896

Discrete Low-drop Regulator

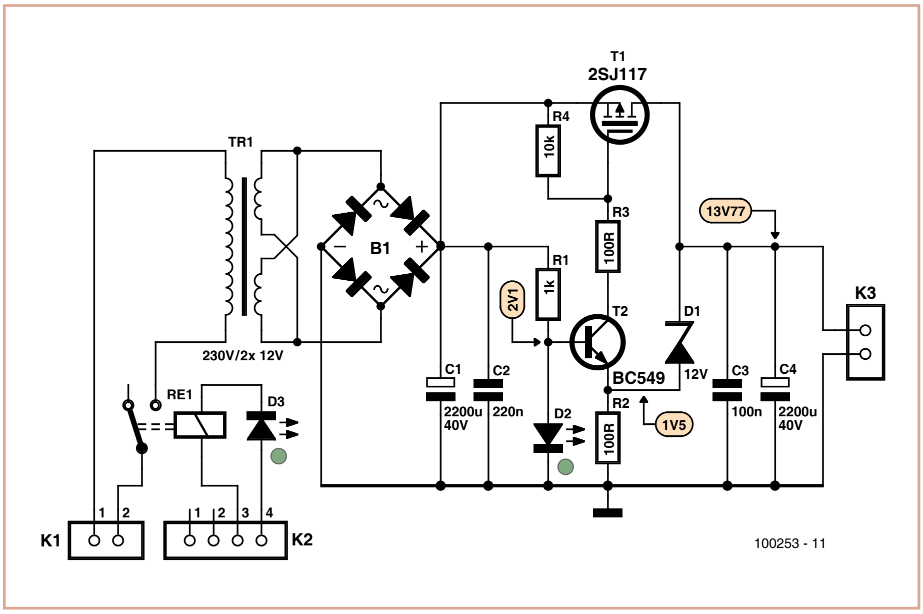
Jac Hettema (The Netherlands)

This circuit was designed to ensure that an amplifier circuit containing a TDA1516Q would not exceed its maximum supply voltage when the load is small. This amplifier is used in a PC to increase the audio power somewhat. The

PC power supply, however, created so much interference that an additional power supply was required.

The power supply has its own power transformer (US: substitute 115 V primary) with a secondary voltage of 12 V AC. After rectification and filtering this results in a DC voltage of about 16 V. The regulator consists of a P-channel MOSFET SJ117, the gate of which is driven via a voltage divider connected to T2. The base of T2 is held at a constant voltage by LED D2, so that the voltage across emitter resistor R2 is also constant and therefore carries a constant current. When the output voltage is higher than about 13.5 V, zener diode D1 will start to conduct and supply part of the current through R2 — as a result the MOSFET will be turned on a little less. In this way there is a balance point, where the output voltage will be a little over 13.5 V (1.5 V across R2 plus the 12 V zener voltage). The regulator is capable of delivering up to about 2 A — in any case it is a good idea to fit the MOSFET with a heatsink.

It is possible to add an optional potentiometer in series with the 12-V zener diode, which will allow a small amount of adjustment of the output voltage.



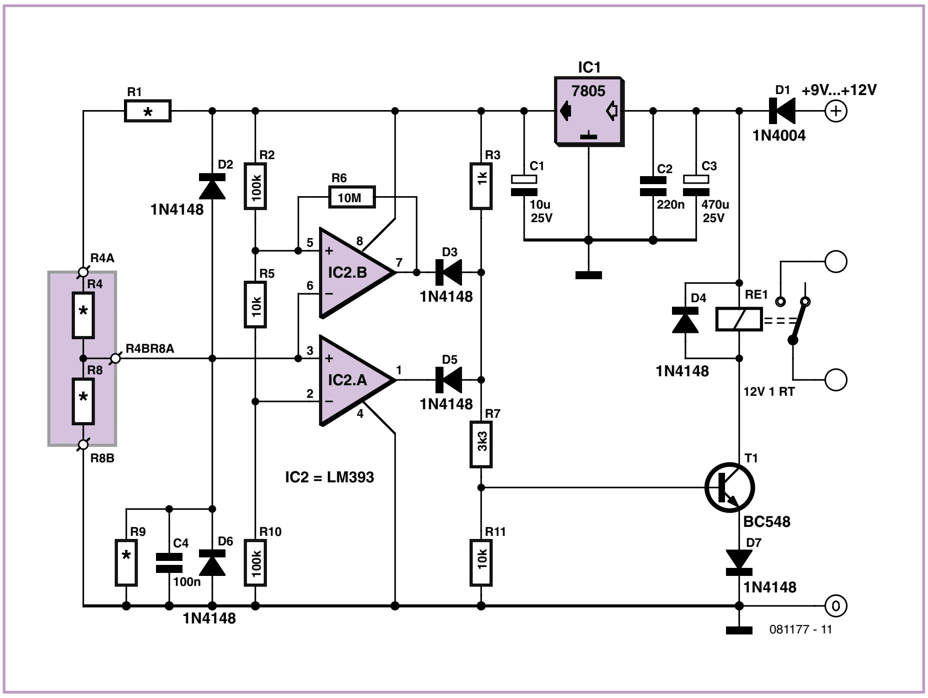
The relay at the AC powerline input ensures that the power supply is only turned on when the PC is turned on. This relay is driven from a 4-way power supply connector from the PC.

(100253-I)

Analog Electronic Key

Christian Tavernier (France)

This circuit uses two comparator that are combined in what is called a window comparator, i.e. resistors R2, R5, and R10 determine a voltage window within which the voltage applied to the junction of D2 and D6 must lie in order for the outputs of IC2.A and IC2.B to both be high at the same time. Given the value used for these resistors, this window is from 10/21 to 11/21 of the comparator supply rail (5 V). If IC2.A and IC2.B outputs are both high at the same time, transistor T1 is saturated via the AND gate formed by D3 and D4, and relay RE1 is energized to operate the electric latch or any other locking device.



The key is defined by the generation of the specific voltage at the junction of D2 and D6, formed, for example, by a simple stereo jack containing the two resistors R4 and R8. Together with R1 and R9, they form a potential divider that needs to be suitably calculated in conjunction with the values of R2, R5, and R10 so that the key can open the lock. Clearly, all this will only work correctly is the supply voltage to these two dividers is stable, which is ensured by IC1, regulating it to 5 V.

If we had set the values for R1 and R9, all the readers of this edition of Elektor would have had the same key, which is clearly not a good idea! So you need to decide for yourself not only R4 and R8, which form the key, but also R1 and R9 which let you customize the ‘lock’. Here are the relationships between the values of resistors R1, R4, R8, and R9 for the key to be able to open the lock:

$10 \cdot R8 \cdot R9 < 11 \cdot (R1 + R4) \cdot (R8 + R9)$
$10 \cdot (R1 + R4) \cdot (R8 + R9) < 11 \cdot R8 \cdot R9$

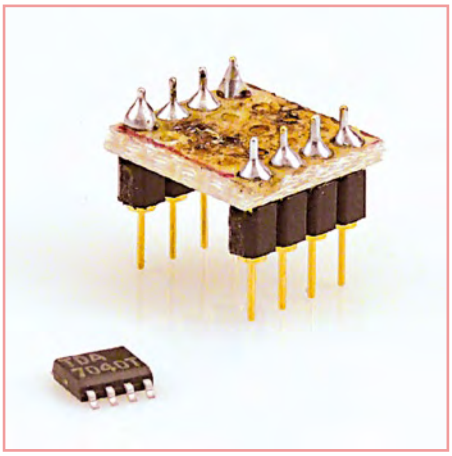
Given the size of the window formed by

R2, R5, and R10, 5 % tolerance resistors are adequate.
Note too that, as the relationships consist of inequalities, and that there are only two (un)equations for four unknowns, this leaves quite a wide choice for the resistor values. We advise you to set at least two of them to preferred values, which will then let you work out the others. If, as is more than likely, this does not result in other preferred values, you'll then need to use series/parallel combinations to obtain the calculated values — or else choose different starting values in order to arrive at a better compromise.

(081177-I)

[1] www.elektor.com/081177

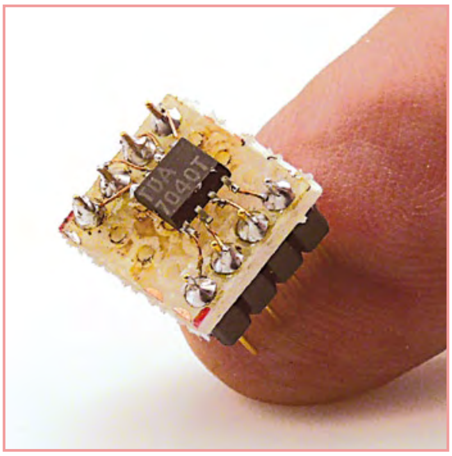
DIY SMD Adapter



Michael Hölzl (Germany)

In order to use an SMD device on a standard prototyping or perf board (breadboard) you will first need to fit it into some sort of carrier or (expensive) professional adapter board with pins at the same raster as the perf board. Such an adapter can also be made quite cheaply; we will take you through the steps using an SO-8 narrow package as an example.
Firstly cut a small rectangle of perf board to act as a chip carrier. It must be long enough to have one pad per IC pin down each side of the IC (in our case 4 pads long). Its width should allow two rows of unused pads either side of the chip with the chip in the center. The next step is to carefully remove all the unused copper pads with a knife so that there is no possibility of any of IC leads shorting with a pad. Once the small piece of board has been cleaned up the IC can be glued centrally onto the board.

The carrier can now be fitted with the connecting pins so that when complete, the whole assembly can be used in the same way as a standard DIP or DIL chip. Solder pins are used here; firstly push the pins into a solderless plug-in breadboard to hold them in position. Place the carrier board over the pins then carefully solder each pin in position on the carrier board.
Now connect each pin to the corresponding IC lead using thin enameled copper wire (ECW). If you are lucky enough to have the self-fluxing type then this job will be much easier. Normal ECW can also be used but it will be necessary to scrape the enamel from the ends and tin them.



Any recommended supply decoupling capacitors can be mounted directly on the carrier board across the supply pins.
The method works well with SO packaged chips. SO-8 devices do not need any enameled wire; the chip leads can be soldered directly to the solder pins. Before powering up the chip make a careful inspection of all the solder joints to ensure there are no unintentional short circuits.

(090614)

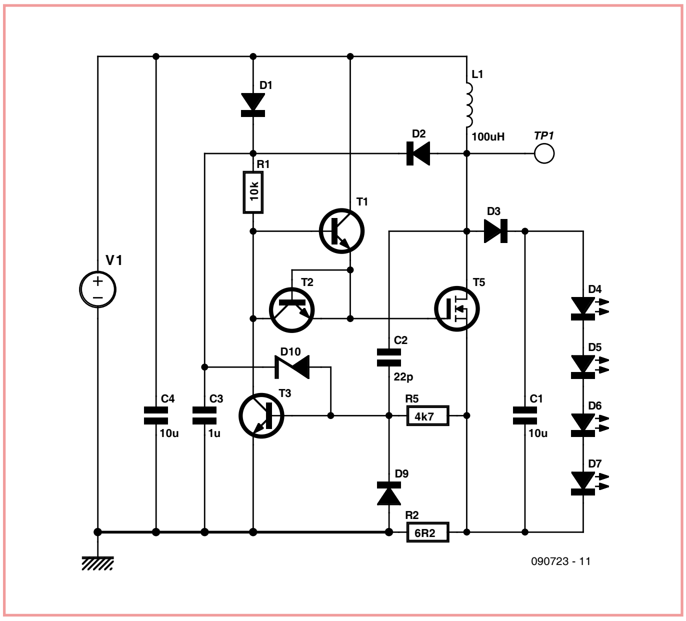
LED Bicycle Light Revisited

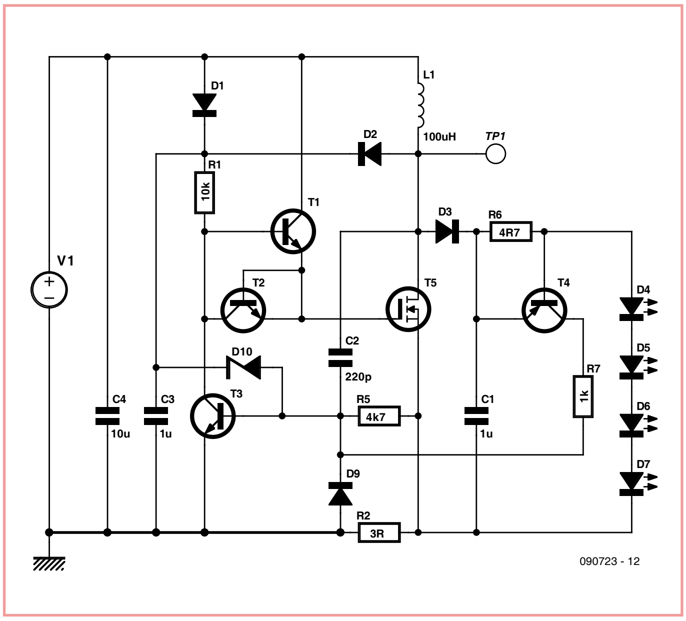
Bernd Schulte-Eversum (Germany)

The LED bicycle light that we described in the July/August 2009 edition of Elektor has proved very popular. The author was particularly struck by the basic design, but as always, there is room for a little improvement! Below we describe two enhanced variations on the original theme.

Both circuits are, like the 2009 original, powered from a 6 V (rechargeable) battery, shown here as V1. The simpler of the two circuits, which consists of four transistors, is in function essentially the same as the original version. It takes the form of a boost converter with feedback provided by the voltage drop across a current sensing resistor, in this case R2. A value of 6.2 Ω for R2 is suitable for use with four white LEDs at D4 to D7, and gives an LED current of approximately 20 mA. The 250 mW Zener diode D10 is provided to limit the output voltage in the case that the LED chain should go open-circuit, pulling the gate of the MOSFET to ground via T3, T1 and T2 if the output voltage exceeds the breakdown voltage of the Zener. A breakdown voltage of between 15 V and 24 V is recommended. L1 is a 100 μH coil with a current rating of at least 0.5 A and should have a very low DC resistance.

Transistor T1 provides a low-impedance source to charge the gate of MOSFET T5. Transistor T2 (the author used an SMD BC846S dual transistor) is wired as a diode, and is responsible for discharging the gate of T5 via T3. This extension to the original circuit means that MOSFET T5 switches more quickly, which improves overall efficiency. As a side-effect the switching frequency also rises significantly. With a switching frequency of over 150 kHz ceramic or film capacitors must be used at the input and output, as electrolytics will gradually fall off in effectiveness. In the original circuit a type NTD4815N MOSFET with an on resistance $R_{DS(on)}$ of 15 mΩ (at V_{GS}=10 V) was recommended, although almost any N-channel MOSFET with similar on-resistance characteristics will be equally suitable.





The second circuit employs five transistors, and differs from the first in that it uses a secondary current regulation loop based around transistor T4. This makes the design more suitable for use at higher LED currents, giving greater current stability in the presence of power supply voltage fluctuations. The voltage drop across resistor R6 due to the current flowing through the LEDs turns transistor T4 on. Via T3 this in turns modulates the switching of T5, hence keeping the output current constant. Transistor T4 is a type BC856B; an alternative device in a leaded package is the BC556B. T3 is a BC546B. The BC846S dual SMD transistor used for T1 and T2 can be replaced by a BC546B (for T1) and a type 1N4148 diode (for T2).

(090723)

Dynamic Limiter

Ton Giesberts (Elektor Labs)

This circuit is a revised version of the Audio Limiter published in the 2002 Summer Circuits edition, which is intended to limit the (possibly excessive) dynamic range of the audio signal from a TV set or DVD player (for example). The original circuit is based on attenuating an excessively strong source signal. Here we take the opposite approach of amplifying the quieter passages. To minimize the typical 'breathing' effect of compressors, the control range is limited to only 24 dB. The gain is adjusted in discrete (non-audible) steps, which avoids non-linearity and thus avoids distortion.

With the component values shown on the schematic diagram, the circuit can boost the gain in 15 steps of 1.6 dB each, yielding 16 levels from 0 to 24 dB. The voltage divider used in the original circuit has been replaced here by negative feedback circuitry using two non-inverting amplifiers. This reduces the number of resistors and allows smaller multiplexers to be used — in this case consisting of two halves of a 4052 IC per channel (the 4052 is a dual 1-of-4 analog multiplexer/demultiplexer).

The entire control logic is the same as before. Although there are two stages per channel, fewer resistors are necessary than with the original design. To allow the overall gain to be controlled in equal steps, the individual amplifiers (IC1A/IC3 and IC1B/IC4) have different step sizes. The gain steps of the first stage are relatively small (0, 1.6, 3.2 and 4.8 dB), while the gain steps of the second stage are relatively large (0, 6.4, 12.8 and 19.2 dB). The total gain can thus be controlled over a range of 0 to 24 dB in 16 equal steps. The individual resistor values are easy to calculate with this approach: (10 kΩ)/($10^{A/20}$ – 1), where *A* is the desired gain and 10 kΩ is the value of R5, R10, R14 or R18. Other gain ranges can also be implemented in this manner (see **table**), but you should bear in mind that steps larger than 1.6 dB may be audible.

The control circuitry is largely made up of simple discrete logic. The multiplexers are driven by an up/down counter (IC8). Window comparators are used to determine the signal level at the output. They are built around two comparators of an LM399 (quad comparator) for each channel. The same reference voltage (across P1), at approximately 1 V, can be used for both channels. The reference voltage can be modified by changing the value of P1 — for instance, 10 kΩ yields around 1.7 V. The con-

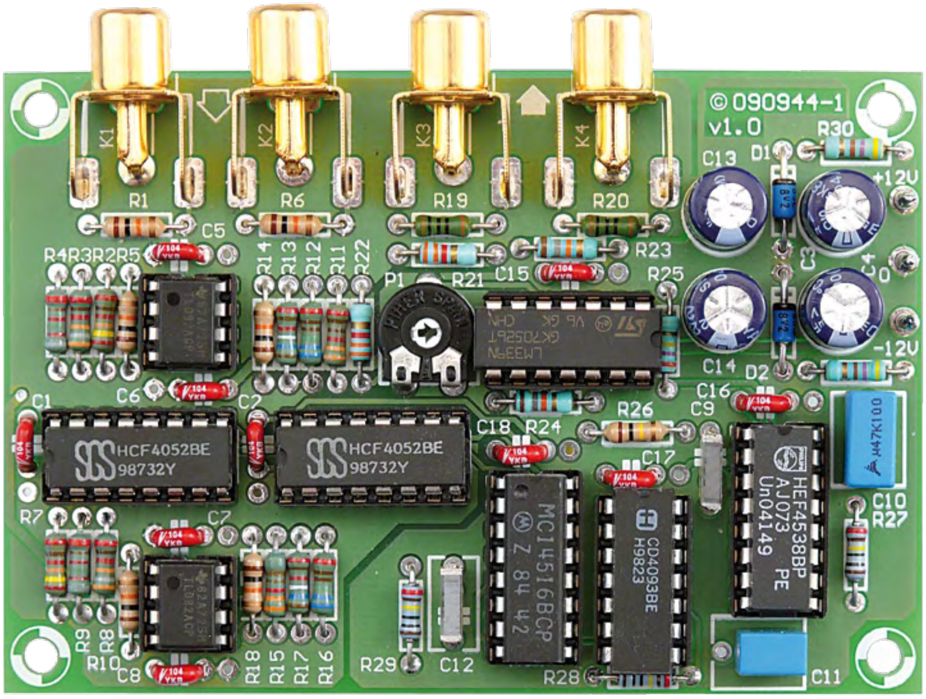
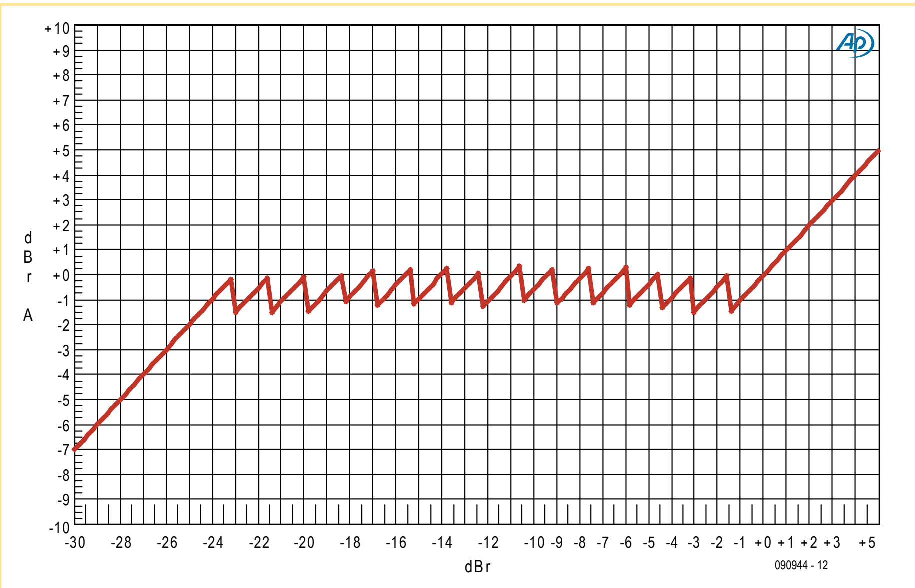
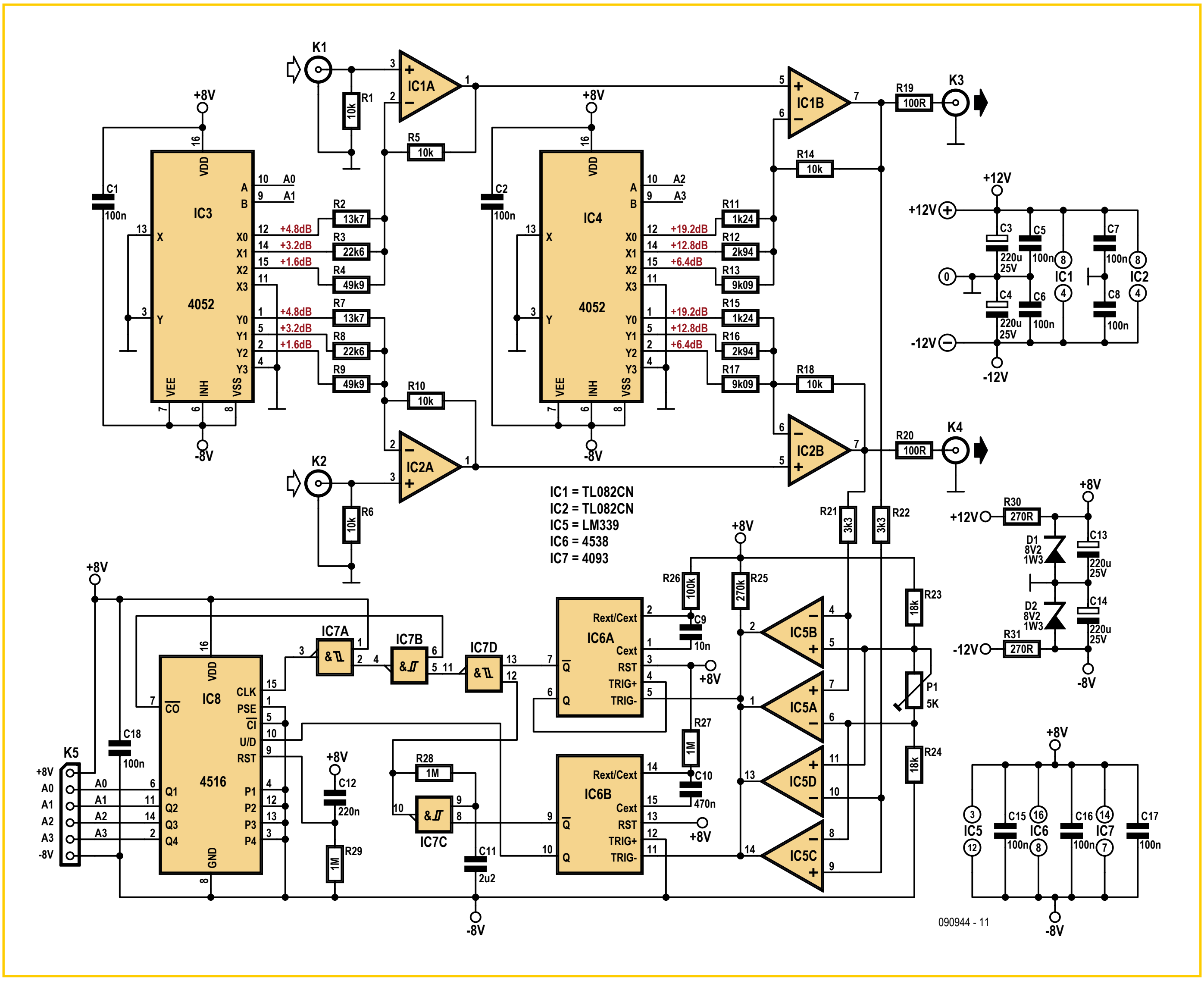


Table. Alternative control ranges (R5 = R10 = R14 = R18 = 10 k)

	15 dB			20 dB		
	Theoretical	E24	E96	Theoretical	E24	E96
R2 & R7	24.24 kΩ	24 kΩ	24.3 kΩ	17.10 kΩ	18 kΩ	16.9 kΩ
R3 & R8	38.62 kΩ	39 kΩ	38.3 kΩ	27.83 kΩ	27 kΩ	28.0 kΩ
R4 & R9	81.95 kΩ	82 kΩ	82.5 kΩ	60.27 kΩ	62 kΩ	60.4 kΩ
R11 & R15	3.354 kΩ	3kΩ3	3.32 kΩ	1.883 kΩ	1.8 kΩ	1.87 kΩ
R12 & R16	6.614 kΩ	6kΩ8	6.65 kΩ	4.142 kΩ	4.3 kΩ	4.12 kΩ
R13 & R17	17.10 kΩ	18 kΩ	16.9 kΩ	11.80 kΩ	12 kΩ	11.8 kΩ





trol circuit responds to the peak level of the output signal. As long as the output signal level is lower than the reference level, oscillator IC7c is enabled by monostable multivibrator IC6b. This causes IC8 to count down slowly (pen 10 of IC6 is low) until the lowest count is reached. The counter is then blocked by IC7b, and the gain is set to the maximum (the X0 outputs of IC3 and IC4 are at ground level). IC6b is triggered when the window comparators generate pulses. The outputs of IC6b remain asserted as long as this occurs (the 4528 is retriggerable), and oscillator IC7c is blocked. IC6a is now triggered by the comparators. The Q output of IC6a is connected to the positive trigger input to prevent retriggering of IC6a. In this situation the counter is clocked by pulses from IC6a (pin 7).

The pulse width is set to 1 ms to prevent the multiplexers from going a few steps too far at high frequencies. If you find the recovery time too long, you can make it shorter by reducing the value of R26. The time delay provided by IC6b ensures that the circuit does not start amplifying the audio signal right away, but instead waits for half a second. This gives the circuit a calmer control characteristic.

The circuit is designed for a minimum gain of 1. Signals larger than the set reference level are passed through unchanged. As the quieter passages in the audio signal are amplified, you can set the volume control of your sound system to match the loudest sound level. A circuit that simplifies the optimal adjustment of P1 is described elsewhere in this Summer Circuits edition.

The logic circuitry operates from symmetrical 8-V supply voltages. They are derived from the symmetrical 12-V supply rails with the aid of two resistors and two Zener diodes. The values of these components as shown on the schematic diagram are dimensioned for the external indicator circuit, which can be connected to K5. The current consumption is approximately 20 mA. If you don't use the indicator, the current consumption can be reduced by 5 mA by increasing the values of R30 and R31 to 470 Ω. The distortion is very low – only 0.001% at 1 kHz with 500 mV input and output levels.

The measured characteristic curve shows the behavior of the circuit. The X axis represents the input signal, while the Y axis represents the output signal. Here 0 dB corresponds to the reference level. The 24 steps of controlled gain adjustment as the input signal level increases are clearly visible here.

A PCB layout for the circuit and the accompanying components list may be downloaded from the Elektor website [1].

(090944-I)

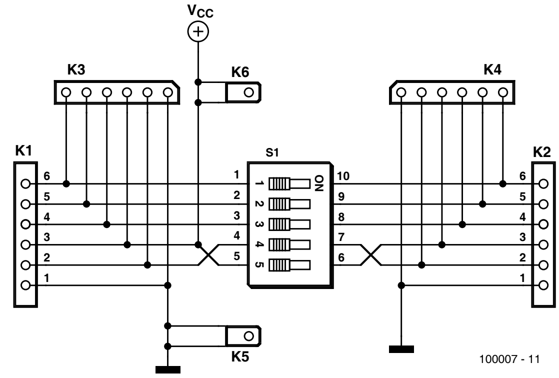
[1] www.elektor.com/090944

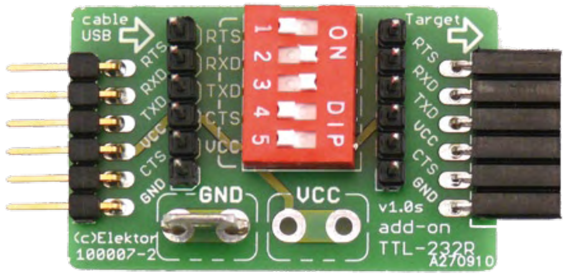
USB/TTL Serial Cable: Extension & Supplement

Antoine Authier (Elektor Labs)

Two years ago, I presented here the USB/TTL serial conversion cables from FTDI [1][2] — wonderful communication and debugging tools. The increasingly frequent use of ARM CPUs in our projects like Scepter, the battery monitor, the engine test bench, etc. has led us to use the 3.3 V version in order to protect the ARM's input/output ports intended for 3.3 V (unless otherwise stated; the data sheets are unclear about this... but better safe than sorry!)

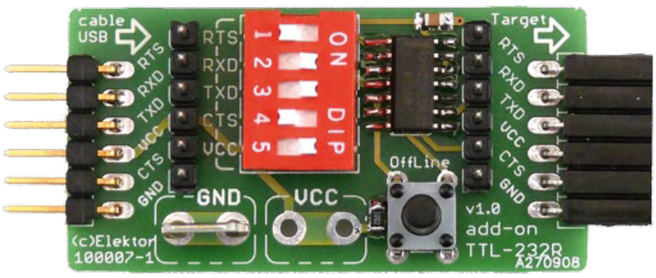
1





From now on, the 3.3 V version of the USB TTL-232R cable will be available in the Elektor online shop with the reference 080213-72. The 5 V version is still available with the reference 080213-71.

While working on various projects, and especially when debugging onboard software



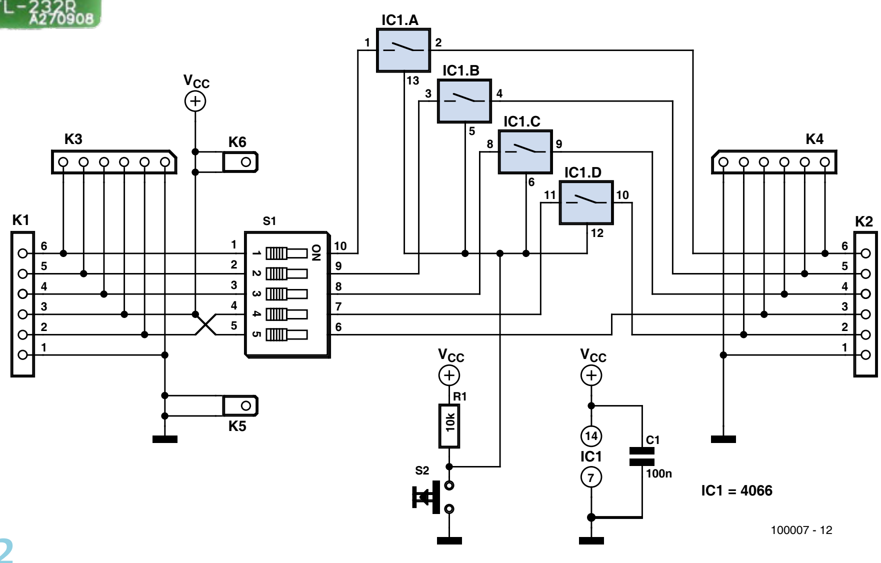
using these cables, I found it was useful to be able to interrupt certain of the signals or to be able to look at them on an oscilloscope. It was then I came up with the modest circuit given in Figure 1. Connectors K3 and K4 make it easy to look at each signal. The miniature 5-way DIP switch S1 lets you interrupt any of the TX, RX, CTS, RTS signals available at the end of the cable. It also lets you cut the 5 V rail coming from the USB cable. By isolating your circuit like this from this voltage, which in certain cases might end up connected directly across some batteries, you will avoid damaging them or even making them explode.

The grounds remain connected. This 0 V reference is present on the FASTON terminal, which is very handy for clipping on multimeter and oscilloscope probe 'croc clips'. A second FASTON terminal offers the USB 5 V rail in case it comes in useful, though I didn't actually fit it.

Note that the order of the signals is changed at the DIP-switch so that the 5 V rail comes at one end, where the switch will be easier to operate with your fingernail.

On the 'deluxe' version circuit shown here, you'll see we've added a 4066 CMOS analog switch, IC1. This makes it possible to disconnect all the serial link's logic signals in one go simply by pressing push-button S2. I noticed in fact that the voltage present on the cable's TX pin is enough to power an ATmega324PA (low-voltage) and prevents hot rebooting of the microcontroller, even if its power is momentarily interrupted. So this button comes to the rescue and makes debugging easier, without having to either unplug the cable or operate the DIP switches for such a short time.

(100007-I)



2

[1] 080213-I USB → serial TTL cable: www.elektor.com/usb-ttl

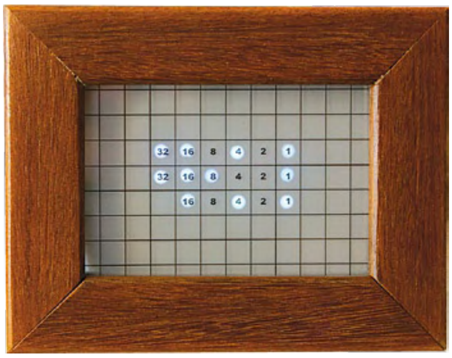
[2] 080470-I USB → RS6232 cable: www.elektor.com/080470

Binary Clock

Sanne-Martijn Kessel (NL)

This clock displays the time in binary using discrete LEDs. The use of Flowcode [1] makes it very easy to program the PIC controller in this project.

The circuit is very simple and can be constructed with individual parts on a piece of experimenter's board or using the relevant E-blocks modules: EB006 (1x PIC Multi-programmer), EB004 (3x LEDs), EB005 (1x LCD) en EB007 (1x switches). The firmware, which can be downloaded from the website for this article [2], determines how this circuit functions. Port B drives six LEDs for indicating the seconds, Port C drives six LEDs for indicating the minutes and port D takes care of driving the five LEDs for indicating the hours. Two pushbuttons on port E let you adjust the time (S1 for the hours and S2 for the minutes). This leaves port A available to drive the LCD display in 4-bit mode. For completeness, this display also shows the time, as well as the day of week (1 to 7).



S3 is used to reset the processor, which also results in the seconds being set to zero. The current through the (white) LEDs is about 11 mA, which means that the total current supplied by the PIC will always remain below 200 mA. The LEDs project their light onto white opaque glass, which is covered by a transparent sheet with numbers printed on it. On top of this is a clear pane of glass. The LEDs are mounted in a frame with holes, so they will always remain neatly in place.

For the power supply you can use a plugtop adapter with a stabilized 5 volt/400 mA output. Goldcap C4 is optional and can be added if you want to stop the circuit from losing the time when there is a brief power cut.

At midnight the time jumps forwards by 54 seconds in order to keep the exact time (if required, this can be changed in the Flowcode). This is necessary because increasing or decreasing the internal counter is either just too much or too little to keep perfect time.

In the photo the time is:

16+4+1= 21 hours (bottom row)

32+16+8+1=57 minutes (middle row) and

32+16+4+1=53 seconds (top row).

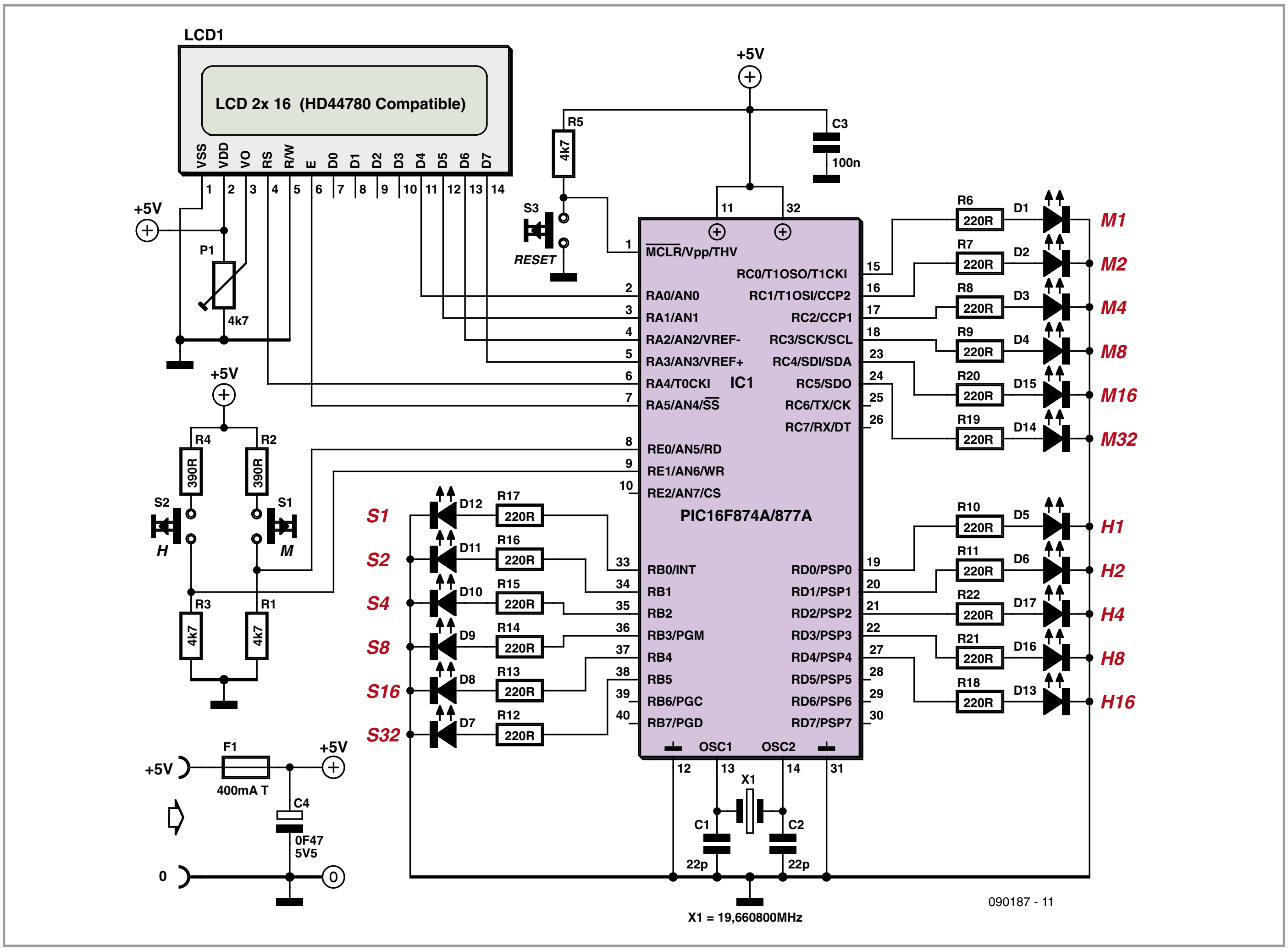
With the circuit housed in a suitable enclosure, you end up with a nice looking designer-clock, which is guaranteed to be noticed by any visitors!

(090187)

Web links:

[1] www.matrixmultimedia.com

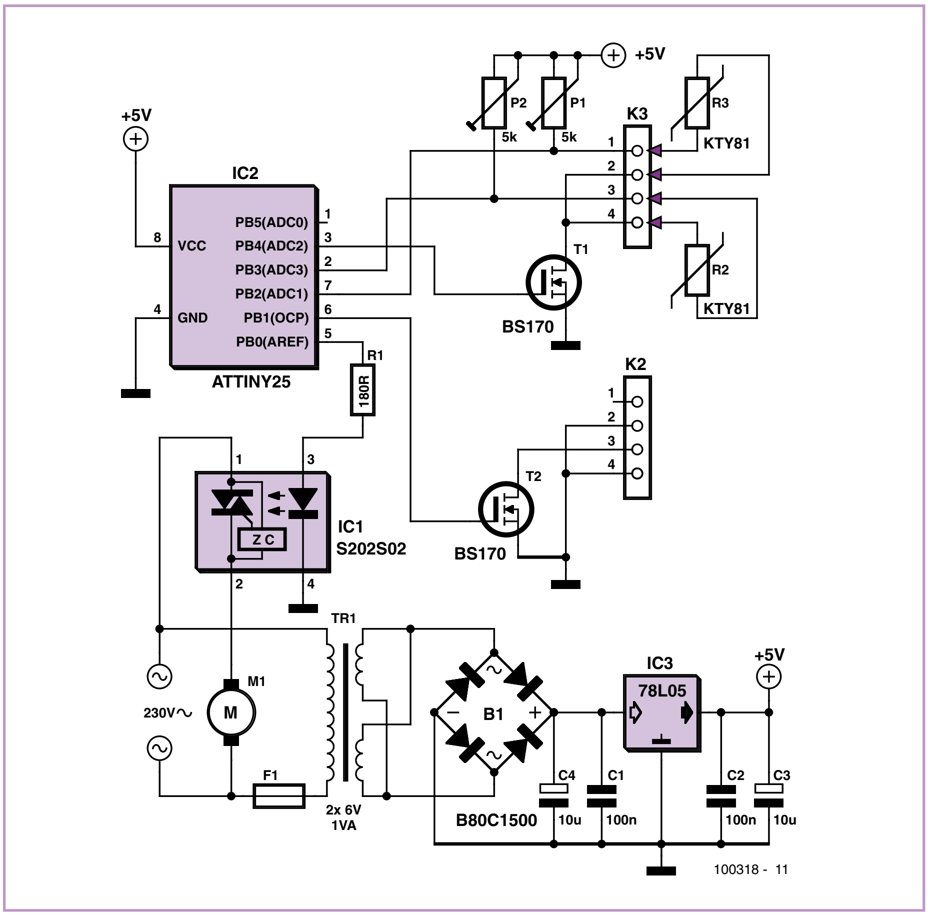
[2] www.elektor.com/090187



Underfloor Heating Controller

Marc Dirix (NL)

Central heating systems that include underfloor heating often leave the extra pump used to pump the water through the underfloor pipes running continuously. The reason for this is that the central heating controller doesn't have a separate control circuit and output for the underfloor heating pump.
This circuit was designed to control the underfloor heating pump independently or via the switch in the living room thermostat. The design has been made very flexible and can be connected in four different ways:



1) Temperature sensor 1 is connected to the inlet pipe of the underfloor heating, Temperature sensor 2 is shorted. The pump is turned on when the inlet pipe becomes warm enough. When the temperature of the inlet pipe drops below the trigger temperature the pump will continue to run for 20 minutes.

2) Temperature sensor 1 is connected to the inlet pipe of the underfloor heating, Temperature sensor 2 is connected to the outlet pipe. This works in a similar way to that in the previous configuration, but also: as long as the inlet pipe is warm the pump will be stopped (temporarily) when the outlet pipe rises above the trigger temperature.

3) Switch input connected to the living room thermostat. As long as the switch (connected to the same input as for Temperature sensor 1) is closed, the pump will run. When the switch opens the pump stops after 20 minutes.

4) Switch input connected to the living room thermostat, Temperature sensor 2 is connected to the outlet pipe of the underfloor heating. This works in a similar way to that in the previous configuration, but also: as long as the inlet pipe is warm the pump will be stopped (temporarily) when the outlet pipe rises above the trigger temperature.

Temperature sensor 2 can also be used to protect the underfloor heating from over-heating. In this case, set the trigger temperature to about 50 degrees and connect the sensor to the inlet pipe of the pump.

The circuit is built around an ATtiny25. Two ADC inputs of the controller measure the voltage across both PTCs. The voltage across the first temperature sensor is compared by the software to a trigger value and zero. When the trigger value is exceeded or the value is zero (due to an external switch), the Motor-power pin (pin 5) is pulled high and the pump is started via the opto-triac. When the pump is started, another output (pin 6) is pulled low at the same time. You can connect external components to this output, such as an indicator lamp.

To prevent a continuous current from flowing through the presets and temperature sensors, the PTCs are connected to ground via a software-controlled FET only when a measurement is made.

A configuration fuse inside the microcontroller is blown so that the internal clock runs at 128 kHz. This is fast enough to run the program and this frequency is divided by 1024 in the prescaler of timer1. Timer1 then counts to 125 and generates an interrupt. This interrupt will occur approximately once per second.
During the interrupt routine the state for the pump is determined. When Temperature sensor 1 exceeds the trigger value or equals zero (switch input), the pump timer will be set to 20 minutes. These 20 minutes are to make sure that the pump remains on for another 20 minutes after the temperature has fallen below the trigger level. If the second temperature sensor goes above the trigger level the pump will be stopped immediately.

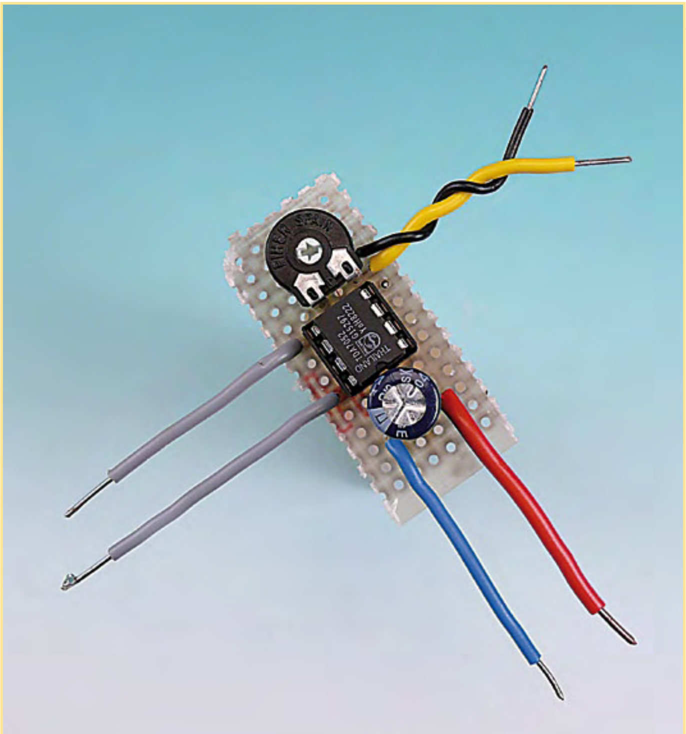
At the end of the interrupt routine a measurement is started by first making the FET conduct so the PTCs are connected to ground. An ADC routine is then run to read in the value. The temperature sensors are measured alternately, so that the measurement interval for each sensor is 2 seconds.

The circuit will turn on the pump for a minimum of 5 minutes during any 18-hour period. For this there is a Summer-timer, which keeps track of how long ago the pump was last on. When the pump is turned on the Summer-timer is reset to zero. If the Summer-timer hasn't been reset for 18 hours (16-bit integer = 65,536 s = 18.2 hours), the pump timer will be set to 5 minutes. As long as this is active, the pump will be on.

US readers should substitute Tr1, M1 and F1 with components suitable for operation at 115 VAC. 60 Hz.

(100318)

Audio amplifier in dinner mint format



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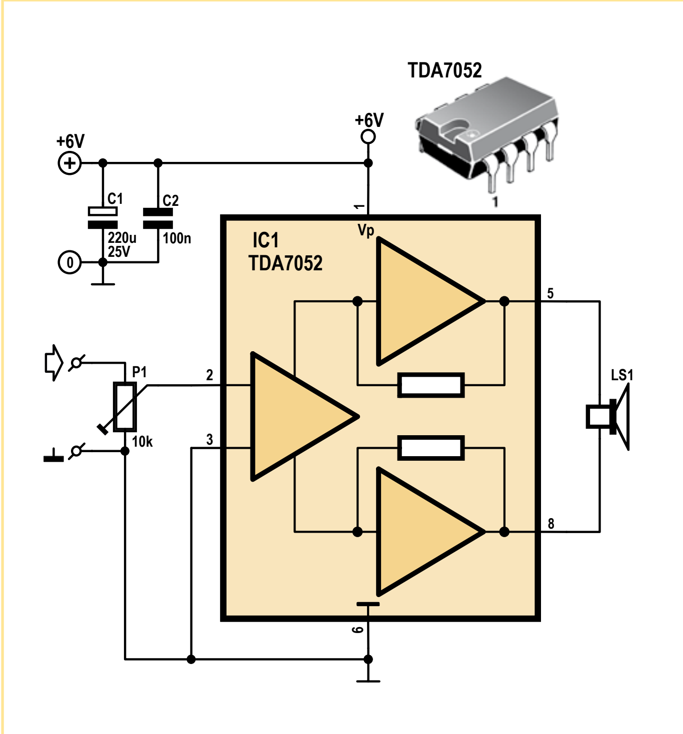


By Ton Giesberts (Elektor Labs)

There are countless situations and systems devisable in which a sound signal needs to be amplified in order to drive a (small) loudspeaker, but where space constraints rule out the use of a regular sized amplifier. For these situations, this sub miniature amplifier is perfect. With some skills it can be assembled to a size smaller than an after dinner mint!

The TDA7052, which was released by Philips a many moons ago, is a typical example of a fully integrated circuit. The only external components required are two decoupling capacitors. That's all.

In the circuit diagram of the amplifier you can find an internal schematic of the integrated circuit. It's easy to see two amplifiers connected in a bridge arrangement. This is done in order to squeeze a 'decent' power from the IC at relatively low supply voltages.

THD+N*	0.09% (1 kHz, 100 mW in 8 Ω) 0.3% (20 kHz, 100 mW in 8 Ω)
P_{max}	750 mW (THD+N = 1%) 1 W (THD+N = 10%, heavily clipped output signal**)
Gain	38 dB (P1 at maximum)
Supply voltage	3–18 V
Current consumption	5 mA (quiescent) 340 mA (1 W continuous power output)

* THD+N = Total Harmonic Distortion plus Noise
** clipping only noticeable at 2% distortion.

preset has been added to the input to prevent the circuit from being overdriven, this will be appreciated in view of the high sensitivity of the TDA7052. If required, this can of course be a real potentiometer with knob and all to adjust things on the fly.

Maximum power output is just over 1 watt, which is more than enough for most applications. The power supply voltage can be up to 18 V, but be aware that voltages above 6 V or so can cause the IC to become hot. When using higher voltages, use a loudspeaker with an impedance greater than 8 ohms or limit the input signal of the amplifier. Don't worry about FUBR-ing the amplifier though. Even though the IC heats up, an internal thermal security will stop anything from blowing up.

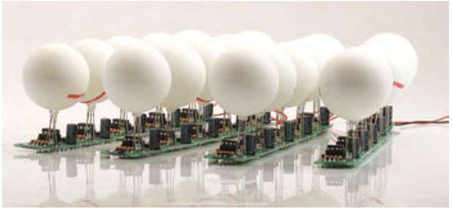
A few measurements were carried out on the prototype and the results in the table show what happened at a supply voltage of 6 volts and a loudspeaker impedance of 8 ohms.

Pretty good results for an amplifier this simple!

The construction of this mini amp is unlikely to cause problems. If you work neatly, the circuit will most definitely work. Some people have taken it as a challenge to make the circuit as small as possible. Whatever you choose to do, we wish you a lot of fun tinkering!

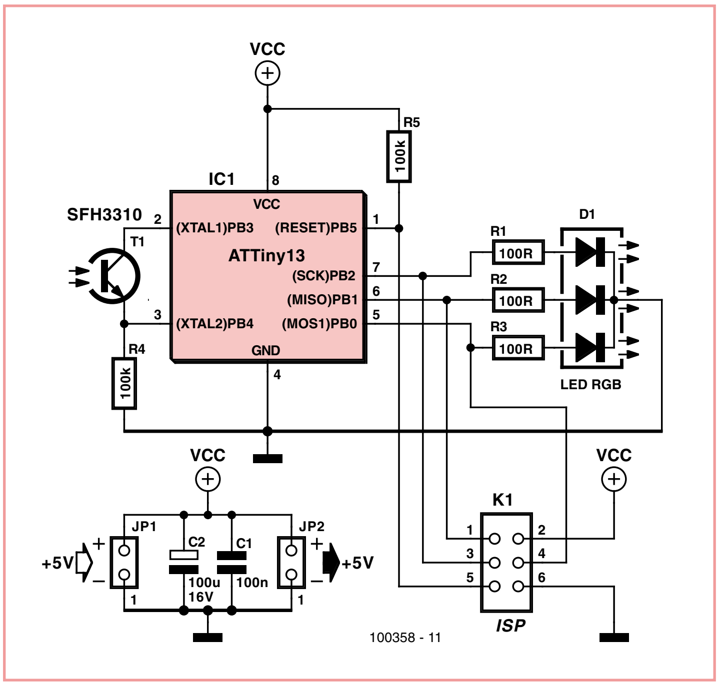
(091100)

RGB Synchronizing Fireflies



Alexander Weber (Germany)

If you like the emergence of visual patterns, be it natural or man made, one you're bound to be impressed by is the 'synchronization' of hundreds or thousands of fireflies. First they flash randomly but after some time and influencing each other, they flash in sync (kind of).
The author was triggered to propose this circuit to Elektor following the publication of "Fun with Fireflies" in the April 2010 edition [1]. The version shown here employs an ATtiny13 microcontroller and just one RGB LED and should be cheap and easy to build in large numbers.



The RGB firefly does not move around, and uses color to express its mood. If all is in sync, it will flash in relaxed and cool blue. If it detects flashes that are not in sync, it will get a bit uncomfortable and the color will slightly change to green, yellow and red.
Note that every firefly acts completely autonomously, i.e. not 'obeying' or trying to achieve, a pre-programmed pattern. As you build more fireflies and allow them to interact, they become increasingly a self organizing system — strength and fun are indeed in numbers!
The firmware running in each firefly determines its behavior, based upon light levels measured by an SFH3310 phototransistor. Talking software now, each firefly has a value that represents the power to flash. This value rises over time. If the power reaches a certain limit, the firefly flashes and the power is reset to zero. If the firefly detects another flash nearby, it increases the power by a small boost value. That way it will flash slightly earlier than last time. Doing so over and over again may lead to all fireflies flashing in sync — and prove the concept of robotic swarming [2].
The main parts in the circuit are the microcontroller, the light sensor and the RGB LED. The sensor and R4 form a potential divider, whose voltage level is read by the ATtiny13 microcontroller through an ADC channel at pin 3. The circuit is designed for a 5 V power supply and has no integrated power regulator. The supply voltage is taken from a 'rail' created by plugging firefly boards to form a row using plug/socket pairs JP1 and JP2 (i.e. these are not jumper positions).
Various types of photoresistors exist. Two different versions were tried and found to work well. Only resistor R4 has to be adjusted in a way that gives a good range of voltage and still limits the current through the photoresistor. Recent experiments showed that a phototransistor outperforms both photoresistors and LDRs. Compared to the LDR, it does not have a memory effect and reacts faster (~5 ms compared to ~50 ms). Eventually the SFH3310 was chosen and 100 kΩ for R4.
One thing to remember while choosing a light sensor, is that the spectral sensitivity of the sensor has to match the human eye sensitivity (~400 nm – ~700 nm).
The software developed for the RGB Synchonizing Fireflies may be downloaded free from the Elektor website [3], compiled and blown into the ATtiny chip via ISP header K1. Readers without access to a suitable programmer may order the ready-programmed ATtiny13(V) chip from Elektor as item # 100358-41.

The construction and use of clusters of these little electronic creatures is copiously illustrated by pictures and a video on the author's website [4],[5], which also provides leads to obtaining kits for this 'embedded-in-biology' project, or is the other way around?

(100358)

[1] www.elektor.com/100014

[2] www.elektor.com/100013

[3] www.elektor.com/100358

[4] http://tinkerlog.com/2009/06/25/64-synchronizing-fireflies/

[5] http://tinkerlog.com/howto/synchronizing-firefly-how-to/

Wireless Alarm Transmitter and Receiver

Christian Tavernier (France)

Here are two circuits that make it possible to add up to eight detectors to an existing alarm system without running a single cable. Each transmitter has a unique number that is reported to the central unit in the event of an alarm, and the transmitter battery condition is monitored. Transmissions between the transmitters and the central unit are coded and are in one of the two ISM frequency bands: 433.92 MHz (US: 315 MHz) or 868 MHz (US: 915 MHz).

The transmitter circuit (**Figure 1**) does not include the actual radio transmitter, as it is compatible with any UHF radio transmitter module with a binary input.

The heart of the circuit (IC1) is a digital data coder. It outputs from its DOUT pin a binary sequence containing an address, coming from inputs A1–A5, and data reflecting the state of inputs D6–D9. The addresses are used here for the 'house' code, while data lines D7,D8,D9 code the transmitter number from 0–7. Line D6 transmits the battery status, measured by comparator IC2.

The detector is a **normally closed** type connected to inputs E1 and E2. In the absence of an alarm and if the battery is OK, IC3.A is inhibited, which also inhibits IC3.B. This prevents IC1 from operating, via its TE input, and also turns off T2, cutting the power to the RF module. The transmitter is then in stand-by and uses very little current.
In the event of an alarm, i.e. opening of the detector contacts, or if the battery is low, IC3.A goes high and enables multivibrator IC3.B, which then generates a r=ectangular signal with a low duty cycle, owing to the large difference in the values of R9 and R10. When this is high, IC1 is enabled via its TE input and T2 is saturated via T1. The radio transmitter module is then powered and transmits the information supplied by IC1. This state continues as long as the alarm has not been cancelled or the battery replaced.

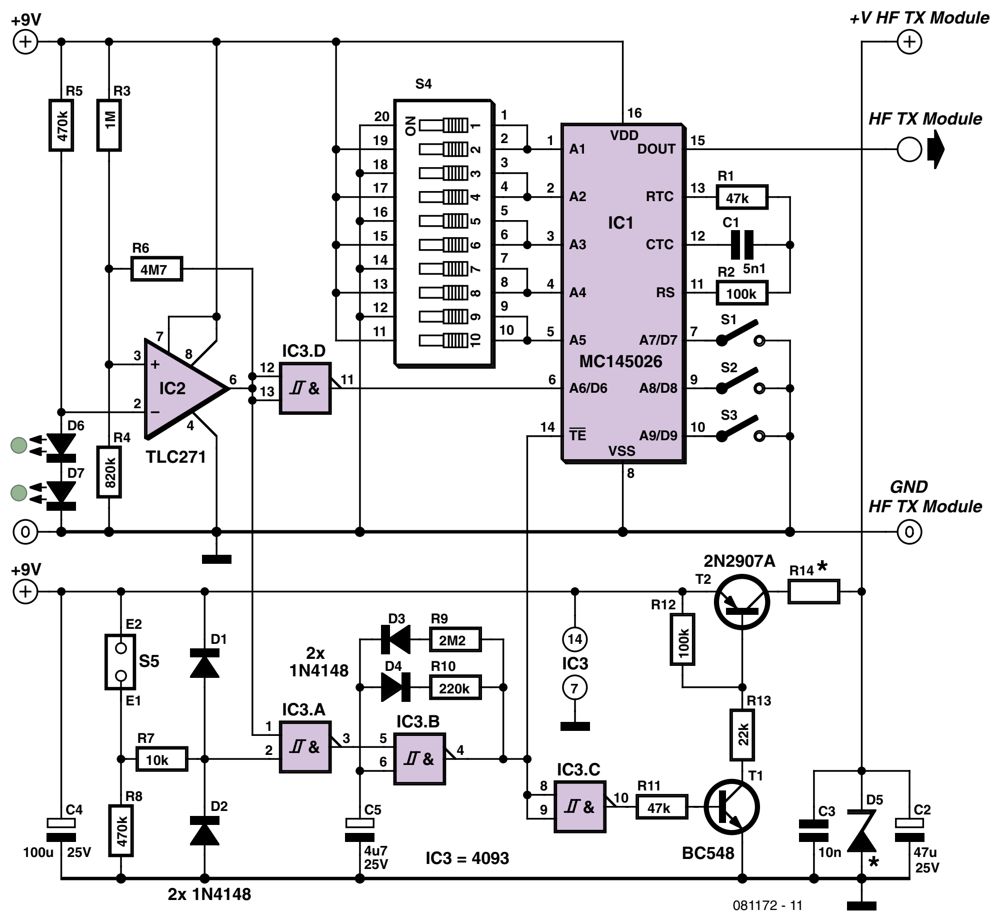
So the module transmits its status for a short time, then goes back into stand-by for a longer period, and so on. This makes it possible to on the one hand to economize battery life, and on the other, to minimize the collisions that might occur if other transmitters were to come on at the same time.

Resistor R14 and zener diode D5 must be chosen according to the supply specifications of the radio module used (usually 5 V at a few tens of mA). It is essential that IC2 be a TLC271, which is the only one able to guarantee very low stand-by power consumption.

The address coding inputs are 3-state inputs. So each input can be connected to ground, to V+, or left floating. Obviously, you need to set the same code on all the transmitter modules and the receiver. The data inputs D7–D9 are binary, and you need to choose a different combination for each transmitter.

The receiver (**Figure 2**) does not include the

1



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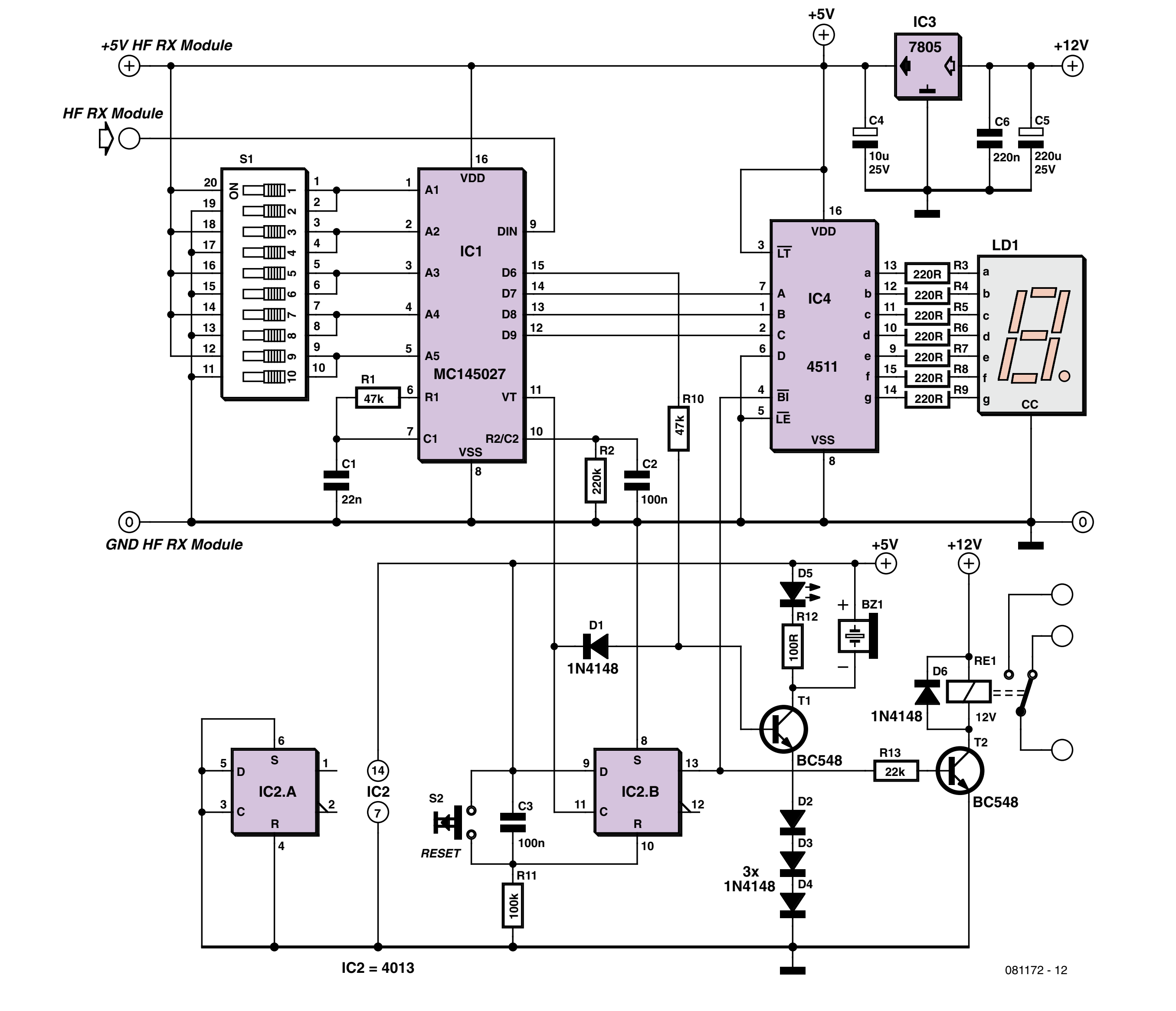


UHF receiver, it's up to you to choose which one to use.

The binary signal from the UHF receiver's output is applied to the input of IC1, which is the natural companion to IC1 used in the transmitters. If there is a clash of addresses, the transmitter's D6–D9 data appear on the same outputs of IC1. In addition, the VT signal goes high each time IC1 receives a valid data sequence.

The three data bits corresponding to the transmitter number are decoded by IC4, a BCD–7 segment decoder. If its BI input is high, display LD1 shows the number of the transmitter that has triggered the alarm. The BI signal comes from a D-type flip-flop (IC2.B) that memorizes the alarm status, as it is triggered by IC1's VT output. It is reset automatically at power-up via C3 and R11, or manually using push-button S2. In an alarm state, the flip-flop also energizes relay RE1 via T2.

When the transmitter battery is exhausted, IC1's D6 output goes high, setting off the audible alarm and lighting LED D5. Looking now at the receiver, we can tell if we have a 'normal' alarm (RE1 energized, no audible warning, LED not lit) or a low battery warning (RE1 energized, audible warning active, LED lit). In both cases, the display indicates the number of the transmitter concerned.

Note that in the event of alarms from several modules, the display indicates the numbers of the modules concerned in turn, but this may be difficult to read if more than two transmitters are operating at the same time.

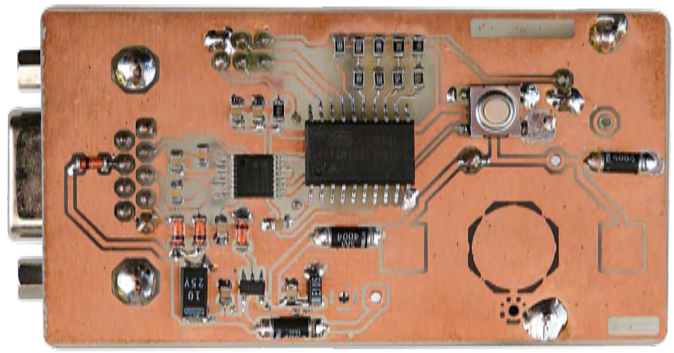
The power supply is stabilized at 5 V, except for the relay supply. This can be provided by a 'plugtop' adaptor or, better still, be tapped off the associated central unit supply, which usually has battery back-up in the event of a power failure.

Remember to code A1–A5 as for the associated transmitters. Note too that, given the circuit used, the audible warning device must be a model with built-in electronics. The relay output should be connected to one of the inputs of the associated alarm system.

(081172-I)

[1] www.elektor.com/081172

Scope Text



Emile Steenbeeke (The Netherlands)

Scope Text is a small circuit based on the ATTiny2313 microprocessor, which can be used to display text on a CRT oscilloscope. The text is shown on the screen as a scrolling message display.

Apart from the ATTiny, you'll find an RS-232 interface chip (MAX3221) and a 3 V voltage regulator in the circuit. The functionality is mainly determined by the firmware, which can be downloaded from the website for this article [1].

The firmware is written in C using WINAVR. A terminal program can be used to enter some text, which is stored in the EEPROM of the processor. A maximum of 100 characters can be stored, with ASCII values ranging from 32 to 128. Each character that is displayed is also sent out via the RS232 port, so you can check what text is stored even if you don't have a scope to hand.

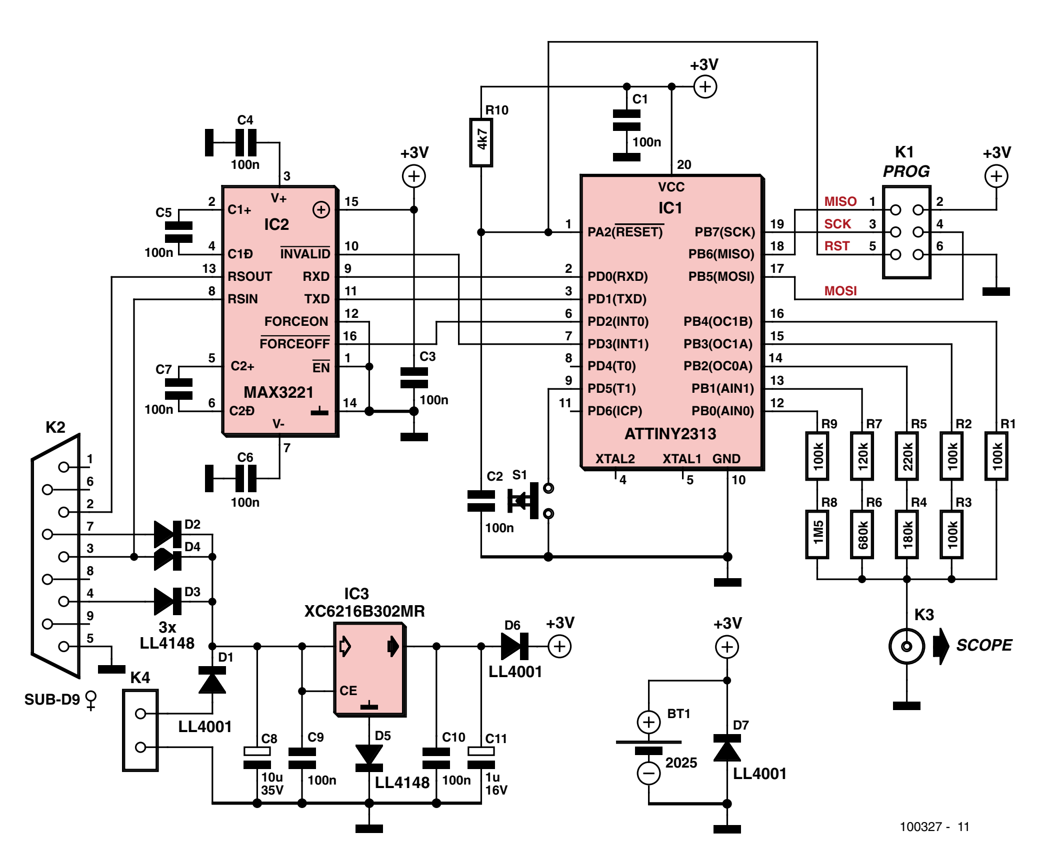
The terminal program is written in Delphi6 PE along with an extra installed component (CPORT310) [2]. The terminal program also makes sure that all RS232 outputs are logic High, so that the circuit can be powered via these signals.

The circuit can therefore be powered from the COM port of the PC, but you could also use a DC power supply or a CR2032 battery. The battery supply is very useful when, for example, you want to surprise a colleague with a 'Happy Birthday!' that scrolls across their scope screen.

When the circuit is turned on the word 'ELEKTOR' appears once on the screen before the text from the EEPROM is shown. When the circuit is battery-powered and an RS232 connection is made, 'RS232 ON' is shown on the screen. This stays on for a while before it scrolls off the screen and is followed by the stored text. When the connection is cut off 'RS232 OFF' appears on the screen. The RS232 chip goes into an auto power-off mode when there isn't an RS232 connection and draws only 1 µA or so, which is good for the battery life.

Each frame is preceded by a short pulse, which can be used to trigger the scope. A clear stable picture is obtained when the scope is set to 1 V/1 ms. Unfortunately, the circuit doesn't work with a digital oscilloscope. There is a switch that can stop the movement of the text. The INI file contains the COM port number used and is automatically generated. If an error message appears that states that the port is not available, this file can be edited so it stores the correct port number.

(100327)



[1] www.elektor.com/100327

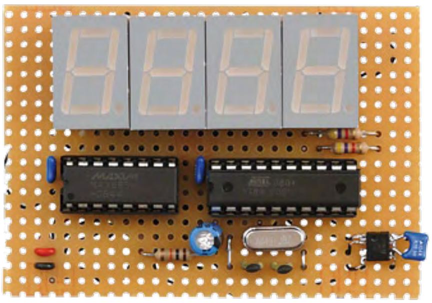
[2] http://svn.isysbus.org/misc/delphi/components

Thermometer with Four-Digit LED Display

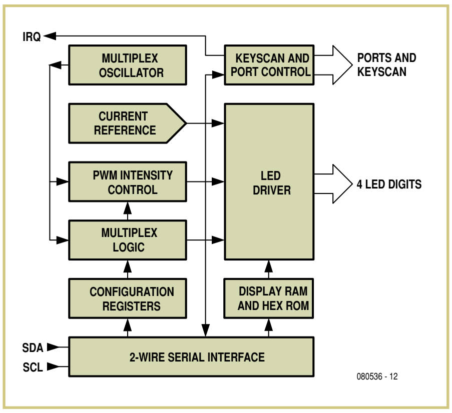
Andreas Köhler (Germany)

Until recently, the Philips SAA1064 LED driver IC has been a sort of unofficial standard for driving seven-segment LED displays. It can be used to implement four-digit displays that can be driven over an I²C bus. However, no matter how it's packaged (DIL24 or SO24) this IC is simply on the large side with its 24 pins. Its minimum supply voltage of 5 V and quiescent current of nearly 10 mA are also not exactly state of the art now.

An attractive alternative for tasks of this sort is the Maxim MAX6958 IC. It is available in the



smaller QSO package with only 16 pins, can operate at 3.3 V, and has a shutdown mode with a current consumption of only 20 µA. Inspired by this progress, the author resolved to design a digital thermometer circuit using this IC. Aside from the MAX6958, four common-cathode LED display modules (Toshiba TLR 324) and an Atmel AT89C2051 micro-



controller (other types could conceivably be used), all that's necessary is a suitable temperature sensor. The selected device, a National Semiconductor LM75, fits well with the rest of the electronics because it is also I²C compatible. The microcontroller clock signal for this simple application can be generated by any crystal with a frequency in the range of 4 to 12 MHz.

While writing the assembly language firmware, the author had to battle with the complexity of the display driver, a consequence of the restricted number of pins. The type of multiplexing used here by Maxim has already been described in detail in Elektor [1].

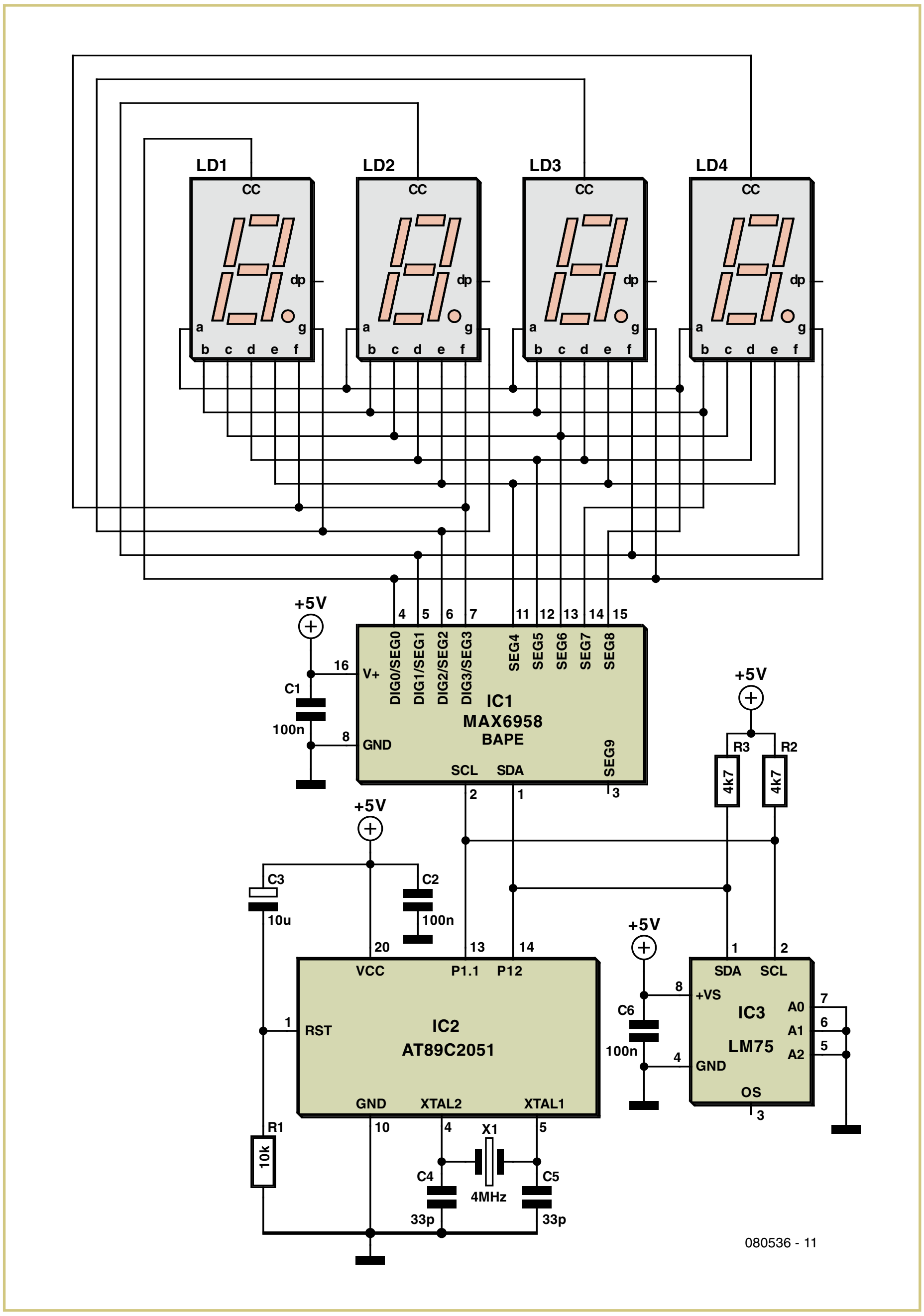
If you want to know what goes on behind the scenes with this driver IC, you can find a full explanation in Maxim Application Note 1880 [2]. Naturally, the Elektor web page for this article [3] offers not only a ready-made hex file but also the author's fully commented source code file, so you can modify the software if you so desire. If you simply want to build the circuit and aren't interested in programming the microcontroller, you can order a pre-programmed device from the Elektor Shop [3].

(080536-I)

[1] Charlieplexing, Elektor July & August 2006; www.elektor.com/060124

[2] www.maxim-ic.com/app-notes/index.mvp/id/1880

[3] www.elektor.com/080536



LED close to the processor will start blinking at a rate of 1 Hz. If you get this far without problems — and honestly I don't see why you shouldn't — then you are up and running. You can now start writing your own applications! If you come up with an interesting project, please do not hesitate to send it to us, we will be happy to evaluate and publish it in Elektor. (And maybe you will get another LPCXpresso, etc. etc., which reminds me that I didn't get a board even though I wrote this article...)

For those of you not having made it to the free LPCXpresso board, you can buy one from most major component suppliers or directly from [2].

(110448)

Internet Links

[1] http://ics.nxp.com/lpcxpresso/

[2] www.embeddedartists.com/products/lpcxpresso/

[3] http://lpcxpresso.code-red-tech.com/LPCXpresso/Home

[4] http://elektorembedded.blogspot.com

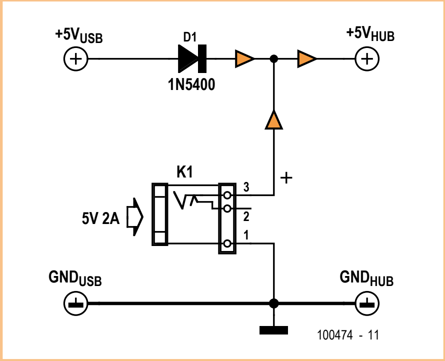
Upgrade your USB Hub

By Kurt Bohnen (Germany)

Problems can arise with USB hubs that are powered from a PC when gadgets plugged into them draw too much current. This is often the case with devices fitted with USB cables that are too long or too thin, causing voltage drop.

There's no need to scrap your old USB hub, however, if you upgrade it using this little circuit and an external power supply. Just cut the 5-V power wire of the USB cable inside the hub and solder a diode (D1) in the pass-through direction. Now connect the 5 V wire from the external power supply to the cathode of this diode. D1 prevents any current from the power supply from flowing back into the PC.

(100474)

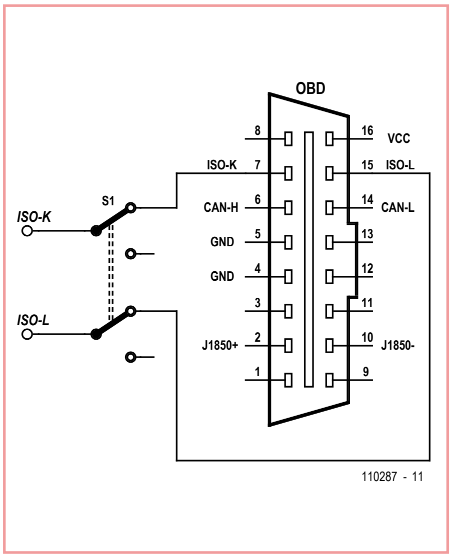


OBD Vehicle Protection

By Florian Schäffer (Germany)

Vehicle immobilizers are fitted as standard to modern cars and heavy goods vehicles. Anti-theft mechanisms have become more sophisticated but so have the methods employed by crooks. Nowadays once the thief has gained access to a vehicle they will most likely use an electronic deactivation tool which seeks to disable the immobilizer, once this has been accomplished a blank transponder key/card can be used to start the engine. In many cases communication with the immobilizer is made using the OBD-II diagnostic connector.

Although the OBD-II protocol itself does not support the immobilizer, the vehicle manufacturer is free to use the interface as necessary for communication, either the standard OBD-II signals or unused pins in the OBD-II connector (i.e. those undefined in the OBD-II standard). Using one of these pathways the immobilizer can usually be electronically disabled.



This may be unsettling news for owners of expensive vehicles but when professional car-thieves call, armed with the latest OBD-II hacking equipment this simple low-cost low-tech solution may be all that you need. The idea is very simple: if all connections to the OBD-II connector are disconnected there is no possibility for any equipment, no matter how sophisticated to gain access via the vehicle's wiring.

The OBD-II connector is usually located underneath the dashboard on the passenger side; once its wiring loom has been identified a switch can be inserted in line with the wires. The switch should be hidden away somewhere that is not obvious. In normal operation you will be protected if the vehicle is run with the wires to the socket disconnected. Make sure however that you throw the switch reconnecting the socket before you next take the vehicle along to a garage for servicing or fault diagnosis.

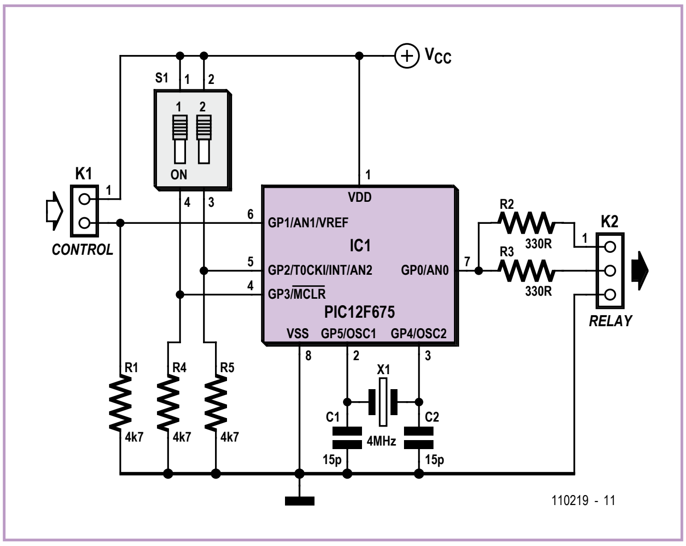
The diagram shows the ISO K and ISO L wires switched. To cover all bases it is wise for every wire to the socket is made switchable except the two earth connections on pins 4 and 5 and the supply voltage on pin 16. Almost every vehicle manufacturer has their own method of vehicle immobilization, by disconnecting every wire it ensures that no communication is possible (even over the CAN bus). Now the innermost workings of your vehicle will be safe from prying eyes. When a hacker plugs in a deactivation tool it will power up as normal but probably report something like 'protocol unrecognized' when any communication with the OBD port is attempted.

(110287)

2/4/6-hour Timer

By Philippe Schmied (Switzerland)

Here's an easy-to-build circuit to drive a solid-state relay for a period that can be selected as two, four, or six hours. This device forms part of a project by the author to control a heating system remotely by telephone (for a holiday home). The aim of the circuit is to avoid the risk of the heating's running for more than a certain time if, in the event of a problem, there is no-one to stop it or put it into frost protection position.



A pulse of one second or longer on pin 6 of the microcontroller sets off the timer and the output is energized. Once the chosen time has elapsed, the microcontroller deactivates the output.

The duration is selected via the DIP switches connected to ports GP2 and GP3:

GP2	GP3	Duration
0	0	0 hr
0	1	2 hr
1	0	4 hr
1	1	6 hr

When choosing a relay to use with this circuit, remember the maximum current the microcontroller output can source is 25 mA. Preferably choose a solid-state relay — you'll find several examples in this issue.

The software has been written in E-Blocks Flowcode and the project is available from [1]. For those who don't have Flowcode, the project also includes a file in C and in assembler language, as well as a HEX file. The pre-programmed microcontroller (PIC12F675 in 8-pin DIL package) is available from the Elektor online store as part number 110219-41 [1].

(110219)

Internet Link

[1] www.elektor.com/110219

ATM18 and Three 1-Wire Thermometers

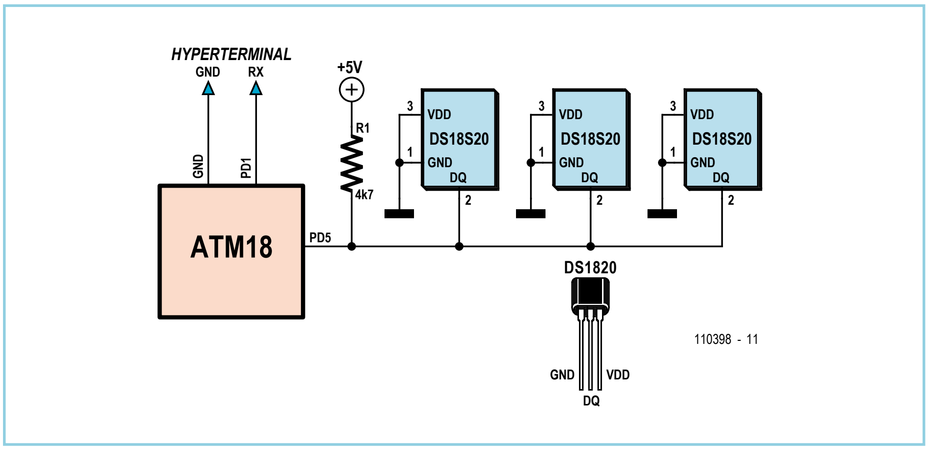
By Grégory Ester (France)

In this circuit, the Elektor ATM18 [1] is in charge of communications and represents the master unit, while the DS18S20 sensors are the slave units. The DS18S20s respond to the orders from the master by sending back to it the temperature they are measuring.

Our circuit makes it possible to measure temperatures from −55 °C to +125 °C (–67 °F to 257 °F) with 9-bit resolution and an accuracy of ±0.5 °C from −10 °C to +85 °C (14 °F to 185 °F). However, the resolution can be improved by using a calculation discussed later, and which is implemented in the firmware written in BASCOM-AVR [2].

The sensors draw their power from the bus ('parasite power' mode, up to a few mA) by exploiting the numerous moments when the bus is at logic high. Given that most of them consume less than 100 µA, we just need to keep an eye on the total number of devices present on this bus. However, it's still possible to power certain Dallas devices locally by feeding a constant voltage of 3–5.5 V.
Each 1-Wire component has a unique 64-bit

key to identify it. The eight LSBs of this key contain the family identifier. The code 10h corresponds to the DS18S20 family of sensors, making it possible to distinguish between 1-wire sensor types from different families that may exist on the same bus.
The DS18S20 has an internal memory (scratchpad) containing the data that are going to help you calculate the temperature measured.
Initially, the program calculates the number of sensors present on the bus and stores in a memory table the unique identifiers that are sent from MSB to LSB to the hyperterminal.



The commands CCh + 44h are then executed, ordering all the sensors to perform the temperature conversion; in this way the scratchpads are automatically updated with the new values, a total of nine bytes per scratchpad.

You now call up each sensor individually by using its unique identifier followed by the command BEh. In this way, each time you can store in a table the contents of the nine scratchpad bytes of the sensor concerned.

The temperature may be negative, and this is where two's complement comes in, to express the result in the sensor memory. The ninth bit corresponds to the tenths. A temperature with higher than 9-bit resolution can be calculated by using the 'count remain' and 'count per C' data, bytes 6 and 7 of the scratchpad. The 'count per C' value is factory set to 16 (10h). The value 'temp read' is obtained by truncating the 0.5 °C bit (bit 0 of the LSB). The temperature in degrees Celsius can then be calculated accurately using the equation:

T = temp read − 0.25 + ('count per C' − 'count remain') / 'count per C'

This is the value that is calculated and sent to the hyperterminal for each of the three sensors.

(110398)

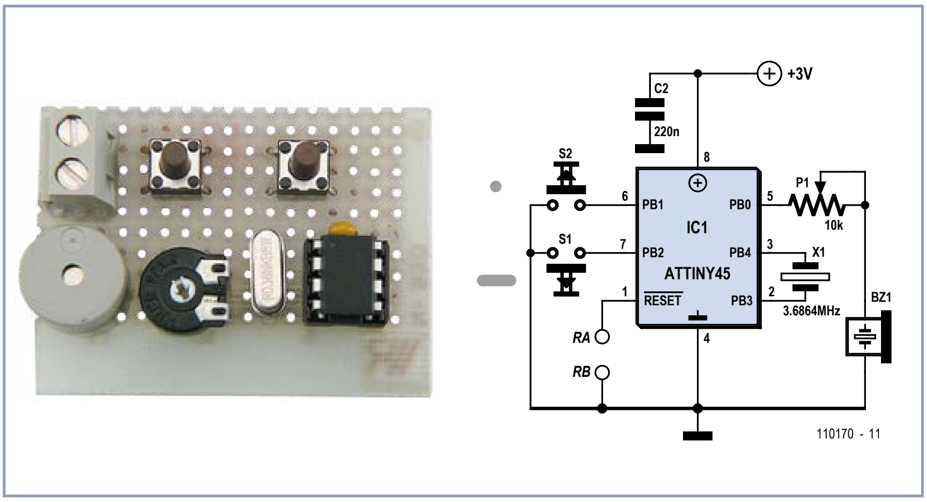
Internet Links

[1] www.elektor.com/071035

[2] www.elektor.com/110398

Morse Clock

By Ralf Beesner (Germany)



Now this is what we call style: the clock circuit described here doesn't just announce the time in Morse code, but the whole user interface is in Morse! The design even includes an alarm function.

When designing this circuit it became apparent that it would not be essential to use a 32 kHz watch crystal in conjunction with the special low-power mode of an ATmega microcontroller. The current consumption of an ATtiny45 in idle mode, running from a standard 3.6864 MHz crystal, can be kept low enough to allow acceptable operation from a battery. In normal operation the consumption is about 0.2 mA, which corresponds to about 1.8 Ah per year.

The crystal must be connected to inputs PB3 and PB4 of the ATtiny45 microcontroller. The buzzer is connected to PB0, leaving PB1 and PB2 available for the dash and dot contacts. Besides the microcontroller, crystal, buzzer and the two buttons the only components required are a decoupling capacitor across the power supply and a volume control potentiometer. The quartz crystal is used without the load capacitors recommended in the datasheet (12 pF to 22 pF). It nevertheless oscillates reliably, but at a frequency perhaps a couple of hundred Hertz too high. This is deliberate: it means that the clock normally runs a little fast, and this is corrected in software by the addition of a small delay to cali-

brate its overall timekeeping.
The circuit should rarely need resetting. A reset button was included in the author's prototype, but in the circuit diagram and suggested printed circuit board layout [1] just a couple of pads are provided.
The supply voltage is 3 V, provided by two AA cells. The printed circuit board is dimensioned so that it can be attached to the back of a dual AA battery holder using two screws.

The clock is entirely controlled by commands in Morse. When the batteries are first fitted, it announces the time as 0000. The quarter-hourly chime (referred to as 'gong' below) is enabled.

The following commands, each consisting of a single character, are available:

- ? List commands
- Z Set time
- T Announce time
- G Gong (chime function) on/off
- C Check: announce gong status, alarm status and so on
- M Set Morse speed
- W Set wake time
- A Alarm on/off
- E Alarm stop (a single press of the 'dot' button)
- K Set calibration delay (1 s to 9 s) (slows clock down)

The commands that set a time expect a four-digit number, entered without spacing or punctuation. The on/off commands expect a zero or a one, and the Morse speed command expects a two-digit number. As soon as a sequence of digits has been entered, the clock repeats them back for confirmation. If a non-digit character is entered, the clock will reply with 'RPT' (for 'repeat'). If too few digits are entered, then after a short delay the clock will again reply 'RPT'. In both cases the clock returns to idle mode, and so the command letter must be repeated before entering the digits again.

The Morse speed setting routine will check whether the requested speed lies in a reasonable range (between 10 wpm and 30 wpm). If this is not the case, the clock will reply 'RPT' and set the speed to 20 wpm, ensuring that it still remains usable.

In the current version of the software the checking of time values is incomplete. The clock will accept times such as '1299': it is up to the user to check that the value is reasonable when it is repeated back in confirmation. The clock will, however, reject times greater than '2359' with the 'RPT' message.
As always the source code for the software is available for free download from the *Elektor* website [1]. The most important subroutine is the interrupt service routine, which is triggered once per second by the timer. The routine counts the seconds and maintains the time of day, expressed in minutes since midnight. When a complete day has elapsed (1440 minutes) the time is reset to zero in the main code.

The main code simply performs the time calculation and checks the button status before returning to idle mode to wait for the next interrupt. To ensure that the clock responds immediately when a button is pressed, PB1 and PB2 are configured to generate 'pin change interrupts'.

Unfortunately we cannot take advantage of the microcontroller's power-down mode, where almost all of its functional blocks are switched off with a single register setting, as we need to keep the crystal running. However, we can use idle mode, where most of the functional blocks still draw some current: we need to switch them off individually. The author has used registers PRR and DIDR0 for this purpose; there may be further options available for saving even more power.

(110170)

[1] www.elektor.com/110170

Pump Controller with Liquid Level Detection

By Guntram Liebsch (Germany)

The circuit described here lets you control a cellar drainage pump so that it turns on when a preset liquid level is reached and turns off again when a different preset level is reached. The author investigated several approaches to the problem.

Commercially available pumps equipped with float switches are not suitable as they are sometimes so powerful that there is a danger that their suction can start to cause movement in the ground beneath the building.

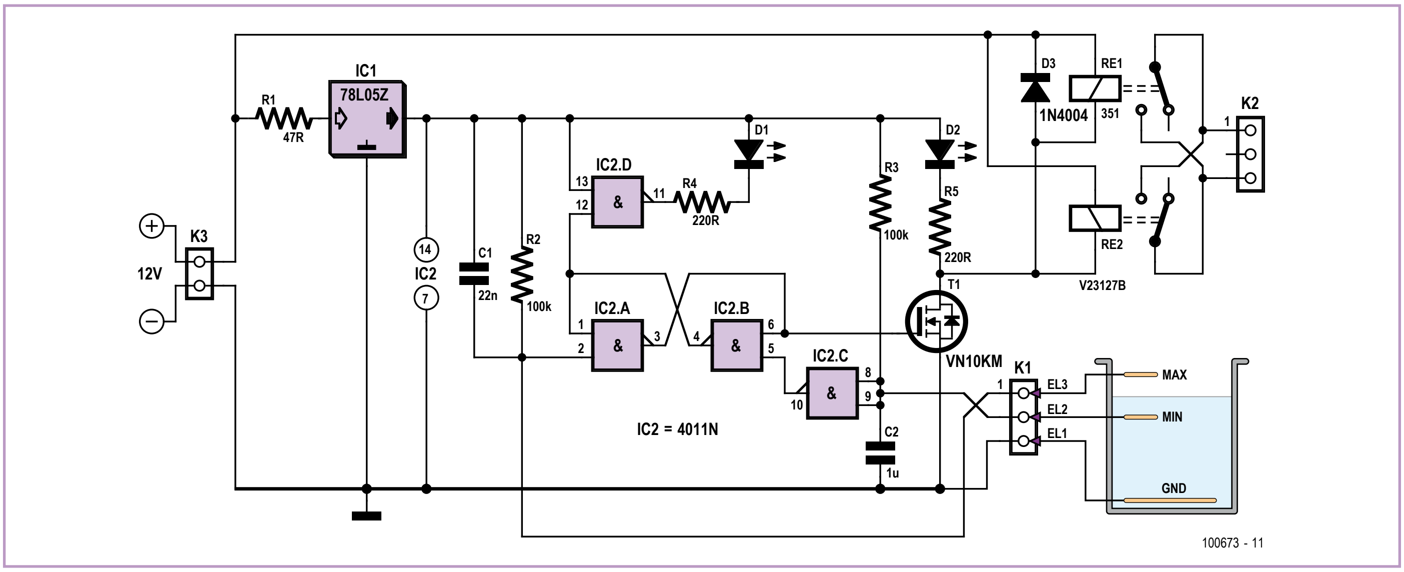
A more reliable approach is used here. A simple circuit determines the level of water using a pair of suitably-spaced electrodes and then pumps out a preset quantity of water. The author has used this circuit over a period of ten years in a sump (a pit dug in the cellar) to detect the presence of any groundwater less than a set level below the cellar floor.

The circuit can be used in two situations.

1. It can be installed in a sump to keep the groundwater level more than a set distance below the cellar floor. In this case a pumping cycle can be designed to reduce the level by say an inch (perhaps a gallon). Because of the small change in level there is no risk of causing movement of the ground below the building.

2. When the heating or the boiler in the cellar must be emptied, for example to replace the sacrificial anode, the water can be drained into a tank and pumped from there to the garden: using this pump control circuit means that the process does not have to be closely monitored.

The circuit has been kept very simple, in the interests of giving good reliability. Gates IC2.A and IC2.B form a bistable flip-flop whose state is flipped by the two electrodes: and this is all done using a single, low-cost, CMOS IC. Power switching is done by a relay, which can equally well be used with either 12 V or conventional 230 V / 115 V pumps. The author uses both types: a 12 V marine pump as the primary pump and, as a backup in case of failure, a conventional pump. The latter is only activated when the water level reaches a higher threshold, which does not occur unless the primary pump has failed. The 12 V system is powered from a car battery (12 V, 70 Ah) which is trickle-charged. Two relays are



shown in the circuit diagram, corresponding to two positions for relays on the printed circuit board with different pin configurations. Only one of the two possibilities is fitted.

The three electrodes are made from solid copper wire with a cross-section of 1.5 mm to 2 mm with the PVC insulation stripped back at the ends. Electrode EL1 acts as ground, EL2 sets the switch-off level and EL3 sets the level at which pumping is triggered. The circuit changes state when a current flows between these electrodes, which happens when water comes into contact with them. These currents, although tiny, lead to electrolysis of the electrode material, and so the electrodes have to be replaced every year or so. The amount of exposed copper on EL1 (the ground electrode) should be twice as long as that on the other two electrodes.

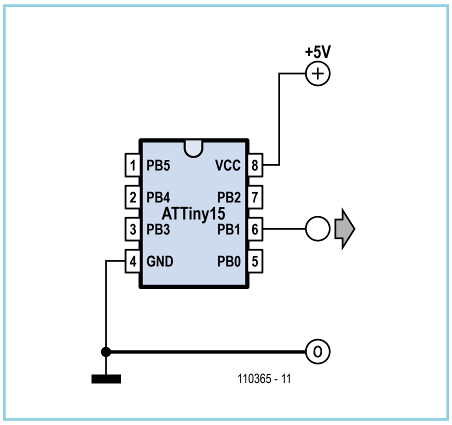
If an AC powered (115 V or 230 V) pump is used, particular attention must be paid to the galvanic isolation of the power supply, to the selection of an appropriate relay, and to the insulation of all wires carrying live voltages. Circuits at live potential should only be installed by suitably qualified personnel.

(100673)

MHz Oscillator using an ATtiny15

By Andreas Grün (Germany)

Most engineers will recognize the problem: Your circuit needs a stable 1 or 2 MHz clock generator (in the author's case it was for a Pong game using an old AY3-8500). A suitable crystal is not to hand so you cobble together an RC oscillator (there are plenty of circuits for such a design). Now it turns out that you don't have exactly the right capacitor so a preset pot is added to allow some adjustment. Before you know it the clock circuit is taking up more space on the board than you had hoped.



Providing the application does not demand a precise clock source a tiny 8-pin microcontroller may offer a better solution to the problem. It needs no additional external components and an old ATtiny15 can be found quite cheaply. Another advantage of the solution is that clock frequency adjustment does not involve changing external components and is not subject to component tolerances.

The microcontroller's internal RC oscillator is already accurately calibrated to 1.6 MHz. With its inbuilt PLL, internal Timer 1 can achieve up to 25.6 MHz [2]. By configuring internal dividers the timer can output a frequency in range of roughly 50 kHz up to 12 MHz from an output pin. The difference between calculated and the actual output frequency increases at higher frequencies. A meaningful upper limit of about 2 MHz is a practical value and even at this frequency the deviation from the calculated value is about 15 %.

The circuit diagram could hardly be simpler, aside from the power supply connections the output signal on pin 6 (PB1) is the only other connection necessary.

The example program, written in Assembler is just 15 lines long! With a program this short comments are almost superfluous but are included for clarity. The code can be downloaded from the Elektor website [1].

The program only needs to initialise the timer which then runs independently of processor control to output the clock signal. The processor can then be put into sleep mode to conserve power. With only 1 % of the program memory used up the remaining 99 % is free for use for other tasks if required.

The OSCCAL register contains a calibration byte which allows some adjustment of the CPU clock. This gives a certain degree of fine tuning of the output frequency. A recommendation in the Atmel data sheet indicates that the CPU clock frequency should not be greater than 1.75 MHz otherwise timer operation cannot be guaranteed.
The more recent ATtiny45 can be substituted for the ATtiny15. In this case the CKSEL fuses should be set to put the chip's Timer 1 into ATtiny15-compatible mode [3]. After adjustment to the program it will now be possible to obtain a higher (or more exact) frequency from the timer, the ATtiny45's PLL can operate up to 64 MHz.

(110365)

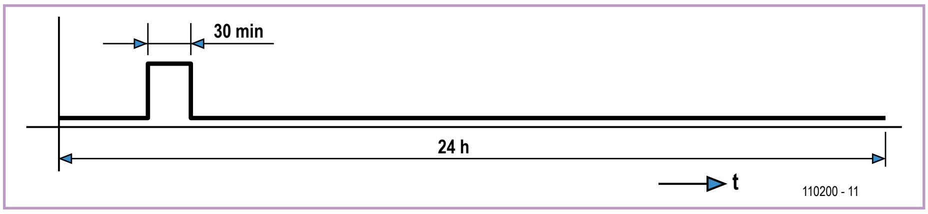
[1] www.elektor.com/110365

[2] www.atmel.com/dyn/resources/prod_documents/doc1187.pdf

[3] www.atmel.com/dyn/resources/prod_documents/doc2586.pdf

Timer for Very Long Periods

By Dirk Visser (Netherlands)



Simple mechanical timers, which you can buy for a couple of pounds in every home improvement center, are suitable for switching something on and off one or more times per day. They can be used to control a wide variety of devices, such as lamps inside or outside the house, lighting for bird cages and aquariums, sump pumps, battery chargers, etc.

If you need to control something over a longer period than the standard 24 hours, you can use two timers with the second one plugged into the first one (see photos). To determine what you can do with this arrangement, you first need to determine how often the load needs to be switched. For example, if the first timer has 48 tabs the shortest 'on' time is 30 minutes in 24 hours. This means that the second timer will run for 30 minutes every 24 hours, so the maximum duration of a full cycle is 48 days. A device such as a charger for diving torches can be connected to the second timer.
To prevent the 'on' time of the second timer from exceeding 24 hours, it is essential to keep the 'on' time of the second timer shorter than that of the first timer.
If a maximum cycle time of 48 days is too short, you can also connect a third timer. With three timers, the maximum cycle time is 2304 days (one 'on' time in approximately 6.5 years).

As you can see from the photos, the second timer may interfere with the tabs of the first timer if they are plugged together with one on top of the other. This can be avoided by turning the second timer by 180 degrees relative to the first one.

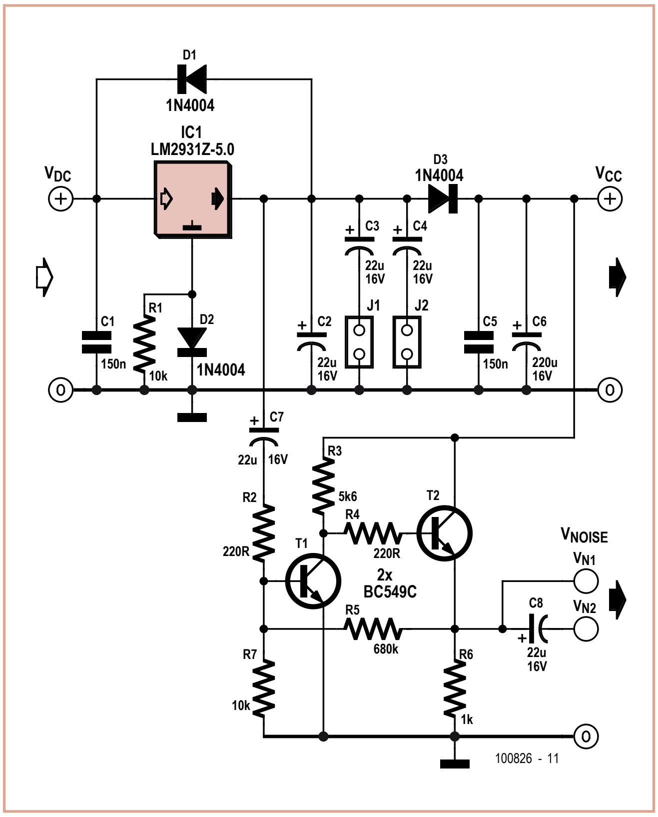
(110200)

LM2931-5.0 is a Random Noise Generator too

By Petre Tzvetanov Petrov (Bulgaria)

The low dropout voltage regulators from the LM2931 series are not just useful for powering microcontroller systems — they can also act as a low-frequency (practically) random noise generator. The random noise could be used in the system for making an ADC (analog to digital converter) produce random numbers, or a digital port purposely 'go haywire' depending on the noise level applied to it, or for other purposes you clever programmers may have in mind.

The output voltage of an LM2931A-5.0 is between 5.19 V and 4.81 V. The same parameter for the LM2931-5.0 is specified as 4.75 V to 5.25 V. The 'Z' suffix indicates a TO-92 package. Both ICs also supply typically 0.5 mV_{rms} worth of output noise across a 100 µF capacitor within the frequency range from 10 Hz to 100 kHz. When amplified more than 200 times, a noise voltage of typically 100 mV can be obtained, which should be enough to randomly toggle a few bits in a 10-bit ADC with a least significant bit (LSB) equivalent to 0.5 mV. These bits could be used individually or collectively to 'construct' larger random numbers.



The schematic shows a power supply providing an output voltage between 4.5 V and 5.5 V and a maximum output current of 80 to 100 mA. Diode D2 lifts the output voltage of the LM2931Z-5.0 IC by 0.6 to 0.7 V. Diode D3 eliminates (approximately) the voltage lift produced by D2. Still on diodes, D1 protects the regulator from reverse voltage.

The output noise of the regulator IC is branched off via C7 and R2 and amplified more than 200 times by T1 and T2. The output resistance of the amplifier is relatively low and the output signal could be used to directly drive the input of an ADCs. The gain of the transistorized amplifier may be changed to requirement chiefly with resistor R3.

Components D3, C5 and C6 reduce the impact of the load (typically a microcontroller system) on the noise seen by the amplifier input.

Jumpers J1 and J2 select the minimum load capacitance between D3 and the regulator output, to strike a compromise between stable operation of the regulator on the one hand and maximum noise output voltage on the other. The jumpers are set or soldered at the final stage when the equipment is tested.

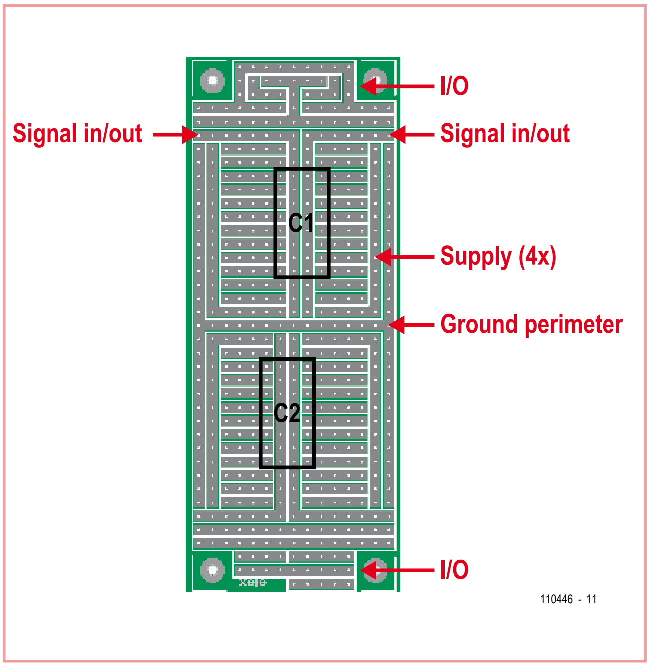
Although the circuit will also work with other voltage regulators like the 78L05, it should be remembered that much lower noise levels may be available, forcing the amplifier gain to be raised considerably.

(100826)

Return of the Elex Prototyping Board

By Luc Lemmens (Elektor Labs)

The magazine *Elex*, a sort of little brother of *Elektor*, was published in Dutch only from 1983 to 1993. It specialized in presenting electronics in an easy, fun manner. Many current Dutch readers of *Elektor* started out with *Elex*, and articles from the magazine are still in demand — the compilation DVD of *Elex* articles is still available.



Although the magazine ceased publication 18 years ago, its legacy is still alive: one small product of *Elex* has refused to die and continues to make life easier for electronics enthusiasts. The Elex prototyping boards were introduced with the first edition of the magazine in the Netherlands. The mission of *Elex* was to present lots of small circuits with a low entry threshold. Ready-made PCBs did not fit in this picture, since they are expensive and readers would have to buy a new board for each project. The solution to this difficulty was to develop a general-purpose breadboard PCB. It drew its basic inspiration from the well-known Vero prototyping boards, which are PCBs in Eurocard format (100 x 160 mm) with parallel copper strips running the length of the board.

Elektor lab staff at the time thought this could be improved on — the boards should be smaller to make them less expensive, and some of the strips, such as supply voltage and ground strips, should be predefined for use as 'rails'. As you can see from the illustration, only two small jumpers are necessary to connect an IC to the supply and ground rails. There are also two strips that run underneath each IC. They are intended to be used as input and output signal lines, but they are also suitable for use as supply lines.

The various strips — ground, supply voltage, spare supply voltage and signal — can be connected as desired to the I/O sections at each end of the board, which can optionally be fitted with connectors. Naturally, these prototyping boards are also suitable for designs using good old discrete components and transistors.

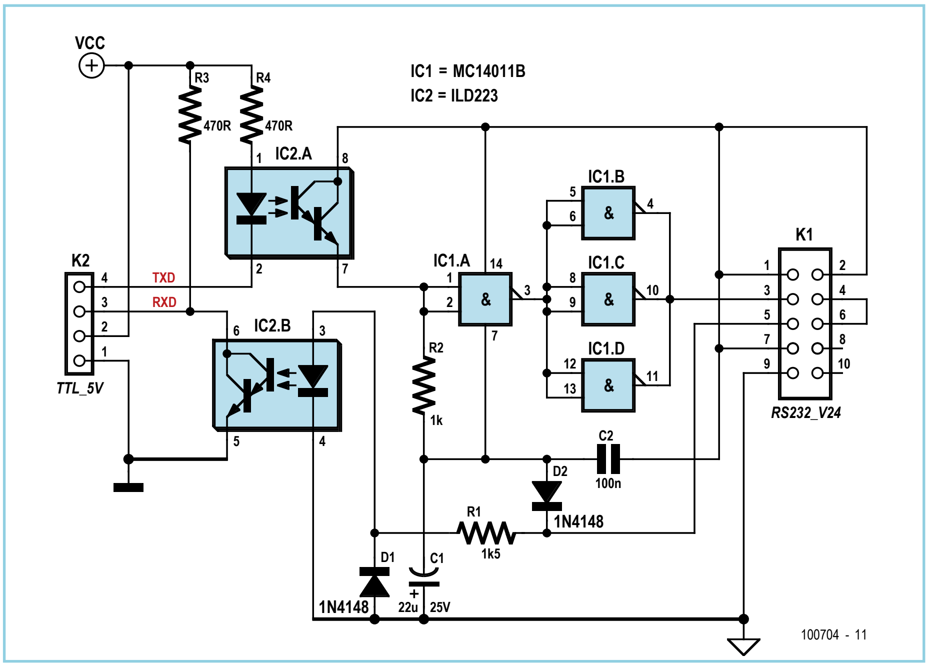
These handy boards are still available in the Elektor Shop under the name 'Elex' (Elex-1, Elex-2 and Elex-4 for single, dual and quad versions respectively). To show how easy it is to put together a small circuit on an Elex board some of the projects in this very edition include a photo of a prototype assembled on an Elex board.

(110446)

RS-232 Level Shifter with Isolation

By Uwe Hunstock (Germany)

This circuit converts between the TTL voltage levels on a UART to the correct levels for an RS-232 interface, with the two sides of the circuit being galvanically isolated from one another. Although ICs are available to do this from manufacturers such as Maxim, they are rather pricey.



In principle the circuit is capable of working at a maximum speed of 4800 baud, but in the lab we only managed speeds of up to about 2800 baud. The reason behind this is the switching time of the optocoupler, which, according to its datasheet, is 15 µs (T_{on}) or 30 µs (T_{off}). Some experimenting with the value of R4 may be worthwhile.

The presence of the optocoupler means that the circuit naturally falls into two isolated, externally powered, halves. The right-hand part of the circuit is powered from the DTR and DSR signals on the RS-232 interface (pin 7 and pin 2 of K1). These handshake signals must therefore not be used by the connected device, and must be held permanently at +12 V. However, since we will be generating negative signalling voltages on this side of the circuit, a simple positive supply is not enough. The trick used here is to tap off the TXD signal on the RS-232 interface via diode D2: in the quiescent state the connected device will be holding this signal at –12 V. Of course, the TXD signal will occasionally go high when the device is transmitting, and so we need C1 to provide a smoothed negative supply.

When something is transmitted to the RS-232 interface, the TXD signal on pin 5 of K1 drives the diode in the optocoupler directly via series resistor R1. However, when pin 5 is at –12 V we must ensure that the reverse voltage across D1 is limited: according to the datasheet the maximum permitted is 6 V.

When a transmission originates on the TTL-level side, the receiver transistor in the optocoupler drives a buffer implemented here using four NAND gates. Each gate is wired as an inverter, and it is easy to see from the circuit how overall inversion of the signal is avoided. Three of the gates are wired in parallel to increase the available output drive.

IC1 is powered from a ±12 V supply and so a CMOS device capable of operating at these voltages must be used. Other logic functions besides NAND could be used, as long as the gates can be wired together to make a driver. Individual CMOS gates such as the TC4S81 could also be used, although these are less likely to be found in the average experimenter's junk box than the 4011 shown.

The 5x2 header K1 can be connected directly to a 9-way insulation displacement D-sub socket using a flat cable. The wiring is as follows.

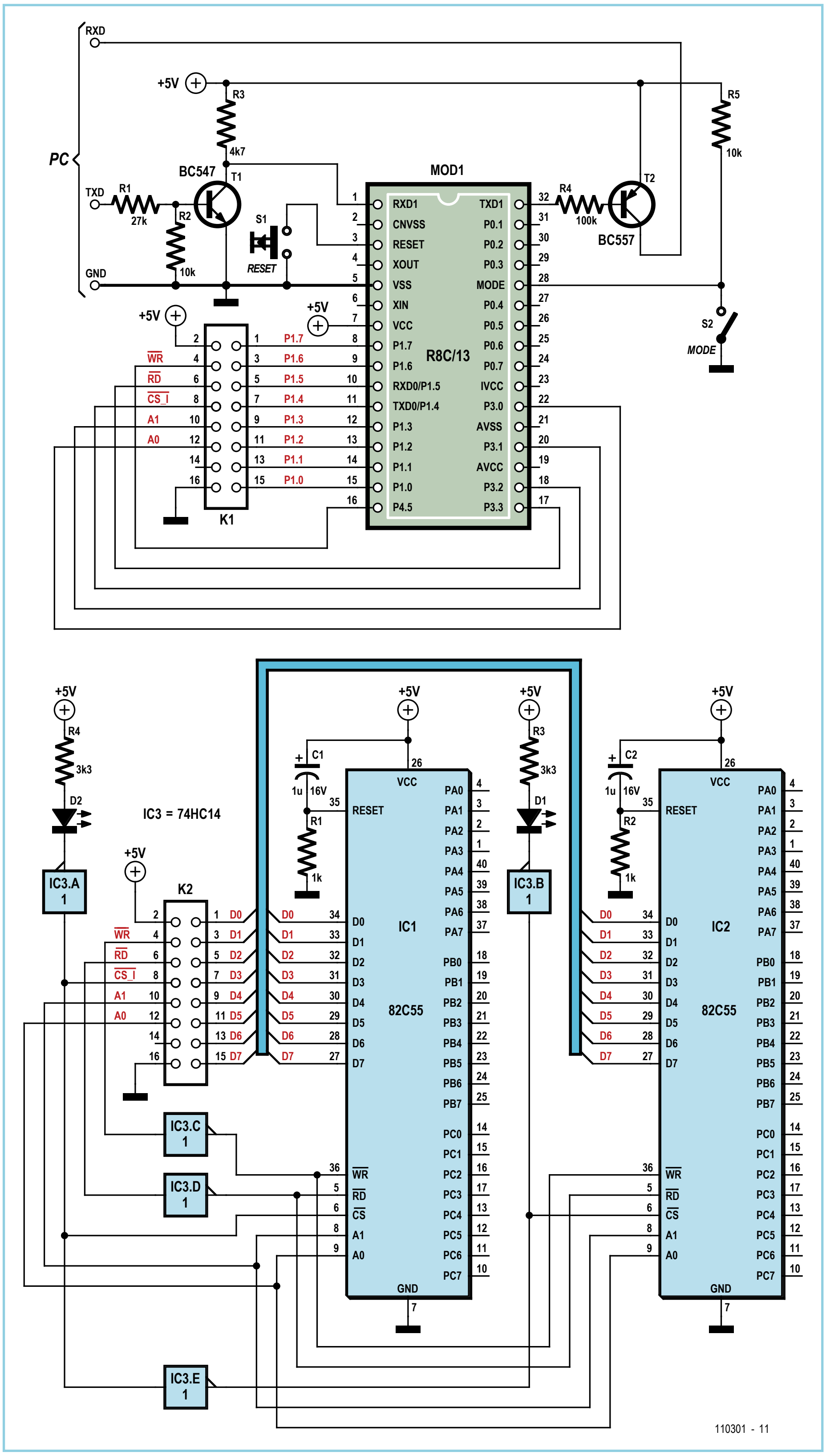
K1	SUB-D9	Signal
1	1	DCD (=High)
2	6	DSR (=High)
3	2	RXD
4	7	RTS (not used)
5	3	TXD
6	8	CTS (not used)
7	4	DTR (=High)
8	9	not used
9	5	GND
10	not used	

(100704)

Extra Port Connections for the R8C/13

By Hermann Nieder (Germany)

The well-known R8C processor module from Elektor's blockbuster R8C Project [1], [2] is easy to program and can be used to control an extremely wide range of applications. Now and again, however, some additional port connections would be handy in larger applications. For this reason we have come up with a simple port expander that uses two 82C55 port modules. Overall this now puts six ports each with eight pins at our disposal and these ports can be used either as inputs or outputs as required.



For RS-232 communication with a PC we shall use the 'minimal' system described in Elektor for December 2005 [1]. In principle, however, you could also make use of the practical USB/TTL cable [3], which would avoid the need for transistors T1 and T2 as well as the wiring for these.

Pins P1.0 through to P1.7 of the R8C/13 are linked to the data inputs of the modules mentioned above. P3.0 and P3.1 serve to address each of the ports. Pin P3.2 allows one of the modules to be selected with the Chip Select line /CS. The signal for this appears unaltered on the first port module and inverted on the second one.

Communication between PC and R8C (at 9600 Baud) is coded as follows. The first byte determines whether data on a port is to be written or read (1 for writing, 2 for reading). The second byte is the port address, in which the first module responds to addresses 0 to 3 and the second to addresses 4 to 7. Control bytes to the port expanders are transmitted using addresses 3 and 7 (see the data sheet [4] for further details). During write operations the third byte is the bit pattern for positioning the port pins. During read operations this bit pattern is sent from the R8C to the PC.

Communication between a PC and the circuitry described can be performed using a terminal program for example. A more convenient solution is the author's PC program (in Visual Basic 5), which uses Burkhard Kainka's functions library RSCOM.DLL, which can be downloaded from his website [5]. As ever, the PC software and the firmware for the controller can be found on the Elektor website [6].

To simplify the software, ports A, B and C of IC1 are used always as output ports and ports A, B and C of the second port module as input ports. At power-up both port modules receive a reset pulse and their ports are all defined as inputs.

After opening a COM interface you need to press the button '8255_1 und 8255_2 vorbereiten' (Prepare 8255_1 and 8255_2) in the PC program. The PC now sends bytes 1, 3 and 128 to the R8C/13, which in turn redefines all ports as outputs.

Now we can use the eight check boxes per port to define which of the individual bits on the outputs of ports A, B or C as appropriate are to be set or rest. Each time the corresponding decimal value of the bit pattern is indicated nearby.

After this pressing one of the 'Send' buttons to transmit the relevant bytes to the microcontroller, which in turn controls IC1.

The PC program polls the input pins (Ports A, B and C) of IC2 continuously. The status of the pins is indicated on screen by colored shapes, with the corresponding decimal value shown alongside.

The PC software is naturally just a starting point and all sorts of upgrades and modifications are possible!

(110301)

[1] www.elektor.com/050179-2

[2] www.elektor.com/r8c

[3] www.elektor.com/080213

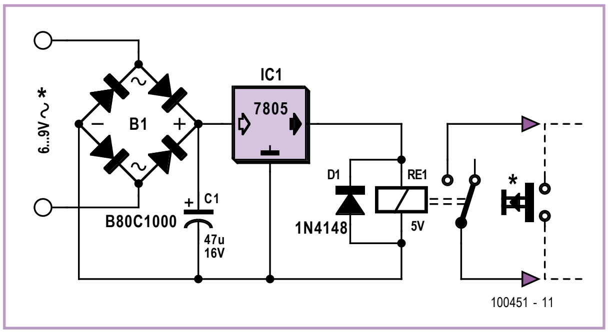
[4] www.intersil.com/data/fn/fn2969.pdf

[5] www.b-kainka.de/pcmessfaq.htm (in German; use Google's translator facility to read in English)

[6] www.elektor.com/110301

Tandem Doorbell

By A. René Bosch (Netherlands)



The author had a problem: the neighbors had exactly the same type of doorbell as he did (actually a 50 Hz buzzer), so it wasn't always clear who needed to answer the door. To avoid confusion, the author augmented the existing doorbell with a wireless model — a reasonably inexpensive option at current prices. All that was necessary for this was to arrange for the existing button and wiring to also actuate the wireless doorbell.

The author opened up the button enclosure of the wireless doorbell and used a multimeter to find out which set of contacts were closed when the button was pressed. This is where the relay output should be connected (see the schematic diagram). The circuit is virtually self-explanatory: when the existing doorbell button is pressed to actuate the buzzer, the voltage is rectified by the bridge rectifier and regulated at 5 V by the 7805. This voltage drives the relay directly, causing the switch in the wireless doorbell button to be shorted. As a result, along with the buzzer a sizeable Big Ben chime indicates that someone is at the door.

Now the author just hopes that his neighbor doesn't copy his idea.

(100415-I)

Audio Level Adapter

By Jörg Ehrig (Germany)

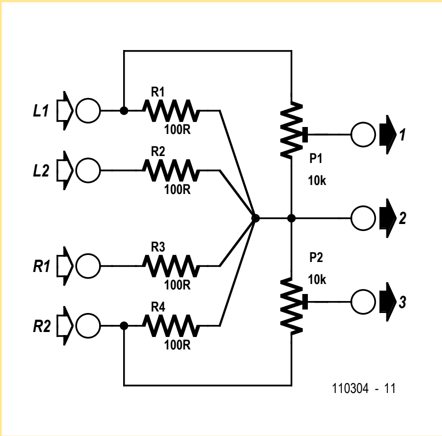
The problem that this circuit is designed to solve appeared when the author was installing a new radio in his Audi A3. The new radio had four outputs for loudspeakers and a line-level output for a subwoofer.

However, the A3 as delivered from the factory already has an amplifier for the rear loudspeakers, as well as the pre-installed subwoofer, in the boot space. The original Audi radio therefore has only line-level outputs for the rear loudspeakers. So, to replace the original radio without making other changes to the installed amplification system, he needed to convert the outputs of the new radio corresponding to the rear loudspeakers into line level outputs.

Most of the commercially-available adapters to do this job contain small transformers for galvanic isolation. These introduce phase shifts and create a certain amount of distortion, which the author was keen to minimize. The result is this simple adapter circuit that does not employ a transformer.

The outputs of most radios available today have a differential (bridge-type) push-pull output stage. There is thus no ground output, just two outputs per channel with a 180 ° phase difference between them. If the outputs are each connected to a common point via a 100 Ω resistor, that point becomes a virtual ground. The ground is relatively stable as (in the stereo case) it has an impedance of 25 Ω. Each output driver is seeing a 200 Ω load: if the amplifier is rated for 50 W output into a 4 Ω load this means that each resistor will dissipate less than 0.5 W. Hence 1 W rated resistors will be more than adequate, especially in view of the fact that typical music has a crest factor of at least five. Even a small DC offset from the virtual ground is not a problem, as most modern amplifiers feature differential inputs or at least allow the ground connection of an input to float.

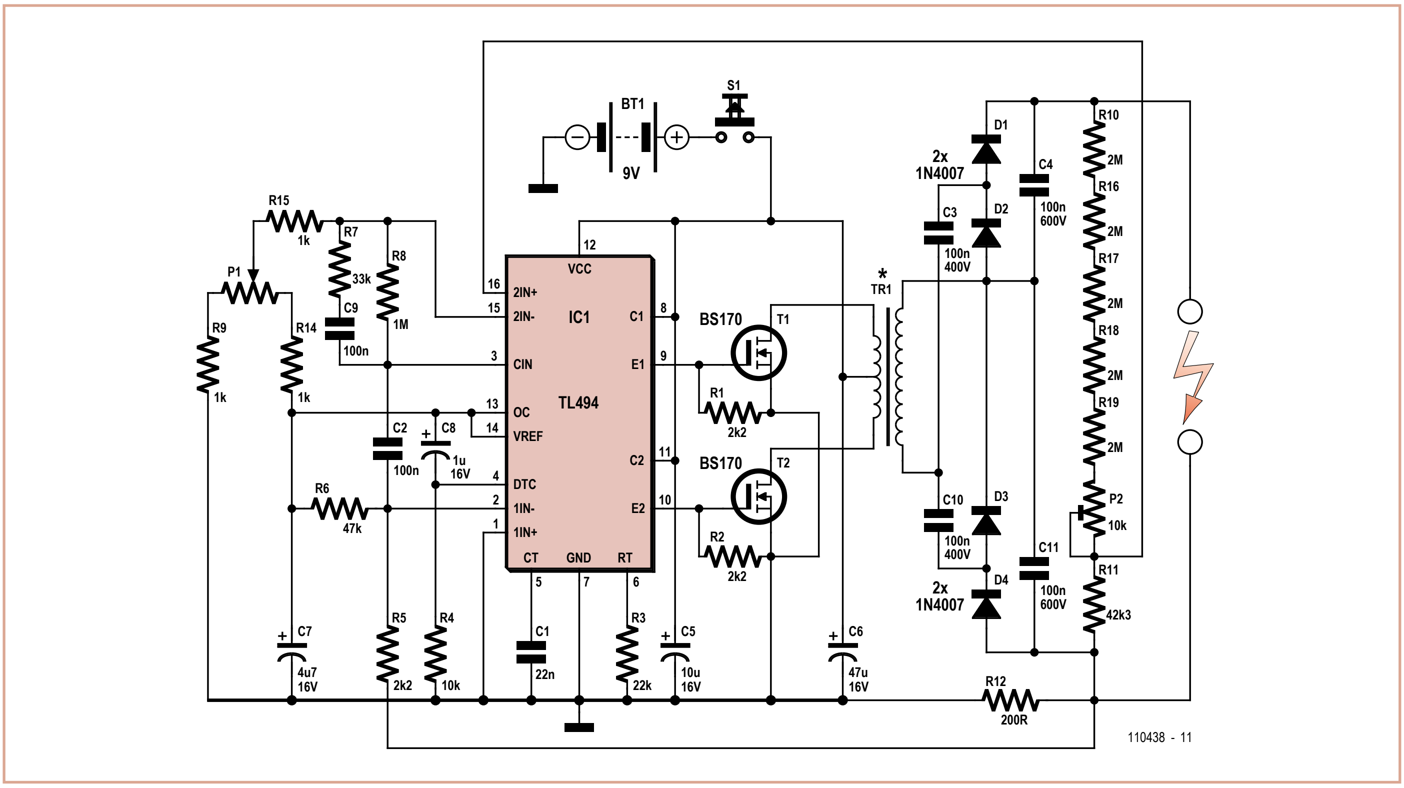
To reduce the signals to line level, each has to be connected to a potential divider: a multi-turn preset potentiometer is ideal. The author used a linear 10 kΩ trimmer to reduce the output voltage level from up to about 12 V_{pp} to around 2 V to 3 V. This latter level is suitable for the input to a power amplifier. An appropriate trimmer setting can be found by ear, adjusting the volume of the rear speakers for the desired balance.



There is no need for a printed circuit board for this project. The 1 W resistors can be soldered directly to the connections of the multi-turn presets, and so the whole thing can be assembled ‘in the air’ and shrouded in heat-shrink tubing. The circuit can then be tucked away in the space behind the radio itself.

(110304)

High Voltage Generator



By Jac Hettema (The Netherlands)

This high voltage generator was designed with the aim of testing the electrical breakdown protection used on the railways. These protection measures are used to ensure that any external metal parts will never be at a high voltage. If that were about to happen, a very large current would flow (in the order of kilo-amps), which causes the protection to operate, creating a short circuit to ground effectively earthing the metal parts. This happens when, for example, a lightning strike hits the overhead line (or their supports) on the railways.

This generator generates a high voltage of 1,000 V, but with an output current that is limited to few milliamps. This permits the electrical breakdown protection to be tested without it going into a short circuit state.

The circuit uses common parts throughout: a TL494 pulse-width modulator, several FETs or bipolar switching transistors, a simple 1.4 VA mains transformer and a discrete voltage multiplier. P1 is used to set the maximum current and P2 sets the output voltage.

The use of a voltage multiplier has the advantage that the working voltage of the smoothing capacitors can be lower, which makes

them easier to obtain. The TL494 was chosen because it can still operate at a voltage of about 7 V, which means it can keep on working even when the batteries are nearly empty. The power is provided by six C-type batteries, which keeps the total weight at a reasonable level.
The 2x4 V secondary of AC power transformer (Tr1) is used back to front. It does mean that the 4 V winding has double the rated voltage across it, but that is acceptable because the frequency is a lot higher (several kilo-Hertz) than the 50 Hz (60 Hz) the transformer is designed for.
The final version also includes a display of the output voltage so that the breakdown voltage can be read.

From a historical perspective there follows a bit of background information.
In the past a different system was worked out. Every high-voltage support post has a protection system, and it isn't clear when the protection had operated and went into a short-circuit state due to a large current discharge.

Since very large currents were involved, a certain Mr. Van Ark figured out a solution for this. He used a glass tube filled with a liquid containing a red pigment and a metal ball. When a large current discharge occurred the metal ball shot up due to the strong magnetic field, which caused the pigment to mix with the liquid. This could be seen for a good 24 hours after the event. After a thunder storm it was easy to see where a discharge current took place: one only had to walk past the tubes and have a good look at them.

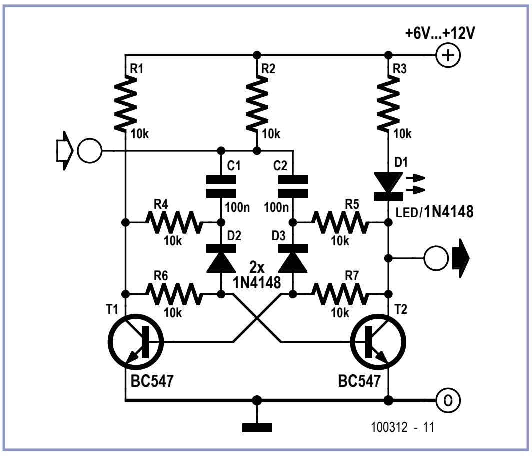
Unfortunately, things didn't work out as expected. Since it often took a very long time before a discharge occurred, the pigment settled down too much. When a discharge finally did occur the pigment no longer mixed with the liquid and nothing was visible. This system was therefore sidelined, but it found its place in the (railway) history books as the 'balls of Van Ark'.

(110438)

Tachometer Pulse Divider

By Sjabbo van Timmeren (Netherlands)

The author is a motorbike racer in the Classics class of a Dutch Motorcyclists Association. He recently replaced the contact points on the engine of his motorbike (a 500-cc BSA Goldstar with a single-cylinder four-stroke motor) by an electronic ignition. The new ignition system produces a spark for every rotation of the motor, compared with a spark for every two rotations with the contact points, so there are twice as many spark pulses. As a result, the tachometer indication was no longer correct.
A new tachometer suitable for use with an electronic ignition (such as a Krober unit) is rather pricey at around $250. Accordingly, the author first looked through past Elektor July & August issues for a suitable divider circuit—after all, it should be possible to solve this problem with a bit of electronics. It didn't take long to find something suitable in the form of a monostable multivibrator. The circuit shown here required only a couple of changes to the original design, and now the original tachometer again shows the right motor speed. Final tally: problem solved for $7; $243 saved, and the priceless pleasure of setting the bike right yourself.



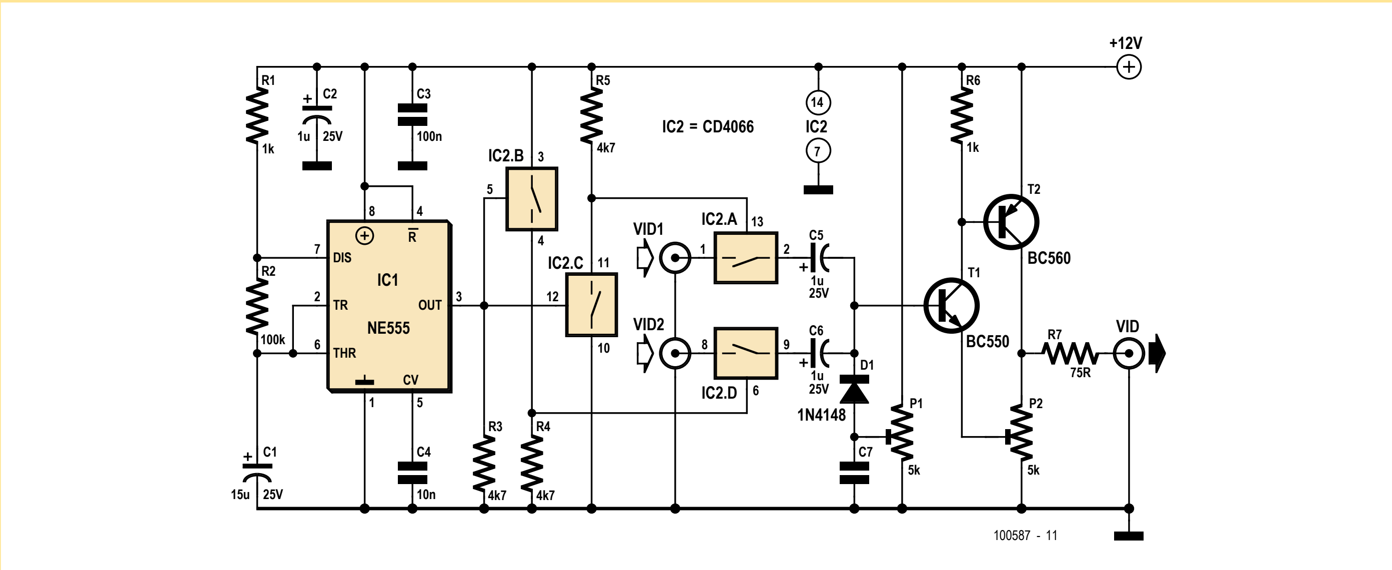
(100312)

Video Switch for Intercom System

By Jacob Gestman Geradts (France)

Nowadays a lot of intercom units are equipped with video cameras so that you can see as well as hear who is at the door. Unfortunately, the camera lens is perfectly placed to serve as a sort of support point for people during the conversation, with the result that there's hardly anything left see in the video imagery.
One way to solve this problem is to install two cameras on the street side instead only one, preferably some distance apart. If you display the imagery from the two cameras alternately, then at least half of the time you will be able to see what is happening in front of the door.
Thanks to the video switch module described here, which should be installed on the street side not too far away from the two cameras, you need only one monitor inside the house and you don't need to install any additional video cables.

Along with a video switch, the circuit includes a video amplifier that has been used with good results in many other Elektor projects, which allows the brightness and the contrast to be adjusted separately. This amplifier is included because the distance between the street and the house may be rather large, so



it is helpful to be able to compensate for cable attenuation in this manner.

The switch stage is built around the well known 4060 IC, in which switches IC2a and IC2d alternately pass one of the two signals to the output. They are driven by switches IC2b and IC2c, which generate control signals that are 180 degrees out of phase.

The switching rate for the video signals is determined by a clock signal from an 'old standby' 555 IC, which causes the signals to swap every 2 seconds with the specified component values.

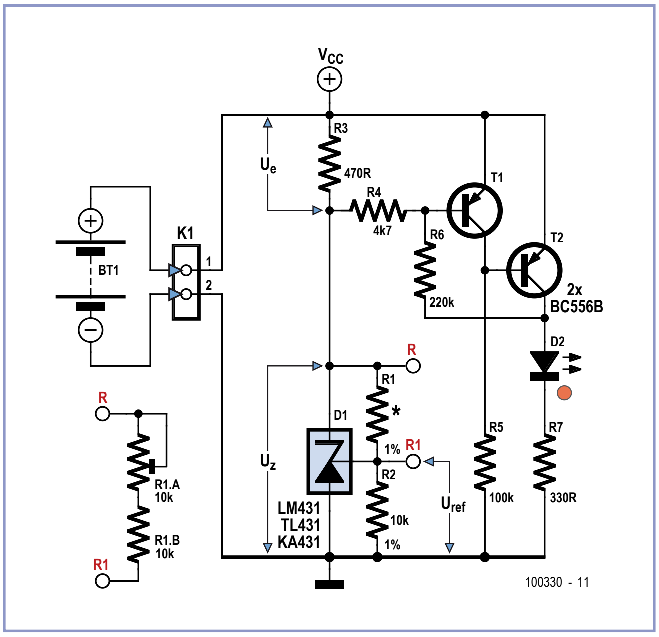
Naturally, this circuit can also used in many other situations, such as where two cameras are needed for surveillance but only one video cable is available.

(100587)

Flat Battery Indicator

By Wolfgang Fritz (Germany)

This small circuit was developed to monitor the battery in a model hovercraft. The lift in the model is produced by an electric motor driving a fan. To avoid the possibility of discharging the rechargeable battery pack too deeply, the design lights a conspicuous LED mounted on the model when a preset threshold voltage is reached. The circuit only uses a few components, which helps keep the total weight of the model down.



The circuit connects to the model only across the two points where the voltage to be monitored can be measured. These also supply power to the circuit. The best place to connect the circuit is not at the battery terminals, but rather at the motor connections.

The circuit is suitable for use with nominal battery voltages of 4.8 V to 9.6 V (four to eight 1.2 V cells). For example, if there are six cells in the battery, its nominal terminal voltage will be 7.2 V. A discharge threshold voltage of around 1 V per cell is appropriate, which means that for six cells the threshold is 6 V. We now need to set the voltage U_Z across the adjustable Zener diode D1 (an LM431) to about 0.5 V less than the threshold voltage at which we want LED D2 to light.

This voltage is controlled by the choice of the value of resistor R1. As indicated in the circuit diagram, this is done with the help of a trimmer potentiometer (R1.A) with a fixed resistor (R1.B) in series. Using the suggested values (10 kΩ for both the potentiometer and the fixed resistor) allows the discharge threshold voltage to be set between about 5.5 V and 8 V. For lower or higher voltages R1.B should be made correspondingly smaller or larger.

Once the desired value of U_Z has been set the total resistance (R1.A plus R1.B) can be measured and a single fixed-value resistor of this value substituted at R1.

In the example mentioned of a six-cell battery, a voltage of 7.2 V will appear at the emitter of T1 when the battery is charged. At its base is U_Z, which should be 5.5 V (6 V – 0.5 V) in the case of a discharge threshold voltage of 6 V. As long as the battery voltage remains at least 0.5 V higher than U_Z, T1 will conduct and T2 will block, with the result that LED D2 will not light. If the battery voltage should fall below about 6 V (U_Z + 0.5 V), T1 will block, T2 will conduct and LED D2 will light.

To ensure stable operation of the circuit R6 provides a small amount of switching hysteresis. By adjusting the resistor value between 100 kΩ and 220 kΩ the amount of hysteresis can be varied.

The current drawn by the circuit itself is less than 5 mA (as measured with a battery voltage of 7.2 V). When the LED lights an additional 10 mA (the LED current) is drawn, for a total of around 15 mA.

The adjustable Zener diode can be replaced by a fixed Zener with a voltage 0.5 V less than the desired threshold. Resistors R1 and R2 can then be dispensed with. A flashing LED can be used for D2 (without series resistor R7). An acoustic alarm can be provided by replacing D2 and R7 by a DC buzzer with a suitable operating voltage.

(100330)

Current Source for Grounded Load

By Stephen Bernhoeft (UK)

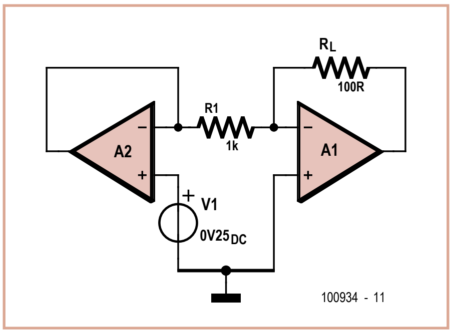
Creating a current source (as opposed to current sink) for driving a grounded load can be a bit awkward. Admittedly the suggested circuit cheats a little in that the load is tied to virtual ground; still it is potentially useful.

Two control loops are involved here:

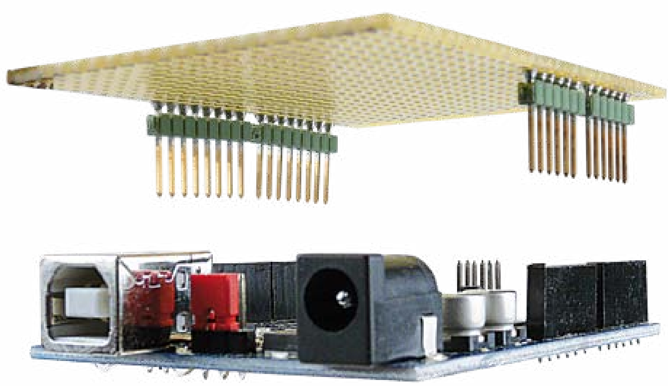
Opamp A1 maintains the 'cold' end of the load at virtual earth and

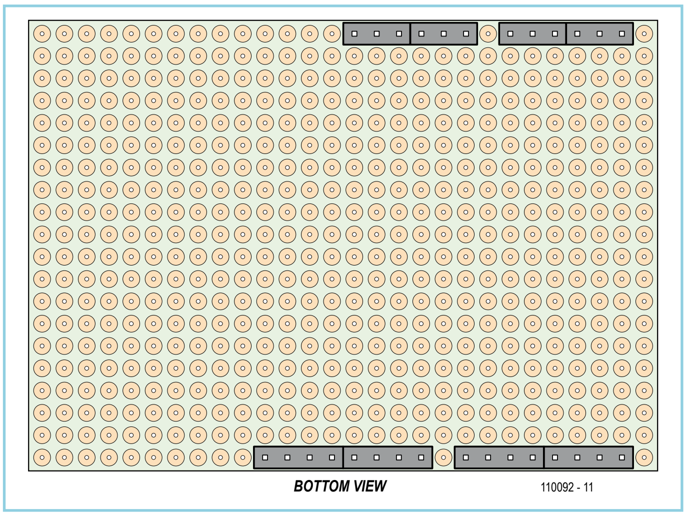
A2 sets a current $I = -V1/R1$, which also flows through the load R_L.

(100934)



Arduino Shields





By Michael Gaus (Germany)

The Arduino microcontroller platform is rather popular. One significant reason for this is the wide availability of a range of daughter boards (which are called 'shields' in Arduino terminology) containing additional items of hardware, which can quickly and easily be plugged into and unplugged from the mother board.

It is easy enough to make a shield board yourself. The relevant header sockets are always found in the same place across the Arduino 'Uno', 'Duemilanove' and 'Diecimila' board versions and all have the same pinouts, which means that a DIY shield can be used in conjunction with any of these three boards.
For hardware all we need is a standard piece of perforated prototyping board and headers with a 0.1 inch (2.54 mm) pitch. The correct position for the headers can be obtained from the drawing (which is viewed from the underside of the board).
The easiest way to start is first to plug the headers directly into the sockets on the Arduino motherboard. Then fit the prototyping board over the headers. Leave a small gap between the underside of the prototyping board and the plastic carrier of the header in each case to allow for soldering there later. Unfortunately the distance between the sockets on the Arduino boards is not an integer multiple of 0.1 inch, and so it is necessary to bend the headers slightly to make them fit.
Turn the Arduino printed circuit board over and then attach the headers to the prototyping board with solder joints on its underside.

The photograph shows an example Arduino shield constructed in this way. The components of the expansion circuit can be mounted on the top side of the prototyping board and soldered on its underside. Ordinary wire can be used to connect between the components and the header pins.

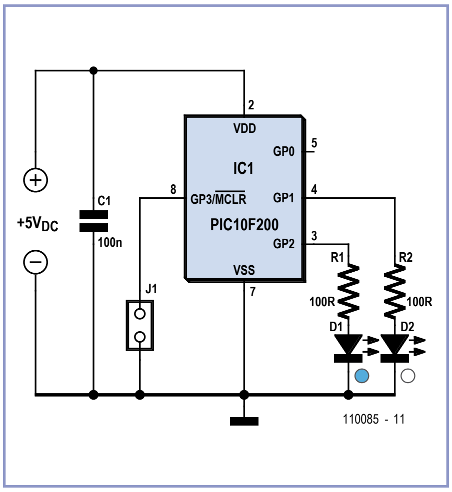
(110092)

Arc Welding Effect

for Model Railway Layouts

By Erhard Stark (Germany)

Now and again modelers looking to add something special and individual to their layout will want a miniature arc welding simulator. This project demonstrates that you need barely anything more than a microcontroller and the right software.
The circuit shown here uses a PIC10F200 microcontroller to illuminate LEDs D1 and D2 with differing frequencies and time lags. To ensure the effect produces the characteristic flashes of arc welding the two LEDs should be fixed as close together as possible. The insertion and removal of the welding electrode is represented by short breaks in the flickering. To cut off the welding light the circuit we must either remove the supply voltage or else ground pin 8 (GP3). J1 provides an elegant approach to the latter solution. The welding effect is active with the jumper removed.
The software for the microcontroller can be downloaded free from the web at [1]. The configuration of the PIC is included in the ASM file but can also be carried out by setting all configuration bits to zero manually.



(110085)

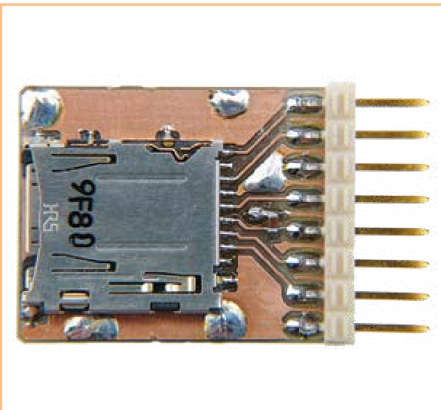
[1] www.elektor.com/110085

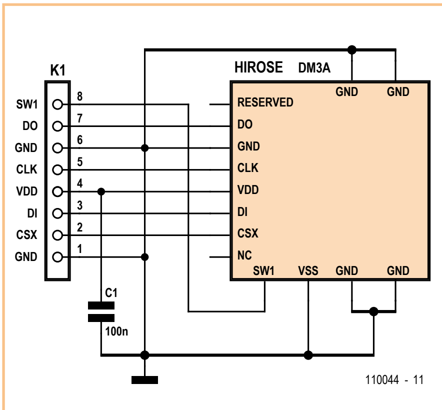
MicroSD Card Connectors

By Albert Bitzer (Germany)

A large number of microcontroller circuits make use of SD memory cards. At the same time the Internet contains many program libraries and countless sample applications.

In many projects — with scale models for instance — an SD card is simply not compact enough.
One solution is the significantly smaller MicroSD card [1]. The firm Hirose [2] has a corresponding card socket in its portfolio, which can be bought from Farnell [3] or Digikey [4].





Type DM3 is available in three versions: as push-push type DM3A, as the hinged variant DM3C and as the push-pull connector DM3D. These connectors can be soldered simply with a normal soldering iron.

To make things easier for miniature-minded enthusiasts the author has compiled a small Eagle library covering all three types. This can be downloaded as a zip-archive from the Elektor website [5].

Also covered there is an experimenter/adapter board on which the connections of the card connector DM3A are taken out to connector strips in order to simplify connection to a microcontroller (possibly mounted on perfboard or breadboard (Veroboard or Vector Board).

(110044)

[1] www.sdcard.org/developers/tech/sdcard#microsd

[2] www.hiroseeurope.com/

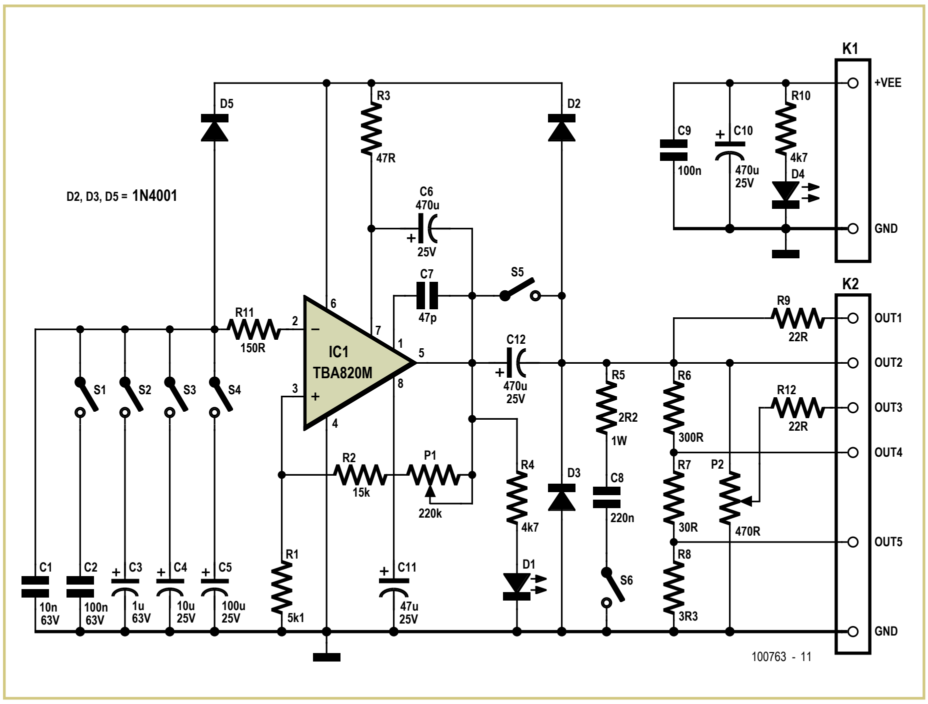
[3] www.farnell.com

[4] http://dkc1.digikey.com/se/en/tod/Hirose/DM3/DM3.html

[5] www.elektor.com/110044

Simple Low Cost Square Wave Generator & Tester

By Petre Tzvetanov Petrov (Bulgaria)



This square wave generator and tester is based on audio amplifier chip type TBA820M. It is presented as a design idea for further refinement and optimizing of component values by way of experiment.

The circuit has five frequency ranges covering <0.1 Hz to >70 kHz. It will be found useful for testing cables, communication equipment, electrical interfaces, loudspeakers, headphones, electrical bulbs, transformers, LEDs, couplers, inductors, buzzers, ultrasonic equipment, etc. or wherever you need a signal in the range from below 0.1 Hz to 25 kHz and up with controlled frequency, amplitude and drive capacity. For example, driving heavy capacitive or inductive loads is no problem, nor supplying up to one watt of output power.

The generator's frequency ranges are selected with switches S1–S4. To be able to use a DIP switch with four positions the smallest capacitor, C1, is always connected but there's no objection against adding a fifth switch. With C1 at around 10 nF and a total resistance of 15 kΩ between pins 5 and 3 of the TBA820M IC the maximum output frequency is of the order of 70–100 kHz. However with reproducibility in mind it is recommended to limit the frequency to below 50 kHz.

D5 and R11 provide a discharge path and a protection resistor for the larger capacitors. Switch S5 allows the DC component from the TBA820M to be blocked or passed to the generator outputs. S6 should be closed when driving heavy reactive loads to eliminate undesired high frequency oscillations. Potentiometer P1 controls the frequency of the output signal.

OUT1 is the main output protected with stopper resistor R9. It is used to test unknown circuits where large capacitance or inductances could be present, or circuits presenting a few volts themselves. R9 may be dimensioned to suit the application and can take a value between 22 to 100 ohms at a dissipation of 0.5 to 2 watts.

OUT2 is the direct output from the integrated circuit. It's used to test loudspeakers, transformers, lines sure to have no voltage on them, etc. The output power depends on the supply voltage and is around 2 W into 8 Ω at V_{EE} = 12 V. The load does affect the OUT2 signal frequency and amplitude to a small extent but that's not an issue in most applications.

OUT3 is a level controlled output using potentiometer P2. This output is protected by R12 taking a value from 22 to 220 Ω depending on the application. The output is used to test headphones, audio lines, small loudspeakers, transformers, amplifiers, buzzers, LEDs, etc.

OUT4 and OUT5 are used mainly to test amplifiers, lines and headphones but will find many other applications. The amplitude on OUT4 is one tenth of OUT2 and the amplitude on OUT5 is 1/100th.

All outputs are protected against short circuit to the ground. Diodes D2 and D3 afford some under voltage and over voltage protection on every output.

The slew rate of the output signal of the generator with no additional load is more than 20 V/µs and depends slightly on the brand of TBA802M used and the method of wiring it (PCB or free wired).

R2 and P1 together present a resistance range of 15 kΩ to about 250 kΩ. Although the generator will work with a 1 MΩ pot there is a little benefit to be gained due to the higher parasitic capacitance, inductance and noise. On the other hand, an additional linear potentiometer with a value equivalent to 5–10% of that of P1 could be included in series with P1 to achieve better accuracy of the frequency adjustment.

The generator's supply voltage range is relatively wide at 4–16 VDC (V_{EE} connection). The unit is particularly suitable for operation from a 12 volts car battery with a typical voltage of around 13.2 V.

(100763)

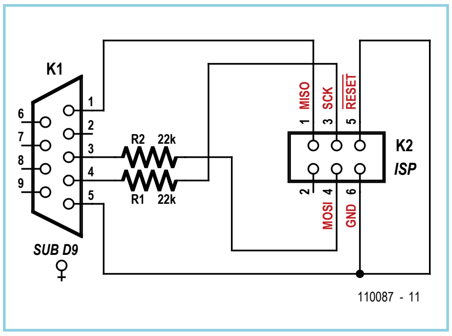
'SCAP' AVR Programmer

By Michael Gaus (Germany)

Many newcomers to AVR programming would love to build their own low-cost programming device, but they face a chicken-and-egg problem: many of the designs themselves use an AVR microcontroller; this needs to be programmed, and so they first need to make a programmer...

This is where the SCAP (Serial Cheap AVR Programmer) can come in handy. It is a very simple programming device using a minimum of components, and it can be connected either directly to a PC's RS-232 interface or to a USB interface via a USB-to-RS232 converter.

The circuit includes a nine-way D-sub socket (K1) which can be connected to the PC's serial port or to the USB-to-RS232 converter. The circuit takes advantage of the internal protection diodes on the AVR's I/O pins to V_{CC} and GND, and the two series resistors R1 and R2 are thus needed to limit the current flowing through these diodes. The values are chosen to keep this current below 1 mA. The RS-232 interface can be as high as ±15 V. At –15 V the AVR's internal protection diode to GND limits the voltage on the I/O pin to a minimum value of –0.7 V, while at +15 V the protection diode to V_{CC} limits the pin voltage to a maximum value of V_{CC}+0.7 V. Now, because the values of the series resistors R1 and R2 are relatively high, the charging and discharging of the AVR's input capacitance is considerably slower than if it had been driven directly by a push-pull stage, and this limits the maximum permissible frequency on SCK for reliable operation. The wiring of K2 corresponds to the standard six-way Atmel ISP connector.



The well-known open source program AVRDUDE is an essentially universal programming tool that can very easily be configured to work with SCAP: see [1] and [2]. The configuration file avrdude.conf needs to have the following section added to it:

```
# ------------------------------------------------------------------------------
# Serial Cheap AVR Programmer (SCAP)
# reset=rts sck=dtr mosi=txd miso=dcd

programmer
  id     = "scap";
  desc   = "Serial Cheap AVR Programmer, reset=rts sck=dtr mosi=txd miso=dcd";
  type   = serbb;
  reset  = 7;
  sck    = 4;
  mosi   = 3;
  miso   = 1;
;
# ------------------------------------------------------------------------------
```

This adds a new programmer called 'scap', which can then be selected as the device to be used for programming using the command-line option '-c scap'.

Even though the reset pin of the microcontroller is tied permanently to GND in the circuit, it must still be defined for AVRDUDE. If AVRDUDE fails to establish a connection with the AVR device to be programmed, the power to the device must be interrupted briefly to cause it to perform a power-on reset.

Here is a sample command to invoke AVRDUDE. We have assumed that SCAP is connected to COM1 with an ATmega8 as the target device (this corresponds to the command-line option '-p m8') and that the hex file to be programmed is test.hex.

```
avrdude -P com1 -p m8 -c scap -i
   300 -U flash:w:test.hex:i
```

The instruction to slow down SCK is specified by the command-line option '-i 300', which gives a delay of 300 µs. This makes the programming operation rather slow. Depending on the type of interface used (normal RS-232 or a USB-to-RS-232 converter) it may be possible to reduce the delay value to as little as 50, which will make programming faster. If SCAP is being used just to solve the chicken-and-egg problem mentioned at the start of this article, then programming speed will not be of any great concern.

(110087)

Internet Links

[1] AVRDUDE: www.nongnu.org/avrdude/

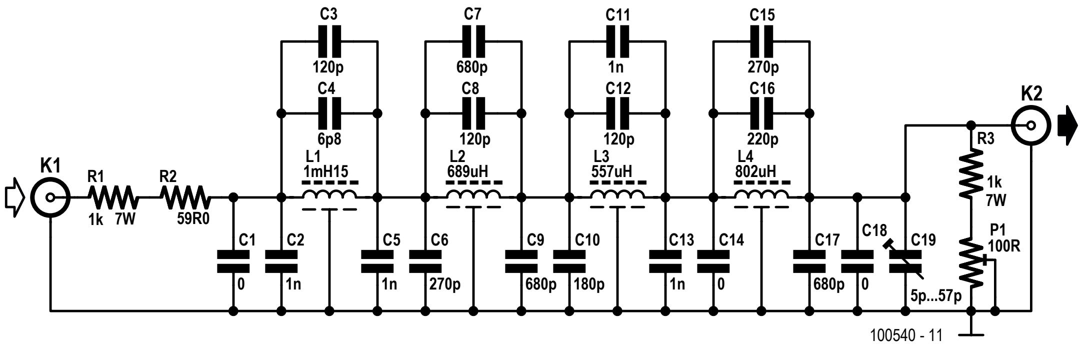
[2] AVRDUDE version for Windows: www.mikrocontroller.net/attachment/69851/avrdude-5.10.zip

Measurement Filter for Class D

Ton Giesberts (Elektor Labs)

This filter is an improved version of a filter published six years ago in Elektor (Passive 9th Order Elliptical Filter, July/August 2005, [1]). At the time, this filter was designed for carry out measurements on a Class T power amplifier (Elektor *ClariTy*, June 2004, [2]). The accuracy of our measuring equipment was found to get worse when the frequency components above 200 kHz became too strong, hence the need to remove these with a very steep filter.

The aim of the present design is to create a filter that has less distortion at 20 kHz and which can cope with higher voltages, so that it also becomes suitable for more powerful Class D power amplifiers. The theoretical values have remained the same as those in the original circuit, and the circuit itself has hardly changed. The biggest improvement is in the way the inductors are made. These are now substantially larger and have an air-gap, which reduces the distortion.

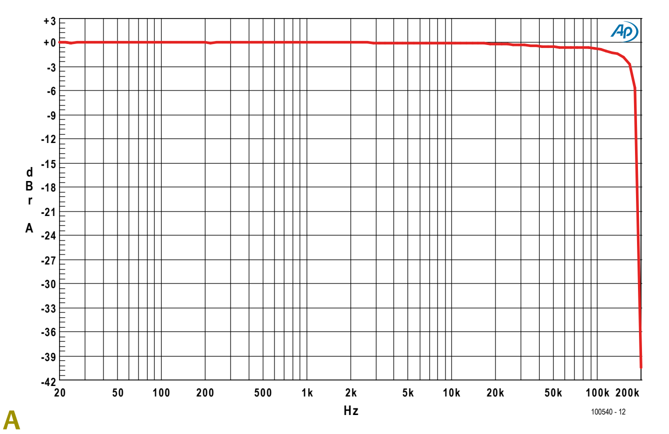


The number of turns for each coil was derived using the stated value of the inductivity factor of the core material (A_L). If you have an accurate inductance meter, you could measure the coil before soldering it onto the PCB. It won't always be possible to obtain the exact values for the coils because the smallest change in the winding is half a turn. Measure the wound coil and calculate the real A_L value using the formula:

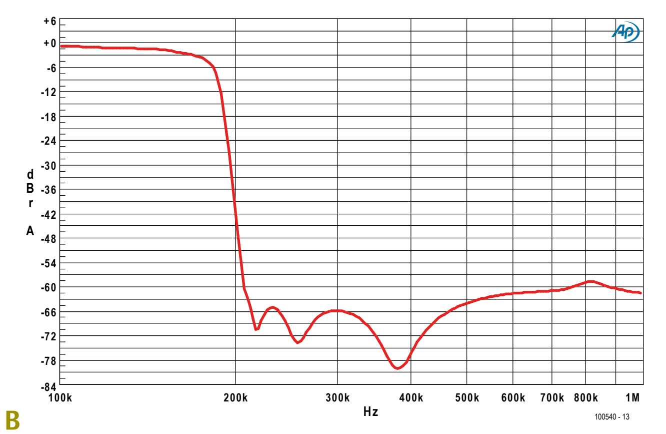
$$A_L = L/N^2$$

where L is the measured inductance and N is the number of windings. You can then recalculate the number of turns using the new A_L value, which should give you a more accurate number. Should fewer turns be required, you can simply remove them from the coil. Should you need more, you can add a new winding to a connection and connect the end to a third pin. Look carefully at the PCB layout (can be downloaded freely from [3]) to find out between which pins the coils have to be connected.

On either side of the coil former is a row of six



A



B

connection pins. Three pins on one side are always connected to three pins on the other side. The most practical approach is to connect the ends of the coil to the two pins at the front, pin 1 and pin 12. When the inductance value has to be corrected and some turns have to be added, the extra winding can be connected to the first and second (or eleventh and twelfth) pins. The first (twelfth) pin, to which the coil was originally connected should then be cut back to the former, so that it can no longer make any contact with the PCB.

With the coils that we made for our prototype we had to adjust three of the four in this way. The measured values for L1 through L4 in our case were: 1.16 mH, 689 µH, 555 µH and 816 µH.

The frequency response of the passband can be seen in **Figure A**. The amplitude at 20 kHz is attenuated by only 0.17 dB (compared with 1 kHz) and 39 dB at 204 kHz. When we compare the response with frequency response B from the July/August 2005 article, you can see that there is less ripple up to 180 kHz. The reason for this can be found in the lower *Q* factor of the coils now used, which makes the graph deviate slightly from the theoretical ripple that is common to elliptical filters.
The frequency response of the passband and the stopband can be seen in **Figure B**. The frequencies in the stopband are, apart from a little bump around 800 kHz, attenuated by more than 60 dB. The bump is caused by the various component tolerances, including those of the 1% capacitors.
We tested the filter with the maximum output voltage of our analyzer, which is 13 V.

COMPONENT LIST

Resistors

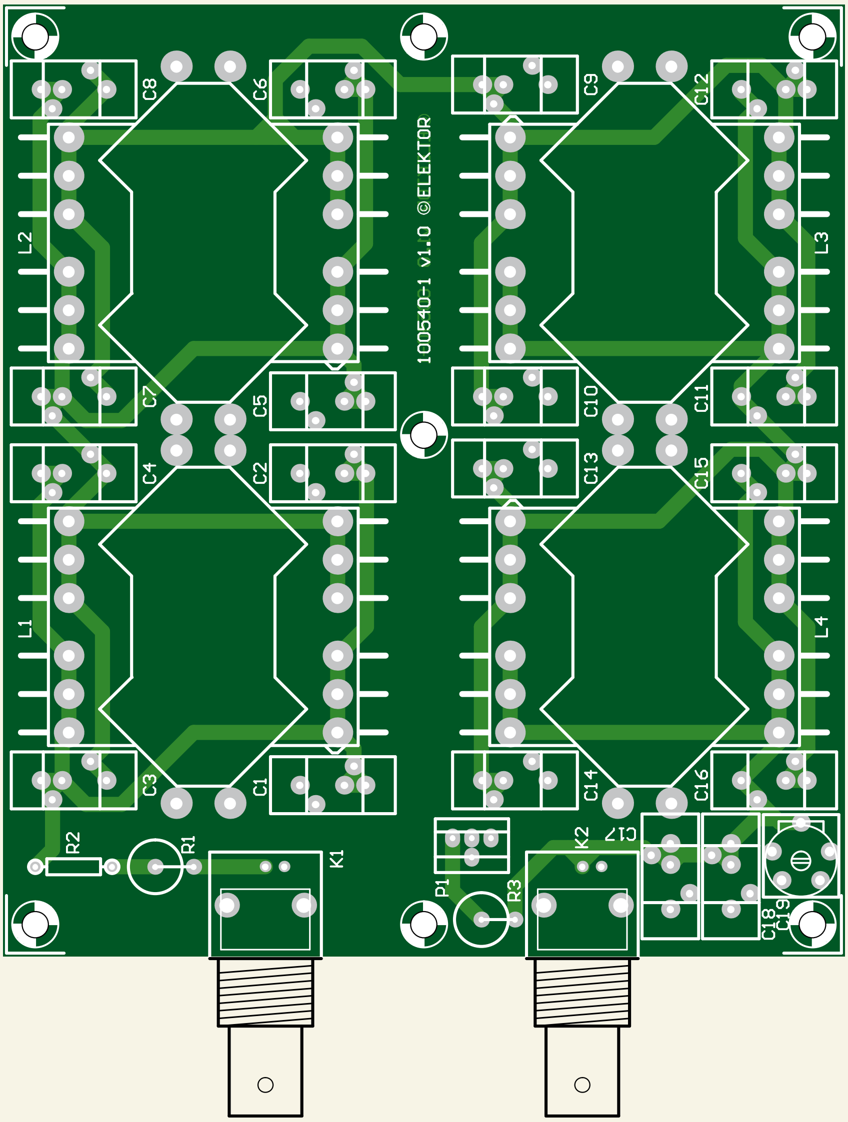
R1,R3 = 1kΩ, 5%, 7 W (Tyco Electronics ER581K0JT)
R2 = 59Ω, 1%, 0.6W*
P1 = 100Ω, 10%, 0.5W, 24 turn trimpot (Vishay Spectrol M64W101KB40)

Capacitors

C1,C14,C18 = not used
C2,C5,C11,C13 = 1nF, 1%, 500V, silver mica (Cornell Dubilier CD19FD102FO3F)
C3,C8,C12 = 120pF, 1%, 500V, silver mica (Cornell Dubilier CD15FD121FO3F)
C4 = 6.8pF, 1%, 500V, silver mica (Cornell Dubilier CD15CD(6.8)DO3F)
C6,C15 = 270pF, 1%, 500V, silver mica (Cornell Dubilier CD15FD271FO3F)
C7,C9,C17 = 680pF, 1%, 500V, silver mica (Cornell Dubilier CD19FD681FO3F)
C10 = 180pF, 1%, 500V, silver mica (Cornell Dubilier CD15FD181FO3F)
C16 = 220pF, 1%, 500V, silver mica (Cornell Dubilier CD15FD221FO3F)
C19 = 5-57pF PTFE trimmer, 250V, (Vishay BCcomponents BFC2 809 08003)

Inductors (incl. materials)

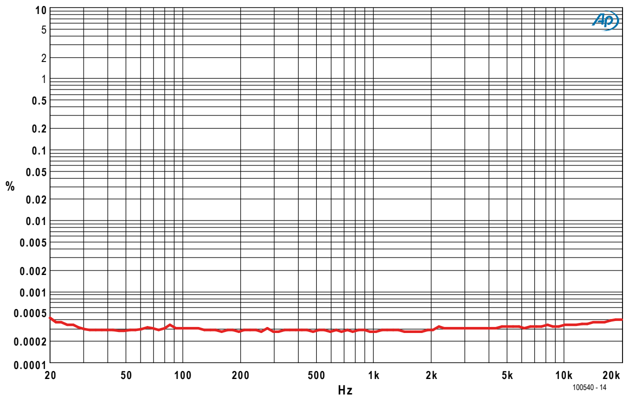
L1 = 1.15mH, 85 turns 0.8 mm enamelled copper wire*
L2 = 689µH, 65.5 turns 0.8 mm enamelled copper wire*
L3 = 557µH, 59 turns 0.8 mm enamelled copper wire*
L4 = 802µH, 71 turns 0.8 mm enamelled copper wire*
L1-L4 core = RM14 core set, 160nH (A_L) N41 (Epcos B65887E160A41), e.g. RS Components #212-6772
RM14 12-pin coil former (Epcos B65888C1512T1), e.g. RS #212-6839
RM 14 clamp, stainless steel spring (Epcos B65888A2002X, 2 per coil), e.g. RS Components #647-9323
RM 14 isolation washer. base (Epcos B65888B2005X), e.g. RS Components #180-121
0.8 mm enamelled copper wire (Pro Power ECW0.80). Nearest US equivalent: AWG20



Miscellaneous

K1,K2 = BNC socket, PSB mount, angled, 75Ω (Tyco Electronics 1-1478032-0)
Locking washer, BNC/TNC (Tyco Electronics 1-1634817-0)
Nut, BNC/TNC (Tyco Electronics 1-1634816-0)
* see text

The distortion caused by the filter at this voltage can be seen in **Figure C**. The graph is just about the same as the bottom measurement limit of our analyzer. At some point in the future we'd like to develop a separate amplifier that is able to output 70 V_{rms} at 20 kHz with an extremely low distortion figure. We'll then be back with a graph that shows the input voltage against distortion. The distortion at 1 kHz and a bandwidth of 22 kHz is less than 0.00018%. With a bandwidth of 80 kHz the distortion plus noise (THD+N) increases slightly to about 0.00028%. The distortion at 20 kHz and a bandwidth of 80 kHz is about 0.0004%.



C

Since the filter was designed to cope with higher voltages we had to use power resistors. With a voltage of 70 V_{rms} across 1 kΩ the power is about 5 watts; the recommended resistors in the parts list are rated at 7 watts. The input resistor is a combination of a power resistor and a smaller resistor. We suggest that you measure the value of R1 and then calculate the value for R2. The sum of their values should be 1060 Ω. In our prototype we had to replace R2 with a resistor of 73.2 Ω, to compensate for the tolerance of R1.

At the output of the circuit, multiturn trimpot P1 can be used to set an attenuation of 2 at 1 kHz. Capacitor C19 can be used to compensate for the parasitic capacitance of the cable and the input of the analyzer, although this has more of a theoretical benefit than a practical one.

When you build this filter you have to make sure that you buy the correct set of cores (see the part numbers in the parts list). There are other cores with different sizes of the air gap and there some without an air gap at all. We have chosen the biggest air gap (smallest A_L value). This means that more turns have to be wound, with the result that the coil can be wound closer to the required theoretical inductance. Another advantage of the air gap is that the tolerance in the inductivity factor (A_L) is only ±3%. Without the air gap it's stated as +30/–20% !

(100540)

Internet Links

[1] www.elektor.com/044042

[2] www.elektor.com/030217

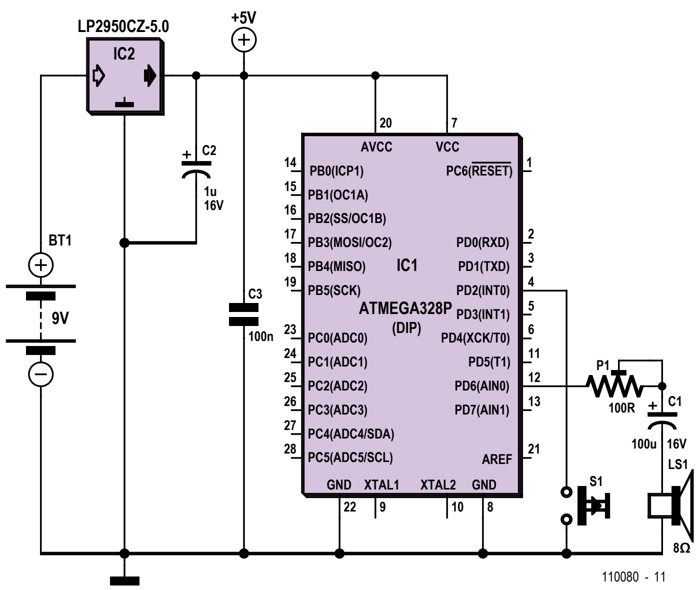
[3] www.elektor.com/100540

WAV Doorbell

by Michael Gaus (Germany)

This electronic doorbell is essentially a small WAV file player based around an ATmega328P. When a guest presses the bellpush the device is activated and plays out a short WAV file using its built-in PWM module. This means that you can customise the sound of your doorbell in just the same way as you can the ringtone on your mobile phone. What's more, you can load any sound you like into the device. The WAV file is stored in the on-chip flash memory in the microcontroller: no external storage is necessary.

To keep the number of components to a minimum, we have dispensed with the sort of low-pass filter that would normally be required on the PWM output of the AVR microcontroller. Instead we simply connect to a small loudspeaker via just an electrolytic and a series resistor. Note that it would not be appropriate to connect the PWM signal directly to an amplifier or to powered speakers without a proper low-pass filter, as distortion can result.



When power is applied the unit immediately plays the stored doorbell sound, and the AVR microcontroller then enters a low-power standby mode. Pressing the bell push button causes the microcontroller to leave standby mode and play the WAV file again.

The WAV file must have the following characteristics: 'RIFF WAVE' format, 8 bits per sample, mono, and a sample rate of 8 kHz. The ATmega328P has a total of 32 Kbytes of flash memory, of which 1 Kbyte is reserved for the firmware. This leaves 31744 bytes for the WAV file, enough for an audio file with a length of nearly four seconds. The firmware occupies the address range from 0x0000 to 0x03FF, and the WAV data start at 0x0400.

If the audio file is not available in the PCM WAV format described above, the freeware tool Audacity [1] can be used to convert it. Open the original file in Audacity and set the 'project rate' to 8000 Hz in the bottom left-hand corner of the window. It is also possible to select parts of the waveform (such as periods of silence at the start or end) and delete them. To convert from stereo format to mono, click on the small arrow in the box containing the file name and select 'Split stereo track'. Then the right channel can for example be deleted with a click on the 'X' and the left channel can be converted to mono by clicking on the small 'Mono' arrow. Under 'Edit > Preferences' the export file format must be set to 'WAV (Microsoft 8-bit PCM)', which is uncompressed. To save the file, select the desired region and click on 'Export as WAV' in the 'File' menu. This should result in a suitable file. To confirm this, right-click on the file in Windows Explorer and check the format in the file information under 'Properties'.

The tool 'hex2bin' [2] is used to convert the WAV file into a hex file suitable for programming into the ATmega328P. The tool takes the binary WAV-format file, changes it to Intel hex format, and inserts the result into the hex file that contains the AVR code. The output of the tool is thus a single hex file that contains both the firmware and the WAV file information that need to be programmed into the ATmega328P. The whole conversion process can be set in train using the 'convert.bat' batch file.

The firmware determines the length of the WAV file from its header information and uses this to play out the contents of the file for the correct duration.

A ready-made hex file, called 'tuergong.hex', comprising both the firmware and a WAV file making a 'ding-dong' sound is available free in the ZIP archive accompanying this project. This hex file can be programmed directly into the ATmega328P. The hex file 'code.hex' in the directory 'firmware/default' contains just the firmware, with no built-in WAV file. This is the place to start if you want to incorporate your own WAV file, combining it with this hex file using the batch script mentioned above.

The code for the ATmega328P was developed in AVR Studio using the free WinAVR C compiler. The complete project, including the hex file, can be found in the 'firmware' directory in the ZIP archive, which in turn can be downloaded at [3]. The fuse bits in the AVR must be programmed as follows: low fuse byte: 0xE2; high fuse byte: 0xD9; extended fuse byte: 0xFF.

(110080)

Internet Links

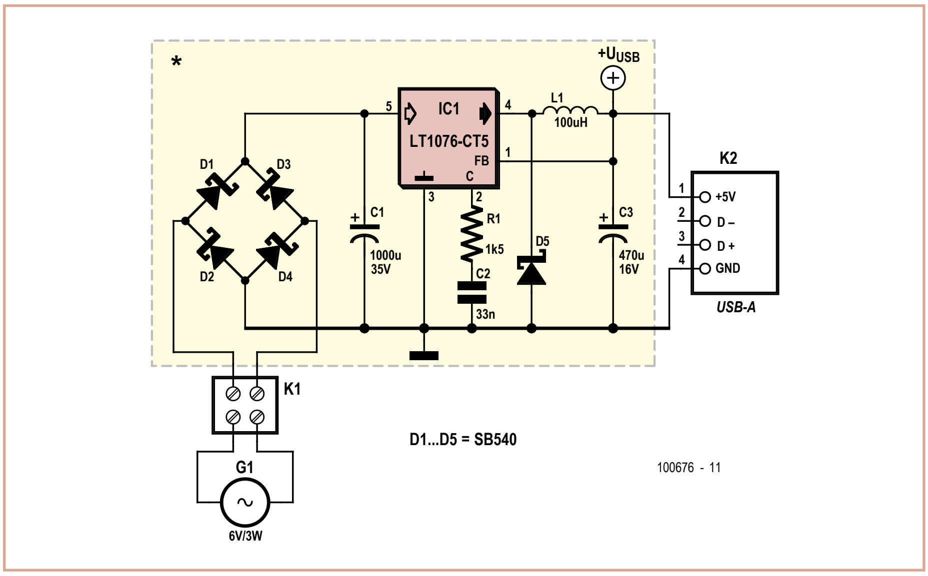
[1] http://audacity.sourceforge.net/

[2] http://hex2bin.sourceforge.net/

[3] www.elektor.com/110080

USB Charger using Pedal Power

By Werner Wille (Germany)



Keen cyclists will no doubt have sometimes thought that it would be nice to have some kind of on-board power supply to charge a mobile device such as a phone or a satnav while on the road. The circuit described here shows to how this can be achieved quite simply, using power from the bicycle's dynamo and a switching regulator.

The alternating voltage delivered by the bicycle's dynamo is converted to DC using a full-wave rectifier (comprising diodes D1 to D4) and a smoothing electrolytic (C1). We have chosen Schottky diodes for the bridge rectifier as their forward voltage drop is only about half that of normal silicon diodes (approximately 0.3 V rather than 0.75 V per diode at 1 A). This is all the more important because the LT1076-CT5 switching regulator requires an input voltage of at least about 8 V to provide a regulated 5 V output suitable for powering or charging mobile devices using their USB connector. Smoothing capacitor C1 is charged up to the peak value of the alternating voltage delivered by the dynamo; for most hub dynamos the typical peak output voltage is in excess of 10 V. Under load the typical voltage is of course lower, but still enough for the LT1076-CT5 as long as Schottky diodes are used and C1 has a value of at least 1000 µF.

The LT1076-CT5 is an integrated 2 A step-down converter whose output voltage is automatically fixed at 5 V if the feedback connection FB (pin 1 on the IC) is connected directly to the output voltage at electrolytic C3. As with all switching regulator designs, C3 should have a low ESR (equivalent series resistance): the Panasonic FC series of capacitors is suitable. The circuit arrangement generally reflects the recommendations in the Linear Technology datasheet [1]. The 100 µH inductor used for L1 should be rated for a DC current of at least 1 A (DC resistance less than 0.3 Ω).

The circuit can easily be constructed on perforated prototyping board. The USB output cable can be fashioned by cutting a USB extension cable in two and soldering the bare ends of the part with the USB socket to the output terminals on the board. It is of course important to observe correct polarity! To protect the circuit against the elements it is a good idea to pot the whole thing in resin once the USB cable has been soldered and secured using a strain relief.

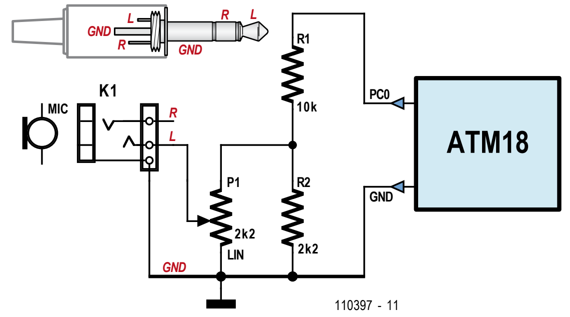
(100676)

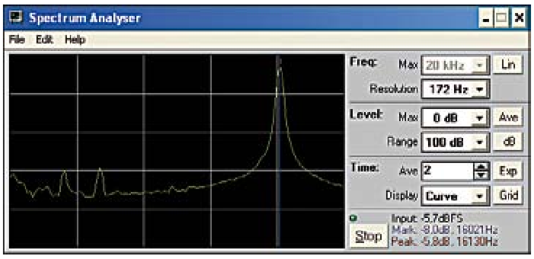
Internet Link

[1] www.linear.com/product/LT1076-5

ATM18 Youth Repellent

By Grégory Ester (France)





From what's written on the cover of Bert van Dam's book entitled "50 New Applications for PIC Microcontrollers" [1], some of you might think that the projects, which address programming 16/18 PICs in JAL in a well-paced and very detailed way, are not really compatible with your favorite processor and programming language.

But then again, maybe you'd like to produce all these applications without diving into a new language and without investing in a new programmer. So, why not draw inspiration from the author's ideas, while still remaining faithful to your usual s/w tools and h/w bits? It would be a shame to pass up on a good, appealing project.

The description of the youth repellent circuit described here begins with these words: "Have you ever dreamt of a non-violent way of driving away those groups of noisy indolent youngsters who are always hanging about under you peaceful windows? [...] If you are an adolescent, this project will enable you to produce a secret signal, inaudible to adults!"

The very high-pitched sound at 16 kHz that generated by this project will be unpleasant above all for adolescents and young children whose hearing is still unimpaired. The principal ingredients are an ATM18 board [2] and a sounder connected to PC0 on the ATM18 in series with a 100 Ω resistor. Sprinkle the whole thing with a little firmware written in BASCOM-AVR and we get our 'youth repellent'.

The piezoelectric sounder has a diaphragm connected to a crystal. Here one pin of the microcontroller is employed to make this diaphragm vibrate at a certain frequency and thus emit a sound that we're going to arrange to make unbearable.

Timer0 is used to produce a square wave signal at a defined frequency. The timer is incremented each time a pulse is received, and an interrupt is triggered when the register overflows. The register containing the state of the counter is write-accessible, so it is possible to set an initial preloaded value that will modify the overload frequency. Since the overflow resets the counter to zero, the interrupt routine will need to load the register each time with the starting value.

The 16 MHz quartz crystal clock frequency requires the use of a prescaler. Pre-dividing by 8, and if PC0 is inverted each time timer0 overflows, the formula

$$f = 16 \times 10^6 / 8 / preload\_value / 2$$

will enable you to directly obtain the sound frequency as a function of preload_value. In theory, a value of 62 will allow generation of a frequency of 16.1 kHz.

However, the tasks inherent to the operation of the take a certain amount of time, leading to a difference between the theory and reality. So in practice, you need to use a preload_value of 55 to arrive at a frequency of 16.1 kHz.

If you are an adult over 30, your hearing is liable to not be sensitive to the sound emitted, so how to go about testing this circuit? Well, by using a software spectrum analyzer offered free by Bert van Dam.
The circuit suggested by Bert lets you reduce the sound card's maximum microphone input voltage from 5 to around 0.9 V. Take care, a wiring error here could cause irreparable damage to your PC. After downloading and unzipping the file (available free from [1]), copy/paste the file VBRUN300.DLL from the 'Signal Generator' folder into the 'Frequency Analyser' folder. Your PC's microphone must be enabled and the volume control set to maximum.

Before powering up the whole assembly, set potentiometer P1 of the protection interface to zero. Double-click on the executable file Analyser.exe, then click on 'Run' to start the program. Turn the potentiometer until a peak appears in the signal. Click with your mouse near the peak to move the blue line. The little red line shown in the screen shot will look for the strongest signal in the vicinity of the blue line. The values are visible at the bottom right, next to the 'Stop' button.

Once this project is finished, do like Bert, wait until your children come to visit you in your study, innocently power up the circuit, and wait... You won't have to wait long for their reactions and there's no appeal against the verdict: your repellent works!

(110397)

Note: the use of this sort of device is prohibited in certain countries.

Internet Links

[1] www.elektor.com/products/books/microcontrollers/50-pic-microcontroller-projects.1350471.lynkx

[2] ww.elektor.com/071035

[3] www.elektor.com/110397

Voltage Limiter for Guitar Amplifiers

By Alfred Rosenkränzer (Germany)

Guitar amplifiers using output devices such as the TDA7293 (100 W) or LM3886 (68 W) are surprisingly often damaged as a result of excessive supply voltage in the quiescent state. The transformers are often used so close to their specification that this problem can even be caused by a high mains input voltage. In most countries the domestic AC outlet voltage is permitted to rise as high 10 % above the nominal (published) value.

Since replacing the transformer is not an attractive proposition, the author developed a relatively simple electronic solution to the overvoltage problem: a voltage limiter for the symmetric supply to the amplifier.

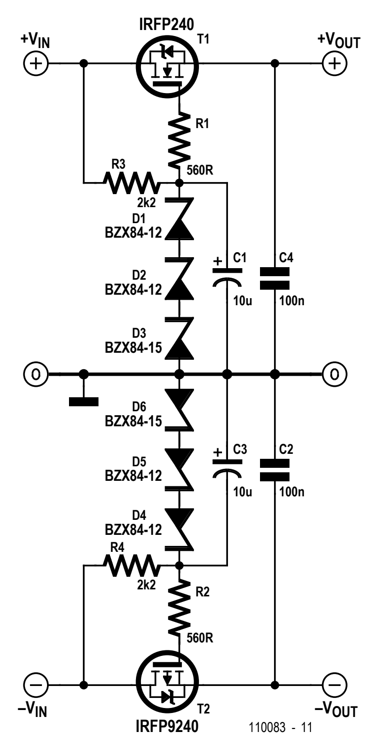
The circuit is based on the classical voltage regulator arrangement of a Zener diode connected to the base of a pass transistor. However, in this version we replace the conventional bipolar transistor with a power MOSFET. The circuit is symmetrical with respect to the negative and positive supplies, and so we shall only describe the positive half.

The input voltage (at most 50 V) supplies the chain of Zener diodes D1, D2 and D3 via resistor R3. The resistor limits the current through the Zener diodes to about 5 mA.
The series connection of Zener diodes has the advantage that their dissipation is divided among them, as well as giving more options for the total voltage drop by judicious selection of individual components. The sum of the diode voltages (39 V with the values given) must be greater than the desired limiting output voltage by the gate-source voltage of the MOSFET. C1 smooths the voltage across the Zener diode chain. The circuit therefore not only limits the voltage, but also reduces the ripple (hum component) on the supply. The gate of the HEXFET is driven via R1. In conjunction with C4, this prevents the FET from oscillating.

Without any load the output voltage is rather higher than expected. With a small load, such as that presented by the output stage in its quiescent state, it falls to the desired value. The circuit then does not provide regulation of the output voltage, but rather a stabilization function.
The operation of the negative half of the circuit is identical to that of the positive half apart from the polarity of the voltages, and hence a P-channel MOSFET must be used there.

It is worth noting that there is a relatively large degree of variation (up to a few volts) in the gate-source voltage of the HEXFETs used. This can be compensated for by selecting the Zener diodes in the chain and the current through them, but for most applications the exact voltage at which limiting begins to occur will not be critical.

The HEXFETs must be provided with adequate cooling. If possible, they can be attached to

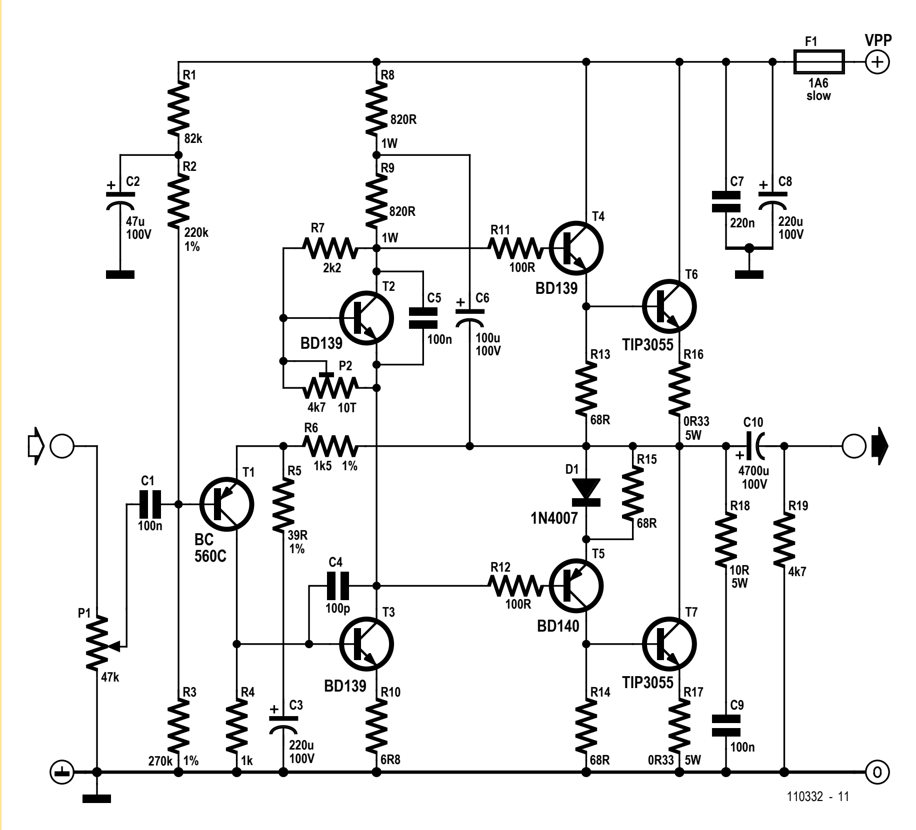


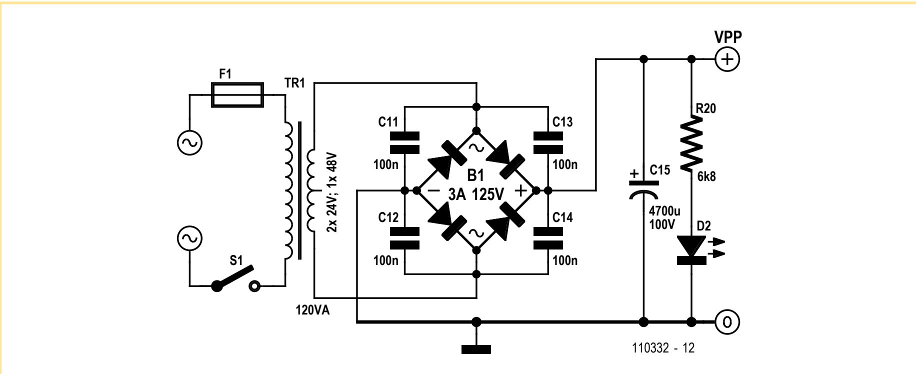
the heatsink already present in the amplifier; otherwise, a separate heatsink will be required. A thermal rating of 2.5 K/W will be suitable.

(110083)

Sixties-style 40 W Audio Amplifier

By Joseph Kreutz (Germany)





In the early 1960s RCA brought out a transistor that was to become truly legendary: the 2N3055. With a pair of these devices, you could put together an audio power amplifier that could deliver a healthy 40 W into 8 Ω. The circuit described here is fully in tune with the spirit of that era. For example, there are only seven active components in each channel, which reflects the design simplicity typical of that era (and actually a timeless quality). This 'retro' power amplifier pumps 45 W into 8 Ω with an input signal level of 0.5 V_{rms}.

It works as follows: the input signal is applied to the base of T1, while negative feedback from the output, attenuated by voltage divider R5/R6, is applied to the emitter of T1. The collector current of T1, which is proportional to the difference between the input and feedback signals, is fed to the base of T2. This transistor draws its operating current through R8 and R9 and provides voltage gain. Capacitor C6 is a bootstrap capacitor that hold the voltage across R9 nearly constant, so that the current through R9 is independent of the amplifier output signal level in the audio band.

Transistors T4–T7 form a quasi-complementary push-pull output stage. In the early 1960s, there simply wasn't any PNP transistor available that was truly complementary to the 2N3055. Designers came up with an ingenious way to get round this problem, which was to use a complementary Darlington pair consisting of a PNP driver transistor and an NPN power transistor. The schematic diagram clearly illustrates what is meant by a quasi-complementary push-pull output stage. Diode D1 provides balanced biasing for the output stage, which helps reduce distortion.

The operating point of the output stage is set and stabilized by transistor T3, which for this reason should be thermally coupled to the output transistors. The amplifier is powered from a single supply voltage at approximately 65 V, which is also 'typical sixties'. Capacitor C1, with a value of 4700 µF, transfers the signal from the output stage to the load and provides a bit of protection for the speaker in case one of the transistors fails.

The amplifier does not have output current limiting. Although this is not a critical shortcoming, a certain amount of caution is advisable. The only protection in this regard is provided by a slow-acting 1.6-A fuse in the supply line, which is intended to limit the damage if anything goes wrong.

The power supply consists of a transformer, a bridge rectifier, four small capacitors and a 4700 µF electrolytic capacitor. This is enough to power a two-channel stereo amplifier. The LED is a power-on indicator and is intended to be fitted on the front panel.

Assembling the circuit is very straightforward. Transistors T3, T4 and T5 should be fitted with heat sinks suitable for a TO126 package and with a thermal resistance less than 20 K/W. Transistors T2, T6 and T7 should all be fitted on a single heat sink with a thermal

Performance figures with an 8.2 Ω resistive load (indicative values)	
THD	0.08%; third harmonic at 1400 Hz; output level 3 V
Bandwith	29 Hz (–3 dB) to over 100 kHz (–0.5 dB) at an output level of 3 Vrms –3 dB at 100 kHz referred to 18 V at 1.0 kHz
Maximum output voltage	19.5 V at the saturation threshold

resistance of 2 K/W or less, using insulating washers and thermal paste.
Before applying power to the circuit for the first time, set P2 to its maximum value, temporarily replace the fuse with a 47 Ω, 5 W resistor, and connect a voltmeter across R17. Then switch on the power.

The voltmeter should indicate 0 V. Now carefully adjust P2 until the voltmeter reads 15 mV, which corresponds to a quiescent current of 50 mA. Then switch off the power and install the fuse in place of the power resistor. After this, check the voltage across R17 again (with the power on) and if necessary adjust it to 15 mV.

This is fun DIY project, cheap and unpretentious. Nevertheless, the sound quality of this amplifier is respectable. The distortion level gives no grounds for complaint. Of course, it's not a figure with an incredible number of zeros after the decimal point, but the idea here is to brush up on sixties technology.

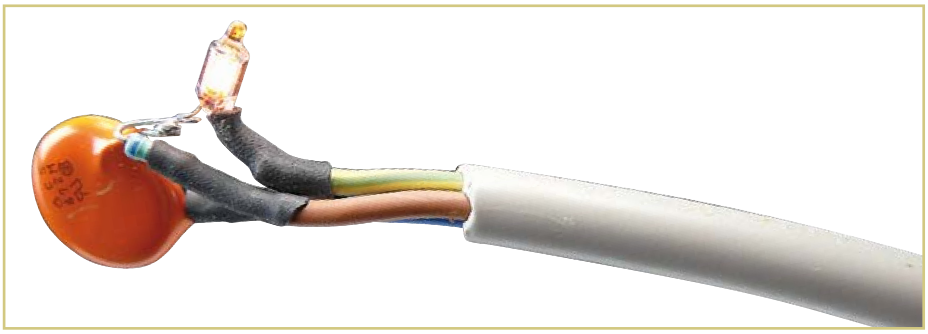
The author has designed two PCB layouts: one for the amplifier and one for the power supply. The layouts can be downloaded from [1] in PDF, Gerber and/or Easy-PC CAD format.

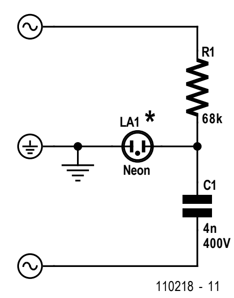
(110332)

Internet Link

[1] www.elektor.com/110332

Belgian Earth Fault Detector





By Marc Mertz (Belgium)

Having been affected by earth fault accidents, the author put together this little circuit. It consist of just three elements: the neon with its original resistor — for example, salvaged from the switch on an AC power bar — and a small capacitor (class Y) salvaged from the electronics of a low-consumption lamp. A larger capacitance makes the neon glow brighter. All this for no money at all. The neon lights only when there is an efficient Earth present. This works well at the author's home, with Live or Neutral either way round. In the Elektor laboratory based in The Netherlands, some concerns were expressed as described in the June 2011 issue [1], as the circuit was sensitive to the relative positions of the Live and Neutral. So the Earth fault detector can also be used as a Phase detector, but probably in Belgium only.
The whole thing can easily be incorporated into a power socket; the author used a small transparent cover to protect the neon.

(110218)

Note. As opposed to the UK and the US, some AC power outlets in Belgium — and all in The Netherlands — are not polarized, i.e. AC power plugs (both earthed and non-earthed) can be inserted either way around.

Internet link

[1] www.elektor.com/110396

Wire Loop Game

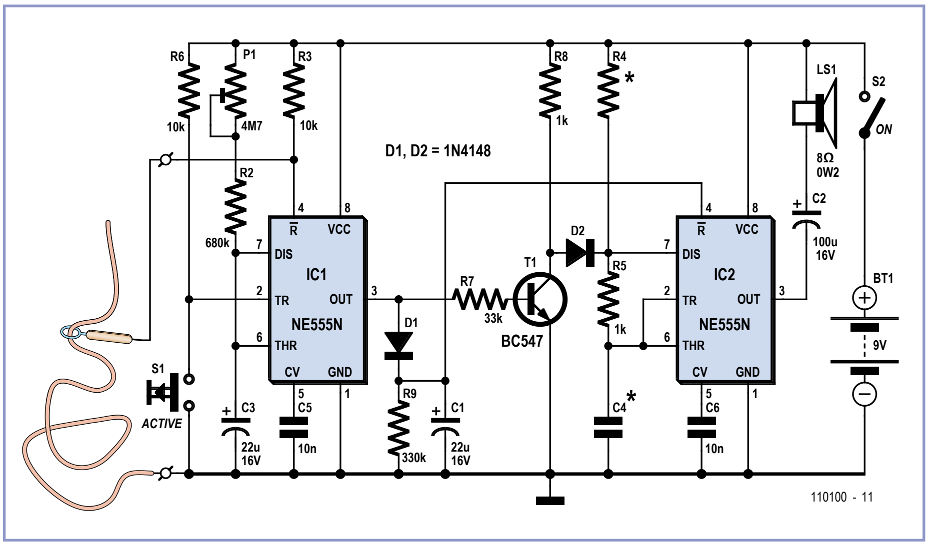
By Andreas Binner (Germany)

In the 'Wire Loop Game', a test of dexterity, the player has to pass a metal hoop along a twisted piece of wire without letting the hoop touch the wire. Usually all the associated electronics does is ring a bell to indicate when the player has lost. The version described here has a few extra features to make things a bit more exciting, adding a time limit to the game and a ticking sound during play.

Two 555 timer ICs are used to provide these functions. IC1 is configured as a monostable which controls the time allowed for the game, adjustable using potentiometer P1. IC2 is a multivibrator to provide the ticking and the continuous buzz that indicates when the player has touched the wire with the hoop.

When the monostable is in its steady state, the output of IC1 (pin 3) is low. T1 acts as an inverter, and D2 is thus forward biased. R8 and R4 are therefore effectively in parallel, with the result that IC2 produces a low

audible tone. The value of R4 is considerably greater than that of R8, and so the frequency of the buzz generated by IC2 is chiefly determined by the value of R8.
When the monostable is triggered, the high level at the output of IC1 is again inverted by T1. D2 is reverse biased and so R8 is effectively removed from the circuit. The frequency of IC2 is now largely determined by the value of R4. The ratio of R4 to R5 and the value of C4 affect the mark and space periods for the multivibrator: for a satisfactory ticking sound short pulses with long gaps between work well.



Whether a sound is produced also depends on the voltage on pin 4 of IC2. When the 9 V supply is connected the monostable is initially inactive and there is no voltage across C1. Pin 4 (reset) on IC2 is thus low and no tone is produced. IC1 is activated by a brief press of S1, which generates a low-going trigger signal on pin 2 to start the game. C1 now charges via D1 and IC2 is allowed to oscillate, generating the ticking sound.

The pulse width of the monostable sets the game duration, and can be adjusted using P1. If the allowed time expires, or if the reset input to IC1 is taken low (which happens when the hoop touches the wire), the monostable returns to the quiescent state. This causes IC2 to generate the low buzz sound. D1 is now reverse biased and C1 discharges through the relatively high-valued resistor R9. After a few seconds the voltage across C1 falls sufficiently that the buzz stops and the circuit is ready for the next player.

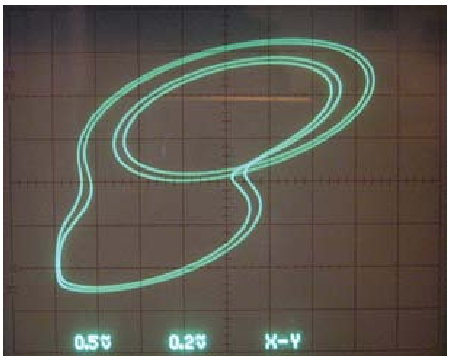
The circuit can be built first on a breadboard, so that the component values can easily be changed to suit particular preferences for game duration and buzz pitch. When suitable values have been selected the circuit can be built more permanently on a printed circuit board. The author used a sheet of plywood to form a base for the game, the twisted wire being fixed to the board and wired to the electronics mounted below it.

(110100)

Chaos Generator

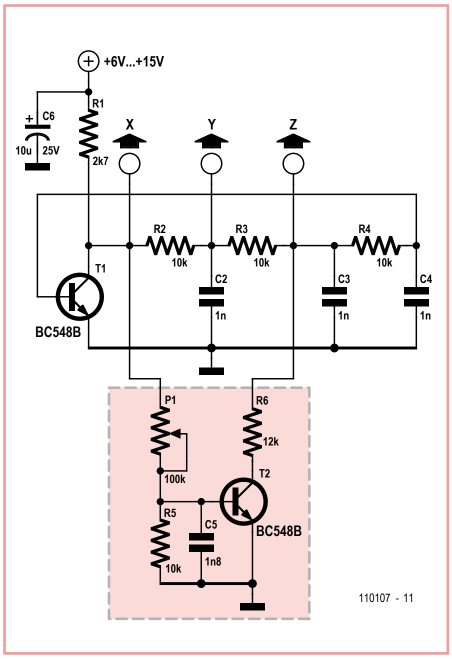
By Lars Keuninckx
(Free University of Brussels, Belgium)

The circuit described here is a chaotic version of a conventional phase shift oscillator. The nice thing about it is that it is simple and cheap. In addition, it operates from a single supply voltage and none of the component values are especially critical.
Without the components inside the dashed outline, the circuit oscillates stably with a distorted sine-wave signal on the collector of T1. The three RC networks produce a net phase shift of 180 degrees at the operating frequency, which combines with the phase shift (signal inversion) of transistor T1 to maintain oscillation.



Adding the components inside the dashed outline results in a quite different situation. The amplitude rises while the oscillator is starting up, and at certain level this causes T2 to go into conduction. This in turn causes resistor R6 to be included in the feedback path, which disturbs the phase relationship and forces the circuit to try to find a different stable operating point.

Under the right conditions this can lead to chaotic operation, in which the circuit does not reach a stable state but instead passes through a succession of closely spaced unstable states. These paths form what is called an



'attractor', which can be readily displayed on an oscilloscope operating in X/Y mode with the following settings:

Channel 1: X, AC, 0.5 V/div
Channel 2: Y, AC, 20 mV/div
V_{CC}: 6 to 16 V

By playing with the setting of potentiometer P1 and the value of the supply voltage, you can force the circuit to depart from stable oscillation and enter chaotic mode at half the previous frequency. This causes very interesting patterns on the oscilloscope (see photo). You can strongly influence the shape of the attractor by adjusting the values of P1, R6, C5 and the supply voltage.

The circuit has four components that are able to store energy, which makes its phase space four-dimensional. What you see on the oscilloscope screen is a two-dimensional projection of an attractor in four-dimensional phase space. Other dimensions can be made visible by connecting the probes to other points, such as Y and Z instead of X and Y.

(110107)

Power Controller

for Electric Convector Heaters

By Gérard Guiheneuf (France)

In Fall or Spring, the weather may be warm enough that we'd like to save money by shutting down the main heating system in our home and just use supplementary heating based on one or more electric convector heaters.

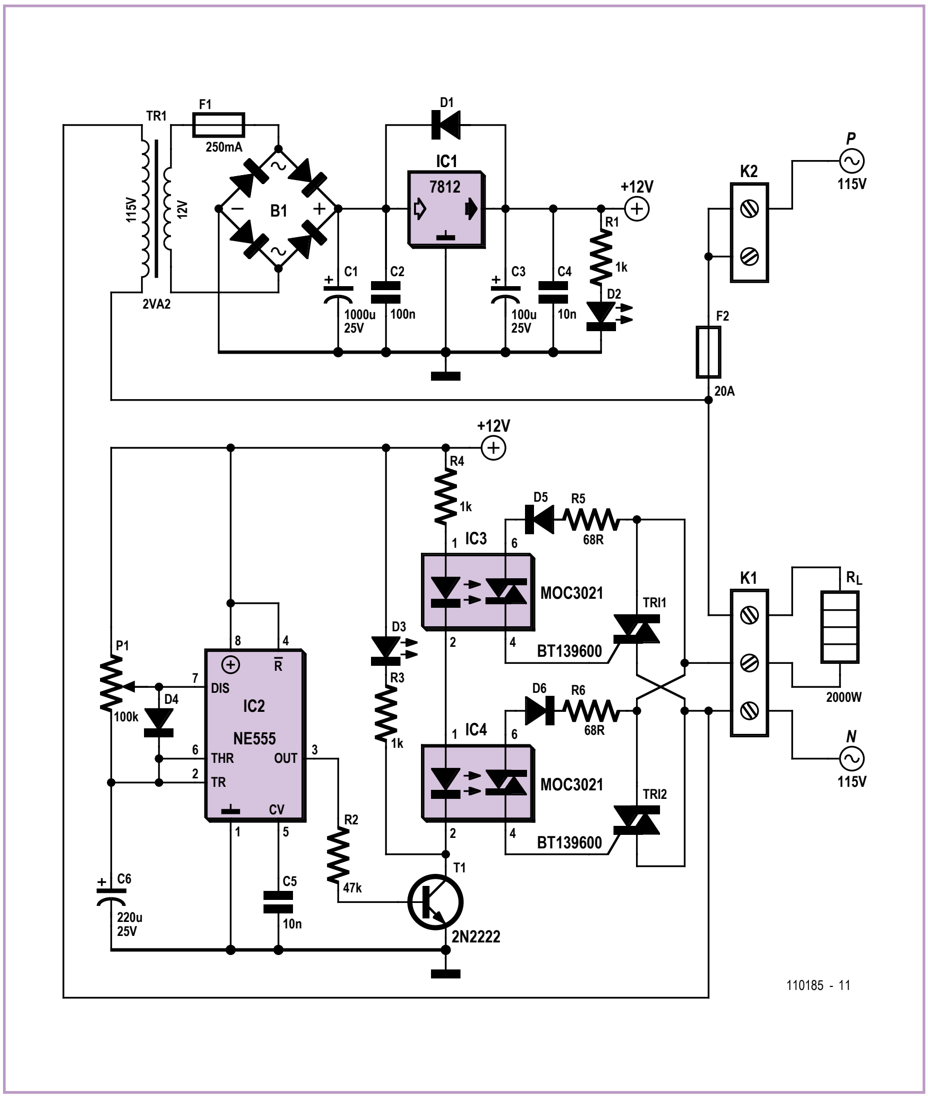
Even though these convectors are quite heavy consumers of electricity, this can be reduced by fitting a power controller between the heaters and the AC power outlet, which will affect the effective power consumption of the convectors.

The circuit diagram is based around the use of the emblematic NE555 IC, used here as an astable multivibrator with variable duty cycle ($D = t_{high} / T$), but at a fixed operating frequency, given by:

$$f = 1 / (0.693 \times P1 \times C6) = 0.0654 \text{ Hz}$$

The duty cycle D of the signal at the output (pin 3) of IC2 will change depending on the position of the wiper of potentiometer P1:

- If the wiper is at mid-travel, the duty cycle D will be 0.5;
- If the wiper is at the +12 V end, the IC2 output signal is zero and hence D = 0;
- If the wiper position takes it down to the voltage on C6, IC2's output supplies a constant voltage of around 11 V and D = 1.



By way of transistor T1, IC2 drives two MOC3021 phototriacs (IC3 & IC4) which provide the isolation between the circuit's 'driver' section and the 'power' section, which is directly connected to the AC powerlines.

Each phototriac drives a power triac (TRI1 & TRI2). These two triacs are fitted in parallel and share the task of supplying the convector (R_L): one triac supplies the positive half-cycle while the other triac supplies the negative

half-cycle. The over-rating of the triacs (high rms current rating: 16 A) combined with their use in parallel and the alternating switching is aimed at reducing heating in the two components and reducing the bulk of the heat sinks employed.
Experimentally, this solution gives rise to low heating of the heat sinks when the controller is powering a 2 kW-rated convector constantly (duty cycle $D = 1$).

The power consumed by the convector with controller is easy to calculate from the simple formula

$$W = P \times t \times D$$

where
W = power consumed in watt-hours (Wh);
P = rated convector power in watts (W);
T = operating time of the convector/controller unit in hours (h);
D = duty cycle set by potentiometer P1.
Example: for a duty cycle D of 0.5 and an operating time of one hour, a 2 kW convector will consume 1 kWh.

(110185)

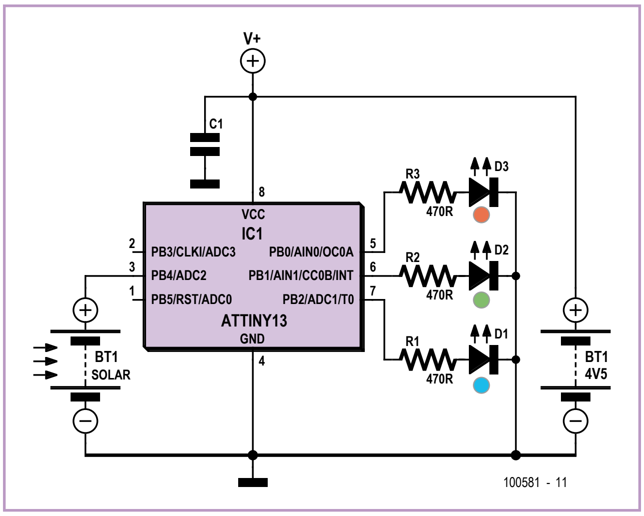
Internet Link

[1] www.elektor.com/110185

RGB Solar Lamp

By Marcel Ochsendorf (Germany)

This deluxe solar-powered light uses a battery and solar cells salvaged from a solar lamp with a four-cell battery (4.8 V nominal terminal voltage).



The circuit can operate from any DC voltage around this value and its current consumption, at 20 mA, is low. This means that the battery can give up to five days of operation. The circuit consists of an Atmel ATtiny microcontroller which drives a red, a green and a blue LED directly from three port pins. Series resistors are of course included to limit the LED current. The microcontroller drives the LEDs in sequence to produce an RGB running light effect. The microcontroller is also responsible for ensuring that the light automatically switches on when it gets dark and off when it is light. The light sensor is made from one of the solar cells from a broken solar lamp (it is more common for the battery to fail rather than the solar cells).

The power output of this cell is not important, as the microcontroller only measures its output voltage using its internal A/D converter connected to pin PB4. The project is ideal for beginners, as a ready-programmed microcontroller is available from the Elektor Shop (order code 100581-41).

The author developed the firmware using Flowcode. Source and hex files for the firmware are available for free download from the project pages on the *Elektor* website at www.elektor.com/100581.

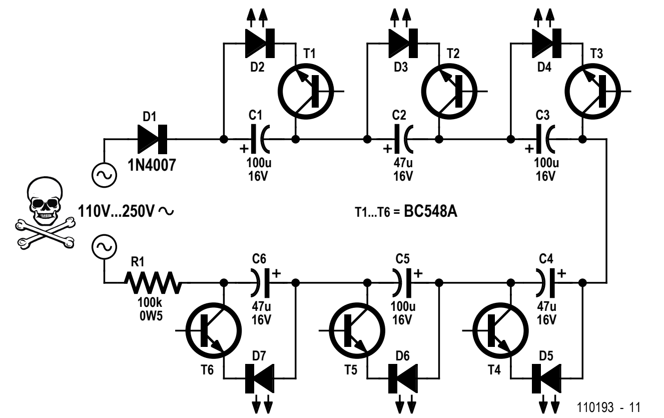
(100581)

LED Multi-Flasher

By Burkhard Kainka (Germany)

The first circuit in **Figure 1** shows a particularly simple LED flasher for AC power operation with six channels. All six LEDs flash entirely at random (not synchronized), producing a totally chaotic display.

This must be the ultimate low energy lamp bulb, consuming a mere 0.2 watts or so. To see it in action take a look at my short video [1] on the Internet.
The project employs my NPN multivibrator circuit described elsewhere in this issue. Each of the six NPN multivibrator circuits (connected here in series) draws the same loading current. By varying the value of the electrolytic capacitors you can change the flashing frequency and brightness. You can make the circuit flash more slowly if you select a value higher than 100 kΩ for the charge resistor R1 or add an additional resistor (in the power feed).
A disadvantage of the circuit is the **risk of death** that arises from the fact that the circuit is connected **directly to the AC power line**. Therefore it is extremely dangerous to touch components of the circuit when live. Therefore it's imperative that you construct the project in a well insulated (touch-proof) plastic case fitted with proper cable restraints (see the Electrical Safety document at reference [2]).
To avoid risks of this kind Figure **2** shows another version of the circuit designed for low voltage operation in the range from 12 to 24 V. Here the NPN multivibrators are pow-



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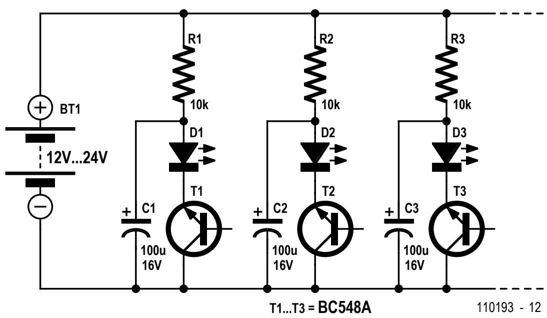


2

ered in parallel (not series) with the operating voltage. Using this method you can also construct longer flasher chains.

(110193)

Internet Links

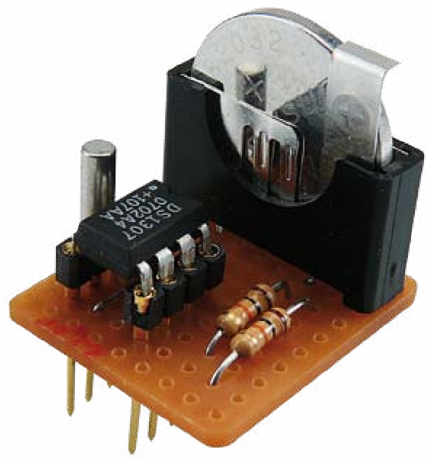
[1] www.youtube.com/user/bkelektronik#p/u/6/lqr-YTf3b9U

[2] www.elektor.com/subs/construction-electrical-safety.83362.lynkx

Time Transporter

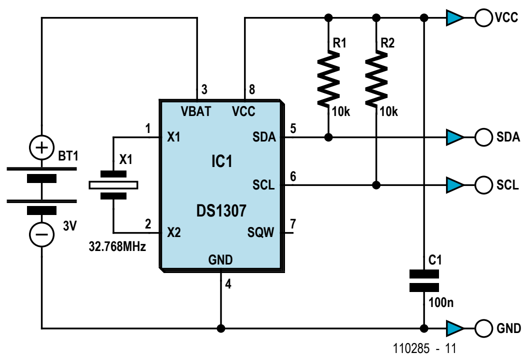
By Jochen Brüning (Germany)

Some microcontroller applications such as those which log or track information often require current time and date information to be stored along with the collected data. A Real Time Clock (RTC) chip such as the IC DS1307 with battery back-up can be used to supply the required information. This particular chip easily integrates into most designs using the absolute minimum of external components. The process of programming the chip in software is simple and is supported in the majority of programming environments. Intrinsic functions, header files and libraries are widely implemented for the device. A quick trawl of the Internet will uncover lots of programming examples.



So far so good except that the chip first needs to be programmed with the current time and date information. This information is maintained and updated (thanks to a keep-alive battery) even when the external circuitry is shut down. To carry out the programming requires connection to a keyboard and display but the additional hardware will only ever be needed for this one-off event.

The design suggested here solves the problem by combining the IC, battery, crystal and peripheral components onto a tiny plug-in PCB. The circuit consists of a small square of prototyping perf board onto which is mounted the IC, a crystal, battery, decoupling capacitor (C1) and two (optional) pull-up resistors for the open collector outputs. An IC socket with extra longs pins (or two modular connector strips) completes the design. The complete RTC module (see photo) is self contained and can be plugged from one circuit to another using its long pins without losing track of time and date. The only requirement in the target system is space for an 8-way DIL socket, wiring to the socket and software to read the time information.



The essential advantage with this approach is that hard and software expenditure in the target system is kept to a minimum, it will only ever need to read the time and date information. The extra hardware and software required to set both time and date are assigned to a separate system, maybe a dedicated breadboard design. Once programmed the ticking clock module can then simply be transferred to the target system.

(110285)

A Few DC Solid-state Relays

By Georges Treels (France)

Good old electromechanical relays are relatively expensive where any significant current has to be switched and switching times must be short. One solution is to go over to solid-state relays (SSRs). In DC mode, MOSFETs offer a very interesting solution, and the various manufacturers today offer devices at less than £4 with amazing performance, in terms of both current and low $R_{DS(on)}$. They're relatively simple to use, in both monostable and bistable modes, so why stint ourselves?

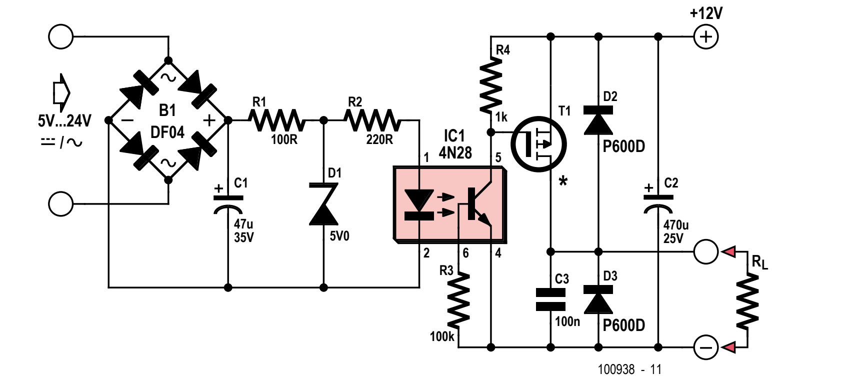
The following circuits will let you switch 10–60 A (or even more if you use configurations with MOSFETs in parallel), with very short switching times. Several configurations are shown, monostable and bistable, capable of switching a load with one side returned to either ground (high side switching) or the positive rail (low side switching). In addition, the monostable configurations offer galvanic isolation and can be driven by signals from 5–24 V, DC or AC. The bistable SSRs are controlled using a simple push-button and a little bit of logic.

Let's start with the monostable SSRs.
Bridge B1 makes it possible to accept any input polarity in the case of a DC control signal, and rectifies the signal in the case of an AC control signal. The network R1, R2, D1 limits the LED current in opto-isolator IC1. The base of the phototransistor in IC1 is connected to ground via R3; its emitter is connected directly to ground.

In the case of a load returned to ground, the gate of T1, a P-channel MOSFET, is driven directly from the collector of IC1. If the load is returned to the positive rail, the gate of T1, this time an N-channel MOSFET, is driven via T2, which inverts the output from IC1.

C2, C3, D2, and D3 protect the MOSFET in the event of loads that are not purely resistive.
Both bistable configurations use the same power stages as the monostables, with an N-MOSFET for loads connected to the positive rail and a P-MOSFET for loads connected to ground.

IC1.A is wired as a simple flip-flop: with the switching threshold set by P1, IC1.A output will change state each time button S1 is pressed. R1 and C1 avoid rapid oscillations while S1 is pressed. IC1 gates B, C, and D directly drive the gate of the P-MOSFET in the case of a load returned to ground. IC1.B inverts IC1.A out-



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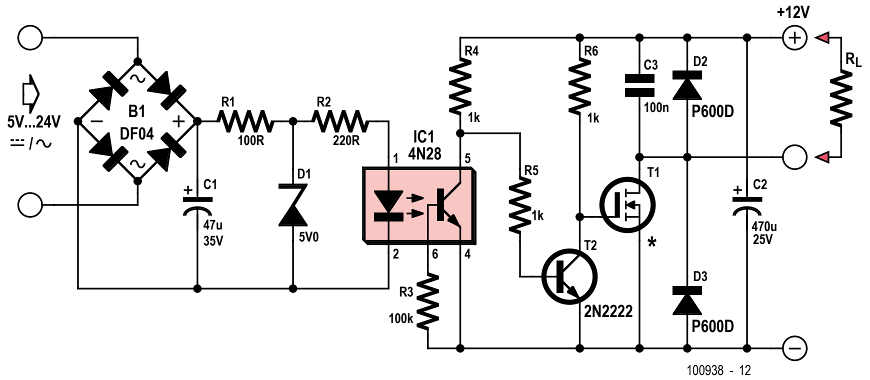

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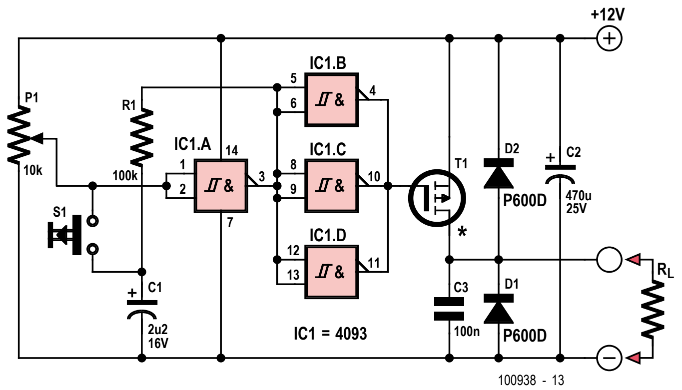

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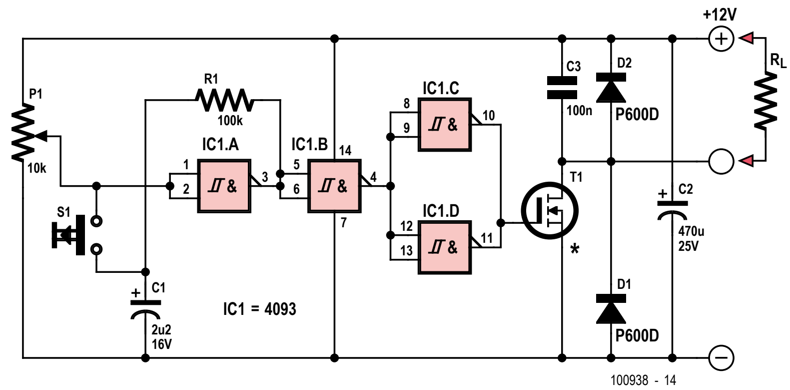


4

put when an N-MOSFET has to be driven (load returned to the positive rail).
In both configurations, the relay remains off at power-on (safety feature).

Concerning the MOSFETs, the table lists a number of possible types. This list is far from being exhaustive and new devices come out regularly. Give preference to a low value of $R_{DS(on)}$ (dissipation) and a good dv/dt specification in the case of 'dirty' loads. Pay attention also to the V_{DS}. Even though most of these transistors can take

Current	N-MOSFET	P-MOSFET
10 A	IRFZ24	IRF9540
30 A	IRFZ44	IRF5210
60 A	IRF2804	SUP75P03-07

60 V, this is not the case for either the opto-isolators or the bipolar transistors used.

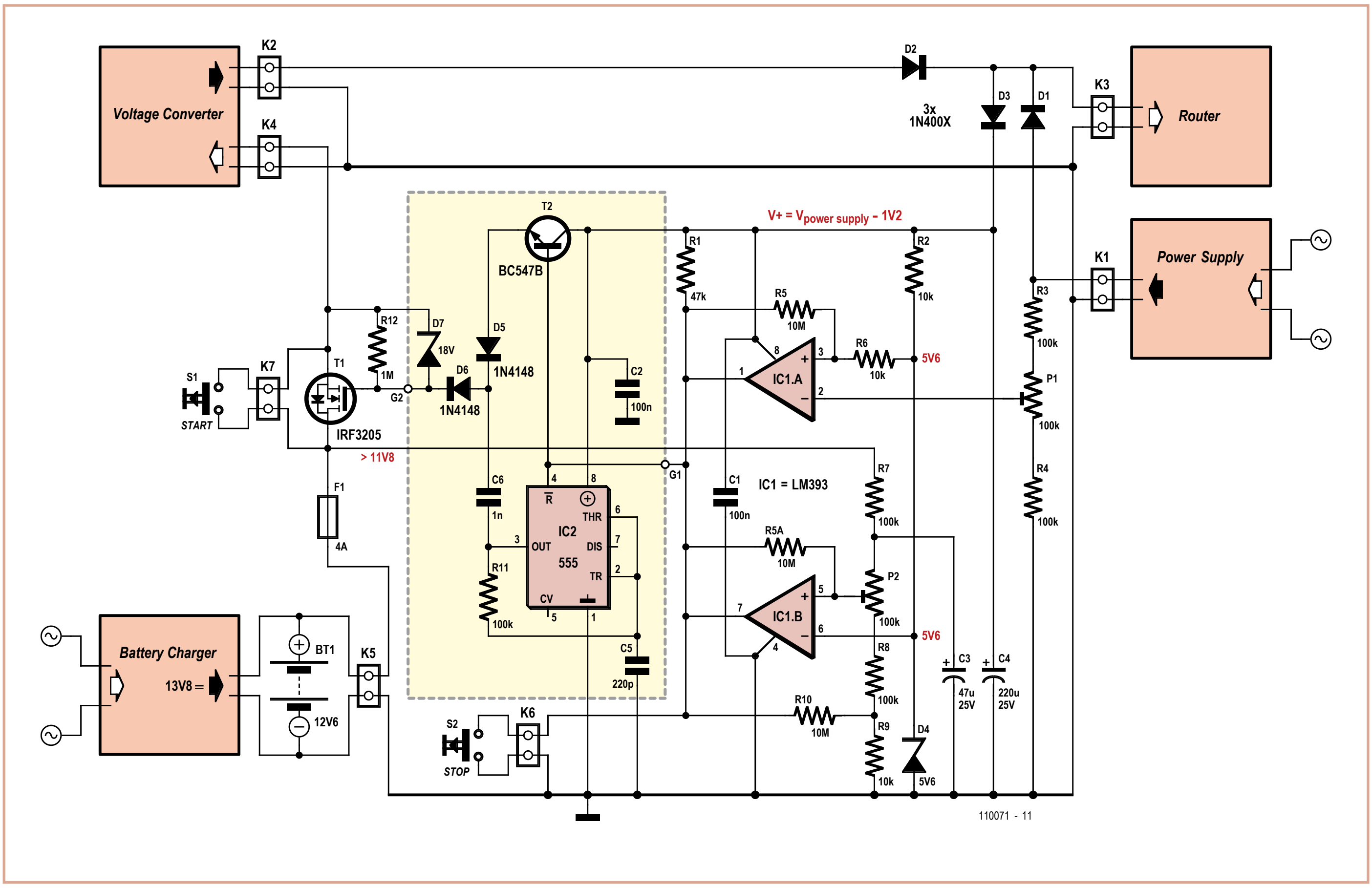
If you are designing a PCB for this type of relay, pay attention to the possibility of heavy currents being carried by the PCB track. For example, three SUP75P03-07 wired in parallel can pass over 200 A! Bear in mind that a PCB track with a copper layer 35 μm thick (i.e. standard) has a resistance of $48 \times 10^{-5} \times L / W$ ohms, where L(ength) and W(idth) are in mm.

(100938)

Internet Link

[1] www.elektor.com/100938

Router UPS



By Jan Lichtenbelt and Anne Offereins (The Netherlands)

It can be handy to have your phone and Internet router continue working for a while after a power failure — for example, if they provide access to a security system.
This requires a backup power supply for the router. The version described here consists of a 12-V lead-acid battery and a voltage converter capable of supplying an output voltage in the range of 15 to 30 V. It has built-in protection to prevent excessive battery discharge. This DIY uninterruptible power supply (UPS) operates in standby mode as long as the mains voltage is present.

The UPS consists of four parts: a backup detector circuit that monitors the supply voltage from the AC mains adapter, a battery circuit that monitors the battery voltage to prevent it from dropping below 11.8 V, a FET switch between the battery and the voltage converter, and a voltage doubler (inside the dashed outline).

To understand how it works, first consider the situation with a router supply voltage above 20 V, for which the voltage doubler is not required. In this case the outputs of comparators IC1a and IC1b (pins 1 and 7) are connected directly to the gate of the FET (G1 is connected to G2).

Under normal conditions the router, which is connected to K3, is powered from the voltage on connector K1. In this situation the voltage on pin 2 of comparator IC1a is higher than 5.6 V. The output on pin 1 is therefore low, and the FET is switched off. If the external voltage on K1 drops out, the voltage on pin 2 of IC1 drops and the output on pin 1 goes high, switching on the FET. In this state the battery and the voltage converter supply power to the router. The battery will gradually discharge, and to prevent the battery voltage from dropping below 11.8 V the output of the second comparator (on pin 7) goes low when the voltage reaches this threshold level, switching off the FET. The battery voltage may rise quickly after the FET is switched off, so capacitor C3 is included to ensure that this does not cause the FET be switched on again.

Switch S1 allows the UPS to start up without an external supply voltage on K1, and capacitor C4 enables the comparators to continue operating in the event of a brief dropout of the two supply voltages on K1 and K2. The emergency stop switch S2 and fuse F1 are included for safety reasons. The voltage converter has a high inrush current, so F1 must be generously dimensioned.

If the router supply voltage is below 19 V, the comparator output level in the high state is too low to achieve a gate–source voltage of 4.5 to 5 V, since the source voltage is always the same as the battery voltage under continuous charging, which is 13.8 V. This means that the gate voltage must be at least 18.3 to 18.8 V, which is difficult or impossible with a router supply voltage under 19 V. This can be remedied by including the voltage doubler, which is built around the well-known 555 timer IC (CMOS version). The frequency of the oscillator (IC2) is approximately 40 kHz. Components C6, D5 and D6 add the AC voltage to the switched supply voltage delivered by T2, which is driven by the comparators in parallel with the timer reset. An 18-V Zener diode (C7) protects the FET gate–source junction against overvoltage.
Be careful to select a 555 with a maximum rated supply voltage sufficient for this application; they are available in 16-V and 18-V versions.
The voltage converter of this UPS is a notebook power converter designed for in-car use, with an input voltage of 12 V, selectable output voltage, and a minimum current capacity of 0.5 A. Most voltage converters can handle this easily. The battery must be connected to a good charger capable of maintaining a lead-acid battery in good condition under prolonged no-load operation. Various designs for this have been described in Elektor in the past.

Adjust P1 for a voltage of approximately 7 V. With a lab power supply connected in place of the battery, adjust P2 for a threshold voltage of 11.8 V.

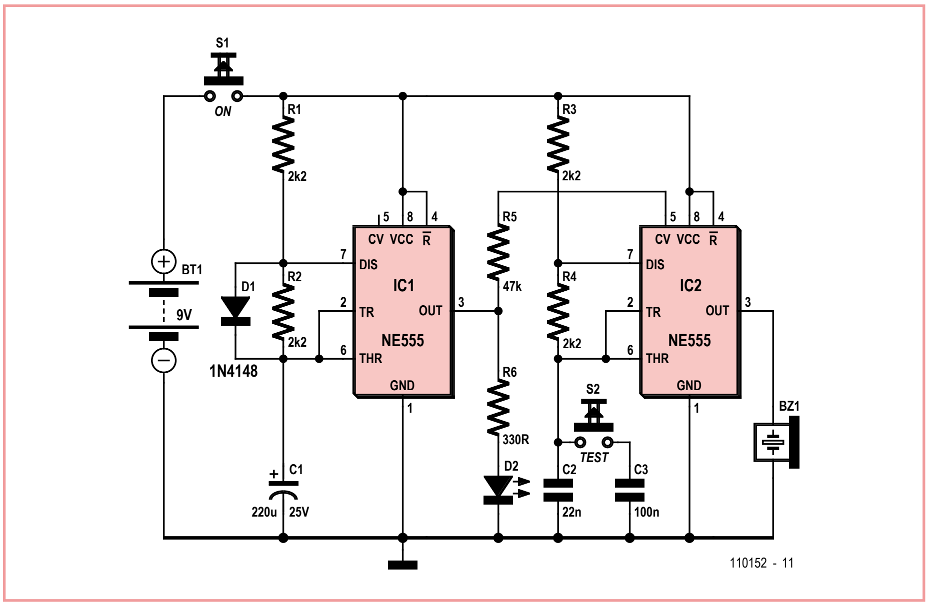
(110071)

Dog Whistle for Ronja

By Stefan Hoffmann (Germany)

Ronja is the author's dog, a beagle-mongrel, who seems increasingly often to need to be called to heel either with a shout or with a whistle. And so the idea came about for an electronic dog whistle that could produce two alternating high-frequency tones. A design like this has several advantages over conventional whistles or calling.

- You can continue to carry on a conversation with your friends without having to stop to whistle or call to your dog.
- Using high frequencies means that the whistle sound is barely audible to (especially older) humans and so is less annoying to other people than conventional whistles or calls. As is well known, dogs have rather better hearing than we do and can hear frequencies of up to 40 kHz.
- The two alternating pitches mean that the dog can more easily distinguish it from other whistles.



The dog whistle is constructed from two standard 555 timer ICs (or a single 556 IC), both wired as astable multivibrators. The first 555 oscillates at around 1.5 Hz and modulates the frequency of the second, which thus switches between two different frequencies every 0.7 seconds or so. The output of the second 555 is connected to a piezo sounder. If the volume from the sounder used is insufficient, a small transistor amplifier can be added between it and the output of the second 555. The circuit draws current only when activated by pressing S1. An optional green LED indicates that the circuit is functioning. When S2 is pressed the output frequencies are reduced, making them more audible to human ears for test purposes.

R1, R2 and C1 set the frequency of astable multivibrator IC1. Diode D1 ensures that the output is a symmetrical square wave, by making C1 charge only via R1 and discharge only via R2.

Turning to IC2, where there is no diode in the circuit, capacitor C2 is charged via R3 and R4 and discharged only via R4. With C2 = 22nF the 555 oscillates at about 10 kHz; with S2 pressed, and hence C3 in parallel with C2, this falls to about 1.8 kHz. Changing C2 to 10 nF results in an even higher frequency (about 22 kHz), which can only be heard by dogs and certain other animals. Setting C2 to 15 nF gives an output frequency of about 15 kHz. IC1 modulates the frequency of IC2 via R5. The green LED D2 is connected to the output of IC1 via a series resistor and thus flashes at the modulation frequency.

The output from the piezo sounder at 10 kHz (C2 = 22 nF) should be loud enough to verify by ear. If desired, a more efficient piezo horn tweeter can be used instead.

(110152)

Small Lamp — Huge Bill

By Leo Szumylowycz (Germany)

Table lamps with a three-step touch-operated dimmer are available in a range of designs. The author bought a couple from a well-known discount shop where they were on special offer. They are ideal as lamps for the bedside table: there is no need to fumble around in the dark for an in-line power switch as the light switches on with a simple touch of its base.

All the author's purchases came fitted with 25 watt E14 bulbs. First impressions were positive as the lamps seemed to work well. However, there was a nasty surprise in store when the author checked the lamp's standby power consumption, which happened to have been omitted from the specifications given by the maker or importer. The power meter showed that with the light completely off, it was still drawing 13 watts! Experiments with the bulb back in gave readings of 18 watts on the lowest brightness, 23 watts on medium and 28 watts on full.

So the consumption at zero brightness is 52 % of the rated bulb power. It is hard to imagine how such a product could make it to market. If you pay 10 pence per kilowatt-hour the energy required to keep the light on standby for a year (113.88 kWh) would come to $13,67, more than the purchase price of the unit itself!

The conclusion is that it is well worth equipping these lights with an external (for example, in-line) switch, so that at least the light can be switched off properly during the day. And always check the standby consumption of a device without an AC on/off switch, ideally before handing over money for it!

(110062)

IR Tester

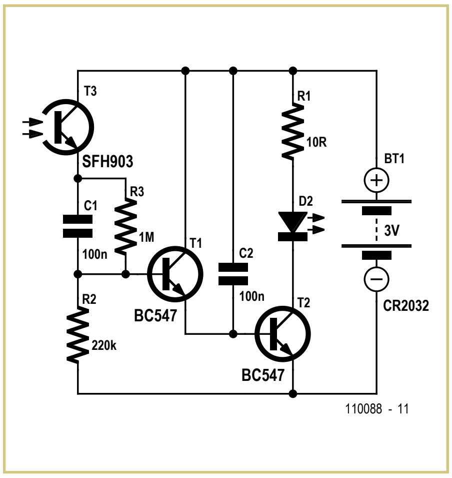
By Georg Schmülling (Germany)

We've all been here: you operate the TV remote and nothing happens. Is the device broken or do you just need to renew the battery? Eyesight alone is no help for testing the operation of the infrared LED. Help is at hand, however, and this circuit will produce a useful gadget that can test all infrared (IR) remote controls simply and rapidly.

The circuit comprises basically a Darlington amplifier stage with three transistors, the first of which is a phototransistor. The combination is very insensitive to ambient light levels. The IR-transistor will also react to (be turned on by) constant (unmodulated) infrared light (incidental light generates base current in the transistor) but in this case a constant DC current flows across R3 and R2. The voltage divider created by these two (high-impedance) resistors ensures that the Darlington amplifier of T1 and T2 that follows cannot be turned on. Using the low supply voltage of 3 V means the voltage on R2 remains below the threshold voltage of the Darlington stage of around 1.2 V (2 x U_{BE}) when the phototransistor conducts.

Events take a totally different course when the phototransistor receives a pulse-modulated IR signal of the kind transmitted by the IR-LED of an infrared remote control. This pulse train with a frequency of 35 to 40 kHz passes straight through capacitor C1, without attenuation, to the base of the Darlington amplifier where it is amplified substantially. The LED illuminates as a result, thus indicating the remote control is working.

Capacitor C2 integrates the amplified pulse train, so that the LED lights visibly even for short bursts of the modulated IR-signal.
It's worth emphasizing the minute quiescent current of under 500 nA drawn by the circuit, meaning that the battery is assured a long life even without an off switch.



The selection of components is not at all critical. For T3 you can use virtually any IR-phototransistor, whilst for T1 and T2 all standard NPN small-signal transistors are suitable.

To simplify construction the author has devised a printed circuit board complete with the milling data files (GBR and HPGL) available for download [1] free at the Elektor website.

110088

[1] www.elektor.com/110088

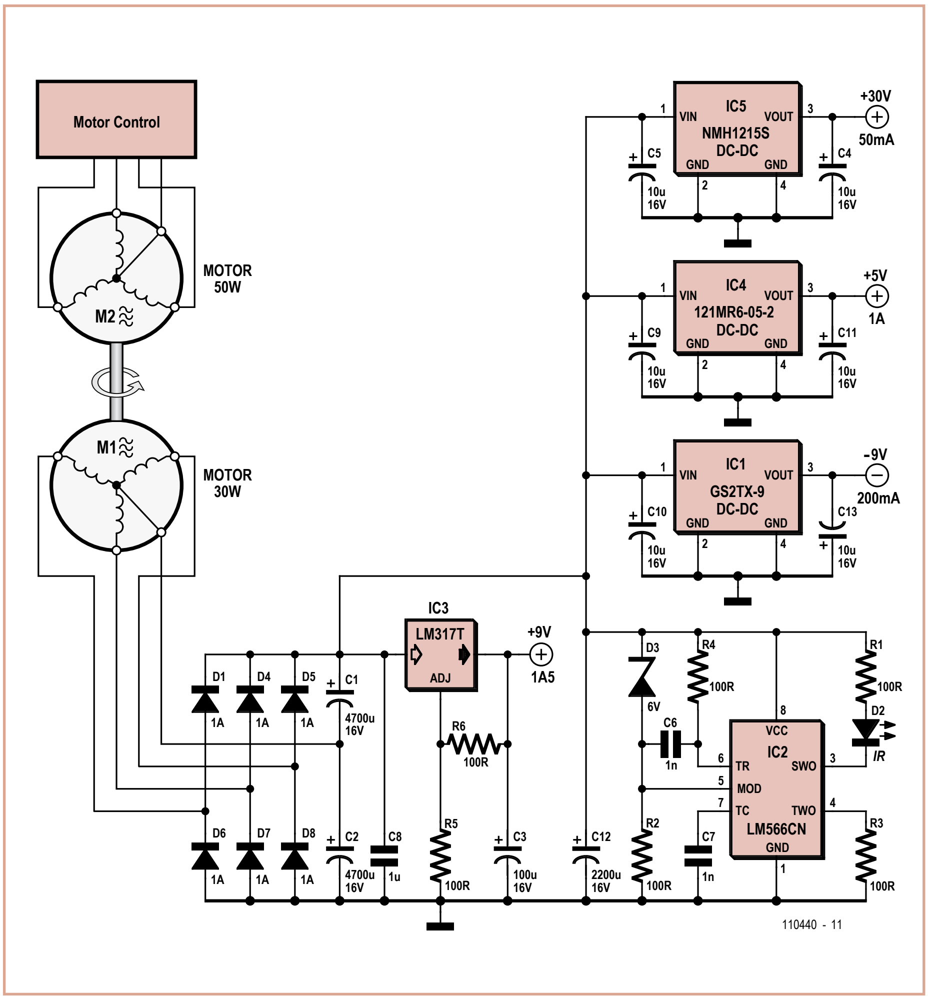
Power Supply with High Voltage Isolation

By Jac Hettema (The Netherlands)

Occasionally you come across some unusual situations when setting up measurement systems.
The author once had to set up a system to register the vibrations and strain supposed to be present in a contactor that operated at a voltage of 25 kV_{AC}.

One of the biggest problems with this project turned out to be the power supply for the measurement system. Since it required a power of about 30 W it wasn't possible to use batteries since the system had to operate for many hours at a time. A logical solution would seem to be to use an isolating transformer, but still... 25 kV_{AC} means a peak voltage approaching 40 kV, and on top of that you would have to include a safety margin. In addition, everything that is connected to high voltage lines should also be able to withstand lighting strikes!

Consequently the isolation should be able to cope with a test voltage of 150 kV, which is a lot to ask of the isolating material.



After extensive research no supplier could be found for a transformer rated at 50 W, 230 V primary, 12 V secondary and an isolation of 25 kV_{AC}. Because of this, a dynamic system had to be used that unfortunately suffers a bit from wear and tear. This system consists of a 50 W 3-phase motor connected up via an isolating drive-shaft to a 30 W generator (a 3-phase servo motor that was used as a generator), which provides the power for the data logger and associated electronics.

Because a 3-phase generator was used, the voltage obtained after full-wave rectification (via D1 and D4 to D8) already looked good, also because the revs of the generator was fairly high. The secondary supply can therefore remain fairly simple. The main supply of 9 V_{DC} is stabilized by IC3, an LM317T. From there it is fed to a few small DC/DC modules (IC1, IC4, IC5), which supply voltages of +5 V, +30 V and -9 V, which are required by the other parts of the circuit. IC2 (LM566, a voltage controlled oscillator) makes LED D2 flash when the supply voltage is present.

(110440)

Analog LED Chaser Light

By Burkhard Kainka (Germany)

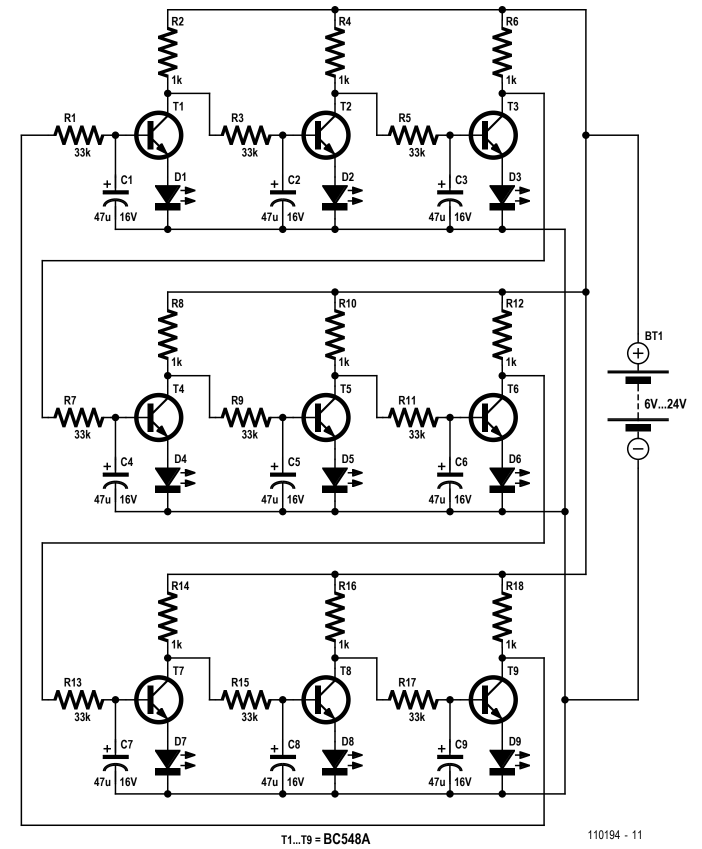
The circuit shown here is formed of nine inverting transistor amplifier stages connected in series with an LED connected between emitter and ground. The output of the final stage connected to the input of the first stage.

The principle is similar to the ring oscillator described by the author elsewhere in this edition. Similar but not identical, since the stages in this circuit have additional delay elements formed of a 33 kΩ resistor and a 47 µF electrolytic. The circuit operates with any odd number of LED stages of your choice, for instance with nine (as shown here).

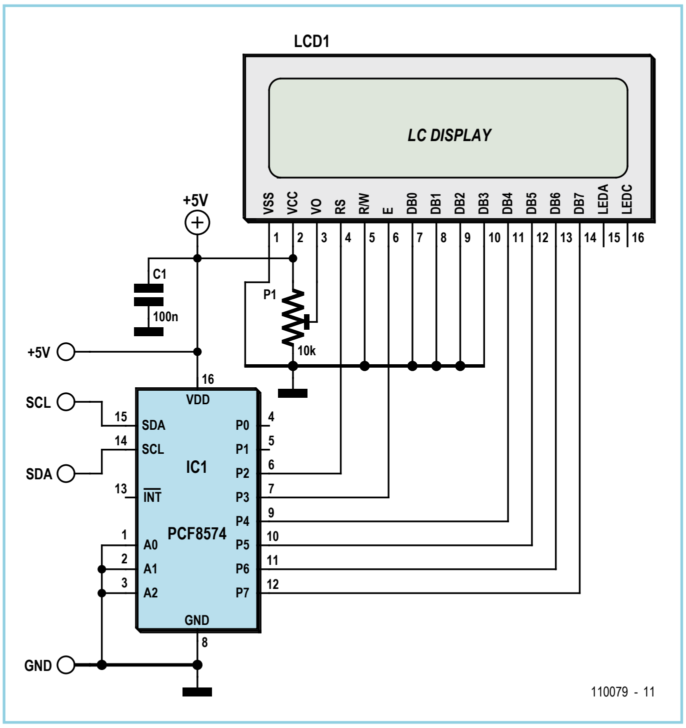
The project oscillates very reliably and the way the twinkling LEDs fade in and out is quite a novelty. If you watch just two LEDs, they look like a simple blinker as there is always one lit LED next to a dark one. But with the lights circulating it looks a lot more complicated. Any disturbance will also travel round the ring. To watch the effect take a look at this You Tube Video:

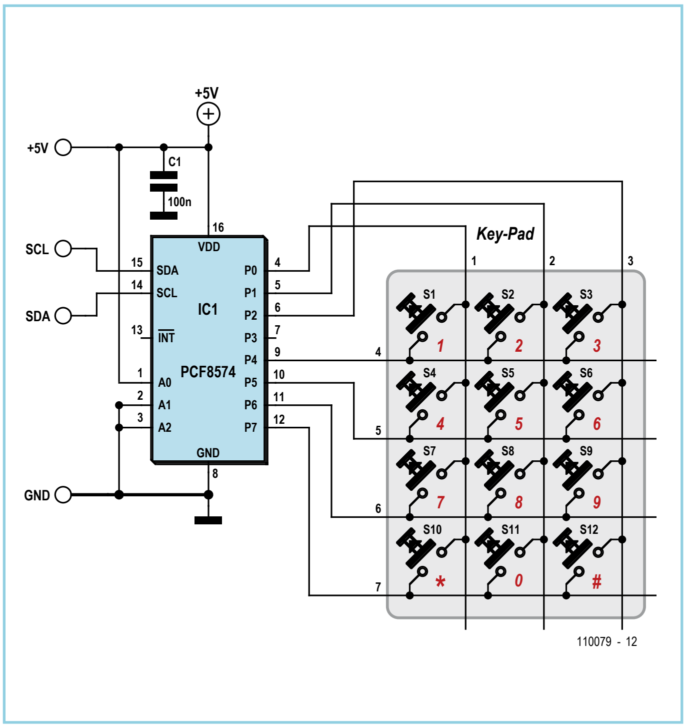
www.youtube.com/user/bkelektronik#p/u/1/-U_vAx_EK_M

(110194)



I^{2}C User Interface





by Joachim Dombrowa (Germany)

Many microcontroller-based projects use an LCD panel and buttons for their user interface. These generally swallow up a large number of the port pins on the microcontroller, making them unavailable for other uses in the application. The circuit shown here offers an HD44780-compatible LCD and a numeric keypad that are connected over an I^{2}C bus. This bus uses just two of the microcontroller's pins: SCL and SDA.

The two circuits can of course be built into a single enclosure connected using these signal lines, making a compact user interface panel. This arrangement also provides a good way of modularizing the overall design of the system, as the same user interface unit can easily be used in conjunction with different microcontroller applications. All you need to check is that the microcontroller supports the I^{2}C interface. One microcontroller that does is the ATmega88, which is used in the ATM18 project and in the ElektorBus experimental board.

At the heart of each circuit is a PCF8574 I/O expander [1]. Note that there are two essentially identical versions of the PCF8574 available, differing only in the I^{2}C address range to which they respond: read the datasheet carefully! The expander operates as a slave device, while the microcontroller acts as bus master. To perform a write operation to the expander using the I^{2}C protocol the master first sends the address of the slave, followed by a data byte. The data byte contains the bit pattern that we want to have appear on port pins P0 to P7. Similarly, a read operation from the slave returns a byte containing the logic levels on P0 to P7.

Let's look at the keypad first. In this circuit the PCF8574 is assigned the address 42 hex (A0 tied High, A1 and A2 tied Low). The keypad is scanned column by column, with port pins P0 to P2 operating as outputs and P4 to P7 as inputs. The bit patterns 1111:1110, 1111:1101 and 1111:1011 are sent in sequence to the device. After each pattern is sent a byte is read back from the device and the upper four bits checked. If, for example, the bit pattern 1111:1110 is output (selecting column 1) and the pattern 1011:1110 is read back, this means that button '7' is being pressed.

In the LCD interface circuit the I/O expander address is set to 40 hex. The display is driven in 'four bit' mode. Since data only need to be sent in one direction (to the LCD), its R/W pin is tied low. RS (register select, set to 0 for a command byte and 1 for a data byte) is driven from port pin P2. The LCD controller accepts a data or command on the falling edge of the E (for

Listing 1

```
void LcdPanel_InitEN (byte nData)
{
// nData = Portpins P2,P4..P7
// Bit 3 = 0 (EN=0)
Twi_WriteByte(0x40, nData);
AppDelay_10us(50);

// Bit 3 = 1 (EN=1)
Twi_WriteByte(0x40, nData | 0x08);
AppDelay_10us(50);

// Bit 3 = 0 (EN=0)
Twi_WriteByte(0x40, nData);
AppDelay_10us(50);
}
```

Listing 2

```
void LcdPanel_SendCmd (byte nCmd)
{
byte nNib;

// High-Nibble
nNib = nCmd & 0xf0;
Twi_WriteByte(0x40, nNib);

// Enable-Puls
LcdPanel_InitEN(nNib);

// Low-Nibble
nNib = (nCmd & 0x0f) << 4;
Twi_WriteByte(0x40, nNib);

// Enable-Puls
LcdPanel_InitEN(nNib);
}
```

'enable') signal, connected to port pin P3. Unfortunately you cannot control the pins individually, and so we need to logically OR the value of the E signal bit with the status of the other port pins to create the byte to be sent. Listing 1 shows a fragment of C code to send an enable pulse to the LCD.

The second C code fragment shows how a command byte is sent to the LCD panel, split into a high nibble followed by a low nibble. The same approach is used for data bytes to be sent to the LCD, but in this case bit 2 in the assembled output byte has to be set, so that pin P2 will go High.

(110079)

Internet Link

[1] www.nxp.com/documents/data_sheet/PCF8574.pdf

Universal 3-wire Flasher Unit

for Scooters

By Georges Treels (France)

Standard scooter flasher units have two major drawbacks. First of all, they need a high enough operating current to make them switch. Hence it's impossible to operate in 'LED' mode (at less than 5 W). Secondly, they offer little or no audible warning if you forget to turn the indicator off. As scooter indicators aren't self-cancelling, many riders forget to turn them off.

The simple solution with two diodes and a sounder is effective, but quite a nuisance in town, as the beep-beep soon becomes irritating. So the aim of this project is to solve this problem. It works with loads of around 1–40 W.

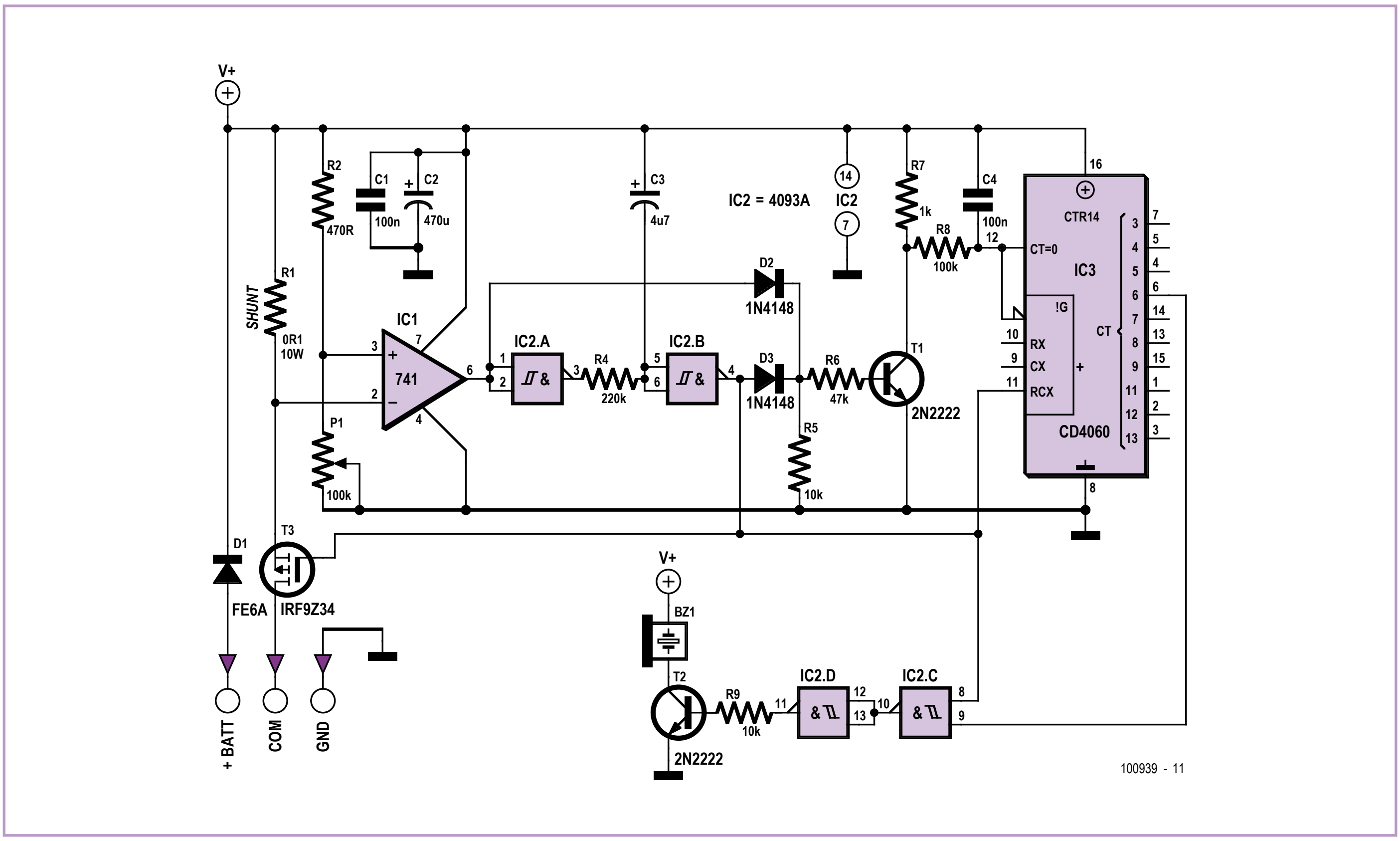
D1 protects the circuit against reversed polarity. This diode can handle up to 6 A in a small package.

Together, R1, T3, and IC1 form a current detector. IC1 is wired as a comparator and switches cleanly according to the current flowing in R1 and the setting of P1.

IC2.A and IC2.B are wired as a monostable. As soon as IC1 output goes high, R4 starts charging C3. IC2.B then goes high and T3 turns off. IC1 then switches over, IC2.B follows it a little later, and T3 turns on again. And so on...

D2, D3, R5, R6, and T1 form the equivalent of a NOR gate driving the reset of the counter that follows. This means the counter can be reset even without turning off the ignition. The counter is reset as soon as both pins 1 and 4 of IC2 are low together.

The counter IC3 is a CD4060 wired so that its output Q6 goes high every 64 pulses on pin 11. As the network R4/C3 times the switching at around a second, after around a minute IC3 output Q6 goes high and, via IC2.C,



IC2.D, and T2, the sounder operates in time with the indicator.
In the download for this article [1], you'll find the author's PCB design and a few photos of the project. The width of the board is based on the inside diameter of a 32 mm PVC tube, i.e. the standard diameter of normal flashers. The length is determined by the board's track requirements, but is well below the size the majority of scooters can accommodate.

Remember to heavily tin the tracks carrying high currents. The MOSFET doesn't need a heatsink. Fix the PCB inside the tube using hot-melt glue, taking care not to glue up the preset P1!

(100939)

Internet Link

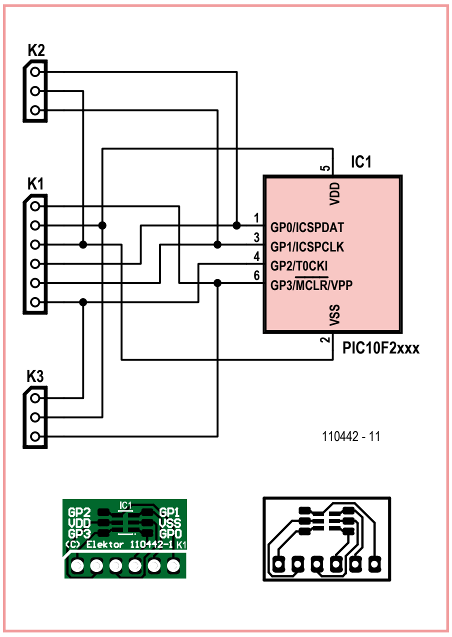
[1] www.elektor.com/100939

Breakout Board for PIC10F2xx (SOT23-6)

By Luc Lemmens (Elektor Labs)

Microcontrollers come in all sorts and sizes, and it's very tempting to use them everywhere, even for very simple tasks. Tiny, inexpensive microcontrollers especially suited to very simple tasks, such as the Microchip PIC10F2xx family, are also available. Thanks to their compact size and their ability to source or sink 25 mA on their I/O pins, these miniature microcontrollers are a good choice for driving LEDs directly in miniature lighting effect devices.

They can also operate from a 2-V supply voltage, which allows them to be powered directly by batteries (such a button cells). However, their small dimensions have a few drawbacks, especially for developing prototypes. The first drawback is that the IC leads are so small that soldering is not easy, and the lead pitch makes them difficult to use with a breadboard or perforated prototyping board. Another problem is that they can only be programmed in-system, which means that you always need an extra header for programming (even if you can find a suitable ZIF socket for a programmer, it will cost you an arm and a leg).



The small PCB described here is intended to make it easier to use Microchip PIC10F2xx devices in the SOT23-6 package without making the entire arrangement so big that you could just as well use a DIL version of the same IC.
Although the easiest way to solder the six-lead IC to the board is to use solder paste and a hot-air iron, it is in fact possible to do this with a normal soldering iron. Any excess solder can be removed with desoldering braid.
All leads are brought out to SIL connector K1, which has a more conventional 100-mil pitch and mates perfectly with a breadboard or piece of perfboard for prototype development. What's more, it is a one-to-one match to the connector of a Microchip PICkit2 or PICkit3 programmer.

The pads for the IC pins are surrounded by larger pads that can be used as attachment points for wires, resistors, LEDs and so on. Once the prototype and the firmware are finalized, the portion of the board outside these pads can be sawn off and/or filed down to make it easier to fit the board in a miniature enclosure.

(110442)

Regulator for Three-Phase Generator

By Jac Hettema (The Netherlands)

This regulator was designed for use with a generator with a higher output voltage. This type of generator can be found on some boats and on vehicles for the emergency services. They are really just an adapted version of the standard alternator normally found in cars. The field winding is connected to the 12 V (or 24 V) battery supply, whereas the generator winding is configured for the AC grid voltage (230 V or 115 V). This AC voltage now has to be kept stable via the 12 V field winding. Although it's perfectly possible to use a switching regulator for this, we deliberately chose to use the old and trusted 723.

The generator is a three-phase type, with the field winding rated for 12 V_{DC}. The output voltage of the generator depends on its revs and the current through the field winding.

Since the output voltage is relatively high, it is fed via optocouplers to the 723, which is used in a standard configuration. The output is fed via driver T1 to two 2N3055's, connected in parallel, which supply the current to the field winding.

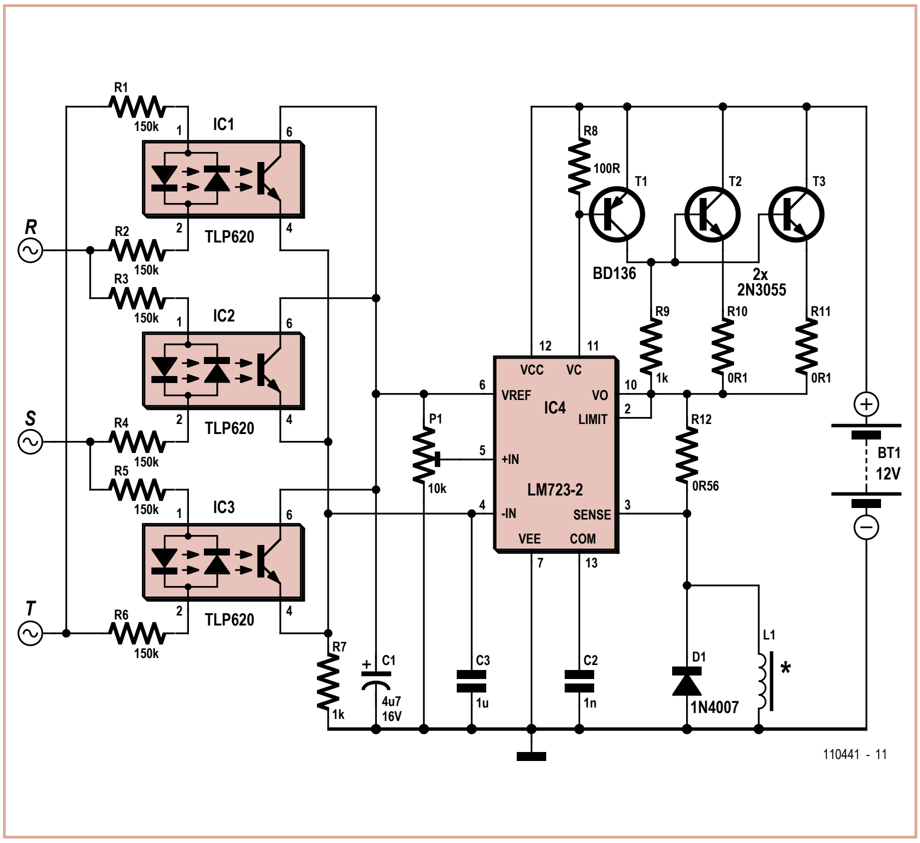
In the prototype we used TLP620 optocouplers. These are suitable for use with alternating voltages because they have two anti-parallel LEDs at the input. The regulation works quite well with these, with the output voltage staying within a small range across a wide range of revs. However, the sensitivity of the two internal LEDs can differ in this type of optocoupler, since it's not always possible to ensure during the manufacturing process that the distance between each LED and the phototransistor is exactly the same.

For a more precise regulation it would be better to use two individual optocouplers per phase, with the inputs connected in anti-parallel and the outputs connected in parallel.

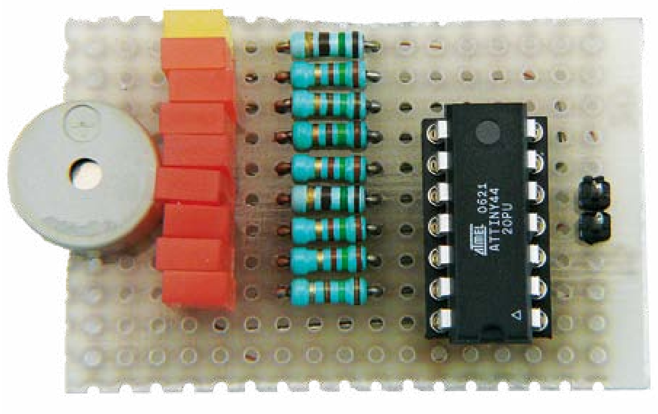
In order to ensure that there is sufficient isolation between the primary and secondary side you should make a cutout in the PCB underneath the middle of each optocoupler.

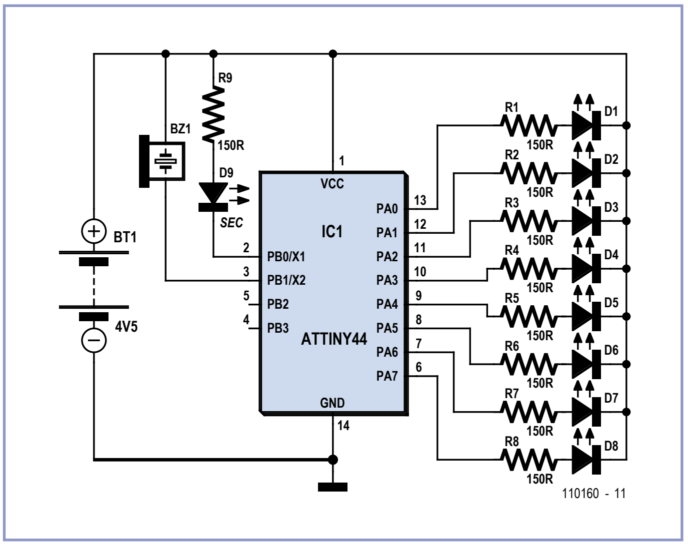
Instead of a BD136 for T1 you could also use a TIP32 or something similar. For T2 and T3 it's better to use a type with a plastic casing, rather than a TO3 case.

(110441)



Jogging Timer





by Stefan Hoffmann (Germany)

Regular physical exercise is important, especially for those of us who spend most of our day sitting at the lab bench. Jogging is one of the most popular and effective forms of exercise, and it is i mportant to have a systematic training regime.

That is where the jogging timer described here can help. Every ten minutes it emits a brief tone using its piezo buzzer and it indicates how many of these ten-minute periods have elapsed using a series of eight LEDs. Thus the electronics engineer on the jog can save him- or herself the price of a special purpose watch.

At the beginning of the training period, switch the device on and tuck it in your pocket.

Since the device has an acoustic signal, there is no need to look at it to check progress, and you can devote your full concentration to your running. If you wish, however, you can glance at the display at any time to see how many ten-minute periods have elapsed so far.

The circuit is based on an Atmel ATtiny44 microcontroller programmed using BASCOM. On power-on it carries out a brief test of buzzer and LEDs. A timer interrupt causes the 1 Hz LED to flash so that it is always possible to check that the timer is running, and at the same time a seconds counter is incremented. Every ten minutes a sound is produced using the buzzer and a further LED is switched on.

The BASCOM source code is available free at [1]. The code is easy to modify and the free demo version of BASCOM is adequate to compile it.

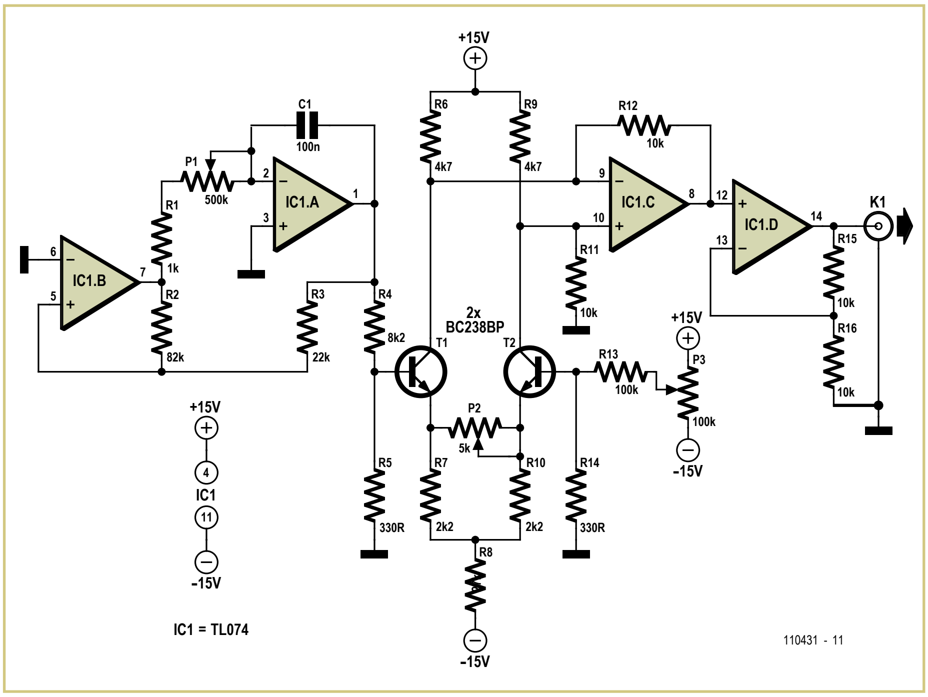
(110160)

[1] http://www.elektor.com/110160

Triangular Wave Oscillator

with Sine Wave Converter

By Jac Hettema (The Netherlands)



This design resulted from the need for a partial replacement of the well-known 8038 chip, which is no longer in production and therefore hardly obtainable.

An existing design for driving an LVDT sensor (Linear Variable Differential Transformer), where the 8038 was used as a variable sine wave oscillator, had to be modernized. It may have been possible to replace the 8038 with an Exar 2206, except that this chip couldn't be used with the supply voltage used. For this reason we looked for a replacement using standard components, which should always be available.

In this circuit two opamps from a TL074 (IC1.A and B) are used to generate a triangular wave, which can be set to a wide range of frequencies using P1. The following differential amplifier using T1 and T2 is configured in such a way that the triangular waveform is converted into a reasonably looking sinusoidal waveform. P2 is used to adjust the distortion to a minimum.

The third opamp (IC1.C) is configured as a difference amplifier, which presents the sine wave at its output. This signal is then buffered by the last opamp (IC1.D). Any offset at the output can be nulled using P3.

(110431)

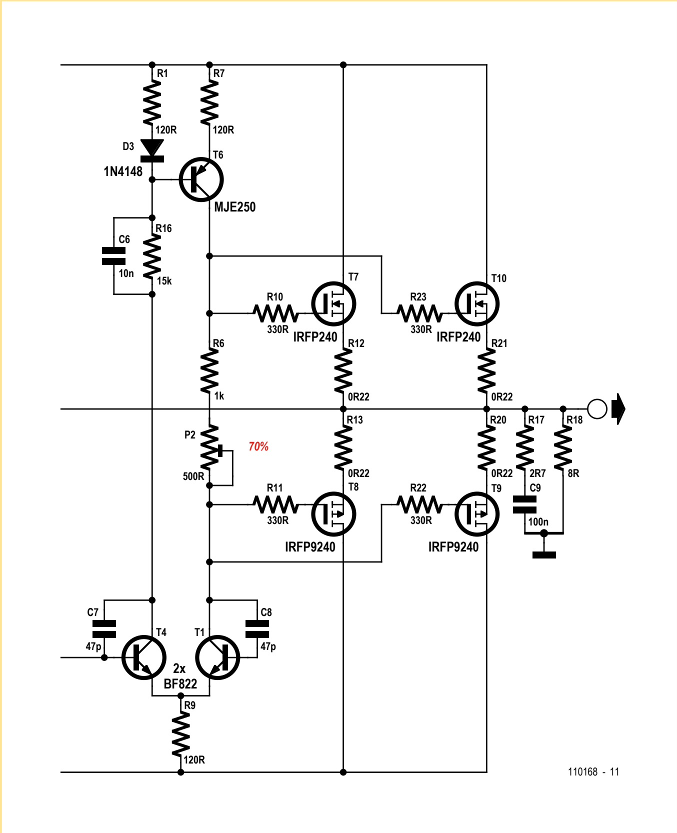
Equalizing HEXFETs

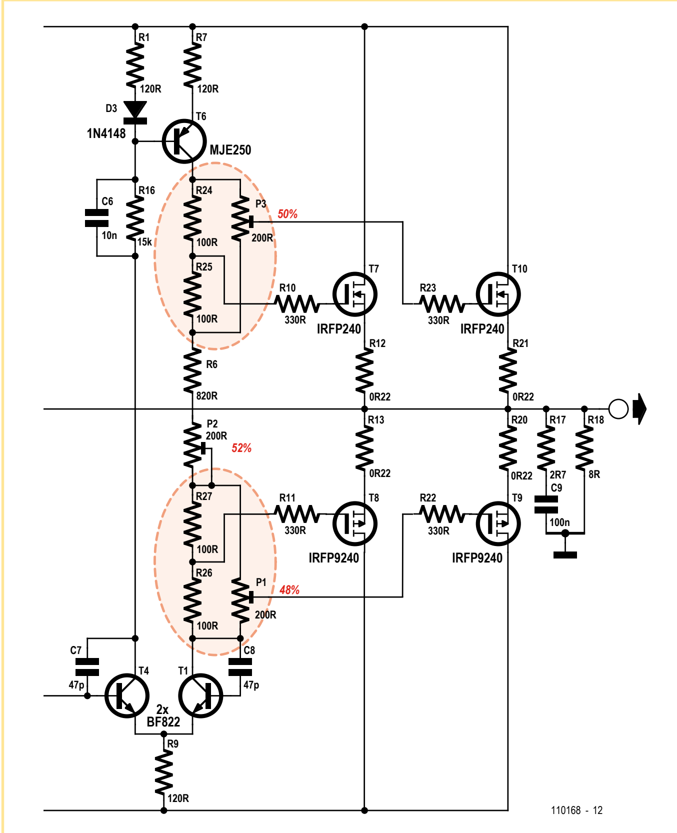
By Alfred Rosenkränzer (Germany)

When experimenting with audio output stages featuring multiple HEXFETs it quickly becomes apparent that the total power is not divided equally among the individual transistors.

The reason for this lies in the wide part-to-part variations in gate-source voltage, which in the case of the IRFP240 (or IRFP9240) can be from 2 V to 4 V. Source resistors in the region of 0.22 Ω as commonly seen in amplifier circuits (see example circuit extract) help to counteract this, but usually not to a sufficient extent.

One possible solution to this problem is to 'select' the transistors used so that their gate-





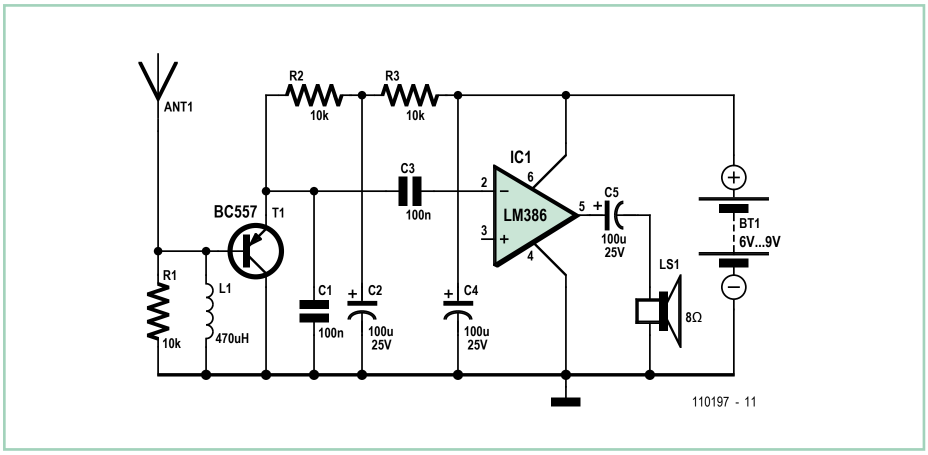
source voltages match as closely as possible. For building prototypes or very short production runs this is feasible, but requires additional manual effort in testing the components, and, of course, more transistors must be ordered than will finally be used.

The circuit idea shown here allows differences in gate-source voltage between pairs of transistors to be compensated for by the addition of trimmer potentiometers: the idea has been tested in simulation using Simetrix. The second circuit extract shows the required changes.

(110168)

Wideband Receiver for Spark Transmissions

By Burkhard Kainka (Germany)



In the early years of radio technology spark transmissions ruled the (air) waves. They occupied a relatively wide bandwidth, in what came to be known as the long waveband. The receivers used had a corresponding bandwidth, as 'wide open' as the proverbial 'barn door'. Most were simple detectors without an amplifier stage.

Today when you operate an electric light switch you produce a wideband spark that's audible on some radios as a crackle from long through to short waves. The same occurs with intermittent breaks in cables, high voltage strikes, defective transformers, poorly suppressed electric motors and all kinds of contacts that open and close.

With a suitable receiver it's possible to track down the source of these problems. Tests using normal radios are largely unsuccess-

ful, simply because they display restricted bandwidth and are too effective at suppressing short interference pulses. After some research the best results were obtained with a wideband Audion receiver.
The requirements for this kind of receiver are totally different from normal radio reception: the receiver must have bandwidth as wide as possible, with maximum sensitivity in the long wave region. A further special request: since the wave packets of a single spark are often extremely short, the receiver should integrate them into a longer pulse whose spectrum should lie well inside the audible range.
As for the circuit, the audion stage in the collector circuitry detunes the input circuit. To prevent self-oscillation we need to add a 10 kΩ resistor. Using an oscilloscope you can see extremely short pulses on the emitter of the BC557 being broadened. The amplitude is frequently sufficient to drive the final amplifier into limiting. A 1 µs long input pulse results in a circa 1 ms long audio pulse in the loudspeaker.

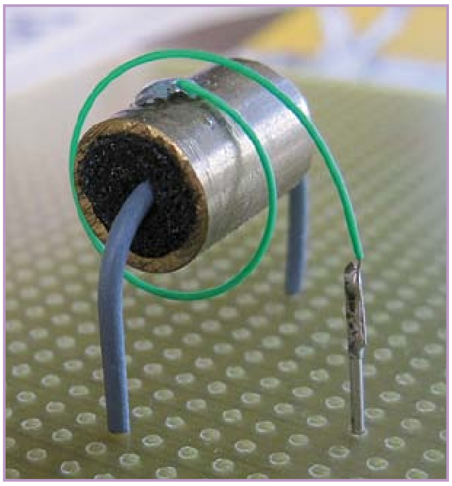
(110197)

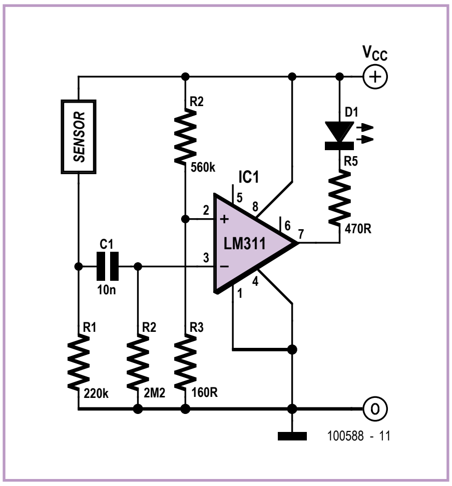
Cheapest Ever Motion Sensor

By Antoni Gendrau (Spain)

The RS-455-3671 sensor used in the Automatic Rear Bicycle Light project published in the July/August 2010 edition can be replaced by a motion sensor that costs nothing instead of a fiver or thereabouts.

The replacement is a homemade device, built from components easily found in the workshop of any electronics enthusiast. Effectively it works as a variable resistor, depending on the acceleration force to which the device is submitted. A prototype presented a resistance of 200 kΩ when not moving, and 190 kΩ when dropping about 1 cm.





Constructing is easy. Cut off a piece of about 10 mm of copper tubing. Take a piece of conductive foam, the kind used to protect integrated circuits. Cut a rectangular piece of 10 x 50 mm. Roll up firmly until it can be push-fitted securely into the copper cylinder. Then insert a conductive wire through the center of the cylinder, bend it and (optionally) add protective plastic sleeving to each side. This is the first contact. Finally, solder a thin wire to the copper cylinder. This is the second contact.
The foam resistance is pressure dependent. Consequently, when the device moves due to an external force, the inertia of the cylinder causes varying pressure in the foam, resulting in a small change of resistance between the inner conductor and the cylinder. Because of that, it's important to ensure the cylinder vibration is not restricted in any way by the connecting wire or the PCB.

The comparator circuit shown here is capable of resolving the resistance change of the proposed foam/wire/copper sensor, allowing it to detect the motion of a vehicle for alarm or other purposes.

(100588)

Repeatable COM Port Enumeration

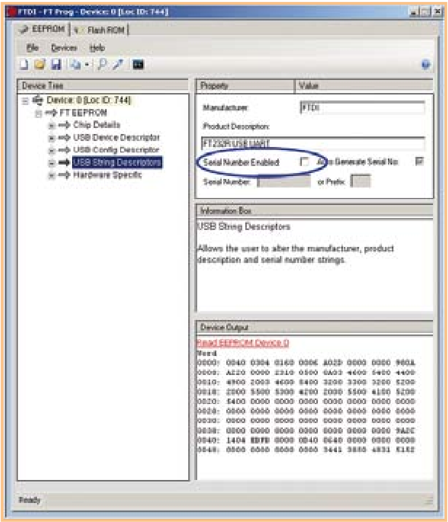
By Michael Gaus (Germany)

The popular FTDI FT232R USB UART converter chip is used in many projects where a USB interface is required. However, there is an unfortunate effect that occurs if you use many peripherals with this device in them on one computer simultaneously. When the computer enumerates its USB peripherals it assigns COM port numbers to the devices in ascending order as it detects them: this means that the COM port number of each board needs to be set manually each time in the corresponding software. It would be much more convenient if each physical USB port on the PC always corresponded to the same COM port number. Luckily, there is a way to do this.

During manufacture the USB converter chip is programmed not only with a vendor ID (VID) and a product ID (PID) but also a unique serial number in its on-chip EEPROM [1]. When Windows detects a device with a new VID, PID and

serial number it kicks off the familiar 'new hardware found' process and automatically allocates a new COM port number.
The handy tool 'FT_Prog' (available for free download from the manufacturer's website [2]) allows the FT232R to be reconfigured in a simple way to avoid the serial number being taken into account during enumeration [3]. The procedure is as follows.

1. Connect the FT232R to the USB port. Since in a factory-fresh FT232R the serial number is still 'enabled', the device will as usual be allocated the next available COM port number.
2. Start up the 'FT_Prog' tool. Make sure that the virtual COM port allocated to the FT232R device in question is not being kept open by a terminal program or other application software.
3. Under 'Devices' click on 'Scan and Parse'.
4. Click on 'USB String Descriptors' and remove the tick by 'Serial Number Enabled'.
5. Under 'File' click on 'Save As Template': this stores the configuration.
6. Under 'Devices' click on 'Program', and then once more on 'Program'.



Once the programming process is complete it is essential to click on 'Cycle Ports', which will enumerate the FT232R devices afresh. The FT232R will now be allocated a COM port number that corresponds to the physical USB port.
A disadvantage of this process is that each factory-fresh FT232R device that is to be programmed will initially be assigned a new COM port number when it is first connected. If you have a large number of FT232Rs to program on the same PC, you may run out of available ports. This can be circumvented by adding a new entry to the Windows registry (although this is not a job for the faint-hearted!).
In the registry under
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\UsbFlags\
make a REG_BINARY entry called 'IgnoreHWSerNum04036001' and set its value to 01. Now all new FT232Rs will also be assigned a (virtual) COM port number based on the physical USB port to which they are connected.

(110207)

Internet Links

[1] www.ftdichip.com/Documents/AppNotes/AN_123_How%20COM%20Ports_Are%20Allocated%20on%20Driver_Installation.pdf

[2] www.ftdichip.com/Support/Utilities.htm

[3] www.ftdichip.com/Support/Documents/AppNotes/AN_124_User_Guide_For_FT_PROG.pdf

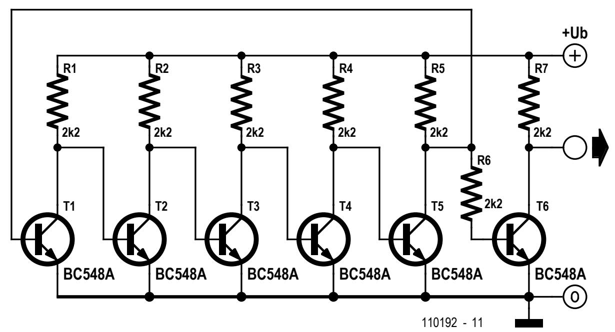
Ring Oscillator

By Burkhard Kainka (Germany)

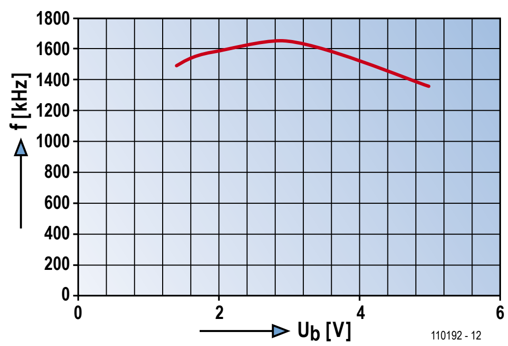
The ring oscillator comprises a number of inverting transistor amplifier stages connected in series, in which the output of the final stage is connected to the input of the first stage.

You have the choice of using three, five, seven or nine stages. The only condition is that the number must be odd, not even. A feature of this circuit is that no capacitors are required. Oscillators of this kind are used widely in integrated circuits, for instance in microcontrollers.

In principle we are dealing with an amplifier with negative feedback that reaches oscillation as a result of the high total amplification. In the circuit shown in **Figure 1** five stages are employed. To avoid affecting the ring a buffer stage is used for uncoupling the oscillator signal. All resistors in the circuit have a value of 2.2 kΩ and all transistors are type BC548A.
The oscillator produces a frequency upwards of 1 MHz, which is somewhat dependant on the power supply voltage (see **Figure 2**). An average maximum frequency of 1650 kHz is produced with an operating voltage of 3 V.



1



2

The ring oscillator can be viewed in its broadest sense as a run-time oscillator. The signal run-time of all five stages amounts to half the oscillation period, in other words exactly 300 ns at 1.65 MHz. Every individual stage then has a run-time of 60 ns. At higher operating voltages the delay introduced by each stage increases somewhat, because the transistors are driven heavily into saturation.

(110192)

Scepter: Driving a Touch Screen Arduino-style

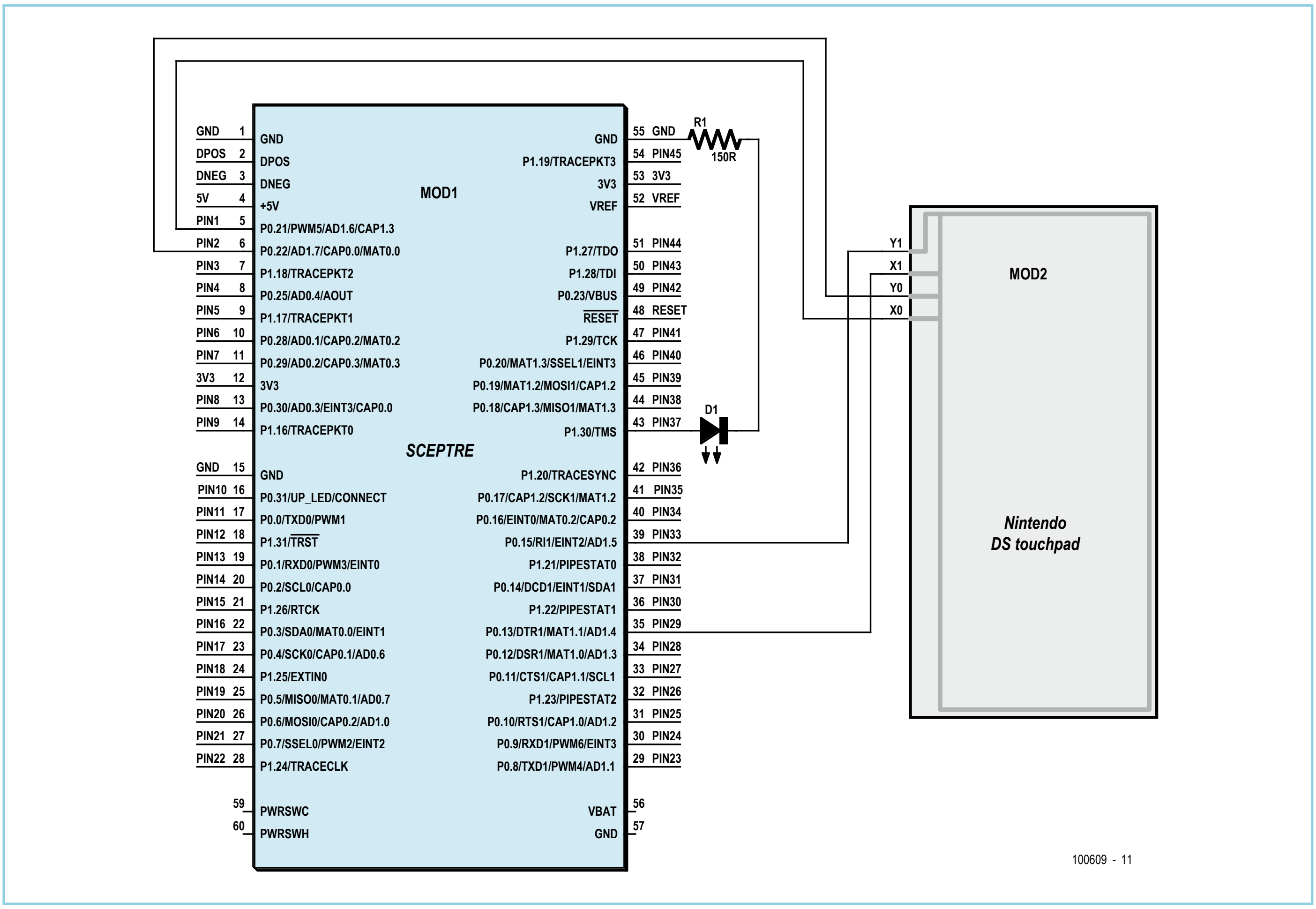
By Clemens Valens (France)

It's not hard to find inexpensive replacement resistive touch screens for the Nintendo DS games console on the Internet. When the Scepter was being designed, the idea of using it with this type of touch screen had already been considered — indeed, that's why a space was left between connectors K6 and K7 (to run the connecting wires).

When designing a board, lots of things are often planned for, but not necessarily all implemented. Thus one of the things planned was a library for programming the Scepter like Arduino, i.e. using a 'sketch', a 'loop', and X and Y are all it takes to find the position (x,y) where it is being pressed. In practice, each potentiometer actually has a pair of wipers, which are the contacts of the other potentiometer. When a voltage is applied to the X potentiometer, the voltage is read off one of the two Y potentiometer contacts, and vice versa. Thus when driving this type of screen, the ports driving the X and Y potentiometers are constantly changing roles: at one moment they act as outputs to apply a voltage to the potentiometer, and the next moment they act as analog inputs to measure the wiper voltage.

varnish at the point where this flexible PCB is at its widest.

Now let's turn to programming Arduino-style. To start off, we have renamed the Scepter's usable ports to obtain a total of 45 'pins'. Then, a table was drawn up showing these pins and the corresponding possible functions they can have, which enables us to find out if a certain pin can be used for a certain function. PIN4 for example can be used as a digital input, digital output, analog output (a real one!), and an analog input. Now, in the software, we can declare a digital output like this `pinMode(PIN37,OUTPUT)`



a number of reconfigurable (input/output) 'pins'. So why not drive the touch screen in this Arduino manner — thereby killing two birds with one stone? Well, that's just what we're going to do here.

A resistive touch screen is nothing more nor less than two X and Y potentiometers whose wiper positions are determined by the position where you press on the screen. The potentiometers are powered in turn and the wiper voltages measured. Two measurements

So to drive a resistive touch screen with only four ports, the ports need to be reconfigurable. On the Scepter, the plan was to use ports P0.13, P0.15, P0.21, and P0.22 (which also offer ADCs AD1.4–AD1.7) for driving a touch screen. It's not hard to connect up the screen to the Scepter. You can use the special miniature Nintendo DS connector (which can be found on the Internet), but you can also just solder the wires directly onto the screen's flexible PCB, after scratching off a bit of the

and if PIN37 is capable of fulfilling this function, it will be a digital output. The `digitalWrite(PIN37,HIGH)` function then allows us to set a high on PIN37; the `digitalWrite(PIN37,LOW)` function sets it low. For the analog side of things, just as in Arduino, a pin becomes an analog input (output) (if this is possible, of course) as soon as we go and read from it (write to it).

Driving the touch screen now becomes simple:

```
pinMode(PIN2,INPUT);            // Y0 digital input
pinMode(PIN1,OUTPUT);           // X0 digital output
pinMode(PIN29,OUTPUT);          // X1 digital output
digitalWrite(PIN29,HIGH);       // X1 → high
digitalWrite(PIN1,LOW);         // X0 → low
value= analogRead(PIN33);       // Read voltage on "wiper" Y1
```

Then repeat these instructions, but changing PIN1 to PIN2 and PIN29 to PIN33 to obtain the other coordinate.

Note that even when reading only one analog input (Y1), the potentiometer's other pin (Y0) must be disconnected from the screen in order to avoid the measurement's being influenced. This is why is has been declared as a digital input.

A number of Arduino-style analog outputs, i.e. 490 Hz PWM outputs, have also been implemented.

In order to communicate with a computer like an Arduino, the functions `Serial _ begin`, `Serial _ write` and `Serial _ write _ int` are available. The difference in the notation compared with Arduino is simply due to the fact that the Arduino library for the Scepter is programmed in C and not C++.

In order to simulate an Arduino 'sketch', we first call the *setup* function from `main`, then `main` will periodically call the `loop` function from an endless loop. Take a look at the `sketch.c` file [1] to see just how close the result is to a real Arduino sketch.

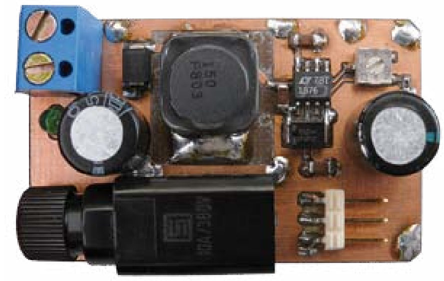
The source codes (`app _ touchpad`) and the updated Scepter library are available from [1].

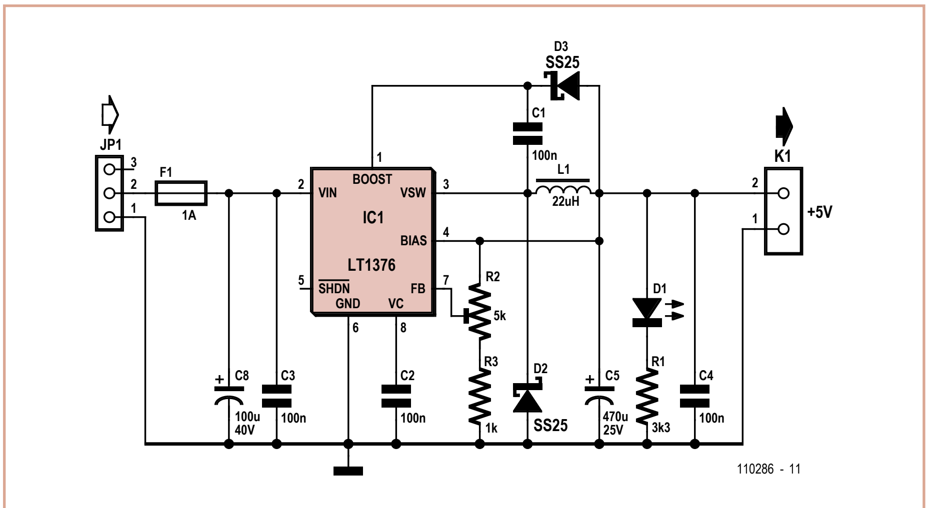
(100609)

Internet Link

[1] www.elektor.com/100609

DC/DC Converter using LT1376





By Albert Bitzer (Germany)

A switching regulator with an adjustable output voltage is a handy weapon in the battle to reduce heat dissipation in circuits. The step-down converter described here can be used with input voltages from 7.5 V up to 25 V and can deliver an output current of up to 1.5 A. At its minimum output voltage of 3.3 V the circuit can even operate from a 5 V input.

The circuit is built around a Linear Technology LT1376 and is mostly based on the design given in the device's datasheet [1]. The minimum inductance and current rating of choke L1 depend on the maximum output current desired from the circuit. For example, at 0.6 A an inductance value of 5 µH is suitable; at 1 A the minimum value is 10 µH; and at 1.5 A a 20 µH inductor is required. In the circuit diagram we show a value of 22 µH.

The maximum possible output voltage obtainable depends on the input voltage available and the required output current: the datasheet contains all the relevant information. The adjustment range of R2 should be sufficiently large in all cases to allow output voltages from 3.3 V to 14.5 V to be obtained. With the component values shown the expected typical characteristics of the circuit are as follows.

U_{IN}	U_{OUT}	I_{OUT} (max)
5 V	3.3 V	1.5 A
8 V to 10 V	5 V	1.4 A
12 V to 18 V	10 V	1.3 A

The maximum available output current is also highly dependent on the quality of choke L1 and electrolytic capacitor C5. For the inductor, the DC current and resistance ratings are critical in addition to its inductance. The current rating should be at least double the maximum desired output current of the circuit and the DC resistance as low as possible. For the capacitor, a low ESR is essential.

The author has designed a small printed circuit board (measuring 31 mm by 52 mm) for assembling the circuit: the board also has space for a protection fuse. The layout and schematic files are available for free download in Eagle format at [2].

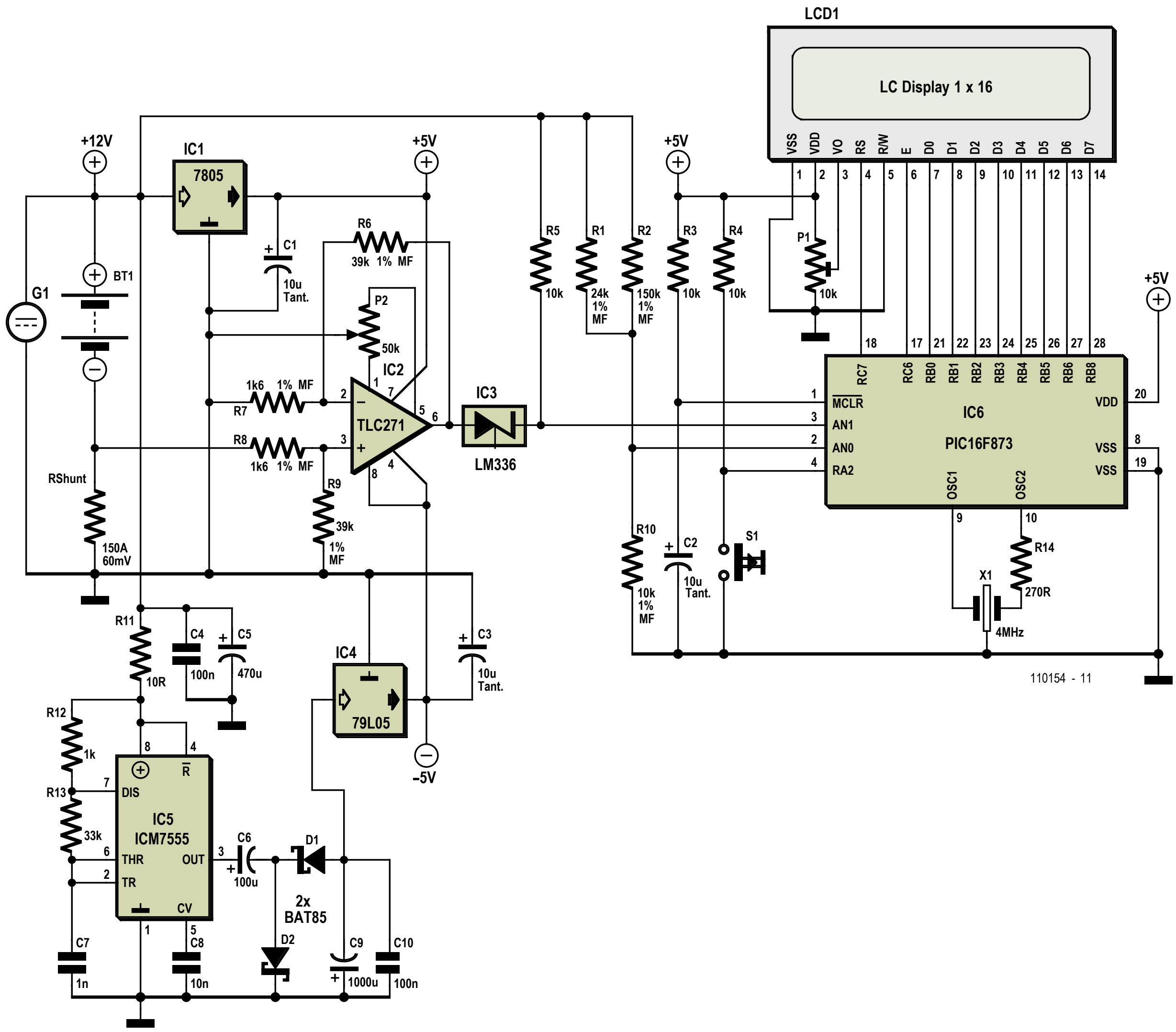
(110286)

Internet Links

[1] www.linear.com/product/LT1376 (datasheet)

[2] www.elektor.com/110286 (downloads)

Battery Charge Monitor



By Dieter Kohtz (Germany)

The circuit described here provides monitoring of the charge status of a battery by the continuous measurement of charge and discharge currents. The battery current is integrated over time (respecting its sign), and net consumption is shown on a display. The charge stored in the battery can be calculated as a result of this process, and this calculation does not involve the battery's terminal voltage.

The current flowing out of or into the battery is passed through a 0.4 mΩ series resistor in the circuit. Power for the circuit is drawn from the battery under test. The TLC271 operational amplifier, wired as a differential amplifier, requires a symmetrical supply in this application, and for this reason a diode pump circuit driven by a 7555 CMOS timer IC acting as an astable multivibrator is included to generate a negative voltage. The ±5 V supplies for the opamp are then derived using positive and negative fixed voltage regulators. The +5 V supply also powers the rest of the circuit, including the LCD panel.

The current sense amplifier is designed to produce a signal suitable for subsequent digital processing as follows. A current of between +150 A and –150 A produces a voltage drop across the shunt of between +60 mV and –60 mV. The gain of the amplifier is chosen that a current of ±150 A corresponds to a range of ±300 LSBs in the output of the ten-bit ADC inside the microcontroller. With a reference voltage of 5.00 V this in turn corresponds to a voltage range of ±1.466 V. The required gain is thus 1466/60= 24.43. Metal film resistors are used to set the gain with sufficient accuracy. The LM336 voltage reference at the output of the opamp offsets the output voltage by 2.5 V, half the reference voltage of the ADC. Small errors in this voltage can be compensated for by adjusting the offset voltage of the opamp.

To measure the battery voltage, whose nominal value is 12 V, it is connected to the second ADC input via a voltage divider. If there is 15 V across the battery the divider is designed to produce an output voltage of 4.888 V, which corresponds to 1000 LSBs at the ADC output. Again, the voltage divider can be constructed with sufficient accuracy using metal film resistors.

The measurement results are shown on a one-line LCD panel. The firmware running in the PIC16F873A microcontroller provides the following functions.

1. Measurement of voltage and current at regular intervals.
2. Integration of current values (respecting sign) over time to measure total net consumption.
3. Storage of calculated net consumption values in internal EEPROM.
4. Selectable display of current, voltage and net consumption.

The program is written in assembler and the main part consists of four loops with execution times of 45 ms, 225 ms, 1125 ms and 72 s. The processor is idle within the 45 ms loop, whose timing is controlled by TMR0: the purpose of the loop is solely to make overall timing precise. Every 225 ms the button is polled, to see if the user wishes to cycle the display through current, voltage and consumption readings. In the third loop, every 1125 ms, voltage and current readings are taken. After each ADC conversion result is fetched it is converted into a format suitable for display. Each current reading is added into an accumulator, taking account of its sign. The 1125 ms loop is executed 64 times, so that over a period of 72 s a total of 64 current readings are summed. After 72 s have elapsed a mean current is calculated by dividing this sum by 64. The reason behind using a 72 s averaging period is that the main purpose of the circuit is to integrate current over time. In a digital system this cannot be done continuously: the readings have to be sampled. In the conversion results for the current readings, 1 LSB corresponds to 0.5 A, and averaging these values over 72 s = 0.02 h means that one LSB in the final result neatly corresponds to a consumption of 0.01 Ah.

The program takes account of the fact that when charging not all the current flowing into the battery ends up as stored charge: a multiplicative correction factor of 0.7 is applied.

The prototype of the circuit was constructed on a piece of perforated stripboard. First P1 is used to adjust the contrast of the LCD. Then offset potentiometer P2 is set by putting the unit into current display mode with no battery connected (and hence with 0 V across the current sense resistor), and adjusting for a zero reading. This compensates for any offset error in IC2 as well as for the tolerance in the 2.5 V reference IC3.

The software for the microcontroller (hex file and source code) is available for download free of charge from the Elektor website [1]. One further note: the first six entries in the PIC's EEPROM are set to zero when it is programmed. This is necessary because the program reads these entries to initialise its consumption counter at power-up.

(110154)

Internet Link

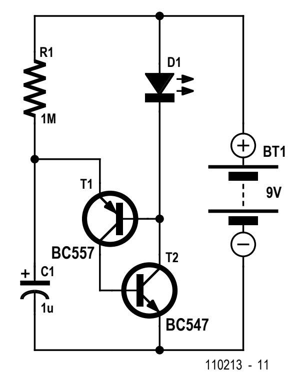
[1] www.elektor.com/110154 (free software download)

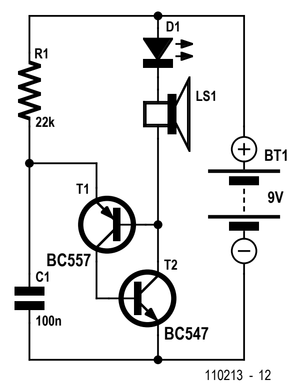
Mini Flasher

Frank de Leuw (Germany)

This LED flasher is made up from just five components and is an ideal circuit for novices to experiment with. Operation of the circuit is quite easy to understand.

With a battery connected to the circuit capacitor C1 is charged through the 1 MΩ resistor R1. The capacitor is connected to the emitter of the PNP transistor (BC557). This transistor's base junction is connected to the positive 9 V supply via an LED. So the potential at the base junction will be equal to the supply voltage minus the forward voltage drop of the LED. A red LED will give a forward voltage drop of around 1.6 V so the voltage level on this transistor's base junction will be 9 V – 1.6 V = 7.4 V.





When the rising voltage on the capacitor reaches a level to forward bias the base-emitter junction of the PNP transistor current will start to flow through its emitter-collector junction. The current flow causes the base-emitter junction of the NPN transistor to become forward biased, switching it on. Now it's conducting its collector will be close to ground potential, pulling both the LED cathode and the PNP transistors base to ground, reinforcing the ON condition of the PNP transistor and causing a relatively high current to pass through the LED to emit a flash.

When the capacitor is discharged the transistors turn off again and the process is repeated. The values given in the circuit diagram (C1 = 1 µF, R1 = 1 MΩ) will make the LED flash briefly once every two seconds.

The circuit will still run with a battery voltage as low as 2 V and uses so little current that a new 9 V battery will keep the circuit flashing for many months in continuous operation.

Even old 9 V batteries with too little charge left to power other applications could be used to power the circuit.

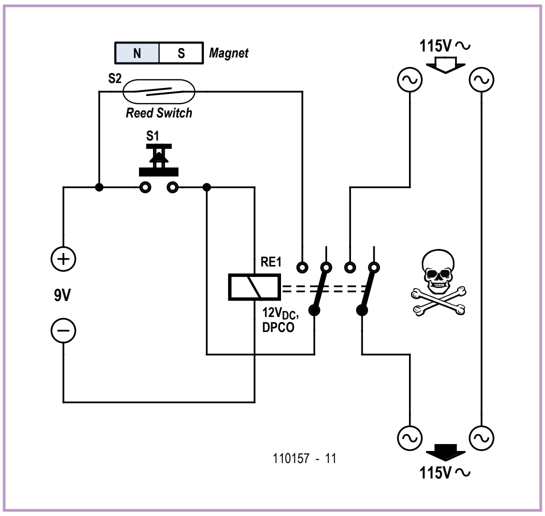
The second circuit diagram shows that the basic circuit can be simply modified to make a metronome or tone generator. A low-power 8 Ω loudspeaker is now connected in series with the LED. The sound produced by the loudspeaker will either be a repetitive click or a tone depending on the values of capacitor C1 and resistor R1. Reducing the values of R1 and C1 will make the circuit oscillate more quickly. The second circuit uses values of 22 kΩ for R1 und 100 nF for C1.

(110213)

Automatic AC Power Switch

for the Holiday Home

By Stefan Hoffmann (Germany)



Electrical appliances accidentally left on in (holiday) homes left unoccupied for a short or a long period consume power unnecessarily and can present a fire hazard. Everyone will be familiar with those nagging thoughts, a few miles down the road from the house: “Did I remember to switch off the coffee machine? The lights? The oven?”

Hotel rooms are often equipped with a switch near the main door which enables the power supply to everything in the room only when the plastic card (which might contain a chip or have a magnetic strip or a pattern of holes) that serves as the room key is inserted. The circuit idea given here to switch off lights and other appliances is along the same lines. The solution is surprisingly simple.

A reed contact is fitted to the frame of the main entrance door, and a matching magnet is attached to the door itself such that when the door is closed the reed contact is also closed. To enable power to the house, press S1 briefly. Relay RE1 will pull in and complete the circuit for all the AC powered appliances in the house. The relay will be held in even after the button is released via the second relay contact and the reed contact (‘latching’ function).

As soon as the main entrance door is opened, the reed contact will also open. This in turn releases the latch circuit and consequently the relay drops out. The various connected appliances will thus automatically and inevitably be switched off as soon as the house is left.

The circuit is principally designed for small holiday homes, where this mode of operation is particularly practical.

Of course, for any circuit that deals in AC powerline voltages, we must mention the following caution.

Caution: shock hazard!

Construction and connection of this circuit should only be carried out by suitably-qualified personnel, and all applicable electrical safety regulations must be observed. In particular, it is essential to ensure that the relay chosen is appropriate for use at domestic AC grid voltages and is suitably rated to carry the required current.

(110157)

Experimental Hall Sensor

By Burkhard Kainka (Germany)

Hall sensors can of course be purchased but making them yourself is far more interesting (and satisfying)!

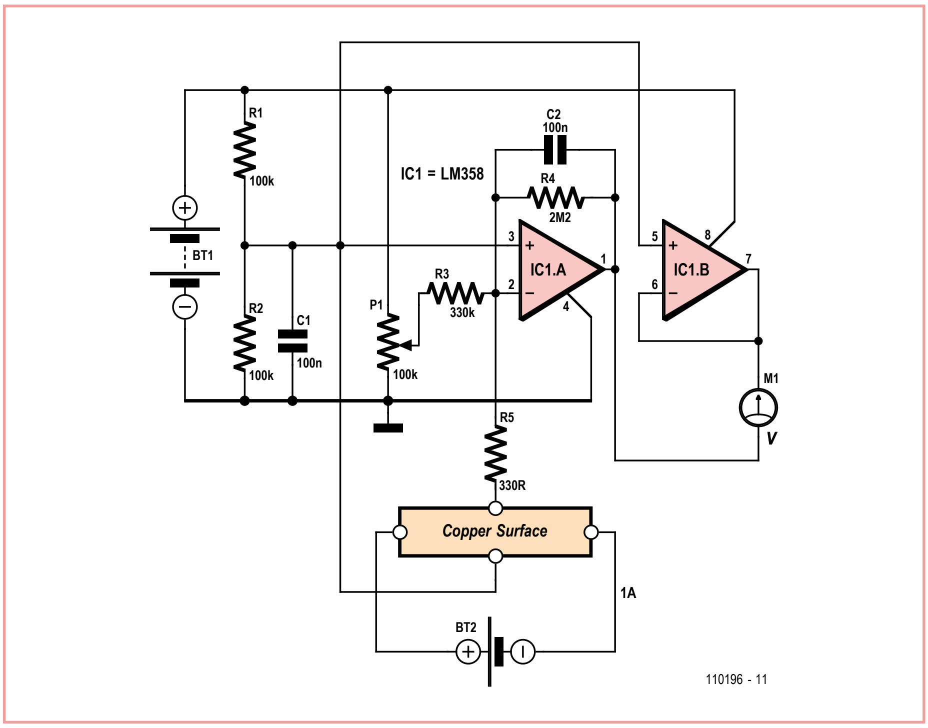
According to the theory the crucial thing is to use a touch layer that’s as thin as possible; the length and width are unimportant. An ‘obvious’ starting point for our trials would be copper, which in the form of printed circuit board material is easy to find and handle. Copper-clad board may be obvious but not ideal, because it has a very weak Hall constant. Nevertheless we should be able to use it to demonstrate the Hall effect by using very powerful magnets in our sensor.

To achieve detection we need the highest possible level of amplification. In the circuit shown here the voltage amplification is set by the relationship of the two feedback resistors of the first op-amp. With the values given (2.2 MΩ and 330 Ω) produce a gain of 6,667. This also creates a convenient bridge connection for taking measurements. The trimmer potentiometer allows fine adjustment. With zero setting that’s accurate to within millivolts we could use this test point to measure Hall voltages of well below a microvolt. Finally in this way we could also measure the flux density of a magnet.

Copper has a Hall constant of $A_H = -5.3 \cdot 10^{-11}$ m^3/C. The thickness of the copper layer is $d = 35$ µm. The Hall voltage then amounts to:

$$V_H = A_H \times I \times B \,/\, d$$

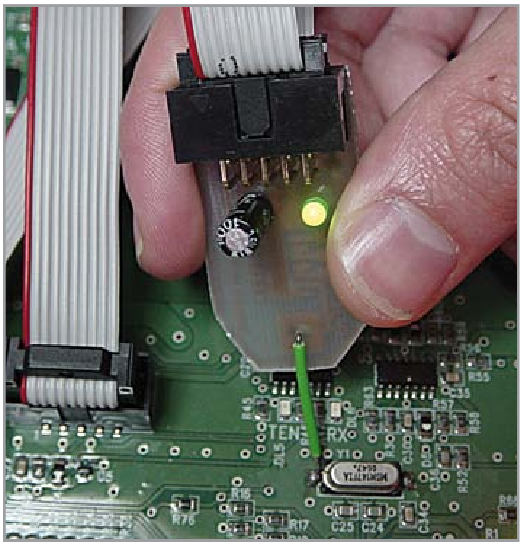
When the field $B = 1$ T and current $I = 1$ A a Hall voltage of $V_H = 1.5$ µV is produced. The 6,667-fold gain then achieves a figure of 10 mV. The circuit thus has a sensitivity of 10 mV per Tesla. That said, adjusting the zero point with P1 is not particularly easy. The amplifier has a separate power supply in the form of a 9 V battery (BT1). To take measurements we connect a lab power supply with adjustable output current (BT2) to the Hall sensor (the copper surface) and set the current flowing through the sensor to exactly 1 A. Then the zero point must be adjusted afresh.



Next we place a strong Neodymium magnet below the sensor. The output voltage of the circuit should now vary effectively by several millivolts. Note that there are several effects that can influence the measurements we take. Every displacement of the magnet will produce an induction voltage in the power feed wires that is significantly greater than the Hall voltage itself. Every time you move the magnet you must wait a while to give the measurements time to stabilize. With such small voltage measurements problems can also arise with thermal voltages due to temperature variations. It's best not to move and inch — and to hold your breath as long as possible!

(110196)

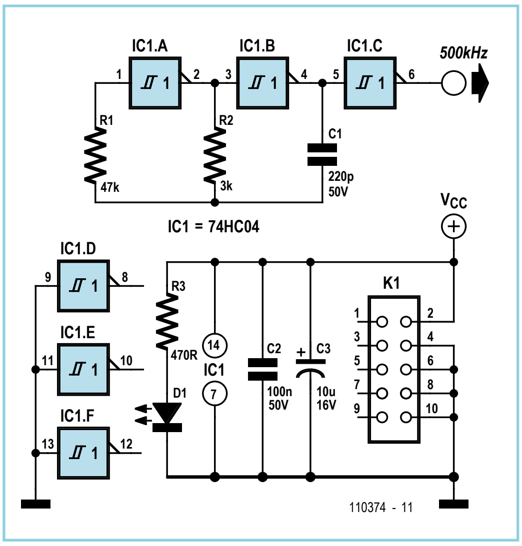
Reanimating Probe for AVR µC



By P. Rondane (France)

"AVR device not responding" When this discouraging message appears while you're programming your Atmel microcontroller, that's where the problems really begin! The problem is often due to incorrect programming of the fuse bits. This is where the unblocking probe comes into play...

Once the whole thing is powered up, all you have to is use one hand to apply the tip of the probe to the microcontroller's XTAL1 input and then use your other hand to go ahead and program it with your favorite software. And there, your microcontroller is saved!



The electronics are as simple as can be, the aim being to design something cheap and easy to reproduce. It consists of an oscillator generating a rectangular wave at around 500 kHz, built using a 74HC04. This circuit will also work with a 74HC14, but depending on the make of IC, the frequency of around 500 kHz may vary by around ±50 kHz. This doesn't affect the operation of the probe.

The unblocking board is connected using a

ribbon cable, terminated with two female HE10/10 connectors. The pinout of the HE10/10 connector is the same as used in the majority of circuits, but of course it can be adapted for an HE10/06 connector.
The first connector is connected to the board to be unblocked, which allows powering of the electronics. The second connector is connected to the ISP programmer (STK200 compatible). The contact at the crystal is made using a needle, to ensure contact even through a board that has been varnished. There's no need to unsolder the crystal for this operation.

The PCB design in Eagle format is available from [1].

(110374)

Internet Link

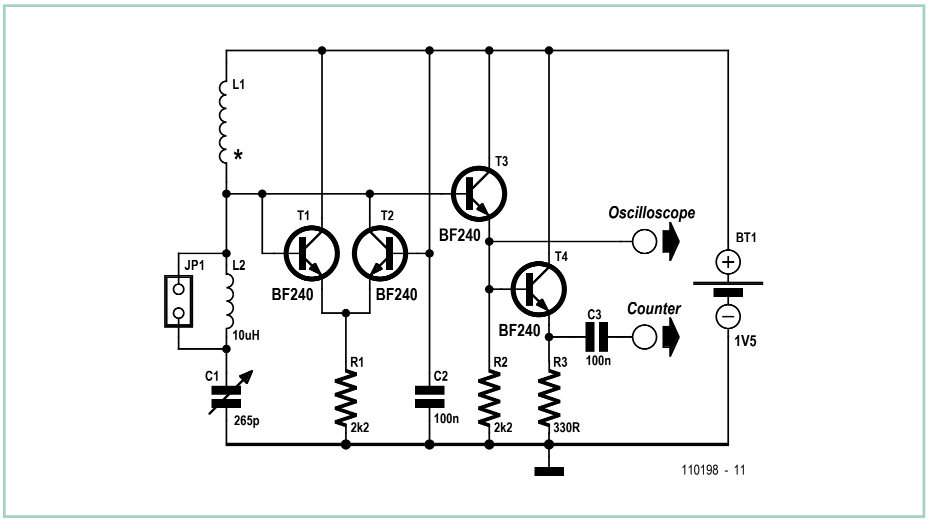
[1] www.elektor.com/110374

Minimalist Dip Meter

By Burkhard Kainka (Germany)

In days gone by a radio amateur always had a dip meter close to hand in his 'shack'. Now that people can afford oscilloscopes, the poor old dip meter has lost its importance and is frequently no longer to be seen. Actually this is a shame because many tasks are much easier to carry out with a dip meter. Anyone who's interested (perhaps the second time around) can easily build one rapidly with this very simple but adequate circuit. The interesting question is namely what do you actually need from a dip meter?

- A visual display of the dip? Nope, the 'scope can handle that task.
- A large frequency scale? Not necessary, as you can connect a frequency counter for this.
- A selection of coils? We don't need these because we can use a jumper to change range (no coils to lose any more!).



The sensor coil L1 has ten turns and is wound using an AA-size battery as a former. This coil will allow us to over the range from 6 MHz to 30 MHz. With jumper JP1 open an additional fixed inductance of 10 µH comes into circuit. The frequency measurement range is then from 2.5 MHz to 10 MHz. The switch may be replaced by a jumper.

To take measurements you hold a resonant circuit close to the sensor coil. Tune the rotary capacitor C1 slowly to and fro in order to find the resonant frequency, at which the oscillator amplitude decreases somewhat. The frequency can then be read directly off the oscilloscope. To obtain a very accurate measurement you can additionally connect your frequency counter to the second output.

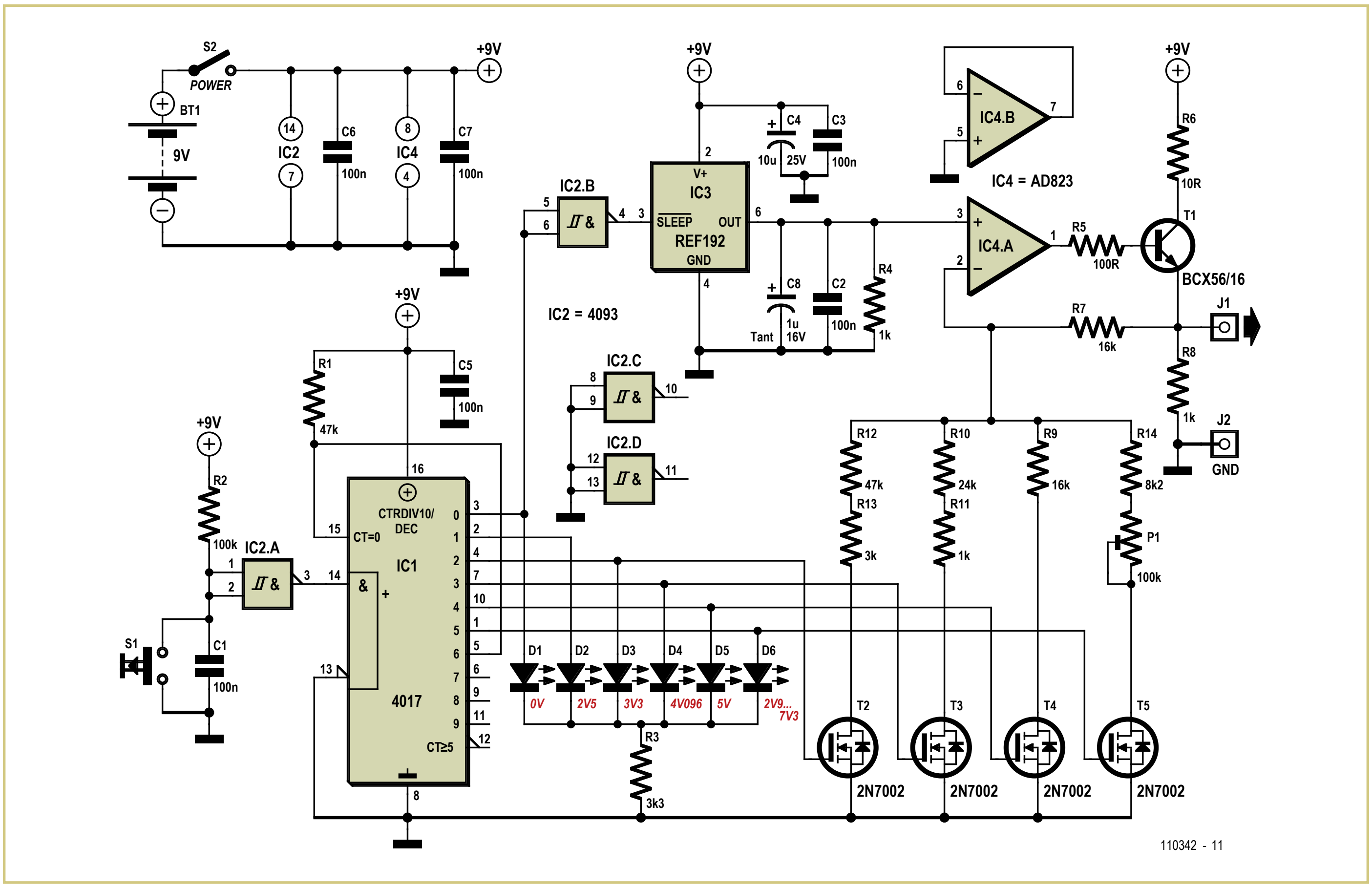
(110198)

Variable Voltage Injector

By Gerd Haller and Michael Gaus (Germany)

When testing circuits and fault finding there is often a need to inject a defined DC voltage level at some point on the circuit. It may, for example be necessary to apply a logic level on the input of a digital gate or a reference voltage level on the input of an analog circuit.
With this handy piece of kit you can select one of five fixed voltage levels of 0 V, 2.5 V, 3.3 V, 4.096 V or 5 V. In addition the output can supply a variable voltage in the range of 2.9 V to 7.3 V adjustable via a pot.

A stable 2.5 V reference voltage is sourced from a REF192 low voltage reference chip. This level is then multiplied by the gain of an opamp with switchable DC gain to produce the output voltage levels.
A ten stage Johnson counter type 4017 selects the amp's gain setting. A pushbutton provides the clock signal to the counter. An RC filter followed by Schmitt trigger IC2.A suppresses unwanted signal transitions generated by pushbutton contact bounce. A Johnson counter only ever has one output high at any one time so each



press of the button advances this high to the next output. The outputs switch FETs which in turn connect the voltage divider networks to ground to produce the different gain settings. The outputs also have LEDs, giving a visual indication of the output voltage level setting.

Counter output 6 is connected back to the reset input so that after the sixth output the counter is reset to the beginning again.

To produce a 0 V output level the voltage reference chip is switched into sleep mode and the 1 KΩ resistor R4 ensures a 0 V output.

Power supply for the circuit is provided by a standard or rechargeable 9 V battery. To make the design easy to use it can be mounted in a plastic casing to fit comfortably in the hand. The output signal can then be connected to a test probe extending from the case. An earth connection is also necessary and can take the form of a flying lead terminated in a croc clip for connection to the test circuit earth.

(110342)

Oil Temperature Gauge

for 125 cc Scooter

By Georges Treels (France)

Lots of Far-Eastern scooters are fitted with GY6 engines. These already elderly units are sturdy and economical, but if you want to “push” the power a bit (so-called ‘Racing’ kits, better handling of the advance, etc.), you soon find yourself faced with the problem of the engine temperature, and it becomes essential to fit a heatsink (often wrongly referred to as a ‘radiator’) on the oil circuit. Even so, in these circumstances, it’s more than reassuring for the user to have a constant clear indication of the oil temperature. Here are the specifications we set for the temperature gauge we wanted to build:

- no moving parts (so not meter movement), as scooters vibrate a lot!;
- as cheap as possible (around £12);
- robust measuring transducer (avoid NTC thermistors and other ‘exotic’ sensors);
- temperature range 50–140 °C. (122 – 291 °F);
- audible and visual warning in case of dangerous temperature;
- compact;
- waterproof.

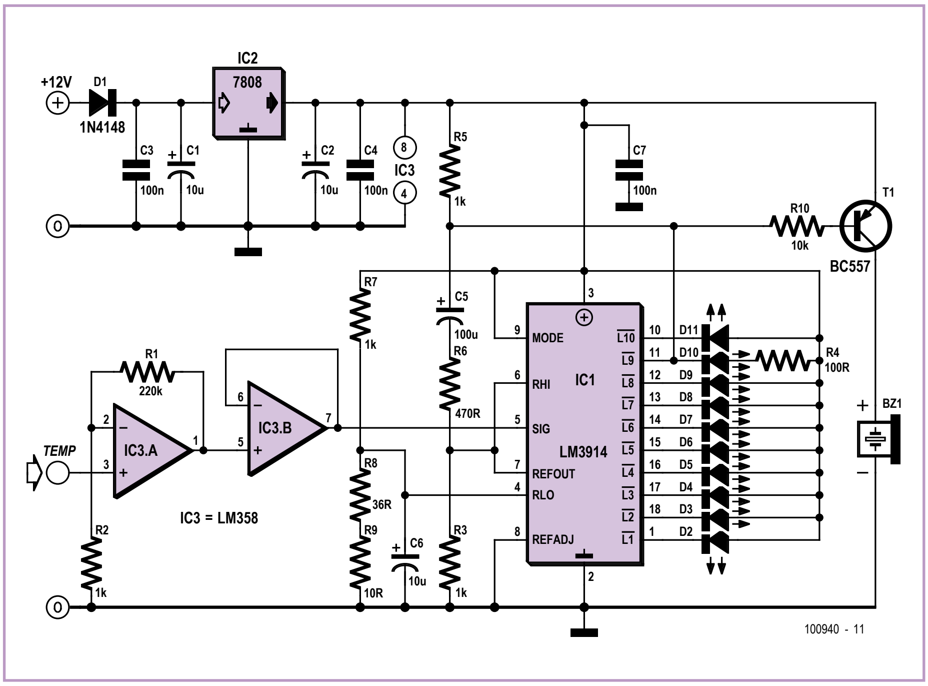
Let’s start by the sensor. This is a type-K thermocouple, as regularly used by multimeter manufacturers. Readily available and fairly cheap, these are robust and have excellent linearity over the measurement range we’re interested in here. The range extends from

2 mV to 5.7 mV for ten measurement points. The positive output from the thermocouple is applied to the non-inverting input of IC3.A, wired as a non-inverting amplifier. Its gain of 221 is determined by R1 and R2. IC3 is an LM358, chosen for its favorable characteristics when run from a single-rail supply. IC3.B is wired as a follower, just to avoid leaving it powered with its pins floating.

IC3.B output is connected to pin 5 of IC1, an LM3914. This very common IC is an LED display driver. We can choose 'point' or 'bar' mode operation, according to how pin 9 is connected. Connected as here to the + rail, the display will be in 'bar' mode. Pin 8, connected to ground, sets the full scale to 1.25 V. R3 sets the average LED current. Pin 4, via the potential divider R7/R8+R9, sets the offset to 0.35 V. Using R8 and R9 in series like this avoids the need for precision resistors.

As per the LM3914 application sheet, R4-R5-R6 and C5 will make the whole display flash as soon as D10 lights (130 °C = 226 °F). Simultaneously, via R10 and T1, the (active) sounder will warn the user of overheating. Capacitor C6 avoids undesirable variations in the reference voltage in 'flashing' mode.

IC2 is a conventional 7808 regulator and C1–C4 filter the supply rails. Do not leave these



out! D1 protects the circuit against reverse polarity.

The author has designed two PCBs to be fitted as a 'sandwich' (CAD file downloadable from [1]). In the download you'll also find a document with a few photos of the project. You'll note the ultimate weapon in on-board electronics: hot-melt glue. Better than epoxy (undoable!) and quite effective against vibration.

(100940)

Internet Link

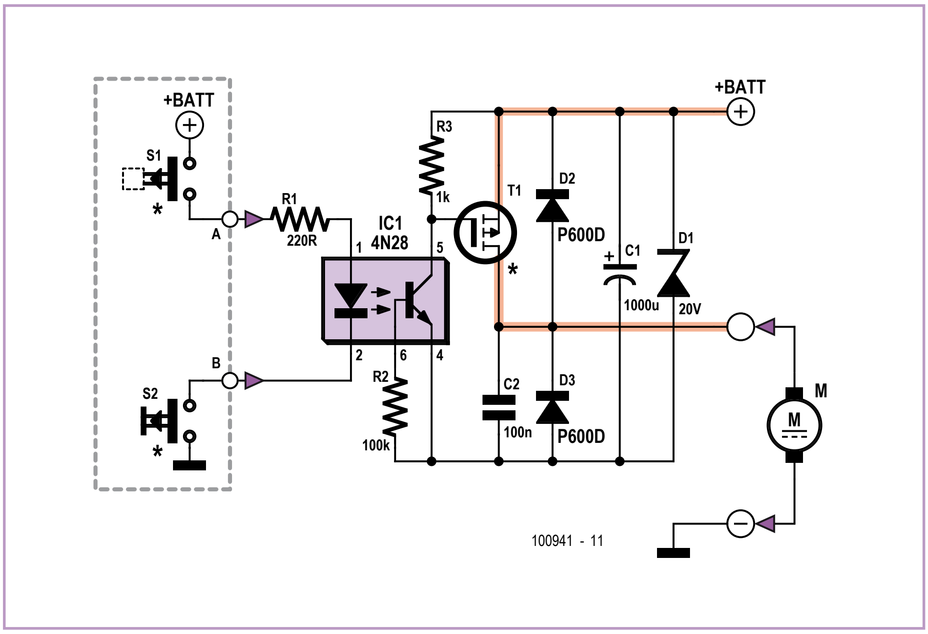
[1] www.elektor.com/100940

70 A Solid-state Starter Relay

By Georges Treels (France)

Overall, electromechanical scooter starter solenoids are cheap enough — but the downside is that they're not very reliable. The contact resistance increases over time, the coil can be open-circuited due to the vibration, and sometimes the power contacts weld up. One solution is to replace them with a solid-state relay. In DC mode, we'll need to use a MOSFET transistor.

As is often the case in automotive systems, the supply negative is connected to the chassis ground, which means we'll need to use a P-channel MOSFET. The current to be switched is relatively high, between 55 and 100 A (depending on engine capacity and compression), so we need a transistor with a very low $R_{DS(on)}$ capable of carrying a large I_{DS}. Since the starter is a DC motor with brushes, it



generates considerable voltage spikes that are quite destructive for the driving device, whence the need to protect everything very well.

A look at the wiring diagrams for various scooters reveals that the safety switch on the brake (which has to be applied first) supplies +12 V, but the starter button (to be operated next) connects to ground. One simple solution is to use an opto-isolator. While we're on the subject, let's just note that this technique means this circuit can be used for many other applications too.

And finally, the circuit must be 'Plug-n-Play', i.e. usable with the original connector, thereby limiting the circuit dimensions to 50 × 50 mm.
Building a PCB capable of handling a current of 70 A needs a few calculations. The resistance R_T of a copper track with thickness E of 35 µm (0.035 mm) with length L and width W is calculated from

$$R_T = 1.7 \times 10^{-5} \times L \,/\, (E \times W) \quad [\Omega]$$

where E, L, and W are in mm, and T = 25 °C). The component positions mean our tracks can be 15.25 × 44 mm, thus each track represents 1.4 mΩ, or 0.7 mΩ if we use a double-sided board. At 75 A, the total voltage drop will be around 100 mV and the power dissipated 7.5 watts. The SUP75P03-07-E3 MOSFET from Vishay Siliconix (Farnell part no. 1794812) offers an $R_{DS(on)}$ of 7 mΩ at 75 A, i.e. 3.5 mΩ if we put two in parallel. In this case, the voltage drop is 0.263 V and the power dissipated in each transistor is around 10 watts. The end result is that we get an overall voltage drop of around 360 mV and a total dissipation of around 27.5 watts.

Let's take a look now at the circuit diagram. On the left, everything within the dashed rectangle corresponds to the original wiring of the majority of Chinese scooters. R1 sets the current in the 4N28 opto-isolator LED to around 25 mA and R2 biases the base of the phototransistor. The phototransistor collector is connected directly to the gates of the two MOSFETs T1 wired in parallel. At rest, the MOSFETs are held off by R3, but start to conduct when both contacts S1 and S2 are made, thanks to D3 and the low impedance of the starter motor. Once the starter turns, the charge on C2 ensures that the circuit will continue to function.

Components C1, D1, C2, D2, and D3 protect the circuit against the interference produced by a load that is anything but purely resistive. Tests and measurements have been carried out on a scooter using a GY6 engine type CJ12M. The average consumption was 53 A: 49 A at bottom dead center (minimum compression) as against 57 A at top dead center (maximum compression). The voltage drop measured at the circuit terminals was strictly identical to the theoretical value. After three hours' testing, at a rate of one start every five minutes, no heating was detected.

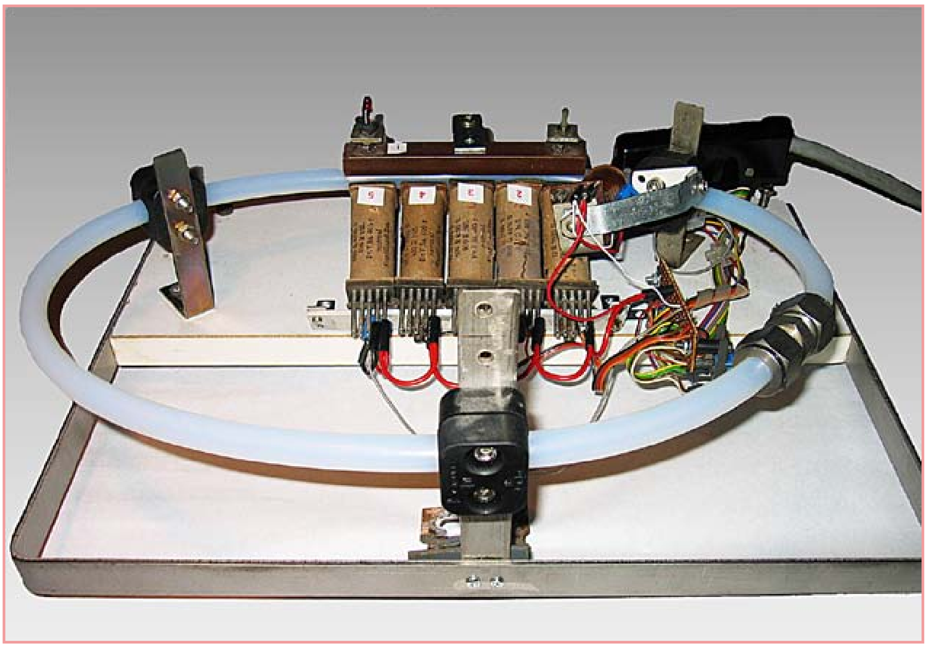
(100941)

Internet Link

[1] www.elektor.com/100941

Maglev Demo

By G. van Zeijts (The Netherlands)



After reading a Wikipedia article on maglev trains [1], the author — like anyone fascinated by technology — was curious to know how they work. He discovered that they use a rather sophisticated system consisting of lots of magnets and coils along with controllers, which lifts and propels the train. However, the basic principle is very simple and consists of coils that attract or repel metal objects or other coils, thereby causing something to move. He thought it would be fun to build a device that demonstrates this principle.

The mechanical part of the author's device consists of length of transparent tubing with an internal diameter of 10 mm, which is bent into a closed oval shape and joined smoothly by a coupling. The oval tube is clamped in a slanted position, with the upper part up to 30 mm higher than the lower part. A steel ball with a diameter of 8 mm, taken from a ball bearing, is located inside the tube. A coil called the 'holding coil' is located near the lowest portion of the tube, with additional coils (L1 to L5) positioned near the holding coil in sequential order.

Before the ball is put into motion, the holding coil is energized to capture the ball in order to give it a well-defined starting position. After the ball comes to rest, the holding coil is de-energized and L1 is energized briefly, causing the ball to move fairly quickly towards L1. After this, coils L2 to L5 are energized briefly at the right times to cause the ball to accelerate and roll all the way around the oval loop. The results depend on the times when the coils are switched on and off, and the main challenge in this project is to determine the right timing for energizing the coils.

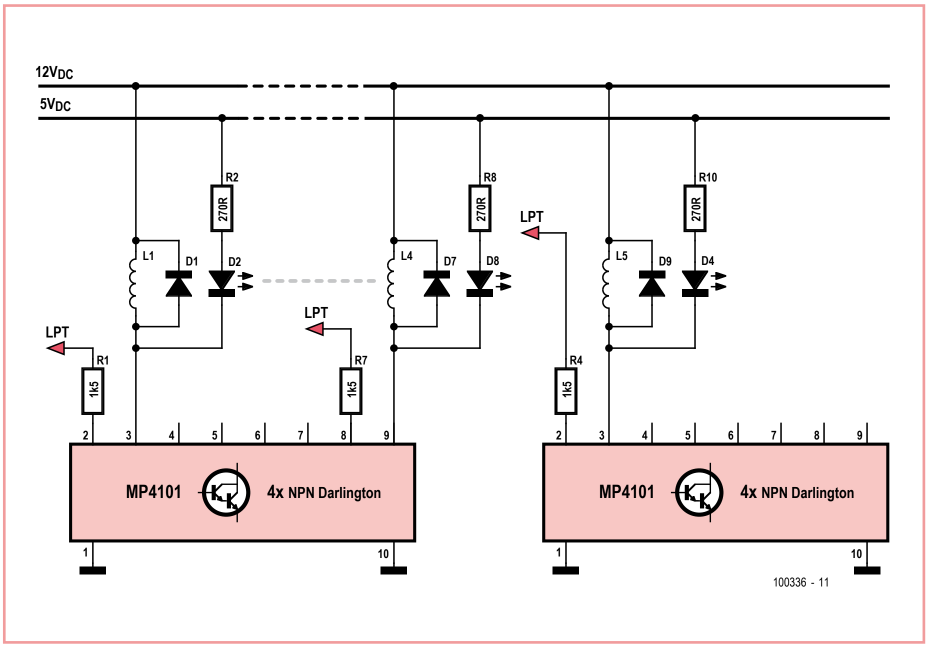
The schematic diagram of the control circuitry is very simple. It consists of a set of NPN Darlington transistors – one for each coil – connected between the pins of a PC parallel port connector and the coils. The author used quad Darlington ICs (type MP4101) for this purpose. These quad power drivers were commonly used in dot-matrix printers, which are now obsolete and have been (or are being) discarded in large quantities at municipal waste collection centres. Some examples of well-known quad drivers are the STA401A, STA405A, MP4101 and MP4105. These quad Darlington drivers are especially easy to use because they require very few external components. However, discrete Darlington pairs would work just as well.

All of the coils used in the author's device (heavy-duty relay coils) have a resistance of 12 Ω and operate from a 12 V DC supply voltage. The indicator LEDs have 270-Ω series resistors and operate from 5 V. They light up when the associated coils are energized.

The PC software is written in Visual Basic 5 and works fine under Windows XP. It can be download free of charge from the Elektor website [2]. The code is extensive commented. The coils are driven from the parallel port using a simple interface. The module InpoutV4.bas must be included in the project. It allows the parallel port to be used under Windows XP for controlling external devices with Visual Basic code. The file Inpout32.dll should be placed in the folder C:\Windows\System32.

The program displays two windows after it is launched:

- 'For Operation'
  This is intended for normal use. It allows the user to use various numbers of coils, as desired.
- 'For Adjustments'
  This can be used to experimentally determine the values of the timing parameters,



which depend on the speed of the computer and the construction of the demo device.

The time when each coil is energized must be determined. The previous coil is automatically de-energized at the same time. The timing is implemented in the program using a simple counting routine. Of course, timers could have been used instead.
With both methods, Windows makes it difficult to maintain constant timing because it repeatedly 'steals' brief time intervals while a user program is running in order to handle other tasks, such as managing the keyboard interface. Under Windows 95 and 98, the modules Ports.bas and Ports.dll allowed Visual Basic to use the Real Time command (with the parameter 'true' or 'false') to prevent this from happening while a user program was running. This made it much easier to get the timing right, since Windows was prevented from doing its own thing(s). Unfortunately this is can't be done under Windows XP, since Microsoft is making direct access to the ports increasingly difficult for users.

(100336)

Internet Links

[1] http://en.wikipedia.org/wiki/Maglev_(transport)

[2] www.elektor.com/100336

Mini Experimental Board for ATtiny45

By Claude Frayssinet, F6HYT (France)

This very simple little development board was designed for carrying out tests on the 8-pin AVR microcontrollers from Atmel. Any 8-pin IC with power on pins 8 (+5 V) and 4 (0 V) can be used, checking of course that the programming pins are the same as on the ATtiny45 for which this board was made.

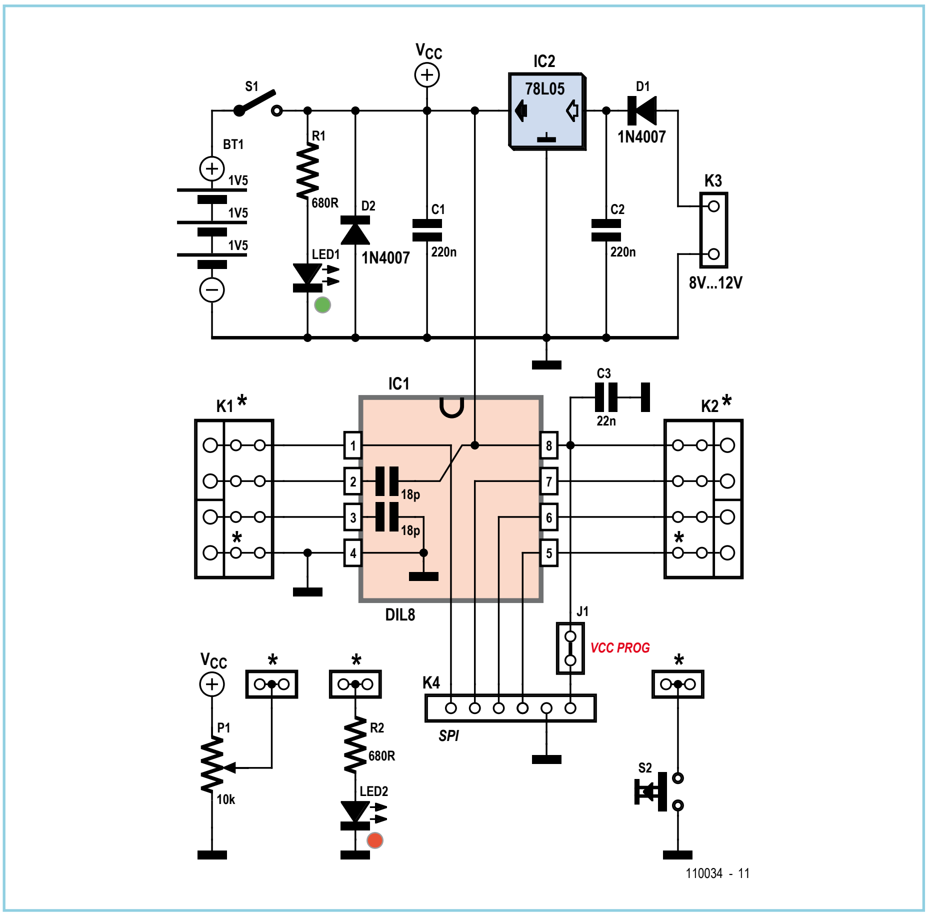
The IC's eight pins are brought out onto two rows of PCB pins and two screw terminal blocks (K1 and K2) with a 0.2" (5.08 mm) pitch.

There are three possible ways to power the board: from an external 8–12 V (15 V) PSU via a standard power socket; from a 5 V rail via the programmer's ISP connection (if the jumper is fitted); or by three 1.5 V cells via a switch. If batteries are not being used, a prototyping area with solder pads is available. There's an LED to indicate the presence of power.

For experimenting, there are three tools on the board. First of all, a simple logic probe with an LED and its current-limiting resistor, then a potentiometer adjustable between V_{CC} and ground, which gives us a variable voltage for the A/D converters, and lastly a pushbutton which makes to ground when pushed.

Although SPI access connector K4 is shown as 6-pin in the circuit diagram, a 10-pin HE10 connector is actually used on the circuit board.

Two 18 pF SMD capacitors are provided for a crystal oscillator. These don't interfere with operation even if a crystal is not used.



Their rather unorthodox connection (one to ground, the other to +5 V) has made it possible to simplify the PCB layout slightly.
The 1N4007 diodes can be either conventional or SMD types, as can the resistors and certain of the decoupling capacitors.
Printing the component layout onto glossy photo paper using an ink jet printer gives a very clean finish that is also extremely robust (even against alcohol).
The PCB design, component overlay, and a few photos are available on [1].

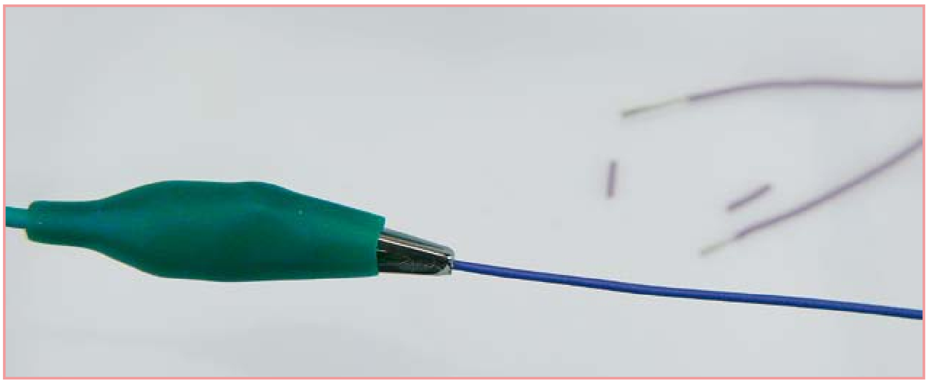
(110034)

Internet Link

[1] www.elektor.com/110034

Low-cost Wire Stripper

By Luc Lemmens (Elektor Labs)



There are already lots of tools and methods available for stripping insulation from wire. Some people do this with their teeth, and stripping pliers are available in all sorts and sizes. In many cases you can also use scissors, cutting pliers or a sharp knife. However, most tools do not work well with very fine wire — either the insulation is simply stretched a bit or the wire itself is damaged so much that you have to cut it shorter and try again.

The need for wire strippers for fine wire, as well as the solution, both came from an unusual source. In the world of doll houses and miniatures, tiny incandescent lamps with very thin, flexible leads are used for lighting. The vendor of these lamps also sells what they call a 'stripping tool' for them, which is simply an ordinary alligator clip of the sort commonly used on the test bench for connecting test leads or as a clamp in 'third hand' devices. Quite inexpensive sets of test leads with alligator clips on each end are also available.

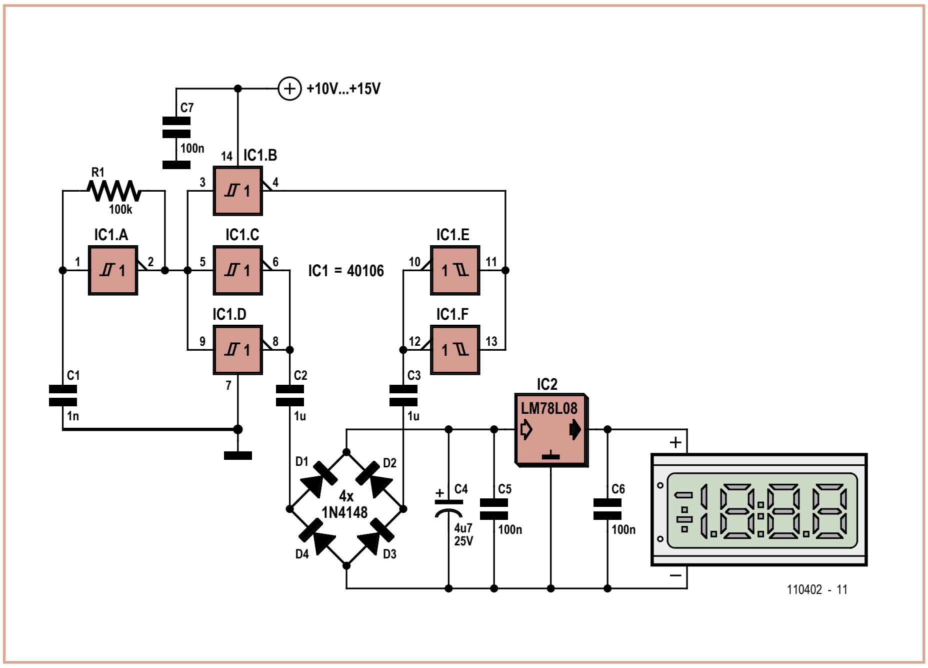
It turns out that these clips, without any sort of modification, are very suitable for stripping insulation without damaging the wire. In fact, the cheapest types give the best results because the spring force should preferably be as low as possible. However, the teeth of the jaws must mesh nicely together, as otherwise the clip is not suitable for use with thin wire. It takes a certain amount of dexterity to use this tool. Place the wire neatly between the jaws and then apply just enough force with your thumb and index finger to cut through the insulation. After this you can pull off the insulation. Depending on the type of wire and the thickness of the insulation, it may take a few tries to get this right, but anyone with a feel for the task will soon be turning out good results.

Pleased with our new tool, we immediately set about trying it out on other difficult insulation stripping tasks. Our first test was with flat cable — an obvious choice — and we found that the individual wires could be stripped clean in a jiffy with no significant effort. Next came battery holders: the leads of some 9 V battery holders are rather stiff and the insulation is thick relative to the wire diameter, which makes stripping them a tricky task with ordinary wire strippers. Here again the alligator clip did an excellent job. Even if it isn't designed as a wire stripper, it works very well in practice.

(110283)

Floating Supply for Panel Meters

By Georges Treels (France)



There are a lot of digital voltmeter modules on the market today at advantageous prices. Apart from their very high input impedance, they have the advantages of being accurate, versatile, compact, and also quite elegant. The flip side of the coin, however, is that they usually exist in two versions:

- The 'really cheap' which require isolation between their supply voltage and the voltage being measured.
- The 'more expensive' (expect double!) which accept a common ground.

Considering the low power consumption of these modules (around 1 mA), it is simple and worthwhile to design a little circuit that will allow isolation for this type of equipment.

IC1 is a 40106 CMOS hex Schmitt inverter. Its first gate IC1.A is wired as an oscillator by way of R1 and C1, at a frequency of around 10 kHz. IC1.B inverts the signal, so that gates IC1.C / IC1.D and IC1.E / IC1.F can be driven in antiphase. The signal is output via C2 and C3, rectified by a diode bridge, filtered by C4 and C5, and stabilized by IC2 and C5 to a value of 8 V. The input supply voltage, decoupled by C7, is not very critical, somewhere between 10 and 15 V.

It would be hard to make it simpler…
The whole of the circuit fits onto a single-sided PCB 24.3 × 27.94 mm, easy to fit behind most display modules. The PCB design is available from [1].

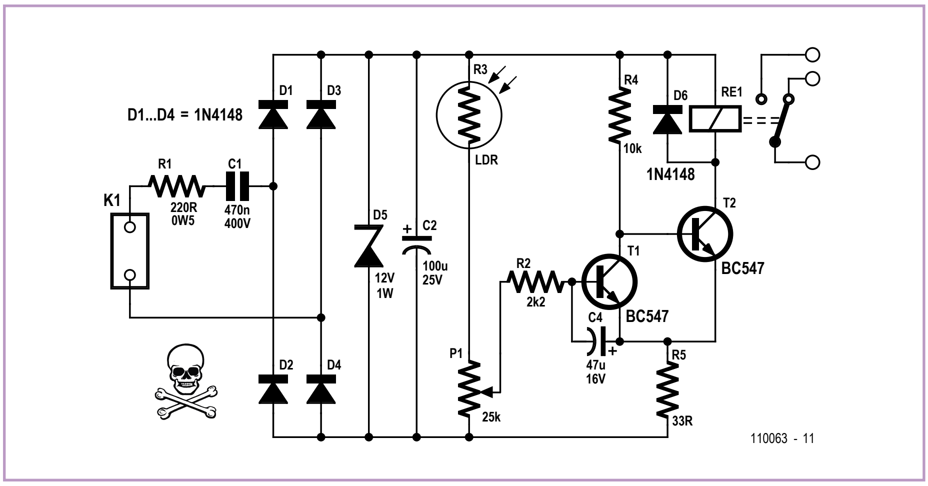
(110402)

Internet Link

[1] www.elektor.com/110402

Twilight Switch

By Theo de Wijs (Thailand)



Although ready-made twilight switches for exterior lights are available in every home improvement shop, any self-respecting electronics enthusiast would rather put together something from a few components that happen to be lying around.

The circuit described here does not require an AC power transformer. Instead, the voltage is reduced by series capacitor (C1) connected directly to the mains voltage via a current-limiting resistor. The AC voltage is rectified by D1–D4, and the resulting DC voltage is limited by D1 and smoothed by C2. An LDR (R3) is used to detect the light level. The resistance of the LDR is high when there is little or no light. The resulting voltage on the base of T1 is very low, cutting off the transistor. This causes T2 to be driven into conduction by the current through R4, thereby energizing the relay so that the exterior light connected to it is lit.

When sufficient light falls on the LDR, the voltage on the base of T1 rises and it is driven into conduction. This diverts the base current away from T2, with the result that the relay drops out. The switching level can be adjusted with the potentiometer. Capacitor C4 provides a bit of hysteresis to prevent the circuit from jittering near the threshold level.

The entire circuit should be fitted in an insulated enclosure, since it is connected directly to the AC powerlines. The component values are not especially critical. However, the coil of relay Re1 must be have a low operating current (no more than a few dozen milliamperes).

The author used a type JJM1-12V relay from Panasonic in the prototype.

(110063)

Emitter-Follower Audion

By Burkhard Kainka (Germany)

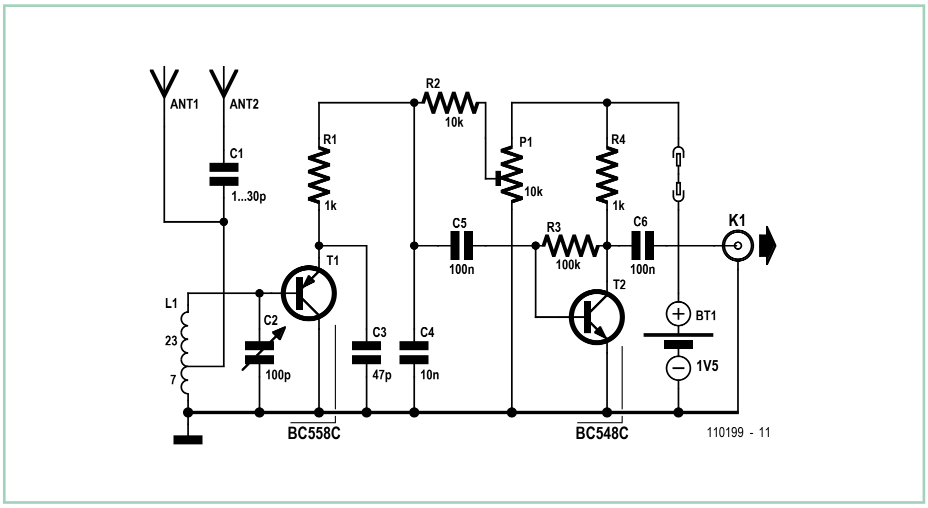
A shortwave audion receiver using only two transistors and a single 1.5 V battery — that must be the ideal entry level into shortwave receiver technology. Just add an active PC loudspeaker for very convincing performance.

A special feature is the audion circuitry that uses a BC558C PNP transistor working in emitter follower mode. This function works thanks to the few picofarads of internal capacity between the transistor's base and emitter. This produces a capacitive voltage divider, enabling the transistor to operate as a three-point oscillator, also known as a Hartley oscillator. Only a minute amount of emitter current is required to go into oscillation. The trimpot (trimmer potentiometer) is used to adjust the audion for AM reception so that it does not quite oscillate (immediately before oscillation sets in), for CW (telegraphy with keyed carrier) and SSB (single-sideband) reception it is set slightly higher.

Decoupling and amplification of the audio signal is handled by the second transistor. The signal on the output connector K1 is at line level, with an output impedance of about 1 kΩ.

Either of the two antenna connections ANT1 and ANT2 can be used. A good ground (earth) connection is essential for this circuit, in which case a short indoor wire antenna of less than a meter in length connected to ANT1 will be sufficient to pull in countless broadcast stations. For DX (long distance) reception an external antenna is better, for example an aerial 'long wire' of around ten meters (30 ft.) length. In this case the ANT2 connection must be used. The coupling to this input is slightly weaker in order to reduce resonance and offset any reaction (feedback). As a general rule, the longer the antenna, the smaller the value of coupling capacitor C1.

(110199)



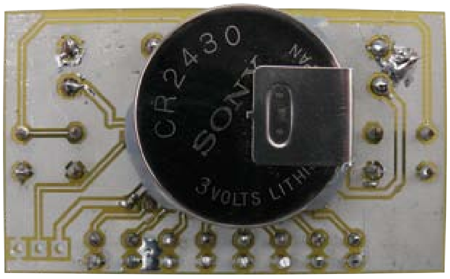
LED Chase

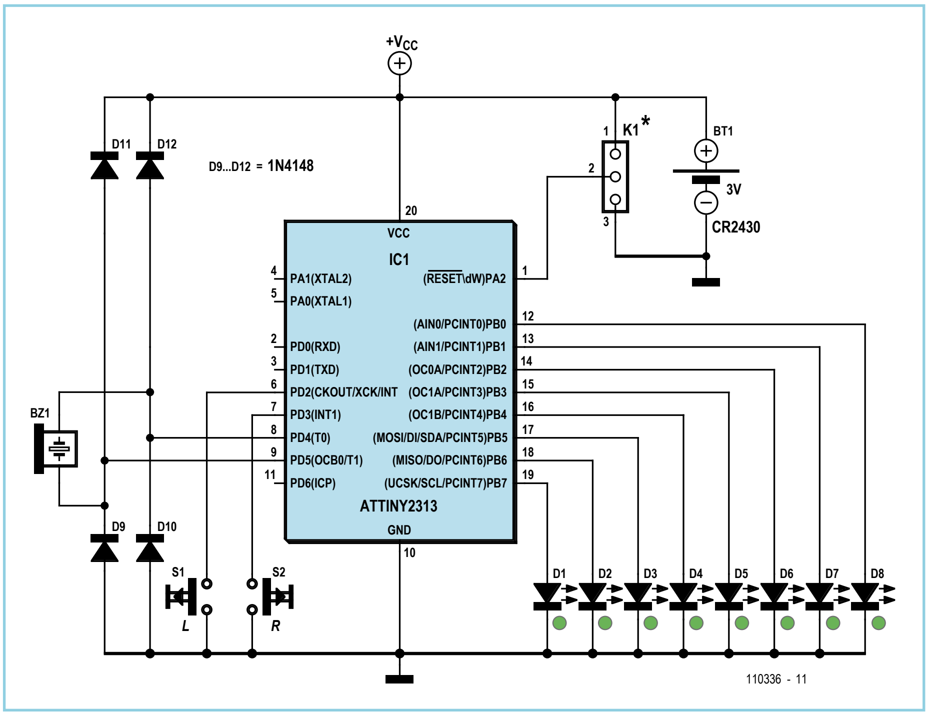
By Alexander, Friedrich and Klaus ten Hagen (Germany)

LED Chase is a game that flashes one of eight LEDs randomly, the LEDs being arranged in a row. If the LED on the extreme right or left lights and the corresponding button (L or R) is pushed at the same time, a sound is generated. Next, the LEDs light up individually in sequence and then start 'hopping' faster. Wrong pushes of the Left or Right button cause a low sound to be generated. The 'wrong' LED flashes rapidly and the LED-hopping is slowed down for a new round. If no button is pushed for 60 seconds the LED Chase game will automatically power down. A video showing the game in use, and the rules explained by one of the authors, is available on Youtube [1].

The LED Chase electronics consist of an ATtiny2313 microcontroller, a buzzer, two buttons (L and R), eight LEDs and a 3 V lithium button cell. K1 is the debugWIRE connector which according to Atmel allows "full debugging on the finished product [in combination with AVR Studio]". The buzzer is driven in a bridge configuration to achieve a usable sound level. The four diodes D9–D12 are necessary to avoid spurious restarts if a buzzer with a good amount of inductance is used. You may also consider using a small high impedance (>32 Ω) loudspeaker instead of the buzzer.

LED Chase uses the ATtiny's 16-bit timer to generate a timeout that activates the micro's 'sleep' mode with a quiescent current of only 200 nA. The project was designed using C in





AVRstudio4, LabCenter Proteus VSM and Ares for the PCB. The project software is a free download from [2].

The authors' PCB pictured here was designed single-sided to keep the cost down. The PCB design file is on the Elektor web page for the project [2]. A cover was designed for the underside of the board to prevent moist (sweaty!) fingers causing false contacts. You can have the cover produced at www.shapeways.com using the free Google SketchUp file also found in archive 110336-1.zip at [2].

In terms of bells & whistles, the authors plan to expand the game with a RingTone (RTTTL) interpreter. This will enable nice jingles to be played, for example, to celebrate a correct button push or to increase the beats-per-minute as the user reaches higher play levels. Unfortunately the larger software needed exceeds the 2 K flash capacity of the ATtiny2313 and an ATtiny4313 will be needed to upgrade the game using the same PCB.

(110336)

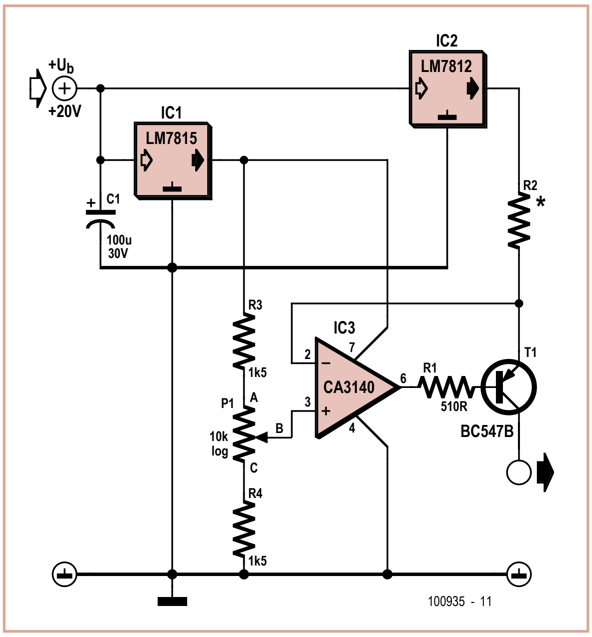
[1] www.youtube.com/watch?v=P2D1VtV8NhY

[2] www.elektor.com/110336

Constant Current Source

Adjustable Down to 0 mA

by Jürgen Okroy (Germany)



The simplest way to make an adjustable constant current source is to use a voltage regulator in a suitable configuration: an example of what is needed is given in the LM317 datasheet. However, this design does not allow the current to be adjusted down to zero. The design given here gets around that limitation.

Simply use two separate fixed voltage regulators with different output voltages to ensure that the opamp is always operated within its specification. The first voltage regulator provides 15 V both as a power supply to the opamp and as a voltage reference for the voltage divider formed by R3-P1-R4. P1 is used to adjust the reference voltage that appears on the non-inverting input to the opamp (pin 3 of IC3). The opamp now adjusts via T1 the current at the output of the circuit (i.e., from the collector of T1 to ground) in such a way that the voltage at the emitter of T1 (the instantaneous voltage) is maintained equal to the voltage at the wiper of P1 (the reference voltage). For all this to work it is of course necessary that a load is connected at the output of the circuit, so that a current can flow to ground.

The voltage range offered by adjusting P1 is determined by the resistances in the voltage divider comprising R3-P1-R4. With the voltage on the wiper of P1 at a minimum the maximum possible output current flows: this maximum current in turn depends on the value of resistor R2. The values shown give an available current range of 0 mA to 100 mA with R2 = 100 Ω and a range of 0 mA to 30 mA with R2 = 330 Ω.

The calculations are as follows: we need a voltage range at the wiper of P1 from 2 V or less (at maximum current, with 10 V or more across R2) to at least 12 V (at minimum current, with 0 V across R2). To enable you to achieve this range while still allowing for a small tolerance in the track resistance of the potentiometer, a value of 1.5 kΩ is used for R3 and R4, thus increasing the actual voltage range to 1.73 V to 13.27 V.

Since the circuit provides a constant output current rather than output voltage, the actual voltage at the output will naturally vary. As the output current *I* rises the voltage drop across R2 (*I* x R2) also rises and so the output voltage correspondingly falls.

(100935)

Water Level Detector

By André Thiriot (France)

To monitor the filling of a bath, a water-tank, or a swimming pool, or to warn when a gully is overflowing, here's a very simple water level detector built around a CD4011 CMOS quad NAND chip.

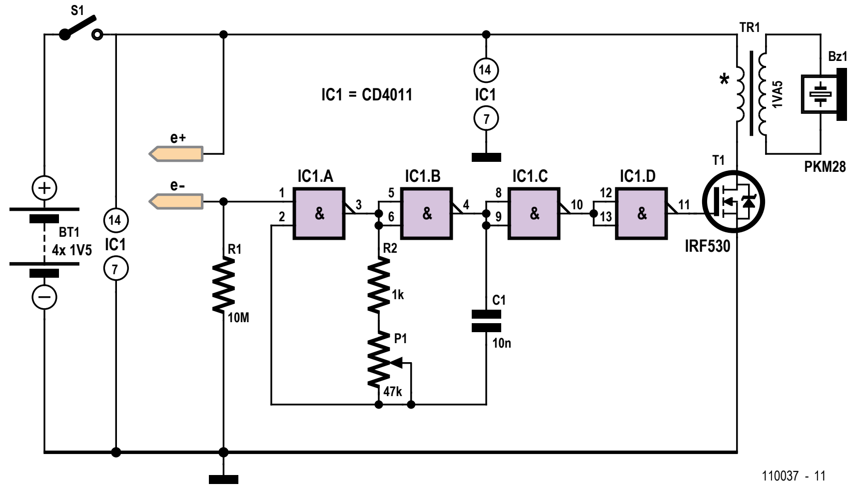
Gates IC1.A and IC1.B are wired as an astable multivibrator. The oscillator frequency is determined by C1, R2 and preset P1.

When quiescent, resistor R1 pulls the input to gate IC1.A down to logic low, which therefore by default blocks the operation of the oscillator in the absence of water. When water is present between the e+ and e−

electrodes, IC1.A is taken high, enabling the oscillator. The output signal from gate IC1.B is shaped by IC1.C to obtain a rectangular waveform. Gate IC1.D inverts the signal so that transistor T1 is held off in the absence of water, which avoids current flowing in the primary of transformer TR1 when the system is at rest. TR1 is a 12 V 1.5 VA AC power transformer wired as a step-up transformer i.e. with the low-voltage winding connected to T1. The transformer's step up ratio affords 'passive' amplification of the signal present at the drain of T1. The transformer's high voltage winding is connected to piezo sounder BZ1 (e.g. Murata; the '28' indicates the diameter) which produces the audible warning.

In order to optimize the sound output of the unit, you'll need to adjust P1 so as to set the oscillator frequency to the resonant frequency of the piezo transducer; this setting can be done by ear.

The electronics and batteries can be housed into a salvaged case (for example, the kind of oval box found inside giant chocolate 'surprise' eggs). The electrodes, formed from simple rigid copper wires, pass out through the case; the join is made watertight using epoxy adhesive.



(110037)

Internet Link

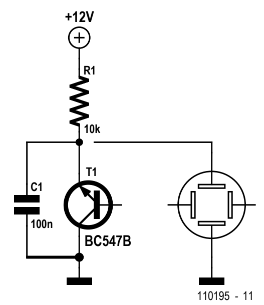
[1] www.elektor.com/110037

NPN Relaxation Oscillators

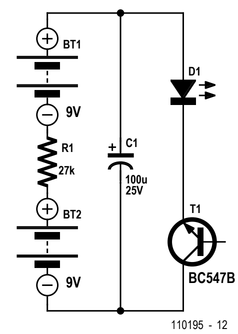
By Burkhard Kainka (Germany)

If you've read old textbooks on electronics basics you may recall how it's possible to create a multivibrator from just a neon lamp and a capacitor. The circuit of the simple multivibrator shown in **Figure 1** works in exactly the same way but using an NPN transistor instead of a neon lamp and at a much lower voltage. Anyone can check this out because the function is so basic. But why?

The author explains the circuit function like this: In inverse operation (emitter positive with respect to the collector) the NPN transistor has a negative characteristic (which can easily be checked) between its emitter and collector. At around 9 V the base-emitter diode displays the well known avalanche effect. When this occurs the charge carriers in the junction (barrier) layer are so thick and fast that they release further charge carriers. The number of charge carriers grows just like an avalanche and with them so does the current. This corresponds exactly to the same effect in a 9 V Zener diode. The internal resistance of this diode remains positive, however. The inverse transistor now adds to this effect. The emitter and collector do indeed exchange roles but the symmetrical principle of its construction means that the transistor functions equally in inverse operation. We can measure a slight current gain from about 3 to 10. The transistor still functions due to fact that the charge carriers pass through the thin base layer to reach the junction barrier. And now comes the salient point: it's precisely in this barrier layer that the avalanche effect takes place. There are still more charge carriers, which liberate yet more of them, producing an avalanche squared (so to speak). Once this avalanche is triggered, a weaker voltage is all that's necessary to maintain the effect. The collector current thus amplifies the avalanche effect and assures the negative characteristic. The strength of the discharge current is sufficient to drive an LED (see **Figure 2**). For this we need nevertheless a voltage greater than 9 V. The circuit functions adequately with two almost dead (discharged) 9 V batteries. The LED will still flash for a long time, right until the very last drop of energy in the batteries. The flashing frequency will slow down as the battery runs down.



1



2

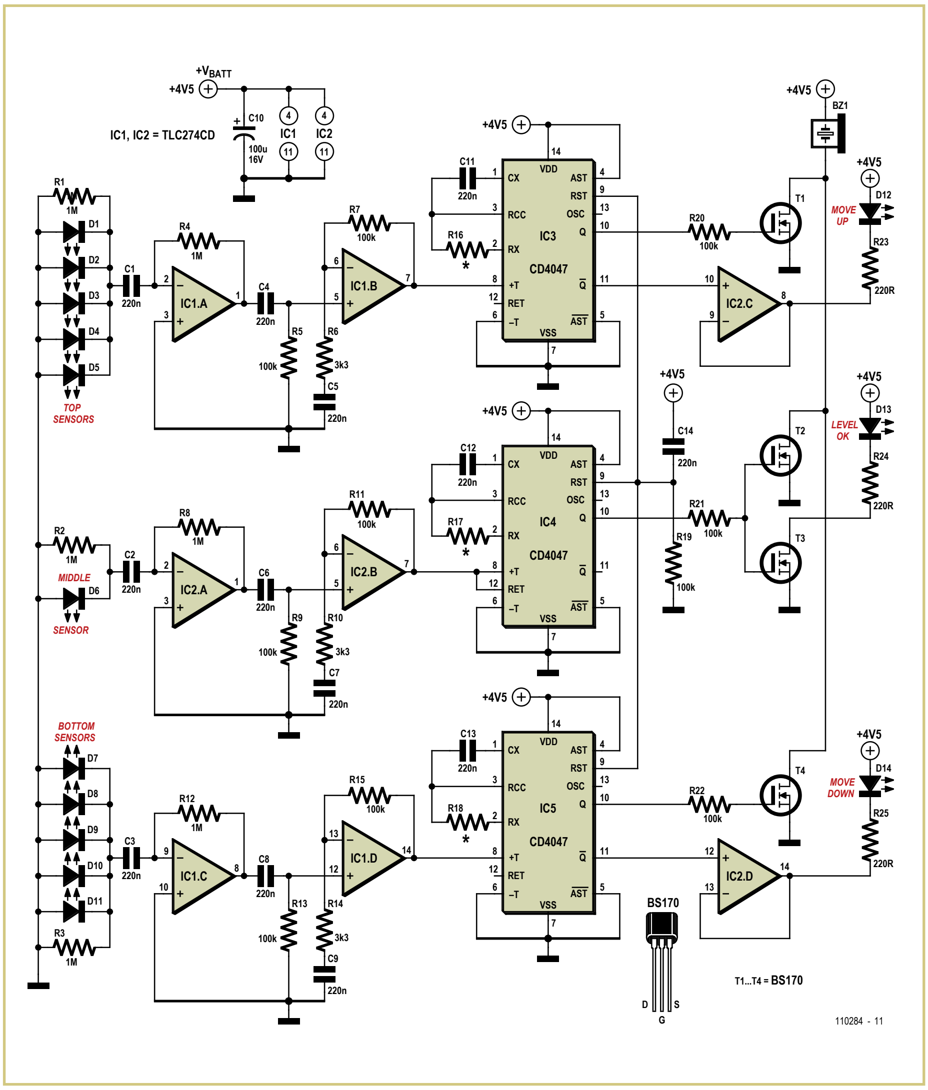
For mechanical reasons and to simplify construction, the charge resistor is fitted between the batteries.

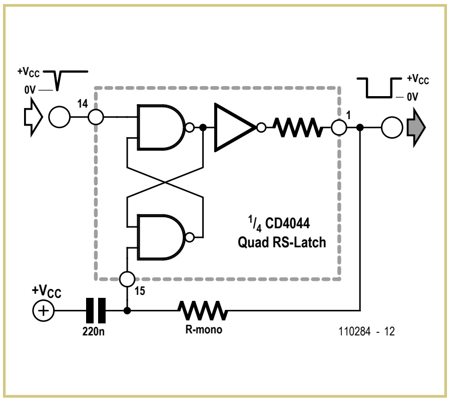
(110195)

Laser Level Detector

By Cyriel Mabilde (Belgium)

Rotating laser levels, which are very handy for setting objects in a room or garden at the same height, are available at prices of a few dozen pounds. At relatively large distances and for outdoor use, the light from the rotating laser beam is often not easy to see, and the laser beam detector described here can be useful in such situations. The detector works well at distances up to 50 meters (150 feet) and consists entirely of standard components. The detector is housed in a plastic case that can be fixed to an object (such as a post or a beam). It has three LEDs and a beeper that indicate whether the object should be raised or lowered.





LEDs with a transparent package and integrated lens (round surface) are used as sensors. The top and bottom detection zones each have five LEDs and two opamps (IC1a & IC1b or IC1c & IC1d), which drive the 'Move Up' and 'Move Down' indicator LEDs. The middle sensor LED drives the 'OK' indicator LED via two opamps (IC2a & IC2b).

The rising edges of the opamp output signals trigger three separate monostable multivibrators (type CD4047). If desired, the circuit shown inside the dashed outline (one gate of a CD4044 quad RS latch) can be used in place of each of the monostable multivibrators. In this case the output signal has the opposite polarity, so the BS170 N-channel MOSFET must be replaced by a P-channel type.

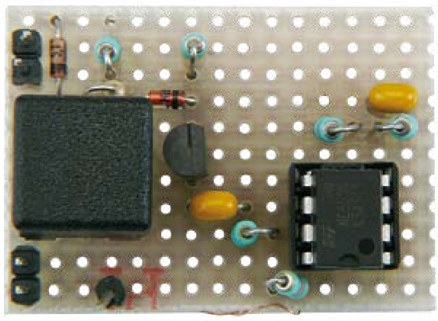
The monostable time of the middle retriggerable MMV should be longer than the rotation period of the laser (e.g. with a 2 rpm laser it should be longer than 500 ms) so that the beeper will emit a continuous tone. Most rotating laser levels have variable speed, so this can also be achieved by adjusting the speed if necessary. The monostable times of the upper and lower MMVs are dimensioned to generate clearly distinguishable short and long beeps, respectively. The three MOSFETs (T1, T2 and T3) are configured as a wired-OR gate to drive the shared beeper. The fourth MOSFET (T4) drives the 'OK' LED.
The circuit can be housed in an enclosure together with three penlight cells.

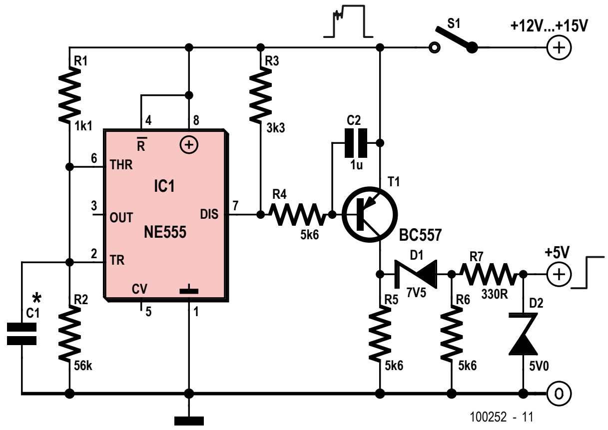
(110284)

Debouncer for 12 V Contacts

by Jürgen Okroy (Gemany)

Usually some effort is required if it is desired to use the positive edge of a switched 12 V signal (for example from a 12 V horn relay in a car) in a digital system. Digital systems place particular requirements on the signals they use, and the RS flip-flop often used for debouncing purposes does not provide a complete guarantee against interference. If, furthermore, there is no auxiliary 5 V supply available for the debounce circuit, we must





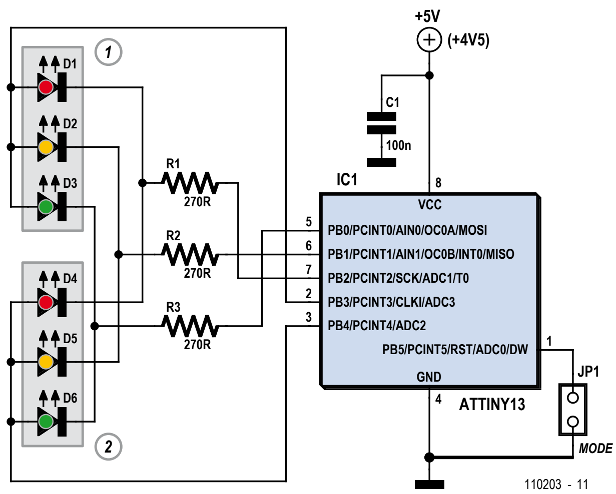
turn to a device such as the 555 timer IC to clean up the signal.

The circuit shown suppresses any bounces during a brief initial period that starts from the first rising edge of the signal. This period has a duration of a few milliseconds, and is determined by the value of capacitor C1: if C1 = 1 µF the period lasts about 2 ms and if C1 = 2.2 µF it lasts about 4 ms. Furthermore, when the signal returns to 0 V the circuit sharpens up this falling edge, making the resulting output signal closer in form to the ideal rectangular pulse.

(100252)

Roadwork Traffic Signals for Modelers

By Michael Gaus (Germany)



Anyone looking to add more activity to the highways in a miniature landscape should welcome this project for controlling temporary traffic signals. Just a few components are needed to control two traffic signals realistically.

Each traffic signal comprises three LEDs (red, yellow and green), each of which has its anode connected to the others. The signals can either be home-made or bought ready-made, for example [1]. Control of the light aspects (phases) is handled by an AVR microcontroller type ATtiny13. Since the software for the two signals is sequential and involves multiplexing, this circuit provides a total of three series resistors for the LEDs and five inputs to the microcontroller.

The traffic lights can be operated in two different modes. With jumper JP1 inserted the control includes a combined red+yellow phase, as used for example in Germany and Great Britain. Remove JP1 and this phase is suppressed and the lights change direct from red to green (as in France and the USA for instance). This enables two different color sequences to be followed.

For the clock source we use the internal oscillator of the ATtiny13 with a divide-by-8 prescaler to achieve a clock frequency of 1.2 MHz. The software handles the multiplexing by a timer whose interrupt routine is called up every 5 ms and instructs the current color to be displayed alternately to one or other of the two signals.

The manufacturer's settings for the fuse bits in the ATtiny13 are fine for this circuit, meaning they do not need to be reconfigured. The software for the microcontroller is already available to download from [2]. The source code was produced with the evaluation version of AVR's CodeVision C compiler, which is free for private, non-commercial use. Although code length is limited to 4 KB, this is perfectly adequate for this application [3].

(110203)

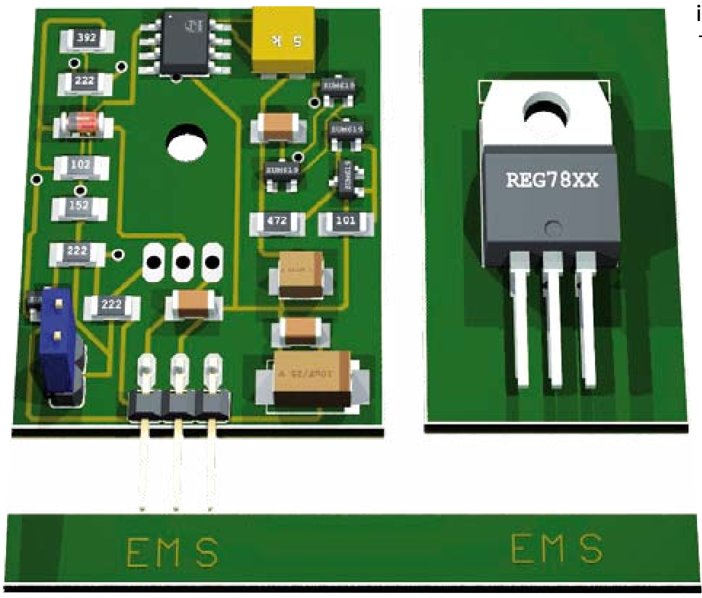
Internet Links

[1] http://shop.conrad-uk.com/1/2-a2-uk0241272__busch-h0-2-traffic-signal-additional-set-5901-.html?q=Ho%20model

[2] www.elektor.com/110203

[3] www.hpinfotech.ro/html/download.htm

Adjustable Low-Dropout Voltage Regulator



By Michel Defrance (France)

This circuit is based on a design for a low-dropout voltage regulator in the book *303 Circuits* (published by Elektor in 1998). The author adapted the design to make the output voltage adjustable, and he designed a new PCB for SMDs. However, the power transistor is still an 'old-fashioned' type.

The following changes were made to the original design:

- The 4.7-V Zener diode is replaced by a TL431 shunt regulator, which has good stability and generates an output voltage that can be varied with a 5-kΩ potentiometer, which allows the output voltage to be adjusted over the range of 5 to 16 V.
- The 390 Ω is replaced by a current mirror consisting of transistors T5 and T6. The operating point of the current mirror is set by R3 and the TL431. The stability of the output voltage depends on the cathode current of the TL431. The data sheet specifies a minimum value of 1 mA for good regulation, so with 1.7 mA at an output voltage of 5 V the margin is more than adequate.
- The output stage consists of two transistors (T1 and T2) in a Darlington configuration. Resistor R9 ensures that the base–emitter voltage of T1 is always sufficient to keep T1 conducting, even at very low output current levels.
- D1 was an AA119 germanium diode; it is replaced by an MELF4148.
- To ensure that the regulator starts up properly, the value of R8 is reduced from 100 kΩ to 3.9 kΩ.
- Output filtering is integrated on the board in the form of C1 and C4.

The PCB design [1] is double-sided. All of the SMDs are fitted on one side, and the BD136 is fitted on the other side (the copper side). If desired, the power transistor may be fitted with a heat sink and insulating washer. However, the low-drop design makes a heat sink largely unnecessary. The small PCB can be fitted in place of a conventional voltage regulator IC, since JP1 is pin-compatible.

Setup is very simple: remove JP2, connect a voltmeter to pin JP2-2, and adjust P1 to obtain the desired voltage at the output. Now replace JP2, and you're done. Bear in mind that the input voltage must be at least 1 V higher than the output voltage.

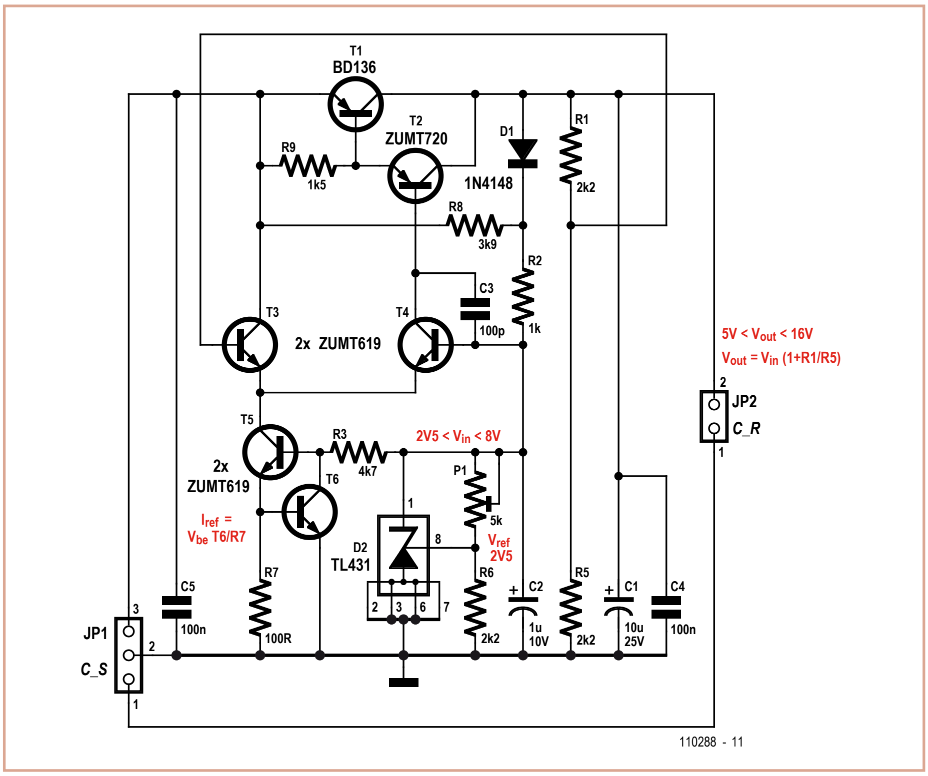
The transistor types are not critical; any pin-compatible equivalent type can be used. You could even use leaded types instead of SMDs — for example, BC547s for the NPN transistors and a BC557 for T2, which is the only PNP transistor other than the power transistor.

The table shows several readings measured with an output voltage of 7.39 V, which was used to drive two white LEDs connected in series. V_{IN} = 9 V, $V_{IN,min}$ = 8.20 V.

(110288-I)

Internet Links

[1] www.elektor.com/110288

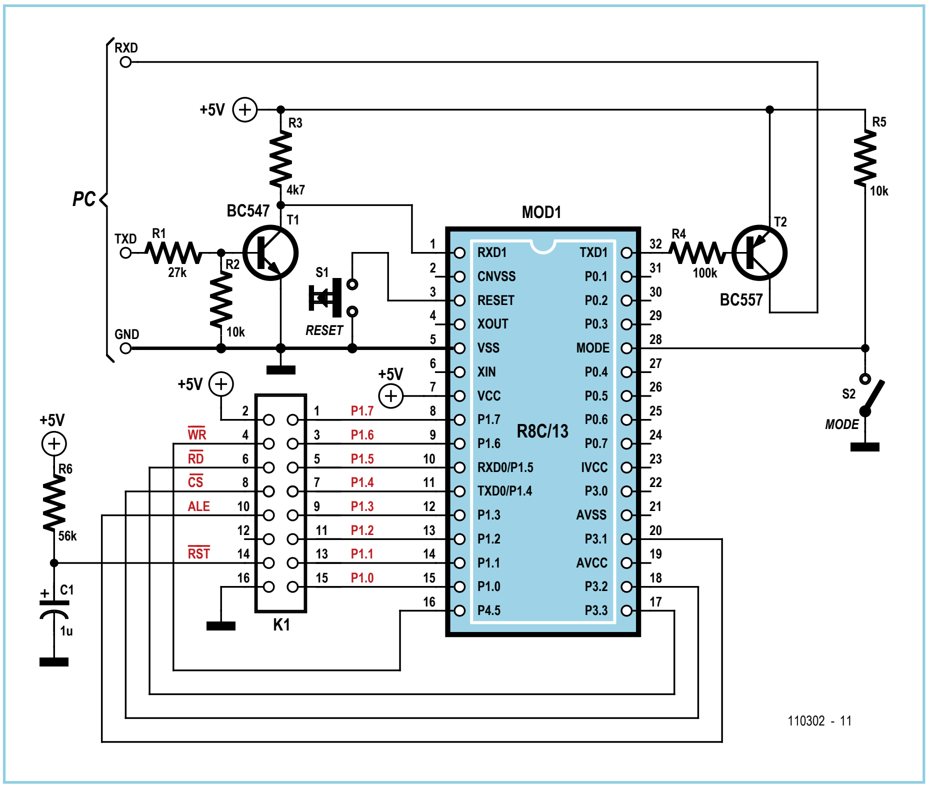


Load [Ω]	V_{OUT} [V]	Error [V]	I [mA]
680	7.39	0	10
390	7.37	0.02	18.8
220	7.37	0.02	33.5
100	7.35	0.04	73.5
33	7.31	0.08	220
10	7.20	0.19	720

Make Your R8C/13 Speak CAN

By Hermann Nieder (Germany)

This little processor board from the big Elektor R8C Project has certainly attracted some attention over time [1], [2]. And with good reason, as it's so easy to incorporate into your own microcontroller applications. This article explains how to hook it up to CAN bus [8], [9].



In Elektor for December 2005 [1] we demonstrated a 'minimalist' system that enabled the controller to be programmed using a RS-232 interface. The same minimal hookup is used this time around, together with the same programming (with help from the bootloader included in the R8C) and communication with a PC using RS-232. The combination uses a USB/TTL cable, which obviates the need for transistors T1 and T2 or the wiring for them.

For CAN communication we can use the CAN interface board out of the November 1999 edition of Elektor[3]. Also used is the SJA1000 CAN controller from Philips together with a PCA82C250 CAN transceiver.

The 2x8-pin contact strip shown in the circuit diagram is linked direct to plug-in connector K3 of the CAN bus interface. With a bit of skill and a short length of flat cable you can also make up an adapter for the very similar 'CAN bus interface for PCs' (Elektor June 2000), which is equipped with a 25-pin SUB-D plug-in connector [4].

The CAN controller can access 32 registers [5]. To define a register of the SJA1000 from the R8C we first output an address on port P1. Then ALE is set and reset to accept this byte. Following this the data byte is output over port P1. Finally /WR is changed from 1 to 0 in order to transfer the data byte into the register selected previously.

When reading a register the address must first be transferred to the CAN controller as described above. Next we need to prepare port P1 of the R8C for the read operation. A set and reset of /RD will read the byte out of the selected register address.

The author has written a PC program in Visual Basic 5 for receiving and composing CAN messages. The program uses Burkhard Kainka's functions library RSCOM.DLL von, which can be downloaded from his website [6]. The firmware for the controller relies in part upon the R8C routines already published in Elektor, since it would be a shame to have to reinvent the wheel afresh. As always, the PC software and the firmware for the controller can be downloaded for nothing from the Elektor website [7].

The RS-232 communication between PC and R8C operates at 9600 Baud. For CAN communication you have a choice of transmission rates: either 20 kbit/s or 50 kbit/s. This value is set at initialization time by pressing the corresponding radio button in the Visual Basic schedule.

During initialization the contents of registers 0 to 31 of the SJA1000 are set out sequentially in a list box.

When a data packet is received labels appear to the right of the list box for the two registers 20 and 21 (the first two bytes of the receive buffer). Also indicated there is the identifier of the packet as well as the RTR bit that separates CAN-Remote frames from data frames.

To identify the sender you enter a value in the text field provided for this purpose. There is also a check box for the RTR bit that can be set or unset. These inputs are handled by the radio button marked 'Identifier'. In addition there are labels on the right that identify the contents of registers 10 and 11 (the first two bytes of the send buffer) together with the status of the RTR bit. Pressing the radio button to refresh the register display will assure you whether the desired alterations have been made.

In the same way the individual register contents can also be changed directly. Separate buttons are provided for selecting each of the two reset modes of the SJA1000. A further button triggers the CAN controller to start transmitting. Another button clears the receive buffer.

The author has already carried out quite a number of experiments along these lines. If you have two R8C/13 boards and two CAN bus interfaces available and launch the PC program twice (or run it on two PCs), you can hold 'conversations' across the CAN bus, which the software visualizes rather well.

(110302)

Internet Links and References

[1] www.elektor.com/050179-2

[2] www.elektor.com/r8c

[3] Controller Area Network (CAN), Elektor November 1999

[4] www.elektor.com/000039

[5] www.nxp.com/documents/data_sheet/SJA1000.pdf

[6] www.b-kainka.de/pcmessfaq.htm (in German; use Google's translator facility to read in English)

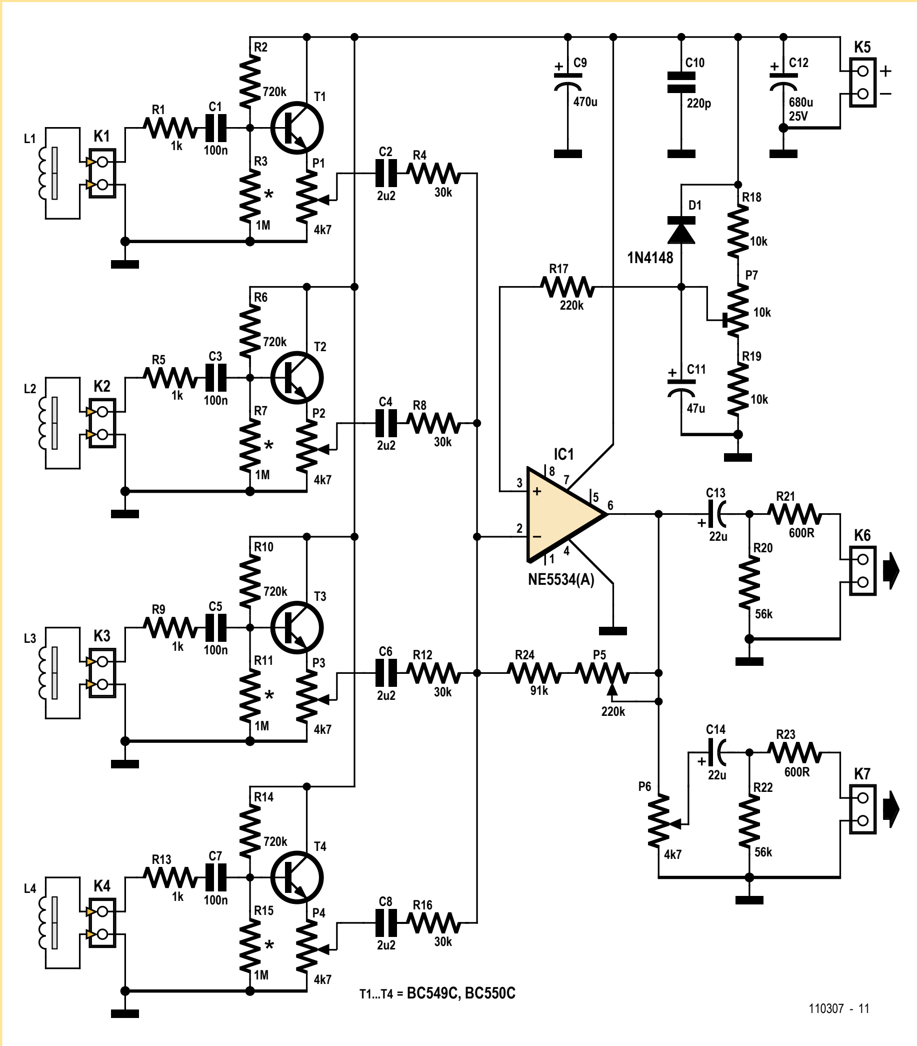
[7] www.elektor.com/110302

[8] http://en.wikipedia.org/wiki/Controller_area_network

[9] http://www.canbuskit.com/what.php

Electric Guitar Preamp, Mixer and Line Driver

By Petre Tzvetanov Petrov (Bulgaria)



Depending on its design an electric guitar may have anything from one to six pickup elements. Classic (acoustic) guitars could also benefit from one or more retrofitted pickups. Each pickup has a specific sound depending on the type of sensor and the location on the instrument.

When a guitar has more than one pickup these can be connected together with or without additional components. However it is preferable for each pickup signal to be buffered individually. These buffered and possibly amplified signals should be level-adjusted in order to produce the desirable effect (or 'sound'). After that they are mixed and sent to the next stage of the audio processing equipment.

Most guitarists agree that pickup elements cannot drive cables longer than about 6 feet without risking significant signal degradation. Guitar pickups typically require a load resistance above 50 kΩ and sometimes higher than 200 kΩ, hence a preamplifier/buffer is often inserted, whose main function is not high gain but to enable cables between 10 and 30 feet to be connected representing a capacitance between 90 and 180 pF/m.

In the circuit shown here, each pickup has its own input buffer with a transistor configured as an emitter follower. Each stage has a gain slightly lower than unity. This is not an issue because most pickups provide significant signal levels, typically well over 200 mV_{pp}.

The input resistance of the first stage exceeds 200 kΩ, which is appropriate for most inductive pickups on the market. If higher input resistance is needed the 1-MΩ resistors marked with asterisks could be omitted, and the 720-kΩ ones may be increased to 1.2 – 1.5 MΩ. This will raise the stage's input resistance to around 500 kΩ. To ensure the highest possible undistorted signal can be developed at the output of the first stages, the collector-emitter voltage (V_{CE}) of T1–T4 should be about half the supply voltage.

It is important for the first transistor in the buffer to have low noise and high DC gain. The types BC549C and BC550C and the venerable BC109C are perfectly suitable in this respect while the BC546C, BC547C and BC548C may also be considered.

The buffered signal from each pickup is adjusted with a potentiometer and sent to the summing circuit of the mixer. The next active element is an audio operational amplifier type NE5534 or NE5534A (IC1), which provides the required amount of signal buffering. The 5534(A) has low noise, low distortion and high gain. It can drive a 600 Ω line when necessary, but the preferred load is above 2 kΩ. Its amplification is adjustable between 3 and 10 with feedback potentiometer P5. At higher values of the gain some limiting and distortion of the output signal is 'achieved', which may well be a desirable side effect. The maximum undistorted amplitude of the output signal depends on the supply voltage. If higher gain is needed the value of P5 may be increased to 470 kΩ.

Output K7 has a volume control potentiometer (P6), which could be omitted if not used or required. Both outputs K6 and K7 are capable of driving 600 Ω loads including high-impedance headphones.

The circuit is simple to test and adjust, as follows:

1. check that V_{CE} on T1–T4 is approximately half the supply voltage;
2. with no input signal, adjust trimpot P7 for about half the supply voltage at the output of IC1. If precise regulation of the opamp's output offset is not required P7 may be omitted and R17 connected to the junction of R18 and R19.

The supply voltage is between 12 V and 24 V. It is possible to run the unit off a 9 V power supply but the lower supply voltage will limit the output amplitude and gain. The current consumption from a 9 V battery is typically 10 mA. Two 9 V batteries connected in series is the preferred solution.

The undistorted output amplitude is up to 6 V_{pp} at a 12 V supply with 2 kΩ loads at the outputs. The unit's frequency band exceeds 20 Hz – 20 kHz. Distortion and noise were found to be negligible in view of the application.

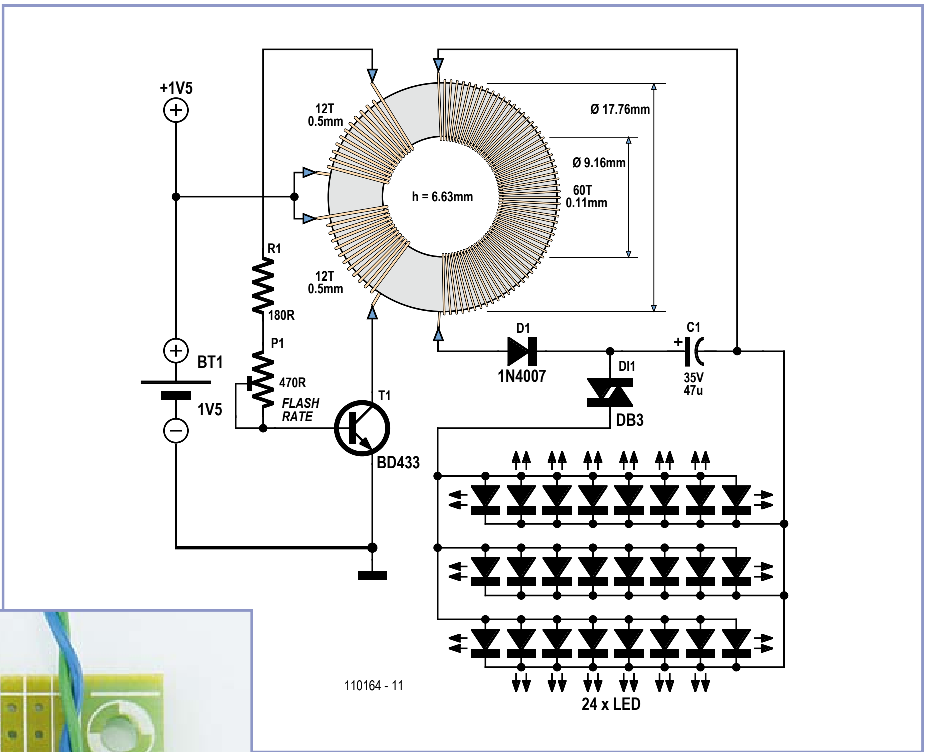
(110307)

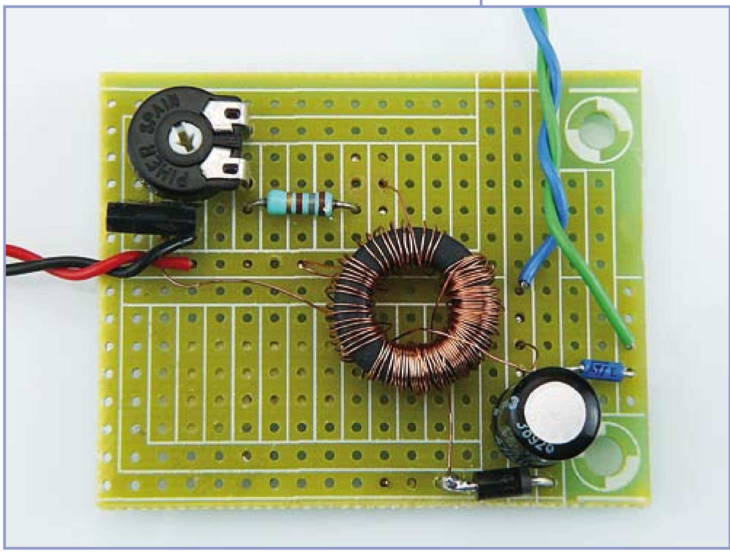
Zero-IC 24-LED Pulsed Cycle Light

By Ian Field (UK)

Cyclists' pulsing LED lights are eye catching and much more conspicuous than a steady light, so it was decided to make provision for the other half who don't have one. The aim was to use cheap, recycled components only.

At £3.99 ($6.50) the most expensive bit was the 24-LED work light with magnet and retractable hook. The DB3 diac could be less easy to find; one was liberated from an 18-watt Philips CFL. Don't buy the lower wattage types as you'll find that the Philips 8 W and 11 W versions normally don't have a DB3 diac.
The prototype was originally built with a 2SD1266 transistor which was replaced by the more common BD433, a TO126 device which should be cooled adequately. The part





most likely to cause sourcing difficulties is the ferrite toroid core. The one used has an inner and outer diameter of 9.16 mm and 17.76 mm respectively and a thickness of 6.63 mm. It was liberated from a scrap PC motherboard — ask the local computer shop for an old dead motherboard to salvage components.

Electrically the circuit has been made as simple as it can possibly be — a bog standard blocking oscillator. The downside is you have to wind 60 turns of very thin wire on a toroid! The winding wire was liberated from a 6-volt power adapter. Put the two 12 turn windings on first (0.5 mm/AWG24). The 60 turn winding is easier if you wind half one way then half the other. Cut about one meter (just over three feet) of the thin wire (0.1 mm/AWG38) and feed it through the toroid, then hold the two ends and let the weight of the core find the middle. Hold the first start (middle) and wind 30 turns (tape the loose end to an AA battery and let it hang to one side so it doesn't get caught up in the end you're winding); when you've wound 30 turns, free up the other end and feed that through 30 times to make a total of 60 turns.

For the collector & base windings, the easiest way to avoid phasing the windings is to wind on the first 12 turns, then pull out a loop and tightly twist it back to the core before putting on the second lot of 12 turns. The center tap is the +1.5 V power connection and as the two windings are identical either end can be collector or base — that only leaves phasing the secondary. If the circuit only flashes a few times a minute, reverse the leads and it will flash from about normal for a cycle light or you can turn the 470 Ω pot until it flashes dizzyingly fast. The 180 Ω resistor is to protect the transistor from excessive base current.

On the secondary side, the pulses are rectified by a UF4007 diode to charge an electrolytic capacitor. Every time the voltage on the capacitor reaches about 32 V the diac triggers and dumps the charge into the 24 parallel connected LEDs. The DB3 diac carries pulses of 2 A which is plenty to flash the LEDs. The 47 µF electrolytic was selected empirically for a good pulse brightness, bumping this up to 100 µF would make the pulses really intense — but for how long!

As an afterthought, while the pulsing light is very conspicuous to other road users on well lit roads, it's not so good for actually seeing where you're going on unlit cycleways away from the main roads and street lamps. The obvious solution is a second flash rate pot and a changeover switch. The unit as is can be adjusted to a flash rate not that far short of persistence of vision. A switch to change over to the maximum flash rate would make it easy to navigate an unlit cycleway in total darkness.

Along with the usual reminder about type approval and road legality in some countries, readers should be advised that the most rapid flash rate can be irritating (even confusing!) to drivers and should only be used in unlit areas away from the road. It is also worth pointing out that the maximum flash rate puts a greater strain on the components — especially the battery.

(110164)

Protecting PE Water Pipes against Frost

using Electric Fence Tape

By Pierre Vignisse (France)

Tapes for electric fences are available in various qualities and forms, with differing characteristics. They are usually made by interweaving threads in polyethylene, nylon, or some other synthetic material with several strands of wire in stainless-steel, copper, or some other conductor, of relatively small diameter (from one to several tenths of a mm in diameter).

For information, a 1 m-long stainless wire has a resistance of around 23 Ω for a diameter of 0.2 mm, and hence 5.75 Ω for a diameter of 0.4 mm. Thus a tape's linear resistance may vary from a few milliohms to several ohms per meter, depending on the number of strands, their diameters, and the nature of the conductors. But don't worry, you won't have to calculate it, just measure it — assuming it isn't specified by the manufacturer.

Some rudimentary tests show that a 2 Ω/m tape carrying a current of 1 A raises the temperature (inside foam pipe insulation) by around 15 °C. Thus in theory, to withstand temperatures down to −15 °C (5 °F), it would be necessary to dissipate 2 W/m inside foam pipe insulation. Thus even with just a simple 50 VA transformer, it is possible to perfectly simply cover 25 m of PE piping (polyethylene, and hence insulating).

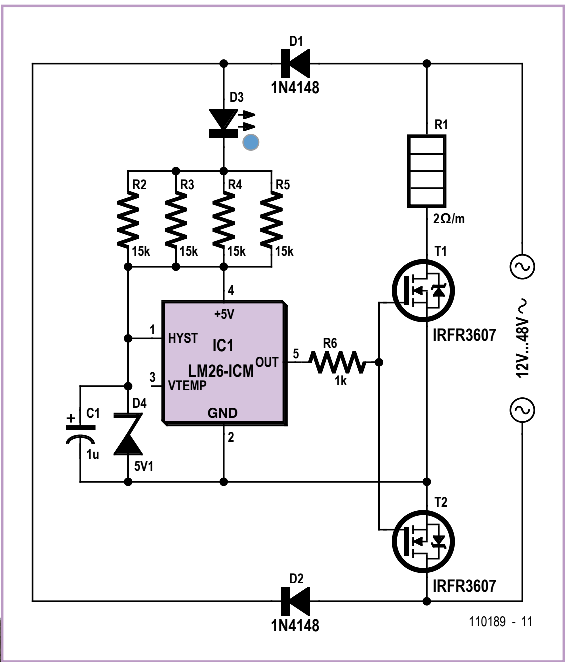
Since we have a choice of linear resistance, we can produce a heating tape of a given length while powering it from a safety voltage (less than 50 V_{AC}) with no danger for either us or for animals. So we have

$$P = V^2 / R = R \times I^2 = 2$$

with P in W/m, R in Ω/m and V in V/m. If L is the total length in meters, and since $V_{TOTAL} < 50\ V_{AC}$, then $R < 1250 / L^2$ [Ω/m] and we need $I > L / 25$ [A]. Knowing that for 2 W/m, $V = \sqrt{(2R)}$ and $I = \sqrt{(2/R)}$, we can work out everything.

However, we do need to take care not to use a current likely to upset the temperature measurement — excessive heating of the driver transistors could disturb the operation of the circuit. The example below will cope with 2 A without any problems.

Construction is based, on the one hand, on the use of two IRFR3607 power MOSFETs ($R_{DS(on)}$ 9 mΩ, $V_{DS(max)}$ = 75 V) and on the other, on the LT1172, a thermostat operating at 0 °C (push-pull output, 2 °C hysteresis, ultra-low power consumption of 40 µA maximum @ 5 V, SOT223 package). An LED will indicate that power is present, and another could be put in parallel with the tape.



Resistors R2–R5 (SMD 1206 shape) have been used in order to be able to handle the dissipation for the proposed voltage range while ensuring 3 mA in the zener diode, but if the voltage is reduced, the number of resistors can be reduced proportionately. The HYST pin of the LM26 is returned to the 5 V rail in order to select hysteresis of 2 °C. C1 is chosen primarily with respect to the C_{ISS} of the MOSFETs — it must be enough to maintain the charge on them without significant loss of gate voltage (5 V here).

On the PCB [1], the sensor has been kept apart in order to avoid its operation being disturbed by the 0.6 watts dissipated in R2–R5 and the power dissipated by the transistors. The copper planes even out the temperature around the sensor. The board should be pseudo-tropicalized with four coats of transparent varnish, as it is going to be mounted outdoors.

The tape has to be prepared, and this is perhaps the most tedious part of the job. Normally, the installation will require a current return conductor — unless you decide to use tape for both feed and return, either doubling the power, or reducing the current by a factor of √2 to compensate. However, you are going to have to unravel the ends of the tape in order to make positive, reliable connections. The tape used is 2 cm (0.8 inch) wide, so you can fix the return wire and insulate it completely where it passes metal elbows and tees using 5 cm (2 inch) wide adhesive 'duct' tape, available in any DIY store. A more expensive solution is to use heat-shrink sleeving.

To complete the connections, all you need is a soldering iron and some ring terminals and terminal blocks.

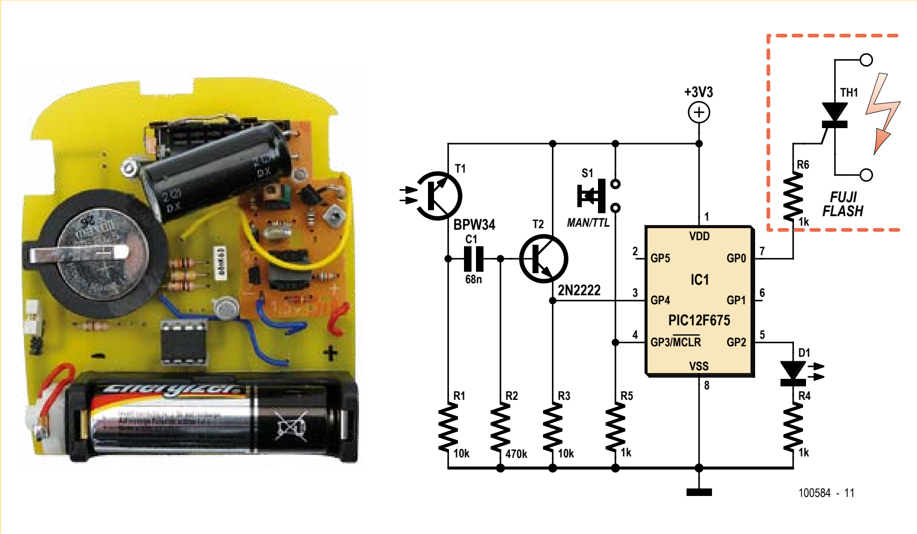
Then, you still have to attach the tape to the piping... If you're using automatic drinking troughs, you may need to make a loop under the trough to heat that too; don't forget to reposition the foam pipe insulation properly. Lastly, position your board outdoors, high up (2 m / 7 ft.) and preferably horizontal for greater effectiveness. Going about it this way, the piping will be heated up before it is affected by freezing.

(110189)

Internet Link

[1] www.elektor.com/110189

Slave Flash for Underwater Camera



By Daniel Savel (France)

The flash module in this circuit comes from a Fuji disposable camera. The author's design is based on various ideas on this subject that can be found on the Web. The guide number [1] of the flash is approximately 14 in the air and close to 6 underwater. The flash intensity is not adjustable.

This flash unit is primarily intended to be used for underwater photography, which is why the author fitted it in a case originally used for a Nikon Coolpix 7900. Of course, it can also be used for dry-land photography. The flash module is powered by a 1.5-V battery, which must supply approximately 30 to 40 mA to charge the capacitor. The control portion is built around a PIC12F675, which is powered by a 3-V button cell. Its current consumption is practically negligible — just a few milliamperes while the flash is active and only 600 nA the rest of the time, when the microcontroller is in the standby state. For this reason, the unit does not have an on/off button. The flash from the Fuji camera is triggered by a mechanical contact that is actuated at the same time as the camera shutter. Here this contact is replaced by an MCR-100-8 thyristor with a 1-kΩ resistor in series with the gate. These two components are fitted directly on the Fuji flash module.

There are many different types of disposable camera, each with its own type of flash module. However, these modules are all similar, so you can easily adapt the design described here to whatever type you can put your hands on. Pay attention to the voltages, and don't forget to connect the grounds of the flash PCB and the logic circuitry together. Schematics for many of these flash modules are often available on the Web, so it shouldn't be difficult to find something close to what you actually have.

The firmware [2] has three operating modes: manual, pseudo-TTL (through the lens, which means that the light level is measured through the lens) and sleep. In manual mode the flash it triggered when you press the shutter button. In pseudo-TTL mode there are a few short flashes before the main flash (commonly used for red-eye reduction). The number of pre-flashes varies from one camera to the next, and even from one shot to the next. In pseudo-TTL mode, the firmware gets around this problem by waiting for 100 ms after the first flash before it tries to detect the exposure flash. LED D1 lights up if the pre-flash has been detected but the main flash has not been detected after the 100-ms delay.

The contribution of the slave flash to the exposure of the subject is not included in the measurement made by the camera, but instead simply adds to the light from the master flash – hence the designation 'pseudo-TTL'. Although the author considered the option of a true TTL design, or at least adjustable flash intensity, this requires a very specific transistor (25AAJ8 or equivalent) that is very difficult to obtain.

(100584)

Internet Links

[1] http://en.wikipedia.org/wiki/Guide_number

[2] www.elektor.com/100584

Arduino Nano Robot Controller

By François Auger (France)

This circuit is intended to be fitted onto the front of the BOE-Bot mobile robot described in [1]. Although there's nothing to stop you using this circuit with any microcontroller, it has been designed for connecting to the Arduino Nano support board [2]. This support board is a suitable size for fitting to this robot and can be connected to two servomotors driving the robot by way of connectors that have been provided for this purpose.

The circuit shown here allows a mobile robot to detect information about its immediate surroundings by means of two microswitches (end-of-travel detectors), two photoresistors, and three infrared proximity detectors. All this will enable the microcontroller to steer the robot correctly by sending appropriate commands to the servomotors.

The interface circuit for the three infrared detectors is standard, and has already been used in [3]. Potentiometers P1, P2, and P3 let you adjust the current drive to the transmitting diodes, and hence the maximum distance at which the detector will be able to detect the presence of an obstacle. The 2.2 kΩ resistors protect the microcontroller against the accidental short-circuits that might occur if the microcontroller pin is configured as an output and generates a logic level different from that generated by the detector.

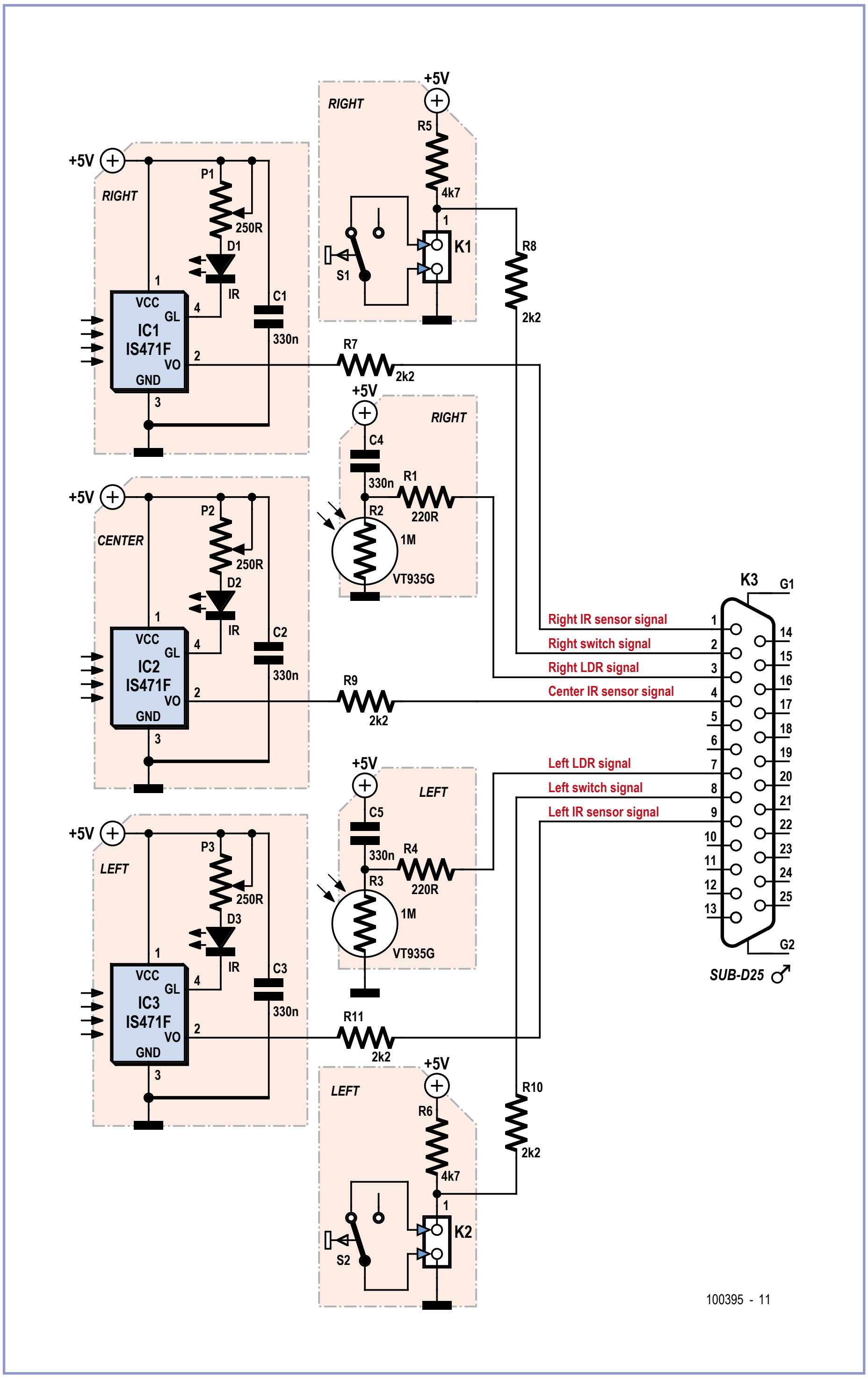
The microswitches make it possible to detect the presence of an obstacle on the route and thus avoid collisions. They force the microcontroller's input pin low.

The two photoresistors make it possible to follow a reflective track, so the robot can follow a path marked out on the ground. They are connected in such a way as to allow us to measure their resistances using just a single logic input/output: at the outset, the microcontroller pin is configured as an output and set high to discharge the capacitor. Then the pin is configured as an input, which puts it into high impedance. The capacitor charges via the photoresistor, so the pin goes from logic 1 to logic 0 after a time that is proportional to the time constant RC. Hence by measuring the time it takes the pin to go from 1 to 0, we can measure the value of the photoresistor, and thus the intensity of the light falling on it.

An additional expansion board that includes a quick prototyping area make it easier to connect the Arduino Nano support board with additional circuits (electronic compass, real-time clock, maths co-processor, accelerometer used as an inclinometer, and so on).

On the web page for the article [4] you'll find a few test 'sketches' along with the PCB design for the additional expansion board.

(100395)



Internet links

[1] Basic Stamp Programming Course, Elektor, September–December 1999.

[2] www.elektor.com/100396

[3] Basic Buggy, Elektor, April 1999.

[4] www.elektor.com/100395

Universal Tester for 3-pin Devices

By Georges Treels (France)

Most 3-terminal active components can be tested statically using just an ohmmeter. But when you have a lot of these devices to test, the procedure soon becomes boring. That's where the idea came from to combine fast, easy testing for these types of device into a single instrument.

The unit described here enables you to test NPN and PNP bipolar transistors, N- or P-channel FETs or MOSFETs, UJTs, triacs, and thyristors. Regardless of the type of device, the tests are non-destructive. Universal connectors allow testing of all package types, including SMDs (up to a point). The unit lets you change from one type of device to another in a trice. It avoids using a multi-pole switch, as they're too expensive and hard to find.

Here's how to build a versatile instrument at a ridiculously low cost.

IC1 is a 4066 quad CMOS switch which will let us switch between bipolar transistors and FETs. LEDs D1–D4 tell us about the condition of the test device, when we press the 'Test' button.

The 4066 can only handle a few milliamps, not enough for the other component types to be tested, hence the reason for using relay RE1. This 12 V relay offers two NO contacts. The first applies power to the UJT test circuit, the second applies it to the triac and thyristor test circuit.

Extensive testing has shown that the best way to test UJT transistors is to do so dynamically, with the help of a relaxation oscillator. Network R11/C1 sets the oscillator frequency to around 2 Hz. On pin B1 of the UJT we find a nice sawtooth, which is not of much interest to us here. However, pin B2 gives good but very short pulses. IC2, wired as a monostable, lengthens these pulses so they can be clearly seen via LED D5.

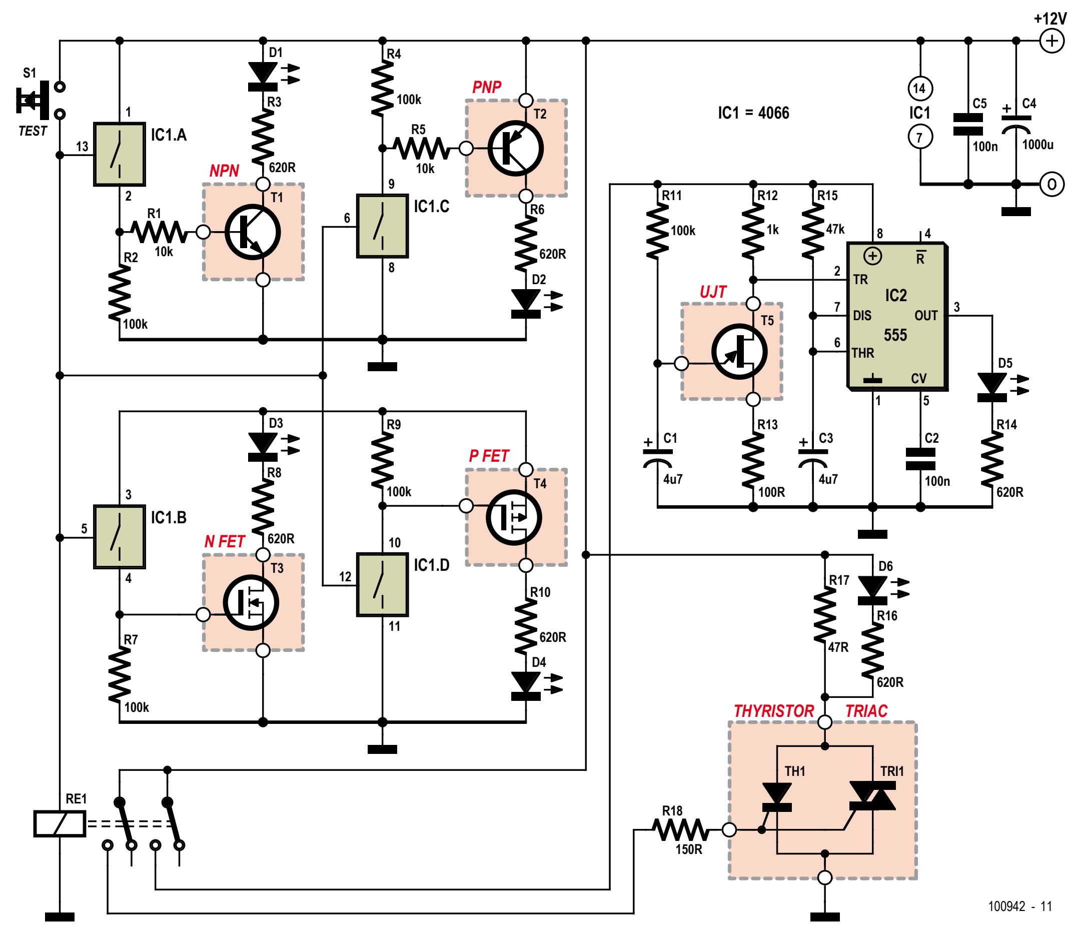
The relay's second pole is going to drive the thyristor's or triac's trigger pin. The value of R18 is a good compromise with respect to the varying trigger currents for this type of device. Resistor R17 is important, as the holding current must be high enough for a triac; 250 mA is a good compromise. LED D6 tells you if the device is in good condition or not; but watch out, the test result must be confirmed by briefly cutting the power in order to reset the triac.

On the web page for this article [1] you'll find the author's CAD files (PCB layout and front panel) along with some photos of his project. On the prototype, the LEDs and the 'Test' button were wired onto the copper side of the PCB. The six female connectors for the devices being tested were salvaged, but there are lots of models available on the market (the pitch is standard). The test cable crocodile clips must be as small as possible for testing SMD devices.

(100942)

Internet Link

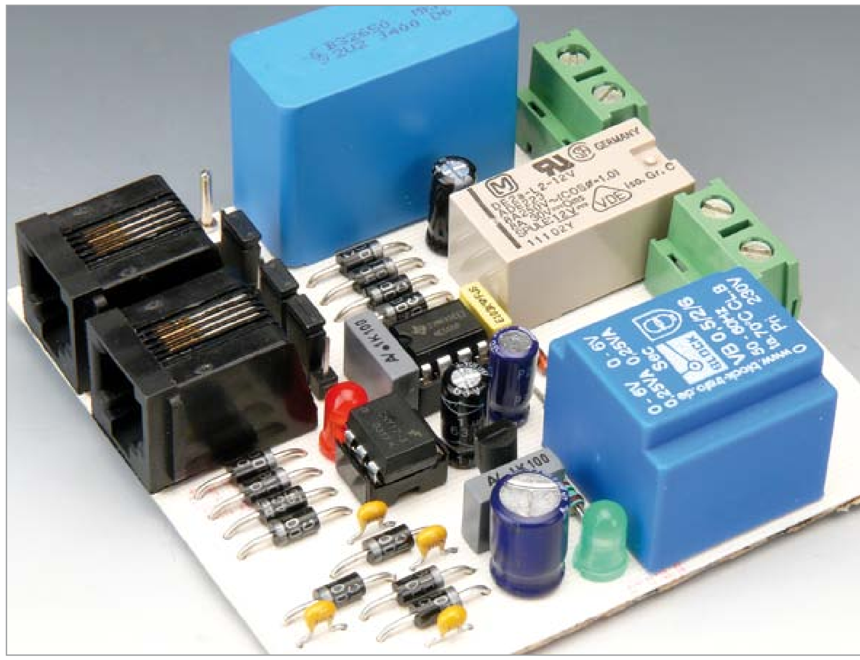
[1] www.elektor.com/100942



Goodbye Standby

Telephone without standby current

By Uwe Reiser (Germany)



Energy saving has been a hot topic for some forty years now. In the early years the focus of public, political and specialist attention was on the large-scale users of energy, but now attention is also turning to the much more numerous smaller-scale users, on the principle that ‘many a mickle makes a muckle’. After a series of bans imposed on ordinary incandescent light bulbs and the introduction of energy-saving bulbs in all shapes and sizes, the EU has recently started to take a look at the energy use of appliances in standby mode. Limits have been set that affect even small mains adaptors. However, one appliance, of which there are many millions in use in the country, and which wastes energy round the clock, has surprisingly somehow managed so far to avoid proper scrutiny: the humble fixed-line telephone.

The author, however, had not failed to notice this needless loss of energy. It had been a source of mild irritation for some time that even the most state-of-the-art fixed-line telephone is doing nothing most of the time except waiting for an incoming call, and yet needs a mains adaptor drawing power all day. It is perhaps worth knowing that most older telephones [1], [2], such as the type 706, draw no current at all when idle. This would be the ideal to which the author would aspire: a current draw in standby mode of zero. Furthermore, the energy-saving circuit itself should be as efficient as possible, preferably switching itself off completely as well.

You will now no doubt be wondering how the author managed to satisfy these requirements. The fundamental question is how a circuit that draws no current can detect when it needs to come into operation. This is indeed possible and in fact not as problematic as it might appear. As is well known, the fixed-line network operator feeds an AC voltage of up to about 60 V down the analog line as a ringing signal; when the receiver is picked up to answer or place a call, a DC voltage appears on the line and a current flows.

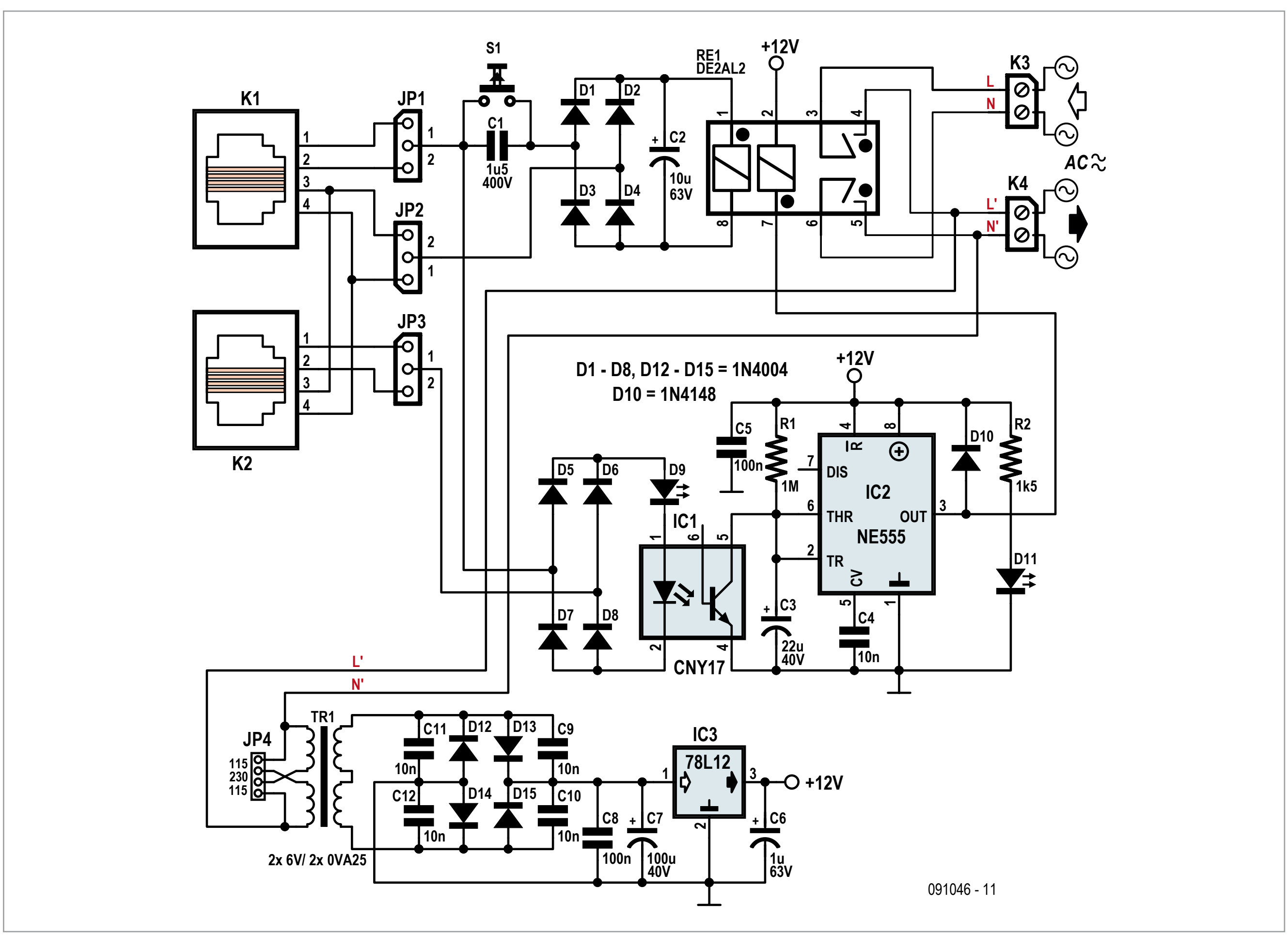
Now to the circuit. The ringing voltage is passed via C1 to the bridge rectifier formed by diodes D1 to D4. The result is smoothed by C2 and pulls in bistable relay RE1. The mains voltage is then passed via the contacts of this relay to the telephone’s mains adapter, which then leaps into action to power the telephone. Mains is also applied via this relay to the rest of the energy-saver circuit. The telephone will ring, and the call can be picked up and answered as usual. If the user wants to place a call, he first presses button S1, which causes the DC voltage across the ‘a’ and ‘b’ wires to pull in relay RE1. The number can now be dialled.

All that remains is to explain how the energy-saver circuit knows when the call is over, or, indeed, has not been picked up in the first place. This job is done by timer IC2 (a device almost as elderly as the type 706 telephone!), connected here as a monostable with a period set by R1 and C3 of 30 s. After this period has expired the second, opposing, coil of RE1 is energized and the relay drops out. The telephone and energy-saver circuit are now without power. This behavior is perfect for the case where a call is not answered. However, calls often last longer than half a minute and it is not ideal to have to keep pressing S1 to retrigger the monostable.

That is where optocoupler IC1 comes in. It, together with an indicator LED, is driven via the bridge rectifier formed by diodes D5 to D8 which are in series with the telephone line. The loop current thus flows also through these LEDs as long as the receiver is lifted. This keeps the top end of C3 at ground potential throughout a call, holding the output of IC2 high. Thirty seconds after the receiver is replaced all the loads are disconnected.

The relay and the optocoupler serve to keep the low-voltage electronics and the telephone line isolated from the mains supply. The bistable relay used must be a type where the two coils are completely separate, and hence with a total of four coil connections. A red LED is best for D9, which lights while the receiver is lifted, because of its low forward voltage. The energy-saver circuit itself naturally consumes some power during a call. However, thanks to the 0.5 W transformer used and the simple, efficient electronics, it amounts to only a few milliwatts. This is small compared to the savings that can be expected when the unit is idle.

As you can see from the photograph of the prototype and from the component mounting plan, an Elektor printed circuit board has been designed for this project [3]. No SMDs are involved, and so populating the board should present no difficulties. Four- or six-way RJ11 sockets may be used. The board can be mounted in an enclosure that is fitted between the telephone and the wall plate. Jumpers J1 to J3 determine whether the circuit responds to the line wired to pins 1 and 4 or to pins 2 and 3. All three jumpers must be in the same position (position 1 or position 2). The transformer we have suggested has two 115 V primary windings and so can be configured using J4 for 115 V or 230 V operation. For 115 V operation

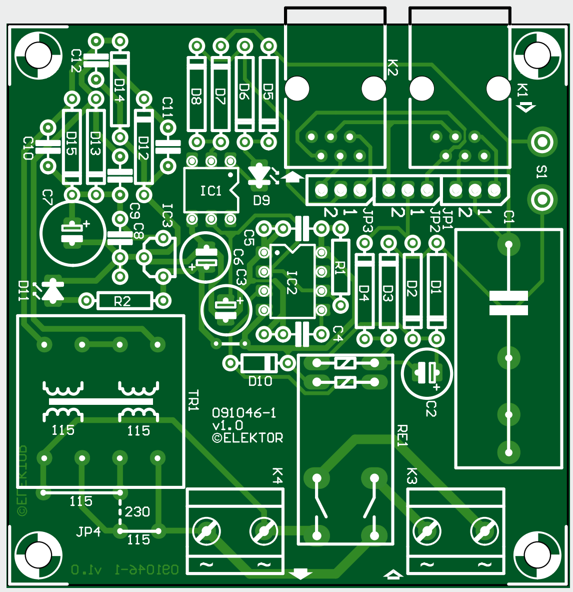


COMPONENT LIST

Resistors
R1 = 1MΩ
R2 = 1.5kΩ

Capacitors
C1 = 1.5µF 400V, MKT, pitch 15 or 22.5 or 27.5 mm
C2 = 10µF 63V, radial, pitch 2.5mm, diam. 6.3mm
C3 = 22µF 40V, radial, pitch 2.5mm, diam. 6.3mm
C4 = 10nF, pitch 5 or 7.5mm
C5,C8 = 100nF, pitch 5 or 7.5mm
C6 = 1µF 63V, radial, pitch 2.5mm, diam. 6.3mm
C7 = 100µF 40V, pitch 2.5mm, diam. 8.5mm
C9,C10,C11,C12 = 10nF, ceramic, pitch 5mm

Semiconductors
D1–D8,D12–D15 = 1N4004
D9 = LED, red
D10 = 1N4148

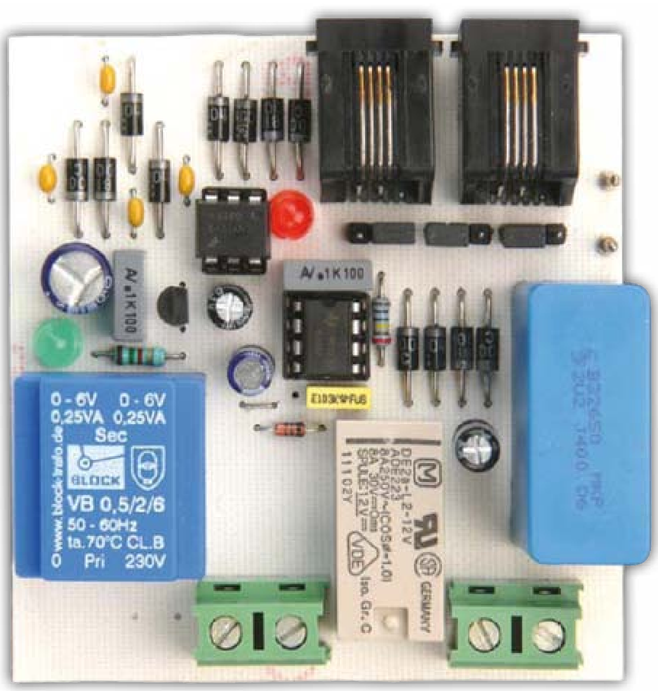


D11 = LED, green
IC1 = CNY17 (DIP6)
IC2 = NE555 (DIP8)
IC3 = LM78L12

Miscellaneous
K1,K2 = RJ-11, PCB mount (4 or 6-pin)
K3,K4 = 2-way PCB screw terminal, pitch 7.5mm
JP1,JP2,JP3 = 3-pin pinheader, pitch 0.1 inch, w. jumper
JP4 = 1 wire link for 230VAC or 2 wire links for 115VAC (see text)
RE1 = Panasonic DE2a-L2-12V, 2 8 A/250 VAC contacts, 2 720 Ω/12 V coils, bistable
S1 = pushbutton, 1 make contact, 1 A
TR1 = power transformer, AVB0,5/2/6, 2x115 V primary, 2x6 V secondary, 0.5 VA
PCB # 091046 (see [3])

two links are fitted in the outer positions; for 230 V operation a single link is fitted in the middle position. The jumper arrangement precludes fitting all three links at once, which would have the unfortunate effect of short-circuiting the mains supply. If a transformer with a single appropriate primary winding is used, these links are not needed.

One final word on telephones. There are some models that are not ready for operation for ten to fifteen seconds after being powered up. These are not ideal for use with this circuit, as one or perhaps more rings will be lots when a call is received. Also, some telephones with integrated (non-cassette-based) answering machines either forget their stored messages or rapidly exhaust their back-up batteries when power is lost, and these also are not ideal.



Caution. Modification or home construction of circuits connected to the PSTN (public switched telephone network) is subject to local regulation and may not be legal.

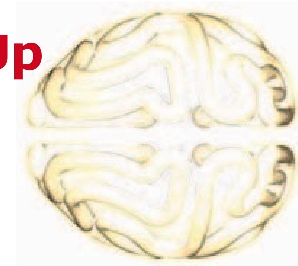
(091046)

Internet Links:

[1] www.telephonesuk.co.uk/phones_pre1960.htm

[2] www.telephonesuk.co.uk/phones_1960-80.htm

[3] www.elektor.com/091046



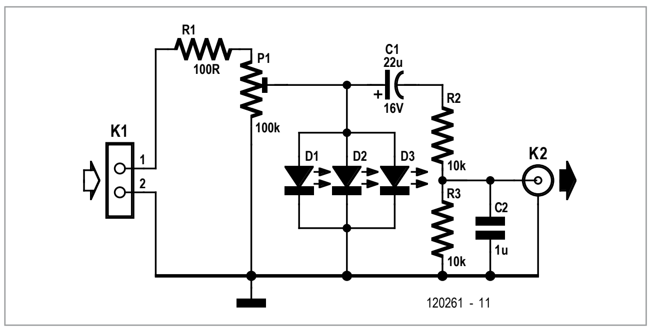
Noisy LEDs

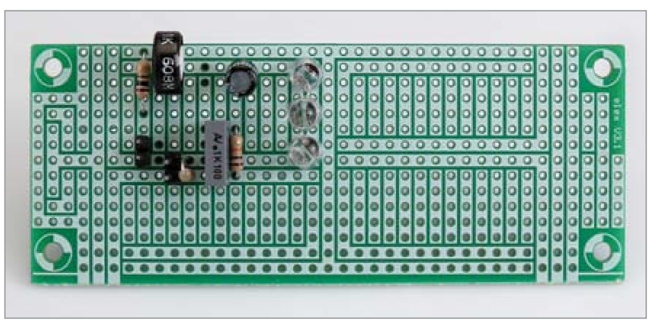
Simple generation of complex sound effects

By Ralph Willekes (Belgium)

These days there are many types of intelligent LEDs available. These LEDs flash or change their color, slowly or quickly and with different color combinations. Those LEDs that gradually change from color to color (so-called rainbow LEDs) were found to be particularly suitable for an alternative application. They happen to produce incredibly complex sounds when they are connected as shown in this circuit.

Potential divider R1/P1 limits the current through the LEDs and has a significant impact on the sound produced. The value can be set between roughly 100 Ω and 100 kΩ. In this circuit it was achieved using a resistor and a preset. If you want to keep things very simple you can get rid of the preset and experiment a bit with series resistor R1. The circuit works with a single LED, but the addition of more LEDs leads to more interesting sounds because the LEDs end up ‘fighting’ each other for the energy. C2 and resistor R2 form a low-pass filter. Start with a value of about 10 nF in order to hear the full range of sounds. For a ‘heavier’ sound you can increase C2 to about 1 µF or even 10 µF. C1 avoids the presence of any DC voltage at the output.





The supply voltage to the circuit can be anywhere between about 4 V and 10 V (depending on the value of R1 and the LEDs used).

Make sure that you turn the volume down fully on your amplifier before you connect this circuit, since level of the output signal can vary significantly.

(120261)

Internet Links

Demo film: http://youtu.be/z_aOeCGBZlk

Version using different LEDs and 4.7 µF for C2: http://youtu.be/vbITTveORRA

COMPONENT LIST

Resistors:

R1 = 100Ω
R2,R3 = 10kΩ
P1 = 100kΩ

Capacitors

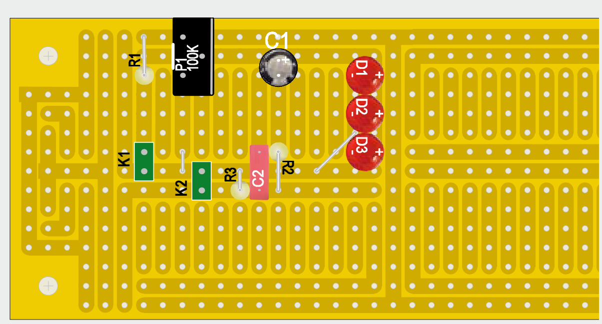
C1 = 22µF 16V
C2 = see text

Semiconductors

D1,D2,D3 = rainbow LED, preferably mixed types

Miscellaneous

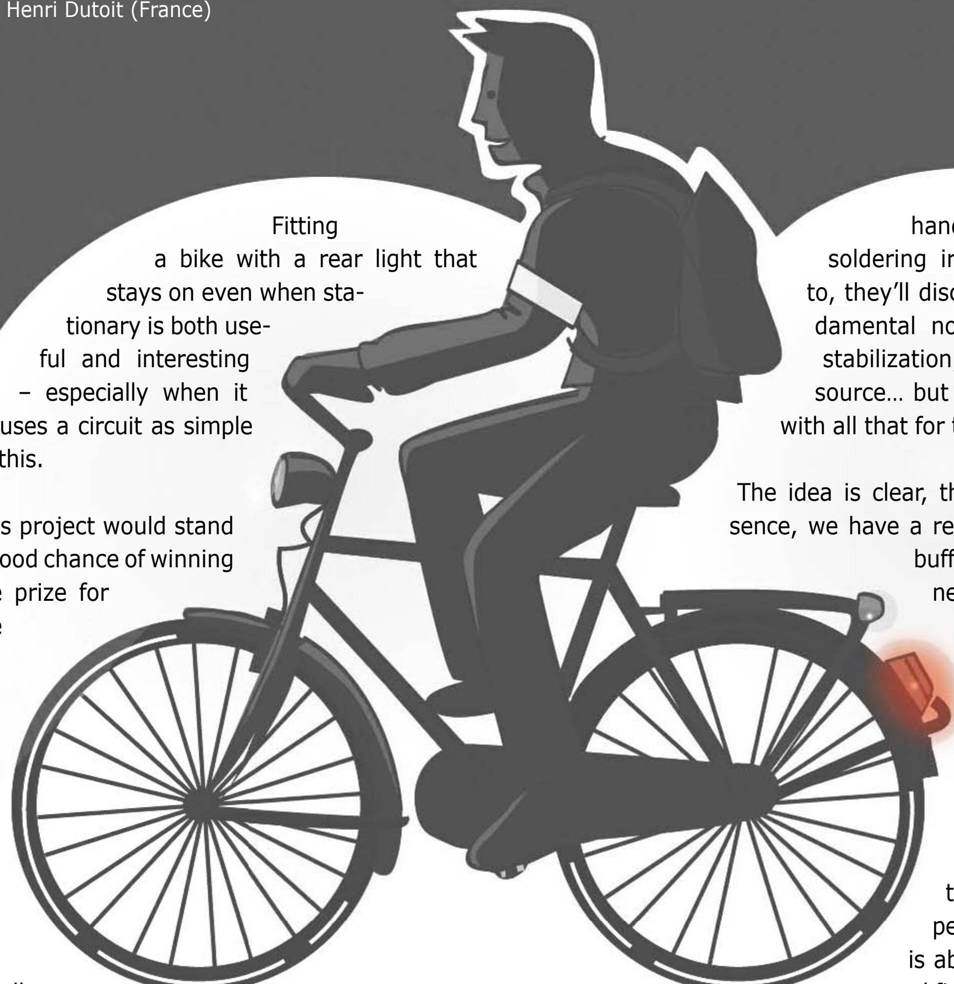
‘Elex’ type experimenter’s board



Bicycle Rear Light

one super LED and 10 components last 5 minutes

By Henri Dutoit (France)



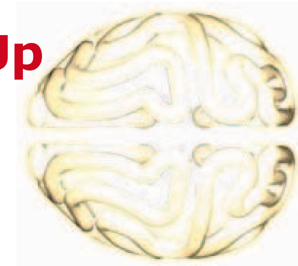
Fitting a bike with a rear light that stays on even when stationary is both useful and interesting – especially when it uses a circuit as simple as this.

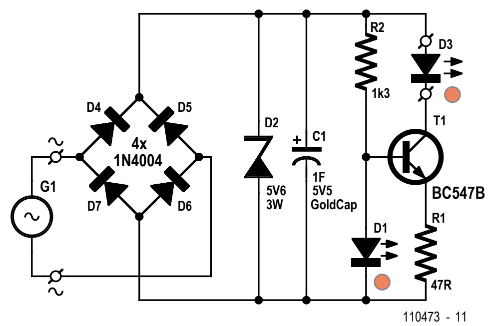
This project would stand a good chance of winning the prize for the smallest circuit in this edition. This is, moreover, the reason why it's been chosen here, as Elektor has already published at least two or three versions that are more elaborate, but not necessarily any better. This version is stripped right down to the bare essentials, but stays on for 5 minutes; it also provides an excellent pretext for trying to get young people interested in electronics, who maybe want nothing more than to get their hands on the soldering iron. If they want to, they'll discover here some fundamental notions like rectification, stabilization, the constant current source… but don't let's scare them away with all that for the moment.

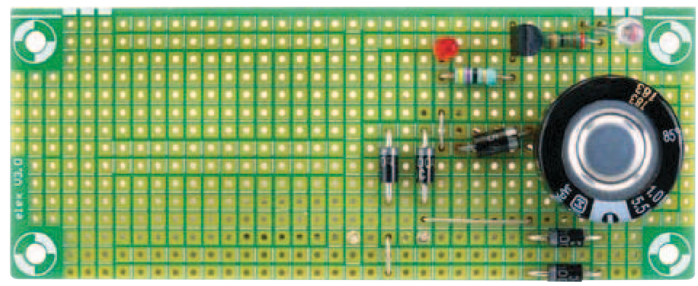
The idea is clear, the solution illuminating: in essence, we have a rectifier, a very high capacitance buffer capacitor, and a high-brightness LED.

The alternating voltage from the dynamo (G1 on the circuit diagram) is rectified by 4 diodes, which works out cheaper than a single bridge-rectifier. Once it has been charged up by a few turns of the pedals, a single 1 farad supercapacitor, known as a GoldCap, is able to keep the LED D3 lit for a good five minutes when the bike is stationary. Before seeing how this LED works, let's take a look at the supercapacitor, on whose terminals the rectified voltage must not exceed the voltage stated by the manufacturer, i.e. 5.5 V. So we're going to be using a 5V6 zener diode to clip the peaks of the pulsing direct voltage. There's no risk that the current supplied by a bike dynamo is going to harm this device, which is capable of dissipating a power of 3 W. If you are a bit dubious, you can always go

The idea is clear, the solution illuminating.







for a capacitor with a higher voltage rating, for example the DK-6R3D105T from Elna America (available from Digi-Key) which, as its type number suggests, can handle 6.3 V. Another advantage of this device is its lower series resistance compared with the Panasonic type we tested (30 Ω instead of 50 Ω), which means that when fully charged, its voltage will be slightly higher.

With the GoldCap, using an AC voltage of 6 V @ 50 Hz, we measured a DC voltage of 4.8 V with 0.76 V residual ripple.

T1 and the two components associated with it, R2 and the LED D1, form a constant current source. Even when the supercapacitor discharges, these ensure that the brightness of the powerful LED D3 remains stable. It needs to be able to handle a continuous current of at least 20 mA.

This current is determined by the value of R1. The table gives an idea of the way the voltage across R1 changes with time once the bike has stopped. After six minutes, the voltage has dropped right off and the current in the LED is now only 5 % of its nominal value.

Stop	U_{R1}
0	1 V
2 min	0.5 V
3.5 min	0.25 V
4.5 min	0.1 V
6 min	0.05 V

To make the circuit easy to build, we suggest building it on prototyping board or breadboard. **Watch out!** Don't forget to make the break in the topmost track, otherwise T1 and D3 will receive the alternating voltage!

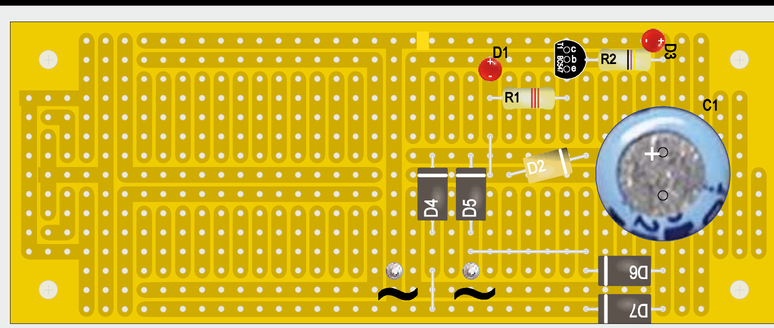
(110473)

COMPONENT LIST

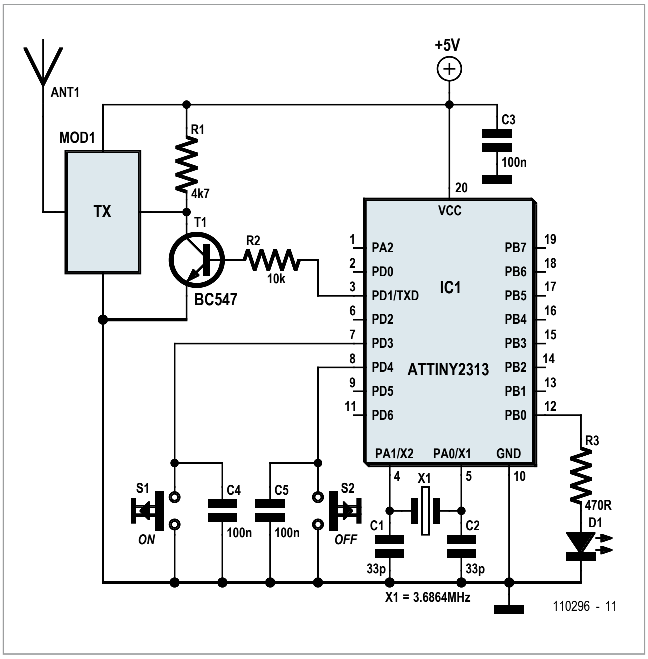
Resistors
R1 = 47Ω
R2 = 1.2kΩ

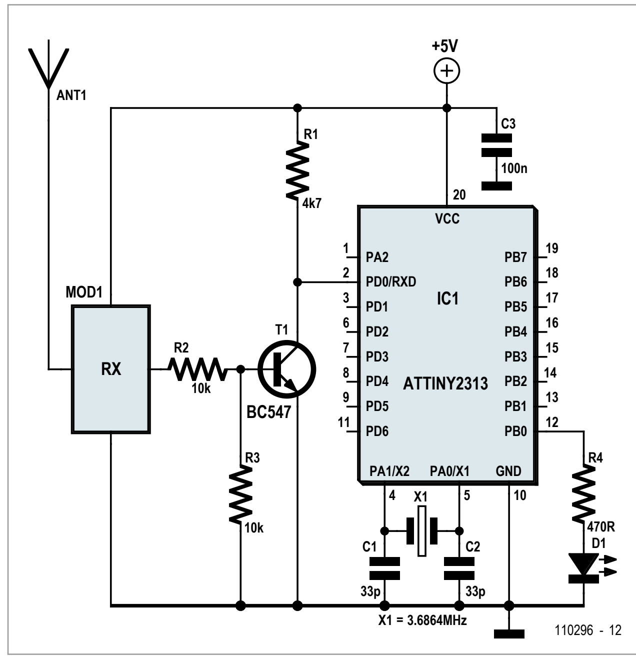
Capacitors
C1 = 1F 5.5V, e.g. Panasonic EECF5R5H105

Semiconductors
D1 = LED, red, standard (V_f = 1.7V)
D2 = zener 5.6V 3W
D3 = LED, red, high brightness, e.g. MCL034URC (I_{max} ≥ 20 mA)
D4–D7 = 1N4004
T1 = BC547B
Elex-1 (UPBS-1) prototyping board



ATtiny Goes Wireless





By Jürgen Stannieder (Germany)

In many application areas it can be very handy to be able to control something wirelessly. This circuit shows how an ATtiny microcontroller can be used to switch an appliance on and off remotely with a little help from wireless transmitter and receiver modules available from Conrad Electronic. If needed, it is very easy to extend the project to include additional commands.

To demonstrate the principle of operation we represent the appliance to be controlled by a red LED at the receiver end. At the transmitter end, buttons S1 and S2 are responsible for the 'on' and 'off' switching functions (see left-hand circuit diagram). When one of these buttons is pressed it pulls the corresponding input of the microcontroller (PD3 or PD4) to ground. The software running in the microcontroller recognizes the input and converts it into a command message. In this case the message consists of the single character 'E' to switch the appliance on and 'A' to switch it off. The command message is emitted at output PD1 (TXD) of the ATtiny, where it is inverted by T1 and then sent to the Conrad transmitter module. The inverter is needed here as the TXD output (as is conventional) returns high when no message is being sent. Without the inverter this would mean that the transmitter would always be active when no message was being sent: with the arrangement shown the transmitter is idle between messages. Crystal

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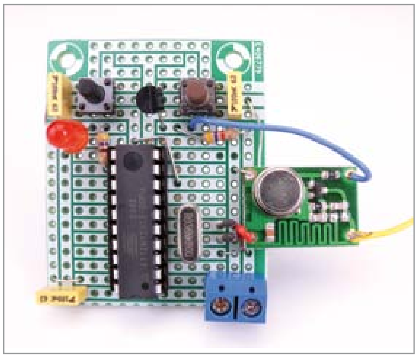
- Receiver: 110296-42
- ELEX-1 (UPBS-1) prototyping board
- Free software download

Products and downloads available via www.elektor.com/110296



COMPONENT LIST

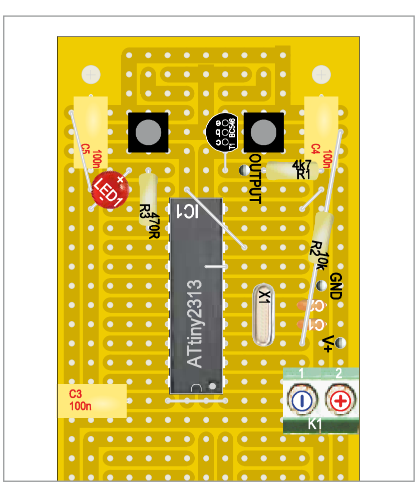
Transmitter

Resistors
R1 = 4.7kΩ
R2 = 10kΩ
R3 = 470Ω

Capacitors
C1,C2 = 33pF
C3,C4,C5 = 100nF MKT, 5mm

Semiconductors
LED1 = 5mm, red
T1 = BC547C, TO-92
IC1 = ATtiny2313 DIP-20, programmed, Elektor # 110296-42)

Miscellaneous
X1 = 3.6864 MHz quartz crystal, HS49/S case
S1,S2 = pushbutton, e.g. B3F-1000
TX = Transmitter module from 433 MHz AM transceiver set, Conrad Electronics # 130428
DIP20 socket
ELEX-1 (UPBS-1) board (1/2)



X1 produces the clock for the microcontroller, the 3.6864 MHz frequency used allowing easy generation of baud rates from 9600 baud to 76800 baud. We configure the microcontroller to run at 9600 baud, which gives reliable operation with the radio modules. LED D1 and its series resistor are present in the circuit to give feedback to the user when the microcontroller registers an input. The LED lights when either of the buttons is pressed.

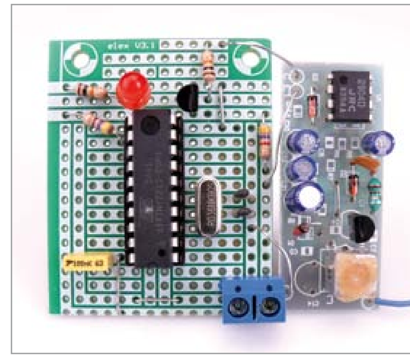
At the receiver end (see right-hand circuit diagram) the signal from the receiver module is passed to another microcontroller which then processes the received information. Because the signal was inverted prior to transmission, it must be returned to its uninverted form by inverter T1. The software in the microcontroller reads the signal in at its PD0 (RXD) input. Depending on whether its sees the letter ‘E’ or ‘A’, it turns LED D1 on or off. Again, the microcontroller receives its clock from crystal X1, with a frequency of 3.6864 MHz.

The 433 MHz radio transmitter and receiver modules used in this project are available as a set from Conrad [1]. Construction is relatively straightforward. It is worth noting that the antennas on the transmitter and receiver modules are tuned appropriately at the factory and should not need further adjustment. The circuit can conveniently be built on an Elektor Universal Prototyping Board Size-1 (UPBS-1, a.k.a.ELEX-1) cut into two halves (see photographs and mounting plans). The author managed to achieve reliable communication between the two modules within his house over a distance of 12 m (40 ft).

(110296)

Internet Link:

[1] www.conrad-uk.com/ce/en/product/130428/



COMPONENT LIST

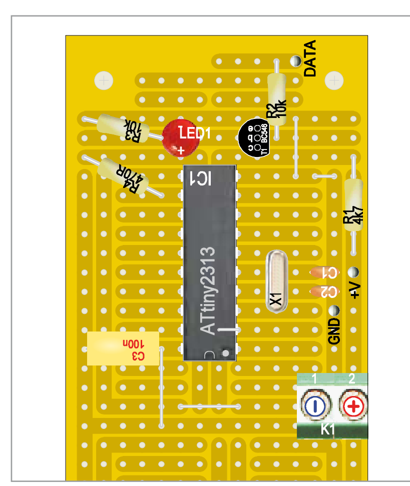
Receiver

Resistors
R1 = 4.7kΩ
R2,R3 = 10kΩ
R4 = 470Ω

Capacitors
C1,C2 = 33pF
C3 = 100nF MKT, 5mm

Semiconductors
LED1 = 5mm, red
T1 = BC547C, TO-92
IC1 = ATtiny2313 DIP-20, programmed, Elektor # 110296-41)

Miscellaneous
X1 = 3.6864 MHz quartz crystal, HS49/S case
RX = Receiver module from 433 MHz AM transceiver set, Conrad Electronics # 130428
DIP20 socket
ELEX-1 (UPBS-1) board (1/2)



A Zero Current Switch

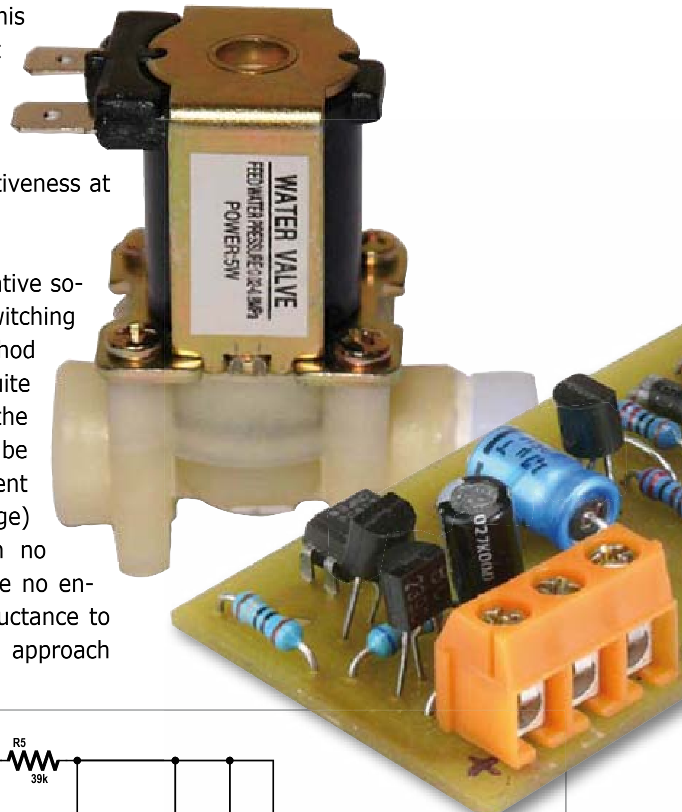
For inductive Loads

By Matthias Haselberger (Germany)

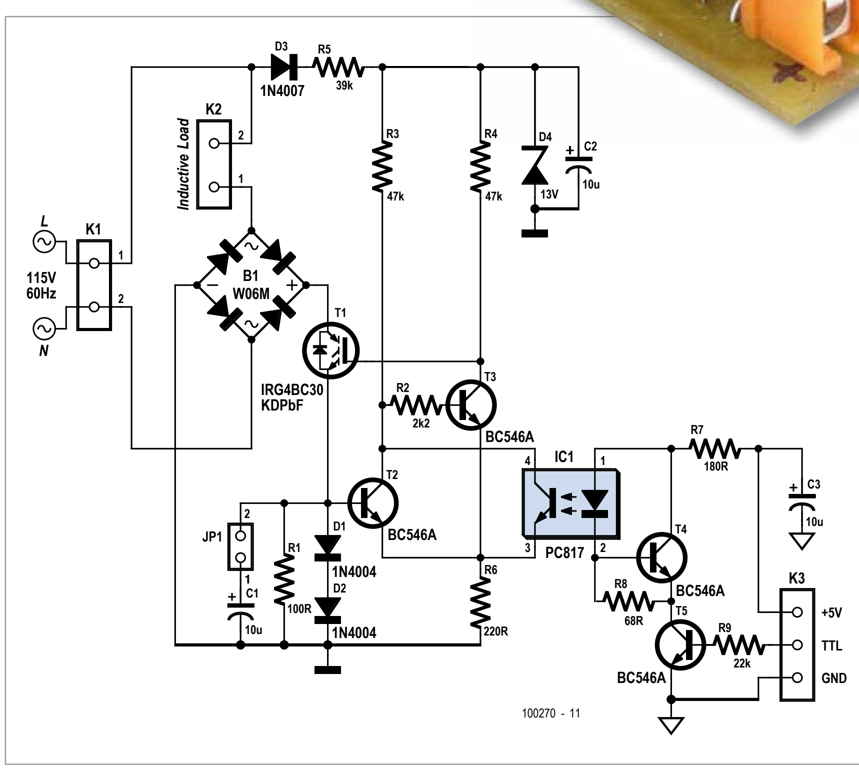
Relays or contactors are often used to switch mains powered inductive loads such as motors, valves or electro magnets. When the device is switched off an arc can form across the relay contacts as they open. This leads to premature relay failure if measures are not taken to suppress the spark. In addition to relay damage the high voltage spark causes interference and EMC issues. The most common method of suppressing the arc is to connect a snubber in parallel to the contacts. This device is a series resistor and capacitor network. Now when the contacts break, energy stored in the inductor has a path to dissipate through the snubber to generate a small amount of heat in the resistor. Typical values of the snubber components are R = 1 to 100 Ω and C = 10 to 1000 nF.

Relay contacts open at unpredictable times during the mains AC cycle; at the time of maximum current the induced 'back-EMF' and contact arcing problems mentioned above will be most severe. Semiconductor relays using thyristors or triacs will always turn off when the voltage across them passes through zero, for a load with a highly reactive power component the voltage and current will be phase shifted so that this point corresponds to the instant of maximum current. A snubber will be an essential component in this situation.

Snubbers are however not completely unproblematic; a small current will continually flow through the snubber RC network (and load) when the contacts are open. Not only is this wasteful but with a very light load such as a fan, it can often be enough to keep the fan running. Increasing the value of R reduces its effectiveness at suppressing arcs.

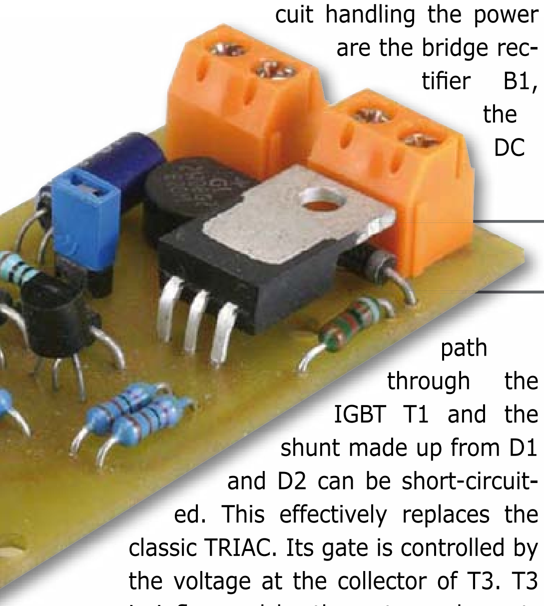


There is however an alternative solution to the problem of switching inductive loads. The method suggested here is really quite simple: make sure that the inductive load can only be switched off when the current waveform (not the voltage) passes through zero. With no current flowing there will be no energy stored in the load inductance to cause problems. Using this approach



it's possible to dispense with the snubber completely. This was the train of thought that passed through the authors mind and set him on the path to design this zero-current switching electronic relay.

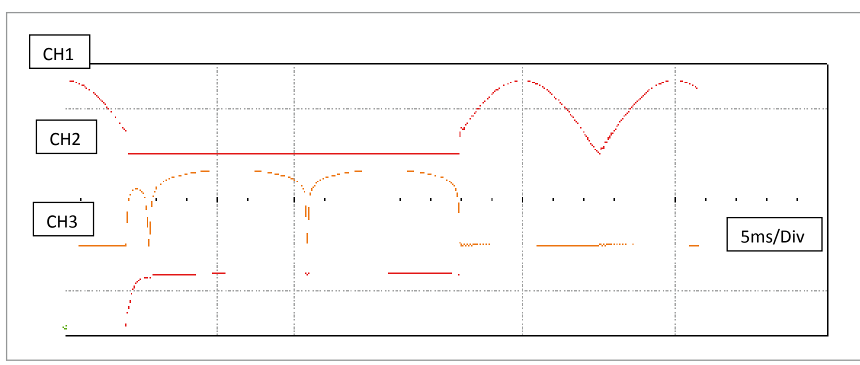
So to the solution: The parts of the circuit handling the power are the bridge rectifier B1, the DC



path through the IGBT T1 and the shunt made up from D1 and D2 can be short-circuited. This effectively replaces the classic TRIAC. Its gate is controlled by the voltage at the collector of T3. T3 is influenced by the optocoupler output and also the zero current detector made up from D1, D2 and T2.
When the load is switched off there is no current flowing and T2 will be off, T3 will be conducting and T1 will be off. A high on the TTL input turns the photo transistor in IC1 on which shorts the base-emitter junction of T3, turning it off and bringing T1 into conduction thereby switching the load on.

To turn the load off the TTL input is brought low to turn off the photo transistor. T3 can now only be turned on when T2 turns off. T2 remains conducting until the load current passes through zero when the voltage across D1 and D2 drops to zero. So after the TTL input goes low, the load remains switched on until load current sinks to (almost) zero. Just what we wanted.
The author simulated the circuit using the Multisim11 software from National Instruments (NI). The resulting diagrams confirmed the circuit function using inductive loads. CH1 shows the voltage at the collector of T1 and CH2 the voltage at the emitter of T1 and the base of T2 which corresponds to the absolute value of current flowing in the load. CH3 shows the control voltage applied to the gate of T1. A phase shift of 20 ° between the voltage and current waveform is used in this simulation. The author confirmed the simulation results with observations of the finished working circuit. Those of you interested in the simulation details can look at the 'Elektor3_10.ms11' file associated with this project which can be downloaded from the Elektor website

Snubber-free switching



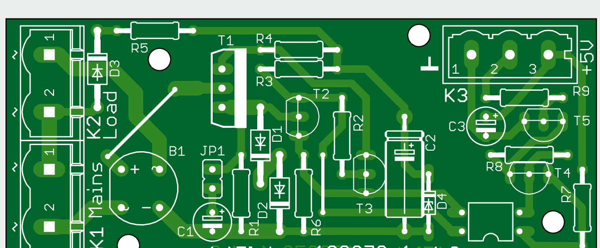
COMPONENT LIST

Resistors
R1 = 100 Ω
R2 = 2.2kΩ
R3,R4 = 47kΩ
R5 = 82kΩ 1%, 0.6W 350V (Vishay MRS25000C8202FCTOO)
R6 = 220Ω
R7 = 180Ω
R8 = 68Ω
R9 = 22kΩ

Capacitors
C1,C3 = 10µF 100V 20%, pitch 2.5mm, diam. 6.3mm
C2 = 10µF 63V, axial, 10 x 4.5mm

Semiconductors
D1,D2 = 1N4004
D3 = 1N4007
D4 = BZX79-C13 (13V 05W)
B1 = WO6M, 600V 1.5A
T1 = IRG4BC3OKDPbF
T2..T5 = BC546A
IC1 = PC817 (see text)

Miscellaneous
PCB # 100270 [1]



[1]. An evaluation version of the Multisim simulation software is available from NI [2].

A few more circuit details: R1 ensures that the voltage at the base of T2 really does go to zero when the current waveform passes through zero. D4 limits the V_{CE} of T2 and T3 and also the V_{GE} of T1 to a safe value. Capacitor C1 together with the jumper position JP1 allows the circuit to be used in situations where the AC load is lightly inductive. It allows some adjustment of the turn-off point of T2 (and T1) to the actual zero crossing point of current in the cycle. An IGBT type device has been used for T1 because the higher switching threshold of the gate voltage is more suited to this application than a high voltage MOSFET. Practically any optocoupler can be used for IC1, its switching speed is not critical.

A PCB is available for the project. The layout doesn't use any SMD's so assembly is very easy. The PCB can be obtained from the Elektor shop or the layout files in Eagle format can be downloaded free of charge [1] allowing you to produce your own. Be aware that the circuit is directly connected to the mains, some parts of the circuitry and PCB tracks carry lethal voltage levels. It is therefore vital to observe all the appropriate health and safety precautions. The use of 1N4004 diodes allows load currents up to 1 A, corresponding to a power rating of 230 VA. Transistor T1 does not need a heat sink at this power level. To make the design suitable to handle a higher current is not just a simple matter of swapping D1 and D2 for higher current versions. It will also be necessary to beef-up the PCB tracks handling the load current, B1 must also be replaced and T1 will require a heat sink.

(100270)

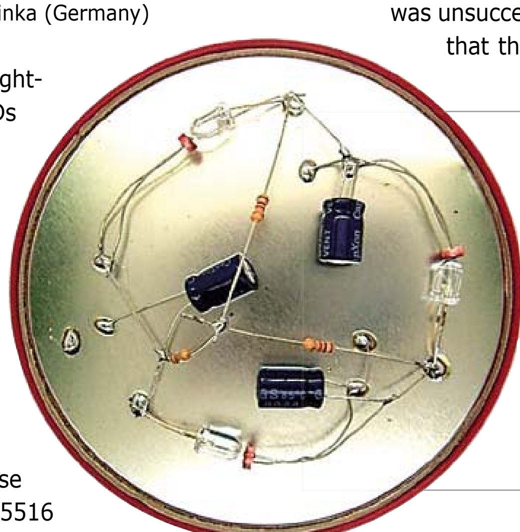
Internet Links

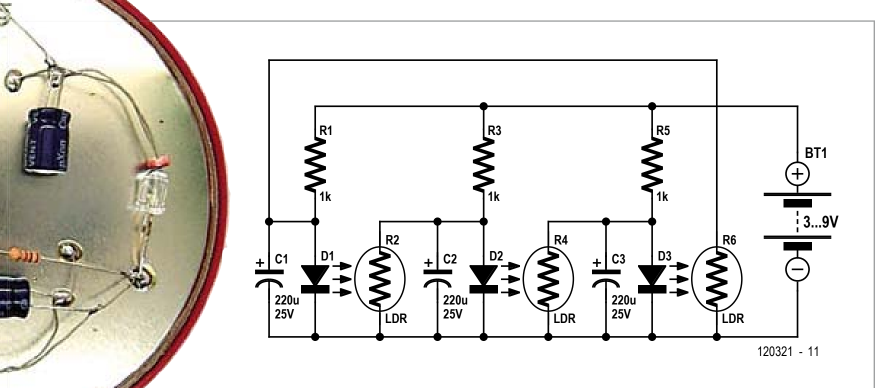
[1] www.elektor.com/100270

[2] www.ni.com/multisim

LED-LDR Ring Oscillator

By Burkhard Kainka (Germany)





Can high-brightness white LEDs and light-dependent resistors (LDRs) be used to make an oscillator? I decided to have a go. For the experiment I chose type PGM5516 LDRs which have a relatively low resistance (5 kΩ to 10 kΩ at 10 lux). A ring oscillator configuration was used, with each LED placed directly next to its neighboring LDR (see circuit).

The first test, without the capacitors, was unsuccessful. I had hoped that the natural slow response of the LDRs would be enough to start oscillation, but the oscilloscope proved me wrong.

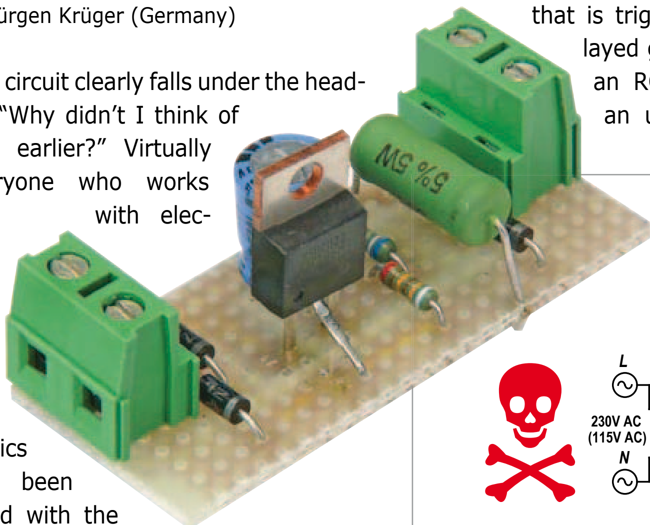
Only by adding the 220 µF electrolytic capacitors could I get the oscillation to start, using a power supply of between 3 V and 9 V. The oscillation frequency rises with supply voltage. At 3 V the circuit must be kept in darkness (and the result is a very low-energy running light!). At 2.7 V the circuit draws 0.9 mA and is disturbed by even the smallest amount of ambient light.

(120321)

Soft AC Line Start

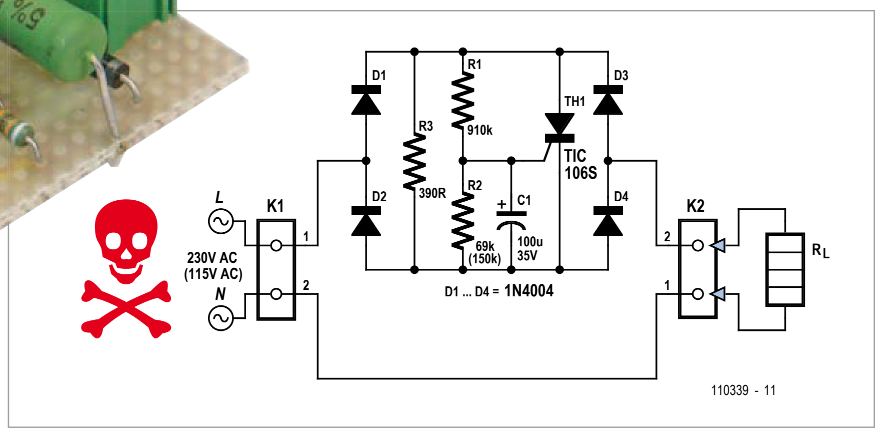
Small Circuit, Big Effect

By Jürgen Krüger (Germany)



This circuit clearly falls under the heading “Why didn’t I think of that earlier?” Virtually everyone who works with electronics has been faced with the need or desire to limit the inrush current of a large load. In the distant past this was achieved by placing a hefty resistor in series with the supply line and using a contactor (or a relay with a bit of additional electronics) to short out the resistor shortly after the load is switched on. Although this does the job, it’s an electromechanical solution and therefore subject to wear, bulky and not especially elegant. Now you have the option of putting together a microcontroller circuit that uses an analog input to detect the presence of AC line voltage and an internal timer to generate a delayed trigger for a triac that shorts out the series resistor. This also does the job, but it’s actually a bit of overkill.

Mr Krüger adopted a logical approach and came up with a minimalistic circuit that not only does the job, but does it with remarkable simplicity. Although the simplest solution would be a triac that is triggered by a delayed gate signal from an RC network with an upstream series diode, it suffers from the fact that triacs with unipolar triggering have different trigger sensitivities for positive and negative half-waves. This means that when the load is switched on, it is possible for one or more negative half-waves to get lost. This is not so nice with inductive loads such as transformers, since they may become saturated and as a result cause exactly what you are trying to avoid: a blown fuse or tripped circuit breaker.



For this reason, the author chose to implement a slightly more complicated version. The basic principle is the same as with the series triac, but with an SCR incorporated in the DC arm of a bridge rectifier instead. That’s all there is to it. An SCR also has the advantage that the necessary trigger current can be significantly lower than with a triac.

The proposed type (TIC106) typically triggers at a gate current of 60 µA. This allows resistors R1 and R1 to have relatively high values. These resistors in combination with C1 determine the trigger delay, which is dependent on the component tolerances and can be as much as several hundred milliseconds. A 5 W type should definitely be used for R3, since it has to dissipate a considerable amount of power during this brief interval.

The author has used series circuits of this type fairly often as soft-start circuits for incandescent lamps, which as is well known have low cold resistance. Particularly when you use an inverter to convert 12 V DC to 230 C AC for camping, high inrush currents with a 100-watt incandescent lamp can be enough to cause start-up problems with the inverter, even with a 300 watt rating, or fry the lamp. Relatively large transformers can also generate high peak currents during switch-on if they

happen to be switched on exactly at the zero crossing point and become saturated due to inadequate core magnetization.

With the specified components and component values, the circuit can be used for loads up to 230 VA. Higher currents require heavier-duty diodes and an SCR with a higher current rating, as well as a heat sink for the SCR. With such modifications you should bear in mind that high-current SCRs require higher trigger currents, so the values of R1 and R2 should be reduced and the value of C1 should be increased. Another option would be to use separate drive logic, but that would detract from the elegant simplicity of the circuit. The value or R3 should be adapted to the intended use or desired inrush current level.

(110339)

Knitting Counter

By Marian van Hal (Netherlands)

Knitting always involves a lot of counting as you have to keep track how many rows you've knitted and how many should follow. This can of course be done with pen and paper, but it's more fun with an electronic variant using a microcontroller.

This counter has the following functions:

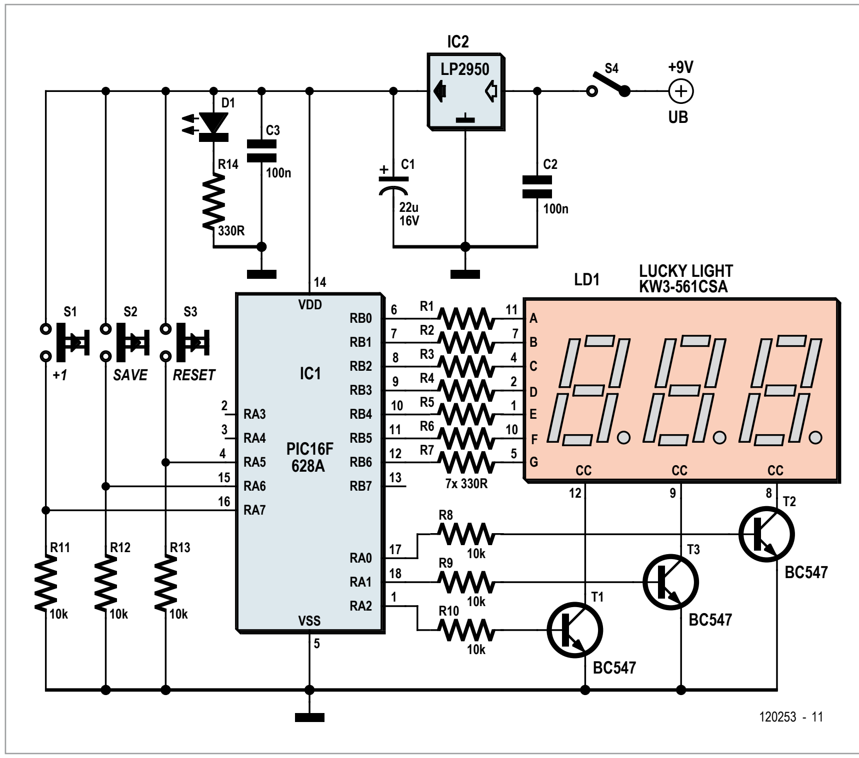
- Switch S1 increases the counter by one.
- Switch S2 saves the current count in the EPROM memory of the microcontroller.
- Switch S3 resets both the counter and internal memory to zero.

Switch S4 turns the device on and off. When it is turned on the display will show the value stored in the internal memory.

The display and counter function are turned off after about 5-10 seconds in order to improve the battery life. Pressing S1 turns the display and functions back on again. An LED shows when the circuit is switched on, even with the display blanked. A low dropout voltage regulator (LP2950) is used the get the maximum usage from a 9 V battery.

At the heart of the circuit is a PIC 16F628A. The three digits of the LED display (a common cathode type) are multiplexed via the PIC. The software is written in PICbasic from Proton and can easily be modified if required. Since the author has only recently started with programming microcontrollers, the software has not made use of timers or interrupts. Despite that, the display is still turned off after some time, but this is achieved solely by the software.

The circuit is built on a standard experimenter's board and the component layout was developed using the program Lochmaster from Abacom [1].



The basic, asm and hex files can be freely downloaded from [2].

(120253)

Internet Links

[1] www.abacom-online.de/uk/html/lochmaster.html

[2] www.elektor.com/120253

COMPONENT LIST

Resistors

R1–R7,R14 = 330Ω
R8–R13 = 10kΩ

Capacitors

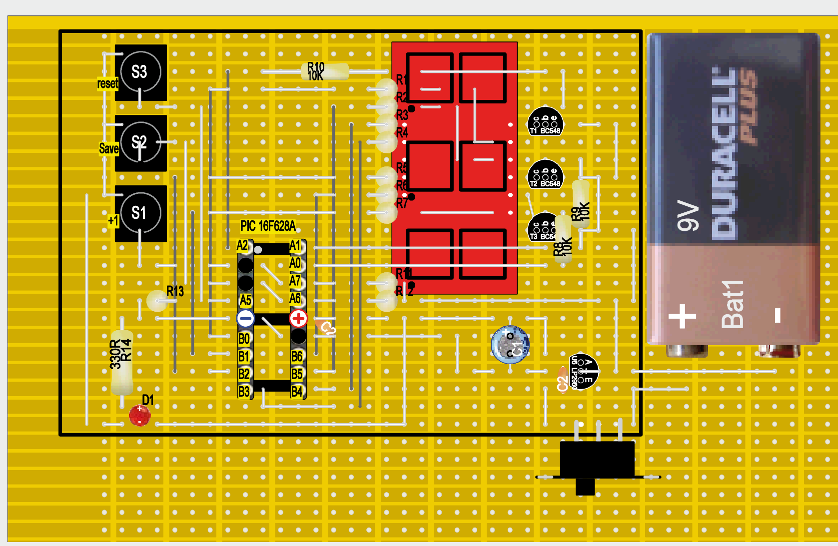
C1 = 47µF 16V
C2,C3 = 100nF

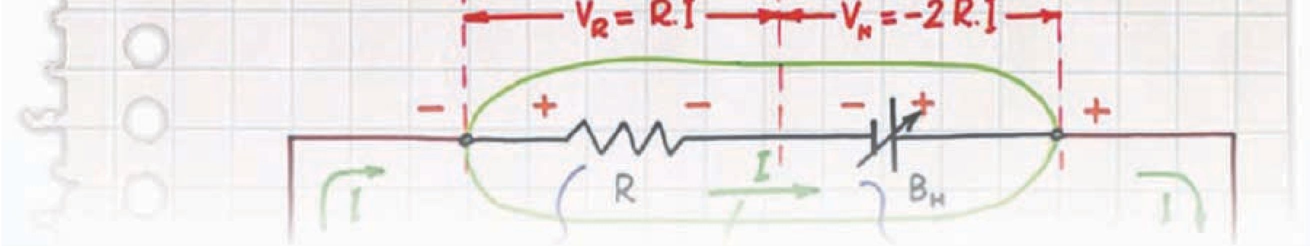
Semiconductors

D1 = LED, red, 5 mm
Display = KW3-561-CSA (Lucky Light) or 3 discrete 7-segment displays (CC)
T1,T2,T3 = BC547
IC1 = PIC16F628A, programmed

Miscellaneous

S1,S2,S3 = pushbutton with make contact
S4 = slide switch with make contact
9V battery with clip-on connector
Piece of experimenter's board

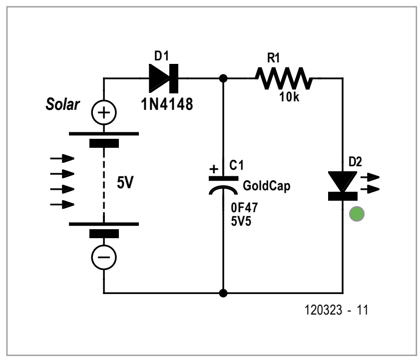




‘Green’ Solar Lamp

By Burkhard Kainka (Germany)

Energy saving is all the rage, and here is our small contribution: how much (or rather how little) current do we need to light an LED? Experiments with a super-bright 1 W green LED showed that even one microamp was enough to get some visible light from the device.



Rootling in the junk box produced a 0.47 F memory back-up capacitor with a maximum working voltage of 5.5 V. How long could this power the green LED? In other words, if discharged at one microamp, how long would the voltage take to drop by 1 V? A quick calculation gave the answer as 470 000 seconds, or about five days.

Not too bad: if we use the capacitor for energy storage in a solar-powered lamp we can probably allow a couple more microamps of current and still have the lamp on throughout the night and day. All we need to add is a suitable solar panel. The figure shows the circuit diagram of our (in every sense) green solar lamp.

(120323)

Power LED Driver

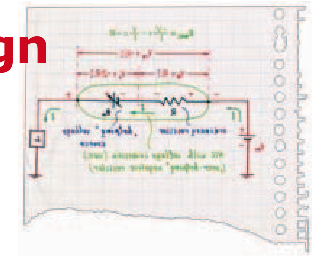
By Michael Hölzl (Germany)

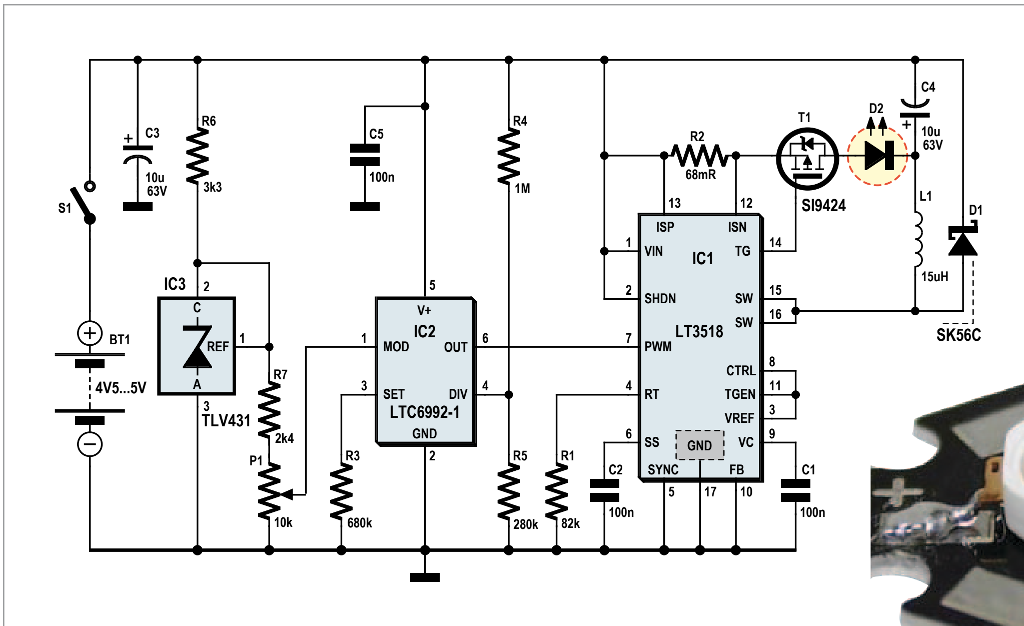
If you want to operate power LEDS with a truly constant current – which significantly prolongs the lifetime of the lamp – and avoid the power loss resulting from using a constant voltage supply with a series resistor, you need a suitable constant current source. However, the only way to achieve really good efficiency is to use a switching regulator. Altogether, this means that you need a switching regulator designed to generate a constant current instead of a constant voltage.

With this in mind, the author started working on the development of a LED pocket torch with especially high efficiency. Along with using high-capacity rechargeable batteries to maximize operating life, it’s worthwhile to be able to reduce the brightness, and therefore the operating current of the LEDs, when you don’t need full power. Accordingly, the author incorporated a dimming function in the design, based on operation in PWM mode in to reduce power losses to an absolute minimum.

As you can see from the circuit diagram, the author chose an LT3518 switching regulator IC, which is a buck/boost converter optimized for LED operation. Here it is used as a down converter (buck mode). This IC can achieve better than 90% efficiency in this mode, depending on the input voltage. According to the typical application circuit on the data sheet [1], its switching frequency can be set to approximately 170 kHz by selecting a value of 82 kΩ for R1. To maximize overall efficiency with this type of IC, the voltage drop over the sense resistor used to measure the current flowing through the LED should be as low as possible. This particular device operates with a voltage drop of 100 mV, corresponding to a current of just under 1.5 A with the specified value of 68 mΩ for R2. This value proved to be suitable for the Cree LED used by the author. At this current level, a diode with a power rating of at least 6 W should be used for D1.

IC1 has an additional property that is ideal for this application: the connected LED can be dimmed by applying



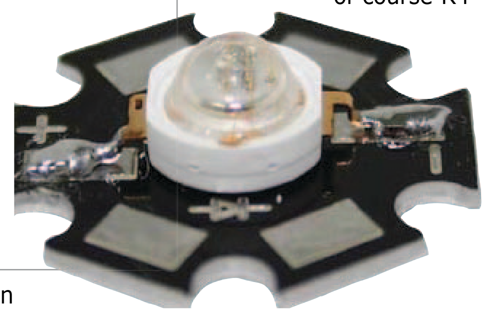


a PWM signal to pin 7 of the IC, with the brightness depending on the duty cycle. Obviously, the PWM frequency must be lower than the switching frequency. The PWM signal is provided by IC2, a special voltage-controlled PWM generator (type LTC6992 [2]). The duty cycle is controlled by the voltage applied to the MOD input on pin 1 (range 0–1 V). The resistor connected to pin 3 determines the internal clock frequency of the IC according to the formula f = 1 MHz × (50 kΩ/R3). This yields a frequency of approximately 73.5 kHz with R3 set to 680 kΩ, which is much too high for controlling IC1. However, the PWM IC has an internal frequency divider with a division factor controlled by the voltage applied to pin 4, which in this circuit is taken from voltage divider R4/R5. The division factor can be adjusted over the range of 1 to 16,384. The division factor with the specified component values is 64, resulting in a PWM frequency of around 1,150 Hz. If you want to be able to generate a PWM signal with an adjustable duty cycle over the full range of 0 to 100%, you must use the LTC6992-1 option. The -4 option, which provides a range from 5 to 100%, might be an acceptable alternative.

To prevent the duty cycle (and thus the brightness of the LED) from depending on the battery voltage, which gradually drops as the battery discharges, IC3 generates a stabilized 1.24 V control voltage for potentiometer P1. Series resistor R7 reduces the voltage over P1 to 1 V, which exactly matches the input voltage range of the LTC6992.

All capacitors should preferably be ceramic types, in particular due to their low effective series resistance (ESR) as well as other favorable characteristics. However, only capacitors with X5R or X7R dielectric should be used; capacitors with type Y dielectric have very poor temperature characteristics.

The supply voltage is limited to 5.5 V by the maximum rated supply voltage of IC2. The author used four NiMH rechargeable cells connected in series, which yields a voltage that is just within spec. With an operating voltage in the range of 4.5 V to 5.5 V, you must use an LED that can operate at less than 4 V. This eliminates devices with several chips connected in series on a carrier, which is very often the case with power LEDS rated at over 5 W. These devices require a correspondingly higher supply voltage, which means more cells connected in series. This is only possible if the supply voltage for IC2 is reduced by a 5 V voltage regulator or other means, and of course R4



must also be connected to this lower supply voltage.

Finally, a few words about soldering. An exposed thermal pad must be provided on the PCB for the LT3518, and the rear face of the IC must be soldered to this pad. The author obtained good results by dimensioning the exposed pad large enough to extend beyond the outline of the IC. When assembling the board, first tin the pad and the rear face of the IC. Then heat the pad with a soldering iron. When the solder melts, withdraw the tip of the soldering iron to the edge of the pad and simultaneously place the IC on the pad and align it. After this the pins can be soldered.

The author produced a two-sided PCB, and the CAD layout data (Target) can be downloaded from the Elektor website [4].

(120201)

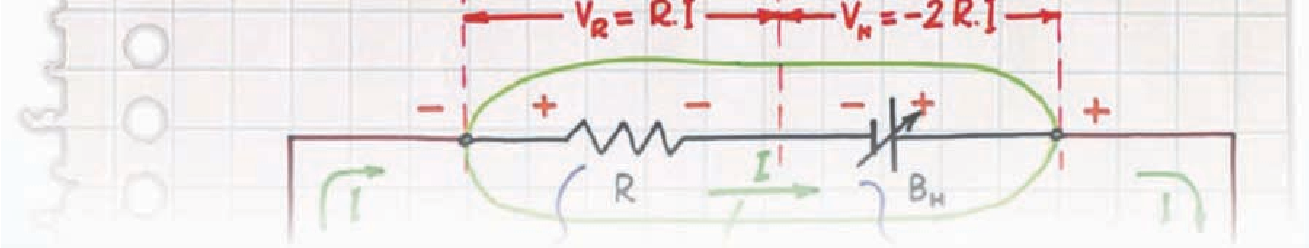
Internet Links

[1] www.linear.com/product/LT3518

[2] www.linear.com/product/LTC6992

[3] www.ti.com/product/tlv431

[4] www.elektor.com/120201



DC Protection for Speakers

By André Aguila (Burkina Faso)

I'm in the process of building myself a single-ended class A MOSFET amplifier consisting of two mono blocks, and I don't want to use a coupling capacitor between amplifier and the speaker. So I needed a circuit that would protect the speaker against DC voltages; I have given it a dual role:

- DC protection in the form of a device to disconnect the speaker in the presence of a DC voltage greater than ±1 V, using an LM358;
- speaker connection delayed by around 5 s after powering the amplifier, using a 555.

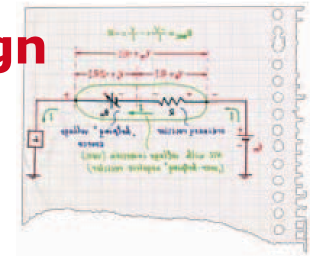
I've drawn inspiration from various ideas gleaned from the Internet, but I don't think this circuit actually exists anywhere in quite this form. Obviously, for a stereo system, you'll need a protection circuit for each channel.

The output signal from the audio amplifier without an output capacitor is applied to the normally-open contacts of relay Re1, and also to the input of the DC voltage detects formed by an RC integrating network and comparators, whose output drives the relay control stage and an LED indicator.

The network R6/C4 is a low-pass filter that heavily attenuates the audio signal but will allow any positive or negative DC component through to the inputs of dual comparators IC2a and IC2b, which are protected from excessive voltage by diodes D1 and D2.

IC2a output goes from +12 V to −12 V when the voltage on its negative input is higher than that on the positive input, while IC2b output goes from +12 V to −12 V when the voltage on its positive input is lower than that on the negative input. The values of resistors R7, R8, and R9 in the potential divider set the DC voltage detection thresholds to around +1 V for IC2a and –1 V for IC2b.

To disable the relay if a positive or negative DC voltage is detected, all that remains to be done is to combine the LM358 outputs. As these are not open-collector outputs, diodes D4 and D6 form a wired-OR gate to avoid short-circuiting them. If there is a positive DC voltage on the amplifier output, IC2a output will go from +12 V to −12 V and disable the relay by turning off T2, while IC2b output remains at +12 V. If a negative DC voltage is present at the input to our protection circuit, the roles of IC2a and IC2b outputs are reversed.



Transistor T1 inverts the output from the 555, wired as a monostable, which is high (here that means ground) for around 5 s after power is applied. T1 is then turned off, as its base is at the same voltage as its emitter, and thus holds T2 off: the relay remains de-energized. At the end of the time delay, the 555 output falls (−12 V), T1 conducts and the relay is energized via T2.

I've carried out a lot of testing and tried several types of relay, finally choosing a high-quality 24 V type designed for speakers, and I'm very pleased with the circuit. Preset P1 makes it possible to adjust the operating threshold of the relay chosen according to its coil resistance. The choice of a 2N1711 for T2 is justified by both its availability and its gain, higher than a BD139, for example. Don't worry if it gets hot, its junction can withstand up to 175 °C.

The protection circuit is mains powered via two symmetrical regulator (IC3 and IC4) which will need to be fitted with small heatsinks of the transformer secondary voltage is high. It should theoretically be between 12 and 25 V, but given the fluctuation in AC line voltage, it's wiser to limit it to a range of 15 to 22 V.

As the power drawn from the transformer is modest — around 3 VA is more than enough — it would be feasible to use quite a small transformer to allow the protection circuit to be fitted within the speaker being protected.

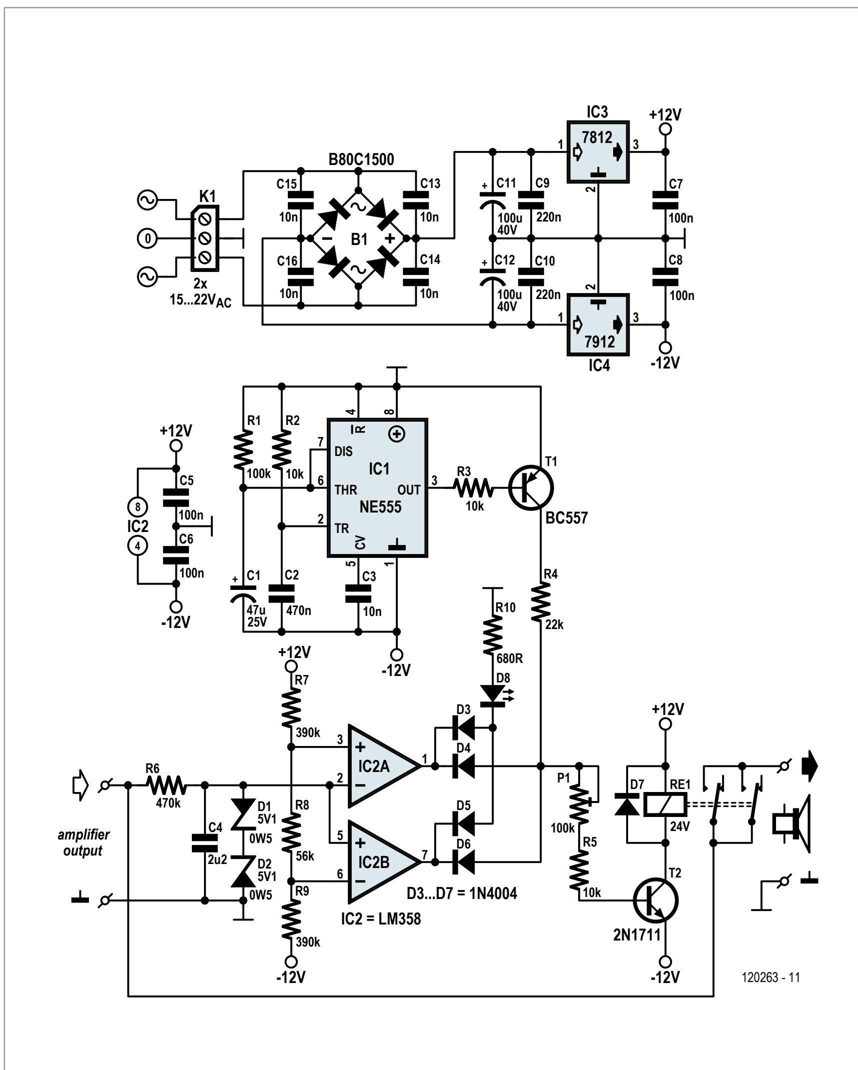
You will note that the 555 is powered between the center zero rail (which is its positive rail) and the −12 V rail.

Choosing a low-current LED for D8 will let you save a few tens of milliamps, at least when the diode is lit. In this case, the value of R10 will increase from 680 Ω to 4.7k so as to reduce the current to 2 mA instead of 15 mA!

When testing, bear in mind that when the protection circuit input is open-circuit, the two opamps receive no bias voltage. So to test their operation, you'll need to apply a DC voltage source.

(120263)

I've drawn inspiration from various ideas gleaned from the Internet, but I don't think this circuit actually exists anywhere in quite this form.



Bulb-2-LED Bicycle Light Conversion

By Anders Gustafsson (Finland)

Elektor is all over the globe, starting out from Holland. The same with bicycles, which are even older. All the way from Åland Islands N60 E20 (check that out), Anders Gustafsson wrote 2 us: "I just got so fed up with my bicycle light. I ride the bike to and from work every morning and with fresh batteries the light was acceptable. Problem was that the batteries wore down real fast so I was wondering what a LED could do. The original bulb, an Osram PR2 2.4 V 0.5 A should produce 10 lm. A Cree XP-E should produce 114 lm at 350 mA. I opted for a slightly lower current, or 320 mA, powering the LED from a constant-current switcher which will produce a constant current down to a battery voltage of 1.5 V. To get the output where I wanted, I used a Khatod KLCP 20CR lens with a 6-degree angle."

Besides a circuit diagram of a simple voltage step-up converter based on a Linear Technology LT1618 chip [1]. Anders kindly included a few photographs of his reworked bicycle light, which are reproduced here mainly as food for thought.

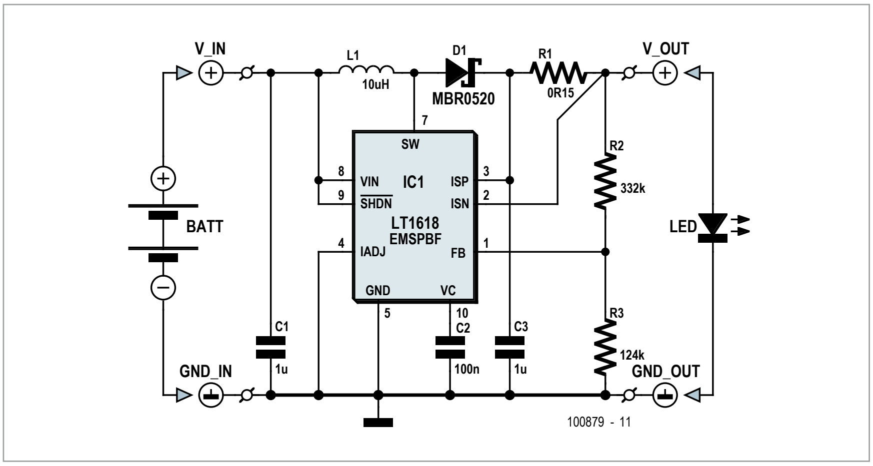
The great thing about the LT1618 is that it can operate as a constant-current, constant-voltage source. The fixed-frequency, current mode switcher is rated to operate from an input voltage between 1.6 V to 18 V. Its high switching frequency of 1.4 MHz permits the use of small inductors and capacitors.

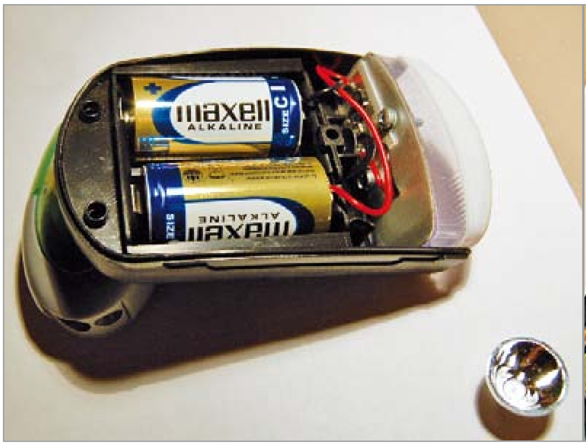
Here we use constant-current mode and power the converter from two (thick!) 1.5 V batteries to obtain a LED current that's remarkably steady around 320 mA.

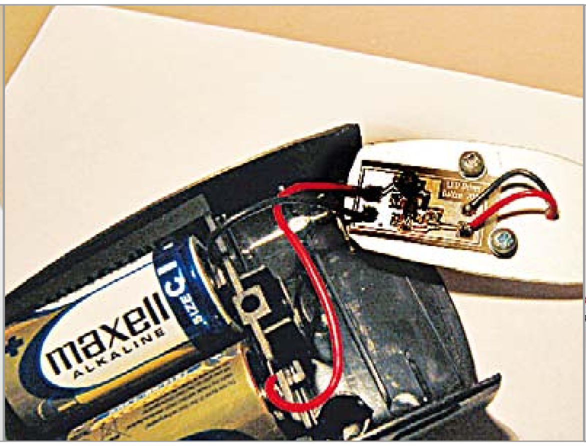
The values of R2 and R3 in the voltage at the output are set up for V_{out} = 4.64 V using

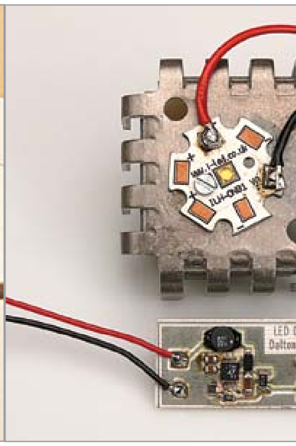
$$R2 = R3\left(\frac{V_{out}}{1.263} - 1\right)$$

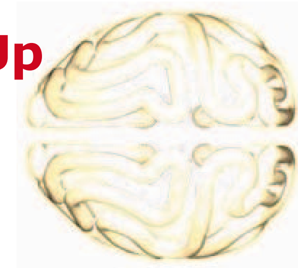
which is fairly arbitrary but bearing in mind that some absolute maximum has to be set. For sure the desired con-

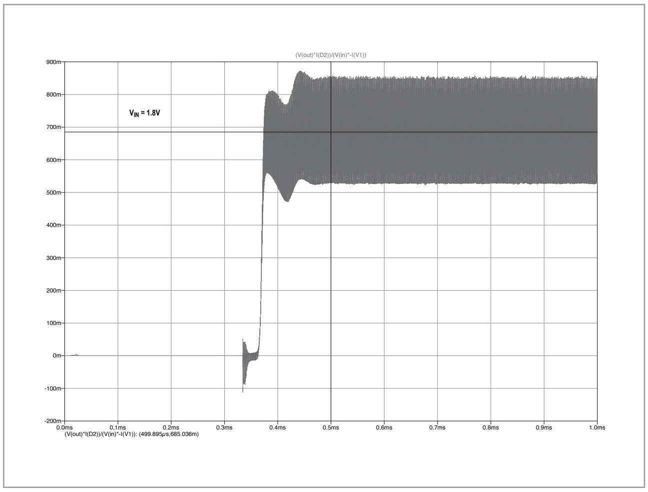


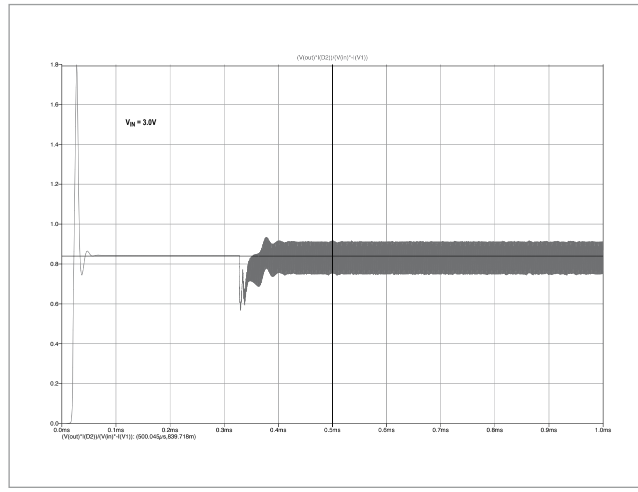












stant current of about 320 mA has priority as we aim to power an LED 'to the max'. With the IADJ pin (4) of the chip tied to ground the nominal current sensing voltage is 50 mV (appearing between the ISP and ISN pins). Here we have a constant current like

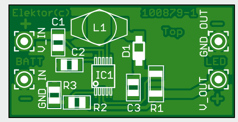
$$I = \frac{0.05V}{0.15\Omega} = 0.33A$$

which is just right to push that Cree LED into producing a very bright light beam in darkest Åland Islands and beyond, even if the batteries are juiced. Theoretically! So, Elektor Labs grilled the converter, measured its performance and drew up a table with selected results. In conclusion, the circuit does a good job both when powered from two dry cells (source = 3.0 V) or from two rechargeables (source = 2.4 V). The more mAh's proudly print-

Measured performance

Source [V]	Source [A]	V_{out} [V]	I_{out} [mA]	Efficiency (%)
1.3	0	1.3	-	
||				
1.7	0.45	2.89	-	
1.8	0.71	2.95	329	75.9
||				
2.3	0.62	3.03	323	68.9
||				
2.8	0.45	3.03	320	76.9
||				
3.2	0.38	3.03	321	80.0

COMPONENT LIST



Resistors
R1 = 0.15Ω size 1206
R2 = 332kΩ size 0805
R3 = 124kΩ size 0805

Capacitors
C1,C3 = 1µF X5R, size 0805
C2 = 100nF X5R, size 0805

Inductor
L1 = 10µH, 7.3x5mm, e.g. TT Electronics HM7610100LFJTR

Semiconductors
D1 = MBR050
IC1 = LT1618EMS (Linear Technology)

Miscellaneous
PCB # 100879-1 from www.elektorpcbservice.com

ed on the batteries, the longer your LED headlight shines.
Next we decided to put the start-up response of the converter through an LTSpice simulation, specifically at the lower end of V_{in} (1.8 V) and the nominal value (3.0 V) as it is often found that these converters fail to start when the batteries are flat. The run-in behavior of the 1.4 MHz oscillator in the LT1618 can be seen in both images.
Space being at a premium in the bicycle headlight the choice of SMD parts rather than through hole should be obvious. Hence a very small circuit board was designed and printed here. If you experiment with the circuit on your workbench, do not forget to attach a heatsink to the LED as it is likely to die without one. Even a U-style finned heatsink for TO3 devices does a good job.

(100879)

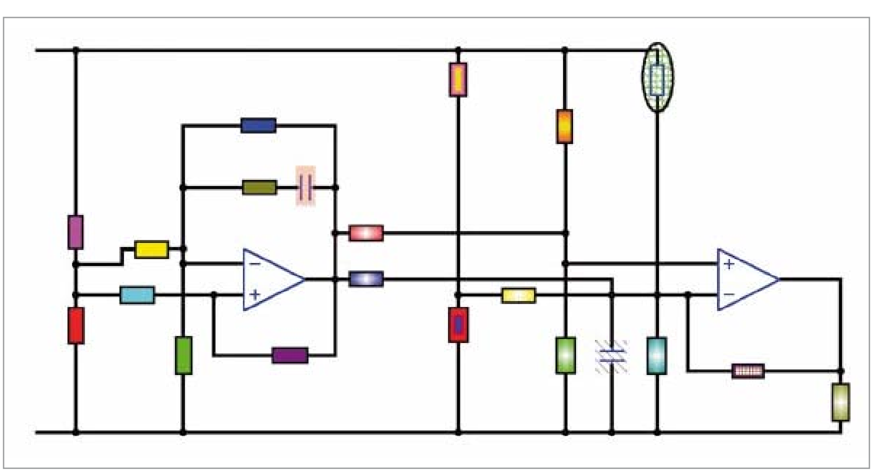
Internet Link

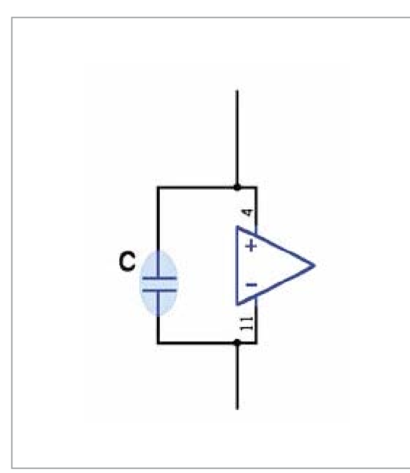
http://cds.linear.com/docs/Datasheet/1618fas.pdf

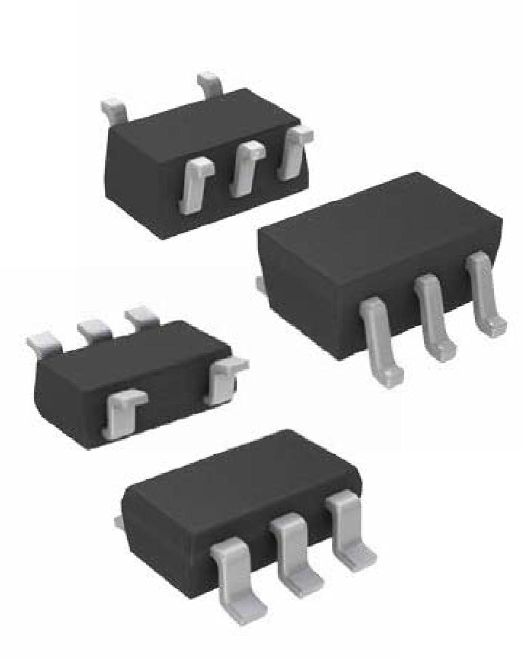
EZ-SMD OpAmp Tweaker Board

By Dietmar Schröder (Germany)

When working on electronics projects containing one or more operational amplifiers (opamps), the associated resistors and capacitors often have to be exchanged in order to change, optimize or generally adjust the circuit's behavior. Doing so is remarkably easy when using SMDs (surface mount devices) so these tiny components may be preferred over the 'good old' through-hole versions. Mini-MELF resistors are especially easy-going in this respect.







To be able to quickly assemble a circuit containing an opamp, a truly versatile and universal PCB was developed that's suitable for '1206' components. It was designed to be suited for a SOIC-14 quad opamp, like the ubiquitous TL074. It is laid out as a single-sided board and quite small, so it can easily be etched on a piece of circuit board idling somewhere in your workshop. A pdf file representing the track layout of the board can be downloaded free of charge from the Elektor website [1].
The board routing was designed such that hookup wire is rarely called for to complete the circuit you are putting together. There are some extra universal pads though for the more demanding cases. There are also several solder jumpers which can be conveniently shorted using a blob of solder, if necessary.

Looking at the PCB design, one half of the left side got copied and appears mirrored on the right with only a few alterations, hence the result is almost symmetrical, except for the supply voltage decoupling capacitor (marked 'C'). This is connected between the positive and negative supply rails (not from supply to ground, since this could inject supply ripple into the ground rail).

Putting it all to work, fill in the necessary components in the schematic and — using the colors in the illustrations printed here — populate the PCB accordingly using whatever components you need for your design. Note that the schematic printed here shows just two opamps, i.e. half the actual circuit. The schematic is also available for downloading at [1], so you can conveniently print it and fill in the component values as many times as you like, keeping your documentation up to date as you proceed to Fame & Glory with your project.

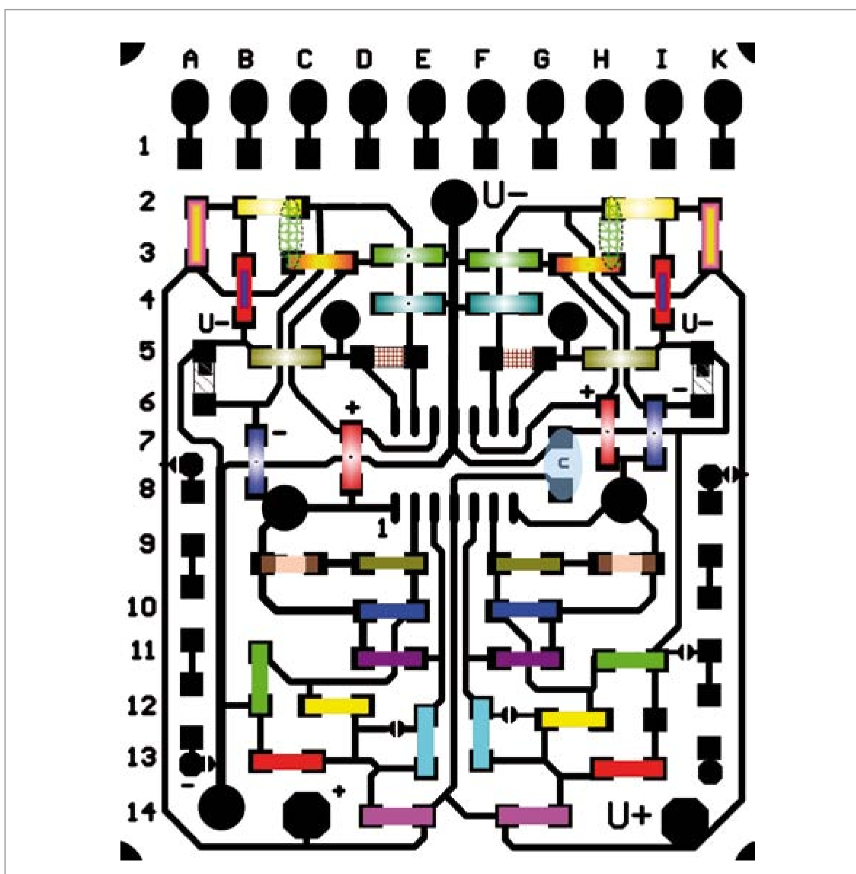
There's nothing tricky with, or difficult about, this universal 'prototyping tool'.

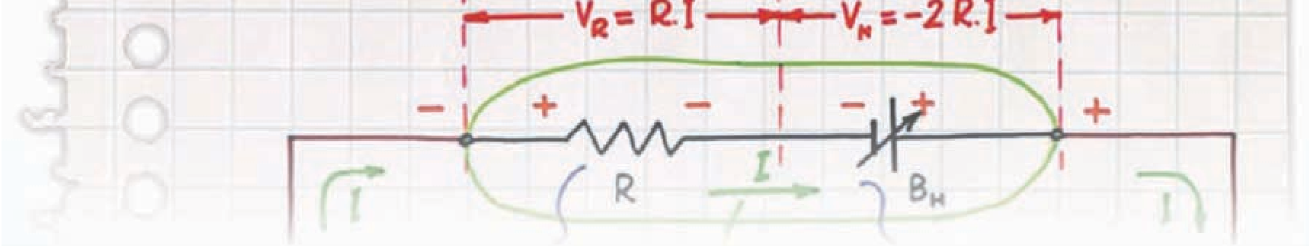
There's nothing tricky with, or difficult about, this universal 'prototyping tool', so feel free to give it a try and personally verify that it works a treat when developing circuits hands-on.

(110737)

Internet Link

[1] www.elektor.com/110737





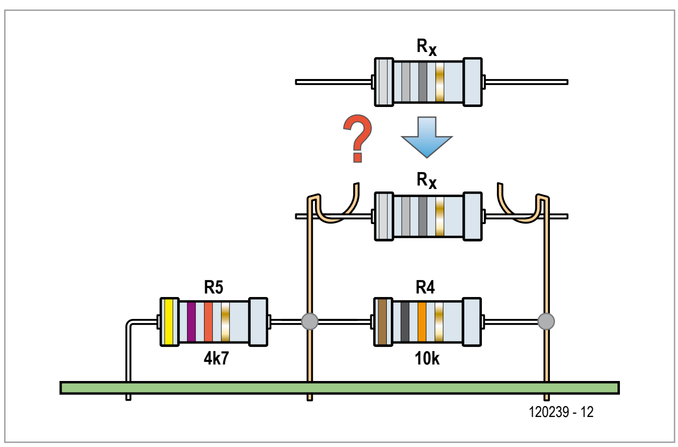
Room for a Small One?

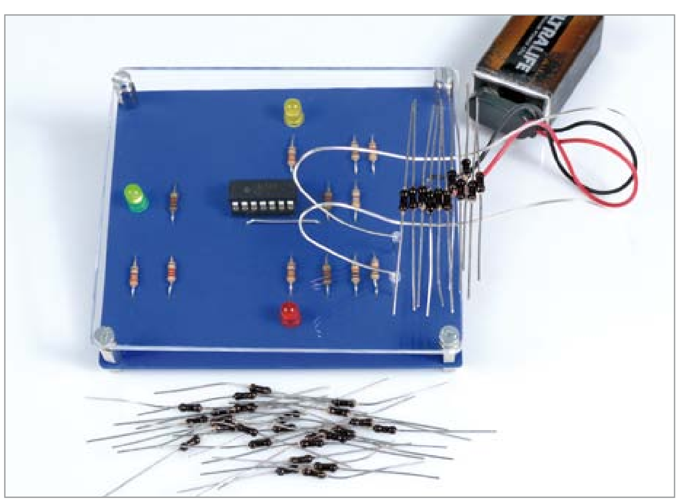
By Stefan Hoffmann (Germany)

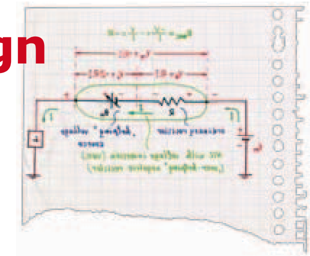
As practically every *Elektor* reader will attest, electronics can be a lot of fun. The circuit described here, a small electronic game for two or more players, proves the point. The game takes the form of a balance, with weights being represented by resistors.

The players take turns to place resistors (whose values they do not know) on one 'pan' of the electronic balance, which is formed by two bent wires. The 'counterweight' is another resistor, whose value is also not known to the players. The state of the balance is indicated by three LEDs of different colors: yellow, indicating that the pan is too light; green, indicating balance; and red, indicating that the pan is too heavy. The object of the game is to place as many resistors as possible on the electronic balance without lighting the red 'too heavy' LED. Bonus points are awarded to a player who can get into the relatively narrow central zone corresponding to perfect balance.

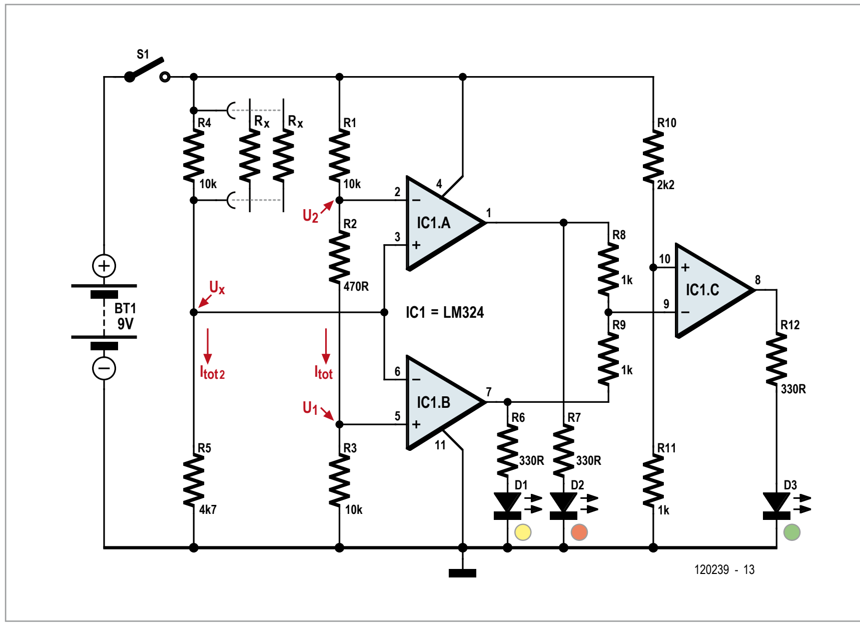
The circuit is based around a number of voltage dividers and three operational amplifiers, used as comparators. When switch S1 is closed the 9 V supply is provided to the circuit and the game is started. The first voltage divider is formed by resistors R4 and R5. The two wires that play the role of the balance pan are at either end of R4. If resistor R_x is absent, as at the beginning of the game, the voltage U_x will be around 2.88 V. As the game progresses, more and more resistors are added at R_x between the two wires. These resistors are all in parallel with R4. The more resistors are added to the electronic balance, the lower the total resistance between the ends of resistor R4 and so the higher the voltage U_x. The voltage divider formed by the three resistors R1, R2 and R3 is responsible for determining the voltages that are the thresholds for the comparators to which they are connected, and hence for the boundaries between the different states in which the balance can be. With the values given in the circuit diagram we obtain a value for U_1 of about 4.4 V and for U_2 of about 4.6 V. If U_x is lower than 4.4 V the output of IC1.B will swing to the positive supply rail. This will in turn light the yellow LED to indicate that the balance pan is too light. If U_x is greater than 4.6 V the output of IC1.A will swing to the positive supply rail and the red LED will light to indicate that the balance pan is too heavy. If U_x lies between 4.4 V and 4.6 V then the system is balanced. In this situation the







voltages at both the output of IC1.A and the output of IC1.B will be at 0 V and therefore the voltage at the inverting input of IC1.C will also be 0 V. The voltage divider formed by resistors R10 and R11 set the voltage at the non-inverting input of IC1.C at about 2.81 V, and as a result when the system is balanced the output of IC1.C will be at the positive supply voltage and the green LED will light. The voltage divider formed by resistors R8 and R9 produces a voltage half-way between the output voltages of IC1.A and IC1.B and feeds this into the inverting input of IC1.C. The consequence of this is that the green LED only lights when the system is balanced.



There are various ways that the game could be played: the author's suggestion is as follows. At the beginning of the game each player receives ten resistors, whose colored bands have been made unreadable using a black felt-tip pen (see photograph). Players then take it in turns to add one of their resistors to the electronic balance. If the yellow LED remains lit he receives ten points and play passes to the next player. If the red LED lights the player loses his points and the round is over. If the green LED lights, the player receives ten points for his resistor and then doubles his score. In this case also the round ends. Instead of playing a resistor a player can 'fold' and leave the round, halving his current score. Play then passes to the next player, who must choose whether to add another resistor or also fold, again halving his score. If the next player chooses to play and the yellow light remains on, he receives ten bonus points, and, if the green LED lights, he receives the ten bonus points and doubles his score. However, if the red LED lights, the player loses his points as before. At the end of each round each player adds his points to his running total. It is best to play as many rounds as there are players, so that each has one turn to start the game.

For the 'weights' the author recommends using fifty 100 kΩ resistors, five 47 kΩ resistors, three 33 kΩ resistors and three 22 kΩ resistors. The more low-value resistors there are the quicker each round will tend to be.

(120239)

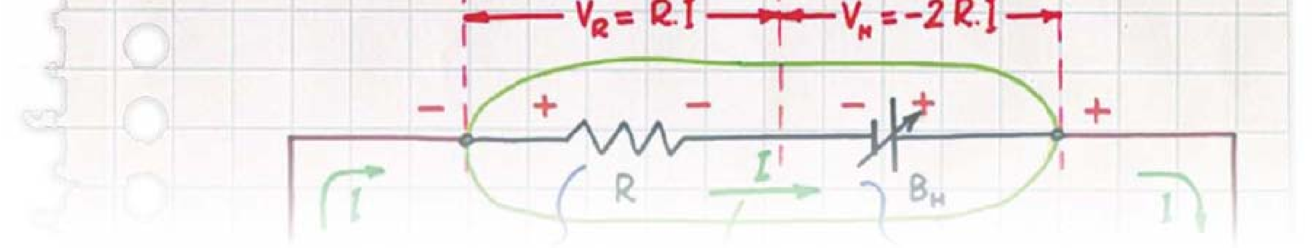
LC Oscillator with Pot Tuning

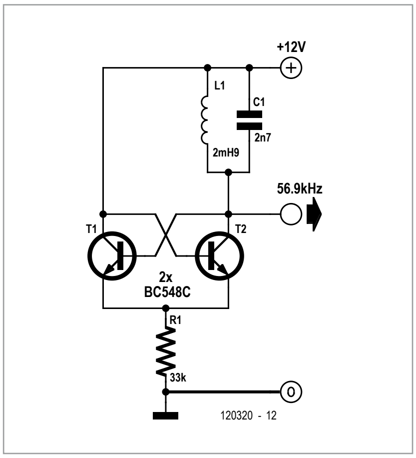
By Burkhard Kainka (Germany)

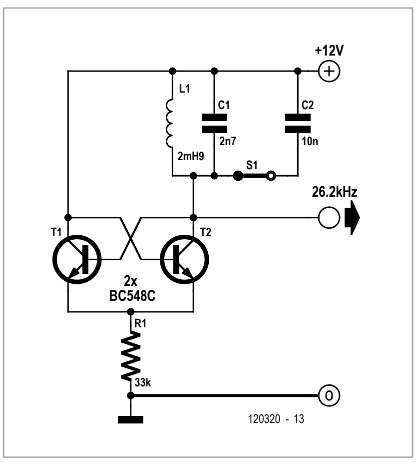
An LC oscillator is usually adjusted using a variable capacitor. However, for frequencies below around 100 kHz this calls for a variable capacitor with a value in the nanofarad range, which is somewhat impractical. In many situations, however, a potentiometer can be used instead.

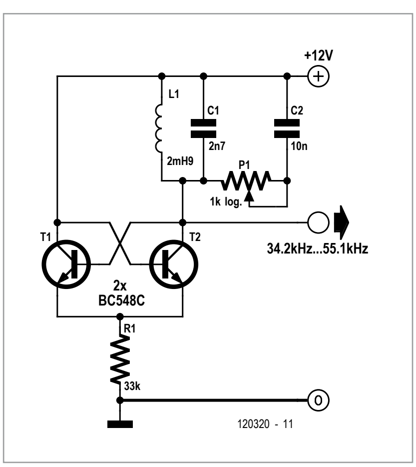
We start by looking at an oscillator using a 2.9 mH inductor salvaged from a low-energy lightbulb and a 2.7 nF capacitor (see upper circuit). The theoretical resonant frequency of this combination is 56.9 kHz.

The circuit operates from a supply voltage as low as 1 V, as the resonant circuit has a high Q factor. If an extra 10 nF capacitor is wired in parallel the resonant frequency falls to 26.2 kHz. The Q factor is reduced and so the gain in the circuit must be increased, and a supply voltage of at least 2 V is needed.









Using a switch it is possible to select between the two frequencies (see middle circuit).

And now the subtle bit: instead of the switch we use a 1 kΩ potentiometer (see lower circuit). In this form the frequency of the oscillator can be smoothly adjusted using the potentiometer, almost as if we were using a 10 nF variable capacitor. Experience shows that using a linear potentiometer gives a rather non-linear frequency adjustment, and so it is preferable to use a logarithmic potentiometer. A further problem is the high level of damping: the energy loss needs to be made up for with higher gain, and so with a higher emitter current. This can be achieved either by reducing the emitter resistor or by increasing the supply voltage.

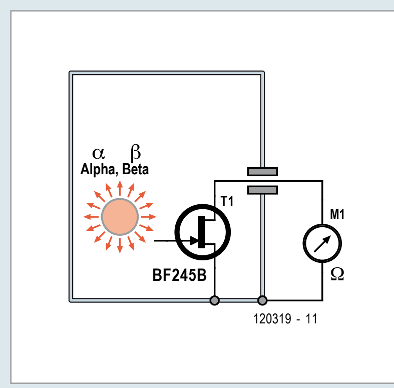
Experiments show that the maximum frequency coverage possible is around a 2:1 range. If the two capacitors are very different in value the damping in the middle of the frequency range is so great that oscillation stops. With the values shown in the circuit diagram the frequency can be adjusted between 34.2 kHz and 55.1 kHz.

(120320)

FET Radiation Meter

By Burkhard Kainka (Germany)

What must be the simplest possible radiation meter consists of just a BF245 JFET and an ohmmeter. Ions produced as a result of the radiation charge up the gate of the FET and thus change its resistance. The FET needs to be enclosed in a metal tin to screen it from electric fields and from ions that might normally be present in the atmosphere. After taking a calibration measurement we can experiment by placing various samples inside the tin.

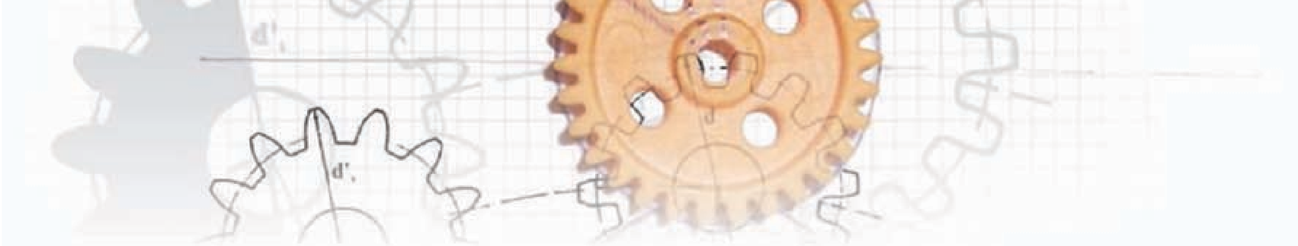


The device was tested using a small sample of pitchblende (a uranium ore), a ^{241}Am source taken from a smoke alarm, and a gas mantle, still in its paper sleeve. The results were as follows.

Reference (no sample)	160.2 Ω
Pitchblende	156.3 Ω (–3.9 Ω)
^{241}Am source	155.9 Ω (–4.3 Ω)
Gas mantle	159.0 Ω (–1.2 Ω)

The results are clear: when a sample is placed near the FET it becomes positively charged, reducing its drain-source resistance. The experiments above were repeated several times and showed good reproducibility. In practice it takes around half a minute for the FET's resistance to settle.

(120319)



16 Ways to Switch your AC Power On

By Vladimir Mitrovic (Croatia)

Connect this microcontroller controlled switch between an ordinary AC Power On/Off switch and the load, and you have 2^4 (say, sixteen) ways available for managing how and when the load actually gets powered. Your options are listed in the table!

As soon after the AC outlet voltage (230 VAC or 115 VAC) is applied to the Live (L) and Neutral (N) input terminals (USA: G; Ground), the voltage across C2 will rise above 2.7 V and the ATtiny13 microcontroller (IC1) will start to execute the program held in its flash memory. The program controls the logical state of output pin PB4 in order to switch the power supply to the load on and off. In detail:

if PB4 is at '1', the current through the LED inside optoisolator IC2 is interrupted causing the internal triac driver and triac Tr1 to be held Off; consequently no current flows through the load connected to the AC Power output terminals;

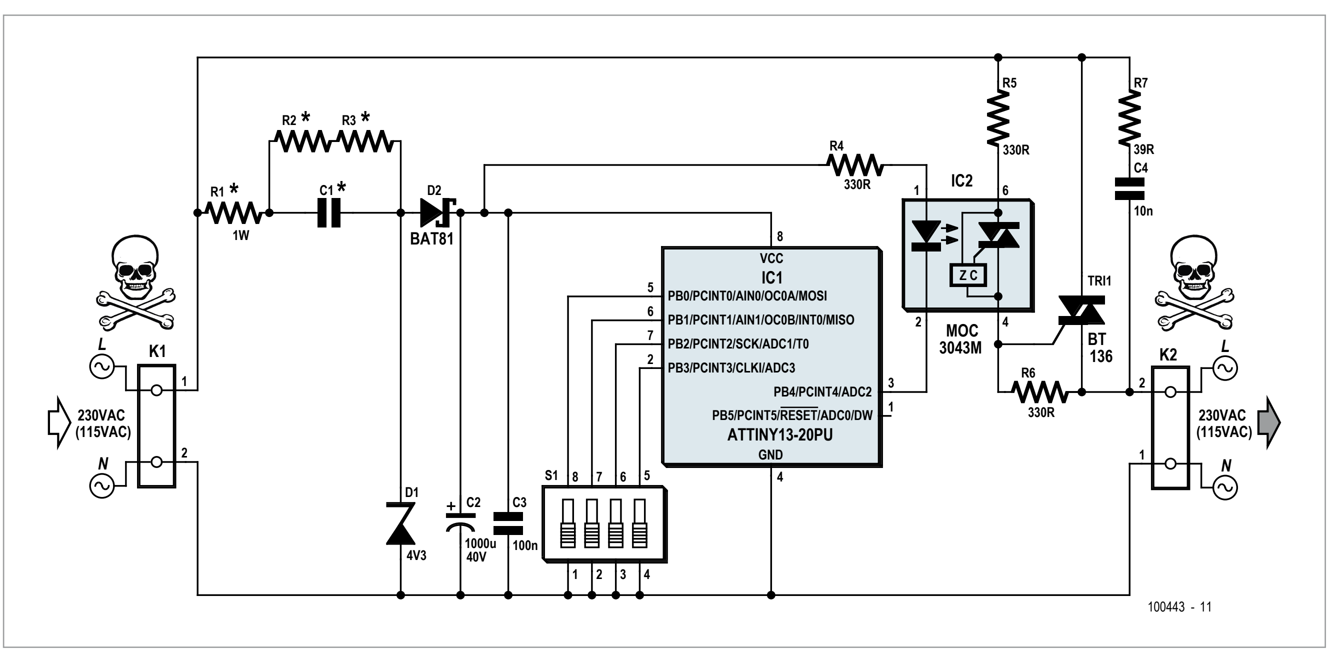
if PB4 is at '0', current flows through the LED inside IC2, the internal triac driver and Tr1 are switched On; consequently AC current flows through the load connected to the output terminals.

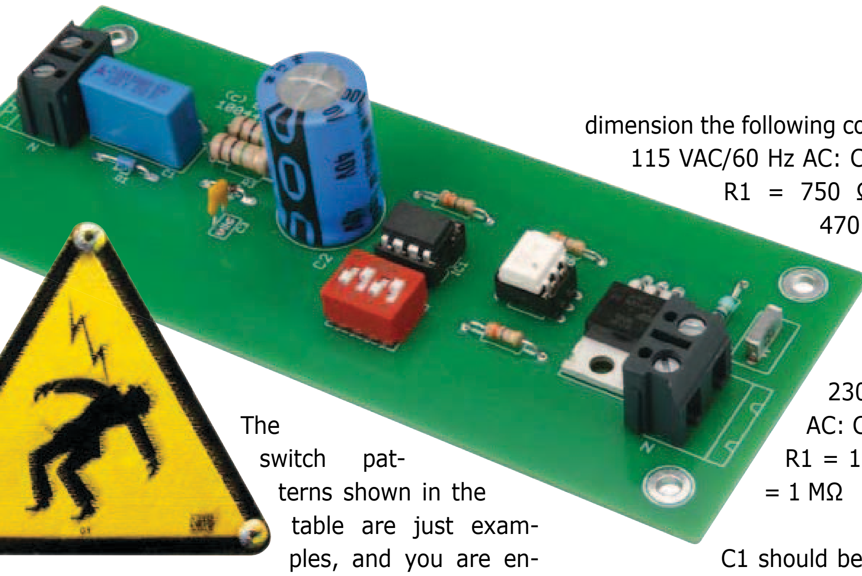
The circuit, in particular, the ATtiny13 firmware, has full control of the power distribution to the load as long as the AC Power On/Off switch (not shown here) is on. For example, the program can switch on the load with a delay, keep the load switched on for a predetermined time period, switch the load on and off according to some pattern… you name it!

An example Bascom-AVR program called "EE_prog_switch.bas" is written to illustrate the possibilities. The program is a free download from [1]. 'Bascom-AVR is supplied by MCS Electronics — a free Demo version limited to 4 KB source code size is available [2].

Initially the program checks the state of configuration switches S1-S4 and calls the relevant pre-programmed routine from a set of 16 — see the table.

'One-shot' routines will execute only once; to repeat them you should switch the AC Power switch ahead of the circuit Off and On again. Routines with a repeating pattern ('once every...') will execute in a loop as long as the AC Power is on. If you want to select a different pattern, you should switch AC Power off and flip to another setting on S1-S4. The new setting will be recognized the next time your AC Power switch is switched to On.





The switch patterns shown in the table are just examples, and you are encouraged to define and implement other patterns that suit your applications. If there is only one On/Off pattern that the switch should follow, you can omit switches S1-S4 and thus make the circuit even simpler.

It should be noted that the design does not accommodate for precise timing. The overall accuracy primarily depends on the accuracy of the ATtiny's internal RC oscillator (<10%; <3% if calibrated), while the Wait routines in Bascom-AVR are accurate to within 1%.

Depending on your local power grid, dimension the following components:

115 VAC/60 Hz AC: C1 = 0.68µF; R1 = 750 Ω; R2,R3 = 470 kΩ

230 VAC/50 Hz AC: C1 = 0.33µF; R1 = 1.5kΩ; R2,R3 = 1 MΩ

C1 should be an X2 class capacitor with a minimum specified operating voltage of 250 VAC; for example, WIMA MKP-X2, WIMA MP3-X2, Epcos MKP X2 or similar, rated for 250, 275 or 305 VAC voltages. As these capacitors are normally available with ±20% tolerance, the value is calculated to ensure 10 mA of current even in a worst-case, i.e. when the capacitance is significantly out of tolerance. As a matter of fact, the total AC current flow through C1 exceeds 20 mA, but half the current is 'lost' because of the half-wave rectification. Most of the current flows through the LED inside IC2: some 5-6 mA when switched on (if necessary, adjust the value of R4 to keep this current within range). The ATtiny13 runs on its internally calibrated 9.6 MHz oscillator, but the clock frequency is lowered to 600 kHz to keep power consumption under 1 mA. The rest of the current flows through zener diode D1 which acts as a shunt regulator and provides a reasonably stabilised voltage for the circuit. You can expect about 4.4 V across C2 when IC2 is switched off, which will drop to some 3.4 V when IC2 is switched on. The actual values depend primarily on D1.

Resistor R1 limits the inrush current during power-on, but sadly also causes some unwanted losses during operation. You may use a 1 watt non-flammable resistor in place of R1, but a better solution would be to use a NTC resistor. Unfortunately, we were unable to find an appropriate NTC for limiting the inrush current to 200 mA. Therefore, two series connected Epcos NTC thermistors may be considered with a

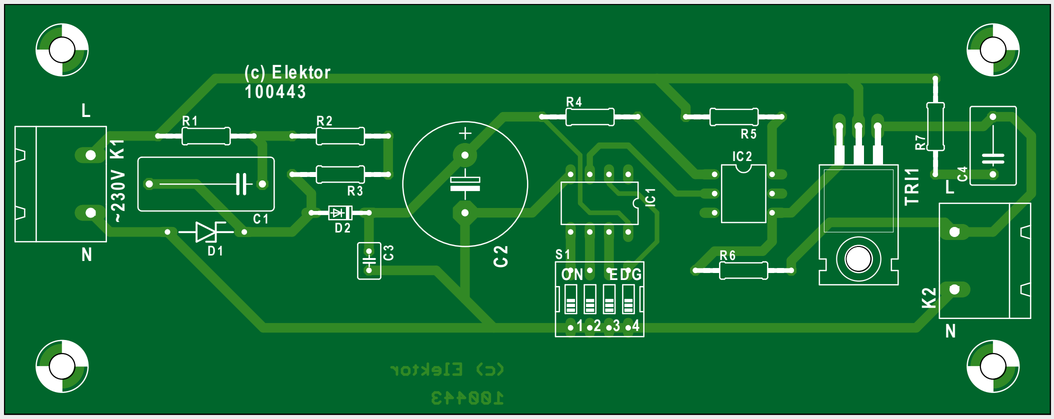
Description of the pre-programmed routines (example program)

S4	S3	S2	S1	switch on	switch off
off	off	off	off	as soon as AC power is switched on	never
off	off	off	on	as soon as AC power is switched on	10 minutes after switch-on
off	off	on	off	as soon as AC power is switched on	30 minutes after switch-on
off	off	on	on	as soon as AC power is switched on	60 minutes after switch-on
off	on	off	off	10 minutes after AC power is switched on	never
off	on	off	on	30 minutes after AC power is switched on	never
off	on	on	off	60 minutes after AC power is switched on	never
off	on	on	on	10 minutes after AC power is switched on	10 minutes after switch-on
on	off	off	off	10 minutes after AC power is switched on	30 minutes after switch-on
on	off	off	on	10 minutes after AC power is switched on	60 minutes after switch-on
on	off	on	off	once every 20 minutes	10 minutes after switch-on
on	off	on	on	once every 30 minutes	10 minutes after switch-on
on	on	off	off	once every 60 minutes	10 minutes after switch-on
on	on	off	on	once every 12 hours	1 hour after switch-on
on	on	on	off	once every 24 hours	1 hour after switch-on
on	on	on	on	never	never

COMPONENT LIST

Resistors
R1 = 1.5kΩ 1W
(115VAC: 750Ω)
R2,R3 = 1MΩ
(115VAC: 470kΩ)
R4,R5,R6 = 330Ω

Capacitors
C1 = 0.33µF 250VAC, MKP (115VAC: 0.68µF) (see text)
C2 = 1000µF 63V radial
C3 = 100nF
C4 = 10nF class X1/Y2



Semiconductors
D1 = 4.3V 0.5W zener diode
D2 = BAT85
IC1 = ATtiny13-20PU, programmed, Elektor # 100443-41
TRI1 = BT136

Miscellaneous
K1,K2 = 2-way PCB screw terminal, pitch 7.5mm
SW1 = 4-way DIP switch block

PCB # 100443-1 from www.elektorpcbservice.com

resistance of 680 Ω (at 25°C). These thermistors are intended for temperature measurement and compensation, but work well as inrush current limiter, too. For 115 VAC, it is safe to use just one 680 Ω NTC thermistor.
The BT136 triac is rated for 4 A_{RMS} on-state current. Consider replacing it with a stronger device if the load current can be expected to exceed 3 A. Components R7-C4 form a snubber network and may not be necessary depending on the particular triac and load used.

A 1-second delay is provided at the beginning of the example program. Therefore, the expression "as soon as the power is switched on" from the table should be read as "1 second after the power is switched on". This was found necessary as the voltage across C2 rises slowly at power-up and there is not enough power to switch on IC2 and Tr1 until the voltage across C2 reaches more than 3.5 V. A 1-second delay will allow the voltage across C2 to reach at least 4 V before the program actually starts to run, which will ensure that IC2 and Tr1 can be reliably switched on at the very beginning of the program.

The ATtiny13's fuse bits should be set during programming to enable the On-chip Brown-out detection (BOD) circuit to monitor the VCC level with a trigger level fixed to 2.7 V, and to configure the micro to run on the calibrated internal RC oscillator at 9.6 MHz clock frequency. It is the programmer's (i.e. your!) responsibility to set a divide-by-16 prescale factor at the beginning of the program to lower the clock frequency to 600 kHz. If you are not into programming microcontrollers, order your ATtiny13 ready programmed from Elektor (# 100443-41) [1].

Caution. The circuit is at Live AC potential and potentially hazardous to touch. Never work on the circuit while it is connected to the AC power outlet. The circuit must be enclosed in an approved enclosure preventing any part of it from being touched. When in doubt, ask for the assistance of a qualified electrical engineer.

(100443)

Internet Links

www.elektor.com/100443

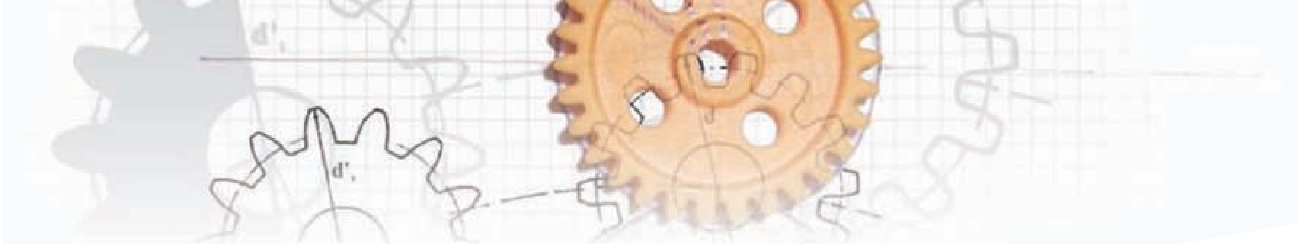
www.mcselec.com

Elektor Products & Services

- Bascom-AVR source code file: # 100443-11.zip, free download from www.elektor.com/100443
- Ready programmed ATtiny13: #100443-41, www.elektor.com/100443
- Printed circuit board # 100443-1: www.elektorpcbservice.com

A snippet of the BascomAVR source program.

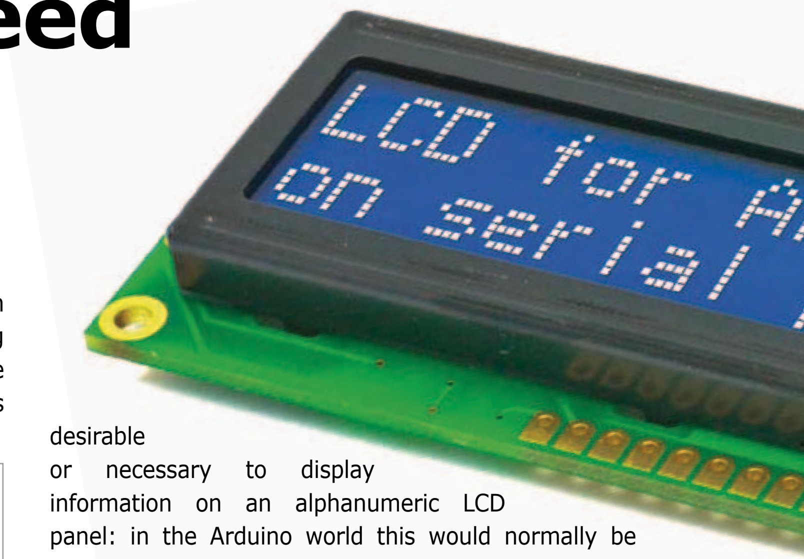
```
Dim S1_s4 As Byte , Minute As Byte , Hour As Byte

Control_pin Alias Portb.4
Sw_on Alias 0
Sw_off Alias 1

Config Clockdiv = 16                    'clock = 600kHz
nop

Config Pinb.4 = Output
Control_pin = Sw_off                    'switch off the load

Config Pinb.0 = Input
Config Pinb.1 = Input
Config Pinb.2 = Input
Config Pinb.3 = Input
Portb = Portb Or &B00001111             'enable pull-up resistors
Wait 1
S1_s4 = Pinb And &B00001111             'read S1-S4...

Select Case S1_s4                       'and execute corresponding routine
   Case &B00001111
      Control_pin = Sw_on
   Case &B00001110
      Control_pin = Sw_on
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_off
   Case &B00001101
      Control_pin = Sw_on
      minute = 30 : Gosub Wait_minute
      Control_pin = Sw_off
   Case &B00001100
      Control_pin = Sw_on
      minute = 60 : Gosub Wait_minute
      Control_pin = Sw_off
   Case &B00001011
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_on
   Case &B00001010
      minute = 30 : Gosub Wait_minute
      Control_pin = Sw_on
   Case &B00001001
      minute = 60 : Gosub Wait_minute
      Control_pin = Sw_on
   Case &B00001000
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_on
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_off
   Case &B00000111
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_on
      minute = 30 : Gosub Wait_minute
      Control_pin = Sw_off
   Case &B00000110
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_on
      minute = 60 : Gosub Wait_minute
      Control_pin = Sw_off
   .
   .
```



Arduino LC’Deed

Control a display using a (virtual) serial port

By Michael Gaus (Germany)



The Arduino platform provides an easy way to get started in the world of microcontrollers, and is enjoying ever-increasing popularity. What’s more, there is a wide range of compatible hardware and software available. In many projects it is desirable or necessary to display information on an alphanumeric LCD panel: in the Arduino world this would normally be accomplished using a ‘shield’ (daughter board) carrying the LCD. However, there is a much simpler way, as we shall see. Dot-matrix alphanumeric LCD panels by and large conform to a ‘standard’ in that most types are compatible with one another in terms of their supply voltage, pinout and control interface, and in the command set supported by the LCD’s controller. If we examine the pinout of one of these LCDs we see immediately that in principle it could be connected directly to the sockets on a Uno, Diecimila or Duemilanove Arduino board. It is therefore not necessary to go to the trouble of building a shield.

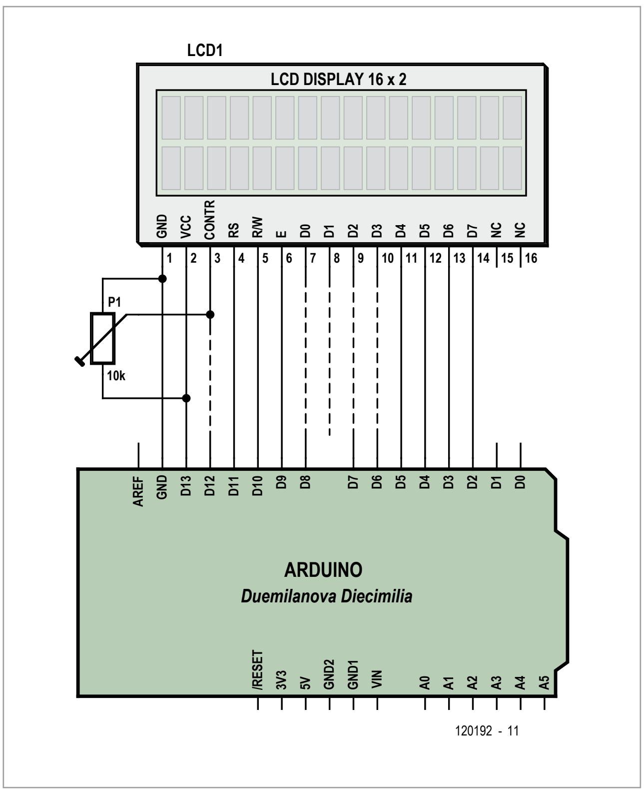
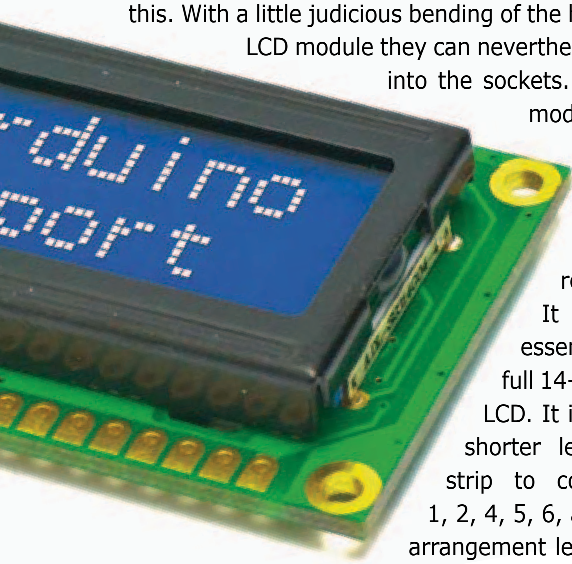


Table: Pinout of a ‘standard’ LCD	
Pin	**Signal**
1	GND
2	VCC
3	V0 (contrast)
4	RS
5	RW
6	E
7 to 14	D0 to D7

The LCD’s controller must be an HD44780 or compatible device, and the pinout of the module must adhere to the ‘standard’ mentioned above (see table). It is important that the display supports four-bit interface mode, since when we fit the module directly not all of the LCD’s data lines will be connected. The display must also be able to run from a 5 V power supply. And one final requirement: the pins on the LCD must have a pitch of 2.54 mm so that a corresponding header can be soldered directly to it.

Finding a display meeting all of the above conditions might sound like quite a task, but in fact there are surprisingly many suitable modules, the *Elektor* ‘standard LCD’ [1] included. First solder a 14-way header to the LCD (or several shorter headers: see below). The display can now be fitted to the Arduino’s sockets so that pin 1 of the LCD mates with the GND pin of the Arduino board, the adjacent pins connect to ‘Digital 8’ to ‘Digital 13’, and pin 14 of the LCD mates with Arduino pin ‘Digital 2’. Arduino pins ‘Digital 0’, ‘Digital 1’ and ‘AREF’ remain unconnected: see the circuit diagram.



Unfortunately the two socket rows that include the digital pins on the Arduino board are not spaced a multiple of 2.54 mm apart: in fact, the distance is somewhat less than this. With a little judicious bending of the header pins on the LCD module they can nevertheless be made to fit into the sockets. Pin 8 of the LCD module will then find itself dangling in free space between the Arduino's two rows of sockets.

It is not absolutely essential to solder a full 14-way header to the LCD. It is sufficient to use shorter lengths of header strip to connect just pins 1, 2, 4, 5, 6, and 11 to 14. This arrangement leaves Arduino pins D12, D8, D7 and D6 free for use as inputs or outputs for other purposes.

The power supply for the LCD module is provided by Arduino pin D13. The firmware running in the device must configure this line as an output and set it to a high level to turn on the LCD. Since LCDs of this type generally have a current consumption of less than 10 mA, the output pin has no difficulty in handling the load. A trimmer is required to allow the contrast voltage of the LCD to be set: this can easily be soldered directly to the pins on the LCD. Most LCD modules need a contrast voltage of between 0 V and 1 V.

For greater mechanical stability the LCD module can be mounted on nylon spacers.

To demonstrate how to drive the LCD from the Arduino the author has written an example program (called a 'sketch' in Arduinoese), which can be downloaded for free from the web pages accompanying this article [1]. In the sketch file 'arduino_lcd.pde' two lines must be adjusted to reflect the number of lines in the LCD module and the number of characters per line. These are defined as the constants LCD_ROWS and LCD_COLUMNS respectively: the default values provided are suitable for a two-row, 16-column display. When the system is reset the greeting 'Arduino LCD' should appear: if it does not, it may be that the contrast voltage is not correctly set.

The icing on the firmware cake is that the display can also be controlled from a PC over the Arduino's USB connection, using a virtual COM port and either a terminal emulator program or more specialized software. By default the interface runs at 9600 baud, but this can be changed in the setup() function with a suitable call to Serial.begin().

Commands and text to be displayed can be sent over the serial interface. Commands always begin with a backslash character ('\', ASCII value 0x5C), followed by a sequence of bytes whose length depends on the command.

To set the cursor position a total of four bytes is required. The command starts with the backslash, followed by a single ASCII decimal digit representing the desired row (for example, '1' for row 1 or '2' for row 2). Next come two ASCII decimal digits giving the desired column (for example, '01' for the leftmost column or '16' for column 16). A complete example might be '\105', which would move the cursor to row 1, column 5. To erase all the text on the display, send '\c' (the 'c' standing for 'clear').

The icing on the firmware cake is that the display can also be controlled from a PC over the Arduino's USB connection.

Commands and text can be intermingled in a compact fashion. For example, sending '\201Hello World!' will cause the string 'Hello World!' to appear on the second line of the LCD. To display a backslash character it must be doubled in the transmitted string: '\\'.

The 'Serial Monitor' in the Arduino IDE can be used for testing.

(120192)

[1] www.elektor.com/120192

Elektor Products & Services

- Software (free download): 120192-11.zip
- Suitable LCD module (2 by 16): 120061-71

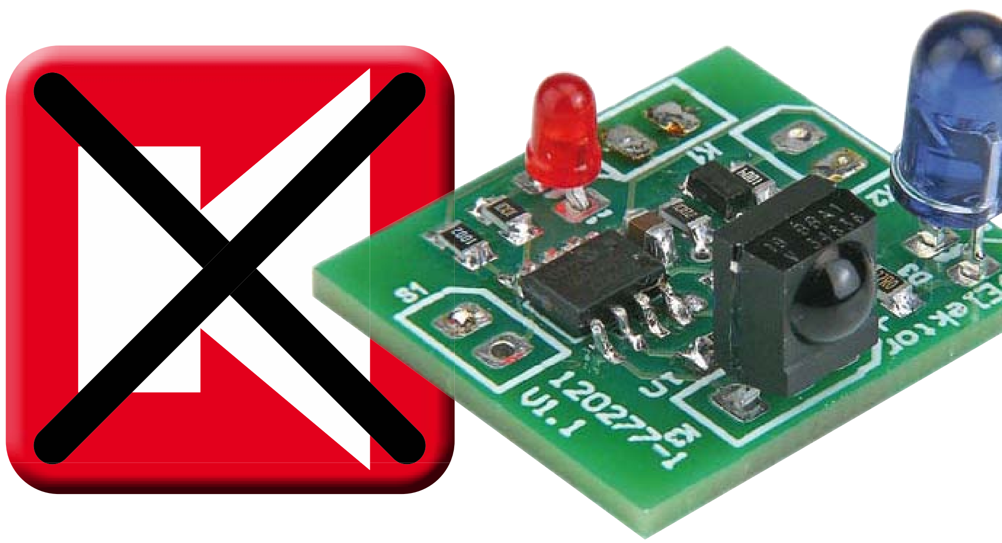
Products and downloads available through www.elektor.com/120192

Mini-Mute

Kill noisy TV commercials with one stroke

You must know the feeling: you're watching a great movie and all of a sudden a commercial comes blasting into the room. Your instinctive response is to turn down the sound or press the mute button – but where's the zapper?

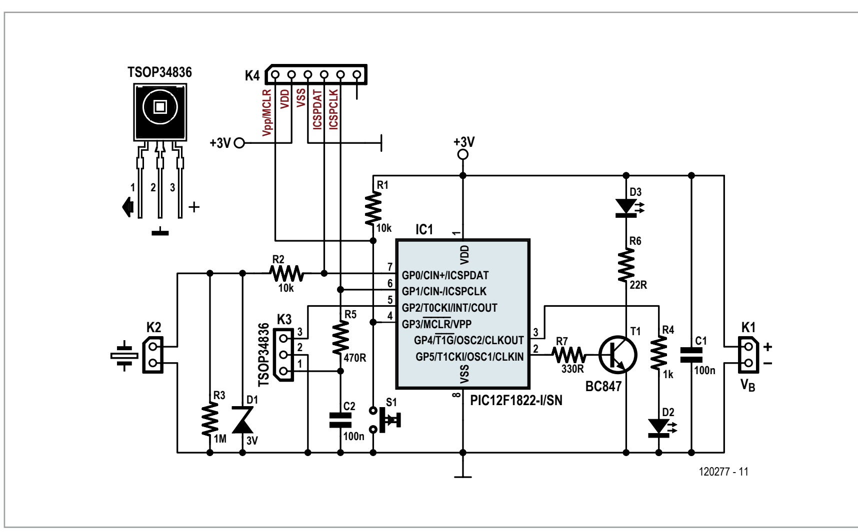
By Peter de Bruijn (Netherlands)



This handy circuit does the job for you. It converts your coffee table into one big button: if you rap on the table, the TV sound is muted right away. When the film resumes, you can restore the sound by rapping on the table again.
The circuit uses a piezoelectric transducer fitted in the bottom of an enclosure. The transducer acts as a shock sensor. The transducer is fitted at the rear of the enclosure touching a screw that rests on the table, and two feet are fitted at the front to improve the operation of the transducer. A yoke made from a length of solid electrical wire provides a mount for an IR transmitter that sends the mute command to the television set. This gives the IR transmitter a clear view of the television set, even if cups and the like are standing on the table.

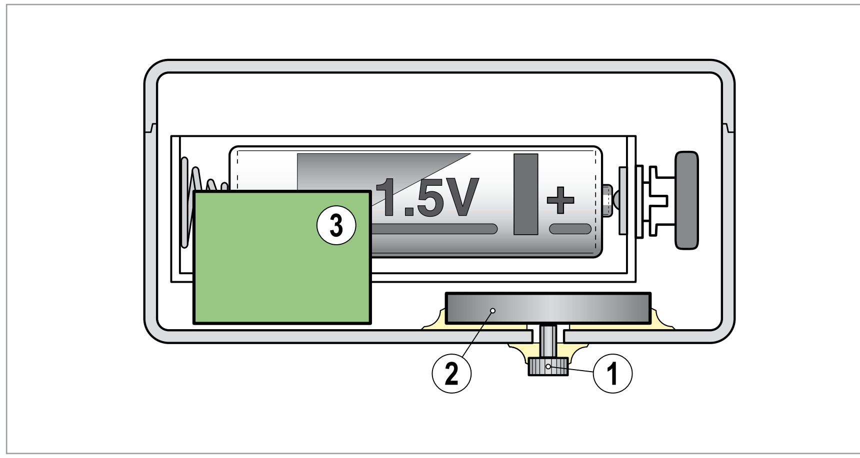
Just a PIC

The circuit is very simple and essentially consists of an 8-pin PIC microcontroller. The piezoelectric transducer is connected to the GP0 input, and zener diode D1 limits the maximum voltage applied to the input. The GP5 output drives an IR LED via transistor T1 to send IR commands to the television set. Pushbutton S1 allows the circuit to learn the right mute command. If it is pressed and held for a while, indicator LED D2 lights up and the mute code transmitted by the original remote control unit can be read in using an IR receiver module (type TSOP34836) connected to K3. This code is stored in the PIC. Connector K4 is used for programming the PIC. The pinning is compatible with the Microchip PICkit programmer, among others.



The circuit can be powered by a 3 V button cell or two 1.5 V cells in a bat-

tery holder. The circuit draws less than 100 nA in the quiescent state (ultra low sleep mode), so a power switch is not necessary.
The PCB for the advert killer has been kept very small by using predominately SMDs. Note: the prototype version shown in the photo does not have a programming connector, but this connector is present in the final version.



Construction

The circuit board and a pair of 1.5 V cells can easily be fitted in a standard box measuring 5 × 2.5 × 7 cm (2 × 1 × 2 3/4 inch). Of course, a much smaller box can be used with a button cell. Remember to program the PIC before closing the box (the source and hex code are available at [1]).

Drill a hole the bottom of the box at the rear so that the middle of the piezoelectric transducer is accessible from outside when the box is resting on its base. Then secure the piezoelectric transducer in the bottom of the box with hot-melt glue or silicone adhesive. Thread a screw into the hole until it touches the transducer. Glue the screw firmly in place (see the accompanying construction drawing: (1) screw, (2) piezoelectric transducer, (3) PCB).
At the front of the box, fit two feet to enhance the operation of the vibration sensor.
Fit a bracket (made from 2.5 mm² / AWG13 electrical wire, for example) on the box for mounting the IR LED. This gives it a free view of the television set.
With a bit of imagination, you can transform the box into something that looks nice on the table. For instance, the author 'dressed up' the prototype with a toy dragon.

Use

Start by learning the right mute code. Press and hold the button until the indicator lamp (D2) lights up (longer than 3 seconds). Hold the original remote control a few centimeters in front of the IR receiver and press the Mute button twice. If the code is received properly, it will be saved and the circuit will return to normal mode. If no code is received within 10 seconds or a bad code is received 6 times, the program automatically returns to normal mode. The learning function works with virtually every remote control unit.

Now you can place the advert killer on your coffee table or the like. Tap the table or the box when you want to switch the TV sound on or off. The sensitivity can be optimized by choosing the right location on the table.

The advert killer also responds to cups set down hard on the table, but everyone quickly learns not to do this, and it has the advantage that the table is less likely to be damaged.

(120277I)

Internet Link

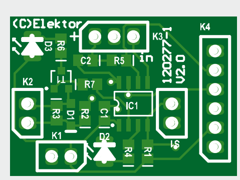
[1] www.elektor.com/120277

COMPONENT LIST

Resistors
(SMD0805)
R1,R2 = 10kΩ
R3 = 1MΩ
R4 = 1kΩ
R5 = 470Ω
R6 = 22Ω 0.25W
R7 = 330Ω 0.25W

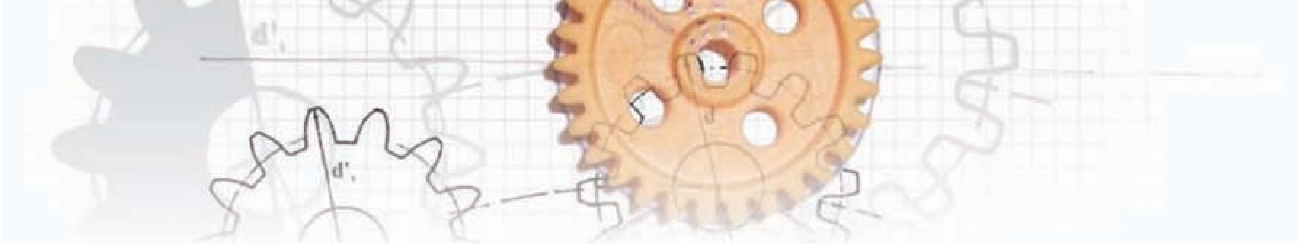
Capacitors
(SMD0805)
C1,C2 = 100nF

Semiconductors
D1 = 3V 0.375W zener diode (SOD123F)
D2 = LED, low current, red, 3mm
D3 = IR-LED, 5mm (e.g. Vishay TSUS5202)



T1 = BC847 (SOT23)
IC1 = PIC12F1822-I/SN (SOIC8)
IR receiver module, 36kHz (e.g. TSOP34836)

Miscellaneous
K1,K2,S1 = 2-pin pinheader, pitch 0.1 in. (2.5mm)
K3 = 3- pin pinheader, pitch 0.1 in. (2.5mm)
K4 = 6- pin pinheader, pitch 0.1 in. (2.5mm)
Piezo buzzer (e.g. Kingstate KPEG165)
Pushbutton with make contact, panel mount
2 AA or AAA batteries with holder, or 3-V button cell
PCB # 120277-1

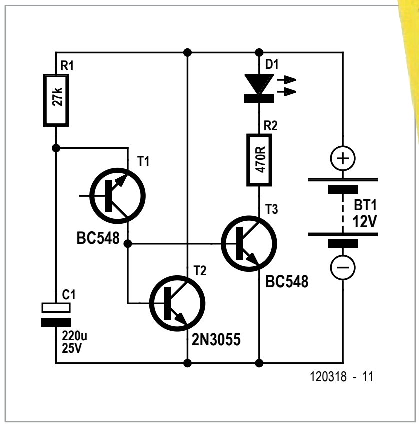


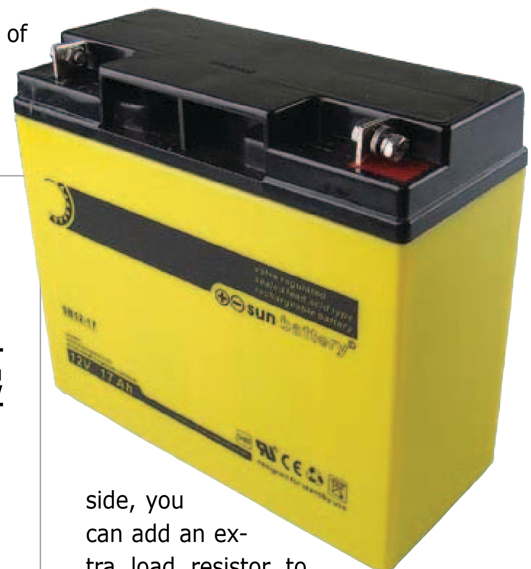
Battery Maintainer

By Burkhard Kainka (Germany)

The author found that a long-neglected gel battery in a hand-held vacuum cleaner had gone high-resistance. It took some effort to make it usable again, by alternately applying voltages of opposite polarities to it. A reverse voltage can help to break down the internal non-conducting layers which can form when the battery is left idle. The battery is now back in action and charging and discharging as normal.

Unfortunately, however, the battery will probably start to fail again if we once more leave the appliance lying around unused for a while. To prevent this happening the author applied a well-known technique: the battery is intermittently presented with a very brief high-current load. The circuit shown here does the job: every two seconds it draws a current of about 1 A for 2 ms. This corresponds to an average current of about 1 mA, which is of comparable magnitude to the self-discharge of the battery. Although the circuit does not consume much energy, it can keep the battery fresh.





The circuit is based on the NPN relaxation oscillator from the 2011 Project Generator Edition of Elektor (www.elektor.com/110195), here delivering the base current for the power transistor. In the prototype the current was measured at around 1 A: to be on the safe side, you can add an extra load resistor to the circuit.

The LED indicates when each current pulse occurs, which also serves as an indication of the battery's charge state: the less frequently the LED flashes, the lower the battery voltage.

(120318)

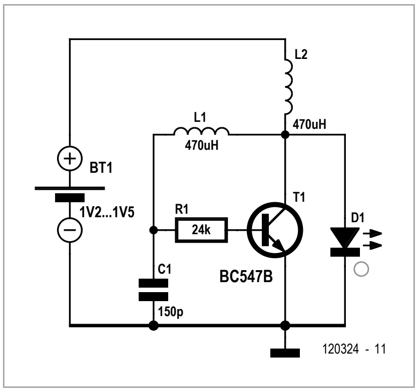
One-transistor Voltage Converter

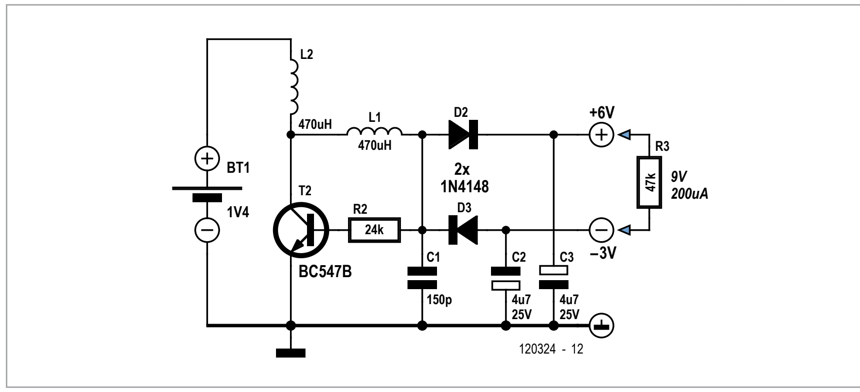
By Burkhard Kainka (Germany)

Taking apart a solar-powered lamp revealed a single-transistor voltage converter circuit that allowed an LED to be driven from a 1.2 V cell. The l/h diagram shows the circuit (with slight modifications). The circuit oscillates at about 500 kHz and, at a cell voltage of 1.4 V, draws 11 mA with a respectably bright LED. The circuit works down to a supply voltage of 0.8 V.

The oscilloscope shows 3 V_{pp} at the LED, as expected. The left-hand coil and the capacitor form a series resonant circuit, excited by the collector of the transistor which alternates periodically between conducting and blocking. When the transistor is off the upper coil dumps its stored energy so that the voltage on the collector rises to about double the cell voltage.

A sine wave voltage of 35 V_{pp} (!) was measured across the capacitor in the resonant circuit. Using a two-channel

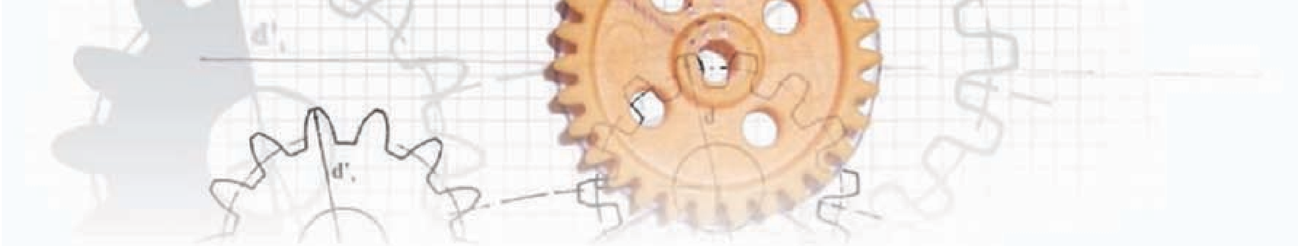




oscilloscope showed the phase relationships: the resonant circuit shifts the phase by about 90 degrees. The base resistor coupled with the base capacitance and the Miller capacitance (http://en.wikipedia.org/wiki/Miller_effect) of the transistor add a further phase shift.

The voltage increase obtained using the series resonant circuit can be used to make a bipolar voltage converter, for example to power operational amplifiers (see r/h diagram). Two electrolytic capacitors and two diodes rectify the voltage. The circuit can deliver a voltage difference of 9 V at 0.2 mA, which is enough for a low-power opamp.

(120324)



Elex Board Layout in LochMaster

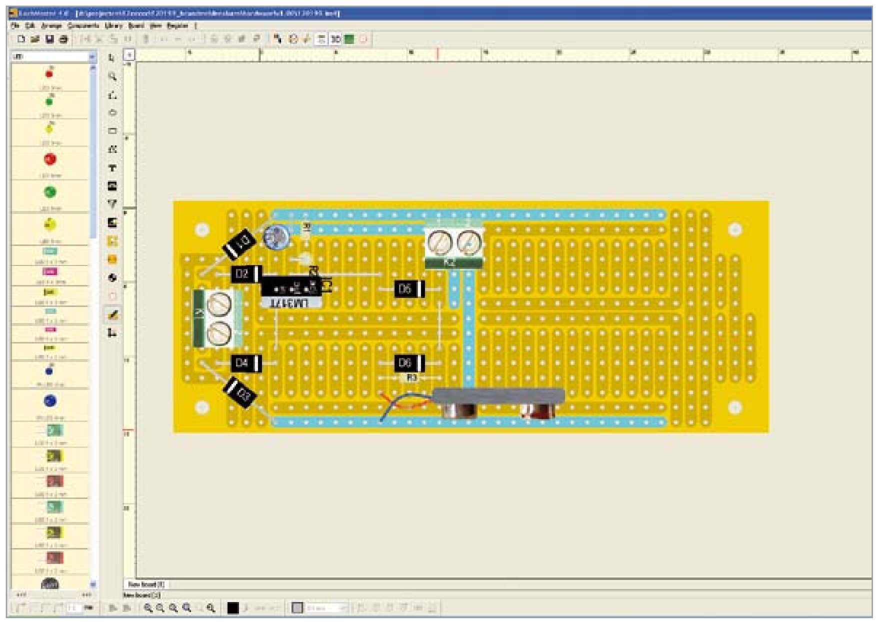
By Luc Lemmens (Elektor Labs)

For the construction of (small) through-hole prototype boards use is often made of stripboard (Veroboard), a fast and easy way to build relatively tidy and usable circuits in conjunction with wire-wrap or tinned copper wire.

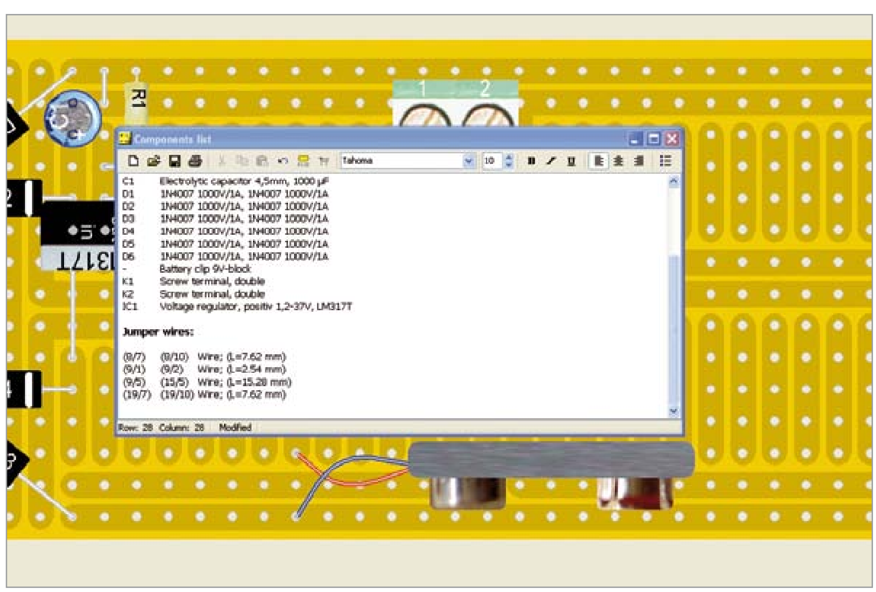
Stripboards come in many types and sizes and Elektor has its own variant: the prototyping boards that were designed for Elex projects and which are still available from our shop. These boards which also go under the type name of 'UPBS-1', -2 (Universal Prototyping Board Size-1 or -2) come with a thoughtfully laid out set of tracks, so that a small circuit can be created using a minimum number of wire links.

an affordable and simple aid for the design of the layout of components and wire links onto stripboards, using a computer

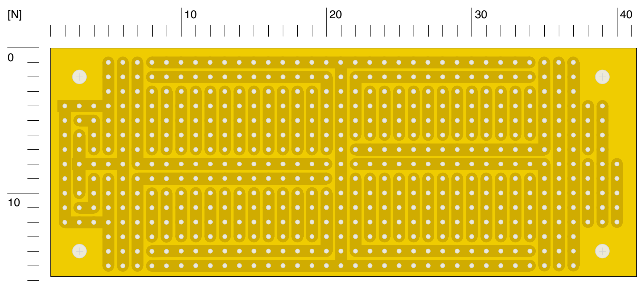
Just as with 'real' PCBs the success or failure of the board and the simplicity of the layout depend on the amount of thought put into the placement of the components. The PC program LochMaster from Abacom [1] is an affordable and simple aid for the design of the layout of components and wire

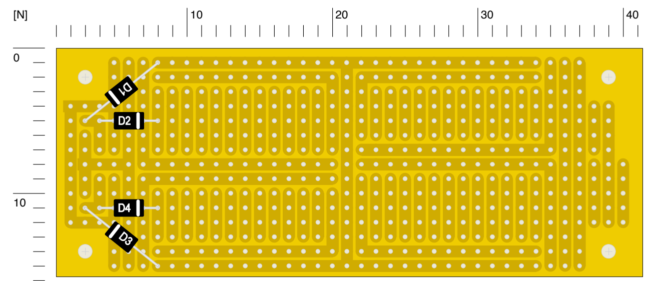


When you click on a track whilst in test-mode you can see which other tracks and links are connected together.

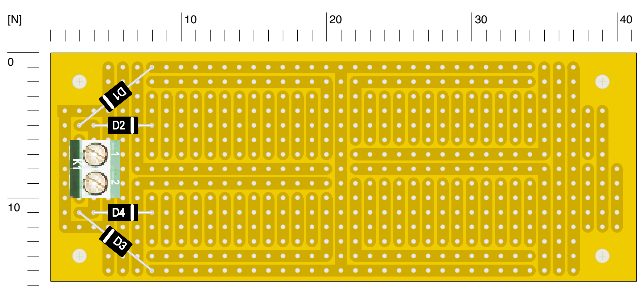


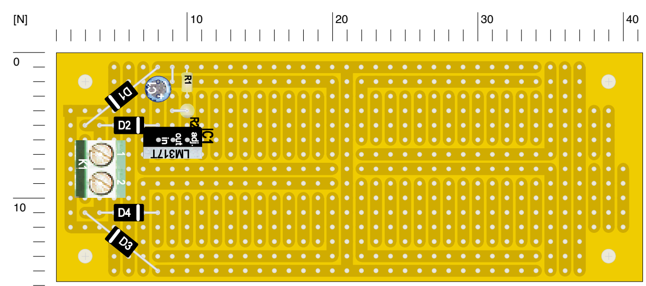
LochMaster can also generate a parts list, including an overview of any wire links.





links onto stripboards, using a computer. The program comes with extensive libraries with standard components that can be placed with just a few mouse clicks.
Wire links can be easily added and everything can still be moved about or modified. Before you build the actual circuit you can carry out a simple connection check so you can find short circuits or open connections and correct them before doing any soldering. The end result is a fairly realistic representation of the board, which can be printed out and be used as a template for the soldering.





LochMaster also comes with a set of templates of the layout for various prototyping stripboards. We have added the track layouts of our own Elex boards to these. The templates are available as a free download from the Elektor website [2]. You can add these templates by saving them in the 'Board Layouts' folder of the LochMaster folder. When you start a new design in LochMaster (from menu, File –> New), this folder opens automatically and you simply select the required layout.

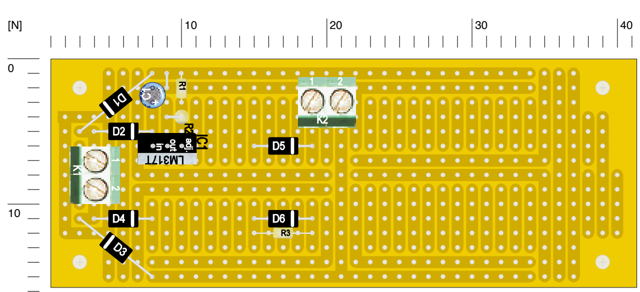
You can't really compare the facilities of LochMaster with those of a professional PCB design package and there are several areas in which there is room for improvement. However, it is still a very useful development tool, which we gladly make use of at Elektor Labs!

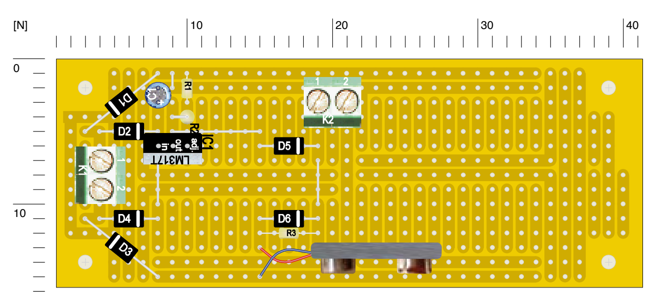
(120301)

Internet Links

[1] www.abacom-online.de/uk/html/lochmaster.html

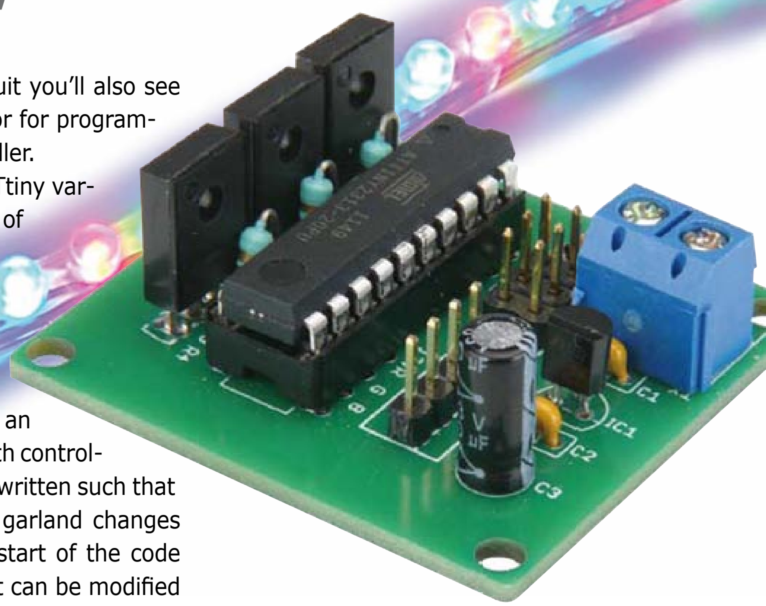
[2] www.elektor.com/120301





LED Garland Controller

All the colors of the rainbow



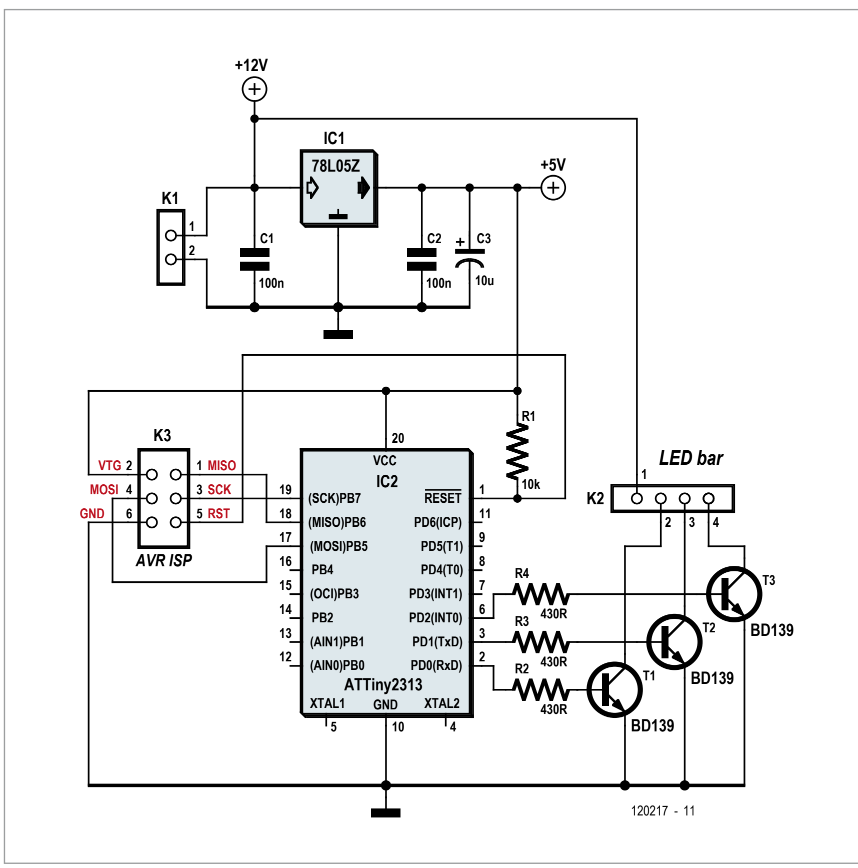
By Koen Beckers (Netherlands)

These days you can buy various types of LED garlands at a reasonable price. With these you can illuminate various objects indoors or outdoors with interesting lighting effects. When you use a garland with RGB LEDs you can even create a range of colors or continuously cycle through the color spectrum.

In this case the author wanted to enhance several kitchen cabinets with a novel lighting system. To this end a waterproof LED garland with built-in resistors was chosen. This type of garland can be obtained from e.g. [1]. The strip is available in lengths up to 5 m (approx. 16 ft) and it comes with double-sided sticky tape so it can be mounted onto any clean, flat surface. The supply voltage required by the LEDs is 12 V and the power requirements for the strip used by the author is 7.2 watts per meter.

Various types of controller can be bought to drive such RGB LED garlands, but as an electronics hobbyist you 'just' design one yourself of course, so that it does exactly what you want it to do. The design for this circuit turns out to be very simple: an ATtiny2313 microcontroller surrounded by a 5 V voltage regulator and three power transistors. The latter are driven via base resistors from port pins PD0 to PD2 of the microcontroller. In the circuit you'll also see a 6-way ISP connector for programming the microcontroller.

The program in the ATtiny varies the brightness of the R, G and B LEDs using an internal pulsewidth controller. The program was written such that the color of the LED garland changes continuously. At the start of the code are several items that can be modified



to suit your preference before programming the microcontroller. For example, the speed and the number of color changes can be modified, or a self test can be activated. If this is selected then just after the circuit is switched on, it will show the colors red, green and blue sequentially, followed by white. This way it is easy to verify that all LEDs in the strip are still working.

The current consumption of the LED garland is in practice very close to that stated by the manufacturer. Each LED color takes a current of just over 200 mA/m.

When the transistors specified in the circuit are used (BD139, I_{Cmax} 1.5 A) you could in theory drive a strip with a length of 1.5/0.2 = 7.5 m. In practice it's best to limit this to about 5 m.

For higher currents you can change the BD139 to a TIP122. This can handle 5 A so that it should be able to cope with LED garlands up to a length of 20 m. Remember that in that case you'll need a power supply that is rated at least at 12 A at 12 V.

If you decide to use the TIP122 there is no need to modify the printed circuit board. Although the pinout is different, it is the mirror image of that on the BD139. The TIP122 can simply be mounted the other way round, with the heatsink tab facing the outside, which makes it possible to mount the transistors on a common heatsink next to the PCB. Note that the PCB tracks are not designed to cope with currents of 10 A or higher.

It can happen that the R, G and B labeling is incorrect on some LED garlands, so it's best if you check that they correspond to the correct LEDs before connecting the LED garland to the PCB.

The source and hex code for the program can be downloaded from the Elektor website [2].

(120217)

Internet Links

[1] www.ledlightdepot.co.uk/9-led-waterproof-flex-strip

[2] www.elektor.com/120217

COMPONENT LIST

Resistors

R1 = 10kΩ

R2,R3,R4 = 430Ω

Capacitors

C1,C3 = 100nF

C2 = 10µF 16V radial

Semiconductors

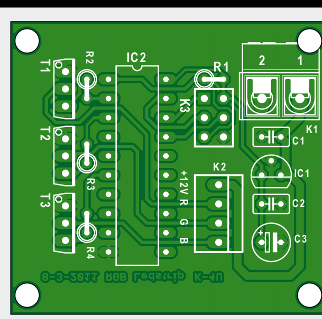
T1,T2,T3 = BD139 (or TIP 122, see text for mounting)

IC1 = ATtiny2313-20PU, programmed

IC2 = 78L05Z

Miscellaneous

K1 = 2-way-PCB terminal block, pitch 5mm



K2 = 4-pin pinheader, pitch 2.5mm

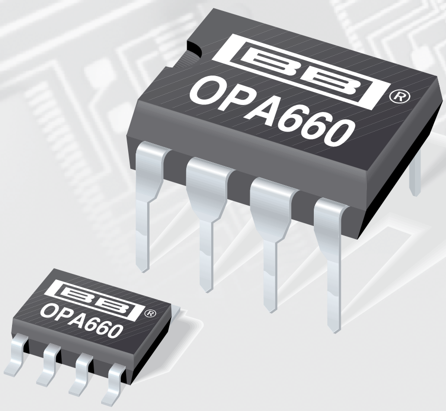
K3 = 6-pin (2x3) pinheader, pitch 2.5mm

PCB # 120217-1, see [2]

Component Tips

By Raymond Vermeulen (Elektor Labs)

OPA660: Diamonds are not forever



The OPA660 is no more. It has been obsolete for many years, although a few distributors like Rochester Electronics still have some in stock. The successor is the OPA860, but it is not entirely the same. The integrated buffer has a greater gain bandwidth and a higher slew rate, but the original open-loop amplifier has been changed to a closed-loop version. This eliminates the option of using it as a differential amplifier, despite the fact that this was one of the most attractive features of the OPA660 (see the application note [1]).

A few words about the heading of this item: the OPA660 was not made from diamond, but it was often called a 'diamond transistor'. This nickname comes from the symbol for a transconductance amplifier. The operating principle of a transconductance amplifier is very similar to that of a normal transistor, and the pins even have the same names: base, emitter and collector.

However, no external bias is necessary and if you apply an AC voltage with no DC offset to the base, you get an AC voltage with no DC component on the collector. This can be handy because it reduces the external component count. The transconductance can be adjusted by varying the current into pin 1 [2].

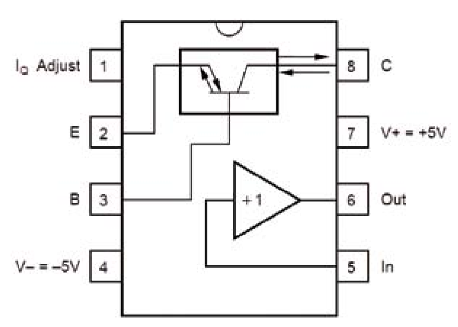
You may be wondering what this is good for. Well, audiophiles will probably use it to make simple amplifiers. Others may be inclined to do something with analog video, and people with a digital bent will be pleased with the steep signal edges, If you do find a use for it, please tell us about the results. I'm keen to know what you discover.

[1] 400 MHz differential amplifier with an OPA660: www.ti.com/lit/an/sboa049/sboa049.pdf

[2] OPA660 data sheet: www.ti.com/lit/ds/symlink/opa660.pdf

(120389)

Parameter	Condition	Value
OTA and buffer input impedance		1 MΩ || 2.1 pF
Buffer slew rate	5 V step	3000 V/µs
Buffer output bandwidth	V_o = ±1.4 V	800 MHz



Chateau Rising Damp

An ATM18 hygrometer

By Grégory Ester (France)

The elasticity and condition of the corks in your best bottled wines vary according to the humidity in the ambient air. So to avoid unpleasant surprises, you need to monitor the humidity and correct the value, which must be neither too high nor too low. The relative humidity varies according to the temperature of the ambient air, hence our ATM18 hygrometer is going to display both humidity and temperature.

And even if you're not a wine connoisseur, you'll be able to use this application to monitor the ambient air quality. Extreme levels are bad for your health and comfort in the home. Air that is too

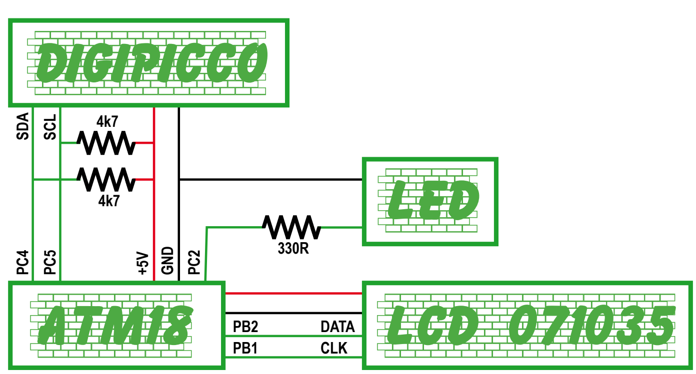


Figure 1. Wiring block diagram.

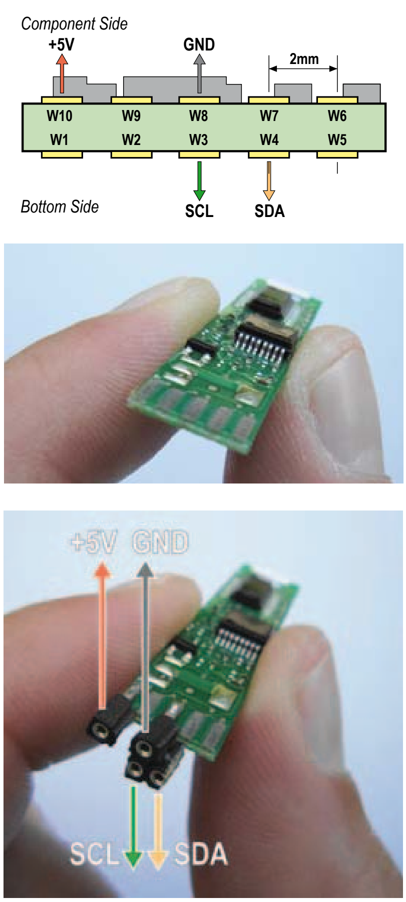


Figure 2. Soldering the single-pin sockets.

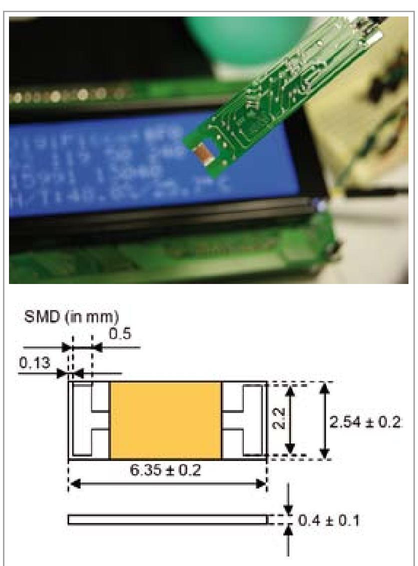


Figure 3. Air humidity detecting surface.

dry weakens the skin and respiratory system, while excessive air humidity can lead to moulds, allergic reactions, and stimulate the proliferation of dust mites. We'd be foolish to forego the benefits of electronics.

For this application, I chose the DigiPicco digital detector [1]; its characteristics are given in **Table 1**. It is supplied calibrated, which makes it easy to use. The signals connections are made via large tinned copper pads.

Once all the ingredients for the hygrometer have been brought together, it takes only a few minutes to connect up the hardware as per the block diagram (**Figure 1**): the data processing and display are going to be handled here by two circuits published by Elektor in 2008 – the ATM18 board [2] and a 2-wire display [3].

Preparation and implementation

Four single-pin sockets (**Figure 2**) are used to simplify feeding the power to the DigiPicco module and accessing the clock signal (SCL/Serial CLock) and data line (SDA/Serial DAta) that are needed for synchronous communication via the I²C bus. So it just takes a few wires simply plugged in to provide the electrical link between the DigiPicco module and the ATM18. Thanks to the extremely simple instructions offered by the famous Bascom-AVR, we can access, at clock rate, the temperature and humidity image bytes supplied by our DigiPicco module.

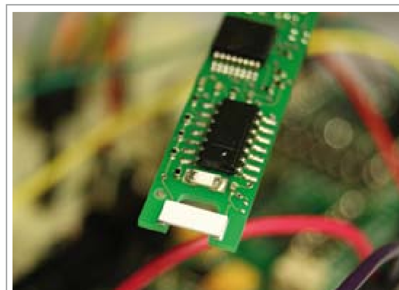


Figure 4. Close-up of the detectors.

DigiPicco, MaxiService!

The DigiPicco module from IST [4] has everything you need to be able to talk to it easily thanks to I²C communication and conveniently read the ambient temperature and relative humidity of the air you are breathing.

The P14 capacitive humidity detector [5] is formed by a porous electrode soldered directly to the base board. In **Figure 3**, we can see that the detector has a large exchange area, giving it improved sensitivity.

An SMD version PT1000 detector is used to measure the temperature. In **Figure 4**, we can clearly see the two detectors that convert the two physical quantities to be measured into electrical values.

Table 1. Characteristics of the humidity / temperature detector	
temperature measured	from –25 °C to +85 °C
relative humidity	from 0 to 100 %
communication	serial via I²C bus
accuracy	< ±3 %RH (15 to 85 % RH @ 23 °C) < ±0.5 °C (–25 to +85 °C)
temperature detector	PT1000
humidity detector	P14
current consumption	< 3 mA
supply voltage	5 V

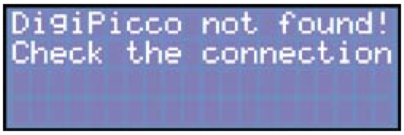


Figure 5. You'll need to check everything again…

Figure 6. Isn't it nice when everything works?!

Just four bytes!

The address is factory-preconfigured to $F0 during manufacture. If the module is missing on the bus, the error message in **Figure 5** will be displayed. In this event, you'll need to check everything again.

Because this project is firmly intended to be instructive, I've made it display certain elements of the collected or calculated data (**Figure 6**). On the first line, the address visible is scanned automatically at start-up. The second line displays the most significant and least significant bytes corresponding to the humidity of the air; there then follow the most and least significant bytes of the temperature measured.

A little calculation lets us display the two results: the relative humidity for the first value on line 3, followed by the temperature. In point of fact, for the two quantities detected, the bytes are received in the order 'most significant byte' followed by 'least significant byte'. As a result, we need to offset the most significant byte eight bits to the left by multiplying it by 256, after having masked its MSB (01111111 = 0x7F) by means of a logical AND. Add to this the least significant byte and the result is a binary word coded in 15 bits.

A quick glance at the source code file will enable you to link the above explanations to the instructions.

The detector transfer functions are linear (0x0 – 0x7FFF (0 – 100 % RH), 0x0 – 0x7FFF (–40 to +125 °C). The proportional relationship lets us deduce the final values — here a relative humidity of 50.2 % for a measured temperature of 24.7 °C.

The display is updated every second; the 3 mm yellow LED indicates the activity on the I²C bus.

Note that in the current situation, it takes around 5 s to go from 100 % relative humidity to around 50 %. You can test this yourself by blowing close to the P14 detector. It will take around 5 s to return to the initial value.

(110488)

Internet Links

[1] http://uk.farnell.com/ist/digipicco-tm-basic-i2c-g/sensor-humidity-module/dp/1778051?Ntt=digipicco

[2] www.elektor.com/atm18

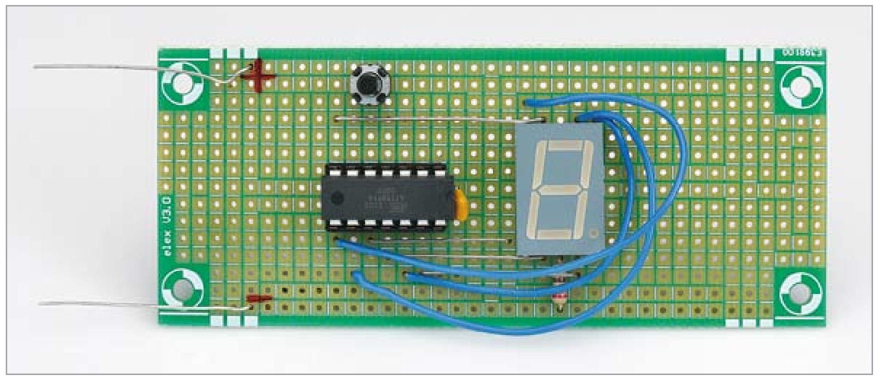
[3] www.elektor.com/071035

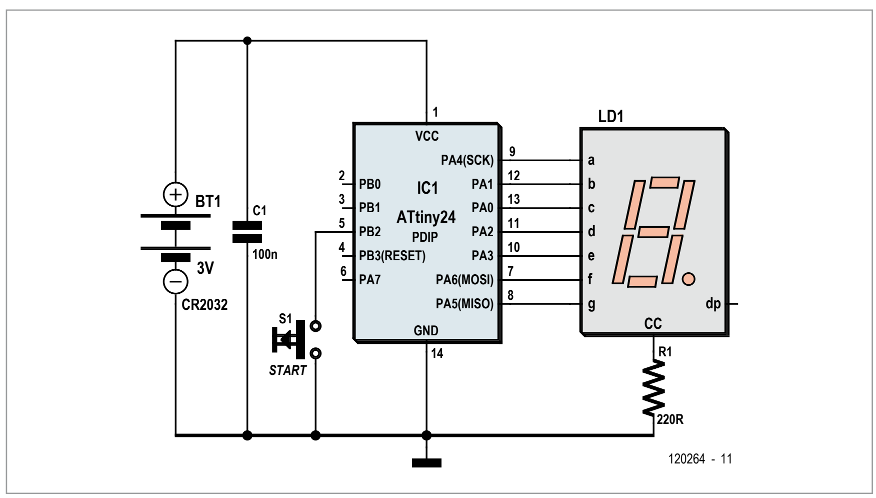
[4] http://www.ist-ag.com/

[5] http://www.ist-usadivision.com/resources/datasheets.php

Economical 7-segment Display

By Jörg Trautmann (Germany)





Current consumption is always an important consideration when designing battery-powered devices. This circuit shows how a seven-segment display can be driven by a microcontroller in a way ideally suited for such applications. Furthermore, we even economise on component count!

In a conventional circuit where a single digit is displayed each individual segment is provided with its own current-limiting resistor through which it can be continuously driven. If the current consumption is 5 mA per segment then the total current draw when displaying an '8' will be 35 mA. If multiple digits are to be displayed, they are normally multiplexed in a sequential fashion so that only one digit is driven at a time. In this case the total maximum current draw remains at 35 mA per digit.

The circuit described here uses only one series current-limiting resistor per seven-segment display, and it is possible to reduce the total current consumption to 5 mA per displayed digit. The trick is to use multiplexing at the segment level, realized in software in a microcontroller (in this example an ATtiny24).

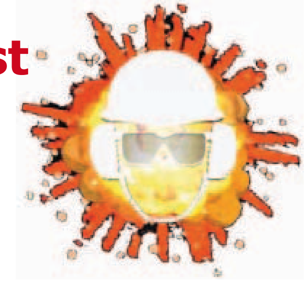
In the software each digit to be displayed is represented by a seven-bit string. Each position in the string corresponds to a segment to be driven and can take on the value 0 (for 'off') or 1 (for 'on'). For example, the digit 6 could be represented by the string '0111111', with all segments except the first being illuminated. The software examines the elements in the string one by one in sequence and turns the corresponding segment on or off (see listing). The time period allotted to each segment is about 2 ms and so the digit is refreshed at about 70 Hz, giving a flicker-free display.

As an example application of this technique the author has designed a digital die (see the circuit diagram). As long as input pin PB2 is held low by the user holding down button S1, a counter counts through the digits from 1 to 6 at a 1 kHz rate. When S1 is released the counter's current value is shown on the seven-segment display. There are only a few components in the circuit and so the whole thing can easily be constructed on a piece of prototyping board or on the ELEX-1 (UPBS-1) experimental printed circuit board. The

Elektor Products & Services

- Free software download
- Ready-programmed microcontroller: 120264-41
- Prototyping board: ELEX-1 (UPBS-1)

See www.elektor.com/120264



microcontroller is available ready-programmed from Elektor. A type CR2032 battery provides the circuit with a 3 V power supply, which is smoothed by capacitor C1. The output ports of the ATtiny24 are capable of switching currents of 5 mA without difficulty and so they can be connected directly to the corresponding inputs of the seven-segment display module. Only one segment is ever active at any one time and so R1 acts as a current-limiting resistor for the entire display. Be careful when selecting a display that it only includes one LED in each segment, as otherwise the supply voltage of 3 V will not be high enough.

In the interests of reducing power consumption button S1 has a further function: if it is held for more than two seconds, a minus sign flashes on the display for a few seconds and then the microcontroller switches into sleep mode. Current consumption in this mode is less than 1 µA. A further press of S1 will wake the microcontroller up again. If the user forgets to put the microcontroller to sleep, it will automatically switch to this mode two minutes after the last roll of the die. These functions obviate the need for an extra switch to interrupt the power supply.

(120264)

Listing

```
Sub Show_number(byval Number As Byte)

For J = 1 To 7    'display segments in multiplexed fashion
     digit = Mid(a(number), J, 1) 'extract segment value as
digit
     Port_value = Val(digit) 'state to be written to output port
(0 or 1)
     Select Case J
     Case 1
                Porta.0 = Port_value
     Case 2
                Porta.1 = Port_value
     Case 3
                Porta.2 = Port_value
     Case 4
                Porta.3 = Port_value
     Case 5
                Porta.4 = Port_value
     Case 6
                Porta.5 = Port_value
     Case 7
                Porta.6 = Port_value
     End Select
     Waitms 2     'shine segment for 2 milliseconds
     Porta = &B00000000  'clear all segments to zero
Next J

End Sub
```

MOSFET Circuit Breaker

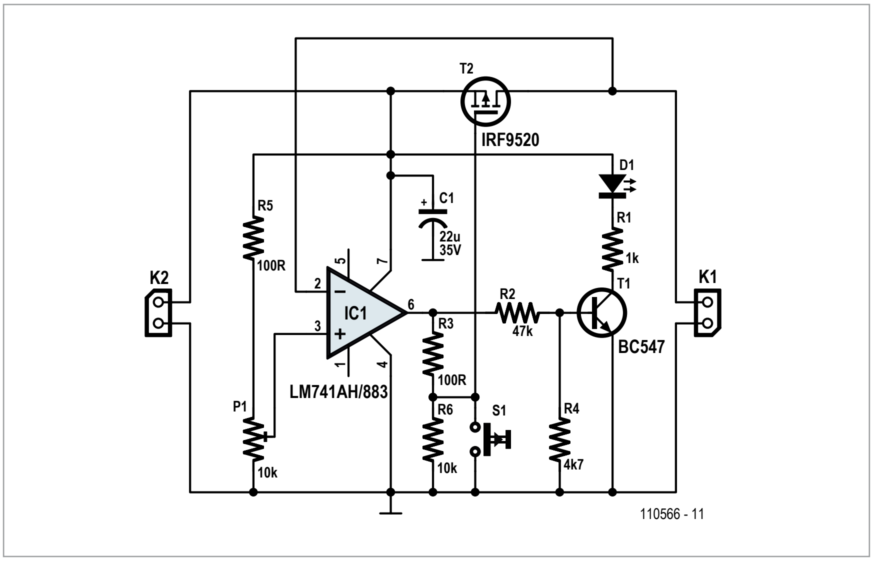
By Georges Treels (France)

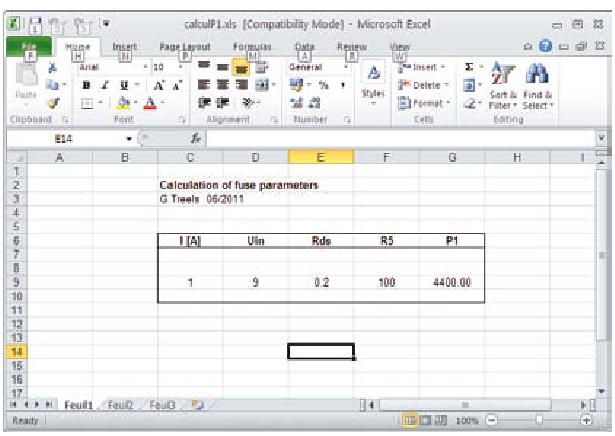
Cutting the power rapidly in the event of an overload implies monitoring the current through the load. This is usually done either by measuring the voltage difference across a series resistor, or by using a Hall-effect current sensor. This second solution is certainly appealing, but the cost of these sensors is still quite high, and they're not all that easy to implement. The disadvantage with the first solution is the voltage drop across the series resistor.

Having come to this conclusion, I had the idea of combining both methods by using a P-channel MOSFET as both disconnecting device *and* series resistor. To achieve this, I turn a (minor) drawback of MOSFETs to advantage: their drain/source resistance.

Opamp IC1 is wired as a comparator monitoring the voltage difference between the drain and source of the MOSFET T2, which is wired in series with the power rail to be monitored. This voltage drop is a function of the current flowing into the load, and hence through T2, and the latter's drain/source resistance. Now T2 will be turned on as long as its gate is kept at 0 (by R6).

The trigger threshold for IC1 is adjusted by preset P1 (in conjunction with R5). If this threshold is exceeded, IC1's output goes high, which turns off T2 via R3. At the same time, T1 turns on and LED D1 lights to show there is a fault. The circuit-breaker has tripped, and everything is safe again.





IRF9520					
I	**U**	**R_{ds}**	**U_{ds}**	**R5**	**P1 : theoretical value**
10	9	0.5	5	220	176
10	12	0.5	5	220	308
10	24	0.5	5	220	836
5	5	0.5	2.5	220	220
5	12	0.5	2.5	220	836
5	24	0.5	2.5	220	1892
1	5	0.5	0.5	220	1980
1	12	0.5	0.5	220	5060
1	24	0.5	0.5	220	10340
0.1	5	0.5	0.05	100	9900
0.1	12	0.5	0.05	100	23900
0.1	24	0.5	0.05	100	47900

Once the cause of the overload has been corrected, all we have to do to turn T2 back on is to force its gate to 0 by briefly pressing S1. The function of R3 is to protect IC1 output from excess current while S1 is pressed.

In order to make this circuit-breaker function, we just need to determine a few parameters for it:

- choice of MOSFET
- maximum current
- working voltage

then all we have to do is calculate the values for R5 and P1 accordingly.

Let's call the voltage on IC1's non-inverting input U_{ref}, the circuit-breaker input voltage U, the drain/source current I, and lastly, the MOSFET's internal resistance R_{ds}.

We can write that $U_{ref} = U \times P1 / (R5+P1)$

The voltage on pin 2 of IC1 is:

$U - (I \times R_{ds})$

So $P1 = [R5 \times (U - I \times R_{ds})] / (I \times R_{ds})$

Example:

U: 9 V

MOSFET R_{ds}: 0.5 Ω

I: 1 A

R5: 100 Ω

We will get:

P1 = 1,700 Ω, i.e. 2 kΩ in a practice.

If these little calculations bother you, don't worry, you can use a spreadsheet to do them for you (screen shot).

Depending on the (P-channel) MOSFET used, this system turns out to be very flexible. By skillfully combining R_{ds}, and I_{max} drain/source, it is possible to monitor currents from 1 to 100 A, or even more.

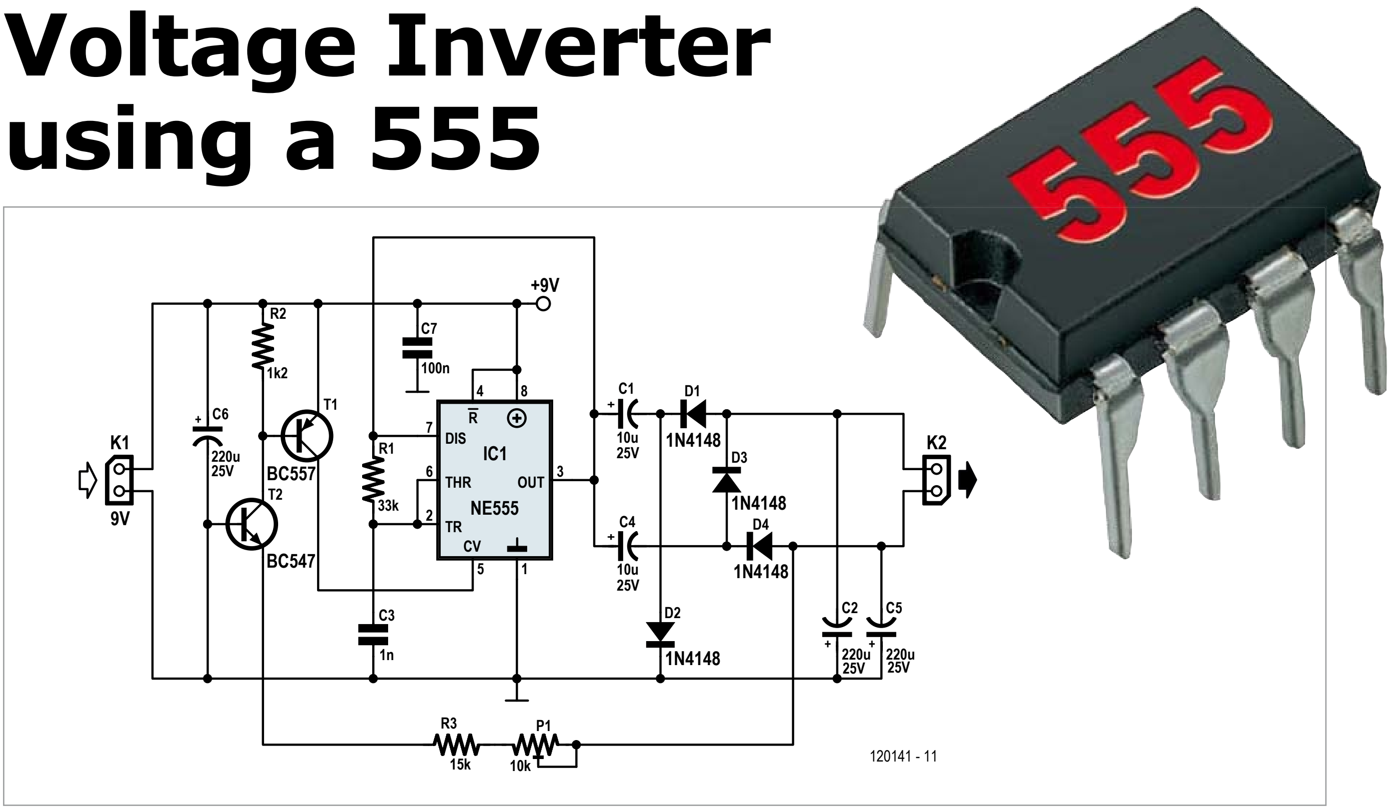
Of course there's a downside to everything, and this circuit isn't perfect either. To detect weak over-currents, you'll need to choose a MOSFET with quite a high drain/source resistance. You'll also need to recalculate the trigger threshold if the input voltage changes. By way of an example, the table gives practical values for a circuit-breaker from 5–24 V and 0.1–10 A, based on the common, cheap IRF9520 MOSFET.

In general terms, for this sort of circuit to be reproducible, you need to make allowance for the component tolerances, in particular the MOSFET's R_{ds} resistance, which is quite sensitive to device temperature.

In my view, the advantages more than outweigh the disadvantages, as this electronic circuit-breaker is compact, works every time and without fine tuning, while P1 lets you cover a wide current range.

(110566)

Voltage Inverter using a 555

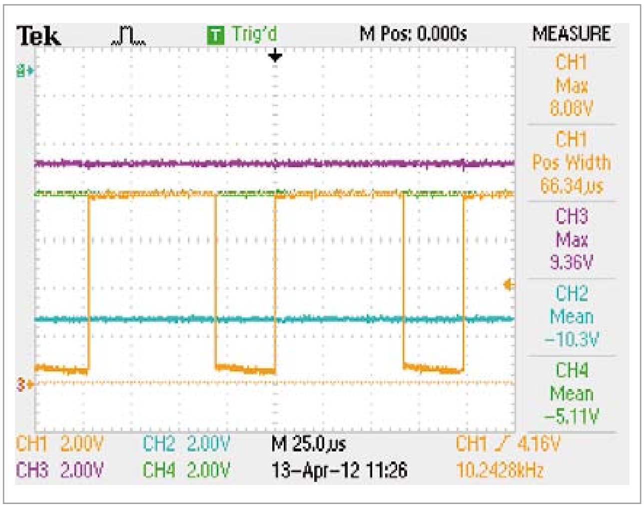


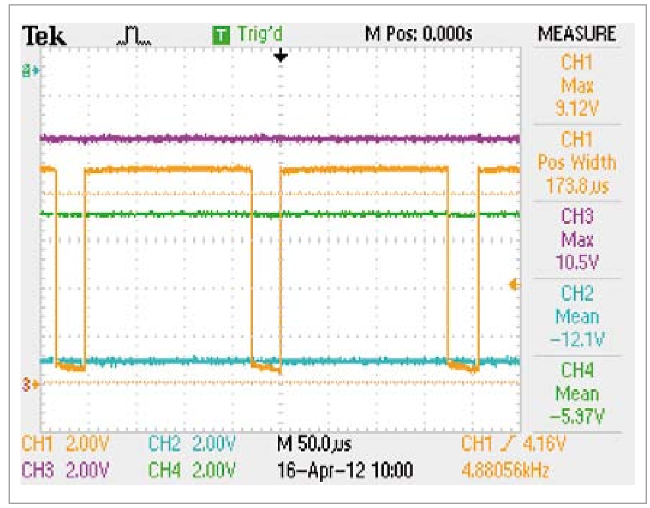
By Peter Krueger (Germany)

In many circuits we need to generate an internal adjustable voltage. This circuit shows how it is possible to use a trusty old NE555 timer IC and a bit of external circuitry to create a voltage inverter and doubler. The input voltage to be doubled is fed in at connector K1. To generate the stepped-up output at connector K2 the timer IC drives a two-stage inverting charge pump circuit.

The NE555 is configured as an astable multivibrator and produces a rectangular wave at its output, with variable mark-space ratio and variable frequency. This results in timing capacitor C3 (see circuit diagram) being alternately charged and discharged; the voltage at pin 2 (THR) of the NE555 swings between one-third of the supply voltage and two-thirds of the supply voltage.

The output of the NE555 is connected to two voltage inverters. The first inverter comprises C1, C2, D1 and D2. These components convert the rectangular wave signal into a negative DC level at the upper pin of K2. The second inverter, comprising C4, C5, D3 and D4, is also driven from the output of IC1, but uses the negative output voltage present on diode D3 as its reference potential. The consequence is that at the lower pin of output connector K2 we obtain a negative voltage double that on the upper pin.





Now let us look at the voltage feedback arrangement, which lets us adjust this doubled negative output voltage down to the level we want. The NE555 has a control voltage input on pin 5 (CV). Normally the voltage level on this pin is maintained at two-thirds of the supply voltage by internal circuitry. The voltage provides a reference for one of the comparators inside the device. If the reference voltage on the CV pin is raised towards the supply voltage by an external circuit, the timing capacitor C3 in the astable multivibrator will take longer to charge and to discharge. As a result the frequency of the rectangle wave output from IC1 will fall, and its mark-space ratio will also fall.

The source for the CV reference voltage in this circuit is the base-emitter junction of PNP transistor T1. If the base voltage of T1 is approximately 500 mV lower than its emitter voltage, T1 will start to conduct and thus pull the voltage on the CV pin towards the positive supply.
In the feedback path NPN transistor T2 has the function of a voltage level shifter, being wired in common-base configuration. The threshold is set by the resistance of the feedback chain comprising resistor R3 and potentiometer P1. When the emitter voltage of transistor T2 is more than approximately 500 mV lower than its base voltage it will start to conduct. Its collector then acts as a current sink. Potentiometer P1 can be used to adjust the sensitivity of the negative feedback circuit and hence the final output voltage level.
Using T1 as a voltage reference means that the circuit will adjust itself to compensate not only for changes in load at K2, but also for changes in the input supply voltage. If K2 is disconnected from the load the desired output voltage will be maintained, with the oscillation frequency falling to around 150 Hz.

A particular feature of this circuit is the somewhat unconventional way that the NE555's discharge pin (pin 7) is connected to its output (pin 3). To understand how this trick works we need to inspect the innards of the IC. Both pins are outputs, driven by internal transistors with bases both connected (via separate base resistors) to the emitter of a further transistor. The collectors of the output transistors are thus isolated from one another [1].

The external wiring connecting pins 3 and 7 together means that the two transistors are operating in parallel: this roughly doubles the current that can be switched to ground.

The two oscilloscope traces show how the output voltage behaves under different circumstances. The left-hand figure shows the behaviour of the circuit with an input voltage of 9 V and a resistive load of 470 Ω connected to the lower pin of output connector K2. The figure on the right shows the situation with an input voltage of 10 V and a load of 1 kΩ on the lower pin of output connector K2. The pulse width and frequency of the rectangle wave at the output of IC1 are automatically adjusted to compensate for the differing conditions by the feedback mechanism built around T1 and T2.

Because of the voltage drops across the Darlington output stage in the IC (2.5 V maximum) and the four diodes (700 mV each) the circuit achieves an efficiency at full load (470 Ω between the output and ground) of approximately 50 %; at lower loads (1 kΩ) the efficiency is about 65 %.

(120141)

[1] http://en.wikipedia.org/wiki/555_timer_IC

AVR MultiTool

Measure, control, experiment

By Dr Andreas Eppinger (Germany)

You've just got hold of the latest whizzy IC and can hardly wait to start experimenting with its functions. It is highly likely that, like many modern devices, it will be controlled over an I²C or SPI interface.

What would be useful at this point would be some kind of versatile hardware tool based on a microcontroller that could talk to these interfaces, as well as providing a few digital I/Os and perhaps also a PWM output. Ideally the tool should be controlled using a simple protocol over a serial port, which would allow a PC to be used to issue commands to it for maximum flexibility. Purists can hack away using a terminal program; those more comfortable with a graphical user interface can easily rustle up something suitable. In principle we might want to execute a set of commands in sequence, and this can be achieved using macros to automate things.

Most modern microprocessors, such as AVR microcontrollers, already include the peripheral interfaces needed to carry out such experiments. A ready-made processor board with all the required pins brought out on header strips would make a good basis for all-singing-all-dancing hardware for measurement, control and experimenting. For the 'AVIOM' (*A*VR *V*ersatile *I/O M*odule) the author chose an Arduino Nano board (see photograph). This board basically consists of an ATmega328P and a USB interface for talking to a PC. In the lab we have also successfully tested the design using an Arduino Uno board. Alternatively, it is easy enough to construct a compatible module with an ATmega328P and a few support components. If a ready-made USB-to-serial TTL-level cable is used, the corresponding converter chip on the board can be dispensed with. The do-it-yourself approach is made possible by the fact that Arduino hardware and software is all open source: the hardware reference design, the programming environment and a wealth of software examples are available for free download from the Arduino homepage [1]. The large figure shows which pin on the board is responsible for which function.

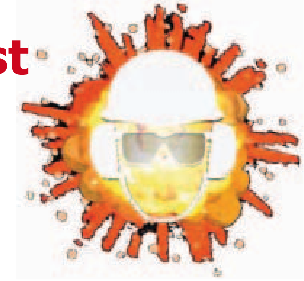
Using a ready-made module means that we are free to concentrate more on the software aspects of the project. Quite a lot needs to be done in this direction: the firmware running on the Arduino needs to configure the Timer/Counter/PWM, I²C, SPI and UART modules, as well as set up the four analog channels and eight digital ports.

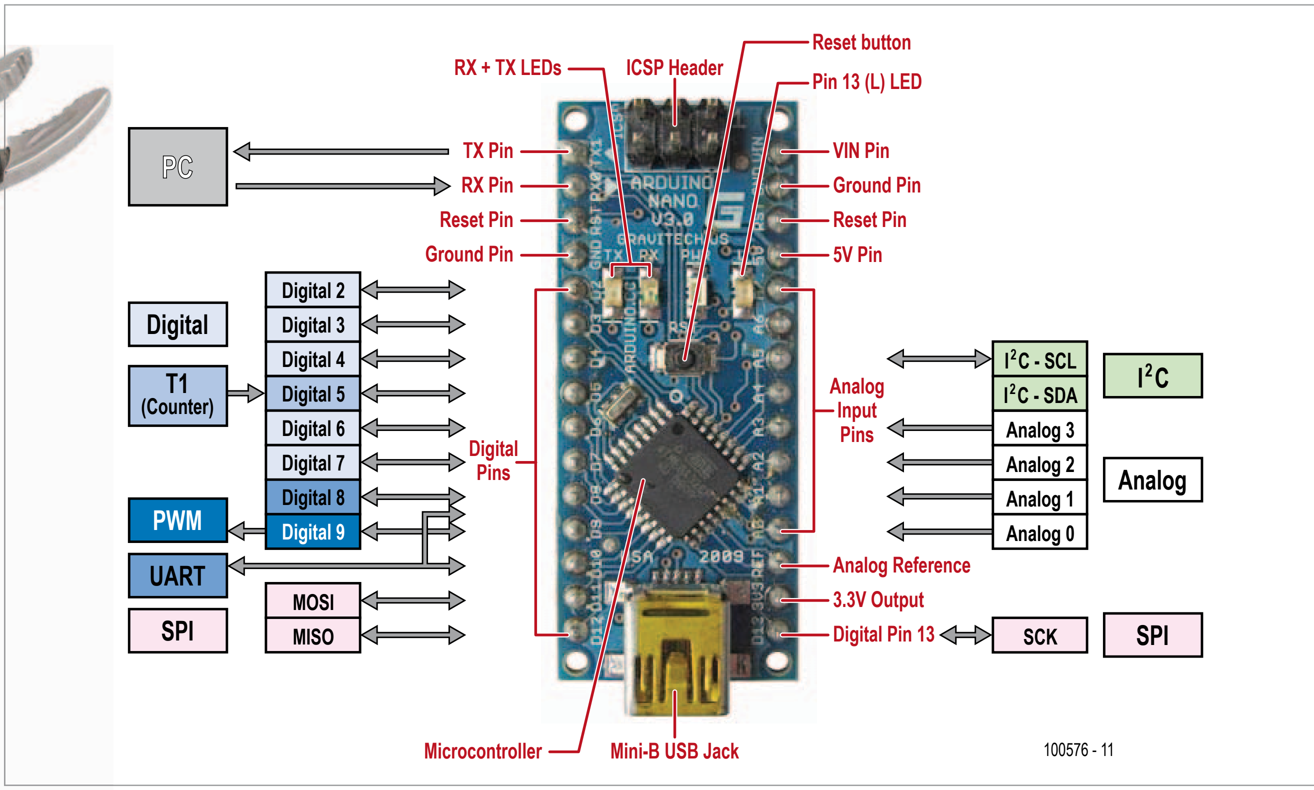
There are two ways in which the device can be controlled from a PC.

- Use a terminal. A simple terminal emulator program suffices, and the short commands make interactive control of all functions easy. Sequences of commands can be defined as macros, stored and then subsequently played back.

- Write a program. The hardware can be controlled using a program written in Visual C# 2010 with a graphical user interface, written specifically for this project by the author. The user interface even allows Python scripts to be created and executed to automate the operation of the hardware.

We will now look at the various parts of the software one by one. For simplicity the AVIOM operates in one of a range





of different modes, such as 'analog', 'digital' and 'wait'. The operating mode is selected by sending a full stop character '.' followed by a single letter abbreviation as follows.

.a	Analog
.d	Digital
.c	Configuration
.e	EEPROM access
.i	I²C
.l	System LED
.m	Macros
.r	SRAM access
.t	Timer/Counter
.u	UART
.w	Wait

In each mode there are three basic commands available: help ('?'), status ('#') and command line ('%'). The help command '?' causes the built-in help system to list the available commands. The '#' command displays status information. The percent character '%' introduces a command line: this means that subsequent characters are collected until the end of the line (indicated by a CRLF) and then executed. Within the commands themselves capitals are distinct from lower-case letters. Each command consists of letters, numeric values, or a combination of the two. A complete list of commands would occupy more space than we have available here, but is available for download from the Elektor website [2]. As a taster will we show here some of the commands available in analog, system LED and wait modes.

Analog mode (.a):
'1' Display the value read from ADC channel 1
's' Read all four of the ADC channels and display their values

System LED mode (.l):
'h' Switch system LED on
'l' Switch system LED off
's' Read system LED status

Wait mode (.w):
hhh Wait for hhh (hex) milliseconds (hhh = 000 to FFF)

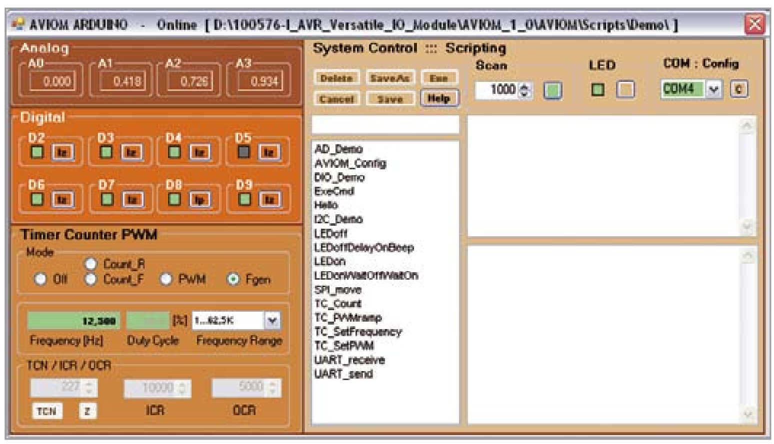
Commands (and this goes also for mode-changing commands) can be strung together into sequences, as hinted at above. For example, the following sequence switches on the system LED and then reads analogue channel 3: '.lh.

a3;'. A semicolon can be used to mark the end of a command sequence.

The sequence '.mdA .ll.w100.lh.m' defines a macro called 'A' which turns the system LED off for 256 ms and then turns it on again. The macro can be executed using the command '.mA'.

On reset, the system automatically executes the macro called '0'. This macro can therefore be used to store all the commands and settings that need to be executed whenever the AVIOM system is booted.

As mentioned above, the 'multi-tool' can also be controlled by a program running on a PC, written by the author using Visual C# 2010. The screenshot shows the graphical user interface in action.



The ADC values are shown at the top left under 'Analog'. Pressing the 'Scan' button starts a cyclic reading of ADC values: below to the left the cycle timing can be set in milliseconds.

connection has been successfully established the field turns green and the rest of the user interface is activated; otherwise the field remains gray.

The C# software uses the 'ALab' framework developed by the author, which offers a very wide range of basic functions for using a PC to control operations in a microprocessor network. Communication between the PC and network nodes is done using messages which are kept in queues. Replies received are processed and displayed in the AVIOM user interface. The whole thing is of course written with a little help from threads.

One of the most important features of the PC software is scripting. Scripts, written in the Python programming language, can be entered in the script text window. To do this, the AVIOM system uses the freely-available IronPython ('Python for .NET') implementation [3].

The scripts are stored as text files in a workspace directory. A complete list of the script files found there is shown in the list

Automation using macros and scripts

The area marked 'Digital' shows the current state of the digital pins. Clicking on the relevant button switches a pin between output, high-impedance-input, and input-with-pull-up-resistor modes. Clicking on the display (when in output mode) changes the state of the output.

Radio buttons are used to change settings in the area marked 'Timer Counter PWM'. In 'Count_R' mode the counter counts rising edges, while in 'Count_F' mode it counts falling edges. Clicking 'TCN' reads the current value in the counter and clicking 'Z' resets it.

In PWM or frequency generator mode ('Fgen') the 'Frequency' and 'Duty Cycle' fields are enabled. Since only integer values are allowed in the AVR's ICR and OCR registers, the actual frequency and duty-cycle values are displayed, which may differ somewhat from the values the user has entered.

The COM port that is used for communication with the AVIOM module is set under 'COM:Config' at the upper right. Once a

box in the middle of the screen. The working directory can be changed by clicking on the 'C' button.

If a script is selected in the list box, the name of the file will appear in the text box above it and can be edited there if necessary. A copy of an existing script with a new name can be created by editing the filename suitably and clicking on 'SaveAs'.

If you have entered or edited a script in the large window at the bottom right, you can try it out using 'Exe' or by double-clicking the script name in the list box. The file will automatically be saved first. Text output from the script (from 'print' commands) and error messages appear in the window above. Make sure that 'scan' mode is not active when executing scripts.

User script files are automatically provided with a header that imports a few handy name spaces and defines two special

objects: 's' for system functions and 'a' for AVIOM functions. The AVIOM object 'a' is an essential part of any script file. All AVIOM commands that can be executed by a Python script are implemented as methods of this object. (A click on the 'Help' button lists the built-in functions.) In many cases the methods return 'true' or 'false' to indicate whether the command was successful or not. A complete list of the AVIOM script commands can be found in the document available from the Elektor website.
The following example shows how commands can be executed.

```
#
# Demo: TIMER COUNTER
# set pwm
#
f = 1.0
dc = 7.0
res = a.TCPpwm(f, dc)
print "PWM f = ", res, "  DutyCycle = ",dc,"%"
```

Further examples can be found in the 'Demo' workspace. Note that the 'I2C_..._PCA8581' demonstration scripts only work when a suitable EEPROM device is connected.

You will doubtless now want to try the system out for yourself. The first step is to install version 1.0 of the Arduino development environment [1].
The download from the *Elektor* website includes a directory 'AVIOM_1_0' which should be copied to any convenient place on the computer. It is now a good idea to create a shortcut to the file '..\AVIOM_1_0\AVIOM\AVIOM\bin\Release\AVIOM.exe".
The next step is to launch the Arduino IDE and set the 'sketchbook' location to point to the directory '..\AVIOM_1_0\ARDUINO'. Connect the Arduino board and select the 'sketch' 'AVIOM_Arduino_1_0', compile the program and load the hex file into the microcontroller.
A first test can be carried out using a terminal emulator program (with settings 115200 baud, 8N1) or using the author's dedicated program, which can be run by clicking on the shortcut. The demonstration scripts should appear in the script list. And away you go!

(100576)

Internet Links

[1] www.arduino.cc

[2] www.elektor.com/100576

[3] http://ironpython.net

TAPIR Sniffs it Out!

Ultrasensitive wideband E-smog detector

Attention boy scouts, professionals and grandfathers! This electrosmog sleuth offers you two extra senses to track down noise that's normally inaudible. TAPIR also makes a nice project to build: the kit comprises everything you need — even the enclosure, ingeniously made from the PCB proper.

By Thijs Beckers (Elektor UK/INT Editorial)

Why build an electrosmog ('E-smog') detector? The answer is quite simple. More and more of our everyday objects are based on some sort of electrical 'core': your toothbrush, camera, cellphone, TV set, and so on. Each and every one of these devices generates electrical radiation in some way. There are of course rules manufacturers should abide by, but that doesn't mean that devices are completely free from electrosmog.
In fact, even with the widespread 'CE' certification stamped onto your device, it is not certain that a device complies with all the rules and doesn't interfere with other electronic devices. Ever tried calling someone (or, when receiving an incoming call) holding your mobile phone close to a cheap alarm clock radio, or a set of low-end PC speakers? (your guitar amp probably loves those cellphones too…)

An E-smog detector is designed to detect the 'radiant misbehavior' of nearby electronics. The TAPIR — short for *Totally Archaic but Practical Interceptor of Radiation* — is a simple design capable of detecting, and audibly pinpoint, any source of electric or — with the appropriate antenna — magnetic field. Its application area extends from home use (*"Where can I sit without being microwaved?"*), to practical use (*"Where's that Wi-Fi-antenna aimed at?"*), to professional use (*"Who the devil is jamming me?! I'm trying to do some sensitive measurements here!"*).

Listen in on electromagnetic pollution

It's even suitable as a first SMD soldering project — with your (grand)child — since it's so easy (and fun!) to assemble.

Different fields

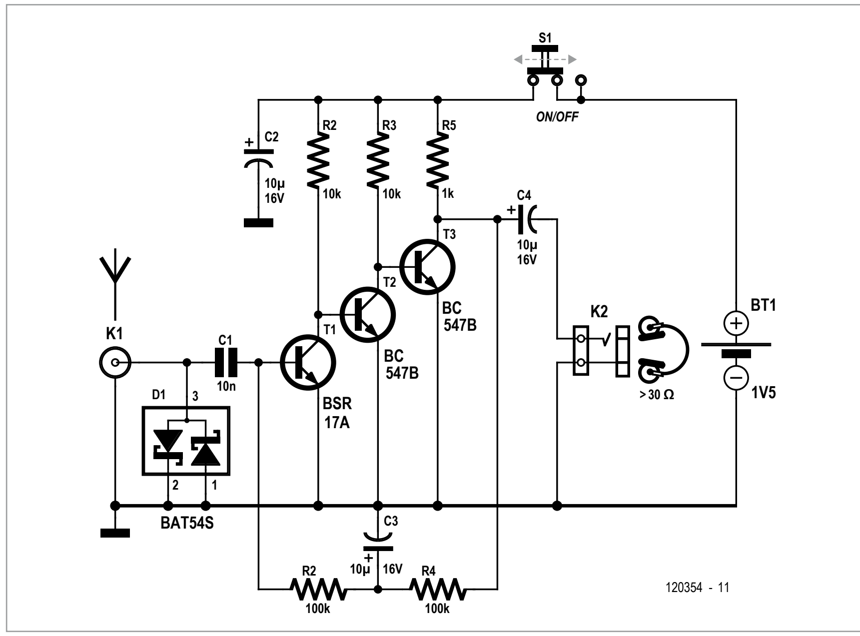
TAPIR is able to detect electric as well as magnetic fields of high frequencies. Magnetic fields are mostly generated by transformers and loop antennas, while electric fields are emitted by high voltage transmission lines, EL backlights and old mopeds passing by. Electromagnetic fields are a combination of both fields, mostly occurring in the 'far field' at a larger distance from the generating object.

Two different antennas can be connected to TAPIR, each optimized for one type of field. Magnetic fields are detected with a ferrite cored coil, while electric fields are detected with a rod antenna, which can be constructed very easy from a piece of installation wire.

How does it work?

The schematics show the simplicity of the design and are very similar to an Elektor circuit published in 2005. Basically it consists of a three-stage low-frequency amplifier with high gain. There is no low-pass filter in the circuit, consequently high frequencies are passed on to the gain stages. This way the non-linear characteristics of the transistors have a demodulating effect on these high frequency signals, so they can also be heard via headphones. The bias point of the gain stages is automatically adjusted via a DC feedback path from the output through R4 and R1. To suppress the AC component C3 is added, which shorts this part of the signal to ground.

The output voltage level has an offset of about 0.7 volts, hence C4 is added to remove this offset and protect any connected headphones (or other devices). The total gain is high enough to be able to 'hear' the intrinsic noise of transistor T1, so it's best to pick a low noise transistor for this. We went for the BSR17A, which has far better noise figures at high frequencies than a BC847B. Signals of mere microvolts are audible via headphones connected to the output.



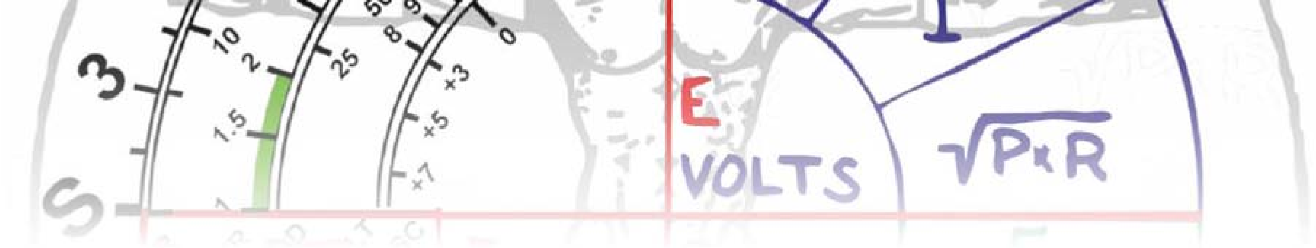
The whole circuit starts to operate from 1.2 to 1.5 V, so a single AAA cell can be used as its power source. The low supply voltage also acts as a kind of limiter; even if strong signals drive the amplifier into saturation, the output levels and thus the headphone levels never become excessive.

Don't flee 4 the SM-Dee

This E-smog detector is available as a low-cost kit [1] with the PCB and all the components included (except the batteries). Worried about soldering those tiny SMD components? No need! Even though there are some components with the '0805' shape, it can all be done with your standard tools, provided you have a reasonably small soldering tip at hand for your soldering iron, and a pair of precision tweezers.

First, clean up your desk! You might drop an SMD component from your tweezers in which case you want to be able to find it again... Assuming the light conditions on your desk are optimal, you may begin with opening the first bag and sorting the components, with or without the help of our online assembly manual [1]. Now you're ready to start soldering.

To get the hang of it, start with some larger components, switch (S1) and the headphones jack (K2). Be frugal



with the solder on K2, otherwise you may have some trouble assembling the PCBs together into the housing. When finished, remove PCB #2 and #4 from the panel and flatten the sides where it used to be held into place. Now you're ready to start with the 'real deal'.

A convenient way to solder SMDs is to 'wet' *one* pad first. Hold the end of the solder wire (thin wire is preferred) onto the pad and *shortly* touch it with the solder tip. A thin layer of solder should now cover the pad with some flux from the core still active. Now use tweezers to align the component onto the PCB, holding it down while you gently touch the lightly tinned soldering pad with your soldering iron again, reflowing the solder. The flux now helps the tin to flow, creating a solid connection between the component and the pad. You may even reheat the pad to position the component better.

When the component is in position, solder the other pad by pushing the solder wire onto the pad and shortly touching it with your soldering iron. The flux should work its magic and evenly spread out the solder onto the pad and the solder connection of the component.
Short soldering actions create the tidiest connections. But do make sure you're actually soldering and not only wetting the pad or the component. Adding some fresh solder to the first pad while shortly reheating it can tidy it up if you made it a little messy.
Now you're ready to proceed with the rest of the components.

Cubism, it's a work of art

When finished, remove PCB #3 from the panel using a fretsaw. Make sure there's a small ridge left. This is needed to put the PCBs together forming its housing. Solder the RCA connector (K1) onto the PCB.

Now we're going to solder PCBs #5, 6 and 7 onto PCB#3. Remove the PCBs from the panel, leaving a short pin in place where it used to be connected to the panel. Place PCB #3 in front of you with K1 pointing away. Now put PCB #5 in its place, making sure it's perpendicular and the soldering pad for the PCB pillar is at the RCA connector side pointing upwards. Solder the pad on the right corner only, so adjustments are easier later on.

Put PCB #6 in place, again making sure it's perpendicular. The PCB pillar pad should be pointing upwards and away from the RCA connector. Solder the right corner pad only. Finally put PCB #7 in its place and solder all three pads.

Continue sliding PCB #4 into its place. K2 should be right through the hole in PCB #7. The small ridges on PCB #5 and 6 should enter the cut-outs on PCB #4. Now solder the 'lower' PCB pads of PCB #4 to PCBs #3, 5 and 6, starting from the middle, pressing the PCBs together tightly. Don't forget to solder the 'normal' pads between PCB #3 and 4 next to K2. Put PCB #4 down and solder the RCA connector onto PBC #4. Also solder the 'upper' PCB pads to the rest of the PCBs.
Put PCB #2 in place and solder it to the rest of the PCBs, making sure it all stays nice and square. Make sure all pads are soldered! Solder the two M2×6 PCB pillars in place. They should be flat on the PCB and right in the middle. Bracket tweezers can be helpful with this. Use a sharp drill to countersink the screws into PCB #1 and check if the last PCB (#1) fits nicely. If needed, correct the position of the PCB pillars. Place the spring and a battery (AAA type) and close the lid. Your TAPIR is now ready for use.

Constructing antennas

To detect electric fields, a simple rod antenna can be constructed using an RCA connector and 20 cm (8 inches) of electrical installation wire (or any type of wire, but installation wire is quite stiff and can be bent the way you like).

Strip 3 mm (0.1 inch) off the isolation and solder the wire to the center pin of the RCA plug. When locating interference on circuit boards a small loop at the end of the rod could prove useful.

Magnetic fields are picked up by an inductor-based antenna. This antenna is constructed using a piece of installation wire as a frame to hold the coil, while one end of the coil is connected to the center pin of the RCA plug and the other to the outer connection. Make sure the 'ground' (outer connection) is securely connected to the TAPIR, otherwise the inductor acts as an electric field antenna. More detailed information about the construction can be found on our website [1].

COMPONENT LIST

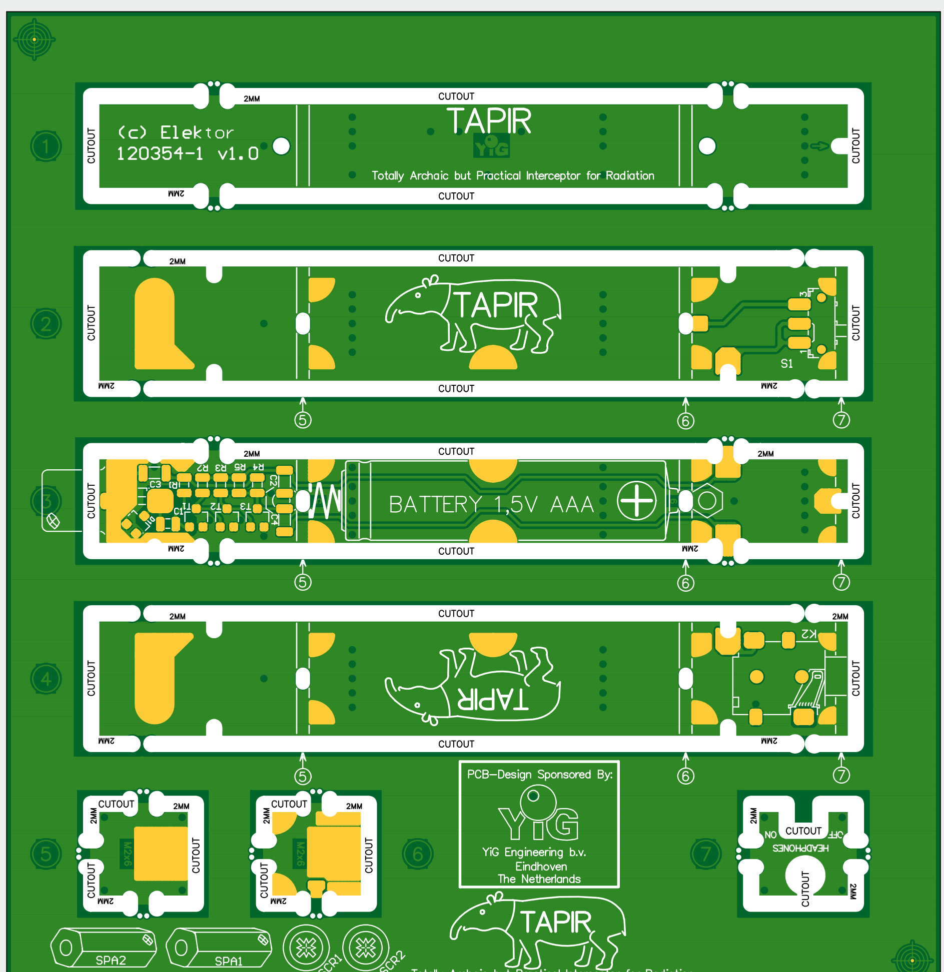
Resistors (SMD 0805)
R1,R4 = 100kΩ
R2,R3 = 10kΩ
R5 = 1kΩ

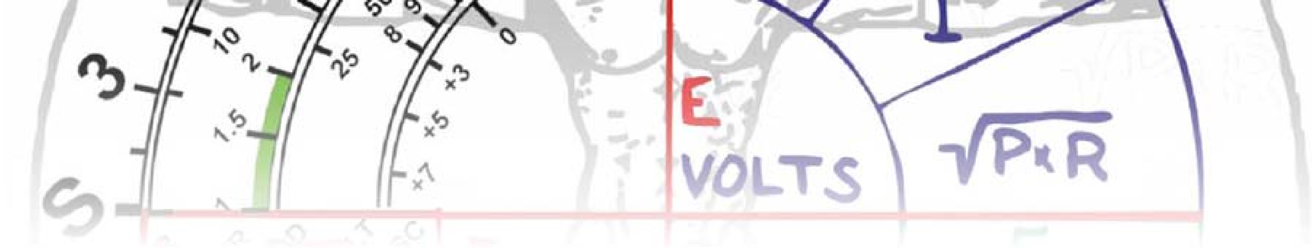
Capacitors
C1 = 10nF 50V, SMD 0805
C2,C3,C4 = 10µF 25V, SMD 1206

Semiconductors
D1 = BAT54S
T1 = BSR17A
T2,T3 = BC847B

Miscellaneous
K1 = RCA socket, SMT
K2 = mini jack SMT, CIU
S1 = switch, JS102011SAQN
PCB #120354-1, see [1]
Battery spring
Two PCB pillars, M2×6
Two Phillips screws, M2×6
Two RCA connectors
Two pieces of installation wire, approx. 20 cm (8 inch)
One inductor coil (H-field antenna)

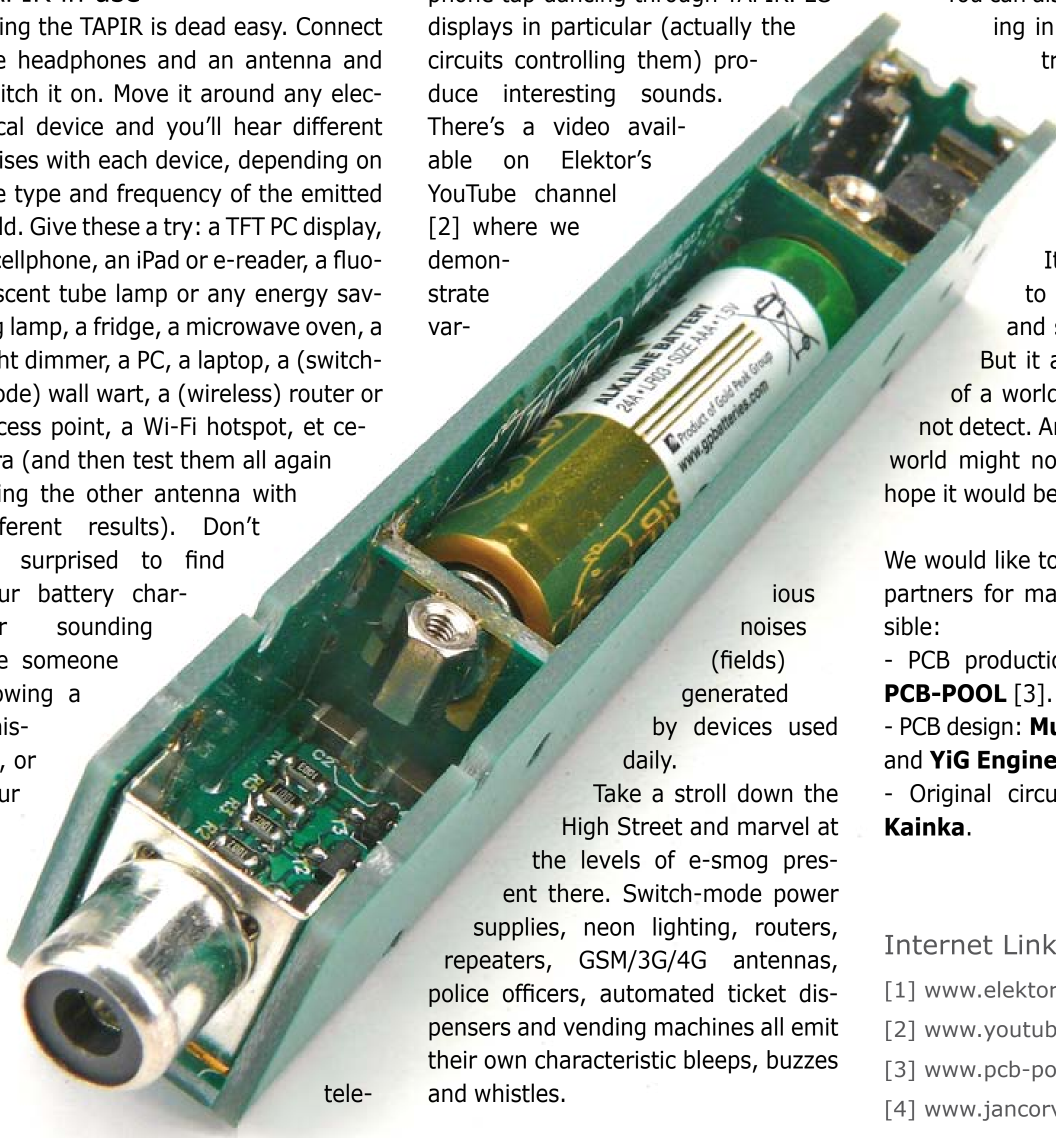
A kit consisting of the PCB and all the needed parts (AAA cell excluded) is available from Elektor [1] order no. 120354-71.





TAPIR in use

Using the TAPIR is dead easy. Connect the headphones and an antenna and switch it on. Move it around any electrical device and you'll hear different noises with each device, depending on the type and frequency of the emitted field. Give these a try: a TFT PC display, a cellphone, an iPad or e-reader, a fluorescent tube lamp or any energy saving lamp, a fridge, a microwave oven, a light dimmer, a PC, a laptop, a (switch-mode) wall wart, a (wireless) router or access point, a Wi-Fi hotspot, et cetera (and then test them all again using the other antenna with different results). Don't be surprised to find your battery charger sounding like someone blowing a whistle, or your telephone tap dancing through TAPIR. LC displays in particular (actually the circuits controlling them) produce interesting sounds. There's a video available on Elektor's YouTube channel [2] where we demonstrate various noises (fields) generated by devices used daily.



Take a stroll down the High Street and marvel at the levels of e-smog present there. Switch-mode power supplies, neon lighting, routers, repeaters, GSM/3G/4G antennas, police officers, automated ticket dispensers and vending machines all emit their own characteristic bleeps, buzzes and whistles.

You can also use TAPIR for listening in on the inductive loop transmission system frequently present in museums and other public places.

It's actually quite fun to have access to a sixth and seventh set of senses. But it also makes one aware of a world our own senses cannot detect. And what goes on in this world might not be as nice as you'd hope it would be.

We would like to thank all contributing partners for making this project possible:

- PCB production: **Beta LAYOUT / PCB-POOL** [3].
- PCB design: **Museum Jan Corver** [4] and **YiG Engineering**.
- Original circuit design: **Burkhard Kainka**.

(120354)

Internet Links

[1] www.elektor.com/120354

[2] www.youtube.com/ElektorIM

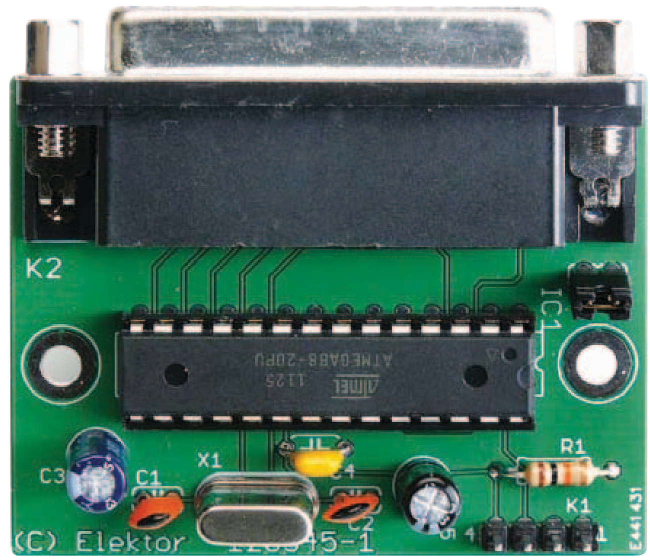
[3] www.pcb-pool.com

[4] www.jancorver.org/en/index.htm

USB Control Board

USB-to-LPT bidirectional adapter

By Abraham Vreugdenhil (Netherlands)



There's still a lot of electronic hardware around that's designed to be operated from the legacy printer port (LPT) of a PC, but this port is virtually extinct on modern PCs. With the aid of an ATmega88 and associated firmware and software, a relatively fast link can be implemented between the PC and an LPT port via the USB port.

In the past the LPT (or Centronics) port was often used to drive a wide variety of stepper motors, lamps and relays, detect the positions of limit switches, and read other types of signals. It provided a fast and versatile interface. Modern PCs (both desktop and laptop) no longer have this port. It has been replaced by the USB port. For control or measurement tasks, you can use devices such as the well-known LabJack or the Velleman K8055D board. These are both nice devices, easy to use and easy to control from your own application software. However, they have one major shortcoming: speed. These devices work with USB 1.1, which means that every command or measurement takes 20 ms. This may not seem like much — until you want to do something that requires short latency, such as driving a stepper motor. Here you need three commands per step, so each step takes 60 ms. This limits the maximum speed to 16 steps per second, which is much too slow.

Options

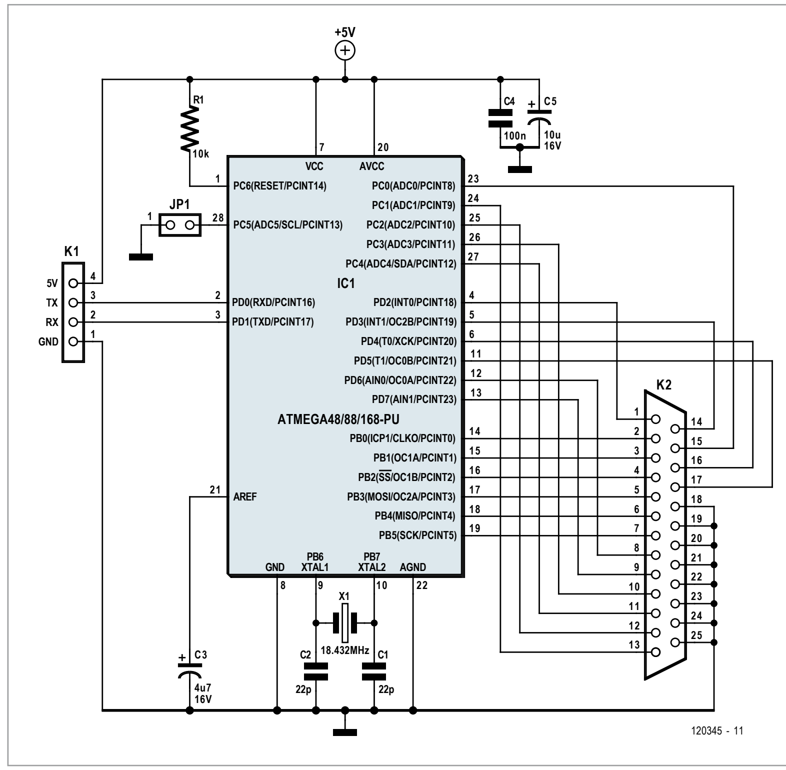
There is another option: you take a USB/serial adapter cable and connect it to a microcontroller. The microcontroller then receives data from the PC at high speed (using USB 2.0) and uses this data to perform control and measurement tasks. A variety of USB/serial conversion ICs are commercially available. The best known ones come from FTDI, but suitable devices are also available from Silicon Labs (CP210x) and Prolific (PL2303). The latter device is often used in a wide variety of commercial USB/serial adapter cables, which are sold under various names. It is probably the most widely used converter.

If you look at the differences between these converters, you discover a few surprises. When you use a test program to transmit a large number of individual bytes, the FTDI converter tops out at only 340 bytes per second, while the Prolific and Silicon Labs converters can handle 1000 bytes per second. This makes a considerable difference when you want to drive a stepper motor in real time. Unfortunately, the Prolific and Silicon Labs ICs are very difficult to obtain in small quantities for hobby use. However, complete USB/serial cables based on the PL2303 or the CP210x are available on eBay with prices in the range of 3 to 10 dollars. They output TTL-level signals, which can be connected directly to a microcontroller.

Hardware

For this project we chose a USB/serial adapter cable with a Prolific IC (PL2303) and connected it to an ATmega88. These two devices communicate with each other at a rate of 115,200 baud. This allows you to send something from the PC in just 1 ms. The author also selected a Conrad stepper motor board (SMC1500/800) to drive the stepper motor. In addition to the 8-bit data bus, this board uses the Enable signal to put data on the board's output. To make our USB control board as general-purpose as possible, we decided to add a jumper to allow selection of either fast SMC mode or normal LPT mode.

The hardware is straightforward. The USB/serial converter is connected to the Rx and Tx pins of the ATmega88 (or ATmega88P). The clock rate is set by an 18.432 MHz crystal, which is a good choice for serial communication at 115,200 baud. The jumper for selecting the two modes is connected to microcontroller I/O pin PC5, and the other I/O pins are routed to the LPT connector. This gives us a fully wired LPT port, so the full range of functions of this port can be implemented.



Software

The software for the ATmega88(P) is written in Bascom AVR (Prog 1). When the program starts up, it check whether jumper JP1 is present.

If it is, the program jumps to SMC mode. When a character is received on the serial port, it is placed on the 8-bit output of the LPT port and the Enable/Strobe pin is briefly pulled low. If a limit switch is connected to the SMCxx board and its status changes, the result is sent back to the PC.

If jumper JP1 is not present, the program jumps to LPT mode. Here it looks for incoming data. The response varies, depending on the second character of the received data string. If it is '1' or '3', the value of the next character in the string is placed in register 1 (data bus 8-bit output) or register 3 (data bus 4-bit output) of the LPT port. If the second character is '2', register 2 (5-bit data bus input) is read and the resulting data is sent back to the PC via the serial interface and the USB/serial converter. The data can then be processed in the PC.

Control from the PC

The PC sees the USB control card as a normal COM port, but usually with a high number. Visual Basic 6.0 can only handle COM port numbers from 1 to 9, so you have to use Device Manager to change the COM port number to something lower than 10.

In Visual Basic, place a COM object on your form. You can then use it to send and receive serial data.

First you have to configure the COM port with the right settings:

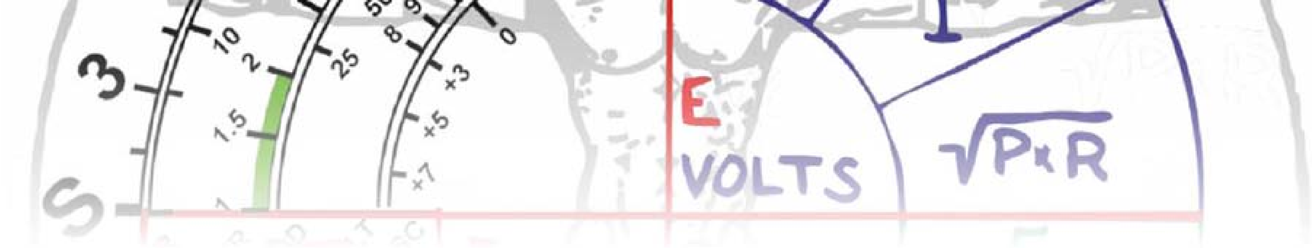
```
MSComm1.CommPort = COM port number (see Device Manager)
MSComm1.Settings = "115200,N,8,1"
MSComm1.RThreshold = 1
MSComm1.PortOpen = True
```

In SMC mode you only have to send a data byte; the USB control card generates the Enable/Strobe signal automatically:

```
transmit = Chr(DataByte)
MSComm1.Output = transmit
```

In LPT mode you can access several registers corresponding to the registers of the legacy LPT port. They can be read or written individually:

```
transmit = "#1" & Data & Chr(13)      ' 8-bit data bus OUT
MSComm1.Output = transmit
```




```
temp = “?2” & Chr(13)          ‘ 5-bit data bus IN
MSComm1.Output = temp

transmit = “#3” & Data & Chr(13)       ‘ 4-bit data
bus OUT
MSComm1.Output = transmit
```

The USB control card sends a response to the second command above. It can be handled by the following bit of Visual Basic code:

```
Private Sub MSComm1_OnComm()  ‘ for incoming data
Dim indata As String
Dim Info As byte

If MSComm1.InBufferCount > 2 Then
MSComm1.InputLen = 0
indata = MSComm1.Input
indata1 = Mid(indata, 2, 1)
Info = Asc(indata1)
End If

End Sub
```

Things to watch out for

The PL2303 (built into a USB connector with attached cable) is readily available on eBay at prices in the 4 dollar range, including shipping costs. Make sure you are getting a four-pin cable. The 5 V pin is necessary for supplying power to the circuit.

When programming the ATmega88(P), make sure you get the fuse bit settings right (see the screen dump in the download file for this project [3]).

If you connect the USB control board to a different USB port, the computer may assign a different COM port number to the board. Check for this, or always use the same USB port. The supply voltage for the microcontroller and the operating voltage for the LPT port are taken from the USB/serial converter. Only a limited amount of power is available with this arrangement, so you should restrict yourself to driving a few ICs (e.g. buffers) or LEDs. In other words, you can’t drive a motor or other power device this way.

The free version of Bascom AVR, which you can use to compile the software and program the ATmega88, can be downloaded from the website [1].

Final remarks

The USB control card was developed for a hobbyist club, to allow a small lathe to be controlled in real time using Visual Basic and the SMC1500/800 driver board. The successful results can be seen in a YouTube video [2].
The source code for the ATmega88 firmware, a program for testing data transmission rates, and a program for bit bashing via the USB port are collectively available in a free download zip file on the Elektor website [3].

(120345)

Internet Links

[1] www.mcselec.com

[2] http://www.youtube.com/watch?v=maxNgXApeOQ&feature=channel

[3] www.elektor.com/120345

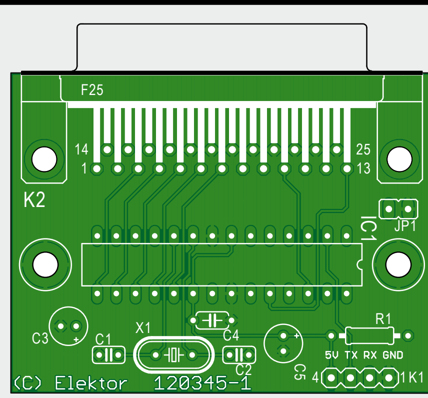
COMPONENT LIST

Resistors
R1 = 10kΩ

Capacitors
C1,C2 = 22pF
C3 = 4.7µF 16V radial
C4 = 100nF
C5 = 10µF 16V radial

Semiconductors
IC1 = ATmega88(P), DIL-28 case

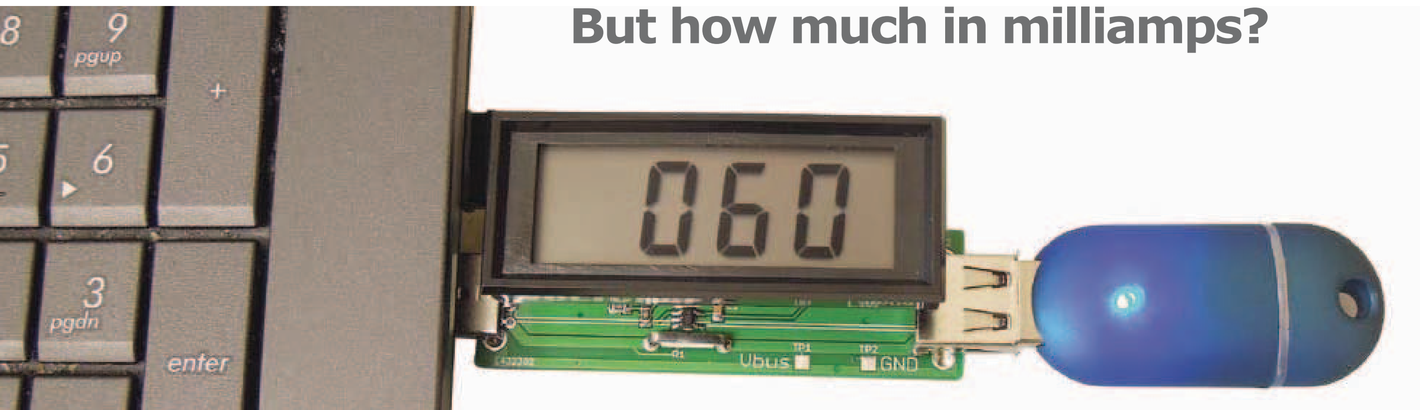
Miscellaneous
X1 = 18.432MHz quartz crystal



K1 = 4-pin pinheader, pitch 2.5mm
K2 = DB25 socket, right angled pins, PCB mount
JP1 = 2-pin pinheader with jumper
PCB # 120345 (see [3])

I’ve Got the USB Power

But how much in milliamps?

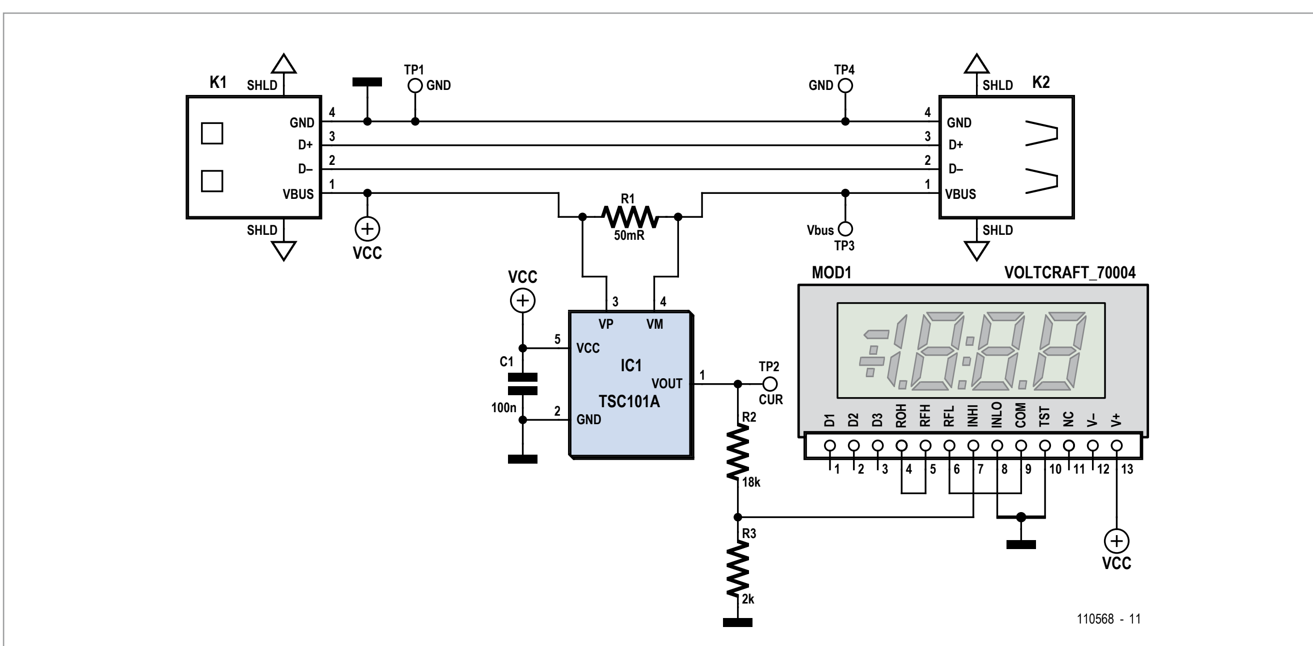


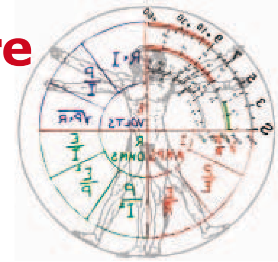
This small tool allows you to monitor current consumed by any USB device plugged into your PC, showing the value on a voltmeter module. Alternatively, why not trace it on the oscilloscope?

By Miroslav Batěk (Czech Republic)

More and more devices have USB connectivity and many engineers design devices which are powered by the USB port. However if you want to measure the current drawn from the USB port you’ll soon find that’s not a simple affair. You have a few choices though like disconnecting the circuit and connecting the ammeter in series with your device, or insert series resistors in the Vbus line and measure voltage across them.

Both solutions are quite simple but have disadvantages. Your ammeter or series resistor could introduce a considerable voltage drop, causing problems to the





COMPONENT LIST

Resistors

R1 = 0.05Ω 1W 1%, Welwyn OAR1-R050FI (Farnell # 1200363)
R2 = 18kΩ (SMD 0805)
R3 = 2.00kΩ (SMD 0805)

Capacitors

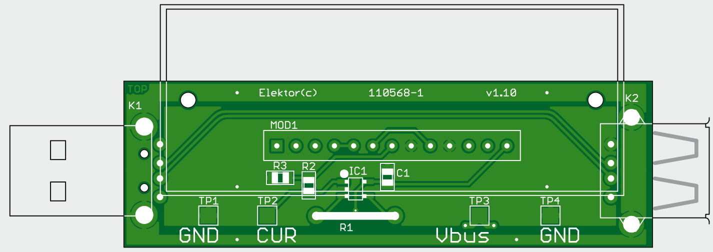
C1 = 100nF X7R (SMD 0805)

Semiconductors

IC1 = TSC101A, TSOP-5 case

Miscellaneous

K1 = USB-A male connector (plug), PCB mount, through hole
K2 = USB-A female connector (socket), PCB mount, through hole
MOD1 = Voltcraft 70004 LCD panel meter module; Conrad-Uk.com # 121065-89
PCB # 110568-1 from www.elektorpcbservice.com



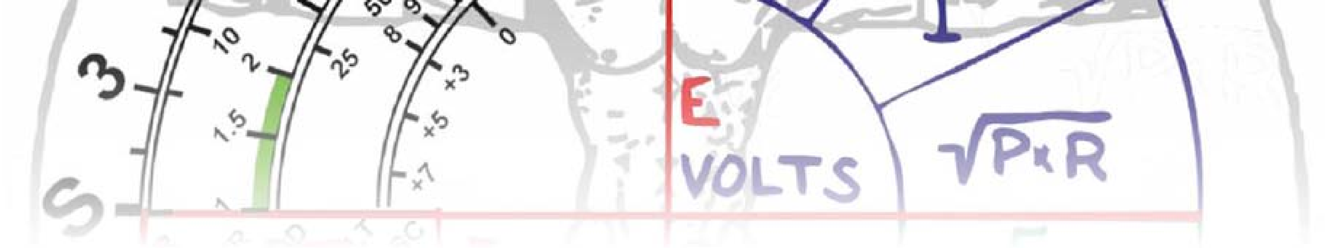
USB device. Moreover if you want to watch the current on your 'scope you have to use a differential probe, or two probes, because the current is not measured relative to ground. In case you insert the series resistor in the GND line, the voltage levels for the USB device and the USB host will be different as a result of the voltage drop.

The small tool presented here solves the problems by incorporating a high-side current sense circuit. There are a few methods of making a high-side current sense circuit, like a standard opamp or instrumentation amplifier with a few resistors. Here we went for an integrated circuit type TS101, which is basically a high-side current monitor [1]. This IC doesn't need any external components except the current sensing resistor.

The schematic of the USB Power Monitor shows two USB (type A) connectors. One is male (plug type) and the other, female (socket type), meaning our little circuit is connected in series with the USB device whose current consumption you are keen to know. Data lines D+, D– as well as GND are passed 'straight through'. Shunt resistor R1 sits in the Vbus line, turning the current through it into a corresponding voltage (drop). This gets amplified by IC1 and converted such that it exists relative to ground. C1 is the supply decoupling capacitor for IC1. Components R2, R3 are a voltage divider to match the TSC101A's output voltage to the input of the Voltcraft 70004 voltmeter module. Note that there are three versions of the TSC101, suffixed A, B and C, each having a different gain. The A version used here has 20 V/V. Each version also has a slightly different bandwidth.

In practice, you'll notice that the resolution of the proposed meter is limited at low currents and that's why a separate current test point, TP2, is available. The millivolts measured on TP2 equate to milliamps of current consumed by the USB device. Sticklers for precision may measure the Vbus voltage on TP3.

At 500 mA theoretical maximum current from the PC the voltage drop of our circuit is just 25 mV which is negligible for most if not all USB devices.



The circuit is built on a double-sided PCB shown here and it's available ready made [2]. USB connectors K1, K2 and shunt resistor R1 are through-hole components. R1 is a 1% precision 4-wire connection shunt resistor type OAR1-R050FI specially designed for this purpose. The rest of the parts are surface mount. The TSC101A comes in a TSOP-5 package which is not too difficult to solder if you use a fine tipped soldering iron.

If you mount a 13-pin 0.1 inch pitch socket strip on the converter board, the Voltcraft module may be plugged on top of it.

The monitor should work first time and there are no adjusting points. Simply connect it between your PC or charger and your USB device, and read the current from the display.

To close off, here are some results from measurements carried out by the author:

Elektor Flash drive	32 mA (Idle)		58 mA (Copy files)
USB Hub	100 µA (standby)	45 mA (idle)	75 mA (Flash drive connected)
USB Flashlight	7 mA (Battery check)		55 mA (Charging)
HTC Legend	430 mA (initial charging current, from PC)		560 mA (initial charging current, from AC line charger)
Ipad 2	570 mA (charging current at 30% from PC with Asus Ai Charger tool)		

(110568)

Internet Links

[1] www.st.com/internet/com/TECHNICAL_RESOURCES/TECHNICAL_LITERATURE/DATASHEET/CD00153725.pdf

[2] www.elektor.com/110568

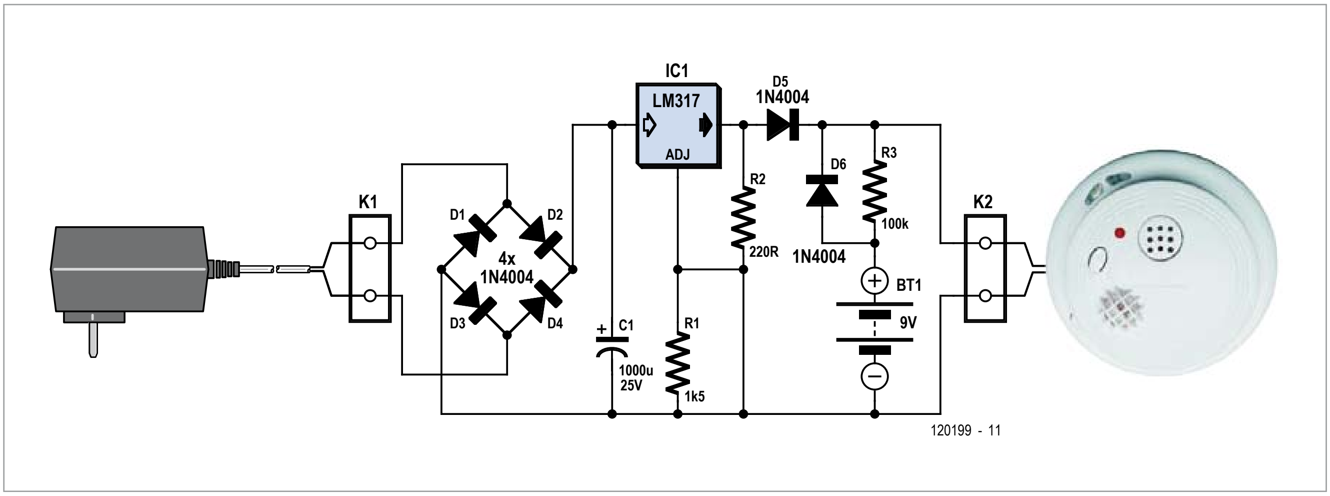
Smoke Alarm Power Supply

Simple but effective

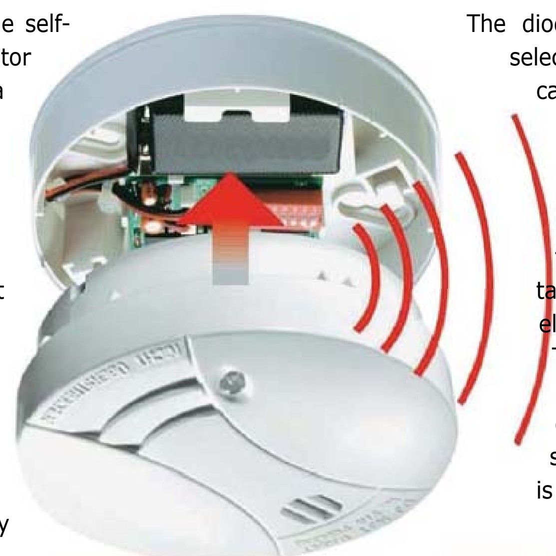
By Jacob Gestman Geradts (France)

Smoke alarms are extremely useful devices, but they suffer from one significant disadvantage, which is that they're battery powered. This can't really be avoided, since a smoke alarm should still function when the AC grid cuts out. Unfortunately, it still runs off the battery even when the AC line supply is present, with the result that for some types of smoke alarm you need to replace the batteries at an alarming rate. This circuit lets the smoke alarm run off the AC grid normally, and only switches to the battery when it is really necessary, in other words, when there is a power cut.

The circuit itself is fairly simple, but as is often the case, the circuit's strengths are in its simplicity. In this instance an AC power adapter is used to power the smoke alarm. The circuit has been designed such that just about any type of adapter can be used. The polarity of the power plug isn't important and it doesn't matter if the power adapter outputs an alternating or direct voltage, thanks to the presence of a bridge rectifier (D1 to D4). The only thing to watch out for is that the output voltage of the adapter should be 9 V or more. After the bridge rectifier and smoothing capacitor is voltage regulator IC1 (an LM317), which keeps the voltage constant. The output voltage of the IC can be varied by adjusting the value of resistor R1. D5 and D6 make up an 'electronic switch' that automatically selects the highest supply voltage for the smoke alarm, so either the AC line supply or the battery supply. R1 has to be chosen such that there is a reverse voltage of about half a volt across diode D6 (with a full 9 V battery) when the smoke alarm is switched on. This prevents the battery from discharging, unless



the AC power fails. To mitigate the self-discharge of the 9 V battery, resistor R3 has been added, which delivers a minute current that can somewhat compensate for the self-discharge of the battery. This will keep the battery in a charged state for as long as possible. (Note from the editors: this method is usually not recommended with normal (i.e. non-rechargeable) batteries, as it can sometimes result in battery leakage. However, due to the very high value of R3 it's very unlikely to happen. For those of you who want to be absolutely safe, you can just leave out R3.



The diodes aren't critical and have been selected from the 1N4000 series, in this case with a larger than required 400 V rating. The electrolytic capacitor may also be larger, both in value and in voltage. AC power adapters often output a somewhat higher voltage than is stated, which should be taken into account when choosing the electrolytic capacitor.

The condition of the battery can easily be tested (once a week) by switching off the AC adapter and running the self-test of the smoke alarm whilst it is being powered only by the battery.

(120199)

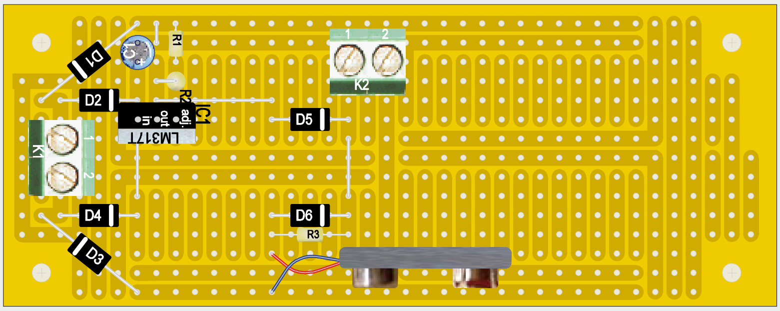
COMPONENT LIST

Resistors
R1 = 1.5kΩ
R2 = 220Ω
R3 = 100kΩ

Capacitors
C1 = 1000µF 25V

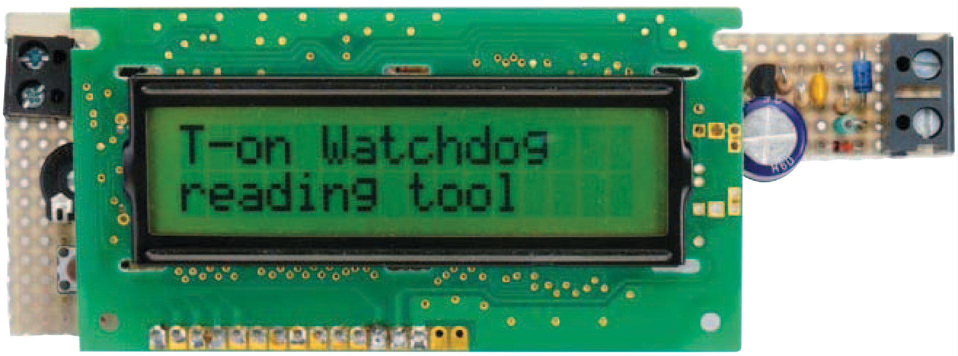
Semiconductors
D1–D6 = 1N400x
IC1 = LM317

Miscellaneous
K1,K2 = 2-way PCB terminal block, pitch 5mm
'Elex' prototyping board



Equipment 'ON' Counter for 68 Years Max.

By Vladimir Mitrovic (Croatia)



Have you ever wondered how long a piece of electric equipment has been switched on and consuming AC power? The simple circuitry shown here counts the seconds of the ON time periods and keeps the total accumulated time in the EEPROM inside the ATtiny13 microcontroller. Just read the EEPROM with the help of an appropriate ISP programmer or the dedicated readout circuit and you will know how "old" the equipment really is!

The watchdog

It is supposed that the equipment is AC-outlet powered because the microcontroller counts cycles of the AC grid voltage. The input terminals should be connected after the equipment Power (On/Off) switch (or relay) or to the secondary winding of a power transformer. Any voltage upwards of about 4 VAC, 50 Hz or 60 Hz, will be appropriate if resistor R1 is chosen correctly.

Returning to the schematic of the pulse counter, zener diode D2 limits the AC voltage to 4-5 V_{pp} square-wave(ish) pulses which are used not just for the system timing, but also to power the circuit via D1/C1. Soon after the (AC) power is switched on, the voltage

Stop! Calculate R1 first

The microcontroller needs less than 1 mA to function properly, and at least 1 mA should flow through D2 for it to do its stabilizing act. Therefore, at least 2 mA should flow through R1. Its maximum permissible value can be calculated with the following formula:

$$R1 = \frac{V_{AC} \times 1.4 - 3.5}{2} [k\Omega]$$

The 3.5 constant in the formula comes from the estimated voltage across D2; at such low currents, you should expect a slightly lower voltage across a zener diode than rated. Some experimentally proven values for R1 are given in the table below. You can always use a smaller value for R1, at the cost of higher power consumption. With values for R1 as given in the table, the total power consumption of the circuit is 10-50 mW depending on the input voltage.

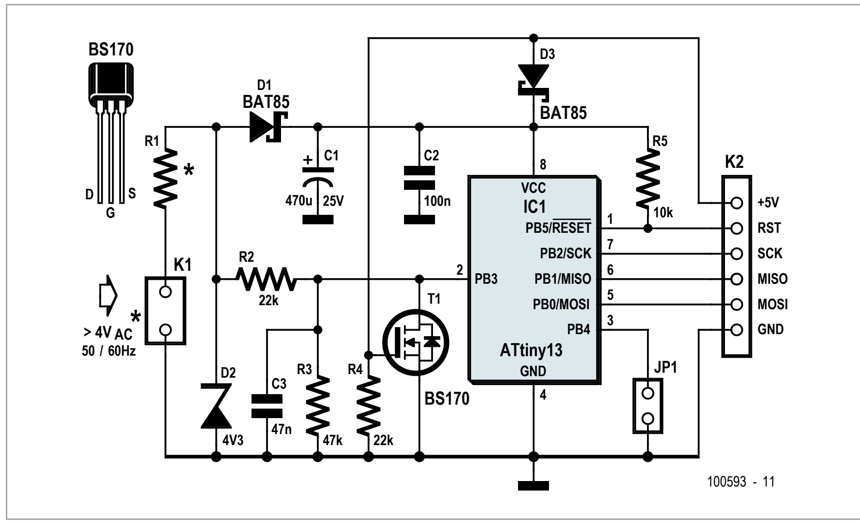
If you experiment with values for R1, be sure that the DC voltage across C1 is not lower than 3 V, and not exceeding 5 V.

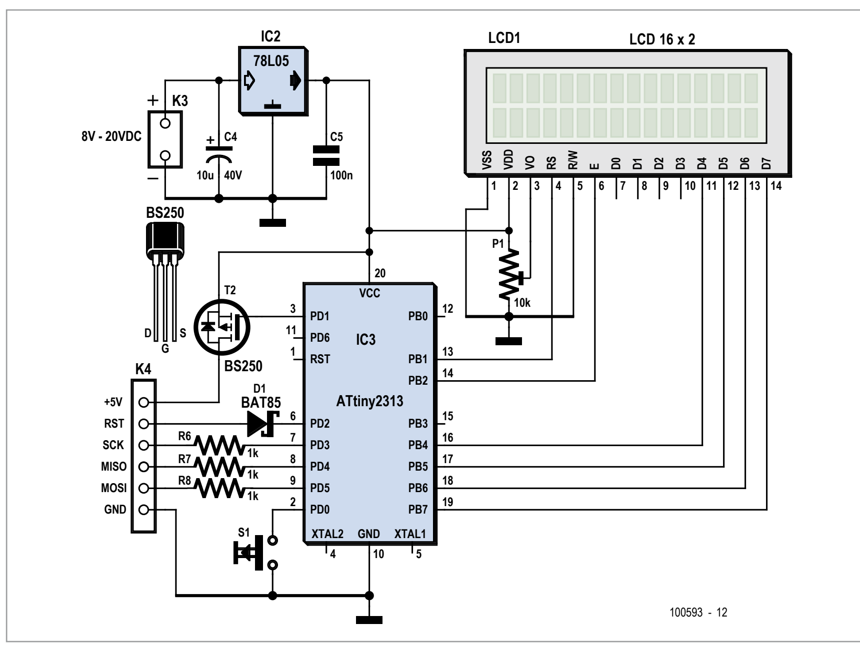
R1 as a function of input voltage

Input voltage	R1
4–5 V AC	1 kΩ
5–6 V AC	1.5 kΩ
6–8 V AC	2.2 kΩ
8–10 V AC	3.3 kΩ
10–12 V AC	4.7 kΩ
12–15 V AC	6.8 kΩ
15–18 V AC	8.2 kΩ
18–22 V AC	10 kΩ

across C1 rises to a value at which the microcontroller starts to execute the program inside its memory. Initially the program reads the previously accumulated time from the internal EEPROM and starts to count pulses at the ATtiny13's PB3 input. Every level change at this input is recognized, so there will be 100 or 120 transitions per second depending on the grid frequency (50 Hz or 60 Hz). As soon as a single transition is counted, the microcontroller enters Idle mode. This way, the average consumption of the microcontroller is kept under 0.5 mA. Simultaneously, Timer0 counts clock pulses. Once started, it will count to the top value, overflow and cause an interrupt. This would happen after some 50 ms in the absence of input pulses. However, the input pulses are not just being counted. They also repeatedly reset the Timer0, preventing it from reaching the top value. Therefore, as long as the input pulses are present, Timer0 will not overflow and the associated interrupt will not execute.

When the input voltage is switched off, the voltage across C1 starts to decrease. The capacitance of C1 is sufficient to keep the microcontroller working for at least one second. However, if the input voltage is switched off, the pulses at PB3 disappear abruptly. Without being reset, Timer0 will cause an interrupt some 50 ms after the last transition at the PB3 input has occurred. The interrupt wakes up the microcontroller from Idle mode and causes the associated interrupt subroutine to be executed. This effectively writes the second counter back to the EEPROM. This way, the counter state gets preserved when the supply voltage drops under the safe level. The EEPROM writing procedure lasts takes about 10 ms and then the microcontroller enters Idle mode again and waits for one of the following events to happen:





- If the power is switched on again within a short period of time, i.e. before the voltage across C1 drops significantly and still is within the safe operating area, the microcontroller will wake up and start to count input pulses as soon as they occur.
- If the voltage across C1 drops below 2.7 V, which happens a few seconds after switch-off, the ATtiny13's on-chip Brown-out Detection (BOD) circuit will reset the microcontroller.

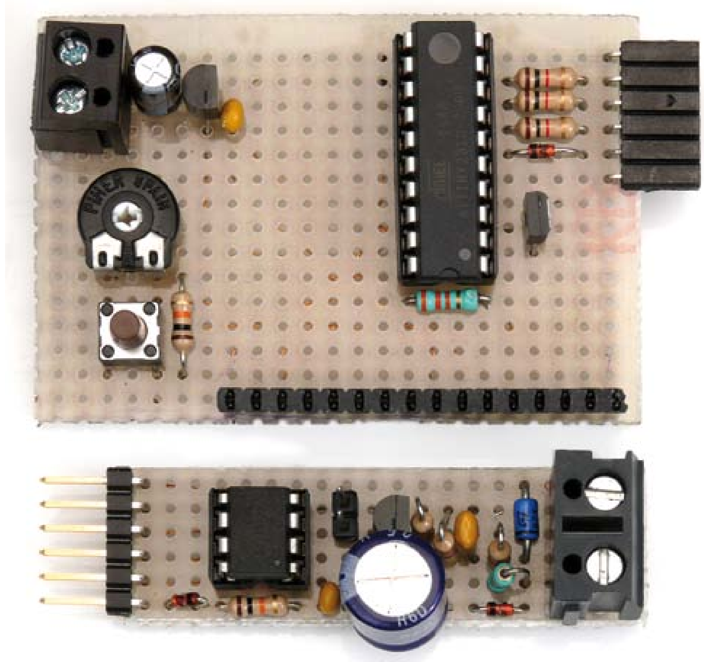
The BOD circuit should be activated during the programming session, and the BOD trigger level should be set at 2.7 V (BODLEVEL fuse 1 = 0, BODLEVEL fuse 0 = 1). This will ensure that the microcontroller stops running before the supply voltage drops under the safe level, when the RAM contents would be corrupted as well. When activated, the BOD circuit constantly monitors the V_{CC}

level during operation by comparing it to the fixed trigger level. If the supply voltage drops below 2.7 V, BOD will reset the microcontroller and keep it in this state as long as the supply voltage does not reach the safe value again. Waking from reset, the microcontroller will read the accumulated time from the EEPROM, and continue to count from that value.

Back at the input of the circuit, the value of R1 should be chosen according to the input voltage, as its purpose is to limit the input current — see the text box on R1.

Readout circuit

For sure you'll want to read the counter value from time to time. In order to keep the circuit as simple as possible, no display was provided initially, and readings were taken using a low-voltage in-system programmer (ISP). Eventually a dedicated reading tool was developed and its schematic is shown here. The heart of this circuit is an ATtiny2313 microcontroller that produces all control signals required to read the contents of the Watchdog's EEPROM, converts them to a readable form and displays them on a 2x16 characters alphanumeric LC display. If you use the proposed readout circuit, you can connect it to the Watchdog circuit regardless whether the equipment in which the Watchdog is embedded is powered or not. Be very careful if the Watchdog is connected directly to the AC line voltage! If the Watchdog is active (i.e. if the equipment is switched on), the readout circuit should be switched on before it is connected to the Watchdog. This ensures well defined logical levels on all of the connecting lines, which will not disrupt the Watchdog operation. Failing to switch on the readout before connection to the working Watchdog might reset the Watchdog and cause a loss of time accumulated after the last switch-on. If the Watchdog is not active (i.e. if the equipment is switched off) it is irrelevant if the readout is switched on or off at the moment of connection.



To read and display the measured time, just press the S1 pushbutton on the readout board for a short time. The readout will first activate the +5 V voltage, with the following consequences on the Watchdog:

- If the Watchdog was inactive, the +5 V signal from the readout will power-up the ATtiny13 microcontroller and simultaneously switch transistor T1 in the Watchdog on, which in turn disables the program in ATtiny13 from running.
- If the Watchdog was already powered up and active, the +5 V signal from the readout opens T1 only. This will short-circuit the PB3 input to ground and prevent pulses from D2 from reaching PB3, forcing the ATtiny13 to write the counter to the EEPROM.

In other words, whatever state the Watchdog was in previously, the +5 V signal will ensure that the ATtiny13 microcontroller is switched on and that the data in its EEPROM are up to date. Shortly after switching the +5 V signal on, the readout starts to communicate with the Watchdog and read the contents of its EEPROM. As soon as the reading is done, the readout switches the +5 V signal off, recalculates the data and displays the time in the "ddddd:hh:mm:ss" form (days, hours, minutes and seconds). However, bear in mind that the overall accuracy depends on the power grid frequency stability and long time intervals will not be accurate to a second!

Besides reading, the readout can also erase the Watchdog's EEPROM if necessary. The erasing procedure is similar to the reading procedure, except for one detail: you should press S1 and keep it depressed for at least 3 seconds in order to erase the counter in the ATtiny13 microcontroller.

If you use an ordinary ISP programmer to read the Watchdog EEPROM, be sure to switch off the equipment in which the Watchdog is embedded before the programmer is connected to the Watchdog! The ISP programmer should provide a 5 V supply for the Watchdog. The counter is written in the EEPROM starting from the address 0, in the form of a 4B variable (type Long), LSB first, and represents the ON time measured in seconds. It will be necessary to do some calculations to decipher it (the readout does it for you!). The counter can be erased with an ISP programmer as well — if you erase the EEPROM memory. Note: erasing the EEPROM memory will write binary 1s in the whole memory. This will set –1 instead of 0 as the starting counter value, but such inaccuracy may be totally neglected.

Programs

Two Bascom-AVR programs were written for the project:

EE_T_on.bas is a program for the ATtiny13 micro in the Watchdog. Be sure to set the CKSEL fuses for: calibrated internal RC Oscillator running at 9.6 MHz, and to set BODLEVEL fuses as explained before. Erase the EEPROM during the programming session to reset the counter before first usage.

EE_T_on_reading_tool.bas is a program for the microcontroller in the readout circuit. Set the CKSEL fuses for: calibrated internal RC Oscillator running at 8 MHz.

Now get on the Internet! Both programs are in archive file 100593-11.zip for free downloading from [1], which is also the place for ordering ready-programmed micros for the project. Burn-a-Chip@Home fans: a free demo version of Bascom-AVR is available from [2], and Elektor also has books in its portfolio on this wonderful little compiler [3].

(100593)

Stop Again! Electrical safety!

Should the circuit be connected directly to an AC outlet, consider replacing R1 with a series connection of:

- a 2.2-kΩ / 1-watt resistor and a 100 nF capacitor (for 115 VAC/60 Hz grids) or
- a 4.7-kΩ / 1-watt resistor and a 68 nF capacitor (for 230 VAC / 50 Hz grids).

In both cases, the capacitor should be rated for direct connection to the AC line voltage (for example, WIMA MKP-X2, WIMA MP3-X2, Epcos MKP X2 or similar).

Caution.

The entire circuit is at Live AC potential and potentially hazardous to touch. Never work on the circuit while it is connected to the AC power outlet. The circuit must be enclosed in an approved enclosure preventing any part of it from being touched. When in doubt, ask for the assistance of a qualified electrical engineer.

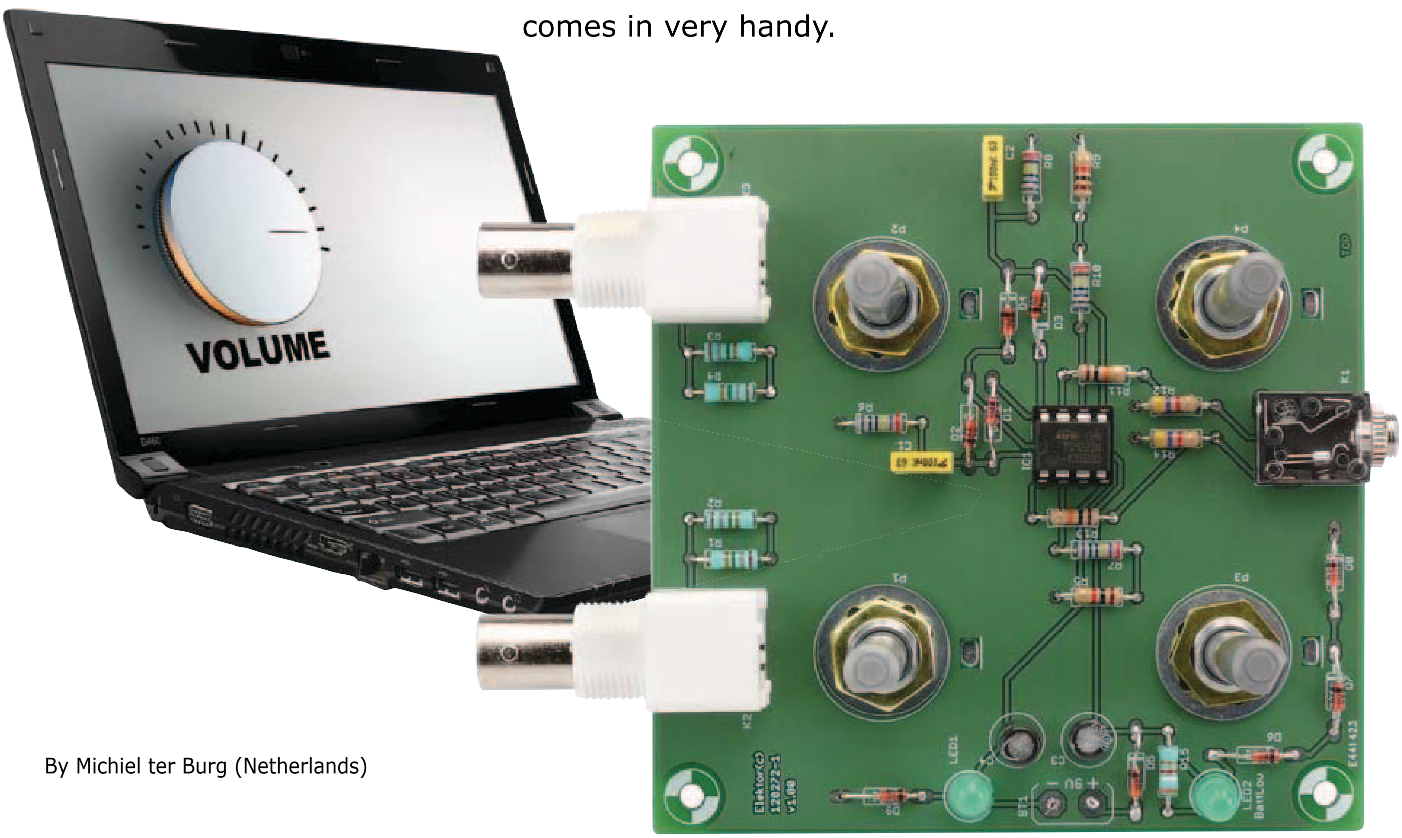
Internet Links

1. www.elektor.com/100593
2. www.mcselec.com
3. www.elektor.com/products/books.255.lynkx

Universal Measurement Amplifier/Attenuator

For laptop or PC

A computer is very suitable for making (audio) measurements thanks to the sound card that is usually built in. Unfortunately, the audio input on laptops is usually too sensitive to measure somewhat larger AC voltages. A small amplifier/attenuator circuit then comes in very handy.



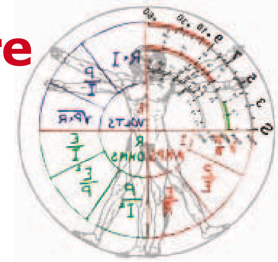
By Michiel ter Burg (Netherlands)

If you build or repair audio equipment yourself, you don't always need an oscilloscope. Any direct current or voltage can be measured with a multimeter. You can do a lot more if you happen to have a better model that can also measure (small) AC voltages.

For more advanced measurements such as the frequency response or the distortion it is very handy to use the sound card in a computer combined with some software. A laptop or notebook can also function without an AC outlet, which means you'll avoid earth loops and hum during measurements. However, a laptop often has just an oversensitive (microphone) input, so that you need to make a range of voltage dividers for your measurements.

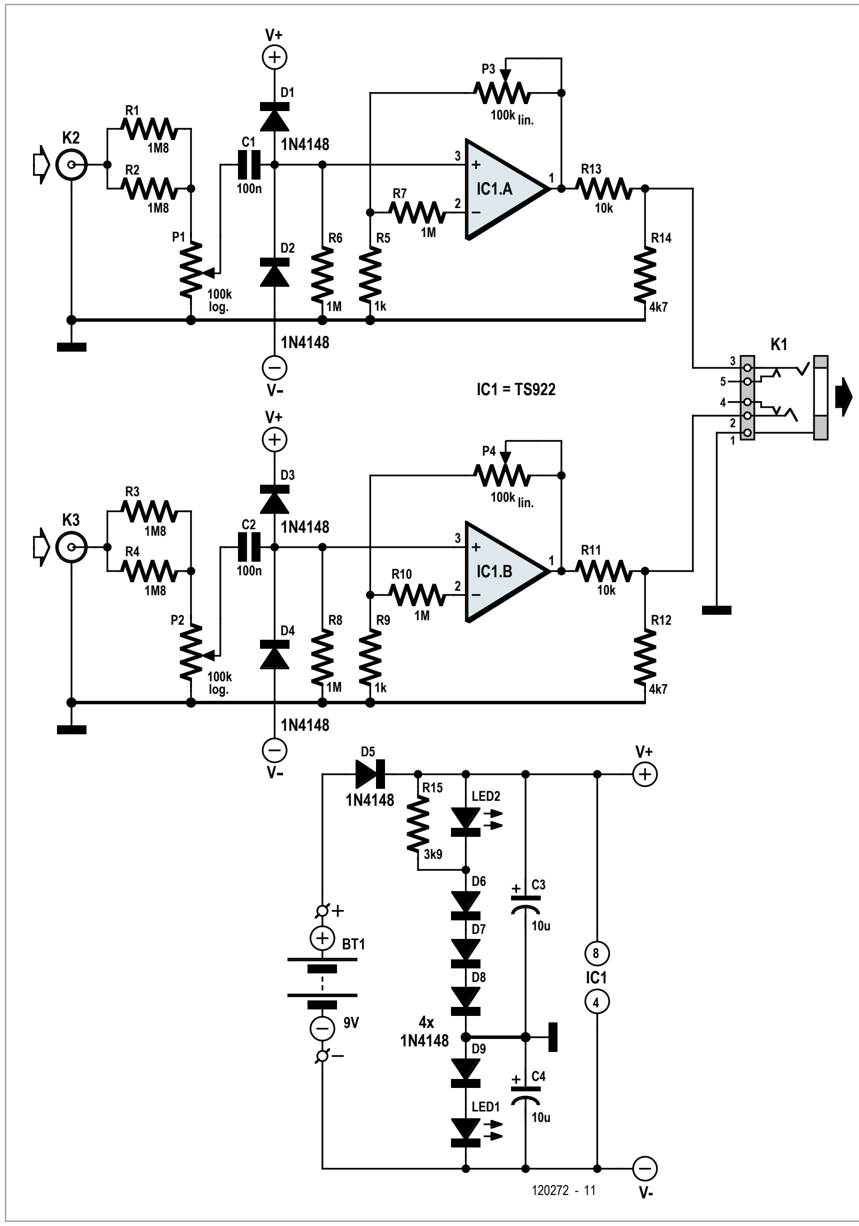
This measurement amplifier has been designed especially for these situations. It has an adjustable input attenuation and an input impedance of 1 MΩ, so that standard scope probes with built-in attenuators can be used for even larger AC voltages.

The input signal is first attenuated and then amplified to get the required



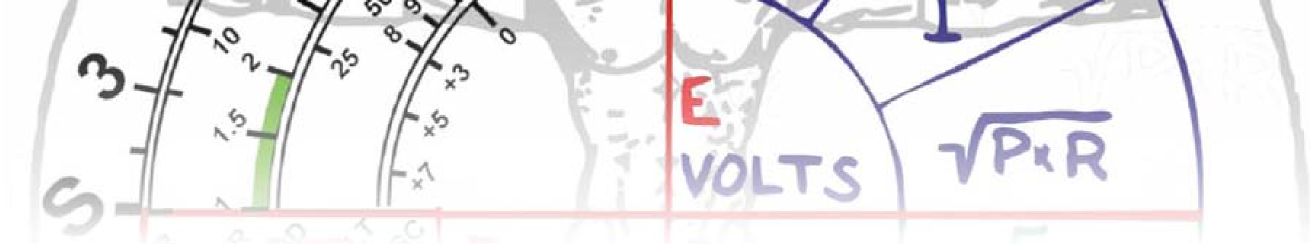
transfer function. The input is DC coupled. The input signal is attenuated by at least a factor of 10; with the help of logarithmic potentiometers P1 and P2 the signal can be attenuated further. C1 and C2 provide DC decoupling after the input attenuators to prevent irritatingly large time-constants caused by high-impedance probes. This is followed by an amplification stage (built round IC1.A and IC1.B). Potentiometers P3 and P4 are used to vary the gain of this stage between 1x en 100x. Bear in mind what the value of the GBP (Gain Bandwidth Product) is for the opamp used. The author first tried an LM258 and a TS912, which should have a GBP of about 1 MHz (typical). In practice a bandwidth of 15 kHz was measured with the gain set to 30x and a 9 V supply voltage. This means that the GBP was 450 kHz, although that can be compensated for by the measurement software. The best opamp is a TS922 (GBP of 4 MHz), which managed the complete audio bandwidth at a gain of 100x. This is also the type that was used in the prototype built at Elektor Labs.

The power is supplied by a 9 V battery that has its voltage split into a negative and positive component with a Ground in between. LED2 functions as a Low-Battery LED (it has to be a type that lights up at 2.5 V); the addition of R15 makes it light up when the battery voltage is above 7 V, which is high time to replace or recharge the battery!



a computer sound card running measurement software makes a useful tool

The inputs of the opamps are protected by diodes against very high input voltages or electrostatic discharges, since you can never be sure what voltages you'll find in (switched off) audio circuits, especially when valves are used! A printed circuit board has been designed for this project, which has room for all components, including the connectors and potentiometers. The layout can be downloaded freely from the usual place [1]. Standard through-hole components have been used throughout, which makes the construction very easy. The potentiometers are put through the solder side of the board and screwed into place, after which the solder tags are bent onto the pads on the board and subsequently soldered.



COMPONENT LIST

Resistors

R1–R4 = 1.8MΩ
R5,R9 = 1kΩ
R6,R7,R8,R10 = 1MΩ
R11,R13 = 10kΩ
R12,R14 = 4.7kΩ
R15 = 3.9kΩ
P1,P2 = 100kΩ potentiometer, logarithmic law
P3,P4 = 100kΩ potentiometer, linear law

Capacitors

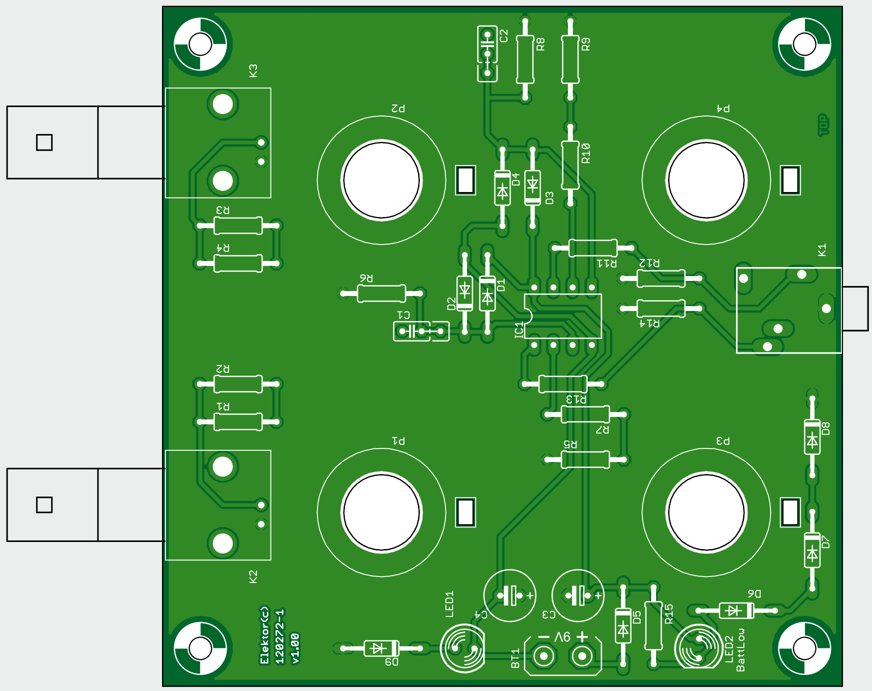
C1,C2 = 100nF MKT, pitch 5mm
C3,C4 = 10µF 16V, 6mm diam., pitch 2.5mm

Semiconductors

D1–D9 = BAT48 (DO-35 case)
IC1 = TS922IN (dual opamp, DIP-8 case)
LED1,LED2 = LED, green, 5mm

Miscellaneous

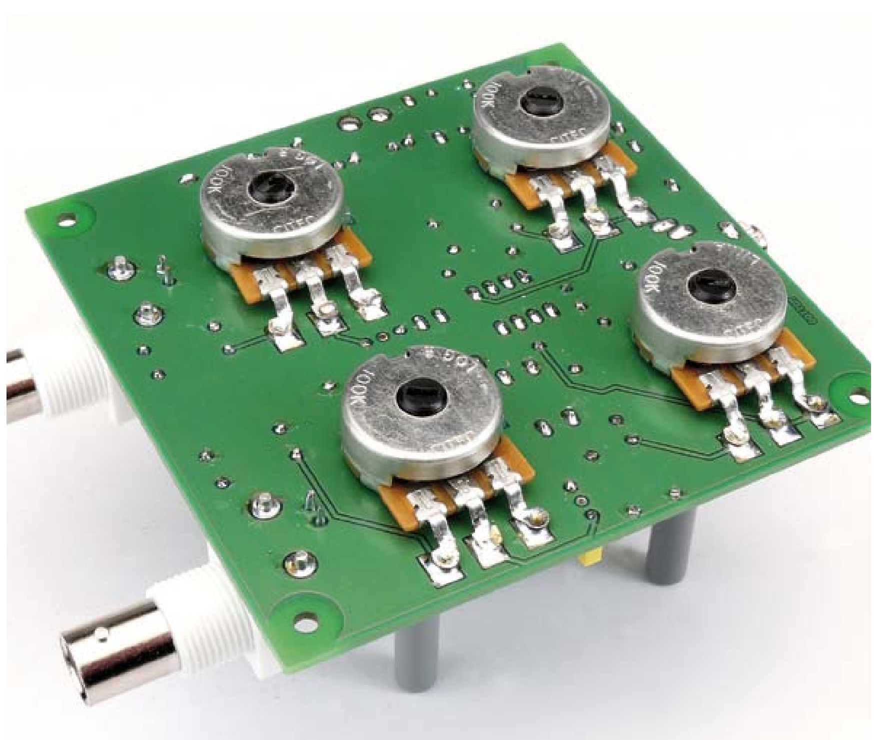
K1 = 3.5mm stereo socket (e.g. Lumberg 1503-09)
K2,K3 = BNC connector, right angled pins, PCB mount (e.g. TE connectivity 1-1337543-0)
BT1 = 9V battery clip
PCB # 120272-1 (www.elektor.com/120272)



Since logarithmic input potentiometers can deviate by as much as ±20% it is best to calibrate them after they have been mounted in the box. The calibration should be carried out in steps of 10 dB (= a factor of 3.1623) using the measurement software. First mark out the calibration points on a piece of paper placed over the potentiometer, then scan this into the computer and use a drawing package to create a professionally looking scale.

During the calibration P3 and P4 should be set to a gain of 1x, which is normally only used with very small input signals that still need some amplification.

(120272)

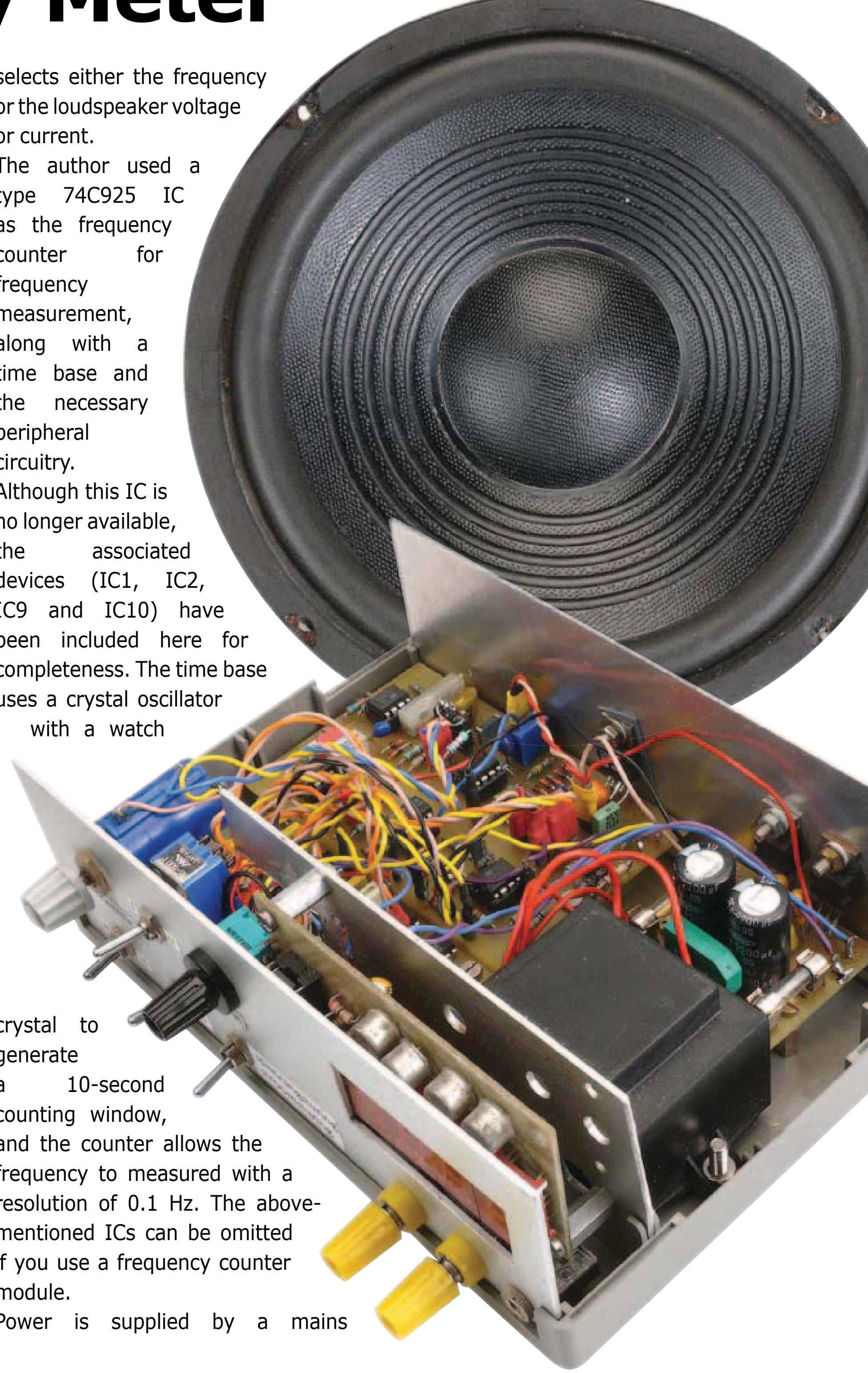


Internet Link

[1] www.elektor.com/120272

Loudspeaker Resonant Frequency Meter

By Jac Hettema (Netherlands)



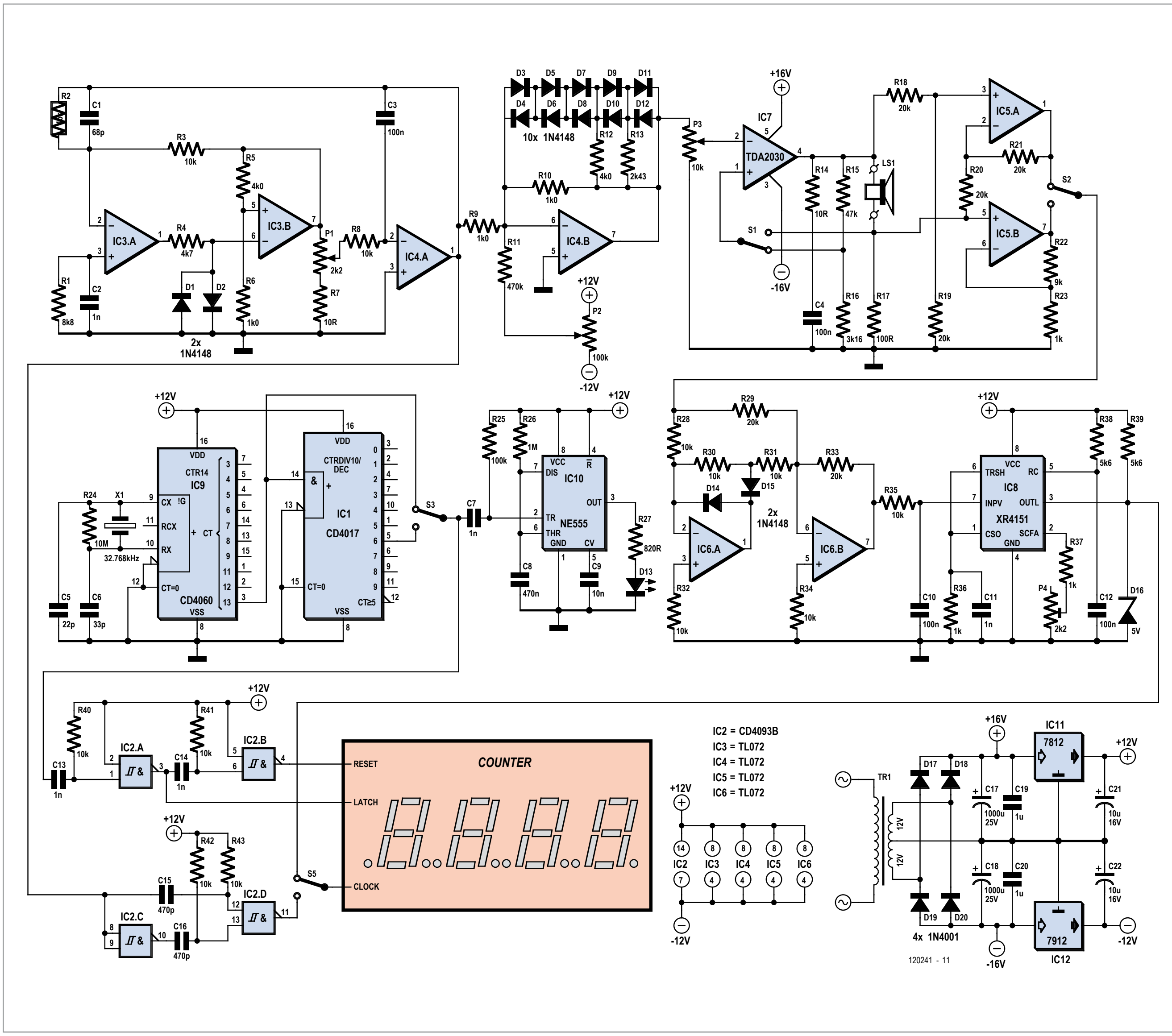
This system is designed to facilitate the determination of loudspeaker resonant frequencies. What components do you need for this? A good variable oscillator, an amplifier, and meters for reading the frequency and the voltage. The oscillator here is based on the function generator described in the April 1995 issue of *Elektor Electronics*. Only the sine-wave function is used here. The main advantage of this oscillator is that it can be adjusted over a wide frequency range with a single potentiometer. If you use a ten-turn potentiometer for this, you can set the frequency very precisely. The sine-wave signal also has a very stable amplitude and low distortion.

The sine-wave signal generated by IC3 and IC4 is fed to the output amplifier (TDA2030) via potentiometer P3. Switch S1 allows the amplifier to be operated in two different modes: constant voltage and constant current. The latter option is helpful for determining the position of the peak amplitude at the resonant frequency, since this can best be seen with constant-current drive.

The loudspeaker voltage is measured by IC5a, which is wired as a differential amplifier with a gain of 1. IC5b converts the loudspeaker current into a voltage. Switch S2 selects one of these two outputs, and the selected measurement signal is fed to an active rectifier built around IC6a and IC6b. The rectifier output is fed to IC8, a voltage to frequency converter (type XR4151). Its output signal is routed via S5 to a frequency counter. Switch S5 selects either the frequency or the loudspeaker voltage or current.

The author used a type 74C925 IC as the frequency counter for frequency measurement, along with a time base and the necessary peripheral circuitry. Although this IC is no longer available, the associated devices (IC1, IC2, IC9 and IC10) have been included here for completeness. The time base uses a crystal oscillator with a watch crystal to generate a 10-second counting window, and the counter allows the frequency to measured with a resolution of 0.1 Hz. The above-mentioned ICs can be omitted if you use a frequency counter module.

Power is supplied by a mains



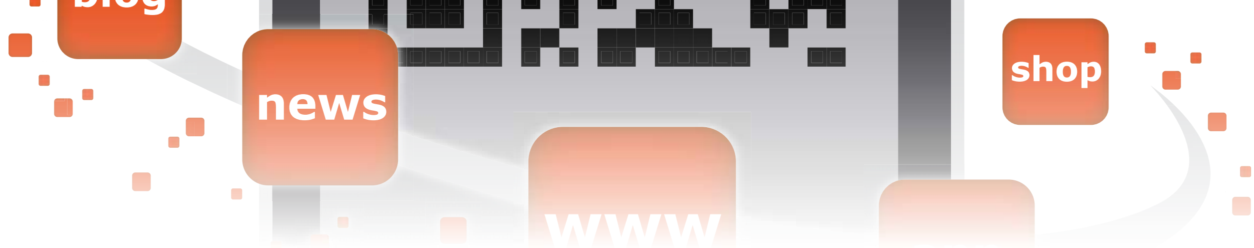
transformer rated at 2 × 12 V, followed by a pair of voltage regulators. The output amplifier is powered from the unregulated supply voltage.

When making measurements, take care that the measuring voltage does not become too high. If the loudspeaker has a nominal impedance of 4 Ω, the impedance at the resonant frequency can easily be a factor of 10 greater. If you measure with constant current, this will cause the voltage on the loudspeaker at the resonant frequency to be 10 times the normal value. The loudspeaker voltage must always be well below the clipping voltage of the output amplifier. A clipping indicator could be a useful addition.

Before starting to make a measurement, ensure that the level control P3 is set to zero. Then increase the level until the loudspeaker generates a barely audible tone. Set switch S2 to voltage measurement mode and adjust the frequency with P1 to maximize the measured voltage. The measured current at this point should not deviate from the initial value. If it does, repeat the measurement with a lower setting of P3.

At the maximum loudspeaker voltage, read the frequency from the counter. This is the resonant frequency of the loudspeaker.

(120241)



Shoo Heron!

Outsmart a clever bird

More and more pond owners suffer from herons that help themselves to the fish in the pond. Although several devices are for sale in the trade to scare away herons, they are often not completely effective. The ‘perfect’ heron scarer doesn’t exist, unfortunately. These birds have a justified reputation for their intelligence! Even electric wire fencing doesn’t work, as the heron just steps over it. However, the system described here was found to work very well.

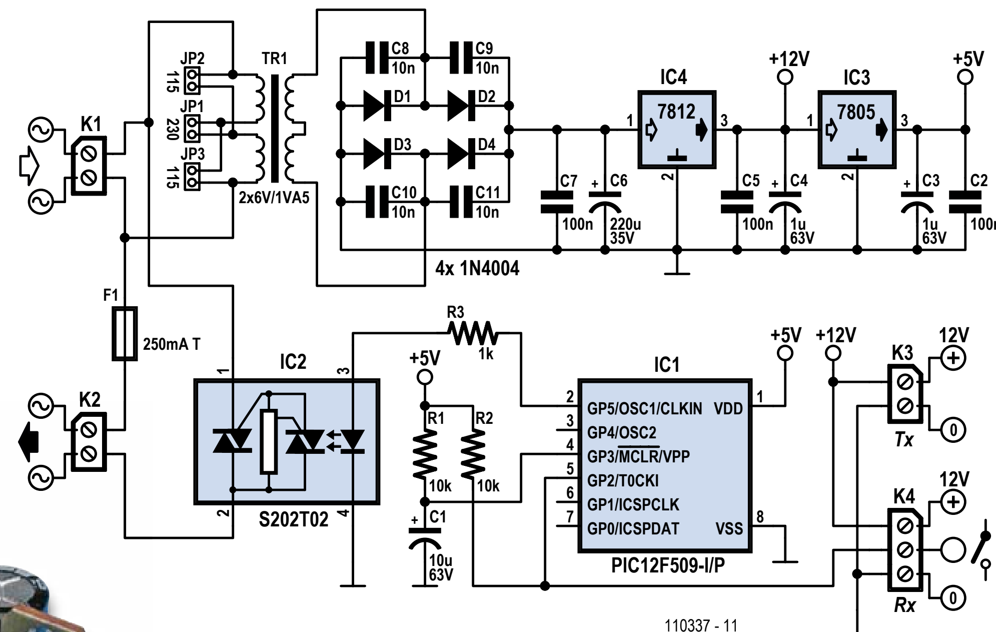
By Will J.B. Hus (Netherlands)

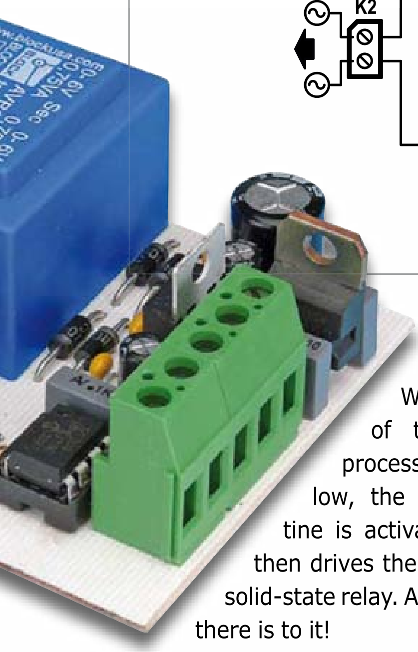
If you have ever observed herons, you will have noticed that they always approach a pond from some distance. The idea is to protect the pond with an invisible barrier that is connected to a powerful water spray. Herons dislike being sprayed and will leave. Furthermore, they can’t easily determine what causes the spray to start.

The protection consists of an infrared transmitter and receiver that are mounted close to each other. The beam is made to go round the object to be protected (the pond) by means of a series of mirrors. Should the infrared beam be broken, it causes an electromagnetic valve to open, which causes the spray of water to start. The heron definitely doesn’t like this! For the mirrors you could use rear-view mirrors, for example, mounted on a small post. The best height is about 20 to 30 cm (8 to 12 inches).

This setup should also fit other types of surveillance systems

The infrared transmitter and receiver used in this project came as a set and are widely available (e.g. from Conrad). The receiver has a ‘normally open’ (NO) contact. The rest is taken care of by a simple microprocessor that drives a solid-state relay (IC2). The relay of the receiver module is closed when the





beam is broken.

When pin 2 of the microprocessor goes low, the spray routine is activated. Pin 5 then drives the LED of the solid-state relay. And that's all there is to it!

The extremely simple program turns on the sprayer three times for five seconds. To avoid that the sprayer is turned on continuously, when the beam is permanently broken for example, the routine has a loop that is only exited when the beam is restored again. As usual, the program for the microprocessor can be downloaded from the Elektor website [1].

A PCB has been designed for this circuit, which contains the power transformer, voltage regulators, microcontroller and solid-state relay. The infrared transmitter and receiver and the electromagnetic valve are easy to connect to the board, using screw terminals.

To set up the system properly requires a high level of precision. The transmitter, receiver and the mirrors have to be

COMPONENT LIST

Resistors

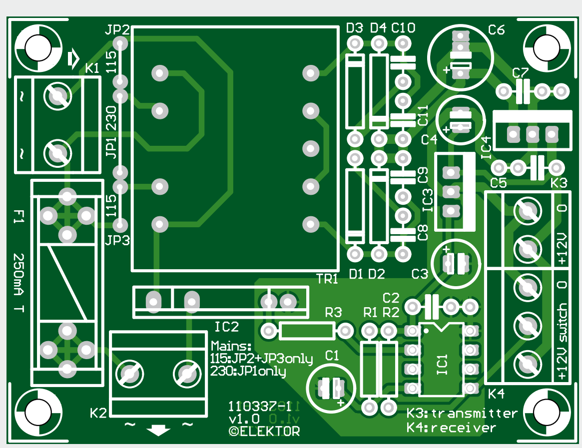
R1,R2 = 10kΩ
R3 = 1kΩ

Capacitors

C1 = 10μF 63V radial, pitch 2mm
C2,C5,C7 = 100nF, pitch 7.5mm
C3,C4 = 1μF 63V radal, pitch 2mm
C6 = 220μF 35V radial, pitch 3.5 or 5mm
C8–C11 = 10nF, pitch 5mm

Semiconductors

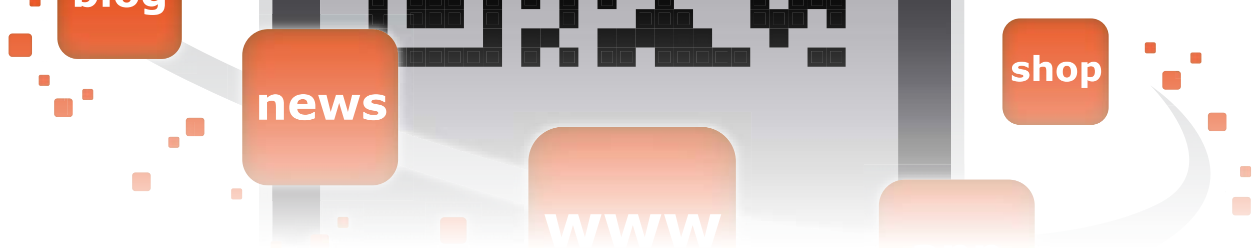
D1–D4 = 1N4004
IC1 = PIC12F509-I/P, programmed



IC2 = S202T02F
IC3 = 7805
IC4 = 7812

Miscellaneous

F1 = fuse, 250mAT, w. PCB mount holder and cap
K1,K2 = 2-way PCB terminal block, pitch 7.5mm
K3 = 2-way PCB terminal block, pitch 5mm
K4 = 3-way PCB terminal block, pitch 5mm
TR1 = power transformer, secondary 2x6V, 1.5VA (e.g. Block AVB1,5/2/6)
PCB # 110337-1



lined up exactly. This is best done using a simple laser pointer. First, the laser pointer is put in front of the transmitter and pointed at the first mirror. A piece of masking tape on the mirror can make it easier to see the laser light. From then on, you follow the same procedure for all successive mirrors until you get to the receiver. This is something best done at dusk or at night! Once that is done, the transmitter and receiver have to be aligned as well as possible with the first and last mirrors respectively.

If possible, you should use twin beam modules for the transmitter and receiver. This will prevent smaller birds or even a falling leaf from breaking the beam.

With only minor modifications, this system can also be used for other security purposes. The output is capable of switching all kinds of AC line powered devices.

(110337)

Internet Link

[1] www.elektor.com/110337

Tiny Compass

By Wilfried Wätzig (Germany)

A compass is an invaluable orientation aid, especially when you're traveling by foot or bicycle. Some smartphones and navigation systems do not have built-in compasses, so they can determine direction only if you move fairly quickly. Old-fashioned hiking or cycling maps also still have their place, since they provide a much better overview than any display. Accordingly, the author went looking for a robust compass, and it quickly became clear that what he wanted was an electronic model — and of course, of his own design. The implementation of this sort of project is simplified by the fact that compass models with simple interfaces are available commercially. The author decided on a module with the designation HDMM01, which can be obtained from Pollin Electronic [1]. It incorporates a type MMC2120MG two-axis magnetic field sensor from Memsic. All you need to do is provide the module with a 5 V supply voltage, and you can read out the compass data from a two-pin I²C port (most easily done with a microcontroller).

The compass circuit is built around an ATtiny84, which communicates with the compass module MOD1 over the I²C bus. The two pull-up resistors R5 and R6 have standard values. The circuit can be powered from a 9 V battery, among other options. The voltage regulator reduces the input voltage to 5 V.

The compass direction is indicated by a set of 16 LEDs, divided into in four groups of four LEDs each. The cathodes of the LEDs in each group are connected together, and the common cathode lead is connected to a port pin via a series resistor. Sets of four LED anodes are also connected to common port pins. If suitable signals are generated on the port pins, only one LED at a time will be lit, and this arrangement needs only eight port pins instead of sixteen.

The intelligence of the circuit is vested in the microcontroller firmware, starting with the I²C interface. This is necessary because the ATtiny84 does not have a hardware I²C interface (which Atmel calls 'Two Wire Interface' or TWI), but instead only a 'Universal Serial Interface' (USI). The I²C functionality must therefore be emulated using

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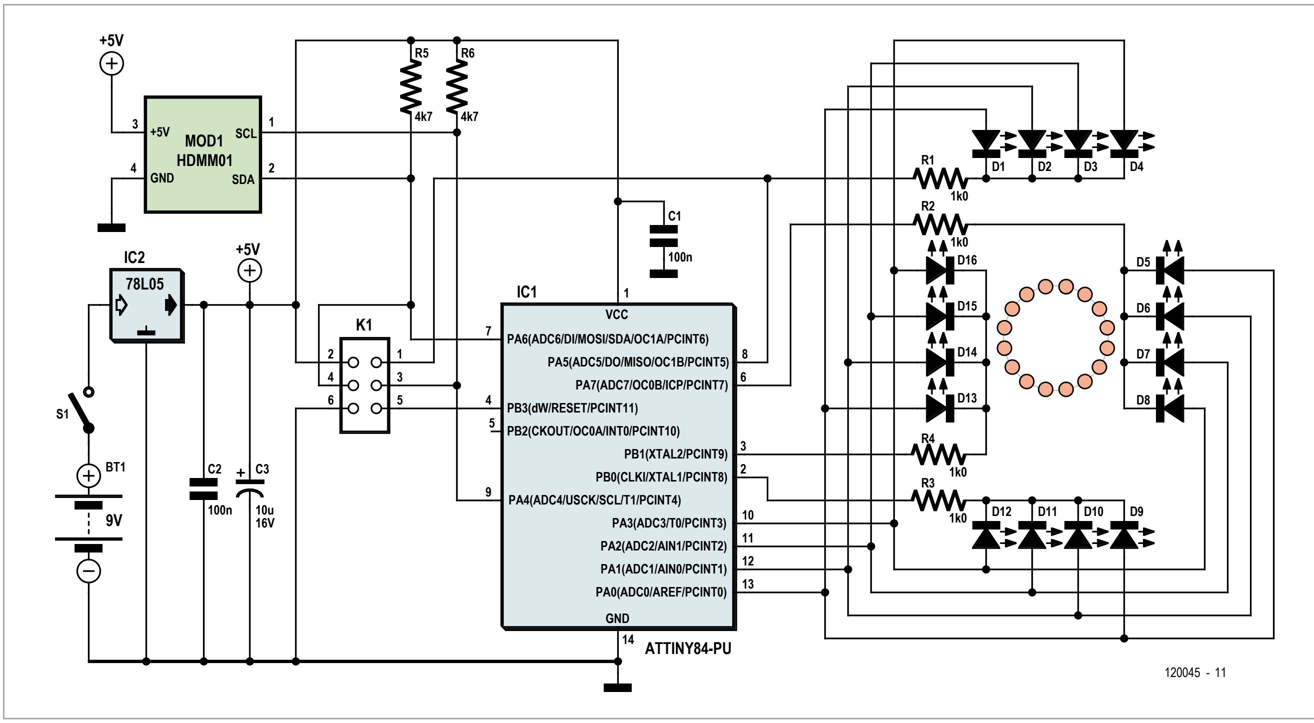


the USI, in the manner described in an Atmel application note [3].

The compass module supplies the X and Y components of the magnetic field as signed numbers. The corresponding quadrant can be determined from the signs of the numbers, and the angle within the quadrant can be obtained using the expression *Angle = arctan(abs(Y/X))*, where the function *abs()* returns the absolute value of the quotient of *Y* and *X*. The average values of *X* and *Y* are calculated from a set of eight samples in an endless loop in the main routine of the firmware and are used to compute the angle. From this the LED that points to the north can be determined. To allow the direction to be indicated with sufficient precision, the LEDs should be arranged in a circle with equal spacing and in the same sequence as shown on the schematic diagram. LED D1 must be aligned to the top edge of the module (oriented so that the IC marking can be read normally). For best results, you should use another compass to calibrate the assembly and adjust the orientation of the module (connected to the circuit by loose wires) accordingly. Then secure the module to the PCB with a drop of heat-melt glue.

The firmware (source code for WinAVR and hex code) can be downloaded from the Elektor website. The main routine is contained in the file tiny_compass.c; the routine USI_TWI_Master.c handles I²C communication and the routine led_driver.c drives the LEDs. The microcontroller can be programmed directly on the PCB via connector K1. The fuse bits must be configured as follows: EXT = 0xFF, HIGH = 0xDF, LOW = 0xE2. If you don't want to program the microcontroller yourself, you can buy a pre-programmed device from the Elektor Shop [4] (order number 120045-41).

(120045)

Always on the right path

Internet Links

[1] www.pollin.de

[2] www.pollin.de/shop/downloads/D810164D.PDF

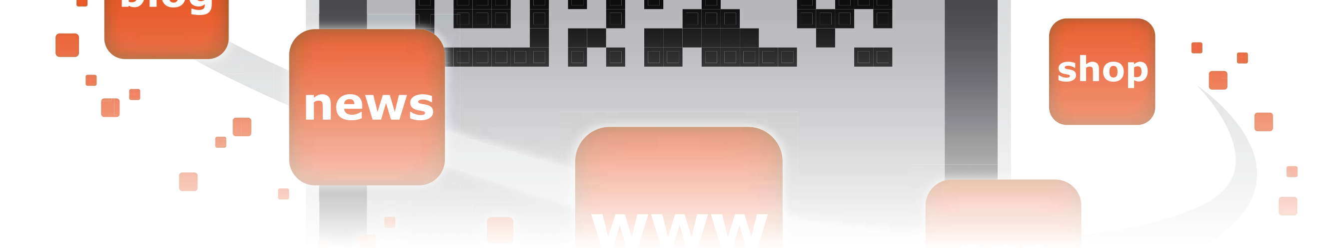
[3] www.atmel.com/Images/doc2561.pdf

[4] www.elektor.com/120045

Elektor Products & Services

- ATtiny84 microcontroller (pre-programmed): # 120045-41
- Free software download: 120045-11.zip

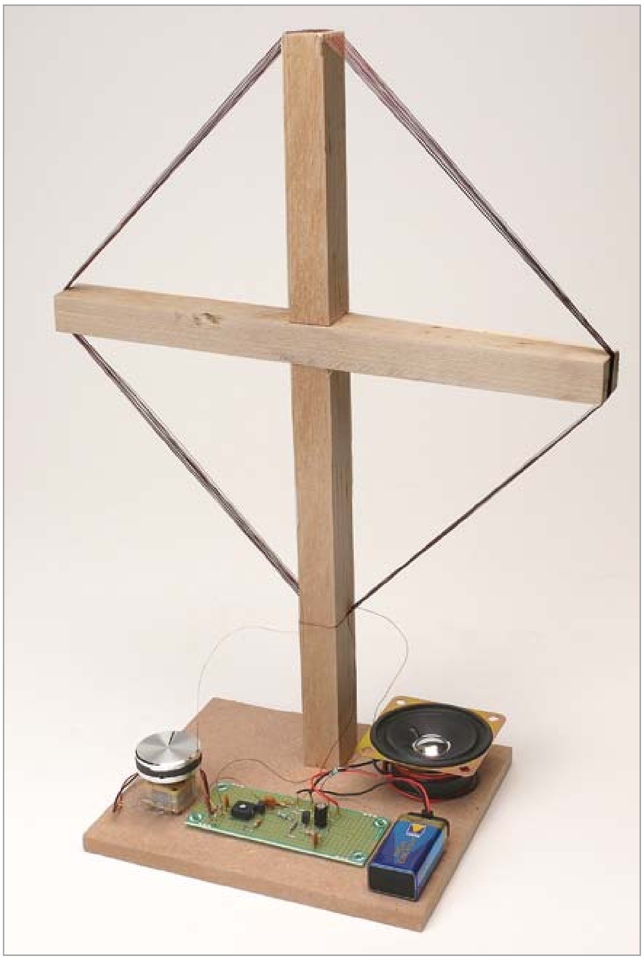
All products and downloads are available from the web page for this article: www.elektor.com/12004



Two-Transistor Regenerative Receiver

DIY Retro Radio

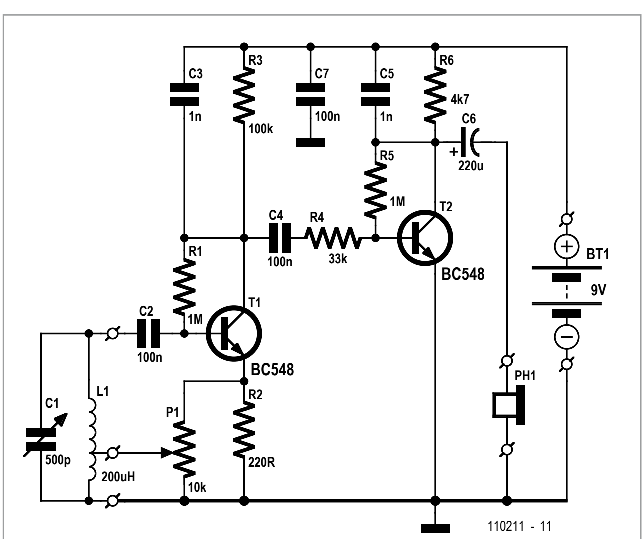
By Frank de Leuw (Germany)



Regenerative? What's that? In the age of Twitter and smartphones, you can't assume that things not related to the Internet are still generally known — or maybe they are? Amazingly, Google delivers nearly 80,000 hits for the search term 'regenerative receiver' and much more for the German name Audion, even though it lacks a lower-case i as a prefix ('iAudion' also exists, but it yields only 12,000 hits). From this we can conclude that this type of receiver is not entirely unknown nowadays, even if some of the search results have nothing to do with radio circuits.

In any case, it's a reasonable assumption that you all have idea of what 'regenerative' means. If not: it's a super-simple but nevertheless sensitive type of radio receiver. If you want to know more, check the references. The Wikipedia entry on this topic [1] is also quite extensive. The author is a fan of the many HF experiments and projects dreamed up by the well-known Elektor author Burkhard Kainka. Based on Kainka's regenerative receiver circuit, the author developed an especially simple but high-performance version using modern components — a regenerative receiver using only garden-variety transistors, but with good reception characteristics. The author has published a version of this design on his website [2].

The Elektor version, which is perhaps a bit easier to build yourself, is described here. Instead of breadboard construction, which was common in the days before PCBs were invented, the component layout of the design presented here has been optimized with the Lochmaster 4 program for assembly on an Elex prototyping board (a.k.a. UPBS-1 and available from the Elektor Shop).



First a few words about the circuit. A noteworthy feature is that both transistors are type BC548 in the 0815 package. Apparently types that are actually designed for audio use are adequate for use with HF signals in the medium-wave broadcast band from 0.5 to 1.6 MHz, which is what we're interested in here.

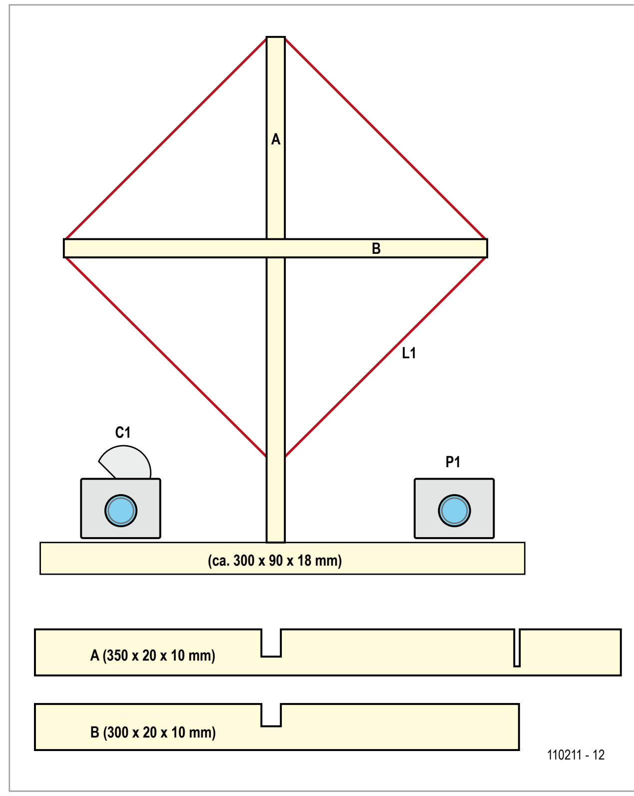
Share

Variable capacitor C1 and coil L1 form the usual parallel resonant circuit that determines the receiver frequency. The special feature of a regenerative receiver is that an active component, or more precisely the gain of an active component, is used to implement a form of feedback that is adjusted to the point where the circuit is just on the edge of oscillation. This reduces the load on the resonant circuit and increases its selectivity, and the high gain makes the receiver fairly sensitive. The active component in this case is T1. The feedback is provided by P1 and the tap on L1. Here T1 does double duty: it provides HF gain and (thanks to the nonlinear characteristic of the BE junction) it demodulates the AM signals commonly transmitted in the MW band.

T2 provides additional gain for the audio signal. A small loudspeaker or (preferably) headphones can be connected to coupling capacitor C6. The headphones should have high impedance to improve matching. For this reason, it's a good idea to connect the two earphones in series.

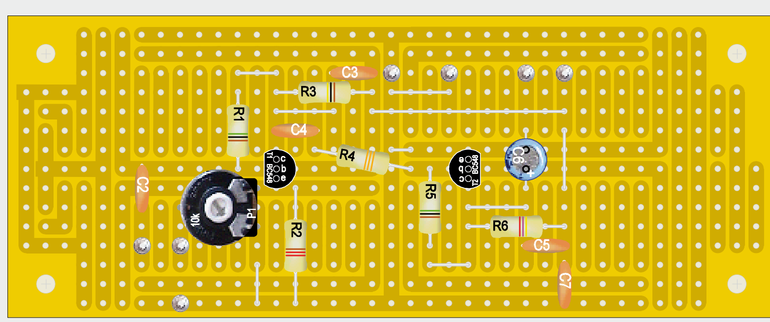
Assembling the circuit is straightforward thanks to the layout for the prototyping board. A bit more dexterity is required for making the aerial, but even here you don't need much more than the usual hobbyist tools. You can have planks and laths sawn to the dimensions given in the components list in any home improvement shop for a small charge.

Fit the PCB in the middle of the baseboard between the variable capacitor on the left and the potentiometer on the right. Screw the lath cross to the baseboard behind the PCB as shown in the photo of the prototype (note: in the prototype the author fitted a trimpot directly on the PCB instead of using an external potentiometer; this is also shown in the component layout for the Elex board). Wind 20 turns of enamelled copper wire on the cross, with a tap at the end of the fifth turn. The exact arrangement is not as critical as it might appear to an HF novice.



The prototype built in the Elektor lab drew 1.4 mA from a 9 V battery. The measured frequency range with this construc-

COMPONENT LIST



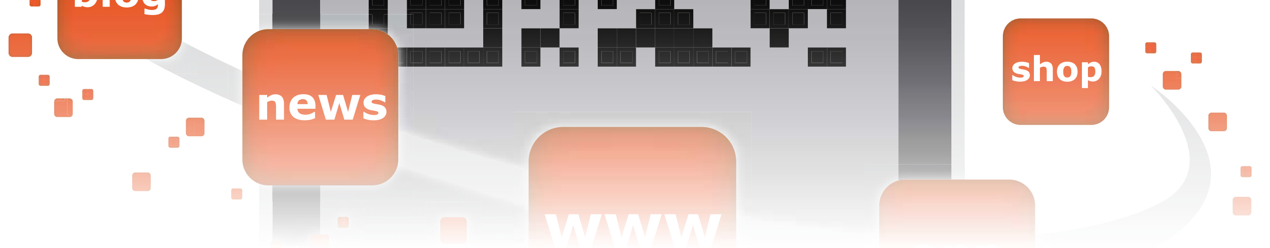
Resistors
R1,R5 = 1MΩ
R2 = 220Ω
R3 = 100kΩ
R4 = 33kΩ
R6 = 4.7kΩ
P1 = 10kΩ potentiometer, linear

Capacitors
C1 = 500pF tuning capacitor, see text
C2,C4,C7 = 100nF ceramic, pitch 2.5mm
C3,C5 = 1nF ceramic, pitch 5mm
C6 = 220µF 16V, radial, pitch 5mm

Inductors
L1 = loop antenna, 20 turns ECW, tap at 5 turns (see text)

Semiconductors
T1,T2 = BC548

Miscellaneous
Prototyping board type Elex-1
9V battery w. clip
Small loudspeaker or headphones (see text)



tion was 0.4 to 1.4 MHz. The reception quality is surprisingly good, once you get the hang of adjusting the feedback with potentiometer P1. In terms of reception, the regenerative receiver can hold its own against superheterodyne receivers. If you want to connect an amplifier instead of headphones, you can replace R6 by a potentiometer with the positive end of C6 connected to its wiper.
If you can't scare up a suitable variable capacitor rated at 500 pF or so, you can purchase the VCAP4 from [3] and connect the two 265-pF gangs in parallel. Incidentally, in the Elektor lab it was necessary to reduce the turns count of the aerial loop by three in order to roughly match the receiver frequency range to the MW band. In our opinion this regenerative receiver is not only a good example of a loop aerial receiver, but also a good candidate for a 'father and son' project where you can try out lots of things and learn from them. And don't forget that a loop aerial receiver is a directional receiver!

(110211)

Internet Links

[1] en.wikipedia.org/wiki/Regenerative_circuit

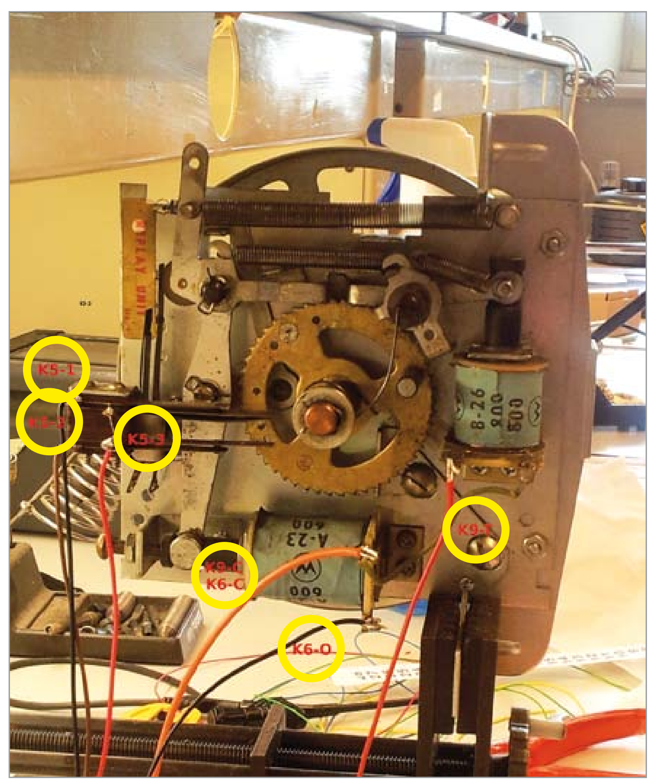
[2] www.elektronik-radio.de/39994.html (in German)

[3] www.ak-modul-bus.de/ (in German)

Same PCB Shoots Again!

A thermometer with an unusual readout

By Luc Lemmens (Elektor Labs)



In the April 2012 edition of Elektor we published a design for a thermometer that uses two counter wheels from a 1960's pinball machine to display the temperature. With few minor modifications to the firmware, a credit unit from a pinball machine can also be used as a display device.
The counters used in the original design are a pair of modules normally used in a pinball machine to show the player's score. Each module can display a number from 0 to 9. These modules can only count up, which means that a change from 2 to 1 requires spinning the counter wheel all the way around to reach the new position.
EM pinball machines contain another type of counter called the credit unit, which shows how many games the player can still play before inserting more coins in the machine. It has a wheel that can display a number from 1 to 20. Some credit units can even go as high as 37 (the experts in this area disagree on the highest number ever). Unlike score counters, credit units can count down because they have a dual mechanism and two actuator coils. These units also have contacts to indicate the zero and maximum positions of the wheel. The numbers are smaller than those on score counters, and the available range of numbers is usually not especially large — but this can be taken as a challenge for developing version 2.0 of the thermometer.
Two contacts, two coils and two digits; what can we do with that? The readout is a bit different, but the circuitry for the previous version of the thermometer has everything we need for driving this unit as well. With a few changes in the con-

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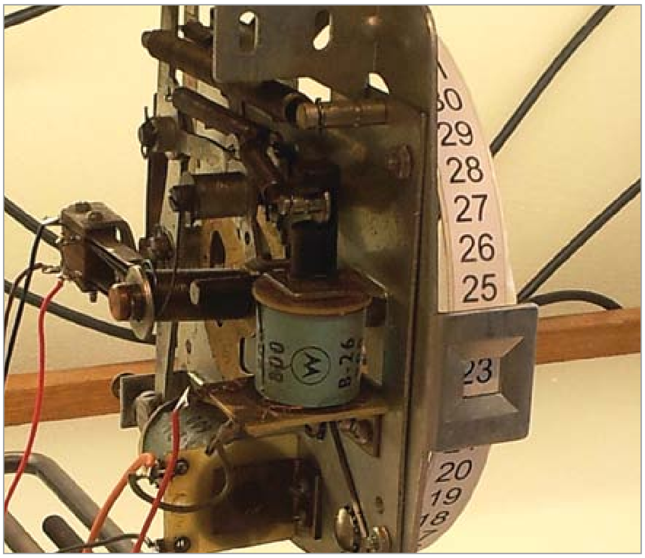


nections and of course a few modifications to the firmware, it should certainly be possible.

The vast majority of the original firmware is unchanged; only the readout routine has changed. The algorithm for this is not difficult. After power-up, the microcontroller pulses the counter until it reaches the zero position. This position is signalled by the opening of the zero contact. Next, the temperature is measured and a pulse is sent to the counter for each measured degree Celsius to increase the indicated number. The circuit waits 15 minutes before making a new measurement. The new value is compared with the previous value and the difference between the two is translated into the number of steps up or down that are necessary to show the right temperature. That's all easy enough, but with a 20-credit unit — such as we had here in the lab — the range is rather limited and not even sufficient for measuring the room temperature.

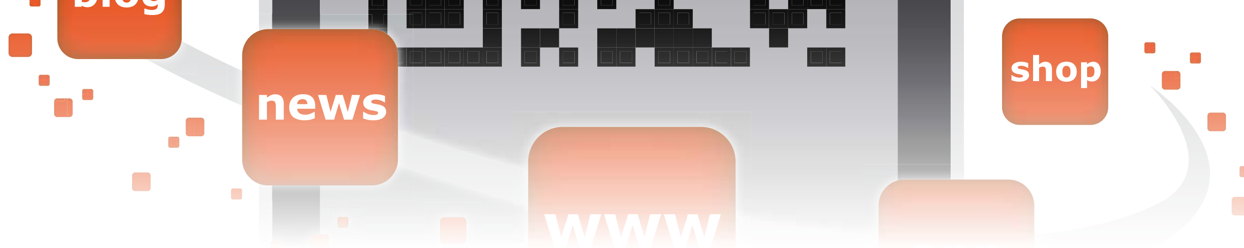
The wheel has enough room for more numbers, and in principle the unit could certainly make more steps; if necessary it could even turn the wheel in a full circle with a modified mechanism. Our credit unit came from a pinball machine made by Williams, but a unit from another brand is equally suitable (just like the counters for the previous version), such as Bally or Gottlieb. Credit units also differ somewhat from one brand to the next, and some manufacturers occasionally make changes to their own modules, but the connections and operation are always the same. A bit of exercise with a graphic design program on the computer delivers a nice strip of paper with a series of numbers from 0 to 48, which can be taped onto the original wheel. However, there's a bit more to be done. As already mentioned, the unit has a contact that indicates when the wheel has reached its maximum count. On the photo you can see the contact for the 0 position at the left, and to the right of it a ratchet wheel with two pins fitted to it. The upper pin opens the zero contact when the wheel has been rotated far enough anti-clockwise, and the lower pin opens the maximum-position contact when the wheel reaches the maximum position in the clockwise direction. We removed the second pin to make the range as large as possible. In the worst case the pin intended to operate the contact for the zero position will also operate the contact for the end position. If this happens, the firmware prevents the wheel from stepping any further.

The new firmware for the ATtiny2313 used in the original circuit published in the April 2012 edition (PCB # 110673-1) is available on the web page for this project [1].

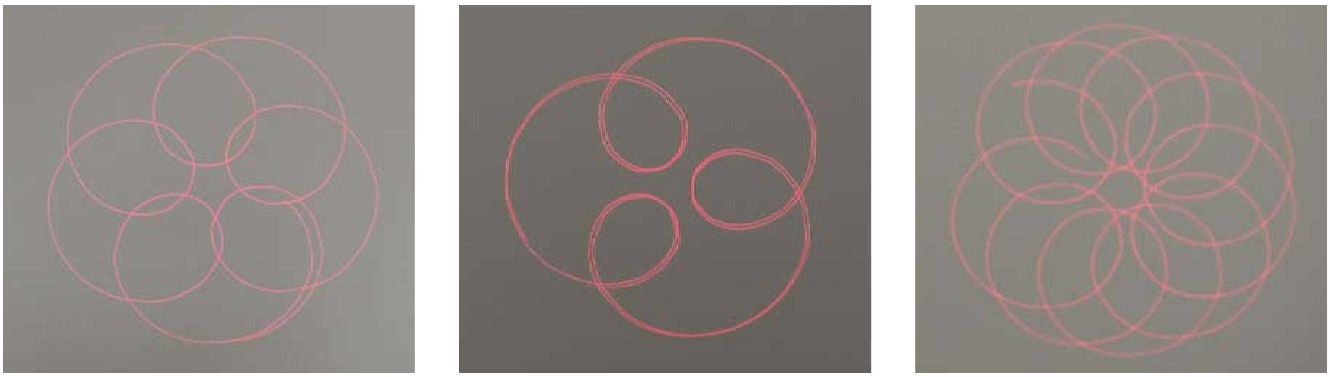
(120251)

Internet Link

[1] www.elektor.com/120251

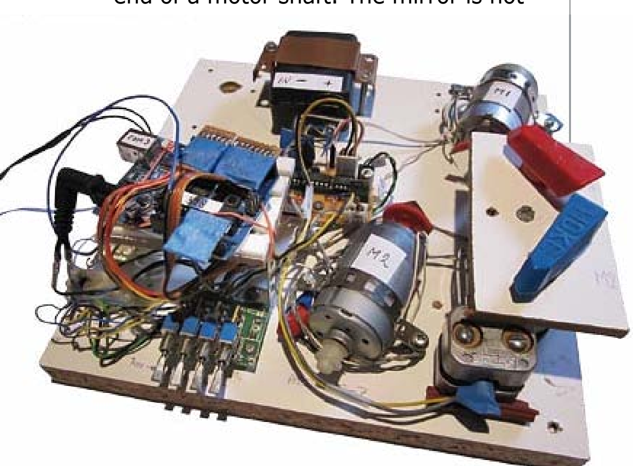


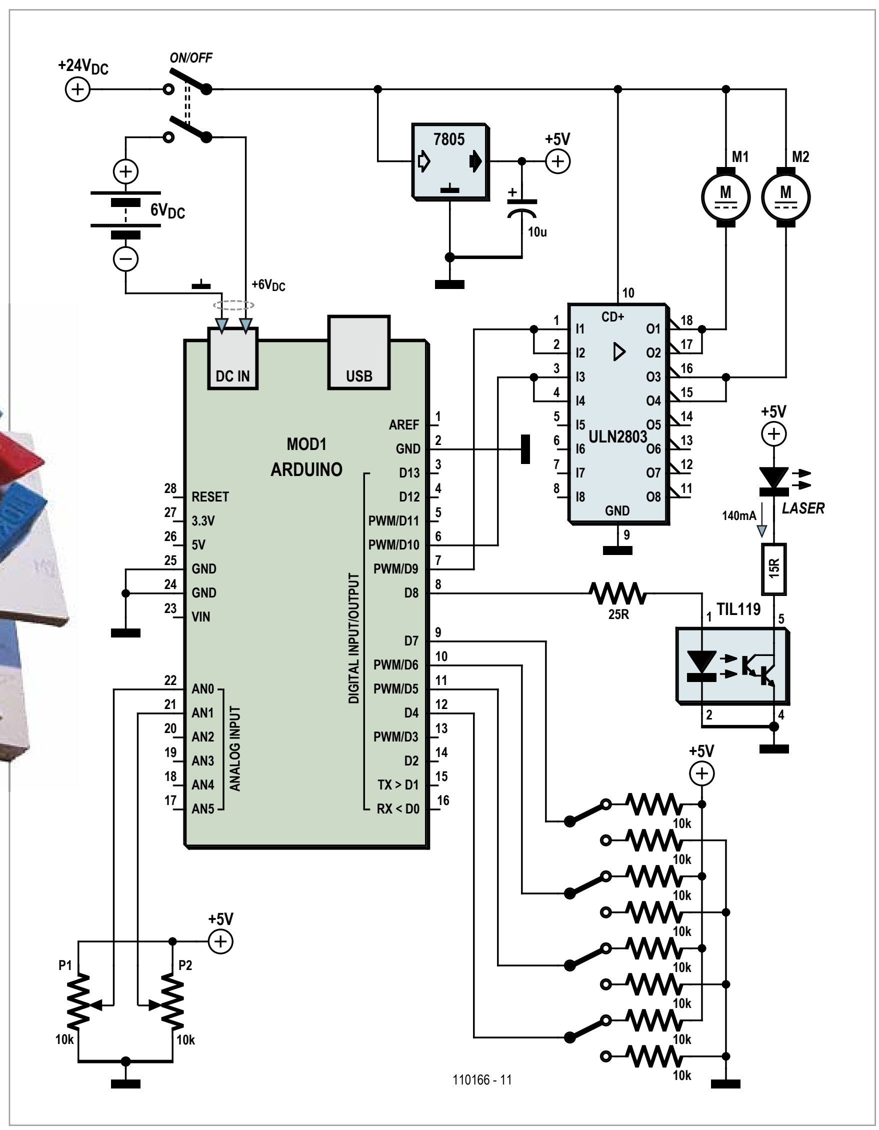
Laser Projection with Arduino



By G. van Zeijts (The Netherlands)

This device can project attractive laser beam patterns on virtually any desired surface. The basic idea is to manipulate the path of a laser beam from a source such as a laser pointer. The beam is deflected by a small mirror fitted to the end of a motor shaft. The mirror is not



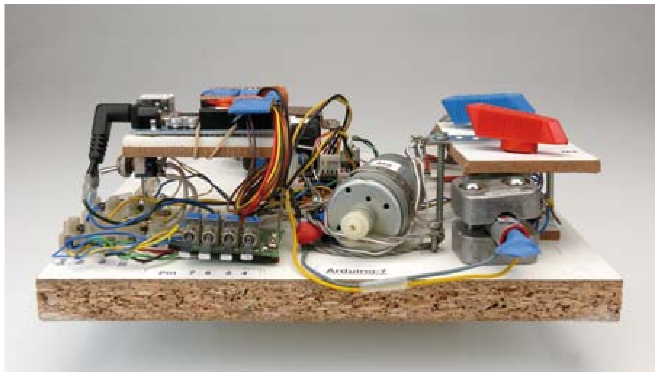


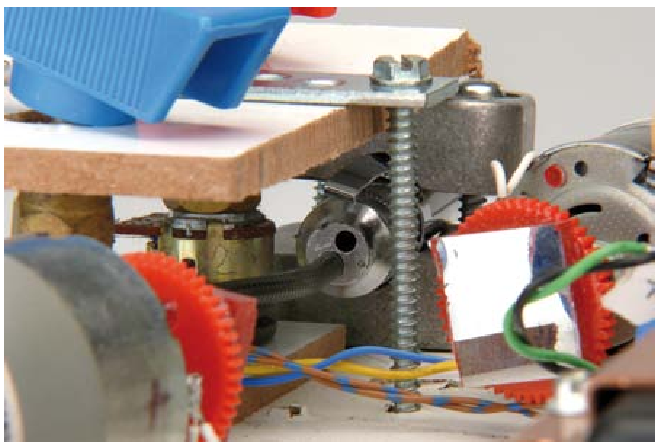
perfectly perpendicular to the axis of the shaft, so the originally linear beam path is converted into a cone. This cone strikes a second mirror on end of the shaft of a second motor. The beam from the second mirror goes to the projection surface.

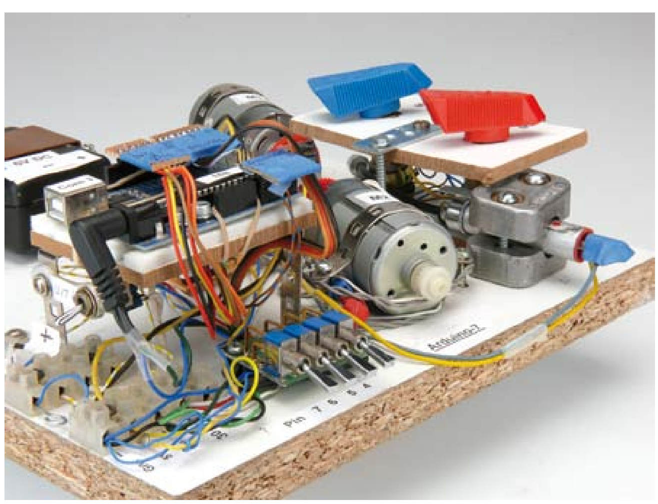
The motor speeds are high enough that viewers see a stationary figure instead of a moving point of light, thanks to the persistence of human vision. A wide variety of fascinating figures can be created by varying the speeds of the motors.

All of this is controlled by an Arduino microcontroller, using a program written in C. The software can be downloaded free of charge from the web page for this article [1].

The speeds of the two motors are set by potentiometers P1 and P2 (which are fitted with the red and blue knobs in the photo), whose positions are read by the microcontroller. The microcontroller converts these two input signals into PWM outputs that determine the speeds of the motors.
The rest of the circuit diagram is simple. The outputs of the Arduino MCU are fed directly to the ULN2803 driver IC, which can handle up to 500 mA per channel. The two motors (scavenged from printers) operate at 24 V with current consumption well below 500 mA. To be on the safe side, two channels of the ULN2803 are wired in parallel for each motor.
The laser diode is energized by the microcontroller immediately after start-up and is always on. It is powered







from a 5-V supply voltage. The current is limited to approximately 140 mA by a 15-ohm resistor. To avoid problems with pulse noise from other supply rails, the Arduino is powered from a separate 6 V source, such as a rechargeable battery.

The author used the potentiometers to find various combinations of motor speeds that produce attractive figures. They have been arranged in sequence to provide a show lasting several minutes, with a repeating series of fascinating figures in an automatic loop. This is included in the C code. This loop, as well as other pre-programmed figures, can be selected using a set of four switches. A short video demonstrating the projected figures can be viewed on Elektor's YouTube channel [2].

(110166)

Internet links

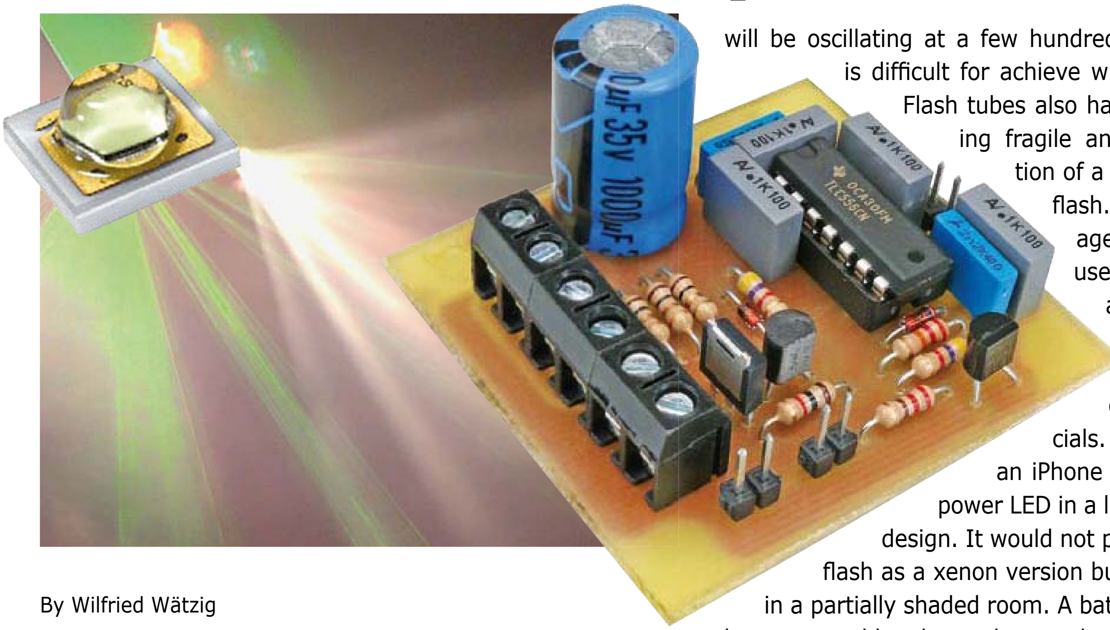
[1] www.elektor.com/110166

[2] www.youtube.com/ElektorIM

Caution: laser beam!

Always be careful when working with laser beams. The light emitted by the laser diode in a laser pointer is relatively harmless and does not cause any problems if the beam passes quickly through your field of vision, but you should **never look directly into a stationary laser beam**, even if the laser power is very low.

Mini Stroboscope

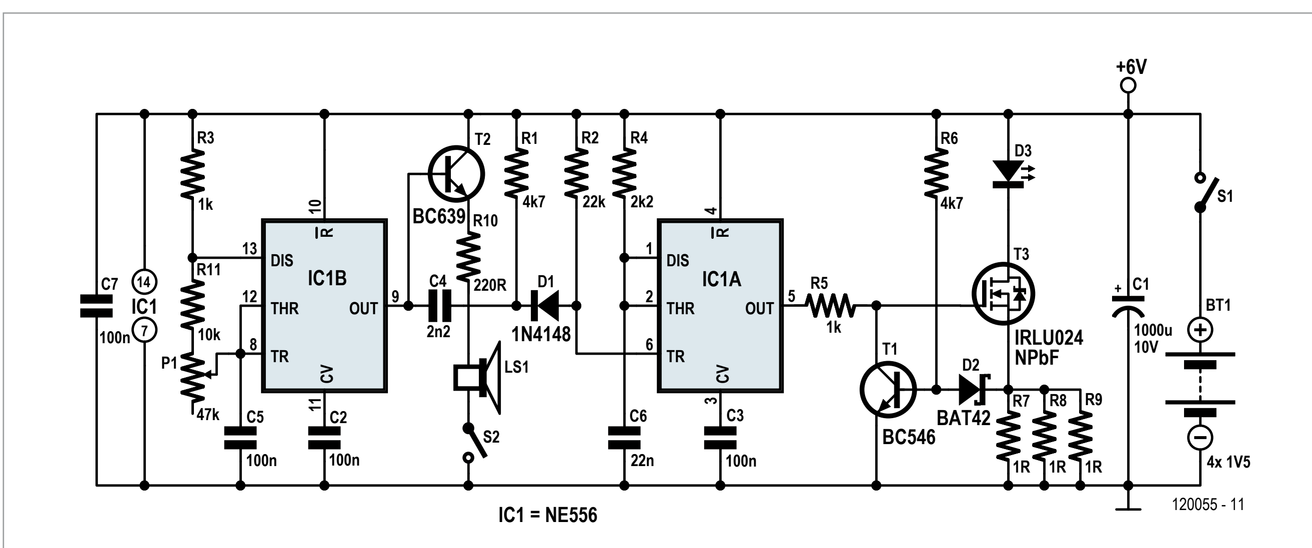


By Wilfried Wätzig

Physics teachers often rely on test equipment to make certain phenomena observable. Stroboscopes are useful for getting a closer look at vibrating strings and rotating motor parts. Conventional stroboscopes however will often not flash at a rate fast enough to 'stop' the motion for observation. The author is of the belief that a hands-on physical demonstration is worth a hundred hours of 'chalk and talk' whiteboard explanations.

Strings vibrating at a frequency high enough to be audible will be oscillating at a few hundred hertz. This flash rate is difficult for achieve with a xenon flash tube. Flash tubes also have a reputation for being fragile and require the application of a high DC voltage for the flash. The words 'lethal voltage', 'fragile' and 'glass' used in the same sentence as 'classroom environment' are likely to arouse the interest of health and safety officials. An alternative (not just an iPhone strobe app) is to use a power LED in a low-voltage stroboscope design. It would not produce such an intense flash as a xenon version but still be bright enough in a partially shaded room. A battery powered LED stroboscope would make a robust and useful teaching tool.

This was reason enough for the author to set about designing and building this mini stroboscope using an LED light source. The design is built around the NE556; the dual-version of the biggest selling chip ever designed. One half of this chip (IC1B) takes care of the flash frequency generation and is therefore configured as a standard astable multivibrator. Variable pot P1 allows the flash rate to be adjusted from around 120 to 650 Hz. The design includes a switchable loudspeaker in the emitter path of T2 to make the flash



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frequency audible. Transistor T2 is only necessary if you, like the author, use the CMOS version of the NE556.

The second half of the dual timer chip is configured as a monostable multivibrator to provide a pulse shaping function. The differentiating RC network formed by C4 and R1 produces a 10 µs pulse on the positive and negative edges of the output signal from IC1B. The negative going pulse is transferred to the trigger input of IC1.A via diode D1. R4 and C6 are chosen so that IC1.A gives a 50 µs positive output pulse in response to the trigger pulses.

The pulses are connected to the gate of MOSFET T3 via resistor R5. LEDs are driven by a constant current source, in this circuit the voltage drop across the shunt resistors R7, R8 and R9 is added to the forward conduction voltage V_F of D2 to control transistor T1. When the voltage drop over the shunt resistors reaches 300 to 350 mV T1 begins to conduct the drive voltage of T3 to ground thereby limiting current through the LED to around 1 A. C1 effectively reduces the source impedance of the power supply so that high current pulses can be delivered to the LED even when the circuit is powered by four AA size dry batteries.

The author used an LED 'OSLON SSL LCWCQ7P' type LED from OSRAM. According to its data sheet [1] this small LED can be pulsed with a current of 2 A for 50 ms. Running with 1 A pulses of 50 µs duration neither the LED or T3 will require any additional cooling. This particular LED has an electrically isolated 'thermal pad' between the two power connections which can be used as a heat sink contact point. With a heat sink in place the LED will be able to pass a higher current. IC1.A outputs a constant pulse width so the LED dissipates more power if the value of C5 is reduced to increase the maximum strobe flash frequency. It is of course possible to experiment with more powerful LEDs and to increase the LED current by reducing the size of the three parallel shunt resistors. T3 still has a little more in hand even when running with a pulse current of 3 A in this application. To achieve maximum brightness it is better to avoid warm white LED variants. Higher colour temperatures are perceived as being brighter.

Using the suggested components and a CMOS version of the NE556 the LED current has an average value of around 20 mA when running at 650 Hz. With the speaker switched on this rises to around 40 mA. Using the standard non-CMOS version of the NE556 increases the current drain by about 5 mA.

The author has supplied a PCB layout for this design. It uses standard non-SMD components so assembly is very simple. The PCB can be ordered from the project web site [2] where the layout files are also available for download.

(120055)

Internet Links

[1] http://catalog.osram-os.com/catalogue/catalogue.do?favOid=000000020000263308030023&act=showBookmark

[2] www.elektor.com/120055

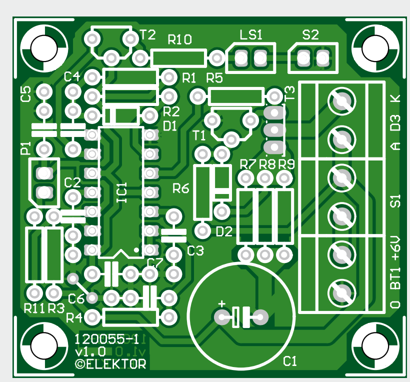
COMPONENT LIST

Resistors
R1,R6 = 4.7kΩ
R2 = 22kΩ
R3,R5 = 1kΩ
R4 = 2.2kΩ
R7.R8.R9 = 1Ω
R10 = 220Ω
R11 = 10kΩ
P1 = 47kΩ, potentiometer, linear

Capacitors
C1 = 1000µF 10V, radial, pitch 5mm, diam. max. 13mm, 1 A ripple current (Farnell # 1165601)
C2,C3,C5,C7 = 100nF, MKT, pitch 5 or 7.5mm
C4 = 2.2nF, MKT, pitch 5 or 7.5mm
C6 = 22nnF, MKT, pitch 5 or 7.5mm

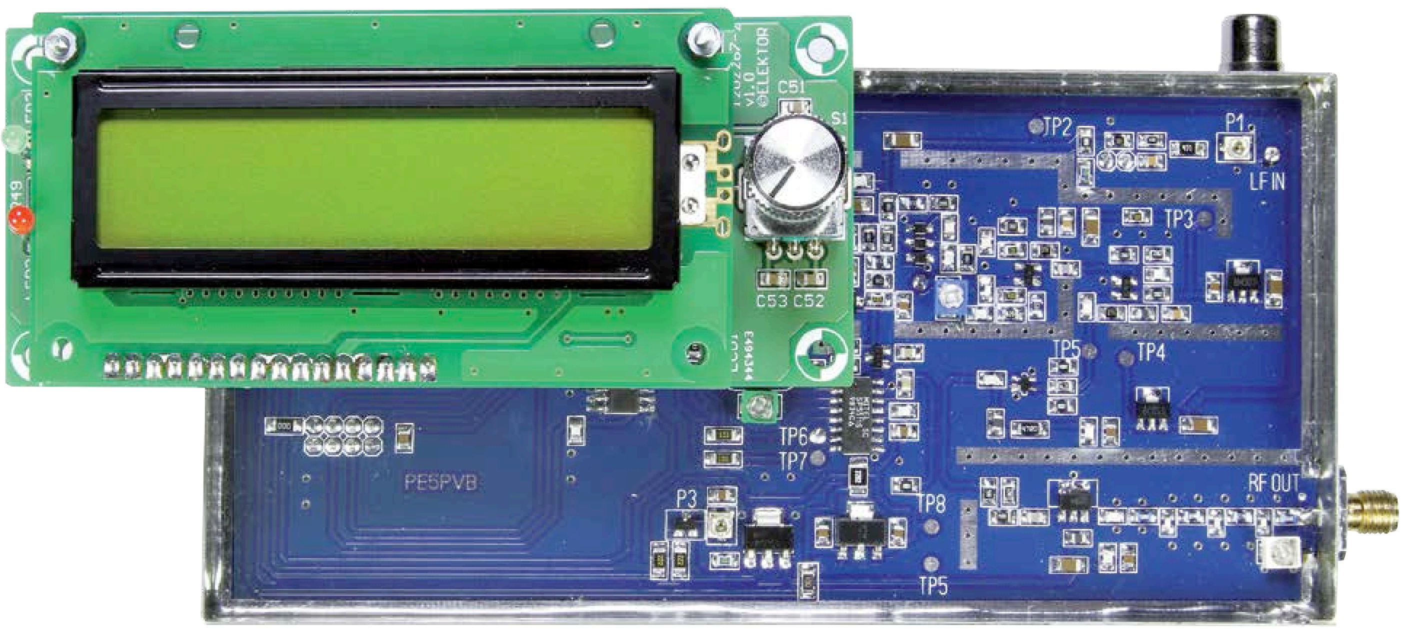
Semiconductors
D1 = 1N4148
D2 = BAT42
D3 = Power-LED, OSRAM type LCW CQ7P. PC-KTLP-5J7K
T1 = BC546
T2 = BC639
T3 = IRLU024NPbF (TO-251AA)
IC1 = TS556 or TLC556 (DIP16)

Miscellaneous
S1 = on/off switch, 1 A
S2 = on/off switch
LS1 = loudspeaker, 8Ω 200mW
BT1 = 4 pcs AA alkaline battery with holder
3 pcs 2-way PCB screw terminal blocks, pitch 5mm, for BT1, S1 and D3
3 pcs 2-way pinheader, pitch 0.1", for LS1, S2 and P1
PCB # 120055-1 (see text)



Wideband 70-cms FM Exciter

With 130 mW output power



By **Sjef Verhoeven, PE5PVB**
(The Netherlands)

Most amateur radio transmitters are not actually designed for transmitting wideband audio signals with high fidelity. However, the wideband 70-cms (430–440 MHz) FM exciter described here is up to the task, with an audio bandwidth of 20 Hz to 100 kHz.

Technical Data

- Frequency range 430–440 MHz in 25 kHz steps
- Audio bandwidth 20 Hz to 100 kHz
- PLL lock time less than 1 s
- Supply voltage 12–15 V
- Current consumption approx. 250 mA at 130 mW RF output power

Just about everyone has played with walkie-talkies at some time. They're nice for wireless conversations, but radio links of this sort suffer from poor sound quality and the fact that only one person at a time can talk. Licensed radio amateurs ('hams') have been communicating in this manner since the early days. With the right choice of equipment, frequency and antenna, radio amateurs can connect to each other all over the world in various ways.

But what options are there if you want to establish a connection with good sound quality? In this article we describe the design of a complete broadband FM audio exciter for the 430–440 MHz section of the 70 cms band (in the US, the band extends from 420-450 MHz). The output signal is not unlike you find in the VHF FM broadcast band, which means that the audio bandwidth is approximately 20 Hz to 100 kHz. Thanks to this large audio bandwidth, it is fairly easy to set up audio chat sessions with several transmitters and relatively low distortion. This is similar to Teamspeak or other chat tools, but without jitter, codec distortion, echo and delay. With the right antennas, antenna height and possibly an amplifier, you can easily make QSO's (connections) over a distance of tens of miles, or even as much as 200 miles under the right weather conditions.

An amateur radio license of the appropriate class is needed to operate this exciter. You can obtain this license from the relevant national or local authorities after passing a technical exam. The aim of this is to prove that you have sufficient theoretical knowledge to be able to operate radio transmitting equipment safely, in compliance with statutory provisions, and without causing interference. Among other things, this means that using this exciter as a transmitter to broadcast music for anyone who wants to listen is not permitted. The technical exams for amateur radio licenses are usually administered several times a year in various places. In many countries, volunteers provide ham radio training. In the US, see www.arrl.org/licensing-education-training. In the UK, http://rsgb.org/main/faq/how-to-become-a-radio-amateur-faq/.

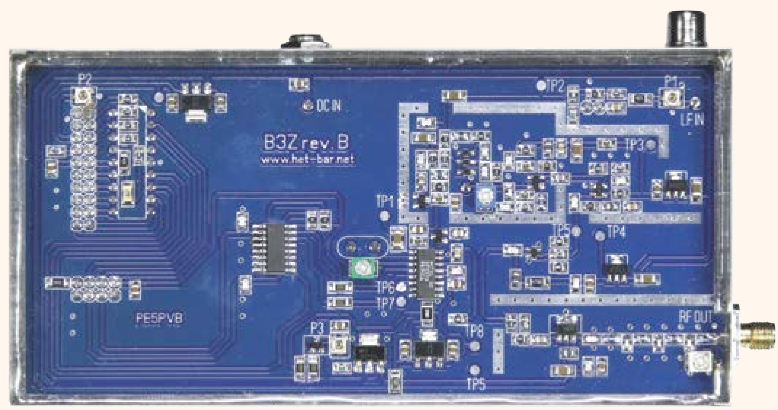
You can use a scanner or a receiver with wideband FM capability to receive the signal. A downconverter, which converts the 430–440 MHz band to a different band such as 90–100 MHz, is often used for this purpose. This allows you to use an ordinary FM radio to listen to the signal.

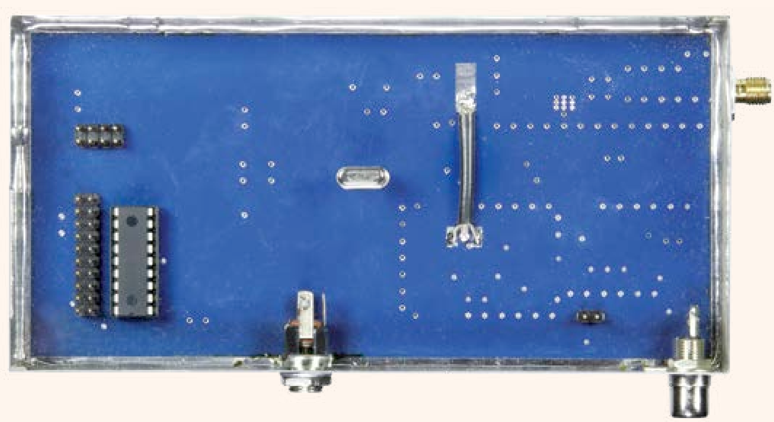
Schematic

We opted for a Colpitts oscillator to generate the RF signal for the exciter. It is built around a dual-gate MOSFET (T2). This oscillator operates at the transmit frequency. In a Colpitts oscillator, the frequency is determined by a parallel resonant circuit consisting of a capacitive voltage divider and a coil. In this case capacitors C23 and C25 form the voltage divider and L4 is the coil. The coil consists of a short piece of thin coax cable, which essentially works the same way as a stripline. Modulation due to mechanical vibration can be largely avoided by using relatively flexible cable, such as RG174. Feedback is necessary to make the circuit oscillate, and this is provided by resistor R25. Many Colpitts oscillator circuits use direct feedback without a resistor, but practical

Construction Tips

- Use only ceramic capacitors, even for values above 1 µF.
- Most resistor and capacitor packages are 0805, but a few are 1206.
- If you make your own PCB, ensure that it has enough vias. This is particularly important in and around the RF section.
- Use inductors **without** ferrite cores. This is especially important in the oscillator stage, since ferrite is a known cause of noise.
- Fit the entire circuit in a sheet metal enclosure. The PCB layout is designed with standardized dimensions.
- First prepare the sheet metal enclosure (holes for DC, audio and RF connectors). Then place the bare board in the enclosure and solder it all around on both sides. Fit the components only after the board has been fully mounted in the enclosure.





- Power the exciter from a clean supply voltage. Some switch-mode power supplies have frequency components on the output voltage that are directly audible as noise or whistles. A conventional power supply is always the best choice.

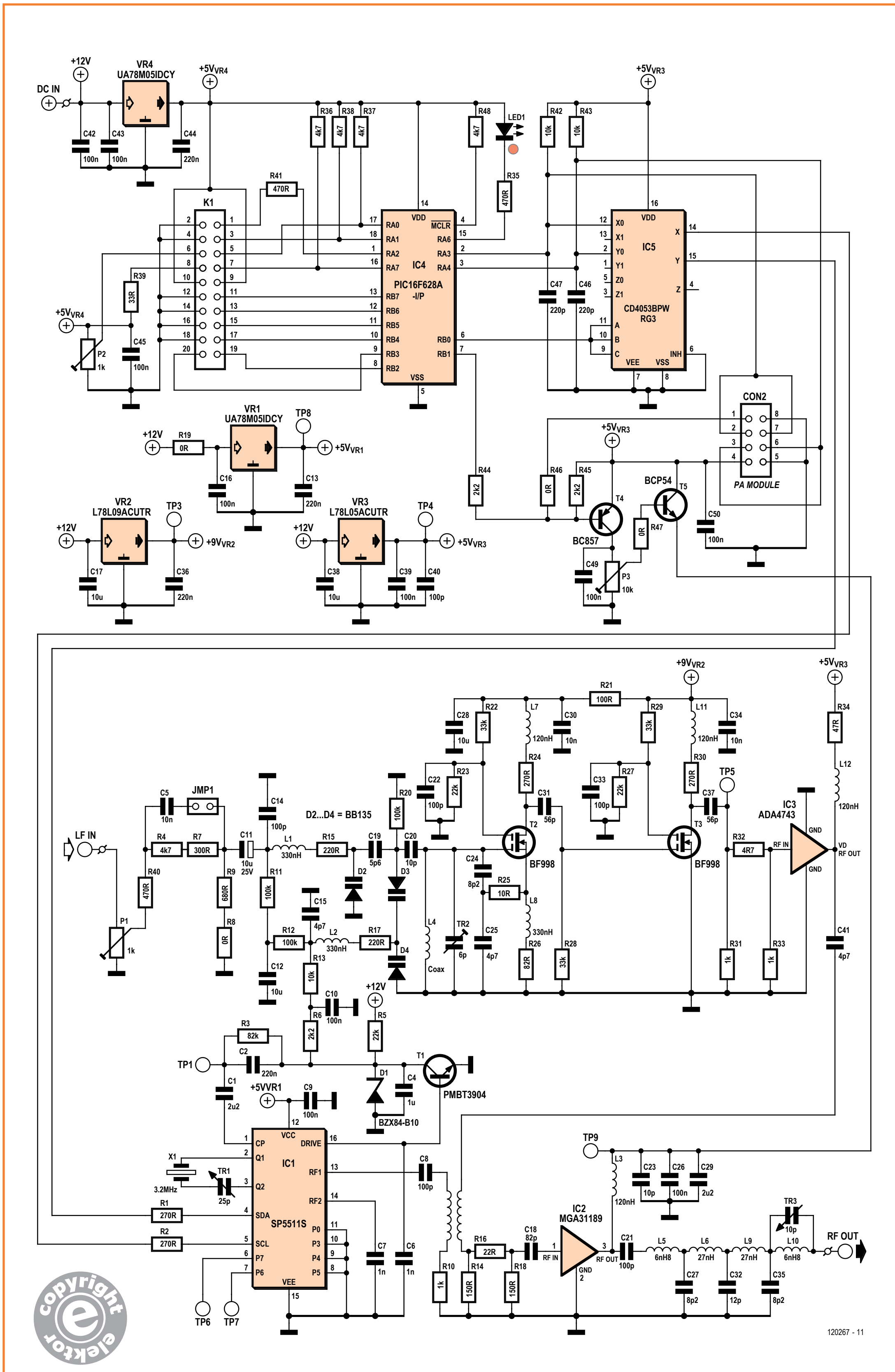


Figure 1.
Schematic of the main circuit board with the microcontroller and RF section.

experience shows that a bit of resistance makes the circuit more stable, with a cleaner frequency. Trimmer TR2 is provided to allow the oscillator to be adjusted to the desired frequency range. Diodes D3 and D4 are varicaps driven by a control voltage. This allows the frequency to be tuned electrically over a range of approximately 30 MHz.

Since this is an FM exciter, we need to be able to modulate the frequency of the carrier signal according to the amplitude and frequency of the audio signal. This is done with the aid of varicap diode D2. Varying the voltage on this diode affects the capacitance of the LC circuit, which causes a frequency deviation. To keep the modulation as linear as possible, we opted to use different varicap diodes for tuning and modulation. To avoid excessive differences in modulation depth between low and high frequencies, the modulation varicap is biased by a high-impedance voltage divider consisting of R11 and R12, with C12 added to improve stability. Inductor L1 prevents excessive capacitive load from the modulation circuit, which could otherwise cause the oscillator to stop working. Capacitor C14 provides HF decoupling for the modulation input and additionally ensures that the upstream part of the modulation path does not affect the resonant frequency of the oscillator circuit. Finally, components C5, R4, R7, R8 and R9 provide (defeatable) pre-emphasis. If necessary, you can increase the value of R8 as desired to reduce the pre-emphasis attenuation. The design is dimensioned for a pre-emphasis of 50 µs.

A buffer stage at the output of the oscillator, which is also implemented using a dual-gate MOSFET (T3), keeps the loading of the oscillator output as uniform as possible to maintain the stability of the RF signal.

The RF signal, at a power level of approximately 1 mW, is attenuated slightly to provide a good match to the next amplifier stage. In recent years the market has been flooded with a large variety of monolithic microwave integrated circuits (MMICs). These devices are specifically designed to amplify signals in the microwave frequency range. The main advantage of these ICs is that they make it easy to amplify RF signals without using tuned circuits. This avoids additional circuit complexity, cuts down on board space, and considerably reduces the cost of the overall circuit. For our design we chose MMICs from Avago Technologies, in part because they are a good fit with the circuit and in part because it's important to choose MMICs that are readily available. The first MMIC (IC3, type ADA4743) amplifies the RF signal to about 40 mW. This signal is attenuated and then fed to an MGA31189 (IC2). This MMIC has a rated output power of 250 mW. However, in this circuit we limit the supply voltage of IC2 to a maximum of 4.2 V (provided by the combination of T4 and T5), so the output power is a good deal lower—about 120 to 130 mW. This is a nice power level for driving a final amplifier, which in many cases will be an RF power module.

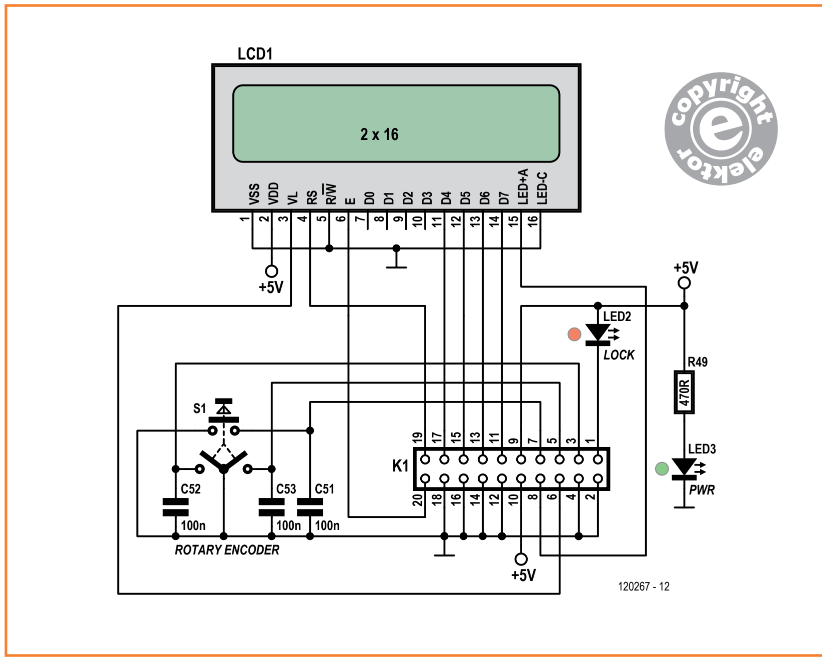


Figure 2.
The operator control section includes a rotary encoder and a 2x16-character LCD module.

A phase locked loop (PLL) is used here to set the desired frequency and keep it tuned precisely. This involves passing the transmit frequency through a frequency divider and comparing the output signal with a reference signal. If there is any difference, a control voltage tries to adjust the frequency to reduce the difference until the divided-down RF signal and the reference signal are in phase. In our circuit this control voltage is applied to varicap diodes (D3 and D4) after filtering by a loop filter. The loop filter is essential and must be dimensioned to keep the PLL from responding too fast. This is because the oscillator is frequency modulated, so the frequency varies according to the applied audio signal. If the PLL responds too fast, the sound quality of the

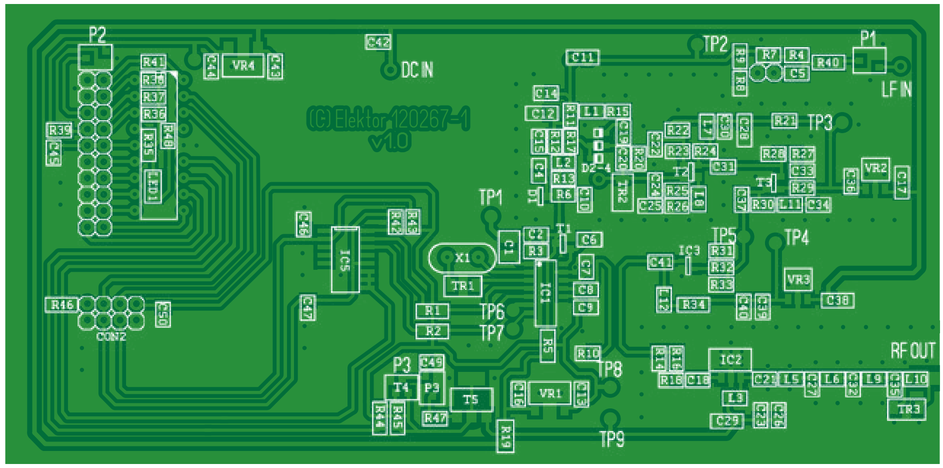


Figure 3.
The main PCB has components fitted on both sides.

modulated signal will be affected. It is therefore important to find a good balance between maximum bandwidth (approximately 180 kHz) and frequency stability. In this circuit we use an SP5511 or TSA5511 (IC1) for the PLL. These devices are readily available and affordable. These PLL ICs were originally intended to be used in TV tuners (including satellite tuners). They are often seen in older-model television, video recorder or satellite tuners. The smallest frequency increment this PLL can generate is 50 kHz with a 3.2 MHz crystal. However, what we want here is a step size of 25 kHz. This can easily be achieved by using the second harmonic of the RF signal as the input to the PLL. This signal is tapped off between IC3 and IC2 using inductive coupling.

The PLL IC is controlled by a microcontroller (IC4, type PIC 16F628A) over an I²C bus. A major shortcoming of the PLL IC is that it generates crosstalk between the I²C bus and the charge pump and driver stages. This results in a ticking sound in the transmitted audio signal at the clock rate of the I²C data. The author's intention was to be able to control not only the exciter but also the power amplifier (if used) or other hardware over the I²C bus. The data for this, which in such case would not be intended for the PLL, would also be audible. In the present design this problem has been solved by placing an HEF4053 (IC5) between the I²C bus and the PLL IC. When the data on the I²C bus is not intended for the PLL, the I²C link to the PLL is blocked. This is a very low-cost and effective solution.

The exciter is controlled using a rotary encoder with a built-in pushbutton. Along with two LEDs and the display module (see **Figure 2** for the schematic), it is located on a separate PCB which is connected to K1. In operation, you simply select the transmit frequency and then press the rotary encoder to confirm the setting. The corresponding data is sent to the PLL IC, and the PLL status is read out. When the PLL indicates that the phase difference between the divided-down RF signal and the reference signal has been reduced to zero, this information is fed back to the microcontroller. The microcontroller then lights up LED2 (the PLL Lock indicator). It also switches on the supply voltage to the final MMIC, so that the exciter only outputs an RF signal when it is actually operating at the selected transmit frequency. The supply voltage of the final MMIC can be adjusted with potentiometer P3, which allows the output power to be reduced to any desired level down to approximately 1 mW. This makes the exciter suitable for use with a wide variety of final amplifiers. The eight-pin header CON2 can be used to connect a external device to be controlled by the microcontroller, such as a final amplifier.

When the author began working on this design, he was not especially familiar with microcontroller programming. He started off with the PIC Simulator IDE. This is a very simple software development environment that uses its own version of Basic. The nice thing about this software is that it includes a complete simulator, so you can fully simulate the software before loading

it into a microcontroller. A drawback is the limited calculation options. To avoid making thing too complicated, the author chose to work with two different counters. One of these counters handles the frequency readout, while the other provides the divisor. In other words, if you raise the transmit frequency on the display by 25 kHz, the counter setting for the divisor is increased by 1. At the lower and upper ends of the frequency band covered by the exciter (430 MHz and 440 MHz), the counter for the divisor is preset to a default value.
All necessary information for this project (PCB layouts, components list, source code and hex code files for the microcontroller) is available on the Elektor website [1].

Operation

The entire exciter is operated using a single rotary encoder with a built-in pushbutton. You select a new frequency by turning the encoder knob. When you do this, “TUNE” appears in the top left corner of the display. When you press the encoder knob, the new frequency is saved in memory and the exciter is tuned to this frequency. When the PLL is locked, the Lock LED lights up and the output stage is switched on. If the PLL cannot achieve lock, the Lock LED remains dark and the indication “PLLERR” is displayed. If the PLL does not receive any data over the I²C bus, the indication “I2CERR” is displayed. In both cases the microcontroller will try to keep trying to configure the PLL until it achieves lock.

Construction

When building RF circuits, especially at relatively UHF, it is important to keep all connections as short as possible. The ground level should also be kept as ‘cold’ or ‘earthy’ as possible. That’s why there are so many vias in the layout of the author’s prototype PCB (shown at reduced scale in **Figure 3**). If you want to make your own PCB, it is very important to include these vias. The board is designed to be fitted in a sheet metal box measuring 74 x 148 mm, which is a commercially available size. The board must be soldered to the sheet metal of the box along all edges on both the top and the bottom sides. This provides an optimal ground connection. Fitting the board in a sheet-metal box and soldering it all around are very important. A DIY box made from PCB material is not suitable for this circuit.
The construction procedure used by the author is as follows. First clamp the bare board in the sheet-metal box and fit all necessary chassis components. An SMA chassis-mount connector is recommended for the antenna connection. If you use a bulkhead connector, it can easily be soldered to the sheet metal. This also eliminates the need for screws. The connectors for the supply voltage and the audio input can be fitted in any desired location. A Cinch (RCA) chassis-mount connector is a good choice for the audio connection.

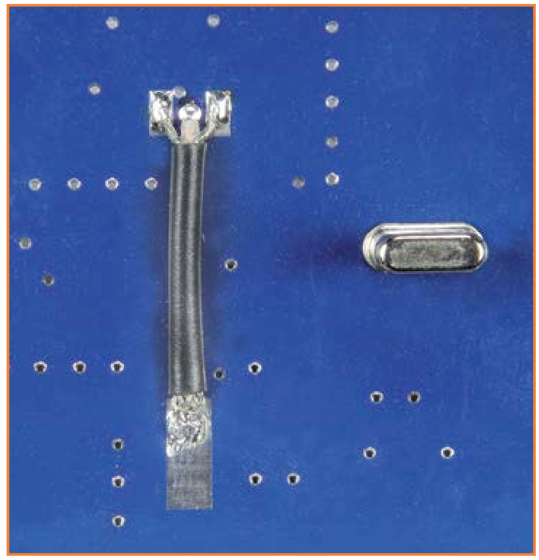


Figure 4.
Along with the microcontroller and several headers, a length of coax cable acting as the oscillator coil is fitted on the bottom side of the board.

All SMDs are located on one side of the board, while three pin headers, the coax stripline and the microcontroller are on the other side. **Figure 4** shows a detail view of the stripline. It consists of a length of flexible coax cable measuring 4 cm, with both ends soldered to the PCB. At one end the center conductor and the braid are joined together and soldered to the PCB. At the other end the braid must be divided in two and soldered to the ground plane as shown in the photo, with the center conductor soldered to the pad between these two points.
After this you should assemble the circuit section by section. Start with the oscillator. Check that it oscillates in the 400–500 MHz range. You can use a frequency counter or a spectrum analyzer for this. Then fit the components for the buffer stage and the two MMIC amplifier stages. Provide a temporary supply voltage connection for the final MMIC so that it also operates. Check the RF signal with an RF millivoltmeter or other suitable instrument.

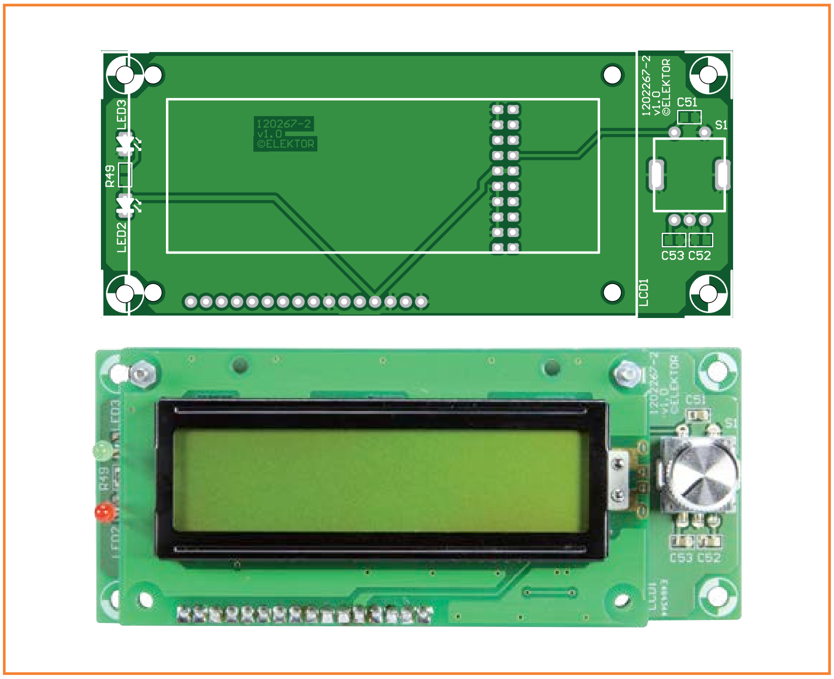


Figure 5.
The control board is fairly simple and easy to build. However, note that the 2x10-pin header for the connection to the main board must be fitted on the rear side.

If the RF portion works properly, you can then assemble the PLL and microcontroller portions of the circuit. Use an 18-pin socket for the microcontroller, and program the microcontroller before inserting it in the socket.

The operator controls are located on a separated PCB as illustrated in **Figure 5**. Assembly of this board is straightforward. All components (except one) are fitted on the side with the component overlay. You can use a 16-pin header with a matching connector to connect the display module. On the rear side of the board, fit a 20-pin header for connection to K1 on the main board with a 20-lead flat cable.

Adjustment

- Connect the exciter (with the display) to the supply voltage. Adjust P2 for the best display contrast.
- Then adjust the frequency to 435 MHz. Using a ceramic or plastic trimmer tool, slowly rotate TR2 until the transmit frequency is 435 MHz. Measure the voltage at TP1 and turn TR2 until the measured voltage is approximately 6 V. Now you can use a frequency counter or spectrum analyzer to set the transmit frequency to exactly 435.0 MHz with TR1.
- Then adjust P3 for maximum RF power. Next you have to adjust the notch frequency. A spectrum analyzer is necessary for this. Measure the second harmonic at 870 MHz and adjust TR3 for minimum power. If you do not have a spectrum analyzer, you can use an RF millivoltmeter and adjust TR3 for maximum output power. However, you should bear in mind that filtering will be suboptimal in this case. This must be dealt with in the power amplifier connected after the exciter.
- Check that the exciter works properly at both 430 MHz and 440 MHz. Fit a jumper in the pre-emphasis jumper position and connect an audio source, such as a CD player. Then adjust P1 for optimal audio amplitude without distortion.

The 70-cm FM exciter is now ready for use. We realize that some radio amateurs do not have a lot of experience with soldering SMDs by hand. If there is sufficient interest, the author is willing to assemble and adjust a number of boards at a reasonable price. If you are interested in this, please contact the author directly at [2].

(120267-I)

Internet Links

[1] www.elektor.com/120267

[2] pe5pvb@het-bar.net

Adjustment Points

P1	Modulation depth (audio)
P2	LCD contrast
P3	Output power
TR1	Fine tuning (reference oscillator)
TR2	Coarse tuning (RF oscillator)
TR3	Second harmonic filter notch frequency

Test Points

TP1	PLL control voltage
TP2	Modulation signal after pre-emphasis
TP3	Oscillator voltage (9 V)
TP4	Driver stage voltage (5 V)
TP5	Output stage voltage (0–4 V)
TP6	PLL divider output frequency
TP7	PLL reference frequency

Smartphone A/V Remote Control

Transmitter plus App for Android devices

By **Peter Zirngibl**
(Germany)
(info@pezitec.com)

The best types of universal remote controller come equipped with a large touch screen, just like the one on your Smartphone. So why not use your phone to control all the A/V appliances at home?

Armed with a Smartphone you can surf the Web, send emails, text, chat, download and listen to music, take and post photos and video clips, listen and view TV stations, navigate, place bets and yes, even make phone calls to anywhere on the globe. Tens of thousands of Apps are also available to make the Smartphone the most universal, configurable control and communication device ever created. It is not surprising that there are also Apps which allow you to control the newer generation of home WLAN-equipped A/V equipment. The WLAN interface allows signals from the phone to be routed through to control the equipment directly without the need for additional hardware. Older A/V equipment generally only have the more traditional IR remote control interface and Smartphones still have no built-in IR transmitter.

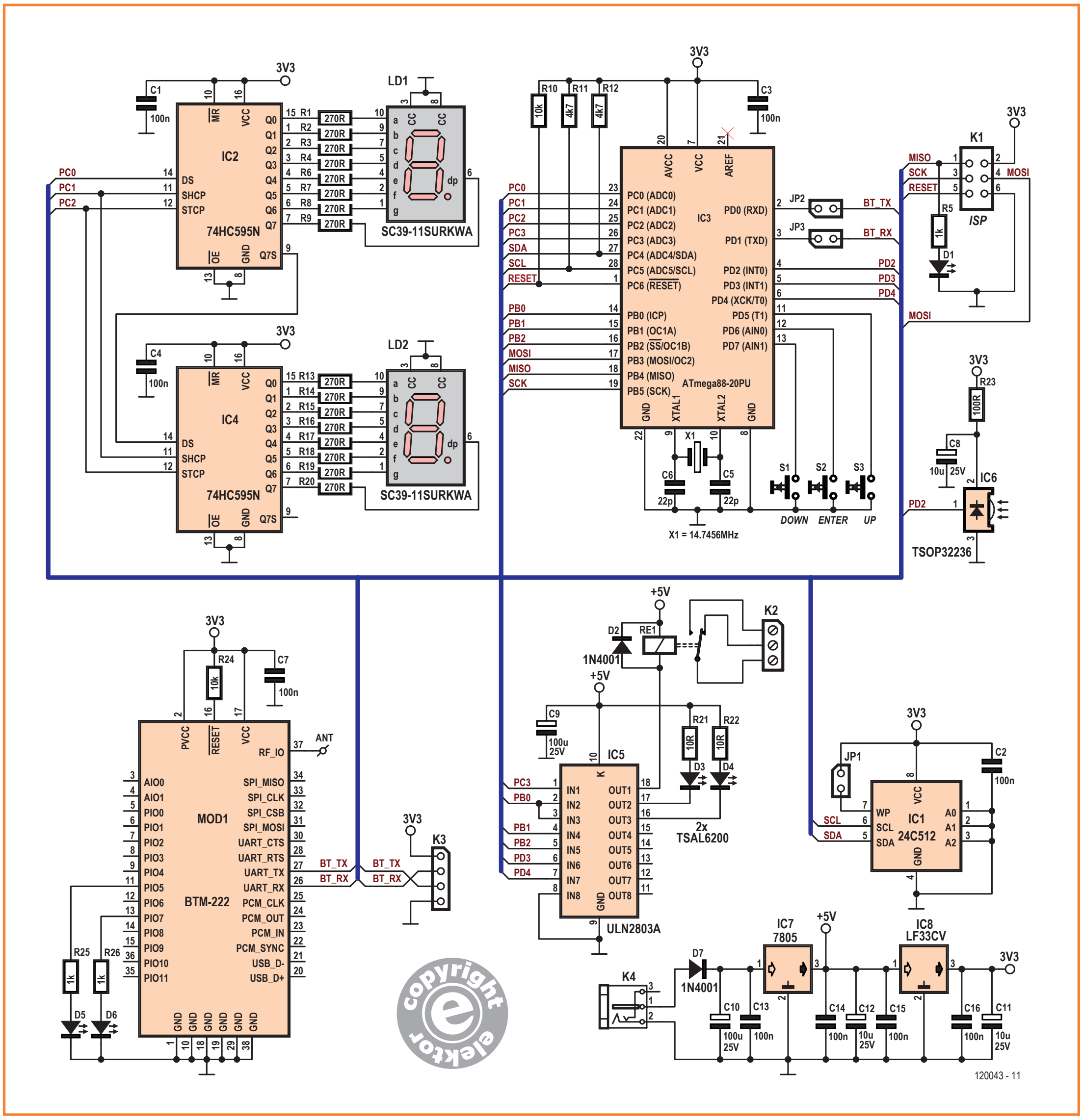


Figure 1.
The high level of integration in the Bluetooth module reduces circuit complexity.

The vital bit of kit missing here is an intelligent adapter that can on one side communicate with the phone using Bluetooth and on the other, transmit IR signals to control the A/V equipment. Intelligence, in this context generally means that a device has the ability to 'learn' a sequence of commands. This of course implies that a learn process is necessary. The adapter needs to know the particular variant of remote control that is in use and which button controls which feature of the controlled equipment. Simple, low cost universal remote controllers are pre-programmed with thousands of different command sets for all the different makes of equipment. They are generally only able to control a few basic commands like PLAY or STOP. It is not possible to edit the commands and a learn function is only possible with the more expensive types of universal remote controller.

Some of the better types are able to execute macros which involve a sequence of commands (e.g. Watch a DVD = switch on DVD player, TV, AV receiver, then configure the correct video and audio channel). This procedure is also possible with the Bluetooth-IR adapter described here.

The newer, better quality (and more pricey!) type of universal remote controllers can now be conveniently programmed using a PC. To cut down on the software expenditure for this project we decided against this approach. In this design the adapter is programmed by reading the IR signals directly from the original remote controller.

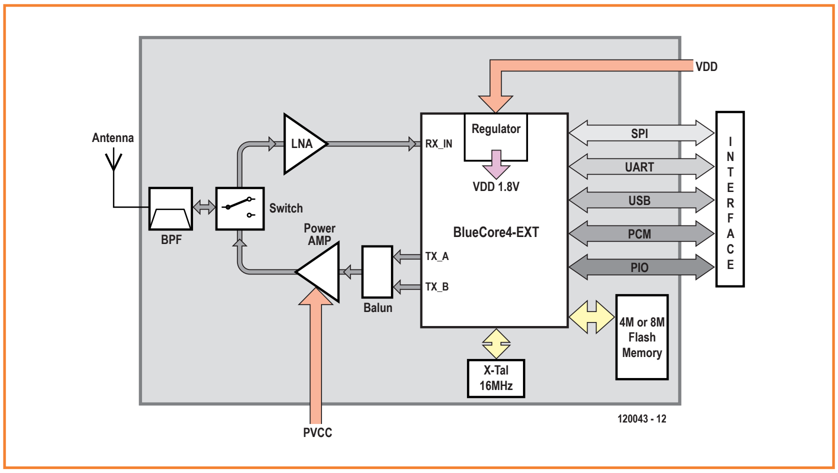


Figure 2.
Block diagram of the BTM-222 Bluetooth module.

This means that the IR remote transmitter is placed in front of the IR adapter's receiver and the command transferred. How this is exactly accomplished will be covered in more detail later, first we will take a closer look at the hardware.

A radio-linked controller

The circuit diagram given in **Figure 1** indicates that there really isn't too much hardware used in the adapter design. It basically consists of a small Atmel type ATmega88 microcontroller together with some peripheral components:

- A 24C512 EEPROM with 512 kBit memory and I2C interface to store the programmed codes.
- An infrared receiver module type TSOP32236
- Two IR transmitter diodes type TSAL6200 driven by a ULN2803 driver chip.
- A two character 7 segment display with an HC595 8-bit shift register to show the programmed codes and program status.
- Three pushbuttons UP, DOWN and ENTER, for programming and operating.
- In-System-Programming interface K1.
- A relay with changeover contacts driven by the peripheral driver chip.
- Voltage regulators for +5 V and 3.3 V

You have probably seen all of these features many times before in many other circuits, however the real star of the show here is the BTM-222 Bluetooth module from Rayson. A description of the module is contained in the data sheet [1]. The module is small, portable, easy to program and above all (around $10 a pop) affordable. In time, as we move to a more wireless future, all peripherals will probably communicate using devices like this. The BTM-222 is a class 1 device giving it a range of up to 300 ft. As you can see from its block diagram in **Figure 2** it includes many serial interfaces and from these the UART must be favorite for microcontroller communications. Data throughput of the UART (and the USB interface) in the BTM-222 is guaranteed at the full data rate of 921 Kbit/s. The BTM-222 UART used with a microcontroller requires hardly any additional components. The communication parameters are factory set to the standard 8N1 setting:

- Baud rate 19,200 Baud
- 8 data bits
- No parity
- 1 stop bit

The microcontroller only needs to open the corresponding UART channel. As required, parameters and other properties of the module can be accessed using the so-called 'AT command' set of instructions. More information on this aspect is contained in the BTM-222 data sheet [1]. The settings are stored in an internal flash memory. The 'blue' core of the module is clocked by an internal 16 MHz oscillator. The output signal is

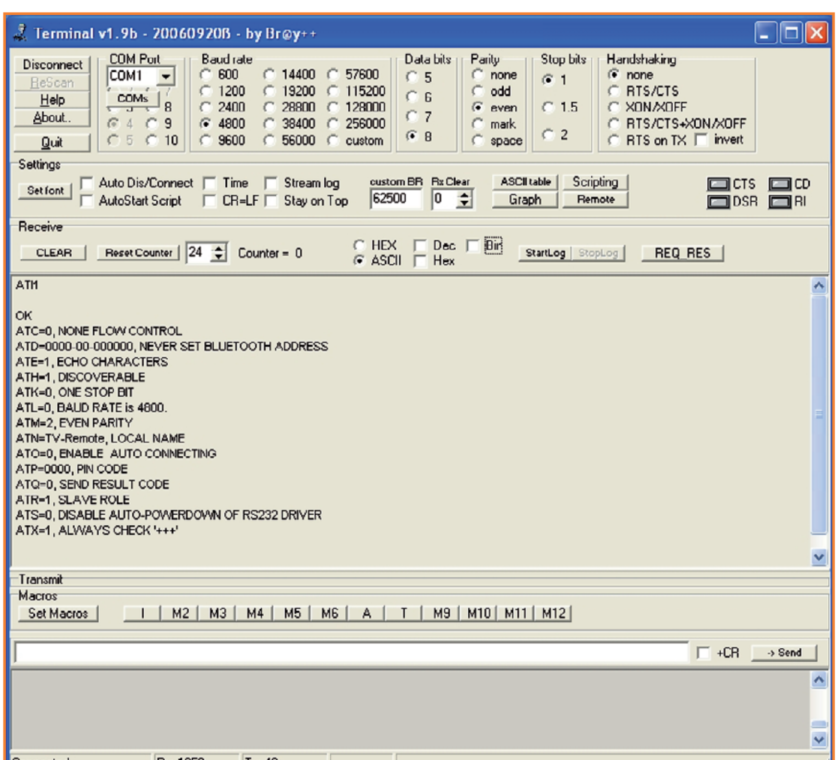


Figure 3.
A terminal program is used to set up the Bluetooth module to the displayed parameters.

fed to a balun and then to an RF power amplifier producing a signal of +18 dBm at the aerial. For signal reception the BTM-222 switches the received signal to a low-noise amplifier block (LNA) followed by a band-pass filter to reduce out-of-band signal interference. The BTM-222 does not require any external aerial; a short length of PCB track can be used. Here we have used a short piece of wire.

The module provides some status output signals: the data status (LED D5 on pin 11) and the connection link status (LED D6 on pin 13) are both used in the circuit. There is also an operating voltage status indicator output from pin 14 but we have not used it in this application.

BTM222 set up

Initially the Bluetooth module needs to be configured with the correct parameters. First remove jumpers JP2 and JP3 to disconnect communications with the microcontroller. Connect the BTM-222 to a PC using, for example a TTL-232R cable from FTDI, connected to K3. The cable carries a 5 V line (connecting to pin 1 of K3) which must not be allowed to make contact with the BTM-222 supply (this is at 3.3 V, and its upper limit of 3.6 V must not be exceeded). It is therefore important to leave pin 1 of K3 unconnected and power the Bluetooth module from the board power supply.

Run a terminal emulation program such HyperTerminal or Hterm on a PC (**Figure 3**), select a (virtual) COM port, to which the Bluetooth module is connected and use the serial port settings given above for the BTM-222 serial interface. Check to see if the module reacts to the `ATI` command; this should cause all the module settings to be dumped to the screen. If there is no response check that the 3.3 V supply, the COM port settings and the connections on K3 (TxD/RxD switched?) are in order. If you are unsure of the module settings or maybe suspect that the BTM-222 is not operating correctly you can pull pin PIO4 high for a minimum of three seconds to reset the module to its factory settings.

Change the UART settings to 4800 Baud (ATL = 0), even parity (ATM = 2), no handshake flow control (ATC = 0). Adjust the terminal emulator settings after each parameter change. Finally you can change parameters such as the module name or the Bluetooth connection PIN code as you wish.

Turn on the Smart phone (or other Android device), check that the BTM-222 has been detected and enter the PIN for the connection. When everything is in order turn the remote control unit off, disconnect the PC and place the two jumpers in positions JP2 and JP3.

The Remote App

Once the *Remote_Control.APK* App has been installed the Android Smart phone will be capable of remote control. Bring up the App to begin pairing with the BTM 222 module. Choose the Bluetooth device using SELECT DEVICE and use CONNECT to establish a connection to the device. LED D6 lights up indicating that the module is connected to an Android device and D5 flashes when data is being received.

The transmitted value (0 to 99) plus a line feed character tells the adapter which memory location is referenced. In playback mode the command received from the Bluetooth module can be evaluated. The principle is really simple: ‘2/n’ is received and the adapter jumps to memory position 2, and transmits the command stored in this position (in this case turning up the volume of device 1). Commands 73 and 74 do not produce any IR signal but instead operate a relay. Command 73 closes the relay contacts for two seconds while command 74 toggles the relay contact state between off and on. Connector K2 provides connection to the contacts, allowing external equipment to be switched on and off.

Figure 4 shows the App running in all its glory on a Smartphone. With the left/right arrows at the top you can choose between five different devices. For each device you can choose to enter a name in the text box and store it with the Save button. The name is retained so it appears

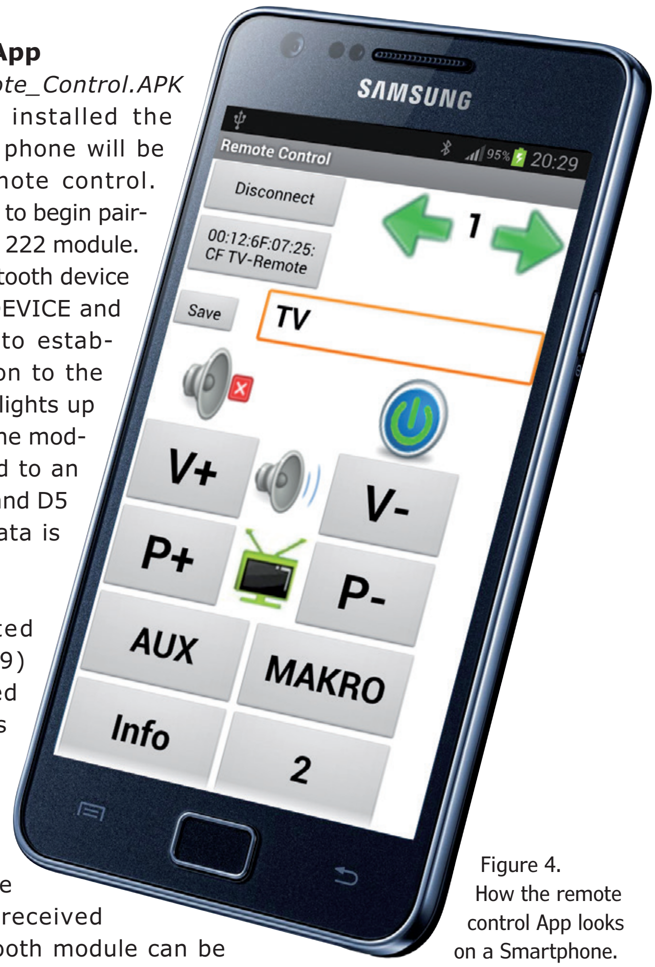


Figure 4. How the remote control App looks on a Smartphone.

when the App is next started. In addition you can add a description to the functions 1 to 10. Press the EDIT button, choose the button to edit and enter the text. Press SAVE to store the text. This sequence is the same for every device.

Camera, action!

The controller software is divided into two parts; the programming mode and the operational mode. In programming mode the remote controller infrared command signals are recorded in the adapter memory in the following manner: First it is necessary to clear the serial EEPROM. This is accomplished by pressing all three buttons simultaneously and applying power to the adapter. When the seven segment displays show `dE` (delete) the three buttons can be released. The complete erase process takes a few minutes before `00` is shown in the display.

To record the commands in programming mode hold the ENTER button (pin PD6 to GND) before connecting the supply voltage. On the seven segment displays `Pr` should flash three times (Programming mode). Now find a memory position from 0 to 99 using the UP/DOWN buttons (pin PD5 and pin PD7) and select it using the ENTER button. The display will show the symbol `-` indicating its readiness. The remote controller can now be bought within 2 to 10 cm to the IR receiver and the required command button on the remote controller pressed once (once only!) Try to complete this process quickly to reduce the chance of recording some interference. The display should now show `io..` as confirmation. Recording a macro is possible for each device, each macros can contain up to six commands. Macros are stored in the same way that single commands are stored.

COMPONENT LIST

Resistors
R1-R4,R6-R9,R13-R20 = 270Ω
R5,R25,R26 = 1kΩ
R10,R24 = 10kΩ
R11,R12 = 4.7kΩ
R21,R22 = 10Ω
R23 = 100Ω

Capacitors
C1,C2,C3,C4,C7,C13,C14,C15,C16 = 100nF
C5,C6 = 22pF ceramic
C8,C11,C12 = 10µF 25V radial
C9,C10 = 100µF 25V radial

Semiconductors
D1,D5,D6 = LED, red, 3mm, low current
D2,D7 = 1N4001
D3,D4 = TSAL6200 (Vishay) 940nm IR transmitter diode
LD1,LD2 = SC39-11SURKWA (Kingbright) 7-segment-LED display, 10mm
IC1 = CAT24C512LI-G (On Semiconductor)
IC2,IC4 = 74HC595N
IC3 = ATmega88-20PU (Atmel), programmed, Elektor # 120043-41 [2]
IC5 = ULN2803APG
IC6 = TSOP32236IR (Vishay) 36kHz IR receiver
IC7 = 7805
IC8 = LF33CV (STMicroelectronics)
Mod1 = BTM-222 (Rayson) Bluetooth module

Miscellaneous
X1 = 14.7456MHz quartz crystal
Re1 = 6V SPDT relay (1x c/o contact), Finder 43.41.7.006.2000
S1,S2,S3 = tactile switch, SPNO, round

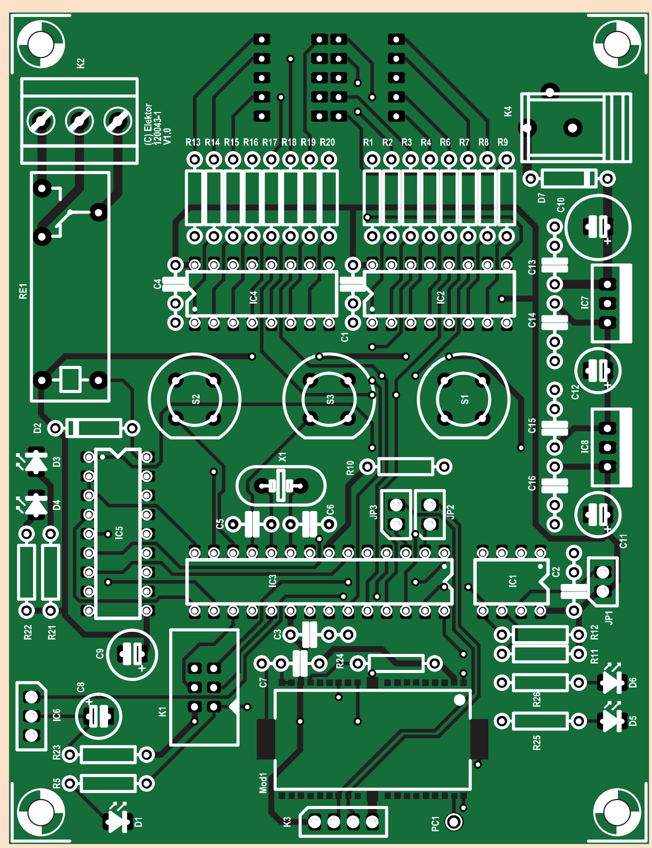


Figure 5.
The circuit board layout.
All of the user interface elements are located on the underside.

When the IR signals are recorded the pulse widths are stored as *Unsigned integer Variables,* buffered and then saved to the EEPROM. To program another command it is necessary during the confirmation display (`io.` flashing) to hold the ENTER button after programming to generate a μC reset.

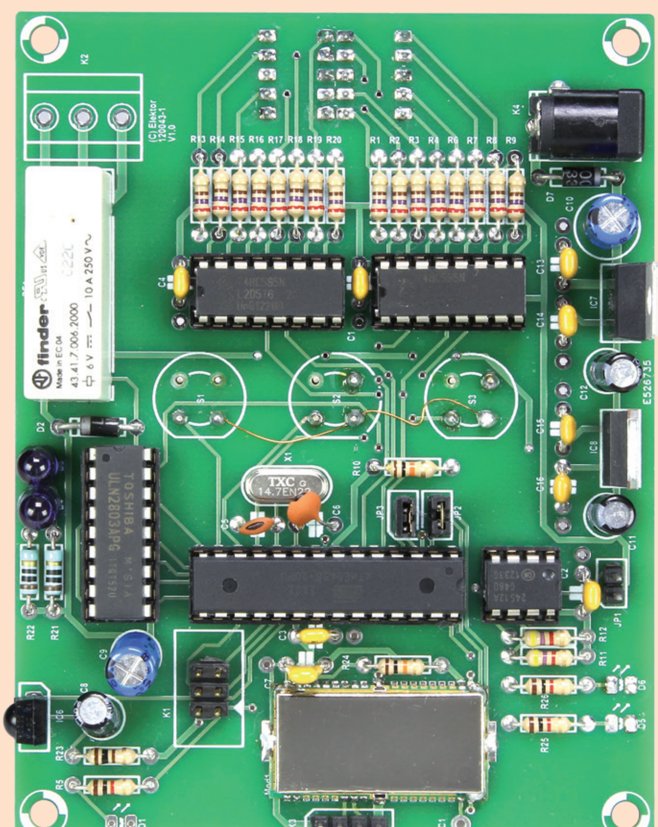
With no other button pressed during reset the program automatically jumps into playback mode. Now using UP/DOWN buttons you can select the command you have just stored and press ENTER to transmit it over the IR diode to switch the A/V equipment. This will show if the command was correctly stored.

On the PCB

A PCB for the remote control adapter is available from the Elektor shop [2], where you can also order a preprogrammed microcontroller. Use this link to find the compiled App and the firmware source code. A look at the PCB layout should allay any fears for the home constructor; although the Bluetooth module has an SMD outline connections are spaced at 1.25 mm and are relatively easy to solder by hand with a standard fine tipped iron. Correct placement of this module is important prior to soldering. Pin 1 can be identified by a small round dot on the metal screen (on the side by the aerial). This pin should be orientated near the PC1 label on the PCB. The thick pads along the long sides and at the ends are at ground potential and connected to the module's continuous earth plane.

Once the module has been soldered in position the other through-hole components can be fitted. It is recommended to mount the IC components

JP1,JP2,JP3 = 2-pin pinheader with jumper
K1 = 6-pin (2x3) pinheader
K2 = 3-pin PCB screw terminal block, pitch 5mm
K3 = 4-pin SIL connector
K4 = low voltage adaptor socket, 2.1mm
PCB 120043-1 [2]



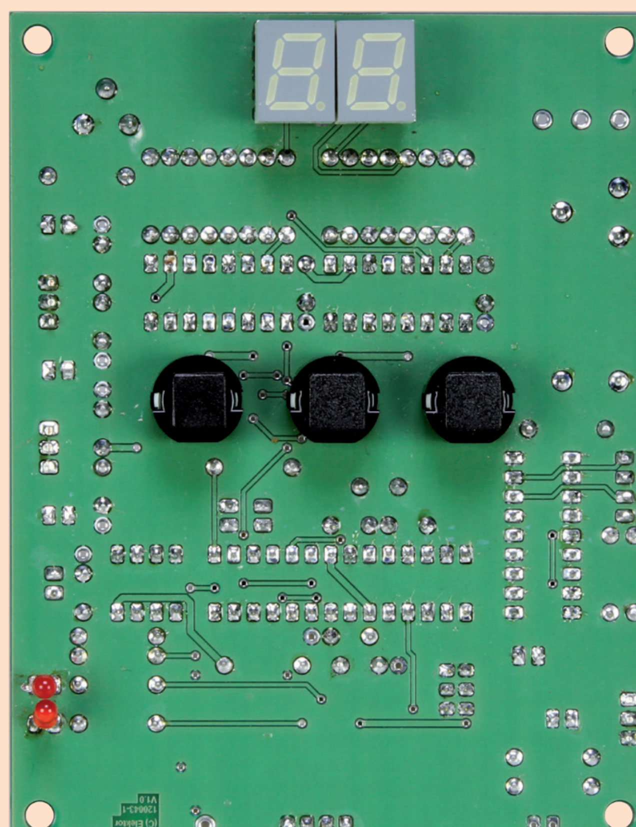


Table 1. Assignment of memory position and function

Function	Device				
	1	2	3	4	5
MUTE	0	8	16	24	32
ON/OFF	1	9	17	25	33
VOL+	2	10	17	26	34
VOL-	3	11	19	27	35
PRG+	4	12	20	28	36
PRG-	5	13	21	29	37
AUX	6	14	22	30	38
MAKRO	7, 75-79	15, 80-84	23, 85-89	31,90-94	39, 95-99
Function 1	40	50	60		
Function 2	41	51	61		
Function 3	42	52	62		
Function 4	43	53	63		
Function 5	44	54	64		
Function 6	45	55	65		70
Function 7	46	56	66		71
Function 8	47	57	67		72
Function 9	48	58	68		73 1)
Function 10	49	59	69		74 2)

1) Relay on for 2 s 2) Toggle relay

using sockets. Both seven segment displays, the three push buttons, D5 and D6 are fitted to the PCB underside. This leaves all the 'HID' devices on the same side of the board which makes it simpler to install into a case. A simple short length of cable is suitable as an aerial. According to the calculation at 2.4 GHz (13 cms band) the aerial should be around 3.1 cm (λ/4), but the length is not too critical and for this application we only need relatively short range communication. The main thing to remember is that if the unit is fitted in a metal housing please ensure that the aerial extends outside the case.

(120043)

Internet Links

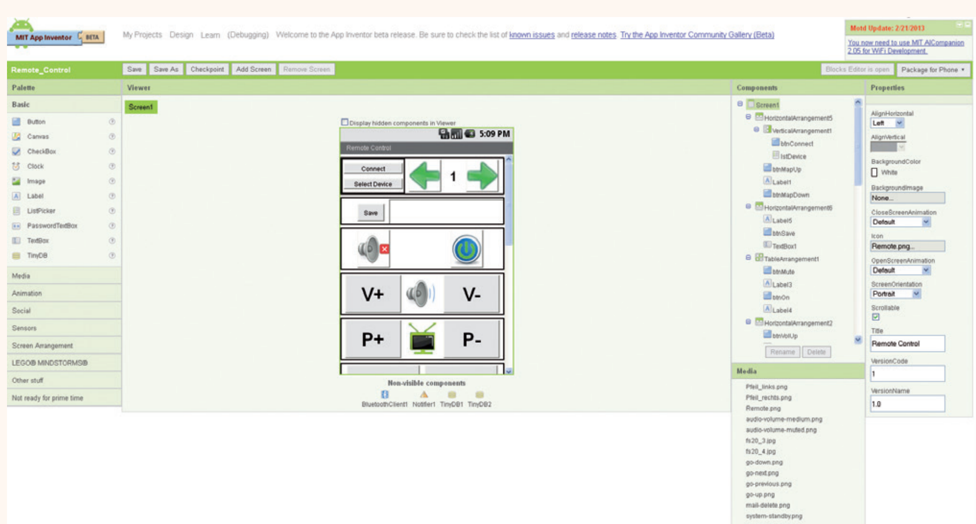
[1] www.mikrocontroller.net/wikifiles/f/fc/BTM222_DataSheet.pdf

[2] www.elektor.com/120043

[3] http://appinventor.mit.edu

App Editing

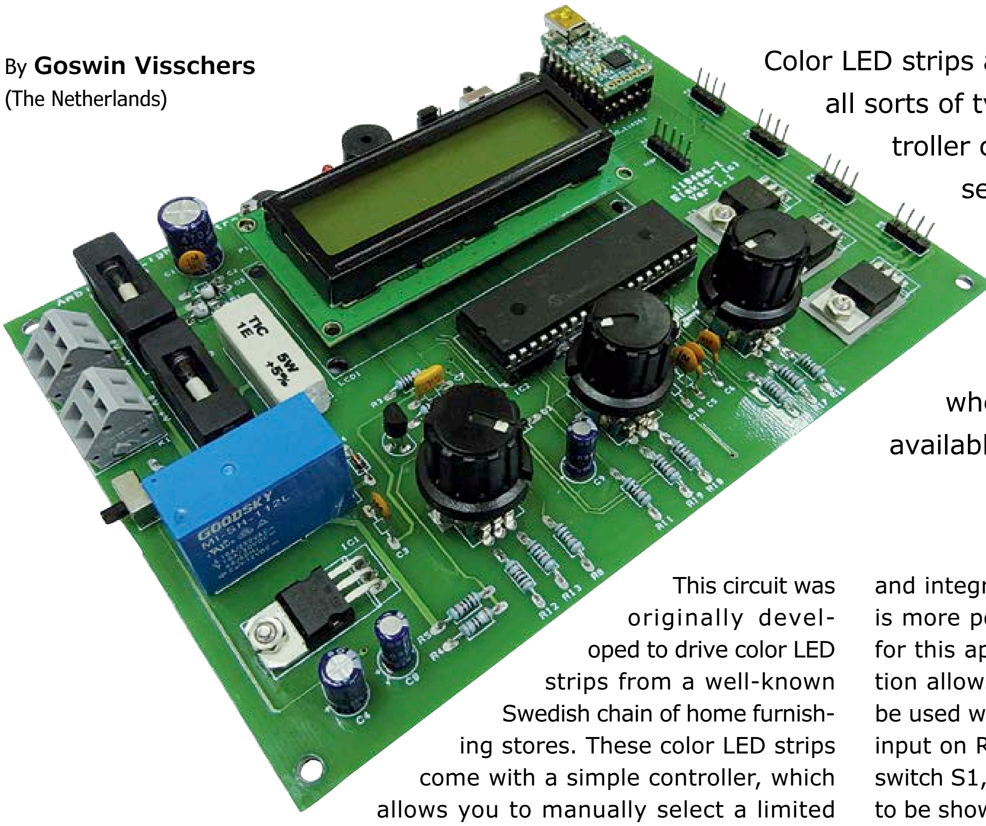
The App was developed using MITs App Inventor [3]. To make changes to the App it is first necessary to create a Gmail account and then login to the web site [3]. Load *Remote_Control.ZIP* under 'My Projects' of the App-Inventor in 'More Options' -> 'Upload Source'. The App can then be edited and compiled on line and the resulting file '*Remote_Control.APK*' can be downloaded to the PC or installed directly to an Android device.



Ambience Lighting Controller

Setting the mood with RGB LEDs

By **Goswin Visschers**
(The Netherlands)



Color LED strips are now available at low cost in all sorts of types and sizes. With the controller circuit described here, you can set your own colors and even configure and run complete lighting programs. The controller is battery powered, so it can be used in places where AC power is not readily available.

This circuit was originally developed to drive color LED strips from a well-known Swedish chain of home furnishing stores. These color LED strips come with a simple controller, which allows you to manually select a limited number of colors. This restriction stimulated the author to develop a DIY controller with more capabilities. The resulting 'ambience lighting controller' is suitable for all RGB LEDs and LED strips that can operate from a 12 V supply voltage with a series resistor for current limiting.

In the author's intended application it was not possible to power the LED strips from the AC line, so the controller is designed to operate from a 12 V gel-cell battery.

The basic features of the circuit are described in the inset.

Schematic diagram

As you can see from the schematic in **Figure 1**, the circuit is fairly simple. The author chose a PIC16F887 for the microcontroller on account of its integrated EEPROM (for convenient storage of lighting programs), extensive I/O capacity and integrated ADC. Although the PIC16F877A is more popular, a sibling device was selected for this application because its ADC configuration allows the ADC inputs on RA0 and RA1 to be used without requiring any reference voltage input on RA2 or RA3. Here RC3 is connected to switch S1, which allows the battery charge state to be shown on the LCD module in two different ways. Connector K6 is the ICSP port for in-circuit programming of the microcontroller.

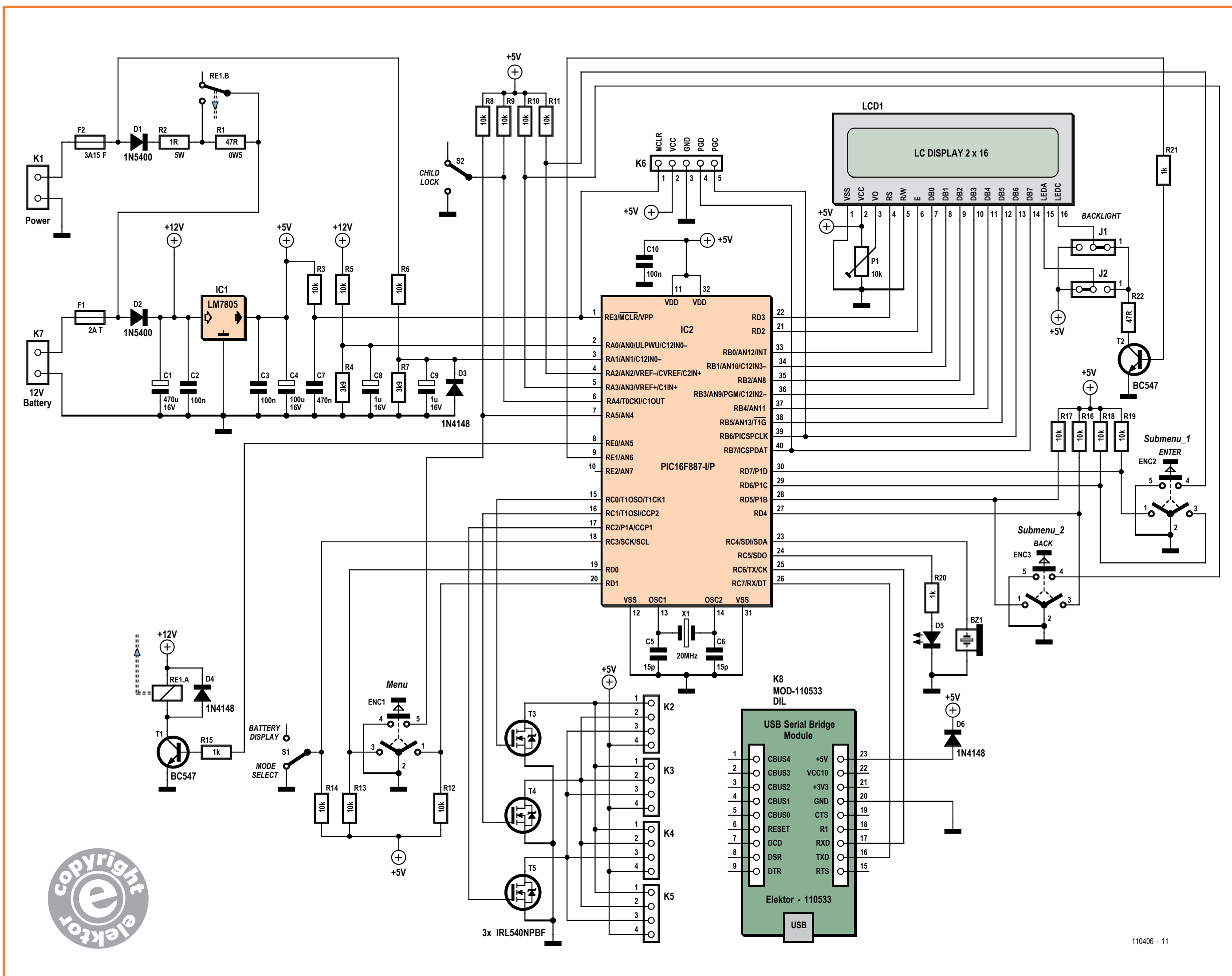
The microcontroller is clocked at 20 MHz by crystal X1. This relatively high clock frequency is necessary because the clock signal is divided by 4 inside the microcontroller. The resulting 5 MHz signal is essential for the PWM control function implemented in software.

The display module, a standard type with two lines of 16 characters (which is available in the Elektor Shop), is connected to port RB. If you use a different type of LCD, the polarity of the supply voltage for the backlight can be changed (if necessary) using jumpers in positions J1 and J2. Transistor T2 switches off the backlight after 10 seconds with no user input. The contrast can be adjusted with trimpot P1. Unlike most circuits

Features

- Supply voltage range 11–15 V
- Constant brightness over operating voltage range
- LC display (2 lines of 16 characters)
- Up to 13 user-definable colors with adjustable RGB values
- Three user-definable lighting programs with 20 color changes. The maximum duration for each color is 255 s, and the maximum duration of the transition to the next color is also 255 s. Both times can be set in increments of 1 s.
- Continuous operation with any one of the three defined programs
- Acoustic alarm when the battery is discharged, with automatic switch-off of the LED strips
- LED indicator for remaining battery charge
- Built-in charging circuit for the battery, with automatic switchover to trickle charge
- “Child lock” to prevent changes to color settings or programs
- Optional remote control via RS232/USB converter

Figure 1.
Schematic diagram of the RGB lighting controller, which is built around a PIC16F887 microcontroller.



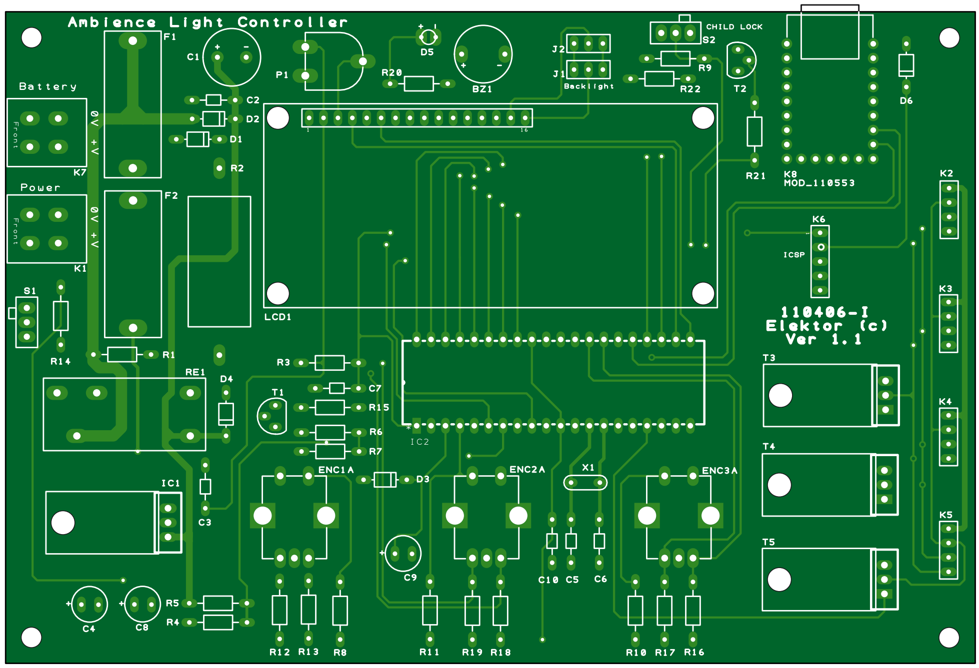


Figure 2.
The operator controls and LCD are also mounted on the PCB.

with an LCD module, here the LCD is driven in 8-bit mode instead of 4-bit mode. This simply represents a design choice, since the microcontroller has enough I/O pins available.

The color intensity of the connected LEDs is determined by pulse width modulation. Although the microcontroller has enough PWM outputs available for this purpose, the author decided not to

COMPONENT LIST

Resistors
R1 = 47Ω 0.5W
R2 = 1Ω 5W
R3,R5,R6,R8-R14,R16-R19 = 10kΩ
R4,R7 = 3.9kΩ
R15,R20,R21 = 1kΩ
R22 = 47Ω
P1 = 10kΩ preset, horizontal

Capacitors
C1 = 470µF 16V radial
C2,C3,C10 = 100nF
C4 = 100µF 16V radial
C5,C6 = 15pF
C7 = 470nF
C8,C9 = 1µF 16V radial

Semiconductors
D1,D2 = 1N5400
D3,D4,D6 = 1N4148
T1,T2 = BC547B
T3,T4,T5 = IRL540 (International Rectifier, Newark/Farnell # 8651078)
IC1 = LM7805
IC2 = PIC16F887, programmed, Elektor # 110406-41)
D5 = LED, red, 3mm

Miscellaneous
X1 = 20 MHz quartz crystal
F1 = fuse, 2AT (slow), with PCB mount holder
F2 = fuse, 3.15AT (slow) with PCB mount holder
BZ1 = active (DC) buzzer (with internal oscillator)
RE1 = relay, 12V, 1 c/o contact @ 2A min. (e.g. Finder 40.31.7.012.0000; Newark/Farnell # 1169158)
MOD1 = Elektor USB-FT232R breakout-board (BOB) [1]
S1,S2 = slide switch, angled pins, PCB mount (e.g. C&K OS102011MA1QN1; Newark/Farnell# 1201431)
S3,S4,S5 = rotary encoder with integrated pushbutton (e.g. Alps EC12E2424407; Newark/Farnell # 1520813)
K1,K7 = 2-pin PCB screw terminal block, 5mm lead pitch
K2,K3,K4,K5 = 4-pin pinheader, 0.1’’ pitch
K6 = 5-pin pinheader, 0.1’’ pitch
LCD1 = LCD 2x16 characters, with backlighting (e.g. Elektor # 120061-71))
J1,J2 = 3-pin pinheader with jumper, 0.1’’ pitch
40-pin DIL-socket for IC2
PCB 110406-1 [2]

use them in order to simplify the routing of the prototype circuit board. For this reason, the PWM function is programmed in software. The LEDs are driven by the power MOSFETs T3, T4 and T5, which are designed to operated from TTL-level signals. The RGB LED strips (maximum 4) are connected to connectors K2 to K5. Each of the MOSFETs can easily supply several amps without extra cooling.

Bz1 is a buzzer with a built-in oscillator, so you only need to apply the supply voltage to get a penetrating acoustic tone. The control elements consist of three rotary encoders with built-in pushbuttons.

The RA0 and RA1 leads of the microcontroller are used as A/D converter inputs. The RA0 input measures the battery voltage, while the RA1 input detects whether a battery charger with a supply voltage above 14 V or so is connected. Voltage dividers R5/R4 and R6/R7 reduce the sensed voltages so they fall within the measuring range of the microcontroller. Capacitors C8 and C9 decouple any ripple voltage on the sense lines.

The schematic also includes a serial to USB converter module (Elektor BOB, order no. 110553-91 [1]), which can be used for linking to a PC if so desired. The circuit can be controlled remotely using a number of commands in a terminal emulator program. For more information about this, see the user guide (free download [2]).

The supply voltage is regulated by a conventional 7805 together with a few capacitors (IC1, C1–C4) and a diode (D2) for polarity protection. The value of fuse F1 in the power supply stage depends on the load. A 2-A slow blow fuse should be adequate with 6.5-ft (2-meter) LED strips, but to be on the safe side you should measure the load current in the actual application. Naturally, you should do this with all colors set to maximum intensity.

Connector K7 is the power input connector for a gel-cell battery, and an AC adapter with an output voltage of approximately 15 V at 2 A or more can be connected to K1. Transistor T1 drives relay RE1, which in turn shorts out resistor R1 when the battery has to be charged. The relay type is not critical—as long as the contacts can switch 2 A and the coil voltage is 12 V. See “Operation” for more information about the relay.

The circuit draws only 25 mA or so in operation, or approximately 50 mA with the backlight on.

PCB

Figure 2 shows the PCB layout designed at Elektor Labs for this lighting controller. Only leaded components are used, so board assembly is easy even if you don’t have a lot of soldering experience. All components are fitted on the side with the component overlay. Using flat-jawed pliers, bend the leads of the voltage regulator and the MOSFETs at a right angle before fitting them to the board, so that they lie flat on the board after they are soldered. These components do not need heat sinks for normal use.

The microcontroller (optionally available preprogrammed) should be fitted in a socket. If you want to use a serial link to a PC, you should install the Elektor USB FT232R breakout board. It can be fitted directly on the PCB, or you can use a pair of 9-pin SIL socket strips.

Software

The program for this circuit was written in ANSI C using MPLAB and compiled using a full-function Hi-Tech C compiler running in evaluation mode (45 day trial license). The “lite” version of this compiler is not suitable in this case because it does not provide sufficient optimization, with the result that the executable code is too large for the 8 KB of program memory in the microcontroller. The source code and hex code, as well as the PCB layout, are available on the Elektor website [2] for free download. As usual, you can order a pre-programmed microcontroller in the Elektor Shop.

The key component of the software is the interrupt service routine (ISR). This routine was optimized using the stopwatch function of MPLAB to minimize its execution time.

The ISR is divided into several subroutines that can be executed every 100 µs, 5 ms, 100 ms or 1 s. The ISR is called every 100 µs, and it uses counters to ensure that the subroutines are executed at the previously mentioned intervals.

To reduce memory usage, a counter was initially used to determine the 1-ms and 100-ms intervals. A modulus calculation (which yields the remainder of a division operation) was performed each time the interrupt was called (every 100 µs), and if the remainder was zero, a 1 ms interval had expired. During debugging with the stopwatch function it turned out that this modulus calculation took so much time that it would be better to use a second counter to determine the 1 ms intervals.

The automatic light level control works as follows. The nominal PWM clock frequency is 100 Hz at 11 V. If the battery voltage is higher than 11 V, the LEDs will be brighter if the duty cycle remains the same. If the duty cycle is adjusted according to the battery voltage, a new duty cycle has to be calculated for each color. A much simpler method is to leave the 'on' time the same and reduce the PWM clock frequency as the voltage rises. This means that the calculation only has to be performed once to obtain the same result.

Listing 1

```
fade_step_red = current_red_value - next_red_value;
fade_step_green = current_green_value - next_green_value;
fade_step_blue = current_blue_value - next_blue_value;
fade_step_red = fade_step_red * 100;
fade_step_green =  fade_step_green * 100;
fade_step_blue = fade_step_blue * 100;
fade_step_red = fade_step_red / fade_time;
fade_step_green =  fade_step_green / fade_time;
fade_step_blue = fade_step_blue / fade_time;
```

Listing 2

```
tmp_red_value = fade_tmr * fade_step_red;
tmp_green_value = fade_tmr * fade_step_green;
tmp_blue_value = fade_tmr * fade_step_blue;
tmp_red_value = tmp_red_value / 100;
tmp_green_value = tmp_green_value / 100;
tmp_blue_value = tmp_blue_value / 100;
red_value = next_red_value + tmp_red_value;
green_value = next_green_value + tmp_green_value;
blue_value = next_blue_value + tmp_blue_value;
```

The difference between PWM clock frequencies of 100 Hz and 90 Hz is not visually noticeable.

Another bit of software that caused headaches for the programmer with the code for the color transitions. The calculation is very simple in principle: take the PWM value for each color, calculate the difference between this value and the next value, and spread the result over the transition time. Then raise or lower the PWM value for each color at each step during the transition interval (here the transition interval is given in increments of 100 ms).

The result of the division is typically a decimal fraction, which means that floating point variables have to be used for the calculation and for storing the values.

The PIC16F microcontrollers are simple 8-bit devices, and the compiler had a lot of trouble handling these "big" floating-point variables. This led to timing problems and errors in the compiled code. The solution to this problem was relatively simple. Multiplying and dividing integers takes less time and memory than working with floating point numbers. Accordingly, the difference between the PWM values for each color is first multiplied by 100 and then divided by the transition time, as shown in the following code segment (Listing1).

At every step during the transition interval (every 100 ms), the current PWM value is calculated and then divided by 100. The result is an integer "rounded off" to two decimal points, rather than a decimal number (Listing 2).

With this approach, an 8-bit microcontroller can handle color transitions without significant performance problems.

Operation

After the controller is switched on, it first shows a welcome message on the display consisting of its name and version number. The menu becomes available 1 second later. Operation of the controller is self-explanatory, but an extensive User Guide is also available as a free download [2].

You can scroll through the menu using rotary encoder ENC1. First you see the three options *Run Program <x>* (where *x* is 1, 2 or 3) for running one of the defined programs. Select one of the three programs and press *Enter* (the pushbutton of ENC2). To return to the menu, press *Back* (the pushbutton of ENC3).

The menu option *Charge Battery* selects monitored battery charging mode. First connect a 15-V battery charger, and then select this option. In this mode the relay is energized and shorts out resistor R1, so that more current can flow into the battery. The color LED strips are switched off to prevent potential damage from the higher than usual input voltage. When the battery voltage reaches 13.8 V, the relay is released. This reduces the battery charging current to the trickle charge

level, and the color LEDs are switched on again. The *Battery Charge* option shows the charge level of the battery in steps of 10%. The value is determined by measuring the battery voltage and expressing it as a percentage, where 0% corresponds to 0% and 13.8 V corresponds to 100%. LED D5 indicates the charge state of the battery. The LED is lit constantly when the battery is fully charged (13.2 V). When the battery starts to get low, it blinks for one second with a duty cycle that depends on the remaining battery charge. If the battery is nearly empty, the LED lights up very briefly. When the battery is so low that the color LEDs must be switched off, the buzzer start beeping.
Switch S2 provides a Child Lock function. When it is closed, the *Edit Program <x>* and *Edit <color>* menu options are not available.
To adjust a color setting, select *Edit <color>*, press *Enter*, and use the rotary encoders to set the red, green and blue levels over the range of 0 to 100%, in steps of 1%. Press *Enter* to save the new settings, or press *Back* to return to the menu without saving the new settings.
To configure a program, first select *Edit Program <x>* and then press *Enter*. Then use rotary encoder ENC1 to select the color, rotary encoder ENC2 to set the *Hold* time, and rotary encoder ENC3 to set the transition time.

(110406-I)

Internet Links

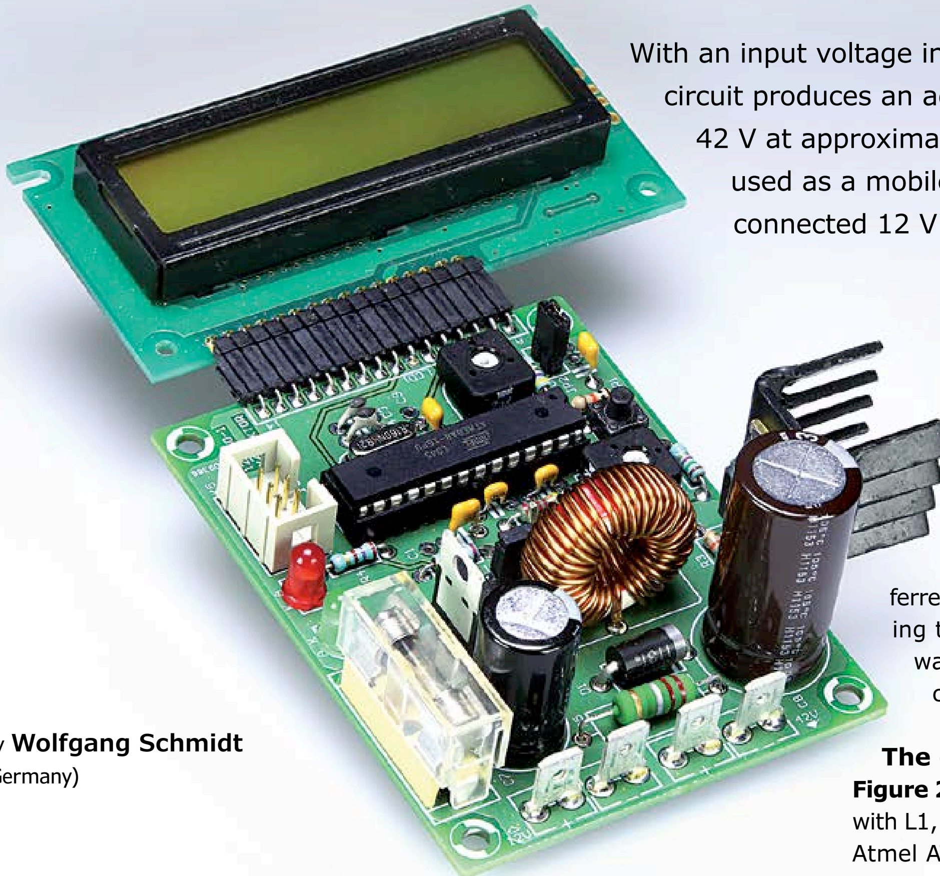
[1] www.elektor.com/110553

[2] www.elektor.com/110406

PWM Step Up Converter

Get up, stand up...

With an input voltage in the range from 8 to 16 V this circuit produces an adjustable output voltage up to 42 V at approximately 1 A. It can for example be used as a mobile charger for up to three series connected 12 V Lead-Acid batteries.



By **Wolfgang Schmidt** (Germany)

A step-up or boost converter circuit converts a low voltage into a higher value output voltage. The circuit consists of an inductor, a capacitor, a diode and a switch (transistor) that's turned on and off by a pulsewidth modulated (PWM) signal. One switch cycle has a period *T* made up of an on-time t_1 and an off-time $T - t_1$.

During the PWM signal on-time the switch is closed (lower diagram **Figure 1**). The input voltage U_e is connected across the inductor L1 and providing the supply U_e has low enough impedance will produce a linearly rising current I_L through the coil, storing increasing energy in the magnetic field. When the switch opens, the coil's collapsing magnetic field induces a reverse voltage across the coil. This induced voltage is added to the supply voltage in the circuit, and provides a forward current flow through the diode where the energy is stored in the capacitor. It can be said that the energy in the coil's magnetic field—which is stored largely in the ferrite core—is transferred through the diode to the capacitor during the switch-off stage. Those of you who want to explore the subject a little deeper can go to this introduction [1].

The circuit

Figure 2 shows how the step-up converter circuit with L1, D1, C8 and MOSFET T1 is configured. An Atmel ATmega8-16PU microcontroller together with the appropriate firmware produces the PWM signals to switch MOSFET T1. The PWM signal is produced from pin PB1 with a frequency of 66 kHz, using the internal fast-PWM mode. The output voltage is controlled by the mark/space ratio of the PWM switching waveform, and the microcontroller must be able to sense the output voltage level in order to control the waveform. This voltage feedback takes place over the voltage divider network formed by R6, R7 and P2. The preset is necessary because the data sheet indicates that the reference voltage level may be between 2.3 and 2.9 V and P2 allows some degree of calibration of the circuit. If the resistor values do not allow enough adjustment or if the value of R7 (43 kΩ) is difficult to source, adjustments in the firmware can be made to compensate. To set up the circuit you can use a known accurate DVM to measure the output voltage and tweak the preset until the displayed value corresponds to the value on the DVM.

The microcontroller's built in A/D converter gives a resolution of 10 bits. The firmware calculates the voltage using a voltage divider network consisting of 47 kΩ (R7+P2) and 2.7 kΩ (R6). This set up gives a measuring resolution of 46 mV (((49.7 kΩ/2.7 kΩ)×2.56 V)/1023). The voltage reading shown on the 2×16 character LCD can be seen to change in steps of 0.04 V or 0.05 V.

Step-up converters using this topology do not have any built-in current limiting. To reduce the possibility of overload a shunt resistor R5 is included in the ground output pin, and the voltage drop is measured by a second A/D input of the controller. The firmware now regulates the mark/space ratio of the converter switching waveform to reduce output current before the converter enters into discontinuous mode.

The networks formed by C10, C11/R8 suppress any RF noise on the analog A/D inputs. The LCD is used to display operational parameters (via menu selection) such as the output voltage and current. The circuit is provided with three push buttons: S1 resets the microcontroller while S2 and S3 provide increment/decrement control of the output voltage. With both buttons pressed at the same time the software will enter current limit mode as shown on the display. In this mode S2 and S3 can now be used to increase and decrease the current limit setting. A short time after the last push button activity the display reverts to voltage display.

LED D3 indicates that an input voltage is present, if its goes out fuse F1 may have blown indicating that the circuit is possibly drawing excessive current or that the external power supply has developed a fault. D2 indicates that the current limiter is active.

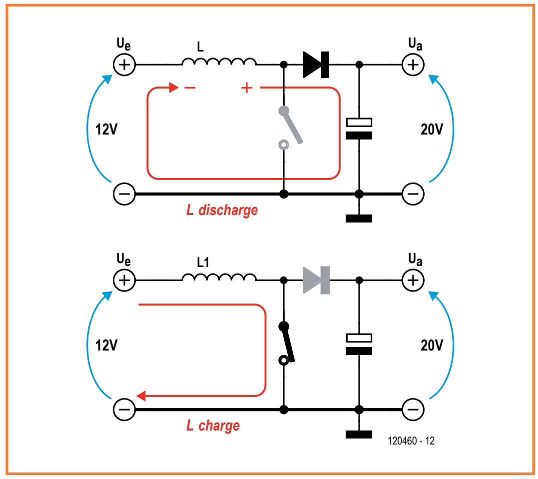


Figure 1.
The two phases of the step-up conversion process.

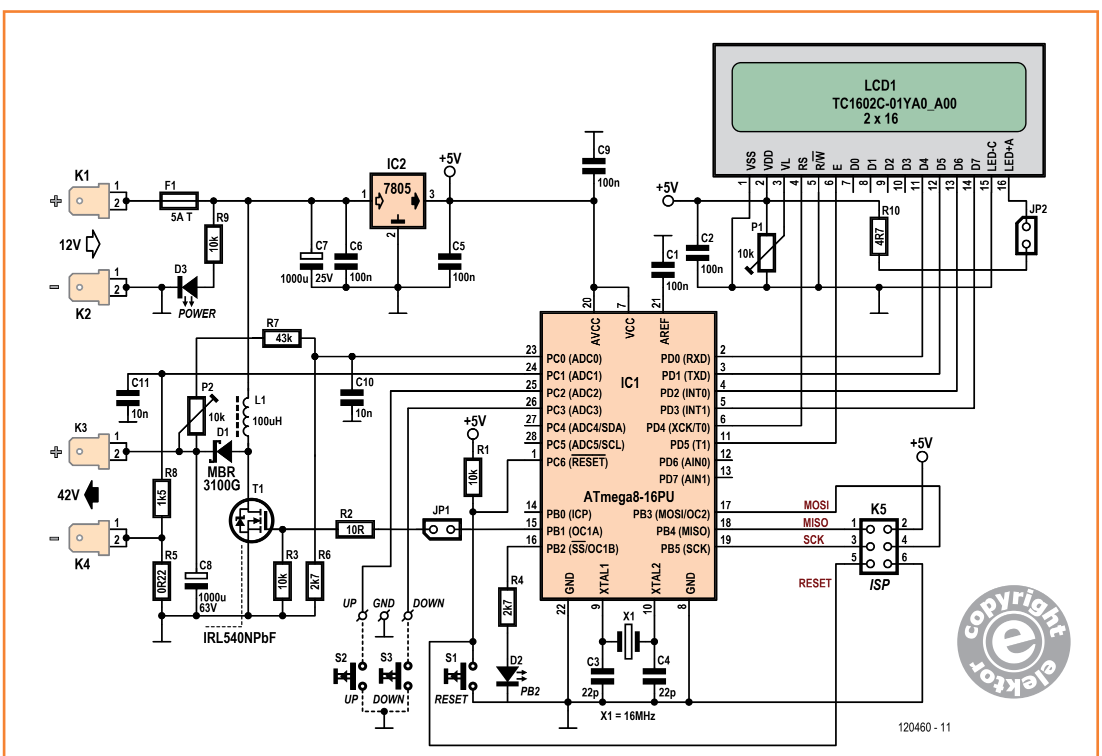


Figure 2.
The microcontroller-regulated step-up converter.

Putting it all together

The reset button S1 is fitted directly to the board because it should only be necessary to access it occasionally. Push buttons S2 and S3 are connected by flying leads to the pads on the PCB: Up, GND and Down. The buttons can be either two PCB mounted push buttons fitted to a small square of perf board or the larger panel mounted type fitted directly on the front face of the enclosure.

The two LEDs should, of course also be mounted where they can be seen. Preset P1 provides contrast adjustment of the LCD module. Jumper JP2 enables the LCD back light and can be replaced by a switch if required.

A small finned heat sink is used to keep the MOSFETs cool. A heat sink with a thermal resistance of 21 K/W is sufficient for output current up to 1 A. A standard radial-leaded or TO220 outline version of diode D1 can be used. Check the corresponding data sheet to ensure the correct polarity of the TO220 outline.

The electrolytics C7 and particularly C8 used in the switching circuit require some attention. At a switch frequency of 66 KHz it is important to use the low-loss type capacitors specified in the parts list. Standard electrolytic capacitors are unsuitable for this application.

For testing the unit in the lab we fitted the LCD display board with a pin header strip and plugged it directly into a box header strip fitted to the edge of the PCB. This proved ideal for testing purposes but when the unit is fitted into a project box or some other form of enclosure it may, for example be more practical to mount the display on the underside of the PCB. Fit a small square of insulating material between the display and the PCB to avoid any possible short circuits. (I normally fit a thin sheet of Pertinax or Paxoline between the boards).

A standard ISP connector is fitted at K5 to enable microcontroller programming. The controller needs to be powered up via the 7805 voltage regulator IC2 during the programming process. The supply voltage on pin 2 of K5 is used by the programming adapter (the AVRISP mkII for example) to determine the microcontroller's supply voltage (3.3 V or 5 V).

During the programming phase the controller's outputs are undefined so a jumper (JP1) is included in the connection to the MOSFET's gate. This should be removed during programming to ensure that the MOSFET remains off. Otherwise the MOSFET can switch on via PB1 and short circuit the supply voltage causing the fuse to blow. R3 pulls the gate to ground when JP1 is removed ensuring it remains off. Be careful to remember to remove this jumper before programming! R2 reduces switching point instability produced by the high gate capacitance of T1.

The MOSFET gate capacitance introduces a delay whenever the MOSFET switches on or off. This gives rise to increased power dissipation in T1 because the source-drain is not switching immediately between off and on but passing through a resistive stage where power is dissipated in the device. A higher switching current would be able to remove the gate charge faster and result in a faster MOSFET switching times with less heat dissipation. A standard ATmega output can only supply around 30 mA drive current and is therefore a relatively weak current source.

The maximum output voltage level is limited by the voltage rating of D1 and T1. These two components would therefore be some of the first candidates to consider replacing to improve the circuit specification. The circuit as it stands is only really intended to show how a basic step-up converter can be built and act as a stimulus for further improvement.

Work in progress; the firmware

The source code as it stands is written in BASCOM-AVR, and as usual it is available for free from the Elektor website [2]. As it stands it implements a very basic charge pump regulator and there is certainly plenty of room for improvement. These improvements include some critical points like the implementation of a true lead-acid battery charger with several charge phases.

The input current is approximately 3.5 times higher than the output current, hence the slow-blow fuse with a value of 5 A at the input.

The prototype was tested on two different lead acid batteries. A curious behavior was noted during testing; with a current setting of 0.2 *C* for example (which is relatively high for a Lead-Gel battery) the battery voltage quickly dropped after the maximum voltage setting had been reached and the charger switched off. In practice, using this software it is necessary to observe the charging process and know when to terminate the charge cycle.

COMPONENT LIST

Resistors
R1,R3,R9 = 10kΩ 5% 250mW
R2 = 10Ω 5% 250mW
R4,R6 = 2.7kΩ 5% 250mW
R5 = 0.22Ω 5% 1W
R7 = 43kΩ 1% 600mW
R8 = 1.5kΩ 5% 250mW
R10 = 4.7Ω 5% 250mW
P1,P2 = 10kΩ 20% 0.15W, preset, horizontal

Capacitors
C1,C2,C5,C6,C9 = 100nF 5% 63V, ceramic, 5mm or 7.5mm pitch
C3,C4 = 22pF 5% 50V, 5mm pitch
C7 = 1000µF 20% 25V, radial, Ø12.5mm, 5mm pitch (Panasonic EEUTP1E102, Avnet/Farnell # 1890543)
C8 = 1000µF 20% 63V, radial, Ø16mm, 7.5mm pitch (Nichicon UPW1J102MHD, Avnet/Farnell # 2112865)
C10,C11 = 10nF 10% 100V, 5mm pitch, ceramic

Semiconductors
D1 = MBR3100G
D2 = LED, red, 3mm
D3 = LED, green, 3mm
T1 = IRL540NPbF
IC1 = ATmega8-16PU, programmed, Elektor # 120460-41)
IC2 = 7805

Inductors
L1 = 100µH 5A 20%, radial 25mm, 8mm pitch (Würth Elektronik 7447070, Avnet/Farnell # 2082537)

Miscellaneous
F1 = fuse, 5A, slow, with PCB 20x5 mm holder and cap
JP1,JP2 = 2-pin pinheader, 0.1’’ pitch, with jumper
K1-K4 = AMP plug, PCB mount, 0.2’’
K5 = 6-pin (2x3) pinheader, 0.1’’ pitch
S1 = tactile switch, 6x6 mm, SPST-NO
S2,S3 = pushbutton, SPNO, PCB or chassis mounting *
PC1,PC2,PC3 = solder pin, 1.3mm diam. for S2, S3
Heatsink type FK230SAL1 (Fischer Elektronik)
X1 = 16MHz quartz crystal, HC49/US, 50ppm, C_{load} 18pF
LCD1 = LCD 2x16 characters (Elektor # 120061-71)
PCB # 120460-1

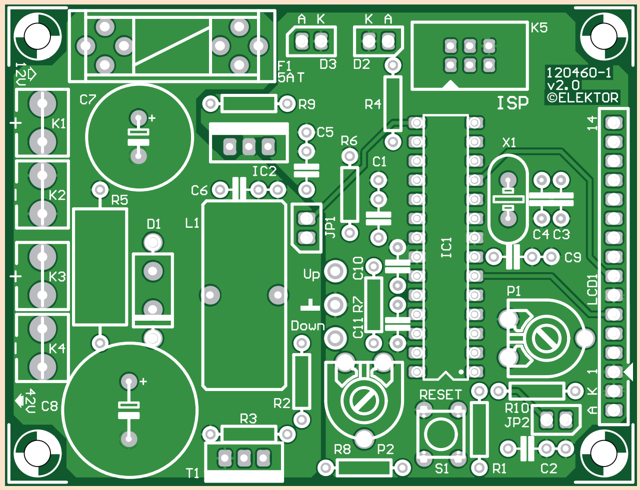


Figure 3. The step-up converter PCB.

The software as it stands does not provide a slick user interface offering a selection of sophisticated battery charging methods. The aim of this project is more to demonstrate how such a charger could be made and due to the open nature of the design and software, gives an opportunity for interested readers to hack as required and implement their own improvements.

A suggestion: The complete recharge cycle of a lead-acid (Gel) type battery should consist of two to four phases [3]. A (not fully) flat battery can be charged in the ‘bulk-phase’ using a constant current (0.1 to 0.2 C is reasonable), until a terminal voltage of 2.4 V per cell is achieved (This is as far as we go in the firmware in its present form. The battery will have approximately 80 % of a full charge at this point). Now the voltage is limited to the final terminal voltage, while the charge current is measured until it sinks to below one tenth of its maximum value. This second, so-called ‘absorption-phase’ almost completely charges the battery to around 98%, and the final ‘float-phase’ requires the terminal voltage to be reduced to 2.23 V per cell. The battery can now remain connected to the charger in this phase without the cell starting to gas.

You may be wondering what happened to the fourth phase; well this is only necessary when the battery is deeply discharged (below 1.75 V per cell). In this state the battery is nursed back to health using a small trickle charge until the cell reaches its lower voltage threshold.

If you have been working on software improvements to this design or have started, but reached an impasse, why not visit our project page [4] and share your experiences!

(120460)

Internet Links

[1] Switch mode basics: http://schmidt-walter.eit.h-da.de/smps_e/smps_e.html

[2] www.elektor.com/120460

[3] Charging lead-acid batteries: www.batterystuff.com/kb/articles/battery-articles/battery-basics.html#9

[4] www.elektor-projects.com

Charge-a-Phone on NiMH

with the Elektor USB Power Pack

By **Ton Giesberts**
(Elektor Labs)

The goal of this project is to allow standard AA size rechargeable batteries, like NiMH, to effectively charge portable devices like smartphones and tablets through the USB connector.

In numbers, there are probably more chargers around for NiMH than for Lithium-ion or Lithium-polymer batteries. If you wanted to use the latter you'd have to integrate the charger circuit, making the 'battery pack' more expensive and complex. Keeping the batteries separate from the enclosure still leaves the *option* to use Li-ion or LiPo. Luckily their initial voltage (3.6–3.7 volts) is almost the same as three NiMH batteries in series. Also, by using a separate battery holder, you're able to exchange discharged batteries with fresh ones without having to charge first, or open the enclosure. That's a big plus if your phone, tablet or e-gizmo is in serious need of charging and you're in the middle of nowhere.

How many batteries to use?

The circuit has to produce 5 V and be able to deliver up to 1 A of output current. Four freshly charged NiMH batteries can have a voltage well above 5 V, so it seems prudent to keep the number at three. However, in USB speak '5 V' is nominal, the actual range being 4.35 V to 5.40 V. Although that's in favor of four batteries again, we still wish to produce a 5.00 V supply that's accurate, if only because some designers use the USB voltage as a reference (keep that limited to non-critical applications). Three.

Boost converter TPS61030

The lower voltage of three batteries implies the use of a smaller battery holder but also the need for a boost converter. There's an excellent device available from Texas Instruments, the TPS61030. It's a synchronous boost converter with an internal 4-amp switch and an efficiency of 96 % (dependent on input voltage and output current of course). The converter also has an (optional) Low Battery Comparator to prevent deep discharging of the batteries. An extra undervoltage lockout (1.6 V) prevents the converter from malfunctioning. The internal reference voltage is 0.5 V, making it easy to calculate the voltage divider for the correct output voltage. Here 1.8 MΩ is used for R3, and 200 kΩ for R4. According to the datasheet, only if R4 is significantly lower than 200 kΩ then an extra capacitor for stability is necessary in parallel with R3. Here a 10 pF cap is used just to be sure.
Resistor R2 should be low enough to eliminate the input current of the comparator (about 10 nA). A value of 500 kΩ is recommended. The comparator level is around 500 mV with a hysteresis of

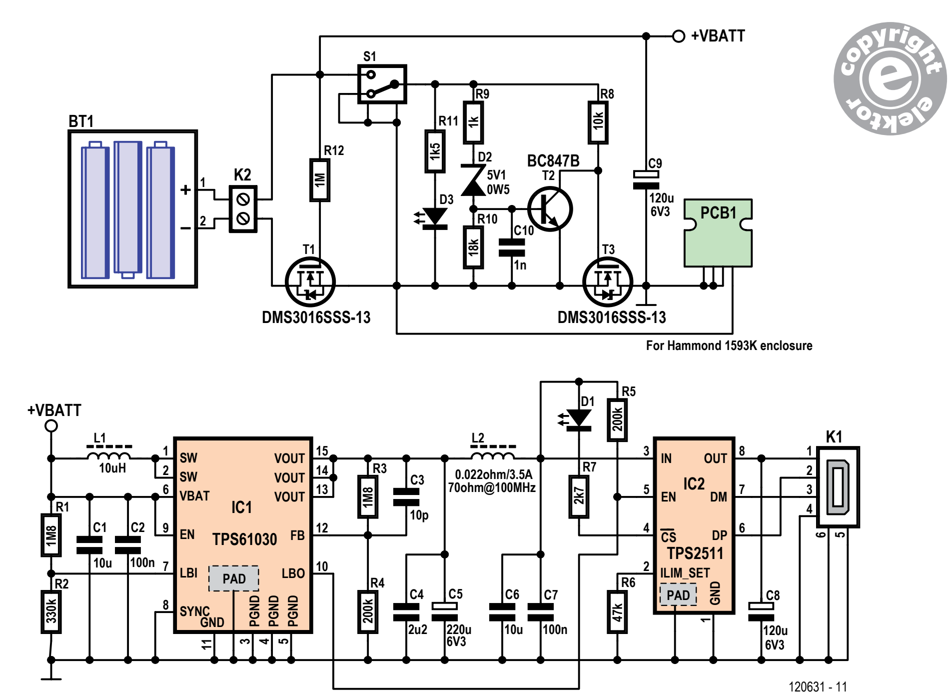
10 mV. A threshold of 1.1 V was chosen to define one fully drained battery. Values of 1.8 MΩ for R1 and 330 kΩ for R2 result in a theoretical threshold of 3.23 V. If the total battery voltage drops below this threshold the output of the comparator goes Low (LBO). This output is used to disable the output circuit.
The decoupling of the input voltage by C1, C2 is in accordance with the recommendations in the datasheet. The decoupling of the output voltage depends on the maximum output ripple. A few millivolts is ideal, but the ESR of the capacitors in particular, as well as the board layout will result in a higher value in practice. Theoretically the ripple should be around 1 mV with an output buffer capacitor of 220 µF. In practice about 60 mV was measured across C5 (3.50 V in, and 1 A load). C5 has a rated ESR of 20 mΩ at 100 kHz. The switching frequency of 600 kHz is a lot higher, and the higher switching current accounts for the higher ripple voltage. To suppress switching noises a ferrite bead (L2) is placed in series with the output circuit. This way the ripple voltage is also reduced. The final output capacitor (C8) reduces the ripple voltage even further. For the calculation of the inductor a change of 10 % of the maximum average inductor current was taken into account. At 3.20 V the average inductor current is close to 2 A. Given de formula in the datasheet (*SLUS534E*), this gives an inductor value of about 10 µH.
The Sync pin can be used to operate the converter in different modes. We selected Power Save by connecting Sync to ground, which improves efficiency at light loads (the device then operates discontinuously). The converter only oper-

Measurements and Specifications

Input voltage range	3.3 – 4.1 V
Maximum input current	1.7 A (V_{in} = 3.33 V)
Output voltage	4.93 V (no load)
	4.92 V (0.3 A load)
	4.82 V (1 A load)
Low battery threshold	3.25 V
Overvoltage protection	4.30 V
Efficiency	95 % (3.52 V_{in}; 0.3 A out)
	90 % (3.52 V_{in}; 1 A out)
Supply current (no load)	4.5 mA (V_{in} = 3.6 V)
Power LED lights at	1.6 V

Losses measured at 1 A output current:

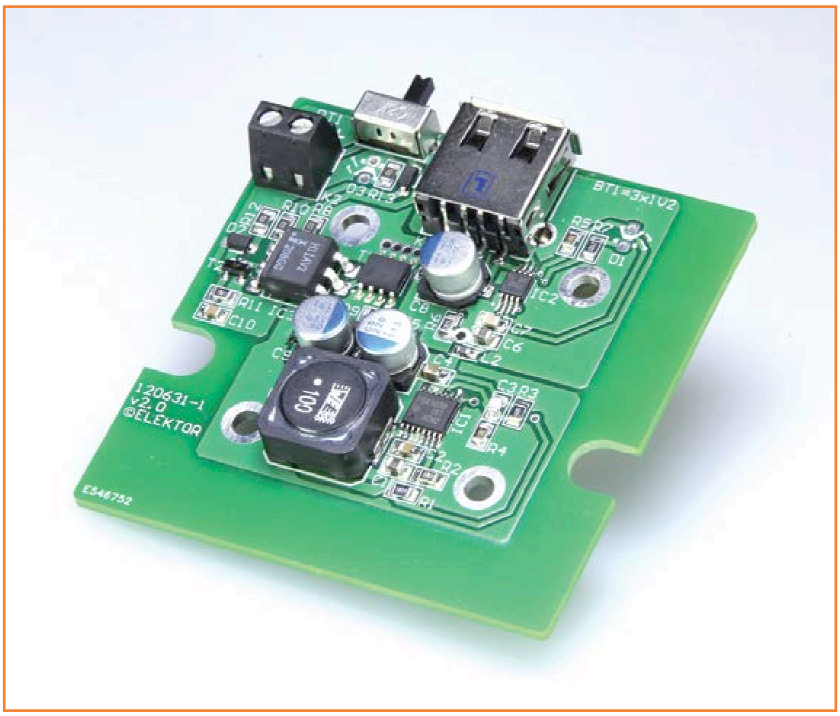
Across T1 and T3 (each)	23 mV (1.7 A input current)
From L2 to USB connector on PCB	85.3 mV
Across IC2	80 mV
USB connection (each)	13 mV



ates when the output voltage drops below a set threshold. On the down side, the output ripple voltage increases slightly. With no load, an 80-mV sawtooth was noticed with a 150-ms period. But it got better rapidly with increased loading.

TPS2511: glue for USB

A special IC type TPS2511 is used for controlling the output. Texas Instruments calls it a *USB Dedicated Charging Port Controller and Current Limiting Power Switch* but we still liked it. Here's why. It's often not enough to just put 5 V on a USB connector and get a device to work.



It's great that phone & gizmo manufacturers increasingly fit their devices with USB connectors as the charge port, but chargers are unlikely to be compatible between fruit and non-fruit platforms, and different manufacturers. For example, some devices expect specific voltages on the data lines, or simply a connection (resistor) between the data lines to recognize a charger (Dedicated Charger Port or DCP). The TPS2511 supports three of the most common protocols:

- USB Battery Charging Specification, Revision 1.2 (BC1.2);
- Chinese Telecommunications Industry Standard YD/T 1591-2009;
- Divider Mode.

For an exhaustive description of all possibilities of the TPS2511, please refer to the Texan datasheet (*SLUSB18*).

The TPS61030 can deliver 2 A at a battery voltage of 3.3 V, and the TPS2511 can handle this current also. But at 1 A output current and 3.33 V input voltage the converter already draws 1.7 A from the batteries. At 2 amps output current this will be more than doubled, because of the higher losses. Also, the battery capacity drops at higher output currents. That's why the TPS2511 is connected to work as a 5-watt charger. Its DP pin is connected to the D– line, and the DM pin to the D+ line of the USB connector. The current limit is set marginally higher than needed (R6 = 47 kΩ), preventing the TPS2511 from premature output voltage limiting.

The Current Sensing Report pin is not used in the expected way. Instead of compensating voltage loss by changing the feedback of the converter (not really necessary at 1 A maximum output current) the pin is used to drive an LED (D1). When D1 lights up you know that more than half of the maximum output current is being drawn. The LED current is a little over 1 mA. As already mentioned, the Low Battery Comparator output drives the EN (Enable) pin of the TPS2511. This way the output voltage is cut off in case the batteries are flat. R5 is needed because the comparator output is in high impedance state when not active.

Polarity and overvoltage guard circuits

The battery pack connection to the PCB is by way of a screw header (0.15'' lead spacing). So in practice it's possible for the batteries to be connected the wrong way around. To prevent damage to the circuit and still have virtually no losses when properly connected, a small n-channel power MOSFET (T1) is used, purposely the wrong way around. When connecting the batteries with the proper polarity, the body diode is in the conducting direction, and the MOSFET is fully turned on, its gate positive with respect to the source through R12. There's no problem with the current flowing from source to drain. In case the batteries are connected the wrong way around the gate is negative and the MOSFET is turned off and the body diode effectively blocks the battery voltage. The maximum permissible gate voltage of the MOSFET used is 12 V, which also constitutes the maximum voltage the circuit will survive. At 1.7 A input current the MOSFET(s) drop a minuscule 23 mV (measured on prototype). To avoid having to use an expensive heavy duty on-off switch, the overvoltage protection is combined with a smaller—hence much cheaper—switch. The overvoltage protection is kept simple. When the supplied voltage is too high a zener diode (D2) is used to switch on an n-p-n transistor (T2) which in turn cuts off the gate voltage of MOSFET T3, which is connected as you would expect. The 5.1-V zener diode already conducts below the specified zener voltage. At a battery voltage of 3.60 V the current through D2 is about 12 μA. At 4.25 V, it's over 30 μA. This can easily be measured across R9, which prevents the current through the zener diode from snowballing when the input voltage exceeds 5.70 V or so. In case the overvoltage protection acts too early (due to possible tolerance of the zener diode), feel free to adapt R10, remembering that a lower value gives a higher threshold. The overvoltage protection is needed in case an AC power adaptor—hopefully set to less than 12 V out—or a 9-V battery is connected. The TPS61030 can withstand 7.00 V (absolute maximum, 5.50 V recommended). The problem with the boost converter is that the output voltage rises when the input voltage exceeds the regulated output voltage (here, 5.00 V nominal).

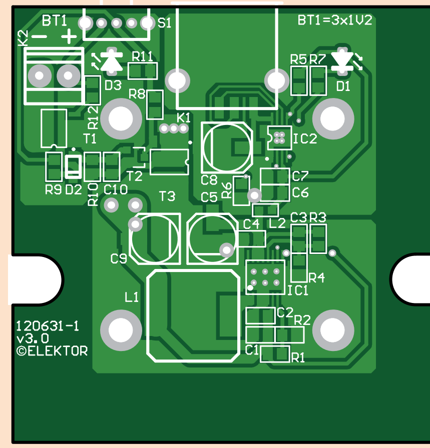
Construction

The PCB is specifically designed for a Hammond Manufacturing enclosure (see parts list). It's cheap and easy to adapt to our application. The PCB is fixed with four self-tapping screws, and the top and bottom halves with two longer ones. The front and back are separate panels. In one panel only, three holes have to be drilled. The holes for the USB connector and switch should be aligned with the parts on the PCB. The same is true for two holes for the LEDs in the top cover. The exact placement of the hole for the two wires to the external battery holder is not that critical—there's a large margin to play with. It can be located anywhere else for that matter. A power jack may also be used—there's more than enough room in the other panel. Avoid any extra contact resistance where possible, as it will reduce the efficiency of the device as a whole.

The holes for fixing the PCB are also used to connect the board's top and bottom power planes. Be aware that the hole next to screw header K2 is not connected to ground but the net between T1 and T3. Connecting this net to ground will not cause any damage but simply turn on the circuit. The other three holes are connected to ground, however the hole next to IC2 is specifically output ground. It's assumed the PCB is placed in the above mentioned hard plastic (ABS) enclosure. Finally, do not touch junction R3/C3/R4 with the circuit in operation. This is a high impedance point and any hum introduced here may destroy IC1.

(120631)

COMPONENT LIST



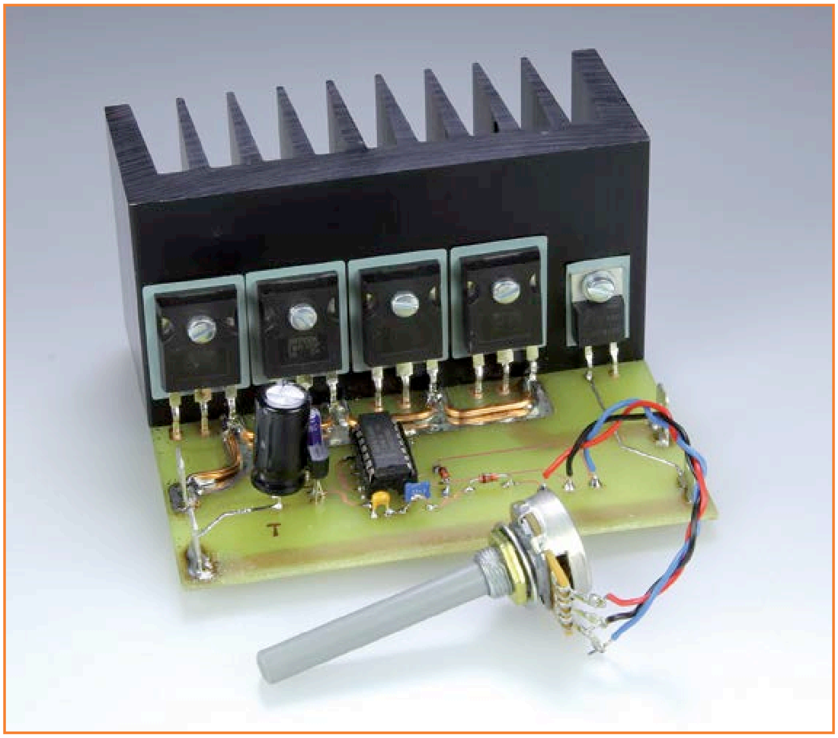
Resistors
(0805, 125mW)
R1,R3 = 1.8MΩ 1%
R2 = 330kΩ 1%
R4,R5 = 200kΩ 1%
R6 = 47kΩ, 1%
R7 = 2.7kΩ, 5%
R8 = 10kΩ, 5%
R9 = 1kΩ, 5%
R10 = 18kΩ, 5%
R11 = 1.5kΩ, 5%
R12 = 1MΩ, 5%

Capacitors
C1,C6 = 10μF 10V 20%, X5R, 0805 (Taiyo Yuden LMK212 BJ106MG-T)
C2,C7 = 100nF 50V 10%, X7R, 0805
C3 = 10pF, 50V, ±0.5pF, C0G/NP0, 0805
C4 = 2.2μF 6.3V, 10%, X5R, 0805
C5 = 220μF 6.3V, 20%, SMD, Ir=2.8A (Nichicon PCS0J221MCL1GS)
C8,C9 = 120μF, 6.3V, 20 %, SMD, Ir=2.8A (Nichicon PCS0J121MCL9GS)
C10 = 1nF, 50V, 10%, X7R, 0805

Inductors
L1 = 10μH, 5A, 0.025Ω, 20% (Würth Electronics 74477110)
L2 = ferrite bead, 70Ω @ 100MHz, 3.5A, 0.022 Ω, 0603 (Murata BLM18KG700TN1D)

Semiconductors
D1,D3 = LED, red, 3mm through hole (low current)
D2 = 5.1V zener diode, 0.5W (SOD123), Diodes Inc. MMSZ5231B-7-F
IC1 = TPS61030PWPG4 (Texas Instruments)
IC2 = TPS2511DGN (Texas Instruments)
T1,T3 = DMS3016SSS-13 (SO8)
T2 = BC847B

Miscellaneous
K1 = USB connector, type A, receptacle, PCB mount, SMD
K2 = 2-way vertical screw header, 0.15'' (3.81mm) pitch (Phoenix Contact MKDS 1/2-3.81)
S1 = Slide switch, SPDT, right angle, 100mA (C&K Components OS102011MA1QN1)
Enclosure, 66.22 x 67.22 x 28.00 mm (Hammond Manufacturing 1593KBK)
PC board screws (#4 x 1/4" self-tapping, 6.4mm, Hammond Manufacturing 1593ATS50)
BT1 = 3 AA battery holder, snap contact (Keystone 2475) + battery clip (BUD Industries HH3449)
3 NiMH batteries. PCB # 120631-1 v3.0



Big Amps DC Motor Driver

By **Ton Giesberts (Elektor Labs)**

This simple circuit is designed for use with all kinds of DC motors up to 40 amps. Basically it's just a simple oscillator driving a bunch of power MOSFETs. The oscillator is a rudimentary RC type around a single Schmitt trigger device (IC1a) from a 40106 hex inverter package. When the wiper is turned towards D2, potentiometer P1 gives maximum voltage to the output. The two diodes prevent short-circuiting the output to the input. At the extremes of P1, the charge and discharge times are minimal. In the prototype of the circuit the negative-going pulse was found to be 1 µs wide, and 1.6 µs for the positive pulse.

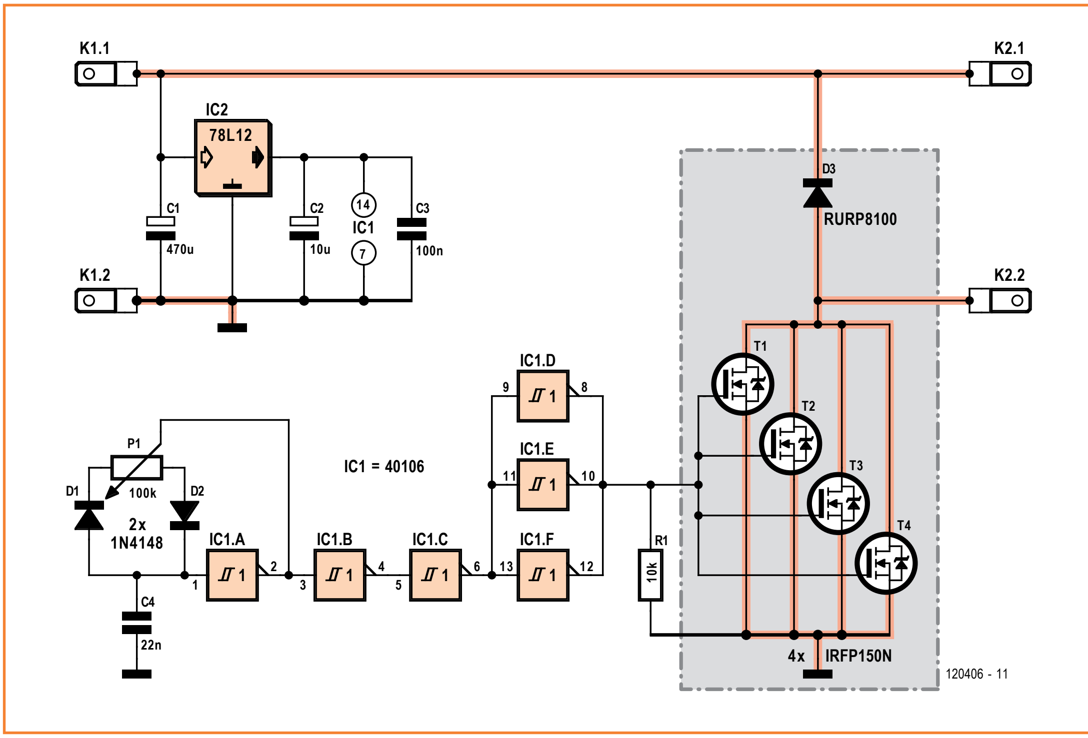
The next two inverters, IC1b and IC1c, clean up the oscillator signal, driving a buffer stage comprised of three inverters in parallel, IC1d, IC1e and IC1f. Resistor R1 was added to hold off the MOSFETs in case the 40106 is absent. The total input drive capacitance of the four MOSFETs amounts to almost 8 nF—clearly too much for the buffer to fully charge and discharge when P1 is turned to its extreme positions. That's convenient however because in practice it allows the motor driver to manage the full output voltage span (i.e. 0–100 %).

The operating frequency is in the 1 kHz ballpark. On a prototype 1.07 kHz was measured. Diode D3 at the output suppresses the reverse energy (back emf) generated by inductive loads, which includes all DC motors.

High output currents and back emf are issues here. On an early prototype of the board, the tracks to D3 were too narrow, and when testing the circuit with one of the motors in an Elektor Wheelie one of the tracks burned out. Fully loaded, each of the two motors used in the Wheelie draws up to 20 A at 24 V. The circuit was tested at 40 A and 24 V with a resistive load. However, the PCB as designed and supplied is not able to handle such high currents. The solution is to beef up the copper tracks carrying high current with pieces of 13 or 14 AWG (approx. 2.5 mm^2) massive copper wire. Possibly two paralleled pieces of 16 AWG (approx. 1.5 mm^2) are easier to get into place. For this reason the PCB does not have solder stop masks. The thicker lines in the schematic provide a global indication of where high currents can be expected to flow. The supply for the 40106 is no more than a 78L12 voltage regulator (IC2) with the usual entourage of decoupling capacitors large & small.

The speed control potentiometer may be mounted off the board and connected with light duty wires. The heatsink is best secured to the PCB with 3-mm (6 BA) screws. Make sure the heatsink doesn't come in contact with the solder pads for the MOSFETs. Then determine the correct positions of the transistor mounting screws, and D3. To prevent mechanical stress within the semiconductor legs, give them a light bend—there are special tools available for this—and only then locate the positions for the holes. Tap 3-mm (approx. 1/8'', 6 BA) threading. Don't forget to isolate all semiconductors on the heatsink. Because of the low switching frequency there's a good chance you can hear a whine from the DC motor—it's pretty normal and no cause for alarm.

(120406)



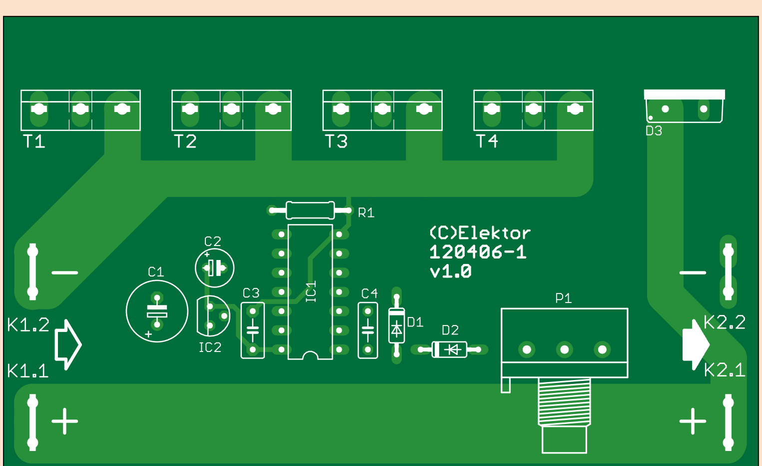
COMPONENT LIST

Resistors
R1 = 10kΩ, 5%, 0.25W
P1 = 100kΩ, 20%, linear potentiometer, 0.2W

Capacitors
C1 = 470µF 35V, 20%, 3.5mm lead spacing
C2 = 10µF 25V, 20%, 2mm lead spacing
C3 = 100nF, 50V, 20%, ceramic, 5mm lead spacing
C4 = 22nF, 100V, 20%, ceramic, 5mm lead spacing

Semiconductors
D1,D2 = 1N4148
D3 = RURP8100
T1-T4 = IRFP150N
IC1 = 40106
IC2 = 78L12

Miscellaneous
4 pcs. FastOn spade terminal (tab), straight, PCB mount, 0.2’’ (5.1mm) lead spacing
Heatsink, 1.9K/W, 100 x 40 x 50 mm, Fischer Elektronik type SK 92/50 SA
TO-3P silicone elastomer insulation (T1-T4)
TO-220 device insulating kit; mica sheet + bush (D3)
PCB # 120406-1 v1.0



X-Treme Inrush Current Limiter

A controlled start for Big Electrolytics & Co.

By
Raymond Vermeulen
(Elektor Labs)

This all-analog, microcontroller free (!) project got designed in response to cries for help from a diehard model plane enthusiast on the Elektor staff. He likes to fly large high powered models. One problem he ran into was self-destructing power connectors when connecting the battery pack to the plane (i.e. the motor controller). Every time the damage was due to heavy sparking, due in turn to high inrush currents.

Those were expensive sparks as it turned out, because the connectors are 6-mm diameter, gold plated types. Clearly an inrush current limiter is called for to ensure a controlled, spark-free initial current flow rather than a thump and a small explosion. Such a regulator did not drop from the skies however, and took some time to develop at Elektor Labs. Below is a digest of how the project evolved from doodling to a working model keeping everyone happy.

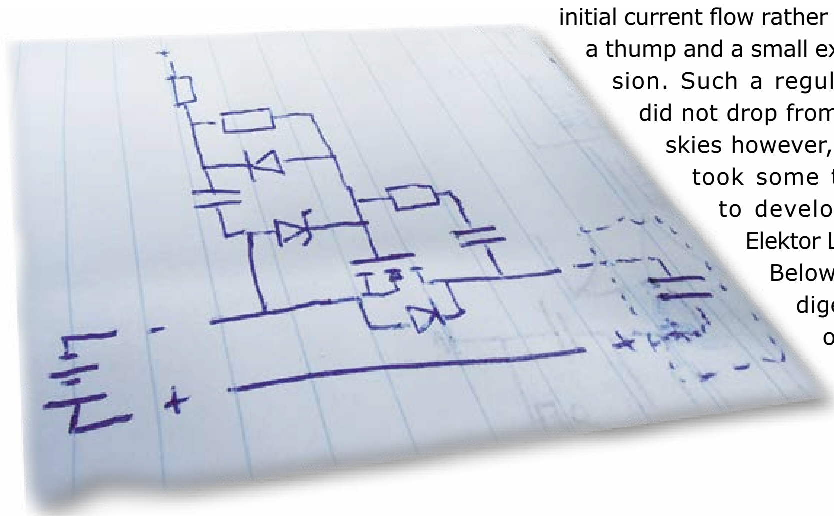


Figure 1.
A Bob Pease style sketch of an idea for an inrush current limiter.

Good guidance was found in Motorola Application Note number *AN1542* [1]. Using rough concept sketches (**Figure 1**) an inrush current limiter got designed for 37 volts battery power and a 200 amp load in normal operation. To achieve a low overall $R_{ds(on)}$ it is best to use a couple of MOSFETs in parallel. After an LTspice simulation run, the pain appeared to be not in the amps but in the load capacitance responsible for the inrush current, so the circuit got designed for the worst case scenario. Still, there were concerns about the safe operating area of the MOSFETs. To test the water, measurements were carried out on a small 10-A 3-phase BLDC motor driver, and that turned out to have "just" 120 µF input capacitance. A bit later a bigger motor controller turned up specified for 120 A, and this was found to represent an input capacitance of 13,800 µF (13.8 mF) at an ESR of about 2.7 mΩ.

Moving towards a practical circuit the type IPB017N06N3 MOSFET from Infineon was chosen mainly based on the promise of 1.7 mΩ of 'on' resistance per device, not forgetting relatively low cost and ready availability from the distributors.

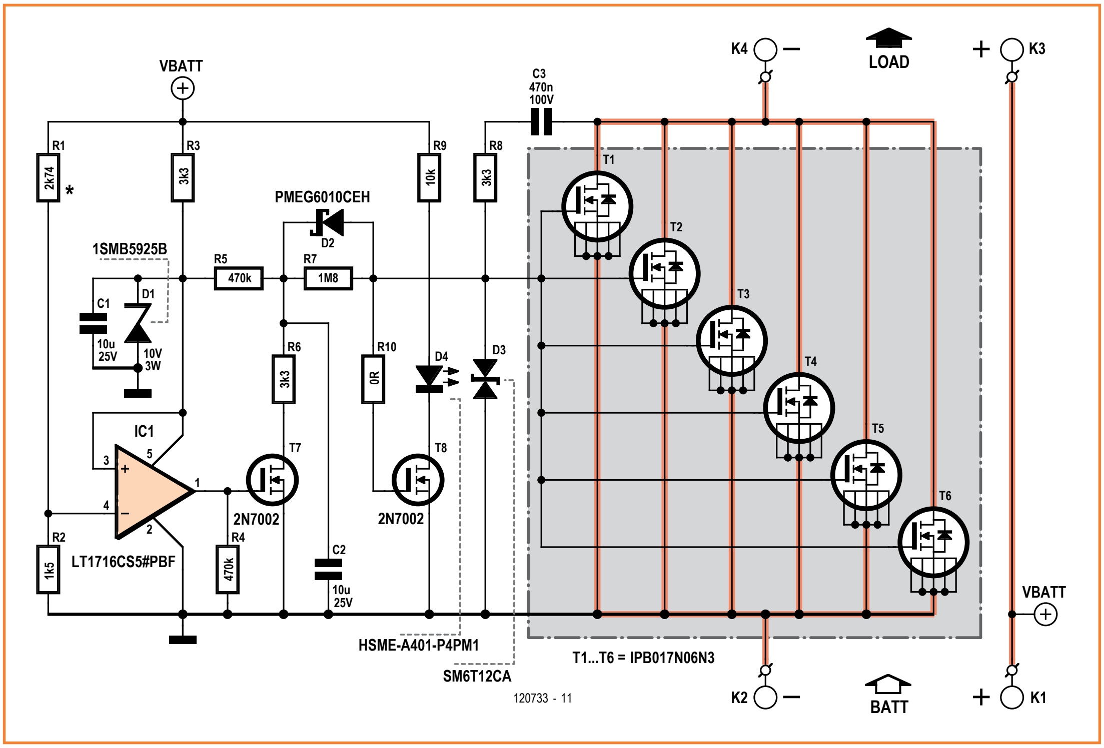


Figure 2.
Schematic of the X-Treme Inrush Current Limiter.
High current PCB tracks are highlighted and thicker.

Now the question remains: how many MOSFETs do we need?

Back to the LTSpice simulation, now using the IPB017N06N3 model, some component values were in need of tweaking. Also, a heatsink was found—cheap, standard size (1/2-brick) and with predrilled holes.

Looking at the schematic in **Figure 2** there are some marked differences with the version proposed in *AN1542*. Motorola shape the current into a square wave, causing a sudden current and power surge which slowly dies out. By contrast, the circuit shown here has the current increase slowly, resulting in a sawtooth shaped current. Consequently, the power dissipation graph (P_{FET}) looks like an inverted parabola. **Figure 3** shows the basic waveforms—arguably they respect the safe operating area of the MOSFETs far better than *AN1542*.

A TVS (transient voltage suppression) diode, D3, helps to protect the MOSFETs in case of accidental polarity reversal.
An early prototype was tested with a 15,000 µF (15 mF) capacitor with and without a resistive load, connecting to a 40-V supply through the X-Treme circuit. Everything seemed to function as expected, although with no resistive load connected, the undervolts lockout did not function correctly on the falling edge.

As a final test, the circuit was used with a BLDC controller driving a 10 kW motor, unloaded, drawing 8.5 amps at continuous speed and 20 to 30 amps when throttling. Tests were done at 37 V and 48 V, doing ‘cold starts’ several times over. Although cables and connectors got noticeably warm, the MOSFETs and the rest of the circuit remained cool. No “thump” sounds were heard (so customary from high-current loads), or exploding capacitors.

Table 1. Trip value / battery voltage dependency

Battery Type (Lithium)	Battery Volts	V_{trip}	R1
4S	12 – 16.8 V	11 V	180 Ω
5S	15 – 21 V	14.2 V	620 Ω
6S	18 – 25.2 V	16.8 V	1 kΩ
8S	24 – 33.6 V	22.9 V	1.87 kΩ
10S	30 – 42 V	28.9 V	2.74 kΩ
11S	33 – 46.2 V	31.8 V	3.16 kΩ
12S	36 – 50.4 V	34.9 V	3.6 kΩ

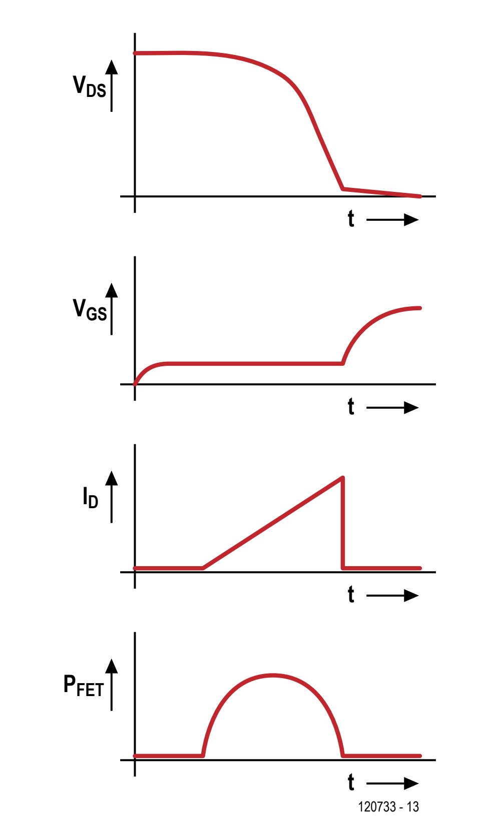


Figure 3.
Our circuit results in a reverse-parabolic shape for the power dissipation of the MOSFETs.

This flagged the go-ahead for the design and production of a single-sided (!) TH/SMD circuit board—the component layout is shown in **Figure 4**. The value of R1 sets the trip voltage, hence is dependent on the battery voltage. The interdependencies are listed in **Table 1**. In practice, the circuit should not be used with battery voltages lower than 12 volts. Fortunately that's a rare occurrence in high-power (BLDC) motor applications—you can easily see why.

The circuit board potentially carries extremely high currents, both 'surge' and 'continuous', meaning **you have to strengthen all MOSFET source and drain PCB tracks, and the whole length of the BATT– and BATT+ PCB tracks, with pieces of 2.5 mm² (13 AWG) solid copper wire, preferably two in parallel**. Most of this plumbing work is in the area covered by the heatsink later. If you find 1.5 mm² copper wire (16 AWG) easier to juggle with, that's fine also but do three or even four pieces in parallel. Also apply generous amounts of solder along the tracks and the copper wires—it's a bit like Plumbing-4-Beginners. If for some reason your board comes with a solder mask on the above mentioned tracks, remove the masking material and expose the copper by scratching with a sharp hobby knife. The pre-tin and install the helper wires.

The battery and load connections K1-K2 and K3-K4, must be made using high quality terminals of your choice, preferably gold plated. Get the best you can find, round or flat ('FastOn' / spade type), whichever you prefer, as long as you solder them straight to the PCB tracks. Remember, every milliohm counts in this circuit and you do not want to lose motor power or torque during takeoff, now do you. To prevent polarity reversal, consider using a 'socket' (female) and

COMPONENT LIST

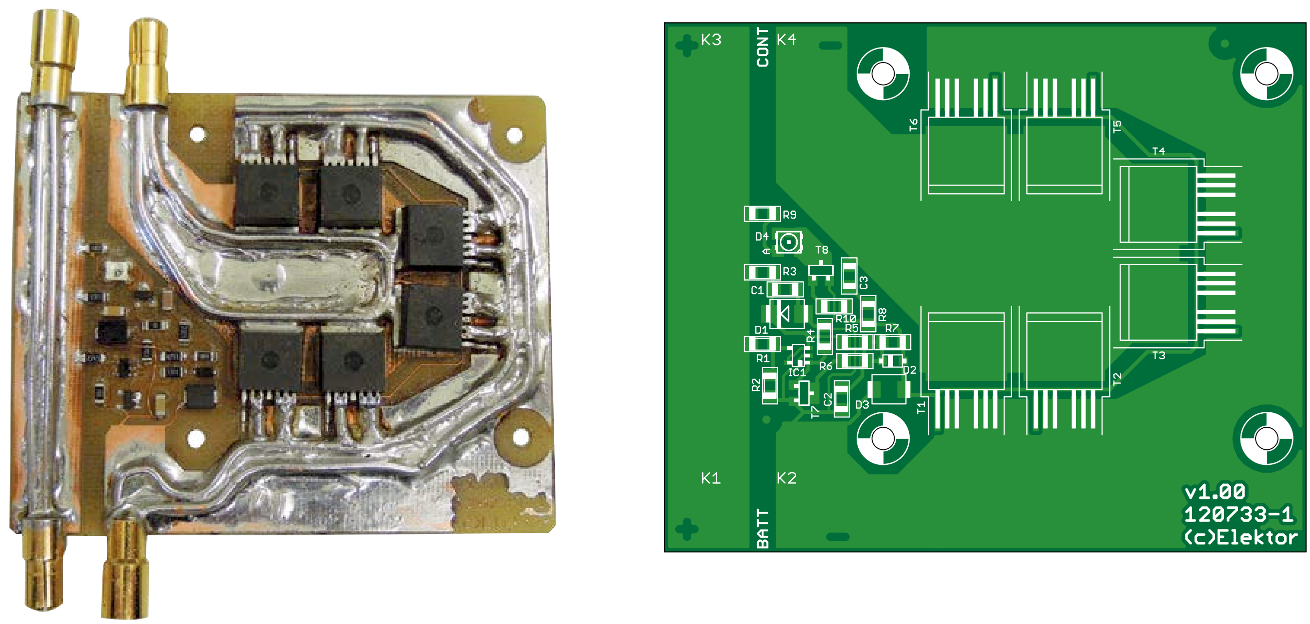
Resistors
(All 0.25 W, 1%, SMD 1206)
R1 = 2.74kΩ *
R2 = 1.5kΩ
R3,R6,R8 = 3.3kΩ
R4,R5 = 470kΩ
R7 = 1.8MΩ
R9 = 10kΩ
R10 = 0Ω

Capacitors
C1,C2 = 10µF 10% 25V, X5R, 1206
C3 = 470nF 10% 100V, X7R, 1206

Semiconductors
D1 = 1SMB5925B zener diode, SMB (Newark/Farnell # 1894811)
D2 = PMEG6010CEH, Schottky diode, NXP, SOD-123F (Newark/Farnell # 1510694)
D3 = SM6T12CA, TVS diode, STmicroElectronics, SMB (Newark/Farnell # 9885870)
D4 = HSME-A401-P4PM1, LED, green, Avago, PLCC-4 (Newark/Farnell # 1058419)
IC1 = LT1716CS5#PBF, comparator, Linear Technology, SOT-23-5 (Newark/Farnell # 1417738)
T1,T2,T3,T4,T5,T6 = IPB017N06N3, N-MOSFET, Infineon, TO-263-7 (Newark/Farnell # 1775519)
T7,T8 = 2N7002, N-MOSFET, Diodes Inc., SOT-23 (Newark/Farnell # 1713823)

Miscellaneous
K1-K4 = high current connectors, male & female pairs, gold plated *
Heatsink, ½ brick form, Aavid Thermalloy type 241204B92200G, dim. 60.96mm x 57.91mm x 11.4mm (Newark/Farnell # 1703176)
PCB 120733-1

* user configurable component, see text



a ‘plug’ (male) connector on the + and – battery lines. The same can be done on the + and – output lines.

The MOSFETs are flat on the board, and the heatsink is on top of them with thermally conductive sheet material held pressed in between. The heatsink is secured with four corner M3 bolts or screws, with two M3 nuts on each bolt acting as standoffs, i.e. between the board surface and the flat side of the heatsink. The total standoff height is approximately 5 mm. The bolts should be lightly tightened so as to barely compress the heat conductive sheet material.

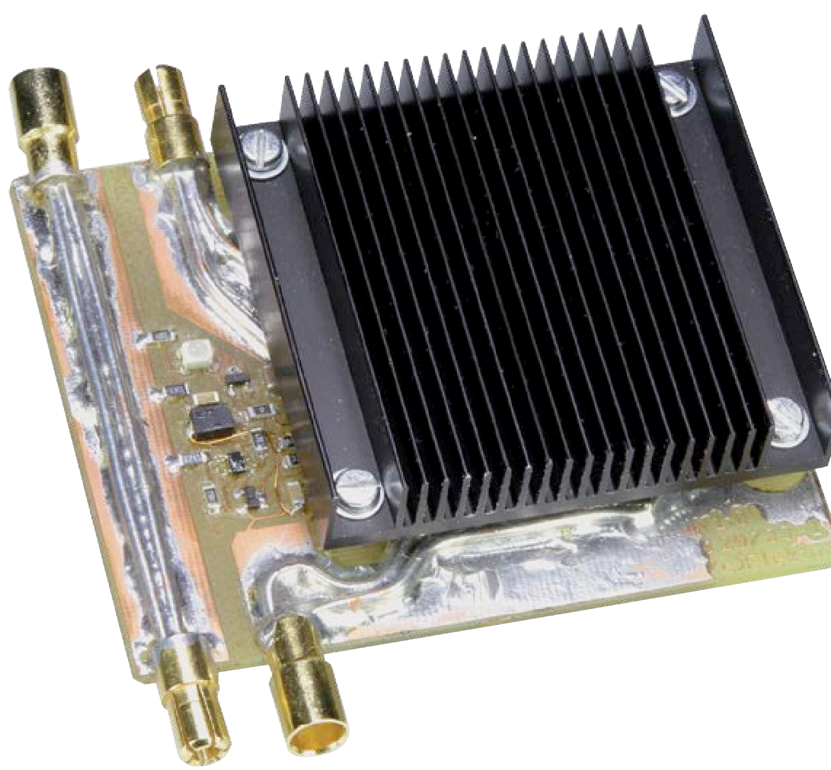
Although we’ve talked mostly about motor controllers for R/C models here, the circuit is suitable for any 12-40 V DC load that represents a very low resistance initially, including big electrolytic reservoir capacitors and lamp filaments.

(120733)

[1] AN1542:
www.bonavolta.ch/hobby/files/MotorolaAN1542.pdf

[2] IPB017N06N3 datasheet:
www.infineon.com/dgdl/IPB017N06N3_Rev2.2.pdf?folderId=db3a30431441fb5d01148ca9f1be0e77&fileId=db3a30431ddc9372011e264a7ab746ea

Figure 4.
The circuit board design is compact and designed for the heatsink to physically cover the MOSFETs. The copper track layout as shown is not suitable for direct use. You have to strengthen all PCB tracks carrying the load current with pieces of solid copper wire.



Acoustic Spirit Level / Tilt Alarm

An ATtiny45 design with many uses

By **Jörg Trautmann**
(Germany)

This little project was inspired by a tilt sensor circuit which first appeared in our 2010 Special Projects Edition. The idea was to build a simple multi functional tilt sensor. The resultant design has two main uses; it functions as an acoustic three-axis spirit level or a security movement detector.

The original purpose of this device was to assist in leveling large garden tables on uneven ground. Away from buildings it is difficult to find any reference points to assist in setting up the tables, and conventional spirit levels can be a bit cumbersome. It is however not only useful for leveling tables, it also serves as a security monitor to sense the movement of some object; place it on a table or any other item worth protecting, if anyone tries to move it the alarm sounds and the thief is sent off with a start.

How it works

The circuit shown in **Figure 1** comprises an Atmel ATtiny 45 microcontroller and an MMA7260QT. The MMA7260 is an integrated 3-axis acceleration sensor which has already featured in this magazine back in 2007 and also in the Special Projects (summer) Edition of 2010 where it was used in a large USB tilt sensor with an LCD screen [1]. The small integrated circuit is fixed to a small PCB (**Figure 2**) and has three analog output signals. The signal produced is proportional to acceleration; at +1 *g* the output voltage is 2.45 V.
The ATtiny45 microcontroller from Atmel [2] includes a number of built-in A/D converters, three of which we use here to measure acceleration or level of tilt from the three sensors. The A/D converters use an internal voltage reference of 1.1 V so it is necessary to scale the three sensor output voltages using a voltage divider network. Based on the sensor parameters the resistors R1, R3 and R5 have a value of 470 kΩ and resistors R2, R4 and R6 have a value of 330 kΩ. The 2.45V maximum output voltage from each of the sensors is thereby scaled down to around 1 V and optimal measurement resolution is achieved in the A/D conversion process.

The microcontroller firmware uses changes in the X, Y and Z parameters to influence the output frequency of three tone generators.
When the sensor is on a flat and level surface the tone generators remains quiet. As soon as one of the sensors detects a movement of more than approximately ±2° on any axis, the tone begins to sound and varies as the tilt increases. The push button S1 is use to calibrate the unit and also to select operational mode. When the button is held down for longer than 5 s the unit is switched into alarm mode.
The voltage on the board is regulated by a low-drop voltage regulator type LP2950CZ3.3, producing an optimal 3.3 V for both the microcontroller and tilt sensor. A 9-V 6LR22 (PP3) size battery will provide enough energy to keep the circuit running for a long time. During testing

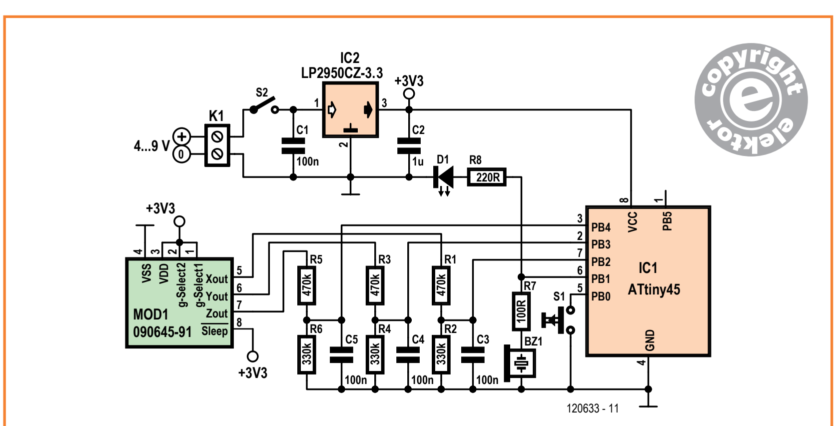
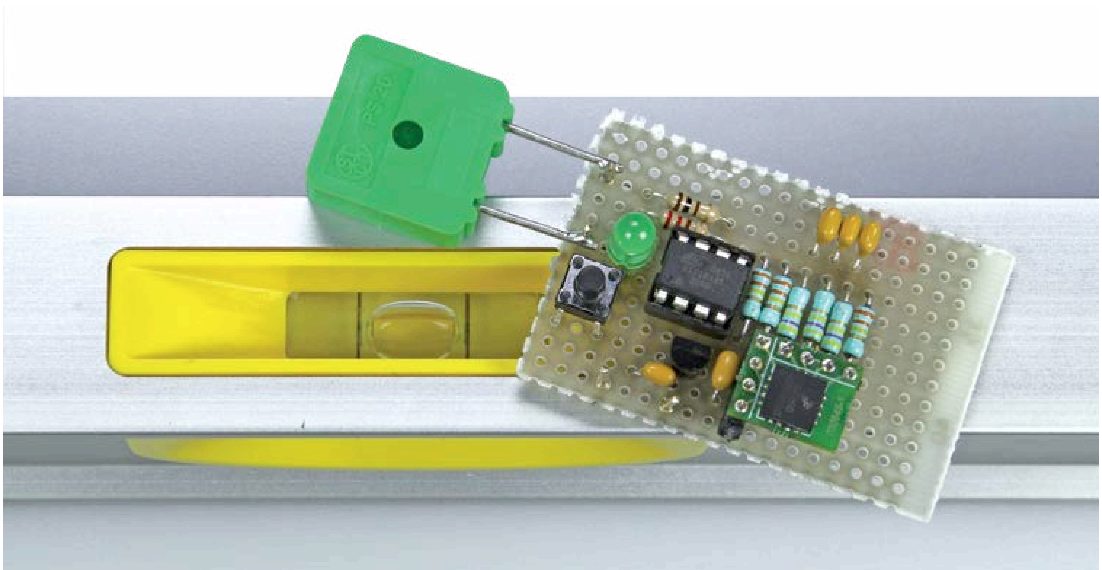


Figure 1.
The tiny circuit can be fitted onto a small piece of breadboard.



it was found that the circuit would still function with a supply voltage as low as 3.6 V. Maximum current was measured at 4.56 mA and averaged around 3.06 mA with the LED blinking and the tone sounding.

Construction and operation

Construction of the circuit is relatively simple and can be made using small piece of breadboard such as the prototyping board called ELEX-1. When the finished circuit is first powered up the red LED will light continuously and the loudspeaker should remain silent. If this is not the case then remove power and double check your circuit construction. The first time the circuit is switched on it is necessary to carry out a calibration process which will then act as the reference attitude. Place the circuit board on a flat, level surface and hold down button S1 for approximately 1 s. When the push button is released the LED will extinguish indicating that the calibration is complete and the values have been stored. The unit should not be emitting any sounds now. When the board is waggled you should hear three over lapping beep tones. The LED will also flash and the tone frequencies increase as the angle of tilt increases. With the PCB returned to a level position the tones cease and the LED turns off. Once the unit is fitted into a project case you can quickly begin to develop a feel for when the unit is level.

To use the unit as a movement alarm first place it on the device you want to protect (the surface does not need to be horizontal) and press button S1 now hold down S1 again for a few seconds until the LED starts to flash regularly. Once the push button is released the circuit is primed. Now when the unit is tilted by more than approximately 20 degrees it sets off a loud rising and falling alarm siren. A brief press of S1 silences the siren. The unit still functions in alarm mode until power is turned off. It will always power up in ‘spirit level’ mode. The most recently stored attitude calibration values are again used as the reference plane.

The program

The firmware for this project is written in BASCOM AVR and can be downloaded from the project web page [3]. Port pin PB1 is configured as an output to drive the piezo buzzer. PB0 is used as an input with its internal pull up resister enabled. The A/D converters ADC0, ADC1 and ADC2 use the internal voltage reference of 1.1 V. When push button S1 is pressed (PB0=Low) for approximately 1 s the measured values are stored in EEPROM and used as the calibration values. The next time

Figure 2.
The sensor chip on the adapter PCB.

Please note

The MMA7260QT from Freescale is no longer manufactured. It may still be possible to find examples at some stockists but the outlook is not good. At the time of writing (April 2013) we have 67 modules reference number 090645-91 in the Elektor warehouse. These are available on a first come, first served basis! The software (BASCOM-AVR) should however be fairly easy to adapt to enable other types of sensor to be used in this design [4].

the circuit is powered up, the same values will be used as reference. The logic used to evaluate the switch status on PB0 is so programmed that calibration of the unit is only possible when the unit is not in alarm mode. In alarm mode a press of S1 resets the alarm. The button S1 therefore performs two functions.

A full measurement cycle consists of seven readings from each of the three analog channels taken within 210 ms, the values given are then averaged. This method has shown to give excellent measurement accuracy and stability. It is relatively easy to alter the sensitivity of the unit operating in either mode by changing the Trigger_value variables declared in the software.

If you want to use the firmware as it stands and don't feel the need to make any alterations, it's a simple job to order a pre-programmed controller from the Elektor shop. Alternatively, go ahead and program your own micro.

(120633)

Internet Links

[1] www.elektor.com/070829

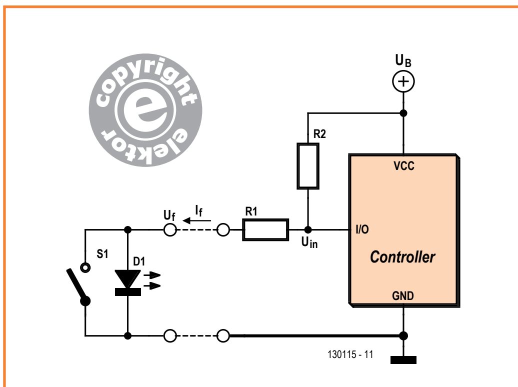
[2] www.atmel.com/devices/ATTINY45.aspx

[3] www.elektor.com/120633

[4] Low-g acceleration sensor: www.freescale.com/webapp/sps/site/taxonomy.jsp?nodeId=01126911184209#2

2-Wire Interface 3.0

By **John Hind** (UK)



Klaus Jürgen Thiesler's '2-Wire Interface' was published in Elektor magazine in the form of both basic [1] and low-current [2] versions. Each variant used two transistors and a handful of other components to hook up an LED and a pushbutton to a microcontroller. The author still felt driven to simplify this arrangement further and can now provide a solution that, with only two resistors and a single I/O pin, could hardly be minimalized any more. Unless you know better!

Reducing the number of components means the microcontroller has to work somewhat harder. This solution makes the assumption that an I/O pin can be toggled between input and output, which is virtually always the situation. The circuit is able to light the LED as output in 'High' state and assess the status of the switch when the LED is not alight. If you take a look at the state table, the first two lines (numbered 1 and 2) should

Table 1						
Status	**I/O Pin**	**State**	**Switch**	**LED**	**I_f**	**U_{in}**
1	Input	High	open	off	$(U_B - U_f) / (R1 + R2)$	$U_f + I_f * R1$
2	Input	Low	closed	off	$U_B / (R1 + R2)$	$I_f * R1$
3	Output	High	open	on	$(U_B - U_f) / R1$	U_B
4	Output	High	closed	off	$U_B / R1$	U_B

Table 2					
LED color	**U_f**	**I_f**	**@ 5 V: R1 | R2**	**@ 3.3 V: R1 | R2**	**@ 2.1 V: R1 | R2**
Red	1.7 V	10 mA	330 Ω | 470 kΩ	160 Ω | 220 kΩ	39 Ω | 56 kΩ
Orange, Yellow	2.1 V	10 mA	300 Ω | 430 kΩ	120 Ω | 180 kΩ	-
Green	2.2 V	10 mA	270 Ω | 390 kΩ	110 Ω | 160 kΩ	-
Blue, White	3.6 V	20 mA	68 Ω | 200 kΩ	-	-

make things clear. The I/O pin is switched as an input and the voltage U_{in} applied to it, according to the status of the switch, is interpreted as 'low' or 'high' so long as resistors R1 and R2 have been selected correctly to match the supply voltage U_B (most microcontrollers have an upper switching threshold in the region of 0.5 U_B).

So far, so good. But how can the switch be polled in states 3 and 4, when the I/O pin is functioning as an output? Quite simply in fact. Several times a second the pin is turned into an input for an extremely short period. In this way, for less than a blink of the eye, we have state 1 or 2, which thanks to the sluggishness of the human eye (persistence of vision, as it is called) is not even noticeable. If it is established then that the pushbutton switch is depressed, the pin remains in state 2 until it is released again, as state 4 would not make any difference (the LED remaining unlit), other than unnecessary current flows. Following this the controller switches back immediately into state 3, making the LED illuminate again.

In the firmware of the microcontroller we can implement not just basic debouncing but also 'de luxe' functions such as variable brightness for the LED, achieved very simply by toggling rapidly between states 1 and 3. Imagination knows no boundaries here!

The author developed his solution around the PIC16F883 [3]. This type operates with internal pull-up resistors that can be activated exactly as on the well-known AVR controllers. In principle, particularly if you reduced U_B, you could replace R2 with this internal resistor. Unfortunately these pull-ups have values exclusively in the range from 10 to 50 kΩ, which could lead to the LED lighting dimly (but definitely visibly) in state 1. The firmware therefore enables the pull-up only as long as necessary for polling the pushbutton switch, to ensure this effect is not bothersome.

In any event R2 must be selected so that the switching threshold of the input is definitely exceeded, since the forward voltage U_f drops with small currents. This very effect can become a problem when using a red LED and 5 V operating voltage. In this situation an ordinary silicon diode in series with the LED will help. Dimensioning the resistors relative to the supply voltage and according to LED color is set out in another table. With differing currents you will need to do some calculation.

(130115)

[1] 2-Wire Interface for Illuminated Pusbuttons, Elektor April 2012, www.elektor.com/110572

[2] 2-Wire Interface version 2.0, Elektor January & February 2013, www.elektor.com/120071

[3] Firmware: www.elektor.com/130115

Accurate Universal Measurement Interface

Accuracy—quite simply

By **Michel Defrance**
(France)

Most microcontrollers have a built-in digital-to-analog converter (DAC), but what can we do when this isn't accurate enough? Look no further: the solution is right in front of you.

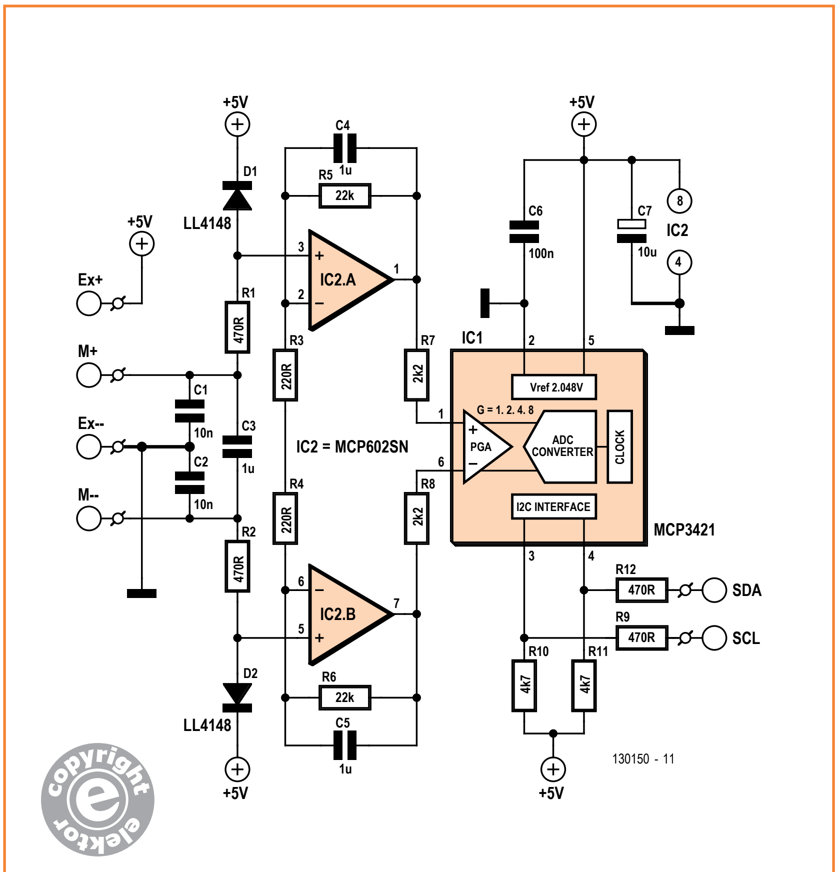


Figure 1.
Circuit of the measurement interface.

Table 1. Input voltage range as a function of MCP3421 gain.	
MCP3421 gain	**Input voltage range**
1	−20 mV to +20 mV
2	−10 mV to +10 mV
4	−5 mV to +5 mV
8	−2,5 mV to +2,5 mV

Electronics engineers very often need to measure low voltages with great accuracy, for example, the voltage from a pressure or temperature detector, or the output voltage of a Wheatstone bridge (often of the order of a millivolt). Microcontrollers are handy and fairly easy to program, but everyone knows that the accuracy of their converters isn't brilliant (often 8/10/12 bits). In addition, to measure low voltages, these need to be processed, often with the help of op amps.

Confronted yet again by this same problem, I decided to find a solution that would be both satisfactory and reusable. The inspiration was there alright, all it now needed was the perspiration bit. The requirements were clear: I needed an interface that would be easy to connect to any microcontroller and easy to put together using common, cheap components. Two ICs in the Microchip catalogue caught my eye:
- the MCP602 high-performance amplifier;
- the MCP3421 18-bit programmable ADC with I²C interface, built-in 2.048 V reference, and programmable amplifier.

Instrumentation amplifier

When we want to process low voltages for digitizing, we often use a configuration called an instrumentation amplifier, built using three op amps. Here, I'm using the MCP602's two op amps IC2A and IC2B in a differential configuration to drive the programmable-gain amplifier in the MCP3421. The output voltage of this first stage will be proportional to the voltage difference between the circuit's measuring inputs M+ and M− (**Figure 1**). The gain of the first stage is given by:

$G1_{+} = 1 + R5/R3$

$$G1\_ = 1 + R6/R4$$

Since we want the amplification of the voltage at the M+ input to be the same as that for the M− input, we'll choose R5 = R6 and R3 = R4. With the values shown on the circuit, we'll have:

$$G1 = 1 + 100 = 101$$

Make sure you select 1% tolerance resistors for R3–R6, otherwise you risk having a serious asymmetry in the input stage. Let's move on to the second stage, built around amplifier/ADC IC1. Used in symmetrical mode, it accepts voltages from −2.048 V to +2.048 V between its pins 1 and 6. Since the gain G2 of the amplifier it contains is software-programmable, it will be possible to select different ranges for the input voltage from the first stage. The total gain of the circuit $G = G1 \times G2$ will thus vary between 101 for $G2 = 1$ and 808 for $G2 = 8$.

Table 1 gives a list of the possible values. If these ranges don't suit you, change the value of R3–R6.

Powering

The interface is powered at 5 V. In the presence of weak signals, noise from the power supply can become a problem—and this circuit is no exception. Whatever type of supply you choose, it must be accurate and generate as little noise as possible. Using 18-bit accuracy conversion, the slightest supply noise will interfere with your measurements. I also recommend using a soft-start power supply so as to reduce drift due to variations in component characteristics. It would be possible to use software delay timing for this, but that wouldn't benefit all the components on the board. In [1] I suggest just such a power supply, based around an MIC2941 low-loss regulator from Micrel.

Construction and use

Construction of the 35 × 25 mm PCB (**Figure 2**) ought not to cause any problems for readers familiar with SMDs. If you design your own PCB, to obtain optimum performance, do adhere to the advice given in the MCP3421 data sheet. This is also very helpful when it comes to using the project. Watch out for the MCP3421's I²C address: this depends on the exact type number of the device you buy. This is also detailed in the data sheet.

Specifications

- 18-bit conversion
- I²C interface
- Software-programmable gain

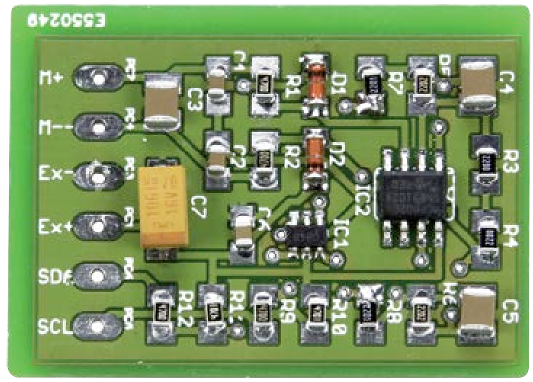


Figure 2.
View of the author's PCB.

By way of an example, I've developed an application around a PIC18F452 (or PIC16F876A) microcontroller which displays the voltage read from the MCP3421 via the I²C bus on the LCD. You'll find that elsewhere in this issue. It measures the low voltage (a few millivolts) from a strain gauge wired into a Wheatstone bridge. The PIC receives the digitized voltage from the MCP3421, and the PICBASIC program converts the value into pressure. The ADC output voltage and the pressure then appear on an LCD. This program shouldn't be too hard to port to an Arduino, for example. You'll be able to use this inexpensive circuit (less than $20) in lots of different projects. And you won't have a reason any longer to curse the ADC in your favorite microcontroller.

(130150)

Internet Links

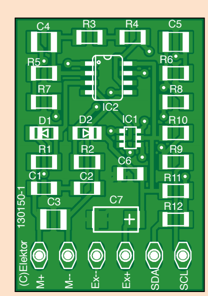
[1] www.elektor-labs.com/node/3053

COMPONENT LIST

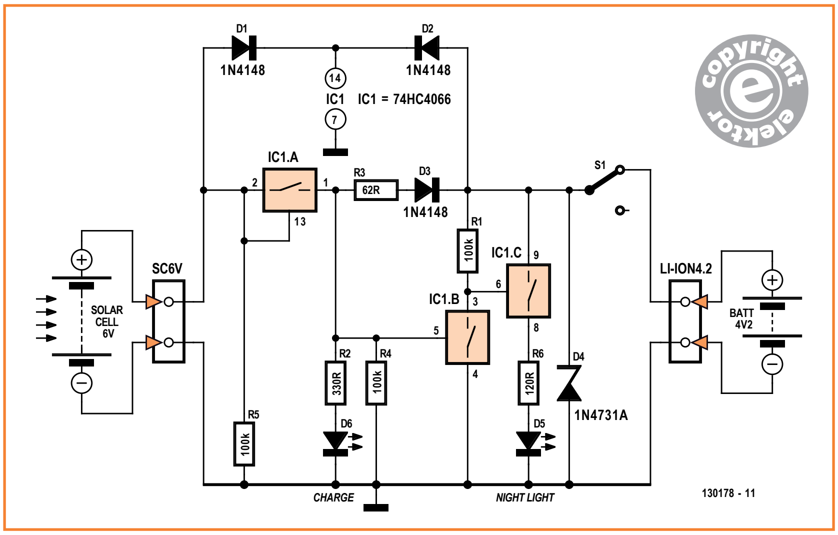
Resistors
R1,R2R9,R12 = 470Ω 5%
R3,R4 = 220Ω 5%
R5,R6 = 22kΩ 1%
R7,R8 = 2.2kΩ 5%
R10,R11 = 4.7kΩ 5%

Capacitors
C1,C2 = 10nF 50V 10%
C3,C4,C5 = 1µF 50V 10%
C6 = 100nF 50V 10%
C7 = 10µF 16V 10%, electrolytic

Semiconductors
D1,D2 = LL4148
IC1 = MCP3421A1T
IC2 = MCP602SN



Solar-Powered Night Light with Li-ion Backup



By
Michael A. Shustov
(Russia)

This night light has two power sources: a solar cell with a peak output voltage of about 6 V, and a Li-Ion cell with a voltage between 3.7 V and 4.2 V. Three (of four) electronic switches in a 74HC4066N (IC1) control the device operation. IC1 gets its supply voltage through diode D1 or D2 depending on which power source supplies the highest voltage. Consequently the 4066 gets any value between 3.7 V and 6 V to operate off.

At daytime the voltage supplied by the solar cell reaches the peak value typically around 6 volts. IC1a is closed due to the High level at its control input (pin 13), so the Li-ion battery gets charged with about 10 mA through resistor R3 and diode D3 connected in series. At the same time LED D6 lights to indicate the battery is being charged. Switch IC1b is closed too, causing switch IC1c to be open and LED D5 to remain dark.

If the voltage supplied by the solar cell drops below 1/3 of IC1's supply voltage, i. e. below 1.3 V or thereabouts, switch IC1a opens and the 'Charge' LED goes out. The voltage at the control input of switch IC1b drops to zero, causing he switch to open. Consequently switch IC1c closes, connecting the 'Night Light' LED to the battery through resistor R6, which sets the LED current to 10-13 mA. Feel free to select the color—the prototype had a green LED.

The battery charging rate as well as the intensity of the LEDs may be adjusted by adapting R3, R2 and R6, observing a maximum current of 20 mA through the '4066 switches. Zener diode D4 prevents excessive battery charge voltage levels. Switch S1 when opened prevents the battery from being discharged when the circuit is in storage, or not in use for some reason.

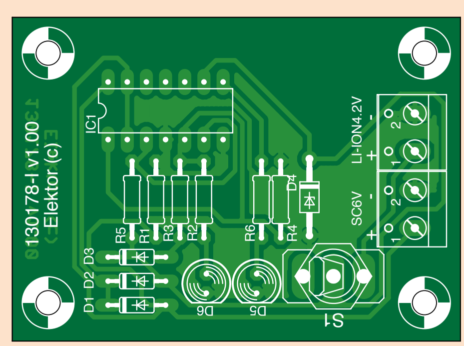
(130178)

COMPONENT LIST

Resistors
R1,R4,R5 = 100kΩ 1% 0.25W
R2 = 330Ω 1% 0.25W
R3 = 62Ω 1% 0.25W
R6 = 120Ω 1% 0.25W

Semiconductors
D1,D2,D3 = 1N4148
D4 = 1N4731A zener diode (4.3V)
D5 = LED, 5mm, color of choice
D6 = LED, red, 5mm
IC1 = 74HC4066

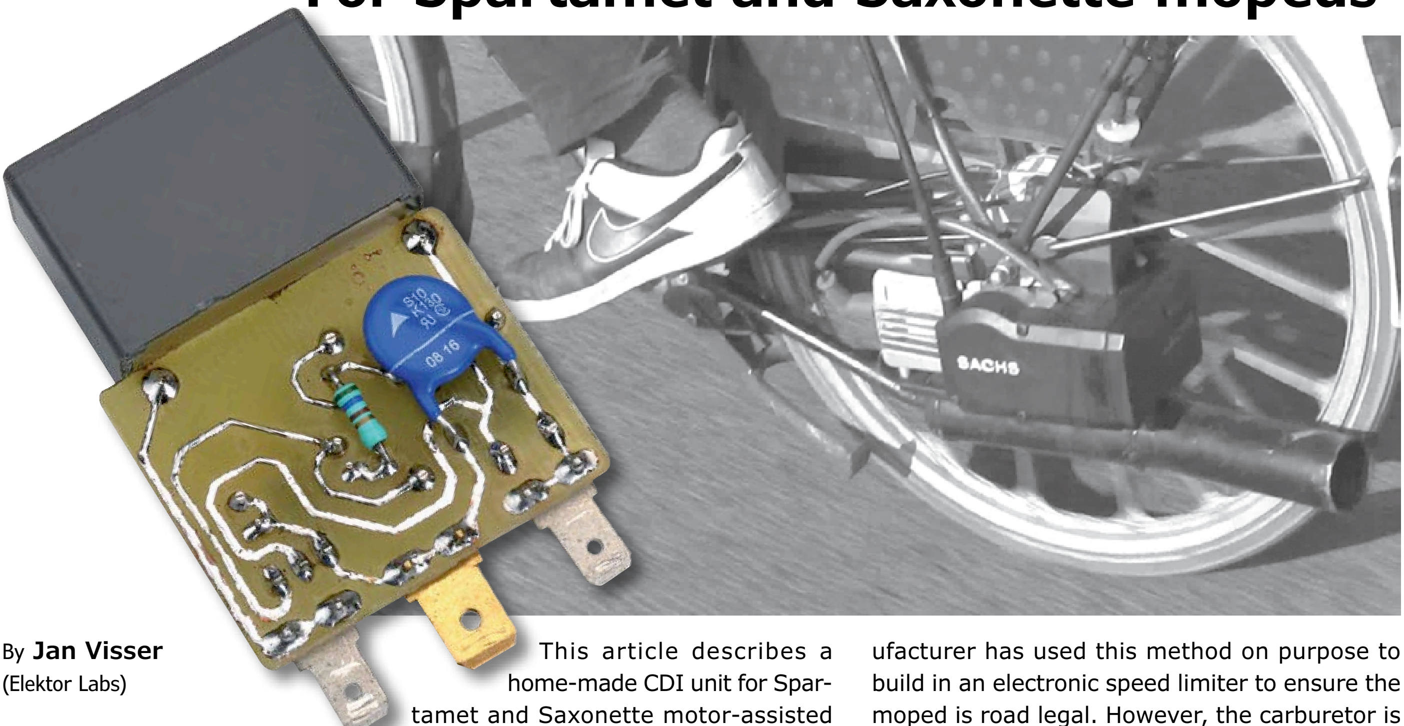
Miscellaneous
S1 = toggle switch, Newark/Farnell # 1310879
PCB # 130178-1



Connectors marked SC6V and LI-ION4.2V = PCB terminal block, lead pitch 5mm

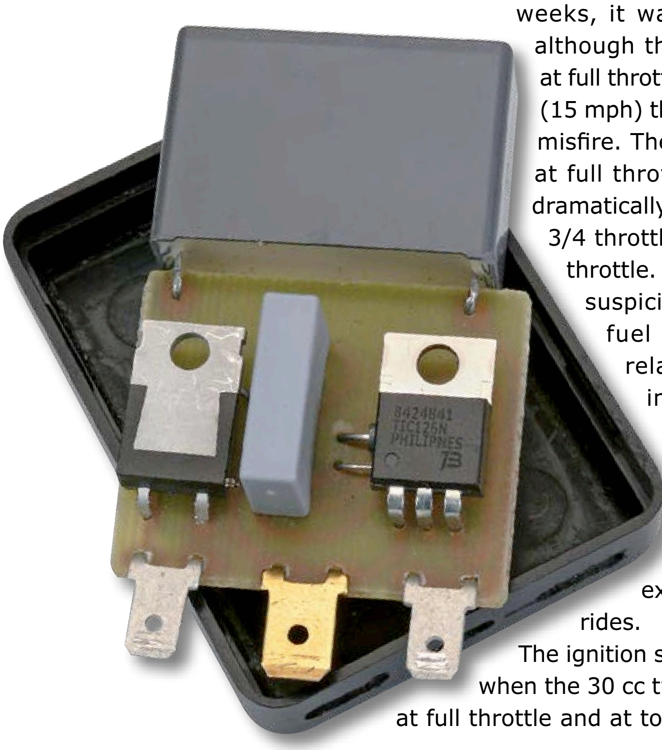
CDI Ignition

For Spartamet and Saxonette mopeds



By **Jan Visser**
(Elektor Labs)

This article describes a home-made CDI unit for Spartamet and Saxonette motor-assisted bicycles (mopeds).



Having been virtually forced to use a Spartamet to travel between home and work for three weeks, it was noticeable that although the moped ran fine, at full throttle and at top speed (15 mph) the ignition began to misfire. The fuel consumption at full throttle also increased dramatically: from 118 mpg at 3/4 throttle to 71 mpg at full throttle. There was a strong suspicion that the higher fuel consumption was related to the misfiring of the ignition; this was confirmed after some further thought and having checked the spark plug and exhaust after several rides.

The ignition starts to skip sparks when the 30 cc two-stroke engine is at full throttle and at top speed. The manufacturer has used this method on purpose to build in an electronic speed limiter to ensure the moped is road legal. However, the carburetor is not limited and it happily continues to deliver the fuel mixture, which ends up unburnt in the exhaust. Apart from the fact that this has a negative impact on the fuel consumption, it doesn't do the exhaust any good either. There will be more of a carbon build up in the exhaust, which means it has to be replaced sooner.

You could of course open up the existing CDI (Capacitive Discharge Ignition) unit and modify it, but since this is completely encased in potting compound this is not something we would recommend. Instead, we investigated what was required to produce the sparks without limiting the rpm. The result of this can be seen in the schematic shown here.

Since the ignition coil and pickup coil are mounted next to the flywheel of the engine we only have to concern ourselves with the electronics that make a capacitor discharge into a coil at just the right moment.

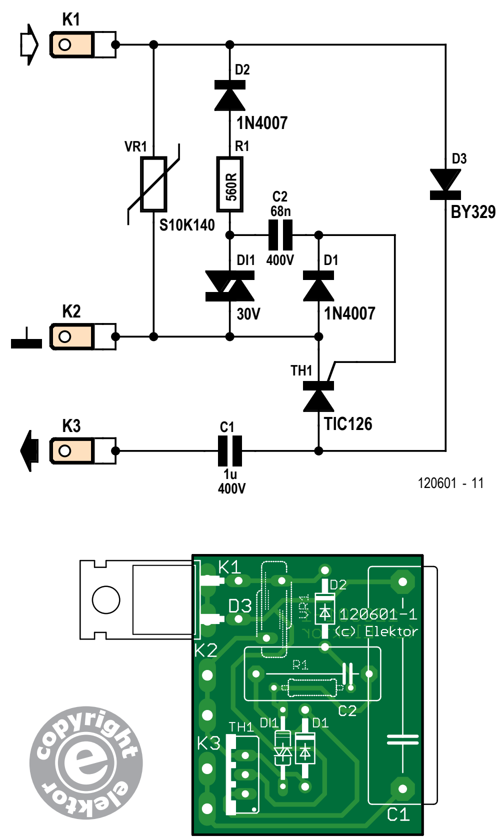
The input is connected to a pickup coil that delivers a single pulse for every revolution of the flywheel. The output is connected to the ignition coil that supplies the high voltage pulse to the spark plug. Capacitor C1 stores the electrical energy and is charged up via D3. When there is a pulse at the input it triggers the thyristor into conduction, which connects C1 to ground so it can discharge into the ignition coil. That is all there is to it!

A single sided PCB has been designed for the circuit (the layout can be downloaded from [1]). However, note that the components are mounted on both sides of the board. This was necessary in order to keep the circuit the same size as the original CDI unit. Its dimensions are 59x38x24 mm. The photos of the prototype make this clearer. First mount D1, D2, DI1 and C2 onto the component side. You should then solder diode D3 and thyristor TH1 onto the board. These should be bent over so they're level with the board, with D3 ending up on top of D2 and T1 on top of D1 and DI4. The MKP capacitor (C1) ends up alongside the board. The varistor (VR1) and resistor (R1) are then mounted onto the solder side of the board. And finally you should solder the three spade terminals onto the board.
For the enclosure you can use a small box from Hammond (001100), Conrad Electronics part number 540830-89, although an acrylic home-made box (cassette or cd case) is an alternative. Once the board has been populated and connected you can check if the ignition produces any sparks. If it all works and the spark plug is sparking happily you can put the circuit in its enclosure and fill it with potting compound. If you fail to do this it is very likely that the circuit will soon stop working properly, since the ignition is subject to quite a lot of vibration.
There are two types of CDI unit in use, one made by Motoplat (red) and one made by Prüfrex (blue). In both cases the earth is connected to the middle connector of the CDI unit. If you accidentally connect the input and output the wrong way round the CDI unit won't produce a spark. All you need to do when this happens is to swap the red and blue wires over.
When the circuit was installed and put into use the effect was immediately noticeable. The engine runs much smoother at full throttle and it no longer misfires. The average fuel consumption was also found to have improved considerably to 166 mpg.
Since the little engine has its own mechanical limitations (carburetor, exhaust, compression ratio), the top speed won't increase by a huge amount: we found it to be about 2 to 2.5 mph higher. The biggest advantages are of course the better running of the engine and the improved fuel consumption.

(120601)

Internet Link

[1] www.elektor.com/120601



COMPONENT LIST

Resistors
R1= 560Ω
VR1 = S10K140 varistor

Capacitors
C1 = 1µF 400V MKP
C2 = 68nF 400V MKS

Semiconductors
D1,D2 = 1N4007
D3 = BY329
DI1 = diac D30 (alternative: ER900 or DB3)
TH1 = TIC126N

Miecellaneous
3 pcs 6.3-mm (0.25'') Fast-on (spade) terminal plugs, PCB mount
PCB 120601-1, see [1]

Connection Details for the CDI Unit

Motoplat: black coil with a red CDI unit
Prüfrex: blue/gray/red coil with a blue CDI unit

Motoplat	**Prüfrex**
a = yellow	a = black
b = blue	b = red
c = red	c = blue

The connection details are shown on top of the CDI unit. Should you connect the red and blue wires the wrong way round you won't get a spark, and you won't damage the coil or CDI unit.

Simple Servo Tester

Basic test gear for modelers

By **Bernhard Kaiser**
and **Michael Gaus**
(Germany)

When a servo motor starts to malfunction there is generally not much to see from the outside to help diagnose the problem. That's why every modeler's toolbox should have one of these handy units!

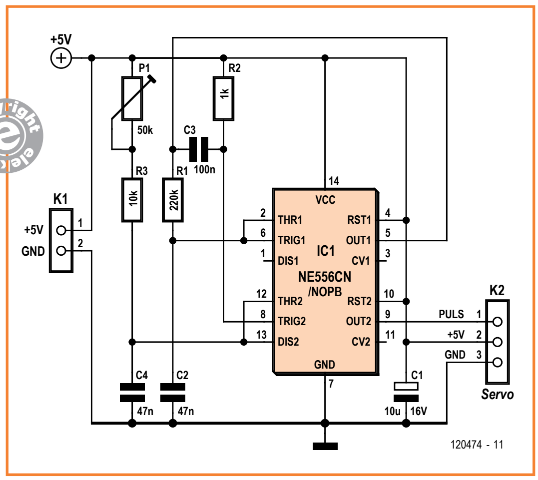
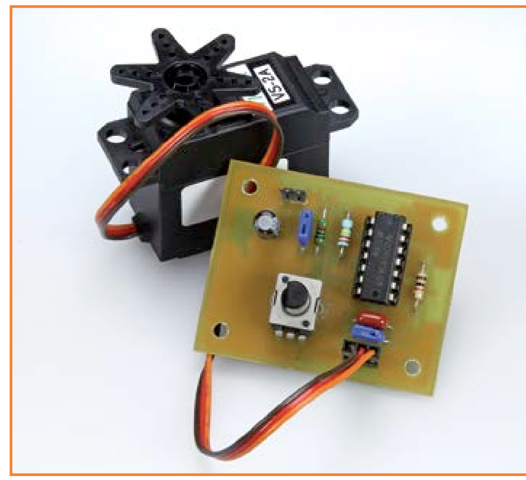


Figure 1.
The circuit uses a dual timer IC.



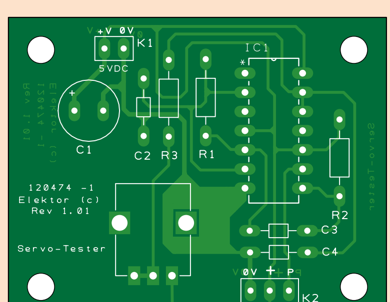
Servos are one of the basic components used in all branches of model building. They are small, lightweight, low cost and are remarkably easy to control. Model building servos connect directly to an RF receiver unit. They typically have just three connections: positive supply (+5 V), ground (GND) and control (Pulse) lead, which supplies a control signal to move the servo arm. The signal on this lead is pulsewidth modulated and supplied by the receiver. Positive pulses with a length of 1 ms cause the servo arm to move fully to one end of its travel while 2 ms pulses move the arm fully in the opposite direction. Pulse widths between these limits move the arm to an intermediate position proportional to the pulsewidth. A pulsewidth of 1.5 ms centers the arm. The pulse repetition rate is approximately 20 ms i.e. 50 Hz but this rate is not too critical.

When you suspect that the model is not behaving as it should it could be a problem with the remote control transmitter, receiver or a servo motor. This handy unit allows you to quickly test the servo and eliminate it (or otherwise) from your lines of enquiry. This pulse generator design

COMPONENT LIST

Resistors
R1 = 220kΩ
R2 = 1kΩ
R3 = 10kΩ
P1 = 50kΩ linear potentiometer

Capacitors
C1 = 10µF 16V, 7.5mm pitch
C2,C4 = 47nF
C3 = 100nF



Semiconductors
IC1 = NE556CN

Miscellaneous
K1 = 2-pin pinheader, 0.1'' pitch
K2 = 3-pin pinheader, 0.1'' pitch
PCB 120474-1
DesignSpark-project files can be downloaded from [1].

Figure 2.
The ready made PCB makes circuit construction a cinch.

shown in **Figure 1** is one of the basic bread and butter circuits known to almost all engineers.

A Two timing circuit

The pulse generator is made up of a dual timer chip type NE556, the output pulse width is controlled by the position of a potentiometer. The combination of resistor R1 and capacitor C2 in timer 1 of the NE556 produces the repetition rate of the pulse. This timer output signal at pin 5 has an approximately symmetrical mark space ratio. The negative going edge of the output signal is used via C3 to trigger the second timer which then produces a positive going output pulse at pin 9. The width of this pulse is defined by the values of capacitor C4 and the combined resistance of R3 and P1. Pot P1 thereby gives control of the pulse width.

During tests it was found that the circuit with the component values specified here produced a pulse width in the range of 0.5 to 2.6 ms which more than covers the standard pulse width range used by these types of servomotors. For this reason P1 should not be turned fully to either end of its travel otherwise the connected servo will go past its intended end position and hit the mechanical stops, possibly damaging the servo. Before the circuit is powered up ensure that the control knob P1 is roughly mid position. The pulse repetition rate of the circuit was found to be 18 ms.

The vast majority of servos operate with a supply in the range of 4.8 to 6 V. Here the operating voltage is in the range of 5 to 6 V which can be supplied by four AA primary cells or rechargeables.

To make a neat job and simplify construction we have made a PCB for this design (**Figure 2**) which is available from the Elektor Shop [1]. All components have standard (non SMD) outlines so fitting the components should not pose any problems.

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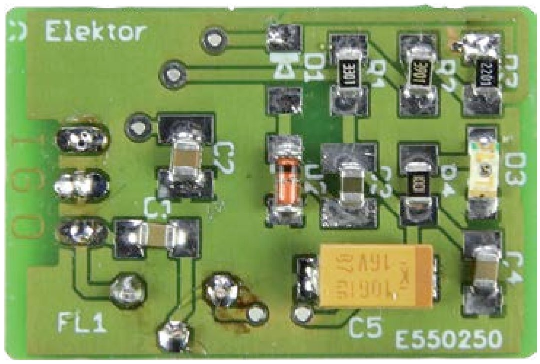
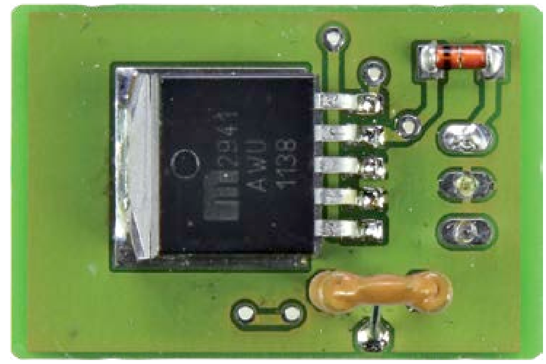
Internet Link

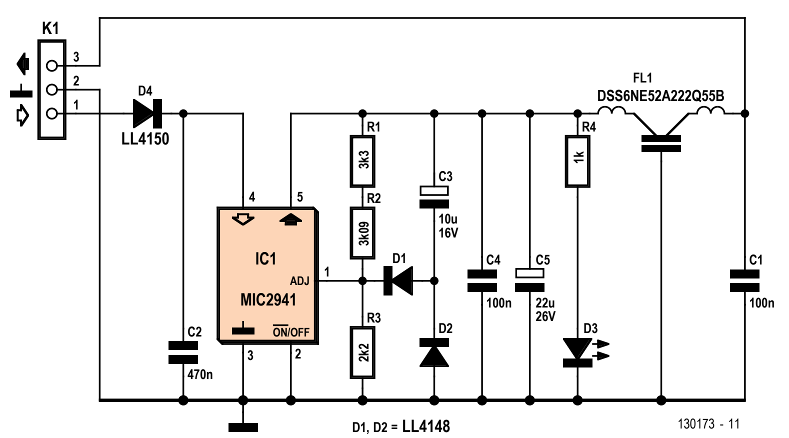
[1] www.elektor.com/120474

Slow-Start Stabilizer





By Michel Defrance
(France)



Your everyday 7805 regulator is not the best choice for powering accurate measurement circuits and A/D converters, mainly because it generates too much noise, and exhibits spurious behavior at power on. Taking our Universal Precision Measuring Interface as an example we have a type MCP3421 A/D converter with a resolution of 18 bits. To be able to exploit the high resolution to the last bit, the supply rail must be absolutely stable and free of noise. In addition, the supply voltage should rise slowly when turned on, allowing the components in the measuring circuit to stabilize in terms of bias voltages and temperature. Of course, that can also be accomplished by using a software timer, but doing so has an effect for a couple of components only.

The circuit described here meets all conditions mentioned and can easily serve as a replacement for an ordinary 7805, because the circuit board has about the same size, and the connections are identical. That does mean however that everything got designed in SMD technology due to limited space.

The regulator used is a MIC2941 from Micrel. It's is a low-dropout regulator in which the output voltage is set using a resistance divider, just as with an LM317. The design is simple but effective. The supply voltage is set by (R1 + R2)/R3, resulting in 5 V here. Diode D4 serves as polarity protection. Furthermore, a bunch of capacitors is present for decoupling and noise suppression. At the output an EMI filter is included (FL1). The DSS6NE52A222Q55B is a 3-pin component from Murata, containing two coils separated by a capacitor to ground.

The delayed appearance of the supply voltage is accomplished by capacitor C3. When the supply is switched on, initially the voltage at junction R2/R3 remains at virtually 0 V. Next, the capacitor is charged via R3 charged in a about 20 ms, causing the output voltage to rise slowly (see screendump). Diodes D1 and D2 prevent negative voltage ending up at the regulation input, causing the capacitor to be discharged via R2.

The circuit can deliver an output current of at least 1 A. With no cooling however a few tens of mA are possible at an input voltage of 12 V. The

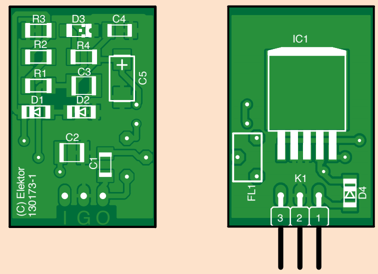
COMPONENT LIST

Resistors (SMD 1206)
R1 = 3.3kΩ
R2 = 3.09kΩ
R3 = 2.2kΩ
R4 = 1kΩ

Capacitors
C1,C4 = 100nF (SMD 1206)
C2 = 470nF (SMD 1210)
C3 = 10µF 16V (SMD 1210)
C5 = 22µF 10V (SMD 2312)

Semiconductors
D1,D2 = LL4148
D3 = LED, low current, shape 1206
D4 = LL4150
IC1 = MIC2941AWU TR (TO-263)

Miscellaneous
EMI suppression filter type DSS6NE52A222Q55B (Murata)
PCB # 130173-1, see [1]



PCB artwork is available as a free download of the Elektor website [1].

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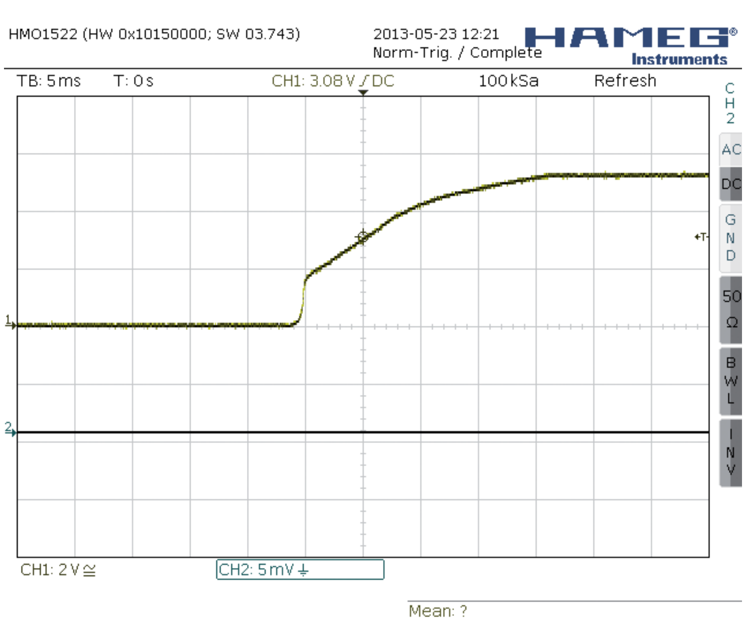
Internet Link

[1] www.elektor.com/130173



8x Relays and Much More

Expansion modules for Linux and other controller boards

By **Benedikt Sauter** and **Jens Nickel**

In the April edition we presented an expansion PCB for the Elektor Linux board and mentioned at the same time that this could be used with other controller boards as well. Meanwhile the development team at Embedded Projects has been working hard designing a whole raft of extra extension boards that are available from Elektor. As an appetizer, so to speak, here is a card with eight relays.

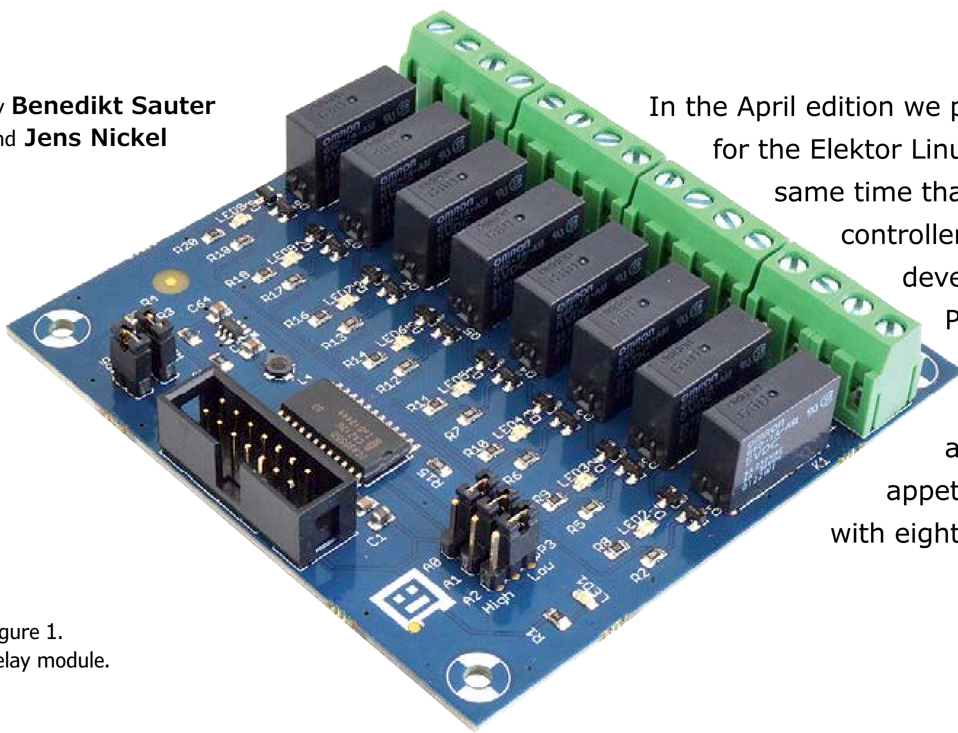


Figure 1.
Relay module.

The relay module (**Figure 1**) is driven using the 14-pin *Gnublin Connector*, just like the Linux Extension Board featured back in April. As an *Embedded Extension Connector* it is also used on the Xmega Webserver Board from Elektor (see next issue) and we are planning further controller boards equipped with this connector. The expansion board is ideal for newbies for whom Linux is (still) too complicated and equally suited to 'power users' who prefer to develop their programs using 'bare metal', in other words without the aid of an operating system.

The relay board, like the Elektor Linux board, originated from the firm Embedded Projects, run by Benedikt Sauter [1]. It's one of a whole series of expansion boards (see boxout) that all mate with the EEC connector mentioned above, providing as it does pins for SPI, I²C, PWM, analog inputs and digital inputs/outputs. On the other hand, Elektor Labs have been working on modules using a 10-pin expansion connector (*Embedded Communication Connector*) for UART/TTL connections with one another (see boxout). A small zoo is growing up of controller boards and expansion boards that can be combined flexibly—microcontroller fans can look forward to an interesting time over the coming six months!

Relay card

The circuit diagram of the relay card can be seen in **Figure 2**. As with the Linux Extension Board, a port expander PCA9555 (IC1) addressed over the I²C bus increases the number of digital outputs available to 16, of which eight are used here. The address of the I²C module can be preset using

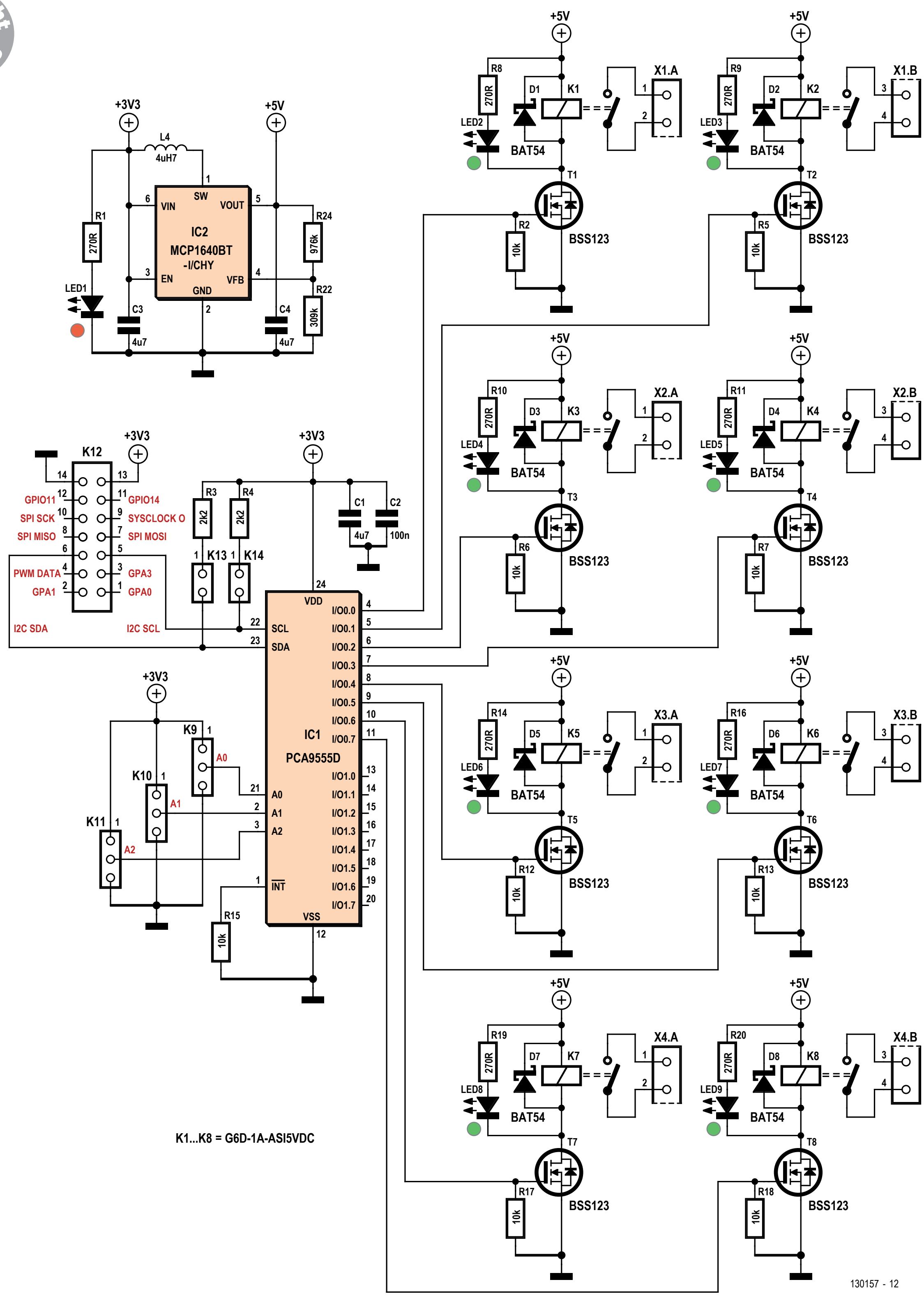


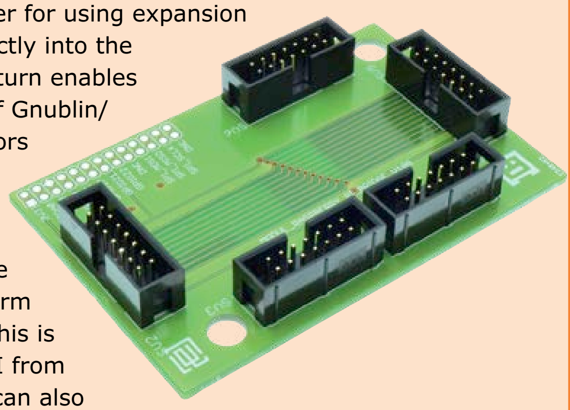
Figure 2.
Circuit diagram of the relay module.

Expansion modules for the Gnublin/ Embedded Extension Connector (selection)

8x relays (130212-91)
4x20 text display (130212-92)
Stepping motor driver (130212-93)
I/O expander (130212-94)
Temperature sensor (130212-95)
Distributor board 'Bridge Module' (130212-71)
Raspberry Pi adapter 'GnuPi' (130212-72)

These and other boards are available from Elektor [2]. In each case the boards come with SMD components preinstalled, with leaded components supplied in the kit for DIY assembly.

Raspberry Pi Adapter



The Raspberry Pi adapter board 'GnuPi' increases the system's flexibility even further for using expansion boards. It plugs directly into the Raspberry Pi and in turn enables the use of a range of Gnublin/ EEC plug-in connectors [2]. In this way all the expansion boards shown can also be used with the new computer platform that's all the rage. This is neat: the C/C++ API from Embedded Projects can also be used with the Raspberry Pi. To convert a Gnublin/Elektor Linux board application to work on the Raspberry Pi all you need do is alter one single line of code:

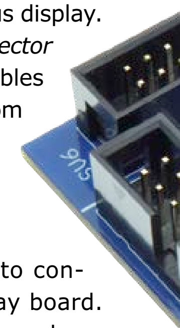
```
#define BOARD_GNUBLIN  →  #define BOARD_RASPBERRYPI
```

Expansion modules for the Embedded Communication Connector

RS485 interface (under development)
RS232 interface (planned)
433 MHz radio module (under development)
Bluetooth using the BTM-222 (planned)
WLAN using the WizFi220 (planned)
USB using BOB (planned)

More on this subject at the Elektor.Labs website [8].

jumpers K9 to K11. Pull-up resistors for the I^2C bus can be implemented using K13 and K14. The digital outputs IO 0.0 to IO 0.7 of the port expanders each drive a FET, with in turn operates a relay. An LED for each serves as status display. The *Gnublin/Embedded Extension Connector* is equipped with a 3.3 V pin, which enables the expansion boards to be powered from the controller board. A step-up converter (IC2) is built in to provide the 5 V coil voltage for the relay.



A length of flat ribbon cable serves to connect the controller board and the relay board. The Embedded Projects development gang have already thought about the option of hooking up several expansion boards at the same time; a distributor board (**Figure 3**) is available from Elektor too [2].

C/C++ API

We have already shown in [3] and [4] how you switch the outputs of the port expander ICs in Linux. But there is now an even simpler option. Benedikt Sauter and his comrades-in-arms have written a complete C/C++ API for controlling the expansion cards with great ease. You can incorporate the functions in programs that you write yourself but a number of short command line tools are also available. More on this in the next edition, in which we'll introduce the other extension boards.

A first taster of the C/C++ API is given in the listings. Listing 1 shows how you can access the digital inputs and outputs of the Elektor Linux board easily. Listing 2 demonstrates how you can read in values via the analog input. And Listing 3 shows how you operate the relay card.

The new API [5] also clarifies the route into the world of Embedded Linux for beginners, managing without the more complex features of C like, for example, the Pointer. For the names of functions the developers have in part borrowed from the corresponding Arduino functions. If you're interested, you are of course welcome to cast a glance at the source code [6].

Debian for the Elektor Linux board

Not only has the Gnublin Linux system been enhanced with new hardware but the software side has also been updated. If you feel inclined,

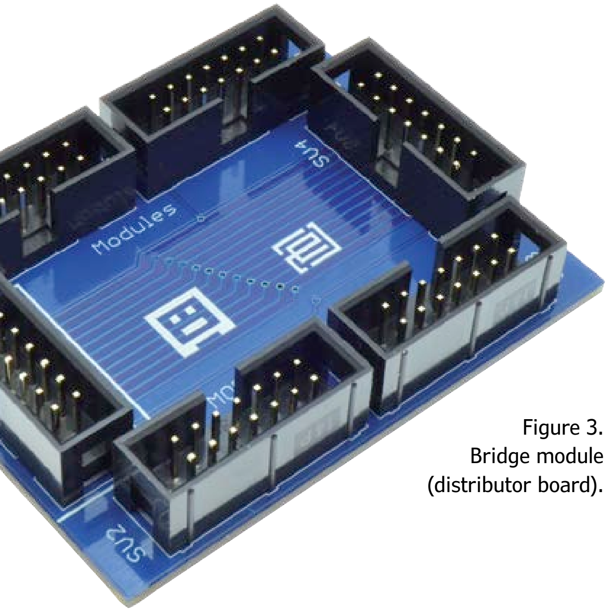


Figure 3.
Bridge module
(distributor board).

Listing 1: Digital output control on the Elektor Linux board.

```
#define BOARD_GNUBLIN
#include "gnublin.h"

int main()
{
   gnublin_gpio gpio;

   gpio.pinMode(3,OUTPUT);

   while(1){
     gpio.digitalWrite(3,HIGH);
     sleep(2);
     gpio.digitalWrite(3,LOW);
     sleep(2);
   }
}
```

you can now equip the Elektor Linux board with a Debian system (in place of the ELDK file system). Debian is very easy to install on the SD card (it doesn't matter whether you are using the 8 MB or 32 MB version of the board); you can find instructions on the Internet [7].

(130157)

Internet Links

[1] sauter@embedded-projects.net

[2] www.elektor.com/gnublin

[3] www.elektor.com/120596

[4] www.elektor.com/120518

[5] http://wiki.gnublin.org/index.php/API

[6] https://github.com/embeddedprojects/gnublin-api

[7] http://wiki.gnublin.org/index.php/GNUBLIN-Elektor

[8] www.elektor-labs.com/ECC

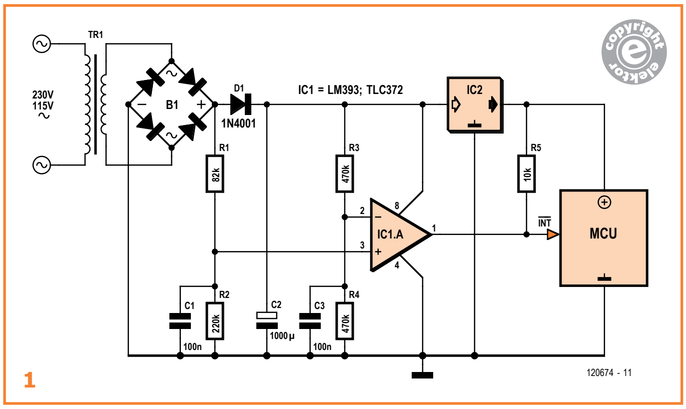
Listing 2: Reading a value on the analog input.

```
#define BOARD_GNUBLIN
#include "gnublin.h"

int main()
{
   gnublin_adc ad;

   while(1){
        printf("AD value %i \n",ad.getValue(1));
   }
}
```

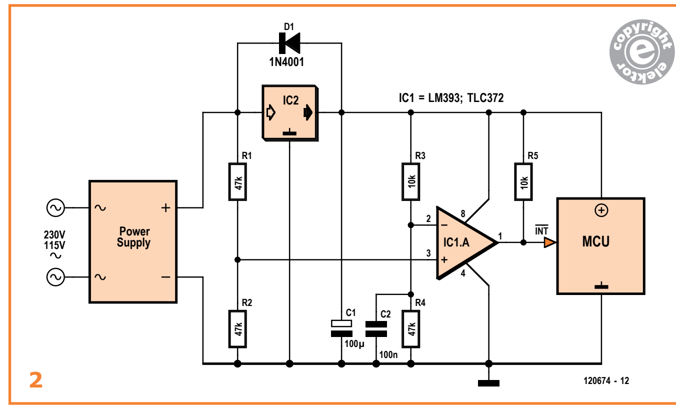
Listing 3: Driving the relay card.

```
#define BOARD_GNUBLIN
#include "gnublin.h"

int main() {
  gnublin_module_relay relay;

  relay.setAddress(0x24);
  relay.switchPin(4, ON);
  sleep(2);
  relay.switchPin(4, OFF);
}
```

Store it Quickly 2.0



1



2

By **Jürgen Werner**
(Germany)

Some microcontroller applications require status information or other important data to be stored to EEPROM immediately as power to the equipment is turned off or fails. When power is resumed this information will then be available for use as required. To solve this problem Rainer Reusch developed a circuit (**Figure 1**) and it appeared in Elektor magazine as a Design Tip [1]. The principle behind this original circuit is that the voltage at the anode of D1 falls sooner than voltage across reservoir capacitor C2. A comparator evaluates these levels and outputs a signal to the microcontroller indicating that the input voltage has fallen. Thanks to D1 and C2 voltage at the non-inverting input to IC1.A falls faster than the voltage at the inverting input. This produces a Low level at the comparator output, triggering an interrupt. As long as there is sufficient energy stored in the reservoir capacitor, the microcontroller now has time to store all important data to EEPROM before the supply rail sinks too low.

The circuit functions effectively, at least in simple situations. One problem is that it takes a few milliseconds to write data to EEPROM cells. The value of C2 must therefore be larger than is strictly necessary since it must also act as a reservoir to supply the regulator when input voltage falls. Apart from that the calculation of C1, for the ripple voltage is not so easy. Even more of a problem is if the power is supplied from a wall wart type adapter which includes built-in voltage regulation or switch-mode supply. In this case the circuit cannot work because the voltage at the input to R1 does not fall fast enough thanks to the reservoir capacitors integrated into the adapter. These shortcomings led the author to set about tweaking the original design; the result can be seen in **Figure 2** which is both a better and simpler solution. The comparator has now been moved to after the voltage regulator. With this configuration we are comparing the input voltage with the voltage output from the regulator. We no longer need the diode in series with the voltage regulator. The reservoir capacitor C1 does not need to be so big now. The biggest improvement however is that now the circuit is not dependant on how quickly the input voltage falls. When the voltage from the power adapter sinks the level on the output of the regulator is held constant by regulator action. When dimensioned correctly the voltage divider at the non inverting input of the comparator produces an input voltage lower than the level at the inverting input, generating a low output to trigger an interrupt in the microcomputer.

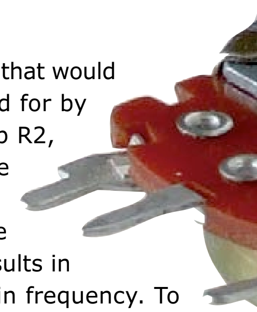
The circuit values have been calculated assuming the mains adapter has a 9 V output and the voltage regulator produces 5 V. D1 protects the regulator from current flowing in the reverse direction. With C1 equal to 100 µF and a load current of 5 mA the microcontroller has at least 17 ms in which to store data to EEPROM. An edge triggered interrupt is used here. When it is possible to disable power-hungry features of the microcontroller such as any A/D converters, that'll give extra time to store data.

(120674)

[1] Store it Quickly! Elektor January 2009, www.elektor.com/080379

Wideband Wien Oscillator with Single-Gang Pot

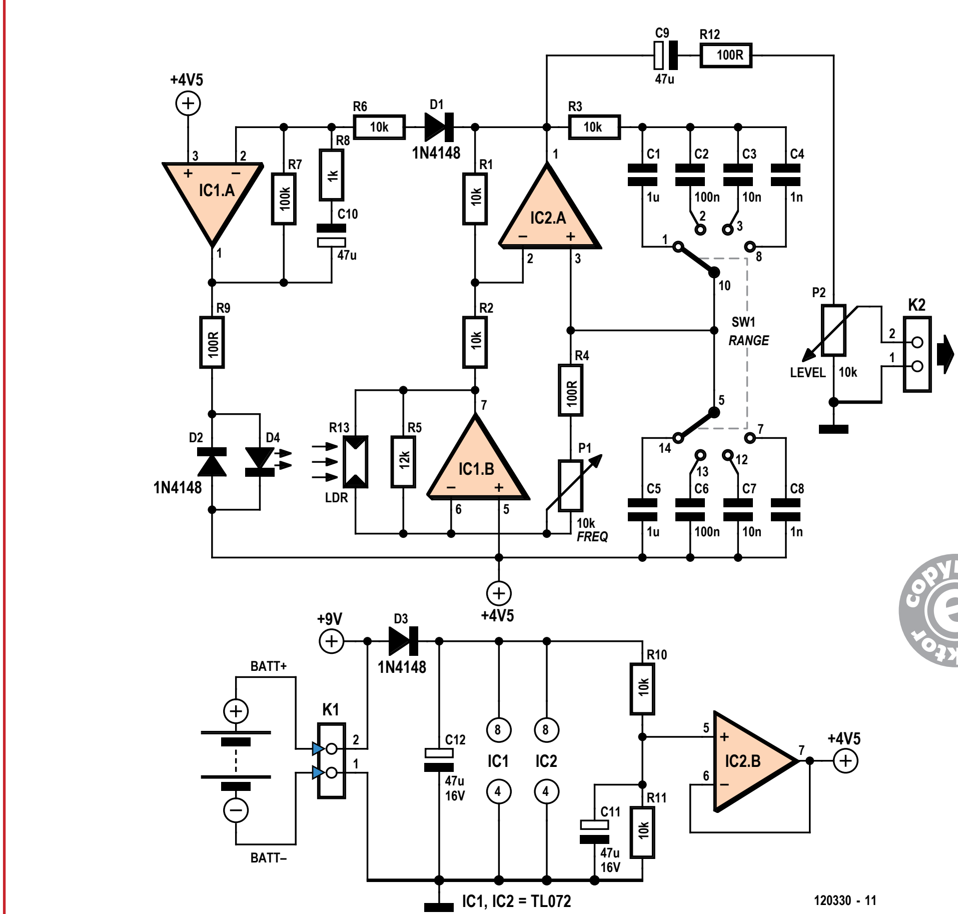
By **Merlin Blencowe**
(United Kingdom)

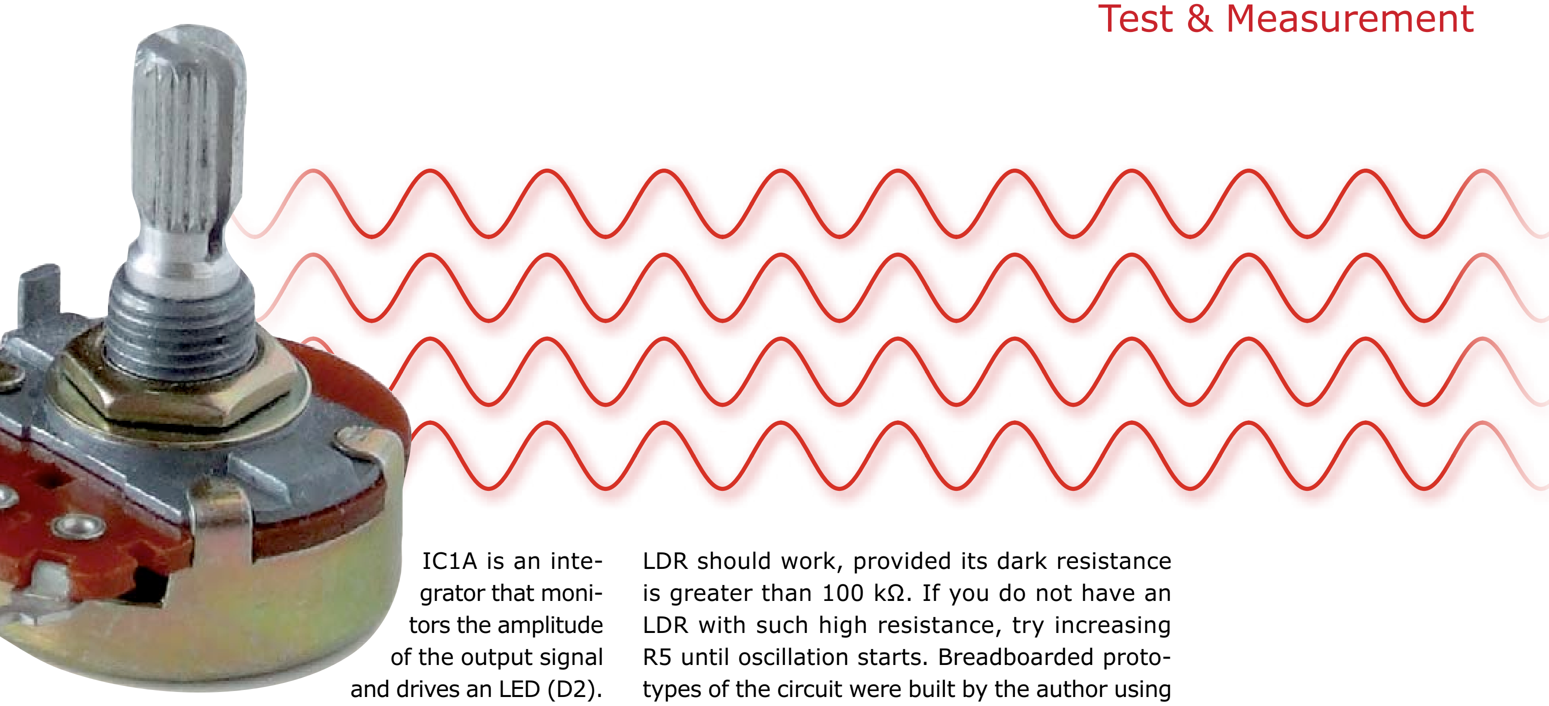


This Wien bridge oscillator (after Max Wien, 1866–1938) produces a low-distortion sine wave of constant amplitude, from about 15 Hz to 150 kHz. It requires just four opamps and will work off a single 9-volt battery. Also, unlike most Wien bridge oscillators, it does not require a dual-gang potentiometer for tuning.

Op amp IC2b provides an artificial ground so that the circuit will operate from a unipolar supply (9 V battery or power pack). IC2a is the main amplifier for the oscillator. The frequency range is divided into four decades by 2-pole, 4-way rotary switch SW1.

Only one arm of the Wien network is varied, but the change in positive feedback that would normally result is compensated for by IC1b, which works to bootstrap R2, thereby changing the negative feedback enough to maintain oscillation. A *linear* change in the resistance of the tuning pot results in a roughly *logarithmic* change in frequency. To get a more conventional linear change a log-taper pot is used wired so that rotating the knob anticlockwise causes frequency to increase. You could use an anti-log pot the other way around if you prefer, but these things are notoriously hard to find.





IC1A is an integrator that monitors the amplitude of the output signal and drives an LED (D2). This must be mounted facing the LDR (light dependent resistor) and shielded from ambient light (for example, with a piece of heat-shrink tubing). IC1a is then able to control the gain of IC2a so that oscillation is maintained with minimum distortion.

The maximum output amplitude of the generator is about 2 V_{p-p} when the LED and LDR are mounted as close as possible. Distortion is less than 0.5 % in the lowest range, and too low for the author to measure in the higher ranges. Any LDR should work, provided its dark resistance is greater than 100 kΩ. If you do not have an LDR with such high resistance, try increasing R5 until oscillation starts. Breadboarded prototypes of the circuit were built by the author using dual and quad opamp packages, and both work equally well.

The DesignSpark schematic and circuit board design files for this project are available for downloading from www.elektor.com/120330.

(120330)

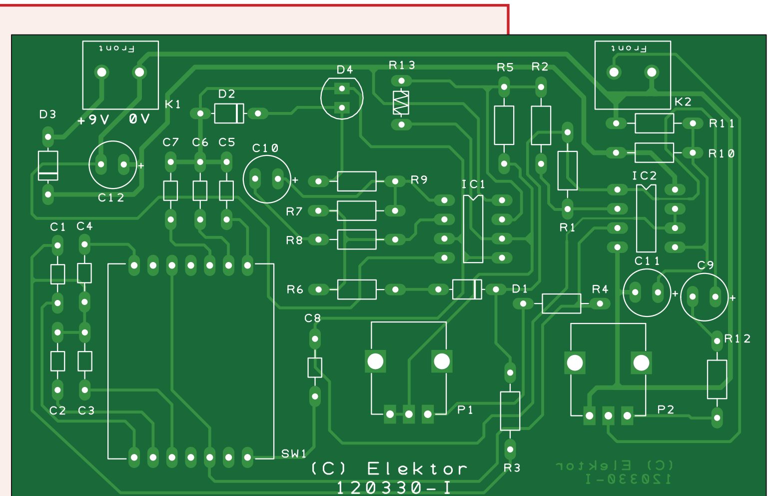
COMPONENT LIST

Resistors
R1,R2,R3,R6,R10,R11 = 10kΩ
R7 = 100kΩ
R4,R9,R12 = 100Ω
R5 = 12kΩ
R8 = 1kΩ
P1,P2 = 10kΩ potentiometer, logarithmic law
R13 = LDR, R(dark) >100kΩ, e.g. Excelitas Tech type VT90N1 (Newark/Farnell # 2568243)

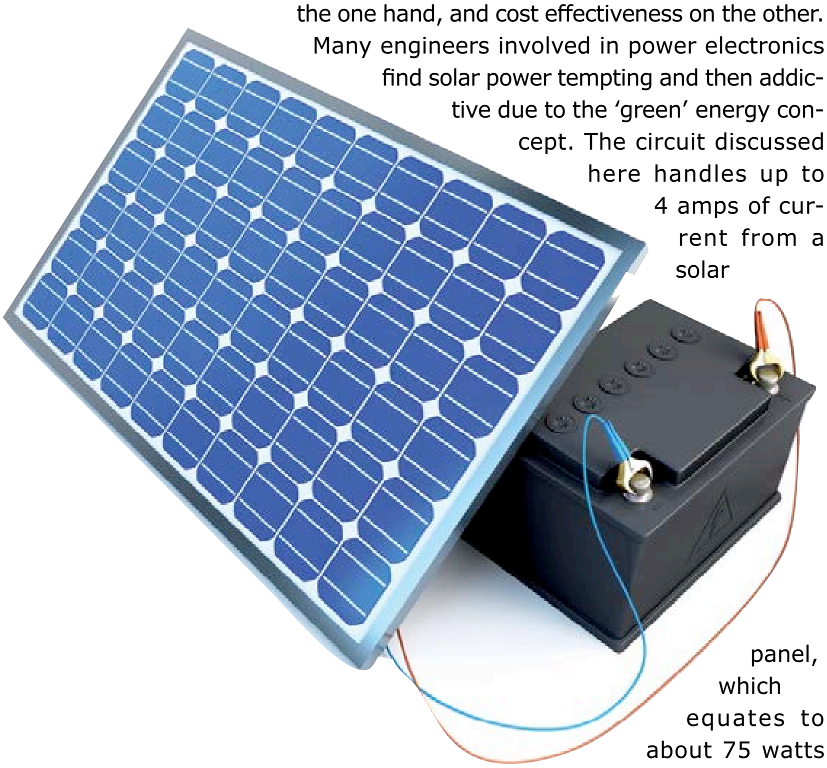
Capacitors
C1,C5 = 1µF solid
C2,C6 = 100nF
C3,C7 = 10nF
C4,C8 = 1nF
C9-C12 = 47µF 16V, electrolytic, radial

Semiconductors
D1,D2,D3 = 1N4148
D4 = LED, red, 5mm
IC1,IC2 = TL072ACP

Miscellaneous
SW1 = 2-pole 4-position rotary switch, C&K Components type RTAP42S04WFLSS
K1,K2 = PCB terminal block, 5mm pitch
PCB # 120330-1



4 Amps Photovoltaic Charge Controller



By **T. A. Babu** (India)

The use of solar photovoltaic (PV) energy sources is increasing due to global warming concerns on the one hand, and cost effectiveness on the other. Many engineers involved in power electronics find solar power tempting and then addictive due to the 'green' energy concept. The circuit discussed here handles up to 4 amps of current from a solar panel, which equates to about 75 watts of power. A charging algorithm called 'pulse time modulation' is introduced in this design.

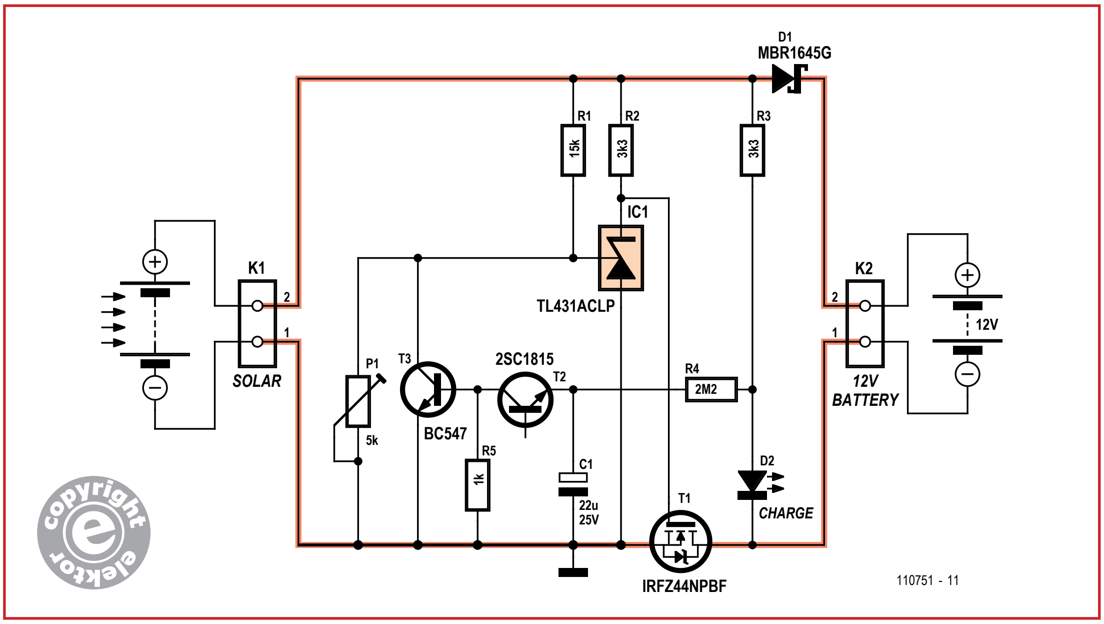
The current flow from the solar panel to the battery is controlled by an N-channel MOSFET, T1. This MOSFET does not require any heat sink to get rid of its heat, as its $R_{D\text{-}S(on)}$ rating is just 0.024 Ω. Schottky diode D1 prevents the battery discharging into the solar panel at night, and also provides reverse polarity protection to the battery. In the schematic, the lines with a sort-of-red highlight indicate potentially higher current paths.

The charge controller never draws current from the battery—it is fully powered by the solar panel. At night, the charge controller effectively goes to sleep. In daytime use, as soon as the solar panel produces enough current and voltage, it starts charging the battery.

The battery terminal potential is divided by resistor R1 and trimpot P1. The resulting voltage sets the charge state for the controller. The heart of the charge controller is IC1, a type TL431ACZ voltage reference device with an open-collector error amplifier. Here the battery sense voltage is constantly compared to the TL431's internal reference voltage. As long as the level set on P1 is below the internal reference voltage, IC1 causes the MOSFET to conduct. As the battery begins to take up the charge, its terminal voltage will increase. When the battery reaches the charge-state set point, the output of IC1 drops low to less than 2 volts and effectively turns off the MOSFET, stopping all current flow into the battery. With T1 off, LED D2 also goes dark.

There is no hysteresis path provided in the regulator IC. Consequently, as soon as the current to the battery stops, the output of IC1 remains low, preventing the MOSFET to conduct further even if the battery voltage drops. Lead-acid battery chemistry demands float charging, so a very simple oscillator is implemented here to take care of this. Our oscillator exploits the negative resistance in transistors—first discovered by Leo Esaki and part of his studies into electron tunneling in solids, awarded with the Nobel Prize for Physics in 1973.

In this implementation, a commonplace NPN transistor type 2SC1815 is used. When the LED goes out, R4 charges a 22-µF capacitor (C1) until the voltage is high enough to cause the emitter-base junction of T2 to avalanche. At that point, the transistor turns on quickly and discharges the capacitor through R5. The voltage drop across R5 is sufficient to actuate T3, which in turn alters the reference voltage setting. Now the MOSFET again tries to charge the battery. As soon as the battery voltage reaches the charged level once more, the process repeats. A 2SC1815 transistor proved to work reliably in this circuit. Other transistors may be more temperamental—we suggest studying Esaki's laureate work to find out why, but be cautioned that there are *Heavy Mathematics Ahead*.



As the battery becomes fully charged, the oscillator's 'on' time shortens while the 'off' time remains long as determined by the timing components, R4 and C1. In effect, a pulse of current gets sent to the battery that will shorten over time. This charging algorithm may be dubbed Pulse Time Modulation.

To adjust the circuit you'll need a good digital voltmeter and a variable power supply. Adjust the supply to 14.9 V, that's the 14.3 volts battery setting plus approximately 0.6 volts across the Schottky diode. Turn the trimpot until at a certain point the LED goes dark, this is the switch point, and the LED will start to flicker. You may have to try this adjustment more than once, as the closer you get the comparator to switch at exactly 14.3 V, the more accurate the charger will be. Disconnect the power supply from the charge controller and you are ready for the solar panel. The 14.3 V setting mentioned here should apply to most sealed and flooded-cell lead-acid batteries, but please check and verify the value with the manufacturer. Select the solar panel in such a way that its amps capability is within the safe charging limit of the battery you intend to use. The DesignSpark schematic and circuit board design files for this project are available for downloading from www.elektor.com/110751.

(110751)

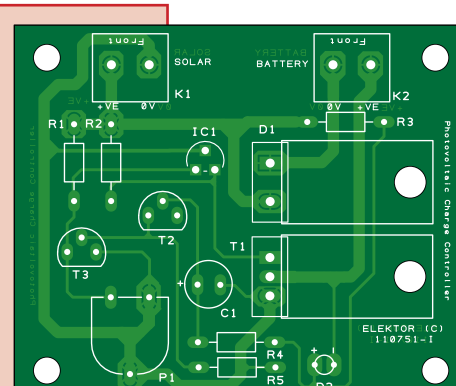
COMPONENT LIST

Resistors
R1 = 15kΩ
R2,R3 = 3.3kΩ 1%
R4 = 2.2MΩ
R5 = 1kΩ
P1 = 5kΩ preset

Capacitors
C1 = 22µF 25V, radial

Semiconductors
D1 = MBR1645G (ON Semiconductor)
D2 = LED, 5mm
IC1 = TL431ACLP (Texas instruments)
T1 = IRFZ44NPBF
(International Rectifier)
T2 = 2SC1815 (Toshiba)
(device is marked: C1815)
T3 = BC547

Miscellaneous
K1,K2 = 2-way PCB terminal block,
lead pitch 5mm
PCB # 110751-1



Starting a Schematic Design

By **Neil Gruending**
(Canada)

Last time I talked about how DesignSpark uses technology files to store configurations settings. In this article we'll start a new project and start a schematic design. We'll start by configuring the DesignSpark libraries and then we'll set up a schematic title block so we can create a nice looking schematic.

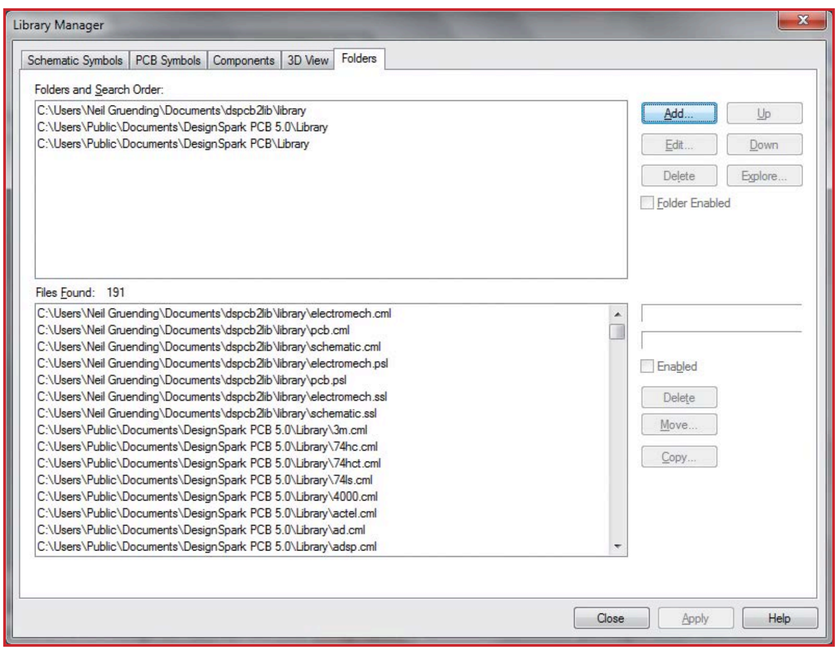


Figure 1.
Inspecting DesignSpark's library paths.

Configuring the libraries

DesignSpark uses library files to organize all of your design information. Schematic symbols are one library type and PCB footprints are another. They are then combined to make a component library that you can use to place parts and documentation symbols into your design. The only difference between a documentation symbol and a regular component is that a documentation symbol contains either a schematic symbol or a PCB symbol, but not both. If you would like more information about DesignSpark's library system and how it works, there is a good tutorial at [1]. In this article we will make a schematic documentation symbol to use a title block in a schematic but before we do that we need to double check DesignSpark's library search paths. You do that by going into the 'Files -> Libraries...' menu and selecting the 'Folders' tab. Here you will see a screen that looks something like **Figure 1**.

You want to make sure that the directory where you are storing your library files is listed as the first item in the 'Folders and Search Order' box which in my case is 'C:\Users\Neil Gruending\Documents\dspcb2lib\library'. You can reorder the directory list by selecting the directory that you want to move and using the Up/Down buttons. I would recommend that you don't save any changes or new files into the DesignSpark system default library folders just in case the libraries get overwritten in a future upgrade.

Now that the library paths are set up, you can create a new schematic symbol library to store our schematic title block by selecting the 'New Lib...' button on the 'Schematic Symbols' tab. Then select the 'New Item...' button to open up a blank schematic symbol page. For more information you can review the symbol creation tutorial on the DesignSpark website [1].

Creating a schematic title block

I personally always use title blocks on a schematic to make them look much more professional and to help to document a design. DesignSpark is different from other packages because schematic title blocks are stored in a schematic component library instead of a template file or technology file which means that DesignSpark will ignore any drawing elements in a schematic technology file. DesignSpark comes with several title block templates in its Schema library in several different sizes like A4 and Letter, but I prefer to use Tabloid (11 in. × 17 in.) for my designs. I also prefer to use a more traditional documentation area that takes up less of the drawing area. In my last article I showed you how to use truetype fonts in a schematic technology file, but there is a downside to using them in a schematic title block. That's because DesignSpark shifts truetype fonts slightly downwards when printing a schematic to a PDF file. That normally doesn't matter for things like reference designators but in title blocks where text alignment is more important you'll definitely notice. Therefore I chose to use stroke fonts for my title block, which is shown in **Figure 2**.

I recommend that you name the various text styles so that they're easy to modify later. In my case I ended up with the styles shown in **Figure 3**.

The numbers and letters around the drawing area frame use the text style 'Frame' and the field descriptions use the text style 'Title-small'. Field items use the style 'Title'. Since DesignSpark doesn't support project variables you have to add the text strings to the title block manually, which is why all of the title block fields are blank in the schematic component. Also, you don't have to add these text styles to the schematic technology file because they will be copied into the schematic when you add the title block.
Once you've finished editing the title block, save it to the schematic symbol library you created earlier so that we can create a schematic document symbol. The first step is to open the Library Manager ('File->Libraries...') and go to the Components tab. You can create a new component library by selecting the 'New Lib...' button and then create the document symbol by clicking on the 'New Item...' button which will open the 'New Component' window. Here you can give the component a name and select your title block symbol. Unchecking the 'PCB Symbol' check box will make the component a schematic document symbol like we need. Save your changes and let's start a new DesignSpark project.

Creating a new project

DesignSpark uses projects to collect all of the relevant information about a design like schematics and PCB documents in one place. The main reason for using a project is to allow a set of schematic sheets to be linked to a PCB design. The linked schematic sheets can then act as one large project where global net information is shared and all component designators are unique.

Creating a new DesignSpark project is simple. Go into the 'File -> New' menu to open the 'New Design' window, select 'Project' and then press 'OK'. You will then be prompted where to save the new project and then a blank project will be created for you. Now you can add existing files to the project by using the 'Project -> Add Files to Project...' menu. Adding new items to a project is done by opening the 'New Design' window, but before clicking on OK make sure you check the 'Add to Open Project' box.

Conclusion

Now that we can create projects and create nice looking schematic templates, the next step is to start drawing your design using components from the DesignSpark libraries. You can also create and use your own libraries with some extra component attributes that will make it easier to generate bill of material (BOM) listings later. The title block I've drawn here (**Figure 4)** is available from my dsppcb2lib project on Bitbucket at [3].

(130181)

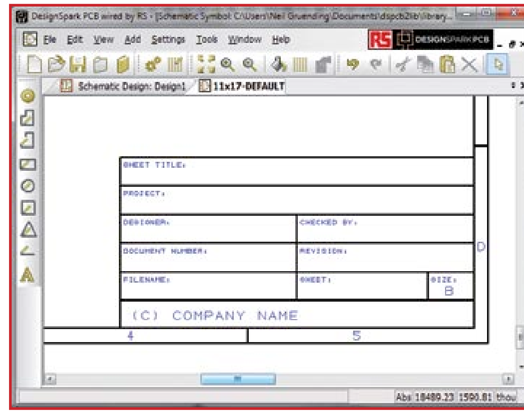


Figure 2.
Structure and layout of the schematic title block.

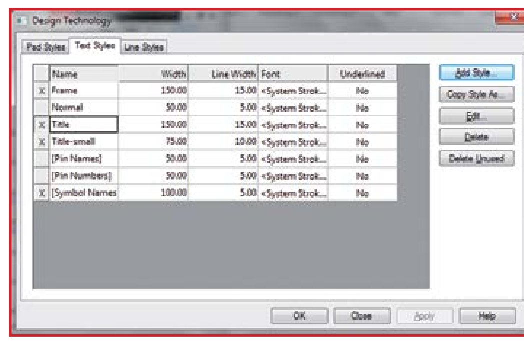


Figure 3. Text formatting in the title block.

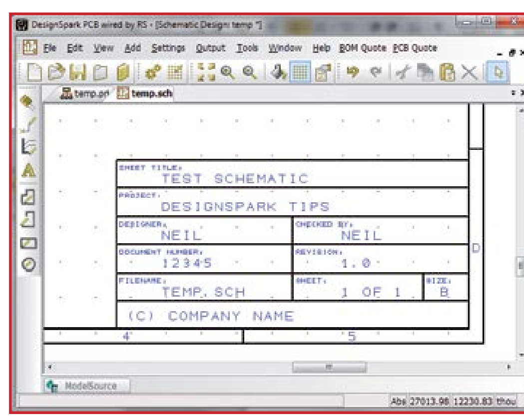


Figure 4. A completed schematic title block.

Internet References

[1] www.designspark.com/tutorial/components-library-structure-library-manager

[2] www.designspark.com/tutorial/components-creation-with-symbol-footprint-wizards

[3] https://bitbucket.org/neilg/dspcb2lib

SMD Desoldering Tip

By **Thijs Beckers,**
Associate Editor

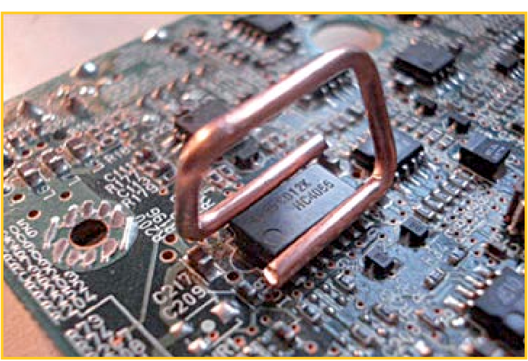
If an engineering problem appears daunting and complex that does not always equate to the solution being expensive and/or high tech. Elektor Labs resident Luc Lemmens supplied a valuable tip on a method of desoldering surface mount ICs he found on the Internet. All you need are precision pliers, a short piece of solid copper wire—like electrical installation wire—a decent solder iron and some solder tin, and a pair of tweezers. When desoldering ICs with leads at two opposite sides of the case, it is suggested you start by folding the copper wire as shown in the first photo. Make sure the wire contacting the pins is as straight as possible, making sure it touches as many IC pins as possible. Now apply some solder to the wire where heat needs to be transferred (second photo). This improves the heat transfer to the IC pins and the PCB pads significantly.
Press the wire on the chip pins as shown in the third photo and heat it with a decent soldering iron, all the while making sure the pins at both sides of the IC are in full contact with the wire. When the solder has melted, quickly remove the IC from the PCB using tweezers.

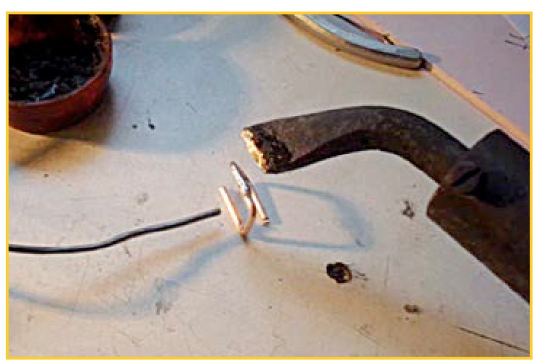
With a little custom folding of the copper wire, even ICs with pins at all four sides of the package can be desoldered using the above method. Shape the copper wire in a similar way, as pictured in the fourth image.

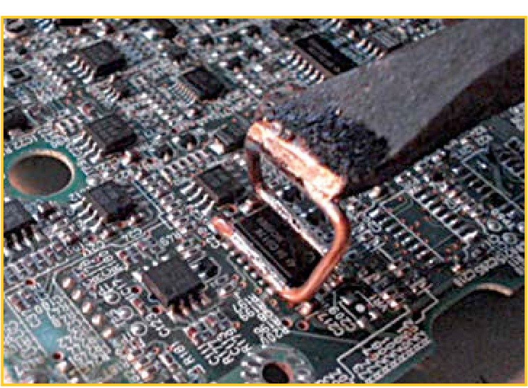
Watch out for damage to the IC as well as the PCB by overheating, and keep the time you apply heat limited to just melt the solder and be able to securely remove the IC. An IC that's been subjected to overheating, meaning it's been soldered on either too long or at an excessive temperature will obviously be DBR (damaged beyond repair). As is the precious circuit board, where too much heat will result in copper pads becoming detached from the PCB surface. Once you get the hang of it and perform this little trick correctly wielding your solder, solder iron and copper wire, you will damage neither IC nor PCB.

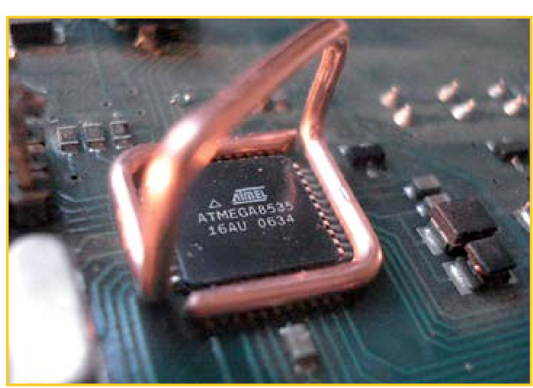
(130099)

Found on http://youtu.be/dCUSwADP6DE.





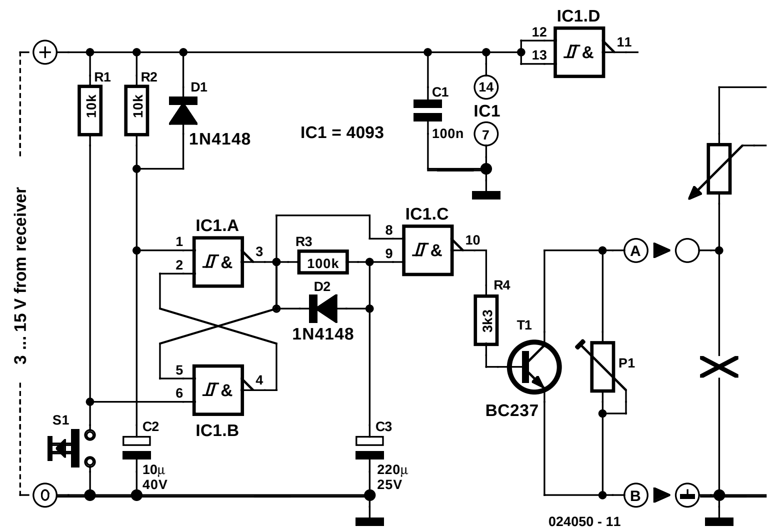




Waking to Music

001

U. Reiser



Inexpensive clock radios do not have separate slumber and wake-up volume settings. However, with a small, easily fitted circuit you can go to sleep with quiet music and still be sure of waking up on time. This is achieved without the cumbersome fitting of a second potentiometer. Instead, the circuit boosts the volume level somewhat relative to the set level. For this purpose, the ground lead of the volume pot is opened and a trimpot is inserted. The setting of this trimpot is a matter of personal taste and also depends on the setting of the 'real' volume pot. As a general rule, you should use around one quarter of the setting of the original pot. A transistor is connected in parallel with P1 in order to short-circuit the trimpot and thus guarantee that the volume can be fully reduced to zero. Both of the additional components should be soldered directly to the original pot for better hum suppression.

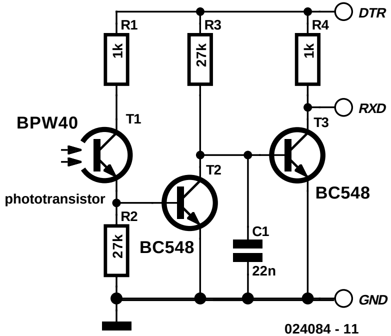
An R-S flip-flop made from AND gates and delay networks is used to control the transistor. The flip-flop (IC1a and IC1b) is set with a High level at the output of IC1a by a Low pulse from RC network R2/C2. The signal from IC1a reaches the two inputs of IC1c after being delayed by R3 and C3. If both of these inputs are High, IC1c cuts off the transistor. Due to the time delay, the wake-up music begins at the reduced volume level and then changes to the set level when the time delay expires. The volume level can be reduced manually by pressing reset switch S1, which pulls the input of gate IC1b Low and causes the R-S flip-flop to toggle to the opposite state. The bistable stage remains in this state until the supply voltage is switched off.

(024050-1)

Simple IrDA Receiver

002

B. Kainka



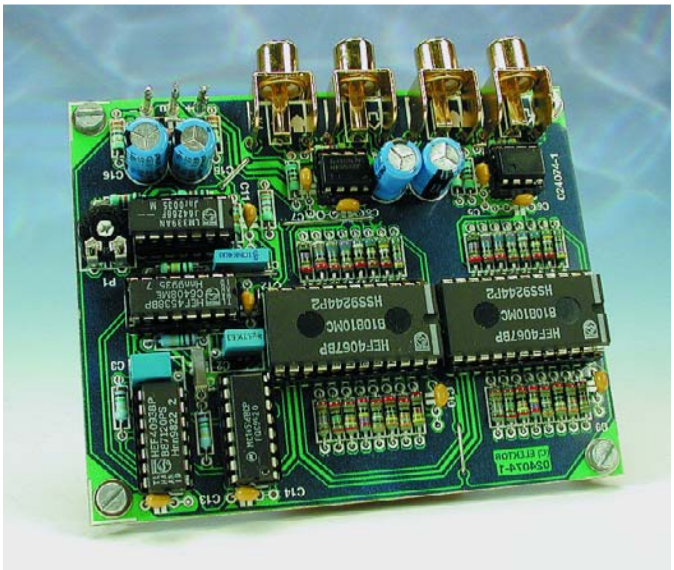
Palm Pilots are just one of the devices that use the IrDA standard for infrared data communication. Most Desktop PCs are not equipped with an IrDA interface so this simple circuit conveniently converts the PC serial port into an IrDA receiver. The circuit needs to detect and stretch the received infrared pulses so that the output signal conforms to the standard serial data format. The circuit is designed to operate at 9600 Baud and uses just two NPN transistors and a phototransistor. The 22-nF capacitor performs the job of lengthening the signals. It is important to ensure that the DTR signal is set to a high state on the serial port settings because this signal is used as the power supply to the circuit. The sample program listed below is written in HotPaw Basic for the Palm and tests the interface by sending a short greeting followed by a sequence of integers.

```
#irdatx.bas
open “com1:”,9600, ir as #5
 print#5,”Hello”
for n= 1 to 100
 print#5,n
 a= fn wait(1)
next n
close #5
end
```

(024084-1)

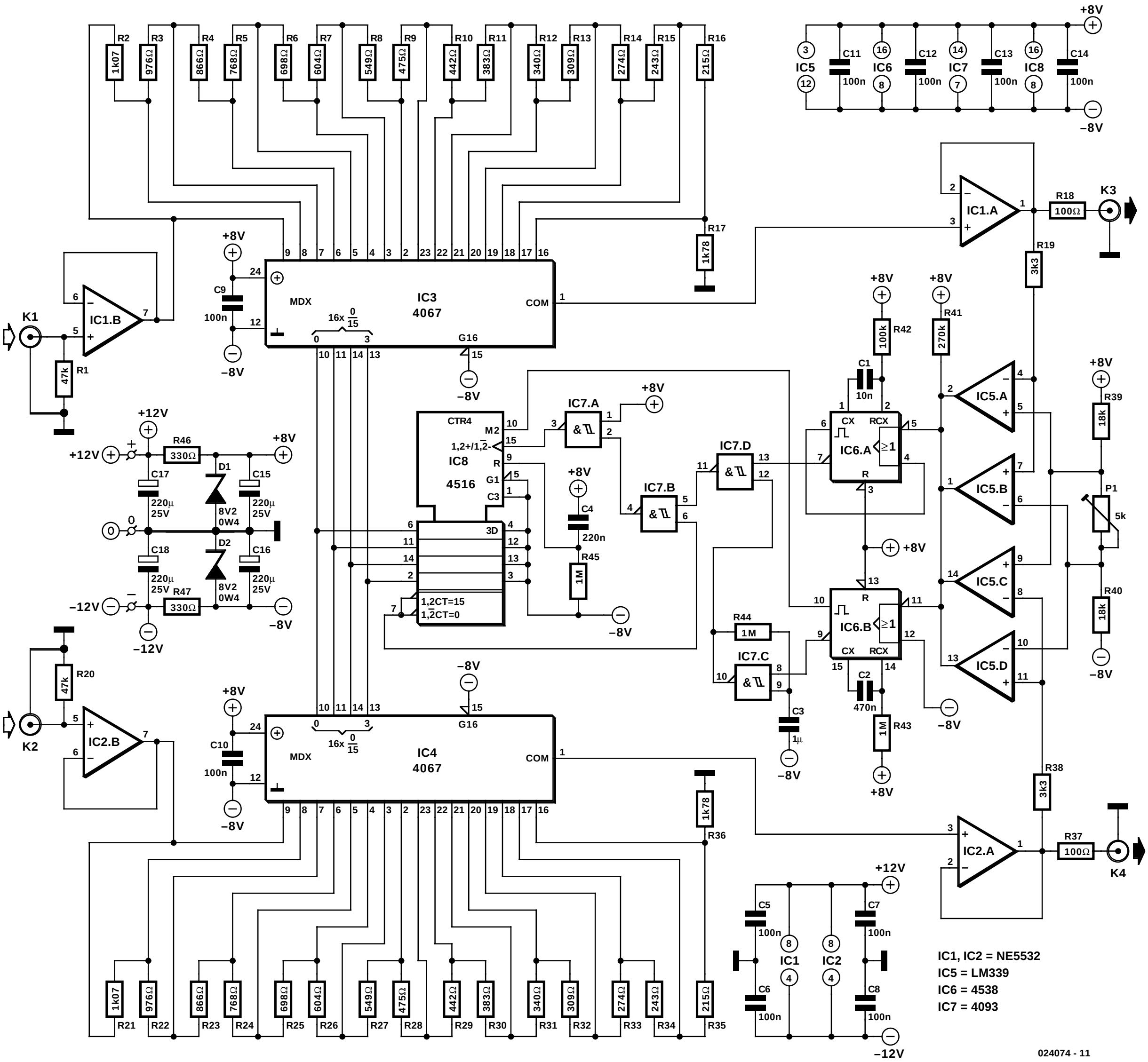
Audio Limiter (for DVD)

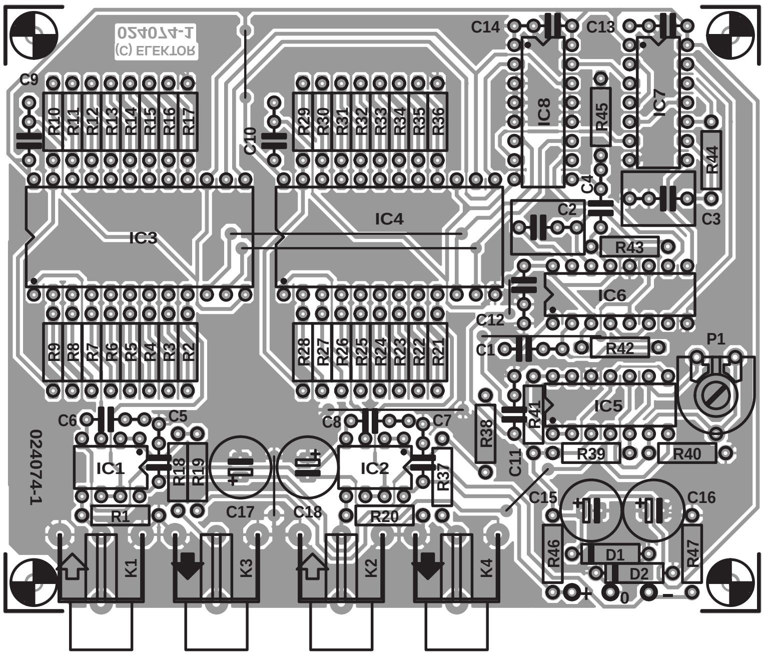
003

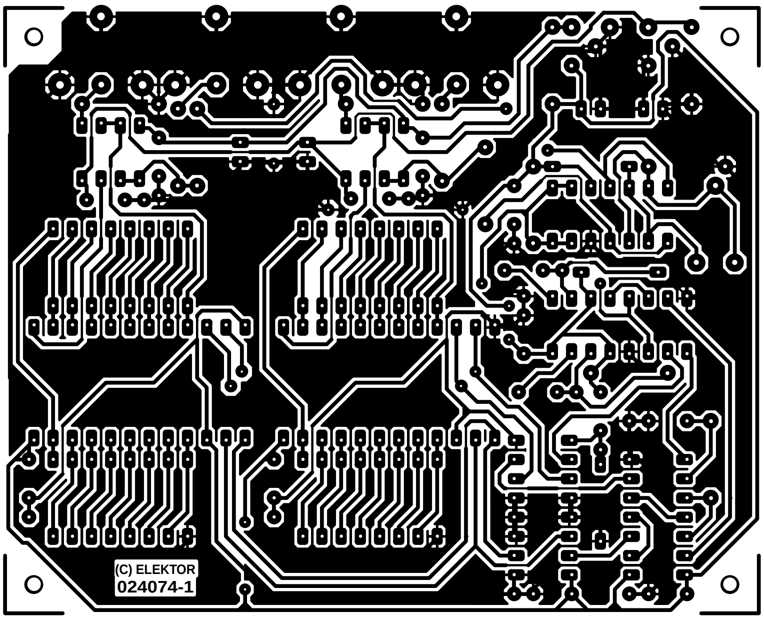


Those of you who are lucky enough to possess a DVD player and have watched a movie with lots of special effects, will certainly have noticed that the dynamic range of the audio can be very extreme. So much so that during normal use it is desirable to take steps in the form of an automatic volume limiter. If the DVD player is connected to an audio installation, then it is, in principle, not difficult to install such a limiter between the player and the audio system. It is important, of course, that the limiter does not introduce any distortion.

The audio limiter presented here limits the volume practically immediately and then slowly returns it to the normal level. The principle of operation is the same as that of a classical volume control. For each channel, the limiter comprises a voltage divider (R2 to R17 and R21 to R36) and a 16-channel analogue multiplexer/de-multiplexer type 4067 (IC3 and IC4). The voltage dividers are buffered at both the input and the output by a dual







COMPONENTS LIST

Resistors:
R1,R20 = 47kΩ
R2,R21 = 1kΩ07
R3,R22 = 976Ω
R4,R23 = 866Ω
R5,R24 = 768Ω
R6,R25 = 698Ω
R7,R26 = 604Ω
R8,R27 = 549Ω
R9,R28 = 475Ω
R10,R29 = 442Ω
R11,R30 = 383Ω
R12,R31 = 340Ω
R13,R32 = 309Ω
R14,R33 = 274Ω
R15,R34 = 243Ω
R16,R35 = 215Ω
R17,R36 = 1kΩ78
R18,R37 = 100Ω
R19,R38 = 3kΩ3
R39,R40 = 18kΩ
R41 = 270kΩ
R42 = 100kΩ
R43,R44,R45 = 1MΩ
R46,R47 = 330Ω
P1 = 5kΩ preset

Capacitors:
C1 = 10nF
C2 = 470nF
C3 = 1µF MKT, lead pitch 5 or 7.5 mm
C4 = 220nF
C5-C14 = 100nF ceramic
C15-C18 = 220µF 25V radial

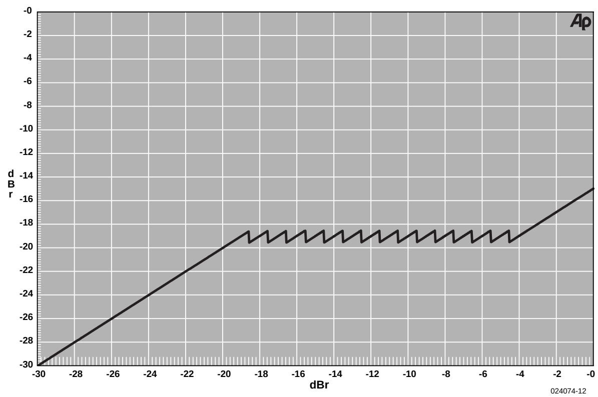
Semiconductors:
D1,D2 = zener diode 8V2 0.4W
IC1,IC2 = NE5532
IC3,IC4 = 4067
IC5 = LM339
IC6 = 4538
IC7 = 4093
IC8 = 4516

Miscellaneous:
K1-K4 = cinch (RCA) socket, PCB mount, e.g., Monarch T-709G
PCB, order code **024074-1**

opamp. The limiter has a control range of 15 dB in steps of 1 dB, which, to the ear, results in a smooth control. When the limiter is not active, the amplification is equal to 1.

The detection of the level occurs at the output with the aid of a window comparator for each channel (IC5a to d). To keep things simple, only the absolute peak value is measured and compared with an adjustable reference (R39/P1/R40). The reference voltage can be adjusted from 0 to 1 V. At the maximum output signal of 2 V_{rms} this means an attenuation of 9 dB of the maximum output voltage. The range of the limiter is intentionally limited to 15 dB, to make sure that not the entire dynamic range is removed. The best setting is that when during normal volume (a conversation for example) the limiter does not yet act, but starts to reduce the level at a few dB more than that.

The outputs of the comparators provide the trigger pluses for the two monostable multivibrators (IC6) that provide the correct drive for the binary up/down counter (IC8). We make use of the falling edges of these pulses because they are steeper. IC6a turns every trigger pulse into a 1-ms pulse for the counters. This way it is avoided that at the highest frequencies the limiter will immediately limit to the maximum amount, but that a short amount of time is required (the attack time). This design has the feature that at frequencies below 1 kHz the lim-



iter needs 15 times the period of the applied signal to limit to the maximum extent. With a pure 20 Hz signal this will take 0.75 seconds, but in practice the signal is much more complex and therefore will occur much faster.

IC6b is triggered at the same time as IC6a and has, in combination with a number of NAND-gates, a dual function. On the one hand, the counter pulses from IC6a are passed on via IC7c and IC7d whenever IC6b is active. $\overline{Q}$ of IC6b will be 'low', the output of IC7c 'high' and IC7d is enabled. In the other hand, the Q output of IC6b defines the counter direction. With every clock pulse the multiplexers will connect a lower tap of the voltage divider to the output. IC7b and IC7a make sure that the carry out (also called terminal count) prevents the counter from wrapping around (both when counting up and down). Once the input signal has reduced back down and after the period of IC6b, the oscillator IC7c will be released and the counter will count down. The time it takes for the level to start to increase is defined by IC6b and amounts to approximately half a second (t = R43 ? C2). The rate at which the increase happens is determined by the frequency of oscillator IC7c.

A few test results for completeness' sake (0dBr = 2 Vrms):

Current consumption:	± 26 mA
THD+N	
at 1 kHz :	0.0012% (0 dBr, Gain = –15 dB)
at 20 kHz:	0.0058% (0 dBr, Gain = –15 dB)
at 20 Hz to 20 kHz:	0.0054% (10 dBr, Gain = 0 dB)

R45/C4 form a power-up reset for the counter. The power supply voltage for the opamps is higher than the voltage for the digital circuitry because the opamps have a knee-voltage of a few volts at the output and have a common mode range at the input that is smaller than their power supply voltage. This way, maximum use can be made of the available voltage range of the multiplexers. The power supply for the digital section of the circuit is provided by two zener diodes D1/D2 and decoupled by R46/C15 and R46/C16, and in this way is nicely symmetric around the analogue ground level. Considering the logic levels for the trigger pulses, the comparators are also connected to the digital power supply. The total current consumption of the entire circuit is around 26 mA.

In conclusion, the adjacent graph clearly shows how the limiter influences the audio signal, because the output signal is shown as a function of the input signal with a large number of measurement points. When the input signal is slowly increasing, the output signal will follow the input until the set level is reached. Once the input signal exceeds the reference value the output amplitude is immediately reduced by 1 dB; the output then continues to follow the input until the output level reaches the reference again, etc. This will occur up to 15 times in total, at which point the output will follow the input, but attenuated by 15 dB.

(024074-1)

4-Bit Decimal Display

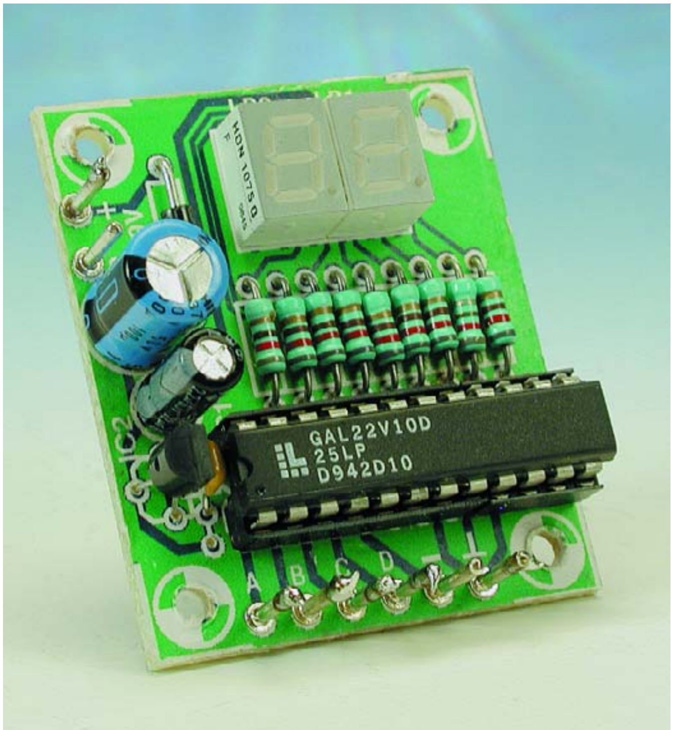
004

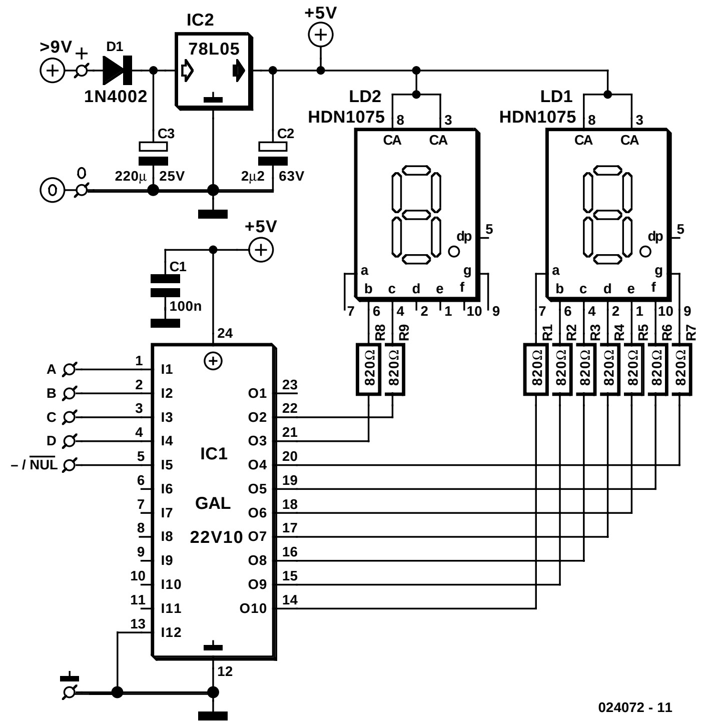
Display driver ICs are available in several standard implementations. This circuit makes use of a GAL 22V10 to drive two 7-segment displays without multiplexing. A 4-bit binary code at inputs A/B/C/D is converted to a decimal number. An example of an application is the 'Audio Limiter (for DVD)', but take note of the voltage levels! The multiplexers used there are driven by a 4-bit binary counter. This circuit will give a better indication of the behaviour and settings of the limiter.

The segments that have to light up with the various input bit combinations are shown on the accompanying table.

This table is used as the basis for writing the equations that result in the program for the GAL. Use can be made of either the max- or the min- terms depending on whichever results in the smallest number. The outputs are active low, because they are able to sink more current than they can source. The resistors R1 through R9 are selected such that the resulting current through each of the segments is about 3mA. The displays, therefore, must be common-anode. The displays used here are very small, the characters are only 7 mm tall (the displays are 10 mm high in total). The printed circuit board is actually intended to be more of an example, because in the final application it may be more desirable to fit LD1 and LD2 on a separate PCB.

As can be seen from the table, there is an extra feature when the inputs are 0000, in which case only a single dash is displayed (segment g of LD1). When the corresponding input is left open a dash is visible (low level will give a '0'). With the aforementioned limiter this means that no attenuation is taking place.





The circuit is provided with its own 5-V regulator (78L05, take note of the dissipation!) so finding a suitable power supply should not be problem. The current consumption is a minimum of about 60 mA (indication '–') to about 85 mA maximum (indication '10'). The jedec file you'll need to program the GAL may be obtained as a Free Download from the *Elektor Electronics* website. The PCB shown here is unfortunately not available ready-made.

(024072-1)

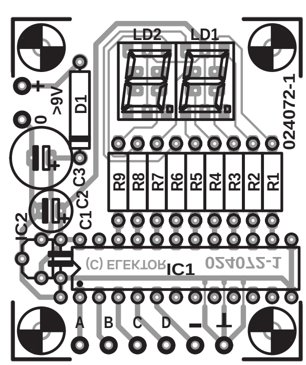
	b2	c2	a1	b1	c1	d1	e1	f1	g1	D	C	B	A
–	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	1	1	1	1	1	1	0	0	0	0	0
1	0	0	0	1	1	0	0	0	0	0	0	0	1
2	0	0	1	1	0	1	1	0	1	0	0	1	0
3	0	0	1	1	1	1	0	0	1	0	0	1	1
4	0	0	0	1	1	0	0	1	1	0	1	0	0
5	0	0	1	0	1	1	0	1	1	0	1	0	1
6	0	0	1	0	1	1	1	1	1	0	1	1	0
7	0	0	1	1	1	0	0	0	0	0	1	1	1
8	0	0	1	1	1	1	1	1	1	1	0	0	0
9	0	0	1	1	1	1	0	1	1	1	0	0	1
10	1	1	1	1	1	1	1	1	0	1	0	1	0
11	1	1	0	1	1	0	0	0	0	1	0	1	1
12	1	1	1	1	0	1	1	0	1	1	1	0	0
13	1	1	1	1	1	1	0	0	1	1	1	0	1
14	1	1	0	1	1	0	0	1	1	1	1	1	0
15	1	1	1	0	1	1	0	1	1	1	1	1	1

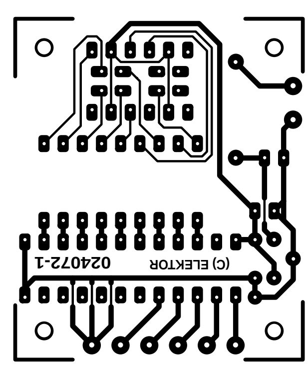
COMPONENTS LIST

Resistors:
R1-R9 = 820Ω

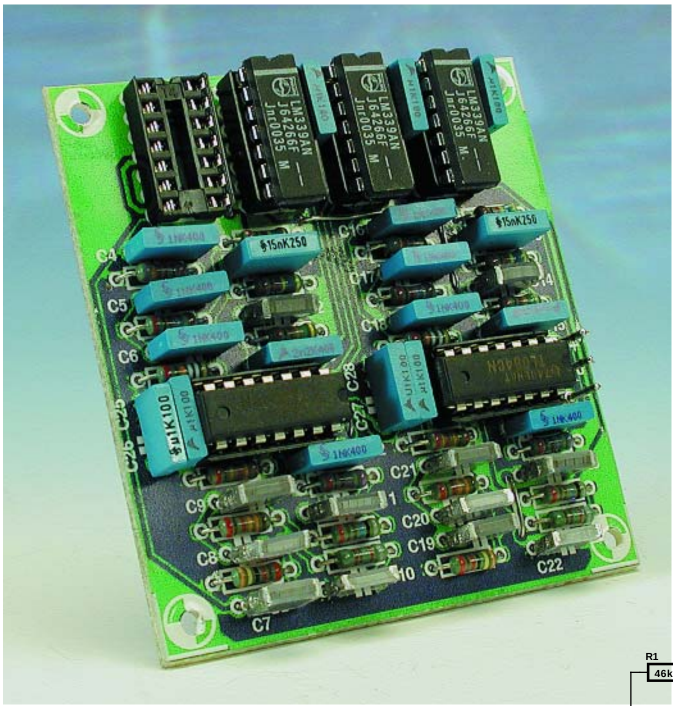
Capacitors:
C1 = 100nF ceramic
C2 = 2µF2 63V radial
C3 = 220µF 25V radial

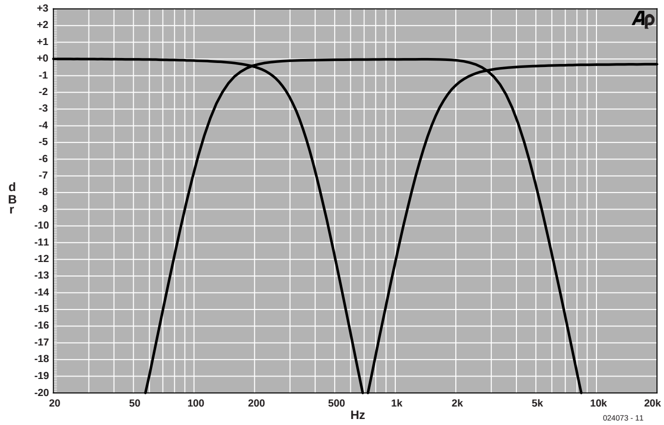
Semiconductors:
D1 = 1N4002
IC1 = GAL22V10
IC2 = 78L05
LD1,LD2 = HDN1075





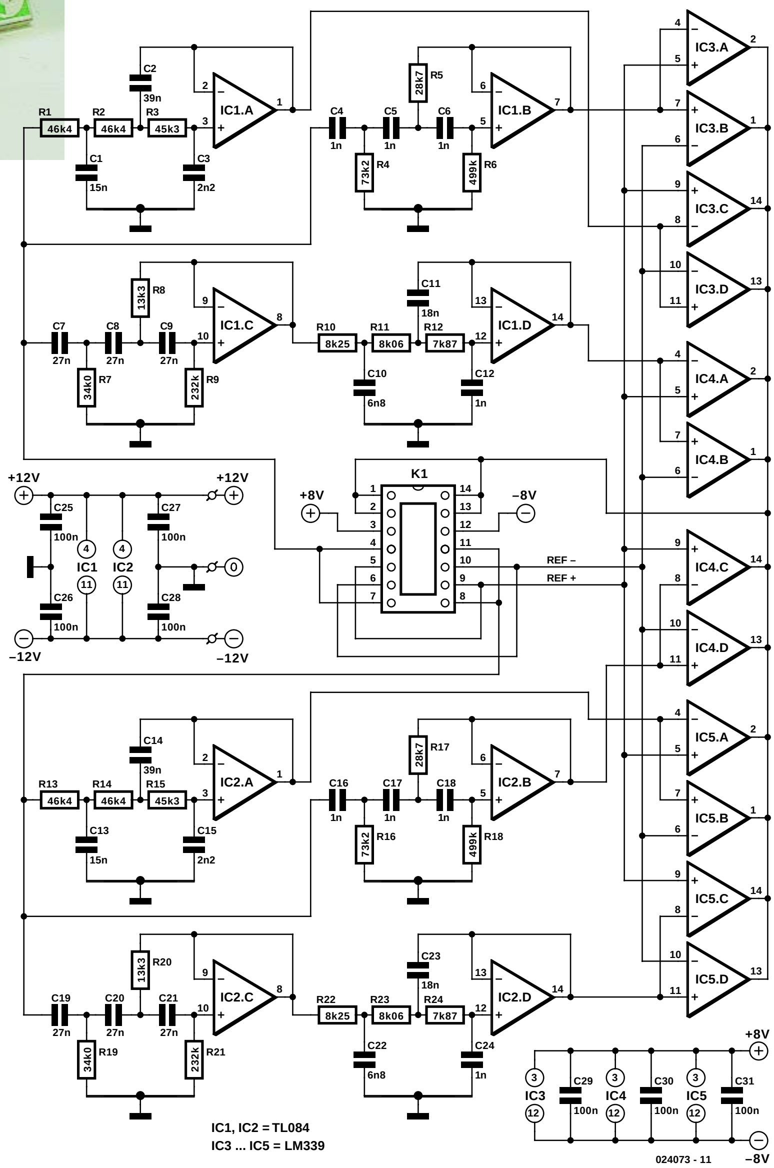
Filter for Audio Limiter (for DVD) 005





In the 'Audio Limiter (for DVD)' circuit, the peak values of the audio signals are used to reduce the dynamic range of the sound. A possible disadvantage is that the entire audio spectrum is used to determine the level, so that peak levels in the low or high frequencies may lead to suppression of, for example, voices in the mid frequency range. If we divide the spectrum into three ranges and for each range a separate window comparator defines the signal level then the signals in one range will have a smaller influence on the other two ranges. It is the intention of this filter, therefore, that the notorious 'breathing' of the limiter is reduced.

The filters proposed here are standard 3rd order types with crossover frequencies of 200 Hz and 2.5 kHz. IC1a/IC2a form the low-pass filters for the low range, IC1b/IC2b are the high-pass filters for the high range, and IC1c/IC2c and IC1d/IC2d the high- and low-pass respectively for the mid range. The crossover frequencies are not simply the corner frequencies of the filters, but these frequencies have been calculated such that the curves cross when the attenuation is 0.25 dB. This way the detected amplitude remains approximately equal across the entire audio spectrum. The real corner frequency with a 3rd order Butterworth is a ratio of 1.6 further away than the –0.25 dB point. The curve shows what this looks like in practice.

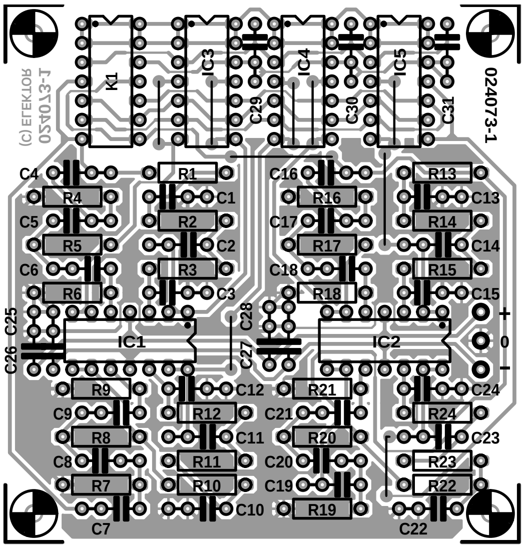


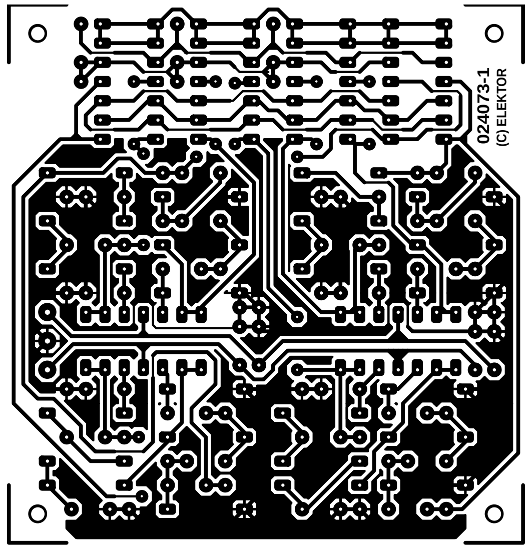
At the crossover from the mid to high range, the high-pass filter has a little more damping and it appears therefore that the crossover point has shifted slightly. This is of no real consequence in practice.

The connection to the audio limiter is made with a 14-pin DIL-connector to the socket for the comparator of this limiter. This filter utilises the same DIL connector (K1) so that the connection can be made with a short length of ribbon cable. The power supply for the comparators is also connected through this ribbon cable to supply power for the filter. The power for the opamps, however, has to be taken from the power supply with three separate wires. The increase in current consumption of the limiter is about 15 mA.

In addition, a couple of small changes have to be made to the limiter: R19 and R38 (both 3k3) have to be replaced with 47-Ω resistors. Otherwise the input impedance of the filters will affect the level of the input voltage. The PCB shown here is unfortunately not available ready-made.

(024073-1)





COMPONENTS LIST

Resistors:
R1,R2,R13,R14 = 46kΩ4
R3,R15 = 45kΩ3
R4,R16 = 73kΩ2
R5,R17 = 28kΩ7
R6,R18 = 499kΩ
R7,R19 = 34kΩ0
R8,R20 = 13kΩ3
R9,R21 = 232kΩ
R10,R22 = 8kΩ25
R11,R23 = 8kΩ06
R12,R24 = 7kΩ87

Capacitors:
C1,C13 = 15nF
C2,C14 = 39nF
C3,C15 = 2nF2
C4...C6,C12,C16,C17,C18,C24 = 1nF
C7,C8,C9,C19,C20,C21 = 27nF
C10,C22 = 6nF8
C11,C23 = 18nF
C25-C31 = 100nF

Semiconductors:
IC1,IC2 = TL084
IC3,IC4,IC5 = LM339

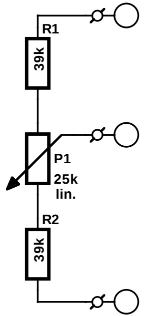
Miscellaneous:
K1 = 14-way DIL connector (2 off)
14-way flatcable

Joystick Replacement

006

The joysticks used in games and modelling contain two potentiometers with a resistance of about 100 kΩ, which turn through 60 to 90 degrees. In fact only one third to one quarter of the total resistance is used in these potentiometers. The diagram shown here should be used when making your own joystick with ordinary potentiometers that turn through 270 degrees. The values for R1 and R2 are given as guidelines only and their optimal value should be found through trial and error. It will be easier if you temporarily replace R1 and R2 with a combination of a fixed resistor and a preset, since it can be a time consuming job to determine the correct values; this is because each of the resistors affects the other.

(024064-1)



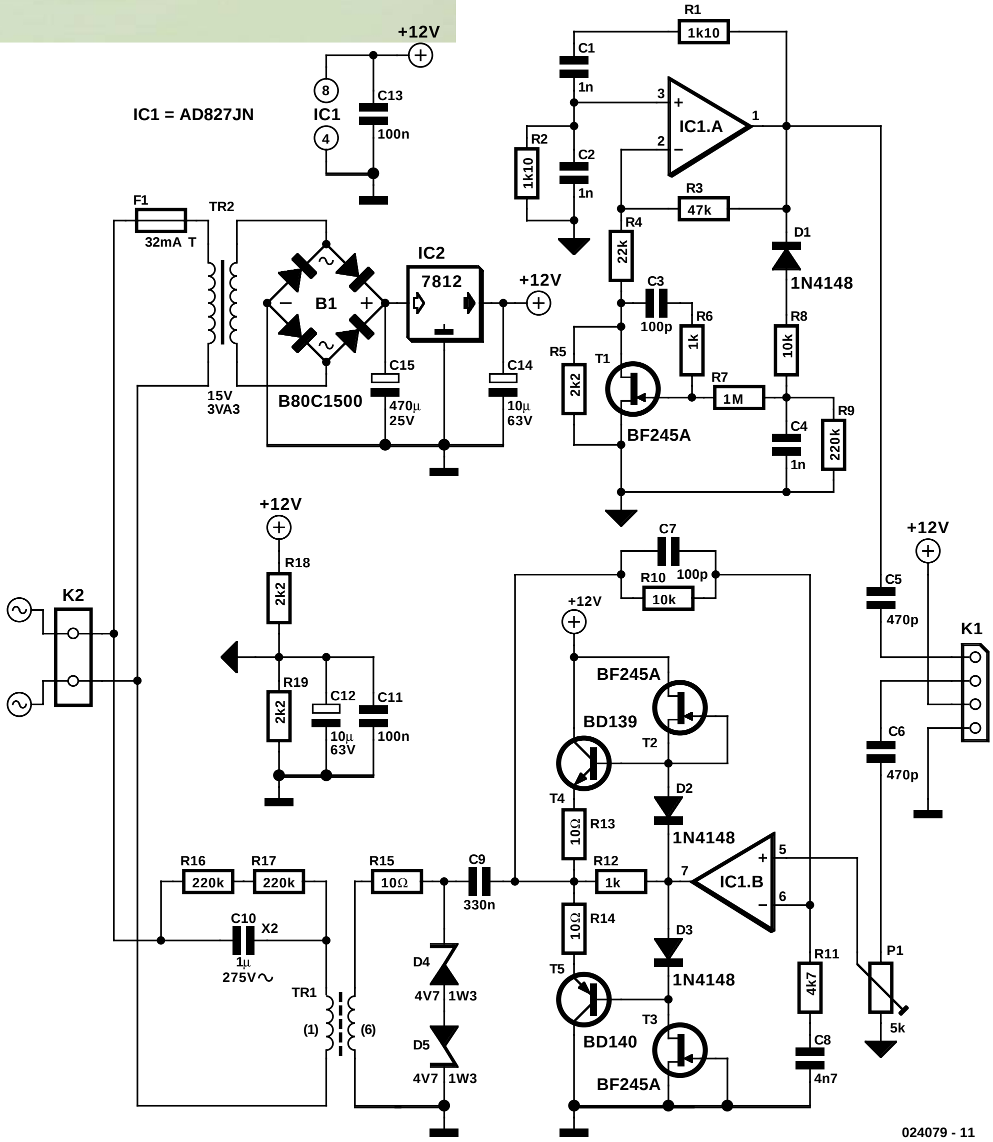
Mains Remote Transmitter

007

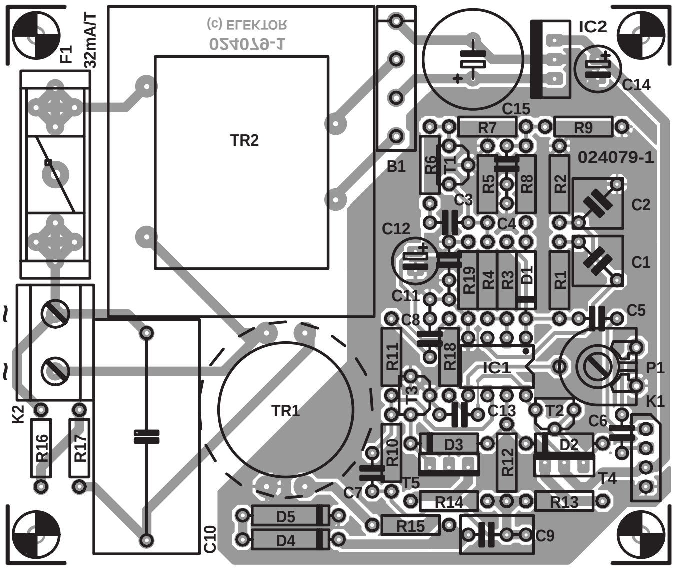
This circuit can be used to superimpose a 143-kHz carrier on the mains voltage, which allows various applications to be realised. One example is the 'Mains Remote Switch'. Besides the power supply, the circuit consists of only a sine-wave oscillator, a buffer stage and an output transformer for isolation from the mains network.

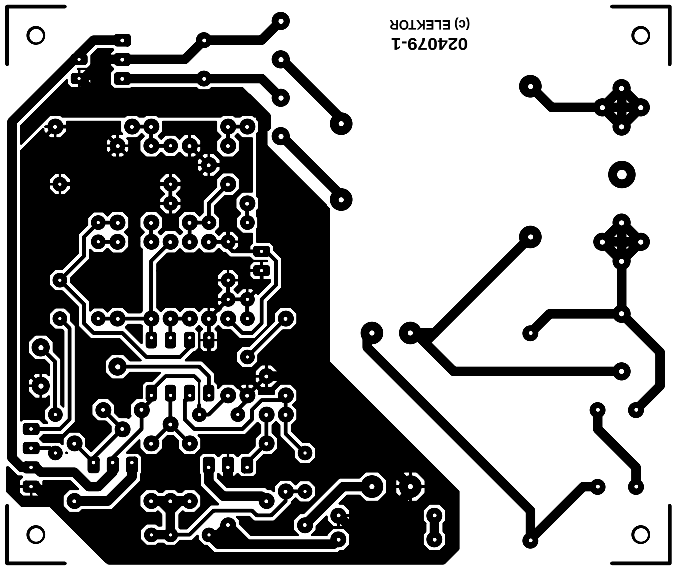
The oscillator, which is built around IC1a, is a standard Wien-bridge design whose frequency is determined by R1, C1, R2 and C2. The combination of R3, R4 and the amplitude stabilisation circuitry built around T1 provides a gain of 3. FET T1 is used here as a controllable resistance, with R6, R7 and C3 providing a certain amount of linearisation of the channel resistance. The output voltage is rectified by D1 to obtain a negative voltage (with respect to virtual ground), which is smoothed by C4/R9 and applied to the gate of T1 via R7. If the amplitude increases, the channel resistance increases due to the larger negative gate voltage, so the gain of IC1a decreases. The characteristic of the FET thus determines the output voltage of the oscillator. With the type BF254A used here, the peak-to-peak value of output voltage is approximately equal to half the supply voltage, but it must be noted that the FET characteristics are subject to a considerable degree of device-to-device variation.

A type AD827 was selected for the opamp since it is fast enough to have a minimal effect on the oscillation conditions. The frequency is set to 143 kHz, since this value happens to fall nearly in the middle of the band from 140 kHz to 148.5 kHz (Cenelec standard 50065-1) when E24 values are used for the frequency-determining



024079 - 11





COMPONENTS LIST

Resistors:
R1,R2 = 1k10 1%
R3 = 47kΩ
R4 = 22kΩ
R5,R18,R19 = 2kΩ2
R6,R7 = 1MΩ
R8,R10 = 10kΩ
R9,R16,R17 = 220kΩ
R11 = 4kΩ7
R12 = 1kΩ
R13,R14,R15 = 10Ω
P1 = 5kΩ preset

Capacitors:
C1,C2 = 1nF 1%
C3,C7 = 100pF
C4 = 1nF
C5,C6 = 470pF
C8 = 4nF7
C9 = 330nF
C10 = 1µF 275VAC, Class X2, lead pitch 27.5 mm
C11 = 100nF
C12,C14 = 10µF 63V radial
C13 = 100nF ceramic, lead pitch 5 mm
C15 = 470µF 25V radial

Semiconductors:
D1,D2,D3 = 1N4148
D4,D5 = zener diode 4V7 1.3W
T1,T2,T3 = BF245A
T4 = BD139
T5 = BD140
IC1 = AD827JN Analog Devices (Farnell)
IC2 = 7812

Miscellaneous:
K1 = 4-way pinheader
K2 = 2-way PCB terminal block, lead pitch 7.5mm
B1 = B80C1500 (rectangular case) (80V piv, 1.5A)
F1 = fuse, 32mAT (slow), with PCB mount holder and cap
Tr1 = 6:1 N30 core 16x6.3 mm EPCOS B64290L45X830 (Farnell)
Tr2 = mains transformer 15V >3VA, dims. 35x41mm, e.g., Hahn BV EI 382 1193 (15 V/4.5 VA) or Block VB 3,2/ 1/ 15 (15 V/3.2 VA, short-circuit resistant)

components. For general use, the maximum allowed voltage in this band is 116 dBµV.

The oscillator output is passed to the buffer stage IC1b via header K1. K1 provides the extra feature of allowing this signal to be modulated or coded using an external circuit. Depending on the circuit used for this purpose, it may be necessary to bypass C5. A potentiometer is placed at the input of IC1b to compensate for the tolerance variations of the oscillator. This allows the circuit to be adjusted to meet the requirements of the standard.

Two small power transistors (the 'old faithfuls' BD139 and BD140) are wired as complementary emitter followers in the output stage of the buffer. The quiescent current through the output stage depends on the voltage drop across D2/D3 and the value of the emitter resistors R13 and R14. Here the quiescent current is only a few milliampères. The maximum signal excursion is determined by the current sources T2 and T3 and the current gain of the output transistors. R12 provides better behaviour in the zero-crossing region.

In order to ensure a certain amount of isolation from the mains network, an output transformer (Tr1) is used. From the point of view of safety, though, it's a good idea to regard the entire circuit as being connected to the mains potential and to bear this in mind when fitting it into an enclosure and using it in other applications. The primary winding of the transformer is driven via C9. The turns ratio of the transformer is chosen such that the maximum allowable value is achieved, but nothing significantly greater than this. Since the impedance of the mains network is a few tens of ohms, at 143 kHz a rather large capacitor (C10) is needed to isolate the 230-V mains voltage from the 143-kHz carrier signal. An X2 type must necessarily be used for this capacitor. R16 and R17 are placed in parallel with C10 to immediately discharge the voltage on K2 in the unlikely event that fuse F1 blows. R15, D4 and D5 protect the output of the amplifier stage against noise pulses and switch-on phenomena (i.e., against possible current spikes passing through C10).

Now for a couple of practical points. You will have to wind transformer Tr1 yourself, but this is not particularly difficult. The primary consists of 6 turns and the secondary is 1 turn. The core is an EPCOS type with a diameter of 16 mm, made from N30 material. Both windings are made using 1-mm diameter wire with synthetic insulation (total diameter 2.5 mm). The primary winding is split into two equal halves such that the secondary fits exactly between them. The leads of the transformer thus emerge on opposite sides. In order to increase the maximum insulation resistance, the original bare wire can be replaced by vanished wire.

The power supply follows the standard recipe of transformer, bridge rectifier and electrolytic capacitor, followed by a voltage regulator (IC2). Since the circuit operates from asymmetric supply voltages, voltage divider R18/R19 and decoupling capacitors C11/C12 are necessary to reference IC1 to half of the supply voltage. The supply voltage is also fed to connector K1 so that the stabilised +12 V is also available for possible expansion circuits.

(024079-1)

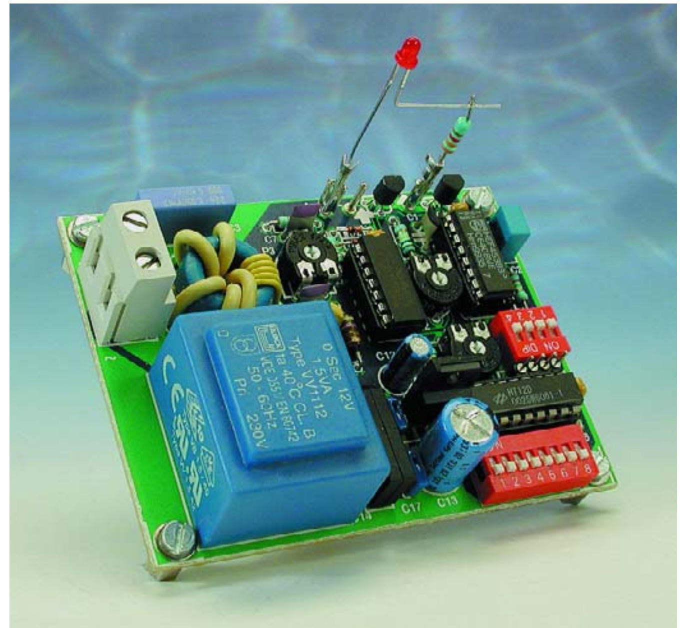
Mains Remote Control: Decoder 008

This receiver/decoder forms part of a simple mains network remote control system, which also includes the 'Mains Remote Transmitter' and the 'Mains Remote Encoder'.

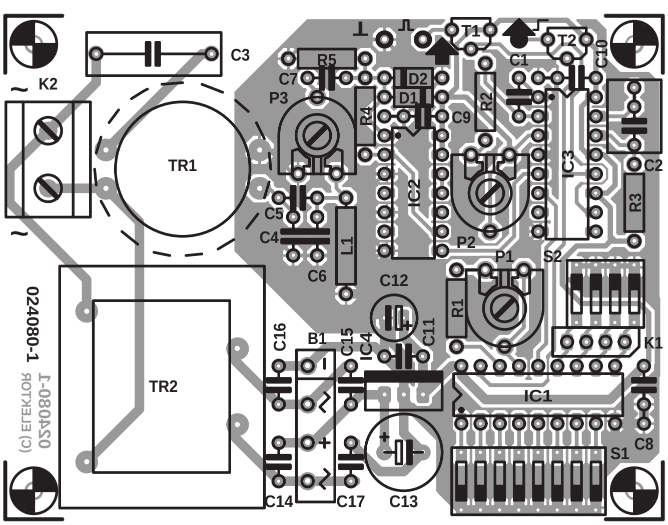
The decoder is built around IC1, which is a Holtek type HT12D or HT12F. For the receiver we use the same circuit as in the 'mains remote switch', namely a passive circuit tuned to approximately 143 kHz, since we assume that the transmitter is powerful enough to provide an adequate signal.

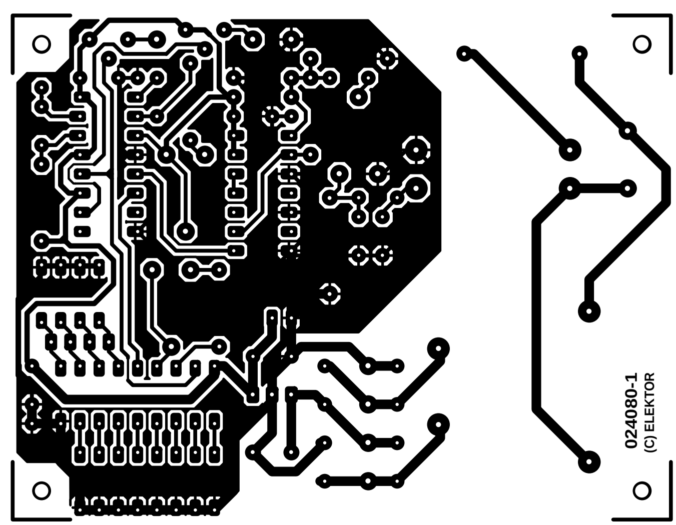
Two 4069U inverters (IC2) are used to convert the received signal to TTL levels. D1 and D2 provide extra protection against noise pulses and the like. The sensitivity can be adjusted using P3, but you should bear in mind that overdriving IC2 can cause corruption of the data. The trick with IC2 is that a small offset applied to the first buffer causes the second buffer to be displaced from the middle (which can be checked using a multimeter), so that the following monostable multivibrator (IC3, a 4538) receives a usable burst as a trigger signal. IC3a is retriggerable, which means that if a trigger pulse arrives within the set time, the output pulse is extended. However, if the set pulse width is too long, the output pulses are extended so much that the decoder will not recognise them as valid data.

IC3a thus recovers the originally sent code. P2 is added to the circuit to allow the pulse length to be adjusted as accurately as possible, but an oscilloscope is required for this. In practice, the adjustment is not all that critical and P2 can be simply set to its midrange position.



The output of IC3a is fed to the decoder (IC1), which compares the recovered code with the settings of S1 and S2. If the received code matches these settings, output VT goes High

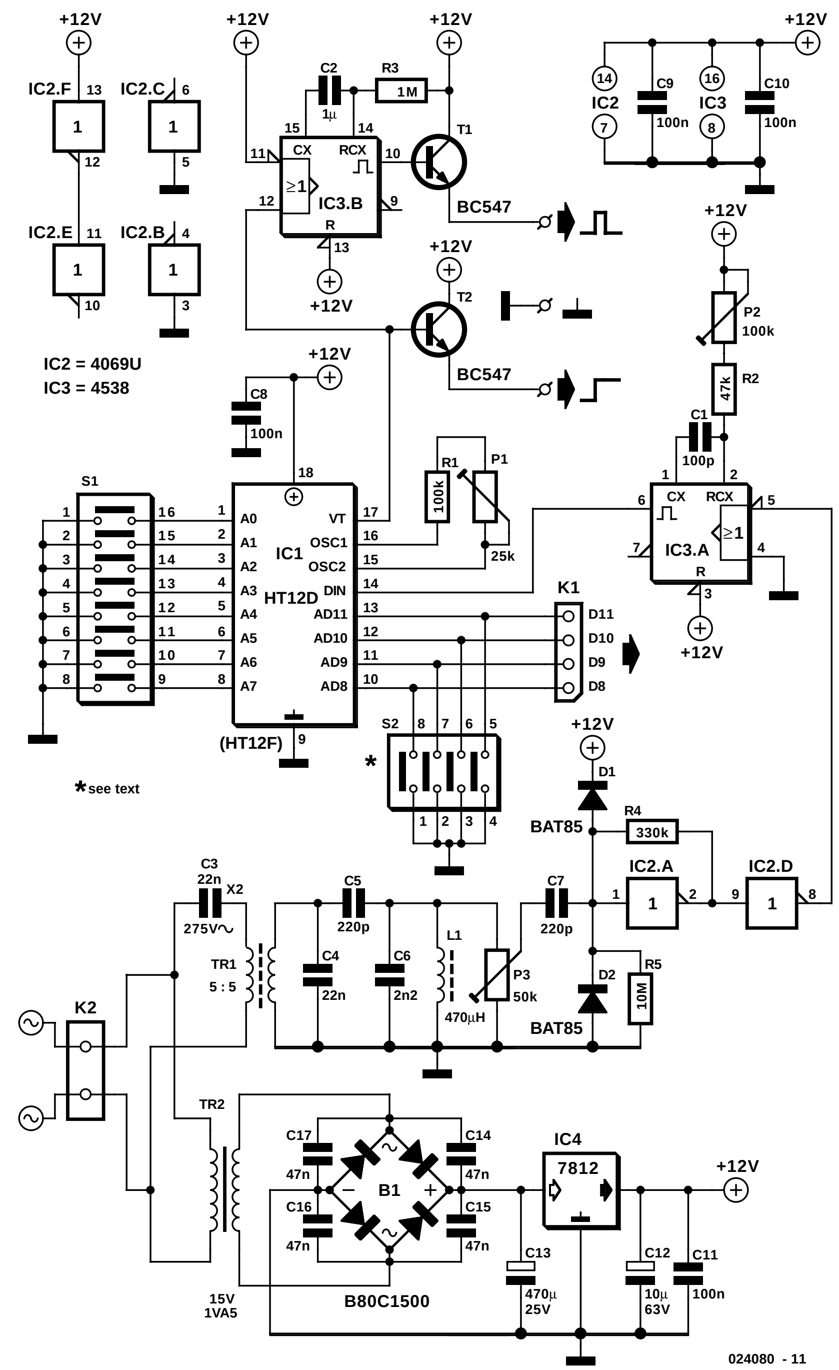




and some sort of application can be energised via buffer T2. If you have in mind connecting an active buzzer to the buffer output, you must thoroughly decouple it using a 10-mH coil in series and a 100-µF/16-V electrolytic capacitor in parallel, since these buzzers can be a source of stubborn interference. The second monostable (IC3b) is used to generate a supplementary pulse with a duration of roughly one second. The pulse length can be modified (by changing R2 and/or C2) to meet the needs of a particular application that requires a certain minimum duration. T1 acts as a simple buffer for this output.

As already noted, in principle two different types of decoder can be used: HT12D or HT12F. The HT12D has four data-bit outputs (AD8–AD11), with the data being made available on the SIL header K1. In this case it is better not to fit S2. If an HT12F is used for the decoder, K1 has no function, but a 12-bit address can be set.

Naturally, the oscillator of the decoder should be tuned to match the encoder used with the transmitter. For the HT12D/F, the oscillator frequency is 50 times that of the encoder. That means that here the oscillator must be set to around 112 kHz.



COMPONENTS LIST

Resistors:
R1 = 100kΩ
R2 = 47kΩ
R3 = 1MΩ
R4 = 330kΩ
R5 = 10MΩ
P1 = 25kΩ preset
P2 = 100kΩ preset
P3 = 50kΩ preset

Capacitors:
C1 = 100pF
C2 = 1µF MKT, lead pitch 5mm or 7.5mm
C3 = 22nF 275VAC, Class X2
C4 = 22 n ceramic, lead pitch 5mm
C5,C7 = 220pF
C6 = 2nF2 ceramic, lead pitch 5mm
C8,C9,C10 = 100nF
C11 = 100nF ceramic, lead pitch 5mm
C12 = 10µF 63V radial
C13 = 470µF 25V radial
C14-C17 = 47nF ceramic, lead pitch 5mm

Inductor:
L1 = 470µH miniature choke

Semiconductors:
D1,D2 = BAT85
T1,T2 = BC547
IC1 = HT12D/F (Holtek) (Farnell) *
IC2 = 4069U
IC3 = 4538
IC4 = 7812

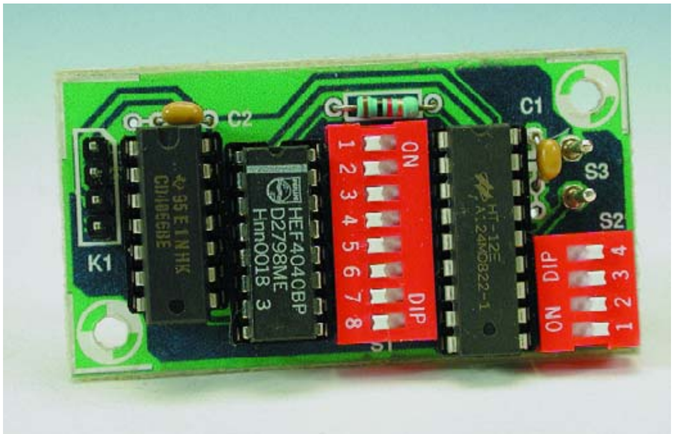
Miscellaneous:
K1 = 4-way pinheader
K2 = 2-way PCB terminal block, lead pitch 7.5mm
S1 = 8-wayDIP-switch
S2 = 4-way DIP-switch *
B1 = B80C1500 (rectangular) (80V piv, 1.5A)
TR1 = N30 ring core 16x6.3 mm EPCOS B64290L45X830 (Farnell) *
TR2 = mains transformer 15V/1.5VA, short circuit resistant, e.g., Block type VB 1,5/1/ 15

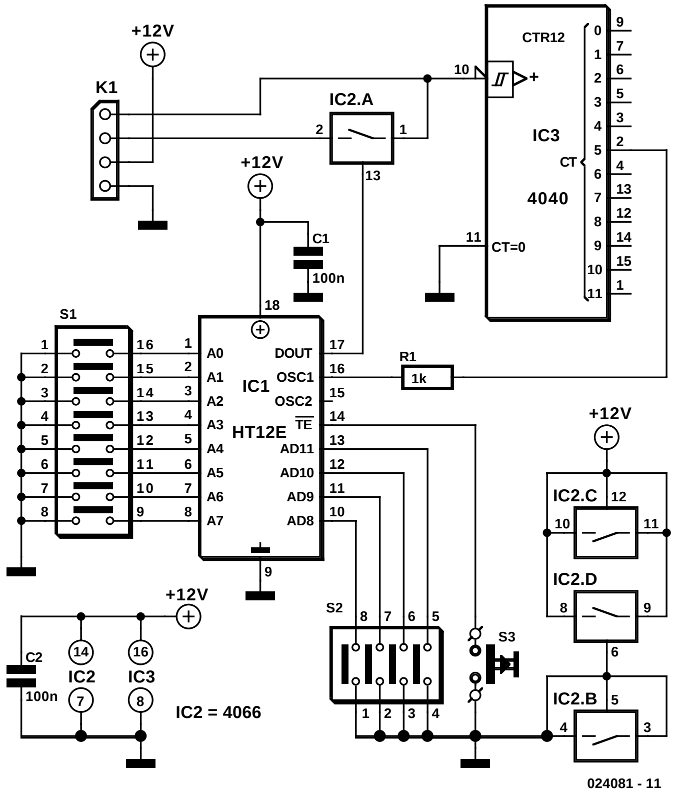
* see text

According to the related curve on the data sheet, thisrequires an external resistance of approximately 115 kΩ to be connected between the OSC1 and OSC2 pins. This can be precisely set using P1, and the potentiometer also allows for adjustments to compensate for various tolerances.
The power supply for the circuit is designed according to the usual standard configuration, with the transformer (Tr2) being intentionally somewhat overdimensioned to provide extra capacity for powering small applications (buzzer, LED etc.). Building the circuit is a simple task if the illustrated printed circuit board is used. Since the power supply (including the transformer) is fitted on the circuit board, the amount of wiring required is minimal.

(024080-1)

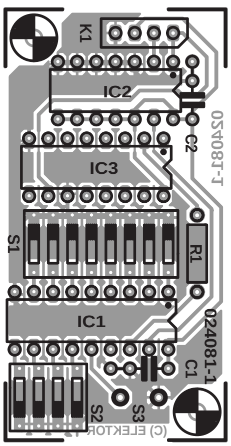
Mains Remote Control: Encoder 009

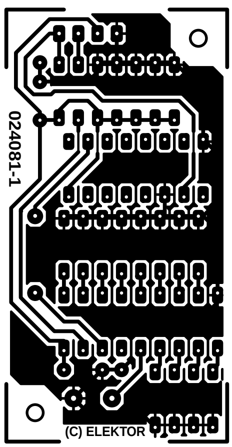




This application can actually be considered to be a slight adaptation of the standard use of the Holtek HT12E encoder (www.holtek.com). We have used this IC several times already, so it does not need any further explanation. The small circuit described here is intended to be used as an extension to the 'Mains Remote Transmitter', but it also clearly illustrates how the IC can be used in a non-standard manner.

The HT12E is normally used with its internal oscillator by connecting a resistance between the OSC1 and OSC2 pins. Here we instead use the carrier frequency of the transmitter. For this purpose, connector K1 of the transmitter is connected to K1 of the encoder. The 143-kHz signal generated by the oscillator in the transmitter is divided by 64 by the counter (IC3), producing an oscillator frequency of approximately 2.2 kHz for IC1. **Note**: for this application, coupling capacitor C5 in the





COMPONENTS LIST

Resistors:
R1 = 1kΩ

Capacitors:
C1,C2 = 100nF

Semiconductors:
IC1 = HT12E Holtek
(Farnell)
IC2 = 4066
IC3 = 4040

Miscellaneous:
K1 = 4-way SIL-header
S1 = 8- way DIP-switch
S2 = 4- way DIP-switch
S3 = pushbutton, 1 make contact

transmitter must be bypassed in order to ensure that IC3 receives a sine-wave signal centred at half the supply voltage as a clock signal. The Philips type 4040 used here has a Schmitt-trigger clock input, which allows the sine wave to be used as a source of ‘clean’ clock pulses.

The HT12E has an output that is not internally modulated (DOUT, pin 17). The carrier wave from the transmitter is modulated by using a type 4066 analogue switch to switch the carrier on and off. The nice thing about this is that the switching is synchronous, since the data output of the encoder is derived from the carrier wave. Instead of using an IR LED modulated at 36 kHz, here we modulate a 143-kHz signal and transmit the remote control signal via the mains network.

The encoder is enabled using S3. S1 and S2 determine the address of the transmitted code, with the setting of S2 serving as the transmitted data in the receiver if an HT12D decoder is used. R1 provides a certain amount of decoupling for the capacitor of the HT12E oscillator circuit. The remaining switches of the 4066 are not used. The maximum current consumption with S3 pressed is around 0.6 mA.

The illustrated circuit board layout is approximately the size and shape of a matchbox and guarantees problem-free construction of the encoder.

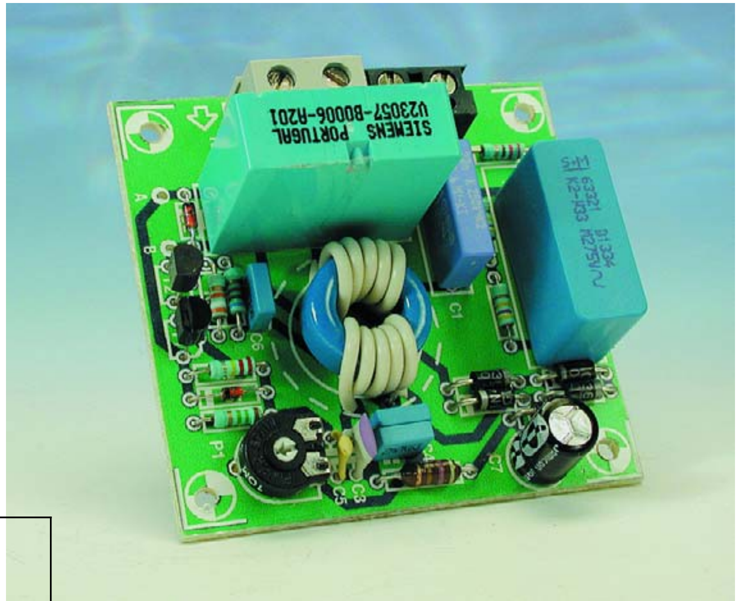
(024081-1)

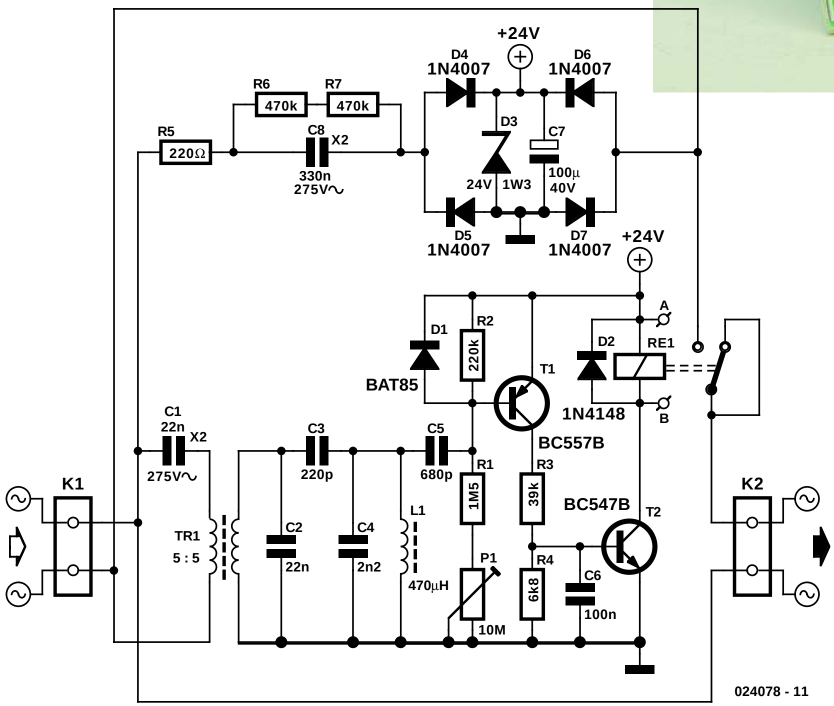
Mains Remote Switch

010

This compact design forms a remotely operated switch that receives its control signal via the mains voltage. The switch is operated using the ‘mains remote transmitter’ described elsewhere in this issue. With this transmitter, a switch should be connected between pins 1 and 2 of K1. Depending on the application, this must be either a press contact or a make contact.

The idea of the ‘mains remote switch’ is that a relay is energised in order to connect the mains voltage on K1 through to K2. The ‘receiver’ (a somewhat exaggerated term for such a simple design) is formed by Tr1 and the tuned circuit L1/C4. The network C1/Tr1/C2 serves as a coupled circuit tuned to the frequency of 143 kHz generated by the transmitter. The selectivity is determined by L1/C4 and is primarily dependent on the standard suppression coil L1.





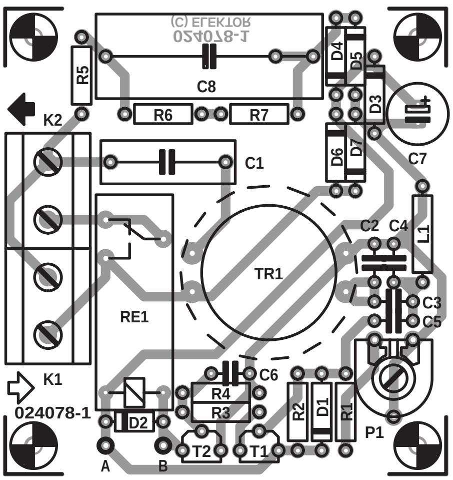
Gain for operating the relay is provided by T1. The amplified signal is smoothed by C6 and provides the voltage necessary to cause T2 to conduct and energise the relay. The voltage divider formed by P1, R1 and R2 provides a bias voltage for T1 in order to increase the sensitivity of the receiver. This also allows the relay to be energised without a received signal. D1 ensures that C5 does not become charged and prevents T1 from conducting even more. The operation of the circuit is based on the fact that the incoming signal is sufficiently strong to overcome the hysteresis of the relay. Once the signal is no longer present, the relay must naturally again release.

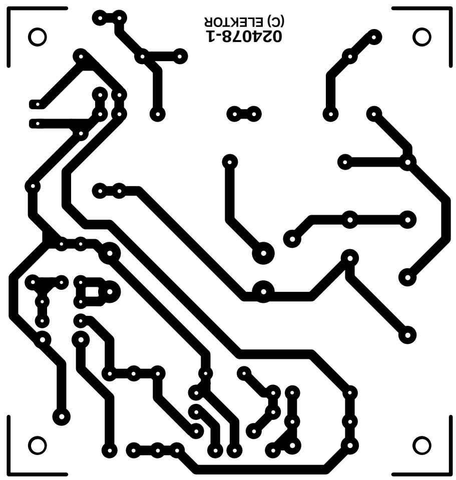
To be honest, it must be noted that the simple design of this circuit has the disadvantage that its sensitivity may be somewhat inadequate, depending on household circumstances. One possible solution is to reduce the frequency of the transmitter to the region between 95 and 125 kHz. The values of C1, C2 and C4 will then have to be modified to match, so this is something for readers who like to experiment.

Do not forget that just as with the transmitter, the entire circuit (once it has been switched on, of course) is connected to the mains potential. Power for the transistor stage and the relay is taken directly from the mains voltage using a capacitive voltage divider; R5 is only necessary to limit the current through the diodes to a safe value on switch-on. Rectification is provided by diodes D4–D7 and filtering by C7. The impedance of C8 is low enough to provide sufficient current. The no-load voltage (when T2 is not conducting and the relay is not activated) is limited by zener diode D3. R6 and R7 discharge C8 immediately after the circuit is disconnected from the mains, in order to prevent any dangerous voltage from remaining on the input terminals.

Connections A and B are provided for test purposes and also allow something other than the relay to be energised (but keep in mind that the circuit is electrically connected to the mains network!). The pinout of the relay is standard, so a type other than that shown in the components list can also be used, as long as you make sure that the operating voltage is 24 V and the operating current does not exceed 28 mA.

(024078-1)





COMPONENTS LIST

Resistors:
R1 = 1MΩ5
R2 = 220kΩ
R3 = 39kΩ
R4 = 6kΩ8
R5 = 220Ω
R6,R7 = 470kΩ
P1 = 10MΩ preset

Capacitors:
C1 = 22nF 275VAC Class X2, lead pitch 15mm
C2 = 22nF, lead pitch 5 mm
C3 = 220pF
C4 = 2nF2, lead pitch 5mm
C5 = 680pF
C6 = 100nF, lead pitch 5 mm
C7 = 100µF 40V radial
C8 = 330nF 275VAC, Class X2, lead pitch 22.5mm or 27.5mm

Inductors:
L1 = 470µH

Semiconductors:
D1 = BAT85
D2 = 1N4148
D3 = zener diode 24V 1.3W
D4-D7 = 1N4007
T1 = BC557B
T2 = BC547B

Miscellaneous:
K1,K2 = 2-way PCB header, lead pitch 7.5 mm
Tr1 = 5:5 turns 1mm dia. isolated wire on N30 ring core 16x6.3 mm, B64290L45X830 EPCOS (Farnell # 311-0266)
Re1 = PCB relay, 1 c/o contact, 8A 24V 1200Ω, e.g., Schrack # V23057-B0006-A201

Modem Line Protection

011

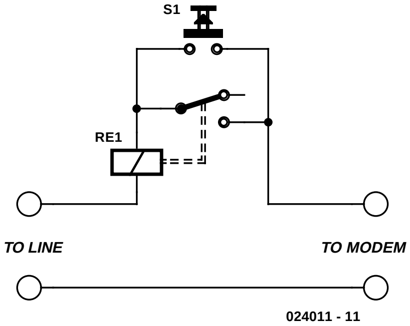
V. Steensgaard

We haven't yet experienced this first-hand, but it seems to occur more often that when some websites are visited they switch the Internet connection over to a premium rate dial-up number. This is of course very irritating, because it is hardly noticeable and it certainly costs a lot more.

This circuit is simplicity itself, but still offers effective protection against these practises. The circuit consists of nothing more than a push-to-make switch and a reed relay with a home-wound coil and is connected to the phone line in series with the modem. During the dial-up the switch has to be pushed down for a while (a bit earlier really, or otherwise the modem won't be able to detect the dial tone). Once the modem is 'off hook', the pushbutton can be released. The current in the phone line then keeps the reed relay energised, maintaining the connection.

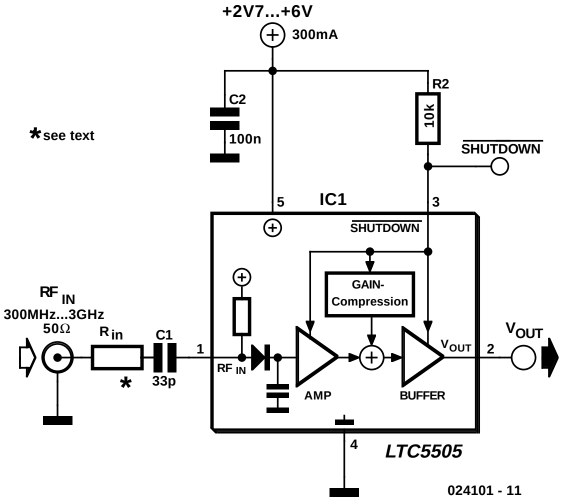
When an attempt is made to switch to a different number, the line has to be dropped first, no matter how quickly this happens. The reed relay opens at any interruption of the current, stopping these tricks in their tracks. No matter how clever the programmer is at the other side, this simple hardware protection cannot possibly be circumvented!

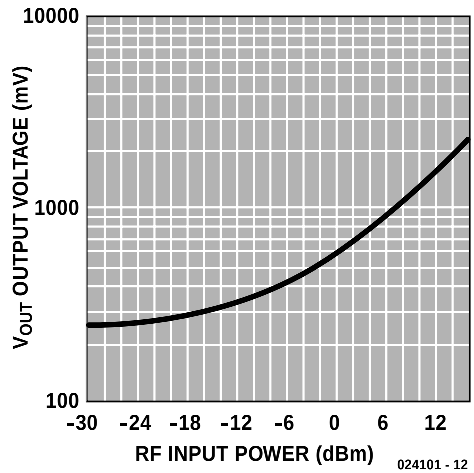
A guideline for the construction of the reed relay coil is to wind about 200 turns of 0.1 mm or 0.2 mm copper enamelled wire round the relay. The complete reed relay can also be bought from the author via his website: http://home.worldonline.dk/~wildsto/sdb/. For completeness we should mention that a patent has been applied for.



(024011-1)

300-3000 MHz RF Detector 012





An RF detector with a dynamic range of 40 dB can now be obtained from Linear Technology (http://www.linear-tech.com/pdf/5505i.pdf). The type LTC5505, housed in an SOT23 SMD package, can handle input frequencies between 300 MHz and 3 GHz for input signal levels between –32 dBm and +18 dBm (0 dBm = 1 mW into 50 Ω). There are two versions having different input level ranges, as shown in the table.

Version	Input power range	R_{in}
LTC5505-1	–28 dBm to +18 dBm	20 Ω
LTC5505-2	–32 dBm to +12 dBm	0 Ω

The LTC5505-1 is intended to be used for the upper range of signal levels. A series input resistor (R_{in}) in combination with the internal input resistance attenuates the input signal. For both versions, the input impedance is approximately 50 Ω.

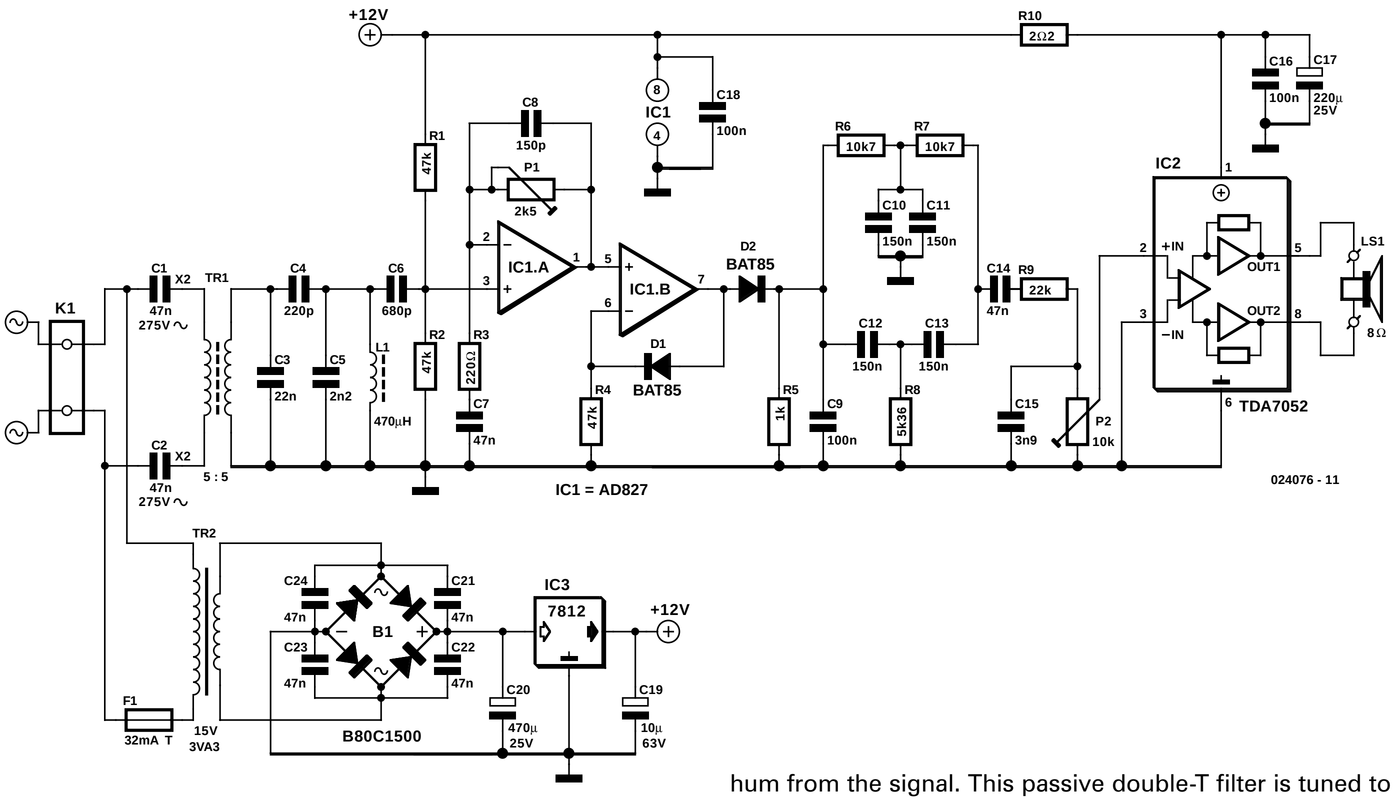
The LTC5505 contains a Schottky diode used as a detector, which is temperature compensated by additional circuitry. The IC requires an operating current of only 0.5 mA at a supply voltage between +2.7 V and +6 V. An active-Low shutdown input can be used to disable the detector. In the disabled state, the IC draws less than 2 μA.

The output voltage of the detector ranges from +280 mV to more than +2 V, depending on the input signal level, with a load current capacity of around 1 mA. A gain compression block reduces the output level at high RF levels in order to keep the output signal within the stated range, whose upper limit is set by the minimum supply voltage of +2.7 V.

Using this detector IC, simple diode detectors can be replaced by a component of the same size having significantly better characteristics.

(024101-1)

AM Demodulator for Intercom 013



This circuit should be considered as more of an experimental circuit for AM demodulation, than as a practical application. In the associated 'AM modulator' we have raised the problems caused by mains hum, getting in the way of interference-free operation of the AM mains intercom. When the transmitter and receiver are not coupled through the mains then the quality is perfectly adequate.

The 'receiver' used here is the same as found in the 'mains remote switch' and 'mains remote control decoder' (C1 to C5/TR1/L1). The capacitor that connects the small toroidal transformer to the mains has been split into two, making the circuit a little bit safer. But please note: **the complete circuit should be considered as being at mains potential.** So don't solder to the circuit or take any measurements while it is switched on.

The input signal is first amplified to the right level by a fast opamp (AD827). P1 can be adjusted to give this stage a maximum gain of 20 dB. The actual demodulator is about as simple as you can get, since it consists of nothing more than a diode, a capacitor and a resistor (D2/R5/C9). Due to the RC time constant and the diode the voltage across the capacitor follows the envelope of the AM carrier wave. The circuit of IC1b, D1 and R4 make the characteristics of diode D2 somewhat more linear. This effect is fairly small, so if simplicity of the circuit is important you could leave this part out.

The filter following this stage attempts to remove the worst hum from the signal. This passive double-T filter is tuned to 100 Hz because that was the strongest component of the interference. But in practice all harmonics of 50 Hz are present, too many to suppress with a simple filter. Because the sensitivity of the power amplifier used here is fairly high, the double-T filter is followed by a potential divider and first order high-pass and low-pass filters (C14/R9/P2/C15). This keeps as much of the speech signal as possible, while removing more of the interference.

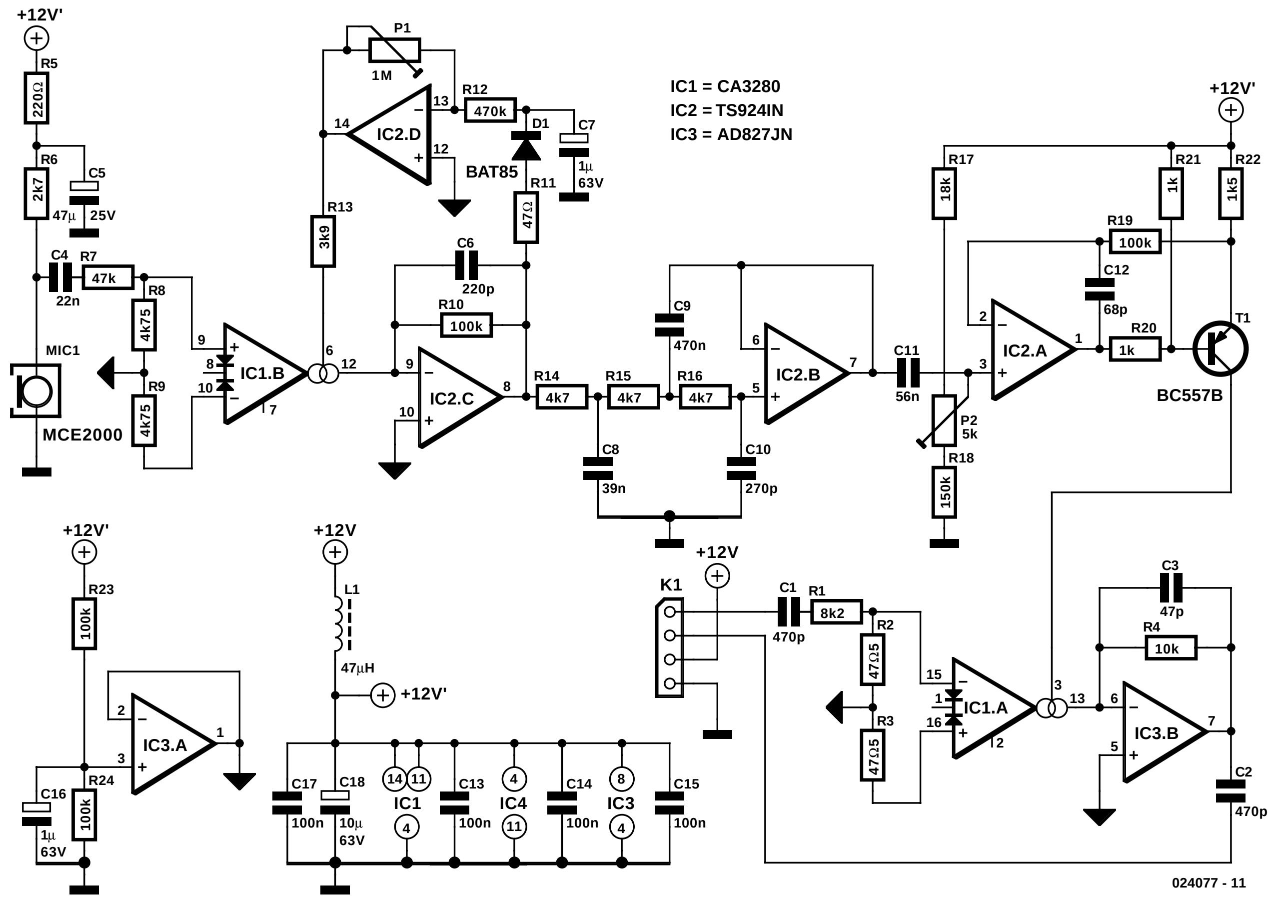
The power amplifier is a TDA7052 (IC2) that is meant for 6 V operation but which can also be used at 12 V. Take care that it doesn't consume too much power (if you can get hold of one, a 16 Ω speaker is better). The amplification is approximately 40 dB. IC2 has been well decoupled from the supply by R10/C16/C17. Constructors have to make sure that both the ground and the +12 V for the power amplifier are taken directly from the regulator and are not used to supply any other part of the circuit. Preset P2 is used to set the volume level, although a 'real' (logarithmic) potentiometer could also be used.

The power supply uses a standard circuit: a bridge rectifier (B1) with suppression capacitors (C21 to 24), a smoothing capacitor (C20), a 7812 regulator (IC3) and a final decoupling capacitor.

The quality of the circuit could be improved by replacing the passive filter with higher order active filters (possibly switched-capacitor types), but this is clearly only something to try for dedicated experimenters.

(024076-1)

AM modulator for Intercom 014



This circuit was originally designed as a simple mains intercom for use in the home. To complete the circuit you could use the 'Mains Remote Transmitter'. We have to admit that our tests with the mains intercom where somewhat disappointing due to a persistent audible mains hum from the speaker. That doesn't diminish the usefulness of the AM modulator as such, and it is still a very useful circuit for experimentation with this type of modulation. The accompanying receiver is called 'AM demodulator for Intercom'.

The circuit consists of a microphone amplifier with a presettable automatic gain control (IC1b/IC2c/IC2d), a speech filter (IC2b) and the actual modulator (IC1a/IC3b/IC2a/T1). Because an asymmetrical power supply is used, the circuitry round IC3a has been added to provide a virtual ground which has its potential at half the supply voltage.

The hart of the circuit is formed by a dual OTA (IC1, a dual operational transconductance amplifier), of which one is used for the microphone amplifier and the other for the AM modulator. It would be too much to give a detailed description of the operation of an OTA; it suffices to give a brief explanation of the various parts.

The potential divider (R7/R8) at the input of IC1b protects it against excessive inputs. The current output is converted into a voltage by buffer stage IC2c. The level of transconductance of IC1b is controlled by the bias input (pin 6). The current fed to this pin (I_{ABC}, amplifier bias current) is limited by R13 to a maximum of 1.5 mA. The peak level of the output from IC2c is rectified by D1 and C7 and fed back as a control current to the OTA via inverting buffer IC2c. When the output voltage of IC2c increases, so will the voltage across C7, resulting in a smaller bias current and a reduction in the amplification of the microphone signal. This effect is most pronounced with preset P1 at its maximum setting. As P1 is turned down the amplification level of the microphone amplifier becomes more constant. With P1 fully closed the amplification is a constant 38 dB. With P1 at its maximum, the gain is automatically varied by up to 30 dB. P1 can therefore be used to set up the microphone amplifier as required.

R6 is used to bias the electret microphone (in this case a MCE2000 from Monacor). R5 and C5 decouple the supply to the microphone. Since the bandwidth of the microphone is much greater than that available in the 'Mains Remote Transmitter', a 3rd order Chebyshev filter (IC2b) has been added directly after the microphone amplifier, which has 3 dB ripple and a bandwidth of just 3.15 kHz.

The signal is then fed to current source T1/IC2a. The circuit round T1 functions as a current source that can be modulated: a 'constant' current that varies linearly according to the processed microphone signal. This current is then used as bias current for OTA IC1a, causing the signal that is fed to pin 1 of K1 to appear at the output of IC3b with its amplitude modulated. IC2a compares the voltage across emitter resistor R22 with its input, causing the current through T1 to vary linearly with the voltage at pin 3. R19 and C12 are added for stability and potential divider R20/R21 stops the output of IC2a from clipping. The maximum bias current is about 3.5 mA.

The amplification of modulator IC1a/IC3b has purposely been kept a bit below 1 (it can be varied with P2 between 0.5 and 0.6), since 100% modulation will cause the maximum amplitude to be equal to the input voltage thereby overdriving the transmitter. K1 has the same pin-out as the connector on the transmitter board; the supply is taken from pins 3 and 4. The total current consumption is about 25 mA. The output signal from IC3b is connected to pin 2 of K1. The circuit was designed for use in close proximity with the transmitter, so no limiting resistor was added to the output. When a longer (shielded) cable is used between the two, you should connect at least a 47 Ω resistor in series with the output. A fast AD827 was chosen for opamp IC3, so that the modulator can easily cope with the 143 kHz signal.

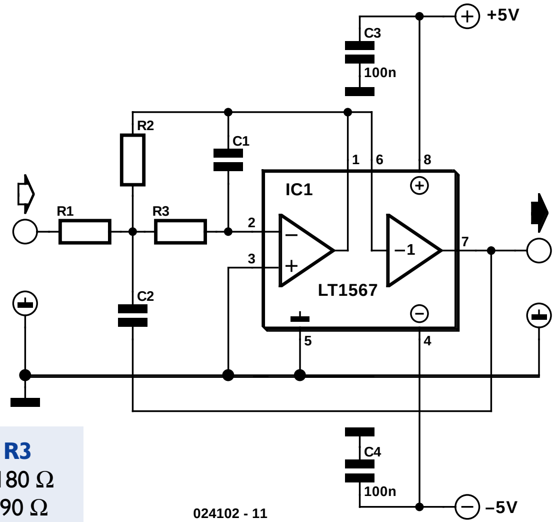
(024077)

5 MHz Active Lowpass Filter 015

In the LT1567 Linear Technology (www.linear-tech.com/pdf/1567i.pdf) has produced a component specially developed for building analogue filters with cutoff frequencies up to 5 MHz. It contains two wide-bandwidth operational amplifiers, the second of which has a fixed configuration as an inverting amplifier with unity gain. To construct a lowpass filter just two external capacitors and three resistors are required.

Example component values for corner frequencies of 1 MHz, 2 MHz, and 5 MHz are shown in the table.

(024102-1)



Filter	C1	C2	R1, R2	R3
Chebyschev 0.1 dB ripple, 1 MHz	120 pF	180 pF	1050 Ω	1180 Ω
Chebyschev 0.1 dB ripple, 2 MHz	120 pF	180 pF	523 Ω	590 Ω
Chebyschev 0.1 dB ripple, 5 MHz	120 pF	180 pF	205 Ω	232 Ω
Butterworth, 2 MHz	180 pF	180 pF	604 Ω	309Ω

Lithium-Ion Charger

016

Lithium-Ion cells require a totally different charging protocol to that for NiCd or NiMH cells, a protocol that has to be followed precisely. During the last year we have already published two articles regarding the charging of this type of cell. This time we're using a new IC (so it may still be difficult to obtain!) made by Linear Technology (www.linear.com), which is very small and can therefore be built into the cell permanently, but is also suitable for use as an 'ordinary' charger.

It is designed to charge one cell at a time, at a current of 500 mA. When a new cell is connected and power is applied (in any order), the charging process begins. First the temperature of the cell is checked with the help of the NTC. The charging will only start if the temperature is between 0 and 50 °C. When Lithium-Ion cells have been discharged too deeply they should at first be charged very gently, at a current of only 50 mA, as long as the cell voltage is below 2.49 V.

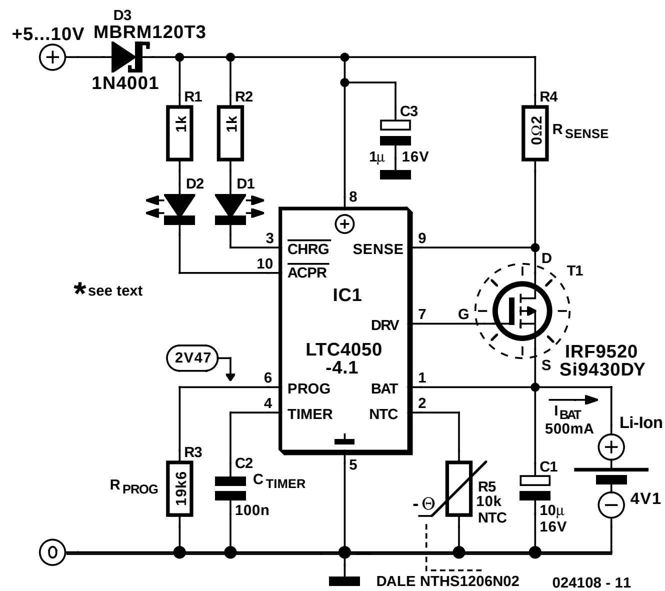
Above that voltage the charge current is increased to a nominal 500 mA, until the maximum voltage of 4.1 V (or 4.2 V, depending on the type) has been reached. The cell voltage is now held at this level, causing the charge current to gradually decrease until the cell is fully charged. When the charge current has reduced to 50 mA, the charging stops and the cycle is complete. As an extra safety measure the IC also contains a timer that stops the charging process after a specific time, even if the current hasn't yet fallen below 50 mA.

The phases described above are indicated by LED D1. During the charging of the cell it will light up brightly. When the charging stops due to the current having fallen below 50 mA, it is lit dimly. And when the timer stops the charging process, the LED will be off.

When the charging process has completed, the supply is obviously no longer required. The charger circuit itself can be left connected to the cell since it only draws about 5 to 7 µA, so there is no need to worry that the charger would quickly discharge the cell. A new charge cycle will begin when an empty cell is connected and power is applied. A new cycle will also automatically start (as long as power is applied) when the cell voltage drops below 3.88 V (3.98 V).

The charge current can be modified by adjusting R3 and R4 according to the following formula: $I = (2.47/R3) \times (800/R4)$. The maximum charge time is determined by C2; the formula used here is: time = (C2 × 3 hours) / 0.1 µF. The timer doesn't start until the cell voltage reaches 4 V. LED D2 is lit when the voltage supplied to the charger is high enough.

T1 is a P-channel MOSFET, which can be virtually any power type. It could even be replaced by a PNP darlington, with its emitter connected to R4. NTC R5 should be mounted as closely as possible to the cell, so that the cell temperature is measured accurately. It won't be easy to find the NTC used in this circuit, but the accuracy of the 0 en 50°C temperature limits aren't that important. Since its resistance at 25°C is 10 k, it



could even be replaced by a fixed 10 k resistor. Obviously the temperature protection will then no longer function.

For D1 and D2 you should use low-current (also known as high efficiency) LEDs. D3 can be any 1 A Schottky diode, or an ordinary diode such as the 1N4001 if it doesn't matter that there is a slightly bigger voltage drop.

There is one final point, which most of you probably know: Lithium-Ion cells may absolutely never be charged at voltages greater than 4.1 V (4.2 V) because they could explode under those circumstances. It should be stated on the cell whether it is a 4.1 V or 4.2 V type, otherwise you will have to refer to information provided by the manufacturer. The LTC4050 comes in two versions, with '-4.1' or '-4.2' as a suffix. The IC is only available in a SMD package (MS10).

(024108-1)

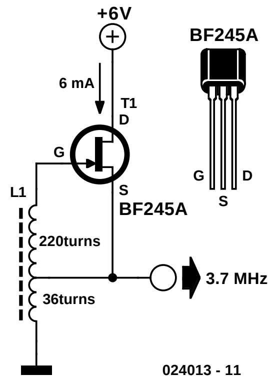
2-component Hartley Oscillator 017

G. Baars

Although Elektor never actually launched a design contest under the name “low component-count oscillators” the author was challenged by ‘Three Component Oscillator’ published in July/August 2001. The result is shown here, representing a reduction in component count of no less than 33.3%! The audio field has been left though in favour of RF.

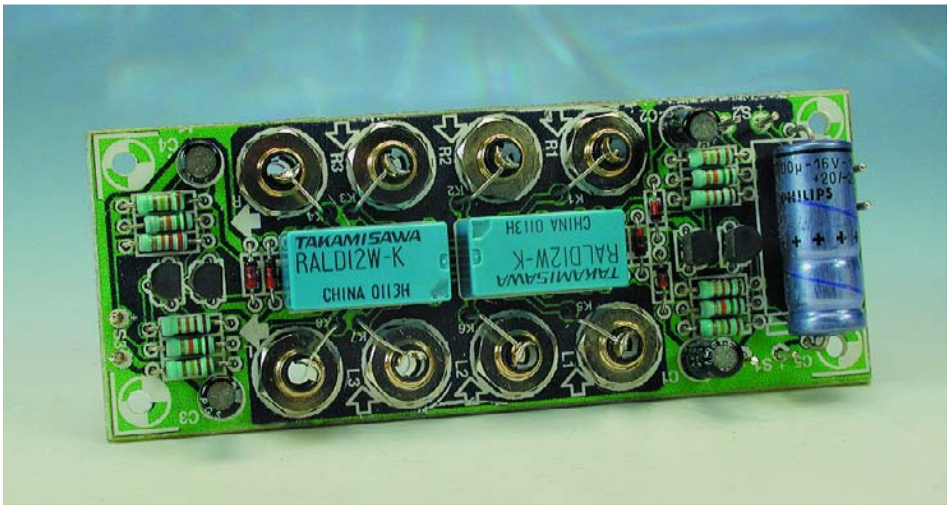
This Hartley oscillator can be built from just one FET and a coil. The coil has a tap to provide the amount of positive feedback the circuit needs to start and maintain oscillation. The stray capacitances presented by the FET gate and the coil wires are enough to make the circuit resonate at about 3.7 MHz with the coil data given in the diagram. The internal diameter of the coil is about 8 mm and no core was used. Moving the tap up towards the gate will reduce distortion but at some point the oscillator will throw in the towel and refuse to start.

(024013-1)



Audio Switchbox

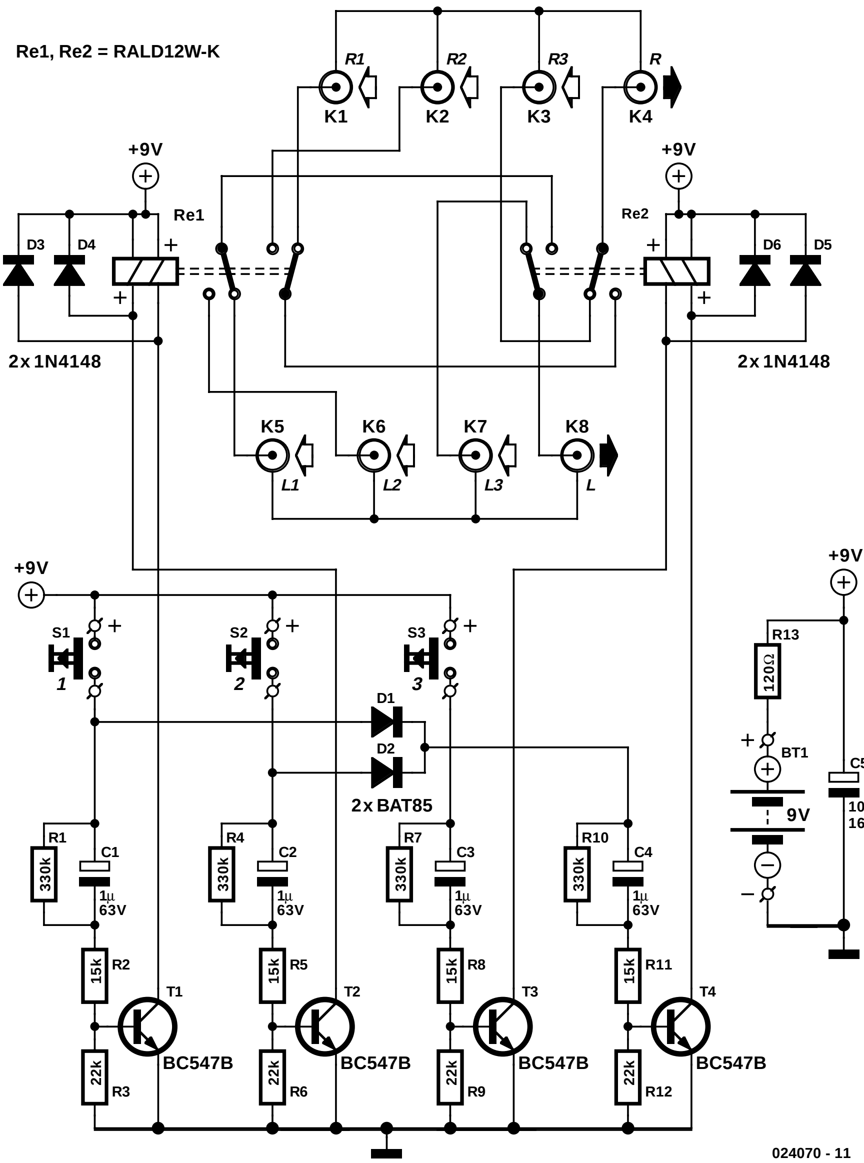
018

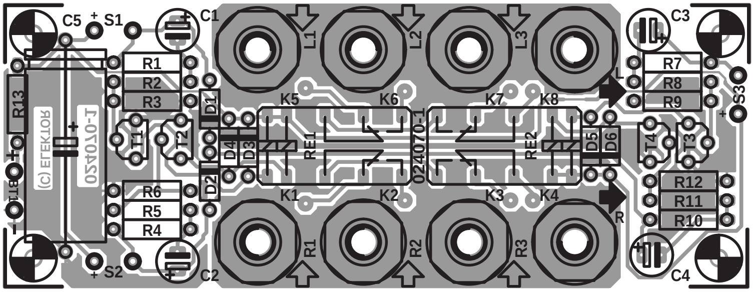


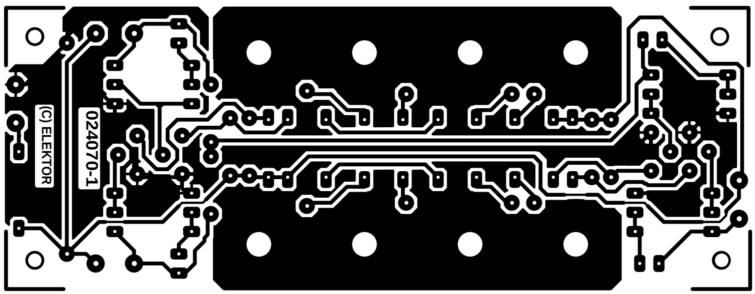
This circuit is intended as an extension for (pre-) amplifiers, to increase the number of inputs. Ever since the introduction of MD-recorders, DVD players, etc. the owners of older amplifiers have had a chronic shortage of inputs. The application of this switchbox also makes it possible to loop the audio outputs from the DVD player and video recorder to the audio system, without the need to turn on the TV. This is very handy when the audio installation is positioned some distance away from the video system and you only wish to listen to the sound from the DVD/MP3 player, for instance.

The circuit makes use of two bistable relays, which have two changeover contacts each. This makes the circuit nice and compact and also avoids the need of exerting considerable force on the shaft of a rotary switch. The relays can now be operated with three small buttons (S1 to S3). The relays are 12-V models, which operate just fine on a 9-V battery. In order to reduce the power consumption to virtually zero, a number of differentiator networks (C1/R2, C2/R5, C3.R8 and C4/R11) have been designed that generate the necessary pulses for the relay windings. Every relay has a SET and RESET winding.

The third stereo input is directly connected, via the normally-closed contacts of relay Re2, to the output. The other two inputs are connected via Re1 to the normally-open contacts of Re2, and from there to the output. To select the third input only Re2 has to be reset. That is the purpose of the small circuit around T3. When pressing S3, T3 is made to conduct for a sufficiently long period (several milliseconds) via C3/R8/R9, to ensure that the relay switches over. R7 is required to discharge C3 quickly when the pushbutton is released. The differentiator networks have the advantage that even when the pushbutton remains activated the current consumption is still very low (<25 μA). Only the initial







COMPONENTS LIST

Resistors:
R1,R4,R7,R10 = 330kΩ
R2,R5,R8,R11 = 15kΩ
R3,R6,R9,R12 = 22kΩ
R13 = 120Ω

Capacitors:
C1-C4 = 1µF 63V radial
C5 = 1000µF 16V axial

Semiconductors:
D1,D2 = BAT85
D3-D6 = 1N4148
T1-T4 = BC547B

Miscellaneous:
K1-K8 = cinch (RCA) socket, chassis mount
S1,S2,S3 = pushbutton
Re1,Re2 = RALD12W-K (12 V/960 Ω) Takamisawa (Conrad # 50 33 98-60)
BT1 = 9V battery with clip

pulse amounts to a little over 0.5 mA. We can therefore expect the battery to last several years (beware of possible leaks).
If the first or second input is desired then Re1 has to be set or reset via S2/T2 and S1/T1 respectively. Re2 has to be set when S1 or S2 is pressed. The fourth differentiator network takes care of this. When S1 or S2 is pressed, D1/D2 and the small circuit around T4 generate a set pulse for Re2, so that Re1 will be selected.
A 1000-µF electrolytic capacitor in parallel with the battery acts as an 'emergency power supply' when the battery is nearly exhausted. Every pulse at 9 V amounts to nearly 10 mA. The relays are industry-standard types and pin-compatible with the common V23042-B2203-B101 from Siemens (called Schrack these days). R13 limits the 'short-circuit current' (through C5) when the battery is first connected.
The connections for the three pushbuttons appear on the PCB in the locations where they were most convenient, in order to keep the PCB as small as possible. Whoever is tempted to use a slide switch has to keep in mind that in that case there is always one closed contact and a small current flow as a consequence. To facilitate testing, the power supply (marked with '+') is available next to each connection. If the three pushbuttons are mounted on a panel a single common '+' will suffice of course. The PCB shown here is unfortunately not available ready-made.

(024070-1)

Fan Monitor

019

The MAX6684 from Maxim (http://pdfserv.maxim-ic.com/arpdf/MAX6684.pdf) is a device for monitoring fans. Available in an 8-pin small outline SMD package the IC is capable of detecting if the fan is jammed or if it is turning too slowly. Although the device itself requires a supply voltage in the range +3.3 V to +5 V, it can be connected to fans operating on up to +24 V and drawing currents of up to 250 mA. An internal sense resistor to ground (PGND) is used to detect the current pulses of the fan motor and the pulses are processed according to their shape and frequency. A power MOSFET, with an on resistance of around 1 Ω, is connected between SENSE and PGND.

The open drain $\overline{\text{FAIL}}$ signal goes low to indicate a fail condition when:

(a) the current drawn by the fan falls below 35 mA_{pp} (AC component);

(b) the current drawn by the fan rises above 600 mA;

(c) the fan rotation rate falls below about 700 revolutions per minute (25 Hz AC component);

(d) the die temperature of the chip rises above +160 °C (over-temperature protection).

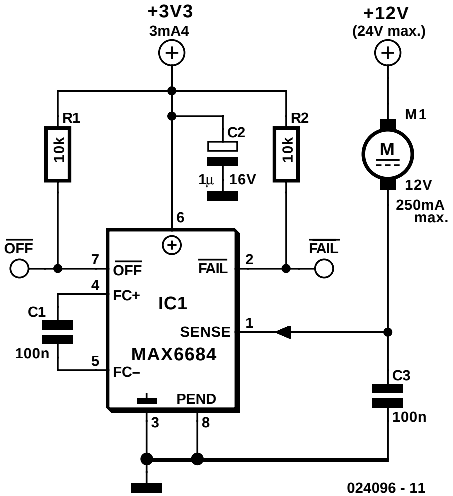
In the first case the fan remains switched on, whereas in case

(b) the device will try to start the fan again every 62 ms. If the over-current condition persists, the MAX6684 will turn off again within 2 ms and wait another 60 ms. In case (c) also the fan remains switched on. The lower rotation rate threshold for this case is mainly determined by the coupling capacitor between FC+ and FC-. The value should be determined experimentally if necessary.

If the fan already has internal protection against jamming it will automatically switch itself off. Then the $\overline{\text{FAIL}}$ signal is only active during the period when the fan tries to restart itself. If the fan rotation rate threshold detector does not work reliably, a 100 µF electrolytic capacitor connected in parallel with the fan may help.

The $\overline{\text{OFF}}$ input can be used to turn the fan on and off.

(024096-1)



Overvoltage Protection

020

W. v.d. Voet

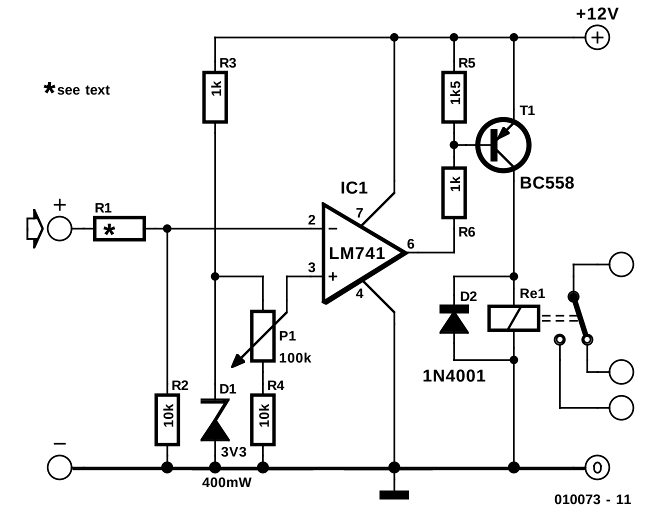
This is a tried and trusted design for the protection against overvoltages that can be configured for your own needs. The circuit can also be used to detect undervoltages; in that case the inputs of IC1 have to be changed over.

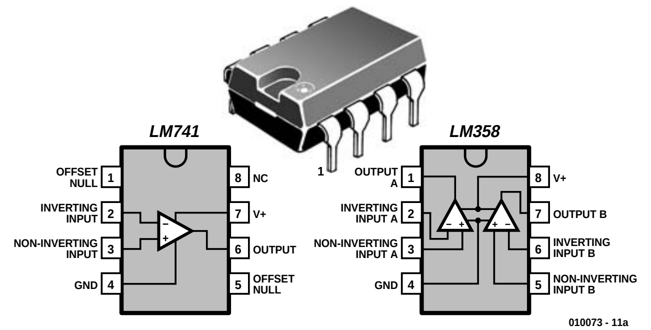
The operation is straightforward. When the input voltage becomes too large, the voltage at pin 2 (inverting input) of IC1 becomes higher than the reference voltage at pin 3 (non-inverting input). The output of the opamp will in that case become 'low'. (It's just like a maths lesson: *higher* times *inverting* can be thought of as + times – and that results in –.) This then drives T1 on, which in turn supplies power to the relay. The contacts of the relay can then be used to isolate the equipment from the supply.

The circuit doesn't have any hysteresis, so in principle there is a possibility that the relay could chatter. In practice it won't be that bad, because the voltage will rise a bit further when the protected equipment is turned off.

We've chosen a supply voltage of 12 V for the circuit, but in practice any voltage between 12 V and 24 V is suitable. The coil of the relay should work at the chosen supply voltage; so select a relay with a working voltage the same as that of the supply, or if you already have a relay, make the supply voltage equal to the operating voltage of the relay. It doesn't have to be exact, as long as you stay within plus or minus 10%. Keep in mind that a BC558 (T1) can switch at most 50 mA. Should the relay require more current, replace T1 with a BC516; this can switch a maximum of 0.5 A (in practice 0.25 A).

The voltage reference is simply derived from a zener diode (D1). The zener voltage isn't critical and a value of 5.1 V may even be better than the 3.3 V used here, because the change





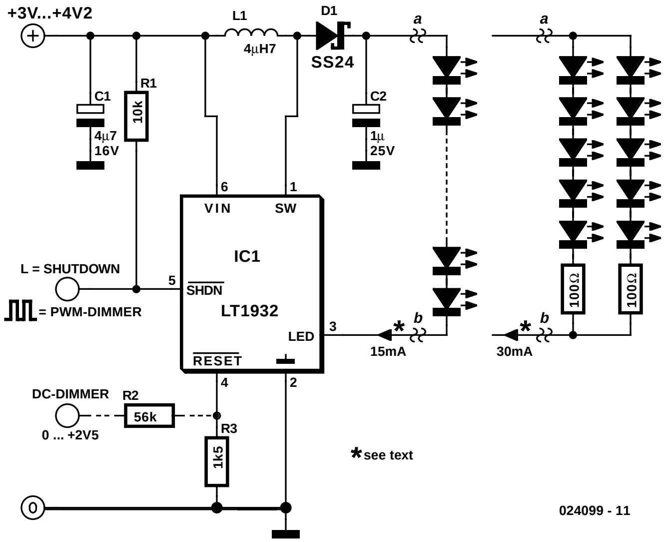
in zener voltage due to a temperature change is then at a minimum. R3 should have a value that lets a current of at least 3 mA flow through the zener. Keep in mind that according to the datasheet for the 741 the input voltage at which the 741

switches should be at least 1.5 V higher than the voltage at pin 4 (this is the so-called common-mode voltage). So the voltage set by P1 at pin 3 should not be less than 1.5 V. In practice a lower voltage is possible, down to about 1 V. It would be better to use a value between 47 kΩ and 100 kΩ for R4; this reduces the adjustment range somewhat, but at least the voltage can never be set too low. If you really want the lower range to extend down to 0 V, then you should choose a different opamp, such as half a LM358.
Resistor R1 forms a potential divider in combination with R2. R1 should have a value such that the voltage at pin 2 is about equal to the voltage at the wiper of P1 when that is in its mid position; that is about 2.4 V. The following formula is used to calculate the value for R1: it is equal to the required turn-off voltage minus 2.4 V, divided by 240 µA. So for protection against voltages greater than 100 V, R1 should be 407 kΩ; in practice you would use 390 kΩ.
The current consumption of the circuit is only a few mA plus the relay current.

(010073)

LED Flashlight

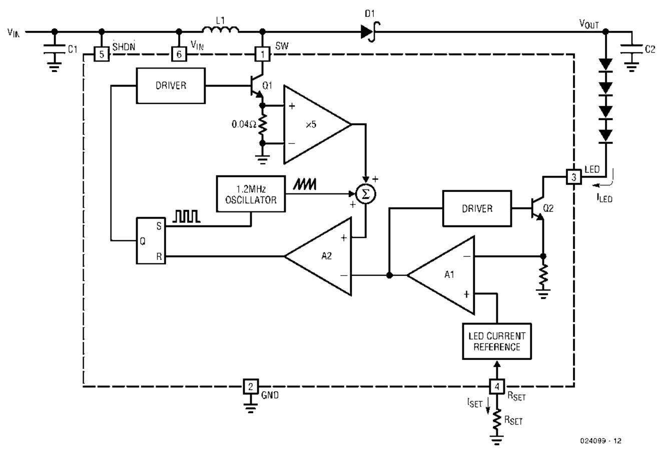
021



Up to eight LEDs can be connected in series but if more are required it is possible to use two parallel networks of five series connected LEDs. In this configuration it is necessary to include a resistor in each arm of around 100 Ω to prevent one of the arms from hogging all the current.

A pulse width modulated square wave applied to the Shutdown ($\overline{SHDN}$) input will dim the LEDs. Alternatively an external variable supply connected via a 56 kΩ resistor to the R_{SET} input can also act as a dimmer.

(024099-1)



If you need to drive a number of white LEDs to provide display backlighting or for a white-light torch what's the best way to configure them? If they are wired in series then the forward conduction voltage of the chain will be greater than the output from a typical battery. Connect them in parallel and current becomes a problem. To keep the light output constant it is also necessary to maintain a constant current through the LEDs despite a falling battery voltage.

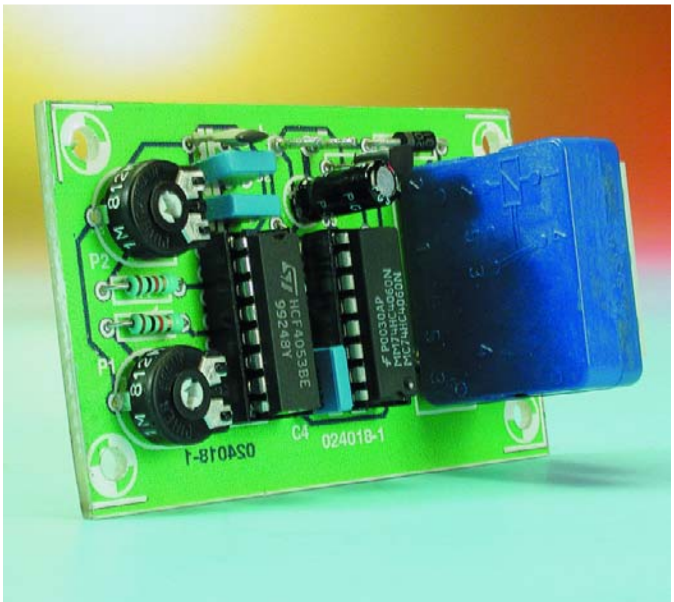
The LT1932 from Linear Technology (www.linear-tech.com/pdf/1932f.pdf) is an efficient solution to the problem. This chip operates at a low supply voltage and contains a switched mode regulator circuit supplying an output current defined by an external resistor at the R_{SET} input. The 4.7 µH inductor must be a type suitable for use in switched mode circuits; it stores energy in the ferrite cores magnetic field during switching.

Number of LEDs	Operating voltage	Efficiency	R_{SET}	I_{LED}
2	1.8 to 3.0 V	75 %	4kΩ53	5 mA
3	1.8 to 3.0 V	75 %	2kΩ26	10 mA
4	1.8 to 3.0 V	75 %	1kΩ5	15 mA
5	2.0 to 3.0 V	70 %	1kΩ13	20 mA
6	2.7 to 4.2 V	75 %	750 Ω	30 mA
8	3.0 to 4.2 V	70 %	562 Ω	40 mA
10 *	2.7 to 4.2 V	75 %		

* *Two parallel arms of 5 LEDs connected in series together with a 100 Ω resistor*

On/Off Timer

022



If you need an adjustable 'on' or 'off' time for some application, then this is the circuit you have been looking for. A problem that often occurs when adjusting timers is that the individual times affect each other. This circuit completely solves this problem because the time defining elements — both R and C — are switched over. That means that there is an RC pair (P1 + R3 and C1) for the 'off' time and another pair (P2 + R4 and C2) for the 'on' time.

The relay is not energised when there is a logical zero at the base of T1. This same zero causes, via input pins 10 and 11 of IC1, pin 12 to be connected to pin 14 and pin 2 to pin 15 of IC1. By contrast, a logical one (relay energised) causes pin 13 to be connected to pin 14 and pin 1 to pin 15.

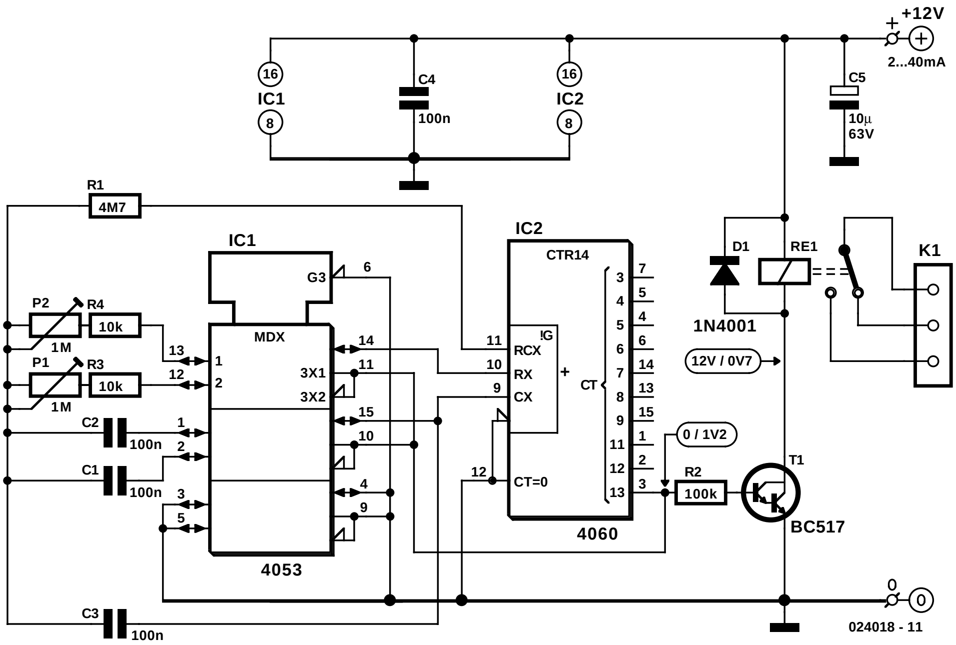
With the values shown, the oscillator period (this can be measured at pin 9 of IC2) can be adjusted from 4 to 200 ms. Since IC2 divides the frequency by 8,192 the resulting time period is adjustable from 32.8 seconds to 27.3 minutes. If a shorter period of time is desired C1 (or C2) has to be reduced,

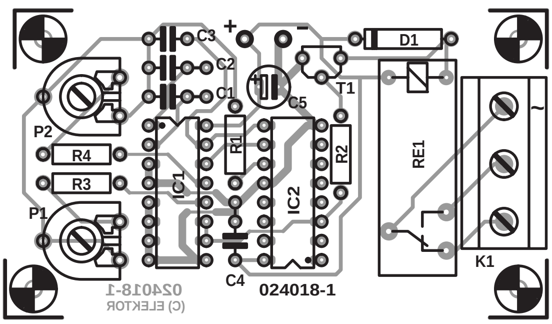
COMPONENTS LIST

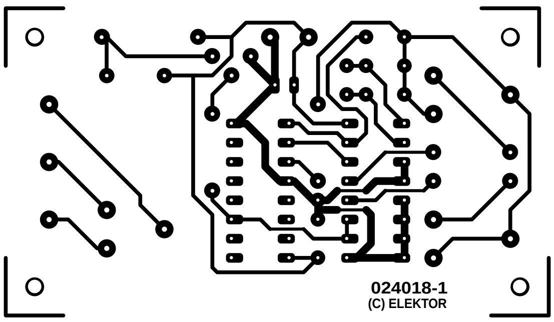
Resistors:
R1 = 4MΩ7
R2 = 100kΩ
R3,R4 = 10kΩ
P1,P2 = 1MΩ preset

Capacitors:
C1,C2,C4 = 100nF
C3 = 100pF
C5 = 10µF 25V radial

Miscellaneous:
D1 = 1N4001
T1 = BC517 (Darlington)
IC1 = 4053
IC2 = 4060
Re1 = E-card relay, 12V coil,
V23057 B0002 A201 (Schrack)







increase for a longer period. C1 and C2 need to be film capacitors or bipolar electrolytics; if these are not available it is possible to make one yourself by connecting two ordinary electrolytics in series, with the positive terminals together.
The power supply voltage for the timer may range from 5 to 15 V. It is preferable that you choose the same value as the rated operating voltage of the relay. The relay shown in the parts list is a 12-V type that is able to switch 230 VAC at several amps. The PCB for this project is unfortunately not available ready-made.

(024018-1)

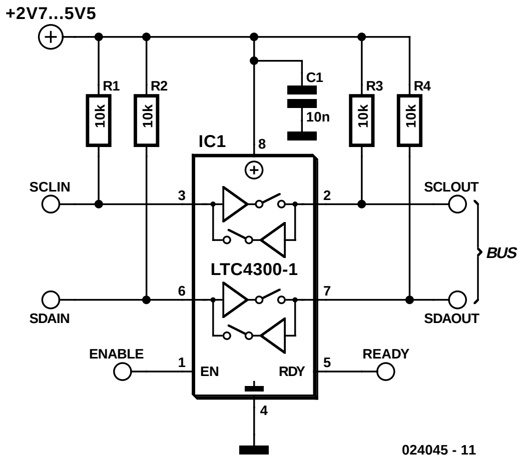
I^2C Hot Swap

023

Now that we've become used to USB you really appreciate the facility to connect or disconnect devices without having to turn the power off first. This was also true for RS232 (but not with LPT), but you never felt at ease with it. I^2C or SMBus devices are unfortunately not hot swappable.

A component that solves half of the problem (the switching part) has been introduced recently by Linear Technology. The LTC4300 is a 2-wire interface buffer that can isolate the signals between peripherals and the bus, making it possible to add another device to the bus at any time, without causing any interference. The next step is more difficult and you will have to find the solution for this yourself: you have to find a way to detect when there is no activity on the bus. At that time the interface chip can be enabled, causing the peripheral to be connected to the bus.

The buffer contains active pull-ups, permitting the use of high-value (10 kΩ) pull up resistors.



More information about the LTC4300 can be found at www.linear.com.

(024045-1)

Level Shifter

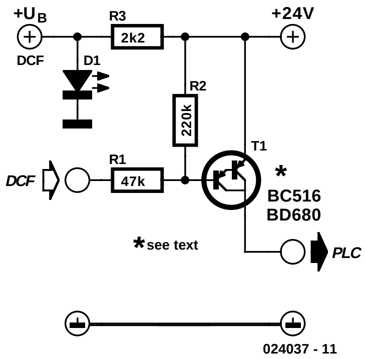
024

R. Koegler

In order to connect the open-collector output of a standard Conrad DCF receiver module (order number 121177), which has a relatively low operating voltage of 1.5–15 V and an NPN open-collector output, to a PLC requiring a positive-switching 24-V signal at around 150 mA, level shifting is necessary. This can be achieved in a simple manner using a miniature relay connected between the positive supply voltage for the module and the DCF module output, as shown in **Figure 1**. In this case the current load on the DCF output must not exceed 1 mA.

All that is needed for this solution is a 15-V miniature relay with a suitable coil voltage that does not require the DCF output to sink more than 1 mA. There are no special requirements on the PLC side, since the contacts of just about any relay can switch 24 VDC at 150 mA.

Besides the electromechanical solution, there is also an electronic solution. Two resistors and a transistor are all you need, as shown in **Figure 2**, if you are prepared to do without electrical isolation between the two devices.

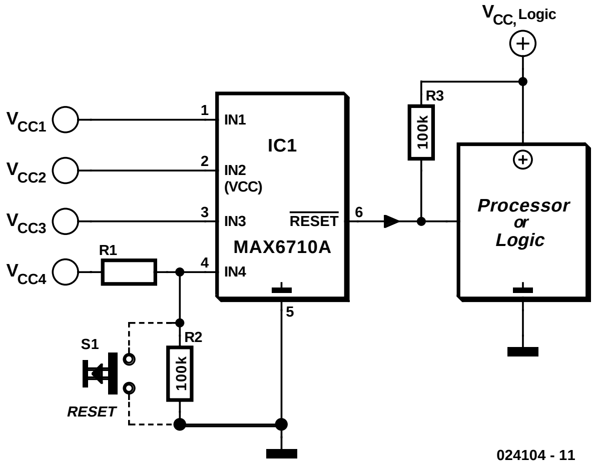


Any desired type of Darlington transistor without a built-in resistor can be used, as well as a p-channel MOSFET. This means that a BC516 or BD680 is suitable, but not a TIP142! The circuit grounds of the two devices are connected together. Naturally, this compact level shifter can be used for other applications as well; the application shown here illustrates how an open-collector output can be connected to a system having a different supply voltage.

(024037-1)

Fourfold Voltage Monitor

025



A Maxim MAX6710 IC (http://pdfserv.maxim-ic.com/arpdf/MAX6710.pdf) can be used to monitor four supply voltages. If any monitored voltage drops below the threshold voltage set by the manufacturer, the IC triggers a Reset signal. This signal remains active for 140 ms after the voltages on all four inputs rise above the threshold voltage, in order to reliably reset the connected system.

The fourth input (IN4) can be freely programmed using an external voltage divider. Its threshold voltage is set to 0.62 V. To calculate the values of the voltage divider resistors R1 and R2, you can choose a value for R2 (100 kΩ, for instance) and then calculate the value of R1 using the formula

$$R1 = R2 \cdot \left(\frac{V_{CC4,th}}{0.62V} - 1 \right) = R2 \cdot \left(\frac{U_{ALARM}}{0.62V} - 1 \right)$$

The IC takes its power from the voltage applied to IN2, with a current consumption of only 35 μA. A faultless reset signal can be generated with a voltage of only 1 V present at IN1 or IN2. The IC is available in an SOT23 SMD package. A selection of the available types is shown in the table.

If it is necessary to be able to generate a reset signal using a manually operated pushbutton, a pushbutton switch can be simply connected in parallel with resistor R2 in order to connect input IN4 to ground when the button is pressed. In this case, R1 is required for current limiting.

(024104-1)

Type	IN1	IN2	IN3	IN4
MAX6710 A	5 V	3.3 V	2.5 V	0.62 V *
MAX6710 B	5 V	3.3 V	2.5 V	0.62 V *
MAX6710 C	5 V	3.3 V	1.8 V	0.62 V *
MAX6710 D	5 V	3.3 V	1.8 V	0.62 V *
MAX6710 E	0.62 V *	3.3 V	2.5 V	1.8 V
MAX6710 F	0.62 V *	3.3 V	2.5 V	1.8 V
MAX6710 G	5 V	3.3 V	0.62 V *	0.62 V *
MAX6710 H	5 V	3.3 V	0.62 V *	0.62 V *
MAX6710 I	0.62 V *	3.3 V	2.5 V	0.62 V *
MAX6710 J	0.62 V *	3.3 V	2.5 V	0.62 V *
MAX6710 K	0.62 V *	3.3 V	1.8 V	0.62 V *
MAX6710 L	0.62 V *	3.3 V	1.8 V	0.62 V *
MAX6710 M	0.62 V *	3 V	2.5 V	0.62 V *
MAX6710 N	0.62 V *	3 V	2.5 V	0.62 V *
MAX6710 O	0.62 V *	3 V	1.8 V	0.62 V *
MAX6710 P	0.62 V *	3 V	1.8 V	0.62 V *
MAX6710 Q	0.62 V *	V_{CC}	0.62 V *	0.62 V *

* programmable using voltage divider R1/R2

Low-Drop Current Source

026

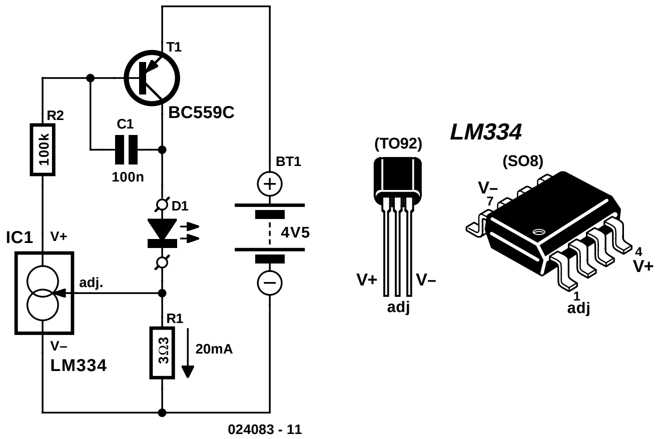
All simple constant-current sources generally operate on the same principle: a current is allowed to flow through a resistance and some sort of regulator is used to try to hold the voltage across this resistance constant. If this is done using a transistor, there must be a voltage drop of approximately 0.6 V over the resistor in order to forward bias the base. However, in some cases this yields an excessive loss, so an opamp with a reference source is used instead. The type LM334 adjustable current source has all of this ‘on board’ and regulates with a voltage drop of 64 mV. The associated schematic diagram shows a practical example of a current source using this indestructible IC. Here R1 is the sense resistor that determines the current level. Its value is calculated using the formula

$$R1 = 0.064 \div \text{current}$$

For example, for a current of 20 mA the value of R1 must be 3.2 Ω.

The illustrated circuit is exclusively intended to be used for small voltage spans and small currents, since T1 can dissipate 100 mW at most. However, you are free to experiment with other components and component values. With the values shown on the schematic, the circuit is eminently suitable for powering a white LED with an operating voltage of 3.6 V from a 4-V lead-acid battery or a 4.5-V battery.

(024083-1)



Supply sequencer

027

It is often the case with electrical systems using more than one power supply that the supplies must be switched on in a defined sequence to avoid electrical damage that may otherwise occur. The MAX6820 chip from Maxim (http://pdfserv.maxim-ic.com/arpdf/MAX6819-MAX6820.pdf) contains all the necessary control circuitry to perform this function in one package. The chip samples the primary supply V_{CC1} at its input SETV (pin 3) via the potential divider formed by R1 and R2. When the voltage at this pin rises above 0.62 V a timer is initiated in the chip. At the end of this timer period the GATE output switches an N-channel MOSFET to connect V_{CC2} through to the secondary circuitry. Both V_{CC1} and V_{CC2} must be greater than 2.125 V otherwise the chip will detect an undervoltage condition and turn off the MOSFET. The values of R1 and R2 can be calculated using the equation:

$$R1 = R2\ [(V_{TH} / V_{TRIP}) - 1]$$

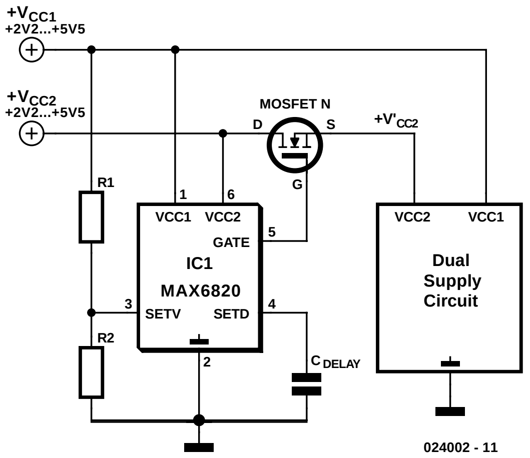
Where
V_{TH} = triggering threshold voltage
V_{TRIP} = 0.62 V

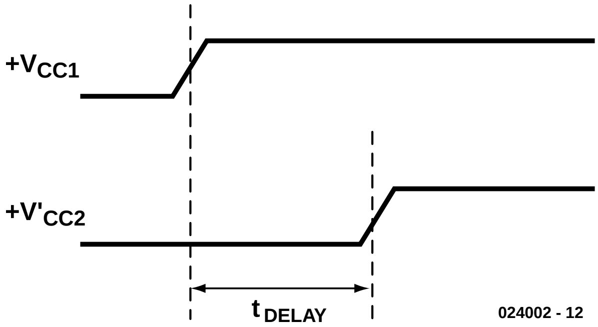
Capacitor C_{DELAY} gives the time delay t_{DELAY} and is calculated using the equation:

$$t_{DELAY} = 2.484 \times 10^6 \times C_{DELAY}$$

Where
The units for C_{DELAY} are µF.
t_{DELAY} is in seconds.

The MAX6820 uses an integrated charge pump to drive the MOSFET gate ensuring that the N channel MOSFET is fully enhanced with a low R_{DS} ON. To select a MOSFET choose one with a suitable R_{DS} ON for a V_{GS} bias of 5 V to 6 V. A BSP17, for example, may fit the bill and comes in a SOT223 package. The MAX6819 performs the same function but has a fixed time delay of 200 ms. This device has no need for an external timing capacitor so the C_{DELAY} input is replaced by an ENABLE input.





(024002-1)

Lithium Torch

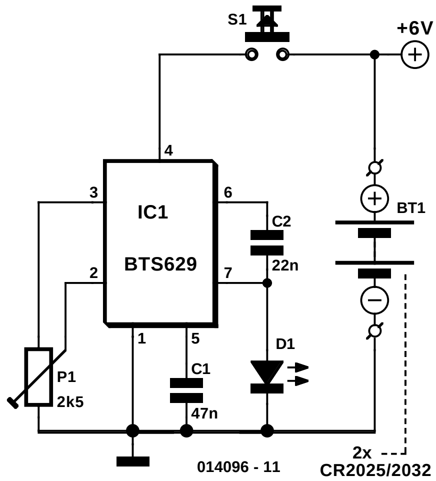
028

This mini pocket torch combines the advantages of Lithium button cells with a super-bright white LED. The lithium cells are small, have a long shelf life and have very little self-discharge. The LED has very high efficiency, an extremely long life expectancy and a modest current consumption (20 mA). In combination this results in an exceptionally long-life pocket torch.

It is unfortunate that a Lithium cell has a voltage of only 3 V, while a super-LED has a forward voltage of 3.5 V. One cell will not suffice and we therefore will have to connect two in series. That results in a power supply voltage of 6 V, and at a current limit of 20 mA we need a series resistor of (6 - 3.5) / 0.02 = 125 Ω. Very annoying, because this resistor causes a power loss of 2.5 × 0.02 = 50 mW. Compared to the power consumption of the LED (3.5 × 0.02 = 70 mW) this would mean that nearly 42% of the energy would be wasted!

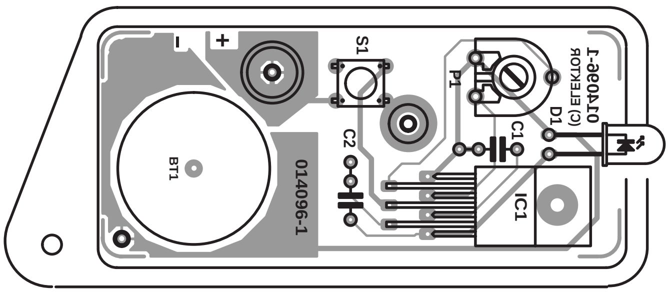
By using an integrated pulse-width modulator from Siemens, the BTS629, this power loss can be limited to about 10%. In combination with two CR2025 cells with a capacity of 170 mAh, the pocket torch will have an expected operating time of 15 hours. Two CR2032 (230 mAh) cells will last an astonishing 21 hours! Another advantage of the IC that has been used here, is that the pulse width, and hence the brightness of the LED, can be smoothly adjusted with P1.

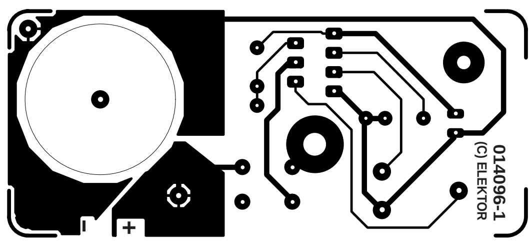
The compact printed circuit board for this pocket torch has been designed so that it fits exactly inside the key ring enclosure UM14 from KM. The PCB has a 20 mm diameter hole for the button cells. The negative terminal for the button cells is made with a piece of paperclip soldered to the bottom. For the positive terminal, on the topside of the PCB a flat terminal can be attached with the aid of an M3 bolt and nut, as can be



seen in the photograph. The PCB shown here is unfortunately not available ready-made.

(014096-1)





COMPONENTS LIST

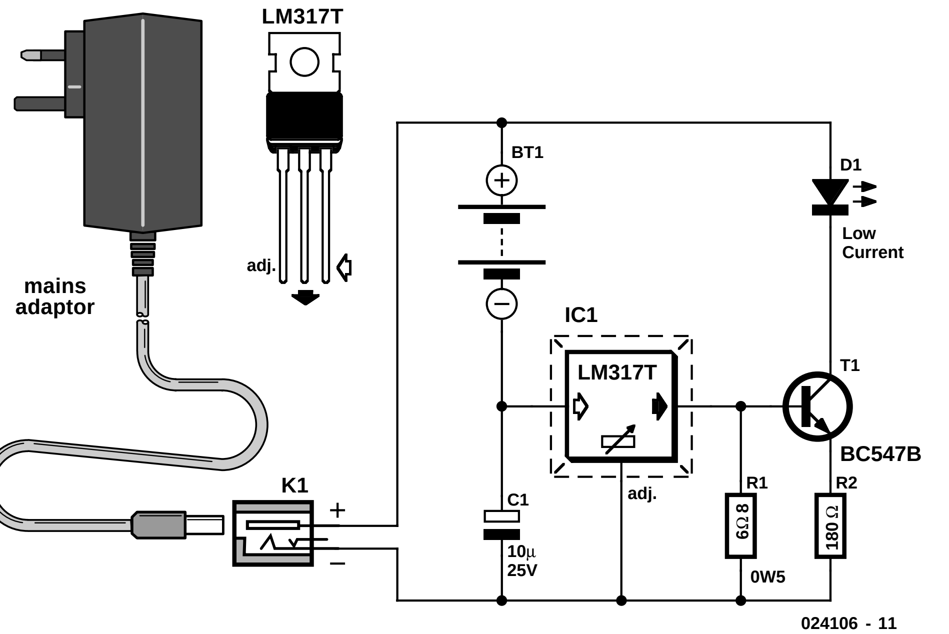
Resistors:
P1 = 2kΩ5 preset

Capacitors:
C1 = 47nF
C2 = 22nF

Semiconductors:
D1 = super HR LED, white
IC1 = BTS629
(Conrad Electronics # 1759 86)

Miscellaneous:
S1 = pushbutton (e.g., Farnell # MCDTS-5M)
BT1 = 2 off CR2025 or CR2032
Case: KM type Box UM14 (Nedis)

NiCd/NiMH Battery Charger 029



Here we have yet another excellent universal battery charger that is easy to build and can be used to safely charge practically all commonly used NiCd and NiMH penlight cells. The only downside of the universal approach is that it is not a fast charger, since it works with the well-known standard charging current of one tenth of the battery capacity in combination with a charging time of 10 to 14 hours.

With the advent of nickel–metal hydride rechargeable batteries, capacities have increased and it is no longer necessary to worry about the memory effect. This means that a topping-up charge can be used at any time, and if this is done using the above-mentioned current of one tenth of the battery capacity the charging time is not critical. In other words, the battery is guaranteed to be fully charged after 10 to 14 hours and there is no danger of overcharging, so it does not matter if you accidentally charge for 20 hours. If you are certain that the battery is only half empty, you can restore its full capacity by charging for around 6 to 7 hours.

Currently, penlight cells (AA) commonly have a capacity of 1500 to 1800 mAh (milliampère–hour), so the charging current should be 150 to 180 mA. If you want to charge several cells at the same time, you can simply connect them in series, since the same charging current will then flow through all the cells and they will all be charged simultaneously.

The question is thus how to obtain a current of 180 mA. The most elegant and accurate solution is to use a current source. Here we have 'misused' a type LM317 voltage regulator as a current source. The well-known LM317 three-lead regulator is designed to adjust its internal resistance between the IN and OUT leads to maintain a constant voltage of 1.25 V between the OUT and ADJ leads. If we chose a value of (1.25 ÷ 0.180) = 6.94 Ω for R1, then exactly 180 mA will flow. Since in practice you cannot buy a resistor with this value, we have chosen a value of 6.8 Ω, which is available. For convenience, an indicator LED has been added to the charger. This LED is illuminated only when current is actually flowing, so it can be used to verify that the batteries are making good contact.

In order to allow a current of 180 mA to flow, we require a certain voltage. The maximum voltage across a cell during charging is 1.5 V, and the current source needs around 3 V. If you charge only one cell, a supply voltage of 4.5 V is adequate. If you charge several cells in series, you need 1.5 V times the number of cells plus 3 V. For four cells, this means a supply voltage of 9 V. If the supply voltage is too low, the charging current will be too low. A supply voltage that is greater than necessary is not a serious problem, since the circuit ensures that the charging current cannot exceed 180 mA.

The required voltage can be conveniently obtained from a standard unstabilised mains adapter (or 'battery eliminator'), with a 300-mA type being highly suitable for supplying the required 180 mA. It is usually possible to select several different voltages with such an adapter, and it is recommended to choose the lowest voltage for which the indicator LED of the current source still lights up well.

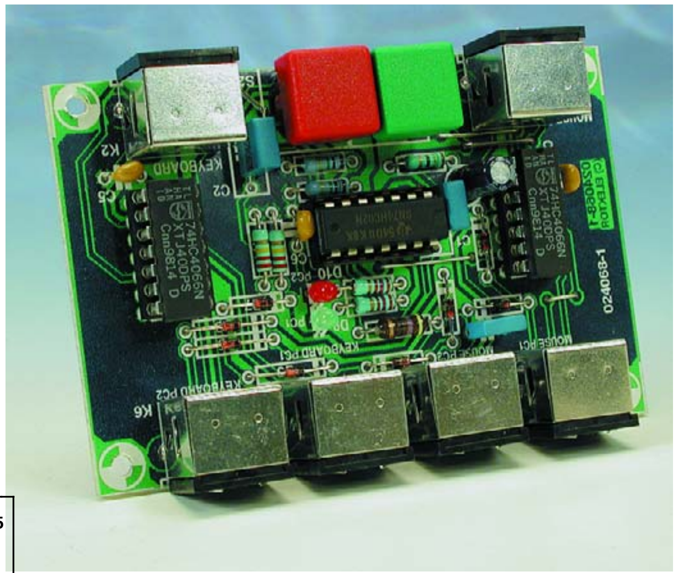
We should mention a couple of practical points. First, any desired colour of LED may be used, but it must be a high-efficiency (low-current) type, since such LEDs are brightly illuminated with a current of 2 mA as used here. When charging several cells in series, the cells should naturally be placed in a battery holder. Although it is not all that important for use with this charger, we would like to point out that the quality of most battery holders is very poor. The interconnecting springs sometimes have a resistance of as much as 1 Ω (!), which can result in considerable losses (a cell loaded at 1 A will then provide a voltage of only 0.2 V...).

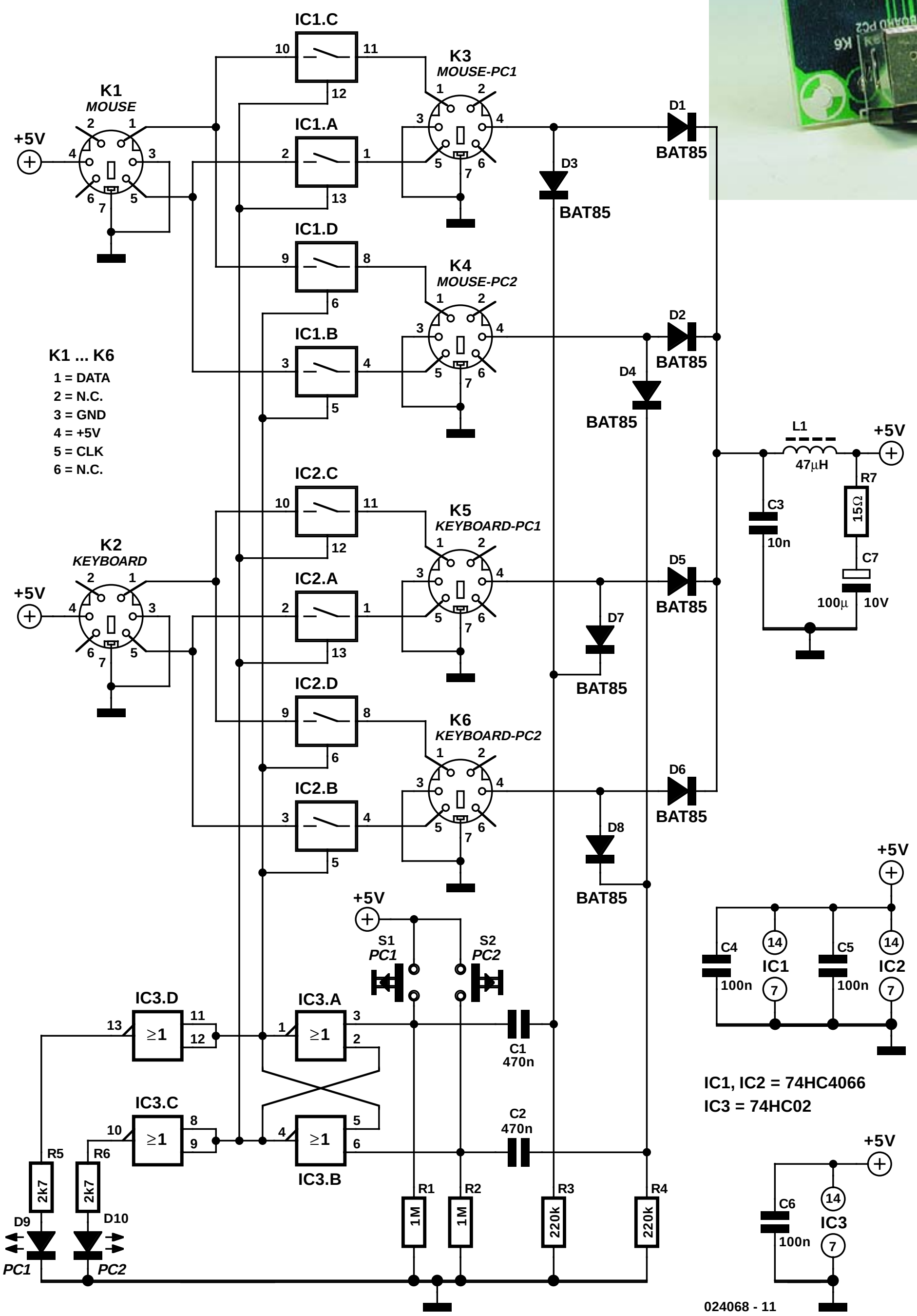
Finally, note that the LM317T (the 'T' refers to the package type) must be fitted with a heat sink. Although it will not be destroyed by being overheated, it's no fun to burn your fingers and it's naturally not particularly good for the charger to become so hot. A Fischer SK104 heat sink (approximately 10 K/W, available from Dau Electronics) is a suitable type.

(024106-1)

030 Keyboard/Mouse Changeover Switch

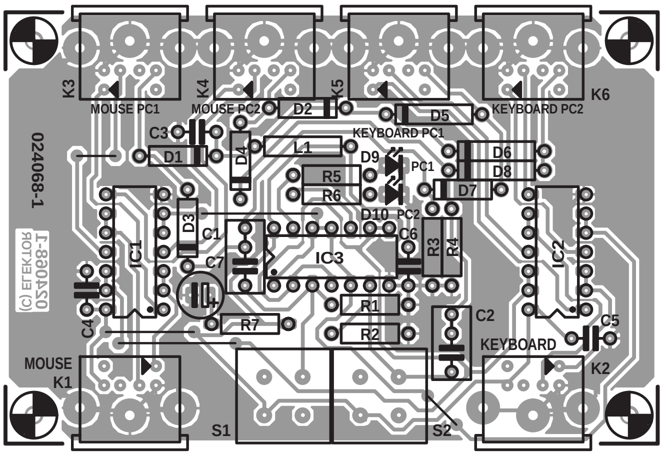
Old PCs are usually not immediately discarded after the purchase of a new one, but often remain in use for certain tasks. To avoid being tied to two keyboards and two mice when operating two PCs it would be nice if there was some kind of simple switch that would easily change the keyboard and mouse over from one PC to the other. That is the purpose of this circuit. The connections are made with four PS/2-cables (male/male). If one of the PCs requires a 5-pin DIN connector, an adapter cable or plug is also necessary. For the mouse an adapter plug from PS/2 to 9-pin Sub-D is also available, if required.

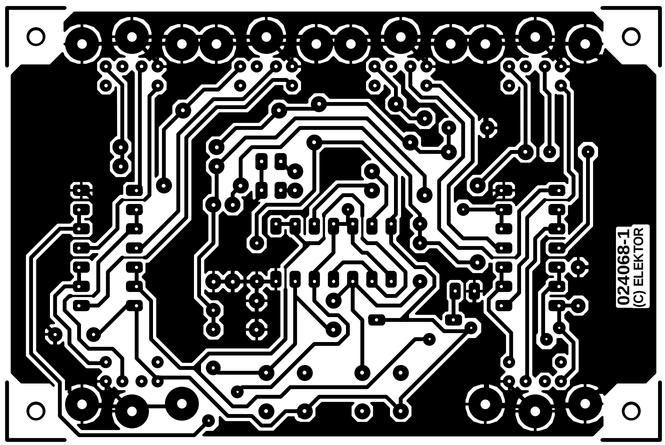




The operation of the whole circuit is quite simple. The power supply is obtained, with the aid of diodes D1, D2, D5 and D6, from the four connections to the PCs. Only one of the connections, K3 through to K6, to the PC needs to be powered up for this circuit to operate. L1 prevents any noise that may be present on the PC power supply from reaching the circuit. The power supply so obtained is directly connected with the keyboard and mouse.

Standard analogue switches from the HC-logic family (74HC4066) are used for the changing-over of the signal connections (clock and data). IC1 and IC2 are put to work as double pole changeover switches. To prevent short-circuiting the signals from both PCs, IC1 and IC2 are driven by a flip-flop with NOR-gates (IC3a and IC3b). Pushbuttons S1 and S2 change the state of the circuit. If both inputs of the flip-flop are made active, both outputs of the flip-flop will be 'low' and neither of the PCs is connected through. The LEDs D9 and D10 indicate which PC is currently connected to the keyboard and mouse. If no PC is connected then both LEDs are lit (this happens when





both S1 and S2 are pressed simultaneously). For a visually pleasing effect, the parts list indicates switches from ITT-Cannon with a red and green actuator so that the colour of the switches corresponds to the colour of the LEDs.

It is important that when the PC first starts up or re-boots the switch is in the correct position or no keyboard or mouse will be detected. In the first case the voltage that appears when the PC is switched on is used to trigger the flip-flop into the correct state: D3 and D7 for PC1, and D4 and D8 for PC2. R1/C1 and R2/C2 generate the reset pulses; the duration of nearly half a second is more than sufficient. R3 and R4 are necessary to discharge C1 and C2. Electrolytic capacitor C7 ensures proper decoupling of the power supply. The job of R7 is to limit the charging current through the BAT85 power supply diodes when the PS/2 cable is first connected.

The current consumption is about 1 mA and is almost entirely attributable to the LEDs. We conclude with a few things that are worth knowing. When shutting down the PC it appears that under Windows the mouse from certain manufacturers becomes deactivated. Make sure then, that when shutting down one PC, the other one is selected as quickly as possible, or this PC may not respond to the mouse any more. Also make sure that both PCs have the same mouse driver installed.

(024068-1)

COMPONENTS LIST

Resistors:
R1,R2 = 1MΩ
R3,R4 = 220kΩ
R5,R6 = 2kΩ7
R7 = 15Ω

Capacitors:
C1,C2 = 470nF
C3 = 10nF, lead pitch 5mm
C4,C5,C6 = 100nF ceramic, lead pitch 5mm
C7 = 100µF 10V radial

Semiconductors:
D1-D8 = BAT85
D9,D10 = red and green LED, 3mm, high efficiency
IC1,IC2 = 74HC4066
IC3 = 74HC02

Inductors:
L1 = 47µH

Miscellaneous:
K1-K6 = mini-DIN6/PS2 socket (female), PCB mount
S1,S2 = pushbutton, e.g., ITT/Cannon switch D6-C-40 (square, red) and/or D6-C-50 (square, green); optional snap-on button BTN-D6-40 (red) BTN-D6-50 (green)
PCB, order code **024068-1**

Battery Voltage LED

031

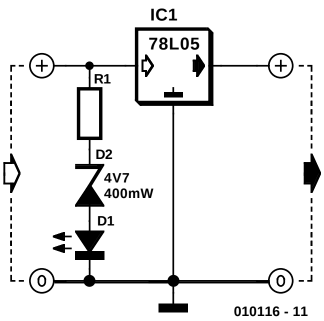
H. Bartelink

In many small battery powered apparatus it is common to have an LED act as a combined indicator for 'power-on' and 'battery state'. The most commonly seen circuit fir this is shown in Figure 1. Although it is assumed that a 78L05 is used in all circuits to be discussed, the concepts can be extended to other (low-drop) voltage regulators as well.

The 78L05 requires a minimum input voltage of 6.5 V to work properly. In Figure 1, the LED voltage will be about 1.8 V, with the zener diode dropping 4.7 V and the resistor, the excess voltage above 6.5 V. Note that a low-current LED is recommended because of its modest current requirement of just 2 mA. Once the battery voltage drops below the sum of the zener voltage and the LED voltage, the LED is turned off.

In the case of the circuit in **Figure 2**, assuming that the load current is more than a few milli-amps, the current flows through the LED-resistor combination. The value of the resistor is worked out to pass slightly less than the minimum load current. In that case, the LED will help to shunt some current past the regulator, while not wasting battery power as in Figure 1. For loads over 20 mA, work out the resistor value so as to let the regulator do more work. As the battery is drained

1



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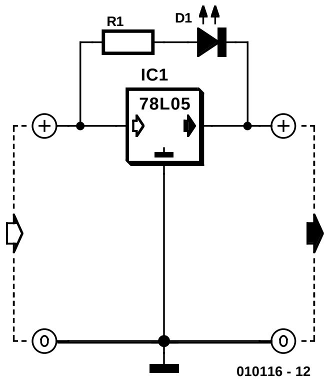

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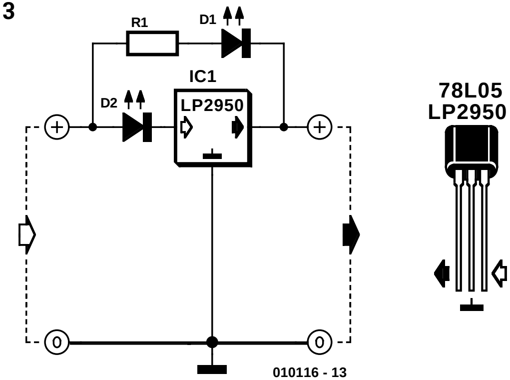


the LED will dim and eventually turn off as the battery voltage starts to approach the minimum working voltage of the regulator.

In **Figure 3**, two LEDs are used with different turn-on voltages (i.e., different colours). If the regulator used is a low-drop type with a minimum voltage drop smaller than about 0.1 V, then LED D1 is the low-battery indicator and LED D2, the power-on indicator. For this to work, D1 must have a turn-on voltage which is about 0.2 V higher than that of D2.

The LEDs in Figures 2 and 3 may be 2-mA types or the more commonly found standard 20 mA ones. Note that the maximum current through a normal LED should not exceed 50 mA or so.

(010116-1)

Telephone Watchdog

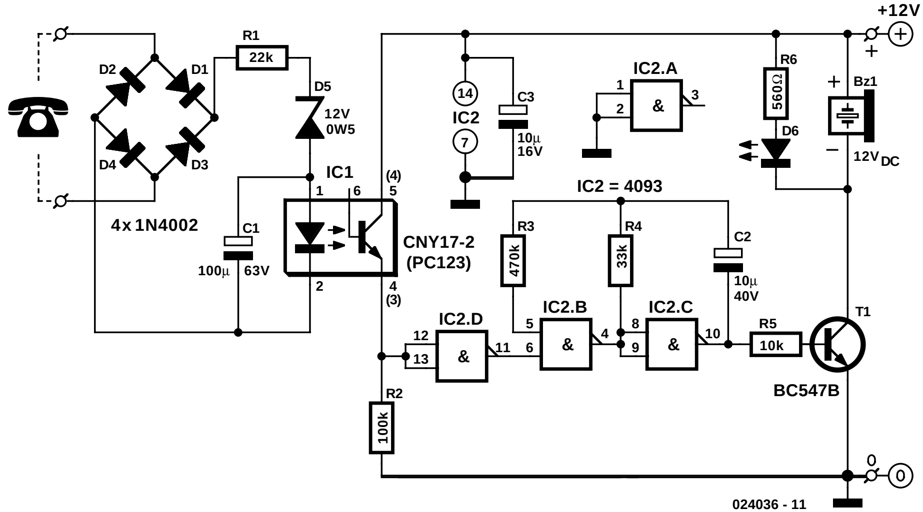
032

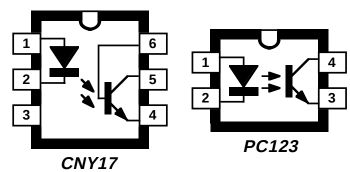
T. Hareendran

This simple circuit will tell you, by sounding a buzzer and flashing a LED, that a telephone line is in use.

If the telephone line is free, it will carry a steady direct voltage of something between 48 and 60 volts. This is well above the zener voltage of D5 so optocoupler IC1 is switched on and consequently the oscillator built around IC2 is held disabled.

When the line is in use, i.e., a telephone extension is ‘off hook’, the line voltage drops to a level below the zener voltage of D5, and the oscillator is enabled. LED D6 will flash and buzzer Bz1 will produce intermittent beeps. Note that the buzzer is a DC type.



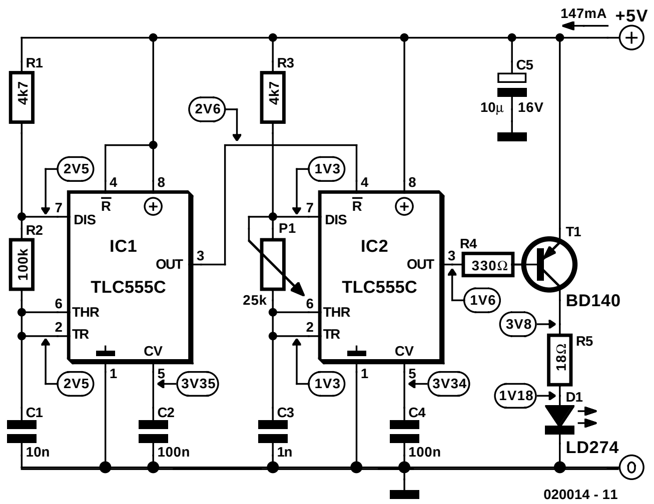


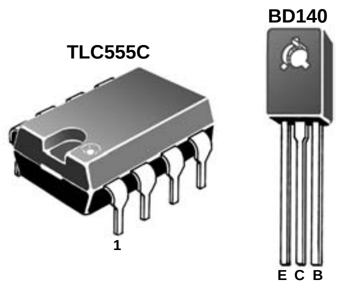
The circuit is best (and most safely) powered by a mains adaptor with an output of 12 Vdc. Since the current consumption is minimal at just 25 mA or so, the smallest adapter you can find will be okay to use.

Both optocoupler types indicated in the circuit diagram meet a 5-kV isolation breakthrough specification. The PC123 from Sharp though has ‘bent out’ pins and so meets the isolation distance requirement of 6 mm for equipment connected to the mains, which may well be extended to public telephone systems. The CNY17 does not meet the 6 mm spec and is strictly speaking not safe to use unless you bend out the pins yourself and refrain from using an IC socket.

(024036-1)

Simple Infrared Light Barrier 033





Pradeep G.

This infrared alarm can be used to detect persons passing through doorways, corridors and small gates. The transmitter emits a beam of infrared light which is invisible to the human eye. The buzzer at the output of the receiver is activated when the light beam is interrupted by a person passing through it. The transmitter and receiver circuits shown here have been designed for a range of several meters, almost independent of ambient light conditions. Only in the rare case of the receiver sensor being exposed to bright, direct sunlight, some screening measures have to be added.

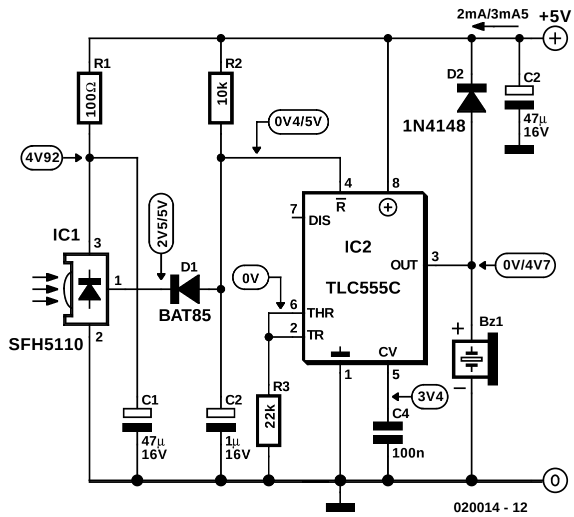
The transmitter does not emit a continuous infrared signal, Rather, it is modulated, that is, the 36-kHz carrier used to pulse the IRED (infrared emitting diode) on and off is itself switched on an off at a rate of about 300 Hz. The reason for doing so is that most infrared sensors, including the ones suggested in the diagram do not respond very well to continuous incidence of infrared light. Switching the IR source off, even for a small period, allows IR detectors to 'recuperate', and so optimise their ability to minimize the response to ambient light.

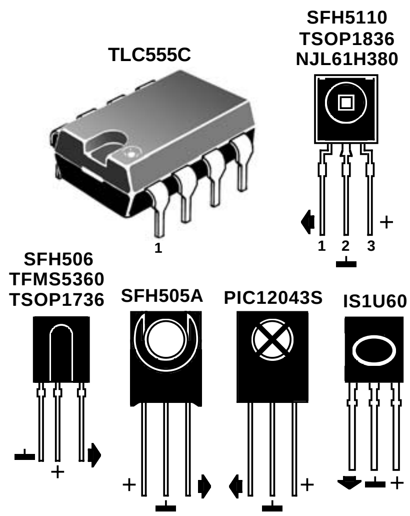
The transmitter consists of two oscillators built around the ubiquitous 555 IC. Here, the current-saving CMOS version TLC555 (or 7555) is used. Alternatively, the two 555's may be replaced by a single TLC556 (or 7556). IC1 is the 300-Hz generator, IC2, the 36-kHz source. The IRED type LD274 is pulsed at a relatively high peak current via driver transistor T1. If in your application the distance covered by the IR beam is relatively short, the value of resistor R5 may be increased to save on current consumption. Preset P1 is adjusted for a carrier frequency of 36 kHz exactly (failing test equipment, adjust it for optimum range).

The receiver is equally simple and also based on a CMOS 555. As long as the sensor picks up infrared light from the transmitter, the reset input of the 555 IC is held low and the buzzer is silent. Components D1 and C2 act as a low-frequency rectifier to cancel the effect of the 300-Hz modulation on the transmitter signal. When the infrared light beam is interrupted, the oscillator built around the 555 is enabled and starts to produce a warning tone.

Finally, the test values indicated in the circuit diagram are average dc levels measured with a DVM, under light/no light conditions. In fact, most test points carry rectangular or sawtooth waveforms.

(020014-1)





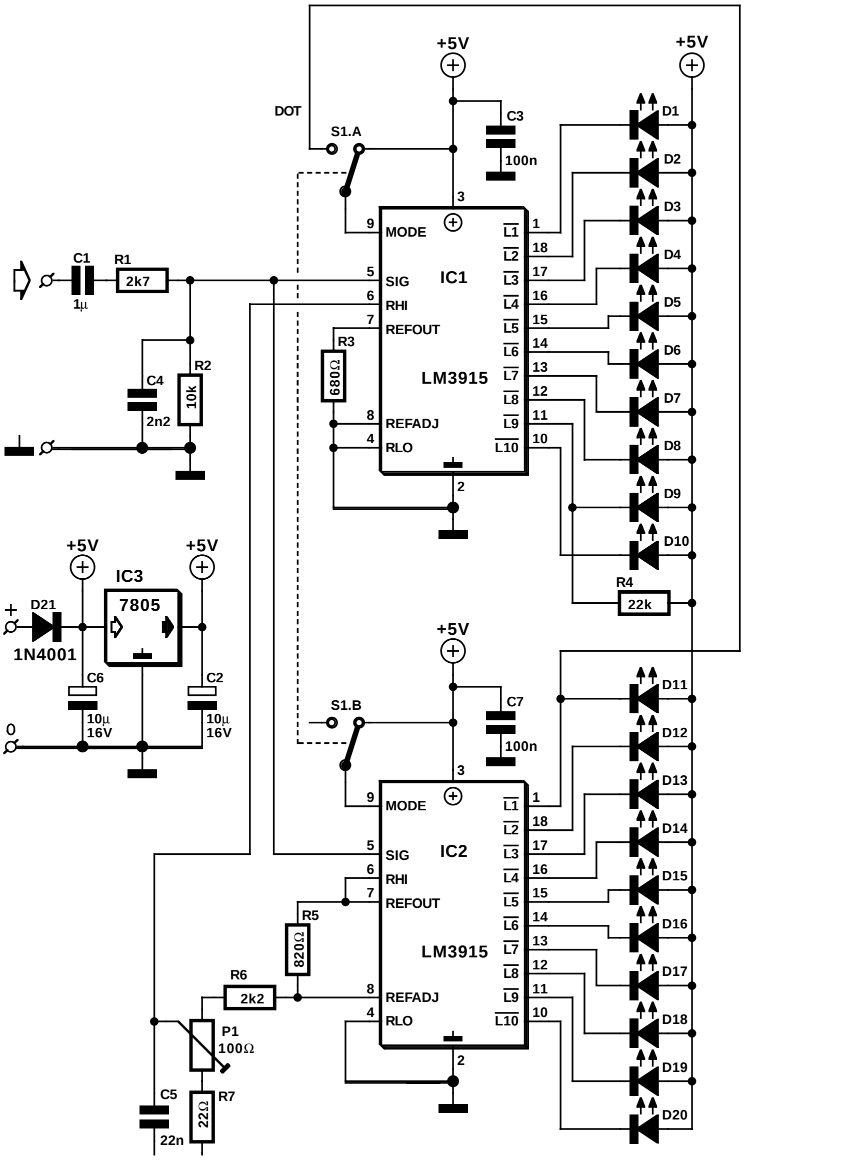
60-dB LED VU Meter

034

Rikard Lalic

Most of the analogue audio media, including radio broadcasting, stick within 60 dB dynamic boundaries. This VU Meter was designed to be used as a desktop instrument with home audio appliances, so it has its own power supply. Driven by an AC musical signal taken directly from low impedance loudspeaker connectors, i.e. **in** parallel with loudspeakers, and having linear frequency response, it covers 60 dB dynamic range in 3 dB steps using 20 LEDs in a bargraph. Low component count and simplicity enable the circuit to be housed in a small box or behind a transparent shield like a small acrylic desktop photo holder.

The LM3915 IC from National Semiconductor senses voltage levels and drives 10 LEDs, providing a logarithmic 3 dB/step analogue display, and so covering a 30 dB range. LED current drive is programmable and regulated. The IC contains adjustable voltage reference source and an accurate 10-step 22-kΩ voltage divider array. A ground referenced, ±35V-proof input buffer amplifier, capable of sensing down to ground, is driving 10 comparators referenced to the voltage divider. Applying an additional resistor in series with the input raises input protection to ±100 V. Two LM3915N (IC1 and IC2) are cascaded here to achieve a total dynamic range of 60 dB. R5 programs the LEDs current on IC2 while network R5-R6-P1-R7 sets the reference voltage that determines the full-scale input signal level of IC2. In this case it is set to 5.0V. The full scale level of IC1 is derived from this reference and shifted 30 dB below that of IC2. It is precisely preset using the P1, with R3 programming the LED current supplied by IC1. The value of R3 is smaller than R5 to compensate for IC2's internal voltage divider which is connected in parallel with the reference voltage source in IC2. The adapted value of R3 ensures that that there is no difference in LED brightness between IC1 and IC2.



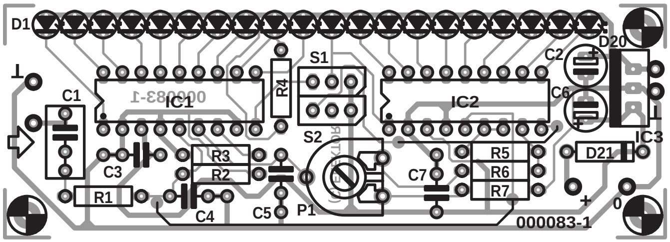
The audio signal to be measured arrives at pins 5 of IC1 and IC2 via C1-R1-R2-C4. R1 and R2 form a voltage divider and C4 is added for RF suppression. With R1 at 2.7 kΩ as shown in the schematic, full-scale indication is reached at 6.4 V_{rms} (which equals 10 W across 4 Ω). Depending on the output power of your amplifier, suitable values fro R1 and C4 may be selected from **Table 1**. As the VU-meter input is connected across the loudspeaker, power, *P*, and voltage, *U*, equate like

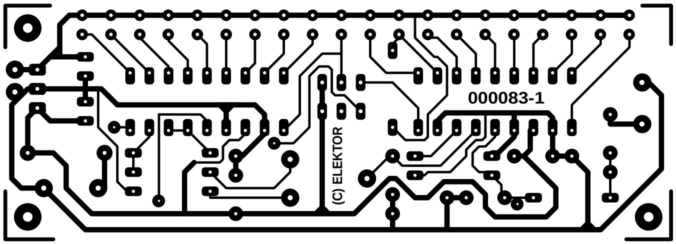
$$P = U^2 / Z$$

where *Z* is the loudspeaker impedance in ohms. Each lower

Table 1.

Loudspeaker	4 Ω	4 Ω	4 Ω	8 Ω	8 Ω	8 Ω	16 Ω	16 Ω	16 Ω
Power	10 W	50 W	100 W	10 W	50 W	100 W	10 W	50 W	100 W
R1	2.7 kΩ	18 kΩ	30 kΩ	6.8 kΩ+1.1 kΩ	30 kΩ	47 kΩ	15 kΩ	47 kΩ	68 kΩ+2.2 kΩ
C4	2.2 nF	470 pF	330 pF	1 nF	330 pF	330 pF	470 pF	330 pF	270 pF





COMPONENTS LIST

Resistors:

R1 = 2kΩ7 (see text)
R2 = 10kΩ
R3 = 680Ω
R4 = 22kΩ
R5 = 820Ω
R6 = 2kΩ2
R7 = 22Ω
P1 = 100Ω

Capacitors:

C1 = 1µF 63V (MKS, MKC)
C2,C6 = 10µF 16V radial
C4 = 2nF2 (see text)
C3,C7,C9 = 100nF
C5 = 22nF

Semiconductors:

IC1, IC2 = LM3915N
IC3 = LM7805
D1-D20 = LED

order LED in the chain indicates 50% power or 70.71% voltage of the first higher LED.

The threshold for LED #1 is just 7.0mV, so both noise and internal buffer and comparator offset voltages may influence the readout at the very low end of the LED bargraph (first few LEDs). Capacitors C4 and C5, proper wiring and correct PCB layout should help to maintain a good degree of noise immunity.

For **a** stereo version of the VU meter the metering circuits shown here should be duplicated. The power supply has already been dimensioned for a stereo version. A mains adaptor with an output voltage of about 8 Vdc is an inexpensive and safe way to power the circuit. The LED voltage is reduced to +5.0 V by regulator IC3 in order to keep the power dissipation of IC1 and IC2 within safe limits.

A double-pole switch, S1, allows the readout to be switched to ‘dot’ mode instead of ‘bar graph’.

Although its artwork is shown here, the printed circuit board designed for the LED VU meter is not available ready-made. IC3 needs no heatsinking.

The VU meter requires only one, simple adjustment. Connect a DVM to pin 6 of IC1 and adjust preset P1 to see 158 mV (5.0 V / 31.62), that is, –30 dB relative to the voltage present on pins 7 and 8 of IC2.

Finally, this VU meter must not be used with BTL type of audio amplifiers which could be found in some car radio receivers but only with common-ground type of amplifiers.

(000083-1)

Active Band-pass Filter up to 5 MHz

035

Constructing an active bandpass filter is greatly simplified by using the LT1567 from Linear Technology (www.linear-tech.com/pdf/1567i.pdf). The circuit shown here uses relatively few external components to build a 2nd order bandpass filter with a centre frequency of 1 MHz and a –3 dB bandwidth of 0.71 MHz. The centre frequency gain will be unity. The circuit should be driven from a low impedance source so that R1 will define the circuit gain. To recalculate the bandpass filters components for other frequencies the filter bandwidth ($BW_{-3\ dB}$) is given by:

$$BW_{-3\ dB} = 1 / (2\pi RC).$$

while the centre frequency (f_0) is given by:

$$f_0 = BW_{-3\ dB} \times \sqrt{(A_0 + 1)}$$

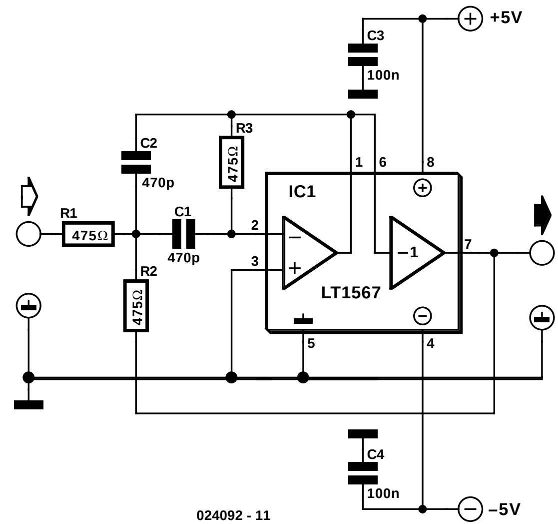
Where:

R=R2=R3 and C=C1=C2.

A_0 (gain at f_0) = R / R1.

$f_{0(max)}$ (maximum centre frequency) = 5 MHz / A_0

(024092-1)



Low-cost Position Sensor

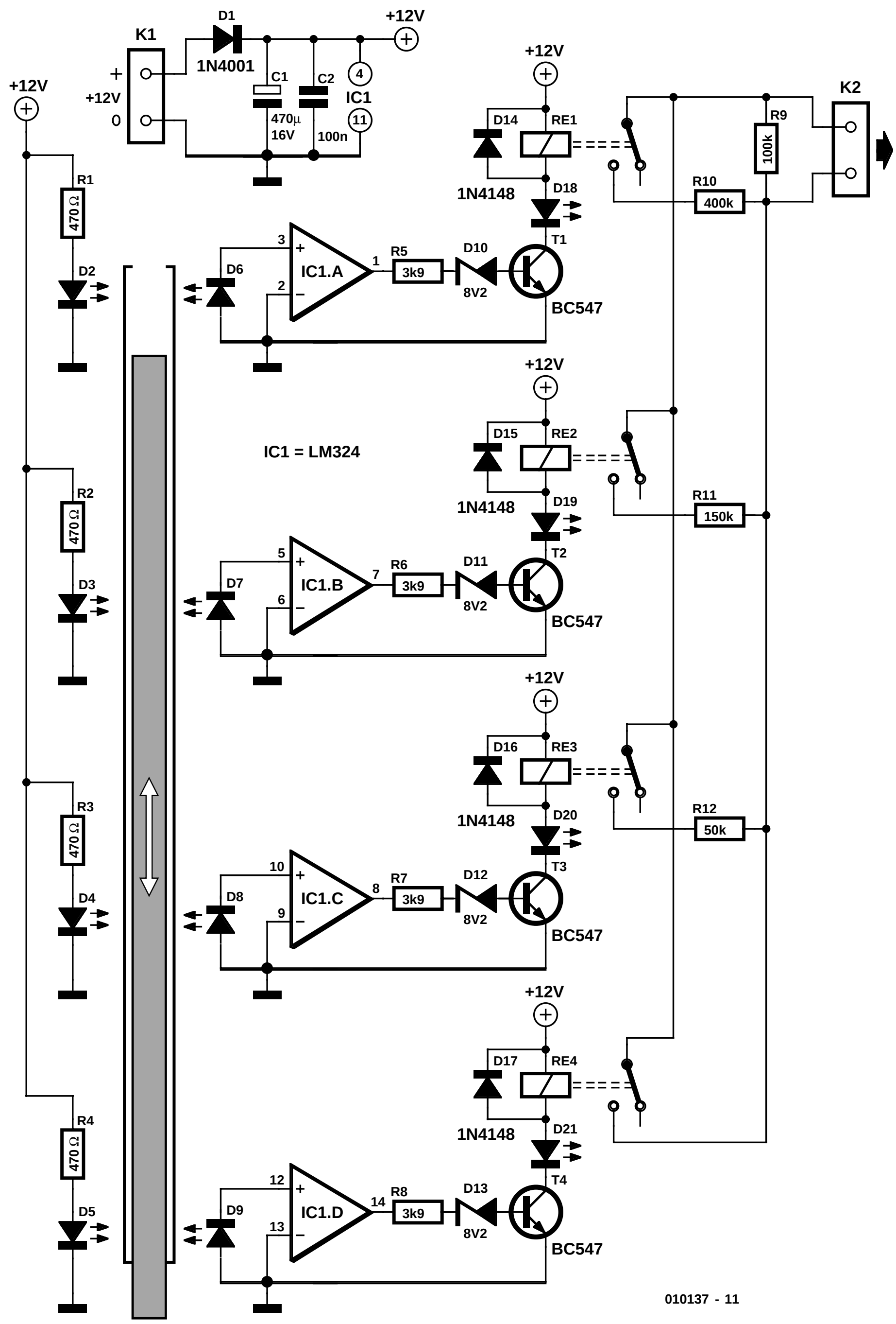
036

H. Lindberg

Ever wanted to build a positioning encoder? Here's one and you do not even need any sensors. The circuit uses an LED as a light emitter and another LED as a light receiver. This is possible due to the ability of the LED to generate a very tiny current when light is shining into it, almost like a small solar panel. A red LED is used because tests indicated that they gave the best results. It is possible though to use a different colour than red and the best combination might be found by trial and error. Please note that not all red LEDs give the same result, so you might have to get hold of a few different types and then find the best one. When a receiver LED is not illuminated by its associated sender device, it will prevent a tiny current of about 50 nA from flowing out of opamp pin 3 to ground. Once the LED is illuminated, this current is allowed to flow. In fact, even more current flows because the 'solar cell' quality of the LED causes pin 3 to go negative with respect to ground.

Because of the series-connected LEDs D18-D20, the supply voltage, Vcc, will have to be a few volts higher than the relay coil voltage. If that is the case, the values of R1-R4 are subject to experimenting because the operation of the light barriers depends on the supply voltage and the efficiency of the LEDs used.

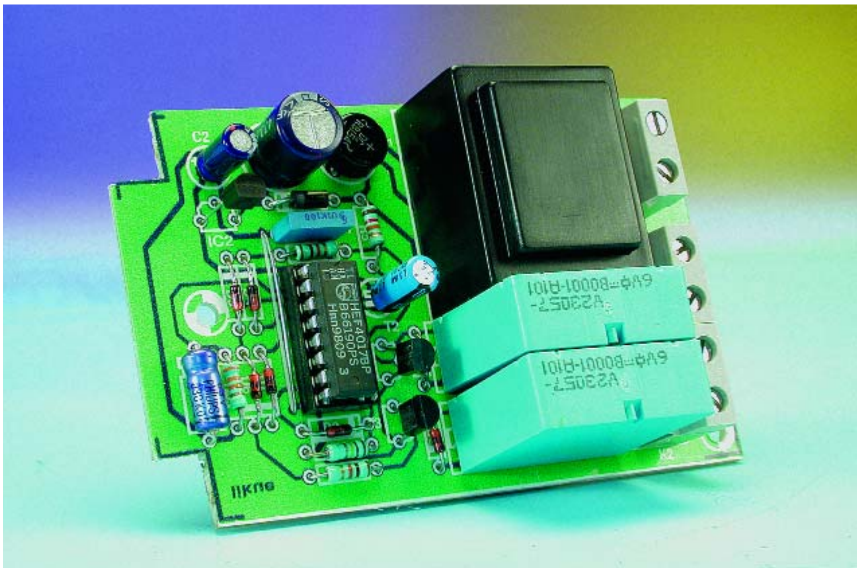
The LEDs (transmit and receive) are mounted onto the sides of a tube and can 'see' each other through two 3-mm holes. The light barrier is then "broken" when a rod is inserted into the tube. This approach can of cause be multiplied as many times as required. Here, four barriers are shown, which allow up to five rod positions to be detected. Each position, including 'rod not inserted' is translated into a discrete resistance value which is created by connecting resistors in parallel, and may be measured on the output connector for further processing by an ADC or what have you. The values of the resistors on the relay contacts may be adapted to suit your needs.



The LM324 opamp is a quad type, making the layout a bit easier. On the output of each opamp, a series resistor and a zener diode ensure proper voltage levels for the buffer transistor, which drives the relay. Across each relay coil sits a back EMF protection diode (always a good idea to add). As a matter of course, the transistor driving the relay has to be able to handle the required coil current.

(010137-1)

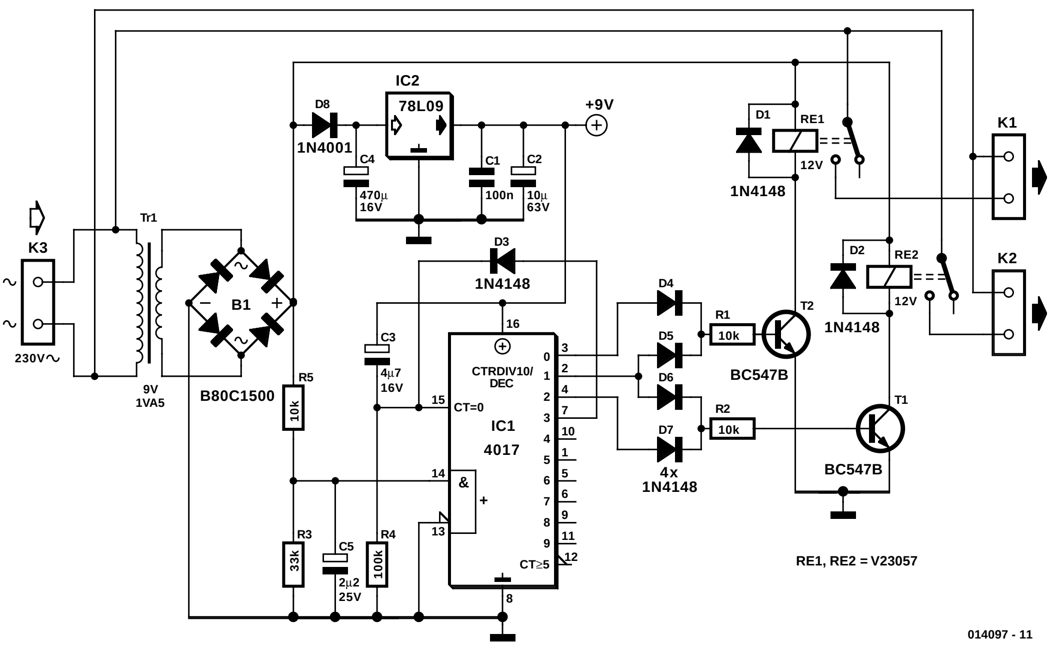
Multi-Position Mains Switch 037



The circuit shown here was born out of necessity after one of our colleagues had just renovated his kitchen and realised afterwards that there were not enough switches. Obviously he was not too keen to partially demolish the kitchen to install a few additional wires in the already tiled wall. That's how the idea arose to develop a clever electronic circuit that would operate two lamps with only one switch.

All this appeared to be easy to realise by adding a small circuit, consisting of a decade counter, a diode network, two relays and a low voltage power supply. The schematic shows how simple the design of the 'multi-position' extension really is. K3 is connected to the switched wires that go to the original light. K1 and K2 are the connections for the two new lamps.

The operation is simply based on the fact that at every low to high transition at the CLK input of IC1 the active output moves over by one position. In combination with the diode network D4 through D7 this ensures that with a single wall switch it becomes possible to control two outputs. When the mains voltage is applied to K3 for the first time, Q0 will be high and Re1 will be energised. When the mains switch is briefly switched off and then on again it will have no consequences for the 9-V power supply, because C4 is quite large. But this will result in a trigger pulse on the CLK input, so that Q1 will now be high and via D5 and D6 both relays are energised. After another off/on cycle of the mains switch, Q2 will be high, relay Re1 will de-energise and only Re2 is still activated. If we repeat the off/on cycle once more we're back at the starting position and only Re1 is



COMPONENTS LIST

Resistors:

R1,R2 = 10kΩ
R3 = 33kΩ
R4 = 100kΩ
R5 = 10kΩ

Capacitors:

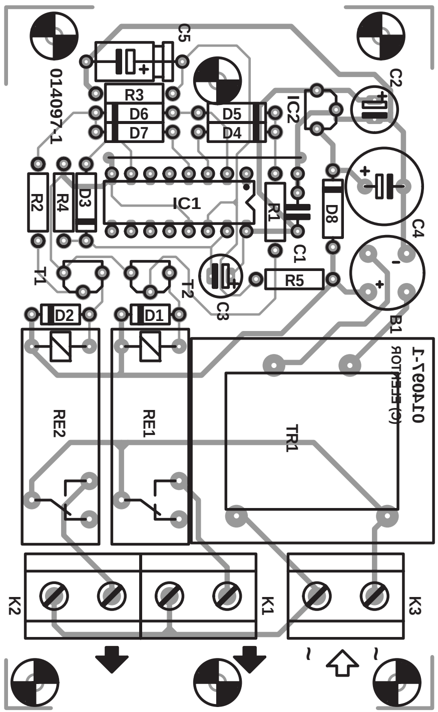
C1 = 100nF
C2 = 10µF 63V
C3 = 4µF7 63V radial
C4 = 470µF 16V radial
C5 = 2µF2 63V axial

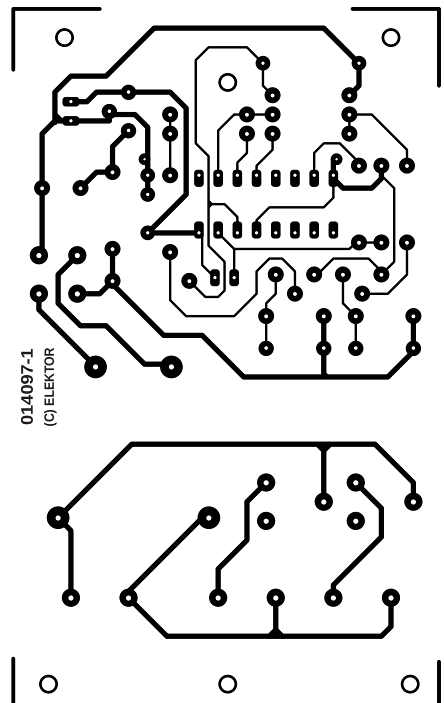
Semiconductors:

D1-D7 = 1N4148
D8 = 1N4001
T2,T3 = BC547B
IC1 = 4017
IC2 = 78L09

Miscellaneous:

K1,K2,K3 = 2-way PCB terminal block, lead pitch 7.5mm
Tr1 = mains transformer 9V 1.5VA, e.g., Hahn EI 3022021
B1 = B80C1500 (round case) (80V piv, 1.5A)
Re1, Re2 = 12V relay, e.g., V23057 B0002 A101 12V (Schrack)
Case, Bopla, OKW or Schyller





energised. If the switch remains in the ‘off’ position then both relays will also be off.

A printed circuit board has been designed for this extension so that the entire circuit will fit without any problems in a waterproof enclosure from OKW, Bopla or Schyller. The 9-V transformer is also fitted on the PCB. PCB screw terminals can be used for K1, K2 and K3. Since the circuit is directly connected to the mains voltage we emphasise that the well-known safety rules need to be observed. When making any measurements or performing other operations on the circuit is it absolutely necessary to first break the connection to K3! Unfortunately, the PCB shown here is not available ready-made.

(014097-1)

Pushbutton Switch

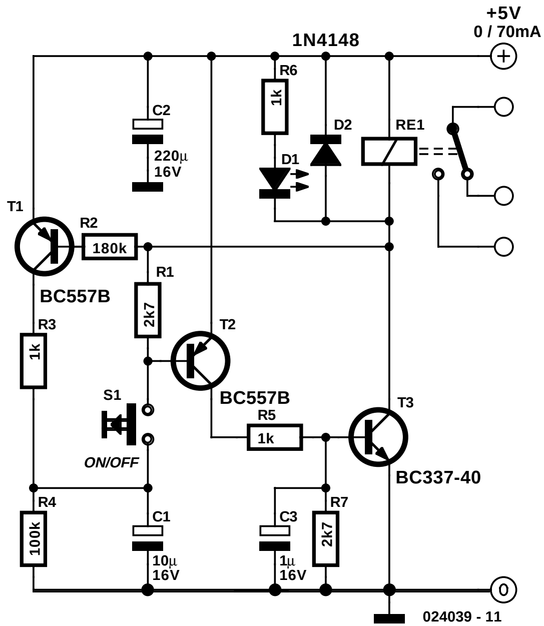
038

K. Lorenz

This circuit acts like a two-position switch but is operated using a pushbutton. After power has been applied, the circuit is in the following initial state: the bases of T1 and T2 are at the positive supply potential and the base of T3 is at ground potential. All transistors are cut off. The other contact of the pushbutton is at ground potential. No current flows through the relay coil and the status LED is off.

If the pushbutton is pressed, T2 and (after a slight delay due the RC network) T3 switch on. The collector of T3 is now nearly at ground potential, so current flows through the relay coil and the function LED is illuminated. T1 can also switch on. This situation is stable, since ground potential can reach the base of T2 via R1, so nothing changes when the pushbutton is released. C1 is charged via R3 to cause a positive potential to be present at the pushbutton. If the pushbutton is now pressed again, it connects a positive potential to the base of T2 instead of the ground potential. This causes everything to toggle back into the initial state.

Similar operation can be obtained using a thyristor circuit, and in fact T2 and T3 form a sort of thyristor. However, the circuit shown here is largely independent of the voltage and current demands of the connected load. The relay coil should be suitable for the supply voltage (5–12 V) and should not draw more



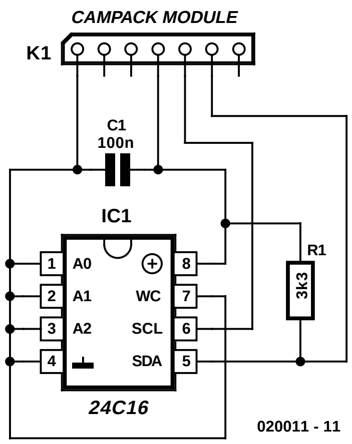
than 250 mA, since otherwise T3 will go up in smoke. With our lab prototype, we measured a current consumption of 70 mA in the ‘on’ state and less than 0.1 mA in the ‘off’ state.

(024039-1)

Memory Expansion for Futaba R/C Transmitters

039

1



2

COMPONENTS LIST

Resistors:
R1 = 3kΩ3

Capacitors:
C1 = 100nF

Semiconductors:
IC1 = 24C16

Miscellaneous:
K1 = 7-way connector (2 mm lead pitch!), e.g., Farnell # 672-348

In the model buildingworld a lot of transmitters are used with a built-in microprocessor. This processor occupies itself with carrying out, among other things, mixing functions, null point control of the servo, reversal of the servo, etc. This provides two significant advantages. On the one hand there is no need to purchase expensive analogue mixers again, because all of that is now implemented in software. On the other hand, you can use different settings for different models, because the various settings can be stored in non-volatile memory. However, many transmitters have very limited capacity in this respect. If desired, the memory can be expanded by purchasing a memory module. Expansion of the memory has the advantage that you can copy the current settings via the transmitter and then experiment with the settings in order to optimise them without losing the original data.

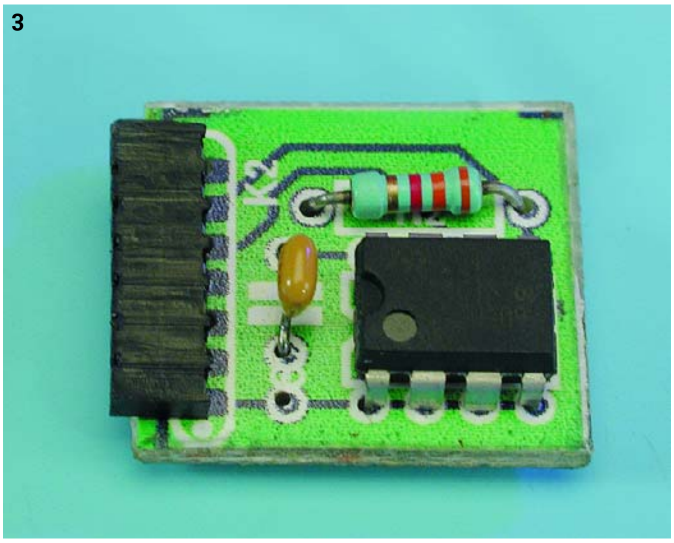
The circuit diagram, **Figure 1**, shows such a module. This module is intended as a replacement for the CamPack modules for use with Futaba transmitters. It is obvious from the schematic that the circuit doesn't amount to much. The memory element is a 24C16 EEPROM. This device, with a capacity of 2 kilobytes, has an I^2C interface, so that only a few connections are required to access it.

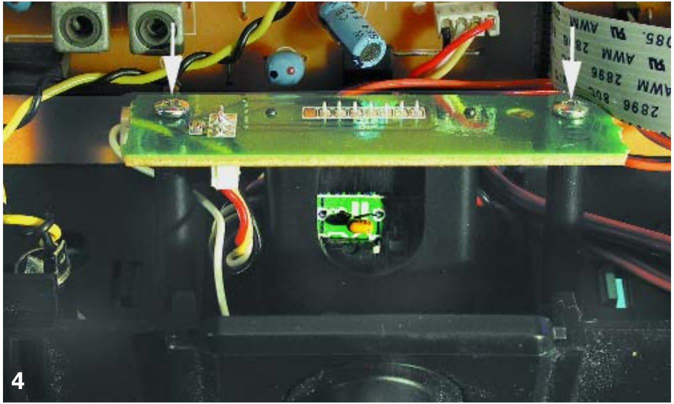
The assembly of the printed circuit board (**Figure 2**) can be accomplished in record time. It is important to note that IC1 (as can be seen in **Figure 3**) is not fitted in an IC socket, otherwise the circuit will not fit inside the transmitter! Also note that the connector used has a pitch of 2 mm, instead of the more usual 2.54 mm! After assembly has been completed (and the PCB has been carefully checked for short-circuits), the circuit can be fitted in the transmitter. The component side of the board needs to point in the direction of the antenna. It will also fit the other way around, but the consequences are less pleasant…

It is rather difficult to install the PCB in the slot in the transmitter that is specifically intended for this purpose, because our PCB is much smaller than the commercially available CamPack. It is therefore much better to take a different approach. First we have to open the transmitter, using exactly the same procedure as when replacing the battery. After this, the two screws that hold the small PCB with the expansion connector have to be removed (**Figure 4**). This small PCB can be found in the vicinity of the antenna. Once this little PCB has been removed it is easy to plug in the memory module (**Figure 5**: note the correct orientation!). Finally, fasten the original PCB again and replace the cover on the transmitter.

As soon as the Futaba radio control transmitter is turned on you will see a message indicating that the memory is being formatted. This takes a while, but only happens the first time. Once formatting has been completed the memory module is ready for use. From now on, instead of the original two,

3

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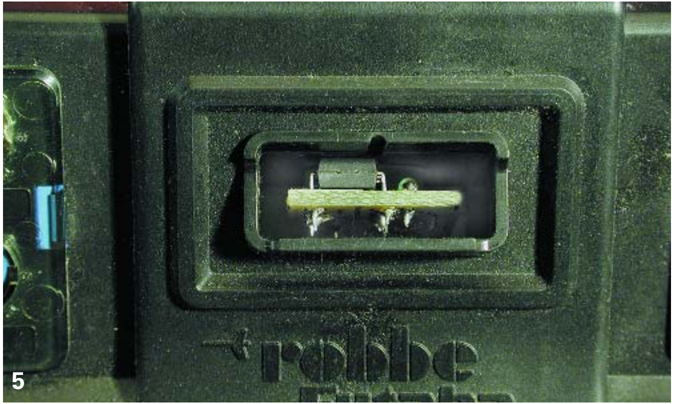


5

we are able to store no less than 27 models in memory. Those of you who think that is still not enough can always build additional modules (also useful as back-up for the present settings). The PCB for this project is unfortunately not available ready-made.

(020011-1)

Audio Combiner

040

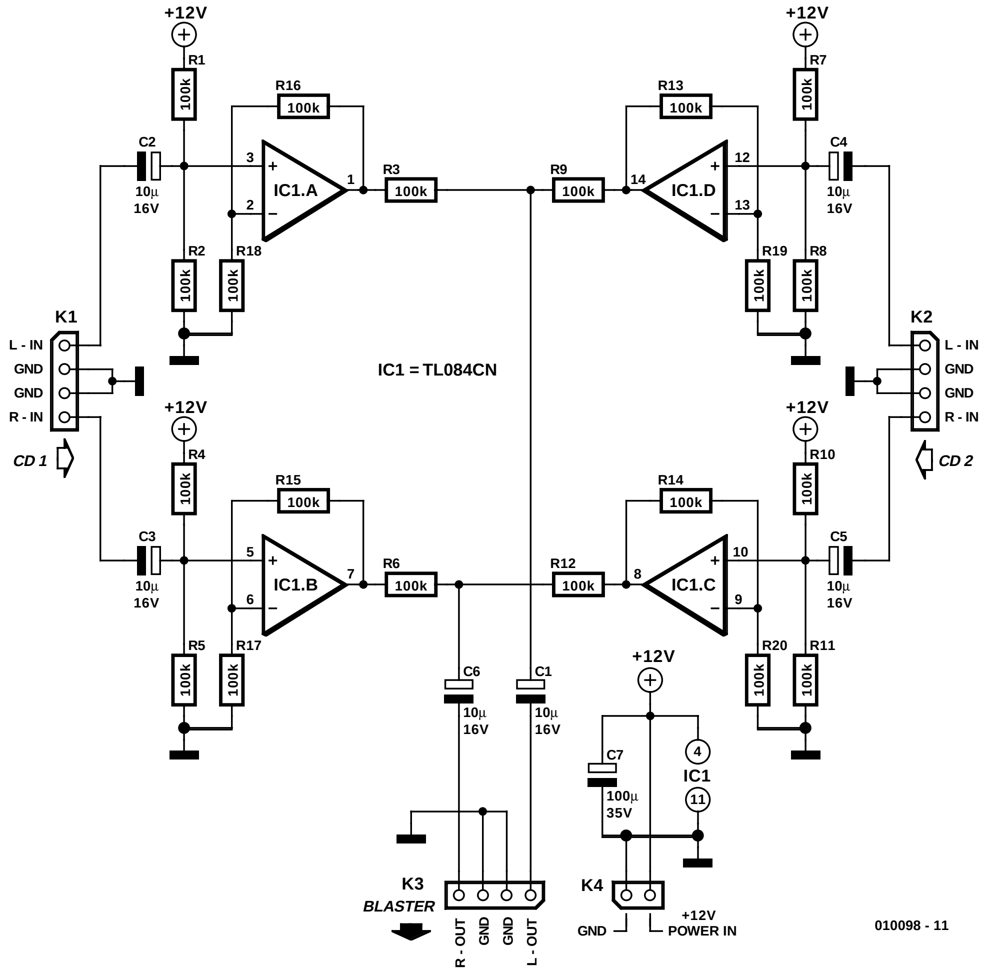
P.v.d.Hurk

This circuit arose from the need to couple the outputs of two CD-ROM drives to the input of a single sound card. Simply ‘stacking’ the connectors is possible but not particularly elegant, and the result is somewhat unpredictable due to mutual interference between the two drives. Using a quad opamp and handful of passive components, it is possible to quickly put together a mixer that first buffers the signals before adding them together. This completely eliminates any possibility of feedback or mutual interference.

The actual addition of the two stereo signals is performed by R3/R9 and R6/R12. Since these resistors also form voltage dividers that reduce the amplitude of each signal by half, the gain of the four buffer amplifiers is set to 2 as compensation.

The required 12-V supply voltage can be drawn from the PC without any problems. The current consumption of the entire circuit is practically negligible.

(010098-1)



Mini Audio DAC

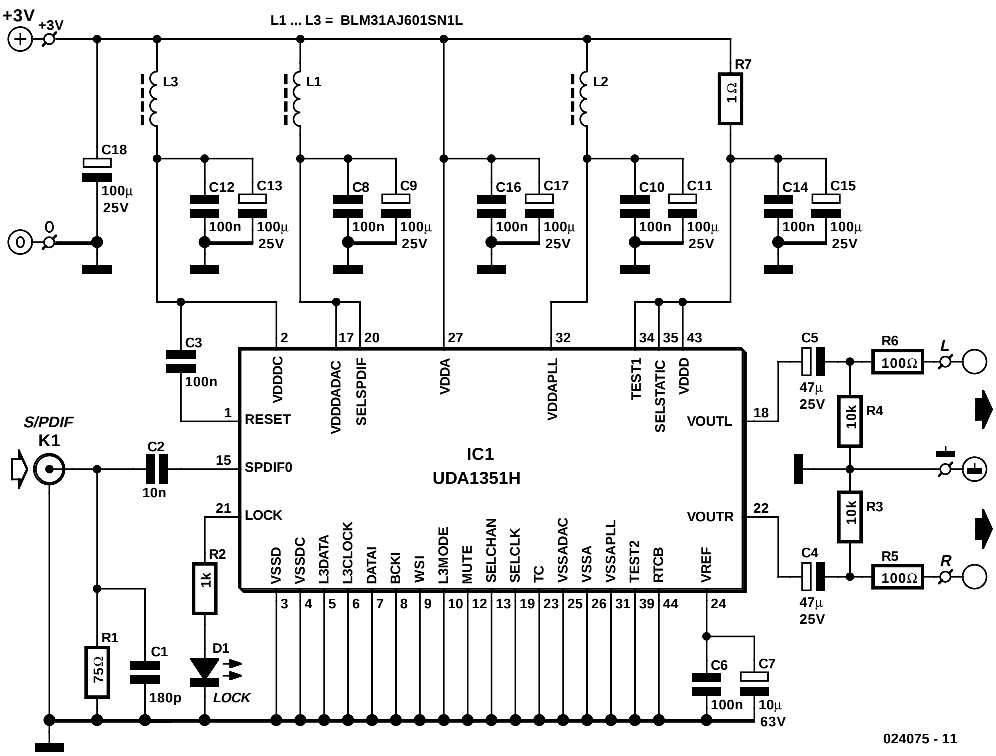
041

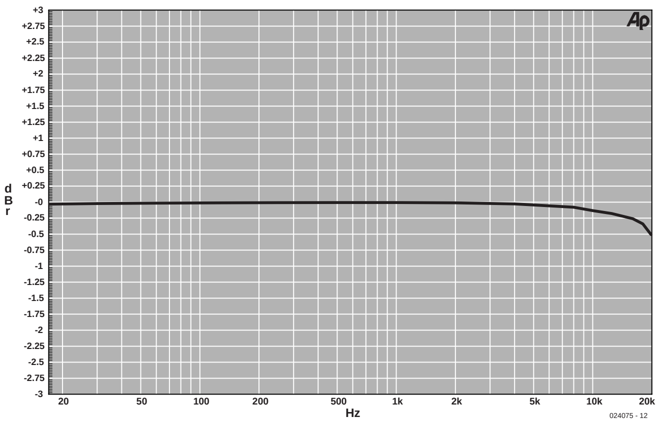
In the February 2002 issue of *Elektor Electronics*, we described an S/PDIF tester, consisting of a special decoder IC with integrated D/A converter. Two implementations of the 'IEC 60958 audio DAC' from Philips could be used here: the UDA1350ATS or the UDA1351TS. The latter has a frequency range up to 96 kHz. However, a number of readers were disappointed that this circuit was not accompanied by a PCB design. That is the reason that we present a similar 'Mini Audio DAC' here, this time with matching PCB layout.

The IC that has been used here, the UDA1351H, belongs to the same family as the aforementioned types, but is packaged in a different housing. The advantage of the SOT307-2 (QFP44) package is that the pins are a little further apart (0.8 mm instead of 0.65 mm), which makes soldering with a normal soldering iron considerably easier. The single sided PCB has been made as compact as possible and is fitted with components on both sides. The majority of components are on the actual component side, but six ceramic SDM capacitors have been placed on the copper side close to the IC, to obtain optimum decoupling. The are also three decoupling inductors in SMD packages, which are also on the solder side for the same reason. Including the cinch-connector the PCB is not larger than 51?37 mm.

For short duration use, two AA batteries may be used as power supply, but at 44 kHz the circuit draws a current of 22 mA and at 96 kHz, 33 mA, which is a little bit too much for a battery power supply. D1 indicates that a usable input signal has been detected. R3 and R4 ensure that output electrolytics C4 and C5 are charged even when no load is present, while R5 and R6 are the usual limiting resistors for capacitive loads. The output consists of three PCB pins, so that you can, depending on the application, fit cinch (RCA) chassis connectors or a jack to connect a headphone.

For a detailed description of the IC we refer you the article mentioned above and the datasheet for the UDA1351H. We conclude by listing the specifications, measured at a power supply voltage of 3 V.

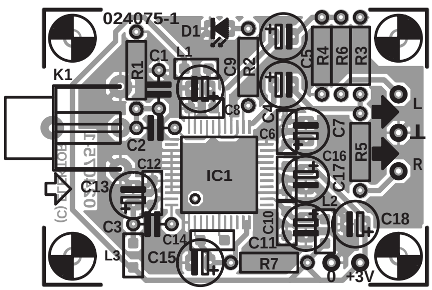


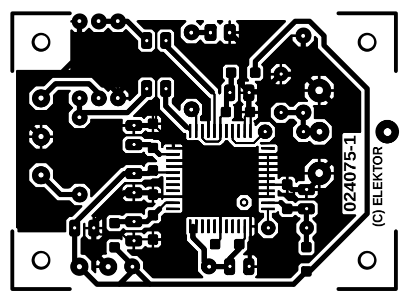


– I_{supply}: 8 mA (no signal, LED off)
22 mA (f_s = 44.1 kHz)
33 mA (f_s = 96 kHz)
– Nominal output signal: 900 mV
– THD+N (1 kHz, f_s = 44.1 kHz): 0.0033 % (B = 22 kHz)
0.04 % (B = 80 kHz)
– THD+N (1 kHz, f_s = 96 kHz): 0.003 % (B = 22 kHz)
0.011 % (B = 80 kHz)

The graph shows the amplitude characteristic, measured with a test CD. As can be seen, the attenuation is only about 0.5 dB at 20 kHz! The PCB shown here is unfortunately not available ready-made.

(024075-1)





COMPONENTS LIST

Resistors:
R1 = 75Ω
R2 = 1kΩ
R3,R4 = 10kΩ
R5,R6 = 100Ω
R7 = 1Ω

Capacitors:
C1 = 180pF
C2 = 10nF ceramic, lead pitch 5mm
C3 = 100nF ceramic, lead pitch 5mm
C6,C8,C10,C12,C14,C16 = 100nF, SMD shape 1206
C4,C5 = 47µF 25V radial
C7 = 10µF 63V radial
C9,C11,C13,C15,C17,C18 = 100µF 25V radial

Inductors:
L1,L2,L3 = Murata BLM31AJ601SN1L (Farnell # 581-094)

Semiconductors:
D1 = high-efficiency LED, dia. 3mm
IC1 = UDA1351H (Philips)

Miscellaneous:
K1 = cinch (RCA) socket, PCB mount, e.g., Monarch T-709G

Digital Transformer

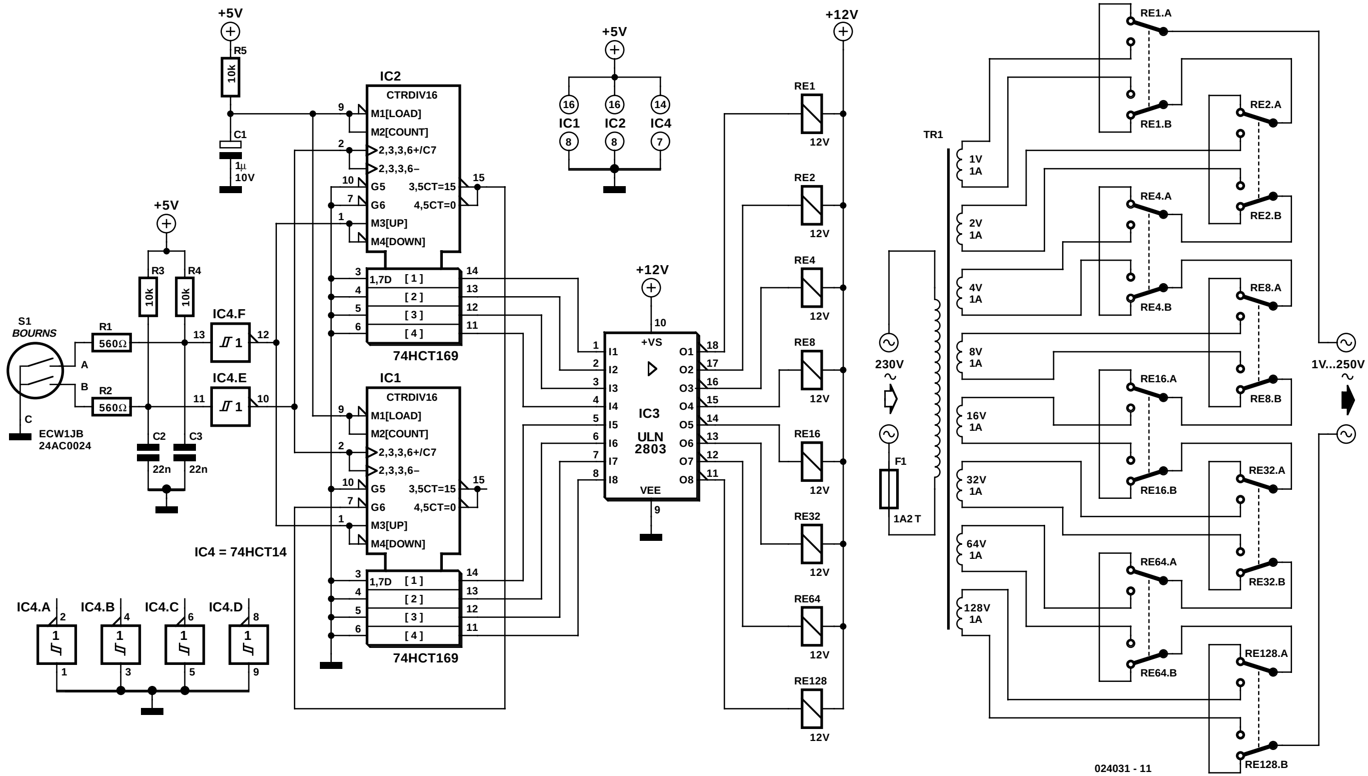
042

D. Barth

An electrically isolated variable transformer is actually an obligatory piece of equipment in every electronics lab. However, many people are put off by the high price of such a device. In a hobby lab, a professional variable transformer is usually grossly overdimensioned, so it's possible to save a lot of money with a little bit of handiwork. All that you need is a transformer kit for the desired power level and a bit of electronics (**Figure 1**). This approach can be used to construct a binary-controlled transformer for ac voltages in the 1 to 255-V range with 1-V steps.

The working principle is based on a binary-valued series of eight isolated transformer secondaries, each having a voltage that is twice that of the previous one (1, 2, 4, 8, 16, 32, 64 and 128). These can be combined to achieve the desired ac output voltage. In order to allow the output voltage to be continuously adjusted (to the extent that this can be said to be the case with 1-V steps), a rotary pulse generator connected to an up/down counter is used. The pulses from the generator are offset with respect to each other, which makes it possible to determine the direction of rotation. After passing through a network that suppresses contact bounces, the pulses are applied to the cascaded counters to cause them to count up or down.

The counter outputs energise a set of relays via the ULN2803



power driver, and the relay contacts tap off the corresponding voltages. The output voltage should be checked by connecting an ac voltmeter.

Please observe the usual safety precautions for equipment carrying mains voltages when building this digital transformer.

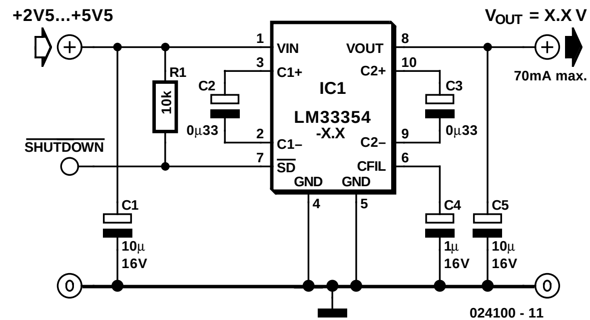
(024031-1)

Constant Voltage

043

When batteries are used to power a circuit, there is always the problem that the battery voltage drops during operation. A National Semiconductor type LM3354 IC (www.national.com/0ds/LM/LM3354.pdf) can provide a solution to this problem. It contains a dc/dc converter that operates as a buck converter in step-down mode when the input voltage is too high, and which can also handle input voltages that are too low by operating as a boost converter in step-up mode. All of this works without any coils using switched-capacitor technology. Several capacitors are charged to the input voltage and then connected by an internal matrix switch either in series (step-up) or parallel (step-down). The output voltage is regulated by varying the duration of the switch-on phase. The LM3354 is available in several versions for various voltages.

The IC is clocked at 1 MHz and works with input voltages between +2.5 V and +5.5 V. At maximum output current, the minimum input voltage is 2.9 V (3.4 V for the 5-V version). A Low signal level applied to the Shutdown input can be used to disable the converter. The efficiency of the IC ranges from 75% to 85%. Thermal overload protection prevents damage to the IC from overloads.



Type	Minimum input voltage	Output voltage	Current (max.)
LM 3354-1.8	2.5 V @ <80 mA	+1.8 V	90 mA
LM 3354-3.3	2.5 V @ <70 mA	+3.3 V	70 mA
LM 3354-4.1	2.5 V @ <40 mA	+4.1 V	90 mA
LM 3354-5.0	2.9 V @ <30 mA	+5.0 V	90 mA

(024100-1)

Two Keyboards on one PC

044

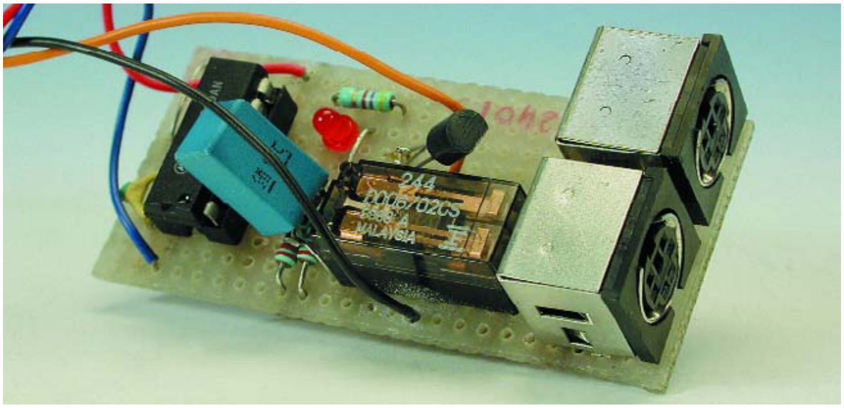
This circuit does the exact opposite of what most of this type of changeover switches attempt to do. Usually a changeover switch is used with two PCs and one keyboard. This version however makes it possible to operate one PC with two keyboards. K1 is connected to the PC for this purpose while K2 and K3 are connected to two keyboards.

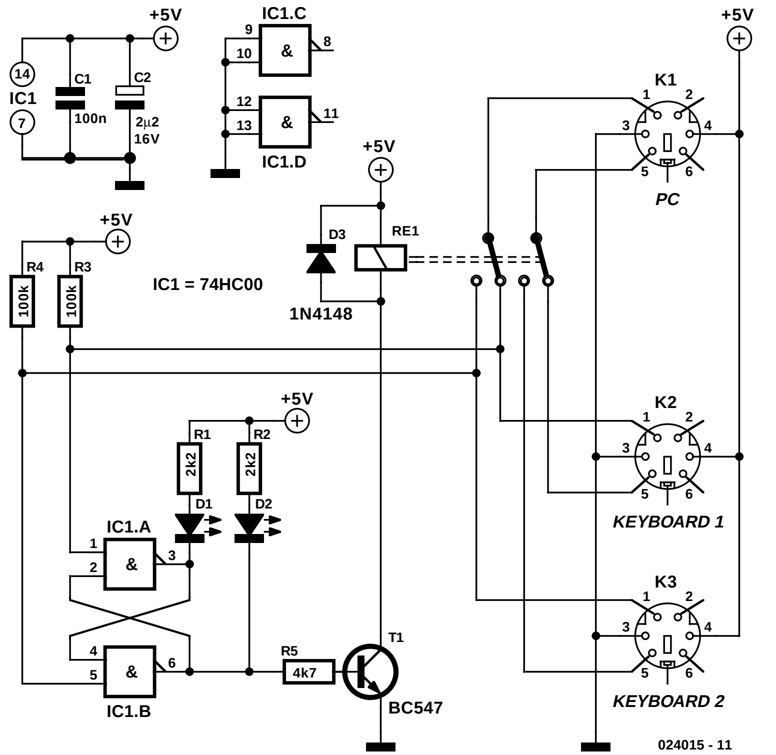
The data outputs of the keyboards are high in the idle state. As soon as a key is pressed the keyboard will serially transmit the data. The data line will now also be low from time to time. This low level is detected and remembered by the flip-flop circuit around IC1.

If the signal originates from K3, the output on pin 6 will be high. Transistor T1 will conduct via resistor R5, which causes the relay to activate. The signals on K3 are then connected straight through to plug K1. This situation will persist until a signal on the data line of K2 is transmitted. In that case the flip-flop will reverse and pin 6 will be low. The signal at resistor R5 will no longer cause transistor T1 to conduct and the relay will be in the rest position. The signals at connector K2 are now connected to plug K1. The LEDs D1 and D2 indicate which keyboard is connected to the PC.

The changeover of the signals via the relay is relatively slow, so the first keystroke is not properly transmitted to the PC. This means that when changing over the first keystroke will always be lost. Also take into account that when the PC is first switched on, the state of the flip-flop is random, so it is not clear which keyboard is initially connected to the PC.

(024015-1)

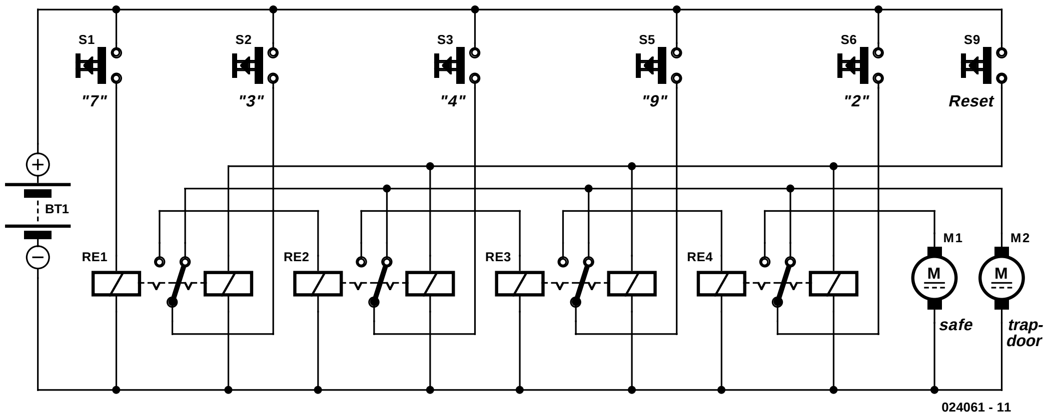




Treasure Chest using Relays 045

B. Kainka

There exist special types of relay that have peculiar characteristics. Next to the 'normal' types in the catalogue we find the so-called 'latching' types which have two stable states. There are two types of latching relay, with either one or two coils. Types with just one coil are reset by applying a reverse-polarity voltage to the coil, while those with two coils are reset by applying a voltage (of the same polarity) to the second coil. It is the version with two coils that we will use in this circuit. It takes only a brief pulse of current to switch the relay's state; then it will remain in that state until reset using the other coil. Suitable latching relays are available, for example, from Conrad Electronics: they offer versions with coil voltages of 6 V (at 110 mA), 12 V (at 50 mA) and 24 V (at 27 mA), with one or two sets of changeover contacts.



The combination lock for a treasure chest can be constructed from such relays, rather than the microcontrollers more commonly employed these days. To open the treasure chest, the rightful owner needs simply to press the keys in a set sequence, whereupon the relays switch over in turn from left to right. After the last press a motor is switched on that operates the mechanism which unlocks the treasure chest. Once the valuables have been taken out, the circuit is reset by pressing the reset button.

The unauthorised intruder, should he dare to try the circuit, will find that as soon as he for example presses button 4, without having pressed 7 and 3 first in the correct order, a second motor starts up — which releases the trapdoor, dropping the intruder into the snakepit below!

(024061-1)

3-dB Chebyshev Filter/Amplifier 046

Elsewhere in this collection of small circuits a 1-dB version of a third-order Chebyshev filter can be found. This 3-dB version is a bit steeper after the corner frequency. The inherent disadvantages are the increased ripple in the pass-band and more ringing in response to a square wave. The indicated frequency is the corner frequency at –3 dB. This time as well, two tables are printed here. **Table 1** shows an implementation with three equal resistors for the filter section and the theoretical values for the capacitors. In the case of a high-pass filter, three equal capacitors can be used. The resulting 'oddball' values can be synthesised by combining values from the E96 range.

Table 2 indicates more practical values for the filter section, by selecting E12 values for the capacitors and theoretical values for the resistors (which can be built by combining 1% components). It is best to use a very fast opamp so that the transfer function is not unduly influenced, particularly with higher gains or at higher frequencies.

(024116-1)

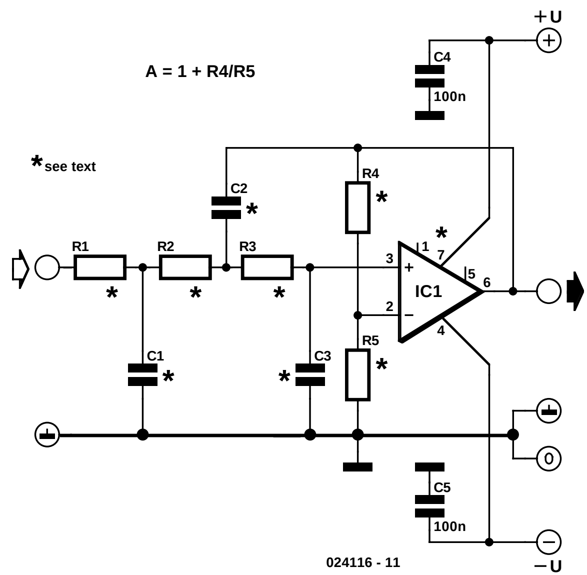


Table 1 : 3x10kΩ, 1 kHz (f_c = –3 dB)

A[dB]	C1	C2	C3
0	57.571 n	619.02 n	403.12 p
5	65.696 n	23.996 n	10.205 n
6	66.756 n	21.061 n	11.442 n
10	70.926 n	14.003 n	16.197 n
14	75.498 n	10.032 n	21.240 n
20	83.776 n	6.3885 n	30.059 n

Table 2 : 1 kHz (f_c = –3 dB), C's : E-12

A[dB]	C1	R1	C2	R2	C3	R3
0	56 n	10.299 k	560 n	10.493 k	390 p	12.171 k
5	68 n	9.3222 k	22 n	11.270 k	10 n	10.235 k
6	68 n	9.8636 k	22 n	9.6024 k	12 n	9.4615 k
10	68 n	10.665 k	15 n	9.5068 k	15 n	8.6424 k
14	82 n	8.7960 k	10 n	10.416 k	22 n	9.7338 k
20	82 n	10.508 k	6.8 n	9.4462 k	33 n	8.8083 k

Super Simple NiCd/NiMH Charger 047

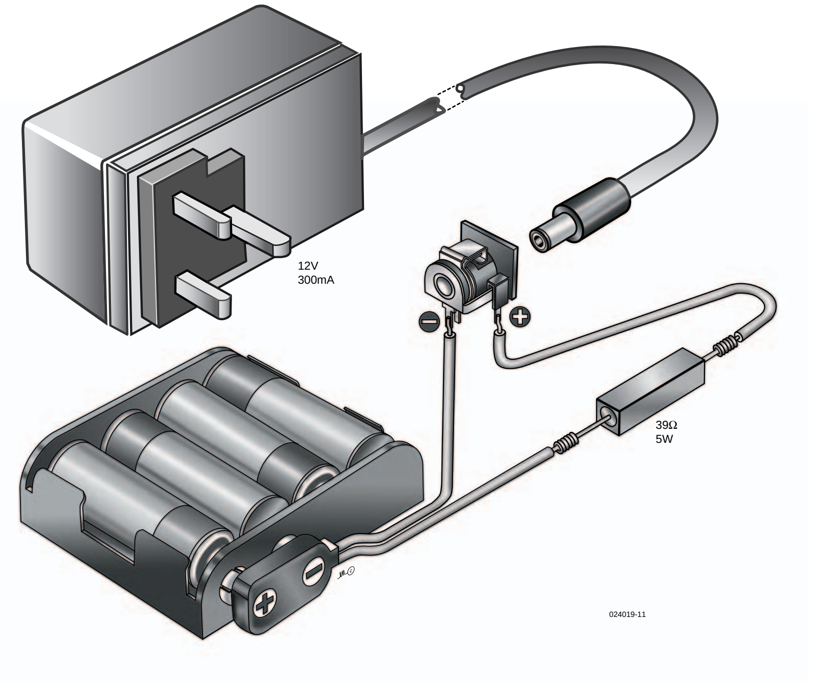
A few years ago the charging of Nickel Cadmium cells was a fairly standard procedure. An AA sized NiCd cell used to have a capacity of 500 or at most 600 mAh. You bought or built a charger that was rated for that capacity and you could use it to charge virtually all AA NiCd cells. The capacity of these popular rechargeable cells has increased enormously, especially since the advent of Nickel Metal Hydride cells. Nowadays AA cells are available in any imaginable capacity up to 1800 mAh (at the time of writing). This is of course a welcome development, but it also introduces a few problems. When you already have a charger for 600 mAh cells it is irritating to have to buy a new charger when you buy some new 1800 mAh cells. To avoid the need to purchase two or three expensive chargers, we'll describe a simple charging process that is suitable for any NiCd or NiMH cell and which can be built in only quarter of an hour.

For a safe charging process we choose a charging current of 1/10 the value of the cell capacity, *C*. Why? At this current the cell can never be damaged, even if it is accidentally left in the charger for several days. At higher currents it can be fatal for the cell if it is overcharged. This can occur when we forget to remove the cell from the charger, but also when the cell is still half full when charging starts. The normal charging period will then be too long as well. At a current of 0.1 *C* these problems won't occur. We don't have to worry about the notorious memory effect; new NiCds haven't had this for several years and NiMH cells never suffered from this in the first place. It is therefore no longer necessary to discharge the cells first. (There are some exceptions to this rule: when large peak currents are drawn from the batteries, such as in model cars and cordless drills, the recommendation is that the cells should occasionally be discharged and charged at high currents.)

After following the next example, anybody should be able to make his or her own charger:

We'll assume that the cell has a capacity of 1800 mAh. That means that the cell will be able to deliver a current of 1800 mA for one hour, or 900 mA for two hours, and so on. It will be charged with a current of 1/10 the current it can deliver for one hour, making 1800/10 = 180 mA. After 10 hours the cell should be fully charged, but because there are always losses and we want to be completely sure that the cell is fully charged, the charging period should be 14 hours. As we said previously, the cell may be charged for longer, but if we charge it for a shorter period it may not be fully charged.

For the power supply we'll use an ordinary 12 V mains adapter. Keep in mind that an unregulated adapter usually has a voltage of 13 V or more; if you want to know the exact figure you should measure it with a multi-meter during the charging process. In this example we'll assume 12 V. To draw a current of 180 mA (= 1/10 C) at a voltage of 12 V Ohm's law tells us that the value of the required resistance is 12/0.18 = 66.7 Ω. But there is also a voltage drop across the cell of about 1.4 V when it is being charged. Keeping that in mind, the resistor should be (12–1.4)/0.18 = 58.9 Ω. The resistor will become rather warm, so we should choose one that can dissipate at least (12–1.4) × 0.18 = 1.9 W. In practice we'll choose a 5 W or even a 10 W type, otherwise it could become too hot.



It is of course not possible to buy a 58.9 Ω resistor, so we have to choose one of the nearest standard values of 56 Ω or 68 Ω. It is always best to choose the slightly higher value (in this case 68 Ω), because there will be a reduced current and that is safer. The calculations don't have to be exact, because the capacity of the cell will most likely differ from that stated by the manufacturer. The cell is put in the battery holder, the resistor and plug are connected and Bob's your uncle. Do take care that the polarity of the connection is correct: the negative terminal of the cell goes to the negative output of the adapter and the positive terminal of the cell goes to the positive output of the adapter via the resistor. If the cell is connected the wrong way round it will be **discharged** instead, and could well become damaged!

It is also possible to recharge more than one cell at a time. Take a battery holder for the correct number of cells and calculate a new value for the resistor. For two cells you should subtract 2 times 1.4 = 2.8 V from the 12 V supply, for three cells 3 times 1.4 = 4.2 V, and so on. The maximum number of cells that may be charged at a time is six; the value of the resistor is then (12–8.4)/0.18 = 20 Ω and the heat dissipated is 0.65 W. In this case we should choose a 22 Ω resistor rated at 5 W, so it won't become very hot.

You may think that you could charge a few more cells, such that the resistor becomes unnecessary; after all, the resistor only wastes energy. But if you try that, you will find that the charging current becomes overly dependent on factors over which you have no control, such as the value of the mains voltage and the charging voltage. We don't mind sacrificing some energy to obtain a stable charging current. That is what the resistor is for.

And finally a warning: Lead-acid batteries and Lithium-Ion cells should **absolutely not** be charged with this charger!

(024019-1)

Optical CD-ROM Output

048

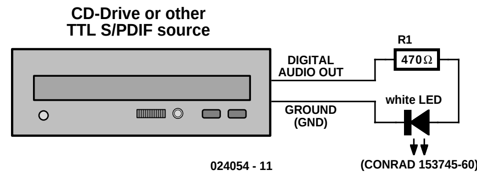
Many CD-ROM drives have in addition to the analogue output also a digital S/PDIF output, in the form of two pins, typically next to the analogue connections and which are generally unused. It is quite straightforward to connect a Toslink module to these pins to add an optical output. The 5-V power supply that this module requires can easily be tapped off the power supply connector of the drive. But it can also be done simpler and cheaper: just connect a series resistor and an LED (**Figure 1**).

It is necessary however, to use an LED that emits light at roughly the same wavelength as a Toslink module (660 nm). An ordinary red LED is fairly close and it appears that others have succeeded in getting an optical connection to work with one of these components (for example, refer to http://members.tripod.com/~Psych/super-cheap-toslink.html). However, a considerable amount of current was required, and in general it is not specified how much current the digital output can safely deliver. Therefore, the author of the circuit proposes to use a buffer IC between the CD-ROM drive and the LED (**Figure 2**).

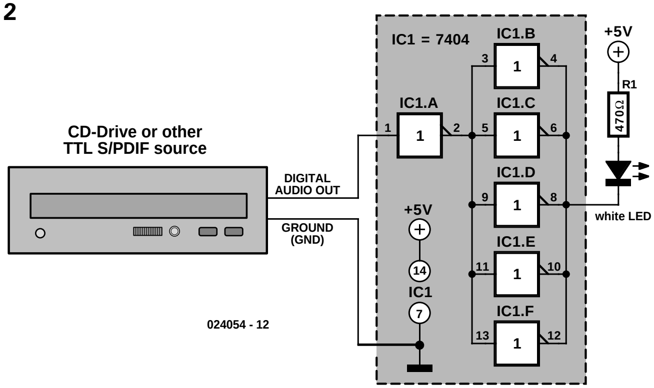
We experimented in the lab with different red LEDs that we had on hand, but none of them provided satisfactory results. It did work, though, with a super-bright, white, 5-mm LED, the current through which could be reduced to 3 mA. A load current this small is unlikely to worry or damage any output.

Also, Thomas de Bruijn provides on www.minidisc.org/cdrom_opticalout.htm a very good suggestion for an enclosure for the LED: the plastic housing from a 3.5-mm jack plug is eminently suitable. The connector part is removed, which then provides sufficient room in the back shell for the 5-mm LED and the resistor. An additional advantage is that a Toslink connector fits nicely in the thread of the back shell.

1



2



NB: when Windows Mediaplayer version 7 is used to play back CDs, the default value ‘digital copying’ is set. This means that the PC reads the CD data (music in this case) from the IDE interface and is not available at the S/PDIF output. To solve this, in Mediaplayer go to ‘Options’ under the Tools menu and select the tab ‘CD Audio’. Disable the ‘digital copying’ option.

(024054-1)

Elektor Electronics USB Interface under Linux

049

H. Jung

With the use of Linux becoming increasingly common, including among the readers of *Elektor Electronics,* there is growing interest in Linux drivers for *Elektor Electronics* interface projects. One of the most successful projects in recent years was the USB interface presented in the September 2000 issue, for which a driver for Windows 98 was developed, but not for Linux. It's time to set that right!

Linux supports USB in kernel versions 2.4.0 and above. For kernel versions 2.2.16 and above, there is also limited USB support. In principle, there are two options for accessing a USB device:

- access via a user-supplied module incorporated into the kernel that communicates with the interface;
- access via the USB file system (usbdebfs), which can also execute the Control Request provided by the USB interface.

Here we take the approa ch of using our own kernel module, which is a piece of code that can be dynamically loaded into the operating system kernel as well as dynamically deleted, and which implements a particular function – such as accessing the *Elektor Electronics* USB interface. This not only makes it very easy to test the code, it also means that the operating system kernel is not burdened with unnecessary code.

The `cy3640.o` kernel module is a modified version of a driver that we found on the Internet for the Cypress Starter Kit, which uses the same hardware as the *Elektor Electronics* USB interface.

This module provides access to all of the functions implemented in the interface using `ioctl routines`, which are special calls for devices that do not fit into the normal read/write scheme. Each `ioctl` employs a 4-byte structure that is used to transfer values and return results. A typical call sequence is shown in **Listing 1**. The calls that have been implemented are listed in **Table 1**.

The file descriptor is hard-coded in the module and employs USB Major Number 180 and Minor Number 128.

In order to activate the module, it must be loaded into the kernel using the command `insmod cy3640.o`. The command `lsmod` can be used to verify whether this was successful. In addition, the file descriptor must be created once using the command

```
mknod /dev/usb-elektor
  c 180 128
```

Listing 1. Typical ioctl calling sequence

```
// build the transfer structure
cmd.val1 = CY3640_READ_ROM;
cmd.val2 = addr;
cmd.val3 = 0;
cmd.val4 = 0;

// call the ioctl
ioctl(fd,CY3640_READ_ROM,&cmd);

// output the results
printf("rom at addr 0x%02x is
0x%20x\n",addr,cmd.val2);
```

Table 1. ioctl functions

Ioctl	In	Out
CY3640_PING	-,-,-,-	status,-,-,-
CY3640_SET_BRIGHTNESS	-,brightness,-,-	status,-,-,-
CY3640_READ_TEMP	-,-,-,-	status,temp_low,temp_high,button
CY3640_READ_PORT	-,port,-,-	status,value,-,-
CY3640_WRITE_PORT	-,port,value,-	status,-,-,-
CY3640_READ_RAM	-,address,-,-	status,value,-,-
CY3640_WRITE_RAM	-,address,value,-	status,-,-,-
CY3640_READ_ROM	-,address,-,-	status,value,-,-

Table 2. Access library functions

Function	Remarks
`void set_device (char *device)`	Sets the name of the device file. Must always be the first function called.
`void brightness (int val)`	Sets the brightness of the green LED.
`unsigned char read_port (int port)`	Reads the specified port.
`void write_port (int port, int val)`	Writes the specified port.
`unsigned char read_ram (int addr)`	Reads the specified RAM address.
`void write_ram (int addr, int val)`	Writes the specified RAM address.
`unsigned char read_rom (int addr)`	Reads the specified ROM address.
`float read_temp (void)`	Reads the temperature.
`int read_button (void)`	Reads the state of the pushbutton.
`int ping_device (void)`	Tests whether the interface is operational.

and its access privileges must be set to read/write for everyone using the command

```
chmod 0666 /dev/usb-elektor
```

Root privileges are required for these operations.

The module must be reinstalled each time the system is started up. Automatic installation using `usbmgr` or hotplug scripts is not possible.

In order to avoid having to use the rather tedious ioctl programming every time, an access library containing the functions listed in **Table 2** has been created. This hides the `ioctl` calls from the user.

The Linux counterpart to Visual Basic in Windows is called Tcl/Tk. Tk is an interpreter that provides a graphic user interface and into which dynamic libraries can be loaded. These features make it an ideal testing tool for rapidly generating user interfaces.

The download file for this project, number **010065-11**, contains the previously described access libraries and the kernel modules for kernel versions 2.2.x and 2.4.x. It also contains a shared library for use with Tcl/Tk and several demo programs, as well as the illustrated Tcl/Tk application in both German and English versions.

(010065-1)

Recommended literature:

The Universal Serial Bus (USB).
Elektor Electronics September 2000
(description of the USB interface).

www.linux-usb.org
Introductory site for USB under Linux, including access to the USB mailing lists

The Linux USB subsystem, Brad Hards, Sigma Bravo Pty Ltd.

Programming Guide for Linux USB Device Drivers. Detlef Fliegel.
http://usb.cs.tum.edu

A USB Driver for the Cypress USB Starter Kit. Craig Peacock.
www.beyondlogic.org/usb/cypress.htm

Practical Programming in Tcl and Tk. Brent B. Welch.
Prentice Hall, 1999.

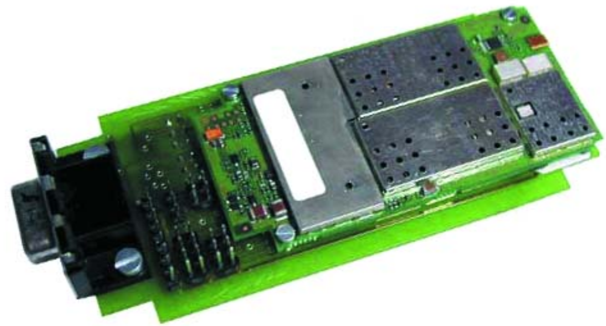
GSM Modem

050

Interfacing your own equipment to GSM devices has been made difficult by the manufacturers because they don't use standard connectors, very little information is made available, and a few other similar reasons. This is a pity since the AT command set has been extended especially for GSM. These AT commands have been used for years in ordinary modems and are fairly easy to use. The arrival of GSM has led to the addition of a number of commands, making the sending of SMS messages and such like possible.

If you tried to interface an off-the-shelf GSM phone to your own circuit, you would first have to find out which signals go to which pins on the GSM connector. If you only need to use AT commands, then it is sufficient to look for the RxD and TxD pins and a ground on this connector. Unfortunately this is only half the work, since you still have to find a plug that fits into the GSM connector. These two obstacles prevent many people from experimenting with GSM. And that is despite the fact that there are many applications where the addition of a GSM link would be very useful.

UbiCom, a German company, has recently begun to market several GSM products, of which the GSM Triband Modem and GSM Dualband Modem are highly suitable for experimentation with GSM. These GSMs have been specifically designed to be incorporated in existing equipment and therefore don't have a display, a keypad or any other unnecessary extras. Obviously this also keeps the cost down, which is a bonus.



These modems can be used with a standard RS232 cable; just connect a power supply and antenna and you're ready to start experimenting! You do of course have to insert a valid SIM card into the GSM.

As far as driving the GSM is concerned you are on your own, but it is not difficult to control the GSM with AT commands using a microprocessor. As an example, this could be used to transmit the current room temperature or to receive an SMS message that causes the microprocessor to set your room thermostat to a specific temperature.

More information about these GSM modems can be found on the Internet (www.ubicom.de). We're not sure how widely these are available, but it should always be possible to order the devices directly from UbiCom. (024105-1)

Audio input Selector

051

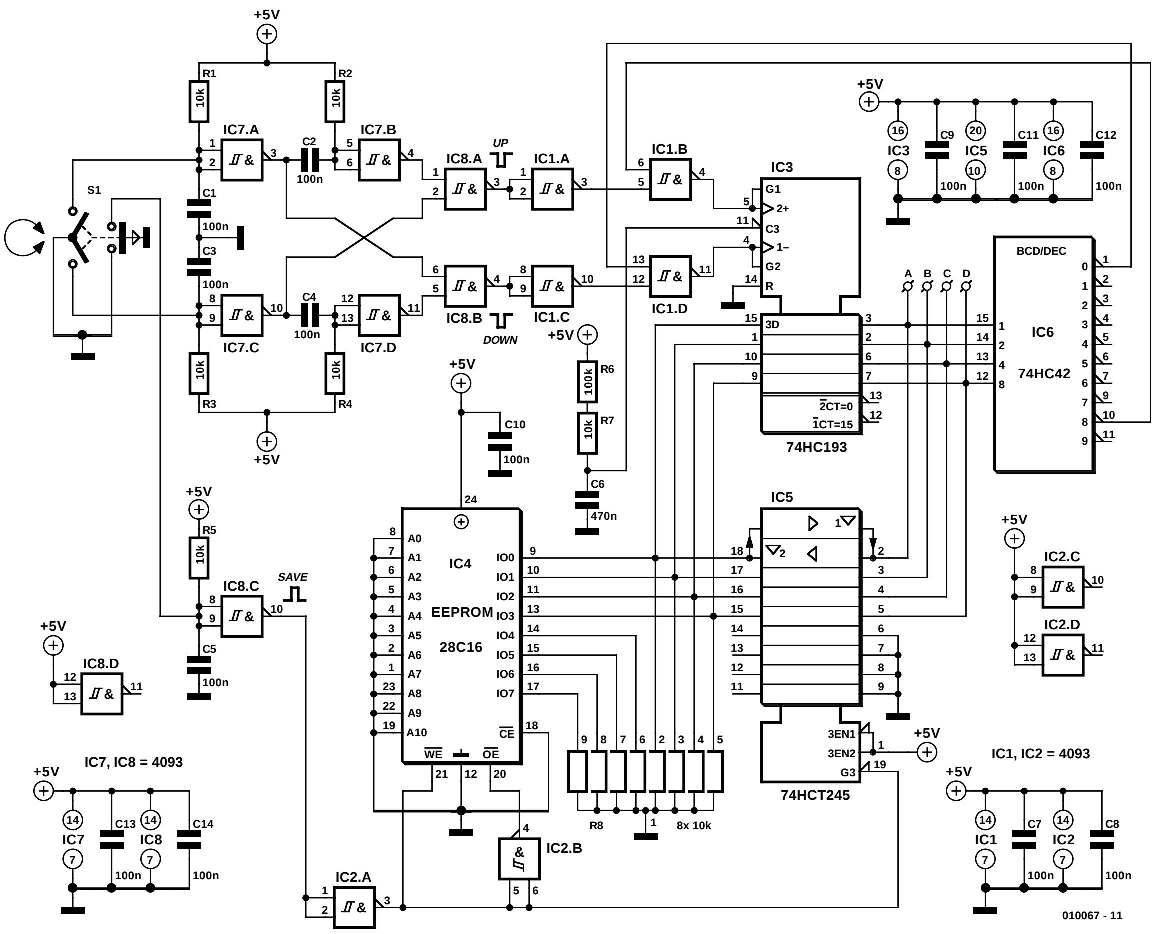
F. Lux

This circuit, designed for audio applications, allows the user to select which input signal will be enabled when the system is switched on. The setting is not fixed, but is stored in an EEPROM which is read when power is applied. Fortunately, because of the falling price of EEPROMs, this is not an expensive proposition. The switch used here is a shaft encoder with rotation outputs and a pushbutton (Conrad Electronics catalogue number 70 55 94). The circuit to determine the direction of rotation has appeared before in *Elektor Electronics*. A debounce circuit has been added for the pushbutton. The heart of the circuit is a presettable decimal or binary up/down counter (IC3, either a 74HC193 or a 74HC192) with separate clock inputs.

The clock pulses from the shaft encoder are first inverted by IC1.A and IC1.C. The signals are then passed to NAND gates IC1.B and IC1.D: the other inputs of these gates are used as control inputs to enable the clock pulses to be passed through or not. Assuming the control input is high, the clock signal is passed on to counter IC3. Each negative edge causes the counter to count up or down by one. The outputs of the counter are connected to BCD-to-decimal decoder IC6. The '0' and '8' outputs of this decoder are connected to the control inputs of the NAND gates on the 'down' and 'up' clock inputs respectively. This means that negative edges from the shaft encoder will be blocked when the counter is in the appropriate state, and the counter can therefore only count in the opposite direction.

When the pushbutton on the shaft encoder is pressed the output of the counter at that moment is stored in the non-volatile EEPROM. The pushbutton signal is connected to the enable input of bus driver IC5 via IC2.A, a NAND gate connected as an inverter. If the button is not being pressed, the enable input is high, so all outputs are high impedance, and IC5 is effectively not present. However, when pin 19 goes low the 4-bit value on the output of counter IC3 is driven on to the preset inputs of the counter and on to the I/O pins of EEPROM IC4.

At the same time the EEPROM is put into write mode by taking its WE input low and its OE input high. The data are then stored at location 0 (since the address pins A0 to A10 are held low). As soon as the pushbutton is released, the data outputs of the bus driver return to the high impedance state. The EEPROM



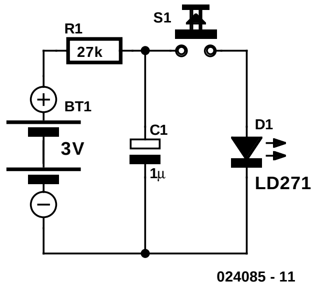
switches back into read mode (with WE high and OE low), and presents the stored counter value to the preset inputs of the counter. As long as the load input of the counter IC3 remains high, the output of the counter is not affected. When the load input goes low, the values at the preset inputs are transferred to the count outputs A to D. This is exactly what happens when power is applied to the circuit: C6 charges slowly, applying an active-low pulse to the load input of IC3. Since the EEPROM is in read mode at power-up, the data stored at address 0 will be available at the preset inputs to the counter and be transferred to the outputs by the low pulse on the load input.

(010067-1)

Simple IrDA Transmitter

052

B. Kainka



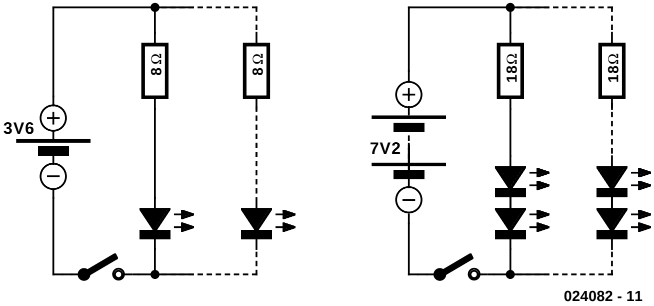
Communication over the IrDA port uses a relatively complex protocol but its possible to send a single character using just a few components. In many cases this will be sufficient to control a Palmtop. This circuit generates a single pulse of IR light that is interpreted by the Palmtop as a data byte with the value 255. The circuit could hardly be simpler, a 1 µF capacitor is charged via the 27 kΩ resistor and when the switch is pressed this charge will flow through the diode to generate an IR light pulse. The values have been optimised for a communication speed of 9600 Baud but the actual pulse length is not critical. The listing shows a simple receiver program for this IrDA signal. The IR interface is opened with the command `ir` and the line `get$(#5,0)` reads a single byte from the interface, if nothing has been received it will return –1. Each time a character is received a counter will be incremented and displayed on the screen and a short sound will be generated.

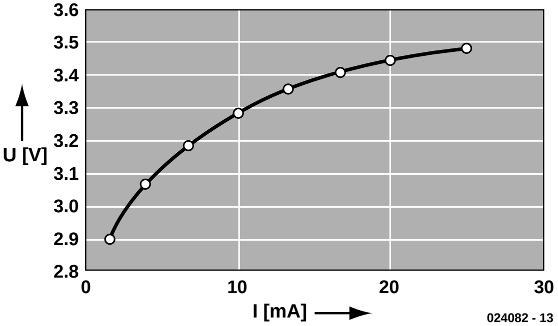
```
#irdacount.bas
open "com1:",9600,ir as #5
z=0
draw -1
while 1
n =get$(#5,0)
if n>-1
  z=z+1
  t$=str$(z)
  draw t$,75,60,2
  sound 800,100,63
endif
wend
```

(024085-1)

Economical White LED

053





The general assumption is that white LEDs operate at a voltage of 3.6 V and a current of 20 mA, which is about right. Lithium Ion cells coincidentally have a voltage of exactly 3.6 V, which seems to be convenient. However, we can't just connect an

LED to a voltage source (the cell), because the current could become too large and the LED could be damaged. That is why they are usually driven by a current source, but the energy dissipated in the current source is of course lost. Besides, a current source can only function properly when it drops a few volts, which we don't have in this case.

But is it necessary to have a 'real' current source? The amount of light given off by an LED is obviously dependent on the current flowing through it, but our eyes are easily fooled. It is easy to tell the difference in brightness between two different LEDs mounted next to each other, but when you turn on an LED momentarily and then turn it on again a bit later at a different brightness you will barely notice the difference. So as far as the eyes are concerned, there is not much difference whether the LED operates at 10, 20 or 30 mA (!). The conclusion is that we don't really need an accurate current source, but that a 'bad' current source will suffice, limiting the current to safe levels.

With that in mind we get a very simple yet efficient design, where the current source consists of a resistor of a few ohms combined with the internal resistance of the LED, which is about 10 ohm at 20 mA. You can add as many branches in parallel as you like.

It can often be difficult to obtain a single 3.6 V cell, but camcorder battery packs with two cells (7.2 V) are widely available. The circuit remains simple at 7.2 V: two LEDs in series with a current limiting resistor of about double the value. Here too you can have as many branches as you like.

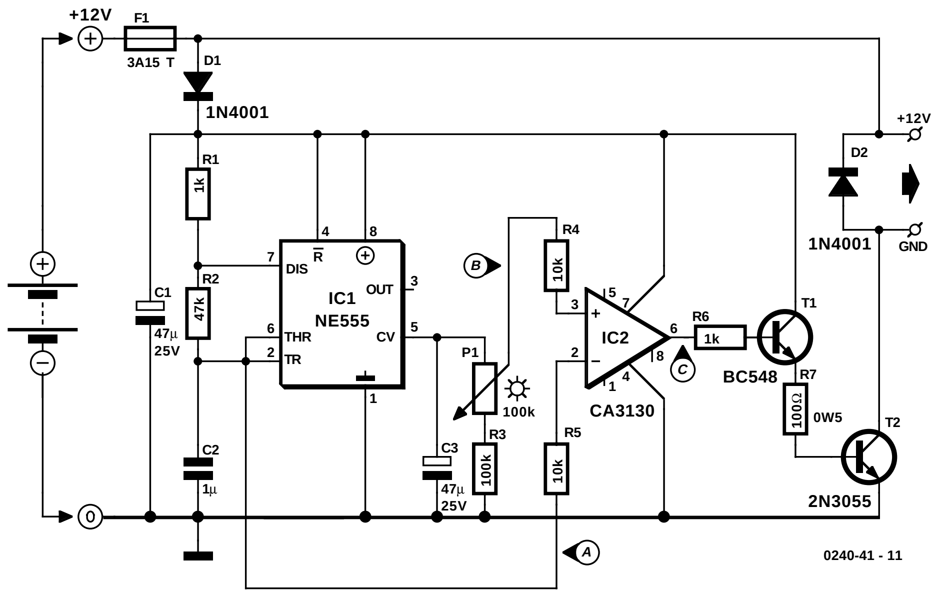
To determine the value of the current limiting resistor you should look at the graph, which shows the relationship between the operating voltage and current of a white LED. As an example we'll show the calculations for the current limiting resistor for an LED current of 20 mA: (3.6-3.44) / 0.02 = 8 Ω. So at 3.6 V the current is 20 mA, at 3.7 V it is about 27 mA and at 3.5 V about 16 mA. In practice the values shown in the circuit of 8 Ω at 3.6 V and 18 Ω at 7.2 V may be increased a little; values of 15 Ω and 33 Ω respectively still work well.

(024082-1)

Direct Current Dimmer

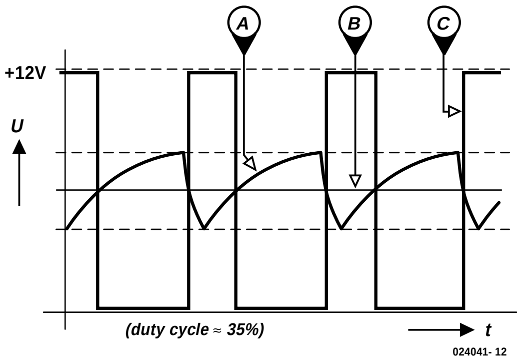
054

A. Schilp



This energy saving, 12-V controller is nearly universally applicable. In addition to controlling battery powered lighting in a car, boat or caravan it is also quite able to control the speed of a model train. In essence, this circuit converts the 12-V DC voltage into a rectangular pulse train with a duty cycle that is adjustable from 0 to 100%. The circuit can be divided into four sub-circuits: the saw-tooth generator built around IC1, reference network P1/R3/C3, comparator IC2 and driver stage T1/T2. The comparator compares the generated sawtooth voltage (1) with the reference voltage (2). This reference voltage is adjustable between the lower and upper limits of the sawtooth voltage with P1. When the saw-tooth voltage is greater than the reference the output of the comparator will be 'high'. Since the saw-tooth voltage, with its fixed frequency, is continuously crossing the reference voltage, a rectangular waveform (3) appears at the output of the comparator, the duty cycle if which can be determined with P1.

The driver stage, with its large current amplification, ensures that the voltage up to a load current of 3.15 A will remain sufficiently square. By varying the reference with P1 we can change the width of the pulses in the pulse train. This affects the average voltage to the load and therefore also the power drawn by it. The current through T2 is always largest when the voltage drop across it is smallest (saturation) and smallest when the voltage drop is the greatest. T2 therefore, needs to dissipate only very little power and needs to be cooled only when used with highly inductive loads. Diode D2 protects



against reverse connections and acts as freewheeling diode for inductive loads.

Returning to the sawtooth generator, IC1 is a 555 timer configured as an AMV, which is tuned to 65 Hz with R2/C2. With such an AMV the square wave at pin 3 is typically used, but this time we are more interested in the charge/discharge voltage across C2. This is, strictly speaking, not a pure sawtooth but is nonetheless very suitable as a sawtooth for this controller. If it turns out that the controlled lamp flashes visibly, it is possible to raise the frequency by lowering the value of C2. Because of the behaviour of the load and the dissipation of T2 it is not recommended to increase the frequency beyond 200 Hz, even though the circuit will work without problems at frequencies greater than 10 kHz.

C2 is charged and discharged by the 555 between the bottom limit of 1/3 and the upper limit of 2/3 of the power supply voltage. These limits are defined by three internal resistors of 5 kΩ each. These also give the IC its name. In order to adjust the frequency the upper limit is made available to the outside world via the control input (pin 5). This voltage is stabilised by C3 and directly made available to P1. The lower limit is defined by making the resistance of P1 and R3 equal, so the voltage division is the same as the internal resistors in the 555, with which they are effectively in parallel.

(024041-1)

LED Voltage Tester

055

B. Kainka

A universal voltage tester should respond to both dc and ac voltages. The usual types with glow-discharge lamps only work with voltages greater than around 100 V. The circuit shown in **Figure 1** uses a Darlington circuit formed by two NPN transistors and can detect voltages of less than 1 V. It can also be used to test continuity. Here the positive terminal of the battery serves as the 'ground' connection. Consequently, an input current flows even with a high-impedance connection, but this current increases when a voltage source with the proper polarisation is included in the loop. A supplementary piezoelectric buzzer allows the circuit to also be used as an audio-frequency signal tracer.

The tester can be used in the following manners:

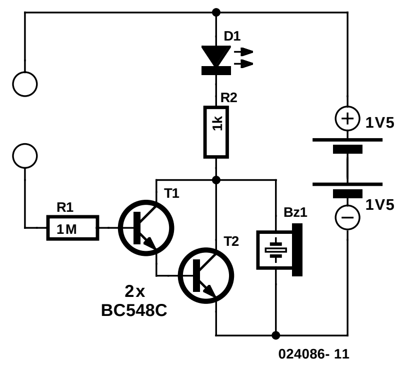
– Continuity between the two terminals or connection via the fingers: the LED lights.
– Testing a battery with the positive terminal connected to the input: the LED becomes brighter.
– Testing a voltage with the negative terminal connected to the input: the LED becomes darker or is off.
– With an ac voltage, the LED current is modulated, so the LED flickers and the buzzer sounds.

All of this can be built into the enclosure of a key finder, since the essential components are already present: a battery holder, a LED and a piezoelectric transducer. Alternatively, the tester can be fitted into the case of a ballpoint pen or a length of plastic tubing (see Figure 2).

An interesting experiment can be performed using this circuit. One person holds the probe tip, while a second person holds the opposite terminal. If they walk over a carpet or synthetic floor covering, the LED lights up with each step. This is a consequence of charge separation between the floor and the shoes.

(024086-1)

1



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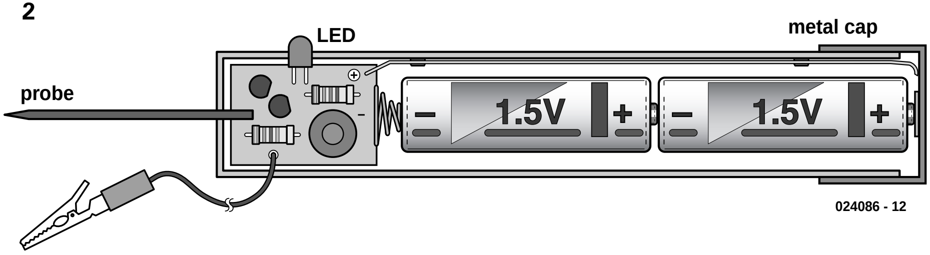


Instrumentation Amplifier

with an electrically isolated input

By B. Schädler

The instrumentation amplifier described here has two important features. Its input is electrically isolated and it has no fewer than 16 input and output ranges that can be selected for many types of signal conversion.

Most commercial instrumentation amplifiers provide a number of input ranges, but their outputs are usually restricted to one or two voltage ranges and a similar number of current ranges. In this circuit there is a wide choice of input and output ranges: seven unipolar voltage ranges (varying from 0 to 100 mV to 0 to 10 V), seven bipolar voltage ranges (±100 mV to ±10 V) and two current ranges (0 to 20 mA and 4 to 20 mA). The output can be chosen to follow the input on a 1:1 basis, but conversion between any of the ranges is also possible.

Selecting the input and output range is simply done using two DIP switches. The accuracy of all ranges is very good; with careful selection of the resistors a precision of 0.1% is achievable. Two voltage references (IC12 and IC13) are used to maintain accuracy, and presets are used at several critical points.

The electrical isolation is achieved using an optoisolator made by HP (HCNR200 or -201). Its linearity is 0.01%. An alternative part would be the Siemens IL300.

The circuit can be split into three parts:

1) Input stage (with quad opamp IC1) and optoisolator IC3.
2) Amplification and conversion of the optoisolator output into a voltage output.
3) Current output stage.

Input stage

S1A is used to select between a voltage and current driven input. The open position corresponds to the voltage input. The input impedance then is about 1 MΩ, determined by resistors R3 and R1/R2. Capacitor C1 is used to suppress any spikes in the input signal, although a suppression diode could be used instead. Closing S1A changes the input to current mode with an impedance of 50 Ω.

IC1.B functions as a buffer, with IC1.A providing gain/attenuation as required. The gain is changed using switches S1B through S1E. Switch S1F is opened when a current range of 4 to 20 mA is required. For all other ranges the negative voltage reference is connected to the output of IC1.B via R8 and has a negligible effect.

All unipolar inputs are converted to a range of 0 to –1 V at the output of IC1.A; bipolar inputs become +1 V to –1 V. The next stage around IC1.C is used to turn a bipolar ±1-V-signal into a voltage of 0 to +1 V. When S1G is open the –1 V-signal is simply inverted by IC1.A; with the switch closed the gain of IC1.C is halved, while at the same time a reference voltage is added via R16/R17, causing the output to be in the range of 0 to +1 V.

This is followed by the optoisolator (IC3). The internal LED illuminates two photodiodes. One of these is connected back to the input of the output opamp; the other goes to the inverting input of opamp IC1.D. During normal operation the current through R18 and R19 is 'neutralised' by an identical current, but of opposite polarity, delivered by the photodiode. In other words, the opamp drives the LED such that the above condition is satisfied. Assuming that no current flows into the input of the opamp, the photodiode current will be equal to the driving voltage (0 to +1 V) divided by R18+R19. The photodiode current therefore varies from 0 to 50 µA, a value that keeps IC3 operating in its optimum linear range.

Since any current flow into the inverting input of the opamp affects the linearity of the whole circuit, a type has been chosen with a very low input bias current: the OP497 made by Analog Devices. The LT1097 made by Linear Technology is also suitable. If high linearity is not so important it is possible to use a cheaper FET opamp, such as the TL074.

Output stage

The second photodiode in IC3 is connected directly to the inverting input of IC2.A. Since there will be slight differences in the currents sourced by the diodes in the optoisolator, the

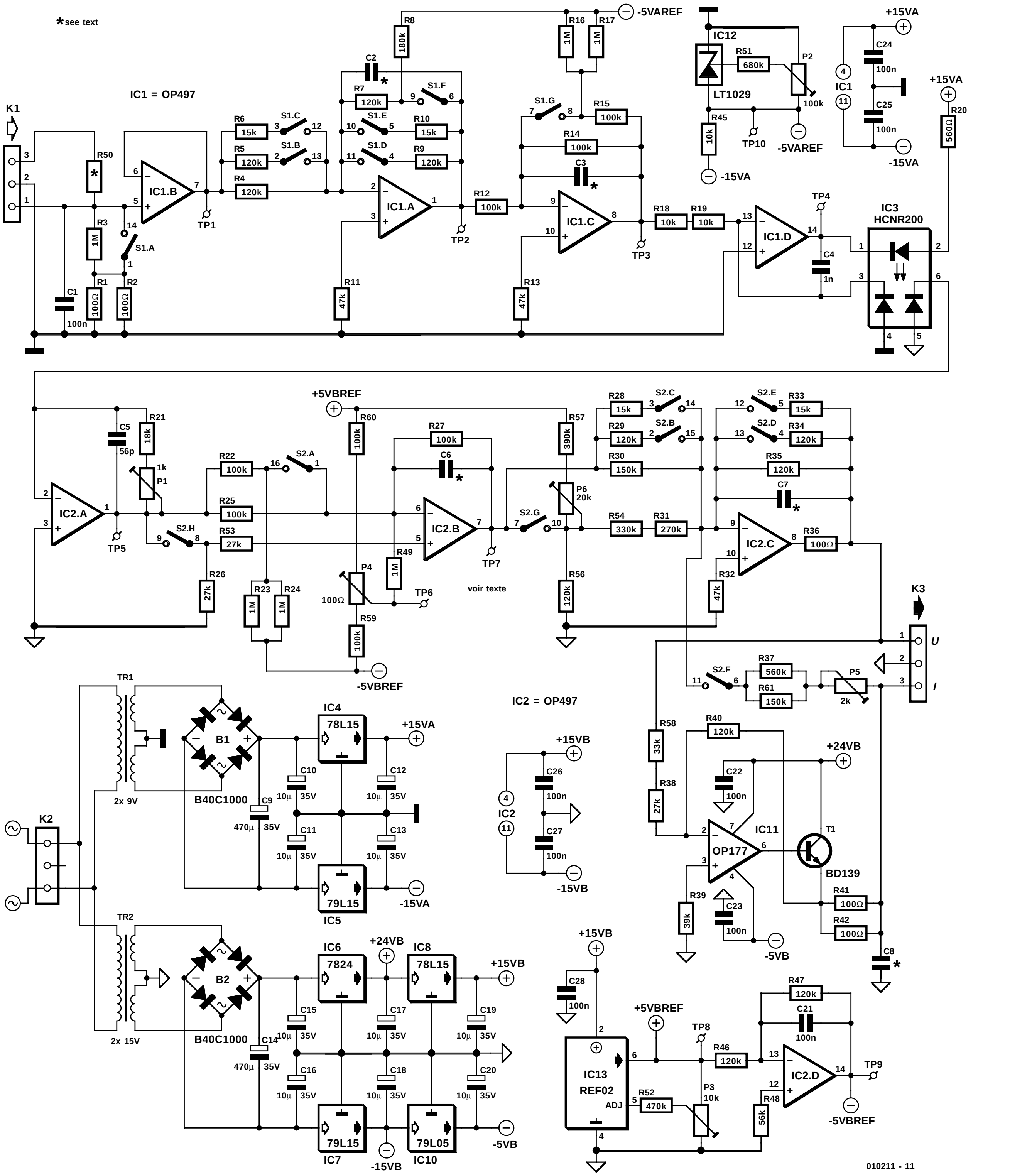


Figure 1. The input of the instrumentation amplifier is electrically isolated from the output by optoisolator IC3.

gain of this opamp has been made adjustable by the addition of P1. When correctly adjusted, the output of IC2.A will be 0 to +1 V.

The next stage with IC2.B is used to give either a unipolar or bipolar output. With S2A open the output is a unipolar 0 to –1 V, with S2A closed the output is a bipolar –1 V to +1 V. At this point any offset errors introduced in the amplifier can be minimised by P4.

The voltage output stage is more or less the same as that at the input; S2B - S2E set the required gain/attenuation. When the voltage output is selected S2G needs to be closed and S2F open. With S2F closed and with the gain of the voltage output stage set at 0.5, IC11 and IC2.C form a voltage to current converter. The gain of IC11 itself is set at a factor of 2.

Table 1. Setting the DIP switches for the various input and output ranges.								
Input		**S1-G**	**S1-F**	**S1-E**	**S1-D**	**S1-C**	**S1-B**	**S1-A**
0..+10V		0	1	1	1	0	0	0
0.. +5V		0	1	1	1	0	1	0
0.. +2V		0	1	0	1	0	0	0
0.. +1V		0	1	0	0	0	0	0
0.. +500mV		0	1	0	0	0	1	0
0.. +200mV		0	1	0	1	1	1	0
0.. +100mV		0	1	0	0	1	1	0
-10V.. +10V		1	1	1	1	0	0	0
–5V.. +5V		1	1	1	1	0	1	0
–2V.. +2V		1	1	0	1	0	0	0
–1V.. +1V		1	1	0	0	0	0	0
–500mV.. +500mV		1	1	0	0	0	1	0
–200mV.. +200mV		1	1	0	1	1	1	0
–100mV.. +100mV		1	1	0	0	1	1	0
0.. 20mA		0	1	0	0	0	0	1
4.. 20mA		0	0	0	0	0	0	1
Output	**S2-H**	**S2-G**	**S2-F**	**S2-E**	**S2-D**	**S2-C**	**S2-B**	**S2-A**
0..+10V	0	1	0	0	0	1	1	0
0.. +5V	0	1	0	0	1	1	1	0
0.. +2V	0	1	0	0	0	0	1	0
0.. +1V	0	1	0	0	0	0	0	0
0.. +500mV	0	1	0	0	1	0	0	0
0.. +200mV	0	1	0	1	1	0	1	0
0.. +100mV	0	1	0	1	1	0	0	0
–10V.. +10V	0	1	0	0	0	1	1	1
–5V.. +5V	0	1	0	0	1	1	1	1
–2V.. +2V	0	1	0	0	0	0	1	1
–1V.. +1V	0	1	0	0	0	0	0	1
–500mV.. +500mV	0	1	0	0	1	0	0	1
–200mV.. +200mV	0	1	0	1	1	0	1	1
–100m.. +100mV	0	1	0	1	1	0	0	1
0.. 20mA	1	1	1	0	1	0	0	0
4.. 20mA	1	0	1	0	1	0	0	0
1 = closed								

The reason for the choice of these gains lies with the supply voltage of IC11: in order for the current output to drive a large resistive load (at least 1 kΩ), it needs a high supply voltage of +24 V. There is therefore no choice but to use a reduced negative supply of –5 V, which obviously restricts the negative output swing of the opamp. It is for this reason that the gain of IC2.C is set at a factor of 0.5. Since IC11 is only required to supply a positive output and its output swing is very large, setting the gain of IC11 to 2 causes the overall gain of the current source to be unity.

When calibrated correctly, the maximum output current depends only on the driving voltage (0 to +1 V) of the current source and parallel resistors R41/R42 (50 Ω). Another condition is that the feedback resistor has to be exactly 120 kΩ – 50 Ω; which can be adjusted precisely with P5.

To turn the current mode of the amplifier to 4 to 20 mA, switch S2G is opened, causing a small voltage to be added to the input of the current source. Since the maximum output current should remain at 20 mA, the gain is adjusted slightly at the same time.

Since the current source requires a positive input voltage, inverting opamp IC2.B is effectively bypassed by closing switch S2H. Preset P6 is used to set the range exactly to 4 to 20 mA.

And finally, capacitors C1 -C7 should be mentioned. These capacitors are used to limit the bandwidth of the circuit. With a value of 1 nF the bandwidth is about 100 Hz and with 100 pF it is about 10 kHz, with an input signal of ±10 V. Choosing too small a value for C4 and C5 can give rise to unwanted oscillations, with C4 being very critical.

Power supply

As shown in the circuit diagram, the power supplies for the input and output stages are completely isolated. The supply for the input stage is kept fairly simple since only a symmetrical ±15 V is required. This is provided by a standard circuit using two voltage regulators (IC4 and IC5). The supply for the output stage consists of four voltages: ±15 V for IC2 and +24 V/–5 V for IC11. As can be seen, the rectified voltage of TR2 is first fed to IC6 and IC7, providing +24 V and –15 V. These supplies are then fed to IC8 and IC9 to give +15 V and –5 V.

The power consumption of the complete circuit is very low, making it possible to use small 1.5 VA PCB mounted transformers for TR1 and TR2.

Calibration

As far as the construction of this circuit is concerned, it is very much a DIY project. The author did design a PCB for his own use, but it had undergone so many modifications during the development of the circuit that the layout was no longer suitable for reproduction. Aspiring hobbyists will therefore have to design their own PCB for this circuit.

The calibration of the circuit is a meticulous task, which should be followed carefully. Fortunately, it isn't very difficult.

1) Switch on the amplifier and all calibration instruments (power supply, multimeter) and let them settle for about fifteen minutes.
2) Adjust P2 and P3 to set the voltage references to their nominal value (test points TP8, TP9 and TP10). Remember that there are two ground points!
   - Adjust P4 for an offset of 0 V at its wiper (TP6).
3) Use Table 1 to set the DIP switches for an input of 0 to +1 V and connect a voltage of 1.000 V to the input. Check that TP1 is +1.0 V, TP2 is –1.0 V and TP3 is +1.0 V.
4) Connect the multimeter to the other ground and set S2 to an output range of 0 to +1 V.
5) Adjust P1 to get +1.0 V at the output of IC2.A (TP5).
6) Short the input to ground. Use P1 and P4 to adjust the output to its exact value. Do the same again with an input of 1.000 V. The voltages at TP7 should now be 0 to 1 V for the unipolar range and +1 V to –1 V for the bipolar range.
7) With an input range of 0 to +1 V switch over to a current output and connect an ammeter between pin 3 of K3 and ground. Adjust P5 with a minimum and maximum load (1 kΩ) to give a 20 mA output current. Use P4 to set the 0 mA point.
8) Switch over to the 4 to 20 mA range and adjust P6 to give exactly 4 mA. If necessary, P1 and P4 can be adjusted to provide the best accuracy.
9) With bipolar inputs and outputs use P4 to adjust the offset to 0 V (input at 0 V). Next, adjust the gain (P1) with a positive input, then connect a negative input, but don't check the output. Again (with the input at 0 V) adjust the offset and with a positive input, the gain. Step 9 should be repeated until the best accuracy has been achieved.

Finally

The ground reference point for input signals and the multimeter should always be that at the input connector. The measurement of the input voltage should also be taken at the input connector. It is recommended to check that none of the opamps is oscillating. Especially IC1.D and IC2.A can be sensitive to this; increasing C4 and C5 in value should help.

If required, R41/R42 can be changed to select different output current ranges. Do take care that the supply transformer is rated for that current.

By choosing different values for resistors R1, R2/R3, as well as R50, virtually any input voltage can be measured.

(010211-1)

Despite the fact that the lack of a PCB prevented us from testing this circuit thoroughly in the Elektor labs, we felt that this design was worthy of publication. We can't comment directly from our own experiences on the usefulness of this circuit. Theoretically, the circuit seems to be in order and it is clear that the author has put a great deal of thought into the design. (Ed.)

Speed Measurement System
March 2002, p. 12-17
(010206-1).

In circuit diagram no. 010206-11 (lower part of Figure 4), the pin numbers on connector K1 should be mirrored, i.e., pin 1 should be pin 5, pin 2 should be pin 4, etc.
In diagram 010206-12 (upper part of Figure 4), the designations “IR sender” and “IR receiver” should be transposed.

These corrections do not affect the PCB designed and supplied for the project.

DTMF Codelock
March 2002, p. 56-57
(010110-1).

Pins 4 and 5 of comparators IC3-IC6 should be connected to ground, not to +5 V as shown in the circuit diagram.

DCI PLC
June 2001, p. 10-18
(000163-1)

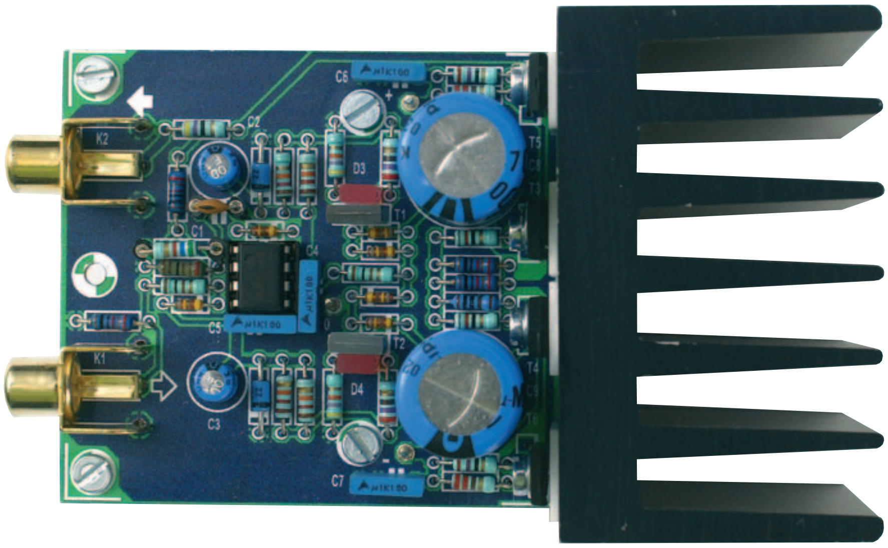
The article text fails to mention that connector K1 is mounted at the underside of the board.
The photographs on pages 16 and 17 show an early prototype of the DCI PLC with K1 mounted at the solder side.

Serial Interface
for Dallas 1-Wire Bus
April 2002, p. 30-34
(020022-1)

On the component overlay (Figure 2), the labels for solder pins ‘D’ and ‘ground’ should be transposed.

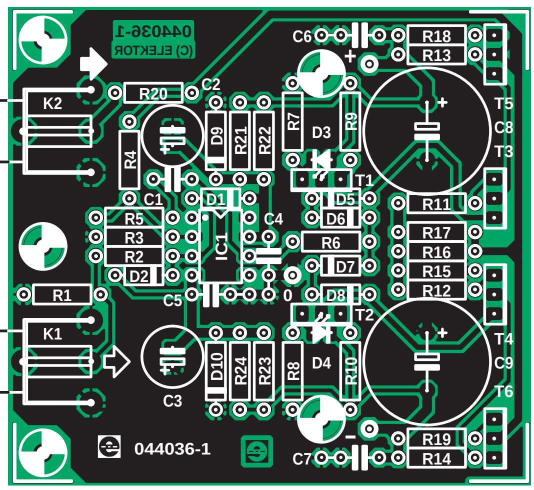
High Voltage Amplifier

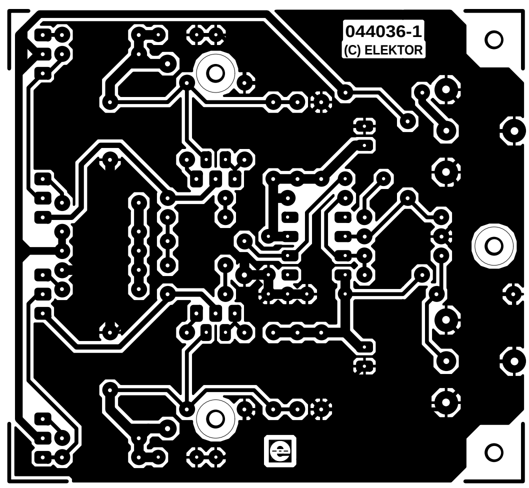
Audio analysers, such as the Audio Precision series have signal generators that for certain test purposes do not have a sufficiently high output voltage. That is why we have designed this 'booster' amplifier stage. It provides the same amount of voltage as a 300-W amplifier into 8 Ω. Applications for this amplifier include the testing of measuring filters or an automatic range-switching circuit.



The amplifier can, with a ±75 V power supply, generate 50 V_{RMS}, with an input signal of 5 V_{RMS} from the signal generator. In other words, the voltage gain is set to 10 times. In many cases the full bandwidth of the generator is not available at maximum output voltage. For this reason the amplifier gain is a little more than what is actually required for this application.

The graph shows the distortion (THD+N) as a function of output voltage. It is obvious that at 1 kHz (curve A), from about 10 V with 10 kΩ load, the limit of the Audio Precision has been reached. The steps in the curve are caused by range switching in the analyser. At less then 10 V, the measurement is mostly noise.





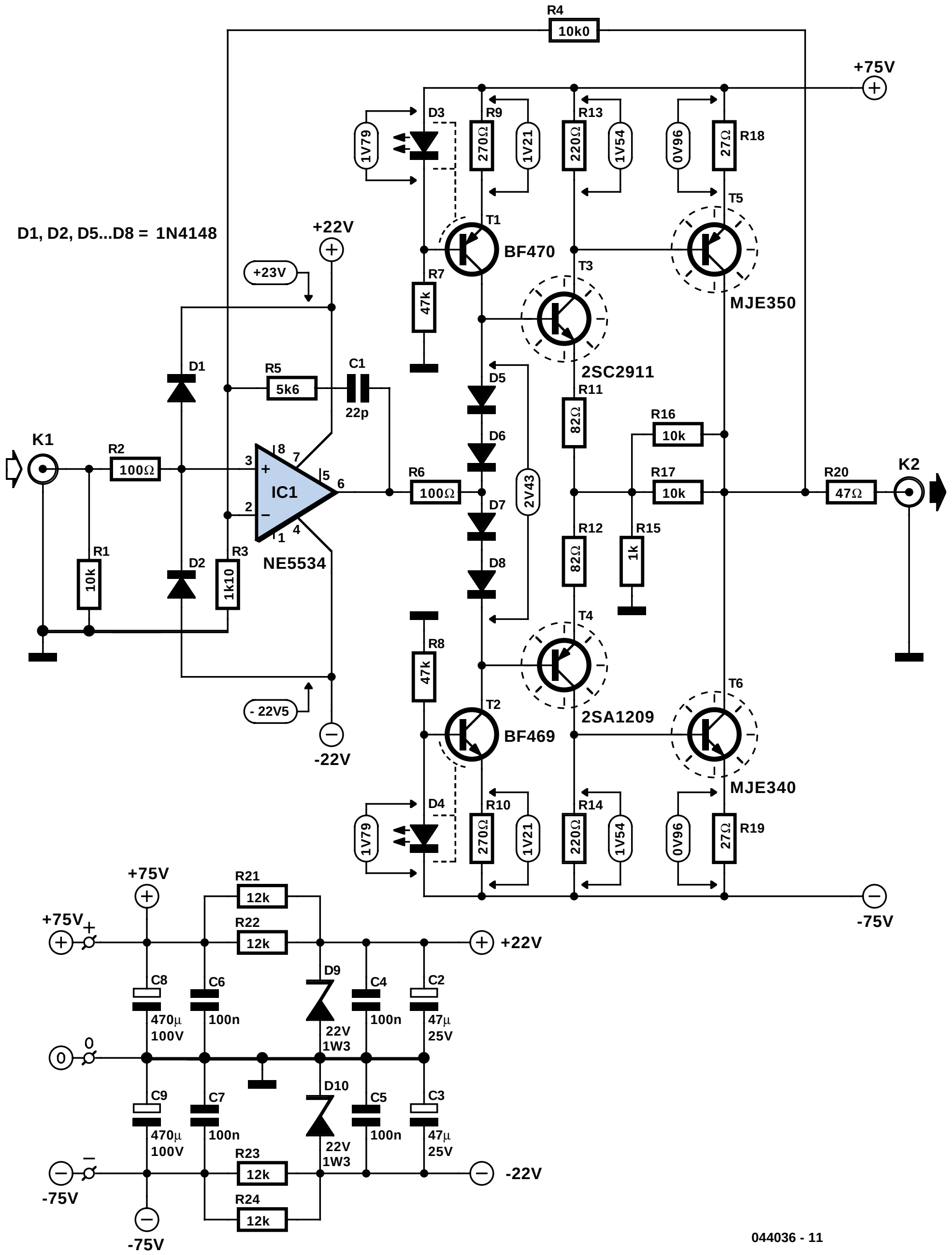
COMPONENTS LIST

Resistors:
R1,R16,R17 = 10kΩ
R2,R6 = 100Ω
R3 = 1kΩ10
R4 = 10kΩ0
R5 = 5kΩ6
R7,R8 = 47kΩ
R9,R10 = 270Ω
R11,R12 = 82Ω
R13,R14 = 220Ω
R15 = 1kΩ
R18,R19 = 27Ω
R20 = 47Ω
R21-R24 = 12kΩ

Capacitors:
C1 = 22pF
C2,C3 = 47µF 25V radial
C4-C7 = 100nF (C6/C7: 100V!)
C8,C9 = 470µF 100V radial

Semiconductors:
D1,D2,D5-D8 = 1N4148
D3,D4 = rectangular LED, red
D9,D10 = zener diode 22V 1.3W
T1 = BF470
T2 = BF469
T3 = 2SC2911
T4 = 2SA1209
T5 = MJE350
T6 = MJE340
IC1 = NE5534

Miscellaneous:
K1,K2 = cinch socket, PCB mount, T-709G from Monacor/Monarch
Heatsink, 2.5 K/W (e.g. Fischer type SK100, 50mm height)
PCB, order code 044036-1 from The PCBShop



From 20 kHz (curve B) the distortion increases slowly, but with only 0.008% at 50 V remains small even at nearly full output! Both curves were measured with a bandwidth of 80 kHz.

The amplifier is built around the old faithful NE5534 and a discrete buffer stage. The buffer stage has been designed as a symmetrical compound stage, which maximises the output voltage. The advantage of the compound stage is that it is possible to have voltage gain. This possibility has been taken advantage of, because the NE5534 can operate from a maximum of only ±22 V (and that is pushing it!). We make the assumption that the opamp can supply 15 V_{peak} without distortion. There is, therefore, 4.7-times gain required in the compound-stage. This is set with the local negative feedback R15, R16 and R17. The values are as small as possible to enable the use of normal resistors. At first glance, the gain should in theory be 6 times, but the stages T3 and T4 influence the local feedback. When driven with DC, the dissipation in R16 (R17) will be a maximum of about 0.3 W.

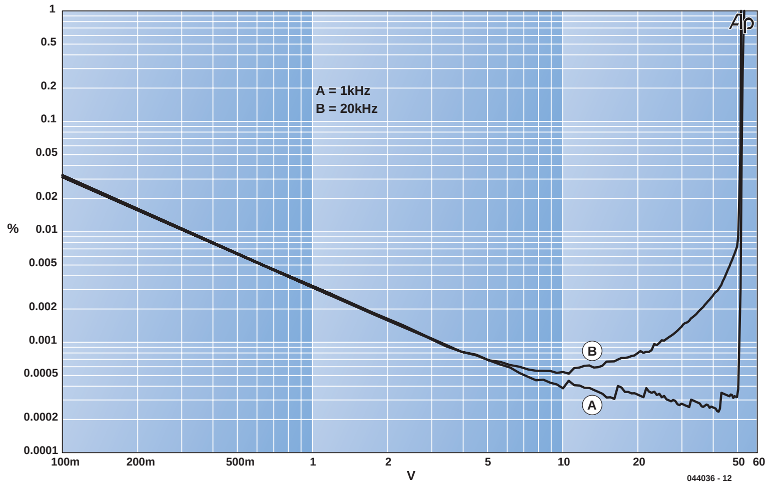
For T5 and T6, the MJE340 and MJE350 were selected. This pair has been practically unrivalled for many years. At a collector/emitter voltage of 150 V, the MJE350 can carry a collector current of 40 mA. The output stage is, with an idle current of 35 mA through T5 and T6, well into class-A operation. Local and total feedback requires a maximum of 20 mA. Despite this ‘no load’ the output transistors are well within their safe operation area. The minimum load is a few kΩ.

The amplifier is not short-circuit proof. If necessary, R20 can be increased to 1 kΩ or a current limit circuit can be added. However, this is likely to reduce the quality of the amplifier.

The drivers T3 and T4 are a couple of new transistors from Sanyo. These have a considerably better linearity (h_{FE}) and have a lower capacitance than the MJEs. The maximum collector/emitter voltage is 160 V. At this value (DC), up to 7 mA may be processed (or 20 mA for 1 s). The actual operating voltage for these will in practice be about 100 V. With a current setting of 7 mA, these transistors are operating well inside their safe operating area. These are details that have to be taken into account because of the high power supply voltage.

T3 and T4 are, with the aid of four 1N4148 diodes, biased at a fixed current, so it is not necessary to adjust the quiescent current. The current through these diodes is set with two symmetrical current sources to a value of about 4.5 mA (T1 and T2). BF-series devices were selected for this application because they have even lower capacitance. Should the availability of the BF469 and BF470 prove to be a problem then it is possible to substitute the same devices as used for T3 and T4, i.e. 2SC2911 (NPN) and 2SA1209 (PNP) respectively.

This stage is driven from the middle of D5 through D8, so that the opamp only needs to deliver the amount of current to compensate for the difference in current between T3 and T4. R6 protects the output of IC1 from any possible capacitive feedback from the output stage. The overall feedback loop is set with R4 and R3. This has been quite accurately adjusted for a gain of 10 times (A = 1 + R4/R3), so the actual value is 10.09 times. R5 and C1 are the compensation network for the entire amplifier by providing the opamp with local feedback. Note that if you change the gain of the amplifier, the compensation network has to change as well. An NE5534 has internal compensation when the gain is 3 or greater. So the ratio between R5 and R3 must be greater than 2.

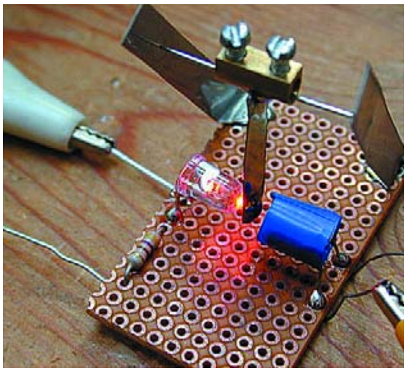


The bandwidth of the amplifier at 11 MHz is quite good (measured at 40 V_{rms}). R2, D1 and D2 provide input protection. R1 determines the input resistance, which is 10 kΩ. The value of R1 may be increased, but the result will be a higher output offset. The bias current of IC1 can easily be 0.5 μA and that explains the offset of 50 mV at the output. For most applications this value will not cause any problems.

The power supply for the opamp is derived from the ±75-V power supply using two zener diodes. This is designed with two parallel resistors so that it is not necessary to use special power resistors. C6 through C9 decouple the output stage and C2 through C5 decouple the opamp. The total current draw of the prototype, after it had warmed up, was about 57 mA. The ‘High voltage supply’ elsewhere in this issue can be used as the power supply.

(044036-1)

Attitude Sensor



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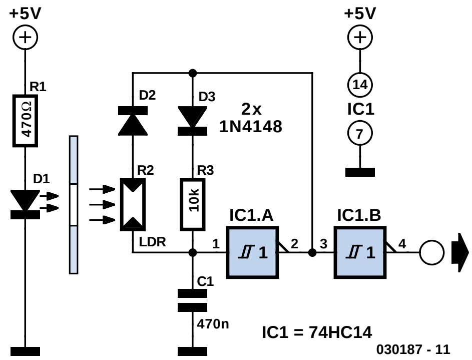


Bernd Oehlerking

The circuit presented here (in two versions) uses a light barrier as a position sensor. In the first version (**Figure 1**), the light barrier consists of an LED (D1) for the light source and a LDR (R2) for the receiver. The LDR is part of a CMOS oscillator that generates a digital signal (pulse waveform) whose high/low ratio (duty cycle) and frequency depend on the intensity of the impinging light. With the arrangement shown in the photo, the sensor is used together with a positioner. The light-dependent resistor is more or less obscured by a pendulum, so the duty cycle and frequency of the output signal depend on the position of the actuator. If the LED and pendulum are omitted, the light falling on the light-dependent resistor can also be used to directly determine the frequency and duty cycle.

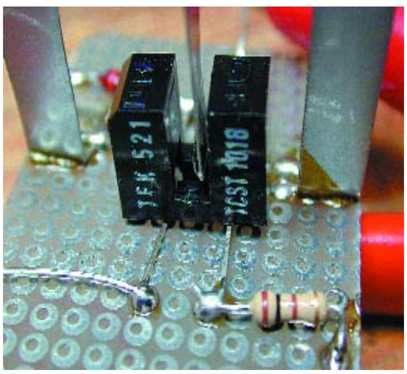
The second version (**Figure 2**) represents a refinement of the positioning mechanism. As can be seen in the photo, it differs from the first version by using a slotted light barrier. The pendulum that swings in the slot of the light barrier is formed by two simple strips of tinplate (which can be cut from a tin), which are bound together using a cloth-covered elastic band. A bit of solder applied to the end of the strips provides the pendulum weight.

As in the first version, the light receiver (photodiode) of the slotted light barrier is more or less obscured depending on t he position of the positioner. The photodiode in turn drives a pulse generator made from two CMOS Schmitt-trigger inverters, whose duty cycle and frequency are highly variable. A dc voltage that directly indicates the position of the pendulum can be generated from the pulse waveform using a low-pass RC network connected to the output of the generator.

Suitable types of slotted light barriers are for example the TCST 1018 and TCST 2000 (Conrad).

The idea for this positioner came from working with a multi-rotor helicopter whose motor speeds had to be adjusted if the helicopter threatened to tip over. There are certainly other possible applications (such as a tremor sensor) for this sensor, which is easy to build and adjust and which responds to only a few degrees of tilt with a large change in duty cycle.

(030187-1)



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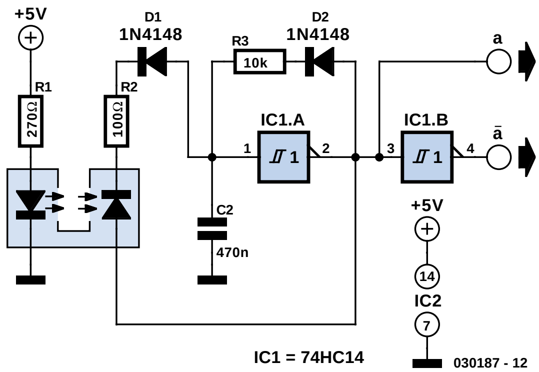
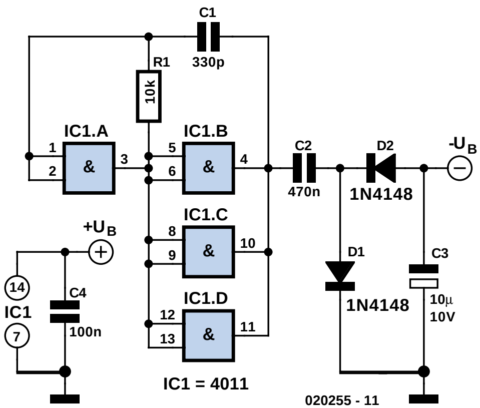
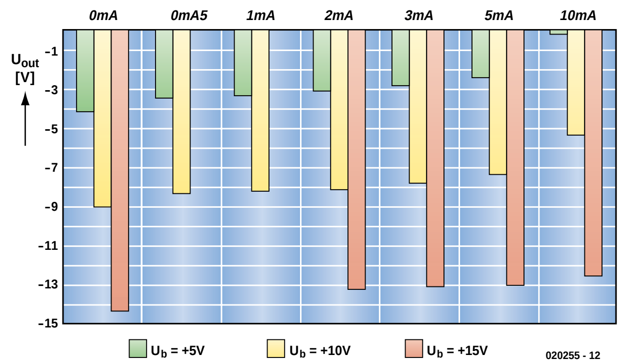


Negative Auxiliary Voltage





Ludwig Libertin

Some circuits need a negative supply voltage that only has to supply a small current. Providing a separate transformer winding for this (possibly even with a rectifier and filter capacitor) would be a rather extravagant solution. It can also be done using a few gates and several passive components.

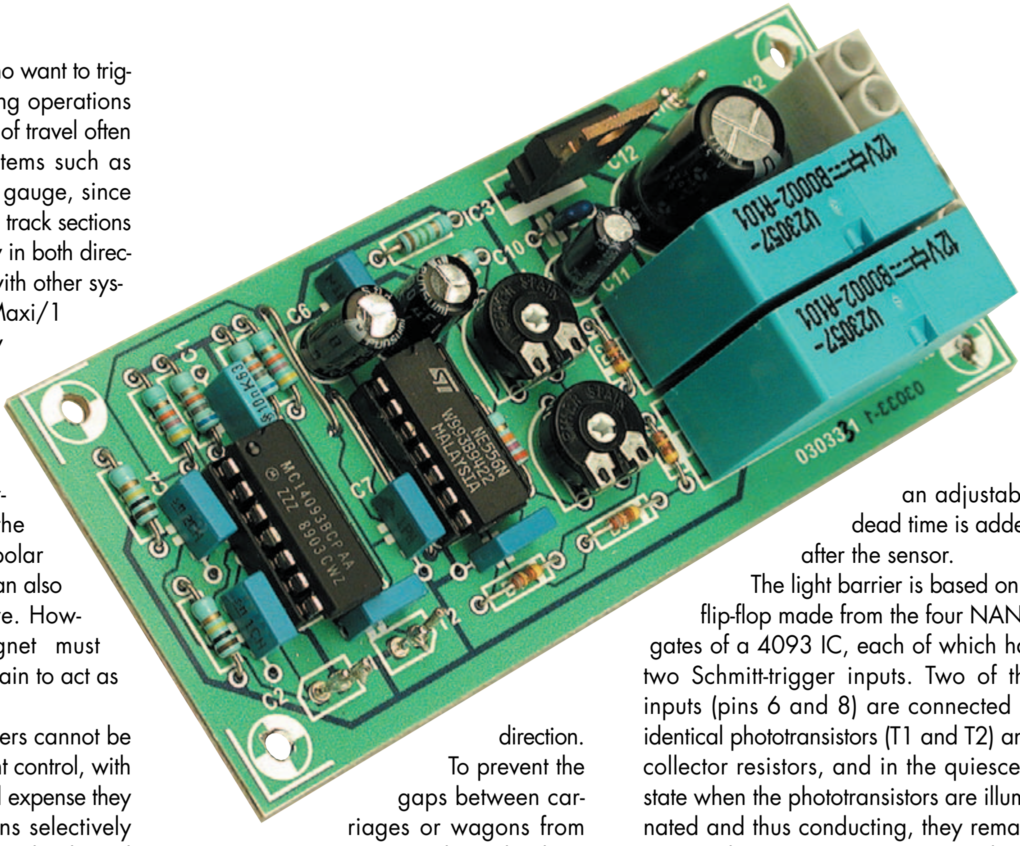
The combination of gate IC1a and the other three gates (wired in parallel) forms a square-wave generator. D1 and D2 convert the ac voltage into a dc voltage.

As a CMOS IC is used here, the load on the negative output is limited to a few milliampères, depending on the positive supply voltage (see chart), despite the fact that three gates are connected in parallel. However, as the figure shows, the negative voltage has almost the same magnitude as the positive input voltage, but with the opposite sign. If a clock signal in the range of 10–50 kHz is available, it can be connected to the input of IC1a, and R1 and C1 can then be omitted.

(020255-1)

Direction-Sensitive Light Barrier

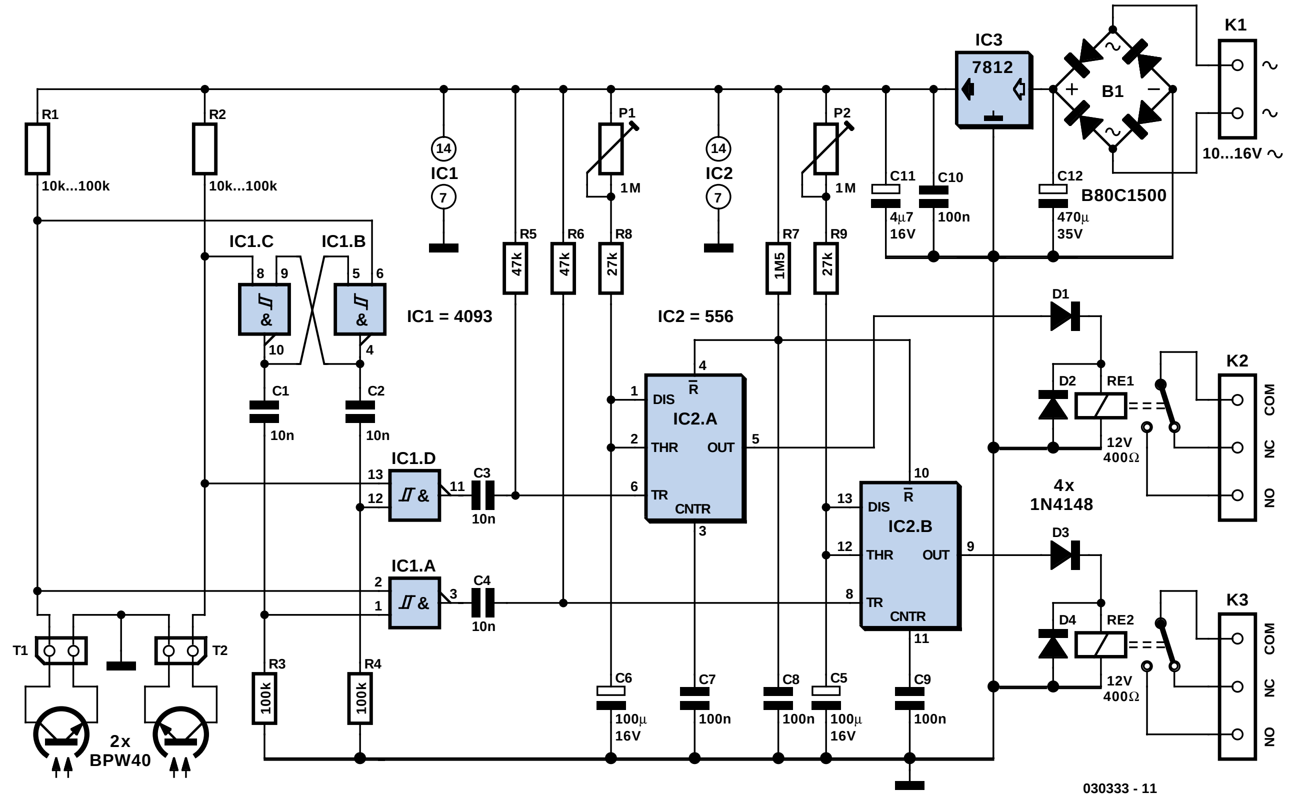
Robert Edlinger

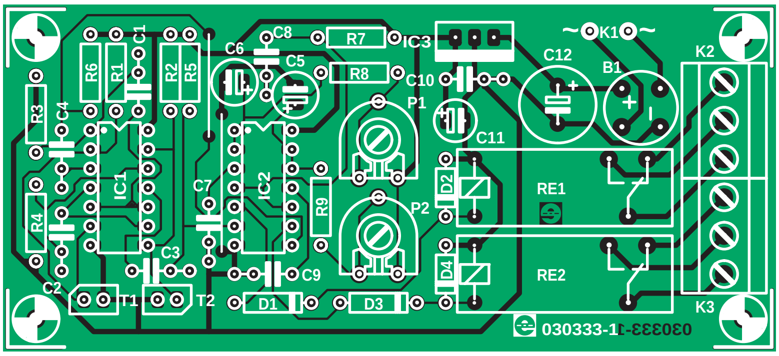


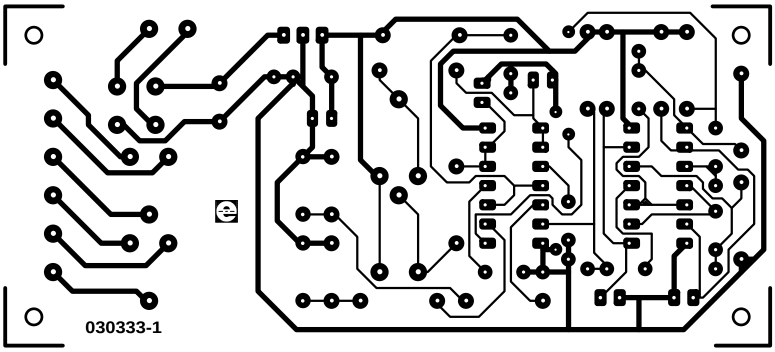
Model railway hobbyists who want to trigger train-controlled switching operations depending on the direction of travel often have things easy with systems such as Märklin HO or Miniclub Z gauge, since the corresponding switching track sections can be actuated individually in both directions. Things are different with other systems, such as the Märklin Maxi/1 gauge. Here it's necessary to use selective switching hardware for this purpose. A popular approach is to use reed switches together with permanent magnets fitted to the bases of the vehicles. Unipolar and bipolar Hall switches can also achieve the same objective. However, a permanent magnet must always be present on the train to act as a trigger element.

Although normal light barriers cannot be used for direction-dependent control, with a bit of additional effort and expense they can be built such that trains selectively trigger switching operations in the desired direction. To prevent the gaps between carriages or wagons from generating undesired pulses, an adjustable dead time is added after the sensor.

The light barrier is based on a flip-flop made from the four NAND gates of a 4093 IC, each of which has two Schmitt-trigger inputs. Two of the inputs (pins 6 and 8) are connected to identical phototransistors (T1 and T2) and collector resistors, and in the quiescent state when the phototransistors are illuminated and thus conducting, they remain Low. Both gate outputs (pins 4 and 10)







COMPONENTS LIST

Resistors:
R1,R2 = 10-100kΩ (see text)
R3,R4 = 100kΩ
R5,R6 = 47kΩ
R7 = 1MΩ5
R8,R9 = 27kΩ
P1,P2 = 1MΩ preset

Capacitors:
C1-C4 = 10nF
C5,C6 = 100µF 16V radial
C7-C10 = 100nF
C11 = 4µF7 16V
C12 = 470µF 35V

Semiconductors:
B1 = B80C1500 (80V piv, 1.5A)
D1-D4 = 1N4148
IC1 = 4093
IC2 = 556
IC3 = 7812
T1,T2 = BPW40

Miscellaneous:
RE1, RE2 = 12V relay (400Ω), 1·changeover contact
K1 = 2 solder pins
K2,K3 = 3-way PCB terminal block, lead pitch 5mm
PCB, order code 030333-1 from The PCBShop

are then High. If a vehicle now blocks one of the phototransistors (for example T1, although the circuit naturally works the other way around as well), the signals on the input and output of gate IC1d change levels. The output of gate IC1c is not affected by this, even though its ‘internal’ input (pin 9) goes low. If the vehicle also blocks T2 as well, nothing changes until it has travelled past T1. When that happens, the pin 4 output goes High again, but the pin 10 output toggles Low. When the vehicle has finally passed both phototransistors, pin 10 also goes back to the High level. The flip-flop is then restored to its original state.

For this behaviour to take occur, phototransistors T1 and T2 must be arranged such that when a vehicle passes by, at first only one of them is blocked, them both, and finally only the other one. This means that the distance between the phototransistors must always be less than the length of the vehicle.

When an output level changes, a pulse with a duration of around 10 ms appears at the input of gate IC1b (pin 12) or IC1a (pin 1). The time constants are determined by the timing networks (R3/C1 and R4/C2). As a High level (generated by the obscured phototransistor) is required on the other gate input (pin 13 or 2) to allow the pulse to pass through the gate, only one of these two pulses can proceed further to act as a trigger signal for the subsequent timer stage.

The two identically configured timers of the 556 dual timer IC function as monostable multivibrators, and thus act as pulse stretchers. Each of them drives an output relay with switchover contacts. The time constants of the monostables can be varied over the range of 3–170 s using the adjustment networks P1/R8/C6 and P2/R9/C5, independent of the supply voltage. RC network R7/C8 ensures that the two timers are in the quiescent state (outputs Low) after power is switched on. Freewheeling diodes D2 and D4 are essential with inductive loads; they bypass the counter-EMFs generated by the relay coils. D1 and D3 keep the voltage across the freewheeling diodes away from the timer outputs. If you want to have a visual operation indicator, D1 and D3 can be replaced by red LEDs with a voltage drop of 1.6–2.0 V. As the circuit dissipates a fair amount of power, a small heat sink is recommended for the fixed voltage regulator (IC3), to keep it from overheating.

We have designed a circuit board layout for this circuit, which can be fitted with components fairly quickly. Don’t overlook the (single) wire bridge between C6 and R5, and ensure that the electrolytic capacitors, diodes, transistors and ICs are fitted the right way around. The ICs can be fitted in sockets if you wish.

As the circuit board is relatively large, it probably should be mounted ‘under the floor’. In that case, the phototransistors will have to be fitted off the board. The leads from the phototransistors to the circuit board should be screened and certainly not be longer than around 10 cm.

The values of the two collector resistors (R1 and R2) for phototransistors T1 and T2 can be varied over a wide range (10 kΩ to 100 kΩ) in order to match the sensitivity to specific conditions. However, increasing the resistance not only increases the response sensitivity and thus the range, it also increases the susceptibility to interference from stray light (which is any how rather high). If you have to deal with bright stray light (direct sunlight or fluorescent lamps in the immediate vicinity), you should fit the transistors with lengths of small-diameter plastic tubing blackened on the inside and/or IR filters with maximum sensitivity in the invisible spectral range of 800–900 mm.

Small incandescent lamps (16 V, 1 W), which naturally also emit IR light, are suitable as light sources. If a visible light source is undesirable, the lamps can be almost completely ‘camouflaged’ using infrared filters. The other option is to invest in IR diodes: high-power types such as the SFH485 (100 mA max, 950 nm) allow barrier widths of more than 10 cm without any lenses. With suitable reflectors (with or without lenses), the range can be significantly increased. A value of 180 Ω / 1 W is recommend for the series resistor.

This bidirectional light barrier is suitable for a variety of tasks. For instance, one relay output can serve as a layover switch in one direction, while a train travelling in the other direction can cause a turnout or points to be actuated. A voice recorder prepared with whistle or bell signals can also be triggered by one of the relays. Flashing warning lights can also be driven, or the relays can act as an automated 'signalman' for barrier gates.

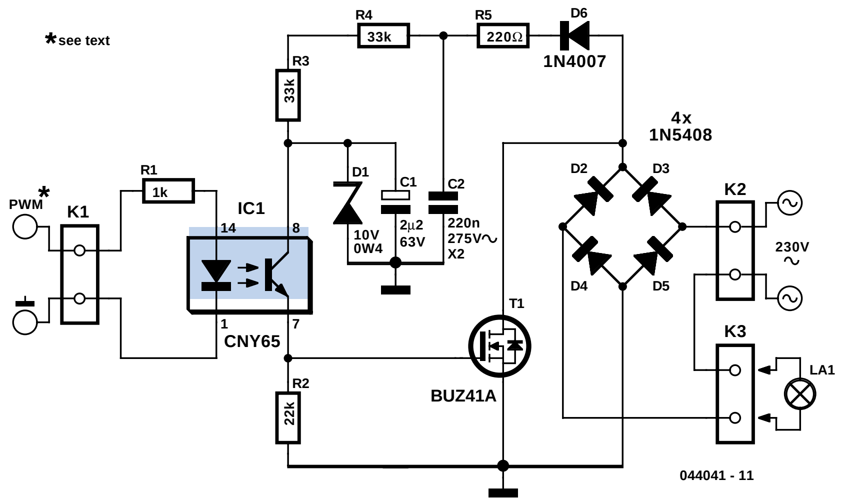
Naturally, this light barrier circuit can also be used for all sorts of counting tasks or as an alarm generator in domestic situations, if the nature of the object to be detected makes this possible. If only relatively short pulses (on the order of a tenth of a second) are needed, for instance to drive a counter, the RC networks that determine the timer values must be correspondingly modified. Photoresistors in miniature packages can be placed so close together that entomologists could even use the circuit to count exactly how many bees or bumblebees fly in or out.

(030333-1)

Dimmer with a MOSFET

Ton Giesberts

This circuit shows that dimmers intended for use at mains voltage do not always have to contain a triac. Here, a MOSFET (BUZ41A, 500 V/4.5A) in a diode bridge is used to control the voltage across an incandescent bulb with pulse-width modulation (PWM). A useful PWM controller can be found elsewhere in this issue. The power supply voltage for driving the gate is supplied by the voltage across the MOSFET. D6, R5 and C2 form a rectifier. R5 limits the current pulses through D6 to about 1.5 A (as a consequence it is no longer a pure peak rectifier). The voltage across C2 is regulated to a maximum value of 10 V by R3, R4, C1 and D1. An optocoupler and resistor (R2) are used for driving the gate. R1 is intended as protection for the LED in the optocoupler. R1 also functions as a normal current limiting device so that a 'hard' voltage can be applied safely. The optocoupler is an old acquaintance, the CNY65, which provides class-II isolation. This ensures the safety of the regulator. The transistor in the optocoupler is connected to the positive power supply so that T1 can be brought into conduction as quickly as possible. In order to reduce switching spikes as a consequence of parasitic inductance, the value of R2 has been selected to be not too low: 22 kΩ is a compromise between inductive voltages and switching loss when going into and out of conduction. An additional effect is that T1 will conduct a little longer than what may be expected



from the PWM signal only. When the voltage across T1 reduces, the voltage across D1 remains equal to 10 V up to a duty cycle of 88 %. A higher duty cycle results in a lower voltage. At 94 % the voltage of 4.8 V proved to be just enough to cause T1 to conduct sufficiently. This value may be considered the maximum duty cycle. At this value the transistor is just about 100 % in conduction. At 230 V mains voltage, the voltage across the lamp is only 2.5 V lower, measured with a 100-W lamp.

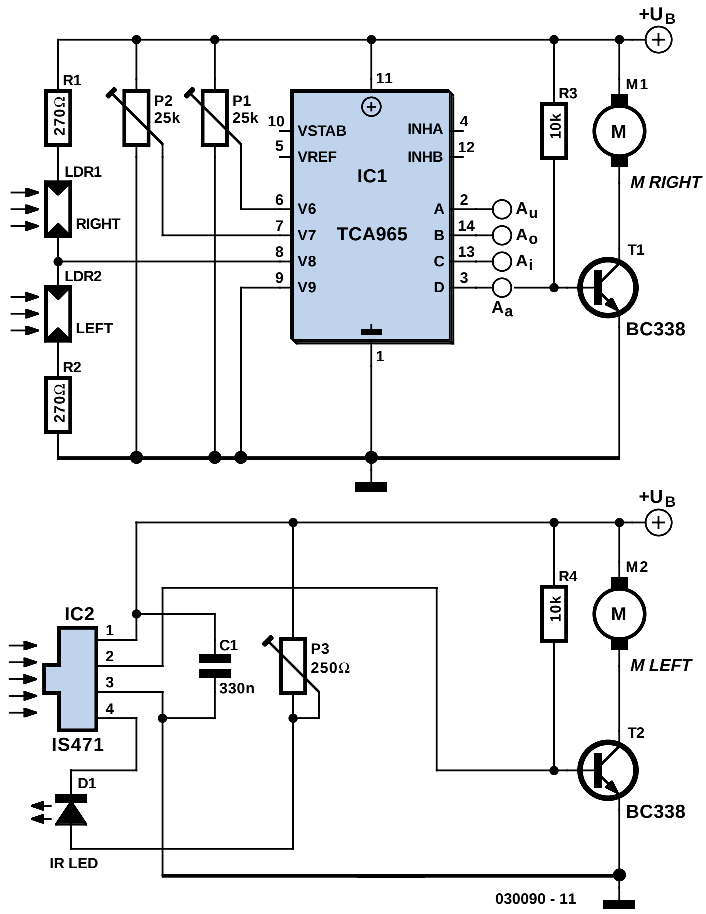
Just to be clear, note that this circuit cannot be used to control inductive loads. T1 is switched asynchronously with the mains frequency and this can cause DC current to flow. Electronic lamps, such as the PL types, cannot be dimmed with this circuit either. These lamps use a rectifier and internally they actually operate off DC.

A few remarks about the size of R3 and R4. This is a compromise between the lowest possible current consumption (when the lamp is off) and the highest possible duty cycle that is allowed. When the duty cycle is zero, the voltage across the resistors is at maximum, around 128 V with a mains voltage of 230 V. Because (depending on the actual resistor) the voltage rating of the resistor may be less than 300 V, two resistors are connected in series. The power that each resistor dissipates amounts to a maximum of 0.5 W. With an eye on the life expectancy, it would be wise to use two 1-W rated resistors here.

(044041-1)

Discrete Robot

Gerhard Nöcker



This simple robot, which responds to light and avoids obstacles, can be built without using a microcontroller, programmer or PC. The only 'special' component in the circuit is a window discriminator (a fancy version of a window comparator).

Resistors R1 and R2 in combination with light-dependent resistors LDR1 and LDR2 form a voltage divider (with the current being limited by R1 and R2 for bright light). Window discriminator TCA965 compares the mid-point voltage with an upper threshold value (adjustable using P1) and a lower threshold value (adjustable using P2). Outputs A_U, A_I, A_O, and A_A go High if the voltage lies below, inside, above or outside this window, respectively; otherwise they remain Low. Output A_A switches transistor T1, which drives the right-hand motor. The light-dependent resistors can be attached on the left and right sides of the vehicle, or at the front and rear. This causes the robot to turn to the right, due to the motor on one side being stopped, until the desired lighting relationship is restored. The vehicle will then continue to travel in a straight line until the lighting relationship again changes, at which point it will again turn, and so on.

You can experiment with various behaviour patterns by using the other outputs of the window discriminator. If a transistor is provided for each of the A_U and A_O outputs of the TCA965, the robot can be made to travel toward or away from a light source, depending on the connections. Using the window discriminator, the robot will operate under the rules of a three-point controller (left, straight ahead, or right). If you fit the light-dependent resistors in a box under the vehicle together with a light source, you can try to have the robot follow a black line on a white background.

A reflective IR sensor enables the robot to respond to obstacles. This not as simple as it might seem, since the Sharp IS471 operates the IR LED with pulsed light and uses sophisticated detection processing. When an obstacle is detected, the output (pin 2) goes Low and blocks transistor T2. This causes the motor to stop, and the vehicle will rotate about the stationary wheel until the obstacle is no longer in its path. The sensitivity of the IS471 can be set using P3. As its range is only around 10–15 cm, the vehicle must not travel too quickly, since otherwise it will not be able to avoid obstacles in time.

This part of the circuit is also open for experimentation. If a relatively large and fast robot requires an obstacle detector (or isn't fitted with the IS471), an ultrasonic detector can also be used. Suitable complete construction kits are available from Conrad, for example. You can also fit a suitable mechanical pushbutton switch mounted on a flexible rod. The obstacle detector can also drive a warning buzzer or a lamp; the circuit leaves lots of room for your own ideas.

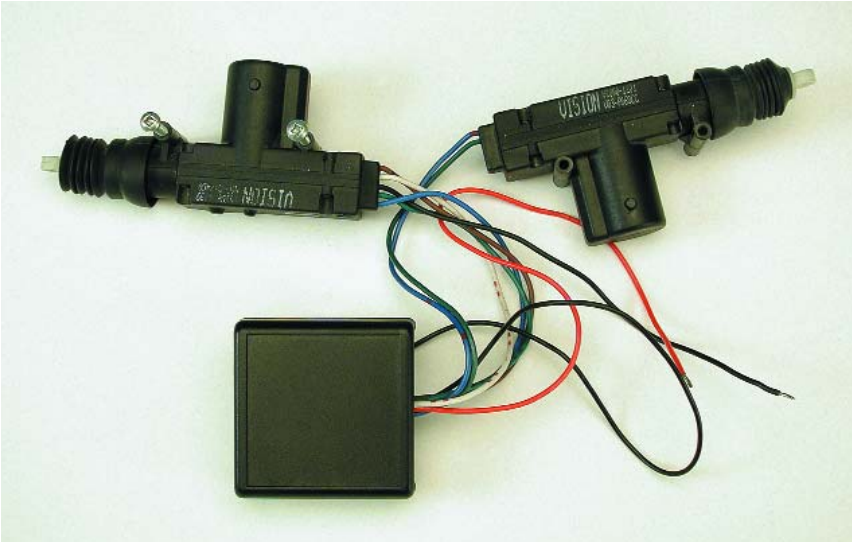
The circuit works over a wide range of supply voltages from 4.5 to 16 V. If larger motors are used, transistors with increased power-handling capacity and heavier batteries are necessary. The author connected two 4.8-V rechargeable batteries in series and used BC388 transistors as drivers for Lego micromotors. You can build the robot entirely according to what you have in your parts box. The mechanical elements can also be freely selected, but they partially determine the behaviour and operation of the robot. The author's robot is made from a Lego chassis with a prototyping board holding the circuitry attached using elastic bands. The motors are fitted on the left-hand and right-hand sides. The third wheel at the front can turn freely.

One problem must be mentioned: if an obstacle is detected while an incorrect lighting relationship is present, the vehicle remains standing. In this case, a bit of logic could be added to cause both motors to rotate in reverse. However, that would require directional switches for the motors or motor driver ICs (L293D). The simple circuit would become more complicated and larger, and at some point you would end up using a microcontroller after all — but that's just the point of the story.

(030090-1)

Car Central-Locking System

Christian Vossen



For a few pounds you can buy a kit from any automotive accessory shop that will allow your car to be fitted with a central-locking door system. Such a kit essentially comprises a number of motors. There is also a control unit that enables the whole system to function. Here we show an example of such a unit.

There are 5-wire motors and 2-wire motors. The 5-wire version is used in doors that have a key-lock.

There are 2 connections for the motor itself and 3 connections for the sensor part (an 'open' and a 'close' contact). These sensors determine whether the door is to be unlocked or locked. If there is no key lock in the door, these sensors are superfluous and a 2-wire motor can be used.

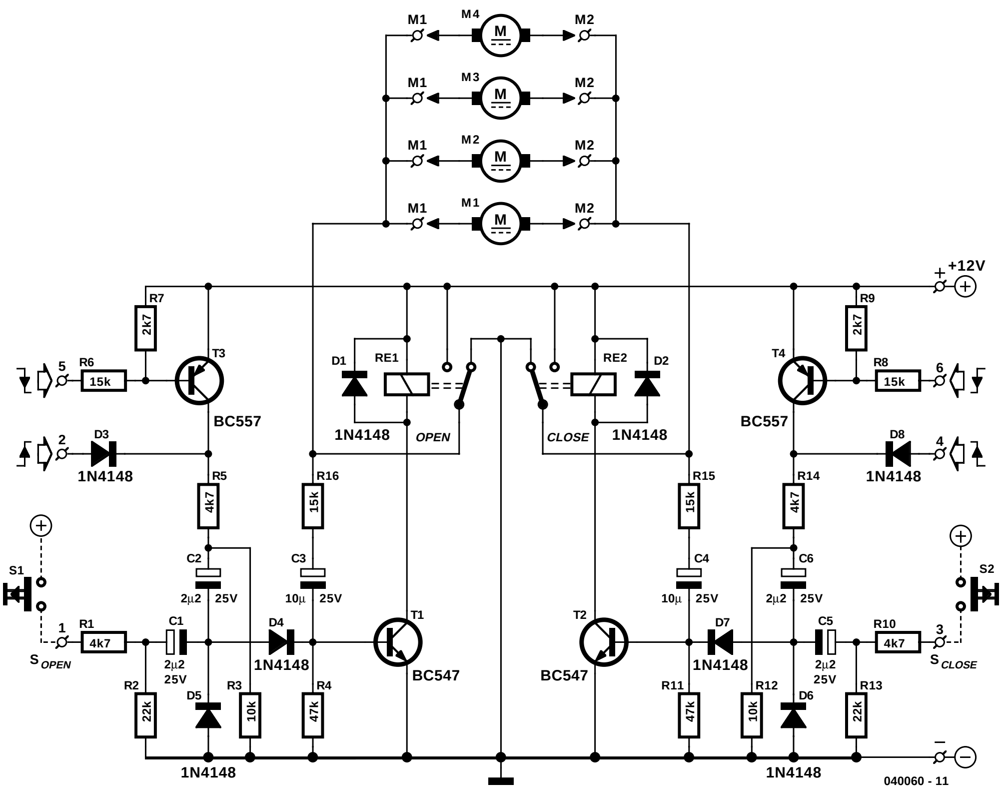
The polarity of the motor determines whether the locking mechanism goes up or down. By making a circuit that simply reverses the polarity of the motor, the door can be either locked or unlocked.

The winding of the motor is connected between M1 and M2 in the schematic. When relay Re1 is energised, all motors will, for example, rotate anti-clockwise. By activating Re2 the motors will rotate clockwise. This depends on the actual polarity of the motor, of course.

The sensors are connected to R1 and R10. Here you have to pay careful attention. If Re1 causes the door to unlock, then Re1 has must obviously be connected to the 'open' contact. In that case, Re2 is for locking the doors and R10 is then connected to the 'close' contact. The R/C-combinations R16/C3 and R15/C4 ensure that the relays are energised for a certain amount of time (obviously this can be changed if this time is too short or too long for your doors). This time has to be just long enough to lock or unlock the doors. The third wire of the sensors is the common and has to be connected to +12 V.

The RC circuits at the inputs S_{open} en S_{close} ensure that the motors are driven only once when the door is locked or unlocked.

In addition, there is a provision to allow the unit to be connected to a car alarm. There are two types of alarm available,



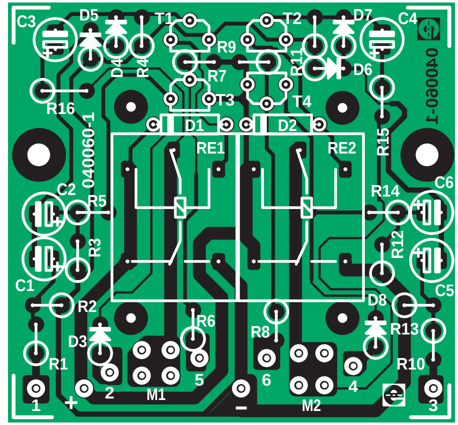
with positive or negative control. In order to make the unit universally applicable, both types of alarm can be used. The circuit around T3 and T4 makes this possible. The diode inputs (D3 and D8) react to a rising edge, R6 and R8 react to a falling edge. An RC time constant is used here as well to ensure that both relays are energised only once.

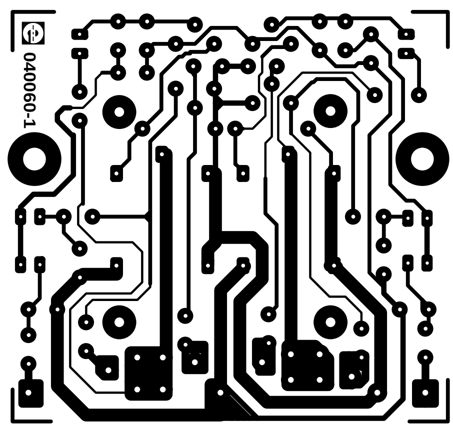
Maybe this is stating the obvious: a motor unit has to be built into each door. All motor wires and sensor wires are connected in parallel to the electronics.

The actual type of relay is not critical. The type indicated has the following properties: coil 12 V/400 Ω; max. switching current 12 A (AC), max. switching power 1200 VA.

Finally, a car is a hostile environment for electronics. Ensure good connections, use automotive connectors and crimp these on the wires using the appropriate crimping tool. Solder connections in wires are best avoided. They have the tendency to break where the wire transitions into the solder connection when the wire is subject to vibration. Fasten the wires at regular intervals.

(040060-1)





COMPONENTS LIST

Resistors:

R1,R5,R10,R14 = 4kΩ7
R2,R13 = 22kΩ
R3,R12 = 10kΩ
R4,R11 = 47kΩ
R6,R8,R15,R16 = 15kΩ
R7,R9 = 2kΩ7

Capacitors:

C1,C2,C5,C6 = 2µF2 25V radial
C3,C4 = 10µF 25V radial

Semiconductors:

D1-D8 = 1N4148
T1,T2 = BC547B
T3,T4 = BC557B

Miscellaneous:

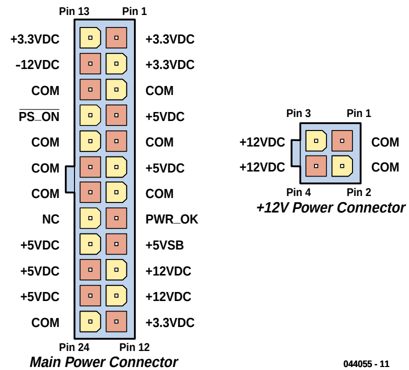
RE1,RE2 = PCB mount relay, 12 V, 1 x changeover, size 19x15.5x15.5 mm (e.g. Conrad Electronics # 504289)
PCB, order code 040060-1 from The PCBShop

BTX

Karel Walraven

What did you say BTX was again? Well, it's just the successor of ATX! ATX is the collective term for the electrical and mechanical characteristics of the present generation of motherboards in your PC. There is now a new standard in its place, BTX (**Balanced Technology eXtended Form Factor**), with the main advantages of more compact dimensions and better heat removal. When grouping the components on the PCB, careful attention is paid to power dissipation and the possibility of efficiently removing the heat. This is necessary because the CPU meanwhile needs to dissipate 100 W and a respectable video card can easily dissipate 50 W. That is why there has to be serious consideration of how the heat can be removed from the case, where wide cables and other obstacles are no longer allowed to be in the way (also refer to SATA elsewhere in this issue). That the energy consumption is continually increasing can be deduced from the ever more powerful PSU units. While 10 years ago a 150-W power supply was quite adequate, these days 350 or 400 W is the norm. With the BTX standard, there is the assumption of a fan for the power supply (just as before), but also a separate second cooling circuit for the motherboard, drawing in cold air from outside the case and blowing out warm air via a separate path, completely independent of the fan in the power supply.

BTX power supplies will also be able to supply more power. There is a new standard for the power supply connector that increases the number of pins from the current 20 to 24 ('Main power connector'). The first 20 pins keep the same functionality as with ATX motherboards (only -5 V has been omitted!). The extra 4 pins are for more 3.3-V, 5-V and 12-V connections (refer figure). In addition, there has to be a separate 4-way connecter ('+12 V power connector') that's intended to power the CPU only.



(044055-1)

5 volts from the Mains

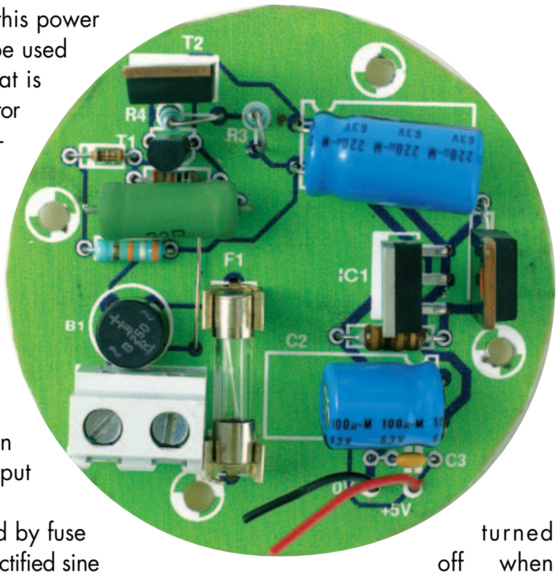
Paul Goossens

Sometimes we would like to hide certain equipment to prevent cluttering up our living room or any interior in general. A number of devices lend themselves to be built into a wall adapter. Think of a remote-control extender, for example.

All these devices need a power supply and we would prefer to use the mains so that no external connections are required for the power supply.

The power supply in this article is intended for exactly these situations, namely converting the mains voltage to a 5-V power supply voltage. The accompanying PCB fits exactly in a round wall socket enclosure.

A power supply is usually fitted with a transformer to reduce the voltage and also provide galvanic isolation between the device and the mains. In this power supply a transformer cannot be used because of lack of space. That is why we use a step-down regulator here. A problem with most step-down regulators is that they cannot be supplied directly from the mains. Hence, in this schematic (**Figure 1**) we first create a rough power supply voltage of around 40 V using passive components and subsequently present it to step-down converter IC1. The converter can operate from a maximum input voltage of 45 V.



The mains voltage is first fused by fuse F1 and then converted to full rectified sine wave by the bridge rectifier.

FET T2 is used as a switch, which is turned off when the voltage is greater than 40 V. The gate of T2 is driven via R3 and R4. As soon as the voltage exceeds the value of 40 V, transistor T1 will conduct which causes the gate-drain voltage of T2 to be so small that T2 stops conducting. Because of this, electrolytic capacitor C1 cannot charge any further and the maximum voltage across C1 is therefore limited to about 40 V.

This voltage is converted by IC1 and surrounding components to a 5-V power supply voltage. The maximum output current is 1 A.

The PCB (**Figure 2**) that has been designed for the power supply fits, as mentioned before, in a round wall socket enclosure. Note that resistor R1 and the link have to be soldered first, then comes R5, in the air above R1 because of the tight space.

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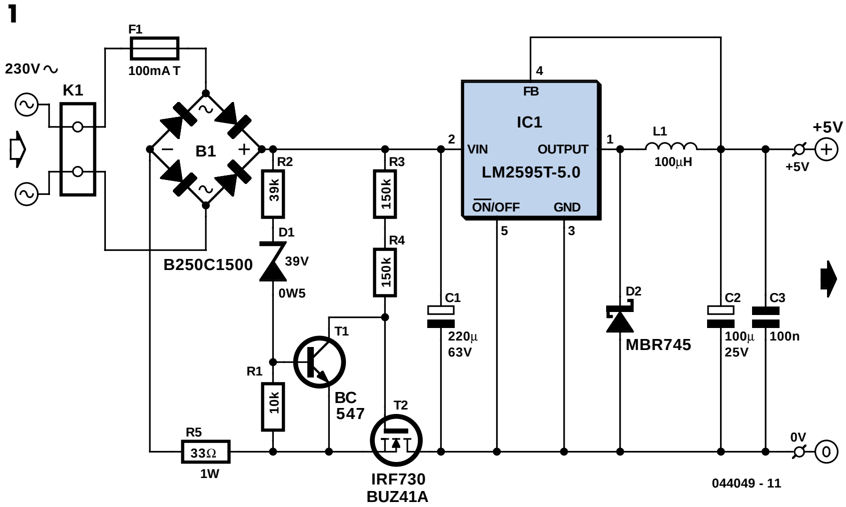

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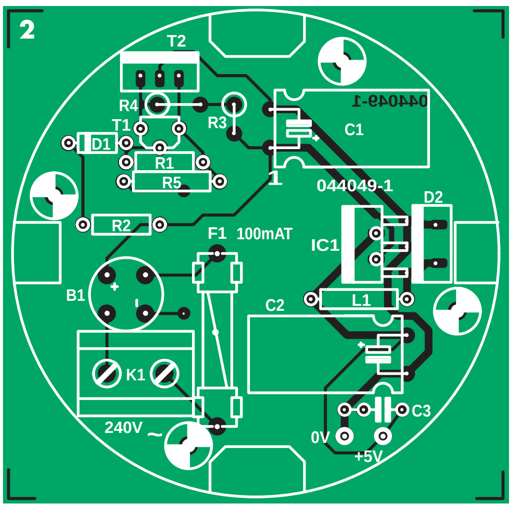

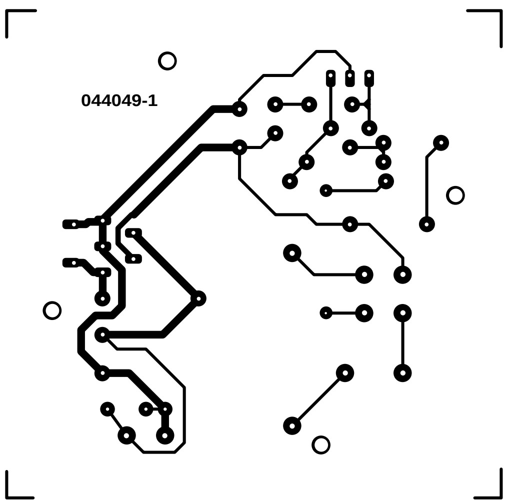

Populating the remainder of the PCB should not present any difficulties. When mounting the PCB, do note that it is directly connected to the mains, so make sure no conductive parts can be touched when the circuit is in use. The mounting holes are separated less than 6 mm from the PCB traces so the board has to be secured with plastic screws in order to satisfy the safety requirements. Also, after fitting the board, a cover has to be mounted over the PCB so that it is impossible to touch the PCB when the wall socket is opened. As always, you cannot be too careful when dealing with mains voltages!

(044049-1)

COMPONENTS LIST

Resistors:
R1 = 10kΩ
R2 = 39kΩ
R3,R4 = 150kΩ
R5 = 33Ω

Capacitors:
C1 = 220µF 63V radial
C2 = 120µF 25V radial
C3 = 100nF

Semiconductors:
B1 = B250C1500, round case
D1 = zener diode 39V, 0.5W
D2 = MBR745
IC1 = LM2595T-5.0
T1 = BC547B
T2 = IRF730 or BUZ41A

Miscellaneous:
F1 = fuse, 100 mAT (slow), with PCB mount holder and cap
K1 = 2-way PCB terminal block, lead pitch 7.5mm
L1 = 100µH choke
PCB, available via The PCBShop

I²C and SMBus

Paul Goossens

The I²C-bus has been dealt with before in *Elektor Electronics*. Most readers will know that this bus requires only two signals to communicate between, for example, a controller and one or more ICs in a circuit. We may also assume that it is well known that this bus was developed by Philips and is used mainly in televisions, video recorders, tuners, etc.
Unfortunately, the I²C-bus lacks a number of features that manufacturers of computer motherboards require. They therefore developed their own bus, which has been derived from the I²C-bus. This bus goes by the name SMBus (System Management Bus). The main task for the protocol is to provide communications between the processor and various temperature sensors, battery management/charging-chips and even memory modules, etc. in a PC. Because the SMBus has been derived from the I²C-bus, there are obviously a number of similarities. It is in many cases even possible to let components with an I²C-bus communicate with those with an SMBus and vice versa.

The similarities

Both bus protocols make use of the same start and stop mechanism. A start-condition can be recognised by the falling edge on the data line while the clock line remains high. With a stop-condition, a rising edge appears on the data line while the clock line is high. These two conditions are the only situations where the data line may change level when the clock line is high. This can be seen in **Figure 1**.

Following the start condition there is the 7-bit address that has to be unique for each device connected to the bus.
Another similarity is that the bus has a single pull-up resistor for each signal and the connected chips drive these signal lines with an open-source output, as can be seen in **Figure 2**. This forms a so-called wired-OR configuration. As soon as one of the chips pulls a signal line to ground, the signal will have a low level, irrespective of what the other chips try to do.

The differences

Naturally there are also a number of differences between the two protocols. We start with the clock speed. With I²C-bus this can vary from 0 to 100 kHz in NORMAL mode and up to 400 kHz in FAST mode. With the SMBus, the clock speed has to be between 10 kHz and 100 kHz. The minimum speed is the result of an additional provision of the SMBus. If the clock line is low for more than 35 ms a time-out situation occurs. All chips on the bus have to detect this time-out and ignore all communications until a valid start-condition occurs. This prevents one chip from disabling the entire communication of the bus.

Another difference is the specified levels for logic high and logic low. In the I²C-specifications a low level is defined as 1.5 V, while with the SMBus a level less than 0.8 V is required. The high-level is different as well: with I²C this has to be a minimum of 3 V, while with the SMBus a level of 2.1V or higher is considered a high level.

This difference in the required voltage levels would indicate that both protocols cannot be used with each other. In practice this is not so much of a problem, since most chips will generate signals that range from about zero to nearly the power supply voltage.

The outputs of an SMBus IC are specified to be able to sink at least 100 µA, while I²C requires a minimum sink current of

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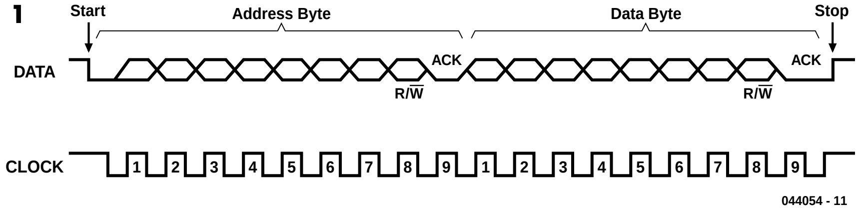

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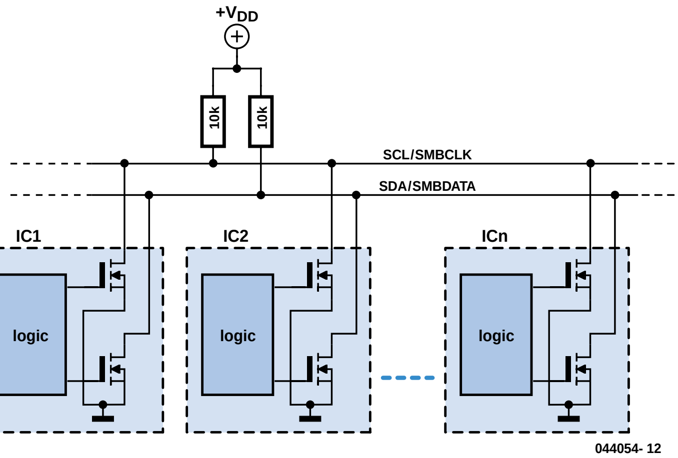


Finding the correct signals in a PC

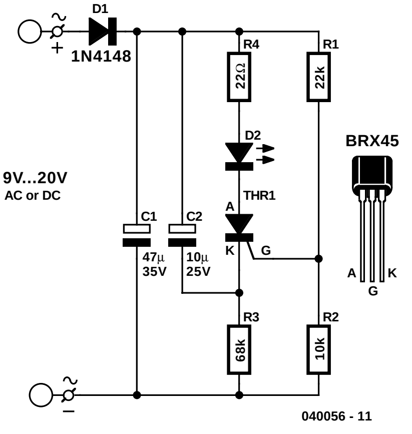
To experiment (at your own risk!) with the SMBus (and I²C) it is necessary to find the signals Vcc, GND, SMBCLK and SMBDATA in the PC. The easiest place to find these signals is on the memory modules. Every memory module has besides the memory chips a small EEPROM, which contains the necessary information about the memory module for the BIOS. These EEPROMs all communicate via the SMBus. This is therefore the ideal location to tap into the required signals.

3 mA. All this is related to the fact that the SMBus is also used in laptops and therefore have to be a little thrifty with power consumption. This means a higher pull-up resistor is required. A value of 10 kΩ is usually a good starting value so that both SMBus-ICs and I^2C-ICs can communicate together on the same bus.

There are also a number of subtle differences, such as maximum bus capacitance, rise- and fall-times, etc, but nothing that will prevent you from connecting an I^2C chip to the SMBus or the other way around.

(044054-1)

Unusual LED Blinker



Robert Edlinger

This LED blinker manages with only a few components and is dimensioned to operate from an ac supply in the range of 4–16 V (6–24 V dc). As its current consumption is less than 1 mA, it's also suitable for long-term battery-powered operation. It thus offers several advantages in various applications, compared with using the well-known 555 timer IC as an astable multivibrator. Depending on the values of the timing components, the blinking rate ranges from 1 to 1.5 Hz. Although the duration of each blink is only a few milliseconds, a high brightness level is achieved by using a relatively high LED current. There are numerous potential applications for this circuit in model railway systems, in both stationary and moving equipment.

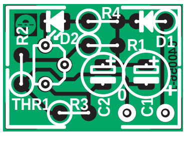
An small, inexpensive thyristor serves as an oscillator. Voltage divider R1/R2 holds the voltage on the gate lead (G) to approximately 20 % of the supply voltage. Capacitor C2 charges via R3. This causes the voltage on the cathode (K) to drop until it is around 0.5 V to 1 V below the gate voltage (depending on the thyristor type), at which point the gate current is sufficient to trigger the thyristor.

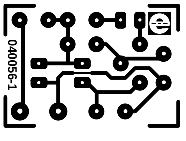
Capacitor C2 then discharges via the cathode-anode junction, R4 and the LED. The only purpose of R4 is to limit the LED current to a permissible value. After C2 has discharged, the cathode–anode junction is again cut off, since the resistance of R3 is so high that the sustaining current level (which is less than 5 mA for the BRX45–57 family) is not achieved. The next blink cannot occur until C2 has again charged.

The blinking rate can be adjusted over a wide range by varying the values of R3 and/or C2. The listed thyristor is recommended for use in this circuit due to its high gate current sensitivity (<0.2 mA). Practically any model railway transformer or bell transformer can be used as a power source. A half-wave rectifier and small filter capacitor are adequate for rectifying the supply voltage.

The components can be fitted to a small printed circuit board or a small piece of perforated board. The blinker can also be powered from a dc source (5–24 V). In that case, D1 provides reverse-polarity protection.

(040056-1)





COMPONENTS LIST

Resistors:
R1 = 22kΩ
R2 = 10kΩ
R3 = 68kΩ
R4 = 22Ω

Capacitors:
C1 = 47µF 35V
C2 = 10µF 25V

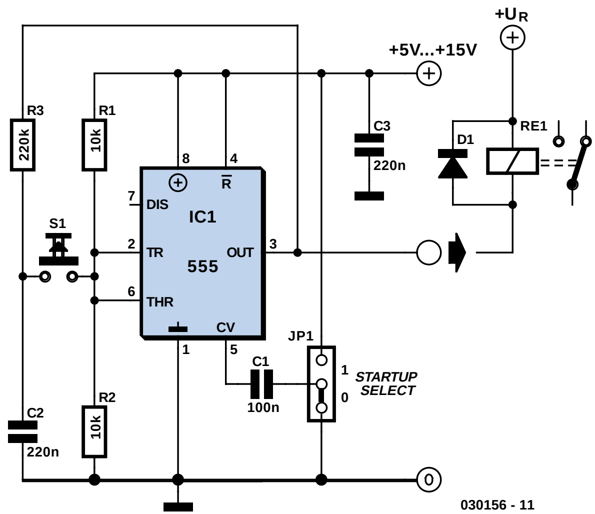
Semiconductors:
D1 = 1N4148
D2 = low-current LED
THR1 = BRX45

Miscellaneous:
PCB, order code 040056-1 from The PCBShop

On/Off Button

Ger Langezaal

It features at least once in every Small Circuits collection: the 555 timer. In this simple circuit we give the chip a little more attention than usual (refer to 'The Eternal 555' in the July/August 2004 issue). It is astonishing what can be built with a 555. Here at *Elektor Electronics* we are always infatuated with simple circuits using this IC, such as the one shown here. The 555 is used here so that a single pushbutton can operate a relay. If you press the button once, the relay is energised. When you press it again the relay turns off. In addition, it is possible to define the initial state of the relay when the power supply is switched on.



The design is, as previously mentioned, very simple. Using R1 and R2, the threshold and trigger inputs are held at half the power supply voltage. When the voltage at the threshold pin becomes greater that 2/3 of the power supply voltage, the output will go low. The output goes high when the voltage at the trigger input is less than 1/3 of the power supply voltage.

Because C2, via R3, will eventually have the same level as the output, the output will toggle whenever the pushbutton is pressed. If, for example, the output is low, the level of the trigger input will also become low and the output will go high!

C1 defines the initial state of the relay when the power is applied. If the free end of C1 is connected to V_{CC}, then the output is high after power up; the output is low when C1 is connected to ground.

(030156-1)

NiMH Charger for up to six Cells

Paul Goossens

It is impossible to imagine present day society without any batteries. Count the number of gadgets in your house that are powered from batteries, you will be stunned by the number of batteries you will find.

The majority of these devices use penlight batteries and if you're a little environmentally conscious you will be using rechargeable batteries. A few years ago these batteries were invariably NiCd types. However, these batteries suffer from a relatively high rate of self-discharge and from the so-called memory-effect. It is now more common to use NiMH batteries. The advantage is that these batteries do not suffer from the memory-effect and generally also have a much higher capacity, so that they last longer before they have to be recharged again.
From the above you can conclude that every household these days needs, or could use, a battery charger. A good charger needs to keep an eye on several things to ensure that the batteries are charged properly. For one, the charger has to make sure that the voltage per cell is not too high. It also needs to check the charging curve to determine when the battery is fully charged. If the charging process is taking too long, this is an indication that something is wrong and the charger must stop charging. Sometimes it is also useful to monitor the temperature of the cells to ensure that they do not get too hot.

The circuit presented here is intended for charging NiMH batteries. The MAX712 IC used here contains all the necessary functionality to make sure that this happens in a controlled manner. **Figure 1** shows the schematic of the charger. The heart of the circuit is easily recognised: everything is arranged around IC1, a MAX712 from Maxim. This IC is available in a standard DIP package, which is convenient for the hobbyist because it can be directly fitted on standard though-hole prototyping board.
IC1 uses T1 to regulate the current in the battery. R1 is used by IC1 to measure the current. While charging, IC1 attempts to maintain a constant voltage, equal to 250 mV, across R1. By adjusting the

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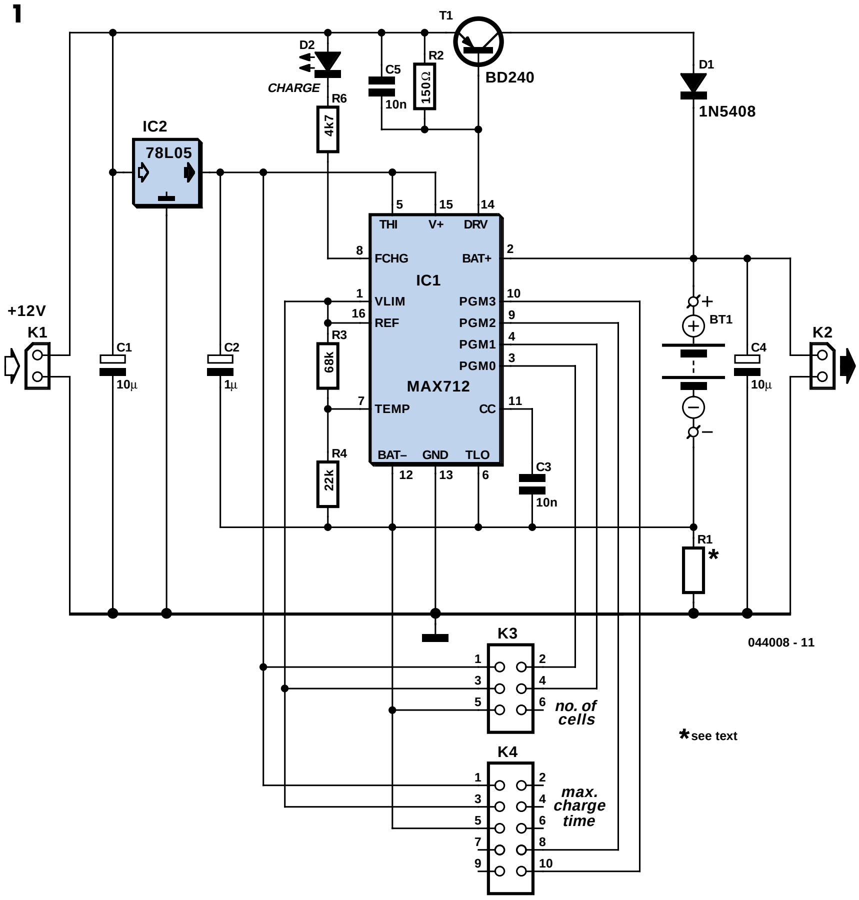

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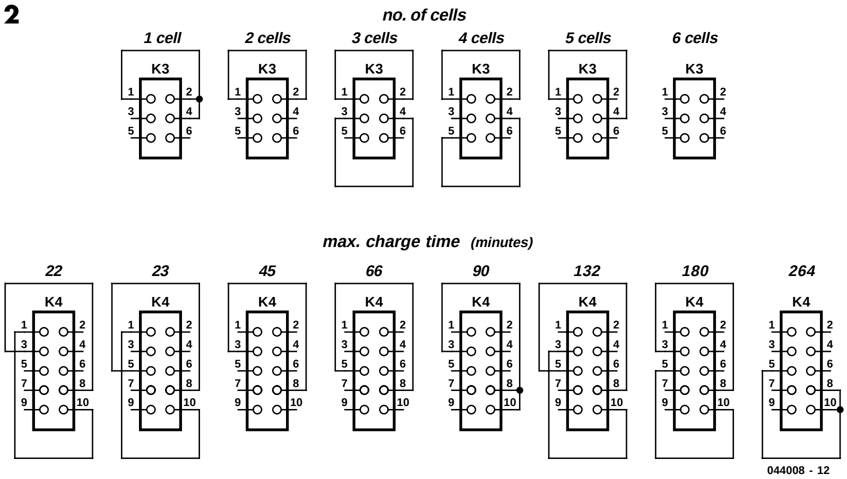

value of R1 the charging current can be set. The value of R1 can be calculated using the formula below:

$R1 = 250\ \text{mV} / I_{\text{charge}}$

For a charging current of 1 A, the value of R1 has to be 250 mV / 1 A = 0.25 Ω. The power dissipated by R1 equals $U \times I = 0.25 \times 1 = 250$ mW. A 0.5-watt resistor will therefore suffice for R1.
Transistor T1 may need a small heatsink depending on the charging current and supply voltage.
IC1 needs a small amount of user input regarding the maximum charging time and the number of cells in the battery to be charged. IC1 has four inputs, PGM0 to PGM3, for this purpose. These are not ordinary digital inputs (which recognise

only 2 states) but special inputs that recognise 4 different states, namely V+, Vref, BATT– or not connected. To make this a little bit more user friendly, we've brought out the necessary connections to 2 connectors (K3 and K4). A number of dongles have been made (**Figure 2**) that can be plugged into these connectors and set the number of cells and the maximum charging time.

When determining the maximum charging time we have to take into account the charging current and the capacity of the cells that are connected. The charging time can be calculated with the formula:

$$T_{charge} = C_{cell} / I_{charge} \times 1.2$$

where C_{cell} is the capacity in Ah (e.g., 1200 mAh = 1.2 Ah).

After the nominal charging time has been calculated, we can use the first dongle that has a value that is equal or greater than the calculated charging time. For example, if we calculated a maximum charging time of 38 minutes, we have to select the dongle for 45 minutes.

When IC1 is replaced by a MAX713, the charger becomes suitable for charging NiCd batteries (but not suitable for NiMH batteries any more!). The only difference between these two ICs is the value of the detection point at which the cell(s) are considered to be completely charged. The ICs are otherwise identical with regard to pin-out, method of adjustment, etc. To make it easy to swap between the ICs, we recommend an IC-socket for IC1.

(044008-1)

On-Train Radio Camera

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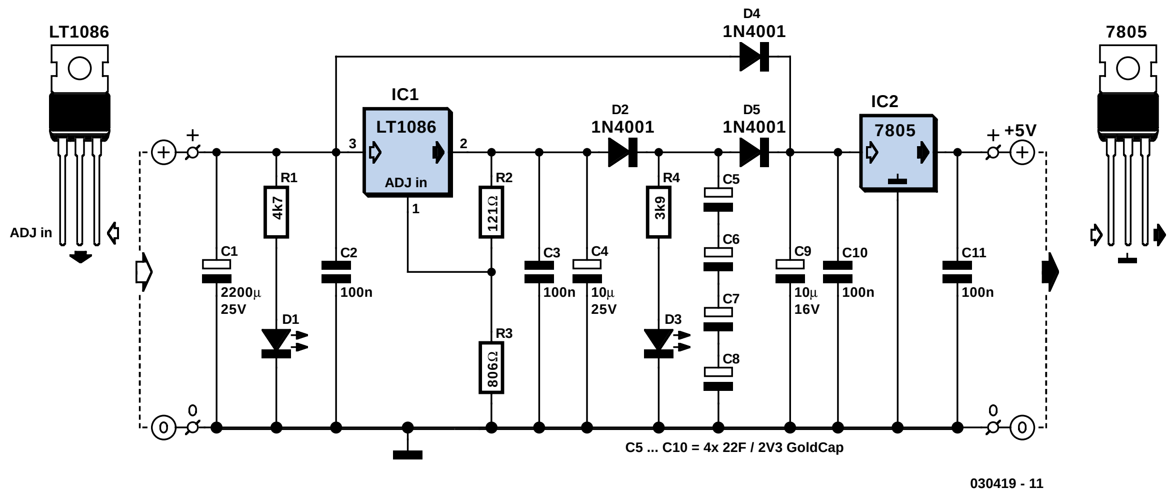


Bernd Oehlerking

A radio camera on a model railway should transmit constantly while the train is moving and continue transmitting for a few minutes after the train stops. But if the train starts up again after a relatively long halt, imagery should be transmitted immediately. Consequently, the power source for the camera cannot be rechargeable batteries (since they take too long to charge), nor can it be primary batteries (for environmental reasons). Instead, GoldCaps provide a good alternative. They can be charged in no time flat, and they assure sufficient reserve power for operating the radio camera for a few minutes.

Coming from the left in the schematic shown in **Figure 1**, the dc voltage arrives at the supply circuit and is buffered by capacitor C1, which bridges brief power interruptions.

The actual reserve power source consists of four GoldCaps connected in series, each rated at 22 F / 2.3 V, which yields a net capacitance of 5.5 F / 9.2 V. The maximum charging voltage must never exceed 9.2 V. This is ensured by a modern adjustable low-drop voltage regulator (LT1086), which is set to a nominal output voltage of 9.57 V by resistors R2 and R3 (since there is an 0.6-V voltage drop across D5). The LT1086 can handle a current of 1.5 A (with current limiting), so even completely empty GoldCaps can be charged in a few seconds. Whenever the dc voltage is present, the GoldCaps are charged via D2.

When the dc voltage is present, the camera is not powered from the GoldCaps, but instead directly from the track via D4. Diode D5 prevents this voltage from reaching the bank of capacitors, and D4 prevents the GoldCaps from discharging via the track when no voltage is present on it. D4 and D5 thus form a sort of OR gate.

The radio camera used by the author requires 5 V and draws a current of approximately 70 mA. This means the circuit must have an output stage consisting of a 'normal' 7805 fixed voltage regulator and the usual capacitors (C9 C10, C11).

The two low-current LEDs respectively indicate whether voltage is present on the track and whether the storage capacitors are charged. They can also be omitted.

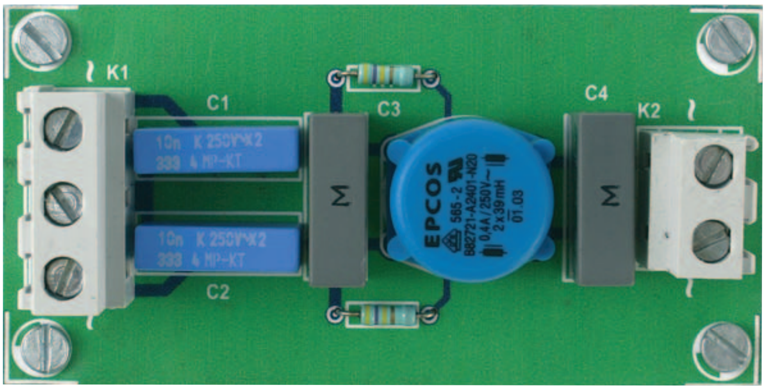
The 100-nF capacitors must be placed as close as possible to the voltage regulators.

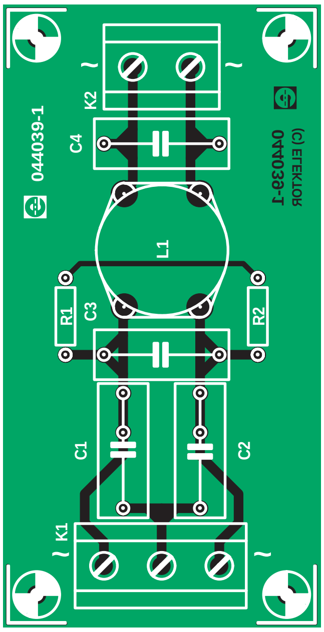
(030419-1)

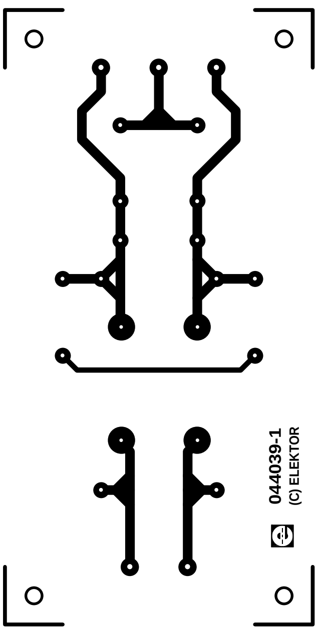
Universal Mains Filter

Ton Giesberts

There are plenty of mains filters available, with or without sockets, with or without a switch, etc. In any case, this filter is very versatile as far as the maximum working current is concerned. It so happens that the footprint of the coil remains the same for different currents. Depending on the required specification, you can use a specific coil (which the manufacturer calls a 'Current-Compensated Ring Core Double Choke').



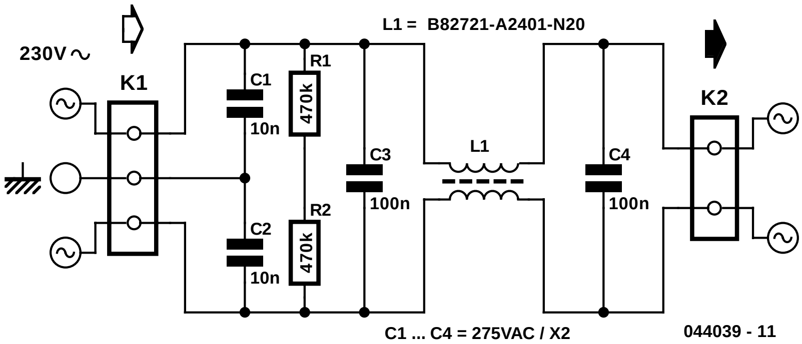




The table below lists a suitable range of coils made by Epcos. When we designed the PCB we chose the smallest size that still gave a wide selection of maximum currents.

Be careful that you don't use a vertical version of the coil. These appear to be pin-compatible, but they have different connections. They would cause a severe short-circuit on this PCB! For this reason we haven't included them in the table (they have a K instead of an A in their order code).

This filter is suitable for use up to 3.6 A (a good 800 VA). In practice there should be no need to use different val-



I_R (A)	L_R (mH)	$L_{S,typ.}$ (µH)	$R_{S,typ.}$ (mΩ)	Ordering code horizontal version
0.4	39	450	2000	B82721-A2401-N20
0.4	27	270	1700	B82721-A2401-N21
0.5	18	260	1500	B82721-A2501-N1
0.7	10	90	600	B82721-A2701-N20
1.2	6.8	70	280	B82721-A2122-N20
1.5	3.3	37	190	B82721-A2152-N1
2.0	1.0	13	90	B82721-A2202-N1
2.6	0.4	6	60	B82721-A2262-N1
3.6	0.4	6	35	B82721-A2362-N1

ues for the capacitors. You should make sure that you obtain the correct lead spacing and that they're X2 types. For the 100 nF capacitors provision is only made for a lead spacing of 15 mm (as these are the most common). For the 10 nF capacitors you can use either 10 or 15 mm types.
A final warning: always take great care when working with mains voltages!

(044039-1)

COMPONENTS LIST

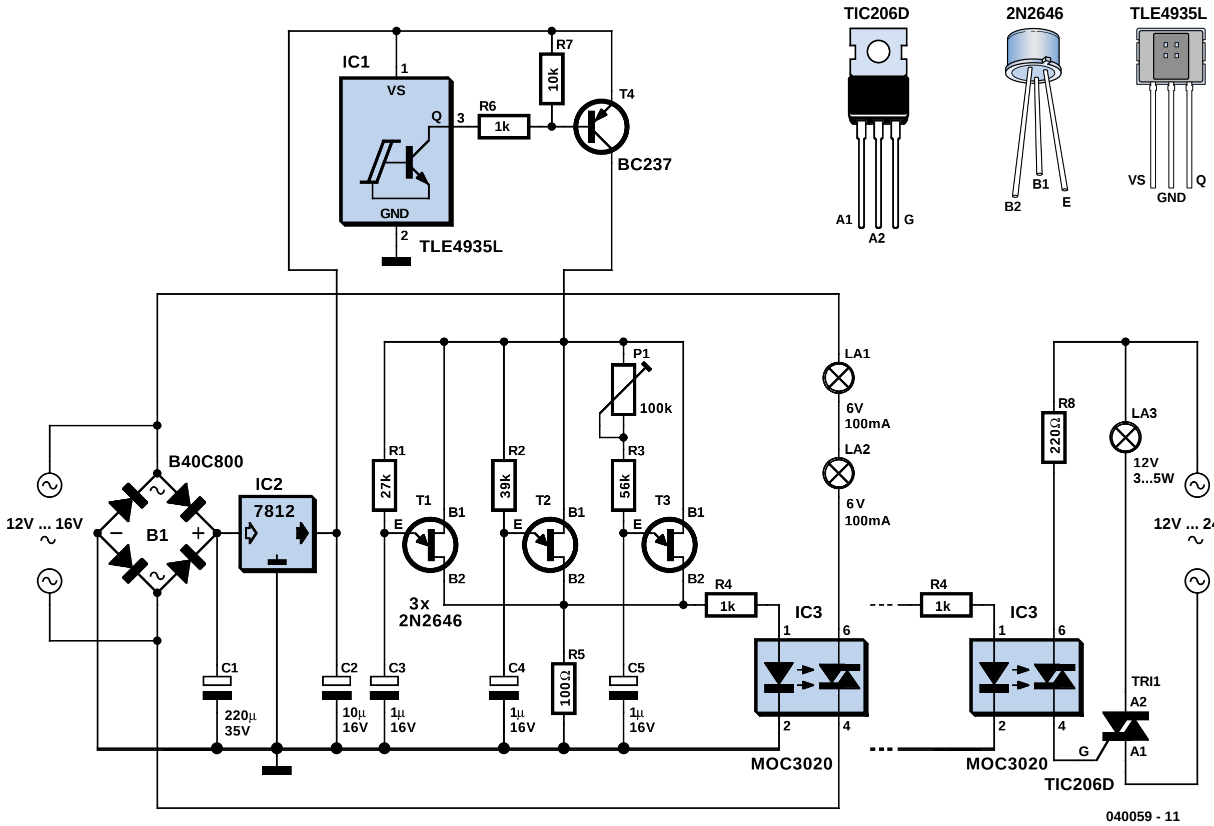
Resistors:
R1,R2 = 470kΩ

Capacitors:
C1,C2 = 10nF 275 V_{AC} X2, lead pitch 10 or 15mm
C3,C4 = 100 n/275 V_{AC} X2, lead pitch 15mm

Inductors:
L1 = B82721-A2401-N20, Epcos (Farnell 976-477)

Miscellaneous:
K1 = 3-way PCB terminal block, lead pitch 7.5mm
K2 = 2-way PCB terminal block, lead pitch 7.5mm

Flickering Light II



Robert Edlinger

In the July/August 2004 issue we published a flickering light for use in models that uses a microcontroller to minimise the component count. Regardless of whether you want to effectively imitate a house fire, a campfire, or light from welding, the circuit described here fills the bill without using a microcontroller, although it does use a larger number of components (including some truly uncommon ones).

The circuit is based on three oscillators, which are built using unijunction transistors (UJTs). Each oscillator has a different frequency. The output voltages are mixed, which produces the flickering effect.
A unijunction transistor consists of an n-type bar of silicon between two ohmic (non-barrier) base contacts (B1 and B2). The effective resistance is controlled by the p-type emitter region. The designation 'transistor' is a somewhat unfortunate choice, since it cannot be used for linear amplification. UJTs are suitable for use as pulse generators, monostable multivibrators, trigger elements and pulse-width modulators. If a positive voltage is applied to the emitter (E), the capacitor charges via the resistor. As soon as the voltage on the emitter reaches approximately half the supply voltage (for a 2N2645, the value lies in the range of 56–75 %), the UJT 'fires' and the capacitor discharges via base B1 and the resistor, generating a positive pulse. The UJT then returns to the non-conduct state, and the process just described repeats periodically. The frequency can be approximately given by the formula

$f \approx 1/(RC)$

The frequency is independent of the value of the supply voltage (which must not exceed 35 V). The maximum emitter blocking voltage is 30 V, and the maximum permissible emitter current is 50 mA. The values of resistors R1, R2 and R3 can lie between 3 kΩ and 500 kΩ. If necessary, the frequency can be varied over a range of 100:1 by using a trimpot instead of a fixed resistor.
The frequencies from the three pulse generators are mixed by connecting them to the IR diode of a triac optocoupler via R4. The optocoupler, a type MOC3020, K3030P or MCP3020, can handle a maximum load current of 100 mA. The triac triggers at irregular intervals and generates the desired flickering light in the two small lamps, L1 and L2, which are connected in series to the transformer secondary.

The light effect can be noticeably improved by using a MOC3040, which contains a zero-voltage switch, since it s generates irregular pauses of various lengths when suitable frequencies occur in the individual oscillators. The zero-voltage switch does not switch while the current is flowing, but only when the applied ac voltage passes through zero. An integrated drive circuit (zero crossing unit) allows full half-waves or full cycles to pass (pulse-burst control) Due to the flickering effect arising from its switching behaviour, it is not suitable for normal lighting, but here this just what we want. This version of the optocoupler is also designed for a maximum current of 100 mA.
For a small roof fire or the light of a welding torch in a workshop, two small incandescent lamps connected in series and rated at 6 V / 0.6 A (bicycle taillight

bulbs) or a single 12-V lamp (rated at 100 mA) is adequate. If it is desired to simulate a large fire, a triac (TIC206D, rated at 400 V / 4 A, with a trigger current of 5 mA) can be connected to the output of the circuit and used to control a more powerful incandescent lamp.

As continuous flickering looses its attraction for an interested observer after a while (since no house burns for ever, and welders also take breaks), it's a good idea to vary the on and off times of the circuit. This is handled by a bipolar Hall switch (TLE4935L), which has such a small package that it can fitted between the sleepers of all model railway gauges, including Miniclub (Z Gauge), or even placed alongside the track if a strong permanent magnet is used. If a magnet is fixed somewhere on the base of a locomotive such that the south pole points toward the package of the Hall switch (the flattened front face with the type marking), the integrated npn transistor will switch on and pull the base of the external pnp transistor negative, causing the collector–emitter junction to conduct and provide the necessary 'juice' for the unijunction transistors. If another traction unit whose magnet has it s north pole pointing toward the Hall switch passes a while later, the switch will be cut off and the flickering light will go out. Of course, you can also do without this form of triggering and operate the device manually.

(040059-1)

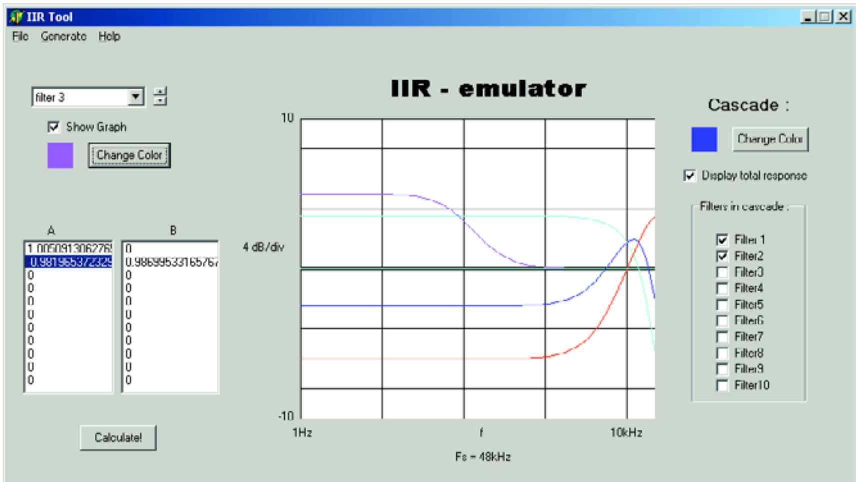
IIR Tool

Paul Goossens

In the digital domain, analogue signals can be easily manipulated without requiring different hardware for each operation (as is necessary for analogue circuits). Other important advantages are that no noise is added during the operation (provided it is programmed correctly) and that mathematical algorithms are easier to implement.
Unfortunately, the design of a digital filter is not that straightforward. There are several methods for implementing a digital filter. A relatively efficient filter implementation is the IIR (Infinite Impulse Response) type. The filter is mathematically represented as:

$$x[n] = a_0 \cdot y[n] + a_1 \cdot y[n-1] \ldots - b_1 \cdot x[n-1] - b_2 \cdot x[n-2] \ldots$$

Where x[n] is the output signal and y[n] is the input signal.
The values of the coefficients a_x and b_x determine the transfer function and therefore the characteristics of the filter. Calculating the coefficients for a particular filter is often a stumbling block for designers. To make this task much easier, we have written a program that not only calculates the coefficients for simple filters, but can also determine the frequency characteristic of IIR filters where the user calculated the coefficients themselves.
This software is available from the Free Downloads section at www.elektor-electronics.co.uk under number **044050-1** (select month of publication). It does not need to be installed — double clicking the filename *IIRTool.exe* is sufficient to launch the program.
This program can simulate up to 10 different IIR filters. As an additional bonus, it is possible to cascade multiple filters in order to examine the total frequency characteristic.
Initially, after starting the program, all filters are set as all-pass and without delay. At the top left you can see that filter1 is

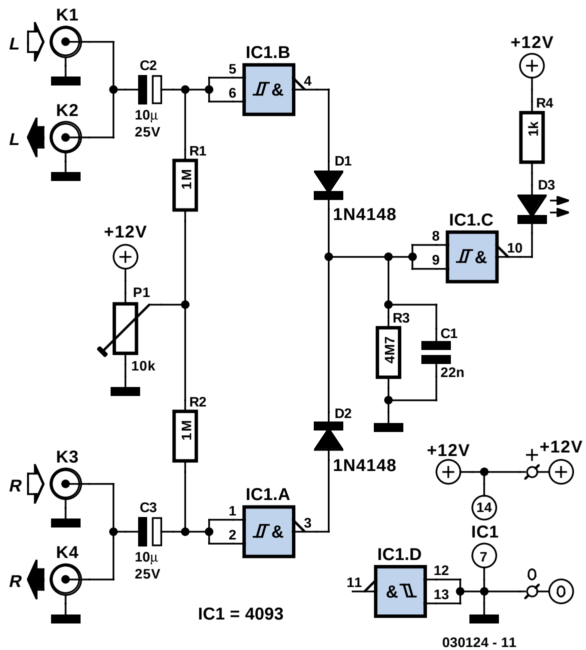


selected. The coefficients that are shown on the screen belong to this filter. To enter your own coefficients for this filter you only need to click the desired coefficient after which you can type in the new value. For example, try changing a_1 (the second value at the top of the column near a) from 0 to 0.5. Immediately after this change you will note that the graph of the frequency characteristic has changed.
At top left you can select another filter. Choose filter2. In the windows below it, the coefficients belonging to filter2 appear. This time change a_1 to –0.5. There now appears a second frequency characteristic. This looks like the reverse of filter1. The colour of each filter curve can be changed by clicking the button *change color*. This makes it easier to distinguish the separate graphs.
In order to know what the total frequency characteristic will look like when a signal propagates through both these filters we can select filters 1 and 2 under the button *cascade*. Another curve will appear in the output window, which is the result of the two filters cascaded.
The program is not only able to simulate filters but can also generate 3 different types of simple filters. These generators can be found under the menu *generate*. Here you can choose from bass-, mid- or treble-filters.
With the bass and treble filter you can choose the cutoff frequency and the desired gain or attenuation. The bass filter provides gain or attenuation of frequencies lower than the cutoff point. The treble filter does the same for frequencies higher than the cutoff point.
A practical example: first select filter number 3, then choose *generate* followed by *bass*. In the window that appears, give the parameter *frequency* a value of 100 and *gain* a value of 5. *Gain* is the location where we enter the gain or attenuation (in dB). Now click the button *OK*. The program will now quickly calculate the required coefficients. As a consequence the coefficients of filter 4 are changed and the result is shown in the graph. Generating a treble filter follows exactly the same method.
Finally, the program can also design a mid filter. This filter provides gain/attenuation of signals around a specific frequency. When entering the parameters you will find, besides *frequency* and *gain*, a third parameter, namely Q. This represents the quality factor of the filter. The higher the Q factor the narrower will be the frequency range of the filter. A Q factor between 0.6 and 2 is typical for audio applications.

(044050-1)

Simple Audio Peak Detector

Flemming Jensen



This audio peak detector allows a pair of stereo channels to be monitored on a single LED.

Identical circuitry is used in the left and right channels. Use is made of the switching levels of Schmitt trigger NAND gates inside the familiar 4093 IC. The threshold level for gate IC1.A (IC1.B) is set with the aid of preset P1, which supplies a high-impedance bias level via R2 (R1). When, owing to the instantaneous level of the audio signal superimposed on the bias voltage by C3 (C2), the dc level at pins 1 and 2 (5 and 6) of the Schmitt trigger gate drops below a certain level, the output of IC1.A (IC1.B) will go High. This level is copied to the input of IC1.C via D2 (D1) and due to the inverting action of IC1.C, LED D3 will light. Network R3-C1 provides some delay to enable very short audio peaks to be reliably indicated.

Initially turn the wiper of P1 to the +12 V extreme — LED D3 should remain out. Then apply 'line' level audio to K1 and K3, preferably music with lots of peaks (for example, drum 'n bass). Carefully adjust P1 until the peaks in the music are indicated by D3.

The circuit has double RCA connectors for the left and right channels to obviate the use of those rare and expensive audio splitter ('Y') cables.

(030124-1)

Thrifty 2-Hz Clock

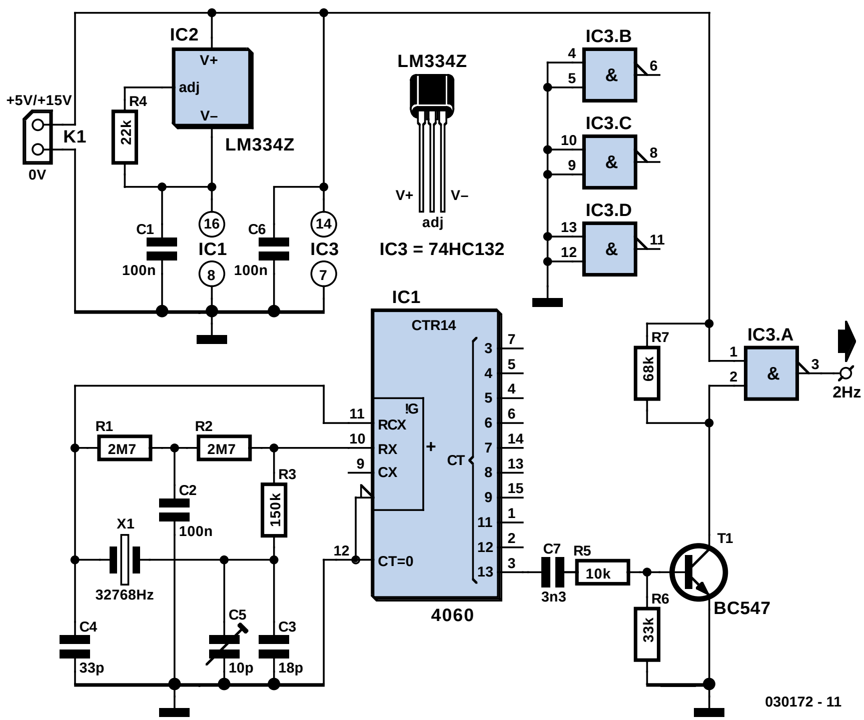
P.C. Hogenkamp

CMOS circuits are known for their low current consumption. This is particularly important for battery-powered circuits. Unfortunately, oscillators often require quite a bit of current. We therefore propose this oscillator circuit that has a very low current consumption (about 3 µA).

The circuit is powered from a type LM334Z current source. The current has been set with R4 to about 3 µA. This is sufficient to power IC1 and the oscillator circuit around X1. The oscillator generates, with the aid of a cheap watch crystal and a few surrounding parts, a signal that is subsequently applied to the divider in the 4060 and results in a frequency of 2 Hz at pin 3 (output Q13).

The level of the output pulses is a lot lower than the nominal 5-V power supply voltage (IC1 is after all powered from a current source with very low current). That is why the signal on pin 3 of IC1 is amplified and inverted by T1. IC3a finally turns it into a proper square wave with acceptably steep edges.

(030172-1)



Voltage Monitor

Paul Goosens

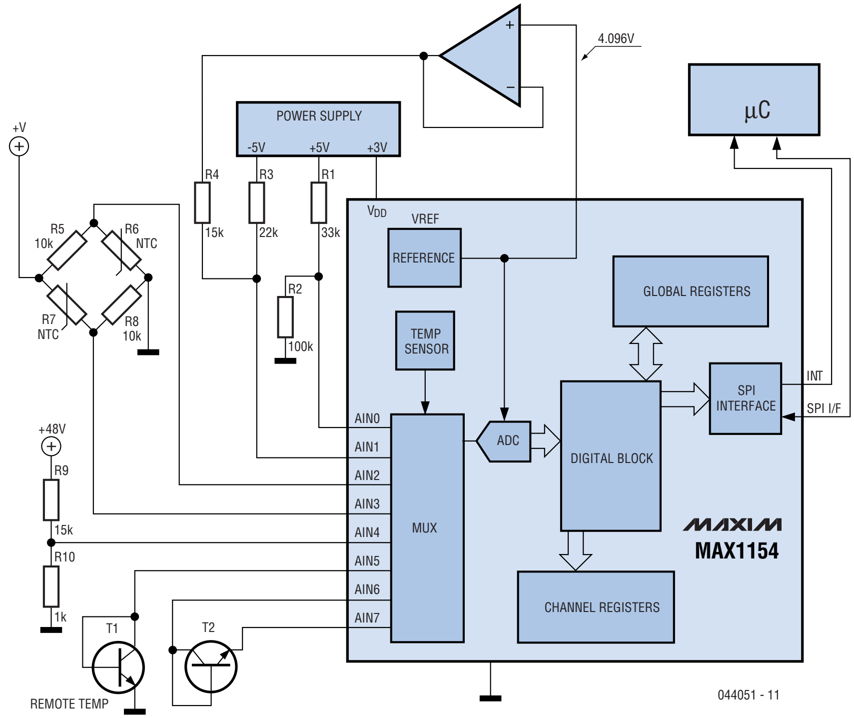
It is often necessary to monitor the power supply voltage in a piece of equipment. When the device takes its power from a battery, the input voltage can change and provide an indication of how much energy is left. Even a device powered from the mains can benefit from keeping an eye on the (various) power supply voltages in the circuit and take the necessary steps in the event of a fault condition.

If a slightly intelligent reaction is required for this situation, it is obvious to do this with a microcontroller. This requires the microcontroller to periodically measure the voltages with one or more A/D converters and decide whether the values are correct or whether something is the matter.

This naturally costs processor time and makes the firmware a little more complicated. This can become a problem, particularly when other functions have to be carried out on a regular basis as well.

Fortunately, chip manufacturer Maxim has a number of ICs in its line-up specifically for this purpose. These ICs all have as task to monitor a number of voltages and when these do not conform to certain requirements the IC generates an interrupt, which indicates to the microcontroller that something has gone wrong.

The MAX1153 and MAX1154 are provided with a 10-bit ADC, while the MAX1253 and MAX1254 are provided with a 12-bit ADC. All these ICs are capable of monitoring 8 external voltages and



2 internal voltages. These 8 external voltages can also be programmed for temperature sensors, where an external diode can be used as a simple and cheap sensor.

For each channel, a maximum and minimum voltage or temperature can be specified. As soon as the input voltage or temperature falls outside this range the interrupt output goes low. If desired, a glitch suppressor can be individually configured for each channel. A recursive averaging filter is also available and it is even possible to specify how many successive samples have to be outside the range before the interrupt is generated. The sample-rate of the ADC is also adjustable, to a maximum of 90 ksamples/s.

The SPI bus serves as interface to the controller and requires only four signals to communicate. For more information you can visit the Maxim website:

www.maxim-ic.com

(044051-1)

On-line Conversions

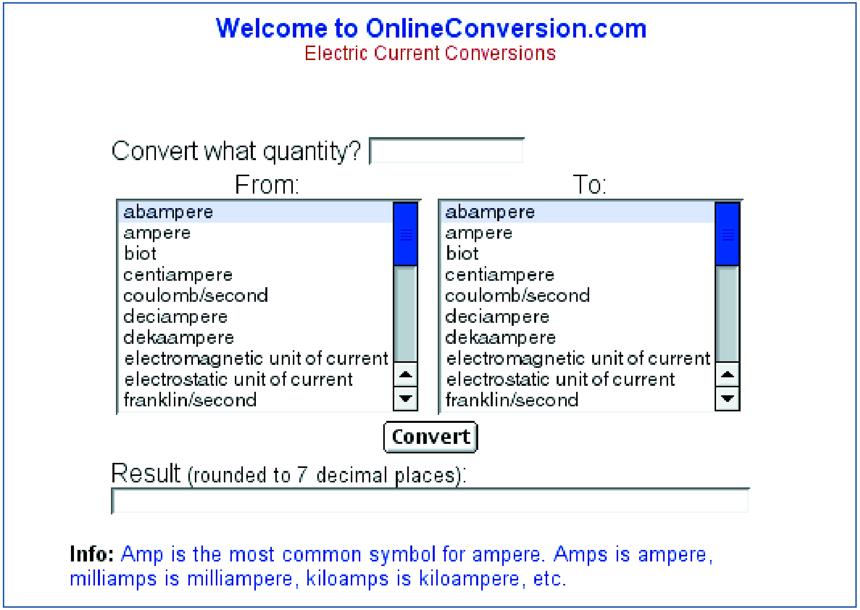
Luc Lemmens

From time to time you may come across a unit of measure that's completely unfamiliar. It also happens that the name sounds vaguely familiar, but you just can't remember the fine points. Althoug the Internet probably contains numerous sites that can help out, the most comprehensive one is probably

www.onlineconversion.com.

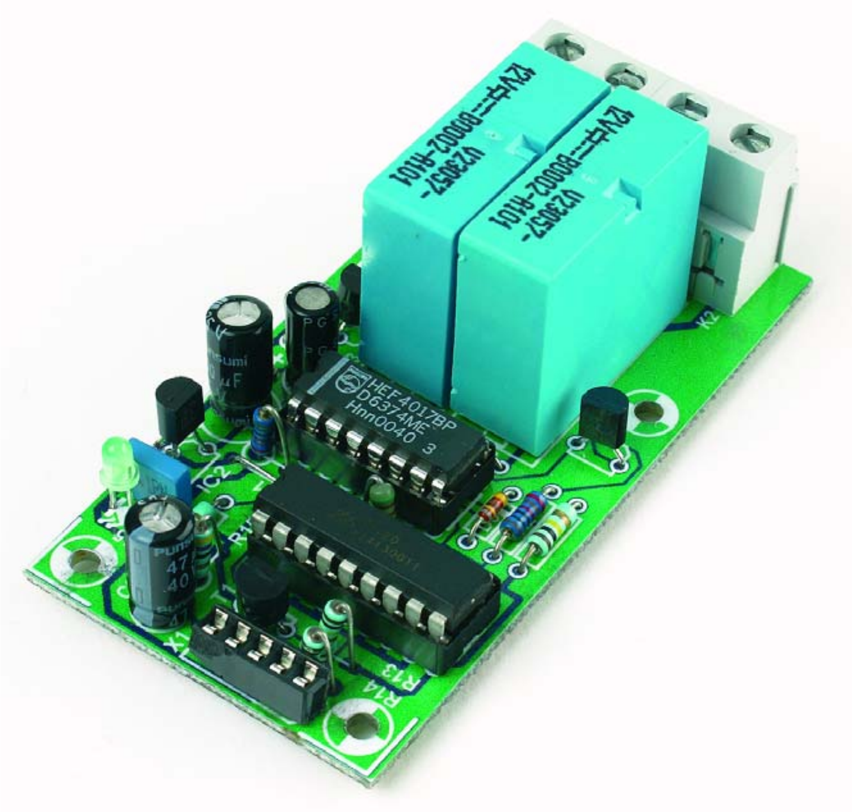
Here you can convert physics quantities such as, for example, lengths, velocity and forces. There are also conversion tools for currencies, clothing sizes and terminology used in cookbooks. Although the title of this article may imply otherwise, some parts can be downloaded and used off-line.

(044052-1)



IR Multi-Position Switch

Peter Verhoosel



This multi-position switch is operated by the IR transmitter with HT12R described elsewhere in the issue.

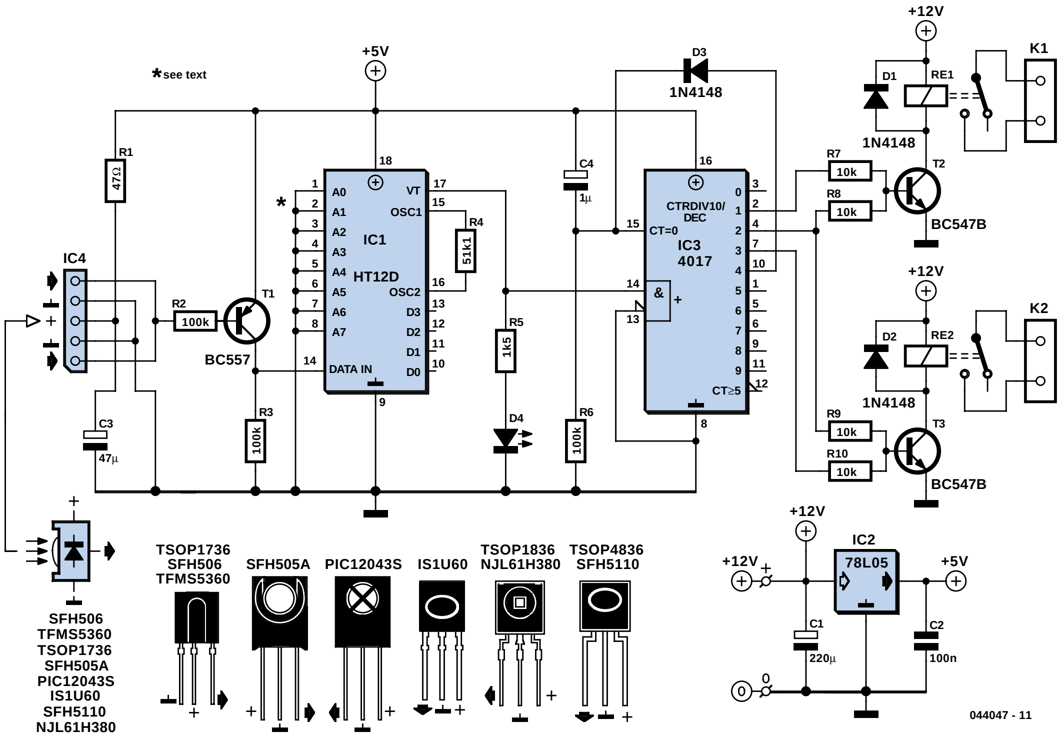
The signal transmitted by the transmitter enters the circuit through infrared detector IC4. At the output the demodulated signal is available, that via R2 and T1 is routed to the input of IC1 (decoder type HT12D). Like the encoder IC, this IC has already been described in *Elektor Electronics* on multiple occasions and we will therefore not describe it again here. On the PCB the address lines of IC1 are by default connected with a thin trace to ground. The default address is therefore zero. By cutting the trace with a sharp knife the corresponding address input can be made logic high.

This change of address is only necessary if multiple transmitters are active in the same house.

When the programmed address code corresponds with the address code of the IR transmitter, pin 17 of IC1 will be high for as long as the transmitted signal is available. LED D4 will light up.

This pulse is presented to the clock input of IC3, a decade counter. After each pulse the decade counter will make the next output high and the previous output will go low again.

When the power supply is switched on, C4 and R6 ensure that the IC is reset; the first output is high and all the others are low. This is the reason that relays are connected only from the second output onwards.



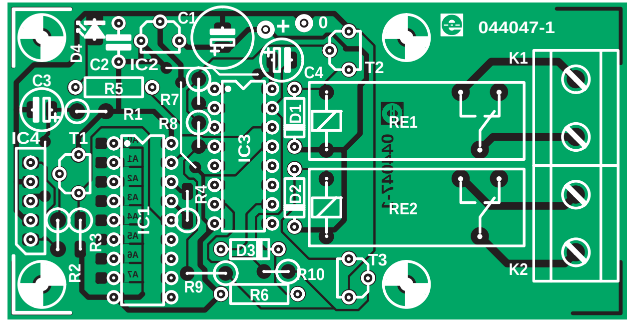
COMPONENTS LIST

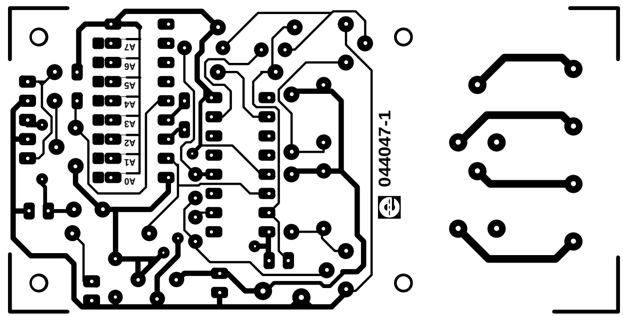
Resistors:
R1 = 47Ω
R2,R3,R6 = 100kΩ
R4 = 51kΩ1
R5 = 1kΩ5
R7-10 = 10kΩ

Capacitors:
C1 = 220µF 16V radial
C2 = 100nF
C3 = 47µF 10V radial
C4 = 1µF 10V radial

Semiconductors:
D1,D2,D3 = 1N4148
D4 = LED, red, high-efficiency
T1 = BC557
T2,T2 = BC547B
IC1 = HT12D (Holtek)
IC2 = 78L05
IC3 = 4017
IC4 = SFH506-40 or equivalent

Miscellaneous:
Re1,Re2 = 12-V relay, e.g., Siemens V23057-B0002-A101
K1,K2 = 2-way PCB terminal block, lead pitch 7.5mm
PCB, available from The PCBShop





After the first pulse is transmitted, Re1 will be switched on via R7 and T1. The next pulse causes both Re1 and Re2 to be switched on. After the next pulse only Re2 will be on.

The reset-input of the decade counter is connected via D3 to output Q4. This causes the switch to return to the rest position after the next pulse.

(044047-1)

LM4906 Boomer® Audio Power Amp

Source:
National Semiconductor

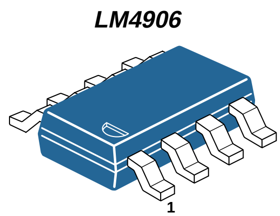
The well-known LM386 is an excellent choice for many designs requiring a small audio power amplifier (1-watt) in a single chip. However, the LM386 requires quite a few external parts including some electrolytic capacitors, which unfortunately add volume and cost to the circuit.

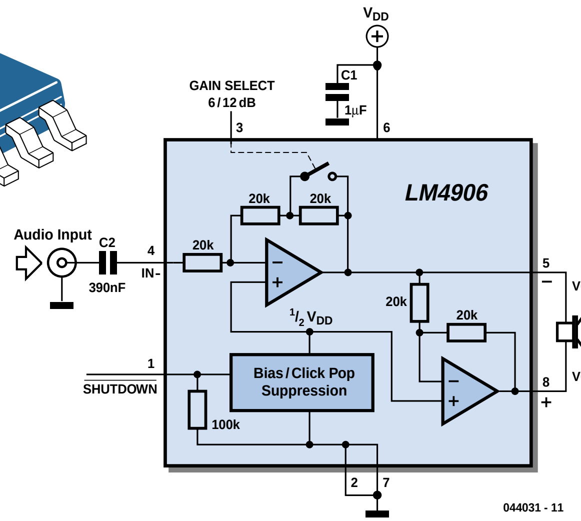
National Semiconductor recently introduced its Boomer® audio integrated circuits which were designed specifically to provide high quality audio while requiring a minimum amount of external components (in surface mount packaging only).

The LM4906 is capable of delivering 1 watt of continuous average power to an 8-ohm load with less than 1% distortion (THD+N) from a +5 V power supply. The chip happily works with an external PSRR (Power Supply Rejection Ratio) bypass capacitor of just 1 µF minimum. In addition, no output coupling capacitors or bootstrap capacitors are required which makes the LM4906 ideally suited for cellphone and other low voltage portable applications.

The LM4906 features a low-power consumption shutdown mode (the part is enabled by pulling the SD pin high). Additionally, an internal thermal shutdown protection mechanism is provided. The LM4906 also has an internal selectable gain of either 6 dB or 12 dB.

A bridge amplifier design has a few distinct advantages over the single-ended configuration, as it provides differential drive to the load, thus doubling output swing for a specified supply voltage. Four times the output power is possible as compared to a single-ended amplifier under the same conditions (particularly when considering the low supply voltage of 5 to 6 volts).





When pushed for output power, the small SMD case has to be assisted in keeping a cool head. By adding copper foil, the thermal resistance of the application can be reduced from the free air value, resulting in higher PDMAX values without thermal shutdown protection circuitry being activated. Additional copper foil can be added to any of the leads connected to the LM4906. It is especially effective when connected to VDD, GND, and the output pins.

A bridge configuration, such as the one used in LM4906, also creates a second advantage over single-ended amplifiers. Since the differential outputs, Vo1 and Vo2, are biased at half-supply, no net DC voltage exists across the load. This eliminates the need for an output coupling capacitor which is required in a single supply, single-ended amplifier configuration.

Large input capacitors are both expensive and space hungry for portable designs. Clearly, a certain sized capacitor is needed to couple in low frequencies without severe attenuation. But in many cases the speakers used in portable systems, whether internal or external, have little ability to reproduce signals below 100 Hz to 150 Hz. Thus, using a large input capacitor may not increase actual system performance. Also, by minimizing the capacitor size based on necessary low frequency response, turn-on pops can be minimized.

Further information from:
www.national.com.

(044031-1)

Model Railway Short-Circuit Beeper

R. Edlinger

Short circuits in the tracks, points or wiring are almost inevitable when building or operating a model railway. Although transformers for model systems must be protected against short circuits by built-in bimetallic switches, the response time of such switches is so long that is not possible to immediately localise a short that occurs while the trains are running, for example. Furthermore, bimetallic protection switches do not always work properly when the voltage applied to the track circuit is relatively low.

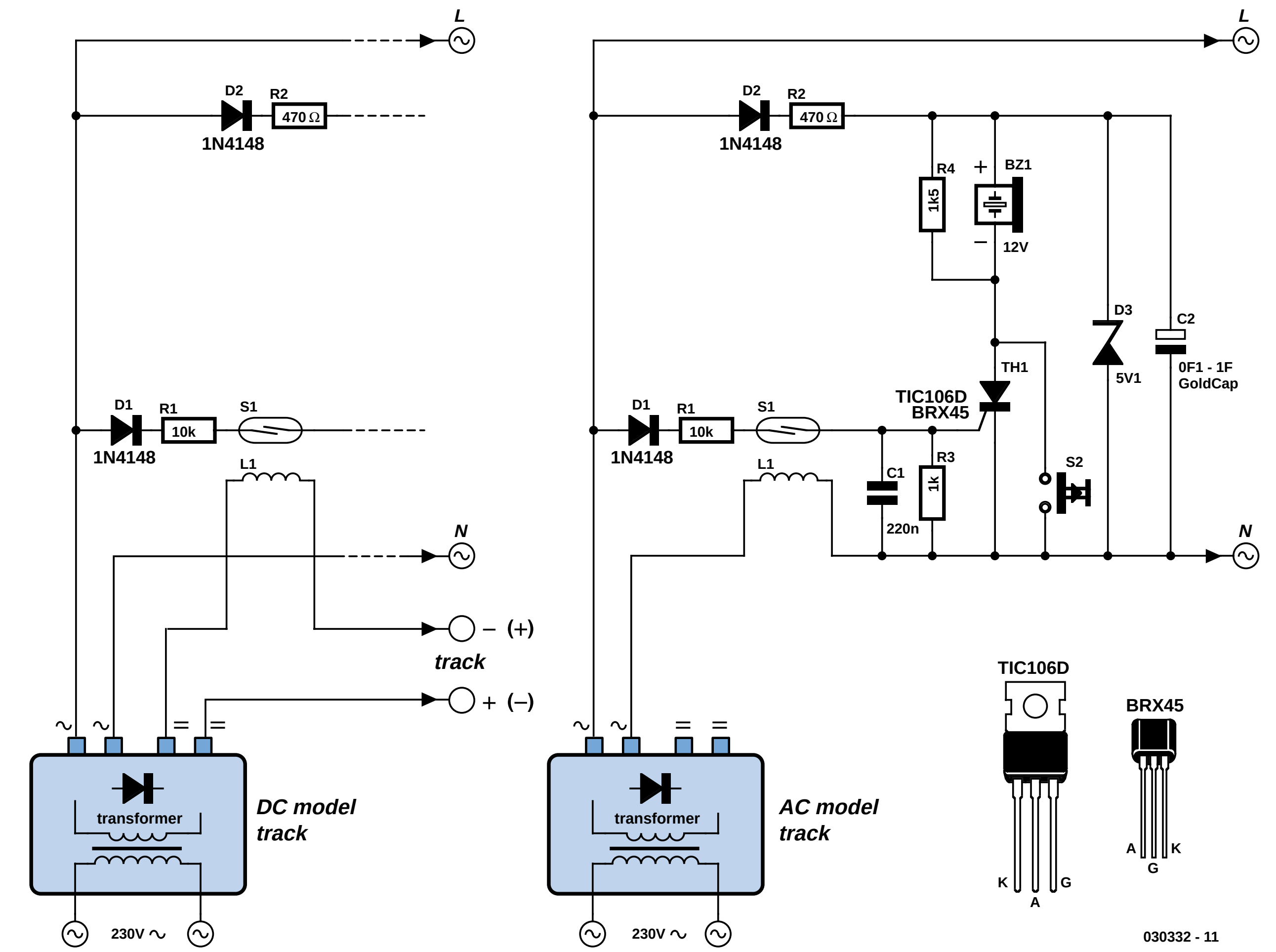
The rapid-acting acoustic short-circuit detector described here eliminates these problems. However, it requires its own power source, which is implemented here in the form of a GoldCap storage capacitor with a capacity of 0.1 to 1 F.

A commonly available reed switch (filled with an inert gas) is used for the current sensor, but in this case it is actuated by a solenoid instead of a permanent magnet. An adequate coil is provided by several turns of 0.8–1 mm enamelled copper wire wound around a drill bit or yarn spool and then slipped over the glass tube of the reed switch. This technique generates only a negligible voltage drop. The actuation sensitivity of the switch (expressed in ampère-turns or A-t)) determines the number of turns required for the coil. For instance, if you select a type rated at 20–40 A-t and assume a maximum allowable operating current of 6 A, seven turns (40 ÷ 6 = 6.67) will be sufficient. As a rule, the optimum number of windings must be determined empirically, due to a lack of specification data.

As you can see from the circuit diagram, the short-circuit detector is equally suitable for AC and DC railways. With Märklin transformers (HO and I), the track and lighting circuits can be sensed together, since both circuits are powered from a single secondary winding.

Coil L1 is located in the common ground lead ('O' terminal), so the piezoelectric buzzer will sound if a short circuit is present in either of the two circuits. The (positive) trigger voltage is taken from the lighting circuit (L) via D1 and series resistor R1. Even though the current flowing through winding L1 is an AC or pulsating DC current, which causes the contact reeds to vibrate in synchronisation with the mains frequency, the buzzer will be activated because a brief positive pulse is all that is required to trigger thyristor Th1. The thyristor takes its anode voltage from the GoldCap storage capacitor (C2), which is charged via C2 and R2.

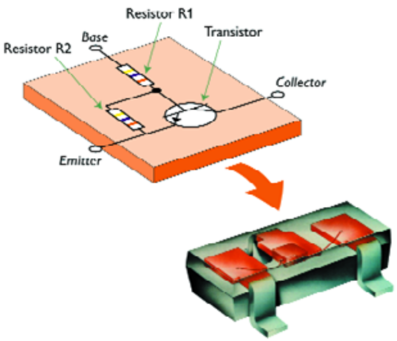
The alarm can be manually switched off using switch S1, since although the thyristor will return to the blocking state after C2 has been discharged if a short circuit is present the lighting circuit, this will not happen if there is a short circuit in the track circuit. C1 eliminates any noise pulses that may be generated.

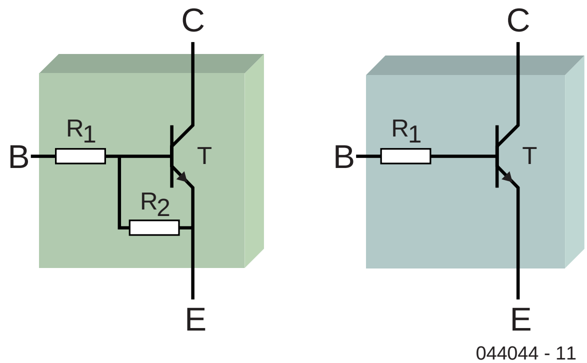


As a continuous tone does not attract as much attention as an intermittent beep, an intermittent piezoelectric generator is preferable. As almost no current flows during the intervals between beeps and the hold current through the thyristor must be kept above 3 mA, a resistor with a value of 1.5–1.8 kΩ is connected in parallel with the buzzer. This may also be necessary with certain types of continuous-tone buzzers if the operating current is less than 3 mA. The Zener diode must limit the operating voltage to 5.1 V, since the rated voltage of the GoldCap capacitor is 5.5 V.

(030332-1)

Resistor-Equipped Transistors (RETs)





Paul Goossens

Developments in the electronics area (or is it an arena?) are never at a standstill. Whenever there is something substantially new to report it is almost always related to complex chips. However, Philips proves that new developments are possible even with what you thought were dead-standard components. For example, take the new range of transistors with the name 'RET' – meaning *Resistor Equipped Transistor*.
The novelty with this new range of transistors is that they have a base resistor included. Some versions also have a resistor from base to emitter.
These new transistors enable engineers to design even smaller devices because the space required on the PCB has been reduced as a consequence. An additional advantage is that the total component count is reduced.
The new transistors are available in both PNP and NPN versions. For the package, the designer can choose from a number of SMD packages as well as the familiar TO-92. The maximum power dissipation depends on the package and varies from 150 mW to 500 mW for the single transistor chips.
There are also chips with two transistors, where each chip is provided with either one or two resistors. With these you can choose between a maximum dissipation of 300 mW or 600 mW.
A complete overview of the available RETs can be found on the Internet at: http://www.semiconductors.com/acrobat/literature/9397/75012514.pdf.

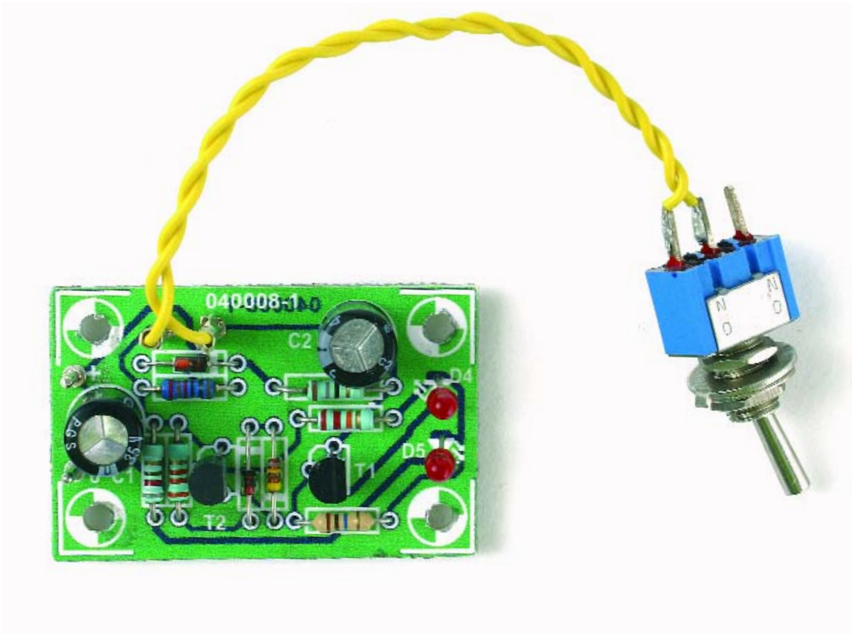
(044044-1)

source: Philips

Low-Drop Constant Current Source

for Ultrabright LEDs

Olaf König

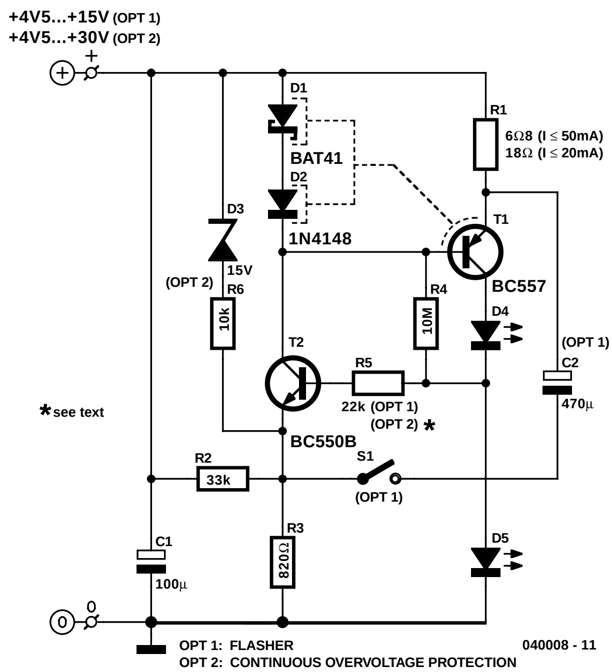


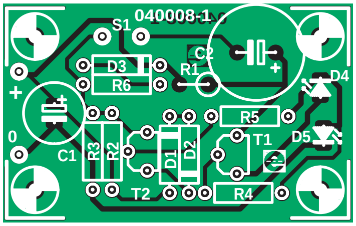
Ultrabright LEDs are becoming increasingly attractive for use in lighting and warning-signal applications. LEDs must be operated at a constant current to ensure that they continue to emit light at the same brightness. The usual approach is to use a series resistor, but in order to prevent the non-linear voltage/current characteristic, the NTC property of the LED and variations in the supply voltage from affecting brightness, we'd like to have something better.

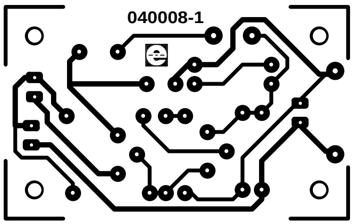
The circuit described here is a low-drop constant current source for ultrabright LEDs with blinking capability, for use in headlights, taillights, dog blinkers, light chains, car alarms and the like. It provides a constant current of 20 mA with a supply voltage of 4.5–30 V, or 50 mA with a 4.5–12 V supply. The voltage drop of the circuit is only 0.6 V, so practically the entire supply voltage can be used for the LEDs.

When the supply voltage is switched on, D5 generates a start-up voltage if the circuit is exposed to light (an LED can generate a photoelectric current). To enable the constant-current source to also reliably start up in the dark, R4 provides an initial base current to T1 and T2. In any case, both transistors initially only pass a small amount of current. But since each transistor provides the base current for the other one, the current rises to its setpoint value. The setpoint is stably maintained as follows. The voltage across D5, less the base–emitter voltage of T2, is also present across R3 (R5 has no effect at the beginning). A stabilised current thus flows through R3. Most of the constant current flowing through T2 comes from D1 and D2, with only a secondary contribution from the base current of T1. The voltage across D1 and D2 is also stable, due to the stabilised current. This voltage, less the base–emitter voltage of T1, is present across R1, where it causes a constant current to flow through T1 and D5 (and D4 if present). This closes the loop. The circuit thus consists of two constant-current sources that stabilise each other. That's the basic principle.

R2 increases the voltage across R3. This causes the current to be reduced proportional to the supply voltage, which further stabilises the current. R2 is thus configured such that the current actually decreases slightly as the battery voltage increases. This causes T1 to be driven into full saturation at low voltages. D2 is intended to compensate for the base–emitter voltage of T1, while Schottky diode D1 provides the 'miserly' voltage drop across R1. D1 and D2 are thermally coupled to T1. As a result, with increasing temperature the current is more likely to decrease than increase. LED D4 is included in the circuit to prevent T2 from having to go into saturation at low operating voltages. That wrings out an extra 0.2 V or so. In this way, the battery is mercilessly sucked dry when is







COMPONENTS LIST

Resistors:
R1 = 6Ω8 or 18Ω (see text)
R2 = 33kΩ
R3 = 820Ω
R4 = 10MΩ
R5 = 22kΩ or 0 Ω (see text)
R6 = 10kΩ

Capacitors:
C1 = 100µF 40V radial
C2 = 470µF 40V radial

Semiconductors:
D1,D2 = BAT41 or similar Schottky diode with I_F>80mA
D3 = zener diode 15V, 0.5W
D4,D5 = LED (see text)
T1 = BC557B
T2 = BC550B

Miscellaneous:
S1 = switch (see text)
PCB, order code 040008-1 from the PCBshop

becomes weak. It's totally defenceless. However, rechargeable batteries should never be deep-discharged!
Overvoltage protection should be included if the circuit is intended to be used for general experimentation or with LED chains. In case of overvoltage, D3 starts conducting and takes current away from T2 (which is essentially what R2 does as well). To prevent overheating of T1, particularly with a current of 50 mA, the current is sharply reduced for voltages greater than approximately 15 V. The upper voltage limit is then practically determined solely by the maximum collector voltage (U_{CE}) ratings of the two transistors.
An LED chain can best be inserted in series with the supply voltage, in order to avoid making any changes to the circuit. Naturally, at least D5 must still remain in the circuit.
R5 and C2 form part of the blinking circuit. R5 and C1 smooth out large current spikes and RF oscillations during blinking operation. Low-impedance feedback is provided by C2. The resulting pulses are long enough to be clearly visible and short enough to use as little energy as possible. The duty cycle is only 10 %. However, at base voltages less than 5 V (with two LEDs fitted) it increases to 50 %, with an accompanying decrease in current. Below 4.6 V, shortly before the circuit 'runs dry', the pulse heads toward to zero. The 10-% pulses achieve the rated pulse current level of 100 mA for 50-mA LEDs, and they have such steep edges that two blinkers connected to a single power source blink in unison if they are not decoupled by at least 1 Ω. The voltage fluctuations on C2 are so small (approximately 0.6 V) that hardly any energy is lost.
We have designed a small printed circuit board for the constant-current source, which could hardly be easier to build and does not require any comments. Diodes D1 and D2 are placed immediately next to T1 and thus adequately thermally coupled. For a maximum constant current of 50 mA, the value of R1 should be 6.8 Ω, while for 20 mA a value of 18 Ω should be used. Naturally, the value of R1 can be increased even more to reduce the value of the constant current any the desired level.
If T1 does not have the anticipated current gain of 140, R3 should be reduced to 680 Ω. The current flowing through diodes D1 and D2 should be at least three times the base current of T1. Naturally, the base current flowing through T2 is not multiplied. The value of I_{R3} is thus 4 × I_{BT1} (since I_{BT2} can be neglected). As D5 determines the voltage across R3, we thus have the formula:

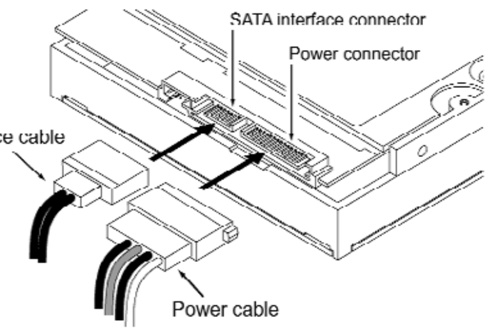
$$R3 \leq \beta_{T1} \times [(U_{D4} - 0.65\ V) / (4\ I_{const})]$$

The maximum permissible value of U_{R1} is 340 mV. From the author's experience, when setting the level of the constant current it helps to try several diodes for D2 with different tolerance values. In stubborn cases of excessively high current levels (or if you want to be on the safe side but don't want to or can't measure, adjust or whatever), you can simply connect two 1N4148s in parallel. This will cause the operating point to lie somewhat lower on the characteristic curve.
Another important tip for avoiding eye injury (retina damage): never look directly at an ultrabright LED, especially in the dark!

(040008-1)

SATA

Karel Walraven

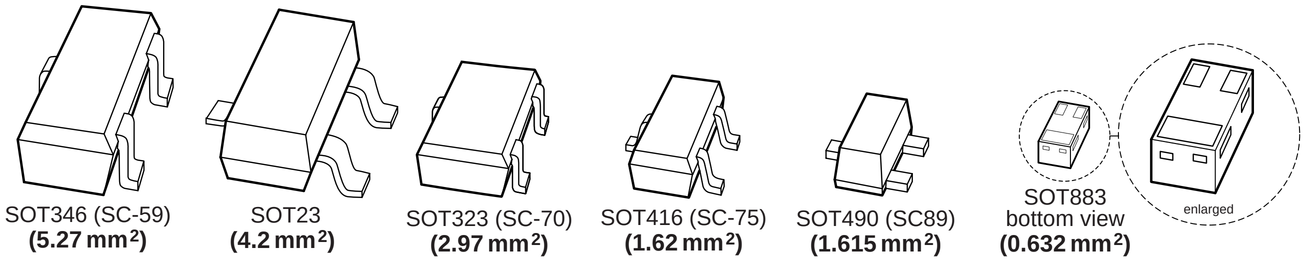


There is a new standard these days for connecting hard disks and DVD drives: SATA. You may already have noticed that new PCs don't contain the wide 40- or 80-pin ribbon cables any more, but the hard disk is connected with a slender 7-way cable. Even the corresponding power supply connector is different with a SATA drive and now has 15 connections instead of 4. This is clearly illustrated in the drawing: The *large* connector provides power and the *small* connector is the data connection. The power supply connector provides 12, 5 and 3.3 V and two ground connections.

SATA means Serial ATA. ATA is the connection standard that at present has been the most common for hard disks, CD and DVD drives. At the time of writing the ATA100 bus with a data transfer speed of 100 Mbyte/s is the most widespread. A number of manufacturers use the slightly faster ATA133 bus. That is pretty much the end of the line; it has not been possible for the industry to increase the speed even further using simple means. In order to increase the speed of the interface between motherboard and HDD, a serial connection was selected. At first glance this appears to be an perplexing choice! The parallel ATA bus operates with 16 bits simultaneously; the serial bus therefore has to be at least 16 times faster to obtain the same equivalent speed. That is why SATA operates at a clock speed of 1500 MHz and reaches a data transfer speed of 150 MByte/s; versions with 3 GHz and 6 GHz clock speed are planned.
The industry made this choice because, in the end, it is cheaper to have a solution with one data channel at very high speed than trying to increase the speed of all 33 signals in the ATA connection. The data connection has a balanced outgoing and a balanced return connection, plus three ground connections. The signal amplitude is not 5 volts any more, but only 0.25 volts. The symmetrical connection and the small signal amplitude together result in a fast, low interference and energy efficient connection. In addition, the cable is allowed to be much longer: 1 m instead of 45 cm with ATA.
Another big difference is that each device (HDD, DVD) has its own cable and connection to the motherboard. With the current ATA standard two devices can share the same cable. As a consequence various jumpers (master, slave) disappear and the interface can (in principle) always operate at maximum speed.
Additionally, the contacts in the connectors are of different length, so that hot-plugging (connecting or disconnection without switching the power off) becomes possible. The expectation is that this interface will satisfy the requirements for the next ten years.

(044053-1)

Modern SMD Packages



Paul Goossens

Parts in SMD packages are becoming more and more frequent in DIY circuits. Sometimes they are used because of better performance, usually as a consequence of the shorter PCB traces between the various parts. The result of this is a lower self-inductance so the circuit exhibits better RF behaviour.
Another reason components in an SMD package are selected is simply because the equivalent parts in a 'through-hole' package are no longer being manufactured.
All those different packages have naturally resulted in several new standards for packages. Here we show a number of common SMD packages with three terminals.

In particular, note the difference in dimensions for the various packages. Arguably a SOT346 package is a lot easier to solder than a SOT490 package. It is obvious then, that a SOT883 package is going to be the most difficult to solder. Not only is the package extremely small, but in addition, the terminals are underneath. This means that it cannot be soldered with a soldering iron. To solder these, you would have to resort to using a hot plate, an iron or even better: an SMD oven.

(044045-1)

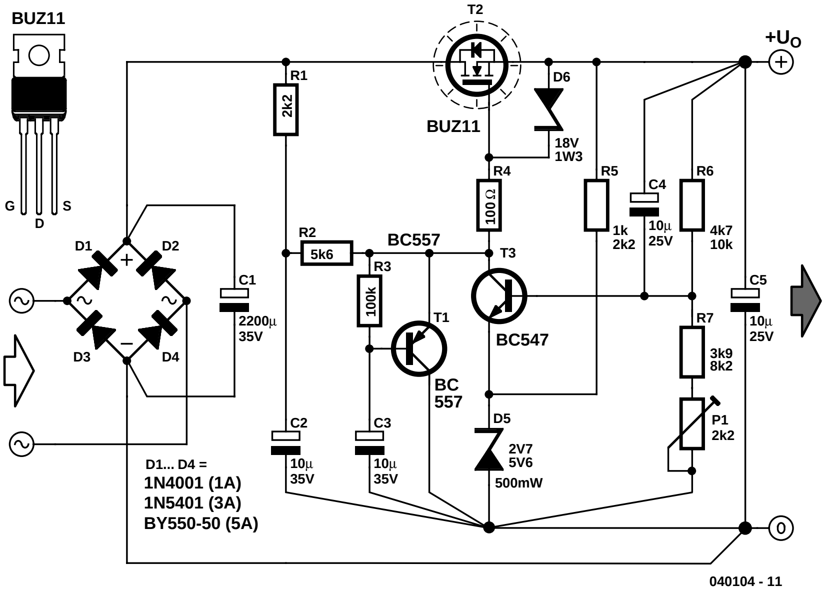
Stable Filament Supply

Dr Alexander Voigt

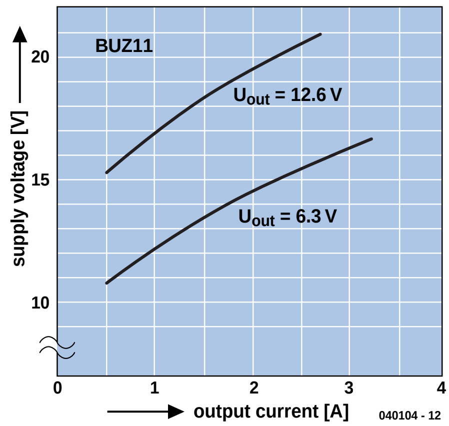
Valves are enjoying increasing popularity in audio systems. With the European 'E' series of valves, such as the ECC83 (12AX7) and EL84 (6BQ5), the filament voltage is 6.3 V. Depending on how the circuit is wired, the ECC 81–83 series of twin triodes can also be used with a filament voltage of 12.6 V. In earlier times, the filament voltage was usually taken directly from a separate transformer winding, which (in part) was responsible for the well known 'valve hum'.

With regard to the signal path, current valve circuits have hardly experienced any fundamental changes. In high-quality valve equipment, though, it is relatively common to find a stabilised anode supply. Mains hum can have a measurable and audible effect on input stages whose filaments are heated by an ac voltage. The remedy described here is a stabilised and precisely regulated dc filament voltage. The slow rise of the filament voltage after switching on is also beneficial. The exact setting of the voltage level and the soft start have a positive effect on the useful life of the valves.

Figure 1 shows a voltage regulator meeting these requirements that is built from discrete components. The two sets of component values are for a voltage of 6.3 V (upper) and 12.6 V (lower). Thanks to the fact that the supply works with a constant load, it can do without special protective circuits and the additional complexity of optimum regulation characteristics for dynamic loads.



1



2

The circuit in Figure 1 consists of a power MOSFET configured as a series-pass regulator and a conventional control amplifier. Zener diode (D5) sets the reference potential. A constant voltage is thus present at the emitter of the BC547 control amplifier (T3). The current through D5 is set to approximately 4–5 mA by series resistor R5.

The output voltage UO (the controlled variable) acts on the base of the control amplifier (T3) via voltage divider R6/R7. If the output voltage drops, the collector current of T3 also decreases, and with it the voltage drop across load resistors R1 and R2. The voltage on the gate of the MOSFET thus increases. This closes the control loop. The values of the resistors forming the voltage divider are chosen for the usual tolerances of Zener diodes, but they must be adjusted if the diode is out of spec (which can happen).

The load resistance of the control amplifier is divided between R1 and R2. The current through the load resistance and the collector current of T3 are practically the same, since the MOSFET draws almost no gate current. Filter capacitor C2 is connected to the junction of R1 and R2 to reduce residual hum. Electrolytic capacitor C4 and power supply filter capacitor C1 serve the same purpose. The hum voltage also depends on the magnitude of the load current.

The voltage drop over the series-pass regulator is nearly the same for an output voltage of 6.3 V or 12.6 V. With a BUZ11 and a load of 1 A at 6.3 V, for instance, the average voltage across the source–drain channel is approximately 7 V. The power dissipation of 7 W requires a corresponding heat sink.

The slow rise of the output voltage is due to the presence of timing network R3/C3 and T1. When power is switched on, T1 holds the gate of the MOSFET at nearly ground level. As C3 charges, T1 conducts increasingly less current, so ultimately only the control transistor affects the gate voltage.

The mains transformer must be selected according to the required load current. The required value of the input voltage can be read from the chart. The transformer should have a power rating at least 30 % greater than what is necessary based on the calculated load dissipation. Where possible, preference should be given to a filament voltage of 12.6 V. When twin triodes in the ECC81–83 series are used, for example, the power dissipation in the series pass transistor is lower with a voltage of 12.6 V.

(040104-1)

IR Transmitter with HT12E

Peter Verhoosel

IR (infra-red) transmitters containing the encoder-IC HT12E from Holtek have been published in *Elektor Electronics* on previous occasions. The interesting aspect of this design is that the entire IR-transmitter has been squeezed into a handy key ring.

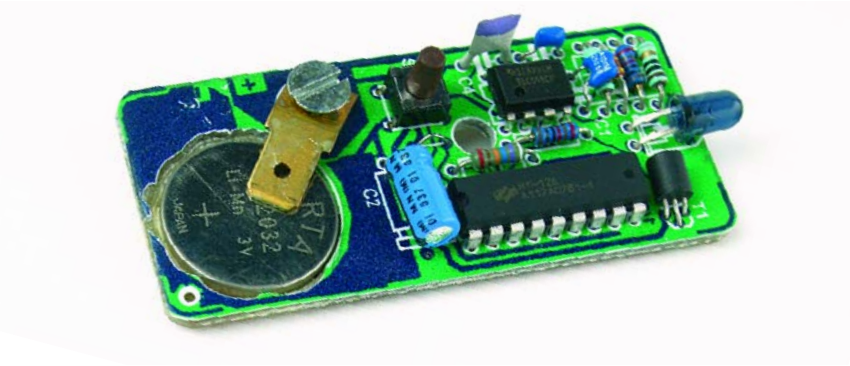
The operation of the encoder IC HT12E has already been thoroughly dealt with in earlier publications. It will suffice to mention here that an address can be programmed on inputs A1 through to A8. This address has to be set the same as in the receiver.

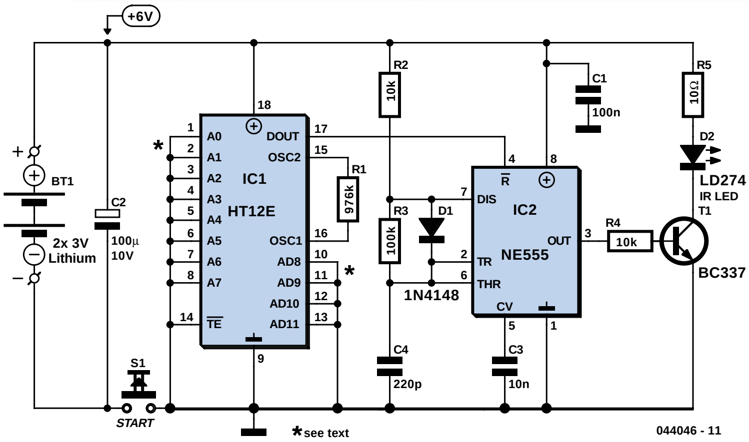
On the circuit board, the address lines are connected to ground with a thin piece of track so that address zero is selected. By cutting the track with a sharp knife the corresponding input can be made logic high. This change of address is only necessary when more than one transmitter is active in the same house.

The same story applies to the four data lines, but that is not relevant if you use the IR Multi-Position Switch published elsewhere in this magazine.

The generated code is available on pin 17 of IC1, which is modulated with the aid of IC2 on a carrier of 40 kHz. Transistor T1 drives the infrared LED via R4, so that an IR code is transmitted.

Two Lithium cells of 3 V each power the circuit. The circuit is only powered when transmit pushbutton S2 is pressed. The life expectancy of the batteries is during normal use more than a year!





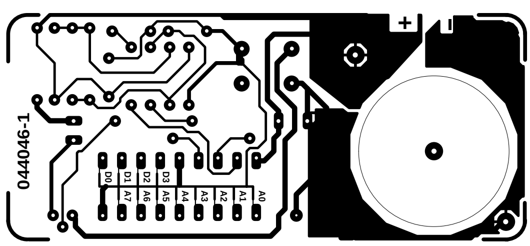
The construction itself should be no problem. However, note the height of the components. For this reason an IC socket cannot be used.

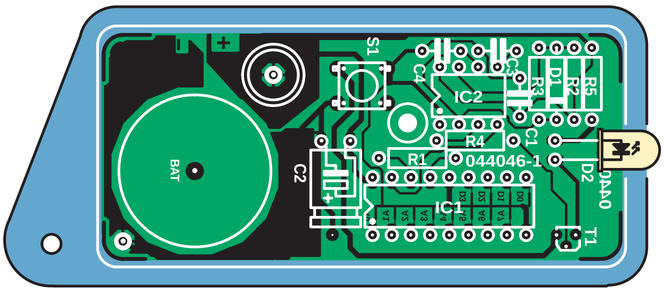
A paperclip soldered to the bottom acts as a battery holder, this is ground.

For the top part of the battery holder we use an automotive connector and an M3 bolt.

Because the height of T1 can be a problem when closing the enclosure, the device is best bent flat on the PCB before soldering.

(044046-1)





COMPONENTS LIST

Resistors:
R1 = 976kΩ
R2,R4 = 10kΩ
R3 = 100kΩ
R5 = 10Ω

Capacitors:
C1 = 100nF
C2 = 100µF 10V radial
C3 = 10nF
C4 = 220pF

Semiconductors:
D1 = 1N4148
D2 = IRED (e.g., LD274)
IC1 = HT12E (Holtek)
IC2 = TLC555
T1 = BC337

Miscellaneous:
S1 = miniature pushbutton (HAK)
Enclosure: KM series Box UM14
PCB, available from The PCBShop

Airflow Monitor

Gregor Kleine

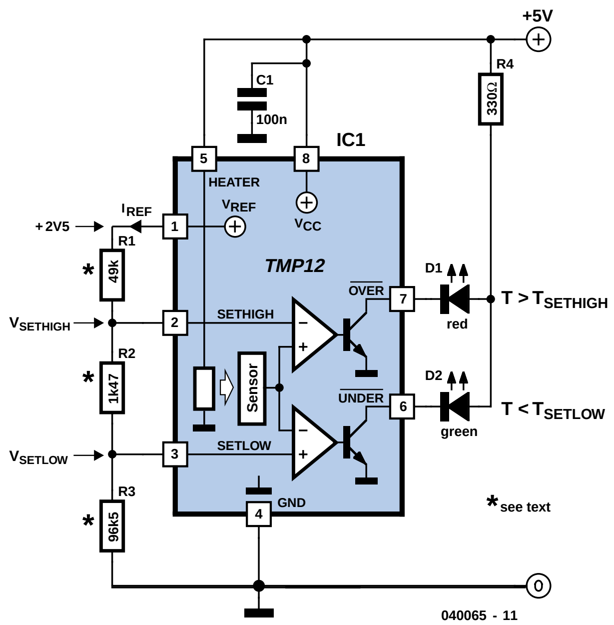
Fans are usually monitored by measuring their operating currents. If the current lies within a certain range, it is assumed that the fan is spinning properly and providing a stream of cooling air. If it falls below a lower threshold or exceeds an upper threshold, something is wrong with the fan: it is either defective or blocked by some sort of object.

The cooling airflow generated by a fan can be directly monitored using the Analog Devices TMP12 sensor IC (www.analog.com). This IC contains a temperature sensor and a heater resistor, as well as two comparators and a reference-voltage source. **Figure 1** shows the complete circuit diagram of an airflow monitor. The voltage divider formed by R1, R2 and R3 defines the temperature thresholds and the hysteresis for the switching points (via the current IREF flowing through the resistor chain). The internal heater resistor can be powered directly from the supply voltage via pin 5 (Heater), but an external resistor (R5) can also be connected in series between the supply voltage and pin 5 to reduce the internal power dissipation of the IC. The circuit output is provided here by two LEDs driven by the open-collector outputs $\overline{\text{UNDER}}$ (pin 6) and $\overline{\text{OVER}}$ (pin 7).

The operating principle of the TMP12 IC is that it is warmed by the integrated heater resistor and cooled by the airs flow. If there is no airflow or the airflow is insufficient due to a defective fan or obstructed air inlet, the temperature increases until the amount of heat dissipated by the IC (by conduction to the circuit board or other means) balances the amount of heat generated inside the IC. **Figure 2** shows this in the form of two curves. The power dissipation of the internal 100-Ω heater resistor is plotted on the X axis. This can be as much as 250 mW if pin 5 is connected directly to +5 V. If the heater resistor is not dissipating any power, the sensor will be at approximately ambient temperature, which is here taken to be +50 °C. If the power dissipated by the heater resistor increases, the level to which the temperature of the IC will rise can be read from the two curves, which show the situation with and without cooling airflow. As indicated, the temperature thresholds TSETHIGH and TSETLOW are dimensioned such that with the amount of power converted into heat by the resistor (in this case, 250 mW), the temperature for the curve with cooling airflow lies between the two temperature thresholds. Here the threshold temperatures are +55 °C and +60 °C.

The voltage divider R1/R2/R3 determines not only the absolute positions of the temperature thresholds, but also the hysteresis of the switching points. The hysteresis is determined by the current IREF flowing through the resistor chain. The associated formulas are shown in **Figure 3.** Here ΔT is the hysteresis, which in this case is set to 2 °C and yields a value of 17 μA for IREF. The node voltages for the voltage divider can now be determined from the threshold temperatures, which in this case yields VSETHIGH = 1.666 V for an upper threshold

1



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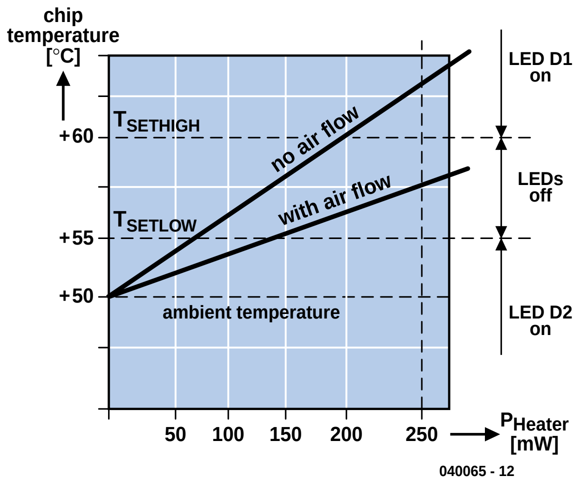

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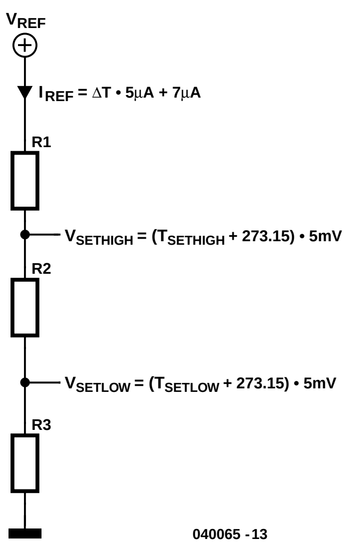


of +60 °C and V_{SETLOW} = 1.641 V for a lower threshold of +55 °C As V_{REF} = 2.5 V, the values of R1, R2 and R3 can now be readily calculated from the current and the voltage drops across the resistors. The values calculated in this manner are shown in the schematic diagram, without taking into account whether such values are actually available. As the temperature thresholds used here are relatively close together, the actual values of the resistors must be quite close to the calculated values. This can be achieved by connecting standard-value fixed resistors in series and/or parallel, or by using trimpots.

The TMP12 can be used to generate digital monitoring signals for a processor or switch on a supplementary fan (via a driver stage connected to the outputs). Another possible application is controlling an oven that is switched off by the TMP12 when it reaches its set-point temperature. Such an oven can be used to operate a crystal oscillator at an elevated temperature in order to make it insensitive to temperature variations (a crystal oven). According to its data sheet, the IC can be used at temperatures between –40 °C und +125 °C.

(040065-1)

Zero Gain Mod for Non-Inverting Opamp

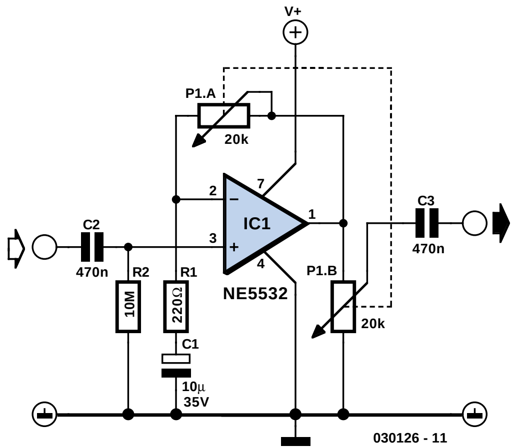
Flemming Jensen

Electronics textbooks will tell you that a non-inverting opamp normally cannot be regulated down to 0 dB gain. If zero output is needed then it is usual to employ an inverting amplifier and a buffer amp in front of it, the buffer acting as an impedance step-up device.

The circuit shown here is a trick to make a non-inverting amplifier go down all the way to zero output. The secret is a linear-law stereo potentiometer connected such that when the spindle is turned clockwise the resistance in P1a increases (gain goes up), while the wiper of P1b moves towards the opamp output (more signal).

When the wiper is turned anti-clockwise, the resistance of P1a drops, lowering the gain, while P1b also supplies a smaller signal to the load. In this way, the output signal can be made to go down to zero.

(030126-1)



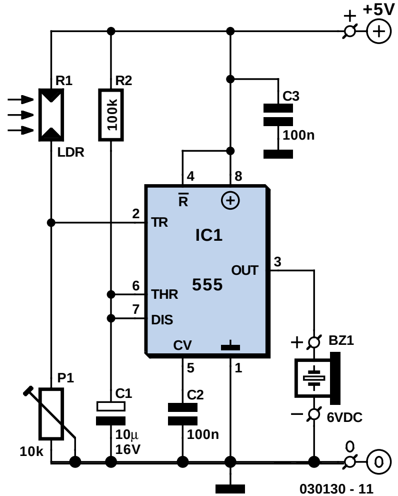
Simple Darkness Activated Alarm

Myo Min

Most darkness activated alarms employ opamps and some logic ICs. Here, a less expensive approach is shown based on the eternal 555, this time in monostable multivibrator mode. Components R2 and C1 represent a one-second network. When the LDR (light dependent resistor) is in the dark, its resistance is high, pulling pin 2 of the 555 to ground. This triggers the monostable and the (active!) 6-volt piezo buzzer will sound. Preset P1 is adjusted depending on ambient light levels.

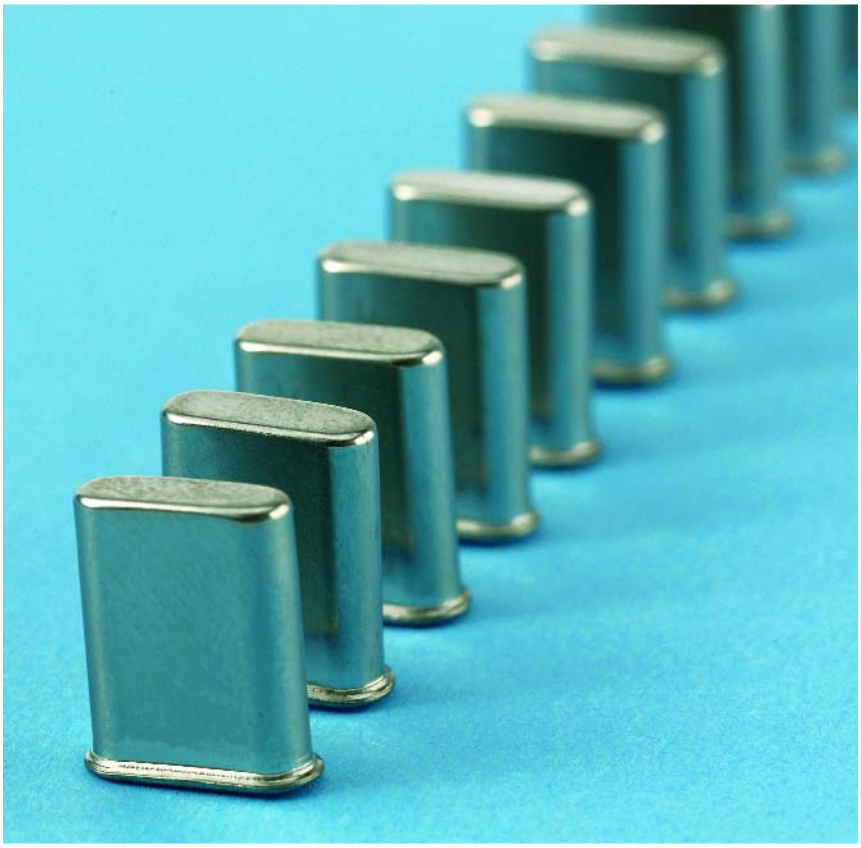
The circuit may be fitted on a wall in your home. Assuming P1 has been set for the existing ambient light level, the shadow cast by anybody entering the room or hallway will trigger the alarm.

(030130-1)



CMOS Crystal Frequency Multiplier

Gert Baars

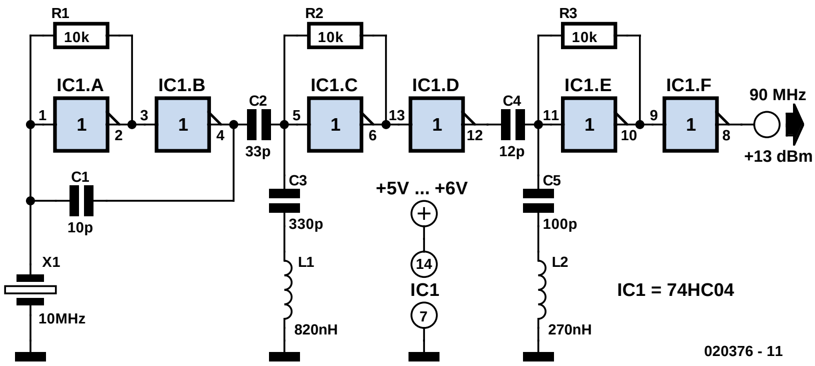


Crystals usually operate at fundamental frequencies up to about 15 MHz. Whenever higher frequencies are required a frequency multiplier is placed after the crystal oscillator. The resulting output signal is then a whole multiple of the crystal frequency. Other frequency multipliers often use transistors, which produce harmonics due to their non-linearity. These are subsequently filtered from the signal. One way of doing this is to put a parallel L-C filter in the collector arm. This filter could then be tuned to three times the input frequency. A disadvantage is that such a circuit would quickly become quite substantial.

This circuit contains only a single IC and a handful of passive components, and has a complete oscillator and two frequency triplers. The output is therefore a signal with a frequency that is 9 times as much as that of the crystal.

Two gates from IC1, which contains six high-speed CMOS inverters, are used as an oscillator in combination with X1. This works at the fundamental frequency of the crystal and has a square wave at its output. A square wave can be considered as the sum of a fundamental sine wave plus an infinite number of odd multiples of that wave. The second stage has been tuned to the first odd multiple (3 x).

We know that some of our readers will have noticed that the filter used here is a band-rejection (series LC) type. Worse still, when you calculate the rejection frequency you'll find that it is equal to the fundamental crystal frequency! The fundamental frequency is therefore attenuated, which is good. But how is the third harmonic boosted? That is done by the smaller capacitor of 33 pF in combination with the inductor. Together they form the required band-pass filter. (The same applies to the 12 pF capacitor in the next stage.) Through the careful selection of components, this filter is therefore capable of rejecting the fundamental and boosting the third harmonic! Clever, isn't it?

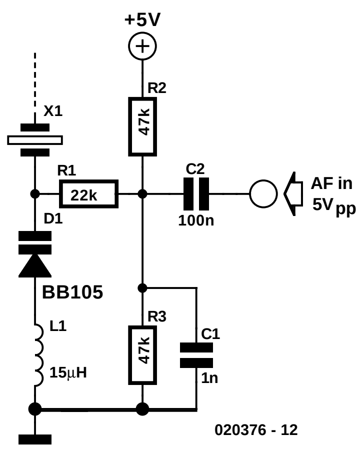


The output in this example is a signal of 30 MHz. The inverter following this stage heavily amplifies this signal and turns it into a square wave. The same trick is used again to create the final output signal of 3 times 30 MHz = 90 MHz.

At 5 V this circuit delivers about 20 milliwatt into 50 Ω. This corresponds to + 13 dBm and is in theory enough to drive a diode-ring balanced mixer directly.

The circuit can be used for any output frequency up to about 100 MHz by varying the component values. When, for example, an 8 MHz crystal is used to obtain an output frequency of 72 MHz (9 x 8 = 72), the frequency determining inductors and capacitors have to be adjusted by a factor of 10/8. You should round the values to the nearest value from the E12 series.

Another application is for use in an FM transmitter; if you connect a varicap in series with the crystal, you can make an FM modulator. An added bonus here is that the relatively small modulation level



is also increased by a factor of 9. Crystals with frequencies near 10 MHz are relatively easy to find and inexpensive, so you should always be able to find a suitable frequency within the FM band. A crystal of 10.245 MHz for instance would give you a frequency of 92.205 MHz and 10.700 MHz results in an output of 96.300 MHz.

You may find that the circuit operates on the border of the HC specifications. If this causes any problems you should increase the supply voltage a little to 6 V.

(020376-1)

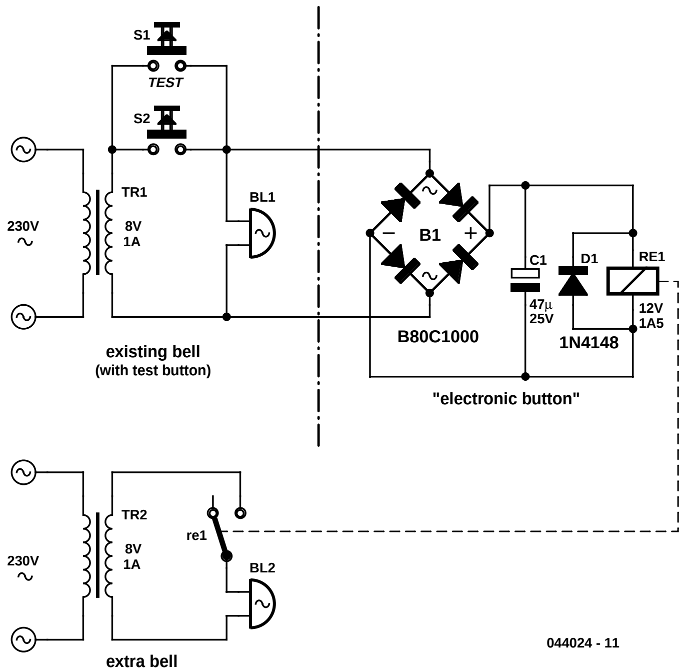
Doorbell Cascade

René Bosch

Sometimes you have to do it the hard way, even if doing it the easy way is an option. That is the case here. The intention is to add a second doorbell in parallel with the existing bell. This does not, in principle, require any electronic components. You would simply connect the second bell to the first one. But if the existing bell transformer is not rated for the additional load then this is not a good idea! An option is to buy a new and larger transformer. But bigger also means more expensive! Moreover, replacing the existing transformer can be an awkward job, for example when it is built into the meter box.

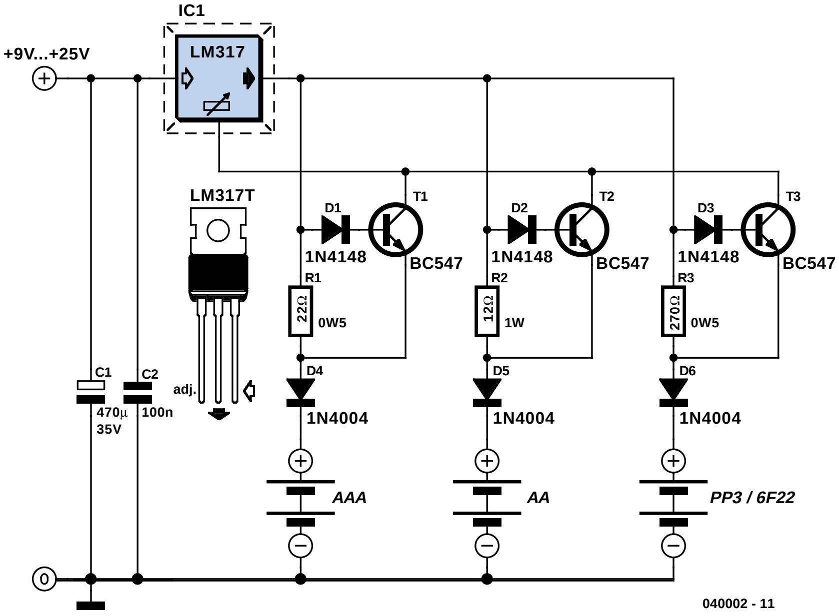
So we follow different approach. This circuit is connected in parallel with the existing bell. This is possible because the current consumption is very small compared to the load of the bell. The bridge rectifier rectifies the bell voltage when the push-button is pressed. This will then close the relay contacts. These contacts are the 'electronic' button for the second bell, which is powered from its own cheap bell transformer.

(044024-1)



Switchless NiCd/NiMH Charger

Myo Min



This circuit may be used to replace the single current limiting resistor often found in dirt cheap battery chargers. The alternative shown here will eventually pay off because you no longer have to throw away your NiCds after three months or so of maltreatment in the original charger.
The circuit diagram shows an LM317 in constant-current configuration but without the usual fixed or variable resistor at the ADJ pin to determine the amount of output current. Also, there is no switch with an array of different resistors to select the charge currents for three cell or battery types we wish to charge: AAA, AA and PP3 (6F22).
When, for example, an empty AAA cell is connected, the voltage developed across R1 causes T1 to be biased via voltage dropper D1. This results in about 50 μA flowing from the LM317's ADJ pin into the cell, activating the circuit into constant-current mode. D4 is included to prevent the battery being discharged when the charger is switched off or without a supply voltage. The charging current *I* is determined by R1/R3/R3 as in

$$R(n) = (1.25 + V_{sat}) / I$$

where V_{sat} is 0.1 V.

The current should be one tenth of the nominal battery capacity — for example, 170 mA for a 1700-mAh NiCd AA cell.
It should be noted that 'PP3' rechargeable batteries usually contain seven NiCd cells so their nominal voltage is 8.4 V and not 9 V as is often thought.
If relatively high currents are needed, the power dissipation in R1/R2/R3 becomes an issue. As a rule of thumb, the input voltage required by the charger should be greater than three times the cell or battery (pack) voltage. This is necessary to cover the LM317's dropout voltage and the voltage across R(n).
Two final notes: the LM317 should be fitted with a small heat sink. With electrical safety in mind the use of a general-purpose mains adapter with DC output is preferred over a dedicated mains transformer/rectifier combination.

(040002-1)

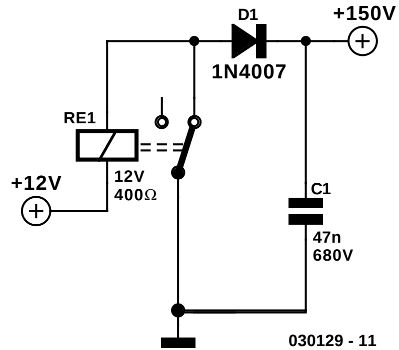
SMPSU with a Relay

Myo Min

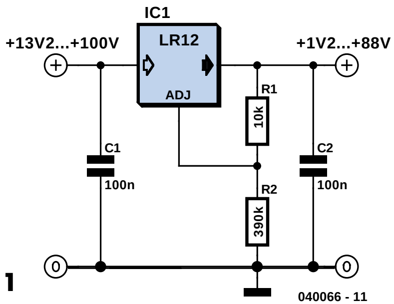
Switched mode power supply units (SMPSUs) are popular but difficult to build oneself as well problematic when it comes to understanding their design principles. Building your own SMPSU typically requires a lot of expertise, hard to find components and time. The circuit shown here is educational only and devised to demonstrate the principle of the step-up switch mode circuits. It is not intended to be incorporated in a 'real' design.

Relay Re1 has a normally-closed (NC) change-over contact and is connected to act as a vibrator. When power is applied to the circuit, the relay is energized and actuates its contact. This action may appear to break the circuit. However, the energy stored in the relay coil will produce an induced voltage which is fed to D1 and C1 for rectification and smoothing. The output voltage will be of the order of 150 V and strongly dependent on the type of relay used. In general, the faster the relay, the higher the output voltage. The circuit will oscillate at a low frequency (100-200 Hz), and a buzzing sound will be heard from the relay.

(030129-1)



100 V Regulators



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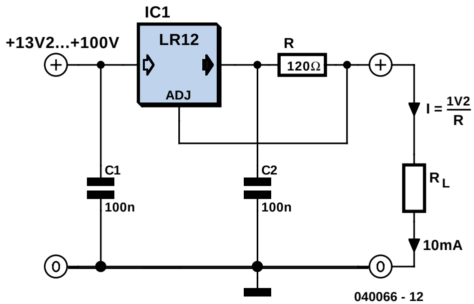


2

Gregor Kleine

Standard three-legged voltage regulator chips like the LM317 can cope with an input voltage of up to about 30 V, a few high-voltage types can handle 60 V but if that is still not sufficient for your application the company Supertex (www.supertex.com) produce devices that can withstand much higher input voltages. The regulator type LR8 has a maximum input voltage of 450 V and can supply an output current of 20 mA. The LR 12 has a better output current of 50 mA but with a maximum input voltage of 100 V, and the output voltage can be adjusted up to 88 V.

The output voltage is defined by a potential divider chain connected between the output and the ADJ (adjust) input pin. The regulator simply changes its output voltage until the divided voltage at the ADJ input is equal to 1.2 V. The output voltage can be more precisely expressed as a function of R1 and R2 in the formula:

$$V_{OUT} = 1.2\text{ V } [1 + (R2/R1)]$$

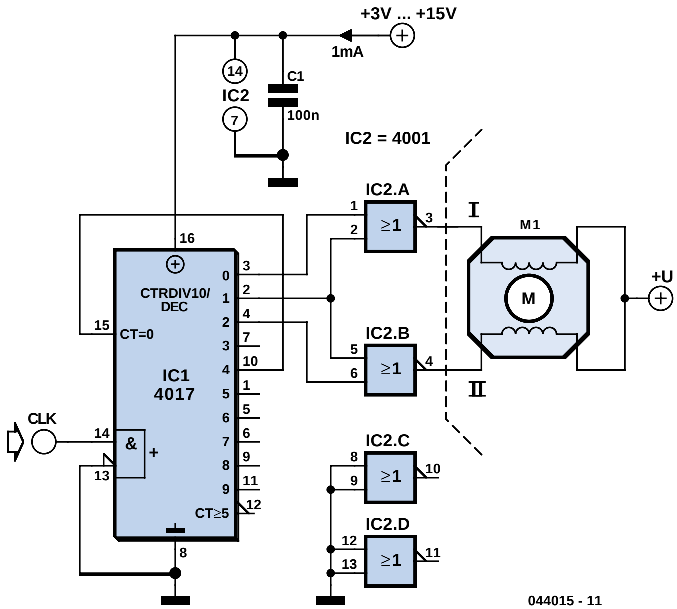
$$R2 = R1 \cdot [(V_{OUT}/1.2\text{ V}) - 1]$$

The current through R1 and R2 must be greater than 100 µA.
Just like conventional voltage regulators the LR12 can also be configured as a constant current source. Again the regulator simply adjusts its output voltage until it measures 1.2 V at the ADJ input. For a constant current of 10 mA the value of the series resistor is equal to the resistance that will produce a voltage drop of 1.2 V when 10 mA passes through it. As mentioned above the maximum output current is limited to 50 mA. A capacitor of 100 nF is necessary at the output to ensure stable regulator operation.
The LR12 is available in SO-8, TO-92 and TO-252/D-PAK outlines.

(040066-1)

Stepper Motor Generator

Stepper motors are a subject that keeps recurring. This little circuit changes a clock signal (from a square wave generator) into signals with a 90-degree phase difference, which are required to drive the stepper motor windings. The price we pay for the simplicity is that the frequency is reduced by a factor of four. This isn't really a problem, since we just have to increase the input frequency to compensate.

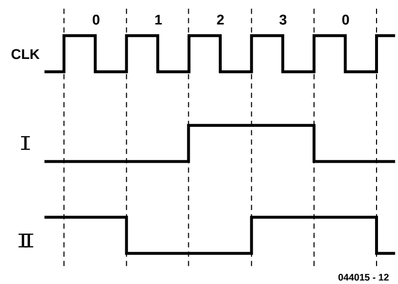


The timing diagram clearly shows that the counter outputs of the 4017 are combined using inverting OR gates to produce two square waves with a phase difference. This creates the correct sequence for powering the windings: the first winding is negative and the second positive, both windings are negative, the first winding is positive and the second negative, and finally both windings are positive.

Internally, the 4017 has a divide-by-10 counter followed by a decoder. Output '0' is active (logic one) as long as the internal counter is at zero. At the next positive edge of the clock signal the counter increments to 1 and output '1' becomes active. This continues until output '4' becomes a logic one. This signal is connected to the reset input, which *immediately* resets the counter to the 'zero' state. If you were to use an oscilloscope to look at this output, you would have to set it up very precisely before you would be able to see this pulse; that's how short it is.

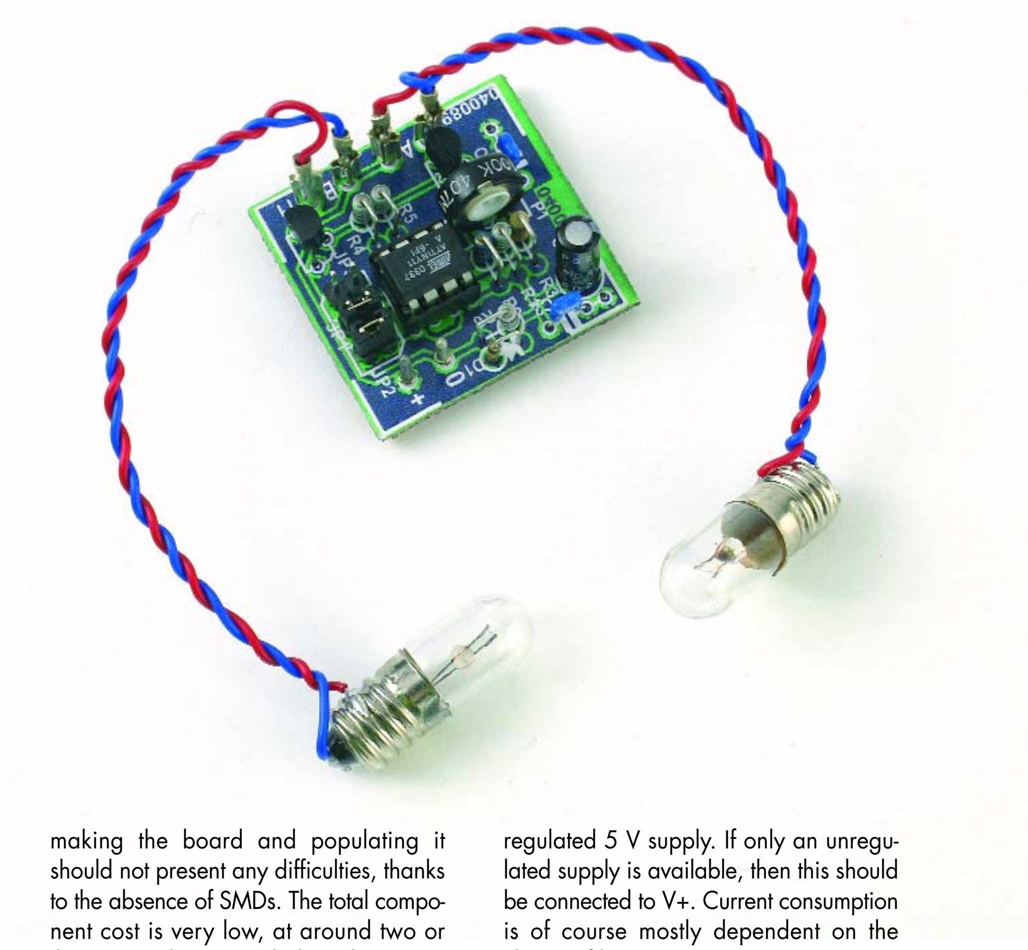
The output of an OR gate can only supply several mA, which is obviously much too little to drive a stepper motor directly. A suitable driver circuit, which goes between the generator and stepper motor, was published in the May 2004 issue of *Elektor Electronics*.

(044015-1)



Intelligent Flickering Light

Andre Frank



Whether it is required to simulate an open fire in a nativity scene, a forest fire in a model railway landscape, a log fire in a doll's house or simply for an artificial candle, neither steady light nor the commercially-available regularly flickering lights are very realistic. The circuit described here imitates much better the irregular flickering of a fire.

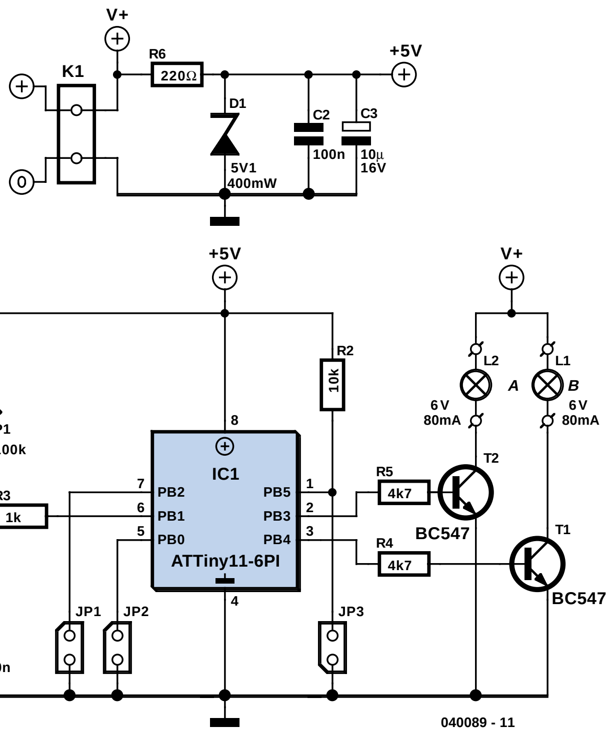
For maximum flexibility, and to reduce the component count to a minimum, a microcontroller from the Atmel ATtiny range has been selected to generate the flickering pattern. Two miniature light bulbs, each driven by a transistor, are controlled using a PWM signal to produce eight different light levels. Potentiometer P1 in the RC network adjusts the speed of the clock to the microcontroller, and hence the speed of the flickering.

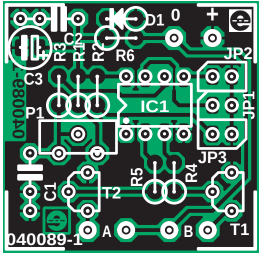
Generating the light levels in software is straightforward in practice, but the underlying theory is far from simple: hence the 'intelligent' in the title. Using a digital pseudo-random number generator (an 8-bit shift register with feedback arranged according to the coefficients of a primitive polynomial) a sequence of period 255 can be produced. In order that the flickering is not too violent, the sequence is smoothed using a digital FIR low-pass filter which takes the average of the last two sample values. If desired, a jumper can be fitted that compresses the dynamic range of the output by adding in a fixed basic intensity. The result is an irregular flickering which closely resembles that of a fire. A further option allows the brightness values to be read from a look-up table instead of using the sequence generator; this option obviously gives the greatest flexibility. A jumper gives the choice of two different tables.

The look-up tables can be used to produce other decorative light effects, such as a light fader, or the continous mixing of two differently-coloured lights. It could even be used to imitate rotating flashing lights on a model. If the design were expanded to three channels, it would be possible to connect three miniature light bulbs in red, green and blue (or an RGB LED) and generate arbitrary colour patterns.

The printed circuit board is just the size of a postage stamp and so should be easy to fit within small models or model landscapes. The board is single-sided, and making the board and populating it should not present any difficulties, thanks to the absence of SMDs. The total component cost is very low, at around two or three pounds, not including the circuit board. Power can be obtained from any regulated 5 V supply. If only an unregulated supply is available, then this should be connected to V+. Current consumption is of course mostly dependent on the choice of lamp.

(040089-1)





COMPONENTS LIST

Resistors:
R1,R4,R5 = 4kΩ7
R2 = 10kΩ
R3 = 1kΩ
R6 = 220Ω

Capacitors:
C1,C2 = 100nF
C3 = 10µF 16V

Semiconductors:
D1 = 5.1V zener diode, 400 mW
T1,T2 = BC547
IC1 = ATtiny11-6PI (programmed)

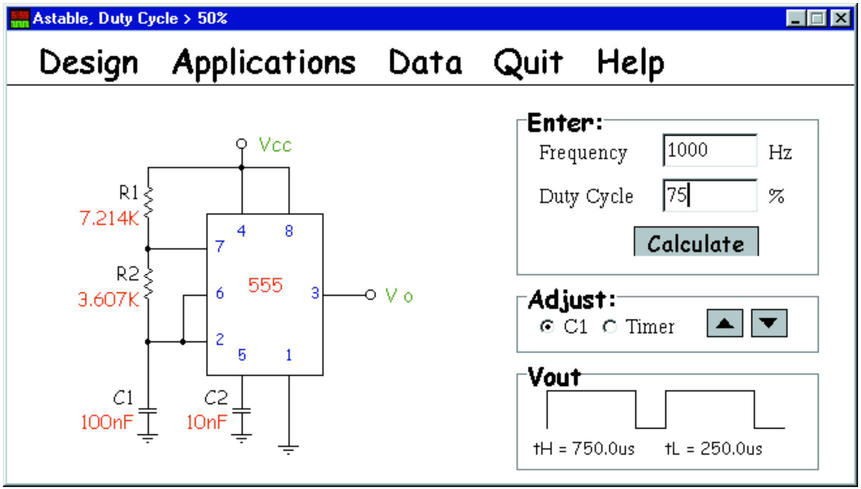
Miscellaneous:
L1,L2 = 6V / 80mA miniature lamp
PCB no. 040089-11, available from **The PCBShop**
Project software: file **040089-11**, Free Download

The Eternal 555

Karel Walraven

You may not realise this, but the 555 timer IC has been in existence for over 30 years. The chip was originally manufactured by Signetics. In the first three months following its introduction (1972) over half a million of them were sold. Moreover, it has stayed successful: since that time the 555 has been the most popular IC sold every year! Nowadays it makes sense to use the CMOS version of this IC, since it consumes significantly less power.

Virtually everything regarding the 555 can be found at www.schematica.com/555_Timer_design/555.htm. A program can be downloaded from this site, which easily calculates the values for the R-C components. The program is suitable for both the astable and bistable modes. The 'adjust' buttons are used to switch between the single 555 and the double version (the 556). When a different value is chosen for C1, the resistors change automatically.



(044020-1)

Reset IC with Selectable Voltages

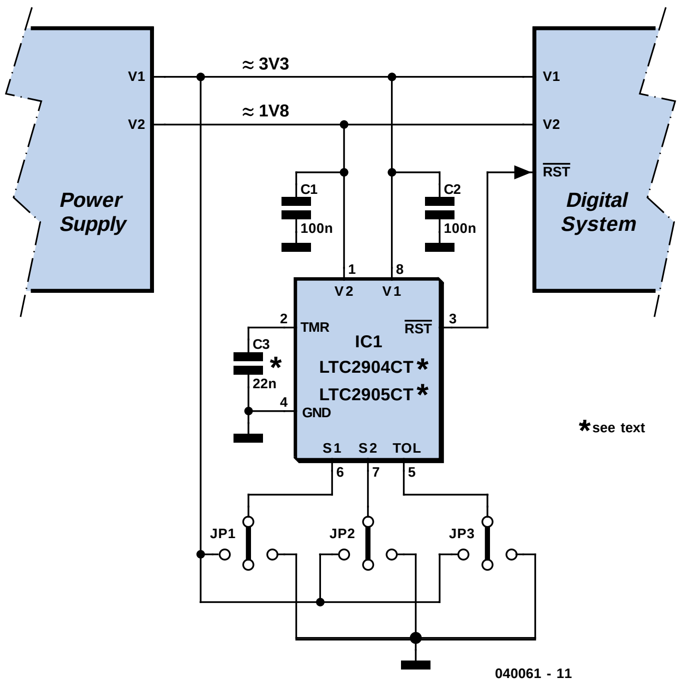
Gregor Kleine

Modern digital systems work with a supply voltage of +3.3 V, and sometimes they also need an additional, lower supply voltage, such as 1.8 V, 1.5 V or even 1.2 V. To generate a reset signal from these two voltages, it was previously necessary to use a separate reset IC for each voltage, and each IC had to be individually dimensioned for the voltage it monitored.

The Linear Technology LTC2904/5 (www.linear.com/pdf/29045f.pdf) can be programmed for two voltages. The voltages are selected using the S1, S2 and TOL inputs according to whether they are connected to V1, connected to ground or left open. The IC can be configured for the voltages shown in the table.

The tolerance for the two voltages can be set using the TOL pin. The effect this has on the internally determined reset threshold

S1	S2	V1	V2
V1	V1	5.0 V	3.3 V
open	ground	3.3 V	2.5 V
V1	open	3.3 V	1.8 V
open	V1	3.3 V	1.5 V
open	open	3.3 V	1.2 V
ground	ground	2.5 V	1.8 V
ground	open	2.5 V	1.5 V
ground	V1	2.5 V	1.2 V
V1	ground	2.5 V	1.0 V



is that the larger the tolerance, the lower the internal threshold is set.

The $\overline{\text{RST}}$ output (pin 3) is an open-drain output. It goes Low when at least one of the two voltages drops below the programmed threshold level. There is a time delay before the reset signal is de-activated after the voltages rise above the threshold level. With the LTC2904, this delay has a fixed value of 200 ms, while with the LTC2905 it depends on the value of the capacitor connected to the TMR pin:

$$t_{delay} = 9\ \text{ms/nF}$$

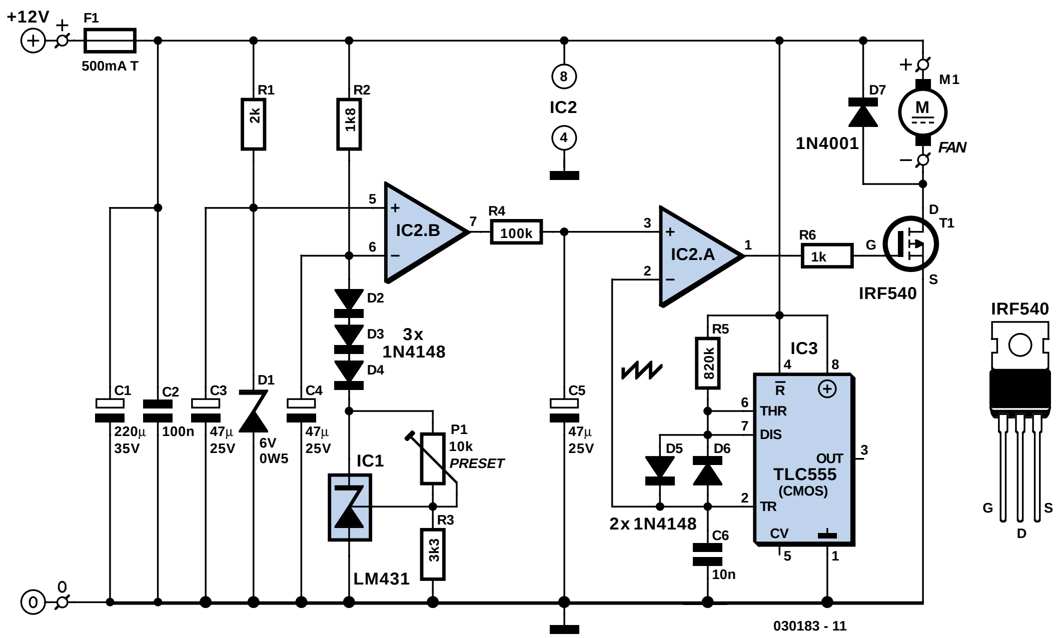
This expression is valid for delay times between 1 ms and 10 s.

In place of the TMR connection (pin 2), the LTC2904 has an open-drain RST output that is complementary to the $\overline{\text{RST}}$ output, which means it is active High.

(040061-1)

TOL	Tolerance
V1	5 %
open	7.5 %
ground	10 %

Monitor Life Xtender



Myo Min

This circuit was designed to protect a computer monitor from overheating. It is recommended to attach this circuit to power users' monitors!
Most computer monitors of the CRT type fail owing to over-heating. After one or two hours of use, the rear of a monitor may become as hot as 45 degrees C, or 20 degrees above ambient temperature. Most heat comes from the VGA gun drivers, the horizontal circuit, vertical circuit and power supply. The best possible way to extract heat and so prolong monitor life (and save the environment) is to add a brushless fan, which is lighter, energy-wiser and more efficient than a normal fan.
In the diagram, diodes D2, D3 and D4 sense the monitor's temperature. These diodes have a total negative temperature coefficient of 6 mV per degree Celsius. To eliminate noise, shielded wire should be used for the connection of the temperature sensor to the circuit sensor.
The +12-V supply voltage is borrowed from the computer's power supply. Alternatively, a mains adapter with an output of 12 VDC may be used. C1 and C2 are decoupling capacitors to eliminate the ripple developed by switching or oscillation. R1 provides bias current to D1, a 6-V zener diode acting as a reference on the non-inverting pin of opamp IC2.B. IC1, a 'precision shunt regulator' raises the sensor diodes' voltage to just over 6 V depending on the adjustment of P1. C4 is the decoupling capacitor with the sensor network.
Integrator network R4-C5 provides a delay of about 3 seconds, transforming the on/off output signal of IC2.B into an exponentially decreasing or increasing voltage. This voltage is fed to pin 3 of the second opamp, IC2.A.
The hard on/off technique would produce a good amount of noise whenever the load is switched, hence an alternative had to be found. IC3, a TLC555, is used as an astable multivibrator with R5 and C6 controlling the charging network that creates a sawtooth voltage with a frequency of about 170 Hz. This sawtooth is coupled to pin 2 of IC2.A, which compares the two voltages at its input pins and produces a PWM (pulsewidth modulated) output voltage. The sawtooth wave is essential to the PWM signal fed to power output driver T1 by way of stopper resistor R6. The power FET will switch the fan on and off fan according to the PWM drive signal.
The back emf pulses that occur when T1 switches on and off are clamped by a high-speed diode, D7.
Initially, turn P1 to maximum resistance. Blow hot air from a hair dryer onto the sensor-diodes for a minute or so, then get the temperature meter near the sensor diodes and adjust P1 slowly towards the minimum resistance position with a digital meter hooked up on pin 7 of IC2.B. Roughly calibrate the temperature to 40 degrees C. At this temperature, the meter will show approximately 12 V.
The circuit will draw about 120 mA from its 12-V supply.

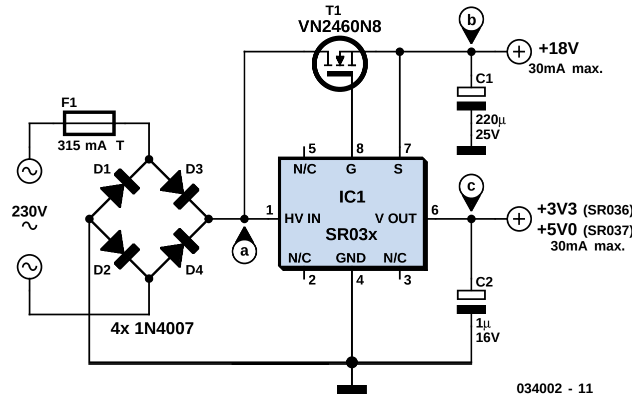
(030183-1)

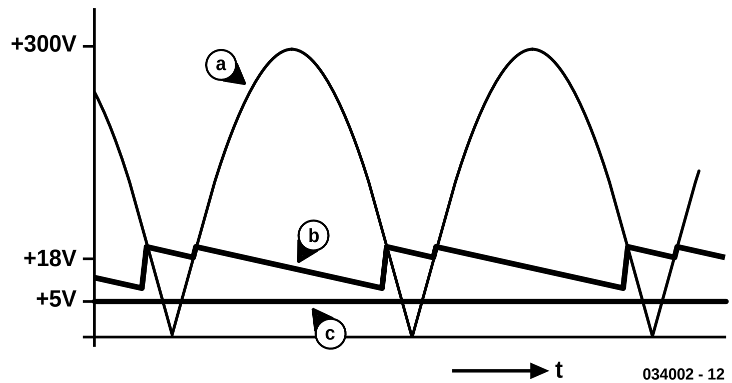
3.3 V or 5 V Direct from the Mains

Gregor Kleine

The SR03x range of voltage regulator chips from Supertex (www.supertex.com) connects directly to the rectified mains supply and provides a low-current 3.3 V or 5.0 V output without the need for any step-down transformer or inductor.
The circuit requires a full-wave rectified mains voltage input (**waveform a**). A built-in comparator controls a series-pass configured MOSFET. The MOSFET is only switched on whenever the input voltage is below an 18 V threshold. A 220 µF capacitor is used to smooth out fluctuations so that the resultant voltage has a sawtooth waveform (**waveform b**) with a peak value of 18 V. This unregulated voltage is connected to the source input of the chip (pin 7) and an internal voltage regulator produces a regulated output (**waveform c**) of 3.3 V for the type SR036 or 5.0 V for the SR037.

Normally you would expect to see a reservoir capacitor fitted across the output of a full wave rectifier in a power supply circuit but in this case it is important to note that one is **not** fitted. For correct operation it is necessary for the input voltage to fall close to zero during each half wave.



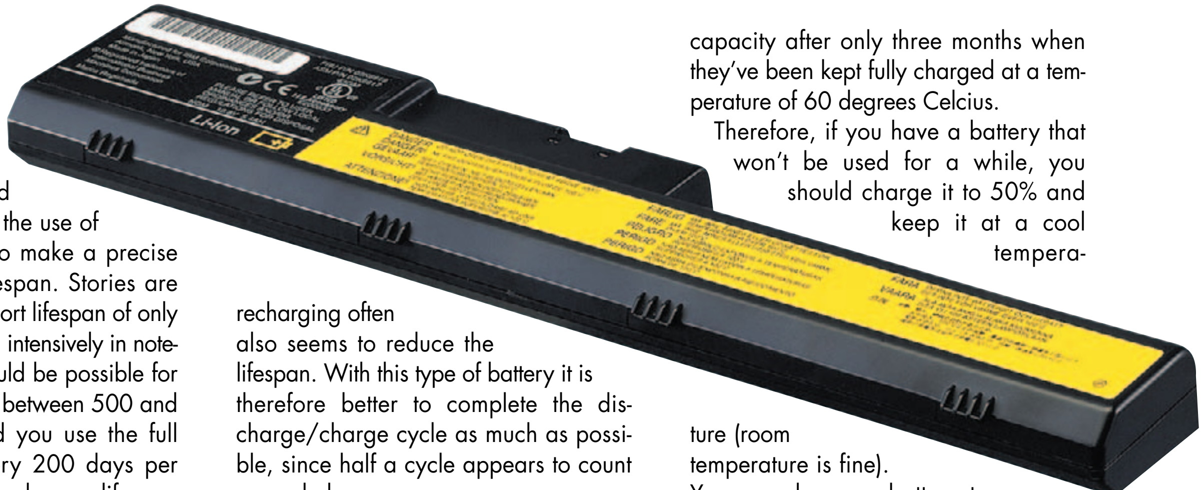


Warning: This circuit must only be used in a fully encapsulated enclosure with no direct connections to any external circuit. It is important to be aware that the circuit is connected to the mains and the chip has lethal voltages on its pins! All appropriate safety guidelines must be adhered to.

(034002-1)

Lifespan of Li-Ion Batteries

Karel Walraven



New technologies can introduce new problems. We haven't really had enough experience in the use of Lithium-Ion batteries to make a precise statement on their lifespan. Stories are floating around of a short lifespan of only a few years when used intensively in notebooks, whereas it should be possible for them to last anywhere between 500 and 1,000 cycles. Should you use the full capacity of the battery 200 days per year, it should in theory have a lifespan of about three years. But even when the battery has gone through only 100 cycles it appears to have lost some capacity.

With nickel-cadmium and nickel-hydride cells it is recommended that they are never fully discharged, nor fully charged. The NiMH battery used by Toyota in the 'Prius' car operates between 40 % and 80 % of capacity and has an 8-year guarantee. If it was used between 0 and 100 % it wouldn't even survive one year of intensive use.

Lithium-Ion batteries appear to behave differently. Discharging by 20 % and recharging often also seems to reduce the lifespan. With this type of battery it is therefore better to complete the discharge/charge cycle as much as possible, since half a cycle appears to count as a whole one.

A second aspect is the oxidation of the electrodes. They begin to deteriorate right from the moment of manufacture and that process is unavoidable. This causes a gradual reduction in the useable capacity. Although this process can't be stopped, it can be slowed down. The key words here are 'low temperature' and 'not fully charged'. It is ironic that this is the exact opposite to the conditions found in a typical notebook: the battery is kept fully charged and the temperature is often around 40 degrees Celcius. There have been reports of batteries losing half their capacity after only three months when they've been kept fully charged at a temperature of 60 degrees Celcius.

Therefore, if you have a battery that won't be used for a while, you should charge it to 50% and keep it at a cool temperature (room temperature is fine).

You can charge a battery to 50 % of its capacity by reducing the charging voltage to about 3.9 V. In any case, you should check the output voltage of the charger and take away a few tenths of a volt. Accidents can happen when the charging voltage is too high!

Another cause of failure is when the battery is deeply discharged due to self-discharge. To avoid damage the battery voltage should never drop below 2 V. At room temperature this means that the battery should be checked once or twice a year, and recharged if necessary.

(044023-1)

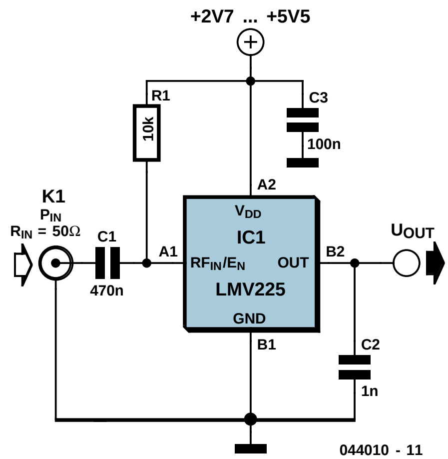
Linear RF Power Meter

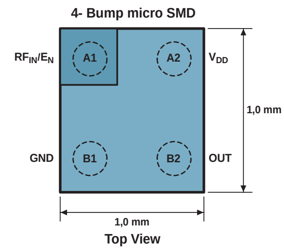
Gregor Kleine

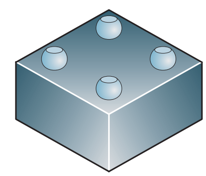
The National Semiconductor LMV225 is a linear RF power meter IC in an SMD package. It can be used over the frequency range of 450 MHz to 2000 MHz and requires only four external components.
The input coupling capacitor isolates the DC voltage of the IC from the input signal. The 10-kΩ resistor enables or disables the IC according to the DC voltage present at the input pin. If it is higher than 1.8 V, the detector is enabled and draws a current of around 5–8 mA. If the voltage on pin A1 is less than 0.8 V, the IC enters the shutdown mode and draws a current of only a few microampères. The LMV225 can be switched between the active and shutdown states using a logic-level signal if the signal is connected to the signal via the 10-kΩ resistor. The supply voltage, which can lie between +2.7 V und +5.5 V, is filtered by a 100-nF capacitor that diverts residual RF signals to ground. Finally, there is an output capacitor that forms a low-pass filter in combination with the internal circuitry of the LMV225. If this capacitor has a value of 1 nF, the corner frequency of this low-pass filter is approximately 8 kHz. The corner frequency can be calculated using the formula

$$f_c = 1 \div (2 \pi C_{OUT} R_o)$$

where R_o is the internal output impedance (19.8 kΩ). The output low-pass filter determines which AM modulation components are passed by the detector.
The output, which has a relatively high impedance, provides an output voltage that is proportional to the signal power,



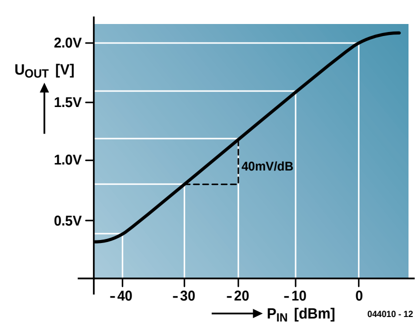




with a slope of 40 mV/dB. The output is 2.0 V at 9 dBm and 0.4 V at –40 dBm. A level of 0 dBm corresponds to a power of 1 mW in 50 Ω. For a sinusoidal waveform, this is equivalent to an effective voltage of 224 mV. For modulated signals, the relationship between power and voltage is generally different. The table shows several examples of power levels and voltages for sinusoidal signals. The input impedance of the LMV225 detector is around 50 Ω to provide a good match to the characteristic impedance commonly used in RF circuits. The data sheet for the LMV225 shows how the 40-dB measurement range can be shifted to a higher power level using a series input resistor.
The LMV225 was originally designed for use in mobile telephones, so it comes in a tiny SMD package with dimensions of only around 1 × 1 mm with four solder bumps (similar to a ball-grid array package). The connections are labelled A1, A2, B1 and B1, like the elements of a matrix. The corner next to A1 is bevelled.

(044010-1)

dBm	mW	Ueff (Sinusoid)
–40	0.0001	2.24 mV
–30	0.001	7.07 mV
–20	0.01	22.4 mV
–10	0.1	71 mV
0	1	224 mV
10	10	707 mV



Adjustable Zener Diode

Dieter Bellers

A Zener diode is the simplest known type of voltage limiter (**Figure 1**) As soon as the voltage exceeds the rated voltage of the Zener diode, a current can flow through the diode to limit the voltage. This is exactly the right answer for many protection circuit applications.

However, if it is necessary to limit a signal to a certain voltage in a control circuit, Zener diodes do not provide an adequate solution. They are only available with fixed values, which are also subject to a tolerance range. What we are looking for is thus an 'adjustable' Zener diode. Such a component would be useful in a heating controller with a preheat temperature limiting, for example, or in a battery charger to provide current limiting.

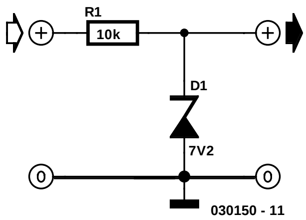
The answer to our quest is shown in **Figure 2**. Assume for example that the output voltage must not exceed 6.5 V. The control voltage on the non-inverting input is thus set to 6.5 V. Now assume that 4.2 V is present at the input. The result is that the maximum positive voltage is present at the opamp output, but the diode prevents this from having any effect on the signal. However, if the voltage rises above 6.5 V, the output of the opamp goes negative and pulls the voltage back down to 6.5 V. The current is limited by R3.

Another example is a situation in which exactly the opposite is required. In this case, the voltage must not drop below a certain value. This can be easily achieved by reversing the polarity of the diode.

Another option is a voltage that is only allowed to vary within a certain voltage window. It must not rise above a certain value, but it also must not drop below another specific value. In the circuit shown in **Figure 3**, the left-hand opamp provides the upper limit and the right-hand opamp provides the lower limit. Each opamp is wired as a voltage follower.

(030150-1)

1



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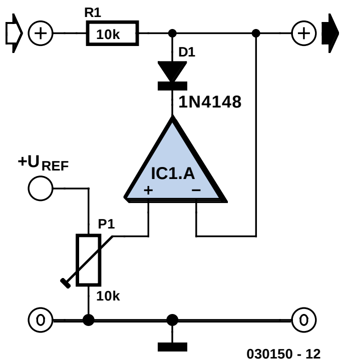

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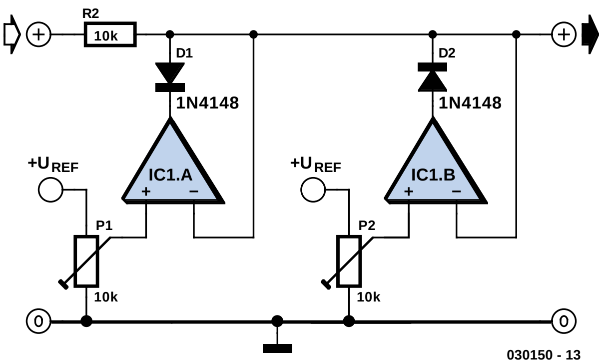


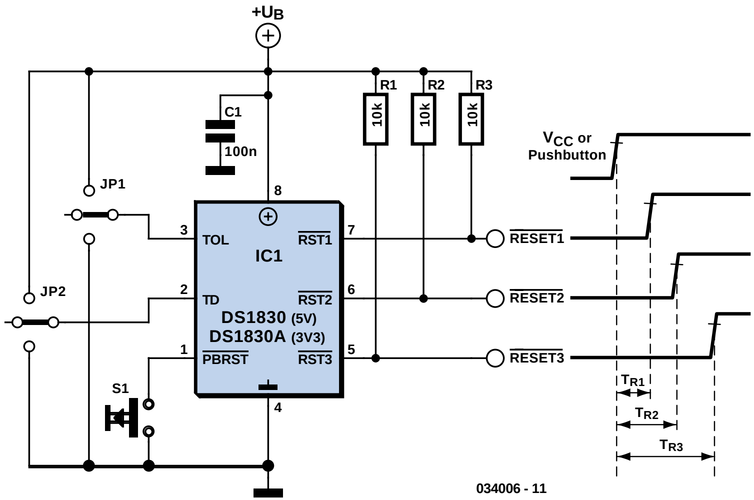
Reset Sequencer

Gregor Kleine

It is often necessary in complex designs to provide a sequence of reset pulses to different parts of a circuit to ensure the whole design functions reliably. The DS1830 from Maxim (www.maxim-ic.com) provides three sequenced open-drain reset outputs. This chip is designed for 5 V systems but a 3.3 V version (DS1830A) is also available. Both are offered in a range of package outlines including DIP, SO and µSOP.

Two inputs give the chip some degree of programmability of its characteristics: The TOL input defines the chips tolerance to power supply fluctuations before a reset sequence is triggered. Jumper JP1 allows the TOL to be connected to Ub (Vcc), ground or left open circuit and will result in the following three reset thresholds:

TOL	5 V	3,3 V
+Ub	Ub · 0.95	Ub · 0.95
0 V	Ub · 0.90	Ub · 0.90
open	Ub · 0.85	Ub · 0.80



The TD input allows the length of the reset signal to be programmed and jumper JP2 gives the following three possibilities:

TD	T_{R1}	T_{R2}	T_{R3}
0 V	10 ms	50 ms	100 ms
open	20 ms	100 ms	200 ms
+Ub	50 ms	250 ms	500 ms

The $\overline{\text{PBRST}}$ (pushbutton reset) allows a manual reset button to be connected to the chip. This input has a built-in 40 kΩ pull up resistor and can also be driven by a digital output or used to cascade additional devices to provide more sequenced reset signals.

(034006-1)

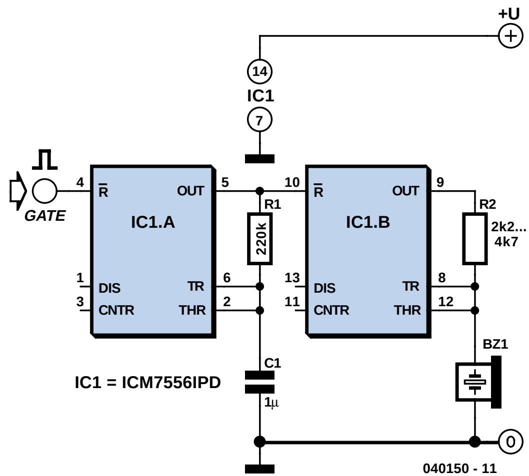
Gated Alarm

Rev. Thomas Scarborough

Sometimes the need arises for a simple, gated, pulsed alarm. The circuit shown here employs just four components and a piezo sounder and is unlikely to be outdone for simplicity. While it does not offer the most powerful output, it is likely to be adequate for many applications.

A dual CMOS timer IC type 7556 is used for the purpose, with each of its two halves being wired as a simple astable oscillator (a standard 556 IC will not work in this circuit, nor will two standard 555's). Note that the CMOS7556 is supplied by many different manufacturers, each using their own type code prefix and suffix. The relevant Texas Instruments product, for instance, will be marked 'TLC556CN'.

The circuit configuration used here is seldom seen, due probably to the inability of this oscillator to be more than lightly loaded without disturbing the timing. However, it is particularly useful for high impedance logic inputs, since it provides a simple means of obtaining a square wave with 1:1 mark-space ratio, which the 'orthodox' configuration does not so easily provide.



IC1.A is a slow oscillator which is enabled when reset pin 4 is taken High, and inhibited when it is taken Low. Output pin 5 of IC1.A pulses audio oscillator IC1.B, which is similarly enabled when reset pin 10 is taken High, and inhibited when it is taken Low.

In order to simplify oscillator IC1.B, piezo sounder X1 doubles as both timing capacitor and sounder. This is possible because a passive piezo sounder typically has a capacitance of a few tens of nanofarads, although this may vary greatly. As the capacitor-sounder charges and discharges, so a tone is emitted. The value of resistor R2 needs to be selected so as to find the resonant frequency of the piezo sounder, and with this its maximum volume. The circuit will operate off any supply voltage between 2 V and 18 V. A satisfactory output will be obtained at relatively high supply voltages, but do not exceed 18 V.

(040150-1)

Long-Interval Pulse Generator

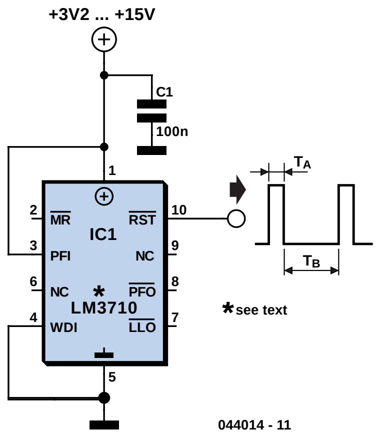
Gregor Kleine

A rectangular-wave pulse generator with an extremely long period can be built using only two components: a National Semiconductor LM3710 supervisor IC and a 100-nF capacitor to eliminate noise spikes.

This circuit utilises the watchdog and reset timers in the LM3710. The watchdog timer is reset when an edge appears on the WDI input (pin 4). If WDI is continuously held at ground level, there are not any edges and the watchdog times out. After an interval T_B, it triggers a reset pulse with a duration T_A and is reloaded with its initial value. The cycle then starts all over again. As a result, pulses with a period of $T_A + T_B$ are present at the $\overline{RESET}$ output (pin 10).

As can be seen from the table, periods ranging up to around 30 seconds can be achieved in this manner. The two intervals T_A and T_B are determined by internal timers in the IC, which is available in various versions with four different ranges for each timer. To obtain the desired period, you must order the appropriate version of the LM3710. The type designation is decoded in the accompanying table. The reset threshold voltage is irrelevant for this particular application of the LM3710. The versions shown in bold face were available at the time of printing. Current information can be found on the manufacturer's home page (www.national.com). The numbers in brackets indicate the minimum and maximum values of intervals T_A and T_B for which the LM3710 is tested. The circuit operates with a supply voltage in the range of 3–5 V.

(044014-1)



LM3710 type designation

LM3710 a b cc ddd

a = output circuit: X = CMOS,
Y = open drain
b = timing (see table)
cc = package: MM = MSOP,
BP = micro SMD
ddd = reset threshold voltage (e.g., '450' for 4.50 V)

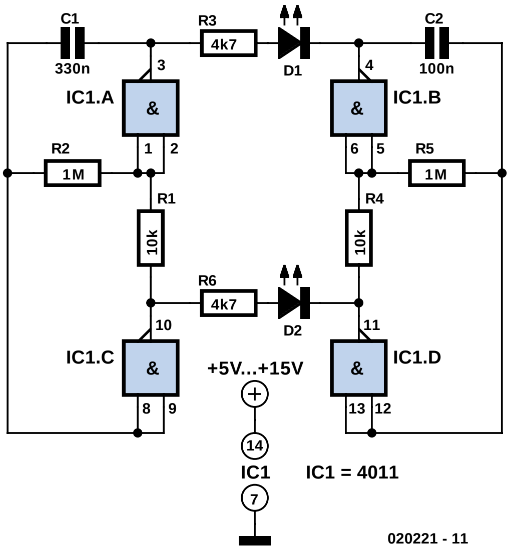
	TA = 1,4 ms (1-2 ms)	**TA = 28 ms** (20-40 ms)	**TA = 200 ms** (140-280 ms)	**TA = 1,6 s** (1.12-2.24 s)
T_B = 6,2 ms (4.3-9.3 ms)	LM3710 XExxx	LM3710 XFxxx	LM3710 XGxxx	LM3710 XHxxx
T_B = 102 ms (71-153 ms)	LM3710 XJxxx	LM3710 XKxxx	LM3710 XLxxx	LM3710 XMxxx
T_B = 1,6 s (1.12-2.4 s)	LM3710 XNxxx	LM3710 XPxxx	LM3710 XQxxx	LM3710 XRxxx
T_B = 25,6 s (17.9-38.4 s)	LM3710 XSxxx	LM3710 XTxxx	LM3710 XUxxx	LM3710 XVxxx

T_A = Reset Timeout Period
T_B = Watchdog Timeout Period

Irregular Flasher

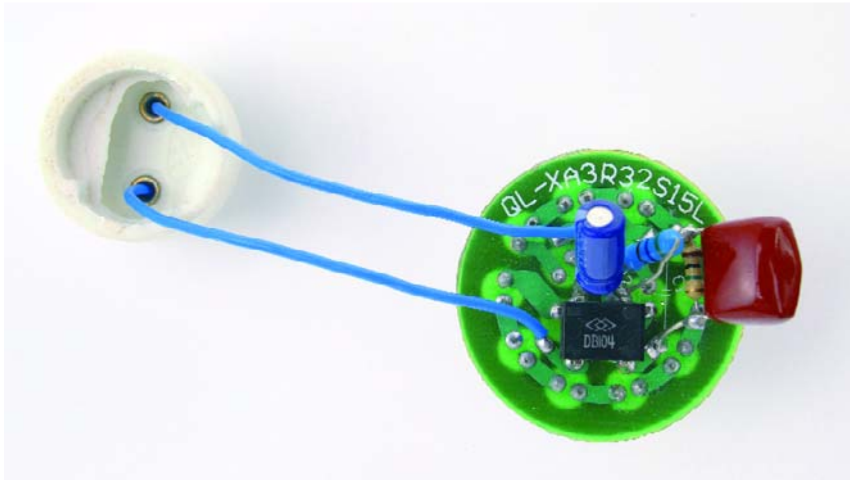
Ludwig Libertin

Two multivibrators with different frequencies can be built using the NAND gates of a 4011 IC. If the output of IC1.B is positive with respect to IC1.C, LED D1 is on. As the levels of IC1.A and IC1.D are exactly opposite, D2 is always on when D1 is off, and the other way around.
The two oscillators have different frequencies, which are determined by the values of R2/C2 and R5/C5 respectively according to the formula
$f_0 = 1 \div (1.4\ RC)$
With the given component values, the frequencies are 2.2 Hz and 7.2 Hz. Low-current LEDs should be used, since the CMOS IC cannot sink or source sufficient current for 'normal' LEDs. The values of series resistors R3 and R6 are suitable for a supply voltage of 12 V, in which case the current consumption of the circuit is around 5 mA. However, in principle the 4011 can be operated over a supply voltage range of 5–15 V. Higher currents can be provided by the HC family (supply voltage 3–6 V) or the HCT family (5 V). Incidentally, the part number of the quad gate IC in the HC family is HC7400.



(020221-1)

White LED Lamp



Did it ever occur to you that an array of white LEDs can be used as a small lamp for the living room? If not, read on. LED lamps are available ready-made, look exactly the same as standard halogen lamps and can be fitted in a standard 230-V light fitting.

We opened one, and as expected, a capacitor has been used to drop the voltage from 230 V to the voltage suitable for the LEDs. This method is cheaper and smaller compared to using a transformer. The lamp uses only 1 watt and therefore also gives off less light than, say, a 20 W halogen lamp. The light is also somewhat bluer.

The circuit operates in the following manner: C1 behaves as a voltage dropping 'resistor' and ensures that the current is not too high (about 12 mA). The bridge rectifier turns the AC voltage into a DC voltage. LEDs can only operate from a DC voltage. They will even fail when the negative voltage is greater then 5 V. The electrolytic capacitor has a double function: it ensures that there is sufficient voltage to light the LEDs when the mains voltage is less than the forward voltage of the LEDs and it takes care of the inrush current peak that occurs when the mains is switched on. This current pulse could otherwise damage the LEDs. Then there is the 560-ohm resistor, it ensures that the current through the LED is more constant and therefore the light output is more uniform. There is a voltage drop of 6.7 V across the 560-Ω resistor, that is, 12 mA flows through the LEDs. This is a safe value. The total voltage drop across the LEDs is therefore 15 LEDs times 3 V or about 45 V. The voltage across the electrolytic capacitor is a little more than 52V.

To understand how C1 functions, we can calculate the impedance (that is, resistance to AC voltage) as follows:

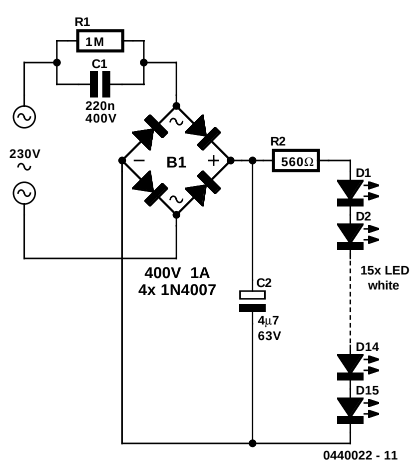
$$1 / (2\pi \cdot f \cdot C), \text{ or:}$$

$$1 / (2 \cdot 3.14 \cdot 50 \cdot 220 \cdot 10^{-9}) = 14k4.$$

When we multiply this with 12 mA, we get a voltage drop across the capacitor of 173 V. This works quite well, since the 173-V capacitor voltage plus the 52-V LED voltage equals 225 V. Close enough to the mains voltage, which is officially 230 V. Moreover, the latter calculation is not very accurate because the mains voltage is in practice not quite sinusoidal. Furthermore, the mains voltage from which 50-V DC has been removed is far from sinusoidal.

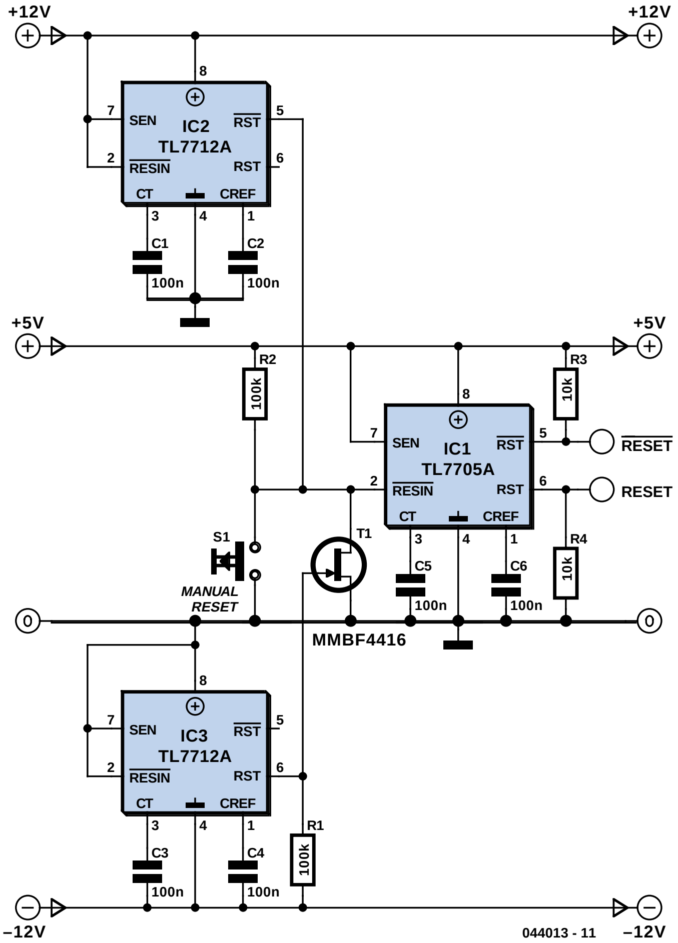
Finally, if you need lots of white LEDs then it is worth considering buying one of these lamps and smashing the bulb with a hammer (with a cloth or bag around the bulb to prevent flying glass!) and salvaging the LEDs from it. This can be much cheaper than buying individual LEDs…

(044022-1)



Reset from Multiple Power Supplies

Gregor Kleine



Processor based systems usually require a voltage supervisor chip to produce a clean reset pulse to the processor whenever a 'brown-out' condition of the power supply is detected. More complex designs employing multiple power supplies can be unreliable if some of the supplies are not supervised. The circuit described here monitors all the supply rails in the system (here +12 V, –12 V and +5 V) and provides a reset pulse to the processor whenever it detects any are not within tolerance.

IC1 (TL7705A) generates a processor reset if the 5 V rail falls below 4.55 V. The value of the capacitor fitted to pin 3 defines the reset pulse width t_d according to the formula:

$$t_d = 12 \cdot C_T \cdot 10^3$$

With C_T in µF the value for t_d is given in µs. A capacitor of 100 nF for example, will produce a reset pulse of around 1.2 ms. Pin 6 (RESET) outputs an active-high pulse and Pin 5 ($\overline{\text{RESET}}$) an active-low pulse. The outputs are open collector types so an external pull-down and pull-up resistor (respectively) is required.

The $\overline{\text{RESIN}}$ input (Pin 2) of IC1 is driven from two TL7712A supervisors monitoring +12 V (IC2) and –12 V (IC3). The TL7712A generates a reset when the supply voltage falls below a threshold level of 10.8 V. The open collector output $\overline{\text{RES}}$ (Pin 5) of IC2 is connected to the $\overline{\text{RESIN}}$ pin of IC1 and pulled up to 5 V via a 100 kΩ resistor. The open collector output of IC2 can be directly connected to the reset input of IC1 but the output of IC3 must be connected via a level shifting device before it can be connected to the reset input of IC1 because the voltage level at the output of IC3 goes negative. JFET transistor T1 is used to perform the necessary level shifting. The JFET turns off when the voltage at its gate-source junction is between –2.5 V and –6 V. When IC3 is issuing a reset signal the RES output (pin 6) will go up to ground potential and cause T1 to conduct and trigger a reset of IC1. At all other times the RES output of IC3 will be pulled to a minus voltage via the 100 kΩ resistor which then causes T1 to stop conducting and release the reset. A manual reset push button can also be connected to $\overline{\text{RESIN}}$ of IC1 if required. The SENSE input (Pin 7) of the TL77xx chips is connected to the positive supply rail. The reference input (pin 1) is fitted with a 100 nF capacitor to reduce the effects of fast transients.

The JFET type MMBF4416 is available from Conrad Electronic (www.conrad.de), order no. 14 28 08

(044013-1)

LED Light Pen

Myo Min

Physicians and repair engineers often use small light pens for visual examination purposes. Rugged and expensive as these pens may be, their weak point is the bulb, which is a ‘serviceable’ part. In practice, that nearly always equates to ‘expensive’ and / or ‘impossible to find’ when you need one.

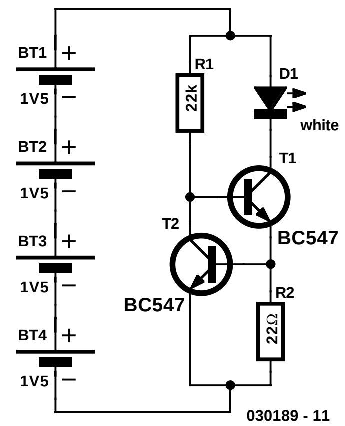
LEDs have a much longer life than bulbs and the latest ultra bright white ones also offer higher energy-to-light conversion efficiency. On the down side, LEDs require a small electronic helper circuit called ‘constant-current source’ to get the most out of them.

Here, T1 and R1 switch on the LED. R2 acts as a current sensor with T2 shunting off (most of) T1’s base bias current when the voltage developed across R2 exceeds about 0.65 V. The constant current through the white LED is calculated from

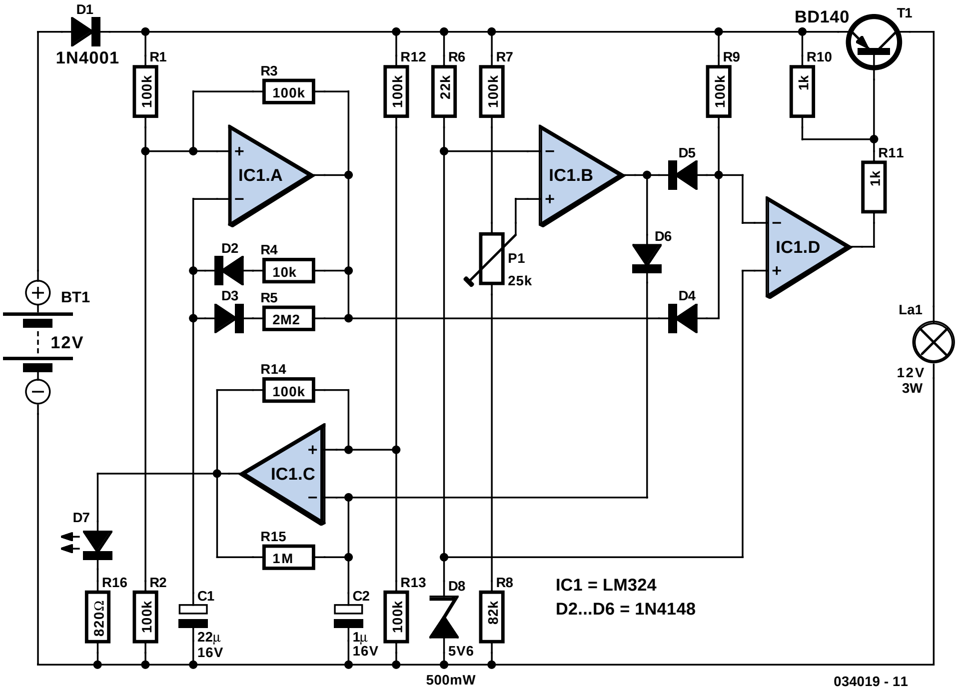
$$R2 = 0.65 / I_{LED}$$

With some skill the complete circuit can be built such that its size is equal to an AA battery. The four button cells take the place of the other AA battery that used to be inside the light pen.

(030189-1)



Storage Battery Exerciser



Ludwig Libertin

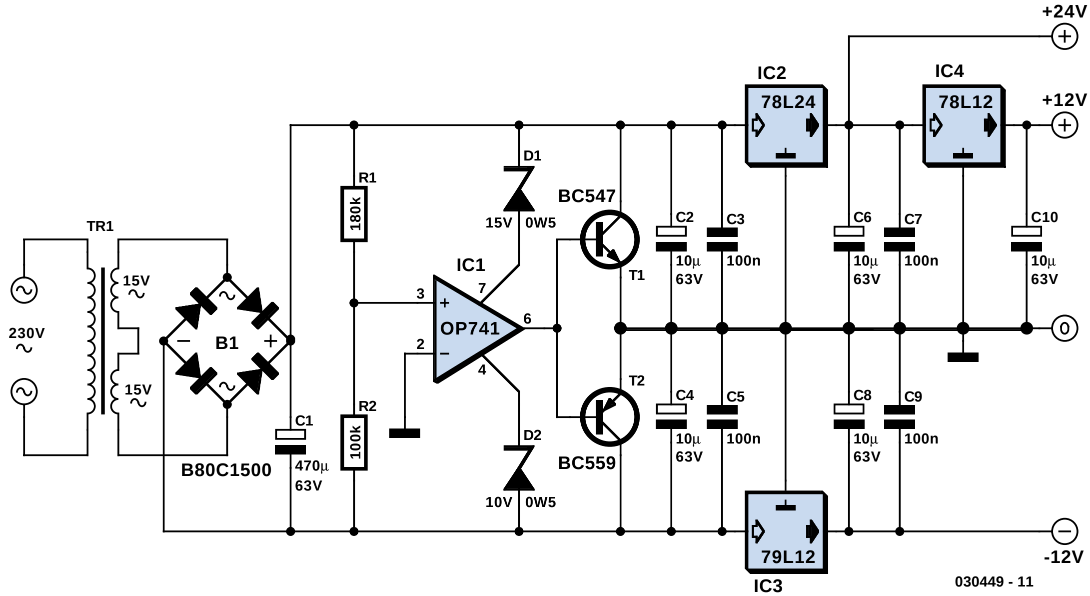
A motorcycle or boat battery that is not needed over the winter is usually charged before being put away for the winter, after which it remains standing unused for months on end. As a result, it accumulates deposits of lead sludge, which can result in reduced capacity or even complete failure of the battery. If you don't keep active, you rust! To avoid this, it's necessary to keep the battery active even during the winter. This circuit does such a good job of exercising the battery that it doesn't have to be recharged during the winter. It only has to be fully charged again in the spring before being used again.

IC1.A is an astable multivibrator with an asymmetric duty cycle. The output is High for around 0.6 s and Low for around 40 s. IC1.B is wired as a comparator that constantly monitors the battery voltage. Its threshold voltage is set to 11.0 V using the trimpot. As soon as the battery voltage drops below this value, the comparator goes Low and D6 is cut off, allowing the second astable multivibrator IC1.C to oscillate at approximately 1.2 Hz. LED D7 then blinks to indicate that the battery must be charged.

As long as the battery voltage is greater than 11 V, IC1.B is High. IC1.A is Low most of the time, and in this state D4 conducts and the inverting input of IC1.D is Low. This means that IC1.D is High most of the time, with T1 cut off. T1 only conducts during the 0.6-s intervals when IC1.A is High. In this state it allows current to pass through the lamp (12 V / 3 W), which forms the actual load for the battery. After this, darkness prevails again for 40 s. The average current consumption is approximately 5 mA. At this rate, a relatively new 40-Ah battery will take around one year to become fully discharged. However, this can vary depending on the condition of the battery, and it may be necessary to 'top up' the battery once during the winter.

(034019-1)

Triple Power Supply



Bernd Schädler

Inexpensive miniature transformers normally provide one or two secondary voltages, which is sufficient for generating a set of positive and negative supply voltages, such as are needed for operational amplifier circuits. But what can you do if you need an additional voltage that is higher than either of the supply voltages (such as a tuning voltage for a receiver?). This circuit shows a simple solution to this problem, and it certainly can be extended to suit other applications. Using a 2×15-V transformer, it generates positive 24-V and 12-V supply voltages and a negative 12-V supply voltage.

The little trick for generating the +24-V output consists of using IC1 to create a virtual ground. This is based on a well-known circuit with a voltage divider formed by two equal-valued resistors, which divide the voltage Ub across the rectifier from approximately 40 V down to 20 V. This Ub/2 potential is buffered by an opamp, which allows this virtual ground to drive a load. The present circuit uses the same principle, but instead of being divided by a factor of 2, the voltage across the rectifier (approximately 40 V) is divided unequally by R1 and R2. The resulting potential, which is buffered by the opamp and the subsequent transistor output stage, lies approximately 15 V above the lower potential, and thus around 25 V below the upper potential.

The three voltages are stabilised using standard 100-mA voltage regulators, as shown in the schematic.

The supply voltages for the opamp are also asymmetric. Thanks to the low current consumption, this can be managed using two Zener diodes.

You must bear in mind that the secondary voltage generated by an unloaded miniature transformer is significantly higher than its rated secondary voltage. The following results were obtained in a test circuit using a 1.6-VA transformer with two 15-V secondary windings: the positive and negative 12-V outputs could be loaded at around 10 mA each, and the 24-V output could be loaded with approximately 20 mA, all without any drop in any of the output voltages. For small circuits such as a 0(4)–20-mA instrumentation loop, this is fully adequate. For more complex circuits or switched loads, additional compensation may be necessary.

(030449-1)

Save Energy

Despite our best efforts, a lot of energy is still wasted imperceptibly. We insulate our homes, install high efficiency boilers and buy low energy light bulbs. But it doesn't end there as far as electrical consumption is concerned. Many other items in the home consume electrical power, but here we concentrate on mains adapters (also called 'wall cubes' or 'battery eliminators'). Take a good look around the house to see how many you have, and you could soon find about ten of them: phone charger(s), battery chargers, mini-vac, telephone, answering machine, the radio in the kitchen, modem, and so on. The disadvantage of these adapters is that they easily consume from 1 to 2.5 W under no load, without you getting anything in return (apart from some heat, of course). When five mains adapters are in use, each consuming 2 W, they'll take one kilowatt-hour every 100 hours, at a cost of 7 p. And 100 hours amounts to only 4 days! In a year, this is 87.6 times as much, or a bit over £6 per year. And if ten adapters are in use this amounts to over £12.

Something can be done about this, of course. The simplest way is to switch off all adapters when they are not in use. Most of you do this already, surely. There are probably a few adapters that have to remain switched on at all times though. There is an alternative for these as well: take a look at those modern switched-mode adapters! They no longer have a bulky transformer, just a switched-mode supply. They are (unfortunately) a bit more expensive, but tend to be smaller and give a better regulated output voltage. The quiescent power consumption of these adapters really is very small.

(044028-1)

Pseudo Track Occupancy Detector

for Märklin Digital Systems

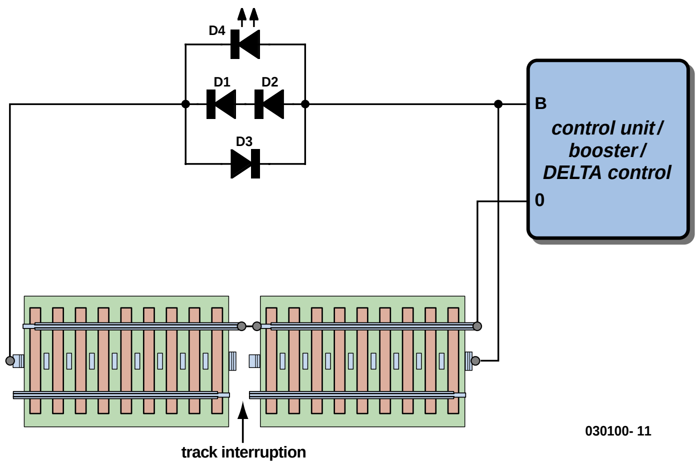
Nils Körber

Track occupancy detectors are needed for hidden yards and other sections of track that are hard to see, but they are also necessary for block operation. The circuit described here uses an LED to indicate track occupancy for digitally controlled Märklin HO model train systems (including Delta Control). In contrast to a real track occupancy detector, which detects all vehicles, it only responds to vehicles that draw traction current. This means it can be used without making complicated modifications to the rolling stock and track, since it is only necessary to gap the third rail. This circuit is thus especially suitable for retrofitting to existing installations, and it is equally well suited to M, K and C tracks.

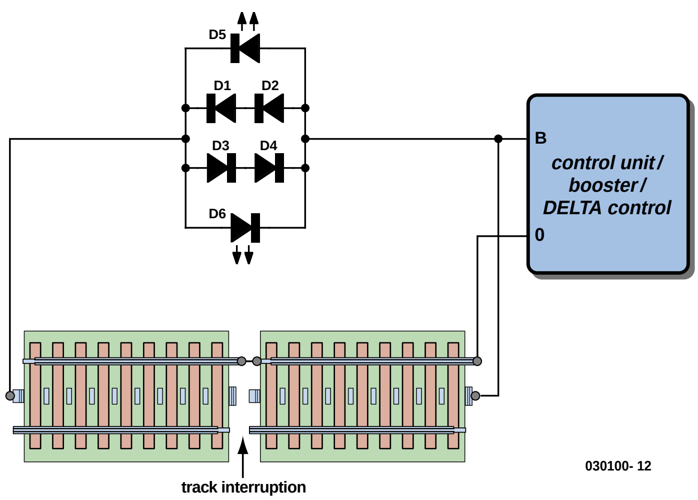
The basic idea of the circuit is simple. If a locomotive enters the monitored track section, a current flows through the motor. This current is sensed and generates an indication. With a Märklin Digital system, power is provided to the locomotive via a controller or a booster in the form of a square-wave voltage. The voltage levels on the rails are approximately –15 V and +15 V. Digital control information is transferred by a continuous sequence of alternating plus and minus levels. This means that the detector circuit must be able to respond to AC signals.

In **Figure 1**, the monitored track section on the left is connected to the ground terminal '0' via the rails. The third rail, with conducts the traction current to the locomotive, is isolated from the rest of the system (special third-rail insulators are available for this purpose), and it is connected to the 'B' terminal of the controller or booster via the detector circuit. If a locomotive travels over the monitored track section, the positive component of the drive current flows through diodes D1 and D2, while the negative component flows through D3. With a motor current of approximately 250 mA, the voltage drop across a single diode (1N4001 types are used here) is a good 1 V.

1



2



The voltage drop across the two diodes connected in series (D1 and D2) is sufficient to illuminate LED1. Although the locomotive will travel somewhat slower due to the voltage drop, this will not cause any problems. A second detector can be obtained by connecting an additional diode to the circuit as shown in **Figure 2**. This causes a second LED to illuminate for negative drive current.

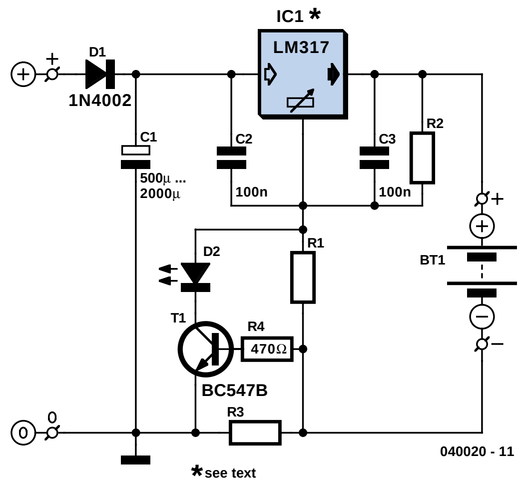
Due to the pulse trains and fluctuations in the traction current, the LED illumination is not constant, but instead flickers more or less strongly. Other traction-power loads, such as coach lighting or taillights, will also generate an 'occupied' indication. In such cases, the LED will remain illuminated even if the locomotive is standing still with no current flowing through the motor. Sometimes the quiescent current through a decoder is sufficient to cause the LED to illuminate (a little bit) even if the locomotive is standing still.

Another possibility is to use an optocoupler instead of an LED. This would allow the circuit to be connected to an s88 detection module.

(030100-1)

Simple NiCd Charger

Wolfgang Schmidt



A simple NiCd charger can be built using 'junk box' components and an inexpensive LM317 or 78xx voltage regulator. Using a current limiter composed of R3 and a transistor, it can charge as many cells as desired until a 'fully charged' voltage determined by the voltage regulator is reached, and it indicates whether it is charging or has reached the fully charged state. If the storage capacitor (C1) is omitted, pulsed charging takes place. In this mode, a higher charging current can be used, with all of the control characteristics remaining the same.

The operation of the circuit is quite simple. If the cells are not fully charged, a charging current flows freely from the voltage regulator, although it is limited by resistor R3 and transistor T1. The limit is set by the formula

$$I_{max} \approx (0.6\ V) \div R3$$

For I_{max} = 200 mA, this yields R3 = 3 Ω. The LED is on if current limiting is active, which also means that the cells are not yet fully charged.

The potential on the reference lead of the voltage regulator is raised by approximately 2.9 V due to the voltage across the LED. This leads to a requirement for a certain minimum number of cells. For an LM317, the voltage between the reference lead and the output is 1.25 V, which means at least three cells must be charged (3 × 1.45 V > 2.9 V + 1.25 V). For a 78xx with a voltage drop of around 3 V (plus 2.9 V), the minimum number is four cells.

When the cells are almost fully charged, the current gradually drops, so the current limiter becomes inactive and the LED goes out. In this state, the voltage on the reference lead of the regulator depends only on voltage divider R1/R2. For a 7805 regulator, the value of R2 is selected such that the current through it is 6 mA. Together with the current through the regulator (around 4 mA), this yields a current of around 10 mA through R1. If the voltage across R1 is 4 V (9 V – 5 V), this yields a value of 390 Ω. The end-of-charge voltage can thus be set to approximately 8.9 V. As the current through the regulator depends on the device manufacturer and the load, the value of R1 must be adjusted as necessary.

The value of the storage capacitor must be matched to the selected charging current. As already mentioned, it can also be omitted for pulse charging.

(040020-1)

Voltage Levels Control Relays

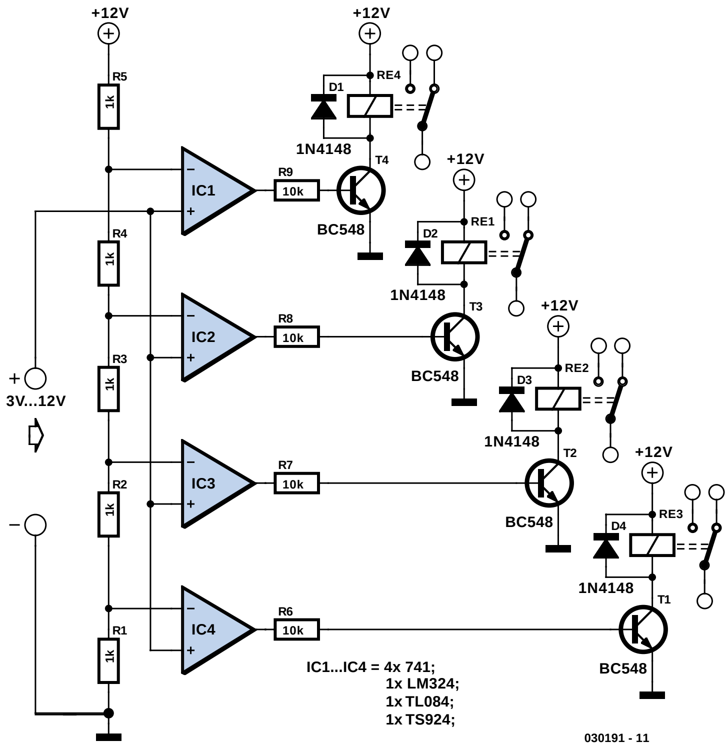
Raj. K. Gorkhali

This circuit proves that microcoprocessors, PCs and the latest ultra-accurate DACs are overkill when it comes to controlling four relays in sequence in response to a rising control voltage in the range 2.4 V – 12 V. By using equal resistors in ladder network R1-R5, equal intervals are created between the voltages that switch on the relays in sequence. Each resistors drops 1/5th of the supply voltage or 2.4 V in this case, so we get +2.4 V = Re1, +4.8 V = Re2, +7.2 V = Re3, +9.6 V = Re4. Obviously, these switching levels vary along with the supply voltage, hence the need to employ a stabilised power supply.

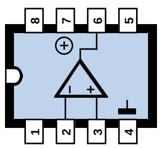
Looking at the lowest level switching stage, when the control voltage exceeds 2.4 V, IC1 will flip its output to (nearly) the supply level. The resulting current sent into the base of T1 is limited to about 1 mA by R6. With T1 driven hard, relay Re1 is energised by the collector current. Because the BC548 has a maximum collector current spec of 100 mA, the relay coil resistance must not be smaller than 120 ohms. Nearly all current consumed by the circuit goes on account of the relay coils, so depending on your relays a pretty hefty power supply of up to 500 mA may be required.

When dimensioning the ladder network to create the desired switching levels, it is good to remember that the 741 will not operate very well with input voltages below 1.5 V or above 10.5 V, while voltage levels outside the supply range (i.e., negative or above +12 V) are out of the question.

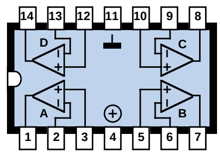
If you do need a switching level in the range 0-1.5 V, consider using an LM324, which contains four opamps in one package. For the high side of the range (10.5 to 12 V), a TL084 or a 'rail-to-rail' opamp like the TS924 is required. However, the TS924 cannot be used with supply voltages above 12 V.



741

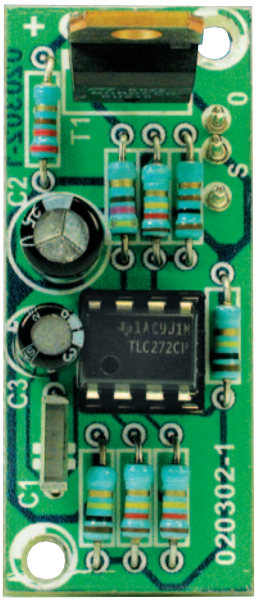


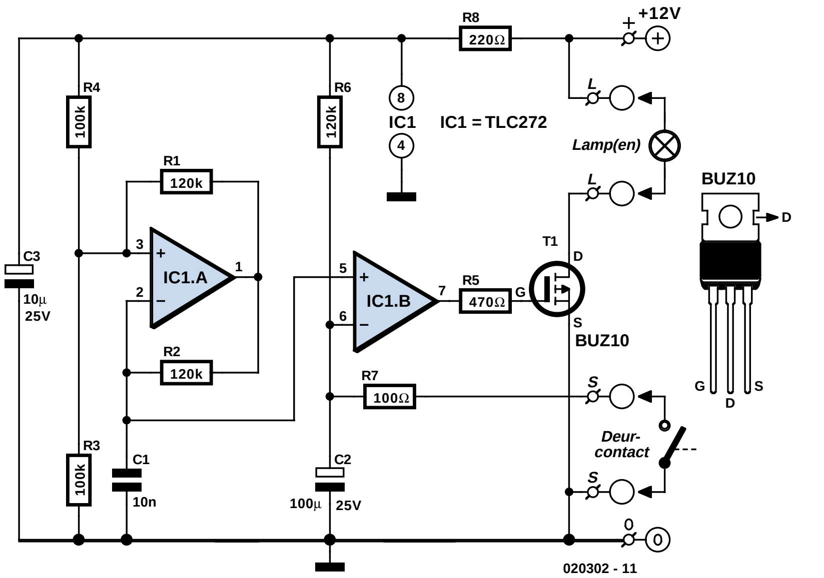
LM324
TL084
TS924



(030191-1)

Luxury Car Interior Light





Cuno Walters

This circuit belongs to the 'car modding' category. This is similar to the popular case modding in the computer world and has found its way into a substantial proportion of cars. The modifications vary from light effects to complete movie playback systems. This circuit is much more modest, but certainly still worth the effort. It provides a high quality interior light delay. This is a feature that is included as standard with most modern cars, although the version with an automatic dimmer is generally only found in the more expensive models. With this circuit it is possible to upgrade second hand and mid-range models with an interior light delay that slowly dims after the door has been closed.

The dimming of the light is implemented by means of pulse-width modulation. This requires a triangle wave oscillator and a comparator. Two opamps are generally required to generate a good triangle wave, but because the waveform doesn't have to be accurate, we can make do with a single opamp. This results in the circuit around IC1.A, a relaxation oscillator supplying a square wave output. The voltage at the inverting input has more of a triangular shape. This signal can be used as long as we do not put too much of a load on it. The high impedance input of IC1.B certainly won't cause problems in this respect. This opamp is used as a comparator and compares the voltage of the triangular wave with that across the door switch. When the door is open, the switch closes and creates a short to the chassis of the car. The output of the opamp will then be high, causing T1 to conduct and the interior light will turn on.

When the door is closed the light will continue to burn at full strength until the voltage across C2 reaches the lower side of the triangle wave (about 5 V). The comparator will now switch its output at the same rate of the triangle wave (about 500 Hz), with a slowly reducing pulse width, which results in a slowly reducing brightness of the interior light.

R8 and C3 protect the circuit from voltage spikes that may be induced by the fast switching of the light.

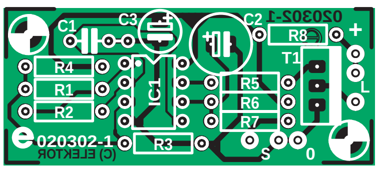
The delay and dimming time can be adjusted with R6 and C2. Smaller values result in shorter times. You can vary the dimming time on its own by adjusting R1, as this changes the amplitude of the triangle wave across C1. R7 limits the discharge current of C2; if this were too big, it would considerably reduce the lifespan of the capacitor.

There is no need to worry about reducing the life of the car battery. The circuit consumes just 350 µA when the lamp is off and a TLC272 is used for the dual opamp. A TL082 will take about 1 mA. These values won't discharge a normal car battery very quickly; the self-discharge is probably many times higher.

It is also possible to use an LM358, TL072 or TL062 for IC1. R8 then needs to have a value between 47 Ω and 100 Ω.

Since T1 is always either fully on or fully off, hardly any heat is generated. At a current of 2 A the voltage drop across the transistor is about 100 mV, giving rise to a dissipation of 200 mW. This is such a small amount that no heatsink is required. The whole circuit can therefore remain very compact and should be easily fitted in the car, behind the fabric of the roof for example.

(020302-1)



Components list

Resistors:
R1,R2,R6 = 120 kΩ
R3,R4 = 100 kΩ
R5 = 470 Ω
R7 = 100 Ω
R8 = 220 Ω

Capacitors:
C1 = 10 nF
C2 = 100 µF 25V
C3 = 10 µF 25V

Semiconductors:
T1 = BUZ10
IC1 = TLC272CP

Miscellaneous:
PCB available from ThePCBShop

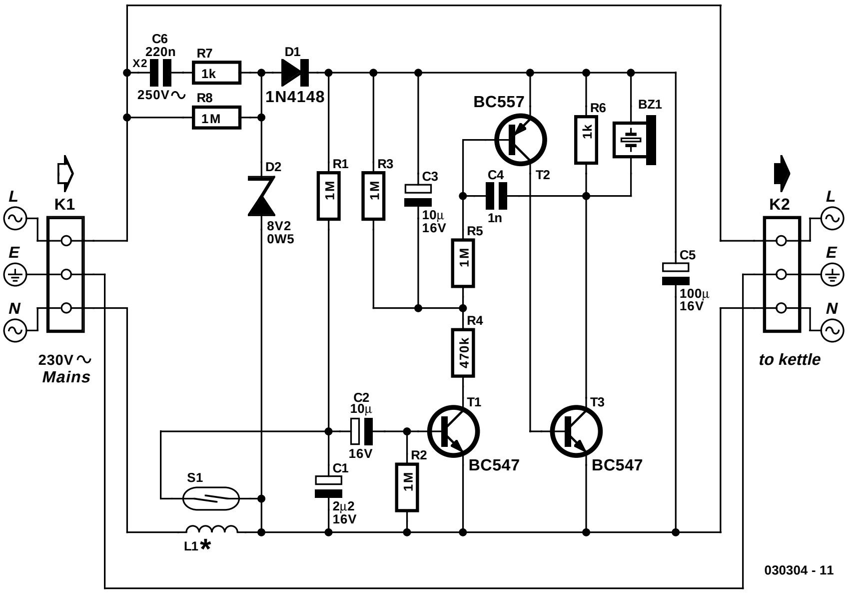
Whistling Kettle

Bart Trepak

Most electric kettles do not produce a whistle and just switch off when they have boiled. Fitting a box of electronics directly onto an electric kettle (or even inside!) to detect when the kettle has boiled is obviously out of the question. The circuit shown here detects when the kettle switches off, which virtually all kettles do when the water has boiled. In this way, the electronics can be housed in a separate box so that no modification is required to the kettle. The box is preferably a type incorporating a mains plug and socket.

In this application, the current flowing in coil L1 provides a magnetic field that actuates reed switch S1. Since the current drawn by the kettle element is relatively large (typically 6 to 8 amps), the coil may consist of a few turns of wire around the reed switch. The reed switch is so fast it will actually follow the AC current flow through L1 and produce a 100-Hz buzz. The switching circuit driven by the reed switch must, therefore, disregard these short periods when the contacts open, and respond only when they remain open for a relatively long period when the kettle has switched off.

The circuit is based on a simple voltage controlled oscillator formed around T2 and T3. Its operation is best understood by considering the circuit with junction R4/R5 at 0 V and C4 discharged. T2 will receive base current through R5 and turn on, causing T3 to turn on as well. The falling collector voltage of T3 is transmitted to the base of T2 by C4 causing this transistor to conduct harder. Since the action is regenerative, both transistors will turn on quickly and conduct heavily. C4 will therefore charge quickly through T2's base-emitter junction and T3. Once the voltage across C4 exceeds about 8.5 V (leaving less than 0.5 V across T2's b-e junction), T2 will begin to turn off. This action is also regenerative so that soon both transistors are switched off and the collector voltage of T3 rises rapidly to +9 V. With C4 still charged to 8.5 V, the base of T2 will rise to about 17.5 V holding T2 (and thus T3) off. C4 will now discharge relatively slowly via R5 until T2 again begins to conduct whereupon the cycle will repeat. The voltage at the collector of T3 will therefore be a series of short negative going pulses whose basic frequency will depend on the value of C4 and R5. The pulses will be reproduced in the piezo sounder as a tone.



The oscillation frequency of the regenerative circuit is heavily dependent on the voltage at junction R4/R5. As this voltage increases, the frequency will fall until a point is reached when the oscillation stops altogether. With this in mind, the operation of the circuit around T1 can be considered. In the standby condition, when the kettle is off, S1 will be open so that C1 and C2 will be discharged and T1 will remain off so that the circuit will draw no current. When the kettle is switched on, S1 is closed, causing C1 and C2 to be discharged and T1 will remain off. C3 will remain discharged so that T2 and T3 will be off and only a small current will be drawn by R1. Although S1 will open periodically (at 100 Hz), the time constant of R1/C1 is such that C1 will have essentially no voltage on it as the S1 contacts continue to close.

When the kettle switches off, S1 will be permanently open and C1/C2 will begin to charge via R1, causing T1 to switch on. C3 will then begin to charge via R4 and the falling voltage at junction R4/R5 will cause T2/T3 to start oscillating with a rising frequency. However, once T1 has switched off, C3 will no longer be charged via R4 and will begin to discharge via R3 and R5 causing the voltage at R4/R5 to rise again. The result is a falling frequency until the oscillator switches off, returning the circuit to its original condition. As well as reducing the current drawn by the circuit to zero, this mimics the action of a conventional whistling kettle, where the frequency rises as more steam is produced and then falls when it is taken off the boil.

The circuit is powered directly by the mains using a 'lossless' capacitive mains dropper, C6, and zener a diode, D2, to provide a nominal 8 V dc supply for the circuit.

A 1-inch reed switch used in the prototype required about 9 turns of wire to operate with a 2-kW kettle element. Larger switches or lower current may require more turns. In general, the more turns you can fit on the reed switch, the better, but do remember that the wire has to be thick enough to carry the current.

It is strongly recommended to test the circuit using a 9-volt battery instead of the mains-derived supply voltage shown in the circuit diagram. A magnet may be used to operate S1 and so simulate the switching of the kettle.

Warning. This circuit is connected directly to the 230-V mains and none of the components must be touched when the circuit is in use. The circuit must be housed in an approved ABS case and carry the earth connection to the load as indicated. Connections and solder joints to components with a voltage greater than 200 volts across them (ac or dc) must have an insulating clearance of least 6 mm. An X2 class capacitor **must** be used in position C6.

(030304-1)

Programmable-Gain Amplifier

Gregor Kleine

The gain of an operational amplifier is usually set using two external resistors. If you wish to have adjustable gain, you can use a digitally controlled multiplexer to select several different gain-setting resistors.

Such an arrangement using several ICs can now be replaced by the Linear Technology LTC 6910 single amplifier or LTC 6911 dual amplifier. These ICs incorporate all of the gain-setting components and can be programmed to eight different gain settings using three digital control inputs. The amplifier is always configured in the inverting mode and features rail-to-rail input and output. The input and output can be driven to within a few tens of millivolts of the supply voltages. At a gain of 100, the bandwidth still extends to approximately 100 kHz.

With a unipolar supply, the supply voltage for the LTC 6910/6911 can range from+2.7 V to +10.5 V. With a bipolar supply, the IC can be operated at ±1.4 V to ±5.25 V. There are several different versions of the IC, which are identified by the suffix -1, -2 or -3. The gains for the various combinations of the digital control signals are shown in the table.

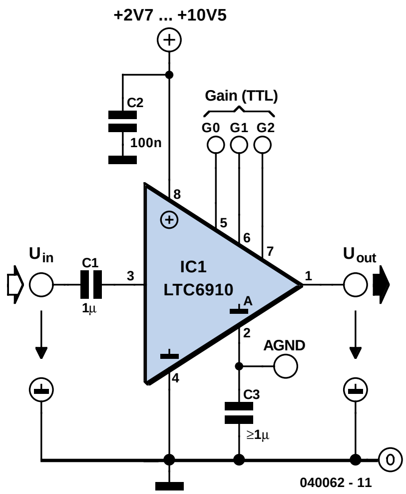
It should be noted that due to the internal arrangement of the resistors, the input resistance of the amplifier can range from 1 kΩ to 10 kΩ, depending on the gain setting. This means that a low-impedance signal source must be used to avoid affecting the configured gain setting.

The AGND pin (pin 2) is the non-inverting input of the internal opamp. It is connected to an internal voltage divider consisting of two 5-kΩ resistors between V+ und V–. When a single supply voltage is used, a capacitor with a value of at least 1 µF must be connected to this pin (**Figure 1**). With a bipolar supply, AGND can be connected directly to signal ground (**Figure 2**). Note also that with a unipolar supply, a coupling capacitor is required at the input, and possibly also at the output, since the input and output are internally biased to half the supply voltage. These coupling capacitors will determine the lower corner frequency of the amplifier.

(040062-1)

G2	G1	G0	LTC6910-1	LTC6911-1	LTC6911-2	LTC6910-3
0	0	0	0	0	0	0
0	0	1	–1	–1	–1	–1
0	1	0	–2	–2	–2	–2
0	1	1	–5	–5	–4	–3
1	0	0	–10	–10	–8	–4
1	0	1	–20	–20	–16	–5
1	1	0	–50	–50	–32	–6
1	1	1	–100	–100		

1



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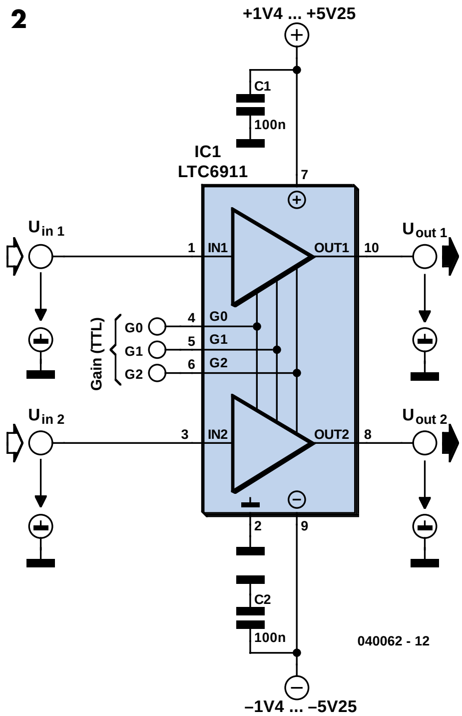
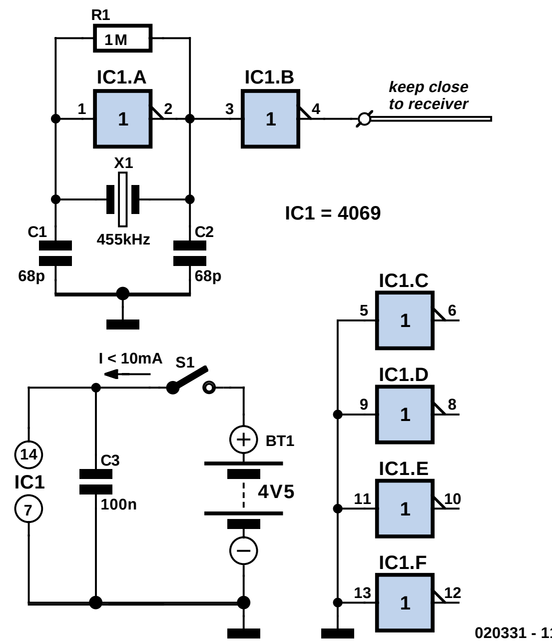


SSB Add-On for AM Receivers

D. Prabakaran

Given favourable radio wave propagation, the shortwave and radio amateur band are chock-a-block with SSB (single-sideband) transmissions, which no matter what language they're in, will fail to produce intelligible speech on an AM radio. SSB is transmitted without a carrier wave. To demodulate an SSB signal (i.e. turn it into intelligible speech) it is necessary to use a locally generated carrier at the receiver side. As most inexpensive SW/MW/LW portable radios (and quite a few more expensive general coverage receivers) still use plain old 455 kHz for the intermediate frequency (IF), adding SSB amounts to no more than allowing the radio's IF to pick up a reasonably strong 455-kHz signal and let the existing AM demodulator do the work. The system is called BFO for 'beat frequency oscillator'.

The heart of the circuit is a 455-kHz ceramic resonator or crystal, X1. The resonator is used in a CMOS oscillator circuit supplying an RF output level of 5 V_{pp}.

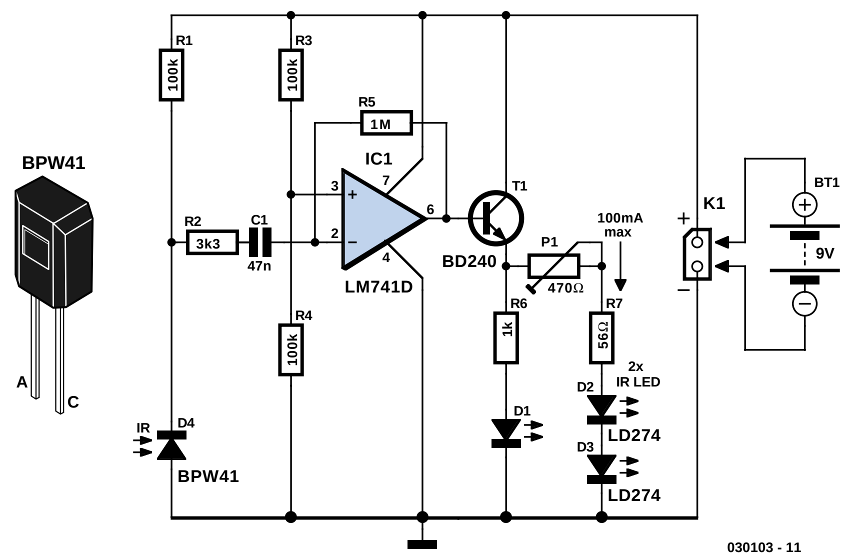


which is radiated from a length of insulated hookup wire wrapped several times around the receiver. The degree of inductive coupling needed to obtain a good beat note will depend on the IF amplifier shielding and may be adjusted by varying the number of turns. All unused inputs of the 4069 IC must be grounded to prevent spurious oscillation.

(020331-1)

Simple Infrared Control Extender

Raj. K. Gorkhali



Lots of consumer electronic equipment like TV sets, VCRs, CD and DVD players employs infrared remote control. In some cases, it is desirable to extend the range of the available control and this circuit fits the bill, receiving the IR signal from your remote control and re-transmitting it, for example, around a corner into another room.

Photodiode D4 is connected to the inverting input of a 741 opamp through resistor R2 and capacitor C1. Since the BPW41 photodiode (from Vishay/Telefunken) needs to be reverse-biased to turn light energy into a corresponding voltage, it is also connected to the positive supply rail via R1. The non-inverting input of the '741 is held at half the supply voltage by means of equal resistors R3 and R4.

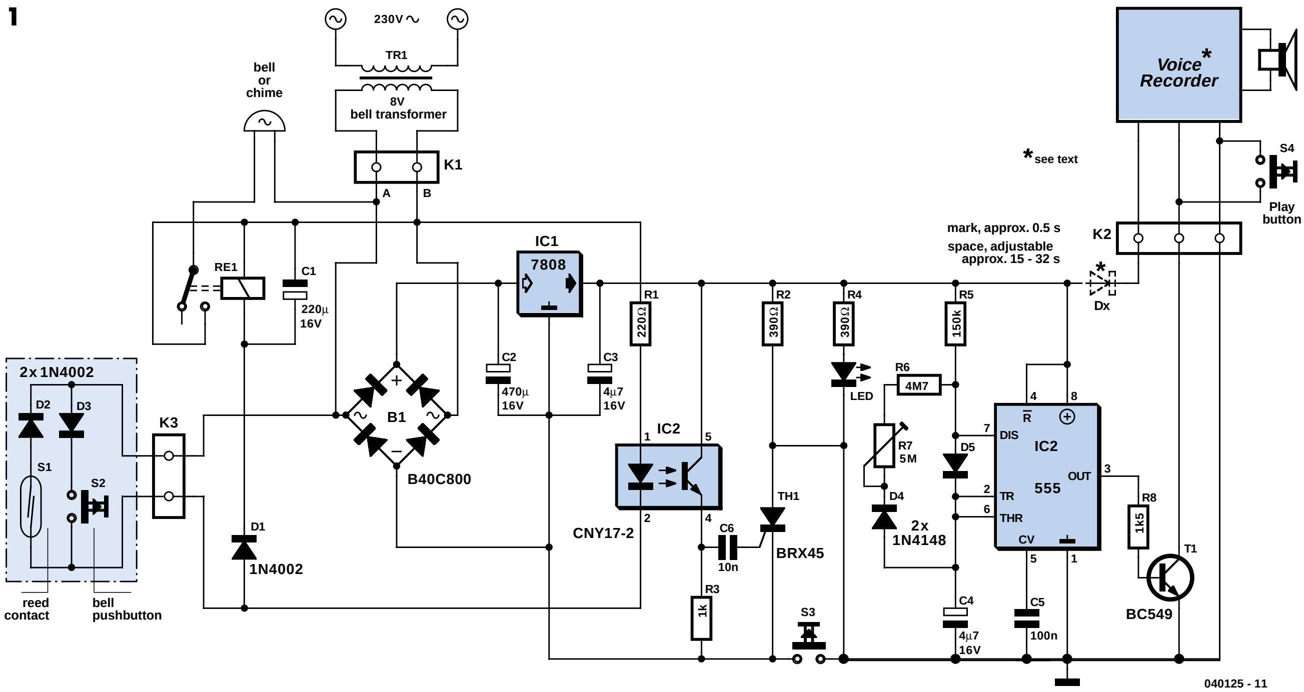
The opamp is followed by a BD240 afterburner transistor capable of supplying quite high current pulses through IR LEDs D2 and D3. However, the pulsed current through the LD274s should not exceed 100 mA or so, hence a fixed resistor is used in series with preset P1. D1 is an ordinary visible-light LED that flashes when an IR signal is received from the remote. With regard to the setting of P1, do not make the IRED current higher than necessary to reliably reach the final destination of the IR signal. Also, the currents mentioned above are peak levels — due to the small duty factor of the IR pulses, the average current drawn from the battery will be much smaller.

The directivity of the IR LEDs — and consequently the range of the control extender — may be increased by fitting the devices with reflective caps.

(030103-1)

You Have Mail!

1



Robert Edlinger

If your letterbox is some distance from your house, you will find a monitoring device useful to indicate when new post has arrived. This can take the form of a US-style visible flag; a more modern alternative uses a 433 MHz radio transceiver. The big advantage of the solution presented here is that is can use an existing two-core bell cable, without requiring any further power source. The arrival of post is signalled by a blinking LED; for added effect, a digital voice recorder can also be connected which will, at regular intervals, announce the fact that the letterbox needs emptying. The device is silenced by a reset button.

The circuit uses one half-cycle of the AC supply to power the bell or buzzer, and the other half-cycle for the post indicator. Suitably-oriented diodes in the device and in the letterbox ensure that the two signals are independent of one another (**Figure 1**). The bell current flows from K1.A through D3, bell-push S2, D1 and the relay back to K1.B. C1 provides adequate smoothing of the current pulses to ensure that the relay armature does not vibrate. The bell is operated by the normally-open relay contact. If the bell is actually a low-current piezo buzzer, then it can be connected directly and the relay dispensed with.

During the half-cycle for the letterbox monitor current flows from connection K1.B on the bell transformer through current-limiting resistor R1, the LED in the optocoupler, reed contact S1 (a microswitch can also be used) and D2 and finally back to K1. If the reed contacts are closed, the LED in the optocoupler will light and switch on the phototransistor. A positive voltage will then appear across R3 which will turn the thyristor on via C6. The red LED will indicate that post has arrived. Pressing S3 shorts out the thyristor, reducing the current through it below the holding value.

A small extra circuit can be added to provide continuous letterbox monitoring. This takes the form of a voice recorder whose ‘play’ button is operated by transistor T1. T1 in turn is driven by a 555 timer IC. In the usual 555 timer circuit, where the device is configured as an astable multivibrator, the mark-space ratio cannot be set with complete freedom. Here two diodes provide separate charge and discharge paths for capacitor C4. When capacitor C4 is charging, D5 conducts and D4 blocks: the charge rate is determined by R5. When discharging, D4 conducts and R6 and the potentiometer determine the rate. The values shown give a pulse length of approximately 0.5 s with a delay of between 15 s and 32 s. The short pulse is sufficient to trigger the voice recorder module via transistor T1 connected across its ‘play’ button.

The voice recorder module (e.g. Conrad order code 115266) is designed to run from a 6 V supply. The maximum recording time is 20 s and the current consumption is 20 mA when recording and between 40 mA and 60 mA when playing back. Since our supply is at 8 V, the excess voltage must be dropped using between 1 and 3 series-connected 1N4148 diodes (shown as D_x in the circuit diagram). The final voltage should be checked using a multimeter. Alternatively, a 7806 can be used without suffering a significant loss in volume.

If it is desired to use a piezo buzzer to provide an acoustic signal, the pulse length should be increased to at least 2 s. In this case, R5 should be increased to 560 kΩ or 680 kΩ: the pulse length, t_{on}, is 0.7·R5·C4, and the interval between pulses, t_{off}, is 0.7· (R6+R7)·C4. Suitable buzzers are available with a wide range of rated voltages.

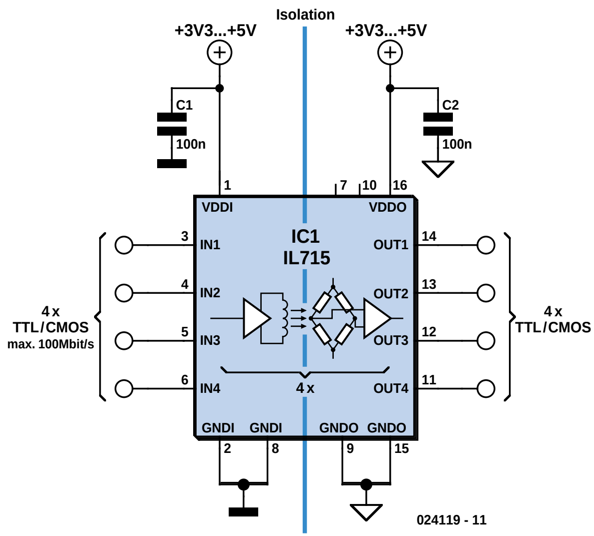
(040125-1)

Digital Isolation up to 100 MBit/s

Gregor Kleine

When it is necessary to send a digital signal between two electrically isolated circuits you would normally choose an optoisolator or some form of transformer coupling. Neither of these solutions is ideal; optocouplers run out of steam beyond about 10 MHz and transformers do not have a good low frequency (in the region of Hertz) response. The company NVE Corporation (www.nve.com) produces a range of coupler devices using an innovative 'IsoLoop' technology allowing data rates up to 110 Mbaud.

The example shown here uses the IL715 type coupler providing four TTL or CMOS compatible channels with a data rate of 100 Mbit/s. Inputs and outputs are compatible with 3.3 V or 5 V systems. The maximum isolation voltage is 2.5 kV and the device can cope with input transients up to 20 kV/µs. The company produce many other configurations including bi-directional versions that would be suitable for RS485 interfacing.

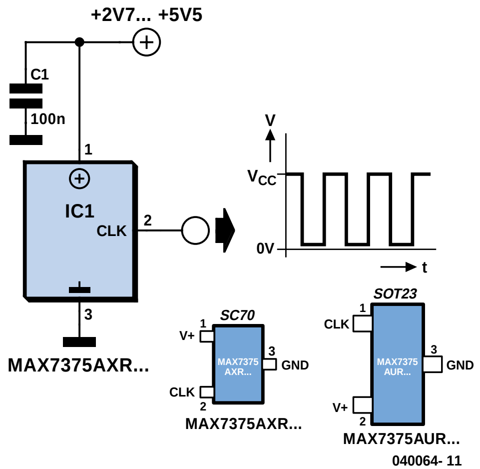


The IsoLoop coupler is based on relatively new GMR (GiantMagnetoResistive) technology. The input signal produces a current in a planar coil. This current generates a magnetic field that produces a change in resistance of the GMR material. This material is isolated from the planar coil by a thin film high voltage insulating layer. The change in resistance is amplified and fed to a comparator to produce a digital output signal. Differences in the ground potential of either the input or output stage will not produce any current flow in the planar coil and therefore no magnetic field changes to affect the GMR material. Altogether the circuit provides a good electrical isolation between input and output and also protects against input signal transients (EMV).

(024119-1)

One Component Oscillator for 1 to 10 MHz

Gregor Kleine



Maxim (www.maxim-ic.com) has produced a completely self-contained TTL oscillator chip in a very small three-pin outline. The MAX7375 family of oscillators operates in the range of 1 MHz up to around 10 MHz, (depending on device suffix) and requires no external components. It may be necessary to fit a 100 nF decoupling capacitor across the supply pins if the chip is sited further than a few centimetres from any other decoupling capacitor. The specified supply voltage range is between 2.7 V and 5.5 V while current consumption is dependant on clock frequency; at 4 MHz the chip takes 4 mA while at 8 MHz this rises to 6.5 mA. The device is available in an SOT23 package outline (MAX7375AUR) or in the even smaller SC70 outline (MAX7375AXR). Note that the pin-out definitions for these two outlines are not identical, the functions of pins 1 and pin 2 are swapped.

The accuracy of the output frequency is guaranteed to be within ±2 % of nominal with a supply voltage of 3 V. Over the entire temperature range this rises to a maximum of ±4 %. This chip is currently available in a range of seven frequencies shown in the table below. The TTL push-pull output stage can sink and source up to 10 mA. The rise and fall times of the oscillator output are in the order of 5 ns while the mark-space ratio lies between 45 % and 57 %.

The MAX7375 offers a smaller, more cost-effective and mechanically more robust alternative to the conventional crystal or ceramic filter type of oscillator. The device has a wide operating temperature range of –40 °C to +125 °C and this makes it particularly suitable for automotive applications.

SOT23 MAX 7375AUR...	SC70 MAX 7375AXR...	Nominal Output Frequency
...105		1 MHz
...185		1.8432 MHz
...365		3.579545 MHz
...375		3.6864 MHz
...405		4 MHz
...425		4.1943 MHz
...805		8 MHz

(040064-1)

Power Flip-Flop Using a Triac

R. Edlinger

Modern electronics is indispensable for every large model railroad system, and it provides a solution to almost every problem. Although ready-made products are exorbitantly expensive, clever electronics hobbyists try to use a minimum number of components to achieve optimum results together with low costs. This approach can be demonstrated using the rather unusual semiconductor power flip-flop described here.

A flip-flop is a toggling circuit with two stable switching states (bistable multivibrator). It maintains its output state even in the absence of an input pulse. Flip-flops can easily be implemented using triacs if no DC voltage is available. Triacs are also so inexpensive that they are often used by model railway builders as semiconductor power switches. The decisive advantage of triacs is that they are bi-directional, which means they can be triggered during both the positive and the negative half-cycle by applying an AC voltage to the gate electrode (G). The polarity of the trigger voltage is thus irrelevant. Triggering with a DC current is also possible.

Figure 1 shows the circuit diagram of such a power flop-flop. A permanent magnet is fitted to the model train, and when it travels from left to right, the magnet switches the flip-flop on and off via reed switches S1 and S2. In order for this to work in both directions of travel, another pair of reed switches (S3 and S4) is connected in parallel with S1 and S2. Briefly closing S1 or S3 triggers the triac. The RC network C1/R2, which acts as a phase shifter, maintains the trigger current. The current through R2, C1 and the gate electrode (G) reaches its maximum value when the voltage across the load passes through zero. This causes the triac to be triggered anew for each half-cycle, even though no pulse is present at the gate. It remains triggered until S2 or S4 is closed, which causes it to return to the blocking state.

The load can be incandescent lamps in the station area (platform lighting) or a solenoid-operated device, such as a crossing gate. The LED connected across the output (with a rectifier diode) indicates the state of the flip-flop.

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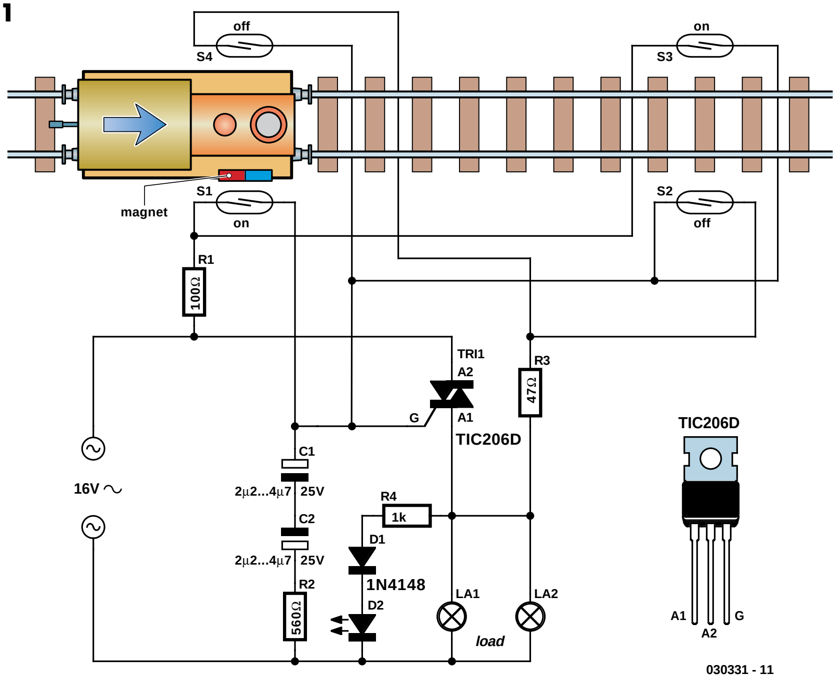


The circuit shown here is designed for use in a model railway system, but there is no reason why it could not be used for other applications. The reed switches can also be replaced by normal pushbutton switches.

For the commonly used TIC206D triac, which has a maximum current rating of 4 A, no heat sink is necessary in this application unless a load current exceeding 1 A must be supplied continuously or for an extended period of time. If the switch-on or switch-off pulse proves to be inadequate, the value of electrolytic capacitor C1 must be increased slightly.

(030331-1)

Buck/Boost Voltage Converter

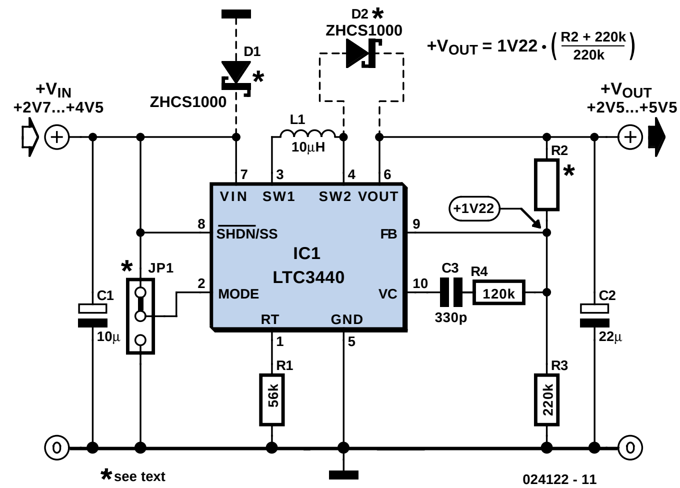
Gregor Kleine

Sometimes it is desired to power a circuit from a battery where the required supply voltage lies within the discharge curve of the battery. If the battery is new, the circuit receives a higher voltage than required, whereas if the battery is towards the end of its life, the voltage will not be high enough. This is where the new LTC 3440 buck/boost voltage converter from Linear Technology (www.linear.com) can help. The switching regulator in **Figure 1** converts an input voltage in the range +2.7 V to +4.5 V into an output voltage in the range +2.5 V to +5.5 V using one tiny coil. The level of the output voltage is set by the voltage divider formed by R2 and R3. The device switches as necessary between step-up (or 'boost') operation when V_{in} is less than V_{out}, and step-down (or 'buck') operation when V_{in} is greater than V_{out}. The maximum available output current is 600 mA. The IC contains four MOSFET switches (**Figure 2**) which can connect the input side of coil L1 either to V_{in} or to ground, and the output side of L1 either to the output voltage or to ground. In step-up operation switch A is permanently on and switch B permanently off. Switches C and D close alternately, storing energy from the input in the inductor and then releasing it into the output to create an output voltage higher than the input voltage. In step-down operation switch D is permanently closed and switch C permanently open. Switches A and B close alternately and so create a lower voltage at V_{out} in proportion to the mark-space ratio of the switching signal. L1, together with the output capacitor, form a low-pass filter. If the input and output voltages are approximately the same, the IC switches into a pulse-width modulation mode using all four switches.

Resistor R1 sets the switching frequency of the IC, which with the given value is around 1.2 MHz. This allows coil L1 to be very small. A suitable type is the DT1608C-103 from Coilcraft (www.coilcraft.com). The IC can be shut down using the SHDN/SS input. A 'soft start' function can also be implemented by applying a slowly-rising voltage to this pin using an RC network. The MODE pin allows the selection of fixed-frequency operation (MODE connected to ground) or burst mode operation (MODE=V_{in}). The latter offers higher efficiency (of between 70 % and 80 %) at currents below 10 mA. At currents of around 100 mA the efficiency rises to over 90 %. A further increase in efficiency can be obtained by fitting the two Schottky diodes shown dotted in the circuit diagram. These operate during the brief period when both active switches are open (break-before-make operation).

(024122-1)

1



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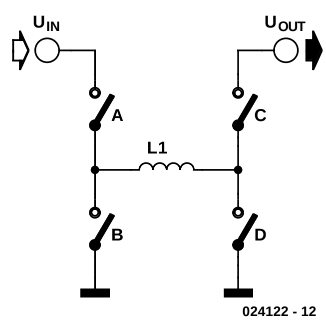
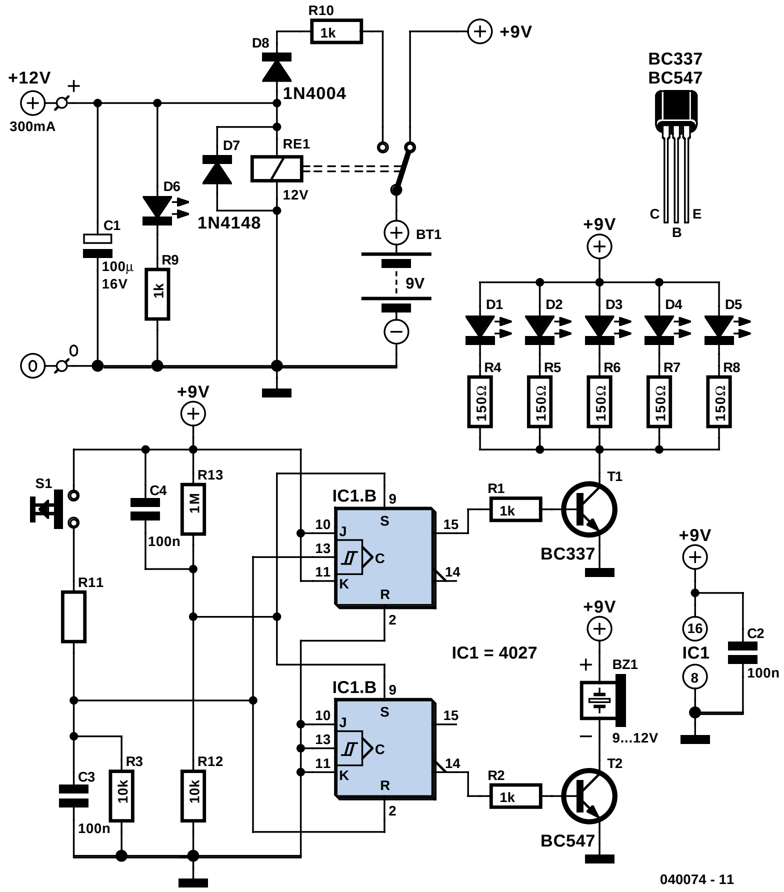


Mains Voltage Monitor



Goswin Visschers

Many electronics hobbyists will have experienced the following: you try to finish a project late at night, and the mains supply fails. Whether that is caused by the electricity board or your carelessness isn't really important. In any case, at such times you may find yourself without a torch or with flat batteries. There is no need to panic, as this circuit provides an emergency light.

When the mains fails, the mains voltage monitor turns on five super bright LEDs, which are fed from a 9 V battery (NiCd or NiMH) or 7 AA cells. A buzzer has also been included, which should wake you from your sleep when the mains fails. You obviously wouldn't want to oversleep because your clock radio had reset, would you?

When the mains voltage is present, the battery is charged via relay Re1, diode D8 and resistor R10. D8 prevents the battery voltage from powering the relay, and makes sure that the relay switches off when the mains voltage disappears. R10 is chosen such that the charging current of the battery is only a few milliamps. This current is small enough to prevent overcharging the battery. D6 acts as a mains indicator.

When the relay turns off, IC1 receives power from the battery. The JK flip-flops are set via R12 and C4. This causes T1 and T2 to conduct, which turns on D1-D5 and the buzzer.

When the push button is pressed, a clock pulse appears on the CLK input of flip-flop IC1b. The output then toggles and the LEDs turn off. At the same time IC1a is reset, which silences the buzzer. If you press the button again, the LEDs will turn on since IC1b receives another clock pulse. The buzzer remains off because IC1a stays in its reset state. R11, R3 and C3 help to debounce the push button signal. In this way the circuit can also be used as a torch, especially if a separate mains adapter is used as the power supply.

As soon as the mains voltage is restored, the relay turns on, the LEDs turn off and the battery starts charging. The function of R13 is to discharge C4, preparing the circuit for the next mishap.
If mains failures are a regular occurrence, we recommend that you connect pairs of LEDs in series. The series resistors should then have a value of 100 Ω. This reduces the current consumption and therefore extends the battery life. This proves very useful when the battery hasn't recharged fully after the last time.

In any case, you should buy the brightest LEDs you can get hold of. If the LEDs you use have a maximum current of 20 mA, you should double the value of the series resistors! You could also consider using white LEDs.

(040074-1)

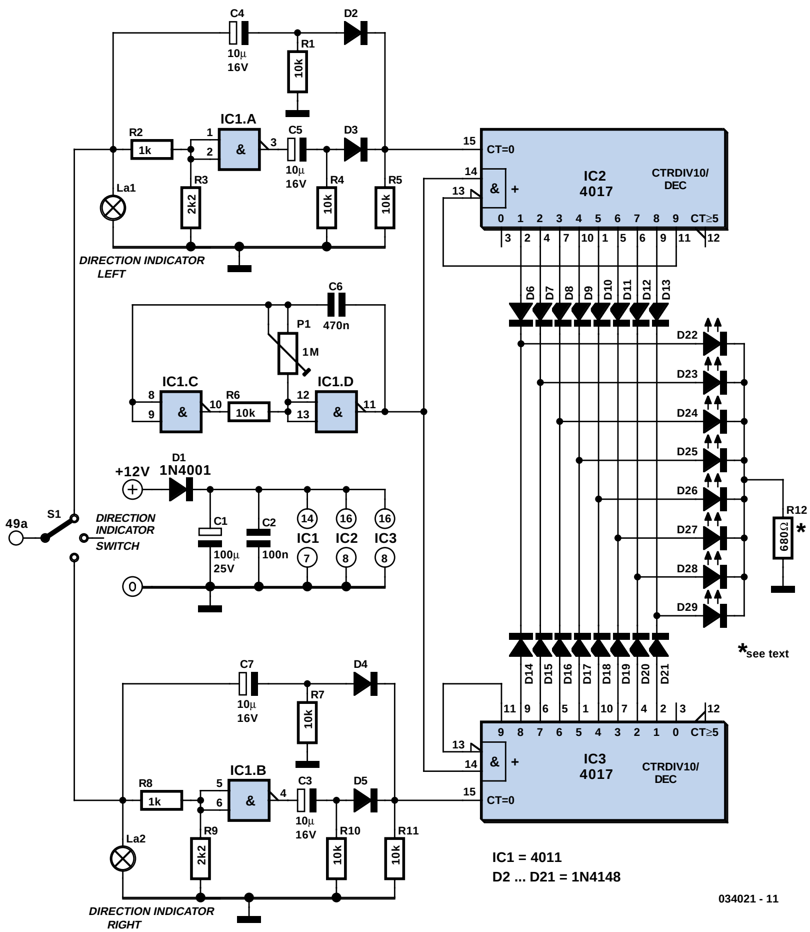
Blinker Indicator

Ludwig Libertin

This circuit represents a somewhat unusual blinker indicator for use in a car or model. The running-light display progresses toward the left or the right depending on which directional signal is activated. That's pretty cool if you're fond of light-show effects.

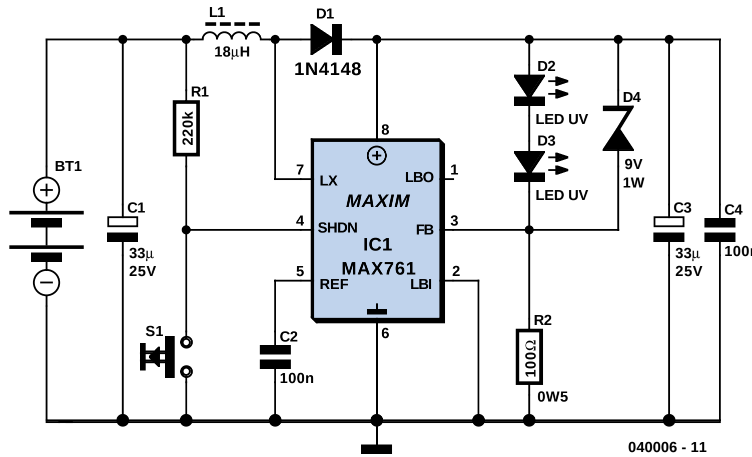
The circuit consists of two counters (IC2 and IC3), which are reset to zero via C4 or C7 respectively whenever a blinker lamp (La) illuminates. The running-light display thus runs through once and then stops, since the highest counter output is connected to the Enable input. When the lamp goes out, a new reset pulse is issued to the relevant counter by NAND gate IC1.A or IC1.B respectively, and the counter counts all the way up again. The progression rate of the display can be adjusted to the right speed using P1. Only one LED is on at a time (except for the hazard blinker). This allows the brightness to be easily adjusted using R12. Incidentally, the circuit can also be modified by replacing the normal diodes with LEDs, with all of the cathodes connected to ground via R12.

(034021-1)



UV Torch Light

Myo Min



UV (ultra-violet) LEDs can produce eye-catching effects when their light is allowed to interfere with certain colours, particularly with reflected light under near-dark conditions. Also try shining some UV light on a diamond…

Most UV LEDs require about 3.6 V (the 'blue' diode voltage) to light. Here, a MAX761 step-up switching IC is used to provide constant current to bias the UV diode. The IC employs PWM in high-current mode and automatically changes to PFM mode in low or medium power mode to save (battery) power. To allow it to be used with two AA cells, the MAX761 is configured in bootstrapped mode with voltage-adjustable feedback. Up to four cells may be used to power the circuit but they may add more weight than you would like for a torchlight.

To prolong the switch life, R1 is connected to the IC's SHDN (shutdown) pin. Less than 50 nA will be measured in shutdown mode. Electrolytic capacitor C1 is used to decouple the circuit supply voltage. Without it, ripple and noise may cause instability. The one inductor in the circuit, L1, may have any value between about 10 and 50 μH. It stores current in its magnetic field while the MOSFET inside the MAX761 is switched. A toroid inductor is preferred in this position as it will guarantee low stray radiation. D1 has to be a relatively fast diode so don't be tempted to use an 1N400x because it has a too slow recovery time.

The circuit efficiency was measured at about 70%. R2, the resistor on the feedback pin of the MAX761 effectively determines the amount of constant current, I, sent through the UV LEDs, as follows:

$$R2 = 1.5 / I$$

where I will be between 2 mA and 35 mA.

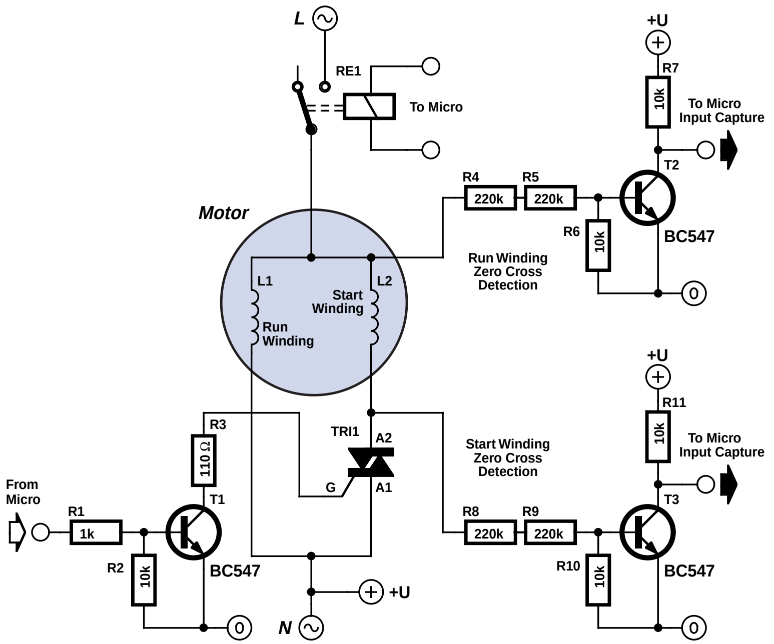
Zener diode D4 clamps the output voltage when the load is disconnected, which may happen when one of the UV LEDs breaks down. Without a load, the MAX761 will switch L1 right up to the boost voltage and so destroy itself.

(040006-1)

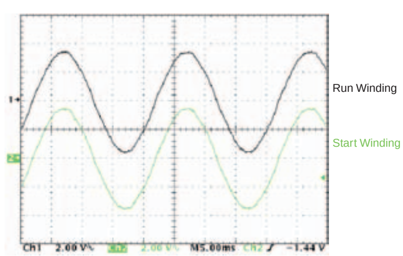
Motor Turn/Stall Detector

Karel Walraven

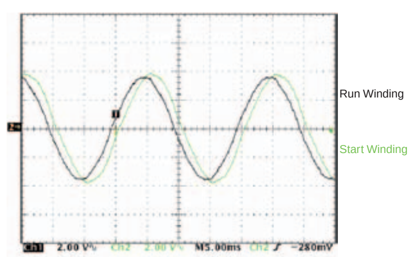
In single phase AC induction motors, often used in fridges and washing machines, a start winding is used during the starting phase. When the motor has reached a certain speed, this winding is turned off again.
The start winding is slightly out of phase to the run winding. The motor will only start turning when the current through this winding is out of phase to that of the run winding. The phase difference is normally provided by placing a capacitor of several µF in series with the start winding. When the motor reaches a minimum speed, a centrifugal switch turns off the start winding. The circuit diagram doesn't show a centrifugal switch; instead it has a triac that is turned on during the staring phase. For clarity, the series capacitor isn't shown in the diagram.
Once the motor turns it will continue to do so as long as it isn't loaded too much. When it has to drive too heavy a load it will almost certainly stall. A large current starts to flow (as the motor no longer generates a back EMF), which is limited only by the resistance of the winding. This causes the motor to overheat after a certain time and causes permanent damage. It is therefore important to find a way to detect when the motor turns, which happens to be surprisingly easy.
When the motor is turning and the start winding is not used, the rotation induces a voltage in this winding. This voltage will be out of phase since the winding is in a different position to the run winding. When the motor stops turning this voltage is no longer affected and will be in phase with the mains voltage. The graph shows



044027 - 11



044027 - 12



044027 - 13

some of the relevant waveforms.
More information can be found in the application note for the AN2149 made by Motorola, which can be downloaded from their website at www.motorola.com. We think this contains some useful ideas, but keep in mind that the circuit shown is only partially completed. As it stands, it certainly can't be put straight to use. We should also draw your attention to the fact that mains voltages can be lethal, so take great care when the mains is connected!

(044027-1)

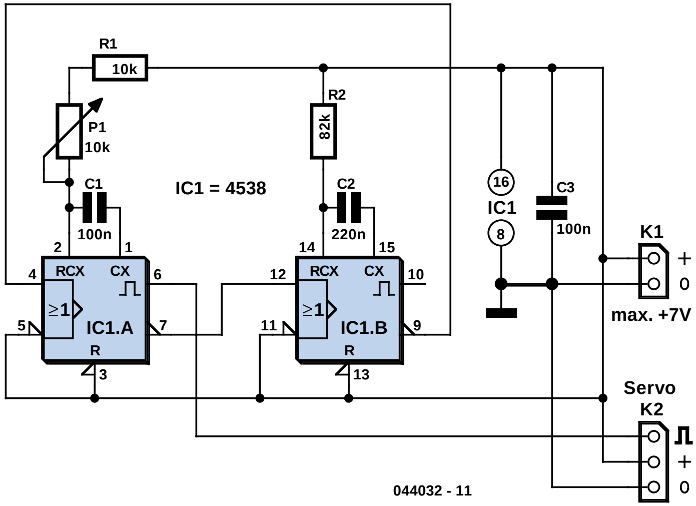
Servo Tester using a 4538

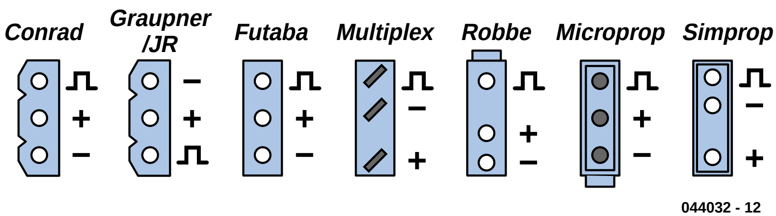
Paul Goossens

There are times when a small servo tester for modelling comes in very useful. Everybody who regularly works with servos will know several instances when such a servo tester will come in handy. The function of a servo tester is to generate a pulsing signal where the width of the positive pulse can be varied between 1 and 2 ms. This pulse-width determines the position the servo should move to. The signal has to repeat itself continuously, with a frequency of about 40 to 60 Hz. We have already published other servo testers in the past. These circuits often use an NE555 or one of its derivatives to generate the pulses. This time we have used a 4538 for variety. This IC contains two astable multi-vibrators.

You can see from the circuit diagram that not many other components are required besides the 4538. The astable multi-vibrator in a 4538 can be started in two ways. When input I_0 (pin 5 or 11) is high, a rising edge on input I_1 (pin 4 or 12) is the start signal to generate a pulse.

The pulse-width at the output of IC1a is equal to (R1+P1)×C1. This means that when potentiometer P1 is turned to its minimum resistance, the pulse-width will be 10 k × 100 n = 1 ms. When P1 is set to maximum (10 k), the pulse-width becomes 20 k × 100 n = 2 ms.





At the end of this pulse inverting output $\overline{Q}$ generates a rising edge. This edge triggers IC1.B, which then generates a pulse. The pulse-width here is 82 k × 220 n ≈ 18 ms. At the end of this pulse the $\overline{Q}$ output will also generate a rising edge. This in turn makes IC1.A generate a pulse again. This completes the circle.

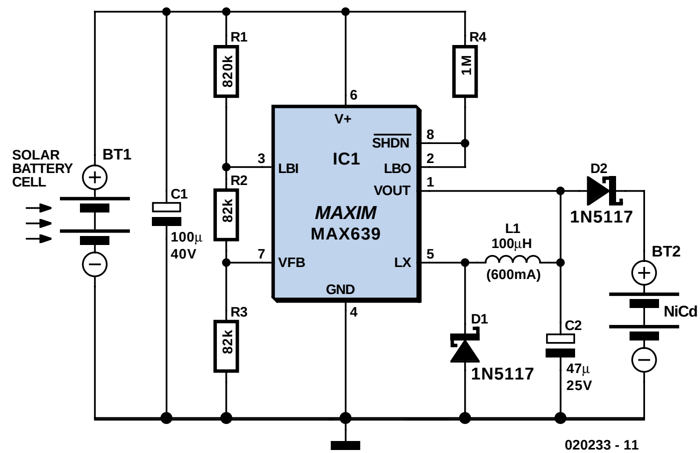
Depending on P1, the total period is between 19 and 20 ms. This corresponds to a frequency of about 50 to 53 Hz and is therefore well within the permitted frequency range.

(044032)

Solar-Powered High Efficiency Charger

D. Prabakaran

This is a simple NiCd battery charger powered by solar cells. A solar cell panel or an array of solar cells can charge a battery at more than 80 % efficiency provided the available voltage exceeds the 'fully charged' battery voltage by the drop across one diode, which is simply inserted between the solar cell array and the battery. Adding a step-down regulator enables a solar cell array to charge battery packs with various terminal voltages at optimum rates and with efficiencies approaching those of the regulator itself. However, the IC must then operate in an unorthodox fashion (a.k.a. 'Elektor mode') regulating the flow of charge current in such a way that the solar array output voltage remains near the level required for peak power transfer.



Here, the MAX639 regulates its input voltage instead of its output voltage as is more customary (but less interesting). The input voltage is supplied by twelve amorphous solar cells with a minimum surface area of 100 cm^2.

Returning to the circuit, potential divider R2/R3 disables the internal regulating loop by holding the V-FB (voltage feedback) terminal low, while divider R1/R2+R3 enables LBI (low battery input) to sense a decrease in the solar array output voltage. The resulting deviation from the solar cells' peak output power causes LBO (low battery output) to pull SHDN (shutdown) low and consequently disable the chip. LBI then senses a rising input voltage, LBO goes high and the pulsating control maintains maximum power transfer to the NiCd cells. Current limiting inside the MAX639 creates a 'ceiling' of 200 mA for I_{out}. Up to five NiCd cells may be connected in series to the charger output.

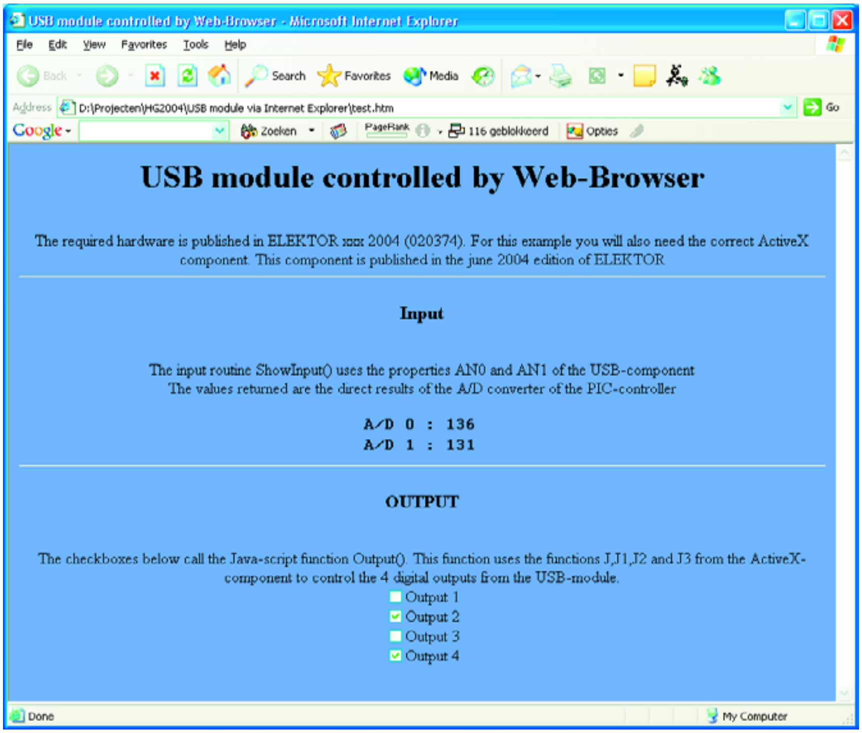
When 'on' the regulator chip passes current from pin 6 to pin 5 through an internal switch representing a resistance of less than 1 ohm. Benefiting from the regulator's low quiescent current (10 microamps typical) and high efficiency (85 %), the circuit can deliver four times more power than the single-diode configuration usually found in simple solar chargers.

Coil L1 is a 100-µH suppressor choke rated for 600 mA.

(020233-1)

USB Converter Controlled via HTML

Paul Goossens



In this issue we publish an ActiveX component, which can be used to control the USB analogue converter (*Elektor Electronics*, November 2003). In this way, programmers can use C/C++, Delphi, VB etc. to include the converter in their own application.

It is maybe less well known that these ActiveX components can also be used from web browsers that support scripts and ActiveX. For this reason we've created an example HTML file, which uses JavaScript and ActiveX to control the USB converter. This file is available as a Free Download from http://www.elektor-electronics.co.uk/ (044034-11).

To place an ActiveX component onto a web page you have to make use of the <OBJECT> tag. In this a name and a CLASSID have to be specified. This CLASSID is a number that indicates which type of ActiveX component should be used. Since it is impractical to remember all these number by heart, Microsoft have made a program available called ActiveX Control Pad. With this program it becomes easy to place an ActiveX component onto a web page and adapt its properties to your own liking.

Now that we've placed the ActiveX component onto the page, we can use JavaScript to send commands to this component or get it to return information. Here the JavaScript part sets up a communication channel with the USB converter when the page is opened. It also starts a timer that calls the function ShowInput() every half a second.

The functions in JavaScript are very similar to those found in C. The three functions used in this example are simple enough for anyone with a bit of programming experience to follow. An important detail that should be mentioned is that every ActiveX component on the page is given a name during the initialisation. In this case, we have given the meaningful name 'USB' to the component that takes care of the communication with the USB module. The two labels on this page have been creatively named as 'Label1' and 'Label2'.

The previous tale sounds good, but does it work in practice? Everybody who has a USB analogue converter from the November 2003 issue of *Elektor Electronics* and who has installed this month's ActiveX component, can try it out very quickly. The USB converter first has to be connected via a USB cable. Then you should open the file 'test.htm'. If you have a web browser that supports ActiveX and JavaScript (such as Internet Explorer), you should see the web page as shown here. The values of the A/D converter are refreshed on the screen twice per second and the tick-boxes at the bottom of the screen let you change the state of the four digital outputs.

JavaScript is not very powerful when compared with other programming languages such as C, C++, Delphi, etc, but has the advantage that it is relatively easy to understand. Furthermore, everybody who has a standard Windows operating system installed on their PC can get started straight away.

(044034-1)

Steam Whistle

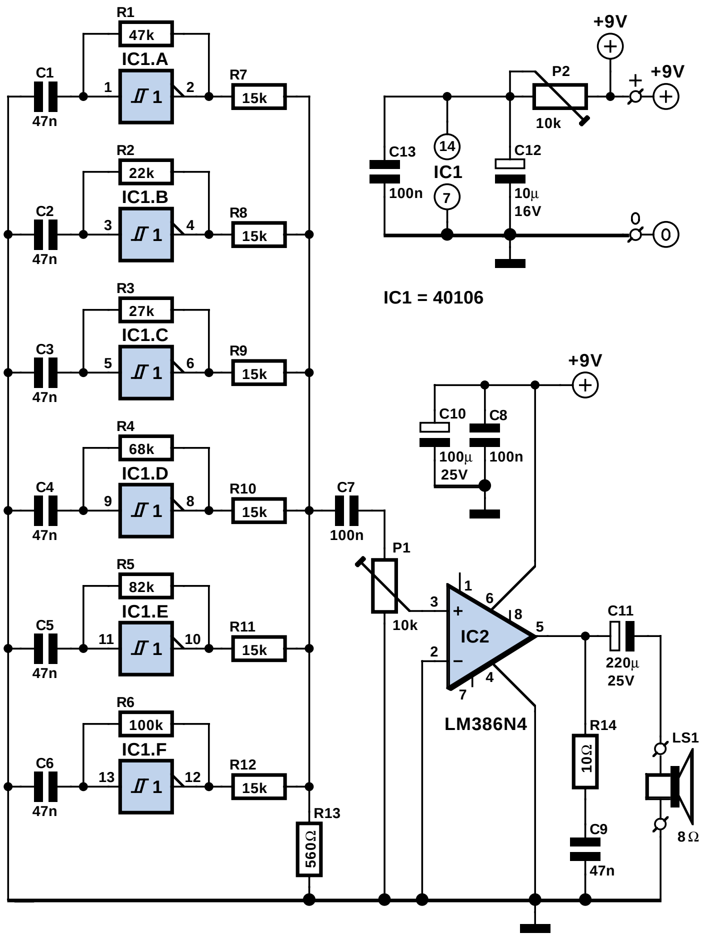
Gert Baars

This circuit consists of six square wave oscillators. Square waves are made up of a large number of harmonics. If six square waves with different frequencies are added together, the result will be a signal with a very large number of frequencies. When you listen to the result you'll find that it is very similar to a steam whistle. The circuit should be useful in modelling or even in a sound studio.

This circuit uses only two ICs. The first IC, a 40106, contains six Schmitt triggers, which are all configured as oscillators. Different frequencies are generated by the use of different feedback resistors. The output signals from the Schmitt triggers are mixed via resistors. The resulting signal is amplified by IC2, an LM386. This IC can deliver about 1 W of audio power, which should be sufficient for most applications. If you leave out R13 and all components after P1, the output can then be connected to a more powerful amplifier. In this way a truly deafening steam whistle can be created.

The 'frequency' of the signal can be adjusted with P2, and P1 controls the volume.

(044002-1)

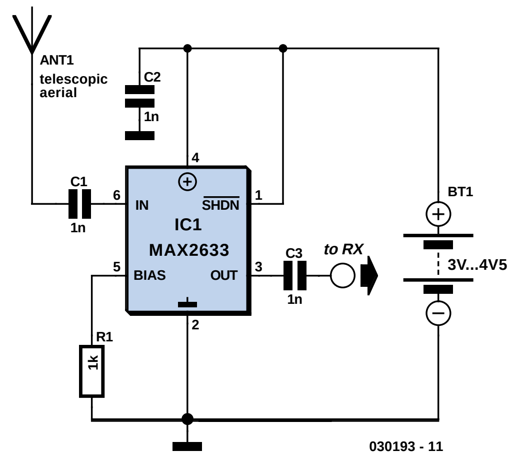


Single-Chip VHF RF Preamp

D. Prabakaran

Here is a high performance RF amplifier for the entire VHF broadcast and PMR band (100-175 MHz) which can be successfully built without any special test equipment. The grounded-gate configuration is inherently stable without any neutralization if appropriate PCB layout techniques are employed. The performance of the amplifier is quite good. The noise figure is below 2 dB and the gain is over 13 dB. The low noise figure and good gain will help car radios or home stereo receivers pick up the lower-power local or campus radio stations, or distant amateur VHF stations in the 2-metres band. Due to the so-called threshold effect, FM receivers loose signals abruptly so if your favourite station fades in and out as you drive, this amplifier can cause a dramatic improvement.

The MAX2633 is a low-voltage, low-noise amplifier for use from VHF to SHF frequencies. Operating from a single +2.7 V to +5.5V supply, it has a virtually flat gain response to 900 MHz. Its low noise figure and low supply current makes it ideal for RF receive, buffer and transmit applications. The MAX2633 is biased internally and has a user-selectable supply current, which can be adjusted by adding a single external resistor (here, R1). This circuit draws only 3 mA current.



Besides a single bias resistor, the only external components needed for the MAX2630 family of RF amplifiers are input and output blocking capacitors, C1 and C3, and a V_{CC} bypass capacitor, C2. The coupling capacitors must be large enough to contribute negligible reactance in a 50-Ω system at the lowest operating frequency. Use the following equation to calculate their minimum value:

$$C_c = 53000/\ f_{low} \qquad [pF]$$

Further information: www.maxim-ic.com.

(030193-1)

Codec Complete

Paul Goossens

Digital audio equipment usually contains an A/D and a D/A converter. In practice a codec is used for this. This is a chip where both converters are built-in and which often includes standard inputs and outputs for digital audio, such as I^{2}S. Apart from this codec there is often a requirement for a microphone input and headphone output as well.

Texas Instruments have made a new codec, the TLV320AIC28, which has an integrated microphone pre-amplifier and a 400 mW headphone amplifier. A few other practical functions have also been added to this chip, such as 2 I/O pins for use in push-button control, microphone detector, etc.

It is therefore extremely suitable for use in combination with headsets.

The chip can be controlled via an SPI interface, which means that most micro-controllers can communicate easily with this codec. As we said earlier, the audio interface can take an I^{2}S signal, but the audio interface is very flexible, as with many other codecs, and can cope with several other audio formats.

Should you be on the lookout for a codec and you intend to use a microphone input and headphone output, then this one makes an excellent choice. More information for this codec can be found in its datasheet at the website of Texas Instruments:

http://focus.ti.com/docs/prod/folders/print/tlv320aic28.html

(044043-1)

Mains Failure Alarm

Myo Min

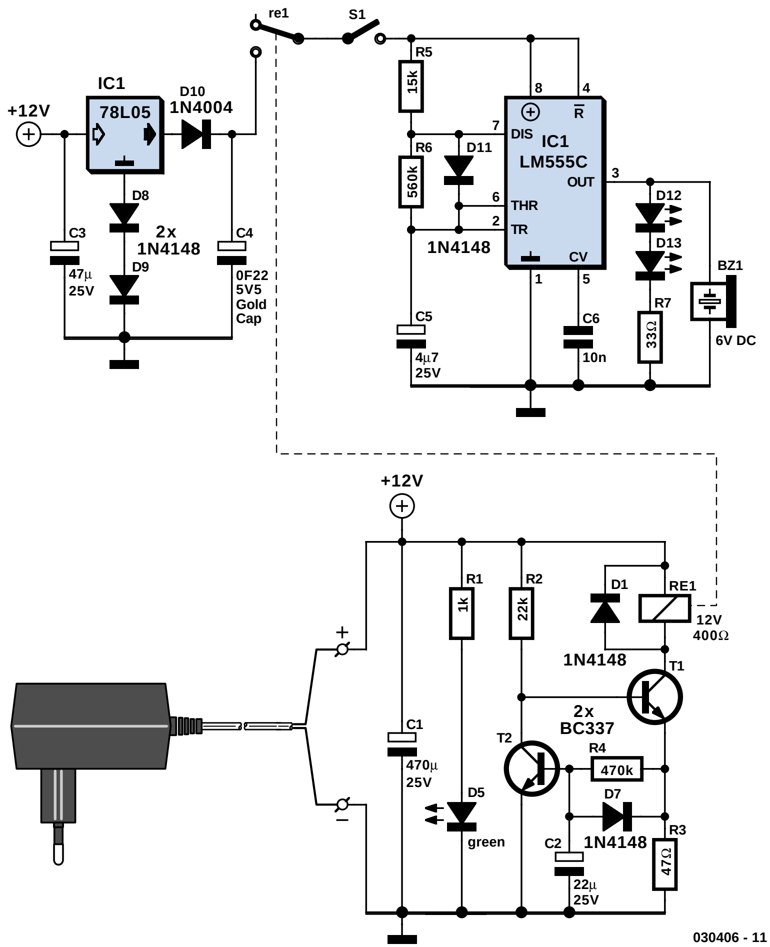
This circuit was designed to produce an audible alarm when the mains power is interrupted. Such an alarm is essential for anyone whose livelihood depends on keeping perishable foodstuffs in cold storage.

The circuit is powered by a 12-V mains adapter. LED D5 will light when the mains voltage is present. When the mains voltage disappears, so does the +12 V supply voltage, leaving the voltage regulator IC1 and relay driver T1-T2 without power. The relay driver, by the way, is an energy-saving type, reducing the coil current to about 50% after a few seconds. Its operation and circuit dimensioning are discussed in the article 'Relay Coil Energy Saver'.

The value of the capacitor at the output of voltage regulator IC1 clearly points to a different use than the usual noise suppression. When the mains power disappears, Re1 is de-energised and the 0.22 F Goldcap used in position C4 provides supply current to IC2. When the mains voltage is present, C4 is charged up to about 5.5 volts with IC1 acting as a 100-mA current limit and D10 preventing current flowing back into the regulator output when the mains voltage is gone. According to the Goldcap manufacturer, current limiting is not necessary during charging but it is included here for the security's sake.

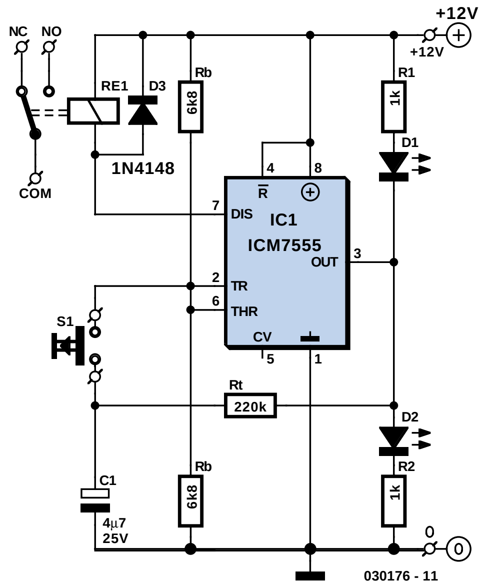
The CMOS 555 is configured in astable multivibrator mode here to save power, and so enable the audible alarm to sound as long as possible. Resistors R5 and R6 define a short 'on' time of just 10 ms. That is, however, sufficient to get a loud warning from the active buzzer. In case the pulses are too short, increase the value of R5 (at the expense of a higher average current drawn from the Goldcap).

(030406-1)



Push Off / Push On

Trevor Skeggs



The ubiquitous 555 has yet another airing with this bistable using a simple push-button to provide a push-on, push-off action. It uses the same principle of the stored charge in a capacitor taking a Schmitt trigger through its dead-band as previously published as 'Pushbutton Switch' (038) in the *Small Circuits* collection of 2002.

Whereas the Schmitt trigger in that reference was made from discrete components, the in-built dead-band arising from the two comparators, resistor chain and bistable within the 555 is used instead.

The circuit demonstrates a stand-by switch, the state of which is indicated by illumination of either an orange or red LED, exclusively driven by the bipolar output of pin 3.

Open-collector output (pin 7) pulls-in a 100-mA relay to drive the application circuit; obviously if an ON status LED is provided elsewhere, then the relay, two LEDs and two resistors can be omitted, with pin 3 being used to drive the application circuit, either directly or via a transistor. The original NE555 (non-CMOS) can source or sink 200 mA from / into pin 3.

Component values are not critical; the 'dead-band' at input pins 2 and 6 is between 1/3 and 2/3 of the supply voltage. When the pushbutton is open-circuit, the input is clamped within this zone (at half the supply voltage) by two equal-value resistors, Rb. To prevent the circuit powering-up into an unknown condition, a power-up reset may be applied with a resistor from supply to pin 4 and capacitor to ground.

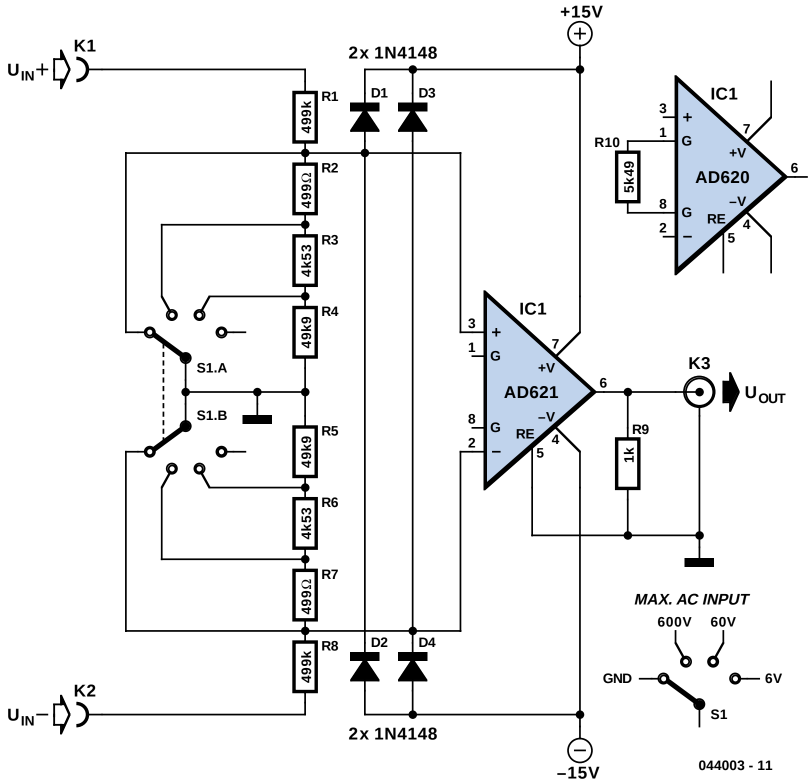
A capacitor and high-value resistor (Rt) provide a memory of the output state just prior to pushing the button and creates a dead time, during which button contact bounce will not cause any further change. When the button is pressed, the stored charge is sufficient to flip the output to the opposite state before the charge is dissipated and clamped back into the neutral zone by resistors Rb.

A minimum of 0.1 µF will work, but it is safer to allow for button contact-bounce or hand tremble; 10 µF with 220 kΩ gives approximately a 2-second response.

(030176-1)

Meter Adapter with Symmetrical Input

Aart Rombout



In contrast to an ordinary voltmeter, the input of an oscilloscope generally has one side (GND) connected to ground via the mains lead. In certain situations this can be very problematic. When the measuring probe is connected to a circuit that is also connected to ground, there is a chance that a short is introduced in the circuit. That the circuit, and hence the measurement, is affected by this is the least of your problems. If you were taking measurements from high current or high voltage (valve equipment) circuits, the outcome could be extremely dangerous!

Fortunately it is not too difficult to get round this problem. All you have to do is make the input to the oscilloscope float with respect to ground. The instrumentation amplifier shown here does that, and functions as an attenuator as well. The AD621 from Analog Devices amplifies the input by a factor of 10, and a switch at the input gives a choice of 3 ranges. A 'GND' position has also been included, to calibrate the zero setting of the oscilloscope. The maximum input voltage at any setting may never exceed 600 V_{AC}. Make sure that R1 and R8 have a working voltage of at least 600 V. You could use two equal resistors connected in series for these, since 300 V types are more easily obtainable. You should also make sure that all resistors have a tolerance of 1% or better.

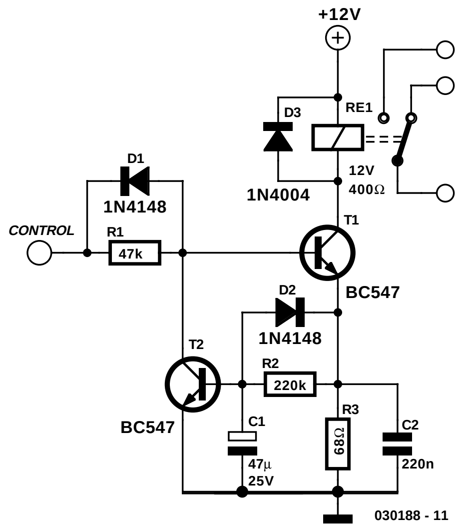
Other specifications for the AD621 are: with an amplification of 10 times the CMRR is 110 dB and the bandwidth is 800 kHz. If you can't find the AD621 locally, the AD620 is a good alternative. However, the bandwidth is then limited to about 120 kHz.

The circuit can be housed inside a metal case with a mains supply, but also works perfectly well when powered from two 9 V batteries. The current consumption is only a few milliamps. You could also increase R9 to 10 k to reduce the power consumption a bit more.

(044003-1)

Relay Coil Energy Saver

Myo Min



Some relays will become warm if they remain energised for some time. The circuit shown here will actuate the relay as before but then reduce the 'hold' current through the relay coil current by about 50%, thus considerably reducing the amount of heat dissipation and wasted power. The circuit is only suitable for relays that remain on for long periods.
The following equations will enable the circuit to be dimensioned for the relay on hand:

$R3 = 0.7 / I$
Charge time = $0.5 \times R2 \times C1$

Where I is the relay coil current.
After the relay has been switched off, a short delay should be allowed for the relay current to return to maximum so the relay can be energised again at full power. To make the delay as short as possible, keep C1 as small as possible. In practice, a minimum delay of about 5 seconds should be allowed but this is open to experimentation. The action of C2 causes the full supply voltage to appear briefly across the relay coil, which helps to activate the relay as fast as possible.
Via T2, a delay network consisting of C1 and R2 controls the relay coil current flowing through T1 and R3, effectively reducing it to half the 'pull in' current. Diode D2 discharges C1 when the control voltage is Low. Around one second will be needed to completely discharge C1. T2 shunts the bias current of T1 when the delay has elapsed. Diode D1 helps to discharge C1 as quickly as possible. The relay shown in the circuit was specified at 12 V / 400 ohms. All component values for guidance only.

(030188-1)

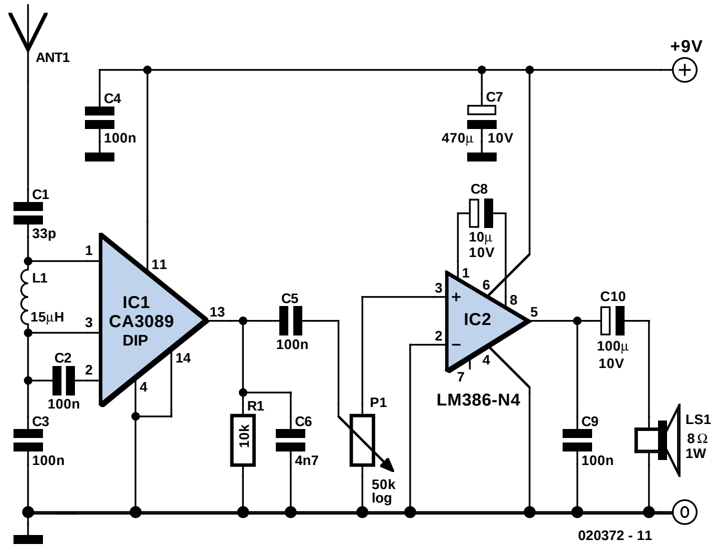
Shortwave Monitor

Gert Baars

This broadband AM receiver enables you to 'monitor' the shortwave radio band. The circuit has been deliberately designed to have low selectivity and is most sensitive in the range from 6 to 20 MHz. This frequency range contains most of the shortwave broadcast stations.

In this configuration, whichever station has the strongest signal will be the easiest to hear. An interesting fact is that the signal strength of stations in this band changes quite a lot. This is because the ionosphere reflects the radio signals. Because this layer of the atmosphere is in constant motion, the received signal strengths from different directions are subject to continuous variation. During testing of our prototype Radio Netherlands World Service, Radio Finland and Deutsche Welle alternated as the strongest station at regular intervals. This receiver not only gives a good indication of the myriad of stations on offer in the shortwave band but is also an excellent tool for monitoring the state of the ionosphere.

The circuit actually consists of no more than an RF and an AF amplifier. The high-frequency amplification is carried out by the IF stage of a CA3089. This IC is actually intended for FM receivers, but the FM section is not used here.



The internal level detector provides a signal of sufficient strength to drive an audio amplifier directly. An LM386 was selected for this task. This IC can directly drive an 8-Ω loudspeaker or headphones without any difficulty.

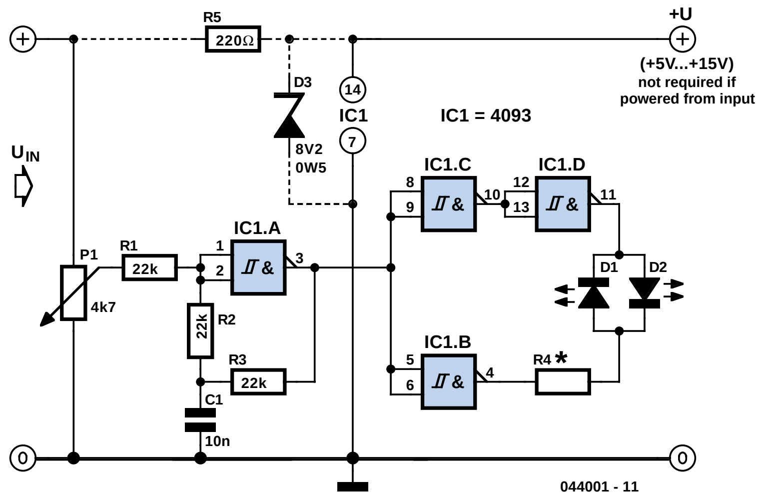
The power supply voltage is 9 V. Because of the modest power consumption a 9-V battery is very suitable. In addition, the circuit will work down to a voltage of about 5.5 V, so that the battery life will be extra long.

The antenna will require a little experimentation. We obtained reasonable results with a piece of wire 50 cm long. A length of wire in the range of 5 to 15 meters should provide even better results at these frequencies.

(020372-1)

Two-LED Voltage Indicator

Bart Trepak



There are many applications where the accuracy of a digital or analogue (bar graph) is not required but something better than a simple low/high indicator is desirable. A battery charge level indicator in a car is a good example.

This simple circuit requiring only two LEDs (preferably one with a green and red LED in a single package), a cheap CMOS IC type 4093 and a few resistors should fulfil many such applications. With a suitable sensor, the indicator will display the relevant quantity as a colour ranging from red through orange and yellow to green.

IC1.A functions as an oscillator running at about 10 kHz with the component values given, although this is not critical. Assuming for the moment that R1 is not commented, the output of IC1.A is a square wave with almost 50% duty cycle. The voltage at the junction of R2 and C1 will be a triangular wave (again, almost) with a level determined by the difference in the two threshold voltages of the NAND Schmitt trigger gate IC1.A. IC1.B, IC1.C and IC1.D form inverting and non-inverting buffers so that the outputs of IC1.C and IC1.D switch in complementary fashion. With a 50% duty cycle, the red and green LEDs will be driven on for equal periods of time so that both will light at approximately equal brightness resulting in an orange-yellow display.

With R1 in circuit, the actual input voltage to IC1.A will consist of the triangular waveform added to the dc input V_{in}. As the input voltage varies, so will the oscillator duty cycle causing either the red or the green LED to be on for longer periods and so changing the visible colour of the combi-LED. The actual range over which the effect will be achieved is determined by the relative values of R1 and R2, enabling the circuit to be matched to most supply voltages. With the component values given and a supply of 8 volts, the LED will vary from fully red to fully green in response to input voltages of 2.5 V and 5.6 V respectively. To monitor a car battery voltage, the battery itself could be used to power the circuit provided a zener diode and dropper resistor are added to stabilise the IC supply voltage. This is shown in dashed outlines in the circuit diagram. With an 8.2 V zener the dropper resistor should be around 220 Ω and R1 has to be reduced to 4.7 kΩ.

The LED brightness is determined by R4. As a rule of thumb,

$$R4 = (V_{supply} - 2) / 3 \quad [k\Omega]$$

and remember that the 4093 can only supply a few mA's of output current.

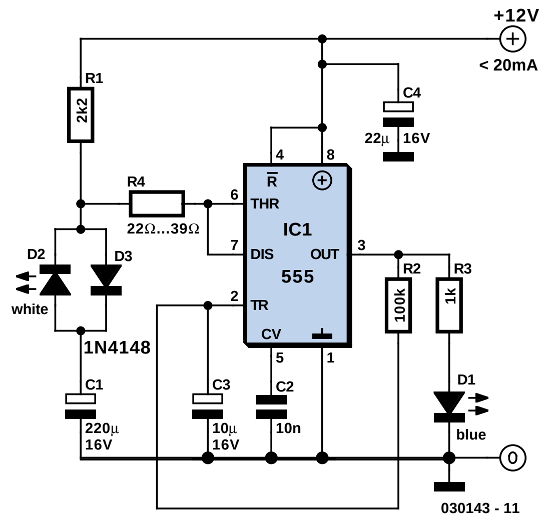
Applications of this little circuit include 'non critical' ones such as go/non-go battery testers, simple temperature indicators, water tank level indicators, etc.

(044001-1)

Bluish Flasher

Myo Min

This circuit is innovative in more than one way and therefore belongs *per se* in Elektor's Small Circuits Collection. Firstly, it demonstrates how the combination of a blue and a white LED can be used to give a realistic imitation of a camera flashlight. Secondly, the good old 555 IC is used in a way many of you may never have seen before — alternately monostable / astable — without too much in the way of external parts.



Initially C3 will be empty, pulling output pin 3 to +12 V and causing the blue LED, D1, to light via R3. Next, C3 will charge up via R2. Meanwhile C1 has been building up charge through R1 and D3. If the voltage on C3 reaches about 8 V (two-thirds of 12 V), pin 3 of the 555 will drop Low. So does pin 7, causing the white LED to light, pulling its energy from C1. This energy drops quickly, causing D2 to dim in an exponentially decaying fashion, just like a camera flashlight. Now, because the 555's output has dropped Low, the voltage on C3 will decrease as well. Ad soon as a level of 4 V is reached (one third of 12 V), the above cycle is repeated.

Resistor R4 limits the current through the 555 to safe levels. You may want to experiment with the latest hyper-bright white LEDs. SDK's AlInGaP LEDs, for example, are claimed to light three times as brightly as regular white LEDs.

A number of blue LEDs may be connected in series instead of just one as shown in the circuit diagram. Unfortunately, that is not possible at the 'white' side. For the best visual effect, the white blue LEDs should be mounted close together. When fitted close to the extra brake light in your car, the bluish white flash is sure to make even persistent tailgaters back off. Note however that this use of the circuit may not be legal in all countries.

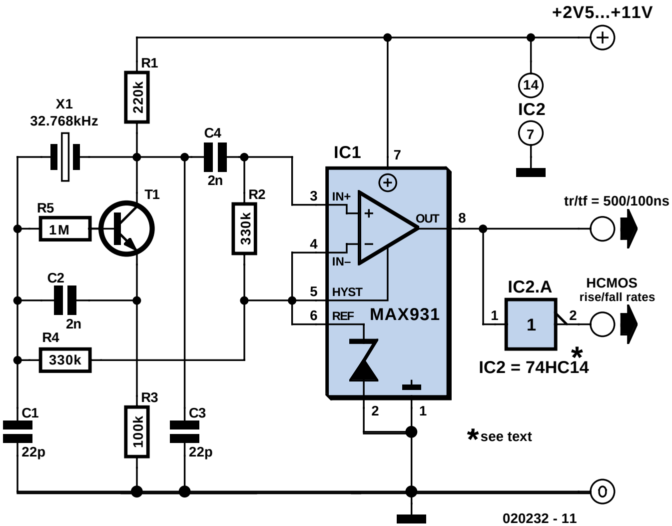
(030143-1)

Very Low Power 32-kHz Oscillator

D. Prabakaran

The 32-kHz low-power clock oscillator offers numerous advantages over conventional oscillator circuits based on a CMOS inverter. Such inverter circuits present problems, for example, supply currents fluctuate widely over a 3-V to 6-V supply range, while current consumption below 250 µA is difficult to attain. Also, operation can be unreliable with wide variations in the supply voltage and the inverter's input characteristics are subject to wide tolerances and differences among manufacturers.

The circuit shown here solves the above problems. Drawing just 13 µA from a 3-V supply, it consists of a one-transistor amplifier/oscillator (T1) and a low-power comparator/reference device (IC1). The base of T1 is biased at 1.25 V using R5/R4 and the reference in IC1. T1 may be any small-signal transistor with a decent beta of 100 or so at 5 µA (defined here by R3, fixing the collector voltage at about 1 V below Vcc). The amplifier's nominal gain is approximately 2 V/V. The quartz crystal combined with load capacitors C1 and C3 forms a feedback path around T1, whose 180 degrees of phase shift causes the oscillation. The bias voltage of 1.25 V for the comparator inside the MAX931 is defined by the reference via R2. The comparator's input swing is thus accurately centred around the reference voltage. Operating at 3 V and 32 kHz, IC1 draws just 7 µA.



The comparator output can source and sink 40 mA and 5 mA respectively, which is ample for most low-power loads. However, the moderate rise/fall times of 500 ns and 100 ns respectively can cause standard, high-speed CMOS logic to draw higher than usual switching currents. The optional 74HC14 Schmitt trigger shown at the circuit output can handle the comparator's rise/fall times with only a small penalty in supply current. Further information on the MAX931 from: www.maxim-ic.com.

(020232-1)

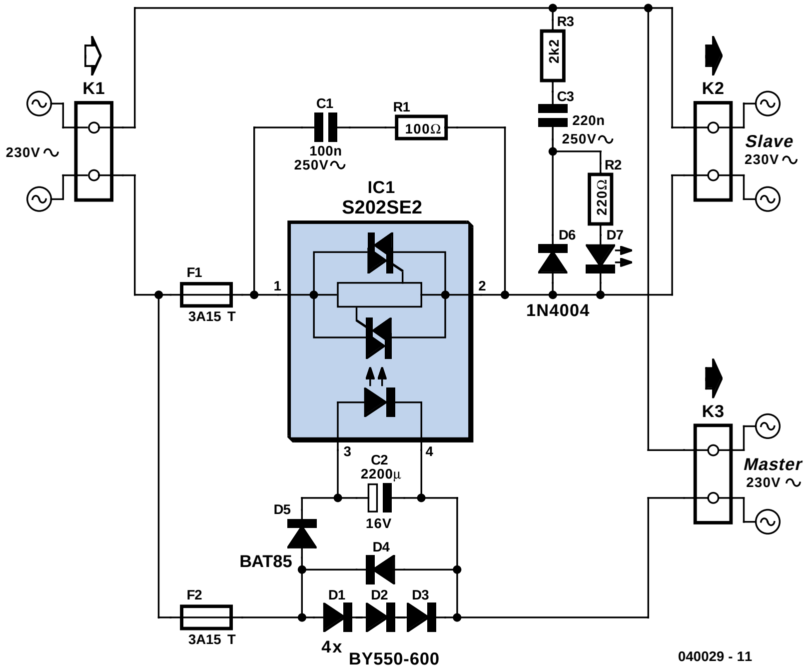
Master/Slave switch

Karl Köckeis

In this age of enlightenment any sort of relationship that could be described as master/slave would be questionable but for the purposes of this circuit it gives a good idea of how it functions. The circuit senses mains current supplied to a 'master' device and switches 'slave' equipment on or off. This feature is useful in a typical hi-fi or home computer environment where several peripheral devices can all be switched on or off together.

A solid-state relay from Sharp is an ideal switching element in this application; a built-in zero crossing detector ensures that switching only occurs when the mains voltage passes through zero and any resultant interference is kept to an absolute minimum. All of the triac drive circuitry (including optical coupling) is integrated on-chip so there are very few external components and no additional power supply necessary. This makes the finished design very compact.

Diodes D1, D2, D3 and D4 perform the current sensing function and produce a voltage on C2 when the master equipment is switched on. A Schottky diode is used for D5 to reduce forward voltage losses to a minimum. The circuit is quite



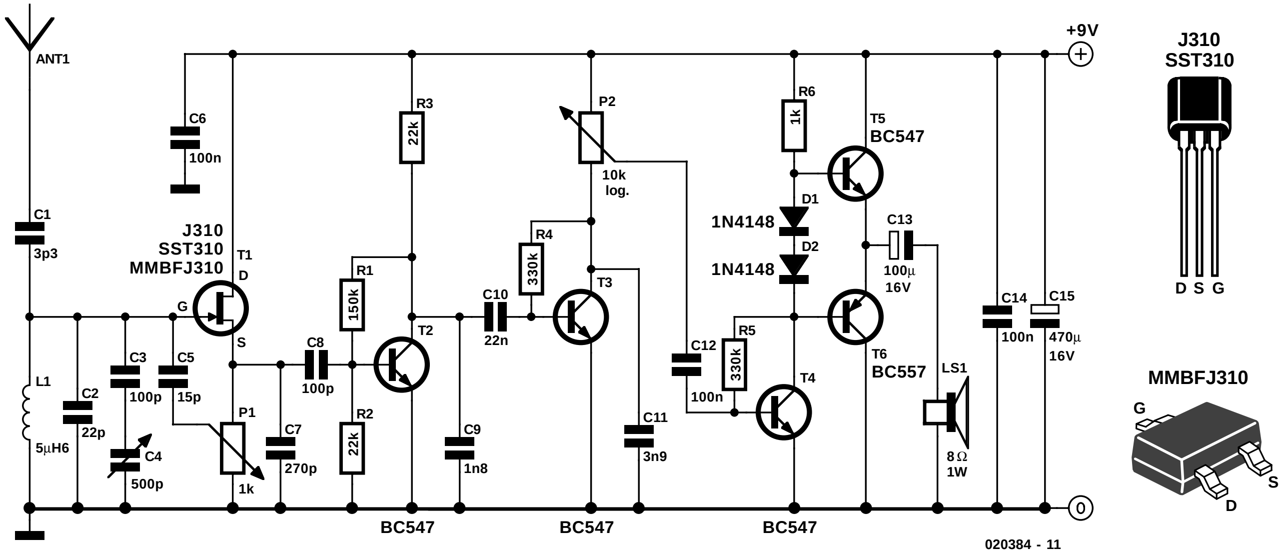
sensitive and will successfully switch the slave even when the master equipment draws very little mains current.

The RC network formed by R1 and C1 provides some protection for the solid-state relay against mains-borne voltage transients.

Warning: This circuit is connected to the mains. it is important to be aware that the chip has lethal voltages on its pins and all appropriate safety guidelines must be adhered to! This includes the LED, for safety it must be fitted behind a transparent plexiglass shield.

(040029-1)

Tuned Radio Frequency (TRF) Receiver



Gert Baars

Superheterodyne receivers have been mass-produced since around 1924, but for reasons of cost did not become successful until the 1930s. Before the second world war other, simpler receiver technologies such as the TRF receiver and the regenerative receiver were still widespread.

The circuit described here is based on the old technology, but brought up-to-date a

The most important part of the circuit is the input stage, where positive feedback is used to achieve good sensitivity and selectivity. The first stage is adjusted so that it is not quite at the point of oscillation. This increases the gain and the selectivity, giving a narrow bandwidth. To achieve this, the potentiometer connected to the drain of the FET must be adjusted very carefully: optimal performance of the receiver depends on its setting. In ideal conditions several strong stations should be obtainable during the day using a 50 cm antenna. At night, several times this number should be obtainable.

The frequency range of the receiver runs from 6 MHz to 8 MHz. This range covers the 49 m and the 41 m shortwave bands in which many European stations broadcast. Not bad for such a simple circuit!

The circuit employs six transistors. The first stage is a selective amplifier, followed by a transistor detector. Two low-frequency amplifier stages complete the circuit. The final stage is a push-pull arrangement for optimal drive of the low-impedance loudspeaker. This circuit arrangement is sometimes called a '1V2 receiver' (one preamplifier, one detector and two audio-frequency stages).

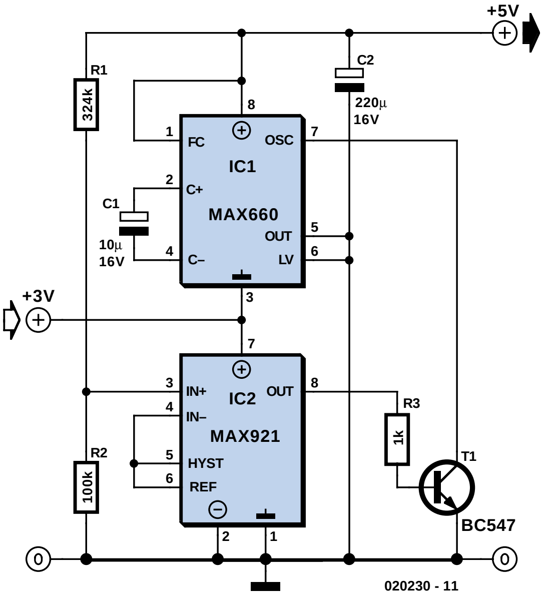
Setting-up is straightforward. Adjust P1 until the point is reached where the circuit starts to oscillate: a whistle will be heard from the loudspeaker. Now back off the potentiometer until the whistle stops. The receiver can now be tuned to a broadcaster. Occasional further adjustment of the potentiometer may be required after the station is tuned in.

The receiver operates from a supply voltage of between 5 V and 12 V and uses very little current. A 9 V PP3 (6F22) battery should give a very long life.

(020384-1)

Inductorless 3-to-5 Volts Converter

D. Prabakaran



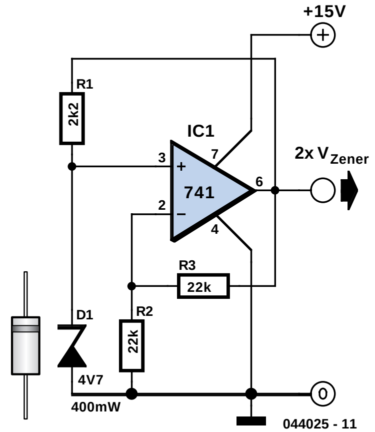
By configuring a comparator and a transistor to control the oscillator in a charge pump circuit, you enable the pump to generate a regulated output of — in principle — any desired value. Charge pump ICs can either invert or double an input voltage (for example, 3 V to –3 V or 3 V to 6 V). The charge pump itself does not regulate the output voltage and one running off 3 V is not normally capable of generating intermediate output voltage levels like 5 V. However, by adding a comparator and a reference device, you can create arbitrary output levels like 5 V and regulate them as well.

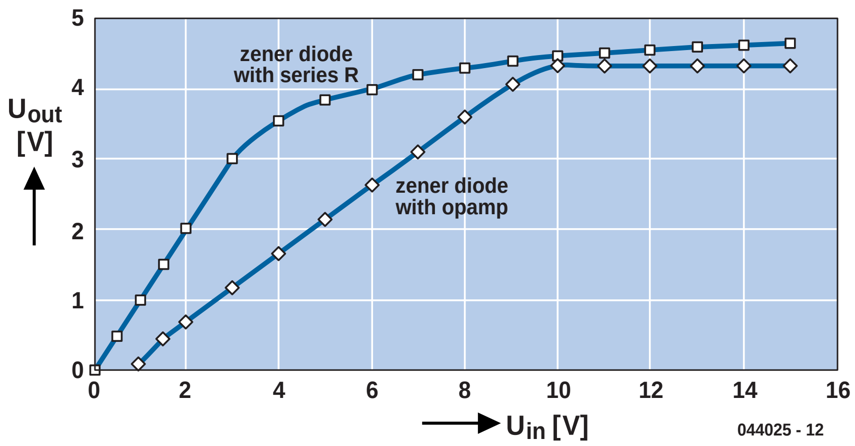
Charge pump IC1 (a MAX660) has an internal oscillator whose 45 kHz operation transfers charge from C1 to C2, causing the regulated output to rise. When the feedback voltage (pin 3 of IC2) exceeds 1.18 V, the output of comparator IC2 (a MAX921) goes high, turning off the oscillator via T1.

The comparator hysteresis (easily added on IC2) is zero here simply because no hysteresis is required in the control loop. The oscillator when enabled generates two cycles, which is sufficient to drive V_{OUT} slightly above the desired level. Next, the feedback turns the oscillator off again. The resulting output ripple will depend mainly on the input voltage and the output load current. Output ripple may be reduced at the expense of circuit efficiency by adding a small resistor (say, 1 Ω) in series with C1. You'll find that ripple also depends on the value and ESR associated with C1 — smaller values of C1 transfer less charge to C2, producing smaller jumps in V_{OUT}.

(020230-1)

Stable Zener Reference





Karel Walraven

Nowadays some first-rate voltage references are available. Take the LM385 for example: this is available for different voltages and even comes in an adjustable version. What is more, the current consumption may be kept very small (10 µA). But as often happens, you may not have one to hand when you need one for an experimental circuit.
In that case, you could use an ordinary zener diode for the reference. Unfortunately, they have a somewhat higher internal resistance (about 5 Ω), which means they won't be very stable when the supply voltage varies.
The solution is right in front of us: use the stabilised zener voltage as the supply voltage! This is obviously only possible if the stabilised voltage is higher than the zener voltage. It therefore has to be amplified a little. This is exactly what this circuit does: it amplifies it by a factor of two. The current limiting resister should be chosen such that a current of 1 to 3 mA flows through the zener diode. Manufacturers usually state the zener voltage at a current between 3 to 5 mA.
The zener diode is fed from a stabilised voltage and hence has a very stable operating point, which is independent from the supply voltage. The graph speaks for itself. It is clear that the output voltage is much more stable. The graphs have been plotted to different scales to make the comparison easier. In reality the opamp output is twice the zener voltage.
Zener diodes also have a temperature coefficient, which is smallest for types with a zener voltage around 5 volts.
Virtually any type of opamp should be suitable; even our old friend the 741 works well enough.

(044025-1)

PWM Modulator

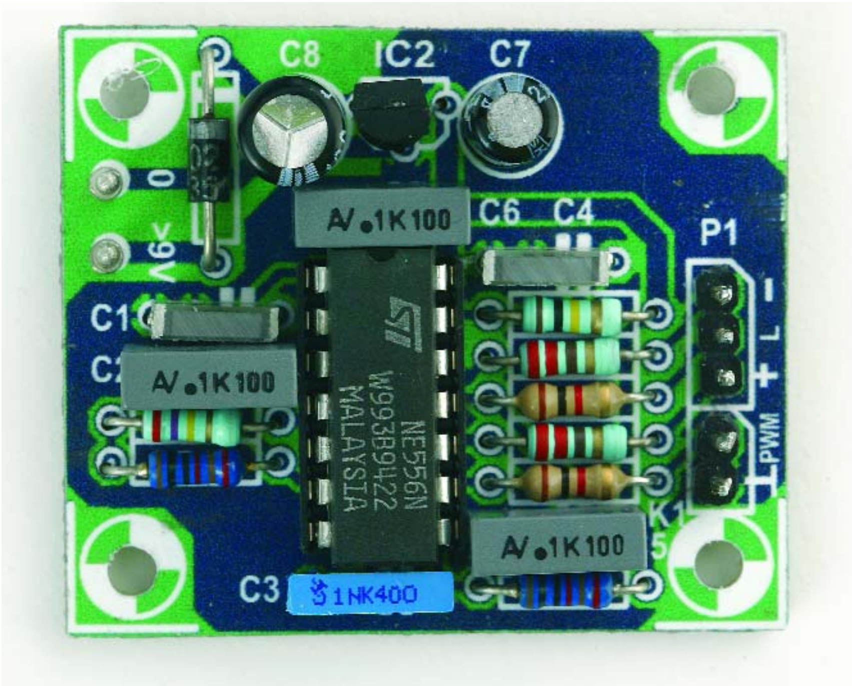
Ton Giesberts

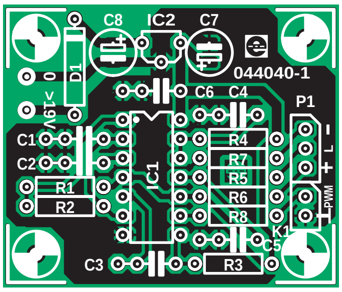
If you ever thought of experimenting with pulse-width modulation, this circuit should get you started nicely. We've kept simplicity in mind and used a dual 555 timer, making the circuit a piece of cake. We have even designed a small PCB for this, so building it shouldn't be a problem at all. This certainly isn't an original circuit, and is here mainly as an addition to the 'Dimmer with MOSFET' article elsewhere in this issue. The design has therefore been tailored to this use.

A frequency of 500 Hz was chosen, splitting each half-period of the dimmer into five (a low frequency generates less interference). The first timer is configured as a standard astable frequency generator. There is no need to explain its operation here, since this can easily be found on the Internet in the datasheet and application notes. All we need to mention is that the frequency equals

$$1.49 / ((R1+2R2) \times C1) \quad [\text{Hz}]$$

R2 has been kept small so that the frequency can be varied easily by adjusting the values of R1 and/or C1. The second timer works as a monostable multivibrator and is triggered by the differentiator constructed using R3 and C3. The trigger input reacts to a rising edge. A low level at the trigger input forces the output of the timer low. R3 and C3 have therefore been added, to make the control range as large as possible. The pulse-width of the monostable timer is given by 1.1x·R4x·C4 and in this case equals just over a millisecond. This is roughly half the period of IC1a. The pulse-width is varied





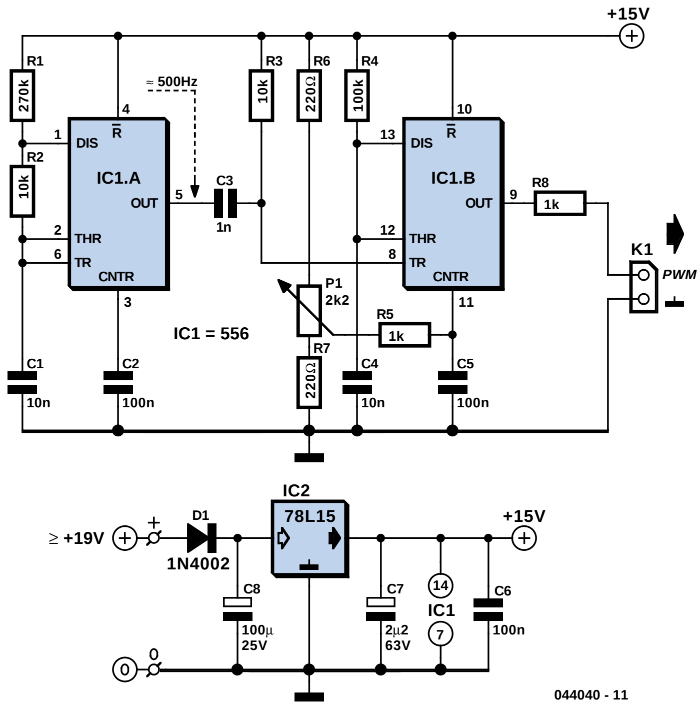
COMPONENTS LIST

Resistors:
R1 = 270kΩ
R2,R3 = 10kΩ
R4 = 100kΩ
R5,R8 = 1kΩ
R6,R7 = 220Ω
P1 = 2kΩ2, linear, mono

Capacitors:
C1,C4 = 10nF
C2,C5,C6 = 100nF
C3 = 1nF
C7 = 2μF2 63V radial
C8 = 100μF 25V radial

Semiconductors:
D1 = 1N4002
IC1 = NE556
IC2 = 78L15

Miscellaneous:
P1 = 3-way pinheader
K1 = 2-way pinheader



using P1 to change the voltage on the CNTR input. This changes the voltage to the internal comparators of the timer and hence varies the time required to charge up C4.

The control range is also affected by the supply voltage; hence we've chosen 15 V for this. The voltage range of P1 is limited by R6, R7 and R5. In this design the control voltage varies between 3.32 V and 12.55 V (the supply voltage of the prototype was 14.8 V). Only when the voltage reaches 3.51 V does the output become active, with a duty-cycle of 13.5 %. The advantage of this initial 'quiet' range is that the lamp will be off.

R8 protects the output against short circuits. With the opto-coupler of the dimmer as load, the maximum current consumption of the circuit is about 30 mA.

(044040-1)

Xilinx JTAG Interface

Paul Goossens

In September 2002 we published a JTAG interface that was compatible with the programming software from Altera. Unfortunately, the software from Xilinx didn't work in combination with this interface. The interface published here *is* compatible with the software from Xilinx, so you can use it to program their range of CPLDs and FPGAs.

The circuit is very simple and consists of just two ICs and a handful of discrete components.

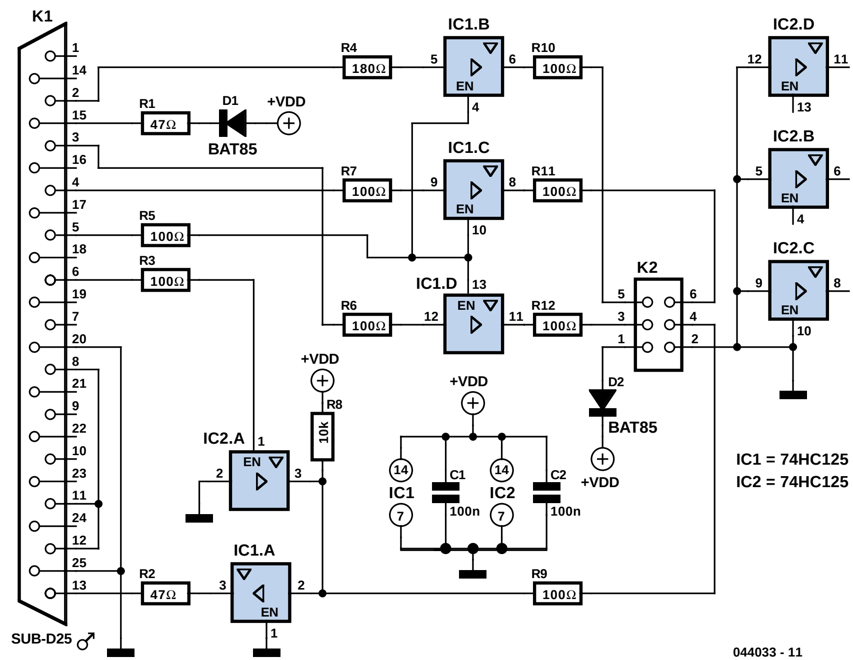
Connector K1 is connected to the PC using a 1:1 printer cable with a 25-way sub-D connector at each end. Connector K2 is connected to the JTAG interface of the device being programmed. The pinout for connector K2 is shown in **Table 1**. If the device uses a different type of programming connector, K2 will have to be adapted accordingly.

The circuit can be easily built on a piece of prototyping board. Since there isn't any real standard for the programming connector, it is very likely that the connections to K2 have to be modified; in that case, a ready-made PCB isn't very useful.

(044033-1)

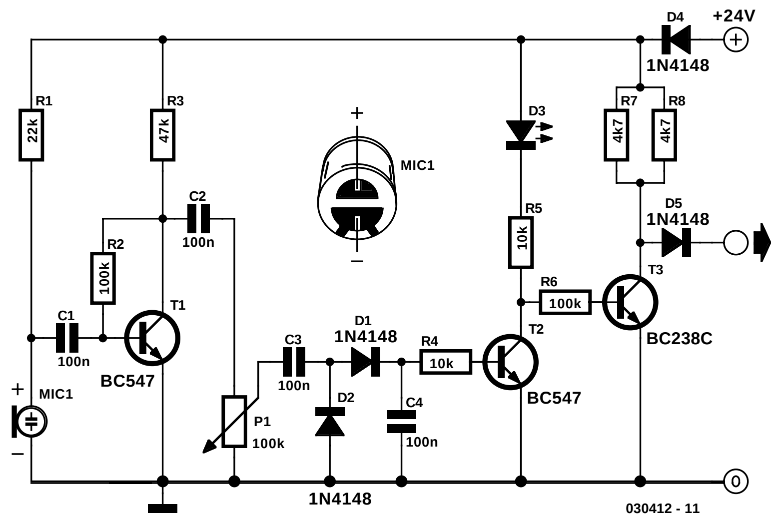
Table 1. Pinout for K2

	FPGA	CPLD
1	Vdd	Vdd
2	GND	GND
3	CCLK	TCK
4	D/P	TDO
5	DIN	TDI
6	/PROG	TMS



Acoustic Sensor

Engelbert Göpfert



This acoustic sensor was originally developed for an industrial application (monitoring a siren), but will also find many domestic applications. Note that the sensor is designed with safety of operation as the top priority: this means that if it fails then in the worst-case scenario it will not itself generate a false indication that a sound is detected. Also, the sensor connections are protected against polarity reversal and short-circuits. The supply voltage of 24 V is suitable for industrial use, and the output of the sensor swings over the supply voltage range.

The circuit consists of an electret microphone, an amplifier, attenuator, rectifier and a switching stage. MIC1 is supplied with a current of 1 mA by R9. T1 amplifies the signal, decoupled from the supply by C1, to about 1 V_{pp}. R7 sets the collector current of T1 to a maximum of 0.5 mA. The operating point is set by feedback resistor R8. The sensitivity of the circuit can be adjusted using potentiometer P1 so that it does not respond to ambient noise levels. Diodes D1 and D2 rectify the signal and C4 provides smoothing. As soon as the voltage across C4 rises above 0.5 V, T2 turns on and the LED connected to the collector of the transistor lights. T3 inverts this signal.

If the microphone receives no sound, T3 turns on and the output will be at ground. If a signal is detected, T3 turns off and the output is pulled to +24 V by R4 and R5. In order to allow for an output current of 10 mA, T3's collector resistor needs to be 2.4 kΩ. If 0.25 W resistors are to be used, then to be on the safe side this should be made up of two 4.7 kΩ resistors wired in parallel. Diode D4 protects the circuit from reverse polarity connection, and D3 protects the output from damage if it is inadvertently connected to the supply.

(030412-1)

Xport

Paul Goossens

The Gameboy Advance (GBA) already has its own power supply, processor, keypad and an LCD display. In addition, the system bus is made available externally. All this is ideal as the basis for your own embedded system.

In the October 2000 issue of *Elektor Electronics* we published an expansion for the Gameboy: a digital oscilloscope. With the arrival of the Xport, made by Charmed Labs, the development of an embedded system based on the GBA has become a lot easier.

The Xport is a complete development system. Apart from the expansion board, the necessary software is also supplied.

The hart of the circuit on the expansion board is an FPGA made by Xilinx. Depending on the version you'll get an FPGA with either 50 K or 150 K gates on the board. Using the free development software from Xilinx, you can program your own designs into the FPGA.

The board also has a 4 Mbyte flash memory. This memory stores the program for the GBA as well as the configuration for the FPGA. Since the FPGA loses its configuration when power is removed, it must reload the configuration every time that it is powered up. This takes place automatically thanks to a CPLD on the expansion board. Two version of the Xport come with an extra 16 Mbyte of SDRAM. This memory can be used by both the processor and the FPGA.

Communication with the outside world is well provided for, with 64 I/O signals on board, in addition to the programming and debug connector!

As mentioned earlier, the system consists not only of hardware. The PC software included is a C-compiler (GCC), complete with essential libraries, debugger and a programmer application.

On top of this, there is an operating system (eCos) and its bootloader. There are also various examples included (which should be in every good development kit), so you can start using the Xport soon after get your hands on it.

(040153-1)

Internet:

www.charmedlabs.com

Home Network for ADSL

Karel Walraven

The increased availability of fast ADSL Internet connections has made it more attractive to install a small RJ45 Ethernet network in the home. Not only can you exchange files between computers, you will also have fast Internet access for everybody! This does of course require an ADSL modem with a router. It's not possible to use a simple USB modem on its own.

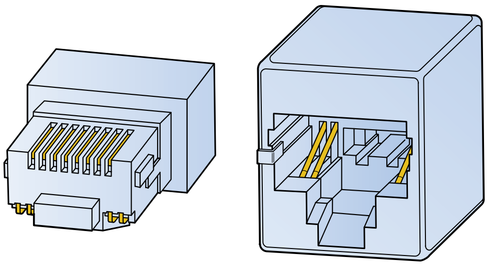
For laptops we recommend wireless Ethernet connections. If you find the laying of cables too difficult or inconvenient you can also add wireless capabilities to 'ordinary' PCs. You should bear in mind that the range of wireless connections could sometimes be disappointing.

When a network is set up round a router you should use a star configuration for the cabling. This means that only a single PC is connected to each router socket. The connecting cable may have a maximum length of 90 m and usually terminates at a connection box. You should use a CAT5 cable with 8 conductors for this, which is suitable for speeds up to 100 Mb/s. The 8 conductors are arranged in 4 pairs, with each pair twisted along the length of the cable. It is extremely important that the wires of each pair are kept together and that they are kept twisted as much as possible. At the connector ends you should therefore make sure that the non-twisted sections of the cable are kept as short as possible, at most a few centimetres. Should you fail to do this you may find that the network won't operate at the full rated speed or possibly cause interference.

The wiring itself is very simple. Connect the plugs to the cables such that each pin connects to the corresponding pin at the other end. So pin 1 to 1, 2 tot 2 and so on. This also applies to all patch leads between the connection boxes and PCs (or if you prefer, the cable can go directly to the PC, without a connection box). It is only when two computers are connected directly together without a router that a crossover cable is required.

The plugs are attached to the cable using a special crimping tool. It is also possible without the tool, using just a screwdriver, but this isn't easy and we don't recommend that you try it.

The wires in the cable have different colours and there are no official standards in Europe how you use them (EN50173). However, the colour code in the American T568B standard is often used:



044007 - 11

1	**orange/white**
2	**orange**
3	**green/white**
4	**blue**
5	**blue/white**
6	**green**
7	**brown/white**
8	**brown**

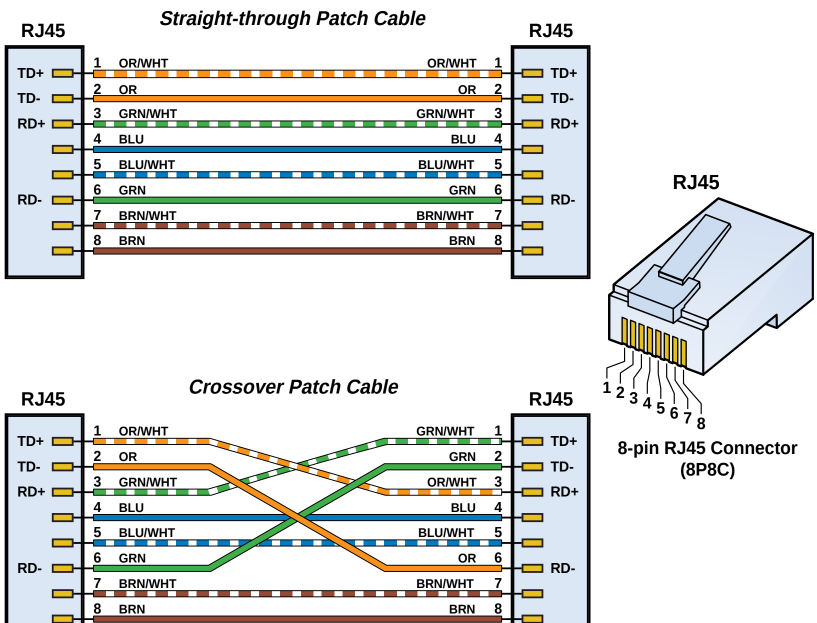
The coloured/white wires and the solid coloured wires alternate nicely. For Ethernet cabling you only need connections 1, 2, 3 and 6. The central contacts on pins 4 and 5 are in the middle of the green pair and may be used for analogue telephones. You then have to make sure that 4 and 5 aren't connected to the Ethernet plugs because the voltages found on analogue telephone lines are high enough to damage an Ethernet card and/or router. Wires 4 and 5 should then be routed to an RJ11 telephone socket. We don't recommend it, but it is possible.

It is also possible to pass ISDN signals through the same RJ45 plugs and cabling. In this case you can't use the same cable for both Ethernet and ISDN, since the latter uses pins 3/6 and 4/5.

If you use patch cables it helps to keep things organised by using coloured cables. Blue for Ethernet (red for a crossover cable), yellow for analogue telephones and green for ISDN. Sticky labels or coloured cable markers can also be used for identification when you can't get hold of coloured cables.

A new standard has recently been introduced, although you probably won't use it in the home for a while. Since around two years ago you can also use a GG45 connector, which is compatible with RJ45. This has 4 extra contacts and is suitable for speeds up to 600 Mb/s (Category 7/Class F).

(044007-1)



044007 - 12

001

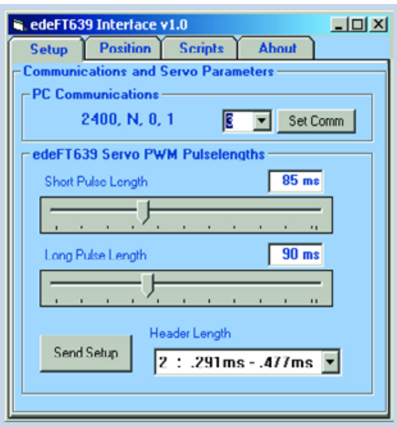
FT639 One-Chip Servo Controller

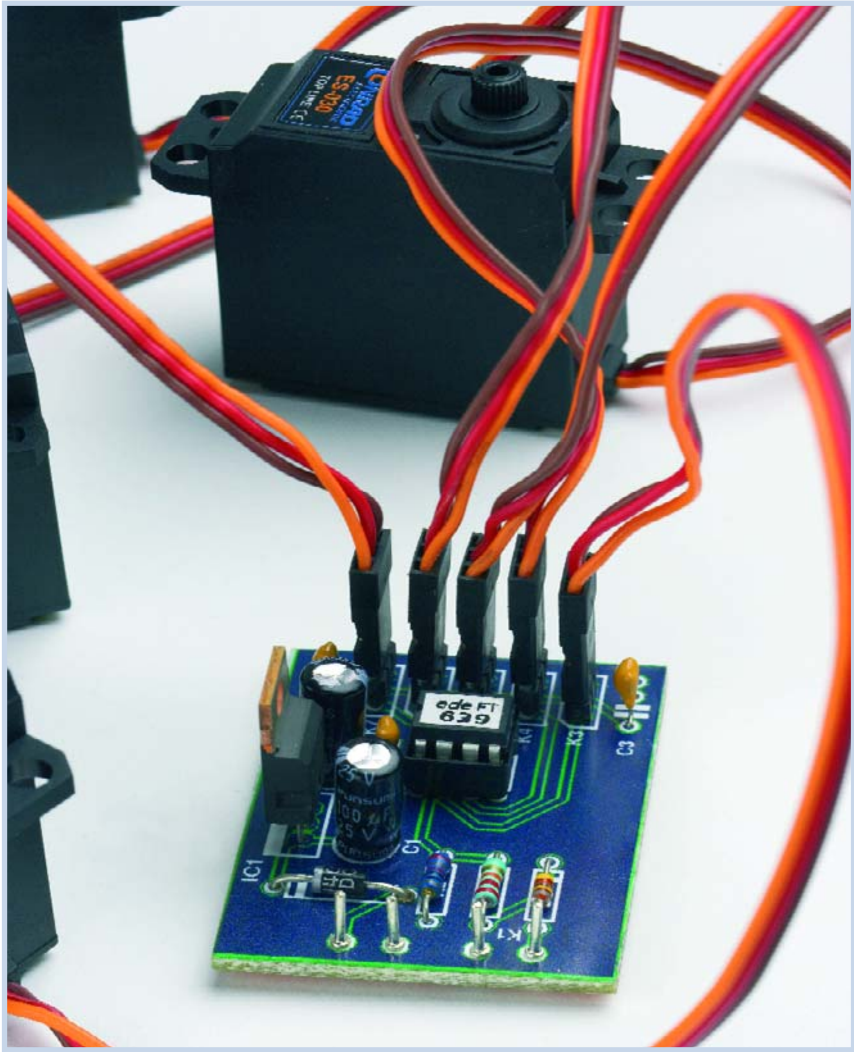
Luc Lemmens

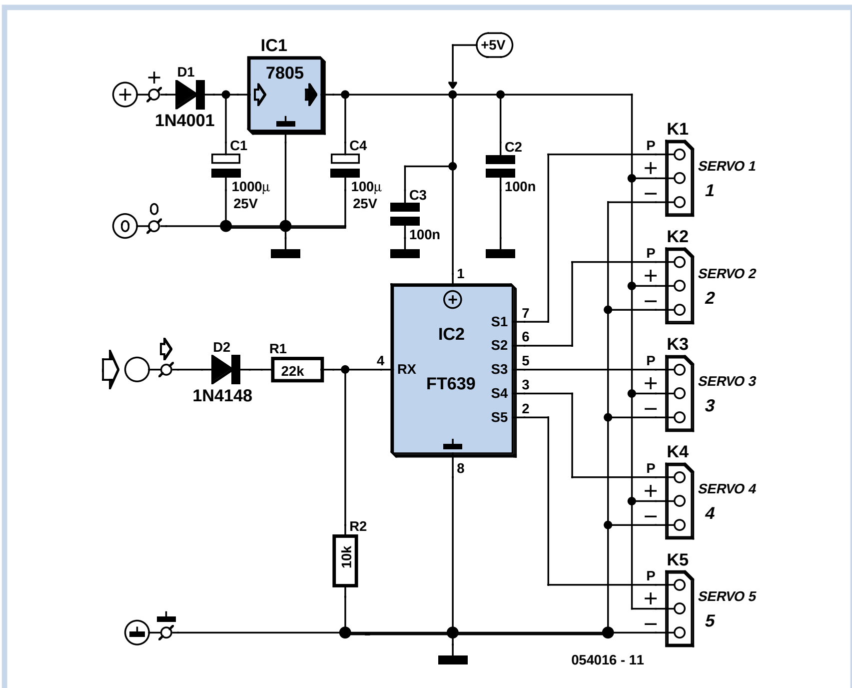
To beginners in electronics, servos have a great appeal, probably because you can do lots of real-life 'things' with them. However, long faces soon appear and pages are turned when a servo control has to be designed and built. Even if that can be done with the good old 555 chip and a handful of parts, the next objection from the new generation is that '*it ain't computer-controlled*'.

The edeFT639 is an 8-pin chip that will control five servos through one 2400-baud serial line. As you can see from the schematic, the only external components required are a decoupling cap, plus two resistors and a diode to withhold the negative swing of the RS232 line the circuit is connected to. In case TTL-swing (5 V) serial control is available, such as in PIC or Parallax Stamp systems, the control signal to the edeFT639 may be applied directly to pin 4.

The serial data format is a dead simple **2400 bits/s, no parity, 1 stop bit** so you can practice away using any ter-



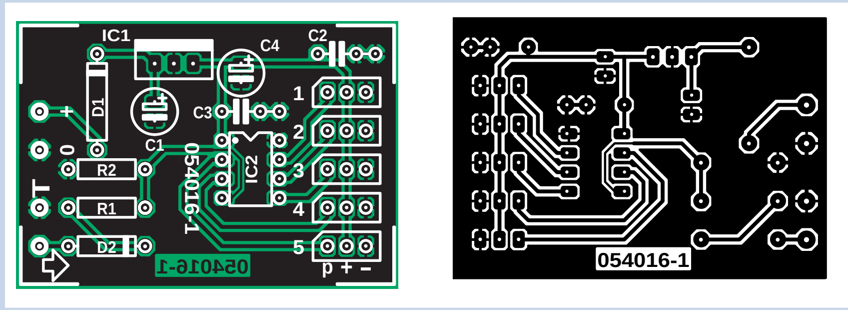




minal emulation or general purpose serial comms utility like HyperTerminal.

The edeFT639 will always start in Setup mode, then switch to Active Mode. The chip can set a servo to one of 256 positions from 0 to 90 degrees using a 'short' pulse (1 ms) or from 0 to 180 degrees using a 'long' pulse length. The starting position of each individual servo can also be adjusted by using a different header length. Full details about bit-banging the device over a 2400-baud serial line are given in the 'FT639 Ferret' datasheet, which also contains a simple program (in QBASIC) showing the nitty-gritty of talking to the device using software and the PC's printer port (LPT:). The 'get-to-know-u' program can be downloaded from the Elab Inc. website (see below) and should not be too difficult to convert into PIC or AVR code. On the same website we also found a Visual BASIC programming example complete with source & executable code to illustrate how the edeFT639 servo controller can be driven via Windows and RS232 (see screendump).

Apart from the edeFT639 chip and its input protection network R1/R2/D1, the PCB shown here also accommodates a simple step-down voltage regulator. RC Modellers wishing to use the circuit in a plane or boat may want to exchange the 7805 for a low-drop regulator and omit D1 in order to juice the craft battery. The servos are connected via the usual 3-pin connectors. As servo manufacturers use different pinouts for pulse (p), ground and +5 V on their connectors, you should check the data available.



(054016-1)

Source:
Elab Inc. (formerly FerreTronics) FT639 Ferret datasheet. www.elabinc.com

COMPONENTS LIST

Resistors:
R1 = 22kΩ
R2 = 10kΩ

Capacitors:
C1,C4 = 100µF 25V radial
C2,C3 = 100nF

Semiconductors:
D1 = 1N4001
D2 = 1N4148
IC1 = 7805
IC2 = edeFT639 (Elab Inc.; www.elabinc.com)

Miscellaneous:
5 off 3-way SIL pinheader
Evaluation software (VB application) from Elab Inc. wesbite
PCB, ref. 054016-1 from The PCBShop

GigaBit Crossover Cable

002

Henri Derksen

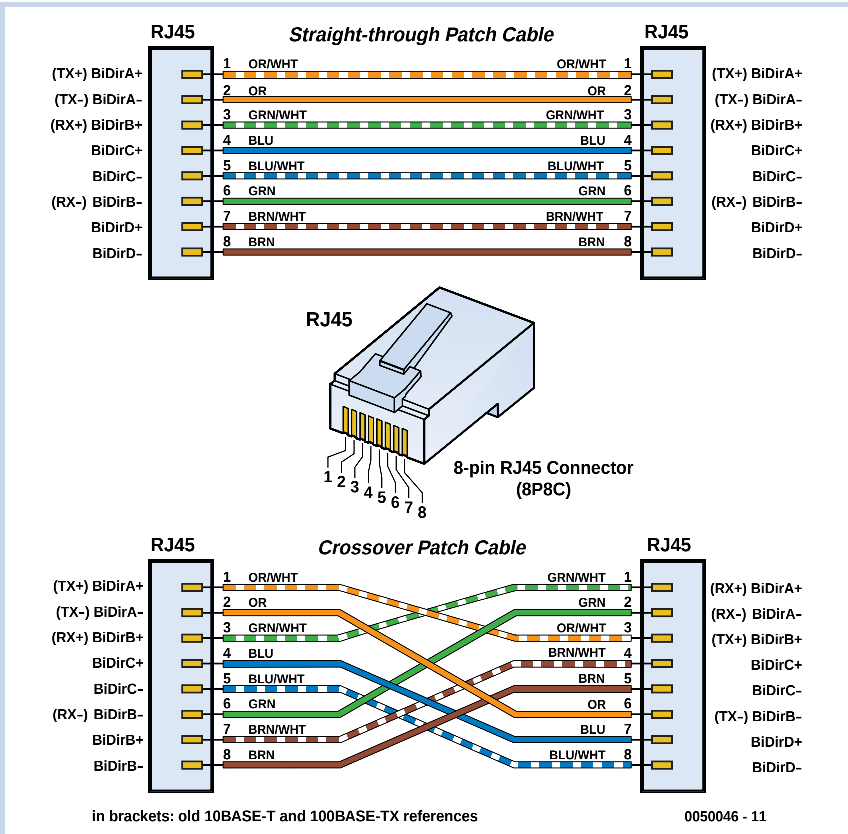
We previously described a crossover cable in last year's Summer Circuits issue ('Home Network for ADSL', p. 81). However, that cable cannot be used for GigaBit links, since all eight conductors are important in that case.

A GigaBit link uses four signal pairs. If the cable is longer than 8 metres, it is also necessary for each paired set of conductors to be twisted together. Otherwise crosstalk will occur, which will cause data communication errors.

A crossover cable that is suitable for 1000-Mbit networks must have all of the conductors connected differently at one end. TX is thus connected to RX, and the two other pairs are also swapped. The connection scheme is shown clearly in the drawing.

Naturally, such a cable can also be used in a 10-Mbit or 100-Mbit network, but it is not suitable for use in combination with lines for an analogue telephone, such as was suggested in the article in the 2004 Summer Circuits issue.

(050046-1)



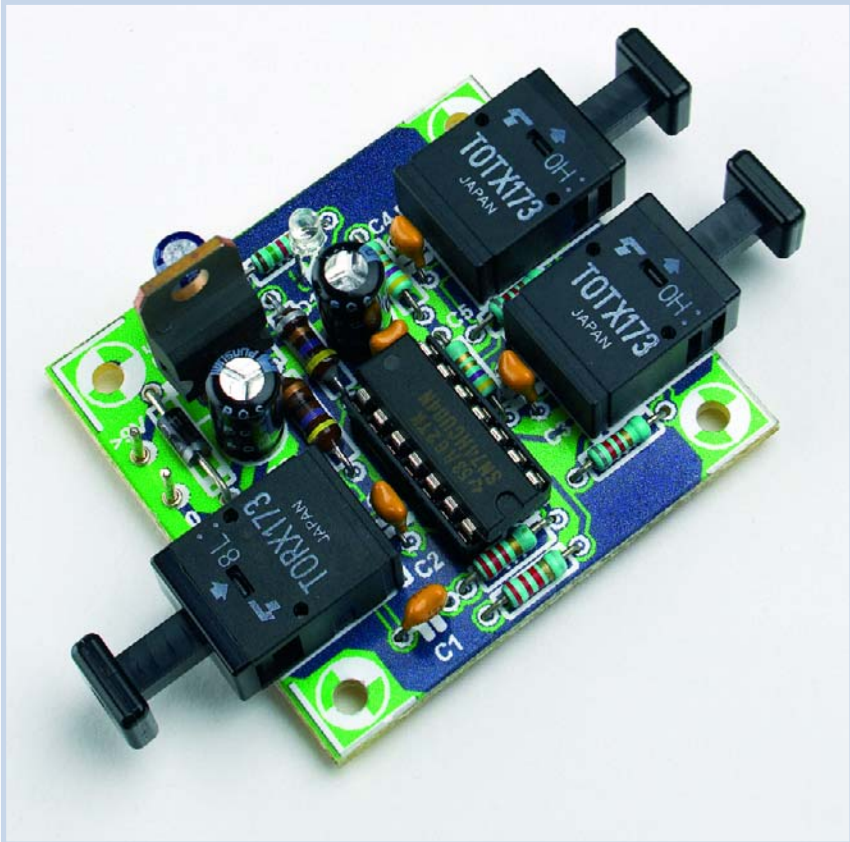
003

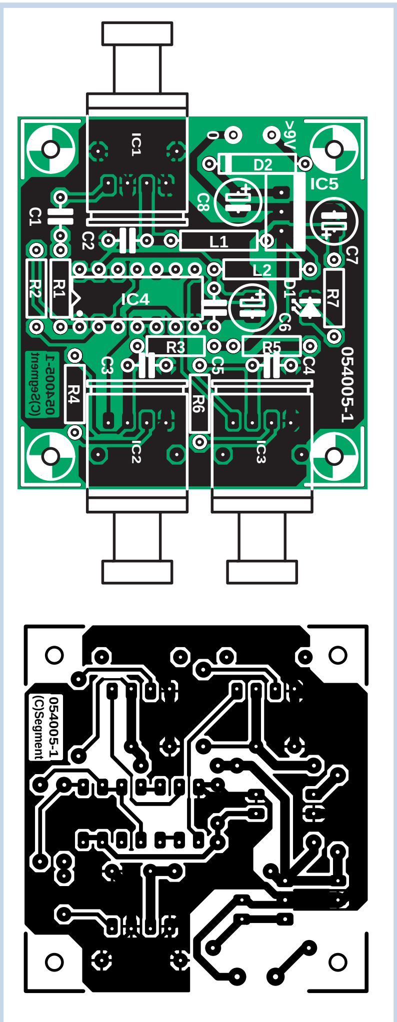
Toslink Repeater/Splitter

Ton Giesberts

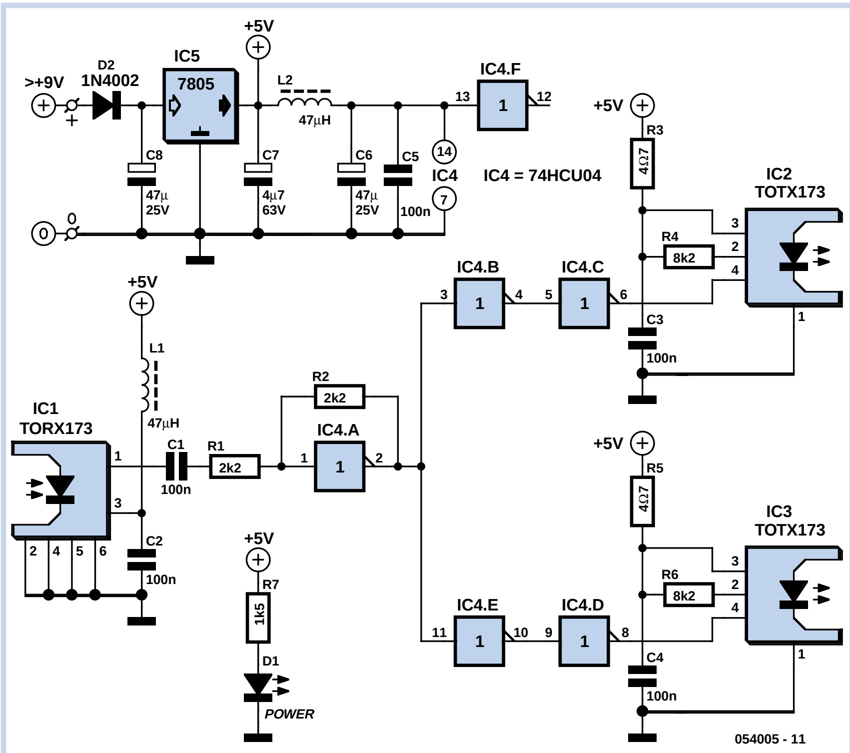
The purpose of this circuit is not only to extend an optical digital audio connection (Toshiba Toslink) but also to function as a splitter, so that two devices can be connected to one Toslink output.

The circuit consists of the standard application for the Toslink receiver module TORX173 (IC1) and the Toslink transmitter module TOTX173 (IC2 and IC3), that we have used on previous occasions. Inverters from a 74HCU04 are connected between the input and output and act as pulse restorers. To keep the quality as high as possible, each of the transmitter modules is driven individually. The first inverter is AC-coupled and ensures that the received S/PDIF signal is centred on the threshold of the inverter. The other inverters (except one) amplify the signal to the maximum output voltage before presenting it to the transmitter modules.





For the power supply a standard 7805 was selected with D2 as reverse polarity protection. L2 decouples the power supply voltage of IC4 some more. This does L1 for IC1 and R3 and R5 for IC2 and IC3 respectively. R4 and R6 are required



for the internal adjustment of the transmitter modules. The required power supply voltage amounts to a minimum of 9 V and can be provided by a mains adapter. A panel mount socket can be fitted in the enclosure (that you can choose yourself) to suit the plug on the mains adapter. A printed circuit board has been designed for the circuit that contains all the components. Two pins are provided to connect the power supply. LED D1 indicates that the power supply is present. The current consumption without optical signal is 103 mA. When the cables are connected and with a frequency of 48 kHz, the current is 70 mA. This is because the transmitter modules will now turn the internal LEDs on and off (when there are no cables connected, the LEDs are on continuously). At 96 kHz the current is about 3 or 4 mA higher.

An FFT (fast fourier transform) analysis shows that the noise floor with a 16-bit PCM signal is about 40 to 45 dB higher compared to a 24-bit PCM signal.

(054005-1)

COMPONENTS LIST

Resistors:
R1,R2 = 2kΩ2
R3,R5 = 4Ω7
R4,R6 = 8kΩ2
R7 = 1kΩ5

Capacitors:
C1-C5 = 100nF
C6,C8 = 47µF 25V radial
C7 = 4µF7 63V radial

Inductors:
L1,L2 = 47µH

Semiconductors:
D1 = low-current LED, red
D2 = 1N4002
IC1 = TORX173
IC2,IC3 = TOTX173
IC4 = 74HCU04
IC5 = 7805
PCB, ref. 054005-1 from The PCBShop

Optical Mixer

004

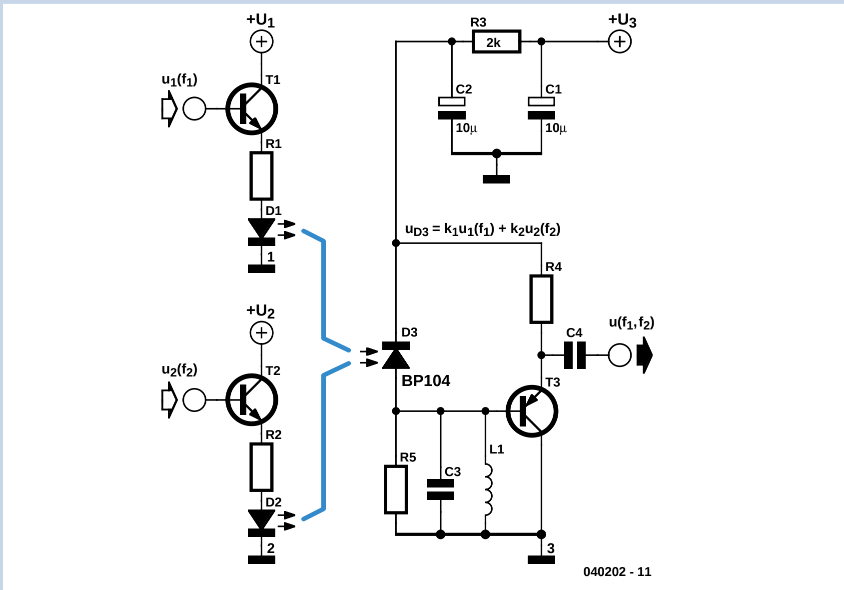
Peter Lay

Mixing signals at different frequencies is common practice in many areas of electronics. Audio systems, communications systems and radio systems are typical application areas.

With conventional frequency mixers, feedback capacitance can cause the signal sources to be affected by the output signal, thus making supplementary filter circuits necessary. The signals from the individual signal sources can also affect each other.

In an optical mixer, LEDs or laser diodes are used to first convert the signals to be mixed into optical signals. The light beams are then aimed at a shared photosensor (a light-sensitive resistor, photodiode, phototransistor, or photovoltaic cell). The current in the output circuit is thus controlled by the mixed input signals, so signal from the photosensor is the sum of the input signals. The amount of feedback capacitance can be made quite small, depending on the construction. Another benefit is that the input and output circuits have separate grounds, which can be electrically connected if necessary. This operating principle directly encourages experimentation. Additional input stages can be added to act on the shared photosensor. If the receiver signal is applied to a component with a curved characteristic, such as a diode, this produces amplitude modulation, which can be used in a heterodyne receiver. If the difference between the frequencies of the two input signals is small, a beat effect occurs. The components must be selected according to the frequency range that is used.

(040202-1)



Formulas

Input signal voltages: $u_1(f_1) = \hat{u}_1\sin(\omega_1 t+\varphi_1)$

$u_2(f_2) = \hat{u}_2\sin(\omega_2 t+\varphi_2)$

Voltage across the photosensor: $u_{D3} = k_1\hat{u}_1\sin(\omega_1 t+\varphi_1) + k_2\hat{u}_2\sin(\omega_2 t+\varphi_2)$

Key:

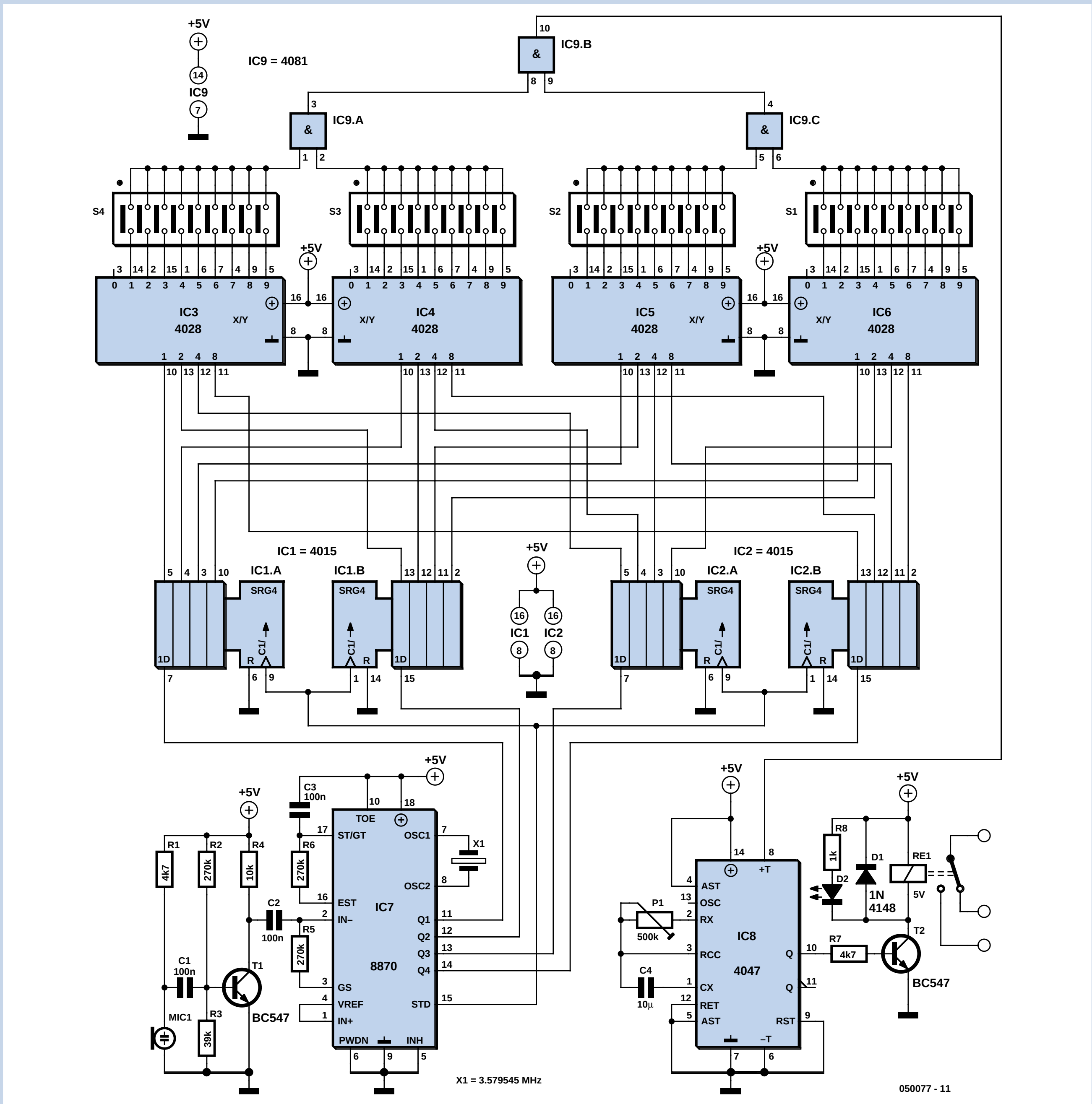
$u_1(f_1)$ first input signal at frequency f_1

$u_2(f_2)$ second input signal at frequency f_2

u_{D3} receiver signal generated by superposition of the two input signals

k_1, k_2 optoelectronic coupling factors (empirically determined)

005 Mobile Phone Operated Code Lock



Heikki Kalliola

Suitcase numberwheels and doorside keypads have evolved from well-known code locks, to hot topics now mainly due to Dan Brown's bestseller novel *The daVinci Code*.

The main ideas behind the lock described here are minimum obtrusiveness and minimum user interface.

A typical code lock is operated with a four-digit secret code and the lock can be opened by presenting this code. The lock described here has no buttons or keypad at all, a small hole or other hiding place for the microphone capsule is enough.

Nowadays practically everyone has a keypad in the pocket — it's on your mobile phone! The lock listens to mobile phone keytones (DTMF tones) and responds to the valid, pre-set four digit code. No visible interface is needed as the microphone capsule can be located behind a small hole. Note that the mobile is used 'off-line', so no phone expenses are involved.

Electret microphone M is connected via transistor amplifier stage T1 to the input pin (2) of DTMF-receiver/decoder IC7. The decoder's four-digit output word (on pins 11, 12, 13, 14) and 'valid digit present' flag (pin 15) are connected to two shift registers, IC1 and IC2. A rising edge on pin 15 of the '8870 chip triggers each shift register to read its input code and shift it by one increment.

Shift register outputs are connected to BCD to Decimal-converters type 4028 (IC3-IC6). The register status is shown as a high signal level at certain pins of DIP switches S1-S4. Depending on the switch settings, one combination causes High

levels at all AND gate inputs and the lock is opened for a moment.
Due to the operation of the shift registers, the latest input digit appears on IC3's outputs. So if the desired code is, for example, 2748, S1 contact 2, S2 contact 7, S3 contact 4 and S4 contact 8 are closed.

When four digits in sequence match with the code set by the switches, relay RE1 is activated for a user-defined time. Upon a rising edge on input pin 8, monostable multivibrator (MMV) IC8 pulls pin 10 high for a moment, activating relay Re1 via transistor T2. The duration of active time can be adjusted with the preset between pins 2 and 3. A green LED can be connected across the relay coil to indicate lock opening.

The minimum distance from the microphone is about 20 cm.

(050077-1)

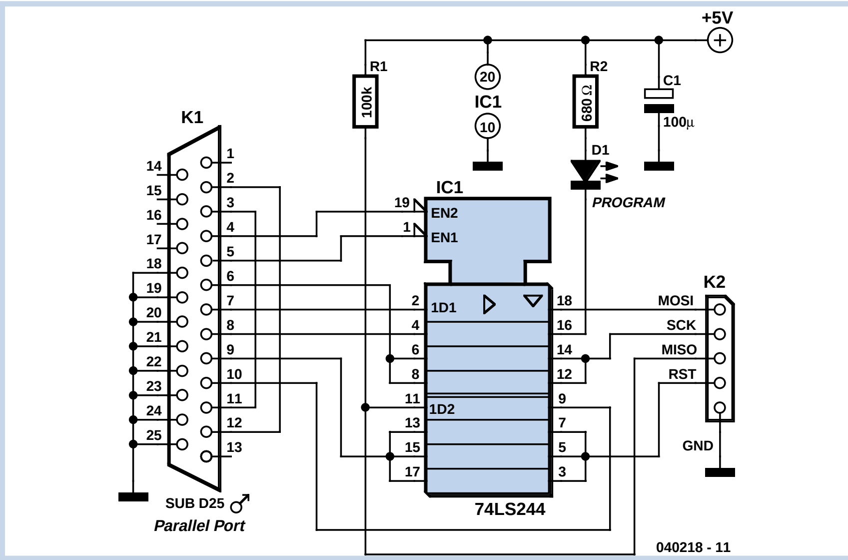
Minimalist Microcontroller

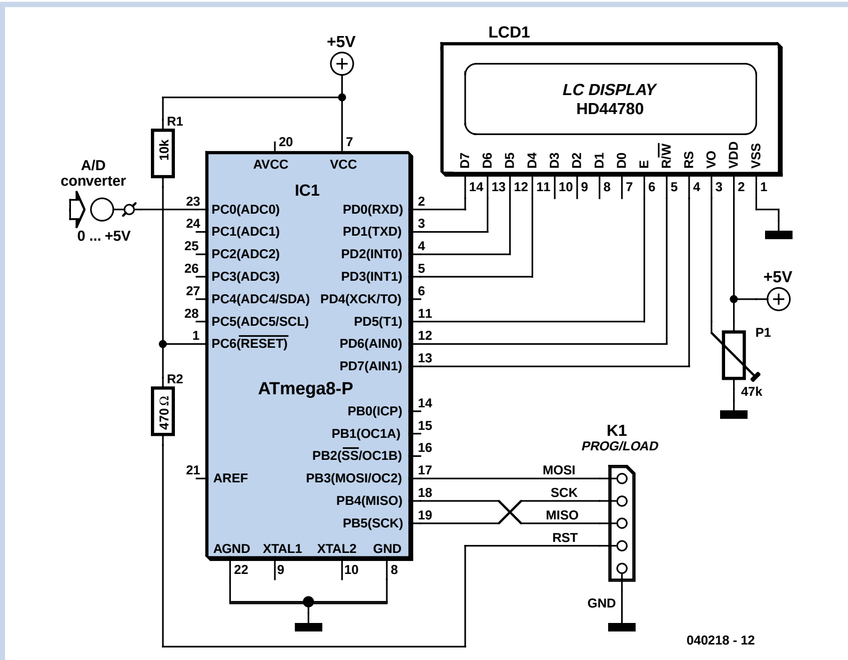
006

Christoph Fritz

They say that things were always better in the old days, although perhaps they were not thinking of microcontrollers and their complex support circuitry. In the ATmega8, microcontroller specialists Atmel have introduced a device that lets you construct a prototype circuit using just two resistors and one potentiometer in addition to the microcontroller chip. Not even a crystal is required: an internal 8 MHz oscillator provides the clock. We thus have a four-component circuit that is a powerful and practical development kit; not only that, it can be programmed directly from the parallel port of any PC without additional hardware. Incredible!
The circuit shown offers a number of I/O pins and an A/D converter input; not only that, it is ready to be connected to a commercially-available liquid crystal display. The whole thing can be built on a simple prototyping board, and no heroic soldering skills are required.
Software, in the form of a C compiler (AVR-GCC under Linux or WinAVR under Windows) is available for free on the Internet. Example applications, expansion ideas, programming tools and code collections are also widely available. And, since the circuit is so simple, it can easily be modified to use other types of microcontroller from Atmel: just take a look at the relevant data sheets and determine which pins are used for the various functions.

(040218ts)





Links:

Introduction to development tools

- for Linux etc.:
www.nongnu.org/avr-libc/user-manual/install_tools.html
- for Windows:
www.avrfreaks.net/Tools/showtools.php?ToolID=376

Procyon AVRlib

(examples and libraries):
http://hubbard.engr.scu.edu/embedded/avr/avrlib/index.html

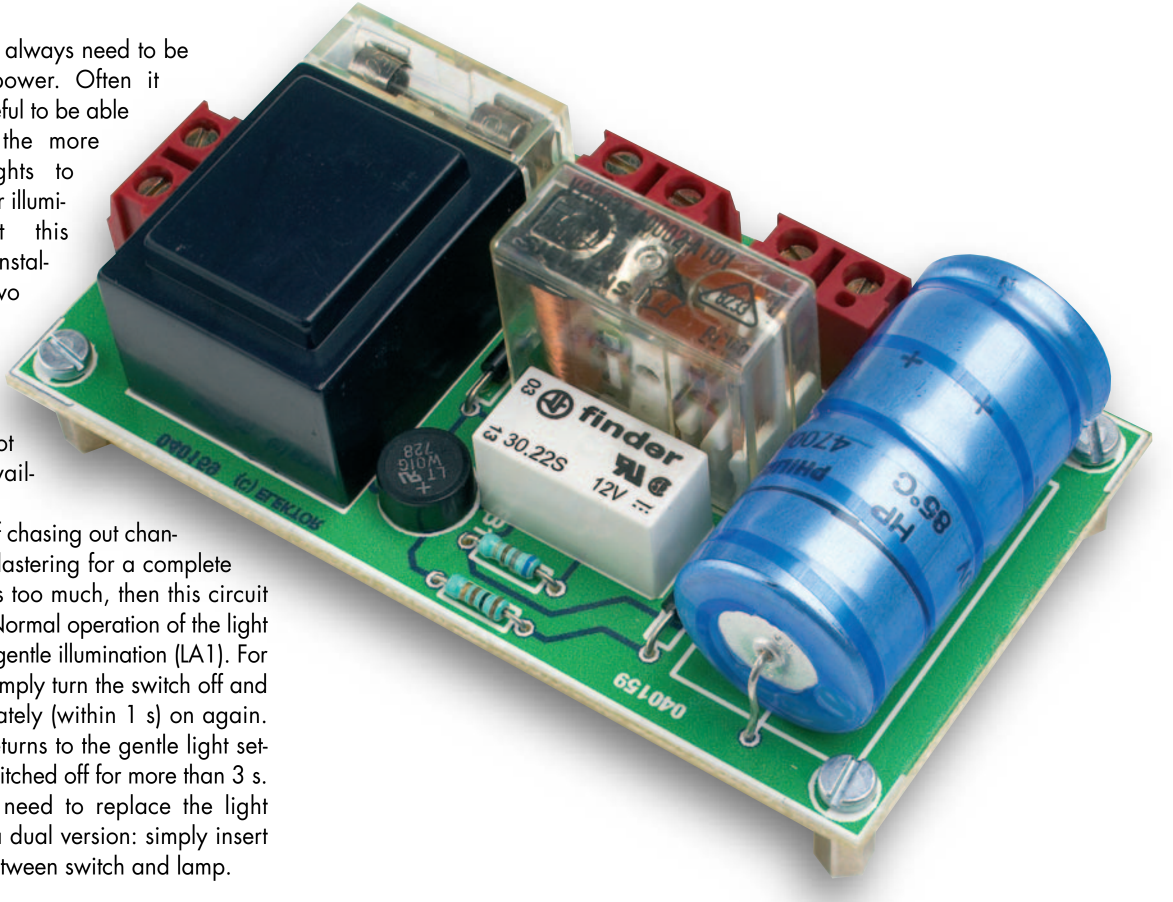
JTAG-Hardware:

http://avr.openchip.org/bootice

WinAVR:
http://winavr.sourceforge.net

007 Energy-saving Switch

Helmut Kraus



Lights do not always need to be on at full power. Often it would be useful to be able to turn off the more powerful lights to achieve softer illumination, but this requires an installation with two separately-switchable circuits, which is not always available.

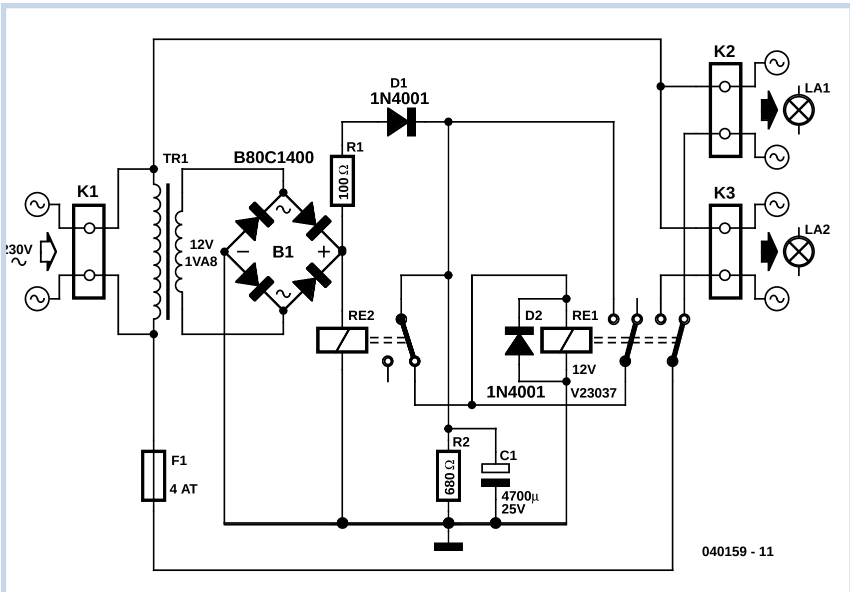
If the effort of chasing out channels and replastering for a complete new circuit is too much, then this circuit might help. Normal operation of the light switch gives gentle illumination (LA1). For more light, simply turn the switch off and then immediately (within 1 s) on again. The circuit returns to the gentle light setting when switched off for more than 3 s. There is no need to replace the light switch with a dual version: simply insert this circuit between switch and lamp.

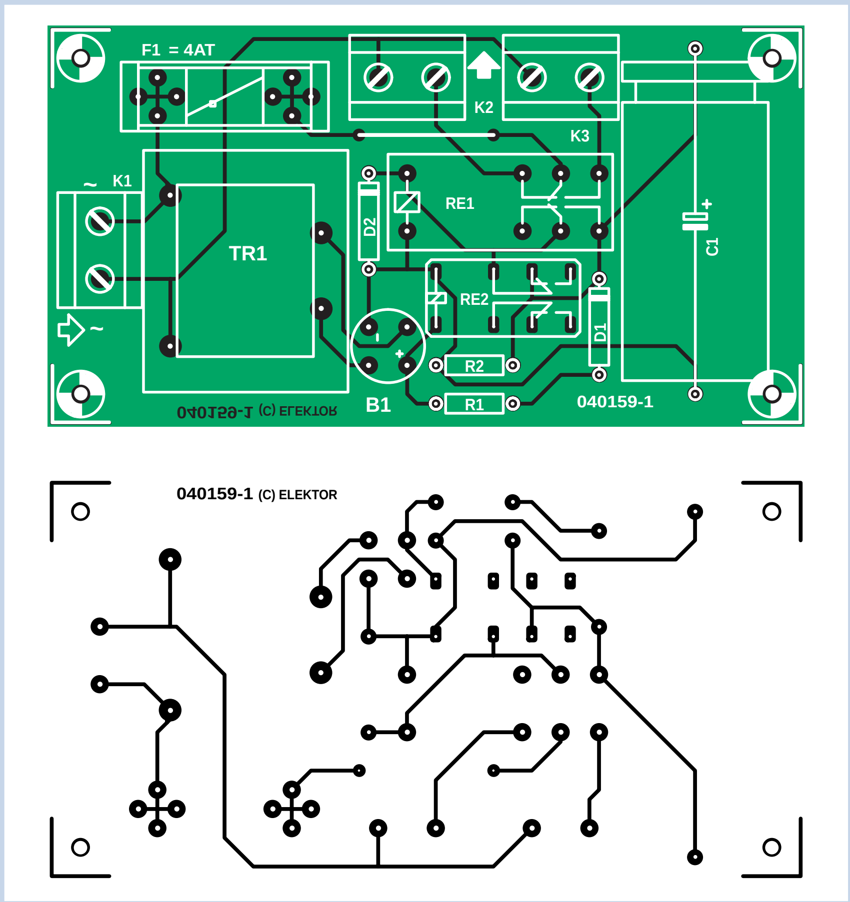
How does it work? Almost immediately after switch-on, fast-acting miniature relay RE2 pulls in, since it is connected directly after the bridge rectifier. Its normally-closed contact then isolates RE1 from the supply, and thus current flows to LA1 via RE1's normally-closed contact. RE1 does not have time to pull in as it is a power relay and thus relatively slow. Its response is also slowed down by the time constant of R1 and C1. If the current through the light switch is briefly interrupted, RE2 drops out immediately. There is enough energy stored in C1 to activate RE1, which then holds itself pulled in via a second, normally-open, contact. If current starts to flow again through the light switch within 1 s, LA2 will light. To switch LA1 back on it is necessary to turn the light switch off for more than 3 s, so that C1 can discharge via R2 and RE1. The printed circuit board can be built into a well insulating plastic enclosure or be incorporated into a light fitting if there is sufficient space.

(040159-1)

Caution:

the printed circuit board is connected directly to the mains-powered lighting circuit. Every precaution must be taken to prevent touching any component or tracks, which carry dangerous voltages. The circuit must be built into a well insulated ABS plastic enclosure.





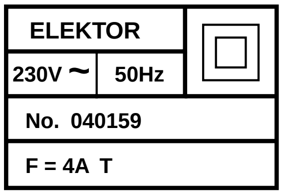
COMPONENTS LIST

Resistors:
R1 = 100Ω
R2 = 680Ω

Capacitor:
C1 = 4700µF 25 V

Semiconductors:
D1,D2 = 1N4001

Miscellaneous:
K1,K2,K3 = 2-way PCB terminal block, lead pitch 7.5 mm
F1 = fuse, 4AT (time lag) with PCB mount holder
TR1 = mains transformer, 12V @ 1.5 VA, short-circuit proof, PCB mount
B1 = B80C1400, round case (80V piv, 1.4A)
RE1 = power relay, 12V, 2 x c/o, PCB mount
RE2 = miniature relay, 12V, 2 x c/o, PCB mount



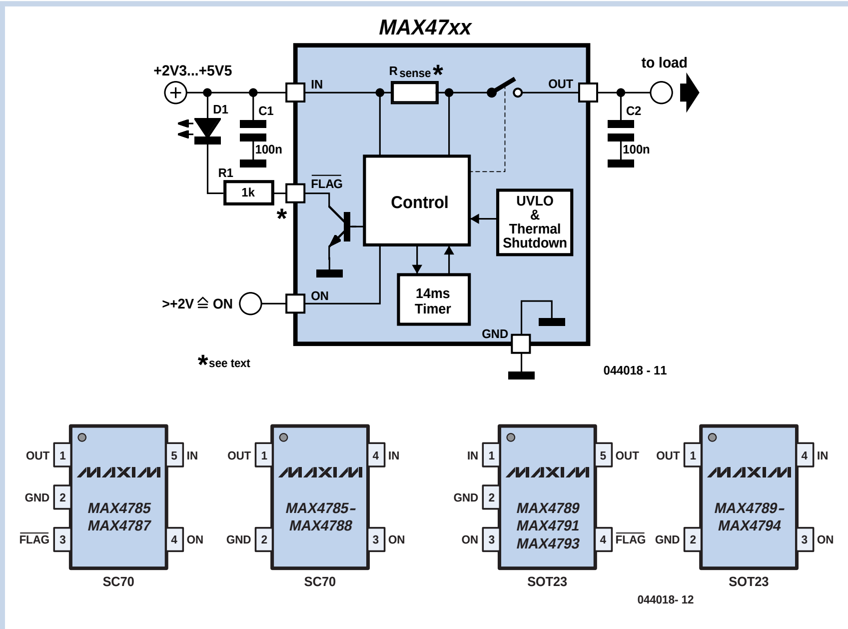
Overcurrent Cutout Switches

008

Gregor Kleine

Overcurrent sensors using external low-resistance sense resistors are fairly common. However, the members of a new family of ICs from Maxim (www.maxim-ic.com) feature an internal sensor resistor and a switch for disconnecting the load if the current limit is exceeded. The members of this IC family are listed in the table.

There are two sorts of overcurrent switches in the family. The types listed in the 'Latching' column store any occurrence of an overcurrent condition and indicate it at the FLAG output until they are switched off and then on again by a pulse on the ON input. The types in the 'Auto-Retry' column automatically attempt to reconnect the load after a delay time. When the delay time expires, they check whether an overcurrent recurs, and if necessary they immediately switch off again. The auto-retry types do not have a /FLAG output. They switch on for approximately 40 ms every 300 ms (typical) to measure



the current. During this 40-ms 'blanking time', the IC checks whether the current is less than the selected limit level. The latching types have the same time delay before the switch opens and the FLAG output is asserted. The FLAG output can act as signal for a microcontroller or simply drive an LED. In the latter case, the input voltage must be greater than the forward voltage of the LED. R1 must be dimensioned for the desired current through the LED. Capacitors C1 and C2 provide decoupling and prevent false triggering of the IC by spurious voltage spikes.

The MAX47xx family of ICs operates over a supply voltage range of +2.3–5.5 V. The ICs have undervoltage lockout (UVLO) and reliably switch off when the current exceeds the type-specific limit, even if the current flows in the reverse direction (from the load to the input). The table indicates the possible range of the overcurrent threshold for each type. For instance, a given MAX2791 might switch off at a current as low as 250 mA. However, other examples of the same type will not switch off until the current reaches 350 mA. The same threshold values apply to reverse currents. An overtemperature cutout circuit protects the IC against thermal destruction.
The latching types come in a 5-pin SMD package, while the auto-retry types without a /FLAG output manage with only four pins. The 50-mA and 100-mA versions fit into the tiny SC70 package. The types for higher current levels require an SOT23 or SOT143 package.
There are also other Maxim ICs with similar functions, such as the MAX4795–MAX4798 series with typical cutoff thresholds of 450 mA and 500 mA. Finally, there are the MAX4772 and MAX4773, which have a programmable threshold that can be set to 200 mA or 500 mA using a Select input. However, the IC types mentioned in this paragraph require a different circuit arrangement than what is shown here.

Latching	Auto-Retry	min. Limit	max. Limit	Package
MAX 4785	MAX 4786	50 mA	120 mA	SC70
MAX 4787	MAX 4788	100 mA	240 mA	SC70
MAX 4789	MAX 4790	200 mA	300 mA	SC70
MAX 4791	MAX 4792	250 mA	375 mA	SOT23/143
MAX 4793	MAX 4794	300 mA	450 mA	SOT23/143

(044018-1)

009

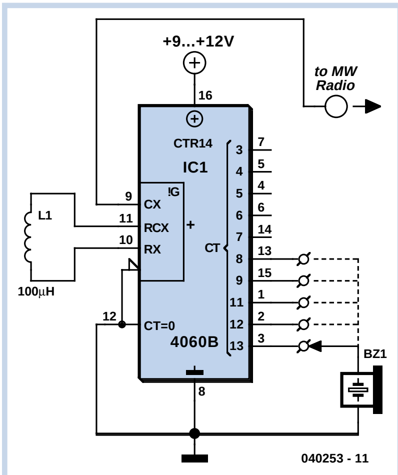
Simple Oscillator / Pipe Locator

Rev. Thomas Scarborough

Sometimes the need arises to construct a really simple oscillator. This could hardly be simpler than the circuit shown here, which uses just three components, and offers five separate octaves, beginning around Middle C (Stage 14). Octave # 5 is missing, due to the famous (or infamous) missing Stage 11 of the 4060B IC. We might call this a Colpitts ‘L’ oscillator, without the ‘C’. Due to the reactance of the 100-µH inductor and the propagation delay of the internal oscillator, oscillation is set up around 5 MHz. When this is divided down, Stage 14 approaches the frequency of Middle C (Middle C = 261.626 Hz). Stages 13, 12, 10, and 9 provide higher octaves, with Stages 8 to 4 being in the region of ultrasound.

If the oscillator’s output is taken to the aerial of a Medium Wave Radio, L1 may serve as the search coil of a Pipe Locator, with a range of about 50 mm. This is tuned by finding a suitable heterodyne (beat note) on the medium wave band. In that case, piezo sounder Bz1 is omitted. The Simple Oscillator / Pipe Locator draws around 7 mA from a 9-12 V DC source.

(040253-1)



010

Audio Click/Pop Suppressor

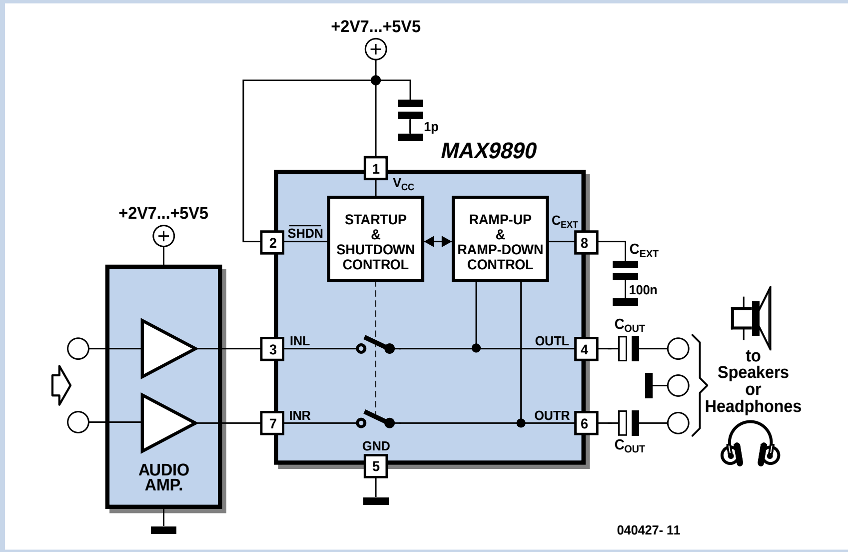
Gregor Kleine

Audio amplifier circuits with a single supply voltage have output coupling capacitors that produce audible clicking or popping sounds when the supply voltage is switched on, since they must be initially charged to half the supply voltage. Similarly, a clicking or popping noise can be produced by the discharge current when the supply is switched off. The capacitance (C_{out}) of the output capacitors cannot be reduced, since it determines the lower limit of the frequency range. The process of establishing the DC operating point in upstream amplifier stages also generates switch-on and switch-off noises. For headphone outputs in particular, this can be remedied using an 8-pin IC from Maxim (www.maxim-ic.com), the MAX9890, which can be connected between the output stage and the output capacitors to suppress irritating clicks and pops.
The secret of the MAX9890 is that it changes the shape of the charging current for the output capacitors from an abrupt (and thus audible) step to an opti-

mised S-shaped curve that has such a low frequency that it does not produce any audible sound. After the capacitor has been charged, two integrated switches are enabled to connect the audio amplifier outputs to the already charged coupling capacitors. When the supply voltage is switched off, these switches open immediately and the coupling capacitors discharge slowly via internal 220-kΩ resistors. There is also an undervoltage detector that opens the switches if the supply voltage is less than +2.5 V. A shutdown input (/SHDN, pin 2) allows the headphone output to be selectively disabled. Inside the IC, the *Startup and Shutdown Control* section controls the switches and the *Ramp Up and Ramp Down Control* section controls capacitor charging and discharging.

Capacitor C_{EXT} generates a switching time delay after the supply voltage is applied. During the switch-off process, it powers the internal circuitry responsible for discharging the coupling capacitors. A 100-nF capacitor is adequate for this purpose.

The switch-on delay is 200 ms (MAX9890A) or 330 ms (MAX9890B). The A version is adequate for coupling capacitors up to 100 µF, with the B version being preferred for capacitors up to 220 µF. With coupling capacitor values larger than this, switch-on noises may still be audible under certain conditions.



The MAX9890 operates over a supply voltage range of +2.7–5.5 V, draws only around 20 µA of current, and is specifically protected against electrostatic discharges up to ±8 kV. The input voltage on INL and INR must lie between 0 V and the supply voltage level. Click and pop suppression is 36 dB. The additional distortion factor is specified by the manufacturer as 0.003 % (THD+N) for a 32-Ω headphone load. The power supply rejection ratio is typically 100 dB. The IC is available in two different SMD packages; the pinout shown here is for the TDFN package.

(040427-1)

http://pdfserv.maxim-ic.com/ en/ds/ MAX9890.pdf

IR Testing with a Digital Camera

011

Dirk Gehrke

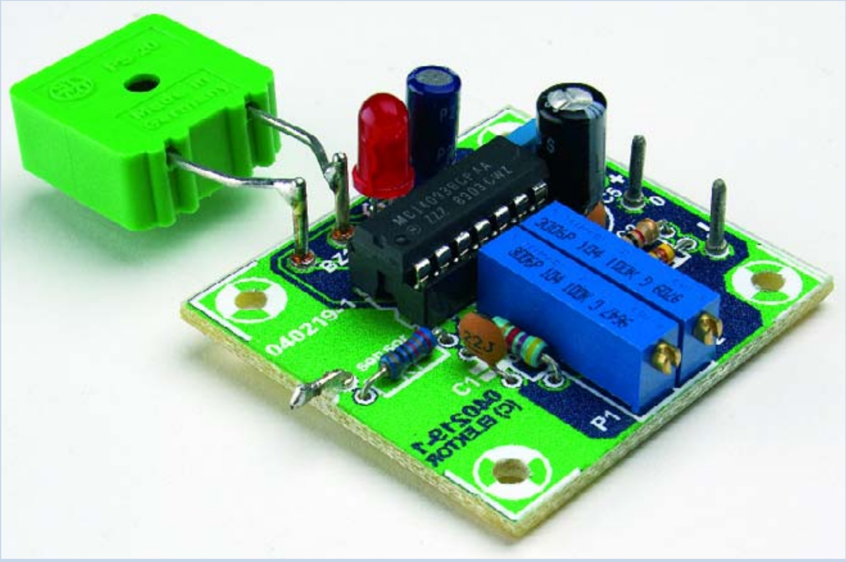
If a device fails to respond to an IR remote control unit, the problem is often in the remote control, and it usually means that the batteries are dead. If the remotely controlled device still doesn't respond to the IR remote control after the batteries have been replaced, you're faced with the question of whether the remote control is not sending a signal or the device isn't receiving it properly. After checking for trivial errors, such as incorrectly fitted or defective batteries, the next thing you should check is whether the remote control transmits a signal. In the past, you would have needed an IR tester or a special IR detector card (as shown in the photo) for this. Nowadays you can use a digital camera (still or video), which is commonly available in most households. That's because the CCD chip is sensitive to infrared as well as visible light, which allows pictures to be taken at night to a certain extent.

If you switch on the camera and the display, aim the remote control unit toward the camera, and press one of the buttons on the remote control, you should see a blinking light coming from the IR LED. If the LED remains dark, you can safely assume that the remote control unit is defective.

(040446-1)

012 Proximity Switch

Rev. Thomas Scarborough



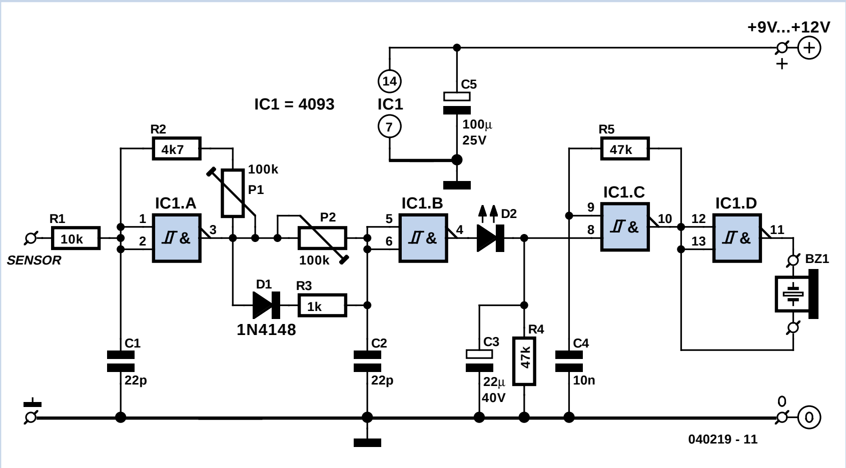
This circuit is for an unusually sensitive and stable proximity alarm which may be built at very low cost. If the negative terminal is grounded, it will detect the presence of a hand at more than 200mm. If it is *not* grounded, this range is reduced to about one-third. The Proximity Switch emits a loud, falling siren when a body is detected within its range.

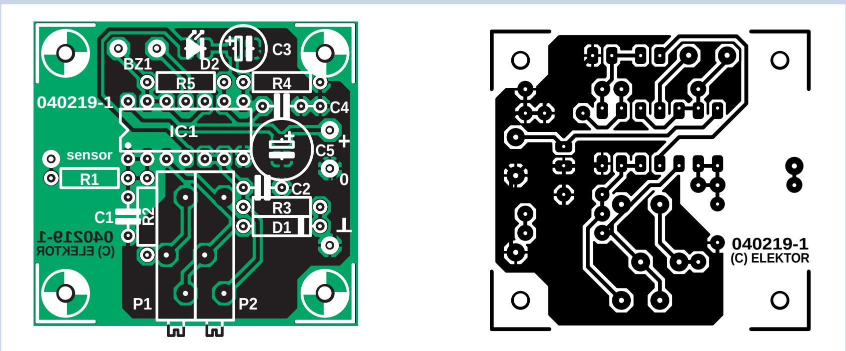
A wide range of metal objects may be used for the sensor, including a metal plate, a doorknob, tin foil, a set of burglar bars — even a complete bicycle. Not only this, but any metal object which comes within range of the sensor, itself becomes a sensor. For example, if a tin foil sensor is mounted underneath a table, metal items on top of the table, such as cutlery, or a dinner service, become sensors themselves.

The touch plate connected to the free end of R1 detects the electric field surrounding the human body, and this is of a relatively constant value and can therefore be reliably picked up. R1 is not strictly necessary, but serves as some measure of protection against static charge on the body if the sensor should be touched directly.

As a body approaches the sensor, the value of C1 effectively increases, causing the frequency of oscillator IC1.A to drop. Consequently capacitor C2 has more time to discharge through P2, with the result that the inputs at IC1.B go Low, and the output goes High. As the output goes High, so C3 is charged through LED D2. D2 serves a dual purpose —namely as a visual indication of detection, and to lower the maximum charge on C3, thus facilitating a sharper distinction between High and Low states of capacitor C3.

The value of R4 is chosen to enable C3 to discharge relatively quickly as pulses through D2 are no longer sufficient to maintain its charge. The value of C3 may be increased for a longer sounding of the





COMPONENTS LIST

Resistors:
R1 = 10kΩ
R2 = 4kΩ7
R3 = 1kΩ
R4 = 47kΩ
R5 = 47kΩ
P1,P2 = 100kΩ multiturn cermet, horizontal

Capacitors:
C1,C2 = 22pF
C3 = 22µF 40V radial
C4 = 10nF
C5 = 100µF 25V radial

Semiconductors:
D1 = 1N4148
D2 = LED, red
IC1 = 4093

Miscellaneous:
BZ1 = AC buzzer
PCB, ref. 040219-1, from The PCBShop

siren, with a slight reduction in responsiveness at the sensor. When C3 goes High, this triggers siren IC1.C and IC1.D. The two NAND gates drive piezo sounder X1 in push-pull fashion, thereby greatly increasing its volume. If a piezo tweeter is used here, the volume will be sufficient to make one's ears sing.

The current consumption of the circuit is so low a small 9-V alkaline PP3 battery would last for about one month. As battery voltage falls, so sensitivity drops off slightly, with the result that P1 may require occasional readjustment to maintain maximum sensitivity. On the down side of low cost, the hysteresis properties of the 4093 used in the circuit are critical to operation, adjustment and stability of the detector. In some cases, particularly with extremely high sensitivity settings, it will be found that the circuit is best powered from a *regulated* voltage source. The PCB has an extra ground terminal to enable it to be easily connected to a large earthing system. Current consumption was measured at 3.5 mA stand-by or 7 mA with the buzzer activated.

Usually, only P1 will require adjustment. P2 is used in place of a standard resistor in order to match temperature coefficients, and thus to enhance stability. P2 should be adjusted to around 50 k, and left that that setting. The circuit is ideally adjusted so that D2 ceases to light when no body is near the sensor. Multiturn presets *must* be used for P1 and P2.

Since the piezo sounder is the part of the circuit which is least affected by body presence, a switch may be inserted in one of its leads to switch the alarm on and off after D2 has been used to check adjustment. Make sure that there is a secure connection between the circuit and any metal sensor which is used.

(040219-1)

013

Discharge Circuit

Gregor Kleine

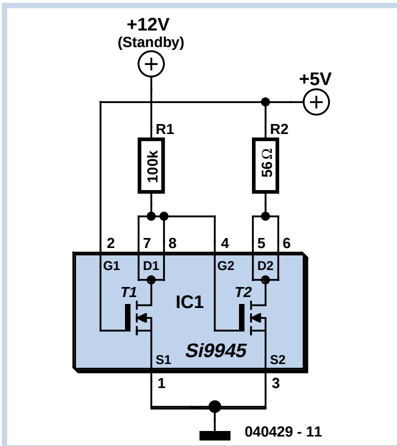
The author encountered a problem with a microcontroller system in which the +5-V supply voltage did not decay to 0 V sufficiently quickly after being switched off. A certain residual voltage remained, and it declined only very slowly. As a result, certain system components could not perform a clean reset if the power was quickly switched on again.

To remedy this problem, a very simple circuit was used to discharge the +5-V supply. It consists of two resistors and a type Si9945 dual MOSFET from Vishay Siliconix (www.vishay.com/mosfets). These MOSFETs switch fully on at a threshold gate voltage between +1 V and +3 V. MOSFET T2 connects discharge resistor R2 for the +5-V supply line to ground if the voltage on its gate exceeds the threshold voltage.

When the +5-V supply is switched off, the first MOSFET (T1), whose gate is connected to the +5-V supply voltage, no longer connects pull-up resistor R1 to ground, so the standby voltage is applied to the gate of T2 via R1. This requires the standby voltage to remain available for at least as long as it takes to discharge the +5-V supply, even when the system is switched off.

R2 is dimensioned to avoid exceeding the 0.25-W continuous power rating of a type 1206 SMD resistor. It may be necessary to change the component value for use in other applications.

The circuit can be constructed very compactly, since the dual MOSFET is housed in an SO8 SMD package, but it can also be built using 'ordinary' individual FETs, such as the BS170.



(040429-1)

http://www.vishay.com/doc?70758

014

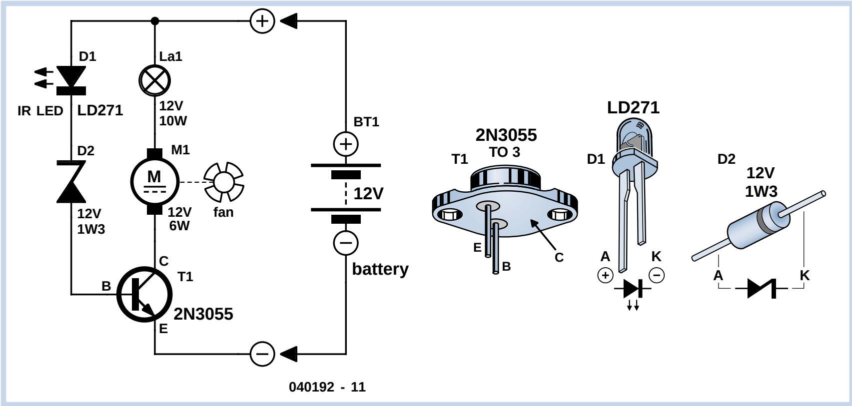
Gentle Battery Regulator

Wolfgang Zeiller

This small but very effective circuit protects a lead-acid battery (12-V solar battery or car battery) against overcharging by a solar module when the incident light is too bright or lasts too long. It does so by energising a fan, starting at a low speed when the voltage is approximately 13.8 V and rising to full speed when the voltage exceeds 14.4 V (full-charge voltage). The threshold voltage (13.8 V) is the sum of the Zener diode voltage (12 V), the voltage across the IR diode (1.1 V), and the base-emitter voltage of the 2N3055 (0.7 V).

In contrast to circuits using relays or IC amplifiers, the circuit has a gradual switching characteristic, which avoids relay chatter and the constant switching on and off near the switching point produced by a 'hard' switching point. The circuit does not draw any current at all (auto power-off) below 13 V.

Pay attention to the polarisation of the Zener and IR diodes when building the circuit. The transistor must be fitted to a heat sink, since it becomes hot when the fan is not fully energised (at voltages just below 14 V). A galvanised bracket from a DIY shop forms an adequate heat sink. The indicated component values are for a 10-W solar module. If a higher-power module is used, a motor with higher rated power must also be used. The circuit takes advantage of the positive temperature coefficient of the lamp filament. The filament resistance is low at low voltages and increases as the voltage rises. This reduces the speed of the fan to avoid generating an annoying noise level. The lamp also provides a form of finger protection. If you stick your finger into the fan blade, the lamp immediately takes over the majority of the power dissipation and lights brightly. This considerably reduces the torque of the fan. An ordinary 10-W or 20-W car headlight (or two 25-W headlights in parallel) can be used for the lamp.



Don't try to replace the LED by two 1N4001 diodes or the like, replace the ZPY12 by a ZPY13, or fit a series resistor for the LED. That would make the 'on' region too large.

(040192-1)

015

Telephone Line Watchdog

Dick Sleeman

Circuits have been published on earlier occasions that keep an eye on the telephone line. This simple circuit does it with very few components and is completely passive.

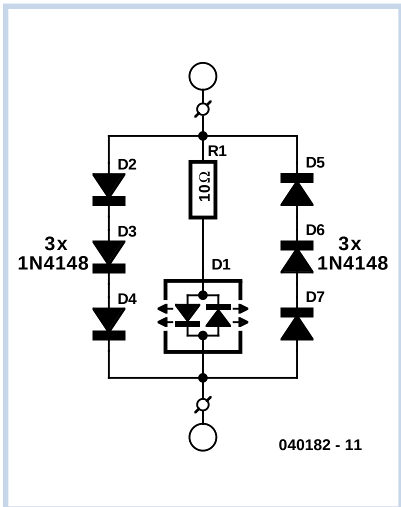
The operating principle is simplicity itself. The circuit is connected in series with one of the two signal lines. It does not matter which one of these two is used. When the telephone receiver is lifted off the hook, or the modem makes a connection, a voltage will appear across the four diodes. This voltage is used to drive the duoLED. Depending on the direction of the current, either the red or the green part of the duoLED will light up.

In some countries, the polarity of the telephone line voltage is reversed after a few seconds. This does not matter with this circuit since a duoLED has been used.

Depending on the polarity of the line, the current will flow through either one branch or the other. The 22-Ω resistor is used as a current limiter, so that both colours are about the same brightness.

The duoLED can be ordered from, among others, Conrad Electronics (part number 183652). You can, of course, also use another, similar LED. For the diodes use the ubiquitous 1N4148.

(040182-1)



016

Comparing Signed Integers

Paul Goossens

Every once in a while it is necessary to compare two signed integers with each other. Unfortunately, some programming languages do not support signed integers. This problem presented itself with a design in Verilog. This language has a direct method of comparing two unsigned integers. With comparing we mean determining whether integer A is more than or less then integer B, or equal.

After some thought for an efficient solution we found the following:

By inverting the MSB (Most Significant Bit) of both signed integers, both can be compared as unsigned integers with the correct result. "How can this be?", you will ask. The solution is simple.

The difference between an unsigned integer and a signed integer is that the MSB of an unsigned integer has a value of 2^n, while that same MSB of a signed integer has the value -2^n. With positive numbers nothing special happens, that means, the value is the same whether they are treated as signed or unsigned. With a negative number (where the MSB=1 and is therefore significant) the value increases by $2*2^n$ (instead of -2^{n-1} the weight of the MSB becomes 2^{n-1}). By inverting the MSB, 2^{n-1} is added to both negative and positive numbers. A necessary condition is that the

MSB of a signed value is equal to '1' (thus indicating a negative value) and zero for an unsigned value. In this way the relative difference between the two numbers remains exactly the same. In the example you can see clearly that after the operation the value of each has been increased by exactly 128, provided they are both considered as unsigned integers. This is independent on whether the original integer was positive or negative. Now both numbers can be compared as unsigned integers with (of course) the correct result!

(054004-1)

Decimal value of bits within an 8-bit integer

7	6	5	4	3	2	1	0	
–128	64	32	16	8	4	2	1	signed
128	64	32	16	8	4	2	1	unsigned

Example: 10011100 = signed –100

inverting MSB:

00011100 = unsigned 28

00001111 = signed 15

10001111 = signed 143

Resistor Colour Band Decoder

017

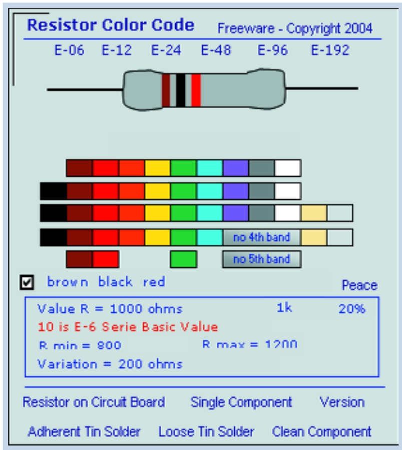
Carlos Alberto Gonzales

Despite claims to the contrary by the non-initiated, electronics is still very much an exact science, so unless your memory is rock-solid you can not afford to make a mistake in reading a resistor value from the colour bands found on the device. So why not use the computer for the job? The program supplied by the author comes as an Excel spreadsheet that does all the colour-to-value converting for you in response to a few mouse clicks.

The program is extremely simple to use. Just click on the various colours to put them on the virtual resistor. Check the colour band structure against the real resistor on a board, on the floor or in the 'spares allsorts' drawer. The window below the colour bands will indicate the resistor's E series, nominal, high/low values and tolerance. The program supports the E6 and E12 through E192 series.

The program may be obtained free of charge from www.elektor-electronics.co.uk as archive file **040203-11.zip** (July/August 2005).

(040203-1)



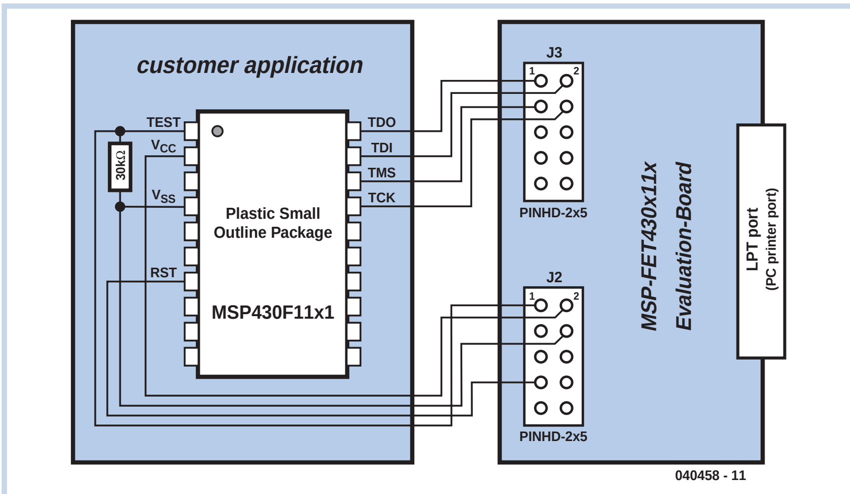
MSP430 Programmer

018

Dirk Gehrke

For many applications, programming a microcontroller after it has been soldered to the circuit board in the target application is more convenient than using a separate programmer. With the Texas Instruments MSP430F11x1, this can be done quite easily using the JTAG pins.

The Flash Emulation Kit makes it very easy to develop programs for the MSP430, debug the programs and program them into the microcontroller. However, prototype testing usually reveals a need for minor improvements to the software. The MSP430 has a JTAG port that can be enabled by applying a High level to the



TEST pin. The registers, RAM and Flash memory can be read and written via this interface. Naturally, this feature can also be used in the target application. However, it's important to bear in mind that the associated pins have dual functions. For in-circuit programming, you will need a 20-way SOJ test clip (available from 3M, for example) that can grip the pins of the SO IC package in the soldered-in state. A total of eight pins must be connected to the Flash Emulation Kit to allow the microcontroller to be programmed.

It's important to ensure that a High level is applied to the /RST pin for the duration of the programming process, and a supplementary 30-kΩ resistor must be connected to the TEST pin to ensure a well-defined Low level.

(040458-1)

References and software

[l] IAR Embedded Workbench Kickstart Version 3 Rev. D Document ID: slac050d.zip

[2] MSP430F11X(1) Flash Emulation Tool (US $49)

[3] MSP-FET430 Flash Emulation Tool [http://focus.ti.com/lit/ug/slau138a/slau138a.pdf]

[4] http://www.msp430.com

019 Micropower Voltage Regulator

Reinhold Oesterhaus

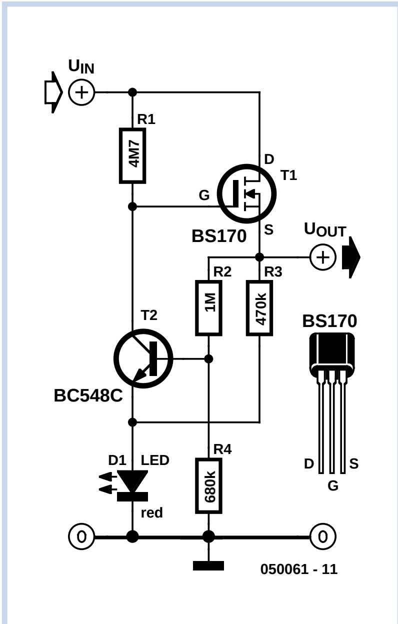
This circuit was developed to power an AVR microcontroller from a 12 V lead-acid battery. The regulator itself draws only 14 µA. Of course, there are dedicated ICs, for example from Linear Technology or Maxim, which can be used, but these can be very hard to get hold of and are frequently only available in SMD packages these days. These difficulties are simply and quickly avoided using this discrete circuit.
The series regulator component is the widely-available type BS170 FET. When power is applied it is driven on via R1. When the output voltage reaches 5.1 V, T2 starts to conduct and limits any further rise in the output voltage by pulling down the voltage on the gate of T1. The output voltage can be calculated as follows:

$$U_{OUT} = (U_{LED} + U_{BE}) \times (R4 + R2) / R4$$

where we can set U_{LED} at 1.6 V and U_{BE} at 0.5 V. The temperature coefficients of U_{LED} and U_{BE} can also be incorporated into the formula.

The circuit is so simple that of course someone has thought of it before. The author's efforts have turned up an example in a collection of reference circuits dating from 1967: the example is very similar to this circuit, although it used germanium transistors and of course there was no FET. The voltage reference was a Zener diode, and the circuit was designed for currents of up to 10 A. Perhaps *Elektor Electronics* readers will be able to find even earlier examples of two-transistor regulators using this principle?

(050061-1)



020 Garage Timer

Daniel Lomitzky and Mikolajczak Tyrone

The circuit described here is a testament to the ingenuity of two young designers from a specialist technical secondary school. The 'garage timer' began as a school electronics project and has now made it all the way to publication in our Summer Circuits special issue of *Elektor Electronics*. The circuit demonstrates that the application possibilities for the 555 and 556 timer ICs are by no means exhausted. So what exactly is a 'garage timer'?

When the light switch in the garage is pressed, the light in the garage comes on for two minutes. Also, one minute and forty-five seconds after the switch is pressed, the outside light also comes on for a period of one minute. The timer circuit is thus really two separate timers. Although the circuit for the interior light timer is relatively straightforward, the exterior light timer has to deal with two time intervals. First the 105 second period must expire; then the exterior light is switched on, and after a further 60 seconds the light is turned off. To realise this sequence of events, a type 556 dual timer device, a derivative of the 555, is used. The first of the two timers triggers the second after a period of 105 seconds. The second timer is then active for 60 seconds, and it is this timer that controls the exterior light. The interior light timer is triggered at the same moment as the dual timer. In this case a simple 555 suffices, with an output active for just two minutes from the time when the switch is pressed. Push-button S1 takes over the role of the wall-mounted light switch, while S2 is provided to allow power to be removed from the whole circuit if necessary. The circuit could be used in any application where a process must be run for a set period after a certain delay has expired.

For the school project the two garage lights are simulated using two LEDs. This will present no obstacle to experienced hobbyists, who will be able to extend the circuit, for example using relays, to control proper lightbulbs. The principles of operation of type 555 and 556 timers have been described in detail previously in *Elektor Electronics*, but we shall say a few words about the functions of IC1a, IC1b and IC2. When S1 is pressed (assuming S2 is closed!) the trigger inputs of both IC1a and IC2 are shorted to ground, and so the voltage at these inputs (pins 6 and 2 respectively) falls to 0 V. The outputs of IC1a and IC2 then go to logic 1, and D2 (the interior light) illuminates.

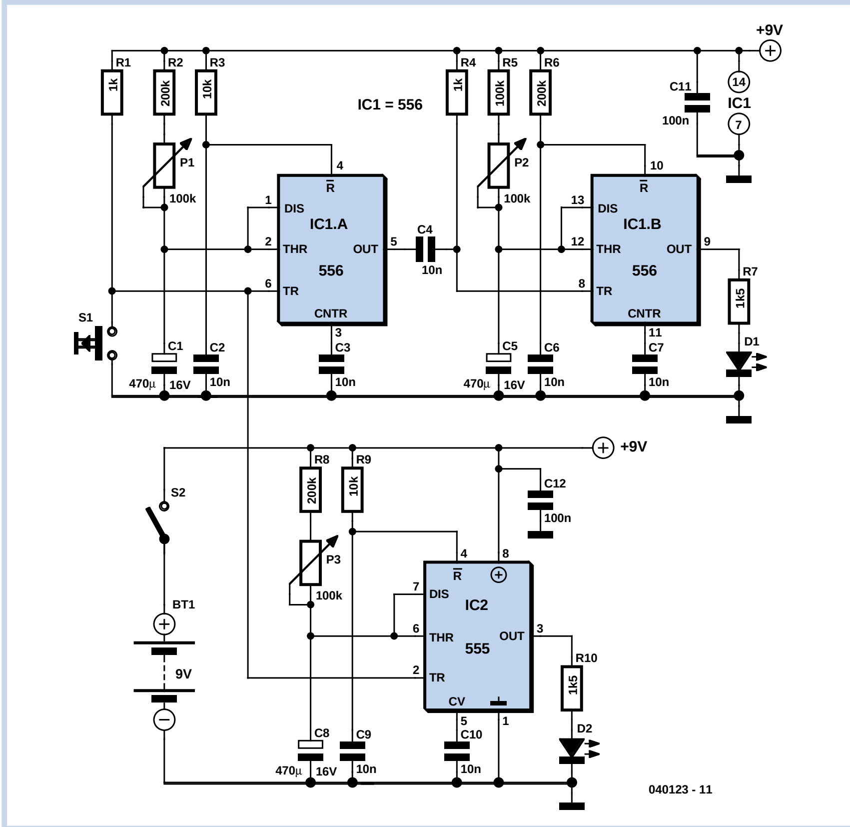
Capacitors C1 and C8 now start to charge via P1 and R2, and R8 and P3 respectively. When the voltage on C8 reaches two thirds of the supply voltage, which happens after 120 seconds, the output of IC2, which is connected as a monostable multivibrator, goes low. D2 then goes out. This accounts for the interior light function.

Likewise, 105 seconds after S1 is closed, the voltage on C1 reaches two thirds of the supply voltage and the output of IC1a goes low. Thanks to C4, the trigger input of IC1b now receives a brief pulse to ground, exactly as IC1a was triggered by S1. The second monostable, formed by IC1b, is thus triggered. Its pulse duration is set at one minute, determined by C5, R5 and P2. D1 thus lights for one minute. Potentiometers P1, P2 and P3 allow the various time intervals to be adjusted to a certain extent. If considerably shorter or longer times are wanted, suitable changes should be made to the values of C1, C5 and C8. The period of the monostable is given by the formula

$$T = 1.1\ RC$$

where T is the period in seconds, *R* the total resistance in ohms, and *C* the capacitance in farads.

(040123-1)



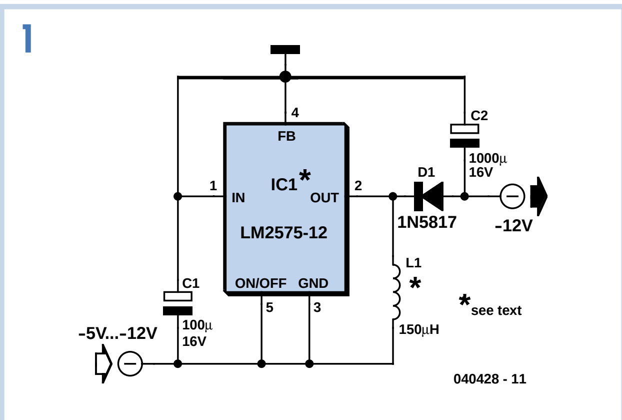
Negative-Output Switching Regulator

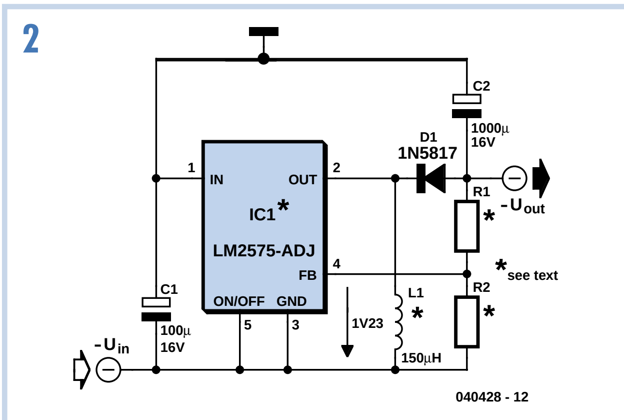
021

Gregor Kleine

There are only a limited number of switching regulators designed to generate negative output voltages. In many cases, it's thus necessary to use a switching regulator that was actually designed for a positive voltage in a modified circuit configuration that makes it suitable for generating a negative output voltage.

The circuit shown in **Figure 1** uses the familiar LM2575 step-down regulator





from National Semiconductor (www.national.com). This circuit converts a positive-voltage step-down regulator into a negative-voltage step-up regulator. It converts an input voltage between –5 V and –12 V into a regulated –12-V output voltage. Note that the output capacitor must be larger than in the standard circuit for a positive output voltage. The switched current through the storage choke is also somewhat higher. Some examples of suitable storage chokes for this circuit are the PE-53113 from Pulse (www.pulseeng.com) and the DO3308P-153 from Coilcraft (www.coilcraft.com).

The LM2575-xx is available in versions for output voltages of 3.3V, 5 V, 12 V and 15 V, so various negative output voltages are also possible. However, you must pay attention to the input voltage of the regulator circuit. If the input voltage is more negative than –12 V (i.e., V_{in} < –12 V), the output voltage will not be regulated and will be lower than the desired –12 V. The LM2575 IC will not be damaged by such operating conditions as long as its maximum rated input voltage of 40 V is not exceeded. High-voltage (HV) types that can withstand up to 60 V are also available.

Although the standard LM2575 application circuit includes circuit limiting, in this circuit the output current flows via the diode and choke if the output is shorted, so the circuit is not short-circuit proof. This can be remedied by using a Multifuse (PTC) or a normal fuse.

There is also an adjustable version of the regulator with the type designation LM2575-ADJ (**Figure 2**). This version lacks the internal voltage divider of the fixed-voltage versions, so an external voltage divider must be connected to the feedback (FB) pin. The voltage divider must be dimensioned to produce a voltage of 1.23 V at the FB pin with the desired output voltage. The formula for calculating the output voltage is:

$$V_{out} = 1.23\ \mathrm{V} \times (1 + [R1 \div R2])$$

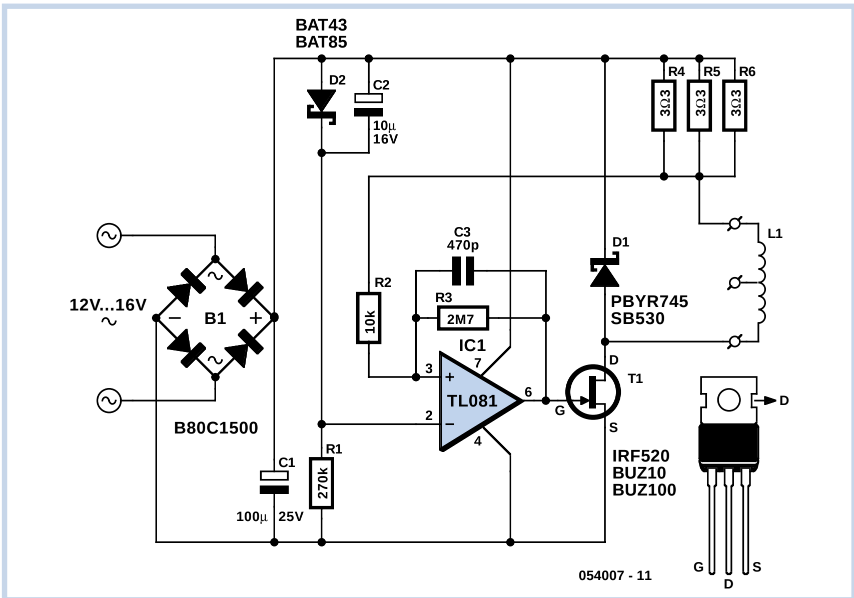
The electrolytic capacitors at the input and output must be rated for the voltages present at these locations.

(040428-1)

022

Converting a DCM Motor

Karel Walraven



We recently bought a train set made by a renowned company and just couldn't resist looking inside the locomotive. Although it did have an electronic decoder, the DCM motor was already available 35 (!) years ago. It is most likely that this motor is used due to financial constraints, because Märklin (as you probably guessed) also has a modern 5-pole motor as part of its range. Incidentally, they have recently introduced a brushless model.

The DCM motor used in our locomotive is still an old-fashioned 3-pole series motor with an electromagnet to provide motive power. The new 5-pole motor has a permanent magnet. We therefore wondered if we couldn't improve the driving characteristics if we powered the field winding separately, using a bridge rectifier and a 27 Ω current limiting resistor. This would effectively create a permanent magnet.

The result was that the driving characteristics improved at lower speeds, but the initial acceleration remained the same. But a constant 0.5 A flows through the winding, which seems wasteful of the (limited) track power. A small circuit can reduce this current to less than half, making this technique more acceptable.

The field winding has to be disconnected from the rest (3 wires). A freewheeling diode (D1, Schottky) is then connected across the whole winding. The centre tap of the winding is no longer used. When FET T1 turns on, the current through the winding increases from zero until it reaches about 0.5 A. At this current the voltage drop across R4-R7 becomes greater than the reference voltage across D2 and the opamp will turn off the FET. The current through the winding continues flowing via D1, gradually reducing in strength. When the current has fallen about 10% (due to hysteresis caused by R3), IC1 will turn on T1 again. The current will increase again to 0.5 A and the FET is turned off again. This goes on continuously.

The current through the field winding is fairly constant, creating a good imitation of a permanent magnet. The nice thing about this circuit is that the total current consumption is only about 0.2 A, whereas the current flow through the winding is a continuous 0.5 A.

We made this modification because we wanted to convert the locomotive for use with a DCC decoder. A new controller is needed in any case, because the polarity on the rotor winding has to be reversed to change its direction of rotation. In the original motor this was done by using the other half of the winding.

There is also a good non-electrical alternative: put a permanent magnet in the motor. But we didn't have a suitable magnet, whereas all electronic parts could be picked straight from the spares box.

(054007-1)

023

Phantom Supply from Batteries

Ton Giesberts

Professional (directional) microphones often require a phantom supply of 48 V. This is fed via the signal lines to the microphone and has to be of a high quality. A portable supply can be made with 32 AA-cells in series, but that isn't very user friendly. This circuit requires just four AA-cells (or five rechargeable1.2 V cells).

We decided to use a standard push-pull converter, which is easy to drive and which has a predictable output voltage. Another advantage is that no complex feedback mechanism is required.

For the design of the circuit we start with the assumption that we have a fresh set of batteries. We then induce a voltage in the secondary winding that is a bit higher than we need, so that we'll still have a high enough voltage to drive the linear voltage regulator when the battery voltage starts to drop (refer to the circuit in **Figure 1**).

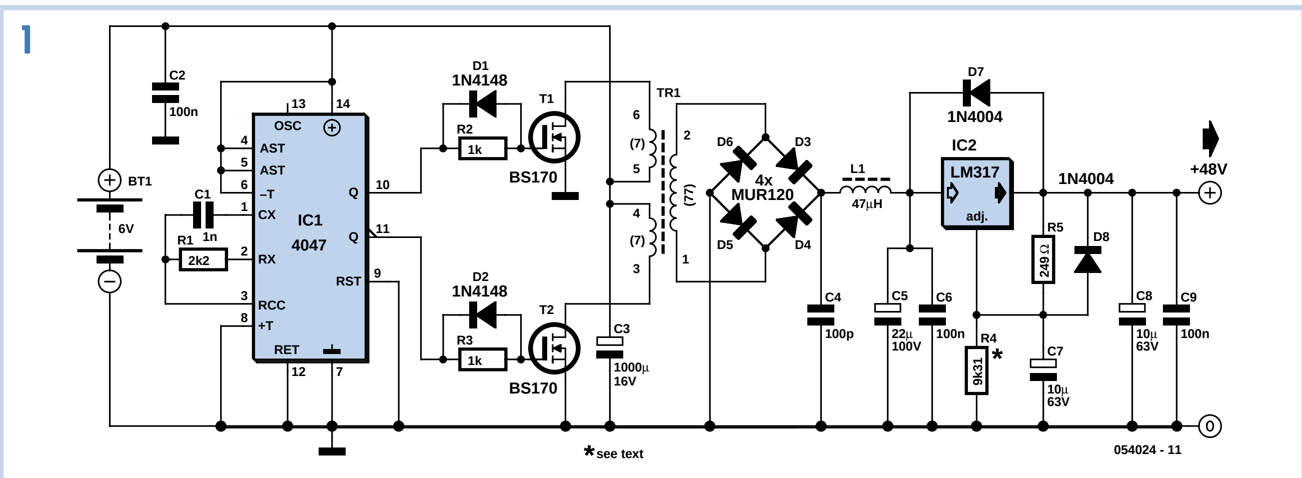
T1 are T2 are turned on and off by an astable multivibrator. We've used a 4047 low-power multivibrator for this, which has been configured to run in an astable free-running mode. The complementary Q outputs have a guaranteed duty-cycle of 50%, thereby preventing a DC current from flowing through the transformer. The core could otherwise become saturated, which results in a short-circuit between 6 V and ground. This could be fatal for the FETs.

The oscillator is set by R1/C1 to run at a frequency of about 80 kHz. R2/R3 and D1/D2 make T1 and T2 conduct a little later and turn off a little faster, guaranteeing a dead-time and avoiding a short-circuit situation. We measured the on-resistance of the BS170 and found it was only 0.5 Ω, which isn't bad for this type of FET. You can of course use other FETs, as long as they have a low on-resistance.

For the transformer we used a somewhat larger toroidal core with a high A_L factor. This not only reduces the leakage inductance, but it also keeps the number of windings small. Our final choice was a TX25/15/10-3E5 made by Ferroxcube, which has dimensions of about 25x10 mm. This makes the construction of the transformer a lot easier. The secondary winding is wound first: 77 turns of a 0.5 mm dia. enamelled copper wire (ECW). If you wind this carefully you'll find that it fits on one layer and that 3 meters is more than enough. The best way to keep the two primary windings identical is to wind them at the same time. You should take two 30 cm lengths of 0.8 mm dia. ECW and wind these seven times round the core, on the opposite side to the secondary connections. The centre tap is made by connecting the inner two wires together. In this way we get two primary windings of seven turns each.

The output voltage of TR1 is rectified by a full-wave rectifier, which is made with fast diodes due to the high frequency involved. C4 suppresses the worst of the RF noise and this is followed by an extra filter (L1/C5/C6) that reduces the remaining ripple. The output provides a clean voltage to regulator IC2. It is best to use an LM317HV for the regulator, since it has been designed to cope with a higher voltage between the input and output. The LM317 that we used in our prototype

1



worked all right, but it wouldn't have been happy with a short at the output since the voltage drop would then be greater than the permitted 40 V. If you ensure that a short cannot occur, through the use of the usual 6k81 resistors in the signal lines, then the current drawn per microphone will never exceed 14 mA and you can still use an ordinary LM317. D7 and D8 protect the LM317 from a short at the input.

There is virtually no ripple to speak of. Any remaining noise lies above 160 kHz, and this won't be a problem in most applications.

The circuit can provide enough current to power three microphones at the same time (although that may depend on the types used). When the input voltage dropped to 5.1 V the current consumption was about 270 mA. The reference voltage sometimes deviates a little from its correct value. In that case you should adjust R4 to make the output voltage equal to 48 V. The equation for this is: R4 = $(48–V_{ref}) / (V_{ref} / R5+50\mu A)$.

To minimise interference (remember that we're dealing with a switched-mode supply) this circuit should be housed in an earthed metal enclosure.

(054024-1)

Simple Short-Circuit Detection

024

Karel Walraven

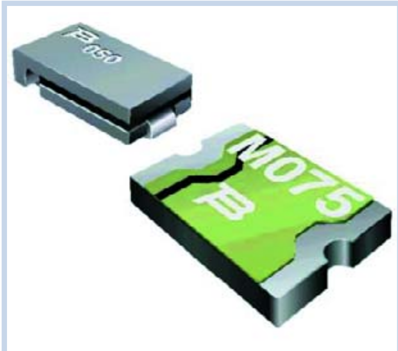
This circuit is suitable in every situation where over-current protection is required. Here we give an example from the model train world.

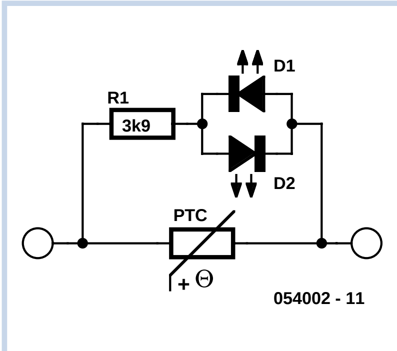
Every seasoned model train enthusiast knows that there is nothing worse than having to find the cause of a short-circuit. On a small model railway with one locomotive it is obviously fairly easy, but on large layouts all locomotives stand still when there is a short and then you have to check each one in turn to find the culprit. If the track is divided into sections then we can use this super simple circuit to make our lives a lot easier.

A multifuse is inserted into one of the supply lines for each of the sections. (A multifuse is also called a multiswitch, polyfuse or polyswitch, depending on the manufacturer). This is a type of fuse that cools down and conducts normally again once the short has been removed.

The advantage is that only the section with the short becomes isolated. All the other locomotives in the other sections continue to move. The stationary locomotive is in principle the culprit, but it's quite likely that several locomotives aren't moving since not all of them would be travelling in the first place. For this reason we connect an LED indicator across each multifuse, making it clear which section caused the problem. You can choose any colour LED, but we recommend that you use low-current types that emit a lot of light at only a few mA. The value of the current limiting resistor may be changed to give an acceptable LED brightness.

As long as the current is small, the resistance of the multifuse is also low and there will barely be a voltage drop. At high cur-





Model	V_{max} (V)	I_{hold}	I_{trip}	Initial resistance (Ω)		Max. time to trip	
				Min.	Max.	I (A)	t (s)
MF-R005	60	0.05	0.10	7.3	11.1	0.5	5.0
MF-R010	60	0.10	0.20	2.50	4.50	0.5	4.0
MF-R017	60	0.17	0.34	2.00	3.20	0.85	3.0
MF-R020	60	0.20	0.40	1.50	2.84	1.0	2.2
MF-R025	60	0.25	0.50	1.00	1.95	1.25	2.5
MF-R030	60	0.30	0.60	0.76	1.36	1.5	3.0
MF-R040	60	0.40	0.80	0.52	0.86	2.0	3.8
MF-R050	60	0.50	1.00	0.41	0.77	2.5	4.0
MF-R065	60	0.65	1.30	0.27	0.48	3.25	5.3
MF-R075	60	0.75	1.50	0.18	0.40	3.75	6.3
MF-R090	60	0.90	1.80	0.14	0.31	4.5	7.2
MF-R090-0-9	30	0.90	1.80	0.07	0.12	4.5	5.9
MF-R110	30	1.10	2.20	0.10	0.18	5.5	6.6
MF-R135	30	1.35	2.70	0.065	0.115	6.75	7.3
MF-R160	30	1.60	3.20	0.055	0.105	8.0	8.0
MF-R185	30	1.85	3.70	0.040	0.07	9.25	8.7
MF-R250	30	2.50	5.00	0.025	0.048	12.5	10.3

rents the resistance increases, which causes a voltage drop across the multifuse that is large enough to light up the LED. As we don't know the direction of the current flow (the train could be moving either forwards or backwards and digital controls use an alternating current) we connected two LEDs in parallel with opposite polarities.

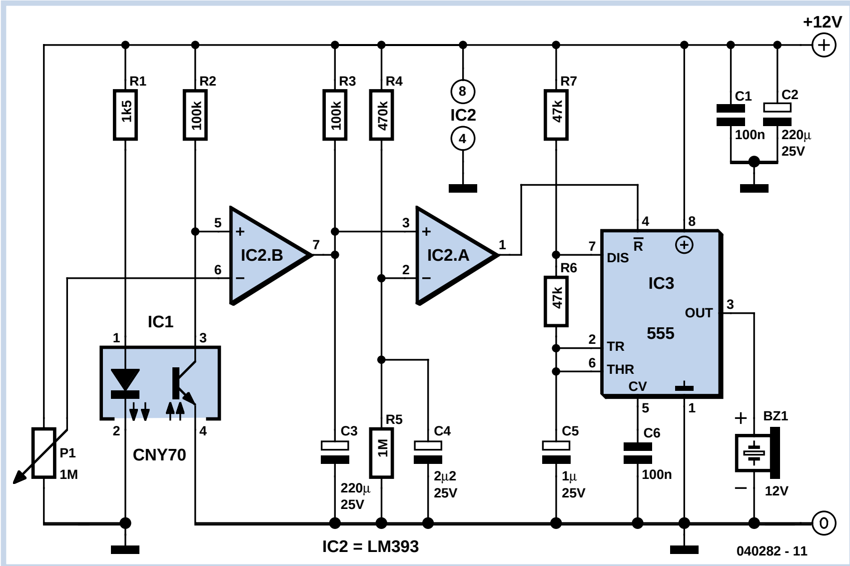
Multifuses are available for many different trip currents. Choose a value that is slightly higher than the maximum current consumption of a locomotive in a section. The table below shows the characteristics of several types from the MF-R series made by Bourns. (Raychem is another well-known manufacturer of polyswitches.) I_{hold} is the current at which the multifuse still conducts normally, I_{trip} is the short-circuit current.

(054002-1)

025 Reflection Light Barrier with Delay

Goswin Visschers

This circuit can be used to check, for example, whether the door of a refrigerator has been properly closed. An LED sends out a beam of light, which, if the door is closed, is reflected. An optical sensor (CNY70) then detects the amount of light. If the sensor does not receive the right amount of light, the buzzer will sound after about a minute. When the door is closed (and the CNY70 receives enough light again), the buzzer turns off.



The power supply for the circuit requires about 12 mA at 12 V. Potentiometer P1 adjusts the sensitivity of the sensor. The sensor works reliably from a distance of one centimetre. If the current through the LED is increased, the distance can be increased a little. The delay can be adjusted with C3. C4 provides extra filtering for the reference voltage. The buzzer would otherwise switch on with a 'chirping' sound. The well-known NE555 is used to drive the buzzer. The buzzer is driven with a duty cycle of 2:1, which improves the audibility.

(040282-1)

026 Swapping Without a Buffer

Paul Goossens

Most programmers will have their own library of commonly used snippets of code. One task that appears very often is the exchange of the contents of two variables. The code for this usually looks as follows:

```
int c;

c=a;
a=b;
b=c;
```

Table 1.

	A	B
initial state →	10101010	11001100
A = A ^ B →	01100110	11001100
B = A ^ B →	01100110	10101010
A = A ^ B →	11001100	10101010

There doesn't appear to be anything wrong with this, but it does make use of a third variable and this takes up more memory. In general, modern processors tend to have enough memory on board, but it never harms being economical with the available memory.

Another way in which the variables can be exchanged is shown below:

```
a=a^b;
b=a^b;
a=a^b;
```

It isn't immediately obvious that the contents of the two variables are exchanged.

XOR truth table

In1	In2	Output
0	0	0
0	1	1
1	0	1
1	1	0

However, the operation of this code is really quite simple.

We make use of the Boolean law that a^b^a = b, where the '^' symbol stands for a bitwise exclusive-or (XOR).

One consequence of this law is that when we know that the content of register A is the XOR of two variables, where the value of one is known, we can recover the value of the unknown variable by XORing register A with the known value. It shouldn't come of much of a surprise that many encryption systems make use of this technique.

We can imagine that it may still not be clear how the XOR routine works, so we've shown in the **Table** what each step of the program does. It should now be clear that at the end of the code the contents of variables a and b have been exchanged. You could try this yourself with pen and paper. You'll find that it works with any values for a and b.

(054019-1)

Cable Tester

027

Uwe Reiser

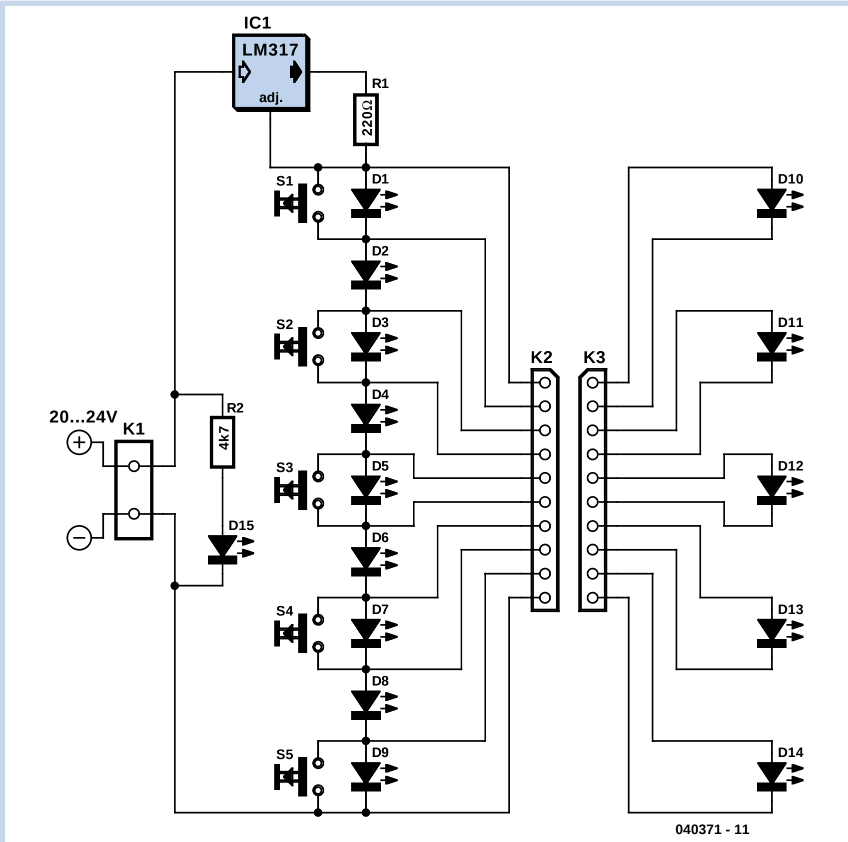
Microcontroller-based circuits for testing cables, sometimes in conjunction with a PC, are easy to use and very flexible. For the hobbyist, however, the complication of such devices is not justified. The circuit described here is an economical, but nevertheless easy-to-understand tester for cables with up to ten conductors.

The basic idea for the cable tester is to apply a different voltage to each conductor in the cable at one end. The voltage seen at the other end of the cable is indicated by light-emitting diodes. The eight reference voltages are generated using a row of nine LEDs connected in series (D1 to D9). The first and and the tenth conductors are connected to the positive and negative terminals of the power supply respectively. The LEDs are powered from a constant current source, which allows us to dispense with the current-limiting series resistor that would otherwise be necessary. For the constant current source we use a type LM317 voltage regulator. R1 is selected using the formula

I_{const} = 1.25 V / R1

to produce a current of 5 mA. This part of the circuit forms the transmitter end of the cable tester. The conductors of the cable under test can be connected to the transmitter in any order. The receiver consists of five LEDs whose connections are taken directly from terminal block X3. If the corresponding points in the two parts of the circuit are wired to one another using a working cable, all the LEDs on both receiver and transmitter sides will light.

If there is a fault in the cable, the following situations are possible.



- Two LEDs opposite one another fail to light: two conductors are crossed or shorted.
- Only the LED on the transmitter side lights: one or both of the conductors in the pair is broken.
- One of the even-numbered LEDs on the transmitter side (D2, D4, D6 or D8) fails to light: there is a short between the outer conductors of the neighbouring pairs.
- Several neighbouring LEDs fail to light: the conductor corresponding to the first unlit LED is crossed with the one corresponding to the last unlit LED, or they are shorted.
- If all LEDs light on both sides, there is still a chance that two pairs might be interchanged. Buttons S1 to S5 can be used to test this: the same LED should extinguish on each side when the button is pressed. If the wrong LED goes out on the receiver side, a pair must be swapped over.

More complicated effects can result from

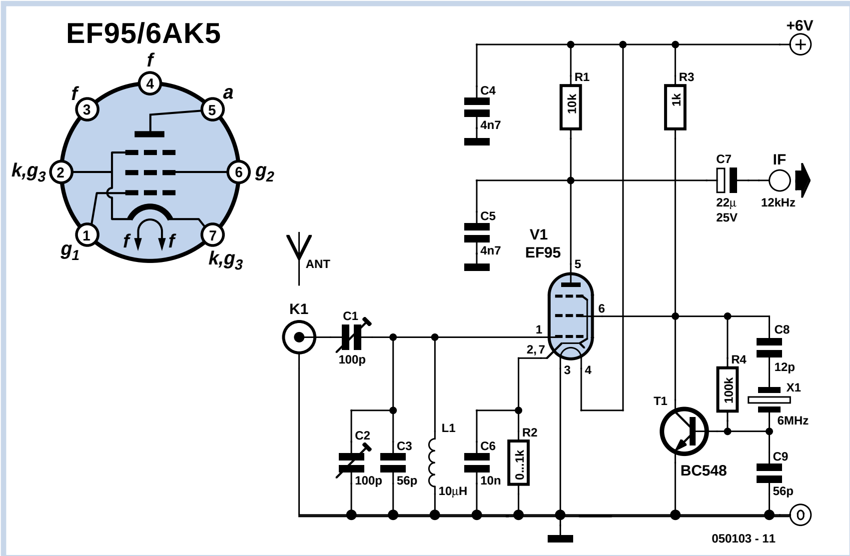
combinations of these five faults.
Different colours of LED have different forward voltage drops, and so the same type of LED should be used throughout. The required current can be put into the formula to calculate R1, which can then be altered if necessary. Of course, these remarks do not apply to the power indicator LED (D15). The LM317 used for the constant current source can only deliver the calculated current if its input voltage is at least about 3 V higher than the voltage required at its output. The load voltage depends on the number of LEDs in the transmitter and on their forward voltage drop. For nine red LEDs at least 20 V is required.

(040371-1)

028 DRM Direct Mixer Using an EF95/6AK5

Burkhard Kainka

This hybrid DRM receiver with a single valve and a single transistor features good large-signal stability. The EP95 (US equivalent: 6AK5) acts as a mixer, with the oscillator signal being injected via the screen grid. The crystal oscillator is built around a single transistor. The entire circuit operates from a 6-V supply. The receiver achieves a signal-to-noise ratio of up to 24 dB for DRM signals. That means the valve can hold its own against an NE612 IC mixer.
The component values shown in the schematic have been selected for the RTL2 DRM channel at 5990 kHz. That allows an inexpensive 6-MHz crystal to be used. The input circuit is built using a fixed inductor. Two trimmer capacitors allow the antenna matching to be optimised. The operating point is set by the value of the cathode resistor. The grid bias and input impedance can be increased by increasing the value of the cathode resistor. However, good results can also be achieved with the cathode connected directly to ground.

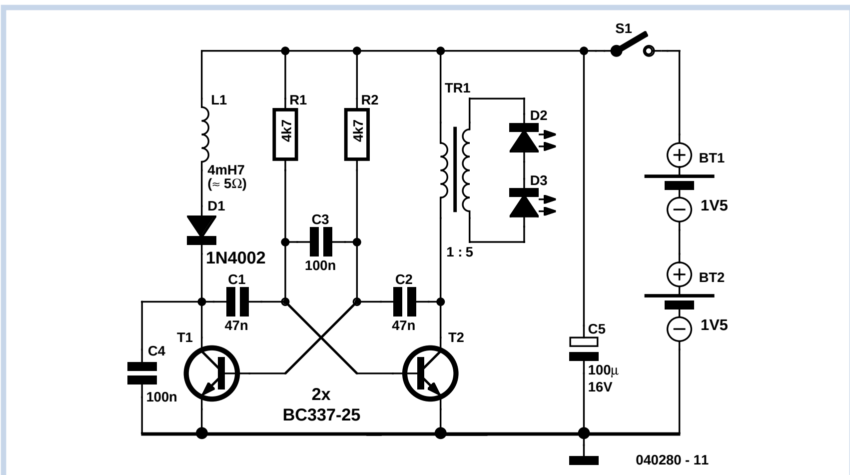


(050103-1)

029 Two-Cell LED Torch

Wolfgang Zeiller

It sometimes comes as a bit of a shock the first time you need to replace the batteries in an LED torch and find that they are not the usual supermarket grade alkaline batteries but in fact expensive Lithium cells. The torch may have been a giveaway at an advertising promo but now you discover that the cost of a replacement battery is more than the torch is worth. Before you consign the torch to the waste bin take a look at this circuit. It uses a classic two-transistor astable multivibrator configuration to drive the LEDs via a transformer from two standard 1.5 V alka-



line batteries. The operating principle of the multivibrator has been well documented and with the components specified here it produces a square wave output with a frequency of around 800 Hz. This signal is used to drive a small transformer with its output across two LEDs connected in series. Conrad Electronics supplied the transformer used in the original circuit. The windings have a 1:5 ratio. The complete specification is available on the (German) company website at www.conrad.de part no. 516236. It isn't essential to use the same transformer so any similar model with the same specification will be acceptable.

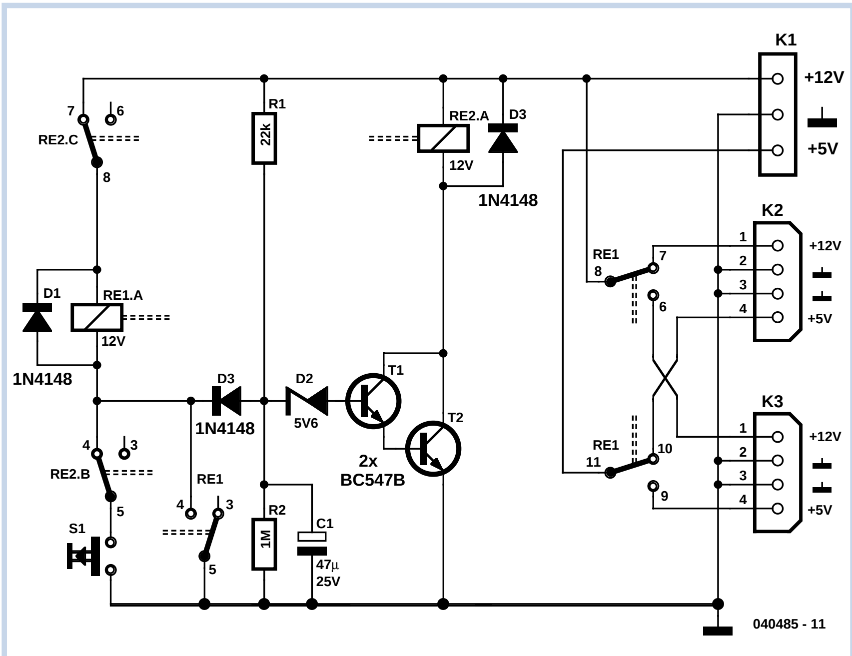
The LEDs are driven by an alternating voltage and they will only conduct in the half of the waveform when they are forward biased. Try reversing both LEDs to see if they light more brightly. Make sure that the transformer is fitted correctly; use an ohmmeter to check the resistance of the primary and secondary windings if you are unsure which is which. The load impedance for the left hand transistor is formed by L in series with the 1N4002 diode. The inductance of L isn't critical and can be reduced to 3.3 mH if necessary. The impedance of the transformer secondary winding ensures that a resistor is not required in series with the LEDs. Unlike filament type light sources, white LEDs are manufactured with a built-in reflector that directs the light forward so an additional external reflector or lens glass is not required. The LEDs can be mounted so that both beams point at the same spot or they can be angled to give a wider area of illumination depending on your needs. Current consumption of the circuit is approximately 50 mA and the design is even capable of producing a useful light output when the battery voltage has fallen to 1 V. The circuit can be powered either by two AAA or AA size alkaline cells connected in series or alternatively with two rechargeable NiMH cells.

(040280-1)

Hard Drive Switch

030

Dieter Brunow



Readers of *Elektor Electronics* who have both a PC and children face a particular problem. Since the young tend not to be too circumspect in their surfing habits, parents' files are in permanent danger of being infected with viruses or deleted. There is also the risk of children or their friends gaining unauthorised access to files not intended for their eyes.

Perhaps a separate PC for the children would take up too much space or is ruled out for pedagogical reasons; in that case, the solution is to install two separate hard drives in the PC, one for the children and one for the adults. Ideally the two hard drives will each carry their own operating system and have their own software installed. As long as things are arranged so that the children can only boot their own drive, the parents' data will remain secure. All that is required, besides a second drive, is a specially-designed hard drive switch. This can be achieved, as has already been described in *Elektor Electronics*, by switching the two drives between master and slave modes using the IDE cable, and only activating the master drive in the BIOS. However, the IT skills of children should not be underestimated: the BIOS is easily changed back. The solution described here is a bit more secure.

Both drives are bootable and configured as masters. One is connected to IDE bus 1, and the other to IDE bus 2. The power supply voltages (+12 V and +5 V) are, however, only applied to one drive at a time.

In principle, a simple double-pole changeover switch would do the job, but that has the disadvantage that it is possible to forget to reset the switch to child mode after use, especially if the switch is hidden. A better solution is to have to press a (hidden) button during boot to put the machine into parent mode. We will now see how this is done.

If the button is not pressed when the PC is switched on, then, after a short delay of about 0.7 s (determined by R1, C1, D2 and the base-emitter junction threshold voltage of the Darlington pair formed by T1 and T2) RE2 pulls in. RE1 remains unenergised and hence the children's drive connected to K2 is active. Subsequently pressing S1 has no effect since RE1 has been isolated by the contacts of RE2.

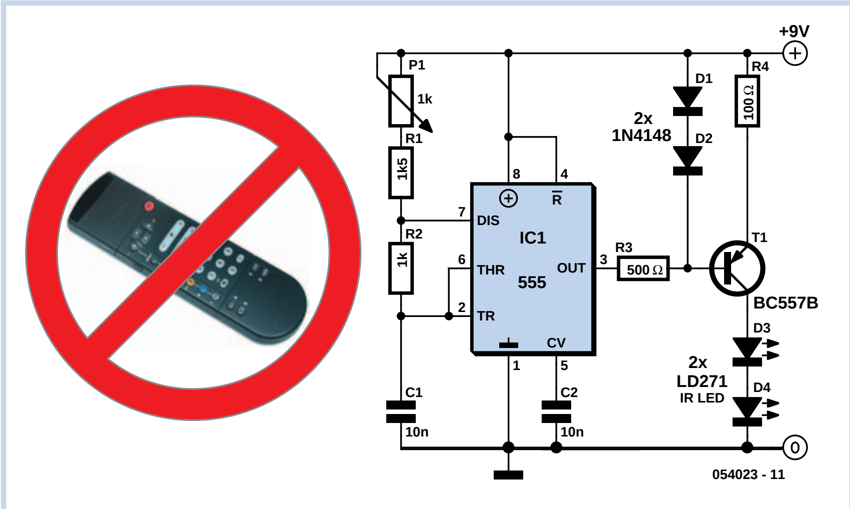
If the secret button is pressed, either briefly or continuously, during the 0.7 s sensitive period after the computer is switched on, RE1 pulls in immediately and holds itself in this state. D3 now prevents RE2 being subsequently activated. Since the contacts of RE1 have changed over, the PC now boots from the parents' drive. It is impossible to forget to return the computer to child mode, since the computer will always start up in this mode if the secret button is not pressed.

A 12 V miniature relay with contacts rated for 100 mA is suitable for RE2. The contacts of RE1 should be rated for the currents taken by a typical hard disk drive (say 2 A to 3 A). A key switch can be used instead of a secret button as a last resort against resourceful children, since the circuit will continue to operate correctly if S1 is left in parent mode permanently while the computer is on.

(040485-1)

031 Remote Control Blocker

Paul Goossens



This circuit was designed to block signals from infrared remote controls. This will prove very useful if your children have the tendency to switch channels all the time. It is also effective when your children aren't permitted to watch TV as a punishment. Putting the TV on standby and putting the remote control out of action can be enough in this case.

The way in which we do this is very straightforward. Two IR LEDs continuously transmit infrared light with a frequency that can be set between 32 and 41 kHz. Most remote controls work at a frequency of 36 kHz or 38 kHz.

The disruption of the remote control occurs as follows. The 'automatic gain' of the IR receiver in TVs, CD players, home cinema systems, etc. reduces the gain of the receiver due to the strong signal from the IR LEDs. Any IR signals from a remote control are then too weak to be detected by the receiver. Hence the equipment no longer 'sees' the remote control!

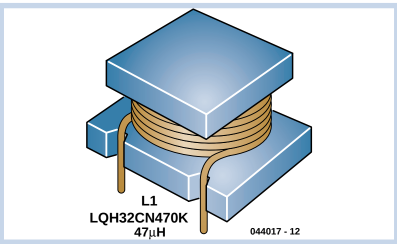
The oscillator is built around a standard NE555. This drives a buffer stage, which provides the current to the two LEDs.

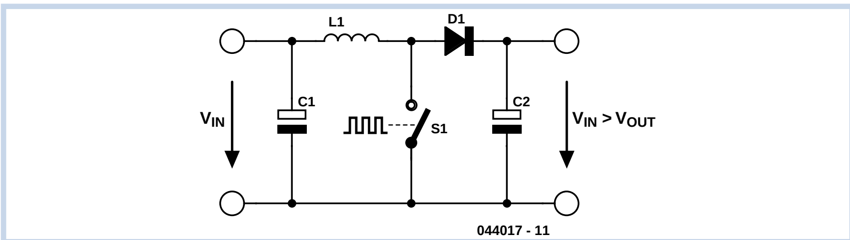
Setting up this circuit is very easy. Point the IR LEDs towards the device that needs its remote control blocked. Then pick up the remote control and try it out. If it still functions you should adjust the frequency of the circuit until the remote control stops working.

This circuit is obviously only effective against remote controls that use IR light!

(054023-1)

032 Converter IC with Integrated Schottky Diode





Gregor Kleine

Conventional step-up switching regulator ICs need at least one external Schottky diode and have the disadvantage that there is no effective output short-circuit current limiting. This means that very large currents can flow via coil L and Schottky diode D. Such currents can overload upstream components or destroy circuit board tracks.

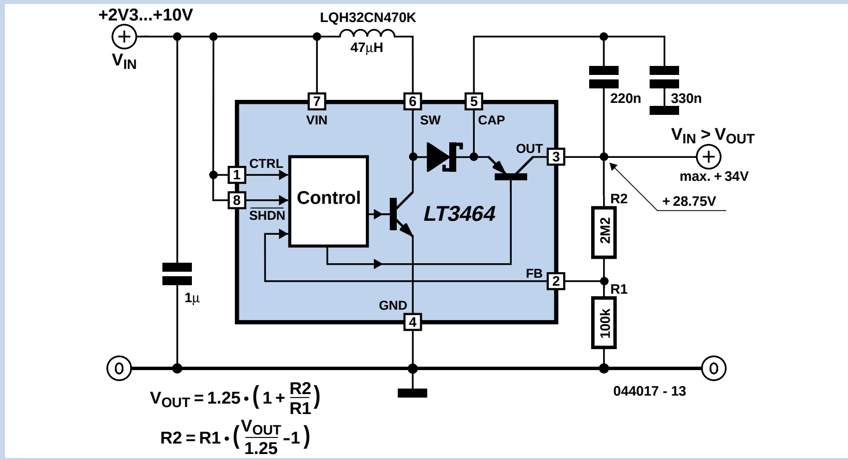
This situation is now remedied by the new LT3464 step-up switching regulator from Linear Technology (www.linear.com) in an 8-pin SOT23 package. Not only does it have an integrated Schottky diode, it also has an internal switching transistor that isolates the output from the input voltage in

the shutdown mode. The switching transistor also has short-circuit current limiting that becomes effective at around 25 mA. The IC operates with input voltages between +2.3 V and +10 V and can supply an output voltage as high as +34 V. The amount of output current that can be drawn increases as the input voltage increases. For example, the maximum output current is 15 mA with an input voltage of +9 V and an output voltage of +20 V. A quite common application is generating +12 V from a+5-V source, for which the maximum output current is 20 mA.
The output voltage is regulated via the Feedback pin (pin 2), with the voltage being determined by resistors R1 and R2 according to the formulas

V_{OUT} = 1.25 V × (1 + [R2 ÷ R1])

R2 = R1 × ([V_{OUT} ÷ 1.25 V] – 1)

Voltage divider R1/R2 can also be connected to the CAP pin (pin 5) ahead of the switching transistor. This avoids having an open-loop condition when the output is switched off, but it reduces the accuracy of the output voltage setting. The circuit shown here generates a voltage spike when the IC is switched back on, since the feedback loop drives up the voltage on the CAP pin when the loop is open.
A Murata type LQH32CN470K coil (47 µH) is used here as a storage choke due to its very compact construction. Other types of storage chokes in the range of 10–100 µH can also be used. The input capacitor, the capacitor connected to the CAP pin (pin 5), and the capacitor connected to the OUT pin (pin 3) are multilayer ceramic types (X5R and X7R).



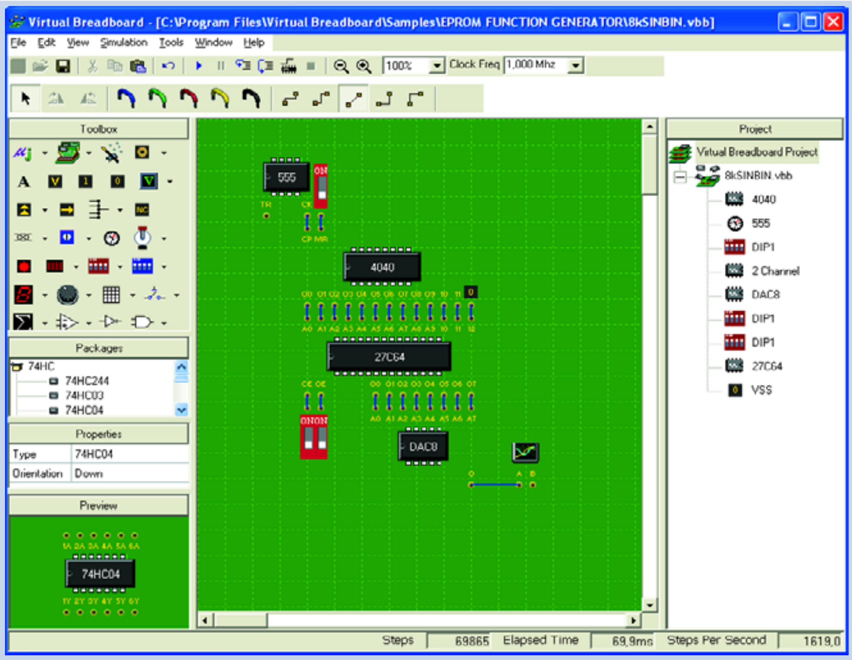
(044017-1)

Virtual Prototyping Board

033

Paul Goossens

It is often very useful to test a small circuit before designing the printed circuit board. Often a small piece of prototyping board, also known as breadboard, perfboard or veroboard, is used for this. An alternative approach is to use simulation software. This is usually faster and more convenient. If the circuit doesn't work as expected, then such software makes it very easy to try something different.
Most of the software available for this purpose is pretty expensive. However, there are fortunately also a number of freeware programs available.
On of those is 'Virtual Breadboard'. This program can be downloaded from www.muvium.com.
This software allows for the simulation of digital circuits. A library with a number of standard parts is also provided. A small disadvantage is that the ICs are shown as they appear in reality, instead of a schematic block that indicates which functions each IC has.
What is very practical however is that the simulator can also simulate PIC-microcontrollers and the BASIC-stamp. This allows not only the hardware to be tested, but the software as well. Reprogramming is done in no time. You only need to load the new HEX file and can test immediately.
This program is not as extensive as the expensive, professional software packages, of course, but if you would like to test some small circuits (possibly including a PIC microcontroller or BASIC Stamp) then it is certainly worth it to check this program out!



(054003-1)

034 Compact 200 W Output Stage

Ton Giesberts

There is no doubt that this small power amp packs a punch. It is capable of delivering a healthy 200 W into 4 Ω. Into 8 Ω it can still output 125 W (see **Figure 2**). These large power outputs are made possible through the use of Darlington transistors made by Sanken, the SAP16N and its opposite number, the SAP16P (in our prototype we used their predecessors, the SAP15N and P, because the SAP16 versions were not available at that time). These power transistors have an emitter resistor built in, as well as a diode for temperature compensation. Because of this, the whole emitter follower stage has just two components (and a preset for setting the quiescent current, shown in the circuit in **Figure 1**).

One small disadvantage is that the transistors have to operate at a relatively low

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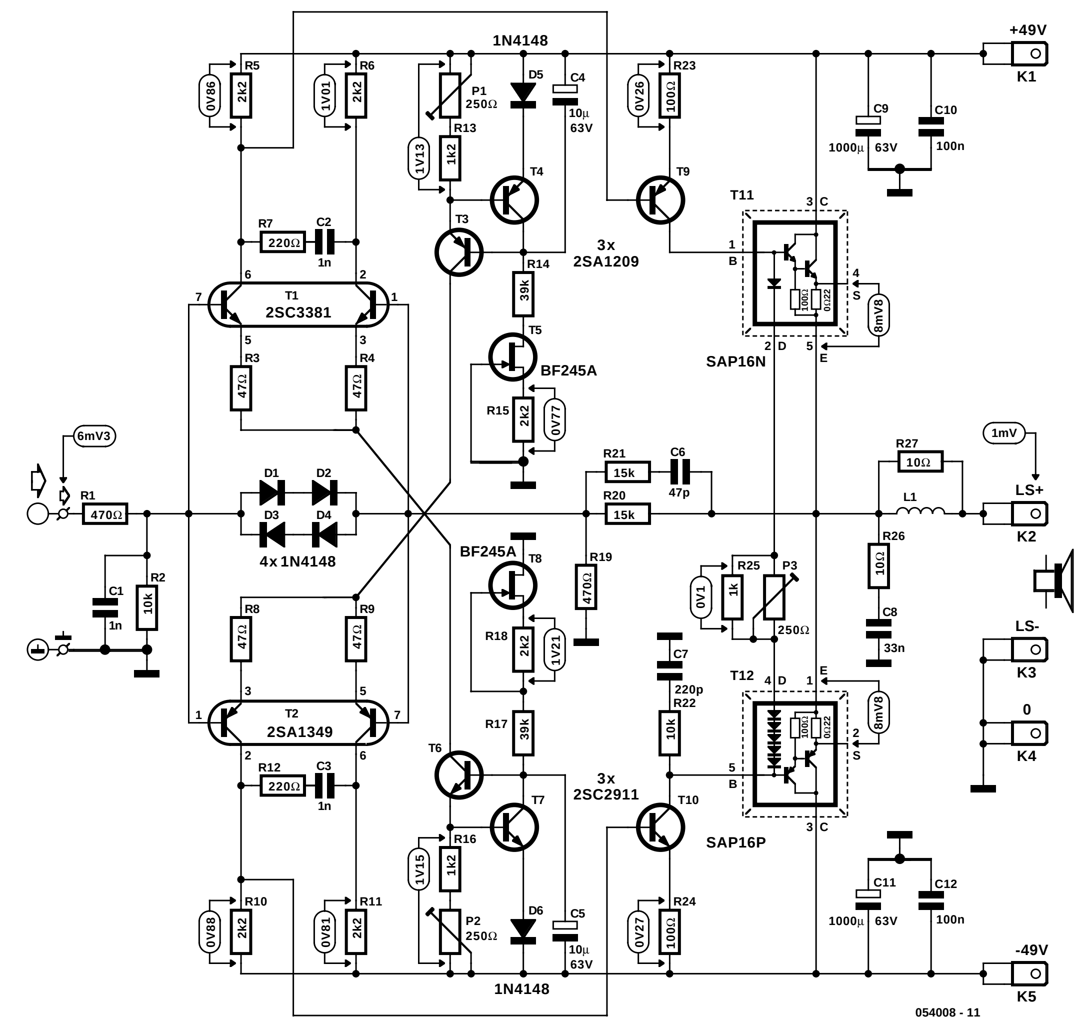


quiescent current, according to the datasheet. This causes an increase in distortion and a reduction in bandwidth. The current through the diodes has to be set to 2.5 mA, when the quiescent current will be 40 mA. This has the advantage that the driver transistors (T9, T10) do not need heat sinks, which helps to keep the circuit small.

The amplifier is of a standard design and doesn't require much explanation. The input is formed by two differential amplifiers (T1, T2), which are each followed by a buffer transistor (T9, T10). T9 and T10 together make a push-pull stage that drives the output transistors.

For T1 and T2 we've used special complementary dual transistors made by Toshiba. These, along with the driver transistors, have been used previously in the *High-End Power Amp* in the March 2005 issue. The driver transistors are a complementary pair made by Sanyo, which have been designed specifically for these applications.

Compensation in the amplifier is provided by R7/C2, R12/C3, R21/C6, R22/C7 and R26/C8. The dual transistors are protected by D1 to D4. The output inductor consists of 8 turns of 1.5 mm diameter enamelled copper wire (ECW).

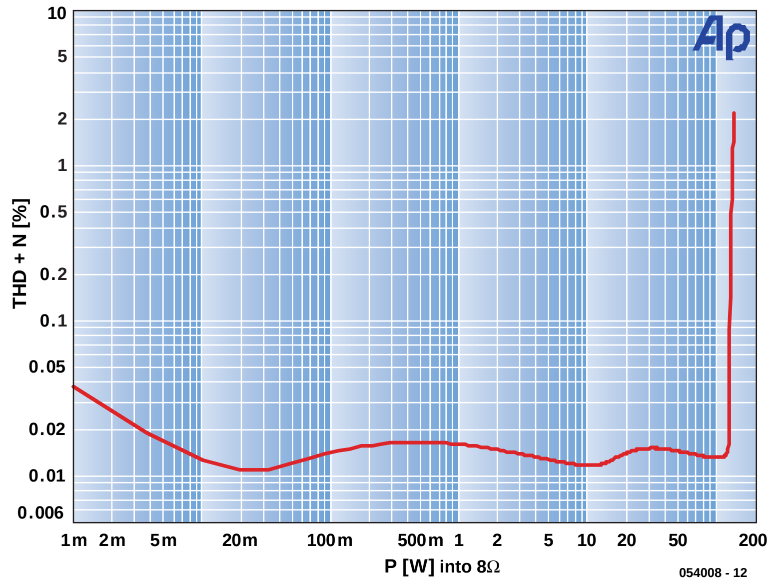
Since the current through the diodes is just 2.5 mA, the operating point of T9 and T10 has to be set precisely. This operating point is determined purely by the operating point of the differential input amplifiers. Since the ambient temperature affects the operating point, any potential drift in the operating point of T9 and T10 is compensated for by the current sources of the differential amplifiers.

The voltage drop across D5 (D6) and the base-emitter voltage of T4 (T7) determine the current through P1 (P2) and R13 (R16). T4 (T7) controls the voltage at the base of T3 (T6) and creates a constant current that is independent from the supply voltage. Since the voltage across D5 (D6) and T4 (T7) depends on the temperature, the voltage at the base of T10 (T9) has been temperature-compensated as well as possible. T3 and T4 (T6 and T7) are fed by a simple constant current source built around JFET T5 (T8), which makes the differential amplifier around T2 (T1) even less dependent on the supply voltage. R14 (R17) restricts the maximum voltage across T5 (T8), which may not exceed 30 V. According to the datasheet the JFET current should be about 0.5 mA, but in practice a deviation of up to 50% is possible. The actual value is not critical, but the voltage across the JFET must

Specifications

Input sensitivity		1 V_{eff}
Input impedance		10 kΩ
Sine-wave power	8Ω	125 W, THD+N = 1 %
	4Ω	200 W, THD+N = 1 %
Bandwidth		135 kHz (1 W/8Ω)
Slew rate		20 V/µs
Signal/noise ratio		101 dB (1 W/8 Ω, 22 Hz to 22 kHz)
		104 dBA
THD+noise		0.014 % at 1 kHz (60 W/8Ω)
Damping factor		>700 (1 kHz)
		>400 (20 kHz)

2



COMPONENTS LIST

Resistors:
R1, R19 = 470Ω
R2, R22 = 10kΩ
R3, R4, R8, R9 = 47Ω
R5, R6, R10, R11, R15, R18 = 2kΩ2
R7, R12 = 220Ω
R13, R16 = 1kΩ2
R14, R17 = 39kΩ
R20, R21 = 15kΩ
R23, R24 = 100Ω
R25 = 1kΩ
R26, R27 = 10Ω 1W
P1,P2,P3 = 250Ω preset

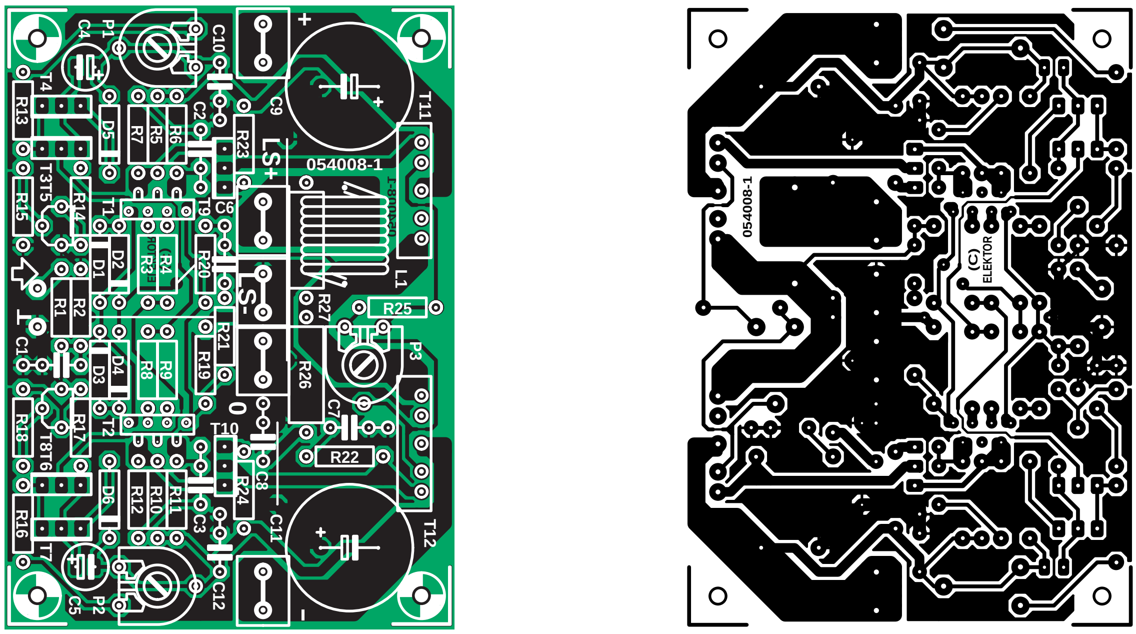
Capacitors:
C1,C2,C3 = 1nF
C4, C5 = 10µF 63V radial
C6 = 47pF
C7 = 220pF
C8 = 33nF
C9, C11 = 1000µF 63V radial
C10, C12 = 100nF

Inductors:
L1 = 8 turns 1.5mm dia. ECW, inside diameter 10mm.

Semiconductors:
D1-D6 = 1N4148
T1 = 2SC3381 (Toshiba) (Huijzer; Segor Electronics)
T2 = 2SA1349 (Toshiba) (Huijzer; Segor Electronics)
T3,T4,T9 = 2SA1209 (Sanyo) (Farnell # 410-3841)
T5, T8 = BF245A
T6, T7, T10 = 2SC2911 (Sanyo) (Farnell # 410-3853)
T11 = SAP16N (Sanken) or SAP15N (Farnell # 410-3749)
T12 = SAP16P (Sanken) or SAP15P (Farnell # 410-3750)

Miscellaneous:
K1-K5 = 2-way spade terminal, PCB mount, vertical
Heatsink <0.5 K/W
Mica washers for T11 en T12, e.g., Conrad Electronics # 189049.
4 wire links on PCB
PCB, ref. 054008-1 from The PCBShop

3



always stay below the maximum value (also take into account any possible mains voltage variations). If you do need to reduce the voltage, that should be done by **lowering** the value of R15 (R18). This causes the voltage across R14 (R17) to increase and hence the voltage across the JFET will drop.

P1 and P2 are required to compensate for various tolerances. With the input open circuit you should set the output to zero, while keeping the current through T9 and T10 as close as possible to 2.5 mA. This can be measured across R23 and R24. It is not a problem if the current is a few tenths of a mA more than this.

The quiescent current is set by P3. In the reference design a 200 Ω preset is used. We have put this together using a (standard) preset of 250 Ω in parallel with a 1 kΩ resistor. An incidental advantage of this parallel resistor is that it limits any possible current spikes when the wiper of the potentiometer makes a bad contact during the adjustment of the quiescent current.

This amplifier provides a good opportunity to experiment with the Sanken transistors. If you want to use the output stage in a complete power amplifier (refer to the print layout in **Figure 3**), you will need to add an input decoupling capacitor, a power-on delay with a relay for the loudspeaker and a beefy power supply. The input decoupling capacitor is certainly a necessity, since the offset is determined by the various tolerances and differences between the complementary transistors. In our prototype the input offset was 6.3 mV for a 0 V output voltage. This is amplified by a factor of 33, which would result in an output offset of over 200 mV if the input was shorted by, for example, a volume control.

Elsewhere in this issue is a design for a small board, which contains an input decoupling capacitor (MKT or MKP) and a relay with a power-on delay.

(054008-1)

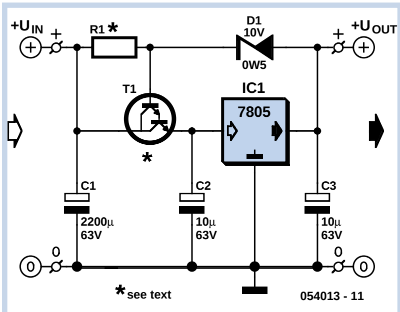
035

Protection for Voltage Regulators

Ton Giesberts

People often forget that many voltage regulator ICs have an upper limit (usually 35 V) on the input voltage they can handle. That applies primarily to types with a fixed output voltage. Adjustable voltage regulators also have a maximum voltage specification, in that case between the input and output (commonly 40 V). The input voltage must thus be limited to that level in a fault situation in which the output is shorted.

This circuit shows a way to allow such regulators to be used in situations with higher input voltages. Although the solution consists of an additional three components, it is simple and can be built using commonly available components. The voltage across the regulator is limited by the combination of T1 and zener diode D1 to a value that allows the regulator to work properly with loads up to the maximum rated load. R1 provides an adequate operating current for D1 and the bias current for T1. It's a good idea to use a Darlington type for T1 in order to keep the value of R1 reasonably high. The current through D1 is only 10 mA with an input voltage of 60 V. Naturally, we also measured what the circuit does when no load is connected. Surprisingly



enough, the nominal output voltage of 5.02 V increased to only 5.10 V (with a 60-V input voltage).

In our experiments, we used a BDV65B

for T1 and a value of 4.7 kΩ for R1. If you want to ensure that the circuit is truly short-circuit proof with an input voltage of 60 V, you must use a transistor that remains within its safe operating area at the maximum input voltage with the short-circuit current of the regulator (which can exceed 2 A). The BDV65B and TIP142 do not meet this requirement. The maximum voltage for the BDV65B is actually 40 V, and for the TIP142 is 50 V. If the transistor breaks down, the regulator will also break down. We verified that experimentally.

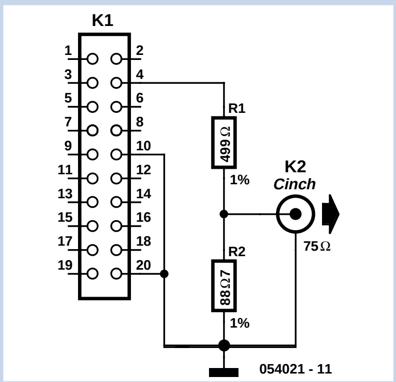
One possibility is to add SOA protection for T1, but that amounts to protecting the protection. Another option is to relax the requirements. For that purpose, R1 must provide enough current to ensure that T1 receives sufficient current in the event of a short circuit to keep the voltage across T1 lower, but that doesn't make a lot of difference in practice, and it also increases the minimum load. Besides that, it should be evident that adequate cooling for T1 and IC1 must be provided according to the load.

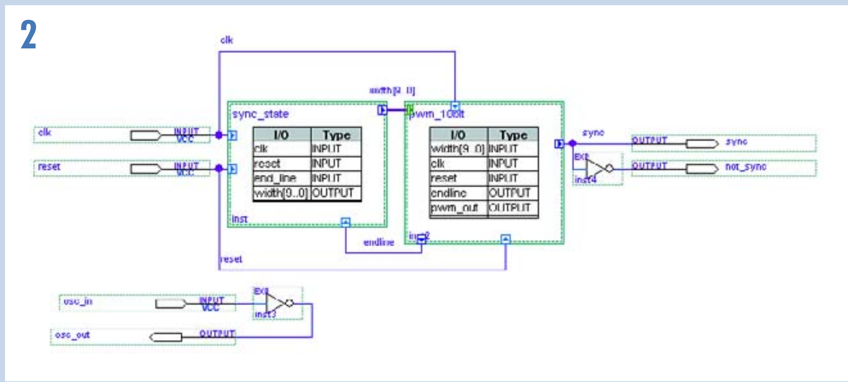
Ripple suppression is only marginally affected by the protection circuit, since the input is already well stabilised by T1, but the current through D1 does flow through the output. The presence of C2 must also be taken into account. In this circuit, with an adjustable voltage regulator such as the LM317 and an output voltage greater than 40 V, C2 will cause the voltage to be briefly higher than 40 V in the event of a short circuit, which can also cause the IC to be damaged. In that case, it will be necessary to find a different solution or use a different type of voltage regulator.

(054031-1)

Video Sync Generator

036





Paul Goossens

All video signals include synchronisation signals, which help the television set keep the horizontal and vertical deflection synchronous with the picture. For experimental purposes, it can be handy to build a generator for these synchronisation signals.

Synchronisation signals have a rather complicated structure. It's not easy to generate them accurately using analogue circuitry. By contrast, a design based on a CPLD is a lot easier. This design uses the experimenter's board described in the May 2004 issue ('Design Your Own IC').

The hardware extension for this generator is shown in Figure 1. The extension could hardly be simpler. The 20-way connector must be connected to connector K3 of the experimenter's board by a flat cable. The synchronisation signals on pin 4 are routed to the output connector via voltage divider R1/R2.

R1 and R2 perform two tasks in this circuit. First, they provide the correct output impedance of 75 Ω. Second, they reduce the signal amplitude from around 4 V to 0.6 V. If the circuit is connected to a television set with an input impedance of 75 Ω, the maximum output voltage will be only 0.3 V, which complies with the specifications for the CVBS signal.

As you've surely guessed by now, the majority of the design is contained in the CPLD. We generated this design in Quartus 4.2. The top-level schematic is shown in Figure 2. As can clearly be seen from that diagram, the design consists of three separate sections. In combination with the crystal on the circuit board, the inverter at the bottom provides the clock signal. The crystal must generate a frequency of 10 MHz for this circuit. If a different crystal is already fitted, it must be replaced by a 10-MHz type.

The clock signal finds its way back into the circuit via another input at the top left. It ensures that both parts of the circuit operate synchronously.

The section named 'sync_state' keeps track of which part of the video signal is being generated. Here it should be remarked that each video line is divided into two parts in this circuit. That is done because the synchronisation signal occurs at twice the normal rate during the vertical retrace interval.

The 'width' output indicated how long the output signal should remain low. Assertion of the 'endline' input indicates to the subcircuit that the current portion of the video signal is ready and the next portion of the video signal can be processed. The 'sync_state' block then produces the associated value at the output.

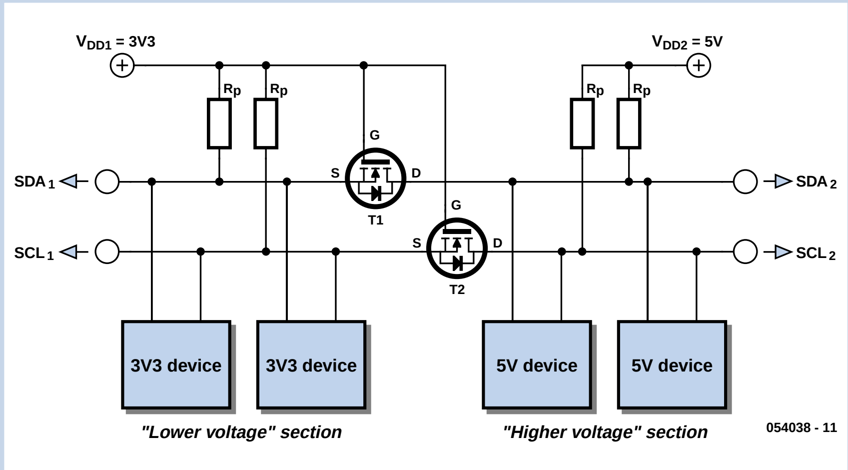
The final block bears the revealing name 'pwm_10bit'. As its name suggests, this section (which is actually implemented as part of the program code) generates a pulse on the output whose width is equal to the value of 'width'. This PWM counts from 0 to 319, which corresponds to a total duration of 32 µs (half of one video line) at a clock frequency of 10 MHz. This period is divided into 320 intervals of 0.1 µs each. The PWM sets the 'endline' output high during the next-to-last interval. You might expect that this signal would be active during the final interval of the period, but making it active one interval earlier gives the

'sync_state' block at least one clock cycle to generate a new 'width' value.
Naturally, the design files for the IC can be downloaded from the *Elektor Electronics* website (www.elektor-electronics.co.uk). The file number is **054021-11.zip**. After compilation, the final result uses 65 macrocells. The number of macrocells can be reduced by optimising the overall code. For instance, there are several obvious places where the design can be made more efficient, but a few somewhat less optimisations are also possible. Try it for yourself, and see how much you can optimise the design. Your efforts might just spark an interesting discussion on our website Forum!

(054021-1)

037 Bidirectional I²C Level Shifter

Luc Lemmens



In some cases I²C signals need to be level-converted if they are exchanged between (sections of) logic systems operating at different supply voltages. For example, one section of a circuit may work at 5 V while a newly added I²C device is happy at just 3.3 V. Without a suitable bidirectional level converter, signals from the 5-V system may disrupt or even damage the SDA/SCL inputs of the 3.3-V device, while the other way around signals emitted by the lower voltage device may not be properly detected.
As shown in the diagram, two n-channel enhancement MOSFETs inserted in the SDA and SCL lines do the trick. Note that each voltage section has its own pull-up resistors Rp connected between the respective supply rail (+3.3 V or +5 V) and the MOSFET source or drain terminals. Both gates (g) are connected to the lowest supply voltage, the sources (s) to the bus lines of the lower voltage section, and the drains (d) to the same of the higher voltage section. The MOSFETs should have their source connected to the substrate — when in doubt check the datasheet.
Other supply voltages than 3.3 V and 5 V may be applied, for example, 2 V and 10 V is perfectly feasible. In normal operation VDD2 must be higher than or equal to VDD1.

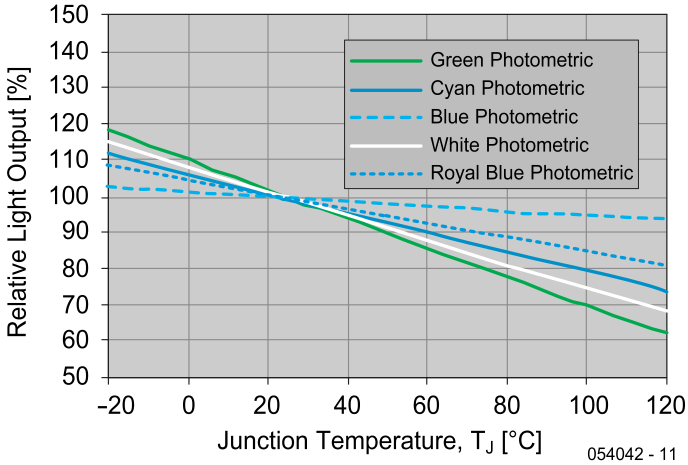
(054038-1)

Source:
Philips Semiconductors
Application Note AN97055.

038 Luxeon LEDs

Karel Walraven

It won't be very long before your new sitting room lamp will last forever. While our parents had to replace the lamp at least once a year, these days the energy-efficient lamps last five to ten times as long. Our children will buy an LED lamp once, which will keep working until their grave. Granted, what is written here is possibly a slight exaggeration, but that the development is in the direction of increased lifespan and higher efficiency is beyond dispute.
The company Lumileds (from Agilent and Philips) has as its goal the development of LEDs that are suitable for lighting. That is why they are available in various shades of white: 3200 K (warm white), 4100 K (commercial white) and 5500 K (cool white). By combining multiple LEDs of different brightness in one fitting, the different fittings will have equal brightness, even if you buy another new one years later.
With respect to power output, there are models rated 1 W and 5 W, and when you read this, the range is quite likely to have grown. Because the light output and life expectancy are strongly related to temperature, not only unmounted LEDs are available but also types integrated with a heatsink. This series has the beautiful name of Luxeon Star LED, because the



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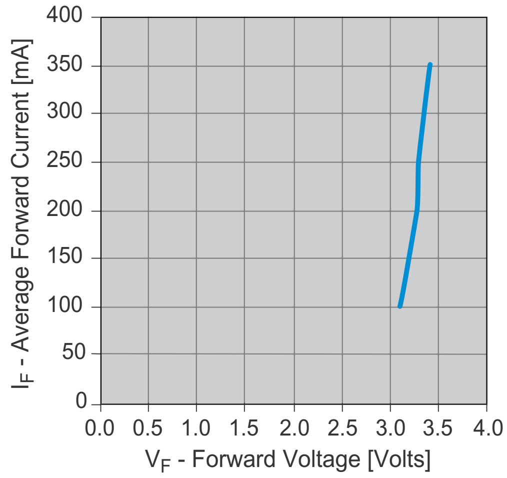


054042 - 12

heatsink has somewhat of a star shape. Because of the heatsink it is possible to use the Luxeon Star LED at the rated current without any additional measures. For the 1-watt type that is 350 mA DC. The current may be as high as 500 mA of the LED is multiplexed, however the average value may not be higher than 350 mA. Don't use a switching frequency of less than 1 kHz, otherwise the temperature of the chip varies too much. The 3-watt type can be driven with a maximum of 1 A, also when multiplexing.

If you are going to use the LEDs at these limits it is advisable to drive them with an electronically controlled current source, so that you can be sure that the limits are not exceeded. In general this is not necessary, since a slightly lower current does not reduce the brightness much. This is because the brightness reduces significantly when the temperature of the chip increases. This can be as much as 10 % per 20 degrees of junction temperature! It is therefore always a good idea to provide the LED with as much additional cooling as is practicable, for example by mounting the heatsink on a thermally conducting part of the fitting. We recommend that you choose a current which is a little less than the maximum value. A simple current limiting resistor is then all you need and additional electronics is not required. For examples and calculations see:

www.luxeonstar.com/resistor-calculator.php

Note that the LED, in contrast to a halogen lamp, requires DC. So in the event of an AC power supply, apart from the resistor, it is also necessary to add a bridge rectifier between transformer and LED!

More information can be found in the *Custom Luxeon Design Guide*, which can be downloaded from:

www.lumileds.com/pdfs/AB12.PDF

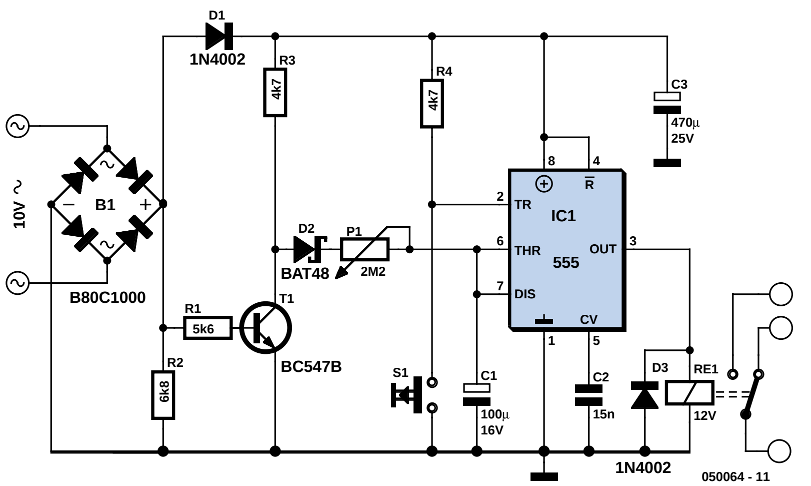
(054042-1)

Extended Timer Range for the 555

039

Ton Giesberts

Anyone who has designed circuits using the 555 timer chip will, at some time have wished that it could be programmed for longer timing periods. Timing periods greater than a few minutes are difficult to achieve because component leakage currents in large timing capacitors become significant. There is however no reason to opt for a purely digital solution just yet. The circuit shown here uses a 555 timer in the design but nevertheless achieves a timing interval of up to an hour!

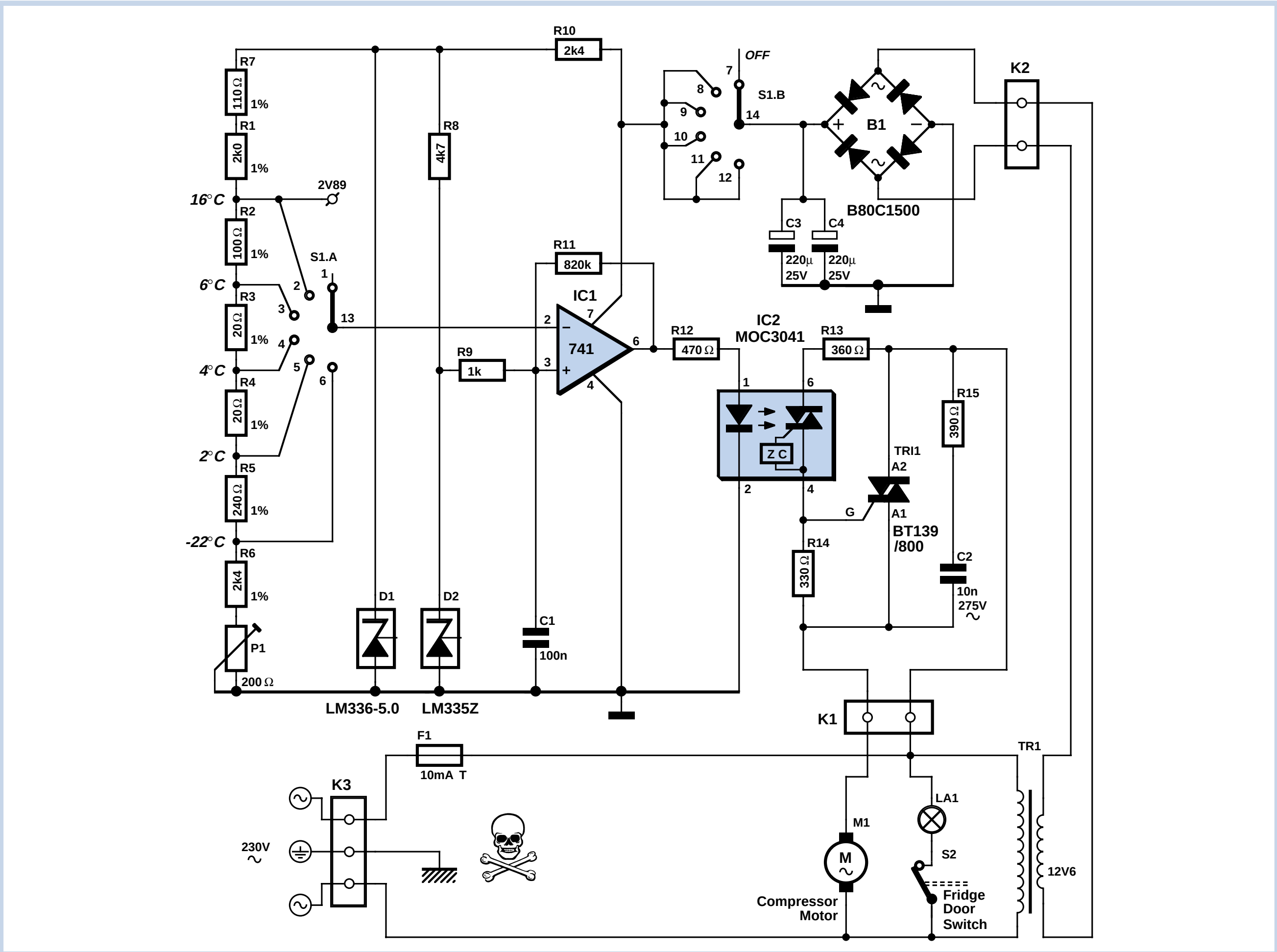


050064 - 11

The trick here is to feed the timing capacitor not with a constant voltage but with a pulsed dc voltage. The pulses are derived from the unsmoothed low voltage output of the power supply bridge rectifier. The power supply output is not referenced to earth potential and the pulsing full wave rectified signal is fed to the base of T1 via resistor R1. A 100-Hz square wave signal is produced on the collector of T1 as the transistor switches. The positive half of this waveform charges up the timing capacitor C1 via D2 and P1. Diode D2 prevents the charge on C1 from discharging through T1 when the square wave signal goes low. Pushbutton S1 is used to start the timing period. This method of charging uses relatively low component values for P1 (2.2 MΩ) and C1 (100 to 200 µF) but achieves timing periods of up to an hour which is much longer than a standard 555 circuit configuration.

(050064-1)

040 Fridge Thermostat



Tony Beekman

What to do when the thermostat in your fridge doesn't work any more? Get it repaired at (too) much expense or just buy a new one? It is relatively simple to make an electronic variation of a thermostat yourself, while saving a considerable amount of money at the same time. However, be careful when working with mains voltages. This voltage remains invisible and can sometimes be fatal!

This design allows for five temperatures to be selected with a rotary switch. By selecting suitable values for the resistors (R1 to R7), the temperatures at the various switch positions can be defined at construction time. With the resistance values shown here, the temperature can be adjusted to 16, 6, 4, 2 and –22 °C. 16° C is an ideal temperature for the storage of wine, while 6, 4, and 2 degrees are interesting for beer connoisseurs and the minus 22°degrees position transforms the fridge into a large freezer. Note for wine connoisseurs: to prevent mould on the labels, it is necessary to place a moisture absorber or bag of silica gel in the fridge.

The circuit is built around an old workhorse among opamps, the 741. D1 provides a stable reference voltage of 5 V across the entire resistor divider. P1 allows adjustment of the voltage at the node of R1 and R2. To use the above-mentioned temperatures as setpoints this voltage needs to be adjusted to 2.89 V.

D2 is a precision temperature sensor, which can be used from –40 to +100 °C. The voltage across this diode varies by 10 mV per Kelvin. In this way D2 keeps an eye on the temperature in the fridge.

The reference voltage derived from the voltage divider (selected with S1) is compared by IC1 with the voltage across the temperature sensor. Based on this, the 741 switches, via the zero voltage crossing driver (IC2), a triac that provides voltage to the compressor motor. The zero voltage crossing IC switches only at the zero crossings of the mains voltage, so that interference from the compressor motor is avoided when turning on.

The power supply for the circuit is provided by a simple bridge rectifier and fil-

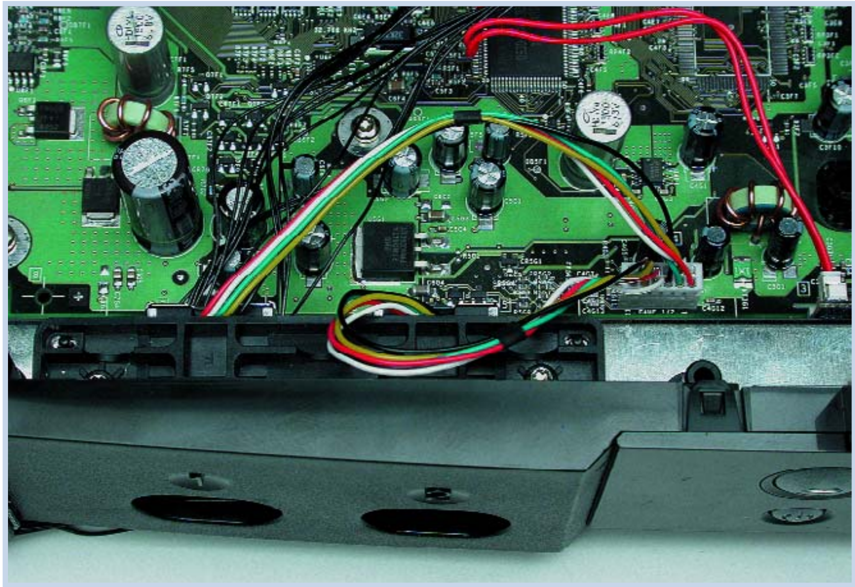
tered with two electrolytic capacitors of 220 µF each.
The design can also be used for countless other uses. You can, for example, make a thermostat for heating by swapping the inputs of the opamp.
Keep in mind the safety requirements when building and mounting the circuit.

(050025-1)

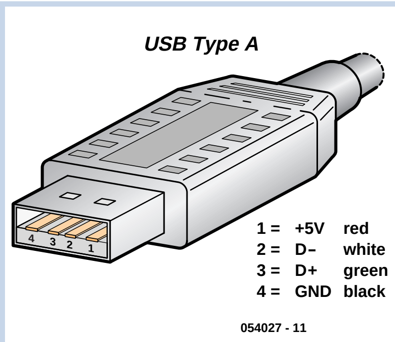
USB for the Xbox

041

Paul Goossens



The Xbox is the well-known Microsoft game computer. The fact that the Xbox is based on PC technology should hardly be surprising, since Microsoft specialises in this computer architecture.
It's also not especially remarkable that if you open up an Xbox, you'll find several well-known ICs from the PC world. In fact, the Xbox is actually a PC. The major difference between the Xbox and a normal PC is that the operating system is stored entirely in Flash memory and users cannot add any functionality to the system. There is also a protection system that prevents any software from being accepted if it does not have a digital signature from Microsoft.
At least, that was the intention. Naturally, there are people who have cracked the Xbox protection system and use the Xbox as a PC to run Linux. We plan to publish more information about this in *Elektor Electronics* in the near future. The biggest problem with running Linux on an Xbox is that there is no keyboard for the Xbox. That's what we want to remedy here.
As usual with game computers, the Xbox has connectors for controllers (enhanced joysticks) for playing the games. The Xbox has four such connecters on the front of the enclosure. They have a form that is totally new to us. After a bit of detective work, it turns out that the signals on these connectors are actually quite familiar: they're USB signals.
Once you know that, it's easy to connect a keyboard to the Xbox. If you fit a standard USB connector somewhere on the enclosure and wire it to the signal lines for one of the connectors, you can then connect a USB keyboard. Another benefit of this is that most types of USB memory sticks can be used by the Xbox as Xbox memory cards. USB memory sticks are a lot less expensive than 'genuine' Xbox memory cards.
The wires to the connector at the front can be clearly seen in **Figure 1**. The yellow wire is not important for our purposes. The other wires are used for the actual USB signals. A nice detail is that Microsoft uses exactly the same colours for these wires as those specified in the USB standard, which makes them much easier to recognise.
For the installation, you will some wire and a USB connector (Type A). That's the same type of connector as the USB connectors in a PC. **Figure 2** shows an example of such a connector, along with the proper pin numbers.
Find a place on the Xbox where the connector can be fitted. It's easy to make a hole in the case with a small hand-held router or a drill and a small file. Next, make connections between the four wires leading to the Xbox connector and the four terminals of the USB connector, as shown in **Table 1**.
It's a good idea to check the connections before using the modified unit, in order to ensure that there aren't any shorts between the lines. As a second test, we recommend checking whether a voltage can be measured between pin 1 of the USB connector (+3.6 to 5 V) and pin 4 (ground) after the Xbox power has been switched on. If the test results are all OK, the USB connector is ready for use.
USB keyboards (and USB mice) are supported by Xbox Linux, and some Xbox games also use a USB keyboard to make it easier to control the game and/or chat with other players.



054027 - 11

Table 1. USB connections

Pin 1 (red) : +5 V

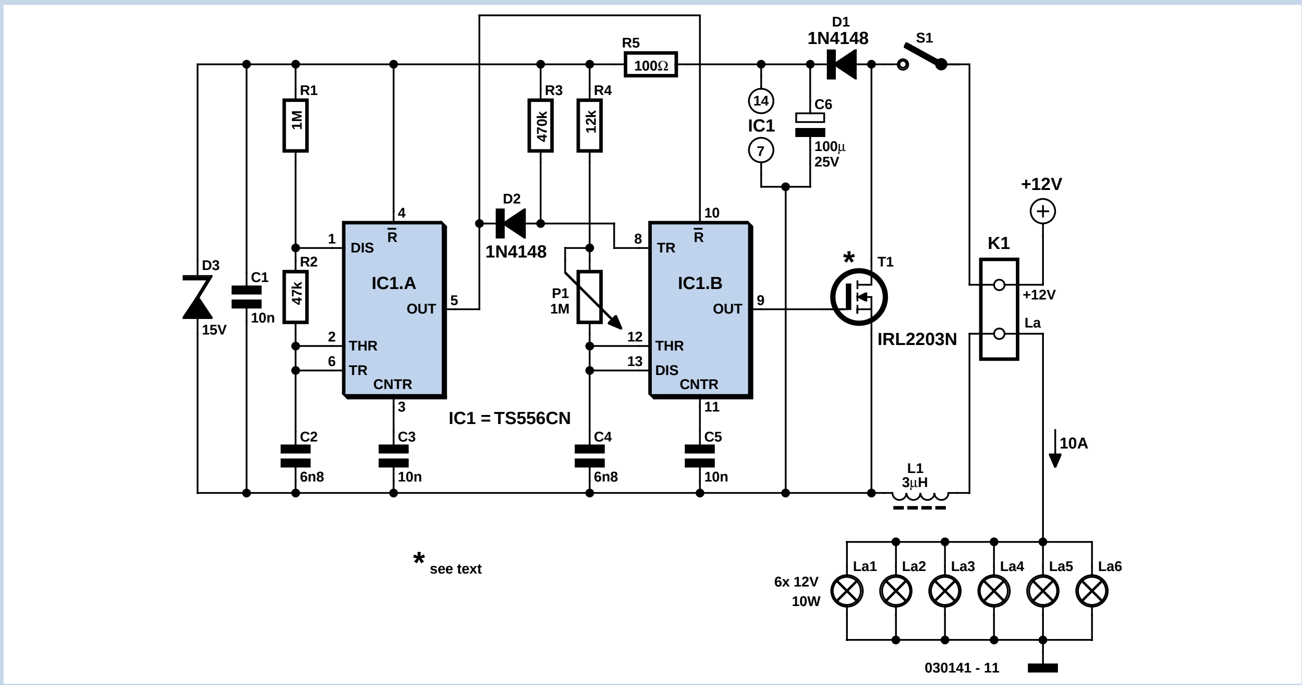
Pin 2 (white) : D–

Pin 3 (green) : D+

Pin 4 (black) : GND

(054027-1)

042 12-V Dimmer



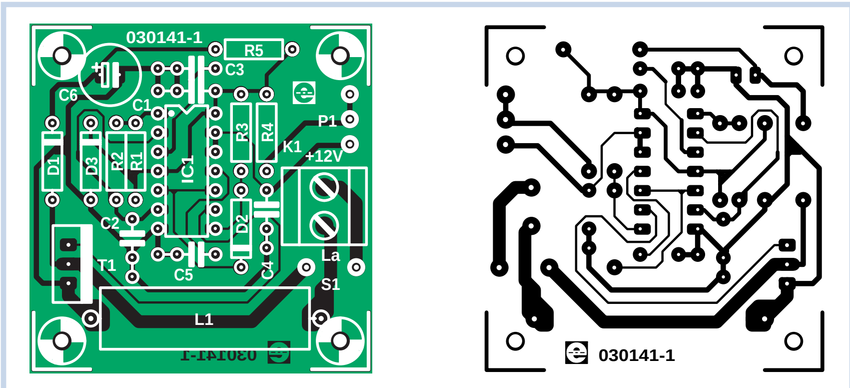
John Dakin

A dimmer is quite unusual in a caravan or on a boat. Here we describe how you can make one. So if you would like to be able to adjust the mood when you're entertaining friends and acquaintances, then this circuit enables you to do so.

Designing a dimmer for 12 V is tricky business. The dimmers you find in your home are designed to operate from an AC voltage and use this AC voltage as a fundamental characteristic for their operation. Because we now have to start with 12 V DC, we have to generate the AC voltage ourselves. We also have to keep in mind that we're dealing with battery-powered equipment and have to be frugal with energy.

The circuit that we finally arrived at can easily drive 6 lamps of 10 W each. Fewer are also possible, of course. In any case, the total current has to be smaller than 10 A. L1 and S1 can be adapted to suit a smaller current, if required. Note that the whole circuit will also work from 6 V.

IC1 is a dual timer. You could also use the old faithful NE556, but it draws a little more current. IC1a is wired as an astable multivibrator with a frequency of 180 Hz. IC1b is configured as a monostable and is triggered, via D2, from the positive edge at the output of IC1a. The length of the pulse that now appears at the output of IC1b is dependant on the position of P1. IC1b will be reset whenever the output of IC1a goes low, independent of the pulse duration, set with



COMPONENTS LIST

Resistors:
R1 = 1MΩ
R2 = 47kΩ
R3 = 470kΩ
R4 = 12kΩ
R5 = 100Ω
P1 = 1MΩ preset

Capacitors:
C1,C3,C5 = 10nF
C2,C4 = 6nF8
C6 = 100µF 25V radial

Semiconductors:
D1,D2 = 1N4148
D3 = zener diode 15V /1.3W
T1 = IRL2203, BUZ10, BUZ11, BUZ100 or BUK455 *
IC1 = TS556CN (CMOS) or NE556N (not CMOS)

Miscellaneous:
L1 = 3µH 9A suppressor coil * (e.g., Farnell # 976-416)
K1 = 2-way PCB terminal block, lead pitch 5mm
S1 = on/off switch, 10A
PCB, ref. 030141-1 from The PCBShop

* see text

P1, R4 and C4. This guarantees that the dimming is smooth, even when the brightness is set to maximum.

The output of IC1b (pin 9) drives the gate of MOSFET T1. When the duration of the pulses at the gate increases, the average time that the MOSFET is in conduction will also increase. In this way the brightness of the lamps is controlled. T1 conducts about 96 % of the time when the brightness is set to maximum. In this configuration, this can never be 100 %, because the 4 % of the time that the FET does not conduct is necessary to charge C6. If the FET were to conduct with 100 % duty cycle, the power supply for the circuit would be effectively short-circuited. C6 allows the circuit to ride through the conduction period of the FET. D1 ensures that the charge cannot leak away via the FET during the 'on' period.

In the schematic, an IRL2203N is indicated for T1, but in principle you could use just about any power transistor (for example, BUK455, BUZ10, BUZ11 or BUZ100). The IRL2203 does however, have a very low 'on' resistance ($R_{DS\ ON}$) of only 7 mΩ and can switch 12-V loads up to 5 A without a heatsink. If you choose a different MOSFET (with higher $R_{DS\ ON}$) or use the circuit in a 6-V system then you will likely need a heatsink. Using the IRL2203N with six lamps rated 12 V / 10 W, T1 dissipates only 170 mW. At 6 V and 10 A this becomes 680 mW.

The circuit itself consumes about 0.35 mA at maximum brightness and about 1.25 mA at minimum.

The power supply is derived from the power system via D1 and C6. Zener diode D3 provides protection against voltage surges. The main purpose of R5 is to limit the current through D3, in the event it becomes active. L1 reduces interference that could be caused by the fast switching of the transistor.

We have designed a small printed circuit board for the circuit. The construction is very simple. The PCB is quite compact in order to facilitate the replacement of existing switches. Keep in mind that the CMOS-parts, IC1 and T1, are sensitive to static electricity.

(030141-1)

Low-cost LiPo Charger

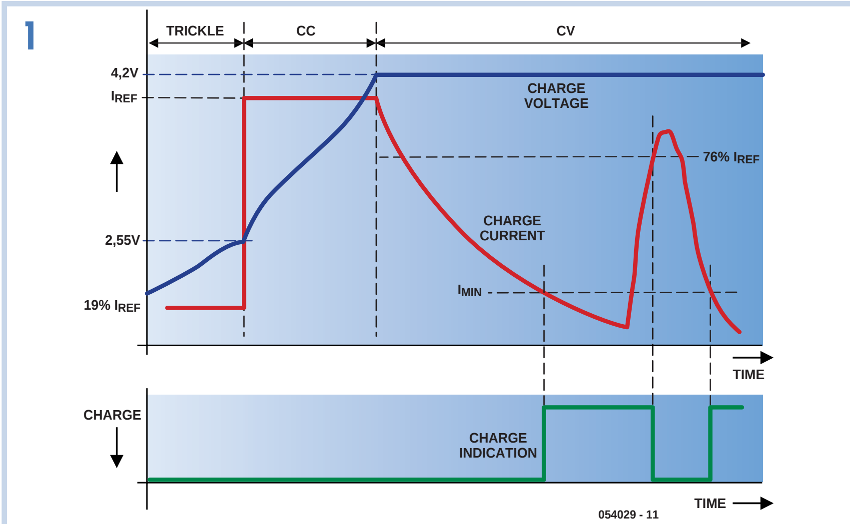
043

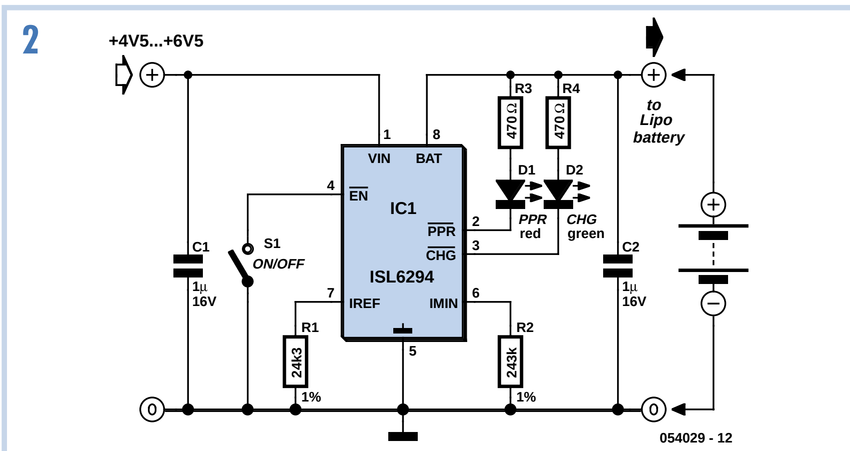
The charging of Lithium-Polymer (LiPo) cells takes place very differently to that of the well known NiCd and NiMH cells. This aspect has previously been covered in *Elektor Electronics*. And this isn't the first LiPo charger that we've published, but it is undoubtedly the smallest!

Chip manufacturer Intersil has designed a LiPo charger IC that requires a minimum of external components. Since the IC itself is also extremely small (2×3 mm), the complete charger can be kept very small as well. This lets us design a charger that can easily be built into various pieces of equipment, especially when we use SMDs for all external components.

For those of you who don't know how a LiPo cell should be charged, we'll give a short explanation. When the cell voltage is very low (<2.5 V), it should be charged using a small current (see **Figure 1**). This current is typically less than 0.1*C* (where *C* is the nominal battery capacity). When the voltage has risen sufficiently, but is still below 4.2 V, the cell is charged with a constant current. Most LiPo manufacturers specify a current of 1*C* for this stage. The voltage across the cell may not exceed 4.2 V, so the charger has to keep an eye on this as well. At this constant voltage the current through the cell will slowly reduce while the charge in the cell increases.

At the point when the cell voltage is 4.2 V and the charging current has dropped to 0.1*C*, the cell is about 80-90% charged, depending on the manufacturer. Most chargers decide at this point that the cell is fully charged and switch to trickle charging the cell.





Our charger works in exactly the same way. There are two parameters that can

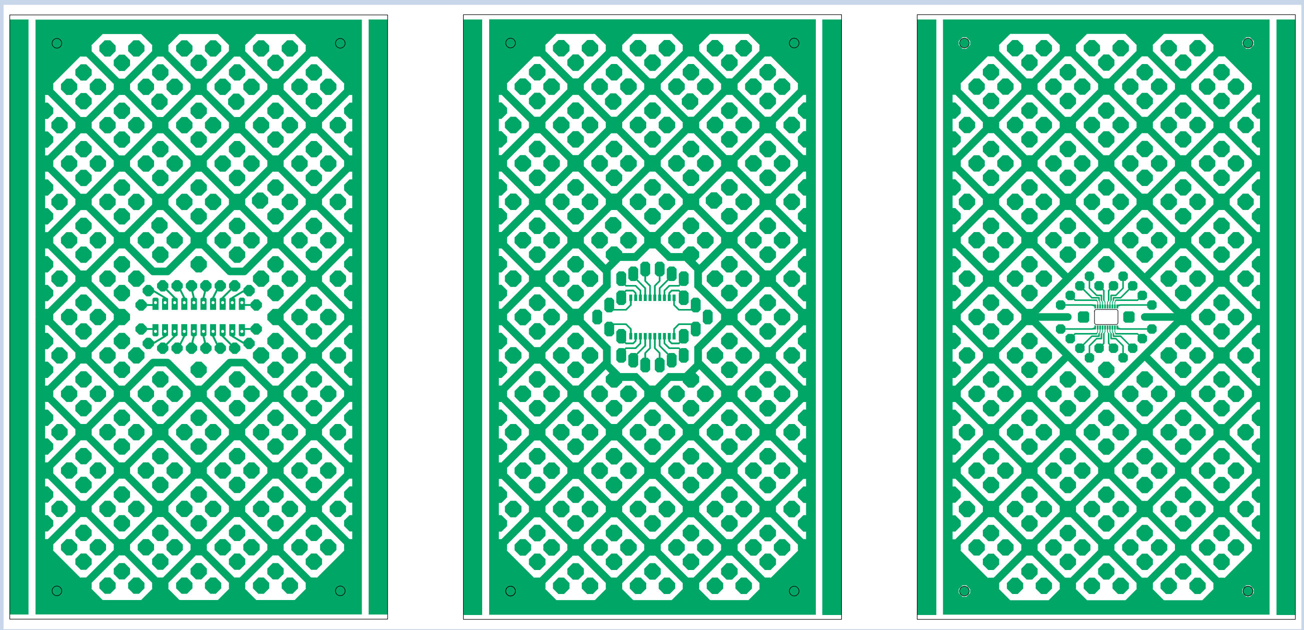
be adjusted in this charger, which are the normal charging current and the trickle charge that flows when the cell is 'full'. In the circuit of **Figure 2** resistor R1 sets the charging current to about 500 mA, and resistor R2 sets the trickle charge current to about 45 mA.
R3, R4, D1 and D2 are optional in this design and provide the user with status information. D1 shows when the charging process is busy and D2 indicates that the correct input voltage is present.

If you want to use different maximum and minimum charge currents you should use the following formulae for R1 and R2:
R1 = 12×10^3 / I_{ref}
R2 = 11×10^3 / I_{min}

Keep in mind that the accuracy of the current source at 500 mA is about 10%; this drops to about 30% at 50 mA. You should therefore be conservative in your choice of charging current so that you keep below the manufacturer's maximum recommended charging current.

(054029)-1

044 DIL/SOIC/TSSOP Experimenting Boards



Wolfgang Steimle

Whenever you want to put a circuit together quickly, it will take too long to design a PCB for it first. In that case, the experimenting PCBs shown here are eminently suitable.

Three variations are available: 20-pin DIL package, 20-pin SOIC package and a 20-pin TSSOP package. If you use an IC with fewer pins, then you simply don't use some of the solder pads.

The remaining part of each PCB is filled with solder pads, which are arranged in groups of four. In between is a continuous copper pattern. By connecting this copper grid to ground, the boards are also suitable for RF designs.

The layouts for the various PCBs are shown here at a reduced scale. You can download the true scale layouts from the *Elektor Electronics* website (in pdf format). The file number is **040289-1.zip**. They are also available ready-made from *Elektor Electronics* (refer to SHOP pages or website), the part numbers are **040289-1**, **-2** and **-3**.

(040289-1)

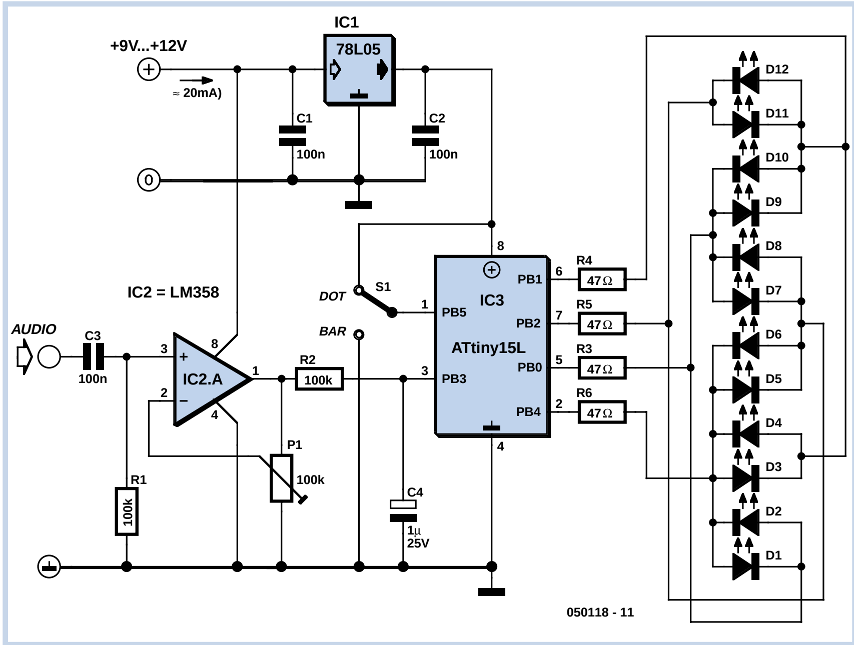
045 Digital VU Meter

Robin van Arem

The circuit presented here has the same functionality as the renowned LM3914, an LED driver that can control 10 LEDs. The circuit shown here can even drive 12 of them, with only 4 outputs. A necessary requirement is that low-current LEDs are used.
The audio signal is amplified by (half of) an LM358 opamp. P1 allows adjustment of the gain and therefore the sensitivity.

One input of the opamp is connected to ground so that only the positive half of the input signal is amplified and is effectively rectified at the same time. The combination of R2/C4 then performs an averaging function after which the signal is converted to a digital value by the 8-bit ADC in the Attiny15L microcontroller. Subsequently, the 12 LEDs are then controlled through a method called 'charlieplexing'. Switch S1 selects between dot and bar mode. The power supply is regulated with the usual 7805. The maximum current consumption amounts to 20 mA at 13.8 V. Power supply voltages of up to 30 V are not a problem, since the LM358 can deal with a maximum of 33 V at least (a 7805 can typically deal with 35 V). The minimum voltage at which the circuit will operate is around 7 V.

The software can be downloaded in the form of a hex file from our website at www.elektor-electronics.co.uk, The file number is **050118-1.zip**. After the code has been programmed into the ATtiny, it is necessary the disable the external reset with the appropriate fuse,



since the reset pin in this circuit is used as an output.

Those among you who would like to know more on the subject of charlieplexing are referred to www.maxim-ic.com.

(050118-1)

The chip is also available ready-programmed as no. 050118-41.

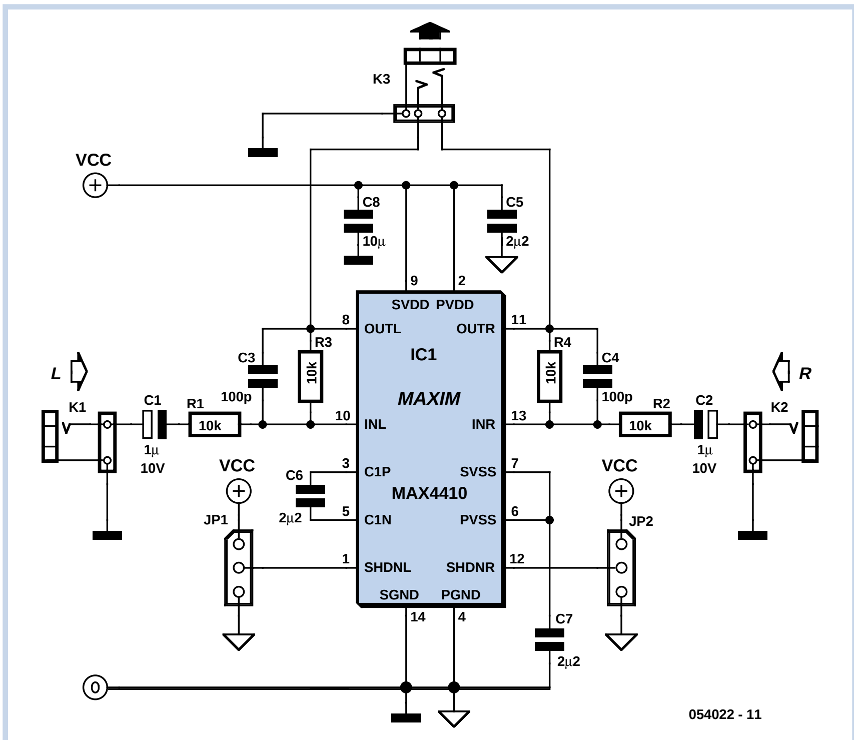
3 V Headphone Amplifier

046

Ton Giesberts

Many new devices require a headphone connection, but due to the high level of integration and miniaturisation there is usually little room left. The low supply voltage and/or battery voltage also causes problems. If no special techniques are used, the output power and headroom are severely limited.

The MAX4410 made by Maxim overcomes these problems not just by virtue of its small size, but also by including an internal supply inverter (charge-pump). This requires only two small external ceramic SMD capacitors (C6 and C7). The supply voltage to the output stage is now symmetrical and the outputs are therefore relative to ground (no DC offset). This gets round the need for large output capacitors to stop a DC voltage from reaching the headphones. A DC-coupled output can also be implemented using two bridge amplifiers, but virtually all plugs for stereo headphones are asymmetric and use 3-pole connectors (common ground), which can't be connected to a bridge output.

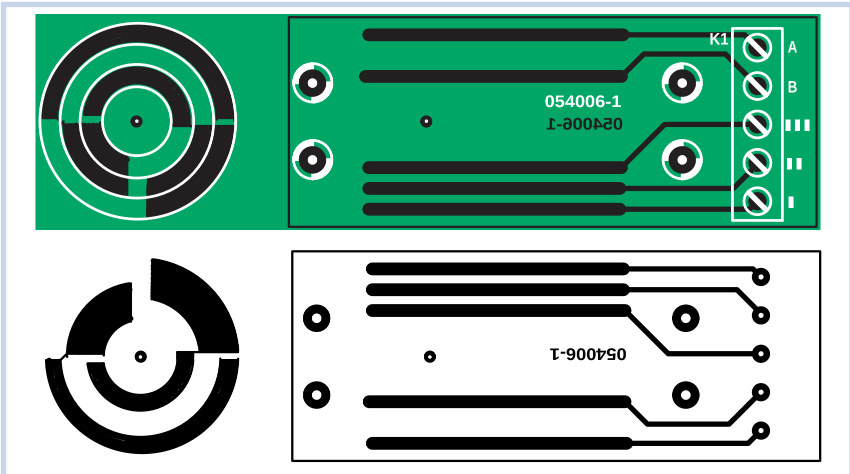


Each channel can be individually turned off (SHDNL and SHDNR) by jumpers JP1 and JP2. During normal operation these two inputs should be connected to the

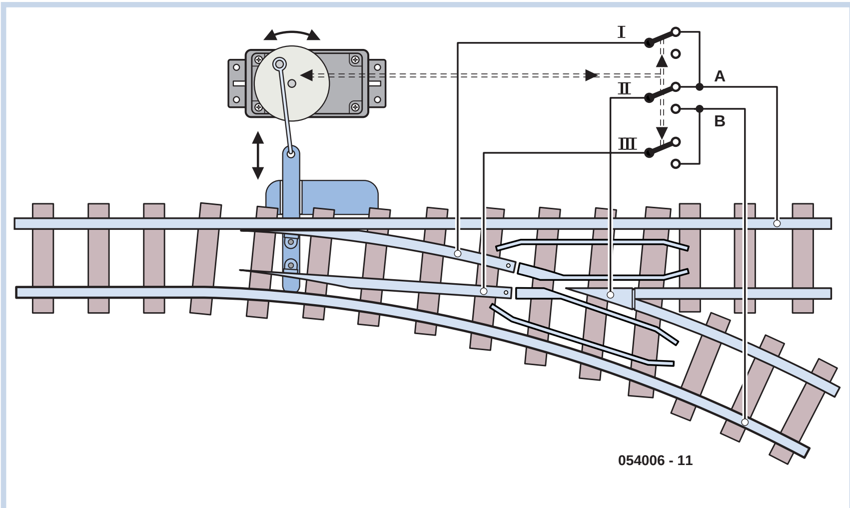
positive supply. When both channels are turned off the charge pump is also switched off and the current consumption drops to about 6 µA.
The IC also has thermal and short-circuit protection built in. The IC switches to standby mode when the supply voltage is too low and it has a circuit that prevents power-on and off plops at the outputs. The recommended supply voltage is between 1.8 V and 3.6 V. The IC can deliver about 80 mW per channel into a 16 Ω load. The power supply should be able to output at least 200 mA. In practice this means that when you use a power supply that also powers other circuits, it should have at least 300 mA in reserve.
The amplifiers are configured in inverting mode with a gain set by the ratio of two resistors (R3/R1 or R4/R2); the input impedance is determined by R1 and R2. C1 and C2 are required to decouple any possible DC-offset from the inputs. In the MAX4410 evaluation kit these are small tantalum capacitors, but we don't recommend these for use in audio applications. Plastic film types would be much better, although they take up much more room.
HF decoupling is provided by 100 pF capacitors connected in parallel with R3 and R4. These set the bandwidth of the amplifiers to just over 150 kHz. The typical distortion is 0.003%. For more details you should refer to the MAX4410 datasheet. It is also worth looking at the datasheet for the associated evaluation kit.
The choice of capacitors for decoupling etc., their positioning on the board and the overall layout are very critical and demand a lot of attention. Furthermore, the 14-pin TSSOP package (with a pin spacing of 0.65 mm) and SMDs in 0402 packages make it very difficult to construct this circuit yourself. The IC is also available in a (much more difficult to solder) UCSP 16 package (ball grid array, only 2.02 by 2.02 mm).

(054022-1)

047 Servo Points Actuator



Karel Walraven



Servos for model making can also be used for completely different purposes besides model airplanes, boats and cars. As an example, here a servo is used to operate a set of points for a model railway system. The points are directly actuated by a length of steel wire connected to the servo arm, and they move quietly and smoothly, so the illusion is no longer spoiled by that irritating click-clack sound. The voltage on the point tongues and nose is also switched over by the servo.
As an example for DIY construction, we have designed two small PCBs that can be attached to a servo with a bit of glue. The larger board should be glued to the case of the servo, while the smaller (round) board should be glued to the arm. Several contact strips made from phosphor bronze must be soldered to the larger board. Phosphor bronze is a copper alloy with good spring characteristics. Almost all relay contacts arms are made from this material. It can be obtained from Conrad, among other sources, in the form of small sheets that can be cut or sawn into strips. Any desired switching scheme can be created by devising a suitable pattern of cop-

per tracks. The actuator works as follows: in the straight-through state, one tongue and the nose are connected to rail B. When the points are moving, both tongues and the nose are floating, since there is a gap between the segments with no copper. Just before the points reach the turn-out state, the other tongue and the nose pick up the voltage from rail A.

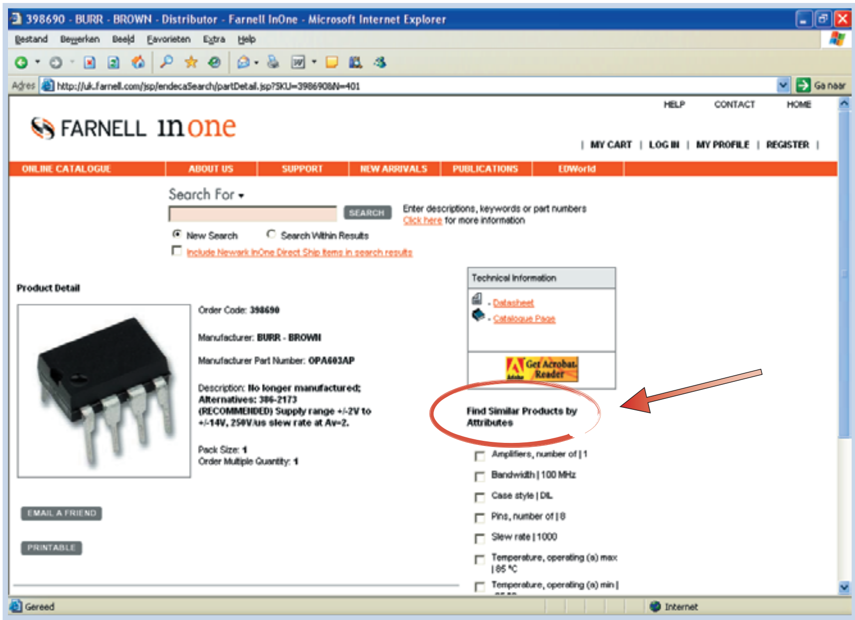
Te PCB shown here is available through The PCBShop.

(054006-1)

Searching for Components

048

Karel Walraven



This is a tip we think you'll appreciate: the large mail-order firms have a lot of information on their sites that can be quite handy even if you never order anything from them. As an example we can mention www.Farnell.com. If you're looking for a certain component, you can simply use the search menu to retrieve its most important characteristics and immediately see whether it is still generally available and approximately what it costs. The full data sheet is also usually available.

If the component is no longer available or you're looking for an alternative for some reason, you can use the 'find similar products by attributes' function to find several similar products. You can refine your choice in several steps until you finally end up with the components with the desired properties. You can't get the same type of results on a manufacturer's site, because such sites are usually limited to the manufacturer's own products, while a dealer also shows competitive products and you can directly compare their availability and prices. That means you can make things a lot easier for yourself, since it takes time to check out all the manufacturer sites, with the added risk that even if you find a suitable component it may turn out to not be available unless you plan to buy 100,000 at the same time.

(054039-1)

Short-Wave Superregenerative Receiver

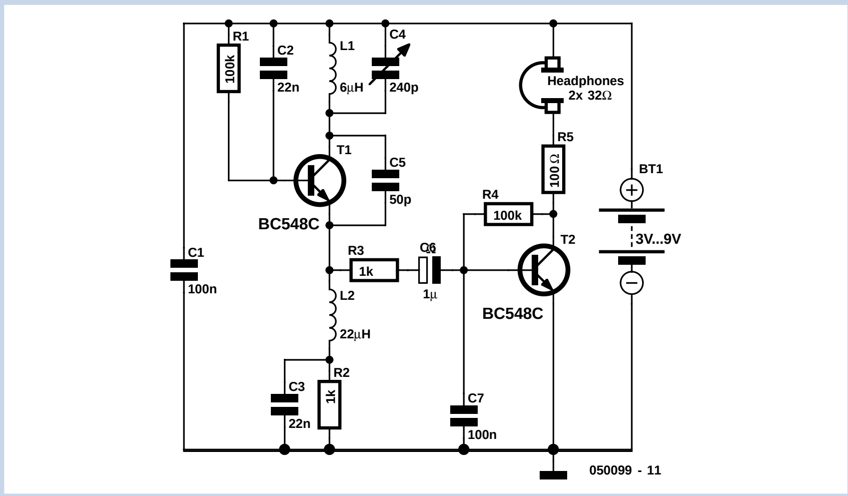
049

Burkhard Kainka

Superregenerative receivers are characterised by their high sensitivity. The purpose of this experiment is to determine whether they are also suitable for short-wave radio.

Superregenerative receivers are relatively easy to build. You start by building a RF oscillator for the desired frequency. The only difference between a superregenerative receiver and an oscillator is in the base circuit. Instead of using a voltage divider, here we use a single, relatively high-resistance base resistor (100 kΩ to 1 MΩ). Superregenerative oscillation occurs when the amplitude of the oscillation is sufficient to cause a strong negative charge to be applied repeatedly to the base. If the regeneration frequency is audible, adjust the values of the resistors and capacitors until it lies somewhere above 20 kHz. The optimum setting is when you hear a strong hissing sound. The subsequent audio amplifier should have a low upper cutoff frequency to strongly attenuate the regeneration signal at its output while allowing signals in the audio band to pass through.

This experimental circuit uses two transistors. A Walkman headphone with two 32-Ω earphones forms a suitable output device. The component values shown in the schematic diagram have proven to be suitable for the 10–20 MHz region. The coil consists of 27 turns wound on an AA battery serving as a winding form. The circuit produces a strong hissing sound, which diminishes when a station is received. The radio is so sensitive that it does not require any antenna to be connected. The tuned circuit by itself is enough to receive a large number of European stations. The circuit is usable with a supply voltage of 3 V or more, although the audio volume is greater at 9 V. One of the major advantages of a superregenerative receiver is that weak and strong stations generate the same audio level, with the only difference being in the signal to noise ratio. That makes a volume control entirely unnecessary. However, there is also a specific drawback in the short-wave bands: interference occurs fairly often if there is an adjacent station separated from the desired station by something close to the regeneration frequency. The sound quality is often worse than with a simple regenerative receiver. However, this is offset by the absence of the need for manual feedback adjustment, which can be difficult.



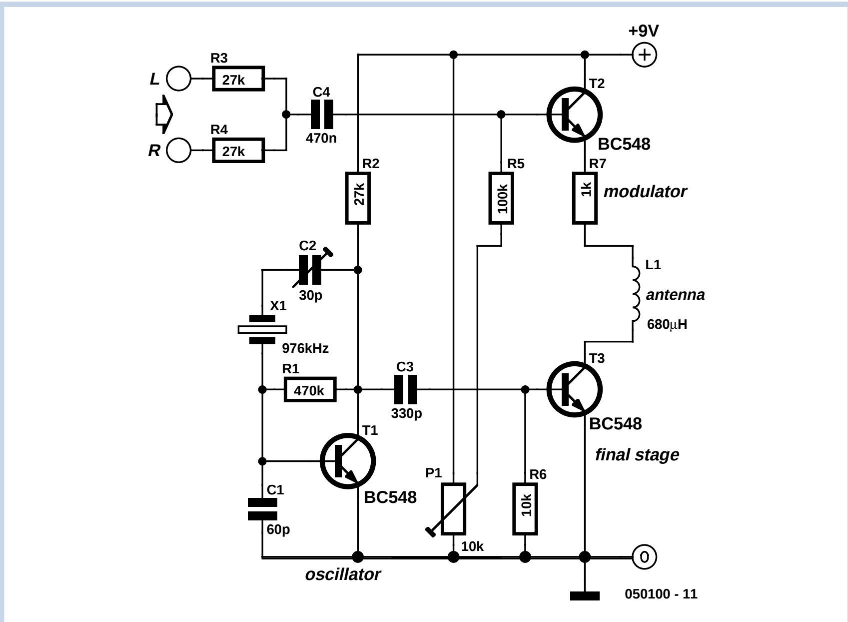
(050099-1)

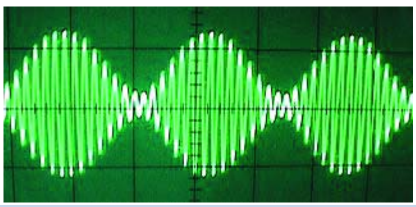
050 Medium-Wave Modulator

Burkhard Kainka

If you insist on using a valve radio and listening to medium-wave stations, you have a problem: the existing broadcasters have only a limited number of records. Here there's only one remedy, which is to build your own medium-wave transmitter. After that, you can play your own CDs via the radio.

The transmitter frequency is stabilised using a 976-kHz ceramic resonator taken from a TV remote control unit. Fine tuning is provided by the trimmer capacitor. If there's another station in the background, which will probably be weak, you can tune it to a heterodyne null, such as 981 kHz. As an operator of a medium-wave transmitter, that's your obligation with respect to the frequency allocations. And that's despite the fact that the range of the transmitter is quite modest. The small ferrite coil in the transmitter couples directly into the ferrite rod antenna in the radio.
The modulator is designed as an emitter follower that modulates the supply voltage of the output amplifier. As the medium-wave band is still mono, the two input channels are merged. The potentiometer can be adjusted to obtain the least distortion and the best sound. The RF amplifier stage has intentionally been kept modest to prevent any undesired radiation. The quality of the output signal can also be checked using an oscilloscope. Clean amplitude modulation should be clearly visible.
The medium-wave modulator can simply be placed on top of the radio. A signal from a CD player or other source can be fed in via a cable. Now you have a new, strong station on the radio in the medium-wave band, which is distinguished by good sound quality and the fact that it always plays what you want to hear.





(050100-1)

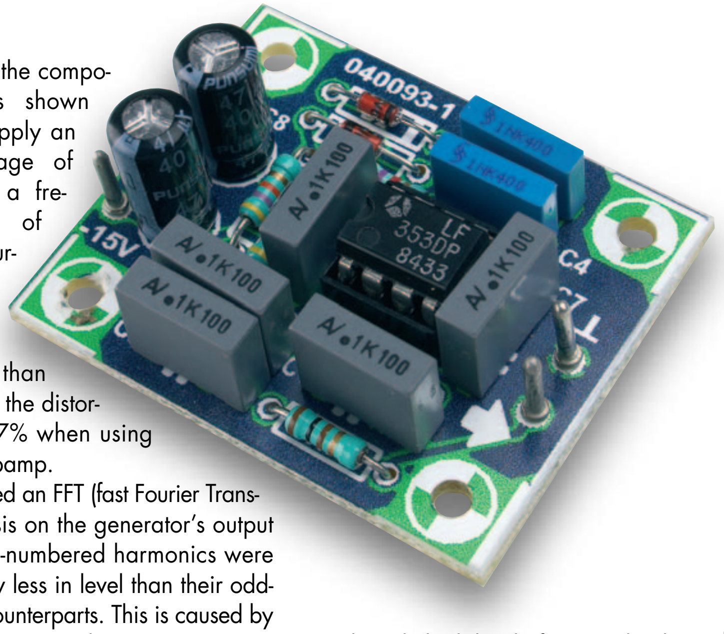
Filter-based 50 Hz Sinewave Generator

Myo Min

When it comes to designing a reliable 50-Hz oscillator, the disadvantage of the good old Wien Bridge oscillator is the difficulty to adjust its own gain. If the gain is higher or lower than the optimum value, the Wien Bridge often fails to work properly.

The circuit shown here combines the functions of a low-pass filter and an integrator, presenting a novel approach to creating a precision 50-Hz source with relatively low distortion.

The circuit is free from any kind of gain setting network. Opamp IC.1B and R3/C4/C5 act as an inverting integrator effectively converting the incoming sine wave (from IC.1A) into a square wave with a good amount of harmonics. R4, D1 and D2 divide the square wave to the desired level. For optimum switching speed, a matching number of series-connected low-power switching diodes like the ubiquitous 1N4148 may be used instead of the zener diodes. The output voltage is directly proportional to the zener diode values. The second opamp, IC.1A and its surrounding components R1, C1 acts as a two-pole low-pass filter supplying the 50-Hz output signal via R5. Theoretically, the filter roll-off is at 24 Hz, which means the base frequency of 50 Hz is also attenuated to some degree. That is not too serious as long as higher harmonics are properly attenuated. The design with the component values shown here will supply an output voltage of 1.24 V at a frequency of 49.6 Hz. Current consumption was measured at less than 5 mA, while the distortion was 3.7% when using an LF353 opamp.



We performed an FFT (fast Fourier Transform) analysis on the generator's output signal. Even-numbered harmonics were found clearly less in level than their odd-numbered counterparts. This is caused by a slight asymmetry in the generator's internal square wave. In our prototype, the FFT graph showed the 3rd harmonic at a relatively high level of –29.2 dB; the 2nd harmonic did much better at just –67.7 dB.

(040093-1)

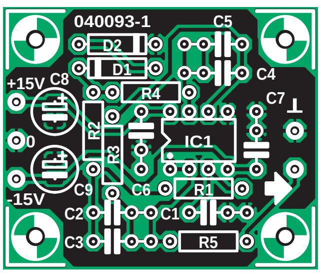
COMPONENTS LIST

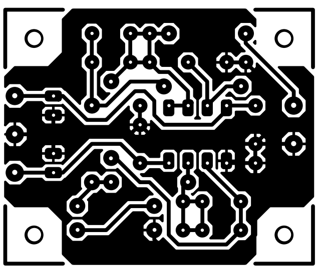
Resistors:
R1,R2,R3 = 47kΩ
R4 = 4kΩ7
R5 = 100Ω

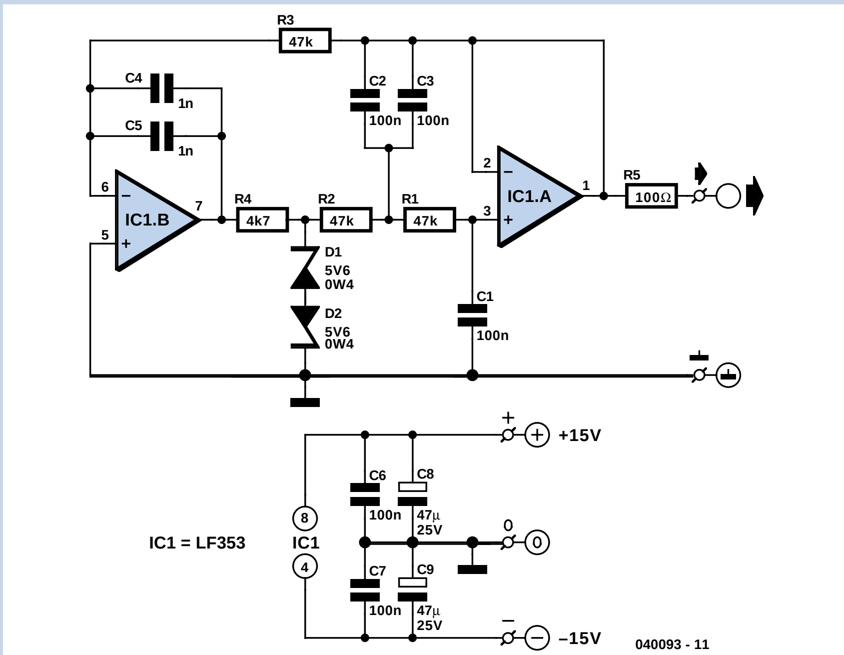
Capacitors:
C1,C2,C3,C6,C7 = 100nF
C4,C5 = 1nF
C8,C9 = 47µF 25V radial

Semiconductors:
D1,D2 = zener diode 5.6V 400mW
IC1 = LF353DP

Miscellaneous:
PCB, ref. 040093-1 from The PCBShop

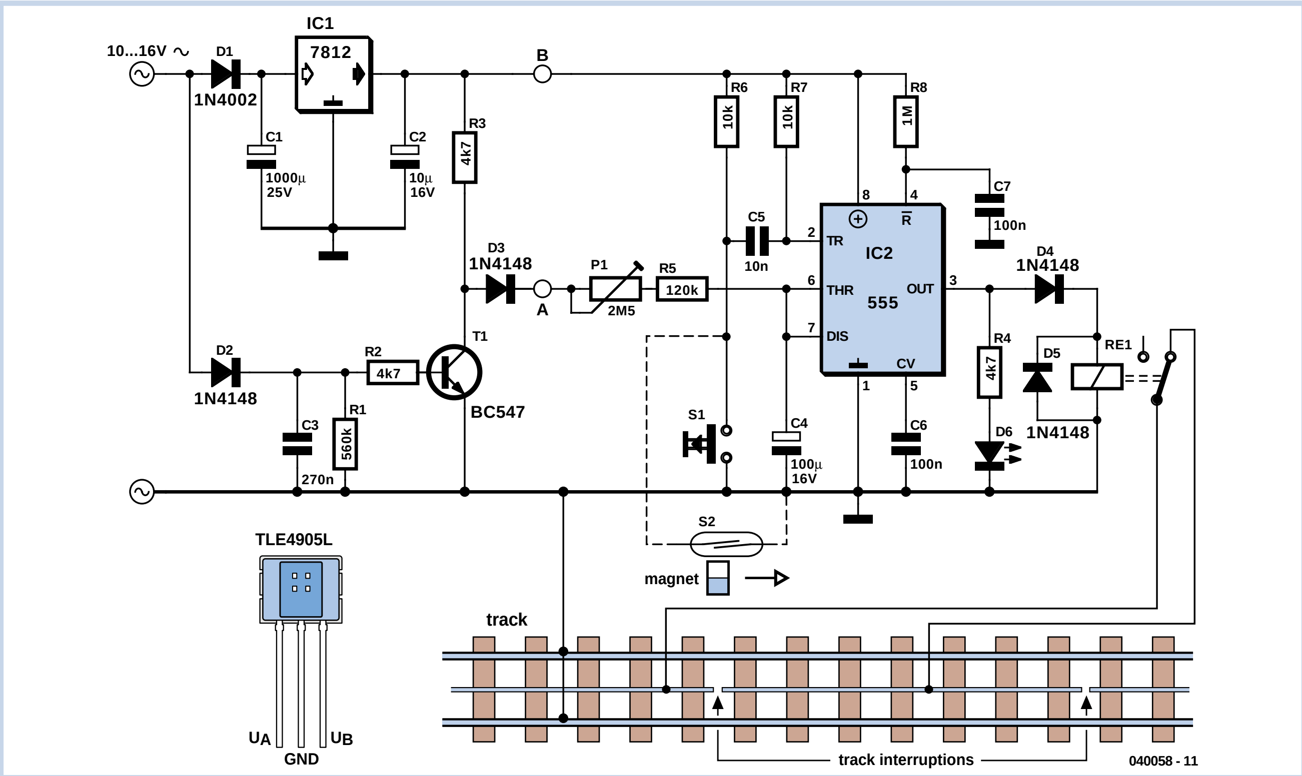






052

Long-Delay Stop Switch



Robert Edlinger

Presettable times for train stops in stations are indispensable if you want to operate your model railway more or less realistically according to a timetable. This circuit shows how a 555 timer can be used with a relatively small timing capacitor to generate very long delay times as necessary by using a little trick (scarcely known among model railway electronic technicians): pulsed charging of the timing network. Such long delays can be used in hidden yards with through tracks, for instance.

As the timer is designed for half-wave operation, it requires only a single lead to the transformer and one to the switching track or reed contact when used with a Märklin AC system (H0 or H1). The other lead can be connected to any desired grounding point for the common ground of the track and lighting circuits.

As seen from the outside, the timer acts as a monostable flip-flop. The output (pin 3) is low in the quiescent state. If a negative signal is applied to the trigger input (pin 2), the output goes high and C4 starts charging via R3 and R4. When the voltage on C4 reaches 2/3 of the supply voltage, it discharges via an internal transistor connected to pin 7 to 1/3 of the supply voltage and the output (pin 3) goes low. The two threshold values (1/3 and 2/3) are directly proportional to the supply voltage. The duration of the output signal is independent of the supply voltage:

$$t = 1.1(R4 + R5) \times C4$$

if the potentiometer is connected directly to the supply line (A and B joined). The maximum delay time that can be generated using the component values shown in the schematic diagram is 4.8 minutes. However, it can be increased by a factor of approximately 10 if the timing network is charged using positive half-waves of the AC supply voltage (reduced to the 10–16-V level) instead of a constant DC voltage.

The positive half-waves of the AC voltage reach the timing network via D2, the transistor, and D3. Diode D3 prevents C4 from being discharged between the pulses. The total resistance of R4 and R5 should not be too high (no more than 10 MΩ if possible), since electrolytic capacitors (such as are needed for C4) have significant leakage currents. Incidentally, the leakage current of aluminium electrolytic capacitors can be considerably reduced by using a supply voltage well below the rated voltage. Capacitor C6 is intended to suppress noise. It forms a filter network in combination with an internal voltage-divider resistor.

If a vehicle happens to remain standing over the reed switch so the magnet holds the contacts constantly closed, the timer will automatically be retriggered when the preset delay times out. In this case the relay armature will not release and the locomotive will come to the 'end of the line' in violation of the timetable. This problem can be reliably eliminated using R6, R7 and C5. This trigger circuit ensures that only one trigger pulse is generated, regardless of how long the reed switch remains closed.

RC network R8/C7 on the reset pin ensures that the timer behaves properly on switch-on (which is far from being something to be taken for granted with many versions of the 555 or 556 dual timer).

Reed switches have several special characteristics that must be kept in mind when fitting them. The contact blades, which are made from a ferromagnetic material, assume opposite magnetic polarities under the influence of a magnetic field and attract each other. Here the position and orientation of the magnet, the distance between the magnet and the reed switch, and the direction of motion of the magnet relative to the switch are important factors. The fragility of the glass housing and the thermal stress from soldering (stay at least 3 mm away from the glass housing) require a heat sink to be used between the soldering point and the glass/metal seal. A suitable tweezers or flat-jawed pliers can be used for this purpose. If you need to bend the leads, use flat-jawed pliers to protect the glass/metal seal against mechanical stresses.

Matching magnets in various sizes are available from toy merchants and electronics mail-order firms. They should preferably be fitted underneath the locomotive or carriage. However, the magnet can also be fitted on the side of a vehicle with a plastic body. In this case the reed switch can be hidden in a mast, bridge column or similar structure or placed in a tunnel, since the distance must be kept to less than around 10 mm, even with a strong magnet. If fitting the circuit still presents problems (especially with Märklin Z-gauge Mini-Club), one remedy is to generate the trigger using a unipolar digital Hall switch, such as the Siemens TLE4905L or Allegro UGN3120. To avoid coupled-in interference, the stop timer should be fitted relatively close to the Hall sensor (use screened cable if necessary). Pay attention to the polarity of the magnet when fitting it to the bottom of the vehicle. With both types of sensors, the South pole must point toward the front face of the Hall IC (the face with the type marking). The North pole is sometimes marked by a dab of paint. Generally speaking, the polarity must be determined experimentally.

Fitting the circuit is not a problem with Z-gauge and 1-gauge tracks, since the distance between the iron parts (rails) and the Hall switch is sufficiently large. In an HO system, some modifications must be made to the track bed of the Märklin metal track. Cut a suitably sized 'window' between one wheel rail and the centre rail in order to prevent secondary magnetic circuits from interfering with the operation of the sensor. Keep the distance between the magnet and the case of the Hall switch between 5 and 10 mm, depending on the strength of the magnet, to ensure reliable actuation.

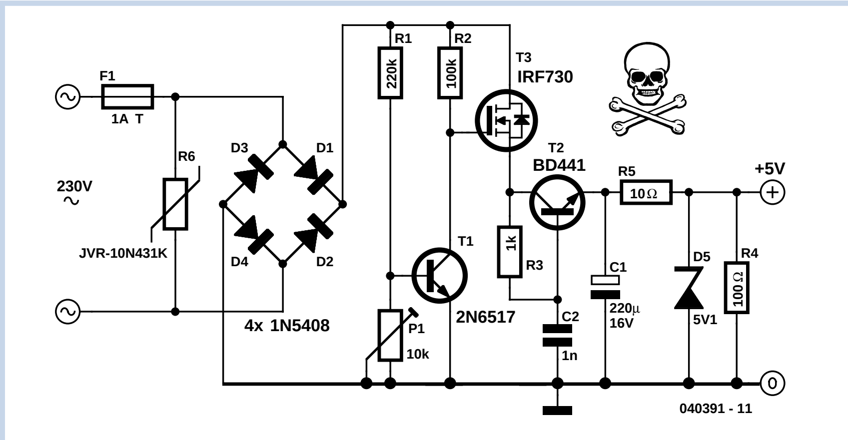
(040058-1)

Transformerless 5-volt Power Supply

053

Srdjan Jankovic and Branko Milovanovic

An increasing number of appliances draw a very small current from the power supply. If you need to design a mains-powered device, you could generally choose between a linear and a switch-mode power supply. However, what if the appliance's total power consumption is very small? Transformer-based power supplies are bulky, while the switchers are generally made to provide greater current output, with a significant increase in complexity, problems involving PCB layout and, inherently, reduced reliability.



CAUTION

The circuit is not galvanically isolated from the mains. Touching any part of the circuit (or any circuitry it supplies power to) while in operation, is dangerous and can result in an electric shock! This circuit should not be built or used by individuals without proper knowledge of mains voltage procedures. Neither the authors nor Elektor Electronics magazine can be held responsible for any harm or injury resulting from use, or inability to use, the information presented in this article.

Is it possible to create a simple, minimum-part-count mains (230 VAC primary) power supply, without transformers or coils, capable of delivering about 100 mA at, say, 5 V? A general approach could be to employ a highly inefficient stabilizer that would rectify AC and, utilizing a zener diode to provide a 5.1 V output, dissipate all the excess from 5.1 V to ($230\times\sqrt{2}$) volts in a resistor. Even if the load would require only about 10 mA, the loss would be approximately 3 watts, so a significant heat dissipation would occur even for such a small power consumption. At 100 mA, the useless dissipation would go over 30 W, making this scheme completely unacceptable. Power conversion efficiency is not a major consideration here; instead, the basic problem is how to reduce heavy dissipation and protect the components from burning out.

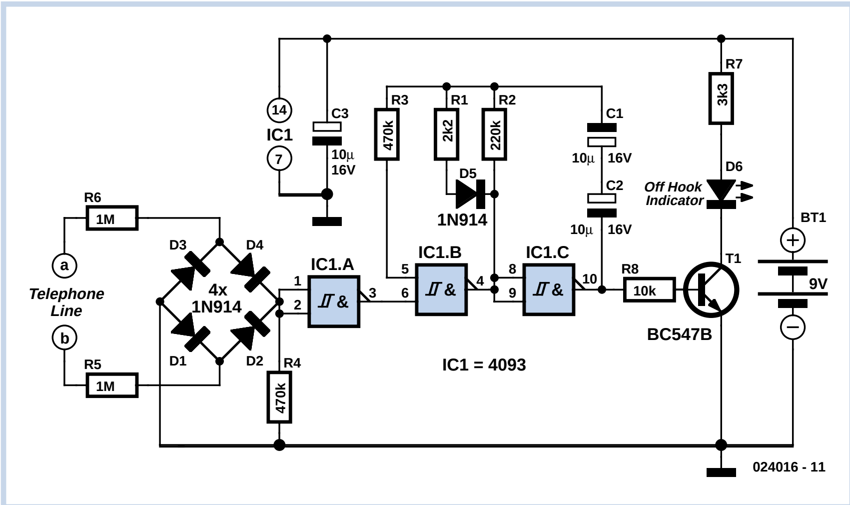
The circuit shown here is one of the simplest ways to achieve the above goals in practice. A JVR varistor is used for overvoltage/surge protection. Voltage divider R1-R2 follows the rectified 230 V and, when it is high enough, T1 turns on and T3 cannot conduct. When the rectified voltage drops, T1 turns off and T3 starts to conduct current into the reservoir capacitor C1. The interception point (the moment when T1 turns off) is set by P1 (usually set to about 3k3), which controls the total output current capacity of the power supply: reducing P1 makes T1 react later, stopping T3 later, so more current is supplied, but with increased heat dissipation. Components T2, R3 and C2 form a typical 'soft start' circuit to reduce current spikes — this is necessary in order to limit C1's charging current when the power supply is initially turned on. At a given setting of P1, the output current through R5 is constant. Thus, load R4 takes as much current as it requires, while the rest goes through a zener diode, D5. Knowing the maximum current drawn by the load allows adjusting P1 to such a value as to provide a total current through R5 just 5 to 6 mA over the maximum required by the load. In this way, unnecessary dissipation is much reduced, with zener stabilization function preserved. Zener diode D5 also protects C1 from overvoltages, thus enabling te use of low-cost 16 V electrolytics. The current flow through R5 and D5, even when the load is disconnected, prevents T3's gate-source voltage from rising too much and causing damage to device. In addition, T1 need not be a high-voltage transistor, but its current gain should exceed 120 (e.g. BC546B, or even BC547C can be used).

(040391-1)

054 Telephone Line Indicator

Flemming Jensen

Many 'busy' indicators for use in telephone systems present undesirable loading of the telephone line. Some circuits are very simple indeed to the extent of only loading the line when it is not in use. The downside is that a (usually green) LED lights when the line is *not* occupied. The author feels that a LED should flash when the line is actually in use by another extension and that the circuit should present a minimal load of the line. The circuit shown here fulfills both requirements. We should, however, not forget to mention its only drawback: its needs to be powered from a battery or an energy-friendly battery eliminator (a.k.a. wall cube or mains adapter). If a high-efficiency LED is used then the current drain from the 9-volt supply will be so small that a standard (170-mAh) 9-V PP3 battery will last for months. Considering that the LED is powered at current of 2 mA by T1, theoretically some 85 hours of 'LED on' time can be obtained.



If, for some reason, you wish to change the flash frequency or on/off ratio (duty cycle) then do feel free to experiment with the values and ratio of R1 and R2. The effect will also depend on the brand of the 4093 IC, its exact logic High/Low switching thresholds and hysteresis.

The circuit is not approved to BABT standards for connection to the public switched telephone network (PSTN). Please check local/national regulations.

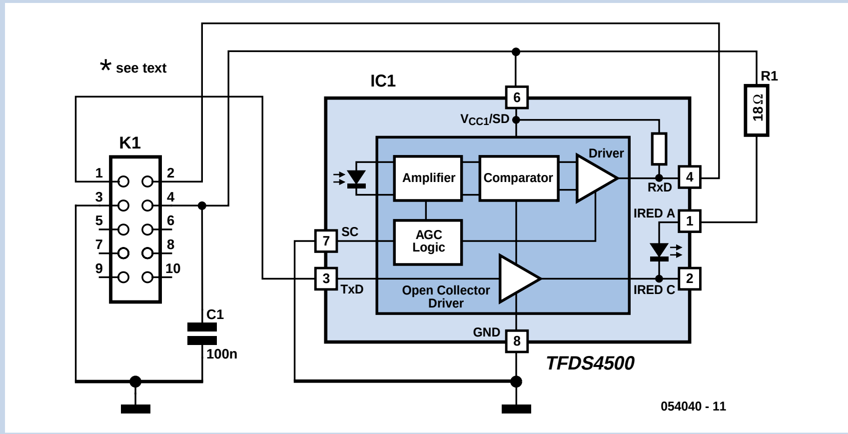
(024016-1)

055 PC IrDA Port

Luc Lemmens

Many PC motherboards (perhaps most of them, in fact) are fitted with a connector for an infrared communication port. That connector is generally not used, since IrDA never became truly successful and has probably already seen its best days. Still, quite a few modern devices that can use this link to communicate with a PC are available, including printers, PDAs, mobile phones, and laptops. However, the link between the above-mentioned connector on the motherboard and the outside world, the IrDA interface, is not supplied with any motherboard and is usually not available in computer shops as an accessory. Fortunately, the necessary hardware is quite simple, and most solder artists should find it dead easy to build it as a 'point-to-point' construction. Selection of the IrDA IC is not critical, and just any about any type is suitable. However, you should check the size of the module when making your purchase, because quite a few types are so small that

they're difficult to solder.
Naturally, the interface must be able to see outside, and it should preferably be fitted at the front of the computer. A cover plate for a free floppy-disk or CD drive bay is quite suitable for this purpose. It's easy to remove from the case, and it should be easy to make a neat opening in it for the interface.
The connection to the motherboard is another story. Unfortunately, the motherboard manufacturers never agreed on a standard for this. That means you'll have to consult your user's manual, and if that documentation is no longer to be found, the manufacturer's website can remedy the situation in 99% of the cases, since most manuals are available as downloads. Be careful: a mistake in the connection can cause serious damage to the motherboard, so check everything thoroughly and carefully before switching on the PC.
The next step is to check the BIOS settings of the PC (to verify that the IrDA port is



enabled) and install the drivers. What this involves varies from one PC to the next, and it also depends on the operating system, so there's no single recipe for it. If you aren't keen on figuring all this out for yourself, you can try searching the Internet. A highly suitable site is www.infrarot-port.de, which clearly explains in German and English what you have to do and has all sorts of settings, drivers and patches, including supplementary explanations and experience with various types of motherboards. That's often what takes the most time in getting this serial interface to start talking.

(054040-1)

Carriage Detection for Model Railway

056

Karel Walraven

Model railway builders know all about this: it is a troublesome job to get a block system to function properly. We present here a simple, reliable and cheap solution on how to fit resistors between insulated wheels, as is used with the two-rail systems that operate a block detection system based on current consumption.

A block, in this case, is an isolated section of rail. It is considered occupied if a load is detected. The locomotive usually has at least some current consumption, even if it is just for the lights. Digital locomotives with a decoder always consume a few milliamps, which is also sufficient for detection. To be able to detect the rolling stock, a little more effort is required. When a single carriage is accidentally left behind in a block, the detector has to be able to sense this and indicate the block as occupied. In order to achieve this, all axles of all carriages have to be fitted with a small resistor, so that a small current can flow.
Carriages with internal lighting have additional sliding contacts (on the wheels) and a small lamp or LED as load. However, it is much too complicated to fit all carriages with additional sliding contacts. That is why it is usual for a resistor to be placed across the plastic insulating sleeve. One of the wheels is isolated with respect to the axle, otherwise the wheels would short circuit the rails. This is, of course, not the intention with a two-rail system. Axles with resistors are available read-made, but are somewhat expensive.
Usually an SMD or 1/8-W type resistor is used, with a value ranging from about 4k7 to 10k. It is mechanically mounted with a little (epoxy) glue and the actual electrical connection is made with conductive glue (often containing silver particles). This will usually last for years, but regular

inspection is required if carriages are subject to rough handling. In addition, conductive glue is expensive, not always available and dries out after a while.
We consider the following a better method: grab the axle with small pliers and carefully pull of the isolated wheel from the axle. Also remove the insulating sleeve. Cut a two cm piece of thin hook-up wire and remove the individual strands. They have to be thin, no more than about 0.1 mm. Put the wheel back on, but now with a 0.1-mm wire between axle and sleeve and opposite that a 0.1-mm wire between sleeve and wheel. You now have created two connections. With a little bit of dexterity you can

solder a resistor to those wires. First practise a little on a few old axles, the example in the pictures isn't the newest model either! Don't forget to glue the resistor down, otherwise the thin wires will certainly break after a short time.

It is also possible to first solder the wires on an SMD resistor and then re-assemble the axle. Do it whichever way you personally find the easiest.

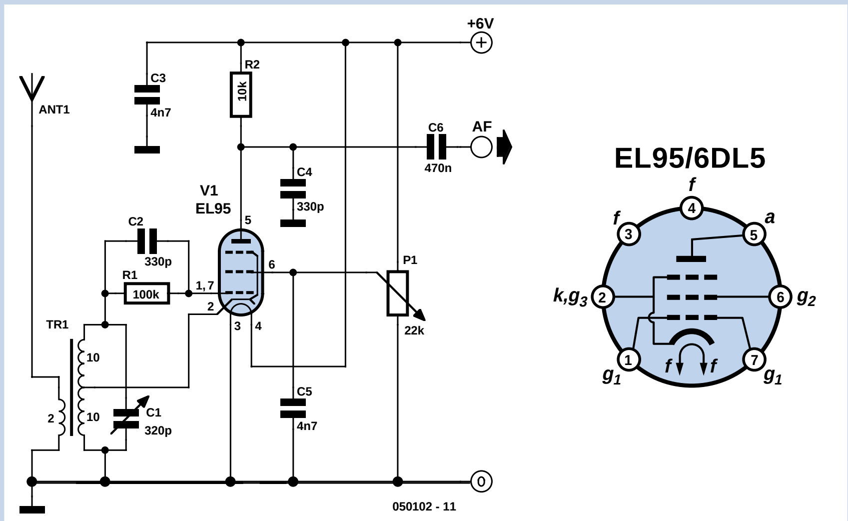
(054017-1)

057

Short-Wave Regenerative Receiver

for AM and DRM

Burkhard Kainka



Is it possible to make a short-wave regenerative valve receiver so stable that it is even suitable for DRM? And is it possible to do this using a 6-V supply, so only a single voltage is necessary for the filament and anode supply? It looks like it might be possible with an EL95, which has good transconductance even at low anode voltages, although it is actually an output-stage pentode instead of an RF valve. Besides that, it draws only a modest 200 mA of heater current. Everything can be operated from a small battery, which eliminates any problems with 50-Hz hum.

The stability depends entirely on the tuned circuit. Consequently, a robust coil with 20 turns of 1.5-mm wire was wound on a PVC pipe with a diameter of 18 mm. With short leads to the air-dielectric variable capacitor, this yields an unloaded Q factor considerably larger than 300.

The schematic shows a regenerative receiver with feedback via the cathode. The amount of feedback is adjusted using the screen grid voltage. The audio signal across the anode resistor is coupled out via a capacitor. No additional gain is necessary, since the voltage level is sufficient for a direct connection to the Line input of a PC sound card. A screened cable should be used for this connection.

A two-turn antenna coil is located at the bottom end of the tuned circuit. It provides very loose coupling to the antenna, which is important for good stability.

Now it's time to see how it works in practice. Despite the open construction, the frequency drift is less than 1 Hz per minute. That's the way it should be if you want to receive DRM. Quite strong feedback should be used, so the regenerative circuit acts like a direct mixer or a self-oscillating mixer stage.

Every strong DRM signal could be seen using DREAM and tuned to 12 kHz. A total of six different DRM frequencies could be received in the 40-m and 41-m bands. If no good DRM stations are available, the receiver can also pick up AM transmitters. In this case, the amount of feedback should be reduced. The PC can be set aside for AM reception, since all you need is a direct connection to an active PC speaker.

(050102-1)

058

Improved DECT Battery Charger

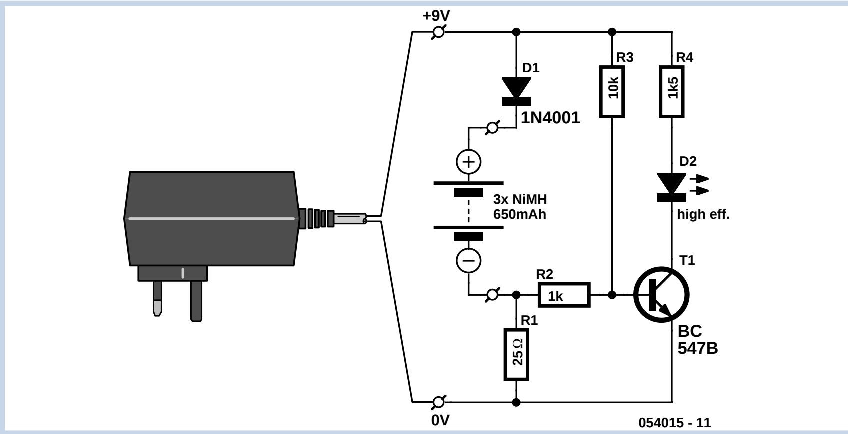
Karel Walraven

After buying a number of DECT telephones, we noticed that these became quite warm while charging. That surprised us, because the manufacturer wrote in the manual that the batteries had to be charged for 14 hours. That would lead you to conclude that the batteries are charged at $^1/_{10}$th of the nominal capacity. But we had the feeling that the batteries were getting rather warm for such a small charging current. That is why we quickly reached for a screwdriver and explored the innards of the charging station. The accompanying schematic reveals what is going on.

The batteries are 'simply' charged from a 9-V mains adapter. In series with the output are a diode and a resistor. A quick calculation shows that a current of about

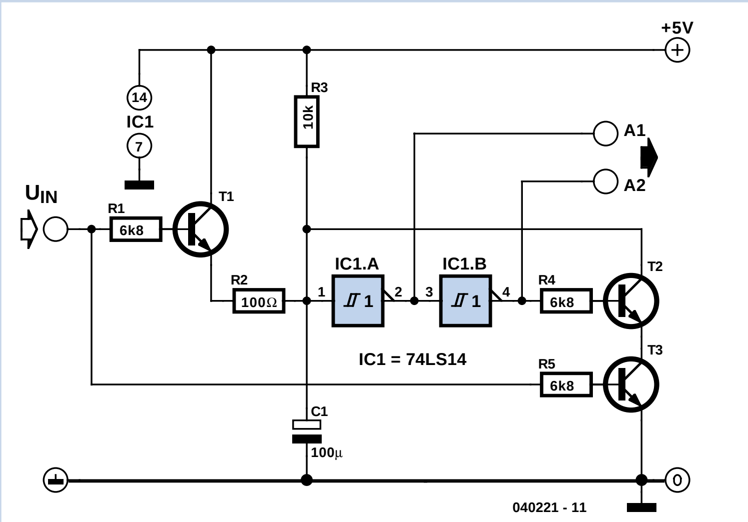
160 mA will flow and this was indeed the case when measured with a multimeter. That means that, for the AAA cells used here, rated at 650 mAh, the charging current isn't $^1/_{10}$ C, but $^1/_4$ C! This is rather high and certainly not good for the life expectancy of the batteries. The remedy is simple: increase the value of the 25 Ω series resistor so that the charging current will be less. We chose a value of 68 Ω, resulting in a charging current of about 60 mA.
You may ask what the purpose of the remainder of the circuit it. This is all required to turn on the LED, which indicates when charging is taking place. During charging, there is a voltage drop of about 4 V across R1. T1 will then receive base current via R2 and the LED turns on. The resistor in series with the LED limits the LED current.
The fact that the batteries are charged with an unregulated supply is not such a problem. The mains voltage will vary somewhat, but with a maintenance charge such as in this application it is not necessary to charge with an accurate constant current, provided that the current is not too high.
For the curious, here is the calculation for the charging resistor: three cells are being charged. The charging voltage of a NiMH cell is about 1.4 V. The voltage drop across D1 is about 0.7 V. That leaves a voltage across the resistor of:
$9_{\text{mains adapter}} - 4.2_{\text{batteries}} - 0.7_{\text{diode}} =$ 4.1 V
Therefore, there flows a current of 4.1/25 = 164 mA.

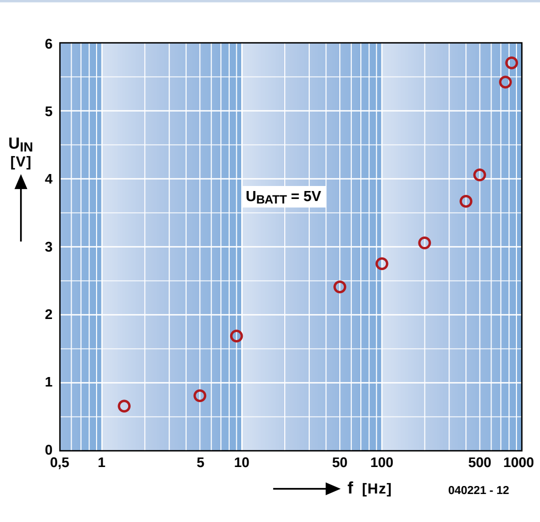
(054015-1)



059

1:800 Oscillator





Bernd Oehlerking

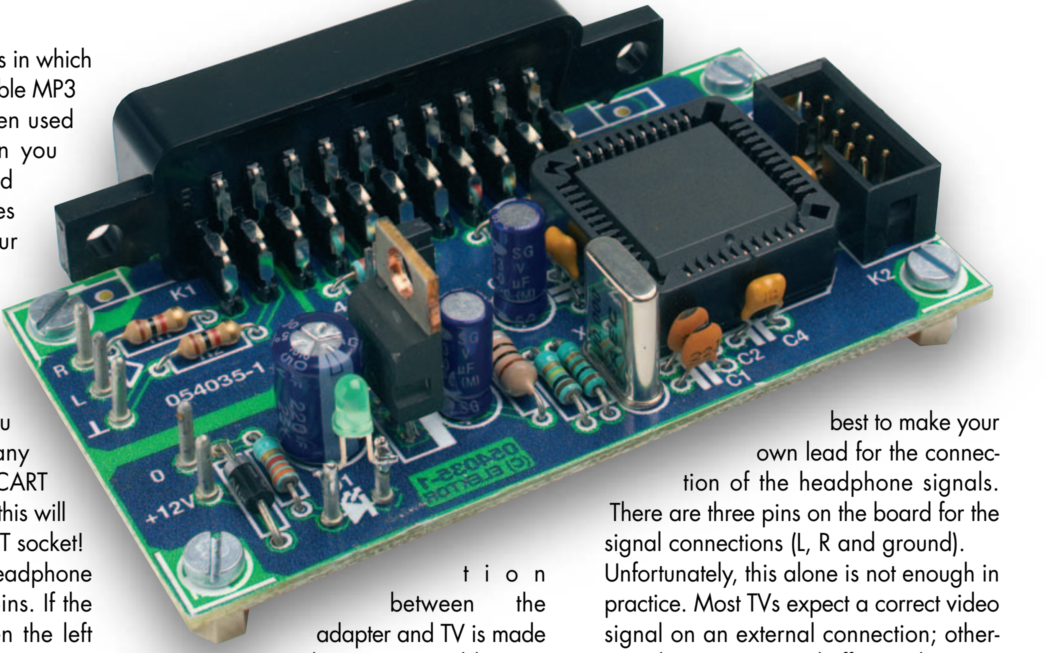
Oscillators are ten a penny, but this one has something special. Its frequency can be adjusted over a range of 800:1, it is voltage controlled, and it switches off automatically if the control voltage is less than approximately 0.6 V.
As can be seen from the chart, the characteristic curve f = f(Ue) is approximately logarithmic. If the input voltage is less than 0.7 V, T1 and T3 are cut off. The capacitor then charges via the 10-kW resistor. The combination of the capacitor, the two Schmitt triggers and T2 form the actual oscillator circuit. However, T2 cannot discharge the capacitor, because T3 is cut off. In this state, a low level is present at A1 and a high level is present at A2. If the input voltage is increased, T3 starts conducting. This allows the capacitor to be discharged via T2, and the circuit starts to oscillate. If Ue is further increased, the capacitor receives an additional charging current via T1 and the l00-Ω resistor. That causes the oscillator frequency to increase. In situations where the duty cycle of the output signal is not important (such as when the circuit is used as a clock generator), this circuit can be used as a voltage-controlled oscillator (VCO) with a large frequency range and shutdown capability.

(040221-1)

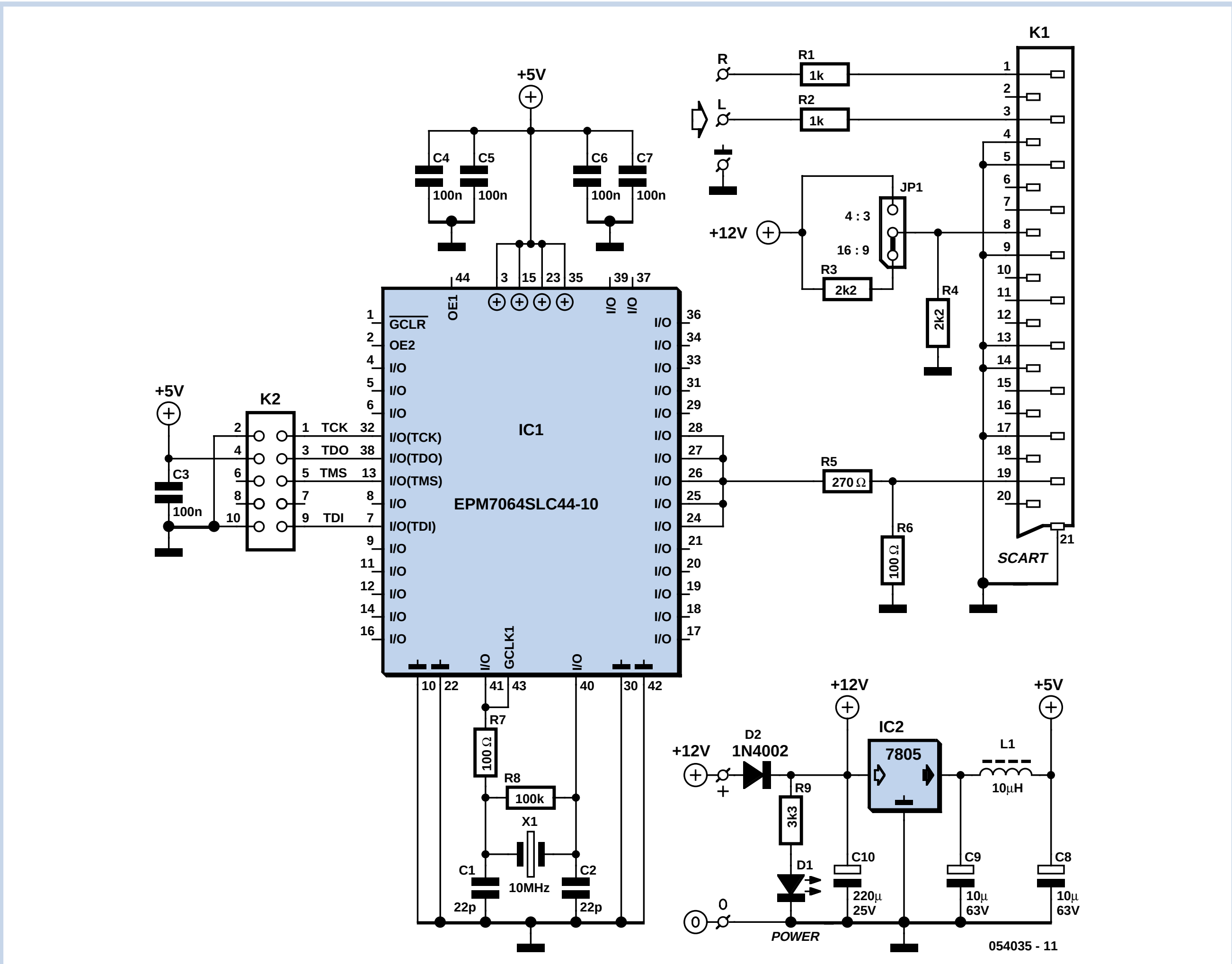
060 MP3 Adapter for TV

Ton Giesberts

Nowadays there are many ways in which you can listen to music. A portable MP3 player with headphones is often used while on the move. But when you need to stay in a hotel and would like to listen without headphones to your favourite music in your hotel room, things become more difficult. Most hotel rooms have a TV, but rarely a music centre.



We have designed a fairly compact adapter that lets you connect an MP3 player (or any other portable device) to the SCART socket of a TV. It is obvious that this will only work if the TV has a SCART socket! The board directly feeds the headphone signals to the correct SCART pins. If the TV only has mono sound, then the left input signal is probably used. The connection between the adapter and TV is made with a SCART cable. It is best to make your own lead for the connection of the headphone signals. There are three pins on the board for the signal connections (L, R and ground). Unfortunately, this alone is not enough in practice. Most TVs expect a correct video signal on an external connection; otherwise the input is turned off (muted). To get

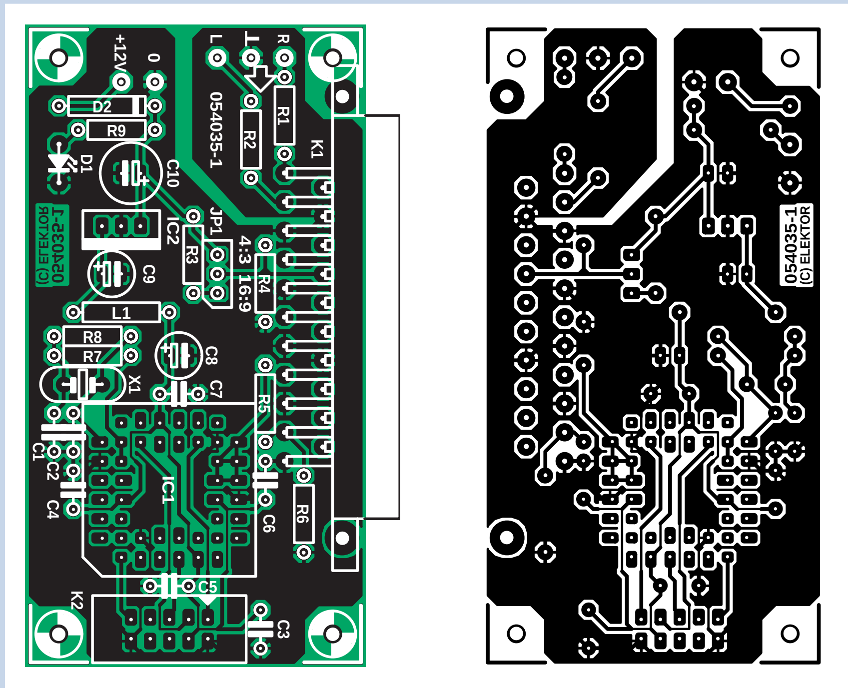


round this problem we used a programmable logic device (IC1, an EPM7064 made by Altera) to generate a video sync signal. More detailed information can be found in the sync generator article elsewhere in this issue. It is sufficient to state that this IC generates a sync signal according to the PAL/SECAM specification. Several outputs are connected in parallel to give a stronger output signal. Potential divider R5/R6 produces a signal that is slightly bigger than a normal video signal (normally 30% of 1 V_{pp} into 75 Ω). The signal is now a bit under 0.5 V_{pp} into 75 Ω. The output impedance of R5/R6 is 75 Ω, which reduces reflections should the cable be incorrectly terminated. ISP connector K2 has been included for those of you who would like to experiment with this circuit (see www.altera.com).

The TV can be automatically switched to an external source using the video-status signal (pin 8). Modern widescreen TVs use this signal to switch between two display modes. A voltage between 9.5 and 12 V results in a 4:3 display and a voltage between 4.5 and 7 V switches to a widescreen format. Jumper JP1 can be used to control this function of the TV. For older TVs the jumper should be in the 4:3 position. In all cases the display remains dark though.

A supply voltage is required for IC1 as well as the video-status signal. This is provided by a mains adapter with a stabilised 12 V output, preferably a modern switch-mode supply. Voltage regulator IC2 provides a stable 5 V to IC1 and K2. LED D1 indicates that the circuit is powered up. The current consumption is mainly determined by IC1 and is about 80 mA.

(054035-1)



COMPONENTS LIST

Resistors:
R1,R2 = 1kΩ
R3,R4 = 2kΩ2
R5 = 270Ω
R6,R7 = 100Ω
R8 = 100kΩ
R9 = 3kΩ3

Capacitors:
C1,C2 = 22pF
C3-C7 = 100nF ceramic, lead pitch 5mm
C8,C9 = 10µF 63V radial
C10 = 220µF 25V radial

Inductor:
L1 = 10µH

Semiconductors:
D1 = LED, low-current
D2 = 1N4002
IC1 = EPM7064SLC44-10 PLC44 with socket (programmed, Publisher's order code **054035-31** *)
IC2 = 7805

Miscellaneous:
JP1 = 3-way SIL header with jumper
K1 = SCART socket (female), PCB mount, angled
K2 = 10-way boxheader
X1 = 10MHz quartz crystal
PCB, Publisher's order code **054035-1** *
Disk, EPM7064 code, Publisher's order code **054035-11** * or Free Download *

* See Elektor SHOP pages or www.elektor-electronics.co.uk

Solar-powered SLA Battery Maintenance

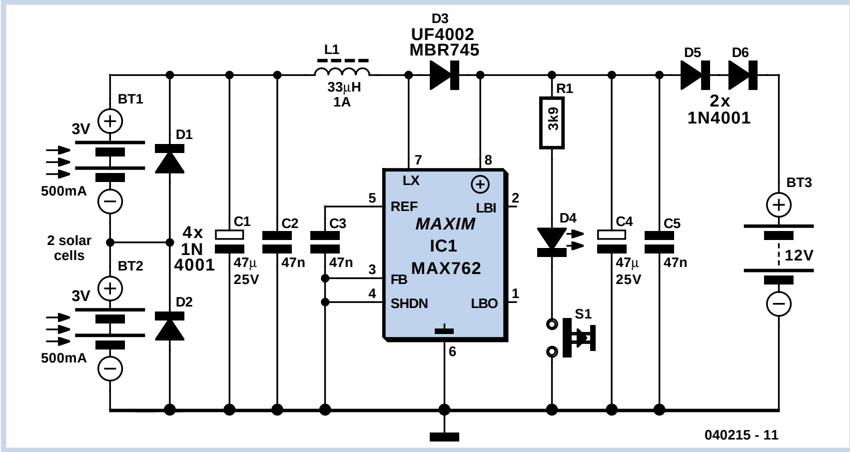
061

Myo Min

This circuit was designed to 'baby-sit' SLA (sealed lead-acid or 'gel') batteries using freely available solar power. SLA batteries suffer from relatively high internal energy loss which is not normally a problem until you go on holidays and disconnect them from their trickle current charger. In some cases, the absence of trickle charging current may cause SLA batteries to go completely flat within a few weeks. The circuit shown here is intended to prevent this from happening. Two 3-volt solar panels, each shunted by a diode to bypass them when no electricity is generated, power a MAX762 step-up voltage converter IC. The '762 is the 15-volt-out version of the perhaps more familiar MAX761 (12 V out) and is used here to boost 6 V to 15 V. C1 and C2 are decoupling capacitors that suppress high and low frequency spurious components produced by the switch-mode regulator IC. Using Schottky diode D3, energy is stored in inductor L1 in the form of a magnetic field. When pin 7 of IC1 is open-circuited by the internal switching signal, the stored energy is diverted to the 15-volt output of the circuit. The V+ (sense) input of the MAX762, pin 8, is used to maintain the output voltage at 15 V. C4 and C5 serve to keep the ripple on the output voltage as small as possible. R1, LED D4 and pushbutton S1 allow you to check the presence of the 15-V output voltage. D5 and D6 reduce the 15-volts to about 13.6 V which is a frequently quoted nominal standby trickle charging voltage for SLA batteries. This corresponds well with the IC's maximum, internally limited, output current of about 120 mA.

The value of inductor L1 is not critical — 22 µH or 47 µH will also work fine. The coil has to be rated at 1 A though in view of the peak current through it. The switching frequency is about 300 kHz. A suggestion for a practical coil is type M from the WEPD series supplied by Würth (www.we-online.com). Remarkably, Würth supply one-off inductors to individual customers. At the time of writing, it was possible, under certain conditions, to obtain samples, or order small quantities, of the MAX762 IC through the Maxim website at www.maxim-ic.com.

(040215-1)



062 Simple Window Comparator

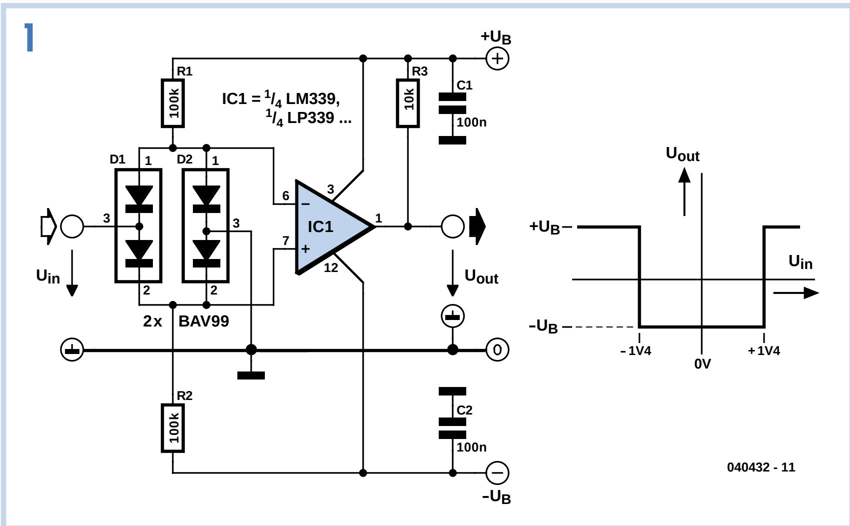
Gregor Kleine

A window comparator that monitors whether its input voltage Uin lies within a defined voltage window can be built using only a few components.

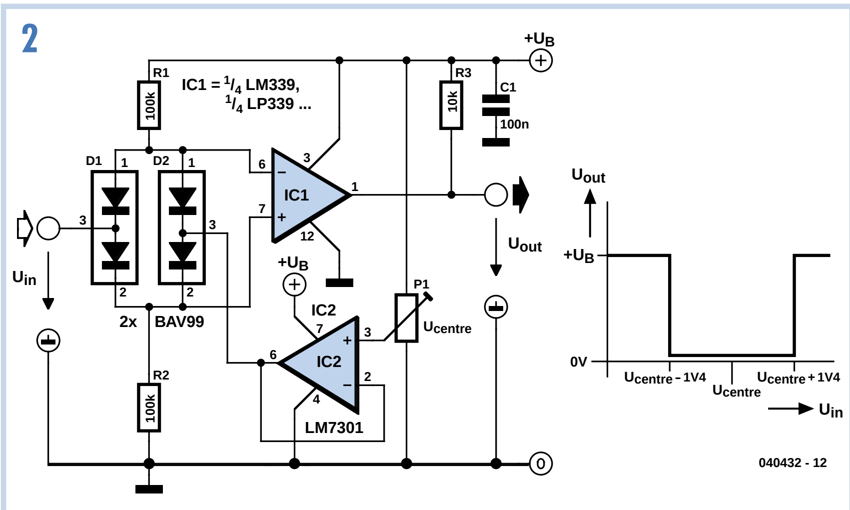
The circuit shown in **Figure 1** is a version that operates with complementary supply voltages. Two diode pairs are connected across the inputs of the comparator IC and supplied with bias currents via R1 and R2. If the input of the circuit is open, the current flowing through diode pair D2a and D2b (whose common terminal is connected to ground) causes the inverting input of the comparator to be at +0.7 V and the non-inverting input to be at –0.7 V. The comparator output is thus at the $-U_b$ level, since the differential voltage at the comparator input is negative. The differential voltage is equal to the voltage on the non-inverting input minus the voltage on the inverting input.

If a positive input voltage is applied, diode D1b conducts and the voltage on the non-inverting input rises. This voltage is always 0.7 V lower than the input voltage. Diode D2b is cut off if the input voltage is positive. If the voltage at the circuit input rises to somewhat more than +1.4 V, the voltage on the non-inverting input will be slightly higher than the voltage on the inverting input, which is held to 0.7 V. The differential voltage between the comparator inputs will thus be positive, and the comparator output will switch to the $+U_b$ level.

1



2



The behaviour of the circuit is similar with a negative input voltage, with the difference being that the roles of the two diodes are swapped. In this case, the non-inverting input of the comparator remains at –0.7 V. If the input voltage drops below –1.4 V, the differential voltage between the comparator inputs again becomes positive, and the comparator output again switches to the $+U_b$ level. Note that the 'Low' output level of the window comparator is $-U_b$ instead of ground, due to the complementary supply voltages.

A version of the window comparator that works with a single supply voltage can be implemented by tying the common terminal of the diodes to a freely selectable intermediate voltage. The schematic diagram for such an arrangement is shown in **Figure 2**, where opamp IC2 acts as a low-impedance source of reference voltage U_{center}. The voltage at the centre of the window can be adjusted to the desired value using the trimpot.

The width of the voltage window is determined by the diodes alone and amounts to twice the forward voltage drop (0.7 V) of a single diode. The width of the window can easily be enlarged by connecting additional diodes in series with D1 and D2. That can be done symmetrically, but it can also be done asymmetrically, such as by only wiring an additional diode in series with each of D1b and D2b. In the latter case, the window will not be symmetric about voltage U_{center} (U_{center} ± 0.7 V), but will instead extend from U_{center} – 0.7 V to U_{center} + 1.4 V.

The circuit works with practically any type of comparator, such as the familiar LM399 or LP399 (low-power) quad comparator IC with supply voltages between ±2 V and ±18 V. IC2 in Figure 2 must be a rail-to-rail type (such as the LM7301) that is rated for the same supply voltage range as the comparator.

(040432-1)

Simple Stepper Motor Driver

063

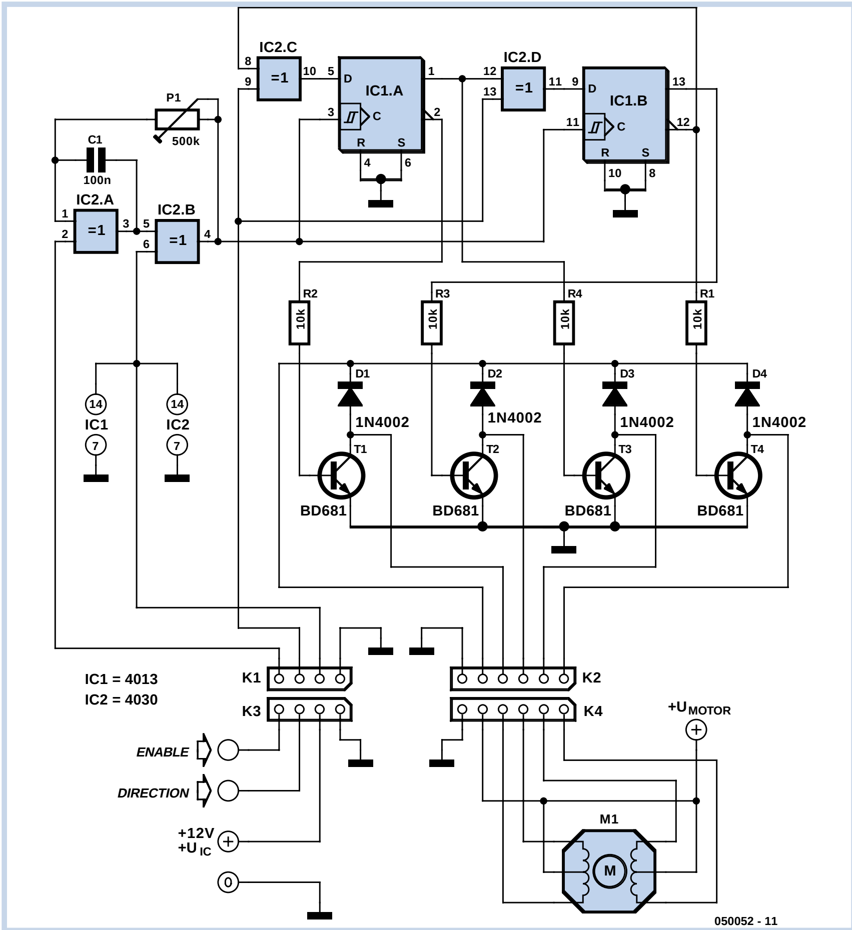
Paul Goossens

There is hardly any field in the world of electro-mechanics that has not found an application for the stepper motor. They are used extensively in the world of model making and as actuators in remote control equipment. In industry, picture scanners and printers are probably the most obvious devices that simply would not function without them, so no excuse is needed to include this very simple 4-phase stepper motor driver design in this collection of circuits. The circuit clock generator is formed from two exclusive OR (XOR) gates IC2A and IC2B together with C1 and P1. A logic '0' on the ENABLE input enables the clock generator and its output frequency is defined by:

$$1.4\ P1C1$$

The output signal from the clock generator is connected to the clock inputs of the two D-type flip-flops IC1.A and IC1.B. These two flip flops are connected together in a ring to form a 2-bit shift register so that the $\overline{Q}$ output of IC1.B is fed back to the D input of IC1.A and the Q output of IC1.A is fed into the D input of IC1.B. This configuration supplies the 4 phase impulses necessary to provide motor rotation. When the DIRECTION input is changed to logic zero IC2C and IC2D operate as non-inverting gates, reversing the phase sequence of the output signals and making the motor spin in the opposite direction.

The actual rotation direction will depend on the sense of the motor windings.



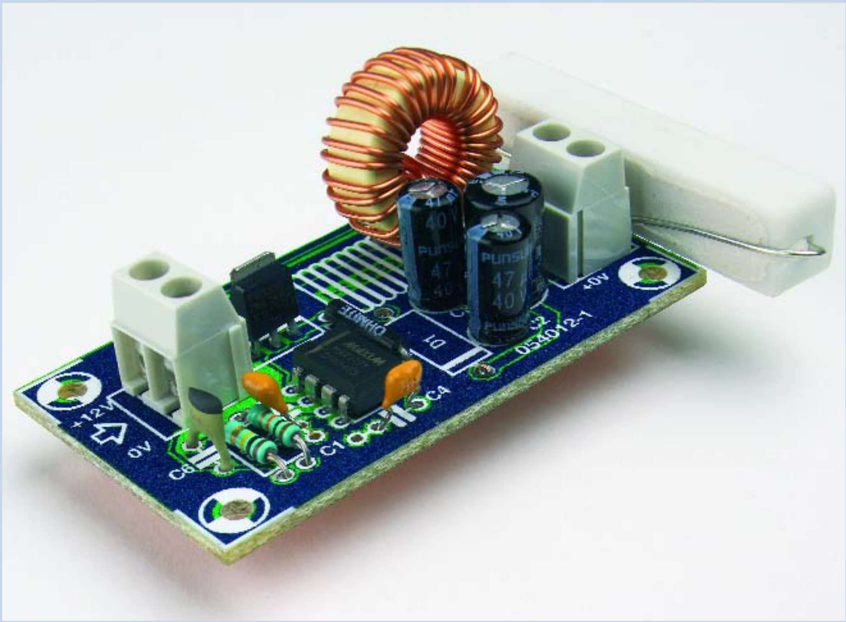
Swapping the outer two coil connections on one of the windings will reverse the direction if this is necessary.

With the components specified the circuit oscillates at a frequency of 10 Hz. The clock frequency can be adjusted between 0.2 and 100 Hz by substituting different values for P1 and C1. It is important to ensure that power drawn by the stepper motor is within the power handling capability of the driver transistors T1 to T4. Diodes D1 to D4 are necessary to conduct away the back-EMF produced each time a drive impulse to each of the motor coils is switched off.

(050052-1)

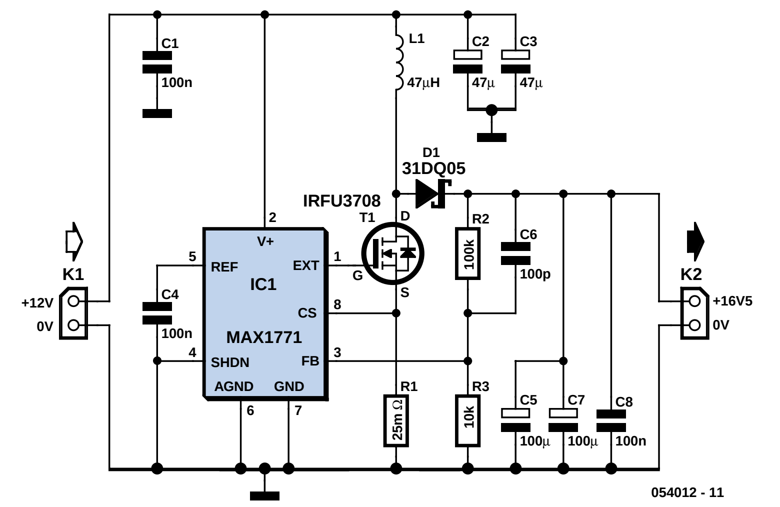
064

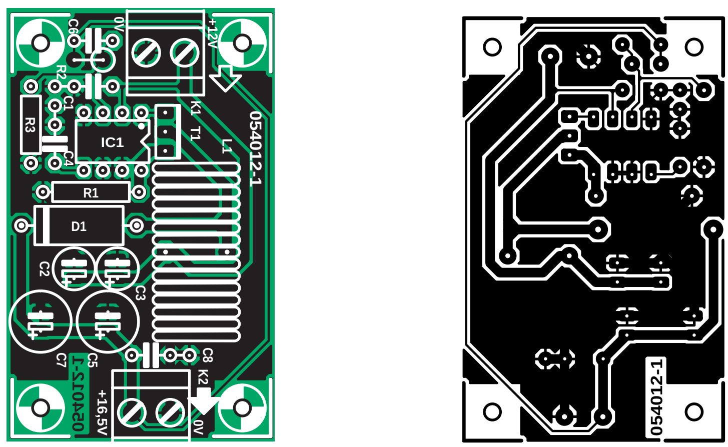
Extension for LiPo Charger



The 'Simple LiPo Charger' published in *Elektor Electronics* April 2005 is a small and handy circuit that allows you to quickly charge two or three LiPo cells. Especially in the model construction world are LiPo batteries used a lot these days, particularly model aeroplanes. It is usual to use a series connection of three cells with these models. Since working with these model aeroplanes usually happens in the field, it would be nice if the batteries could be charged from a car battery. We therefore designed a voltage converter for the LiPo charger concerned, which makes it possible to charge three cells in series. The voltage per cell increases while charging to a value of about 4.2 V, which gives a total voltage of 12.6 V. The converter, therefore, raises the 12-V voltage from the car battery to 16.5 V, from which the LiPo charger can be powered.

A step-up controller type MAX1771 in combination with an external FET carries out the voltage conversion. The IC operates at a moderately high switching frequency of up to 300 kHz, which means that quite a small coil can be used. Because the IC uses pulse frequency modulation (PFM) it combines the advantages





COMPONENTS LIST

Resistors:
R1 = 25mΩ (e.g., Digikey # 2FR025-ND)
R2 = 100kΩ
R3 = 10kΩ

Capacitors:
C1,C4,C8 = 100nF
C2,C3 = 47µF 25V radial
C5,C7 = 100µF 25V radial
C6 = 100pF

Semiconductors:
D1 = 31DQ05 (e.g., Digikey # 31DQ05-ND)
IC1 = MAX1771-CPA (e.g., Digikey # MAX1771EPA-ND)
T1 = IRFU3708 (e.g., Digikey # IRFU3708-ND)

Miscellaneous:
K1,K2 = 2-way PCB terminal block, lead pitch 5mm
L1 = 47µH high current suppressor coil, (e.g, Digikey # M9889-ND)
PCB.,ref. 054012-1 from The PCBShop

of pulsewidth modulation (high efficiency at high load) with very low internal current consumption (110 µA).
The IC is configured here in the so-called non-bootstrapped mode, which means that it is powered from the input voltage (12 V). The output voltage is adjusted with voltage divider R2/R3. This can be set to any required value, provided that the output voltage is greater than the input voltage.

Finally, sense resistor R1 determines the maximum output current that the circuit can deliver. With the 25 mΩ value as indicated, this is 2.5 A.

(045012-1)

Transistor Dip Meter

065

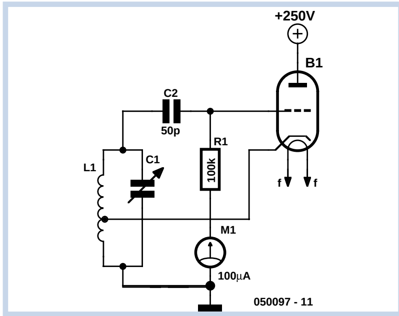
Burkhard Kainka

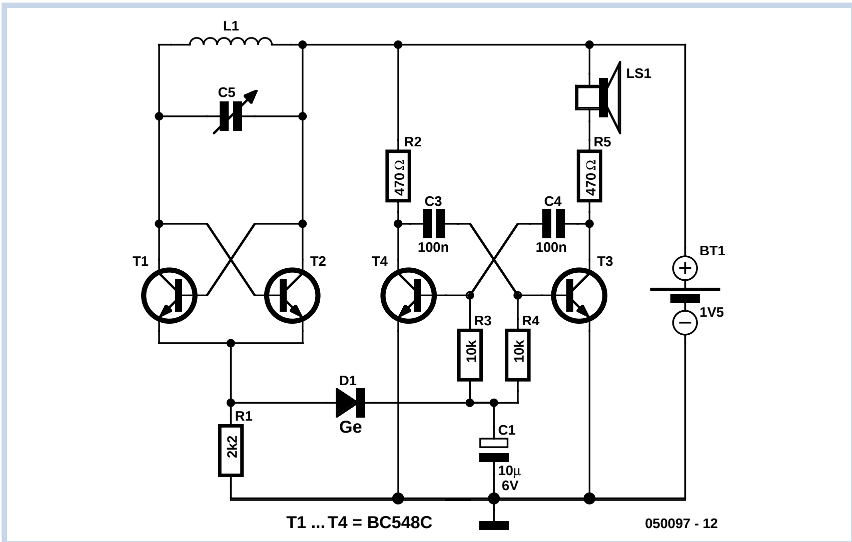
The dip meter consists of a tunable RF oscillator whose resonant circuit is held in the vicinity of a resonant circuit to be checked. If the frequencies of the two circuits match, the circuit being measured draws energy from the oscillator circuit. This can be measured. This type of meter is also called a ‘grid dip meter’, since it was originally built using a valve. The amplitude of the voltage on the tuned circuit could be measured from the grid leakage current. Such meters typically have a set of interchangeable coils and several frequency scales.

A meter that can manage with a low voltage of only 1.5 V can be built using a circuit with two transistors. In addition, a coil tap is not required in this design. That makes it easy to connect many different coils to cover a large number of frequency bands.

If a sufficiently sensitive moving-coil meter is not available, an acoustic signal can be used instead of a pointer display. This involves a sound generator whose frequency increases when its input voltage rises. A resonance dip is then indicated by a falling tone. This acoustic indicator draws less current from the measurement rectifier than a moving-coil instrument. That allows the amplitude of the oscillation to be decreased slightly by reducing the emitter current. This increases the sensitivity, so the dip meter can measure resonant circuits at greater distances.

(050097-1)





Three-component Li-ion Charger

066

Gregor Kleine

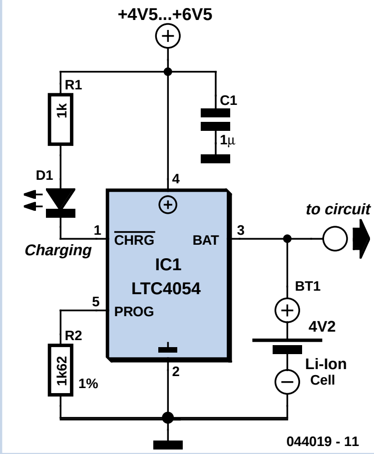
The LTC4054 from Linear Technology (www.linear.com) is a very simple device for charging 4.2 V Li-ion batteries. This SMD IC comes in a five-pin SOT-23 package and needs just two external components (the LED is not absolutely essential): a decoupling capacitor of at least 1 µF and a resistor connected to pin 5 (PROG) to set the charging current. The value of 1.62 kΩ shown here gives a charging current I_{CELL} of 600 mA when the device is in constant current mode. The formula

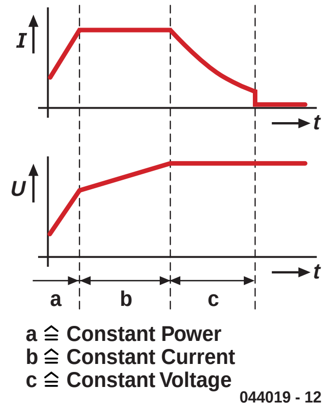
$$I_{CELL} = 1000\ (V_{PROG}/R_{PROG})$$

where V_{PROG} = 1 V, gives the charging current in terms of R_{PROG}.

The device works from a supply voltage of between 4.25 V and 6.5 V and is therefore suitable for connection to a USB port on a computer. To avoid risk of damage to the cells, the charging process is divided into three stages. In the first stage, which is brief, a constant power is delivered to the cell. In the next stage a constant current is delivered, and the cell voltage rises linearly. Finally the devices switches to a constant voltage mode, and the current drops off sharply.

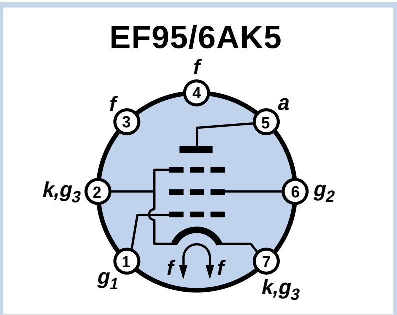
The LTC4054 goes into a high-impedance state when the input voltage falls below a set value to ensure that the battery does not get discharged. The $\overline{\text{CHARGE}}$ pin (pin 1) indicates the charging state. It is an open drain output which is pulled down to ground via a low impedance during charging, allowing an LED to be connected. The pin sinks approximately 20 µA to ground when the Li-ion cell voltage is between 2.9 V and 4.05 V: this is the standby state. If the cell voltage falls below 2.9 V, the LTC4054 begins charging again. $\overline{\text{CHARGE}}$ goes into a high-impedance state if the input voltage is not at least 100 mV higher than the cell voltage. The under-voltage lockout circuit is then activated, with less than 2 µA being drawn from the cell.





(044019-1)

067 DRM Double Superhet Receiver



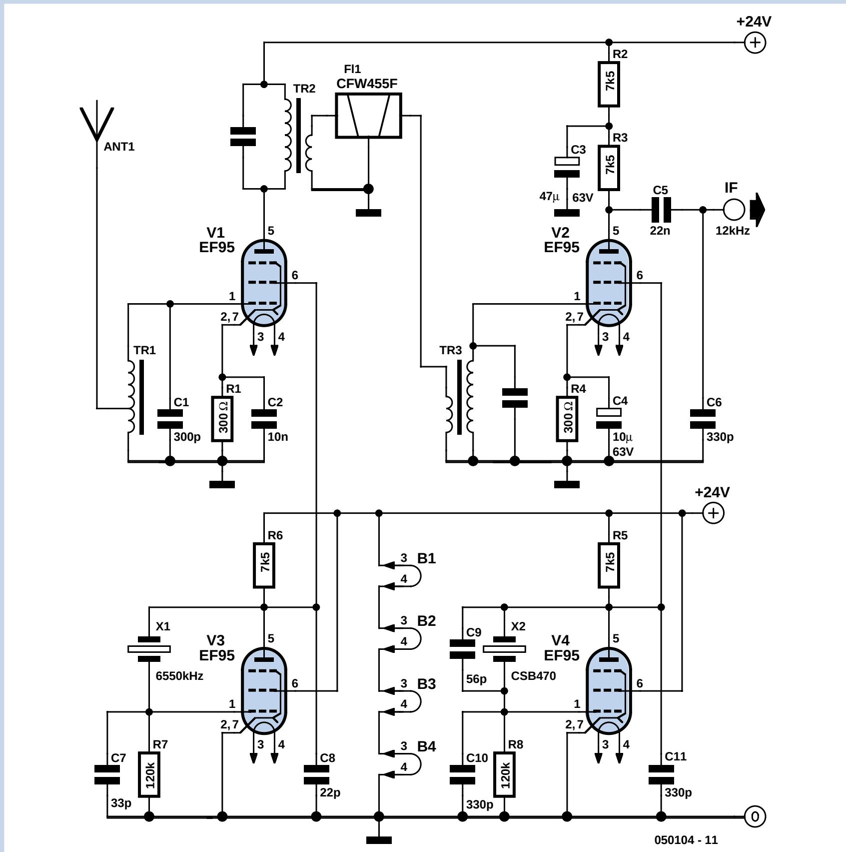
Using an EF95/6AK5

Burkhard Kainka

This receiver arose from the desire to demonstrate that valves are fully capable of holding their own against modern semiconductor devices. Valves often have better large-signal characteristics and less noise. The decisive difference is that the circuit must be designed with higher input and output impedances.

This circuit is built using four EF95 (US equivalent: 6AK5) valves, since this type of valve is small and has proved to operate well with low anode voltages. All four heaters are connected in series and operated from a 24-V supply. That makes it attractive to use the same supply for the anode voltage. The achievable gain is fully adequate.

The receiver is designed for the RTL DRM channel at 6095 kHz. It consists of two mixer stages with two crystal oscillators. A steep-edged ceramic filter (type CFW455F) with a bandwidth of 12 kHz provides good IF selectivity. Thanks to the high-impedance design of the circuit, the valves achieve a good overall gain level.



The receiver performance is comparable to that of the *Elektor Electronics* DRM receiver design published in the March 2004 issue, and it can even surpass the performance of the latter circuit with a short antenna, since the tuned input circuit allows better matching to be obtained. The key difficulty is obtaining a suitable crystal with a frequency of 6550 kHz. Old-style FT243 crystals with exactly this frequency are available from American army radio units. However, it takes a bit of luck to obtain a crystal with exactly the right frequency. It's also possible to use a standard crystal with a frequency of 6553.6 kHz, which yields an IF that is 3.6 kHz too high. However, that shouldn't be a problem if a relatively wide-bandwidth ceramic filter is used. One possibility is the CFW455C, which has a bandwidth of 25 kHz. If the frequency of the second crystal oscillator remains unchanged, the DRM baseband signal will appear at around 9 kHz, approximately 3 kHz below the nominal value. Nevertheless, the signal can easily be decoded by the DREAM software, since it does not depend on the signal being at 12 kHz. Another possibility would be to use the programmable crystal oscillator design published in the March 2005 issue of *Elektor Electronics*.

(050104-1)

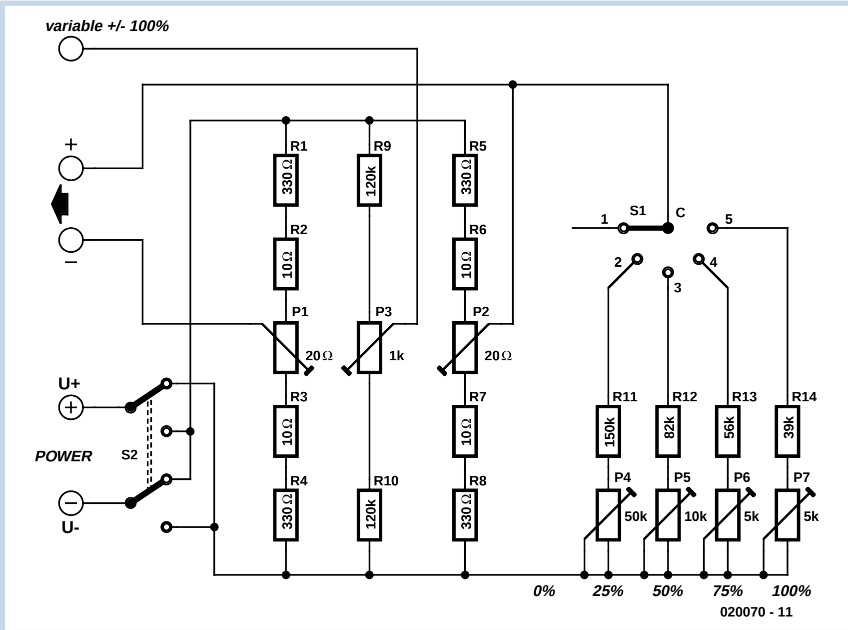
Simulator for Bridge Measurements

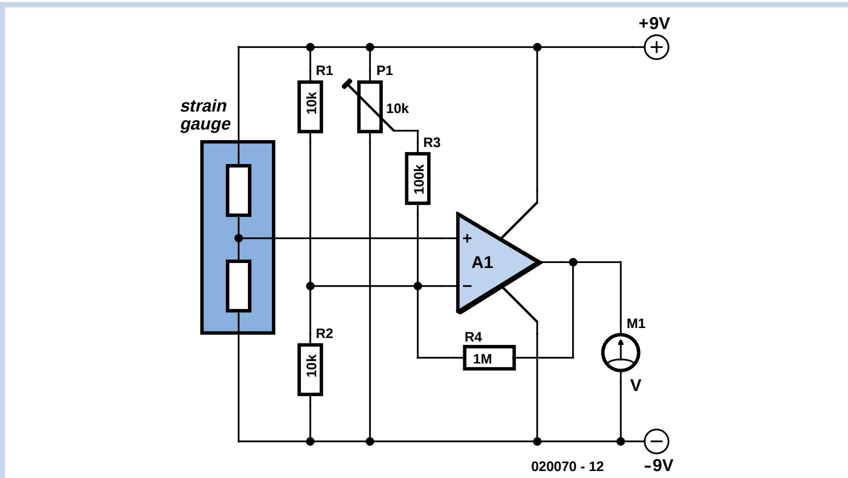
068

Bernd Schaedler

The arrangement of resistors shown here can be used to test bridge amplifiers with differential inputs. Such amplifiers are used in conjunction with strain gauges, for example, or in measuring inductances or capacitances. Because of their symmetrical construction, bridges allow the tiniest variations in the quantity in question (for example, resistance) to be amplified without resorting to complex compensation techniques.

The circuit here simulates small variations in one of the resistors that forms the bridge, as happens in the example of strain gauges. Since only standard metal film resistors are used, it is suitable only for general testing of the connected amplifier. Strain gauges typically have a sensitivity of 2 mV/V. This means that if the supply voltage to the bridge is 10 V, the maximum variation in differential voltage taken from the bridge to the differential amplifier is 20 mV. The resistance of this circuit is rather greater than the 350 Ω typical of strain gauges, but in practice this is not important.





Calibrating the bridge simulator

Ensure that the power supply voltages connected to the positive and negative supply inputs have exactly equal magnitude (+5.000 V and –5.000 V). Now connect a voltmeter between the negative output and ground and adjust P1 so that the meter reads as close to 0 mV as possible. Now connect the voltmeter across the two outputs and set S1 to '0 %'. Adjust P2 until the voltmeter reads as close to 0 mV as possible.

Finally, switch S1 to the '25 %', '50 %', '75 %' and '100 %' positions in turn and adjust the corresponding trimmer potentiometers P4 to P7 to obtain voltages of 5 mV, 10 mV, 15 mV and 20 mV respectively, with the voltmeter still connected between the positive and negative outputs. Once this calibration process has been carried out, you can now simulate a varying bridge resistance by switching S1 with a differential amplifier connected across the positive and negative outputs.

If the variable output is used instead of the positive output, the voltage can be varied continuously over the full positive and negative range using potentiometer P3. Switch S2 allows the polarity of the supply voltage to be reversed.

(020070-1)

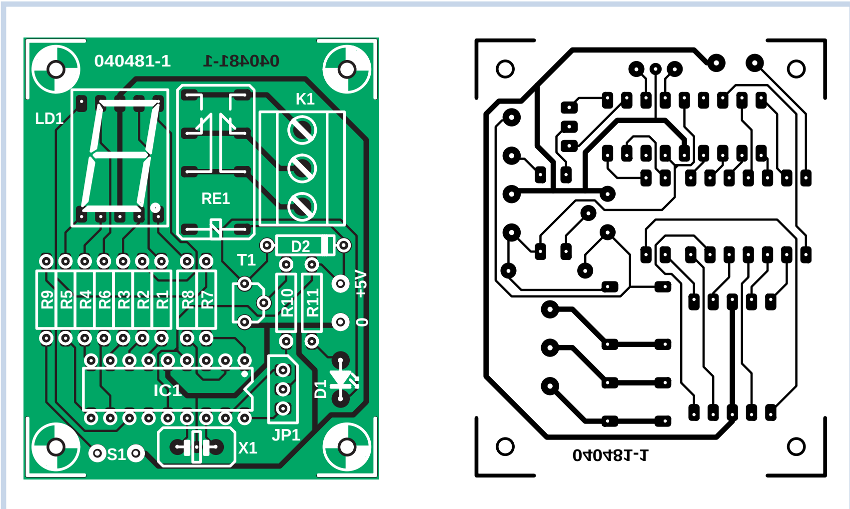
069

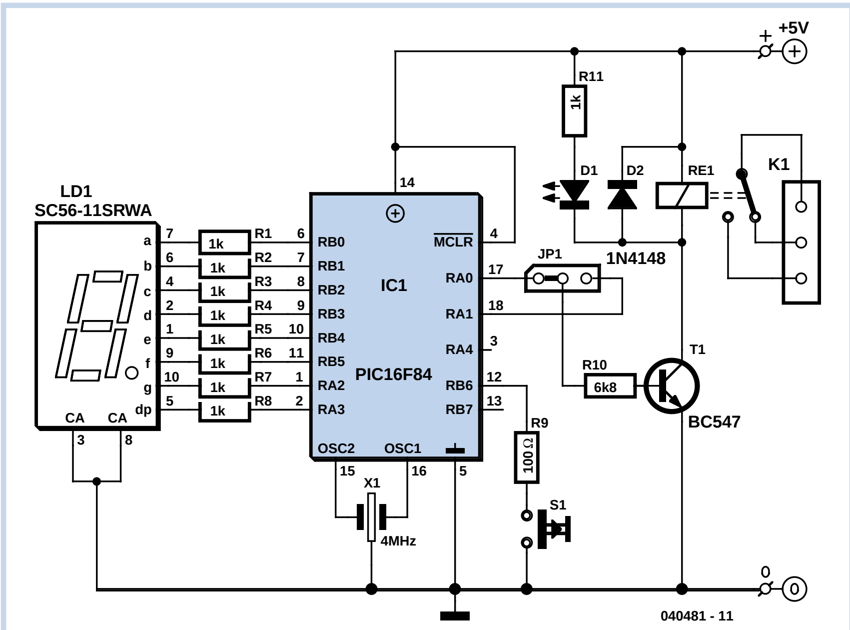
Code Lock with One Button

Zorislav Miljak

The unusual feature of this code lock is that it can be operated with just one pushbutton. In situations where a tamper-proof solution is required this circuit has a great financial advantage: only one robust pushbutton needs to be bought. The disadvantage of this solution is that it takes a little longer to enter the code.

The operation of the code lock is as follows. After pressing the button, the PIC16F84 starts to count at a rate of one hertz. The numbers are visible on the LED display. The button is released once the correct number is displayed. This operation is repeated for the other digits in the code. The time between releasing the button and pressing it again for the next digit may not be more than 15 seconds. After the last digit, the letter ‘E’ (Enter) needs to be entered. If the entered code is incorrect, the display will show an ‘F’ (Fault) for 15 sec-





COMPONENTS LIST

Resistors:
R1-R8, R11 = 1kΩ
R9 = 100Ω
R10 = 6kΩ8

Capacitors:
C1 = 100nF

Semiconductors:
D1 = LED, green, low-current
D2 = 1N4148
IC1 = PIC16F84 (programmed, order code **040481-41***)
LD1 = 7-segment display, red, common-anode (e.g., Kingbright Sc56-11SRWA)
T1 = BC547B

Miscellaneous:
JP1 = 3-way SIL pinheader with jumper
K1 = 3-way PCB terminal block, lead pitch 5mm
Re1 = relay, 5V coil, (e.g., Omron G6A-234P-ST-US-DC5)
S1 = switch, 1 make contact, tamper proof (see text)
X1 = 4MHz ceramic resonator
PCB, ref. 040481-1 from The PCBShop Disk, source and hex code, order code **040481-11***

* see Elektor SHOP pages or www.elektor-electronics.co.uk

onds. If the code has been entered incorrectly three times in a row, the lock will block further input for 1 minute. During this time the display shows a flashing ‘F’.

To alter the code, it is necessary to hold the button until the letter ‘C’ appears (Change code). The display subsequently shows an ‘o’ (Old code). Now enter the (valid) old code, followed by an ‘E’. The PIC now asks for the new code by displaying an ‘n’ (New code). Now enter the new code, also followed by ‘E’. The display now shows ‘c’ (Confirm). Repeat entry of the new code (and once again an ‘E’ as confirmation). The code is now changed. A maximum of 10 digits can be used for the code.

JP1 is used to set whether the relay is energised or de-energised when the correct code has been entered. You can use a standard 5-V regulated mains adapter for the power supply.

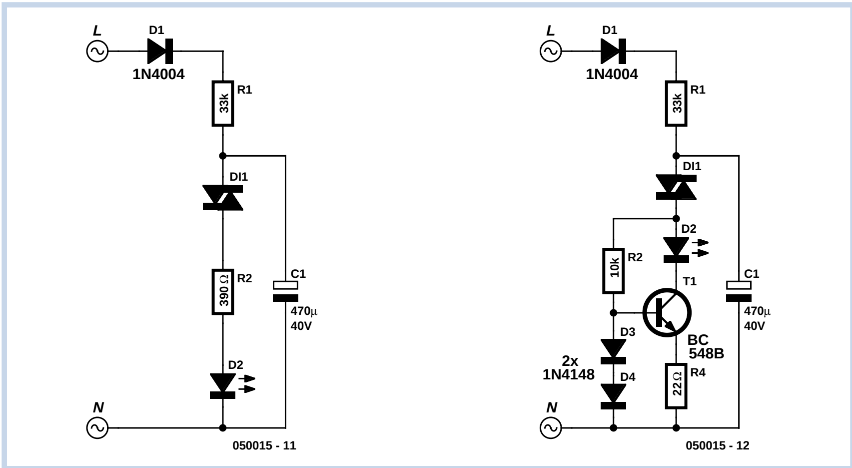
(040481-1)

LED Flasher for 230 V

070

Matthias Haselberger

The small circuit shown here could act as a power indicator for the 230 V mains supply and in terms of efficiency is the equal of classical neon bulbs. Note first that the LED in this circuit flashes rather than lighting continuously, and is therefore also suitable for applications where a flashing light is wanted for decorative purposes or as a gimmick.



Caution: high voltage
This circuit is connected directly to the mains, and it is therefore dangerous to touch any part of it. This goes for the LED itself as well. It is absolutely essential to build the circuit in an insulating touchproof plastic enclosure; see also the safety advice pages.

Diode D1 rectifies the input voltage, and C1 is charged by the rectified mains voltage via R1. When, after a number of half-cycles of the mains, the voltage on C1 exceeds the breakover voltage of the diac D2, the diac conducts and C1 discharges via R2 and light-emitting diode D3. This discharge results in a brief flash of light. A 470 µF/40 V capacitor is suitable for C1. For the diode a 1N4004 can be used, and R1 should have a value of 33 kΩ, be rated at 0.6 W and be suitable for use at 350 V. As an alternative, the value of 33 kΩ can be made up from two (or more) resistors wired in series: for example, 15 kΩ + 18 kΩ or 2 x 10 kΩ and 1 x 12 kΩ. R2 should be 390 Ω. The firing voltage of the diac should be 30 V. Using these values the LED flashes for 0.3 s every second.

(050015-1)

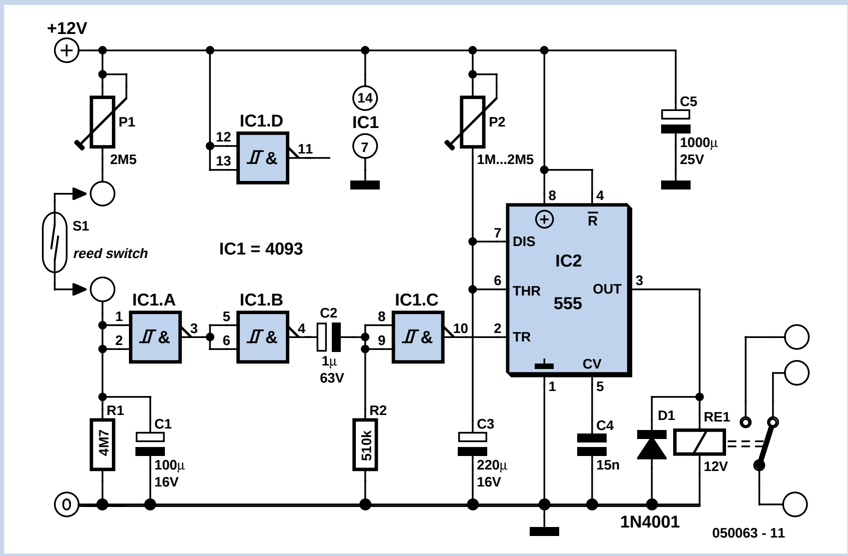
On-demand WC Fan

071

Ton Giesberts

In most WCs with an extractor the fan is connected to the lighting circuit and is switched on and off either in sympathy with the light or with a short delay. Since toilets are sometimes used for washing the hands or just for a quick look in the mirror, it is not always necessary to change the air in the smallest room in the house. The following circuit automatically determines whether there really is any need to run the fan and reacts appropriately. No odour sensor is needed: we just employ a small contact that detects when and for how long the toilet seat lid is lifted. If the seat lid is left up for at least some presettable minimum time t_1, the fan is set running for another presettable time t_2. In the example shown the contact is made using a small magnet on the lid and a reed switch mounted on the cistern. The rest is straightforward: IC2, the familiar 555, forms a timer whose period can be adjusted up to approximately 10 to 12 minutes using P2. This determines the fan running time. There are three CMOS

NAND gates (type 4093) between the reed switch and the timer input which generate the required trigger signal.
When the lid is in the 'up' position the reed switch is closed. Capacitor C1 charges through P1 until it reaches the point where the output of IC1a switches from logic 1 to logic 0. The output of IC1b then goes to logic 1. The edge of the 0-1 transition, passed through the RC network formed by C2 and R2, results in the output of IC1c going to logic 0 for a second. This is taken to the trigger input on pin 2 of timer IC2, which in turn switches on the relay which causes the fan to run for the period of time determined by P2.
The circuit is powered from a small transformer with a secondary winding delivering between approximately 8 V and 10 V. Do not forget to include a suitable fuse on the primary side. The circuit around IC1b and IC1c ensures that the fan does not run continuously if the toilet seat lid is left up for an extended period.

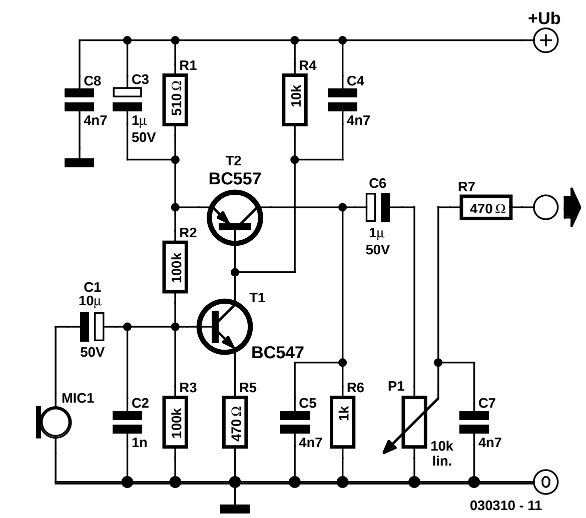


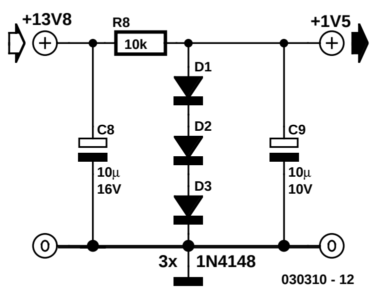
The time constant of P1 and C1 is set so that the fan does not run as a result of lavatorial transactions of a more minor nature, where the lid is opened and then closed shortly afterwards, before C1 has a chance to charge sufficiently to trigger the circuit.

(050063-1)

072

Simple Microphone Preamplifier





for Radio Amateurs

Ludwig Libertin

The technical demands on microphones used with radio equipment are not stringent in terms of sound quality: a frequency response from around 50 Hz to 5 kHz is entirely adequate for speech. For fixed CB use or for radio amateurs sensitivity is a more important criterion, so that good intelligibility can be achieved without always having to hold the microphone directly under your nose. Good microphones with extra built-in amplifiers can be bought, but, with the addition of a small preamplifier, an existing microphone will do just as well.
The project described here uses only a few discrete components and is very undemanding. With a supply voltage of between 1.5 V and 2 V it draws a current of only about 0.8 mA. If you prefer not to use batteries, the adaptor circuit shown, which uses a 10 kΩ resistor, three series-connected diodes and two 10 µF electrolytic smoothing capacitors, will readily generate the required voltage from the 13.8 V supply that is usually available.
There is little that need be said about the amplifier itself. Either an ordinary dynamic microphone or a cheaper electret capsule type can be connected to the input. In the latter case a 1 kΩ resistor needs to be connected between the 1.5 V supply volt-

age and the positive input connection. The impedance of the microphone and of the following stage in the radio apparatus are not of any great importance since the available gain of 32 dB (a factor of 40) is so great that only in rare cases does P1 have to be set to its maximum position.

With a frequency range from 70 Hz to about 7 kHz, low distortion, and small physical size, the preamplifier is ideal for retrofitting into the enclosure of the radio equipment or into the base of a microphone stand.

In case you are concerned about our somewhat cavalier attitude towards distortion: for speech radio the 'fi' does not need to be 'hi'. Quite the reverse, in fact: the harmonics involved in a few percent of distortion can actually improve intelligibility — *it's not a bug, it's a feature!*

(030310-1)

9-in-1 Logic Glue / Level Translators

073

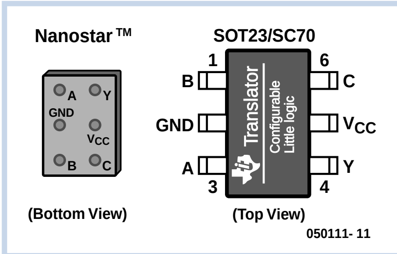
Dirk Gehrke

Two logic devices from revered Texas Instruments, the SN74AUP1T97 and '98 are logic glue components in tiny SOT23 cases. As shown in the diagrams, both the AUP1T97 and its inverting counterpart the AUP1T98 can be configured as voltage level translators with nine different logic functions marked by Schmitt trigger inputs. Apart from their logic function, these devices can also act as voltage level translators between low-voltage logic systems, as follows:

in	out	at Vcc
1.8 V	3.3 V	3.3 V
2.5 V	3.3 V	3.3 V
1.8 V	2.5 V	2.5 V
3.3 V	2.5 V	2.5 V

An example of a level translator could be one converting from 1.8 V LVCMOS to 3.3 V LVTTL or LVCMOS.

The devices, says TI, are tolerant to slow input transitions and noisy signals.



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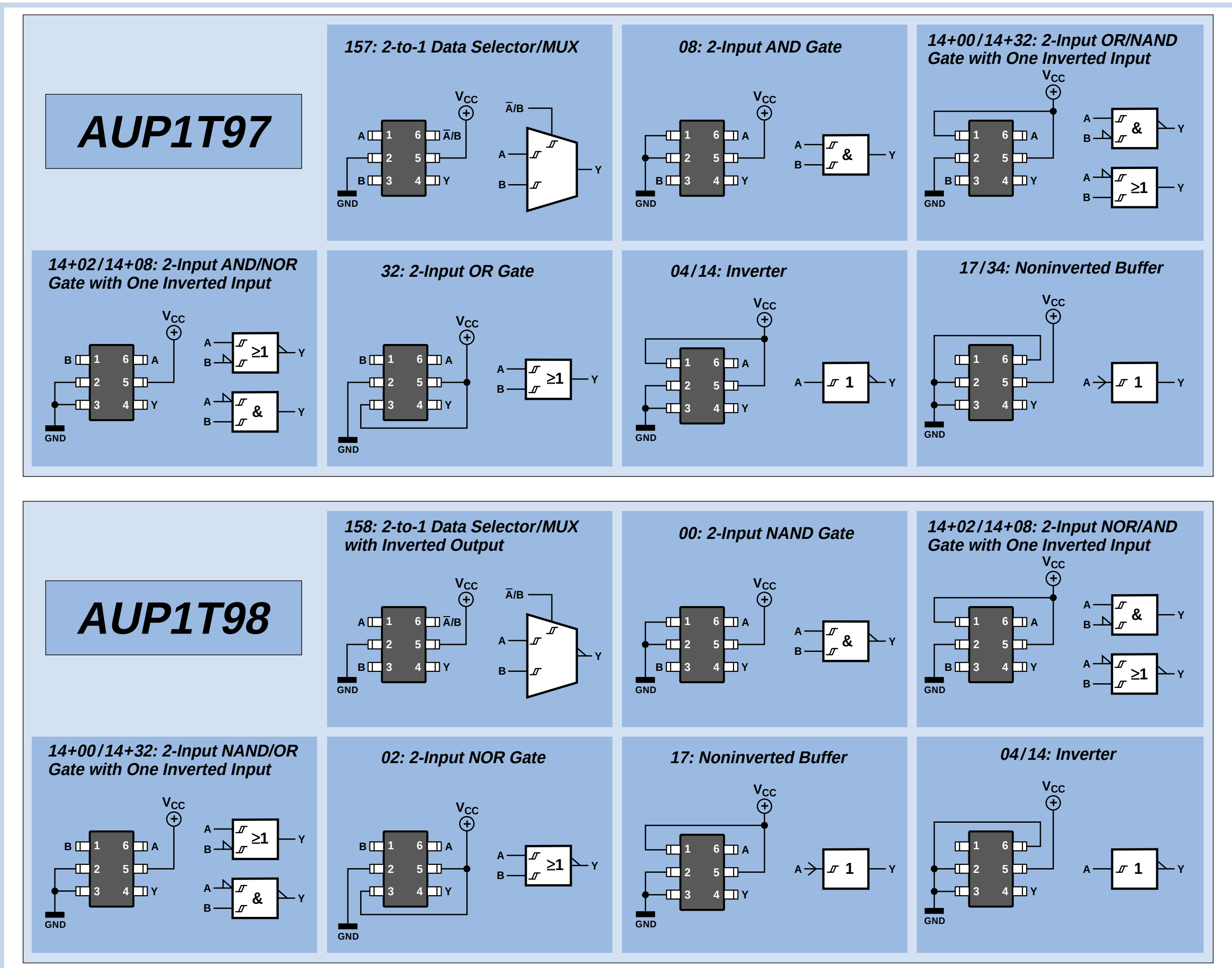
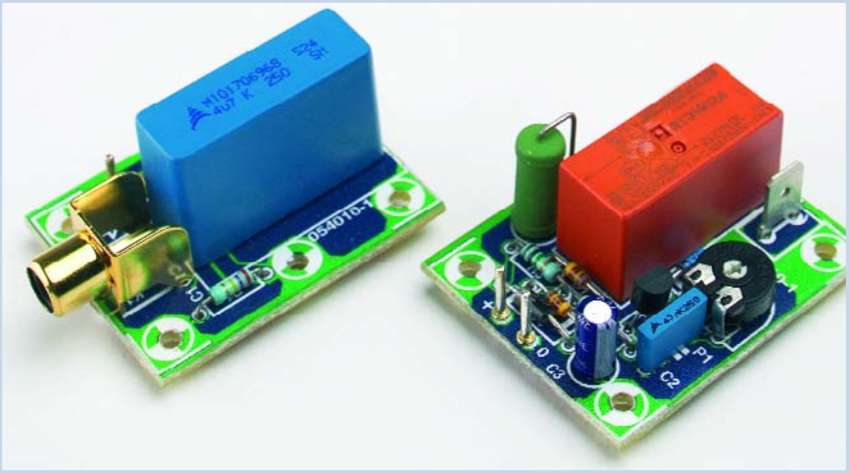


074 Universal I/O for Power Amps

Ton Giesberts



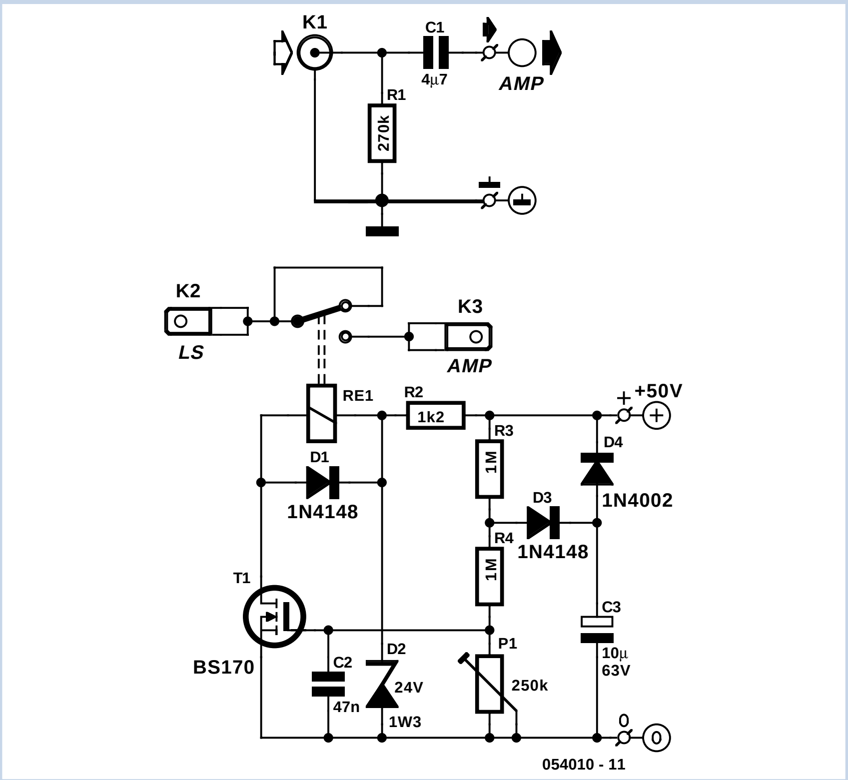
This two-part circuit was designed as an addition to the 'Compact 200 W Output Stage' in this issue. But it is also suitable for use with IC amplifiers that don't have their own power-on delay.

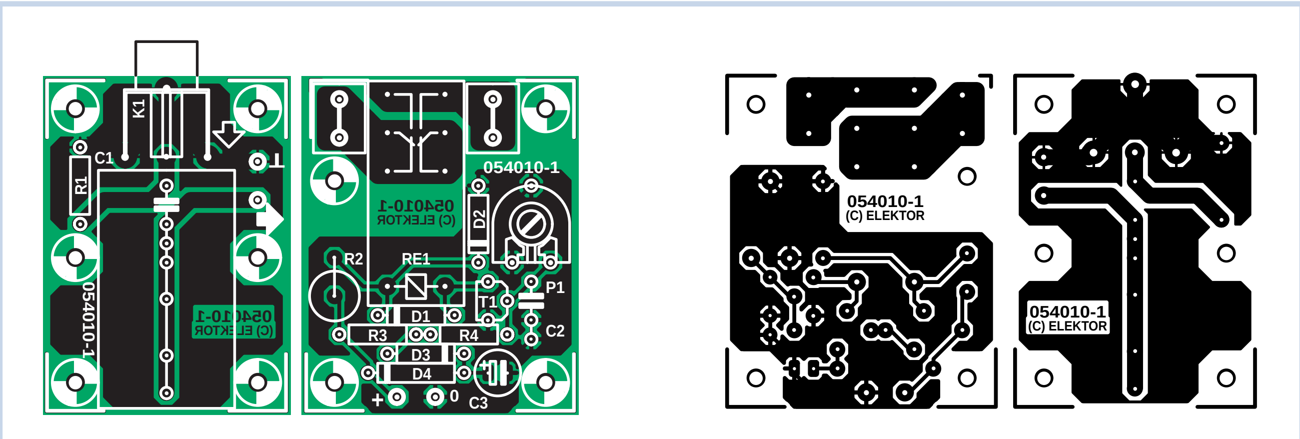
The circuit consists of an input stage (nothing more than a resistor and capacitor) and a power-on delay with a relay for the amplifier output.

A small PCB has been designed for the input signal. This board contains a phono socket, capacitor and a resistor that is connected directly across the input. This resistor keeps the input side of the capacitor at ground level. It prevents any offset voltage at the amplifier input from appearing at the input of this circuit when there is no connection. This would otherwise cause a loud bang from the loudspeaker when a connection was made. We have taken account of the larger size of MKP and MKT capacitors. There are several mounting holes on the board to cater for the various sizes of capacitor. The maximum size is 18×27.5×31.5 mm (WxHxL).

To protect a loudspeaker from a DC offset during the switch-on period a relay needs to be connected in series that turns on after a short delay. This circuit also makes use of the falling supply voltage of the amplifier when it is switched off. This concept also makes this circuit suitable to protect against overloads.

The circuit itself is relatively straightforward. MOSFET T1 turns on relay RE1 when the gate-source voltage rises above 2.5 V. The gate voltage is derived directly from the amplifier supply via potential divider R3/R4/P1. P1 is used to adjust the exact level at which the relay turns on.





This is also used to compensate for the tolerance in the MOSFET threshold voltage. The relay operating voltage is limited to about 24 V by resistor R2. D2 restricts the voltage across T1 from rising above 24 V, stopping this voltage from rising too much when the relay is not actuated It also keeps the voltage at 24 V when a relay with a higher coil resistance is used (see parts list). When a relay with a lower coil resistance is used, the value of R2 needs to be adjusted accordingly. To calculate the value for R2 you should take the minimum acceptable supply voltage, subtract 24 V and divide the result by the current through the relay. This value should then be rounded to a value in the E12 series. There is room on the PCB for a vertically mounted 5W resistor for R2, so it's even possible to use a 12 V relay (D2 should then be changed to a 12 V type as well). D1 protects T1 from induced voltages when the relay is turned off. The voltage at the gate only reaches its end value slowly due to the addition of D3 and C3. D3 prevents C3 from keeping the MOSFET conducting when the voltage drops. When the voltage has fallen below half the normal supply voltage, C3 starts to discharge via D4. In this way the switch-on delay is at a maximum even when the power is turned off and on repeatedly.

It should be clear that this circuit can only be used with amplifiers that are stable until the threshold voltage is reached and hence do not create an offset at the output before the relay turns off.

(054010-1)

COMPONENTS LIST

Resistors:
R1 = 270kΩ
R2 = 1kΩ2
R3,R4 = 1MΩ
P1 = 250kΩ preset

Capacitors:
C1 = 4µF7 MKT or MKP (see text)
C2 = 47nF
C3 = 10µF 63V radial

Semiconductors:
D1,D3 = 1N4148
D2 = zener diode 24V 1.3W
D4 = 1N4002
T1 = BS170

Miscellaneous:
K1 = cinch socket, PCB mount, e.g. Monacor / Monarch T-709G
K2, K3 = spade terminal, PCB mount, vertical, 2 pins
RE1 = PCB relay 24 V/16 A (e.g., Omron G2R-1-24, 1100 Ω, or Schrack RT314024, 1440 Ω)
PCB, ref. 054010-1 from The PCBShop

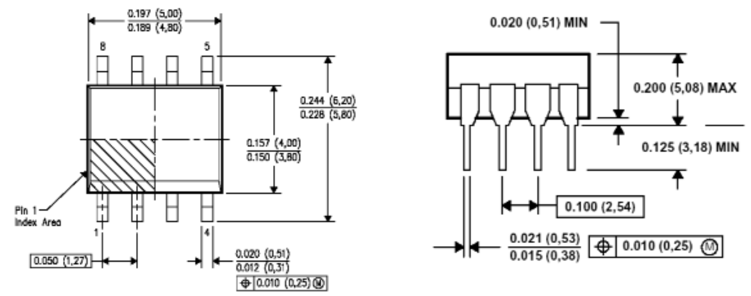
Modifying Stripboard for SO Packages

075

Dirk Gehrke

This technique for modifying standard predrilled prototyping stripboard ('perfboard' or veroboard') to accept SO IC packages is intended to be used for inexpensive breadboard constructions. It provides an economical alternative to using special circuit boards that accept SO packages and increase the lead spacing from 1.27 mm to the 2.54 mm grid spacing. The standard dimensions of SO and plastic DIP packages are shown for comparison in **Figure 1** (with metric dimensions in parentheses).

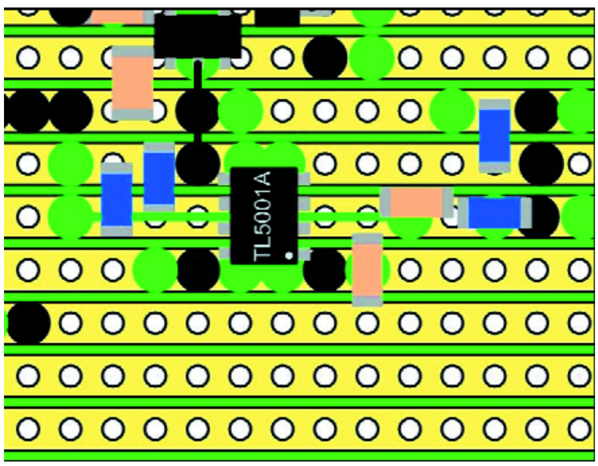
1



The grid spacing of predrilled stripboard is 2.54 mm. Predrilled stripboard is available in various sizes with glass–epoxy or paper–phenolic substrate material. It is commonly sold in Eurocard format with dimensions of 100 × 160 mm To allow an IC in a SO package to be soldered to the predrilled stripboard, a utility knife is used to separate a section of a strip down the middle through the holes, thus reducing the grid spacing from 2.54 mm to 1.27 mm. After being prepared in this manner, the board can accept SO packages. **Figure 2** shows a diagram of simple example application using a TL5001 in a SO package. Here the green points and lines represent cuts that must be made using a strip cutter and/or a utility knife.

(050119-1)

2



076 Remote Control Extension using RF

Transmitter

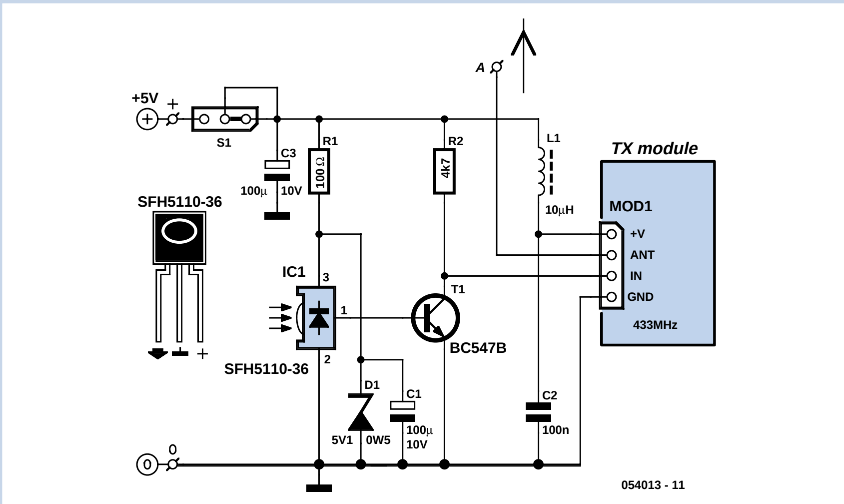
Ton Giesberts

We have, over the years, published numerous variations of remote control extenders in *Elektor Electronics*, but not yet one using RF.

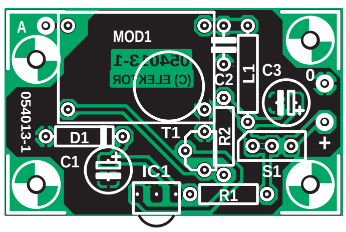
These days, transmit- and receive modules that operate on the well-known 433-MHz licence-free frequency are reasonably cheap and freely available at electronics stores. The circuit described here makes use of the transmitter/receiver combination available from Conrad Electronics, which stands out because of its low price. A disadvantage with this setup is the available bandwidth. At 2 kHz this is quite limited, but still sufficient for our purpose.

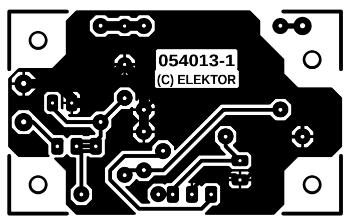
We assume that the RC5 remote control system from Philips is being used. It is now a little dated but still has many applications, particularly for your own designs. The minimum pulse width of RC5 amounts to 0.89 ms. The maximum frequency is therefore 562 Hz [$1/(2 \cdot 0.89 \cdot 10^{-3})$]. This still passes reasonably well through the RF link. However, at the receiver some pulse stretching is required.

The transmitter is simplicity itself. IC1 is an IR receiver for remote control systems. The output signal is active low. The pulses at the output, with RC5, have a minimum length of 0.89 ms. The transmitter is activated with an active high signal that is supplied by T1. When IC1 receives a pulse, T1 will leave conduction and the transmitter is turned on via R2.



The little transmitter module has 4 connections: ground, power (3 to 12 V), data input and antenna output. The transmitter module is mounted on our PCB and connected with four pieces of wire. The overlay makes incorrect assembly just about impossible. You can use a piece of wire of about 15.5 cm long (1/4 λ) as the antenna.





Current consumption in the idle state is about 4 mA and about 5.3 mA while transmitting. For the protection of IC1, a 5.1 V zener diode is connected in parallel with its power supply connections. An excessive power supply voltage is then turned into heat via decoupling resistor R1. That means that a power supply voltage of up to 10 V can be connected to the circuit without any problems (with a

COMPONENTS LIST

Resistors:
R1 = 100Ω
R2 = 4kΩ7

Capacitors:
C1, C3 = 100µF 10V radial
C2 = 100nF ceramic

Inductors:
L1 = 10µH

Semiconductors:
D1 = zener diode 5V1 0.5W
T1 = BC547B
IC1 = SFH5110-36

Miscellaneous:
S1 = miniature slide switch SX254 (Hartmann) (Conrad Electronics # 708062) or 3-way pinheader with jumper
MOD1 = 433.92 MHz AM transmitter module from Conrad Electronics set, # 130428
PCB, ref. 054013-1 from The PCBShop

power rating of at least 0.25 W for R4). A disadvantage is that the circuit draws a little less than 50 mA additional current. You can increase the value of R1, of course, when the power supply voltage is always at the high end of the range. The transmitter module can deal with 3 to 12 V and that limits the maximum supply voltage to 12 V.

According to the datasheet, the current consumption of IC1 is 5 mA. In our prototypes the current consumption was actually lower, less than 3 mA. R1 is then roughly $(U–5.1)/3.5 \cdot 10^{-3}$. However, just to be sure, measure the voltage across the IR receiver and check that it is correct.

You can use other devices for IC1, but keep in mind the current consumption and the pinout of the terminals. Another requirement is that the alternative IR-receiver has an active low output and an internal pull-up resistor. C1, L1 and C2 provide additional decoupling and C3 decouples the common power supply.

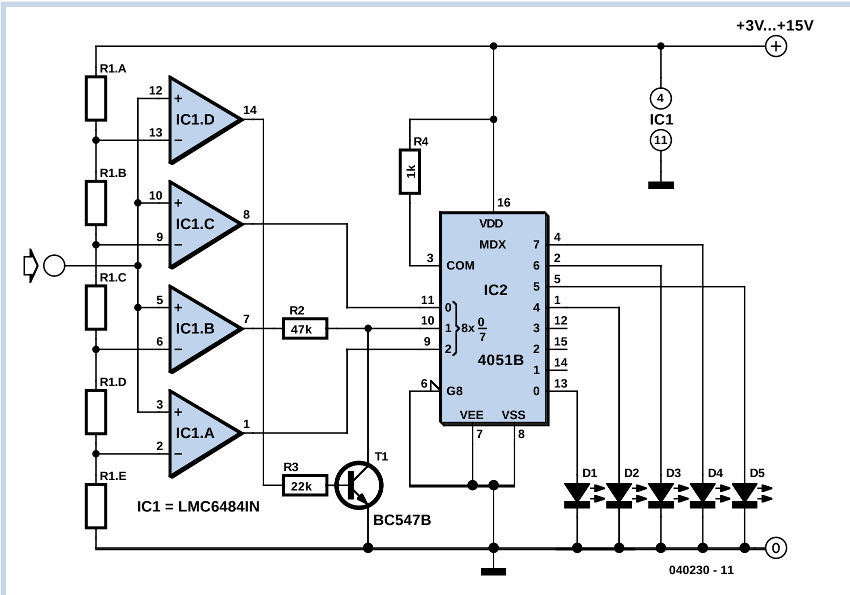
In place of S1 you could just fit a wire link or a 3-way pin header with a jumper. The switch is really only useful when the circuit is powered from batteries.

It is likely that the circuit will be placed in a fixed location and a regulated mains adapter as a power supply is more appropriate. On the PCB there is enough space so that IC1 can be fitted horizontally. The electrolytic capacitors can also be placed horizontally, so that the entire assembly can be quite thin, so that it can easily be mounted between, behind or in something.

(054013-1)

Cheap Dot-mode Bargraph Display

Rev. Thomas Scarborough



The five-stage linear dot-mode bargraph display shown in here has a number of distinct advantages, which may be summarized as:

- the resistor chain is fully customizable;
- IC1's high input impedance results in minimal loading on circuits;
- IC1 and IC2 have a wide supply voltage range, between 3V and 15V
- If a higher supply voltage is used, all colour LEDs may be employed with a single ballast resistor R3.

Four op-amp comparators are used to provide a five-stage output, as follows: as the voltage at the signal input rises, so the outputs of comparators IC1.A to IC1.D go High in succession. This creates the sequence at IC2's binary channel select and output channels shown in the **Table**. The last binary number in this sequence is created as IC1.D goes High, thus pulling IC2 binary input 1 Low through T1. In this way, five of the (IC2) 8-to-1 analogue multiplexer/demultiplexer output channels are utilised to produce a five-stage linear dot-mode bargraph display.

The signal input voltage required to switch any one of IC1's four outputs may be calculated by dividing the supply voltage by the values in the resistor chain. For example, if the supply voltage is 12 V, and all of the resistors in the chain are 10 kΩ, then IC1.C's output pin 8 (and IC2's output channel 6) will swing High as the voltage of the signal input exceeds

$$12\text{ V} \times [(R3+R4+R5) \div (R1+R2+R3+R4+R5)] = 7.2\text{ V}$$

The only aspect of the circuit which might require special clarification is T1. T1 pulls IC2's binary channel select input 1 Low by shorting it to 0 V, thus overriding IC1.B's output pin 7. This creates one additional binary input number (binary 101) for IC2, and adds a fifth stage to the bargraph. A 'logic' MOSFET such as a BUZ11 or IRF510 would also work in this position, and in this case R1 may be omitted.

The LMC6484IN opamp indicated in the circuit diagram is a rail-to-rail type which may be difficult to source. If you use an 'old fashioned' opamp like the LM324, do remember that the input voltage may not exceed the supply voltage minus about 1.5 volts. In the case of the TL074 (TL084), the reverse applies: the input voltage must be comprised between 1.5 volts and the supply rail level. This is called the *common-mode range* of the opamp — check the datasheets!

IC2 Channel Select	IC2 Output Channel
2 1 0	
0 0 0	0
1 0 0	4
1 1 0	6
1 1 1	7
1 0 1	5

Resistor R3 determines the LED current and may need to be adapted to match whatever LEDs you have available for the readout. Since the output current of 4000 series CMOS ICs needs to be observed, it is a good idea to use high-efficiency LEDs of the 2-mA class. The value of R3 is calculated from

$$R3 = (V_b - 2)\text{ volts} / 3$$

where the result is in kilo-ohms.

(040230-1)

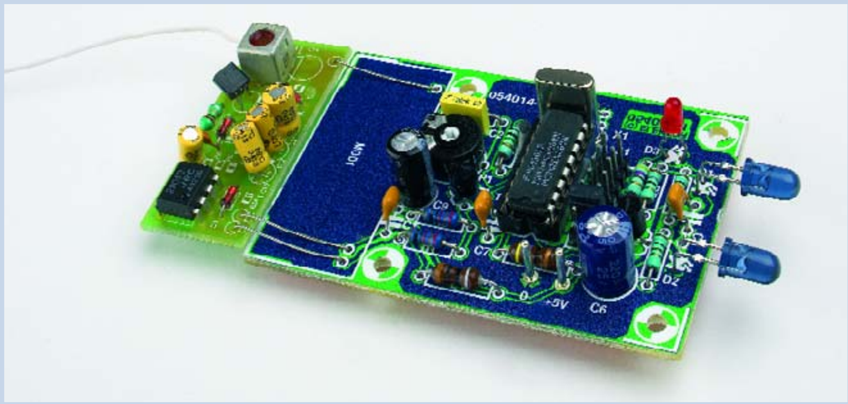
078 RF Remote Control Extender: Receiver

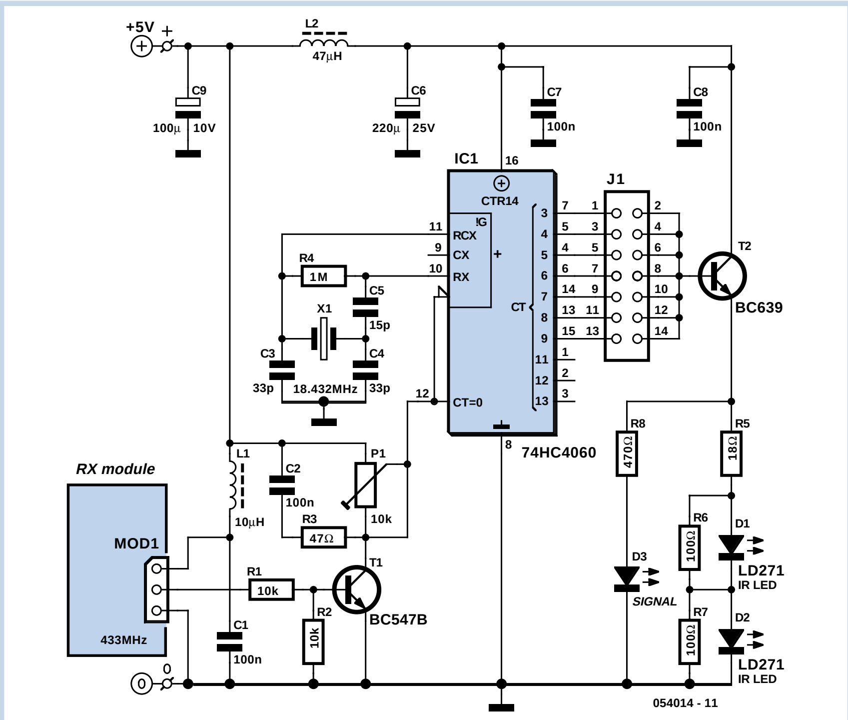
Ton Giesberts

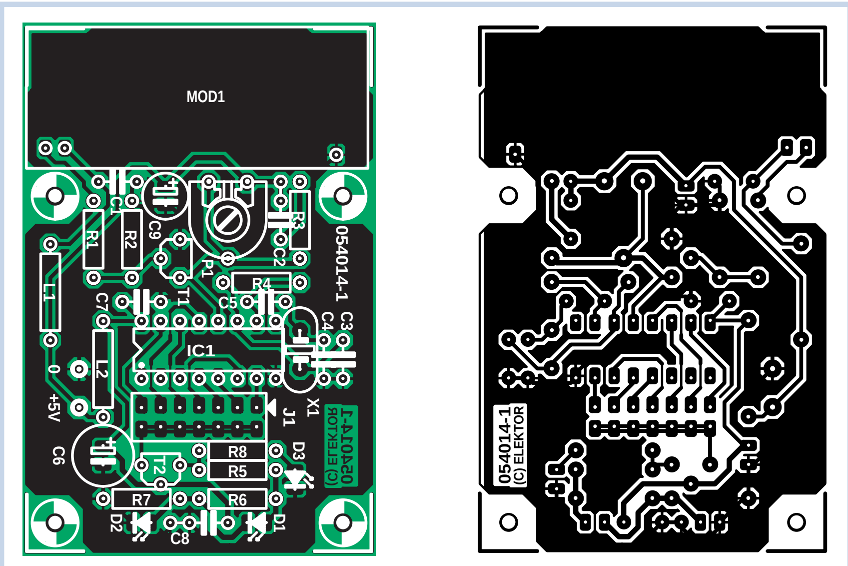
This circuit works together with a transmitter described elsewhere in this issue to form a remote-control extender. Due to its limited bandwidth, the output of the RF receiver module does not exactly reproduce the original pulses from the IR receiver. That problem is remedied here by the circuit around T1. The modulator circuit for the data received from this stage is active low, so the primary function of T1 is to invert the received signal. However, the stage built around T1 also acts as a pulse stretcher in order to restore the original pulse length. Capacitor C2, which is connected in parallel with P1, charges quickly. The maximum current is limited by R3 to protect T1. The discharge time is determined by P1 and C2, and P1 can be adjusted to compensate for various deviations and tolerance errors. The timing should be matched to the RC5 code with P1 set to approximately its midrange position. In practice, the pulse length also proved to be slightly dependent on the signal strength.

T1 provides the reset signal for a 74HC4060 IC (14-stage binary ripple counter with built-in oscillator). This counter restores the original modulation with a frequency of 36 kHz. Each received pulse starts the oscillator, and a frequency of exactly 36 kHz is present on pin 13 (division factor 2^9) if the crystal frequency is 18.432 MHz. Other oscillator frequencies can also be selected using J1, and various combinations are possible using other division factors (for 36 kHz, connect a jumper between pins 11 and 12 of J1). At frequencies below 12 MHz, C5 must be replaced by a resistor with a value of 1–2.2 kΩ (fitted vertically). The main reason for including J1 is to allow the remote control extender to be used with other modulation frequencies. The counter output drives a transistor stage (T2) with two IR diodes (type LD271, but other types can also be used). The current through LEDs D1 and D2 is limited to approximately 90 mA by R18. R6 and R7 are connected in parallel with D1 and D2, respectively, to reduce the turn-off time. A normal LED (D3) is connected in parallel with the IR LEDs to provide a supplementary visible indication of a transmitted signal (IR or RF).

The circuit needs nice stiff 5-V supply,







which means that battery operation is not suitable (unless a hefty electrolytic capacitor is connected across the supply terminals). L1 and L2 ensure that the supply voltage for the receiver module is as clean as possible. The quiescent current consumption is approximately 1.3 mA, and it increases to around 8 mA on average with a good received signal level.

Assembling the circuit board (see **Figure 2**) is straightforward. Naturally, a wire bridge can be used in place of J1 if you only want to use a single IR code. The receiver module is supplied with quite long connection leads and a pre-fitted antenna. It's a good idea to shorten the antenna slightly. With our modules, the length was nearly 18 cm. In practice, a length of 15.5 cm is more suitable at a frequency of 433.92 MHz.

The circuit board is designed to allow the receiver module to be fitted to the board, but we chose to fit it next to the board (along its long axis). That puts the receiver a bit further away from the noise generated by the IR LEDs and the counter, which reduces the interference to signal reception. The module leads are long enough for this. You will also have to experiment with the orientation of the module and the antenna, since the arrangement proved to be critical in practice (the RF aspects, that is).

(054014-1)

COMPONENTS LIST

Resistors:
R1,R2 = 10kΩ
R3 = 47Ω
R4 = 1MΩ
R5 = 18Ω
R6,R7 = 100Ω
R8 = 470Ω
P1 = 10kΩ preset

Capacitors:
C1, C7,C8 = 100nF ceramic
C2 = 100nF MKT
C3,C4 = 33pF
C5 = 15pF
C6 = 220µF 25V radial
C9 = 100µF 10V radial

Inductors:
L1 = 10µH
L2 = 47µH

Semiconductors:
D1,D2 = LD271
D3 = LED, red, high-efficiency
T1 = BC547B
T2 = BC639
IC1 = 74HC4060

Miscellaneous:
J1 = 14 (2x7) way pinheader + 1 jumper
X1 = 18.432MHz quartz crystal
MOD1 = 433.92MHz AM receiver (RX) module from set, Conrad Electronics # 130428
PCB, ref. 054014-1 from The PCBShop

Simple Cable Tester

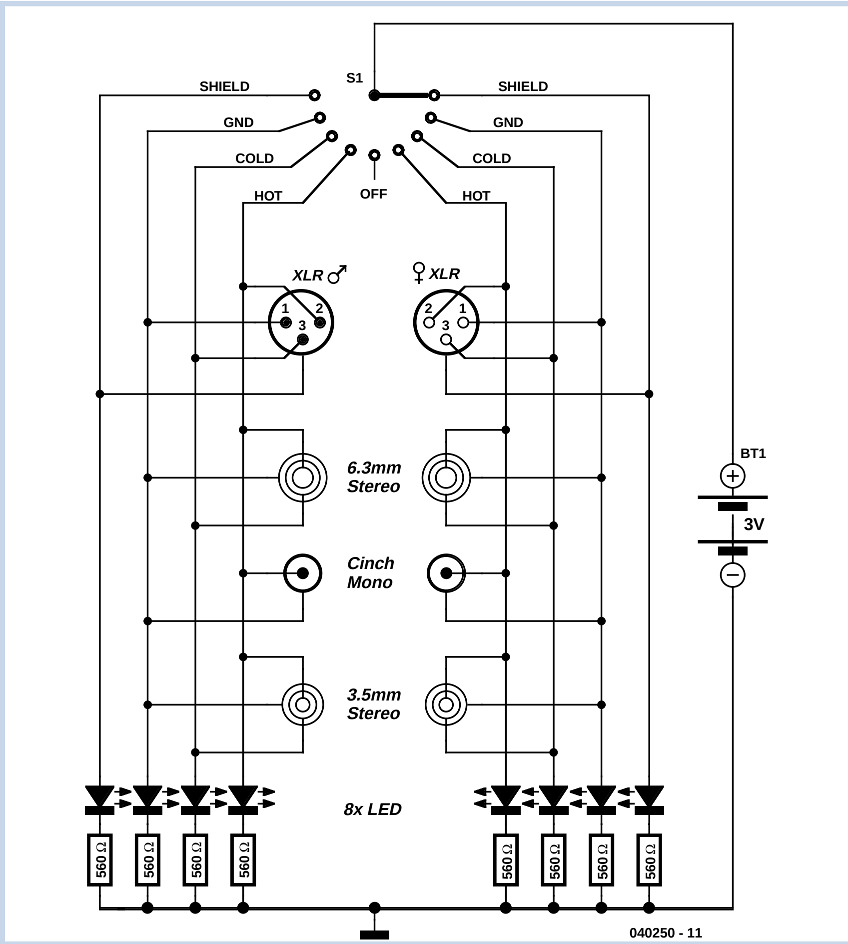
079

Bert Vink

This cable tester allows you to quickly check audio cables for broken wires. Because of the low power supply voltage, batteries can be used which makes the circuit portable, and therefore can be used on location. The design is very simple and well organised: using the rotary switch, you select which conductor in the cable to test. The corresponding LED will light up as indication of the selected conductor. This is also an indication that the power supply voltage is present. If there is a break in the cable, or a loose connection, a second LED will light up, corresponding to the selected conductor. You can also see immediately if there is an internal short circuit when other than the corresponding LEDs light up as well.

You can also test adapter and splitter cables because of the presence of the different connectors. Two standard AA- or AAA- batteries are sufficient for the power supply. It is recommended to use good, low-current type LEDs. It is also a good idea not to use the cheapest brand of connectors, otherwise there can be doubt as to the location of the fault. Is it the cable or the connector?

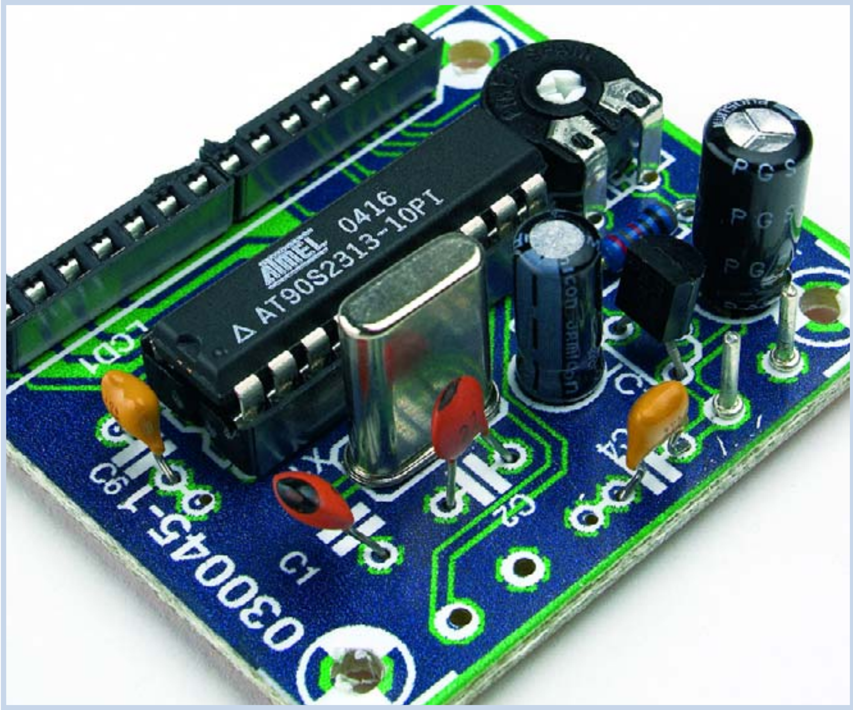
(040250-1)



080

1 MHz Frequency Counter

H. Breitzke



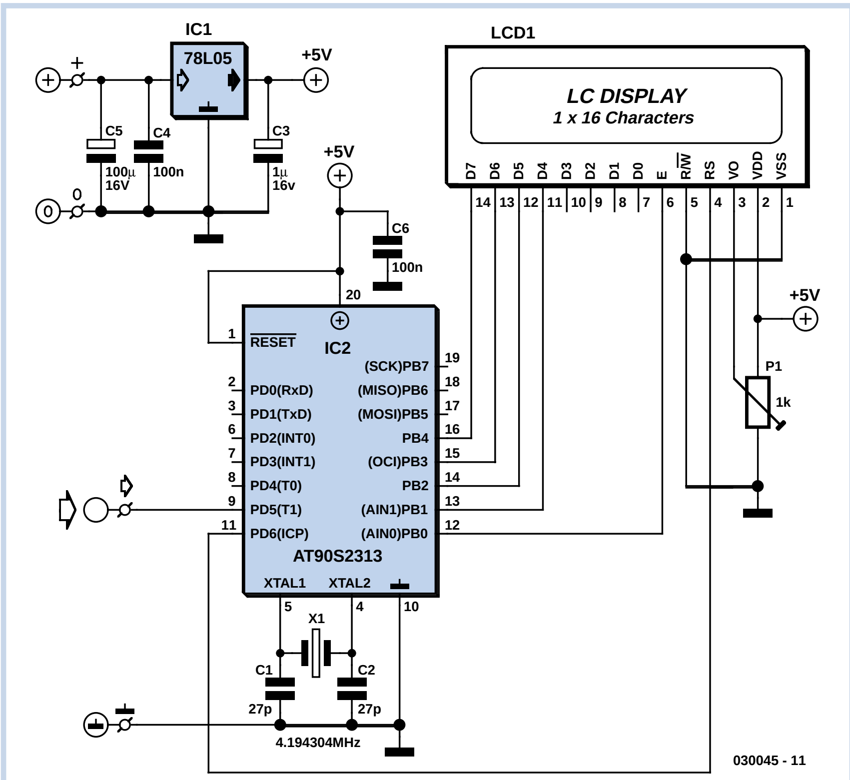
The XR 2206 function generator chip is a very popular device and forms the basis of many analogue function generator designs. A disadvantage of this chip is that in its most basic configuration the output frequency is adjusted manually by rotating an output frequency control knob and lining it up on a printed scale. Without a frequency counter its difficult to tell the value of the output frequency, especially at the high end of the scale. The frequency counter design presented here offers a low cost solution to this problem and achieves good accuracy. Power for the circuit is derived from the dc power supply of the existing function generator. The input signal to the counter is taken in parallel from the TTL output of the XR2206. The frequency counter circuit contains an Atmel AT90S2313 microcontroller together with an LCD display. The frequency counter program is written in Basic.

The fundamental components needed to build a frequency counter are a timer, which is used to time an accurate measurement window and a counter to count the number of transitions that the input signal makes during the measurement window period. The microcontroller contains two internal hardware counters of 8 and 16 bit length and these can be configured as either a timer or counter. Operating with a crystal frequency of 8.388608 MHz the counter achieves an accuracy of 1 Hz at 1 MHz or with a more readily available 4.194304 MHz crystal the accuracy will be 1 Hz with a 500 kHz input signal.
The 16-bit counter is configured as the frequency counter and the input signal is connected to pin 9 at TTL logic levels. A 16-bit counter can only count to a maximum value of 65536 so to extend its range the software keeps note of the number of counter timer overflow interrupts that occur during the measurement window. At the end of the measurement window it multiplies this value by 65536 and adds it to the current value of the counter:

F = interrupts × 65536 + Timer1

The time base is generated by the 8-bit timer which together with a prescaler counts to 1024. Using the crystal frequency from above the timer 0 overflow occurs at a frequency of 32 Hz. The measurement timing window is closed when 32 interrupts have been counted and the frequency of the input signal is calculated and displayed.

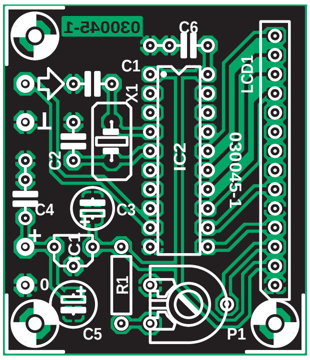
The interrupt rate restricts the maximum input to 1.5 MHz and at this frequency the display will exhibit a jitter of 4 Hz i.e. the displayed frequency will 'wander' by 4 Hz. All input frequencies below 200 kHz should not display any jitter.

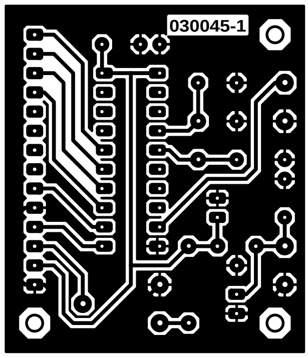


The program is written in AVR Basic and is small enough to be compiled and downloaded to the microcontroller by the free demo version of the BASCOM AVR compiler (Download from: www.mcselec.com). The single line LCD display interface is designed for a Hitachi 16x1 or compatible display. Preset R1 allows adjustment of the display contrast. IC1 provides a regulated 5 V for the microcontroller and display.

The frequency counter accuracy depends on the precision of the crystal and its frequency stability together with capacitors C1 and C2. PAL crystals generally are produced to close tolerances and exhibit low drift. During testing the crystal showed an offset of 60 ppm, which would produce a display error of 60 Hz on a 1 MHz signal. Adjustment of the capacitive loading (C1 and C2) on the crystal was able to 'pull' the crystal frequency and reduce the error to zero. At audio frequencies the counter measures to an accuracy of 1 Hz across the entire audio spectrum without any need for circuit alignment.

(030045-1)





COMPONENTS LIST

Resistors:
R1 = 10kΩ
P1 = 1kΩ preset

Capacitors:
C1, C2 = 27pF
C3 = 1µF / 16V radial
C4, C6 = 100nF

Semiconductors:
IC1 = 78L05
IC2 = AT90S2313-10PI, programmed, order code **030045-41** *

Miscellaneous:
X1 = 4.194304MHz or 8.388608MHz quartz crystal (see text)
LCD1 = LCD Module, 1 line, 16 characters
PCB, ref. 030045-1 from The PCBShop
Disk, project software, order code **030045-11** * or Free Download

* see Elektor SHOP pages or www.elektor-electronics.co.uk

High Voltage Regulator

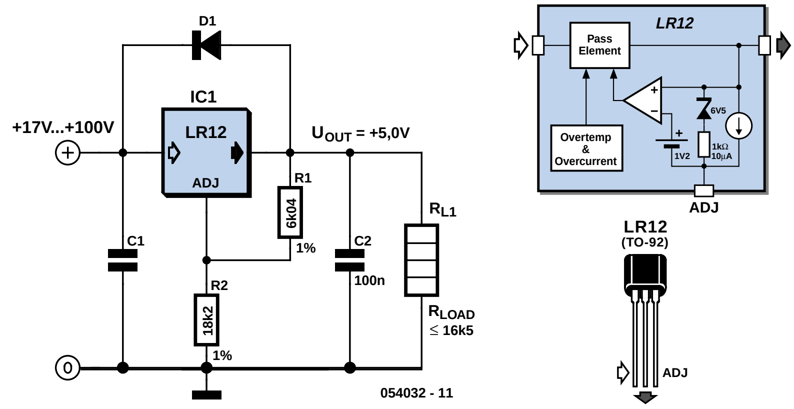
081

Ton Giesberts

The LR12 made by Supertex Inc. is a good choice for applications where a supply voltage of more than 35 to 40 V needs to be stabilised. This small regulator can cope with input voltages of up to 100 V, when the output voltage can be adjusted between 1.2 and 88 V. A small disadvantage is that the input voltage needs to be at least 12 V more than the output voltage.

The regulator keeps the voltage between the output and adjust pin constant at 1.2 V. With a potential divider the output voltage can be set using the following equation:

$V_{out} = 1.2 \times (R2 / R1 + 1) + I_{adj} \times R2.$



The circuit shows a standard application where the LR12 is used as a 5 V regulator. C1 decouples the input voltage. Its value and working voltage depend on the input voltage and the current consumption. The bypass capacitor (C2) is required to keep the LR12 stable. In cases where the voltage at the input may be smaller than at the output an extra protection diode is required, for example a 1N4004.

The output current of the IC needs to be at least 0.5 mA. In the circuit shown here the potential divider made by R1/R2 already draws 0.2 mA. This means that with a 5 V output the load resistor needs to be less than 16k5. If the resistance is higher, the total output current drops below the required value of 0.5 mA.

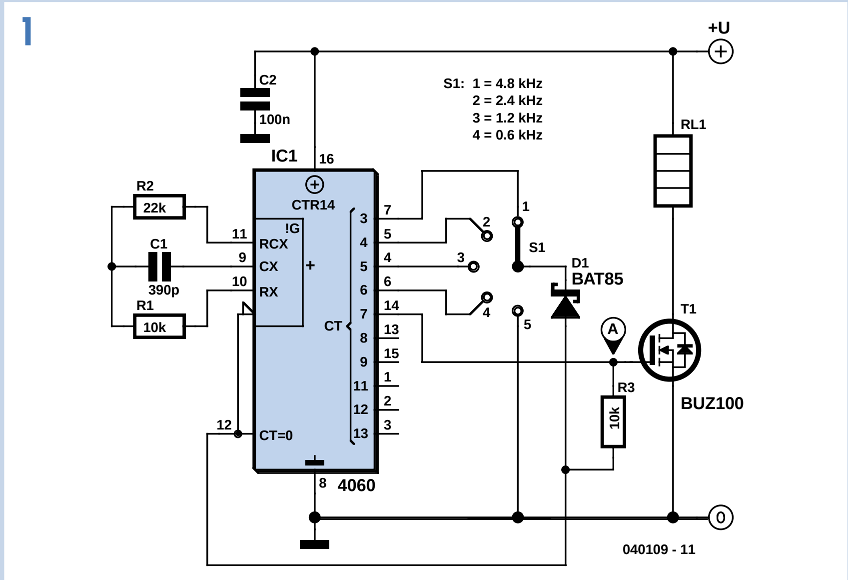
The output current of the LR12, with a 12 V difference between input and output, is limited to 100 mA (max. dissipation of a TO92 package: 0.6 W at 25 °C). The ripple suppression is at least 50 dB. The current consumption of the IC itself is very low at only 5 to 15 µA.

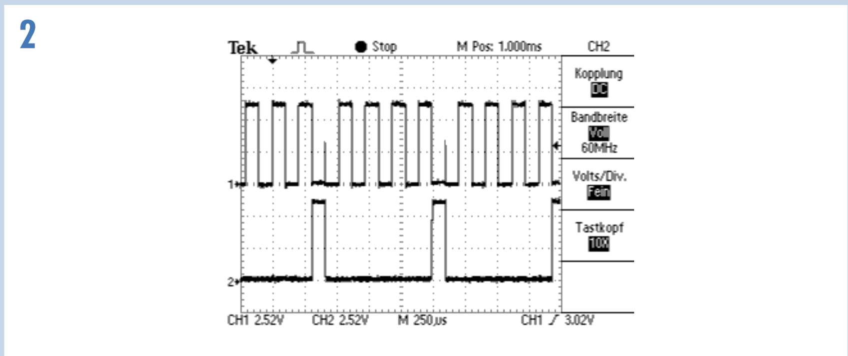
(054032-1)

082 PDM Pulse Generator

Klaus-Juergen Thiesler

This pulse generator, which offers a mark-space ratio that is adjustable in exponentially increasing steps, is a novel use for a familiar IC. It can come in handy in a range of situations: for example, when testing the dynamic regulation characteristics of a power supply. In this test a load is applied to a power supply that draws a square-wave, rather than constant, current. An oscilloscope can then be used to check how quickly the regulator in the power supply responds and to observe any undesirable artefacts in the output such as overshoots or oscillation. A disadvantage of such an arrangement is that the dynamic characteristics of the power supply are only measured at one average current, determined by the mark-space ratio of the current and by its maximum value. Modern computers, for example, draw varying amounts of current depending on what they are doing, and the current can vary over very short timescales. A modern PC power supply must therefore deliver accurate and stable voltages not only under high and intermediate load, but also at low load (in stand-by mode).





The PDM pulse generator is ideal for this situation. As can be seen from the table, S1 allows the mark-space ratio to be adjusted from 1:17 to 1:2. The frequency varies from 566 Hz to 302 Hz, making it suitable for testing PC power supplies. The variation in frequency with mark-space ratio is a consequence of how the circuit works.

At the heart of the circuit is our old friend the CMOS 4060. This includes an RC oscillator circuit and a 14 bit binary counter. The basic clock frequency, which can be calculated using the formula shown, is around 77 kHz for the given values of R1 and C1. The space time is constant at around 1660 µs. When the IC is reset, all outputs are initially low. Consider now the voltage at the gate of T1. If it were not for D1, when Q7 goes high after the 128th clock pulse (the divide-by-2^8 output spends 128 clock periods low and then 128 periods high) IC1 would be reset immediately via R3. T1, and therefore the load, would thus receive extremely short pulses with long pauses between. Because of the switching speed of the IC, the width of the pulses would only be of the order of the ten nanoseconds. A low level via D1 and S1, however, delays the resetting of the IC for exactly as many clock periods as it takes for the output selected by S1 to go high. For example, if Q3 is selected, this happens after a further eight periods. The cycle time is then 128+8 clock periods, of which 128 clock periods are space and just eight are mark. This gives a duty cycle, as shown in the table, of 8/136 or 1/17. If Q6 were used the pulse would be 0.5×2^7 = 64 clock periods wide with

Table 1. Pulse width in exponentially increasing steps

Reset pulse		Q 7 (junction A)				
Switch position	CLR pin connected to	Duty cycle		Frequency *	Period *	Pulse width *
		as percentage	as a fraction **	Hz	µs	µs
1	Q 3	5.9 % approx.	1/17	566	1765	103
2	Q 4	$11\,^1/_9$ %	1/9	535	1868	207
3	Q 5	20.0 %	1/5	480	2082	415
4	Q 6	$33\,^1/_3$ %	1/3	401	2495	830
5	GND	50.0 %	1/2	302	3320	1660

* = measured to ±1 in last digit

** = see text (duty cycle is mark time as a proportion of period, a dimensionless quantity)

the same space period of 128 clocks. The duty cycle in this case is 1/3. If the cathode of D1 is tied to ground, the IC does not receive a reset signal and so a symmetrical square wave with a 128-clock mark and 128-clock space is produced.
T1 functions as a power switch. Load R4 is chosen so that the maximum rated current of the power supply flows when T1 conducts. The average load on the power supply can be calculated using the duty cycle values given in the table. It should go without saying that the current drawn must be within the specification of the power supply, and that R4 must be capable of the necessary power dissipation. At higher currents a heatsink is recommended for T1. It can pass a maximum of 60 A and although it has a very low resistance in the conducting state (just 18 mΩ) it is no superconductor! At currents above about 10 A it starts to get warm.
The oscilloscope traces show the circuit operating at one of the possible mark-space ratios. The upper trace is the basic clock on pin 11 of IC1, and the lower trace shows the signal at test point A, which has a duty cycle of 1/5.

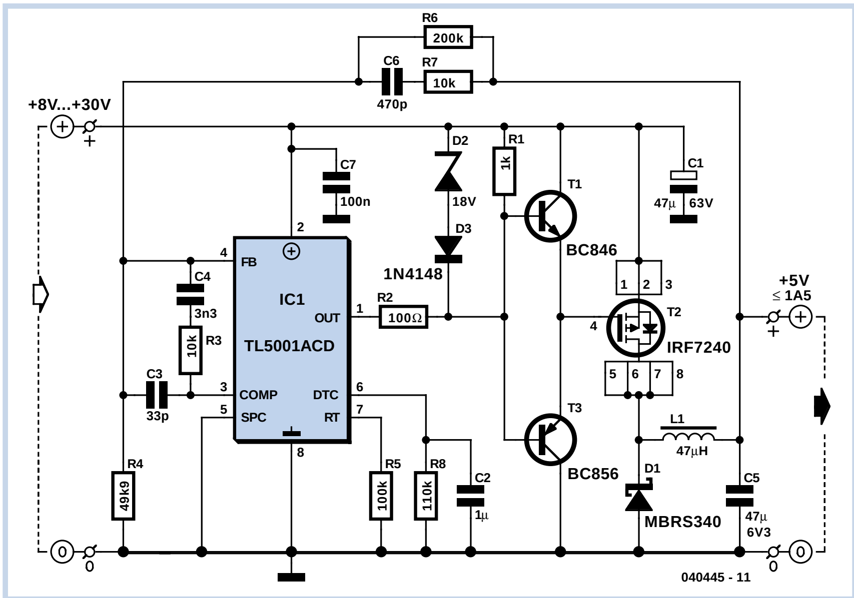
(040109-1)

083

Low-cost Step-down Converter

with Wide Input Voltage Range

Dirk Gehrke



The circuit described here is mostly aimed at development engineers who are looking for an economical step-down converter which offers a wide input voltage range. As a rule this type of circuit employs a step-down converter with integrated switching element. However, by using a more discrete solution it is possible to reduce the total cost of the step-down converter, especially when manufacturing in quantity. The TL5001A is a low-cost PWM controller which is ideal for this project.
The input voltage range for the step-down converter described here is from 8 V to 30 V, with an output voltage of 5 V and a maximum output current of 1.5 A.
When the input voltage is applied the PWM output of IC1 is enabled, taking one end of the voltage divider formed by R1 and R2 to ground potential. The current through the voltage divider will then be at most 25 mA: this value is obtained by dividing the maximum input voltage (30 V) minus the saturation voltage of the output driver (2 V) by the total resistance of the voltage divider (1.1 kΩ). T1 and T3 together form an NPN/PNP driver stage to charge the gate capacitance of P-channel MOSFET T2 as quickly as possible, and then, at the turn-off point, discharge it again.
The base-emitter junction of T3 goes into a conducting state when the PWM output is active and a voltage is dropped across R2. T3 will then also conduct from collector to emitter and the gate capacitance of T2 will be discharged down to about 800 mV. The P-channel MOSFET will then conduct from drain to source. If the open-collector output of the controller is deactivated, a negligibly small current flows through resistor R2 and the base of T1 will be raised to the input voltage level. The base-emitter junction of T1 will then conduct and the gate capacitance of T2 will be charged up to the input voltage level through the collector and emitter of T1. The P-channel MOSFET will then no longer conduct from drain to source. This driver circuit constructed from discrete components is very fast, giving very quick switch-over times.
Diodes D2 and D3 provide voltage limiting for the P-channel MOSFET, whose maximum gate-source voltage is 20 V. If the Zener voltage of diode D2 is exceeded it starts to conduct; when the forward voltage of diode D3 is also exceeded, the two diodes together clamp the gate-source voltage to approximately 19 V.
The switching frequency is set at approximately 100 kHz, which gives a good compromise between efficiency and component size. Finally, a few notes on component selection. All resistors are 1/16 W, 1 %. Apart from electrolytic C1 all the capacitors are ceramic types. For the two larger values (C2 and C5) the following are used:
C2 is a Murata type GRM21BR71C105KA01 ceramic capacitor, 1 µF, 16 V, X7R, 10 %;
C5 is a Murata type GRM32ER60J476ME20 ceramic capacitor, 47 µF, 6.3 V, X5R, 10 %.
D1 (Fairchild type MBRS340T3) is a 40 V/3 A Schottky diode. Coil L1 is a Würth WE-PD power choke type 744771147, 47 µH, 2.21 A, 75 mΩ.
T1 (BC846) and T3 (BC856) are 60 V, 200 mA, 310 mW complementary bipolar transistors from Vishay.
The TL5001AID (IC1) is a low-cost PWM controller with an open-collector output from Texas Instruments.

(040445-1)

084

Noise Suppression for R/C Receivers

Paul Goossens

Receiver interference is hardly an unknown problem among model builders. Preventive measures in the form of ferrite beads fitted to servo cables are often seen in relatively large models and/or electrically driven models, to prevent the cables from acting as antennas and radiating interference to the receiver.

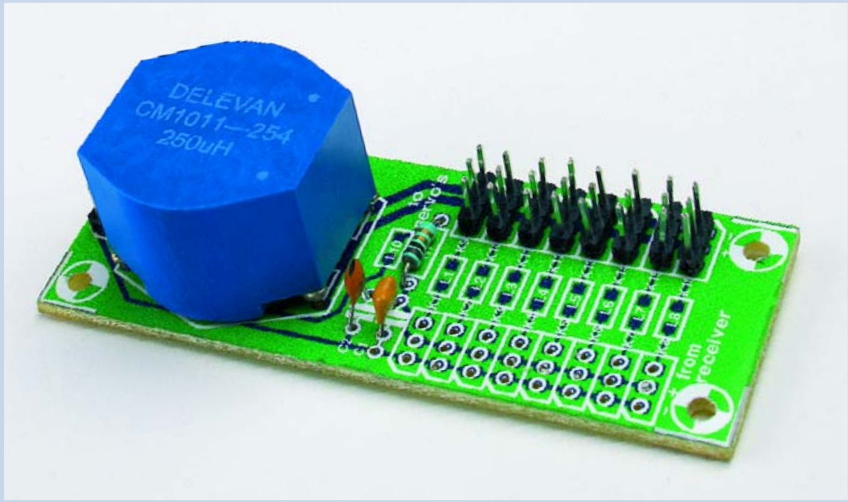
If miniature ferrite beads are used for this purpose, the connector must be first be taken apart, after which the lead must be threaded through the bead (perhaps making several turns around the core) and then soldered back onto the connector.
An interference source can also cause problems in the receiver via the power supply connection. The battery is normally connected directly to the receiver, with the servos in turn being powered from the receiver. The servos can draw high currents when they operate, which means they can create a lot of noise on the supply line. This sort of interference can be kept under control by isolating the supply voltage for the receiver from the supply voltage for the servos.

All of these measures can easily be implemented 'loose' in the model, but it's a lot nicer to fit everything onto a single small circuit board. That makes everything look a lot tidier, and it takes up less space.
The schematic diagram is shown in **Figure 1**. Connectors K1–K8 are located at the left. They are the inputs for the servo signals, which are connected to the receiver by the servo leads. The outputs (K9–K16) are located on the right. That is where the servos are connected. Finally, the battery is connected to K17.

Interference on the supply voltage line due to the motors and servos is suppressed by a filter formed by L10, R1, C1 and C2. L10 is a ferrite-core coil with an impedance of 2000 ohms at 30 MHz. In combination with C1 and C2, it forms a substantial barrier to interference in the 35-MHz R/C band. Signals with frequencies close to the 10.4-MHz intermediate frequency (which is used in many receivers) are also effectively blocked by this filter.

L9 filters out common-mode noise on the supply line for the servos, which effectively means that it prevents the supply lines to the servos from acting as antennas.
Finally, high-frequency currents on the servo signals are filtered out by ferrite beads in order to limit the antenna effects of these connection lines.

(054018-1)



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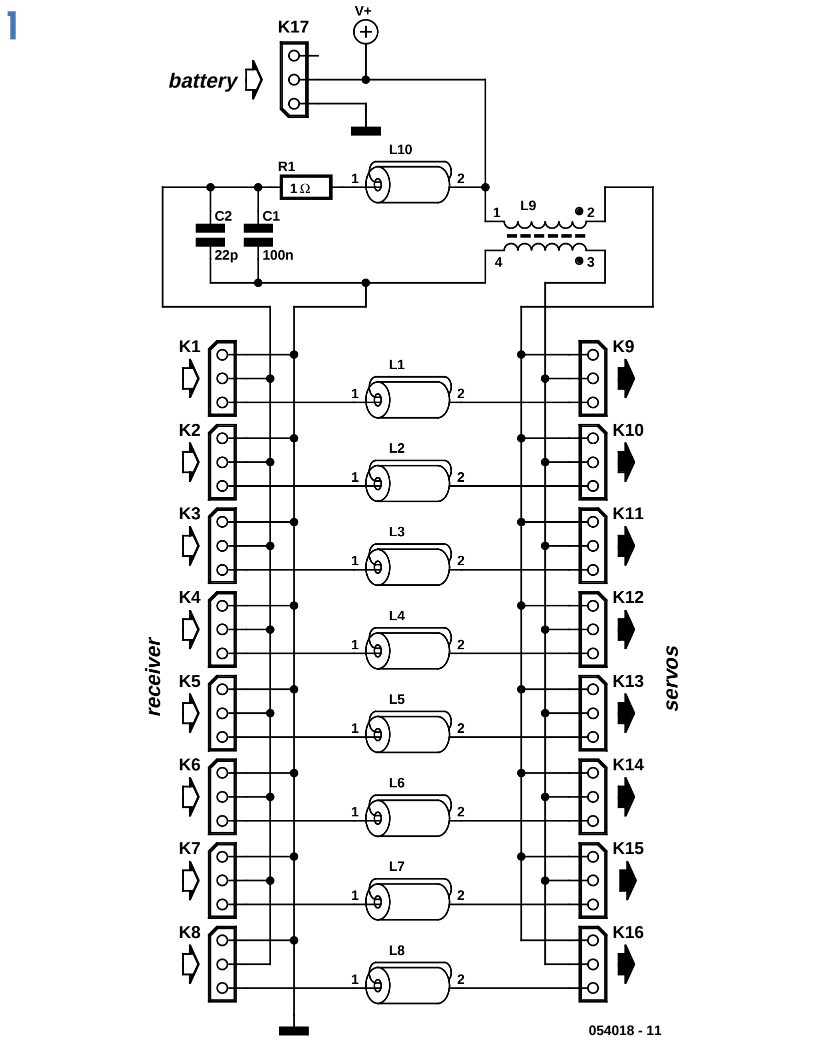
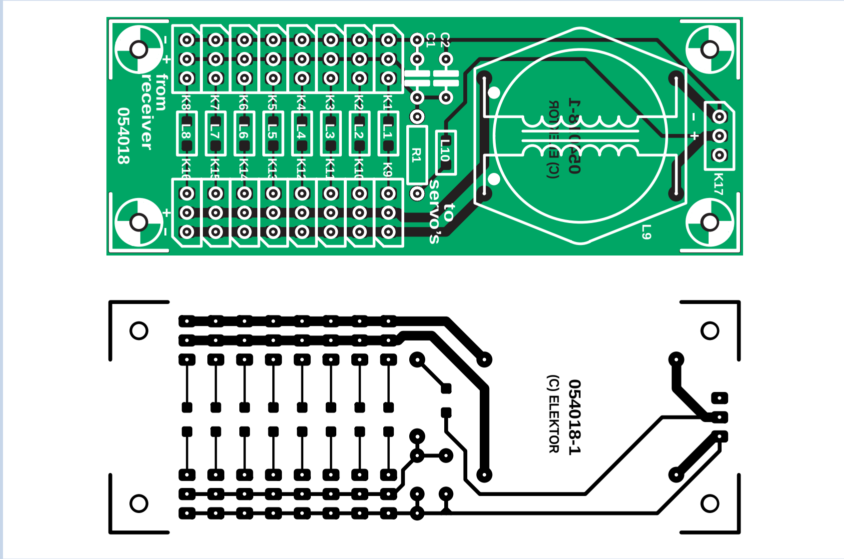


COMPONENTS LIST

Resistor:
R1 = 1Ω

Capacitors:
C1 = 100nF
C2 = 22pF

Miscellaneous:
L1-L8,L10 = ferrite inductor, SMD 1206 (e.g. Digikey # PMC1206-202-ND)
L9 = common-mode coil (e.g., Digikey # CM1011-254-ND)
K1-K8 = servo cable
K9-K17 = 3-way SIL pinheader
PCB, ref. 054018-1 from ThePCBShop



085

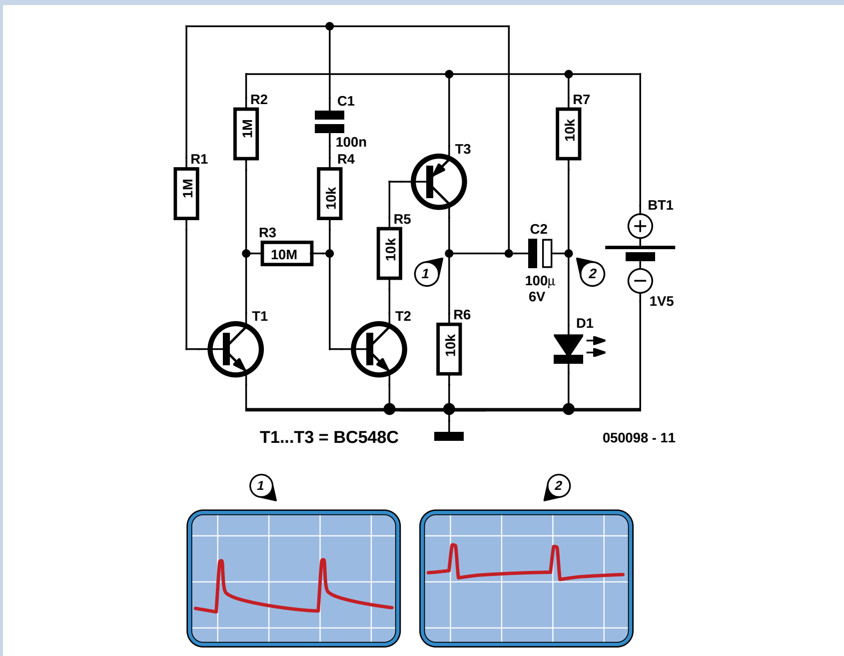
EE-ternal Blinker

Burkhard Kainka

You occasionally see advertising signs in shops with a blinking LED that seems to blink forever while operating from a single battery cell. That's naturally an irresistible challenge for a true electronics hobbyist…

And here's the circuit. It consists of an astable multivibrator with special properties. A 100-μF electrolytic capacitor is charged relatively slowly at a low current and then discharged via the LED with a short pulse. The circuit also provides the necessary voltage boosting, since 1.5 V is certainly too low for an LED.

The two oscillograms demonstrate how the circuit works. The voltage on the collector of the PNP transistor jumps to approximately 1.5 V after the electrolytic capacitor has been discharged to close to 0.3V at this point via a 10-kΩ resistor. It is charged to approximately 1.2 V on the other side. The difference voltage across the electrolytic capacitor is thus 0.9 V when the blink pulse appears. This voltage adds to the battery voltage of 1.5 V to enable the amplitude of the pulse on the LED to be as high as 2.4 V. However, the voltage is actually limited to approximately 1.8 V by the LED, as shown by the second oscillogram. The voltage across the LED automatically matches the voltage of the LED that is used. It can theoretically be as high as 3 V.



The circuit has been optimised for low-power operation. That is why the actual flip-flop is built using an NPN transistor and a PNP transistor, which avoids wasting control current. The two transistors only conduct during the brief interval when the LED blinks. To ensure stable operating conditions and reliable oscillation, an additional stage with negative DC feedback is included. Here again, especially high resistance values are used to minimise current consumption.

The current consumption can be estimated based on the charging current of the electrolytic capacitor. The average voltage across the two 10-kΩ charging resistors is 1 V in total. That means that the average charging current is 50 μA. Exactly the same amount of charge is also drawn from the battery during the LED pulse. The average current is thus around 100 μA. If we assume a battery capacity of 2500 mAh, the battery should last for around 25,000 hours. That is more than two years, which is nearly an eternity. As the current decreases slightly as the batter voltage drops, causing the LED to blink less brightly, the actual useful life could be even longer. That makes it more than (almost) eternal.

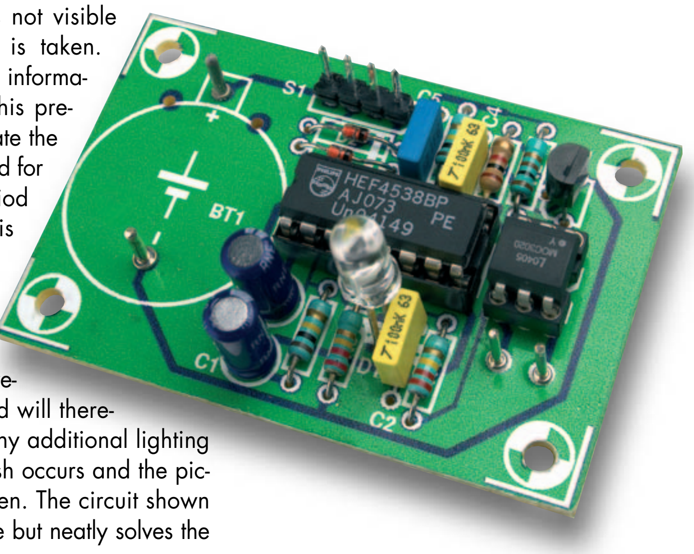
(050098-1)

086 Slave Flash with Red-Eye Delay

Paul Goossens

Digital cameras are becoming more and more affordable. At the economy end of the market cameras are usually equipped with a small built-in flash unit that is ideal for close-ups and simple portraiture. The power rating of the built-in flash unit is quite low so that any subject further away than about 2 to 3 metres (maybe 4 m if you are lucky) tends to disappear into the gloom. You soon become aware of the limitations if you need to photograph a larger group of people say at a function under artificial light in a large hall or outdoors. The majority of these cameras are not fitted with an accessory socket so it is not possible to simply connect a second flash unit to increase the amount of light. Single lens reflex cameras also need additional lighting (e.g. fill-in flash) to reduce the harsh contrast produced by a single light source. For all these cases an additional slave flashgun is a useful addition to the equipment bag. Rather than shelling out lots of cash on a professional slave flashgun, the circuit here converts any add-on flashgun into a slave flash unit triggered by light from the camera flash.

Simple slave flash circuits can have problems because most modern cameras use a red eye reduction pre-flash sequence. This pre-flash is useful for portraiture. It is designed to allow time for the subjects pupils to contract so that the red inner surface of the eye is not visible when the picture is taken. Some cameras use information gathered at this pre-flash time to estimate the light power required for the main flash period and some use this time to fine-tune the autofocus. A simple slave flash circuit will be triggered by the pre-flash sequence and will therefore not provide any additional lighting when the main flash occurs and the picture is actually taken. The circuit shown here is quite simple but neatly solves the pre-flash problem.



With switch S1 set to 'Normal', the pulse produced by D1 when it detects the cam-

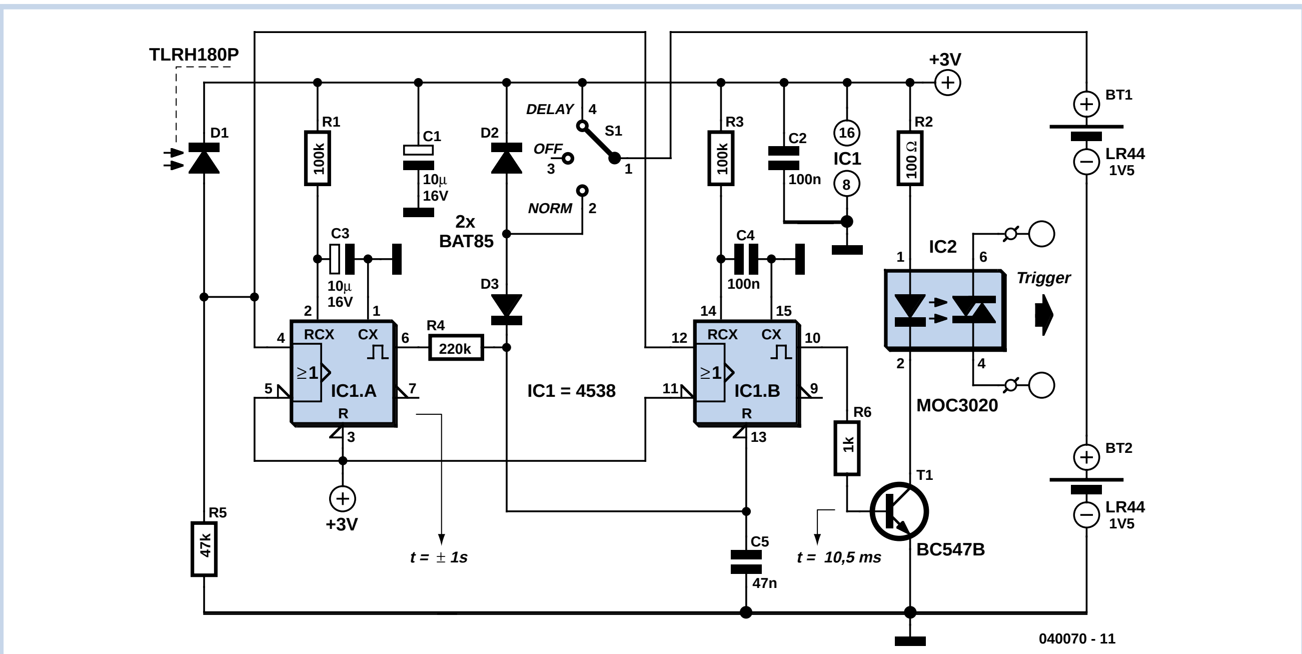
COMPONENTS LIST

Resistors:
R1, R3 = 100kΩ
R2 = 100ø
R4, R5 = 220kΩ
R6 = 1kΩ

Capacitors:
C1, C3 = 10µF 16 V radial
C2, C4 = 100nF
C5 = 47nF

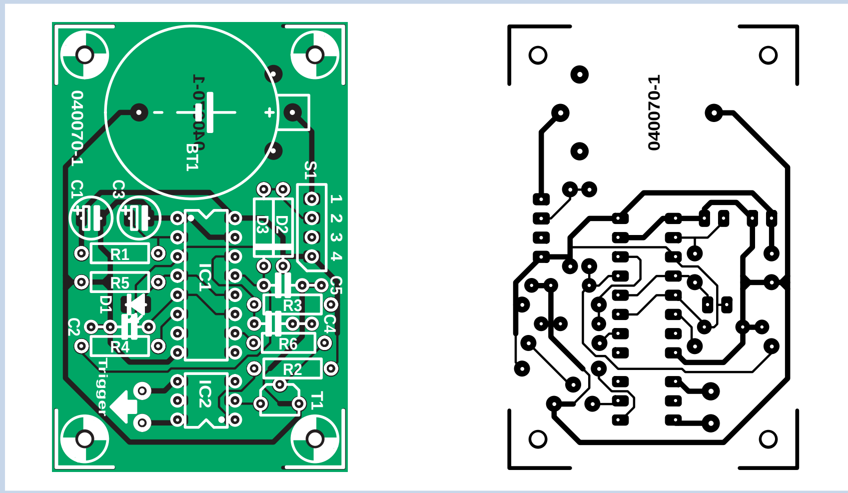
Semiconductors:
D1 = TLRH180P (Farnell # 352-5451)
D2, D3 = BAT85
IC1 = 4538P
IC2 = MOC3020
T1 = BC547B

Miscellaneous:
Bt1 = two 1.5V batteries (LR44) with PCB mount holder
S1 = 3-position slide switch
PCB, ref. 040070-1 from The PCBShop
Cable or adaptor for external flasher



era flash will trigger both monoflops IC1a and IC1b. The output of IC1.A does not perform any useful action in this mode because the logic level on the other side of resistor R4 is pulled high by D3. The output of IC1.B will go high for approximately 10 ms switching T1 on and causing the triac to conduct and trigger the slave flash. The use of a triac optocoupler here has the advantage that the circuit can be used on older types of flashgun triggered by switching a voltage of around 100 V as well as newer types that require only a few volts to be switched.

With switch S1 in the delay position the first flash will trigger IC1.A and its output will enable IC1.B but the low pass characteristics of the filter formed by R4 and C5 slow the rising edge of this waveform so that IC1.B will only be enabled 10 ms after the first flash is detected. IC1.B is now enabled for a period of about 1 s (governed by R1 and C3). When the main flash occurs in this time window it will immediately trigger IC1.B and the triac will be switched as described above.



The circuit requires a supply of 3 V and draws very little current from the two 1.5 V button cells. It will run continuously for quite a few days, should it be accidentally left on. Switch S1 can be either a three-position toggle or slider type.

Circuit construction is greatly simplified and the finished unit looks much neater if it is built on the available PCB. Space is also provided to fit the PCB mounted battery holders. A suitable flash extension cable or adapter can be found in most photo shops.

(040109-1)

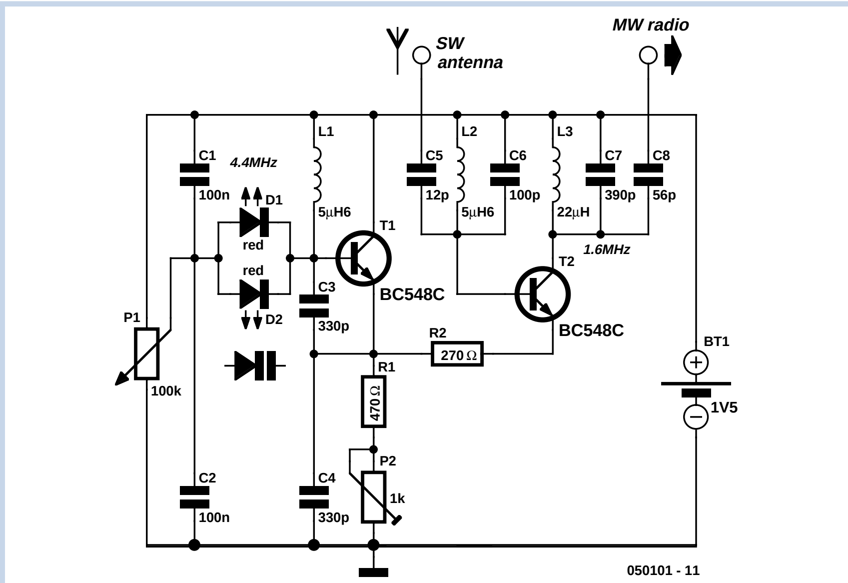
Short-Wave Converter

087

Burkhard Kainka

This short-wave converter, which doesn't have a single coil requiring alignment, is intended to enable simple medium-wave receivers to be used to listen to short-wave signals. The converter transforms the 49-m short-wave band to the medium-wave frequency of 1.6 MHz. At the upper end of the medium-wave band, select an unoccupied frequency that you want to use for listening to the converted short-wave signals. Good reception performance can be obtained using a wire antenna with a length of one to two metres.

The converter contains a free-running oscillator with a frequency of around 4.4 MHz, which is tuned using two LEDs (which act as variable-capacitance diodes!) and a normal potentiometer. The frequency range is set by adjusting the emitter current using a 1-kΩ trimpot. The oscillator frequency depends strongly on the operating point. This is due to the combination of using an audio transistor and the extremely low supply voltage. Under these conditions, the transistor capacitances are relatively large and strongly dependent on the operating point.

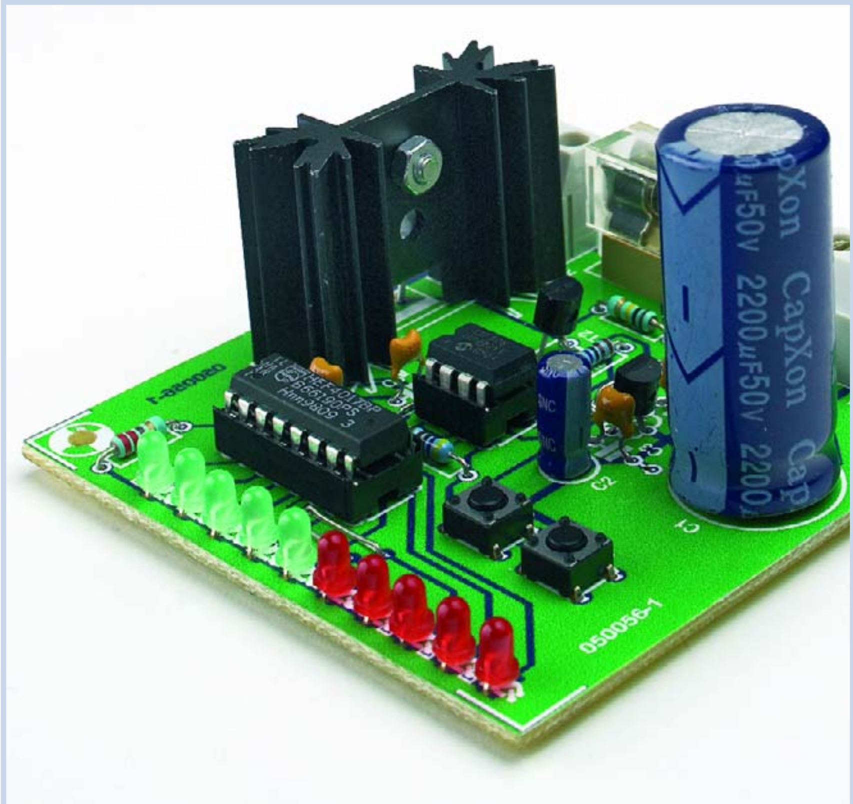


The second transistor forms the mixer stage. If you calculate the resonant frequencies of the tuned circuits, you will obtain 6.7 MHz for the antenna circuit and 1.7 MHz for the output circuit. Additional transistor capacitances and the effects of the coupling capacitors shift each of the resonant frequencies downward. The tuned circuits are relatively heavily damped to obtain bandwidths that are large enough to allow the circuit to be used without any specific alignment. The results are good despite the low collector–emitter voltage of around only 0.6 V, due to the fact that only a modest amount of mixer gain is necessary. The entire circuit also draws less than 1 mA.

(050101-1)

PIC PWM Controller

Jean-Marc Bühler



An efficient and economical method to control the power into a load (for example the speed of a motor or the temperature of a heating element) is to use PWM (Pulse Width Modulation). But things are a little bit more involved of we want an accurate adjustment from 0 to 100 % and an indication of the power.

A little 8-pin microcontroller can do these tasks easily: generating a PWM signal and indicating the power via a 4017 (see schematic).
This configuration of the microcontroller does not require an external reset circuit (so that there is a spare pin), because we use the automatic internal one. A quartz crystal is not required either, since we're using the integrated 4-MHz oscillator, which despite being based on an RC network, is accurate to 1 % thanks to the calibration carried out at the factory.
Once the microcontroller has been provided with a suitable program, it can carry out the instructions from the user by

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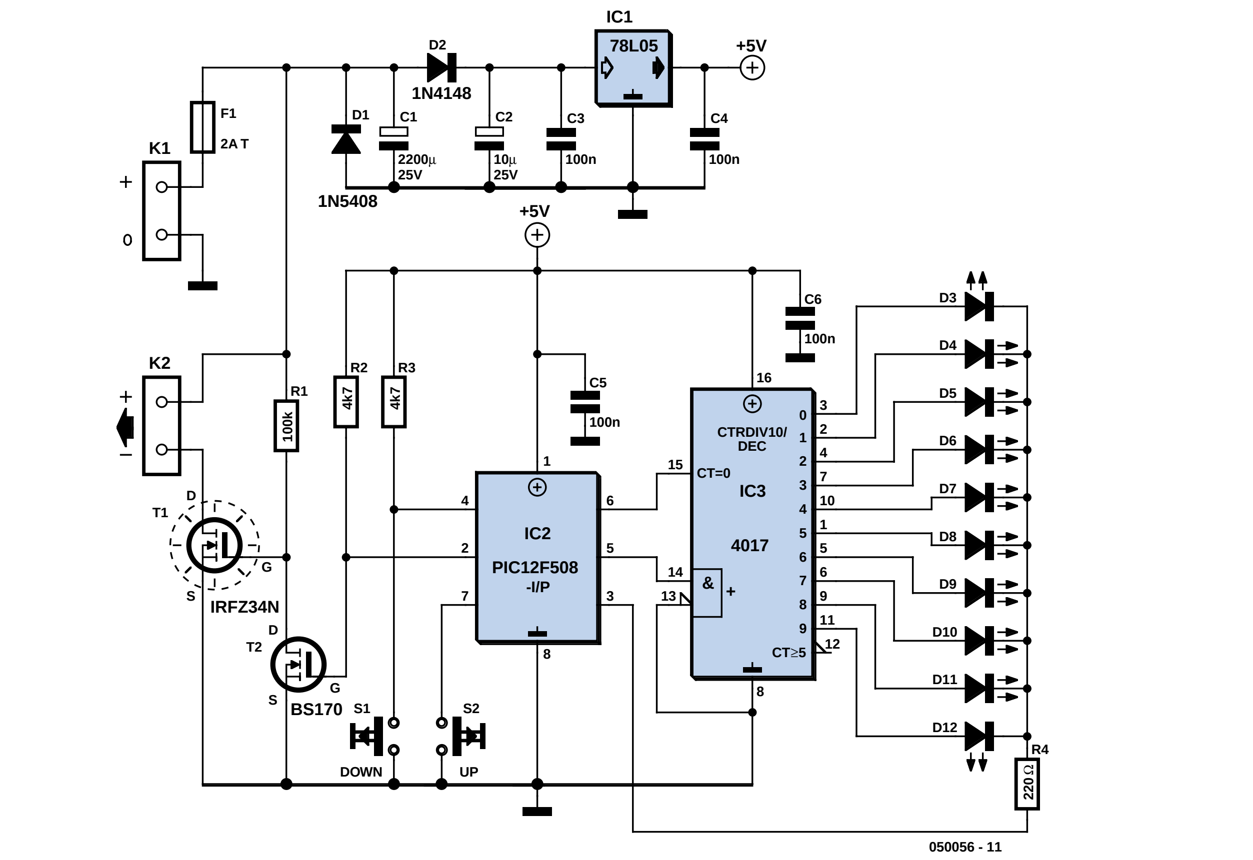


means of two pushbuttons. A PWM signal with a frequency of 100 Hz is generated, while the power is indicated with a classical 4017.

The circuit can be kept very simple because the microcontroller carries out all the complicated tasks. A 78L05 provides the power supply, a 4017 for the indicator and a pair of MOSFETs for the power stage.

Connector K1 receives the input power supply voltage (9 to 12 V at 1 to 5 A). The load to be controlled is connected to K2.

With 2 pushbuttons we can control the power in steps of 10 %. To stop immediately, both need to be pressed at the same time. That concludes the user manual!

A special feature of the circuit is the power indication with the 4017 and 10 LEDs. When first powered up, a back-and-forth running light indicates that the circuit is powered but the output is not active. As soon as the load is switched on with pushbutton S1, the first LED (10%) will light up. The correct operation of the circuit is indicated in an eye-catching manner by flashing the LED that indicates the power, using pin 3 of the controller.

The program is of a very simple design and the source code together with the hex file are available from the *Elektor Electronics* website or on a floppy disk (order code **050056-11**). You are free to add improvements, because there is plenty of space left in the program memory of the controller.

To compile the code (written in C) you can use the evaluation version of the CC5X-compiler (limited to 1024 words, which in our case is more than enough). This is available from the website www.bknd.com/cc5x (choose the Free Edition). Another handy piece of freeware is the ConText editor. It can be found at www.context.cx.

If you would like to experiment with the circuit, it is recommended to use the reprogrammable 12F629. In this case R3 is required. It is not necessary when a 12x508 is used.

When programming, don't forget to check that all the fuses are configured correctly:

Oscillator: Internal_RC
WatchDog_Timer: ON
Master_Clear_Enable: Internal
Code_Protect: OFF

This is particularly important when using the 12C508, because this is an OTP-type (can be programmed only once).

Figure 2 shows the printed circuit board, which, because of the 4 wire links has remained single-sided and provides enough space for all the parts.

T1 only requires a heatsink of you intend to regulate currents greater than 2 A over extended periods of time.

The choice of fuse depends on the current requirements of the load that is connected. T1 and the PCB traces can easily handle 5 A.

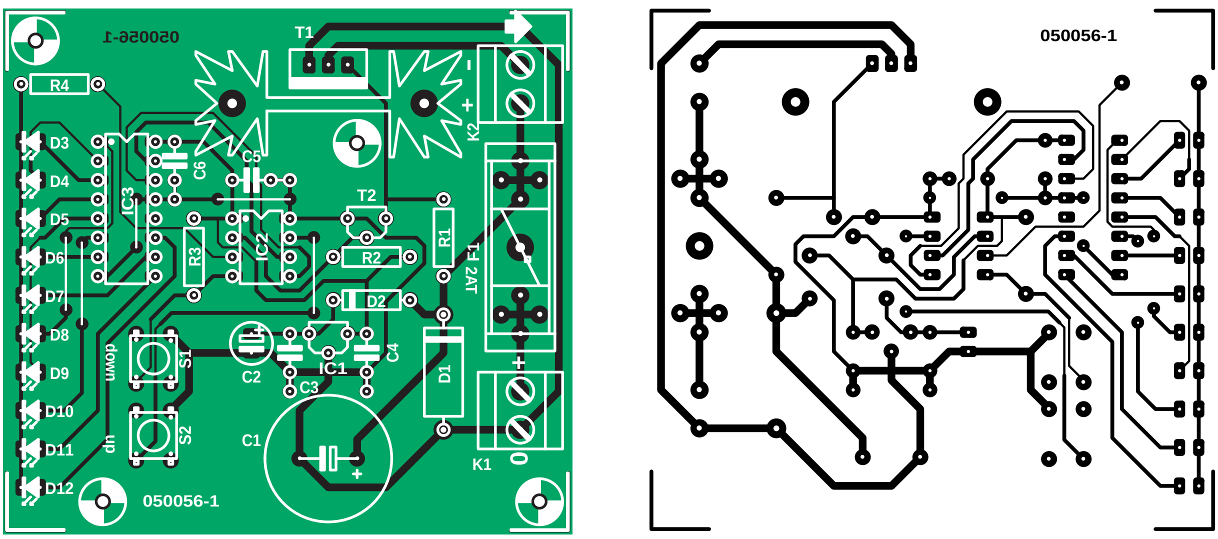
As soon as the power supply is applied to the circuit, fitted with a programmed PIC, the LEDs should light up as a running light. Every button press of S2 increases the on/off ratio with 10 % to a maximum of 100 %.

Thanks to the accurate oscillator in the 12C506, each step of 10 % corresponds to 1 ms and the entire cycle is repeated at a rate of 10 ms, which corresponds to a frequency of 100 Hz. Ideal for small motors.

A final note is that the program uses the watchdog functionality of the 12C508. This generates an automatic reset within 20 ms if the program crashes for some reason (for example large voltage surges). So there is nothing left to be desired regarding the reliability of the circuit…

(050056-1)

2



COMPONENTS LIST

Resistors:
R1 = 100kΩ
R2,R3 = 4kΩ7
R4 = 220Ω

Capacitors:
C1 = 2200µF 25V
C2 = 10µF 25V
C3-C6 = 100nF

Semiconductors:
D1 = 1N5408
D2 = 1N4148
D3-D7 = LED, 3mm, green
D8-D12 = LED, 3mm, red
T1 = IRFZ34N
T2 = BS170
IC1 = 78L05
IC2 = PIC 12C508-I/P
IC3 = CD 4017

Miscellaneous:
K1,K2 = 2-way PCB terminal block, lead pitch 5mm
S1,S2 = pushbutton, 1 make contact, DTS6
F1 = 2 AT (time lag) fuse with PCB mount holder
Heatsink type SK104 (Fischer)
PCB, ref. 050056-1 from The PCBShop
Disk, PIC source and hex code: order code **050056-11** or Free Download

089

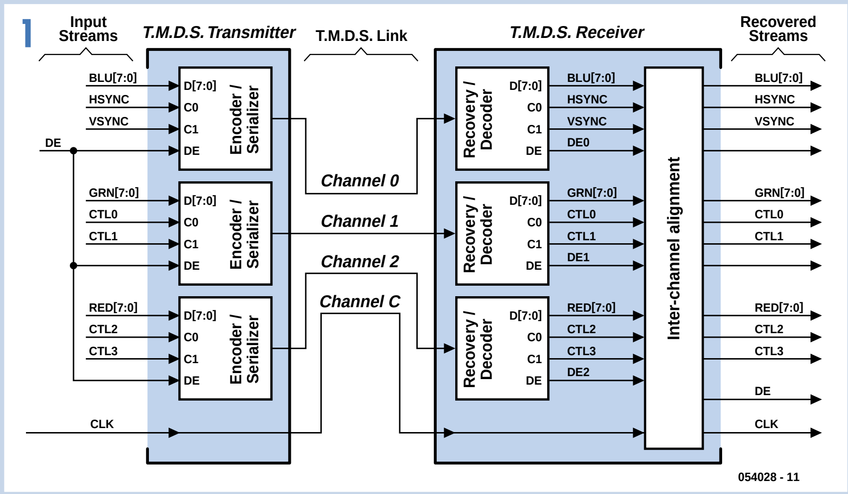
DVI Interface

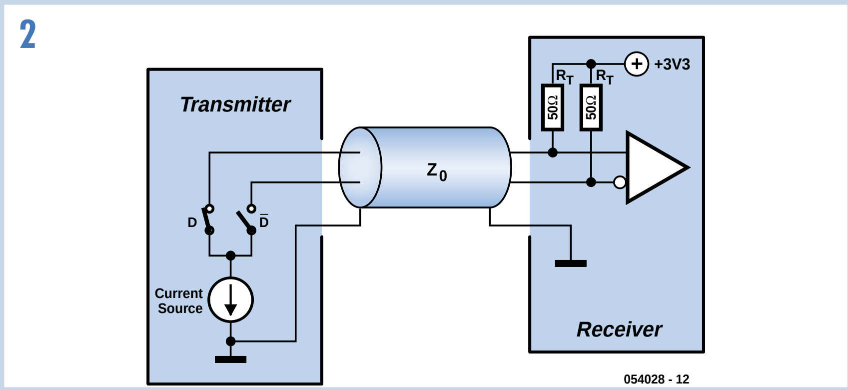
Paul Goossens

The PAL, NTSC and SECAM television standards are all several decades old. Even in this digital era, most people still have television sets that use complex analogue signals complying with these standards.

Nevertheless, the end is nigh for these standards. The DVI standard is on its way to becoming the new standard for transmitting video information. The most important property of this interface is that the information is transferred in digital form (24-bit words) instead of in the form of analogue signals.

Figure 1 shows how the required signals are divided into three data streams in a single-link interface, along with a clock signal. In DVI terminology, the clock signal is called 'Channel C'. A double-link interface with three additional information channels has also been specified to double the bandwidth. Whether these three additional channels are actually used depends on the selected resolution and repetition rate. Each channel consists of a differential signal pair. That makes this interface significantly less sensitive to interference. The technology behind these differential signal pairs is called 'transition-minimized differential signalling', or TMDS for short. **Figure 2** shows how the signals are generated in electronic terms. The connector and associated signal names are shown in **Figure 3** and **Table 1**. Besides the six TMDS signal pairs and clock signal (seven pairs in total), there are several other signals on the connector. DDC Clock and DDC Data allow a connection to be established in accordance with the DDC protocol. That protocol allows a connected device to determine which resolutions and frequencies the monitor can handle. The Hot Plug Detect signal makes it easy to recognise whether a monitor is connected. The +5-V line naturally does not need much explanation. Besides all these digital signals, the (old-fashioned) analogue RGB signals and associated sync signals are still present. Unfortunately, the illustrated connector is not the only type that is available. The illustrated connector is a DVI-I connector. It can transport both analogue and digital signals. There is also a DVI-D (digital only) and DVI-A (analogue only) connector. With the digital version, when you acquire a monitor or playback equipment you have to check both types of equipment to see whether they use a double-link interface (six data channels) or a single-link interface (three data channels).





The DVI 1.0 standard supports several different resolutions. They are listed in **Table 2**. Each resolution can also be

Table 1. DVI interface connector pin assignments

Pin	Signal	Pin	Signal	Pin	Signal
1	TMDS Data2 –	9	TMDS Data 1 –	17	TMDS Data 0 –
2	TMDS Data2 +	10	TMDS Data 1 +	18	TMDS Data 0 +
3	TMDS Data2/4 shield	11	TMDS Data 1/3 shield	19	TMDS Data 0/5 shield
4	TMDS Data 4 –	12	TMDS Data 3 –	20	TMDS Data 5 –
5	TMDS Data 4 +	13	TMDS Data 3 +	21	TMDS Data 5 +
6	DDC clock	14	+5 V supply	22	TMDS clock shield
7	DDC data	15	Ground	23	TMDS clock +
8	Analog Vertical Sync	16	Hot Plug Detect	24	TMDS clock –
C1	Analog Red	C2	Analog Green	C3	Analog Blue
C4	Analog Horizontal Sync	C5	Analog ground		

3

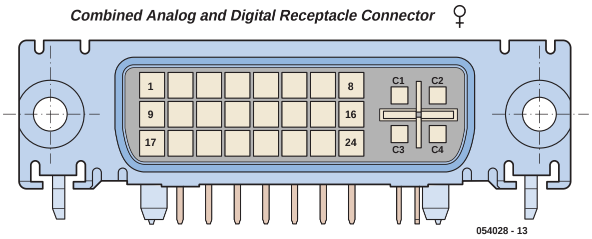


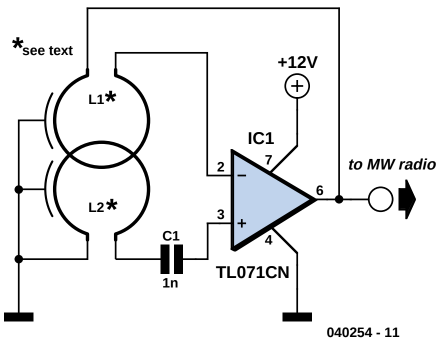
Table 2. Resolutions supported by DVI-1.0	
VGA	640x400
SVGA	800x600
XGA	1024x768
SXGA	1280x1024
UXGA	1600x1200
HDTV	1920x1080
QXGA	2048x1536

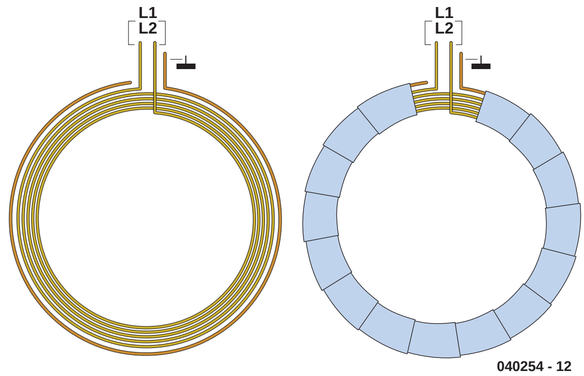
used with a variety of repetition rates, which are 60 Hz, 75 Hz and 85 Hz. That's a good selection of options, which (unfortunately) also makes for a good chance of confusion among consumers.

(054028-1)

CCO Metal Detector

090





Rev. Thomas Scarborough

To the best of the author's knowledge, the metal detector shown here represents another new genre. It is presented here merely as an experimental idea, and operates in conjunction with a Medium Wave radio.

If a suitable heterodyne is tuned in on the medium waves, its performance is excellent. An old Victorian penny, at 180 mm, should induce a shift in frequency of one tone through the radio speaker. This suggests that the concept will match the performance of induction balance (IB) detector types, while employing a fraction of the components.

In principle, the circuit is loosely based on a transformer coupled oscillator (TCO), a well known oscillator type. This essentially consists of an amplifier which, by means of a transformer, feeds the output back to the input, thus sustaining oscillation. On this basis, the author has named the detector a Coil Coupled Operation (CCO) Metal Detector.

In fact the circuit would oscillate even without L2 and C1. However, in this case one would have nothing more than a beat frequency operation (BFO) detector. Coil L2 is added to bring the induction balance principle into operation, thus modifying the signal which is returned to the output, and greatly boosting performance.

This does not mean, however, that we are dealing strictly with an IB detector type, since the design requires a beat frequency oscillator for detection. Also, unlike IB, its Rx section (L2) is active rather than passive, being an integral part of a TCO. Nor is this strictly a BFO type, since its performance far outstrips that of BFO, and of course it uses two coils.

Search oscillator IC1 oscillates at around 480 kHz, depending on the positioning of the coils on the search head. The presence of metal induces changes both in the inductance and coupling of the two coils, thereby inducing a shift in oscillator IC1's frequency.

The output (pin 6) is taken via a screened cable to a Medium Wave radio aerial. A crocodile clip termination would make a convenient connection.

The two coils are each made of 50 turns 30swg (0.315mm) enamelled copper wire, wound on a 120mm diameter former. Each has a Faraday shield, which is connected to 0V as shown. A sketch of the coil is shown in the separate drawing. The coils are positioned on the search head to partly overlap one another, in such a way as to find a low tone on the best heterodyne, which should match the performance mentioned above.

Oscillator IC1 will sustain oscillation no matter which way the coils are orientated — however, orientation significantly affects performance. The correct orientation may be determined experimentally by flipping one of the coils on the search head. Ideally, the coils will finally be potted in polyester resin.

The CCO Metal Detector's search head offers a wide area of sensitivity, so that it is better suited to sweeping an area than pinpointing a find. As with both BFO and IB, it offers discrimination between ferrous and non-ferrous metals, making it well suited to 'treasure hunting'. And if you get fed up with searching, there's always the radio to listen to.

(0x0000-1)

091

Balancing LiPo Cells

Paul Goossens

Things change fast in the electronics world, and that's also true for rechargeable batteries. The rate of development of new types of rechargeable batteries has been accelerated by the steadily increasing miniaturisation of electronic equipment.
LiPo cells have conquered the market in a relatively short time. Their price and availability have now reached a level that makes them attractive for use in DIY circuits.

Unlike its competitors *Elektor Electronics* has already published several articles about the advantages and disadvantages of LiPo batteries. One of the somewhat less well-known properties of this type of rechargeable battery is that the cells must be regularly 'balanced' if they are connected in series. This is because no two cells are exactly the same, and they may not all have the same temperature. For instance, consider a battery consisting of a block of three cells. In this case the outer cells will cool faster than the cell in the middle. Over the long term, the net result is that the cells will have different charge states. It is thus certainly possible for an individual cell to be excessively discharged even when the total voltage gives the impression that the battery is not fully discharged. That requires action – if only to prolong the useful life of the battery, since LiPo batteries are still not all that inexpensive.
One way to ensure that all of the cells have approximately the same charge state is limit the voltage of each cell to 4.1 V during charging. Most chargers switch over to a constant voltage when the voltage across the batter terminals is 4.2 V per cell. If we instead ensure that the maximum voltage of each cell is 4.1 V, the charger can always operate in constant-current mode.
When the voltage of a particular cell reaches 4.1 V, that cell can be discharged until its voltage is a bit less than 4.1 V. After a short while, all of the cells will have a voltage of 4.1 V, with each cell thus having approximately the same amount of charge. That means that the battery pack has been rebalanced.
The circuit (**Figure 1**) uses an IC that is actually designed for monitoring the supply voltage of a microcontroller circuit.

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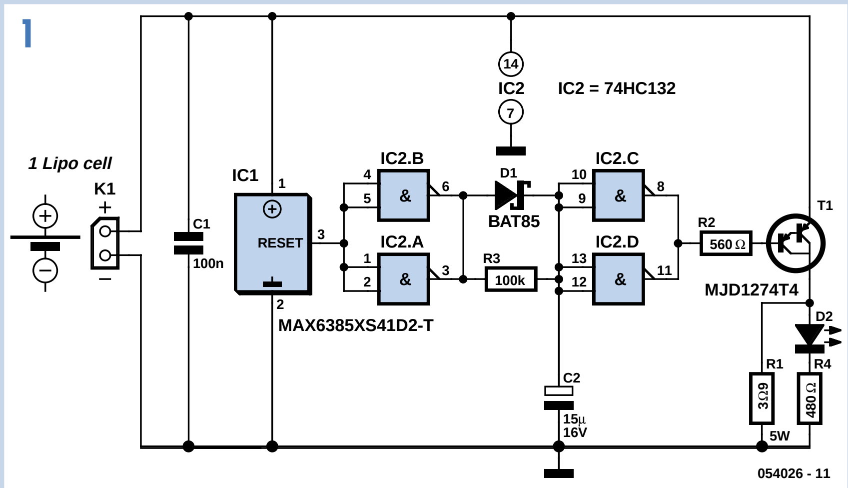

The IC (IC1) normally ensures that the microcontroller receives an active-high reset signal whenever the supply voltage drops below 4.1 V. By contrast, the output goes low when the voltage is 4.1 V or higher.
In this circuit the output is used to discharge a LiPo cell as soon as the voltage rises above 4.1 V. When that happens, the push-pull output of IC1 goes low, which in turn causes transistor T1 to conduct. A current of approximately 1 A then flows via resistor R1. LED D2 will also shine as a sign that the cell has reached a voltage of 4.1 V.
The function of IC2 requires a bit of explanation. The circuit built around the four NAND gates extends the 'low' interval of the signal generated by IC1. That acts as a sort of hysteresis, in order to prevent IC1 from immediately switching off again when the voltage drops due the internal resistance of the cell and the resistance of the wiring between the cell and the circuit. The circuitry around IC2 extends the duration of the discharge pulse to at least 1 s.

Figure 2 shows how several circuits of this type can be connected to a LiPo battery. Such batteries usually have a connector for a balancing device. If a suitable connector is not available, you will have to open the battery pack and make your own connections for it. The figure also clearly shows that a separate circuit is necessary for each cell.

(054026-1)

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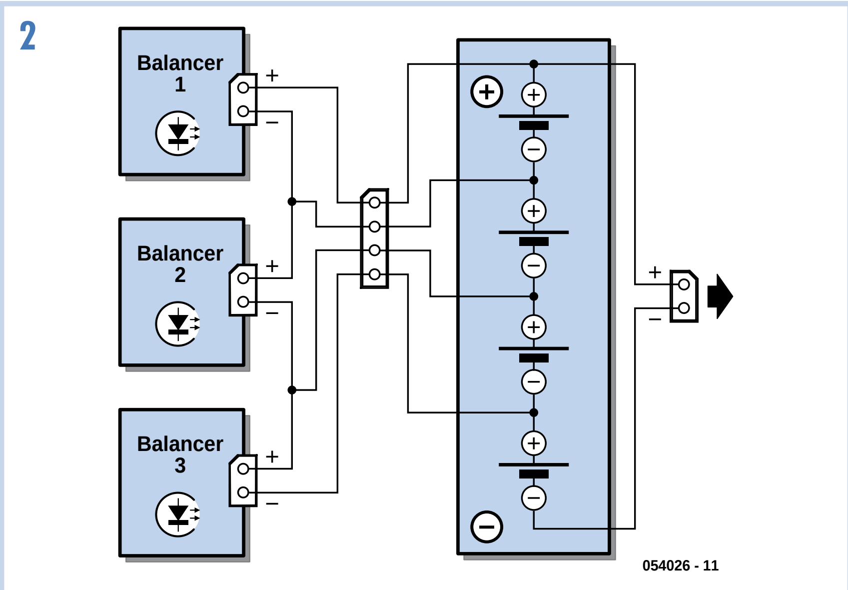

Plant Growth Corrector

092

Paul Goossens

House plants can make things more pleasant and cheerful. However, they have the drawback that they require a fair amount of care, since otherwise their life expectancy is usually quite short. This care is not limited to watering them and occasionally adding a bit of fertilizer to the soil. The problem is that sun-loving plants always try to grow toward the source of sunlight. Regular rotation of these plants can prevent them from growing crooked.

That's not especially difficult with small plants, but it can be a highly unpleasant (and difficult) task with large types, which often have large pots as well.
It's even worse if the plants are located in the garden. These plants always try to grow toward the south (or for readers located south of the equator, toward the north; readers located close to the equator don't have to worry about this!).
One solution is to place a light source on the side of the plant that receives the least amount of sunlight. As the selected light source must be energy-efficient, a standard grow lamp is out of the question. LEDs, by contrast, are a very good choice for this application. Plants contain three different substances that can extract energy from incident light. From **Figure 1**, it can be seen that blue light can be used as a source of energy by all three substances. Red light can only be used by chlorophyll a and chlorophyll b. From this, it can be deduced that blue light is the most suitable source of light for plants, but red light is also quite usable. That's quite fortunate, because red LEDs are a lot cheaper than blue LEDs.
The circuit shown in **Figure 2** can be used as a guide for building your own plant lamp. The AC voltage at the transformer output is converted into a DC voltage by bridge rectifier B1. C1 smoothes this voltage to produce a more constant voltage across the resistor and LEDs. R1 ensures that the proper current flows through the LEDs. These LEDs emit energy in the form of red light. No component values are given here, since suitable values must be selected according to your particular wishes.

The first thing you need to know is the nominal current rating of the LEDs and the

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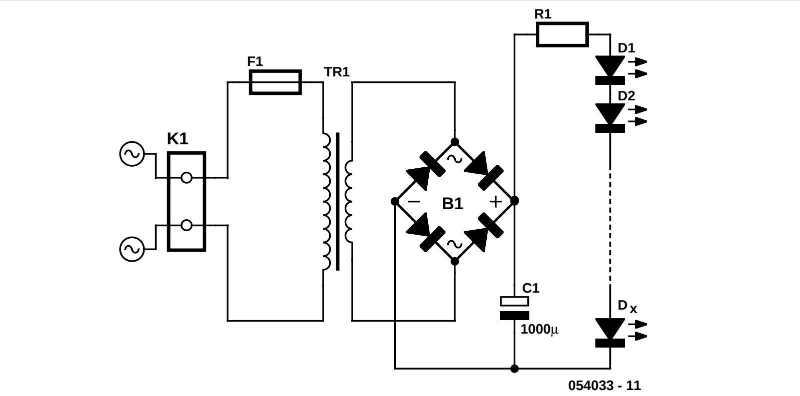

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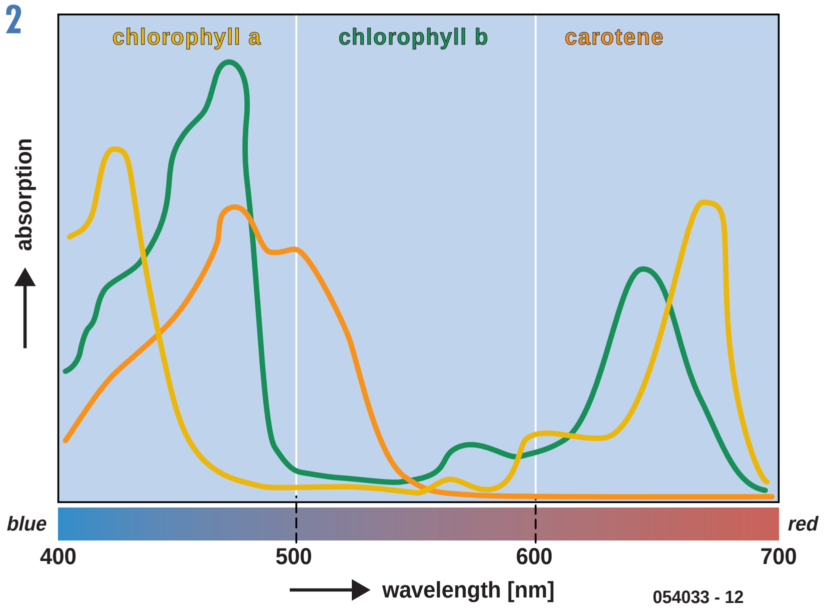


voltage across each LED at the nominal current. The total voltage across the LEDs is then:

$V_{LEDtotal} = V_{LED} \times$ (number of LEDs)

You should ensure that at least 5% of this voltage appears across R1, which means that:

$V_{R1min} = 0.05 \times V_{LEDtotal}$

The voltage across C1 is approximately 1.4 times the output voltage of the transformer, so the secondary voltage of the transformer must be

$V_{xfmr} = (V_{R1min} + V_{LEDtotal}) \div 1.4$

Select a transformer that can provide at least this voltage at the desired nominal current.

Now you can calculate the actual voltage across R1:

$V_{R1} = (1.4 \times V_{xfmr}) - V_{LEDtotal}$

Finally, calculate the value of R1:

$R1 = V_{R1} \div I_{nominal}$

R1 also has to dissipate a certain amount of power, so you have to first calculate this in order to determine what type of resistor to use for R1:

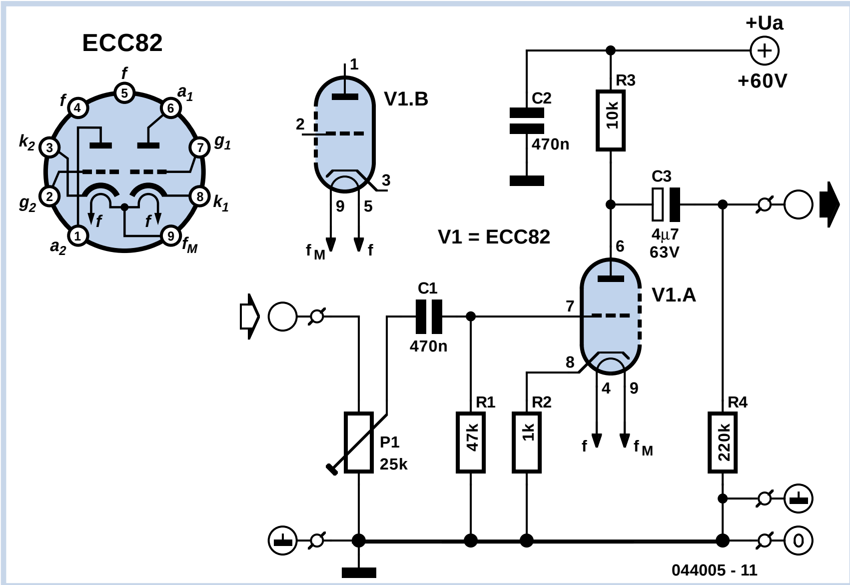
$P_{R1} = V_{R1} \times I_{nominal}$

The value if C1 is not especially critical. Something between 100 µF and 1000 µF is a good guideline value. Ensure that the capacitor is suitable for use with the selected supply voltage.

(054033-1)

093 Valve Sound Converter

Stefan Dellemann



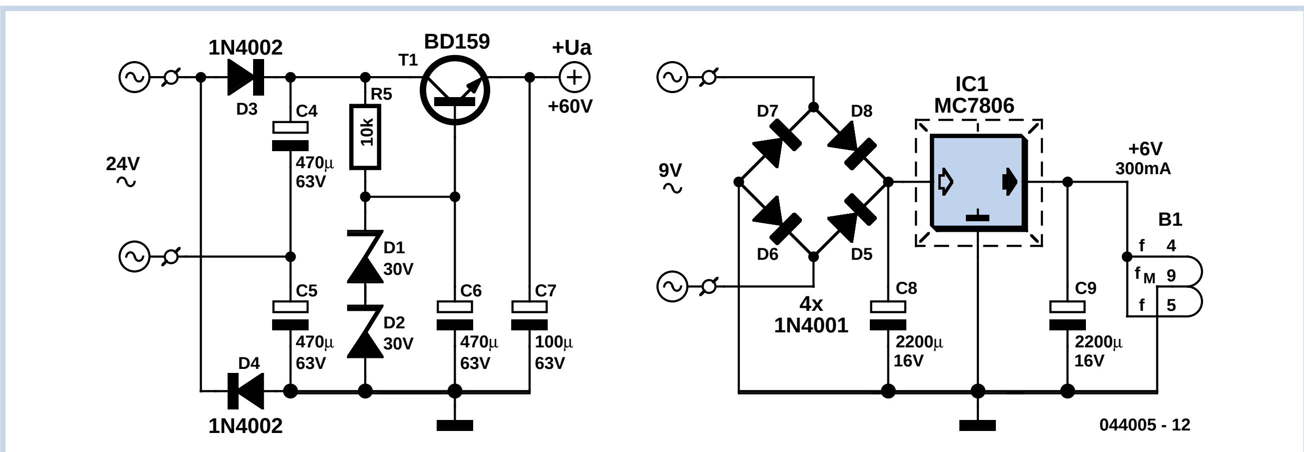
'Valve sound' is not just an anachronism: there are those who remain ardent lovers of the quality of sound produced by a valve amplifier. However, not everyone is inclined to splash out on an expensive valve output stage or complete amplifier with a comparatively low power output. Also, for all their aesthetic qualities, modern valve amplifiers burn up (in the full sense of the word!) quite a few watts even at normal listening volume, and so are not exactly environmentally harmless.

This valve sound converter offers a cunning way out of this dilemma. It is a low-cost unit that can be easily slipped into the audio chain at a suitable point and it only consumes a modest amount of energy. A valve sound converter can be constructed using a common-or-garden small-signal amplifier using a readily-available triode. Compared to using a pentode, this simplifies the circuit and, thanks to its less linear characteristic, offers even more valve sound. For stereo use a double triode is ideal. Because only a low gain is required, a type ECC82 (12AU7) is a better choice than alternatives such as the ECC81 (12AT7) or ECC83 (12AX7). This also makes things easier for homebrewers only used to working with semiconductors, since we can avoid any difficulties with high voltages, obscure transformers and the like: the amplifier stage uses an anode voltage of only 60 V, which is generated using a small 24 V transformer and a voltage doubler (D3, D4, C4 and C5). Since the double triode only draws about 2 mA at this voltage, a 1 VA or 2 VA transformer will do the job. To avoid ripple on the power supply and hence the generation of hum in the converter, the anode voltage is regulated using Zener diodes D1 and D2, and T1. The same goes for the heater supply: rather than using AC, here we use a DC supply, regulated by IC1. The 9 V transformer needs to be rated at at least 3 VA. As you will see, the actual amplifier circuit is shown only once. Components C1 to C3, R1 to R4, and P1 need to be duplicated for the second channel. The inset valve symbol in the circuit diagram and the base pinout diagram show how the anode, cathode and grid of the other half of the double triode (V1.B) are connected. Construction should not present any great difficulties. Pay particular attention to screening and cable routing, and to the placing of the transformers to minimise the hum induced by their magnetic fields.

Adjust P1 to set the overall gain to 1 (0 dB). The output impedance of 47 kΩ is relatively high, but should be compatible with the inputs of most power amplifiers and preamplifiers.

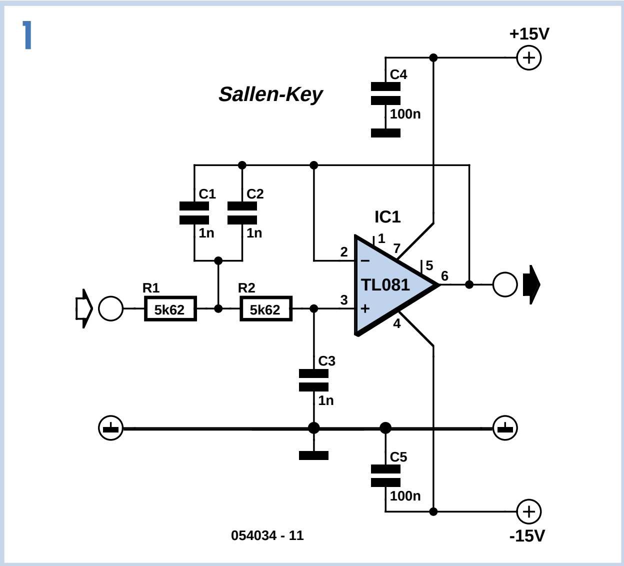
For a good valve sound, the operating point of the circuit should be set so that the audio output voltage is in the region of a few hundred millivolts up to around 1.5 V. If the valve sound converter is inserted between a preamplifier and the power amplifier, it should be **before** the volume control potentiometer as otherwise the sound will change significantly depending on the volume. As an example, no modifications are needed to an existing power amplifier if the converter is inserted between the output of a CD player and the input to the amplifier.

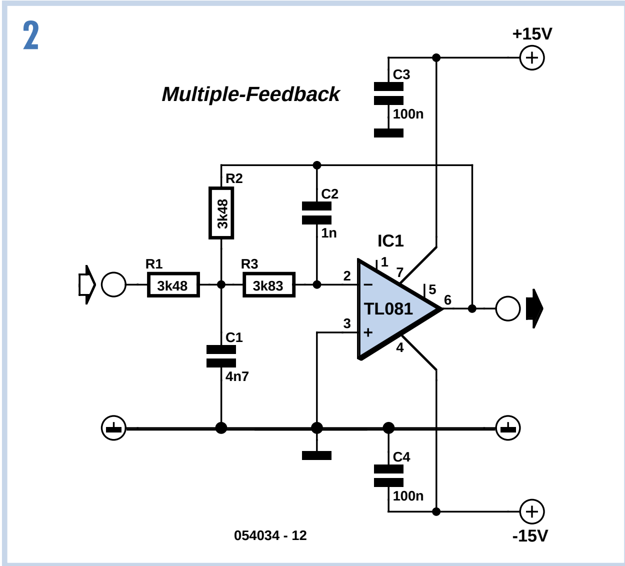
(044005-1)



THD: Sallen–Key versus MFB

094

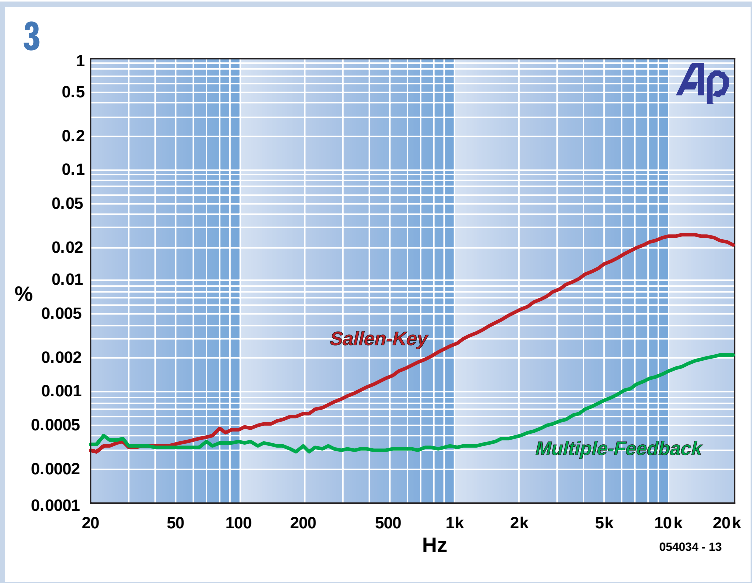




Ton Giesberts

There are various types of active filters, and the Sallen–Key version is probably the most commonly used type. A voltage follower is usually used for such filters, although gain can also be realised using two additional resistors. A disadvantage of this type of filter is its relatively high sensitivity to component tolerances. Measurements made on such filters have shown that component variations affect not only the filter characteristic but also the amount of distortion. However, an advantage is that filters more complex than third-order types can also be realised using a single amplifier stage, although severe requirements are placed on the component values in such cases.

One of the alternatives to the Sallen–Key filter is the 'multiple feedback' (MFB) filter. It owes its name to the fact that the feedback occurs via two paths. The inverting architecture can perhaps be regarded as a slight disadvantage, but that is offset by the fact that non-unity gain can be obtained without using extra components. In addition, the filter is less sensitive to component tolerances. Another drawback is that the implementation is restricted to third-order filters, so additional stages (and thus opamps) are necessary for higher-order filters.



That's all very nice, you might think, but how can multiple-feedback filters be calculated? That's practically impossible to do by hand. Fortunately, various software programs have been developed to do this for you, such as the quite usable FilterPro program from Texas Instruments, which can even calculate component values that exactly match the various E series.

For both types of filter, we designed a 20-kHz low-pass Butterworth bandpass filter using a standard TL081 IC (**Figures 1 and 2**) and then measured the distortion in the output signal for an input signal of 5 V_{rms}. Standard polyester (MKT) capacitors were used in the circuits. To make the ultimate result more distinct, we intentionally used a simple opamp (TL081) and avoided using expensive polypropylene, polystyrene or silver-mica capacitors.

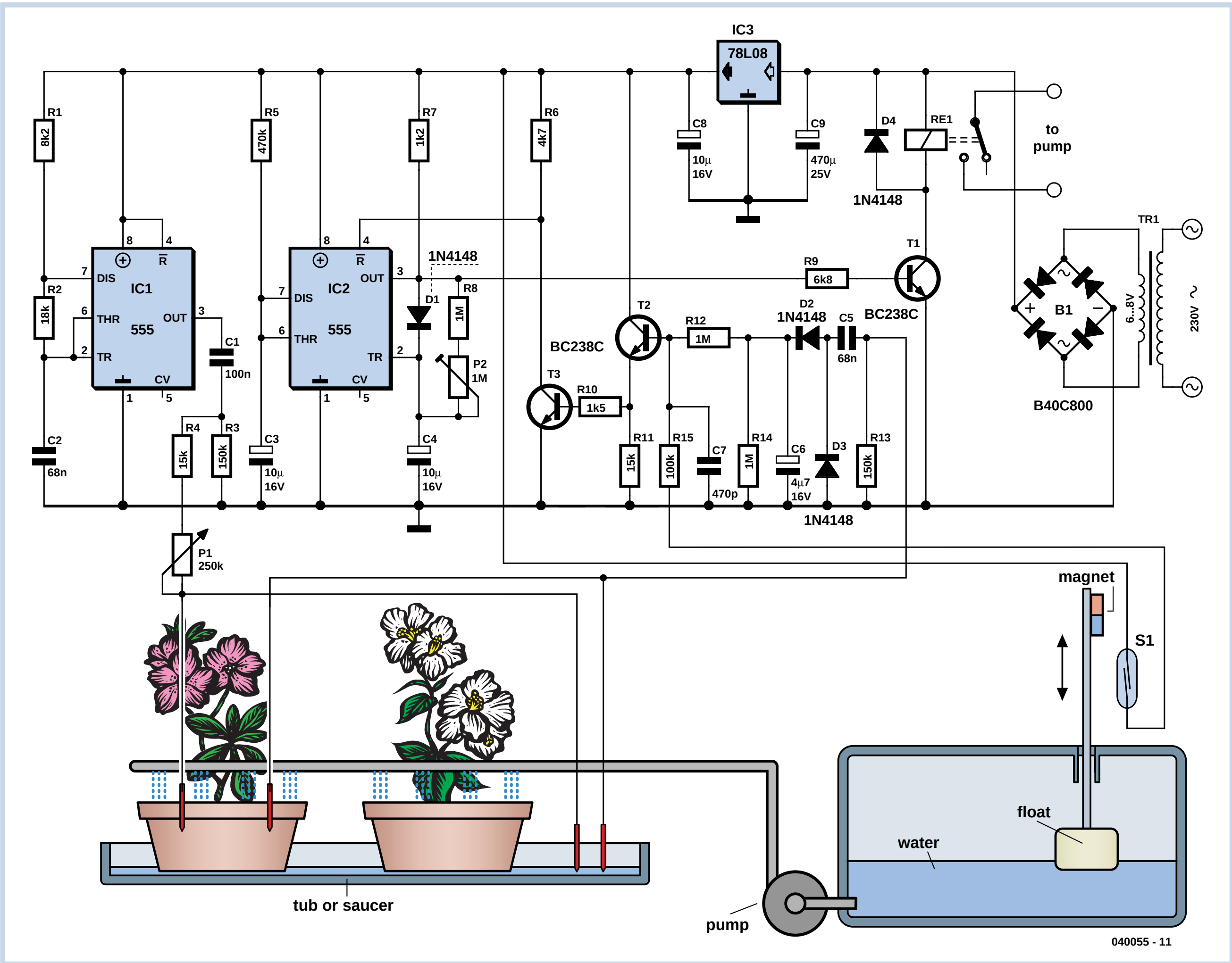
The results of the measurements can be characterised as astonishing. The multiple-feedback filter proved to generate considerably less distortion than the Sallen–Key architecture. **Figure 3** shows the measurements for the two filters, which speak for themselves. The amplitude curves were the same within a few tenths of a dB. The Sallen–Key filter clearly generates up to more than ten times as much distortion at certain frequencies. With the Sallen–Key architecture, better results can be obtained by using better capacitors and opamps (such as an OPA627). From the results, it is clear the multiple-feedback architecture is less sensitive to the components used in the filter.

(054034-1)

FilterPro:
http://focus.ti.com/docs/toolsw/folders/print/filterpro.html

095

An Electronic Watering Can



Robert Edlinger

Summertime is holiday time but who will be looking after your delicate houseplants while you are away? Caring for plants is very often a hit or miss affair, sometimes you under-water and other times you over-water. This design seeks to remove the doubt from plant care and keep them optimally watered.

The principle of the circuit is simple: first the soil dampness is measured by passing a signal through two electrodes placed in the soil. The moisture content is inversely proportional to the measured resistance. When this measurement indicates it is too dry, the plants are given a predefined dose of water. This last part is important for the correct function of the automatic watering can because it takes a little while for the soil to absorb the water dose and for its resistance to fall. If the water were allowed to flow until the soil resistance drops then the plant would soon be flooded.

The circuit shows two 555 timer chips IC1 and IC2. IC1 is an astable multivibrator producing an ac coupled square wave at around 500 Hz for the measurement electrodes F and F1. An ac signal reduces electrode corrosion and also has less reaction with the growth-promoting chemistry of the plant. Current flowing between the electrodes produces a signal on resistor R13. The signal level is boosted and rectified by the voltage doubler produced by D2 and D3. When the voltage level on R13 is greater than round 1.5 V to 2.0 V transistor T2 will conduct and switch T3. Current flow through the soil is in the order of 10 µA.

T2 and T3 remain conducting providing the soil is moist enough. The voltage level on pin 4 of IC2 will be zero and IC2 will be disabled. As the soil dries out the signal across R13 gets smaller until eventually T2 stops conducting and T3 is switched off. The voltage on pin 4 of IC2 rises to a ‘1’ and the chip is enabled. IC2 oscillates with an ‘on’ time of around 5 s and an ‘off’ time (adjustable via P2) of 10 to 20 s. This signal switches the water pump via T1. P1 allows adjustment of the minimum soil moisture content necessary before watering is triggered.

The electrodes can be made from lengths of 1.5 mm^2 solid copper wire with the insulation stripped off the last 1 cm. The electrodes should be pushed into the earth so that the tips are at roughly the same depth as the plant root ball. The distant between the electrodes is not critical; a few centimetres should be sufficient. The electrode tips can be tinned with solder to reduce any biological reaction with the copper surface. Stainless steel wire is a better alternative to copper, heat shrink sleeving can used to insulate the wire with the last 1 cm of the electrode left bare.
Two additional electrodes (F1) are con-

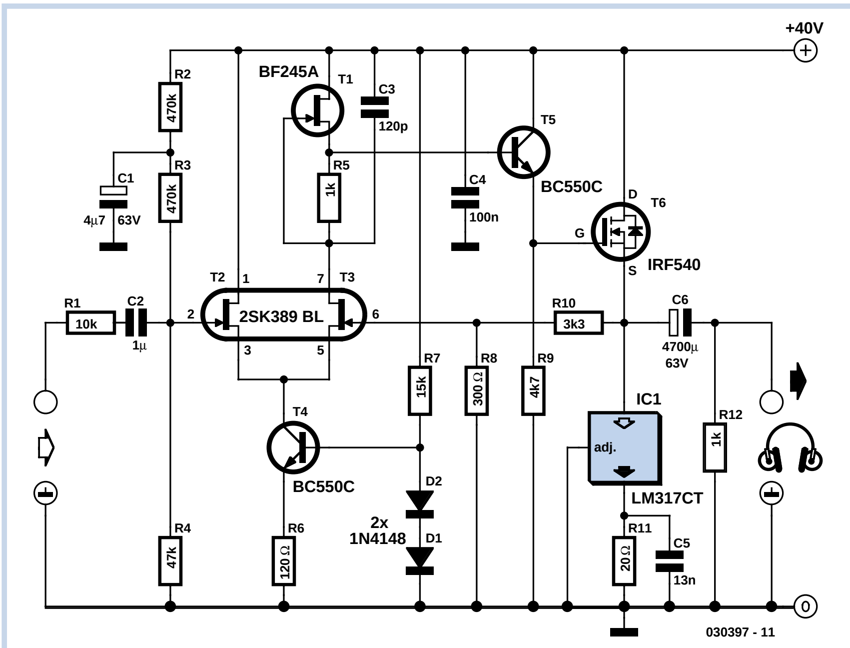
nected in parallel to the soil probe electrodes (F). The F1 electrodes are for safety to ensure that the pump is turned off if for some reason water collects in the plant pot saucer. A second safety measure is a float switch fitted to the water reservoir tank. When the water level falls too low a floating magnet activates a reed switch and turns off the pump so that it is not damaged by running with a dry tank.
Water to the plants can be routed through closed end plastic tubing (with an internal diameter of around 4 to 5 mm) to the plant pots. The number of 1 mm to 1.5 mm outlet holes in the pipe will control the dose of water supplied to each plant. The soil probes can only be inserted into one flowerpot so choose a plant with around average water consumption amongst your collection. Increasing or decreasing the number of holes in the water supply pipe will adjust water supply to the other plants depending on their needs. A 12 V water pump is a good choice for this application but if you use a mains driven pump it is essential to observe all the necessary safety precautions.
Last but not least the electronic watering can is too good to be used just for holiday periods, it will ensure that your plants never suffer from the blight of over or under-watering again; provided of course you remember to keep the water reservoir topped up…

(044055-1)

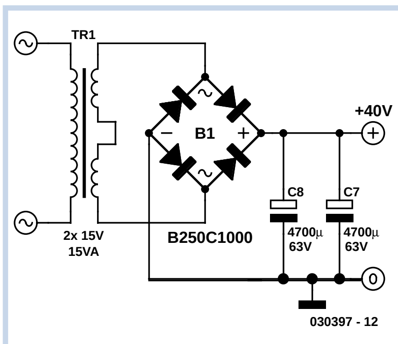
Precision Headphone Amplifier

096

Hergen Breitzke



Designs for good-quality headphone amplifiers abound, but this one has a few special features that make it stand out from the crowd.
We start with a reasonably conventional input stage in the form of a differential amplifier constructed from dual FET T2/T3. A particular point here is that in the drain of T3, where the amplified signal appears, we do not have a conventional current source or a simple resistor. T1 does indeed form a current source, but the signal is coupled out to the base of T5 not from the drain of T3 but from the source of T1. Notwithstanding the action of the current source this is a low impedance point for AC signals in the differential amplifier. Measurements show that this trick by itself results in a reduction in harmonic distortion to considerably less than –80 dB (much less than 0.01 %) at 1 kHz.
T5 is connected as an emitter follower and provides a low impedance drive to the gate of T6: the gate capacitance of HEXFETs is far from negligible. IC1, a voltage regulator configured as a current sink, is in the load of T6. The quiescent current of 62 mA (determined by R11) is suitable for an output power of 60 mW_{eff} into an impedance of 32 Ω, a value typical of high-quality headphones, which provides plenty of volume. Using higher-impedance headphones, say of 300 Ω, considerably more than 100 mW can be achieved.
The gain is set to a useful 21 dB (a factor of 11) by the negative feedback circuit involving R10 and R8. It is not straightforward to change the gain because of the single-sided supply: this voltage divider also affects the operating point of the amplifier. The advantage is that excellent audio quality can be achieved even using a simple unregulated mains supply. Given the relatively low power output the power supply is considerably overspecified. Noise and hum thus remain more than 90 dB below the signal (less than 0.003 %), and the supply can also power two amplifiers for stereo operation.
The bandwidth achievable with this design is from 5 Hz to 300 kHz into 300 Ω, with an output voltage of 10 V_{pp}. The damping factor is greater than 800 between 100 Hz and 10 kHz.
A couple of further things to note: somewhat better DC stability can be achieved by replacing D1 and D2 by low-current red LEDs (connected with the right polarity!). R12 prevents a click from the discharge of

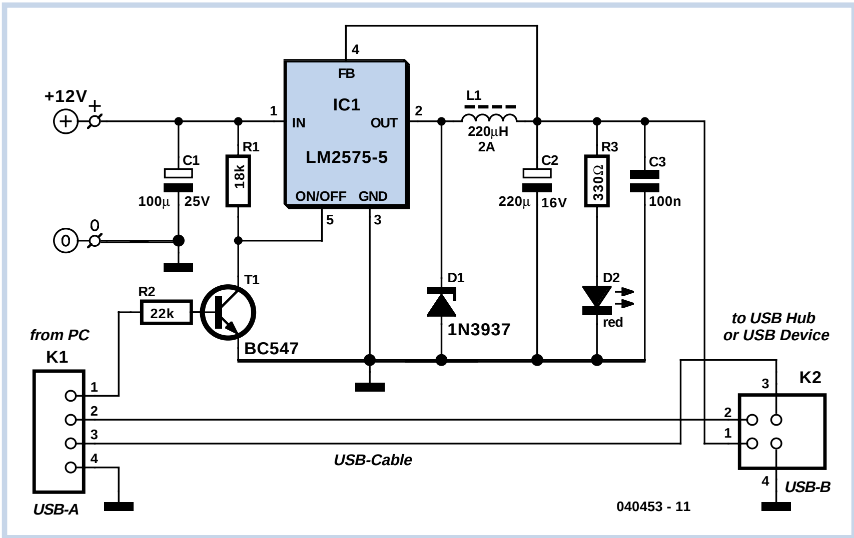


C6 when headphones are plugged in after power is applied. T6 and IC1 dissipate about 1.2 W of power each as heat, and so cooling is needed. For low impedance headphones the current through IC1 should be increased. To deliver 100 mW into 8 Ω, around 160 mA is required, and R11 will need to be 7.8 Ω (use two 15 Ω resistors in parallel). To keep heat dissipation to a reasonable level, it is recommended to reduce the power supply voltage to around 18 V (using a transformer with two 6 V secondaries). This also means an adjustment to the operating point of the amplifier: we will need about 9 V between the positive end of C6 and ground. R4 should be changed to 100 Ω, and R8 to 680 Ω. The gain will now be approximately 6 (15 dB). The final dot on the 'i' is to increase C7 by connecting another 4700 µF electrolytic in parallel with it, since an 8 Ω load will draw higher currents.

(030397-1)

097 USB Power Booster

Myo Min



Power shortage problems arise when too many USB devices connected to PC are working simultaneously. All USB devices, such as scanners, modems, thermal printers, mice, USB hubs, external storage devices and other digital devices obtain their power from PC. Since a PC can only supply limited power to USB devices, external power may have to be added to keep all these power hungry devices happy.

This circuit is designed to add more power to a USB cable line. A sealed 12-V 750 mA unregulated wall cube is cheap and safe. To convert 12 V to 5 V, two types of regulators, switching and linear are available with their own advantages and drawbacks. The switching regulator is more suitable to this circuit because of high efficiency and compactness and now most digital circuits are immune to voltage ripple developed during switching. The simple switcher type LM2575-5 is chosen to provide a stable 5 V output voltage. This switcher is so simple it just needs three components: an inductor, a capacitor and a high-speed or fast-recovery diode. Its principle is that internal power transistor switch on and off according to a feedback signal. This chopped or switched voltage is converted to DC with a small amount of ripple by D1, L1 and C2.

The LM2575 has an ON/OFF pin that is switched on by pulling it to ground. T1, R2, and R1 (pull-up resistor) pull the ON/OFF pin to ground when power signal from PC or +5 V is received. D2, a red LED with current resistor R3, serves to indicate 'good' power condition or stable 5 V. C3 is a high-frequency decoupling capacitor. The author managed to cut a USB cable in half without actually cutting data wires. It is advisable to look at the USB cable pin assignment for safety.

(040453-1)

098 Dual Oscillator for µCs

Ton Giesberts

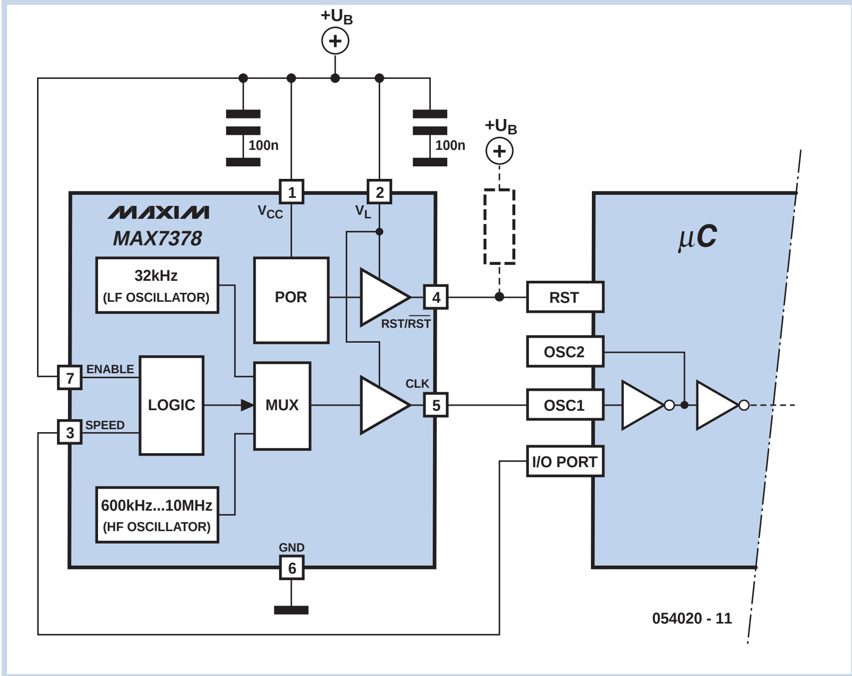
The MAX7378 contains two oscillators and a power-on reset circuit for microprocessors. The Speed input selects either 32.768 kHz (LF) or a higher frequency, which is pre-programmed. The type number corresponds to the standard pre-programmed value and the value of the reset threshold. There is a choice of two threshold values: 2.56 V and 4.29 V. Both thresholds are available with all standard frequencies, which are 1 MHz, 1.8432 MHz, 3.39545 MHz, 3.6864 MHz, 4 MHz, 4.1943 MHz, and 8 MHz. However, any frequency between 600 kHz and 10 MHz is also possible.

An internal synchronisation circuit ensures that no glitches occur when switching between the two oscillators. The Reset output of the MAX7378 is available in three different options. Two of the options are push-pull types, either active low or active high. The third option is open drain, which thus requires an external pull-up resistor. That is the only standard option (which is why a resistor in dashed outline is shown connected to the Reset output). The Reset signal remains active for 100 µs after the supply voltage rises above the threshold voltage. The Reset signal becomes active immediately if the voltage drops below the threshold.

The IC is powered via two separate pins. The V_L pin powers the reset and oscillator circuitry, while the V_{CC} pin powers the remainder of the chip. The two pins must always have the same potential. Good decoupling in the form of two 100-nF ceramic capacitors (SMD types) is also necessary.

The IC is housed in the tiny 8-pin µMAX package and has dimensions of only 3.05 × 5.03 mm including pins, with a pin pitch of only 0.65 mm.

Unfortunately, the accuracy of the oscillators is not especially good. The HF oscillator has an error of ±2% at 25 °C with a 5-V supply voltage and a maximum temperature coefficient of +325 ppm, which doesn't exactly correspond to crystal accuracy, but it is certainly usable for most non-time-critical applications. The error over the full supply voltage range (2.7–5.5 V) is twice as large. The 32.768-kHz oscillator is more accurate, with an error of only 1% at 5 V and 25 °C, although this is still a bit too much for time measurements. The error can be as much as ±3% over the entire supply voltage range. The maximum current consumption is 5.5 mA, which is relatively low.



(054020-1)

Step-up Converter for 20 LEDs

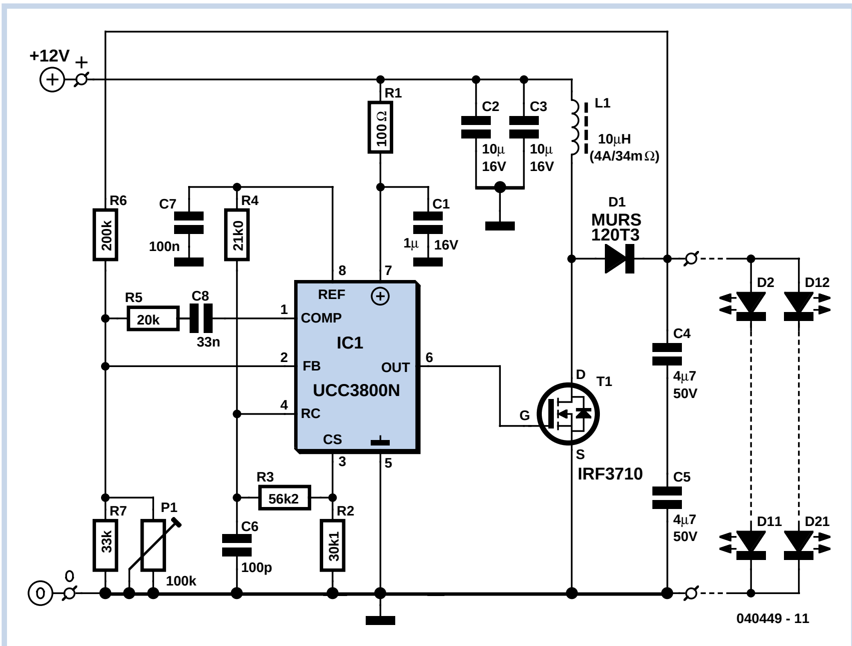
099

Dirk Gehrke

The circuit described here is a step-up converter to drive 20 LEDs, designed to be used as a home-made ceiling night light for a child's bedroom. This kind of night light generally consists of a chain of Christmas tree lights with 20 bulbs each consuming 1 W, for a total power of 20 W. Here, in the interests of saving power and extending operating life, we update the idea with this simple circuit using LEDs.

Power can be obtained from an unregulated 12 V mains adaptor, as long as it can deliver at least about 330 mA. The circuit uses a low-cost current-mode controller type UCC3800N, reconfigured into voltage mode to create a step-up converter with simple compensation. By changing the external components the circuit can easily be modified for other applications.

To use a current-mode controller as a voltage-mode controller it is necessary to couple a sawtooth ramp (rising from 0 V to 0.9 V) to the CS (current sense) pin, since this pin is also an input to the internal PWM comparator. The required ramp is present on the RC pin of the IC and is reduced to the correct voltage range by the voltage divider formed by R3 and R2. The RC network formed by R4 and C6 is dimensioned to set the switching frequency at approximately 525 kHz.



The comparator compares the ramp with the divided-down version of the output voltage produced by the potential divider formed by R6 and R7. Trimmer P1 allows the output voltage to be adjusted. This enables the current through the LEDs to be set to a suitable value for the devices used.

The UCC3800N starts up with an input voltage of 7.2 V and switches off again if the input voltage falls below 6.9 V. The circuit is designed so that output voltages of between 20 V and 60 V can be set using P1. This should be adequate for most cases, since the minimum and maximum specified forward voltages for white LEDs are generally between 3 V and 4.5 V. For the two parallel chains of ten LEDs in series shown here a voltage of between 30 V and 45 V will be required. The power components D1, T1 and L1 are considerably overspecified here, since the circuit was originally designed for a different application that required higher power.

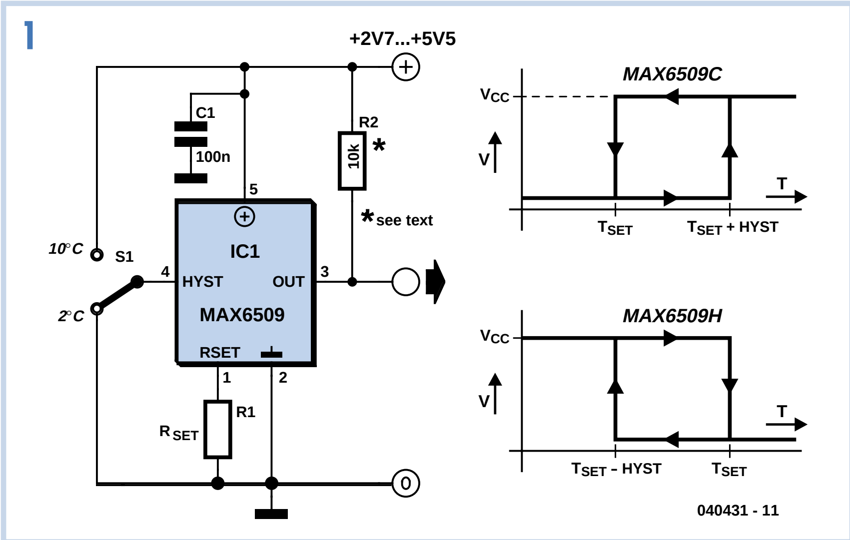
To adjust the circuit, the potentiometer should first be set to maximum resistance and a multimeter set to a 200 mA DC current range should be inserted in series with the output to the LEDs. Power can now be applied and P1 gradually turned until a constant current of 40 mA flows. The step-up converter is now adjusted correctly and ready for use.

(040449-1)

100

Resistor-Programmable Temperature Switch

T in°C	R_{SET}	T in°C	R_{SET}
–40	150 kΩ	35	62 kΩ
–30	136 kΩ	40	57.6 kΩ
–20	122 kΩ	45	53.3 kΩ
–10	108 kΩ	50	49.2 kΩ
–5	102 kΩ	60	41.3 kΩ
0	96.5 kΩ	70	33.9 kΩ
5	92 kΩ	80	27 kΩ
10	86.2 kΩ	90	20.4 kΩ
15	81 kΩ	100	14.1 kΩ
20	76 kΩ	110	8.2 kΩ
25	71 kΩ	120	2.6 kΩ
30	66.5 kΩ	125	0

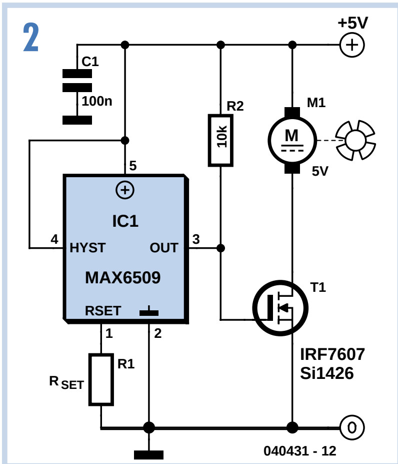


Gregor Kleine

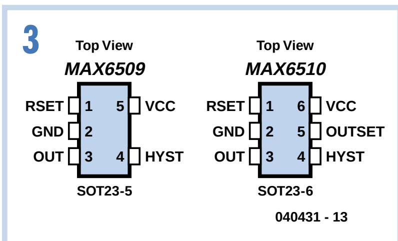
The switching threshold of the MAX6509 temperature switch from Maxim (www.maxim-ic.com) can be programmed over a range of –40 °C to +125 °C using an external resistor. The IC needs only two external components (see **Figure 1**). A hysteresis value of 2 °C (typical) or 10 °C (typical) can be selected by connecting the HYST pin to ground or Vcc, respectively.

The standard version of the IC is the MAX6509C, which pulls its open-drain output to ground when the temperature is below the threshold value set using the resistor. As shown in **Figure 2**, this version of the IC can be used to control a fan via an external MOSFET. The MAX6509H version has an inverted output, which means it is switched to ground when the temperature is above the threshold. A possible application for this version is switching on a heater in an oven when the temperature drops below the set point.

The IC is housed in a SOT232 SMD package (**Figure 3**). The MAX6509 operates over a supply voltage range of +2.7–5.5 V with a supply current of only approximately 40 µA. The resulting self-heating is thus small enough to avoid corrupted temperature measurements (as long as the output transistor is not required to switch high currents to ground). The table lists suitable values of resistor R_{SET} for various threshold temperatures.

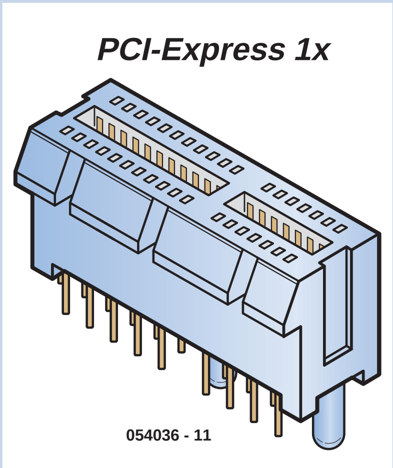


The companion MAX6510 has an output stage that can be configured via a separate pin. The options are active high, active low, and open drain with an internal pull-up resistor. Like the MAX6510, MAX6510 is available in a -C version (open drain when the threshold temperature is exceeded) and an -H version (output pulled to ground when the threshold temperature is exceeded).



(040431-1)

PCI Express



Paul Goossens

Many new PCs now come equipped with one or more PCI Express slots on the motherboard. Eventually, PCI Express will make the old PCI standard obsolete, but for now most expansion cards still use the (old) PCI standard.

The old standard (PCI 1.0) had a maximum bandwidth of 133 MB per second. In the meantime there have been many developments in the computer industry. We can now watch videos over the Internet, as well as listen to the radio. MP3s (also unheard of then) are decoded in real-time, while we might also watch a DVD in another window.

All these applications place a big demand on the PC hardware. To process these data streams efficiently, contemporary PCs have a separate memory bus, another bus for the graphics card (AGP) and yet another bus (PCI) that lets the processor communicate with expansion cards.

There have been several enhancements to the PCI bus (e.g. the 66 MHz PCI bus, 64 bit versions, etc.), but the time has come for a complete overhaul. The result is PCI Express. The x1 version has a bandwidth of 250 MB/s, but other versions are waiting in the wings (including a x16 version) to provide even greater bandwidths.

One way in which the data rate can be increased is to increase the number of bits that are moved at the same time. This technique has already been used in processors to increase their speed. For PCI Express however, a serial transport mechanism was chosen (as with SATA, USB, firewire, etc.).

The slowest version of PCI Express uses a connector with only 26 connections. The connection details for the PCI Express connector are shown in **Table 1**.

There are only four signals on this connector that take care of the actual data transmission via the PCI Express protocol. These are the signal pairs PETn0/PETp0 and PERn0/PERp0. Signal pair PETx0 (PCI Express Transmit 0) moves data from the host (PC) to the slave (slot), while PERx0 (PCI Express Receive 0) moves the data in the opposite direction. The small letter p or n denotes the polarity (positive or negative).

The data has to be in step with a clock signal, provided by the signal pair CLK+ and CLK-.

The rest of the connections are for the supply, plus a few more signals for housekeeping tasks. It is noteworthy that the connector also has a USB port and an SMBus (a type of I_C bus). This bus is used in PCs for power management and system monitoring. PCI Express cards could, for example, return measurements of the supply voltage and temperature. The PC could also put the expansion card into standby mode while it wasn't needed.

Faster versions of PCI Express make use of multiple transmit and receive channels, (hence the '0' in, for example, PERn0). In this way a form of parallelism is still used to provide a speed increase.

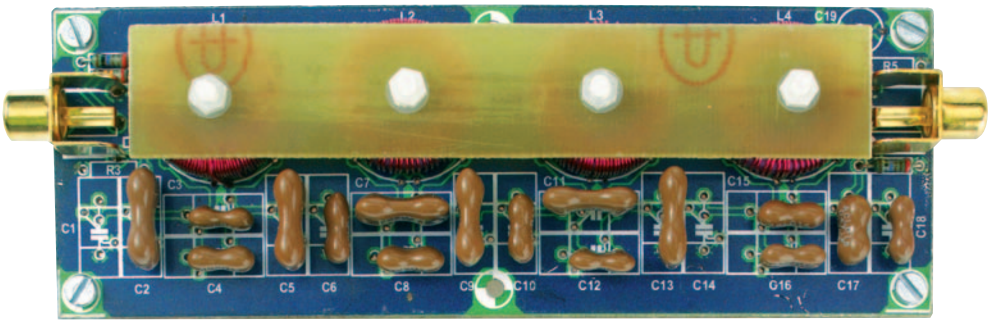
(054036-1)

Table 1

Pin	Name	From	To	Description
1	GND	N/A		Ground
2	USBD–	bidirectional		USB signals
3	USBD+			
4	$\overline{\text{CPUSB}}$	slave	host	Detection of USB device
5	reserved			
6	reserved			
7	SMBCLK	bidirectional		SMBus clock
8	SMBDATA			SMBus data
9	+1.5V	N/A		+1.5V supply voltage
10	+1.5V			
11	$\overline{\text{WAKE}}$	slave	host	Wake-up signal for host
12	+3.3V	N/A		+3.3V supply voltage
13	$\overline{\text{PERST}}$	host	slave	Reset signal
14	+3.3V	N/A		+3.3V supply voltage
15	+3.3V			
16	$\overline{\text{CLKREQ}}$	slave	host	Clock request
17	$\overline{\text{CPPE}}$	slave	host	PCI Express detection
18	REFCLK–	host	slave	Differential clock signal pair synchronous with data
19	REFCLK+	host	slave	
20	GND	N/A		Ground
21	PERn0	slave	host	Differential data signal pair from slave to host
22	PERp0	slave	host	
23	GND	N/A		Ground
24	PETn0	host	slave	Differential data signal pair from host to slave
25	PETp0	host	slave	
26	GND	N/A		Ground

102

Passive 9th-order Elliptical Filter



Ton Giesberts

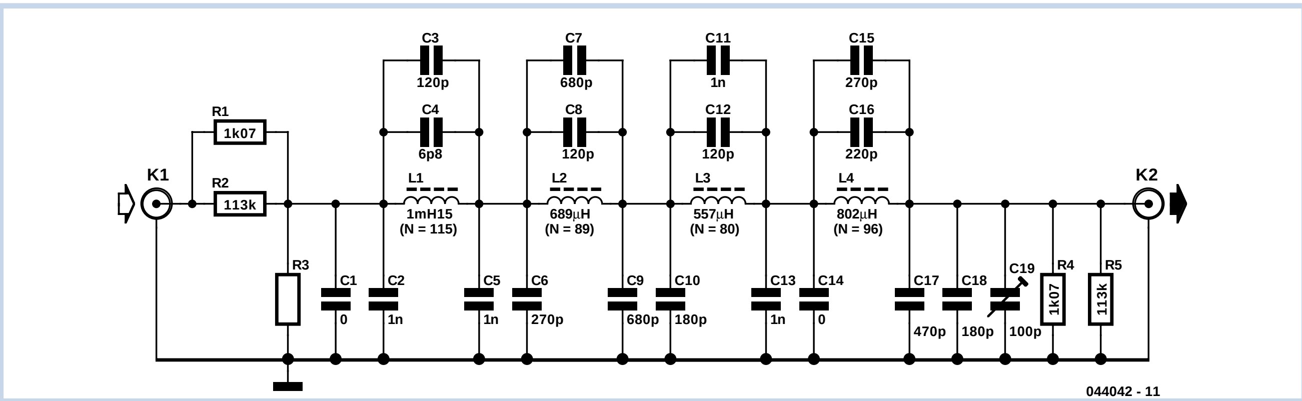
Steep filters can be realised in many different ways, for example by connecting active 2nd to 5th-order sections in series and calculating the component values for the higher order. They can also be made passive, but in practice this has a few difficulties associated with it. You cannot avoid the need for inductors with values that deviate from the standard series. You will have to wind them yourself on a specially selected core. The filter presented here was originally designed to enable measurements to be made on the Class-T Amplifier (yes indeed, the one in *Elektor Electronics,* June 2004).

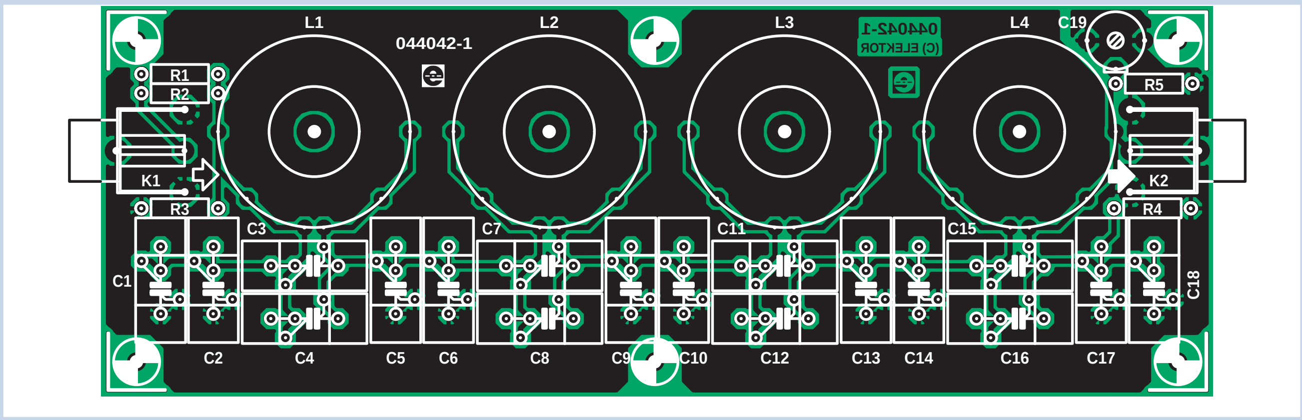
When designing and testing audio equipment, we use a System Two Cascade Plus Analyzer made by Audio Precision. The accuracy of the measurements with this instrument is reduced if frequency components above 200 kHz are present at significant levels. This is the case with our amplifier, particularly at low signal levels. We immediately went for large artillery, namely a 9th-order elliptical filter. During the design of the filter we made use of normalised tables. In the end it became a filter with identical termination impedances, which unfortunately means an attenuation of two times within the pass band. When converting to realistic values we selected pure E12-series values for C1(+C2). All capacitors are arranged as two in parallel in order to closely approximate the calculated value. This applies to the resistors as well. With the inductors there is no way to avoid 'funny' values and series or parallel connections don't make much sense because to achieve a certain quality, standard coils are not appropriate. So we had to think of a solution ourselves. The input and output impedance are theoretically 1.060 kΩ and are approximated quite well with components in parallel (1.05996 kΩ). By making use of a voltage divider it becomes possible for R3 to handle a higher voltage (otherwise note the dissipation of R1!). Any voltage divider needs to have an output impedance of 1.06 kΩ (R1//R2//R3). In the last section, the parasitic capacitance of the connecting cable and input impedance of the analyser has been taken into account. Trimmer C19 can be used to compensate the attached capacitance and R5 can be omitted if the input impedance is about 100 kΩ. A deviation of about 50 pF makes little difference to the amplitude characteristic in the pass-band.

The advantage of an elliptical filter compared to, for example a Chebyshev filter, is to trade off a limited attenuation in the stop- band to a much steeper transition from pass- to stop-band. It suffices to mention that the curve from 180 kHz to 200 kHz falls by more than 60 dB, quite steep and certainly not bad for a passive filter! In practice the attenuation in the stop-band at –63 dB was a little lower than the theoretical value of 60.2 dB, which was the design value.

Frequency characteristic A shows mainly the stop-band and the characteristic behaviour of an elliptical filter can be clearly seen. Frequency characteristic B shows an enlarged version of the ripple in the pass-band, which also shows the phase behaviour of the filter (scale on the right). At 20 kHz the attenuation is only 0.1 dB and the phase shift only -30°. The first dip of only -0.263 dB occurs at about 46 kHz and the attenuation at 100 kHz is only 0.276 dB. Above that, the non-ideal behaviour of the components becomes noticeable and the curve starts to drop a little too soon, but the characteristic elliptical behaviour is still clearly visible at 180 kHz.

The filter proved to be quite useful in filtering the PWM signal and analyse the LF- amplitude. The only disadvantage is the increasing distortion at 20 kHz (from 0.5 V input signal) so that good THD+N measurements can only be done at 1 kHz. This can be seen clearly in Graph C. With 1 W into 8 Ω (2.828 V) the distortion at 1 kHz is less than 0.001%, but at 20 kHz the distortion is





COMPONENTS LIST

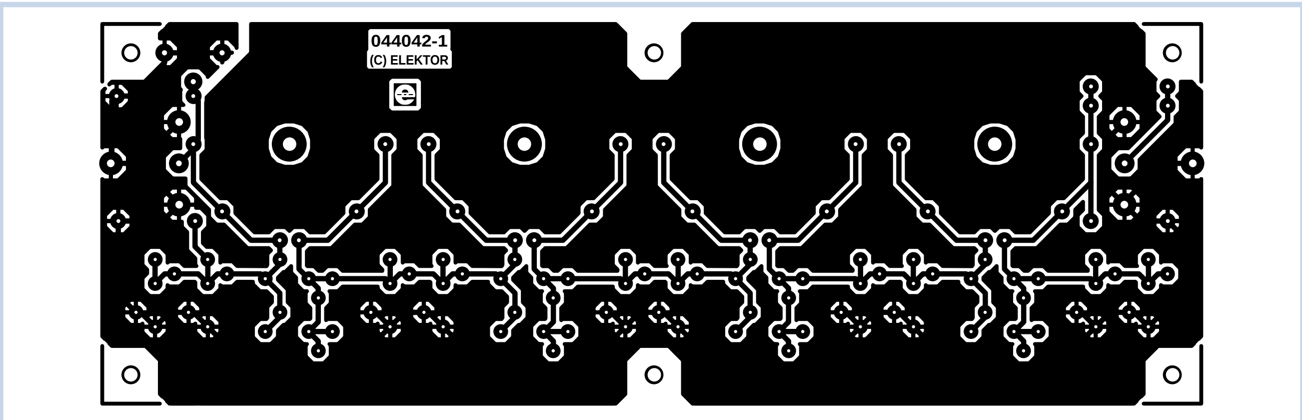
Resistors:
R1,R4 = 1kΩ07
R2,R5 = 113kΩ
R3 = not fitted *

Capacitors:
C1,C14 = not fitted *
C2,C5,C11,C13 = 1nF 500V 1% silvered mica (Farnell 868-012)
C3,C8,C12 = 120pF 500V 1% silvered mica (Farnell 867-901)
C4 = 6pF8 500V 1% silvered mica (Farnell 867-779)
C6,C15 = 270pF 500V 1% silvered mica (Farnell 867-949)
C7,C9 = 680pF 500V 1% silvered mica (Farnell 867-998)
C10,C18 = 180pF 500V 1% silvered mica (Farnell 867-925)
C16 = 220pF 500V 1% silvered mica (Farnell 867-937)
C17 = 470pF 500V 1% silvered mica (Farnell 867-974)
C19 = 100pF trimmer

Inductors:
L1 = 1mH15, 115 turns of 0.5mm dia. ECW on core TN23/14/7-4C65 from BCcomponents (Farnell # 180-009)
L2 = 689µH, 89 turns of 0.5mm dia. ECW on core TN23/14/7-4C65 from BCcomponents (Farnell # 180-009)
L3 = 557µH, 80 turns of 0.5mm dia. ECW on core TN23/14/7-4C65 from BCcomponents (Farnell 1# 80-009)
L4 = 802µH, 96 turns of 0.5mm dia. ECW on core TN23/14/7-4C65 from BCcomponents (Farnell # 180-009)

Miscellaneous:
K1,K2 = cinch socket, PCB mount, e.g., T-709G (Monacor/Monarch)
PCB, available from The PCBShop

* see text



20 times larger. In this measurement the maximum input signal was 13.33 V (maximum from the analyser).

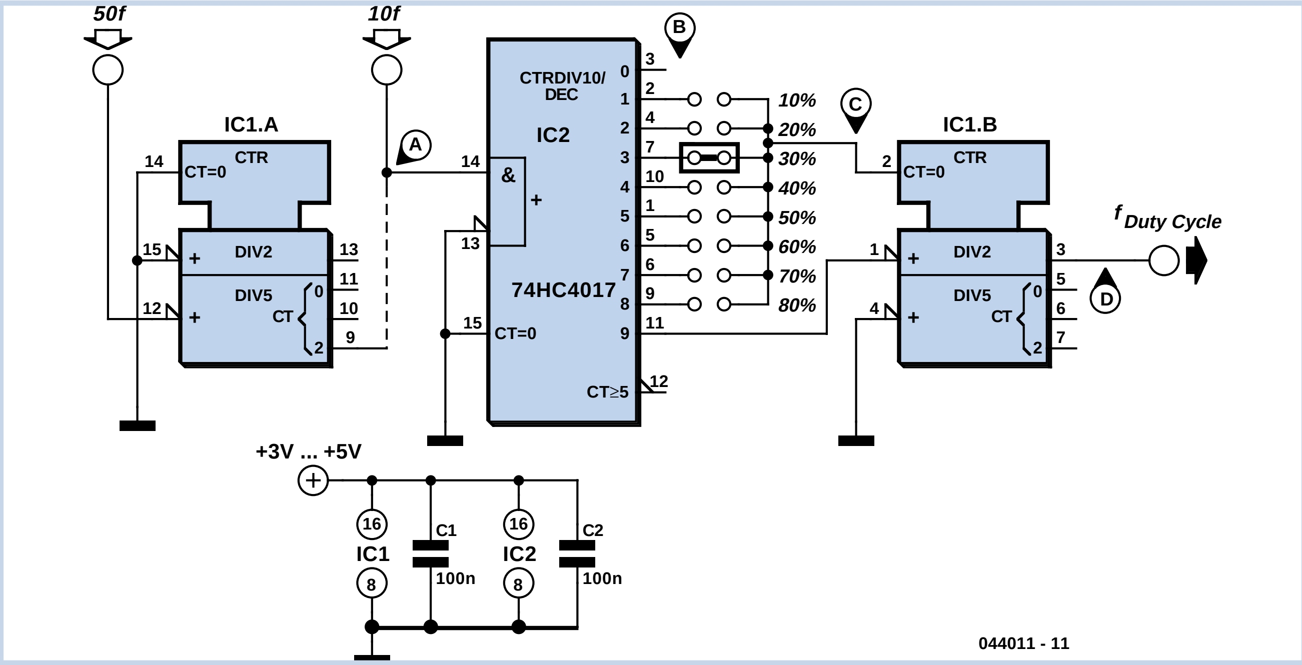
For those who love to experiment and wind inductors, we have also designed a PCB. A low permeability core material (TN23/14/7-4C65) was selected for the inductors, so that saturation and material properties are less of a problem. Unfortunately this results in a higher number of turns, but also means that the inductor value can be made more accurate. A larger core may have resulted in a lower distortion, but it would have been harder to obtain an accurate value. Toroids were selected to minimise mutual coupling — that this was successful is shown in Graph A. It is easiest when winding the cores to calculate the amount of wire required beforehand and then add 10 or more centimetres. You have to wind tightly and put the turns close together to prevent the second layer dropping in between the first layer. This applies to the inside of the ring core. When using 0.5 mm enamelled wire the second layer turns easily fit between the first layer turns. The PCB has been designed such that connections can be made in several places (3 inside a quarter circle). The capacitors are 1% silvered mica types with an operating voltage of 500 V. That way even extreme voltage peaks will not cause any harm. There is also room for 1% tolerance 'Styroflex' (polystyrene) capacitors from Siemens (that are not made any more), which we have used in the past. Other manufacturers also use this shape.

(044042-1)

Theoretical component values

R1//R2 = 1.060 kΩ
R4//R5 = 1.060 kΩ
C1+C2 = 1.000 nF
C3+C4 = 128.0 pF
C5+C6 = 1.277 nF
C7+C8 = 809.0 nF
C9+C10 = 860.4 nF
C11+C12 = 1.125 nF
C13+C14 = 996.8 pF
C15+C16 = 492.7 nF
C17+C18+C19 = 742.4 pF
L1 = 1.148 mH
L2 = 693.3 µH
L3 = 556.4 µH
L4 = 809.6 µH

103 Adjustable Duty Cycle



Gregor Kleine

The circuit shown here can be used to convert a digital input signal having any desired duty cycle into a output signal having a duty cycle that can be adjusted between 10% and 80% in steps of 10%. The circuit is built around a 74HC4017 decade Johnson counter IC. Individual pulses appear on the ten outputs (Q0–Q9) of this IC at well-defined times, depending on the number of input pulses (see the timing diagram).

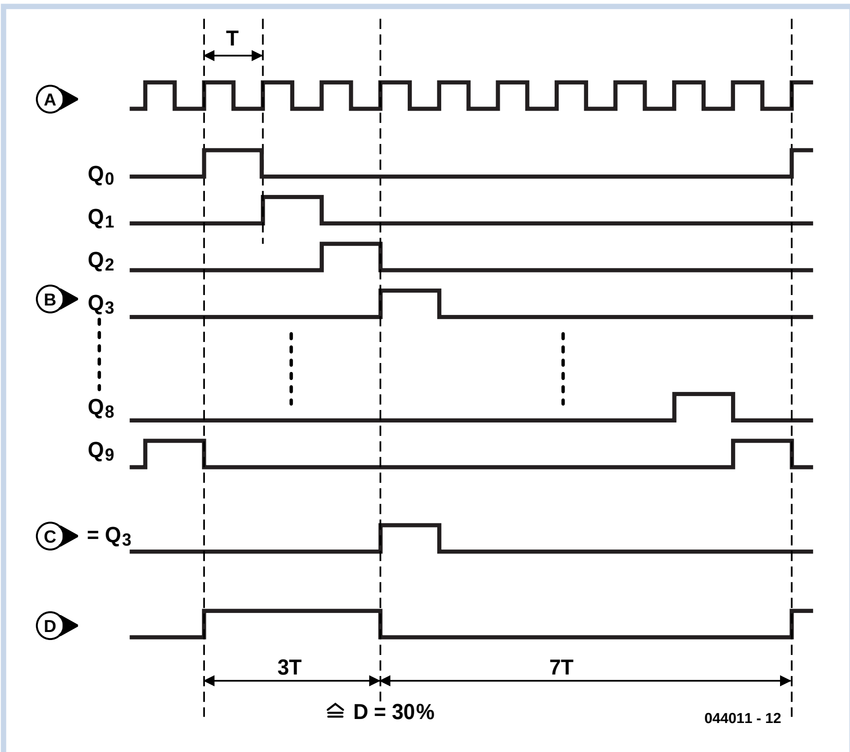
This characteristic is utilised in the circuit. The selected output is connected via a jumper to the Reset input (MR, pin 2) of a 74HC390 counter. A High level resets the output signals of the 74HC390 counter. Q9 of the 74HC4017 is permanently connected to the CP0 input of the counter to set the Q0 output of the 74HC390 (pin 3) High on its negative edge. As can be seen from the timing diagram, which shows the signals for a duty cycle of 30% as an example, this produces a signal with exactly the desired duty cycle.

The circuit cannot be used to produce a duty cycle of 10% (which would be equivalent to taking the signal directly from the Q0 output of the 74HC4017) or 90%. In both cases, the edges of the pulses used for the count input (CP0) and the asynchronous reset input (MR) of the 74HC390 would coincide, with the result that the output state of the 74HC390 would not be unambiguously defined.

The input frequency must be ten times the desired output frequency. If the second half of the 74HC390 is wired as a prescaler, a prescaling factor of 2, 5 or 10 can be achieved, thus allowing the ratio of the of input frequency to the output frequency to be 20, 50 or 100.

If the circuit is built using components from the 74HC family, it can be operated with supply voltages in the range of 3–5 V.

(044011-1)



Bridge-Rectifier LED Indicator

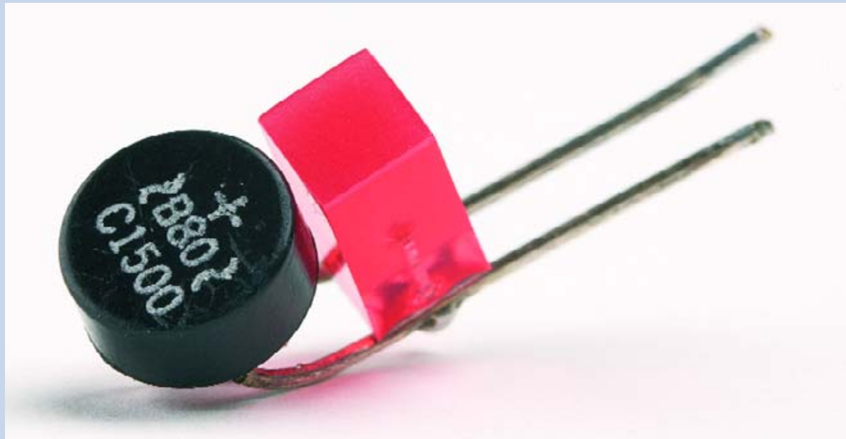
104

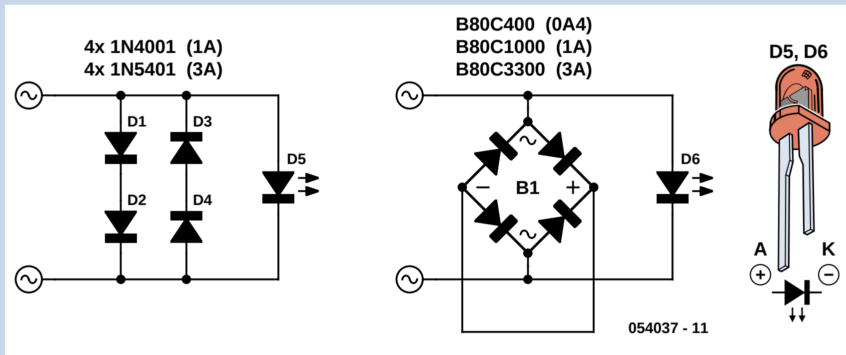
Karel Walraven

Using a few diodes and a LED, you can make a nice indicator as shown in associated schematic diagram that can be used for a lot of applications (with a bit of luck). It's quite suitable for use in series with a doorbell or thermostat (but don't try to use it with an electronically controlled central-heating boiler!). This approach allows you to make an attractive indicator for just a few pennies.

The AC or DC current through the circuit causes a voltage drop across the diodes that is just enough to light the LED. As the voltage is a bit on the low side, old-fashioned red LEDs are the most suitable for this purpose. Yellow and green LEDs require a somewhat higher forward voltage, so you'll have to first check whether it works with them. Blue and white LEDs are not suitable. You also don't have to use modern high-efficiency types (sometimes called '2-mA LEDs' or '3-mA LEDs'). If a DC current flows through the circuit and the LED doesn't light up, reverse the plus and minus leads.

When building the circuit, you'll notice that despite its simplicity it involves fitting quite a few components to a small printed circuit board or a bit of prototyping board. That's why we'd like to give you the tip of using a bridge rectifier, since that allows everything to be made much more compact, smaller and more tidy, and it eliminates the need for a circuit board to hold the components. Besides that, you can surprise friend and foe alike, because even an old hand in the trade won't understand the trick at first glance and will likely mumble something like "Huh? That's impossible."





A bridge rectifier contains four diodes, which is exactly what you need. If you short the + and – terminals of the bridge, you create a circuit with two pairs of diodes connected in parallel with opposite polarity.

Select a bridge rectifier that can handle the current that will flow through it. In the case of a doorbell, for example, that can easily be 1 A. Select a voltage of 40 or 80 V.

Never use this circuit in combination with mains voltage, due to the risk of contact with a live lead.

(054037-1)

Stable USB Power Supply

105

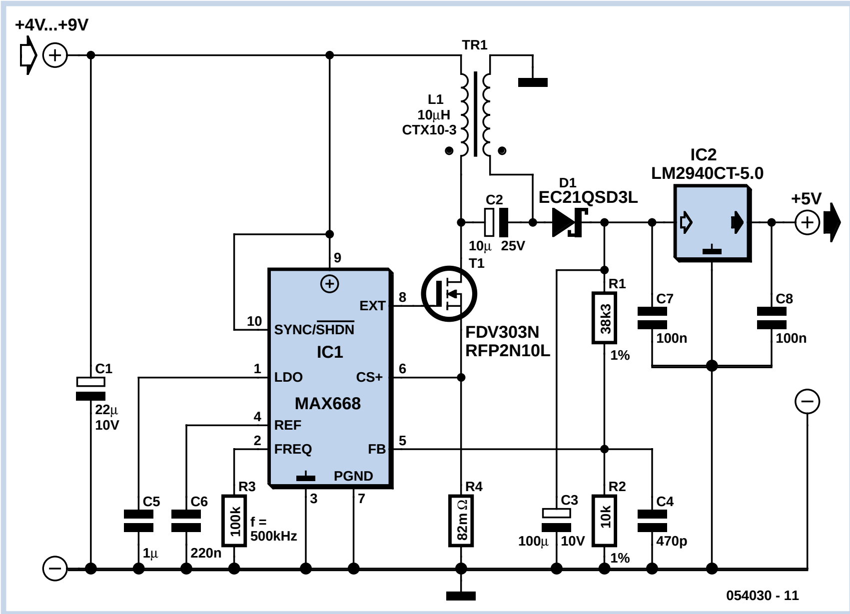
A common problem when an AC mains adapter is used to power a USB device is that the voltage does not match the nominal 5 V specified by the USB standard.

The circuit shown here accepts an input voltage in the range of 4–9 V and converts it into a 6-V output voltage, which is then stabilised to a clean 5-V level by a series regulator. The combined boost/buck converter used here operates on the SEPIC principle. That principle is quite similar to the operating principle of the Cuk converter (see the January 2005 issue of *Elektor Electronics*), but without the disadvantage of a negative output voltage.

The circuit is built around a MAX668, which is intended to be used as a controller for boost converters. The difference between a SEPIC converter and a standard boost (step-up) converter is that the former type has an additional capacitor (in this case C2) and a second inductor (in this case, the secondary winding of transformer L1). If C2 is replaced by a wire bridge and the secondary winding of L1 is left open, the result is a normal boost converter. In that case, a current can always flow from the input to the output via L1 and D1, even when the FET is not driven by IC1. Under these conditions, the output voltage can never be less than the input voltage less the voltage drop across the diode.

The operation of a SEPIC converter can be explained in simple terms by saying that C2 prevents any DC voltage on the input from appearing at the output, so the output voltage can easily be made lower than the input voltage. The second coil causes a defined voltage to be present at the anode of D1. It is also possible to replace the transformer by two separate coils that are not magnetically coupled. However, the efficiency of the circuit is somewhat higher if coupled coils are used as shown here.

The value of resistor R4 is chosen to limit the maximum current to 500 mA, which is also the maximum current that a USB bus can provide according to the specifications. Resistors R1 and R2 cause the voltage across C3 and C7 to be regulated at a value of around 6 V. A low-drop regulator (LM2940) is used to generate a stabilised 5 V from the 6-V output (with ripple voltage). The efficiency should be somewhere between 60 % and 80 %.

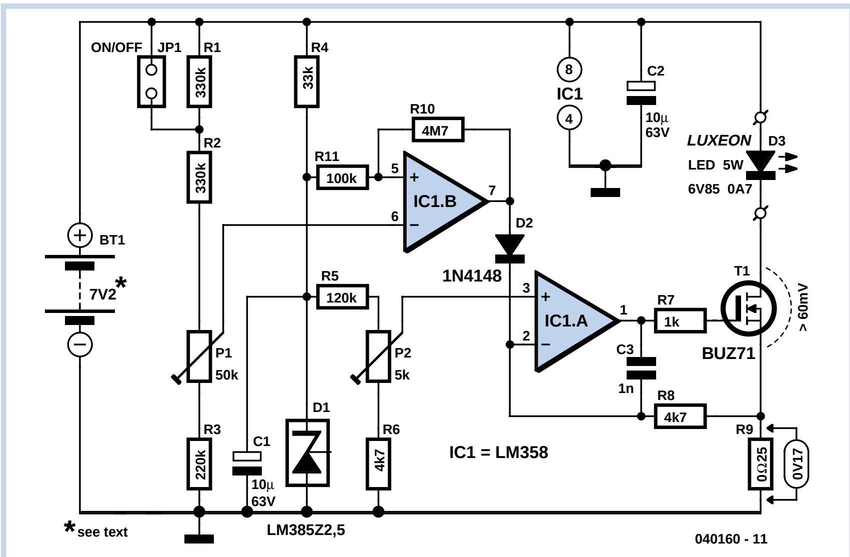


(054030-1)

106 Efficient Current Source for High-power LEDs

Juergen Heidbreder

To get the maximum brightness and working life out of a high-power LED, it needs to be driven at the optimum specified current. Allowing the current to exceed the permitted value is to be avoided at all costs, since it will severely affect the life of the device. A power supply or a battery with a small current-limiting resistor is not really an ideal solution, since not only is energy wasted in heating the resistor, but, if a small value is chosen to minimise this wastage, small changes in the applied voltage will lead to large changes in the current that flows. It is well known that LEDs have a small dynamic resistance in the neighbourhood of their optimal operating point. We will therefore need more in the way of electronics than a simple series resistor to meet our requirements.



The most direct way to provide a highly constant current in the face of relatively small changes in supply voltage is to use a conventional regulated current source. Unfortunately this type of circuit unnecessarily wastes energy in its series transistor, which rather detracts from the charm of using a semiconductor-based circuit. The inefficiency can be mitigated by using a modern device such as a power MOSFET as the series component. Power loss is then limited to that in any current sense resistor that might be used and the dissipation in the relatively small 'on' resistance of the switching transistor.

The circuit suggested here drives a commercially-available Luxeon LED using a BUZ71. The 5 W version of this LED draws 0.7 A. This means that 0.175 V is dropped across R9, making for a power dissipation of 122 mW. T1 has a typical resistance in the 'on' state of 85 mΩ. In the ideal scenario this means that about 60 mV is dropped across it, for a dissipation of at least 42 mW. The supply voltage therefore needs to be about 230 mV higher than the nominal voltage

of the LED (6.85 V). To have something in reserve, 7.2 V, allowing 0.35 V for T1 and R9, is a good compromise. Serendipitously, a series of six NiCd or NiMH cells will give almost exactly this value under load!
A further happy coincidence is that an unregulated mains power supply with a 6 V transformer with bridge rectifier and smoothing capacitor will also give us almost exactly our target voltage when loaded. A 7.5 VA transformer is suitable, along with a 2200 µF/16 V electrolytic smoothing capacitor.

Now to how it works. D1 acts as a reference, with a voltage of 2.5 V being dropped across it. IC1b, together with T1, form a current source, whose current can be set between 360 mA and 750 mA using P2. The otherwise unused opamp IC1a is connected to form an under-voltage cutout switch which prevents a connected battery from being discharged too deeply. The threshold point is set using P1. IC1a is configured as a comparator with a small hysteresis. If its output is high, IC1b is fooled into thinking that the current through R9 is too high, whereupon it switches off the LED. The same happens if R1 is not shorted by a switch. For the purposes of this circuit only opamps with input stages constructed using PNP transistors should be used.
One last look at the energy budget: if six cells are used, the average voltage during discharge will be around 7.4 V. Subtract the nominal voltage of the LED and 0.55 V is left to be converted into heat. About 0.4 W will be dissipated by T1, which therefore will not require cooling. Efficiency is very good, at over 90 %.

(040160-1)

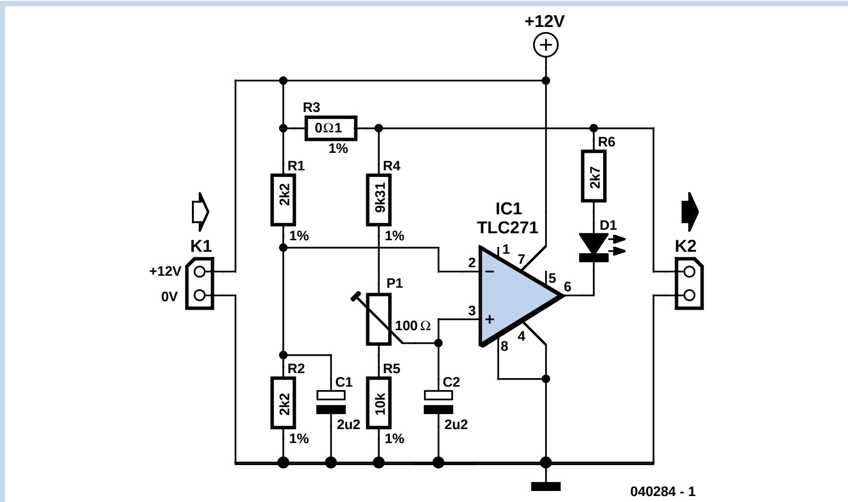
Simple Overcurrent Indicator

107

Myo Min

This circuit eventually surfaced while pondering over the design of a current indicator for a small power supply. Fortunately, it proved possible to employ the supply voltage as a reference by dividing it down with the aid of R1 and R2. C1 is an essential capacitor to suppress noise and surges. The half supply voltage level is applied to the non-inverting pin of opamp IC1. The value of the R3 determines the trip level of the indicator, according to

R3 = 0.4 × (desired voltage drop) / I_{trip}



Actually this is *high side sensing* but the method can be used as low side sensing, too! The desired voltage or sense voltage can be any value between 0.35 V and 0.47 V. If currents greater than about 1 A are envisaged, you should not forget to calculate R3's dissipation on penalty of smoke & smells.

Another voltage divider network, R4, R5 and P1 divide the voltage between supply voltage and desired voltage. This divided voltage, filtered by C2, is fed to the inverting input of IC1 to compare levels. The result causes D1 to light or remain off. Turn P1 to the end of R4 to hold off D1. Then connect a load causing over current and adjust P1 towards the end of R5 until D1 lights. The accuracy of the circuit depends entirely on the tolerances of the resistors used — high stability types are recommended.

(040284-1)

Low-drop Regulator with Indicator

108

Karel Walraven

Even today much logic is still powered from 5 volts and it then seems obvious to power the circuit using a standard regulator from a rectangular 9-V battery. A disadvantage of this approach is that the capacity of a 9-V battery is rather low and the price is rather high. Even the NiMH revolution, which has resulted in considerably higher capacities of (penlight) batteries, seems to have escaped the 9-V battery generation.

It would be cheaper if 5 volts could be

derived from 6 volts, for example. That would be 4 'normal' cells or 5 NiMH-cells. Also the 'old fashioned' sealed lead-acid battery would be appropriate, or two lithium cells.

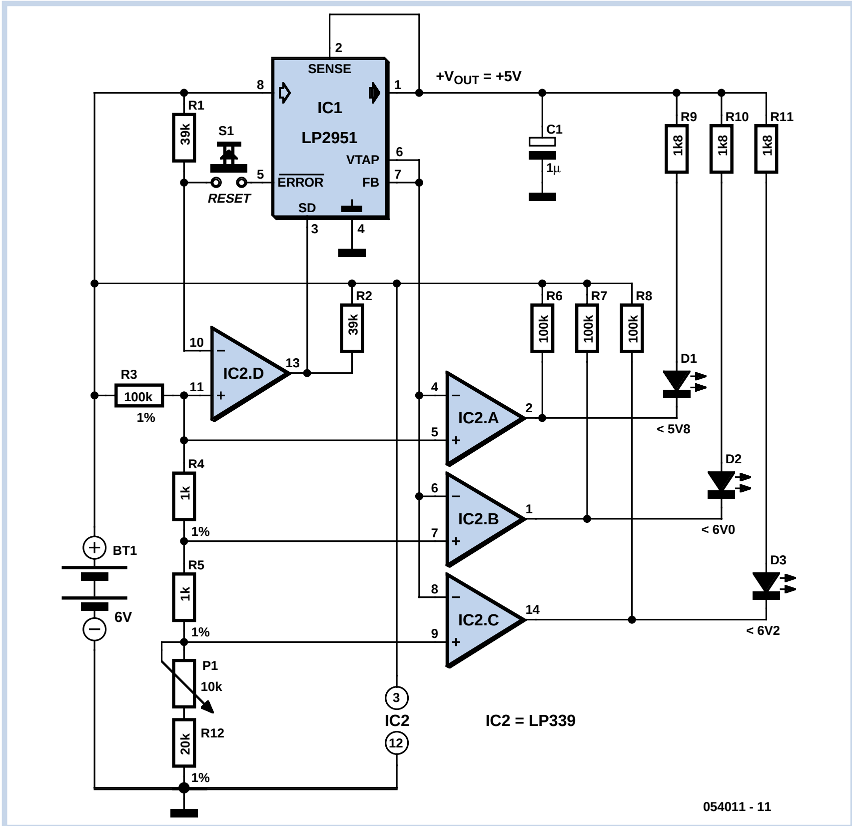
Using an LP2951, such a power supply is easily realised. The LP2951 is an evergreen from National Semiconductor, which you will have encountered in numerous *Elektor Electronics* designs already. This IC can deliver a maximum current of 100 mA at an input voltage of greater than 5.4 V. In addition to this particular version, there are also versions available for 3.3 and 3 V output, as well as an adjustable version.

In this design we have added a battery indicator, which also protects the battery from too deep a discharge. As soon as the IC has a problem with too low an input voltage, the ERROR output will go low and the regulator is turned off via IC2d, until a manual restart is provided with the RESET-pushbutton.

The battery voltage is divided with a few resistors and compared with the reference voltage (1.23 V) of the regulator IC. To adapt the indicator for different voltages you only need to change the 100-k resistor.

The comparator is an LP339. This is an energy-friendly version of the LM339. The LP339 consumes only 60 µA and can sink 30 mA at its output. You can also use the LM339, if you happen to have one around, but the current consumption in that case is 14 times higher (which, for that matter, is still less than 1 mA).

Finally, the LP2951 in the idle state, consumes about 100 µA and depending on the output current to be delivered, a little more.



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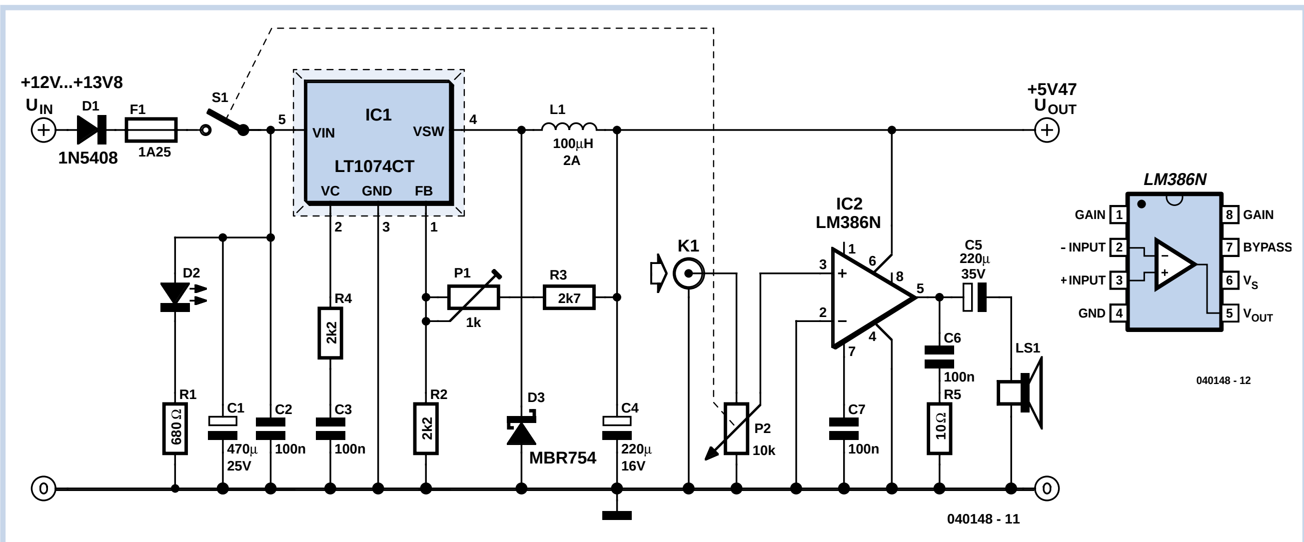
(National Semiconductor application note)

Navigator Assistant

109



René Bosch

These days it is quite common that a hand-held computer (PDA) is used in a car as a navigation system. The author uses, for example, a Dell Axim X5 with TomTom navigator. The PDA is installed in a holder in such a way that the screen is clearly visible to the driver. Such holders do not normally have power and audio connections for the PDA. This circuit offers a solution to both problems: a regulated power supply and an audio power amplifier.

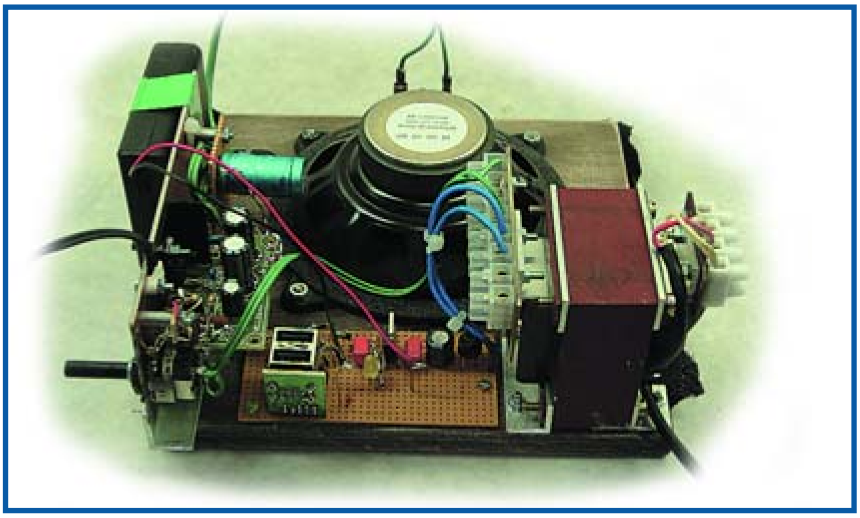
The author originally used an LM350 IC, but it proved to be barely capable of coping with the dissipation when the battery was nearly completely discharged. That is why, in the end, a switching power supply was used. The power supply is designed around an LT1074, a bipolar switching regulator that contains just about all the components required for a so-called buck-regulator. The IC operates at a switching frequency of 100 kHz and can deliver up to 5 A. Coil L1 and diode D3 form part of the flyback circuit. Make sure that these are capable of dealing with the maximum desired output current. Potentiometer P1 is used to adjust the output voltage to the value that is optimum for the PDA that is being used. LED D2 indicates the presence of the input power supply.
The second part, the audio amplifier, is an equally simple design. The circuit really speaks for itself. This is an LM386 in a standard configuration. P2 adjusts the volume.
The amount of power that the LM386 can deliver is about 300 mW. The best results are obtained of you use a special communications loudspeaker. The navigation messages are then very easy to understand.
The gain of IC2 is set to 20. This will usually be sufficient, but you can also increase the amplification. At a gain of 50, it is necessary to connect a series network consisting of a 1k2 resistor and 10-µF electrolytic between pins 1 and 8 of the LM386 (the negative of the capacitor connects to pin 8).
Finding the correct power supply connector for the PDA can be a bit of a problem. So look for a suitable connector before you start to build this circuit. Also be very careful about the correct polarity of the connector.
The circuit can be wired directly to the car's power circuit or connected to the cigarette-lighter socket. In either case a fuse (F1) can be connected in the power supply lead or the plug.

(040148-1)

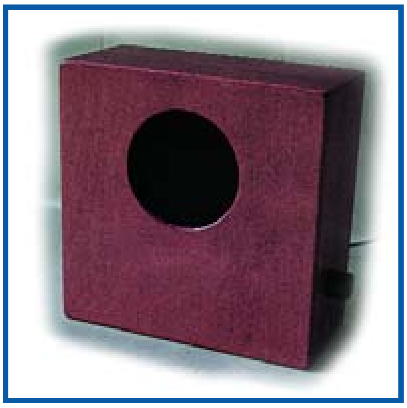
001

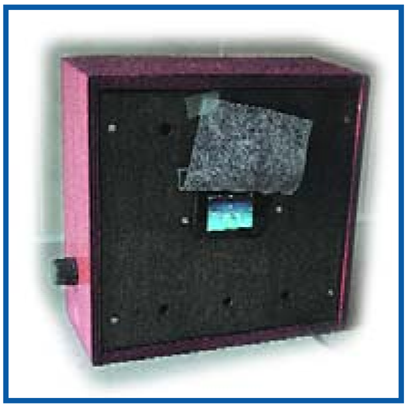
BBC Radio-MP3 for Seniors

Richard Salisbury



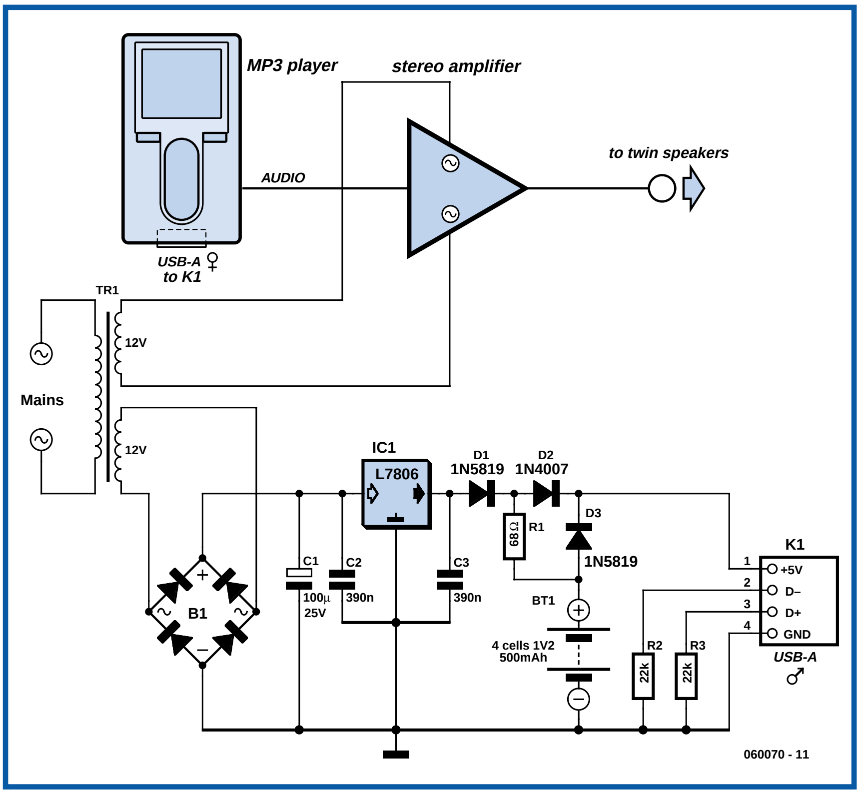
Just recently the author had cause to make an MP3 player for a 93-year old recently moved to a nursing home. There, radio reception turned out to be hopeless, mainly owing to interference from TL lamps. The elderly person involved can neither see well nor has good manipulative skills (arthritis), while learning new





procedures is sure to present problems.
The solution to the radio reception problems was to build an iRiver U10 MP3 player into a speaker box which looks like an old fashioned radio and has only an ON/OFF button and volume control.
The unit is powered by the normal mains and can remain unplugged for about ten hours before it stops. Remarkably, that also happens on being replugged into the mains. Due to a firmware problem of the U10, on 5 volts appearing on the USB connector it assumes it is connected to a computer and stops playing.
The circuit diagram is all straightforward and speaks for itself. The U10 is fixed in a window on the back of the player with the keys locked. Hence, it plays continuously whether the amplifier is on or not (the author used a 15-pound speaker set / amplifier for a computer which switches the 12 volts AC). The transformer was replaced with a double secondary winding to avoid any earthing problems between the USB charging device and the amplifier ground.
The unit is working well and plays the client's favourite music for about 4-3/4 hours, more or less like a personal radio station. Of course, much more music could be loaded on the player since stereo makes no sense and it could be encoded at a slower rate.
An initial problem of the MP3 player's output level not being well matched to the amp input was solved by choosing another amplifier (Velleman K4001) which has a more suitable input sensitivity of 40mV.

(060070-1)



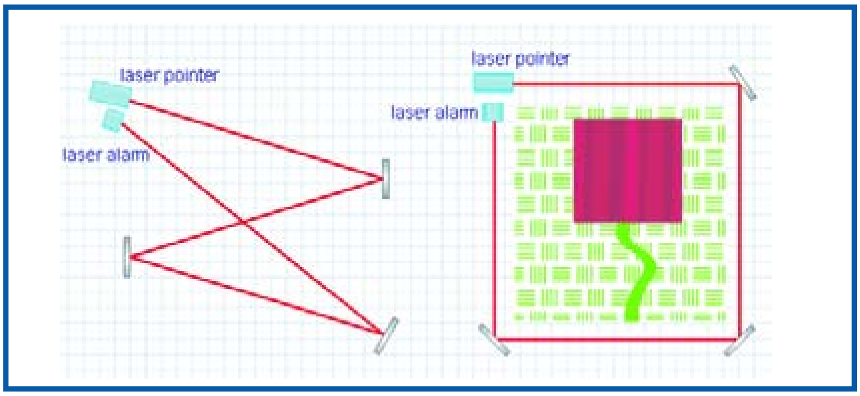
002

Laser Alarm

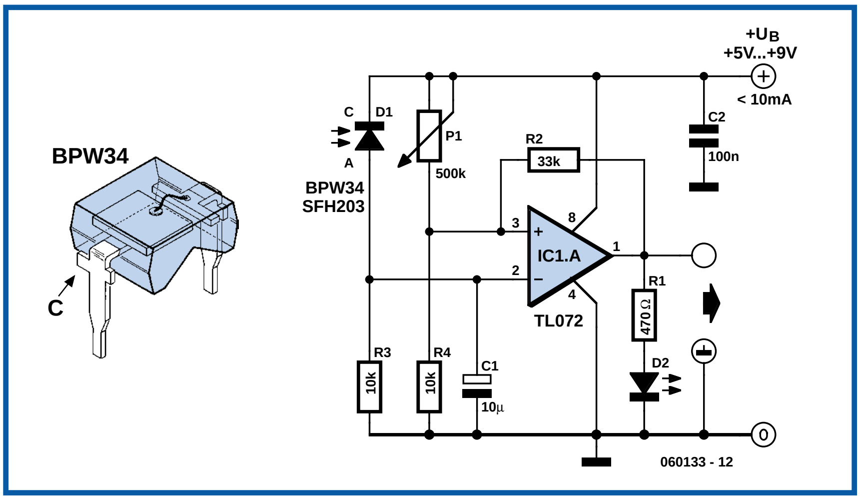
Dimitris Kouzis-Loukas

This circuit is a laser alarm system like the one we see in various movies. It uses a laser pointer beam to secure your valuables and property. Essentially, when the beam gets interrupted by a person, animal or object, the resistance of a photodiode will increase and an alarm will be activated.

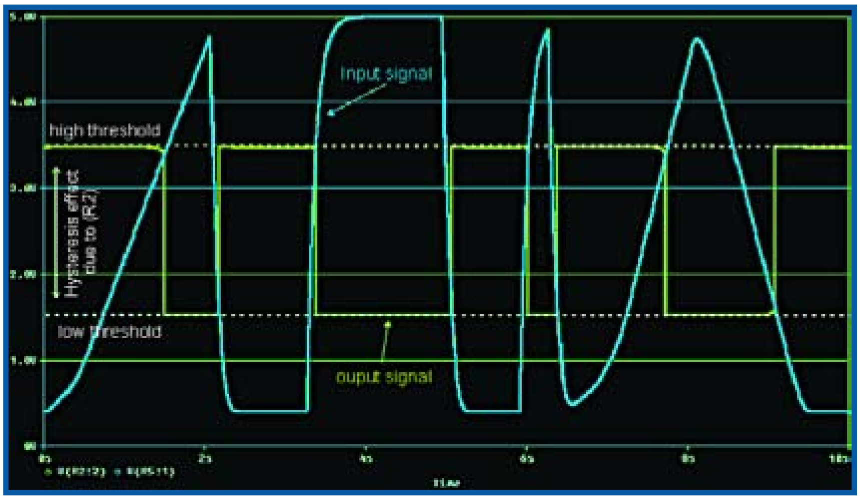
The laser and the receiver can be fitted in same box, sharing a common power supply. As the receiver draws less than 10 mA on average, you'll soon find that the laser is the most current hungry device! Mirrors are used to direct the beam in whatever setup you require. Examples of a passage and an area protected by the alarm are shown in the diagram.



In the circuit diagram we find a TL072 op-amp (IC1.A) configured as voltage comparator between the voltage reference provided by the adjustable voltage divider P1/R4 and the light-dependent voltage provided by the voltage divider consisting of photodiode D1 and fixed resistor R3. When the laser beam is interrupted, the voltage on comparator pin 2 drops below that at pin 3, causing the output to swing to (almost) the positive supply voltage and indicating an alarm condition. This signal can drive a siren, a computer or a light that hopefully will deter the intruder. Alternatively it can be used to 'silently' trigger a more sophisticated alarm. Resistor R2 provides some hysteresis to prevent oscillation when the two comparator input voltages are almost equal. Capacitor C1 makes the circuit immune to short, accidental interruptions of the beam, e.g., by flying insects. If you want your circuit to have faster responses you can reduce its value to 1 µF.



The operation of the circuit is illustrated by the waveform diagram, which also proves the hysteresis action that sets an upper and a lower threshold on the input voltage. You can also see the delay introduced by capacitor C1.



The circuit is simple and could be assembled on a piece of breadboard. After assembling the circuit and testing it, you should mount it in a black box that has just a small hole. You may decide to put the laser in the same box but only if you are sure there is no way the photodiode can 'see' the laser beam directly. The small hole should be filled with a black drinking straw so that only light from the direction of the laser beam can enter. With the appropriate setup of the box and the mirrors, the laser beam is so intense that even direct sunlight cannot affect the operation of the photodiode.

(060133-1)

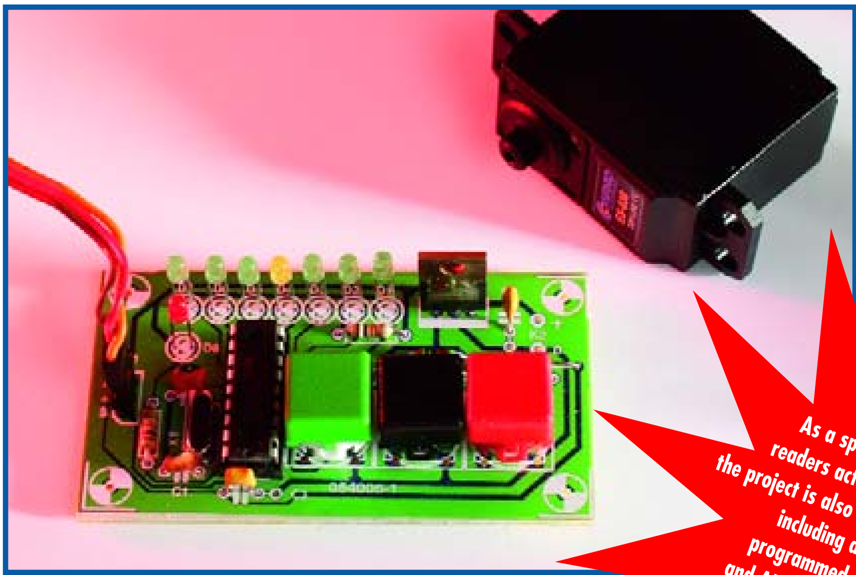
Warning

All safety precautions supplied with the laser you are using must be observed. Laser power should be kept as low as possible.

003

RC Servo Tester/Exerciser

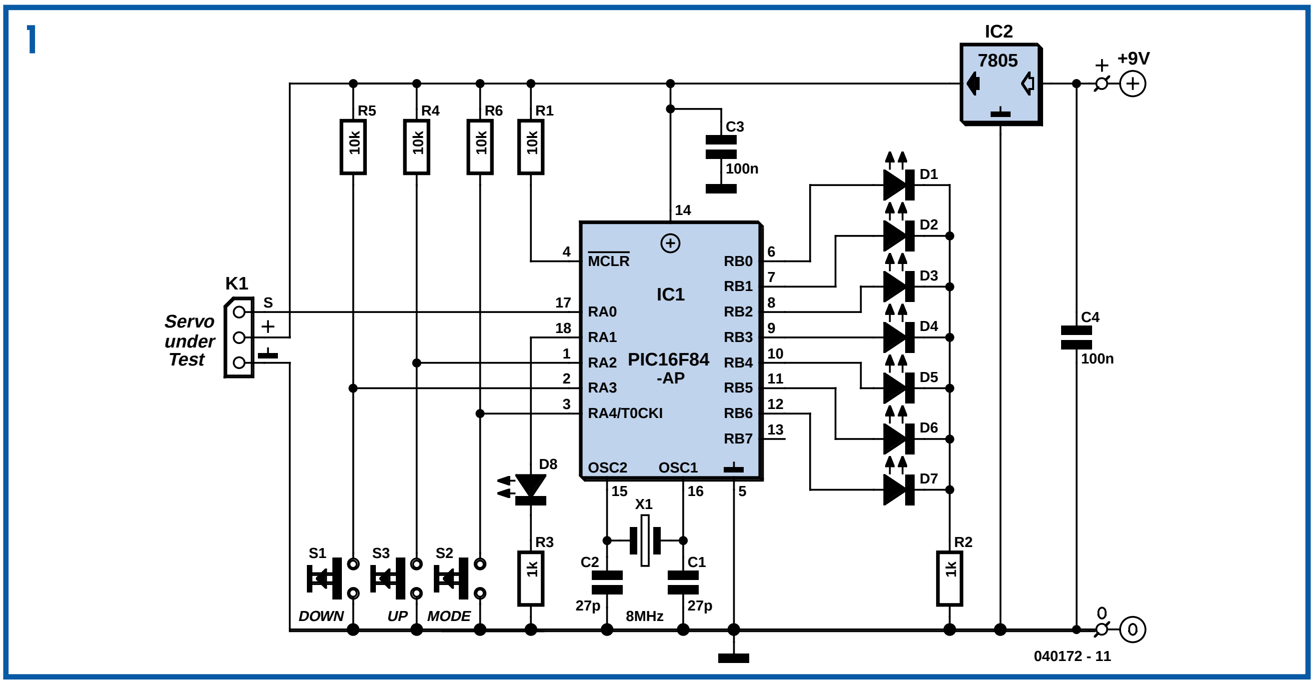
Ray King

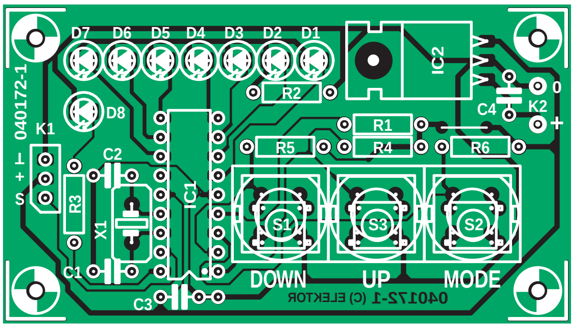


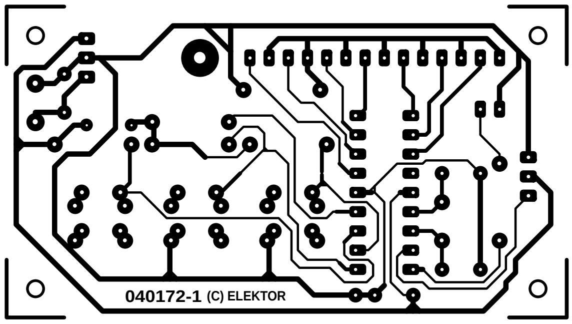
The design presented here is for a device for testing radio control (RC) servos. The present design has features that make it especially useful to people designing and building radio control equipment. By building a number of these devices in a single enclosure an entire radio controlled model can be set up and tested without having to actually use the RC transmitter.

The most unusual feature of this design is that it doesn't use a joystick or similar analogue device to determine the servo position. Instead it gives an output of precisely 1.5 ms that can be changed up or down in steps of 0.166 ms and gives a display on a line of LEDs of the position selected. This is of particular use if you are designing and testing radio control devices that use the receiver output directly, enabling a known pulse width to be applied without resorting to using an oscilloscope. With this facility the devices can be calibrated simply and quickly.
Secondly the device has the ability to switch to an 'exercise' mode. Selecting this mode cycles the servo between the extremes of its travel and serves as a useful quick test of normal servos to verify correct working. A further LED indicates selection of this mode.
Finally the device uses very few components and is extremely cheap to build since the PIC processor carries out all of the timing functions.
The circuitry is a pretty straightforward implementation of the good old PIC 16F84 processor with eight LEDs D1-D8 and three switches S1, S2, S3 connected. The software generates a servo output signal every 20 ms then scans the switches for a button press. Depending on the button pressed the output pulse length will be adjusted accordingly.
When first switched on the circuit will output a servo pulse of 1.5 ms duration and the middle LED of the array will be lit. Pressing the 'up' or 'down' buttons will increase or decrease the pulse width by

As a special service to our readers active in RC modelling, the project is also offered as a kit of parts including all parts, PCB, programmed microcontroller and ABS case. The order code is 040172-71.







COMPONENTS LIST

Resistors
(1/4W 10%)
R1,R4,R5,R6 = 10kΩ
R2, R3=1kΩ

Capacitors
(5mm lead pitch)
C1,C2 = 27pF
C3, C4 = 100nF

Semiconductors
D1,D2,D3,D5,D6,D7 = LED, 3mm, high efficiency, green
D4, D8 = LED, 3mm, high efficiency, yellow
IC1 = PIC16F84(A), DIL18 case, programmed, order code **040172-41**
IC2 = LM2940, TO220 case (or 5V 1A low drop equivalent)

Miscellaneous
X1 = 8MHz quartz crystal, 32pF parallel load capacitance, HC49 case or low-profile model
K1 = 3 way SIL pinheader
S1, S2, S3 = pushbutton, 1 make contact
Case: Hammond 1591ATBU
IC socket 18p
Mains adaptor DC socket
PCB, order code **040172-1**
Project software, free download **040172-11** from Elektor website

A kit of parts is available from Elektor Electronics; order code **040172-71**, see SHOP pages or website. Kit contents as components list.

0.166 ms and the LED display will move as appropriate to show the pulsewidth selected.

At any time the 'mode' button may be pressed which causes the device to switch to/from the 'exercise' mode. A servo connected to the output will cycle repeatedly from end to end of its travel — a useful indication of whether the servo is operational or not.

An Elektor-style PCB was designed for the project and the artwork is shown here. Only one wire is required on the board. The author's own prototype incorporated two of these boards in a single enclosure so that two servos on a model can be tested at once. The board shown in the photograph is a prototype differing from the final version in minor detail.

The source code was written using Proton PIC Basic+ which then compiles into assembler and object code. For those with a PIC programmer, all project software including the hex and source code files is available as a free download, file ref. **040172-11.zip**, from the *Elektor Electronics* website. The PIC is also available ready programmed though Readers Services under number **040172-41**.

Several options are available for powering the circuit. A 9-V PP3 (6F22) battery may look okay at first blush but then it will be exhausted quickly even with small servos. A mains adaptor ('battery eliminator') is possible, but precludes field use. Undoubtedly the most elegant approach, then, is the use of a case with a battery compartment for penlight (AA size) batteries, and then use four alkaline cells or five NiMH rechargeables to obtain a raw supply voltage of 6 V. This will necessitate the use of a low-drop regulator for IC2, like the 4805 or the LM2940 you find suggested here because it will not drain an almost flat battery due to its own current. An on/off switch is also recommended. The standby current consumption of the circuit amounts to about 5 mA.

Finally, PIC burners among you using the hex file should set the config bits as follows: HS (10) (since xtal > 4 MHz); WDTE disable (0); PWRTE enable (0). The other config bits are for code protection and their use is at your discretion.

(040172-1)

IR Remote Control Tester

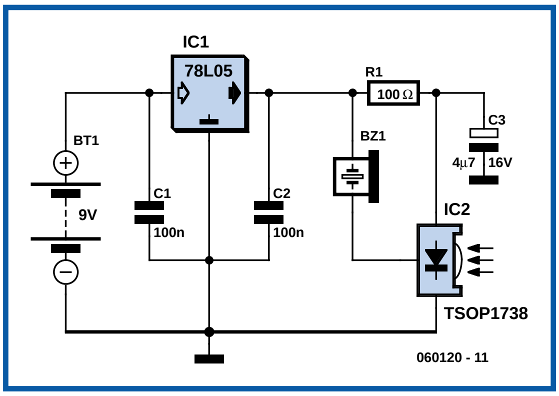
004

Malte Fischer

This small circuit is ideal for checking the basic operation of an infrared remote control unit. The circuit is based on the brilliantly simple idea of connecting a piezo buzzer directly to an IR receiver IC. This method is almost as simple as connecting a photodiode directly to the input of an oscilloscope, but has the advantage that no oscilloscope is needed: the compact unit is always ready to use and much easier to carry around than bulky test equipment.

Operation of the remote control is indicated by the buzzer making a chattering noise. The circuit is very sensitive and has a range of several metres.

The TSOP1738 integrated IR receiver accepts, amplifies and demodulates the IR signal from the remote control, producing an output with a frequency of around 700 Hz. The piezo buzzer is connected to its output, rendering the signal audible.
All the other components are simply concerned with producing a stable 5 V power supply from the 9 V PP3-(6F22) type battery. Instead of the TSOP1738 similar devices from other manufacturers can be used, and of course carrier frequencies other than 38 kHz can be used. The circuit still works if there is a mismatch between the nominal carrier frequencies of the transmitter and receiver IC, but range is reduced. It is still, however, adequate for determining whether a remote control is producing an IR signal or not.



(060120-1)

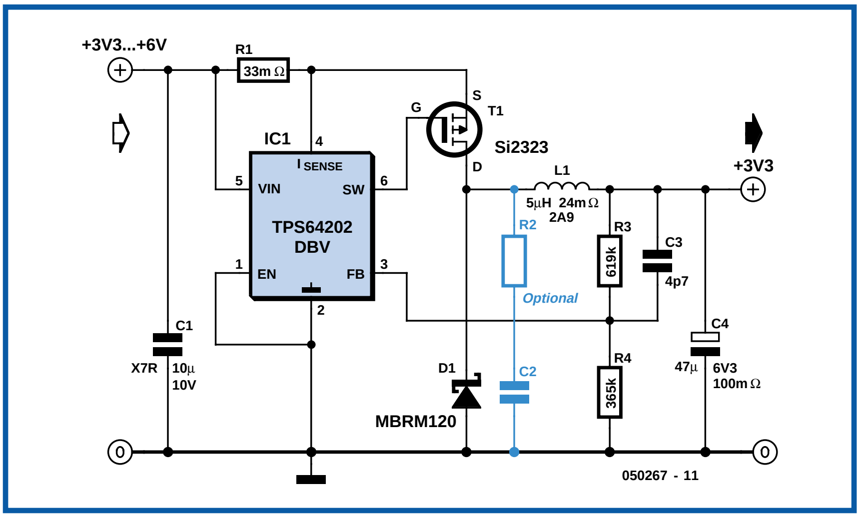
005

Step-Down Converter Controller

Dirk Gehrke, Texas Instruments

The TPS6420x controller is designed to operate from one to three series-connected cells or from a 3.3 V or 5 V supply obtained from a USB port. At its output it can produce 3.3 V at 2 A, suitable for powering a microcontroller-based system. With a suitable choice of external components (inductor, P-channel MOSFET and Schottky diode) the device can be operated over a wide range of possible output voltages and currents. A further advantage is its extremely low quiescent current consumption in power-down mode (100 nA typical) and in no-load operation (20 mA). Also, if the input voltage is less than or equal to the desired output voltage, the device can connect the output directly to the input.

Using just a few external components the TPS6420x can cover an output voltage range from 1.2 V up to the input voltage at up to 3 A, as long as a suitable P-channel MOSFET and Schottky diode are used. The device is an asynchronous step-down converter which, unlike the more widely-used PFM (pulse-frequency modulation) and PWM (pulse width modulation) types, involves a constant on-time and/or constant off-time. Conventional controllers operate in PWM mode at medium to high loads, switching to PFM at lower loads in order to minimise switching losses. The controller described here also adjusts its switching frequency in accordance with the load to achieve a similar effect to the PFM/PWM controllers.



TPS	On time	Off time	Applications
64200	1.6 µs	600 ns	Ideal for high efficiency over the entire range of output loads
64201	1.6/0.8/0.4/ 0.2 µs	600 ns	Reduced on-time for higher frequency operation than TPS64200, with switching frequency outside audio range
64202	0.6/0.8/0.4 µs	300 ns	Ideal for high switching frequency applications where the mark-space ratio approaches 1, such as converting 3.8 V to 3.3 V; the minimum off time determines the switching frequency
64203	0.6 µs	600 ns	Ideal for circuits with a low mark-space ratio where high switching frequency is required, such as converting 5 V to 1.5 V; the minimum on time determines the switching frequency

The circuit diagram shows a classical step-down converter with an input voltage range from 3.3 V to 6 V and an output voltage of 3.3 V at a current of up to 2 A. The optional 33 mΩ shunt resistor provides for current limiting. The TPS64202 offers a minimum on-time selectable between 1.6 ms, 0.8 ms, 0.4 ms and 0.2 ms and a fixed off-time of 300 ns. A MOSFET in the supply voltage path is switched on by the controller for as long as is necessary for the output voltage to reach its nominal value, or until the maximum permissible current, as determined by the shunt resistor, is reached. If the current does exceed this limit the MOSFET is switched off for 300 ns. If the nominal output voltage is reached, the MOSFET is switched off and remains in the off state until the output voltage once again falls below the nominal value. At very low output currents the controller therefore operates in 'discontinuous mode' (DCM). Each switching cycle begins with the current at zero. It rises to the threshold or maximum value, and then falls again back to zero. At the moment of switch-off the Schottky diode causes the residual energy in the inductor to appear as a quickly-decaying oscillation at the resonant frequency of the output filter. This low-energy oscillation in discontinuous mode is normal and has no adverse effect on the efficiency of the converter. It can be damped using the (optional) RC series network.

At higher output currents the switch-down converter operates in continuous conduction mode (CCM). In this mode the inductor current never falls to zero. The output voltage is directly proportional to the switching mark-space ratio in this mode.

If the Si2323 P-channel MOSFET from Vishay-Siliconix is not available, the IRLML6401 (12 V type) or IRLML6402 (20 V type) from IRF can be used instead. Both these types have a higher on resistance, but do offer a lower gate capacitance. An alternative for the Schottky diode suggested is the MBRM140 (available from Digi-Key and Farnell), although this is in an SMB package rather than the Powermite package of the MBRM120. The voltage drop at 1 A is somewhat higher: 0.6 V instead of 0.45 V. The devices are manufactured by IRF and ON Semiconductor.

(050267-1)

Literature at http://www.ti.com:

SOT23 Step-Down Controller, document reference number SLVS485

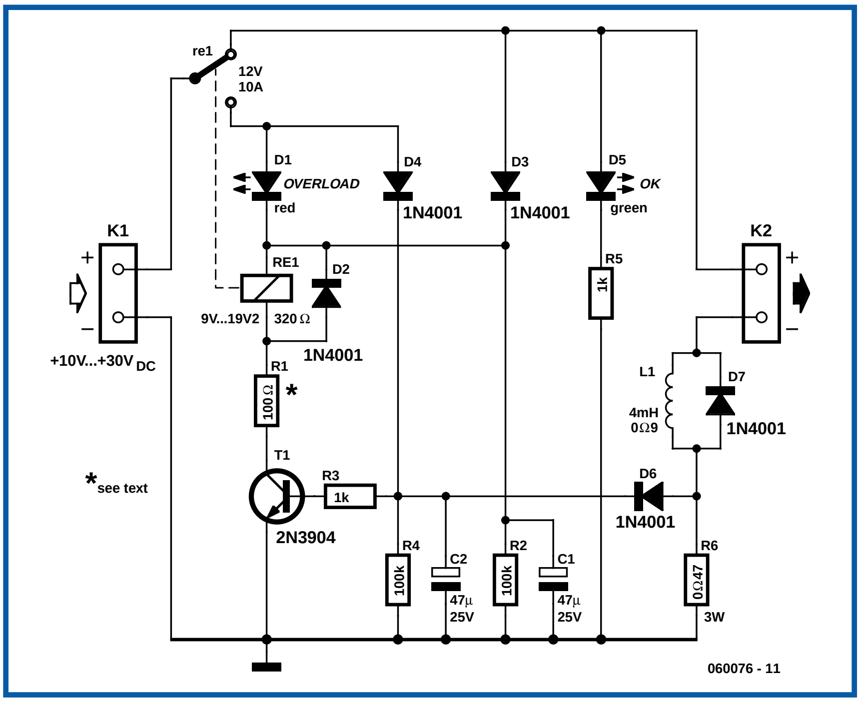
TPS6402 Evaluation Module (3.3 V, 2 A), document reference number SLVU093

006

Fuse Saver

David Clark

This circuit will be particularly useful to those hobbyists who use a 'breadboard' to try out ideas and who also use a simple 'home-made' DC power supply consisting of a transformer, rectifier, smoothing capacitor and protective fuse, that is, one without overcurrent protection!



In this circuit, the detecting element is resistor R6. Under normal conditions, its voltage drop is not high enough to switch on transistor T1. The value of R6 can be altered to give a different cut-off current, as determined by Ohm's Law, if required. When a short circuit occurs in the load, the voltage rises rapidly and T1 starts to conduct. This draws in the relay, switching its contacts, which cuts off power to the external circuit, and instead powers the relay coil directly, latching it in this second state. The circuit remains in this state until the primary power supply is switched off.

Capacitors C1 and C2 hold enough charge (via D3, D4 and D6, which prevent the charge from being lost to the rest of the circuit, whichever state it is in) to keep T1 switched on and power the relay while it switches over, and R2 and R4 provide slow discharge paths. LEDs D1 (red) and D5 (green) indicate what state the circuit is in.

Inductor L1 slows the inrush of current when the circuit is switched on, which would otherwise cut off the circuit immediately. D2 and D7 provide the usual back-emf protection across the coils.

In use, the input of the circuit is connected to the main transformer-rectifier-capacitor-fuse power supply via K1, and the output is connected to the (experimental) load via K2. Note that the input voltage *must* be a floating supply if Vout– is grounded via the load, as Vin– and Vout– must not be connected together.

Some consideration needs to be given to

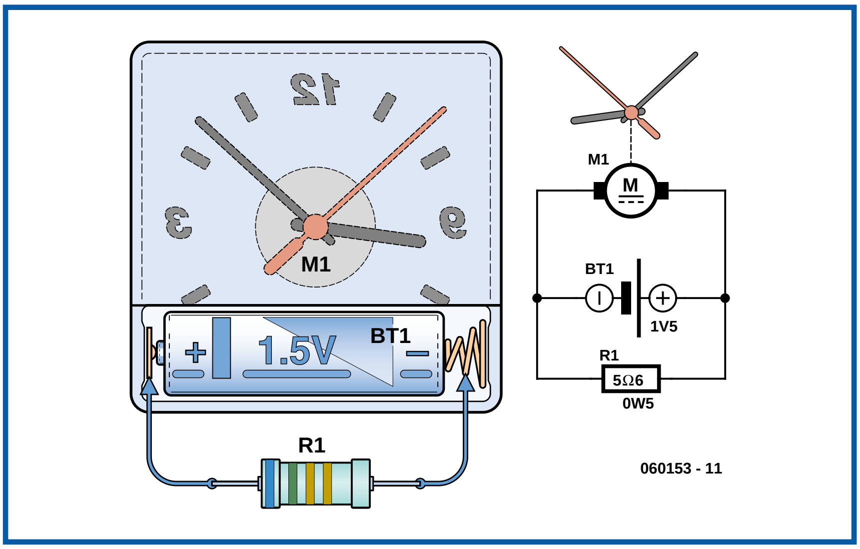
a number of components. First, the choice of relay Re1. For the prototype, this was obtained from Maplin, part number YX97F. This is has a coil resistance of 320 Ω, which with R1 forms the collector load for T1. Its allowed pull-in voltage range is nominally 9 V to 19 V, which limits the input power supply voltage to between around 10 V to 30 V (DC only). R1 could be replaced by a wire link for operation at input voltages below 10 V, or increased in value, as determined by either the application of Ohm's Law once more or trial and error, for an input voltage above 30 V.
Coil L1 was obtained from Farnell, part number 581-240. Finally, the protective fuse for the input power supply should be a 'slow-blow' type; 'fast' fuses will rupture before the relay has time to switch. Also note that this device is meant to save fuses, not replace them. A mains transformer must always be fused if it is not designed to run safely, i.e., without presenting a fire hazard, even if its output has a continuous short-circuit fault.

(060076-1)

007

Hyper-Simple Battery Capacity Tester

J. Van der Sterre



The circuit described here is eminently suitable to indicate the capacity of a battery. We use a cheap electric clock for this. By connecting a resistor across the battery terminals, the battery is discharged somewhat faster than with the clock alone. If we pick a resistor with a value of 5.6 Ω, the discharge current amounts to 1.2 V / 5.6 Ω = 214 mA. If we multiply this with the number of hours that the clock ran after the battery was connected up then we know (approximately) the capacity of the battery.

When discharging a NiCd battery we need to make sure we remove the battery the moment the clock stops running. NiCd batteries do not tolerate too deep a discharge very well. We therefore recommend keeping an eye on the voltage in one way or another, for example by connecting a multimeter in parallel with the resistor.

(060153-1)

008

Design for Märklin Light Signals

Nils Körber

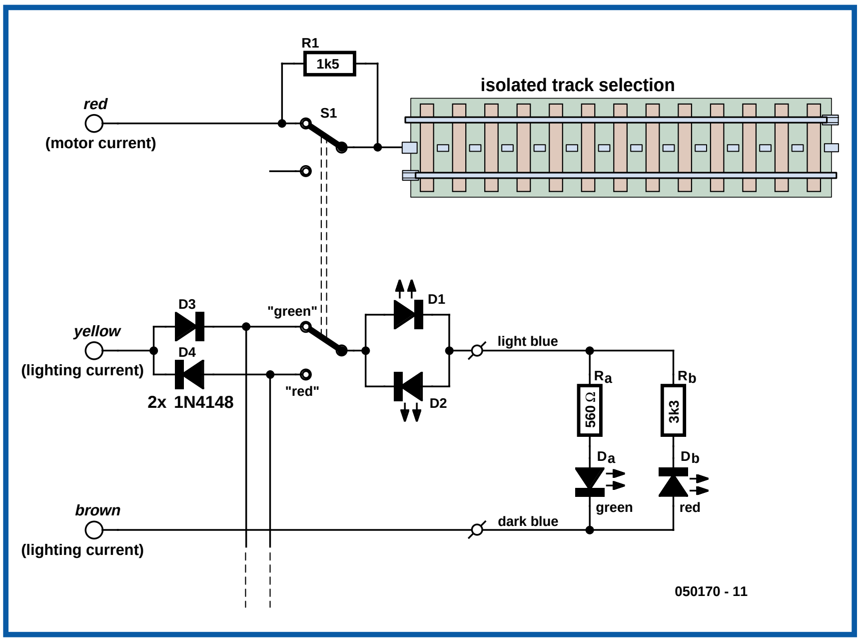
Märklin's light signal Type 74391 (blocking signal) for size HO model railway sets is fairly new and, at 10 euros (£7·00), reasonably affordable. There is, however, a little problem in that its operation requires the use of signal keyboard Type 72750, which makes the setup not only more expensive but also inflexible.
There is, fortunately, another solution, simpler and much more economical, which requires just a switch and two diodes. It is based on the fact that, seen from en electronics point of view, the light signal consists of two anti-parallel-connected LEDs with dropping resistors.

The lower section at the right of the diagram, Da, Db, Ra and Rb represents the typical inner circuit of such a light signal. When the output voltage of the light power source is applied to the circuit, both LEDs light. However, since only a red or green signal is wanted, the voltage is simply applied via diodes D3 and D4. Change-over switch S1 then determines which colour will be seen. Surely a very economical solution.
If in more complex setups it is required to have direct control over which colour the light signal on the track is to be, it suffices to add two further anti-parallel-connected LEDs, D1 and D2, in the connection between switch S1 and the light signal.
So far, so good. But now for a few spe-

cial aspects. Typically, a light signal contains a standard green LED, whereas the red LED is usually a low-current type. Therefore, the dropping resistors have different values. In the present circuit it is therefore necessary for D2 also to be a low-current type. Unfortunately, recent Märklin light signals are already fitted with two low-current LEDs. This can be ascertained by temporarily connecting the present circuit to the light signal and measuring the direct current for the two switch positions. Standard LEDs draw more than 10 mA, whereas low-current types draw not more than 5 mA.

If D3 and D4 are Type 1N4148, it is possible to use the circuit with about five light signals fitted with standard LEDs or with up to twenty fitted with low-current LEDs. If Types 1N4001 are used, up to 1 A can be drawn.

With railway tracks for analogue operation, which normally use 16 V AC power sources, Märklin light signals may be connected directly or via D1/D2. In case of digital tracks that use higher supply voltages, correspondingly higher-value



dropping resistors (or an additional one in series with D1 and D2) must be used. Finally, a tip that is as simple as it is practical. To retain the superb facility of analogue tracks whereby the train does not drive on when the signal is red, but stops automatically, isolate the power line to the last rail before the light signal and power this rail via the second contact of S1 — as already shown in the circuit diagram. Many other hints and advice for model railway enthusiasts may be found on the author's web site: www.koerber-home.de

(050170-1)

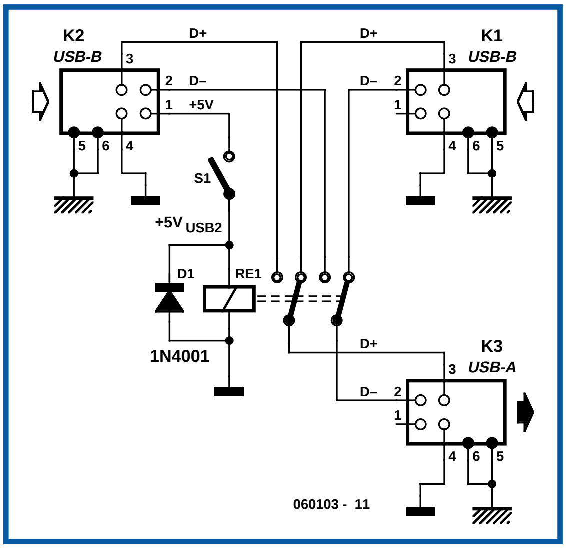
USB Switch for Printers

009

Liam Maskey

This circuit switches a printer's USB connection from a PC to a laptop. What was needed was a method of allowing a laptop to use the printer occasionally while at all other times the printer would be connected to the PC. Instead of unplugging the printer from the PC and then into the laptop, the circuit switches the USB connection automatically.

K1 and K2 are standard type-B USB sockets, while K3 is a USB type-A socket. The USB lead from the laptop plugs into K2 while the PC's USB lead plugs into K1. A USB cable from K3 connects the printer to this circuit. The cable from the PC is always plugged in while the cable from the laptop is only connected whenever this device needs to print.



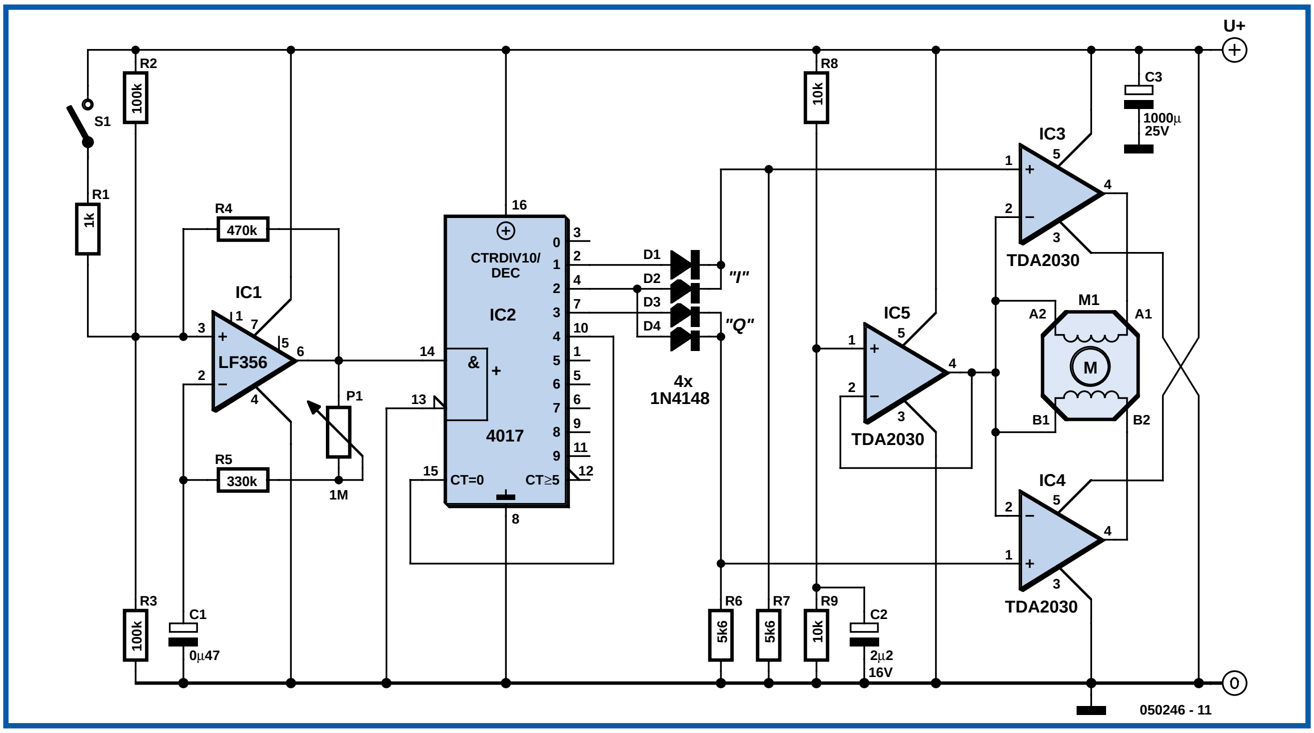
In normal operation the laptop is not connected to K2, so the USB signal to the printer comes from the PC via K1, the normally closed contacts of relay Re1, through to K3 and from there to the printer. Whenever the laptop is connected up, the presence of the 5-volt power signal on its USB port causes Re1 to switch over to the printer's connection to K2 and the laptop. Unplugging the laptop returns control of the printer back to there PC.

The circuit was tested on a USB-1.1 compliant printer and a PC and laptop that had USB-2.0 high-speed ports. The PCB traces for D+ and D– should be kept as short as possible and ideally should be the same length. The relay should be a low-power type (5 V at <100 mA coil current) with two changeover (c/o) contacts.

Switch S1 is only required in situations where the two computers you want to select between are permanently present and connected up to the circuit. The switch then selects the computer having access to the printer.

(060103-1)

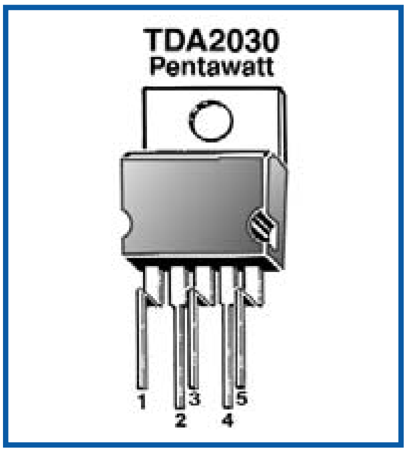
010 Stepper Motor Controller



Gert Baars

Stepper motors are available in several versions and sizes with a variety of operating voltages. The advantage of this general-purpose controller is that is can be used with a wide range of operating voltages, from approximately 5 V to 18 V. It can drive the motor with a peak voltage equal to half the supply voltage, so it can easily handle stepper motors designed for voltages between 2.5 V and 9 V. The circuit can also supply motor currents up to 3.5 A, which means it can be used to drive relatively large motors. The circuit is also short-circuit proof and has built-in overtemperature protection.

Two signals are required for driving a stepper motor. In logical terms, they constitute a Grey code, which means they are two square-wave signals with the same frequency but a constant phase difference of 90 degrees. IC1 generates a square-wave signal with a frequency that can be set using potentiometer P1. This frequency determines the rpm of the stepper motor. The Grey code is generated by a decimal counter in the form of a 4017. Outputs Q0–Q9 of the counter go high in succession in response to the rising edges of the clock signal. The Grey code can be generated from the outputs by using two OR gates, which are formed here using two diodes and a resistor for each gate, to produce the I and Q signals.
Here 'I' stands for 'in-phase' and 'Q' for 'quadrature', which means it has a 90-degree phase offset from the I signal.
It is common practice to drive the windings of a stepper motor using a pair of push-pull circuits for each winding, which is called an 'H bridge'. That makes it possible to reverse the direction of the current through each winding, which is necessary for proper operation of a bipolar motor (one whose windings do not have centre taps). Of course, it can also be used to properly drive a unipolar motor (with centre-tapped windings).
Instead of using a push-pull circuit of this sort, here we decided to use audio amplifier ICs (type TDA2030), even though that may sound a bit strange. In functional terms, the TDA2030 is actually a sort of power opamp. It has a difference amplifier at the input and a push-pull driver stage at the output. IC3, IC4 and IC5 are all of this type (which is economically priced). Here IC3 and IC4 are wired as comparators. Their non-inverting inputs are driven by the previously



mentioned I and Q signals, with the inverting inputs set to a potential equal to half the supply voltage. That potential is supplied by the third TDA2030. The outputs of IC3 and IC4 thus track their non-inverting inputs, and each of them drives one motor winding.
The other ends of the windings are in turn connected to half the supply voltage, provided by IC5. As one end of each winding is connected to a square-wave signal that alternates between 0 V and a potential close to the supply voltage, while the other end is at half the supply voltage, a voltage equal to half the supply voltage is always applied to each winding, but it

alternates in polarity according to the states of the I and Q signals. That's exactly what we want for driving a bipolar stepper motor.
The rpm can be varied using potentiometer P1, but the actual speed is different for each type of motor because it depends on the number of steps per revolution. The motor used in the prototype advanced by approximately 9° per step, and its speed could be adjusted over a range of approximately 2 to 10 seconds per revolution. In principle, any desired speed can be obtained by adjusting the value of C1, as long as the motor can handle it. The adjustment range of P1 can be increased by reducing the value of resistor R5. The adjustment range is 1:(1000 + R5)/R5, where R5 is given in kΩ.
If a stepper motor is switched off by removing the supply voltage from the circuit, it's possible for the motor to continue turning a certain amount due to its own inertia or the mechanical load on the motor (flywheel effect). It's also possible for the position of the motor to disagree with the states of the I and Q signals when power is first applied to the circuit. As a result, the motor can sometimes 'get confused' when starting up, with the result that it takes a step in the wrong direction before starting to move in direction defined by the drive signals.
These effects can be avoided by adding the optional switch S1 and a 1-kΩ resistor, which can then be used to start and stop the motor. When S1 is closed, the clock signal stops but IC2 retains its output levels at that moment, so the continuous currents through the motor windings magnetically 'lock' the rotor in position.
The TDA2030 has internal overtemperature protection, so the output current will be reduced automatically if the IC becomes too hot. For that reason, it is recommended to fit IC3, IC4 and IC5 to a heat sink (possibly a shared heat sink) when a relatively high-power motor is used. The tab of the TO220 case is electrically bonded to the negative supply voltage pin, so the ICs can be attached to a shared heat sink without using insulating washers.

(050246-1)

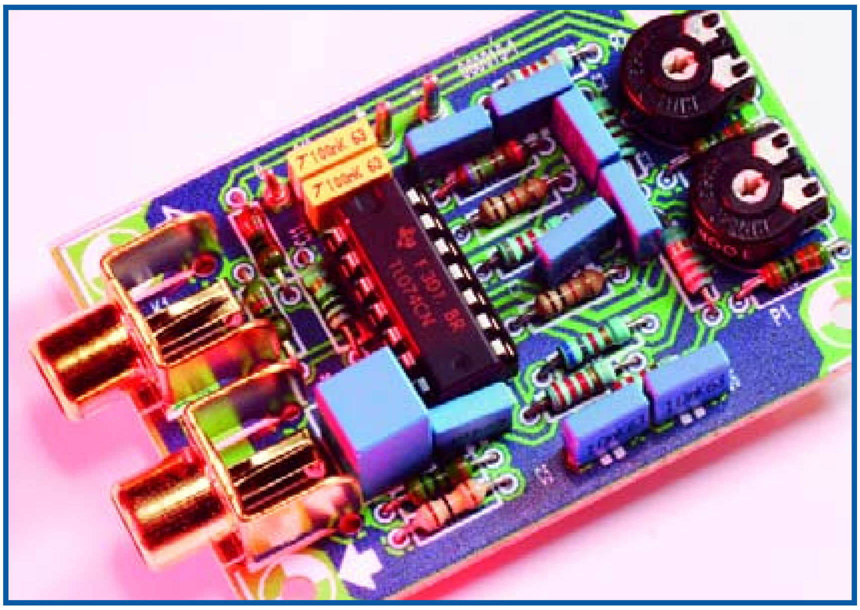
Paraphase Tone Control

011

Ton Giesberts

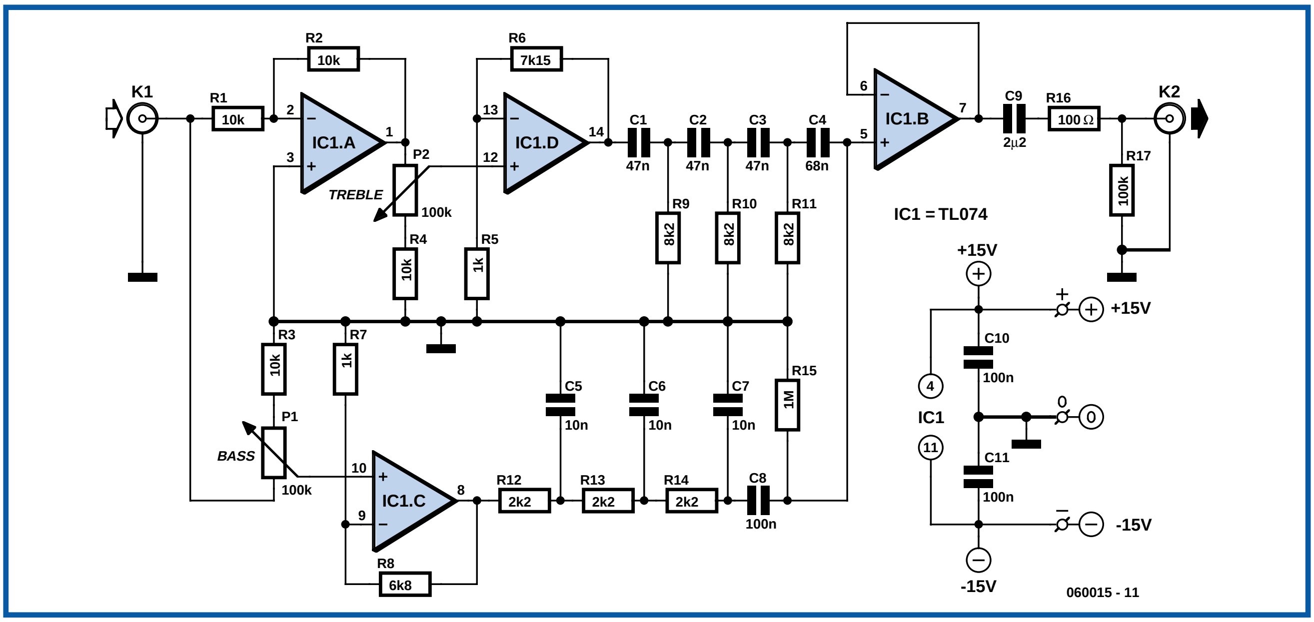
As opposed to the widespread Baxandall circuit (dating back to 1952!) a 'paraphrase' tone control supplies a straight frequency response as long as the bass and treble controls are in the same position. This unique property makes the 'paraphase' configuration of interest if *only* treble or bass needs to be adjusted — it is not possible to adjust both at the same time! Essentially, it's the difference in setting of the tone controls that determines the slope of the frequency response, and the degree of bass/treble correction.

The circuit in **Figure 1** is simplicity itself, based on two networks C1-C2-C3/R9-R10-R11 and C5-C6-C7/R12-R13-R14. The first is for the high frequencies (treble) response, the second, for the low frequencies (bass). The roll-off points have been selected, in combination with C4 and C8, for the sum of the two output signals to re-appear with a 'straight' frequency response again at the output. Roughly equal output levels from the networks are ensured by R6 = 7.15 kΩ and R8 = 6.80 kΩ. However, the operating principle requires the input signals to the two networks to be in anti-phase.
For best operation the networks are driven by two buffers providing some extra gain. The gain of IC1.D is slightly



Specification

Current consumption (no signal)		8 mA
Max. input signal		1 V_{eff} (at max. gain)
Gain	at 20 Hz	+13.1 dB max. –6.9 dB min.
	at 20 kHz	+12.2 dB max. –7.6 dB min
Gain (controls at mid position)		2.38 x
Distortion (1 V_{eff}, 1 kHz)		0.002% (B = 22kHz) 0.005% (B = 80 kHz)



higher than that of IC1.C to ensure the overall response curve remains as flat as possible at equal settings of the tone controls. Because each network introduces a loss of about 1.72 (times), IC1.D and IC1.C first amplify the signal. The gain is set at about 8 (times) allowing input signal levels up to 1 V to pass the circuit at maximum gain and distortion-free. The gain also compensates the attenuation if you prefer to keep the tone controls at the mid positions for a straight response.

To audio fans, the circuit is rewarding to experiment with, especially in respect of the crossover point of the two networks. R3 and R4 determine the control range, which may be increased (within limits) by using lower resistor values here. The values shown ensure a tone control range of about 20 dB.

IC1.B buffers the summed signal across

COMPONENTS LIST

Resistors

R1-R4 = 10kΩ
R5,R7 = 1kΩ
R6 = 7kΩ15
R8 = 6kΩ80
R9,R10,R11 = 8kΩ2
R12,R13,R14 = 2kΩ2
R15 = 1MΩ
R16 = 100Ω
R17 = 100kΩ
P1,P2 = 100kΩ preset or chassis-mount control potentiometer, linear law

Capacitors

C1,C2,C3 = 47nF MKT, lead pitch 5mm
C4 = 68nF MKT, lead pitch 5mm
C5,C6,C7 = 10nF MKT, lead pitch 5mm
C8,C10,C11 = 100nF MKT, lead pitch 5mm
C9 = 2µF2 MKT, lead pitch 5mm or 7.5mm

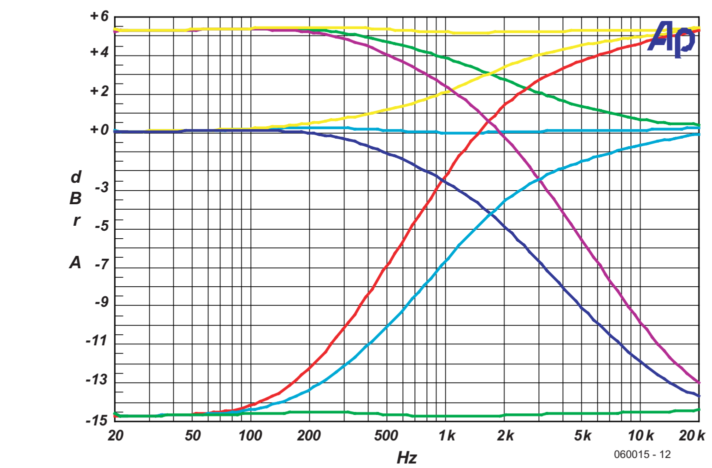
Semiconductors

IC1 = TL074

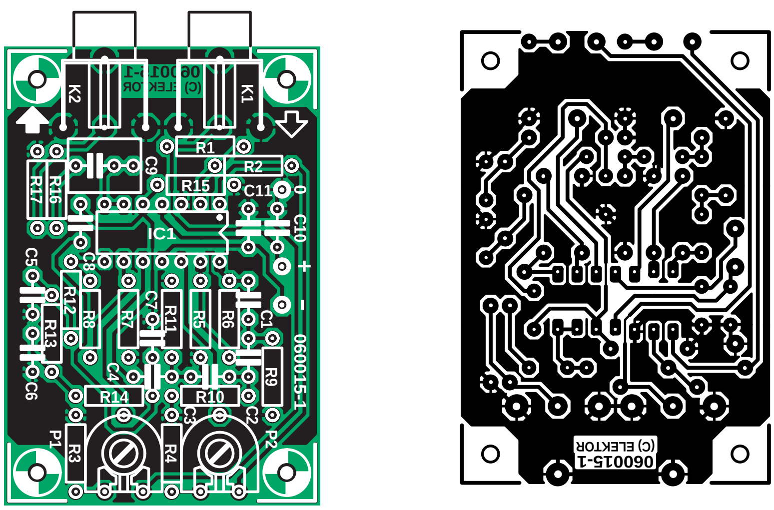
Miscellaneous

K1,K2 = line socket, PCB mount, e.g. T-709G (Monacor/Monarch)
PCB, ref. 060015-1 from The PCBShop

2



3



R15. C9 removes any DC-offset voltage and R16 protects the output buffer from the effects of too high capacitive loads. R17, finally, keeps the output at 0 V.
The choice of the quad opamp is relatively uncritical. Here the unassuming TL074 is used but you may even apply rail to rail opamps as long as they are stable at unity gain. Also, watch the supply voltage range.
The graph in **Figure 2** (produced by our Audio Precision analyser) shows nine response curves obtained by setting the two tone controls to minimum, mid position and maximum. Note that 0 dB is relative to the mid position of the pots!
A simple circuit board was designed for the project (**Figure 3**). Linear-law potentiometers may be fitted directly onto the board. Two boards are required for a stereo application. The relevant connections on the boards are then wired to a stereo control potentiometer.

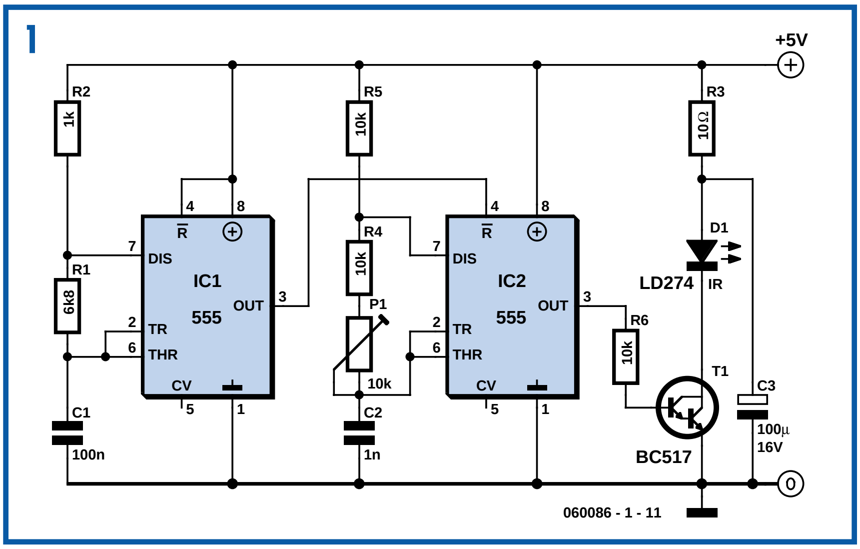
(060015-1)

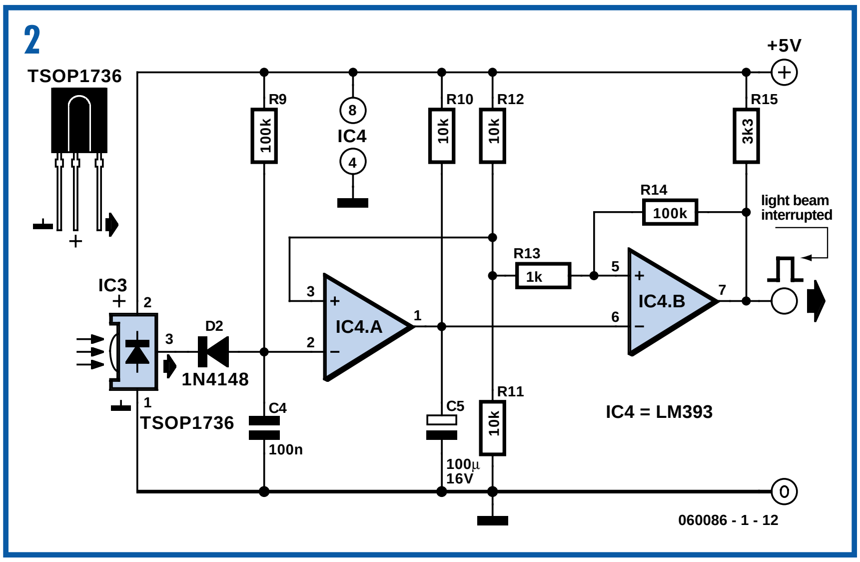
Modulated Light Barrier

012

Heino Peters

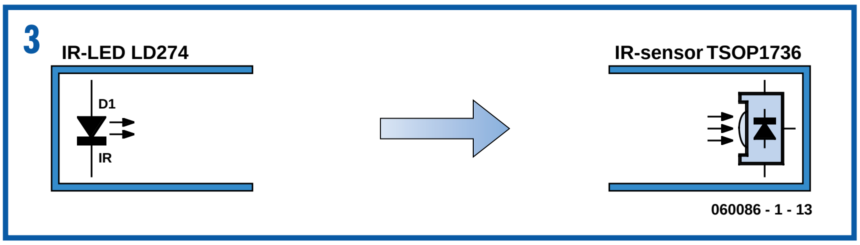
It's good fun to keep an eye on all sorts of things in your environment and on the basis of events in this environment to switch, for example, lamps or buzzers. To help with this, the light barrier described here can be used to guard an entrance. You can use it to signal of someone is walking through the corridor, or to check if the car has been parked far enough in the garage to be able to close the door. The circuit consists of a transmitter, which sends modulated infrared light and a receiver, which recognises this. The circuit used here is almost insensitive to daylight or fluorescent light and therefore can be used outside.
The transmitter (**Figure 1**) generates about 1000 times per second, for a period of 540 ms, a burst of 36 kHz. IC1 has been set with C1, R1 and R2 to a frequency of about 1000 Hz. The output of IC1 ensures that IC2 will oscillate about 1000 times per second for a period of about 540 ms. IC2 is set to a frequency of 36 kHz with C2, P1, R4 and R5. The output of IC2 drives the IR LED D1 via transistor T1. C3 and R3 prevent the reasonably high current through D1 from generating too much interference on the power supply rail.
The receiver (**Figure 2**) is quite a simple design, because IC3 already does a lot of the work for us. When the IC 'sees' an IR-signal with a frequency of 36 kHz, the output of IC3 will become '0'. The transmitter circuit alternates between sending an IR-signal of 36 kHz for 540 ms and is quiet for 470 ms. When this signal arrives at IC3, C4 will discharge via D2. Because the non-inverting input of IC4a is set to 2.5 V, with the aid of R10 and R11, the output of IC4a will be a '1'. In the intervening quiet periods of 470 ms, C4 will partially charge via R8, but this is not of sufficient duration to exceed the voltage of 2.5 V. Only when the light barrier is interrupted will C4 charge far enough that the output of IC4a will toggle and become a '0'. Because IC4a has an open-collector output, C5 will be immediately discharged and the output of IC4b will become a '1'. With R9 and C5 this signal is stretched to about one second. If you increase the value of R9 to 100 kΩ, then this will become about 10 seconds. R12 and R13





are included to prevent chatter of the output around the trigger point, although there is not really a risk of that happening in this circuit. Together with R14, the output of IC4b delivers a clean logic signal that we can use for further processing.

The quickest way of calibrating the frequency of IC2 to 36 kHz, using P1, is with the aid of an oscilloscope. If you do not have one of those, then point the IR-LED D1 at the receiver IC3 and turn P1 so that the voltage on the inverting input of IC4a is as low as possible. Make sure that IC3 during the calibration does not receive too high a signal by placing the IR-LED a considerable distance away or by not pointing directly at the receiver. If this procedure is not that successful then just set P1 to the centre position, this works just fine usually.



You should not have a problem with ambient light with this circuit. If you do have a problem because, for example, there is direct sunlight on IC3, then you will need to place it inside a small tube and point it at the IR LED. In this way no direct sunlight can reach the receiver. If the IR LED and the receiver are placed too close together it is possible that the receiver will sense light reflected off the walls, even when someone is standing between the transmitter and receiver. In this case the solution is also a short piece of tube for both the transmit LED as well as the receiver (**Figure 3**). Make sure that the tubes are opaque (paint black or use water pipe, for example). The wires to the IR LED can be several meters long without any problems. Do not place the receiver IC too far from the circuit.

(060086-1)

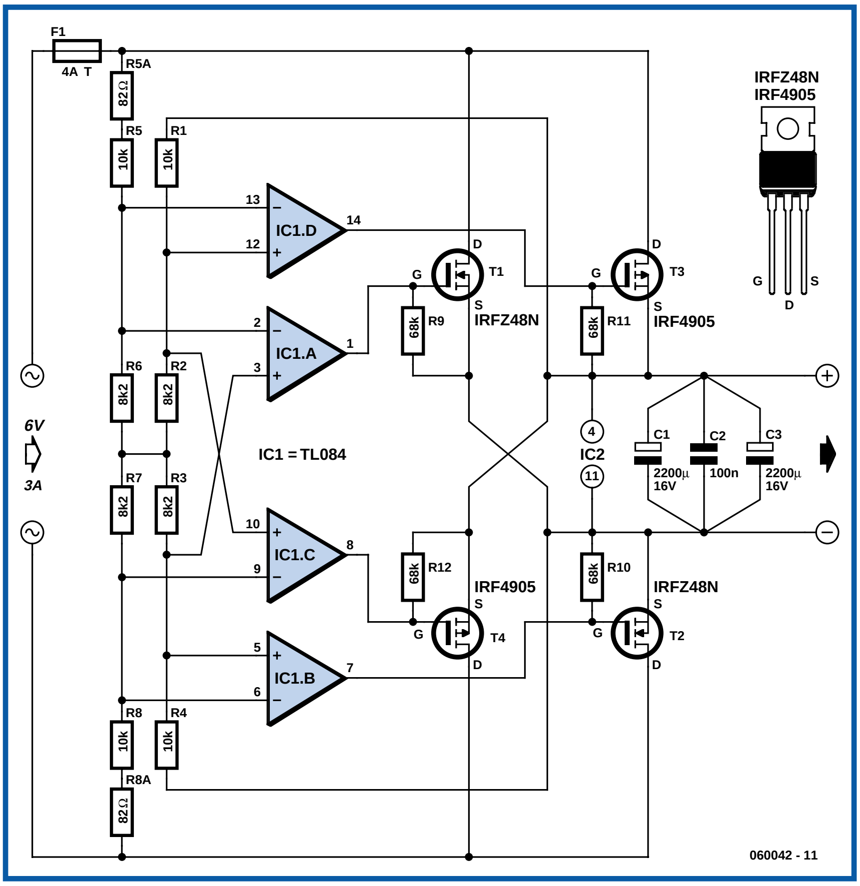
013

Power MOSFET Bridge Rectifier

Wolfgang Schubert

The losses in a bridge rectifier can easily become significant when low voltages are being rectified. The voltage drop across the bridge is a good 1.5 V, which is a hefty 25% with an input voltage of 6 V. The loss can be reduced by around 50% by using Schottky diodes, but it would naturally be even nicer to reduce it to practically zero. That's possible with a synchronous rectifier. What that means is using an active switching system instead of a 'passive' bridge rectifier.

The principle is simple: whenever the instantaneous value of the input AC voltage is greater than the rectified output voltage, a MOSFET is switched on to allow current to flow from the input to the output. As we want to have a full-wave rectifier, we need four FETs instead of four diodes, just as in a bridge rectifier. R1–R4 form a voltage divider for the rectified voltage, and R5–R8 do the same for the AC input voltage. As soon as the input voltage is a bit higher than the rectified voltage, IC1d switches on MOSFET T3. Just as in a normal bridge rectifier, the MOSFET diagonally opposite T3 must also be switched on at the same time. That's taken care of by IC1b. The polarity of the AC voltage is reversed during the



next half-wave, so IC1c and IC1a switch on T4 and T1, respectively.

As you can see, the voltage dividers are not fully symmetrical. The input voltage is reduced slightly to cause a slight delay in switching on the FETs. That is better

than switching them on too soon, which would increase the losses. Be sure to use 1% resistors for the dividers, or (if you can get them) even 0.1% resistors.
The control circuit around the TL084 is powered from the rectified voltage, so an auxiliary supply is not necessary. Naturally, that raises the question of how that can work. At the beginning, there won't be any voltage, so the rectifier won't work and there never will be any voltage...
Fortunately, we have a bit of luck here. Due to their internal structures, all FETs have internal diodes, which are shown in dashed outline here for clarity. They allow the circuit to start up (with losses).
There's not much that has to be said about the choice of FETs – it's not critical. You can use whatever you can put your hands on, but bear in mind that the loss depends on the internal resistance. Nowadays, a value of 20 to 50 mW is quite common. Such FETs can handle currents on the order of 50 A. That sounds like a lot, but an *average* current of 5 A can easily result in peak currents of 50 A in the FETs. The IRFZ48N (55 V @ 64 A, 16 mW) specified by the author is no longer made, but you might still be able to buy it, or you can use a different type. For instance, the IRF4905 can handle 55 V @ 74 A and has an internal resistance of 20 mΩ.

At voltages above 6 V, it is recommended to increase the value of the 8.2-kΩ resistors, for example to 15 kΩ for 9 V or 22 kΩ for 12 V.

(060042-1)

Multimeter as Lightning Detector

014

Karel Walraven

Most digital multimeters have a sensitivity of 200 mV and in input impedance of 10 MΩ. With this information you can calculate that at full scale there will be a current of 20 nA (nano-ampères). In reality you have a very sensitive ammeter in your hand.
Now that we know this, it becomes a mission to do something with that knowledge. In other words, here is a solution that requires a problem...

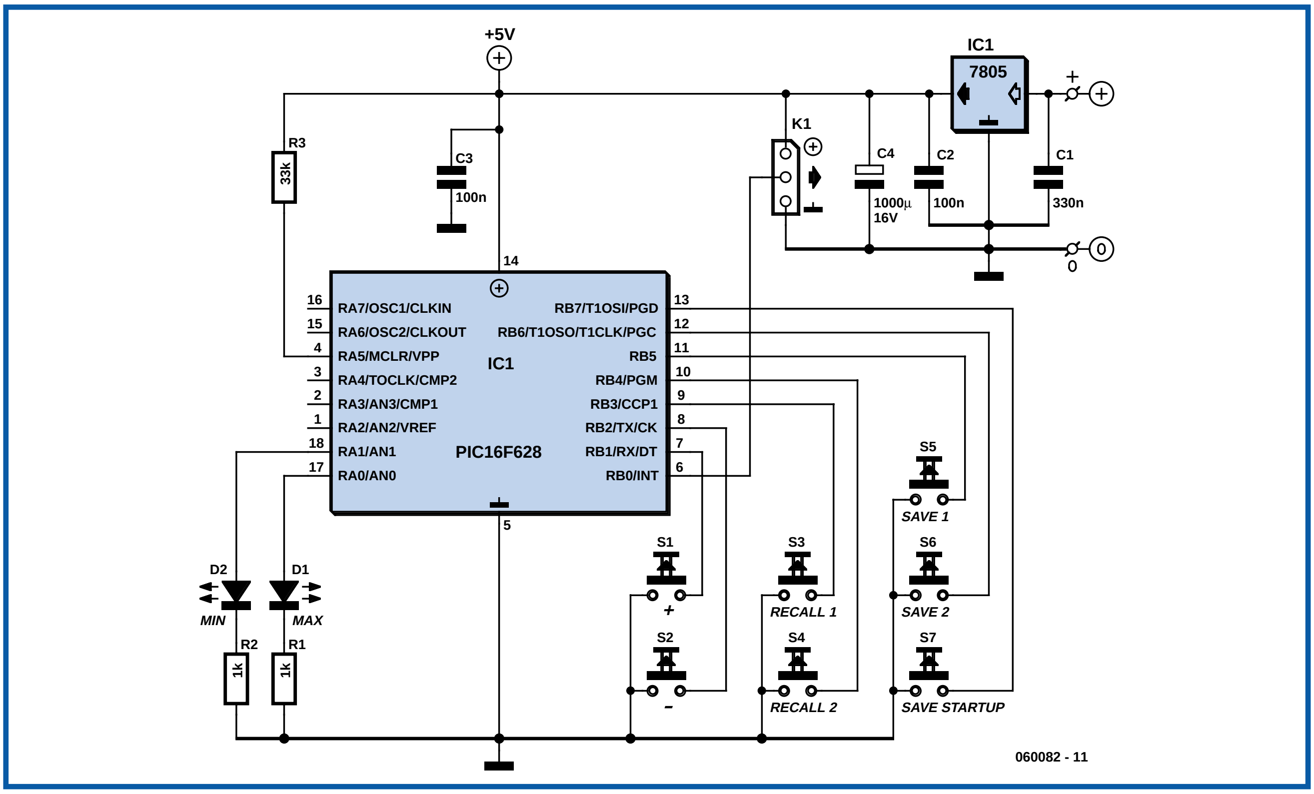
For example, try the following:

Connect the 'COM' of the voltmeter to ground (safety earth from a power point, central heating, plumbing, etc.). Connect an old bicycle wheel spoke or a length of thin copper wire to the 'V' socket so that you get a kind of antenna. When you place this impressive looking apparatus on a windowsill during a thunderstorm and set the meter to the 200 mV range, you will, with a bit of luck, see nice deflections during lightning strikes. A nice thing is that you will see a build-up of static charge long before the flash, and immediately after the lightning flash the charge is gone. Be aware of your own safety and those of others: Don't walk outside with the thing or surreptitiously lead the 'antenna' to the outside. This is really dangerous. In these modern times people still die from lightning strikes!
According to theory it is possible to improve the lightning detector somewhat. A sharp point or edge collects more than a rounded one. You probably have a razor blade somewhere. Attach this razor blade at the top of the antenna. And again, be careful: keep children and pets away.

In the picture you can see an assembly were the top of the antenna has one turn. The razor blade is clamped in this and in addition it is a lot harder to injure yourself this way.
The 'reception' can be improved a lot more by ionising the air in the region of the antenna with the aid of radioactivity. Most of the mantles used in gas and petroleum lamps contain a small amount of radioactive material and also smoke detectors that work with an ionisation chamber are (lightly) radioactive. It is better to leave the smoke detectors alone, because they often contain very poisonous substances, but a piece of lamp mantle could be secured to the razor blade with some two-component epoxy glue.

(064015-1)

015 Preset Circuit for Servos



Elmar Jongerius

This circuit was called into life to operate servomotors from the model world. The emphasis here is remembering certain preset values. For this, the internal memory of a PIC16F628A is used.

The module can be used to automate various mechanical functions. In addition to the usual model building applications, the circuit can also be used for the operation of small cranes, mirrors, etc. The preset-circuit can also be useful when doing demonstrations.

The hardware is very simple by design. When the circuit is powered up, it automatically drives the servo to the initial position. The circuit is operated using seven pushbuttons. The table details the functions of the pushbuttons. The pull-up resistors for the pushbuttons are already built into the PIC and the de-bouncing is handled by the software. Two LEDs are used to indicate the limit values and the power supply is provided by a standard circuit around a 7805. Additionally, it is convenient to use a connector so that a servomotor can be connected easily.

The operation of the servo is done with pulses of different lengths. These pulses need to be repeated about every 20 ms. A pulse duration of 1.5 ms corresponds approximately to the neutral position of the servo. The limit positions of the servo are at pulse durations of about 0.8 and 2.2 ms (this depends on the type of servo).

The program running in the microcontroller consists of a loop, which is repeated every 20 ms and comprises the following steps:

- check for pushbutton presses;
- check for valid values and turn on one of the LEDs if the limit value has been reached;
- send the pulse;
- wait 20 ms.

When checking for pushbutton presses, the IC will immediately carry out the corresponding action, for example storing a value in EEPROM. Because the buttons are checked once every 20 ms, additional de-bouncing is not necessary.

We have a few things that need to be noted regarding the construction of the circuit. Provide sufficient cooling for IC1, particularly if it is used with a high power servo or if the servo is exerting force continuously, for example against a spring.

Also make sure that the servo is connected correctly. Different manufacturers use different colour codes. Fit C3 as close as possible to the PIC. This is because C3 serves to suppress interference from the servo.

The software for the project has been written in PICbasic and includes comments.

No.	Name	Function
S1	Up	Move the servo in the positive direction
S2	Down	Move the servo in the negative direction
S3	Recall 1	Recall the value of Set 1
S4	Recall 2	Recall the value of Set 2
S5	Set 1	Store the current position in Set 1
S6	Set 2	Store the current position in Set 2
S7	Set Initial	Store current position as initial position

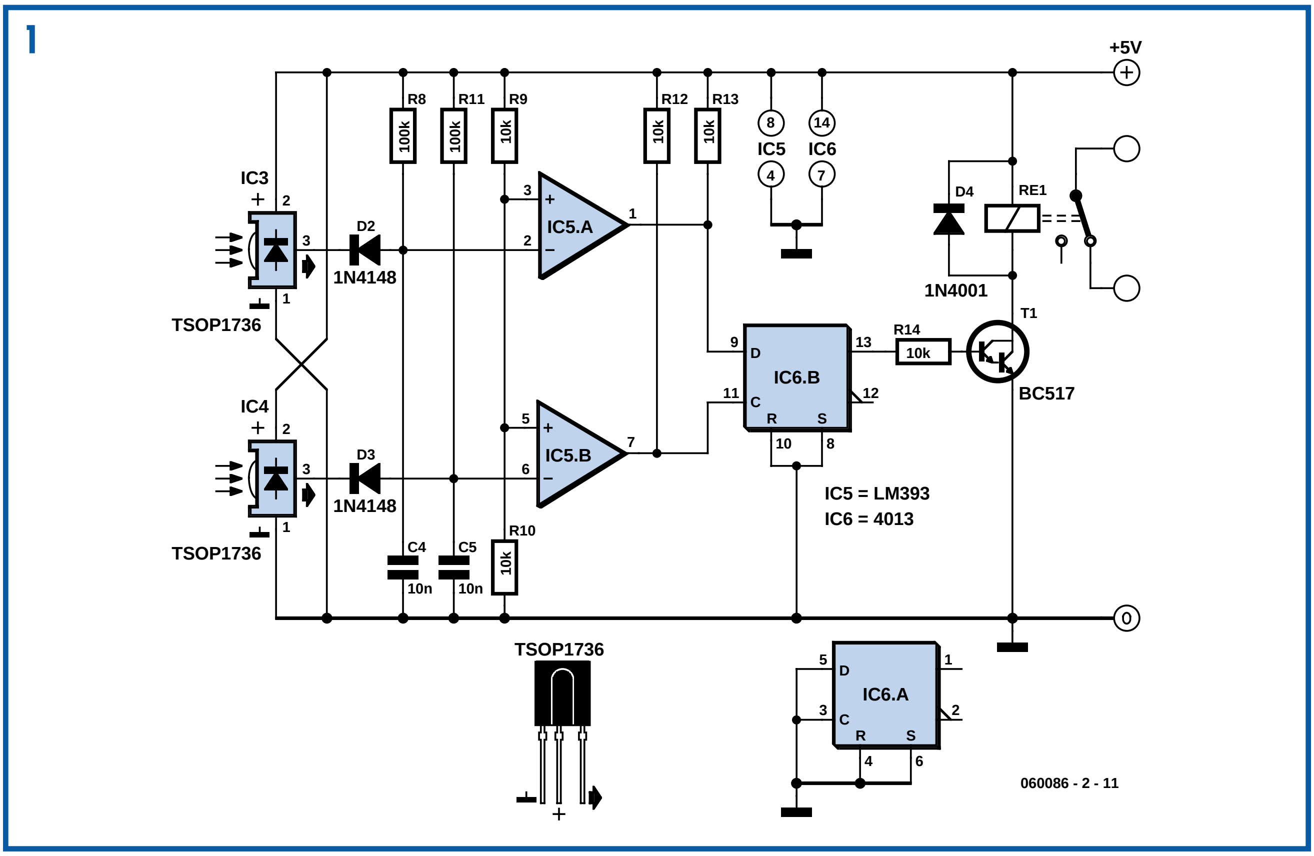
The program is easily compiled and optionally changed with the free Lite version of the Proton PICbasic compiler. It is however necessary to remove the comments.

The program code can be downloaded from www.elektor-electronics.co.uk, you'll find it filed as number **060082-11.zip**. A pre-programmed PIC is available as order code **060082-41**. A version of PICbasic can be obtained from www.picbasic.org.

(060082-1)

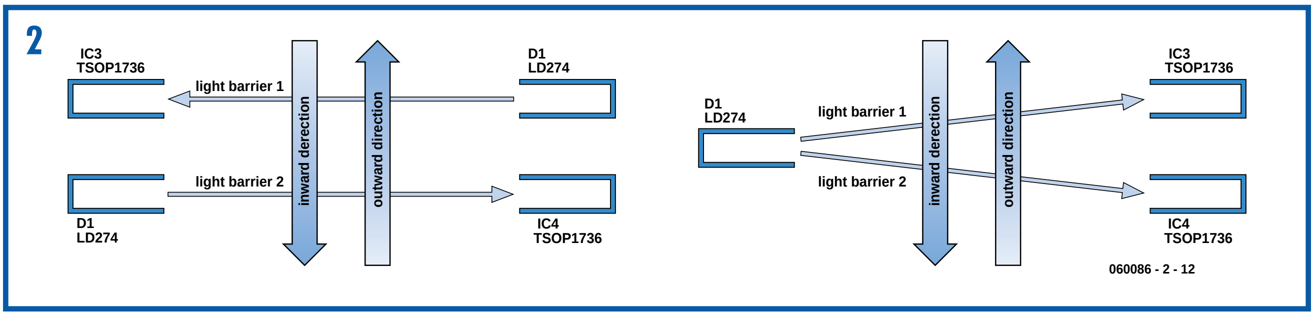
Direction Sensitive Light Barrier

016



Heino Peters

With two light barriers closely positioned one after the other it is possible to establish in which direction they have been crossed. If, for example, you place it at the entrance of the toilet then you can use it to control the lights: on when entering and off when leaving the room. The circuit for this has many similarities with the modulated light barrier appearing elsewhere in this Summer Circuits issue. There are two ways to position the light barriers, namely a completely duplicated installation in opposing directions (this to prevent mutual interference) and a version with one IR transmitter and two receivers. Both types of installation are shown here, which one is most suitable depends on the actual application. When used in a doorway, one transmitter is sufficient if the receivers are placed about 5 cm apart. With a wider passage, an installation with two separate



IR-transmitters is a better solution. This circuit has a range of several meters, even if the sun shines directly on the receiver!

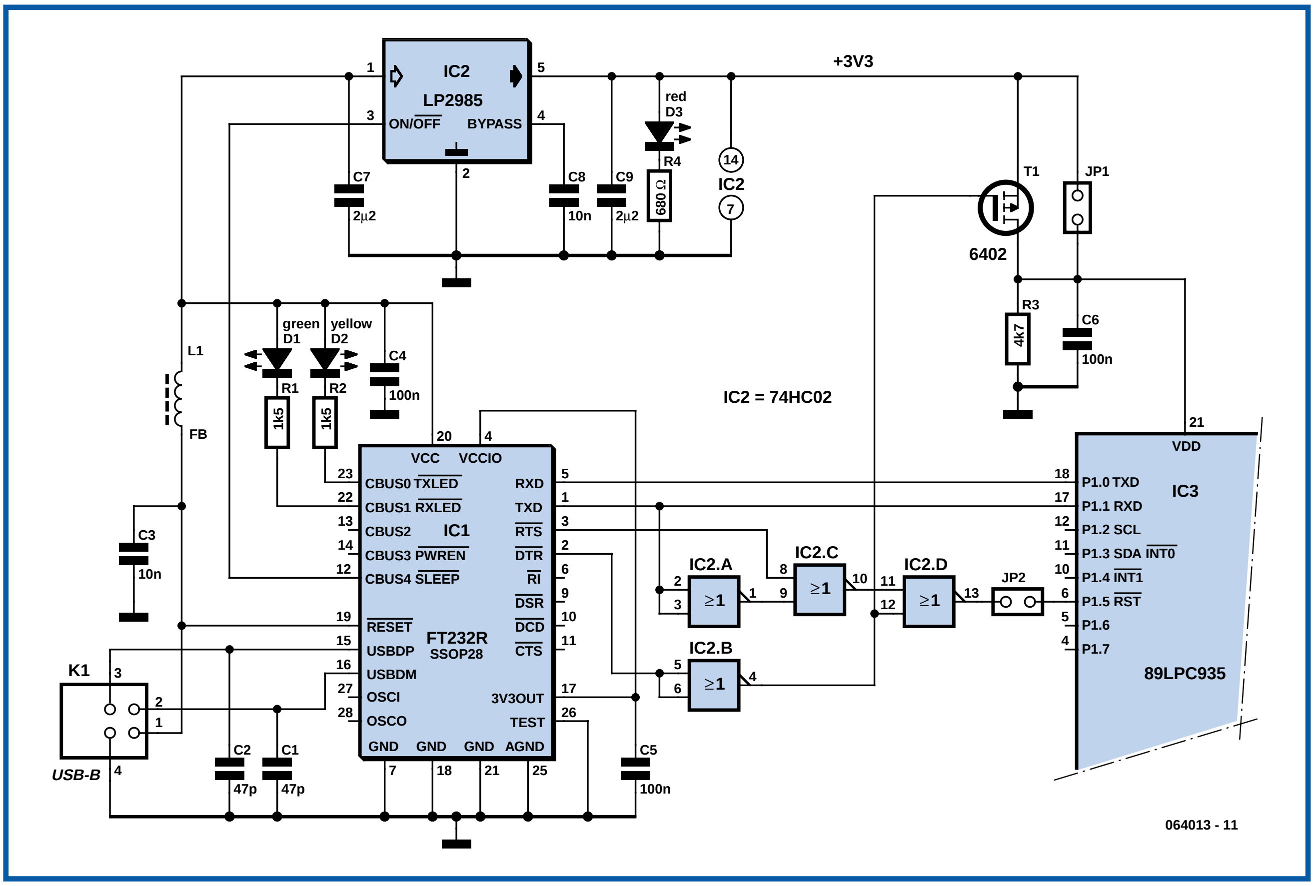
We use the exact same IR-transmitter(s) as for the modulated light barrier. For the installation with two separate IR-transmitters it is sufficient to duplicate R6, T1, D1, C3 and R7 from the circuit of the modulated light barrier. Output OUT (pin 3) of IC2 can drive two of these IR-drivers without any difficulty. The receivers are slightly different than those of the modulated light barrier and the circuit is the same for both types of installation.

We again use the TSOP1736, which is sensitive to IR-light that is modulated at a frequency of 36 kHz. D2, R8 and C4 ensure that the received pulses from IC3 at the output of IC5a result in a '1' when the beam is not interrupted. When the beam is interrupted this output will become a '0' within about 1 ms. In the same way IC5b generates a '0' when IC4 stops receiving IR-light. The 4013 CMOS-IC used here contains two D-flipflops, of which we use only one. The instant that light barrier 2 (IC4) is unblocked again, is used to clock the state of light barrier 1 (IC3) through to output Q1. This signal drives the relay via T2, which operates the light in the room. The circuit therefore turns the light on or off the moment that light barrier 1 is uninterrupted.

(060086-2)

017

89LPC9xx USB Programming



Back in November 2003 you could already read about a small development system for the (then) new series of controllers from the 8051-compatible 89LPC9xx-family. A nice feature of the current 89LPC9xx-series is that these chips can remain in the circuit while (re-)programming. All that's required for this programming is an RS232 port. But because many modern computers do not have an RS232 connection any more, we propose here a USB version. For this we use a well-known USB/RS232-converter chip, the FT232R.

The 89LPC9xx series can be placed in programming mode in two different ways: by transmitting a 'break' over the serial port or by providing three defined reset pulses immediately after power-on. We use the latter method, because this is a hardware solution. This is because the 'break' has to be sensed by software. In plain language: this method only works with a well-behaved program. And this is obviously not always the case in a development environment!

When you also look at the schematic from 2003, you will see that very little has changed. Really the only difference is that the RS232 interface chip has been replaced with the FT232R. As you will know, the USB-interface is terribly slow when the handshake lines such as DTR and RTS are used. Fortunately that is not the case here, since DTR and RTS are used just once at the beginning and end of the programming cycle. The actual programming is done by transmitting commands and data across the serial port.

A few remarks:

To be able to program you will have to change a jumper each time. On the one hand this is a little tedious, but on the other hand it gives a little bit of security. During software development a double pole change-over switch does wonders! Note that the processor is placed in programming mode by three reset pulses after power-on. If the power supply voltage does not drop sufficiently beforehand (<2.7 V), then the processor will not be placed in power-up mode by the brownout circuit and therefore cannot be placed in programming mode either. That is why a resistor of 4k7 has been added to drop the power supply voltage faster and lower. Check the inputs in your application. If these are powered from another voltage then the processor will be powered from its inputs via the protection diodes and programming will not work then!

It is possible (but not necessary) to power the circuit through a low-drop regulator from the USB-connection.

You can also omit L1, but it is better to put a few turns of wire through a ferrite bead.

The pin numbering shown is for the SSOP-28 package.

(064013-1)

DC-coupled Audio Amplifier

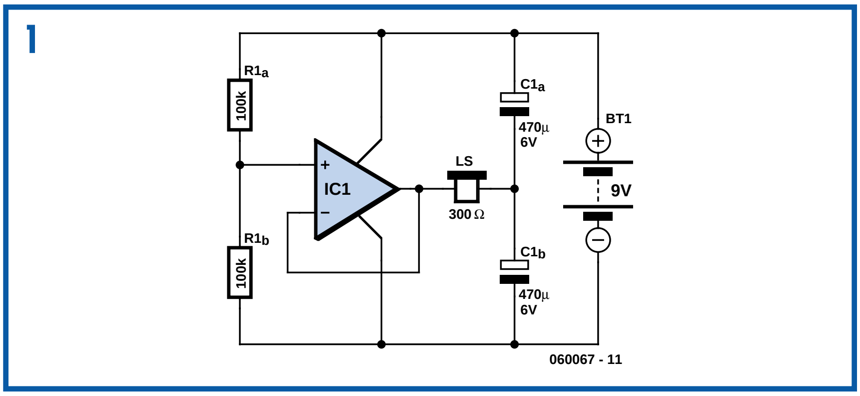
018

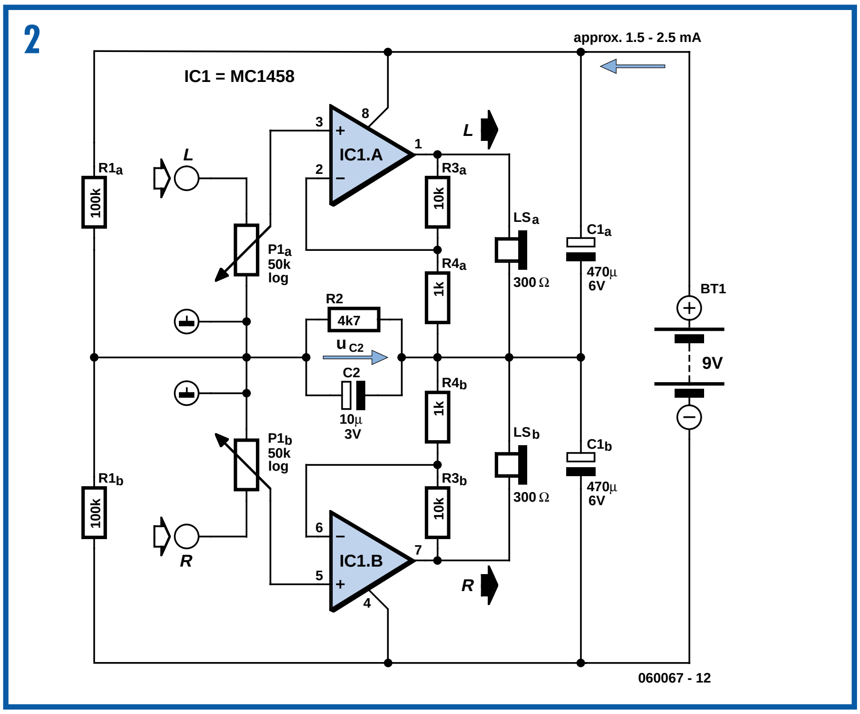
Peter Bitzer

Designs for audio amplifiers with DC coupling to the load are not often encountered these days, even though they offer definite advantages. One advantage is that there is no need for the complication of a second (symmetric) power supply; another is good frequency and phase response. Also, no special electrolytic capacitors are needed for voltage stabilisation, and switch-on 'thump' is much reduced.

To try to rescue this class of circuit from obscurity the author has designed a headphone amplifier working along the lines illustrated in **Figure 1**. It consists of a voltage divider, a voltage follower and the loudspeaker in the headphones, whose other side is connected to the junction of two electrolytic capacitors, providing the virtual earth. The potential at this point is, of course, half the supply voltage. All we need to do now is suitably couple in the audio signal to be amplified.

Figure 2 shows a practical realisation of this idea in the form of a stereo headphone amplifier. The amplifier itself consists of IC1 and P1, R3 and R4 (giving a gain of 11). This part of the circuit demands no further explanation, and the same goes for the voltage divider mentioned above, formed by R1a and R1b. The signal is coupled in via the potentiometers. C2 and R2 have a special purpose: C2 connects the bottom end of the potentiometers (ground for the input signal) to the virtual earth. However, this capacitor creates a feedback path which can lead to oscillation of the amplifier under some circumstances. R2 damps this tendency to oscillate. It is possible to calculate suitable values for these components, but it is better to determine them by experiment. C2 must be sufficiently large

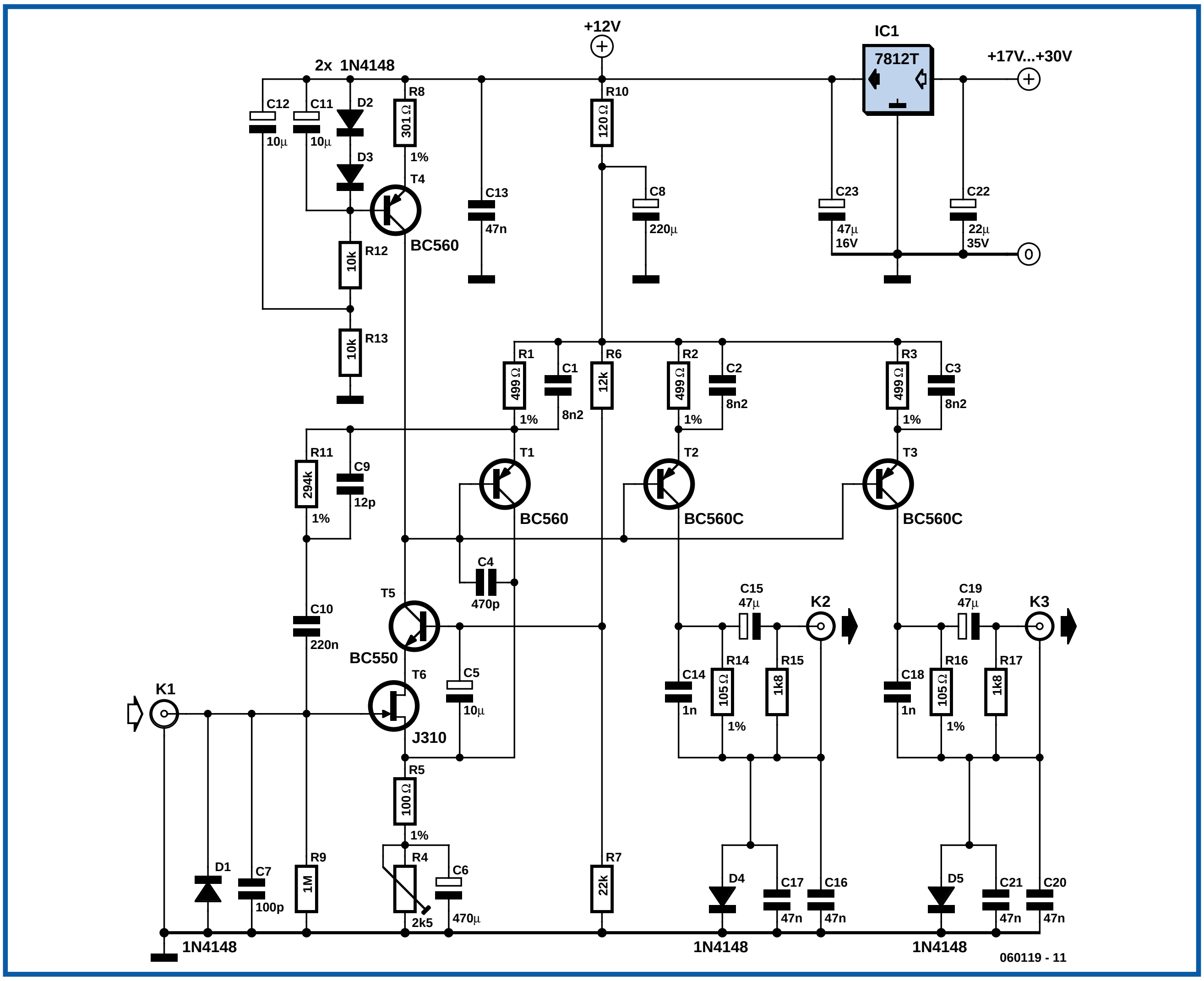




that stray electric fields do not cause unacceptable hum at the output. R2 must be sufficiently large that the voltage at the amplifier's virtual earth stabilises quickly enough after switch-on. The polarity of the electrolytic is unimportant as no significant voltage appears across the network. It is possible to try the circuit out with the C2/R2 network shorted and observe the behaviour of the circuit at switch-on using an oscilloscope. Depending on the degree of asymmetry in the circuit, the voltage at the virtual earth point can take a considerable time to stabilise.

(060067-1)

019 Phono Splitter



Marcel van de Gevel

This circuit is intended to send the signal from a record player with a magnetodynamic (MD) element to two different RIAA-amplifiers without creating any problems with ground loops. A kind of distribution amplifier for phono signals, in other words.

The circuit was originally designed by a local VHF FM broadcast station called 'Haarlem 105'. For the golden-oldies programme, the signals from two record players had to be sent to a large radio mixing panel (which is also the entry point for jingles and presenter microphones). For a programme with modern dance music the signals had to be routed to a small club mixing panel that was positioned between the two record players.

Connecting in parallel was not an option, because it will create a ground loop and the load for the element will be wrong. An RIAA amplifier for each player was not possible either because all the line inputs of the small club mixing panel were already in use. Switching between them was also not desirable; another switch that can be in the wrong position...

The circuit works as follows. The feedback ensures that the signal voltage of the element will be across R5. The signal current that results from this, runs through T1 and, because the bases are tied together, also through T2 and T3. This causes a signal voltage across R14 and

R16. By connecting one side of R14 or R16 to the local ground of the mixing panel, the signal voltage will be between the input and the local ground of the mixing panel. This connection to the local ground of the mixing panel is done via the screens of the phono plugs. The part of the chassis at the output must definitely be isolated.
D4 and D5 operate like a kind of automatic ground lift switch. It is the intention that the ground from the distribution amplifier is connected in one way or another to the ground of the mixing panels, obviously without creating a ground loop. The DC from T2 and T3 flows via the screens of the phono cables and the ground connection back to the distribution amplifier. There is hardly any DC voltage across D4 and D5, so that they do not conduct. As a result the outputs for the signal voltages are well isolated from each other, which reduces the risk of a ground loop.
If there is no connection between the ground of the distribution amplifier and the grounds of the mixing panels then D4 and D5 will conduct. Everything continues to function, but there is a relatively low-impedance connection between the screen of X2 and the screen of X3 via the diode, which can cause a weak ground loop if the grounds of the mixing panels are also connected together via another path.
An input impedance of 47 k is absolutely essential to properly terminate an MD-element. This is realised in this amplifier with feedback via R11. This results in lower input noise compared to simply soldering a 47-kΩ resistor in parallel with the input. Trimpot R4 is required because of the wide tolerance of field effect transistor T6. Adjust R4 so that there is about 1 V across R1. If R4 is a carbon trimpot, then the wiper has to be connected to the positive side (as indicated in the schematic) to prevent anodisation of the wiper.

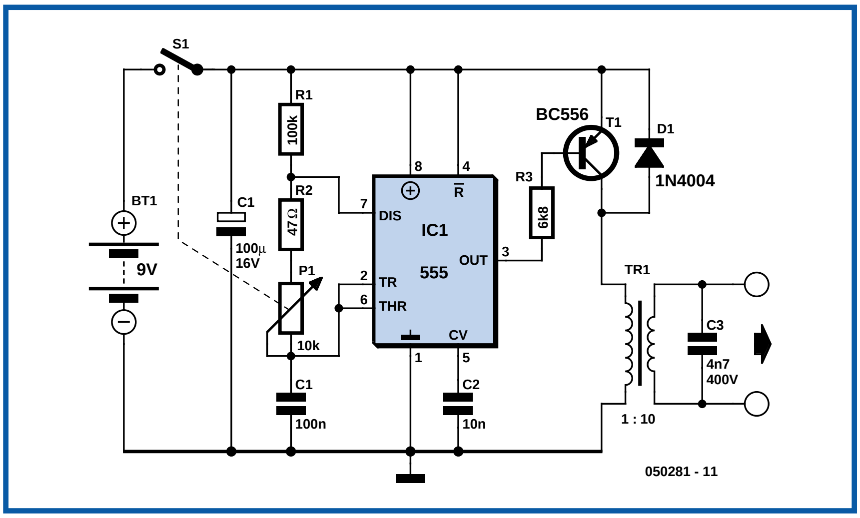
The distribution amplifier has four identical channels, enough for two stereo record players and is powered from one 7812, which does not need a heatsink.

(060119-1)

Transcutaneous Electrical Nerve Stimulator (TENS)

020

Klaus Rohwer



A Transcutaneous Electrical Nerve Stimulation (TENS) device is, put bluntly, a machine for giving electric shocks. The author was prescribed such a device on loan by his orthopaedic specialist. The unit has a large number of programmes, of which he used only one. Measuring the signals at the output of the device in this mode revealed damped oscillations at a frequency of approximately 2.5 kHz, with a repetition rate of approximately 100 Hz. How hard can it be to make such a device ourselves?
The simple circuit uses a CMOS 555 timer to produce a brief pulse which feeds a 1:10 miniature transformer. Together with a 4.7 nF capacitor the transformer makes a parallel resonant circuit: the resonance leads to a considerable increase in the output voltage.
The pulse width can be adjusted using a potentiometer, here shown combined with the on-off switch. Wider pulses produce higher output voltages. Since a peak voltage of up to 200 V can be produced, the transformer must have adequate insulation: Conrad Electronics type 516260-62 is suitable. A low-cost phono socket at the output gives reliable connection to the electrode cable. The adhesive electrodes shown in the photograph (disposable and permanent types are available) can be obtained from pharmacies and medical suppliers. They generally have connectors compatible with 2 mm banana plugs, and so it is possible to make up the necessary cable yourself.
To treat responsive parts of the body, such as the arm, the potentiometer need not be turned up far to obtain the necessary sensation. Less sensitive parts, such as the knee or foot, need a rather higher voltage and hence a correspondingly higher potentiometer setting.
Anyone considering building a TENS unit with multiple (microprocessor-controlled) programmes might wish to read the article ‘Low Impact Muscle Stimulator’ in the April 2000 issue of *Elektor Electronics*. The article is also available for purchase as a pdf file at http://www.elektor-electronics.co.uk.

(050281)

Warning

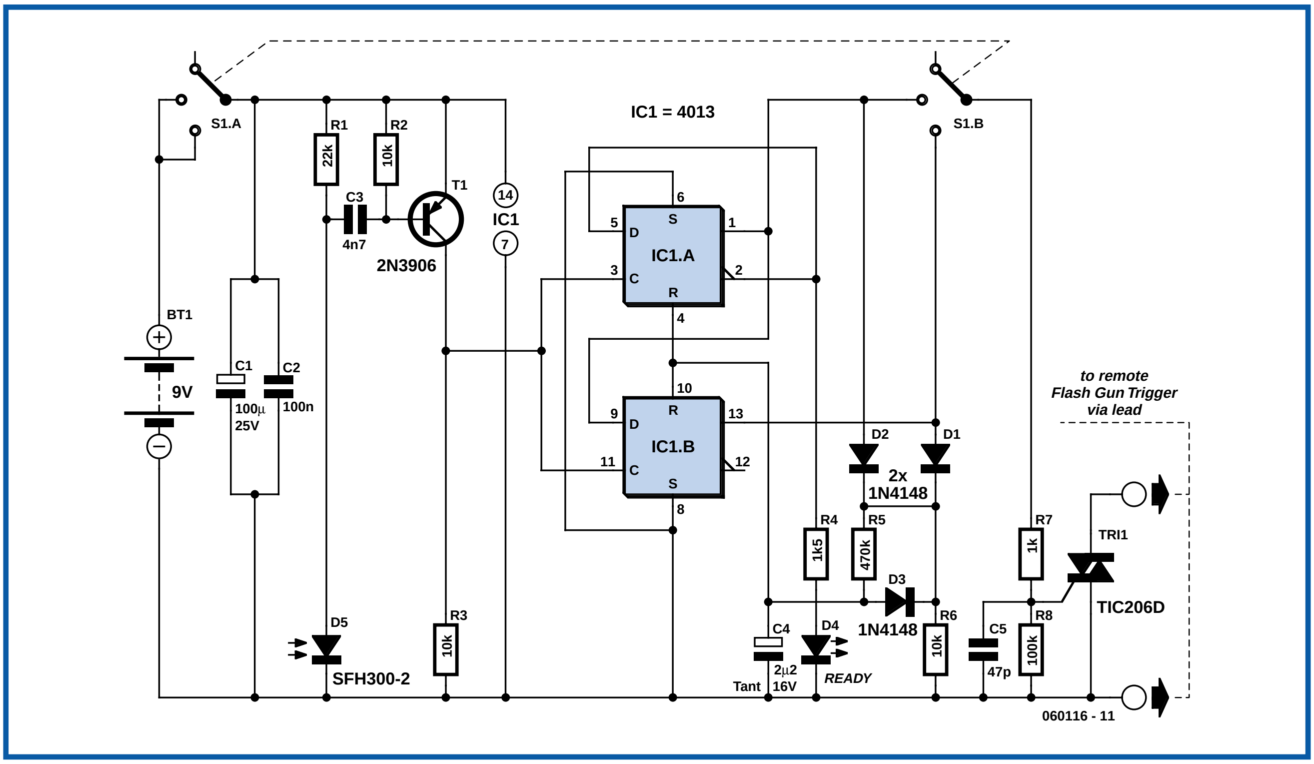
No part of this circuit may be connected to the mains voltage, accidentally or intentionally, by means of any equipment or component including a transformer.

Disclaimer

This circuit is not approved for medical use and must not be used on young children or persons suffering from epilepsy. Medical advice should be sought from your GP before all use.

021

Slave Flash Trigger

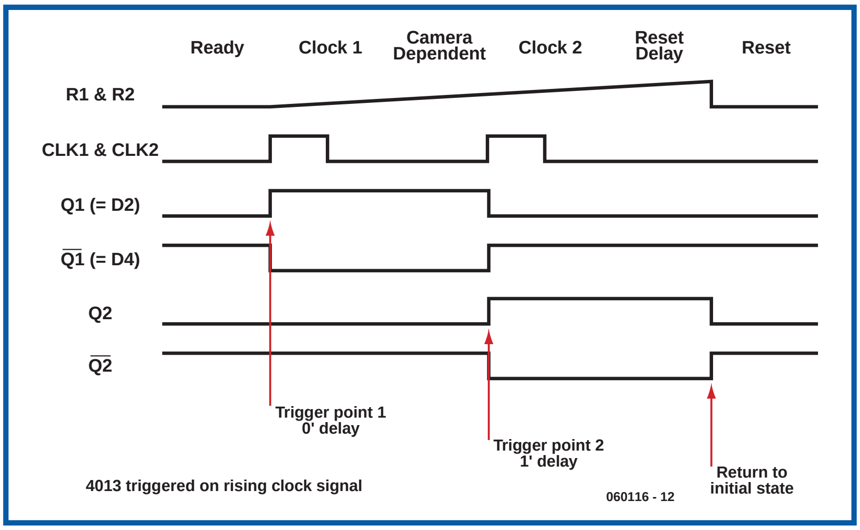


Peter Metcalfe

Using any camera in a dull or dark environment generally requires the use of supplementary light. This is a standard technique, and even where adequate natural lighting exists, to take conventional film pictures with enhanced contrast using a 'fill-in' flash for foreground subjects in shade. A flash is often built into the camera body, but the internal flash is not usually powerful enough to illuminate subjects much more that 3 m or so from the camera. On SLR cameras a hot-shoe is provided for triggering an auxiliary, more powerful flash, but the small pocket cameras are not so equipped. However, it is possible to trigger a slave flash from the camera flash by optical means. Even so, things are not so simple, for some cameras, e.g. Olympus, Nikon, Canon actually fire twice, although it appears to be once to the naked eye. The first flash sets the exposure and the second takes the picture. Help on synchronisation requirements may be found at various websites maintained by professional photographers. See also www.caves.org.uk/flash/docs.html for a series of articles with kits by a caving enthusiast.

The presented trigger circuit optically receive the camera flashes and either fires at the same time as the first flash or has one flash delay before triggering the slave flash. Additional counting circuitry is required for more than one delay (covered by modified circuit not presented here).

Here's how it works. The response of phototransistor D5 to the external camera flash is pulsed by a transistorised amplifier T1 into the dual flip-flop clock IC1. One output of a flip-flop illuminates an LED as a 'ready' signal. A double pole 3-position slide switch, S1, selects none (e.g. for Kodak camera) or one (e.g. for Olympus camera) flash delay before triggering. Both flip-flops are used in the 4013, the clock signal derived from the flash is used (triggered on the rising clock signal) to 'divide by two' and trigger the TIC206 triac on the first or second flash. A simple RC timed reset



mechanism around R6-C4 is used with a relatively long delay (about half a second) before resetting the entire circuit. The advantage of the triac is that a trigger voltage of either polarity can be handled.
The 2N3906 may be replaced by its near equivalent the BC212L. The SFH300-2 photodiode is supplied by Maplin as part number MES NP64U. The triac may also be a TIC126D.

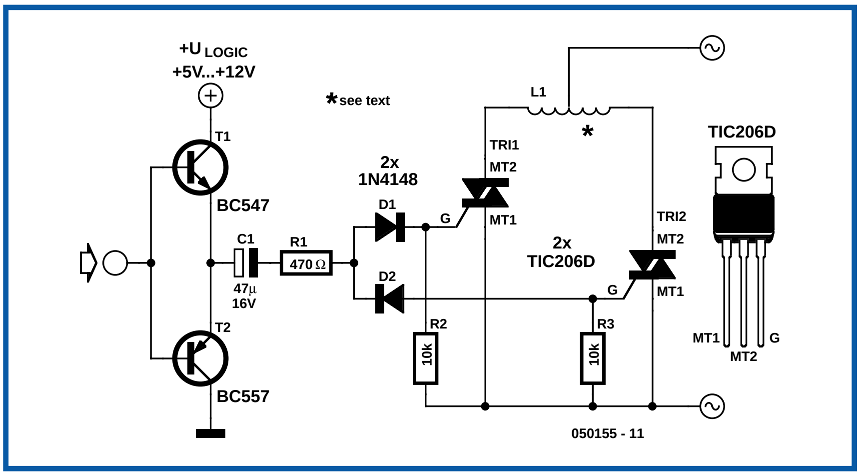
(060116-1)

Model Railway Turnout Control

022

Hans Zijp

This small circuit can be used to control model railway turnouts operated by AC voltages. A logic level in the range of 5–12 V can be used as the control signal. The coils of the turnout are switched using triacs.
Changes in the logic level of the input signal are passed on by the buffer stage built around T1 and T2. The buffer stage is included to boost the current available at the gates of the triacs. If the input goes high, this positive change is passed through via C1. That causes a positive current to flow through D2 (D2 is reverse biased) to the gate of T3. That triac switches on, and power is applied to the turnout coil. This situation persists until C1 is fully charged. No more current flows after that, so the triac does not receive any gate current and switches off.
If the input is set low, a negative current flows briefly via C1. It can flow through D2, but not through D1. T4 is switched on now, and the other turnout coil is energised. This circuit takes advantage of the fact that triacs can be triggered by negative as well as positive gate currents.
If the turnout coils are energised for too long, you should reduce the value of C1. If they are not energised long enough, increase the value of C1.
The TIC206D can handle several ampères, so it can easily drive just about any type of turnout coil.
You can also use a different type of triac if you wish. However, bear in mind that the TIC206 requires only 5 mA of gate current, while most triacs want 50 mA. That will cause the switching times to become quite short, so it may be necessary to reduce the value of R1.



(050155-1)

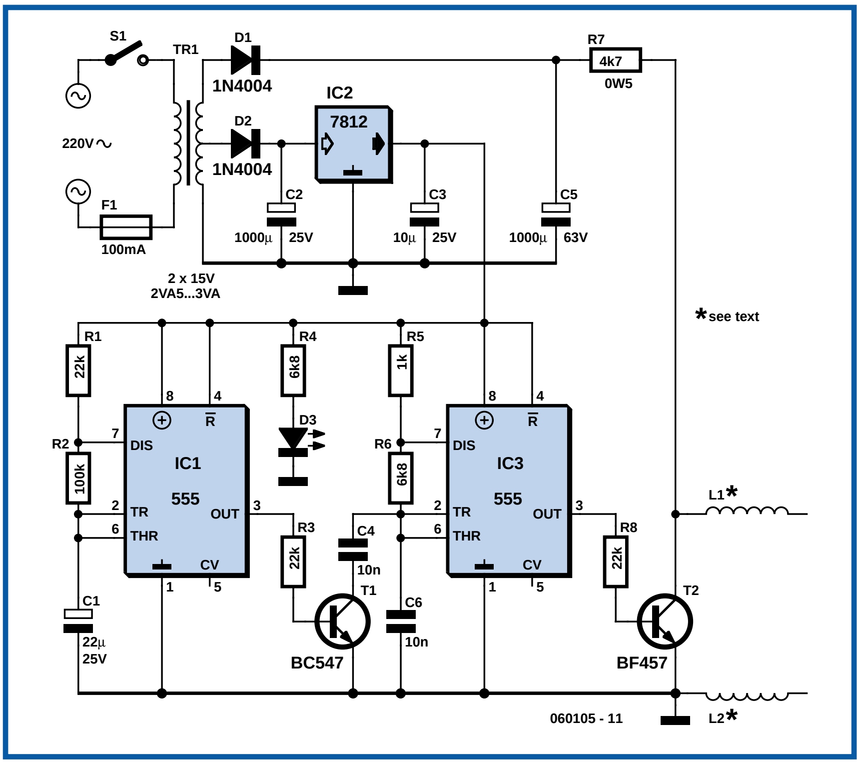
Pipe Descaler

023

Christian Tavernier

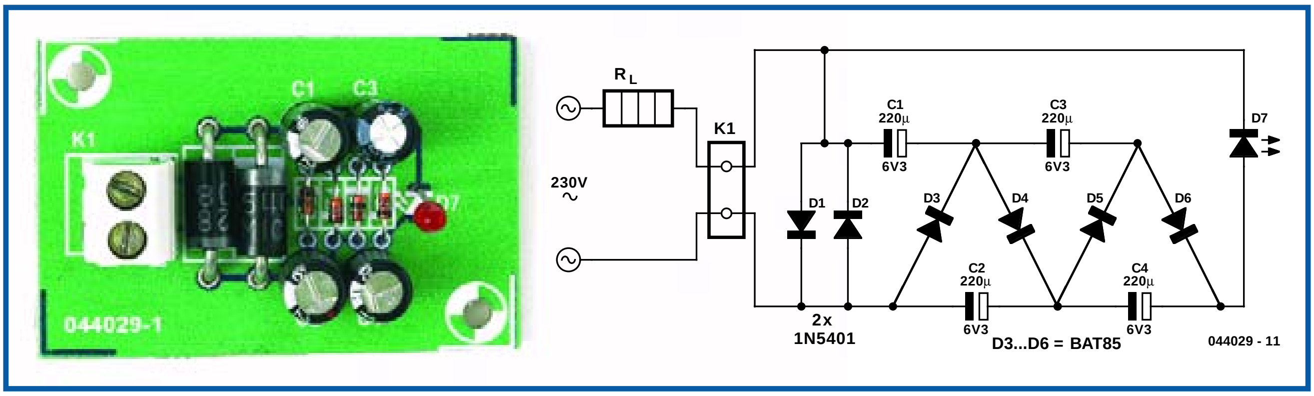
For many years now, magnetic (or electromagnetic) water descaler devices have been showing up on the shelves of Home Improvement and other DIY stores all over Europe. Despite the numerous studies completed on that subject, by manufacturers as well as by various consumer associations, none have been able to conclude on the efficiency of commercial pipe descalers in a decisive manner. Since electronic devices of this type are relatively expensive (especially when we discover what they are made of!), we decided to offer this project to our readers. For the price of a few tens of pounds, you will be able to evaluate the state of your own faucets, pots, and other pipes.
The device we're offering as a project is identical to top-of-the-line items found on sale; in other words, it includes the bi-frequency option because it seemed that would be the best way to fight lime scale deposits. An initial astable oscillator, based on a traditional 555, labeled IC3, functions at around 10 kHz when the only capacitor C6 is operating; in other words, when T1 is blocked. The latter is controlled by another astable oscillator, based on IC1 this time, but which functions at about 1 Hz. When T1 is turned on by IC1, capacitor C4 is effectively in parallel with C6 which divides the frequency produced by IC3 by two, i.e. to about 5 kHz.
In order to have high amplitude signals, the power supply operates with a mid-point transformer utilized in an unconventional way, with simple half-wave rectifica-

tion. The first half of the secondary delivers 15 VAC which, after being rectified, filtered and regulated by IC2, supply stable current of 12 VDC to supply power to the oscillators.
The entire secondary makes it possible to have available, after rectification, approximately 40 VDC which is used to supply power to coils L1 and L2, wound around the pipe systems on which the assembly will work. To do that, IC3 is followed by high-voltage transistor T2 (a BF457 or equivalent) which chops this high voltage to 5 or 10 kHz frequency depending on the state of IC1.
LED D3 lights up to signal that the power supply is present.
Coils L1 and L2 are simple inductors made from insulated flexible wire, with about ten windings each. They have to be wound around the pipes carrying the water to be 'treated' and are spaced about ten centimeters from each other. Neither the material of the pipe system, nor its diameter, should have any influence on the efficiency of the device. Paradoxically, these coils have one end in the air, which may surprise you as much as us but we indicated at the beginning of this article, that our goal with this project is not to explain the principle but rather to allow you to make the same device as those sold in stores, so that you can perform your own tests.



www.tavernier-c.com (060105-1)

024 Mains Indicator



Karel Walraven

It is not always immediately obvious whether a power-consuming appliance is switched on or not. Examples are the lamp in the attic or the shed, or electric heating in an awkward place. A nice solution would be to connect an LED directly in series with the appliance, unfortunately you'd better duck for cover if you tried…
The obvious solution would be to place a (power-) resistor in series with the load and connect an LED with series resistor across it. However, this solution has significant disadvantages, for instance, the power loss is relatively large (easily a few watts). In addition, the value of the resistor should be adjusted depending on the magnitude of the current.
It would be better to insert two anti-parallel diodes in the power lead. Unfortunately, the voltage drop is too low to power an LED. It does work with 6 diodes, for that matter, but the power loss is then also 3 times greater.
We therefore chose a solution with two

diodes, followed by a 4 times voltage multiplier in the form of a cascade rectifier. That is an energy friendly solution. The current through the LED is automatically limited by the internal impedance of the cascade rectifier. The impedance isn't that small, despite the large electrolytic capacitors. Use a low-current LED, otherwise the LED will probably not be bright enough. The 1N5404 used here can handle up to 3 A

(3 A × 230 V = 690 W).

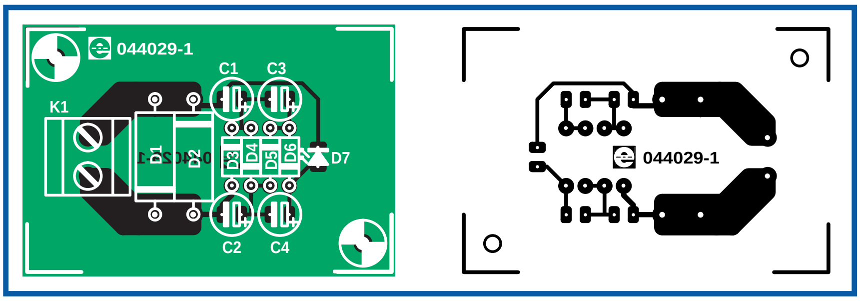
If the power is less than 200 W, you could use two 1N4004s instead.

The voltage across the diodes is a square wave with an amplitude of about 1.3 V_{pp}. The voltage multipliers are used to turn this into the LED voltage. This will only work if the voltage drop across the diodes in the multipliers isn't too large. That is why these diodes are Schottky diodes. These only have about a 0.35 V voltage drop. Exactly which type of Schottky diode that you use is not too important.

You are free to experiment with the value of the electrolytic capacitors. The larger their value, the greater is the amount of current that can be delivered.

Keep in mind that working with mains voltage can be fatal. Build the circuit in such away that there is no risk that live parts can be touched and maintain isolation distances of 6 mm (also in air). For the same reason, use a 5 mm LED (not a 3 mm one!) and fit it as far into the enclosure as possible. Mount the PCB in the enclosure with nylon bolts.

(044029-1)



COMPONENTS LIST

Capacitors:
C1-C4 = 220µF 6.3V

Semiconductors:
D1,D2 = 1N5401
D3-D6 = BAT85 (or any other Schottky diode)
D7 = LED, low current

Miscellaneous:
K1 = 2-way PCB terminal block, lead pitch 5mm
PCB, order code 044029 from The PCBShop

025

Simple Slave Flash

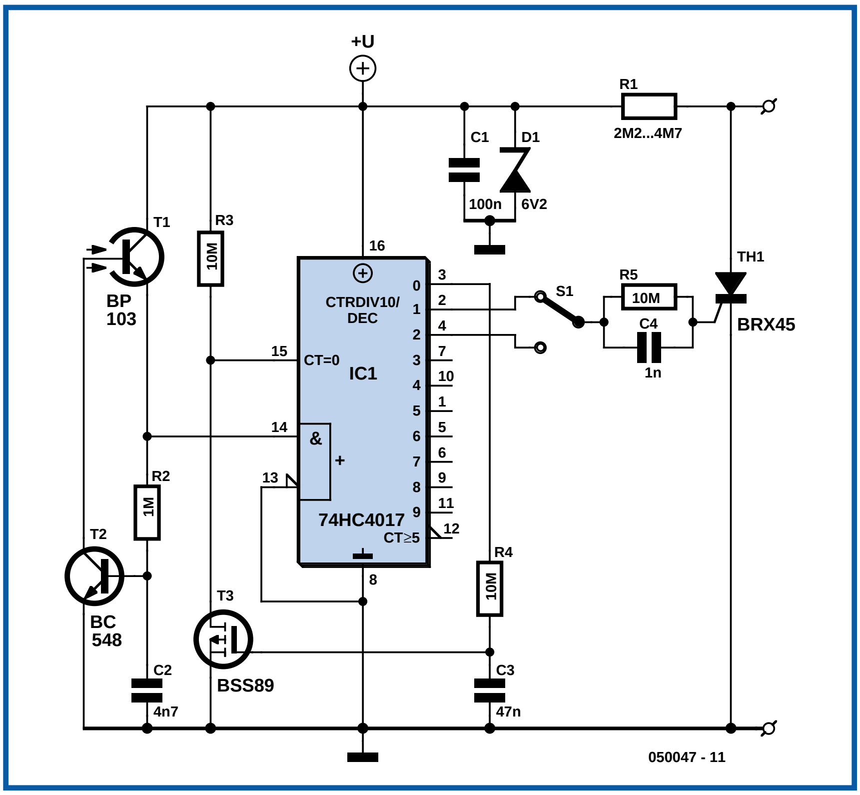
F Roesky

Current designs of slave flash units are, in the opinion of the writer, too complicated and may be simplified without any problems and without losing any of their usefulness as may be seen from the accompanying circuit diagram. This proposed circuit offers a number of advantages:

- no need for an additional power source, since power is derived via the sync contacts of the main flash unit;
- automatic reset (no need for a button);
- operates with new as well as older main flash units (contact voltage >100 V);

In spite of these proven practical properties, the design is simplicity itself. It is controlled by a low-current CMOS decimal counter IC1, a Type 74HC4017, which enables the entire circuit to be powered directly via the sync contacts of the main flash unit via resistor R1 and voltage limiter D1.

The control circuit based on transistor T1



also operates with minimal quiescent current. When a flash is detected, T1 provides a clock pulse to IC1. Depending on the position of switch S1, the low-power thyristor fires on the second or third flash pulse, so that it does not react to the preliminary flash that prevents the red-eye effect. After about 0.4 second, when the main flash unit is discharged, IC1 is reset via R4, C3 and T3. At that instant, the current drain of IC1 increases briefly and the voltage across C1 collapses. This is of no consequence, however, since after at most one second C1 is recharged to a level at which the circuit is operational again.

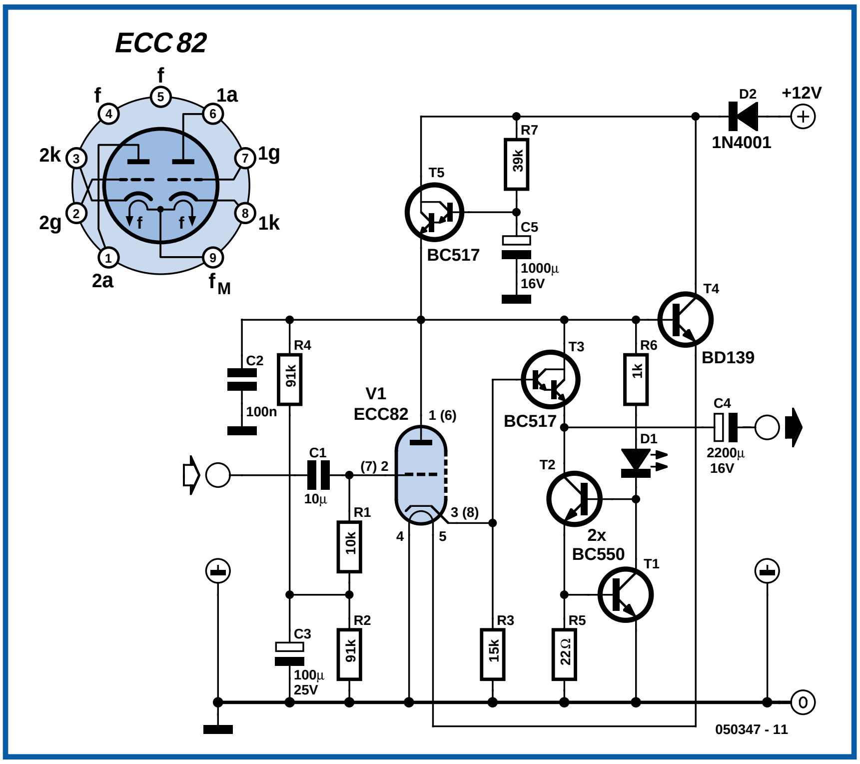
If the circuit is to be polarity-sensitive, connect a small bridge rectifier rated at 400 V between the contacts of the main flash unit and terminals JP1 and JP2.

(050047-1)

026

Hybrid Headphone Amp

Jeff Macaulay



Potentially, headphone listening can be technically superior since room reflections are eliminated and the intimate contact between transducer and ear mean that only tiny amounts of power are required. The small power requirement means that transducers can be operated at a small fraction of their full excursion capabilities thus reducing THD and other non-linear distortions.

This design of a dedicated headphones amplifier is potentially controversial in that (1) it has unity voltage gain and (2) employs valves and transistors in the same design.

Normal headphones have an impedance of 32 Ω per channel. The usual standard line output of 775 mV to which all quality equipment aspires will generate a power of

$$U^2 / R = 0.775^2 / 32 = 18 \text{ mW}$$

per channel across a headphone of this impedance. An examination of available headphones at well known high street emporiums revealed that the sensitivity varied from 96 dB to 103db/mW! So, in practice the circuit will only require unity gain to reach deafening levels.

As a unity gain design is required it is quite possible to employ a low distortion output stage. The obvious choice is an emitter follower. This has nearly unity gain combined with a large amount of local feedback. Unfortunately the output impedance of an emitter follower is dependent upon the source impedance. With a volume control, or even with different signal sources this will vary and could produce small but audible changes in sound quality. To prevent this, the output stage is driven by a cathode follower, based around an ECC82 valve (US equivalent: 12AU7). This device, as opposed to a transistor configuration, enables the output stage to be driven with a constant value, low impedance. In other words, the signal from the low impedance point is used to drive the high impedance of the output stage, a situation which promotes low overall THD.

At the modest output powers required of the circuit, the only sensible choice is a Class A circuit. In this case the much vaunted single-ended output stage is employed and that comprises of T3 and constant current source T1-T2. The constant current is set by the V_{be} voltage of T1 applied across R5. With its value of 22 Ω, the current is set at 27 mA. T3 is used in the emitter follower mode with high input impedance and low output impedance. Indeed the main problem of using a valve at low voltages is that it's fairly difficult to get any real current drain.

In order to prevent distortion the output stage shouldn't be allowed to load the valve. This is down to the choice of output device. A BC517 is used for T3 because of its high current gain, 30,000 at 2 mA!

Since we have a low impedance output stage, the load may be capacitively coupled via C4. Some purists may baulk at the idea of using an electrolytic for this job but he fact remains that distortion generated by capacitive coupling is at least two orders of magnitude lower than transformer coupling.

The rest of the circuitry is used to condition the various voltages used by the circuit. In order to obtain a linear output the

valve grid needs to be biased at half the supply voltage. This is the function of the voltage divider R4 and R2. Input signals are coupled into the circuit via C1 and R1. R1, connected between the voltage divider and V1's grid defines the input impedance of the circuit. C1 has sufficiently large a value to ensure response down to 2 Hz.
Although the circuit does a good job of rejecting line noise on its own due to the high impedance of V1's anode and T3's collector current, it needs a little help to obtain a silent background in the absence of signal. The 'help' is in the form of the capacitance multiplier circuit built around T5. Another BC517 is used here to avoid loading of the filter comprising R7 and C5. In principle the capacitance of C5 is multiplied by the gain of T5. In practice the smooth dc applied to T5's base appears at low impedance at its emitter. An important added advantage is that the supply voltage is applied slowly on powering up. This is of course due to the time taken to fully charge C5 via R7. No trace of hum or ripple can be seen here on the 'scope. C2 is used to ensure stability at RF.
The DC supply is also used to run the valve heater. The ECC82 has an advantage here in that its heater can be connected for operate from 12.6 V. To run it T4 is used as a series pass element. Base voltage is obtained from the emitter of T5. T4 has very low output impedance, about 160 mΩ and this helps to prevent extraneous signals being picked up from the heater wiring. Connecting the transistor base to C5 also lets the valve heater warm up gently. A couple of volts only are lost across T4 and although the device runs warm it doesn't require a heat-sink.

(050347-1)

Antenna Height and Range

027

Gert Baars

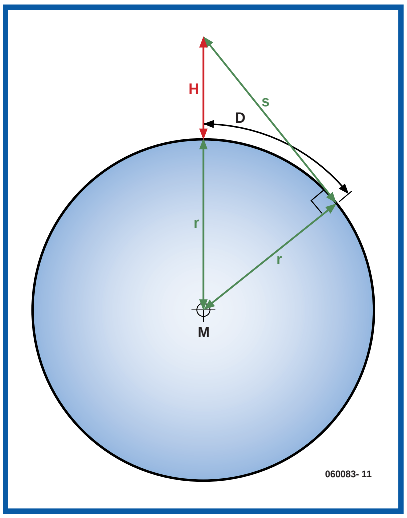
At frequencies below 30 MHz or so, radio transmitters can normally be received over great distances because ceratin layers of the ionosphere reflect radio signals with a certain frequency. These reflections normally do not take place at higher frequencies, so the maximum distance that can be covered is, in principle, limited to the visible horizon. How this theoretical distance can be calculated is explained here.
The accompanying figure indicates the various distances required. *M* is the centre point of the Earth, *r* is the radius, *H* is the height at which the antenna is placed, *s* is the length of the signal path between antenna and horizon and *D* is the distance across the Earth's curved surface. Because in practice *H* will be much smaller than *r*, *s* will be approximately equal to *D*. The signal path *s* between antenna and horizon is perpendicular to the radius of the Earth. This means that we can apply Pythagoras' Theorem to find the relationship between antenna height and distance to the horizon.
According to the Theorem:

$$r^2 + s^2 = (r + H)^2$$
$$= r^2 + H^2 + 2rH$$

Collecting terms results in:

$$s^2 = H^2 + 2rH$$

Because H^2 is much smaller than $2rH$ it can be left out. So it follows that:



$$s^2 = 2rH$$

or:

$$s = \sqrt{(2rH)}$$

The average radius of the Earth is 6,371 km. $\sqrt{(2r)}$ is therefore about 113. The formula can now be simplified to:

$$s = 113\sqrt{(H)}$$

where *s* and *H* have to be expressed in kilometres.
An example: a VHF FM antenna is positioned at a height of 15 m. the maximum distance at which a line-of-sight connection is possible amounts to:
$113\sqrt{(0.015)} = 13.8$ km.

In practice these distances turn out to be larger than those computed using the formula. This has to do with the propagation of electromagnetic fields. It appears that the wave is subject to reflection and does curve a little with the surface of the Earth. This is readily observed with so-called temperature inversion layers. The weather circumstances are such that hundreds of kilometres can be covered without problems using signal frequencies in the VHF range. But even without these special weather conditions the distances that can be covered appear to be larger than predicted by theory, as already mentioned.
With the antenna height of 15 m assumed earlier, the distance that can be covered appears to be of the order of 40 km, instead of the calculated 13.8 km.
How the propagation of electromagnetic waves actually works is a complicated matter covered in many excellent books and publications. However, it is known that at frequencies in the GHz range the distance that can be covered becomes progressively smaller as the frequency increases. This is also the reason why parabolic antennas for SHF frequencies are positioned as high as is practicable. The amount of transmitter power plays a secondary role in all this.
What does matter however, is the height of the receiving antenna. The same formula can be used for this antenna (that is $s = 113\sqrt{(H)}$). The theoretical total distance that can be covered is then the sum of both distances to the horizon.

(060083-1)

028

Simple Hybrid Amp

Frans Janssens

The debate still goes on as to which are better, valves or transistors. We don't intend to get involved in that argument here. But if you can't make your mind up, you should try out this simple amplifier.

This amplifier uses a valve as a pre-amplifier and a MOSFET in the output stage. The strong negative feedback makes the frequency response as flat as a pancake. In the prototype of the amplifier we've also tried a few alternative components. For example, the BUZ11 can be replaced by an IRFZ34N and an ECC83 can be used instead of the ECC88. In that case the anode voltage should be reduced slightly to 155 V. The ECC83 (or its US equivalent the 12AX7) requires 2 x 6.3 V for the filament supply and there is no screen between the two triodes, normally connected to pin 9. This pin is now connected to the common of the two filaments. The filaments are connected to ground via R5.

If you're keeping an eye on the quality, you should at least use MKT types for coupling capacitors C1, C4 and C7. Better still are MKP capacitors. For C8 you should have a look at Panasonic's range of audio grade electrolytics.

P1 is used to set the amount of negative feedback. The larger the negative feedback is, the flatter the frequency response will be, but the smaller the overall gain becomes. With P2 you can set the quiescent current through T2. We have chosen a fairly high current of 1.3 A, making the output stage work in Class A mode. This does generate a relatively large amount of heat, so you should use a large heatsink for T2 with a thermal coefficient of 1 K/W or better.

For L1 we connected two secondary windings in series from a 2x18V/225 VA toroidal transformer. The resulting inductance of 150 mH was quite a bit more than the recommended 50 mH. However, with an output power of 1 W the amplifier had difficulty reproducing signals below 160 Hz. The distortion rose to as much as 9% for a signal of 20 Hz at 100 mW. To properly reproduce low-frequency signals the amplifier needs a much larger coil with an iron core and an air gap. This prevents the core from saturating when a large DC current flows through the coil.

Such a core may be found in obsolete equipment, such as old video recorders. A suitable core consists of welded E and I sections. These transformers can be converted to the required inductor as follows: cut through the welding, remove the windings, add 250 to 300 windings of 0.8 mm enamelled copper wire, firmly fix the E and I sections back together with a piece of paper in between as isolation.

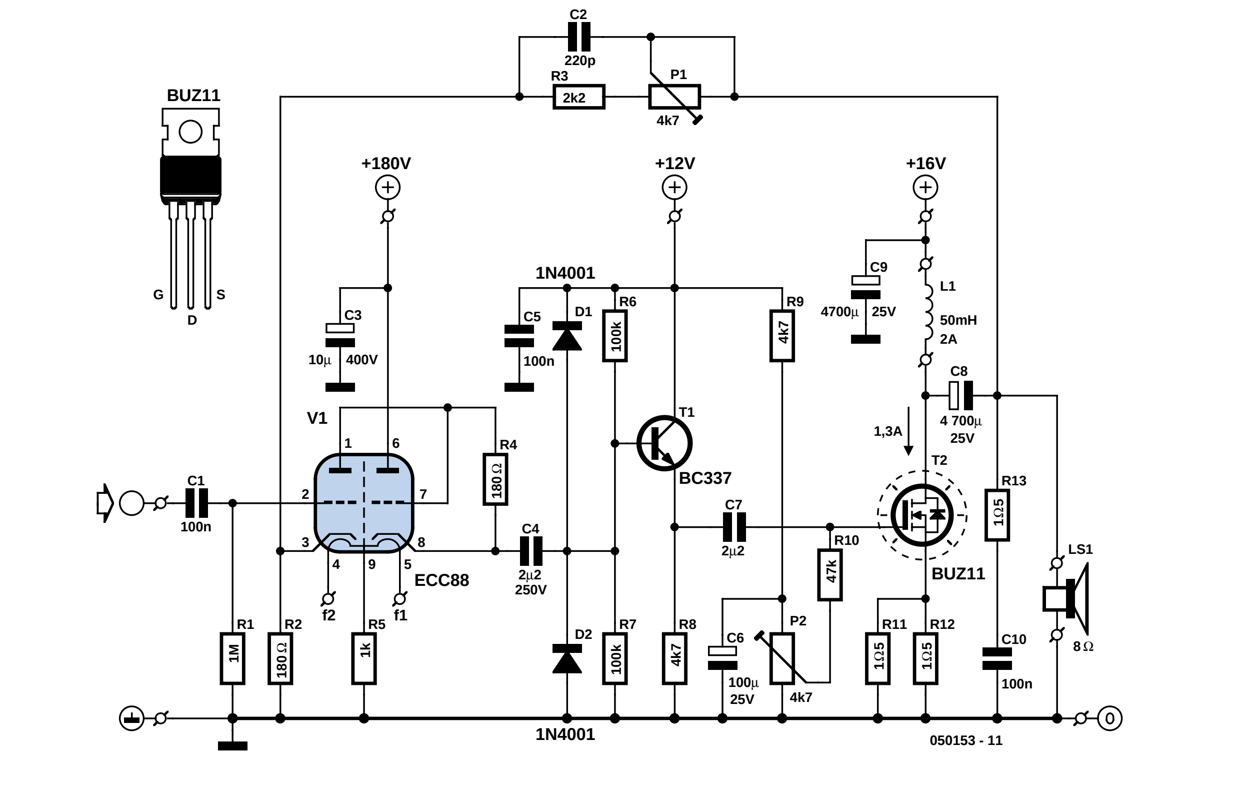
The concepts used in this circuit lend themselves very well to some experimentation. The number of supply voltages can be a bit of a problem to start with. For this reason we have designed a power supply especially for use with this

A few specifications

(IRFZ34N, ECC83, 155 V using 064011-1 and 064016-1, U_{ff} = 12.6 V_{DC}, 8 Ω load, T2 set to 1.3 A)

min. gain	12.3x
max. gain	31.6x
input sensitivity	0.64 V at min. gain
bandwidth	>200 kHz
LF roll-off	11 Hz
THD+N (1 kHz/1W/8Ω)	0.09% (BW = 80 kHz)
supply ripple (100 Hz)	–80 dB (at 1 W output)
P_{max} (1% THD)	7.6 W (1 kHz)
damping factor	17

1



COMPONENTS LIST

Resistors
R1 = 1MΩ
R2,R4 = 180Ω
R3 = 2kΩ2
R5 = 1kΩ
R6,R7 = 100kΩ
R8, R9 = 4kΩ7
R10 = 47kΩ
R11,R12,R13 = 1Ω5 5W
P1,P2 = 4kΩ7 preset

Capacitors
C1 = 100nF 250V MKT, lead pitch 15mm, dim. 7x18 mm max.
C2 = 220pF
C3 = 10µF 400V radial, lead pitch 5 mm ∅ 13mm max.
C4 = 2µF2 250V, lead pitch 27.5 mm, dim. 11x30 mm max.
C5,C10 = 100nF
C6 = 100µF 25V radial
C7 = 2µF2, lead pitch 5 or 7.5mm
C8,C9 = 4700µF 25V radial, lead pitch 7.5mm, ∅ 18mm max.

Inductors
L1 = ≥ 50 mH, not on board, see text

Semiconductors
D1,D2 = 1N4001
T1 = BC337
T2 = BUZ11 (or IRFZ34N)

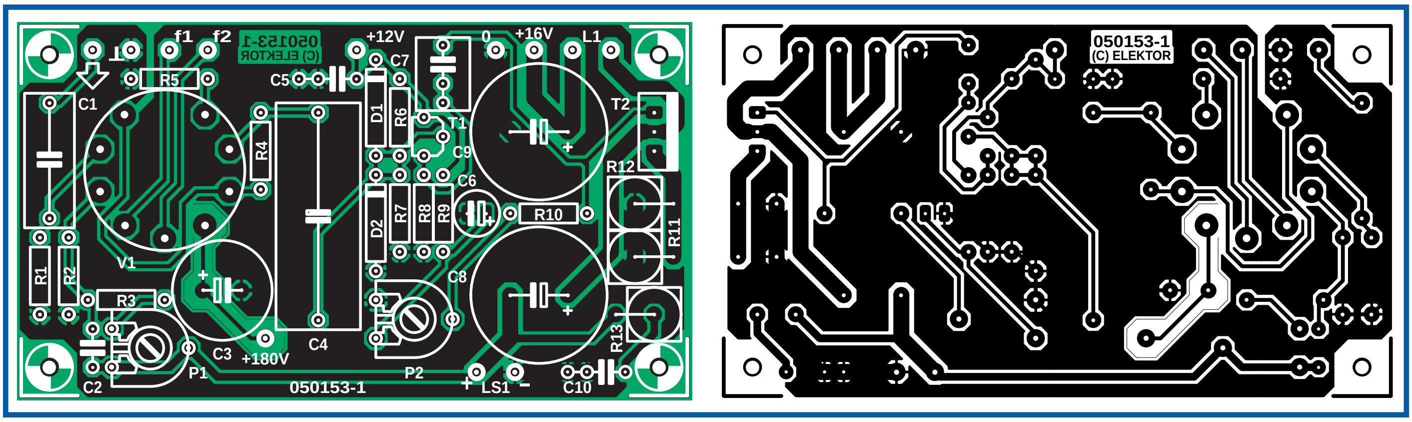
Miscellaneous
V1 = ECC88 with 9-pin valve socket (Chelmer Valve Company)
Heatsink for T2, ≤1 K/W
PCB, ref. 050153-1 from The PCBShop

amplifier (Quad power supply for hybrid amp). This can of course just as easily be used with other amplifiers.

The supply uses a cascade stage to output an unstabilised voltage of 170 V for the SRPP (single rail push pull) stage (V1). During initial measurements we found that the ripple on this supply was responsible for a severe hum at the output of the amplifier. To get round this problem we designed a separate voltage regulator (High-voltage regulator with short circuit protection), which can cope with these high voltages.

If you use a separate transformer for the filament supply you can try and see if the circuit works without R5. During the testing we used a DC voltage for the filament supply.

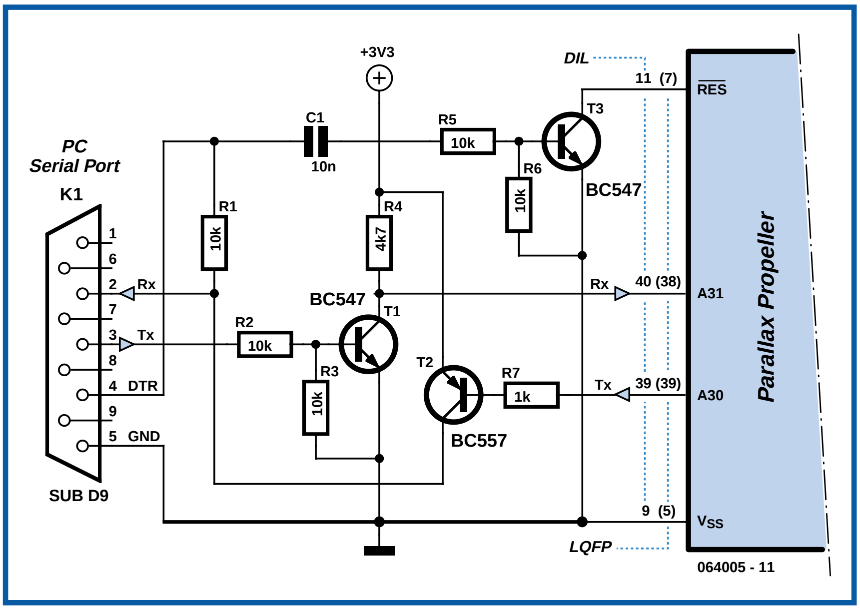
Although you may not suspect it from the test measurements (see table), this ampli-



fier doesn't sound bad. In fact, it is easily better than many consumer amplifiers. The output power is fairly limited, but is still enough to let your neighbours enjoy the music as well. It is possible to make the amplifier more powerful, in which case we recommend that you use more than one MOSFET in the output stage. The inductor also needs to be made beefier. Since this is a Class A amplifier, the supply needs to be able to output the required current, which becomes much greater at higher output powers. The efficiency of the amplifier is a bit over 30%.

(050153-1)

029 Programming the Propeller IC



Parallax, well known for its successful Basic Stamp IC, has recently introduced the Propeller: a new microcontroller with a certain difference. It packs no less than eight 32-bit processors (referred to as COGs in Propeller jargon) into a single package with only 40 pins. That design makes genuine simultaneous multiprocessing possible, and the sophisticated internal structure of the device makes it relatively easy to implement video and signal-processing applications.

The Propeller can be programmed in assembly language or the high-level Spin language. The processor and the programming tools were developed entirely in-house by Parallax, with the hardware being designed from scratch starting at the transistor level. The basic idea behind that was to avoid becoming involved in all sorts of patent disputes with other manufacturers. The result is astounding, and for software developers it certainly requires a change in mental gears.

As is customary with modern microprocessors, the Propeller has a simple serial programming interface. The developer's toolkit from Parallax has a modern USB port for that purpose, but a reasonably simple alternative (illustrated here) is also possible for anyone who prefers to work with the familiar RS232 port. Don't forget that the Propeller works with a 3.3-V supply voltage.

(064005-1)

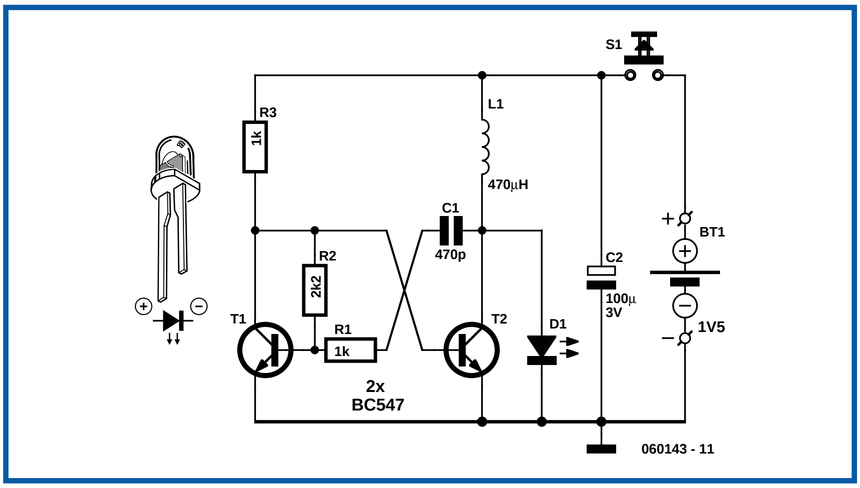
030 LED Phototherapy Unit

Jörg Trautmann

It is widely thought that light can be therapeutic for the human skin and soul. Light at the correct wavelength may also be effective against depression and allergies. There is a wide range of products on the market, at prices from a few tens of pounds to a hundred pounds or so, which are presented as universal remedies for dust allergies or hay fever. If we look at these devices in more detail, we find that their operation is relatively simple to explain.

Common to all the devices is that they emit intense red light with a wavelength of 660 nm. Some biophysicists claim that light of this wavelength can have a positive effect on the human body and can initiate healing processes. This so-called 'phototherapy' is a treatment which is claimed to have an effect against allergic reactions in the body, since it acts against free oxygen radicals and strengthens the immune system, reducing inflammation of the mucous membrane. Since this treatment does not take the form of a medicine, but rather the form of visible light, there is no risk of side-effects. There has been scientific research showing that this therapy does not work in every case, but success rates as high as 72 % have been reported. Since it may not be possible to obtain these devices under the NHS or under private medical insurance, our thoughts naturally turn to do-it-yourself.

For the enclosure we decided to use an old nasal hair trimmer. These can be obtained new for a few pounds, or you may have an old one that can be recycled. The choice of enclosure also dictates the choice of battery: the unit contains a holder for an AA-size cell. The circuit must therefore not only be very compact (there is little spare room in the enclosure), it must also be able to drive a high-brightness red LED from a voltage between 1 V and around 1.6 V. Here again we can indulge in a little recycling: we can re-use the circuit from a Mini Project by Burkhard Kainka for driving a white LED, published in *Elektor Electronics* in June 2002. In this circuit the inductive voltage pulse is limited by the LED itself, ensuring that the output voltage will automatically match the forward voltage of the LED. The circuit is suitable as it stands for driving a high-brightness 660 nm red LED to make a



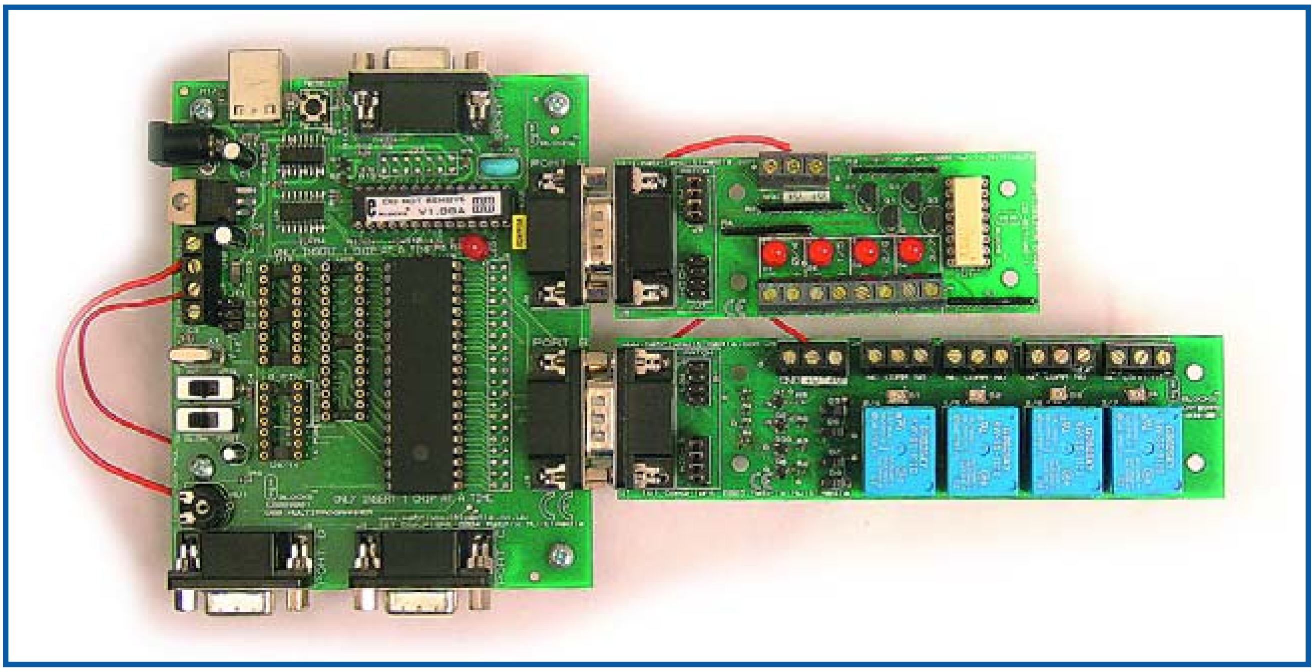
do-it-yourself phototherapy unit.

In view of the small number of components, the circuit can be assembled by soldering them together directly or by using a small piece of stripboard. The circuit can operate from a wide range of voltages, and so we can use either an alkaline AA cell or an AA-size NiMH rechargeable cell with a voltage of 1.2 V. The current consumption of the circuit is about 20 mA. Assuming the circuit has been built correctly, the red LED should light brightly as soon as power is applied. Five to ten minutes' use in each nostril every day should be sufficient to obtain noticeable benefit after two weeks of treatment.

(060143-1)

E-blocks = cheaper PLC design

031



John Dobson

If you are a habitual user of PLCs (programmable logic systems) then you may be frustrated with the fact that you are paying in excess of £ 100 for a simple system that (hardware-wise) contains only a couple of inputs and a couple of outputs which would cost you just over £ 10 if you put it together yourself. Well here is a suggestion that could help you develop your own PLC for a lot less.

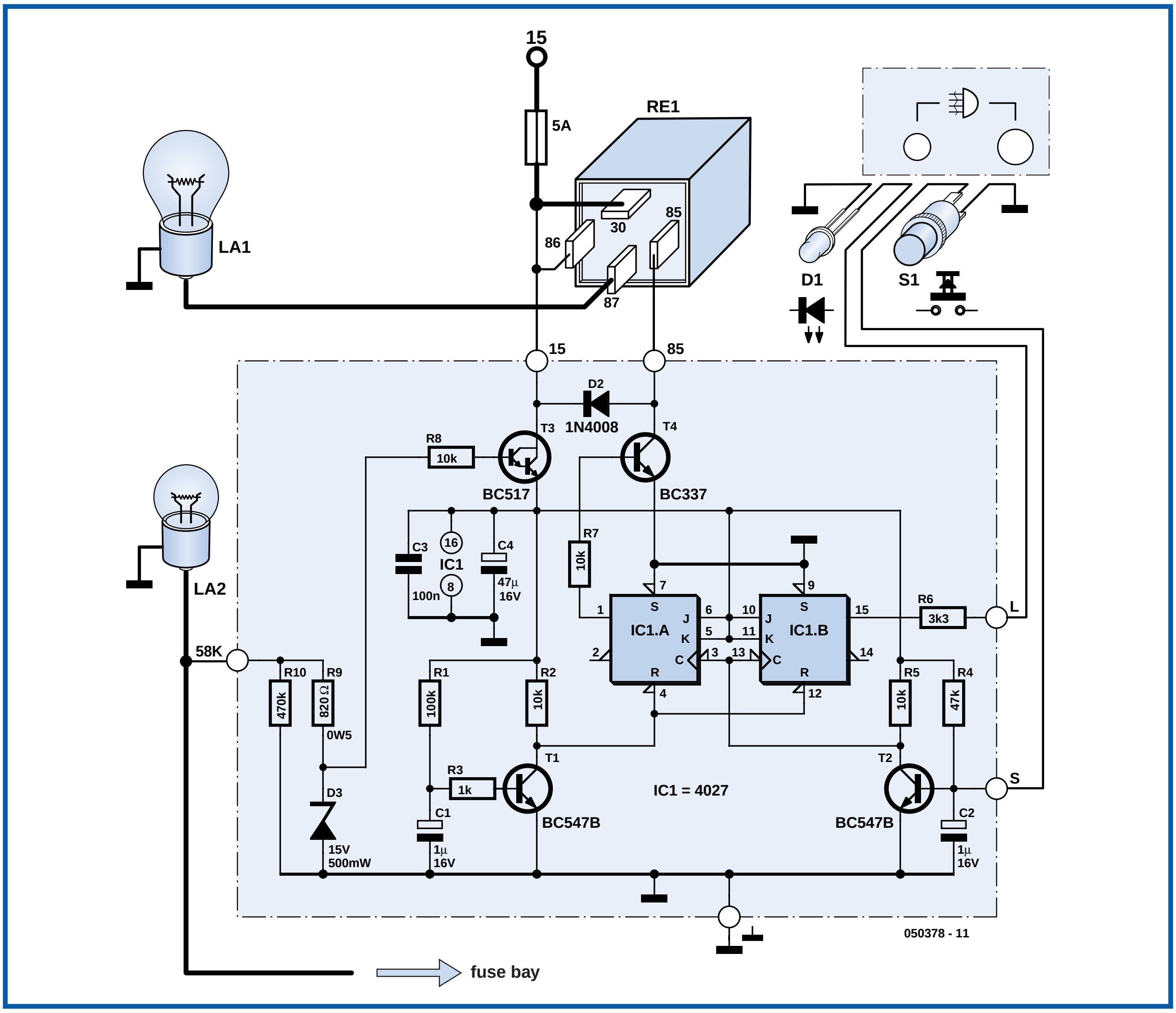
Hopefully you will by now have read about our E-blocks™ solution. There are two new E-blocks available: an opto-isolator board and a relay board. The photograph shows them connected to a PICmicro Multiprogrammer. The combination of a PICmicro programmer, opto-isolators and a relays is functionally equivalent to a PLC, and the flow chart driven program Flowcode, is an easy-to-use graphical development environment which you can use for driving your PLC. The hardware (i.e. circuit boards) are supplied with the complete circuit diagrams so with a little work you can make a circuit board with your own configuration of PLC on it. A motor driving board will be available shortly.

E-blocks modules, sensors and associated software are available through the Elektor Electronics SHOP, see www.elektor-electronics.co.uk

(060079-1)

032

Rear Fog Lamp for Vintage Cars



Eric Vanderseypen

According to current legislation in many countries, vintage cars must also be fitted with a fog lamp at the rear.

In modern cars, there is a bit of circuitry associated with the fog lamp switch to prevent the fog lamp from going on when the lights are switched on if the driver forgot to switch it off after the last patch of fog cleared up.

The circuit described here extends that technology back in time. The circuit is built around a dual JK flip-flop (type 4027).

T3 acts as an emitter follower, and it only supplies power to the circuit when the lights are switched on. For safety reasons, the supply voltage is tapped off from the number plate lamp (L2), because it is on even if you accidentally drive with only the parking lights on. The

wire that leads to the number plate lamp usually originates at the fuse box.
As the states of the outputs of IC1a and IC1b are arbitrary when power is switched on, the reset inputs are briefly set high by the combination of C1, R1 and T1 when the lights are switched on (ignition switch on). That causes both Q outputs (pins 1 and 15) to go low.
IC1a and IC1b are wired in toggle mode (J and K high). The Set inputs are tied to ground (inactive).

The driver uses pushbutton switch S1 to generate a clock pulse that causes the outputs of the flip-flops to toggle. The debouncing circuit formed by C2, R4 and T2 is essential for obtaining a clean clock pulse, and thus for reliable operation of the circuit. C1 and C2 should preferably be tantalum capacitors.
The Q output of IC1b directly drives LED D1 (a low-current type, and yellow according to the regulations). The Q output of IC1a energises relay Re1 via T4 and thus applies power to the rear fog lamp L1. Free-wheeling diode D2 protects T4 against inductive voltage spikes that occur when the relay is de-energised.
In older-model cars, the charging voltage of the generator or alternator is governed by a mechanical voltage regulator. These regulators are less reliable than the electronic versions used in modern cars. For that reason, a Zener diode voltage-limiter circuit (D3 and R9) is included to keep the voltage at the emitter of T3 below 15 V and thus prevent the 4027 from being destroyed by an excessively high voltage.
The supply voltage for the circuit is tapped off from the fuse box. An accessory terminal is usually present there. Check to make sure it is fed from the ignition switch.

Note

This circuit is only suitable for use in cars with 12-V electrical systems and negative ground.

The pushbutton switch must be a momentary-contact type (not a latching type). Ensure that the pushbutton and LED have a good ground connection. Fit the LED close to the button.
The following 'Bosch codes' are used in the schematic:

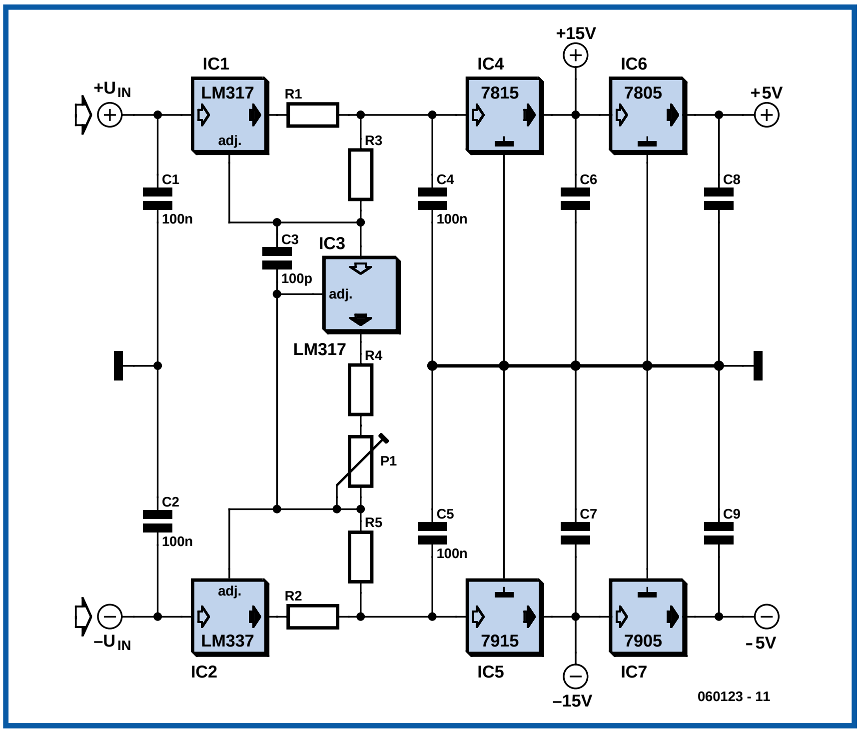
15 = +12 V from ignition switch
58K = number plate lamp
86 = relay coil power (+) IN
85 = relay coil power OUT
30 = relay contact (+) IN
87 = relay contact OUT

(050378-1)

Adjustable Current Limit for Dual Power Supply

033

Malte Fischer



This current-limiting circuit, shown in this example as part of a small bench power supply, could in principle be used in conjunction with any dual-rail current source. The part of the circuit to the left of the diagram limits the current at the input to the dual voltage regulator (IC4 to IC7) so that it is safely protected against overload. The circuit shown produces outputs at ±15 V and ±5 V.
The voltage regulators at the outputs (7815/7805 and 7915/7905) need no further comment; but the current-limiting circuit itself, built around an LM317 and an LM337, is not quite so self-explanatory.
The upper LM317 (IC1) manages the current limiting function for the upper branch of the circuit. The clever part is the combination of the two resistors R1 and R3 between the output and the adjust input of the regulator. In the basic LM317 configuration in current-limiting mode (i.e., as a constant current source), just one resistor is used here, across which the regulator maintains a constant voltage of 1.25 V. The current is thus limited to a value of 1.25 V/R. To obtain a maximum current of 1 A, for example, the formula tells us that the necessary resistor value is 1.25 Ω. Unfortunately it is not practical to try to build an adjustable dual-rail current-limited supply in this way, as stereo potentiometers with a value of 1.2 Ω are extremely difficult, if not impossible, to obtain.

We can solve the problem using the technique of dividing the resistor into two resistors. Only the resistor at the output of the LM317 (R1) serves for current sensing. The second resistor (R3) causes an additional voltage drop depending on an additional (and adjustable) current. When the sum of the two voltages reaches 1.25 V current limiting cuts in. This makes it possible to adjust the current limit smoothly using the current in the second resistor (R3). This can be done simultaneously in the positive and negative branches of the circuit, as the diagram shows.

It would of course be wasteful to arrange for the current flowing in the second resistor to be of the same order of magnitude as the current in the main resistor. We therefore make the value of the second resistor considerably greater than that of the main one. If the main resistor (R1) has a value of 1.2 Ω (giving a maximum current of 1 A), and the second resistor (R3) a value of 120 Ω, the necessary voltage drop is achieved using an extra current of 10 ent limit will be 1 A.

For the negative branch of the circuit the LM337, along with resistors R2 (1.2 Ω) and R5 (120 Ω), performs the same functions.

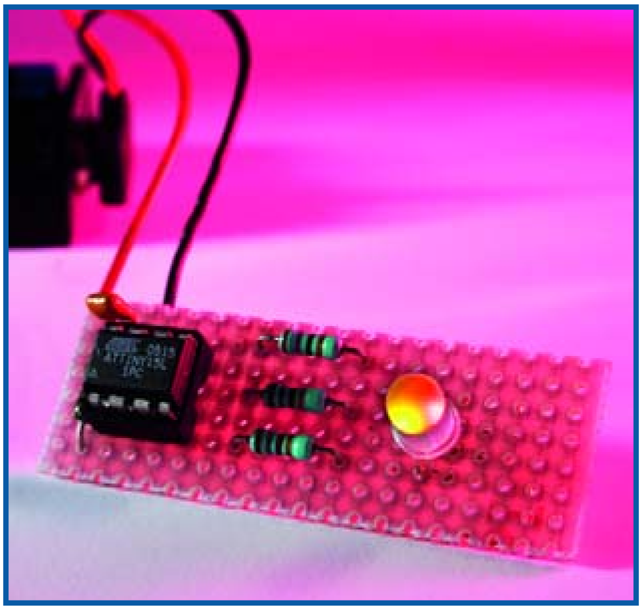
A further LM317 (IC3) is used to set the overall current limit point by controlling the additional current. The resistance used with this voltage regulator, wired as a current sink (R4 in series with P1) determines the additional current and therefore also the output current in both the negative and positive branches of the circuit. Since we also want the total resistance of R4 and P1 to be 120 Ω, we use a value of 22 Ω for R4 and 100 Ω for P1 to give a wide adjustment range for the output current from a few milliamps to 1 A.

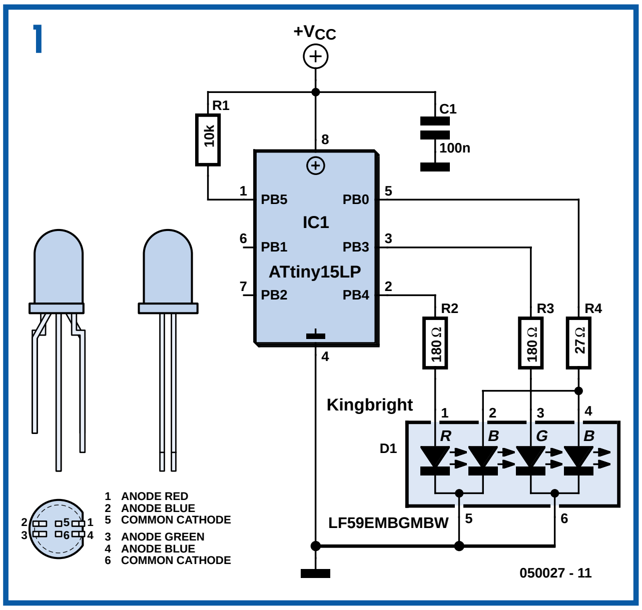
The minimum input voltage for the circuit depends on the desired output voltage and maximum output current. The input to the 7815 should be at least 18 V. We should allow approximately a further 1.2 V + 2.2 V for the voltage drops across IC1 and R1. If we allow a total of 4 V for the current limiting circuit in each branch, this means that the circuit as a whole should be supplied with at least ±22 V to produce well-regulated outputs at ±15 V and ±5 V.

If the symmetrical input voltage is to be provided using a single transformer winding, two diodes and two smoothing capacitors, it important to ensure that the capacitor values are sufficiently large, as there will be considerably more ripple than there would be with full-wave rectification. Depending on the application, capacitors C6 to C9 at the outputs of the fixed voltage regulators can be electrolytics with a value of 4.7 µF or 10 µF. To improve stability, electrolytic capacitors can also be connected in parallel with C1, C2, C4 and C5.

(060123-1)

034 Tiny RGB





Tobias Flöry

This circuit is a good example of a microcontroller design using the absolute minimum of external components. The ATTiny15L microcontroller from Atmel has three of its outputs connected to an RGB LED (or three individual red green and blue LEDs) and produces changing colour patterns. There are of course multicolour LEDs with a controller already built-in on the market but where would be the fun in the ready-built version? You will certainly learn much more by building and programming the design yourself.

The brightness of each LED is controlled using Pulse Width Modulation (PWM). This is accomplished in software and the source code is available to download from www.elektor-electronics.co.uk free of charge as file no. **050027-11.zip**. A pre-programmed controller (part no. **050027-41**) can also be ordered from the online shop at the same address.

The Kingbright RGB LED used in this circuit actually contains one red, one green and two blue LEDs. This helps compensate for the poorer output from the blue LEDs and for the relative insensitivity of our eye to the blue end of the spectrum. The light output thus can produce a better white colour balance. The forward voltage drop of the blue LEDs (4.5 V) is also quite a bit higher than green (2.2 V) or red (2.0 V) so the value of the series resistor (R4) needs to be almost ten times smaller than the series resistors R2 and R3 used for the other LEDs to maintain a similar drive current.

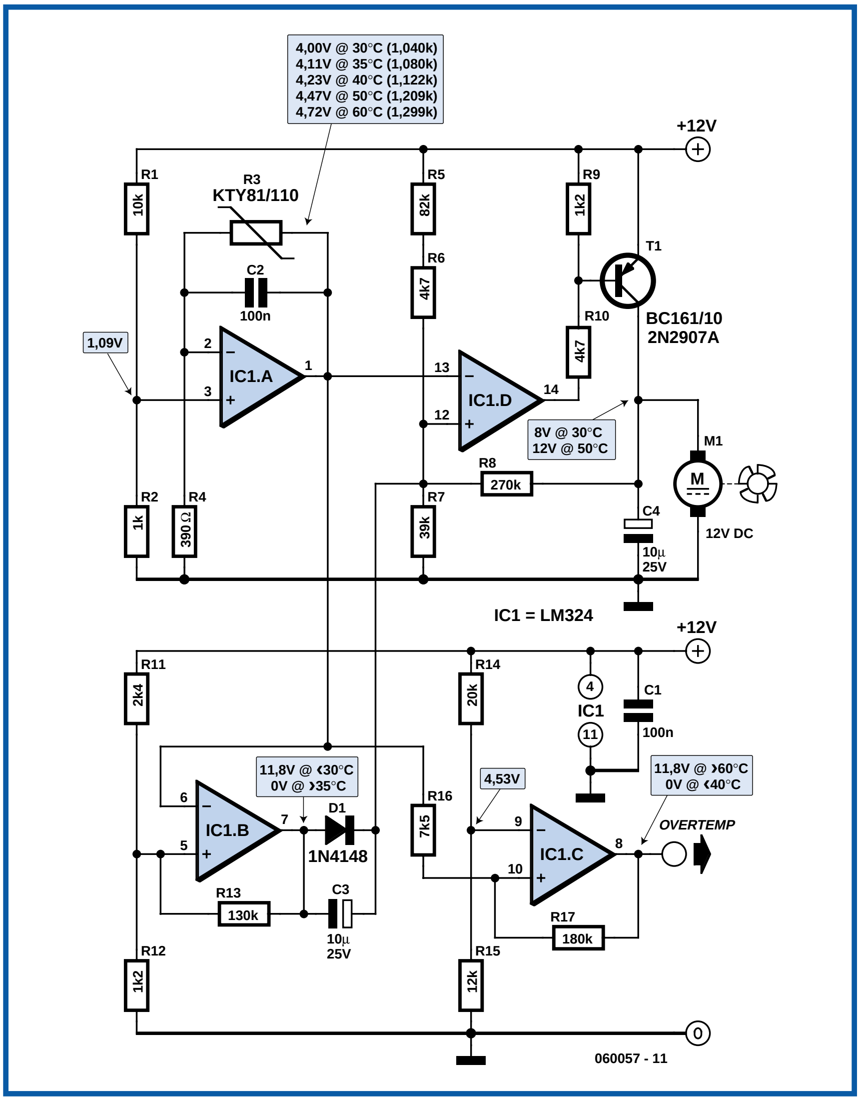
Maximum current consumption of the circuit is approximately 35 mA but the average will be around 25 mA. More information on this design together with some other interesting designs can be found on the author's website at www.floery.net and look for 'tobi's corner'.

(050027-1)

Gentle Breeze

035

Rainer Reusch



Where there is heat, let us bring cooling: a fan will do the job, but unfortunately fans are usually noisy. In many cases there is no need for the fan to run continuously at full speed, and so it makes sense to control the fan speed in response to the temperature of the heatsink or device being cooled, switching the fan off entirely if it should fall to room temperature.

The circuit shown here does this and even offers a little more. The low-cost KTY81-110 is used as the temperature sensor, in a negative-feedback arrangement with an operational amplifier. The temperature-dependent voltage at the non-inverting input to opamp IC1.A leads to a voltage variation at the output (pin 1) from 4 V at 30 °C to 4.72 V at 60 °C. The second stage (IC1.D) converts this relatively small swing and inconvenient voltage offset into the range 8 V to 12 V suitable for the fan. The third operational amplifier works as a comparator. At room temperature its output sits at nearly 12 V and pulls the output of the second stage with it, switching transistor T1 off. If the temperature exceeds 35 °C the comparator switches; diode D1 blocks and the control circuit can operate as normal. The hysteresis of the comparator has been set so that the comparator state will only change again, turning off the fan, if the temperature falls below 30 °C. Capacitor C3 ensures that the fan is run at full voltage for about 0.7 seconds immediately after switch-on, so that the motor will start reliably.

The fourth opamp in the LM324, IC1.C, is used to create an over-temperature warning indicator. This is necessary in case the fan, even running at full speed, is not able to provide enough cooling, or, because of a fault, cannot reach full speed. This opamp is also configured as a comparator. If the sensor temperature reaches a value of 60 °C, the comparator output goes high (to nearly 12 V). The output will only go low again (nearly 0 V) if the temperature falls below 40 °C. An LED (with series current-limiting resistor) can be connected to its output (pin 8); alternatively a transistor could be used to drive a relay.

The circuit is sufficiently accurate without adjustments, but metal-film resistors with a tolerance of 1 % should be used. Some of the values used are from the E24 series. The supply voltage is used as a reference throughout, and so should be well regulated: a 7812 voltage regulator is adequate.

(060057-1)

036

Toothbrush Timer

Friedrich Weigand

It has been known since Einstein that time is relative. This seems to apply particularly to children, who can make seconds and minutes seem like days and years when faced with unpopular chores like cleaning their teeth. To get the little dears to spend the three minutes recommended by experts on their teeth, parents concerned for the dental health of their children can resort to electronic means. And so much the better if you can get your children to help out with building the device!

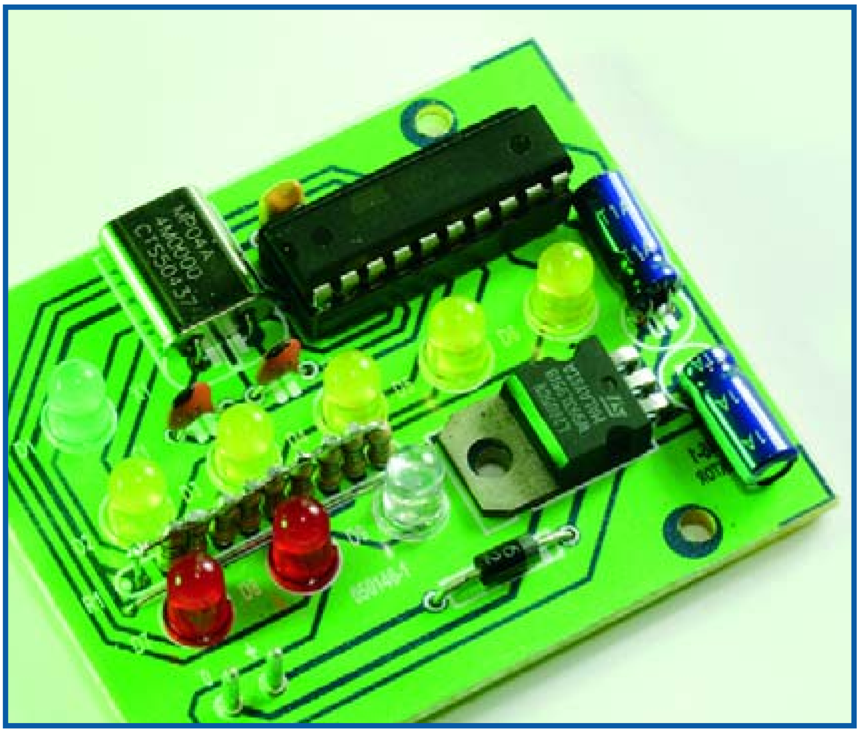
COMPONENTS LIST

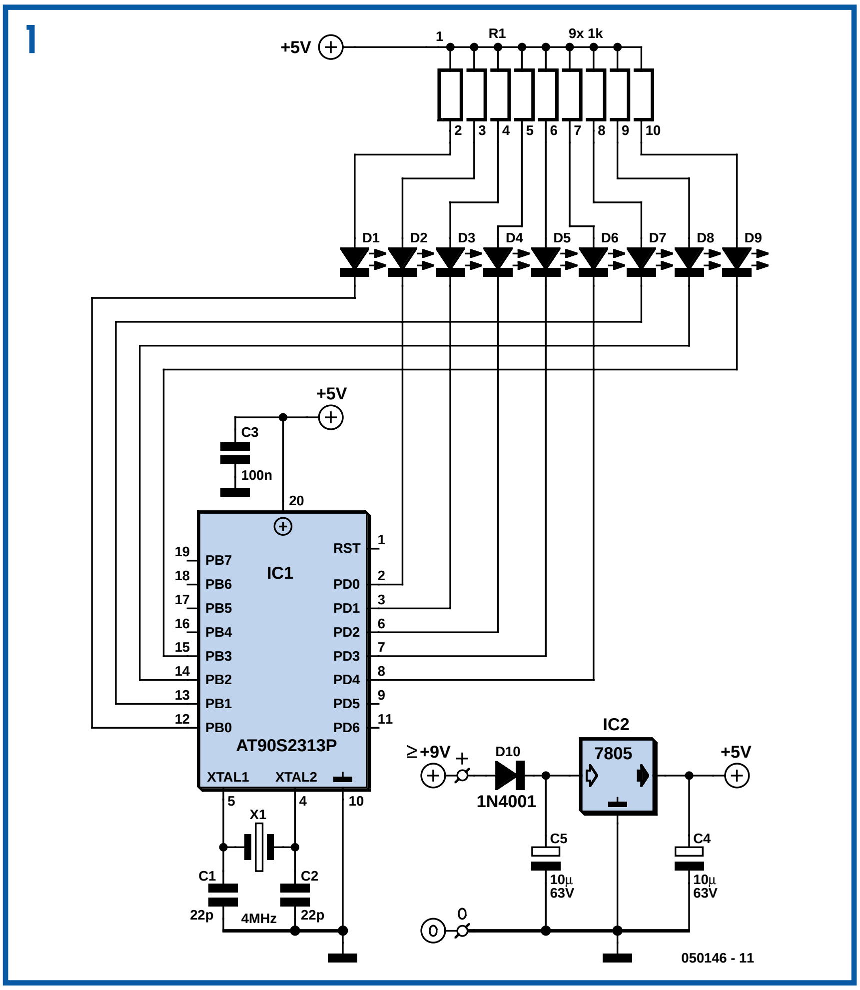
Resistors
R1 = 9-way 1kΩ SIL array

Capacitors
C1,C2 = 22pF
C3 = 100nF
C4,C5 = 10µF, 63V, radial

Semiconductors
D1 = LED, green, low current, 5mm
D2-D6 = LED, yellow, low current, 5mm
D7,D8 = LED, red, low current, 5mm
D9 = LED, blue, 5mm
D10 = 1N4001
IC1 = AT90S2313-10PC (programmed, order code **050146-41**)
IC2 = 7805

Miscellaneous
X1 = 4MHz quartz crystal
Case: e.g. Bopla type BOS 503
1 wire link
PCB, order code **050146-1**



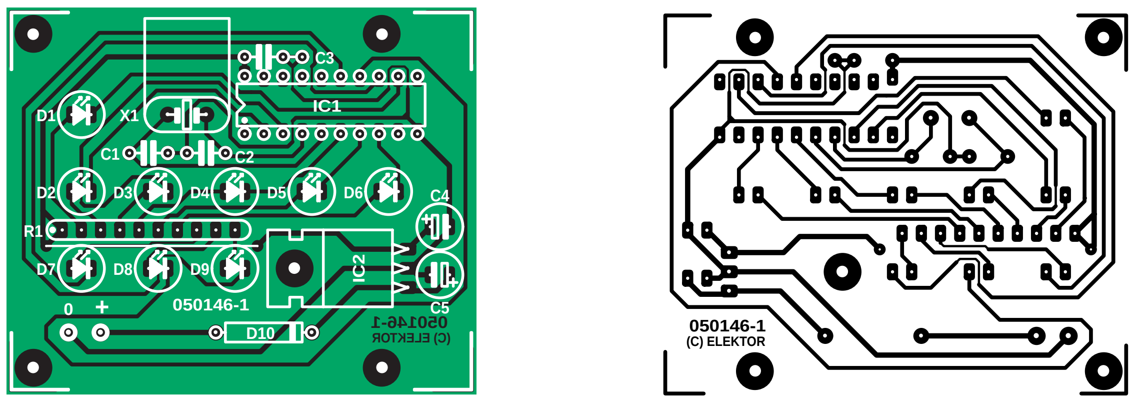


The circuit of the toothbrush timer (**Figure 1**) uses the familiar Atmel RISC AT90S2313 microcontroller, together with an oscillator formed by X1, C1 and C2. The microcontroller is available ready-programmed (order code **050146-41**). It drives a row of LEDs. Green LED D1 flashes every second. The green ten-second LEDs and the red one-minute LEDs light in sequence and remain on until three minutes have elapsed. Then all the LEDs go out and the blue 'finished' LED D9 starts flashing every second, indicating the end of brushing time. The port currents are limited to 2 mA to 3 mA by

the array of 1 kΩ resistors: this is enough for the low-current LEDs, which are used in order to ensure a long battery life. A 5 V fixed voltage regulator (IC2) and decoupling and smoothing capacitors C3 to C5 round off the circuit. Diode D10 prevents damage should the 9 V PP3 (6F22) type battery be accidentally connected the wrong way around.
The whole circuit can be built on the printed circuit board shown in **Figure 2**. There are a few wire links near to the resistor array. The voltage regulator, crystal, C4 and C5 are mounted flat on the board to allow the LEDs to stand above the other components and poke through holes in the enclosure. A socket should be used for the microcontroller. Almost all the components are polarity-sensitive: check carefully before you solder!

(050146)

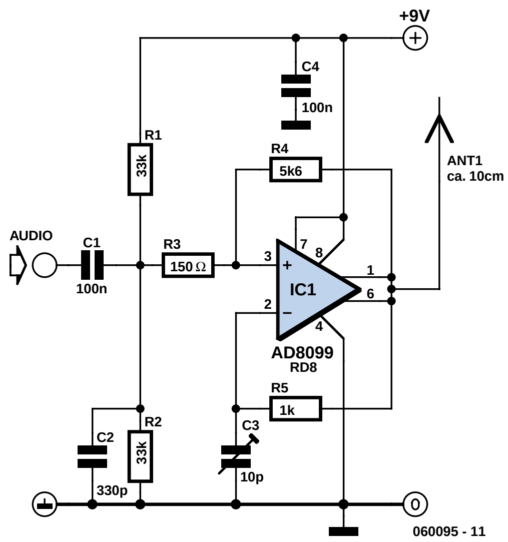
2



Opamp VHF FM Transmitter

037

Gert Baars



ICs that in the past were far too expensive for the hobbyist tend to be more favourably priced these days. An example of this is the AD8099 from Analog Devices. This opamp is available for only a few pounds. The AD8099 is a very fast opamp (1600 V/ms) and has high-impedance inputs with low input capacitance.
The bandwidth of the opamp is so large that at 100 MHz it still has a gain of nearly 40. This means that this opamp can be used to create an RC oscillator. The circuit presented here realises that.
The circuit has a few striking characteristics. Firstly, unlike normal oscillators that contain transistors this one does not have any inductors. Secondly, there is no need for a varicap diode to do the FM modulation.
The opamp is configured as a Schmitt trigger with only a small amount of hysteresis. The output is fed back via an RC circuit. In this way, the trimmer capacitor is continually being charged and discharged when the voltage reaches the hysteresis threshold. The output continually toggles as a consequence. This results in a square wave output voltage. With a 10-pF trimmer capacitor the frequency can be adjusted into the VHF FM broadcast band 88-108 MHz). The frequency of the oscillator is stable enough for this. The output voltage is about 6 V_{pp} at a power supply voltage of 9 V. The transmitter power amounts to about 50 mW at a load of 50 Ω. This is about 20 times as much as the average oscillator with a transistor.
With a short antenna of about 10 cm, the range is more than sufficient to use the circuit in the home as a test transmitter. Because the output signal is not free from harmonics the use of an outdoor antenna is not recommended. This requires an additional filter/adapter at the output (you could use a pi-filter for this).
The FM modulation is achieved by modulating the hysteresis, which influences the oscillator frequency. An audio signal of about 20 mV_{pp} is sufficient for a reasonable output amplitude.
The package for the opamp is an 8-pin SOIC (provided you use the version with the RD8 suffix). The distance between the pins on this package is 1/20 inch (1.27 mm). This is still quite easy to solder with descent tools. If SMD parts are used for the other components as well

then the circuit can be made very small. If necessary, a single transistor can be added to the circuit to act as microphone amplifier. The power supply voltage may not be higher than 12 V, because the IC cannot withstand that. The current consumption at 9 V is only 15 mA.

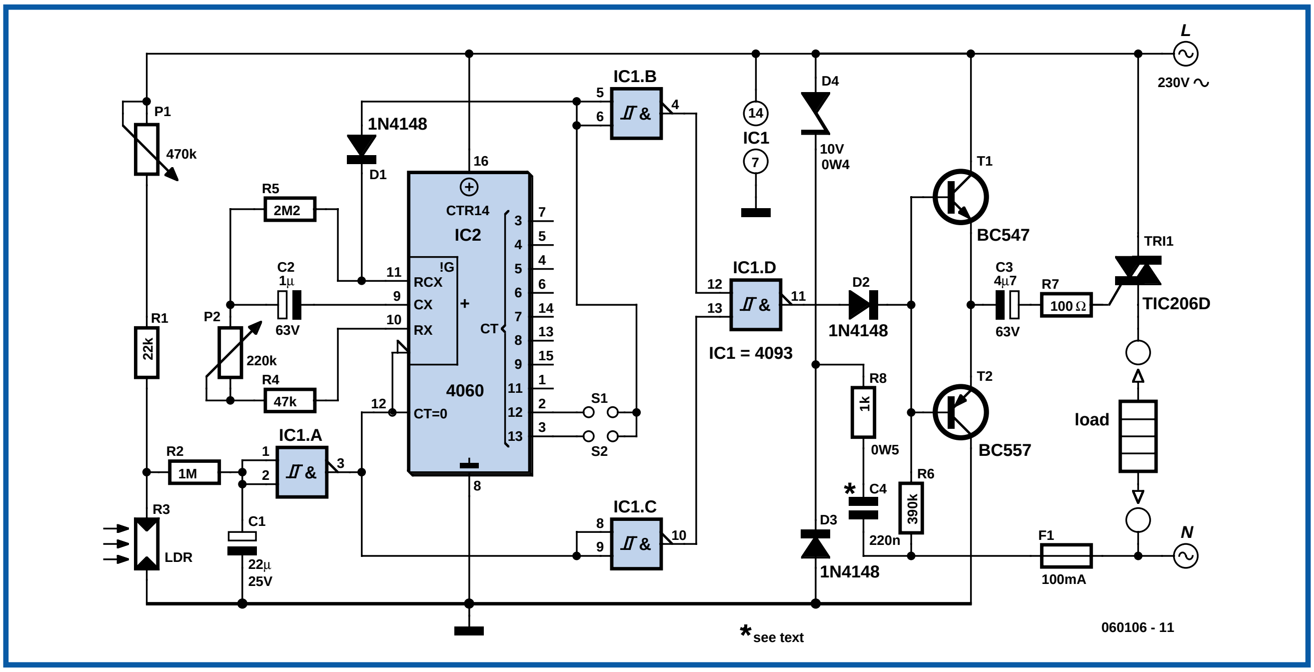
As with all free-running oscillator circuits, the output frequency of this specimen is also sensitive to variations of the power supply voltage. For optimum stability, a power supply voltage regulator is essential.

As an additional design tip for this circuit, we show an application as VCO for, for example, a PLL circuit. When the trimmer capacitor is replaced with a varicap diode, the frequency range can be greater than that of an LC oscillator. That's because with an LC-oscillator the range is proportional to the square root of the capacitance ratio. With an RC oscillator the range is equal to the entire capacitance ratio. For example: with a capacitance ratio of 1:9, an LC oscillator can be tuned over a range of 1:3. With an RC oscillator this is 1:9.

For the second tip, we note that the circuit can provide sufficient power to drive a diode mixer (such as a SBL-1) directly. This type of mixer requires a local oscillator signal with a power from 5 to 10 mW and as already noted, this oscillator can deliver 50 mW. A simple attenuator with a couple of resistors is sufficient in this case to adapt the two to each other.

(060095-1)

038 Presence Simulator



Christian Tavernier

Among the many anti-theft devices that are available, presence simulators have a special role to play. In fact, while an alarm system generally reacts the instant the intrusion is detected, or sometimes a little afterwards, in all cases the damage has already occurred. The purpose of the presence simulator is to stop intrusions beforehand by making crooks think that someone is at home. Working from the principle that the majority of home burglaries, with break-in, happen particularly at night, a properly designed presence simulator turns on the lights as evening falls, then turns them off a few hours later, causing an observer with bad intentions to believe that the premises are occupied.

Creating such a function with a microcontroller is certainly very easy and has already been done many times in the past, but the project we are proposing now is intended for those among you who do not want to, or who cannot program this type of circuit. As a result, our diagram only includes very common logic circuits from the CMOS 4000 family, with quite respectable results.

Ambient light is measured using the LDR R3 and, when it goes below a threshold determined by the adjustable potentiometer (P1) setting, like when night falls, it drives the IC1.A gate output to a low level. This has the effect of triggering triac T3 through gates IC1.C, IC1.D and transistors T1 and T2. At the same time, this clears the reset input from IC2 which is none other than the classic 4060 in CMOS technology.

Considering the values of C2, R4 and P2, the internal continuous oscillator in IC2 functions at a frequency on the order of 5 Hz. Consequently, its output Q12 (pin 2) changes state at the end of approximately one to two hours (depending on the P2 setting) while Q13 (pin 3) does the same, but in two to four hours. Depending on whether a link has been installed on S1 or on S2, gate IC1.B output thus changes state after one to four hours, having the effect of blocking triac TRI1 through IC1.D, T1 and T2. Simultaneously, diode D1 blocks the oscillator contained in IC2 and, therefore, the assembly stops in this state. It is dark, the light was lit for one to four hours, according to the setting of P2 and the wiring of S1 or S2, and it just went out. A return to the initial state can only happen after IC2 is reset to zero, which occurs when its input from reset to zero (pin 12) goes to high level, in other words at dawn and LDR R3 detects lights again.

Thanks to its low consumption, this circuit can be directly powered by the mains using capacitor C4. The latter must be a class X or X2 model, rates for 230 VAC. Such a model, called a self-healing capacitor, is actually the only type of capacitor we should use for power supplies that are directly connected to the mains supply.

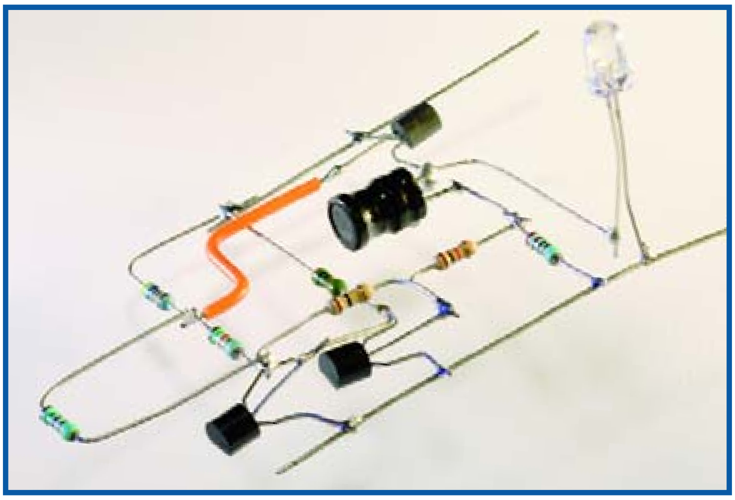
To ensure proper operation, we should pay careful attention to the placement of the LDR, to prevent the device being influenced not only by light from the house to be protected, but also by potential street lights, or even headlights of passing cars. Finally, since it is directly connected to the mains, the assembly must be mounted in an insulating housing, for obvious safety reasons.

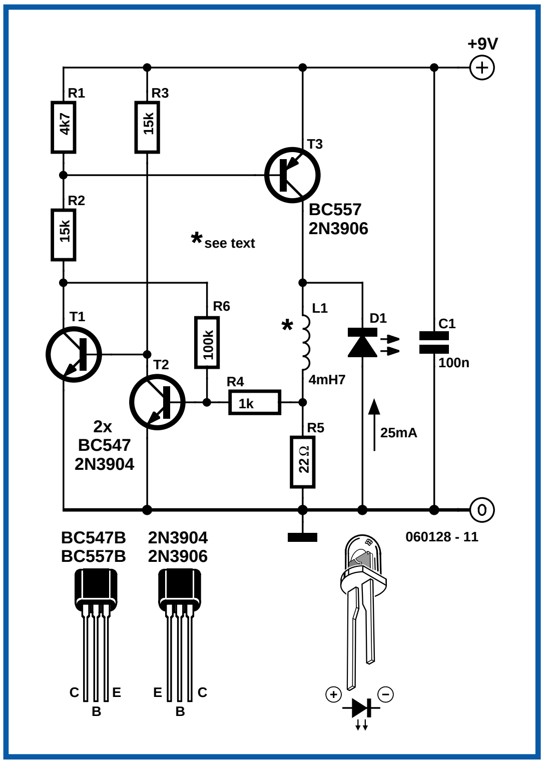
www.tavernier-c.com (060106-1)

Thrifty LED Protector

039

An LED is sure to fail if the current through it is too high. You will soon discover this after you have blown a few up. A simple resistor in series suffices to solve the problem and a better solution is almost inconceivable, because in this case you need only one additional cheap component. As the power supply voltage increases, an increasing amount of power is lost in the resistor. In particular with battery-powered equipment it is worthwhile to make a power-saving version, which does require a few more parts however.





The circuit shown in the figure has deliberately been designed with parts that everyone will have lying around, except perhaps the small coil.

In nearly all modern switching power supplies there is an attempt to monitor the current. It is generally the case that components will fail if the current or power is too high and this is very effectively avoided with this technique. It works like this. Resistor R5 measures the current through the coil and T2 'watches' to make sure it doesn't become too large. L1 will never go into saturation, which could cause T3 to give up the ghost. As soon as the current through R5 increases to about 25 mA, T2 will conduct, T1 will block and T3 will also block. The current cannot flow through T3 any more and will look for another path, in this case through LED D1, which will now light up. By placing D1 in this position it acts in fact as a free-wheeling diode, which is good for the efficiency.

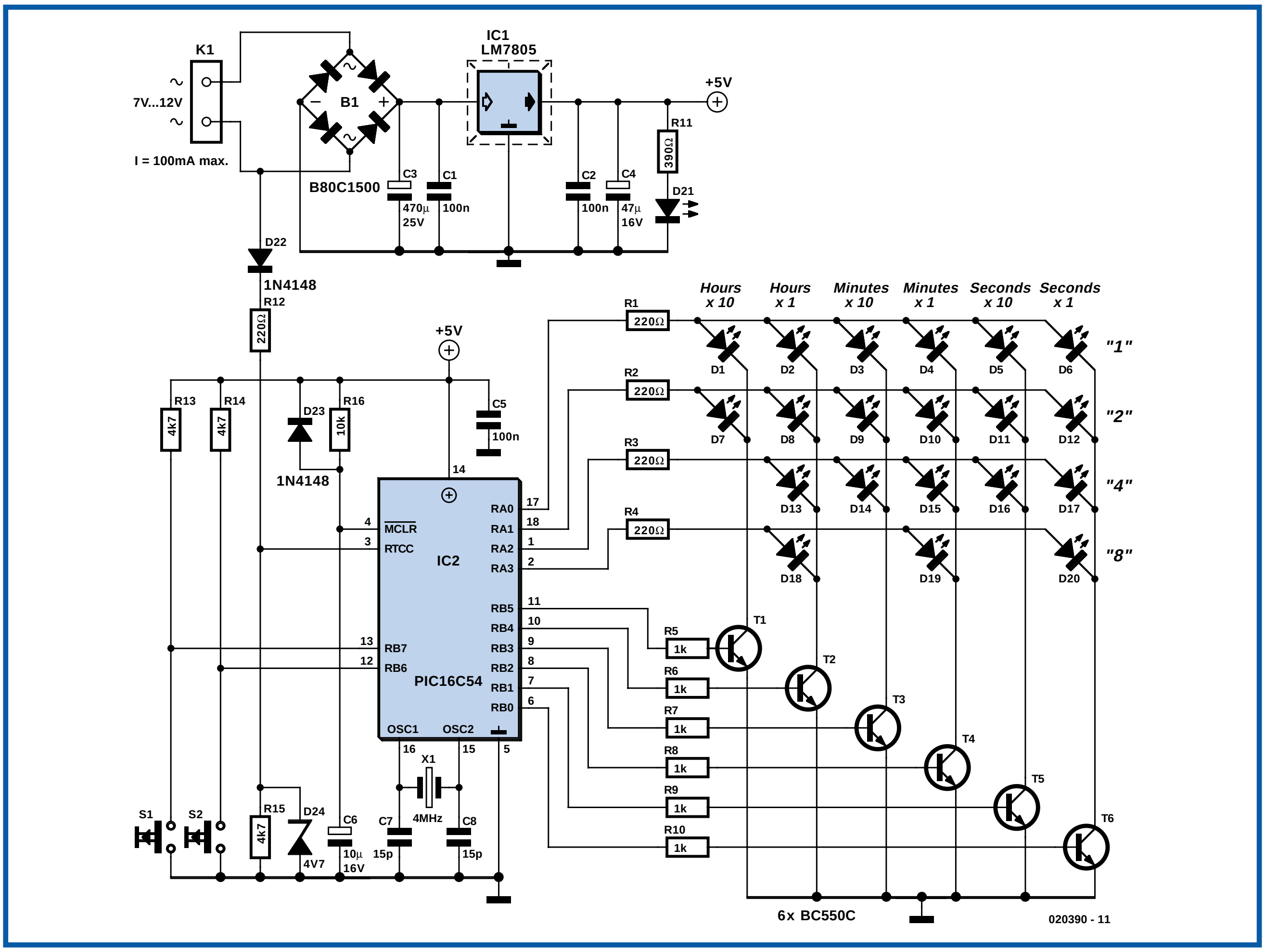
As soon as the current drops, T2 will block again and T3 will conduct. R6 provides a small amount of hysteresis so that the switching frequency of about 50 kHz does not become unnecessarily high (which would increase the loss).

The circuit works from about five volts, depending on the forward voltage of the LED. From about 9 V you will clearly notice the improvement in efficiency. The circuit is suitable for all types of LEDs, including the blue and white ones that need 3.5 V. The voltage that is generated by the coil will automatically adapt. The maximum power supply voltage is 24 V.

A little clarification regarding the choice of coil: the value is not critical, it could just as easily be 3.9 mH or 6.8 mH. Even 10 mH can be used, especially if the power supply voltage is greater than 9 V. The coil does need to be suitable for at least 25 mA. You can usually take a guess based on the physical dimensions of the coil. The coil will have to be at least 15 mm long and have a diameter of 7 mm. Incidentally, there have been great advances regarding coils in the least few years. Modern SMD-coils are much smaller and can nevertheless handle high currents. Unfortunately they are not usually available in values over 1 mH.

(060128-1)

040 Binary Clock

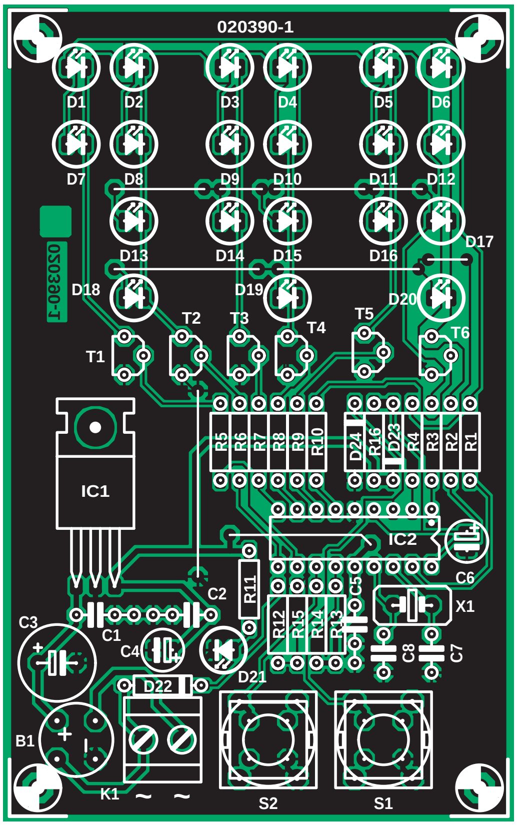


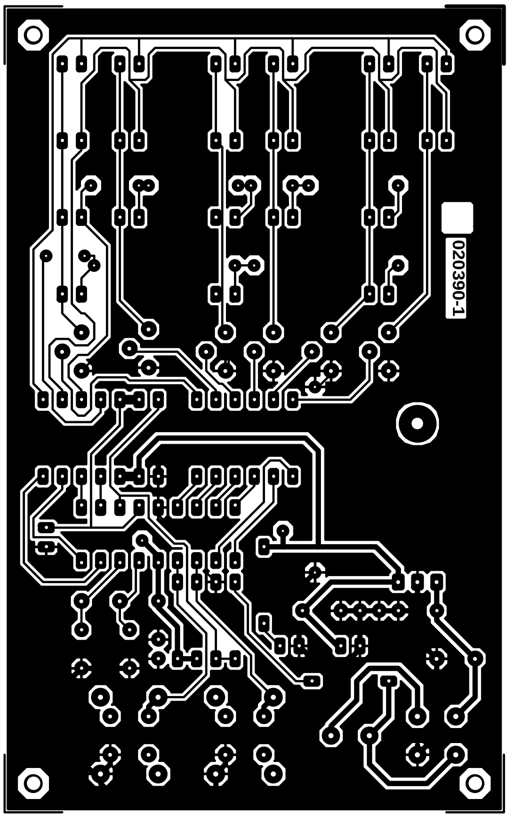
Marco Freitag

Unusual clocks are not uncommon in *Elektor Electronics*. The version presented here is based on the binary clock (not yet on display) in the new Museum of Mathematics in Gießen, Germany (www.mm-gi.de/htdocs/mathematikum/index.php?513), but it is entirely compatible with an ordinary living room. However, the hours, minutes and seconds have been further divided into units and tens to make them easier to read, which yields six columns: tens of hours, units of hours, tens of minutes, units of minutes, tens of seconds, and units of seconds. The values are read row by row from top to bottom: one, two, four, and eight — in other words, binary. With a bit of practice, it's even possible to quickly and easily read the time in a single glance.

The supply voltage for the circuit comes from a simple mains adapter with an ac output voltage of 8–15 V at a maximum output current of 300 mA. The voltage **must not** be rectified, since the microcontroller uses the frequency of the ac voltage (50 Hz) as a clock signal with long-term stability. As PIC16C54 does not have enough output ports to individually drive all of the LEDs, and doing so would also require several additional components, the display is multiplexed. In order to nevertheless make the low-current LEDs nice and bright, the magnitude of the current pulses is made significantly higher than the rated current.

Buttons S1 and S2 can be used to set the time. If you press S2, you will arrive at the setting menu after a brief LED test (all LEDs on). The value of the first column can now be set to any desired value using S2. Pressing S1 takes you to the next column. This continues in the same manner until the configuration mode is exited after the





COMPONENTS LIST

Resistors:
R1-R4,R12 = 220Ω
R5-R10 = 1kΩ
R11 = 390Ω
R13,R14,R15 = 4kΩ7
R16 = 10kΩ

Capacitors:
C1,C2,C5 = 100nF
C3 = 470µF 25V radial
C4 = 47µF 16V radial
C6 = 10µF 16V radial
C7,C8 = 15pF

Semiconductors:
B1 = B80C1500 (80V piv, 1.5A)
D1-D20 = LED, low current, colour to personal taste
D21 = LED
D22,D23 = 1N4148
D24 = zener diode 4.7V, 0.5W
IC1 = LM7805
IC2 = PIC16C54-04/P (programmed, order code **020390-41**)
T1-T6 = BC550C

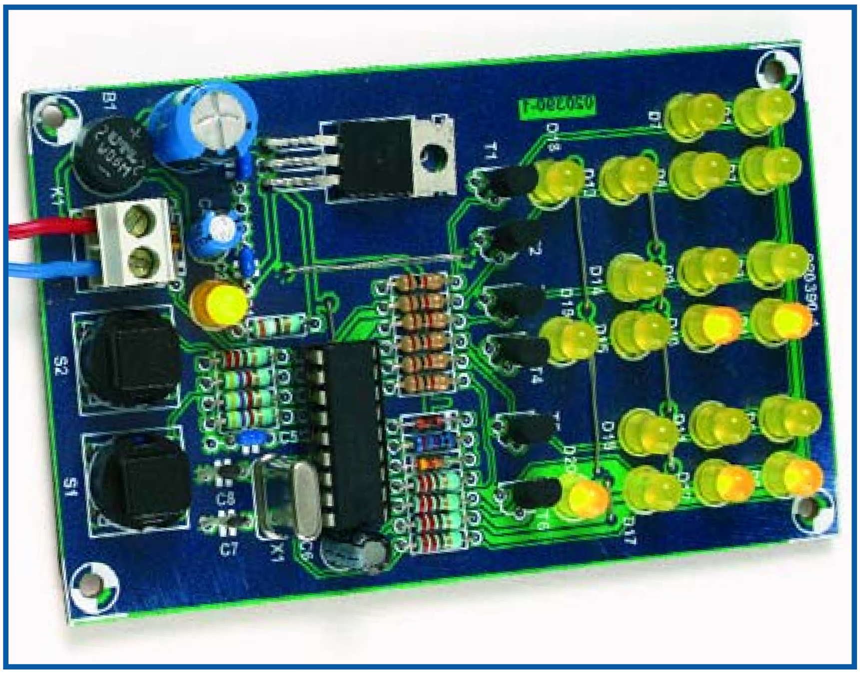
Miscellaneous:
K1 = 2-way PCB terminal block, lead pitch 5mm
S1,S2 = pushbutton, 1 make contact
X1 = 4MHz quartz crystal
Project software on disk: order code **020390-11** or Free Download
PCB, order code 020390-1 from The PCBShop

final column. The clock will continue to run, starting with the newly set value.

We have designed a printed circuit board layout for the binary clock. Fitting the components to the board couldn't be easier, although you mustn't overlook the set of nine wire bridges. As one of them is underneath the microcontroller, the latter must be fitted with a socket. The LEDs should initially be fitted with only one lead soldered in place, after which they must be aligned. The remaining leads should only be soldered after the LEDs are all nicely lined up.

The board can be displayed 'bare' or fitted into a small plastic enclosure. A transparent enclosure is quite practical, since it eliminates the need to drill holes for the LEDs.

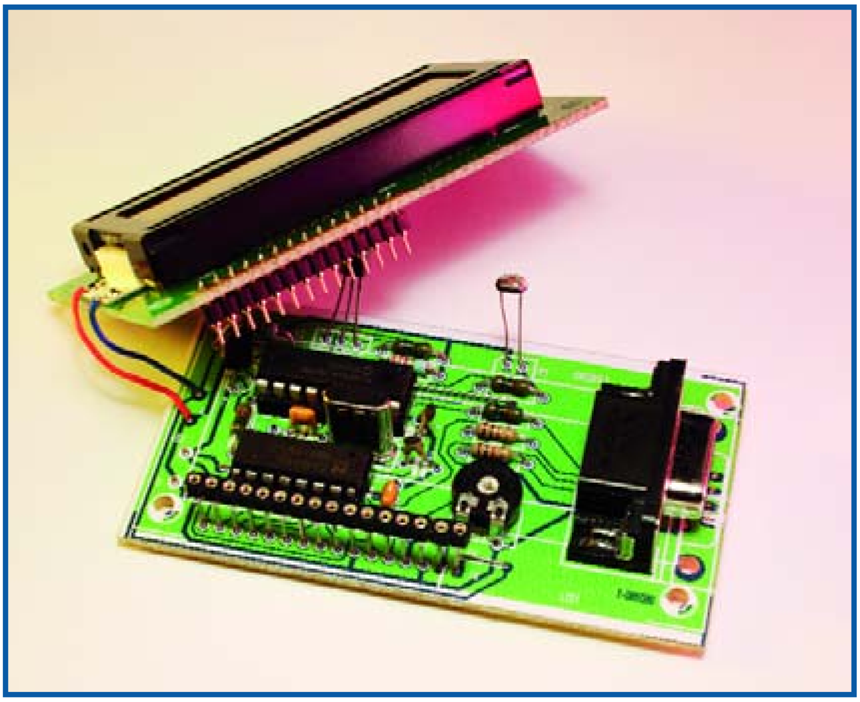
(020390-1)



041

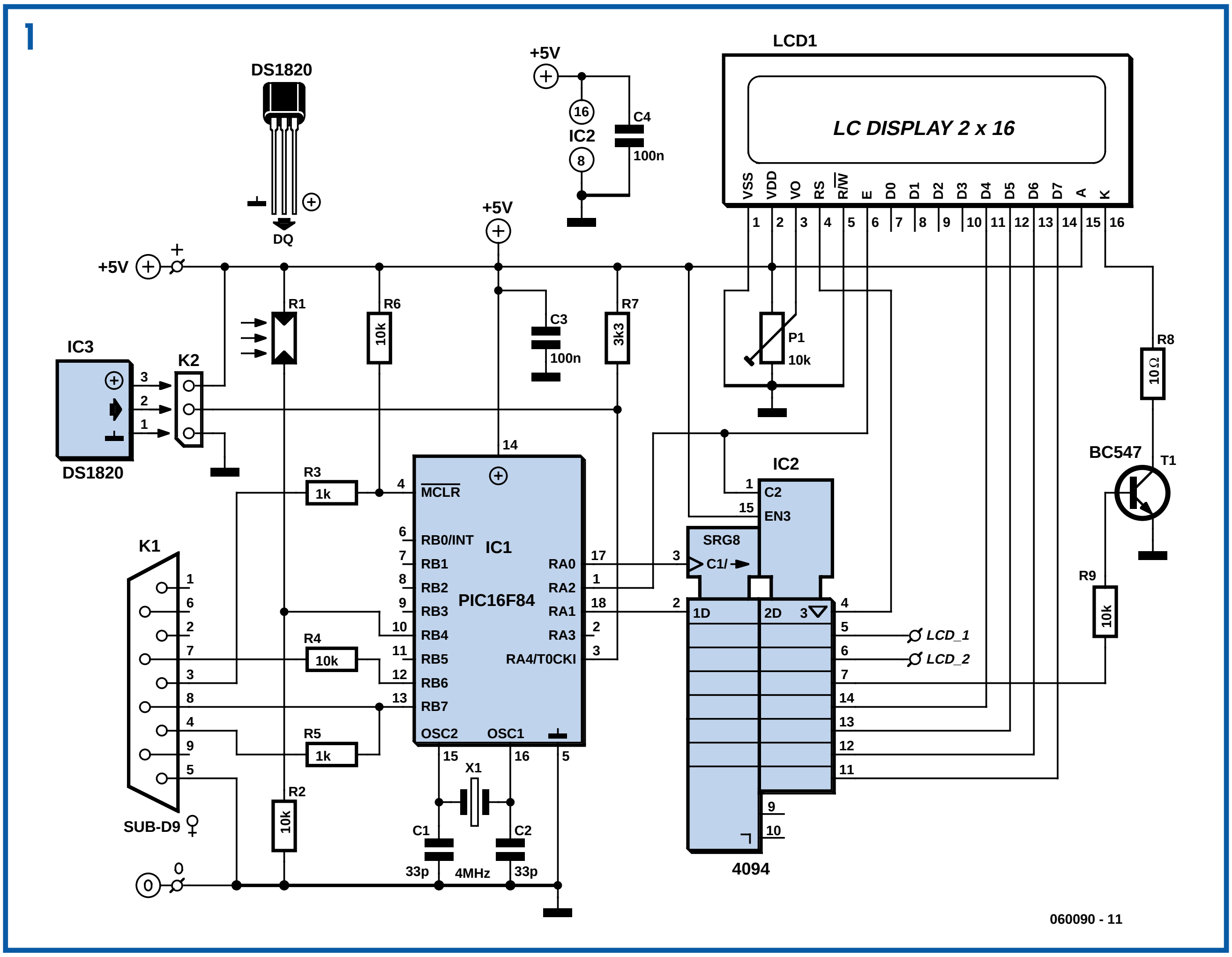
1-Wire Thermometer with LCD

Heino Peters



Although accurate digital thermometers are now available at low cost, it remains exciting and instructive to build one yourself. The present circuit is particularly intended to help the reader in the use of a PIC processor Type PIC16F84 (see www.microchip.com), a temperature sensor with 1-Wire protocol Type DS1820 (see www.maxim-ic.com), an LCD screen with 2x16 characters (HD44780 compatible) and a light sensor with an LDR that determines whether the background lighting of the LCD should be on.

The circuit is provided with a 9-way sub-D connector that enables it to be linked to the COM gate of the PC. This connection also enables the circuit to be programmed as appropriate.
Quartz crystal X1 in combination with capacitors C1 and C2 ensures that the



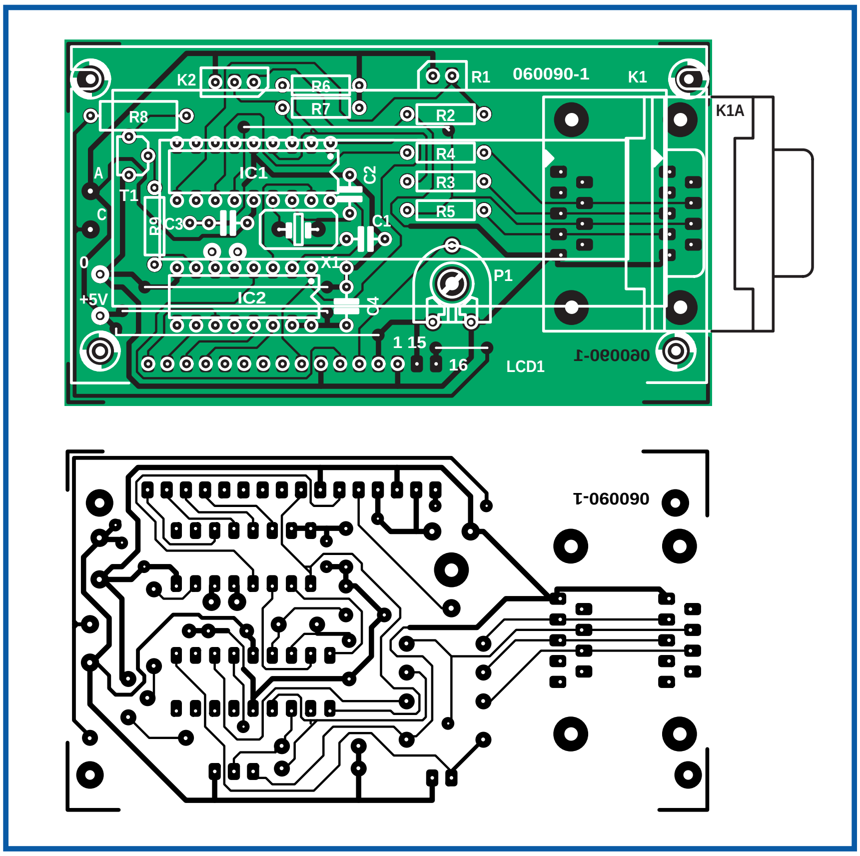
PIC16F84 Configuration bits

Oscillator XT (01)
WDTE off (0)
PWRTE on (0)
CP off (1) (all bits)

PIC processor, IC1, runs at a frequency of 4 MHz and that each instruction in the program lasts exactly 1 μs. This is useful for the timing in the program, which, by the way, is available as a free download on the *Elektor Electronics* website (file no. **060090-11.zip**). Resistors R3, R4 and R5 enable IC1 to be programmed directly by a PC via connector K1. Resistor R1, which may any type of LDR, and R2 form a potential divider that, depending on the ambient light, sets a '0' or a '1' on input RB4 of IC1. The data line of temperature sensor IC3 is connected to terminal RA4 of IC1. This terminal is the only open-collector one of IC1 and is exactly what is needed for the 1-wire data line. Resistor R7 'pulls up' the data line in quiescent operation.

The right-hand section of the diagram enables the display of the temperature. To limit the number of connections to the processor, the LCD is controlled via the series/parallel converter in IC2. The LCD proper is driven in the 4-bit mode (DB4–DB7). Also, the Register Select, RS, and the backlight must be provided with the appropriate signals. IC2 converts the 8 bits provided serially by IC1 into 8 parallel bits. The rising edge of the strobe signal from RA2 instructs IC2 to set the previously received eight bits at the outputs. The falling edge clocks them to the screen via enable input E of the LCD. Since only six of the eight bits are needed, individual extensions may be accommodated at outputs LCD1 and LCD2: for instance, a buzzer or an LED. The combination of R9, T1 and R8 provides a current of 100–200 mA from output Q3 (pin 7) of IC2 to the backlight of the LCD. The contrast of the display may be adjusted with P1.

The associated program is written in assembly code; it may be adapted as needed by downloading development area MPLAB from www.microchip.com Design a project in MPLAB and within this, load the source code available at the Elektor website (the .ASM file). After you have added your own adaptations, make a .HEX image by clicking on the BUILD icon. Then, use the free program NTPICPROG.EXE from Andres Hansson (http://www.geocities.com/CapeCanaveral/7706/ntpicprog.zip) to program the .HEX file in the PIC via the COM gate of the PC. The 5-V supply rail must remain connected during programming. Do not program the PIC with a notebook, but use a desktop PC, since the voltage levels at the COM gate of a notebook often are only 3–5 V, whereas a minimum of 10 V is needed. Also, do not use a USB/RS232 converter, because that usually confuses the timing.



Once you have this setup working, the step to other applications is easy.
The circuit is readily constructed on the printed-circuit boards shown. Start with the wire links, so that they are not overlooked at a later stage. If you do not want to program the PIC yourself, a programmed one may be ordered from Elektor (order code **060090-41**). A power source of 5 V capable of providing a current of up to 100 mA is required.

Note that the circuit does not provide protection against polarity reversal or too high a supply voltage.

(060090-1)

COMPONENTS LIST

Resistors
R1 = LDR (small model)
R2,R4,R6,R9= 10kΩ
R3,R5 = 1kΩ
R7 = 3kΩ3
R8 = 10Ω
P1 = 10kΩ preset, horizontal

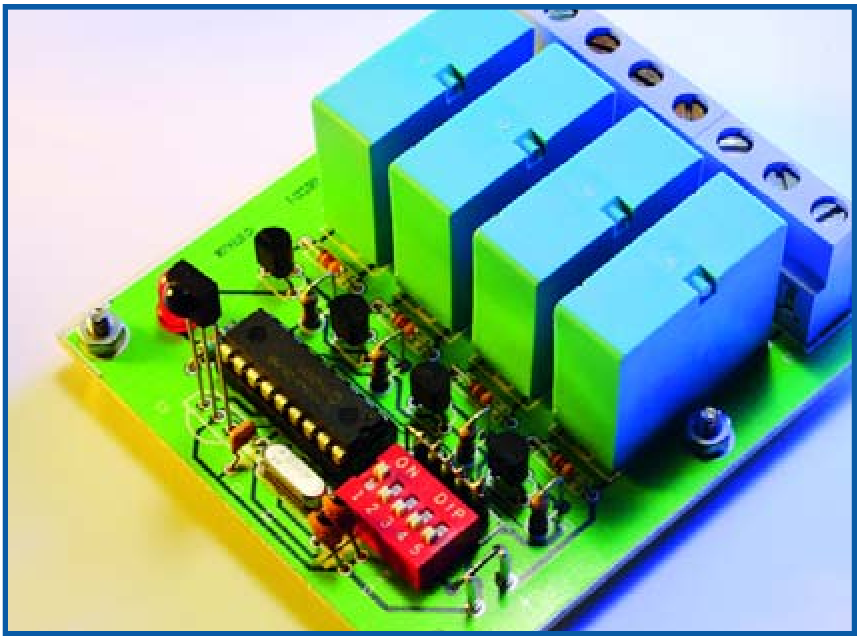
Capacitors
C1,C2 = 33pF
C3,C4 = 100nF

Semiconductors
T1 = BC547
IC1 = PIC16F84A-04CP (programmed, order code **060090-41**)
IC2 = 4094
IC3 = DS1820, DS18S20
LCD = alphanumerical LCD, 2x16 characters, 44780-compatible

Miscellaneous
K1 = 9-way sub-D socket (female), angled, PCB mount
K2 = 3-way SIL pinheader
X1 = 4MHz quartz crystal, parr. cap. 32pF, HC49 case
5 wire links
PCB, ref. 060090-1 from The PCBShop
Source and hex code files, ref. **060090-11**, free download from www.elektor-electronics.co.uk

Easy Home Remote Control

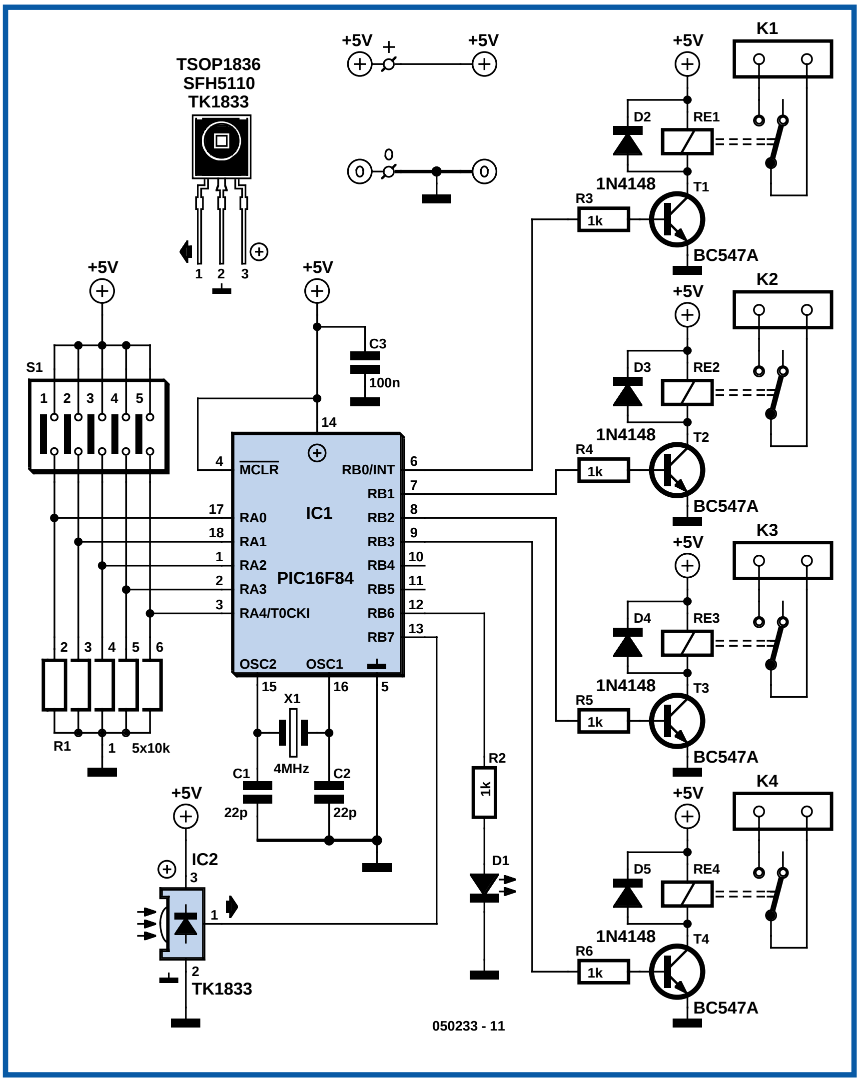
Carlos Ferreira

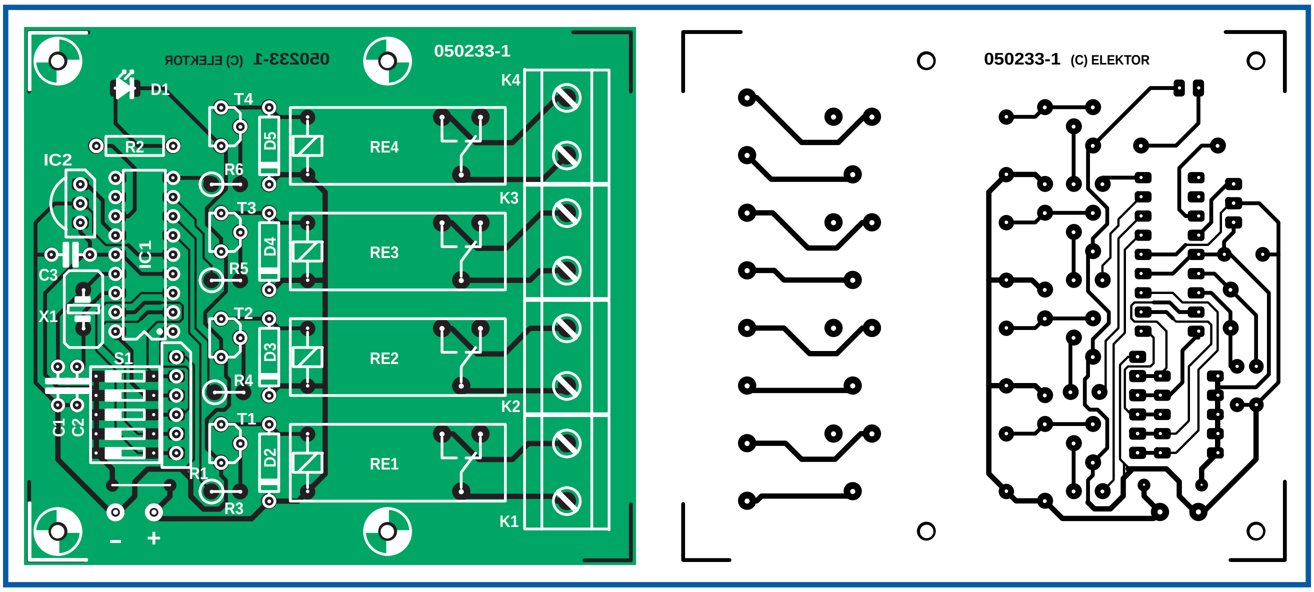


Happens to everyone! You're comfortably installed on your sofa watching TV and then all of a sudden you need to get up to turn the lights on or off, or to draw the curtains. Many living rooms these days have a double head-up ceiling light, a floor lamp and an electric window/curtain control. The idea is to control all these devices, and more, with the TV remote control.

The circuit designed for *maximum indolence in front of the telly* is built around the PIC16F84. The 'F84 was chosen mainly because of its internal EEPROM, which is necessary to store the user-programmable infrared codes. To control such devices as mentioned above, four relays are used, working together with lamp switches in a two way configuration.

Looking at the circuit, the DIP switch block and the associated resistor array connected to microcontroller port A are used to program the IR codes and to select the operation mode for all the outputs (described further on). The IR sensor is connected to port line RB7 on the PIC. The lower nibble (set of 4 bits) of port B is used to control the output relays via 1-k resistors and BC547 transistors. It is also used to control multifunction indicator LED D1 on port line RB6.
Components C1, C2 and X1 generate the microcontroller clock signal while C3 helps to keep the supply voltage as clean as possible.
The circuit should be powered by a 5-V regulated supply capable of providing enough current for the four relay coils (approximately 140 mA per relay) plus a few mA for microcontroller, IR sensor and LED.
The circuit is designed to respond to infrared commands coded to the Philips RC5 protocol. The protocol consists in a frame of 14 bits. The first two bits, always at '1', are used to start the frame. The third bit is the flip bit, this bit indicates when a key is pressed repeatedly. The next five bits are used to identify de system which the message is sent. The last six bits represent the sent command. Note that in RC5 speak a logic '1' is a transition from 0 V to Vcc, and logic '0'





is a transition from Vcc to 0 V, where the period of one bit is 1.7778 ms. Many articles on RC5 have appeared in this magazine.

The software developed for the project is stored in the PIC microcontroller. It allows four different RC5 codes to be saved and used to control the four outputs. For example, your TV remote may be able to control five systems: TV (default), VCR, DVD, AMP, SAT. If, for example, you do not have VCR then the relevant IR codes are available for Easy Home Control. If your remote control is not compatible with RC5 codes, you can buy a cheap universal remote control to do the job.
To avoid the relays changing state owing to a power cut in your home, the state of the relays is saved in the microcontroller EEPROM and retrieved every time the PIC re-initialises.
The actuation of electric curtains differs from lamps as it's necessary to send a short pulse to the relays.
To make the home control more versatile it is possible to control all relays (configurable by the DIP switches) in one of two modes:

- toggle between ON and OFF positions with memory for lamps;
- output pulse for other devices like electric windows-curtains.

If you're a keen energy saver, it is also possible to program an IR code to turn off all the relays (and save 5 V·140 mA = 0.7 watts per relay).

The Easy Home Remote Control is configured as follows.
1. Switch the circuit on with all DIP switches set to OFF.
2. Flip ON switch #5 (switch connected to RA4/TOCK1) to enable programming mode. Using **Table 1**, set the other switches as required to save desired IR codes in EEPROM.
3. Flip OFF switch #5 to select working mode. Using **Table 2**, configure the other switches to select the desired relay mode.

In working mode a fast-blinking LED (D1) means reception of IR codes with no associated function; 1-second blink means programmed IR code was received and corresponding action was

COMPONENTS LIST

Resistors
R1= 5-way 10kΩ SIL array
R2-R6 = 1kΩ

Capacitors
C1,C2 = 22pF
C3 = 100nF

Semiconductors
D1= LED, low current
D2-D5 = 1N4148
IC2 = IR receiver module, e.g., TSOP1836, SFH5110 or TK1833
T1-T4 = BC547

Miscellaneous
X1 = 4MHz quartz crystal
IC1 = PIC16F84, programmed, order code **050233-41** (see Elektor SHOP pages or website)
PCB, ref. 050233-1 from The PCB Shop
Re1-Re4 = PCB mount relay, 5V coil, 140mA.

Table 1. Programming Mode

DIP switch ON (S1)	DIP switch OFF (S1)	Set code for
#1	#2, #3, #4	relay 1
#2	#1, #3, #4	relay 2
#3	#1, #2, #4	relay 3
#4	#1, #2, #4	relay 4
#1, #2	#3, #4	All relays OFF
Note: LED blinks 1 second after code set.		

Table 2. Working Mode

DIP Switch (S1)	OFF = Toggle Mode	ON = Pulse Mode
#1	toggle relay 1	1-second pulse at relay 1
#2	toggle relay 2	1-second pulse at relay 2
#3	toggle relay 3	1-second pulse at relay 3
#4	toggle relay 4	1-second pulse at relay 4
Notes: Led blinks 1 second after any action on relays. Fast blinking of the LED means bad RC5 reception or correct RC5 code but no action associated with it.		

performed. In programming mode, the 1-second blink means the IR code was saved in the microcontroller EEPROM.
The assembly code file for the PIC used in this project is available as a free download from the *Elektor Electronics* website. File number **050233-11.zip** may be found by clicking on Magazine → 2006 → July/August. The PIC is also available ready-programmed from the Publishers as order code **050233-41**.

(050233-1)

Warning
Screw contacts on K1-K4 and PCB tracks to the relay contacts may carry the mains voltage. All relevant precautions must be observed in respect of electrical safety

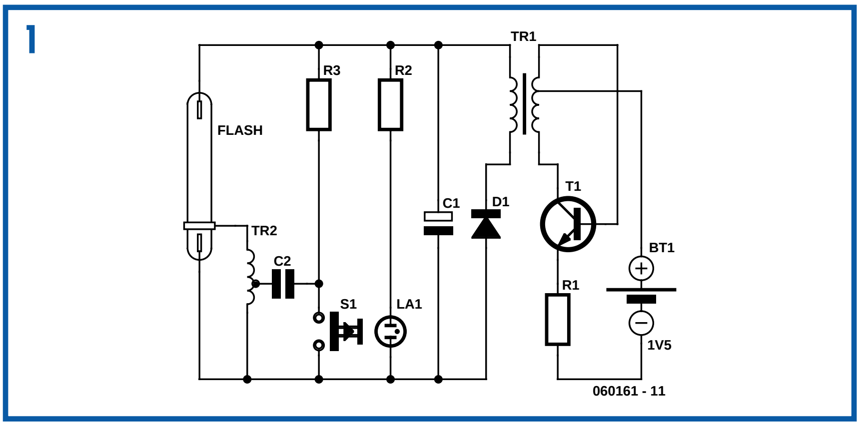
043

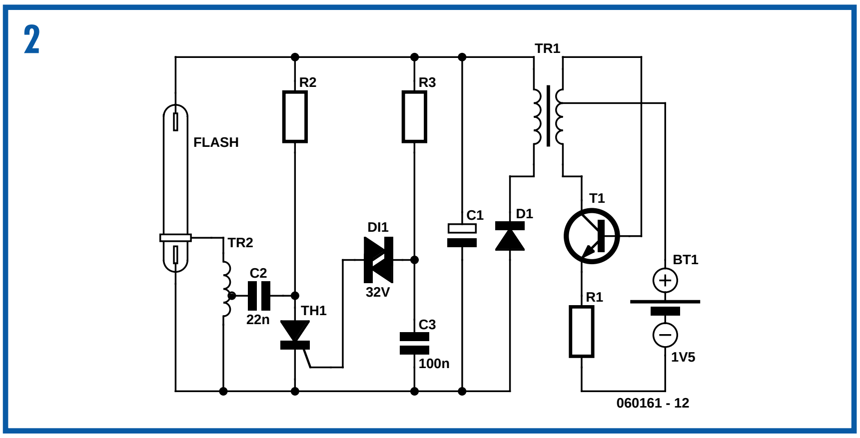
Recycling Flasher Lights

Gérard Guilhem

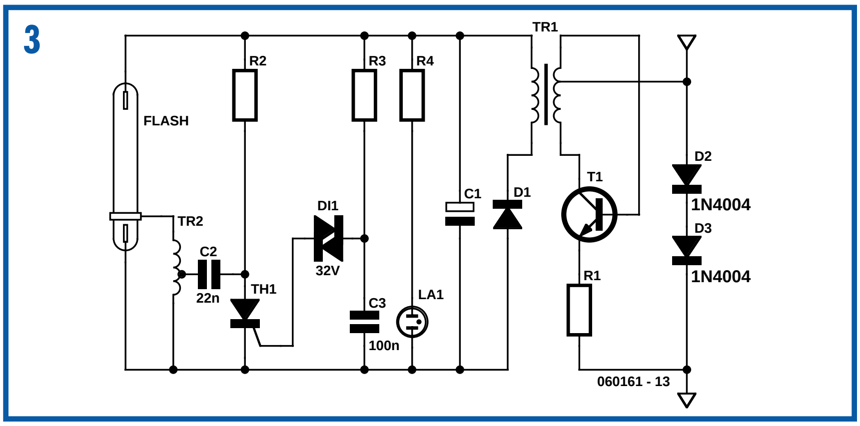
During the Christmas holidays, you lose count of the number of homes lit up like Christmas trees, like fireflies by the thousands which twinkle and flash, outlining words, the shape of designs, characters, or animals.

We are proposing a garland of lights you will not find at your neighbour's house and at the same time to do something good for the environment— because we are going to recycle. The string described here is only composed of electronic photo flasher lights. Only the richest municipalities have the potential to buy this type of decoration due to its hefty price tag, but we are going to make the same at a ridiculously low price.
First step: go to a photographer's shop and kindly ask the shop owner or staff to set aside some used, disposable flash cameras. Staff will normally be very happy to do that because, in any case, these units end up in the trash after being processed. You will need about twenty at least, preferably of the same type, that will make the task easier.
Second step: open each camera, remove the battery, discharge the capacitor (one never knows) and finally, remove the electronic flasher board. Two possibilities: the printed circuit is small and can therefore be used as such after a small modification, or the printed circuit is too big which will force you remove the components you'll be using on a board of your own design.
You should start by copying the diagram and identifying the components. 95% of flasher boards are designed based on the diagram in **Figure 1**.
There are several variations, some surprisingly complex for a disposable module, including a measurement cell and a thyristor, for example. Do not use that kind of model.
It is difficult to imagine a simpler diagram. Transistor T1 is the only active component. Helped by TR1 and R1, it produces approximately 300 V from 1.5 volts supplied by the alkaline battery.
C1 charges progressively and the neon miniature 'Ready' lamp La2 lights up to signal that the energy stored is sufficient to obtain a good flash.
In parallel, and even more rapidly, C2 is charged via TR2 and R3. All that's left to do is wait for the amateur photographer to press button S1, which has the effect of discharging C2 into TR2 that produces the high-voltage pulse necessary to fire neon flashlight La1.
That is precisely what we need, in detail: we are not going to spend the entire evening pressing different buttons to trigger the flash. Therefore, we have to find an automated technique for this process by giving it a somewhat random character.
The result of all these reflections take the shape of the diagram in **Figure 2** which, as compared with the first diagram, has three new components (after having lost two, now useless!).
Thyristor TH1 will be charged from triggering, as soon as the voltage at C3 terminals, charged via R3, exceeds the fir-





ing threshold of the diac DI1 which supplies the trigger current.
A judicious choice of values for R3 and C3 makes it possible to have one flash per second. In order to avoid too high energy consumption, the value of C1 is adjusted to 4.7 µF, even 10 µF, for nicely padded flashes without using too much current.
You will, no doubt, have noticed the absence of the neon miniature bulb and its resistor which are no longer useful.
Last problem to solve: the power supply. We are not going to interrupt the New Year's Eve party to replace used batteries. It is out of the question to power the setup from 1.5 V as the number of flashes we are dealing with, the current would be too high. It would be better to supply 1.5-V voltage to each module, the modules being mounted in series, taking care to limit the current to approximately 500 mA. As illustrated in the partial diagram of **Figure 3**, we will provide each module with a pair of 1N4001 diodes that will produce a drop in voltage between 1.3 V and 1.4 V, and that works out perfectly. The flashers are mounted in series on a wire whose two end points are connected to a DC power supply. We should account for about 1 V per module. We can actually consider that the majority of flashes will occur during charging and will only reach the 1.4 V level a few tenths of a second before the actual flash, the average voltage being around 1 V.



It's reasonable to reserve 24 V for 20 flasher units, with a protection resistor of about 10 Ω to limit the current surges, not forgetting a 1-amp fuse.
The best result will be obtained using an adjustable constant current power supply between 0.5 and 1 A, which allows us to play with the flash frequency. The number of flashes is obviously a function of the current supplied.
It is recommended, for safety reasons, to stay below 40 volts. This corresponds to close to 40 flashlamps (and a few evenings to set them up), but since we still have quite a few months before the holiday season...

What remains is the 'packaging'. Everything depends on the size of the finished module. You could potentially use housing for translucent film in which you drill two holes to force the wires through and ensure an airtight seal.
Another option is translucent heat shrink tubing of the proper size. We will cut an adequate length of tubing, or 4 cm more than the length of the module. The wires are coated with a drop of heat shrinkable glue, then the tubing is retracted. The end is immediately flattened using a flat clamp until totally cooled. Repeat for the other end. This should make for a good airtight seal.
A purposely designed printed circuit will allow you to reduce the size of the module to a minimum.
Average consumption is approximately 12 watts for 20 flasher modules, which is perfectly reasonable and the result obtained is surprising, original and superb.

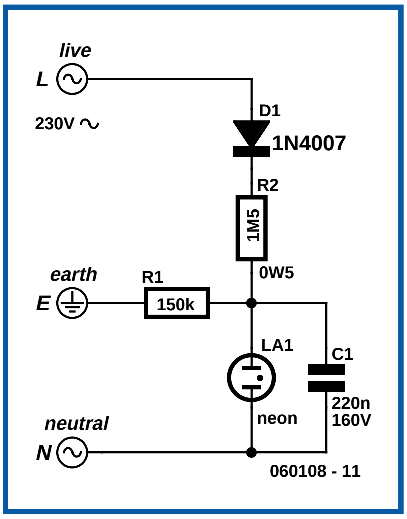
(060161-1)

Earth Fault Indicator

044

Christian Tavernier

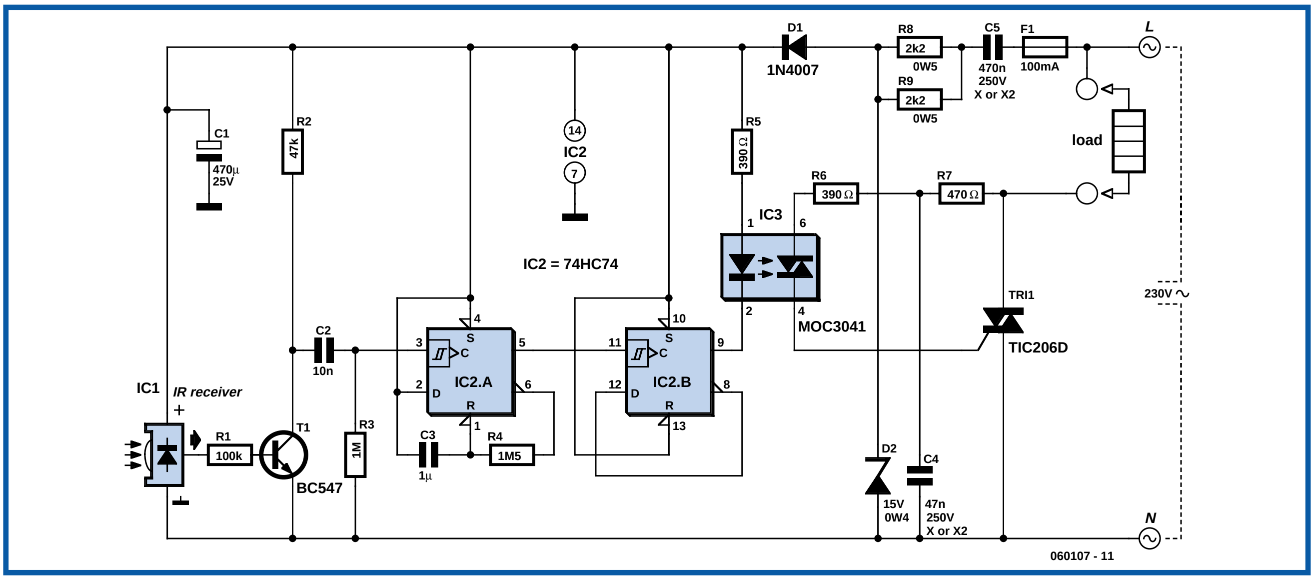
The security of many electrical devices depends today on the availability of an earthed mains outlet. We should remember that these are connected to the frame or to the metal housing of the equipment and so it routes to the protective earth (PE) connections. In this setup, mains voltage, however small, will cause the differential circuit breaker to trip. The circuit breaker is part of any modern electrical installation. This type of security device may however become defective due to common corrosion as we have seen many times on various older household devices, as well as on construction sites. Actually, since these devices are frequently in wet conditions, the screw and/or lug used to connect the earth wire to the device frame corrodes gradually and ends up breaking or causing a faulty contact. The remedy is then worse than the problem because the user, thinking that he/she is protected by earth, does not take special precautions and risks his/her life.
However, all that's needed is an extremely simple system to automatically detect any break in the earth connection; so simple that we ask ourselves why it is not already included as part of all factory production for appliances that carry any such risk, as we have discussed above. We propose it as a project for



you to build using this schematic.
The live wire (L) of the mains power supply is connected to diode D1 which ensures simple half-wave rectification which is sufficient for our use. The current which is available is limited to a very low value by resistor R2. If the appliance earth connection to which our circuit is installed is efficient, this current is directed to earth via resistor R1 and the rest of the circuit is inactive due to insufficient power.
If the earth connection is disconnected, the current supplied by D1 and R2 charges up capacitor C1. When the voltage at the terminals of the capacitor reaches about 60 volts, neon indicator light La1 is turned on and emits a flashing light which discharges capacitor C1 at the same time. This phenomenon is reproduced indefinitely as long as the earth connection has not been restored, and the neon light continues to flash to attract attention in case of danger.
Building the project is not particularly difficult but, since it is a project aimed at human safety, we must take the maximum of precautions concerning the choice of components utilised. Therefore, C1 must have an operating voltage of at least 160 volts while R2 must be a 0.5-watt resistor, not for reasons of power dissipation, but in order to maintain the voltage. The neon light can be any type, possibly used, or it may be part of an indicator light to make it easier to attach to the protected appliance. In the second case, we must obviously get rid of its series resistor which would prevent proper operation here.
During installation of the circuit in the appliance to be protected, we should also clearly mark Live (L) and Neutral (N) (for example, seek Live with a simple screwdriver) because inverting these two wires at this point will disable proper operation.
The final point, which is self-evident considering the principle used here: the earth connection for our setup must be hooked up to the frame of the appliance to be protected at a different point than where the normal earth wire is connected.

www.tavernier-c.com (060108-1)

045 On/off Infrared Remote Control



Christian Tavernier

Most homes today have at least a few infrared remote controls, whether they be for the television, the video recorder, the stereo, etc. Despite that fact, who among us has not cursed the light that remained lit after we just sat down in a comfortable chair to watch a good film? This project proposes to solve that problem thanks to its original approach. In fact, it is for a common on/off switch for infrared remote controls, but what differentiates it from the commercial products is the fact that it is capable of working with any remote control. Therefore, the first one you find allows you to turn off the light and enjoy your movie in the best possible conditions.
The infrared receiver part of our project is entrusted to an integrated receiver (Sony SBX 1620-52) which has the advantage of costing less than the components required to make the same function. After being inverted by T1, the pulses delivered by this receiver trigger IC2a, which is nothing other than a D flip-flop configured in monostable mode by feeding back its output $\overline{Q}$ on its reset input via R4 and C3. The pulse that is produced on the output Q of IC.2A makes IC.2B change state, which has the effect of turning on or turning off the LED contained in IC3. This circuit is an opto triac with zero-crossing detection which allows our setup to accomplish switching without noise. It actually triggers the triac T2 in the anode where the load to be controlled is found. The selected model allows us to switch up to 3 amperes but nothing should stop you from using a more powerful triac if this model turns out to be insufficient for your use.
In order to reduce its size and total cost, the circuit is powered directly from the mains using capacitor C5 which must be

a class X or X2 model rated at 230 volts AC. This type of capacitor, called 'self-healing', is the only type we should use today for power supplies that are connected to ground. 'Traditional' capacitors, rated at 400 volts, do not really have sufficient safety guarantees in this area. Considering the fact that the setup is connected directly to the mains, it must be mounted in a completely insulated housing. A power outlet model works very well and can easily be used to interspace between the grounded wall outlet and that of the remote control device. Based on this principle, this setup reacts to any infrared signal and, as we said before, this makes it compatible with any remote control. On the other hand, it has a small disadvantage which is that sometimes it might react to the 'normal' utilization of one of these, which could be undesirable. To avoid that, we advise you to mask the infrared receiver window as much as possible so that it is necessary to point the remote control in its direction in order to activate it.

www.tavernier-c.com (060107-1)

Charlieplexing

046

Do you think it is possible to drive an 8-digit, 7-segment display with only nine (9) connections? Yes certainly, and here we show you how it's done.

Normally speaking, a 7-segment display has eight LEDs (including the decimal point) that have to be controlled with eight inputs and one common output. The corresponding segments of all the displays are connected together and only one display is activated at a time because each display has its own common anode (or cathode) connection. This requires 8 + 8 = 16 connections, as shown in **Figure 1**. But it is certainly possible to do this with only nine connections, provided the multiplexing is done a little smarter. The notable feature in **Figure 2** is that the common output of each display is also connected to a segment (but each to a different segment). In addition it is necessary that the drive electronics is capable of both sourcing current and sinking current. This works as follows:

To keep things simple we've drawn only two displays in **Figure 3**. CC0 drives both a segment (of display 1) as well as a common cathode (of display 0). When this line is logic zero, the segments from display 0 can be illuminated when they are supplied with current. The segments of display 1 would also like to light up, but there is nowhere for their current to flow. This current has to flow via a segment (the leftmost one in this case) but that segment is connected in the reverse direction! Display 1 remains dark therefore and the same applies to the other six displays.

In **Figure 4** you can see what the path of the current is when CC1 is logic low. The segments from display #1 can now be illuminated.

(060124-1)

You can find more information in application note 1880 from Maxim: www.maxim-ic.com/appnotes.cfm/appnote_number/1880

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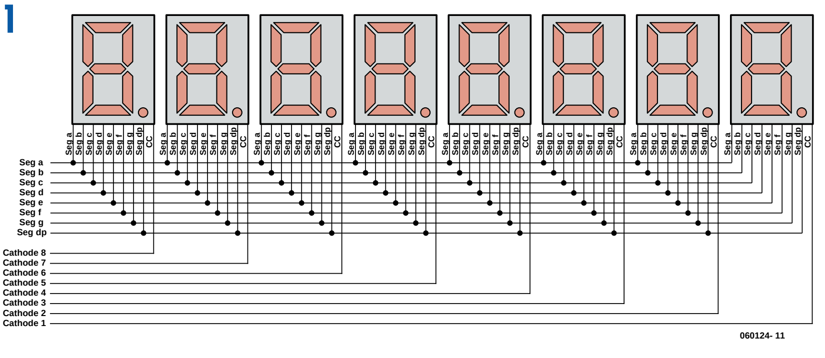

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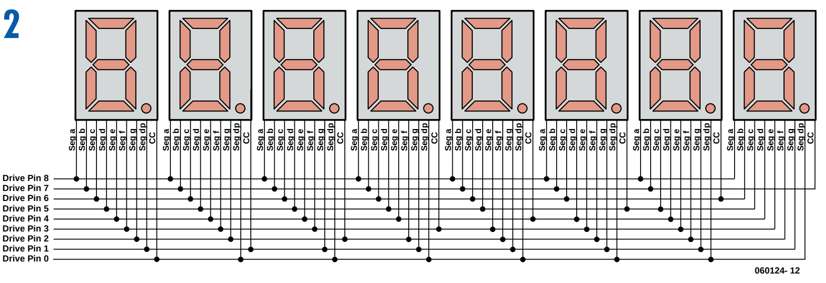

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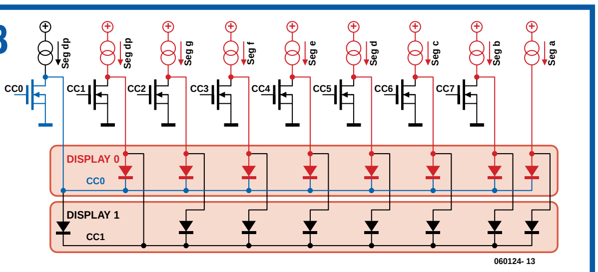

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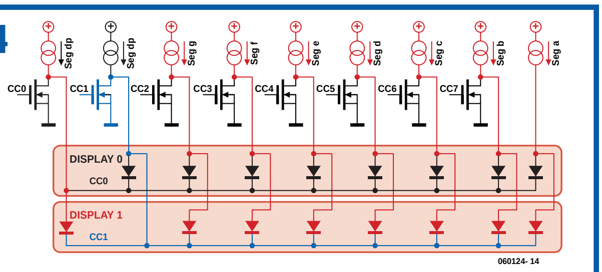


047

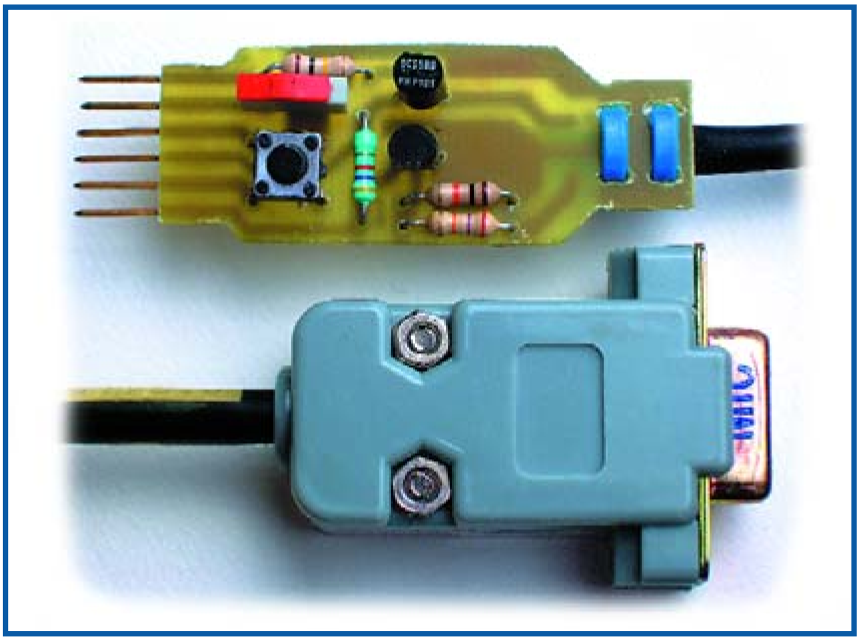
R8CKey

Jean Brunet

The small board shown in the photograph will conveniently replace the installation of several components when using the R8C 16-bit Tom Thumb module for programming.

In **Figure 1**, you'll find the transistors and their corresponding resistors, the Reset button and the Mode switch, all from our first article on the R8C/13.

The R8Ckey is powered by the setup using the K2 6-pin connector which is plugged into socket K3 that normally holds the R8C module. This is used to bypass various components, specifically those which made up the original power supply. The advantage here, of course, is to enable a much easier insertion of the R8C module.



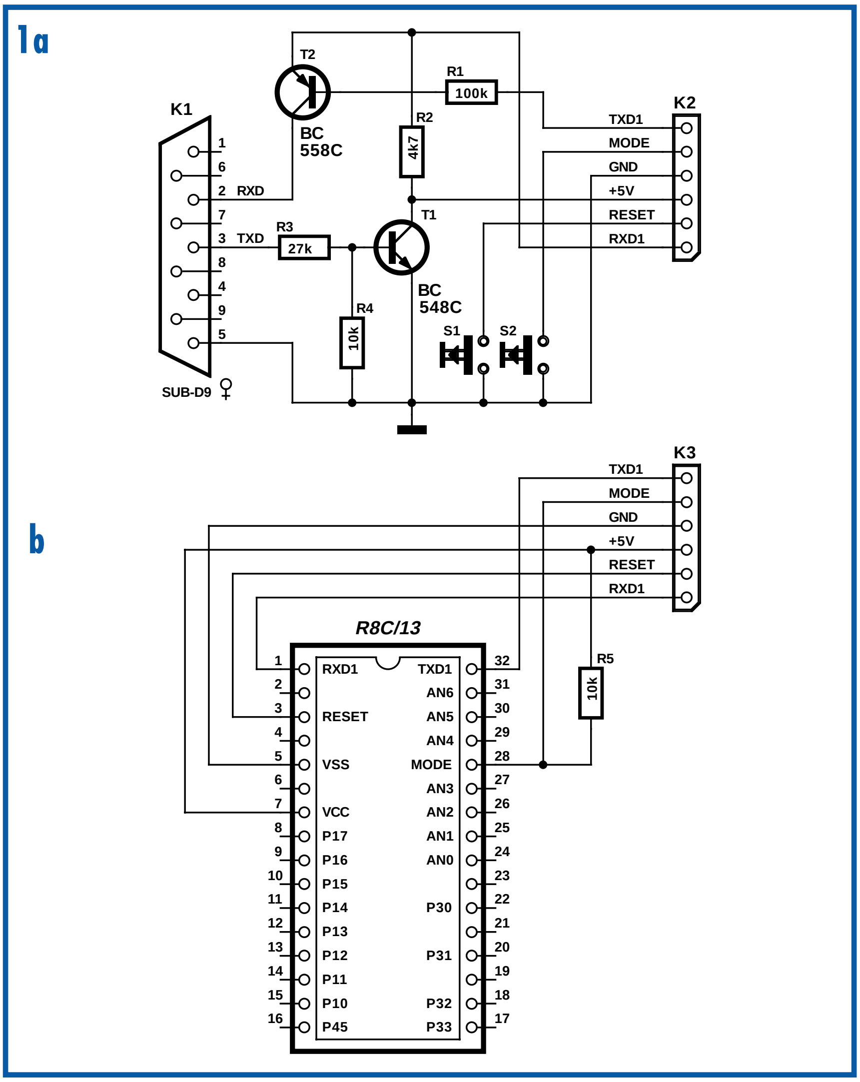
Mounting the R8CKey board

There isn't a lot to say about making the R8Ckey board. The PCB artwork (**Figure 2**) shows that installing the components is extremely easy. Adding a switch, a button and a few passive and active (two transistors) components should not be too difficult.

Begin by soldering the gold-plated single-row 6-contact connector. Solder it with its plastic base in order to retain the proper spacing, then forcefully slide out the plastic part to remove it.

Solder the resistors, the transistors, the Reset button and the slide switch S2.

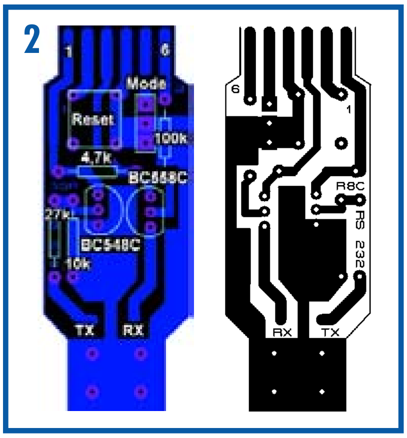
The cable is soldered on the R8Ckey with the braided ground wire directly on the ground layer of the board. Two nylon self-locking cable ties keep the cable in place. At the end of the cable, pin 2 of the RS-232 port corresponds to RxD on the board, while, on the copper side, pin 3 corresponds to TxD, and pin 5 carries ground.

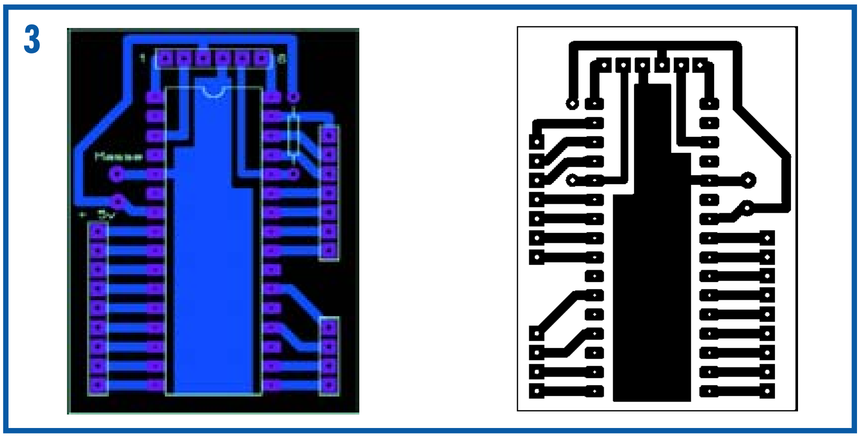


Implementation of the R8CKey

Warning: Make sure the R8Ckey is properly oriented in socket K3. It must be positioned with the copper side toward the R8C. Inversion will destroy the transistors on the board.

The R8Ckey is very easy to use. You only have to insert it into its socket in front of the R8C, respecting the orientation, as we were saying above, the 'copper' side





facing toward the R8C. Then, connect the 9-way sub-D plug to the RS232 port on the PC. Turn the setup on, slide the Mode switch toward the top, and push the Reset button. Now, all that's left to do is start programming the chip.

Installation at the top of the R8C/13

The diagram given in **Figure 1b** is practically 'transparent' because it is limited to a simple 6-pin connector. We propose the component mounting plan for this second board and its track design in **Figure 3**. Making the second printed circuit, the one for the R8C side is very simple, as can be seen in this example.

The only thing to solder on the board being tested is the 10 kΩ resistor connected between the Mode pin (pin 28) of the R8C board socket and the +5 V line.

The PCB artwork was produced in Proteus ARES format and can therefore be used 'as is' with this printed circuit design program. The relevant files can be downloaded from the author's website: http://perso.wanadoo.fr/asnora/R8C/r8ckey.htm

(060175-1)

COMPONENTS LIST

Resistors
R1 = 100kΩ
R2 = 4kΩ7
R3 = 27kΩ
R4 = 10kΩ

Semiconductors
T1 = BC548C
T2 = BC558C

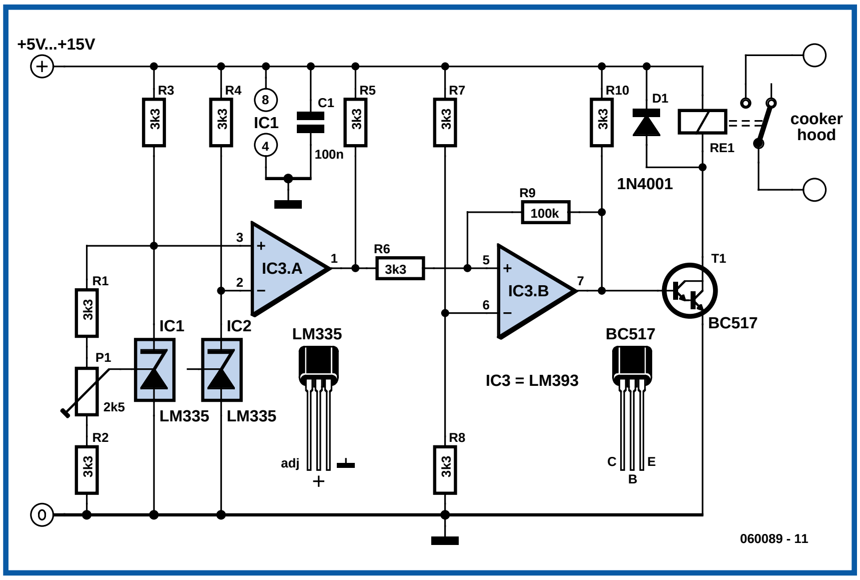
Miscellaneous
S1 = pushbutton (Reset)
S2 = slide switch, PCB mount (Mode)
K1 = 9-way sub-D socket (female) for cable mounting (RS232)
K2 = 6-way gold-plated SIL pinheader
1 m shielded cable with 2 conductors

Automatic Range Hood

048

Heino Peters

Come to think about it, it's a bit strange that range hoods in our kitchens don't switch on and off automatically. After all, a simple temperature sensor under the hood can detect whether a burner is on. The circuit described here goes a step further and compares the temperature under the hood with the temperature just outside the hood. At a certain (adjustable) temperature difference, the hood will be switched on, possibly along with the lamp under the hood. After the burners are shut off, the hood fan and lamp will switch off again by themselves. The advantage of using two sensors is that the hood will have the same switching characteristics in the summer as in the winter.



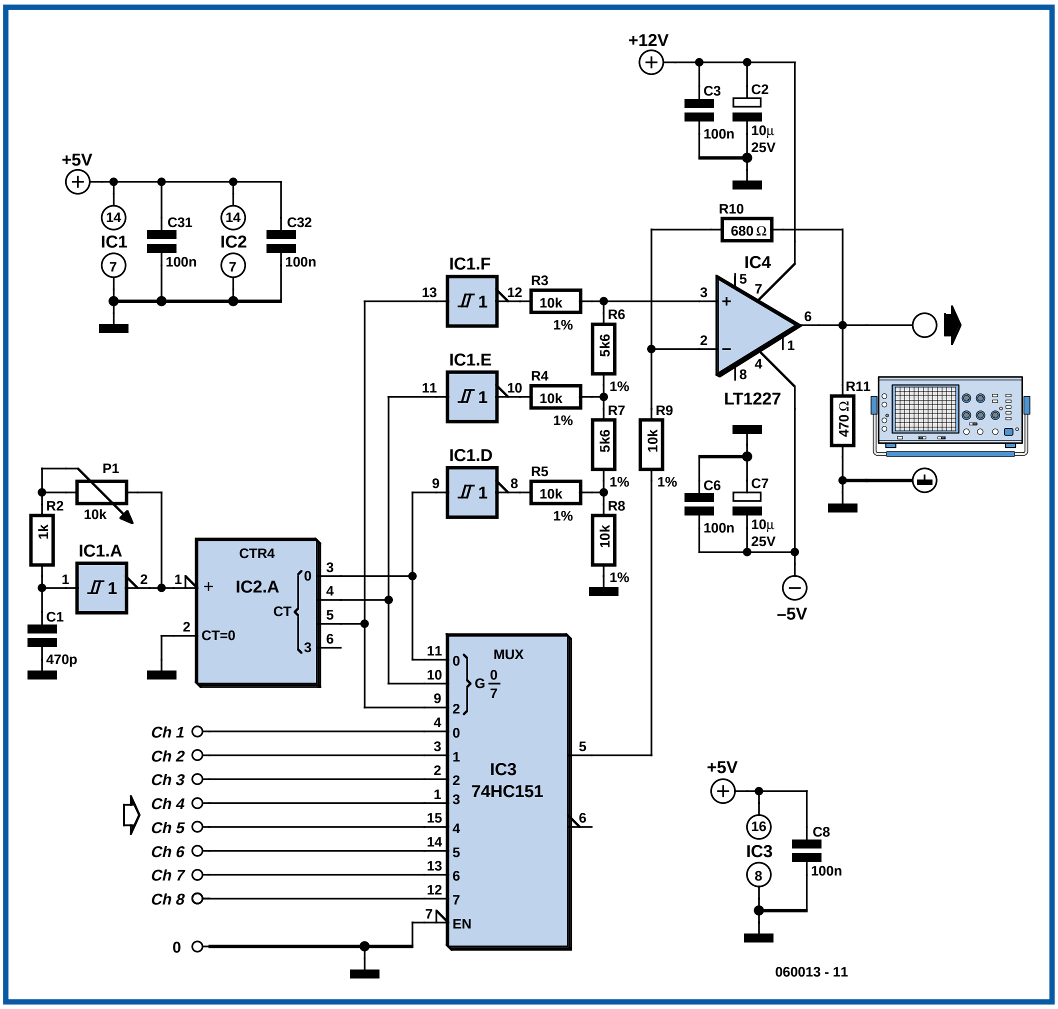
When building the circuit, it's important to ensure that IC1 is located beneath the hood in the middle and IC2 is located next to the hood or above it. If the temperature under the hood is higher than the temperature outside it, the open-collector output of IC3 will be pulled up to the supply voltage by R6. The combination of IC3 and R7–R10 forms a Schmitt trigger, which we need because the output of IC3a does not change immediately from 0 V to the supply voltage (or vice versa) in the transition region. The output of the IC3b will thus be at the supply voltage, which will switch on T1 via R10. That causes the relay to engage and switch on the fan and lamp of the range hood. P1 can be used to adjust the output voltage of IC1 over a range of approximately 0.1 V, which corresponds to around 10 °C. It's a good idea to use a supply voltage that matches the operating voltage of the relay. It's also convenient to fit the relay in a small box with an electrical outlet and plug so it can be easily and safely inserted between the plug and outlet of the range hood.

The circuit works best with a gas cooker, because the heat rises immediately after a burner is lit. With a ceramic or inductive cooking top, it takes a bit longer for the relay to be actuated.

(060089-1)

049 Eight-channel Scope Input

H. Steffes



Two channels are usually sufficient to perform the majority of circuit measurements carried out at the test bench but sometimes it would be useful to be able to see what is going on in more than two places simultaneously. The price of multichannel oscilloscopes however dictates that these are for professional users only. The circuit described here shows that with a little ingenuity it is perfectly possible to expand the numbers of input channels to eight. The circuit has been designed with simplicity in mind and can only be used for viewing digital waveforms.

There are two basic blocks to the circuit diagram; an N to 1 multiplexer and a staircase waveform generator with N output level steps. All the common logic families contain a multiplexer chip in their ranks and the type 74HCT151 (IC3) used in this design is a low-cost eight to one multiplexer which switches any one of the eight input signals through to the common output. If this output was displayed on an oscilloscope the screen would show all eight signals superimposed on each other so it is necessary to separate them vertically. This output signal is therefore mixed with the output of a staircase waveform generator which switches in time with the channel multiplex signal so that each channel is displayed as a different horizontal trace on the screen. Providing the staircase waveform remains in synchronism with the channel multiplexing, each of the eight inputs will be redrawn in the same position one above the other on the screen.

The display is useful for analysing the timing behaviour of simple digital circuits

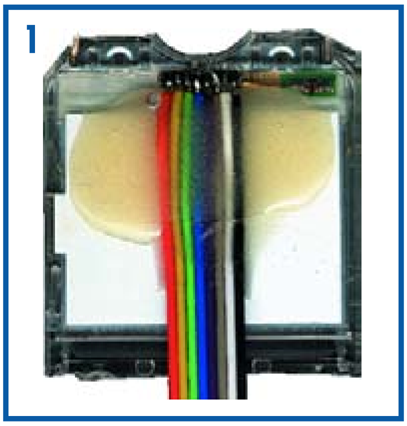
and its eight bit wide input is ideal for monitoring the data bus and input/output ports of a low-speed microprocessor system. The circuit actually is useful as a rudimentary logic analyser for digital circuits using slow clock speeds.
The staircase waveform is generated by an *R/2R* type of resistor network (R3 to R8) driven by the three binary coded outputs of the counter which also switch the multiplexer (IC3). The multiplexer output signal and staircase waveform are now mixed at the inputs of the fast opamp IC4. The oscillator frequency can be adjusted by P1 from 100 kHz to approximately 1.8 MHz. This allows adjustment of the multiplex frequency to suit the type of signal under measurement.
With a switching frequency in the order of 2 MHz it is necessary to display the eight channel outputs on an oscilloscope which has a minimum input bandwidth of around 20 MHz.

(060013-1)

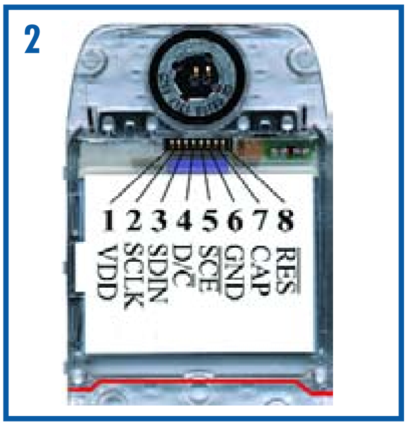
84x48-pixel Graphics LCD

050

1



2



for just a few pounds!

Marcel Cremmel

Alphanumeric displays (having ? lines of *n* characters) are very popular. Reasonably priced, they are rather easy to implement. However, here we are proposing to replace them with a graphics LCD that scores better on a number of aspects:

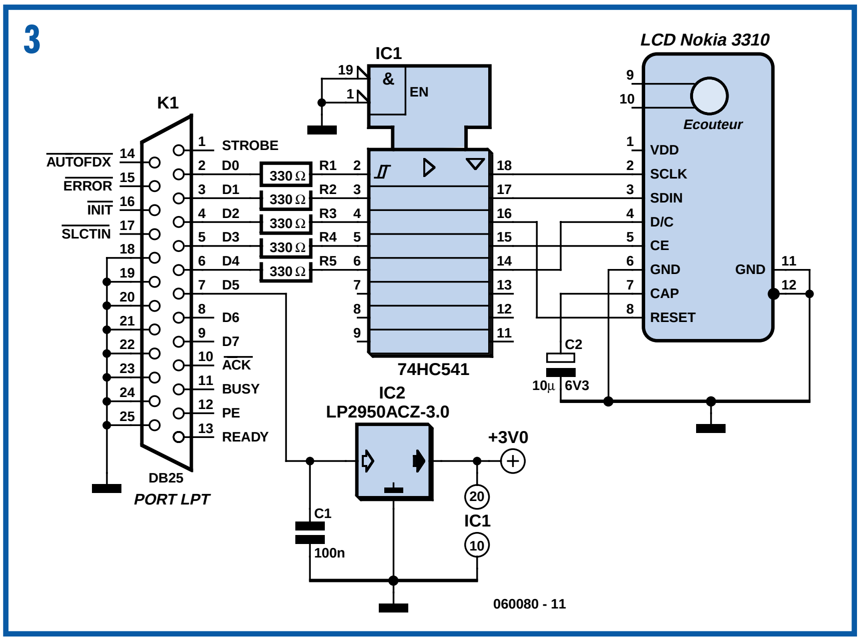
- it's graphic! (84x48 pixels);
- can be used to display up to 6 lines of 14 characters (8x5 matrix);
- anyone can create his/her own character font;
- easy to drive (5-wire synchronous serial connection);
- superior contrast;
- only consumes 110 µA at 3.3 V
- can be backlit
- and what's more it only costs from 2 to 4 pounds, new!

But where can we find this LCD with such an unbeatable price/quality ratio? Actually, we are referring to a part in a widely-distributed product: the LCD in a Nokia 3310 mobile telephone (the 3410 can also be used, the resolution is then 96x64 pixels). You can find numerous sites on the web which sell this product (new or used) as a one-off or in bulk.

After such praise, what is there to criticise? Any difficulty in implementation is due to the connections. The connector is composed of gold-plated 'spring' blades (on the LCD) which rest on solder pads (in the telephone) to establish contact. Two DIY solutions are possible:

1. we solder an 8-wire ribbon cable to the pads (**Figure 1**). Don't forget, the pitch is 1.14 mm !
2. we reproduce the original connection system. Tests have shown excellent reliability with tin-plated solder pads. Inter-

3



ested readers will find artwork for PROTEL software on the Elektor website.

Connector

Do not attempt to extract the display from its plastic casing as the display also includes part of the telephone keyboard. You can get rid of it with a plastic cutout (the red line on the photo in **Figure 2**). Do not cut out the top part if you are planning to use the original connection system — the securing screws can be used to maintain contact pressure.

Power supply

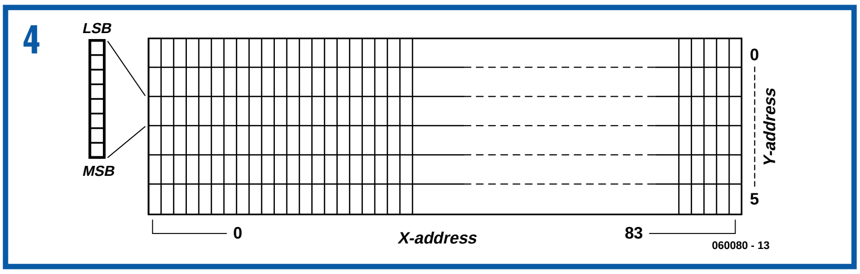
All you need to do is apply a supply voltage of between 2.7 and 3.3 V to the display. The display has its own the DC-DC converter which produces the required current for the LCD, decoupled by C2 (see diagram in **Figure 3**).

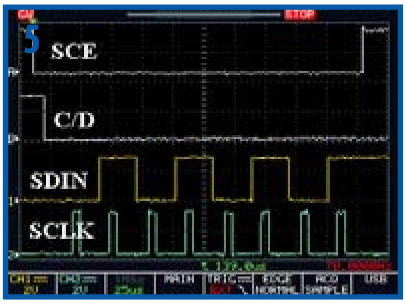
Programming

The LCD uses a controller type PCD8544 from Philips [1]. Full documentation is available on the web. The circuit has a screen memory organised into six lines of 84 bytes, or 504 bytes. The eight bits of a byte represent the states of eight vertical pixels corresponding to the screen (state 1 = black pixel, see **Figure 4**). In order to display text, for example, the program should 'draw' each letter in the screen memory.
Assigning registers for the PCD8544 configuration and for the 'screen' RAM is carried out by a synchronous serial connection:

- SCE : selection of the circuit (5)
- SDIN : serial input output (3)
- SCLK : synchronous clock (2)
- D/C : given selection/command (4)
- RES : Reset (8)

Figure 5 shows the typical timing diagram for writing a command.





You will find a test program in C on the Elektor website (ref. **060080-11.zip**) that has the most common functions: initialisation, write text (two font sizes) and simple drawing (pixel and straight track). It is written for the MSP430 family in the free IAR environment [2] but is easily adaptable to other microcontrollers because it does not rely on hardware from a specific resource (SPI coupler, among other things).
Furthermore, a program called Test_LCD_Nokia_3310 is available (see **Figure 6**). It runs on the PC and is used to test the display connected to the parallel port as shown in the diagram in Figure 3.
The installation of this program is simple: copy the executable to any folder and the TVicLPT.sys file to C:\Windows\System32\Drivers.

Available functions:

- free drawing with the mouse;
- text drawing;
- variable speed scrolling in 4 directions;
- saving the drawing.

The low current consumption of the LCD means it can be powered from the printer output port. However, a 3 V regulator and buffer gates have been added to avoid any risk of damaging or overloading the LCD electronics. For example, the LCD does not seem to like voltages applied to logic inputs in the absence of the supply voltage.

(060080-1)

Internet Links

[1] www.semiconductors.philips.com/products/

[2] MSP430, 4K KickStart Edition v3.40A on www.iar.com

The archive file 'LCD_Nokia' containing all of the files mentioned in this article can be downloaded free of charge from www.elektor-electronics.co.uk

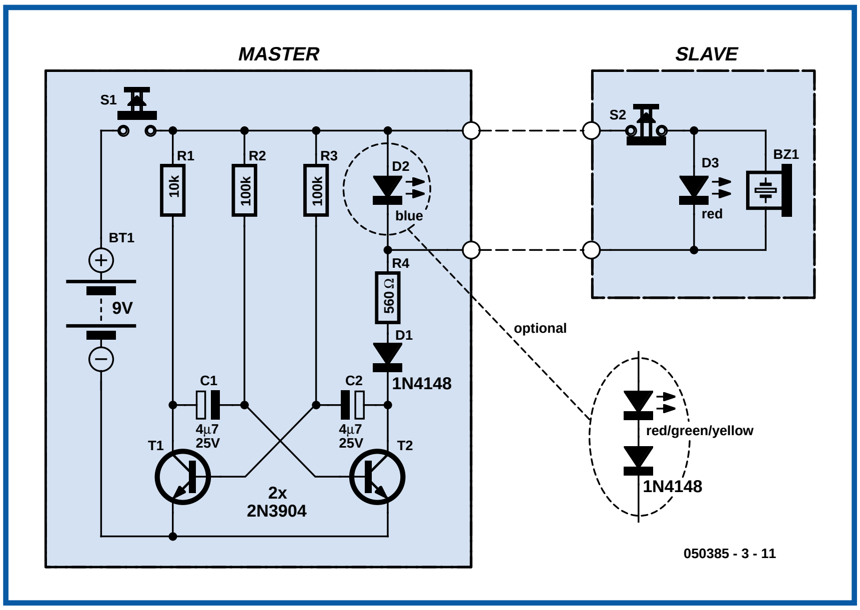
051

Call Acknowledged!

Bart Trepak

This circuit could be used (depending on your circumstances) by a gentleman to summon his butler, a manager his secretary or as in the author's case to call the kids down to dinner without having to shout above the level of the CD player/TV/games console in their bedroom. Rather than resorting to a full-blown intercom system, a simpler solution was envisaged and while a buzzer could easily fulfil this function, this circuit has the advantage of providing a visual indication of a call as well as confirming to the caller that the 'message' has been received. This is especially useful in the latter case, as the call may be easily drowned out by the music playing in the headphones.
The circuit, which requires no complicated switching, uses a simple two-wire

connection between the two stations and utilises the fact that the forward voltage drop of a blue (or white) LED is greater than that of a red, green or yellow one. The circuit is based on a two-transistor multivibrator which is used to pulse a red LED (D3) as well as the buzzer Bz1 on and off at about 1.5 Hz when push button S1 is closed. This frequency may of course be altered if required by changing the values of the capacitors. The diode D1 in series with the collector of transistor T2 is required to isolate the output from the effects of the buzzer circuitry, which would alter the multivibrator frequency.
In principle, the multivibrator could be dispensed with but a pulsed buzzer/flashing led is much more noticeable than a continuous signal especially in noisy conditions. Since the voltage across a red LED is typically about 1.5 V while a blue LED requires at least 2.5 V to 3 V to light, the blue LED will remain off when the call button S1 is pressed. Despite being rated for operation at 3-12 V, most piezo sounders can still produce a piercing sound from the pulsed 1.5-V available across the red LED which should get the attention of even the most



preoccupied teenager.
When the recipient presses the acknowledge (push to break) switch S2, the red LED/buzzer are disconnected allowing the blue LED to flash at the sending station indicating to the caller that his call has been received. Alternatively, if a blue LED is not available, a red or green type in series with a forward biased silicon diode to raise its forward voltage above that of the red LED in the receiver could be used instead.
The circuit may be powered by a 9-V battery, a mains power supply being unnecessary in view of the low power consumption and infrequency of use of the circuit.

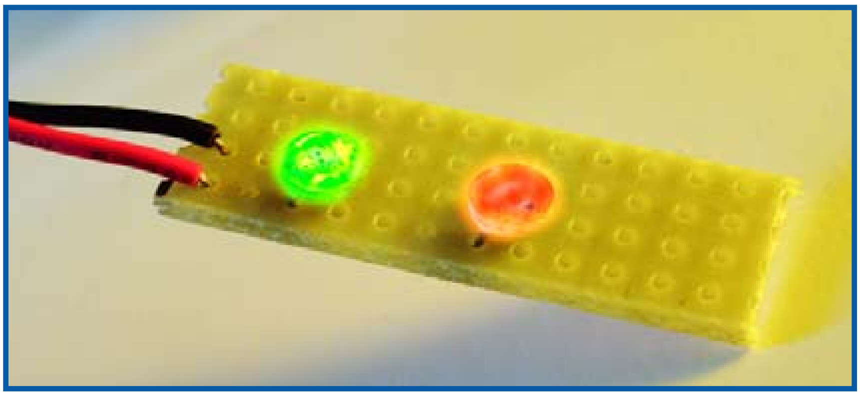
(050385-3)

Multi-Colour Flashing LED

052

Light effects have always been popular. Now that LEDs are available in all sorts of shapes, sizes and colours for reasonable prices, a whole gamut of possibilities has become feasible. Examples are case modding (embellishing PC cases with all kinds of lights, windows, etc.), adorning scooters, motorcycles and cars with various light ornaments, mood lighting in different colours and we could go on.

In *Elektor Electronics* we also regularly feature circuits with LEDs. One circuit flashes LEDs, another drives multi-coloured LEDs. On one occasion standard logic (counters, shift registers, etc.) is used to drive the LEDs, on another occasion a microcontroller is used. But there are also solutions that do not require additional driving electronics.



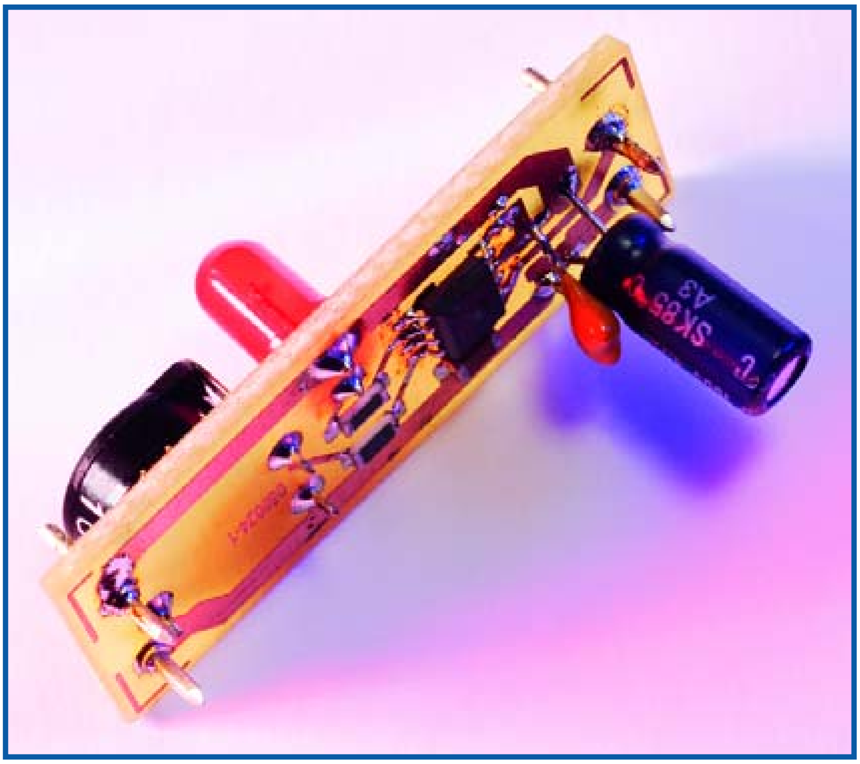
Ordinary flashing LEDs that require no more than a series resistor have been around for donkey's ages. They are quite nice, but spectacular they are certainly not. The company I.C. Engineering offers something much nicer: a three colour LED in a package with a diameter of 5 mm, which also contains all the control electronics. This 'LED' only requires a power supply voltage of 3 V to give a continuous 'light show'. The colours blend slowly from one to another. This effect is even nicer if the components are used next to each other. Because of small variations between LEDs, one LED will change colour a little faster than another, which results in a colourful play of lights. This 'LED' is eminently suitable to make a nice light ornament without too much effort.

(064014-1)

053

USB Fuse

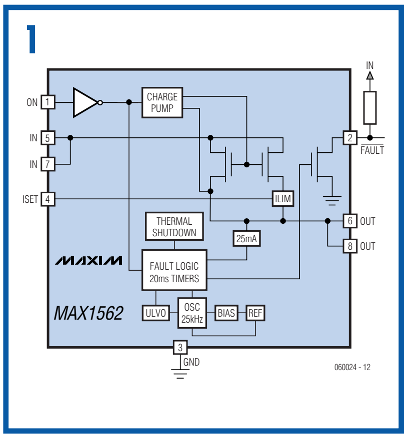
Andreas Köhler

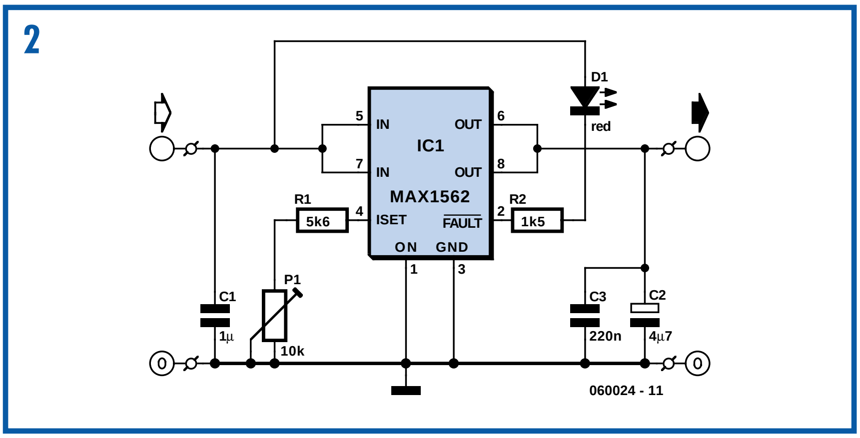


Life in the 21st century would be almost unbearable without some of the computer peripherals that PC users now look on as essentials — take for example the USB powered teacup warmer; this device is obviously an invaluable productivity tool for all users but it could prove a little tiresome if the extra current it draws from the USB port is sufficient to produce a localised meltdown on the motherboard. In a slightly more serious vein a similar situation could result from a carelessly wired connector in the design lab during prototyping and development of a USB ported peripheral. What's needed here is some form of current limiting or fuse to prevent damage to the motherboard.

The MAX1562 shown in **Figure 1** is a purpose-built USB current limiter from the chip manufacturers Maxim. The device operates with a supply voltage from 4.0 to 5.5 V with an operating current of typically 40 μA or 3 μA in standby mode. The circuit introduces a very low resistance in the power line (typically 26 mΩ but guaranteed less than 50 mΩ) from an internal MOSFET. The FET gate bias voltage is generated on-chip from a charge pump circuit.

The chip can distinguish between an overload and a short circuit condition in the supply line by measuring the voltage drop across its internal resistance; if the voltage is less than 1 V a short circuit is assumed and the chip pulses a (limited) output current every 20 ms in an effort to raise the output voltage. This approach will eventually be successful if the short



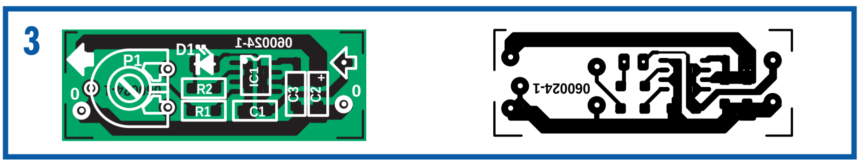


COMPONENTS LIST

Resistors
R1 = 5kΩ6 (SMD 1206)
R2 = 1kΩ5 (SMD 1206)
P1 = 10kΩ preset

Capacitors
C1 = 1µF (SMD 1206)
C2 = 4µF7 10 V, tantalum
C3 = 220nF (SMD 1206)

Semiconductors
D1 = LED, low current
IC1 = MAX1562ESA
PCB, ref. 060024-1



circuit was caused by a large value capacitor across the USB supply pins or an external hard drive which have a high in-rush at start up. If the supply rail is not pulled up within the first 20 ms the $\overline{\text{FAULT}}$ output (pin 2) is driven low.

The output current limit is set by a single resistor on pin 4 (ISET):

$$I_{LIM} = 17120 \; / \; R_{SET}.$$

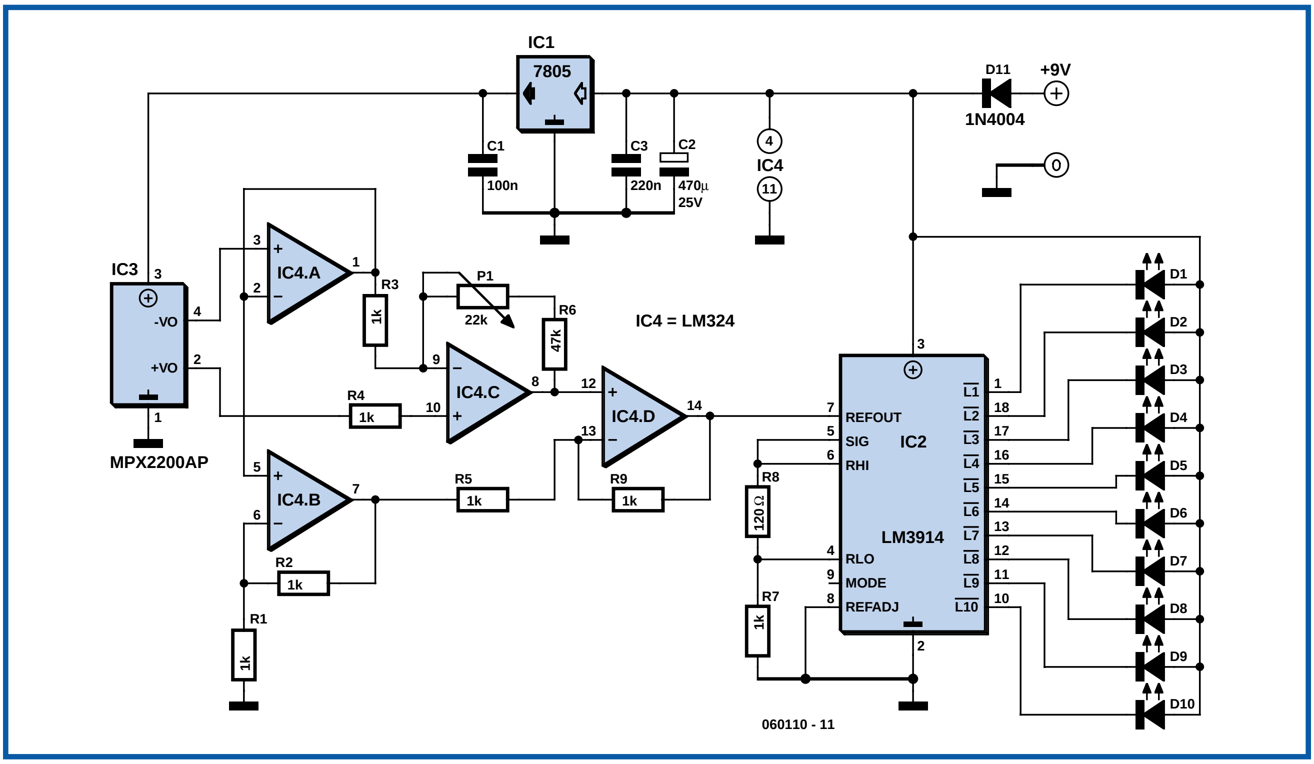
The circuit diagram shows a fixed 5.6 kΩ resistor in series with a 10 kΩ preset giving an adjustable current limit between 1.097 and 3.057 A. This range should be sufficient for the majority of applications. Increasing the preset resistance reduces the current limit level. Any intermittent connection in the preset (caused by a dirty track etc.) will switch the chip into shut down. The MAX1562 also contains a thermal cut out which turns off the output when the chip temperature exceeds 160 degrees C.

Figure 2 shows a diagram of the manufacturer's application circuit. The $\overline{\text{FAULT}}$ output drives an LED via a series limiting resistor which reduces the LED current to 2 to 3 mA. The MAX1562 is available in a HESA variant (with an active high ON signal) or ESA version (with an active low $\overline{\text{ON}}$ signal). The chip is packaged in an 8-pin SMD outline. **Figure 3** shows a small PCB layout for the circuit using mostly SMD components.

(060024-1)

Electronic Torricelli Barometer *

054



Christian Tavernier

Although it does not have the same charm as real mercury barometers with long glass tubes on pieces of carved and polished wood, the Torricelli barometer discussed here is a functional equivalent and electronic replica of the Torricelli barometer. Actually, rather than displaying the atmospheric pressure on the traditional digital displays, we preferred to reproduce the general look of this respected predecessor of electronic barometers. The mercury tube is, of course, replaced by a simple LED scale which, if not as beautiful, is still less toxic for the environment in case of breakage.

As indicated on the drawing, the pressure sensor utilized is a Motorola MPX2200AP. This circuit is adapted for measuring absolute pressure and has a range well suited for atmospheric pressure. Without entering too deep into the technical details, such sensors deliver an output of voltage proportional not only to the measured pressure but, unfortunately, to their supply voltage as well. Hence they must be powered from a stable voltage which is ensured here by the use of IC1.

Since the output of the MPX2200 is differential and at a very low level, we had to resort to the use of four operational amplifiers IC4.A to IC4.D, contained in one LM324, to obtain levels that can be processed easily. As long as potentiometer P1 is adjusted correctly, this group of operational amplifiers delivers a voltage of 1 volt per atmospheric pressure of 1,000 hPa to the LM3914. Since the atmospheric pressure will be within the range 950 to 1040 hPa at sea level, we need to make an expanded-scale voltmeter with this LM3914 in order to better exploit the 10 LEDs that it can control. That is the role of resistors R7 and R8 which

artificially raise the minimum voltage value the chip is capable of measuring.
Consequently, we can 'calibrate' our LED scale with one LED per 10 hPa and thus benefit from a measurement range which extends from 950 hPa to 1040 hPa. In principle, you should not have a need to go beyond that in either direction.
The circuit may be conveniently powered from a 9-volt battery but only if used very occasionally. Since this is usually not the case for a barometer, we advise you to use a mains adaptor instead supplying approximately 9 volts.
Calibration basically entails adjusting the potentiometer P1 to light the LED corresponding to the atmospheric pressure of your location at the time. Compare with an existing barometer or, even better, telephone the closest weather station. They will be happy to give you the information.

(060110-1)

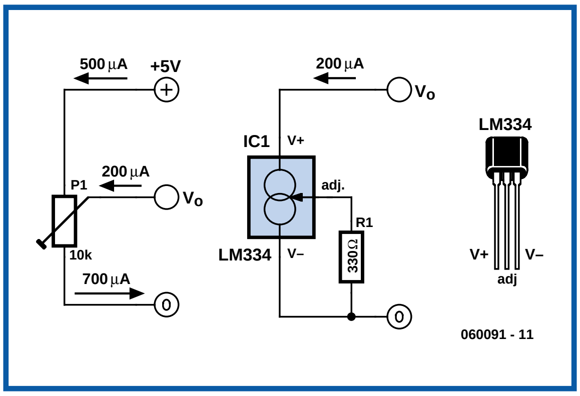
* After Evangelista Torricelli, 1608-1647, Italian physician who proved the existence of atmospheric pressure and invented the mercury barometer.

055

Contrast Control for LCDs

Heino Peters

The adjustment control for the contrast of an LC-Display is typically a 10-k potentiometer. This works fine, provided that the power supply voltage is constant. If this is not the case (for example, with a battery power supply) then the potentiometer has to be repeatedly adjusted. Very awkward, in other words. The circuit described here offers a solution for this problem.



The aforementioned potentiometer is intended to maintain a constant current from the contrast connection (usually pin 3 or V_o) to ground. A popular green display with 2x16 characters 'supplies' about 200 µA. At a power supply voltage of 5 V there is also an additional current of 500 µA in the potentiometer itself. Not very energy efficient either.
Now there is an IC, the LM334, which, with the aid of one resistor, can be made into a constant current source. The circuit presented here ensures that there is a current of 200 µA to ground, independent of the power supply voltage. By substituting a 2.2-kΩ potentiometer for R1, the current can be adjusted as desired. The value of R1 can be calculated as follows:

$R1 = 227 \times 10^{-6} \times T / I.$

Where *T* is the temperature in Kelvin and *I* is the current in ampères. In our case this results in:

$R1 = 227 \times 10^{-6} \times 293 / (200 \times 10^{-6})$
$R1 = 333\ \Omega$

Note that the current supplied by the LM334 depends on the temperature. This is also true for the current from the display, but it is not strictly necessary to have a linear relationship between these two. Temperature variations of up to 10° will not be a problem however.
This circuit results in a power saving of over 25% with an LCD that itself draws a current of 1.2 mA. In a battery powered application this is definitely worth the effort! In addition, the contrast does not need to be adjusted as the battery voltage reduces.
When used with LCDs with new technologies such as OLED and PLED it is advisable to carefully test the circuit first to determine if it can be used to adjust the brightness.

(060091-1)

056

Protection for Telephone Line

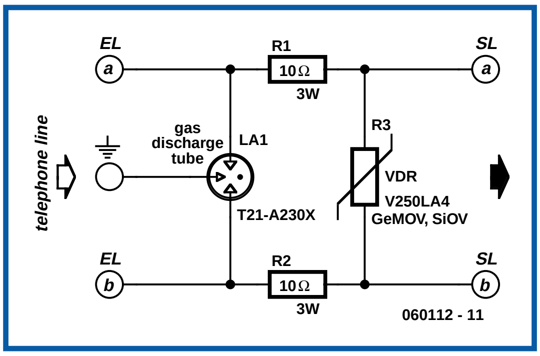
Christian Tavernier

A long time ago when telephones were so simple almost nothing could go amiss from an electrical point of view, Telecom operators installed surge protection on all telephone lines exposed to storm risks. Paradoxically, now that we are hooking up delicate and expensive equipment such as telephones filled with electronics, fax machines, (A)DSL modems, etc., this protection has disappeared.
However, if you have the good fortune to live in the countryside in a building served by overhead telephone lines, there's an obvious risk of very high voltages being induced on the lines during thunderstorms. While we have lost count today of all of the modems, fax machines and other telephones that have been destroyed by a 'bolt of lightning', surpris-

ingly you only have to invest a few pounds to get a remarkably efficient protection device like the one we are proposing here.

During a storm, often with lightning striking near a telephone line, the line carries transient voltages up to several thousands of volts. Contrary to the HV section of television sets or electrical fences, on which practically no current is running, in the case of lighting striking current surges of thousand of amps are not uncommon.

To protect oneself from such destructive pulses, traditional components are not powerful or fast enough. As you can see on our drawing, a (gas-filled) spark gap should be used. Such a component contains three electrodes, insulated from each other, in an airtight cylinder filled with rare gas. As long as the voltage present between the electrodes is below a certain threshold, the spark gap remains perfectly passive and presents an impedance of several hundreds of MW. On the other hand, when the voltage rises above this threshold, the gas is very rapidly ionized and the spark-gap



suddenly becomes a full conductor to the point of being able to absorb colossal currents without being destroyed. The one we are using here, whose size is of the same magnitude as an ordinary one watt resistor, can absorb a standardized 5,000 amps pulse lasting 8/20 ms!

Since we are utilizing a three-electrode spark gap, the voltage between the two wires of the line or between any wire and ground, cannot exceed the sparking voltage, which is about 250 volts here. Such protection could theoretically suffice but we preferred to add a second security device made with a VDR (GeMOV or SiOV depending on the manufacturer), which also limits the voltage between line wires to a maximum of 250 volts. Even if this value seems high to you, we should remember that all of the authorized telephone equipment, carrying the CE mark must be able to withstand it without damage. This is not always the case however with some low-end devices made in China, but that's an entirely different problem.

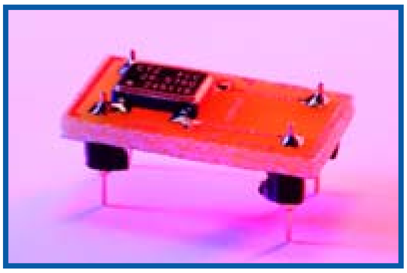
Since pulses generated by lightning are very brief, the ground connection of our assembly must be as low-inductance as possible. It must therefore be short, and composed of heavy-duty wire (1.5 mm^2 c.s.a. is the minimum). If not, the coil, composed of the ground connection, blocks the high frequency signal that constitutes the pulse and reduces the assembly's effectiveness to nothing.

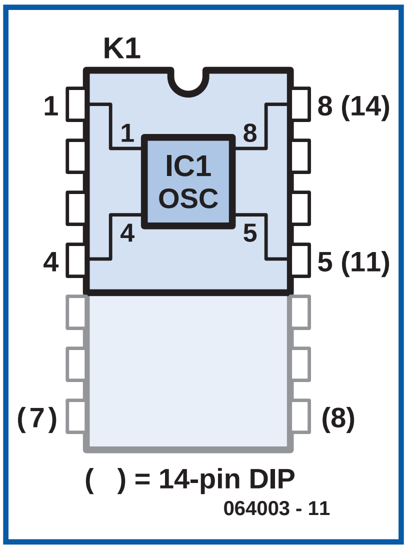
Finally, please note that this device obviously has no effect on the low frequency signals of telephones and fax machines and it does not disturb (A)DSL signals either.

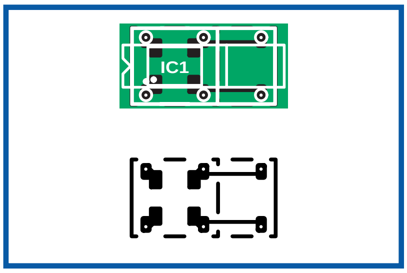
(060112-1)

SMD Crystal-Adapter

057







Ton Giesberts

The idea for this adapter was really born out of necessity. The 24.576-MHz crystal oscillator that is used in the Audio ADC 2000, (24 bit/96 kHz, March 2001) is not (easily) available any more. A colleague who was interested in the circuit and was keen to try out the prototype realised that a 25 MHz oscillator was used at the time. In order to create useful recording material it is of course necessary to use the correct sampling frequency, 48 kHz, that is. This requires 512 times 48000 Hz, or 24.576 MHz. Fortunately this frequency is available as part of a series of oscillators from Citizen, the CSX-750FC series, to be more specific.

These oscillators are housed in a very small SMD package. We originally used the SG531P-series from Seiko Epson in the design for the A/D-converter. This comes in a kind of 8-pin DIL package. So, to nevertheless enable us to use the Citizen version, we designed a very small circuit board that adapts the SMD device with 4 pins to the footprint for the 8-pin DIP version. The connection pin order is the same. In addition, we have made the PCB also suitable for the 14-pin version (SG531P series). This requires two additional pins. These are located at pins 7 and 8 of the 14-pin package and are connected to pins 4 and 5 respectively of the 8-pin package. Pin 1 is in both cases the enable pin and pin 8 (8-pin) and 14 (14-pin) are +5 V. Pay close attention when ordering the oscillator. It so happens that there are also 3.3-V versions (CSX-750FB and FJ). You need a 5-V version for the Audio-DAC.

There is also a third letter after the type number, which indicates the accuracy: C or F for 100 ppm and B for 50 ppm.

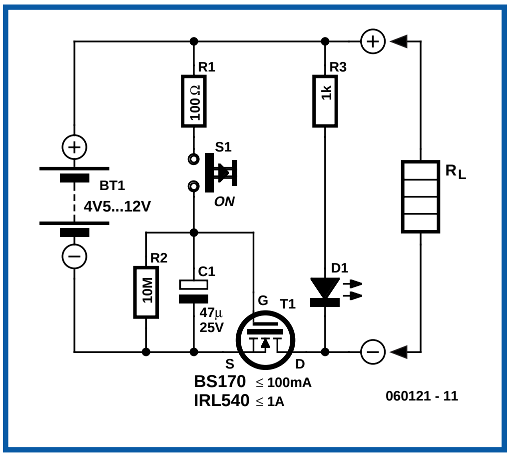
If the PCB is to be used in place of an 8-pin oscillator then you can trim the board along the line that is clearly visible on the solder side of the board. The solder side (copper side) is the top side. Just to be clear: the dot on the package of the CSX750FCC is pin 1 of the oscillator. We used thin pin headers for the connections so that the small adaptor can be fitted into an IC-socket or soldered directly onto a PCB.

The IC is available from Digi-Key.

(064003-1)

058 Battery Saver

This circuit performs a similar function to the 'sleep' button on a radio alarm clock; pressing the button connects the battery supply to some external equipment or circuit (represented by RL) for a preset time period. The period can be extended by pressing the button again before 'time out'. The circuit will avoid the situation where you forget to turn off some battery powered equipment and return to find the battery is flat. Unlike a digital alarm clock sleep function the circuit here is based on a simple analogue timer which uses very few components. Pressing button S1 rapidly charges C1 via R1. When the voltage on C1 exceeds the threshold voltage at the gate of FET T1 it conducts and switches the battery to RL. The drain-source voltage drop introduced by the FET is negligible for the two types of FET specified (for a maximum load current of either 100 mA or 1 A).



T1 remains conducting as long as the voltage on C1 is greater than the FET gate threshold voltage (around 2 V for the FET types specified). The length of the 'on' period depends on three factors; firstly the value of R2 which governs the capacitor discharge current, secondly the capacitance of C1 and finally the supply voltage from the battery BT1. When C1 is charged to a higher voltage it takes longer to fall below the threshold level. The component values given will produce an 'on' time of around 10 minutes with a supply of 5 V. The FET turns off relatively slowly at the end of the 'on' period; this should not cause a problem if the switched equipment uses only analogue circuitry but can lead to a momentary malfunction if the equipment contains digital circuitry.

(060121-1)

059 Electronic Touch Switch

Heino Peters

Mechanical contacts have the disadvantage that they wear out. That is why it is practical to use an electronic 'touch switch' in some situations. With such a touch switch the resistance of the human skin is used for the switching action.

The schematic shows the design of a circuit that senses the resistance of the skin and converts it into a useful switching signal. The touch switch contacts can be made from two small metal plates, rivets, nails, etcetera, which are placed close together on a non-conducting surface. In this circuit a comparator of the type LM393 has been used.

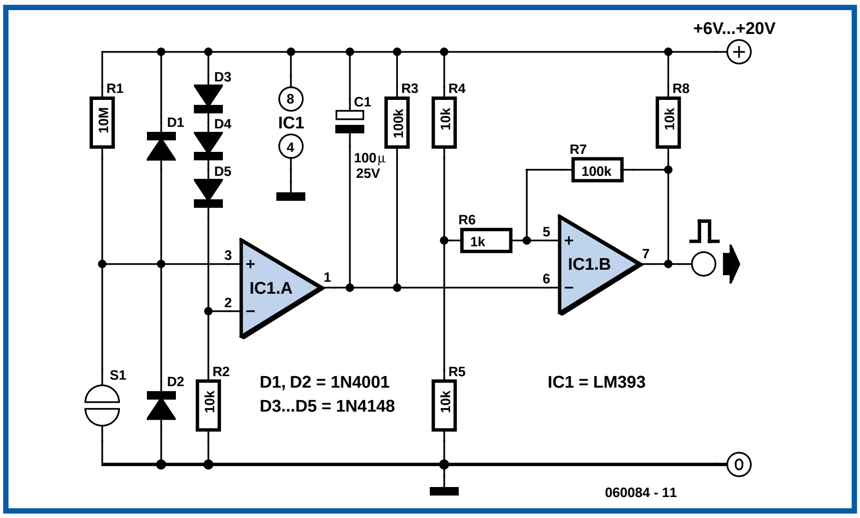
In the idle state there is, via R1, a voltage equal to the power supply voltage on the non-inverting input of IC1a. Because the inverting input of IC1a is set with R2 and D3 to D5 at the supply voltage minus 1.8 V, the open-collector output of IC1.a is, via R3, equal to the power supply voltage. This voltage is inverted by IC1.b.

The voltage at the non-inverting input of IC1.b amounts to half the power supply voltage (through voltage divider R4 and R5) and is lower than the voltage on the inverting input. The output of IC1.b is therefore a '0'.

If the two touch contacts are bridged with a finger, the voltage at the non-inverting input will become low enough to cause the comparator to toggle state. The moistness of the skin results in a resistance of 1 to 10 MΩ.

If this circuit is used in the vicinity of equipment that's connected to the mains, then it can be sufficient to touch only the upper contact to operate the switch, provided that the circuit has been earthed. The body then acts as an antenna which receives the 50 Hz (or 60 Hz) from the mains. This is enough to toggle IC1.a at the same 50 Hz. C1/R3 prevent this 50 Hz from reaching the input of IC1b and provide a useable 'pulse' of about 10 s at the output of IC1.b.

Note that a fly walking across the touch switch conducts enough to generate a switching signal. So do not operate important things with this circuit (such as the heating system or the garage door). Do not make the wires between the touch contacts and the circuit too long to prevent picking up interference.



The power supply voltage for the circuit is not very critical. Any regulated DC voltage in the range from 6 to 20 V can be used.

(060084-1)

Audible Flasher Warning

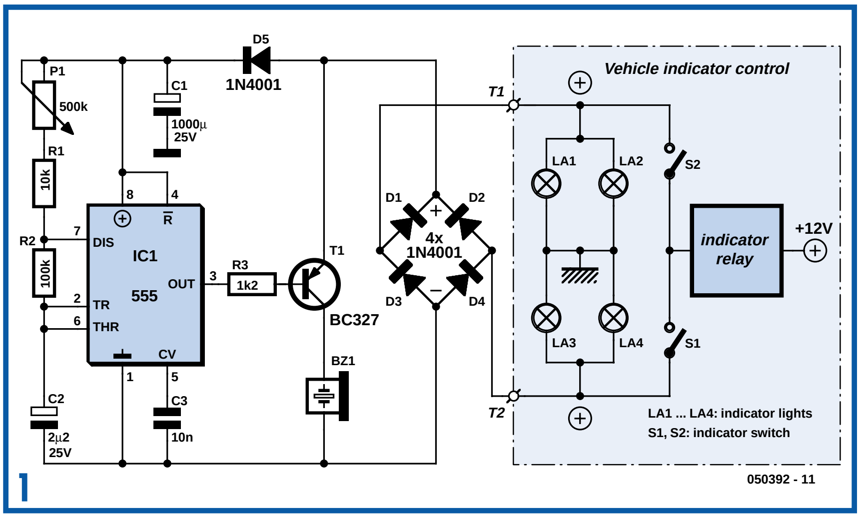
060

Udo Burret

If you're a biker or scooter rider you'll know how easy it is to forget to cancel your flashing indicators after turning without an audible reminder. Constantly glancing at indicator lamps is hardly an option; your eyes should be on the road ahead! The simple circuit shown here provides an audible reminder. The clever bit is the way it doesn't annoy you by beeping the instant you activate the flashers but only after a preset time, in other words when your indicators are active longer than normal.

Supply to the circuit is through the flasher relay. With the indicators activated a squarewave voltage reaches bridge rectifier D1-D4 via terminal T1 or T2, with the other terminal remaining grounded through the indicator lamp that's inactive. The pulsed DC voltage is stored and smoothed in C1, with D5 preventing the electrolytic from discharging during the periods when the flasher voltage is off. This also provides an adequately clean supply voltage for the 555 timer whenever the indicators are operating.

Timer IC1 is used here as an oscillator and controls a piezo sounder by means of transistor T1. The output of the 555 is active Low, meaning that initially the transistor is blocked and the sounder is silent.



The timer always charges and discharges capacitor C2 to a level between a third and two-thirds of the operating voltage, producing an interval of

0.7 x C2 x (R2 + R1 + P1) [s]

The preset enables you to set this delay up to a second or so. The initial delay, before the sounder first operates, is significantly longer, however, because the electrolytic has zero charge. Only after this delay is the output active, for the pulse duration of 0.7 x C2 x R2 (equivalent to about 0.15 seconds), enabling the sounder to operate. This applies only when +12 V is present at the collector of transistor T1, which is the situation when the flasher relay is just switched on and the indicator bulbs light up.

The circuit is built inside a splash-proof enclosure, installed on your machine in a position that's out of harm's way. The audible sounder can be positioned anywhere outside the enclosure if it's a waterproof type. The audible control unit requires only two cable connections, which can be made at any convenient access point.

(050392-1)

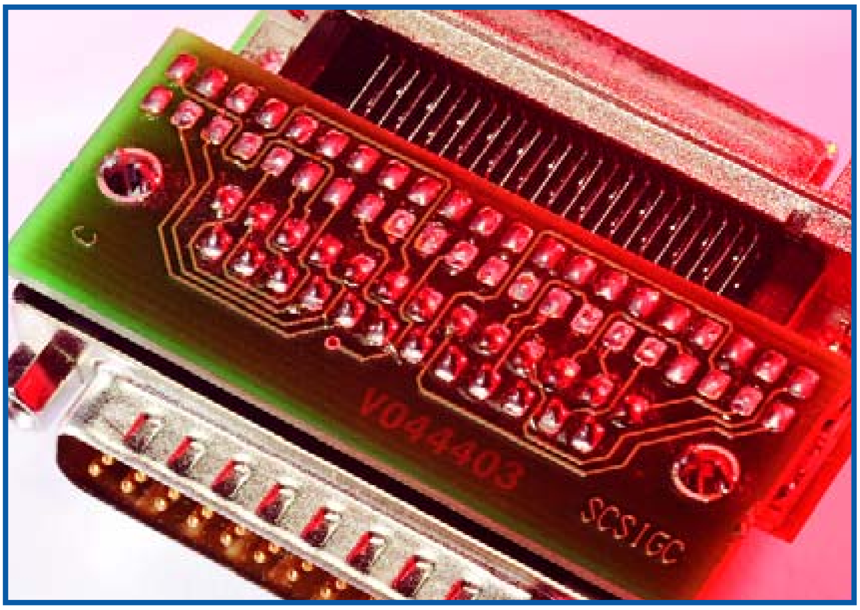
061 SCSI Adapter

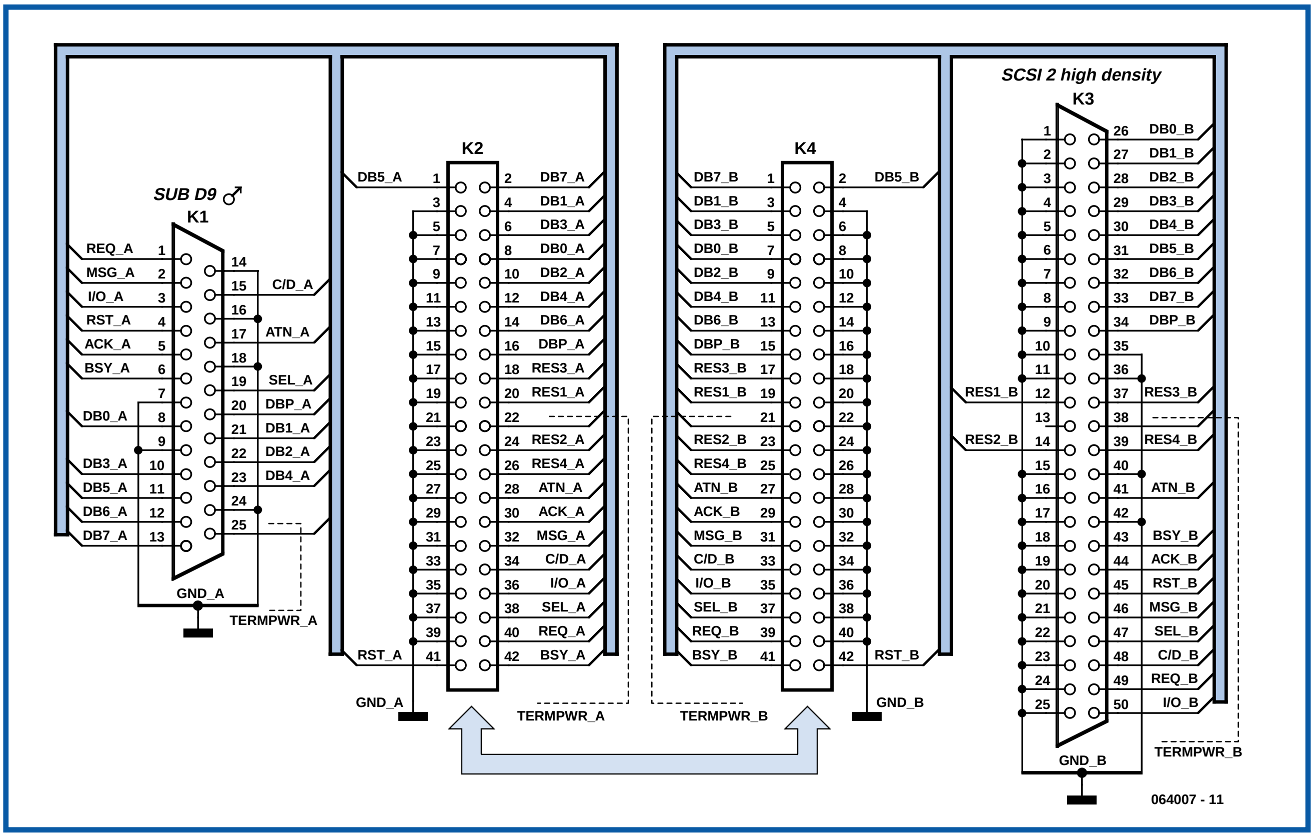
Ton Giesberts

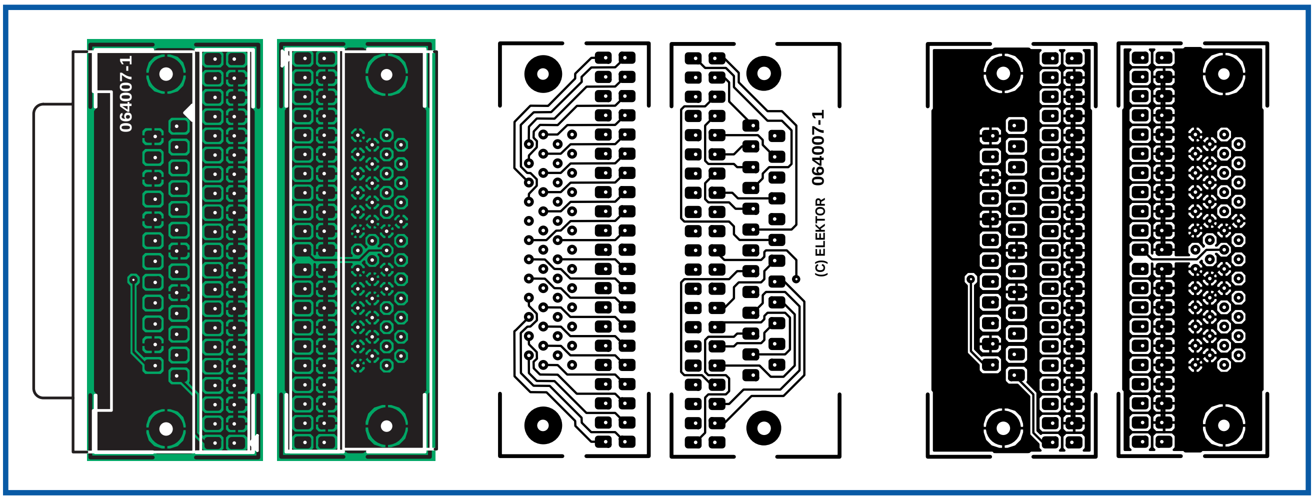
This circuit (admittedly a big word for three connectors), was born out of necessity. Many years ago, when reliable scanners were still being made, there were faster and more expensive models with a SCSI interface. In many cases, as part of the package, a proprietary SCSI controller for the PC was delivered with it. This was typically an ISA bus controller. When upgrading to another SCSI controller (PCI-bus), and also motivated by being able to connect better hard disks and other peripherals, a new cable was required to connect the high-density connector of the new controller to the older 25-way sub-D or 50-way Centronics connector.

In these days of SATA2 and FireWire, the use of SCSI as a fast interface to devices is no longer required, unless you happen to have, for example, a very good quality scanner with SCSI interface. There are converters that can connect a SCSI device to the USB-bus. These have a male high-density connector for the SCSI interface, while the controllers internal to the PC have a female connector. The new cable that you bought cannot be used and you will have to look for another solution. One of these is to make an adaptor, which allows the USB/SCSI converter to be connected directly to the scanner. For the scanner we assumed a 25-way sub-D and for the converter a high-density connector. The schematic shows the necessary connections and their names. We don't discuss this any further, there is plenty of information available on the Internet.

The PCB consists of two parts. One is for







fitting the right-angle 25-way male sub-D connector and the other for the high-density connector. The PCB has been designed in such a way that the two component sides can be connected together via a double row pin header (2?21 pins). By selecting the spacing between the boards just right, so that the height of the connectors is about the same, a robust and compact adapter can be made. The photo shows what the intention is. There is really no opportunity for mistakes. K2 is also K4 and there is therefore only one pin header required. You may have to take into account the locking screws of the male sub-D connector. These are probably already present on the scanner and you will have to remove them from the adapter. The adapter is held in place firm enough without the locking screws.

Unfortunately it turned out that the software for the scanner could not cope with the USB driver for the converter, but that is another story.

(064007-1)

COMPONENTS LIST

K1 = 25-way sub-D plug (male), angled pins, PCB mount
K2,K4 = 2x21-pins pinheader (see text)
K3 = 50-way angled SCSI-2 high-density connector, PCB mount (e.g., Farnell # 369-3752 or # 854-037)
PCB, ref. 064007-1

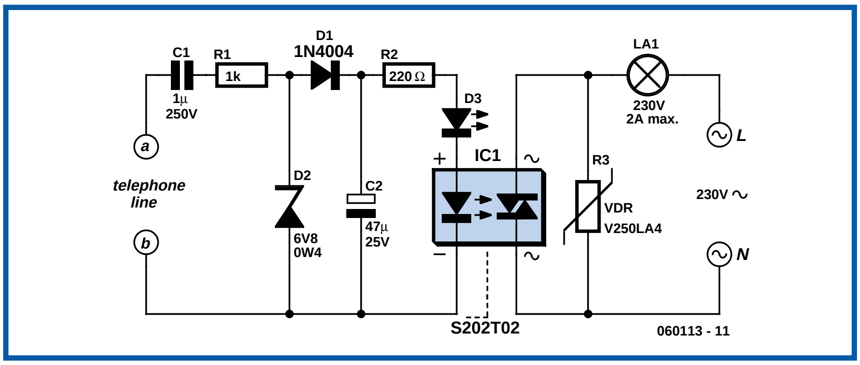
Telephone Ringer

062

Christian Tavernier

If you are lucky enough to have a big house, a large garden, and small children, this project just might interest you. It's actually a telephone ringer capable of making any mains-powered device work from the ringer of your fixed line. With it, you will be able to control a high-powered siren or horn, as you like, in order to relay and amplify the low-level sound of your telephone (making it audible in a big house or in a large garden)! Alternatively, you can make a lamp light (or an indicator light) and so create a 'silent ringer' (helpful when small children are napping). The other interesting part of this simple and inexpensive project is that it doesn't require a power supply, contrary to similar items on sales in the shops.

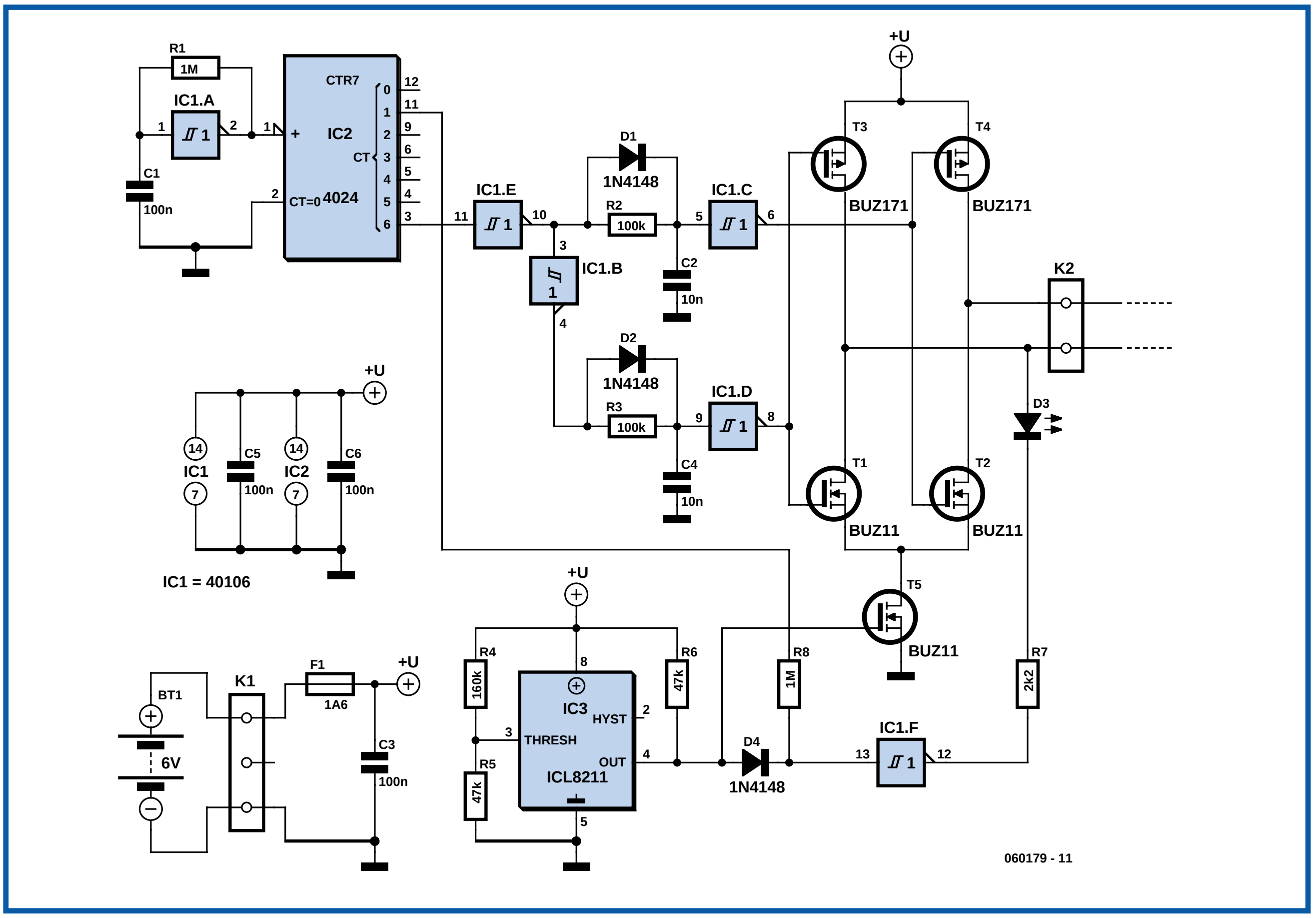
Before examining the drawing and understanding the principle involved, it is important to know that the ringer voltage on a fixed telephone line is pretty high. Since Europe and the EU Commission have not yet interfered, the exact value of this voltage and its frequency varies according to the country, but that's not important here. The line carries direct current whether unoccupied or occupied. Moreover, no more than a few hundred mAs needs to be stolen from an unoccupied telephone line to make the PSTN exchange believe the line is occupied. Therefore, capacitor C1 has the dual role of insulating this project with respect to direct current present on the line while unoccupied, or while occupied, while also allowing the ringer current to pass. The latter is rectified by D1 and clipped by D2 which makes about 6 V DC available to the C2 terminals when a ringer signal is present. This voltage lights LED



D3 which only serves as a visual indicator of proper operation as does the LED contained in IC1. This is a high-power photo triac with zero crossing detection from the mains, which allows it to switch the load it controls without generating even the lowest level of noise. This component, that we might just as well call a solid-state relay, was selected because it is comes in the form of a package similar to a TO220, a little bigger, and equipped with four pins. The pinout will not cause confusion because the symbols shown on our diagram are engraved or printed on the packaging. Since this circuit is not yet very common, we need to mention that it's available from the Conrad Electronics website (www1.uk.conrad.com).
For the purpose of safe operation, the circuit is protected by a GeMOV on the mains side, called Varistor, VDR or SiOV depending on the manufacturer. The model indicated here is generally available. The load will be limited to 2 A, considering the model selected for IC1, which is more than sufficient for the application planned here.
Finally, since a number of components in this circuit are connected directly to the mains power supply, the assembly should be placed in a completely insulated housing for obvious safety reasons.

(060113-1)

063 Slug Repellent



Uwe Kardel

Anyone who has a vegetable garden knows the problem. As soon as the strawberries start to get some colour, a net needs to be placed over the plants to prevent birds from eating the harvest. But what emerges the next morning? Someone still has had a nibble from the nicest strawberry. The culprit is usually still in the neighbourhood: A large brown slug.

Something should be done about this, any right-minded electronics engineer is never going to admit defeat. Special ridges are available from garden centres to stop slugs and there is also a special ribbon shaped material with wires woven in. The power supply comes from a 9-V battery. A practical experiment indicated that slugs were not the least bothered by these current-carrying wires: they nonchalantly climbed right across the ribbon.

A second experiment was done based on a home-made design: Square pieces of PCB material of 5x5 mm were glued on the four corners of a large printed circuit board. Copper wire with a diameter of 1 mm was soldered on the little squares so that the surface of the PCB was completely enclosed. A voltage of 6 V was applied to the copper wire. This worked much better. Two slugs that acted as guinea pigs stayed the entire night on the

PCB. They were, despite the rain, not able to beat the electronic obstacle. Unfortunately, by the morning the copper wire was already badly oxidised.
The search was now on for a practical mechanical construction for this system in the garden. Moreover, AC has to be used for the power supply to limit the corrosion. The first choice was an L-shaped tinplate profile of 12x165 mm. The long side of the metal was pushed deep into the ground to prevent the slugs from crawling underneath. Every 15 cm small pieces of PCB of 10x10 mm were glued on top (250 pieces in total), with the copper wire soldered on top of that. The distance between the tin sheet and the copper wire was about 1.5 mm. The results were excellent: not a single slug dared to cross the barrier. They crawled up to the copper wire and then turned back.
Except, this barrier does not work against flying slugs. Flying slugs? Certainly! These are the slugs that the neighbour finds in his garden and throws across the fence.
After a few months, it was noticed that the battery was exhausted quite quickly and there was also some corrosion. Measurements indicated that during heavy rain the current could increase to about 1 A because of droplets on the copper wire. So, another solution was required. The wires had to be suspended, just like the overhead conductor of a tram.
In the next experiment, a square of 1x1 m was surrounded by a slug barricade where the wire was fastened on the underside of the horizontal piece of tin sheet. Ten slugs were placed inside the square. Nothing happened at first: the slugs sleep during the day. At the fall of dusk they started to move and they appeared to be able to escape the square without effort. They did this by stretching themselves out at a right angle and bypass the copper wire without touching it. This was obviously not a good solution. Therefore, another, new construction was required.
The solution was found by suspending the wire outside the tin sheet, at a distance of about 5 mm. The slugs are then unable to pass without touching the wire and water droplets hang straight down from the wire where there is no tin sheet.
The wires are again soldered to small PCBs, which are screwed to the tin sheet angle profile. For this purpose a hole of 3.2 mm diameter was drilled in the tin sheet every 15 cm. First, the PCBs are screwed to the tin profile, the profile is placed in the garden and bent into the correct shape to enclose the strawberry field. The final step is to attach the wire to the PCBs. During assembly, it is wise to keep a conduction tester at hand and check frequently for short circuits. The smaller the distance between the wire and the tin sheet, the better it works, even against small snails, but as the distance is decreased, the risk of short circuits is increased.
This installation has proved itself in a practical experiment lasting two years. During this time it functioned without problems and keeps slugs out of the vegetable garden.
The AC voltage power supply consists of a clock generator, a driver stage in bridge configuration and an under-voltage detector. The clock generator is formed by R1, C1 and IC1a. No great demands are placed on the clock circuit, except one: Only when the duration of the positive voltage is exactly identical to the duration of the negative voltage is the corrosion of the wires effectively suppressed. That is why IC2 divides the generated frequency by two and in this way guarantees a duty-cycle of exactly 50%. The buffer stages are built around IC1b, c, d and e and provide for a small delay in the drive signal for the driver stage. This prevents that T1 and T3, and T2 and T4 respectively are driven simultaneously. Otherwise the current consumption of the circuit is too high. The circuit alternately turns on T1 and T2 at the same time, or T3 and T4. In this way, a square wave AC voltage of 12 V_{pp} is generated at the output.
IC3, an ICL8211, provides the under-voltage protection. The LED flashes slowly while the battery is in good condition. When the voltage becomes too low, the LED will flash faster. In addition, transistor T5 will block, so that no voltage is applied to the slug barrier any more. This is only necessary if the circuit is powered from a rechargeable battery. If ordinary batteries are used to power the circuit, T5 can be omitted and replaced with a wire link. With a battery power supply it is also a good idea to connect a switch in series with the LED, which is then only turned on when checking the battery voltage. This improves the life expectancy of the battery. This reduces the current consumption from 1.5 mA to 0.4 mA. During damp weather the current consumption increases considerably.

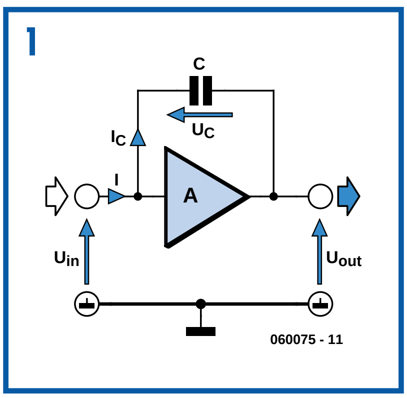
(060179-1)

Miller Capacitor

064

Gert Baars

There are amplifier circuits that have capacitance between the input and output. If the gain is positive, this can lead to oscillations. If the gain is negative, another outcome is the result. We can deduce this from the following theoretical circuit.
An amplifier with a negligibly low output impedance, an infinitely high input impedance and gain A has feedback in the form of capacitor *C* (refer **Figure**



1). The gain *A* is negative. In addition, input current *I*, input voltage *U* and output voltage U_o are also drawn in. The input current *I* is equal to I_c and the input voltage *U* is equal to $U_c + U_o$. U_o in turn is equal to the product $A\ U$. From this follows that

$$U_c = U – U_o = U\,(1 – A).$$

Substituting into the formula the current that flows through a capacitor, $I_c = C(dU_c/dt)$ results in

$$I = C \cdot \frac{dU(1-A)}{dt}$$

We rearrange this as

$$I = (1-A) \cdot C \cdot \frac{dU}{dt}$$

Now we can see that the gain determines the relationship between *I* and *C*. *C* appears to be larger by a factor of (1–A) (note: if *A* is negative, you can actually speak of a factor 1+*A* larger).

This is called the Miller effect. The apparent (larger) capacitance is called the Miller capacitance. When designing signal amplifiers you need to take this capacitance into account. We can actually use this Miller capacitance in other ways. If we make *A* variable, with an adjustable resistor for example, we create a variable capacitor. For this purpose we conceived the following schematic (see **Figure 2**).

C_m is the apparent capacitor between the input of the circuit and ground. If we connect a signal generator via a series resistor to the input and measure the input voltage with an oscilloscope, we can easily determine the corner frequency.

JFET-opamp A1 is necessary to prevent R1 from appearing in parallel with C_m and affecting the corner frequency. A2 is the actual (inverting) amplifier. The gain of A2 is equal to P1/R1. *C* is the capacitor which is enlarged artificially. The remaining components only serve to set the operating point of the circuit. C_b blocks any DC voltages and needs to be relatively large, for example 25 times the maximum C_m.

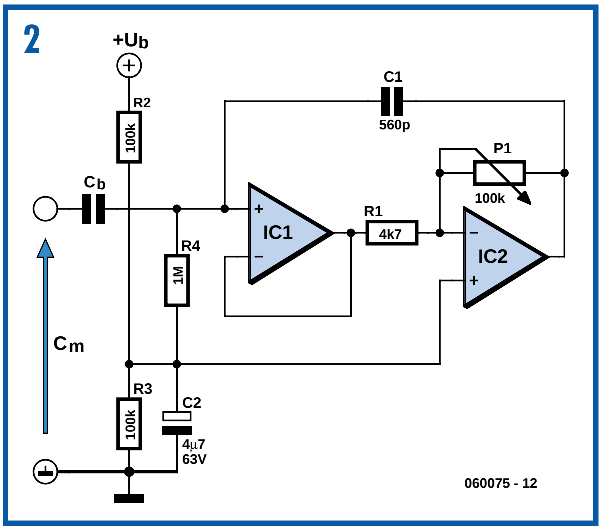
From the test results it appears that C_m is indeed equal to (1+P/R1) *C*. C_m can be varied with a potentiometer from about 560 pF to 12 nF.

As is usually the case, there are a few limitations in practice. The input signal may not be too large. Otherwise, the AC voltage across C_m will cause clipping at the output of the second opamp. At maximum C_m, the gain of A2 is about 20 times. The peak-to-peak value of the input voltage may therefore not be more than about $^1/_{20}$ of the power supply voltage. The circuit will always work well for smaller signals, provided the frequency is not too high.

For A1 and A2 we used an LF356 and TL081 respectively. These are mainly used for frequencies not exceeding 100 kHz. Very fast JFET opamps could extend the useful frequency range to applications in the RF-range. For LF applications we could also use a dual opamp for A1 and A2, such as the TL082.

The value of capacitor C can be changed to suit the application. With opamps of the type AD8099 with a C of 22 pF we can make a (tuning) capacitor with a value from 22 to 440 pF, for use up to 30 MHz. The alternative, a varicap diode that can be varied in capacitance over a range of 20 times (or more) is not used in practice very much any more. Other applications for this circuit are, for example, adjustable LC-filters for audio applications.

(060075-1)

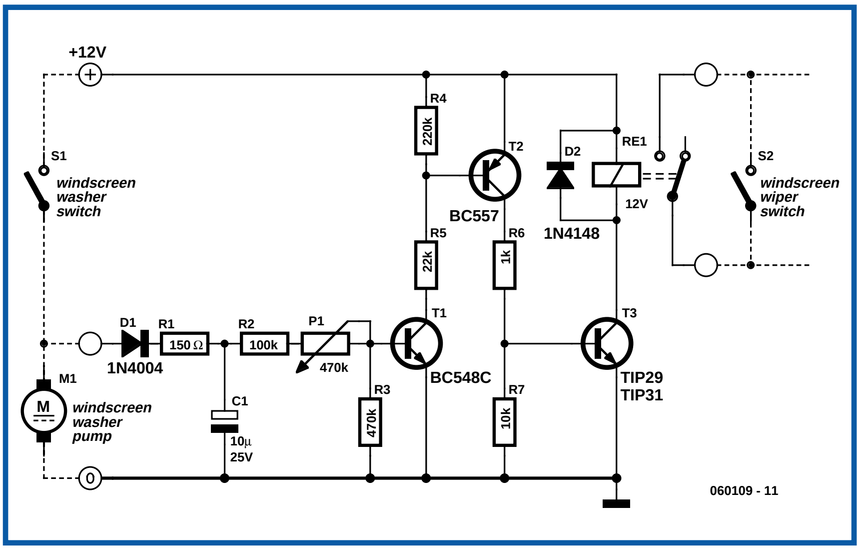


065

Automatic Windshield Washer Control

Christian Tavernier

Most, if not all, recent cars have an impressive amount of electronics, whether it be ABS brake systems, engine control with injection calculators, airbag activation, or other various functions, called comfort functions. Among them is one which we tend to forget because it has become so common today. It turns on the windshield wipers automatically for a few seconds after the windshield cleaner. This practice is almost indispensable because it avoids any dripping of excess rinse product right in the middle of a just-cleaned windshield. Unfortunately, many 'low end' cars or some of the older cars are not equipped with this automatic



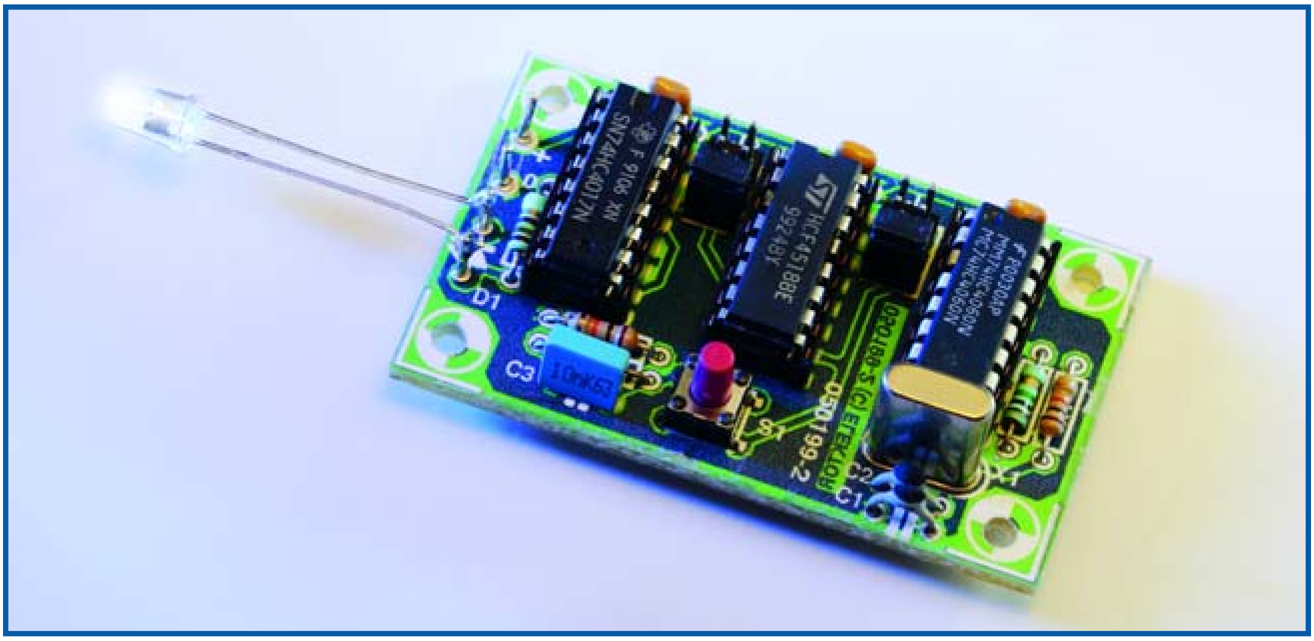
function which is a very nice convenience to have. So, since all that is required is a handful of components that any electronics hobbyist worthy of the name already has in his/her drawer, we will discuss the circuit proposed here.

This project is super simple and simply keeps the windshield wiper activated for a few seconds after the windshield washer control contact has been released.
While the windshield washer pump is operating, the 12 volts delivered by the battery are present at the terminals and are therefore charging capacitor C1. Once the windshield washer has stopped, this capacitor can only discharge through R2, P1, R3, and the T1 emitter-base junction, due to the presence of diode D1.
It thus keeps T1 in the conductive state during a certain time, the exact period of which depends on the setting of P1. T1 in turn saturates T2, which then does the same for T3. The Re1 relay is therefore connected which maintains the windshield wiper in operation because its work contact is wired in parallel to the control switch. Once C1 is sufficiently discharged, T1 is blocked, which then blocks T2 and T3 and deactivates relay Re1.
The type of components is not really critical, even if we indicate specific reference numbers for T3, any low-power npn transistor with a gain over 25 will work. However, considering the amount of power consumed by the windshield wiper motor, relay Re1 will imperatively be an ‘automobile’ relay. You can find very low-priced ones at many car accessory shops (and even at some component retailers). These relays maintain contact under 12 volts and often do not have more than one work contact but they are, in general, capable of cutting off about 20 amps.
Finally, the only delicate point of this project is to properly identify the control wire for the windshield pump on one hand, and the windshield wiper motor on the other. Observing what is happening at the various connections with a simple voltmeter, should get it right without too much difficulty.

www.tavernier-c.com (060109-1)

Optical Pulse Generator

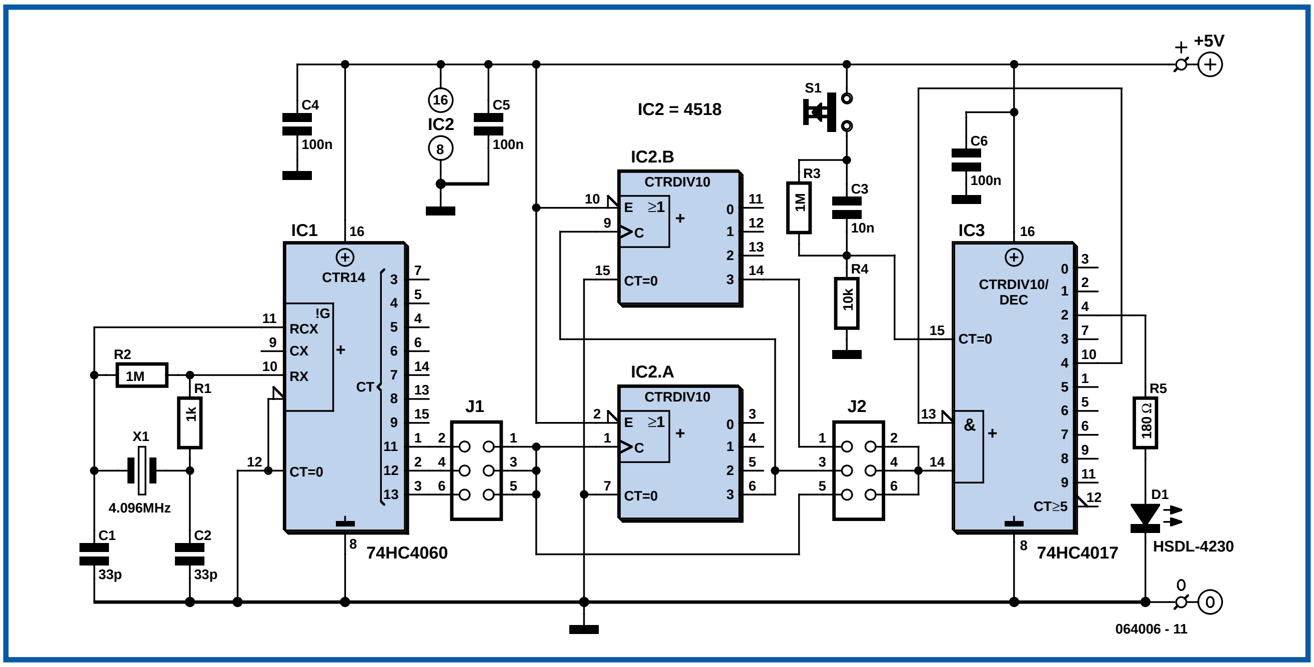
066



This little aid was originally designed to test the Shutter Time Meter from the January 2006 issue. This meter was specifically designed for ‘analogue’ SLR cameras.

In order to measure the exposure time of a camera accurately, it will first have to be checked with a well-defined signal first. This circuit was designed for that purpose. But the circuit can also be used if you need a well-defined pulse for some other purpose.

The circuit is build around a trio of standard logic ICs. Firstly a 74HC4060 (IC1) is used to provide a quartz crystal accurate reference for the duration of the pulses. For the crystal frequency we choose the common 4.096 MHz value. To test all the ranges of the shutter time meter, we choose three different pulse lengths in three different decades, namely: 1 / 2 / 4 / 10 / 20 / 40 / 100 / 200 / 400 ms.
With jumper J1 you select a frequency of 1000, 500 or 250 Hz (see table). The frequency is then passed on to J2 and the dual decade counter IC2 (a 4518). This does not need to be a fast HC-type, since the frequency is at most 1 kHz. With J2 the frequency can be reduced by 1, 10 or 100 times. This frequency is then applied to IC3 (a 5-stage Johnson-counter). This has been set up in such a way that in the end there appears only one single pulse at the output. The advantage of the Johnson-counter is that each



output is free from glitches and has a duration that is exactly equal to the period of the clock input.

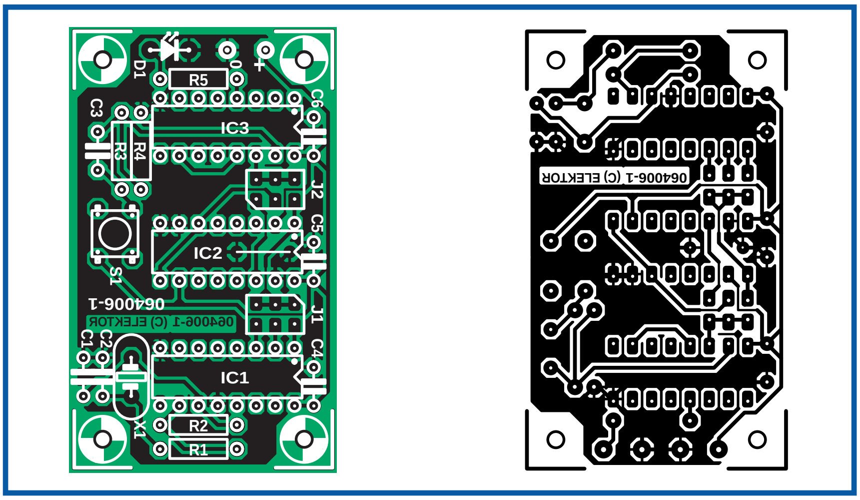
We choose Q2 as the output. Q4 is used to stop the counter. Q0 is only active if we push the reset-button S1. IC3 will then start to count. To ensure that the reset does not affect the duration of the pulse, a differentiating RC-network R4/C3 generates a short reset pulse. R3 ensures that C4 is discharged after releasing S1. Also, just to be sure, we don't use the second counter output but use the third one instead. For the same reason, to stop the counter we use the fifth output. Especially with longer times you will notice that the pulse will arrive at the output a short time after pressing the switch.

R5 drives a current of nearly 20 mA through D1. D1 provides sufficient light for this application to trigger the receiver diode in the shutter time meter. An unusually fast type was selected for the LED, which, with a switching time of 40 ns, has practically no influence on the length of the pulse. If you would like to use another LED then you will have to look closely at the switching time. This needs to be small compared to the duration of the pulse. If you want to use the circuit with a logic level output then you can just omit D1.

If necessary, the pulse lengths can be changed be selecting another crystal frequency. The current consumption in the idle state is less than 2 mA. In our prototype, while the circuit is delivering a pulse, the current consumption increases briefly to about 18 mA.

Do not forget the wire link under IC2 when assembling the circuit.

(064006-1)



J1	J2	Pulse (ms)
1-2	5-6	1
3-4	5-6	2
5-6	5-6	4
1-2	3-4	10
3-4	3-4	20
5-6	3-4	40
1-2	1-2	100
3-4	1-2	200
5-6	1-2	400

COMPONENTS LIST

Resistors
R1 = 1kΩ
R2,R3 = 1MΩ
R4 = 10kΩ
R5 = 180Ω

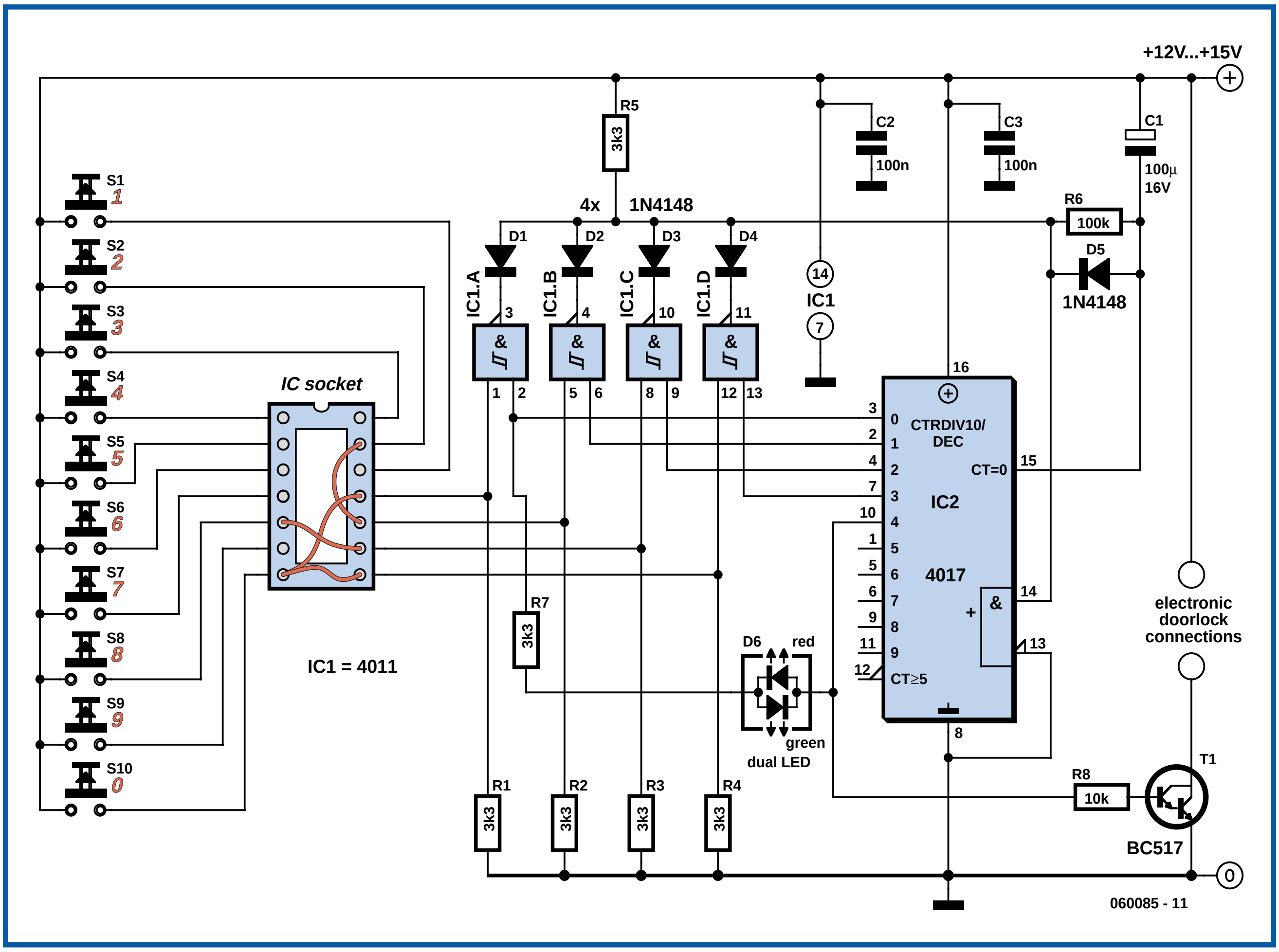
Capacitors
C1,C2 = 33pF
C3 = 10nF
C4,C5,C6 = 100nF ceramic, lead pitch 5mm

Semiconductors
D1 = HSDL-4230
IC1 = 74HC4060
IC2 = 4518
IC3 = 74HC4017

Miscellaneous
S1 = pushbutton, make contact, 6mm
J1,J2 = 3-way pinheader with jumper
X1 = 4.096MHz quartz crystal
1 wire link.
PCB, ref. 064006-1

Hard-Wired Code Lock

067



Heino Peters

Installations with restricted access are often protected using an access code. If you don't have particularly demanding requirements regarding modifying the code, you can manage quite nicely with a static design with the access code fixed in the hardware.

The access code can be set by inserting wire links in the IC socket shown at the left in the schematic diagram. The code '0280' is shown configured in the drawing. The user enters the code with S1–S10. The most important components in this circuit are the four NAND gates (4011 CMOS IC) and the counter with ten decoded outputs (4017 CMOS IC). R1–R4 hold the four pushbutton inputs at ground level if no button is pressed. No measures need be taken to debounce the switch signals, since the circuit simply ignores repeated button presses. In the quiescent state, a '1' is applied to the reset input (pin 15) of IC2, which causes output Q0 (pin 3) of IC2 to be the only output with a '1' level. All other counter outputs are at the '0' level. Dual LED D6 will be on and red to indicate that a code can be entered. If the button for the first digit of the preset code is now pressed (in this case the '0' button), the output of IC1a will go to '0' and the reset input of IC2 will also go to '0' via D1 and D5. When the button is released, a rising edge appears at the clock input of IC2, which causes the counter to be incremented by 1. Thanks to R6 and C1, the reset input of IC2 remains low for around 10 seconds. Output Q1 (pin 2) of the counter is now '1' as a result of the clock pulse, and IC1b is waiting for the second button ('2') to be pressed. If that doesn't happen within 10 seconds, C1 discharges via R5 and R6 to a level that causes IC2 to be reset. Dual LED will again become red, and the user must start entering the code again. However, if the buttons for the each of the remaining digits of the code are pressed correctly within 10 seconds, the Q4 output (pin 10) will ultimately go to '1' and the dual LED will change to green. After 10 seconds, C1 will again be discharged and the dual LED will change back to red. The Q4 output can be used to switch something, such an electronic door latch.

If you want to change the code, you only have to change the configuration of the wire jumpers in the IC socket.

The combination of diodes D1–D4 and R5 acts as an AND gate. If the output of one of the four NAND gates in IC1 is '0' (which is always the case if a correct button is pressed), a '0' is applied to the clock input of IC2 as long as the button is held pressed. If you find a delay of 10 seconds too long, you can reduce the value of R6 or C1. The time is approximately equal to the product of R6 and C1 (R6 x C1).

(060085-1)

068 LM35 to ADC

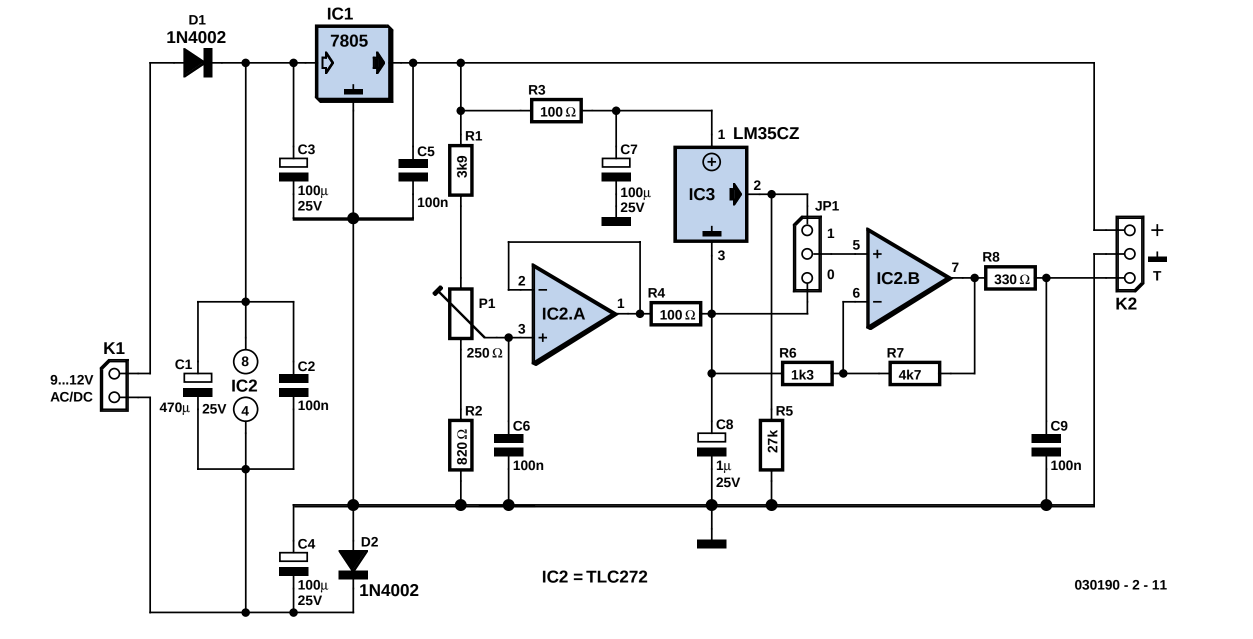
Uwe Reiser

The circuit described here is designed to be used with the 'LED Thermometer' (elsewhere in this issue), but can also be used as a signal conditioner for connection to any analogue-to-digital converter (ADC). The circuit is sufficiently interesting in itself that we have decided to describe it separately. The familiar and popular LM35 temperature sensor produces an output voltage that varies by 10 mV per Kelvin over a temperature range of –55 °C to +150 °C. This is not suitable for driving an ordinary unipolar input of an analogue-to-digital converter with an input range of 0 V to 5 V: we need to add an offset to the sensor voltage and then amplify it.

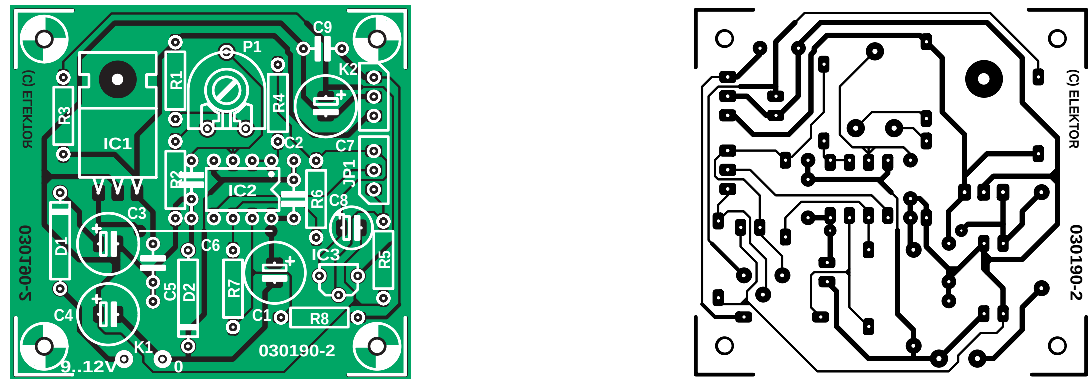
That covers the two main parts of the circuit diagram shown in **Figure 1**. The circuit is designed to allow a measurement range of –24 °C to +84 °C. Over this range, the output voltage of the sensor varies from –240 mV to +840 mV. Both these values must be shifted by a further 0.5 K (or 5 mV) to allow for an extra half a degree at either end of the range. This gives a total voltage range of 1090 mV, and hence a necessary gain of A = 5000 mV / 1090 mV = 4.587. Amplification is done by IC2.B, whose gain is given by A = R7 / R6 + 1. The voltage offset is generated by IC2.A, which shifts the ground of the LM35, to which its output is referred, to a potential of 245 mV × 4.587 = 1124 mV relative to the circuit ground. Overall, this means that the voltage at the output of IC2.B is exactly 0 V at a temperature of –24 °C and 5 V at +84 °C.

These two formulae can be used to select component values for any desired temperature range. Calculating suitable values for the voltage divider formed by R1, P1 and R2 is straightforward. Jumper JP1 allows the circuit to be calibrated: connecting the output of the offset opamp IC2.A directly to the input of amplifier IC2.B simulates the condition of being at the lower extreme of the temperature range.

1



2



COMPONENT LIST

Resistors
R1 = 3kΩ9
R2 = 820Ω
R3,R4 = 100Ω
R5 = 27kΩ
R6 = 1kΩ3
R7 = 4kΩ7
R8 = 330Ω
P1 = 250Ω preset

Capacitors
C1 = 470µF 25V
C2,C5,C6,C9 = 100nF
C3,C4,C7 = 100µF, 25V
C8 = 100µF, 25V

Semiconductors
D1,D2 = 1N4002
IC1 = 7805
IC2 = TLC272
IC3 = LM35CZ

MIscellaneous
K1 = 2 solder pins
K2,JP2 = 3-way pinheader
1 Jumper

The circuit is powered from a mains adaptor with an output of 9 V to 12 V (either AC or DC). Although the current consumption is only around 50 mA, a 1 A fixed voltage regulator is used to produce a stable 5 V supply, since no heatsink is then required. The regulator directly supplies the voltage divider for IC2.A and can also provide power for a connected ADC circuit. The supply for the sensor is decoupled from the rest of the circuit by R3 and C7 to reduce interference. Diode D1 operates either as a rectifier (when an AC supply is used) or as protection against reverse polarity (when a DC supply is used). To avoid the need to use rail-to-rail opamps, diode D2 is used to lift the circuit ground to approximately 0.7 V above the IC's negative supply.

The sensor electronics can be built on the small printed circuit board shown in **Figure 2**. There is a single wire link, between C3 and IC2. It is worth pointing out that not only the sensor, but also all the other components, must be capable of operating over the desired temperature range. The 'C'-suffix versions of the sensor are specified to work from –40 °C to +110 °C, while the 'D' versions are specified to work from 0 °C to +100 °C.

The overall accuracy of the thermometer is highly dependent on the precision of the components used. In particular, R6 and R7 should be as close as possible to their calculated values. The output voltage of the regulator is also important if it is used as the reference voltage for the A/D converter. Deviations from nominal values will result in an expansion or a compression of the overall temperature scale.

(030190-II)

Internet link

www.national.com/pf/LM/LM35.html

ZigBee Switching for Remote Control

069

Richard Hoptroff

The ZigBee standard defines data formats known as 'profiles'. These ensure that products produced by different manufacturers are interoperable.

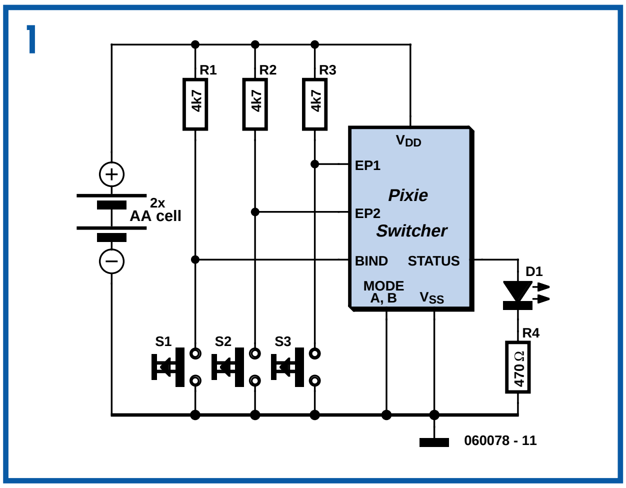
One of the first data formats to be developed out was the Home Controls–Lighting (HC-L) profile. This is designed for sending simple on/off messages, and its main purpose is designed to remove the need to run cables to wall-mounted light switches in buildings. However, that's not to say that you can't use it for switching anything else, for example, to add ZigBee remote control to your projects.

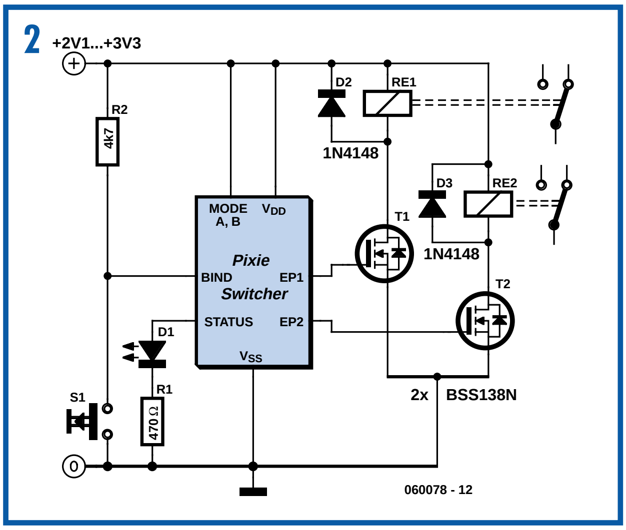
The Pixie Switcher from Flexipanel (www.flexipanel.com) is a commercially available HC-L switching module with integral antenna and up to 8 switching control lines known as endpoints (EPs). When configured as an input, the endpoint voltage is monitored. If it changes state, a message is generated as required. 'On', 'off' and 'toggle' messages are supported by all devices using the HC-L profile. When configured as an output, the endpoint's digital output corresponds to the last message received from a switching input.

Input endpoints to output endpoints correlation is managed by one-time setup procedures called 'joining and binding'. When first powered up, a device will look for a ZigBee network to join. Security permitting, any router node can then allow the new node to become its neighbour in the network.

Once the new node has become a mem-

ber of the network, its inputs and outputs must be 'bound' to corresponding outputs and inputs on other nodes in the network. This is achieved by pressing the 'bind' button on both devices at the same time. One input can control multiple outputs and vice versa. For example, it would be quite feasible for a bedside or hallway switch to turn off all the lights in the house.
A typical application circuit is shown in the schematics, where one Pixie Switcher unit has been configured to have two inputs and the other to have two outputs. This configuration must be done prior to placing the modules in the circuit shown, using the RxD and TxD serial interface pins (not shown).
Figure 1 shows the transmitter. The ModeA and ModeB pins are grounded, so the transmitter will operate in sleep mode and only wake up when a button is pressed. The modules can run at anything between 2.1 V and 3.3 V, so it can be connected directly to two AA batteries.



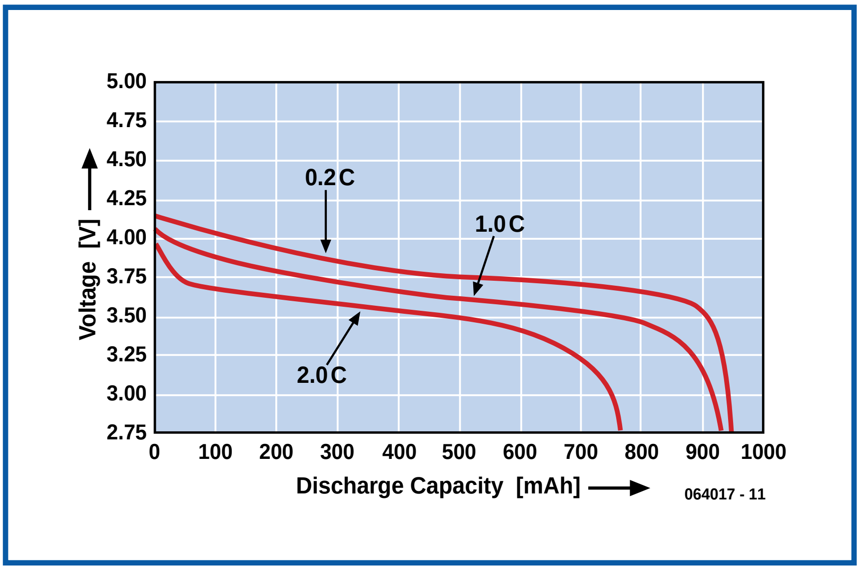


The Bind input and Status LED are only used during joining and binding. When the pushbuttons connected to EP1 and EP2 are pressed, messages are transmitted to the receiver.
Figure 2 is the receiver. By setting ModeB high, it is configured as a router. This means it can allow battery powered sleeping devices (such as the transmitter) to join it as a neighbour. Routers, however, must be always-on and so are not really suited to battery powering. ModeA is also wired High, indicating that this router is in fact a coordinator.
The difference between the two is that when a coordinator powers up, it starts a new network instead of looking for an existing one to join. Every ZigBee network has one coordinator. If further routers nodes were added to this network, they would have to have the ModeA pin low. EP1 and EP2 on the receiver are connected to relays via MOSFET driver transistors. The relay contacts can then be connected to any project circuit.

(060078-1)

070

Measuring Battery Charge



It is not generally known that it is possible to ascertain the extent of charge of a battery with a standard digital voltmeter. It does not apply to all kinds of battery, but it does to, for instance, Lithium-ion batteries.

Although there are quite a few different types of Li-ion batteries, it is possible to generalize to a degree. The graphs in the figure (from Panasonic) show clearly that the terminal voltage of the cell drops in direct relation to the diminution of the charge. This means that a simple voltage measurement suffices to determine the state of charge of the battery. Note that the figure shows three graphs each relating to a given load. This means that the

output voltage must be measured under load conditions to obtain a satisfactory result. Moreover, the value of the load must be known. Also, the battery must be under load for at least a minute.
There are two ways to proceed. If the load is known and constant as, for instance, in a pocket torch, measure the voltage and read the corresponding charge from the graph. If there is no load, or it is not known or variable, apply a temporary load in the form of a resistor. If the value of this is 20 Ω, for instance, use the upper graph (0.2 *C*, 180 mA). If a single resistor is used, this will get quite hot, because it has to dissipate 0.66 W, whereas most standard resistors are only rated at 0.25 W to 0.33 W. It is therefore wise to use a number of resistors in parallel, for example, five of 100 Ω each.
To obtain more exact measurements, first draw the graph of your particular battery. Charge it fully and then connect the load, for instance, the five 100 Ω resistors. Measure the output voltage every five minutes and enter the results on an Excel sheet to give a nice curve. If the 5-minute intervals are not exact, enter the real times and choose 'spread' as curve. Only this type of sheet can cope with irregular measurement intervals. Moreover, Excel is able to transpose the time on the horizontal (*x*-) axis into charge.
Calculate the current during an interval by dividing the mean voltage (start voltage plus final voltage divided by 2) by the resistance. The charge is the current thus computed times the elapsed time.
The graph shown applies to a battery of 900 mAh. A current of 0.2 *C* is then 0.2 x 900 = 180 mA; 1 *C* is 900 mA; 2 *C* is 2 x 900 = 1.8 A.

The proposed method is not suitable for NiCd or NiMH batteries, but it is for lead-acid batteries, provided that the temperature is constant. Bear in mind that an old lead-acid battery has a slightly different graph from a new one.

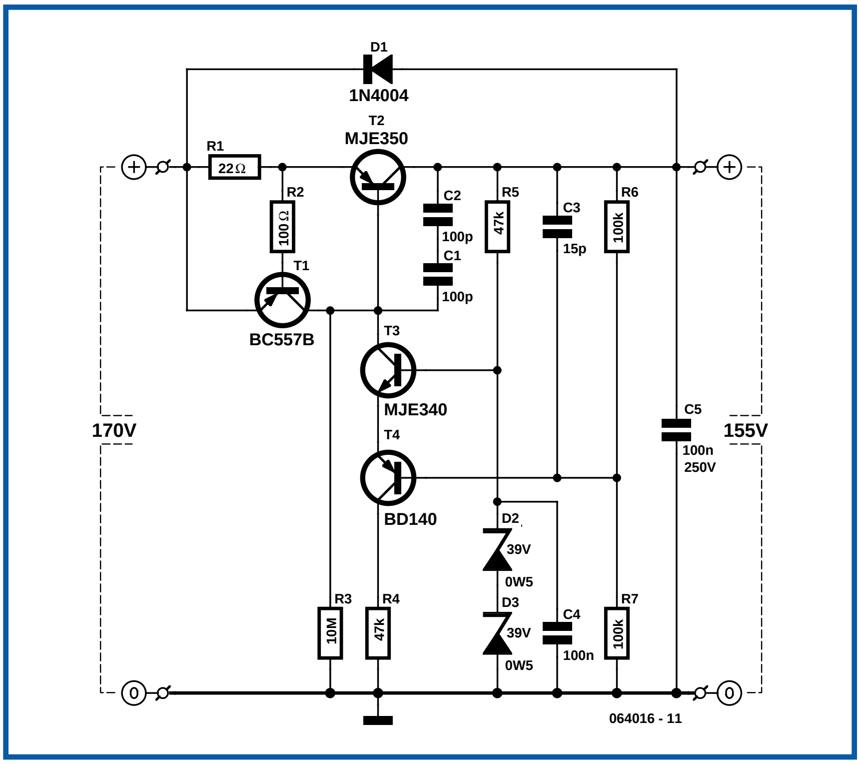
(064017-1)

High-voltage Regulator

071

with Short Circuit Protection

Ton Giesberts



There are many circuits for low voltage regulators. For higher voltages, such as supplies for valve circuits, the situation is different. That's why we decided to design this simple regulator that *can* cope with these voltages. This circuit is obviously well suited for use in combination with the quad power supply for the hybrid amp, published elsewhere in this issue.

The actual regulator consists of just three transistors. A fourth has been added for the current limiting function. The circuit is a positive series regulator, using a pnp transistor (T2) to keep the voltage drop as low as possible.
The operation of the circuit is very straightforward. When the output voltage drops, T4 pulls the emitter of T3 lower. This drives T2 harder, which causes the output voltage to rise again. R4 restricts the base current of T2. C1 and C2 have been added to improve the stability of the circuit. These are connected in series so that the voltage across each capacitor at switch-on or during a short circuit doesn't become too large. You should use capacitors rated for at least 100 V for C1-C3. D1 protects T2 against negative voltages that may occur when the input is short-circuited or when large capacitors are connected to the output.

We use two zener diodes of 39 V connected in series for the reference voltage, giving 78 V to the base of T3. Because R6 is equal to R7 the output voltage will be twice as large, which is about 155 V. T4 acts as a buffer for potential divider R6/R7, which means we can use higher values for these resistors and that the voltage is not affected by the base current of T2 (this current is about the same as the emitter current of T3). This is obviously not a temperature compensated circuit, but for this purpose it is good enough.
The current limiting section built around T1 couldn't be simpler. When the output current rises above 30 mA the voltage across R1 causes T1 to conduct. T1 then limits the base-emitter voltage of T2. R2 is required to protect T1 against extremely fast peak voltages across R1.

R3 is needed to start the regulator. Without R3 there wouldn't be a voltage at the output and hence there wouldn't be a base current in T2. R3 lets T2 conduct a little bit, which is sufficient for the regulator to reach its intended state.
During normal operation with a voltage drop of 15 V across T2 and a current of about 30 mA there is no need for extra cooling of T2. The junction temperature is then 70 °C, which means you can burn your fingers if you're not careful! The lower the input voltage is, the more current can be supplied by this regulator. This current is determined by the SOAR (Safe Operation ARea) of T2. During a short circuit and an input voltage of 140 V the current is about 30 mA and T2 certainly requires a heatsink of at least 10 K/W in those conditions.
To increase the output voltage you should use a larger value for R6. If you want to use a higher reference voltage, you should replace T4 with a MJE350. If you only ever need to draw a few milli-amps there is no need to include T4 and R4. The potential divider (R6/R7) can then be connected directly to the emitter of T3. The ripple suppression of the circuit is about 50 dB. The quiescent current is 2.5 mA and for small currents the dropout voltage is only 1.5 V.

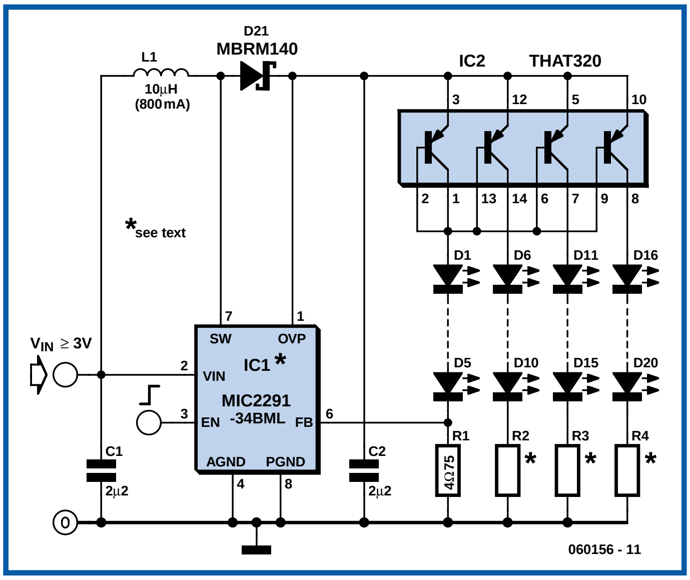
(064016-1)

072

Driver for 20 LEDs

Eberhard Haug

If we wish to use a step-up switching regulator to run several LEDs from, for example, a 3 V battery, we find that the maximum usable mark-space ratio limits us to driving just a few LEDs in series. If we have seven white LEDs in series the total forward voltage will be about 7 times 3.4 V, or 23.8 V, requiring a mark-space ratio of around 90 %. This is the upper limit for many switching regulators. If we want to drive more LEDs, we must divide them into a number of parallel strings, for which the regulator will of course have to supply the necessary current.
There are various ways to drive a parallel array of series-connected LEDs. The simplest approach is to wire a number of chains, each consisting of the same number of LEDs and a series resistor, in parallel, hoping that the total forward voltage of the LEDs in each chain is approximately the same. We can sense the current in a single chain using a sense resistor R, and thereby deliver the same current to the other chains as well. Unfortunately, the assumption that the total forward voltage of the LEDs in each chain is the same is not always borne out in practice.
To get around this problem we can use a multi-way current mirror, which can, for example, be constructed using a bipolar transistor array such as the THAT320. This contains closely-matched PNP transistors. The current mirror function is implemented in the first (regulated) chain by connecting the base and collector of its transistor together; the base and emitter connections of all the transistors are also wired in parallel. Since there will be a small effect on the currents in the other chains, it is best not to dispense with their series resistors R, in the interests of improved current matching.



The circuit shows a type MIC2291 PWM step-up LED driver from Micrel driving a four-by-five LED array. This arrangement leaves the device a little headroom in terms of mark-space ratio and total power. The voltage at the output will be at most 18 V in normal operation. A particular advantage of the MIC2291 in this circuit is its low feedback voltage of 95 mV, which makes for a correspondingly high efficiency. The current in each chain is calculated as follows:

$$I_{LED} = 95\text{ mV}/R1 = 95\text{ mV}/4.7\ \Omega = 20\text{ mA}.$$

The circuit can operated from voltages from 3 V to 10 V. If fewer than five LEDs are used in each chain, or if LEDs with a lower forward voltage are used, the battery voltage may need to be reduced: it must be lower than the total forward voltage drop of the chain. Otherwise, as with any boost converter, an unregulated and potentially damaging current will flow continuously through the LEDs. Also, if the chains contain different numbers of LEDs or if different colour LEDs are used, care must be taken to ensure that the sum of the LED forward voltages is greatest in the first (regulated) chain.
The EN input allows the LED array to be turned on (EN>1.5 V) or off (EN<0.4 V), or dimmed using a PWM signal. An alternative (analogue) dimming technique is also described in the MIC2291 data sheet.
The Schottky diode must be a fast-switching type with a low capacitance and low voltage drop, such as the MBRM140 or SS14. Ceramic capacitors C1 and C2 should be XSR or X7R types with a suitable working voltage. The 10 µH coil must have a rated current of at least

600 mA without saturating, and it should also have as low a resistance as possible. And of course, when building an LED driver circuit with a switching speed of 1.2o the layout and construction of switching regulators should be observed. The MIC2291-34BML and its lead-free counterpart the MIC2291-34YML in a 2 mm by 2 mm MLF package have a 34 V overvoltage protection circuit (and an extra OVP pin); the MIC2291YDS in a 5-pin SOT-23 package is a low-cost version without overvoltage protection. Since we would otherwise have to implement this protection externally, the MLF type is preferred.

(060156)

Internet links

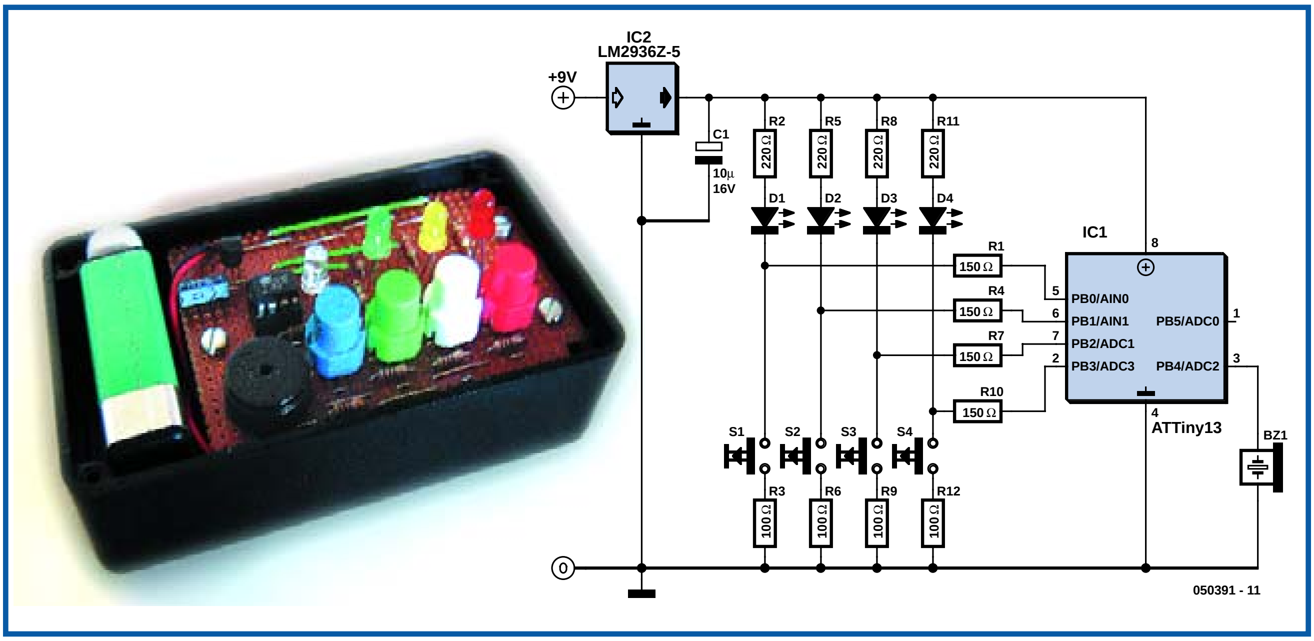
MIC2291 data sheet:
www.micrel.com/_PDF/mic2291.pdf

Application example:
www.micrel.com/_PDF/App-Hints/ah-59.pdf

THAT320:
www.thatcorp.com/300desc.html

Tiny Simon

073



Clive Graham

The ‘Tiny Simon’ game is based upon the ‘Simon says…’ sequence following game which has proved popular over the years. Although not particularly original in concept, this implementation of the game, put together for use by playschool children, has a number of noteworthy features.

The game uses sound (via a piezo-sounder) and light (via four LEDs) to display an extending sequence to the player, who has to follow and repeat back the sequence via a set of four press-switches. If the sequence is remembered correctly, a celebratory tune is played (with light show) and the sequence extended by a further element. If not, the player is shown the correct sequence and, after a short ‘jingle’, is invited to play again.
The circuit is built around an ATtiny13 microcontroller running software written for the project. As you can see from the circuit diagram, the ATtiny13 chip in its 8-pin case does not require much in the way of external components to make an attractive little game that hopefully will keep children busy for a while.
The software was coded in AVR assembler using the freeware Atmel AVR Studio4. It is available free of charge from the Publishers’ website as file number **050391-11.zip**. Careful use of modular programming allows for easy changing of music generated during the game (stored in EEPROM) and other features. An 8-stage maximal length pseudo-random number generator (in software) is used to produce a varied and easily checked light sequence. Feedback taps can be altered in software to produce a different sequence. Each starting point for a sequence is saved in EEPROM, so if power is lost, a new starting point is automatically selected upon power-up. Dynamic I/O switching is used to reduce pin-count — the LEDs and push-buttons are conected to the same pins on the ATTiny13!
The game runs from a 9-volt PP3 type battery. The low quiescent current of less than 8 µA is due to the use of a micropower regulator type LM2936Z-5 and extensive power saving features on the ATtiny13 (the micro draws less than 1 µA!).

Construction is very simple and the parts are inexpensive and easily obtained. The component count is so small that construction of the circuit on a piece of Veroboard is a perfectly acceptable option. The photograph shows an experimental construction of the game is an ABS box. The small, hand-held construction allows easy operation for those with small fingers!

(050391-1)

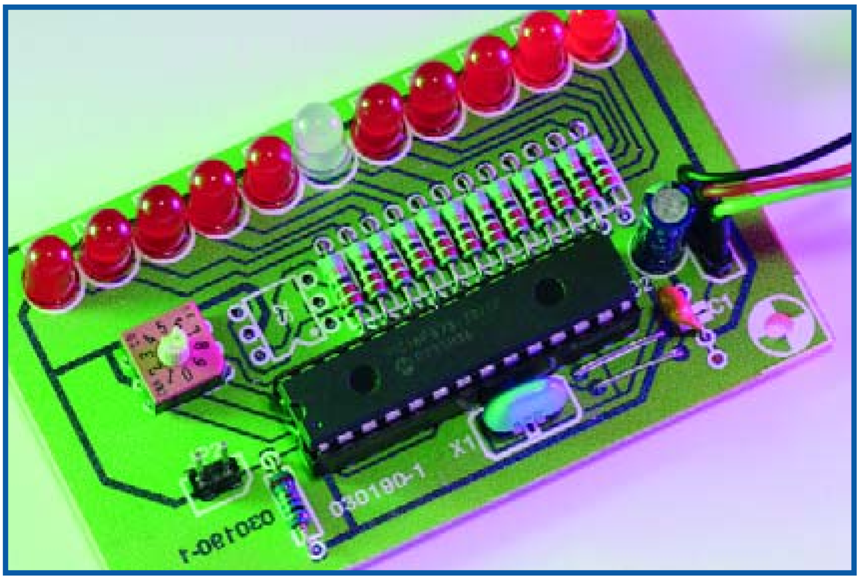
074

LED Thermometer

Uwe Reiser

The circuit described here is the digital and display section of a thermometer; the analogue circuitry and signal conditioning required to use an LM35 temperature sensor are described elsewhere in this issue ('LM35 to ADC'). The analogue-to-digital converter used here is hidden inside a PIC16F873 microcontroller behind the RA5 port pin. It has a resolution of 10 bits (1024 steps), allowing a temperature range of 128 °C to be divided into steps of exactly 128 °C / 1024 = 0.125 °C. Displaying a range of 1024 steps of one eighth of a degree, or even just 128 steps of one degree, on a row of LEDs is hardly practical. A better plan is to specify a desired temperature value and allow the microcontroller to indicate deviations from that temperature over a small range; effectively moving a magnifying glass over the temperature scale.

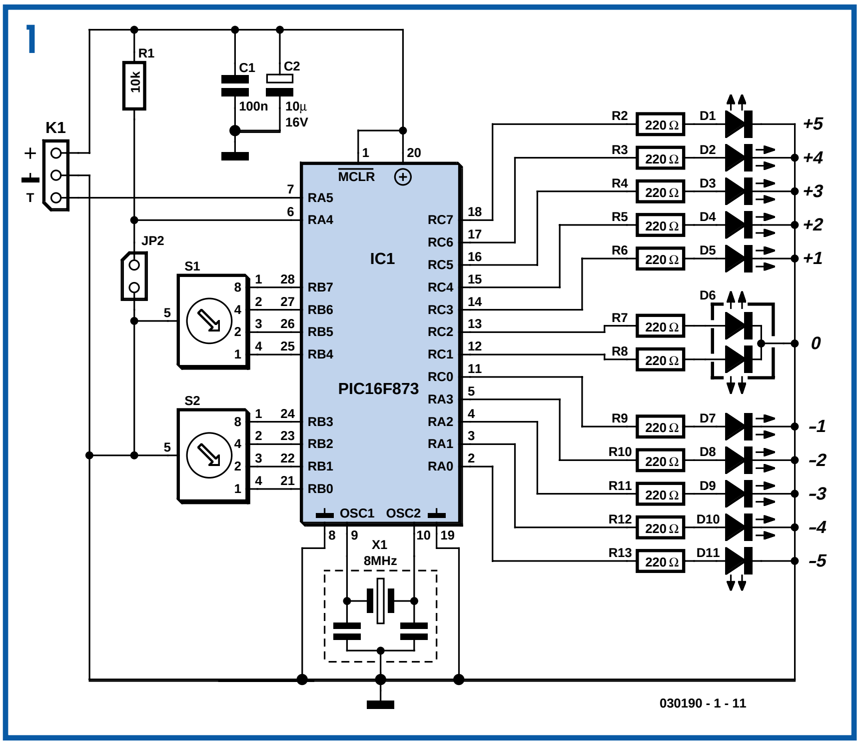
The BCD-encoded switches are used to set the desired centre temperature. When the measured temperature is equal to this value the centre two-colour LED D6 will light green. If the temperature deviates from this value, the LED will light yellow. LEDs D1 to D5 indicate positive deviations and LEDs D7 to D11 indicate negative deviations in steps of one degree. If the overall measurement range is from –24 °C to +84 °C we can therefore set the centre point between –19 °C and +79 °C. Half-degree steps are indicated by two neighbouring LEDs lighting simultaneously. For example, between 19.75 °C and 20.25 °C just one LED will light; between 20.25 °C and 20.75 °C the next LED will also light; and between 20.75 °C and 21.25 °C just the second LED will light. If just the top or bottom LED is lit, it means that the temperature is outside the displayable range. The BCD-encoded switches (S1 for the tens digit and S2 for the units) used to set the centre value have the advantage that there is no need for mental acrobatics converting between decimal and hexadecimal when setting or checking the value. Since negative numbers cannot be set using the switches, the value is expressed as the offset from the bottom of the temperature range. The software updates the displayed value every second if JP2 is fitted; if, however, port RA4 is high (jumper not fitted) a 900 ms delay loop in the software is bypassed and the display is updated at full speed.



A printed circuit board layout is available for the digital section of the thermometer (see **Figure 2**). The two BCD switches are in 6-pin DIL packages and can easily be fitted in sockets so that they can protrude through the lid of an enclosure. If the microcontroller is also be fitted in a socket it may become necessary to stack two or more sockets for the switches. The LEDs are situated at the edge of the board so that their leads can be bent through 90 ° if desired. When the board is populated (not forgetting the wire links near the resonator!) and the soldering has been checked on both boards, JP2 can be fitted and the circuit can be tested.

During initialisation the microcontroller will run a power-on self test: the row of

1



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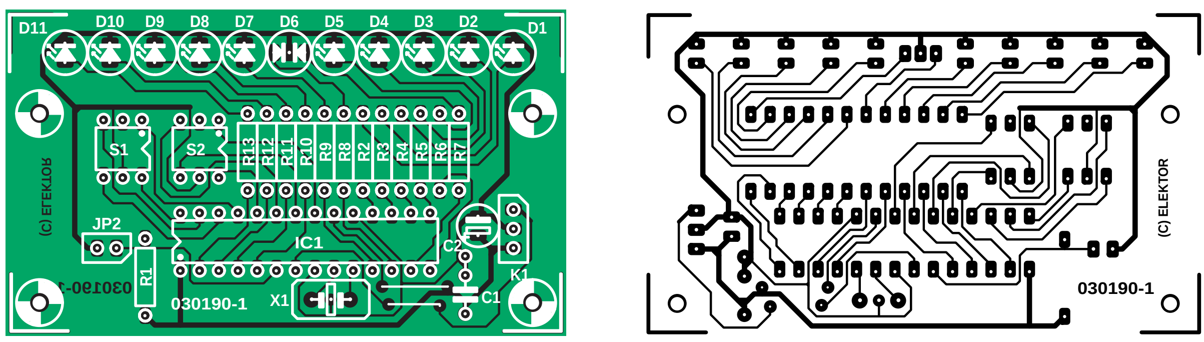


COMPONENTS LIST

Resistors
R1 = 10kΩ
R2-R13 = 220Ω

Capacitors
C1 = 100nF
C2 = 10μF 16V radial

Semiconductors
D1-D5,D7-D11 = LED, 5mm
D6 = TwinLED (DuoLED) green/yellow
IC1 = PIC16F873-20/SP, programmed, order code **030190-41**

Miscellaneous
X1 = 8MHz ceramic resonator (3 pins)
S1,S2 = BCD complement switch (APEM PT65-702)

LEDs is lit in sequence from bottom to top. Each of the 23 possible display patters is shown for 100 ms. Finally the two-colour LED flashes yellow twice, and the unit starts to display the temperature.

Now switch off the power supply, remove JP1 on the digital board and set the BCD switches to the zero position. On the analogue board connect the LM35's ground to the amplifier input (JP1 in position 0). Apply power and adjust P1 until LED D11 lights; this corresponds to the lower limit of the temperature measurement range.

(030190-I)

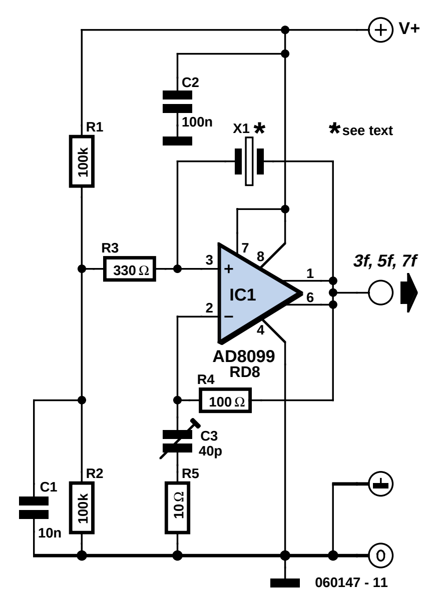
Harmonic Generator with Single Opamp

075

Gert Baars

Quartz crystals have the property that their amplitude/phase characteristic repeats itself at frequencies that are an uneven multiple of the fundamental frequency. There are so-called overtone crystals that are cut in such a manner that they possess this property to a greater extent. However, in principle, any crystal may be used on one or more of its harmonic frequencies. Harmonic generators based on transistors may operate satisfactorily on the 3rd harmonic, but if the 5th or 7th harmonic are wanted, the circuit becomes less reliable and requires frequent adjustment.

This circuit is based on a single, fast opamp and oscillates readily at the 3rd, 5th or 7th harmonic. The opamp is set up as a non-inverting amplifier with the quartz crystal connected between its output and the non-inverting input. The circuit amplification, which in principle must be unity to ensure oscillation, is determined by the network formed by R4, R5 and trimmer capacitor C3. This network is frequency-dependent such that the amplification increases as the frequency rises. The network gain is adjustable with C3. The setting of the capacitor must be such that the gain is too small for oscillation at the fundamental frequency, but sufficient for, say, the 5th or 7th harmonic.



The author uses a standard computer crystal of 10 MHz. Depending on the setting of C3, the circuit provides a stable output at frequencies between 50 and 70 MHz. It should be noted that these frequencies are multiples of the series fundamental frequency of the crystal.

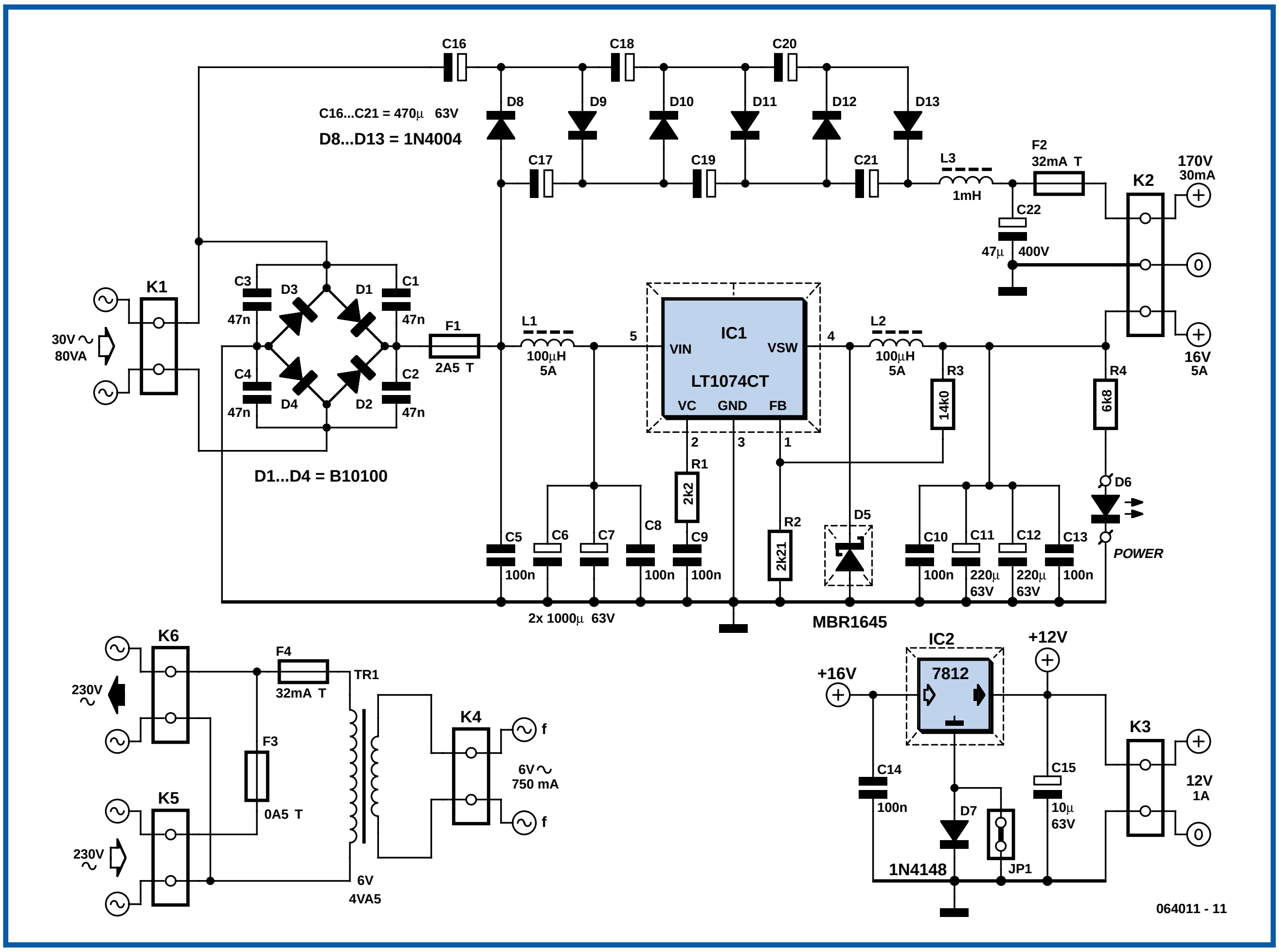
Tuning is carried out simply with a

frequency counter. The output frequency is varied with C3. When the capacitor is roughly at the correct setting, the frequency 'locks' as it were at the harmonic. The area where locking occurs is not well-defined, however, so that the setting of C3 is not critical. When tuning is completed, the output frequency is crystal-stable.

In principle, the circuit may be used for frequencies of up to 100 MHz, when the values of R4 and R5 may need to be reduced. When a crystal with a higher fundamental frequency, say, 15 MHz, is used, the circuit may be tuned to the 3rd harmonic, that is, 45 MHz.
The circuit should be tested with a supply voltage of 5–9 V (the maximum supply voltage for the IC is 12 V).
The peak to peak output voltage has a value of about that of the supply voltage less a few volts. The output can provide a current sufficient to drive relatively low-impedance loads.

(060147-1)

076 Quad Power Supply for Hybrid Amp



Ton Giesberts

This power supply was designed for use with the 'Simple hybrid amp' published elsewhere in this issue. It is of course suitable for use in other applications as well. We've used a cascade generator for the 170 V, a switch mode supply for the 16 V, a series regulator for the 12 V and a separate transformer for the 6.3 V filament supply.
We've chosen an LT1074CT (IC1) for the regulator, which means that the circuit can be built with relatively standard components and will have a high efficiency. The power loss is less with this device compared to a linear voltage regulator. This allows us to use a higher transformer voltage and a smaller cascade section to generate the 170 V (which is required for the SRPP stage in the amplifier). The lower input current also results in smaller losses in the bridge rectifier (D1 to D4).
A standard 12 V regulator (IC2) turns the 16 V into a stabilised voltage for the buffer stage.
When an ECC83 (12AX7) is used in the hybrid amp we could use this 12 V to power the filaments in the valve as well, although we really need 12.6 V. The current taken by the valve is about 150 mA, which means that the 12 V regulator needs to be fitted with a heatsink. This can be a small version of an SK129 heatsink from Fischer (38.1 mm, 6.5 K/W). To increase the voltage by 0.6 V

we've added diode D7 to the ground connection of the regulator. If an output voltage of 12 V is required you should close JP1, which shorts D7.

IC1 and D5 require a little more cooling and for this the 63.5 mm version of the SK129 will suffice (4.5 K/W). Both components can be mounted on opposite sides of the heatsink. You have to make sure that they are electrically isolated from each other and the heatsink! You should take a look at the website of Linear Technology (www.linear.com) and take note of the layout recommendations regarding the use of an LT1074.

You can use standard chokes for L1 and L2, rated at 5 A. If you want to remove more of the residual 100 kHz switching frequency you could always add an extra LC filter at the output. The diodes in the bridge rectifier are B10100's. These are Schottky rectifiers, which have a low forward voltage drop (only 0.7 to 0.8 V at 10 A). We have chosen diodes with a reverse voltage rating of 100 V so we have the option of using an LT1074HVCT instead. This can work with an input voltage of up to 60 V, which means we could use a 40 V_{AC} transformer. The same cascade circuit can then easily generate 220 V_{DC}. The standard LT1074CT can cope with up to 45 V, so we're using IC1 fairly close to the limits of its specifications in this circuit.

A cascade circuit generates the HT supply for the valve. It would also have been possible to use a separate transformer with a bridge rectifier and smoothing capacitor to generate this voltage. But then we'd have to find a 4.5 VA transformer with a 40 V secondary and connect it the 'wrong' way round. As this isn't exactly a standard transformer we dropped that idea.

The source for the cascade generator is now an 80 VA transformer. The capacitors in the cascade circuit have higher values than are strictly necessary. This makes it easier to calculate the expected output voltage. In our case this is 4 x 30 x $\sqrt{2}$ V for the no-load voltage, which comes to nearly 170 V. L3 and C22 filter out any HF interference coming from IC1. When the cascade supplied 20 mA the output voltage dropped to 140 V. At heavier loads we recommend that you use a smaller cascade circuit and a higher transformer voltage (and also use an LT1074HVCT because of the higher input voltage).

The filament voltage for the valve is generated by a 4.5 VA transformer, which in practice had an output a bit above 6 V and therefore came closer to the required 6.3 V. Another solution is to use a special transformer or a stabilised 6.3V_{DC} supply. Any of these will work, so it's down to your own preference which of these you'll use.

It is in principle possible to use the supply for two channels. However, if you use the ECC88 in the amplifier you may find it's necessary to use a separate cascade generator for each channel.

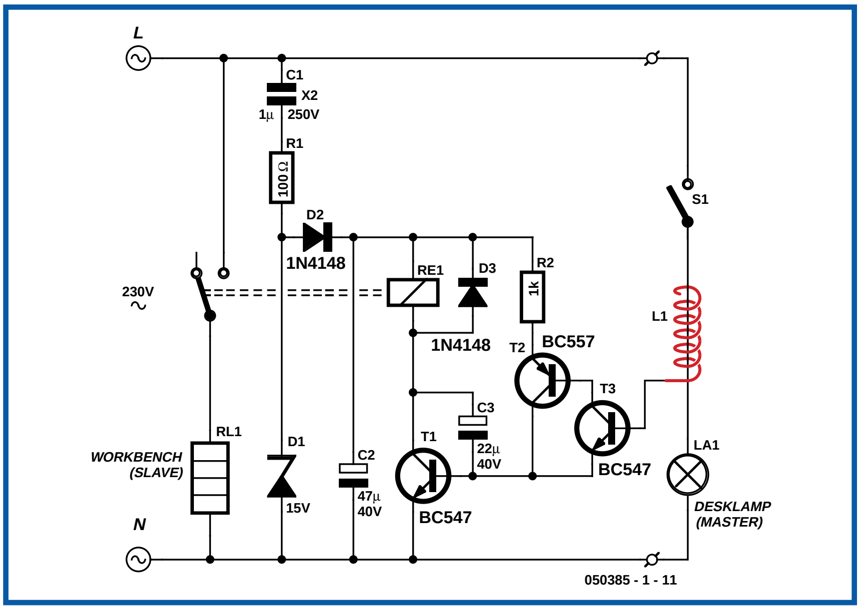
(064011)

Mains Slave Switcher I

077

Bart Trepak

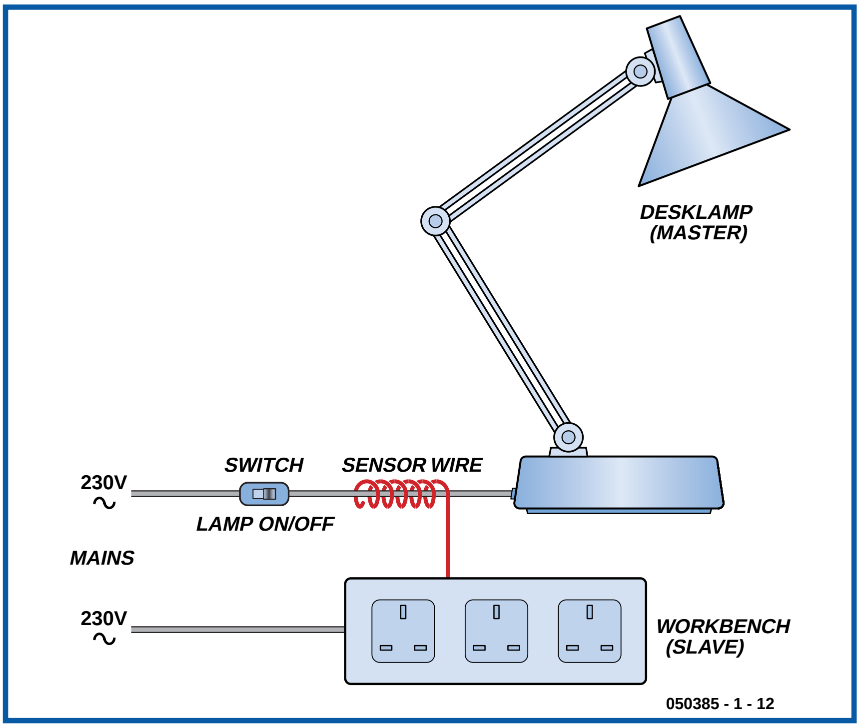
There are many situations where two or more pieces of equipment are used together and to avoid having to switch each item on separately or risk the possibility of leaving one of them on when switching the rest off, a slave switch is often used. Applications which spring to mind are a computer/printer/scanner etc or audio amplifier/record deck/tuner combinations or perhaps closest to every electronics enthusiast's heart, the work bench where a bench power supply/oscilloscope/soldering iron etc are often required simultaneously. The last is perhaps a particularly good example as the soldering iron, often having no power indicator, is invariably left on after all the other items have been switched off. Obviously the simplest solution is to plug all of the items into one extension socket and switch this on and off at the mains socket but this is not always very convenient as the switch may be difficult to reach often being behind or under the work bench.



Slave switches normally sense the current drawn from the mains supply when the master unit is switched on by detecting the resulting voltage across a series resistor and switching on a relay to power the slave unit(s). This means that the Live or Neutral feed must be broken to allow the resistor to be inserted. This circuit, which is intended for switching power to a work bench when the bench light is switched on, avoids resistors or any modifications to the lamp or slave appliances by sensing the electric field around the lamp cable when this is switched on. The lamp

Warning

The circuit itself is not isolated from the mains supply so that great care should be taken in its construction and testing. The sensor wire must also be adequately insulated and the circuit enclosed in a box to make it inaccessible to fingers etc. when it is in use.



then also functions as a 'power on' indicator (albeit a very large one that cannot be ignored) that shows when all of the equipment on the bench is switched on.

The field, which appears around the lamp cable when the mains is connected, can be sensed by a short piece of insulated wire simply wrapped around it and this is amplified by the three stage amplifier which can be regarded as a single super-transistor with a very high gain. The extremely small a.c. base current results in an appreciable collector current which after smoothing (by C3) is used to switch on a relay to power the other sockets. Power for the relay is obtained from a capacitor 'mains dropper' that generates no heat and provides a d.c. supply of around 15 volts when the relay is off. The output current of this supply is limited so that the voltage drops substantially when the relay pulls in but since relays require more current to operate them than they do to remain energised, this is not a problem.

Since the transistor emitter is referenced to mains Neutral, it is the field around the mains Live which will be detected. Consequently, for correct operation the Live wire to the lamp must be switched and this will no doubt be the case in all lamps where the switch is factory fitted. In case of uncertainty, a double-pole switch to interrupt both the Live and Neutral should be used. The sensitivity of the circuit can be increased or decreased as required by altering the value of the T2 emitter resistor. The sensing wire must of course be wrapped around a section of the lamp lead **after** the switch otherwise the relay will remain energised even when the lamp has been switched off.

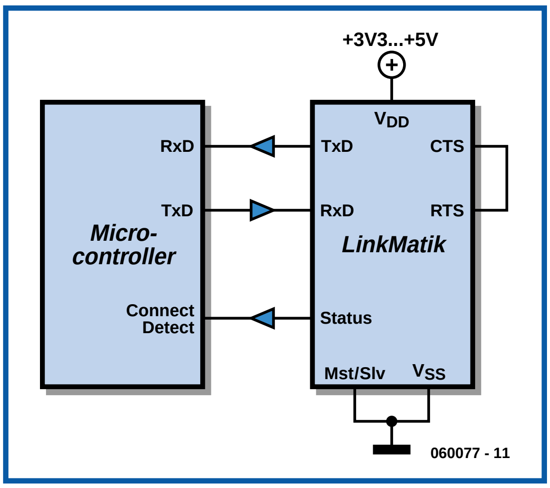
The drawing shows the general idea with the circuit built into the extension socket although, depending on the space available an auxiliary plastic box may need to be used.

(050385-1)

078 Serial to Bluetooth

Richard Hoptroff

When computer makers switched from RS232 to USB, one of the collateral benefits was TTL compatibility with regard to the supply voltage as well as signal levels. Unfortunately, there was also collateral damage, primarily in the form of an enormous increase in the complexity of the data transmission process. All you need for connection to an RS232 serial port is a level converter, but USB requires an extra IC (such as the Cypress CY7C68000 or a special-purpose microcontroller, such as the PIC18F4550) to make data transmission possible. That sounds like a zero-sum game, which raises the question: if you already have to use an extra IC, why not go directly to Bluetooth? And in fact, there are already several Bluetooth modules available, complete with an integrated antenna and simple serial inputs and outputs. However, many of them have the disadvantage that they are controlled using AT commands, which makes it necessary to use an additional controller.



However, there are also autonomous models available, such as the new LinkMatik module (www.flexipanel.com). If its Mst/Slv pin is held low, it waits until something wants to connect to it. If the pin is high, the module actively searches for devices that are ready to establish a connection. That means you can set up a short-range radio link without using a computer by simply coupling two modules together. However, generally speaking you will probably want to control an external device from a PC. In that case, you can let your PC search for devices that are ready to establish a connection. When the PC finds a module, it lists its available services. The service known as 'Serial Port Profile' (SPP) is the appropriate service of the LinkMatik module. If the security function is enabled, you will have to enter the PIN code of the module (set to '0000' when first delivered). Once a connection has been established, the Status pin of the module goes to a high level to indicate that it is ready for bidirectional data transmission. Now you can simply use the familiar TxD and RxD lines to transmit serial data. The RTS and CTS lines are also available for controlling the data flow. If you do not need that function, you can simply connect these two lines together. However, this wireless serial interface does not allow you to use these lines for purposes other than their intended use, as is often done with 'normal' serial interfaces.

As the data is buffered in the module before and after wireless transmission, RTS and CTS are generated locally. These two signals only control data flow to or from the module, but not over the wireless link.

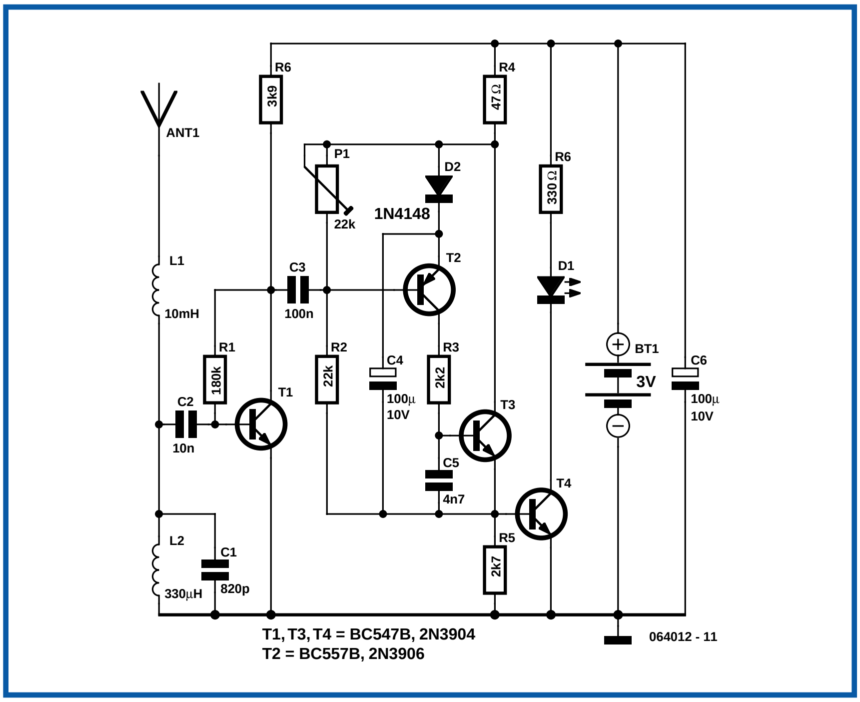
It is generally not possible to have more than one serial link via Bluetooth per PC. However, Bluetooth-2.0 compatible modules have recently become available, and they allow up to four serial links to be used concurrently along with other functions.

(060077-1)

Thunderstorm Predictor

079

Karel Walraven



Sure, listening to VHF FM has great advantages over MW/LW AM from the old days — now we have bright stereo free from interference, fading and noise! However, your FM radio will no longer predict the arrival of a thunderstorm as did the AM radio many years ago — reliably and hours before the trouble was upon you! The crux is that AM detection will faithfully reproduce the effects of lightning and other massive static discharges approaching in a very simple way: they're audible as slight crackling noises in the loudspeaker, almost irrespective of the tuning of the radio!

Assuming no AM radio is available anymore, a dedicated VLF receiver tuned to about 300 kHz can faithfully detect the crackle of approaching lightning. The simple receiver shown here consists of a loosely tuned amplifier driving a kind of flasher circuit that blinks an LED in synchronicity with the lightning bolts. The frequency and intensity of the LED activity indicates the intensity and distance of the storm respectively.

Looking at the circuit diagram, the LED driver is not biased to flash until a burst of RF energy, amplified by T1, arrives at the base of T2. The receiver works off 3 volts and has a negligible standby current of about 350 microamperes which will hardly dent the shelf life of a couple of 1.5-V D-size cells. T2 and T3 form a monostable generator triggered by sudden drops in T1's collector voltage. Preset P1 is adjusted until the LED remains off when you're sure there's no thunderstorm around for a few hundred miles. The value of the LED series resistor is subject to experimentation and LED current. L2, C1 and the antenna are coarsely tuned for resonance at about 300 kHz. Frequency-wise, lightning is a fairly broadband phenomenon so any tuning to between 200 and 400 kHz will be fine for the circuit but make sure you're not accidentally tuned to a nearby VLF transmitter! The input signal is obtained from a 70-cm long piece of stiff wire, with coil L1 inserted for impedance matching and lengthening the antenna electrically.

Warning

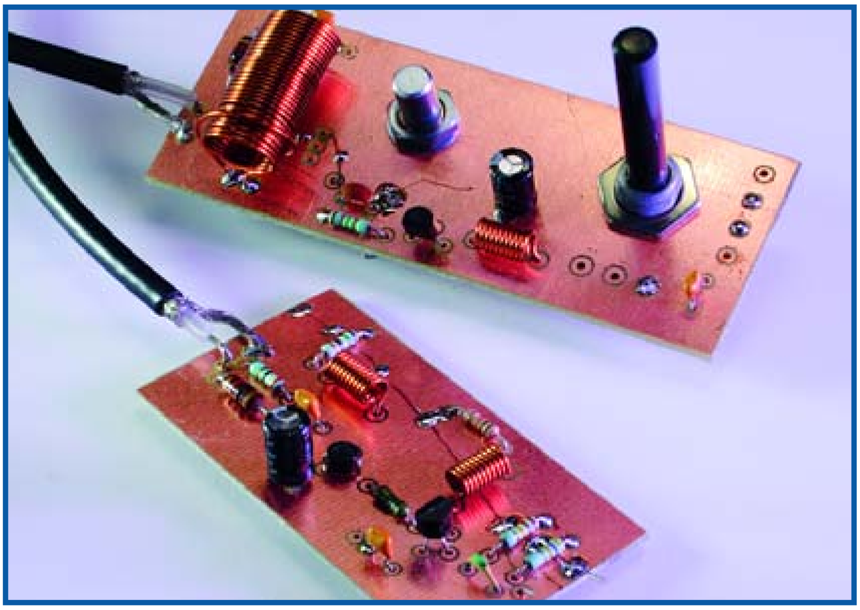
This circuit and in particular the antenna must not be used to attract lightning. Consequently, neither the circuit nor the antenna may be used outdoors and/or powered from the mains.

(064012-1)

080

Active Antenna

Stefan Delleman



Short-wave listeners often are not able to, or allowed to, install a long-wire antenna or other large dimension antenna in or around the home. In such cases, the present active antenna, intended for the frequency range 3–30 MHz, may be found useful. The author used a 1-metre long rod or brass tube with a diameter of 2–6 mm. The circuit consists of two parts, one to be located close to the antenna, while the other should be placed in the associated power supply of the receiver. The two sections may be connected by a coaxial cable of up to 20 m long without causing any discernible attenuation.

The antenna signal is pre-amplified by a two-stage combination, T1-T3. The main amplification is provided by the input transformer, formed by L3, L4, and L5, in the receiver section. This is followed by a switch that enables the frequency range to be selected (3–10 MHz in position LOW, and 9–30 MHz in position HIGH). The signal strength may be adjusted to suit the receiver with potentiometer P1.

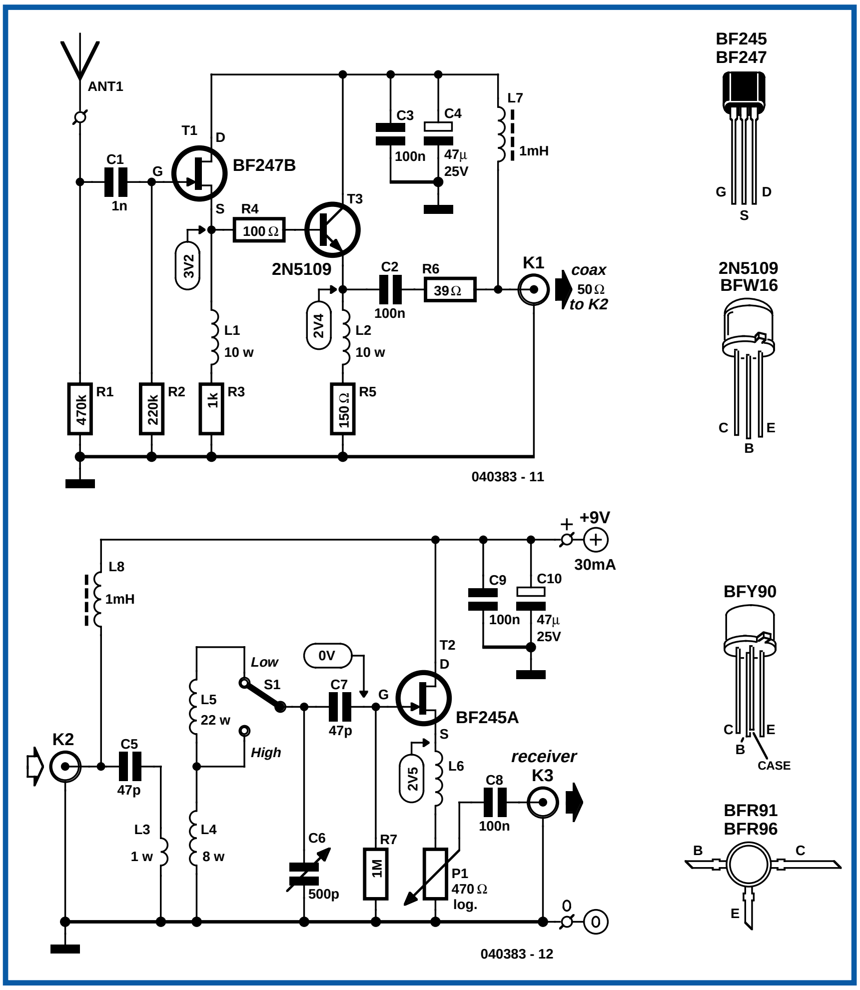
The active antenna is readily constructed with the aid of the two printed circuit boards shown.

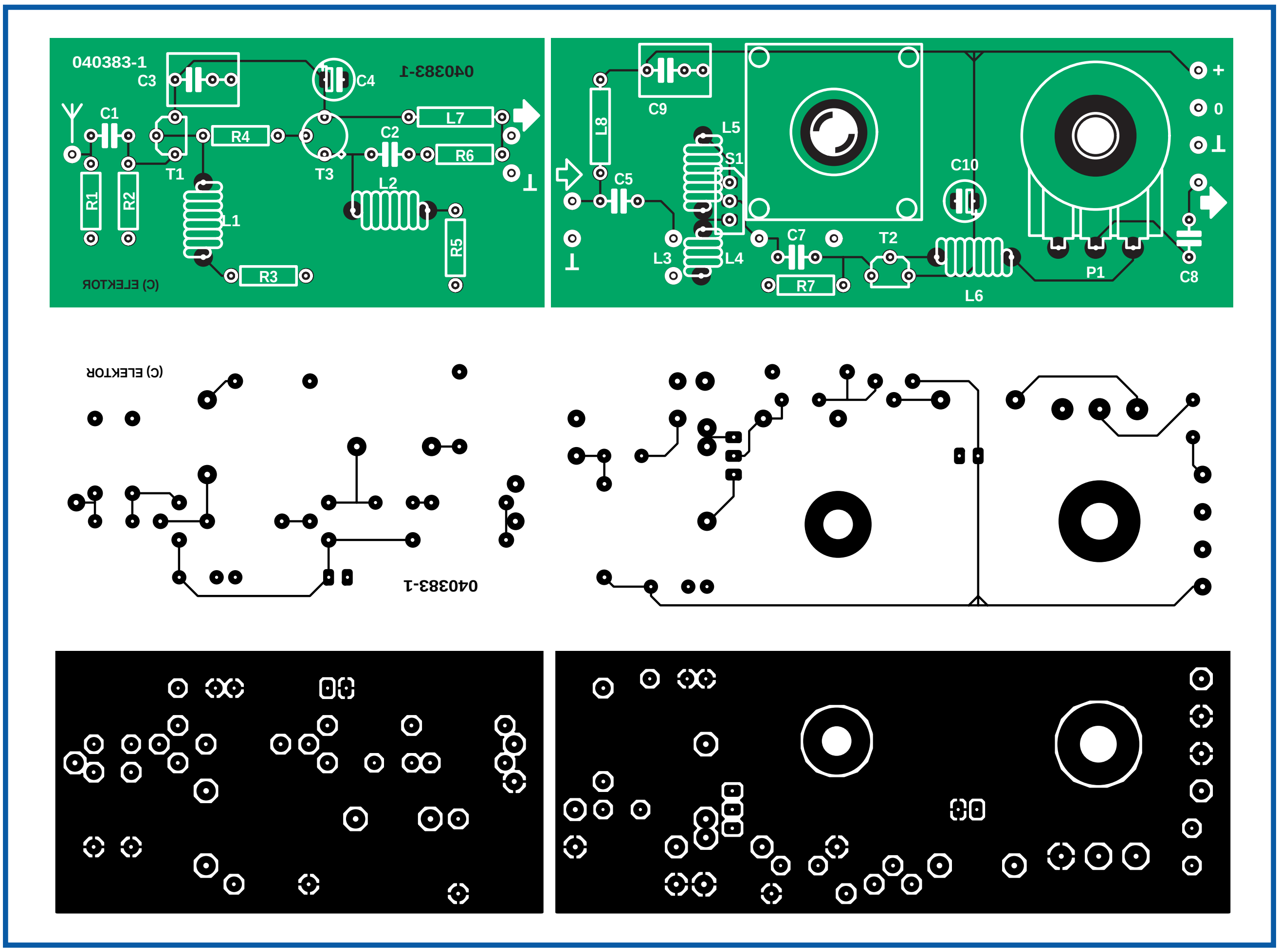
Since we are concerned with only relatively low radio frequencies, the choice of components is not too crucial. Various types of FET may be used: BF245, BF246, BF256, or the SMD variants of these, but do mind their connections! The same applies for the transistors: BFW16, BFY90, BFR91, BFR96; any of these will do.

A few hints for readers who conduct their own experiments. A lower value of capacitor C1 results in a somewhat looser coupling to the antenna, but also in lower signal strength. It may be worthwhile to replace the capacitor with a variable type. Inductor L6 ensures that the output voltage at higher frequencies (30 MHz) is not much higher than at lower frequencies (3 MHz). This is because the Q factor of coils L4 and L5 increases at higher frequencies, which leads to higher amplitudes. This is compensated by L6. This inductor may be omitted and replaced by a wire bridge, but then the output voltages at higher frequencies increases.

Aim at obtaining as tight a coupling as feasible between L4 and L5. Because of this, it is better to wind the two coils as one, that is, 30 turns with a tap than to wind two separate coils (see photograph).

(040383-1)





COMPONENTS LIST

Resistors
R1 = 470kΩ
R2 = 220kΩ
R3 = 1kΩ
R4 = 100Ω
R5 = 150Ω
R6 = 39Ω
R7 = 1MΩ
P1= 470Ω logarithmic

Capacitors
C1 = 1nF
C2,C3,C8,C9 = 100nF
C4,C10 = 47µF 25V radial
C5,C7 = 47pF
C6 = 500pF tuning capacitor

Inductors
L1,L2,L6 = 10 turns 0.7mm ECW, 4mm diameter (wind on 3.5mm drill bit)
L3 = 1 turn 0.7mm ECW, around L4
L4 = 8 turns 0.7mm ECW, 12mm diameter (wind on 10 mm drill bit)
L5 = 22 turns 0.7mm ECW, 12mm diameter (wind on 10mm drill bit)
L7,L8 = 1mH miniature choke

Semiconductors
T1 = BF247B
T2 = BF245A
T3 = 2N5109

Miscellaneous
PCB, ref. 040383-1 from The PCBShop

Alternative Halogen Supply

081

Stijn Coenen

Readers who do not care to modify the power supply of an old PC into a suitable halogen power source (see our April 2006 issue), may find the present design a welcome alternative.

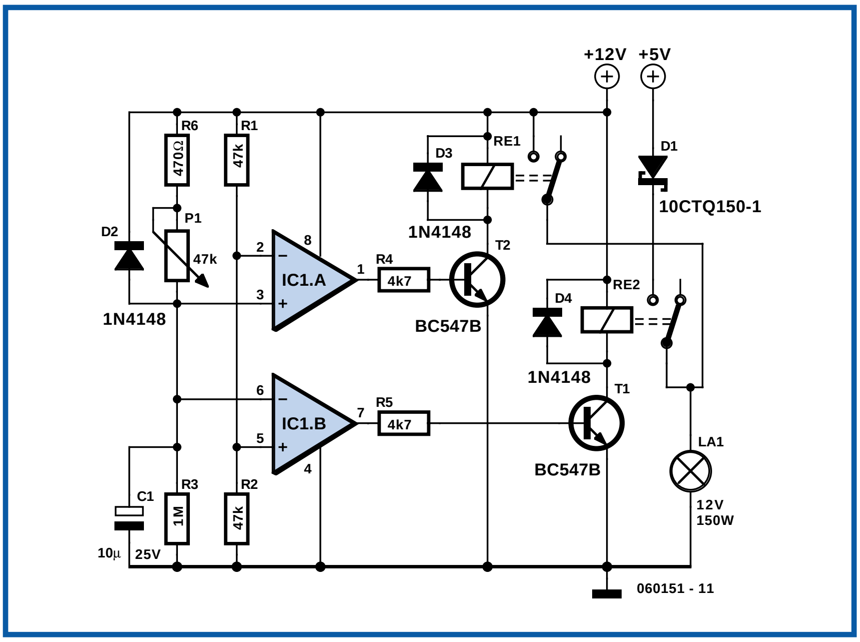
The circuit does not need any changes to the power supply. It allows the halogen lamps to be initially powered from the 5-V rail of the supply via RE2, so that they are preheated. Subsequently, they are powered from the 12-V rail via RE1, while at the same time the 5-V rail is disconnected. This ensures that the current surge through the lamps is so small that the protection in the power supply does not react.

Operation of the circuit is as follows. As soon as the PC supply provides power, IC1.B drives T1 into conduction and RE2 closes. The potential at the non-inverting input of IC1.B is 6 V, while that at the inverting input rises from 0 V. Lamp LA1 is then connected to the 5-V rail.

After a short span of time, the voltage across C1 has risen to a value where

IC1.B changes over, whereupon T1 is cut off. At the same time, IC1.A drives T2 into conduction. The circuit is then decoupled from the 5-V rail and connected to the 12-V terminal. The 5-V rail in the PC power supply is protected against spikes on the 12-V line by D1.
Diode D2 protects IC1 against over-voltage on its inputs should the 12-V rail fail. Resistors R4 and R5 limit the base currents of the transistors. D3 and D4 are quenching diodes.
The time during which lamp LA1 is powered by 5 V is preset with potentiometer P1. The maximum time span is about 0.33 s and the minimum 3.3 ms. The latter is perhaps rather short, but it also depends to some extent on the type of power supply used. Some experimentation may be worthwhile!

(060151-1)

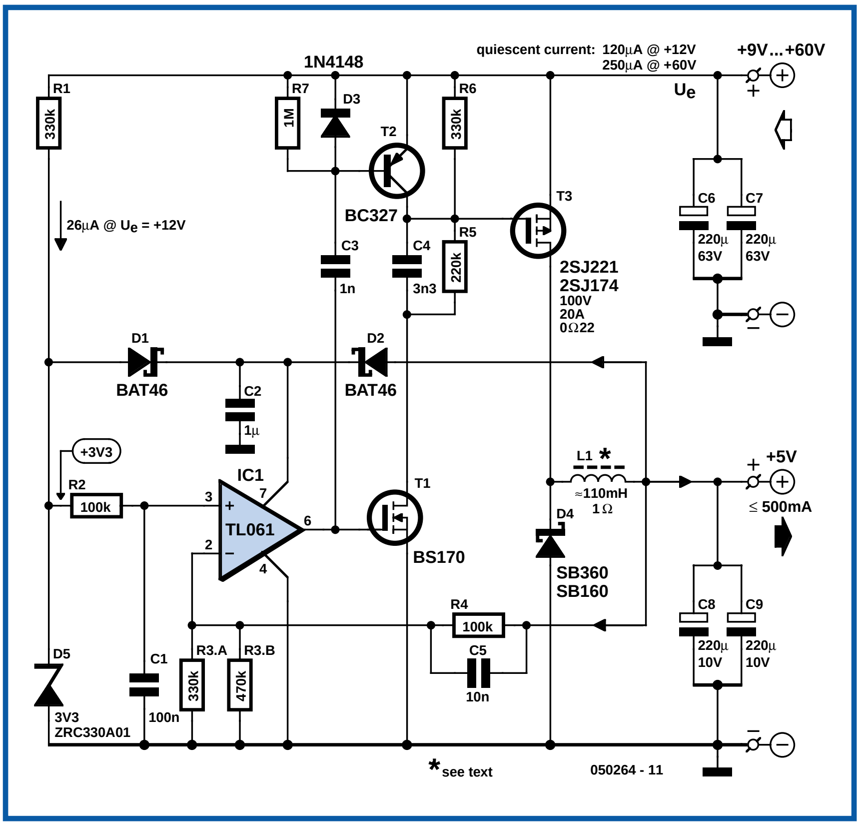


082

Low Loss Step Down Converter

Michel Franke

This circuit arose from the need of the author to provide a 5 V output from the 24 V battery of a solar powered generator. Although solar power is essentially free it is important not to be wasteful especially for small installations; if the battery runs flat at midnight you've got a long wait before the sun comes up again. The basic requirement was to make an efficient step-down converter to power low voltage equipment; the final design shown here accepts a wide input voltage from 9 to 60 V with an output current of 500 mA. The efficiency is very good even with a load of 1 mA the design is still better than a standard linear regulator. The low quiescent current (200 µA) also plays a part in reducing losses.
Some of the components specified (particularly the power MOSFET) are not the most economical on the market but they have been deliberately selected with efficiency in mind.
When power is applied to the circuit a reference voltage is produced on one side of R2. D1 connects this to the supply (pin 7) of IC1 to provide power at start-up. Once the circuit begins switching and the output voltage rises to 5 V, D2 becomes forward biased and powers the IC from the output. Diode D1 becomes reverse biased reducing current through R1. When the circuit is first powered up the voltage on pin 2 of IC1 is below the reference voltage on pin 3, this produces a high level on output pin 6. The low power MOSFET T1 is switched on which in turn switches the



power MOSFET T3 via R5 and the speed-up capacitor C4, the output voltage starts to rise.

When the output approaches 5 V the voltage fed back to the inverting input of IC1 becomes positive with respect to the non inverting input (reference) and switches the output of IC1 low. T1 and T3 now switch off and C3 transfers this negative going edge to the base of T2 which conducts and effectively shorts out the gate capacitance of T3 thereby improving its switch off time.

The switching frequency is not governed by a fixed clock signal but instead by the load current; with no load attached the circuit oscillates at about 40 Hz while at 500 mA it runs at approximately 5 kHz. The variable clock rate dictates that the output inductor L1 needs to have the relatively high value of 100 mH.

The coil can be wound on ferrite core material with a high AL value to allow the smallest number of turns and produce the lowest possible resistance. Ready-made coils of this value often have a resistance greater than 1 Ω and these would only be suitable for an output load current of less than 100 mA.

The voltage divider ratio formed by R4 and R3 sets the output voltage and these values can be changed if a different output voltage is required. The output voltage must be a minimum of 1 V below the input voltage and the output has a minimum value of 4 V because of the supply to IC1.

A maximum efficiency of around 90 % was achieved with this circuit using an input voltage between 9 and 15 V and supplying a current greater than 5 mA, even with an input voltage of 30 V the circuit efficiency was around 80 %. If the circuit is used with a relatively low input voltage efficiency gains can be made by replacing D4 with a similar device with a lower reverse breakdown voltage rating, these devices tend to have a smaller forward voltage drop which reduces losses in the diode at high currents. At higher input voltage levels the value of resistor R1 can be increased proportionally to reduce the quiescent current even further.

(050264-1)

10,000x with One Transistor

083

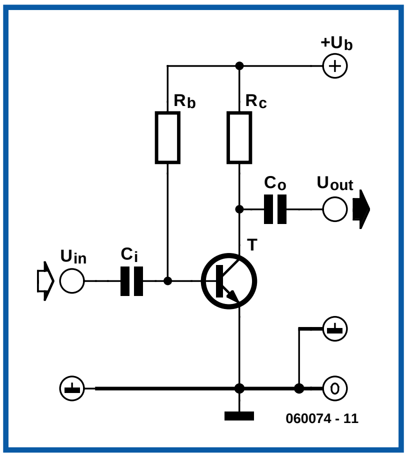
Gert Baars

For a collector follower with emitter resistor, you'll often find that the gain per stage is no more than 10 to 50 times. The gain increases when the emitter resistor is omitted. Unfortunately, the distortion also increases.

With a ubiquitous transistor such as the BC547B, the gain of the transistor is roughly equal to 40 times the collector current (I_c), provided the collector current is less than a few milliamps. This value is in theory equal to the expression q/KT, where q is the charge of the electron, K is Boltzmann's constant and T is the temperature in Kelvin. For simplicity, and assuming room temperature, we round this value to 40.

For a single stage amplifier circuit with grounded emitter it holds that the gain U_{out}/U_{in} (for AC voltage) is in theory equal to SR_c. As we observed before, the slope S is about $40I_c$. From this follows that the gain is approximately equal to $40I_cR_c$.

What does this mean? In the first instance this leads to a very practical rule of thumb: that gain of a grounded emitter circuit amounts to $40{\cdot}I_c{\cdot}Rc$, which is equal to 40 times the voltage across the collector resistor. If U_b is, for example, equal to 12 V and the collector is set to 5 V, then we know, irrespective of the values of the resistors that the gain will be about 40?(12–5) = 280.



Notable is the fact that in this way the gain can be very high in theory, by selecting a high power supply voltage. Such a voltage could be obtained from an isolating transformer from the mains. An isolating transformer can be made by connecting the secondaries of two transformers together, which results in a galvanically isolated mains voltage. That means, that with a mains voltage of 240 V_{eff} there will be about 340 V DC after rectification and filtering. If in the amplifier circuit the power supply voltage is now 340 V and the collector voltage is 2 V, then the gain is in theory equal to 40 x (340–2). This is more than 13,500 times!

However, there are a few drawbacks in practice. This is related to the output characteristic of the transistor. In practice, it turns out that the transistor does actually have an output resistor between collector and emitter. This output resistance exists as a transistor parameter and is called 'h_{oe}'. In normal designs this parameter is of no consequence because it has no noticeable effect if the collector resistor is not large. When powering the amplifier from 340 V and setting the collector current to 1 mA, the collector resistor will have a value of 338 kΩ. Whether the 'h_{oe}'-parameter has any influence depends in the type of transistor.

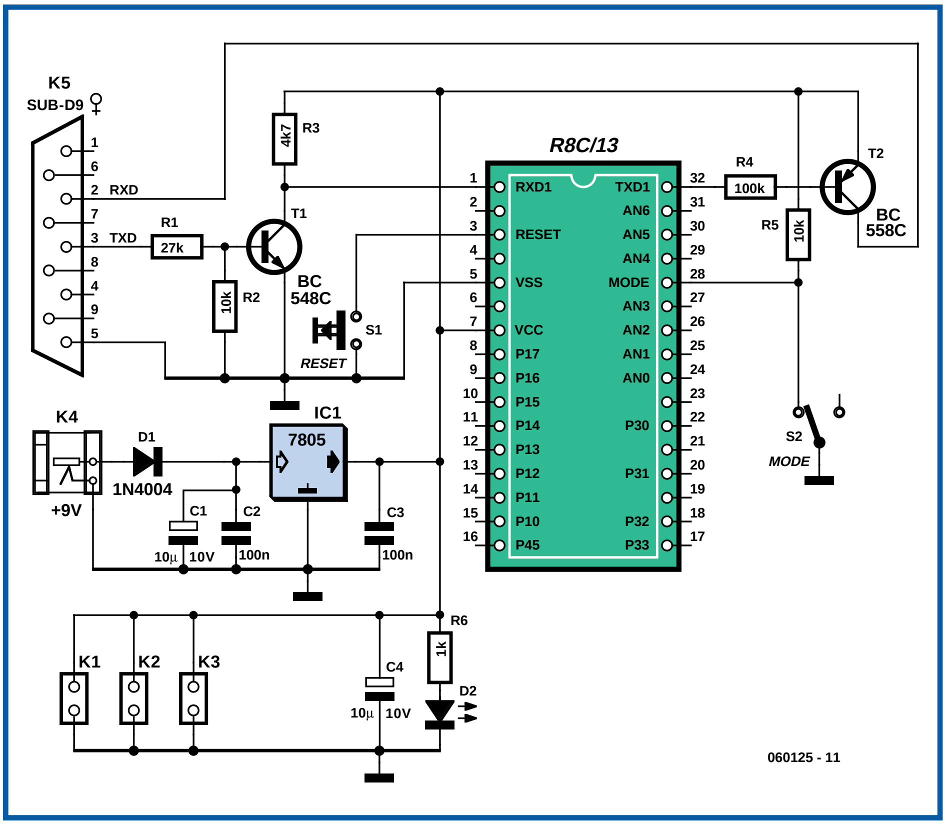
We also note that with such high gains, the base-collector capacitance in particular will start to play a role. As a consequence the input frequency may not be too high. For a higher bandwidth we will have to use a transistor with small C_{bc}, such as a BF494 or perhaps even an SHF transistor such as a BFR91A. We will have to adjust the value of the base resistor to the new h_{fe}.

The author has carried out measurements with a BC547B at a power supply voltage of 30 V. A value of 2 V was chosen for the collector voltage. Measurements confirm the rule of thumb. The gain was more than 1,000 times and the effects of 'h_{oe}' and the base-collector capacitance were not noticeable because of the now much smaller collector resistor.

(060074-1)

084 Programmer Board for the R8C/13

Jean Brunet



This board is a spin-off of the 10-pound 'R8C Tom Thumb' project published in the February 2006 issue of *Elektor Electronics*.

The author has added an LED behind the 5-V regulator and three small connectors (ground (0V); +5 V on the bottom left) to supply power to potential daughterboards. Connectors are linked to the R8C/13 output ports.

The layout of components has been selected in order to ensure easy manipulation. The connections are arranged in the upper area of the board, while the Reset button and Mode switch are found in the lower area. Enough space has been left at around module board so that it is easier to extract it without a special tool.

Following the advice of specialists on Elektor's R8C Forum, the author opted for a 7805 regulator.

The BC558C transistor (upper right) is shifted to the right so as not to complicate handling the R8C/13 Tom Thumb module. In this way, it's easy to install the module on the carrier board, as well as to remove it.

Installation of components

The component type codes and characteristics can be found in the component list; a glance at the photo lets you identify everything, as does the overlay for the components, on the other page.

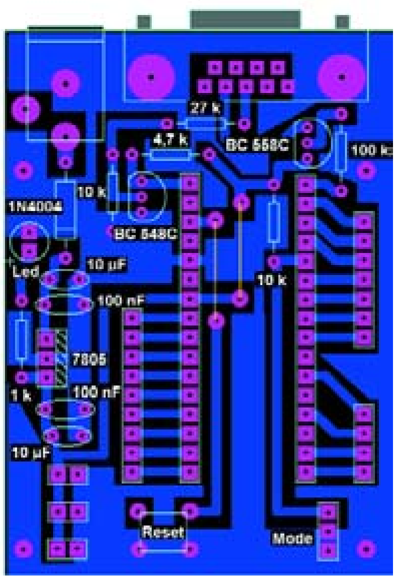
Do not forget to install the wire links and resistor R5 between the links for the R8C module before plugging in the latter.

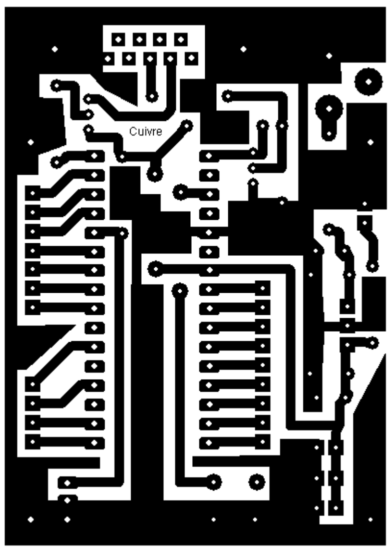
The reset pushbutton is found on the bottom, slightly shifted to the left, and the programming switch is found on the right.

Pay attention to the direction of the switch. It is more practical for the off position to be directed toward the bottom. A test with a simple ohmmeter will help avoid an error in direction. Do the same verification for the reset button. Test and verify that it is actually open when in rest position before soldering it in the correct direction.

Connectors linked to the R8C module are male but there is nothing to stop you from using female connectors, even though the male connectors seem to be sturdier. For the Tom Thumb module, use IC socket strip that can be sectioned.

The component overlay and other PCB artwork (Proteus format) are available on





the author's web page devoted to this project. Lots of other information on the project may be found on the R8C Service Page at

www.elektor-electronics.co.uk/Default.aspx?tabid=110

There the artwork is reproduced in a slightly different form from what you are used to, but it works very well for making your own board. The dimensions of the PCB are 51 x 71.5 mm.

In the file download, this diagram is a mirror image so that the ink comes into contact with the copper, which is preferable during UV illumination. If you are using the diagram printed in the magazine, you should mirror it to obtain the same result.

The author uses an inkjet printer and stacks three transparencies.

To utilise this board, all you need to do is insert the R8C/13 module in its socket, making sure the quartz crystal is turned toward the RS-232 base, as in the photo. Connect the RS-232 cable to the computer and then apply the supply voltage (adaptor supplying between 9 and 12 V).

Testing the board

To test the board, load the program *toggle_all.mot* or compile the program below, whose purpose is to make all of the R8C/13 ports blink.

Now you are fully equipped to better discover the possibilities of the R8C/13 module and to conjure up super applications from this minimal configuration.

Programming

To program the module, all you need to do is to move switch S2 toward the bottom and press the pushbutton to reset the module. Start the FDT Simple interface. In the menu, as an option, check *Autodisconnect* and *Erase device before program*. Load *toggle_all.mot* and click on *program flash*.

After confirming programming, move the Mode switch up and press S1 (reset).

With the help of an LED and a 1-kΩ resistor in series, verify the operation of the R8C outputs one by one. If one of them does not produce LED flashing, you should verify the soldering.

The author, who contributed to a series of pages in the R8C section on the French Elektor site, has his own website at the following address:
http://perso.wanadoo.fr/asnora/R8C/platine_de_programmation.htm

(060125-1)

COMPONENTS LIST

Resistors
R1 = 27kΩ
R2,R5 = 10kΩ
R3 = 4kΩ7
R4 = 100kΩ
R6 = 1kΩ

Capacitors
C1,C4 = 10µF/10V
C23,C3 = 100nF

Semiconductors
D1 = 1N4004
D2 = LED, red, dia. 3mm or 5 mm
T1 = BC548C
T2 = BC558C
IC1 = 7805

Miscellaneous
S1 = pushbutton (reset)
S2 = slide switch, lead pitch 2.5 mm (programming)
K1,K2,K3 = 2-way pinheader
K4 = mains adaptor socket
K5 = 9-way sub-D socket (female), PCB mount
2 lengths of 16-way IC socket strip (for R8C module socket)

Program listing: toggle_all.mot

```
#include "sfr_r813.h"

long t;

void main(void)
{
/*————————————————————————————
- Change on-chip oscillator clock to Main clock -
—————————————————————————————*/

prc0 = 1;             /* Protect off */
cm13 = 1;            /* Xin Xout */
cm15 = 1;            /* XCIN-XCOUT drive capacity select bit
: HIGH */
cm05 = 0;            /* Xin on */
cm16 = 0;            /* Main clock = No division mode */
cm17 = 0;
cm06 = 0;            /* CM16 and CM17 enable */
asm("nop");          /* Waiting for oscillator to stabilise
*/
asm("nop");
asm("nop");
asm("nop");
ocd2 = 0;            /* Main clock change */
prc0 = 0;             /* Protect on */

prc2 = 1;            /* Protect off  to write on pd0 */
pd0 = 0xFE;    /* bits 1 à 7 sur p0. an0 = p0_7, an1 = p0_6
... an6 = p0_1. p0_0 is not present in the device.
pd1 = 0xFF;      /* Set Ports be used for output*/
pd3 = 0x0F;    /* just p3_0 ... p3_3
pd4 = 0x20;    /* just p4_5

while (1)       /* Loop */
  {
  p0 = 0xFE;
  p1 = 0xFF;
  p3 = 0x0F;
  p4_5 = 0x01;
  for (t=0; t<50000; t++);
  p0 = 0x00;
  p1 = 0x00;
  p3 = 0x00;
  p4_5 = 0x00;
  for (t=0; t<50000; t++);
  }
}
```

085

Intelligent Interface for 1 to 8 Servos

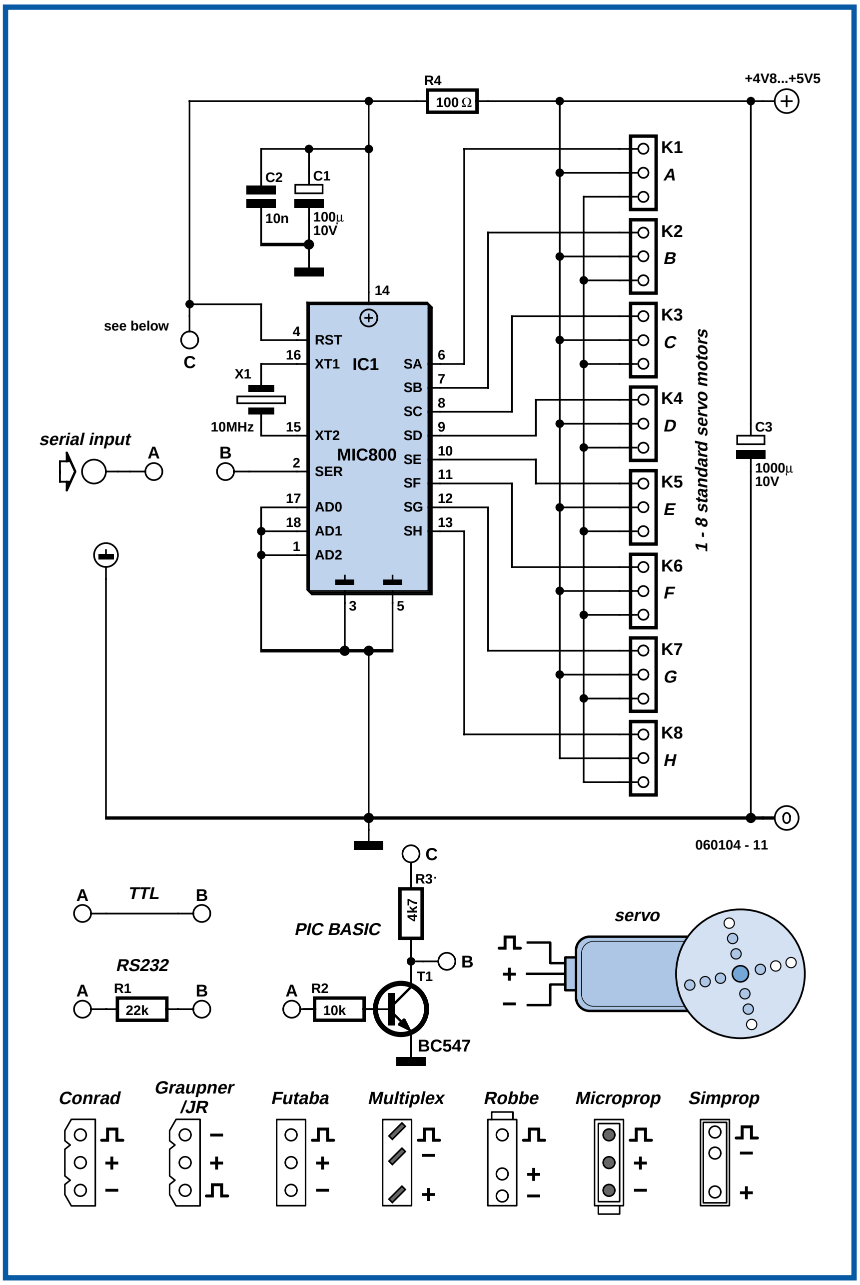
Christian Tavernier

Today, radio-controlled (RC) servos are very common in robotics and there are often many present in one robot. In general, a hexapod utilizes at least three servos, while a simple arm can use between six or seven of them. If the control of such servos remains theoretically easy to produce with a microcontroller, having several within the same robot causes the microcontroller to overload very quickly, spending more time in the end managing servos than doing the calculations necessary to properly operate the robot. In fact, we should remember that a radio control servo is operated with pulses whose width varies from 1 to 2 ms and defines its position. The problem is that these pulses must be repeated at least every 20 ms if we want the servo to stay in position. It is precisely this repetition, multiplied by the number of servos being controlled, that ends up overloading the microcontroller that controls them.

Therefore, we propose a fix for this problem using a specialised circuit capable of controlling one to eight standard radio control servos via very simple controls transmitted by a common asynchronous serial connection. We are referring to the MIC800 from Mictronics (www.mictronics.com). The application schematics could not be simpler.

Not counting a simple quartz crystal (X1) and the usual loading capacitors (C1 and C2), the circuit is directly connected to 1-8 servos it will control. Concerning the serial connection, three different possibilities are offered, depending on what's connected to points A and B are in the diagram:

- one direct connection when there is a TTL control signal from a microcontroller with a UART and capable of supplying serial signals in inverse logic (one Basic Stamp, for example);
- one 22 kΩ resistor, if there is a serial connection with true RS-232 levels;
- one transistor with inverted wiring in the case of TTL control by a microcontroller having a UART, but unable to provide serial signals in inverse logic (PICBasic, for example).



In fact, the MIC800 was designed in order to be directly controlled by any true serial RS232 connection. It thus accepts input signals in negative logic (a logic 1 corresponding to a Low level and vice versa). In the case of a direct TTL connection, and depending on the possibilities of the UART contained in the related microcontroller, it is sometimes impossible to generate such signals. Therefore, we must should an inverter transistor.

Dialogue with the MIC800 occurs at 2,400 baud on 8 data bits, without parity. The syntax of the commands to be sent for controlling the servos is extremely simple and is composed of the next group of coded characters in ASCII *m n xxx* where:

- *m* is a letter included between S and Z which corresponds to the MIC800 address. In fact, if you consult the datasheet available on the Mictronics site (www.mictronics.com), you'll soon notice that you can place up to eight MIC800s on a single serial connector and control up to 64 servos in this way. This option is not utilized here and the address is set to S using pin grounding AD0 to AD2.
- *n* stands for a letter between A and H indicating the servo to control in compliance with the marks, as indicated in our

drawing at the connectors (K1 corresponding to A, and K8 to H).

- *xxx* is a number between 001 and 128 which indicates the position required for the servo, 001 corresponding to the extreme counter-clockwise position and 128 to the extreme position in the other direction.

From a Basic Stamp, all you need to do is write it as shown in the following example:

SEROUT Pin, 16780, [''S'', ''X'', DEC Pos, CR]

where Pin is utilized for the serial port, X is the letter identifier of the servo included between A and H (K1 to K8) and Pos is the desired position included between 1 and 128.

With a PICBasic (www.comfiletech.com) and the same text as below, we would write:

SEROUT Pin, 138, 0, 0, [''S'', ''X'', DEC (Pos), 13]

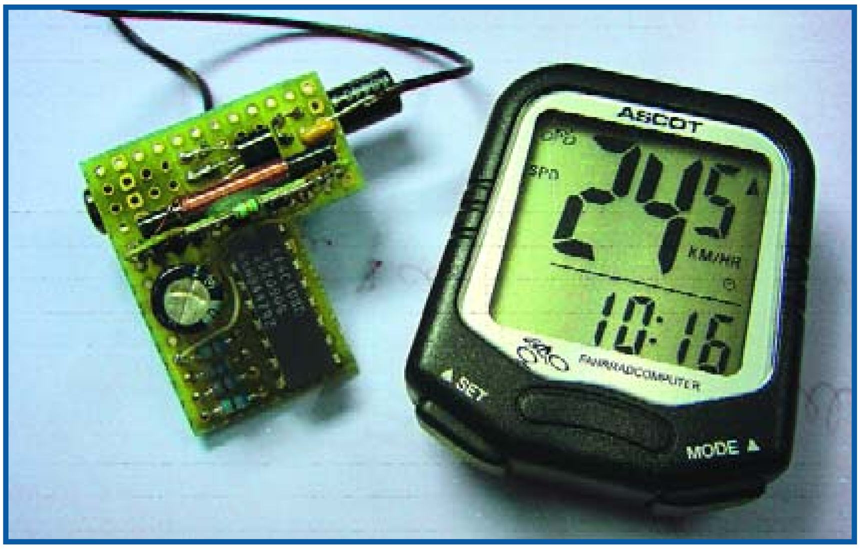
After turning on the MIC800, all outputs of the servo control are inactive. Then, as soon as a command has been sent to a servo destination, the corresponding output automatically generates the pulses required to maintain its position as long as the circuit remains on.

www.tavernier-c.com (060104-1)

Bicycle Speedometer with Hub Dynamo

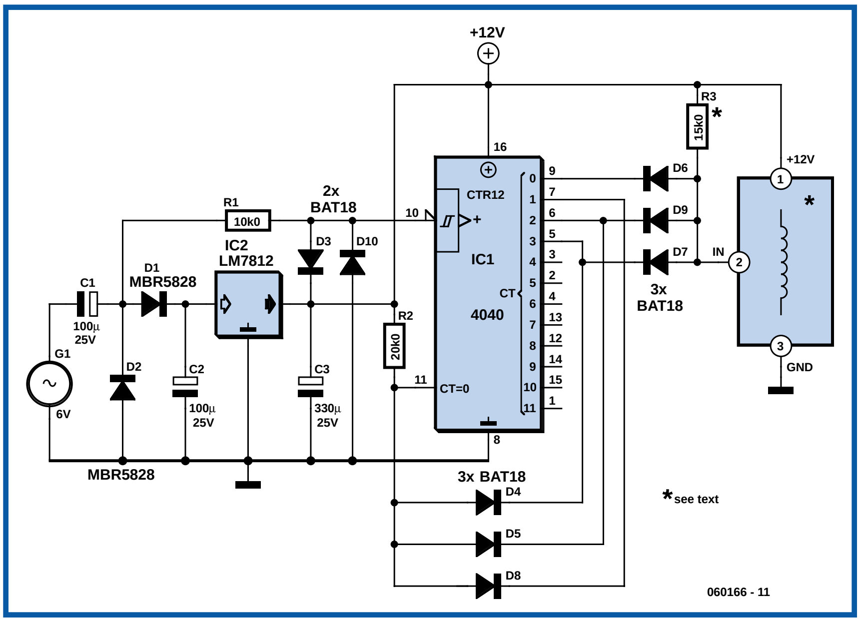
086

Hans Michielsen



The idea for this circuit came when the author had problems with the wireless speedometer on his bicycle. Such a device consists of two parts: the cycle computer itself and a transmitter that is mounted on the front fork. A small magnet is attached to the spokes so that the transmitter sends out a pulse for every revolution of the wheel (as long as everything has been fitted properly). Since the range of the transmitter is limited (about 75 cm), you'll be lucky if it works straight away. And when the voltage of the battery starts to drop you can forget it. The following circuit gets round these problems.

A Shimano NX-30 hub dynamo has 28 poles. This results in 14 complete periods of a 6 V alternating voltage per revolution (when loaded by a lamp; under no load the voltage is much higher). C1, C2, D1 and D2 double the voltage of the AC output. Regulator IC2 keeps the voltage to the transmitter and the divider IC at a safe level (12 V, the same as the original battery). The divider chip (IC1) divides the frequency of the signal from the dynamo by 14, so that a single pulse goes to the transmitter for every revolution of the wheel. This pulse enters the circuit at the point where the reed contact was originally.



The circuit is built inside the front light, since it has enough room and a cable from the dynamo is already present. The distance to the cycle computer is smaller as well in that case.

The following tip can be used if you want to save yourself a few components. In the author's prototype the counter divided by 16 and the setting for the size of the wheel was adjusted to 16/14th of the real size in the setup of the cycle computer. In that case you can leave out D4, D5 and D8.

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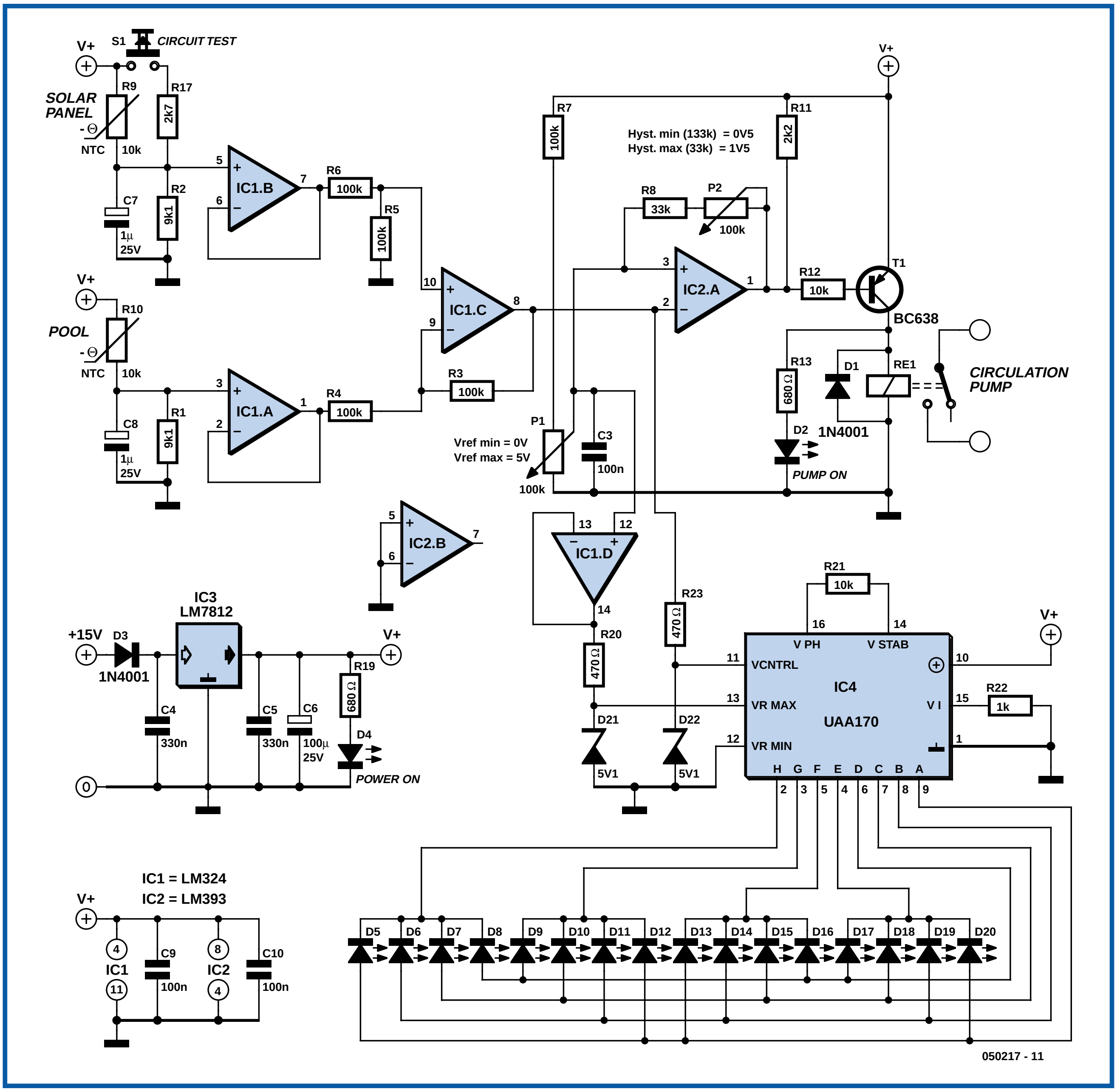
087

Temperature Sensitive Switch for Solar Collector



Tom Henskens

This circuit can be used to turn the pump on and off when a solar collector is used to heat a swimming pool, for example. This way the water in the collector has a chance to warm up significantly before it is pumped to the swimming pool. A bonus is that the pump doesn't need to be on continuously.

The basis of operation is as follows. When the temperature of the water in the solar collector is at least 10 °C higher than that of the swimming pool, the pump starts up. The warm water will then be pumped to the swimming pool and the temperature difference will drop rapidly. This is because fresh, cool water from the swimming pool enters the collector.

Once the difference is less than 3 °C the pump is turned off again.

R10/R1 and R9/R2 each make up a potential divider. The output voltage will be about half the supply voltage at a temperature around 25 °C.

C7 and C8 suppress any possible interference. The NTCs (R9 and R10) are usually connected via several meters of cable, which can easily pick up interference.

Both potential dividers are followed by a buffer stage (IC1a/IC1b). IC1c and R3, R4, R5 and R6 make up a differential amplifier (with unit gain), which measures the temperature difference (i.e. voltage difference).

When both temperatures are equal the output is 0 V. When the temperature of the solar collector rises, the differential amplifier outputs a positive voltage. This signal is used to trigger a comparator, which is built round an LM393 (IC2a). R7 and P1 are used to set the reference

voltage at which the comparator changes state. R8 and P2 provide an adjustable hysteresis. R11 has been added to the output of IC2a because the opamp has an open collector output.
A power switch for the pump is created by R12, T1 and Re1. D1 protects T1 against voltage spikes from the relay coil when it is turned off.
A visual indication of the state of the controller is provided by IC4 (UAA170), a LED spot display driver with 16 LEDs. The reference voltage for the comparator is buffered by IC1d and fed to input VRMAX of the UAA170. R20/D21 and R23/D22 limit the input voltages of IC4 to 5.1 V, since the maximum permissible input voltage to the UAA170 is 6 V.
When there is no temperature difference, LED D20 turns on. As the temperature difference increases the next LED turns on. The full scale of the LED bar is equal to the reference voltage of the comparator. This means that when the last LED (D5) of the UAA170 turns on, the comparator switches state. This is also indicated by D2.
The power supply has been kept fairly simple and is built around a LM7812 regulator. The circuit is protected against a reverse polarity at the input by D3. You have to make sure that the input to the regulator is at least 15 V, otherwise it won't function properly.

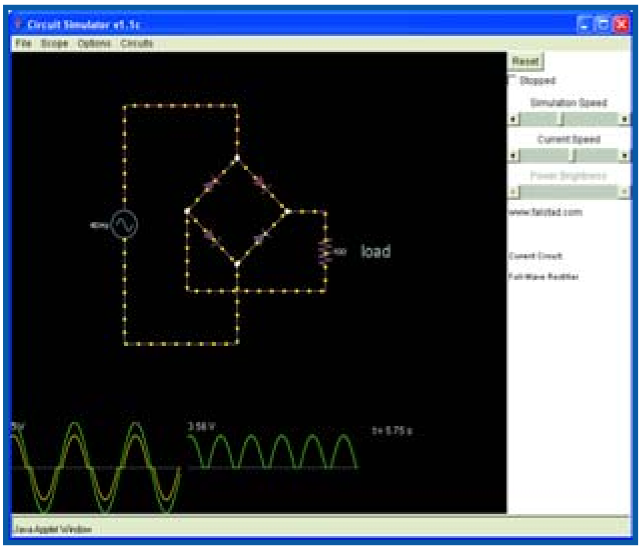
There are a few points you should note regarding the mounting of the NTCs.
NTC R9 should be placed near the output of the solar collector. You should choose a point that always contains water, even when some of the water flows back a little. NTC R10 should be mounted inside the filter compartment (where it exists), which continually pumps the swimming pool water. This will give a good indication of the temperature of the water.

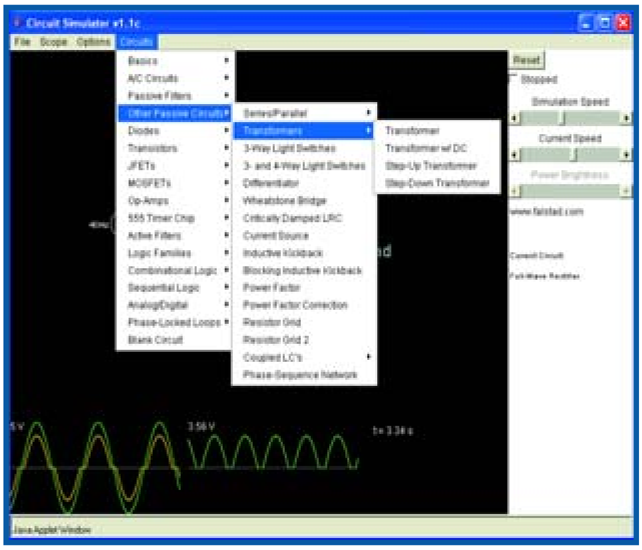
The way the circuit has to be set up depends how it has been installed and is very much an experimental process. To start with, set hysteresis potentiometer (P2) halfway. Then set the reference voltage to about 1.5-2 V with P1.
On a sunny day you can measure the voltage difference to get an idea as to which reference voltage needs to be adjusted.
The hysteresis setting determines how long the pump stays on for, which is until the minimum temperature difference has been reached.

(050217)

Simulation Applets

088





Simulation programs for analogue circuits come in all shapes and sizes, and at various prices. It is often much easier to test a circuit on a PC instead of reaching for the soldering iron.
The website of Paul Falstad contains a free Java applet that illustrates how various basic analogue and digital circuits work. Voltages and currents can be brought to life in simulated scope screens; circuits can be modified by the addition, removal or alteration of components. Unfortunately, the addition of components has not (yet?) been fully implemented in the program: you'll see the added component appear in the circuit diagram, but it won't have any effect in the operation of the circuit. But don't let that spoil your fun. Its usefulness is increased by the addition of a large library of example circuits, which makes this applet educational as well. Each simulation is accompanied by a short description.
The simulations aren't limited to just electronics; other subjects such as physics and mathematics have also been extensively covered. There's more than enough on this website to keep you happily occupied for a few hours…

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Web link

www.falstad.com/mathphysics.html

The electronics simulation can be found under Electrodynamics/Analog Circuit Simulator Applet

089

Universal LCD Module

Ullrich Kreiensen

Interfacing an LCD to a microcontroller system is daily bread and butter for the average electronics engineer. There are innumerable variants and many circuit suggestions for interfacing the six to seven LCD signals to a microcontroller system. In an effort to prevent continual reinvention of the wheel the author of this design used this simple formula:

(LCD module + Atmel controller) +
(a touch of software)
= (universal display module)

to design this versatile display unit and PCB.

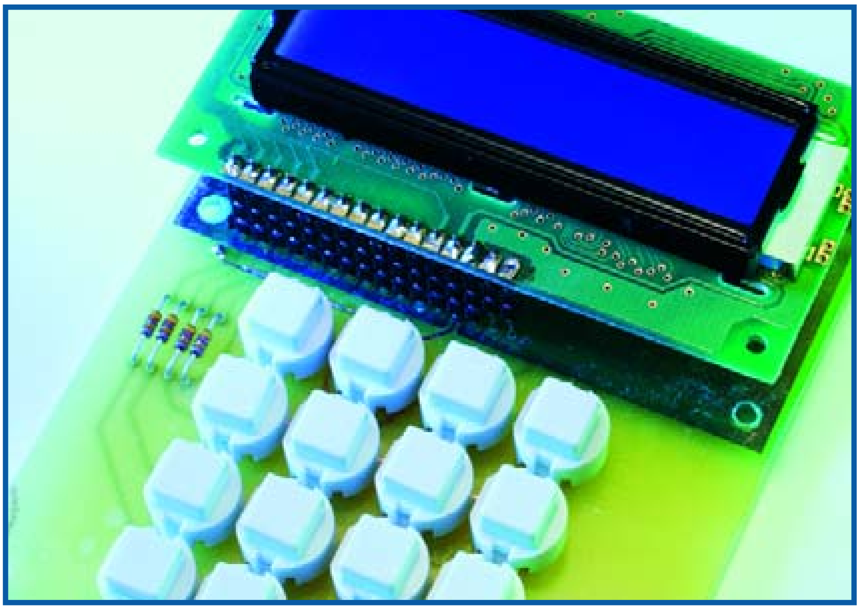
There are no surprises in the circuit diagram in **Figure 1.** A low cost controller type AT90S2313 takes commands from the serial interface and controls a standard 2x16 LCD display module. The controller also decodes key presses on the 4x4 keypad. This configuration is usually sufficient for most applications requiring just a basic user input/output device.

From a hardware perspective there is not too much to describe because all of the functions are performed in software. Transistor T1 controls the brightness of the LED backlight using Pulse Width Modulation (PWM), the average LED current is given by:

$$U_{R1} / R1 \times t_{ON} / t_{ON} + t_{OFF}$$

Where U_{R1} is the voltage at LED+ on K1 minus the voltage drop across A and K on the LCD controller pins and t_{ON}/ $t_{ON} + t_{OFF}$ is the mark-space ratio of the PWM drive signal produced by IC1. The maximum permissible LED current is specified in the display module data sheet.

Software for IC1 can be downloaded from www.elektor-electronics.co.uk for free, the file number is 050259-11.zip.



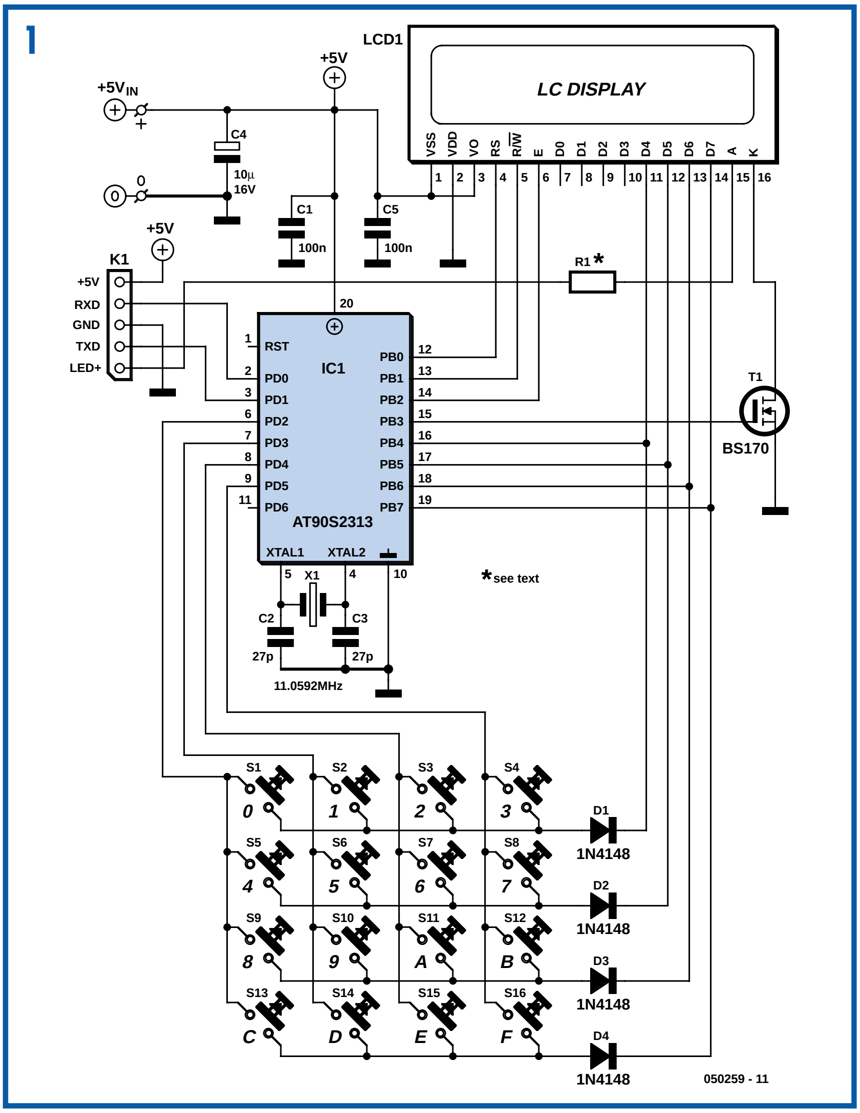


Figure 1.
The universal LCD interface circuit basically consists of a programmed Atmel controller, an LCD module and 16 keys.

COMPONENTS LIST

Resistors
R1 = see text

Capacitors
C1,C5 = 100nF
C2, C3 = 27pF
C4 = 10µF 16V radial

Semiconductors
D1-D4 = 1N4148
T1 = BS170
IC1 = AT90S2313, order code **050259-41**

Miscellaneous
X1 = 11.0592MHz quartz crystal
S1-S16 = pushbutton type D6
LCD module, 2x16 characters
PCBs, ref. 050259-1

A preprogrammed controller can also be ordered from the site shop as item 050259-41. The CodeVision AVR compiler was used for software development. A demo version is available on the Internet but this version contains a restriction of 500 bytes on the maximum code size. A 'modification' in the code gets round this by specifying the larger 8515 controller and then resetting the stack pointer to the correct value for the 2313, the overall effect is to increase the code space to 2 kBytes.

The complete module can be controlled by sending 'escape sequences' to the serial communication port. These consist of an ASCII 'escape' character (27 in decimal) followed by a command character. A list of these commands is given in table 1; they can also be used for control by a general purpose terminal program to facilitate the process of software development and debugging. In addition the display has a 'RAW' mode which writes all subsequent characters directly to the display. An 'Esc N' sequence switches it back to normal

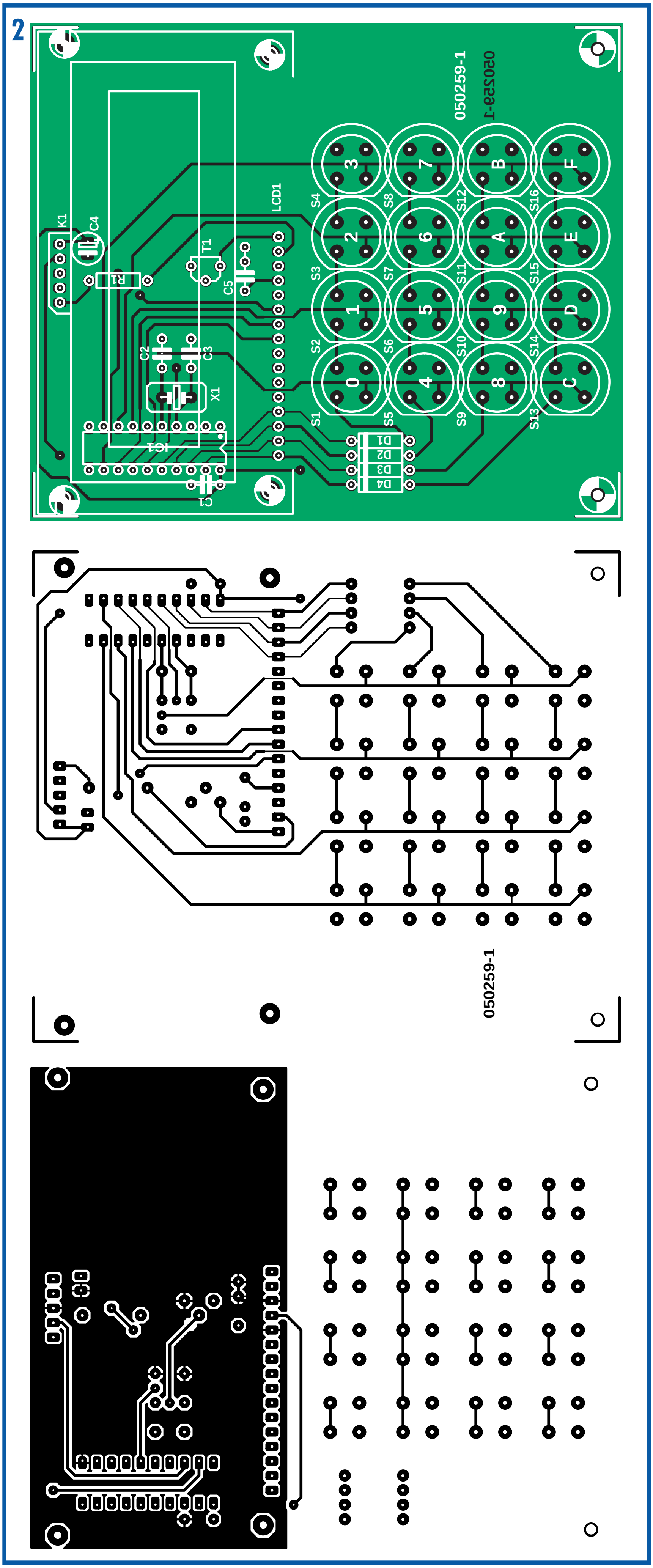


Figure 2.
The finished PCB provides a neat, universal input/output module.

mode. Finally special characters can be created and used for display dimming; further details are contained in the downloadable PDF file.

Figure 2 shows the populated double-sided PCB. The LCD module and keypad are mounted on one side while the controller and all the other components are fitted to the reverse. Fit a good quality socket for IC1 so that it can be easily removed for software updates.

(050259-1)

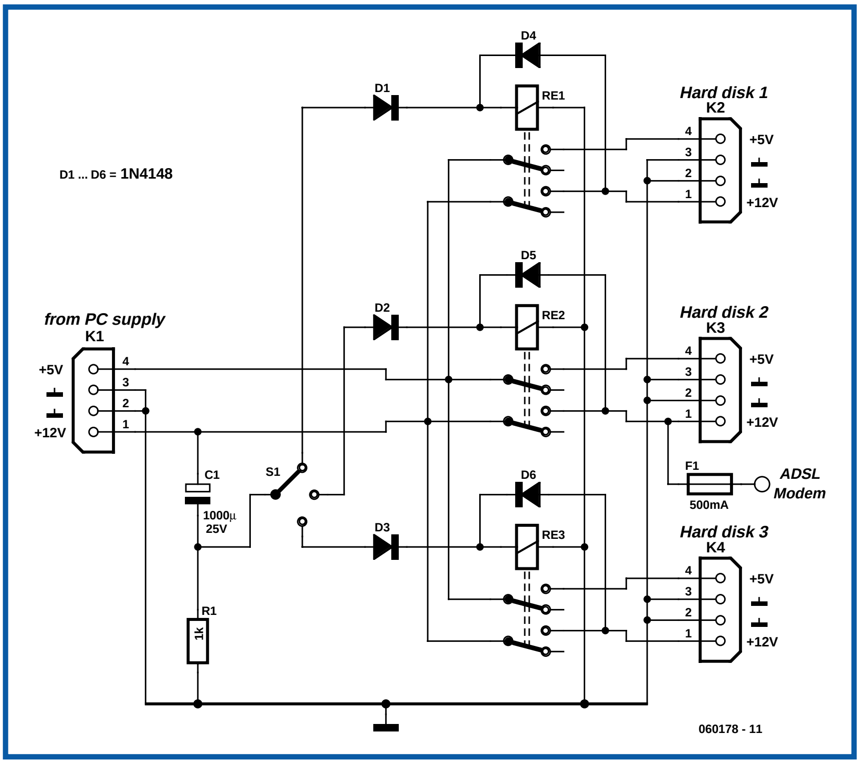
Table 1. Command character function in 'N' mode.

Dec.	ASCII	Function
8	BS	clear the character on the left of the cursor
9	TAB	move the cursor to position 0 or 8
10	LF	Line Feed – change line
11	HOME	cursor to top left hand corner
12	CLR	clear the display
13	CR	cursor to the start of the line
27	ESC	begin the command sequence
28	RIGHT	shift cursor one position right
29	LEFT	shift cursor one position left
30	UP	change the line the cursor is on (like LF)
31	DOWN	change the line the cursor is on (like LF)

090

Hard Disk Switch

Uwe Kardel



In these times with viruses and other threats from the Internet it would be nice to have reassurance that the PC cannot be infected. That is why this circuit was designed. It makes it possible to install multiple hard disks inside the case of a PC, which are separated in such a way that viruses cannot move from one disk to another.

In this case there are three drives installed, one for use of the Internet via ADSL, one for working with email and one for other applications. If data from the Internet never arrives on the third disk, it is effectively protected against viruses. The solution outlined here has been in satisfactory use for a couple of years. There is an additional benefit: if there are ever any problems with the operation of the computer, then it is very easy to change to another hard disk to check if the problem manifests itself there as well. In this case, fault finding can be made much easier.
The circuit operates by only switching over the power supply voltages (5 V and 12 V) of the hard disks. The hard disk is out of service without a power supply. This works without a problem with S-ATA disks. With IDE disks this only works with modern drives. There may only be a combination of hard disks on the relevant port and no CD-ROM, DVD-drive, CD-burner or something similar.

The selection of the desired hard disk is done with a rotary switch. This has to be set to the correct position before the computer is switched on. When the power supply is turned on, one of three relays is driven via diode D1, D2 or D3. The relays are provided with a hold circuit via a second diode (D4, D5 and D6). In this way the selected relay remains energised as long as the power supply voltage is present. After switching on, electrolytic capacitor C1 is charged via R1, so that the common contact of the rotary switch is quickly at 0 V. This prevents an accidental change of hard disk while the computer is in operation.
The ADSL modem is powered from the PC. This power supply voltage is only present if hard disk number 2 is selected. This prevents the use of the Internet if one of the other disks is selected.

(060178-1)

How to! connect your project to the PC

091

John Dobson

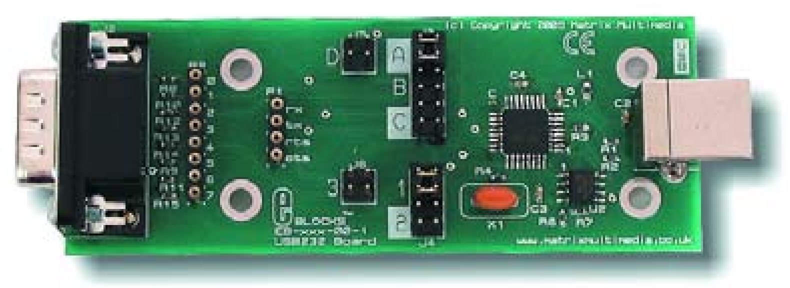
Connecting a project to your computer used to be a simple affair – your microcontroller would have a UART (Universal Asynchronous Receiver Transmitter) which was compatible with the RS232 protocol. You would then simply put a MAX232 converter chip onto the microcontroller and a 9-way D-type socket which linked your design using a standard lead directly to your PC. From an application like Visual Basic, you could then communicate directly to your project using Windows COM routines. Alternatively, you used the parallel port and simply waggled individual pins using the old BASIC [outp] command.

Then **USB** came along to make all our lives "easier". Due to the non-trivial coding required to tame the USB interface in microcontrollers having internal USB connectivity, alternative solutions have emerged – most notably the FTDI chip that acts as an interface between RS232 and USB. You can see this solution on the E-blocks USB232 board in **Figure 1**.

The FTDI device takes care of all the tricky USB negotiation for you and provides a link between a TTL level UART interface on the microcontroller and the USB port on your PC. On the PC side you are supplied with a virtual COM port driver which you can drop into your Visual Basic application, providing compatibility with older programs that worked on the serial port. The FTDI devices also provide DLLs for faster non-com port compatible communication.

Almost all laptop PCs have an **IrDA** port. IrDA is an internationally defined standard for infrared communication that's used on laptops, mobile phones, and PDAs. Implementing the IrDA standard is as difficult as you want to make it: the infrared techniques at the basic physical layer are not that hard, but the actual coding and decoding of data is very complex. Fortunately Microchip offer an IrDA decoder chip or 'stack' which sits between the infrared transceiver and your microcontroller. What's more, an E-blocks module is available (**Figure 2**). On the PC side you will

1



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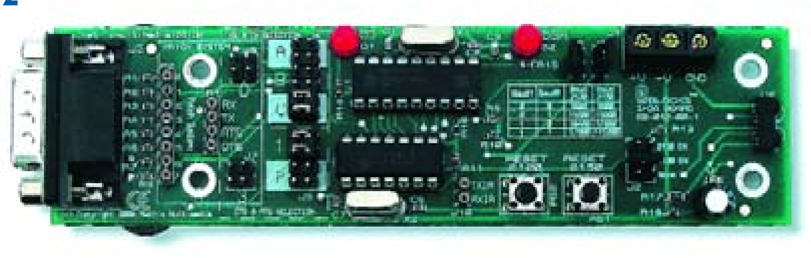


3

find that Windows has a native infrared COM driver which can be used by Visual Basic or your other development system.

Bluetooth was originally specified to replace the cables round the back of your PC. The system has some great advantages: it is a wireless system with a range of up to about 100 meters, and transmission through walls. A number of off the shelf modules are available like the TDK one on the E-blocks Bluetooth module shown in **Figure 3**. This converts Bluetooth into a TTL compatible data stream which can interface directly with any old microcontroller UART. To transfer data or commands, you will need some understanding of the Bluetooth AT protocols. If your laptop does not have Bluetooth then it is possible to buy a low-cost PCMCIA compatible card, or a Bluetooth adaptor for the USB port.

The obvious choice for replacing the RS232 link between hardware projects and your PC would be USB — but this system is currently too complex to implement in a microcontroller. The FTDI drop-in chip will be the easiest choice for replacing the RS232 link, but designers should also consider alternative wireless/infrared solutions which present some significant advantages to the end user.

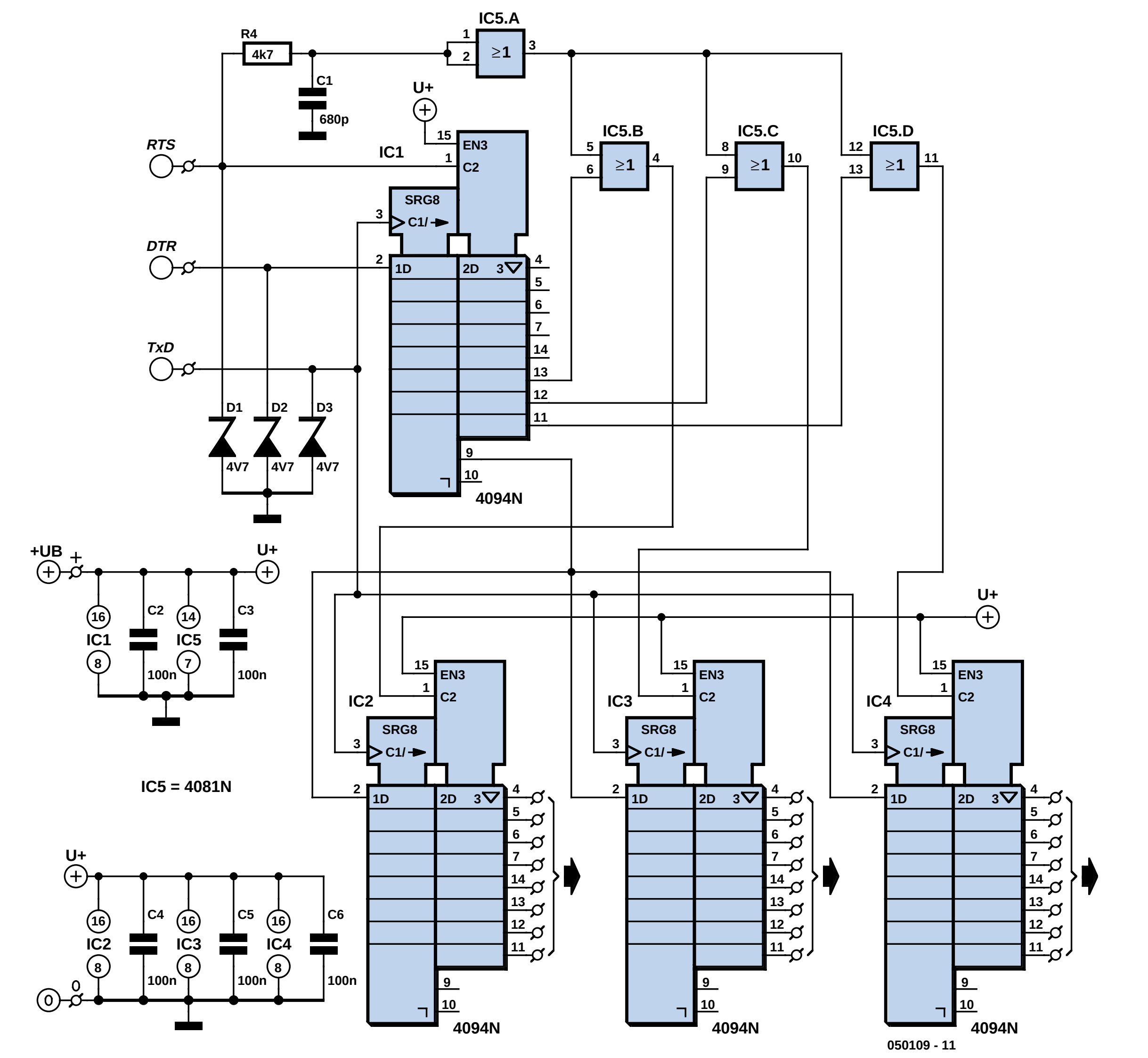
E-blocks modules and associated software are available through the Elektor Electronics SHOP, see www.elektor-electronics.co.uk

(065122-1)

092

Expansion for Universal Interface

1



Roland Plisch

The ‘Universal Interface for Windows’ designed by Burkhard Kainka (*Elektor Electronics*, December 1999 Supplement, page S2) provides for a range of input interfaces along with eight digital outputs, all under direct control of a PC’s serial port. The program (available for free download from http://www.elektor-electronics.co.uk under ‘Magazine’) uses the TXD signal to clock eight data bits from the DTR signal into a 4094 shift register. On the positive-going edge of the RTS strobe it transfers these bits simultaneously to its outputs. This arrangement can easily be extended by adding further shift registers in cascade, allowing data words of (in theory) any desired size to be built up byte by byte.

The circuit in **Figure 1** shows shift register IC1 connected as before to the PCs interface. The serial data pass through this device first, and then, via its serial cascade output (pin 9) to three further 4094s. The last (i.e., eighth) bit of the shift register appears on this cascade pin. The three shift registers IC2, IC3 and IC4 receive their strobe pulses, slightly delayed by R4 and C1, via AND gates IC5.B, IC5.C and IC5.D when the corresponding output (Q6, Q7 and Q8 respectively) of the first shift register is active. The software sends a 16-bit word containing the address and a data byte in a single transfer. For example, to select Q6 and hence IC2, it is necessary simply to add 2048 to the eight-bit data value; for IC3 add 4096, and for IC4 add 8192. The circuit can be extended in similar fashion using the spare outputs of IC1 (pin 4 to pin 7 and pin 14) to control further 4094s.

(050109-1)

093

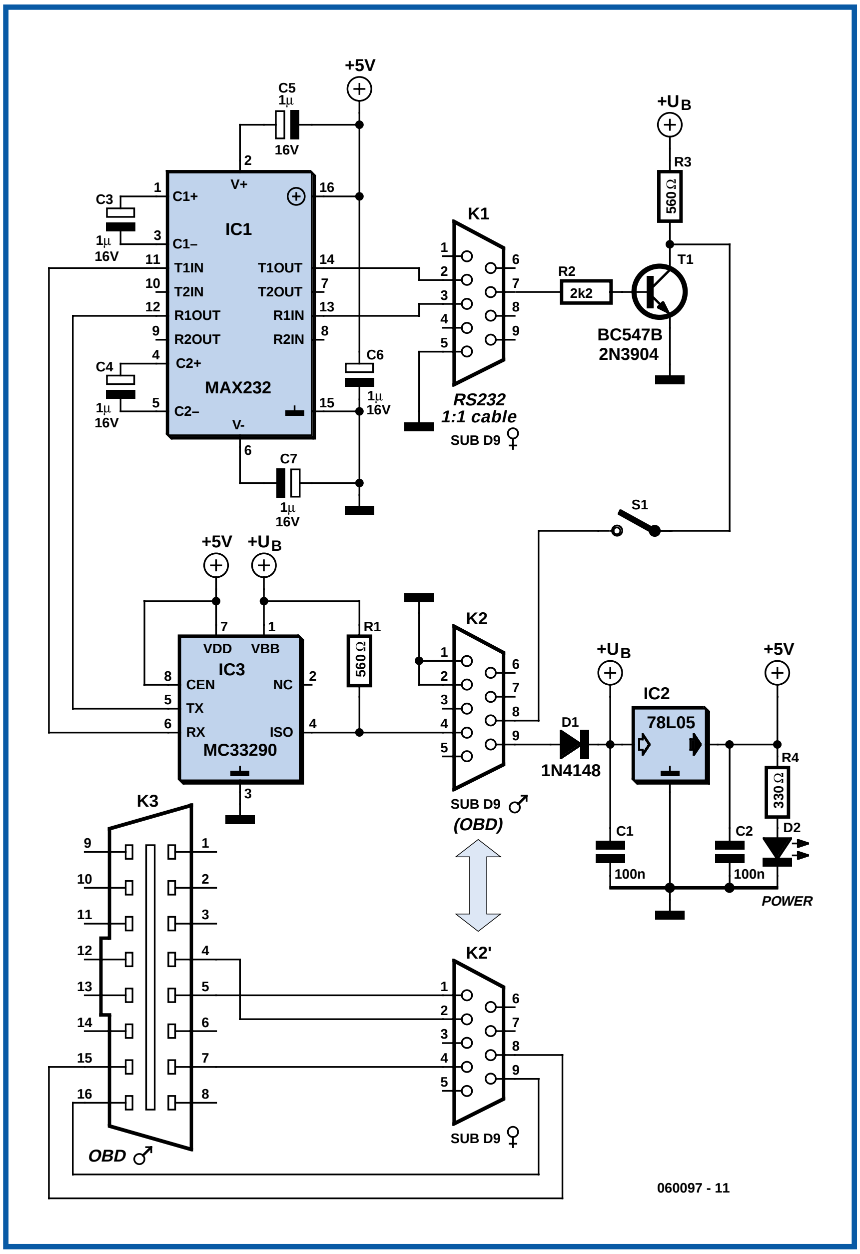
New KW 1281 Interface

Florian Schäffer

Cars made by the Volkswagen/Audi group (VAG) are easy to interface to using the OBD-2 connector: the VAG-COM software allows values to be read out from the car and parameters to be set. The communications protocol used is called KW 1281. Versions of VAG-COM up to 311 require the use of an isolated interface connected to the PC's serial port to protect both the car's computer systems and the PC itself from possible damage. A popular and rather minimal design for the circuit is 'Jeff's interface'; however, this employs optocouplers which are not always readily available from electronic component shops. Also, the optocouplers are run at a rather infelicitous operating point, entailing the use of several trimmer potentiometers and correspondingly complicated adjustments.

The problem can be solved with the use of two interesting ICs: the L9637D from ST Microelectronics and the Motorola/Freescale MC33290D. Both include an ISO 9141-compliant interface. The L9637D, at a price of two pounds or so, is the more expensive, but can withstand voltages of up to 36 V, making it suitable for use with commercial vehicles that use a 24 V supply. At 58 kbit/s it is also too slow to connect to the CAN bus, which can operate at up to 500 kbit/s. The MC33290D is only specified for operation up to 18 V, but is fast enough for OBD over CAN and is therefore the better choice for our circuit. As far as VAG-COM is concerned the difference is not significant, as KW 1281 operates at a maximum speed of just 10400 bit/s.

This chip is responsible for the OBD side of the circuit; on the serial port side we use a MAX232. The MAX232 converts the serial signals between the levels used on the interface and TTL levels, while the MC33290 converts between TTL levels and the ISO levels. The circuit draws power from the car's 12 V supply over the OBD cable. A simple voltage regulator produces the +5 V supply voltage, whose presence is indicated by the LED. To ensure that the circuit remains compatible with older cars, separate provision must be made for connection to the L-line as the ISO interface chip only supports the K-line. We have therefore added a transistor to drive the L-line: the direction of data transfer on this line is only from the PC to the car. Most cars use only the K-line and do not require the L-line at all. We have therefore also added a switch to allow the signal to be isolate from the OBD connector. This allows testing of whether the car uses the L-line for initialisation or not. A straight-through (not a crossed-over null modem) cable is used to connect to the PC.



The components are readily available; the ISO interface chip can be obtained from Farnell or Segor Electronics. No adjustments are required to the circuit, since all the devices used are standards-compliant. The author has made a printed circuit board layout available on his homepage, as both an Eagle file and a PDF. The page also contains much other information, including details of the software.

(060097-1)

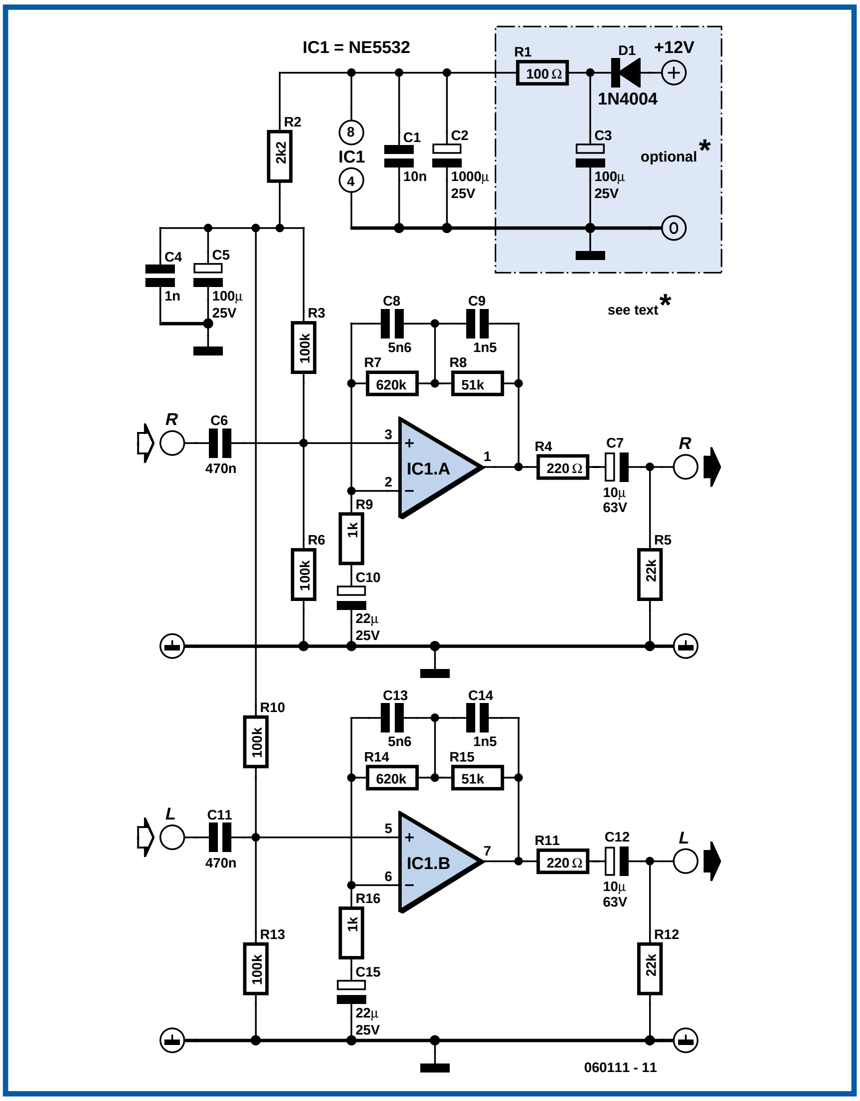
Internet link

http://www.blafusel.de

094

Multimedia RIAA Preamplifier

Christian Tavernier



Even if a large number of album titles once available on vinyl are now, little by little, being proposed as CDs, not all are available and far from it. You may have treasures in your collection that you would like to burn on CDs. First, preserving a CD is easier than preserving a vinyl record, and second, we have to admit that turntables are disappearing, even on fully-equipped Hi-Fi systems. From a point of view of software and PCs, converting from vinyl to CD is not a problem. A large number of programs, whether paid for freeware, are available to re-master vinyl records with varying degrees of success and to eliminate pops, crackles and other undesirable noises. All of these programs work with the sound card of your PC and that, admittedly, is where the problem starts. Most high-quality turntables are equipped with a magnetic cartridge which typically delivers just a few mV. The cartridge signal requires a correction of a specific frequency, called RIAA correction. If our older readers will perfectly recall what RIAA is all about, others from the CD generation may not know what the acronym RIAA stands for, guessing it may have something to do with illegal downloading of music on the Internet.

For mechanical reasons related to the vinyl engraving procedure, high-boost frequency correction is carried out while respecting a very precise curve defined a long time ago by the RIAA (*Recording Industry Association of America*) and, which therefore, quite naturally, was baptized RIAA correction.

Reversing the correction is the role of to the preamplifier for the magnetic cartridge. Since this correction boosts the lowest frequencies, such a preamplifier is very sensitive to all undesirable noises, hums, including, of course, the one coming from the 50-Hz (or 60-Hz) mains power supply. It is important to take that into account while making this project which must be done carefully with respect to grounding and shielding.

The schematic of our preamplifier is very simple because it uses a very low-noise dual operational amplifier. Here the NE5532 is used, whose response curve is modelled by R7, R8, C8, and C9 (or R14, R15, C13, and C14 respectively) in order to match the RIAA correction as closely as possible.

The input has an impedance of 47 kΩ, which is the standardized value of magnetic cartridges, and its 1,000-Hz gain is 35 dB which allows it to supply an output level of a few hundred mV typically required by for the line input of a PC sound cards.

The connection between the cartridge and the input of the amplifier requires shielded wiring to avoid the hum problems discussed above. Likewise we recommend fitting the assembly in a metal housing connected to the electric ground.

With respect to the power supply, three solutions are proposed: If you are a purist and you want to rule out any noise whatsoever, you will utilize a simple 9-V battery. Then, the components outlined with a dotted line will not be useful. Since the circuit only uses a few mA, such a solution is acceptable unless your collection of vinyls is impressive...

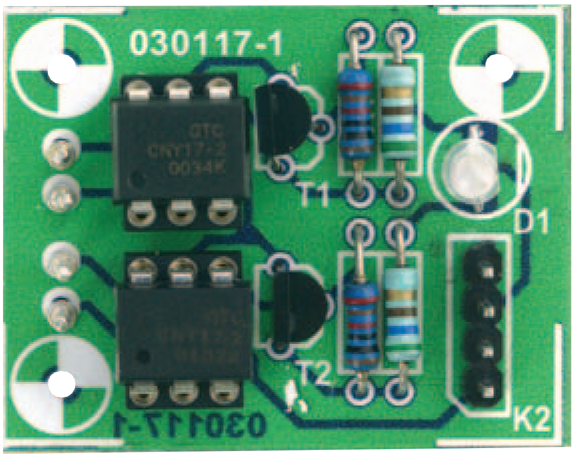
If you desire a more elegant technical solution that might sometimes cause more undesirable noise on the signals, you may want to wire up the components within in the dotted lines and you can steal the 12 V positive voltage available from your PC. A Y-connector inserted on the power supply of one of the internal drives or peripherals will work very well for that.

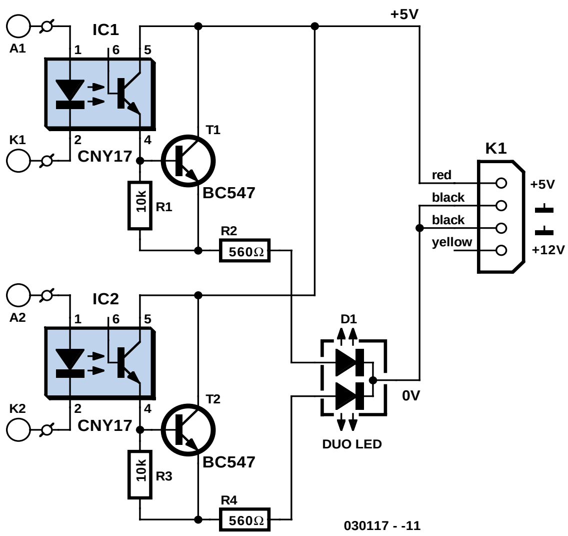
Finally, you may also use a mains adapter set to 12 V and connect it to the +12-volt point of the drawing in order to benefit from additional filtering, which is not a luxury for some.

(060111-1)

Multicolour HD LED

095





Andreas Köhler

Most PC enclosures provide only a single LED to indicate hard disk access, with the LED being connected to the motherboard via a two-pin connector. However, this LED only works with IDE drives, and if a SCSI disk controller is fitted, its activity will not be visibly noticeable. This small circuit remedies that problem using a multicolour LED.

The activity LED for the IDE interface is usually driven by a connected device via one or more open-collector stages. It illuminates if either of the two possible IDE drives is activated. The shared series resistor limits the current and also provides short-circuit protection. Even if the LED is shorted out due to faulty wiring, the current is restricted to a safe level.

An obvious solution would be to have the IDE and SCSI disks drive a shared dual LED, but unfortunately the current flows from the positive supply line through a series resistor, the LED and a transistor to ground. The dual LED would thus have to have a common anode, but no such device exists. All known multicolour LEDs have a common cathode lead. That means they cannot be connected directly, but we're not that easily defeated.

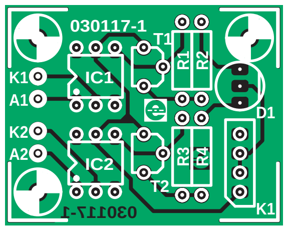
Only a small additional circuit is needed to allow the LED to be driven by the different interfaces.

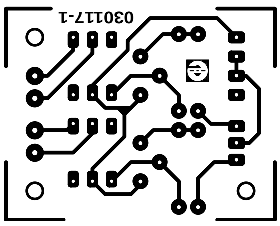
In this circuit, each of the drive signals from the two controllers is fed to an optocoupler, which acts nearly the same as the original LED. The somewhat lower voltage drop of the infrared LED results in a somewhat greater current, but there's hardly any need to worry about overloading. The optocouplers eliminate the problems with the different voltages. On the output side, a Darlington transistor consisting of the phototransistor and a BC547 drives the multicolour LED. The 10-kΩ resistor (whose value of is not critical) provides secure cut-off of the driver transistor. The base of the phototransistor in the CNY17 is left open.

The series resistors for the individual LED elements are dimensioned using the standard formula. It may be necessary to adjust their values slightly, depending on the relative brightness levels. The circuit can also operated from the +12-V line of the power supply if the values of the series resistors for the LEDs are suitably modified. If necessary, a third optocoupler stage can be added to allow a three-colour LED (red, green and blue) to be driven.

The circuit board has been designed to be so small that the components can be fitted in a few minutes and everything can be suspended from the LED in the PC enclosure. A drop of hot-melt glue will prevent the circuit board from becoming dislodged due to vibration. The supply voltage reaches the circuit via a normal small drive connector, to make it easy to obtain the necessary plug. Otherwise, you can also use ordinary solder pins.

(030117-1)





COMPONENTS LIST

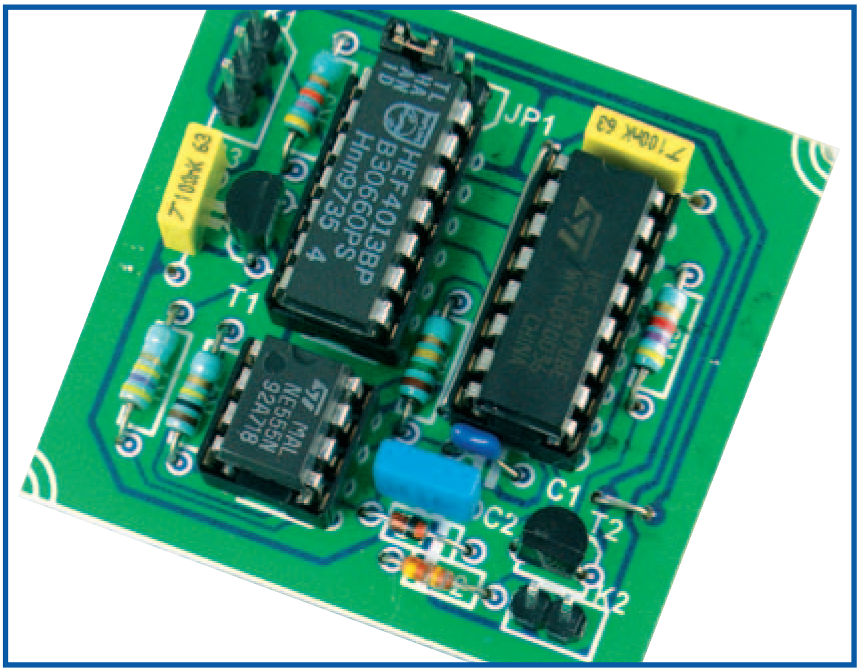
Resistors:
R1,R3 = 10kΩ
R2,R4 = 560Ω

Semiconductors:
D1 = Dual LED with 3 pins (Conrad Electronics # 187496)
IC1,IC2 = CNY17-2
T1,T2 = BC547B

Miscellaneous:
K1 = 4-way SIL connector
Small disk drive connector for PCB mounting, or solder pins (see text)
PCB, order code 030117-1 from the PCBShop

096 RC Switch

Paul Goossens



It is sometimes necessary for an RC (remote control) model to contain some kind of switching functionality. Some things that come to mind are lights on a model boat, or the folding away of the undercarriage of an aeroplane, etc. A standard solution employs a servo, which then actually operates the switch. Separate modules are also available, which may or may not contain a relay.

A device with such functionality is eminently suitable for building yourself. The schematic shows that it can be easily realised with a few standard components.

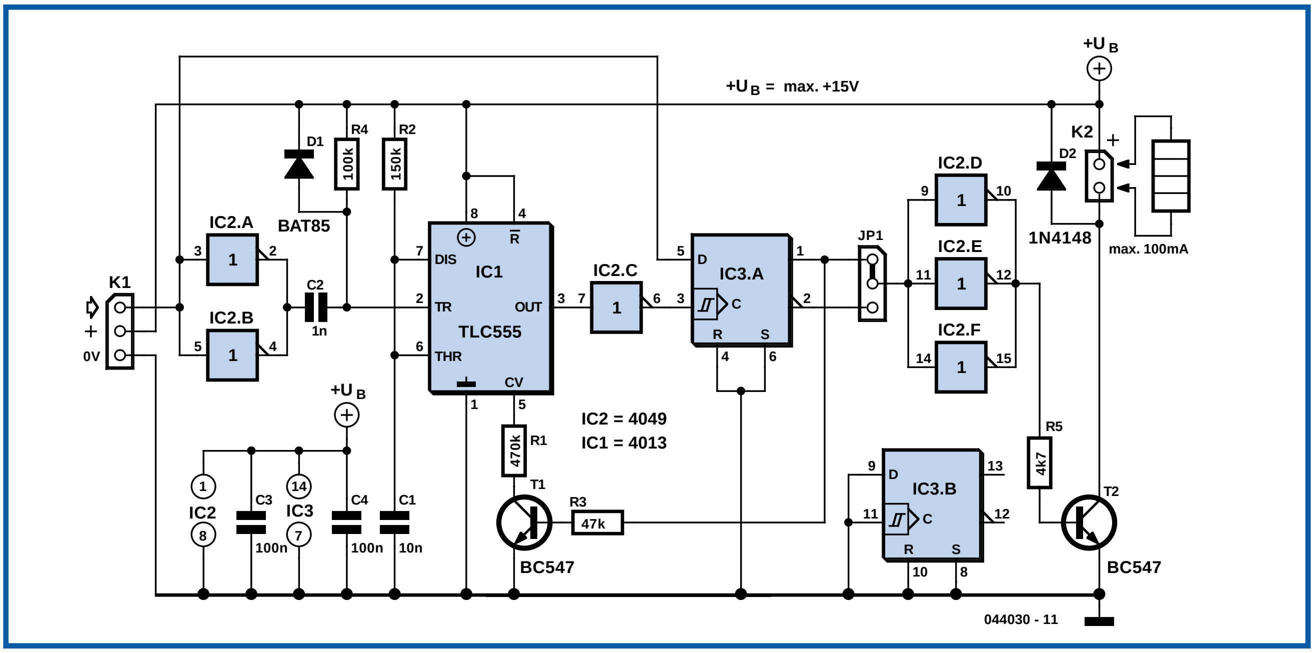
The servo signal, which consists of pulses from 1 to 2 ms duration, depending on the desired position, enters the circuit via pin 1 of connector K1. Two buffers from IC2 provide the necessary buffering after which the signal is differentiated by C2. This has the effect that at each rising edge a negative start signal is presented to pin 2 of IC1. D1 and R4 make sure that at the falling edge the voltage at pin 2 of IC2 does not become too high.

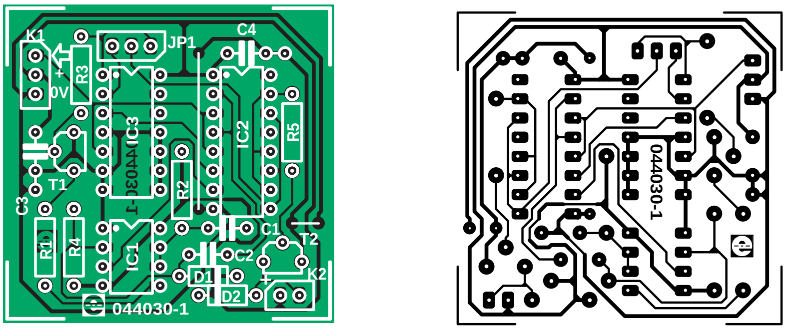
IC1 (TLC555) is an old faithful in a CMOS version. A standard version (such as the NE555) works just as well, but this IC draws an unnecessarily high current, while we strive to keep the current consumption as low as possible in the model.

The aforementioned 555 is configured as a one-shot. The pulse-duration depends on the combination of R2/C1. Lowering the voltage on pin 5 also affects the time. This results in reducing the length of the pulse. In this circuit the pulse at the output of IC will last just over 1.5 ms when T1 does not conduct. When T1 does conduct, the duration will be a little shorter than 1.5 ms. We will explain the purpose of this a little later on.

Via IC2.C, the fixed-length pulse is, presented to the clock input of a D-flip-flop. As a consequence, the flip-flip will remember the state of the input (servo signal). The result is that when the servo-pulse is longer than the pulse form the 555, output Q will be high, otherwise the output will be low.

It is possible, in practice, that the servo





COMPONENTS LIST

Resistors:
R1 = 470kΩ
R2 = 150kΩ
R3 = 47kΩ
R4 = 100kΩ
R5 = 4kΩ7

Capacitors:
C1 = 10nF
C2 = 1nF
C3,C4 = 100nF

Semiconductors:
D1 = BAT85 or similar Schottky diode
D2 = 1N4148
IC1 = CMOS 555 (e.g., TLC555 or ICM7555)
IC2 = 4049
IC3 = 4013
T1,T2 = BC547B

Miscellaneous:
JP1 = jumper with 3-way pinheader
K1 = servo cable
K2 = 2-way pinheader or 2 solder pins
PCB, available from The PCBShop

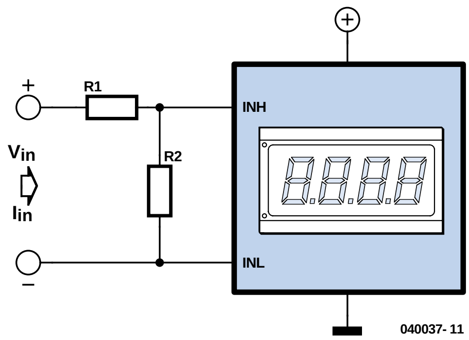
signal is nearly the same length as the output from the 555. A small amount of variation in the servo signal could therefore easily cause the output to 'chatter', that is, the output could be high at one time and low the next. To prevent this chatter there is feedback in the form of R1, R3 and T1. This circuit makes sure that when the flip-flip has decided that the servo-pulse is longer than the 555's pulse (and signals this by making output Q high), the pulse duration from the 555 is made a little shorter. The length of the servo-signal will now have to be reduced by a reasonable amount before the servo-pulse becomes shorter than the 555's pulse. The moment this happens, T1 will stop conducting and the mono-stable time will become a little longer. The servo-pulse will now have to be longer by a reasonable amount before the flip-flip changes back again. This principle is called hysteresis.
Jumper JP1 lets you choose between the normal or inverted output signals. Buffers IC2.D through to IC2.F together with R5 drive output transistor T2, which in turn drives the output. Note that the load may draw a maximum current of 100 mA. Diode D2 has been added so that inductive loads can be switched as well (for example, electrically operated pneumatic valves).

(044030-1)

Increased Range for DVM

097

	Range	R1	R2
V_{in}	2 V	910k	100k
	20 V	1M	10k
	200 V	1M	1k
	2000 V	1M	100 Ω
I_{in}	200 mA	0 Ω	1k
	2 mA	0 Ω	100 Ω
	20 mA	0 Ω	10 Ω
	200 mA	0 Ω	1 Ω



Voltmeter modules are readily available, both as LCD- and LED-versions. A disadvantage of these modules is the standard measuring range of 200 mV DC. So, with such a module you can only measure DC voltages up to 0.2 volts. Fortunately it is not difficult to increase the measuring range to higher voltages. In addition, it is also possible to measure current with these modules.
In order to measure higher voltages we have to reduce the voltage with a potential divider. For this purpose we add R1 and R2. R1 is connected in series with the + input of the module and R2 is connected in parallel with the inputs. In the table we can see the correct ratios of R1 and R2. These modules typically have an

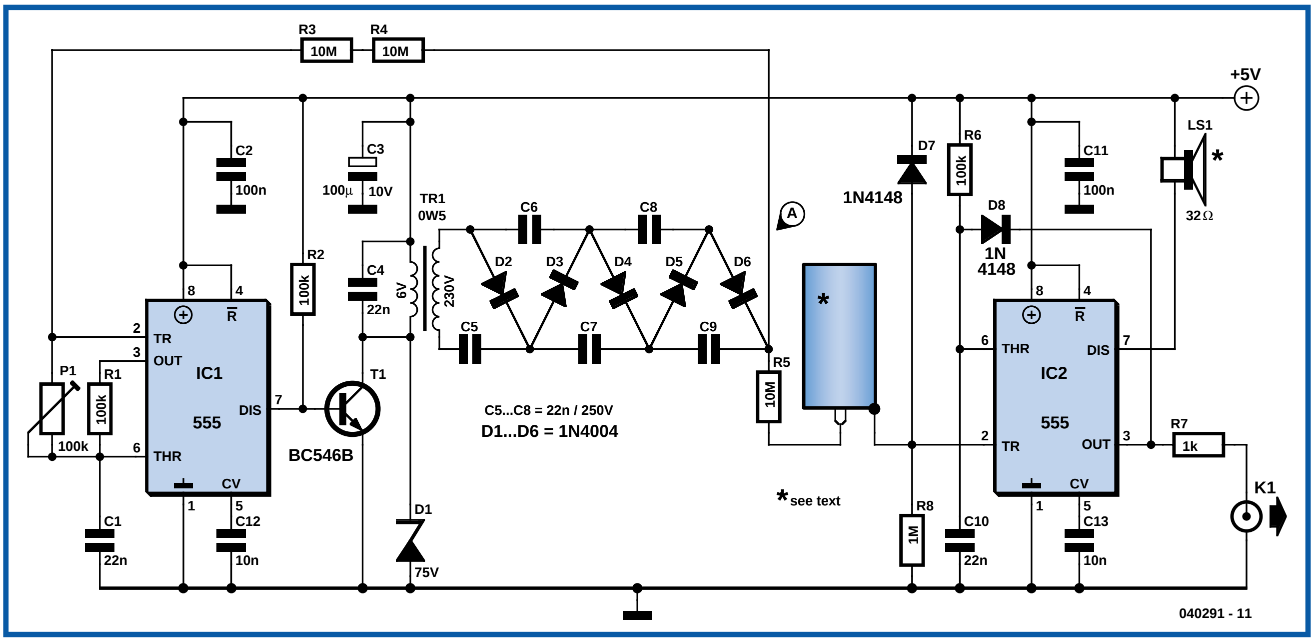
input impedance of more than 10 MΩ. With the attenuator in front of it the input impedance reduces to 1 MΩ, still high enough for most measurements.

To measure current with a voltmeter we first have to convert the current into an equivalent voltage. Resistor values for doing this are also shown in the table.

In contrast with the input impedance of a voltmeter, the input impedance of a current meter needs to be as low as possible. The input impedance of this circuit depends on the range and is practically identical to the value of R2. As a consequence, keep in mind that there is a voltage drop across the meter of up to 0.2 V. When making measurements you have to take into account that lethal voltages can be present in the circuit, particularly with the 200-V and 2000-V ranges. In addition, the specifications of your ordinary, common or garden resistor do not permit these kinds of voltages. When measuring these high voltages suitable resistors need to be used.

(040037-1)

098 Geiger Counter



Malte Fischer

April this year was the twentieth anniversary of the Chernobyl reactor accident. In the days following the incident winds deposited much of the reactor contents across central Europe, Scandinavia and the UK. A large area surrounding the reactor is still off limits but just how much of the fallout is still lying around on our gardens and farmlands? At the time of the release Iodine 131 was responsible for many cases of thyroid cancer but with a half life of 8.1 days this does not pose much of a threat in the long term. Strontium 90 is more of a problem; it has a half life of 28 years and more than 50 % of the fallout still remains. Radio caesium affects the food chain and can contaminate milk, meat and to a lesser extent crops.
Radioactivity is invisible so a detector is needed before we can start to make any measurements; the most common and simplest detector type is the Geiger counter. The design described here uses two NE555 type timer ICs, a small mains transformer and a few other standard components to make a low cost and simple to build Geiger counter. The only fly in the ointment is likely to be locating a Geiger-Mueller (GM) tube; this is not in any way a standard component. The on-line auction site eBay may provide a source of new or used counter tubes or alternatively Google will be useful in identify stockists. A brand new type ZP1300 tube can be purchased from ALRAD [1] at a cost of £55.00 plus VAT. The GM tubes are listed under nuclear products and nucleonics.
The counter tube requires a high voltage in the region of 700 V. IC1 is a NE555 timer configured as an astable multivibrator switching the BC547C transistor which in turn drives the secondary winding of a 6 V mains transformer. An alternating voltage of around 250 V is produced at the primary side which is then multiplied by the classic voltage multiplier configuration consisting of cascaded capacitors and diodes to produce around 700 V DC. The voltage is fed back to the timer input through resistors R3 and R4 to provide some stability of the output voltage.
The counter tube anode is connected to 700 V via a 10 MΩ protection resistor. In normal operation with no radiation detected there will be no current flowing through the tube and gas filling. When a radiation source is brought close to the tube, ionising radioactive rays pass through it and collide with some gas atoms knocking a few electrons out of their shell; this produces a current pulse from the tube terminal which in turn generates a voltage pulse across the 1 MΩ

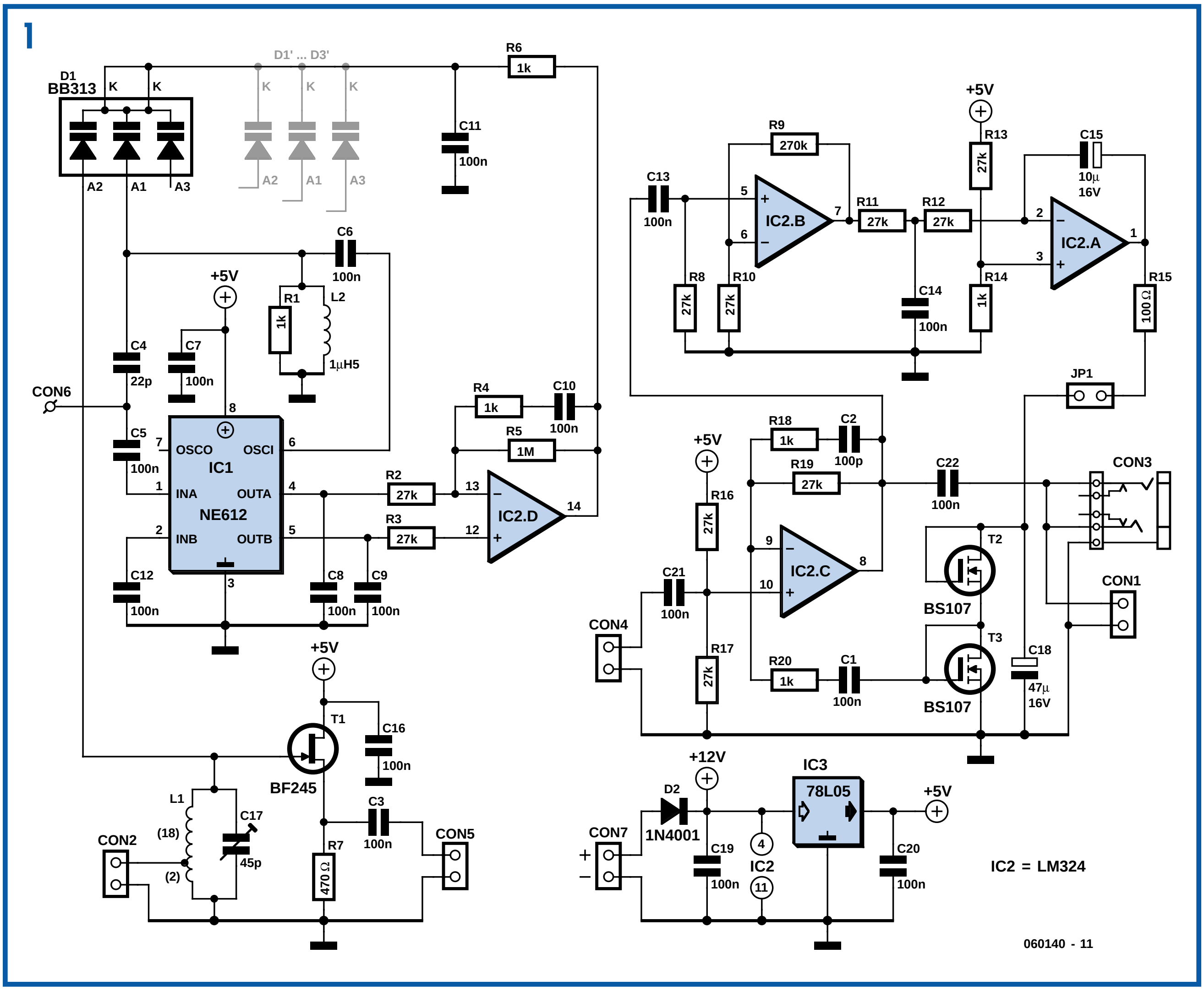
resistor high enough to trigger IC2. The NE555 effectively amplifies the pulse to produce the familiar tick-tick sound of a Geiger counter from the speaker LS1. An external pulse counter can be connected to K1. A copy of an original Philips Geiger tube data sheet is available at http://sbarth.dyndns.org/seiten/geigerzaehler/18550.pdf. Philips tubes are now made by Centronic [2] and their site contains a useful Geiger selection guide.

[1] www.alrad.co.uk
[2] www.centronic.co.uk

(040291-1)

DRM Receiver Upgrade

099

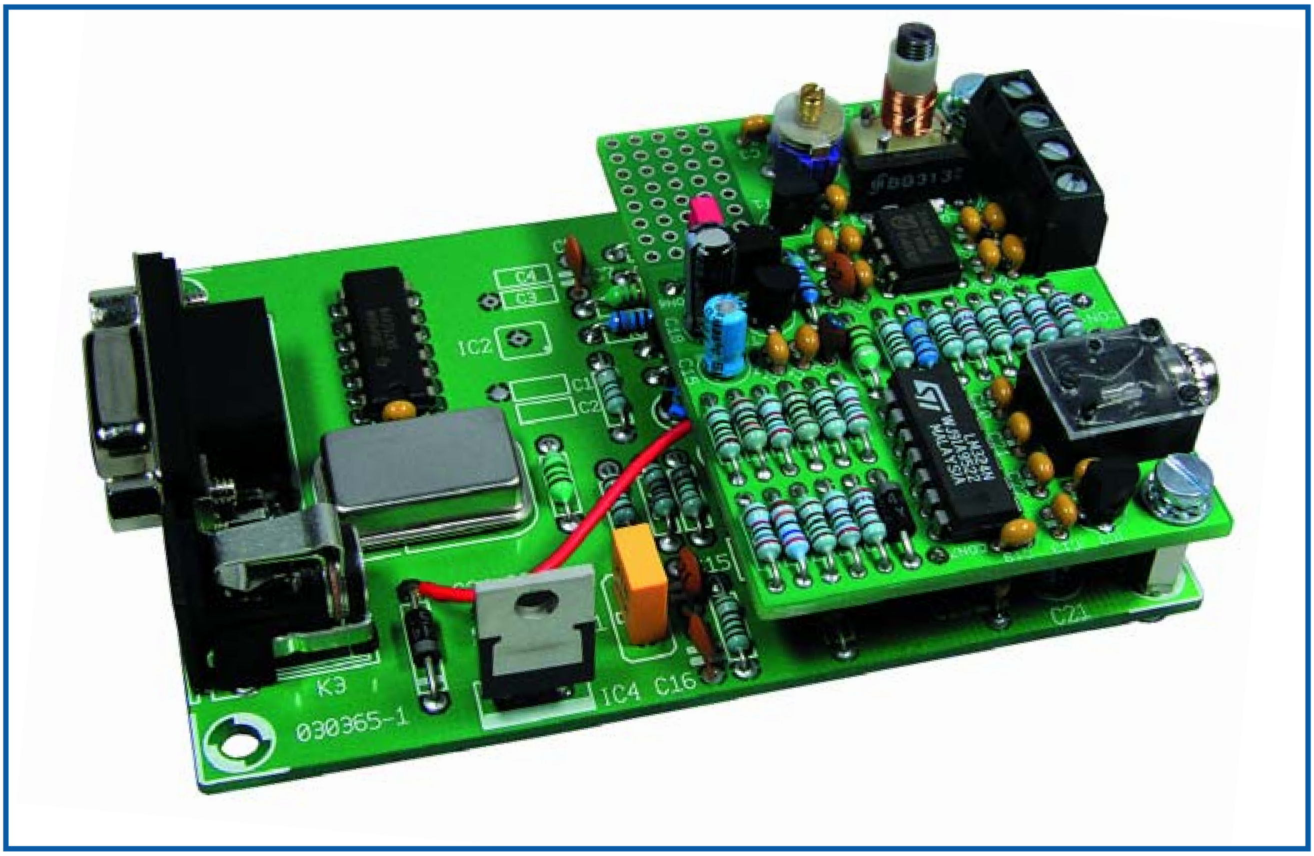


Burkhard Kainka

The DRM Receiver described in the March 2004 issue of *Elektor Electronics* has proved very popular and many thousand of the receivers are already in the field. Its excellent design is both simple and inexpensive. In the best tradition of homebrew construction we have supported the receiver by publishing two add-ons to the basic design; an automatic preselector (11/04) and an automatic gain control (2/06).

Both of these add-ons have been subject to continuous refinement by the author and the resulting combined circuit shown here can now be assembled on a ready-made PCB. This design equips the DRM receiver with an automatically tuned preselector for short wave signals in the frequency range from 3.5 MHz to around 16 MHz and an automatic gain control (AGC). The modifications improve the properties of the basic DRM receiver, in particular giving better image frequency rejection and higher receiver sensitivity so that more distant DRM, AM, SSB and CW broadcasts can be detected.

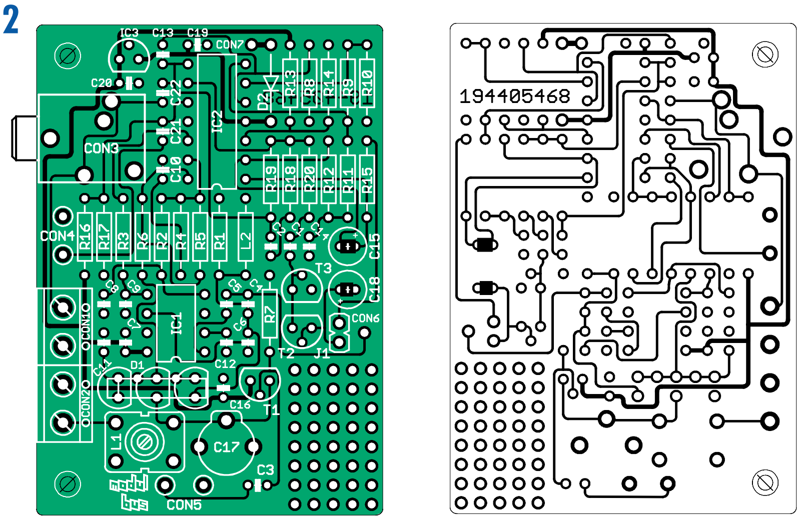
The RF input stage of the circuit in **Figure 1** is tuned by a varicap and passed through the source-follower formed by T1. A tuning voltage is generated by the passive PLL circuit and NE612 mixer. The DDS output signal from the receiver is connected to the input connector CON6.



The type of varicaps used in this design have a capacitance of 480 pF at 1 V. Triple packaged BB313 are shown on the diagram but individual BB112 varicaps can be substituted. An additional (unused) BB313 shown on the diagram facilitates future expansion of the design. The second part of the circuit is an automatic gain control stage built from an LM324 quad opamp which can provide up to 30 dB gain of the 12 kHz IF output signal to compensate for signal fading. Two VMOS transistors type BS107 are used as the controlling element where the drain-source current controls the internal resistance.

The finished PCB in **Figure 2** shows a neat circuit layout, coil L1 consists of 20

2



COMPONENTS LIST

Resistors
R1,R4,R6,R14,R18,R20 = 1kΩ
R2,R3,R8,R10-R13,R16,R17,R19 = 27kΩ
R5 = 1MΩ
R9 = 270kΩ
R7 = 470Ω
R15 = 100Ω

Capacitors
C1,C3,C5-C14,C16,C19-C22 = 100nF
C2 = 100pF
C4 = 22pF
C15 = 10µF 16V radial
C17 = 45pF trimmer
C18 = 47µF 16V radial

Semiconductors
D1 = BB313 or 3 off BB112
D2 = 1N4001
T1 = BF245
T2,T3 = BS107, BS170
IC1 = NE612
IC2 = LM324
IC3 = 78L05

Miscellaneous
J1 = Jumper
CON1,CON2 = 2-way PCB terminal block, lead pitch 5mm
CON3 = 3.5mm jack socket
CON4,CON5 = pinheader or wires
CON6,CON7 = 1mm dia. solder pin
L1 = inductor former with core (Conrad Electronics # 516651) and ECW 0.3mm
L2 = 2µH2 fixed inductor
PCB, ref. 060140-1

Suggested kit supplier:
www.geist-electronic.de

Ready built and tested units from:
www.modul-bus.de

turns of 0.3 mm enamelled copper wire (ECW) with a tap at the second turn up from the ground end of the coil, it is wound on a 5 mm diameter coil former fitted with a screw-in ferrite slug.

The regulated output signal is available at connector CON1 and the stereo jack socket CON3. This PCB is connected to the receiver PCB via connectors CON4 to CON7, jumper JP1 can be removed to disconnect the AGC signal.

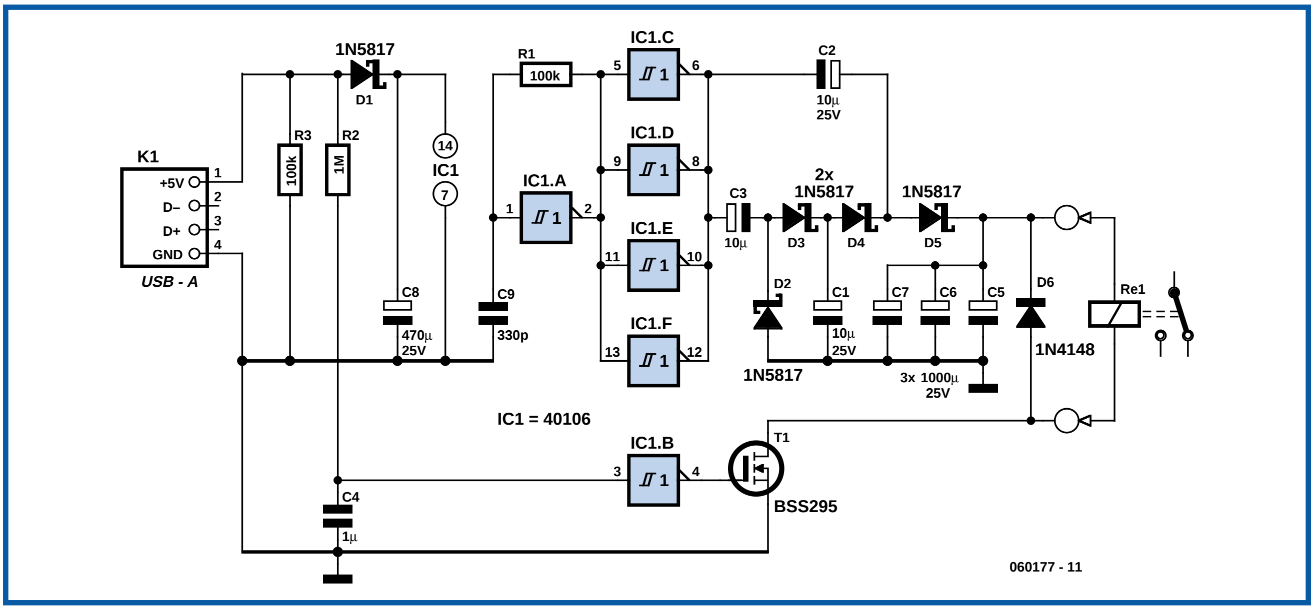
The automatic preselector requires a small amount of alignment to achieve optimum performance. Firstly tune the preselector to a station at the low frequency end of the scale and adjust the ferrite slug in L1 for maximum signal strength. Next tune in to a strong station at the upper end around 15 MHz and adjust trimmer C17 for maximum output signal. These two alignment points give a good synchronisation performance across the entire tuning range. The highest frequency which can be tuned depends on the voltage level on the varicaps so it is important to use a 12 V mains adapter to achieve the widest possible tuning range.

The receiver board uses a 9 V adapter and this limits the upper frequency range.

(060140-1)

Computer Off Switch

100



Uwe Kardel

How often does it happen that you close down Windows and then forget to turn off the computer? This circuit does that automatically. After Windows is shut down there is a 'click' a second later and the PC is disconnected from the mains. Up to now there were no mains switches available with a magnetic coil to turn off the power supply voltage, but now one is available from Conrad Electronics , with the article number 70061 for a price of 12.95 Euro (approx. £ 9.00). Surprisingly enough, this switch fits in some older computer cases. If the circuit doesn't fit then it will have to be housed in a separate enclosure. That is why a supply voltage of 5 V was selected. This voltage can be obtained from a USB port when the circuit has to be on the outside of the PC case.

A PCB design is available for the electronics part, but not for the high voltage part. It is best to solder the mains wires straight onto the switch and to insulate them with heat shrink sleeving.

C8 is charged via D1. This is how the power supply voltage for IC1 is obtained. A square wave oscillator is built around IC1a, R1 and C9, which drives inverters IC1c to f. The frequency is about 50 kHz. The four inverters in parallel power the voltage multiplier, which has a multiplication of 3, and is built from C1 to C3 and D2 to D5. This is used to charge C5 to C7 to a voltage of about 9 V. The generated voltage is clearly lower than the theoretical 3x4.8=14.4 V, because some voltage is lost across the PN-junctions of the diodes. C5 to C7 form the buffer that powers the coil of the switch when switching off.

The capacitors charge up in about two seconds after switching on. The circuit is now ready for use. When Windows is closed down, the 5-V power supply voltage disappears. C4 is discharged via R2 and this results in a '0' at the input of inverter IC1b. The output then becomes a '1', which causes T1 to turn on. A voltage is now applied to the coil in the mains switch and the power supply of the PC is turned off. T1 is a type BSS295 because the resistance of the coil is only 24 Ω.

When the PC is switched on, the circuit draws a peak current of about 200 mA, after which the current consumption drops to about 300 µA. The current when switching on could be higher because this is strongly dependent on the characteristics of the 5-V power supply and the supply rails in the PC.

There isn't much to say about the construction of the circuit itself. The only things to take care with are the mains wires to the switch. The mains voltage may not appear at the connections to the coil. That is why there has to be a distance of at least 6 mm between the conductors that are connected to the mains and the conductors that are connected to the low-voltage part of the circuit. Also refer to the Electrical Safety page published from time to time In this magazine.

(060177-1)

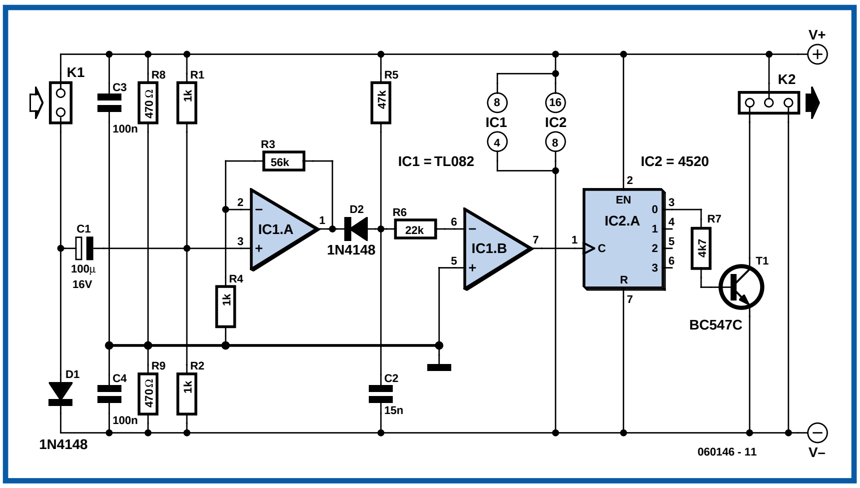
101

Speed Pulse Generator for PC Fans

Stefan Schwarck

This circuit generates speed pulses from the speed-dependent voltage spikes generated by commonly used types of PC power supply fans, which are superimposed on the supply voltage. The pulse signal can be used by the motherboard to monitor the speed of the fan. For this purpose, the pulses are tapped off from a fan connected to K1 via capacitor C1 and amplified by opamp IC1a (one half of a TL082 dual opamp). The second opamp in the Tl082 (IC1b) transforms the resulting signal into a clean rectangular clock signal and passes it to a binary counter circuit in the form of IC2a (4520), which reduces the frequency by a factor of 2. A BC547C transistor (T1) connected to the counter output provides an open-collector output at K2 for connection to the motherboard.

K2 can be connected directly to a fan connector on the motherboard. The 12-V supply voltage for the circuit is also taken from the motherboard via this connector. Components C3, C4, R8 and R9 create an artificial ground potential at half the supply voltage (6 V), which serves as a reference voltage for the opamp. Diode D1 should have the lowest possible voltage drop to minimise the voltage loss to the fan.



The circuit is suitable for use with CPU fans and fans for graphics cards in addition to power-supply fans.

(060146-1)

102

Mains Slave Switcher II

Bart Trepak

Many power woodworking tools such as saws and sanders have a provision for connecting a vacuum cleaner hose to suck up the dust and debris produced by their operation. The problem is of course that the vacuum cleaner must be switched on when the tool is switched on and as the operator's attention must be directed towards the work in hand especially when a blade with large teeth is spinning only inches from his fingers, there is often little incentive to look away to locate the vacuum cleaner switch. This unit was designed to fulfil this function by automatically switching on the vacuum cleaner when the power tool is switched on.

In this circuit, current flow is sensed using a reed relay which is not only cheap but provides a positive indication that current is flowing and dissipates very little power. Reed switches are often used in burglar alarms where they sense the magnetic field from a small magnet but it is also possible to produce a magnetic field by winding a coil around the reed switch and passing a current through this.

The circuit diagram shows a simple mains slave switch based on this idea. The coil may be wound directly onto the reed switch using insulated single core hook-up wire or enamelled copper wire of sufficient gauge to carry the current drawn by the power tool (or master appliance). In practice this should be as thick as possible to cater for any power appliance while still enabling a sufficient number of turns to be accommodated to produce the required magnetic field which will depend on the reed switch and is therefore best determined by

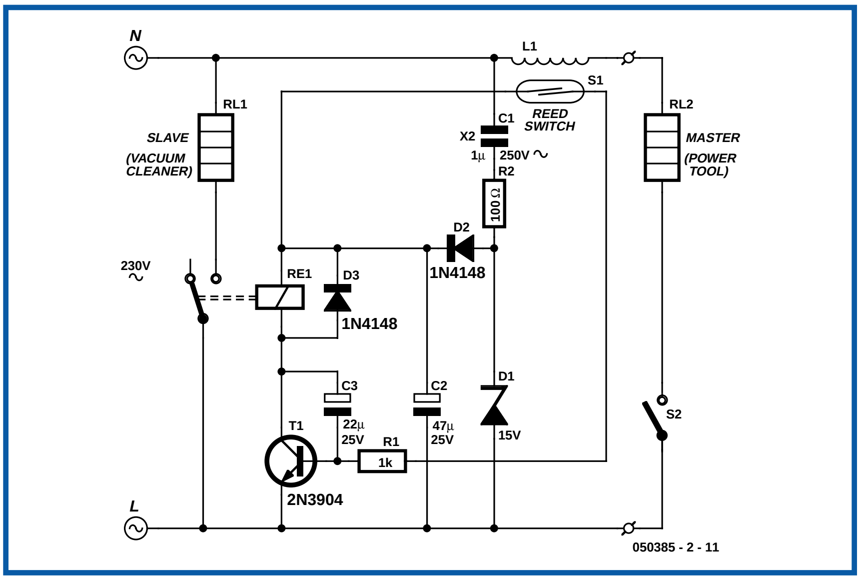
Warning

The circuit is by its nature connected directly to the mains supply. Great care should therefore be taken in its construction and the circuit should be enclosed in a plastic or earthed metal box with mains sockets fitted for the master and slave appliances.

experiment. As a guide, a one-inch reed switch with 40 turns reliably switched on with the current flowing through a 150-watt lamp (approx. 625 mA) but larger reeds may require more turns. If the master appliance draws less current (which is unlikely with power tools) more turns will be required.

The reed switch is used to switch on transistor T1 which in turn switches the relay RE1 and powers the slave appliance. Since reed switches have a low mechanical inertia, they have little difficulty in following the fluctuations of the magnetic field due to the alternating current in the coil and this means that they will switch on and off at 100 Hz. C3 is therefore fitted to slow down the transistor response and keep the relay energised during the mains zero crossings when the current drawn by the appliance falls to zero and the reed switch opens. C1 drops the mains voltage to about 15 V (determined by zener diode D1) and this is rectified and smoothed by D2 and C2 to provide a d.c. supply for the circuit.

The relay contacts should be rated to switch the intended appliance (vacuum cleaner) and the coil should have a minimum coil resistance of 400 Ω as the simple d.c. supply can only provide a limited current. C1 drops virtually the full mains voltage and should therefore be an X2-class component with a voltage rating of at least 250V a.c.



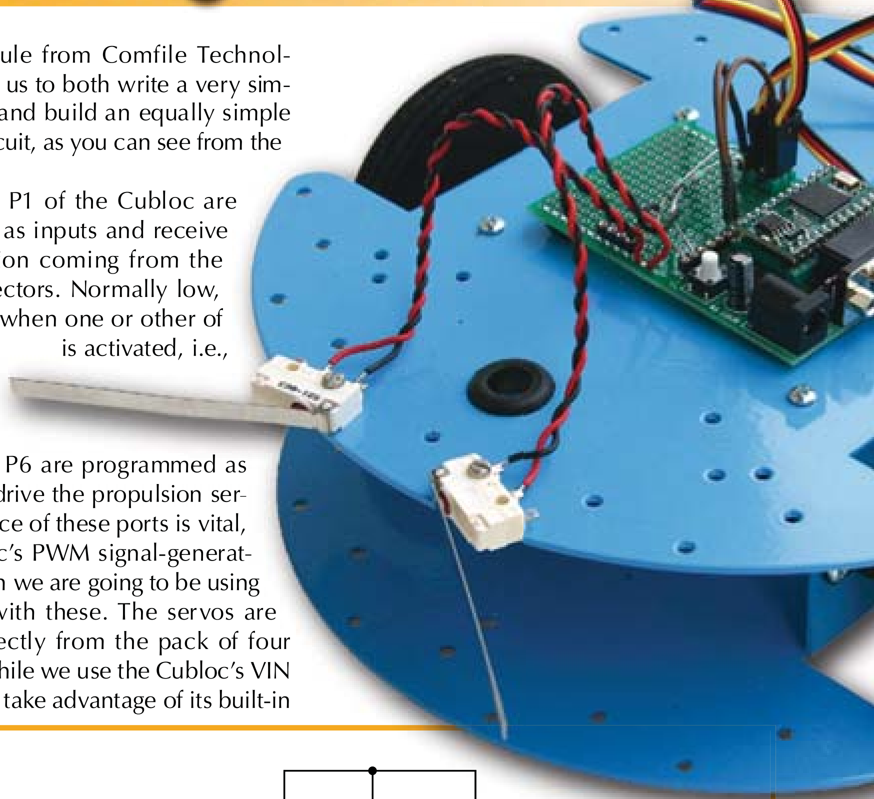
(050385-2)

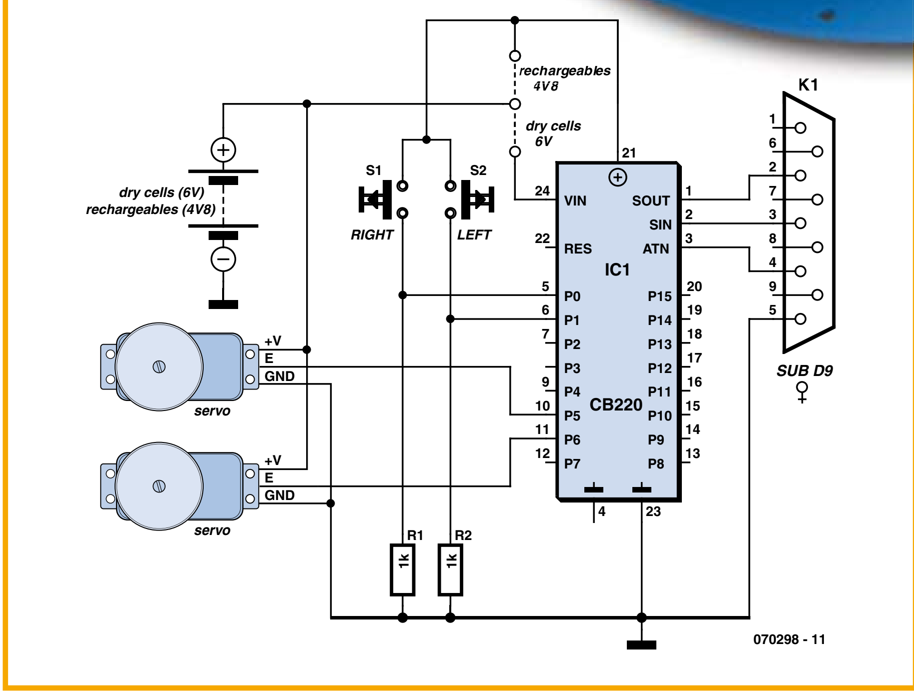
An Obstacle Detecting Robot

C. Tavernier

www.tavernier-c.com

When first trying our hand at robotics, we're generally in a hurry to build a mobile robot that has a degree of autonomy. It's with this aim in mind that we've produced this article, to enable you, in record time, to build a mobile robot capable of detecting and avoiding obstacles. Of course, given the relative simplicity of the solutions employed, it will be fairly easy to catch it out, but as long as you take a little care over the obstacles it might encounter, it'll still create quite an impression. And you'll be able to use this starting point as a springboard for your own developments.
To deal with the mechanical issues that often pose problems for many amateur robot-builders, we're making use of a 'Rogue Blue' base (www.roguerobotics.com), sold as a kit and very easy to assemble without special tools. What's more, this kit is distributed in France by Lextronic (www.lextronic.fr), who can despatch to any of the neighbouring countries.
As you can see from the photo, it consists of two pre-cut circular plates able to accommodate two radio-control servos, used as traction motors. Supplied with the base, these come already modified (as explained elsewhere in this issue) to enable them to turn continuously. Two wheels with large-diameter tyres are also provided, fixing directly onto the servo shafts, while the front and rear of the robot's lower plate have PTFE 'skids' taking the place of a jockey wheel.
Some self-adhesive Velcro lets us secure a battery holder for primary cells or rechargeables between the two circular plates, leaving the whole of the top plate free for the electronics. Given the supply voltage for the servos and the electronics, we have used a 4-cell battery holder that takes four 1.5 V AA (R6) cells, and will also take rechargeable NiMH batteries of the same size, in the event of intensive use.
So as to get our robot up and running quickly, we've used a 'whisker'-type obstacle detector. To achieve this, we use two long-lever microswitches — or two ordinary lever-operated microswitches with a few centimetres of piano wire soldered to them – mounted on the top plate. They are positioned at an angle of around 45–60° to each other, with their centrelines intersecting on the robot's front/back centreline. This gives us one obstacle detector on the front right, and another on the front left.
The robot's brain is entrusted to a Cubloc CB 220 module from Comfile Technology, allowing us to both write a very simple program and build an equally simple electronic circuit, as you can see from the diagram.
Ports P0 and P1 of the Cubloc are programmed as inputs and receive the information coming from the obstacle detectors. Normally low, they go high when one or other of the whiskers is activated, i.e., in the presence of an obstacle.
Ports P5 and P6 are programmed as outputs and drive the propulsion servos. The choice of these ports is vital, as the Cubloc's PWM signal-generating instruction we are going to be using only works with these. The servos are powered directly from the pack of four 1.5 V cells, while we use the Cubloc's VIN input so as to take advantage of its built-in





5 V regulator. However, if you are going to use NiMH rechargeables instead of primary cells, you'll have to use the VDD input to power the Cubloc, as in this case the voltage available is only 4.8 V.
Connector DB9 is designed for connecting the Cubloc to a PC, to program it with the software we'll be suggesting in a moment.
Given the simplicity of the circuit, it can be built on perforated prototyping board or on a CB220-Proto test board, which comes with this connector already pre-wired.
The software needed to control the whole thing is very simple, even for someone with only faint notions about programming. The Cubloc's Basic language is both simple and very powerful. The source listing is available on the Elektor website, as well as the author's own site (www.tavernier-c.com), but it's so short, you can also just type it yourself directly into the Cubloc Studio editor, which is the Cubloc's (free) development tool, and can be downloaded from www.comfiletech.com.
The listing is very easy to analyse. After defining the type of Cubloc in use and the

operating sense of the ports P0, P1, P5, and P6, we also define a variable 'obstacle'. The main program can then commence, in the form of a continuous Do Loop.

We start by testing for one or other of ports P0 or P1 going high, and if this is the case, the robot is stopped by means of the two PWM instructions that follow. Given that we are using modified radio-control servos, remember they are stopped when they receive pulses of 1.5 ms; they rotate at full speed in one direction for 2 ms pulses; and at full speed in the other direction for 1 ms pulses. Note too that, as the servos are mounted in reversed orientations in the Rogue Blue base, they need to rotate in opposite directions to make the robot go forwards or backwards. Because of the mechanical and electrical tolerances, 1.5 ms pulses don't always give exactly stop. So you may need to go back and tweak the first parameter of the PWM instructions (3410 in this example).

Once the robot has stopped, we test to see if the left or right whisker has been activated, and set the variable 'obstacle' accordingly. One last test checks if both whiskers have been activated simultaneously, and if this is the case — meaning the robot has encountered an obstacle directly ahead — reverse drive is applied (2 ms pulses to one servo and 1 ms to the other).

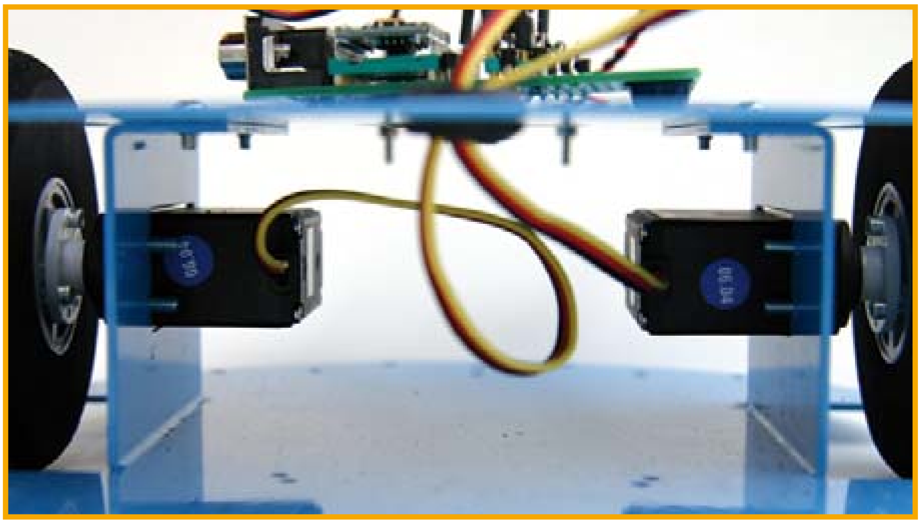
The variable 'obstacle' is then analysed by means of a 'select' box that the Cubloc's powerful Basic has borrowed from C. If the variable 'obstacle' has a value of 0, no obstacle has been encountered and our robot sets off forwards. If the variable 'obstacle' has a value of 1 or 2, an obstacle has been encountered to right or left, and so a quarter-turn is made in the opposite direction. However, if the variable 'obstacle' has the value 3, an obstacle directly ahead has been encountered, and the robot does a complete U-turn.

Watch out! Depending on what you call front/back and left/right on your particular robot, you may need to swap round the successive PWM instructions in the listing we've just given, so that they do indeed produce the movements intended.

You might also need to tweak the first parameter of the various PWM instructions. We explained the reason for this above for stop, but the same thing happens for rota-

Full source listing for obstacle-detecting robot management program

```
' Obstacle avoider robot on a Rogue Blue base

Const Device = CB220

Dim Obstacle As Byte

Input 0         ' Right whisker input
Input 1         ' Left whisker input
Low 5                   ' P5 output for PWM
Low 6                   ' P6 output for PWM
Delay 1000

Do
If In(0)=1 Or In(1)=1 Then              ' Whisker activated?
Pwm 1,3410,32768                        ' Servos stopped
Pwm 0,3410,32768
Pause 800
If In(0) = 1 Then                       ' Right whisker?
Obstacle = 1
Else
Obstacle = 2            ' Left whisker!
End If

If In(0) = 1 And In(1)= 1 Then          ' Right and left whiskers?
Obstacle =3
   End if
Pwm 1,3590,32768                        ' Backward
Pwm 0,3195,32768
Pause 1500
Else
Obstacle = 0                    ' No whisker activated
End If

' Obstacle variable analysis

Select Case Obstacle
Case 0                                  ' No obstacle
Pwm 0,3590,32768                        ' Forward
Pwm 1,3195,32768
Case 1                                  ' Obstacle on the right side
Pwm 0,3600,32768                        ' Slight turn to the left
Pwm 1,3600,32768
Pause 1000
Case 2                                  ' Obstacle on the left side
Pwm 1,3180,32768                        ' Slight turn to the right
Pwm 0,3180,32768
Pause 1000
Case 3                                  ' Head-on obstacle
Pwm 0,3750,32768                        ' Full half turn
Pwm 1,3750,32768
Pause 1500
End Select
Loop
```



tion of the servos at full speed in one direction or the other. If your robot fails to travel in a straight line when running forwards or backwards, it's just because the servos are not turning at the same speed for pulses of the same width. In this case, all you have to do is make minor adjustments to the first parameter of one or the other of the PWM instructions in order to get correct results. Don't be afraid to, the Cubloc's program memory is virtually infinitely reprogrammable (a minimum of 10,000 cycles guaranteed by the manufacturer of the microcontroller it's fitted with!)
After a certain period of use, you'll doubtless realize the limitations of this robot. Then it's up to you to develop it, by adding, for example, obstacle detectors of the same type, but to the rear, an ultrasonic distant obstacle detector, a line-follower function, etc. This issue of Elektor already ought to give you some good ideas to get you started.

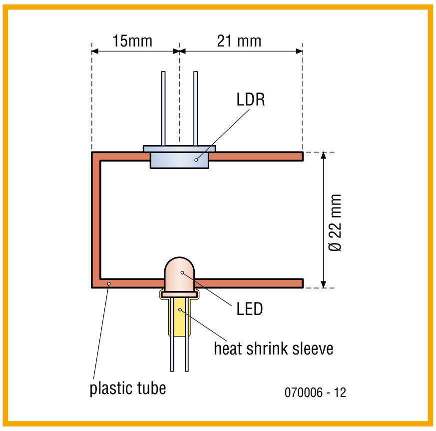
(070298-I)

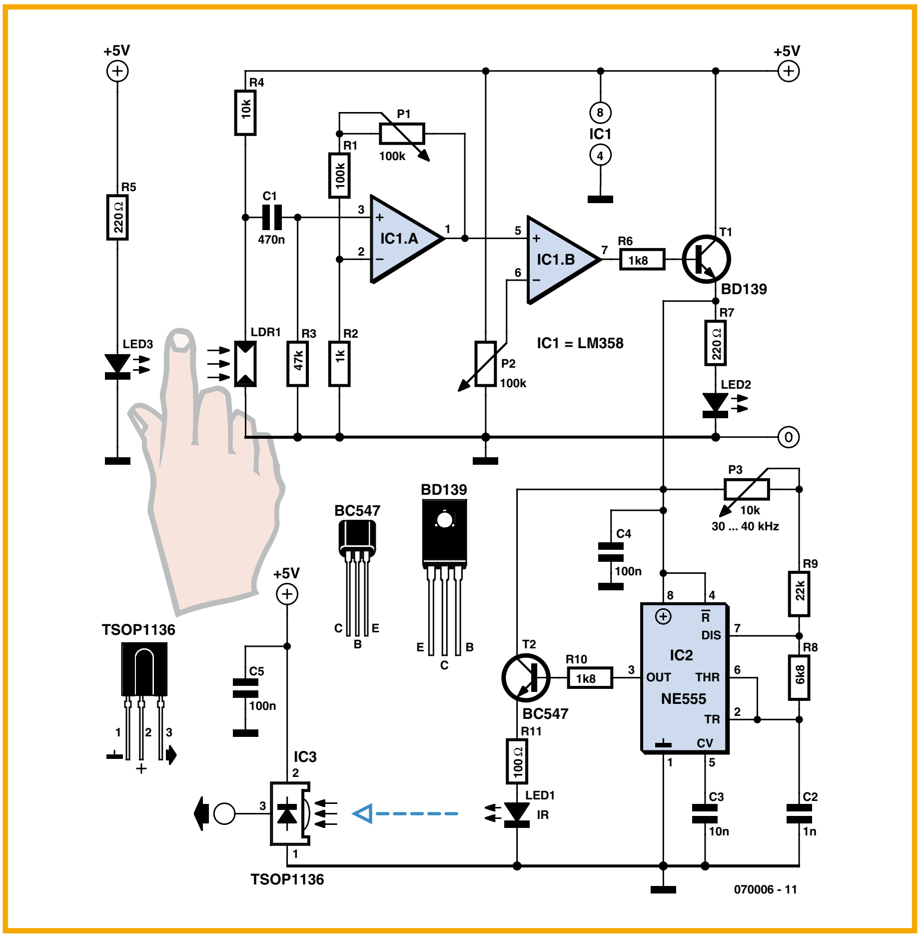
Wireless pulse sensor

For robots and other control applications

Markus Bindhammer

This pulse sensor is designed to be used for communication between man and machine, giving a robot the ability to react to the pulse rate of its human mentor. The digital output of the circuit makes it useful in other applications as well.
The sensor itself consists of an ordinary LDR (with a resistance when illuminated of 300 Ω and a dark resistance of around 10 MΩ) and a bright LED (D1). The LED must have an output of at least 1000 mcd





as light from it must pass through the finger and illuminate the LDR. Now, when the heart pumps a pulse of blood through the blood vessels, the finger becomes slightly more opaque and so less light reaches the LDR. This can be converted into an electrical pulse.
With each pulse the resistance of the LDR, and hence the voltage at the input to opamp IC1.A, changes. The gain of the opamp is set by potentiometer P1 in the feedback path. The sensitivity of the circuit can be adjusted using potentiometer P2 at the input to comparator IC1.B. T1 forms an output driver that not only lights LED D2 to give a local indication of the detected pulse, but also powers up a standard squarewave oscillator circuit built around IC2, a 555 timer. At its output this produces a signal modulated by the pulse, with a frequency that can be set from 30 kHz to 40 kHz using potentiometer P3. A driver stage interfaces the output of the 555 to an IR emitter diode, which can send the modulated signal to IR receiver module IC3. The more power used to drive the IR LED, the greater the range of the link: R11 can be altered to achieve the desired LED current. The demodulated output of the receiver module can be fed directly to a microcontroller. The centre frequency of the receiver module used will determine the correct setting of P3.
A pulse sensor can be made from a simple 40 mm length of plastic tube, closed at one end, chosen to fit snugly over the fingertip. Holes to mount the LED and LDR are made 15 mm from the closed end, and the components are glued suitably into the holes so that they face towards the centre of the tube. The connecting wires are isolated from one another and the whole sensor enclosed in a length of heat-shrink tubing to exclude external light from the LDR. If this construction seems a bit bulky, it is possible to reuse a clip from a commercial heart rate monitor.

(070006-I)

Stereo Robot Ears

Get your robot to home-in on a sound source

Claude Baumann & Laurent Kneip

Service robots of the future will most likely need to act on spoken commands and be able to recognise voices. This article takes a look at one aspect of this behaviour namely locating the position of a sound source using the cross-correlation function. A technique is developed which drastically cuts down on the number crunching so that even a basic microcontroller fitted with binaural sensors can pinpoint a continuous audio signal with an accuracy of just 10 degrees.

The GASTON Lego robot built in 2003 by the students at a school in Luxembourg [1] (main picture) has a number of interesting features the most obvious of which is its rudimentary 'face' which is used to express a limited range of emotions. In addition it is able to detect sounds and turn its head in the direction of the sound source. It uses an array of three microphones together with a microcontroller to make a simple 'precedence sensor' which measures the time difference produced when a sound pressure wave-front (made by a clap or finger click) strikes the microphones.

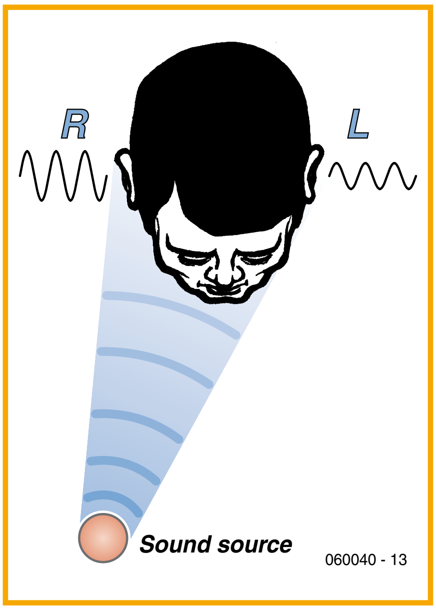


Figure 1. The head acts as a low-pass filter attenuating frequencies above 1 kHz. The ear nearest the sound source will hear the sound louder than the far ear.

Despite its impressive functionality, GASTON cannot work with a continuous audio signal let alone follow a moving sound source. This ability requires a more complex approach which we will go on to investigate here.

How we track down sounds

The human ear is an amazingly complex and sensitive organ. Together with dedicated regions of the brain it enables us to extract meaningful information from the general cacophony which is continually assailing our ears. Amongst other things it has been demonstrated that we are able to identify the bearing (azimuth) of a sound source with an accuracy of just 3°. Applying a crude analogy from engineering systems we could say that the process of hearing uses a number of subsystems. Most obviously we, along with all other creatures (excluding mantids apparently) are equipped with two ears hence 'binaural' which in conjunction with dedicated regions of the brain we use to identify the direction of a sound source using several different methods:

a. Interaural Level Difference — ILD

Low frequencies have wavelengths which are greater than the diameter of the head; they extend around to the far ear with very little loss of amplitude. At frequencies above 1 kHz however the head acts as a low-pass filter providing up to 20 dB attenuation to the signal so there is a significant reduction in the sound level reaching the far ear (**Figure 1**) which enables the brain to estimate the position of the sound source.

b. Interaural Time Difference — ITD

With a sound originating from one side the pressure waves arrive at the ears with a slight time difference. The brain interprets the two signals, applying a type of neural cross-correlation function. The phase shift between the two signals gives the angle of the sound source (the azimuth α).

It can be seen from **Figure 2** that sound emanating from any of the points $M(u,v)$ lying on the hyperbola given by the equations

$$u^2/a^2 - v^2/b^2 = 1$$
$$a = \Delta x / 2$$
$$b^2 = k^2 - a^2$$

where k is the half distance between the ears. These points produce exactly the same time difference at the ears. The term Δx is the distance the sound travels in the time Δt, with $\Delta x = c \times \Delta t$. The speed of sound c equals 343 m/s at 25°C.

The hyperbola approaches the asymptote given by:

$$v = b/a \times u$$

where $\tan(\beta) = b/a$.

$$\beta = \arctan\left(\sqrt{\frac{4k^2}{c^2}\cdot\frac{1}{\Delta t^2} - 1}\right)$$

For R (right ear): $\alpha = 90° - \beta$; for L (left ear) the corresponding $\alpha = -(90° - \beta)$.

The ear must also be able to determine if the sound emanates from in front of or behind the ear and also either from above or below. The points in three-dimensional space where a sound source will produce identical time differences in the left and right ear actually form the surface of a hyperboloid. It is thought that the brain can resolve these spatial ambiguities by detecting subtle changes in the signal spectrum caused by the outer ear shape, absorption/scattering by the torso and head, localising by turning of the head and possibly also by detecting Doppler effects.

Whatever processes the brain uses to resolve the left-right direction problem it is interesting to plug some values into the formula for a sound source positioned in front and to the right of the head. At a bearing $\alpha = 20°$ and assuming an ear separation of 17.5 cm, a time difference of 175 µs will be apparent at the ears. At an azimuth of just 3° the time difference will only be 27 µs. It is difficult to imagine how the brain (with a neuron switching time in the millisecond range) can resolve such short time differences and gives us some insight into the complex processes it is capable of.

The limits of ITD for localising a continuous tone are clear; a sound wave will

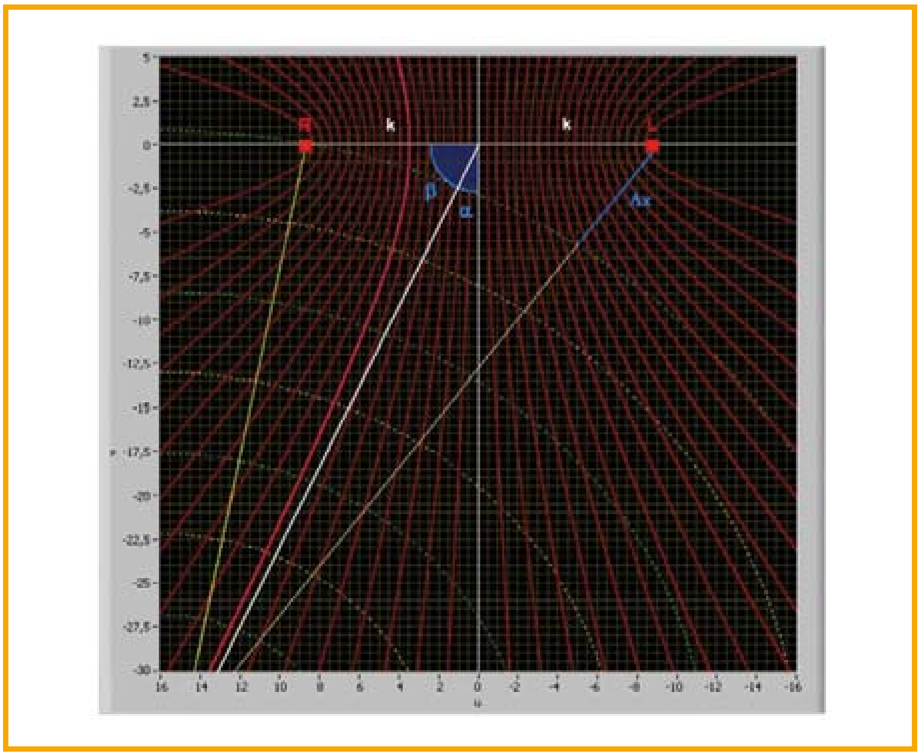


Figure 2. A sound pressure wave from the side will not arrive at both ears at the same time. Points in space where a sound source produces identical delays at the ears are on a hyperbola (red) approaching the asymptote (white). The brain cannot identify the position but only approximate the direction of a sound source anywhere along this line.

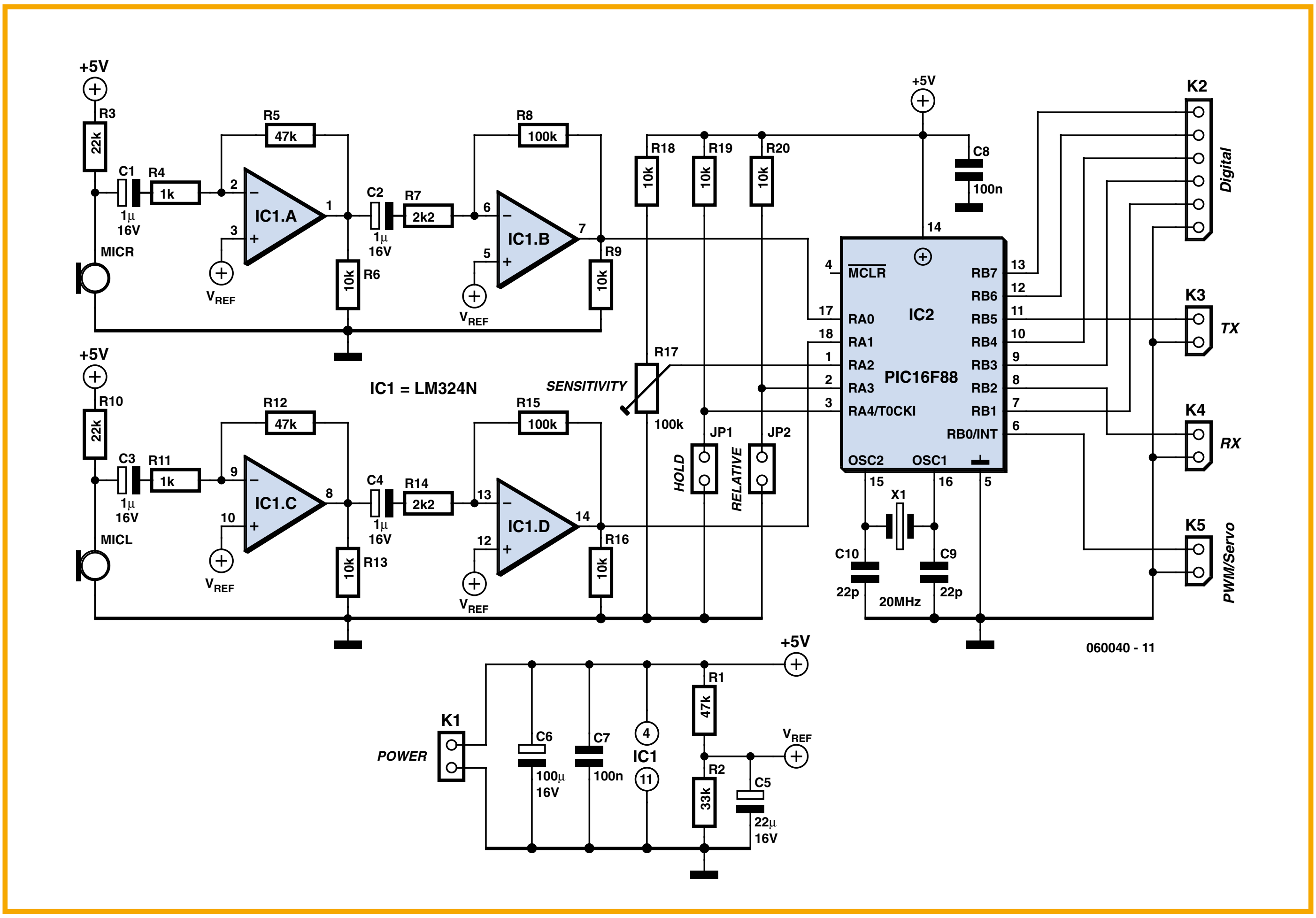


Figure 3. The circuit has two audio channels each with an electret microphone and two-stage amplifier. The two amplifier outputs are connected to the two A/D converter inputs on the microcontroller.

take around 500 µs to travel the distance between the ears which equates to a half cycle or a 180° phase shift between the two signals. At frequencies of 1 kHz and above it is no longer clear if the signal in one ear leads or lags the other ear.

c. The Precedence effect

Strong reflections and standing waves produce localised highs and lows in sound pressure when a continuous tone is reproduced in an acoustically reflective enclosed space, making it almost impossible to pin-point the sound source. When the sound source is discontinuous however it has been shown that the brain is able to identify the source, using a modified ITD measurement it gives precedence to the arrival of the first sound pressure wave at the ears and appears to open a 'neural time window' of around 1 ms for this purpose, ignoring any subsequent echoes. The phase difference of the two signals gives the azimuth bearing of the sound source. The LEGO robot GASTON uses this technique but it is not of much use for continuous sounds.

Cross-Correlation

When there are two identical signals shifted in time, it is common practice to apply the cross-correlation operation to them. Together with Fourier analysis these two operations form the backbone of techniques used in digital signal processing.
The digital cross-correlation is derived from two continuous waveforms as follows: The value at $\Delta t = 0$ is found by sampling the waveforms at intervals t, multiplying the samples from the two waveforms together and then summing them and normalising the result. The cross-correlation at another position, say $\Delta t = 1$ µs is then performed in the same way except this time the second signal is shifted in respect to the first by 1 µs. The maximum sampling rate is chosen to ensure that the processor can perform the necessary calculations along with any other work it needs to do within the sampling time constraints.
It can be determined by the resultant cross-correlation whether the two signals are 'correlated' for example if the first signal is not in phase with the second signal but otherwise very similar the cross-correlation function will show a marked peak corresponding to the phase shift between the two signals. Cross-correlation calculations involve many multiplications and additions; it is hardly surprising that in the DSP world it has a reputation for being particularly processor hungry.

Reducing computer loading

In order to perform cross-correlation with a general purpose microcontroller it is necessary to find ways of reducing the number of computations that the processor is required to make. For this application it is valid to limit the number of phase shifted operations taking into account the distance between the two microphones. It can be shown also that maximising the product sum (cross-correlation function) is equivalent to minimising another function which is much simpler to calculate. For each phase shift the sum of the differences of both values (squared) can be transformed so that cross-correlation function $\gamma(\tau)$ in the equation

$$\begin{aligned}
f(\tau) &= \sum\left[x(t) - y(t+\tau)\right]^2 \\
&= \sum\left[x^2(t) + y^2(t+\tau) - 2x(t)y(t+\tau)\right] \\
&= \underbrace{\sum x^2(t) + \sum y^2(t+\tau)}_{c_1} - 2\sum x(t)y(t+\tau) \\
&= c_1 - 2 \cdot N \cdot \gamma(\tau)
\end{aligned}$$

with $\gamma(\tau) = (2N)^{-1}\,[c_1 - f(\tau)]$.
The value of c_1 is constant for every phase shift while the square of the values are added in each case irrespective of which phase position it is. (N is the constant geometric mean of all the signal values produced by normalising $\gamma(\tau)$). It is evident that when the cross-correlation value is at maximum it corresponds to a minimum of the deviation sum of f. The following expression is therefore valid for our application and makes fewer demands on precious processor resources.

$$g(\tau) = \sum\left|x(t) - y(t+\tau)\right|$$

This expression is a close approximation to cross-correlation. The two measured samples are subtracted (ignore the sign) to give the absolute difference. Summing them produces a non-normalised value which is at a minimum when the waves are correlated. The technique requires far fewer calculations than the classic cross-correlation method and is at least 20 times faster.

Construction of the binaural sensors

The circuit in (**Figure 3**) could hardly be simpler. It consists of two audio channels each with own electret microphone and two-stage audio amplifier. Each audio signal is then fed to two pins of a microcontroller which have been configured as A/D converter inputs. A preset pot, R17, allows sensitivity adjustment.

Bearing data is output every tenth of a second using several different interfaces, which gives the sensor the flexibility to be used in many different types of robot. The 8-bit bearing information is sent from TX serially using a UART (2400 1 N 8), it is also output as a 5-bit parallel digital value. A servo output (PWM/Servo) provides a signal with a width from 1 to 2 ms at a 50 Hz repetition rate suitable for driving a standard modelling servo. Jumper 1 (Hold) is provided for test purposes, it introduces a two seconds pause between readings during which time the last valid output is maintained. Jumper 2 (Relative) defines how the output behaves when the received sounds are too quiet to make a measurement; with it fitted the output returns to the middle position (azimuth $\alpha = 0$), with it removed the output retains its last valid position. This gives the system a degree of flexibility, for example if the microphones are mounted on a robot which can turn and move toward the sound it is better to fit the jumper otherwise the robot continues to turn when no sound is detected. When the microphones are fixed and the output is used to pan a webcam say, it is better to remove the jumper otherwise the camera continually pans back to the centre position when no sound is detected.

The RX input can be used later for microcontroller firmware updates. A 100-kΩ pulldown resistor is used to avoid a floating input.

Timing and resolution

For this application we will consider the frequency range from 200 to 1000 Hz that the processor calculates the ITDs (signal delays) it requires a sufficiently high sampling rate which could only be achieved by careful optimising of the program code. The PIC16F88 architecture is organised so that data from the two channels can be stored in two 96-byte banks (banks 2 and 3) as quickly as possible by switching a single bit and using indirect addressing.

The PIC16F88 contains a 10-bit A/D converter but for this application the two least significant bits are ignored so that we use an 8-bit value. The sampling rate is 20 kHz. The values are smoothed by an FIR-filter. Any erroneous values detected by the program are over-written with the previous correct value.

At a frequency of 1 kHz a 180° phase shift is measured after 0.5 ms i.e. the time taken for ten samples.
The smallest detectable time difference corresponds to a minimum distance of:

d_{min} = 50 [µs] • 343 [m/s] = 1.7 cm

This gives the optimum spacing between the microphones ($2k$) of:

$2k$ = 10 [Samples] × d_{min} = 17 cm

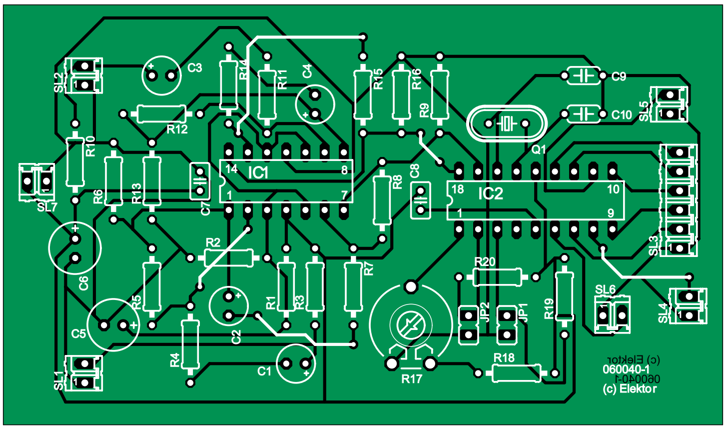


Figure 4. **Component layout of the binaural sensor PCB. The PCB files can be downloaded from (3).**

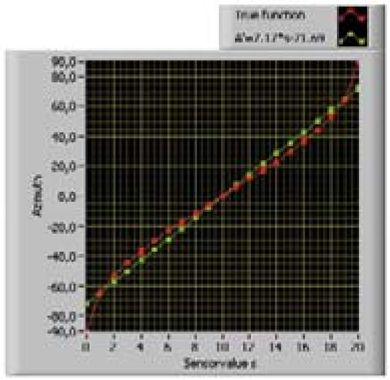


Figure 5. **Resolution of the sound source bearing is a function of its azimuth. The average value is approximately 9°.**

Components list

Resistors

R1,R5,R12 = 47kΩ
R2 = 33kΩ
R3,R10 = 22kΩ
R4,R11 = 1kΩ
R6,R9,R13,R16,R18,R19,R20 = 10kΩ
R7, R14 = 2kΩ2
R8, R15 = 100kΩ
R17 = 100kΩ preset
Rx = 100kΩ

Capacitors

C1,C2,C3,C4 = 1µF 16 V
C5 = 22µF 16 V
C6 = 100µF 16 V
C7,C8 = 100nF
C9,C10 = 22pF

Semiconductors

IC1 = LM324
IC2 = PIC16F88, programmed, order code **060040-41** from Elektor SHOP

Miscellaneous

Q1 = 20MHz quartz crystal
DIL14 socket
DIL18 socket
SL1,SL2,(SL4),SL5,SL6,SL7 = 2-way SIL pinheader (SL4 bridged with a 100k resistor, see text)
SL3 = 6-way SIL pinheader
JP1,JP2 = jumper
MicR, MicL = CZ034 electret microphone insert
PCB, ref. **060040-1**, free artwork download from Elektor website

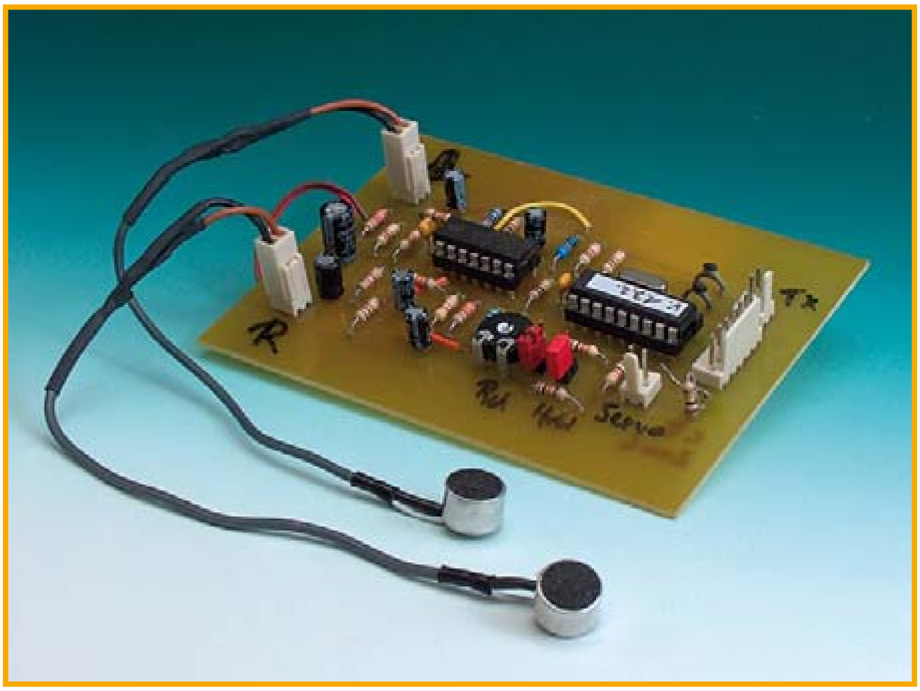


Figure 6. **The binaural sensor prototype.**

When the sound source is at the extreme right or left of the field (azimuth $\alpha = \pm 90°$), a time difference of ±10 samples will be measured. A minimum of 20 calculations are made for the correlation calculation. When the microphones are mounted on either side of a (solid) head this has the effect of increasing the microphone spacing, the pressure wave from one side needs to travel around the curve of the head before it reaches the second microphone. Assuming a sphere with microphones mounted along an axis, the arc length is $r \times \pi$, where r is the radius of the head and should be chosen so that the arc length is not greater than 17 cm.

The accuracy of the bearing calculation is a function of the azimuth of the sound source. It can be seen from **Figure 5** that when the source is central in front of the microphones an accuracy of approximately 5° can be expected while sound from the sides achieve around 11° and only 25° at the edge which all together gives an average figure of 9°. The highly directional nature of the electret microphones response characteristics meant that further study the longitudinal response was not worthwhile.

The PIC16F88 microcontroller used in this project was programmed using the Ultimate_PIC tools which are based on the Labview programming environment. The beta version of Ultimate_PIC is available from The Center for Engineering Education Outreach (CEEO) at Tufts University Massachusetts.

The assembler and hex files for this project Binaural_v132.asm and Binaural_v132.hex can be freely downloaded from the *Elektor Electronics* website [3] where a pre-programmed PIC controller can be ordered as an alternative from the SHOP section. The PCB layout and component placement is shown in **Figure 4;** the PCB artwork files are also available for download from [3].

Construction and Test

A picture of the prototype is shown in Figure 6. Shielded cable must be used to connect the two microphones to the controller board to help reduce pick-up of electrical noise.

The current consumption of just 10 mA can be supplied by almost any 5 V stabilised power unit. The microphones are mounted 17 cm apart, pointing forwards. A 500 Hz tone is an ideal sound source for test purposes but voice/music from a radio is also suitable. Turning the sensitivity preset to the left will increase the sensor sensitivity.
A simple DC output level can also be achieved by connecting a 2*R*/*R* resistor network to the 5-bit Digital output (**Figure 7**). The resultant DC output level is buffered by IC1A.

(060040-I)

Web links

(1) www.convict.lu/Jeunes/RoboticsIntro.htm

(2) www.ultimaterobolab.com

(3) www.elektor-electronics.co.uk

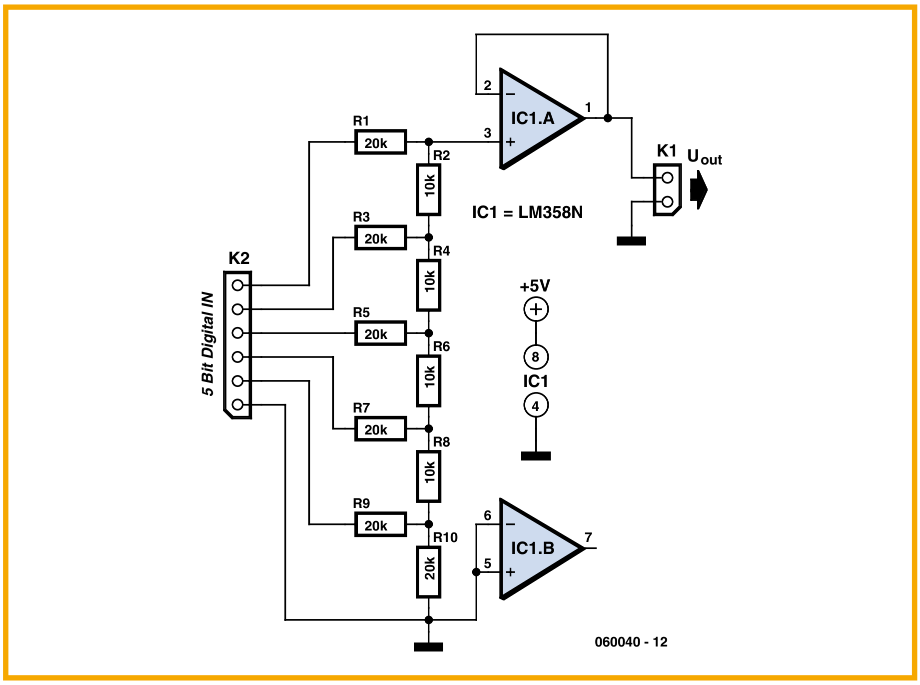


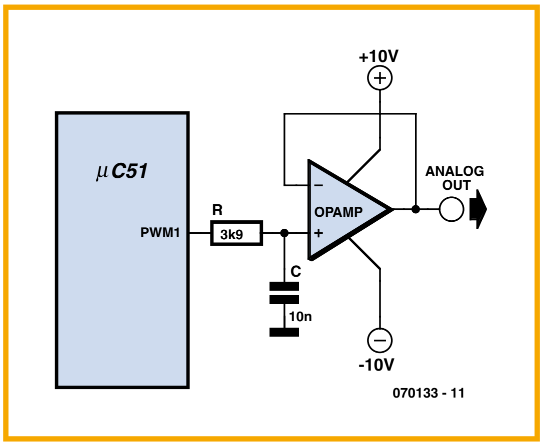
Figure 7. The resistor network functions as a simple D/A converter.

Sensor output values:			
Sound direction	(s+2) 8-bit-Integer (TX)	PWM/Servo	(s+6) 5-bit-Integer (Digital)
Extreme right	22	2 ms	26
Central	12	1.5 ms	16
Extreme left	2	1 ms	6

Simple D/A Converter for Robots

Tilo Gockel

Sometimes it's necessary to add a D/A converter to a microcontroller for a specific application. This can be fairly simply accomplished by interfacing an off-the-shelf D/A converter to the microcontroller's bus. An even simpler and more cost-effective solution based on an application note from Microchip [1] is shown here. A microcontroller produces a PWM (pulse width modulated) digital output signal which is filtered by a low-pass RC filter. Although the PWM signal has a fixed repetition rate the on-to-off ratio is varied from 0 to 100 % which, after filtering gives an analogue output signal proportional to the ratio. A single digital output from a port pin (driven from an on-chip timer for example) can therefore form the basis of an analogue output signal.



Guidelines to calculate values for the RC low-pass filter are given in the application note. Using the values suggested (3.9 kΩ and 10 nF) gives a –3 dB corner frequency of around 4 kHz. When driven by a PWM frequency of approximately 20 kHz the filter will be suitable for outputting audio tones and voice signals with a bandwidth of 4 kHz. This simple filter will attenuate the 20 kHz fundamental PWM frequency by 14 dB which may not sound like much but the human ear has its own high frequency roll-off (the characteristics of which change as we age) so frequencies this high will be barely audible.

Any standard operational amplifier, for example the TL071 can be used in this application. Lower frequency signals all the way down to DC can also be handled by this circuit and in this case the low-pass filter corner frequency can be reduced further which will give better attenuation of the PWM fundamental and reduce ripple on DC output signals. One typical application of the circuit is speed control of a DC motor in accordance with the industry standard ±10V. The circuit will connect to the motor via a suitable power driver stage. In this case the electromechanical properties of the motor itself will act as a low pass filter.

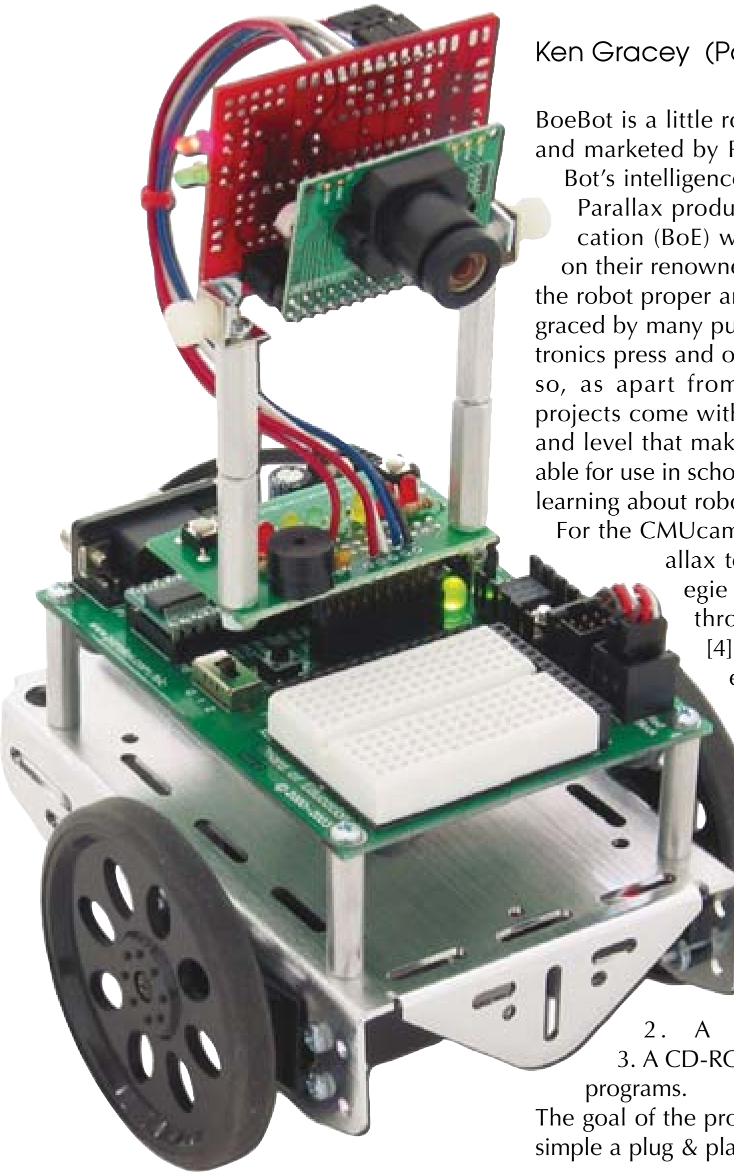
(070133-I)

Web link

(1) http://ww1.microchip.com/downloads/en/AppNotes/00538c.pdf

CMUCam1 Vision System

Seattle Robotics give BoeBot (and other robots) vision!



Ken Gracey (Parallax, Inc.)

BoeBot is a little robot vehicle designed and marketed by Parallax Inc. [1]. BoeBot's intelligence comes from another Parallax product, the Board of Education (BoE) which in turn is based on their renowned BASIC Stamp. Both the robot proper and the BoE have been graced by many publications in the electronics press and on the Internet. Rightly so, as apart from their low cost the projects come with backup of a volume and level that make them perfectly suitable for use in schools and, in general, for learning about robotics [2].

For the CMUcam1 Vision System, Parallax teamed up with Carnegie Mellon University [3] through Seattle Robotics [4]. The product is however only available from Parallax and their distributors like Milford Instruments [5].

The CMUcam1 BoeBot package includes

1. A CMUcam1 mounted on an AppMod user interface board.
2. A printed user manual.
3. A CD-ROM that includes demo programs.

The goal of the product is to give you as simple a plug & play experience as possible. Plug in the hardware, upload the demo code then press the buttons and watch your BoeBot use its new vision system to "see" and respond to its environment.

Purpose

The CMUcam1 AppMod™ vision system consists of a CMUcam1 vision system mounted on a plug in AppMod board. Included on the AppMod board is a simple user interface consisting of two buttons, eight LEDs and one piezo speaker. The user interface serves these three purposes:

1) A simple menu selection system which works with the included demo code to allow you to select and run one of eight robot vision demonstration programs.

2) Provide visual feedback from the LEDs as the demo programs run showing where the CMUcam1 is seeing the tracked target.

3) Indicate the colour of objects it sees by illuminating the corresponding LED (e.g., red LED for a red object).

With some clever circuitry on the AppMod board the two buttons, eight LEDs and one piezo speaker only require four I/O pins on your Basic Stamp2 thereby conserving I/O pins for other uses.

An 8-function demo

With the CMUcam1 AppMod Vision System plugged into the BoeBot AppMod connector the next step is to program the main demo code from the CD-ROM to the Basic Stamp2. The demo code has eight functions, each of which demonstrating a

Table 1. Basic command set

Command	Parameter(s)	Description [1]
\r	none	The 'Enter' or 'Return' key. Set the camera board into an idle state.
GM	none (\r)	Get the Mean colour value in the current image.
L1	value \r	Control the green LED tracking Light.
MM	mode \r	Controls the Middle Mass mode which adds the centroid coordinates to the normal tracking data.
NF	active \r	Controls the Noise Filter setting. It accepts a Boolean value 1 (default) or 0. A value of 1 engages the mode while a value of 0 deactivates it.
PM	mode \r	Puts the board into Poll Mode. Setting the mode parameter to 1 engages poll mode while 0 (default) turns it off.
RS	none (\r)	ReSets the vision board. Note, on reset the first character is a /r.
SW	(x y x2 y2) \r	Sets the Window size of the camera. It accepts the x and y Cartesian coordinates of the upper left corner followed by the lower right of the window you wish to set.
TC	(R_{min} R_{max} G_{min} G_{max} B_{min} B_{max})\r	Track a Colour. Accepts the minimum and maximum RGB (CrYCb) values and outputs a type M or C data packet (set by the MM command).
TW	none (\r)	Track the colour found in the central region of the current Window.

[1] Complete descriptions may be found in the user manual.

Table 2. Advanced commands		
Command	**Parameter(s)**	**Description [1]**
CR	(reg1 value1 (reg2 value2 ... reg16 value16))\r	Sets the Camera's internal Register values directly. The register locations and possible settings can be found in the Omnivision documentation.
DF	none (\r)	Dump a Frame out the serial port to a computer.
DM	value \r	sets the Delay before packets that are transmitted over the serial port.
GV	none (\r)	Gets the current Version of the firmware from the camera.
HM	active \r	puts the camera into Half-horizontal resolution Mode for the DF command and the LM command when dumping a bitmap image.
I1	none (\r)	Uses the servo port as a digital Input.
LM	active \r	Turns on Line Mode which uses the time between each frame to transmit more detailed data about the image.
RM	bit_flags \r	Engage the Raw serial transfer Mode. It reads the bit values of the first 3 (lsb) bits to configure settings.
S1	position \r	Lets you Set the position of servo 1. 0 turns the servo off and holds the line low. 1-127 will set the servo to that position while it is tracking or getting mean data.
SM	value \r	Used to enable the Switching Mode of colour tracking.

[1] Complete descriptions may be found in the user manual.

capability of the CMUcam1.
When you first turn on the BoeBot the eight LEDs on the AppMod interface board will flash several times, then the piezo speaker will beep indicating it is ready. Each function starts with one audible beep and stops with two beeps. The LEDs flash during each function in different patterns to let you know how that function is operating. The eight functions of the demo comprise:

1. Calibrate Lighting – about 20 seconds are needed to allow CMUcam1 to calibrate to the ambient lighting conditions.
2. Sample and Save Colour – it takes about a second to lock onto the colour of an object held in front of the cam; the LEDs will flash and the speaker will beep twice when done. The colour values are saved in the Basic Stamp2 EEPROM.
3. Track Colour – the robot moves forward, backward, right and left to follow the colour of the object saved during function 2.
4. Move & Avoid – the robot will move forward and avoid objects using the vision sensor only. It works by sampling the colour range of the floor in front of the robot.
5. Adaptive Tracking – the robot locks onto the first colour it sees and tracks that colour (it only goes fwd, right and left, not bwd). If it loses the object for about five seconds it then locks onto the next colour it sees and tracks that until it loses that, etc.
6. Line Following – it is assumed a black line about 1.2 cm (.5 in.) wide is present on a white line tracking course.
7. Finger Point and Move – the robot will backup, turn right and turn left in relation to finger pointing. This is done with the CMUcam1 using the same downward facing angle as is used on all the other functions.
8. Show Colour – the robot will light up either all of the red, green or yellow LEDs in response to the colour of the object placed in front of it. This works well with 5-cm diameter coloured rubber ball or plastic block.

For best performance with all of the above functions, the tilt of the camera should be pointing down looking just in front of the robot.

Basic Stamp2sx and Basic Stamp2p

This CMUcam1 AppMod and demo code will also work with the more powerful 2sx and 2p versions of the Basic Stamp. Separate versions of the demo code for each Stamp can be found on the CDROM. The code changes are minor and related to the 2.5 times faster execution speed.
You can do more with the CMUcam1 and the 2sx and 2p Stamps due to their faster speed and larger memory. The Basic Stamp2 is limited to 9600 baud serial interface speed to talk to the CMUcam1 but the 2sx and 2p can both talk to the CMUcam1 at its maximum serial data rate of 115,200 baud. The CMUcam1 is switched to the 115,200 baud rate by removing two jumpers that can be found on its board. The higher baud rate means BoeBot can respond much faster to the vision system.

About the CMUCam and the module

The CMUcam1 is an SX28 microcontroller [6] interfaced with an OV6620 Omnivision CMOS camera [7] on a chip that allows simple high level data to be extracted from the camera's streaming video. The board communicates using a TTL level serial port and has the following functionality:

- Track user defined colour blobs at 17 frames/s
- Find the centroid of the blob
- Gather mean colour and variance data
- Arbitrary image windowing
- 80×143 resolution
- 9600 baud serial communication
- Automatically detect a colour and drive a servo to track an object
- Slave parallel image processing mode off a single camera bus (advanced function)
- Ability to control one servo or have one digital I/O pin (advanced function)
- Adjust the camera's image properties (advanced function)

When using the camera outside, due to the sun's powerful IR (infrared) emissions, even on relatively cloudy days, it will probably be necessary to use either an IR cutoff filter or a neutral density-3 camera filter to decrease the ambient light level. A lens taken from a cheap drugstore pair of sunglasses when placed over the camera lens will allow the CMUcam1 to work in sun lit conditions.

Serial comms and command sets

The serial communication parameters are as follows: 9600 baud, 8 data bits, 1 stop bit; no parity, no flow control (no Xon/Xoff or hardware).
All commands are sent using visible ASCII characters, i.e., 123 is three bytes "123").
Upon a successful transmission of a command, the ACK string should be returned. If there was a problem in the syntax of the transmission, or if a detectable transfer error occurred, an NCK string is returned. After either an ACK or an NCK, an \r is returned. When a prompt ('\r' followed by a ':') is returned, it means that the camera

is waiting for another command in the idle state. White spaces do matter and are used to separate argument parameters. The \r (ASCII 13, carriage return) is used to end each line and activate each command. If visible character transmission exerts too much overhead, it is possible to use varying degrees of raw data transfer ('Raw mode').

The system supports two command sets — basic (**Table 1**) and advanced (**Table 2**).

Utility programs

Also included on the Seattle Robotics CD-ROM are the following utility programs.

Test CMUcam1 to BoeBot communication. This program sets up a 9600-baud serial connection between the Stamp and the CMUcam1. It then tells the CMUcam1 to blink its green LED.

Display CMUcam1 tracking data on debug screen. The first data packet displayed by the Debug screen is the 'S' (Statistics) packet which tells you the colour of the object it is tracking. This will let you evaluate the ability of your camera to track an object. Try different colour objects and different sizes to see the effects on the tracking data. This is an important program that you will re-use many times as you as you find more and more interesting things to do with your CMUcam1 and BoeBot. This program allows you to see and understand exactly what your BoeBot can see with its CMUcam1 vision system.

A short video showing a CMUcam-equipped BoeBot locating a red object may be found at [8].

(070132-I)

Web references

(1) www.parallax.com

(2) www.stampsinclass.com

(3) www.seattlerobotics.com

(4) www.cs.cmu.edu/~cmucam

(5) www.milinst.com

(6) www.ubicom.com/processors/sx/sx_family.html

(7) www.ovt.com

(8) www.seattlerobotics.com/video.htm

Sensor for Line Following Robots

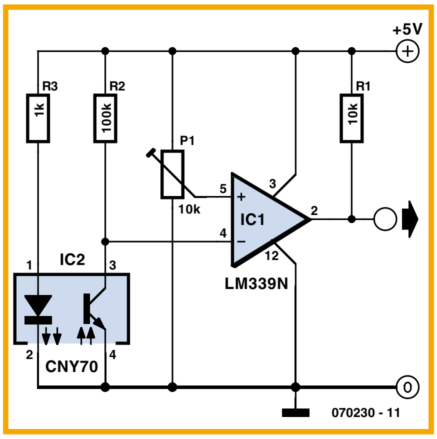
David Gustafik

One of the traditional 'disciplines' in which robots are supposed to compete is the Line Follower Competition. Robots go along a predrawn black line (usually duct tape) on a white-ish surface (usually paper, cardboard or plastic).

This discipline requires special sensors. Usually, these are made out of reflective optosensors (such as CNY70, LTH-209). This sensor contains a phototransistor and an infrared LED. These sensors are pointed at the surface on which the robot is supposed to show off its speed and agility. The LED emits infrared light on the surface and the phototransistor acts as a receiver. The black coloured line to follow reflects far less light than the white surface it is affixed on.

The current that flows through a phototransistor depends on the intensity of the light detected. Therefore, more current will flow through the transistor when it is above a white surface. In this way, the sensor can also be used as a surface detector.

The minimal count of sensors necessary for making a line following robot is… two — one on the left side and one on the right. It is advisable to use at least three sensors – one left, one right and one in the middle as a failsafe precaution against the robot dropping off a table edge.



In this circuit, the voltage on the phototransistor is compared with a reference level set by P1. When IC2 is illuminated, the voltage on it drops. Comparator IC1A compares the voltage against the set reference. If the reference voltage is higher than that on phototransistor, the comparator's output is drops to (almost) zero. This occurs when there is a black line under the sensor. The output signal from the comparator is then connected to either a microprocessor or any control logic that (hopefully) responds by adjusting the course of the robot .

The circuits needs to be calibrated before use. The best method is to set the P1 preset to the centre of its travel. Next, place the sensor above the surface it is supposed to detect, where it is white. Note that the height of the sensor above the surface is important. It doesn't matter that much when using for instance a CNY70, but an LTH209 for example only works in a very small range of heights (around 3.8 mm). If the response from the output of the comparator is good (i.e., pin 2 High) move the sensor above a line. If the result is again as expected (pin 2 Low) you're done calibrating the circuit. If not, repeat the process and adjust P1 until the correct calibration is achieved.

The schematic for only one of four channels that can be made with just one LM339 IC. The pull-up resistor at comparator pin 2 is used because the LM339 has open-collector outputs. R3 determines the current going to the IRLED.

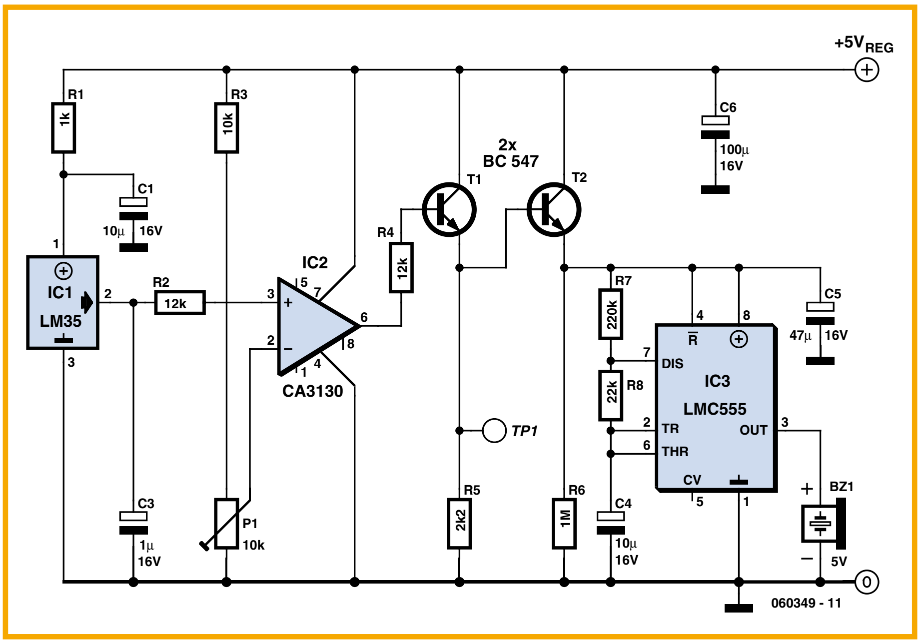
Many comparators can be used, the LM339N just happened to be available. The same may apply largely to the optosensor, but note that many different pinouts exist so check out that datasheet.

(070230-I)

Overheat Detector Alarm/Switch

T. K. Hareendran

At the heart of this circuit is a precision integrated temperature sensor type LM35 (IC1), which provides an accurately linear and directly proportional output in mV, over the zero to +155 degrees C temperature range. The LM35 develops an output voltage of 10 mV/K change in measured temperature. Designed to draw a minimal current of its own, the LM35 has very low self heating in still air.
Here the output of the LM35 is applied to the non-inverting input of a comparator wired around a CA3130 opamp (IC2). A voltage divider network R3-P1 sets the threshold voltage, at the inverting input of the opamp. The threshold voltage determines the adjustable temperature trip level at which the circuit is activated.
When the measured temperature exceeds the user-defined level, the comparator pulls its output High to approx. 2.2 V causing transistor T1 to be forward biased instantly. T2 is also switched on, supplying the oscillator circuit around IC3 with sufficient voltage to start working. The 555 set up in astable mode directly drives active piezoelectric buzzer Bz1 to raise a loud alert. Components R7, R8 and C4 determine the on/off rhythm of the sounder.
A transistor based relay driver may be driven off the emitter of T1 (TP1). Similarly, replacing the piezo sounder with a suitable relay allows switching of high-power flashers, sirens or horns working on the AC mains supply.



(060349-I)

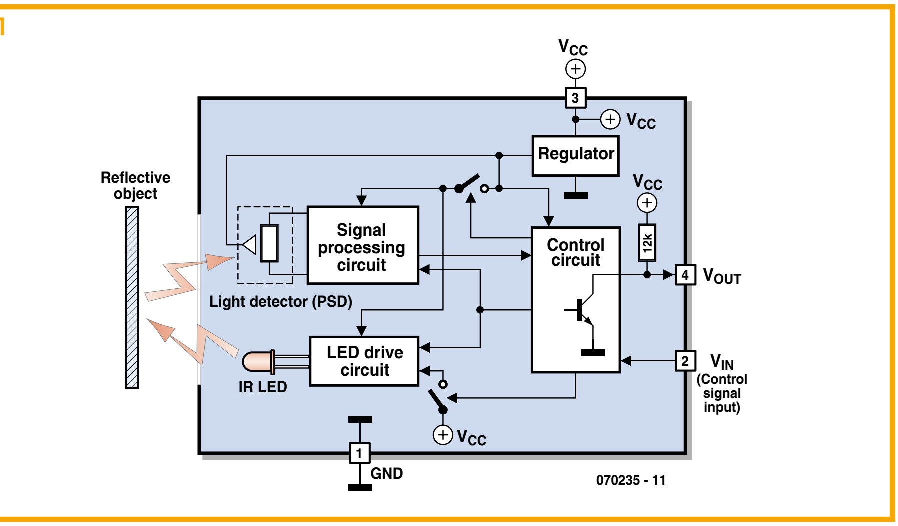
PIC or Basic Stamp IR Telemeter

with a PIC or a Basic Stamp

C. Tavernier

Although the simplest robots may be content to simply detecting obstacles, many robots that require precision in their positioning need to be able to measure distances accurately. To achieve this, it is necessary to use a telemeter, which can be infrared or ultrasonic. IR is very suitable for measuring short distances (a few centimetres up to a few tens of centimetres), while ultrasound is more suitable for distances from a few tens of centimetres to several metres.

1



Although it is still possible to construct a telemeter using standard resources, these days it's not really worthwhile because of the availability of ready-to-use integrated modules that are all relatively accurate, cheap, and compact. Taking a look at IR telemeters, the Sharp range is currently the largest and most readily available, insofar as we wish to stick with products at prices compatible with an 'amateur' robot.
This range, whose part numbers all begin with GP2…, includes telemeters that pro-

Listing 1. Use of GP2Dxx with a Basic Stamp.

```
Vin            con     0                        ' Definition of control input
Vout           con     1                        ' Definition of data output
Measr          var     Byte                     ' Allocation of one byte for the result

Measr = 0                   ' Initialization of variable « Measr »
Read:
Vin = 0                     ' Validation of telemeter
Wait:
IF Vout = 0 THEN Wait       ' Wait until result is available
SHIFTIN Vout, Vin, 2, [Measr]
Vin = 1                     ' Put telemeter to sleep
Pause = 1                   ' Pause as a precaution

' The result of the measurement is available in the variable 'Measr'
```

vide on/off outputs (though these aren't really telemeters as such!), information in analogue form, and information in digital form. Though the versions providing analogue information would appear to be the easiest to use, it's absurd to use them in a robot driven by a microcontroller, which will immediately convert this analogue voltage into a digital signal via its built-in converter so as to be able to make use of it. So it is better to have digital information available right from the outset, even if it might seem a little harder to read at the telemeter output.

In these circumstances, two types are currently readily available: the GP2D02, capable of measuring from 10 cm to 80 cm approximately, and the GP2D021, capable of measuring from 4 to 30 cm approximately. These two types are fully compatible both mechanically and electrically, and so everything we are about to write is equally applicable to both of them.

The principle of an IR telemeter is relatively simple: an LED emits an IR beam that, if it encounters an object, is reflected back towards a photodiode. Left at that, such a system is an on/off type and is really more an obstacle detector than a true telemeter. Although certain of the Sharp telemeters do work along these lines, the two types we've chosen are capable of performing true distance measurement, as the rays reflected by the object are no longer picked up by just a simple photodiode, but by a CCD array.

As a result, the angle of incidence of the reflected beam reaching this array varies according to how far away the detected object is, and hence allows true distance measurement, provided there is a minimal amount of signal processing to exploit the information generated by the CCD sensor.

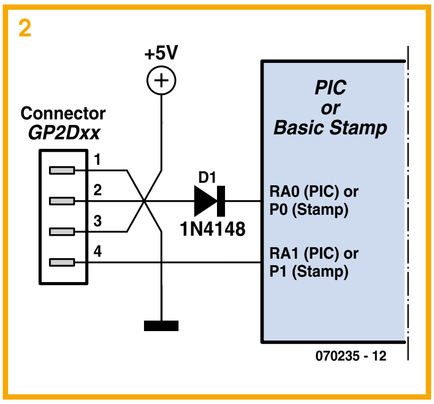
This is the case in the Sharp telemeters of this type, the internal block diagram of which is shown in **Figure 1**. In those telemeters with a measurement validation input (as in the models chosen), the LED is only powered under its control, allowing a very significant reduction in quiescent power consumption. In the other telemeters, it's on all the time.

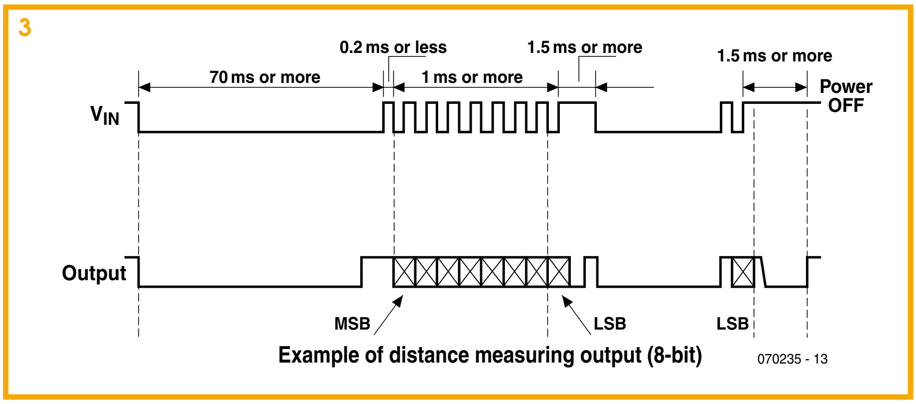
The CCD sensor is followed by a signal processing circuit that allows an output to be generated as either an on/off type signal for the simplest telemeters, an analogue signal, or lastly, 8-bit digital information, as in the models that interest us.

So as to be compatible with a maximum number of robotics solutions, we've opted to show you how to use such a telemeter with either a Basic Stamp or a PIC microcontroller programmed in Basic or machine code.

Listing 2. Use of GP2Dxx with a PIC controller.

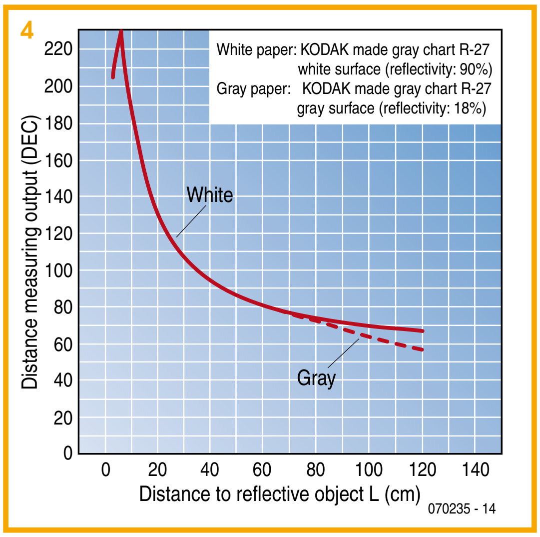
```
Read
BCF     PortA.0                 ' Validation of telemeter
NOP
Wait
BTFSS   PortA,1                 ' Wait until result is available
GOTO    Wait
BSF     PortA,0                 ' Vin goes High
CLRF    Measr                   ' Initialization of the variable 'Measr'
MOVLW   8                       ' Get ready to read 8 bits
MOVWF   Count
BCF     Status,C                ' Zero the carry
NOP
Readbit
BCF     Porta.0                 ' Make clock Low
NOP
NOP
RLF     Measr,f                 ' Rotation of preceding bit
BTFSC   PortA.1                 ' Read data bit
BSF     Measr,0
BSF     PortA.0                 ' Make clock High
NOP
NOP
        DECFSZ Count,f                  ' Count down number of bits to read
GOTO    Readbit

'The result of the measure is available in the variable 'Measr'
```





The telemeter application circuit can be summed up as shown in **Figure 2**, whether it's with a PIC or a Basic Stamp. The GP2D02 or GP2D021 detector is powered all the time, but because it has a control input, it consumes virtually nothing when there is no measuring taking place. A glance at the timing diagram in **Figure 3** shows us that this input is used not just for validating the measurement, but also as a clock for transferring the reading to the V_{out} terminal. Hence it needs to be controlled by the associated microcontroller, but as it must not be subjected to a voltage above 3 V, diode D1 isolates it from the microcontroller output when the latter is high.

The timing diagram in **Figure 3** should enable you to easily follow the listings of the very short programs we've written for using this sensor, whether in Basic, for the Basic Stamp and PICs programmed in Basic, or in PIC assembler, for those of you who prefer machine code.



As far as the Basic Stamp is concerned, just the instruction SHIFTIN is all it takes to read the result of the sensor's measurement. For the PIC, there will obviously need to be a few more instructions to generate the read clock and recover the relevant data. In both cases, these programs provide the digital data returned by the telemeter following the measurement in the variable 'Measr'.

Then it's up to your robot's management program to use this value directly, or to linearise it using a conversion table, if you want to perform actual distance measurement.

In fact — and this is perhaps the sole shortcoming of these telemeters — the information they provide is far from linear, as shown in **Figure 4**.

(070235-I)

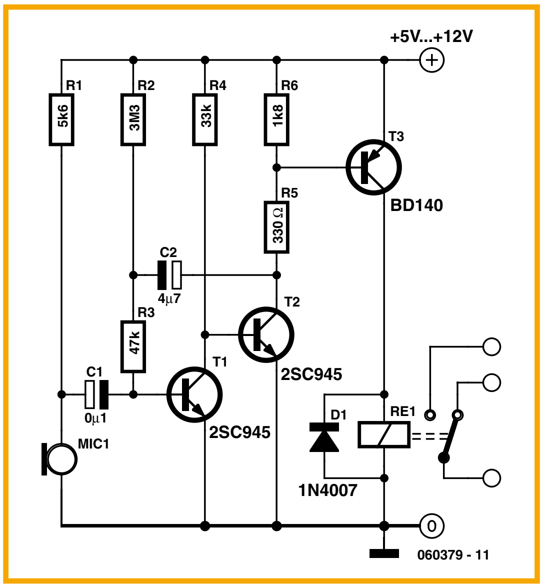
Sound Activated Switch

Hesam Hoshiri

Control by sound may be very useful, not just on a robot but also for a bit of home automation, for example a sound-activated light responding to a knock on the door or a hand clap. The light will be automatically switched off after a few seconds. An alternative use is burglar protection — if someone wants to open the door or break something the light will come on, suggesting that someone's at home.

The circuit can work from any 5–12 VDC regulated power supply provided a relay with the suitable coil voltage is used.

When you first connect the supply voltage to the circuit, the relay will be energised because of the effect of capacitor C2. Allow a few seconds for the relay to be switched off. You can increase or decrease the 'on' period by changing the value of C2. A higher value results in a longer 'on' period, and vice versa. Do not use a value greater than 47 µF.



Biasing resistor R1 determines to a large extent the microphone sensitivity. An electret microphone usually has one internal FET inside which requires a bias voltage to operate. The optimum bias level for response to sound has to be found by trial and error.

All relevant electrical safety precautions should be observed when connecting mains powered loads to the relay contacts.

(060379-I)

A Robot that won’t Lose its Bearings

C. Tavernier

Creating a robot capable of following an exact course without needing any external physical help — like a line marked on the ground, for example — has for a long time been a very tricky operation to achieve. Thanks to the boom in amateur robotics on the one hand, and to the development of new sensors on the other, it is today possible to make robots with functions that only a few years ago would have seemed more like science fiction. And this is just what we’re proposing now, with the construction of a robot capable of detecting terrestrial magnetic North, and hence to follow any angular direction with respect to that, exactly as you would find your bearings using a compass. To do this, it uses a successor to the good old needle compass, in the form of a module made by Devantech called a CMP03 (or CMPS03, depending on versions and documents).

This module, supplied in the form of a small, ready-to-use PCB as shown in the photo, contains two Philips KMZ51 magnetic field sensors mounted at right angles, with their output signals processed by a suitably-programmed PIC16F872 microcontroller. It is capable of delivering angular position information with respect to terrestrial magnetic North with an accuracy of up to a 1/10°. This information is available in the form of a PWM signal where the width of the pulses represents this angle, though in this case the resolution is only 1°. It is also available via an I²C bus that, depending on which register is read in the module, can make this angle available in the form of a 16-bit word, offering a precision of 0.1°.

If a robot is fitted with such a module, it’s then possible at any moment to find out the angle its trajectory is making with magnetic North, and hence to steer it exactly as you would yourself using a compass.

The only ‘problem’ that may arise is the interfacing of the CMP03 module with the microcontroller fitted in the robot. So in order to cater for the greatest number of robotic configurations possible, we’re going to show you how to employ both means of dialogue offered by the module: the PWM signals and the I²C bus.

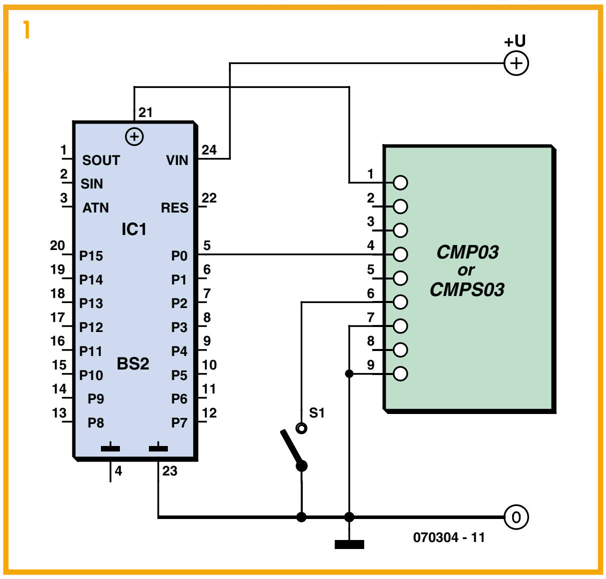


Figure 1 shows a circuit for using the PWM signals. It has been designed for use with a Basic Stamp II, but can be transposed for any PIC microcontroller programmed in Basic that does not have I²C functions.

Interrupt S1, present on pin 6 of the CMP03 module, is not involved in the dialogue process, but makes it possible to calibrate the module as per a procedure given in the documentation, which we won’t reproduce here, as it is perfectly straightforward.

The information supplied by the CMP03 module is a succession of high pulses separated by low states of 65 ms duration. The width of the high pulses indicates the angle of the principal axis of the module with respect to North, according to the following relationship:

Position = (Width – 1) × 10

where:

- Position is the angle in degrees with respect to magnetic North.
- Width is the width of the high pulses in milliseconds.

Reading such information with a Basic Stamp II or a PIC programmed in Basic amounts to just two lines of program:

```
PULSIN 0, 1, PULSE
POSITION = (PULSE –
500) / 50
```

The first line enables the instruction PULSIN to read the high duration of the pulse generated by the CMP03 module. The second line merely applies the above relationship, given that the resolution of the measurement performed by PULSIN is 2 µs in the case of the Basic Stamp II. So we then have the angle in degrees with respect to magnetic North in the variable POSITION.

If you want greater precision, or if your microcontroller does have an I²C interface available, it’s possible to use this interface to dialogue with the CMP03 module, as is shown by way of example in **Figure 2**. It has been designed for a Cubloc CB220 or a PIC programmed in Basic with a compiler that has an I²C library, which is the case for most of them these days.

The only precautions to be taken with this circuit concern the I²C bus pull-up resistors, which do need to be fitted as they are not built in to either the CMP03 module or the microcontroller (whichever type it is). If you are using a PIC programmed in Basic, you also need to ensure you correctly choose the ports intended to handle the SDA and SCL signals of the I²C bus, as certain Basic compilers impose restrictions here.

To be in a position to write the corresponding program, all you then need to know is that the I²C address of the CMP03 module is C0 and that four main registers are accessible to us through this address:

- register 0 contains the module’s software version number;
- register 1 contains the angle coded in one byte. Hence this value changes from 0–255 corresponding to a circle from 0–360°;
- registers 2 and 3 contain the angle,

coded this time in two bytes, in the form of a number between 0 and 3599 (expressed in decimal), which is in fact the angle in degrees multiplied by 10.

From that point on, reading this information via an I²C bus is quite straightforward, as shown in the very short listing below, written for the Basic language of the Cubloc:

```
I2CSTART
Temp = I2CWRITE (&HC0)
Temp = I2CWRITE(0)
I2CSTART
Temp = I2CWRITE(&HC1)
Version = I2CREAD(0)
Temp = I2CWRITE(&HC1)
Position8 = I2CREAD(0)
Temp = I2CWRITE(&HC1)
Position16.byte1 =
I2CREAD(0)
Temp = I2CWRITE(&HC1)
Position16.byte0 =
I2CREAD(0)
```

The first three instructions address the module and select the first register to be read. The next instructions read the four previously-described registers in succession, thus making the software version number available in the variable `Version`, the 8-bit coded angle in the variable `Position8`, and the 16-bit angle in the 16-bit variable `Position16`.

The variable `Temp` is not used for anything, but is required by the particular syntax of the I²C instructions of the Cubloc's Basic. By the same token, the constant 0 that must be present in the `I2CREAD` instructions has no particular meaning.

Hence if you use this listing with a PIC programmed in Basic, a slight adaptation might prove necessary, depending on the compiler you are using.

So, whether you choose the PWM or I²C version for interfacing with the CMP03 module, it gives you position information about your robot's trajectory with respect to magnetic North. All that remains for you to do is to make good use of it so your robot won't 'lose its bearings'.

(070304-I)

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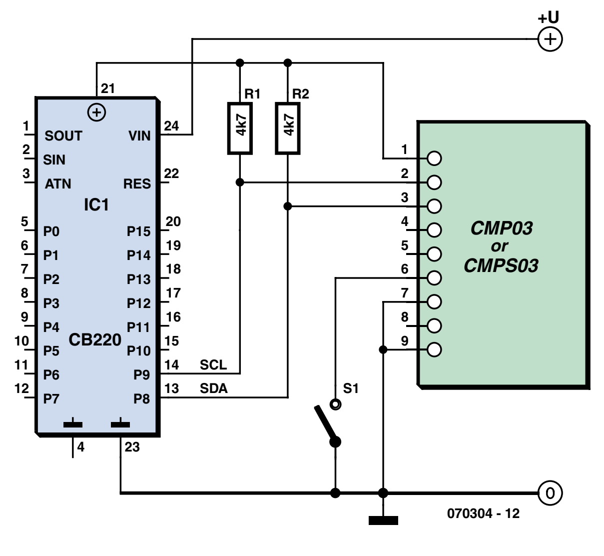

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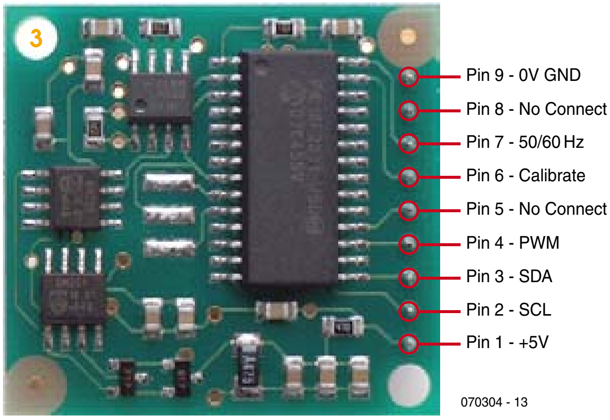


Web Links

Devantech

http://www.robot-electronics.co.uk/shop/Compass_CMPS032004.htm

A little background reading:

http://zedomax.com/blog/zedomax-diy-hack-lets-make-a-digital-compass/

http://zedomax.com/blog/2006/08/16/digital-compass-using-cmps03/

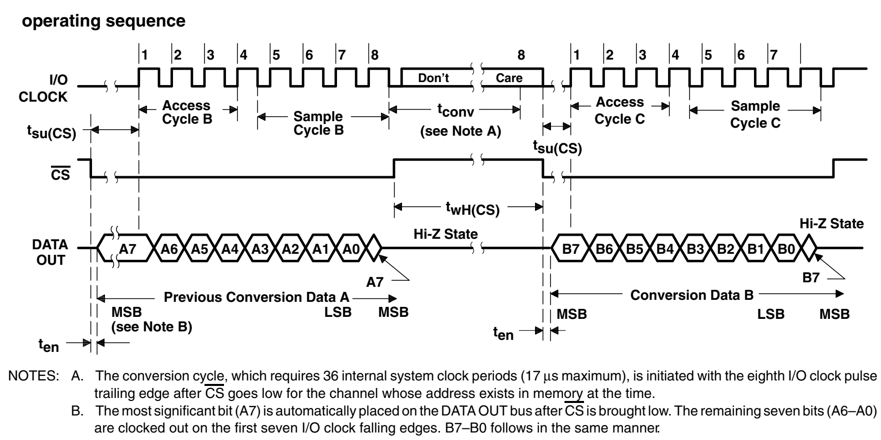
A/D Converter for Robots

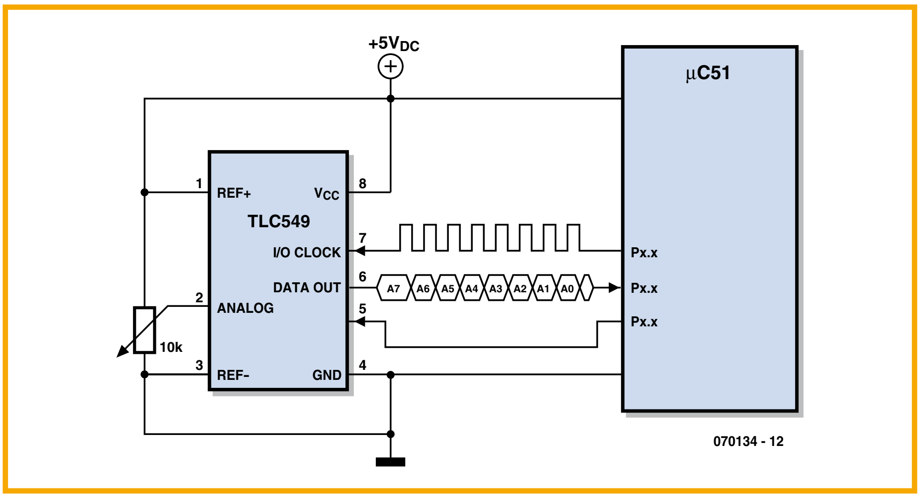
Tilo Gockel

The TLC549CP analogue to digital converter (A/D) from Texas Instruments is a good choice for applications in the field of robotics (especially those using 8051-compatible microcontrollers). These particular converters are readily available, low-cost and easy to use.

A quick look at the TLC549data sheet indicates the timing waveforms for the I/O Clock, DATA OUT and CS signals (Figure 1). A circuit to test the converter was quickly constructed using a variable resistor as a potential divider. Figure 2 shows the simple interface between a TLC549CP and a 8051-compatible microcontroller.

A short function which reads the serial





data from the TLC549 and returns the value addat is given below. Tests with an AT89S8252 Controller-Board (the Elektor Electronics December 2005 Flash Micro Board) indicated that the _wait() can be omitted because the controller runs slowly enough not to need it (faster processors may require it but it has been 'commented out' in this listing). The actual function written in C is:

```
unsigned char ReadADC1() {
unsigned char count;
unsigned char addat = 0;
P1_B2 = 0; // clk
P3_B0 = 0; // Chip Select
P3_B0 = 1; //
//_wait(); // > 20 usek (50kHz)
P3_B0 = 0;
for(count = 0; count
    < 8; count++){
addat = addat << 1;
if (P1_B3 == 1) ++addat;
P1_B2 = 1;
//_wait();
P1_B2 = 0;
}
return addat;
}
```

As an example two TLC549 A/D converters can be wired to a microcontroller to measure the amount of light falling onto two Light Dependant Resistors (LDR). This application will require two of the interface connections shown in Figure 2. Connect the LDR either in place of the variable resistor or in parallel to it.

(070134-I)

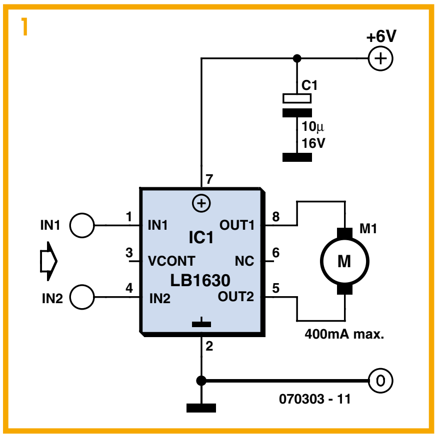
From Cassette Recorder to Robot Propulsion

B. Broussas

There are currently three principal methods for the propulsion of a mobile robot: the modified radio-control servo, the stepper motor, and the DC motor. All have advantages and disadvantages, which are important to be familiar with before making your choice.

The modified radio-control servo offers numerous advantages, the main one being that it offers relatively high tractive power without needing a reducing gearbox, as this is already contained within the servo case. So all you have to do is mount it onto the robot and fix the wheels directly onto its shaft. What's more, a radio-control servo is powered from 4.8 V, which is particularly handy for robots using four 1.2 V rechargeable batteries.

The major drawback of the radio-control servo lies not so much in its pulse drive mode, for which various solutions are proposed elsewhere in this issue, as in the lack of precision in the behaviour of the servo with respect to the pulse width. Although theoretically the servo runs at maximum speed in one direction or the other for pulses of 1 or 2 ms and stops for pulses of 1.5 ms, experience shows that differences of 10–20% in the pulse width needed are sometimes encountered. These differences make it necessary to calibrate the propulsion control programs of robots fitted with servos on an individual basis, thereby ruling out any reproducibility from one model of robot to another.



Stepper motors do not suffer from these drawbacks, but don't usually include any built-in mechanical reduction, meaning you have to provide external reduction if you don't want to end up with too little torque. If you don't fancy building such a device yourself, it's possible to use the 'gearboxes' sold as kits by various robotics or modelling retailers, but experience shows these are usually designed for standard DC motors, and are unsuitable for comparatively bulkier stepper motors. Moreover, driving steppers obliges us to use either a specialized IC, or a collection of logic ICs in association with power transistors.

So if you are forced to fall back on external reduction, for example because you don't want to use a servo, the DC motor then becomes the natural choice, especially since certain 'gearbox' kits are sold with such motors. So, all that remains is to drive them correctly.

Although conventional transistor-based circuits are still usable, there is also one very simple solution, directly inspired by the (old) cassette recorders in which DC motors were widely used. It involves using an LB1630 IC made by Sanyo, which can be cannibalized from many cassette recorders that have been thrown out, or else bought new, from Lextronic for example (www.lextronic.fr).

Available in an 8-pin DIP package, the

LB1630 is ridiculously simply to use, as shown in **Figure 1**. In fact, all it needs to be able to work is one external decoupling capacitor. It's controlled by two logic signals, which are TTL-compatible when the circuit is powered from a voltage of the order of 5 V. The supply must be between 2.5 and 6 V, and must not under any circumstances exceed 7 V, at risk of destroying the IC.
The current drawn by the motor being driven can be up to 400 mA maximum, though peaks up to 2 A are allowed, but only in the form of pulses whose duration may not exceed 50 ms at a duty cycle of 10%.
The protection diodes, vital when driving an electric motor using transistors, are built into the LB1630 and so don't need to be added to the circuit shown.
The two inputs IN1 and IN2 allow logic control of the motor, as per the **Table**.
Inputs IN1 and IN2 of the LB1630 just need to be in opposite states for the motor to turn one way or the other. So it's very easy to control using two parallel port lines from any microcontroller.
Independently of this 'on/off' type control to make the motor run in one direction or the other, the speed can also be controlled. All that is needed is to apply PWM pulses to one or the other of inputs IN1 or IN2.
Figure 2 shows one way of performing this sort of speed control using a Cubloc CB220, which has the advantage over the many other microcontrollers that can be programmed in Basic of being able to generate continuous PWM signals. With such a circuit, all you have to do is write, for example:

```
OUT 6,0
PWM 0, SPEED, 255
```

to make the motor run in one direction at a speed that can be adjusted by means of the variable SPEED, which can vary from 0–255, and:

```
OUT 6,1
PWM 0, (255-SPEED), 255
```

to make it run at the same speed but in the other direction.
Note too that, given that IN1 and IN2 of the LB1630 are logic inputs, several of them can be connected in parallel, so as to control several motors in an identical manner. But watch out! If you're controlling two traction motors positioned back-to-back on either side of a robot, they'll need to turn in opposite directions to make the robot move forwards or backwards. In this case, you need to cross over the inputs to the LB1630s (IN1 of one goes to IN2 of the other and vice-versa) if you are controlling them together, or else wire the motors in opposite senses to the OUT1 and OUT2 outputs.

(070303-I)

Truth table for LB1630 motor control IC.

IN1	IN2	OUT1	OUT2	Motor
H	L	H	L	Forward run
L	H	L	H	Reverse run
H	H	HiZ	HiZ	Stop
L	L	HiZ	HiZ	Stop

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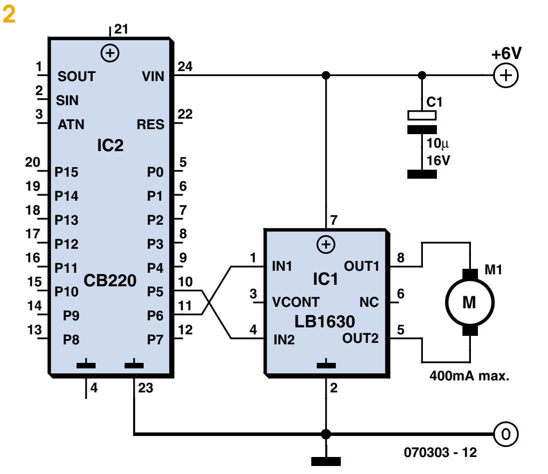


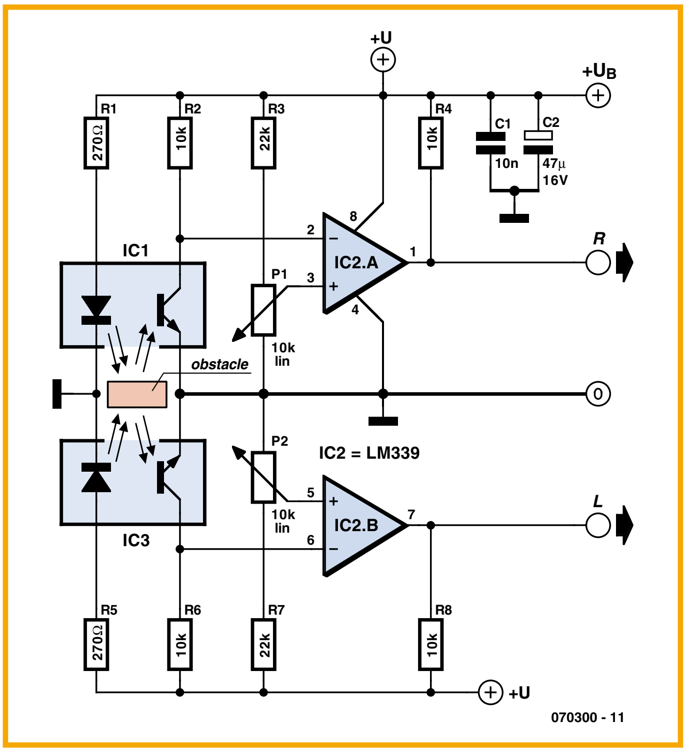
IR Close Object Detector

B. Broussas

Although ultrasound is well suited to detecting distant objects, it is quite unusable for closer objects, i.e. when the detection distance comes down to around a centimetre or less. Under these conditions, two solutions can be used: the bumper or similar device activating one or more microswitches — but that is still a mechanical solution — or the infra-red detector we're suggesting building here, combining the elegance of electronics with freedom from any moving parts.
The principle of such a detector is very simple. A transmitting element, which here is going to be a simple LED, emits a more or less directional beam of IR. Positioned next to this transmitter, a receiving element, which may be a photodiode or phototransistor, is suitably oriented so that under normal circumstances it doesn't receive anything. But as soon as an obstacle is present at a suitable distance, it reflects part of the light emitted by the LED back onto the photodiode or transistor; the presence of an output signal from the latter then indicates the proximity of this obstacle.
The distance up to which this process works properly very clearly depends on numerous factors: the luminous power emitted by the LED, the sensitivity of the detector, but also — and above all — on the reflective properties of the obstacle. A black cat will be much less easily detected than a white wall!
In answer to a question frequently asked in robotics classes, note that this principle works just as well using visible light, but the use of IR simply makes it possible to avoid, to some extent, the sensor is being dazzled by ambient light. Of course, if you use a robot fitted with such a sensor in full sunlight or beneath a halogen spot, this anti-dazzle effect probably won't be very effective, given the high level of IR radiated by such sources!
Note too that this system is not a telemeter, and so is unable to give the slightest information about the distance of the obstacle. The only parameter that actually relates to this distance is the amplitude of the reflected signal, but this depends also, indeed to a very large extent, on the reflective properties of the particular obstacle (think again of that black cat and white wall).
So, our detector is capable of operating over a range extending from a few mm to around 20 mm or so, depending on the type of sensor used. What's more, it's not confined to simple obstacle detection

in the conventional sense. For example, in the case of a robot that's meant to stay on a table, all you have to do is judiciously position such detectors around the underside of the edge of the robot's chassis. As soon as it gets too close to the edge, the sensor stops receiving the signal reflected by the table, indicating that it needs to turn back.

Construction of our IR obstacle detector is very simple, as the figure shows. Given the IC used, it's possible to build two at once, which is not unhelpful. As the detection zone of such a system is relatively limited, we've planned to use two sensors that we've called R and L for right and left, though this doesn't bear any particular relation to their actual positions on the robot. The figure shows the circuit of a single channel, the other is obviously identical; only decoupling capacitors C1 and C2 are common to them both.



The LED in the sensor IC1 is permanently powered via resistor R1, while the collector of the phototransistor in this detector is taken to the positive rail via R2. So when the transistor is off, i.e. when it is not receiving any light, meaning there is no obstacle, we have a voltage at this point approaching the power rail. As the transistor starts conducting, that is, when a sufficiently reflective and/or close obstacle reflects the light emitted by the diode back onto the phototransistor, this level drops. This information is shaped by comparator IC2A, whose switching threshold can be adjusted using P1. In this way, the circuit can be adapted to different sensors and the detection range can be adjusted to some extent. The circuit output is TTL-compatible if it is powered from 5 V and, given the way IC2A's inputs are connected, it is logic high in the presence of an obstacle.

Construction is perfectly straightforward, but the effectiveness of the circuit depends on the correct choice of sensors. We suggest three types that we've tried out, in a price range from around £ 1 to £ 8, but there's nothing stopping you — quite the contrary, in fact — from trying out other types, or even making your own sensor using separate IR LEDs and phototransistors of your own choice.

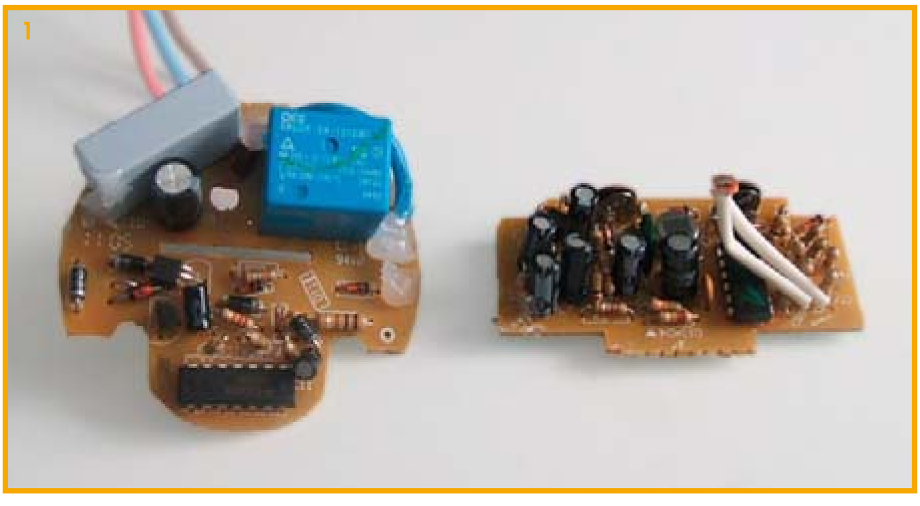
The cheapest sensor is the CNY70 (around £ 1). It only detects at very short distances, of the order of 5 mm, and is easily dazzled by ambient light. At approximately four times the price, we found the HOA709-001 from Honeywell, available from Radiospares, amongst others. It too can only detect up to around 5 mm, but with significantly better efficiency than the CNY70, and it proves harder to dazzle. Lastly, if you double the stakes again (i.e. eight times the price of the CNY70), you can use the HOA1180-003, still from Honeywell, very hard to dazzle and which detects up to a distance of 15 mm.

(070300-I)

PIR-Sensor

Abraham Vreugdenhil

When designing a robot, a choice has to be made as to the types of sensors that it will have. This choice will be determined mostly by the purpose of the robot. But the degree of complexity required in using the sensor and the cost of the sensor also play a role, of course. Sensors that are favourable in these respects are for example bumpers and feelers with micro-switches, IR distance sensors from Sharp and ultrasonic sensors. If we want to detect moving warm objects, such as people and animals, then PIR (passive infrared radiation) sensors from Eltec, in particular, become a consideration, such as the Eltec-442. This is a very nice sensor, but the price is a problem unfortunately, more than 60 dollars. Conrad Electronics also have a PIR



sensor available, the LHI958 (order number 178730) for just over £ 2.50. The disadvantage of this sensor is that an amplifier has to be added in order to obtain a usable

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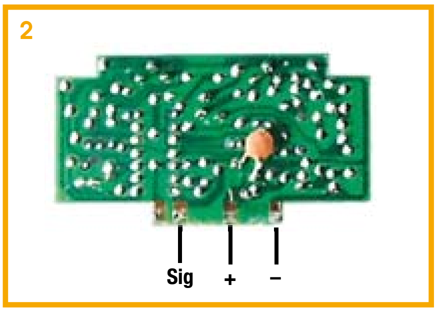

output signal. The documentation for the sensor is not particularly clear about this.

Another solution is a sensor that we often meet in daily life: the well-known movement detector for outdoor lighting, which is available from any builder's market or hardware store for a reasonable price. These are offered for sale at less than £ 7.00. After disassembly of the sensor, the main board with its daughter board remain (**Figure 1**). The daughter board contains the PIR sensor and accompanying electronics. The connection points for the power supply and output signal can be found on the back (**Figure 2**). The sensor is normally powered from 8 V, but it still works well at 5 V.

A robot will often be fitted with multiple PIR sensors that are mounted at different angles. To achieve this, we can mount three sensors on a piece of prototyping board and limit the view of each sensor with a short section of electrical conduit. The length of the conduit determines the field of view. The sensors on their own have a field of view of 140 degrees, so the shielding is definitely required. It is advantageous if the fields of view of the sensors overlap. In this way three sensors can be used to make five detection zones. It is of course also possible to use more sensors so that a greater resolution is obtained.

In this manner it is reasonably cheap to build a nice PIR sensor unit. The one shown in the example (**Figure 3**) comprises three PIR sensors. This sensor unit is easy to build and works well.

(070189-I)

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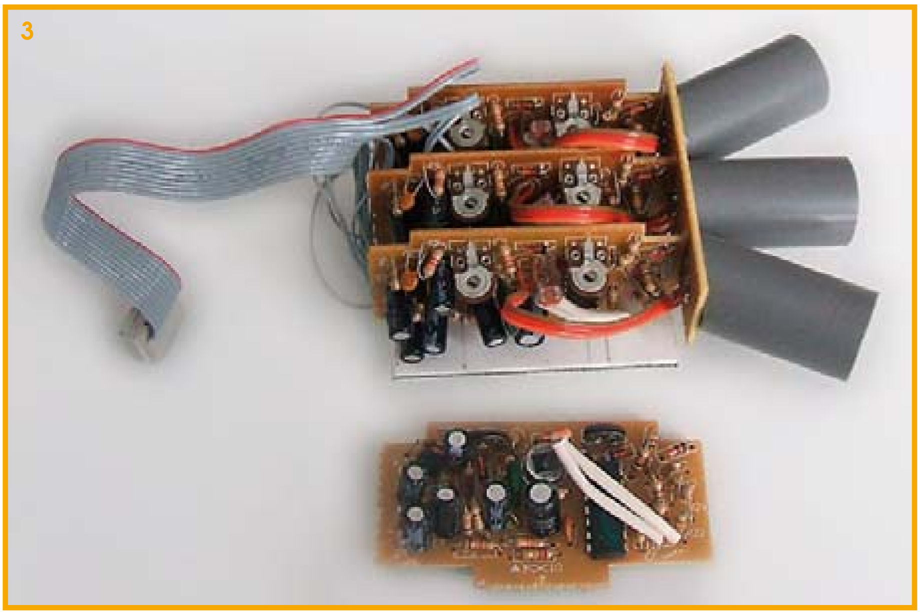
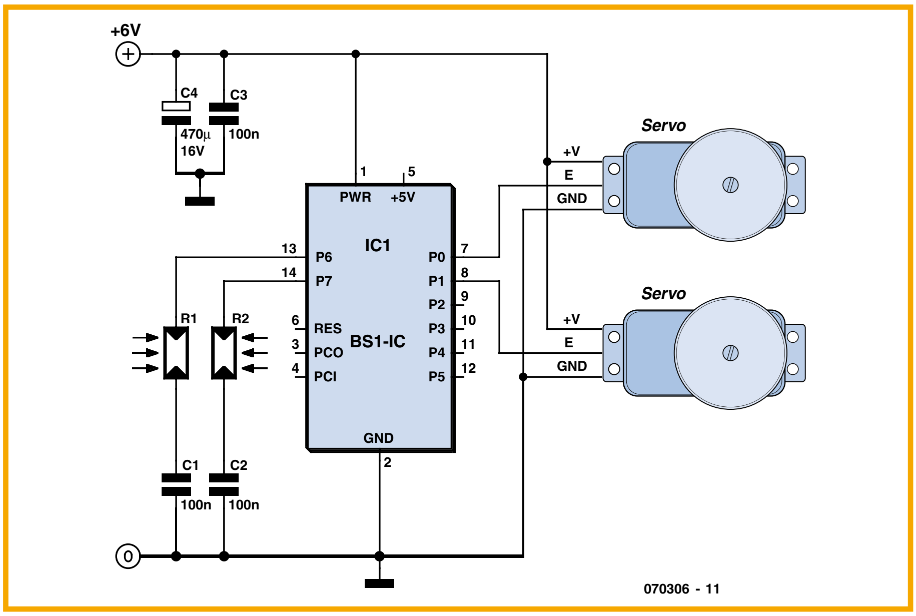


Light-seeking Robot

B. Broussas

Whatever the interest of the many types of robot that can be built today, the mobile robot is still an unmissable stage through which any robotics amateur has to pass, for at least two reasons. The mobile robot presents a concentration of the difficulties, and hence solutions, that may be encountered in robotics. You have to deal with problems of mechanics and kinetics in order to manage its movements, problems of sensors, which can be extremely diverse depending on what we want to detect, or on the other hand avoid, behavioural intelligence problems for processing the information provided by these sensors, etc. But the second reason why the robotics amateur needs to pass through the 'mobile robot' stage is often much less prosaic, as it's simply aimed at impressing the people around you (parents, friends, girl/boyfriend). What could be more impressive than this 'thing' straight out of a 50s sci-fi movie, moving around all by itself following a line on the ground, avoiding chair legs, or responding to a signal from its master?

So, robotics novices of all kinds, you will have realized that a mobile robot is what we're going to suggest constructing. And so you'll be able to see quickly just what your own hands are capable of creating, we've chosen some solutions that are sim-



ple, but no less successful in producing a certain effect.
Quite simply, it's a light-seeking robot — a sort of moth (on wheels) if you prefer, since, just like its counterpart in the living world, it is always going to head for the brightest source it can find in the room where you let it loose.
To simplify construction and enable you to be up and running in just a few hours, or less, after reading this article, we suggest you take advantage of a mechanical base that's available in a kit. Having opted for propulsion using modified servo motors, we suggest two different bases: the Rogue Blue base from Rogue Robotics (www.roguerobotics.com) or the Carpet Rover 2 base from LynxMotion (www.lynxmotion.com). Of course, if you are good at mechanics, there's nothing to stop you building such a base yourself. It just needs to be propelled by two modified radio-control servos, and so will need a jockey wheel at the front and/or rear.
The modification to convert the servos into propulsion motors is explained elsewhere in this issue, but if you have any doubts about doing it yourself, as of quite recently you can also now buy such servos already pre-modified by their manufacturer. Take a look at Lextronic for example for this (www.lextronic.fr).
For our robot's 'brain', to show you it's not always necessary to use the very latest 32-bit microcontroller, we've decided to use the smallest of the Basic Stamps, the Basic Stamp I.
The complete circuit looks like **Figure 1**. The two ports P0 and P1 of the Basic Stamp I are used to drive the right and left propulsion servos. The brightness is measured using two photoresistors or LDRs (still called CdS cells in some literature) connected to ports P6 and P7 of the Basic Stamp I. The odd mode of connection used here makes it possible to use an instruction specific to the Basic Stamp I, the instruction **POT**, which measures the charging time of a capacitor connected to one of its ports, i.e. thereby the resistance of the LDR and thus the brightness falling on it.
For the robot to be able to head towards the brightest part of the room where it is operating, these two LDRs must be mounted pointing forwards, separated from each other by a small piece of cardboard or opaque PCB in such a way they can't both receive the same illumination.
The assembly can be powered by four 1.5 V batteries. This voltage is applied directly to the servos and to the unregulated PWR input of the Basic Stamp I. Watch out! Under no circumstances connect the servo supplies from the Basic Stamp I's + 5 V output – its built-in 5 V regulator wouldn't appreciate it!
The software part of our robot is at least as simple as the hardware part, as you can judge from the listing below:

Listing

```
PINS = 0
DIRS = %00001111
SYMBOL RightStop = 150
SYMBOL LeftSTop = 150
SYMBOL Move = 30
SYMBOL LightDif = b2
SYMBOL RightLDR = b6
SYMBOL LeftLDR = b7
Main :
    POT 7, 128, LeftLDR
    POT 6, 128, RightLDR
    LightDif = RightLDR - LeftLDR
    b0 = RightStop + Move
- LightDif
    b1 = LeftStop - Move + LightDif
    PULSOUT 0, b0
    PULSOUT 1, b1
GOTO Main
```

This listing is very easy to analyse. After an initial phase to define the labels used and the reservation of the RAM in the Basic Stamp I, we go on to measure the light using the instruction **POT**. This instruction returns, in the variable **LeftLDR** (or **RightLDR**), a number representing the resistance of the LDRs connected to P6 and P7 divided by a constant called a scaling factor. You may need to adjust this parameter to suit the characteristics of the LDRs you use.
The values thus obtained are subtracted one from the other to yield information about the difference in lighting between the two cells. The calculation of the pulse lengths to be applied to the servos can then be performed, noting that **RightStop** and **LeftStop** are the values making it possible to make the servos stop, and that **Move** is a parameter intended to set the basic speed of the servos, to which is added or subtracted the result of the difference in illumination.
Hence, for example, if **LightDif** has the value 50, b0 will be 150 + 30 – 50, i.e. 130, while b1 will be 150 – 30 + 50, i.e., 170. Given that the resolution of the **PULSOUT** pulse is 10 µs, the program will thus generate 1.3 ms pulses for one servo and 1.7 ms ones for the other, causing the robot to turn towards the direction of the LDR that is receiving the most light.
So this program is fully functional, but, given the spread in the characteristics of both the servos, with respect to their drive pulses, and the resistance of the LDRs, it will undoubtedly be necessary for you to tweak certain numerical parameters again to obtain satisfactory results. To do so, note that:

- **RightStop** and **LeftStop** are equal to 1/10 of the pulse width that makes the right and left servos stop.
- **Move** lets you define the rotational speed of the servos when the robot is going straight ahead. It is equal to 1/10 of the difference between the pulse width for stop and the pulse width desired for moving straight ahead.
- The coefficients 128 used in the **POT** instructions can also be adjusted between 1 and 255 in order to obtain satisfactory behaviour of the robot, given the LDRs used and the ambient light in the place where the robot is operating.

Note too that if your robot seems to shy away from the light instead of moving towards it, you've probably reversed the wiring between the right and left servos or right and left LDRs (all this is relative, of course, depending on what you call front and back on the robot).
Now it's over to you...

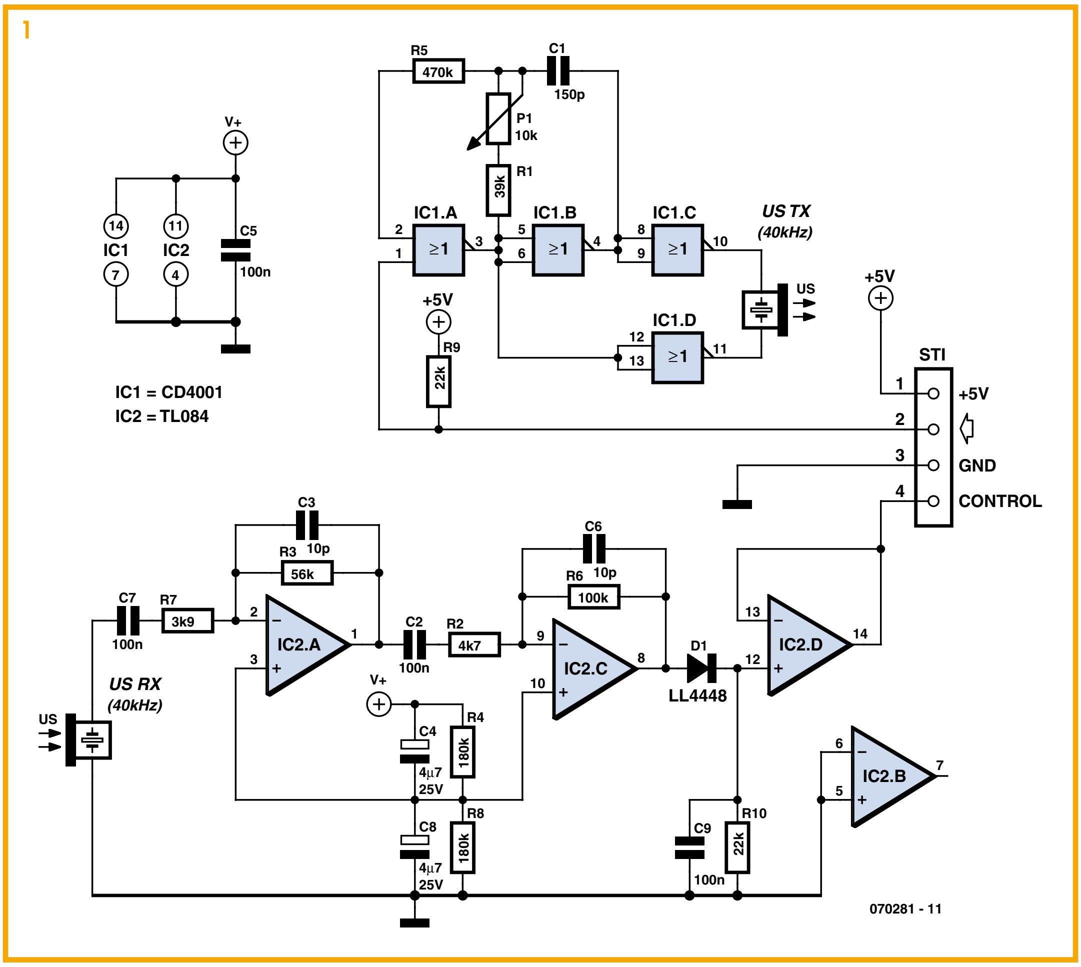
(070306-I)

Bat's Ear

Alexander Wiedekind-Klein

Genau genommen ist To be precise, this ultrasonic distance measuring device is more than just an ear, since it generates pulses of sound at 40 kHz as well as listening for their reflections. The circuit in **Figure 1** is divided into two parts. At the top is the 40 kHz oscillator and a 'push-pull' output stage built around IC1.C and IC1.D. The oscillator is switched on and off according to the 5 V logic level on a control input (pin 2 of K1). P1 is adjusted to set the oscillator frequency exactly equal to the resonant frequency of the ultrasonic transducer, nominally 40 kHz.
Reflected signals are amplified by IC2.A and IC2.C, rectified by D1 and buffered

by IC2.D. This circuit forms the analogue front end, and is connected to a microcontroller for subsequent signal processing. We will look below at the factors that need to be borne in mind when considering the digital signal processing algorithm to be used.



After a burst of ultrasound lasting approximately 2.5 ms is transmitted we sample the envelope of the received signal as delivered by the analogue front end for approximately 50 ms. In this time, sound travels approximately 16 m, and so we have a maximum range of 8 m, because the sound must travel to the distant object and back. **Figure 2** shows a typical received signal. The green rectangular pulse represents the signal at the control input (pin 2 of K1), which switches on the oscillator for the 2.5 ms pulse period. During this time (t_1) we can already see some signal at the output of the receiver, as it is impossible to avoid some direct reception of the transmitted pulse. This effect has to be taken into account in subsequent processing.

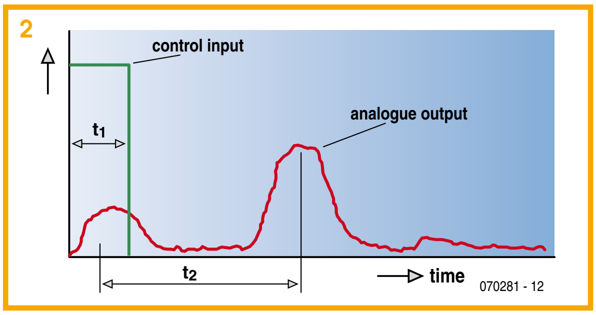
The second peak in the signal, after time t_2, is a reflection from an object. The time is proportional to the distance to the object. Measurement of time t_2 commences at the middle of the transmit burst (i.e., approximately 1.25 ms after the oscillator is enabled), and finishes when the amplitude of the reflected signal reaches its peak value. In air the distance to the object measured in centimetres is easy to calculate: to a good approximation it is equal to the time to the reflection in milliseconds multiplied by 16. For example, a time of 10 ms for t_2 corresponds to a distance of 160 cm.

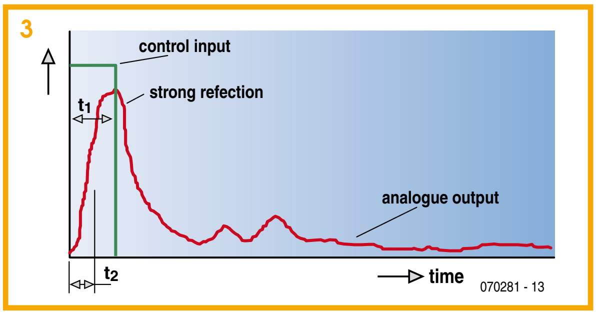
If an object is very near, the reflected sound will be very loud and be received after a very short time, possibly while the pulse is still being transmitted **(Figure 3**). In this case it is best to measure the time taken for the received signal to reach half its maximum amplitude from when the oscillator is switched on. This time can then be used to form an estimate for the distance to the object.

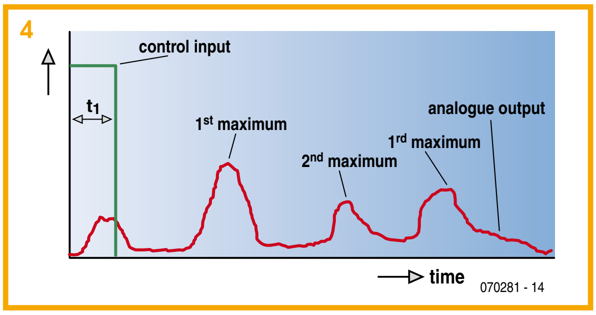
If there is a number of reflecting objects at different distances there will be several reflected pulses of different amplitudes (**Figure 4**). In this case it quickly becomes apparent that if we used a simple threshold detector in place of the microcontroller it would be impossible to get reliable results. A microcontroller with 'intelligent' software could, for example, be programmed to calculate the distance to the nearest object or to report the distances to several objects simultaneously.

Since the only connections to the circuit are a +5 V supply and ground, a control signal for the transmitter and the analogue envelope signal returned by the receiver to the processing hardware, it is straightforward to wire up four copies of the circuit mounted at right angles to one another. In a robotics application this would give the robot the ability to detect objects in any position relative to itself.

(070281-I)



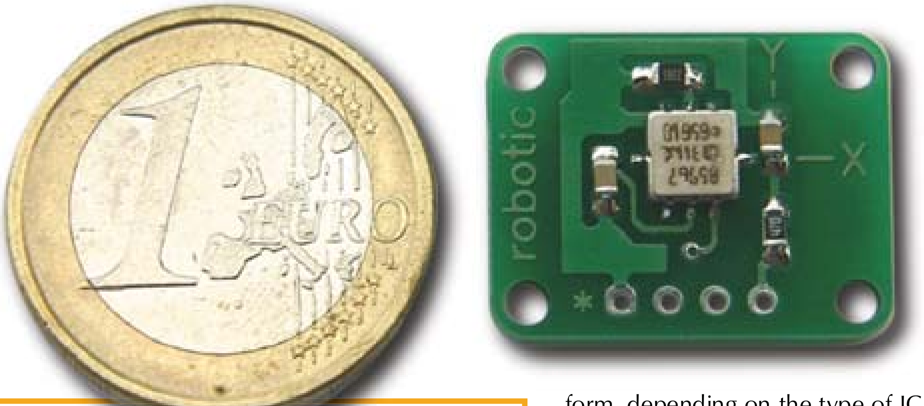




An Inclinometer for Your Robot

C. Tavernier

www.tavernier-c.com



If your mobile robot's sole function is to roam about the tiling or wooden floors of your home, it's not very likely to have much need of the sensor we're going to be describing in this article. However, if it has to confront the harsh realities of the ground of the outside world, with its holes and bumps, an inclinometer may prove extremely useful in order for it not to keel over at the first, ever so slight unevenness.

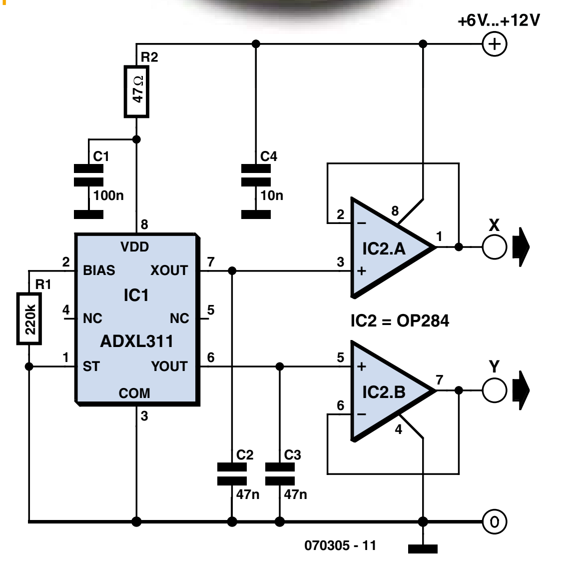
Before electronics knew how to accomplish all the feats that we are used to today, an inclinometer was a purely mechanical system, with all the difficulties of implementation, cumbersomeness, and lack of accuracy this implied. Might as well say that its use in an amateur robot was, if not impossible, at least very difficult.

For a few years now, this has no longer been the case, thanks to the marketing by Analog Devices of 'solid state' accelerometers, i.e. produced in the form of ICs, with no visible moving parts.

In fact, it's still impossible to measure acceleration without employing some kind of moving part, but nowadays this consists of a minute polysilicon structure suspended by four springs of the same material above the chip of the accelerometer IC. When this mobile element is subjected to acceleration, it deforms, and this deformation is revealed by a variation in the capacitance between a plate located on the mobile element and two fixed plates on the chip itself. Two out-of-phase squarewave signals are applied to the fixed plates. When the mobile plate is subjected to acceleration and moves, these become unbalanced, and phase demodulation yields a voltage proportional to the acceleration.

Of course, the user is quite unaware of all this going on, but has available at the accelerometer IC output information reflecting the acceleration registered — in analogue or digital form, depending on the type of IC chosen.

1

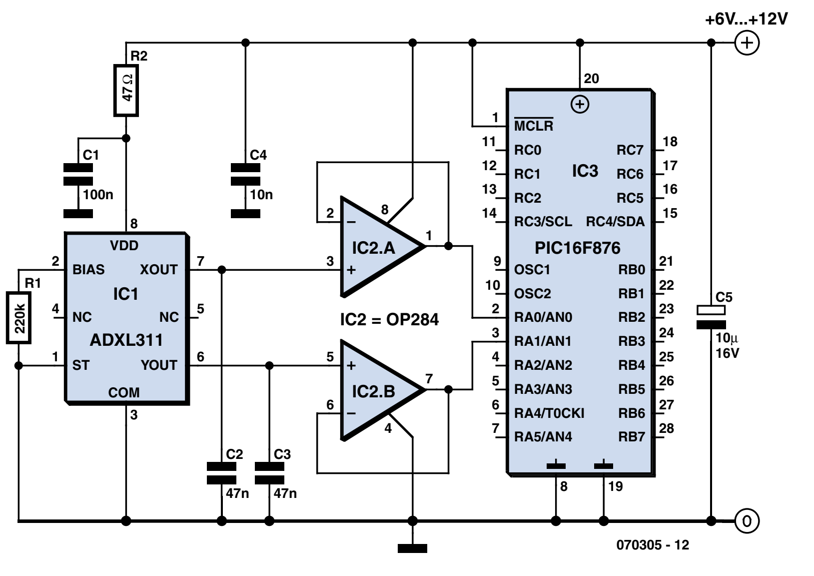


For our robotics application, we have decided to adopt a relatively inexpensive accelerometer in the form of the ADXL311 from Analog Devices. Do note right away, however, that this IC is no longer being produced, but is still widely available from retailers. If it should eventually disappear completely, it could be replaced by the ADXL320, much more recent and electrically compatible, only the pin-out being different.

The ADXL311 actually includes two highly sensitive accelerometers at right-angles, with positioning better than 0.1°. Because of this, and if it is placed parallel to the surface of the Earth, it is influenced by the acceleration due to the Earth's gravity, and so can indicate left/right inclination (roll) or forward/backward (tilt). In this way we create a dual-axis inclinometer.

These inclinations can be exploited in an absolute form if we want to know exactly the angle between the inclinometer, hence the IC carrying it, and the ground, or in a relative form, if we want just a limit indication of what the robot can withstand before it topples over.

2



In the case of the ADXL311 or the ADXL320, the absolute inclination is given by the equations:

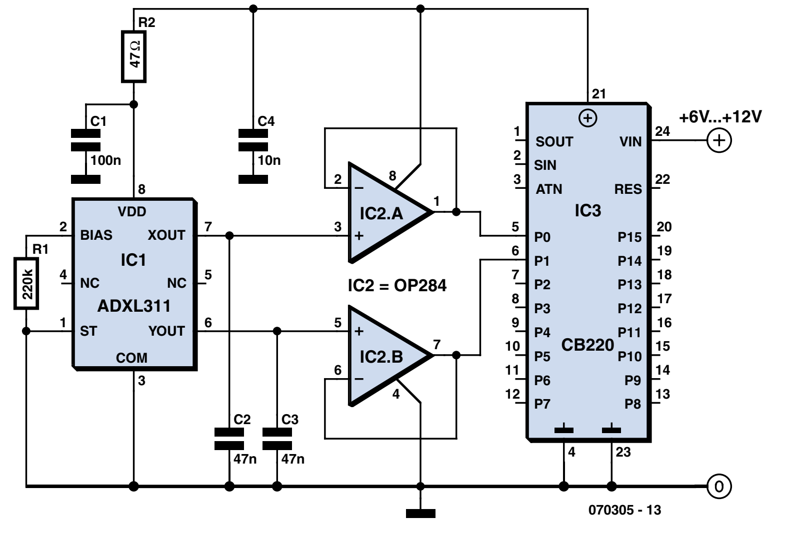
Tilt = arcsin (A_X/A_{X0})

and

Roll = arcsin (A_Y/A_{Y0})

where A_X and A_Y are the analogue voltages supplied by the accelerometer when it is inclined, and A_{X0} and A_{Y0} the voltages supplied when it is perfectly horizontal.
As shown in **Figure 1**, the accelerometer application circuit doesn't amount to very much. The only important elements are in fact capacitors C2 and C3, which filter the accelerometer output voltage. It actually has a passband of several kHz, and can therefore react to very fast vibrations, not at all what we want in an application as an inclinometer. With the values chosen here, the passband is restricted to 100 Hz, easily enough.
The two op. amps arranged as followers avoid any external influence on these filter capacitors and allow the accelerometer to be connected without special precautions to any microcontroller or ADC input.
The only minor problem you might encounter constructing this project is that the accelerometer is in an SMD package, which is not always easy for soldering onto an amateur PCB. There is now a module, ref. Accel, from Lextronic (www.lextronic.fr), that includes all the components in Figure 1 mounted on a tiny 15 × 20 mm PCB (see photo).
Using our accelerometer as an inclinometer involves measuring its analogue output voltages on both axes and subtracting from them the voltages at rest, that is, when the IC socket is perfectly parallel to the ground.
Figure 2 shows an example of the use of this inclinometer with a PIC microcontroller with a built-in ADC, while **Figure 3** shows the same type of circuit, this time with a Cubloc CB220.
We are not giving you a program for exploiting the information supplied by the inclinometer as, in both cases alike, it takes just two instructions to access the tilt or roll information.
So for example you would write

3




```
tilt = Adin(0)
tilt = tilt – 512
' adjust according to the voltage output
' when the inclinometer is horizontal
```

to recover the tilt information using a Cubloc CB220.
While you might write, for example,

```
tilt = Adc_Read(0)
tilt = tilt - 512      ' adjust according to the voltage output
' when the inclinometer is horizontal
```

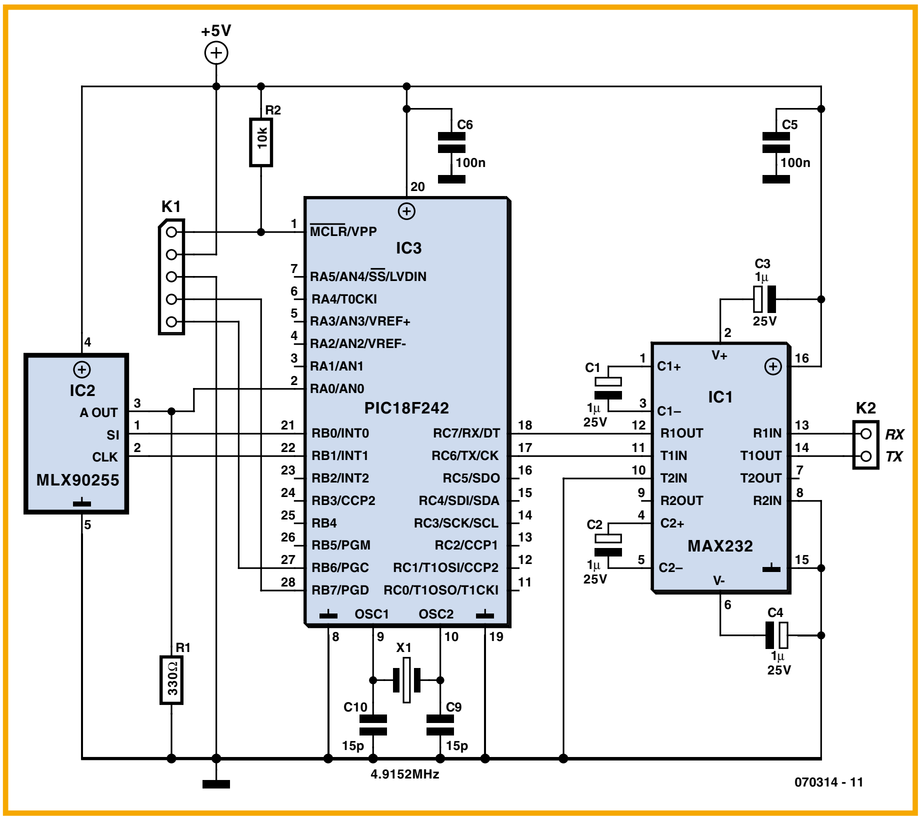
to recover the tilt information with a PIC programmed in Basic (in this example, MikroBasic compiler and 10-bit ADC).
The same instructions will obviously be used for roll, but using analogue channel 1 if you have adopted the circuit diagrams of Figures 2 or 3. Then it only remains for you to exploit this data to prevent your robot's falling over on terrain that's too steep for it!

(070305-I)

Positioning with Photodiode Arrays

Pascal Choquet

Industrial production-line robots require high-resolution sensors to measure the position of robotic actuators so that the tools can be accurately guided onto the work piece. A photo diode array together with an external light source is often used as a sensor in this application. This chip contains a line of photo diodes together with a series of sample and hold (S/H) circuits which take a snapshot of the readings of each photo diodes at the same instant and then outputs these integrated analogue values serially from a single output. The S/H circuits are important because the sensitivity of each element to the light quanta is dependent on the integration period; without the S/H the last element would show the highest sensitivity.
The accompanying table lists the most important properties of some common arrays. The sensitivity is dependant on the active diode surface area and the integration time.
From the outside these arrays look very simple, apart from the two supply connections there are only three signals for connection to a microcontroller: A clock input (CLK), a start impulse (SI) input and an analogue output signal (AO). AO should be loaded with a 330 Ω resistor to ground.
To readout the array values the controller firstly generates the clock signal and then sets SI high (with sufficient set-up time) before a rising clock edge. On successive falling clock edges the value of each individual pixel will be output at AO. The microcontroller reads each level and stores its value.
A feature of the MLX90255 type array is that the first two values read out are dummies, the first of the 128 real values appears at the third clock edge. The two values after the 128th value are also dummies, the read out therefore requires 132 clock edges in total to read all the data and the final 133rd edge reinitialises the shift register. The gain of the pixels at either end of the array is about 15 % greater than those in the centre (cosine weighting) this compensates for the light loss experienced at the edges when the array illumination is provided by a single LED.
The integration period begins at the 18th



Photodiode Array properties				
Array	**MLX90255**	**TLS1301**	**TLS1401**	**TLS208R**
Pixel (* see text):	128 (+ 4*)	102	128	512
Pitch (DPI):	385	300	400	200
Weighting:	Cosine	Equal	Equal	Equal
Length x width (µm):	200 x 66	85 x 77	63,5 x 55,5	120 x 70
Output (V):	0.125 - 2.4	0 - 2.0	0 - 2.0	0 - 2.0

clock edge and continues until the next SI signal. The output values are the result of the previous integration period so if the array is not continuously scanned then it is necessary to make two complete scans to get meaningful results. The first scan cycle after power up is used to initialise digital levels on the chip, the values read are invalid and should be discarded. The integration time is equal to the pixel count minus 18 divided by the clock frequency. The sensitivity can be easily controlled by the microcontroller.

The circuit diagram shown here consists of the photodiode array together with a basic PIC microcontroller and a driver chip for an RS232 serial interface connection. The author has produced a program written in C which can be used in the controller. The source files (**070314-11.zip**) are available to download free of charge from the *Elektor Electronics* website. A scan cycle is initiated using a terminal program by entering 'Strg S'. The values are separated with semicolons so they can be easily used in an Excel table.

Photodiode arrays can be used in robotics for imaging based on the pinhole camera principle, they have also been used in line-following applications where they offer good resolution and can be mounted relatively far away from the floor. Together with a prism or optical grating the array can be used to perform simple yet precise colour recognition.

(070314-I)

Whiskers on Robots

Alexander Wiedekind-Klein

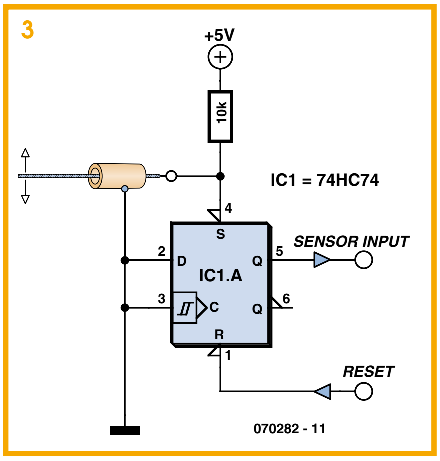
Sometimes sophisticated sensors based on video cameras, infrared or ultrasound are not quite up to the job, and we have to resort to somewhat more primitive switch-type sensors. These work like an animal's whiskers (or 'antennae' on insects), detecting nearby objects in the environment. When disturbed, a sensor sends a pulse to the robot to indicate that an object is present. Sensors that are both sensitive and robust can be made using steel guitar strings. The material is very flexible as well as being conductive. The idea could not be more simple: we pass the wire through a metal tube, and when the wire is in contact with an object in the environment it bends and the two make electrical contact. Responsiveness and sensitivity depend chiefly on the length and stiffness of the piece of guitar string used.

1

Do-it-yourself construction should not present great difficulties even to the most mechanophobic reader: see **Figure 1**. We proceed as follows.

1. Cut a length of steel guitar string (8 cm to 10 cm is enough), and saw off a length of about 2 cm of 4 mm diameter brass tube. Deburr the edges inside and out.
2. Solder a wire to one end of the brass tube and another wire to the end of the guitar string. Insulate the joint on the guitar string using heatshrink tubing.
3. Slide the string into the tube so that only about the first 10 mm from the end of the tube is insulated. Fix the string centrally within the tube using hot-melt glue. Be careful not to allow too much glue to run down inside the tube.

The result should look like **Figure 2**. Of course, you are free to experiment with variations on this construction!
As we have described it this robot whisker is essentially just a simple switch contact. To ensure that even the gentlest collision does not pass unnoticed we recommend that you use the whisker to trigger a flip-flop as shown in **Figure 3**. The microcontroller in the robot can then read the state of the flip-flop at its leisure and then reset it.



(070282-I)

CO Sensor

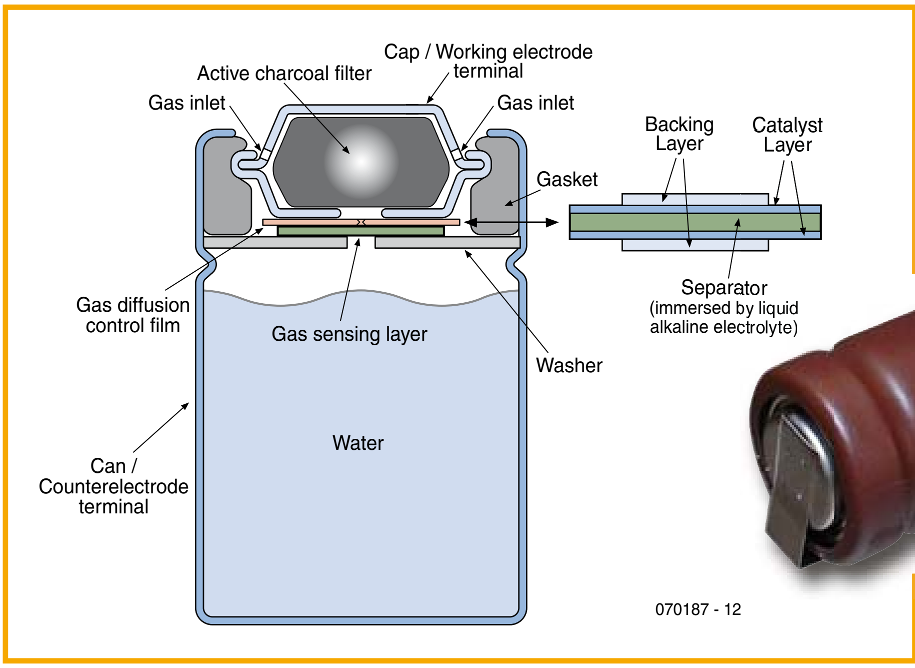


Figure 1. **Internal structure of the sensor.**

The Figaro TGS5042 sensor is a carbon monoxide sensor that is used primarily in industrial applications such as smoke detectors, fire detection equipment and ventilation controllers for indoor car parks and the like. The sensor is quite suitable for use in battery-powered applications, and it has several advantages over conventional sensors. The electrolyte is environmentally friendly, and the housing is leak-proof. The sensor can measure CO concentration up to 1%, and it has a temperature range of –40 °C to +70 °C. The housing has the same form as an AA battery.

A few specifications:

- Suitable for use in battery-powered equipment

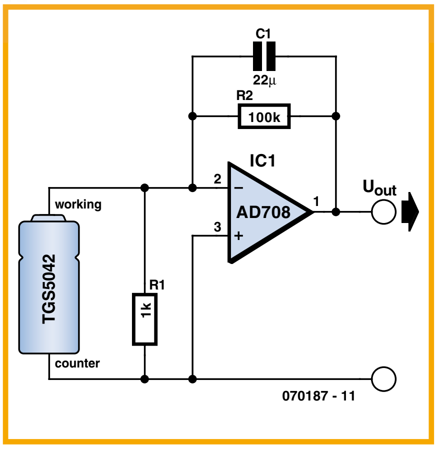


Figure 2. **A simple sample application circuit.**

- High sensitivity and accuracy for CO
- Linear relationship between CO concentration and output voltage
- Low sensitivity to ethanol
- Low sensitivity to other gasses that may be present

Figure 1 shows the internal structure of the TGS5042 sensor. The gas-sensitive layer for CO is located between a stainless-steel ring (counter electrode) and a nickel-plated cap (working electrode). The cap is packed in a sort of film and several supporting layers. All of this is packaged in a cylindrical stainless-steel housing. The lower compartment is filled with water, and the cap end is filled with an activated charcoal filter.

Figure 2 shows the schematic diagram of a basic application circuit for the TGS5042. The sensor generates an extremely small current, which is converted into a voltage by an instrumentation amplifier formed by IC1 and R2. Resistor R1 is necessary to prevent polarisation of the sensor, which might otherwise occur when the circuit is switched off.

It is essential to avoid applying a voltage to the sensor under any conditions. Doing so would permanently damage the sensor. The voltage across the sensor must always be less than 10 mV.

Some potential applications for the sensor are:

- Residential CO detectors
- CO monitors for industrial applications
- Ventilation control for indoor car parks

(070187-I)

Compass Sensor for Lego Mindstorms NXT

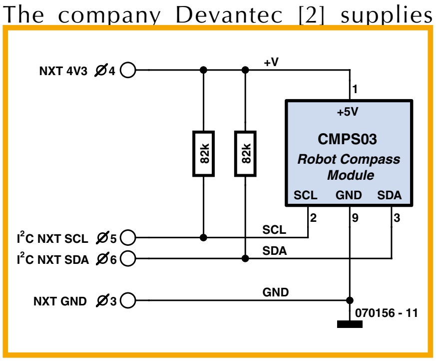
Zeno Otten

A few years ago, a considerable amount of attention was devoted in Elektor Electronics to the construction of sensors for the intelligent control brick (RCX) from Lego Mindstorms [1].

There is now a successor. The NXT is the heart of the new Mindstorms. Using this system, computer hobbyists can develop, build and, in particular, program, numerous robots, to their heart's content .

With the compass sensor that is described here the NXT can determine its direction with an accuracy down to a few degrees. This allows a robot to be built that's capable of navigation.

The company Devantec [2] supplies



a ready-to-go compass module type CMPS03. Two mutually perpendicular Philips KMZ51 hall-sensors are used to detect the Earth's geomagnetic field. With a small PIC-controller a value between 0 and 360 degrees is calculated and made available in digital form at the output of the module. The communication with the outside world takes place via the I²C protocol or via a PWM output.

The module requires a 5 V supply voltage and consumes about 20 mA. This module is eminently suitable for use with the NXT.

The new NXT has the option of connecting sensors that use the I²C protocol. This allows a sensor to be connected to the NXT using an RJ12 plug.

The NXT does not have internal pull-up resistors on the I²C bus. So, these have to be added externally. Lego suggest resistors with a value of 82 kΩ on both the data line (SDA) as well as the clock line (SCL).

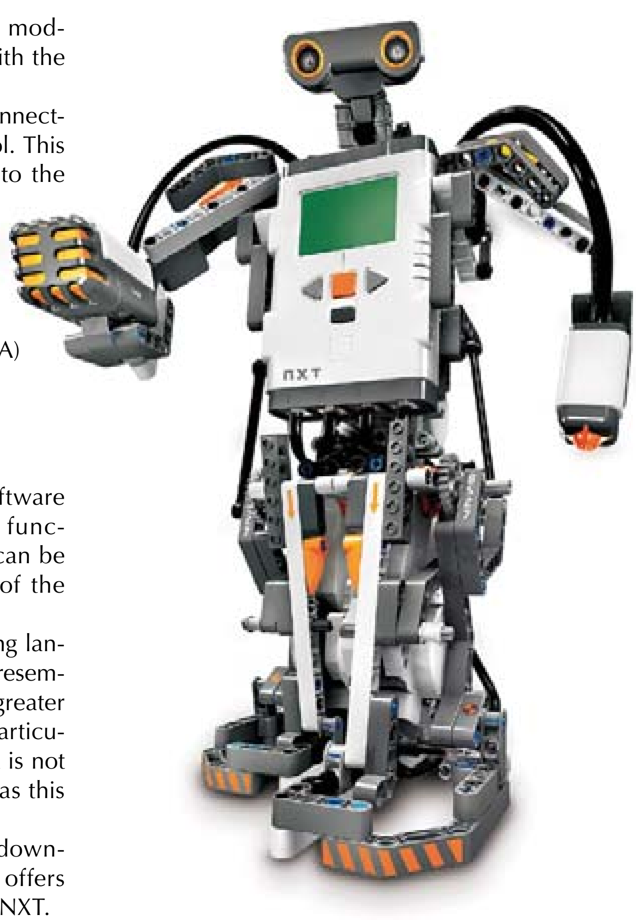
Software

The standard Lego Mindstorms software is based in dragging graphical function blocks. Only the parameters can be changed while the functionality of the blocks is fixed.

Not Exact C (NXC) is a programming language for the NXT that has a strong resemblance to C. This permits a much greater flexibility when programming. In particular when it concerns hardware that is not officially supported by Lego, such as this compass sensor.

The compiler (BricX) [3] can be downloaded free, is simple to use and offers many options for programming the NXT.

The program compass.nxc (which can be downloaded free from the Elektor Electronics website as file number **070156-11.zip)** continually reads the compass sensor. The measured values are then processed by the robot who will sequentially 'point' to North, South, East and West. The values measured by the electronic compass can also be read from the display on the NXT brick.



(070156-I)

References

(1) Compass sensor for Lego RCX, Elektor Electronics July/August 2002

(2) Devantec: http://www.robot-electronics.co.uk/shop/Compass_CMPS032004.htm

(3) BricX: http://bricxcc.sourceforge.net/

Ultrasonic Distant Obstacle Detector

B. Broussas

The first sensor a robot usually gets fitted with is an obstacle detector. It may take three different forms, depending on the type of obstacle you want to detect and also — indeed, above all — on the distance at which you want detection to take place.

For close or very close obstacles, reflective IR sensors are most often used, an example of such a project appears elsewhere in this issue. These sensors are however limited to distances of a few mm to ten or so mm at most.

Another simple and frequently-encountered solution consists of using antennae-like contact detectors or 'whiskers', which are nothing more than longer or shorter pieces of piano wire or something similar operating microswitches. Detection takes place at a slightly greater distance than with IR sensors, but is still limited to a few cm, as otherwise the whiskers become too long and hinder the robot's normal movement, as they run the risk of getting caught up in things around it.

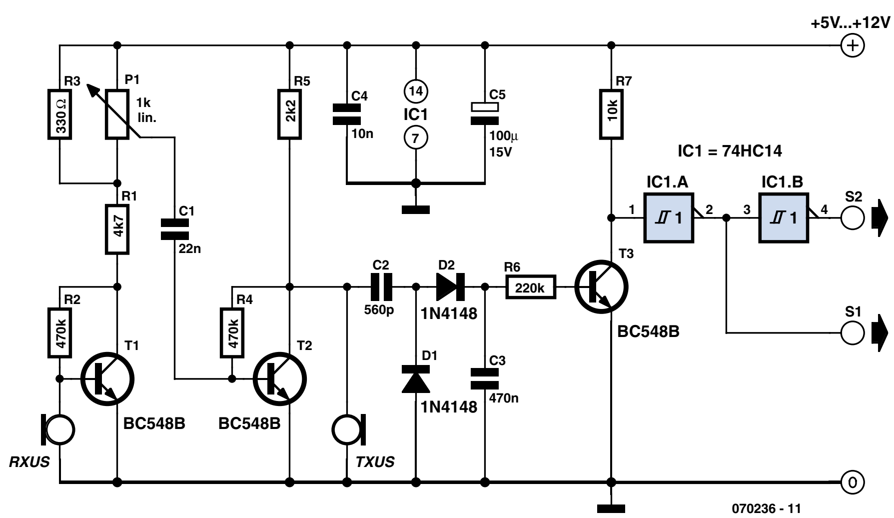
For obstacles more than a couple of cm away, there is another effective solution, which is to use ultrasound. It's often tricky to use, as designers think as if they needed to produce a telemeter, when in fact here we're just looking at detecting the presence or absence of obstacles, not measuring how far away they are.

So here we're suggesting an original approach that makes it possible to reduce the circuit required to a handful of cheap, ordinary components. Our solution is based on the howlround or feedback effect all too familiar to sound engineers. This effect, which appears as a more or less violent squealing, occurs when a microphone picks up sound from speakers that are connected to it via an amplifier. Feeding back the output signal from the speaker into the input (the microphone) in this way creates an acoustic oscillator.

Our detector works on the same principle, except that the microphone is an ultrasound receiver while the speaker is an ultrasonic emitter. They are linked just by a very easily-built ordinary amplifier. Feedback from the output to the input occurs only when the ultrasonic beam is reflected off the obstacle we are trying to detect.

As **Figure 1** shows, the receiver RXUS is connected to the input of a high-gain amplifier using transistors T1 and T2. As the gain of this stage is very high, it can be reduced if necessary by pot P1 to avoid its going into oscillation all on its own, even in the absence of an obstacle. The output of this amplifier is connected to the ultrasonic emitter TXUS, therby forming the loop that is liable to oscillate due to the effect of feedback.

1



When this takes place, i.e. when an obstacle is close enough to the ultrasonic transducers, a pseudo-sinewave signal at their resonant frequency of 40 kHz appears at the amplifier output, i.e. at the terminals of the transmitting transducer. This signal is rectified by D1 and D2 and filtered by C3 and, if its amplitude is high enough, it produces a current in R6 capable of turning transistor T3 on to a greater or lesser extent.

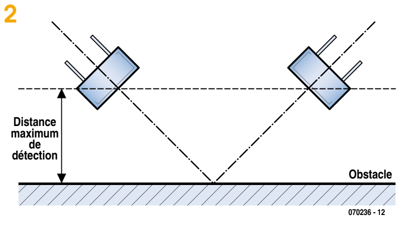
Depending on the nature and distance of the obstacle, this process does not necessarily happen in a completely on/off manner, and so the level available at T3 collector may be quite poorly-defined. The Schmitt CMOS invertors are there to convert it into a logic signal worthy of the name. So in the presence of an obstacle, S1 goes high and S2 goes low.

Powering can be from any voltage between 5 and 12 V. The gain, and hence the circuit's detection sensitivity, does vary a bit with the supply voltage, but in all cases P1 makes it possible to achieve a satisfactory setting.

Although it is very simple, under good conditions this circuit is capable of detecting a normally-ultrasound-reflective obstacle up to around 5 or 6 cm away. If a smaller distance is needed, you simply have to reduce the gain by adjusting P1.

Building the circuit is straightforward. Both transducers are 40 kHz types that can be found in any retailers, and the other components couldn't be more ordinary. However, one precaution is needed when wiring up the transducers. Even though they aren't strictly speaking polarised as such, one of their terminals is common with the metal case, and this is the one that must be connected to the circuit earth, on both emitter and receiver.

2



The circuit should work at once, and all you have to do is adjust P1 to set the detection distance you want — but this is also dependent on the positioning of the transducers. For optimum operation, we recommend you angle them as shown in **Figure 2**.

(070236-I)

Light Sensing with an LED

Andreas Grün

Many robotic applications require a sensor to measure light levels. The conventional approach as shown in **Figure 1** uses an A/D converter to measure the voltage drop across resistor R1 produced by the photo current through a photo transistor. The fixed value of R1 limits the light range which can be measured; a high resistor value is suitable for measuring low light levels while a low resistance is good in bright conditions. The resolution of the A/D converter also plays a part in determining the range of light levels that can be measured.

A little-used property of a standard LED is its reverse-biased photocurrent mode. An LED also produces a light-induced photocurrent but at a much reduced value compared to a photo-transistor. Direct measurement of the current is not so easy but another property of the diode can be exploited which is described in [1]. In this paper it explains that a useful property of a reverse-biased LED is its relatively large capacitance, the technique is to charge up this capacitor and then allow the photocurrent to discharge it. The time taken for the capacitor to discharge is dependant on the amount of light falling on the LED (**Figure 2**). Charging and time measurement can be easily performed using a single I/O pin of a microcontroller and switching it between output mode and high-impedance input mode. The measurement is performed in two stages:

1. The pin is configured as an output and set to high to charge up the LED capacitance (**Figure 3**).
2. The pin is configured as an input Pin (any pull-up resistor is disconnected) and the time is measured until the input voltage level falls below the lower input threshold level (**Figure 4**).

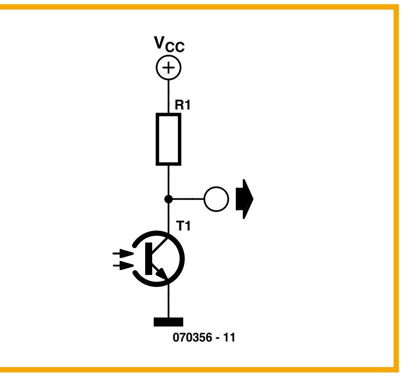
The **Example program** is a listing for an Atmel AVR processor which measures light intensity. The program toggles all the output bits from port A after each cycle so that it produces an output square wave with approximately 50 % duty cycle at a frequency proportional to the measured illumination. The frequency varies from millihertz (in a darkened room) up to several hundred kilohertz when light shines directly onto the LED. This measurement range would be difficult to achieve using an A/D converter. Narrow beam LEDs have a corresponding narrow 'detection angle' making them more directional which may be beneficial in some applications. Different LEDs are sensitive to specific colours which can also be useful in some robotic applications.

(070356-I)

Web link

(1) www.merl.com/publications/TR2003-035/

1



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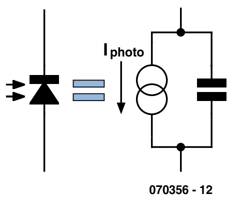

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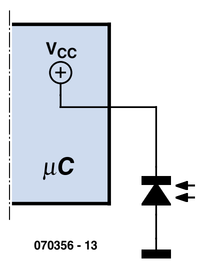

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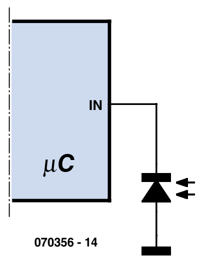


Listing Example program:

```
#include <avr/io.h>
#include <avr/interrupt.h>

#define LEDPIN 0x40    // LED on PB6

int main()
{
  unsigned char cr=0,cb=0;
  DDRB = 0x00;          // PORTB input
  DDRA = 0xff;          // PORTA output for display LEDs
  PORTA = 0;            // off
  PORTB = LEDPIN;       // PB6 hi

  sei();

  while(1)
  {
    if((PINB & LEDPIN) == 0)   // discharge complete
      {
        PORTB = LEDPIN;   // PB6 hi

                          // multiple times
   to get enough charging time
        DDRB |= LEDPIN;   // PB6 output and hi, charges LED
        DDRB |= LEDPIN;   // PB6 output and hi, charges LED
        DDRB |= LEDPIN;   // PB6 output and hi, charges LED
        DDRB |= LEDPIN;   // PB6 output and hi, charges LED

        DDRB &= ~LEDPIN; // PB6 input, still charging w/ pullup
        PORTB = 0;        // switch off pullup
        PORTA ^= LEDPIN; // toggle PORTA for display LEDs
      }
  }

  return(0);
}
```

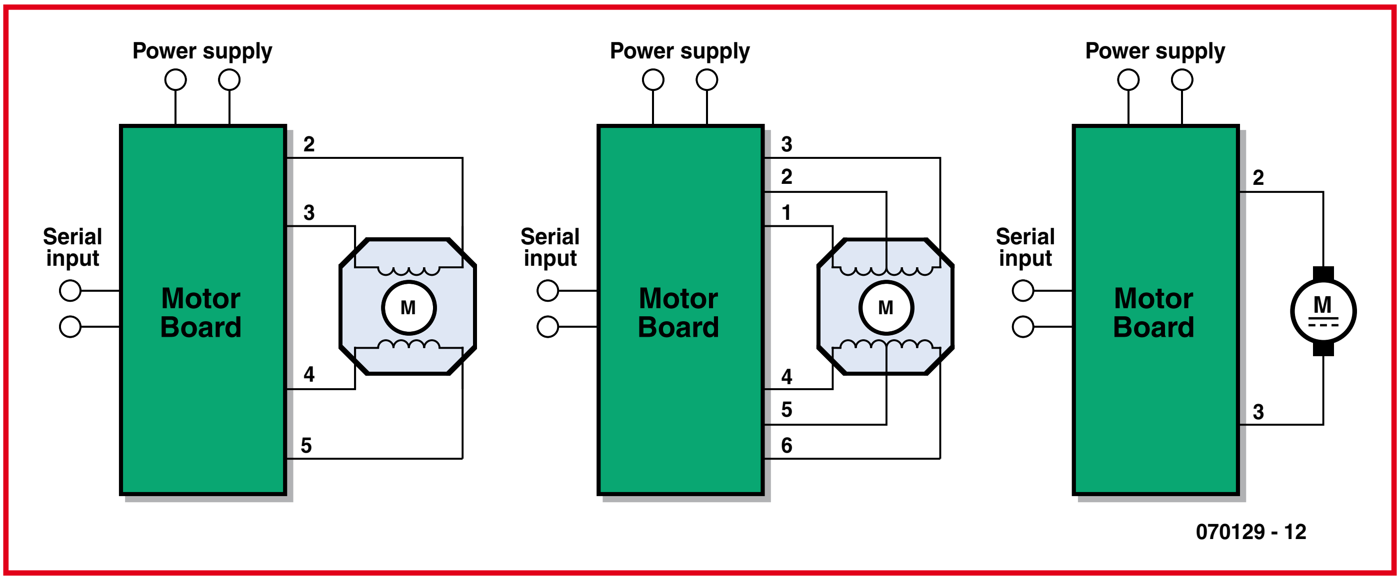


Figure 3. How to connect up your motors.

off switching of DC motors will cause large current spikes, which may cause the controller to shut down the particular motor driver. You can disable the current monitoring but this is not recommended. Overcurrent can cause the L298 to overheat and get destroyed. A 'RESUME' command has to be sent after the motor driver has been switched off to resume motor operations. A grace period is given to enable another command to be sent and try to get the motor unstuck from its current position.

Software

The source code and hex code for the PIC16F628A is available as a free download from the Elektor Electronics website. The file number is **070129-11.zip** (July/August 2007).

(070129-I)

Author's websites and email address

http://telecomms.no-ip.org

www.mcast.edu.mt

jozamm@gmail.com

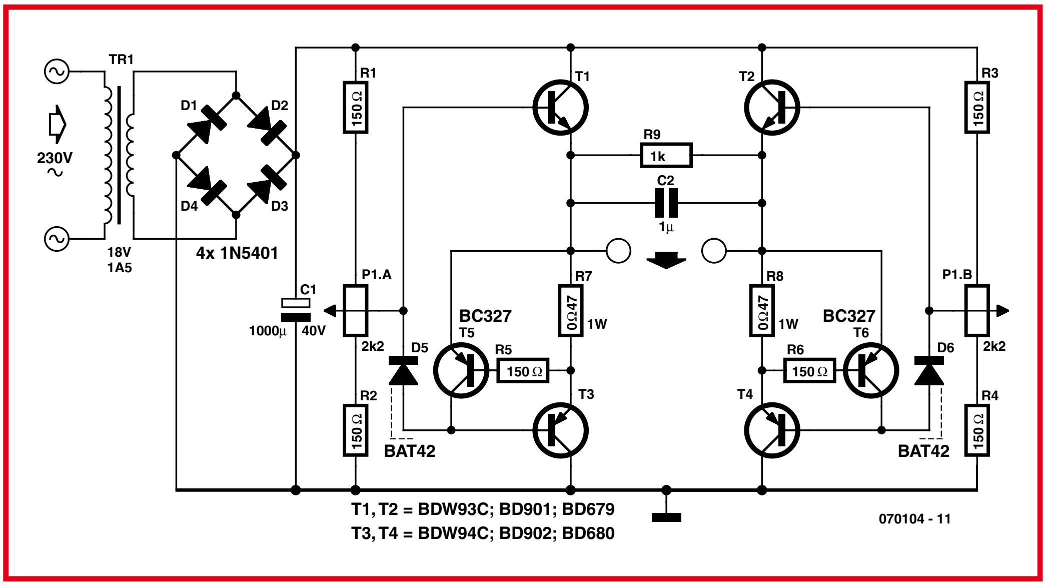
Web links

www.microchip.com

www.st.com/stonline/products/literature/ds/1773.pdf

12 V Bidirectional Motor Control

Stefan Brandstetter



This simple circuit drives DC motors with a maximum current of 1 A and can be built with readily available components. The output voltage is adjustable between 0 and 14 V and the polarity can be changed so that not only motor speed but also rotation direction can be adjusted by turning a knob. The circuit is also ideal as a controller for a DC model railway or small low-voltage hobby tool.

Power for the circuit is supplied by a 18 V mains transformer rated at 1.5 A. Diodes D1to D4 rectify the supply and capacitor C1 provides smoothing to give a DC output voltage of around 24 V. A classic 'H' bridge configuration is made up with transistors T1/T3 and T2/T4. Transistors T5 and T6 together with resistors R7 and R8 provide the current sense and limiting mechanism. The maximum output current limit can be changed from 1 A by using different value resistors for R7 and R8:

$I_{OUT} = 0.6\,V / R$

where R gives the value for R7 and R8. For increased current limit the mains transformer and diodes will need to be changed to cope with the extra current as well as the four transistors used in the bridge configuration. Motor speed control and direction is controlled by a twin-ganged linear pot (P1). The two tracks of P1 together with R1/R2 and R3/R4 form two adjustable potential divider networks. Wiring to the track ends are reversed so that as the pot is turned the output voltage of one potential divider increases while the other decreases and vice versa. In the midway position both dividers are at the same voltage so there is no potential difference and the motor is stationary. As the pot is rotated the potential difference across the motor increases and it runs faster. The voltage drop across D5 and D6 is equal to the forward voltage drop VBE of the bridge transistors and ensures that the motor does not oscillate in the off position with the pot at its mid point.

(070104-I)

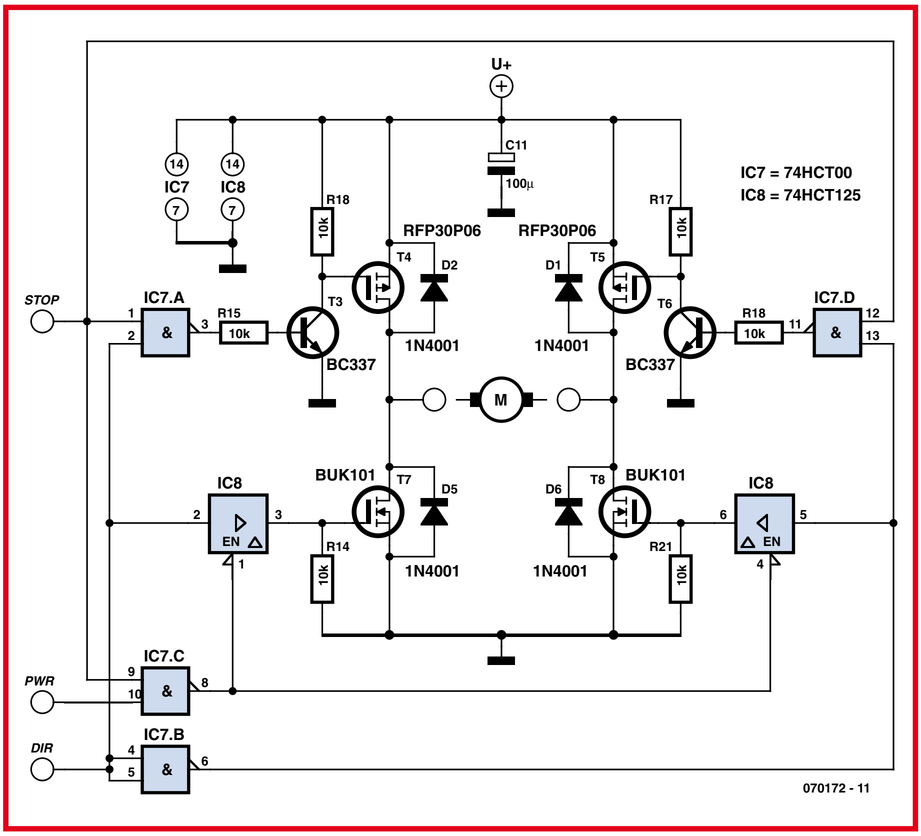
zBot: 10-A Power Stage for DC Motor

Jens Altenburg

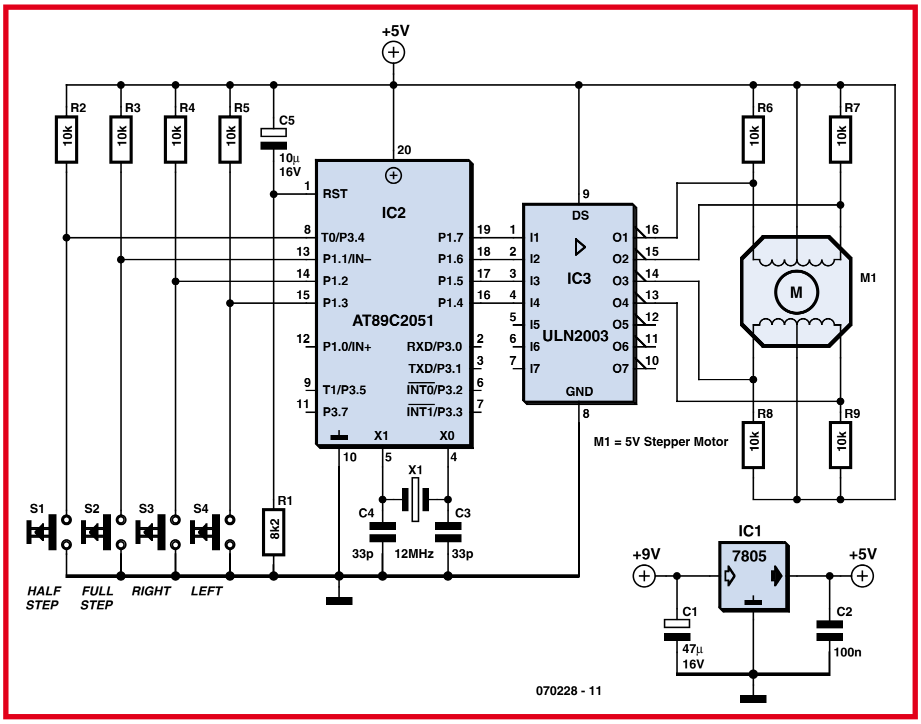
If you look at the chassis of the zBot vehicle[1], you'll find two parts requiring intelligent control: the steering servo and the DC motor.
The so called H-bridge is the normal circuit for electronic control of revolution speed and direction. The DC motor of a Tamiya car is powerful enough to propel zBot at up to 20 miles per hour. The motor then consumes more than 10 A, so we choose high-current power MOSFETs for the driver stage. There are lots of different devices to choose from.
The MOSFET we require has to supply the maximum motor current and, importantly, it has to be switched with gate voltages of about 5 V. In this case, the microcontroller switches the power stage ('low side') directly. For high side driving level shifters are necessary.
The schematic of the H-bridge power stage shows a few inverters, NAND gates and two tri-stateable drivers. These logic functions are very important as the easier way, i.e.., directly controlling all four MOSFET has a fatal disadvantage. In case of a software crash it could happen that two ore more MOSFETs are switched on incorrectly, for example, T4 and T7. In that case, the current through the transistors is limited by the internal resistors of the MOSFETs (about 10 mΩ) only. Such a fatal error would destroy the MOSFETs. The logic functions configured here effectively avoid illegal states.
To control the DC motor, three signals are needed: DIR, PWM and STOP. DIR controls the direction of the motor revolution, PWM the speed, and STOP brakes the motor.
The software module for the DC motor is called `dcm.c`.

(070172-I)

(1) The complete document called Zbot — the Robot Experimental Platform is available for free downloading from the Elektor Electronics website. The file number is 070172-11.zip (July/August 2007).



Complete Stepper Motor Driver



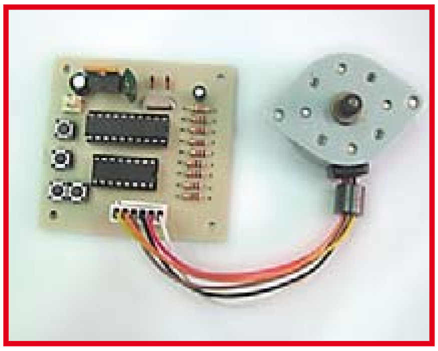


Table 1

Step angle (degrees)	Steps per revolution
0.72	500
1.8	200
2.0	180
2.5	144
5.0	72
7.5	48
15	24

Hesam Moshiri

With this circuit you can make a stepper motor do just about anything it will need to do in robotics application: rotation to the left or right, in full-step or half-step mode.

Stepper motors convert electrical pulses into mechanical movement. In applications like hard disks, printers and photocopiers (to mention but a few), stepper motors are used for rotation and/or accurate position control of mechanical assemblies. Every stepper motor has one permanently magnetic axle called the *rotor*. This is surrounded by a fixed part called the *stator*. Usually, stepper motors have four stator wires with two or one common wire, which is normally connected to the positive supply voltage.

By applying a controlled sequence of pulses to the individual stator windings, the rotor will start to rotate. Stepper motors may differ in size, shape, power, supply voltage, cost, accuracy, and so on, but importantly in the number of steps that make up one complete spindle revolution. This property also determined the step angle as shown in **Table 1**.

For example for a motor specified as having a 1.8-degree angle, 360 / 1.8 = 200 pulses for a complete spindle revolution.

Two pulsing schemes are available to drive the motor: 'full-step' or 'half-step'. The two modes are summarized in **Table 2** and **Table 3** respectively.

Applying half-step pulses to the motor will increase the accuracy at which the spin-

Table 2. Full-step mode.

Rotation to the right (cw)	Step	Winding A	Winding B	Winding C	Winding D	Rotation to the left (ccw)
↓	1	1	0	0	0	↑
	2	0	1	0	0	
	3	0	0	1	0	
	4	0	0	0	1	

Table 3. Half-step mode.

Rotation to the right (cw)	Step	Winding A	Winding B	Winding C	Winding D	Rotation to the left (ccw)
↓	1	1	0	0	0	↑
	2	1	1	0	0	
	3	0	1	0	0	
	4	0	1	1	0	
	5	0	0	1	0	
	6	0	0	1	1	
	7	0	0	0	1	
	8	1	0	0	1	

dle can be turned. In the case of our 1.8-degree angle motor, half-step driving then requires 400 steps per revolution.
Another important advantage of half-step pulsing is more motor power, which usually translates in more torque.
The circuit of the motor driver is designed around an Atmel microcontroller type AT89C2051 ticking at 12 MHz and one high voltage/high current Darlington transistor array type ULN2003.
The motor drive pulses generated by the microcontroller under firmware control are fed to the ULN2003 via four port lines P1.4 through P1.7. The motor's stator windings are connected to the corresponding output pins on the ULN2003. The ULN2003 can supply up to 500 mA on each output pin. Note that a 5-V stepper motor is used in this circuit.
The source code file and the firmware (hex file) for the AT89 micro may be downloaded free of charge from the Elektor website as archive # **070228-11.zip**.
After constructing your circuit, power it up. Press the Full Step or Half Step button. Then press Left or Right and you will see your motor start to rotate using the mode selected. You can change between full and half step at any time.
All this is based on the assumption that you have wired up your motor correctly.
The AT89 source code contains a number of directions to help you 'change wires' in software rather than by soldering and getting confused by the different wire colours.

In practice, you will notice that full-step mode yields higher spindle speed with low motor torque, whereas half-step mode is good for increased torque and accuracy, at the cost of speed. That is why stepper motors powering wheels etc. are controlled such that they start and end their operation in half-step mode, with full step mode in between to achieve maximum speed.

(070228-I)

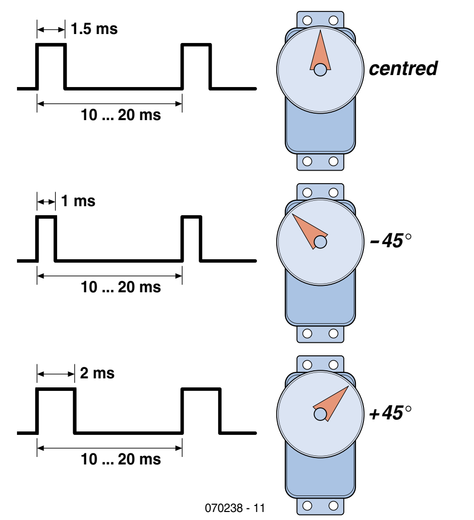
Controlling Servos

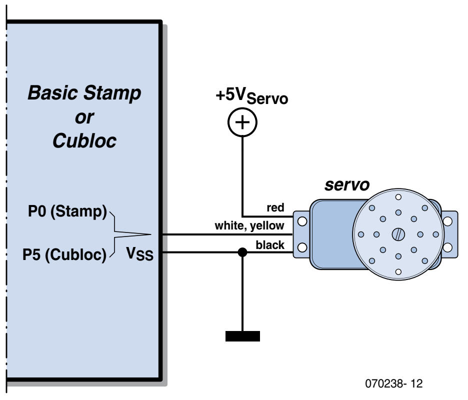
Using a PIC programmed in Basic, a Basic Stamp or a Cubloc

C. Tavernier

Through robotics, radio-control servos are currently experiencing a new lease of life, thanks to their characteristics, which although not originally designed for such applications, turn out in fact to be well suited to it.
Current radio-control servos are very compact, bearing in mind they contain not only their own mechanism, but also dedicated drive electronics, which only need simple TTL or CMOS logic signals as an input. The power they are able to supply can be quite considerable, for the most powerful of them (originally intended for 'large' model planes or boats); and lastly, they are usually supplied with a host of accessories such as crank arms, perforated wheels, etc., making it easier to interface them with the elements to be operated.
There are currently two fundamental ways of using a servo in a robot. The first, described elsewhere in this issue, consists of converting the servo into a propulsion motor, which admittedly is rather taking it away from its original function. The second, which we're going to be looking at here, involves its use for positioning. Whether in an arm, or to turn a platform carrying a camera, a telemeter, or any other unit, our servo is ideal for this.

We won't insult you by telling you what a servo is like, since even if you aren't a radio-control enthusiast, you're bound to have come across them before. However, here are just a few pieces of information that it's important to be aware of so as to be able to make use of them.

1


2


In electrical terms, a servo has just three colour-coded wires. The red and black wires are for powering it, at between 4.8 and 6 V. The third wire, yellow or white (or in practice any colour other than red or black), is used to convey commands to the servo in the form of pulse-width-modulated (PWM) signals.
Figure 1 illustrates both the coding principle of these pulses and the effect they have on the position of the servo. Note first of all that they must be repeated at such a rate that there is not more than 10–20 ms separation between two successive pulses.
In theory, this repetition is not absolutely vital; but with it, the servo will be able to maintain the position set by the width of the pulses received. If the pulses do not repeat, the servo will indeed go to the position dictated by the last pulse received, but, as soon as that stops, the slightest force on its shaft will cause it to lose the position attained.

Notice from the figure:
- a 1.5-ms pulse places the servo in its position referred to as centred or rest;
- a 1-ms pulse makes the servo turn to its maximum anti-clockwise position, which usually represents an angle of 45° with respect to its rest position;
- a 2-ms pulse makes the servo turn to its maximum clockwise position, which too usually represents an angle of 45° with respect to its rest position.

Intermediate positions can be obtained by varying the pulse width between 1 ms and 2 ms. For use in robotics, it is even possible to go further and apply pulses a little shorter than 1 ms or a little longer than 2 ms to the servo, thereby achieving a total angle of rotation of 180°. But watch out! At this point, we have gone outside the specifications for the servo, which is in danger of jamming in these extreme positions, destroying its motor, its electronics — or if you're lucky, both at once!

Connecting a servo to a microcontroller (Basic Stamp, PIC, Cubloc) is very simple, as shown in **Figure 2**. The only point to watch out for is the servo power supply. Given the relatively high current drawn by the servo when it turns, it's best to supply it off a separate voltage rail from the microcontroller. Where this is not possible, you need to ensure excellent decoupling between them — for example, by supplying the servo and the microcontroller via two separate regulators.
As far as the software is concerned, controlling a servo using a Basic Stamp or a PIC programmed in Basic requires only a very few lines of program. In fact, all that's needed is to call up the two instructions PULSOUT and PAUSE.
Here, by way of an example, is a program that makes a servo turn slowly from its extreme position on one side to its extreme position on the other side, and so on. In this way it can, for example, move a sensor in one plane over a total amplitude of 90°, see **Listing 1**.
The instruction PULSOUT generates pulses with a variable duration from 100 × 10 μs to 200 × 10 μs depending on the changing value of the loop variable b2, while the spacing between these pulses is set at 15 ms by means of the instruction PAUSE. This program is written here in Basic Stamp I language, but transposing it for Basic Stamp II or for use with a PIC programmed in Basic only requires modification of the end values and the loop variable b2 increment. The resolution of the instruction PULSOUT is now 2 μs instead of 10 μs, so the various values need to be multiplied by 5.
Using a servo with a Cubloc from Comfile Technology is just as simple, but uses an instruction called PWM, as per **Listing 2**.
In this type of application, the advantage of the Cubloc over the Basic Stamp is that the PWM command generates the pulses indefinitely, even if the program continues on to something else. In the case of the Basic Stamp, the instruction PULSOUT generates only one pulse, and so has to be called from a loop in order to produce them continuously, preventing the Basic Stamp from doing anything else. If you don't want to use a Cubloc, another solution consists in using a specialized IC, like the MIC 800 from Mictronics (www.mictronics.com), which can control up to 8 servos simultaneously in a stand-alone manner (if necessary, refer to the Elektor Summer Circuits edition 2006).

(070238-I)

Listing 1

```
 ' Basic Stamp I and II or in
Basic programmed PIC version

loop:
        for b2 = 100 to 200
                for b3 = 1 to 5
                        pulsout
0,b2  ' servo connected to port P0
                        pause 15
                next
        next
goto loop
```

Listing 2

```
 ' Cubloc Version

Const Device = CB220
Dim Position As Integer
Low 5
' Servo is connected to port P5
Do
        For Position = 2300 to
Position = 4300 Step 20
        Pwm 0, Position, 32768
                Delay 100
        Next
Loop
```

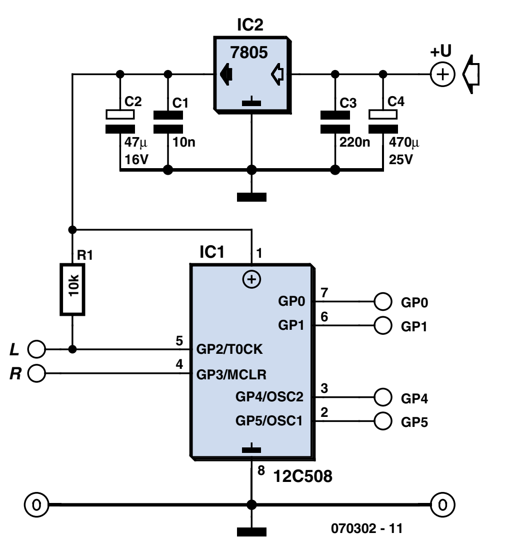
PIC12C508 Stepper Motor Controller

C. Tavernier

www.tavernier-c.com

When we're not using a stepper motor to ensure precise positioning of a robot element, it can be used as a traction motor, in place of the standard modified servos presented elsewhere in this issue. Under these conditions, there's no longer any need to 'count the steps' the motor has to make, as all we want is to make it rotate continuously in one direction or the other.
Several solutions are open to us for driving the motor, a number of which are presented in this issue: using a specialized stepper motor driver IC, using one or more suitably-programmed microcontroller parallel ports, or building a driver based around conventional logic ICs.

1

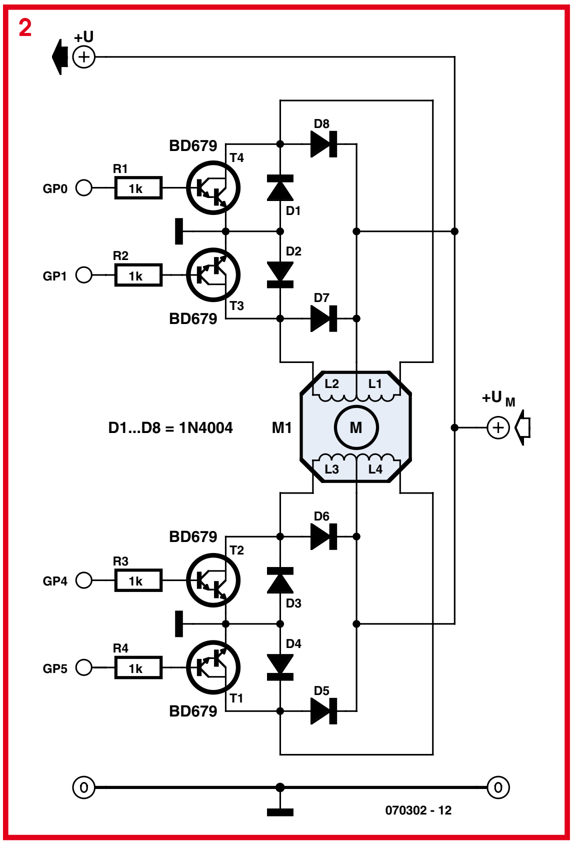


However, these solutions are far from satisfactory when using a stepper motor for traction. They all require pulses to be generated continuously for as long as we want the motor to run, either requiring an additional programmable oscillator, or using up resources from the robot's main microcontroller.
So we've decided to suggest another approach with this stepper motor driver specifically designed for making the motor turn in one direction or another, under the control of a simple logic level. And as the propulsion motors in robots usually go in pairs, we're even going to offer a dual driver, by diverting a very common and inexpensive IC from its original function.
Since a stepper motor used for propulsion doesn't need to be accurate

in terms of positioning, and hence, in the precision of the steps, simple single-pole models are eminently suitable. So, our circuit is designed for motors of this type.

This lets us control the motor via two TTL- or CMOS-compatible logic inputs. When these two inputs, labelled L and R, are logic high or floating (they have their own pull-up resistors), the motor stays still, but in braked mode, since it’s a stepper motor. When the L input is taken to logic low, the motor rotates in one direction (arbitrarily, to the left, whence the label L) while if the R input is taken low, it turns the other way. If both inputs are taken to ground at the same time, the R input has priority, and so the motor turns in that direction.

The motor’s speed of rotation is fixed, but, since we are giving you the source listing of the software used for this application, it’s very easy for you to modify this if it doesn’t suit you, or indeed even to include the possibility of external adjustment if necessary.



The circuit of the ‘intelligent’ part of our controller is shown in **Figure 1,** as you can see it uses a PIC12C508 microcontroller from Microchip. Used here in internal clock and reset circuit mode, it needs no external components for these functions, so all its port lines are available.

Parallel ports GP2 and GP3 are used as inputs, and as GP2 does not have an internal pull-up resistor, this is performed by R1. Parallel ports GP0, GP1, GP4, and GP5 are used as outputs for generating the pulses for the motor windings. These can be amplified by two types of power stages, depending on the type and number of motors to be driven; we’ll take a look at those circuits in a moment.

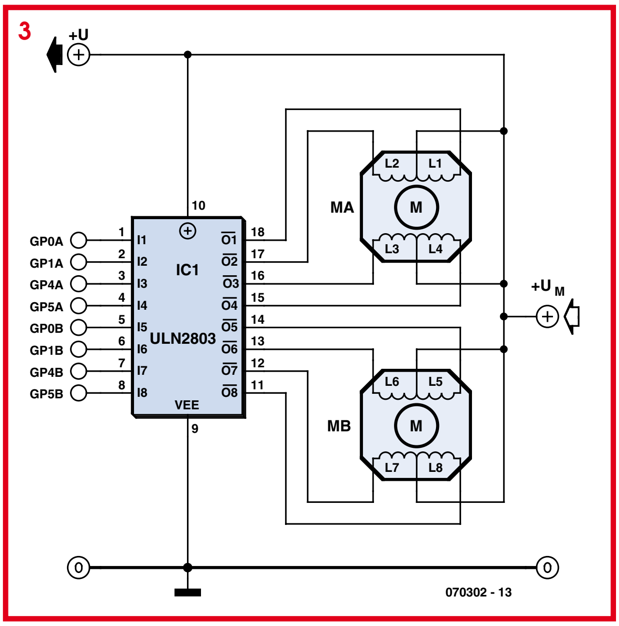
Table 1. Programming step duration by modifying a constant used in the program.

Binary Step constant	duration
10010010	1 ms
10010011	2 ms
10010100	4 ms
10010101	8 ms
10010110	16 ms
10010111	32 ms

The 12C508 needs to be powered from 5 V, derived from the motor supply by means of a conventional 3-terminal voltage regulator IC2.

If the controller is only intended for a single motor, or if the motor to be driven draws more than 500 mA per winding, the power stage shown in **Figure 2** can be used. It employs conventional bipolar transistors that, given their characteristics, are able to switch currents of 3 A. Diodes D1–D8 clip the spurious spikes generated by the abrupt switching of the current in the motor windings and protect the transistors.

However, if the motor used draws less than 500 mA, and more importantly, if you need to drive two motors of this type, an elegant and ingenious solution exists, as shown in **Figure 3**. This uses a standard ULN2803, usually used to drive relays, but which includes eight medium-power Darlingtons along with their protection diodes. So, this IC is able to properly drive any kind of single-pole stepper motor, as long as the voltage required doesn’t exceed 50 V and the current per winding is under 500 mA.



In addition, as the ULN2803 contains eight identical stages, it can be preceded by two controllers like the one in Figure 1 and in this way drive two robot propulsion motors: one on the left and one on the right, marked MA and MB in this figure.

Constructing one or other of these versions is very straightforward. The PIC 12C508 needs to be programmed with the file that you’ll find in object form, as well as in source form, in case you’d like to modify it, on the Elektor website, as well as on the author’s own site (www.tavernier-c.com).

If you build the transistor power amplifier, note that T1–T4 don’t need a heatsink as long as the motor consumption doesn’t exceed 1 A. Otherwise, bolt them onto a small aluminium plate a few cm². To simplify mechanical construction, it can be common to the four transistors, but in this case you’ll need to use the standard insulating accessories of mica washers and shouldered washers, as the collectors of these transistors are connected to the metal parts of their cases.

If you construct the ULN2803-based version, there are no special precautions to be observed, other than to not exceed the IC’s maximum current capacity of 500 mA.

As we are providing you with the full source listing of the software programmed into the 12C508, you’ll be able to modify it to suit your needs. If you are unfamiliar with PIC microcontroller assembler, here are the details you’ll need for the most important modification you might want to make: changing the speed of the control pulses to the motors, and thus, their speed of rotation. The control word may be found in **Table 1**.

To do this, all you have to do is modify the binary constant on the line:

```
MOVLW B’10010101’
```

just above the line containing OPTION in the source listing. With the original value, the duration of one step is 8 ms, but the table above indicates what constant to use according to the step duration that you may want.

(070302-I)

3 Amp PWM DC Motor Controller

Rajkumar Sharma

This circuit is intended for motion control applications, a common occurrence in robotics! This affordable PWM DC Motor controller can control any PMDC motor specified at 12 V to 30 V and 3 Amps max. Motor direction is controlled with a slide switch and motor speed, with an ordinary potentiometer.

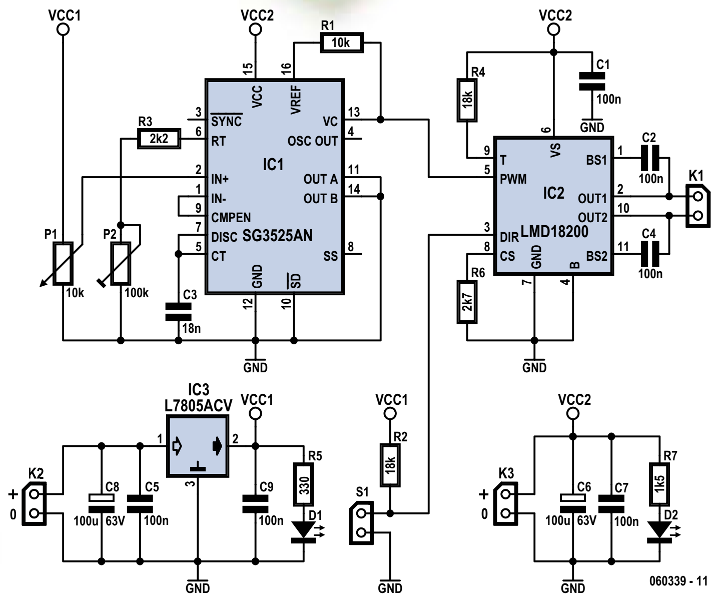
The circuit diagram in **Figure 1** shows ICs type LMD18200 and SG3525 at the heart of the circuit. The SG3525 is a pulsewidth modulator control circuit and the LMD18200, an H-Bridge to enable the motor to be run in both directions.

The SG3525 affords frequency control and duty cycle control. The oscillator frequency is determined by the components attached to pins 5 and 6. Preset P2 serves to adjust the frequency between 1.16 kHz and 35 kHz. Although it is generally recommended to stay above 20 kHz as otherwise the motor will produce audible sound, in some cases that's just not possible depending on the motor you're using. Pot P1 determines the duty cycle, which can be adjusted from 10% to 100% to effectively control the motor speed.' Internal transistors are used in a such a way as to obtain 100% duty cycle. The internal driver transistors are grounded by pins 11 and 14 for alternate oscillator cycles. Pin 16 of the IC is the REF V terminal, which gives 5 V out. Resistor R1 feeds the supply voltage to an internal open-collector transistor for TTL-level PWM output.

Moving on to the LMD18200, slide switch S1 (on header S1) governs the Direction control input (pin 3) to change the direction of the motor from cw to ccw or vice versa. R4 is connected to thermal flag pin T (pin 9), which is not used here. The function may be used to flag a warning when

Features

- Motor supply voltage 12 V to 30 V DC
- Delivers up to 3 amps continuous output
- PWM frequency adjustable from 1.16 kHz to 35.1 KHz
- PWM continuously adjustable by pot
- Duty cycle 0 to 100%
- Direction control by switch
- Shorted load protection
- Thermal shutdown
- No SMD components
- No microcontroller



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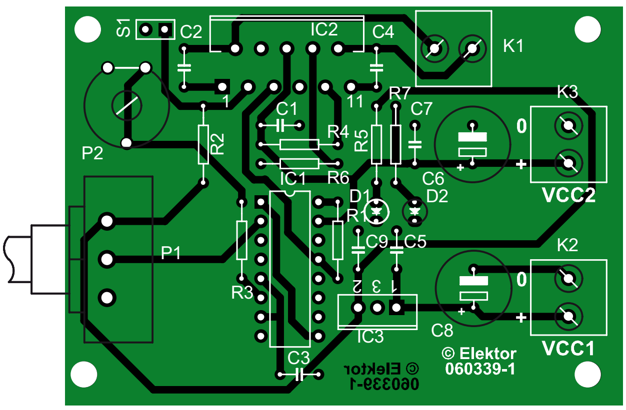


2

the chip temperature is 145 degrees. The IC is automatically shut down when 170 degrees C is reached. Pin 8 of the LMD18200 is the current sense input. R6 connects this pin to ground. The Brake input (pin 4) is hard wired to ground. C2 and C4 at the motor output are 'bootstrap' capacitors. Pins 2 and 10 are the H-Bridge outputs powering the DC motor.
In the power supply section, capacitors C5 through C9 serve to suppress noise on the two supply rails. The L7805ACV voltage regulator for the logic supply accepts any unstabilised DC voltage between 7.5 V to 18 V applied to K2. The other supply connector, K3, is for the motor power. The capacity of the motor supply of course depends on the motor used. If the motor is specified at 12 V then R7 should be 1 kΩ, and if it is 24 V then 1kΩ5 should be fitted. If you want to use a heavy-duty motor consuming more than about 1 A, it may be worthwhile to strengthen the copper tracks to/from K2/K3 with lengths of 1.5 mm² solid copper wire.

COMPONENTS LIST

Resistors

R1 = 10kΩ
R2,R4 = 18kΩ
R3 = 2kΩ2
R5 = 330Ω
R6 = 2kΩ7
R7 = 1kΩ5
P1 = 10kΩ potentiometer
P2 = 100kΩ preset

Capacitors

C1,C2,C4,C5,C7, C9, = 100nF
C3 = 18nF
C6,C8 = 100µF 63V

Semiconductors

D1,D2 = LED
IC1 = SG3525AN
IC2 = LMD18200
IC3 = L7805ACV

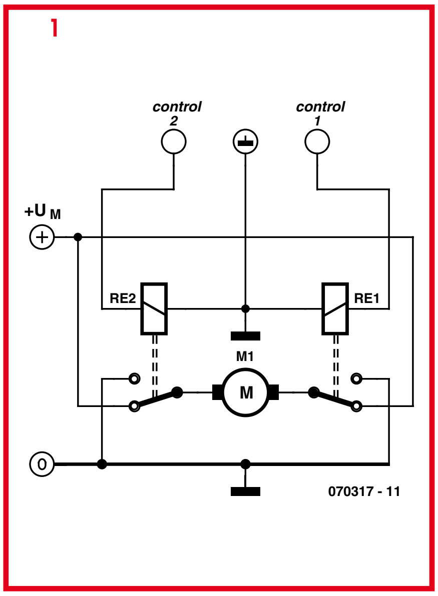
Miscellaneous

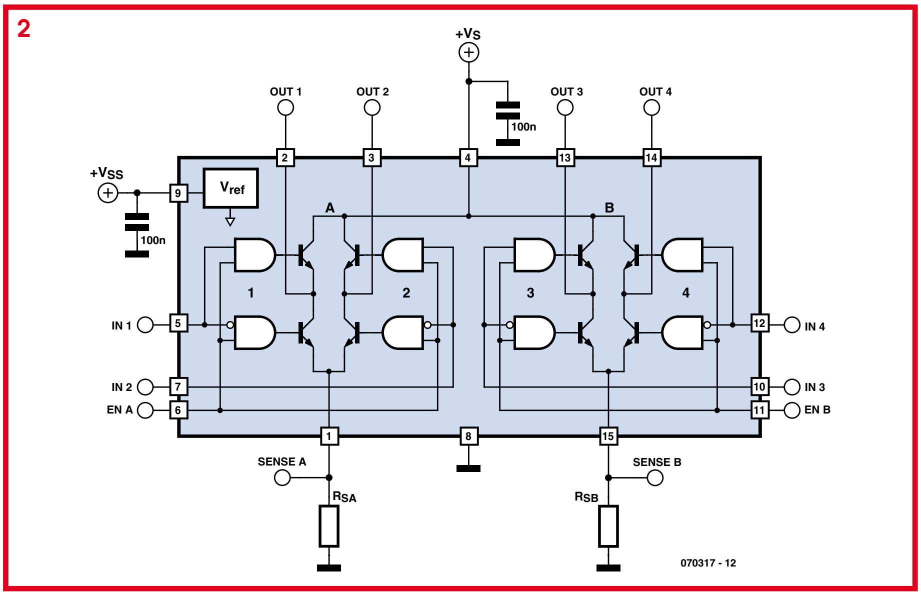
K1,K2,K3 = 2-way PCB terminal block, lead pitch 5mm
S1 = slide switch
PCB, ref. 060339-1 from www.thepcbshop.com

If you want to interface the driver with a source supplying 0-5 V, simply remove potentiometer P1 and apply the analogue voltage to pin 2 of IC.
Figure 2 shows the PCB designed for the driver, which should fit many applications at crucial locations in a robot. After all, most forms of motion of a robot will require a motor of some kind. The board has been designed for compactness whist using leaded components only, i.e., no SMDs in sight here. The copper track layout and component mounting plan are contained in free download no. **060339-1.zip** from our website.

(060339-I)

Driving Higher Power DC Motors

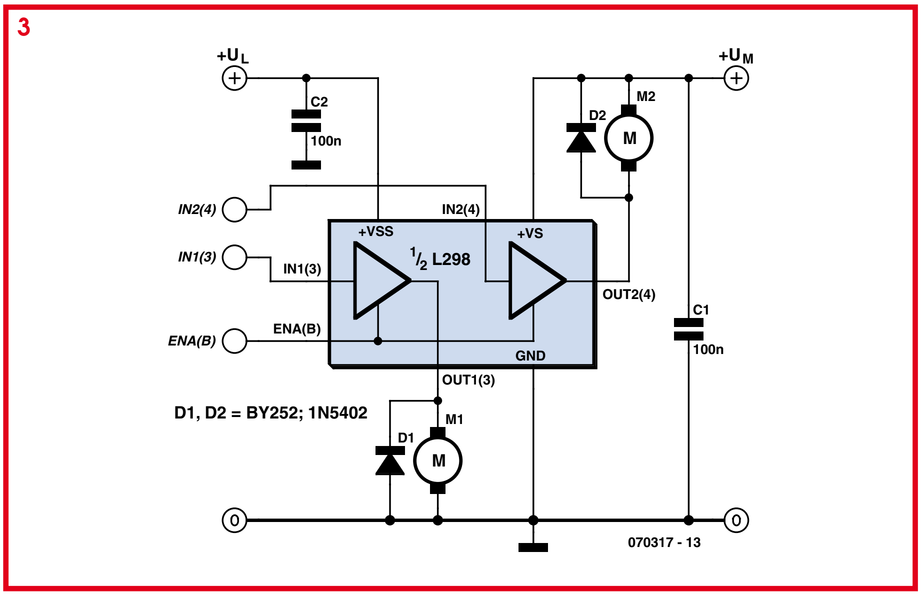




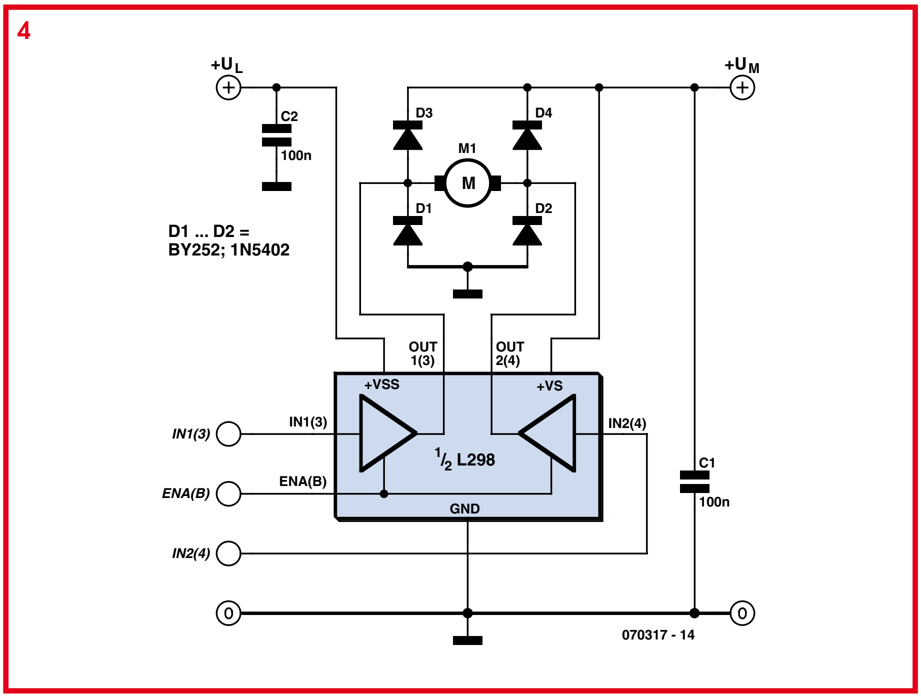
B. Broussas

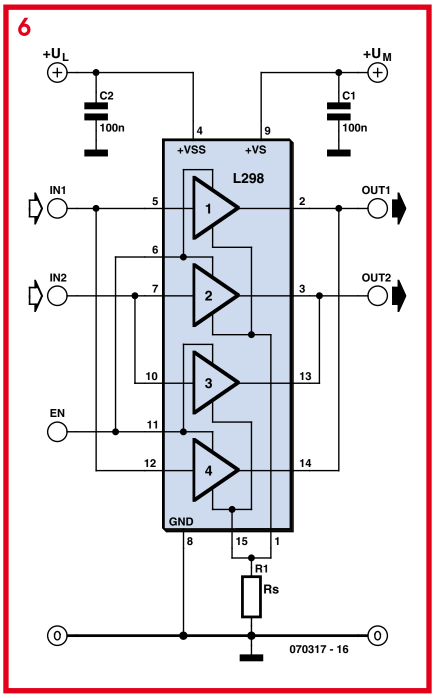
Driving the 'small' motors that may be used in robotics doesn't usually pose much of a problem. Servo motors actually have their own drive electronics, stepper motors can be easily driven by conventional power transistors or by ULN2803 ICs as has been shown elsewhere in this issue, as they rarely draw more than a few hundreds of mA. For small DC motors, simple transistors will suffice, unless you prefer for example the LB1630 from Sanyo, though limited alas to a current of 400 mA and a voltage of 6 V.
On the other hand, as soon as the motor starts drawing 1 A or more, or its supply voltage exceeds 20 V or so, the situation gets more complicated — all the more so because many of you don't much care for power electronics. So, this article hopes to give you a few ideas or research paths for driving such motors.

The first method for controlling a higher-power DC motor is none other than the good old relay, or to be precise, pair of relays. As long as you wire them as shown in **Figure 1**, you have control over the operating direction, depending on which relay is engaged and which is not, as well as a stop control that acts as a very effective electrical brake, when both relays are in the same position. In this situation, the motor is short-circuited and is braked by



its own back emf (electromotive force). Relays capable of switching 10 A and yet only requiring 5 V and a few tens of mA for their coils are commonplace nowadays (see for example the Finder relays) and so can be used in this way without difficulty.
If you don't like this electromechanical solution, we recommend you to use the bridge power IC, one worthy representative of which is the L298 from ST Microelectronics. As its internal block diagram shows (**Figure 2**), this IC includes four bridge power amplifiers, preceded by logic control circuitry. Originally designed for driving 'big' stepper motors, this IC is suitable for a host of other applications, of which here are a few examples.
By virtue of the relative independence of the amplifiers it contains, it can be used to drive four motors, as long as you are content with a single direction of rotation. It is then possible to take one of these motor connections to earth or to the supply rail, as indicated in **Figure 3**. By juggling with the combinations of logic levels on the control and enable inputs of the L298, you can even have two options for motor stopping, as indicated in the table below: the 'freewheel' or unbraked mode, or the braked mode, as seen previously with the relay circuit. **Table 1** shows the relevant logic level combinations.
If the direction of rotation of the motor has to be able to be changed, it is necessary to use a bridge or H connection, as shown in **Figure 4**. Note that it is possible to drive two motors in this way from one L298, since the IC contains four amplifiers. So, a single L298 is usually enough for the right and left propulsion motors of a mobile robot.
Although the circuit does have protection against overheating, be aware that you can increase its operating safety by monitoring the current drawn by the motors. To do this, all that you have to do is to fit a very low value resistor between the SENSE A or SENSE B inputs and earth. All the current drawn by the motor connected to the corresponding amplifier will then pass through this resistance, and by simply applying Ohm's law and measuring the voltage at these inputs, it is possible to monitor this current.
If you don't wish to use this monitoring, you





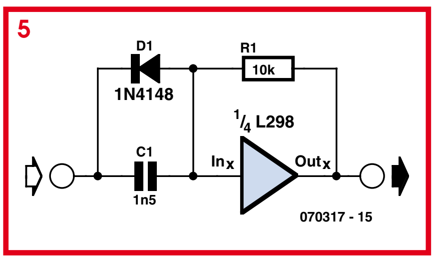


Table 1.

EnA(B)	In1(3)	In2(4)	M1	M2
H	H	H	Braked	Running
H	L	L	Running	Braked
L	X	X	Freewheel stop	Freewheel stop

are recommended to protect the IC against possible shorts of its outputs to earth, which are the most likely to occur in a robot (a motor terminal touching the metal chassis, for example!) In this case, STMicroelectronics recommends the circuit in **Figure 5**. This circuit trips in 10 µs and resets by itself when the short disappears.

The L298 is capable of withstanding a maximum supply voltage of 46 V and each of its power amplifiers can supply a current of 2 A, already a more than comfortable value, even for a relatively heavy mobile robot. If that isn't enough for you, it is also possible to connect the power amplifiers in parallel, as long as you go about it the right way. You then have a maximum output current of 3.5 A. To do this, you must adhere to the circuit in **Figure 6** and no other; that is to say, you must only parallel amplifiers 1 and 4 on the one hand, and 2 and 3 on the other.

Just before we reach the end of our article, do note that the L298 does not include built-in protection diodes, so it is vital to provide them externally as we have done in each of our figures, otherwise the L298 is guaranteed to be destroyed the first time the robot's wheels turn!

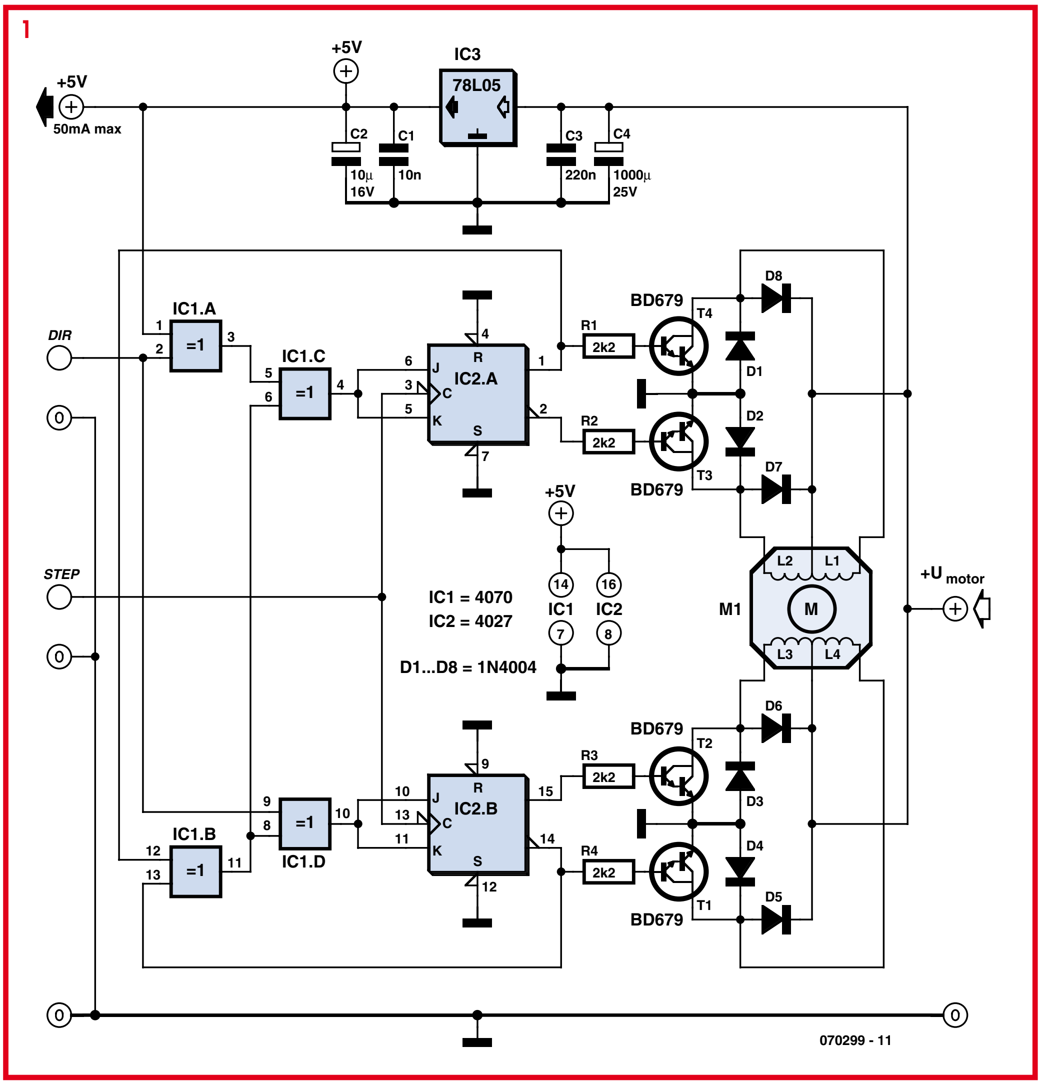
This IC is of course not the only one that can be used for driving higher-power DC motors for robotics applications. More recent and/or higher performance packages do currently exist. But the L298 does have the advantage of being readily available, inexpensive, and able to fulfil a wide range of needs, which to our mind more than justifies this presentation of its various modes of use. And if you are ever so slightly curious, you'll find copious application notes about it on the STMicroelectronics website (www.st.com), which will be a good source of additional ideas for implementing it.

(070317-I)

Driving Stepper Motors: KISS

Without using a specialised IC

B. Broussas



Used a great deal in robotics, where it is a direct competitor for DC motors and radio-control servos, the stepper motor does however suffer from the comparative difficulty encountered in driving it. Unlike its DC equivalents, which rotate as soon as power is applied, the stepper motor requires a succession of pulses applied to its various windings to make it turn. On the other hand, and provided its mechanical capacities are not exceeded, the number of basic steps moved by the motor corresponds to the number of pulses applied to its windings. Hence in this way we have available to us virtually automatic positioning information, impossible to obtain with a DC motor.

In many robots we've seen, driving the stepper motor(s) was the job of a specialized IC, one of the front-runners being the L293 from ST Microelectronics which, despite its age, is still very much current. Yet there are many other solutions, such as direct control by one of the ports of the microcontroller that runs the robot — or the one we are suggesting here, which just uses... two standard CMOS logic ICs!

As you maybe already know, there are actually two types of stepper motor: single-pole motors and 2-pole ones. While the first only need single pulses sent to their four windings, the latter require inversion of the signal polarity applied to the windings. So as not to complicate our circuit unduly, we have designed it for single-pole motors, the timing diagram for which is given in the table below.

Reading the columns of this table from 1 to 4 corresponds to rotation of the motor in one direction, while going from 4 to 1 reverses the direction of rotation. Each column of this table corresponds to one mechanical step of the motor. These steps vary from 1.8° to 7.5°, depending on the type of motor chosen.

So the circuit of our driver without specialized ICs, shown in **Figure 1**, is very simple, since its 'intelligence' is in fact confined to two logic ICs, IC1 and IC2, which are simple exclusive-OR (XOR) gates and a dual J-K flip-flop, while the power stage is built around perfectly ordinary general-purpose bipolar transistors.

The pulses to make the motor turn must be applied to the STEP input. Each pulse makes the motor turn through a single step in one direction or the other; this direction is determined of course by the state of the DIR input. This acts on exclusive-OR gates IC1a and IC1d, used here as programmable invertors.

Remember that an exclusive-OR gate can be regarded as a gate that inverts or not the signal from one of its inputs depending on the state of its other input. This is easy to see from the truth table in **Figure 2**. If input A is '0', the output is the same as the signal applied to input B (0 gives 0 and 1 gives 1). However, if input A is '1', the signal applied to input B appears inverted at the output (0 gives 1 and 1 gives 0). Nothing very new there, but we did want to underline this interpretation of the truth table of the exclusive-OR used as a programmable inverter, as we have noticed that many of you aren't familiar with it (or have forgotten!)

The truly active part of the circuit is formed by the two J-K flip-flops IC2A and IC2B. **Figure 2** sums up the truth table for these flip-flops, which is made simpler here because J and K are always both at the same level. When these inputs are '1', the flip-flops change state at each clock pulse, i.e. for each pulse applied to the STEP input. In the reverse situation, i.e. when J and K are both '0', the outputs Q and $\overline{Q}$ remain in the previous state.

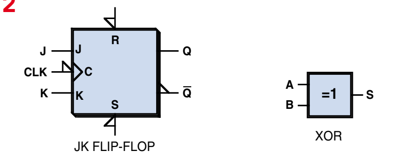
If you still have doubts that this will indeed generate the timings in the table above, arm yourself with some graph paper, a pencil, and some patience, and draw out the timing diagrams of the signals supplied, when DIR is at some arbitrary level of your choice.

The power stage is built using bipolar transistors, protected from the voltage spikes generated by the current switching in the motor windings by diodes D1–D8. With the transistors used, it is possible to switch currents of up to 3 A, allowing plenty of flexibility in the choice of stepper motor.

The logic side of the circuit is powered from a fixed 5 V supply, stabilized by IC3, making the STEP and DIR inputs TTL-compatible. This supply may also be used to power the circuit prior to this driver, as long as you don't exceed around 50 mA with the regulator chosen.

If your motor is powered at 6 V, it is advisable to replace IC3 by an LM2936Z5, for example, which is a low-volts-drop 5 V regulator. For correct operation, the 78L05 originally specified for IC3 requires almost 2 V between input and output — clearly impossible to obtain with a motor supply of only 6 V.

2



CLK	J	K	Qn	Qn + 1
↑	1	x	0	1
↑	X	0	1	1
↑	0	X	0	0
↑	X	1	1	0
↑	1	1	Qo	$\overline{Qo}$
↓	X	X	X	Qn

A	B	S
0	0	0
0	1	1
1	0	1
1	1	0

070299 - 12

Table

Step number	1	2	3	4
Winding 1	1	1	0	0
Winding 2	0	0	1	1
Winding 3	1	0	0	1
Winding 4	0	1	1	0

Still on the subject of the motor supply voltage, note that it can be up to 24 V if necessary. As long as the current drawn by the motor doesn't exceed 1 A, the transistors don't need a heatsink, but one is advisable above that. It need only be a few cm², since the transistors are operating here in switching mode and so dissipate relatively little power.

(070299-I)

Web Link

L293 spec. sheet

http://www.st.com/stonline/books/pdf/docs/1328.pdf

Robot Footballer

by Julian Straub

You will do doubt have seen pictures from 'RoboCup' showing robots booting footballs from one end of the pitch to the other. Building an electromechanical robot like this is entirely within the capability of the hobbyist with the help of a few cheap everyday items.

In order to give the ball a good kick the robot's feet are powered by linear solenoids. Acceleration is more important than force, however, and so we eschew readily-available solenoids which generally operate on 12 V or 24 V and which, although powerful, are much too slow for our purposes.

The integral of force over time (or impulse) produced by a coil with an iron armature depends, disregarding constant factors such as turns count, coil geometry and permeability, on the change in the coil current. The faster we wish to change the current, the higher the voltage we will have to use. And so we need a high voltage supply.

We can generate a high voltage using the flash from a disposable camera of the sort that can sometimes be had for free from photography shops. The camera electronics includes a high-voltage cascade circuit with a storage capacitor for the flash. These components are ideal for pressing into service as part

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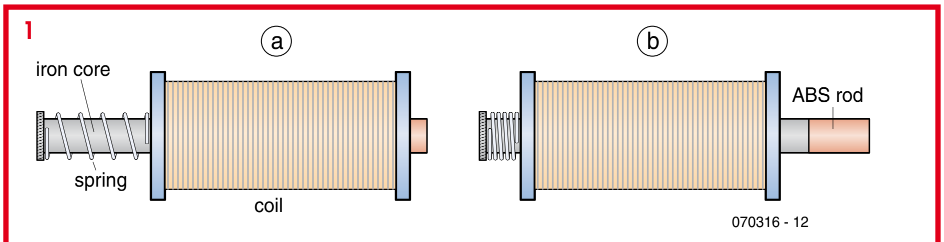
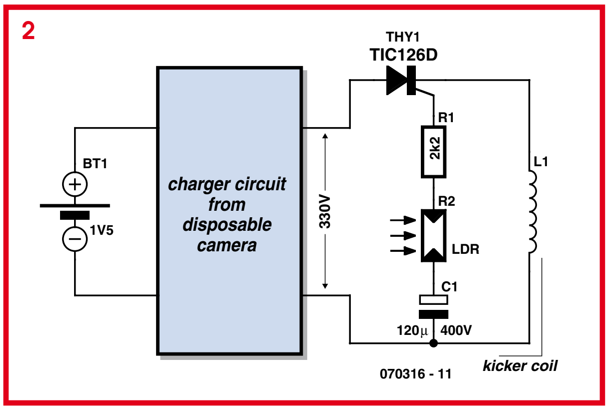


of a robotic footballer.

Open the camera carefully. First remove the battery making sure not to burn your finger by touching the capacitor contacts. For safety's sake discharge the capacitor using a resistor of a few kilo-ohms before removing the printed circuit board. Because we will later want the capacitor to be charged continuously, bridge the power supply switch connections. The circuit in the camera tested by the author (made by Kodak) charges a 120 µF high voltage capacitor to 330 V in 16 s from a 1.5 V battery.

Next we turn to the sewing box for inspiration. We need two cotton reels from which we will fashion inductors using enamelled copper wire. On the one hand it is advantageous to use wire that is very thin so that we can have as many turns as possible and hence a high inductance, while on the other hand the high ohmic resistance of this arrangement limits the maximum current that can be achieved; we need to find a good compromise. To simplify



making the windings with very fine wire, first wrap the coil former with a layer of thin double-sided adhesive tape. This will hold the wire in place as you wind the first layer. Use adhesive tape again after each successive layer of wire. Finally, wrap the finished coil in insulating tape so that just the two connection wires (with extra insulation) protrude.

The two iron cores can with a little luck be found in the clearance bin at an electronics shop. If not, you can resort to do-it-yourself: the cores can be ordered from any metal warehouse that can supply steel rounds. Ensure that you do not buy vanadium steel or a non-ferrous metal. The size should be chosen so that the lengths of metal pass through the cotton reels without too much play. In each drill a hole in one end and fit a small washer to prevent the light compression spring from sliding down. The spring ensures that after each kick (**Figure 1a**) the foot will return smartly to its initial position (**Figure 1b**). The cores are fitted into the coils and a plastic cylinder, which will be the part that actually makes contact with the ball, is attached to the free ends.

Figure 2 shows how simple the drive circuit can be. A type TIC126D thyristor wired between the high-voltage generator and the coil triggers the kick. The thyristor is in turn triggered optically via an LDR, which ensures isolation between the high voltage electronics and the control circuit.

(070316-I)

PIC Indicator Relay

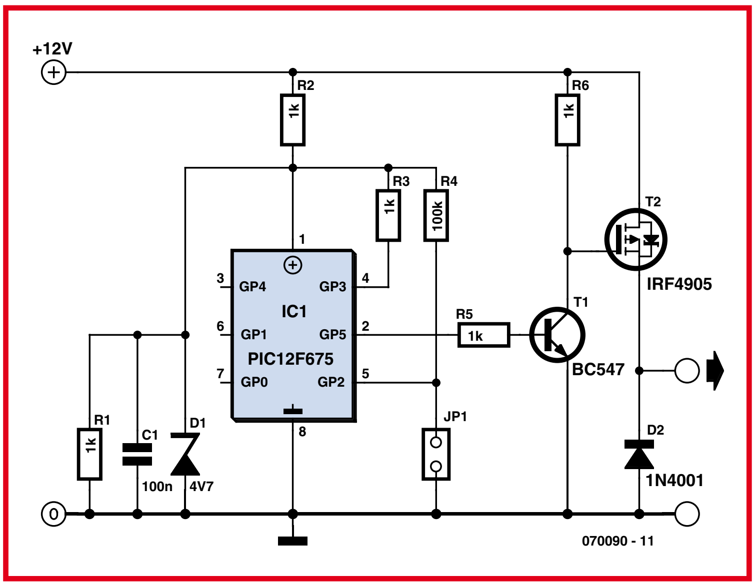
Herbert Musser

Members of the motorcycling fraternity will welcome this design. Some types of motor cycle are notorious for having very short life expectancy of their filament indicator lamps. Vibrations transmitted through the frame are the culprit (especially if the indicators are mounted on the ends of long stalks). After-sales replacement LED lighting clusters are far more reliable but they create another problem: they draw less current than the filament lamp and cause the indicator relay to switch the indicators on and off far too quickly.

The first attempt to solve the problem with an analogue electronic flasher circuit was not successful the first charge cycle of a capacitor was almost twice as long as successive periods, so the flash rate was not constant (maybe an integrator circuit would have given better results).

A better solution was produced using the mini PIC circuit and FET shown here. This design also has a built-in bonus feature; motorcyclists are notorious for forgetting to cancel their indicators so the circuit includes a time-out function (jumper selectable) which automatically cancels the indicator after 120 blink cycles.

The circuit uses very few components and the finished circuit can usually be fitted into the existing indicator relay housing with a space of around 20 mm x 30 mm. The output signal from the PIC controls the driver (T1) which then switches the HEXFET power transistor (T2). The IRF4905 has an extremely low on-resistance of just 20 mΩ and is capable of switching 74 A maximum. The supply (derived from indicator relay) is limited to 4.7 V by diode D1 and smoothed by C1 to reduce the effects of any interference from the motorcycle supply.



Firmware for this design applicable to the PIC controllers 12F629, 12F683 and 12F675 is available to download free of charge from the Elektor Electronics website, look for file # 070090-11.zip.

The finished circuit is reliable, impervious to vibrations, load current changes and best of all can be built for less than 7 pounds (approx. 10 euros).

As a final thought you should check that traffic regulations allow the use of such homemade designs to be fitted to the motorcycle before it is driven on the road.

(070090-I)

Catapult for Robots ...or Other Uses

Pascal Liégeois

In this age of laser rays, it seems anachronistic to talk of catapults — but it's not as absurd as you might think.
Many robot competition themes around the world have involved at some point picking up balls, of different formats according to the competition, and projecting them into a receptacle, often at quite substantial distances for our little robots.

There is one well-known type of very light ball, the ping-pong ball, that is very often used as a projectile in this type of competition.
Besides picking up these balls, projecting them often poses a problem of accuracy and reliability.
In this short article, the author is suggesting his own solution — not necessarily the best in the world, but at least it is proven.
This catapult re-arms all by itself after each shot, within 2 seconds, and it's range can be adjusted by altering the ballistic curve, using just a single potentiometer.
The very simple, cheap electronics don't require any programmable components, and have an output available to tell the carrier about the status of the catapult.

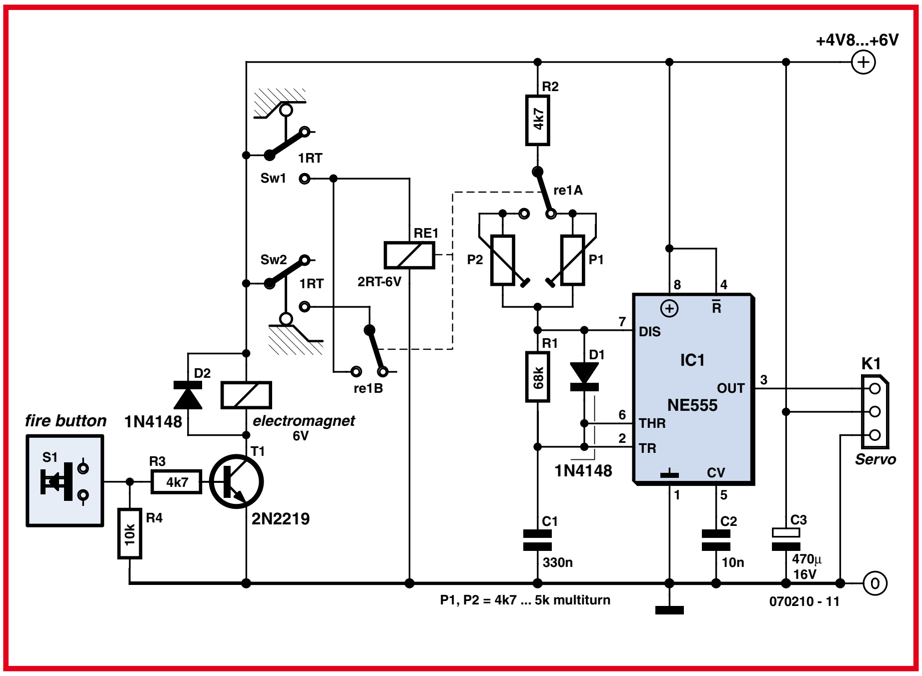


Figure 1. The catapult electronics.

Circuit

The main element of the system is a perfectly ordinary standard servomotor, as used in modelling. This type of actuator is a small marvel, containing as it does a position-servoed motor with step-down gearing, by way of a potentiometer and suitable electronics.
A servomotor is controlled using a fixed frequency signal (50 Hz) whose pulse width is variable, generally from 1 to 2 ms.
To produce this signal here, we use the famous NE555 (IC1) as an astable, wired in such a way as to provide the required frequency. Diode D1 in parallel with resistor R1 determine the duty cycle, and set the negative-going part of the pulse at around 18 ms. The width of the positive-going part is adjustable by means of R2 and P1 or P2.
The output of the 555 feeds the input to the servomotor.

The 'electromechanical' part of the circuit is based on the use of a DPDT relay and two microswitches. Sw1 is used to trigger automatic re-arming of the catapult, while Sw2 fulfils two functions: it gives information about catapult re-arming, and once this re-arming has taken place, it lets us reposition the servomotor in the firing position.

In the circuit diagram, Sw2 is shown operated, corresponding to the catapult's re-armed position.
Referring to the drawing in **Figure 1**, it's easy to follow the operation of the catapult.

When the solenoid is briefly powered via the 'FIRE' input that controls transistor T1, the lever L is released, pulled up by spring R. This lever ends its travel up against the rubber stop G attached to the motor's servo arm, wheel P.
In coming to rest against this stop the projectile is fired, and the lever also operates Sw1, energizing the relay RE1, which in turn latches via its contact re1B and microswitch

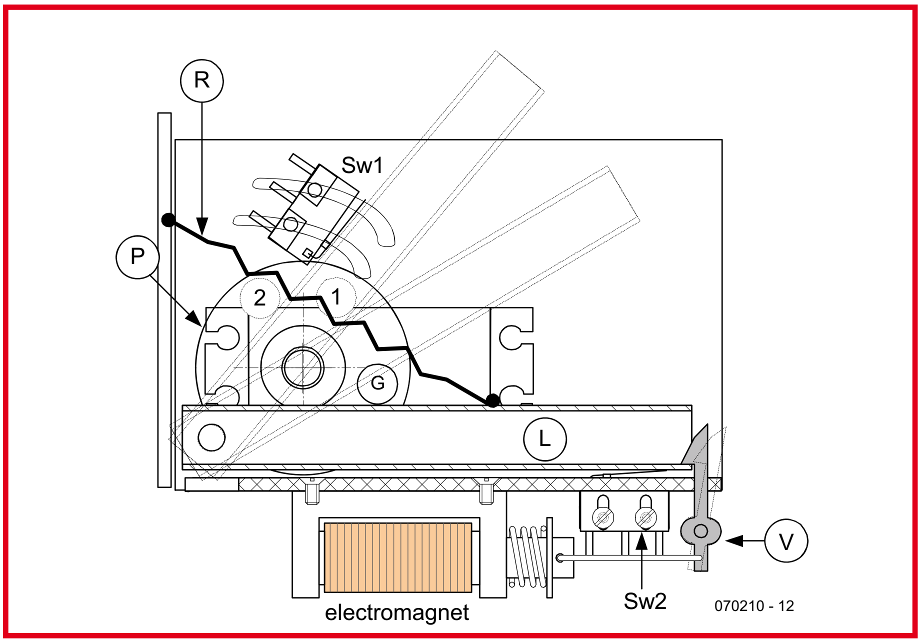


Figure 2. Operating diagram of the catapult.

Sw2 (by this time returned to its rest state). The servo motor starts to turn clockwise and the rubber stop forces the lever back to its re-armed position. At the end of the travel, the lever hooks under the trigger catch; at the same time, Sw2 is operated, and unlatches the relay, which goes back to rest, commanding the servomotor to return to the firing position.
Preset P1 lets us adjust the upper position of the stop and thereby the range of the shot, as explained in **Figure 3**.
P2 lets us set the latching point of the lever in the re-armed position.

Figure 1 shows two firing positions (greyed) of the lever, and the corresponding positions for the rubber stop (numbered 1 & 2).
To adjust the firing range, you simply need to know that, logically enough, in position 1 the ball will go higher, and in position 2 the ball will go less high. Everything depends on how it is being used: if you want to drop a ping-pong ball in a pocket in the ground, it's best to plan on getting there via successive bounces, and so to fire higher. On the other hand, if you are aiming for a basket high up, you need to aim 'spot on' into it, and so allow the lever to go higher.
Once the adjustments have been set, you'll be amazed by the repeatability of this system.

Construction

Electronics
The electronic part is relatively simple and can be built on a small piece of prototyping board. The DIL relay RE1 can be fitted into a turned-pin DIP14 socket.
The servomotor connector can be made using three sections (a 10 mm length) of 2.54 mm (0.1″) pitch SIL pinheader strip. Mark the signal pin, so as to avoid any mistakes when connecting the servomotor.
The IC can be fitted into an 8-pin socket. Presets P1 and P2 should preferably be multiturns, horizontal or vertical.
Check your wiring carefully. Power the circuit without IC1 or the relay fitted. Check the supply rails to IC1 and to the commons of the switches, which will be connected to the circuit via wires of around 10 cm or so. Check the presence of $+V_{CC}$ on the central pin of the servomotor connector.
Connect the 'FIRE' input briefly to $+V_{CC}$ and check that the solenoid operates.

Mechanics
Although not terribly complicated, the mechanics do require a little care all the same.
The drawing in **Figure 2** details the key parts and elements of the system. The chassis is made mainly from a piece of L-section aluminium angle, or an equivalent folded section. The servomotor, fitted with an approximately 35 mm diameter wheel as its servo arm, is mounted on the vertical plane of this angle.

The pivot for the lever is slightly forward of the servomotor shaft. In my own case, I made this lever out of 5 mm square brass tube. This hollow section allows the little catch to hook into the lever once it is re-armed. This catch is operated by the solenoid via a small connecting rod. The solenoid is a 6 V type, mounted under the horizontal plane of our aluminium angle.
The positioning of the microswitches is important, particularly that of Sw2, whose position is set once the optimum re-arming position has been set. This setting can only be done once the electronics described above have been built. Sw2 is mounted onto the angle by way of a small bracket with two oblongs fixing slots, to allow the microswitch to be positioned.

For Sw1, two curved slots will need to be made in the vertical plane, where the servomotor is mounted, so as to be able to adjust the firing range, in conjunction with preset P1.
Once the mechanics have been completely finished, the lever should be put into the lowest position, which will slacken the solenoid spring. Check that the catch hooks properly onto the lever by at least 1 mm. This action must take place without forcing, the solenoid spring must allow the catch to hinge to the right before hooking into the tube.

Check that the solenoid is properly fitted with its return spring, which may be fitted between the coil and the armature, or actually inside the coil, within the space where the armature moves.
The spring must push the armature lightly so that it comes back out of the coil once it has been activated.

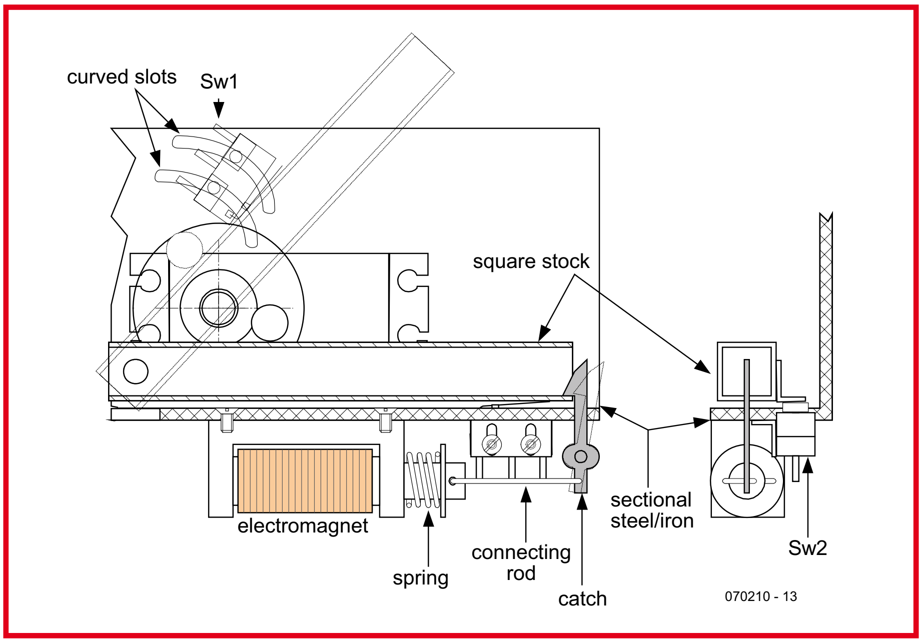


Figure 3. Mechanical construction details.

Adjustment

Setting-up is easy. Don't fit the relay into its socket. Put the lever into the re-armed position and check that the catch holds it properly in the horizontal position. Release the catch and make sure the lever is pulled up properly by the firing spring.
Apply power; the servomotor will take up a random position. Using P2, get the servomotor, via the rubber stop, to position the lever horizontally until the catch engages. Adjust the position of Sw2 so that it is operated by the small bracket attached to the lever. If the servomotor fails to operate, check the circuit, the soldering, and that the servomotor connector is the right way round — i.e. that the signal and earth pins are not reversed.
Turn off the power. Fit the relay into its socket. Re-apply power. The servomotor should take up some random position. Adjust P1 to bring the roller into any firing position (1, for example). Turn off the power and adjust Sw1 so it is operated by the lever in its upper position.

Re-apply power. The catapult should re-arm all by itself and the servomotor should then return to the upper position as described above. Everything is now working. That's fine. Operate the solenoid to check that firing takes place correctly. You can now fit the lever with a support for the projectile (ball).

It's worth noting that the unused NC contact of Sw2 carries $+V_{CC}$ indicating the catapult is re-armed…

(070210-I)

Servo to Motor Conversion

Paul Goossens

Servos, originating from their application in model building, are usually used to operate arms, feet and other 'tools' of a robot. In addition to these obvious uses they are also very suitable as a motor to drive the wheels of a robot, for example. To do this, the standard servo does need to be modified first however.
Servos have been used for a long time in the model construction arena. As a result they are readily available and often at attractive prices.

Standard servo

The purpose of a standard servo is to bring the shaft into a certain position and to keep it there. At the input the servo expects a train of digital pulses. The duration of these pulses determines the position that the shaft has to assume.
The internal electronics uses a potentiometer which is mechanically coupled to the shaft to measure the position of the shaft. If the length of the pulses does not correspond with the present position of the shaft then the electronics will drive the internal motor.
If the shaft is too far too the right then the motor will turn the shaft to the left and the other way around. The instant that the shaft reaches the correct position the motor will be turned off.

Small adjustment

A standard servo is therefore not suitable to turn wheels or similar things. However, with a little bit of tinkering we can make a servo suitable for this job.
The trick is very simple. The potentiometer is replaced by a voltage divider with two 10 kΩ resistors. In this way the electronics 'thinks' that the shaft is always in the centre position.
If we now give the servo a pulse of 1.5 ms duration then nothing happens. The servo will turn the motor off. If we make the pulse duration 1 ms then the servo will attempt to turn the shaft to the left-most position. To that end the servo will let the motor turn to the left. On its sensor input it continues to 'see' that it is in the centre position. The motor will therefore continue to turn to the left.
To let the motor turn the other way we supply a pulse that lasts longer than 1.5 ms (2 ms, for example). The motor stops again when we make the pulse 1.5 ms long.
Note that most servos have a mechanical end-stop, which prevents the shaft from turning any further. We have to remove these two end-stops first otherwise the motor will go up in smoke during testing!

Mechanical

This modification doesn't mean much from the electronics perspective. The skill is to do this in the small housing of a servo. As an example we use a cheap servo from Conrad (Figure 1). On the bottom of the servo are four screws that we remove first. After this, the bottom cover can be removed.
Carefully loosen the cover plate. This contains a number of gears that can easy drop out. We need to know exactly how these are placed in the enclosure, because we need to put them back in the exact same place later on! Taking a picture of the inner works including the gears can be a very handy reference later one when putting the servo back together. Once that is done the servo looks like Figure 2.
Remove the output shaft. This sits on the shaft of the potentiometer. This shaft is fitted with a ridge, which together with 2 ridges in the housing forms the mechanical end-stop. This is undesirable, therefore remove this ridge with a sharp knife (Figure 3).
The next job is to remove the PCB from the housing. Should this not come out easily, then a careful push on the shaft of the potentiometer usually ensures that it comes out of the housing after all. The motor should have a small gear. This will sometimes be caught by the housing. If that is the case you need to retrieve the gear and put it back on the motor shaft.
The potentiometer and motor are easily recognised. We now replace the potentiometer with two resistors. The resistors are each individually soldered to one of the outside connections, where the potentiometer used to be. The other connections for both resistors are then soldered to the middle connection.
Voilà, the servo is now converted. If all is well, your servo will look about the same as our prototype in Figure 4.
What's left to do is to put the servo back together. Make sure that all the gears are in the correct position and everything is free to rotate. Also check that the little gear on the motor is still in the right place.
Finally we screw the bottom cover back in place. The servo is now ready for use, but now as a motor and no longer as a servo!

(070358-I)

1


2


3

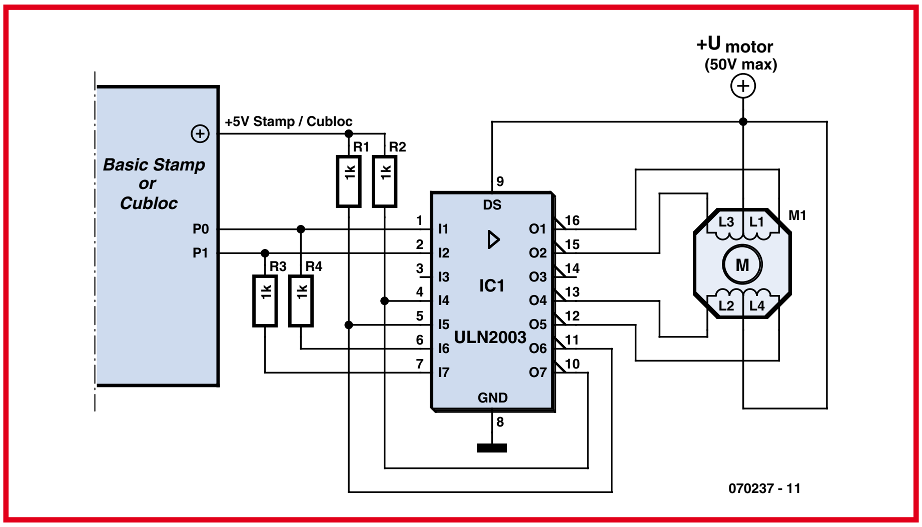

4


5


Driving Stepper Motors

Using a Basic Stamp or a PIC programmed in Basic

C. Tavernier



When we want to motorize a robot, two main solutions are open to us: the DC motor, used alone or in a converted radio-control (RC) servo system, as explained elsewhere in this issue; and the stepper motor. Although the DC motor is very suitable for everything to do with propulsion, the stepper motor is more suitable when it comes to performing precise positioning, as required for a robot arm, a sensor moving in one plane, etc.

But while controlling a DC motor is relatively simple (it turns as soon as it is powered), controlling a stepper motor is a little more tricky. They only turn when their various windings receive pulses, which have to be presented in a quite specific order to make the motor turn one way or the other.

Because of this pulsed drive, these motors don't turn continuously, but in fact advance at each pulse by one basic step — whence their name. The size of these steps can vary between 1.8 and 7.5°, depending on the type of motor used. This stepped advance makes it possible in principle for the program controlling the motor to know its position very accurately. But for this to remain true, we have to take care not to exceed the motor's maximum allowable loading, as in that case the motor might fail to advance for every pulse received, and thus 'skip' some steps.

Another far from negligible advantage of the stepper motor is that if it is powered but does not receive any pulses, it remains blocked where it is. So we have a sort of electric brake — though of course still on condition that the motor's load capacity is not exceeded, as mentioned above.
There are currently two families of stepper motor: single-pole and double-pole. The former are simpler to drive, as all you have to do is apply voltage or not to their windings, while in 2-pole motors, the voltage applied to these windings has to be regularly inverted, slightly complicating the circuitry that's required.
Table 1 indicates the order in which a single-pole motor's windings must be powered to make it turn. Going through the columns of this table from 1 to 4, the motor turns clockwise, while reversing the order changes the direction of rotation. Each column of this table corresponds to one mechanical step of the motor — remember, that's between 1.8 and 7.5 degrees depending on type.
There are numerous specialist ICs on the market for driving stepper motors, and various solutions are on offer in this issue of Elektor, but if your robot uses a Basic Stamp or a PIC microcontroller programmed in Basic, there is an extremely simple and cheap solution for making it drive this type of motor.

All we actually need to do is use a perfectly ordinary ULN2003 or ULN2803,

Table 1

Step number	1	2	3	4
Winding 1	1	1	0	0
Winding 2	0	0	1	1
Winding 3	1	0	0	1
Winding 4	0	1	1	0

```
 ' Control of a unipolar stepper motor
' The step number is put in w1
' The rotation direction is defined by b0

' Variable's definition

Symbol direction = b0
Symbol incr = w1
Symbol index = w2
Symbol delay = b6

' Initialization

dirs = %00000011
pins = %00000001
b1 = %00000001

 ' Here the application program must initialize
 ' incr, direction and delay with the required values

if direction = 0 then incrincr
b1 = b1 ^ %00000011

incrincr:
        for index = 1 to incr
                pins = pins ^ b1
                b1 = b1 ^ %00000011
                pause delay
        next
```

respectively seven-way or eight-way integrated power Darlingtons normally used to drive relay coils. The required software is very simple, thanks to a couple of tips suggested by Parallax (the manufacturer of the Basic Stamp).

The first is to note that the status of windings 1 and 2 on the one hand, and windings 3 and 4 on the other, is always opposite, as indicated in the attached table. Because of this, the motor can be driven using just two of the Basic Stamp outputs, as shown in the very simple circuit we are suggesting.

Windings 1 and 3 are driven from two lines of the Basic Stamp port, after amplification by the ULN2003 (or 2803). Windings 2 and 4 receive these signals after inversion, performed using two of the spare amplifiers in the ULN2003 (or 2803), which is overkill but perfectly practical. Note the presence of the two essential 1 kΩ pull-up resistors, connected to the outputs of the amplifiers in the ULN2003 (or 2803), as the Darlingtons are only open-collector.

The second tip suggested by Parallax consists of directly calculating the sequence of signals to be applied to the Basic Stamp's P0 and P1 outputs, rather than getting these data from a table. All that's actually needed is a simple XOR logic function, as shown in the **program listing**.

This short example of code may be included as is into a more complete application. As can be seen, it makes the stepper motor connected as shown in the figure turn through the number of steps previously loaded into w1. The direction of rotation is determined by the contents of b0. If b0 is anything other than 0, the motor turns one way; if not, it turns the other way. This program also lets us define the wait time between each step, by means of the data used in the PAUSE instruction; the only proviso is not to reduce this delay too much, taking into account the motor being used and the load it is driving.

To be as general as possible, note that this example of code has been written in Basic Stamp I language. So it is fully transposable, without restriction, to any other type of Basic Stamp, as well, of course, as to any PIC programmed in Basic, since the majority of Basic compilers for PICs are compatible with the Basic Stamp I language. It can likewise be easily migrated to a PicBasic or a Cubloc from Comfile Technology.

(070237-I)

Which Brain for my Robot?

A mini practical guide

C. Tavernier

www.tavernier-c.com

More than any other electronics project, these days a robot can virtually not manage without at least one microcontroller to run it. So of course this raises the question of how best to select one, and this article is here to help you in this delicate task. Although the simplest robots can get by with virtually any type of microcontroller programmed in the language of your choice, as the complexity of the robot increases, it becomes clear that certain ICs are more suitable than others for a purely robotic application.

So, after briefly discussing the special requirements typical of robots, we're going to present a certain number of microcontrollers and try to highlight their strengths in a robotics context.

The need creates the system

Compared to a conventional electronic project, a robot possesses certain particular features that have a direct influence on the choice of which microcontroller to fit it with. So whether it is fixed or mobile — and the first robots amateurs build are very often mobile, as these are admittedly the most spectacular — a robot always includes one or more motors. As you've been able to discover throughout this issue of Elektor, these may take the form of radio-control servos, stepper motors, or DC motors. None of these are controlled in exactly the same way, but all of them require the microcontroller to know how to generate pulses more or less repetitively.

Our robot is obviously fitted with sensors. Although the simplest versions make do with simple 'whiskers' or contact-based obstacle detectors, as robots evolve, they become literally covered in sensors, some of which can be highly complex. The information they furnish is most often digital, from the simple on/off information of an open or closed switch to the complex NMEA frames from a GPS receiver. A few, less common sensors also furnish information in analogue form, and it's important not to overlook these ones.

So our robot's microcontroller must have numerous parallel port lines for on/off type information, but also asynchronous and synchronous serial interfaces (I^2C, SPI, etc.) for sensors providing more complex information (electronic compasses, inclinometers, etc.), along with at least one analogue-to-digital converter for analogue information.

So far, everything we've been discussing is still within the scope of all current microcontrollers, and it's not much help to us in choosing. But the situation is actually more complicated than you might think from this discussion, which might be described as 'static'. When our robot is moving, there is a need to simultaneously control its motors, interpret the information provided by the sensors, and take the necessary decisions that entails. On the simplest robots with a small number of sensors, all this can be managed using standard sequential programming; but as soon as the number or complexity of the sensors increases, the situation soon becomes unmanageable. It then becomes necessary to resort to multitasking, i.e. to a mode of operation in which the microcontroller handles the sensors, the motors, and the decision-making all together and 'at the same time'. Sadly, not all microcontrollers or programming languages are able to manage this by a long way.

The last particular feature of robots is that, unlike conventional electronics projects, they are often built by amateurs coming from backgrounds other than electronics. Mechanics, modellers, those who are simply curious all get involved in designing robots. For all these designers, who contribute a great deal to the world of robotics as they have a different view from the electronics enthusiasts, the microcontroller needs to be simple to implement and program. This simplicity sometimes founders on the reef of the multitasking we've just been talking about, but we're going to see that, by judiciously choosing the microcontroller, it is possible to reconcile the irreconcilable.

Ordinary or special microcontrollers?

If electronics no longer holds any secrets for you and if you're not afraid of programming, you can obviously choose a standard microcontroller for your robot. PIC from Microchip, AVR from Atmel, etc. The list is long, especially as each manufacturer offers a wide range of ICs with a great variety of resources.

Hence from Microchip, the PIC18 family is gradually supplanting the PIC16 family that has been delighting amateurs for many years. These new ICs actually perform better, are more powerful, and hardly any dearer. As for the development tools, the unassailable MPLAB, increasingly user-friendly and of course still free, works just as well for either, so the transition is a gentle one. And if the power of the PIC18 isn't enough for you, the PIC24 family is all ready to replace it, as discussed in Elektor issue 343's presentation of the Explorer-16.

It's the same picture with Atmel, where

the AVR ICs from the ATmega range — scarce and expensive just a few years ago — are now within everyone's pocket, with their innumerable internal resources and sometimes impressive memory capacities. Here again, the AVR Studio development tool is free and available from the Atmel website.

In spite of all that, it's not these 'classic' ICs that we're going to be looking at — especially since this subject has already been covered in Elektor (issue 322), but some 'special' microcontrollers that are proving highly successful in robotics because of their easy implementation and the particular features of their programming languages. You're probably familiar with the oldest of them, none other than the famous Basic Stamp – but these days this is far from being the only one. Originally dreamt up by Parallax, this concept has had its imitators, and ever since we've seen numerous microcontrollers coming onto the market aspiring to be its descendants, while of course claiming to do much better. So these ICs are the ones we suggest you choose from.

A forerunner that has aged well

For those of you who might not already know it, the Basic Stamp, developed and marketed in 1993 in the United States by Parallax, is a microcontroller that behaves as if it were directly programmable in Basic — but this particular feature is far from being the only one to have ensured its success. It is also a ready-to-use microcontroller, needing neither a clock crystal, an external reset circuit, nor even a stabilized supply to operate. All this is already built in.

Like any self-respecting microcontroller, the Basic Stamp has to be programmed, but this programming is done in Basic, easy to use and accessible to everyone, to the point it has almost become a standard upon which all its successors have been based. No programmer is required, as it only amounts to… a simple cable to link the Basic Stamp to the serial port of any PC, even an old or very basic model. The development tool, intended for program-writing, is completely free and available for download from the Parallax website.

Even though the simplest of all the Basic Stamps, the Basic Stamp 1, can be used to drive a robot, we unhesitatingly advise using at least the Basic Stamp 2, to benefit from the more numerous resources and a fuller instruction set. What's more, many successors to the Basic Stamp 2 (referred to from now on as BS2) are pin-compatible with it, allowing for possible future upgrading as a robot evolves, without needing to modify the associated electronics.

Figure 1 show both the physical appearance of the BS2 and its pinout, while the functions of the various signals available are listed in **Table 1**. Like all its successors, the Basic Stamp is not a 'true' integrated circuit, but a tiny PCB the size of a 24-pin DIL IC fitted with a number of SMD components, including a microcontroller, its clock and reset circuitry, an EEPROM memory for storing the program, and a 5 V regulator to power it.

Table 1: Pinout for the Basic Stamp 2 in the 24-pin package, adopted by many of its competitors (Basic Atom 24, Cubloc CB220, Javelin Stamp, among others).

Name	Pin no.	Function
S_{OUT}	1	Programming output (PC serial port)
S_{IN}	2	Programming input (PC serial port)
ATN	3	Programming input (PC serial port)
V_{SS}	4 et 23	Ground
P0 à P15	5 à 20	Input/output ports
V_{DD}	21	5 V stabilized output (input if VIN is too low)
RST	22	Manual external reset input (if required)
V_{IN}	24	Unstabilized positive supply from 5–15 V (12 V for 2E, 2SX, and 2P24)

Based on an 'old' PIC16C57 at 20 MHz, the BS2 is programmed directly in Basic, sometimes called PBasic, and is capable of executing around 4,000 instructions per second, while its memory can store around 500 lines of program. Its planetary success, and the word is not too strong, has pushed Parallax to put onto the market other BS2s, whose strong points are summed up here rapidly.

The first evolution to have seen the light of day, the Basic Stamp 2SX or BS2SX, is in fact a significantly faster version of the BS2. It executes on average 10,000 instructions per second, by replacing the BS2's microcontroller with a SX28 from Ubicom. The program memory is also larger, accepting around 4,000 lines of program. All this is of course transparent for the user and the BS2SX instruction set is identical the BS2's, apart from three new instructions to manage this extra memory.

The BS2SX and its relatively large program memory created a demand among certain Basic Stamp users wanting to benefit from this much larger memory, but not needing the speed (and hence the price-tag!) of the BS2SX. So Parallax has offered them the Basic Stamp 2E — simply a 'degraded' ver-

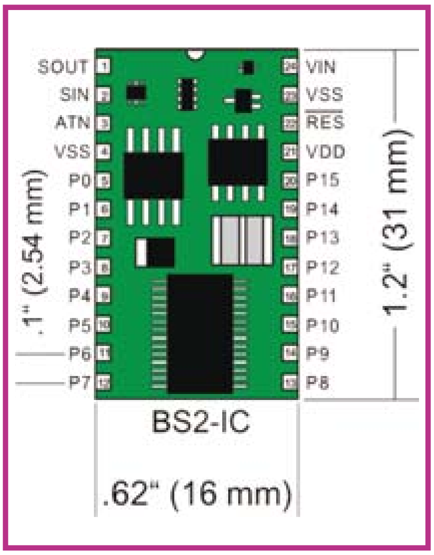


Figure 1. The physical appearance, dimensions, and pinout of the Basic Stamp 2 have been taken up by many of its competitors: Basic Atom 24, Javelin Stamp, Cubloc CB220 amongst others.

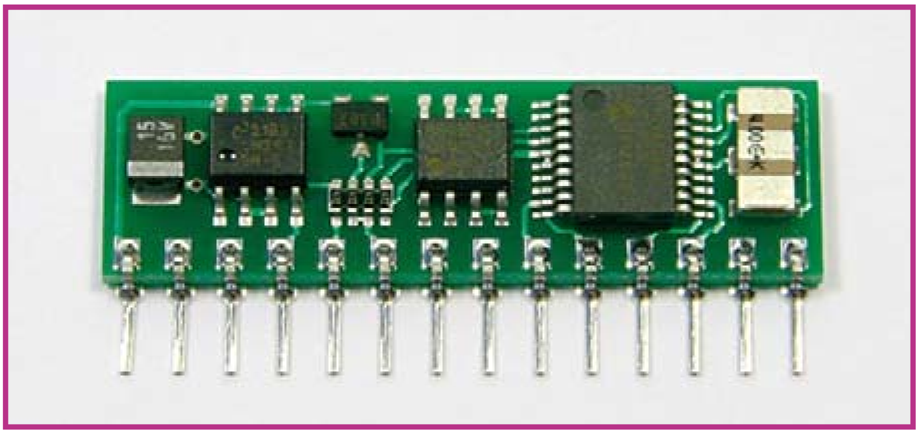


Photo 1. Though it's been a bit left behind now, here's the father of all the Basic Stamps, the Basic Stamp 1.

Table 2: Principal characteristics of the various Basic Stamps and the Javelin Stamp.						
Parameter	**Basic Stamp 2**	**Basic Stamp 2SX**	**Basic Stamp 2E**	**Basic Stamp 2P24**	**Basic Stamp 2P40**	**Javelin Stamp**
Microcontroller	PIC16C57	SX28	SX28	SX48	SX48	SX48
Clock frequency	20 MHz	50 MHz	20 MHz	20 MHz	20 MHz	25 MHz
Program memory (bytes)	2 K	8 x 2 K	8 x 2 K	8 x 2 K	8 x 2 K	32 K
Program memory (instructions)	500	4 000	4 000	4 000	4 000	–
Working memory (bytes)	32	32	32	38	38	32 K
Scratch memory (bytes)	–	64	64	128	128	–
Speed (inst./sec.)	4 000	10 000	4 000	12 000	12 000	8 500
Number of Basic instructions	36	39	39	55	55	0 (Java)
Parallel inputs/outputs	16	16	16	16	32	16
Max. source/sink current per output	20/25 mA	30/30 mA	30/30 mA	30/30 mA	30/30 mA	30/30 mA
Max. source/sink current per chip / per group of 8 inputs/outputs	40/50	60/60	60/60	60/60	60/60	60/60
Programming interface	PC serial port 9,600 baud	PC serial port 9,600 baud	PC serial port 9,600 baud	PC serial port 9,600 baud	PC serial port 9,600 baud	PC serial port 28,800 baud
Supply voltage	5 - 15 V	5 - 12 V	5 - 12 V	5 - 12 V	5 - 12 V	5 - 24 V
Operating current	8 mA	60 mA	20 mA	40 mA	40 mA	80 mA
Stand-by current	100 μA	200 μA	100 μA	400 μA	400 μA	stand-by mode

sion, in terms of speed only, of the BS2SX. So, the Basic Stamp 2E has all the characteristics of the BS2SX, but offers the same program execution speed as the BS2.

The Basic Stamp 2P24s and 2P40s offer more innovations, but can be presented together as their characteristics are identical except for one detail we'll look at in a moment. Apart from being faster than the already fast BS2SX, achieving 12,000 instructions per second, they also have an extended instruction set. The 36 or 39 instructions of the BS2 or BS2SX increase to 55, introducing some very powerful and extremely handy instructions capable of directly driving an LCD alphanumeric display, talking to peripherals over the I²C bus, or driving ICs with a Dallas '1-Wire' bus. This evolution is done cleverly, however, and the same 36 BS2 instructions are included within the 55 instructions of the BS2P24 and BS2P40. The BS2P24 uses a pinout compatible with the other Basic Stamps, while the BS2P40 uses the 40-pin DIL IC format, allowing it to have 16 additional parallel port lines compared with the 24-pin packages.

To help guide your choice, **Table 2** summarizes the most important details of the various versions of Basic Stamp. Note that, for reasons of convenience, it includes the Javelin Stamp, described later.

All these Basic Stamps are wonderful in robots, as their instruction set has really been designed for microcontroller-oriented use. So to make parallel port P2 go high, we simply write `HIGH P2`; to make it generate pulses we use the instruction `PULSIN`; to receive data in asynchronous serial form, we use `SERIN`, while to make it output synchronous serial data we use `SHIFTOUT`.

Because of the very simple and explicit syntax of these instructions, anybody can write programs for a Basic Stamp after just a few hours of practice and with no previous knowledge of programming. Moreover, given the seniority and success of the Basic Stamp, the library of programs available is immense. You only have to do a bit of Googling to see for yourself.

So in our opinion, the Basic Stamp is a good choice for someone wanting to make a start in robotics, even if it does present in our view two drawbacks, of unequal importance: it's still expensive compared to other similar ICs; and it doesn't support multitasking. This point must, however, be taken relatively, inasmuch that a number of microcontrollers that do support it are pin-compatible with the 24-pin Basic Stamps, allowing easy substitution in the event of your robot's evolving in this direction.

Basic Stamp 'clones'

The success of the Basic Stamp has clearly made some people envious, and various products have tried to imitate it, while seeking to overcome some of its shortcomings. At least two products fall into this category: the Basic Atom 24 from Basic Micro and the PICBasic range from Comfile Technology.

Based on a PIC16F876, the Basic Atom 24, pin-compatible with the 24-pin Basic Stamp 2s, has a program memory the same size as the BS2E. Faster overall, at around 33,000 instructions per second, it also offers more internal resources, including an ADC, two PWM ports, and up to a point supports interrupts. Its instruction set is also fuller than the 'classic' Basic Stamps, and is related to that of the Basic Stamp 2P, though is a little fuller because of the increased internal resources. So it may represent a worthwhile alternative to the Basic Stamp, especially since it's a little cheaper to buy.

On the downside, we must note all the same that it isn't multitasking either, and its availability leaves something to be desired, as the product has clearly not enjoyed the success its designers were hoping for (or else it just came on the scene too late). As it is not used a great deal, the library of programs for it is nothing like that of the Basic Stamp.

As for the PICBasic, it is, or rather was, an alternative to the Basic Stamp 2 designed by Korean company Comfile Technology. We won't talk about it here, as it's

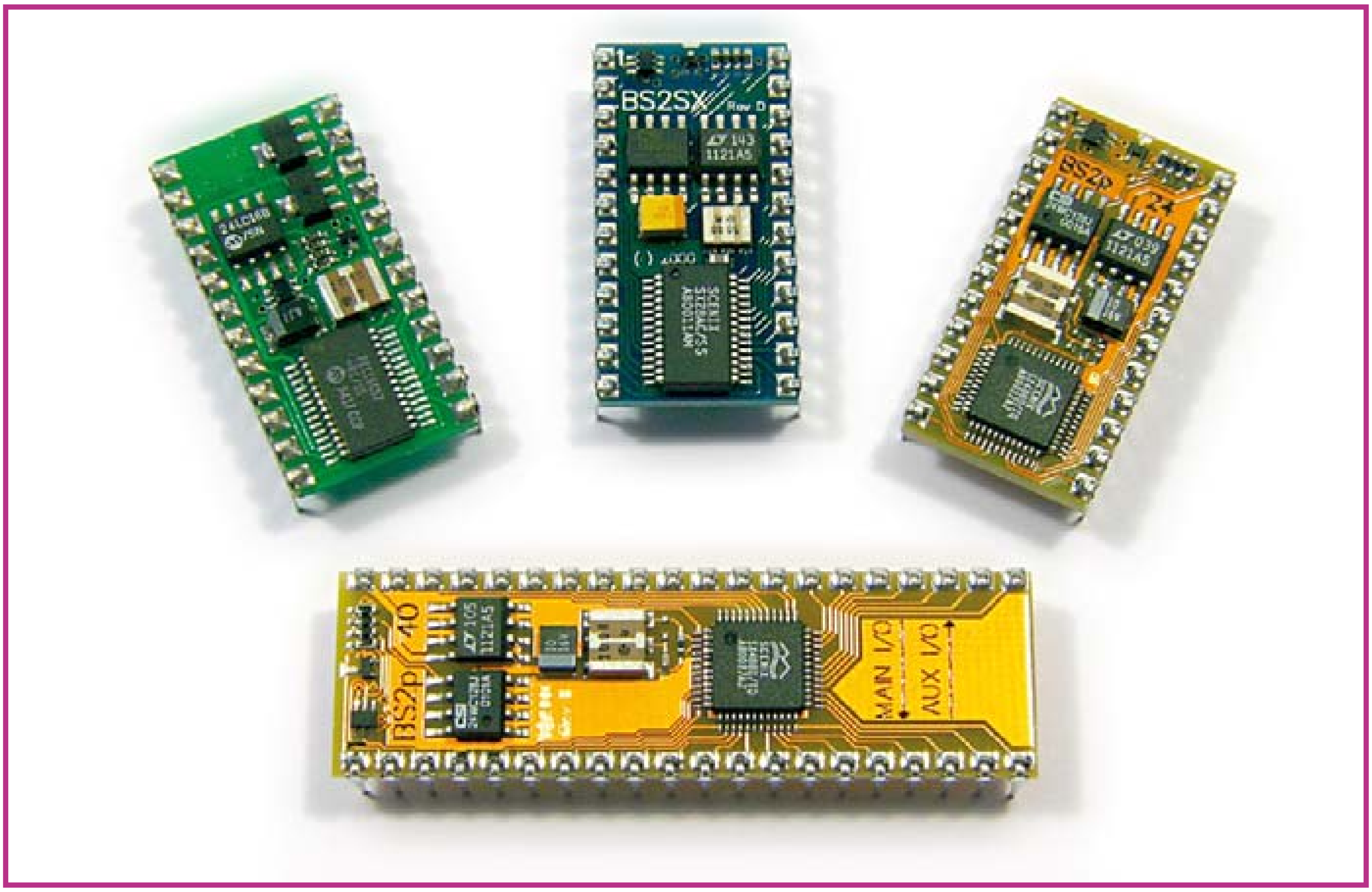


Photo 2. **The Basic Stamp's offspring.**

clearly on the road to extinction, if we are to believe Comfile's website, in favour of the Cubloc range from this same manufacturer. When you discover in a moment the possibilities of the Cubloc, and given that a CB220 (entry-level Cubloc) costs virtually the same as a PICBasic 2S, you'll easily understand why it's being dropped.

A first step towards multitasking

Once again, it is Parallax who made the innovation in terms of multitasking with two distinct products for completely different purposes. The first, and also the oldest, is the Javelin Stamp, much less well known than the Basic Stamp. It has to be said that its price (around £ 45) might have something to do with this...

So the Javelin Stamp is physically like a Basic Stamp 2, but is programmed in Java. Of course, it isn't just that which makes it multitasking, but the fact that it has two operating modes: a foreground mode, where it executes the main program written in Java, and a background mode where a certain number of tasks can be performed independently of, and hence at the same time as, the main program.

These tasks are executed by means of virtual peripherals or VPs of which, as far as background mode is concerned, there are five: UART, PWM signal generator, 32-bit timer, 1-bit ADC, and delta-sigma ADC. So, for example, the background generation of PWM signals proves very interesting for robotics applications, since many motors are controlled by signals of this type. So the Javelin Stamp can, for example, control a robot's motors and convert the analogue information coming from a sensor, while still continuing to execute its main program.

Independently of these specific features, the Javelin Stamp uses a Ubicom SX48 processor operating at 25 MHz, giving it a speed of 8,500 instructions per second; its other key characteristics are summarized in **Table 2**, to let you make a quick comparison with the Basic Stamps.

So the partially multitasking character of the Javelin Stamp does make it an interesting processor for robotics applications, but in our view it suffers from two drawbacks: its excessive price, compared with 'competing' processors; and the fact that it is programmed in Java, which is quite a difficult language to master for anyone who has never done any programming before.

One microcontroller with two heads

The Cubloc range from Comfile Technology is much more innovative in the area of multitasking. As seen in **Figure 2**, showing the Cubloc's internal structure, this microcontroller is in fact a twin one, including on the one hand, a processor programmed in Basic, and on the other, a processor controlled in Ladder. This language, which you may not have heard of, is none other than the language used for programmable automata. The Cubloc's twin processors can of course operate simultaneously, making the Cubloc truly multitasking — provided of course we program in both Basic and Ladder.

To make it easier to get to grips with, it is of course possible to only program it in one language or the other. If you choose Basic, the syntax is close to that of the Basic Stamp with, however, lots of new instructions making it easier to handle PWM signals, or drive an I^2C bus, keyboard interfacing, etc.

Although the Cubloc rage currently comprises four main models, whose key characteristics are summarized in **Table 3**, we recommend starting out with the CB220. Apart from being it's the cheapest of the Cublocs, it's also pin-compatible with the Basic Stamp 2, making it possible to develop a single-tasking application using the latter into a multitasking application, without needing to make the slightest modification to the electronics.

What's more, given that it's based on an ATmega128 at 18 MHz, it can execute around 36,000 instructions per second

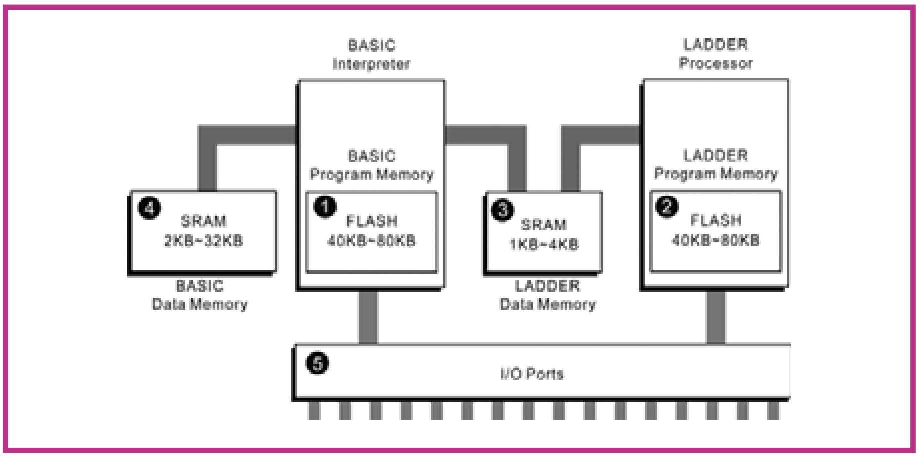


Figure 2. **Internal architecture of the Cubloc CB220.**

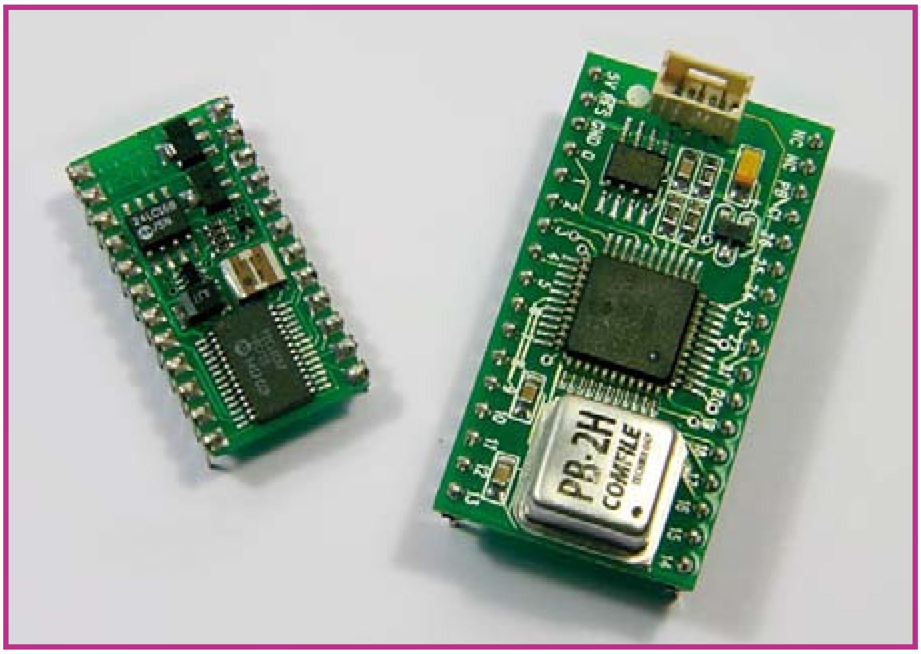


Photo 3. **The PicBasic (right) marked Comfile Technology's entry into the world of these special microcontrollers. It wasn't yet pin-compatible with the Basic Stamp 2 (left).**

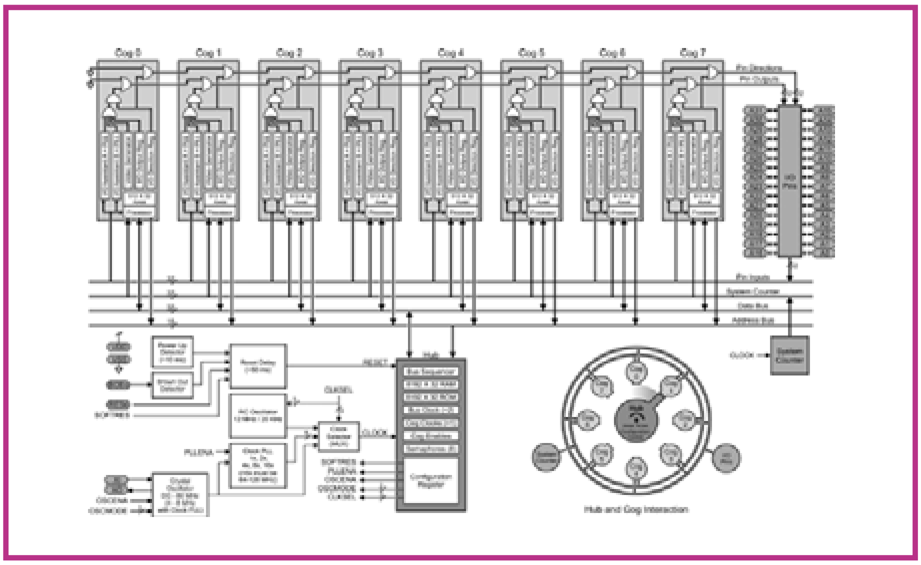


Figure 3. **Internal architecture of the Propeller – impressive, and allowing true multitasking.**

and its program memory offers a very comfortable capacity of 80 kB. Note too that it has an 8-channel 10-bit ADC and a 3-channel, 16-bit DAC capable of generating PWM signals.
So the Cubloc CB220 seems to us a good choice today in terms of processors intended for robotics, as it combines lots of advantages in a single package: hardware compatibility with the Basic Stamp 2, the simplicity of Basic programming, and the possibility of multitasking; all this for a price that is still reasonable compared with the other products in this survey.

And finally, some true multitasking

Rest assured, Elektor readers, we have not been paid to write this article by Parallax, even though it's another of this company's products we're going to be talking about next: the Propeller. We have to admit that ever since the first Basic Stamp came out almost 15 years ago, Parallax hasn't been resting on its laurels. But while the previous products were based on existing processors, the Propeller is a real 'chip' developed by Parallax.

As **Figure 3** shows, even at first glance it's an impressive product, consisting of no less than eight independent functional blocks, the Cogs, each comprising its own processor and some RAM. These Cogs are linked via a bus managed by a Hub that takes care of synchronizing their exchanges. They all share the product's 32 uncommitted input/output lines.
Very few specialized peripherals are built in to the Propeller, but this isn't a problem, given that its programming language, called Spin, is in fact an object-oriented language. So if you need, for example, an RS 232 serial port, you only need to delve into the voluminous object library made available to you by Parallax to find what you're looking for there. You can do the same for generating PWM signals, driving an I^2C bus, an LCD display, etc.
Given that there are eight Cogs available, it's possible to run up to eight different applications simultaneously. So a robot fitted with this sort of processor has no difficulty in managing its wheel motors, while analysing the data from several sensors and taking the relevant decisions.
Of course, Spin is a little daunting and writing your first instructions is a bit of a pain for anyone who's never programmed before — but it's well worth all the effort. What's more, Parallax places at your disposal a forum and above all a space on its website where anyone can upload the various object modules they have developed for the Propeller. This participatory library currently has over 75 object modules covering the most diverse fields, and

Table 3: Principal characteristics of the various Cublocs.				
Parameter	**CB220**	**CB280**	**CB290**	**CB405**
Microcontroller	ATmega128	ATmega128	ATmega128	ATmega2560
Clock frequency	18.432 MHz	18.432 MHz	18.432 MHz	18.432 MHz
Program memory	80 K	80 K	80 K	200 K
Dynamic memory (RAM)	2 K (Basic) 1 K (Ladder)	2 K (Basic) 1 K (Ladder)	24 K (Basic) 4 K (Ladder)	51 K (Basic) 4 K (Ladder) 55 K (pile)
Data EEPROM	4 K	4 K	4 K	4 K
Speed (instr./s)	36,000	36,000	36,000	36,000
Inputs/outputs	16	49	91 (33 entrées, 32 sorties et 26 entrées/sorties)	64
Serial ports	1 RS-232 1 TTL	1 RS-232 1 TTL	1 RS-232 1 TTL	4 RS-232
ADC (10-bit)	8 channel	8 channel	8 channel	16 channel
DAC (16-bit, PWM)	3 channel	6 channel	6 channel	12 channel
External interrupts	–	4	4	4
Fast counters	2 x 32 bits	2 x 32 bits	2 x 32 bits	2 x 32 bits
Real-time clock	–	–	Oui	–
Supply voltage	5 - 12 V	5 V	5 V	5 V
Operating current	40 mA	40 mA	70 mA	50 mA
Package	24-pin DIL (BS2 compatible)	64-pin module	108-pin module	80-pin module

is continually growing.
So if you want to build a robot that requires true multitasking, the Propeller is currently one of the best solutions there is, all the more so because the price is only a quarter of that of a Basic Stamp, a Cubloc CB220, or similar product.

An odd multitasking PIC

We couldn't end this review of special processors for robots without mentioning an IC that's relatively unknown on this side of the world, despite its undeniable interest: the OOPic. As its name might leads us to suppose, this IC is none other than a PIC microcontroller that can be programmed in object oriented language — 'OO' standing for '**O**bject **O**riented' — but that's not all…
The OOPic is in effect a PIC that you will be able to program in the language of your choice: Basic, C, or even Java — but this program will consist of simple scripts calling up objects. These objects, currently 130 of them, are capable of managing virtually anything you can imagine driving with a microcontroller, and, rather than list them here, we'll send you off to the OOPic website to discover them for yourselves.
All these objects are able to operate simultaneously and independently of each other as background tasks while the main program is running. So with an OOPic, it's very easy to produce a multitasking application. But the concept goes further than that. It's possible to link objects together to form what are called virtual circuits that perform complete functions. In concrete terms, this means that objects can exchange data between them, as a background task, without your main program even having to bother about it.

Another advantage, and not the least, of the OOPic is the possibility of networking it; a maximum of 128 OOPics can be connected together to I²C ICs, thanks to a 3-wire bus and without any additional external components. So with the OOPic it's possible to create what is called semi-distributed robot architecture, i.e. to no longer do multitasking, but multiprocessor operation. One processor looks after the management of the propulsion, another this-or-that type of sensor, and so on, while a 'central' processor now only has to look after decision-making on the basis of the information sent to it.
Of course, implementing such an architecture is no longer within the grasp of a robotics novice, but after starting out with a Basic Stamp or a Cubloc, for example, it is still accessible to anyone who cares to take the trouble, especially since it needs no special investment, since the OOPic is programmed in the language of your choice and the objects are available to you free, and programming is done using

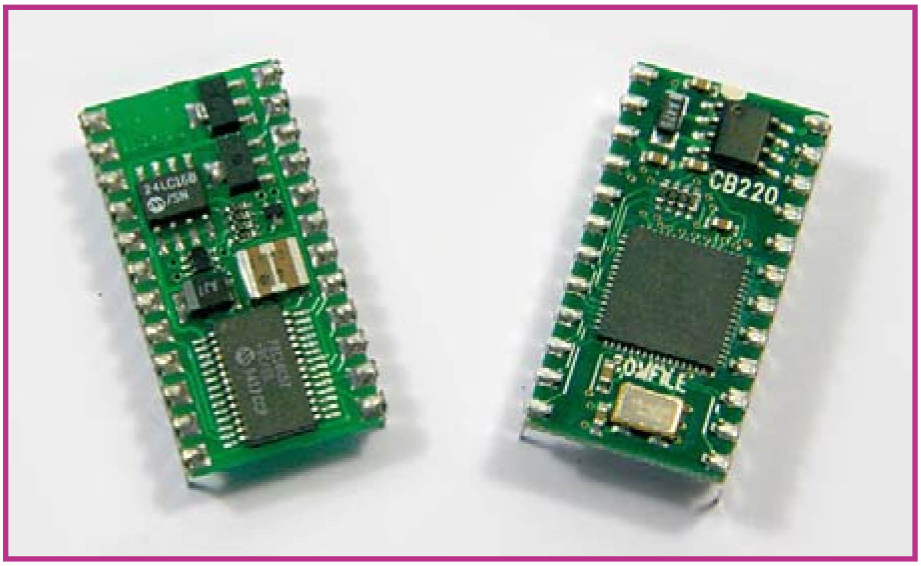


Photo 4. The Cubloc CB220 (right) is directly interchangeable with the Basic Stamp 2 (left).

Photo 5. The development tools for Basic Stamp and Cubloc include a very useful editing terminal.

Photo 6. The Propeller development tool showing an example of Spin — not exactly a barrel of laughs, but the results are worth the effort!

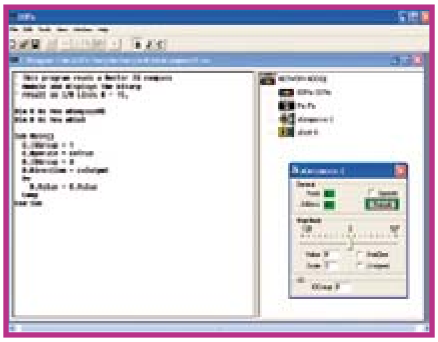


Photo 7. The OOPic development tool allows graphical interaction with the objects used by the program.

a simple cable connected to the parallel port of any PC.

Conclusion

This overview is of necessity incomplete, especially when you think that the programming manual of just one of the ICs presented here runs to at least a hundred or so pages! But we hope that we have helped you discover or re-discover some of the processors that are particularly well suited to robotics and which, while being simple to implement, do not in any way sacrifice performance.

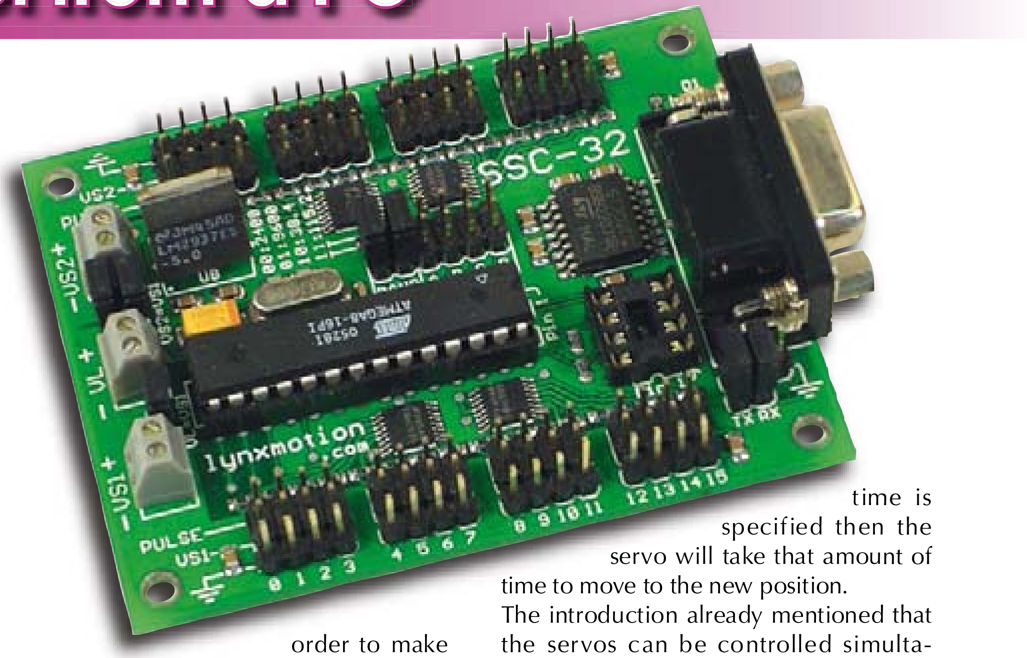
(070319-I)

Addresses

URL	Company	Comments
www.atmel.com	Atmel	Manufacturer of AVR microcontrollers
www.basicmicro	Basic Micro	Manufacturer of Basic Atom
www.comfile.co.kr/english2/	'PicBasic' website	Manufacturer of PicBasic
www.comfiletech.com	Comfile Technology General site	Manufacturer of Cubloc
www.microchip.com	Microchip	Manufacturer of PIC microcontrollers
www.oopic.com	Savage Innovations	Manufacturer of OOPic
www.parallax.com	Parallax	Manufacturer of: Basic Stamp, Javelin Stamp, Propeller
www.tavernier-c.com	–	Author's website

Servo Control from a PC

Bas Lijten



Driving multiple servos via a microcontroller can be quite a problem for many people. Fortunately, a servo controller is available which can be controlled from a PC: the SSC-32.

The SSC-32 is an open-source controller which is connected to the serial port. It has 32 outputs, which makes it possible to control 32 servos simultaneously. Each output can also be used as a general purpose output with TTL levels. In addition, the microcontroller has four digital inputs and there is an extra socket for fitting an EEPROM. This was not being used at the time of writing, but it is likely that it will be used in future updates of the firmware.

The servos that are connected to the controller can be controlled in a very simple way. Only the numbers of the servos to be controlled, the pulse width (position) and the speed or time need to be known in order to make a servo move. If a speed is specified then the servo will move to the required position at that speed. If a time is specified then the servo will take that amount of time to move to the new position.

The introduction already mentioned that the servos can be controlled simultaneously. This is possible by means of a 'Group Move' command. This is done by setting the numbers of the servos, the

pulse width and the time that the movement should take to reach the new position all in one command. In this way all servos move simultaneously.
This Group Move feature can be especially handy if, for example, you would like to make a robot arm move with a fluid motion. The controller carries out its own calculations, such as the speed at which the servos have to turn.
The controller also contains functions to drive a hexapod, a robot with 6 legs. In this way there is no need to come up with an algorithm for the PC to let the robot walk, because the functions are already there to make the robot move its left or right side with a single command.
The code is freely available since the microcontroller contains open-source software. As a result you can add, improve and remove functionality yourself. Not happy with the hexapod code? You can then 'easily' rewrite it.
In the same way you can also add functionality. For example code to move a robot arm to a particular location in a Cartesian coordinate system. By doing so there is no need to control individual servos from the PC but simply send one coordinate to move the arm the correct way.
Because the controller is both easy to drive and easily modified by an experienced programmer it is very suitable for anyone who would like to spend some time with robotics.

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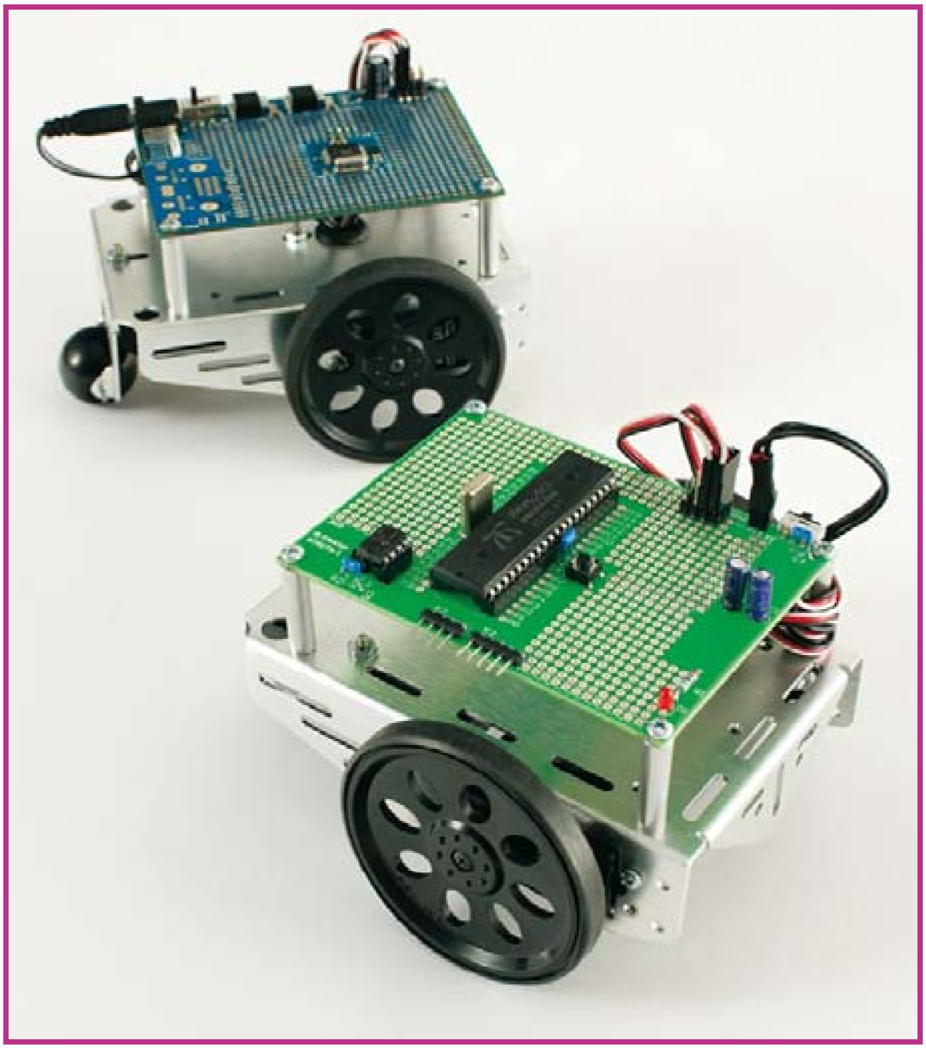
Manufacturer of the controller:
http://www.lynxmotion.com

Propeller Prototyping Board for BoeBot



The Propeller chip made by Parallax Inc. is a bit of a strange animal in the world of microcontrollers. This IC consists of eight 32-bit processor cores that are given access one by one to the peripherals and processor memory. This makes the Propeller extremely fast and it can work without the use of an interrupt mechanism: tasks that used to require an interrupt routine can now be run in their own processor core (called a 'COG' in Propeller-speak). This processor is fast enough to directly drive a VGA monitor for example, and also perform other tasks at the same time as well. We don't have enough space here to go into detail of the operation and the software for the Propeller. All this information and documentation, example applications and extensive development software can be freely downloaded from the Parallax website.

BoeBot

As you may know, Parallax is also the manufacturer of the BoeBot robot kit, a frame with all the required hardware to make a mobile robot that can be equipped with various sensors. All this is controlled by a processor board using a Basic Stamp or Javelin Stamp. The BoeBot with the Basic Stamp was previously covered extensively in a series of articles in *Elektor Electronics*, but that was quite some time ago: end 1999 / early 2000 to be exact. But it's still going strong after all this time, since the BoeBot is even now widely used in education. That was the original purpose of this robot, since 'Boe' stands for 'Board of Education'.

Upgrade

It was only a matter of time before this robot was upgraded with a processor board for the Propeller chip. Parallax has recently brought out a prototyping board

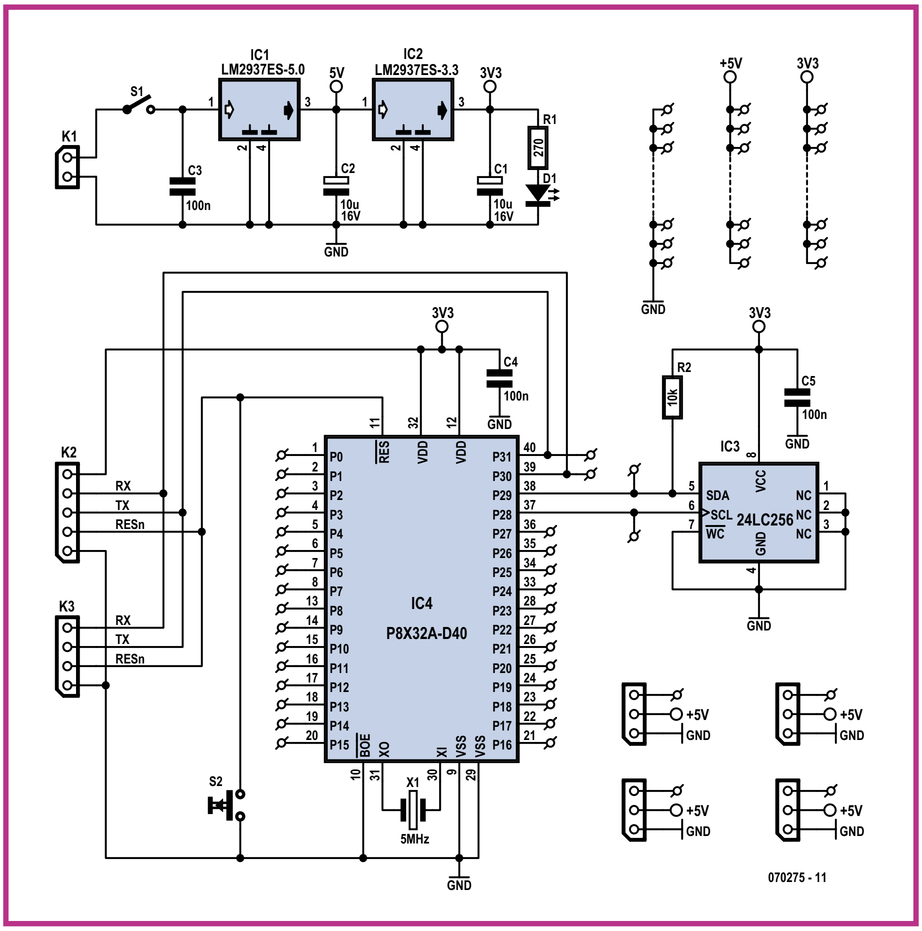


Figure 1: The circuit diagram of the Propeller prototyping board.

that is made to measure for the BoeBot frame. It is noticeable that part of this board now has an ordinary prototyping area for the addition of extra electronics, whereas the 'old' Basic Stamp board came equipped with a mini breadboard. On the Propeller board we therefore have to solder any extra components, which is a bit more time consuming than simply inserting them into a breadboard, but it does make the robot more reliable. Despite being carefully constructed and having well thought out software a robot can still bump into something or become a victim of a passing pet who suddenly discovers a new playmate. When a breadboard is used, some components could become dislodged; with a prototyping board the chances of survival are greater.

The prototyping board is well laid out, has everything you need and is reasonably priced, but we did see a potential disadvantage (especially in education): both the processor as well as the EEPROM are SMD versions. If something is wrongly connected it could mean the end of the processor and in many cases also the end of the board. Not everybody will have the right soldering equipment to replace such parts.

Parallax had no objections when we asked if we could design a version of the board for use with classic DIL ICs. Should something go wrong with one of the ICs on this board it's just a question of simply placing a new chip into a socket (after first finding out what caused the problems, of course!).

These components obviously take up more room of the Boe-Bot frame than their surface mount counterparts. The DIL version of the processor in particular is much larger than its little brother in a LQFP package. Because of this we have left out a few features that were present on the Parallax board, such as the combined VGA, keyboard and mouse connector, since we felt that they're unlikely to be missed in a

Components list

Resistors

R1 = 270Ω
R2 = 10kΩ

Capacitors

C1,C2 = 10µF 16V radial
C3,C4,C5 = 100nF

Semiconductors

IC1 = LM2937ES-5.0
IC2 = LM2937ES-3.3
IC3 = 24LC256
IC4 = Propeller chip P8X32A-D40 (Parallax)

Miscellaneous

X1 = 5MHz quartz crystal
K2 = 5-way SIL pinheader
K3 = 4-way SIL pinheader
S1 = on/off switch
S2 = 1 make contact
4 pcs 3-way SIL pinheader

PCB, order code **070275-1** from Elektor SHOP

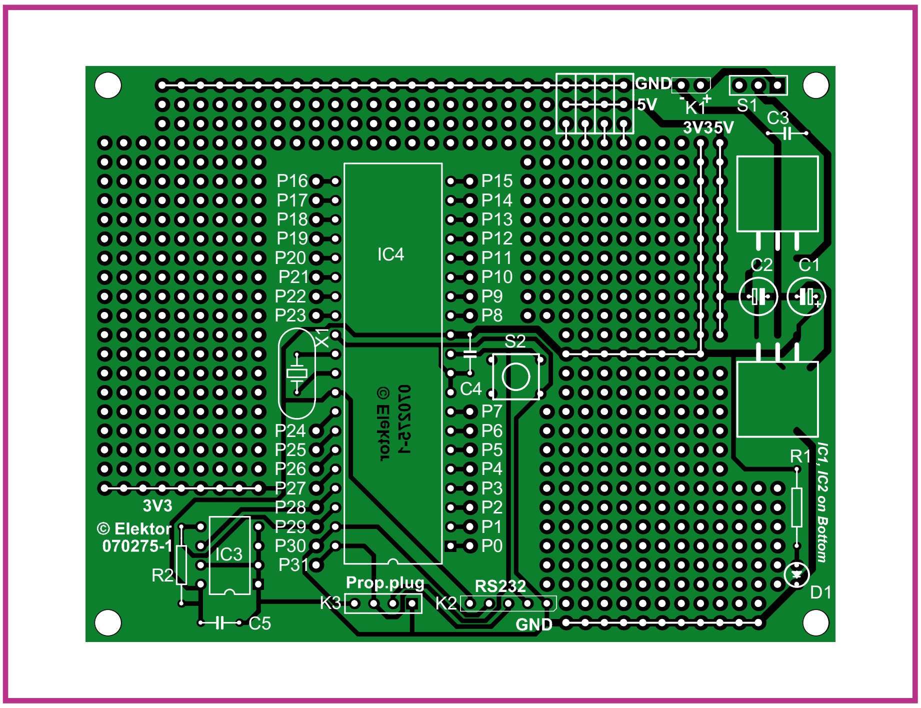


Figure 2: The board layout is single-sided. If you expect to use the prototyping area a lot then a double-sided through-hole plated version would be preferable.

mobile robot.

Circuit diagram

The circuit diagram (shown in **Figure 1**) is conspicuous by its simplicity. Two low dropout voltage regulators provide 3.3 V for the processor and the EEPROM, and 5 V for peripheral devices that require a higher voltage, such as the modified servo motors that propel the BoeBot. Remember that the input pins of the Propeller can't withstand 5 V. Next to S1, the power switch, is a group of four three-pole SIL connectors for the connection of servos and other peripherals that require a 5 V supply.
A power source with a voltage between 5.5 V to 26 V should be connected to K1, but we would advise against using too high a voltage because of the heat dissipation in IC1.
There are two different ways of implementing the programming interface to a PC: K3 is the connector for use with the Propeller Plug by Parallax, which uses a USB link. K2 is used for the simple serial interface that is described elsewhere in this issue.
D1 indicates that the supply voltage is present, and S2 is the reset switch.

Practical side

The PCB is also very straightforward (see **Figure 2**). We have intentionally chosen a single-sided layout because this makes it easier to etch it yourself. Both voltage regulators are soldered on the bottom of the board.
IC3 isn't strictly required to start using the Propeller. When the processor starts it runs its bootloader routine, which first checks if there is a communications link to the host PC and then waits for a program to be downloaded. The user then has the choice of either loading the program into the internal program memory of the Propeller or into the external EEPROM.

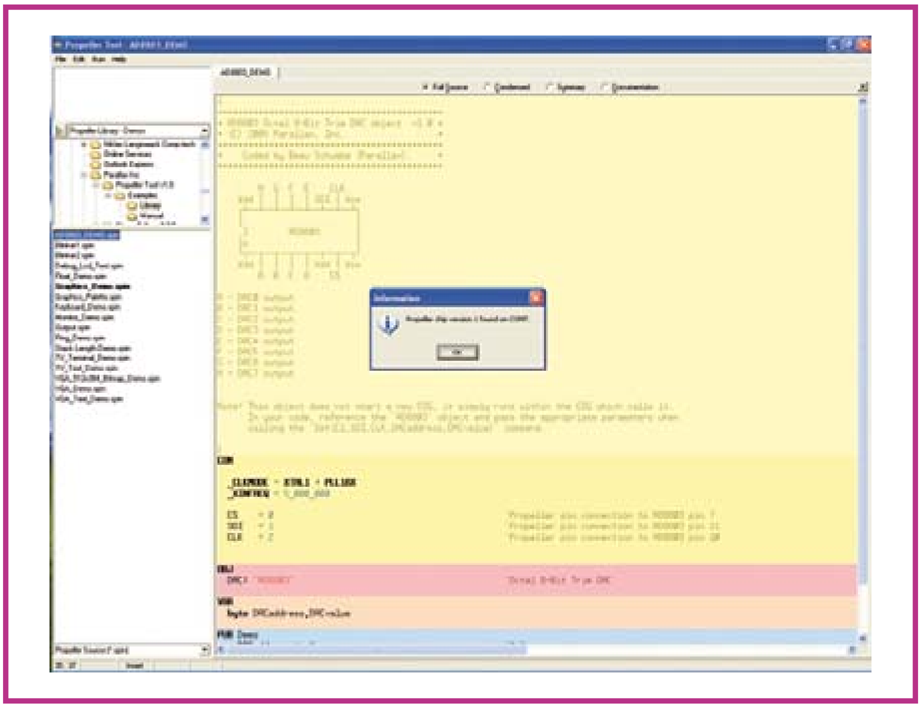


Figure 3: **This message confirms that the Propeller Tool has made a connection and the fun can begin!**

If no communications with a PC are possible, the bootloader will attempt to load a program from the EEPROM; if nothing is found there either, the bootloader stops and the processor turns itself off automatically.
A program can be directly transferred from the PC into the internal program memory and then executed, but remember that this memory is volatile. When the power is turned off, all memory contents are lost.
The crystal can be left out as well, since the Propeller initially uses its internal RC oscillator that runs at a speed of 12 MHz, which is fast enough for most applications. X1 will only be used once the program has set the relevant clock registers.
Once power is applied to the processor and the circuit is connected to the PC, the 'Propeller Tool' should be started and the F7 key pressed (or from the *Run* menu choose the *Identify Hardware* option). The serial ports of the PC are then scanned one by one for the presence of a connection to the Propeller board and if everything is in order a message will appear like the one shown in **Figure 3**. The COM port number will obviously depend on which port the interface is connected to.
Once this message has appeared we can get to work with the Propeller and explore the exiting world of this microcontroller.

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Web Link:

www.parallax.com/propeller

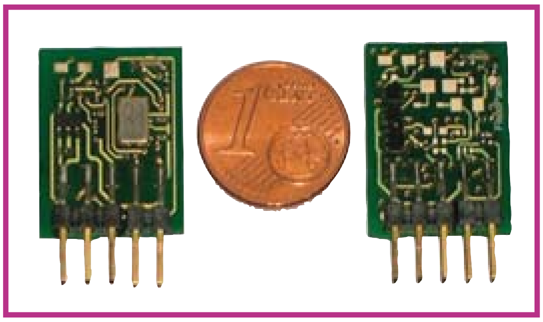
'TEAclipper' Postage-stamp Programmer

Richard Hoptroff

The art of discrete electronics has, over the past decade or so, become subsumed by machine code inside microcontrollers. The firmware is the magic in today's electronic circuits, and rightly so. It's faster, cheaper, easier and more flexible than making changes to the hardware.
Unfortunately, exchanging firmware between people remains in the Dark Ages. If you want to buy someone else's firmware, what can you do? At best you buy a pre-programmed chip from the creator or from a publishing service such as Elektor SHOP or www.hexwax.com. Worst case, you get a hex file and program the microcontroller yourself – provided you have all the necessary equipment to do so. And if there's a bug in the firmware, it's not exactly easy to get an

upgrade.
If only firmware could be more like software. Software is so easy to deliver that we do it without thinking, and as such has generated one of the most profitable industries in the world.

Having the size of a postage stamp, the TEAclipper from FlexiPanel Ltd (www.flexipanel.com) seems a step in the right direction. This microcontroller programmer is an easy, reliable firmware delivery mechanism. It can be pre-loaded with firmware and mailed to a customer, or the customer can download firmware over the internet and send it to the TEAclipper via a USB adapter. The



TEAclipper is then inserted into the target PCB and generates all the signals necessary to program the microcontroller. Connection is via a 5-pin header which also provides power to the TEAclipper.

Since only a temporary connection is required, a socket is not necessarily needed. The pins can be pressed against plated-through holes in the PCB for the few seconds required for programming.

The number of programming cycles can be specified, after which the memory self-erases. This allows firmware to be bought and sold in fixed quantities.
TEAclippers are currently available for programming Parallax's BASIC Stamps and Microchip's PIC Microcontrollers, but support for further microcontroller platforms is planned.

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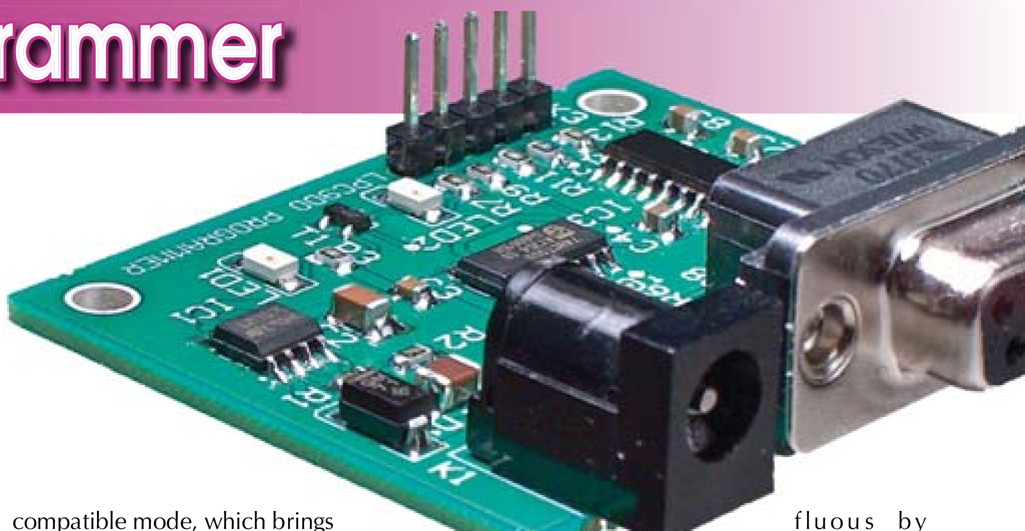
LPC900 programmer



Jürgen Wickenhäuser

The LPC900 family is the Swiss Army knife of 8051-compatible microcontrollers. The 'LPC' in the part number stands for 'low pin count': the NXP (formerly Philips) LPC900 family [1] consists of a range of small and easy-to-use microcontrollers ideal for small-scale high-speed applications. Since the LPC900 family is based on an 8051 core it is easy to learn how to use the devices. However, the LPC900 is more than just a slightly spruced-up version of the 8051. The most important features are as follows:

- 2-cycle high-speed 8051 core (six times as fast as a standard 8051);
- from 1kB to 16 kB of flash memory with full ISP and IAP functionality;
- internal precision 7.3728MHz RC oscillator, ideal for baud rate generation up to 115 kbaud without an external crystal;
- CPUs available in DIL as well as tiny SMD (TSSOP) packages;
- a minimum system requires a single capacitor as the only external component;
- wide range of on-chip peripherals: brown-out detector, watchdog timer, comparators, A/D converter;
- operating voltage 2.4 V to 3.6 V.

The only significant difference from the standard 8051 is the improved I/O structure: they can now also work in a CMOS-compatible mode, which brings many advantages. One important point to note in this regard is than on reset the ports are set to CMOS input mode, and must if necessary be suitably initialised before use.
Otherwise the LPC900 is very easy to use. The datasheet is rendered almost superfluous by the free 'Code Architect' software by Embedded Systems Academy [2]. This tool is capable of creating snippets of C source code directly (see **Figure 1**).

Loading code into the LPC900 microcon-

COMPONENTS LIST

Resistors
R1 = 240Ω SMD (0805)
R2 = 390Ω SMD (0805)
R3,R4,R7,R9,R11,R12,R13 = 1kΩ SMD (0805)
R5,R6,R8,R10 = 220kΩ SMD (0805)

Capacitors
C1 = 4µF7 25V SMD (1206 or 1210)
C2 = 10µF 6V SMD (1206 or 1210)
C3 = 100nF SMD (0805)
C4,C5,C6,C7,C8 = 1µF SMD (0805)

Semiconductors
D1 = GF1M
T1 = BC857 SMD (SOT23)
LED1,LED2 = LED, red, SMD (0805)
IC1 = LM317 SMD (SO8)
IC2 = 74HCT00 SMD (SO14)
IC3 = MAX3232 (SO16)

Miscellaneous
K1 = mains adaptor socket for PCB mounting
K2 = 9-way sub-D socket, angled, PCB mount
K3 = 5-way SIL pinheader
PCB, ref. 070084-1, from www.thepcbshop.com

troller proceeds with a minimum of fuss. When the CPU receives a series of three pulses on its reset pin within a specified time window of being powered up, the CPU jumps to a bootloader, which then proceeds to communicate using the RXD and TXD signals. After code is downloaded these three signals are of course available for their normal use. A five-way cable is required for download.

The hardware required is minimal, as the circuit in **Figure 2** shows. This circuit is capable of supplying the LPC with power and also provides an RS-232 interface, ideal for use with a terminal program. The printed circuit board for the design is shown in **Figure 3**.

Operation is straightforward. The CPU can be powered up and down using the DTR signal. The RTS signal functions as a switch: if RTS is active then signals from RXD are also presented to the reset pin of the CPU, and can thus be used to activate the bootloader. Note that R13 ensures that the supply voltage to the target hardware drops rapidly when it is switched off. It is advisable to limit the capacitance on the 3.3 V rail in the target hardware to approximately 10 µF, since otherwise the microcontroller being programmed might not correctly execute a power-on reset.

The free program ‘Flash Magic’, also from Embedded Systems Academy, can be used to simplify programming the devices. This will be familiar to *Elektor Electronics* readers from the RFID reader project [3]. This tool also includes a suitable terminal program.

An optimising C compiler is also needed to write programs for the LPC900 family. There are various commercial products available; here we will briefly discuss how to use µC/51 [4]. For practically all LPC900 family devices the free demonstration version of the compiler is entirely adequate. The only restriction of the free version is the 8 kB code size limit, but this is already enough to write very complex applications for an 8051-compatible microcontroller,

Figure 1. ‘Code Architect’ is a free tool that makes using the LPC900 microcontroller very straightforward.

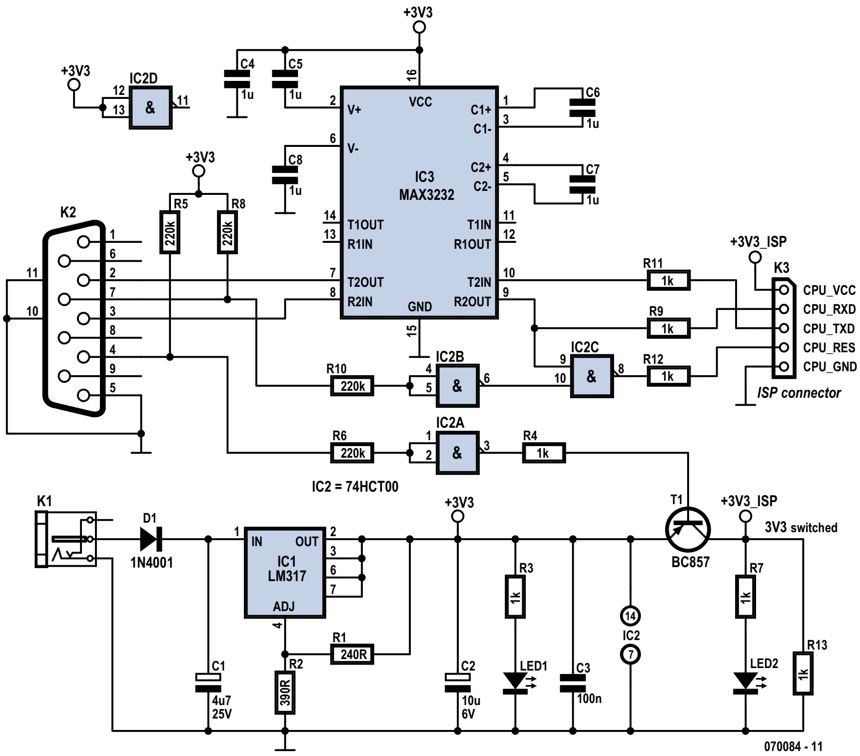


Figure 2. Circuit of the LPC900 programmer.

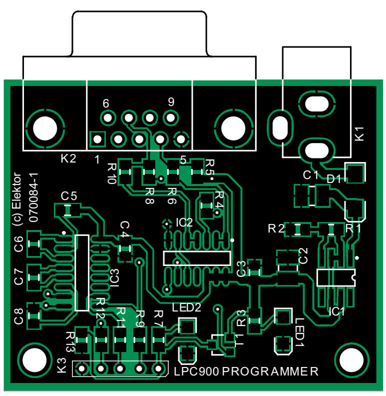


Figure 3. Layout and component mounting plan for the printed circuit board.

Figure 4. Initialisation specific to the LPC900 requires just five instructions.

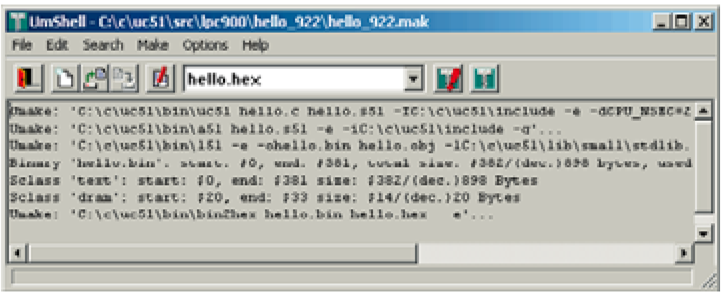


Figure 5. The µC/51 compiler uses a well-structured classical 'make' system.

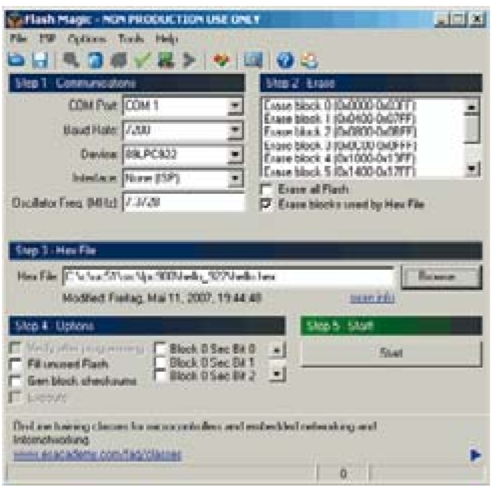


Figure 6. Flash Magic is a free tool for programming LPC microcontrollers.

because the compiler produces very compact code. In particular, the compiler is very parsimonious with the limited internal RAM in the microcontroller, using a graph-based optimisation algorithm to enable multiple re-use of memory areas. For example, even with this very tiny CPU we have a fully-featured 'printf()' function call. The system also includes a reliable and comprehensive floating-point library. The µC/51 system was developed as a tool for the company GeoPrecision [5], and has been used and maintained there for years.

The software tools work very well together and make development very quick: there are just three steps from source code to working program.

For demonstration purposes we used an 89LPC922 with an LED connected to port pin P1.7. The listing shown (**Figure 4**) is an example project included with µC/51 since version 1.20.06. As can be seen from **Figure 5**, the compiler uses a well-structured classical 'make' system. Downloading a program to the microcontroller is an intuitive operation (**Figure 6**). It is recommended that you configure the terminal program embedded within 'Flash Magic' so that it is launched immediately the application is started on the LPC. Note in particular that the RTS and DTR signals must be correctly configured (both active): see **Figure 7**.

(070084-I)

References and links

(1) http://www.standardics.nxp.com/products/lpc900 (NXP, manufacturer of the LPC900 family).

(2) http://www.esacademy.com (Embedded Systems Academy: Flash Magic, Code Architect).

(3) ELEKTOR RFID Reader (using an LPC936), Elektor Electronics, September 2006, p. 26.

(4) http://www.wickenhaeuser.de (µC/51 compiler, demonstration version).

(5) http://www.geo-precision.com (geotechnical research and development).

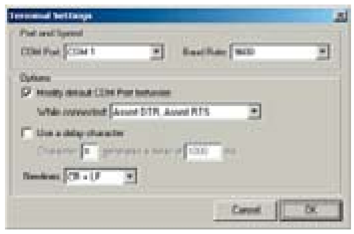


Figure 7. Settings for the RTS and DTR signals in the Flash Magic terminal program.

Low² Cost USB Demo Board

C your way through USB

Martin Valle

Slick graphics, reading analogue values and making them appear in graphs, cockpit-style meters and dials, all on USB… *How do they do it?*

USB Quick & Easy

- 2 analogue inputs (1 on pot)
- 2 digital inputs (switches)
- 4 digital outputs (LEDs)
- 1 (one) IC: PIC18F4550 (available ready-programmed)
- Full suite of software building blocks
- Project software for Builder C++ 6
- Demo program for 2-channel A/D with graph/meter readout on PC

Like this: a single board connected up to the PC via a USB link and sporting an advanced PIC microcontroller. Add some software and there's your USB demo board doubling as a development system to help you discover how USB is implemented on a microcontroller programmed to handle analogue and digital I/O for real world applications.

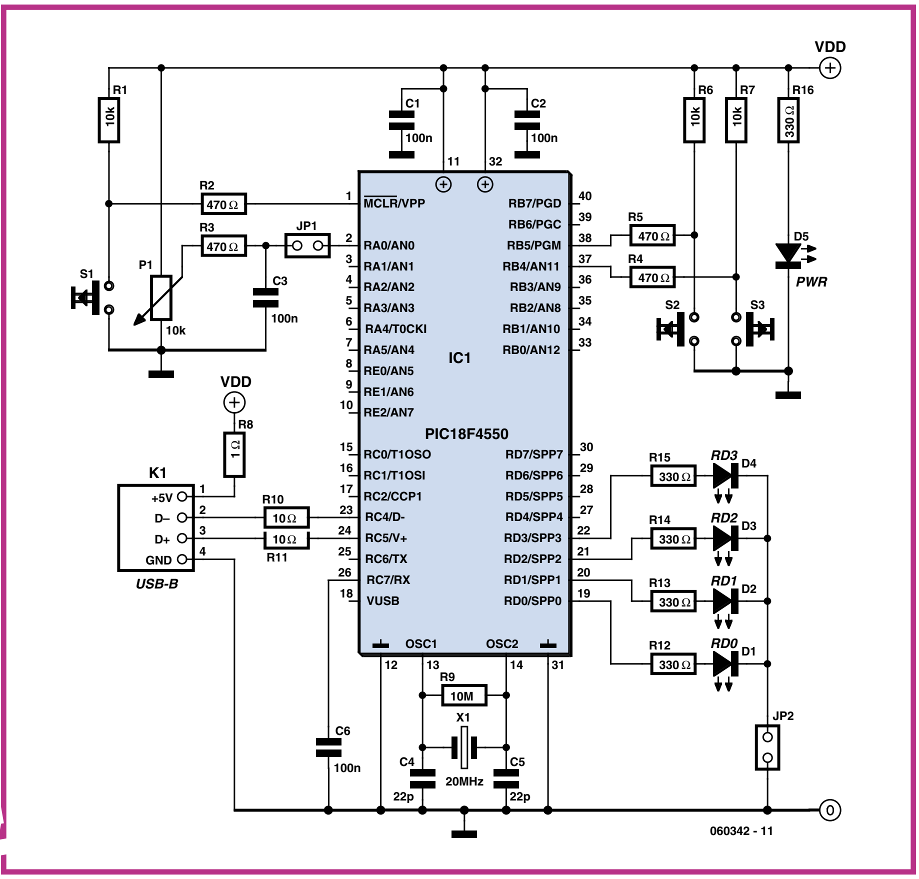


Figure 1. Schematic of the USB demo board.

Hardware

At the heart of the circuit in **Figure 1** is a PIC18F4550 microcontroller from Microchip. This has built-in USB connectivity — if you know how to activate it! The micro is clocked at 20 MHz by quartz crystal X1. The switches (except S1), LEDs (except D5) and the potentiometer connected up to the PIC micro are your basic I/O (input/output) devices.

The circuit should be easy to build on a piece of prototyping board or Veroboard (a.k.a. perfboard or stripboard).

Software

In stark contrast with the minimal hardware, the software for this project is quite extensive. You will like to hear that it's available free of charge from the Elektor website as archive # **060342-11.zip**. The ready-programmed PIC18F4550 for the project is available too, it's item **060342-41** from the Elektor SHOP.

There are actually four zipped files: **MCHPFSUSB.zip** contains all the project components freely available from Microchip plus the custom project for the microcontroller, the demo version software and

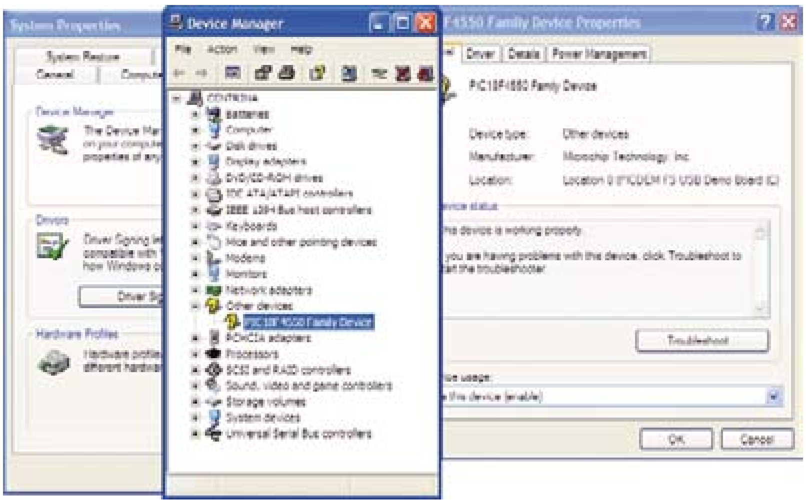


Figure 2. Device Manager showing the installation of the PICDEM FS USB Demo Board.

the bootloader 'talker'.
Project.zip contains all the files needed to build the project in Builder C++ 6.
REQUIRED.zip contains the files of the *project.zip* that you have to copy if you want to make a new project.
Without builder.zip contains all the files needed to run the .exe file without the Builder installed in the computer.

Here's how to process the software.
1. Extract the file *MCHPFSUSB.zip* to the C: root directory. Check that there is no duplicated folder MCHPFSUSB, like: *C:\MCHPFSUSB\MCHPFSUSB\folders_xx*, instead of: *C:\MCHPFSUSB\folders_xx*.
2. Using a suitable programmer, program the PIC18F4550 microcontroller with the file: *C:\MCHPFSUSB\fw_factory_hex\picdemfsusb.hex*. The chip is also available ready-programmed.

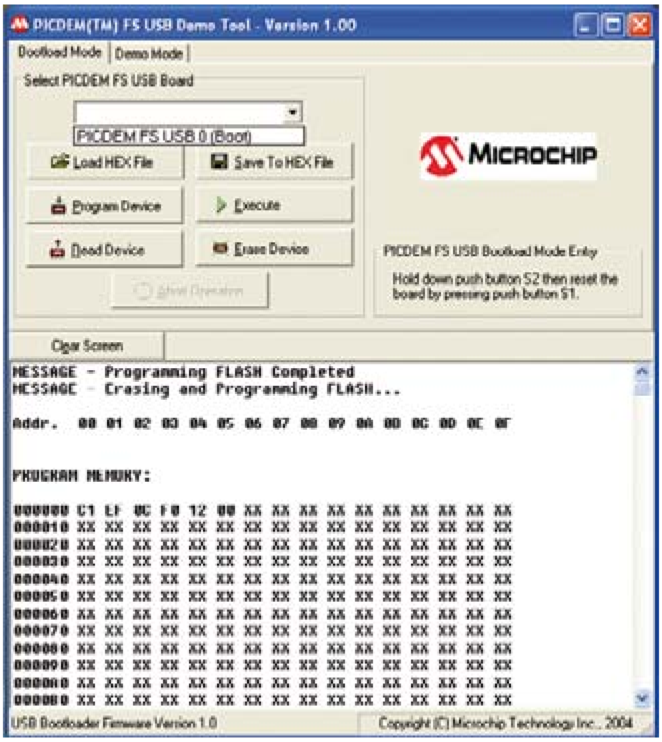


Figure 3. **PICDEM FS USB tool showing the board (device) connected.**

Waking up the F4550

Once you have built the project and checked it for mistakes, you can connect the USB to the host. For the first time connection, Windows XP is recommended. As soon as you connect the board to the host, LEDs D0 and D1 will start to blink, then the host will detect the device as 'PICDEM FS USB Demo Board (C) 2004' and ask for the drivers. You should select the drivers located in:
C:\MCHPFSUSB\Pc\MCHPUSB Driver\Release
Windows will nag that this device does not pass the Windows logo test. Ignore and simply continue the installation of the device.
You can check for the proper installation by exploring in the Device Manager window, it should look like **Figure 2**.
Keep pushbutton S3 (RB4) pressed and the reset the microcontroller by pressing and releasing S1. This procedure takes the microcontroller into 'bootloader' mode. The host will detect a new device, and it is necessary to repeat the driver installation procedure with the same driver location:

C:\MCHPFSUSB\Pc\MCHPUSB Driver\Release

From now on you can load new programs to the microcontroller via the bootloader, following the above sequence using the S3 and reset pushbuttons.
The PC application that communicates with the bootloader is the executable file: *C:\MCHPFSUSB\Pc\Pdfsusb\PDFSUSB.exe*
The Pdfsusb tool must show in the selection square the device connected just as in **Figure 3**.

Demo mode and a small hurdle

If you reset the board without keeping S3 pressed, the microcontroller will run the program loaded in memory (i.e., not the bootloader). The same if you click the '/Execute' button in the application. That's why the first device detected by the host was not the bootloader — it was a program to test with the other part of the Pdfsusb tool (Demo mode), this is the upper left tab behind the Bootload Mode tab. This mode is shown in **Figure 4**. It allows reading an approximation of the position of the potentiometer connected to RA0, control the state of the LEDs connected to RD2 and RD3 and measure a temperature of an SPI sensor that's not actually connected to the board (so don't pay attention to the temperature readings).
The Demo firmware uses a few pins to monitor the USB main voltage (this is not implemented in the schematic). It may happen that this check fails after connecting the device to the computer. Fortunately, the error applies to the **Demo firmware only**, not to the Bootloader. There is an easy way to avoid this — in every project contained in the MCHPFSUSB folder there is a file *C:\MCHPFSUSB\fw\project_name_folder\autofiles\usbcfg.h*. It contains the declarations that are causing the problem. Just comment-out (//) the two SENSE_IO definitions as shown **Listing 1**.
Having done this you can reload the Demo project, or any project for that matter, and all should work fine.

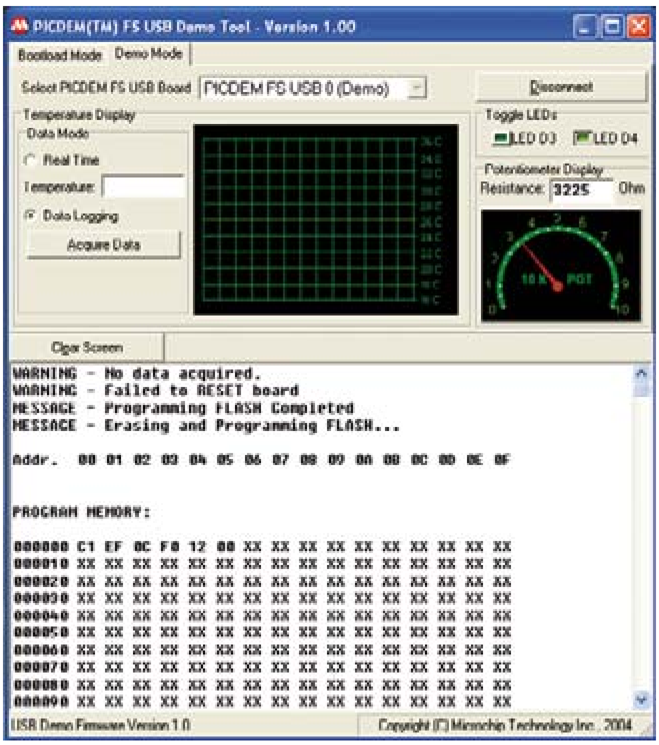


Figure 4. **Demo Mode of the Pdfsusb tool.**

Build it!

Now, it is time to explore the example application. As before, reset the microcontroller with S3 pressed, to run the Bootloader and load the micro with the hex file located in:

C:\MCHPFSUSB\fw\Hid02/_output/ NICAPM.hex

Then, run the program.

You can run the PC application directly without C++ Builder 6 installed in the computer by using the stuff in the archive file called: *without builder.zip*. Obviously the microcontroller must be connected to the host and running the NICAPM firmware.

The window of the demo application should look like **Figure 5**, showing the signals of Channel 0 (AN0, pin 2) and Channel 1 (AN1, pin 3). There's also the archive file called *project.zip* if you want to modify something in the PC project.

If you want to make a new Builder project, you only have to look after two things:

1. Add the hid.lib file by doing:
   Project → Add to project → hid.lib

2. Change the Data alignment from Quad word to byte by doing:
   Project → Options → Advanced Options → Data alignment.

(060342-I)

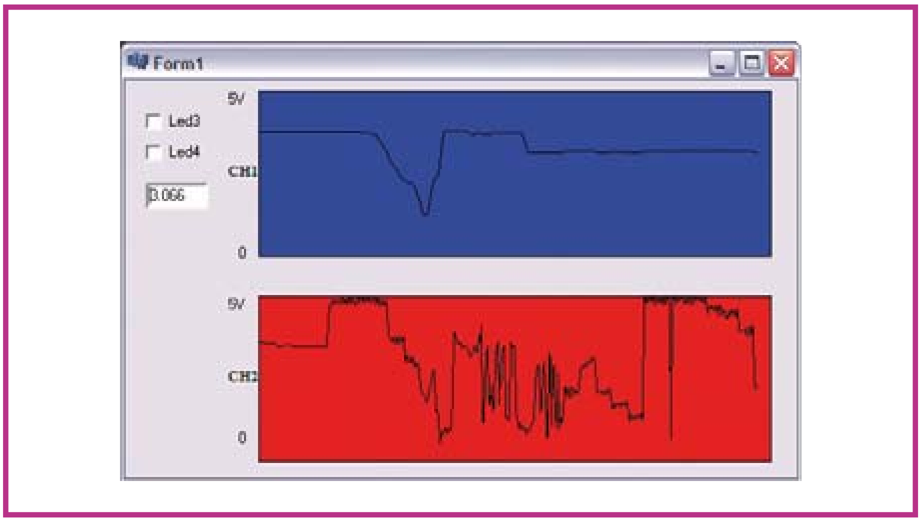


Figure 5. Two ADC Channels and USB of the PIC in action.

Listing 1.

```
/** D E F I N I T I O N S ******************************************/
#define EP0_BUFF_SIZE          8   // 8, 16, 32, or 64
#define MAX_NUM_INT            1   // For tracking Alternate Setting

/* Parameter definitions are defined in usbdrv.h */
#define MODE_PP                _PPBM0
#define UCFG_VAL               _PUEN|_TRINT|_FS|MODE_PP

//#define USE_SELF_POWER_SENSE_IO
//#define USE_USB_BUS_SENSE_IO
```

Optimised STK200/300 Programmer

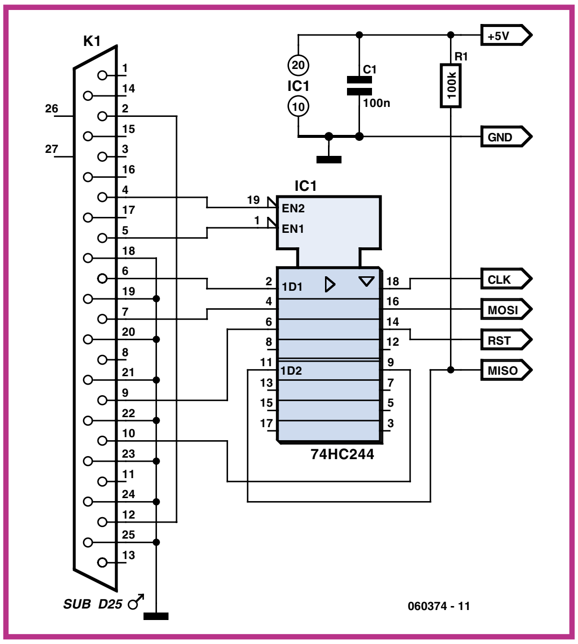
for AVR Micros

Hesam Moshiri

The STK200/300 programmer is found in nearly every programmer software for Atmel AVR microcontrollers. The programmer shown here differs from other, similar, circuits in not requiring any extra power supply for itself, while still offering STK200 as well as STK300 programmer functionality.

In case you did not know, AVR microcontrollers can be programmed in-circuit with only five wires: Clock, MOSI, MISO, Reset and Ground. To these should be added the +5 V supply voltage taken from the microcontroller on the target board.

The programmer schematic contains nothing more than one buffer IC type 74HC244, one 25-pin male sub-D connector for hooking up to the parallel printer port ('Centronics') on the PC, a 100 kΩ pull-up resistor on the MISO line and a .1 µF decoupling capacitor on the +5 V supply rail.



With some tinkering, the complete circuit can be fitted in the sub-D connector housing. A short length of flatcable and a 6-way IDC socket at the target board side complete the programmer. After programming, you simply disconnect the programmer cable from the target board.

The STK200 or STK300 programmer hardware is available in lots of microcontroller programmer software, for example, BASCOM and CodeVision.

(060374-I)

Satnav for Robots

GPS guidance for autonomous vehicles

Ulli Sommer

A (frequently unfulfilled) ambition of every robot builder is to make their machine capable of autonomous navigation. This is an ideal application for a GPS receiver module: these have recently become very cheap to buy. Our GPS-based navigation system is built around an ATmega32, programmed using BASCOM BASIC. It communicates with the outside world using an I²C bus.

Any robotics hobbyist would dream of being able to build a robot which, like the famous Mars Sojourner Rover, can autonomously negotiate unknown terrain. Ideally one would just program in the coordinates of the desired destination and the little chap would make his own way there automatically. Although fully autonomous robots must remain a pipe dream for now, a solution is available to the navigation problem, as we demonstrate here with a circuit board designed to be added to a domestic surveillance robot (see large photograph).

Rather than develop a navigation system from scratch ourselves we make use of low-cost receiver modules that receive and process signals from the GPS satellite positioning system. To this we add a moderately powerful microcontroller that can be programmed using free software.

ATmega at the helm

Our GPS-based navigation system is built around an Atmel ATmega32, which appears at the heart both of the circuit diagram (**Figure 1**) and of the prototype printed circuit board (**Figure 2**). The microcontroller is programmed in a dialect of BASIC using the BASCOM development system, which is widely used and available for free (for the demonstration version at least) download from the manufacturer [1]. Also, the source and object files for the navigation program are available for free download from the *Elektor Electronics* website. The file reference is **070350-11.zip**. An ISP cable is also required, obtainable for example from [3].

Any commercial GPS 'mouse' receiver can be used as long as it has an RS-232 interface. If the interface uses TTL signal levels it can be connected directly to our printed circuit board; if, on the other hand, it uses standard RS-232 levels (up to ±15 V) a MAX232 level shifter must be connected

How to program track points

Before attempting any autonomous journeys we must program a series of set coordinates ('track points') into the navigation system. The first step is to replace the GPS mouse with a (null modem) data cable, connected to a PC. On the PC, start up a terminal emulator program such as Hyperterminal. A terminal emulator is also included in the BASCOM package.

The interface parameters must be set as for the mouse (i.e., to 4800 baud). When connection has been set up, press the reset and programming buttons simultaneously. Then first release the reset button and then the programming button around a second later.

You should see a welcome message (which indicates how to get help) and a prompt on the terminal.

The following commands are also available: 'Data' lists the stored GPS data; 'Input' allows the GPS data to be edited; and 'Reset' restarts the navigation system.

The coordinates of the track points can be determined using a separate GPS system; alternatively, the robot can be moved manually to each track point in turn and the coordinates read off the LCD.

With the track point data programmed in, the robot can be left to its own devices!

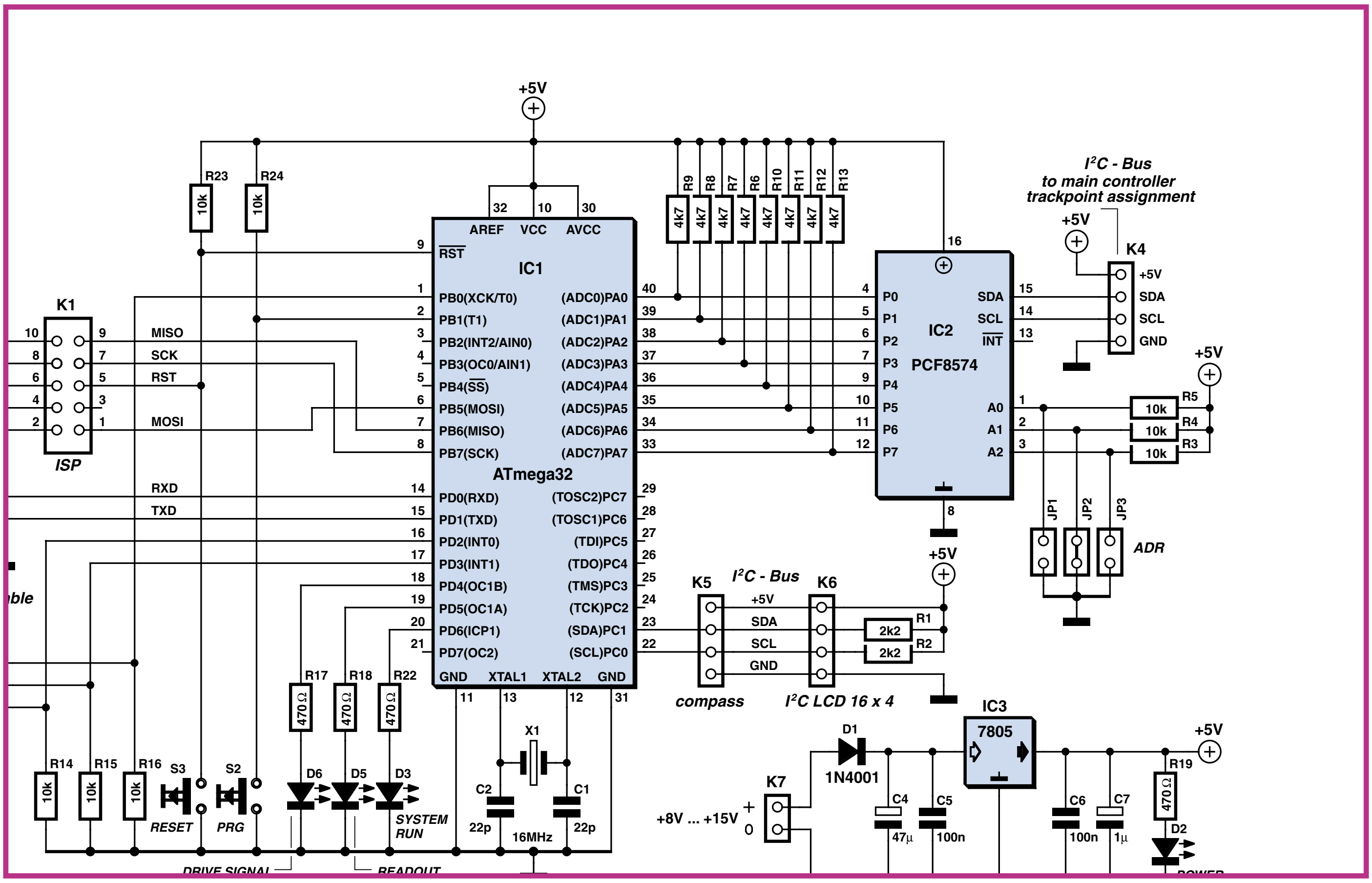


Figure 1. The ATmega32 communicates with the compass and the LCD over an I²C bus; the GPS mouse is connected via RS-232. The PCF8574 I²C interface chip takes on the task of accepting a control byte and making it available on pins 33 to 40 of the ATmega.

in between. Often a robot's main circuit board will already have a suitable level shifter IC on it.

The GPS mouse gives the exact geographic coordinates (latitude and longitude) in a defined format: see text box. It can also determine the compass direction of movement if its speed is more than about 3 km/h to 5 km/h. Since we wish to determine orientation even when stationary we require an additional 'electronic compass' (see block diagram in **Figure 3**). A suitable compass module is, for example, the Devantech CMPS03, available from [4]. This compass is connected to the I²C port on our printed circuit board.

If we want to display the position and orientation we will also need an LCD module. The microcontroller is rather lacking in I/O port pins, and so the most practical solution is to drive the display also via the I²C bus. There do exist LCD modules with built-in I²C interfaces, but an alternative is to use an I²C interface chip such as the PCF8574 [5] (see **Figure 4**). We will see another use of this device in our circuit later on.

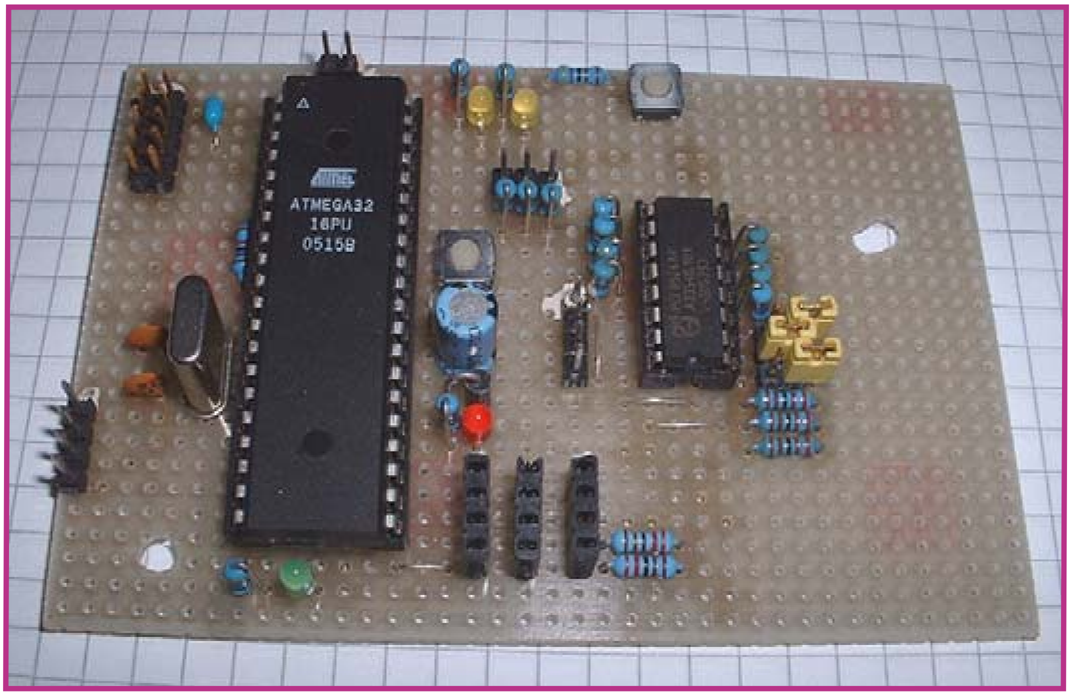


Figure 2. Prototype navigation system printed circuit board for autonomous robots.

Motor control

Of course we do not just want our robot to display where it is; we want it to make its

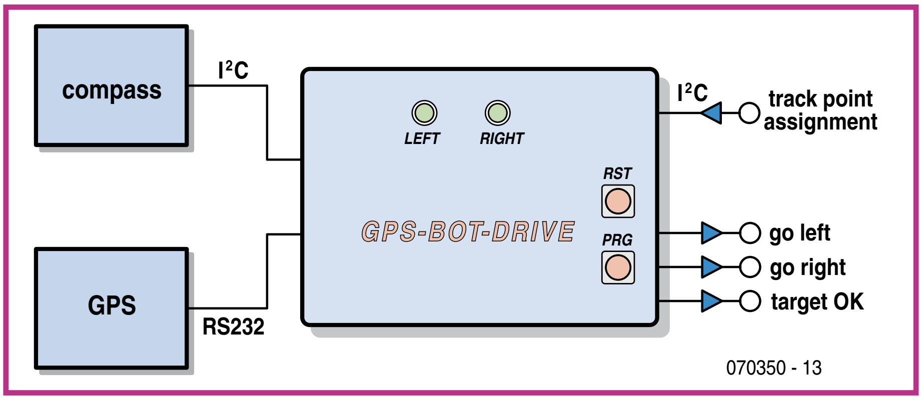


Figure 3. **Simplified block diagram of the navigation system. The buttons are used when programming. Commands for the motors are output on two port pins.**

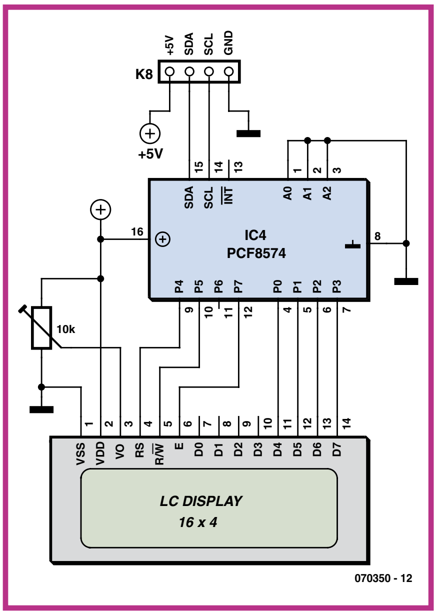


Figure 4. **The LCD is driven over an I²C bus, the PCF8574 interface chip making a second appearance in the circuit (see Figure 1).**

way to our desired destination. In doing this the navigation system outputs direction control information on two pins. Output pins Motor_l and Motor_r combined give the desired direction of travel as follows:

Motor_l	Motor_r	Function
0	0	STOP
1	1	straight on
1	0	turn left
0	1	turn right

Now we need a way to tell the robot navigation system where we want it to go. To do this we first need to program a series of set coordinates ('track points') into the unit, which is done using the cable before attempting any autonomous journeys (see text box). In normal operation the navigation system then only needs to be told which track point it should try to visit next, which can, for example, be done by the robot's main processor.

This second communications challenge is also solved using the I²C bus, which is easy to use from within BASCOM BASIC. A PCF8574 I²C interface chip takes on the task of accepting a control byte and making it available on pins 33 to 40 of the ATmega (see Figure 1). The software configures the device to run in input mode. For a simpler hardware design, it is of course possible to dispense with the interface chip and drive the port pins of the ATmega32 high and low directly and in parallel.
To select, for example, track point 1 using the I²C interface we must send the number '1' to the PCF8574. In BASCOM BASIC this might be done as follows.

```
I2cstart
I2cwbyte &H7A (address of
PCF8574: see data sheet for
addressing scheme)
I2cwbyte 1 (track point number)
I2cstop
```

When the track point selection byte has been sent, the navigation system determines the direction to the destination. This calculated direction is then compared to the current orientation of the robot (obtained from the compass). In this calculation we ignore the curvature of the earth, since we do not expect our robot to embark on long-distance journeys!

If the desired and actual directions are in agreement, the robot advances in a straight line. If, as it moves, the robot should deviate from the line to the destination, the navigation system swings into action and brings it back on course. If the quality of the GPS signal is too poor or too few satellites are visible the robot will wait until an adequate signal is available to recalculate the desired course.

When the destination is reached the robot stops and takes the pin Dest_ok high. This signal can be used by the robot's main processor, for example to load up the next track point so that the machine traces out a predetermined course.

(070350-I)

Web links

(1) http://www.mcselec.com

(2) http://www.elektor-electronics.co.uk

(3) http://www.kanda.com

(4) http://www.robot-electronics.co.uk

(5) http://www.nxp.com/cgi-bin/pldb/pip/pcf8574

GPS mouse data

A typical data packet received from a GPS mouse using the simple $GPGGA protocol might appear as follows.

```
$GPGGA,191410,5212.9324,N,00007.5930,E,1,04,4.4,11.5,M,48.0,M,,*73
```

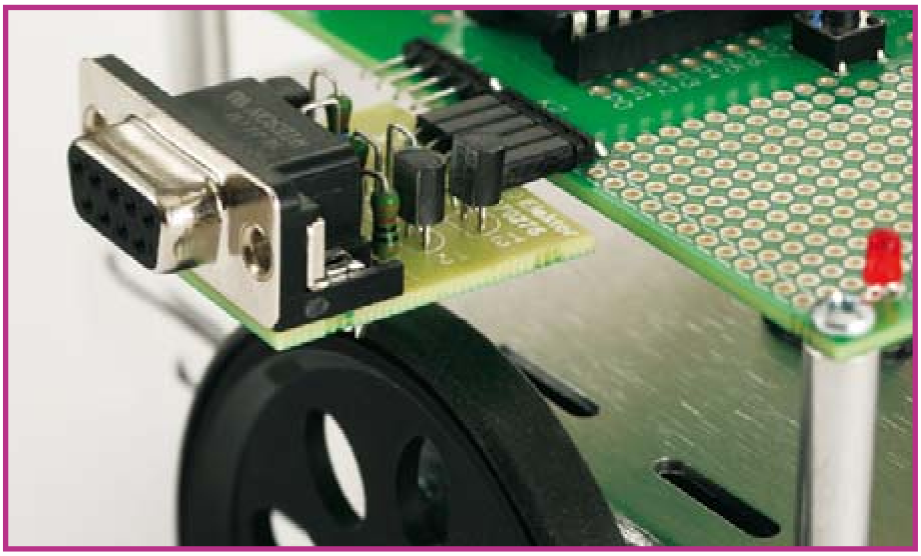
Protocol
Time
Latitude
Longitude
no. of visible satellites
measurement quality (0=insufficient, 1=ok)

Here '$GPGGA' is the protocol type, '191410' the time, '5212.9324,N' the latitude, '00007.5930,E' the longitude, '1' indicates that the reading is valid and '04' is the number of satellites in view. As you can see, this covers all the information we need. All we need to do is switch the GPS mouse to the $GPGGA protocol and set the communication speed to 4800 baud. Other protocols should be disabled, and the reporting interval set to approximately 1 s. The settings are made using the software provided with the GPS mouse.

Serial Interface for the Propeller

Simple and inexpensive

Luc Lemmens



The Propeller prototyping board described elsewhere in this issue needs a programming interface, just like the board available from Parallax. The manufacturer offers the Propeller Plug and the Propeller Clip for this purpose. They can be used to link the board to a PC via a USB port. These mini-boards are fitted with an FTDI FT232 IC, which has appeared quite regularly in the magazine. The difference between the Plug and the Clip is in how they connect to the processor board. The Plug connects to a 4-way SIL header, while the Clip connects to four solder pads at the edge of the board. The latter type of connection was used in the first version of the Propeller demo board, and it is actually no longer relevant. The Propeller Plug is the right USB interface for the prototyping board from Parallax and our prototyping board. This little board costs around twenty euros, but if you want to save a bit of money and prefer to use the old faithful RS232 interface (and your PC has a serial port), you can build the simple serial interface described here.

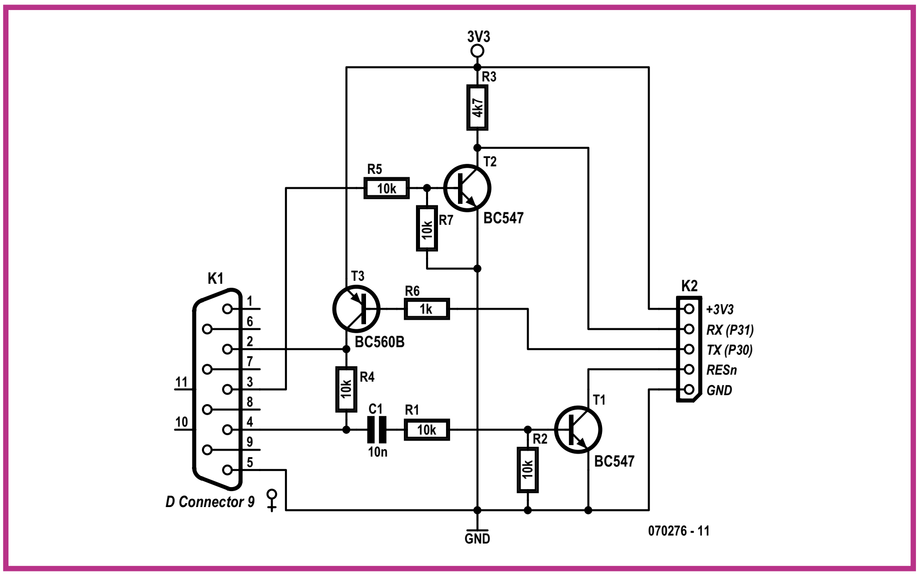
Three garden-variety transistors, a handful of resistors, and a capacitor are all it takes to let the Propeller communicate with a PC via the serial port. The interface actually consists of nothing more than three inverters and level shifters, which enable the Propeller board (which is powered from a 3.3-V supply) to talk to the COM port of a PC, which operates with ±12-V signals.

Connector K2, which provides the link to the Propeller board, has intentionally been laid out with the signal lines in the same sequence as on the Propeller Plug, but here we need an additional line for the 3.3-V supply voltage. This makes it possible to use the interface board with the Parallax board as well. However, in that case a small modification is necessary for the supply voltage connection.

We have designed a small PCB for this circuit, but of course it's no problem to build it on piece of perforated prototyping board instead. With a bit of effort, you can probably even make it so compact that the entire circuit fits in a plug housing for a 9-way RS232 connector.

Fortunately, when you use this interface you don't have to worry about configuring all sorts of settings (baud rate, number of bits and so on) — the Propeller Tool development software does all this for you. Use a 1-to-1 cable for the serial link (not a crossover cable or null modem cable).

(070276-I)



COMPONENTS LIST

Resistors

R1,R2,R4,R5,R7 = 10kΩ
R3 = 4kΩ7
R6 = 1kΩ

Capacitors

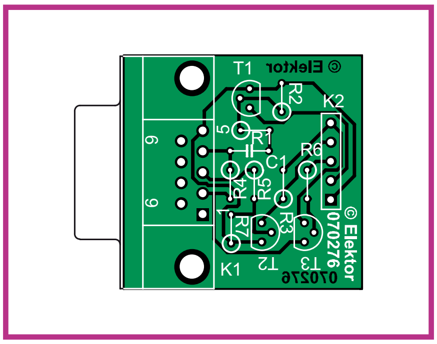
C1 = 10nF

Semiconductors

T1,T2 = BC547
T3 = BC557

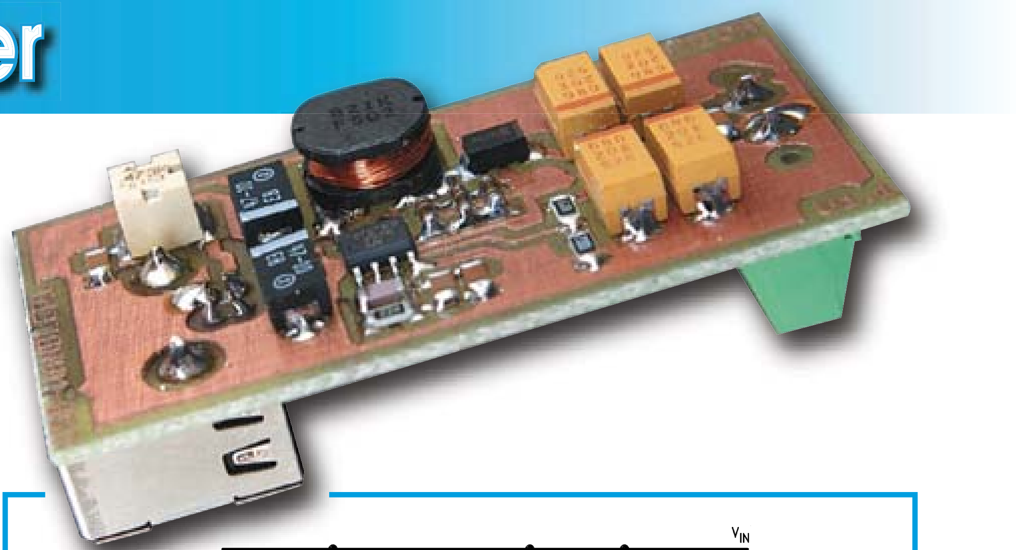
Miscellaneous

K1 = 9-way sub-D socket (female), angled pins, PCB mount
K2 = 5-way SIL socket
PCB, ref. 070276-1 from www.thepcbshop.com



USB Converter

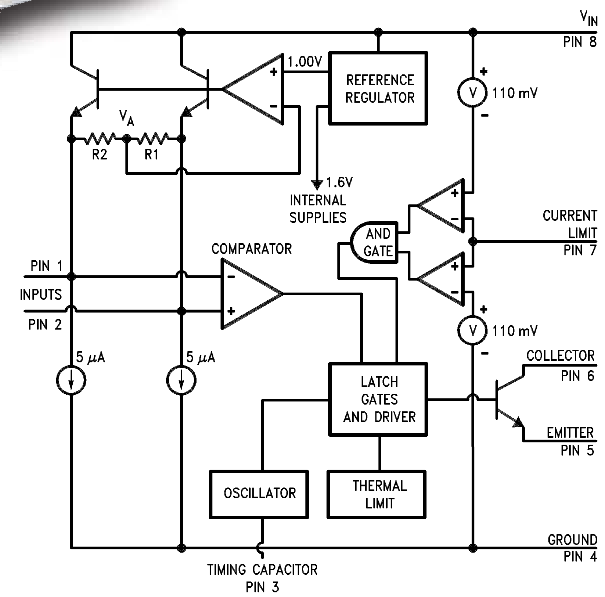
Jörg Schnyder



Does this sound familiar: you buy a small piece of equipment, such as a programming & debugging interface for a microcontroller, and you have to use a clunky AC wall adapter to supply it with power? It's even worse when you're travelling and there's no mains socket anywhere in sight. Of course, you can use the USB bus directly as a power source if the supply voltage is 5 V. If you need a higher voltage, you can use the USB converter described here. This small switch-mode step-up converter can generate an output voltage of up to 15 V with a maximum output current of 150 mA.

The LM3578 is a general-purpose switch-mode voltage converter. **Figure 1** shows its internal block diagram. Here we use it as a step-up converter. The circuit diagram in **Figure 2** shows the necessary components. Voltage conversion is achieved by switching on the internal transistor until it is switched off by the comparator or the current-limiting circuit. The collector current flows through coil L1, which stores energy in the form of a magnetic field. When the internal transistor is switched off, the current continues flowing through L1 to the load via diode D1. However, the voltage across the coil reverses when this happens, so it is added to the input voltage. The resulting output voltage thus consists of the sum of the input voltage and the induced voltage across the coil. The output voltage depends on the load current and the duty cycle of the internal transistor. Voltage divider R5/R6 feeds back a portion of the output voltage to the comparator in the IC in order to regulate the output voltage. C5 determines the clock frequency, which is approximately 55 kHz. Network R4, C2 and C3 provides loop compensation. The current-sense resistor for the current-limiting circuit is formed by three 1-Ω resistors in parallel (R1, R2 and R3), since SMD resistors with values less than 1 Ω are hard to find. The output voltage ripple is determined by the values and internal resistances of capacitors C11, C8, C7 and C6. The total effective resistance is reduced by using several capacitors, and this also keeps the construction height of the board low. L2, C1, C9 and C10 act as an input filter. Ensure that the DC resistance of coil L2 is no more than 0.5 Ω. Use a Type B PCB-mount USB connector for connection to the USB bus. A terminal strip with a pitch of 5.08 mm can be used for the output voltage connector. Of course, you can also solder a cable directly to the board. Two additional holes are provided in the circuit board for this purpose.

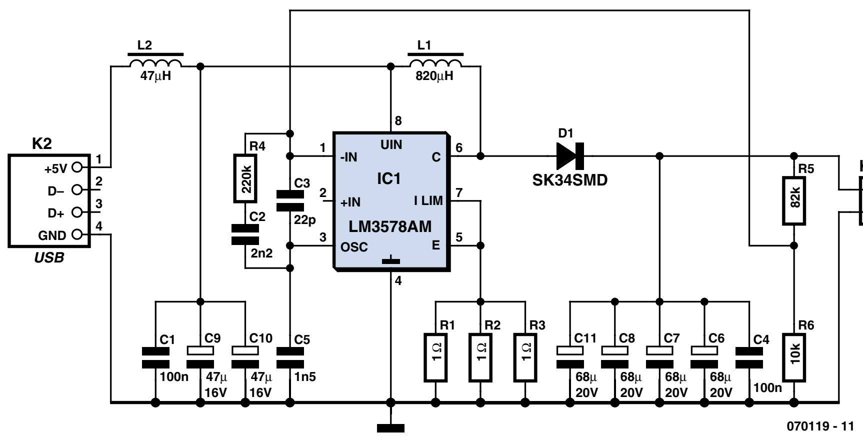
As we haven't been able to invent a device that produces more energy than it consumes, you should bear in mind that the input current of the circuit is higher than the output current. As a general rule, you can assume that the input current is equal to the product of the output current and the output voltage divided by the input



1

R5 and R6 for other output voltages:

6V:	R5 = 47k, R6 = 9,1k
12V:	R5 = 110k, R6 = 10k
15V:	R5 = 130k, R6 = 9,1k



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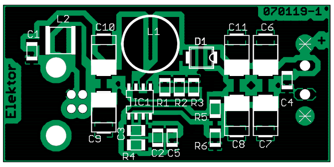


3

voltage and divided again by 0.8. Specifically, with an output current of 100 mA at 9 V, the input current on the USB bus is approximately 225 mA.

Finally, **Figure 3** shows a small PCB layout for the circuit. All of the components except the connector and the terminal strip are SMDs.

(070119-I)

Web link

Author's homepage: www.systech-gmbh-de

components list

(for U_O = 9 V)

Resistors

R1,R2,R3 = 1Ω
R4 = 220kΩ
R5 = 82kΩ
R6 = 10kΩ

Capacitors

(SMD 1206)
C1 = 100nF
C2 = 2nF2
C3 = 22pF
C4 = 100nF
C5 = 1nF5
(tantalum SMD 7343)
C6 = 68µF 20V
C7 = 68µF 20V
C8 = 68µF 20V
C9 = 47µF 16V
C10 = 47µF 16V
C11 = 68µF 20V

Inductors

L1 = 820µH (SMD CD105)
L2 = 47µH (SMD 2220)

Semiconductors

D1 = SK34SMD (Schottky)
IC1 = LM3578AM (SMD SO8)

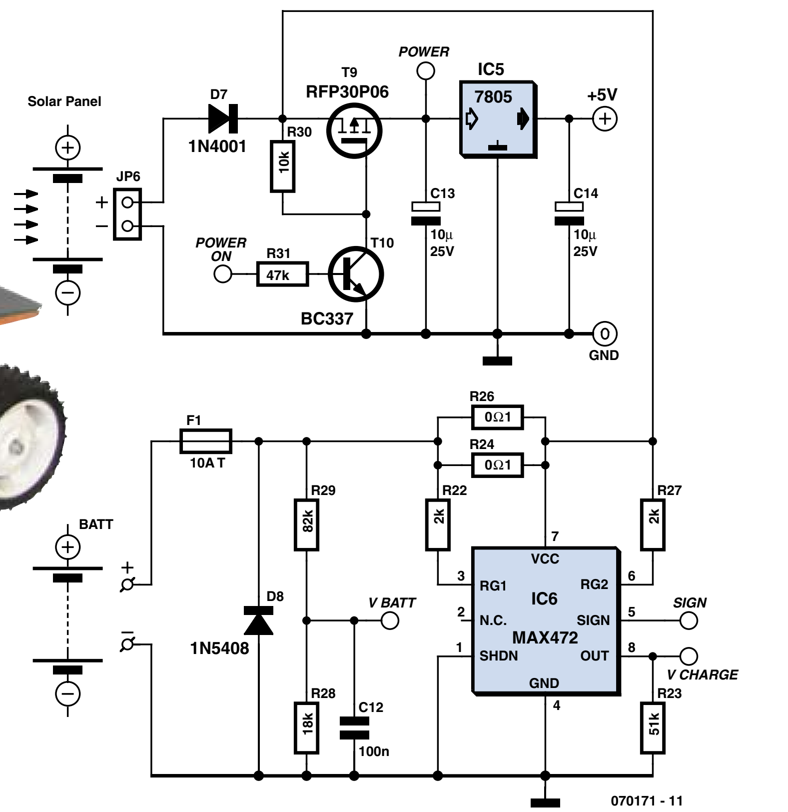
Miscellaneous

K1 = 2-way PCB terminal block, lead pitch 5mm (optional)
K2 = USB-B connector
PCB layout, free download from Elektor website, **070119-1.pdf**

zBot: Solar/Battery Power Supply

Jens Altenburg

One of the most important problems of mobile robot platforms is associated with the power supply. With exception of some special systems, batteries, dry or rechargeable, are the most commonly seen sources of electrical power in robots.



The power supply system of zBot[1] consists of two parts, the main accumulator and the auxiliary battery. The main power source was realised with a NiCd or NiMH battery pack. Its size was adapted to fit the battery holder of the Tamya chassis (six 1.2V/1400 mAh C cells). The main power is activated for DC motor driving and for the servos.

The auxiliary system, two Alkaline AAA batteries, is for the power supply of the microcontroller only.

A third (optional) power source is the solar panel. It is not really necessary for initial experiments but it helps to keep the robot autonomous longer.

The circuit of zBot's main power supply system includes a special feature: the charge control circuit based around a MAX472. For effective operation, we have to know the exact capacity of the battery. Imagining the discharge voltage diagram, we know that the voltage is virtually stable for most of the discharge time and suddenly breaks down when the battery runs out of capacity. This time is very short, so it could happen that the robot could be lost.

A simple voltage control doesn't give us the information we need. The only way to obtain exact values is monitoring the discharging. The MAX472 gives two values, the current through R24//R26 as a proportional voltage at pin 8, and the current direction through the resistors (SIGN). Both values allow calculation of the charging (solar panel) or discharging of the battery pack.

The auxilliary power is shown in the CPU unit. The two alkaline batteries support the CPU, the wireless radio modem and the navigation system (compass) only.

The reason for the division of the power supply is simple. With the help of the auxiliary system, zBot communicates with the operator wirelessly. In this way, the independent power source increases the security of the system.

(070171-I)

(1) The complete document called Zbot — the Robot Experimental Platform is available for free downloading from the Elektor Electronics website. The file number is 070172-11.zip (July/August 2007).

3-A Wide-input Adjustable Switching Regulator

Luc Lemmens

The PTN78060 is a series of high-efficiency, buck-boost, integrated switching regulators (ISR) from good old Texas Instruments (TI).

The caseless, double-sided package has excellent thermal characteristics, and is RoHs compliant.

The PTN78060 devices operate from a remarkably wide input voltage range:

Device	V_{in}	V_{out}
PTN78060Wa(x)	7 to 36 V	2.5 to 12.6 V
PTN78060HA(x)	15 to 36 V	11.85 to 22.0 V
PTN78060AA(x)	9 to 29 V	–15 to –3V

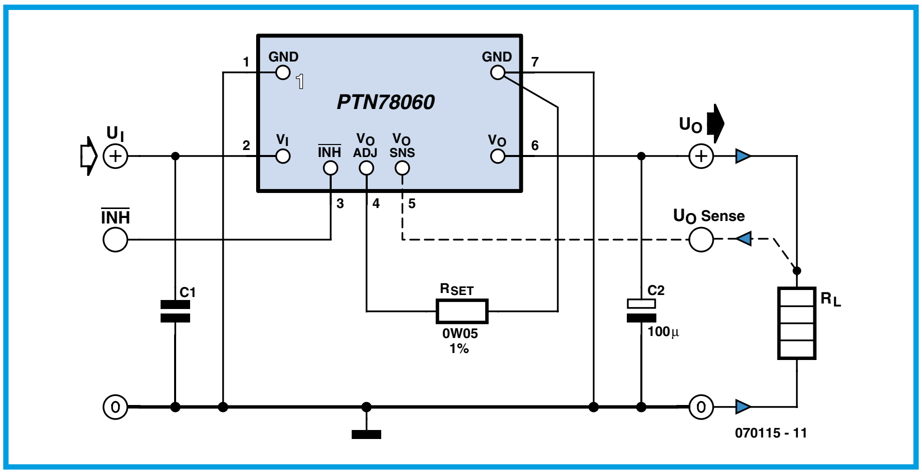
Note that the –A version supplies a negative output voltage.

The devices provide high-efficiency step-down voltage conversion for loads of up to 3 A.

The PTN78060 devices are suited to a wide variety of general-purpose applications that operate off 12-V, 24-V, or tightly regulated 28-V dc power, hence are ideal for running low-voltage electronics from a very high power 24-V battery unit salvaged from an electric wheel chair and migrated into a robot.

The output voltage V_O can be set to any value over a wide adjustment range using a single external resistor R_{SET}, using the equation

$$R_{SET} = 54.9k\Omega \times (1.25V/V_O - V_{MIN}) - R_p$$



Device	V_O (desired) (V)	R_{SET} (standard value) (kΩ)	V_O (actual) (V)	V_I range (V)
PTN780x0W	2.5	Open	2.5	7 to 25
	3.3	78.7	3.306	7 to 33
	5.0	21.0	4.996	7 to 36
	12.0	0.732	12.002	14.5 to 36
PTN780x0H	12.0	383	12.000	15 to 36
	15.0	15.0	14.994	18 to 36
	18.0	4.42	18.023	21 to 36
	22.0	95.3	21.998	26 to 36

If pin 4 is left open, the output voltage defaults to the lowest value. Limiting ourselves to the two positive-output regulators, for the -W version, V_{MIN} and R_p are 2.5 V and 6.49 kΩ respectively; for the -H device, the values 11.824 V and 6.65 kΩ should be used.

For the output to remain in regulation, the input voltage must exceed the output by a minimum differential voltage. Another consideration is the pulsewidth modulation (PWM) range of the regulator's internal control circuit. For stable operation, its operating duty cycle should not be lower than a certain minimum percentage. This defines the maximum advisable ratio between the regulator input and output voltage magnitudes.

For satisfactory performance, the operating input voltage range of the PTN78060x must satisfy the following requirements.

1. For PTN78060W devices supplying output voltages lower than 10 V, the minimum input voltage is (V_O+2 V) or 7 V, whichever is higher.

2. For PTN78060Ws supplying output voltages of 10 V and higher, the minimum input voltage is (V_O+2.5 V).

3. The maximum input voltage for PTN78060W is $10V_O$ or 36 V, whichever is less.

4. For PTN78060H output voltages lower than 19 V, the minimum input voltage is (V_O+3 V) or 15 V, whichever is higher.
5. For PTN78060H output voltages equal to 19 V and higher, the minimum input voltage is (V_O+4 V).

As an example, the **Table** gives the operating input voltage range for some commonly used output bus voltages.
The modules are protected against load faults with a continuous current limit characteristic. Under a load-fault condition, the output current increases to the current limit threshold. Attempting to draw current that exceeds the current limit threshold causes the module to progressively reduce its output voltage. Current is continuously supplied to the load until the fault is removed. Once it is removed, the output voltage promptly recovers. When limiting output current, the regulator experiences higher power dissipation, which increases its temperature. If the temperature increase is excessive, the module overtemperature protection begins to periodically turn the output voltage off.

The inhibit feature can be used wherever there is a requirement for the output voltage to be turned off. The power module switches off the output voltage when the Inhibit control (pin 3) is pulled to ground, for example, by a switching FET.

Finally, good attention should be paid to the quality of the capacitors on V_I and V_O as they determine the regulator stability and overall performance to a substantial degree. Summarizing the extensive information on capacitor selection found in the datasheets, the minimum requirement for C1 is 2.2 µF (!) worth of ceramic capacitors for the –W device and 14.1 µF (!!) for the-H device. Tantalum caps are not recommended.
Similarly, at the regulator output, C2 should be at least 100 µF worth of low-ESR electrolytics.

(070115-I)

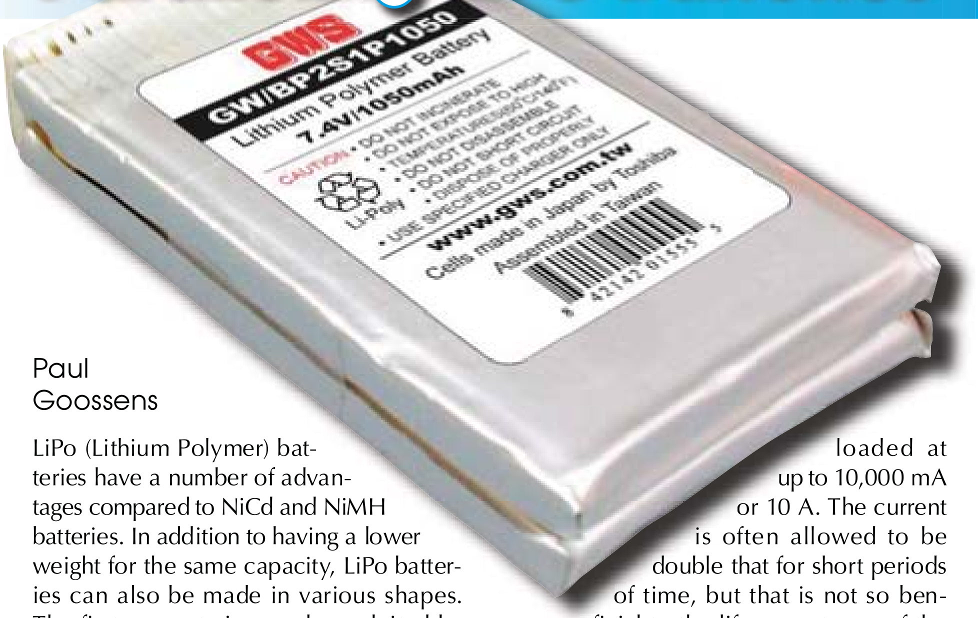
Datasheets

http://focus.ti.com/docs/prod/folders/print/ptn78060h.html

http://focus.ti.com/docs/prod/folders/print/ptn78060w.html

http://focus.ti.com/docs/prod/folders/print/ptn78060a.html

Paralleling LiPo Batteries



Paul Goossens

LiPo (Lithium Polymer) batteries have a number of advantages compared to NiCd and NiMH batteries. In addition to having a lower weight for the same capacity, LiPo batteries can also be made in various shapes. The first property is eagerly exploited by manufacturers of mobile phones, MP3 players and the like.
Beside these advantages, LiPo batteries also have a few disadvantages. One of these disadvantages is that they are not able to supply the same amount of current as their NiCd and NiMH brethren. The maximum current is typically 10 C, where C is the nominal capacity. Newer versions are able to supply 15 C to 30 C continuously, but you will be paying a much higher price for those!
Using a battery rated at 1000 mAh this means that a normal LiPo cell may be loaded at up to 10,000 mA or 10 A. The current is often allowed to be double that for short periods of time, but that is not so beneficial to the life expectancy of the LiPo cells!
There are many cases where we would like to draw more current from the battery. This can be done by connecting multiple cells in parallel.

Current limiting

Connecting multiple cells in parallel is, in principle, a simple soldering job. We don't have to waste any words on that! However, we do have to make sure — before the cells are connected in parallel — that they all have exactly the same voltage across their terminals. If there is even only a small difference between the source voltages then during and after connecting the batteries in parallel a large equalising current can flow. This current will discharge the battery with the higher output voltage and charge the battery with the lower voltage, until both voltages are the same. This equalising current obviously has to be smaller than the maximum charging current (typically 1 C).
Before we can connect the cells in parallel we have to take measures to limit any equalizing current. The difference in voltage is often so small that a simple current regulator does not work properly. However, using a resistor we can limit this current quite easily.

Manual control

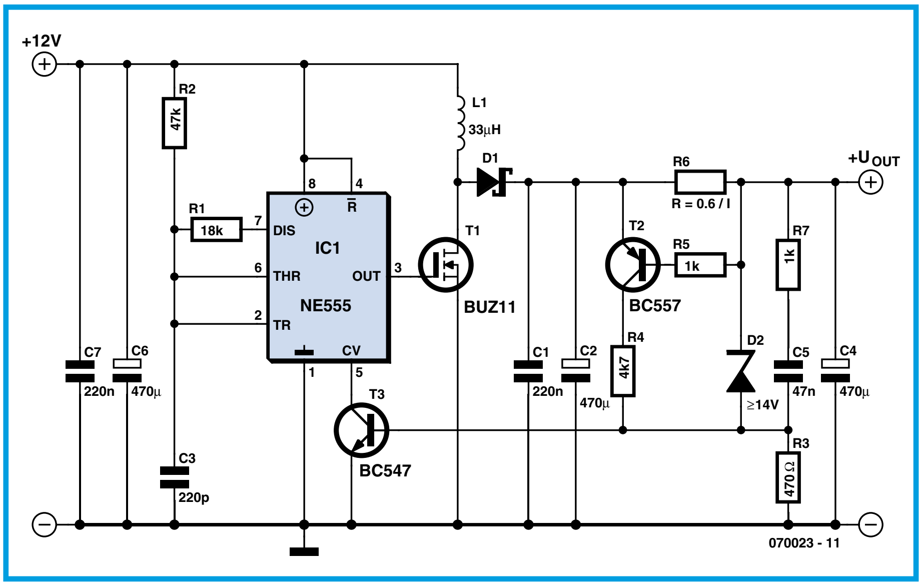
To do this correctly we need to know the maximum charging current for both batteries. We then measure the voltage across both batteries. The difference between these two voltage we call the difference voltage. The negative terminals can now be soldered together. Now we temporarily solder a resistor between the two positive terminals. The value of this resistor has to be at least the difference voltage divided by the maximum charging current.
The battery with the greatest amount of charge will now charge the other battery

at a limited rate. The latter will therefore charge slowly. After a while the difference voltage will reduce and therefore the charging current as well.
If this process doesn't go quickly enough for your liking then you can adjust the resistor value from time to time to increase the charging current again. Both positive terminals may be directly connected together once the difference voltage has dropped so low that a resistor of 10 mΩ would have been enough. A new and more powerful LiPo battery is now a fact.

(070274-I)

Switch-Mode 555 Supply

Martijn Geel



This switch-mode power supply is built around a 555 timer IC. It provides a maximum output voltage of 40 V with a 12-V input voltage. The voltage can easily be set using a Zener diode, and it must be higher than the input voltage (the minimum output voltage is always 12 V).
The NE555 is used in an unconventional way here. In the normal configuration, the output of the oscillator IC is low longer than it is high. With the configuration used here, the output can be high for a shorter time than it is low.
The NE555 switches FET T1 on and off. When T1 is conducting, energy is stored in L1. When T1 stops conducting, this energy is transferred to C1 and C2 via Schottky diode D1, so the voltage on these capacitors rises.
The voltage is limited by Zener diode D2. If the voltage rises above the Zener voltage, the current through the Zener diode causes T3 to conduct. This reduces the voltage on pin 5 of the NE555, which in turn decreases the relative duration of the high level on pin 3. T1 thus conducts for a shorter interval, so less energy is stored in L1 and the output voltage is stabilised.
Current limiting is provided by R6, R5 and T2. If the voltage across R6 is more than 0.6 V, T2 starts to conduct. This drives T3 into conduction, causing the voltage to decrease in order to limit the current.
C5 and R7 provide a soft-start effect. The value of R1 can range from 22 kΩ for an output voltage of 15 V to 10 kΩ for an output voltage of 40 V.
For the sake of safety, limit the Zener voltage to a maximum of 40 V. T1 and T2 can be rated for a maximum of 50 V. The FET is not critical; you may already have one in your spare parts bin that can switch enough current. If the coil becomes warm, the core is too small or the wire is too thin.
The Schottky diode is the only component that is actually critical. Do not use an ordinary diode, since it will become much too hot. You're bound to find a Schottky diode in an old computer power supply (just check for a forward voltage of 0.2 V on the diode range of your multimeter).
The supply shown here can deliver approximately 200 W. The input supply voltage can range from 7 V to 15 V. Don't forget that the maximum voltage the NE555 can handle is 15 V.
Finally, this power supply is not short-circuit proof. A slow-blow fuse on the 12-V side is recommended.

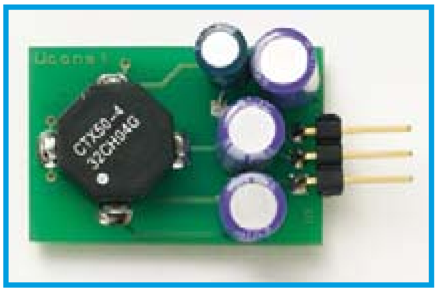
(070023-I)

Voltage Stabiliser

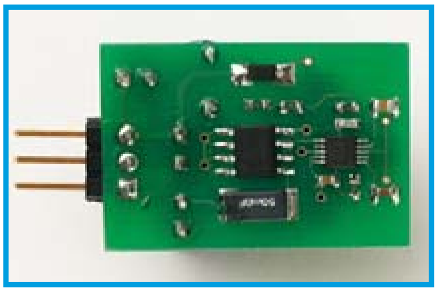
Alexander Wiedekind-Klein

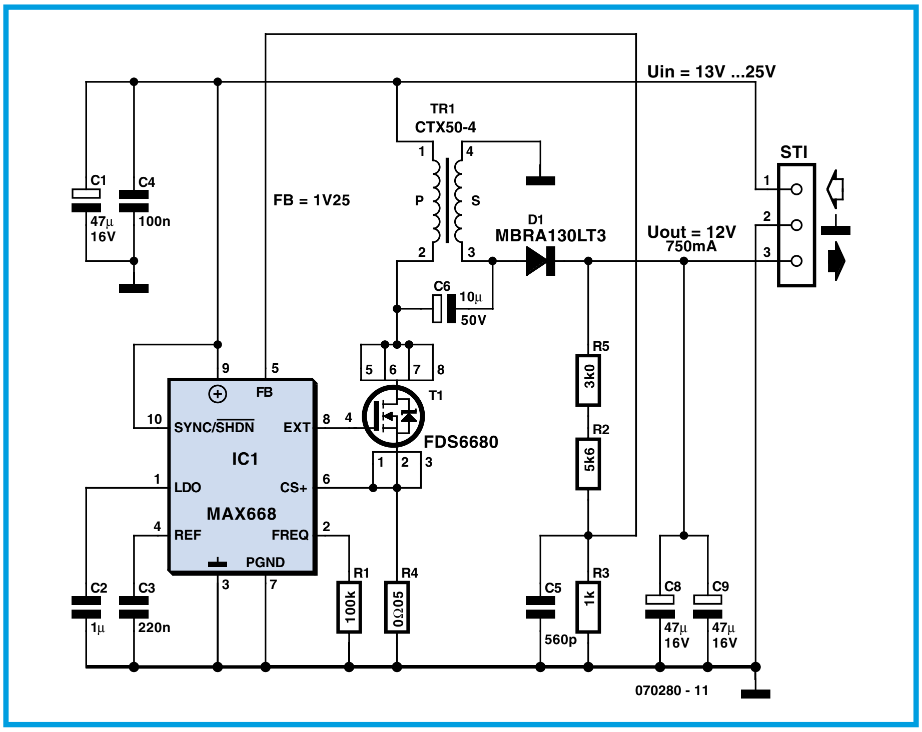
Electric motors used in robot applications often make sudden and heavy demands on their power supply. Although the batteries normally used have a low internal resistance, they nevertheless sometimes have difficulty maintaining their output under load and can be damaged by current spikes. Not all the electronics in the robot can cope with these effects, the voltage regulation provided by ordinary three-terminal devices not always being up to the job. This electronic voltage stabiliser is a solution to that problem.

The circuit is based around a compact switching regulator which is capable of



producing a steady DC voltage of 12 V at its output over input variations from 13 V to 25 V, at loads of up to 750 mA. Its three-





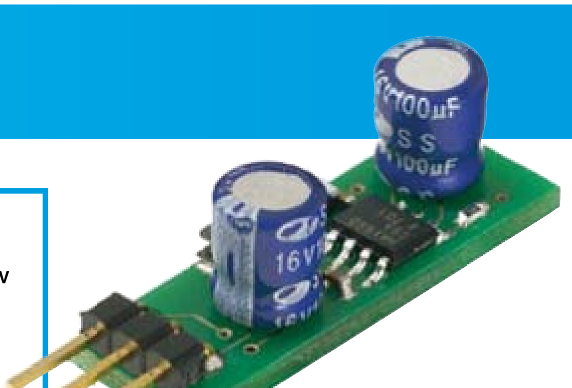
pin form factor makes it a simple replacement for conventional three-terminal voltage regulator ICs. The buck-boost switching circuit uses an SMD power FET for T2, and to achieve high efficiency (approximately 90 %) a Schottky switching diode for D1. The most specialised component is the miniature transformer designed for use in this type of supply. For the prototype we used a Coiltronics CTX50-4.
The current limit is set by R4. The output voltage is scaled by the voltage divider formed by R3 and the series combination of R5 and R2. The output voltage is controlled so that a voltage of 1.25 V appears across R3 and hence on the feedback input (pin 5) of IC1. The circuit can be modified for different output voltages by changing the component values in the voltage divider. For lower output voltages the input voltage can also be reduced correspondingly.

Gerber files for the prototype printed circuit board are available for free download from the Elektor website, ref. **070280-1.zip**. The SMD components used have the following outlines: R1, R2, R3, R5, C3, C4 and C5: 0603; C2: 0805; IC1: SSOP-12; T1: SO-8. All the SMD capacitors are ceramic, and electrolytics C1 and C8 must have a low ESR. R4 is a 50 mΩ SMD resistor rated at 1 W.

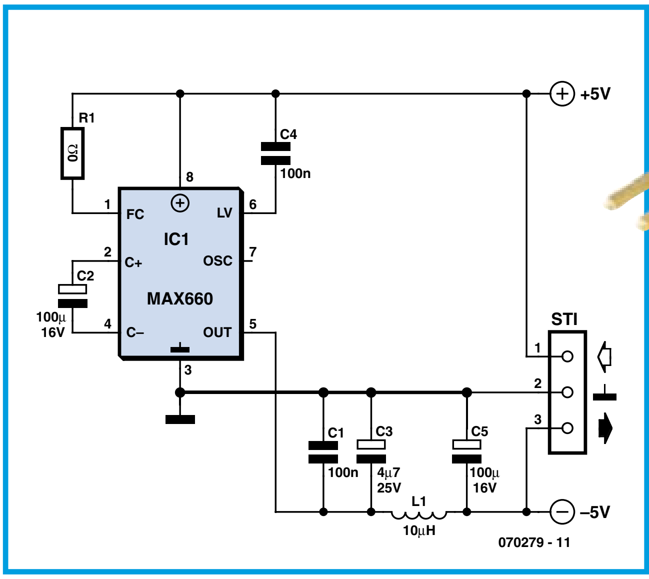
(070280-I)

Mini Power Inverter

Alexander Wiedekind-Klein



Even robot systems occasionally need a negative supply voltage for some purpose or other, and in this kind of application in particular there is a need for an effective circuit that does not make greater demands then necessary in terms of current or space. If a low-current -5 V supply is needed and only +5 V is available, a natural manufacturer to turn to is Maxim, and indeed in this case they do not let us down.



The best-known integrated circuit made by this company is the MAX232, a level shifter for serial ports with an integrated charge pump that does not need an external inductor. Along the same lines, although with a more stable output voltage and higher efficiency, is the MAX660. The device can ‘mirror’ any input voltage between 1.5 V and 5.5 V. With a 5 V input the output is typically –4.7 V with a load of 100 mA. Efficiency at 10 mA is around

96 % and at 100 mA is around 88 %. With an open-circuit output the IC draws a quiescent current of just 120 µA.

There is little to say about the circuit itself. The 0 Ω resistor on pin 1 selects the operating frequency. With R1 fitted, the circuit operates at 80 kHz; without it, at 10 kHz.

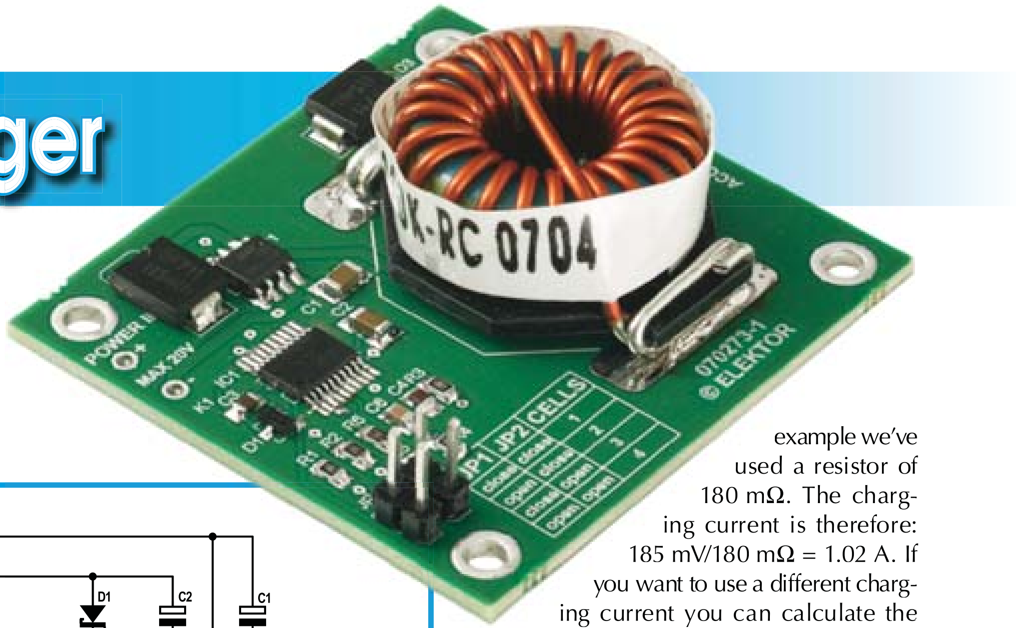
The combination of L1 and C5 slightly reduces ripple on the output voltage; the choice of inductor is not as critical as it would be if it formed part of the switching circuit.

Gerber files for the printed circuit board (which uses some SMD components) are available for download from the Elektor website, ref. **070279-11.zip**. R1, C1 and C4 are 0603 SMDs and C3 is an SMD tantalum electrolytic capacitor. Either the MAX660CSA or the MAX660M can be used; both come in SO8 packages. L1 is a 10 µH SMD inductor rated at 300 mA.

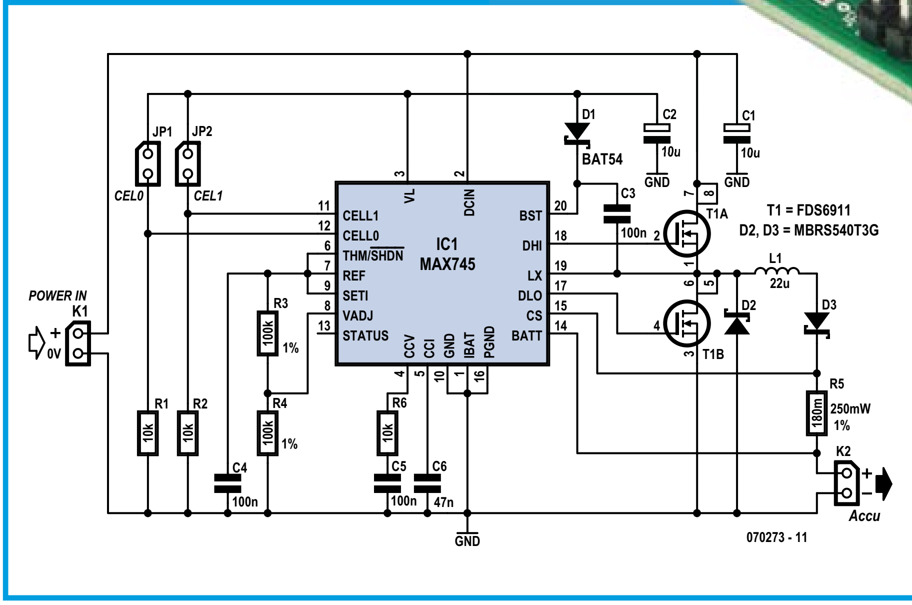
(070279-I)

Lithium Charger

Paul Goossens



Batteries based on Lithium, such as LiPo (Lithium-polymer) and Lithium-Ion ones are ideal candidates to supply a robot with power. Compared to other types of battery they are lighter, which results in a lower mechanical strain on the chassis. The availability is good as well, and they are manufactured in many shapes and sizes.



Charging

The charging of Lithium batteries is a very exact science. If the wrong method is used there is a real chance that they'll burst into flames. For this reason it is only sensible that you always use a proper charger. With the use of a MAX745 such a charger can easily be constructed at home.

During the charging process the charge current should not rise above 1C. This means that for a 1200 mAh battery it may not be charged with a current of more than 1.2 A! Furthermore, the terminal voltage for this type of battery may never rise above 4.25 V per cell. In principle a lithium charger is nothing more than a current source with a (precision!) maximum output voltage.

Charge controller

In our case the charger uses a step-down converter. In this way very little power is wasted in the charger and it can operate without the use of a heatsink. The complete charge controller is inside IC1. A few external components are required for the step-down converter. These are FET T1 and its surrounding components.

The battery voltage is measured via pin 14 (BATT). The voltage difference between BATT and CS is measured by the IC to control the charging current. The IC tries to keep this potential difference to 185 mV. In our example we've used a resistor of 180 mΩ. The charging current is therefore: 185 mV/180 mΩ = 1.02 A. If you want to use a different charging current you can calculate the value for R5 using the formula:

$R5 = 185\ \text{mV} / I_{\text{CHARGE}}$.

A pair of jumpers is used to select the number of cells in the battery. The four possible settings are shown in **Table 1**.

Table 1.

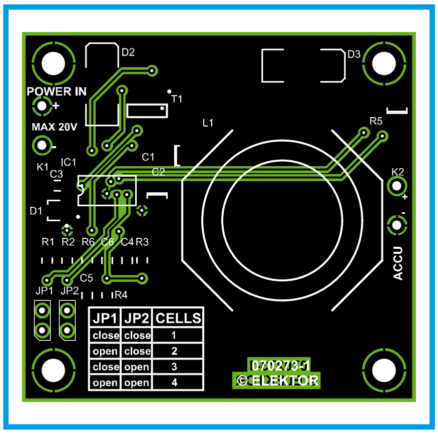
JP1	JP2	Number of cells
Closed	Closed	1
Open	Closed	2
Closed	Open	3
Open	Open	4

These jumpers tell the circuit how many cells are connected in series inside the battery. This is very important, since it determines what the maximum voltage may be across the battery.

The maximum voltage per cell is adjusted via V_{adj} and can be set between 3.95 V and 4.45 V. Resistors R3 and R4 set the terminal voltage to 4.25 V in this case. Because V_{adj} has a narrow operating range we have to use 1% (close tolerance) resistors to set the voltage very accurately!

Construction

Thanks to the use of a double-sided PCB the construction of this circuit is very simple. All components are mounted on the top side of the board. When soldering the



COMPONENTS LIST

Resistors

R1,R2,R6 = 10kΩ (SMD 0805)
R3,R4 = 100kΩ 1% (SMD 0805)
R5 = 0.18Ω 0.25W (SMD 1210), e.g. Digikey P.18SCT-ND

Capacitors

C1,C2 = 10µF 25V (SMD 12010)
C3,C4.C5 = 100nF (SMD 0805)
C6 = 47nF (SMD 0805)

Semiconductors

D1 = BAT54 (SOT-23)
D2,D3 = MBRS540T3G (SMC), e.g. Digikey MBRS540T3GOSCT-ND
IC1 = MAX745
T1 = FDS6911 (SOIC12), e.g. Digikey FDS6911CT-ND

Miscellaneous

L1 = 22µH (JW-MILLER PM2110-220K-RC), e.g. Digikey M8760-ND
JP1,JP2 = jumper with 2-way SIL pinheader
PCB, order code **070273-1** from Elektor SHOP)

coil it may be necessary to let the soldering iron heat up a bit more first. The connecting leads are quite chunky and they require a fair amount of heat to raise them to the correct temperature.

When all parts have been soldered and the circuit has been checked you can power the circuit via K1 with a DC voltage of no more than 24 V. You should always double-check that you have set the jumpers for the correct number of cells before connecting the LiPo or Li-Ion battery! With a charging current of 1 *C* an empty cell should be fully charged in about an hour and a quarter.

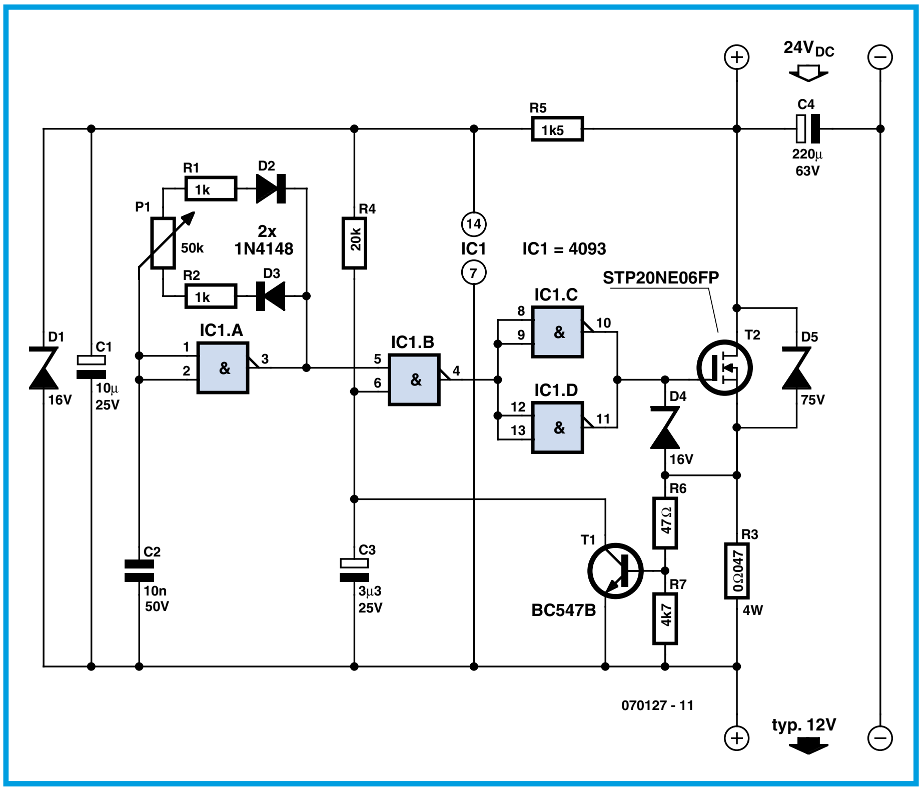
(070273-I)

PWM Voltage Dropper

Von Stefan Brandstetter

This circuit was developed to allow a car trailer, designed for 12 V operation, to be used as a trailer for a van with a 24 V supply. A number of copies of the circuit we made, for the left and right indicators, brake lights, number plate light and reversing lights, and these have been in trouble-free operation for several years. The advantage of this compact circuit is that it dissipates very little power because it uses pulse width modulation. In addition, its quiescent current consumption is practically zero.

A simple pulse generator is constructed using IC1.A, C2, R1 and R2. Normally (when T1 is not conducting) RC combination R4/C3 ensures that IC1.B passes the square wave signal to FET switch T2. Shunt resistor R3 measures the output current. If the maximum safe output current is exceeded, T1 turns on and short-circuits C3; IC1.B no longer passes the square wave signal to the switching transistor. The output current falls to zero, T1 turns off and C3 is recharged via R4. As soon as the input threshold of IC1.B (half the supply voltage) is exceeded, the PWM signal once again starts to drive T2. Thus even if there is a continuous short circuit on the output there will be occasional pulses of output current. R5, D1 and C1 reduce the input voltage of 24 V to a value of 16 V more suitable for powering the CMOS 4093 Schmitt trigger IC. D4 and D5 protect T2 from voltage spikes, which are practically



unavoidable in this circuit because of the inductance of the wiring. Any standard N-channel FET able to withstand 100 V can be used for T2.

With the component values shown the circuit is suitable for use with 12 V lamps at up to 60 W. The current limit, set by R3 (47 mΩ) is around 12 A. The current limit is essential because cold lamps present a very low resistance when voltage is first applied. The mark-space ratio is set to approximately 1:3 (25 % on-time) using P1. The circuit can be modified for use at higher currents, and it can also be used as the basis of a simple and efficient speed controller or light dimmer.

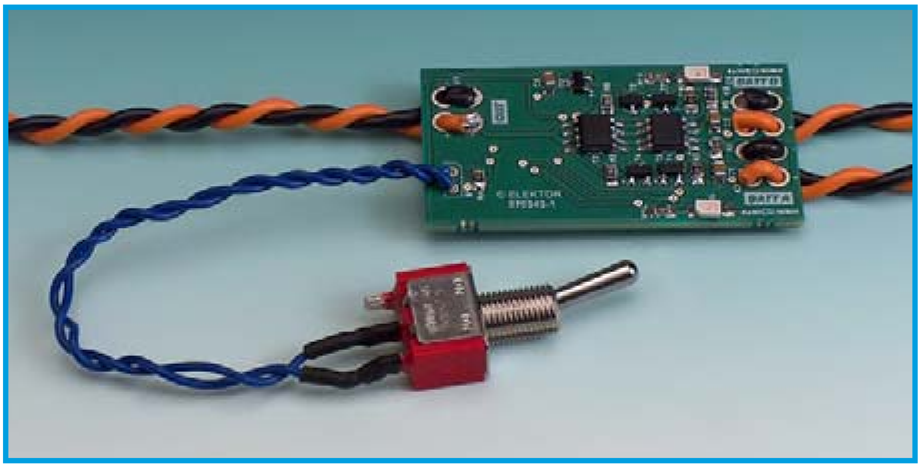
(070127-I)

Dual Battery

For enhanced operational reliability

Paul Goossens

Using rechargeable batteries to power circuits is a proven method for providing energy to mains-independent equipment. A major disadvantage of this is that the battery usually turns out to be empty at the most inopportune moment. As a user, you are unexpectedly confronted with the fact that the circuit suddenly doesn't work any more. Sometimes this is only a minor inconvenience, but at other times it can be a catastrophe. For instance, just imagine what happens to a model airplane if the radio receiver stops working in flight due to an empty battery. We can assure you that the consequences are anything but pleasant.



Solution

The solution to this problem is actually quite simple: use two batteries! When one of the batteries becomes discharged, the second one can take over and continue supplying power.

Of course, all this must happen automatically, so we need a handy circuit that takes care of everything for us.

The design presented here is intended to be used with circuits (such as receivers used in models) that use NiCd batteries composed of four cells. The circuit is quite compact, and thanks to the accompanying PCB populated with SMDs, it is easy to fit into existing equipment.

Simple

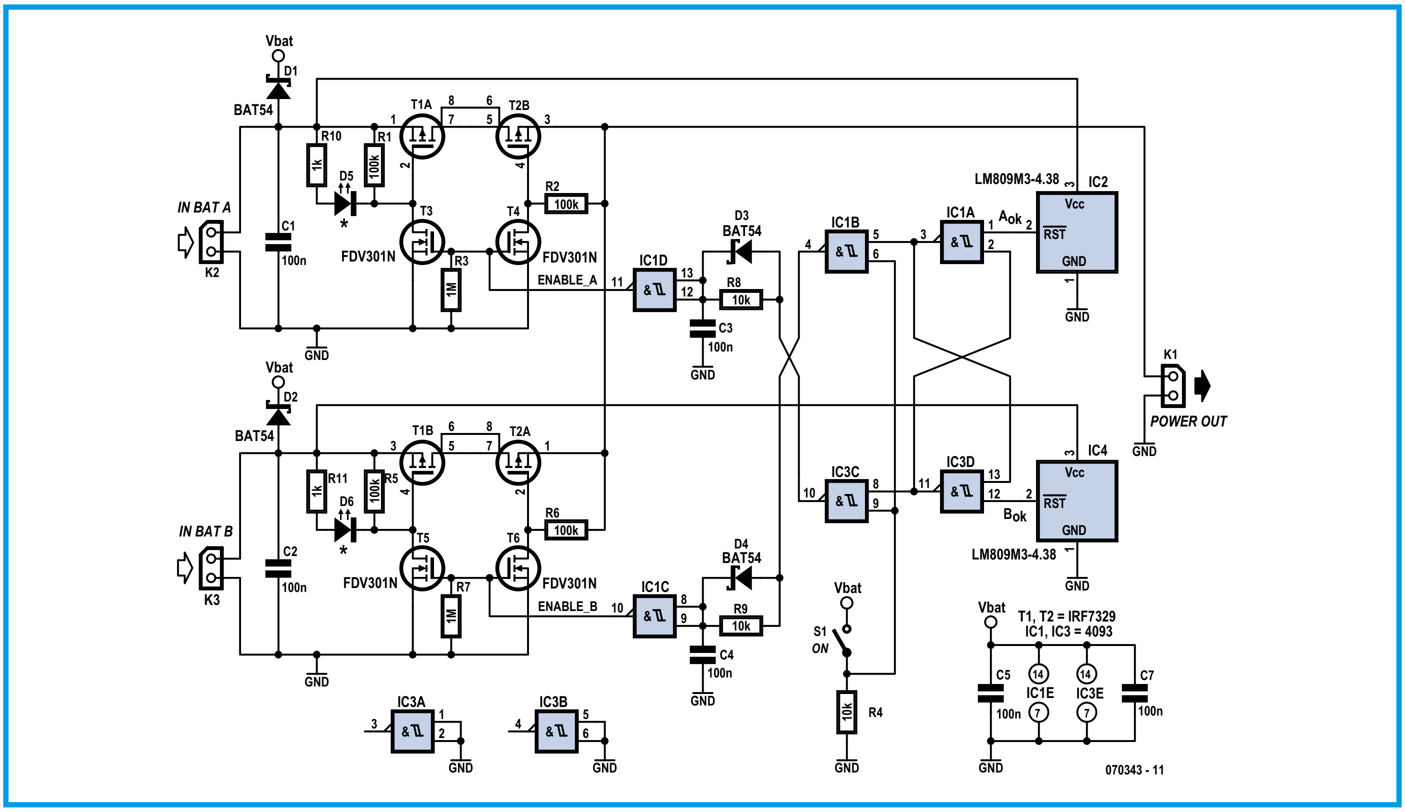
The operating principle is simple: IC2 measures the terminal voltage of battery A. If it drops below 4.38 V, the $\overline{\text{RESET}}$ output goes low, and otherwise it remains high. IC4 does the same thing, but for battery B.

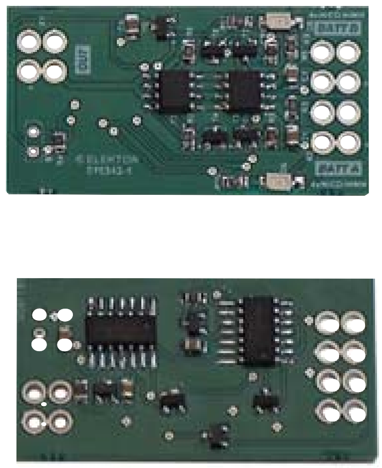
Both signals go to a flip-flop consisting of IC1a and IC3d, which determines which of the batteries is to be used.

If the voltage across battery A is too low, the output of IC1a will always be high. As a consequence, battery B will be active. The same thing applies in reverse to the output of IC3d.

When both batteries are discharged, they will both power the circuit, in keeping with the motto 'better a little bit of juice than no juice at all'.

Components D3, R8 and C3 provide





a switch-on delay that causes battery switch-on to be delayed somewhat. This is because it is undesirable to have both batteries power the circuit at the same time during switchover from one battery to the other. That would cause large equalization currents to flow due to the difference between the terminal voltages of the two batteries.

Switch

The best choice for the switching device is a FET instead of a bipolar transistor. This saves energy, since no base current is necessary. A disadvantage of a MOSFET is that it always has an intrinsic diode. This diode is quite annoying in this circuit, since the one battery can charge the other battery via the diode. A simple solution would be to wire a diode in series to prevent this. Unfortunately, a diode always has a voltage drop (approximately 0.3 V with a Schottky diode).

To solve this problem, we use a second MOSFET wired in the opposite direction. The underlying trick here is that the channel of a FET conducts in both directions when it is switched on. This eliminates the effect of the forward voltage of the internal diode.

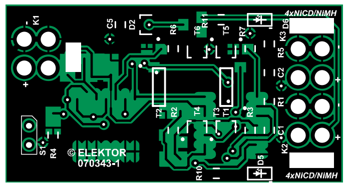
LEDs D5 and D6 indicate which battery is in use.

Use

The circuit is very easy to use. Connect a four-cell NiCd battery to each of the battery inputs (K2 and K3). Then connect output K1 to the circuit to be powered.

Switch on the supply voltage with switch S1. The LEDs now indicate which battery is in use. If things every get so far that both batteries become deeply discharged (Heaven forbid!), this can be recognised by the fact that both LEDs are lit.

(070343-I)



Components list

(all R and C: SMD 0805 case)

Resistors

R1,R2,R5,R6 = 100kΩ
R3,R7 = 1MΩ
R4,R8,R9 = 10kΩ
R10,R11 = 1kΩ

Capacitors

C1-C6 = 100nF

Semiconductors

D1-D4 = BAT54 (SOT-23)
D5,D6 = LED rood (SMD 1206)
IC1,IC3 = 4093 (SOIC-14)
IC2,IC4 = LM809M3-4.38 (SOT-23)
T1,T2 = IRF7329 (SOIC-8)
T3-T6 = FDV301N (SOT-23)

Miscellaneous

Connecting wires
PCB no. **070343-1** (see www.elektor-electronics.co.uk)

Multi-purpose NiCd & NiMH Charger

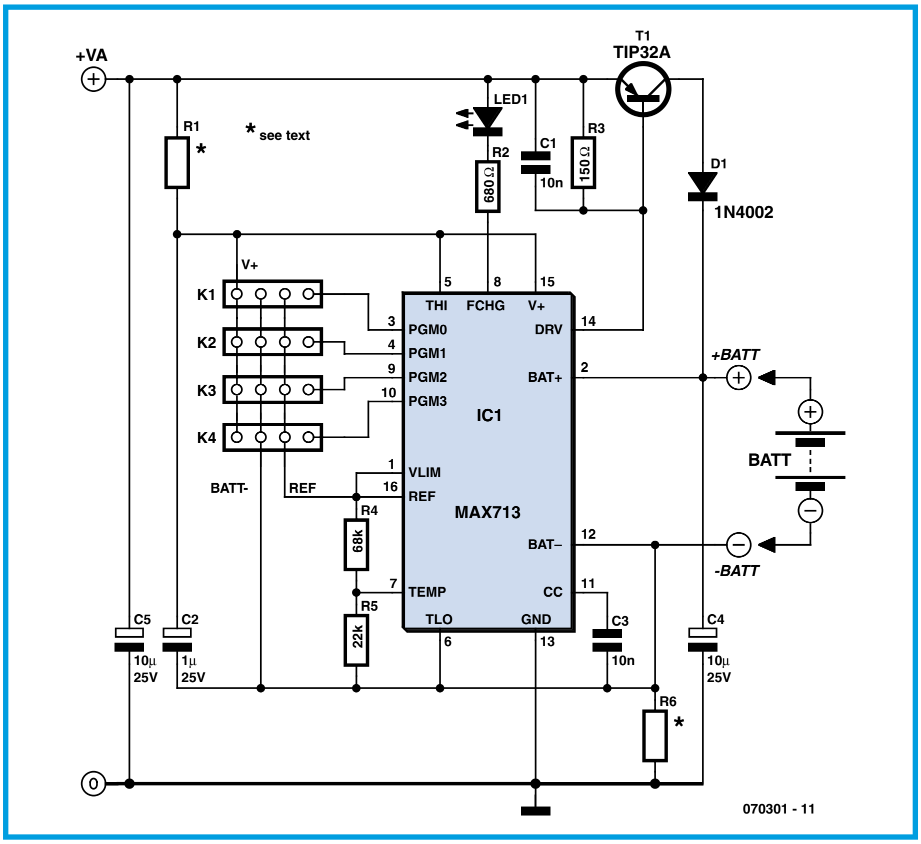
C. Tavernier

www.tavernier-c.com

Unless your robot is frugal enough to make do with primary cells without breaking the bank, or is environmentally-friendly and runs off solar panels, it will probably need to use rechargeable batteries as its energy source.
Although very many chargers are currently available, they're not always suitable for our needs, in terms of the types and number of batteries they can handle. What's more, certain of them do not take very good care of the batteries entrusted to them, which can seriously shorten their life.
So this article proposes building your own tailor-made charger, using an IC that's already old, but still very much current: the MAX713 from Maxim. As all robots are different, we're not going to suggest a completely finished circuit, but will instead explain how to adapt it to suit the characteristics of the batteries you'll be wanting to recharge.
The MAX713's basic application circuit is shown in the figure, but as you can see, certain elements have no values shown. In addition, there are various configuration links. Via these various elements, the MAX713 lets you charge from one to 16 cells (a cell is a basic 1.2 V element), define the charging current, define the end-of-charge float current, and lastly, select the mode for detecting end of charge. As far as the latter is concerned, and so as to be compatible with any batteries you are likely to use in your robot, we've left out the temperature detection method, which requires a thermal sensor (NTC or equivalent) inside the battery. So resistors R4 and R5 in conjunction with the hard-wired links to inputs THI and TLO program the MAX713 into the mode that detects end of charge by voltage variation.
So now let's see how to determine the other elements that are still open to you, so you'll be able to build a charger that's just right for your needs. Note right away that the configuration links can either be hard-wired on the PCB that you'll be designing for your charger, or else connected to multi-way switches to create a multi-purpose charger.
You first need to decide I_{fast}, the charging current for your batteries, whose capacity *C* is expressed in ampère-hours (Ah). This can be calculated from: $I_{fast} = C/t$ where *t* is the desired charging time in hours. Watch out! The MAX713 does not handle times over 4 hours. And take care not to pick a value for I_{fast} above 4*C*, which is currently the maximum current permitted for

fast-charging NiCad and NiMH batteries. If you are able to choose a lower current, so much the better, it will prolong battery life. Program this charging time by wiring pins PGM2 and PGM3 of the MAX713 as per **Table 1**.
Then choose the number of cells to be charged at the same time. For block batteries, you can find the number of cells by dividing the nominal voltage of the battery by 1.2 V. So a 9.6 V battery will contain eight cells. If the number of cells is 11 or more, the circuit can't be used as is, and in that case it's better to charge your batteries in two goes. Program this number by wiring pins PGM0 and PGM1 of the MAX713 as per **Table 2**.
Then choose the unstabilized DC supply voltage for your charger (VA in the figure) so that it is at least 1.5 V higher than the maximum voltage of the battery to be charged. If your battery has less than four cells, this rule no longer applies, as the MAX713 supply has to be a minimum of 6 V.
Then determine the maximum power dissipated in T1 using the following equation:

$$P_D = (V_A - V_{BATTmin}) \times I_{fast}$$



where $V_{BATTmin}$ is the minimum voltage of the battery to be charged. Choose T1 accordingly, if necessary fitting it with an appropriate heatsink.
Then determine the value of resistor R1 so the current drawn by the MAX713 will be 5 to 20 mA, using the equation: R1 = $(V_A - 5) / I$ where I is between 5 and 20 mA.
Lastly, determine the value of resistor R6 by using the equation: R6 = $0.25 / I_{fast}$ and its power by using $P_{R6} = 0.5 I_{fast}$ (theoretically $0.25 I_{fast}$ in fact, but it's best to use a safety factor of 2, hence the modified equation).
Your charger is now operational, and is extremely simple to use; but because of the processors inside the MAX713, it is essential to make the connections to PGM0 to PGM3 before applying power to the circuit, otherwise they may not be taken into account correctly. This is no problem for a hard-wired circuit, but if your charger uses configuration switches at this point, you'll need to power down and power up again to confirm any configuration changes made via these switches.
The LED lights when the charger is in fast-charge mode (at the current I_{fast} determined above). It goes out when fast-charging is over and the charger goes into float charge mode. The current generated in this mode is sufficiently low that the battery may be left connected to the charger indefinitely if necessary.
To make sure our explanation is crystal-clear, here by way of example are the calculations for a charger for a pack of four 1.2 V NiMH batteries with a capacity of

Table 1. Programming charge time via PGM2 & PGM3.

Maximum charge time (min)	PGM3	PGM2
22	V+	REF
33	V+	BATT–
45	O/C	REF
66	O/C	BATT–
90	REF	REF
132	REF	BATT–
180	BATT–	REF
264	BATT–	BATT–

Table 2. Programming number of cells via PGM0 & PGM1.

Number of cells	PGM1	PGM0
1	V+	V+
2	O/C	V+
3	REF	V+
4	BATT–	V+
5	V+	O/C
6	O/C	O/C
7	REF	O/C
8	BATT–	O/C
9	V+	REF
10	O/C	REF
11	REF	REF
12	BATT–	REF
13	V+	BATT–
14	O/C	BATT–
15	REF	BATT–
16	BATT–	BATT–

1,800 mAh that we want to recharge in two hours.

- Calculate I_{fast}: I_{fast} = C/t, i.e., 1.8/2 = 0.9 A or 900 mA.
- PGM2 and PGM3 connections:
PGM2 tied to BATT– and PGM3 tied to REF, as we want a charge time of 2 hours, i.e. 120 minutes (in fact, we'll get a maximum of 132 minutes).
- PGM0 and PGM1 connections:
PGM0 to V+ and PGM1 to BATT– since our battery comprises four cells.
- Determine V_A: V_A = 6.3 V minimum. We'll choose 9 V, to obviate any problems with possible supply voltage variations.
- Power dissipated in T1: P_D = (9 – 4*) . 0.9, i.e. 4.5 W. So we'll choose, for example, a TIP32A, giving us an excellent safety margin (P_{Dmax} = 40 W).
** fully discharged battery voltage estimated at 4 V.*
- Calculate R1: R1 = (9–5)/0.01**, = 400 Ω. We'll use the closest preferred value, i.e. 390 Ω.
*** : a current of 10 mA was chosen.*
- Calculate R6: R6 = 0.25/0.9, = 0.27 Ω.
- Calculate the power in R6: P_{R6} = 0.5 × 0.9 = 0.45 W. So a 0.50-W type is going to be fine.

As you can see, it's taken us all of five minutes to produce a charger tailored perfectly to our needs. Now it's your turn...

(070301-I)

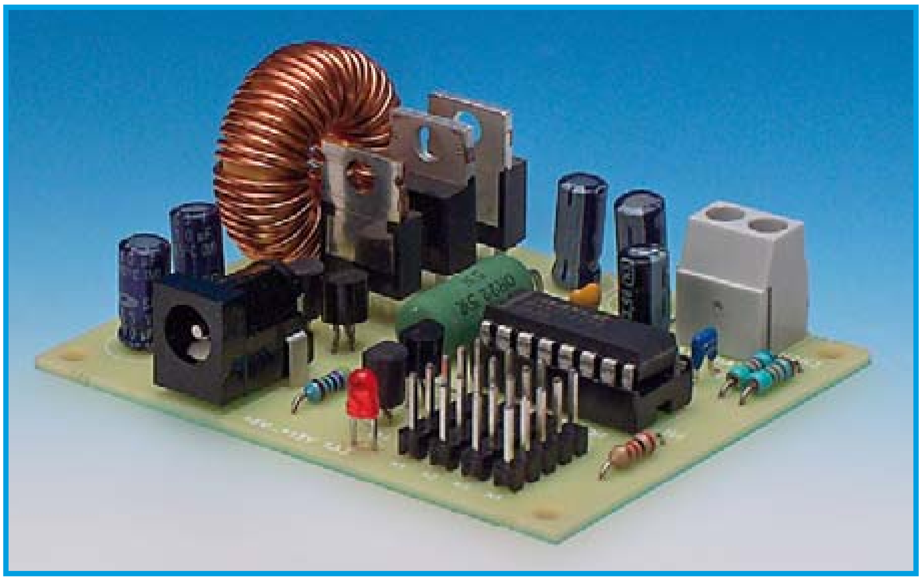
Web Links

MAX713 spec. sheet:

www.maxim-ic.com/quick_view2.cfm/qv_pk/1666

Fast Charger for NiMH Batteries

Antoine Authier
& Karel Walraven



At the time of writing, the latest AA NiMH (Nickel metal Hydride) batteries have a capacity of up to 2900 mAh. Using an original-type conventional battery charger (supplying 125 mA), the charging time will be extremely long.

The charger we propose here should accelerate the recharging process of NiMH batteries, which hare becoming more and more common (we must do our bit for the environment).

The design is based on the MAX712 made by Maxim (Integrated Products to be precise, which was bought by Dallas Semiconductor; quite a long story), operating in switched mode, it can supply a maximum fast charge current calculated as

$$I_{charge} = 250 \text{ mV} / \text{R1}$$

or not less than 1 A if R1 = 0.25 ohms. Under these conditions, the battery will be charged in just over two hours.

The Maxim circuit is not only intelligent, but it also includes an ADC (analogue to digital converter), a system to detect charge completion, a timer, and a temperature monitoring module. The four configuration pins that are included allow users to set the parameters as they please. These pins are used to set the parameters for the number of cells to be charged, the maximum charging period, as well as the method to detect when it is fully charged (inflexion point or negative slope). You can refer to the datasheet to find out more. The MAX712 is intended for NiMH batteries, with charge completion at the inflexion point of the voltage curve ($\partial V/\partial t = 0$).

The maximum power supply voltage is 15 V. The power supply voltage must be at least 2 V above the maximum charging voltage in order to compensate for voltage fluctuations during charging. Therefore, for a maximum charging voltage of 1.6 V per cell, a 15-V power supply voltage is used to charge 8 series-connected batteries. A 12-V voltage level (supplied, for example, by a car battery) is used to recharge six cells. The power supply must be able to supply 1 A. It is important to be certain of its specification. If the requirement is not fulfilled, the integrated circuit will not operate correctly and may not correctly detect completion of the fast-charge (entailing a risk of damage that could affect the connected batteries).

Setting the circuit parameters

- The PRGM0/PRGM1 pins are used to regulate the number of cells to be charged. A note concerning the use of a battery cradle: during recharging: each contact can represent a 1-Ω series resistance, which is seen as a 1-V potential difference at 1 A. The power supply voltage may not be adequate for this configuration — therefore, it is preferable to verify this detail before beginning the project.

- For security reasons, it is preferable to properly configure the maximum charging period with the PRGM2/PRGM3 pins.

- On this setup, the temperature control circuit for the batteries is deactivated.

At the end of the fast-charge, the circuit will power the batteries with a maintenance charge (trickle). Let's examine the circuit's electronics. T1 is uses as a current source supplying the 8 mA necessary to power the MAX712. D3 ensures that the battery does not discharge into the circuit in case it is not powered.

The LED D1 lights up when the circuit is in fast-charge mode. T5 may be mounted on heatsink, if necessary. The characteristics of coil L1 are not critical; a traditional 100 µH/5 A suppressor choke will work fine. The same holds true for diodes D2, D3 and the MOSFET transistor T5; they too are not critical in this application. You can use any Schottky diode that can withstand 3 amps and include any MOSFET with a lower drain resistance.

A compact PCB was designed for the circuit. Mounting the components should be all plain sailing, but do not forget the two wire links on the board. Inductor L1 is a toroid 'suppressor choke' with a good size. Connectors K1-K4 allow different charging parameters to be set up.

Since the calculation principle is the same as for the NiCd charger in the MAX713 in the other article, we refer you to the calculation example proposed there. Use the same tables to set the parameters of this circuit as the ones given in that article.

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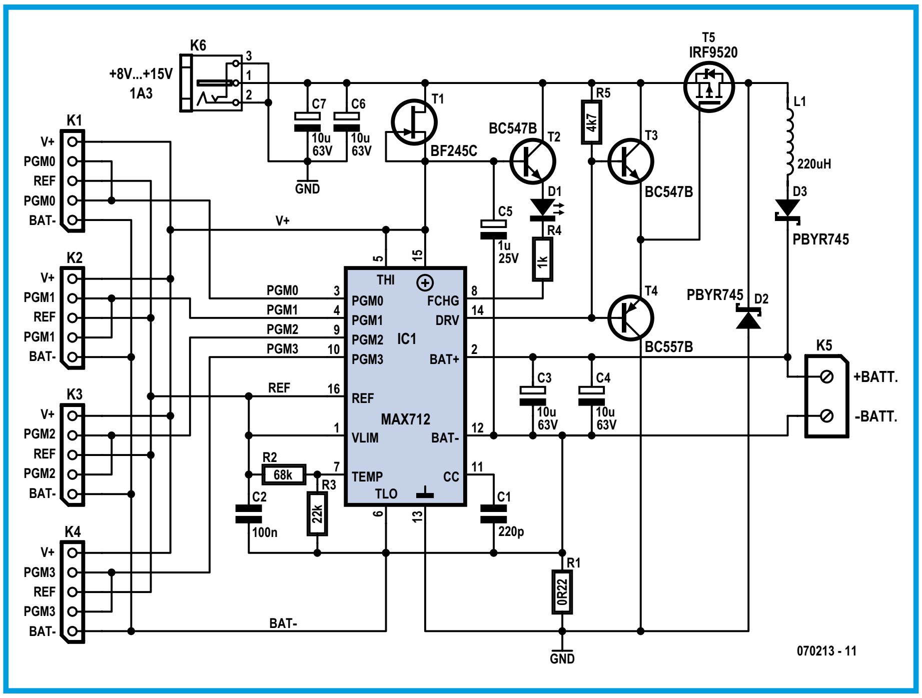


Components list

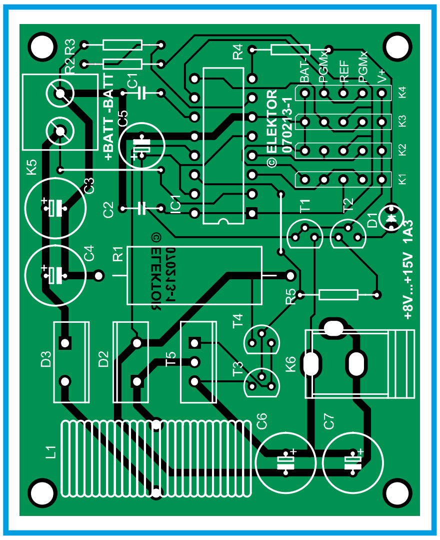
Resistors
R1 = 0.22Ω 5W
R2 = 68kΩ
R3 = 22kΩ
R4 = 1kΩ
R5 = 4kΩ7

Capacitors
C1 = 220pF
C2 = 100nF
C3,C4,C6,C7 = 10µF 63V radial
C5 = 1µF 25V radial

Inductor
L1 = 220µH suppressor choke

Semiconductors
D1 = LED
D2,D3 = PBYR745
T1 = BF245B or -C
T2,T3 = BC547B
T4 = BC557B
T5 = IRF9520
IC1 = MAX712CPE

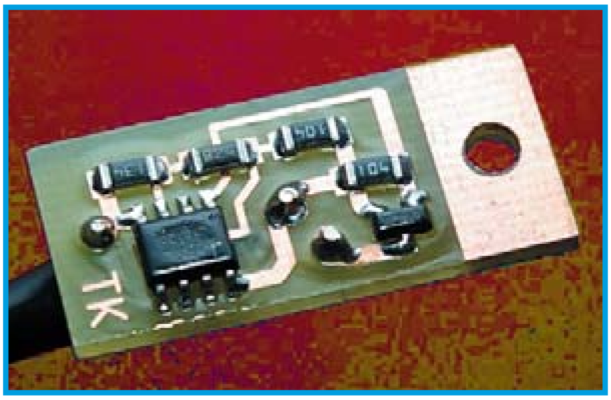
Miscellaneous
K1-K4 = 5-way SIL pinheader
K5 = 2-way PCB terminal block, lead pitch 5mm
K6 = DC supply jack, PCB mount
PCB no. **070213-1**, see Elektor SHOP



Deep Discharge Protection for Rechargeable Cells

Tilman Küpper

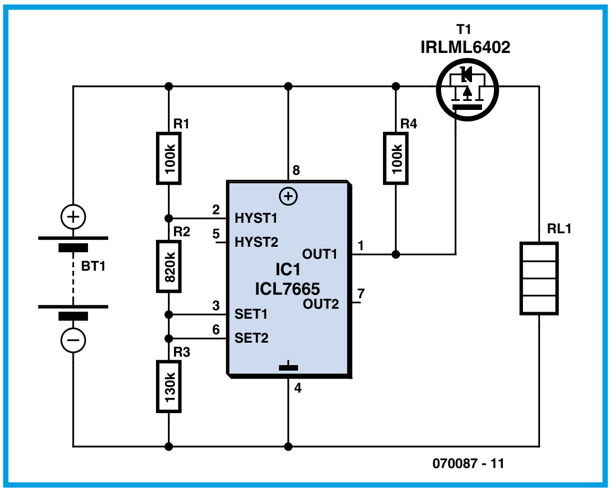
With this circuit built into the power supply of a battery powered device, it will prevent the rechargeable cells from being completely drained when you forget to turn the equipment off. When the battery voltage drops below a pre-set limit (9.5 V in this example) the circuit will automatically disconnect the battery. Power is re-connected when the voltage rises above an upper threshold level (10.5 V here),



this will typically occur after the equipment has been plugged into its recharging station. The circuit is designed to use as little power as possible.

The ICL7665 from Intersil forms the heart of the circuit. This IC contains two comparators together with a voltage reference and consumes just 3 µA. The circuit only uses one of the comparators, the values of resistors R1 to R3 shown in the diagram will cause the circuit to switch at the levels mentioned above. The comparator output switches the P-channel MOSFET T1 which in turn controls power to the load R_{LOAD}.

The switching threshold levels and hysteresis can be changed by using different values of resistor for R1 to R3. Increasing the value of R3 to 300 KΩ will raise the upper threshold level to 12.5 V. The ICL7665 data sheet gives examples of suitable resistor values that can be used here. The PCB layout uses SMD components so the finished circuit takes up very little space when installed in the equipment. A



fine-tipped soldering iron should be adequate to mount the components and there shouldn't be any problems provided you do not choose to use very small resistor packages. Once the circuit has been tested the entire PCB can be protected by encapsulating it with a short length of heat shrink sleeving.

(070087-I)

Links

Data sheet IRL7665: www.intersil.com/data/fn/fn3182.pdf

Data sheet IRLML6402: www.irf.com/product-info/datasheets/data/irlml6402.pdf

LDO Regulator with Soft Start or Tracking

Dirk Gehrke
(Texas Instruments Germany)

The devices described here are tailored to fit the needs of modern DSPs, processors and FPGAs that require low supply voltages at relatively high currents, plus the capability of supply voltage ramp-up and sequencing in a defined manner. The latter two requirements are not easily solved using discrete components. The TPS74x01 family fits the bill.

At the time of writing the family consists of three parts, called TPS74201 (1.5 A with soft-start), TPS74301 (1.5 A with tracking) and TPS74401 (3 A with soft-start). The family is expected to grow soon.

Figure 1 shows a simplified connection diagram for the three devices. These regulators require a low power bias voltage, V_{BIAS}, and a power input voltage, V_{IN}, from which V_{out} will be derived. All three regulators are capable of providing output voltages down to 0.8 V and the device in the QFN package also includes an integrated supervisory circuit with open-drain output that goes to high impedance when the output voltage reaches regulation ('power good' or PG). The TPS74301 can provide up to 1.5 A output current and has a TRACK pin which allows the user to input a ramp signal for the output voltage to follow, effectively implementing either simultaneous or ratiometric sequencing.

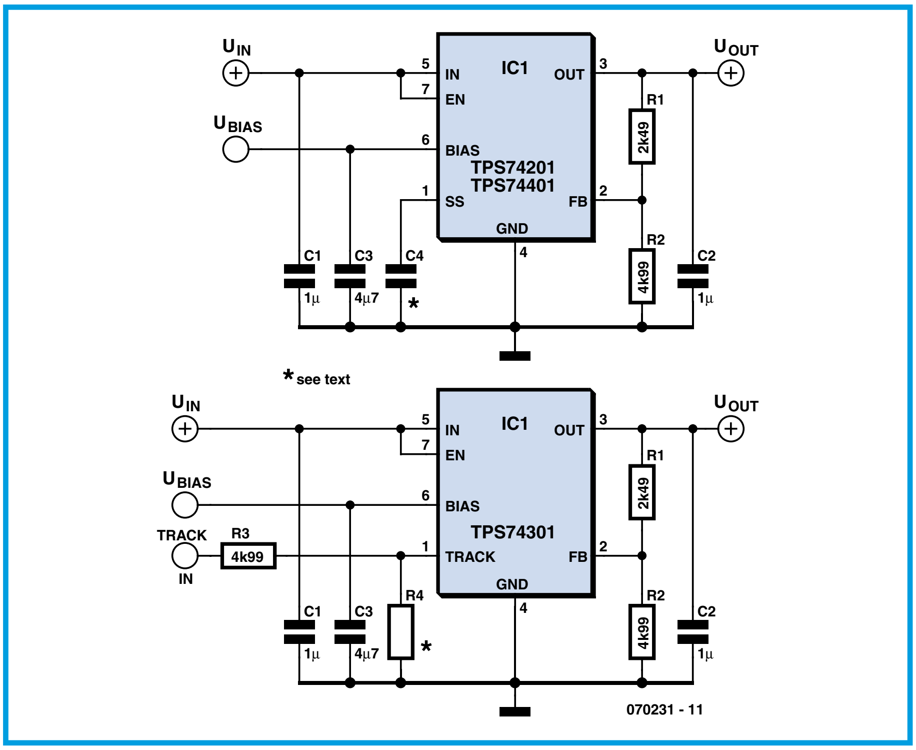


Figure 1. Schematic of TPS74201, TPS74301 and TPS74401 (see text for values of R4 and C4).

The relevant connections are shown separately. The TPS74201 and TPS74401 can provide up to 1.5 A and 3.0 A DC current, respectively, and have an SS pin which allows the user to set the linear ramp rate of the output voltage.

For the TPS74301, the value of R4 (in a voltage divider) allows the user to select either simultaneous or ratiometric sequencing. R4's value is calculated from the equations in the datasheet, assuming an external 3.3-V ramp signal is applied

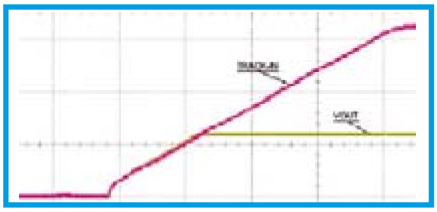


Figure 2. **Tracking LDO TPS74301 with simultaneous startup (R4 = 10kΩ). Timebase: 2 mV/div.**

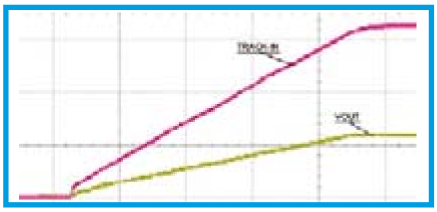


Figure 3. **Tracking LDO TPS74301with ratiometric startup (R4 = 1.78kΩ). Timebase: 2 mV/div.**

to the TRACK IN pin. When the value of R4 selected to be 10 kΩ in this particular example, the output of the TPS74301 will follow the external ramp signal within a few millivolts until the TPS74301 reaches its regulated voltage. This is called *Simultaneous Sequencing* (**Figure 2**). The TPS74301 output voltage will have the same rate of rise (dv/dt) as the external ramp signal but a different soft-start time.

Changing resistor R4 to a value of 1.78 kΩ results in the TPS74301 output voltage reaching its regulated voltage at the same time the externally applied tracking signal reaches its maximum voltage (e.g., 3.3 V). This is called *Ratiometric Sequencing* (**Figure 3**). Although the external ramp signal and the TPS74301 will have different rates of rise, they will have the same soft-start time.

For the TPS74201 and TPS74401 the capacitor value can be used to program the soft-start ramp. In this example, values of 1 nF and 10 nF for C4 were used to realize ramps with 1 ms and 10 ms rise time respectively (**Figures 4** and **5** respectively). With no capacitor attached to this pin the default soft-start time will be 500 µs. This 500-µs start up time is also valid for the TPS74301 when applying a voltage greater than 800 mV to the TRACK pin.

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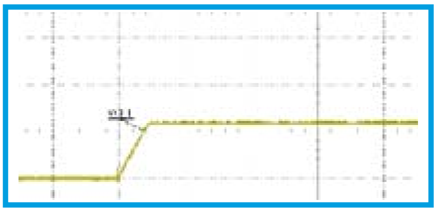


Figure 4. **Soft-Start LDO TPS74201 and TPS74401 with 1ms soft startup (C4 = 1nF). Timebase: 2 mV/div.**

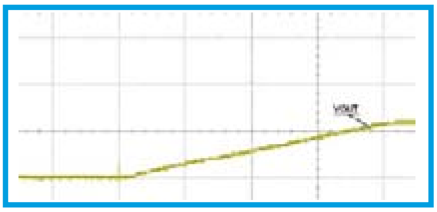


Figure 5. **Soft-Start LDO TPS74201 and TPS74401 with 10ms soft startup (C4 = 10nF). Timebase: 2 mV/div.**

Literature

TPS74401 3.0A Ultra-Low Dropout Linear Regulator, Texas Instruments Literature # SBVS066C.

TPS74301 1.5A Ultra-Low Dropout Linear Regulator with Programmable Sequencing, Texas Instruments Literature # SBVS065C.

TPS74201 1.5A LDO with Programmable Soft-Start, Texas Instruments Literature # SBVS064C

TPS74x01EVM-118 User's Guide, Texas Instruments Literature # SLVU143.

Sequencing Power Supplies in Multiple Voltage Rail Environments by David Daniels, Dirk Gehrke and Mike Segal, Texas Instruments Literature # SLUP228 or http://focus.ti.com/lit/ml/slup228/slup228.pdf

Bolo

Abraham Vreugdenhil

Bolo is a light-seeking robot built into a plastic ball. The advantage of a ball is that if it gets stuck, it can always go back the same way it came. If you put a robot **inside** a ball, it can always back up and then roll away from any obstacle it runs into.

Drive mechanism

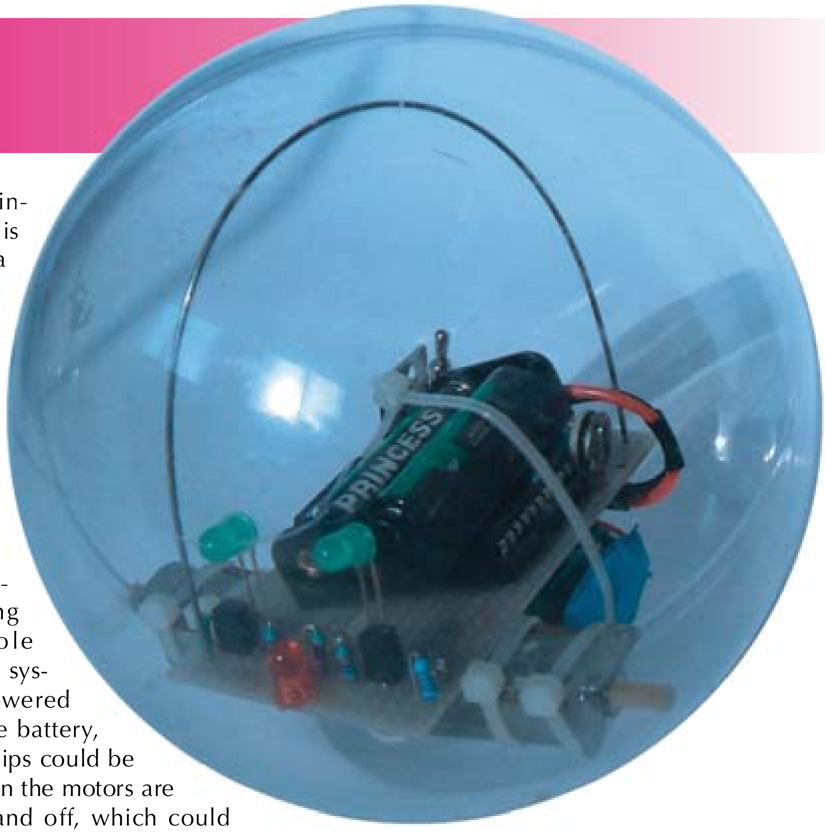
To enable the robot to drive the ball, the shafts of the motors are fitted with lengths of bicycle valve tubing to give them grip. The shafts rest directly on the inner surface of the ball. The robot also has a single support wheel made from a plastic bead. A round hoop is fitted to the top of the robot so it will always land on its 'feet' (wheels) if it is thrown with a swinging motion.

Motors

The rotational speed of the motors is on the high side. If you were to let the robot run continuously, it would pass through the available space rather quickly. To avoid this, the motors are switched on for one second and then off for one second. After they are switched off, the light level is measured and a new decision is made as to which direction the ball should roll for another second.

Electronics

The selected microcontroller is an 89C2051. Among other things, it incorporates a comparator that is used in this design. Two BPW41 photodiodes connected in series are used as the light sensors. The junction of the two diodes is connected to one input of the comparator. A 1-kΩ resistor is connected in series with each BPW41 in order to limit the current through the sensors if the light is excessively bright. A 47-kΩ potentiometer is connected to the second comparator input. This is used to set the light sensitivity. The two eyes are formed by LEDs, which are connected to the microcontroller by a 470-Ω resistor. The two motors are driven by the microcontroller via Darlington transistors. The author did not have these on hand, so an IC with an array of seven Darlington transistors (type ULN2003) was used for the prototype, with only two of the transistors actually being used. If more power is needed, two or more inputs and outputs can simply be connected in parallel to boost the power. The motors are powered by two AAA batteries in series, and the remaining electronics is powered by a 9-V block battery. A 7805 voltage regulator generates a stabilised voltage from this battery. Both voltages can be switched on and off simultaneously using a double-pole switch. If both systems were powered from the same battery, brief voltage dips could be produced when the motors are switched on and off, which could cause the microcontroller to be reset. To prevent this, it's a good idea to use separate supplies for the two systems.



Behaviour and/or extension

A possible extension would be an RC5 receiver, so the robot could receive commands from a 'standard' remote control unit. This would make it possible to steer the ball in a particular direction or select one of several different behaviour patterns

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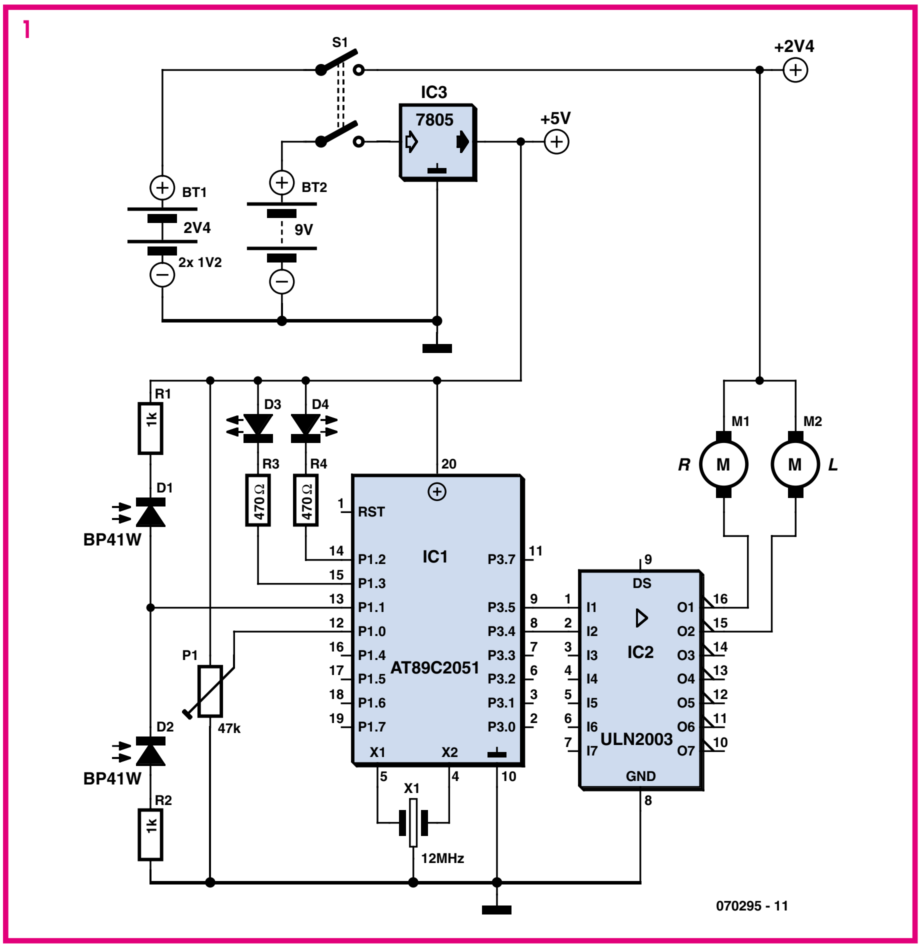
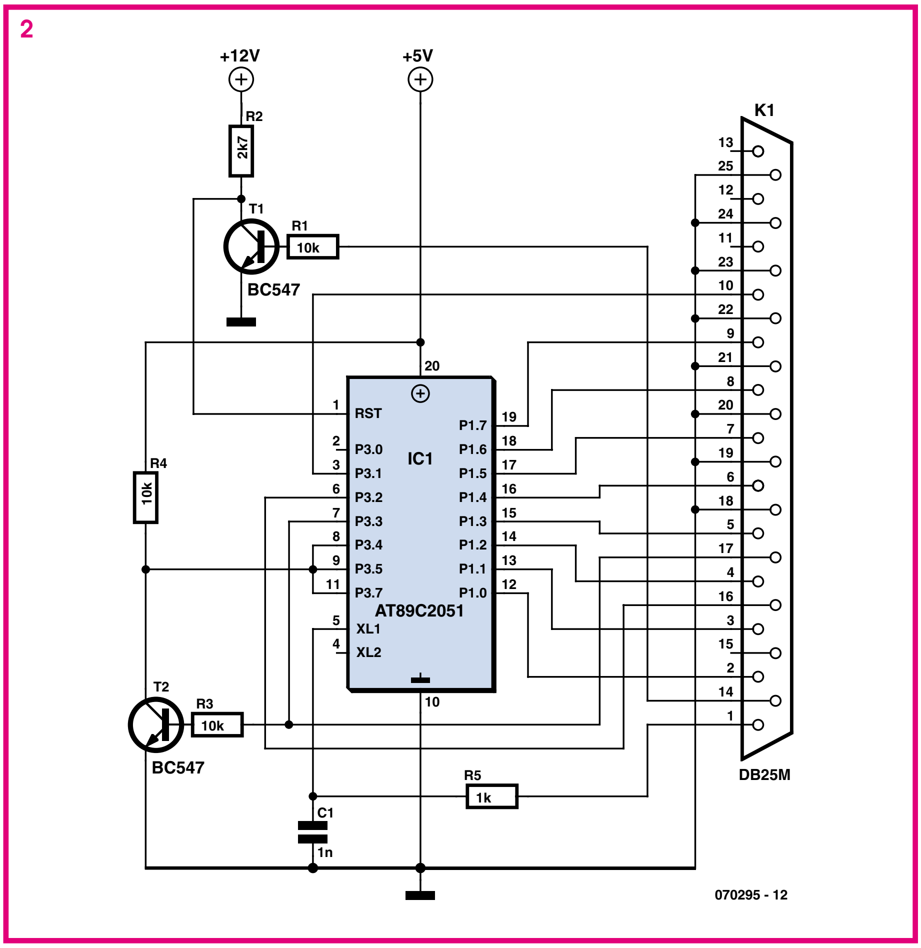




(such as sight seeking, light avoiding, or random). There are many conceivable behaviour patterns for robots. The compiler used for the microcontroller in this robot, BASCOM-8051, provides a specific command for receiving RC5 signals. Such an interface would thus be easy to implement. As it stands, Bolo only behaves as a light-seeking robot.

Programming

The 89C2051 can be programmed using a simple programmer. BlowIt is a programmer consisting of just a few voltage regulators, two transistors, and a few resistors and capacitors [1]. Of course, it also has a 20-pin IC socket and a 25-way D-sub connector. All of this can be assembled on a piece of perforated prototyping board. The author also added a transistor and an LED to indicate when data is being written to the microcontroller. The schematic diagram for the BlowIt programmer and additional information are available on the Internet. This programmer can easily be driven by BASCOM-8051 or BASCOM-LT.

The software for Bolo can be downloaded free of charge from the *Elektor Electronics* website as file no. **070295-11**.

(070295-1)

Web links

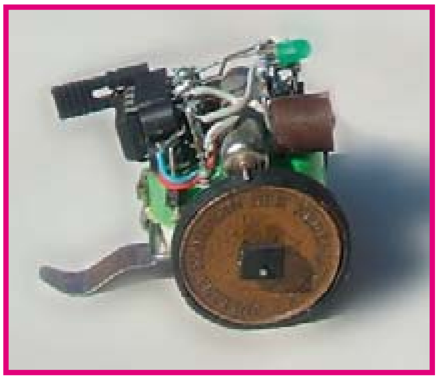
(1) www.geocities.com/dinceraydin/8051/index.html

Het programma voor Bolo is gratis te downloaden van de Elektuur-website (EPS 070295-11).

Antieu-robot

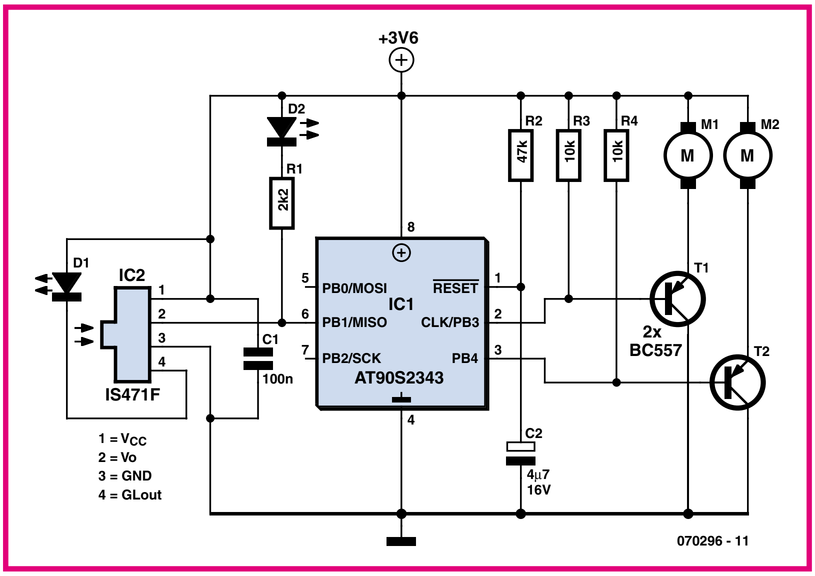
Abraham Vreugdenhil

The name of this robot is actually a bit ambiguous. The hyphen in the name can also be placed in a different position, giving the name 'anti-Eurobot'. This refers to the wheels, which have been made from pre-Euro coins.
The motto of this robot is 'small but functional'. How small can we make a standalone robot?
To start with we'll need very small motors. The author found that the motors used as vibrators in mobile phones were perfectly suitable. These so-called pager-motors are small and run very fast. They normally come with a small weight, which is mounted off-centre on the spindle to generate the vibrations. This can easily be removed with a pair of cutters.
The two motors are driven by a pair of simple BC557 or BC537 transistors. At the base of the transistor we connect a 10 k pull-up resistor. We also require a small processor. The AVR range from Atmel includes an 8-pin version, the 90S2343. Apart from the two supply pins and the reset pin it has 5 I/O pins. This may not look like much, but a simple robot doesn't need many.



The biggest problem is the power source. For this we've chosen a 3.6 V 160 mAh NiMH battery, which has small dimensions. This battery is used as a frame, with the rest of the circuit built around it.
The last component we need is a sensor to detect obstacles. For this we used an IS471F infrared sensor. It reacts to an IR signal that's generated by an IR LED controlled via the same sensor.
And finally we come to the wheels. In keeping with the name of the robot, the author used some old-fashioned Dutch 5-cent pieces for these. We realise that these are difficult to get hold of outside The Netherlands and any other copper coins with a diameter of about 21mm will do as well. Two coins were glued together and we drilled a 1 mm hole through the centre for the axle. A small ring can be cut

from a bicycle inner tube and glued to the coins to make the tyre. The neck of a balloon is also suitable to give the wheels more grip.
If we let the robot travel too fast and then stop it, it would be liable to topple due to its weight and high centre of gravity. Because of this we've limited its speed. This also results in a less nervous looking robot.
The revs of the motors are much too high with a 3.6 V supply. Using a pulse width modulation of 25% reduces it to a manageable level.



We don't let the Antieu-robot ride continuously either, but let it stop at certain intervals. The main reason for this is that it stops it racing to the edge of its area; the other reason is that it gives it a somewhat intelligent and thoughtful characteristic. It almost appears as if it's studying its surroundings before continuing on its journey.
When an obstacle is encountered it will turn left or right, depending on an internal counter. If it still sees the obstacle it continues turning in the same direction until the obstacle disappears from view.

The program gives the robot a simple object avoiding behaviour. The robot rides along until it sees an object, which it will then try to get around. Only about 600 bytes have been used of the available 2 k of program memory. There is therefore sufficient space to program in a more intelligent behaviour or to add an extra sensor and modify the program accordingly.
The Antieu-robot is programmed in BASIC. The code is compiled using BASCOM-AVR. This is a very good compiler made by MCSELEC. For more information and a free demo version go to www.mcselec.com.
As an enhancement you could add a power contact at the top of the Antieu-robot, with a corresponding power source hanging at the right height somewhere in the room. When it makes contact with this power source the robot could take a bit of a rest whilst it recharges its battery.
The program for the Antieu-robot can be downloaded from the Elektor website as file number **070296-11.zip**

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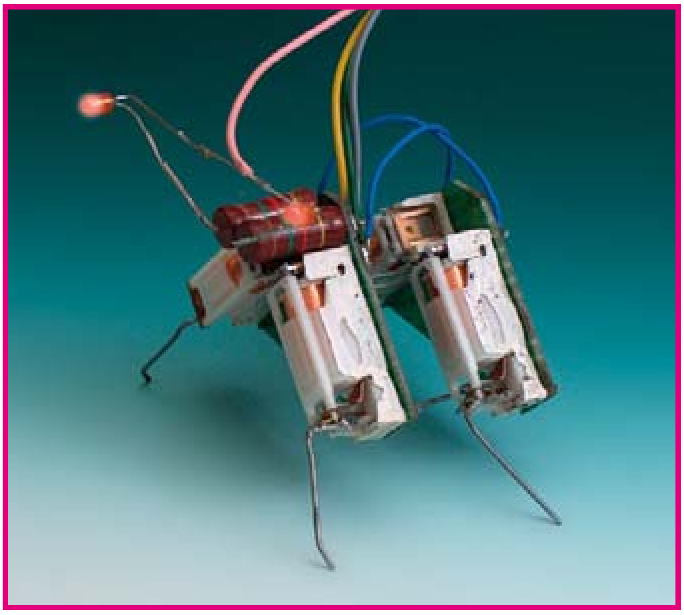
Babybot



There are many conceivable and feasible techniques to give motion to a robot. In most cases ordinary electric motors, servos and stepper motors offer the simplest solution. In particular if the actuators are required to deliver a considerable amount of power. But for very small objects other types of actuators also become suitable, such as the one used in this mini robot.

The term 'robot' may be a little of an exaggeration in this case. This creature has to be controlled from the outside and does not have any other artificial intelligence, but the method of motion is quite unusual and with a little modification could also prove useful in other projects.

BabyBot walks with the aid of four small PCB relays, which have been specially modified for this purpose. The covers have been removed and the legs have been soldered directly to the switching contacts. It will be clear that the step size of the leg will be minimal. After all, the 'stroke' that the switching contact can make is very small.

The legs cannot support and move much weight either. On the one hand this has to do with the limited pulling power of the electromagnet and on the other hand with the fragile construction of the inner workings of these small relays. It is likely that the link from magnet to switching contact will fall apart from time to time.

And this means — depending on the type of relay — a lot of fiddling to put it back in the right place. BabyBot is by no means a real robust construction, but it is useful for experimentation and anyhow, the whole thing looks quite nice.

(070278-I)

Video clip of the walking mini robot:

http://www.xj3.nl/_dreijer/backsite/willem/babybot.avi

Torque is Cheap

Bernhard Spitzer

While on the lookout for low-cost drive solutions the author's eye fell upon a cheap battery-operated cordless screwdriver in an electronics shop (**Figure 1**). These are available for just a few pounds (for example, Conrad order code 481576) and include a powerful '380' motor and a multiple-stage planetary drive. The classification of motors as '380', '540' and so on follows the part numbers in the range produced by Mabuchi Motors. A '380' motor corresponds to the Mabuchi RS380 and has a diameter of 29 mm and a length of approximately 40 mm. The nominal voltage is 6 V with a maximum current of approximately 4 A, with a power of between 10 W and 15 W depending on the model: see, for example, Conrad Electronics order code 244511.

1

To drive a wheel on a robot model we require a bearing on the drive axle. We must also dispense with all the unnecessary parts that come with the motor: first remove the battery case and then the gearbox, by pushing out the two pins (seen in **Figure 1** and **Figure 5** near to where the black and orange parts of the case meet) using a 2 mm pin. With the gearbox removed the two black halves of the case can easily be separated. Now the motor connections must be straightened out in order to remove the reversing switch.

The two halves of the case should now be cut away in such a way that the motor mounting remains intact. Drill a hole at the lowest point of the lower half for a fixing screw. Finally we need a bearing mount to support the wheel, for which we use a small piece of plastic (see the drawing in **Figure 2** for dimensions). For smooth running we use a 15 mm × 10 mm × 4 mm ball bearing designed for use in model cars (for example made by Tamiya). The 15 mm diameter recess (**Figure 3**) can be made using a Forstner bit. The hole in the mounting block should be made at half the motor enclosure diameter from the edge (here 20.3 mm) so that the shaft will later be able to pass exactly through it. The finished bearing mount with bearing fitted is shown in **Figure 4**. The two M3×16 screws are used to fix the mount to the baseplate of the vehicle.

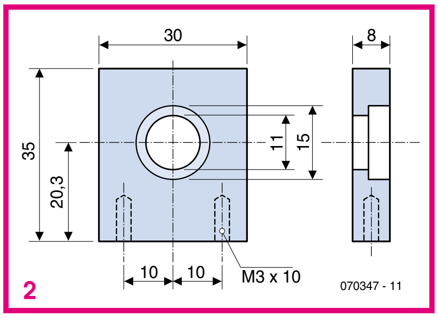


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Figure 5 shows the motor and gearbox ready for installation, with bearing mount fitted. Either wheels with a 10 mm axle hole can be used, glued directly to the shaft, or the wheel can be glued to a screwdriver bit which is then fitted to the motor.

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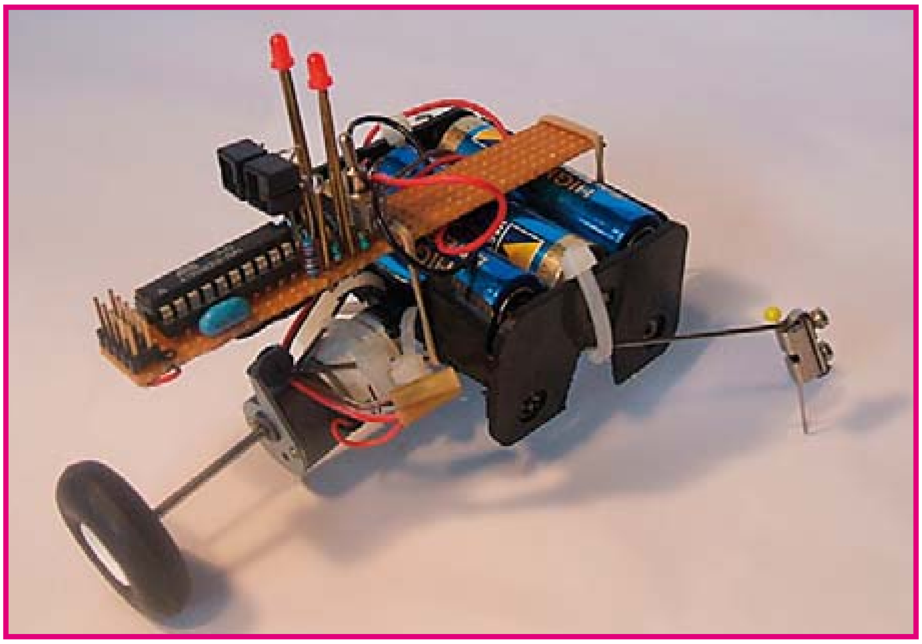
Minimalist Motor



Abraham Vreugdenhil

Eenvoudig, apart en toch een doel, dat The design brief for this robot was that it had to be simple, yet unusual, and also have a specific purpose. But should we really call this a robot? It consists of one motor, one wheel, sensors, a microcontroller, LEDs, batteries and 'legs'. If the motor slowly turns one revolution to the left and then one to the right, and the 'legs' offer more resistance in one direction than the other, the robot will move slightly forward. If it also keeps turning towards the light it becomes a true light seeker.

A detailed description of some of the parts follows.

Wheel

A normal rubber wheel is used for this robot. This gives sufficient grip on the floor, sometimes a bit too much. Particularly in the roll direction, but also perpendicular to the roll direction there is a lot of grip and/or resistance. But any resistance perpendicular to the roll direction will severely restrict the forward movement of the robot. It would have been better to use an omnidirectional wheel instead. These wheels have smaller wheels/rollers at right angles to the rim, reducing the perpendicular resistance to almost zero. This will work much better than a plain rubber wheel.

Sensor

For the lights sensors an old favourite is used, the CNY-70. This sensor consists of an IR LED and an IR photo diode and is usually used to detect and track a line on the floor. It is of course also possible to use just the photo diode of this sensor. If we connect two of these in series, with a resistor at each end to limit the current at high brightness levels, we end up with a neat sensor that provides a voltage at the junction of the two sensors that is proportional to the difference in light intensity on the sensors. This junction is connected to one of the inputs of the comparator in the microcontroller. The other input is connected to half the supply voltage, provided by a potential divider formed by two resistors connected to the positive and negative supply. The output signal of the comparator can be read using an internal variable (bit). This way we know at which side of the robot the light is brighter and we can then steer it in that direction.

Microcontroller and motor driver

Most microcontrollers are capable of sourcing a fair amount of current. In this circuit we use this property to directly drive the motor via the microprocessor. When we need to supply larger currents we just connect a few outputs in parallel.

A microcontroller is of course a necessity in every robot. This time our choice was for an AT90S2313. This can be easily programmed in BASIC with the help of BASCOM-AVR. It has a comparator on-chip, sufficient I/O pins to link together for parallel outputs, etc. An ISP connection is also made available, so it can be easily re-programmed during testing, or at a later stage if you'd like to try out a different program in the robot.

A pair of 3-mm LEDs is mounted above the eyes for show. The LEDs are connected from the positive supply to the processor via 1 kΩ resistors. To complete the robot circuit there is also a battery holder for four AA cells and an on/off switch.

The AT90S software for the Minimalist Motor can be downloaded from the Elektor website as file number **070284-11.zip**.

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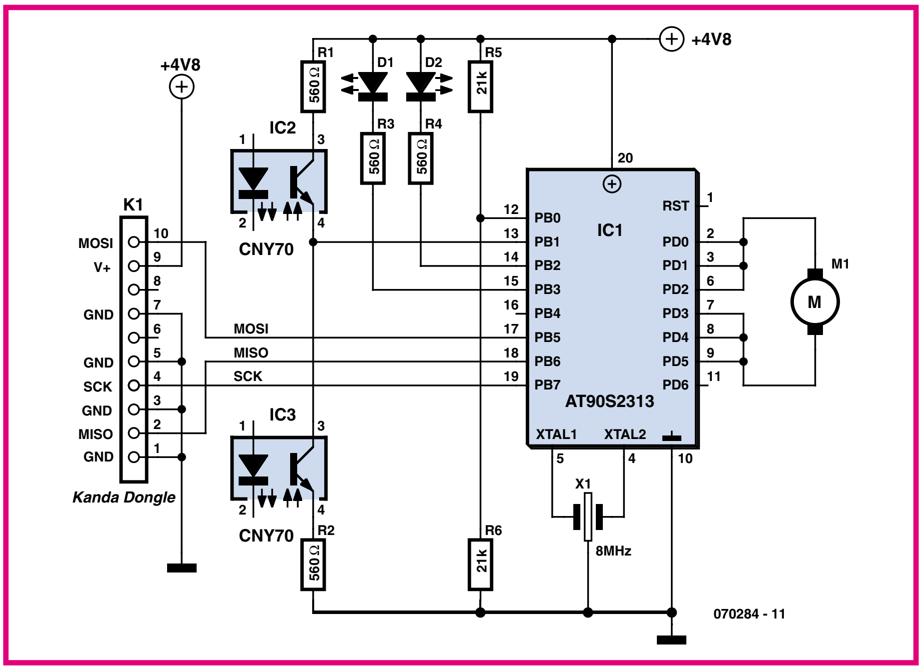
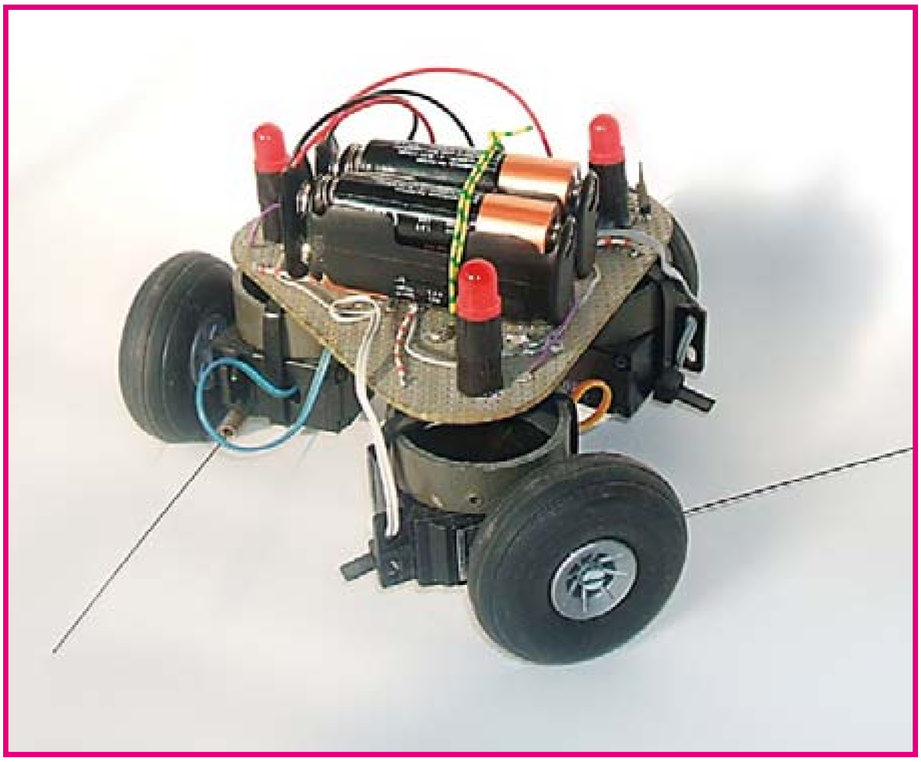


TriBot



Connections to the 89C2051		
Pin	**Function**	**Connects to**
1	RST	
2	RxD	
3	TxD	
4	Xtal2	
5	Xtal1	
6	P3.2	(RC5 expansion)
7	P3.3	Motor 2
8	P3.4	Motor 3
9	P3.5	Motor 1
10	GND	
11	P3.7	LED 1
12	P1.0	Antenna 1
13	P1.1	Antenna 2
14	P1.2	Antenna 3
15	P1.3	LDR 1
16	P1.4	LDR 2
17	P1.5	LDR 3
18	P1.6	LED 2
19	P1.7	LED 3
20	VCC	

Abraham Vreugdenhil

This is a triangular robot with three wheels that can only rotate in one direction. Despite this it can make its way towards a light! That's TriBot.

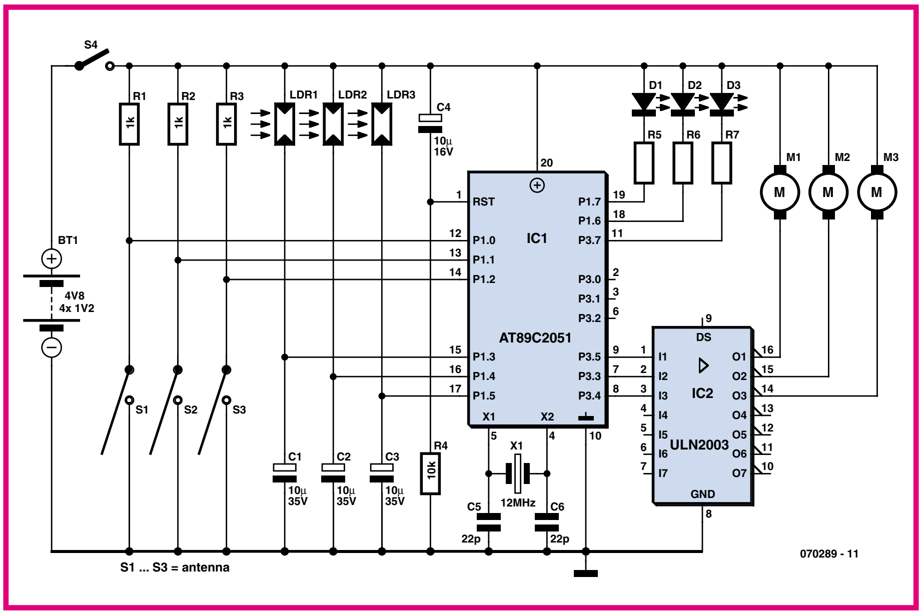
The robot has three LDR light sensors, which are used to determine which side faces the brightest light. It also has three antennae that are used to detect when it is about to bump into something.

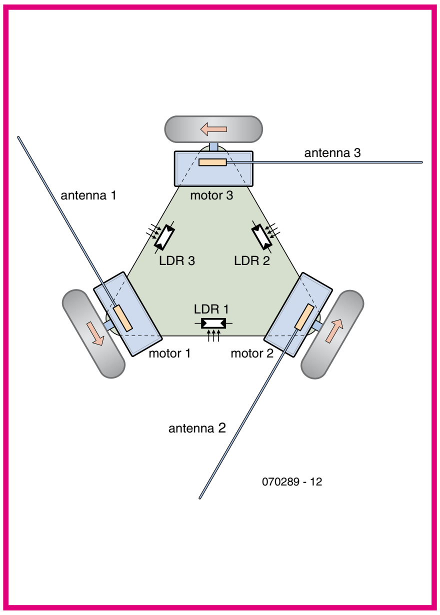
For the processor we used the 89C2051 by Atmel, a nice processor at a reasonable price, which has a 2 k program memory. It is also possible to use a different processor, as long as it has at least nine I/O pins: three for the LDRs, three for the antennae, three for the motors and, if they're available, three for the LEDs.

The measurement of the light intensity via LDRs is implemented using the LDRs in series with a 1 nF capacitor and calculating the RC time-constant. The value of the LDR (which is affected by the light intensity) changes the RC time-constant of this network (if you refer to the program it will make the working clearer).

The compiler used here (BASCOM-LT or BASCOM-8051) has a function that does all the hard work for us: GETRC(pin number).

The antennae are made of copper pipes with a piece of spring-steel wire through the centre. They are separated from each other with a length of isolated wire. When the spring-steel wire is moved it makes contact with the copper pipe, which is





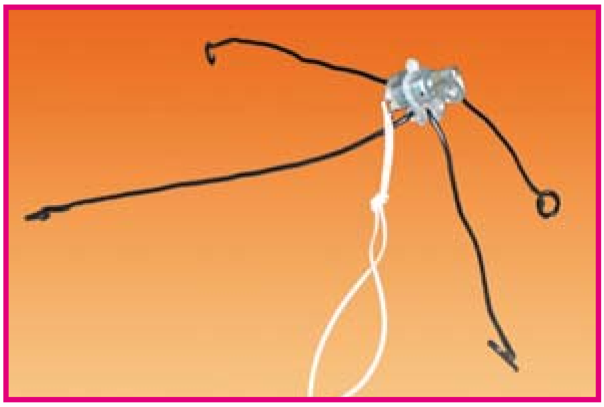
detected by the processor.
The motors are old servos, with all the internal electronics removed. The motors are driven directly via a transistor. They can only be turned on or off and can rotate in only one direction.
When all three motors are turned on at the same time the robot will rotate around its axis. If we then turn one of the three motors off, TriBot will rotate about the stationary wheel. Turning on the stationary motor and turning off another one will cause the robot to 'stagger' in a fairly straight line towards its destination.
To add some visual appeal we've added three 8-mm LEDs. When TriBot is powered up they show a moving pattern and the motors all turn on momentarily (as a self-test). The LEDs are connected in such a way that the LED lights up near the motor that is turned off.
Using three motors to propel the robot in circular motions isn't exactly the most efficient method of travel. (In that case we should have used omnidirectional wheels instead of normal rubber ones.) But that wasn't a requirement for the design of this robot. It just had to look nice and behave in an amusing way.
The program for TriBot can be downloaded from the Elektor website as file number **070289-11.zip**.

(070289-I)

Trembly

Abraham Vreugdenhil

The author made this 'construction' for his daughter, who gave it the name 'Trembly' because this robot moves with such a cute trembling motion.
It consists of a little motor fitted with an eccentric weight, a single terminal block, two short legs at the rear and two long legs at the front, all made from electrical wire. The rear legs are fitted with small rubber feet or caps. The motor shaft is aligned to the longitudinal axis of the long front legs. In other words, the direction of vibration of the eccentric weight is toward the short legs. When the motor is switched on, the eccentric weight causes the robot to start vibrating, with the result that it moves forward.



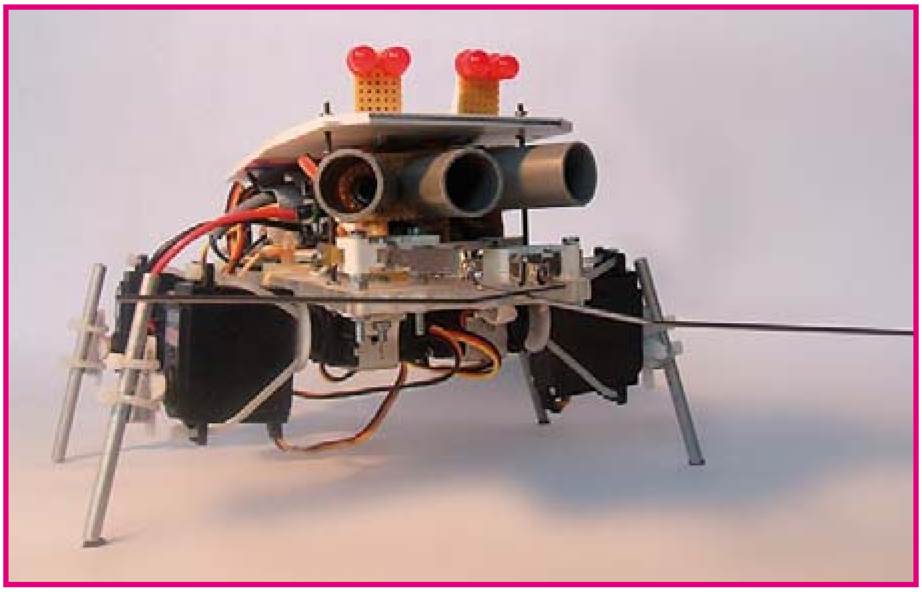
This robot can be built quickly with all sorts of bits and pieces from your junk box, and kids just love it.

(070288-I)

Hunter

Abraham Vreugdenhil

Four-footed walking robots occupy a special place in the gamut of DIY robots. Walking on four legs has always been a challenge. Building these robots thus creates a strong feeling of satisfaction.
Bedsides the choice of this form of locomotion, you have to select the sensors you want to fit to your robot so it can explore its surroundings. In this case, we selected feelers for short-distance sensing in order to avoid objects. In addition, the robot will be able to detect moving warm objects, such as people and animals, at a greater distance using a passive infrared (PIR) sensor.
The choice of microcontroller is also important in designing a robot. It must have an adequate number of I/O lines and sufficient memory capacity. In addition, you have to weigh the cost against the desired functions (which means behaviour).
Behaviour is one of the most important parameters. It determines how the robot will respond to the information it receives from the various sensors.



Servo legs

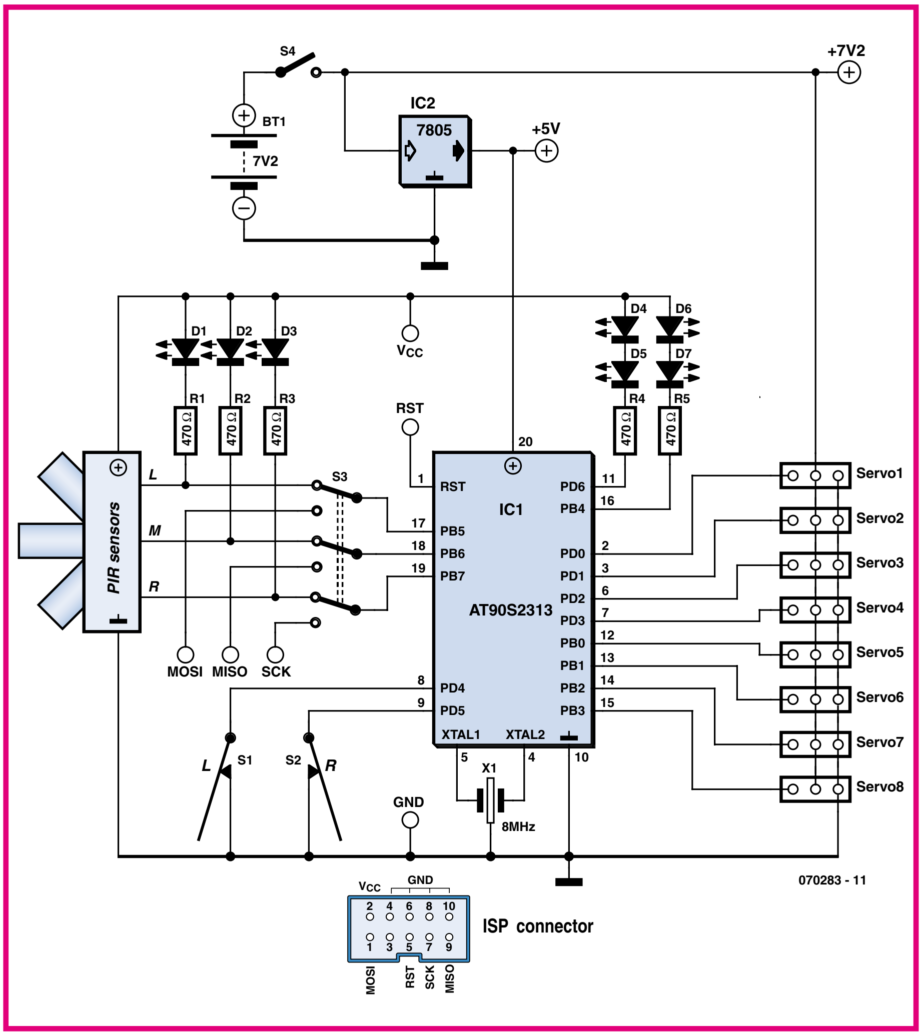
Developing a nice mechanical design for the legs is a difficult task. There are many conceivable possibilities using rods and levers, each of which has its specific advantages and disadvantages. In this case, we decided to use a very simple design.

Two servos are strapped together using cable ties. The housing of one servo is secured to a Plexiglas base plate, and an aluminium rod with a diameter of 6 mm is fitted to the shaft of the other servo. The first servo acts as a hip joint, while the other one acts as a knee joint. All four legs are build using this construction.
If you look at the walking motion of a human leg, you see than the knee joint cannot bend any further forward than the fully extended state. The knee can bend backward much further, up to nearly 180 degrees. By contrast, the hip joint can bend forward as well as backward. The servos are fitted such that the legs of the robot have the same freedom of motion.
The walking motion of each leg is divided into 28 steps. The leg moves backward slowly in 22 steps, and then forward quickly in 6 steps. The positions of the knee and hip servos corresponding to these 28 steps are stored in a table. By operating the servos at a fixed interval using the values from this series of numbers, we obtain a nice walking motion of the leg. The servos on the other side of the robot's body must be inverted, since otherwise these legs would walk backward.

There are four legs, and the number of steps per leg is 28. In order to obtain a stable walking motion, the standard offset between the four legs is set to seven positions in the series of numbers (e.g. left front 1, right rear 8, right front 15, and left rear 22).
To enable the robot to turn, we retard the motion of the two left legs and advance the motion of the two right legs.
When the robot is walking, all 28 steps of the walking motion are always executed before the sensor information is examined again, which means a complete stepping motion of the legs is executed each time. This simplifies the structure of the software and ensures that the legs are always in the same state when a new decision regarding the walking direction must be taken. The feelers have sufficient range of motion that the robot can still manage to move after a full step has been completed.

Feelers

Two simple microswitches are used for the feelers (i.e., antennae or whiskers). A steel wire (bicycle spoke) is attached to each of the microswitches. A sliding clip is fitted to the spoke and then slid over the microswitch. Two nuts are fitted underneath one of the switches so it is not at the same height as the other one. Otherwise the two feelers would interfere with each other too much. The feelers are connected between two microcontroller input pins and ground. No pull-up resistor is necessary, since the microcontroller has built-in resistors. The feeler switches are closed when they are not activated.



Eyes

The eyes of this robot do not function as sensors. They are purely decorative. The eyes consist of two 8-mm red LEDs connected in series. They are powered from the 5-V supply via a 150-Ω current-limiting resistor, and they are connected to an output line of the microcontroller. The eyes switch from on to off after each step, but they remain in a fixed state while the robot is moving backwards or turning, depending on the motion that is being performed.

AT90S2313 pin assignments

Pin	Function	Connection
2	PD0	Left front leg hip
3	PD1	Left front leg knee
6	PD2	Left rear leg hip
7	PD3	Left rear leg knee
8	PD4	Left feeler
9	PD5	Right feeler
11	PD6	Right eye
12	PB0	Right front leg hip
13	PB1	Right front leg knee
14	PB2	Right rear leg hip
15	PB3	Right rear leg knee
16	PB4	Left eye
17	PB5 - MOSI	Left PIR sensor / ISP via jumper
18	PB6 – MISO	Middle PIR sensor / ISP via jumper
19	PB7 – SCK	Right PIR sensor / ISP via jumper

PIR sensor

Various models of PIR are available commercially, such as the Eltec 422 from Acroname. The main disadvantage of this model is its price. There's also the HI-859 from Conrad. Its disadvantage is its inconvenient electrical interface. The signal from this sensor must first be amplified before it can be used.

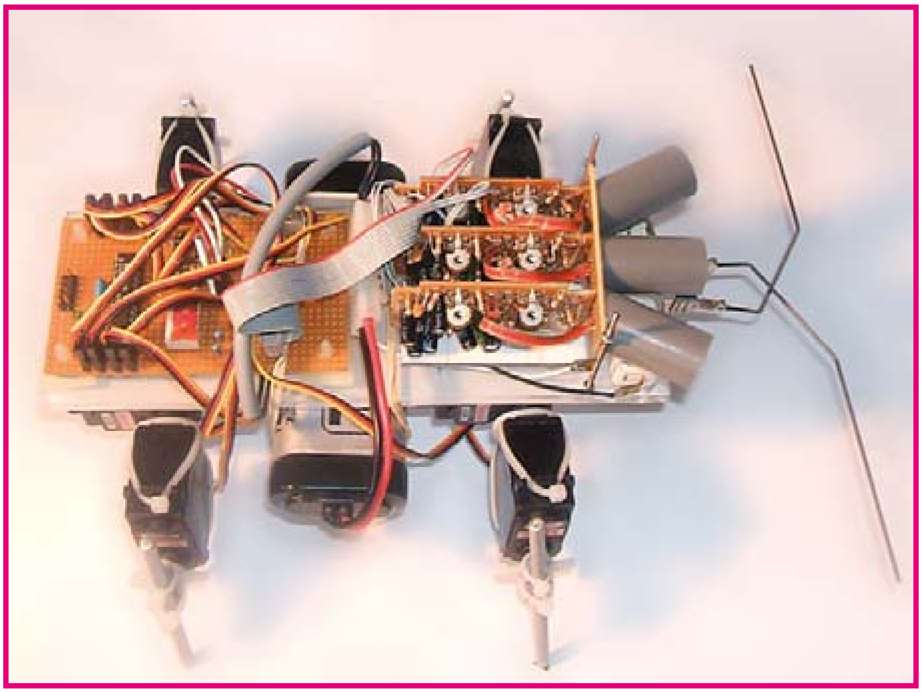
As an alternative, we selected a well-known sensor that is relatively inexpensive: a motion detector available in DIY home improvement shops for less than £ 10.
The first thing to do is to remove PCB with the sensor from the motion detector, after which you can fit the sensor to a separate PCB. Three sensors are placed next to each other so the total field of view can be divided into different regions. This yields more information that can be used to influence the robot's behaviour. The circuit boards for the sensor elements are still useful. They hold all the electronics necessary to generate a digital signal at the output. All of this for less than 10 quid per sensor element!

In principle, each of the sensor elements has a detection field of view of 140 degrees. In practice, the angle is larger than this due to reflections and the like. Collimation and screening by means of pieces of electrical conduit with a length of 2 to 3 cm is thus not a bad idea.
If the sensors are arranged so their fields of view overlap, we can distinguish five sensor regions.

To make the activity of the PIR sensors visible, a LED is connected to the output of each PIR sensor. These LEDs are connected to the 5-V supply via resistors. The LED is on if the PIR sensor does not detect anything, and it switches off if the associated PIR sensor detects a moving warm object.

Microcontroller and compiler

The selected microcontroller is an Atmel AT90S2313 (see the schematic diagram in **Figure 1**). It has 2 kB of program memory, which provides plenty of room to program intelligent behaviour. The AT90S2313 has 15 I/O pins, of which three can be used for ISP. An ISP port is quite handy during testing and in case of future software extensions. This port is fitted to the robot using a 10-way CANDA connector. You can program the device using the Sample Electronics Programmer [1], among other options. Only three resistors are necessary to connect a printer port to this port.
Quite a few I/O lines are necessary for controlling the hardware, which comprises eight servos, two feelers, two LEDs, and three PIR sensors. This makes a total of 15 devices. For this reason, the three PIR sensors are connected to the robot in parallel with the ISP port via jumpers. In normal operation, the PIR sensors are connected to the robot. If a new program must be downloaded to the robot, the jumpers must be switched over to make the ISP port available.



The robot software was programmed in Basic and compiled using BASCOM-AVR [2]. This an excellent compiler for Atmel AVR microcontrollers. The freeware version of BASCOM-AVR can easily handle the 2-kB program capacity of the AT90S2313.
The software for the Hunter can be downloaded free of charge from the *Elektor Electronics* website as item no. **070283-11.zip**.

Power supply

The robot is powered by a 7.2-V rechargeable battery of the type used in models. An on/off switch is fitted to the battery. A regulated 5-V supply voltage for the electronics is generated by a an old friend in this area: a 7805 in a TO220 package. The servos are powered directly from the battery via the switch.

Behaviour

The name of the robot says a lot about its behaviour. It hunts for something. Its job is to detect and follow warm moving targets, such as people and animals. As long as the robot can see something, it will pursue it. If it can't see anything, it advances by five steps in the hope of seeing something. After these five steps it remains standing and waits for new prey. The behavioural rules can be summarised as follows:

1. If nothing is detected, do nothing. (sight = 1)
2. If sight > 1, take one step (sight = sight – 1).
3. Check for obstacles after each step. If an obstacle is detected, walk backward and then turn away from the obstacle. (sight = 6)
4. If sight < 5, check the PIR sensors. If something is detected, turn in the direction of the detected object. The options for the turning direction are: left, forward left, straight ahead (no turn, with sight = 6), forward right, and right. (sight = 6)

Conclusion

The objective was to build a four-legged robot with interesting behaviour. This objective was ultimately achieved, and with a reasonably limited budget. The microcontroller memory is pretty well filled by the current software, but it would still be possible to devise a more efficient behaviour algorithm. This means that there are plenty of options for experimenting with this robot. Thanks to the onboard ISP port, programming the robot is easy. This robot is a means, not an end. Let's hunt!

(070283-I)

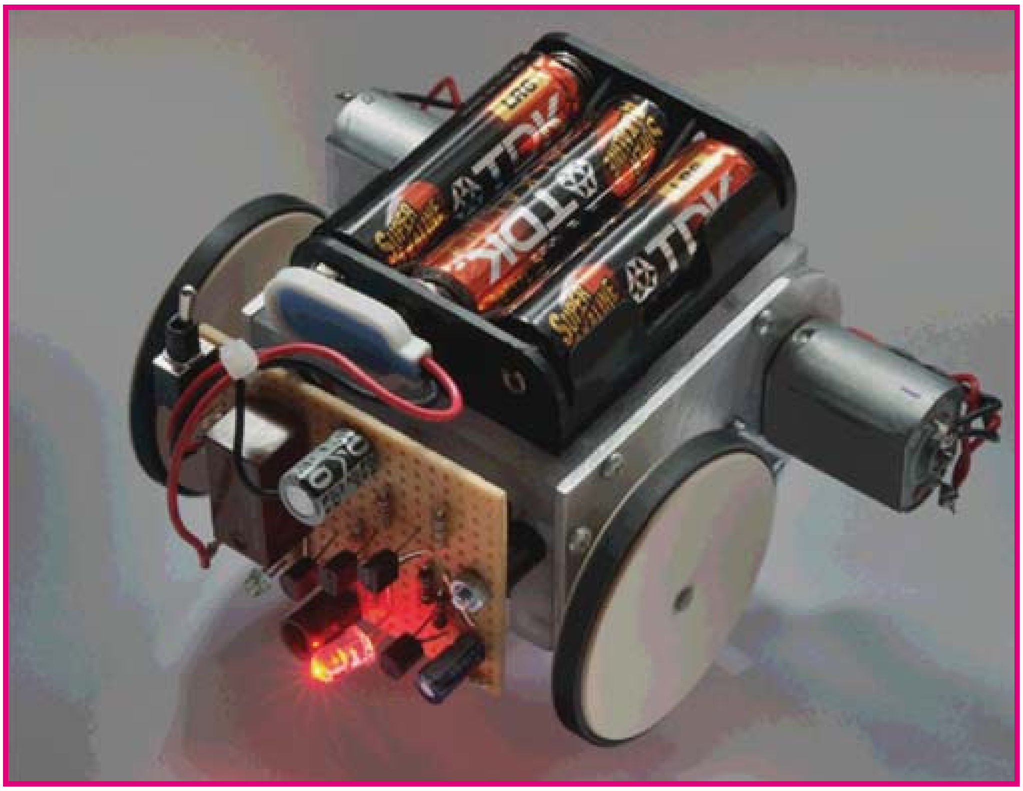
Web Links

(1) http://avrhelp.mcselec.com/Sample_Electronics_cable_programmer.html

(2) www.mcselec.com

Robot MOPS

Markus Bindhammer



MOPS is a small robot which generally bumbles around the floor and performs avoidance manoeuvres whenever it detects an obstacle in its path. MOPS uses a forward facing LED to illuminate its path and a phototransistor to detect light reflected from obstacles, as soon as an obstacle is detected MOPS goes into reverse and turns for a few seconds on its two wheels before setting off again in another direction.

A look at the circuit diagram in **Figure 1** indicates that MOPS is built (rare for this day and age) entirely from discrete components. Resistors R1 to R4 together with C1, T1 and T2 form a multivibrator circuit which continually switches the LED on and off. On power-up current flows through R4 and the base-emitter junction of transistor T1. T1 is therefore conducting and current flows through R1 and the base of T2 which is also conducting. Current through the collector of T2 and R6 lights up the LED. During this time capacitor C1 is charging up and when the voltage level gets sufficiently high the base of T1 becomes reverse biased and T1 turns off. T2 will also turn off along with the LED. C1 begins to discharge until the base of T1 is low enough to begin conducting again. T2 switches on which reinforces the low base voltage on T1 via C1 and the cycle continues.

The LED light source for obstacle illumination does not need to flash, it can be lit continuously but there are two reasons for the flashing LED: firstly it conserves battery power, giving MOPS a longer range and secondly (and more importantly) a flashing light looks much more impressive than a boring old continuous light source.

When reflected light falls on the phototransistor T3 a current flows through R5 to ground which produces a voltage at the base of T4 to make it conduct. The values of R5, P1 and R7 affect the switching threshold so adjustment of P1 will help to reduce spurious detections caused by external light sources. Turning P1 (a preset could be used here instead) so that it

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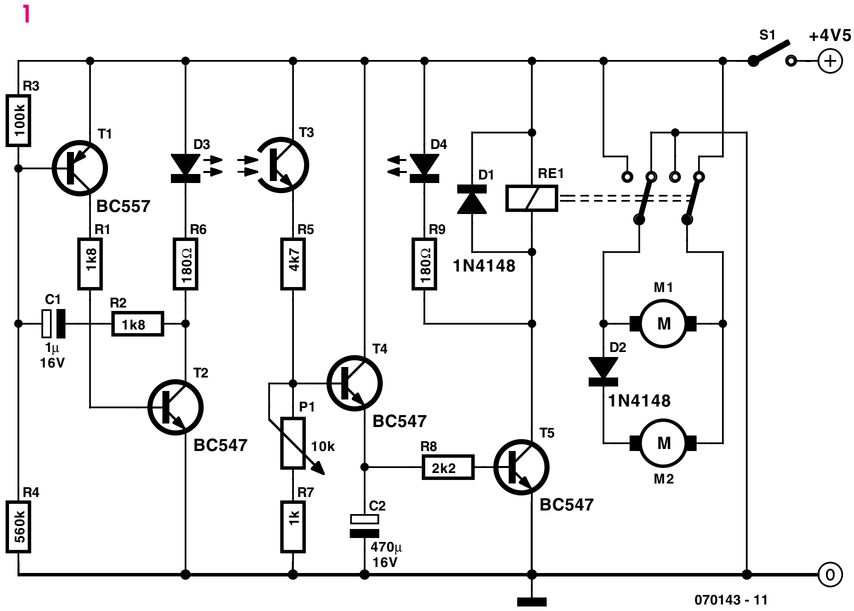

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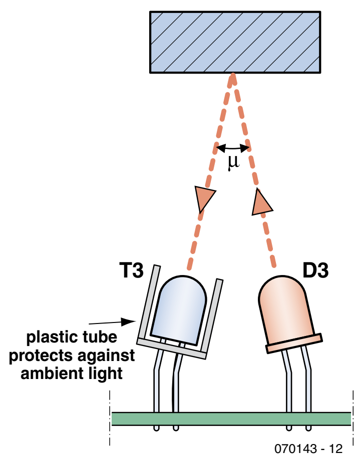
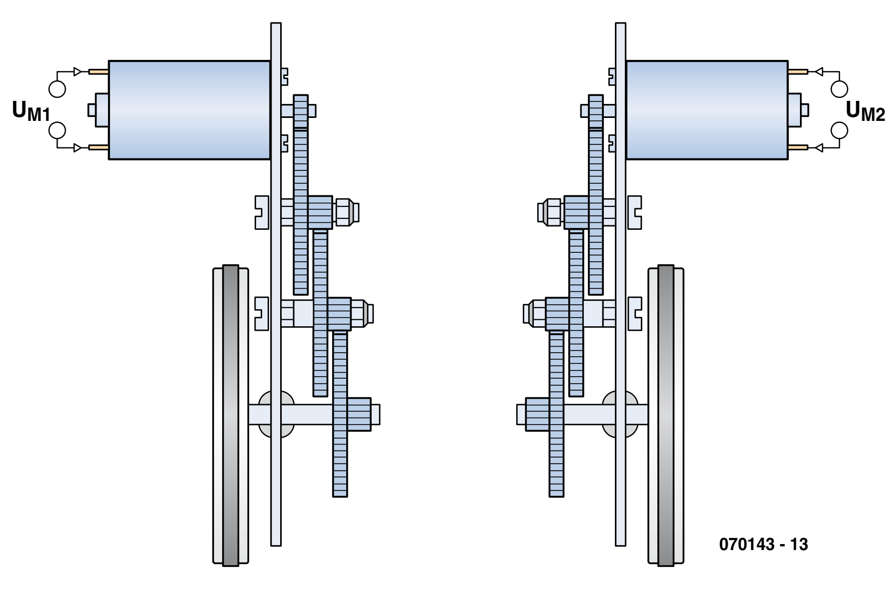


increases its resistance will make T4 more sensitive and vice versa. T4 conducts in synchronism with the flashing LED so capacitor C2 acts as a reservoir capacitor to ensure that once T4 begins to conduct, sufficient energy is stored in C2 to ensure that T5 remains conducting continuously until the obstacle is out of range and T4 switches off. It takes a few seconds for C2 to discharge and during this time MOPs is performing its avoidance manoeuvre.

T5 switches a double pole relay which has the effect of performing this manoeuvre. In normal forward motion the relay switches the positive and negative supplies to both motors and diode D2 is conducting. When an obstacle is detected the relay switches and reverses the polarity of the motor connections. D2 now becomes reverse biased and no current can flow through motor M2 while M1 goes into reverse. This gives MOPS the reverse and turn response to obstacles. A few seconds after the obstacle is no longer detected the relay switches back and MOPS carries on as before but in a different direction.

Figure 2 shows a close up of MOPS's eye mounted in a tube which helps to make obstacle detection more directional and reduces the effects of external light sources. With this set-up it was possible to detect obstacles at a distance of 10 cm. The range depends largely on the reflective properties of the obstacle so darker objects will only be seen at shorter ranges. The circuit can be modified to read microswitches connected to contact feelers mounted on the front of MOPS this will help avoid collisions with matt black objects. **Figure 3** shows the layout of the two motor and gearbox assemblies.

3



(070143-I)

Web link

www.elexs.de/robo1.htm

2.4 GHz Antenna for Robotics Vehicles

Ragnar Jensen

Radio equipment using the license-free 2.4-GHz ISM (industrial/scientific/medical) band is also rife among robotics fans, just think of what you can do with Bluetooth, wireless cameras, remote control, or even a WLAN client or access point fitted on a robot vehicle! Point is, such homebrew applications typically require an antenna that's (1) omnidirectional, (2) 'sort of' flexible in view of the damage and bashing it may have to take and (3) low^2 cost.
The antenna shown here fulfills all three requirements brilliantly. See for yourself, the pictures say more than 1 kwords.
You will need:

- a short piece of 50-Ω coax cable like RG58(C)U with a crimped-on BNC plug ('borrow' a cable from the IT dept.);
- a sharp (hobby) knife;
- a pointed tool like a strong needle or a watchmaker's screwdriver;
- a ruler;
- a soldering iron (optional);
- a hot glue gun;
- common sense and about 30 minutes of your time.

Here goes.

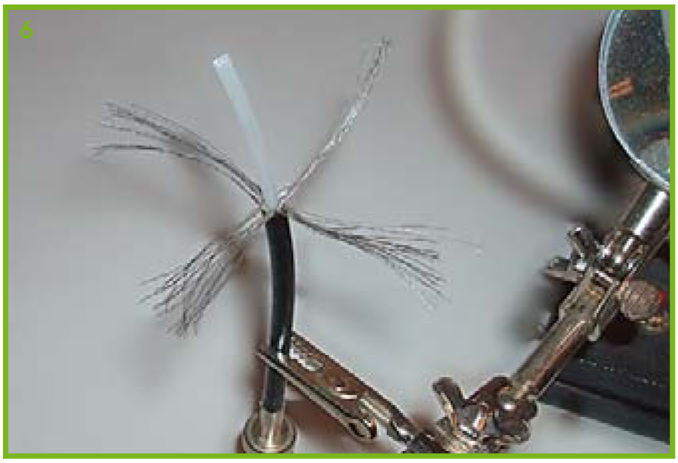
The raw material: a short piece of 50-Ω coax cable.

Cut off about 40 mm of the outer insulation. This will expose the braid that forms the cable shield.

Push down the braid to expose the inner insulation.

Using the pointed tool, carefully unweave the braid strands.

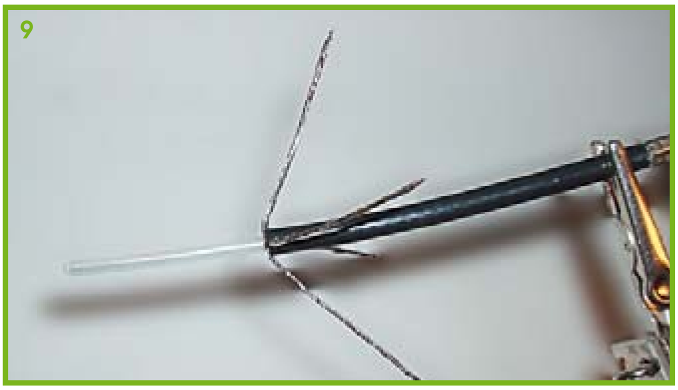
Until your hairdressing looks something like this…



Distribute the strands into four equally sized and likewise spaced bundles (wow, tresses!)

Now bend them into a 45-degree angle with respect to the cable. This angle will result in an antenna impedance of about 50 Ω.

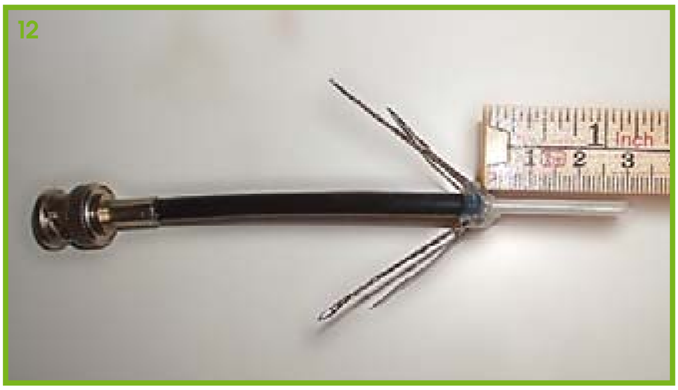
Cover the bundles with solder. Although this step is optional, it does enable the ground plane elements to hold their shape better, and prevents untwisting of the strands.



Done soldering!

Apply a few drops of hot glue…

… will help keep the proper shape.



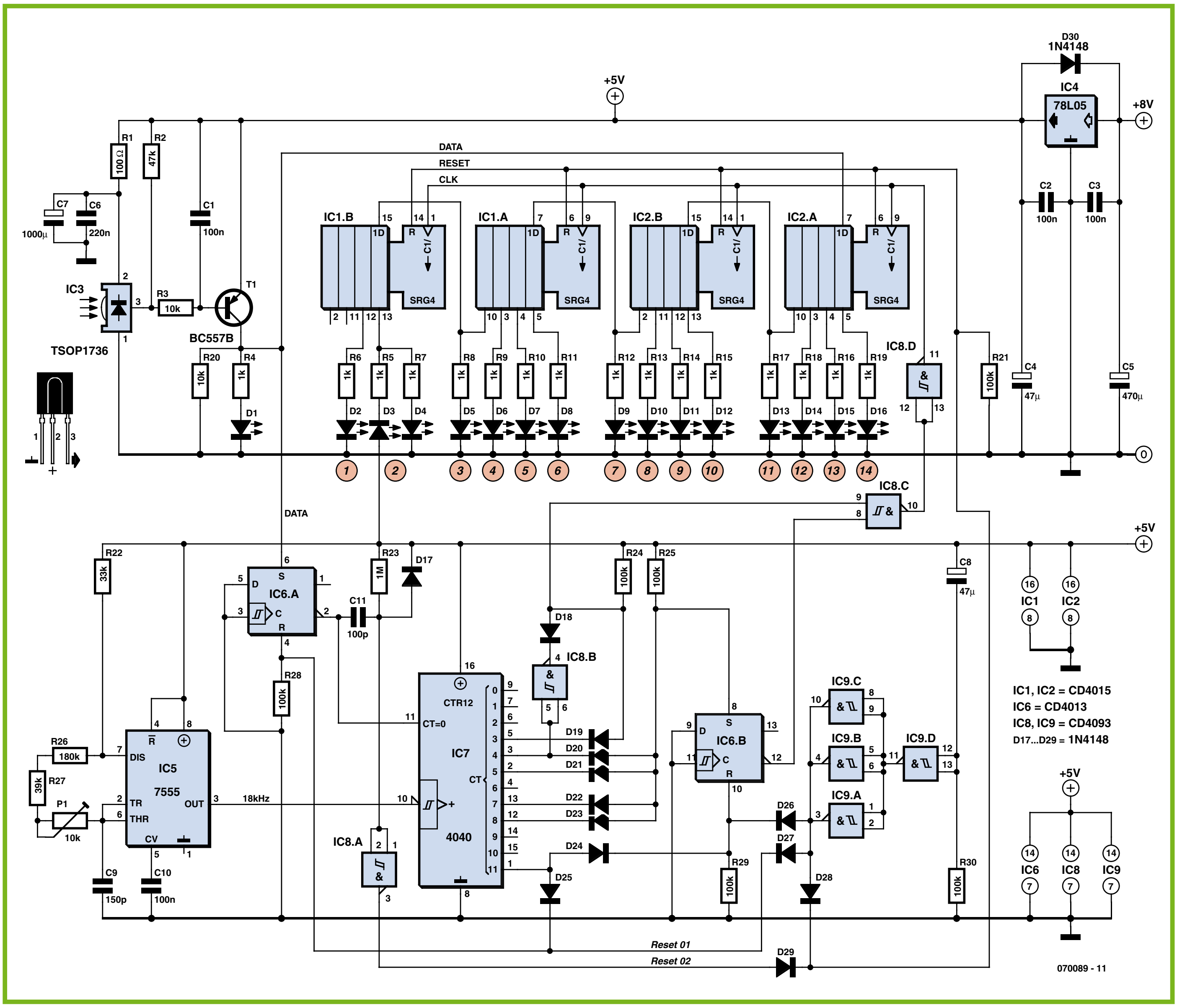
Cut the radials and the radiator to a length of 30 mm (yes that's 0.25 lambda).

And we are done!

(070142-I)

(reproduced with modifications and extensions from CQ-TV issue 217)

Receiver for RC5 Remote Controls



Thomas Möll

Software decoding of remote control signals using the RC5 protocol does not present a significant challenge to a modern microcontroller, while for a pure hardware solution specialised RC5 decoder ICs are available. Nevertheless it is interesting to look at how we might process RC5 signals using ordinary components. This way not only do we learn about how the code works, but also the resulting circuit is easier to adapt to different applications.

Although the circuit was originally designed just to display the address and command emitted by a 'universal remote control' when each button was pressed, it could be used, for example, to add a remote control facility to an audio amplifier using a standard remote control unit. Indeed, virtually any household appliance could be controlled in this way: just choose an address that is not yet allocated and define your own commands.

The TSOP1736 infrared receiver inverts the bits in the received stream. T1 inverts them again so that they are now available with the correct polarity. The LED connected to its collector indicates when data bits are received.

This signal is low (0 V) for the first half of the start bit and high (5 V) for the second half. This pattern represents a '1' bit, and FF01 (CD4013) will be set. The complementary output of this flip-flop will therefore be low, enabling the CD4040 divider. The 18 kHz square wave clock for this divider is generated by our old friend the NE555. At the same time, the differentiator formed by C11 and R23 generates a low-going pulse which is inverted by Schmitt trigger inverter ST8. The resulting high-going pulse is used to clear the CD4015 shift register.

The Q4 output of the CD4040 (pin 5) carries a square wave at 1125 kHz, corresponding to a period of 888.8 µs and a pulse width of 444.4 µs. Output Q5 (pin 3) of the CD4040 is inverted by Schmitt trigger ST4; the output of this gate is therefore initially high. The diode matrix forms an AND gate which sets one input to ST1 high just as Q4 rises for the first time. Since the complementary output of FF02 is also high, a high-going pulse (inverted by ST2) is delivered to the CD4015 shift register, causing it to take one sample of the incoming data stream. This process is repeated 1.333 µs after the start of each bit period, or exactly three-quarters of the way into

each bit. This is the key to the circuit: the value of the signal sampled at this point gives the encoded data bit.
After 14 bits the RC5 packet is complete. At this point a diode matrix forming an AND gate at the outputs of the CD4040 sets FF02. Its output goes low and the clock to the shift register is blocked.

One cycle of the transmit protocol takes 64 bit times. Q11 of the CD4040 counter goes high 32 bit times after the start of the RC5 packet, resetting FF01 and thereby stopping the counter. The data bits at the outputs will be held until a new packet from the transmitter sets FF01 again, whereupon the output is cleared and the bits read in afresh.

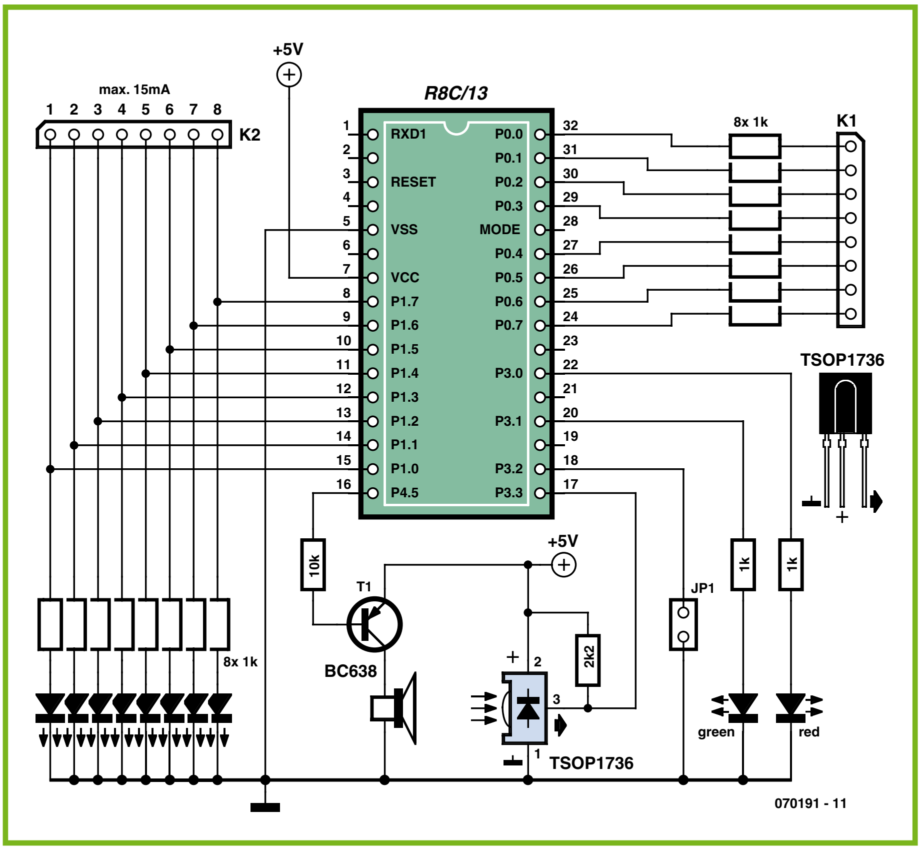
The stop pulse on pin 11 of the CD4040 can be used to validate the output data. When building the circuit it is a good idea to fit a test point at the output of the NE555 so that the 18 kHz clock can be set accurately. All of the timing in the circuit depends on this signal.

(070089-I)

IR Remote Control with the R8C

G. van Zeijts

Over the years various articles have appeared in *Elektor Electronics* about microcontrollers that pick up the pulses from an IR remote control and do something with it.
Unfortunately this capability was not available for the R8C microcontroller until now. That is why the author plunged right in and created this capability, mainly for his own use but also made it available to others who may be interested.
The functionality has been designed in such a way that it can optionally be used with either a Philips (RC5) or Sony remote control.
The system provides a 7-bit code at an output port, to ‘inform’ a computer or other microcontroller which button has been pressed.
The 8 bits of the other output port can be controlled directly with the buttons 2 through 9 of the remote control. This allows 8 digital devices to be directly switched or controlled remotely.
The program has been written in C using the HEW software and has the following functions.
Depending on the position of jumper JP1, pulses from Philips (RC5) are decoded (open) or pulses from Sony (jumper in place).
1. Bit 7 of port P0 indicates whether RC5 or Sony pulses are being used. Bit 7 ‘High’ = RC5 and bit 7 ‘Low’ = Sony.
2. The code for the most recent button that was pressed is on port P0. Bits 0 through to 6 are used for this. Bit 7 is used to indicate RC5 or Sony.
3. The eight bits on port P1 (output) are directly driven high or low with buttons 2 through 9 of the remote control. When the button is pressed for the first time the output goes high. The next press makes the output low. These eight buttons can therefore control eight digital things from a distance. The state of all the bits on port P1 are not affected by pressing any of the other buttons on the remote control, with exception of the following three.
Button ‘1’ makes all eight bits of P1 high.
Button ‘0’ and button ‘off’ make all eight bits of P1 low.
Eight LEDs indicate the present state of the eight bits — they load port P1 with about 3 mA. Via connector K2, P1 can therefore be loaded for ‘heavier’ purposes with a further 17 mA at the very most (but allow a margin just to be safe, so 15 mA max, for example).
4. If RC5 is selected with JP1 (open) and the microcontroller receives pulses from a ‘non-RC5’ remote control (or the other way around) a short alarm signal results:
- The red LED on P3.0 flashes briefly;
- The outputs 0 to 6 of port P0 become ‘0’ (= no standard code);
- Bit 7 of port P0 gives a flashing signal;
- Brief acoustic signal on pin 16 (bit P4.5).



A short description of the schematic:
The well-known TSOP1736 (infra-red detector) is directly connected to the input and its output is pulled high with a 2k2 resistor.
A second input is used to read the state of jumper JP1 (select between RC5/Sony).
Output P0 is used to signal the RC5/Sony-code in hexadecimal form. These outputs can be directly connected to another computer or microcontroller through the 1 k resistors, with the intention that this computer/microcontroller can act on the received code.
Output P1 can be used by the user to switch a ‘digital something’ with an inter-

face circuit that you have to build yourself. (K2 can be loaded with a maximum of 15 mA.)
Low-power LEDs indicate the present state of the eight bits of port P1.
The green LED on pin 20 functions as on/off indicator for the circuit.
It is of course also possible to use a piezo buzzer for the acoustic alarm on P4.5 (P4.5 may be loaded by up to 8 mA).
The software for this project is a free download from the Elektor website — see archive file **070191-11.zip**.

(070191-I)

zBot: Wireless Link

Jens Altenburg

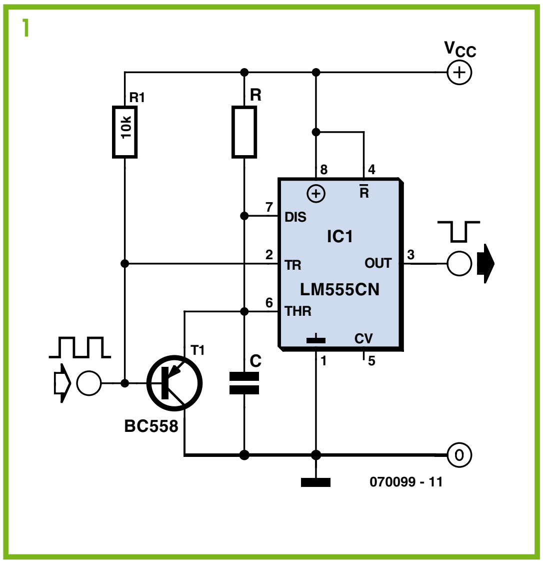
There exist a lot of wireless communication modules, all approved for use within the ISM radio bands (industrial/scientific/medical), for example, 433 MHz, 866 MHz and recently also 2.4 GHz. You get simple and cheap ones with low transmission data rates, and you can find excellent high-speed systems. "How much (will the thing set me back)?" is the most frequently asked question if you search for an RF module. Low-speed non-intelligent modules are cheap; high-speed intelligent ones, pretty expensive. That's easy but it doesn't help.
The CT-Video GmbH (www.ct-video.com) markets a special module with high-speed digital data transmission capability and no intelligence, at a reasonable price. The module is based on a fully integrated transceiver with a digital interface. It is used in zBot[1] with good results.

The module comes as a small fully assembled and tested board. The board includes the complete RF sections. It works in the 433 MHz ISM band and has a transmit power of 10 mW coupled with a receiver sensitivity of about –108 dBm.
For implementing the module in your own projects, a software module is available, too. The module only needs a few resources of the micro, some GPIOs (general purpose input output pin) and one UART channel. The UART has to be programmed to give a baud rate of 76.8 kbits/s. The baud rate needs to be accurate, if not, you'll suffer an effect that manifests itself as low receiver sensitivity.
The software module for the wireless radio is a file called `rf433.c`.

(070173-I)

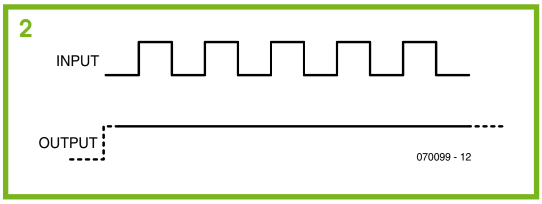
(1) The complete document called Zbot — the Robot Experimental Platform is available for free downloading from the Elektor Electronics website. The file number is 070172-11.zip (July/August 2007).

Removed Pulse Detector



Hesam Moshiri

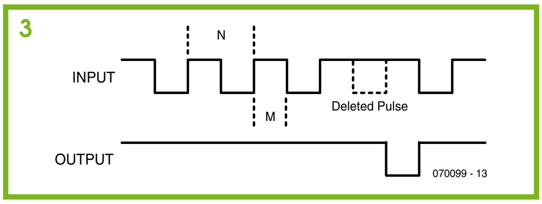
A detector to flag missing pulses is among the more important circuits in robotics. When pulses are applied to the circuit shown in **Figure 1**, the output signal will be continuously High (i.e., nearly V_{CC}) as illustrated in **Figure 2**.



For the detector to operate, certain conditions in respect of pulse timing must be met. With reference to the timing diagram shown in **Figure 3**, the values of components *R* and *C* in the circuit may be calculated from

$$\tau = 1.1\, R\, C$$

taking into account that



$1\ k\Omega < R < 1\ M\Omega$ and $M < \tau < N$

When a correct signal is being applied to the input (Figure 2) the circuit will be triggered by another pulse before the constant time (τ) expires. Therefore the output signal remains High. If one or more pulses are missing, for example, owing to a fault, a bash on the head from refbot Mathilda, or simply bad reception on the remote control channel, the output signal drops Low briefly. The resultant flag signal can be sensed by another circuit, for example, a microcontroller or another sensing that acts on the interruption in the pulse stream. If the worst comes to the worst, the autopilot should be switched on!

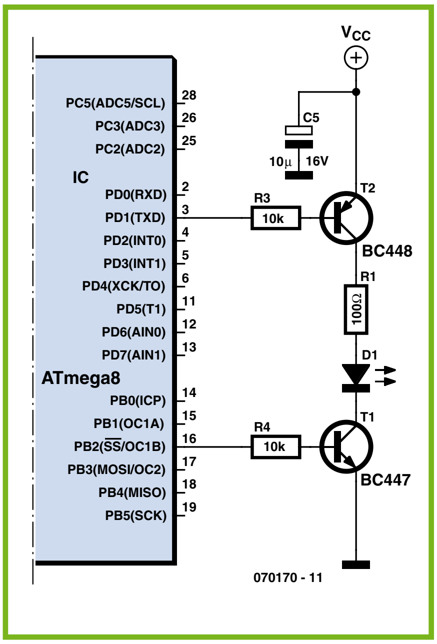
(070099-I)

IR Communications using a UART

Dominik Tewiele

If you wish to set up a medium-range (5 m to 10 m) communication link between two robots or between a robot and a base station, infrared light can be an economical alternative to using radio modules. Tried-and-tested standard protocols and supporting components are available for the modulation necessary to suppress the effect of ambient infrared light. Practically every modern microcontroller sports one or more asynchronous serial interfaces (UARTs), which make perfect partners for IR receivers and transmitters.

An example of a suitable receiver is the TSOP17xx, where the 'xx' stands for the modulation frequency, measured in kilohertz. Its output can be connected directly to the RxD pin of a microcontroller. Because of the open-collector output stage, it is possible to connect several receiver modules in parallel to increase the area covered. The transmitter consists simply of an IR diode and a couple of discrete components. A timer in the microcontroller can



be used to provide modulation, or alternatively an external NE555 can be used. In this example we are using an ATMega8 with Timer1 configured so that the output compare registers OCR1A and OCR1B control the frequency and pulse width of the signal on output PB2. The NPN transistor then applies the required modulation. Here again, we can wire several IR LEDs in parallel to increase the transmit range and coverage angle. The series current limiting resistor for the IR LEDs should be chosen with consideration for the desired range and the maximum pulse current that the LEDs can handle. This last figure can be found on the LED's datasheet, which will also help determine a suitable pulse width to set in the software.

The maximum baud rate that can be achieved will depend on the receiver chosen. Using a TSOP17xx around 1200 baud is possible, which should be adequate for simple control commands. For bidirectional communication it will be necessary to build both a receiver circuit and a transmitter circuit at each end of the link. It is worth bearing in mind that because of the effect of reflections scope for full-duplex operation is rather limited.

(070170-I)

Radio Remote Control for PDAs and Smartphones

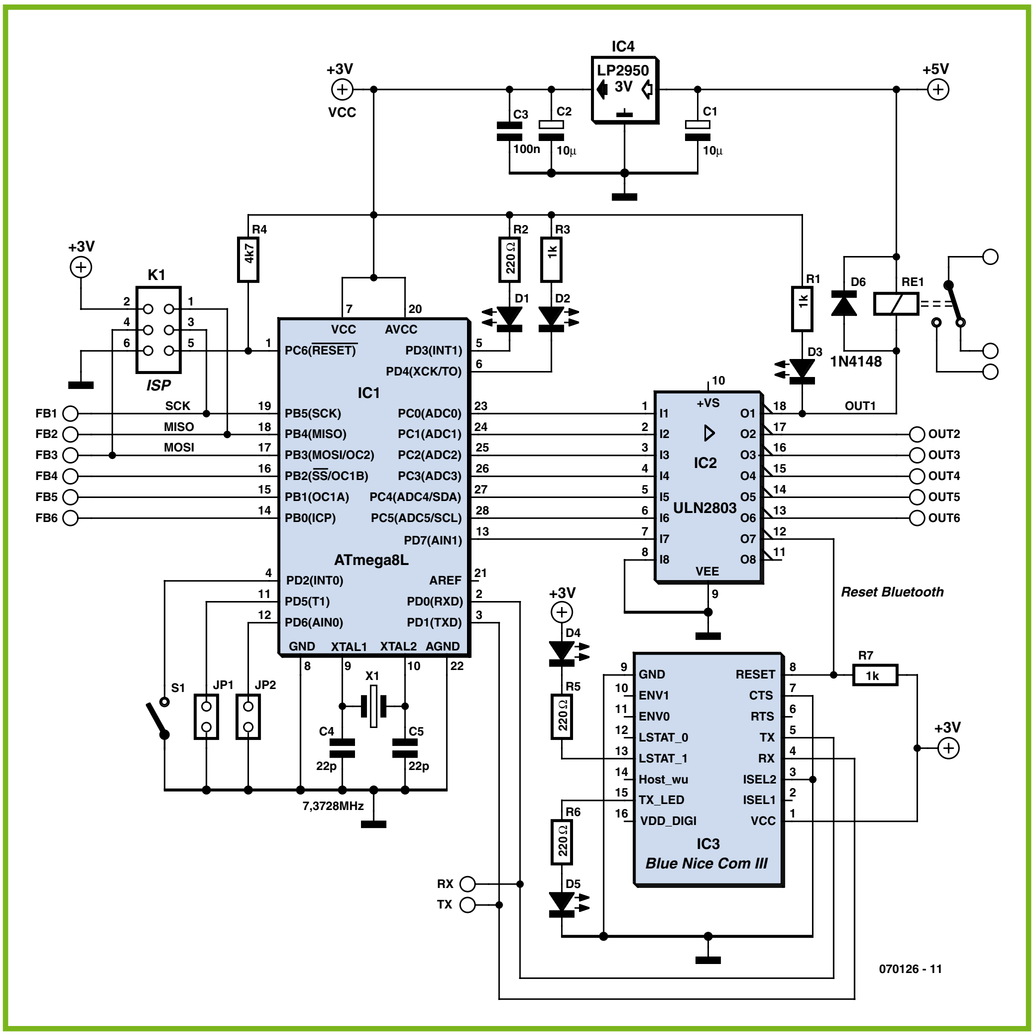
Peter Zirngibl

On his website, under the title 'AVR Blue Remote', the author describes (in German) a Bluetooth-based remote control unit featuring six output relays and six sensor inputs. The site also includes Smartphone software (avrblueremote.exe) and microcontroller software (avrblueremote.hex). These can be used as the basis for projects such as a short-range (up to 10 m or so) remote garage door opener or a remote lighting controller. The software is free for use by private individuals.

Any Smartphone running the Windows Mobile 5.0 operating system can be used as the transmitter. The receiver used is the postage-stamp-sized Blue Nice Com III Bluetooth module with integrated chip antenna from Amber Wireless. The module is based around the LMX9820A from National Semiconductor, and decoded messages are passed over a UART-like interface (TX and RX signals) between it and an Atmel AVR ATMega8L microcontroller. Connected to the outputs of the microcontroller is a ULN2803 octal driver which can comfortably switch enough current to drive power relays. Completing the circuit are a 3 V voltage regulator (type LP2950-3V) and an ISP (in-system programming) connector. Four LEDs indicate the status of the connection: LED1 shows when the microcontroller has received data correctly and LED2 indicates when a timeout has occurred. The Bluetooth module's LEDs indicate the link status (LED3) and transmit mode (LED4).

The printed circuit board layout for the circuit has to meet several constraints. For maximum range there should be no ground plane, conductors, components or other metal parts within 8 mm of the antenna; other requirements are set out in the manual for the module. The microcontroller can be programmed using the ISP interface: you must of course make sure that the pinout of the connector is compatible with that of your programmer. Suitable programmer circuits can be found on the Internet as well as within the pages of *Elektor Electronics*, and further information is provided on Atmel's website. The sensor inputs can be used for any desired purpose or simply left floating.

With the hardware built we next turn to the accompanying Smartphone software. You will first need to install the appropriate version of Compact Framework 2.0 (available for download from Microsoft):



- Windows Mobile 5.0 Pocket PC and Smartphone: NETCFv2.wm.armv4i.cab;
- Pocket PC 2003 and 2003 SE: NETCFv2.ppc.armv4.cab;
- Windows XP: netcfsetupv2.msi.

Next, copy the file avrblueremote.exe to the target platform (for example onto an SD card for use with a Smartphone). The two Bluetooth devices, the Smartphone and the receiver board, now need to be 'paired' (which only needs to be done once). The program can now be started, and the COM port set with a click or two of the mouse on the upward- and downward-pointing arrows. The central square opens the interface, creating a connection with the receiver. The arrows now allow the outputs on the receiver board to be switched on and off; the sixth output is switched by pressing the space key.

Towards the top of the display the six sensor inputs are represented as LEDs. If you should move out of range of the receiver, these LEDs will be extinguished and a timeout bar will appear. If the timeout period should expire without a valid signal being received the interface will be closed.

(070126-I)

Web links

Author's website (in German): http://www.clipswitch.de/avrblueremote.html

Bluetooth module information: http://www.amber-wireless.de/en/produkte/bluetooth/default.php?fnum=109221360256

Bluetooth module manual: http://www.amber-wireless.de/pdf/OPC1601_MA.pdf

LMX9820A datasheet: http://www.national.com/pf/LM/LMX9820A.html

AVR programmer: http://www.atmel.com/dyn/products/tools_card.asp?tool_id=2726

AVR Studio: http://www.atmel.com/dyn/products/tools_card.asp?tool_id=2725

Robot Voice

Pascal Choquet

Fans of the film '2001 a Space Odyssey' will no doubt recall the polite yet sinister voice of HAL, the ship's computer.
It stands to reason that all proper robots need a (not necessarily menacing) voice.

Those of you who imagine that a voice box would require a whole heap of ICs are mistaken; the ISD2500 ChipCorder family of ICs from Winbond contains almost all the necessary hardware in a single IC to record and playback audio messages. Included on the IC is a microphone preamp and AGC suitable for a low-cost electret type microphone, an output amplifier to drive a loudspeaker, memory, an oscillator, an A/D and a D/A converter. There are four basic models; 2560, 2575, 2590 and 25120, the numbers following 25 indicate the available recording time in seconds. The memory capacity of each version is actually the same but longer recording times are achieved by using a lower sampling rate. The chip with the shortest recording time therefore offers the best audio quality.

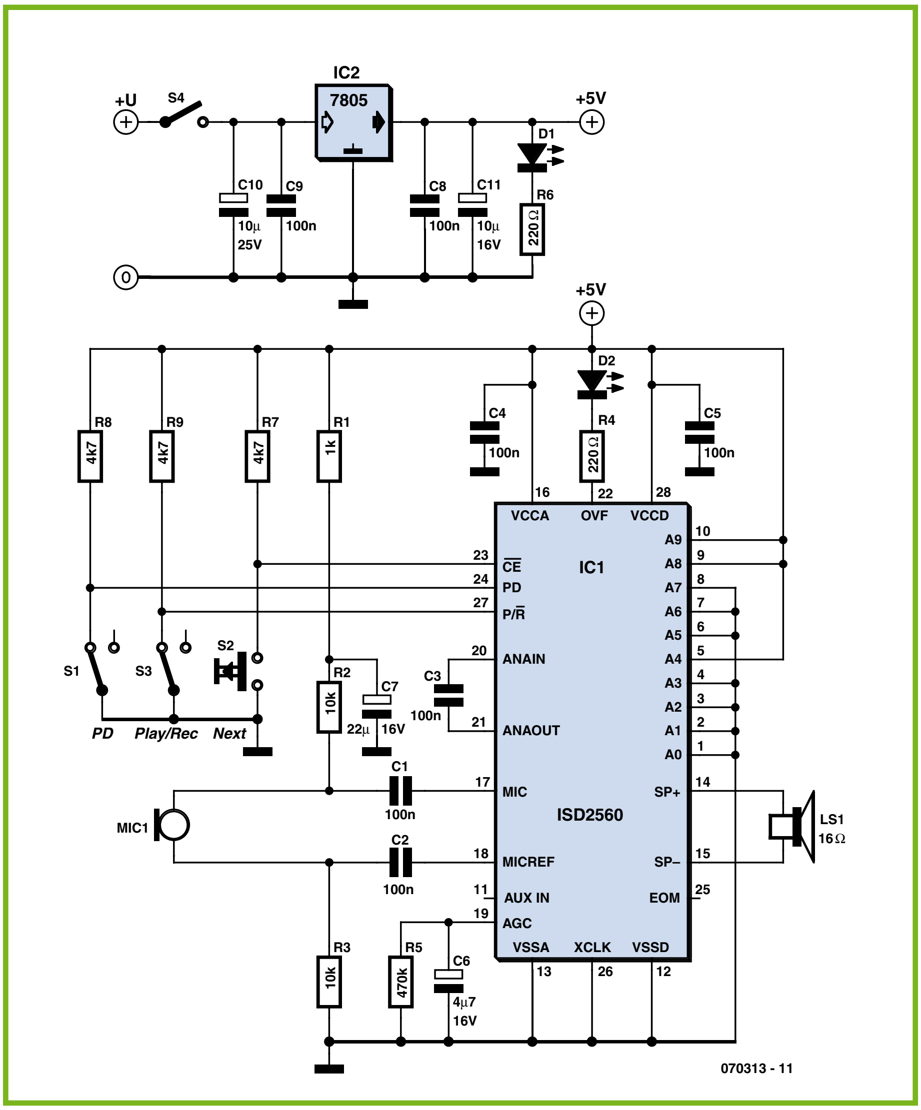
The simplest circuit required to use the device in playback mode only is shown in **Figure 2**, the only external components required are just two decoupling capacitors. This circuit can be used in the robot whilst the circuit shown in **Figure 1** can be used for both recording and playback. A socket for IC1 fitted in both circuits will allow the chip to be moved into the robot once the sounds have been recorded.

Recordings are made by following this sequence.
First switch S3 to record mode (a low on pin 27). A press of S2 now begins the recording which is ended by another press on S2; a third press of S2 starts the next recoding period and so on. This can continue until there is nothing more to record or when LED D2 lights to show that the memory is full. Playback can be performed by momentarily toggling S1 and switching S3 into 'play' mode, now with each press of S2 the recorded messages will be sequentially played back. The recordings can be overwritten by toggling S1, switching S3 to record and then using S2 to start recording from the beginning again.

Some flexibility in the playback mode allows individual messages to be linked together; each recorded message is terminated by an EOM (End Of Message) flag when it is stored in the chip. Instead of storing complete phrases like 'obstacle ahead' for example it is more efficient to store 'obstacle' then 'ahead', 'to the right', 'to the left' and 'behind' and likewise for numbers 'one', 'two', 'hundred' 'point' etc allows voicing of the complete range of numbers from these basic elements.

The minimum playback circuit shown in **u**ses the A0, PD, /CE and /EOM signals interfaced to the robot microcontroller. For playback PD is reset to '0' and to play the first message a low pulse is given on /CE. With A0 at '0' playback occurs at normal speed but with A0 at '1' the chip enters 'fast forward' mode where it advances through the message at 800 times its normal playback speed. When the third message needs to follow the first for example, the processor sets A0 to '1' and pulses /CE low to fast-forward through the second message, waiting for the /EOM flag to go low. Once this occurs A0 is reset to '0' and a low pulse on /CE plays back the third message.

The /EOM output pulse can be less than 10 ms wide so it is better to use it to interrupt the processor rather than just poll its status. An example C code listing has been written by the author for a 16-bit Texas MSP430 microcontroller interfaced to this chip and is available for free download from the *Elektor Electronics* website, ref. **070313-11.zip**.

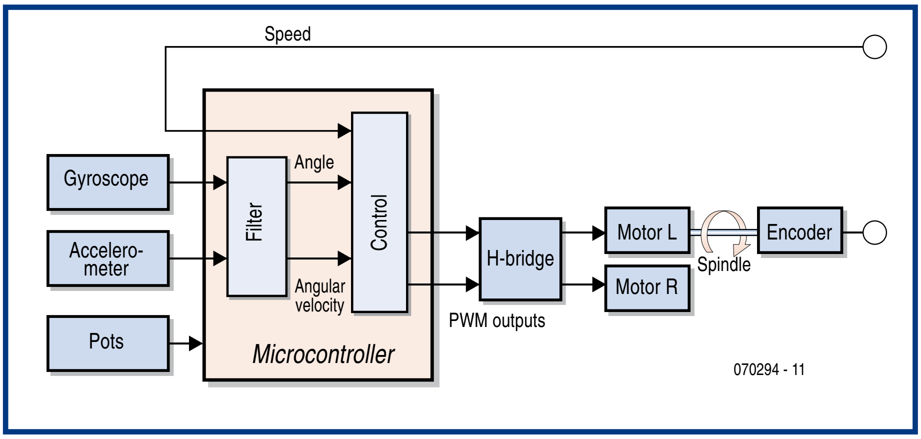


(070313-I)

Web link

www.winbond-usa.com/mambo/content/view/153/283/

Balancing Robot



David den Boer

The most famous balancing robot, also viewed from the general public's perspective, is the Segway, invented by Dean Kamen [5]. This little cart on two wheels is a mode of transport for people, and these days adorns the streets of many large cities. The principle of balancing on two wheels has inspired many robot builders to the construction of such a robot. A few other examples are the NBOT built by D. Anderson [3] and 'Joe le Pendule' built by co-workers at the Polytechnic School in Lausanne [2]. This type of robot comprises a number of sensors and a drive circuit clustered around one or more microcontrollers (**Figure 1**). When building such a robot, a few significant hurdles have to be surmounted. This article will hopefully help with this.

The physics

The principle of a balancing robot is obviously to let the robot move forwards and backwards in such a way that the robot remains upright, the centre of gravity of the robot has to be always directly above the robot. A simple analogy is the balancing of a broom handle on the tip of a finger. This problem is sometimes also known as the 'inverted pendulum problem'. From your physics classes you will no doubt remember that the period of the pendulum is the square root of the quotient of the length and gravity, a longer pendulum therefore has a longer period (see **Equation 1**). Roughly, it can be deduced from this principle that a balancing robot with a high centre of gravity is more stable and thanks to the longer period is easier to keep balanced. A first simple step in obtaining a good functioning balancing robot is therefore building a robot with a high centre of gravity. This can be done by building a tall robot, but also by the high placement of heavy parts, such as the batteries, or by artificially raising the centre of gravity with additional weights at the top of the robot.

Control

A number of variables need to be known to control the robot. The first variable is obviously the angle of the robot: if the robot is not vertical it will continue to fall over. The speed at which this angle changes (angular velocity) is the second variable that is important. If the robot moves through the balancing point with a certain speed, the angle of the robot at that instant is zero degrees. The robot is not stable however, it is, after all, moving through the balance point with a certain angular velocity. This has to be anticipated by the controller; so this angular velocity is also important when controlling the robot. Finally, the speed of the robot is of importance, since it is the intention to control the position of the robot. By feeding these three variables back to the motors the robot can be controlled into a stable position (see **Equation 2**). A mathematical/physical basis of this control strategy can be found in [1], among others, including the derivation of the relevant equations of motion.

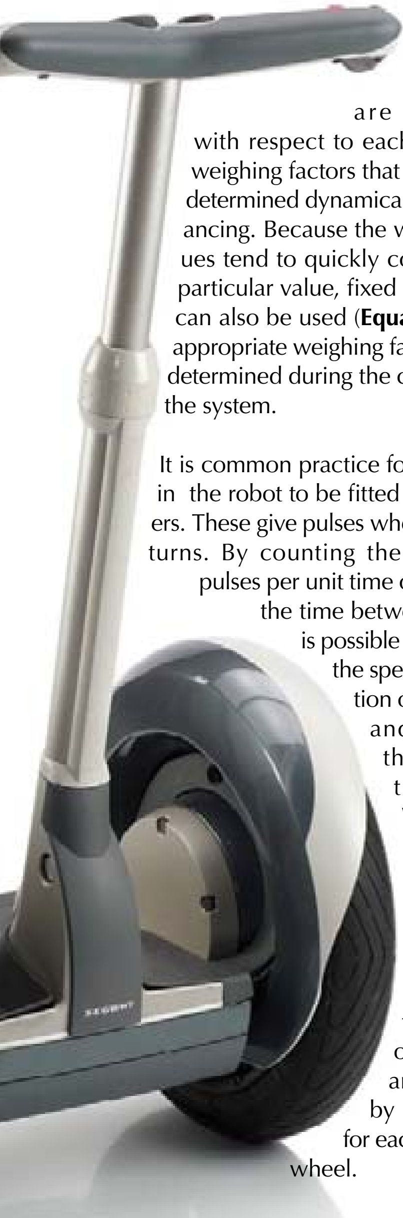
Sensors

To determine the aforementioned variables an accelerometer and a gyroscope are usually used.

With an accelerometer the acceleration that the sensor is subject to can be measured. The direction of acceleration is also measured. A sensor that is frequently used is the ADXL202 from Analog Devices, which can measure acceleration in two mutually perpendicular directions. Because the sensor is also sensitive to the static acceleration due to gravity (g), the sensor can also determine the angle of the robot with respect to the Earth. The acceleration observed by the sensor is shown in **Figure 2** with the vectors *am*1 and *am*2. When the sensor is not subjected to any other acceleration, the sensor is only sensitive to the angle of the sensor with the direction of gravity (and gravity itself, which is constant). As soon as the sensor is also subjected to a dynamic acceleration (*a*), the sensor will observe this as well. This is the case, for example, when the robot is driving forwards or backwards. The resulting acceleration *am*2 then depends on the dynamic acceleration, gravity and the angle. This gives a direct insight into the problem: the instant that the robot moves, the signal from the sensor cannot be used any more to directly determine the angle of the robot.

Using a gyroscope, the angular velocity of the sensor can be determined. The output signal is directly proportional to the speed at which the sensor rotates around its own axis. By simply integrating this signal the angle of the robot can be calculated. The accuracy is a problem however. If the sensor has a small static offset of, for example, 0.1 °/s per measurement then the error after 100 times of measuring and integrating has increased to 10 °. It is possible to build a balancing robot based solely on a gyroscope, but you will see however that after some time the robot will start to swing and become unstable. The small amount of drift that these sensors have is amplified by the process of integration.

By combining a gyroscope an an accelerometer the disadvantages of both sensors can be compensated for. In general this is done with a so-called Kalman-filter. This sums the result from the gyroscope, the value from the accelerometer and the calculated angle from the previous measurement cycle. These three values when summed



are weighted with respect to each other. The weighing factors that are used are determined dynamically while balancing. Because the weighing values tend to quickly converge to a particular value, fixed relationships can also be used (**Equation 3**). The appropriate weighing factors can be determined during the calibration of the system.

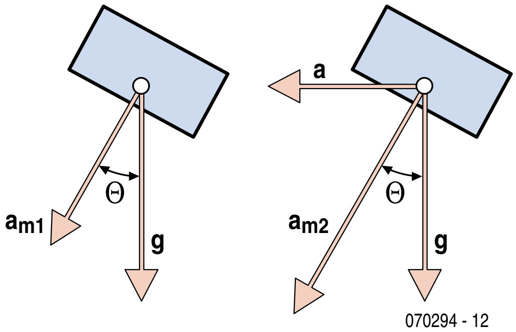
It is common practice for the motors in the robot to be fitted with encoders. These give pulses when the motor turns. By counting the number of pulses per unit time or measuring the time between pulses it is possible to determine the speed of revolution of the wheels and therefore the speed of the robot. Which of these methods gives the highest resolution is determined by the number of pulses that are produced by the encoder for each turn of the wheel.

Actuators

Another special point of interest are the actuators. While balancing the robot the motors have to be frequently switched into the forward and backward direction. However, the combination of motors and gearbox is not without friction or backlash. When the voltage across the motors increases this does not immediately result in power from the actuators, there is a certain amount of offset. This is not a problem in many applications, but in the case of the balancing robot this null point is passed all the time; we are controlling around this null point after all. By compensating for this offset in software when driving the motors the stability of the robot will improve dramatically. Apart from that, the capability of the robot, the nimbleness in staying upright are also determined by the capacities of the motors and batteries. The greater the amount of power that the motors can deliver the better the robot is able to remain upright.

Architecture

In the control loop that is executed by the software in the microcontroller a number of things have to be carried out simultaneously. The sensors have to be read, calculations have to be carried out and the actuators for the robot have to be driven. At the same time it is often also desirable to communicate with a PC for the purpose of data acquisition. For all this it can be a good idea not to use one relatively powerful processor but to use a number of smaller processors which send their data to one central processor. In this way the timing of measuring and controlling can



$T = 2\pi\sqrt{\dfrac{l}{g}}$	
T	period (s)
g	gravitational acceleration (m/s²)
l	length from pivot to centre of mass (m))

$PWM = k_1 \cdot \theta + k_2 \cdot \dot{\theta} + k_3 \cdot v$	
θ	Angle of the robot (°)
$\dot{\theta}$	Velocity at which the angle changes (°/s)
PWM	Drive for the motors 0-100%
v	Speed of the robot (m/s)
$k_1 \ldots k_3$	Feedback factors, constant

$\theta_B[n] = k_4 \cdot \theta_B[n-1] + k_5 \cdot \dot{\theta}_G[n] + k_6 \cdot \theta_v[n]$	
$\dot{\theta}_G[n]$	Angular velocity measured by the gyroscope (°/s)
$\theta_B[n]$	Angle of the robot, calculated in measurement n (°)
$\theta_v[n]$	Angle of the robot, determined by accelerometer in measurement n (°)
$\theta_B[n-1]$	Angle of the robot, calculated in measurement n-1 (°)
$k_4 \ldots k_6$	constants

be divided, which make the programming task a great deal easier.

Sum of parts

A balancing robot consists of a number of parts that together have to hold the robot upright: sensors, any filters, a controller and drive system for the robot. Putting all this together in one go is very ambitious, a better chance of success is obtained by first testing and calibrating the individual parts. A good method for this is the temporary addition of a small arm to the robot. This arm is attached to the robot so that it can hinge with the aid of a potentiometer, which functions as the hinge. The other end of this arm is fitted with a wheel that rests on the floor. When the robot loses its balance the position of the potentiometer changes and therefore also its output. The output of the potentiometer has a direct relationship with the angle of the robot and can be used for calibration purposes. Note that it is important to choose a potentiometer with a shaft that turns easily.
The next step is the controller. Because of the arm, a read-out of the angle is available and this can be used to test and calibrate the controller for the robot. As already mentioned, feedback from the angle of the robot, angular velocity and speed of the robot are essential for the successful control of the robot. It is possible to calculate the necessary feedback factors mathematically. However this makes a complete and detailed physical description of the robot and the behaviour of the motors essential. It is simpler to determine these factors experimentally. This can be done, for example, by connecting a number of digital or analogue potentiometers to the microcontroller. The program that runs in the microcontroller reads the position of the potentiometers and converts the relevant values into feedback values. The calibration can now be done with a lot of patience. A first step is to increase the feedback factor for the angle. If this factor is too small then the robot will react slowly; if this is too large then the robot will quickly oscillate around the balance point. In the latter case the feedback factor can be reduced and the feedback factor for speed can be increased. In this way the robot will quickly gain in stability. A final step can be made by increasing the feedback for speed. This will result in better positioning for the robot. A feedback factor that is too large however will make the robot very unstable.
A second step is the calibration of the sensors. The measurement values from the sensors (gyroscope, accelerometer) can be read into a PC via the microcontroller. Sensors that provide a read-out in the form of a pulse width modulated signal are quite common. By comparing the measured pulse width with the reading from the potentiometer that is mounted to the arm the angle and angular velocity can be easily derived. During the calibration, the drive for the robot can be switched off. By moving the robot back and forth by hand the angle and angular speed are changed and the calibration can be performed. When calibrating the accelerometer it is important to move the robot back and forth very slowly, so that the dynamic acceleration is as small as possible and only the acceleration due to gravity is observed.
A third step is the calculation of the angle and angular velocity: the results from the sensors have to be combined in such a way that the angle of the robot and the speed at which this angle changes is obtained. The calculation that makes this possible has been described above. The weighing factors can be determined by moving the robot for some time (1 minute, for example) and reading the values from the sensors (accelerometer, gyroscope and potentiometer on the arm). A spreadsheet on the PC can subsequently be used to analyse the values and determine the correct values for the weighing factors.

(070294-I)

Web links

(1) http://robotics.ee.uwa.edu.au/theses/2003-Balance-Ooi.pdf This document describes a final year project during which a balancing robot was built. The research is quite detailed with respect to the physical and mathematical modelling of the problem.

(2) http://leiwww.epfl.ch/joe/ Polytechnic school of Lausanne. The website is in French but there are a number of nice movies.

(3) http://www.geology.smu.edu/~dpa-www/robo/nbot/ This is the website of D. Anderson who built the NBOT.

(4) www.dena.demon.nl Dutch website on the construction of a balancing robot.

(5) www.segway.com Importer of the Segway.

(6) www.sparkfun.com

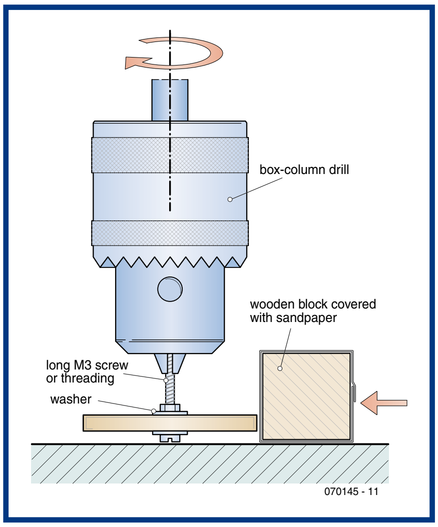
DIY Wheels

Marcus Bindhammer

You don't have to reinvent the wheel for your robot, but you may have to make your own somehow if you can't or don't want to buy them ready made. The handicrafts aspect of making your own wheels is relatively undemanding, and one hand (but not a left hand…) is enough.

Use a compass to draw circles with a diameter of 50 mm on a piece of 5-mm plywood, and then cut or saw the discs out. Drill a 3-mm hole in the centre of each disc.

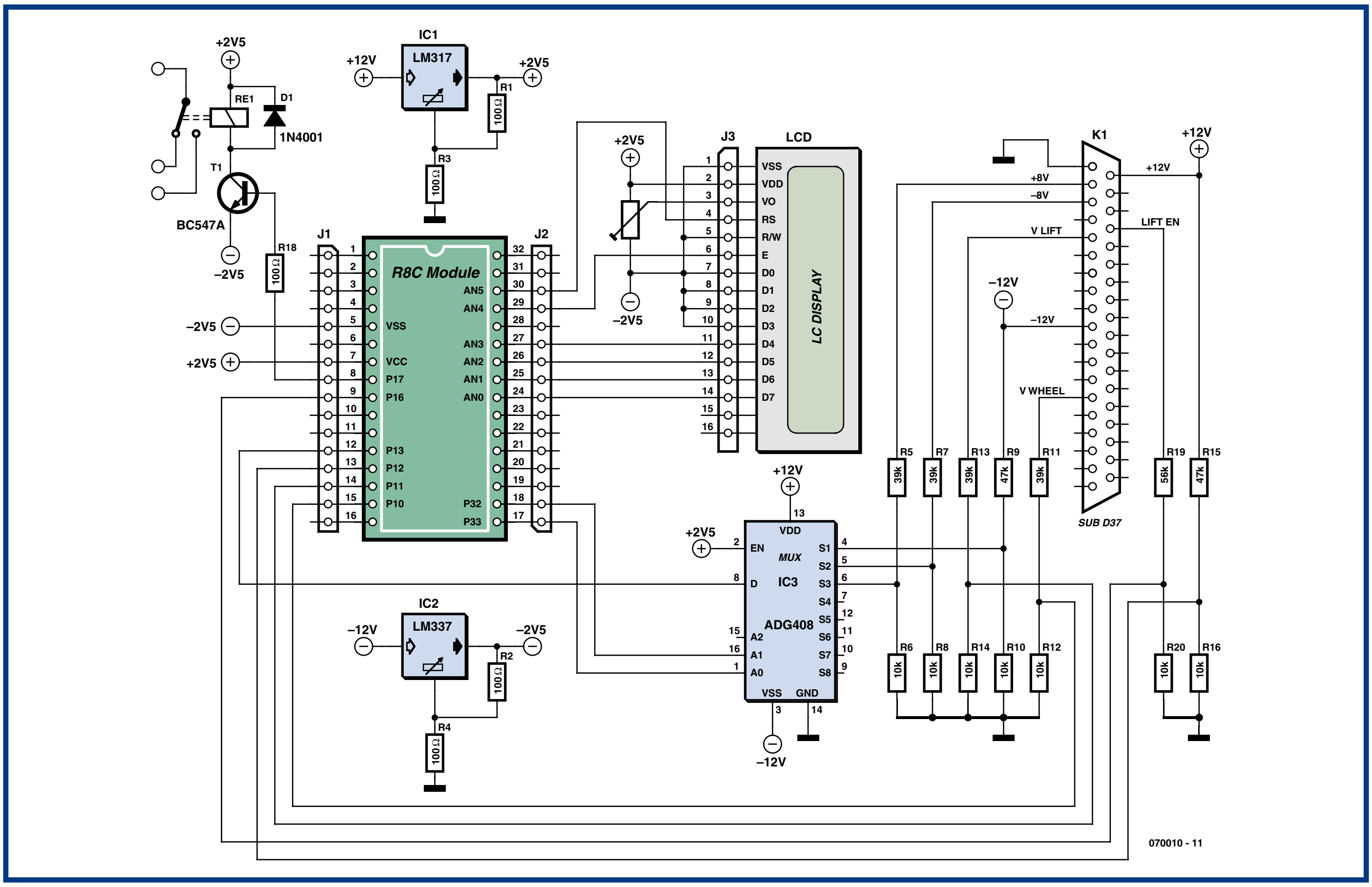
As you can see from the drawing, an M3 screw with a length of at least 30 mm must be fitted in the hole. Now secure the screw using a washer and nut, and then clamp it in the chuck of a drill press. Using a small block of wood wrapped in sandpaper, you can quickly sand the disc into a nice circular shape.



Finally, fit a length of toothed rubber belt around the circumference of each disc (old video recorders are a good source) or glue flat elastic bands to the running surfaces. After you remove the screws, all you have to do is fit the wheels on the axles and secure them with a bit of superglue.

(070145-1)

R8C Measures Negative Voltages



Sven van Vaerenbergh
UH Brussels, Radio Therapy Dept.

The author had to design a monitor circuit for the so-called Hercules Table (an electrically movable platform) at the University Hospital in Brussels that would watch several operating voltages and could stop the table in case of emergency.

The movement of the platform (up/down) is done with a DC voltage between +8 V and –8 V, where the magnitude of the voltage determines the speed and the polarity determines the direction. There are also a number of fixed voltages that need to be monitored.

An R8C module from Elektor Electronics was selected for the implementation of this project, because it is very easy to connect an LCD module to it and because it has a good A/D converter with 10-bit resolution on board.

The connection for the LCD (2×16 char.) is identical to that of the application board in Elektor Electronics (March 2006, page 38). In addition to the controller, a multiplexer of the type ADG 408 is used. This is required because we need to measure multiple voltages.

An unusual requirement for this project is that both positive and negative voltages need to be measured. Normally, the A/D converter of the R8C can only measure voltages between 0 and 5 V. The solution was found by using a symmetrical voltage for the R8C module, that is, ±2.5 V. These voltages are generated by an LM317 and an LM337. We normally connect ground (Vss) to pin 5 of the R8C module. In this case that becomes –2.5 V. In this way we can measure voltages from +2.5 V to –2.5 V. The only places in the schematic that are connected to ground are the voltage dividers for the two voltage regulators (R1 to R4) and the voltage dividers (R5 to R16, R19 and R20) for the signals to be measured (available at connector K1, where all the important signals from the Hercules Table are available).

We can see that the schematic also contains a relay that can be switched by the R8C to immediately stop the table movement. This is optional.

Now we have to take special care when we have negative voltages. The resolution of the 10-bit A/D-converter in the R8C amounts to 5 V/1024 = 0.00488 V per bit. Because of the symmetrical power supply, the converter will give an output value of 512 when the input voltage is zero volts. We can display a minus sign on the LCD when the value is smaller than 512.

In C code it looks like this:

```
        if  ( u < 512 )   // less than
0, then minus sign
        {
         lcddata (45);
         }
```

We also have to adjust the voltage levels in software, because these have been lowered by the 6 voltage dividers. We also have to drive the multiplexer. In C code it looks like this:

```
pd3 _ 3 = 1;     //port 3.3 as output
p3 _ 3 = 0;      //port  3.3  =>  for
channel selection via analogue MUX
pd3 _ 2 = 1;
p3 _ 2 = 0;      //port  3.2  =>  for
channel selection via analogue MUX
```

Three channels are directly connected to the A/D-converter. One channel is multiplexed for the voltages of +8 V, –8 V and – 12V.

(070010-I)

Formula Flowcode Buggy

A low-cost robot not just for schools & education

Bart Huyskens,
St Joseph's institute (Schoten, Belgium)

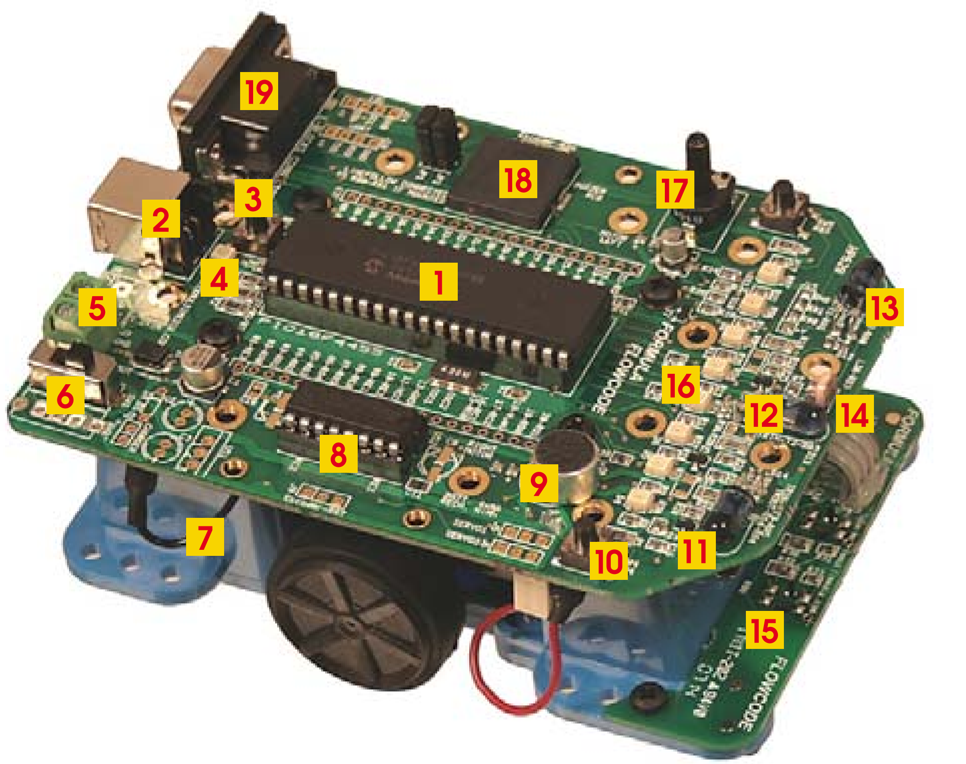
Out of Belgian schools has arrived an £ 85 (125 €) robot buggy that the designer hopes can reverse the decline in the study of electronics and technology across Europe and, potentially, wider.

Like many in the engineering teaching fraternity, the author is increasingly aware that electronics – and most engineering and science related activities – fail to attract young people. To people who have grown up with a fascination for technology this is a great shame and it really is very strange when you consider that young people are fascinated by all things electronic – like i-pods, digital cameras and mobile phones. But for some reason our schools fail to capitalise on this interest and attract young people to technical careers.

Long and hard thought was given about how to solve this and what the real problems are (including the facts that electronics can be mathematical, parts of the subjects are difficult to understand, and it has a very dull image). All sorts of ideas have been tried, and some have partially worked, but not to our satisfaction. There is one exception that stands out – Lego. Lego's NXT robot looks cool, is cool, and is fun to use. But it is expensive, does not really teach anything about electronics, and you can't really 'get under the hood' and use it as a platform for learning more than just simple programming.

About six months ago, during a conversation with engineers at Matrix Multimedia in England, we had an idea that might go some way to solve this problem – a programmable robot buggy of our own, with more functionality than the Lego NXT, that does have 'open architecture' which can be used for a wide range of teaching and learning activities in electronics and technology. In the six months since, we have been working hard to make these ideas come to life and we have called the project 'Formula Flowcode'.

Formula Flowcode is a complete hardware and software robotics solution for learning about electronics and programming. This article describes what Formula Flowcode does, how it works, how we hope it can be used to learn all about robotics...



1. The brains of Formula Flowcode — a PIC18F4455 microcontroller
2. USB socket
3. Master reset switch
4. Programming LED
5. External 5V supply input
6. Power switch
7. Plastic chassis with battery compartment, motors with gearboxes, and 2 wheels.
8. Motor driver chip - a L293D
9. Microphone with sound level amplifier circuit
10. User definable press switches
11. Distance sensor - right
12. Distance sensor - centre
13. Distance sensor - left
14. Light sensor
15. Line following circuit board
16. 8 user definable LEDs
17. Microphone volume control
18. Loudspeaker
19. E-blocks expansion socket

Figure 1. **Formula Flowcode functional parts.**

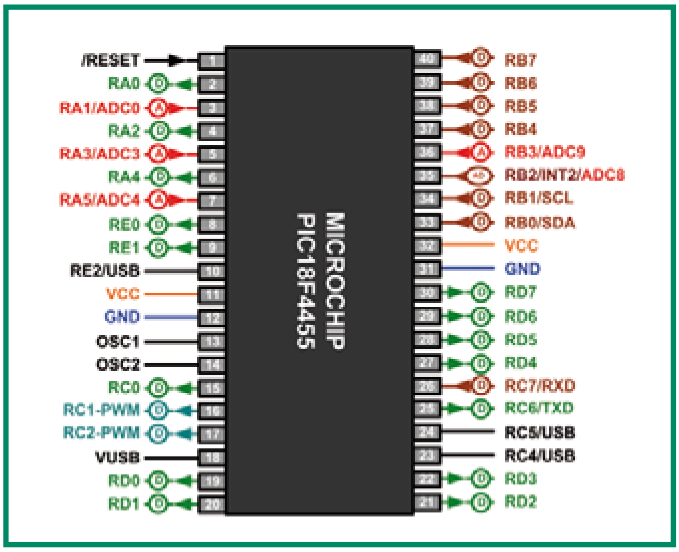


Figure 2. This diagram of the PIC18F4455 is purposely simplified, showing only the actually used functions of the pins of the PIC. D stands for 'Digital I/O' and A for 'Analogue input'.

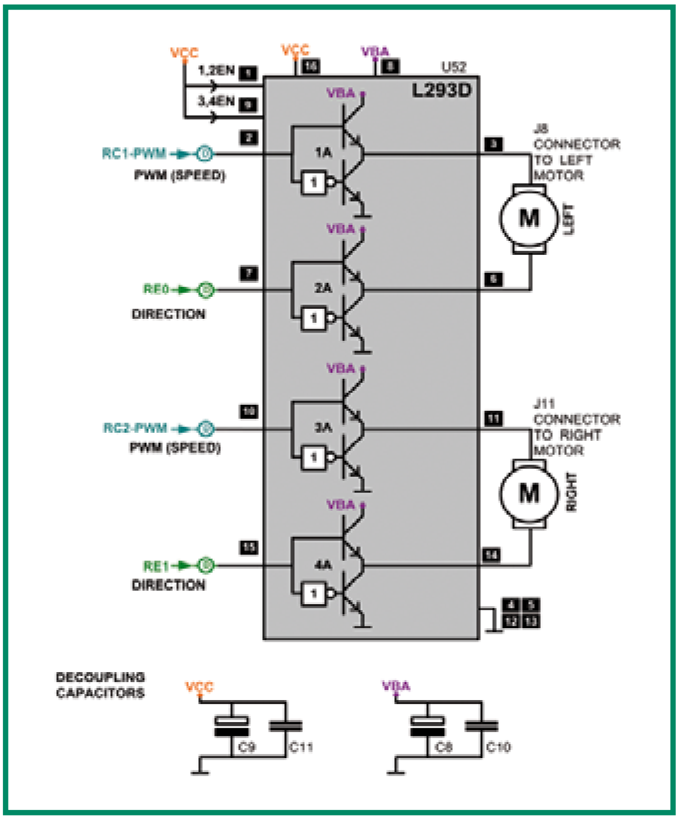


Figure 3. The L293D Double H-bridge motor driver circuit.

And here it is

Figure 1 shows a picture of Formula Flowcode and a list of the components and features on the buggy. But how does it all work? Let's start at the beginning. The whole Buggy is designed around the new and very powerful PIC18F4455 microcontroller from Microchip. This 40-pin device operates at 24 MHz and will execute programs at an amazing speed of 6 MIPS. A meet & greet diagram of this CPU is shown in **Figure 2**. The device connects directly to your USB port and contains a bootloader program so that it can be programmed using a version of Flowcode 3 supplied free of charge with the buggy. The PIC18F4455 has two separate hardware PWM outputs, a UART, I²C, Analogue Inputs, Pin-, Port- and Timer Interrupts and a lot of Digital I/O.

Driving DC Motors

The two DC motors with separate gearboxes are powered by a classic L293D IC with two full H-bridges, see **Figure 3**. The direction and speed of each motor can be programmed separately in Flowcode and this makes the buggy capable of performing the craziest moves you can imagine.
As you can see on the schematic, the L293D uses four PIC outputs for its control. Two outputs (RE0 and RE1) set the direction while two (hardware generated) PWM signals at RC1 and RC2 govern the speed of each wheel.

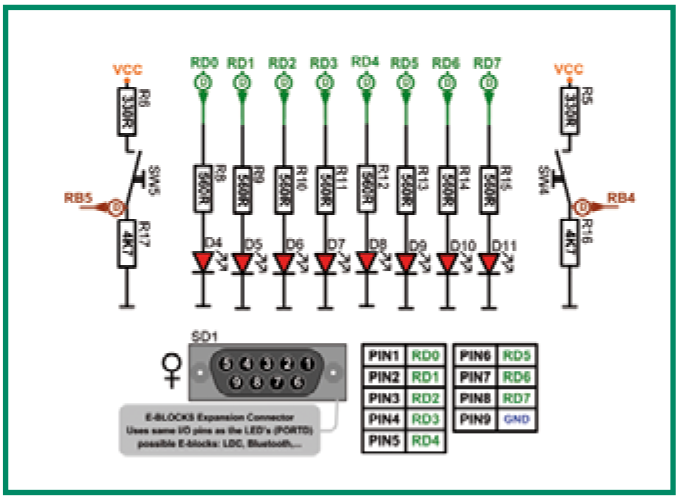


Figure 4. Two switches, eight LEDs and the E-Blocks D-type connector.

LEDs, Switches and E-blocks Expandability

The schematic of the I/O hardware is shown in **Figure 4**. The eight LEDs and two switches at the front of the Buggy will come in handy for your first steps with Flowcode and will prove to be very useful when debugging your more complex programs on this 8-bit PIC microcontroller. In parallel with the eight LEDs, Formula Flowcode has an E-blocks connector. This will give the users the capability of very easily expanding the Buggy with standard E-blocks like LCD, Bluetooth and many more.

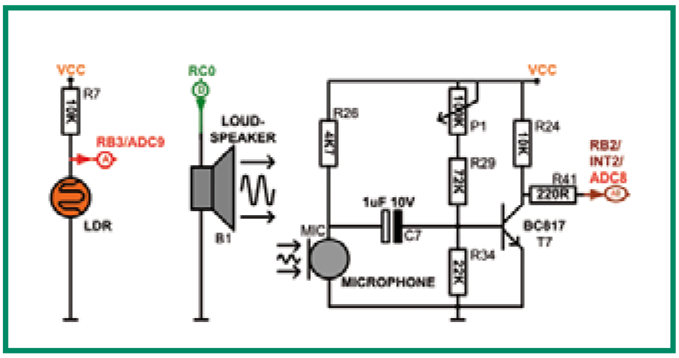


Figure 5. The microphone, loudspeaker and light sensor circuitry.

Sound I/O and light sensor

The buggy can react to sound (hand claps) using the amplified microphone circuit connected to RB2. As shown in **Figure 5**, this sound sensor may be used as a digital input, an external interrupt

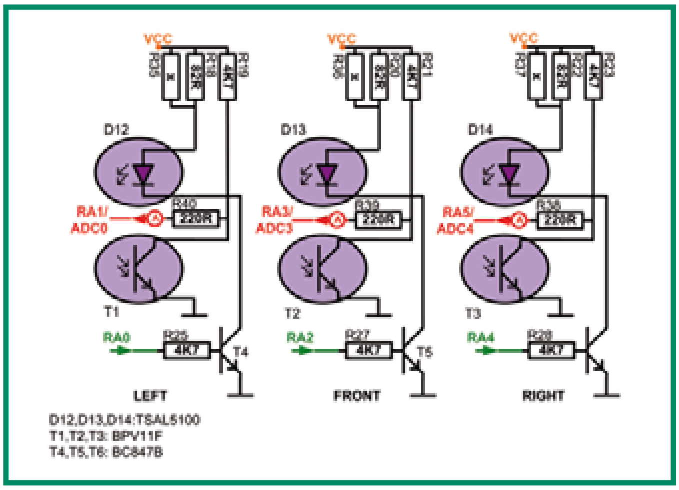


Figure 6. **Distance measurement circuit on board the Formula Flowcode Buggy.**

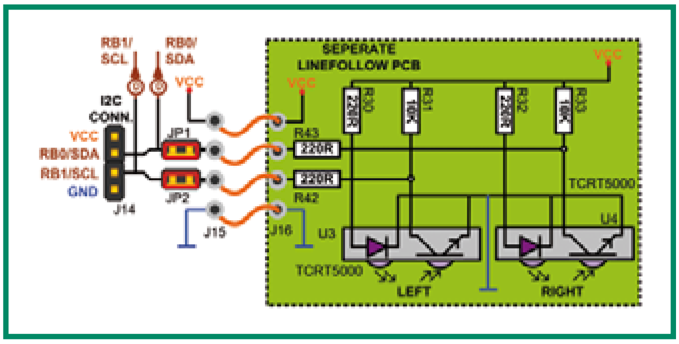


Figure 7. **Line follower circuit.**

or even as an analogue input. The buggy also includes a simple high impedance speaker that can be used to generate frequencies between 100 Hz and 17 kHz. At the front of the buggy is a small forward facing light sensor that allows the vehicle to measure light intensity in the forward direction.

Infrared distance measuring circuit

The buggy also includes three distance sensors on the front, left and right of the main circuit board. **Figure 6** shows the circuit diagram. A single sensor is a combination of an IR LED that emits IR light,

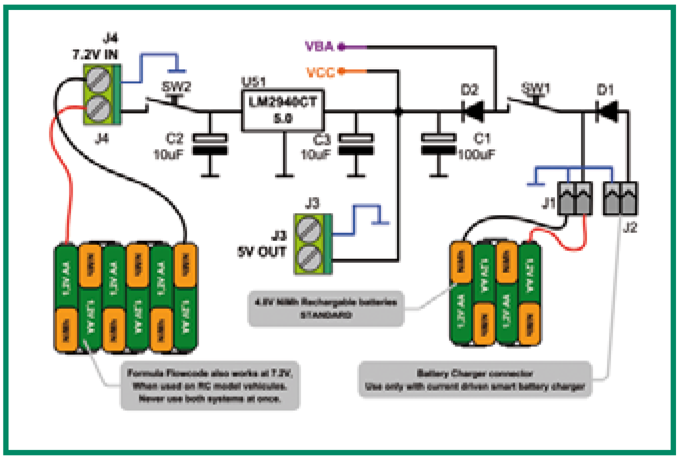


Figure 8. **The simple but all-important power supply.**

and an IR sensitive photo transistor producing an analogue voltage that's inversely proportional to the amount of IR light reflected.

Line following circuit

Also on the front of the buggy is a small daughterboard that contains two I²C intelligent infrared transceivers capable of detecting black and white surfaces at distances from 1 mm up to 6 mm without any error. The circuit is shown in **Figure 7**. These sensors allow the buggy to follow lines on a table or mat.

Power supply

This section of the circuitry is shown in **Figure 8,** using a combination of pictorial elements and of course the schematic. The small chassis is powered from four NiMH AA rechargeable batteries which give between 4 and 6.2 V. The circuit board also has space for additional components that allow you to connect larger batteries to the chassis, using a 5 V regulator.

Additional circuitry

In addition to the standard circuitry discussed above, the chassis is also fitted with a fair number of expansion connectors. These include I²C expansion, wheel encoder inputs, servo inputs, and much more.

Using Formula Flowcode

By now you should have a good idea of how the hardware works and what makes it tick. But how is it programmed, how is it used, and how do students know what to do?
The Formula Flowcode buggy is supplied with a free (reduced functionality) copy of Flowcode – a graphical software language for microcontrollers. Flowcode allows users to directly download a program to the buggy using the USB lead. On removing the USB lead and pressing the reset switch, the buggy starts to run the program.

Courseware for pole position

The new version of Flowcode released with the buggy includes a pulsewidth modulation (PWM) component for controlling the motors. As Flowcode is now available in around 10 languages (including Chinese) it will be usable by children as young as 12 virtually anywhere in the world.

This robot buggy is officially named 'Formula Flowcode', after the Formula Ford where the cars are all identical and winning only comes down to the driver's skills. In this case, winning comes down to the *programming skills* of the user. As you might expect there are a number of separate 'courses' that users have to complete to increase their skills level. These courses start with getting a single LED to light up, and finish with full maze solving using a custom made chassis, using wheel encoders and what have you. This is the really clever idea behind Formula Flowcode — it is great for complete beginners to robotics and electronics, and it will also provide a considerable challenge to those with relevant degrees in electronics and computer science.

The courses include such subjects as:

- Light a single LED;
- Make a 'NightRider' effect on the LEDs on the front of Formula Flowcode;
- Develop a program that uses the on-board light sensor to allow

Formula Flowcode to steer towards the light from a hand held torch;

- Develop a program that allows Formula Flowcode to 'dance to the music'. Every time you clap it must turn through 90 degrees;
- Develop a program that allows Formula Flowcode to follow a 2-metre long line made up from a black insulating tape. Beat a time of 30 seconds;
- Develop a program that allows Formula Flowcode to solve a 64-cell maze using the left-hand wall following technique.

These courses are all explained to students in the form of task-based worksheets. Some are competitive, in terms of time or function, and will form the basis for regional competitions that we hope will be run by Elektor and educational institutions across Europe. Other courses are just for fun or in-depth exploration of programming and hardware features.

Support for all of this will be available on Matrix Multimedia's website forum accessible via www.matrixmultimedia.com where users ask each other questions and swap programs. We also plan to run workshops on Formula Flowcode to get young people up and running and interested in technology.

In addition to this Elektor will be publishing a book which will take users through the process of developing programs and additional circuitry for the buggy. This will form a complete suite of tutorials which will teach technology to budding electronics enthusiasts up to 16 years of age.

(070323-I)

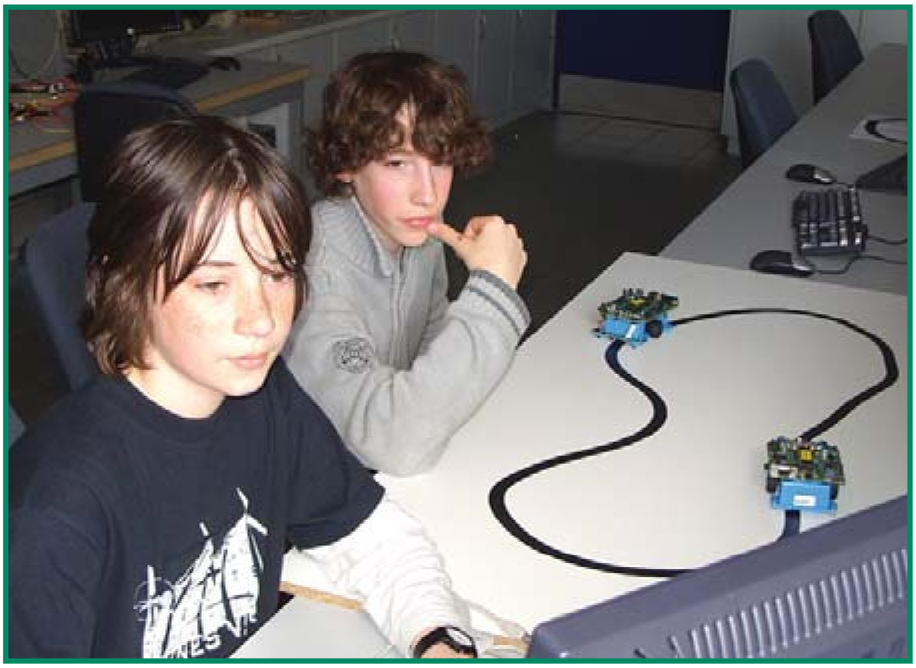


Figure 9. Typical line following exercise.

Pit stop! How can you get involved?

The Formula Flowcode robot buggy was purposely developed to motivate people to want to learn more about robotics and electronics – from 12 year old pupils who have a curiosity about the subject, right up to those enjoying retirement and still wanting to learn and keep mentally active. In the USA the First Robotics programme (www.usfirst.org) has been quite successful at stimulating engineers in industry to collaborate with young people to compete in robotic events. We hope to achieve something similar here; by providing a low cost hardware software robot, providing online support and quality curriculum. By running workshops and competitions we hope people will be captured by electronics. If you feel that our aims are worthwhile and achievable, if you want to take part in this programme, or if you are interested in the competitions and workshops then please let us know. If the level of interest is high then we can write more articles and issue special 'courses' for Elektor readers. The author and his colleagues can be contacted by email on barthuyskens@scarlet.be, or through Elektor.

You can purchase a Formula Flowcode buggy from the Elektor SHOP at a cost of £ 85 or € 125 including VAT.

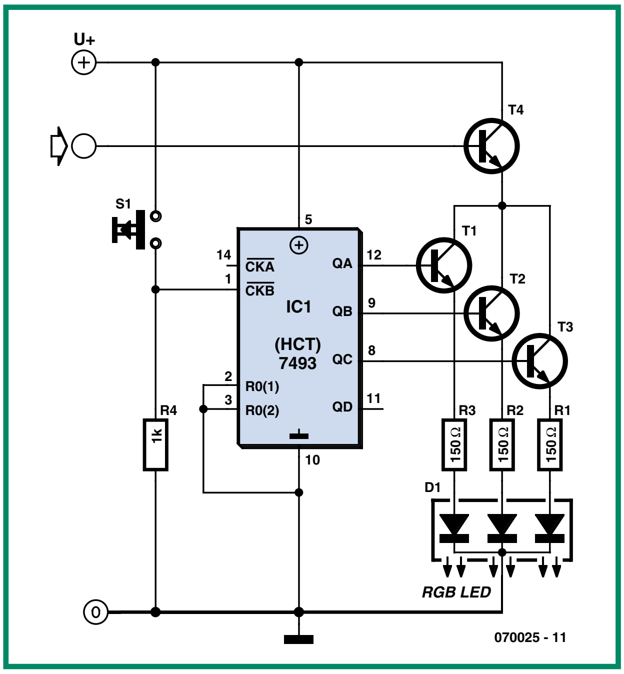
Figure 10. Solving a simple 'left' maze.

Colour Tamer

RGB LED adjustment

Nivard van de Boogaard

With this simple circuit you can easily control the three LEDs in an RGB LED. Each time switch S1 is pushed we increase the (digital) value at the output of the counter-IC, IC1, an HCT7493. So, with each button push, a different LED or combination of LEDs lights up; or, in the case of an RGB-LED, the LED produces a different colour each time. After the highest value the counter will start from the beginning again. In this way all colour combinations will have their turn and there is also no need to build a separate reset-facility. Nice to embellish a robot with, but it also gives a nice effect for a modded PC.



To prevent the outputs of IC1 from being overloaded, we have added T1 through to T3. As soon as an output from the counter-IC becomes active (high), it turns the corresponding transistor on and current will flow though the LED. To limit the current through the LEDs we deployed R1 to R3.

The type of transistor that is used for T1 to T3 is not very critical. Standard LEDs require relatively little current, about 20 mA. A BC337 will therefore work fine, as will a BC547.

The power supply to the LEDs can be switched off with T4. This is handy when, for example, the circuit is built into a PC. As long is IC1 remains powered it will remember its counter value and therefore also the corresponding colour setting of the LEDs or RGB-LED. In this way it is not necessary to adjust the colour every time the PC is switched on. T4 needs to be able to handle more current then T1, T2 and T3, but even a BC847 with its 100 mA maximum collector current rating is still below the limit with three LEDs.

We use R4 to define the logic level (low) on the clock input when the switch is open.

The HCT7493 is a 4-bit binary ripple counter, which internally consists of four master-slave flip-flops that form a divide-by-two and a divide-by-eight. RO(0) and RO(1) can be used to reset these two sections. We don't need the reset function for this application so we connected RO(0) and RO(1) to ground to prevent unwanted behaviour. If need be, the clock input \CKA could be connected to the power supply rail to make this input insensitive to noise.

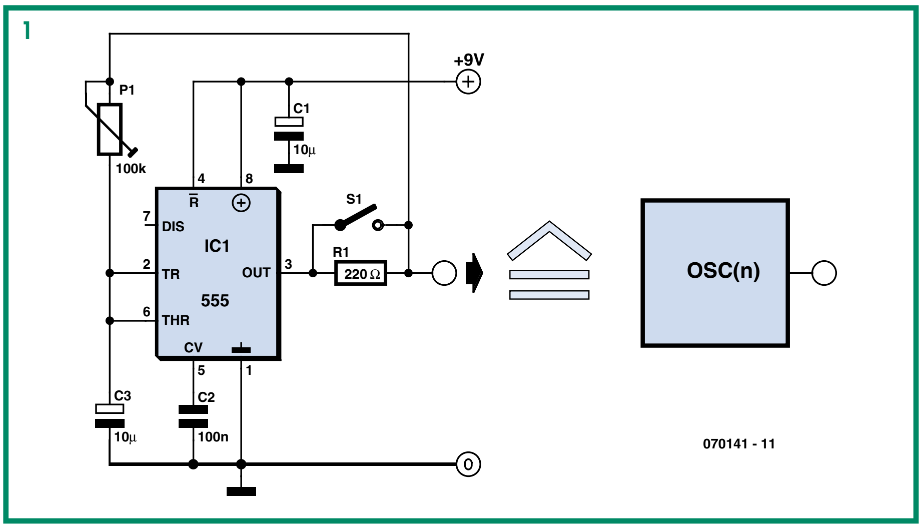
(070025-I)

Chaotic LED Fireflies

Jonathan Hare

Here we couple LED oscillators together to produce some interesting effects for an exclusive optical touch to your robot.

As seen in the circuit diagram in **Figure 1**, instead of using the discharge pin on a 555, the timing capacitor can be charged and discharged using the output (via a preset P1). If we assume the 555's output resistance is very low (i.e. use a bipolar rather than a CMOS 555) this circuit provides a 50:50 mark-space ratio whose output frequency is independent of load. However, if we deliberately increase the output resistance by using a series resistor (R1) the timing will now also be dependent on the current taken by the load (because R1 will effectively drop the available charging voltage to the P1/C3 timing circuit).

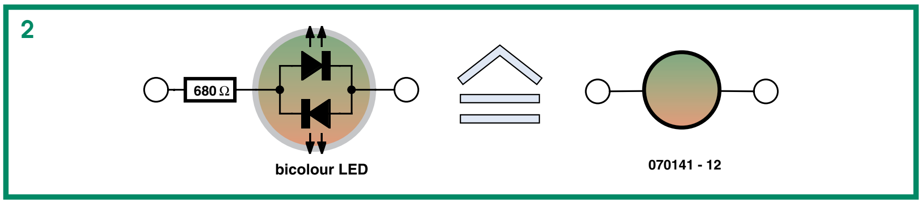


Now, imagine a number of such oscillators whose outputs are connected to each other via current limiting resistors and bi-colour LEDs (**Figure 2**).

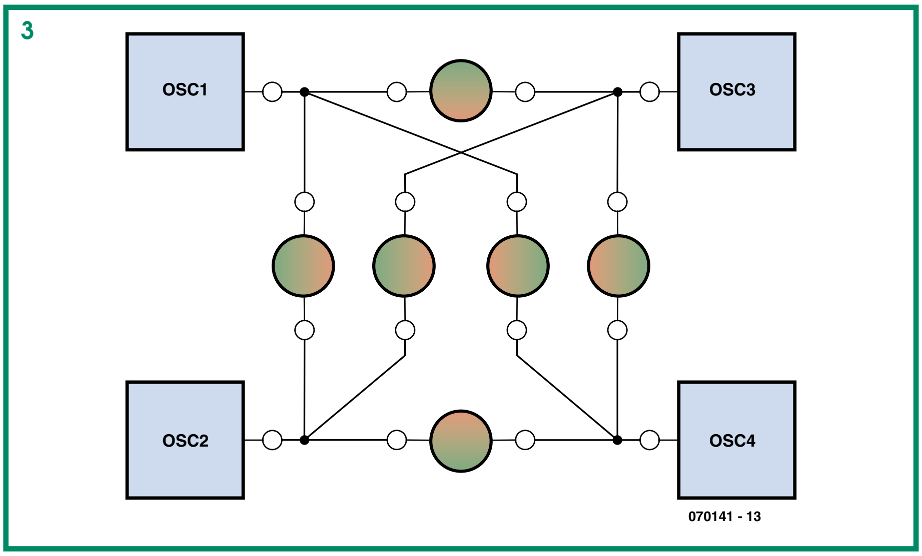
A possible constellation of oscillators and LEDs, each with their own symbol from

Figures 1 and 2, is shown in **Figure 3**. Each oscillator's timing will be dependent on the state of the other oscillators because these will determine the current that flows through the LEDs. For example, if all the outputs are High (or all Low) there will be no potential differences and so no current will flow through the LED circuits. In this case, all the oscillators will be at maximum frequency. Other combinations of outputs will light some of the LEDs and these currents will thus effect each oscillators timing. Chaos rules! The R1s therefore couple the oscillators to each other. A switch across each R1 allows control of the coupling.
Setting the oscillator frequencies to about 2 Hz with the P1s shows the complex flashing of the LEDs switching between off, red and green. Sometimes the LEDs seem to settle down pulsing together. This is rather like an electronic version of what is observed in nature when a group of fireflies congregate in a bush — they pulse together and maybe our little circuit is a simple version of this rather complex natural feedback system.
If the frequency is raised to ca. 100 Hz, varying mixing (beating) of the flashing red and green colours cause a 'wave' of changing colour to go through the array of LEDs.
Including light dependent resistors (LDR) in series with R1 might be a way of making

2



3



each of our LED fireflies 'see' each other. Even without the LDRs, with three or more coupled oscillators there might also be the intriguing possibility of observing chaotic behaviour of the oscillators.

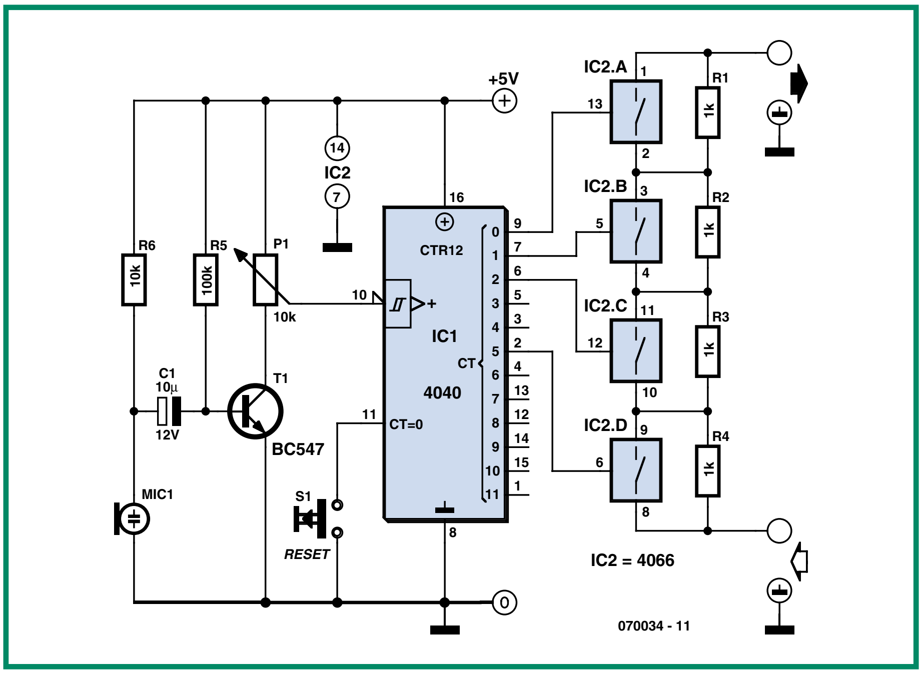
(070141-I)

Stepped Volume Control

Raj K. Gorkhali

Louder music, sirens or speech in response to higher ambient noise levels? This simple circuit has the answer, and it may enable your robot to be at least as noisy or loud-mouthed as the others in an arena.

The circuit consists basically of a microphone, a level detector, a 4-state counter and four analogue switches connected to a resistive ladder network.
Looking at the circuit diagram, the signal from electret microphone M1 is amplified by T1 whose collector voltage appears across a potentiometer. M1 gets its bias voltage through R4. Depending on the setting of P1, the 4040 counter will get a clock pulse when a certain noise level (threshold) is exceeded. The counter state determines the configuration of the four electronic switches inside the 4066 and so the series resistance effectively seen in the audio signal line.
The circuit should be powered from a 9-V regulated supply or a battery and will consume a few milliamps only.

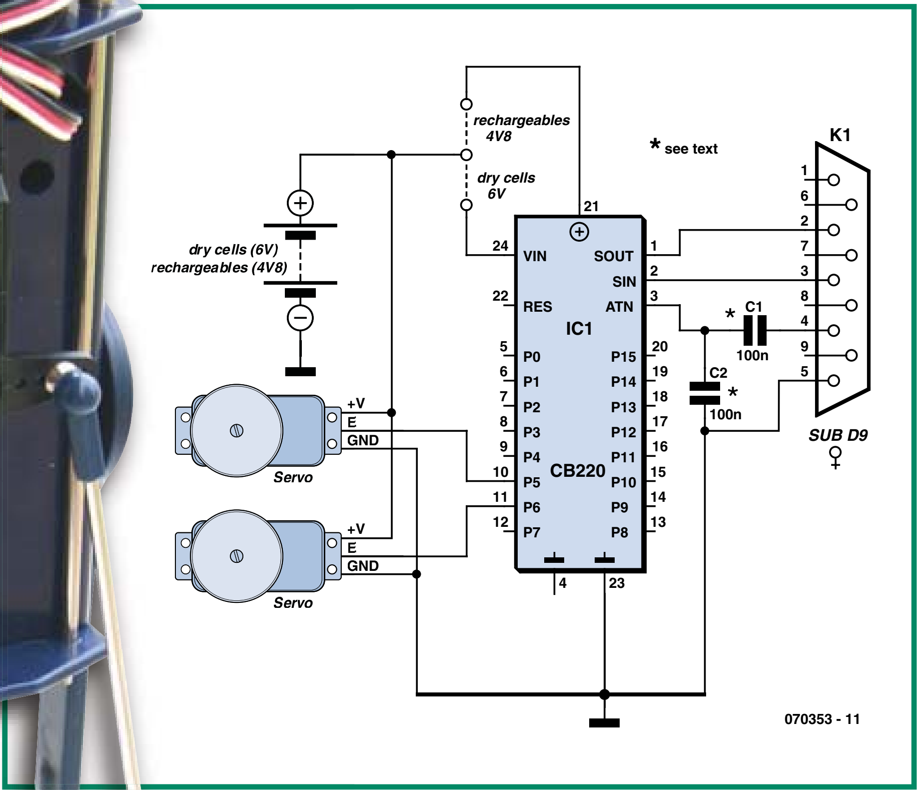


Switch S1 allows the counter to be reset, switching all 4066 switches to off, i.e., the highest attenuation will exist in the audio path as in that case none of the 1-kΩ resistors are shorted out.

To calibrate the circuit, disconnect the 4040 clock input (pin 10) from the wiper of P1, and temporarily ground it through a 100 kΩ resistor. Now pulse the clock input by briefly connecting it to the +9 V line; you will see the counter outputs change state and with them, the bilateral switches in the 4066.

(070034-I)

Walking Works!



C. Tavernier

Although the majority of robots built by amateurs move around using wheels or caterpillar tracks, two categories occupy a place apart because of the spectacular way they move: the hexapod robot, also called spider robot (though spiders actually have eight legs!), and the walking robot. It may seem relatively easy to make the wheels turn using motors, which is the sole requirement in a conventional mobile robot, but reproducing walking, be it of an insect in a hexapod or of a human in a walking robot, might appear markedly more difficult.

In this article, we'll see how to do this for a walking robot, which we've opted to buy in kit form for the mechanical part. Although these days any good handyman can build a 'conventional' mobile robot base, i.e. with wheels or tracks, the mechanical construction of a walking robot is much trickier, mainly because of the particular action involved in walking, which we'll be describing in a moment.

To our knowledge, there are currently only two mechanical kits for walking robots sold at an affordable price: the famous Toddler from Parallax (www.parallax.com) and, closer to home, the Yeti from Arexx Engineering (www.arexx.com).

As these two robots operate in virtually the same fashion, in terms of the principle of

their walking, we settled on the kit for the Yeti, distributed by Lextronic (www.lextronic.fr), as he is slightly cheaper than his brother from Parallax. But everything we say about one is going to be true, with only minor variations, for the other too.
So, these walking robots both consist of two rigid legs, in the sense that they don't have a central articulation like our knee. They consist of two arms (that's a bit much for a pair of legs!) arranged to form a parallelogram, and have a foot articulated either side of the plane that forms.

Although it might not seem very much, all it actually takes to make such a robot walk is two normal — i.e. unmodified — radio-control servos. The first, clearly visible at the front of the robot, controls the feet by means of two long connecting rods, while the other, fitted under the robot's belly, acts on the rear arm of each leg. So having thus set the scene, let's now see how such a figure is able to walk.

To make it easier to follow our explanation, we're going to refer to 'right' and 'left', but obviously this is purely relative. When the robot is at rest, both feet are flat on the ground alongside each other. Then the foot servo turns in a direction that will make the robot's body lean over onto the left foot, which obviously has the effect of lifting the right foot off the ground. Then the leg servo turns too, making the right leg, free to move as its foot is now off the floor, move forward. Then the foot servo turns in the opposite direction, making the robot's body lean over onto the right foot, lifting now the left foot off the floor. The leg servo rotates again to make the left leg, itself now free to move, advance — and thus ends the first step.

As you will note from reading this, or if you have already watched the videos available on both the Parallax website for the Toddler and on the Lextronic site for the Yeti, the robot is actually in a constant state of near imbalance throughout its walk, which can only work correctly if the robot's weight is correctly distributed… and if the servo movements are neither too abrupt, nor too large in amplitude.

Even though these walking robot kits are also available with electronics chassis included, sometimes very elaborate as in the case of the Yeti with an ATMega8 processor from Atmel and its C compiler, a simple Basic Stamp II or a Cubloc CB 220 is enough for taking your first steps (literally as well as figuratively!) As shown in the figure, which applies to both these microcontrollers that are, don't forget, pin-compatible, apart from the microcontroller itself, no other active components are required to make our robot walk.

The servo control inputs are connected from two parallel ports which can be any ones in the case of the Basic Stamp, but must be P5 and P6 in the case of the Cubloc CB 220, as its PWM instructions only work on these two.

Capacitors C1 and C2 call for a comment: C1 and C2 only need to be fitted if using a BS II. If using a CB 220, C1 will be replaced by a wire link, and C2 will not be fitted, its two pads being simply left empty.
All the rest is just a matter of programming, based essentially around the PWM instruction in the case of the Cubloc and around PULSOUT in the case of the Basic Stamp. As you will have gathered from the explanation above, to make our robot walk, all we have to do is make the servos turn alternately in one direction or the other, in a well-defined sequence.

We are offering you two complete source listings for making our robot walk, one for Basic Stamp II and one for Cubloc, on download from the Elektor website or from the author's own site (www.tavernier-c.com). Here are just a few comments to prove to you how simple they are and enable you to adapt them easily to your own needs.
Let's start by recalling that in the Cubloc the instruction PWM is used as follows:

```
PWM port, ratio, period
```

This generates on the corresponding port (0 for P5 and 1 for P6) a PWM signal whose duty cycle is defined jointly by 'ratio' and 'period'. The advantage of the Cubloc is that this instruction lets us generate the relevant signal continuously, as soon as it has been called at least once.
In the case of the Basic Stamp, the instruction PULSOUT is used in the following way:

```
PULSOUT port, duration
```

This generates a pulse on the corresponding port for a period equal to 2 µs multiplied by the value of the 'duration' parameter. The drawback to PULSOUT compared with PWM is that this generation is not repetitive. So if we want to generate repetitive pulses, we need to employ loops, making the Basic Stamp version of the program a little more complicated compared with the Cubloc version.
Lastly, let's remember that a servo takes up the rest position when it receives 1.5 ms pulses, and moves towards its end positions in one direction or the other for pulses of 1.0 ms or 2.0 ms respectively.
From this point on, it's easy to follow one or other of the suggested listings. To put the robot's feet into the rest position, for the Cubloc we write:

```
PWM 0, 3150, 32768
PWM 1, 3150, 32768
```

And for the Basic Stamp II :

```
FOR Pulses = 1 TO 100 STEP 5
        PULSOUT TiltServo, 750
        PULSOUT StrideServo, 750
        PAUSE 25
NEXT
```

In both cases, this causes 1.5 ms pulses to be generated for both servos, hence placing them into the rest position. Note that, in the case of the Cubloc, it is necessary to adjust the 3150 parameters so that they take the servos correctly to the rest position, while for the Basic Stamp, it is necessary to adjust the two 750 parameters for the same purpose.
To lift one foot, we will therefore write for the Cubloc:

```
FOR Position = 3150 TO 2850 STEP
-1
        PWM 0, Position, 32768
        DELAY 1
NEXT
```

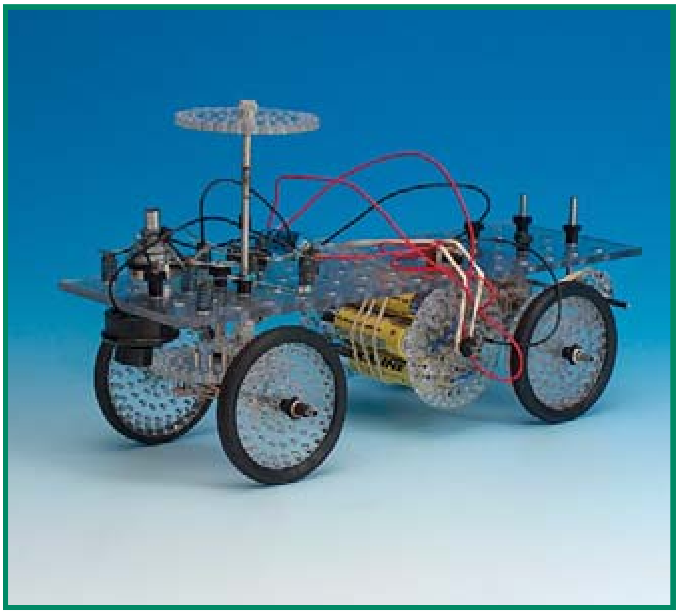
And for the Basic Stamp:

```
FOR Pulses = 750 TO 620 STEP -5
        PULSOUT TiltServo, Pulses
        PULSOUT StrideServo, 750
NEXT
```

Note the increase in 'complexity' created by the fact that, unlike PWM, PULSOUT does not operate continuously. So we need to add into the Basic Stamp's 'lift foot' loop the generation of the pulses that will maintain the leg servo in the rest position. In the case of the Cubloc, this generation is taken care of automatically by the PWM instruction that originally put the servos into the rest position.
We'll leave you to analyse the rest of these two listings for yourself — as you can see, they are in fact nothing but a succession of the groups of instructions we've just been looking at, with numerical parameters each time appropriate for the pulses needed to move the servos into the required positions.
Before ending, let's just clarify that these two listings are extracts only. The Parallax one, originates from the Parallax website (www.parallax.com), from where we strongly recommend downloading the document entitled *'Advanced Robotics with the Toddler Robot'* (available in PDF format) containing a very good survey of the various methods of programming the walk. For the Cubloc, the full program may b be found on the Lextronic website (www.lextronic.fr). We thank Parallax and Cubloc for their kind collaboration.

(070353-I)

Philips ME Construction Kits



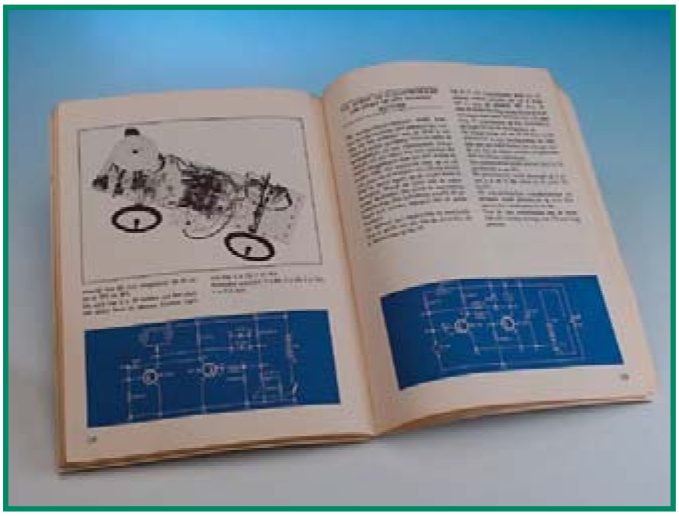
Luc Lemmens

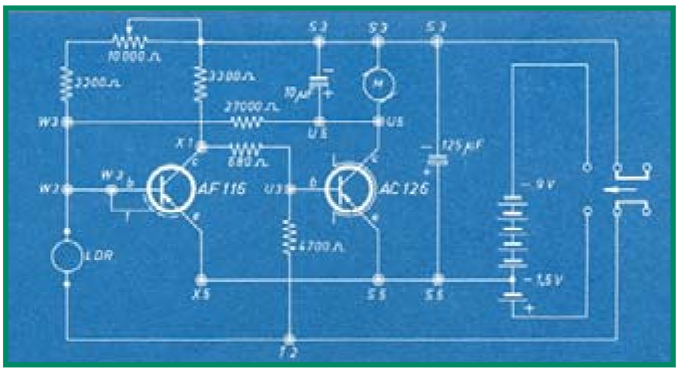
Many of our readers — especially the older generation — will remember the legendary EE (Electronic Engineering) experimenter kits. They were part of the Philips (not 'Phillips') product line for many years, from 1963 until well into the 1980s. Many electronics professionals owe their interest in the field to these kits. The first kits were primarily intended to promote Philips electronic components among hobbyists, but in the later years, the complexity of the designs increased and the range of kits was oriented more towards educational use.

In the late 1980s, Philips sold the electronic experimenting kits business to the German firm Schuco. It continued to sell them until the mid-1990s.

The ME (mechanical engineering) experimenter kits from Philips are much less well known, but they were only available for around five years in the 1960s. It would appear that the ME series was much less successful than the EE series, which is why they were only available for a relatively short time. Anyone who ever tried to work with them — such as the author — will certainly know why they weren't a resounding success like the EE boxes.

The ME kits couldn't compete with other mechanical construction systems that were very popular at the time, such as Meccano and Fisher. Many of the parts were much too fragile for clumsy children's hands, and in some cases the proposed structures did serious damage to the components. In particular, the pins that were used for gearwheels and all sorts of connections between axles were subjected to heavy loads in these designs, and they could head straight for the rubbish bin after the project. Fortunately, these pins and other parts could be obtained as spare parts at that time.





No matter how nice some of the projects looked on paper, they were often not especially solid or robust. As a result, many hours of painstaking assembly work were often rewarded with a mechanical construction that was quite capable of self-demolition. The ME kits used only clamped connections, and in many cases they were not good enough to accommodate all the mechanical forces.

But the nice thing about the ME system was the enormous variety of structures you could make with them — from mechanical clocks to real water pumping installations. There were also construction projects that used parts from the EE series in a combination of mechanical and electronic engineering. An example is the car in the photo. It stops automatically when it drives on top of a dark surface. Nowadays this is a very simple application with quite simple technology, but it had a certain magic for a small boy!

Philips also tried to get even younger children interested in mechanical engineering and thus create a pool of new customers for the ME kits. Philoform, a construction system that

strongly resembled Lego Technic and could be used together with ME, was introduced in 1968. However, the end of the line for these mechanical construction materials from Eindhoven came in 1970.
Incidentally, the first ME kit, the ME1200, had a very strong feature with regard to mechanical engineering. The mechanical parts were housed in a wooden box with a sliding lid. Probably for this reason, they have survived the years relatively intact, and you can regularly find complete or practically complete kits offered on Ebay and similar auction sites. They usually change hands for around twenty to thirty pounds, naturally depending on their general condition. Just as with all old things, there are collectors who are interested in them, and there are various websites where you can find more information.

(070277-1)

Web Links

http://ee.old.no/mechanics

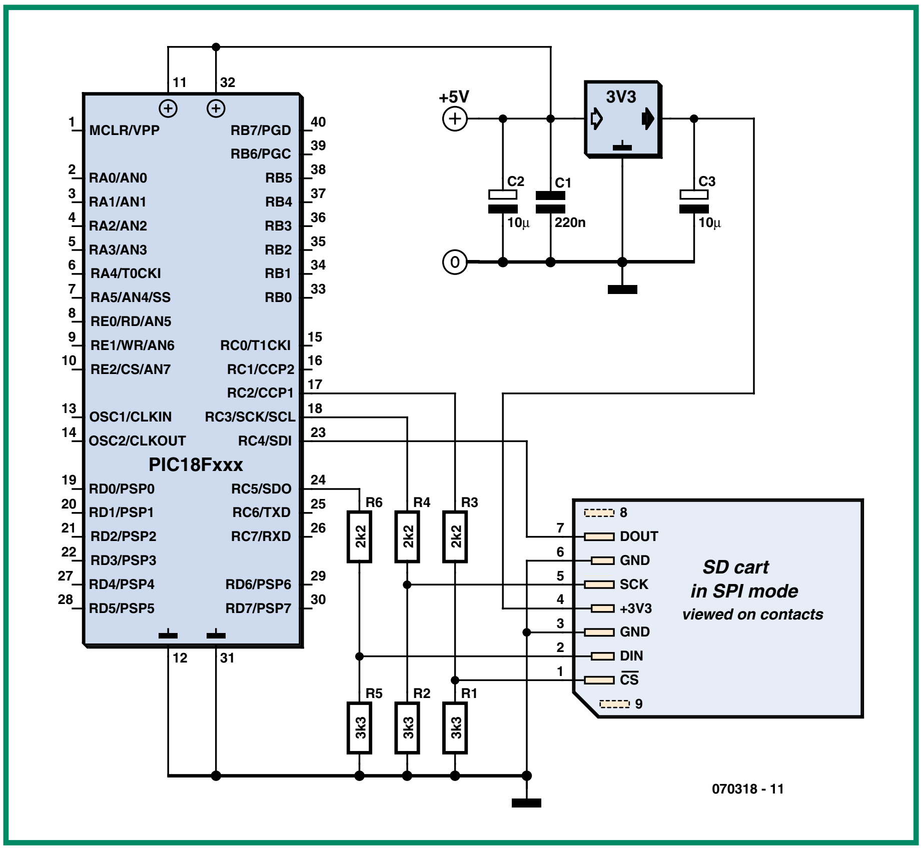
http://sharon.esrac.ele.tue.nl/~pa0ib/bouwdozn/index.html

www.hansotten.com/philipsme1200.html

www.girdersandgears.com/norelco.html

A Robot with an Elephant's Memory

B. Broussas



Although 'just for fun' robotic applications can usually make do with the few bytes to few hundred bytes of Flash memory that's available in most current microcontrollers, certain more 'serious' or more complex applications do need much greater memory capacities. A mobile robot may hold in its memory a complete mapping of an area in the form of co-ordinates like those provided by a GPS, for example. Alternatively, it may be required to collect a large quantity of data furnished by its sensors.
Faced with such a situation, it is of course possible to produce one or more special memory cards using the high-capacity Flash EEPROM packages available on the market today. However, this approach fairly soon comes up against numerous problems. The first is making the necessary PCBs. Most memories of this type are only available in SMD packages, and their close pin spacing makes producing a PCB a tricky job for amateurs, not to mention the difficulty you then have soldering such ICs correctly. The second problem is that as these memories are intended above all for the professional market, they're sometimes very difficult for amateurs to get hold of.
So in this article we're proposing an original solution to this problem, provided your robot is fitted with at least one PIC microcontroller and you don't mind programming it in Basic. You'll agree these are relatively minor constraints, especially when you think that by doing it this way you'll be able to give your robot a gigabyte or even more of memory for just a few tens of pounds!
The memory we've adopted is quite simply the memory sold in the form of SD cards (**S**ecure **D**igital), originally intended for digital cameras and portable music devices. This memory is very inexpensive today (around £ 7 for 1 GB at the time of writing), very compact, and unwaveringly reliable, provided you do not exceed the maximum number of write cycles, which is however hundreds of thousands, or even millions, depending on how optimistic the manufacturers are...
The hardware interfacing of such memory with a PIC microcontroller is relatively easy, as the SD-type memories' mode of operation is compatible with the SPI-type synchronous serial interface available in these microcontrollers. The only thing to watch out for is the electrical levels, as these memory cards work on 3.3 V while the PICs in our robots are most often powered from 5 V. The figure suggests a circuit that can be used with all PIC microcontrollers in the PIC18 family from Microchip.
However, the problem is noticeably trickier when it comes to the software for managing these memory cards. Contrary to what we might at first think, these are not just simple EEPROM Flash memories with serial access, but modules that have their own internal intelligence. So it's not possible to read or write directly to these memories as you would do with an ordinary serial access EEPROM like a 24C16, for example.
The dialogue has to respect a precise protocol, as the card only recognizes and responds to a certain number of com-

mands. We also have access to various internal registers with quite specific purposes. Lastly, the location of the data in the card is not just 'any old how', but follows a principle similar to that found on diskettes and hard disks, using in particular a FAT (**F**ile **A**llocation **T**able) that shows where the data, contained in files as a result, are stored.

Even though it is possible to manage all this information by writing the necessary subroutines yourself in machine language, this is a long, tedious, and error-prone task.

Very fortunately, if you're interested in using such a memory card in your robot, there is one Basic compiler (for PIC microcontrollers only, at the time of writing) that has a full management library available for SD-type memory cards wired as shown in our figure.

This is the MikroBasic compiler from Mikroelektronika, which you can find on the publisher's website (www.mikroelectronika.co.yu), with a working demo version allowing you to try it out before buying. Apart from those standard functions available in all Basic compilers for PICs worthy of the name on the market today, it has a full management library for SD-type memory cards (also for Compact Flash types, but they're not the subject of this article).

We're not going to detail here the sixteen instructions available for manipulating SD cards, especially since you can download the manual for this compiler free of charge from the publisher's website. Just be aware that using this product makes the management of such cards ever so much easier, to say the very least!

So for example, if you have filled a buffer and want to now store it onto the SD card, all you have to do is write:

`status = Mmc_Write_Sector (number, buffer)` where:

- `status` is a variable containing a numeric code returned by the command indicating the outcome of its execution (0 for successful, 1 for an error sending the command, 2 for an error during the writing proper).
- `number` is the number of the SD memory sector we want to write to (we explained above that the data storage is similar to that on a hard disk, and now you can see this in practice).
- `buffer` is the label marking the start of a buffer able to hold up to 512 bytes, which is the size of the SD card sectors.

Reading the information stored on the SD card and transferring it to the robot processor's RAM is just as simple, and amounts to a single line of code:

`status = Mmc_Read_Sector (number, buffer)` where:

- `status` is a variable containing a numeric code indicating the outcome of the execution of the command (0 for success, 1 for failure).
- `number` is the number of the SD memory sector we want to read.
- `buffer` is the label marking the start of a buffer whose size must be at least 512 bytes; this buffer is going to receive the data read from the selected sector on the card.

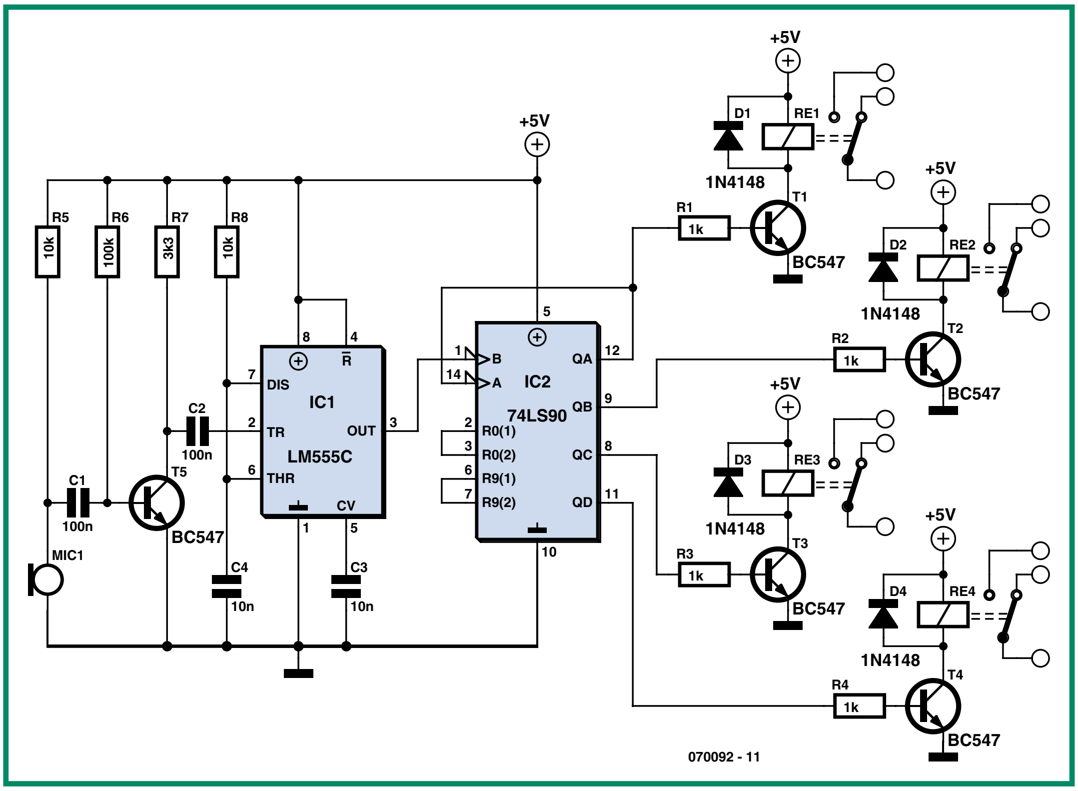
As you will note, it would be difficult for things to be much easier, even though in this article, by nature only a summary, we have not said anything about the card's FAT management instructions. However, the latter are much less frequently used, once the structure of the card is defined, and a detailed, annotated example about these is given in the compiler manual.

So then, if your robot needs lots of memory, lend it the SD card out of your camera and pay a visit to Mikroelektronika (www.mikroelektronika.co.yu).

(070318-I)

Clap Controlled Switcher

Raj. K. Gorkhali



The circuit presented allows you to control home electrical appliances like TVs, fans, lighting, etc. by clapping your hands. Four different electrical equipments can be controlled using changeover contacts on relays.

The circuit diagram shows a condenser (electret) microphone M1 connected to the input of preamplifier T5. The sound picked up by the microphone is preamplified and fed to the input (pin 2) of a 555 timer IC set up in monostable configuration. The output of the 555 is connected to the clock input of a 7490 counter.

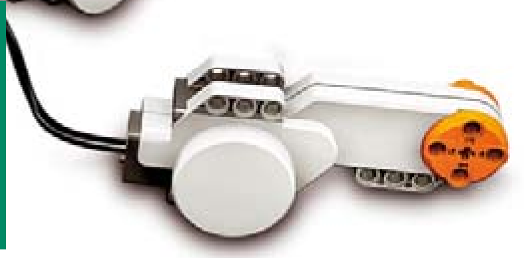
Whenever a pulse arrives at the clock input of IC2 (pin 14), it produces a 4-bit binary equivalent code at its four outputs. As an exam-

ple, when the first pulse is applied to the 555's TRIG input, the binary coded output on the 7490 will be 0001, for the second pulse the output will be 0010, and so on. For the 15th pulse, the output will be 1111. On receiving the next pulse, IC2 automatically cycles back to state 0000.
The counter's four outputs control driver transistors T1 through T4. These, in turn, control the four relays RE1 through RE4, and their contacts, the equipment to be controlled. Four rectifier diodes, D1 through D4, are connected across the four relay coils to prevent back-emf surges upsetting the operation of the circuit.
The circuit can be tested in a simple manner. Power the circuit from a regulated 5 V (or 6 V) supply. Temporarily disconnect the CLKA input of the 7490 from the 555 output. Solder a wire on the CLKA input and use it to touch the positive supply rail. Each time a clock pulse is applied in this way, RE1, RE2, RE3 and RE4 should energise or de-energise in one of 16 different configurations.
Re-establish the connection between IC1 and IC2 and clap your hands near to the microphone. The relays should respond as with the clock pulse test. Finally, connect four electrical devices to the relay contacts.
The use of a 5 V regulated supply is recommended for this circuit. The relay contacts should be rated for 230 VAC as well as for the maximum current the electrical equipment is likely to draw.

All relevant electrical safety precautions should be observed when connecting mains powered loads to the relay contacts.

(070092-I)

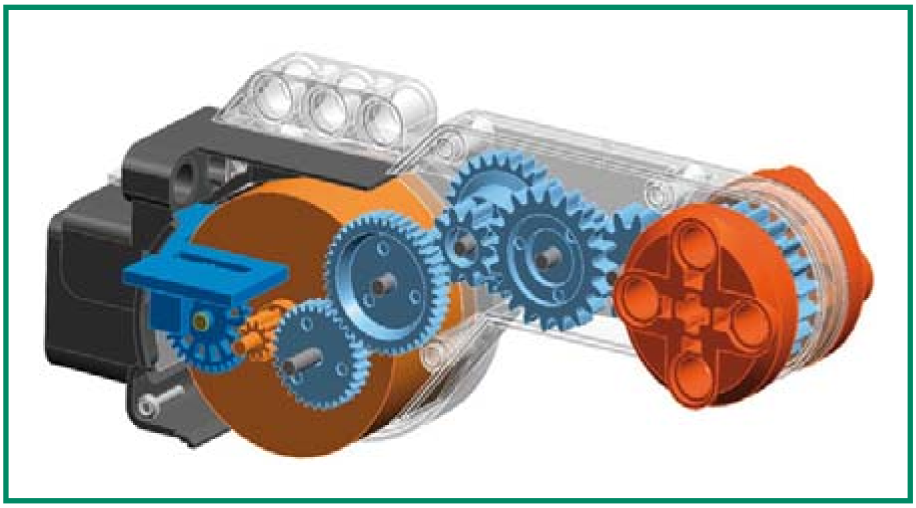
New Lego MINDSTORMS® NXT Motor Block



Antoine Authier

In 2006, the Lego MINDSTORMS® RCX blocks became NXT blocks. They have a quite surprising avant-garde shape — in place of the traditional compact RCX block, for the NeXT generation motor the Lego engineers have opted for a 'pistol' profile.
This block comprises a motor, a rotary encoder, and a step-down gearbox. Its weight is all of 80 g!
The DC motor seems to be a standard type. It is located in the larger-diameter light-grey cylindrical part, under the Lego logo. Powered from 9 V, it draws 60 mA off load with a speed of 170 rpm (360 rpm and around 3.5 mA for an RCX motor).
The internal step-down gearing increases the torque available at the output disc, which is great for power applications. On the other hand, the slower rotation will be seen as a drawback for speed applications.
The data provided by the rotary optical encoder allow the NXT unit software to determine the angle of rotation to the nearest degree. Not having dissected the block, we can only surmise how this precision is obtained from the encoding disc that only has 12 slots. The block contains two electronics assemblies: one is the module that conditions the signal from the optical detector, the other protects against potential overloads. This comprises over-current protection in the form of a resettable Polyswitch® fuse, and a 15 V surge limiter.
At one end of the block is the orange drive disc. At the other end is the RJ11 power input and data output connecter. It has a key to avoid confusion with a standard telephone cable.
Interested readers will find the characteristics and views of the innards of the block on Philo's web pages [1], [2].

(070371-I)



Web links

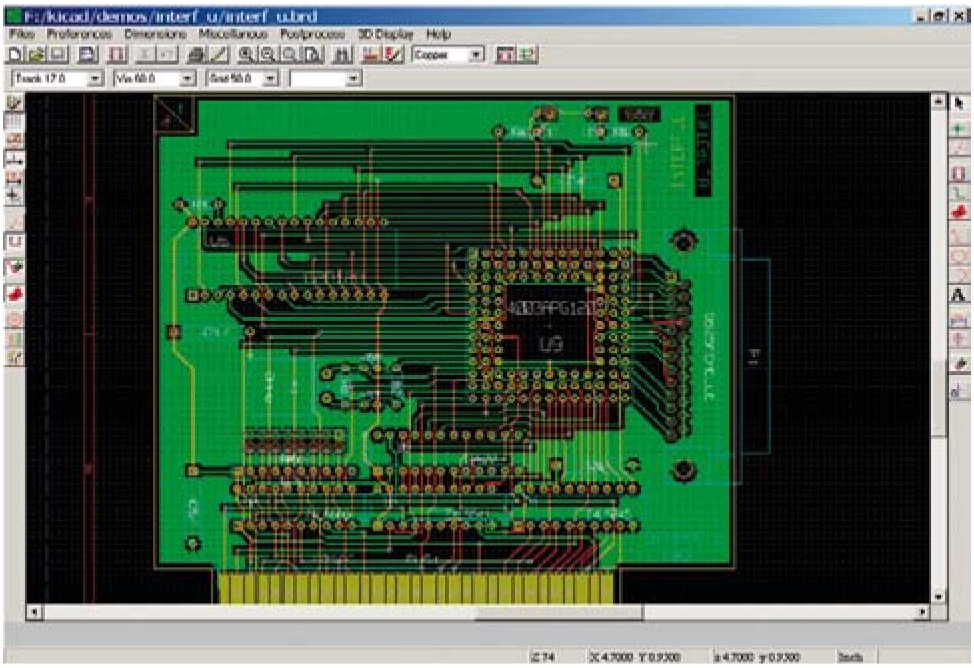
(1) Philo's NXT® motor internals:

http://www.philohome.com/nxtmotor/nxtmotor.htm

(2) Lego® 9 V Technic Motors characteristics compared:

http://www.philohome.com/motors/motorcomp.htm

KiCad: a high-level tool



Electronic CAD available to all

Rémy Halvick

For the month of November, 2005, we had electronic CAD as the theme of Elektor magazine. The issue came with a free DVD packed with software, most of it operating as a Windows demo version. One of the programs stood out due to several unique features. Actually, KiCad is a software package distributed for free under a GPL license, operating in Linux, Windows and Mac OS X environments. As an added treat, this marvel is available in a remarkable number of languages!

Things have greatly changed since the time when electronics hobbyists (professional and/or amateur), peered over schematic diagrams for many hours, drawing circuits with pencil and paper, then produced it all over again for a 'clean' version. Businesses were the first to have the means to utilise CAD software such as Orcad or Protel, on powerful systems with staff especially trained for this task. For a long time, this was too expensive for amateurs.

Electronics fans today are much more spoiled — they can utilise programs that use little resources, at reasonable prices; some even come as 'light' version for free, but with restrictions that seriously limit would-be users.

KiCad was of course included on the free 'Kaleidoscope' DVD. It was developed by a professor/researcher, Jean-Pierre Charras, from the Joseph Fourier University in Grenoble, France, in order to learn programming in C++, as he claims. The first rough drafts were begun in 1992 in DOS, the most recent versions are available as downloads on the university website (see the links at the end of this article).

The supported OSs are numerous in addition to Windows (2000, XP, and W98 with slight restrictions), the others were delivered, tested and ready to operate with Mandriva and CentOS distributions. It also was just integrated into the Debian distribution, thanks to the efforts of a few dynamic volunteers. Users have also compiled sources in numerous other OSs: Solaris, FreeBSD, etc. Mac OS X remains an exception, because, even if KiCad can be compiled on these machines, its operation is currently still hampered by a bug from the Open Source wxWidgets graphic library, used by KiCad. Let's hope that this problem will be resolved soon: the new version will be distributed as soon as that happens, and the same is true for those that operate in Linux and Windows.

KiCad is available in the following languages: French (original language), English, German, Spanish, Portuguese (Brazilian), Italian, Slovenian, and Hungarian for the user interface (GUI).

The user manuals are available in the primary four languages. Versions in German, Hungarian, Polish, Korean and Russian are at various stages of translation. Tutorials are also appearing in several languages: French, English, Brazilian. All of these documents have are created by volunteers who believe in Open Source and free software.

If the price of this software package defies all competition, that does not mean that you will have an 'inferior' tool. Even though KiCad is far from being an overly complicated software package like Orcad and Altium, its qualities are nonetheless remarkable: you can judge by the screenshots. The graphic interface, simple and very easy to learn, is intuitive and powerful, thanks to one of the many features that uses a 3-button mouse. The keyboard shortcuts are limited in number but efficient. The various output formats (printer, Postscript, Gerber, hole-making and automatic placement files) are flawless and adapt to all printers, as opposed to some DOS software.

This software package is composed of:

- **KiCad**: project manager, from which one can launch the following programs.
- **EeSchema**: simple or hierarchical schematic capture.
- **CVPCB**: used to link components with their schematic footprints.
- **PCBNEW**: design of printed circuits.
- **Gerbview**: display of Gerber files.

Installation

KiCad is available on the DVD that accompanied *Elektor Electronics*, November 2006. More recent versions can be downloaded from the websites devoted to KiCad (see links 1 and 2). At the time this article was written, the current version is dated August 28, 2006. Archives in .tgz or .zip format are about 70 MBytes. To install the software package, you just need to decompress the archive in C:\Program Files\ or /usr/local for Linux users, and to place a link pointing to the executable KiCad file in the sub directory X:\kicad\winexe or /usr/local/kicad/linux. That is the extent of it — no further torture will be inflicted on your precious PC.

KiCad

The KiCad project manager (**Figure 1**) allows you to create or select a project; meaning mainly schematics and a printed circuit. In this way, you also have access to the language selection options for the graphic interface and online help.

EeSchema

EeSchema (**Figure 2**) lets you input a simple or tree (hierarchical) structure. The screenshot is used to get an idea of the simplicity of the interface which does not, however, sacrifice functionalities.
The menu toolbar only has three sections: File, Preferences, and Help. In addition to the traditional open/save/print options, the File menu allows you to generate drawing files in PostScript, HPGL, and SVG formats.
In Preferences, you can select which libraries to be used (which will appear when adding components), as well as various options: colour, display and grid pitch (scale), orientation and incremental values for repetitive tasks; all of these options may be modified, of course, if the need should arise, although the default options satisfy most needs. The help menu is very standard.
Three icon bars give you access to most of the tools which you will need. The one on the left lets you manage the graphic 'look': grid display, its pitch, measurement units (millimetres or inches), cursor shape, orientation of the lines (by 45° increments or any orientation); the icon (**A**) lets you display the hidden power connections to the parts.
Due to their small size, we propose icons in a magnified version in Figure 8 with the reference letter. The icon H is actually a double icon.
The upper bar has various tools: file manipulation (open, save); button (**B**) allows you to choose the page format (A4 to A0 and A to E, as well as a custom format defined by the user) and to fill in the various sections of the of the schematic. The next version of KiCad, which apparently is about to be released, will add an Undo/Redo function to **EeSchema.** The next two icons relate to the **Libedit** component display /editor **(Figure 3)**; in fact, you can create any special symbol that you might need for your schematic. The **CVPCB** and **PCBnew** icons follow after the traditional editing tools (cut, copy, paste) and print; we will examine their role a little later. The 4 following tools deal with display: + and – zoom, drawing refresh and auto zoom which lets you have a better look by reframing the entire schematic. These functions are also accessible from the F1 to F4 function keys. When the diagram becomes cluttered, sometimes it is difficult to find R59 or U12; you can then use the search tool by clicking on (**C**).
The following icon **(D)** allows you to generate a netlist in different formats; you can even have yours by creating a plug-in! Before arriving at this point, you would have taken care to number the components, thanks to the automatic annotation tool **(E)**.
The next-to-the-last tool in the top toolbar **(F)** is very useful: it deals with verifying that the electrical rules are respected or DRC (Design Rules Check). The principle is the following: each component pin is defined while it is being drawn as input, output, open-collector, 3-state, etc. The DRC tool will carry out various plausibility checks: output connected to the power supply, unconnected gate input and others; you can define the checks as well as their result: error, warning or no error in the options tab. This is used to avoid gross errors and forgotten connections.
The last icon is for generating the list of components (BOM = bill of material), which will help you with your shopping, especially if you export it to a spreadsheet in order to optimise supply sources.

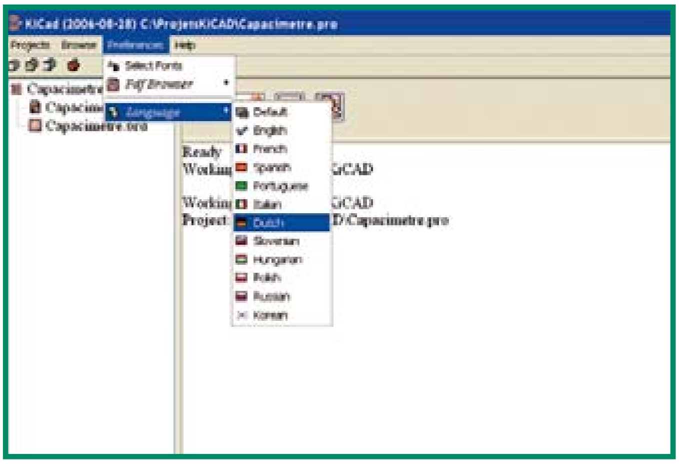


Figure 1. **KiCad is project-based, just like similar products on the market.**

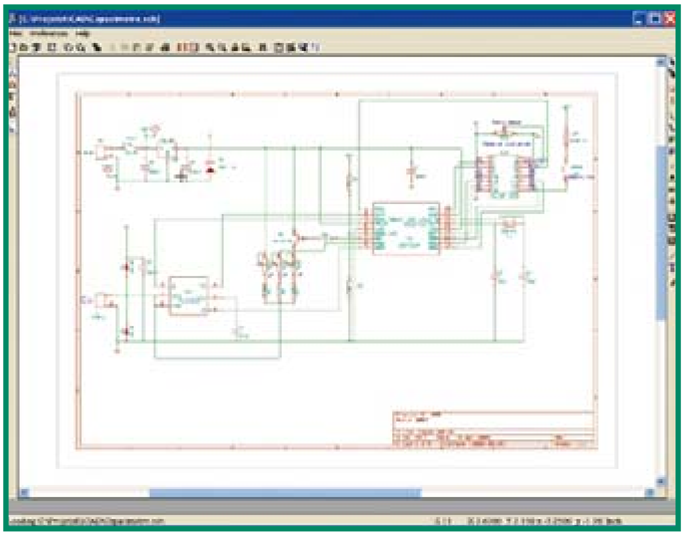


Figure 2. **EeSchema: easy schematic capture.**

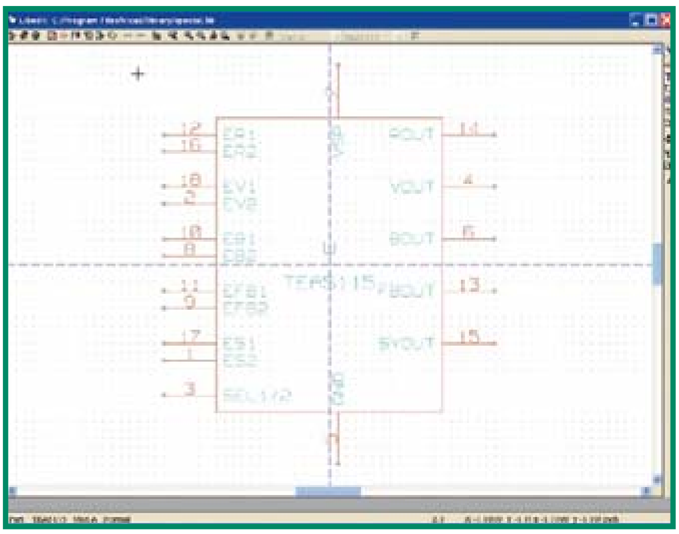


Figure 3. **If you haven't found the component you need on the Internet, there is nothing to stop you from designing it with Libedit!**

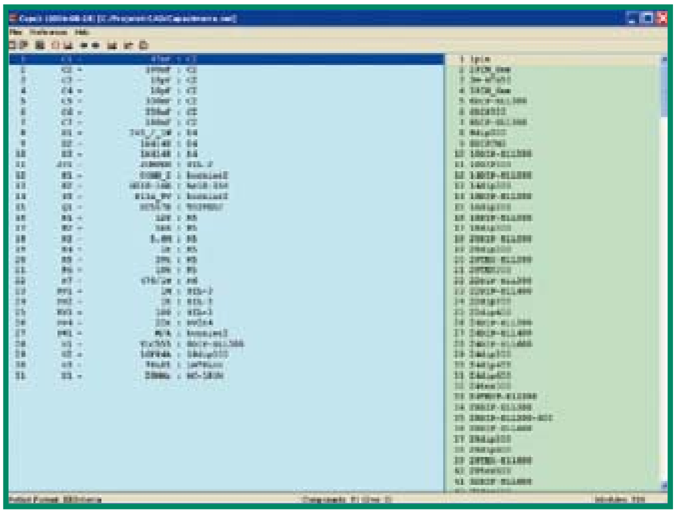


Figure 4. **CVPCB: choice of component case.**

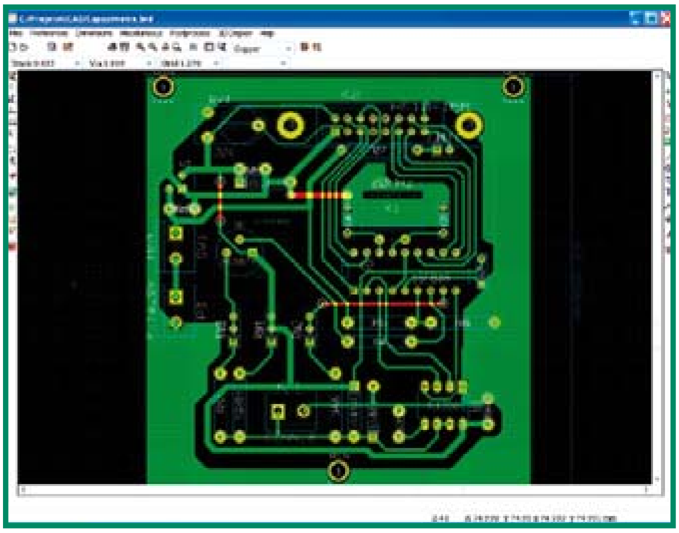


Figure 5. **Design PCBNew printed circuits.**

The right icon bar groups the different drawing tools: adding component (the gate), connection by wire or bus, labels, commentaries and other embellishments that will improve the presentation of your schematic.

The rest of the required commands are accessible from the contextual menus, with one right mouse click. That is one of the strong points of Kicad, which, by proposing the tools at the time they are needed, makes it possible to preserve a clear and easy to grasp interface. Nothing like those heavyweights with their dreadfully cluttered user interface, almost impossible to master by anyone who is not a specialist. These contextual commands are dependent on the part you choose to click on, using the right button. For example, clicking on a component opens the following possibilities: move, orient, edit, copy, or delete the component, front/rear zoom, auto function, recalculate the drawing, select the scale. The menu is adapted depending on whether you clicked on a component, a wire, a text field, etc.

The mouse also makes it possible to display a zone that you will select by clicking with the wheel: without a doubt, efficient and practical!

The status bar, at the bottom of the window, gives you the following information: zoom factor, absolute and relative coordinate of the cursor and measurement units (inches or millimetres).

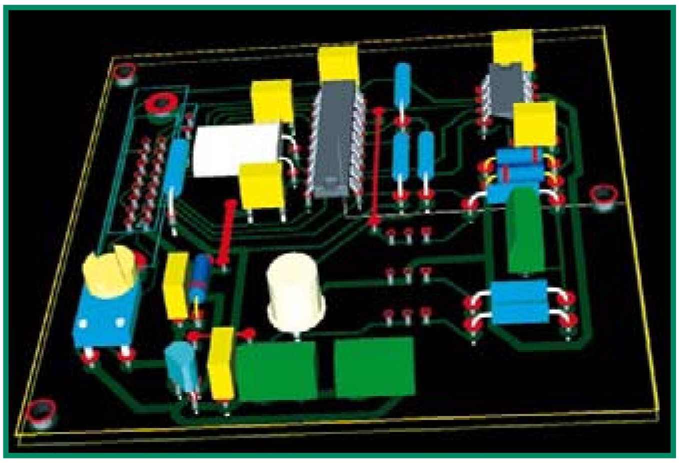


Figure 6. **3D display of the capacitance meter as described in** *Elektor*.

CVPCB

CVPCB, accessible from EeSchema or KiCad, makes it possible to link a case to each component from the net list that you will have created in EeSchema (**Figure 4**). There, also, in addition to the print libraries that come as standard (through-hole or SMC components), you can download many others on the Internet. If you use KiCad intensively, you can eventually use the automatic association system component case that makes it possible to automate this task.

PCBNew

You gain access to PCBNew from the KiCad project manager (recommended), or directly using the icon (**G**) (**Figure 5**). This printed circuit design software is made in the image of EESchema: simple, easy to get used to and easy to use; that does not mean its performance is lagging, here are some examples: 16 copper layers, 12 technical layers (lithography, resist coating, dimensioning, etc.) components, through-hole or SMC, work done to one/ten-thousandth of an inch, dynamic rats-nest, Design Rules Check, ground plane, and it has a very capable high-performance internal router that can operate in a single-sided layer! What more can an amateur ask for? And a 3D view of the board surface just for the visual pleasure. It is shown in **Figure 6**!

But let us begin by the beginning: PCBNew. The general philosophy of this graphic interface is the same as the one for EeSchema: simple, easy approach, but also as efficient, thanks to an intensified utilisation of the mouse and the contextual menus, and the defining of the two operating modes: placement (**H** left) and routing (**H** right). These two modes will affect the contextual menus that will be shown.

We will not insult you by reviewing file menus and preferences, except to remind you of the output formats: PostScript, HPGL, Gerber 274X, and Excellon, in addition to your favorite printer. The 'Dimensions' menu is used to define... the dimensions by default of the traces, vias, pads and texts. The 'Miscellaneous' section groups IC detailing accessories.

The post processors enable the automatic placement file generation of components and hole-making files. This gives you the possibility of having your IC made by a professional, by sending him the necessary files. The '3D' and 'Help' menus speak for themselves.

Under the different menu bars you will find scrolling lists that allow you to easily change the width of the trace, dimensions of the vias, grid pitch number of the layer and zoom.

The icons located on the left of the window are related mainly to what is represented on the screen: display of the polar coordinates in the status bar, measurement units, shape of the cursor, display of the rats-nest (representation by segments of the connections to be routed),

automatic erasing of traces that you have re-routed, display of pads and traces in full lines or in contours, in high-contrast display.
The upper icon toolbar, just like in EESchema, groups the file commands and the selection of the sheet format. The next icon allows you to access the module editor (or footprints) of the components in the unlikely case that the libraries supplied and those available on the Internet are insufficient. Its operation very much resembles the one of the LibEdit component editor, which means you should feel more comfortable with it.

We have no specific comment on the following print and tracing icons except that they resemble the ones in EESchema.
(**D**) is the starting point for designing a printed circuit: reading the netlist. Your components are found 'in bulk' next to your sheet. To spread out the components in order to be able to then gather them, go to placement mode (**I**). With one right click, do global move and place -> Move all of the modules: and all of your components will be carefully aligned. If you prefer, after having defined the contours of your printed circuit (select the PCB contour layer and define a closed figure that pleases you), then Global move and place → Autoplace all of the modules. It will do half of your work by optimising the length of the connections. Any intermediary state is conceivable with the interactive auto placement options.

It is already time to move from placement mode to routing mode with the icon (**J**). With one right click, do Global autorouting → Select layer coupling. It usual to choose a one-sided circuit board; in other words, the top layer will be in copper, just like the lower layer. The autorouting feature (global autorouting → Autoroute all modules), will greatly lessen the work, if it does not route your entire board. All that remains is to finish in manual mode, or to move a few components and re-route the overall project. Manual routing is accomplished, of course, with the mouse, and you will quickly notice that PCBNew knows how to place your traces in a well-disciplined fashion, without laboriously defining the smallest change in orientation. Displaying the rats' nest (**K**), (see **Figure 7**) enables quick and reliable work. If straps are required, they will be shown on the traces on the component layer (in red on Figure 6). Once the routing has been finished, you can add centring targets, dimensioning, and any other graphics such as a logo, copyright symbol, etc.

A wise precaution consists of carrying out a DRC check, in order to ensure that no routing error or short-circuit still exists. All that is left is for you to do is to print or plot, to start with on paper, in order to determine the factor of the precise scaling, setting it to the scale requested by your printer. You can then print a transparent to isolate your IC or to generate the files requested by your supplier. Of course, professionals may demand much more from KiCad; a certain number of companies are already using it around the world.

In conclusion

KiCad is a real windfall for the creative electronics fans among you. It thus becomes possible to create, exchange and modify schematics and printed circuit board designs at will. No more searching for a jack connector with unobtainable placement or 'butchering' a circuit in order to adapt it ever so slightly. With KiCad, you have total freedom, especially if, as we hope, electronic magazines publish more or less finalised versions of schematics and/or PCBs of proposed projects on the Internet, rather than a fixed PDF. That would signify that anyone and everyone can adapt, convert or even transform them at will (maybe with a simulator in the future?.. But hush! nothing has been done on that yet!). Better yet, be assured that in case of problems, help will be available to you rapidly on the user's forum (link [3]).

(060373-I)

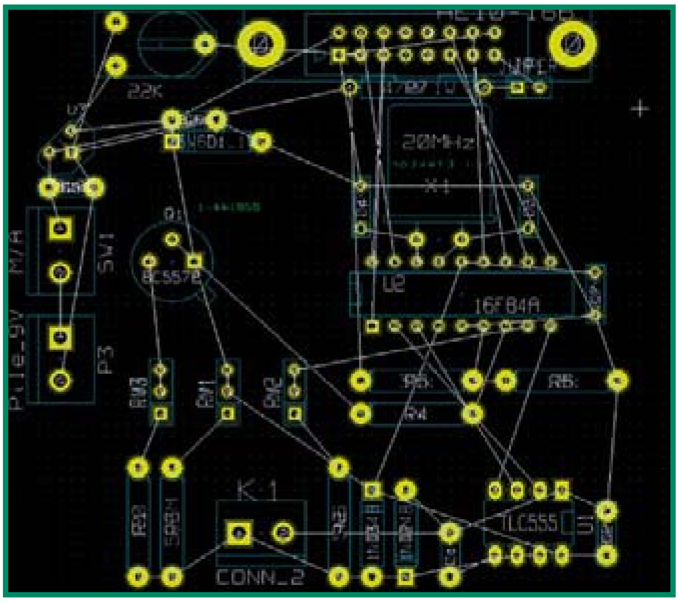


Figure 7. **The rats' nest in white lines.**

Internet links

(1) Kicad 1 homepage
www.lis.inpg.fr/realise_au_lis/kicad/index.htmlx

(2) Kicad 2 hmepage
iut-tice.ujf-grenoble.fr/kicad/index.html

(3) An active group!
http://groups.yahoo.com/group/kicad-users/

(4) Libraries, user guides
http://www.kicadlib.org/

(5) KiCADWiki
http://kicad.bokeoa.com/wiki/index.php/Main_Page

(6) Utilities
http://www.rohrbacher.net/kicad/quicklib.php

(7) Goodies from Brazil: footprints, utilities, etc.
http://www.reniemarquet.cjb.net/kicad.htm

(8) KiCAD, from the professional point of view
http://xtronics.com/reference/kicad.html

(9) Developers
http://developer.berlios.de/projects.kicad

(10) Kicad hosted in a free world
http://kicad.sourceforge.net/en/index.shtml

(11) Kicad, from the Russian point of view.
http://ru.wikipedia.org/wiki/Kicad

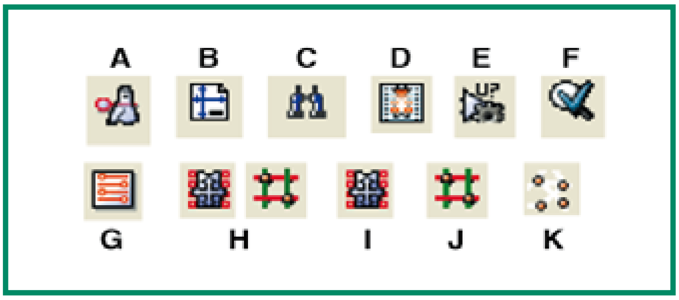


Figure 8. **The main icons on a large scale and in low resolution (the originals are a standard size, 16 x 16 pixels).**

Tracking Solar Panel

Manfred Schmidt-Labetzke

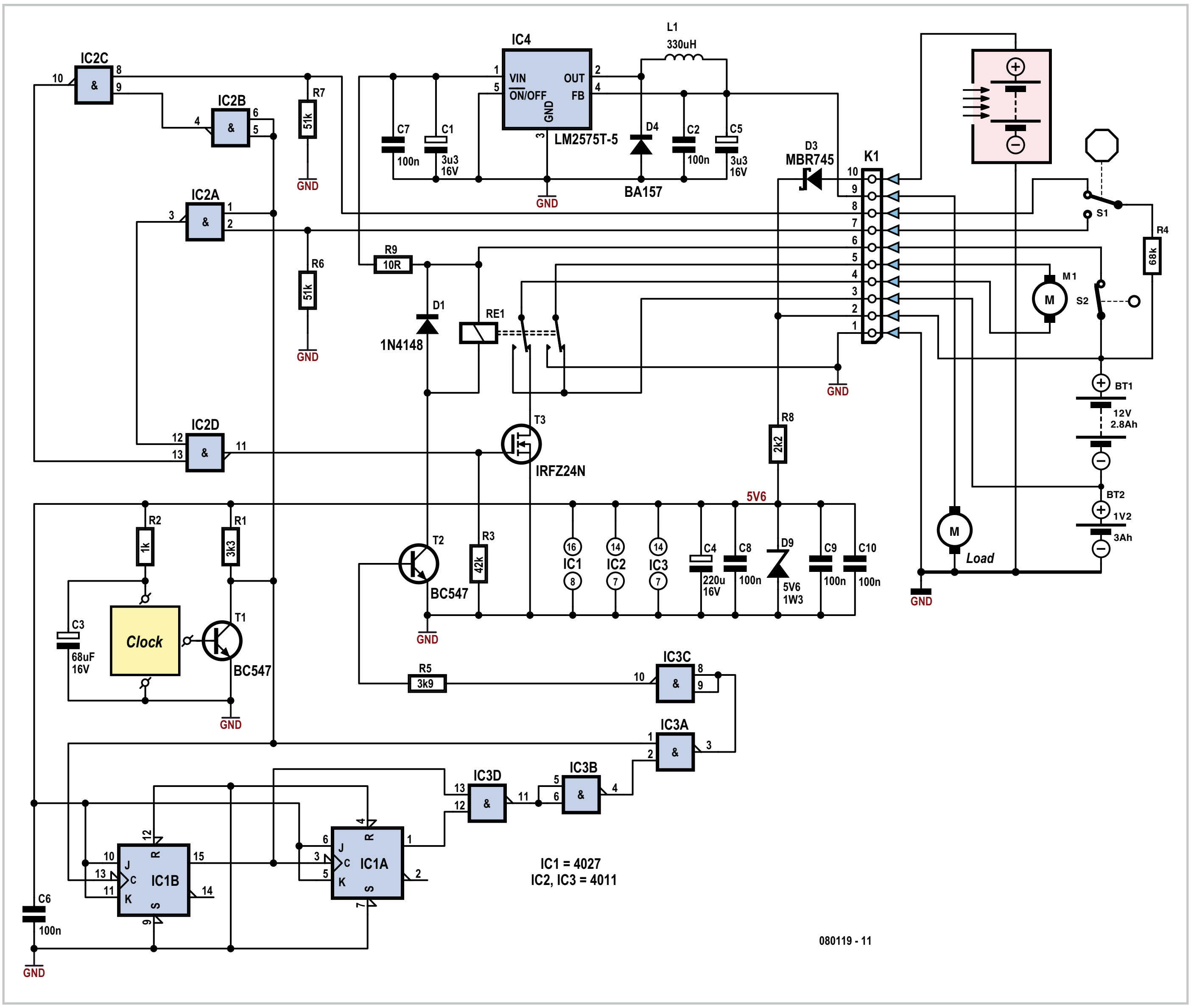
This small 12 V solar power source maintains its orientation towards the sun under control of a timer rather than the more usual light-sensitive arrangement. All the parts needed to build the project can be found in a well-stocked hardware shop or DIY store.

The axle is made from the core of a roller blind with two bearings. Suitable angle brackets are readily available to hold these bearings. The axis of rotation is set vertically, and the whole thing is directly driven by a battery-powered rotisserie motor. This motor already includes a gearbox to give a slow rotation and is capable of turning in either direction, and so one could hardly ask for a more perfect device for the job.

The upper end of the roller blind axle must be filed down to a suitable (generally square) cross section to allow it to be driven by the rotisserie motor.

Now to the electrical department to find a cheap electronic mains timeswitch. The switch must be programmable for at least four on-off cycles per day. For the solar panel itself any 12 V solar charger designed for car, camping or boat use is ideal. It should be at most 0.25 m² in area as otherwise the force of the wind may be too great for the gears in the rotisserie motor's gearbox to withstand. The angle of inclination of the module is fixed, and depends on the latitude at which it is installed.

The mains portion of the timeswitch and the switching relay are not required and are removed. The remainder of the timeswitch will act as a clock which causes the axle to be rotated eight times during the course of each day: each on-to-off or off-to-on transition of the clock will advance the axle by 22.5 degrees from east to west via south. The angle through which the roller



blind axle turns is defined by its octagonal shape: the corners operate a microswitch S1, which is fitted with an actuation lever. The position of the microswitch must be set carefully so that the switch is closed when the lever is pushed aside by a corner and open when between corners. Each time the timeswitch changes state IC2, a CMOS 4011 which contains four NAND gates, switches the drive motor on via p-channel MOSFET T3 for as long as necessary until the microswitch also changes state. Reasonable settings for the timeswitch have been found to be as follows: 7.30 am on; 9.00 am off; 10.30 am on; 12 noon off; 2.00 pm on; 4.00 pm off; 6.00 pm on; and 9.00 pm off.

After eight moves the solar panel has rotated through a total of 180 degrees and points directly west. Counter IC1, constructed from the two CMOS JK flip-flops in a 4027, detects the eighth clock pulse and turns on relay Re1 via IC3. This in turn reverses the polarity of the power to the motor and the panel starts to turn back from west to east. When it reaches its original position facing due east limit microswitch S2, actuated directly by the solar panel, opens. The connected load is also switched on and off by S2, which is open during the night and closed during the day.
The author uses his solar panel to operate a small water pump. For this purpose the output of the panel is regulated to 5 V using a highly efficient switching regulator. Alternatively, 12 V lighting could be powered from the panel, with no need for the regulator.

Of course, both the control electronics and the timeswitch need to be housed in a waterproof enclosure. Energy storage to cover for the inevitable cloudy days can be provided by a 12 V battery comprising ten 2800 mAh AA-size NiMH cells in a suitable battery holder, which can be fitted inside an ordinary electrical junction box. A 3000 mAh D cell is fitted in the battery compartment of the rotisserie motor, wired in series with the 12 V battery and also charged from the solar panel.

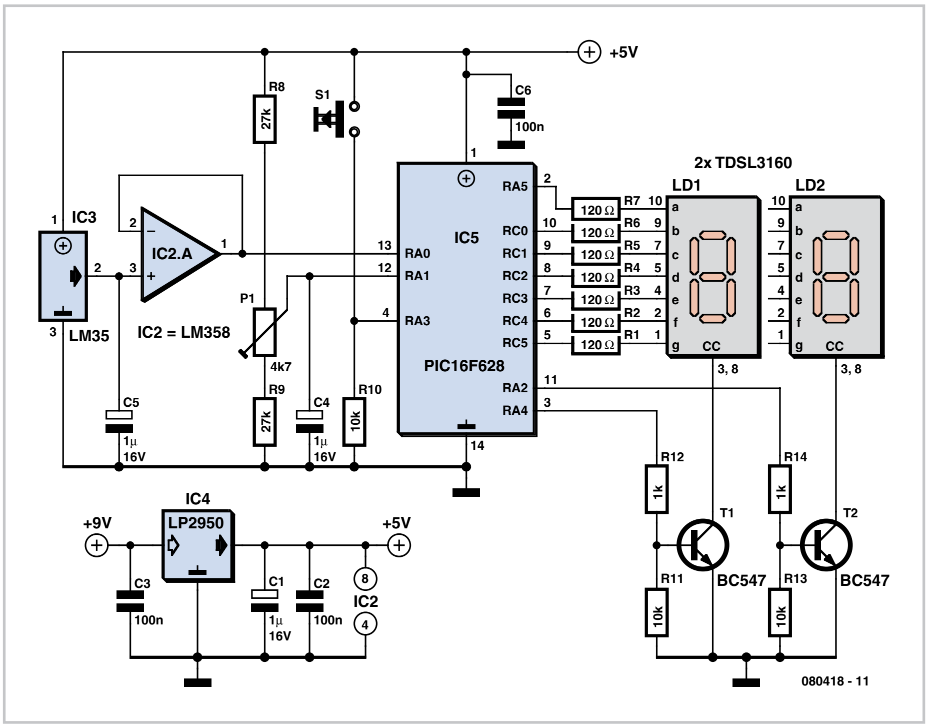
The motor and battery connections from the rotisserie motor are taken to the control circuit using a four-core cable. The rotisserie motor's switch is removed. Resistor and capacitor values shown in the circuit are not particularly critical, and other similar types can be substituted for T1, T2 and T3. A Schottky diode should be used for D3, which prevents current flow back into the solar panel, in order to minimise power losses. The 5 V regulator operates at around 250 kHz and so a high-speed switching diode is needed for D4. Using an ordinary 1N4007 considerably reduces the efficiency of the regulator and is therefore not a good idea. A small toroidal-core inductor is used for L1.

(080119-I)

Portable Thermometer

Joseph A. Zamnit

It's usually is a good idea to check the temperature before setting off for an outdoor activity. Equally important is a temperature check while at the actual place. The former is easy to do using the local TV or the Internet but once you are in the bush or the countryside such a task becomes more difficult. The small circuit described here solves the problem. It is very easy to use and consumes so little current that it will work for the battery's shelf life.
The circuit uses a standard LM35DZ sensor (IC3) whose analogue output voltage is buffered by an LM358 (IC2A). The voltage is read by the microcontroller and converted into a BCD value so it can appear on the multiplexed 7-segment displays. The display will switch off after approximately 30 s unless button S1 is pressed. In this way battery power is conserved. Pressing the button again will show the temperature. In the prototype two 0.56" (14.2 mm) common-cathode (CC) green displays were used to show the current value of the temperature. The meter can show temperatures between 0 and 100 °C.
The first time it is used the meter has to be calibrated against a known reading. Preset P1 can be varied to change the value of the



temperature by about 4 °C. Press the button and then turn the preset until the correct value of the temperature is shown.
The microcontroller used is a PIC16F684. This has been chosen because it has a number of inbuilt functions and most importantly an internal oscillator which obviates the need for an external crystal, freeing up pins for I/O activities.
Two 7-segment displays are connected in a multiplexed fashion. The displays are alternately switched on and off by the BC547

transistors. Each display is blanked before displaying the value to prevent ghosting. A temperature sample is read every 30 s to prevent the value displayed from changing due to fluctuations in the temperature. An LP2950 is used to regulate the supply voltage to 5 V. This is a low dropout regulator which can work down to 6 V hence juicing the battery for the last drop of energy. The thermometer may also be run from three AA dry batteries in series with no series regulator.

The PIC software can be downloaded free of charge from the Elektor website. The archive file number is 080418-11.zip. The software was developed using CCS C.

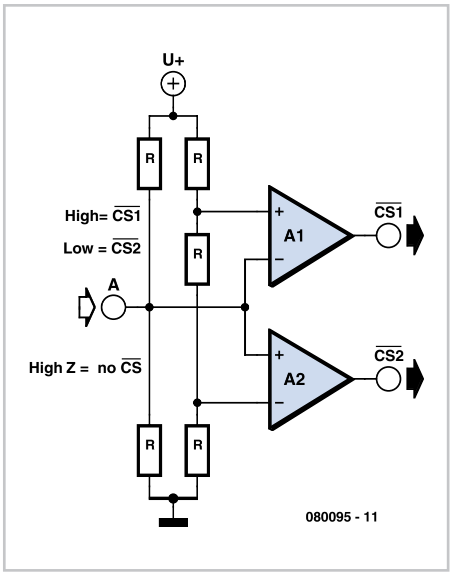
(080418-I)

Multitasking Pins

Roland Plisch

It's entirely logical that low-cost miniature microcontrollers have fewer 'legs' than their bigger brothers and sisters – sometimes too few. The author has given some consideration to how to economise on pins, making them do the work of several. It occurred that one could exploit the high-impedance feature of a tri-state output. In this way the signal produced by the high-impedance state could be used for example as a CS signal of two ICs or else as a RD/WR signal.

All we need are two op-amps or comparators sharing a single operating voltage of 5 V and outputs capable of reaching full Low and High levels in 5-V operation (preferably types with rail-to-rail outputs). Suitable examples to use are the LM393 or LM311. The resistances in the voltage dividers in this circuit are uniformly 10 kilohms.



Consequently input A lies at half the operating voltage (2.5 V), assuming nothing is connected to the input – or the microcontroller pin connected is at high impedance. The non-inverting input of IC1A lies at two-thirds and the inverting input of IC1B at one third of the operating voltage, so that in both cases the outputs are set at High state. If the microcontroller pin at input A becomes Low, the output of IC1B becomes Low and that of IC1A goes High. If A is High, everything is reversed.

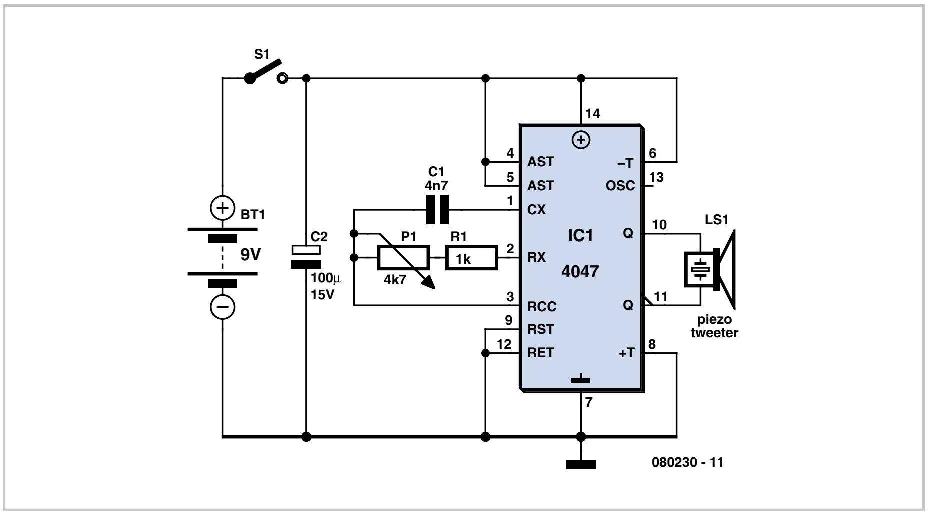
(080095-I)

Environmentally-friendly Mosquito Repeller

B. Broussas

With the return of the fine weather, you'll doubtless be enjoying lazing around of an evening on your patio or in your garden, but even if you're not surrounded by marshes or other shallow water it's very likely some intruding mosquitoes will come along to spoil this idyllic scene.

Although indoors it's easy to get rid of them these days, indeed even to prevent them coming into the house, the same can't be said for the great outdoors. We might mention the well-known Chinese coils – the only thing Chinese about them is undoubtedly their name – which very often drive people away as much as mosquitoes, if not more! Moreover they are nasty things to handle. There are also UV (ultra-violet) 'electrocutors' consisting of a blue lamp surrounded by two closely-spaced grilles between which a high voltage is applied. The mosquitoes (and flies and other flying insects) are supposedly attracted by the colour of the lamp and as they approach, get electrocuted in contact with the two grilles.



The only thing you have to do is pull out the drawer from time to time and get rid of the mass of dead insects.

Even though the effectiveness of these first two products remains questionable, it is less so than the one we're nonetheless going to describe here. We're talking about an ultrasonic mosquito repellent.

The principle, as described by its numerous promoters, is as follows. Only the female mosquitoes bite (that at least is an undisputed scientific fact) and they bite when they need to feed, and above all, to feed their eggs. In this situation, they seek to avoid the males whose 'job' has already been done, and so they fly away from the frequencies emitted by the males when they are on heat. This is where opinions now diverge. According to certain publications, the frequency emitted by the male mosquitoes is said to be around 20–25 kHz, and so within the realm of ultrasound. But according to others, it is in the region of 5–7 kHz instead; frequencies that a human ear, even an elderly one, can still hear very well.

Rather than spending lots of money (of the order of tens of pounds) buying such a device, which moreover generally have a fixed frequency, we're suggesting building one yourself so that you can carry out your own research this summer, especially since the circuit proposed is very simple and cheap to build.

As the figure shows, it uses just a single IC, a CMOS type 4047. This very multi-purpose IC can be wired in very many operating modes, including that of the multivibrator or astable used here. The operating frequency is set by the external components C1, R1, and P1; the latter makes it possible to slightly adjust the frequency, given the uncertainty that exists over the most effective value…

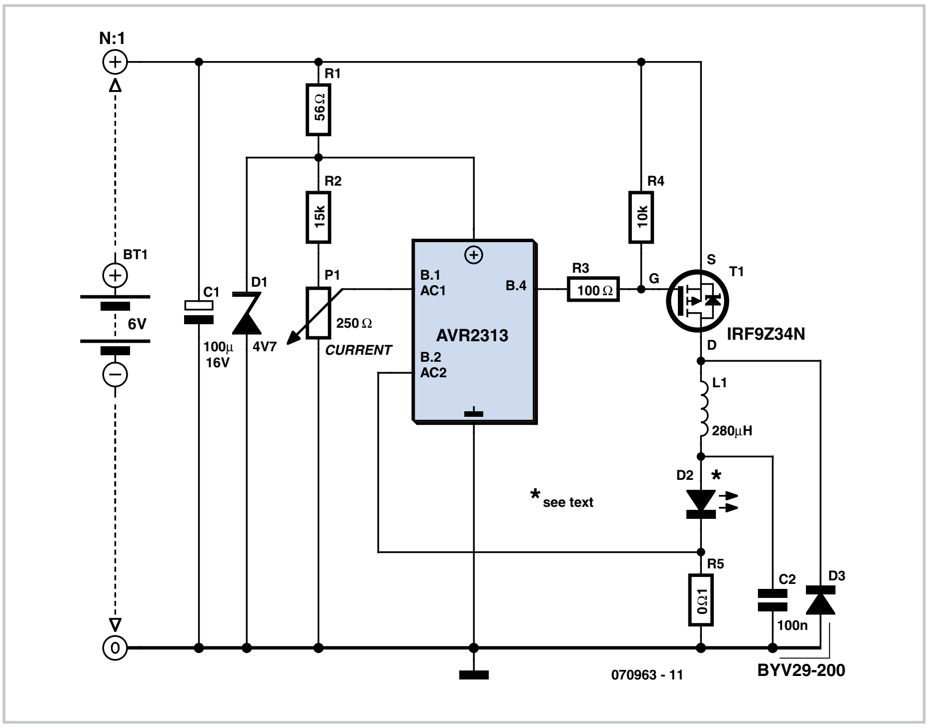
To best reproduce the high frequencies produced by the generator, the output transducer used is a simple tweeter, but it must be a piezo one. Such a tweeter behaves in fact much like a capacitor, and so doesn't overload the CMOS IC outputs that are incapable of supplying a substantial current, as everyone knows who's ever worked with 400 series CMOS logic.

To obtain an output signal of sufficient amplitude while being powered from a single 9 V battery, this tweeter is connected between the 4047's Q and $\overline{Q}$ outputs, making it possible to apply complementary (antiphase) signals to the tweeter so it 'sees' an alternating voltage of double the supply voltage. In purely theoretical terms, this quadruples the output power available. In practice, it's better to regard it as tripling it, but the benefit achieved by doing it this way is nonetheless very real.

All that remains is for you to place the project in the middle of the patio table or beside your lounger in order to get a taste of the calm of a summer's evening without mosquitoes bothering you acoustically or worse, biting. At any rate, that's what we wish for you…

(080230-I)

Dimmable LED Light



Listing

```
'SMPSU for Luxeon LED using PMOS
$regfile = "2313def.dat"
$crystal = 4000000

config pind.0 = output
DDRB = &B00010000        'B.4 =
   Output
ACSR = &B00000000        'Set up
   as a comparator
dim i as byte
Portb.4 = 1     'off

do
Portb.4 = 0     'Switch on
   inductance
do
loop until acsr.aco = 1
   ,When Imax reached -> Switch
   off
Portb.4 = 1
waitus 5
loop
```

Jean-Claude Feltes

As we all know, LEDs are dimmed by altering the current flowing through them, not the voltage. We achieve this effect in this circuit by using an AVR microcontroller (the 2313 from Atmel) operating in comparator mode (**Figure 1**).

The nominal value is preset on comparator input AC1 and compared with the voltage (proportional to the LED current) at AC2.

On power-up the microcontroller sets the gate of the MOSFET (connected to output B.4) to 0 so that it conducts; a linearly rising current then flows through the choke and LED. The voltage drop across the 0.1-Ω shunt resistor is proportional to this current. Once the nominal voltage is reached, the microcontroller switches off the MOSFET and waits a few milliseconds. During this time a linearly decaying current flows through the choke, LED, shunt and recovery diode. Then everything restarts and it happens all over again. The result is a direct current voltage with a triangular waveform overlaid. The Bascom program for the microcontroller (see Listing) is short and simple to understand. Source code and hexfile for the program can be downloaded free of charge at www.elektor.com.

In this circuit we use a 6-V lead-acid gel-cell battery for the power supply; although these are heavy, they are dependable and simple to charge. The 56-Ω resistor and zener diode act to limit and stabilise the microcontroller supply voltage, which is used also as a reference voltage for the voltage divider set with P1.

The LED chosen is a Luxeon LXHL-LW3C (nominal values: 3 watts, U_{LED} = 3.7 V, I_{LED} = 0.7 A). A 100-nF capacitor connected in parallel with the LED and shunt is wired direct to the PCB; this is to eliminate possible interference effects from cable capacity. The 100-µF electrolytic capacitor is vital to smooth the 6 V operating voltage, which would otherwise 'droop' or 'sag'. The choke should not saturate at maximum current but match the load of the current being carried. To avoid generating square-wave effects that could produce false current values, the shunt resistor used should be a carbon film type, not wirewound.

The lamp, used for speleology (cave exploration), has operated very reliably over a lengthy period and is more economical in battery use than a halogen lamp. One problem arose in use when the LED got (far) too hot. It appeared that the current cut-off value was not being observed, due possibly to microcontroller failure or a dirty (or faulty) trimpot. If the latter's wiper loses contact with the carbon track the comparator input becomes open-circuit and can become any old value (as then does the LED current). Installing a watchdog timer could help (to restart the microcontroller promptly), also a pulldown resistor from the comparator input to ground.

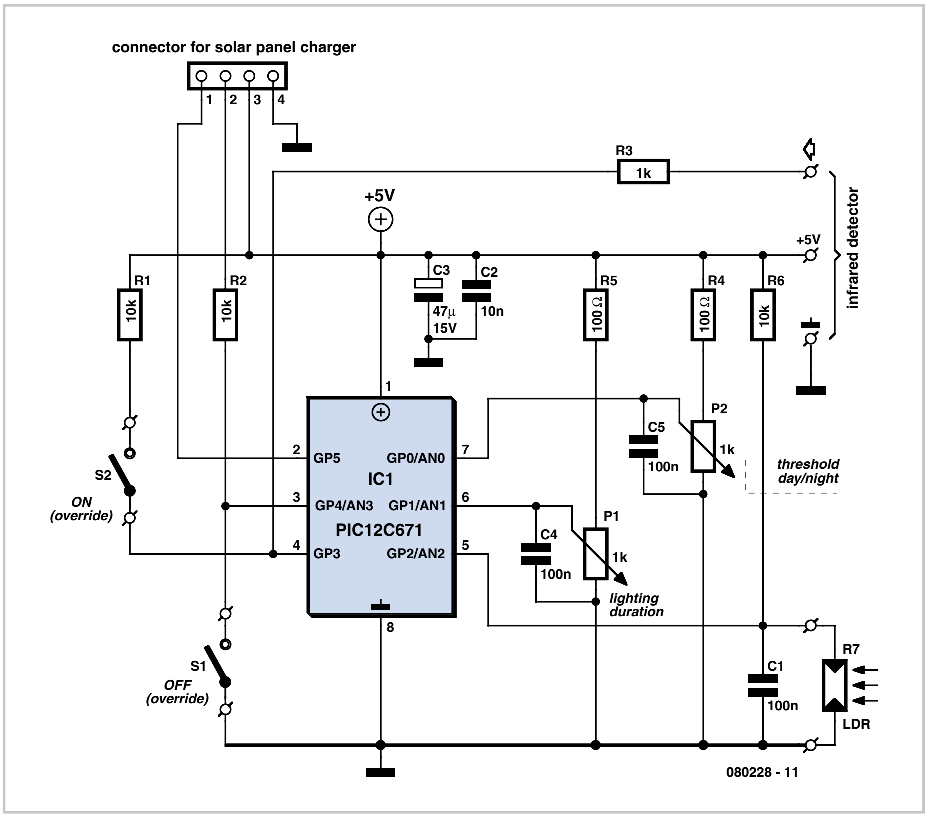
(070963-I)

Solar-powered Automatic Lighting

C. Tavernier

You're doubtless familiar with the little solar-powered automatic lighting units found in DIY stores each year as summer approaches, sold in packs at ridiculously cheap prices. They certainly work, but their electronics and most of all their housings, manufactured for extreme cheapness, have a life expectancy that's proportional to the purchase price…

Our project here adopts a slightly different approach. It's intended for use in conjunction with existing or still-to-be-built garden lighting systems, which in particular may be more powerful than the cheapo stuff mentioned above. The project described here cannot operate alone, but must be used in conjunction with the 'Solar-powered Battery Charger' project described elsewhere in this issue. This charger has a connector already provided to interface directly with the garden lighting systems described here.



So the charger handles the 'intelligent' charging of the battery by the solar panels, while the circuit shown here takes care of the control of the lighting part. Naturally, it includes a photocell, in the form of an LDR (light dependent resistor), to measure the ambient light and, to avoid wasting the precious energy stored in the batteries, a presence detector so as to only light up when there is a need. Furthermore, the detector has a time delay, which makes the lighting unit very convenient in practice.

Given that it has to be used in conjunction with the solar-powered battery charger, the circuit is obviously very simple, as you can see from the schematic diagram. It uses just a single IC, a Microchip type 12C671 PIC microcontroller – i.e. the same type used in the charger, to make your buying easier.

Let's remember that this IC includes an analogue-digital convertor with several inputs, which is obviously going to be put to good use here. It's powered from the stabilized 5 V supplied by the charger, via pins 3 and 4 of the connector provided for this purpose. Take a look for a moment at the charger circuit and note that, when it is used in conjunction with the automatic lighting system, the jumper between pins 1 and 2 of its connector has to be removed. This allows relay Re2 in the charger to be driven by our automatic lighting system, instead of directly by the charger itself. So, the load fed by the automatic charger here comprises the lamps or other lighting devices to be controlled. However, the excessive battery discharge protection is retained, as this information, from output GP4 of the charger's 12C671, is fed to input GP4 of IC1 via pin 2 of the connector.

This same input also receives override (optional) switch S1, which makes it possible to force the lighting off. Input GP3 also receives a switch making it possible to force the lighting on all the time, for example, when you want to admire or show off your garden at night, by overriding the presence detector circuit.

The latter employs a ready-to-use off-the shelf module, since these days it's no longer worthwhile nor sensible to build such a unit from scratch. It's powered at 5 V and provides a logic high output when a presence is detected, which is connected to input GP3. Watch out! Different modules of this type currently on the market exist with various supply voltages and generating high or low levels during detection. One module suitable for this application is available for example under reference PI8377 from Lextronic (www.lextronic.fr) where the author got it from. Some judicious online shopping may be in order to find a local equivalent

The ambient light level is measured using an LDR connected to analogue input AN2, while adjustable potentiometers are connected to both inputs AN1 and AN0. Preset P2 allows adjustment of the day/night threshold according to the characteristics and positioning of the LDR used, while P1 allows adjustment of the duration of the lighting following presence detection, from a few seconds to around ten minutes or so.
The program for the 12C671 PIC is of course available for free download from the Elektor website or from the author's own website: www.tavernier-c.com. The project works immediately and only requires correct setting of P1 and P2 as indicated above.

Finally, it should be noted that that before it can be used with the automatic charger described elsewhere in this Summer Circuits issue, the charger must first be adjusted on its own, as described in the relevant article. In other words, do not connect up the two projects as you will be struggling with an equation with at least two variables that may interact in unexpected ways.

(www.tavernier-c.com) (080228-I)

Web Links and Literature

PI8377 data sheet: www.lextronic.notebleue.com/~lextronic_doc/pi8377.pdf

Application notes for Cubloc™ modules (in French only): www.lextronic.fr/~lextronic_doc/Applications_B.pdf

Downloads

The source code and .hex files for this project are available from www.elektor.com; file # 080228-1.zip.

Fog Lamp Sensor

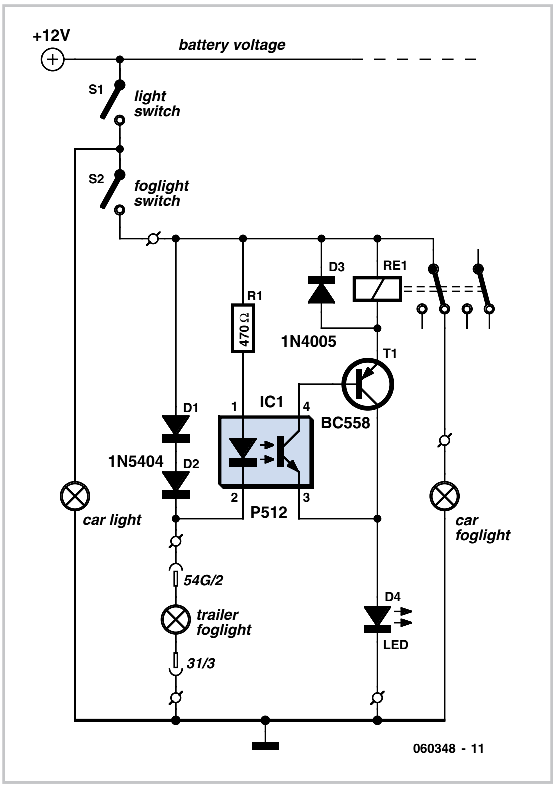
Harrie Dogge

For several years now, a rear fog lamp has been mandatory for trailers and caravans in order to improve visibility under foggy conditions.

When this fog lamp is switched on, the fog lamp of the pulling vehicle must be switched off to avoid irritating reflections. For this purpose, a mechanical switch is now built into the 13-way female connector in order to switch off the fog lamp of the pulling vehicle and switch on the fog lamp of the trailer or caravan.

For anyone who uses a 7-way connector, this switching can also be implemented electronically with the aid of the circuit illustrated here.

Here a type P521 optocoupler detects whether the fog lamp of the caravan or trailer is connected. If the fog lamp is switched on in the car, a current flows through the caravan fog lamp via diodes D1 and D2. This causes the LED in the optocoupler to light up, with the result that the phototransistor conducts and energises the relay via transistor T1. The relay switches off the fog lamp of the car.



For anyone who's not all thumbs, this small circuit can easily be built on a small piece of perforated circuit board and then fitted somewhere close to the rear lamp fitting of the pulling vehicle.

(060384-1)

Battery Discharge Meter

Christian Wendt

Men like their hobbies. The author is a particular fan of fishing, and like many anglers is the proud owner of not only a fishing rod, but also a boat: and this is where the electronics comes in. The author's boat has an electric outboard motor, and with his mind wrapped up in his sport it can easily happen that the battery is allowed to run down, leaving the not very enticing prospect of a long paddle home. Simple approaches, such as computing the optimal point to stop and turn round, are not really satisfactory, as angling involves the boat making a relatively large number of short hops. The author therefore decided to go back to first principles and find an electronic solution.

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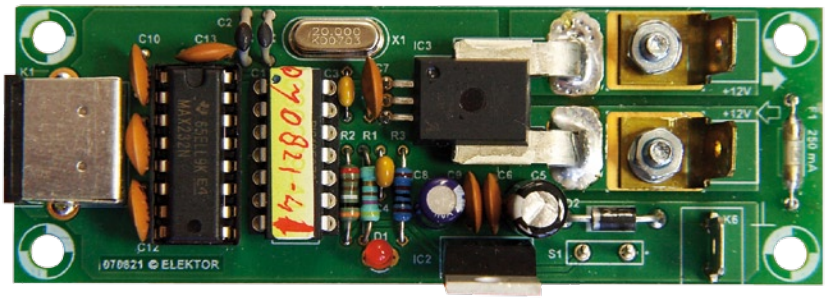

Energy measurement

In order to estimate and show the energy stored in the battery we need an LCD panel, a microcontroller and suitable sensors. In theory we need to measure time (easy enough) and voltage (also easy) as well as current. Energy dissipated in measurement should be minimised (trickier). The product of the three measured values gives electrical energy.

Time measurement is straightforward on a microcontroller. Modern devices have an integrated analogue-to-digital converter which is accurate enough for measuring the battery voltage. It is harder to measure current as the current drawn by the outboard motor is large and it is difficult to avoid dissipating a few percent of the

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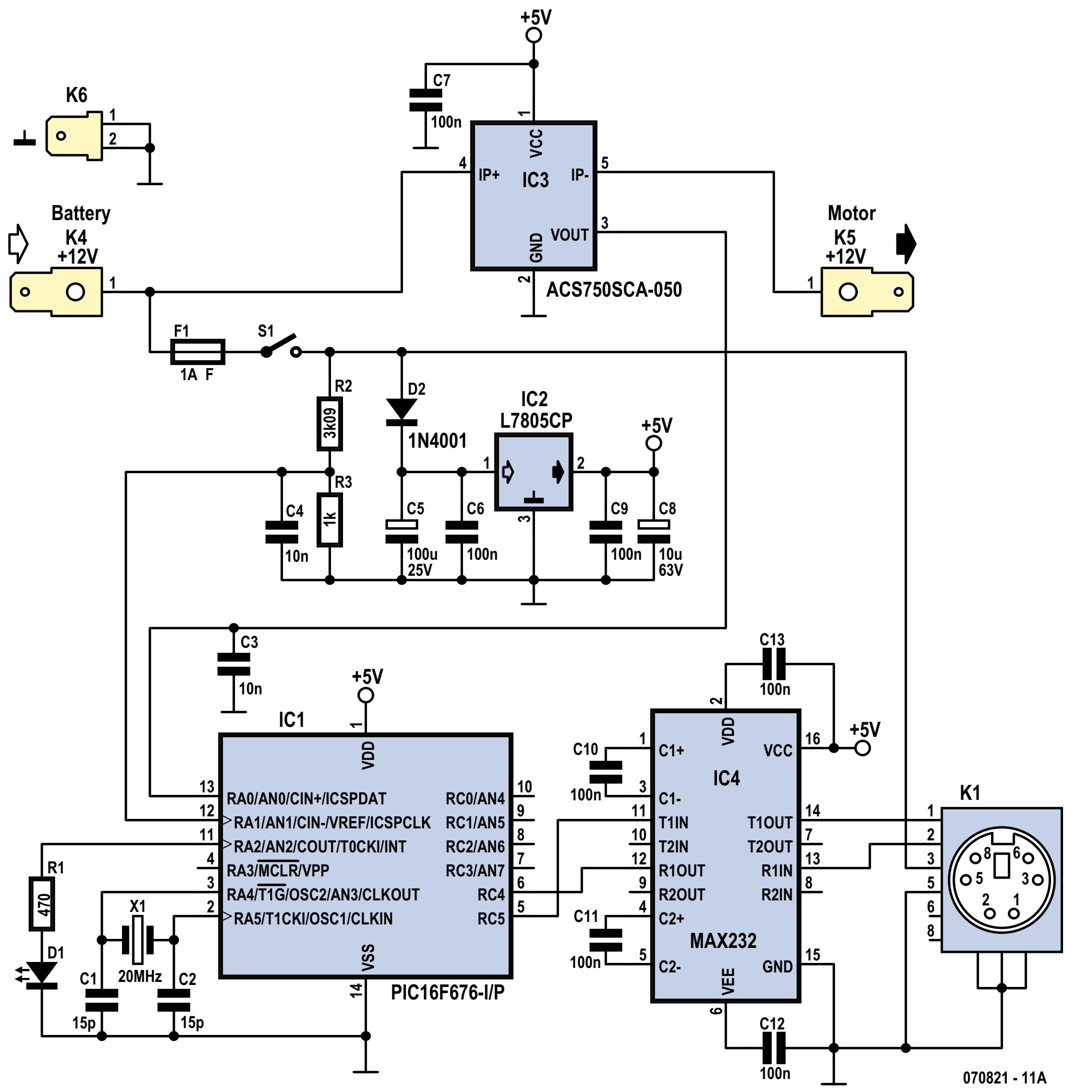


power delivered by the battery in heating up the shunt resistor.

Fortunately there are current sensors available for just this kind of application. The ACS750 [1] is essentially a thick piece of wire with accompanying Hall-effect sensor and conditioning circuitry. The series resistance is 130 μΩ and so the voltage dropped across the sensor is very small. The IC requires a 5 V supply and in the quiescent state (no current flow) has an output voltage of 2.5 V. When a current flows this voltage will rise or fall, depending on the direction of flow. The version used here, the ACS750SCA-050, is linear from –50 A to +50 A with a transfer characteristic of 1 V per 25 A, ideal for feeding into the analogue-to-digital converter in the microcontroller.

In this application voltage measurement is not so critical. The voltage should be monitored in case a fault (such as a bad connection) causes it to drop rapidly. Typically, however, the voltage remains fairly constant and it is adequate to display the charge used in amp-hours (Ah), the unit normally used to express battery capacity.

The capacity of the battery is best determined experimentally: charge the battery, do a few laps of a lake until the battery is completely flat, and let the circuit tell you the capacity in Ah. Make a note of this value. It would be possible to extend the meter to allow the battery capacity to be entered, in order to provide a 'petrol gauge' display calibrated in percent.

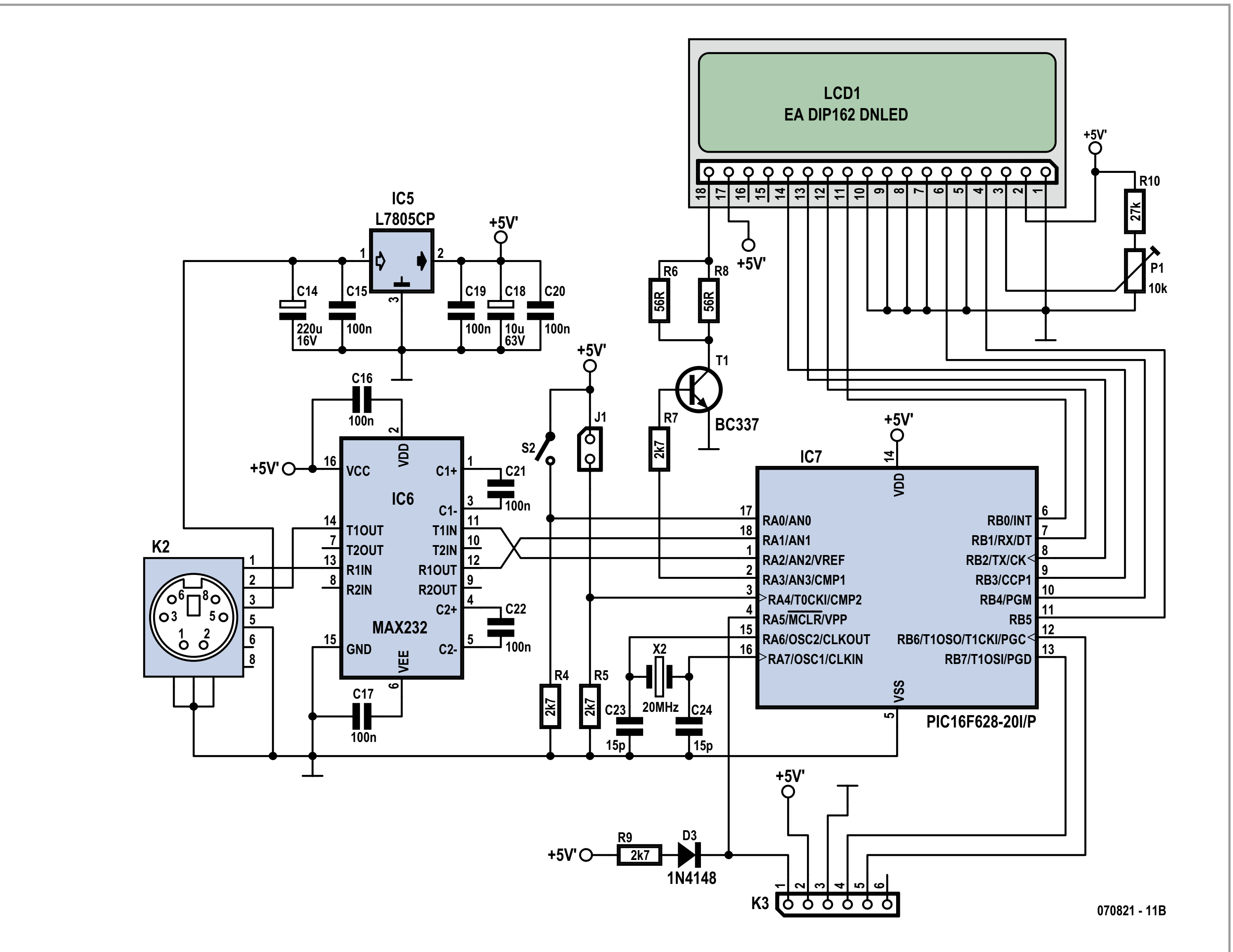
The circuit's 'user interface' consists of a single button which is used (among other things) to reset the Ah counter. If the button is held down when the meter is turned on the counter will be reset to zero; if the button is not held down when the meter is turned on, it will start from the most recent stored value.

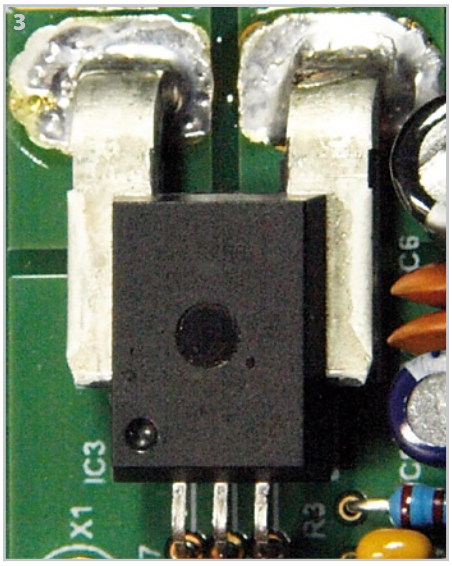
Circuit(s)

In the interests of reliable operation the circuit of the battery meter is divided into two parts. The normal arrangement is that the battery and motor are at the stern of the boat, while the captain is looking forward. A couple of meters of cable are therefore required between the two parts. Data transfer between the two parts of the circuit must be resilient to noise (even that generated by electric eels!).

The author decided to use a microcontroller both in the measurement part of the circuit and in the display part, with an RS-232 serial link between the two. Conversion to standard voltage levels is done using a MAX232 at each end, as shown in the combined circuit diagram (**Figure 1**).

On the sensor side of the system a PIC16F676 is used. It has analogue inputs with a resolution of 10 bits, which, taking into account the effect of the voltage divider formed by R2 and R3, gives a resolution of 20 mV for the battery voltage measurement. LED D1 is an under-voltage alarm, lighting when the battery voltage falls below 10.6 V. RA0 of IC1 is connected directly to the output of current





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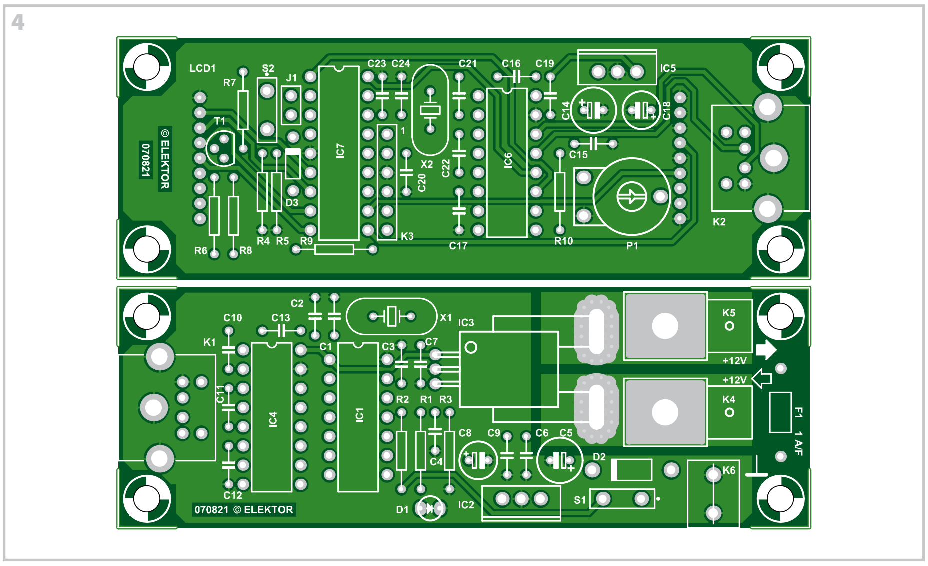

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sensor IC2, giving a current resolution of approximately 125 mA. The measurement results then flow out of the serial port and via the MAX232 over the RS-232 link to the display.

A PIC16F628 drives the display, polls pushbutton S2 and jumper J1, and receives serial data from the measurement unit. Contrast is adjusted using P1, and T1 switches the backlight on and off. With the suggested values for R6 and R8 the backlight current in the prototype was 38 mA. If more brightness is required, lower resistor values can be used as long as the maximum rating for the display (150 mA) is not exceeded.

Each part of the circuit has its own regulated 5 V supply to improve overall reliability. The current consumption of the sensor part is approximately 20 mA, and the display part draws approximately 17 mA with the backlight off.

Circuit board

A printed circuit board has been designed for each half of the circuit, making two small modules that can be connected together using a cable. The only unusual component on the sensor module (**Figure 3**) is the current sensor. The copper tracks that run to it are wide and the tags are fixed to the board with assistance from plenty of solder tinning. Other slightly unusual sights are the miniature fuse with solder connections to the right and the six-pin PCB-mount mini-DIN socket to the left. This socket allows ready-made six-way cables to be used, and the miniature plugs also are conveniently able to pass through small holes. Cables with four-way plugs will of course not fit in six-way sockets.

If you wish to use a different sort of connector, then you should of course dispense with the mini-DIN sockets. The important thing is to ensure that the 12 V supply is provided on the cable along with ground and the RxD and TxD signals.

The LCD panel is fitted directly to the solder side of the display module circuit board (see **Figure 4**). It is therefore best to leave soldering the display until last.

Pin 1 of the display is marked 'LCD1' on the component side of the circuit board. As long as care is taken to observe this, nothing should go wrong with mounting the display.

It is well worth fitting the two microcontrollers in sockets in case you should want to alter the program at a later date. The display board is equipped with a six-way connector K3 to allow in-circuit programming of the microcontroller.

The software for each processor is as always available as source code (for Microchip's MPLAB) and as object code for free download from the Elektor website [2].

Operation

When the unit is switched on using S1 the

COMPONENTS LIST

Sensor module

Resistors
R1 = 470Ω
R2 = 3kΩ09
R43 = 1kΩ

Capacitors
C1,C2 = 15pF ceramic, lead pitch 5mm
C3,C4 = 10nF ceramic, lead pitch 5mm
C5 = 100µF 25V radial, diameter 6.3mm
C6,C7, C10-C13 = 100nF ceramic, lead pitch 5mm
C8 = 10µF 25V, radial, lead pitch 2.5mm
C9 = 100nF ceramic, lead pitch 5mm

Semiconductors
D1 = LED, red
D2 = 1N4001
IC1 = PIC16F676-20I/P, programmed, Elektor SHOP # 070821-41
IC2 = 7805
IC3 = ACS750SCA-050
IC4 = MAX232 (DIP16)

Miscellaneous
K1 = 6-way mini-DIN socket, PCB mount
K4,K5,K6 = spade terminal
2 M3 screws and nuts
F1 = miniature fuse, 1A, fast, for solder mounting
S1 = on/off switch
Mini DIN cable with moulded 6-way plugs for connection of module
X1 = 20MHz quartz crystal, parallel resonance
PCB, ref. 070821-1, from www.thepcbshop.com

Display module

Resistors
R4,R5,R7,R9 = 2kΩ7
R6,R8 = 56Ω
R10 = 27kΩ
P1 = 10kΩ preset

Capacitors
C14 = 220µF 16V radial, lead pitch 2.5mm, diameter 6.3mm
C15,C16,C17,C19-C22 = 100nF ceramic, lead pitch 5mm
C18 = 10µF 25V radial, lead pitch 2.5mm
C23,C24 = 15pF ceramic, lead pitch 5mm

Semiconductors
D3 = 1N4148
T1 = BC337
IC5 = 7805
IC6 = MAX232 (DIP16)
IC7 = PIC16F628-20/P, programmed, Elektor SHOP # 070821-42

Miscellaneous
J1 = 2-way pinheader and jumper
S2 = pushbutton
K2 = 6-way mini-DIN socket, PCB mount
K3 = 6-way pinheader, lead pitch 2.54mm
LCD1 = LCD, 2x16 characters, e.g. EA DIP162 DNLED
X2 = 20MHz quartz crystal, parallel resonance
PCB, ref. 070821-2, from www.thepcbshop.com

display will briefly show:

Accu Control
WEN May 07

and then subsequently:

for reset press
switch... 7

whereupon a seven-second countdown will start.
The current state of the battery will then be displayed: its terminal voltage, instantaneous current, and the remaining battery charge.

If jumper J1 is fitted the zero point of the current sensor can be calibrated by up to ±10 units in the least significant digit.
Every ten seconds the remaining charge value is stored in the EEPROM of the display microcontroller. The display backlight is only enabled while the motor is running or by a brief press of the button. In his prototype the author used a waterproof 'vandal resistant' pushbutton.

Something fishy

No angler is properly equipped to go about his hobby without special glasses that include a polarisation filter to reduce the effect of light reflections from the water. As a result it is possible that the display can appear to be unstable and flickery: sometime legible, sometimes not. When he first saw this effect the author suspected a fault in the electronics or software and it was some time before he realised that the operation of LCDs depends on polarised light, and that the problem was right under (or rather over) his nose.

(070821-I)

Web Links

[1] http://www.allegromicro.com/en/Products/Part_Numbers/0750/

[2] http://www.elektor.com

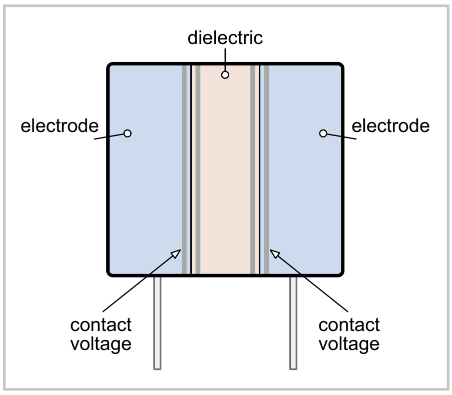
Mysterious Self Charging

Peter Lay

Here we take a light-hearted, exploring yet purposely unscientific look at one of the fundamental effects of physics, namely contact voltage. When two dissimilar materials come into contact an exchange of (negatively charged) electrons occurs so that the donor material losing electrons takes on a net positive charge while the material receiving electrons takes on a negative charge, the overall effect giving rise to a contact potential. This effect occurs to a greater of lesser extent in all materials, the most common examples are the production of static electricity produced by rubbing two different materials together and also the thermo-voltaic effect. So much for the theory, now to practice...

To take what at first sight may seem like a mistaken example of this phenomenon we will need a discharged capacitor and a DVM (digital voltmeter) with a high input impedance. Connect the capacitor terminals to the DVM and short together the capacitor terminals using a length of wire and two crocodile clips. If all is in order the DVM display will read 0 (zero) volts. Now remove the short circuit and closely watch the DVM display as the voltage, microvolt by microvolt slowly rises. The capacitor is gaining charge from somewhere…

This effect is the result of the contact voltage (see diagram). In the capacitor there are two boundaries: (1) the metal electrode and the dielectric and (2) the dielectric and second electrode. At both boundaries free



electrons pass from one material to the other. The two contact voltage sources are connected back to back in series which should cancel out the contact potential. So much for theory, in practice the boundary structure is not entirely homogeneous so that tiny potential differences are present. This produces the small potential difference that we can measure at the terminals.

Aluminium electrolytic capacitors are a little more complex; one terminal is connected to aluminium foil which has an insulating oxide layer; next comes a layer of liquid electrolyte and finally another aluminium foil connected to the other terminal. This structure gives rise to three potential boundaries. In addition, when the capacitor is charged, free electrons from the terminal electrode store energy by producing electrochemical reactions within the electrolyte (a process known as dielectric absorption or 'soakage'). These effects are more pronounced in electrolytics compared to other types of capacitor.

Experimental results indicate that the measured voltage is higher with larger value capacitors. It has also been shown that the voltage exhibits a temperature coefficient; the higher the temperature, the greater the measured voltage.

To explore this characteristic further, a capacitor was carefully heated in a controlled manner. It is important not to use a naked flame or microwave oven; not just to prevent the possible melting or combustion of the external plastic casing, but more importantly to guard against the possible production and release of poisonous fumes. Once an electrolytic capacitor has been heated up in this way it will be irreversibly damaged so that it will no longer be suitable for use in a circuit. Having said that, sometimes it's necessary to sacrifice a few capacitors for the sake of experimentation.

Measurement with a DVM (R_i = 1 MΩ) of a radially leaded electrolytic capacitor with a rated capacitance of 100 µF gave a terminal voltage of 5 mV at 20 °C. At a temperature of 120 °C the potential had risen to 230 mV and the short circuit current was 0.5 µA.
More precise measurements of the capacitor indicated that the voltage source had a source impedance of 852 kΩ and a source voltage of 426 mV. As a first approximation we can say that the correspondence between the terminal voltage and temperature is approximately linear. Using the measurements from the example above we therefore get a temperature coefficient of 2.25 mV/K.

Tests with other capacitors have produced a no-load terminal voltage of over 0.9 V. Several capacitors could be connected in series, not as a potential power source but as a sensor.

Two final notes:
1. The term 'no-load voltage' ignores the 1 MΩ input impedance of the voltmeter, which in series with the 852 kΩ source impedance loads the measured potential.

2. All of the measurements were made using discharged capacitors with no external voltage source.

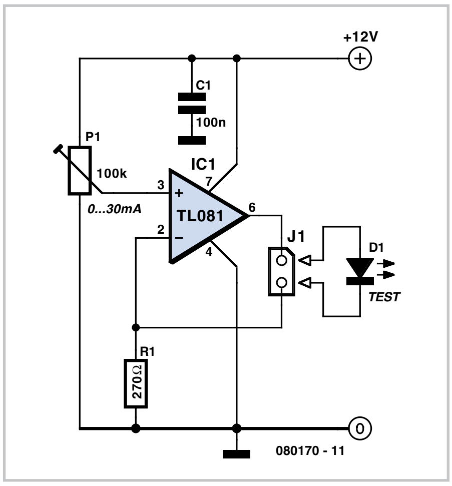
(071153-I)

LED Tester

Henry Schouwstra

This simple LED tester consists of a current source with a potentiometer that can be used to adjust the current. The current source is implemented using a type TL081 opamp.

The output current of the opamp flows through the diode and R2. The voltage drop across R2 is fed back to the inverting input and compared with the reference voltage, which is set with R1 and applied to the non-inverting input. The adjustment range is approximately 0–30 mA, which is suitable for testing all normal LEDs. If you wish, you can connect a multimeter across the LED to measure the voltage on the LED.



For the power source, a good option is to use a small laboratory power supply with the output voltage set to 5 V.

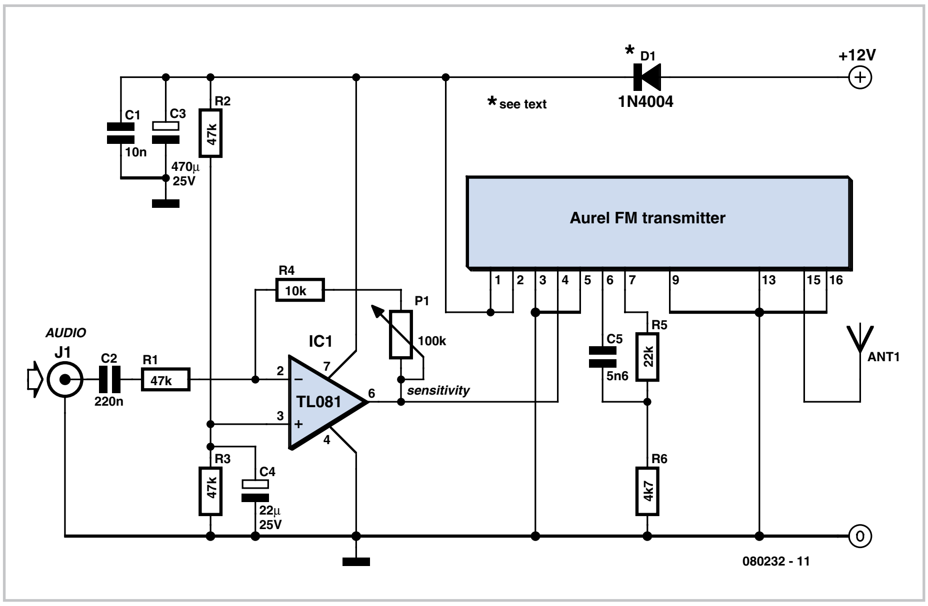
It is convenient to fit the potentiometer with a scale so you can see directly how much current is flowing through the LED. In order to calibrate the scale, you can temporarily connect an ammeter in place of the LED.

(080170-1)

Wireless Audio Transmitter

C. Tavernier

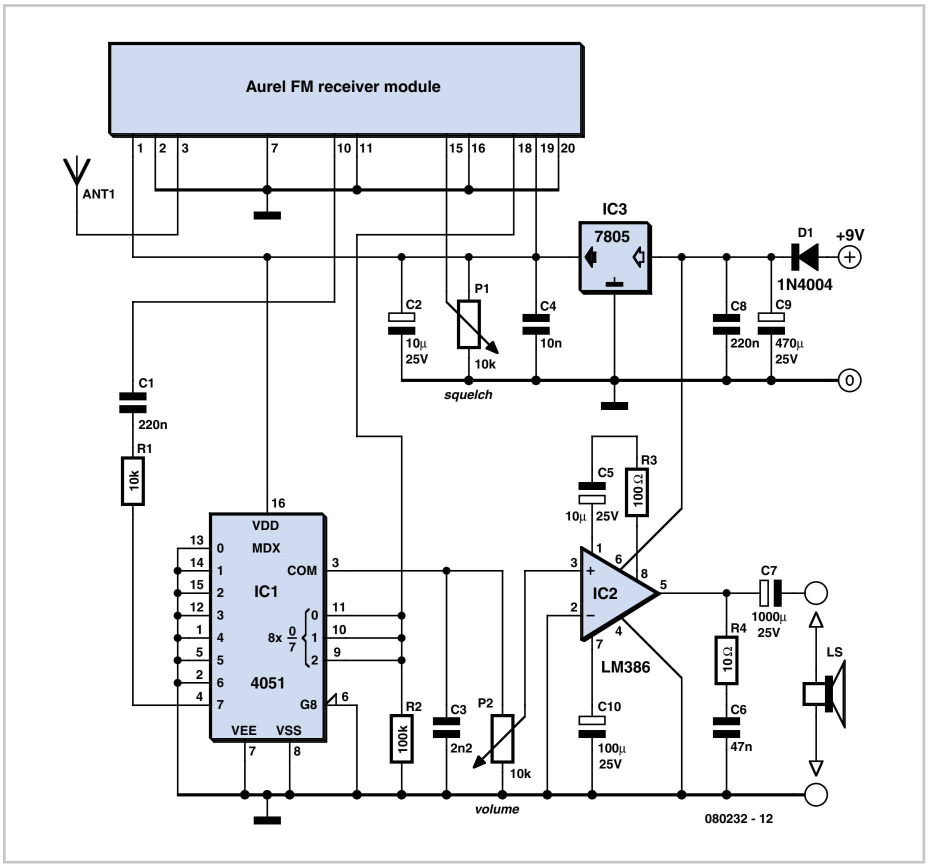
Sitting peacefully under a tree at the bottom of your garden, or stretched out beside your swimming pool, you may feel like listening to your favourite music from your hifi. Rather than turning the volume up beyond reasonable limits and risking upsetting all your neighbours or attracting the wrong audience, we suggest building this little wireless audio transmitter/receiver combination. Using the UHF ISM (industrial, scientific, medical) band and quality FM (frequency modulation), it won't impair the sound quality and will let you listen nice and discreetly.



The transmitter uses a well-known module manufactured for some years now by Aurel as their 'FM audio transmitter'. It works in the licence-free 433.92 MHz band and so allows our project to operate completely legally as the transmitter is type-approved to quite strict technical specifications. Note however the frequency you're using is not exclusive as it is shared by many other wireless devices such as headphones and key fobs for garage doors and so on. The equipment is low-power however and should have a short range.

The Aurel module is a complete FM audio transmitter designed for powering from

12 V. The only external components required, R5, R6, and C5, form the pre-emphasis (high-boost) network specific to frequency modulation.
Used alone, this module offers a typical audio input sensitivity of 100 mV rms. So we are driving it from an opamp with gain adjustable between 0.5 and 5, extending the voltage range from 50 to 500 mV, to make it compatible with any audio device line output. Note in passing that, if you reduce resistor R1 to 2.2 kΩ, you can increase the sensitivity to 2.5 mV so that the transmitter could then be used as a UHF radio mic for use in shows and events, for example.



The power supply can be obtained from a 12 V battery or a 'plug-top' power supply; diode D1 protects the circuit from reversed polarity by.
The receiver is just as simple, since it uses the complementary module to the previous one, again from Aurel, and naturally called their 'FM audio receiver'.
This receiver has a squelch (FM noise silencing) adjustment, set by the voltage applied to pin 15. Potentiometer P1 connected to this makes it possible to adjust the squelch threshold so as to have a receiver that won't output noise in the absence of a signal, using the information provided on pin 18. This is High when a signal is present and Low when absent. Here it drives an 8-into-1 CMOS analogue multiplexer, of which only input 8 is used. This solution employs a very cheap, good-quality analogue switch that is easy to use.
Its output passing via the volume control P2 and is applied to the well-known small integrated power amplifier LM386. The transmitter's RF output power of a few hundred milliwatts is more than adequate for such an application, and its quality likewise, especially if you combine it with a loudspeaker worthy of the name, with a pair of headphones as the next best alternative.
The Aurel receiver module and CMOS multiplexer both require a 5 V supply; this is stabilized by a standard 3-terminal regulator. The circuit as a whole is powered from 9 V, and is also protected against possible reverse polarity by diode D1.
Given the relatively high current consumption of the amplifier, especially if you use it for longer periods, rechargeable NiMH batteries will obviously be preferable to primary cells, which wouldn't last very long and will turn out rather expensive in the long term, as well as bad for the environment.
As far as the antennas are concerned, for both transmission and reception, simple quarter-wave whips ensure a range of a hundred metres or so – even more if line-of-sight. You can of course buy such antennas ready-made, but a simple piece of stiff wire around 17 cm long (i.e. a quarter wavelength at 433.92 MHz) will do the job just as well, and cost a lot less.

Equipped with these two modules you can make the most of your music wherever you like. Don't forget, though, that outdoors, the best music of all is that of birds, that is, the feathered variety.

(www.tavernier-c.com) (080232-I)

Gas Flow Meter

R. Pretzenbacher

The most surprising thing about this circuit is the sensor that it uses: a 4.5 V miniature torch bulb. The glass envelope is (carefully!) broken and then the pieces of glass removed, leaving just the filament intact. The filament forms the actual sensor element (see **Figure 1**).
As you can see from the circuit diagram in **Figure 2**, the bulb filament is supplied with

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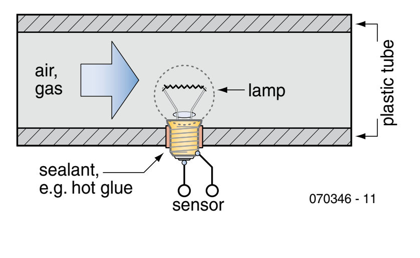


20 mA from a constant current source, with the result that the filament warms up. The current, which can be adjusted using P1, is a compromise between the sensitivity of the unit and its operating life. If the current is too high the filament will reach too high a temperature and sooner or later will burn out. The filament has a positive, although relatively small, temperature coefficient of resistance: the hotter the filament the greater its resistance and so the greater will be the voltage dropped across it at a given constant current.

If air (or another **non-flammable** gas) flows through the pipe in which the filament is mounted, the filament will be cooled and the voltage across it will fall. The greater the air flow the cooler the filament and so the lower the voltage. The relationship between flow rate and voltage is reasonably linear. An important use of this measurement technique is in the air intake of car engines, where an ordinary thin heated wire is used as the sensing element in place of the lamp filament.

Operational amplifier IC1.A is used to subtract the voltage drop across the coil from a voltage produced by the PICAXE microcontroller (IC3) via its PWM output on pin 5, filtered by the RC-network comprising R9 and C5. The second operational amplifier amplifies the residual signal as needed. The gain can be adjusted using P2.
The PICAXE08M from Revolution Education Ltd is a PIC microcontroller that can be programmed in BASIC (see www.picaxe.com). When power is applied the PICAXE automatically goes through the offset calibration procedure, which helps the unit achieve excellent sensitivity. Simultaneously the measured voltage is digitised within the PICAXE. The result of the flow rate measurement is made available both as an analogue voltage (pin 7 of IC1.B) and in digital form on the TTL-level RS-232 output K1. The BASIC program that runs in the PICAXE is available for free download from the Elektor website at http://www.elektor.com, look for file # 070346-11.zip.

The NE555 is present only to provide a small negative voltage of around –2 V for the LM358. This lets us use this low-cost operational amplifier in such a way that its output can swing down to 0 V. The NE555 inverter circuit allows the unit as a whole to be powered from a single 5 V supply.

Using this circuit the author has obtained a usable output signal from 0 V to 3.5 V when measuring very gentle flows from 0 nl/h to only 120 nl/h. He used the circuit to check the operation of an industrial nitrogen (N_2) flow rate meter.

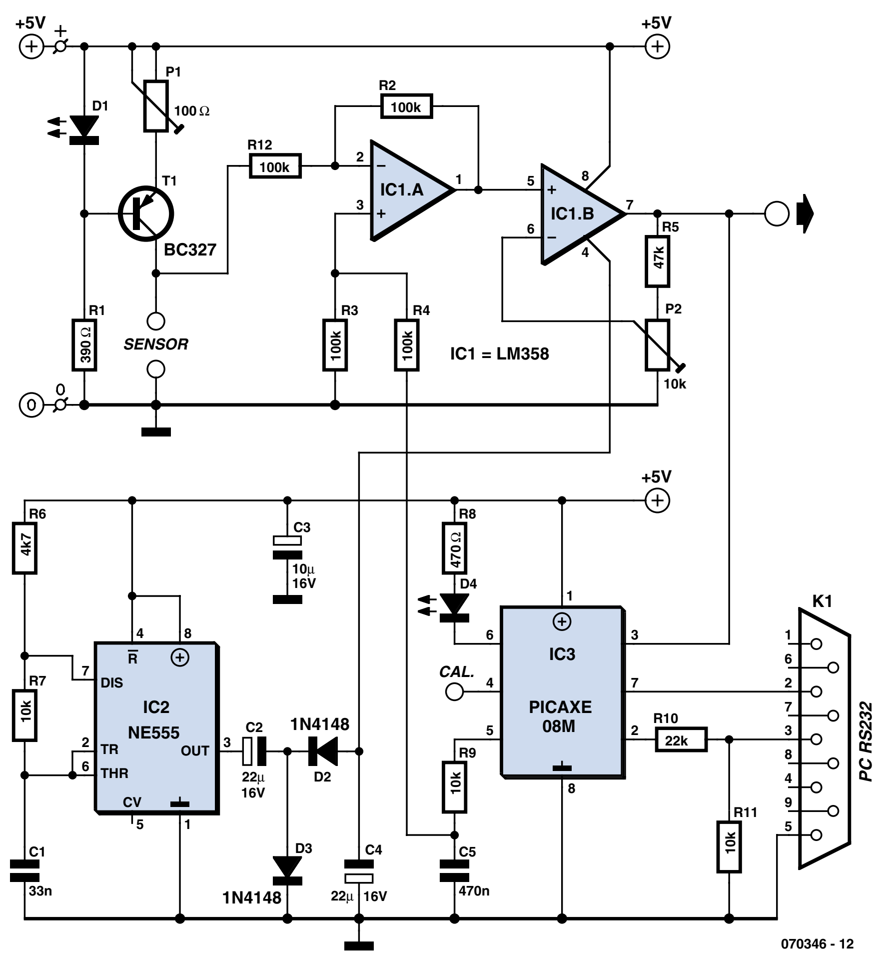
It must be admitted that a circuit as simple as the one described here has a few infelicities. The sensitivity of the unit is highly dependent on the filament used and on the current through the filament (although this is compensated for by the calibration that the PICAXE carries out). Also inconvenient is the strong dependency on the temperature of the gas whose flow rate is being measured. To compensate for this the gas flowing through the pipe must be heated to a defined temperature before being passed over the filament.

And we cannot emphasise strongly enough:

do not under any circumstances use this circuit with flammable gases!

(070346-I)

2

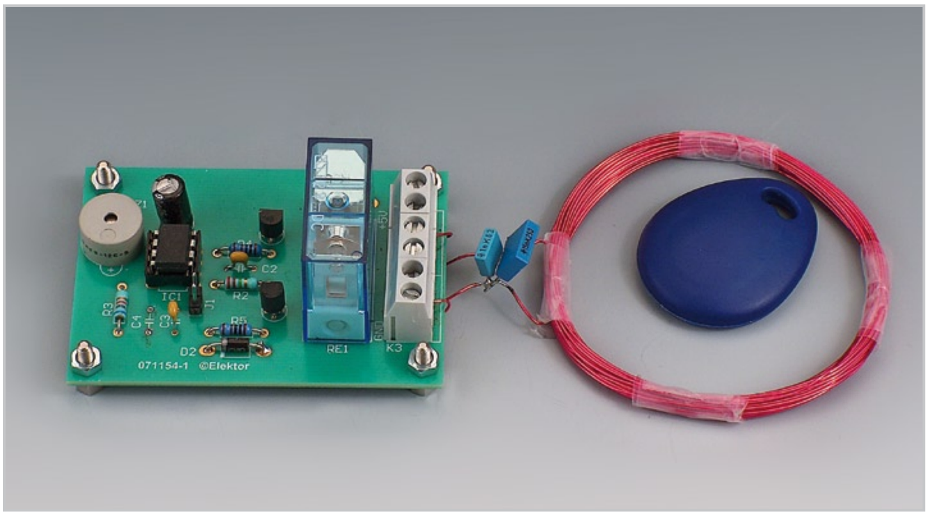


RFID Door Opener

Ralf Künstler

The RFID-based project described here employs a specially-programmed IC from the 'SFChip' (the 'SF' stands for 'Special Function') product family. The SF6107 [1] is an IC designed to work as an RFID receiver for tags that operate on a nominal frequency of 125 kHz. Tags (or, more properly, 'transponder cards') compatible with the EM4102 contain forty bits of data and are available for a pound or two each.

The support circuitry required for the SF6107 consists of just a couple of passive components, two transistors, a hand-wound coil and, if desired, a DC buzzer. As the circuit diagram shows, a complete door opener, capable of recognising a master RFID tag and learning the codes of up to twenty further tags, is not very complicated at all.



The IC drives the coil via pin 3 and T1. Together with C1, the coil forms a parallel resonant circuit. The cable linking the main electronics and the coil can be up to 80 cm long. If the coil is reasonably well adjusted, tags can be read at distances of up to about 3 cm.

The voltage across the coil is demodulated by D2 and then passes via C3 to pin 6 on the IC. An RFID tag in the vicinity of the coil absorbs energy from the field produced by the coil and uses it to subsequently transmit its stored ID code. The IC compares this code against the values it has registered in its memory. If there is a match, T2 is driven on, which in turn activates the relay and then the door lock electromagnet.

Simultaneously the IC emits the ID code of the recognised tag in serial format on pin 2. Alternatively, for audio feedback a piezo buzzer can be connected to this pin. The buzzer will sound whenever the card that is being held next to the coil is recognised. After the IC is reset (either when power is applied or by taking pin 1 briefly down to ground) the IC emits status information on pin 2. This consists of a list of the stored transponder ID codes preceded by their count. In the case of one master tag and two additional tags, the following might be output:

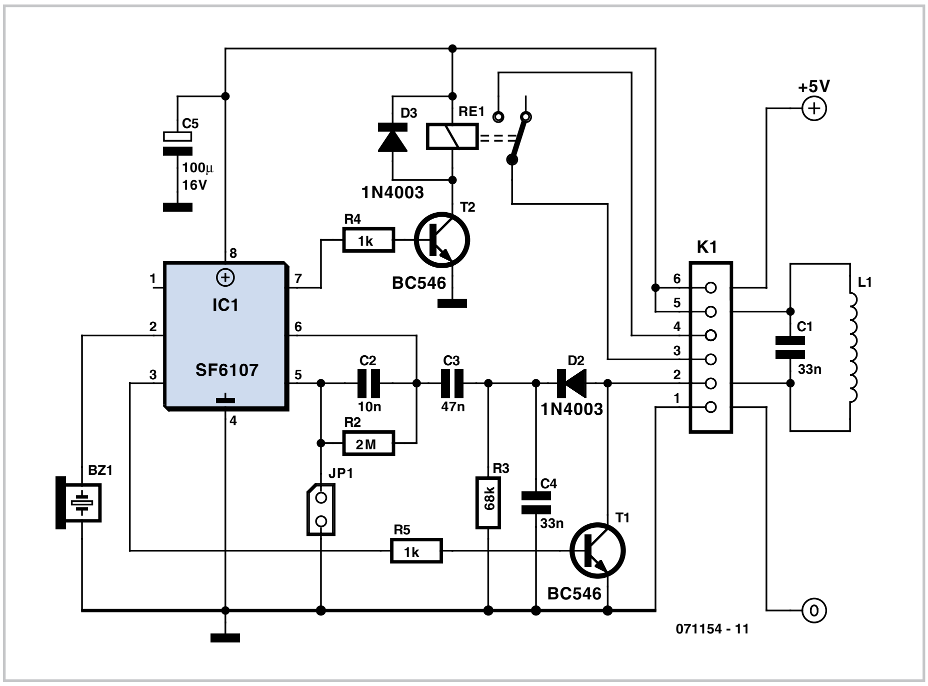
```
#T3
#R00:CC00154423
#R01:CC00154427
#R02:CC00154434
```

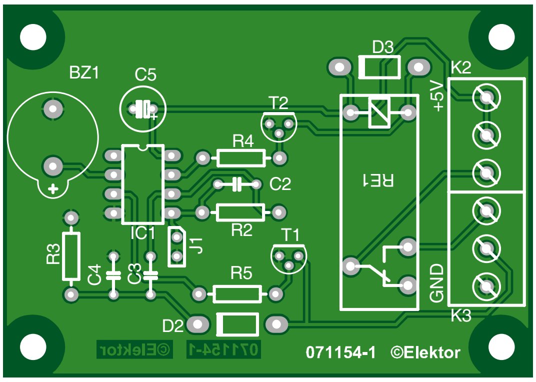
Each line is terminated by a 'CR' and an 'LF'. The first line gives the count of stored tag ID codes. There follow the individual ID codes, starting with the master tag. Each ID code consists of ten hexadecimal digits, making a total of 40 bits. The data transfer format is 9600 baud, 8 data bits, no parity and one stop bit. If a piezo buzzer has been connected to pin 2 it will emit a strange sound during any serial activity.

If, instead of the piezo buzzer, a 10 kΩ pull-down resistor is connected to pin 2, the signal output will be suitable for connecting directly to pin 2 of a 9-way sub-D socket, which can then be taken to a PC using an ordinary serial cable. If, on the other hand, the serial output is to be taken directly to a microcontroller without level-shifting, a 10 kΩ pull-up resistor should be connected A to pin 2. The IC checks which resistor is present at start-up and inverts its serial output if necessary.
Use the following procedure to erase all the stored ID codes prior to reprogramming:

1. Switch the unit off
2. Fit JP1 (this pulls pin 5 to ground)
3. Switch the unit on
4. Wait ten seconds
5. Switch the unit off
6. Remove JP1

Now a master tag (any RFID card) can be read and its ID stored. Hold the tag up to the coil. Then take it away and bring it up





a second time: if the relay is activated then this means that the card has been successfully programmed as the master and its ID code has been stored.

To program further tags into the unit it is necessary to switch it into programming mode. This is done by holding the master tag up to the coil for around one minute. There then follows a twenty-second time window during which further tags can be programmed. Programming mode can be reentered as above to store further tag IDs, up to a maximum of twenty (plus the master tag).

The circuit can be constructed using the printed circuit board shown, whose layout is available for download from the Elektor website. Current consumption with the relay off is around 16 mA.

If a more powerful relay is to be used, drawing more than 100 mA of coil current from the 5 V supply, a BC337 should be used for T1.

For optimum tag reading reliability and range the parallel resonant circuit consisting of the coil and capacitor should have as high a *Q* (quality) factor as possible. Coils made from 0.5 mm enamelled copper wire on a diameter of between 50 mm and 60 mm have given good results. These dimensions are not particularly critical, but it is important that the resonant frequency of the circuit is as close to the operating frequency of 125 kHz as possible.

In our prototype we measured the inductance of a 30-turn coil with a diameter of 55 mm at about 100 µH. It was possible to read RFID tags with values of C1 between about 47 nF and 14 nF, corresponding to resonant frequencies of 71 kHz to 133 kHz.

It is not necessary to have an oscilloscope to adjust the resonant frequency and *Q* factor. An ordinary digital voltmeter measuring the voltage across capacitor C4 (or at the cathode of D2) will do. Different values for C1 can be tried: the higher the measured voltage, the better. With the correct capacitance voltages of more than 8 V are possible.

After these measurements have been carried out and the tag IDs have been programmed into the unit, further tests can be carried out making small adjustments to C1 to obtain maximum reading range.

(071154-I)

COMPONENTS LIST

Resistors
R2 = 2MΩ (or 2MΩ2)
R3 = 68kΩ
R4, R5 = 1kΩ

Capacitors
C1*,C4 = 33nF
C2 = 10nF
C3 = 47nF
C5 = 100µF 25V

Semiconductors
D2,D3 = 1N4003
T1,T2 = BC546*
IC1 = SF6107 (www.sfchip.de)

Miscellaneous
J1 = 2-way pinheader with jumper
BZ1 = piezo buzzer
K2,K3 = 3-way PCB terminal block, lead pitch 5mm
Re1 = relay, 5V, type V23057*
L1 = 100 µH inductor (30 turns 0.5mm ECW, 55mm diameter*
PCB, # 071154-1 from Elektor SHOP or www.thepcbhop.com)

* see text

Web Link

[1] SF6107 information (in German): http://www.smatronic.mine.nu/SF6107.htm

Bell Alarm

Patric 't Kindt

If you use a lamp with a motion sensor for outdoor lighting, the original electrical switch is actually no longer necessary. If you replace the switch with the circuit described here, an acoustical signal will be generated each time the outdoor lamp is switched on. It's thus somewhere between an alarm and a doorbell.

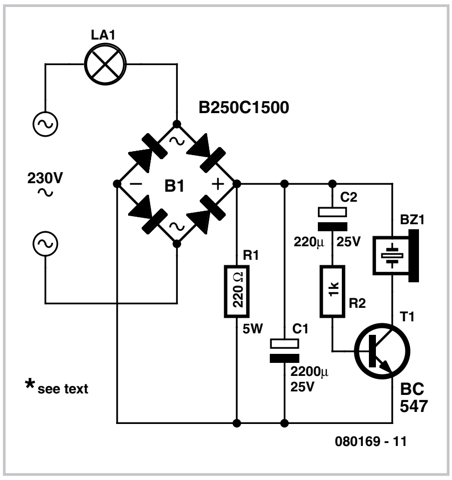
The operating principle is simple. A circuit that causes a voltage drop of only a couple of volts is connected in series with the lamp. As the circuit needs a DC voltage, the current for the lamp is passed through a bridge rectifier. The voltage drop across the circuit is determined by R1. The function of C1 is to smooth the raw DC voltage. Note that this is not an example of peak rectification, but instead of averaging. For this reason, the voltage on C1 is lower than you might expect. Ultimately, the DC voltage on C1 reaches the same value as the average voltage across R1.

For example, consider what happens with a 100-W lamp. For convenience, we can assume that the lamp has a resistance of 529 Ω. If we ignore the voltage across the diodes and the voltage across R1, the current is approximately 0.39 A on average (not 0.43 A). This is because the average mains voltage is only 207 V = (230 × √2) ÷ (π/2). This yields a voltage of approximately 8.5 V on C1. As the buzzer and T1 only draw a few milliampères from C1, in practice the voltage will differ from this value by at most a few tenths of a volt.

Here you should use a DC buzzer with a large operating voltage range. A good example is the CEP-2260A, which has a volt-

age range of 3–20 V (available from Digi-Key and other online sources).
The charging time of C2 determines how long the buzzer remains energised, and here it will be a few tenths of a second. Depending on how much current the buzzer draws, you can increase the value of R2 in order to extend the time (this is certainly necessary with the above-mentioned buzzer type).

Depending on the lamp power, you can consider adjusting the value of R1. This will certainly be necessary if you use a 150-W lamp or larger. In this case, cut the value of R1 in half, primarily because the power dissipation will otherwise be too large. In the example described here, it is around 3 watts.



The bridge rectifier also deserves special attention. A large current can flow briefly when the lamp is switched on 'cold'. A 250-V, 1.5-A bridge rectifier is adequate for a 100-W lamp, but heavier-duty diodes are necessary with higher lamp power – such as the 1N5408 (1000 V / 3 A).

Due to the heat generated by R1, make sure that R1 is located a certain distance away from the other components in the assembled circuit. Also bear in mind that the entire circuit is connected to mains potential. Never make any adjustments while the circuit is connected to the mains! It's thus a good idea to test the circuit before fitting it into the switch box.

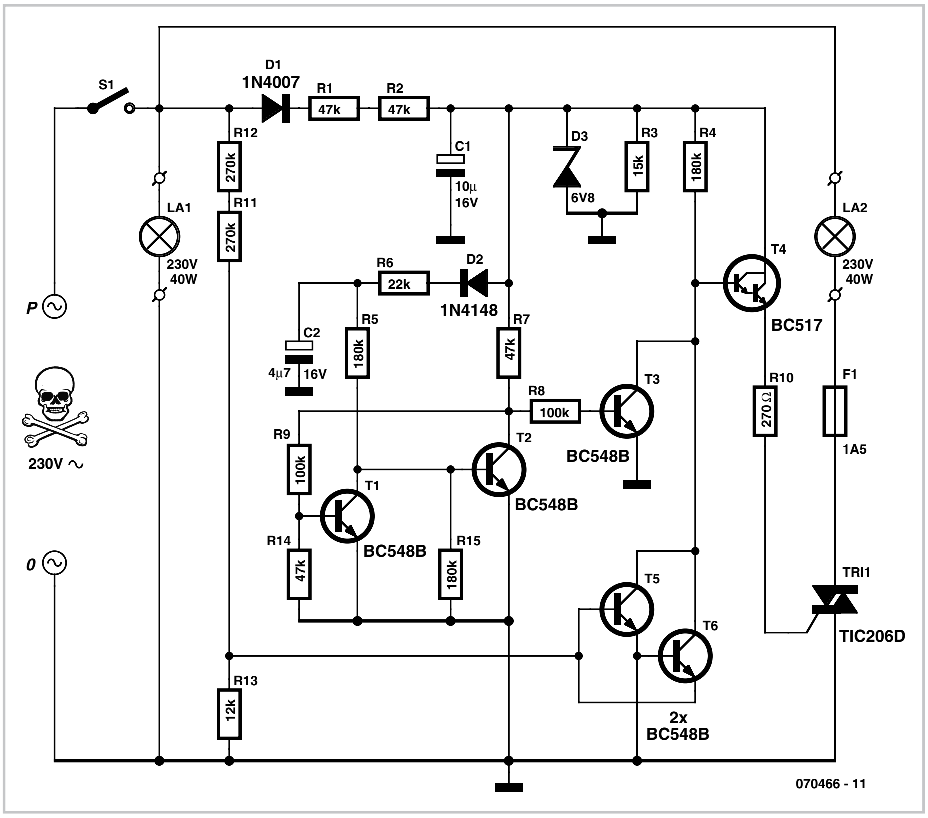
(080169-1)

Smart Chocolate Block

Edmund Martin

What can be done, when two light bulbs in one light fitting are to be switched separately, but only one switch circuit is available? Simple: build a 'smart chocolate block' into the ceiling rose! The circuit is built from discrete components and with a bit of ingenuity can be fitted onto a printed circuit board measuring just a centimetre or two square.

When light switch S1 is operated for the first time lamp La1, which is connected in the usual way, lights; La2 remains dark. Electrolytic capacitor C1 starts to charge via rectifier diode D1 and resistors R1 and R2 until zener diode D3 conducts, limiting the voltage to about 6.8 V. This voltage is used as a supply for the rest of the circuit. The second lamp is connected via a triac and a fuse (1.5 A, medium speed recommended). The triac is triggered by T4, which can only happen when T3 does not pull its base down to ground. The first time the circuit is switched on this is the case, as we shall see below.



Transistors T1 and T2 form a bistable flip-flop with a well-defined power-up state. R14 and R15 cause both transistors to be initially turned off. As the voltage across C1 rises, transistor T1, driven via resistors R7 and R9, turns on. The base drive for transistor T2, which is provided via D2, the low-pass filter formed by R6 and C2, and R5, would arrive a little later, but when T1 turns on it diverts the base current away from T2, which therefore remains turned off. This situation is stable: the base of T3 is not pulled down and so this transistor conducts.

To turn the second lamp on, switch S1 is opened and then, within a second or so, closed again. The effect of this action on the flip-flop is as follows.
When the switch is opened the voltage across C1 falls more rapidly than the voltage across C2. The main reason for this is resistor R3, which is directly responsible for the discharge of C1; C2 can only discharge through the relatively high resistance of R5,

since the other path is blocked by diode D2. This means that T2 is driven via R5 for one or two seconds longer than T1 is driven via R7 and R9. If during this time the supply voltage reappears, it can no longer drive the base of T1 via R7 as T2 is conducting all the current to ground. This situation is also stable, as C2 is recharged via D2 and R6.
When T2 conducts it pulls the base of T3 to ground, so that this latter transistor turns off. Darlington transistor T4 now conducts as its base is pulled high via R4. T4 now provides the trigger current for the triac via current limiting resistor R10, and the second lamp lights.

T5 and T6 together form a zero-crossing detector. It ensures that the triac is never triggered at a moment when the AC mains supply is at a high voltage point in its cycle. This avoids a rapid inrush current into La2, which would give rise to considerable radio interference. Also, trigger current is only required for the triac for a small fraction of the period of one cycle of the mains supply. If this current were drawn continuously from the low voltage supply, C1 would rapidly discharge; R1 and R2 would have to be considerably reduced in resistance, which would increase the heat dissipation of the module, perhaps making it infeasible to build the circuit into a plastic ceiling rose.

Using the component values shown the triac is only driven when the instantaneous mains voltage is less than about 15 V in magnitude. The voltage divider formed by R11, R12 and R13 switches on the transistors T5 and T6 when the voltage is greater than +15V or less than –15 V respectively. The collectors of these transistors, which are connected together, pull the base of T4 down to ground or to a slightly negative voltage when the mains cycle is outside the desired phase window.

Any resistors across which mains voltages will be dropped are formed from two individual resistors wired in series to ensure that the maximum voltage specifications of ordinary 0.25 W components are not exceeded. This applies to R1 and R2, as well as R11 and R12. The whole circuit is at mains potentials and great care must be taken to observe all relevant safety precautions in construction and installation.

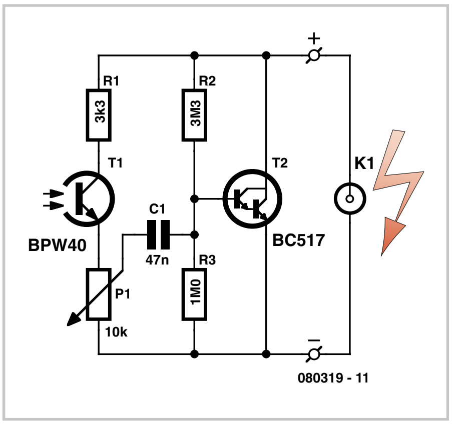
(070466-I)

Slave Flash Trigger

Hermann Sprenger

The flash that is built into digital cameras is designed for indoor photography. At subject distances of greater than five metres or so, the light is usually not powerful enough to take a satisfactory picture. Unfortunately most such cameras do not include a shoe for an external flashgun, and so a light-triggered slave flash is called for.

The flash built into the camera produces a very rapid change in light intensity which is picked up by a phototransistor in the slave.



The pulse is transmitted via C1 to the transistor, which then briefly shorts the contacts on the slave gun together. The sensitivity of the device can be adjusted using P1. The circuit can be connected to the shoe contacts of the slave flashgun using a coaxial cable, or, with space permitting and a nimble bit of DIY, can be built inside it.
The circuit is not suitable for use with flashguns which have a voltage of more than 20 V across the trigger contacts, or with cameras that emit a number of 'pre-flashes' before taking the picture proper.

(080319-I)

Operating Hour Counter

Thomas Rudolphi

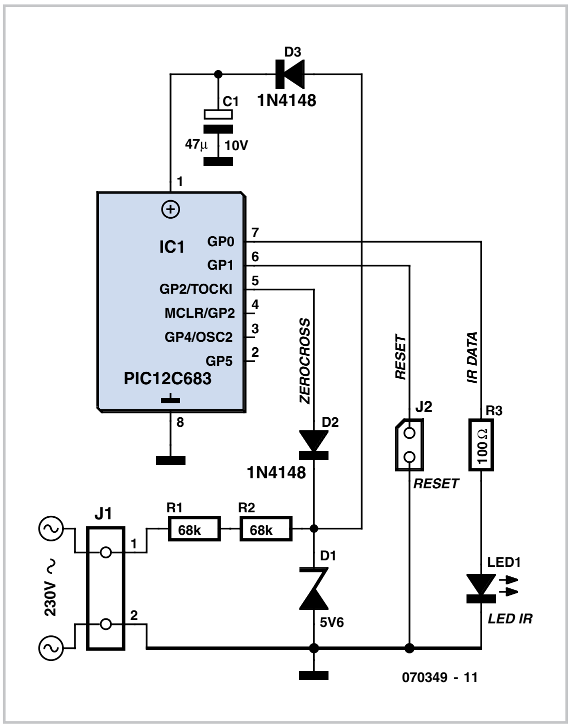
These days there are all kinds of power/energy meters available which can measure the power consumption and the operating costs of mains powered appliances. A prerequisite is that the appliance has a mains plug. However, if the power consumption is known then the energy use of the appliance can also be determined in a much easier way.
The operating hour counter for mains (230 VAC) appliances described here can measure the following, even in difficult to access places:
1. Number of times that it is switched on and off (up to 99999)
2. How long the load (lamp, fan, etc.) has been switched on (up to 99999:59:59 hours, resolution 1 s).

Because the power consumption of the load is known and using the information from the PIC, the energy consumption can then easily be determined using a Microsoft Excel file.

The whole circuit is built around an 8-pin PIC12F682 processor. The circuit draws very little current, so that it can be powered directly from the mains via two series resistors of 68k each (R1, R2). Zener diode D1 limits the positive voltage to 5.6 V and the negative voltage to –0.6V. At the node R2/D1 there is therefore a, more or less, square wave voltage. D3 and C1 provide a filtered voltage for the PIC processor. D2 ensures that at input GP2 with internal weak pull-up there is a square wave voltage of 5 V with a frequency of 50 Hz.

The data is sent every second via IrDA using an IR LED and at a baud rate of 38k4. With R3 the current during the short pulse is limited to about 35 mA.
With J2 the accumulated data can be reset (counter and time back to 0). To do this, the jumper has to be installed before the circuit is turned on, and it's removed again after the circuit is switched off.
The software has been written with the freeware 'SourceBoost' C compiler (see web links). It has the following functions:

- initialisation of the processor (init())
- writing the data to the internal EEPROM
- deriving time information from the 50 Hz zero-crossings (Realtime())
- sending of the IrDA data via an IR-LED (HandleIrDaCommunication())
- power-down detection after which the time information is written to the internal EEPROM.



In the Init() routine the processor is initialised and the ON/OFF counter is incremented by one and the value is saved in EEPROM. It also clears the data in the EEPROM if the jumper is in place.
The main loop (for(;;)) waits for the zero-crossing detection in the CheckZeroCross() routine. As soon as this arrives the time information is updated in Realtime(), which also sends part of the IrDA data every 100 ms. Only a small part of the data is sent to the IR-diode each time to prevent C1 from being discharged too much (relatively large current through the LED).

The CheckZeroCross() routine also checks whether the zero-crossing arrives every 20 ms. If not, then is the power has been switched off and the data has to be saved to the internal EEPROM as quickly as possible (before C1 discharges too deeply).
With a Pocket PC (PDA) (always fitted with an IrDA port as standard) and a terminal program (for example Zterm/PPC, see web links) the data can be very easily read out. The (ASCII-) output is in the form:

C=00000
H=00000:00:00

The circuit can easily (temporarily) be mounted inside, for example, a lamp fitting and must be connected in parallel with the load.

(070349-I)

Downloads

The source and hex code files for this project are available as a free download from www.elektor.com; file # 070349-11.zip.

Web Links

Freeware C-compiler:
www.sourceboost.com/CommonDownload/Binaries/SourceBoostV6.85/sourceboostv685.zip

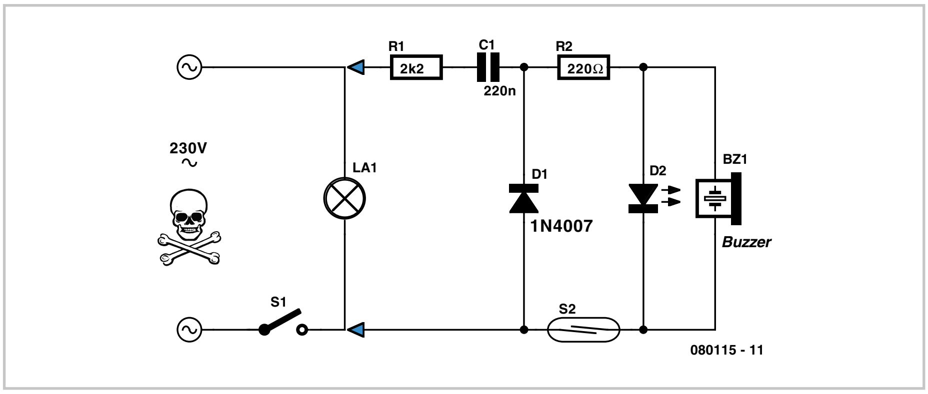
Terminal program for PDA:
www.coolstf.com/ztermppc

Put that Light Out!

Stefan Hoffmann

If you forget to switch off the light after leaving a seldom used room (such as the loft), there's a strong likelihood that it could remain lit for months, running up an expensive power bill in the process. How can we prevent this waste?

It's not hard for electronics enthusiasts to design a little circuit to mitigate the effects of absentmindedness. The notion is simple; if the light is left on when the hatch or door is closed, a rhythmic sounder/buzzer signal produces an alarm that hopefully will not be masked by other noise.



The circuit is powered as long as the lamp bulb is switched on by light switch S1. If the reed switch S2 then signals that the hatch has been closed, the sounder operates. The red LED, mounted outside the loft next to the entry hatch, also indicates that the lamp up there needs to be switched off. The circuit does not use a transformer, meaning that the whole circuit is at mains potential. For this reason the components must be placed inside an insulated plastic case for protection, with no way that people can touch any part of the circuit (this includes the sounder).

The connecting wires to the LED and the reed switch contact must be fully protected to the same touch-proof degree too. For the sounder you can use any type that operates on direct current in the region between 1 V and 3 V. In this circuit the operating voltage is limited by the LED connected in parallel to the buzzer. Using a red LED will provide around 1.7 V to the sounder. The current requirement of this kind of miniature sounder is about 5 mA.

(stefankhoffmann@yahoo.de) (080115-I)

Post-box Monitor

Mathieu Coustans

Or "Has the postman been yet?" This project was born out of the idea of avoiding having to go out to the post-box on a rainy day to see if the postman has been. Whereas in the UK the letterbox is often a slot in the front door, very remote road-side post-boxes are common in other countries.

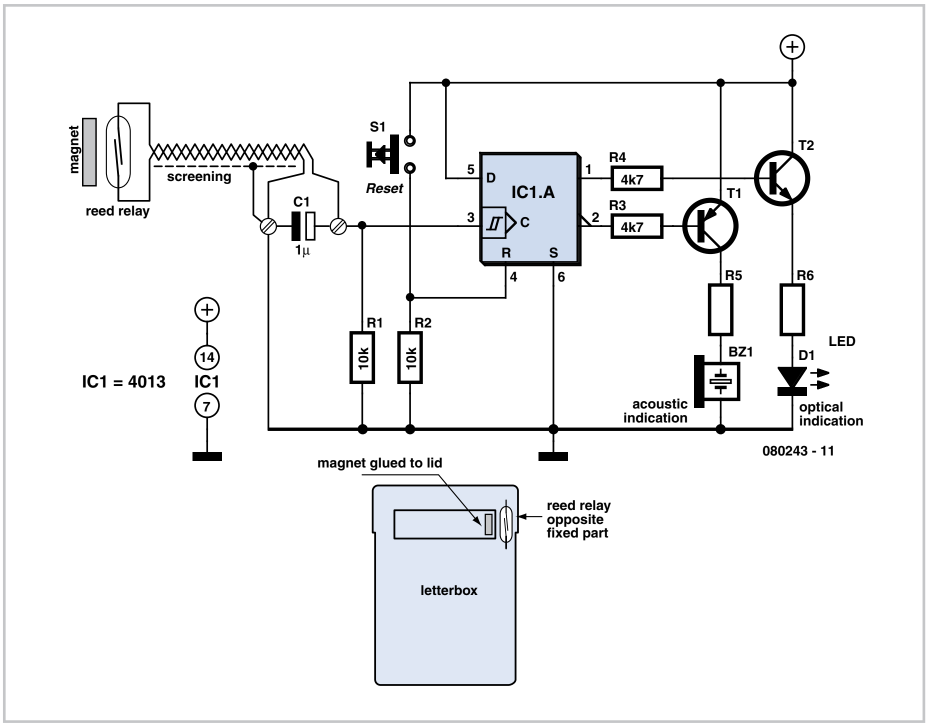
Of course, it rains a lot less in Summer, but it does still happen — and always just when you're expecting an important letter; what's more, not everyone is on holiday, and loads of people go straight indoors without checking their post-box.

It would be nice to have some way of displaying the status of the post-box.

Until very recently, this type of (luxury) accessory was the privilege of private villas fitted with CCTV systems, the rest of us mere mortals not really feeling the need to spy on the postman using a CCTV camera. So the author decided to build a little circuit which is ridiculously cheap to build — in its most basic version, it ought not to cost more than about £ 3.

The author's project was built on prototyping board (perfboard) and uses only very standard components, the object of the exercise being to produce a simple but effective circuit. In its basic version, the circuit in question remembers if the postman has been (it doesn't actually detect the postman, but any kind of post slipped into the post-box by lifting the flap protecting the opening) and can indicate this 'event' visually (an LED) or audibly (buzzer or vocal alarm based on the ISD25xx). However, that the author soon ruled out the latter option because of the noise pollution it generates and the noticeably higher current consumption compared with just an LED.

Those readers who are keen to provide their system with a vocal-type alarm at any cost can take a look at the author's website, where he describes the system he used from the following supplier, before abandoning it. Conrad Electronics sell a module the size of a chewing-gum leaf for around £ 6 [1].



CD4013 truth table					
CL	D	R	S	Q	$\overline{Q}$
Low>High transition	0	0	0	0	1
Low>High transition	1	0	0	1	0
High>Low transition	x	0	0	Q	Q
Immaterial	x	1	0	0	1
Immaterial	x	0	1	1	0
Immaterial	x	1	1	1	1

A glance at the circuit shows how staggeringly simple it is. The central component is a CD4013 logic IC (sequential logic), a D-type flip-flop with reset and priority set to '1', active high. You can find the truth table for the flip-flop in the inset. It's more complicated than it seems at first sight (CL = Clock, D = Data, R = Reset, S = Set, Q = Q output and $\overline{Q}$ = $\overline{Q}$ output).

You can see that this is only triggered once on a rising edge.

This edge is generated by the magnetic leaf switch, since the latter is sensitive to any significant variation in the magnetic field: the simple fact of opening the hinged flap of the post-box to put the post in can be used to produce a change of state in the reed switch. The diagram illustrates the respective positions of the reed switch and magnet.

The author has all sorts of potential developments in mind for his circuit. If the subject intrigues you, why not drop by his blog [2] from time to time, to see how things are developing? — a basic knowledge of French is required, though.

(080243-I)

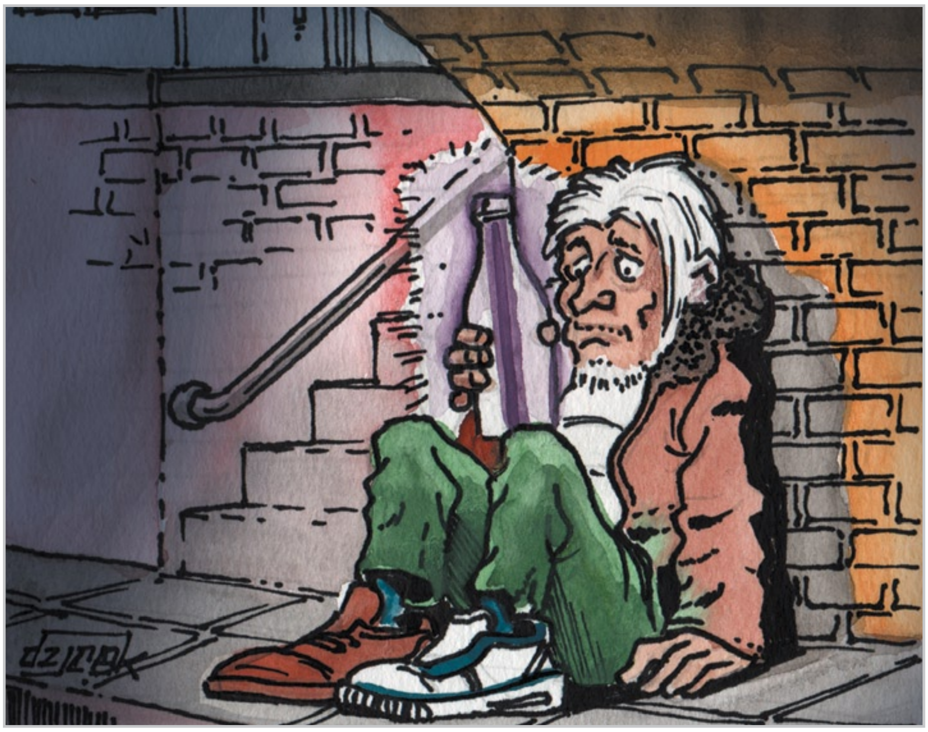
Web Links

[1] Author's website:
http://ludvol.free.fr/articles.php?lng=fr&pg=211

[2] Author's blog:
http://lespace-electronique.blogspot.com

Lamp in a Wine Bottle

Sebastian Westerhold



Electronics need not always be a matter of dry theory or be taken with great seriousness. We were reminded of this by the author, who wrote to us to describe a very peculiar 'circuit':

'My other half Jessica is the kind of woman, rather rare on this planet, who takes a keen interest in the wonderful world of electronics and who shows great forbearance towards the hours I spend immersed in my hobby.

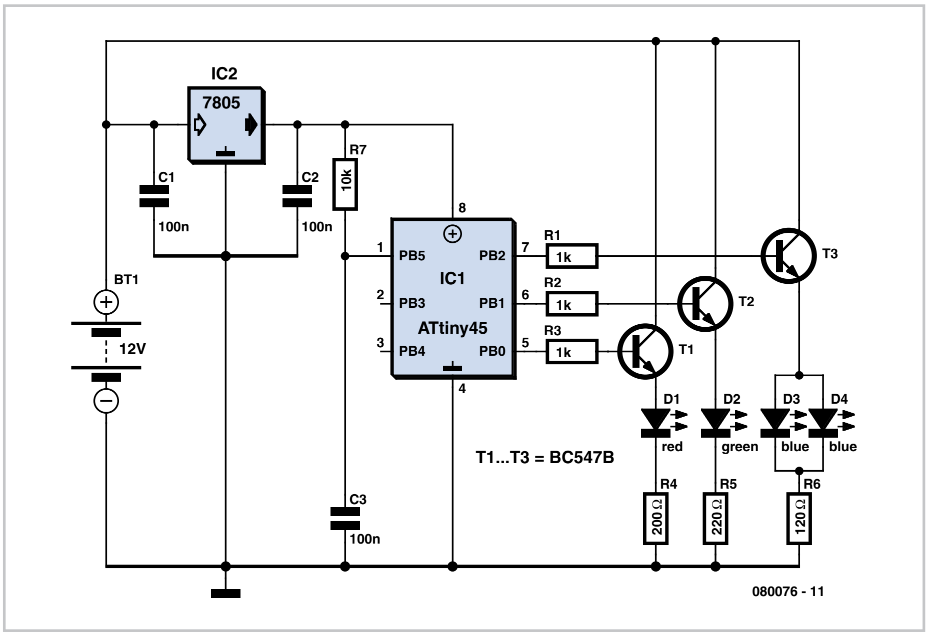
For Christmas 2006 I gave her a soldering iron, a small set of tools and a bundle of components. They went down rather well, and it was not long before LEDs were flashing away under the control of an NE555, 4017 and other bits and pieces.

At some point in the following autumn Jessica asked me to come and look at her latest 'circuit'. On the way down to the cellar I imagined the possibilities for what might await me in my workshop. What I saw, however, I never would have expected: each made from a resistor and a capacitor, artfully soldered together, a pair of earrings! And all RoHS compliant, of course.'

The inventive project described here is also a product of Jessica's creative flair. The couple were experimenting with filling wine bottles with water, and adding various chemical colourants. Then LEDs of various colours were submerged in the liquid, giving strange and beautiful lighting effects. The ultraviolet-active dye 'fluorescein sodium' gives off an intense green light when stimulated using blue, or even better, ultraviolet, LEDs. Rhodamine B is another ultraviolet-active dye: in this case the emitted light is bright red. Both fluorescein sodium and Rhodamine B can be ordered via chemist's shops, or, more economically, over the Internet. Although the prices of these dyes may appear high, only very tiny quantities are needed: one gram of dye is enough for at least ten wine bottles full of water.

Even more spectacular effects can be achieved using a full-colour RGB LED in conjunction with these dyes. The driver circuit, which is an ideal project for beginners, can be built on a small piece of perforated board in half an hour or so. Being microcontroller based, the circuit is very compact. As always, the software is available for download from the Elektor website at http://www.elektor.com. Ready-programmed microcontrollers are also available: the order code is 080076-41.

(080076-I)



Pitch Meter for Model Helicopters

Hanspeter Povel

'Pitch' is the name given to the angle of inclination of the rotor blades of a helicopter. In model helicopters the pitch angle is critically important to flight performance. Typical pitch values lie in the range from –3 degrees to +10 degrees.

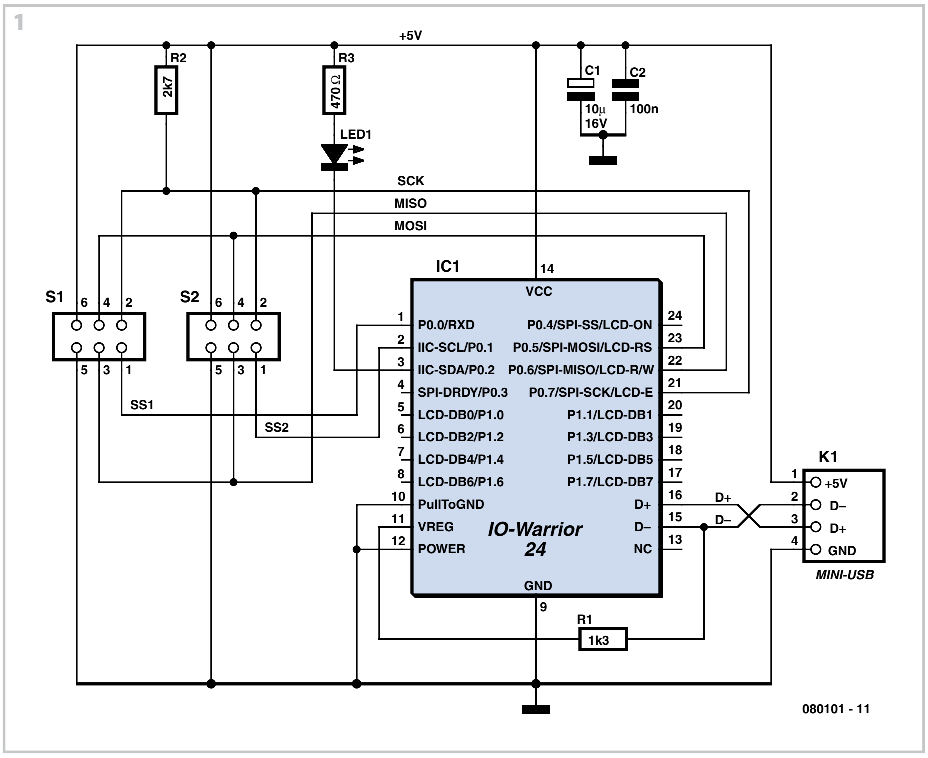
There are various ways to check and set the rotor blade angle. One method uses a flybar rod (which resembles the small auxiliary rotor blade under the main rotor) set horizontal with the help of a spirit level, a protractor fixed to the rotor blade, and a plumb line. The method does work, but the rotor axis must be kept as vertical as possible and the blades as horizontal as possible to obtain an accurate measurement. As so often, a little electronics can make life a lot simpler.

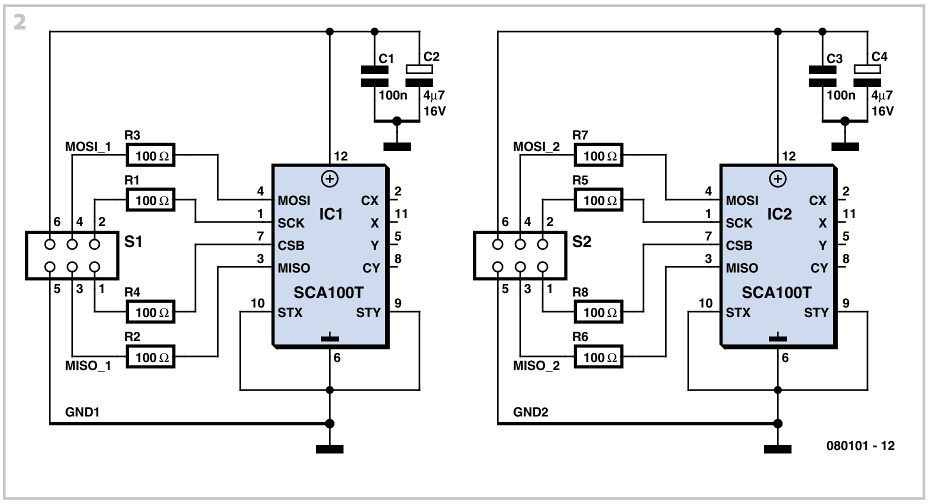
Searching for a suitable IC, the author came upon the SCA100T inclinometer from VTI Technologies [1]. The device is a micromechanical sensor which measures angle on two axes using a capacitive method. The SCA100T-D01 has a range of –30 degrees to +30 degrees and a resolution of 0.0025 degrees. The measured angle can be read out in digital form over an SPI port.

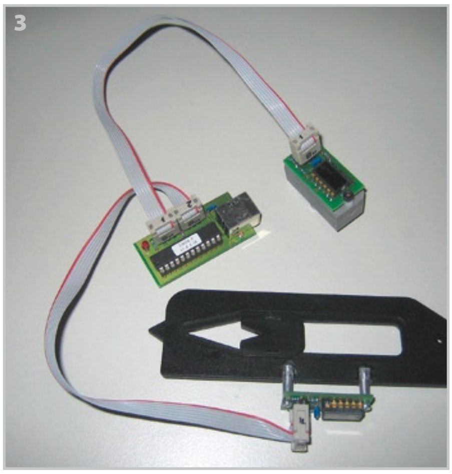
If we want to connect the device to a laptop or desktop PC, we need a suitable interface. A simple approach is to use a ready-made USB-to-SPI converter such as the IO-Warrior 24 from Code Mercenaries [2]. As the circuit in Figure 1 shows, this unit can drive two SPI ports simultaneously, and also sports an LED to indicate operation. The circuit diagram shown in Figure 2 therefore shows how two identical inclinometers are connected to the two SPI ports.

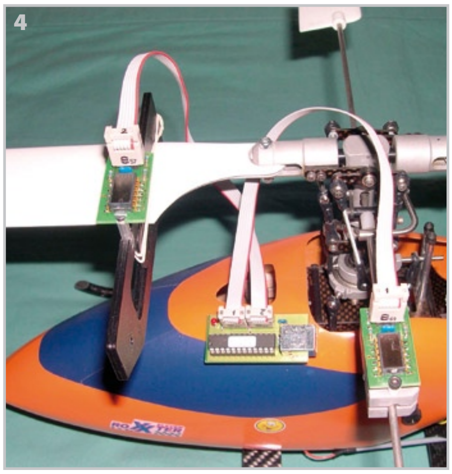
The completed module is shown in Figure 3. One inclinometer is screwed to a black guide plate in order to simplify attaching it to the rotor blade. The other inclinometer, which is mounted on a grey block, is attached to the flybar. The whole assembly is shown in Figure 4, attached to a model helicopter and ready to make some adjustments.

The last piece in the jigsaw is some suitable software running on the host PC. Using the IO-Warrior hardware simplifies matters considerably in talking to the hardware, as libraries are available for download from the Code Mercenaries website to allow access









to the SPI data from programs written in C++ or in Visual Basic. The author plumped for the latter language, as a free development environment for it is available from Microsoft. He then wrote a short Visual Basic program to display the measured angles, rounded off to the nearest tenth of a degree.
The two values measured are the inclinations of the flybar and of the rotor blade. The difference between these two values can be calculated to yield the pitch angle. Since the sensors measure angles on two axes, the less relevant values are shown in smaller text on the display. These values depend on the horizontal alignment of the model and should be less than ten degrees. The sign (positive or negative) of the displayed results can be changed to suit the mounting arrangement with a click on the button marked '+/–'. The Visual Basic software is available as a free download from the Elektor web page for this project.

(080101-I)

Web Links

[1] http://www.vti.fi/en/products-solutions/productfinder/search/motion.html

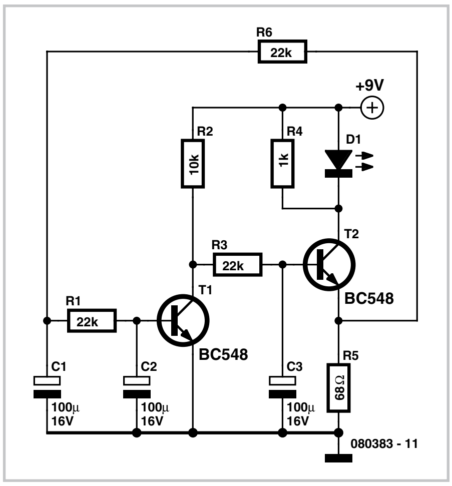
[2] http://www.codemercs.com

Smooth Flasher

Burkhard Kainka

Ordinary LED flashers turn the LED on and off abruptly, which can get a little irritating after a while. The circuit shown here is more gentle on the eyes: the light intensity changes very slowly and sinusoidally, helping to generate a relaxed mood.

The circuit shows a phase-shift oscillator with an adjustable current source at its output. The circuit is capable of driving two LEDs in series without affecting the current. The frequency is set by three RC networks, each of which consists of a 100 µF capacitor and a 22 kΩ resistor.



Operation is largely independent of supply voltage, and the average LED current is set at about 10 mA. The circuit adjusts the voltage across the emitter resistor so that it matches the base voltage of the first transistor (around 0.6 V). The phase shifting network gives rise to the oscillation around this average value.

In the prototype of this circuit we used an ultra-bright red LED.

(080383-I)

Deluxe '123' Game

Stefan Hoffmann

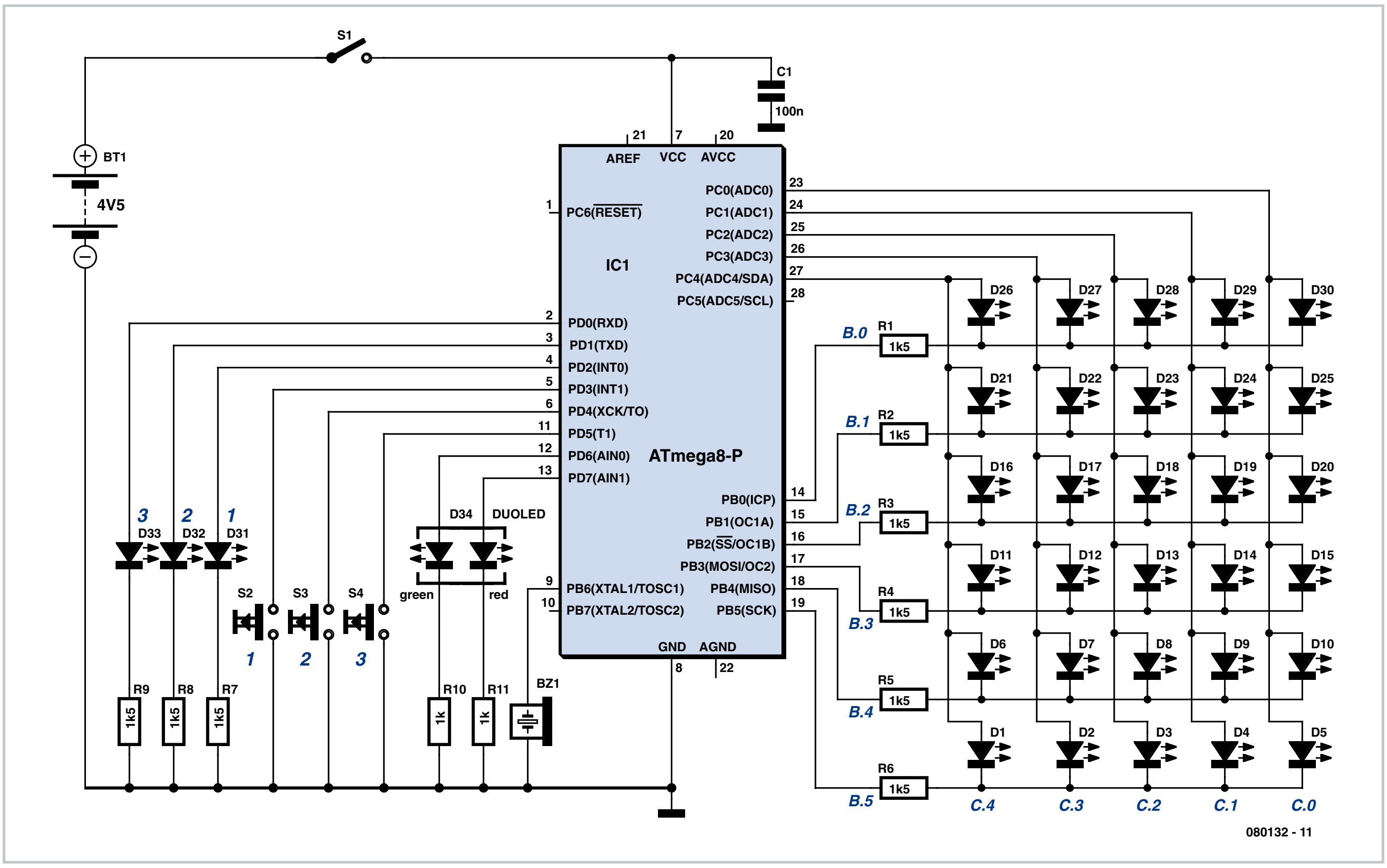
The rules of the '123' Game are described in the '*123 Game – all MCU-free*' article. Naturally, a more luxurious version can be built with a microcontroller. Here you don't have to manipulate a probe tip to play the game, and the playing field is formed by LEDs instead of mini-sockets. A microcontroller drives the LED array, and three input buttons take over the role of the probe tip. In contrast to the simple version, the built-in 'intelligence' of the microcontroller also allows two humans to play against each other.

A 'welcome screen' with various LED patterns is displayed after the circuit is switched on. A bicolour LED then cycles through all three colours (red, green and orange) while waiting for the player to select a game mode:

- Button 1: Human *vs.* MCU; human starts;
- Button 2: MCU *vs.* human; MCU starts;
- Button 3: Human *vs.* human.

The course of play is essentially the same as before. The human player and the computer take turns moving by one, two or three steps. When it's the human's turn to move, he or she presses a button for the desired number of steps ('1', '2' or '3'). The selection steps is confirmed by the '123' LEDs and then performed on the playing field LEDs. The bicolour LED is green when it's the human's turn and red when it's the computer's turn. Purely for effect, the computer does not move right away, but instead 'ponders' a while before moving, and the moves are made slowly, step by step, instead of all at once.
The number of steps the computer wants to move is also shown by the '123' LEDs. The move is then performed on the playing field LEDs. If the human player tries to move past the goal, this is corrected automatically. In the human vs. human mode, the bicolour LED turns orange to indicate that it's the opponent's turn.

The winner is determined by the microcontroller. If the human player wins, the bicolour LED blinks green, and if the computer wins it blinks red. If the opponent wins, the LED blinks orange/red. A beeper gives extra lustre to the 'victory ceremony'. It gives a low beep if the human loses and celebrates a human victory with two high beeps.



The software for the ATmega8 was generated using BASCOM, and it can be compiled with the demo version. The BASCOM source code and a hex file can be downloaded from the www.elektor.com — the archive file number is 080132-11.zip. A pre-programmed microcontroller is also available (order no. **080132-41**).

(080132-1)

Temperature Sensor with 2-Wire Interface

Stefan Dickel

When designing a precision outdoor temperature sensor it is a good idea to electrically isolate the sensor from the signal conditioning circuitry to protect it from voltage spikes such as might be induced by lightning. Digital signal transmission is preferred over analogue as the circuitry is more straightforward, communication is more reliable and subsequent processing of the temperature readings is easier. In the design shown here the signal and the power for the converter circuit are both carried on just two wires.

A type PT1000 temperature sensor is used. This is capable of withstanding temperatures of well over 130 °C (such as might be found in solar heating systems). The voltage dropped across the sensor is taken as input to an Analog Devices AD654 voltage-to-frequency converter. The power rail is then modulated with a square wave signal whose frequency is dependent on the measured temperature. The signal can be carried on a cable over a great distance. At the receiver end an optocoupler provides for electrical isolation.

T1 forms a current source that delivers a constant current of 1 mA into the temperature sensor R2. The current can be adjusted for calibration using trimmer potentiometer P1. The voltage across the sensor is taken to the VIN input (pin 4) of the voltage-to-frequency converter IC1. R4 and C1 are chosen so that the conversion factor is 10 kHz per volt.

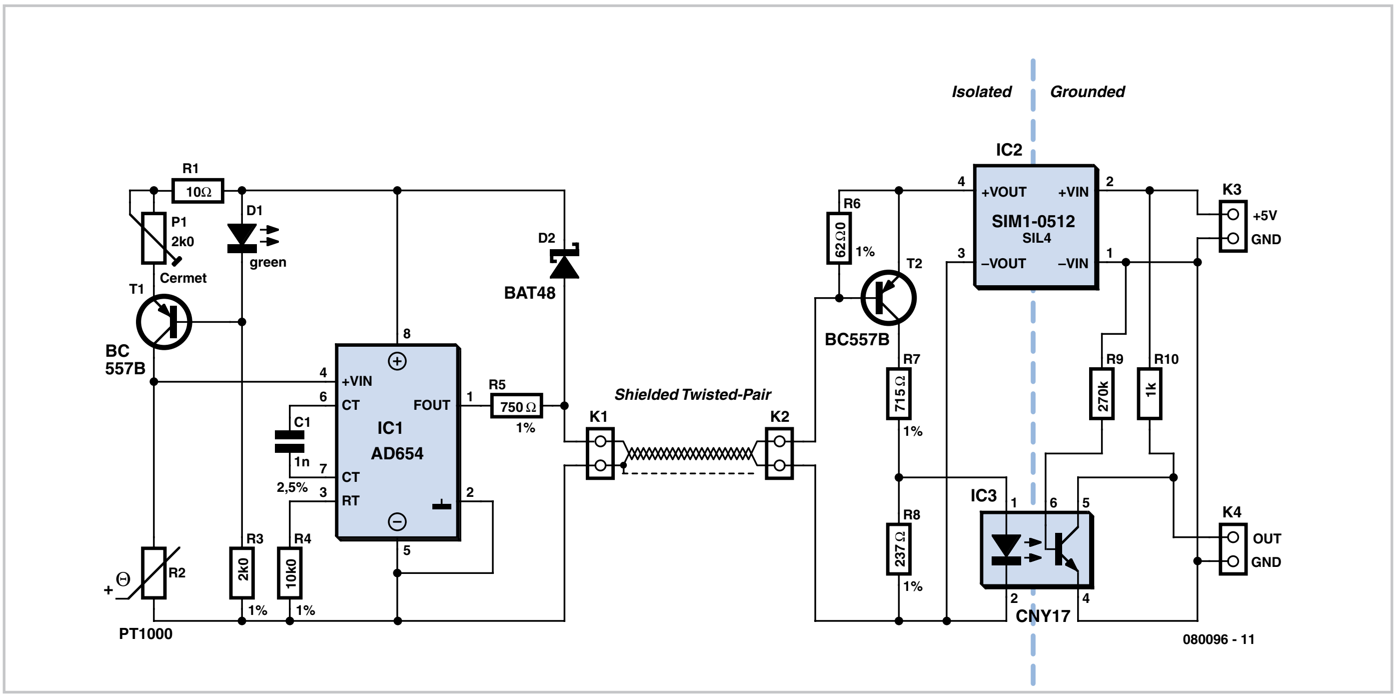
The temperature is given by the formula

$$T = (f - 10000) / 38$$

where T is the temperature in °C and f the frequency in Hz. The frequency therefore ranges from 8.8 kHz (at –30 °C) to 15.7 kHz (at +150 °C).

The output transistor of IC1 has its collector at pin 1 and its emitter at pin 2. Pin 1 is connected to the positive signal line via resistor R5, and pin 2 is taken directly to the negative signal line.

The demodulation function is carried out by the circuit around T2. The value of the current sense resistor R6 is chosen so that when converter IC1 is in its quiescent (off) state T2 is not switched on. When the output transistor of the converter turns on, extra current is drawn from the supply via R5, making the total current drawn considerably higher. In turn, the voltage drop across R6 increases significantly and T2 is turned on. A large collector current now flows through R7, R8 and the LED inside optocoupler IC3. The phototransistor inside the optocoupler is now also turned on.



Finally, at connector K4 the signal is available with a low impedance, suitable for further processing.

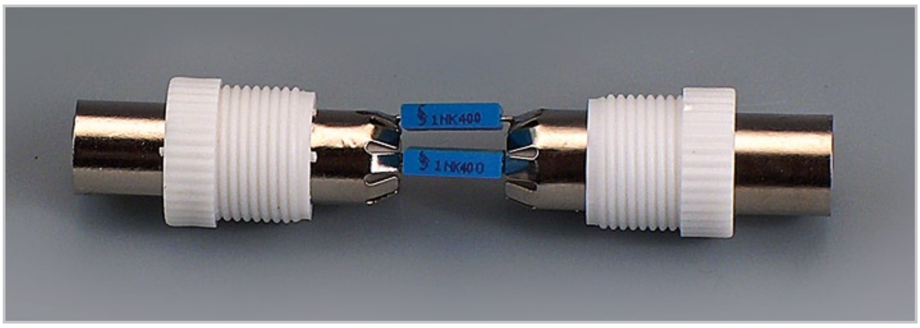
So that we can arrange for the circuit to operate from a single supply we use an isolating DC-DC converter. This not only provides the 12 V needed by the sensor circuit, but also offers up to 1000 V of electrical isolation.

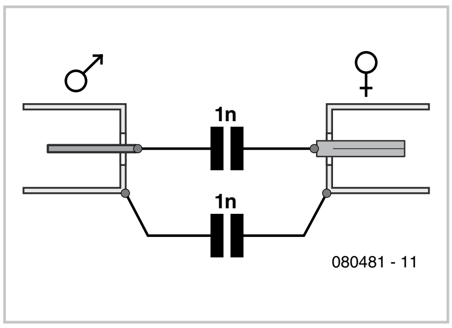
(080096-I)

Video Isolator

Harry Baggen

These days many more audio-visual devices in the home are connected together. This is especially the case with the TV, which may be connected to a DVD player, a hard disk recorder, a surround-sound receiver and often a PC as well. it's highly likely that the PC has a TV-card, which again is connected to the same system. On top of this, there are many analogue connections between these devices, such as audio cables. The usual result of this is that there will be a hum in the audio installation, but in some cases you may also see interference on the TV screen.





This often creates a problem when earth loops are created in the shielding of the video cables, which may cause hum and other interference. The surround-sound receiver contains a tuner that takes its signal from a central aerial distribution system. The TV is also connected to this and

The ground loop problem can be overcome by galvanically isolating the video connections, for example at the aerial inputs of the surround-sound receiver and the TV. Special adaptors or filters are sold for this purpose, known as video ground loop isolators.

Good news: such a filter can also be easily made at home by yourself. There are two ways in which you can create galvanic isolation in a TV cable. The first is to use an isolating transformer with two separate windings. The other is to use two coupling capacitors in series with the cable. The latter method is easily the simplest to implement and generally works well enough in practice.

The simplest way to produce such a 'filter' is as an in-line adapter, so you can just plug

it onto either end of a TV aerial cable. The only requirements are a male and female coax plug and two capacitors. The latter have to be suitable for high-frequency applications, such as ceramic or MKT types. It is furthermore advisable to choose types rated for high voltages (400 V), since the voltages across these capacitors can be higher than you might expect (A PC that isn't connected to the mains Earth can have a voltage as high as 115 V (but at a very low, safe current), caused by the filter capacitors in its power supply.
These capacitors don't need to be high value ones, since they only have to pass through frequencies above about 50 MHz. Values of 1 nF or 2.2 nF are therefore sufficient.

To make the isolator you should connect one capacitor between the two earth connections of the coax plugs and the other between the two signal connections. The mechanical construction has to be sturdy enough such that the connections to the capacitors won't break whenever the in-line adapter is removed forcibly. A good way to do this is to make a cover from a piece of PVC piping for the central part. Wrap aluminium foil round the outside and connect it to one of the plugs, so that the internal parts are properly shielded from external interference. Make sure that the aluminium foil doesn't make contact with the other plug, otherwise you lose the isolation.

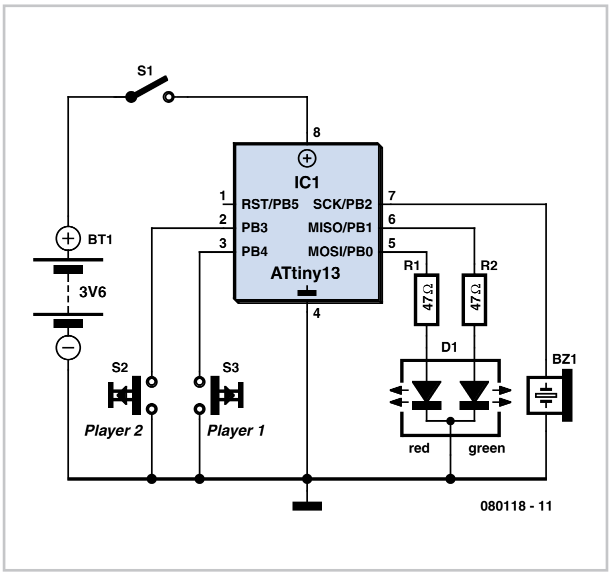
The majority of earth loops will disappear when you connect these filters to all used outputs of the central aerial distribution system where the signal enters the house.

(080481-I)

Reaction Race using ATtiny13

Stefan Hoffmann

This is a reaction timer game between two players, red and green. Each player has a pushbutton in front of him that he must press at just the right moment: not too early and not too late. The aim is to be the first to press the button. The 'right time' is indicated by a multi-colour LED.
Each round of the game runs as follows: after a welcome pattern (flashing red and green, playing two tones), the LED starts to blink red slowly. A player who presses during this phase (too early) is 'punished' by a low-pitched tone and the lighting of the LED in his colour.



After a random time period the LED turns yellow. The first to press during this period is the winner and is rewarded by a rapid flashing of the LED. If the LED goes out again before either player has pressed his button, it is too late and another round of the game starts.
As a glance at the well-commented source code for the microcontroller software shows, the sequence of events and their timing can easily be adjusted as required. Source and object code files are as usual available for free download from the Elektor website (http://www.elektor.com). Ready-programmed microcontrollers are also available.

(080118)

48-V Microphone Supply

Joseph Kreutz

48 V 'phantom' powering has become the standard for professional condenser microphones. The supply (or rather bias) voltage is applied over both wires of the balanced screened cable via two 6kΩ8 resistors (see reference [1]) – the absolute value is not critical, since a variation of ±20% is permitted, but they must be matched to an accuracy of 0.4% or better [2]. Many microphones are fitted with an output transformer, and derive their power from a centre tap on the secondary. If the currents supplied by the two wires of the balanced line, which flow in opposite directions through the two halves of the secondary winding, are not identical, the magnetic fluxes they induce in the core of the transformer do not cancel out properly, and spurious magnetization occurs, causing distortion and a reduction in the microphone's dynamic range.

With an output current of 0.4 A, the PSU described in this article can 'supply' at least 40 microphones. The mains voltage is applied to a 30 VA transformer which supplies 24 V_{rms}. Its secondary feeds a voltage doubling rectifier formed by diodes D1 and D2 and capacitors C3 and C4. Capacitors C1 and C2 suppress the switching noise produced by the rectifier diodes. This voltage-doubling rectifier provides around 72 VDC, and so offers an adequate margin to allow for ±10% fluctuations in the mains voltage.

Voltage regulation is taken care of by

TL783KC regulator IC1 on which an abundant amount of information may be found at [3]. Basically, this is an adjustable regulator in a TO220 package that offers excellent residual ripple and low noise on its output voltage. The TL783KC regulator includes a MOS series pass transistor and accepts an input voltage of up to 125 V, making it an ideal candidate for this application. Diodes D3 and D5 respectively protect the PSU against transients at switch-off and reversed polarity.

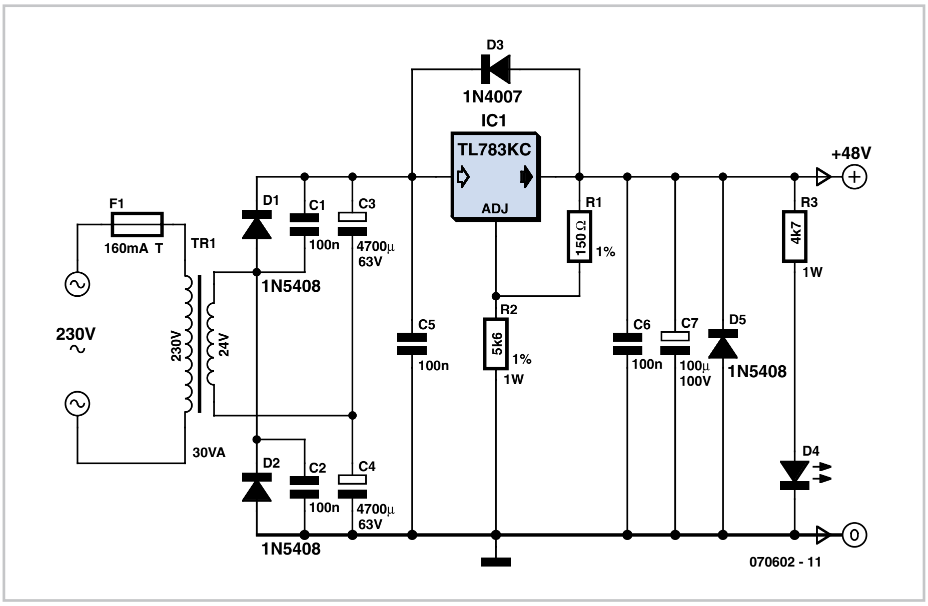
The output voltage is set by resistors R1 and R2 according to the formula:

$$V_{out} = V_{ref} \times (1 + R2 / R1)$$

where reference voltage V_{ref} = 1.27 V.

These resistors should preferably have a tolerance of 1%, and R2 is likely to dissipate 0.5 W. Resistor R3 provides a minimum load that is vital for maintaining the PSU's off-load voltage at 48 V, and is also used to supply LED D4. If the LED is not used, R3 must without fail be connected to ground.
Last but not least, regulator IC1 must be mounted on a heatsink with a thermal resistance of less than 1.5 °C/W using the standard insulating kit: top-hat insulating washer, mica washer, and heat sink compound... make sure you use enough, but not too much!

(070602-I)



Bibliography and Web Links

[1] Microphone Essays, p. 83. Jörg Wuttke, www.schoeps.de/E-2004/miscellaneous.html
(11 MB document in German, downloads via links at bottom of page)

[2] DIN EN 61938 standard

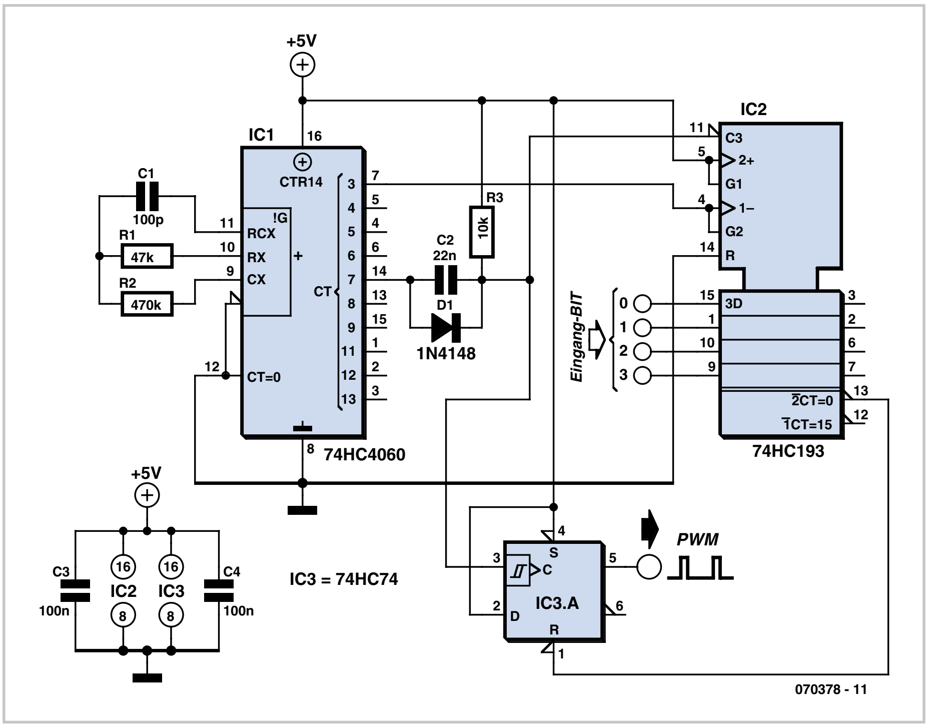
[3] http://focus.ti.com/docs/prod/folders/print/tl783.html

[4] http://en.wikipedia.org/wiki/Phantom_power

Discrete PWM Generator

Alexander Wiedekind-Klein

PWM waveforms are commonly used to control the speed of DC motors. The mark/space ratio of the digital waveform can be defined either by using an adjustable analogue voltage level (in the case of a NE555 based PWM generator) or digitally using binary values. Digitally derived PWM waveforms are most often produced by the timer/counter modules in microcontrollers but if you do not want to include a microcontroller in your circuit it's also quite simple to generate the signals using discrete logic components. An extension of the circuit shown can produce two PWM waveforms from an 8-bit digital input word. Each signal has 15 values. The 8-bit word can be produced for example from an expansion board fitted in a PC or from an 8-bit port of a processor which does not have built-in PWM capability or from a laptop's printer port.



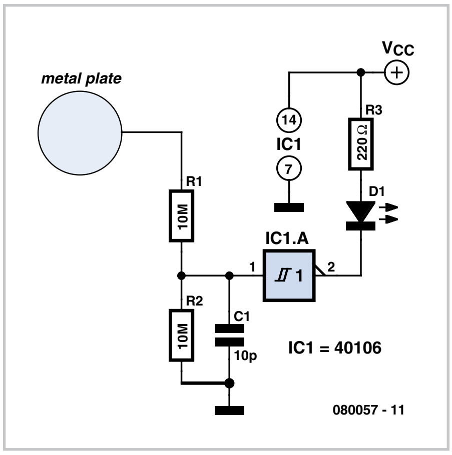
The mark/space ratio is only programmable up to 15/16 rather than 16/16; a binary input of 0000 produces a continuous low

on both outputs turning both motors off. Similar circuits often employ a dedicated 'enable' input to turn the motors off but it is not necessary in this design.
The diagram shows the circuitry required to produce just one waveform. For the full two channel circuit it is necessary to use an additional 74HC193. The clock signal produced by the HCF4060 generator can be used to drive both channels and the free flip flop in the 74HC74 package can be used for the second channel (the corresponding pin numbers are shown in brackets). Altogether the entire two channel circuit can be built using just four ICs.

(070378-I)

Simple One-wire Touch Detector

Lars Näs



This simple circuit can be used to activate whatever you like, for example, by connecting it to microcontroller, relays, secret alarms, robot applications or just turn on LED1 which lights up as long as you touch the metal plate.
The circuit consists of voltage divider R1 and R2, one Schmitt trigger/inverter gate from a 40106 IC, a small capacitor to keep strong RF at bay and LED1 with current limiting resistor R3.
The metal plate is connected via a wire to R1. R1 and R2 together form a voltage divider. Since the current from your body is very small it's understood that R2 has a high value like 10 Megohm to maximise the voltage over R2 so it can be detected by input pin 1 of gate IC1.A. R1 has been added to prevent electrostatic discharge (ESD) energy from damaging the inverter gate input. ESD may occur when you have been charged with an amount of electro static energy by walking on a carpet with rubber soles. You can increase the sensitivity of the detector by experimenting with lower values fore R1 e.g. 1 kΩ and a smaller metal plate.
The value of pull-up resistor R3 is calculated such that the current through LED1 is below its maximum continuous rated value. Most regular LEDs are 20 mA types.
The circuit still works if you remove LED1 and just have the pull-up resistor R3 connected to output pin 2 and then connect a microcontroller input pin directly to pin 2. Do check however that the microcontroller has a weak pull-up (i.e. to $+V_{DD}$) at its port line.

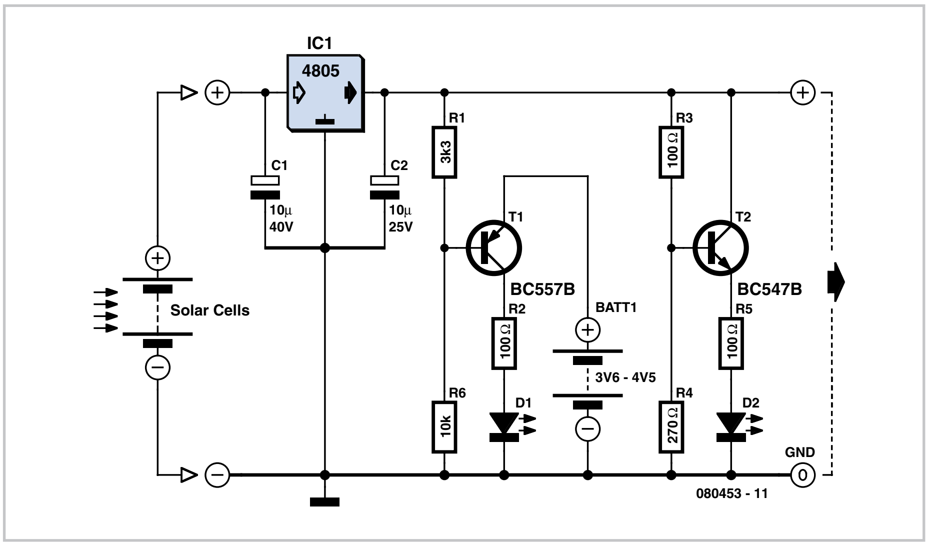
(080057-I)

Solar Cell Voltage Regulator

Reuben Posthuma

This device is designed to be a simple, inexpensive 'comparator', intended for use in a solar cell power supply setup where a quick 'too low' or 'just right' voltage indicator is needed. The circuit consists of only one 5-V regulator, two transistors, two LEDs, five resistors, two capacitors, and one small battery. Although a 4-V battery is indicated, 4.5 V (3 alkalines in series) or 3.6 V (3 NiCd cells in series) will also work.

The specifications of voltage regulator IC1 are mainly determined by the size and number of the solar cells and the current pull of the equipment connected to the output. Here the low-drop 4805 is suggested but other regulators may work equally well as long as you observe the output voltage of the solar cells.



Transistors T1 and T2 are complementary types i.e. one each of the pnp and npn vari-

ety. Although the ubiquitous BC557B (pnp) and BC547B (npn) are indicated, any small-signal equivalents out of the junk box will probably do. The values of voltage dividers R1/R6 and R3/R4 may need to be adjusted according to the type of transistor and its gain, or according to the desired voltage thresholds. Using the resistor values shown in the schematic, LED D2 turns on fully when the voltage is just above 5 volts. LED D1 turns on when the voltage drops below 4.2 volts or so. Between those two thresholds, there is a sort of no man's land where both LEDs are on dimly.
A buzzer or other warning device could be connected across the terminals of LED D1 to give a more substantial warning if the voltage drops below operating limits.

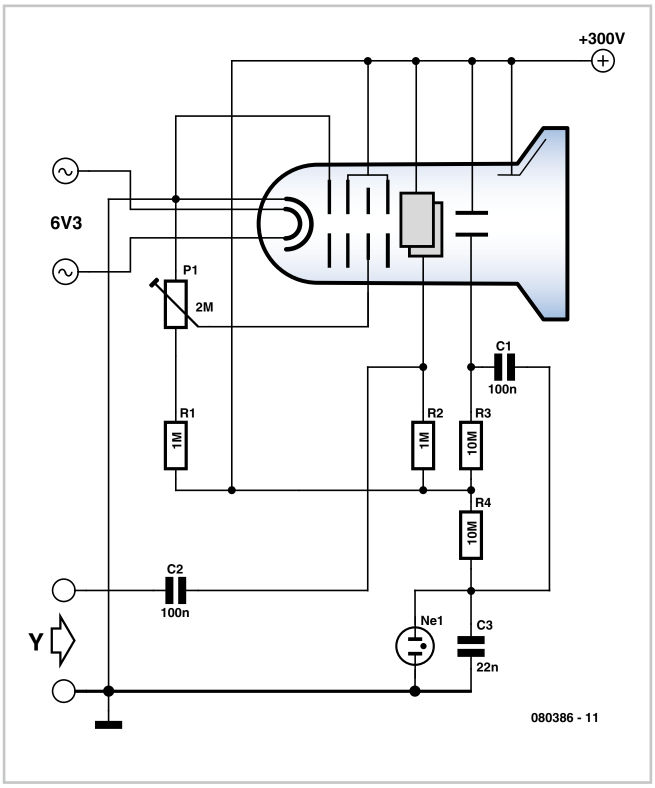
The current consumption of the circuit is about 20 mA at 5 V, and it decreases with the voltage supplied by the solar cells.

(080453-I)

Minimalist Oscilloscope

Burkhard Kainka

If you are the proud owner of an old oscilloscope tube, you may be interested in using it once more for its original purpose. All you need are the right voltages on the right pins: in practice you may need to peer closely inside to find out which pins on the base correspond to the acceleration and deflection electrodes, in particular if there is no part number to be seen on the tube. The tube we had for experimental purposes was a 7 cm model of unknown provenance.



So the first step is to establish which pins correspond to the heater, cathode, grids, deflection plates, and anode. With this done we can make our simple oscilloscope as follows: connect the Y input via a suitable capacitor to one of the Y deflection plates; for X deflection we use a neon lamp oscillator to generate a timebase; and with a focus regulator circuit we have a complete oscilloscope.

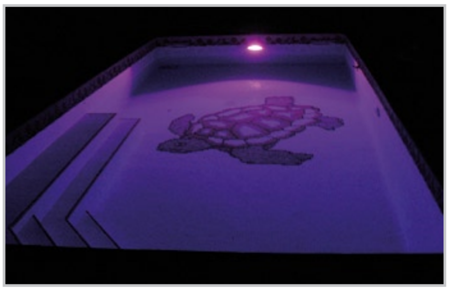
Operation of the horizontal deflection oscillator is visible as the gentle flickering of the neon lamp. Whenever the voltage across the parallel-connected capacitor reaches the strike voltage of the lamp, it is discharged with a brief pulse of current. It is hard to imagine a simpler way to generate a sawtooth waveform. The supply voltage of 300 V is adequate for simple experiments, even if the tube is rated for operation at 1000 V or even more.

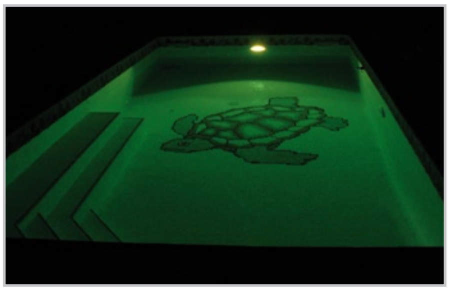
Now, if a signal is applied to the Y input, we should be able to see the waveform on the screen.

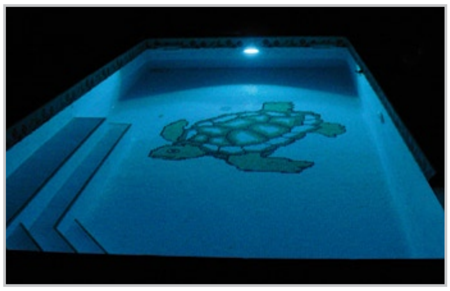
It must be admitted that the design's sensitivity, linearity, trace size, bandwidth and triggering facilities leave a little to be desired. Nevertheless we have shown how little circuitry is required to make a real working oscilloscope.

(080386-I)

Underwater Magic

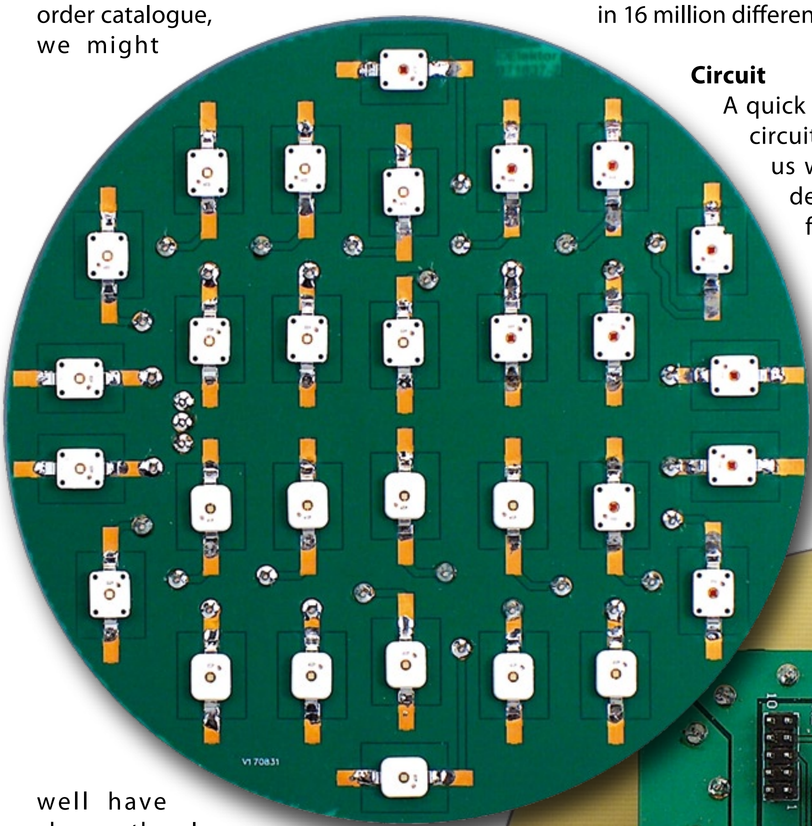


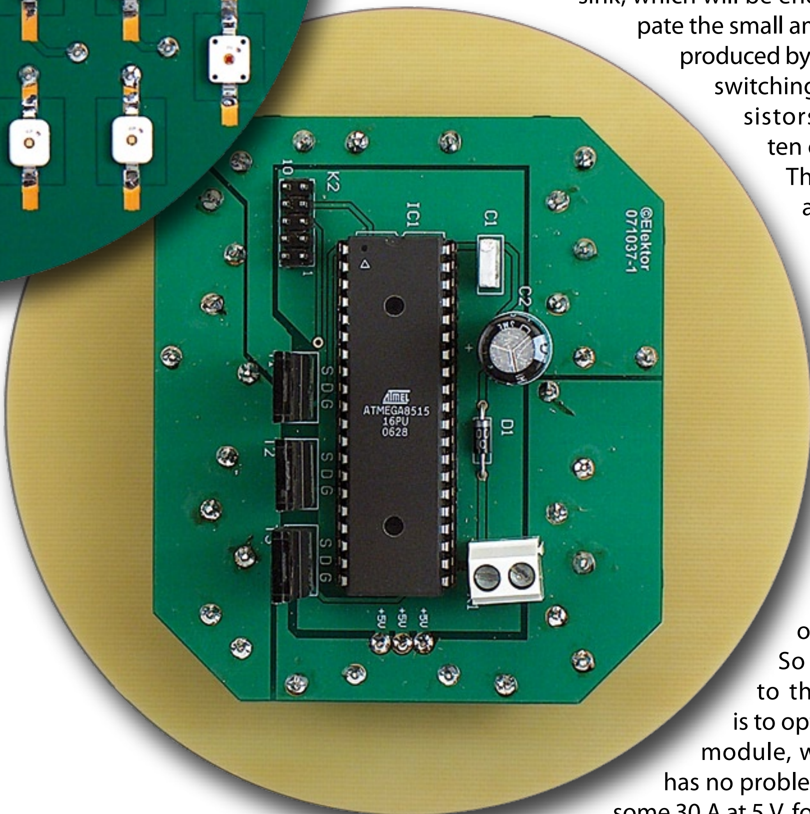




Ludovic Mézière

If we were looking for a slogan to sell this project in some mail-order catalogue, we might well have chosen the slogan "16 Million Colours in the Water in Your Swimming Pool" as its subtitle. In just a few months, we've seen increasingly 'visible' applications for (high) power LEDs. After all, was it not Philips that paid for the illuminations on some of the most famous avenues in the world?
The author of this project took it into his head to give a festive look to his swimming pool as cheaply as possible. The use of a ready-made PC PSU module to supply the power makes it possible to reduce the overall cost of this project very significantly.





Principle

Three PWM (pulse width modulation) generators drive three groups of high-brightness red, green, and blue LEDs using an 8-bit word per colour – which theoretically gives the possibility of lighting the water in 16 million different shades.

Circuit

A quick glance at the circuit might make us wonder if the designer hasn't forgotten something, given the excellent 'readability' of the electronics employed. A microcontroller and no less than three strips of ten or so LEDs, each with its own dropper resistor. Each strip is driven by a transistor, and there you have all the ingredients of this recipe.

The potential of microcontroller IC1, an AT90S8515P from Atmel, is admittedly under-exploited, but the choice of it is justified by the presence of three PWM drivers in the same package, as well as by its very affordable price and excellent availability. The board has an ISP connector (In System Programming), K2, to allow for future software updates.

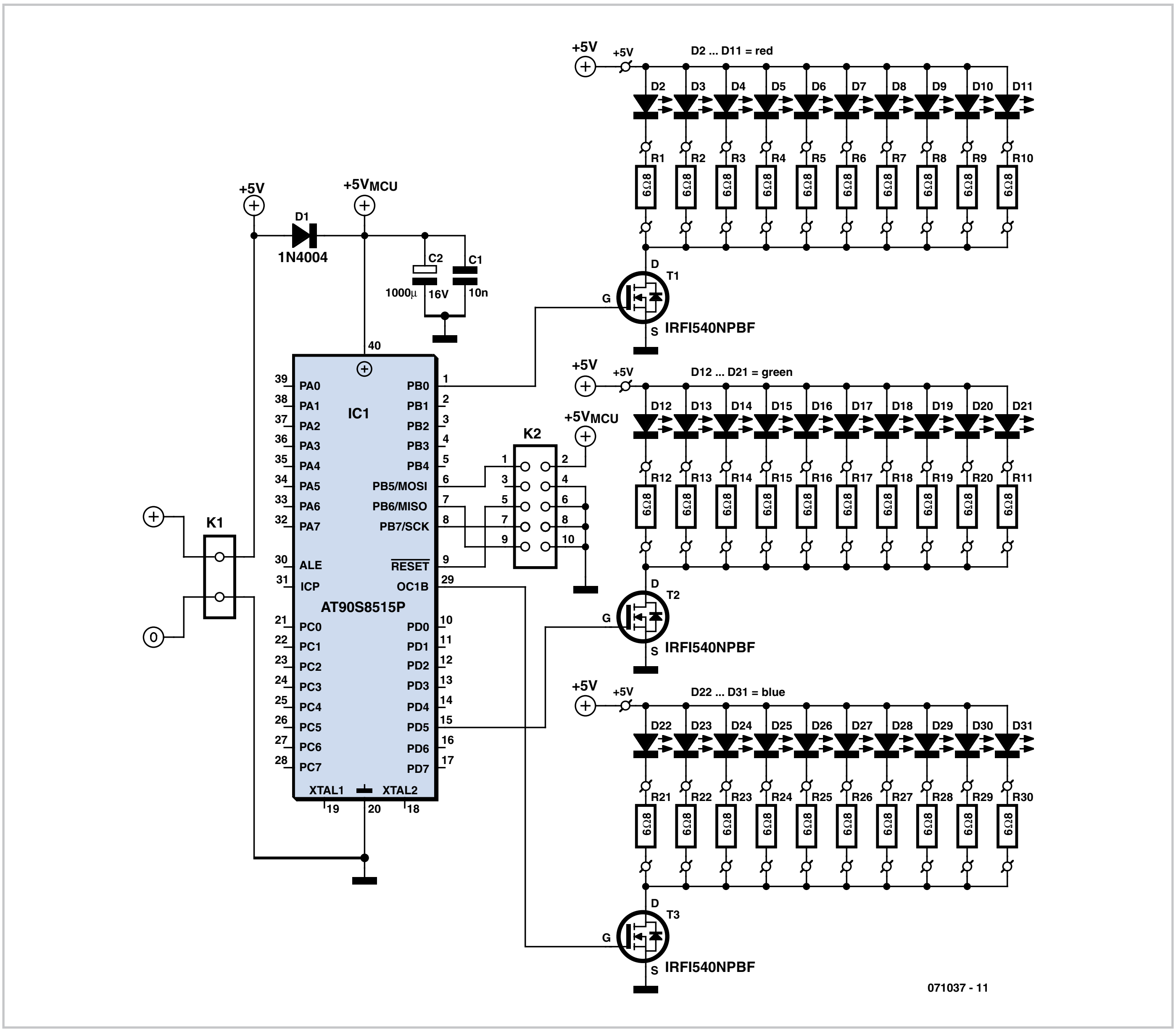
The three PWM outputs drive type IRFI540NPBF MOSFET transistors T1–T3, which have a power dissipation rating that's easily sufficient for this application. You may like to fit them with a small heatsink, which will be enough to dissipate the small amount of heat produced by the transistor switching. These transistors each drive ten or so LEDs. The spot draws a whopping maximum current of nearly 10 amps at 5 V, meaning that a powerful PSU is needed. Building one yourself would turn out expensive. So the solution to this cost issue is to opt for a PC PSU module, which usually has no problems providing some 30 A at 5 V, for only a modest sum. And there you have it — everything has been said that needs to be about the electronics employed. The aspect we're going to tackle in the next paragraph is very important, given its implications…

Construction

As shown in the introductory photo, the whole of the electronics fits onto a pair of printed circuit boards. The LED board is round so it can be fitted easily into a cylindrical body that will conveniently slide into a masonry orifice provided for it in the wall of the swimming pool. The second, smaller board is rectangular, with truncated corners, and it carries the power electronics. The dropper resistors in the LED supply lines also act as spacers for the two boards. The first step in construction is to fit the thirty LEDs on the track side of the round board. Take care to get the polarity correct. This done, we end up with a board as shown in the second photo. You can then move on to fitting the resistors, which should be pushed fully home into the holes provided for them on the LED board and then be soldered into place. The 3 remaining adjacent lands close to the microcontroller and marked '+5V' should be fitted with a piece of insulated solid wire the same length as the final spacing of the two boards.

Now it's time to move on to building the controller board. IC1 could be fitted into a socket (with spring contacts) just in case. Start by soldering the smaller components, capacitors, diode (only fitted if the voltage supplied by the PC PSU is being increased, see next paragraph; otherwise replaced by a wire link). Next, fit the transistors (paying attention to their orientation – their heatsinks should face the outside of the board) and socket K2 (fitting it later once the two boards are piggy-backed is tricky because of the difficulty of access under the controller board).

Once the two boards are built and after having taken the trouble to check your work, you'll be able to mount the controller board piggy-back onto the LED board, taking care to leave a certain distance between them so as to ensure a little air circulation (confined). To do this, all you need do is to slip the leads of the 3 W resistors fitted to the LED board into the corresponding holes all round the edge of the controller board. This operation requires a certain dexterity; you can insert the leads of the first row of resistors, then angle the board slightly so as to insert the leads of the next resistors, cut 2 or 3 mm shorter, and so on. Once all the resistors are in place, you can solder them and trim the leads off.



Now let's move on to the PC PSU module, which needs a little 'check-up' – in fact, it needs a slight modification: its green lead (signal: ps_on) must be connected to ground to enable the power supply to start up. Keep only all the black leads (ground) and all the red leads (+5 V) — the other output wires/leads can all be cut off.

The available power supply allowing, it's worth increasing the 5 V level up to 5.6 V by adjusting the potentiometer in the regulator circuit – this will increase the brightness of the LEDs a little bit. If the voltage is increased in this way, the microcontroller supply is brought back down to 5 V by the use of series diode D1 in the microcontroller supply line. Clearly, if the voltage is not adjusted, D1 should be omitted and a wire link fitted in its place.

This done, the 5 V lines from the PC PSU can be connected to the controller board. It is fitted with a connector, K1, for this purpose, in the form of a pair of pins. Take care to correctly identify the positive (+, closest to the silk-screened legend K1 and the microcontroller) and negative poles (–, the other pin). The three points marked '+5V' should have already been connected to the matching points on the LED board when the two boards were connected together.

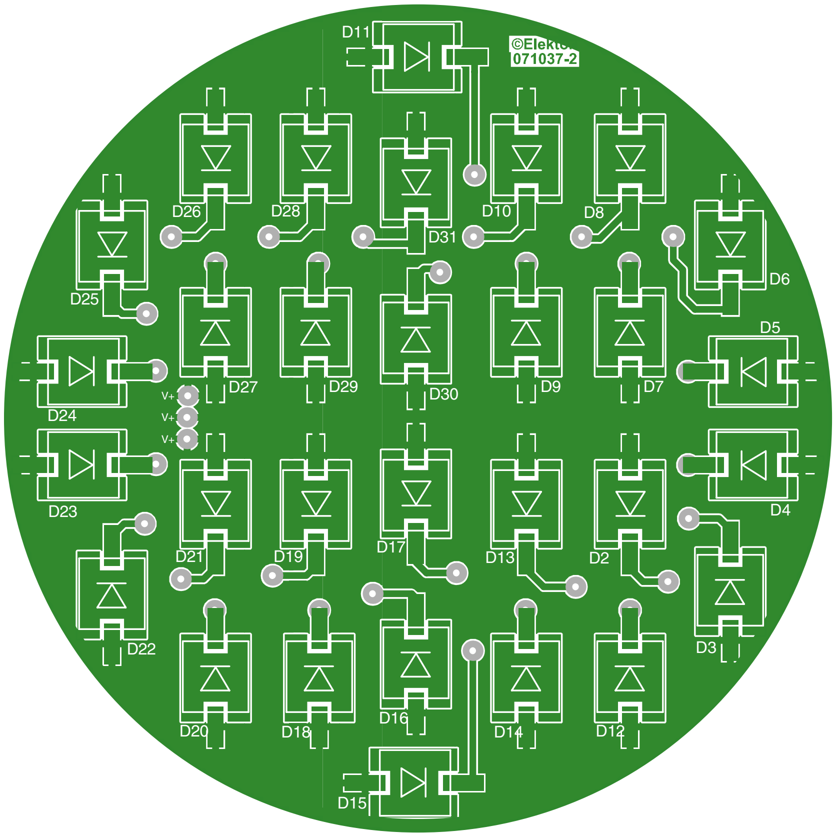
Now all that remains, after checking the quality of your work one last time, is to try it out for the first time. Whatever you fancy, don't look straight at the front side of the LED board (to see if all the LEDs are working!). It should be obvious if it's working OK, the light will gradually change colour. But don't expect to be able to see all 16 million different shades ;-).

Installation

The spotlight should be fitted into a position provided for it in the swimming pool, either in place of a standard spot, or, as the author did, in place of the return flow of a swim-jet system. A sheet of Perspex® fastened using nylon bolts with a silicone seal will ensure it is nice and watertight. A sheet of 'White Frost' – a type of diffusing filter used in video – is fitted behind the plastic window for better diffusion of the light from the LEDs. The PSU module is fitted well out of harm's way in the pool pump space, connected to the piggy-backed boards via an extension of a few metres. To avoid excessive volts drop, this extension should use the thickest cable practical.

Software

The software written for the microcontroller to execute is very simple. It includes



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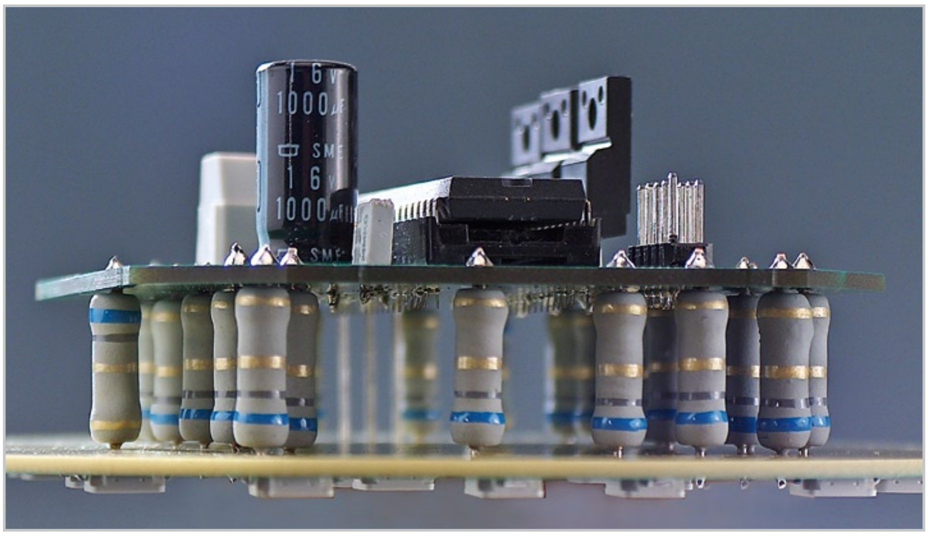


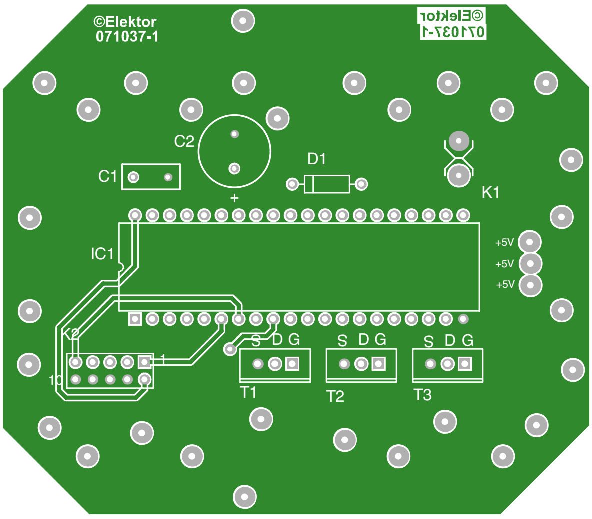
COMPONENTS LIST

Resistors
R1-R30 = 6Ω8/3 W

Capacitors
C1 = 10nF
C2 = 1000 µF 16V radial

Semiconductors
D1 = 1N4004
LED1 - LED10 = Golden Dragon blue LB-W5KM-EZGY-35 from OSRAM
LED11 - LED20 = Golden Dragon green LT-W5KM-HZKX-25 from OSRAM
LED21 - LED30 = Golden Dragon red LR-W5KM-HXJX-1 from OSRAM
T1 à T3 = IRFI540NPBF, isolated
IC1 = AT90S8515P, Atmel, programmed with hex file from archive 071037-11.

Miscellaneous
K1 = 2 solder pins
K2 = 10-way DIL (2x5) pinheader
Heatsink for the 3 transistors (optional)
PC power supply
PCBs, ref 071037-1 (controller) and 071037-2 (LED) available from www.thepcbshop.com



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several subroutines whose function is to light or extinguish a colour instantaneously, and light or extinguish a colour in progressive mode. The primary loop calls these subroutines to create the effects. Each PWM (pulsewidth modulation) receives a value between 00 and FF that determines the mark/space ratio of the signal driving the bases of the transistors. The first part of this loop makes the spot change gradually from one colour to another by combining the three primary colours. The second part, much more dynamic, comprises coloured flashes that appear faster and faster until you get a near-stroboscopic effect.

Results

As shown in the photos, at night the result is impressive. The cat seems to likes it a lot, too, though the wavelength of the red light is soon attenuated as it travels through the water.

(071037-I)

Web Links

[1] AT90S8515P datasheet

www.atmel.com/dyn/resources/prod_documents/DOC0841.PDF

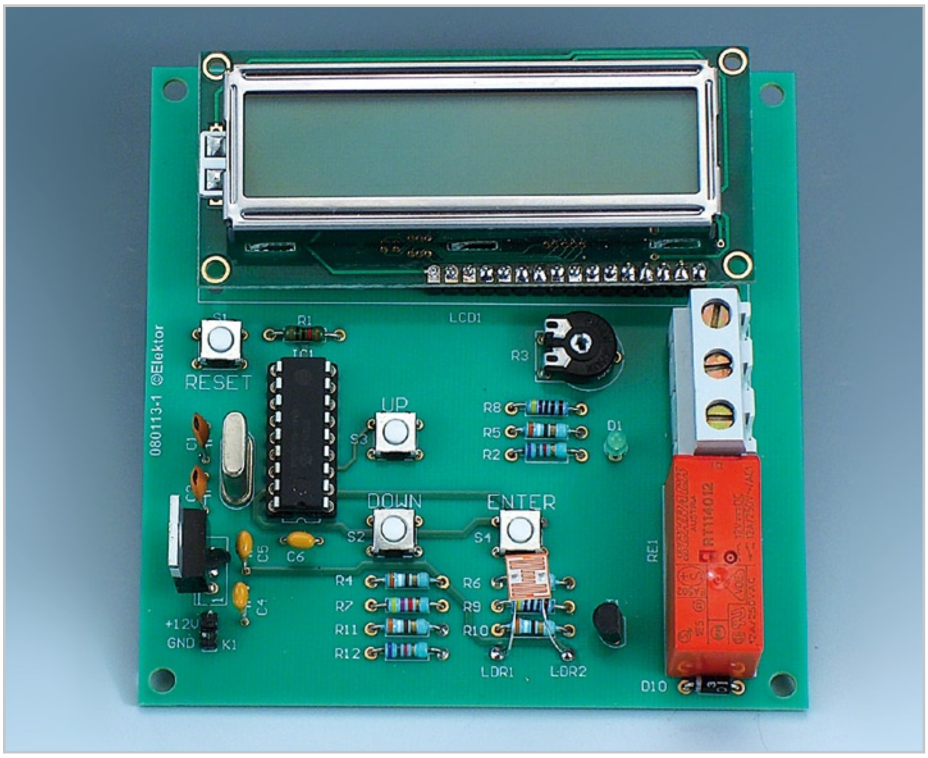
Downloads

The artwork for the two PCBs (071037-1 and 071037-2) can be downloaded from the Elektor website at www.elektor.com.

The source code and .hex files for this project (071037-11.zip) are also available from www.elektor.com

Flowcode for Garden Lighting

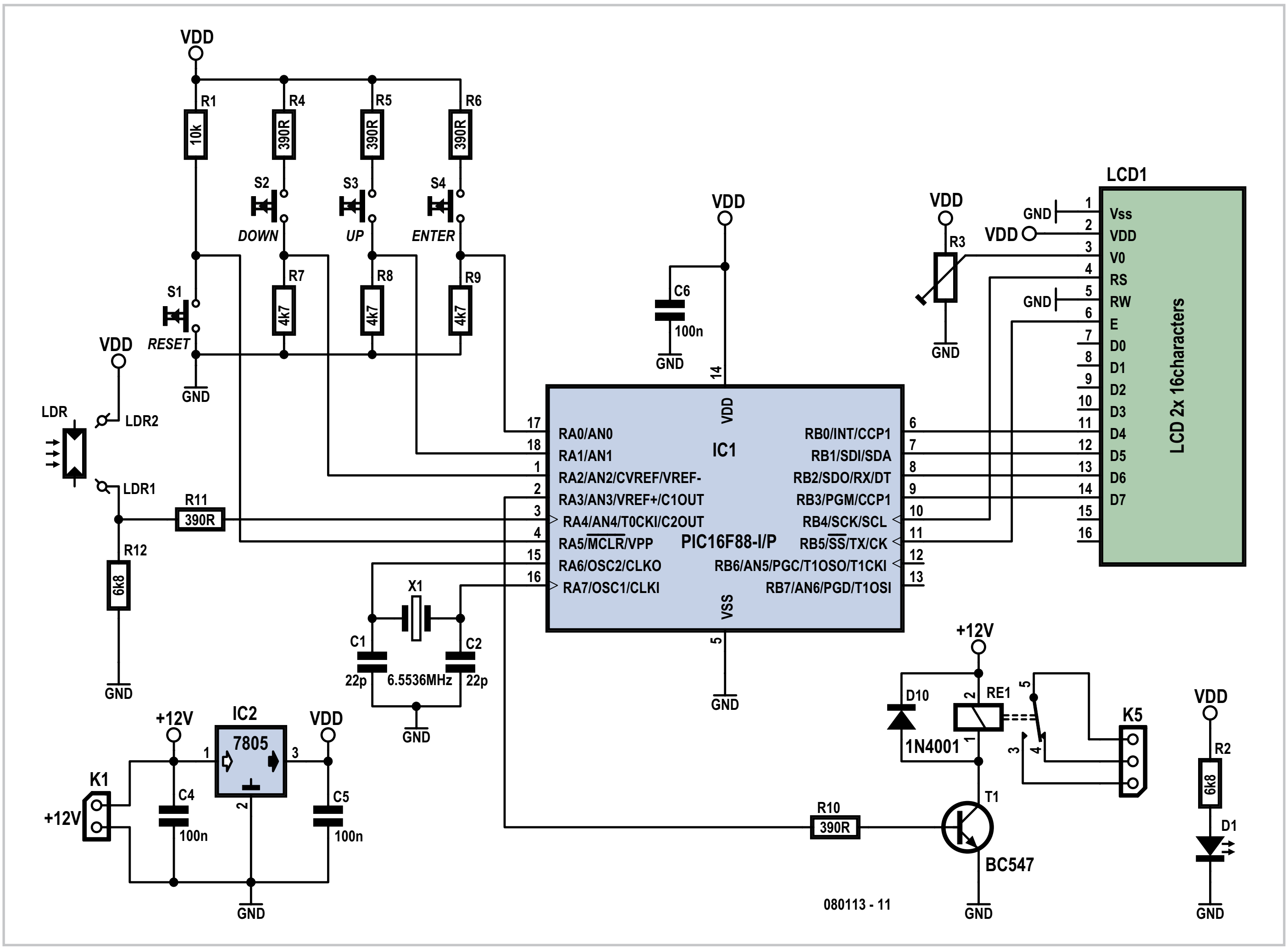
Jan Middel



Flowcode is well known from the many 'E-blocks' projects that have been published by *Elektor* over the last few years. This year's Summer Circuits also has a project that is programmed using Flowcode. The circuit presented here uses a microcontroller programmed with Flowcode to turn garden lights on and off at user-definable times.

At the hart of the circuit is a PIC16F88 microcontroller. It uses a 2 line by 16 character display to show the settings. These can be adjusted using a set of three push buttons. Potentiometer P1 is used to adjust the contrast of the display. Output RA3 of the PIC is used to drive transistor T1, which in turn drives a relay that turns the lights on and off.

The supply voltage is stabilised using a standard 7805 voltage regulator IC. S1 is the reset switch, which is connected to the MCLR input of the PIC. MCLR should be



'high' during normal operation (and 'low' for a reset). Hence this input has been connected to the positive supply voltage via pull-up resistor R1.

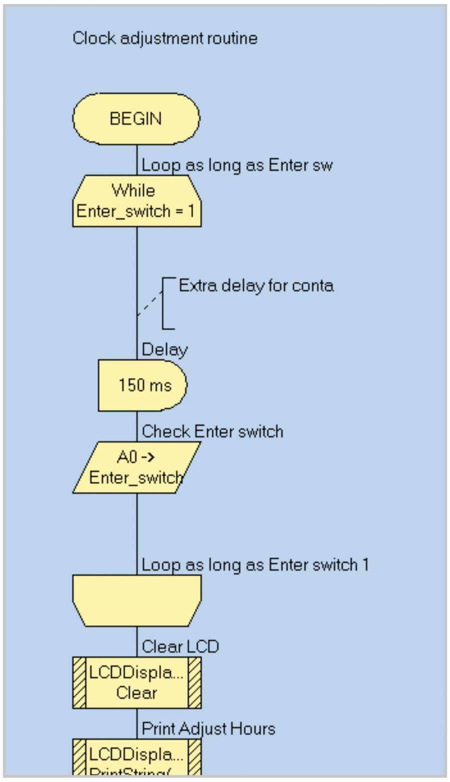
A program has been written in Flowcode that activates the relay when the following conditions apply:

- when it is later than 16:00;
- when the amount of light reaching the LDR is less than an adjustable threshold;
- during the morning between seven and eight o'clock;
- at night the relay is turned off at 23:00 (except on Friday, Saturday or Sunday, when the lights stay on one hour longer).

During the day the display shows at what time the garden lights were last turned on.

The following procedure should be used to set the time: press the Reset switch; the program then shows a welcome message. Next, press the Enter switch. Use the Up and Down switches to set the correct value for the hours. Press the Enter switch to set the minutes (in the same way as for the hours). After pressing Enter again, you are asked for a value for the light threshold. This value is compared with the amount of light falling on the LDR. When the value of the LDR becomes less than the threshold the lights come on.

Another press of the Enter switch takes you to the day-of-week setting. This determines the days when the light stays on for longer at night. A final press of the Enter switch then starts the clock.



It is of course possible to modify the software in certain places. You could for example change the time at which the lights come on in the morning. This function could even be removed completely if you have no need for it.

(080113-I)

Downloads

The Flowcode (.fcf) file for this project, 080113-11.zip, is available on the Elektor website as a free download, as is the layout for the printed circuit board (080113-1.zip).

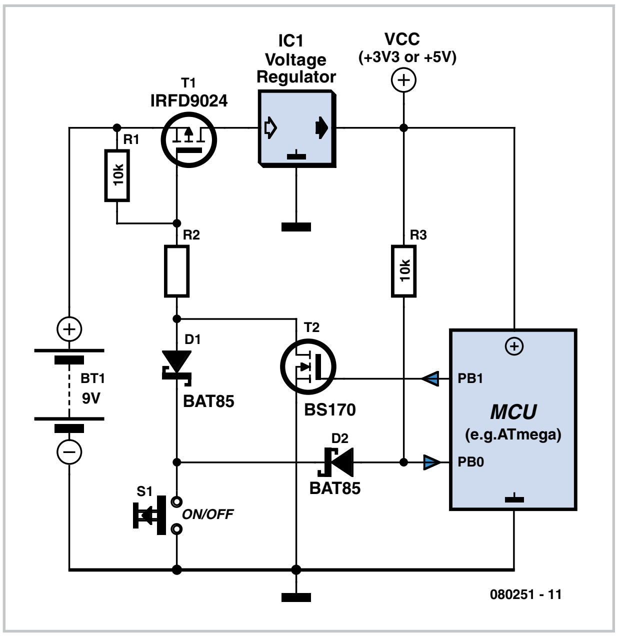
The Gentle Touch

Rainer Reusch

Consumer appliances these days hardly ever have a proper mains switch. Instead, appliances are turned on and off at the touch of a button on the remote control, just like any other function. This circuit shows how a device (as long as it does not draw too high a current) can be switched on and off using a pushbutton.

The approach requires that a microcontroller is already available in the circuit, and a spare input port pin and a spare output port pin are required, along with a little software.

When power is applied T1 initially remains turned off. When the button is pressed the gate of T1 is taken to ground and the p-channel power MOSFET conducts. The microcontroller circuit is now supplied with power. Within a short period the microcontroller must take output PB1 high. This turns on n-channel MOSFET T1 which in turn keeps T1 turned on after the pushbutton is released.



Now the microcontroller must poll the state of the pushbutton on its input port (PB0) at regular intervals. Immediately after switch-on it will detect that the button is pressed (a low level on the input port pin), and it must wait for the button to be released. When the button is next pressed the device must switch itself off: to do this the firmware running in the microcontroller must set the output port pin to a low level. When the button is subsequently released T1 will now turn off and the supply voltage will be removed from the circuit.

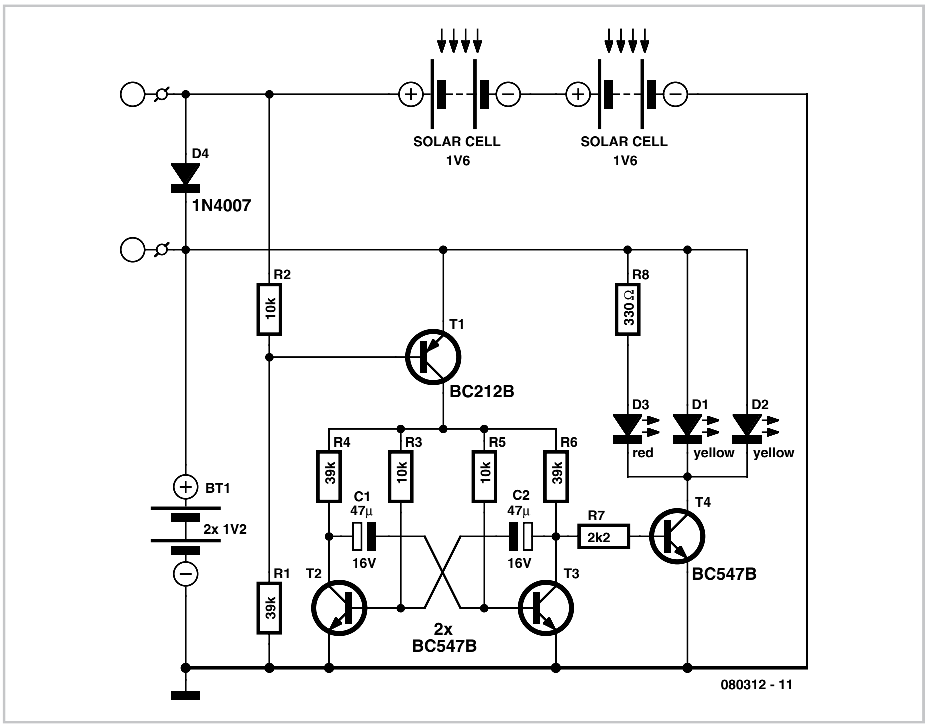
The circuit itself draws no current in the off state, and for (rechargeable) battery-powered appliances it is therefore best to put the switch before the voltage regulator. For mains-powered devices the switch can also be fitted before the voltage regulator (after the rectifier and smoothing capacitor). Since there is no mains switch there will still be a small standby current draw in this case due to the transformer. Be careful not to exceed the maximum gate-source voltage specification for T1: the IRFD9024 device suggested can withstand up to 20 V. At lower voltages R2 can be replaced by a wire link; otherwise suitable values for the voltage divider formed by R1 and R2 must be selected.

The author has set up a small website for this project at http://reweb.fh-weingarten.de/elektor, which gives source code examples (which include dealing with pushbutton contact bounce) for AVR microcontrollers suitable for use with AVR Studio and GNU C. Downloads are also available at http://www.elektor.com.

(080251-I)

High-intensity LED Warning Flasher

Jose Luis Basterra



This circuit was designed as a warning flasher to alert road users to dangerous situations in the dark. Alternatively, it can act as a bicycle light (subject to traffic regulations and legislation). White LEDs only are recommended if the circuit is used as a bicycle front light (i.e. for road illumination) and red LEDs only when used as a tail light.

During the day, the two 1.6-V solar cells charge the two AA batteries. In darkness, the solar cell voltage disappears and the batteries automatically power the circuit.

The flash frequency is about one per second and the LED on-time is about 330 ms. The duty cycle should enable the batteries to power the circuit over night.

The circuit is composed of three parts. Under normal daylight conditions the batteries are charged through diode D4. In darkness, pnp transistor T1 is switched on, supplying battery current to the second part, a low-frequency oscillator comprising T2 and T3.

The third part is the LED driver around T4. It conducts and switches on the LEDs D1-D2-D3 when the collector voltage of T3 swings high. Two LEDs (D1, D2) are 20,000-30,000 mcd high-brightness yellow types and one (D3) is a normal 3-mm red LED for control purposes. Of course it is possible to increase the number of LEDs to obtain higher brightness. However you will run into limitations regarding the maximum collector current of transistor T4. For really high power applications a MOSFET transistor is suggested instead of the common or garden BC547B.

(080312-I)

Stroboscope with Trigger Input

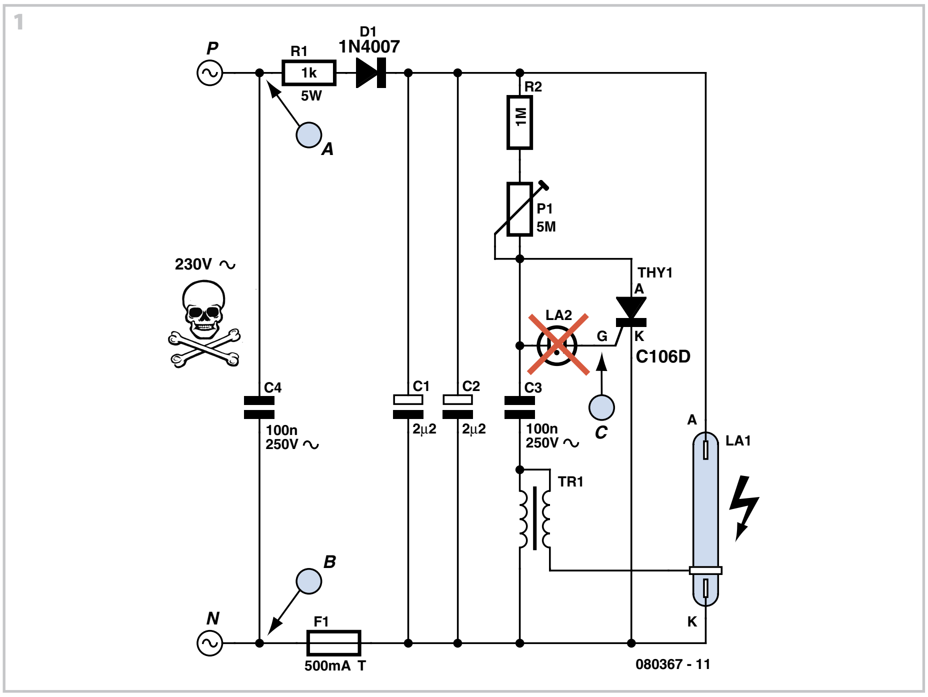
Bernd Oehlerking

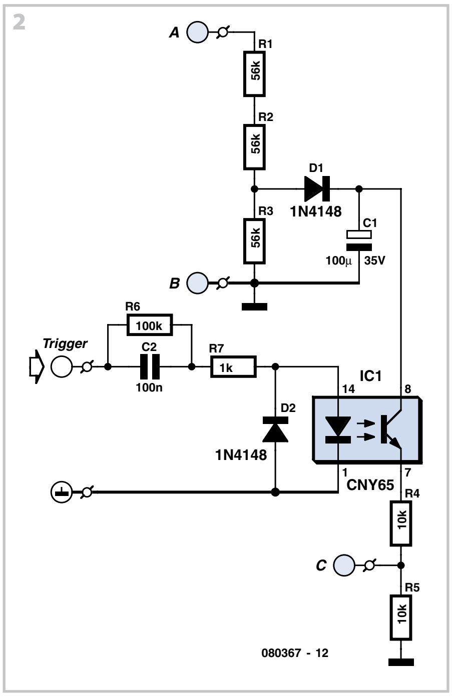
The Conrad Electronics company has a light flash stroboscope kit in its product line (number 580406) which can be easily expanded with an electrically isolated trigger input.

Figure 1 shows the original schematic for the stroboscope. The neon lamp shown in the circuit (and which is used to provide a regular triggering of the flash tube) is removed and the additional circuit shown in Figure 2 is connected to the points labelled ‘A’, ‘B’ and ‘C’. In this way a flash circuit is created that can be activated with an external trigger signal.

The thyristor on the stroboscope PCB (a C106D from ON Semiconductor) requires only 400 µA to be triggered. Via voltage divider R1-R2-R3, diode D1 and electrolytic capacitor C1, a DC voltage of about 8 V is generated from the incoming mains voltage and, with the values shown, can deliver a current of about 1 mA. This voltage is used to supply the trigger pulse (in practice the duration is about 100 µs) via the transistor in the optocoupler and voltage divider R4/R5.

The trigger signal for the LED in the optocoupler is presented via C2/R6 and R7. Diode D2 is connected in anti-parallel with the LED in the optocoupler to protect this LED from an external trigger signal with the wrong polarity. The differential network at the input (C2/R7) ensures that even if there is a long duration input pulse there





is nevertheless only a short pulse sent to the gate. R6 is necessary for the periodic discharge of C2. A standard 5 V digital signal is sufficient for driving this trigger input.

With this expansion circuit it is possible to reach a repetition frequency of more than 20 Hz. Above this frequency the flash tube starts to flash erratically.

The optocoupler used is a CNY65, which easily provides class II isolation (generous space between the connections to the LED on the one side and the transistor on the other side).

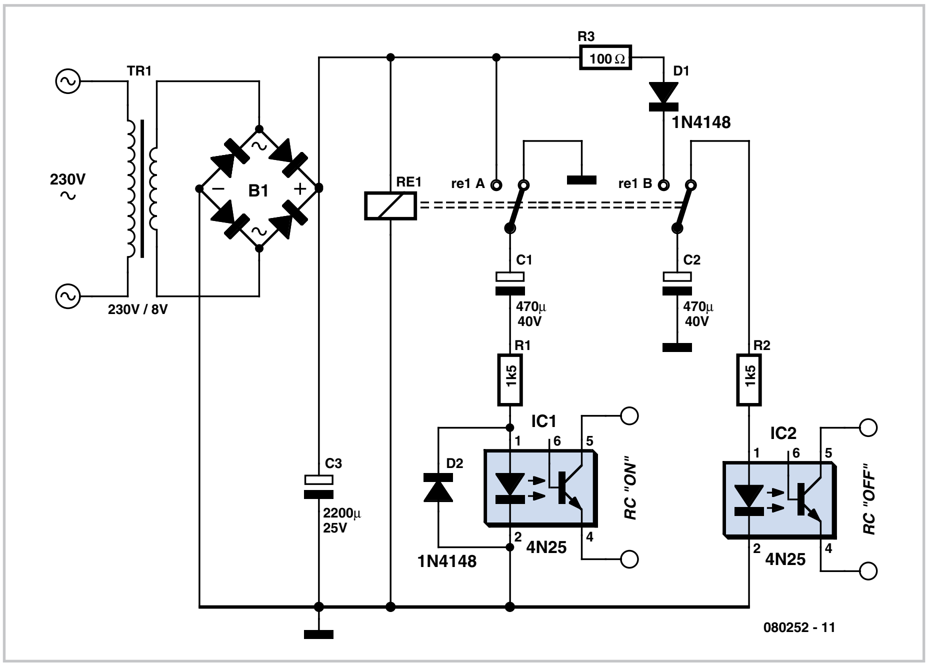
Please note: this circuit operates at high voltages that can be lethal. Even after the mains voltage is removed there may still be dangerously high voltages present across the electrolytic capacitors in the circuit!

(080367-I)

Remote Control Mains Switch

Jaap van der Graaff

As the only electronics engineer in my family and circle of friends, it is sometimes not possible to evade an appeal for help. This time the request came from a friendly elderly lady in a retirement home. In her room the light switch by the door and the pull cord above the bed operate the light fitting on the ceiling in the middle of the room. However, she would prefer that her standing lamp was operated by these switches instead, since she does not actually have a light fitting mounted on the ceiling. This standing lamp has an on/off switch in the power cord and is plugged into a power point. However, it stands rather far from the bed so that she always has to find her way in the dark. A wireless operated power point is not really a consideration, because it is just a matter of time before the remote is lost. Or maybe not?



Behold a feasible circuit. Buy a wireless power point and an enclosure that is big enough for the remote control and a small

piece of prototyping board. On the prototyping board build the circuit according to the accompanying schematic and (carefully) open the remote control and solder wires to the push buttons for 'on' and 'off'. Measure if these are polarised and if that is the case connect them to the 4N25 optocouplers as shown in the schematic, where pin 5 has a higher voltage than pin 4.
The operation is as follows. The lady operates the pull cord or light switch to turn the light on. This causes the mains voltage to be applied to the transformer. The relay is activated which charges C1. While C1 charges, a small current flows through optocoupler 1. The result is that the 'on' button on the remote control is pressed. The remote control switches the corresponding power point on and to which the standing lamp is connected. The standing lamp will therefore now turn on. Capacitor C2 is charged at the same time. If the lady pulls the cord again, or if she operates the switch near the door, the relay will de-energise and C2 discharges across optocoupler #2. This operates the 'off' contact of the remote control and the light goes out.
The remote control continuous to operate from its normal battery and the white enclosure is attached to the ceiling in place of the light fitting. Diode D1 ensures that C1 is discharged when the relay de-energises. D2 ensures that C2 cannot discharge across the relay, but only across optocoupler 2.

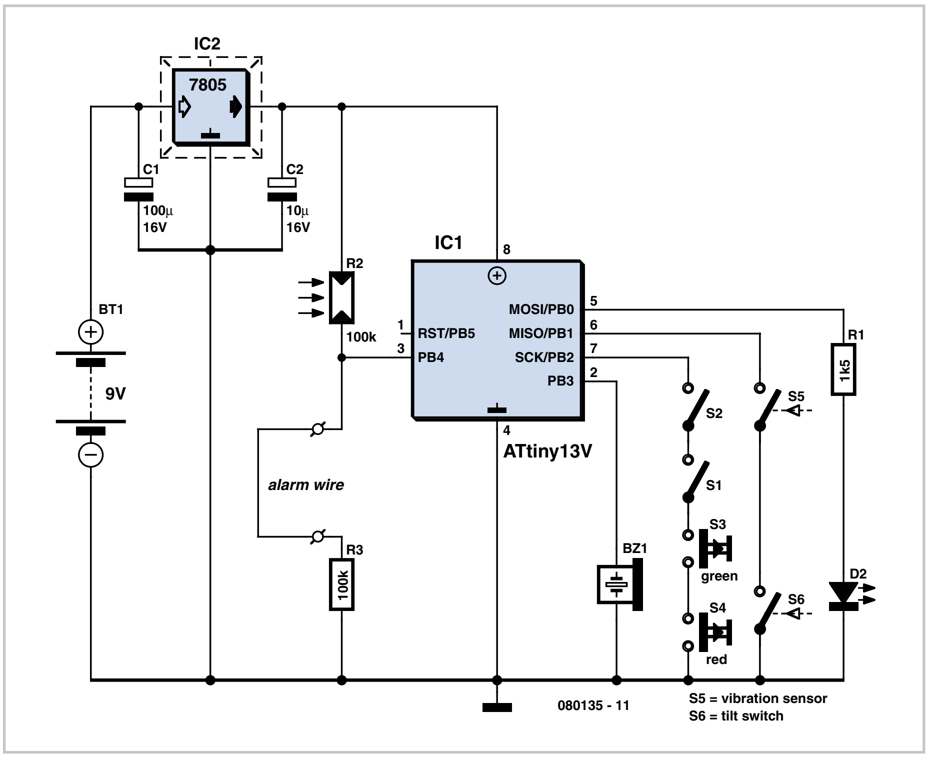
(080252-I)

Tent Alarm

Stefan Hoffmann

Although this alarm is designed to protect valuables left in a tent, it can also be used as a baggage alarm (either on or in one's bags) and in similar situations.

The tent alarm can be triggered by many different sensors. One is a current loop, connected to pin PB4 of an ATtiny13 microcontroller: this could be a thin wire which would be broken by a prospective pilferer caught off his guard. Alternatively, it can be a reed switch contact normally held closed by a magnet, arranged so that the budding burglar will accidentally move the magnet and thus open the contact. This could be used to protect a door or a zip fastener securing a tent.
Another sensor connected to PB4 is an LDR (light dependent resistor). If the LDR is left in a dark place (such as under a sleeping bag) the thief will trigger the alarm if he moves the bag to expose the sensor to light. The resistance of the LDR is about 100 kΩ in the dark and just a few ohms in the light. If only the light sensor is to be used, the alarm wire (or reed contact) socket can be shorted using a jumper. If the LDR is not to be used, it can either be (temporarily) taped over to exclude light from it or (more permanently) replaced by a 100 kΩ resistor.
A third sensor which can trigger the alarm is a vibration detector (S6), which is wired in series with a tilt sensor. The tilt sensor allows the vibration sensor to be disabled when the alarm unit is left upside-down. When the tilt sensor contacts are open, PB1 cannot be pulled low and so no alarm can be triggered.
The unit also features a number of push-buttons and switches connected to PB2.



The arrangement and labelling of these buttons and switches is described below. On the left of the device lies switch S1 with the (deliberately misleading) legend 'Power on/off'. Of course, this does not turn the alarm on and off. On the right of the device is switch S2 with the legend 'Speaker on/off', which, naturally, does nothing of the sort. As you have probably already guessed, the red and green buttons also have nothing to do with arming or disarming the alarm.
These decoys should be enough to annoy and delay all but the most resourceful of robbers. Naturally, once the alarm has been triggered by uncovering the LDR, it will not turn off again if the LDR is then covered.
The only way to disable the alarm is to set S1 and S2 in the correct positions (namely, 'Power on' and 'Speaker on') and hold down the two buttons simultaneously for five seconds. More complicated deactivation procedures can be programmed into the software, in case you are worried that some light-fingered *Elektor* reader (not that such a person exists) will be able to steal your valuables after having seen this article.

The circuit requires a supply voltage of between 3.6 V and 5 V. In the circuit diagram we show a power supply made using a 9 V battery and a 5 V voltage regulator.
The ATtiny13 microcontroller belongs

to Atmel's AVR family, and can be programmed using BASCOM. Source and object code files, including fuse settings, are available in a ZIP archive that is available for free download from the *Elektor* website. The source code can be modified to suit your own application and then recompiled using the free version of BASCOM. The software arranges matters so that the processor enters sleep or power-down mode when the alarm is correctly deactivated; there is no other way to turn the device off. To wake the device up the switches must be set correctly (both to 'on') and the unit shaken briefly. The LED blinks twice to confirm that the device has woken up; after a brief delay of approximately three seconds the alarm is armed. This state is indicated by three flashes of the LED. While the alarm remains in the armed state the LED blinks briefly once every few seconds.

When the alarm is triggered the red LED lights immediately. If it is not disarmed, the alarm sounds after a short pause.

To disarm the unit, both switches again need to be in the 'on' position as described above and both buttons must be pressed. After a double flash, whether the LED is on or off indicates whether the buttons must then be pressed again or not.

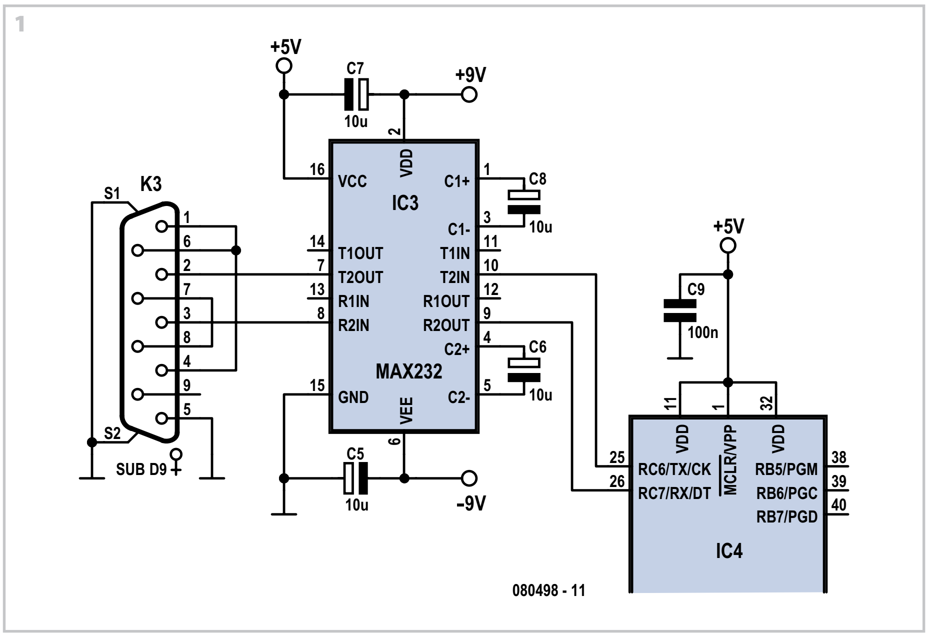
(stefankhoffmann@yahoo.de) (080135-I)

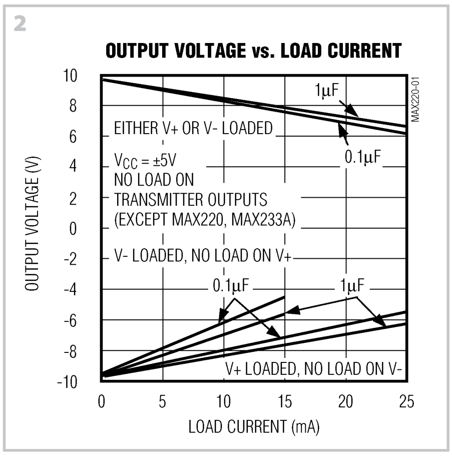
Gratis Symmetrical Opamp Supply Voltages

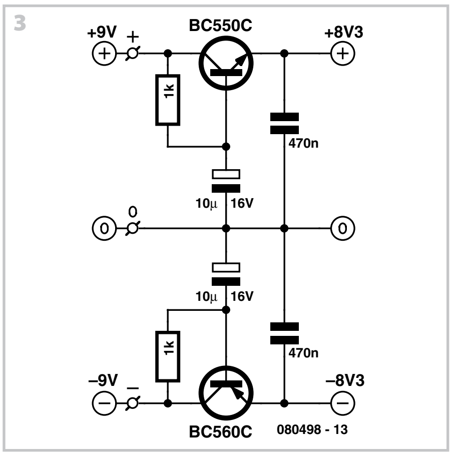
Many ways to obtain a set of symmetrical supply voltages for operational amplifiers and comparators from a single +5-V supply voltage have been described already. The simplest option (including with regard to component availability and price) is to use a MAX232, which is available in the 16-pin DIP package for less than 30 p (50 eurocents).

In nearly all microcontroller circuits with an RS232 port, this IC is already present anyway to provide level conversion between TTl signals (5 V) and RS232 signals (nominally ±12 V), so you can obtain a set of symmetric supply voltages for opamps almost free of charge.

It's not even necessary to add any circuitry around the IC. **Figure 1** shows how a MAX232 is typically wired in a microcontroller circuit**.** The symmetrical voltages (at around ±9 V) generated from the +5-V supply voltage can be taken from pin 2 (V_{DD}; +9 V) and pin 6 (V_{EE}, −9 V) of the IC. As you can see from **Figure** 2, the no-load voltage is nearly 10 V and you can draw up to 5 mA at 9 V, which is enough for most standard opamps and plenty for low-power opamps.







The MAX232 has two charge pumps, each of which has two external capacitors for voltage doubling. These are 10-μF electrolytic capacitors in Figure 1, which yields a somewhat stabler output voltage than the standard circuit with 1 μF as shown in Figure 2. The charge pumps of the MAX232 are operated at an oscillator frequency of around 50 kHz, so the amount of ripple on the output voltage is quite small (typically less than 10 mV with a 2-mA load).
This means that in most cases you can manage without any additional filtering of the output voltage. In sensitive applications, such as amplification of small audio or measurement signals by one or more opamps, it's a good ideal to use a small gyrator circuit for additional suppression of the residual 50-kHz signal. **Figure 3** is an example of such a circuit that has been proven frequently in practice. Of course, you can use other types of complimentary

small-signal silicon transistors, such as the BC547 (NPN) and BC577 (PNP), in place of the BC550 (NPN) and BC560 (PNP) shown on the schematic. Transistors in the current gain class 'B' (such as the BC547B and BC557B) are also suitable, and the values of the capacitors between the bases of the transistors and ground can also be increased (e.g. 100 µF) or decreased (e.g. 1 µF). The voltage drop across the gyrator circuit is only around 0.7 V.

(080498-1)

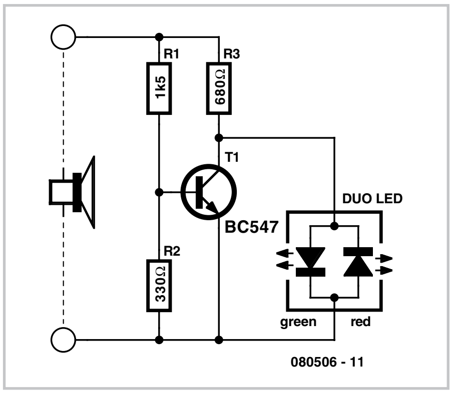
Simple Audio Power Meter

Michiel Ter Burg

This simple circuit indicates the amount of power that goes to a loudspeaker. The dual-colour LED shows green at an applied power level of about 1 watt. At 1.5 watts it glows orange and above 3 watts it is bright red.

The circuit is connected in parallel with the loudspeaker connections and is powered from the audio signal. The additional load that this represents is 470 Ohm (R1//R3) will not be a problem for any amplifier.

During the positive half cycle of the output signal the green LED in the dual-colour LED will be turned on, provided the voltage is sufficiently high. At higher output voltages, T1 (depending on the voltage divider R2/R1) will begin to conduct and the green LED will go out.



During the negative half cycle the red LED is driven via R3 and will turn on when the voltage is high enough. In the transition region (where T1 conducts more and more and 'throttles' the green LED as a result) the combination of red/green gives the orange colour of the dual-LED.

By choosing appropriate values for the resistors the power levels can be adjusted to suit. The values selected here are for typical living room use. You will be surprised at how loud you have to turn your amplifier up before you get the LEDs to go!

The resistors can be 0.25 W types, provided the amplifier does not deliver more than 40 W continuously. Above this power the transistor will not be that happy either, so watch out for that too. Because T1 is used in saturation, the gain (Hfe) is not at all important and any similar type can be used. The power levels mentioned are valid for 4-Ohm speakers. For 8-Ohm speakers all the resistor values have to be divided by two.

(080506-I)

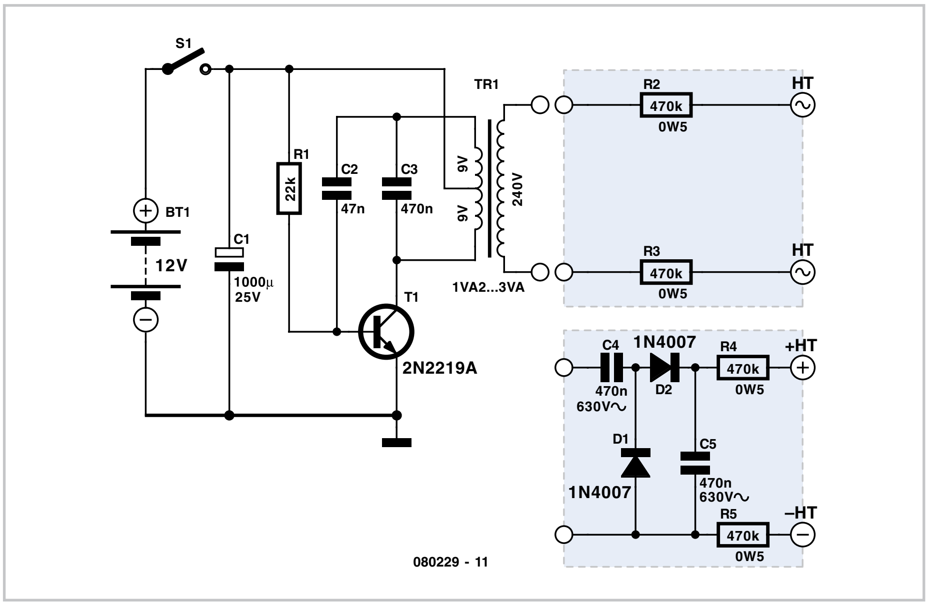
Mini High-voltage Generator

B. Broussas

Here's a project that could be useful this summer on the beach, to stop anyone touching your things left on your beach towel while you've gone swimming; you might equally well use it at the office or workshop when you go back to work.

In a very small space, and powered by simple primary cells or rechargeable batteries, the proposed circuit generates a low-energy, high voltage of the order of around 200 to 400 V, harmless to humans, of course, but still able to give a quite nasty 'poke' to anyone who touches it.

Quite apart from this practical aspect, this project will also prove instructional for younger hobbyists, enabling them to discover a circuit that all the 'oldies' who've worked in radio, and having enjoyed valve technology in particular, are bound to be familiar with.



As the circuit diagram shows, the project is extremely simple, as it contains only a

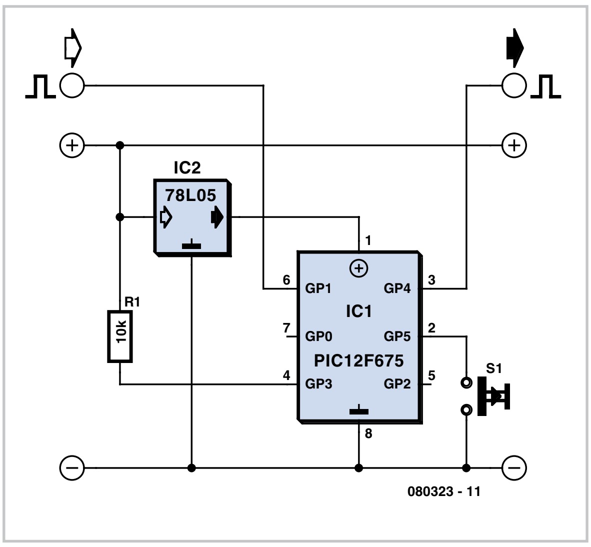
single active element, and then it's only a fairly ordinary transistor. As shown here, it operates as a low-frequency oscillator, making it possible to convert the battery's DC voltage into an AC voltage that can be stepped up via the transformer.
Using a centre-tapped transformer as here makes it possible to build a 'Hartley' oscillator around transistor T1, which as we have indicated above was used a great deal in radio in that distant era when valves reigned supreme and these was no sign of silicon taking over and turning most electronics into 'solid state'. The 'Hartley' is one of a number of L-C oscillator designs that made it to eternal fame and was named after its invertor, Ralph V.L Hartley (1888-1970).
For such an oscillator to work and produce a proper sinewave output, the position of the intermediate tap on the winding used had to be carefully chosen to ensure the proper step-down (voltage reduction) ratio. Here the step-down is obtained inductively.
Here, optimum inductive tapping is not possible since we are using a standard, off-the-shelf transformer. However we're in luck — as its position in the centre of the winding creates too much feedback, it ensures that the oscillator will always start reliably. However, the excess feedback means that it doesn't generate sinewaves; indeed, far from it. But that's not important for this sort of application, and the transformer copes very well with it.
The output voltage may be used directly, via the two current-limiting resistors R2 an R3, which must not under any circumstances be omitted or modified, as they are what make the circuit safe. You will then get around 200 V peak-to-peak, which is already quite unpleasant to touch. But you can also use a voltage doubler, shown at the bottom right of the figure, which will then produce around 300 V, even more unpleasant to touch. Here too of course, the resistors, now know as R4 and R5, must always be present.
The circuit only consumes around a few tens of mA, regardless of whether it is 'warding off' someone or not! If you have to use it for long periods, we would however recommend powering it from AAA size Ni-MH batteries in groups of ten in a suitable holder, in order not to ruin you buying dry batteries.
Warning! If you build the version without the voltage doubler and measure the output voltage with your multimeter, you'll see a lower value than stated. This is due to the fact that the waveform is a long way from being a sinewave, and multimeters have trouble interpreting its RMS (root-mean-square) value. However, if you have access to an oscilloscope capable of handling a few hundred volts on its input, you'll be able to see the true values as stated. If you're still not convinced, all you need do is touch the output terminals…
To use this project to protect the handle of your beach bag or your attaché case, for example, all you need do is fix to this two small metallic areas, quite close together, each connected to one output terminal of the circuit. Arrange them in such a way that unwanted hands are bound to touch both of them together; the result is guaranteed! Just take care to avoid getting caught in your own trap when you take your bag to turn the circuit off!

(080229-I)

Programmable Servo Driver

Gilles Clément

The objective of the circuit described in this Summer Circuits article on all things outdoors is to create a servo motor polarity-inverter, to allow the drive to a model servo motor to be inverted with respect to the command from a radio-control receiver channel. Hence this module is inserted between one of the receiver outputs and the servo motor to be driven.



One of the most obvious applications is to reverse the rotation sense of the servo motor output arm. This feature is useful when all the channels of a receiver are used up and you need to control a second servo motor in parallel with the first one (using a 'Y' cable) but inverting the sense of one of them.

Generally, it is also often useful to be able to adjust the end positions of the output arm and the neutral position independently (when the two servo motors aren't exactly the same or are mounted differently in the two wings, for example).

The movement of servo motors used in modelling is coded using pulse width modulation (PWM). The width usually varies from 1 ms to 2 ms, with the signal repeating at 20 ms intervals (i.e. 50 Hz).

The transmitter controls use potentiometers whose travel defines the pulse width for each channel. These pulses are sent sequentially (as many as there are channels) to the receiver, which decodes them and sends them to the relevant outputs according to the order in which they arrive.
As we've said, the objective here is to invert the travel of a servomotor output arm, while also permitting the whole of the range of movement to be manually shifted so as to adjust the rudder neutral position ('trim').
Let's take a look at the electronics. The microcontroller we've chosen here is the deceptively small 12F675 PIC from Microchip. It's quite extraordinary, a real little eight-legged marvel! Although it is really very small (8-pin DIL), it is capable of doing masses of things.

A 12F675 is in fact the heart of the whole circuit (see circuit diagram).

Of course, for it to work, it needs to have the required .hex file, extracted from the archive file 080323-11.zip (see Downloads). The microcontroller only needs three additional components (excluding the servomotor extension, the most expensive item in this project): a 5 V regulator (78L05) to provide the supply voltage, a miniature push-button used as a control, and one pull-up resistor.

The electronics will fit onto a piece of prototyping board of 9 × 6 holes, making it easy to fit into the scale model concerned. Just a word about the calibration of the internal oscillator. The last byte of the 12F675's program memory contains the calibration value for the internal oscillator, which makes it possible to adjust the clock to 4 MHz within ±1%. Right at the start of your operations, you need to go and read this byte (read the memory) and save it as there is a danger of erasing it when you start programming.
One of the most important aspects of this project is adjusting it (when you are aware of the consequences an error here can have – just try piloting a scale model by reversing the controls!).

Warning: you mustn't touch the transmitter during this stage – i.e. while powering up the receiver – as we are measuring the receiver output signal when the transmitter control is at rest.

We start first of all by confirming the measurement of the input signal, very important in order for the output signal calculation to be correct. Warning: the remark to not touch the transmitter during this stage applies here too, for the same reasons. If the push-button is pressed a second time, the gradual shift of the neutral position starts, then if it is released and immediately pressed again, the movement takes place in the opposite direction. This mode is exited automatically if the push-button hasn't been pressed for 2 seconds. The servomotor 'flutters' a little to indicate the end of the steps.

One conclusion is called for: it works very well, and it doesn't cost an arm and a leg...

Clemgill@club-internet.fr (080323-I)

Web Links

12F675 datasheet
http://ww1.microchip.com/downloads/en/devicedoc/41190c.pdf

Downloads

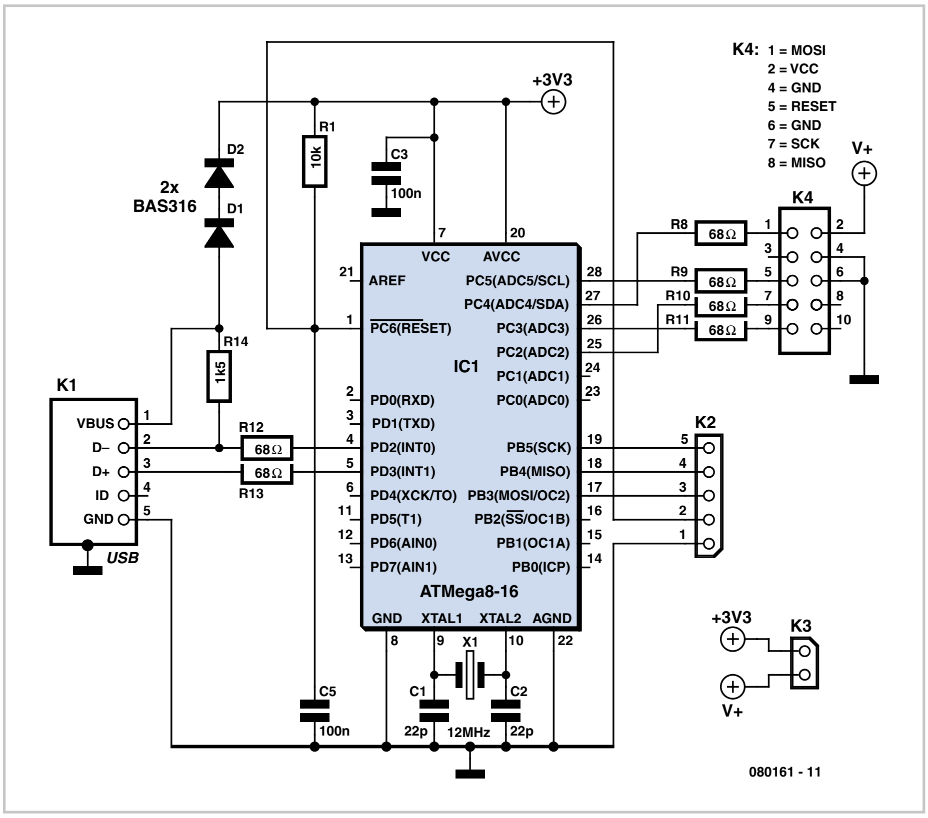
The source code and .hex files for this project are available for downloading from the Elektor website at www.elektor.com; archive file 080323-11.zip.

Simple USB AVR-ISP Compatible Programmer

Nand Eeckhout

Modern PCs rarely have a serial or parallel port any more, to the great regret of anyone who experiments with microcontrollers every now and then. In the old days it was very simple to use the parallel port of a standard PC and program just about any type of AVR microcontroller with it. When you want to do that now, you're first obliged to buy a programmer that communicates with the PC via USB, which immediately raises the threshold of getting started with these microcontrollers. The circuit presented here offers a solution to this.

As you can see from the schematic, this is a very simple circuit, built around a cheap, standard AVR microcontroller plus a handful of passive components. You may have already observed that this microcontroller does not have a USB interface and the circuit does not use a USB to serial converter either. The strength of this circuit is found in the firmware. The USB interface has been implemented in software, as we have shown in an earlier article 'AVR drives USB' in the March 2007 issue. The firmware ensures that the circuit is recognised by the PC as a serial port and communicates with AVR Studio, the standard Atmel development environment, as if it were a 'real' AVR-ISP programmer.



The circuit is easily built on a small piece of prototyping board or even on a breadboard, since the controller is available in a DIP-28 package. If you are going to program the controller yourself (via connector K2) then make sure that you set the configuration fuses so that the internal oscillator uses the external crystal as the clock source.

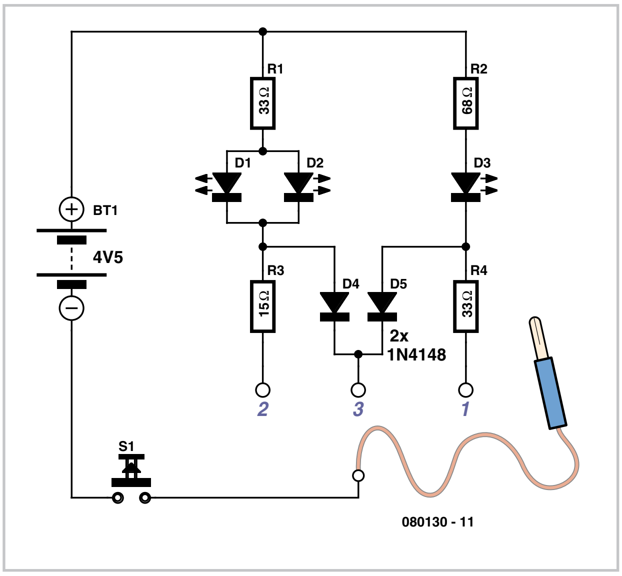
Jumper K3 is provided in the event you would like to power the circuit to be programmed from the USB port. We do not recommend that you do this, however, but sometimes there is no other option. K4 is a 10-way box header which has the same standard pinout that Atmel uses everywhere.

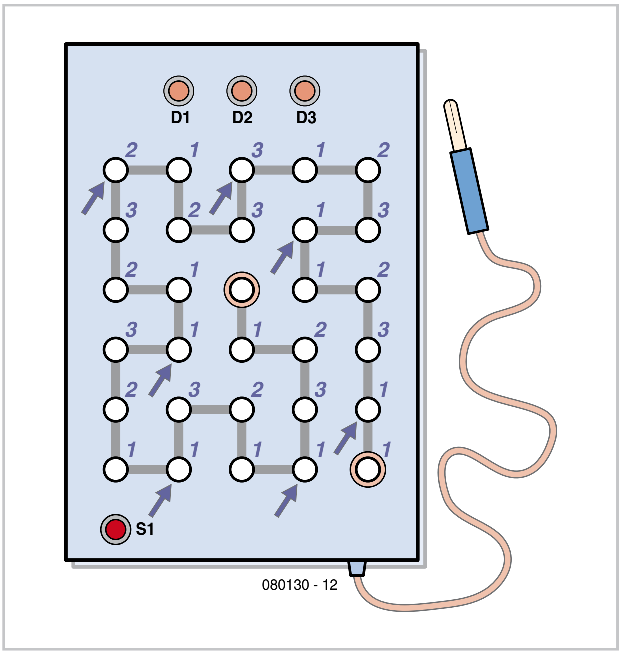
(080161-I)

123 Game – all MCU-free

Stefan Hoffmann

This electronic game pits a human player against the 'machine'. The opponents use a common 'game token' and take turns moving along a path by one, two or three steps, and the winner is the first one to reach the goal exactly. Incredibly enough, this simple version of the '123' game can be built without a microcontroller, and it's almost impossible to beat.





The electronics for this is built using only diode logic (**Figure 1**). The 'input interface' consists essentially of 30 miniature sockets to which a probe tip can be connected to mark the position of the 'game token'. To make the game more compact, the sockets are arranged in a grid so the route along the sockets follows a serpentine path (**Figure 2**). The starting position is at the bottom right, and the goal is in the middle of the playing area. The electronics becomes the 'active player' when the button is pressed. The number of steps it wants to move is shown by three LEDs (one, two or three LEDs light up) at the top of the playing area. Naturally, the human player must move the 'game token' for the machine opponent. The winner is the first one to reach the goal exactly.

How can such simple circuitry represent such a formidable opponent? As already mentioned, the path from the start to the goal is formed by 30 sockets. Each socket has an associated ideal next move. There are three possibilities, of course: 1, 2 or 3. As you can see from the schematic diagram, switch S1 closes the circuit (which means the player asks the 'computer' how many steps it wishes to move) if the probe is touching one of the sockets. All 30 sockets are classified into three types, represented in the schematic diagram by one socket for each type. All sockets belonging to a particular type are simply connected together electrically, which is not shown on the schematic diagram for the sake of clarity.

This is how the LED display works: the player touches the right-hand contact with R4 (only LED D3 lights up), the left-hand contact with R3 (LEDs D1 and D2 light up), or the middle contact with diodes D4 and D5 (all three LEDs light up). The two diodes prevent all three LEDs from lighting up if the player touches the left-hand or right-hand contact.

The key to all this lies in the assignment of the 30 sockets to the three types of logic, which means the three types of ideal next move. Working backward from the goal, no further move is possible when the goal is reached. For this reason, the last socket is not connected to anything. At the socket just before the goal, the 'computer' naturally wants to be exactly one step in front. Consequently, this socket is connected to R4. At the second socket before the goal, the electronics wants to move by two steps. This socket is thus connected to R3. Obviously, three moves before the finish, a three-step is best as it leads to instant victory. Consequently this socket is connected to D4/D5.

The correct response of the 'computer' is shown in **Figure 2** by the number next to each position. As the two opponents take turns playing, the electronics always tries to arrive at a strategically favourable position (marked by the arrows). If the electronics manages to reach one of these positions, it's impossible for the human player to win. This means that the human player can only win by starting first and always making the right move.

(080130-1)

Cheap 12 V/230 V Invertor

B. Broussas

Even though today's electrical appliances are increasingly often self-powered, especially the portable ones you carry around when camping or holidaying in summer, you do still sometimes need a source of 230 V AC – and while we're about it, why not at a frequency close to that of the mains?

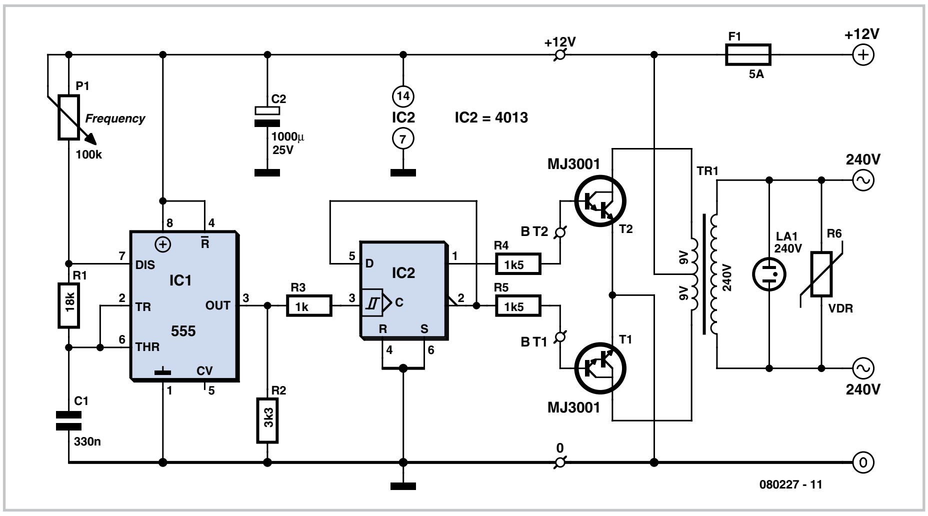
As long as the power required from such a source remains relatively low – here we've chosen 30 VA – it's very easy to build an invertor with simple, cheap components that many electronics hobbyists may even already have. Though it is possible to build a more powerful circuit, the complexity caused by the very heavy currents to be handled on the low-voltage side leads to circuits that would be out of place in this summer issue. Let's not forget, for example, that just to get a meagre 1 amp at 230 VAC, the battery primary side would have to handle more than 20 ADC!

The circuit duiagram of our project is easy to follow. A classic 555 timer chip, identified as IC1, is configured as an astable multivibrator at a frequency close to 100 Hz, which can be adjusted accurately by means of potentiometer P1. As the mark/space ratio (duty factor) of the 555 output is a long way from being 1:1 (50%), it is used to drive a D-type flip-flop produced using a CMOS type 4013 IC. This produces perfect complementary squarewave signals (i.e. in antiphase) on its Q and $\overline{Q}$ outputs suitable for driving the output power transistors.

As the output current available from the CMOS 4013 is very small, Darlington power transistors are used to arrive at the necessary output current. We have chosen MJ3001s from the now defunct Motorola (only as a semi-conductor manufacturer, of course!) which are cheap and readily available, but any equivalent power Darlington could be used.

These drive a 230 V to 2 × 9 V centre-tapped transformer used 'backwards' to produce the 230 V output. The presence of the 230 VAC voltage is indicated by a neon light, while a VDR (voltage dependent resistor) type S10K250 or S07K250 clips off the spikes and surges that may appear at the transistor switching points.

The output signal this circuit produces is approximately a squarewave; only approximately, since it is somewhat distorted by passing through the transformer. Fortunately, it is suitable for the majority of electrical devices it is capable of supplying, whether they be light bulbs, small motors, or power supplies for electronic devices.

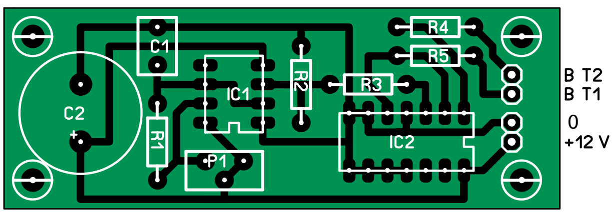


Note that, even though the circuit is intended and designed for powering by a car battery, i.e. from 12 V, the transformer is specified with a 9 V primary. But at full power you need to allow for a voltage drop of around 3 V between the collector and emitter of the power transistors. This relatively high saturation voltage is in fact a 'shortcoming' common to all devices in Darlington configuration, which actually consists of two transistors in one case.

We're suggesting a PCB design to make it easy to construct this project; as the component overlay shows, the PCB only carries the low-power, low-voltage components.

The Darlington transistors should be fitted onto a finned anodized aluminium heatsink using the standard insulating accessories of mica washers and shouldered washers, as their collectors are connected to the metal cans and would otherwise be short-circuited.

An output power of 30 VA implies a current consumption of the order of 3 A from the 12 V battery at the 'primary side'. So the wires connecting the collectors of the MJ3001s [1] T1 and T2 to the transformer primary, the emitters of T1 and T2 to the battery negative terminal, and the battery positive terminal to the transformer primary will need to have a minimum cross-sectional area of 2 mm² so as to minimize voltage drop. The transformer can be any 230 V to 2 × 9 V type, with an E/I iron core



COMPONENTS LIST

Resistors

R1 = 18kΩ
R2 = 3kΩ3
R3 = 1kΩ
R4,R5 = 1kΩ5
R6 = VDR S10K250 (or S07K250)
P1 = 100 kΩ potentiometer

Capacitors

C1 = 330nF
C2 = 1000 µF 25V

Semiconductor

T1,T2 = MJ3001
IC1 = 555
IC2 = 4013

Miscellaneous

LA1 = neon light 230 V
F1 = fuse, 5A
TR1 = mains transformer, 2x9V 40VA (see text)
4 solder pins
PCB, ref. 080227-1 from www.thepsbshop.com

or toroidal, rated at around 40 VA.
Properly constructed on the board shown here, the circuit should work at once, the only adjustment being to set the output to a frequency of 50 Hz with P1. You should keep in minds that the frequency stability of the 555 is fairly poor by today's standards, so you shouldn't rely on it to drive your radio-alarm correctly – but is such a device very useful or indeed desirable to have on holiday anyway?
Watch out too for the fact that the output voltage of this invertor is just as dangerous as the mains from your domestic power sockets. So you need to apply just the same safety rules! Also, the project should be enclosed in a sturdy ABS or diecast so no parts can be touched while in operation.
The circuit should not be too difficult to adapt to other mains voltages or frequencies, for example 110 V, 115 V or 127 V, 60 Hz. The AC voltage requires a transformer with a different primary voltage (which here becomes the secondary), and the frequency, some adjusting of P1 and possibly minor changes to the values of timing components R1 and C1 on the 555.

(080227-I)

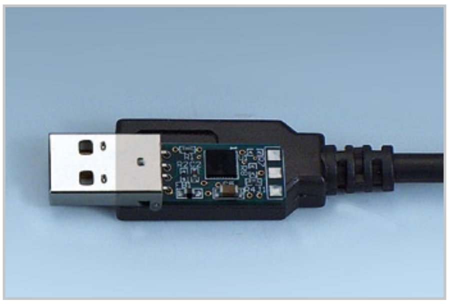
Web Links

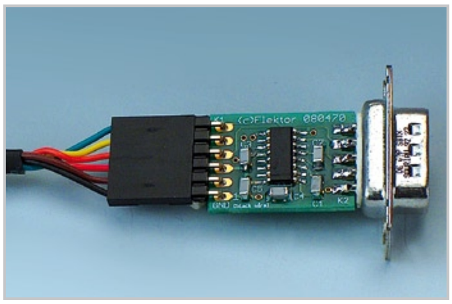
[1] MJ3001
www.st.com/stonline/products/literature/ds/5080.pdf

Downloads

The PCB pattern is available for free download from our website www.elektor.com; file # 0080227-1.zip.

USB <–> RS-232 Cable

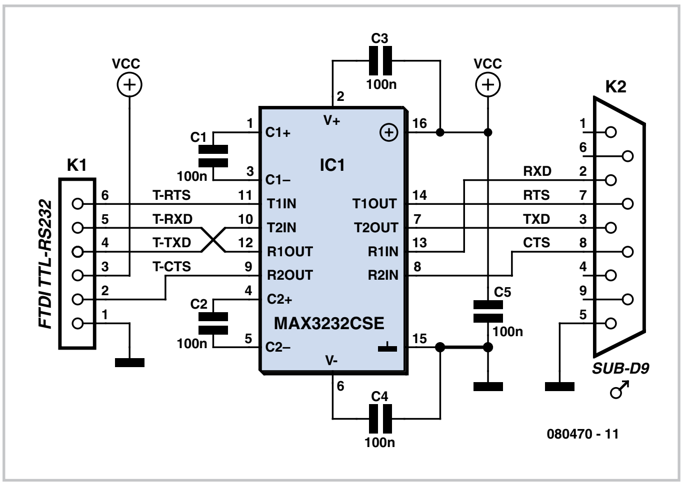




Antoine Authier

This project lets you conveniently connect any computer with USB ports directly to a simple, traditional connector — the 9-pin RS-232 (anyone remembers it?).
It converts the electrical signals from a USB<–>serial TLL convertor to the RS-232 standard. So in a nutshell, it converts a USB port into a standard but basic serial port: only the four basic signals are available.

The USB<–>serial convertor chosen here is the TTL-232R USB to TTL UART cable from FTDI, available as part number 080213-71 and described in the June 2008 issue (see the Elektor website).
The TTL logic signals available on the cable output are converted into RS-232 signals on the tiny board described here.
The voltage level adaptor is a MAX3232 from Maxim. This industry-standard part comprises two transmitters and two receivers, ideal for our USB<–>serial convertor, which itself offers the four fundamental signals of an RS-232 standard port, namely TXD (Transmit Data), RTS (Request To Send), RXD (Receive Data) and DTR (Data Terminal Ready).
Charge pumps built into the IC provide the 12 V levels required by the RS-232 standard. This circuit works equally well from 3.3 V as from 5 V supply rails and supports both these levels on its logic input and outputs. In theory, it also ought to work correctly with the 3.3 V version of the cable mentioned above, the TTL-232R-3V3 – however, we haven't checked this experimentally in the lab.
Instead of the complete cable, you can use just the TTL-232R-PCB module (or TTL-232R-PCB-3V3 for 3.3 V), currently only the former is available from the Elektor Shop.



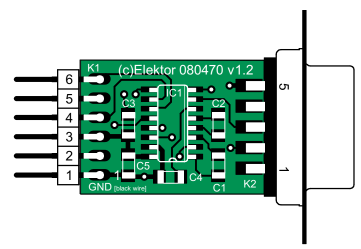
The 1206 cases size SMD (surface mount device) components used here make it possible to achieve a compact board, while still being easy enough to handle by constructors who may not be very used to this type of component, and who, in building this useful little project, will be able to practice and get an idea

COMPONENTS LIST

Capacitors
C1-C5 = 100nF 25V (SMD 1206)

Semiconductors
IC1 = MAX3232CSE (or -ESE)

Miscellaneous
K1 = 6-way right-angled SIL pinheader
K2 = 9-way cable mount sub-D plug (male)
FTDI TTL-232R cable (5.0 V), Elektor SHOP # 080213-71
Piece of large diameter heatshrink sleeving
PCB, ref. 080470-I from www.thepcbshop.com



of how nimble-fingered they are before attacking more complex circuits using SMDs.
No surprises in the construction of the project. Start by soldering the IC and the capacitors, then the connectors.

Use a right-angle 0.1-inch SIL pinheader to reduce the pull on the cable. With a straight header, the cable and board would form a cumbersome and inelegant right angle.

The sub-D connector may be cannibalized from an old cable, as long as it's a male one (i.e. a plug, not a socket). Slide the board between the two rows of pins on the connector and solder these directly onto the PCB copper islands provided.

To finish off, you can protect the whole thing by slipping it into a piece of heat-shrink sleeving of suitable diameter.

(080470-I)

Web Links

http://pdfserv.maxim-ic.com/en/ds/MAX3222-MAX3241.pdf

www.ftdichip.com/Products/EvaluationKits/TTL-232R

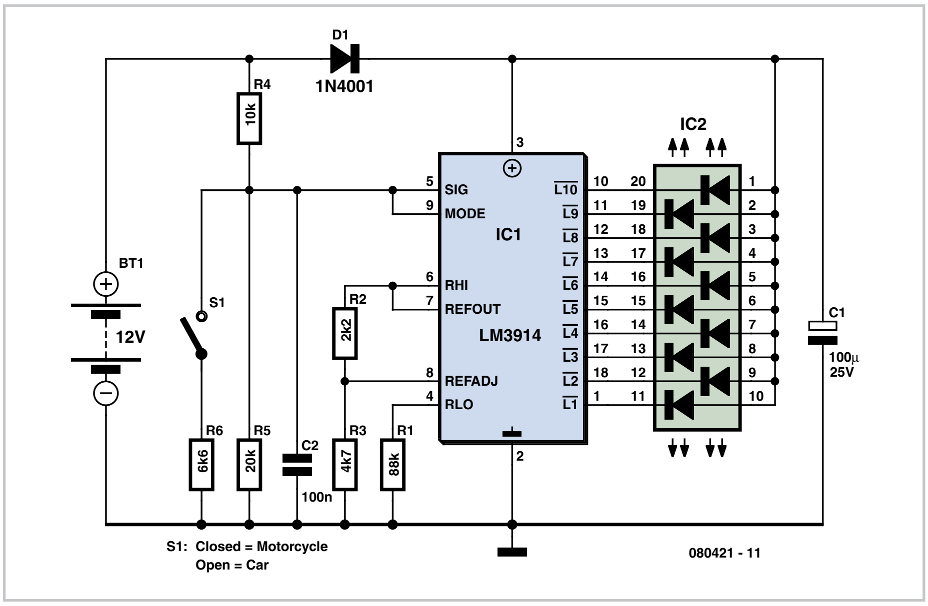
Downloads

The PCB artwork for the board is available for free download from our website (www.elektor.com); file # 080470-1.zip.

Car & Motorcycle Battery Tester

Joseph Zamnit

Going camping nowadays involves taking lots of electronic equipment whether for day to day running or for fun and entertainment. Most of the time a charged lead-acid battery and a power inverter would be used to ensure a smoothly organised holiday where ideally the missus and the children cheerfully use their electric and electronic gear!
With rechargeable lead-acid batteries it's invariably useful — if not essential — to determine whether the power source you're hauling along on your travels is losing capacity and needs to be topped up. The same circuit would also come in handy when going on a car or motorbike trip as it can check the status of a 12 V (car) or a 6 V (motorcycle) battery. Although the circuit draws so little power that it will not noticeably load the battery under test, it should not be left connected permanently.
The circuit employs the familiar LM3914 (IC1) to display the voltage level. The LED readout creates a battery status readout: when the top LED lights, the battery is fully charged. When the bottom LED lights, the battery needs imminent charging!
Switch S1 selects between 12 V and 6 V operation. A series diode, D1, protects the bargraph driver from reverse supply voltage. A colour-coded display with individual LEDs could be used instead of the common-anode bargraph display for better indication of the state of the battery.



(080421-I)

Mobile Phone Data Cable = Interface Converter

Michael Gaus

Nowadays microcontroller circuits that cannot be connected to a PC are hopelessly old-fashioned. One option is to use one of the many types of ready-made USB to serial interface converters to outfit a microcontroller circuit with a MAX232 level converter. However, in some cases it is not so easy to retrofit a level converter if the circuit is already fitted in an enclosure. An example of this is provided by the various Internet routers that clever users employ for novel purposes (with modified firmware).

If you enjoy plying a soldering iron, you can keep everything simple and inexpensive. This is based on the fact that older-model mobile phones did not have any USB circuitry for connection to a PC. Special cables incorporating an interface converter were (and still are) available for these devices. They even included level conversion from

RS232 to digital logic levels. What could be simpler than to use a data cable of this sort? After all, you can obtain these cables very inexpensively via the Web. Another advantage of these cables is that they supply +5 V from the PC, which can be used to power small circuits. The author has found that a cable with type number KQU08A, which was originally designed for use with Siemens C55 mobile phones, is quite suitable.

The 'remodelling' is very easy in principle: you just cut off the mobile-phone connector and solder a five-way socket header in its place. The photo shows that the author also used a small piece of perforated circuit board for improved mechanical strength. The pin assignments are easy: yellow = +5 V, red = ground, blue = RxD, white = TxD, and green = DCD, although the last signal can be ignored in most cases. You should always check the wiring scheme just to be sure.

Note that the RxD, TxD and DCD signals are designed for 3.3 V and are active low. If you are driving a circuit with a 5-V supply voltage, no problems will arise if you connect the TxD line of the cable to the RxD input of a 5-V microcontroller, since the MCU will almost always interpret the signal levels correctly. However, you should connect the TxD output of the MCU to the RxD line of the cable via a voltage divider formed by a 1.8-kΩ resistor in series with a 3.3-kΩ resistor. You can also use a 3.3-V Zener diode in place of the 3.3-kΩ resistor. The load on the 5-V line should be kept at 100 mA or less.

Before you start modifying the cable, it's a good idea to connect it to a PC, install the included driver, and see whether a virtual COM port is configured on the PC for the cable. If this is OK, connect TxD and RxD together and check whether your terminal emulator program can properly receive transmitted data (without local echo enabled).

(080321-1)

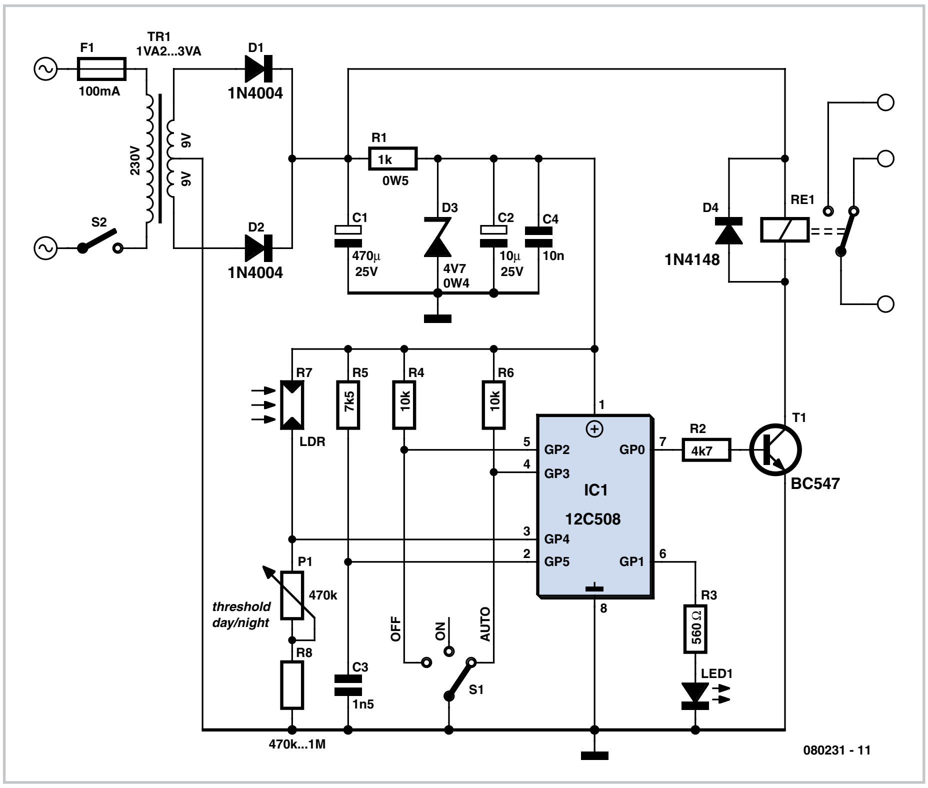
Intelligent Presence Simulator

C. Tavernier

However effective a domestic alarm system may be, it's invariably better if it never goes off, and the best way to ensure this is to make potential burglars think the premises are occupied. Indeed, unless you own old masters or objects of great value likely to attract 'professional' burglars, it has to be acknowledged that the majority of burglaries are committed by 'petty' thieves who are going to be looking more than anything else for simplicity and will prefer to break into homes whose occupants are away.

Rather than simply not going on holiday – which is also one solution to the problem (!) – we're going to suggest building this intelligent presence simulator which ought to put potential burglars off, even if your home is subjected to close scrutiny.

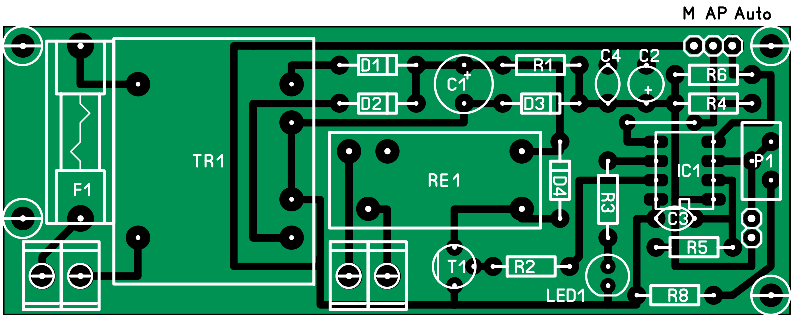
Like all its counterparts, the proposed circuit turns one or more lights on and off when the ambient light falls, but while many devices are content to generate fixed timings, this one works using randomly variable durations. So while other devices are very soon caught out simply by daily observation (often from a car) because of their too-perfect regularity, this one is much more credible due to the fact that its operating times are irregular.



The circuit is very simple, as we have employed a microcontroller – a 'little' 12C508 from Microchip, which is more than adequate for such an application. It is mains powered and uses rudimentary voltage regulation by a zener diode. A relay is used to control the light(s); though this is less elegant than a triac solution, it does avoid any interference from the mains reaching the microcontroller, for example, during thunderstorms. We mustn't forget this project needs to work very reliably dur-

ing our absence, whatever happens.
The ambient light level is measured by a conventional LDR (light dependent resistor), and the lighting switching threshold is adjustable via P1 to suit the characteristics and positioning of the LDR. Note that input GP4 of the PIC12C508 is not analogue, but its logic switching threshold is very suitable for this kind of use.
The LED connected to GP1 indicates the circuit's operating mode, selected by grounding or not of GP2 or GP3 via override switch S1. So there are three possible states: permanently off, permanently on, and automatic mode, which is the one normally used.
Given the software programmed into the 12C508 ('firmware') and the need to generate very long delays so as to arrive at lighting times or an hour or more, it has been necessary to make the MCU operate at a vastly reduced clock frequency. In that case, a crystal-controlled clock is no longer suitable, so the R-C network R5/C3 is used instead. For sure, such a clock source is less stable than a crystal, but then in an application like this, that may well be what we're after as a degree of randomness is a design target instead of a disadvantage.

Our suggested PCB shown here takes all the components for this project except of course for S1, S2, and the LDR, which will need to be positioned on the front panel of the case in order to sense the ambient light intensity. The PCB has been designed for a Finder relay capable of switching 10 A, which ought to prove adequate for lighting your home, unless you live in a replica of the Palace of Versailles.
The program to be loaded into the 12C508 is available for free download from the Elektor website as file number 080231-11.zip or from the author's own website: www.tavernier-c.com.
On completion of the solder work the circuit should work immediately and can be checked by switching to manual mode. The relay should be released in the 'off' position and energized in the 'on' position.
Then all that remains is to adjust the day/night threshold by adjusting potentiometer P1. To do this, you can either use a lot of patience, or else use a voltmeter – digital or analogue, but the latter will need to be electronic so as to be high impedance – connected between GP4 and ground.
When the light level below which you want the lighting to be allowed to come on is reached, adjust P1 to read approximately 1.4 V on the voltmeter. If this value cannot be achieved, owing to the characteristics of your LDR, reduce or increase R8 if necessary to achieve it (LDRs are known to have rather wide production tolerances).



COMPONENTS LIST

Resistors
R1 = 1kΩ 500mW
R2 = 4kΩ7
R3 = 560Ω
R4,R6 = 10kΩ
R5 = 7kΩ5
R 7 = LDR
R8 = 470kΩ to 1 MΩ
P1 = 470 kΩ potentiometer

Capacitors
C1 = 470µF 25V
C2 = 10µF 25V
C3 = 1nF5
C4 = 10nF

Semiconductors
D1,D2 = 1N4004
D3 = diode zener 4V7 400 mW
LED1 = LED, red
D4 = 1N4148
T1 = BC547
IC1 = PIC12C508, programmed, see Downloads

Miscellaneous
RE1 = relay, 10A contact
S1 = 1-pole 3-way rotary switch
F1 = fuse 100 mA
TR1 = Mains transformer 2x9 V, 1.2 -3 VA
4 PCB terminal blocks, 5 mm lead pitch
5 solder pins
PCB, ref. 080231-I from www.thepcbshop.com

Equipped with this inexpensive accessory, your home of course hasn't become an impregnable fortress, but at least it ought to appear less attractive to burglars than houses that are plunged into darkness for long periods of time, especially in the middle of summer.

(www.tavernier-c.com) (080231-I)

Downloads

The PCB layout can be downloaded free from our website www.elektor.com; file # 080231-1.

The source code and .hex files for this project are available free on www.elektor.com; file # 080231-11.zip.

Low-Voltage Step-Down Converter

Steffen Graf

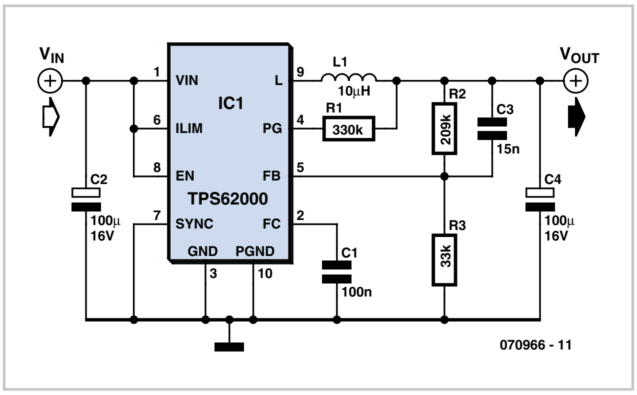
Sometimes you have a situation where you have a 5-V supply voltage but part of the circuit needs a lower supply voltage. A voltage regulator from the Texas Instruments TPS62000 family [1] is a good choice for this if the current consumption is less than 600 mA.
The essential advantages are:
• small (but still manually solderable) SMD package;
• high operating frequency (750 kHz) => small external inductor;
• integrated power MOSFETs => high efficiency (up to 95 %);
• no external switching diode necessary.

You can thus use this device to build a very compact, highly efficient voltage converter. A sample layout generated by the author

is available as a file on the Elektor website.
The TSOP62000 provides an internal reference potential of 0.45 V, which can be used to set the output voltage in the range of 0.5 V to 5 V by means of resistors R2 and R3. The formula for this is:

$V_{out} = 0.45\ \text{V} + (0.45\ \text{V}) \times (R2 / R3)$

For relatively low voltages, the value of inductor L1 should be 10 µH, but a value of 22 µH is better if the output voltage is 3.3 V or more. The input voltage can be anywhere in the range of 2 V to 5.5 V, and of course it has to be higher than the desired output voltage. The output voltage is 3.3 V with the indicated component values and an input voltage of 5 V. If you want to reduce the component count even further, you can use a member of the family with a fixed output voltage. The available voltages are 0.9, 1.0, 1.2, 1.5, 1.8, 1.9, 2.5, and 3.3 V. With this approach you can omit R2, R3 and C3, so the output can be connected directly to pin 5.



(070966-1)

Web Link

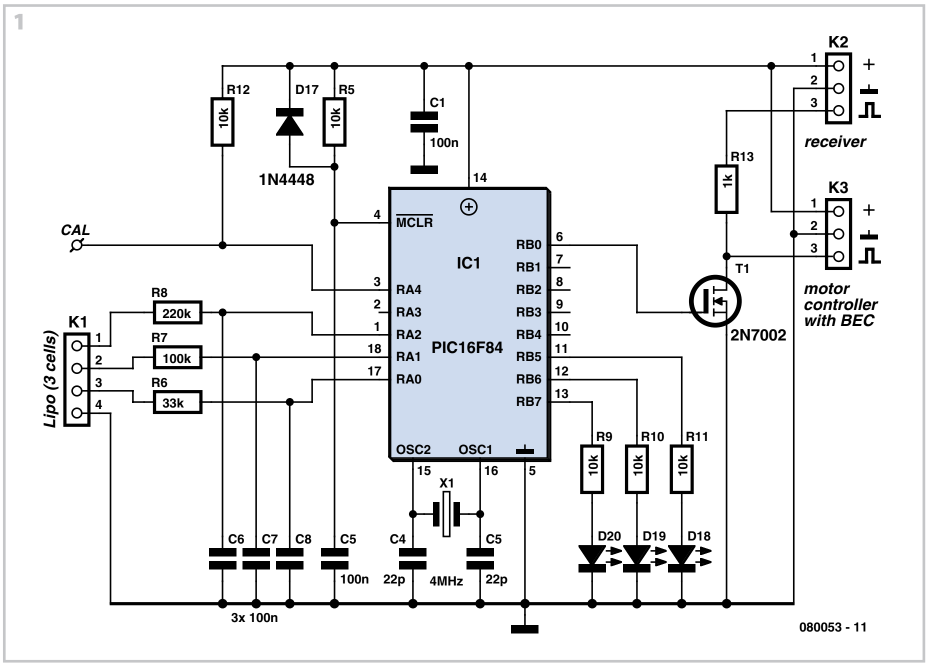
[1] TPS6200 datasheet
focus.ti.com/lit/ds/symlink/tps62000.pdf

LiPo Manager

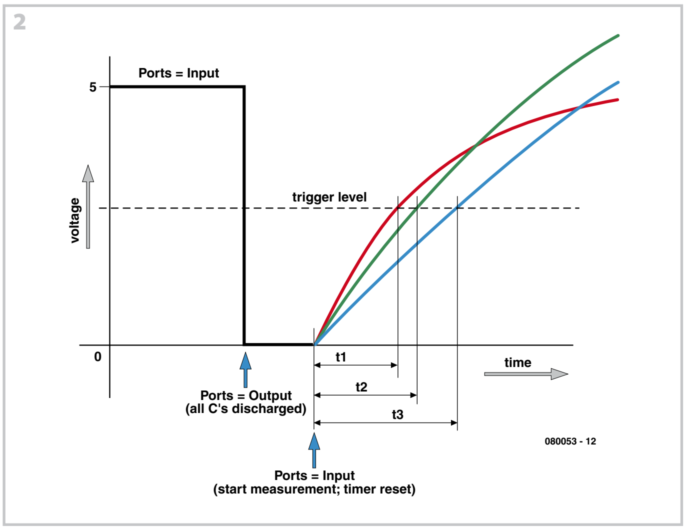
Andreas Graff

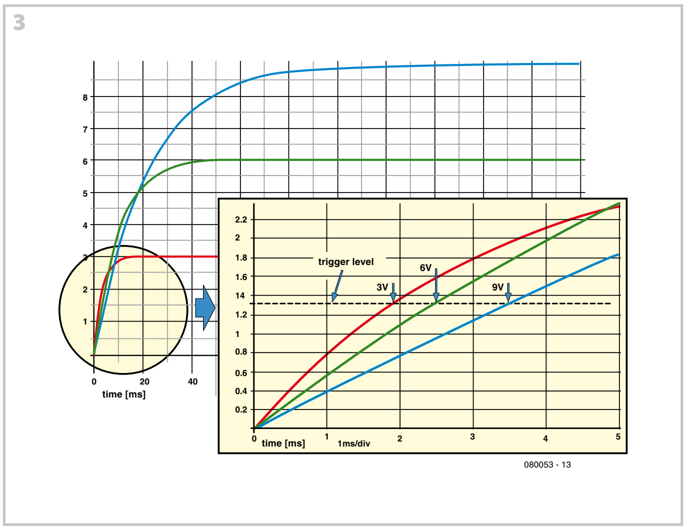
This circuit performs a managerial role for a three-cell Lithium-Polymer ('LiPo') rechargeable power pack used in a model aircraft. It monitors the voltage of each cell during discharge and cuts power to the motor when any cell dips below a voltage threshold. The R/C receiver is also powered from this battery via a Battery Elimination Circuit (BEC) but it remains operational so that the pilot remains in control and can safely glide the aircraft in to land. LEDs indicate which of the three cells caused the power to be cut. The circuit resets once power is turned off and on again.

1



The circuit shown in **Figure 1** measures the three voltage levels without the use of any dedicated hardware A/D converter. The A/D conversion is achieved by applying a voltage to an RC network and measuring the time it takes for the voltage to reach a threshold level (a digital '1'). For this application the technique has a number of advantages: the RC network is a low pass filter which removes any spikes and noise from the measured voltage and the hardware required is small, light and inexpensive.
Before measurement all ports are set to O/P and low so that the capacitors discharge. The ports are now configured as inputs and a timer measures how long it takes the three voltages to reach the threshold (see **Figure 2**).
It is a simple job to calibrate the circuit so it is not necessary to define absolute values for the trigger points. Only the low-to-high time is measured so it is not necessary to take into account any hysteresis levels. The aircraft is only flown within a fairly limited temperature range so it is valid to assume that small variations in the characteristics due to temperature changes can be ignored.
The time constants for all three inputs are chosen so that the time taken for the three voltages to pass the threshold is roughly of the same order of magnitude. The measurements are made on the steep rising edge of the exponential so the measurement sensitivity for all three levels is about the same (see **Figure 3**).
Measurement at the 6 V and 9 V tap must take into account the readings from the cell(s) below so that it can be determined which cell was guilty of triggering the shutdown. The result is shown on one of three LEDs.
The Microchip PIC P16F84 controller incorporates protection diodes on its inputs. The high values of the RC networks series resistors ensure there are no problems of latch-up with inputs of 6 V and 9 V.
During program debugging a serial interface (9600,8,n,1) was implemented in software (TxData on RB3, RxData on RB4), there





is more than enough memory space in the controller so the routine has been left in the program. The routine outputs the (8–bit) decimal value of the actual measurement for channel 1, channel 2 and channel 3. The controller watchdog is enabled to ensure reliable operation.

All the source and hex files for this project are available to download free of charge from the Elektor website at www.elektor.com; the archive number is 080053-11.zip.

To calibrate the circuit it is necessary to short the CAL pin to ground during power up. All three LEDs will light to indicate that it is in calibration mode. All LEDs now extinguish when CAL is released and calibration proceeds as follows:

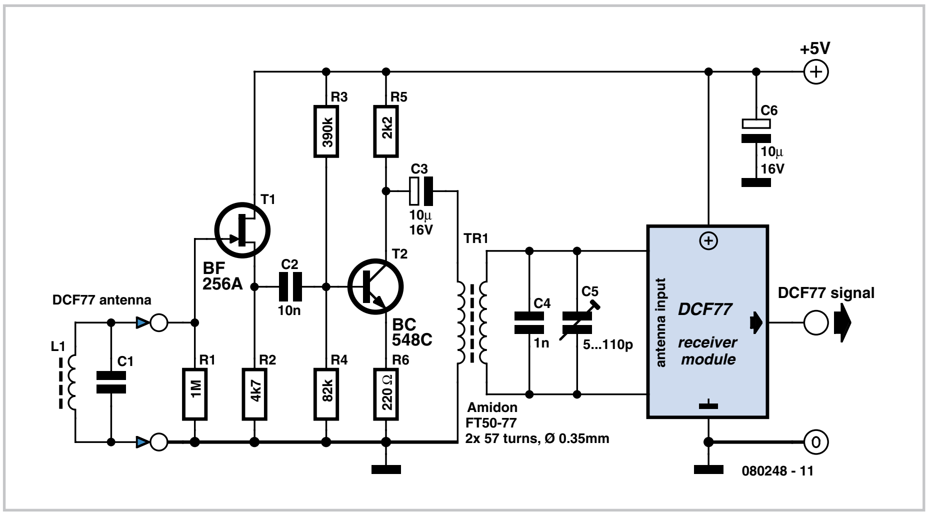
- LED for Channel 1 (D18) lights. Connect the output of a power supply to channel 1 (pin 3 of K1) and adjust the DC output to the correct level for one cell (2.9 V) then momentarily ground the CAL pin.
- LED for Channel 2 (D19) lights. Connect the output of a power supply to channel 2 (pin 2 of K1) and adjust the DC output to the correct level for two cells (5.8 V) then momentarily ground the CAL pin.
- LED for Channel 3 (D20) lights. Connect the output of a power supply to channel 3 (pin 1 of K1) and adjust the DC output to the correct level for three cells (8.7 V) then momentarily ground the CAL pin.

The LiPo manager is now in normal operational mode and ready to go.

(080053-I)

DCF77 Preamplifier

Rainer Reusch



A popular project among microcontroller aficionados is to build a radio-controlled clock. Tiny receiver boards are available, with a pre-adjusted ferrite antenna, that receive and demodulate the DCF77 time signal broadcast from Mainflingen in Germany. DCF77 has a range of about 1,000 miles.

All the microcontroller need do is decode the signal and output the results on a display. The reception quality achieved by these ready-made boards tends to be proportional to their price. In areas of marginal reception a higher quality receiver is needed, and a small selective preamplifier stage will usually improve the situation further.

The original ferrite antenna is desoldered from the receiver module and connected to the input of the preamplifier. This input consists of a source follower (T1) which has very little damping effect on the resonant circuit. A bipolar transistor (T2) provides a gain of around 5 dB. The output signal is coupled to the antenna input of the DCF77 module via a transformer. The secondary of the transformer, in conjunction with capacitors C4 and C5, forms a resonant circuit which must be adjusted so that it is centred on the carrier frequency.

An oscilloscope is needed for this adjustment, and a signal generator, set to gene-

rate a 77.5 kHz sine wave, is also very useful. This signal is fed, at an amplitude of a few millivolts, into the antenna input. With the oscilloscope connected across C4 and C5 to monitor the signal on the output resonant circuit, trimmer C5 is adjusted until maximum amplitude is observed.
It is essential that the transformer used is suitable for constructing a resonant circuit at the carrier frequency. Our prototype used a FT50-77 core from Amidon on which we made two 57-turn windings. It is also possible to trim the resonant frequency of the circuit by using a transformer whose core can be adjusted in and out. In this case, of course, the trimmer capacitor can be dispensed with.

(080248-I)

Camera = Data Store

Stefan Hoffmann

Actually this is a travel tip, not a circuit. If you own a digital camera, then you've got a memory card for computer data as well. Camera memory cards are primarily for storing pictures of course but they are also ideal for backing up data you might need on a journey.

Cameras are not fussy about data formats and with today's memory capacities of typically 2 GB on a cheap SD card, these memory cards provide more than enough storage for photos. This makes memory cards ideal for storing all kinds of emergency information such as details of your reservations, handy addresses, PDF copies of air tickets, travel permits and loads more. If you prefer this data to be independent of the camera you could also keep a separate SD card with this information in your pocket in case your luggage is lost, your briefcase is stolen or your wallet goes walkies. These memory cards are so compact that you could even keep one below a padded insole inside your shoe…

(080152-I)

RC Mains Sockets with Feedback

Jens Nickel

When on a trip to his local DIY emporium to buy light bulbs the author found a set of three radio-controlled mains sockets, plus transmitter, at a bargain price. Before the thought 'those will come in handy one day' had even made the journey from mind to mouth, they were in the trolley. On the journey home numerous ideas for what to do with the devices came to mind, most of which, it must be admitted, were rather fanciful in nature. One thing became apparent: for high-availability mission-critical applications, such as arming the (yet to be implemented, natch) home alarm system, or pre-warming the (not yet fully fitted-out) shed, one key feature was lacking. There was just one tiny LED on the remote control transmitter to show whether the on and off commands were being sent. There was no feedback from the receivers to indicate whether the command sent by the transmitter had been correctly received.

Suddenly the author was reminded of one of the first projects on which he worked as a fresh-faced young Elektor editor.
In 2005, his Elektor lab colleague Peter Verhoosel (who is now enjoying a well-earned retirement) put together an interesting article about novel applications for radio controlled switches. The transmitter was modified so that the sockets could be switched on and off under timer control [1].
Suddenly inspiration struck and the author was off to the DIY shop to buy another set of radio controlled mains sockets. With a few more pounds invested in the project, he was ready to start experimenting.
The idea was to use the two systems together to make a remote switch suitable for 'safety critical' applications.
A multi-way extension lead is plugged into the remotely switched socket, and the apparatus to be switched is plugged into one of the sockets on the extension lead. An ordinary mains adaptor is plugged into another of the sockets on the extension lead. Usually an adaptor with a 12 V output will be required.
Now we turn to the second transmitter-receiver set. The transmitter has to be mod-

ified a little by taking the contacts normally used for the battery to a suitable socket so that the unit can be powered from the mains adaptor. One of the 'on' buttons on the transmitter must also be bridged by a small switch. There is the possibility of a small difficulty here if the two transmitter-receiver sets are configured to operate on the same channel. In general this configuration cannot be changed, and so the best solution is to use button 1 on the first set to switch the remote device and button 2 on the second set to send the feedback signal.

The rest is obvious enough: the socket at the receiver end of the second set will now indicate whether the remote appliance has been properly powered up. One possibility would be to use the second receiver socket to power an LED night light or similar device.

The system is armed by closing the switch that shorts the pushbutton on the second transmitter, and (if it has a power switch) turning on the mains adaptor. And amazingly, the prototype worked first time: a press of the 'on' switch of the first transmitter switched on the remote socket, powered up the extension lead, and triggered the second transmitter into sending its feedback. The second receiver socket duly turned on, indicating that the original transmission had been successfully received.

(080500-I)

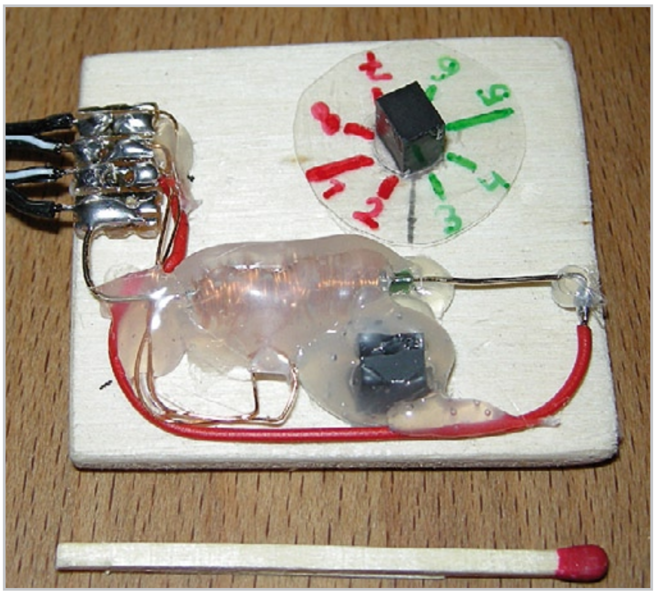
Web Link

[1] http://www.elektor.com/magazines/2005/october/remote-control-operator.57913.lynkx

Magnetic Flip-Flop

Bernhard Schnurr

The sensitivity of a reed switch can be affected by the judicious nearby placement of small magnets. Also, reed switches exhibit a certain amount of hysteresis: there is a distinct difference between the level to which the magnetic field strength must rise for the switch to pull in and the level to which it must fall for the switch to drop out.

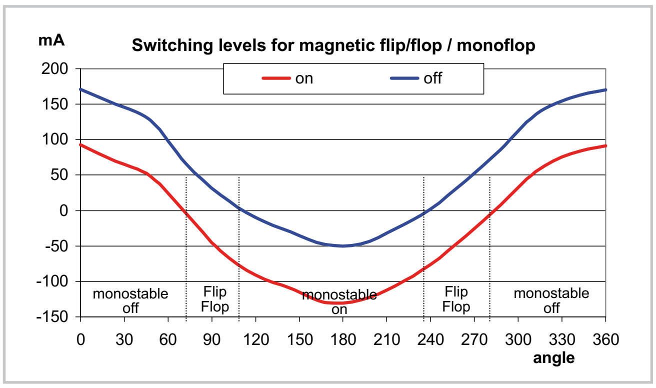


These properties in combination allow us to make an element with two stable states: a flip-flop. All we need is a permanent magnet strategically placed in the vicinity of the switch.

In practice getting the arrangement right is tricky, as the distance from the switch must be correct to within a fraction of a millimetre. However, once the right position is found, we have a bistable element that can be switched using either a second magnet or a small coil. The state of the element is preserved without power.

Since the adjustment required to achieve symmetrical behaviour is so critical, it is simplest to employ a second magnet, somewhat further away than the first. The behaviour of the system can be adjusted over a wide range by carefully rotating this second magnet, and it is now relatively easy to obtain reliable bistable operation.

The drive coil can be made using about a metre of enamelled copper wire wound



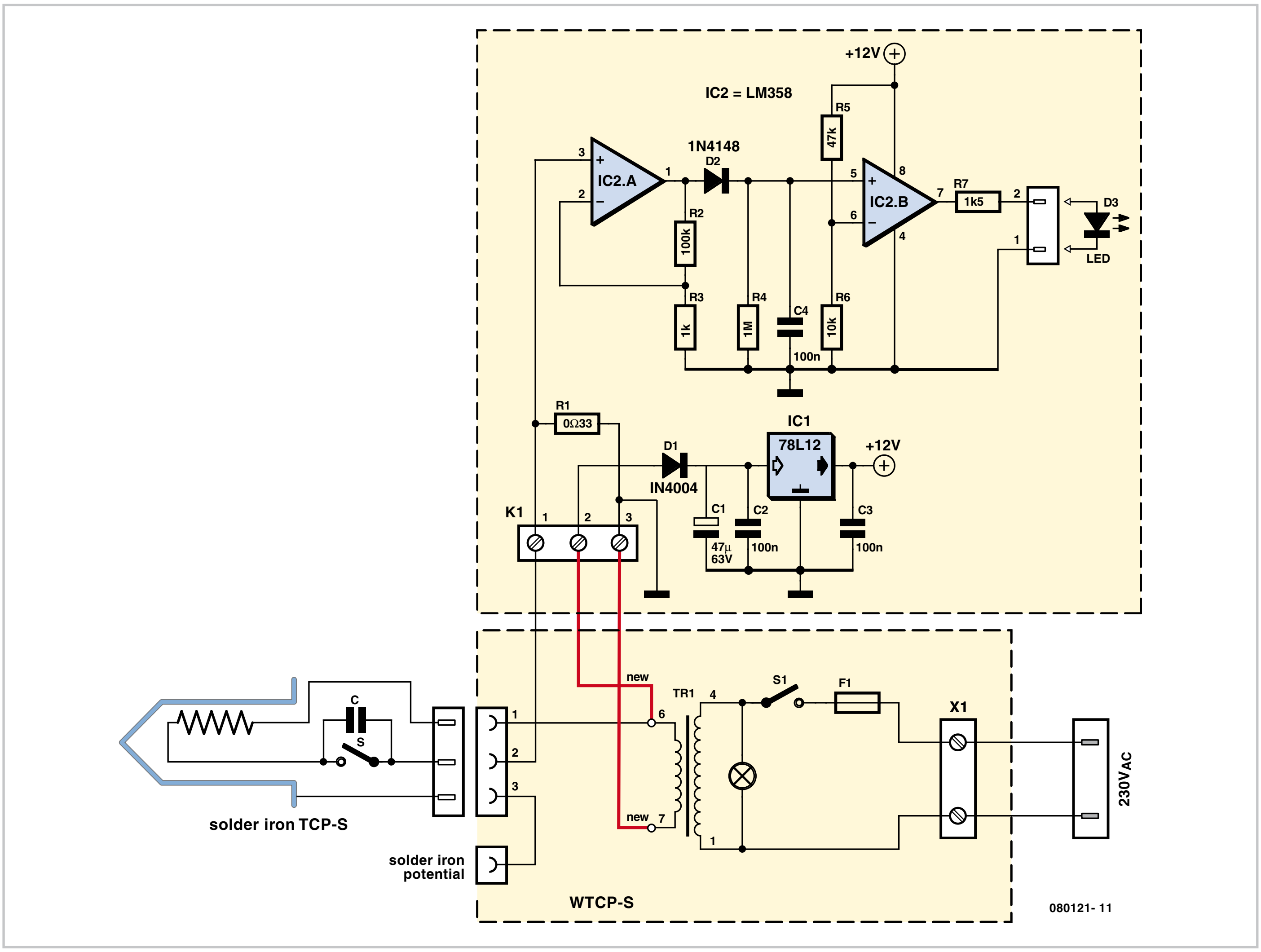
using a 2.5 mm drill bit as a temporary former. The coil is then fixed at the most sensitive point along the reed switch. The prototype shown in the photograph switches with a coil current of approximately 40 mA.

It is also possible to obtain other behaviours. One possibility is a normally-on reed contact with the contact broken when the coil current exceeds a certain value, forming a kind of electronic fuse. Equally, we can produce a normally-off contact which makes at a defined coil current: essentially a configurable relay. With the prototype shown we achieved switching currents of up to approximately 180 mA, and with the second magnet correctly adjusted it is possible to achieve switching currents down to just one milliamp.

The graph shows the points at which the reed switch changes state, as a function of the angle at which the second magnet is placed and on the coil current. The curve is not particularly smooth, as you might expect from genuine measured data. Without the second magnet the contact pulls in at 63 mA and drops out at –17 mA.

(071158-I)

Indicator for Weller Soldering Stations



Heinz Kutzer

Many of the soldering stations produced by Weller/Cooper Tools Group use the 'Magnastat' principle to control the bit temperature. The interchangeable bits are fitted with a magnetic cap which pulls on a contact in the iron and completes a circuit to switch power to the heating element. When the magnet in the tip reaches a predefined temperature (the so-called 'Curie temperature') it loses its magnetism and releases the switch contact. The process is reversible so that the contact is remade as the temperature falls. A number stamped on the cap identifies its operating temperature: 5 = 260 °C, 6 = 310 °C, 7 = 370 °C and 8 = 425 °C. When used with lead based solders a 370 °C bit is the usual choice. The heating element is switched on when the tip is below this temperature and off when it is above it, keeping the tip temperature constant.

It is fair to say that the Weller solder station is probably the most commonplace piece of test gear you are likely to encounter in labs and electronics departments up and down the country. They have a good reputation for reliability and the circuit suggested here is an add-on indicator lamp to show when the soldering tip is up to temperature. The circuit described here is intended to be installed in the housing which forms the base of the soldering iron. An LED fitted to the front panel indicates when the iron is heating. The circuit works by measuring the voltage difference dropped across a shunt resistor fitted in series with the heating element in the iron. It is not necessary to carry out any calibration on the circuit.

This design can be fitted to the WTCP-S, WTCP 50 and WTCP 51 soldering iron stations from Weller.

The add-on indicator circuit can be seen in the uppermost dashed box of the circuit diagram, the lower box represents the internals of the soldering iron station. A transformer in the base supplies 24 V to the heating element in the iron and is connected via a cable and three pin plug/socket on the base unit. The heating element has an impedance of 12 Ω which produces an average current of 2 A and a peak value of 2.822 A. Using a 33 mΩ resistor for the shunt (R1) gives a voltage drop of 93 mV (peak) when the element is heating.

IC2 is a LM358 type dual operational amplifier. The amplifiers are powered from a single-ended power supply and IC2.A is configured as an amplifier with a gain of 100. It amplifies the positive half waves of the voltage dropped across the shunt R1. The resulting output signal charges up capacitor C4 to approximately 10 V via diode D1 when the element is on. IC2.B is configured as a comparator and resistors R5 and R6 set the reference voltage to around 2.1 V. When the element is heating the comparator output is positive and the LED lights. As the operating temperature is reached the magnetic switch opens and the voltage across C4 is discharged through R4 (time constant = 100 ms) and the LED turns off. Power for the circuit is derived from the 24 V transformer in the solder station. Diode D1 performs half wave rectification and C1 is a reservoir capacitor to produce a DC voltage for the 12 V voltage regulator (IC1).

The maximum offset voltage for the LM358 is only 7 mV, with a gain of 100 this can produce an output offset of 0.7 V which is well below the 2.1 V comparator threshold and is not likely to be a problem so it is not necessary to fit any form of offset adjustment.

(080121-I)

Play the Guitar – Recycle Tip

Wisse Hettinga

You'll find a pair in every attic, at every jumble sale you will see a few in a box, every hobbyist has at least about four or so among their collection of bits and pieces: old sets of PC speakers!

After having served commendably for a few years on either side of the monitor they were disconnected and disappeared into the nooks and crannies mentioned above.

This though, does not need to spell the end for these speaker sets. Anyone who calls themselves a bit of a guitar player will always have a need for a practice amplifier.

And especially so if it can work from batteries as well.

The recipe is simple. The little speaker box without the amplifier you still throw away. The speaker with the amplifier can be used as is; connect your guitar with an adapter plug going from jack to mini-jack.

The output of the electric guitar does not match the input of the amplifier very well. But don't panic, a matching network between them, spruce it up a bit with some spray paint (black) and You Play the Guitar!

(080495-I)

Automatic Range Switching

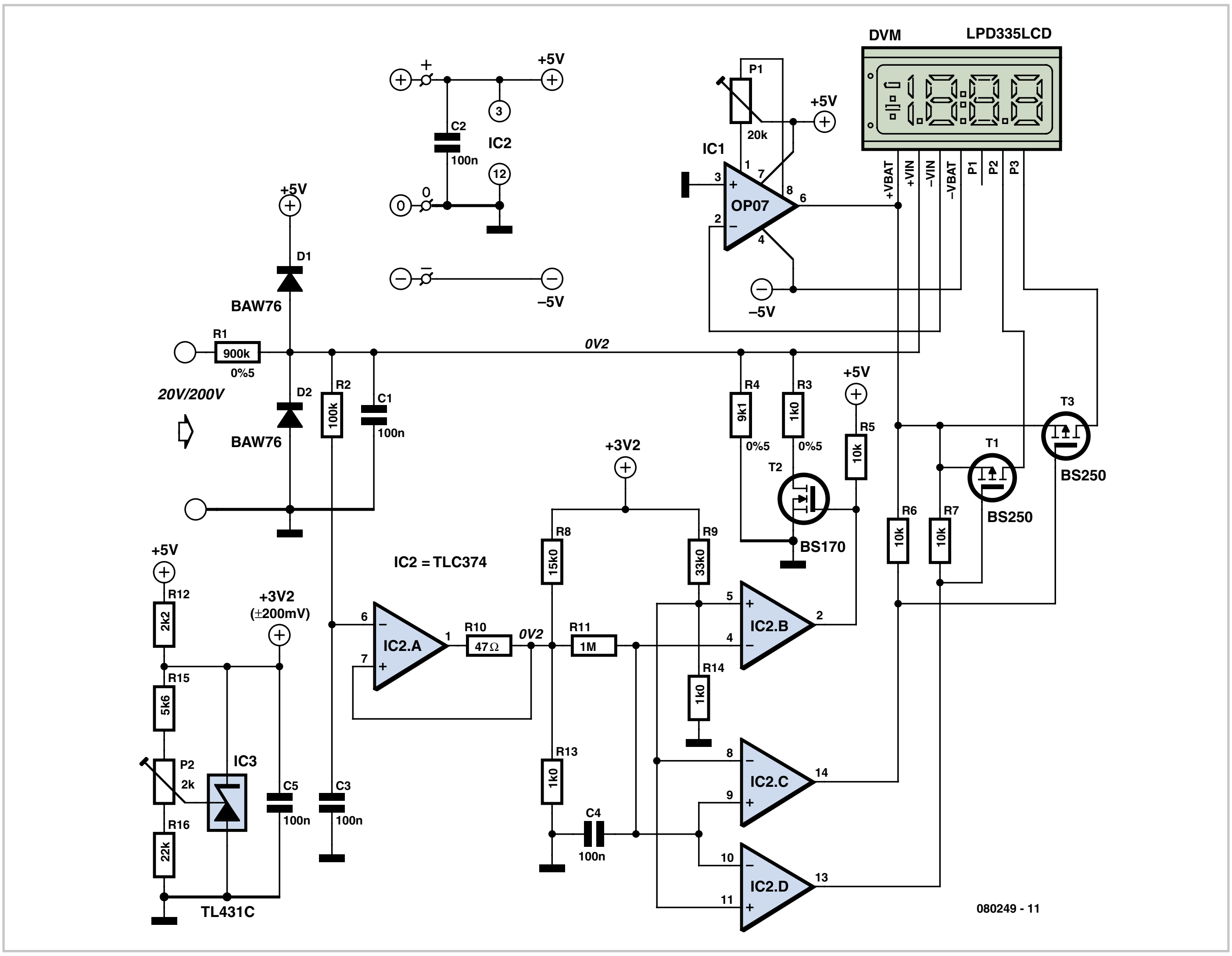
Rainer Reusch

You can pick up a 3½-digit digital voltmeter module nowadays for a little as a couple quid. This is a simple and expensive way to fit out a piece of equipment with an instrument. Most modules are based on the well-known ICL7106 IC. They operate from an ordinary 9-V battery, and they only provide a fixed measuring range (200 mV or 2 V). The accessory circuit described here converts a DVM module into a voltmeter with 20-V and 200-V measuring ranges, with the added bonus of automatic range switching. This requires a ground-referenced symmetrical supply voltage (±5 V) instead of a battery. An inexpensive TL431C is also used to generate an adjustable reference voltage from the supply voltage. The circuit described here uses an LCD module with a fixed measuring range of 200 mV. It has three pins for driving the decimal point; two of them are used here.

This is how the circuit works: IC1 converts the voltage to be measured by the DVM module into a ground-referenced voltage. This part of the circuit is based on a design idea from Carsten Weber [1] that was published in the June 2005 issue of *Elektor Electronics*.

If the input voltage is less than 20 V, the voltage divider formed by R1 and R4 reduces it by a factor of 100. Transistor T2 is cut off, so R3 has no effect on the division ratio. The voltage at the junction of voltage divider R8/R13 is 200 mV because the open-collector output of comparator IC2A is in the high-impedance state. If the input voltage rises above 20 V, IC2A changes state and the voltage at the junction of voltage divider R8/R13 drops to less than 20 mV. In response to this, the output of comparator IC2B goes high and T2 conducts. R3 is now connected in parallel with R4. This yields a division factor of 1000 (200-V range). Of course, the larger division factor also causes the input voltage of IC2A to drop. To prevent this comparator from changing back to its previous state (which would cause the circuit to act like a sort of oscillator), the value of R10 must be chosen such that the voltage at the junction of voltage divider R8/R13 is less than 20 mV, as previously mentioned. The calculated value (with R10 in parallel with R13) is approximately 9.6 mV. In practice, the value is around 18 mV due to the resistance of the output transistor of the comparator. This means that the circuit will switch back to the lower voltage range when the input voltage drops below approximately 18 V. The amount of hysteresis can be set by adjusting the value of R10. However, the circuit will oscillate if the value is too high. Film capacitors C1, C3 and C4 suppress noise and create a certain amount of inertia for range switching. This prevents frequent back-and-forth switching in the threshold region.

The other two comparators of IC2 supply mutually complementary output levels that depend on the measuring range. The associated decimal points of the DVM module are driven via p-channel FETs.



The circuit has two trimpots: P1 is used to correct for the offset voltage of the operational amplifier (IC1), while P2 is used to set the threshold level for range switching. For this purpose, first adjust the trimpot to produce the maximum possible reference voltage (around 3.4 V). Next apply an input voltage that causes a display reading of 19.99 (which ideally means 19.99 V). Now turn P2 until the measuring range switches. As a check, reduce the input voltage to force the measuring range to switch back, and then slowly increase the input voltage again. The ideal setting is reached when the measuring range switches before the DVM module displays an 'overrange' indication.

(080249-1)

Reference

[1] DVM Without Isolation,
Elektor Electronics June 2005.

Active Rectifier

Dr. Thomas Scherer

Diodes make admirable rectifiers and are simple and economical, but unfortunately they also exhibit forward voltage drop, and hence also power loss. The losses in ordinary silicon diodes are of the order of 0.7 W/A to 1 W/A, and for Schottky diodes the losses are in the region of 0.4 W/A to 0.5 W/A. In a bridge rectifier these losses are doubled, as the current path is always through two diodes in series.

These considerations led to the development by Wolfgang Schubert two years ago of an active rectifier using suitably-driven power MOSFETs, published in the 2006 Summer Circuits issue of *Elektor*. The circuit was highly symmetrical, consisting of a quad opamp and four MOSFETs, forming a bridge rectifier with a very low voltage drop.

However, reports in the *Elektor* online forum indicated that some people had experienced problems with the circuit. Curiosity aroused, the author was prompted to look more closely at the design, and so he built a version in order to test it more thoroughly. It appeared that the outputs of the TL084 did not always swing close enough to the positive and negative rails to switch the FETs off fully. Time for some modifications.

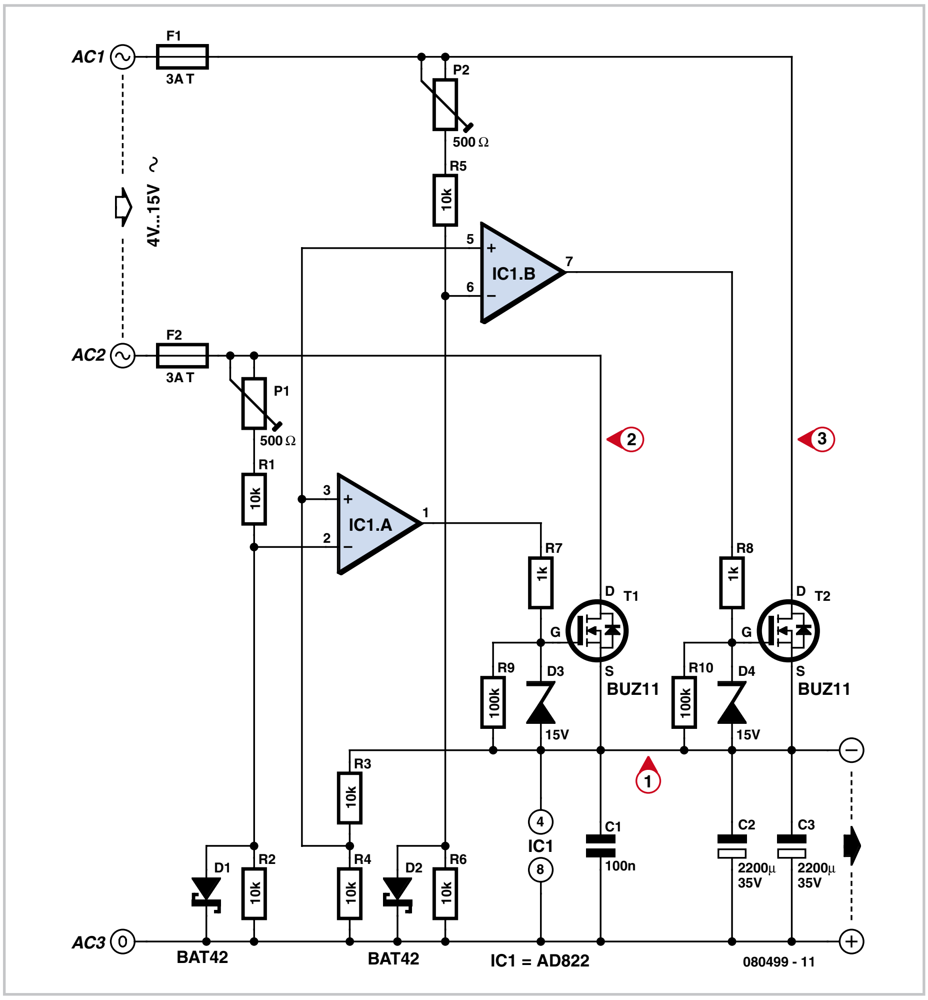
The first thought was, why not use a transformer with a centre tap on its secondary winding? Then we only need to simulate the action of two diodes, reducing circuit complexity and cost, as well as power losses, by nearly a factor of two. It also means that we do not have to find complementary p-channel FETs.

The second thought was, instead of using 1 % resistors, why not use two trimmer potentiometers and allow an adjustment to find the optimal switching voltages for the pseudo-diodes?

The result of these considerations was the circuit shown here, which roughly resembles one half of the original design. AC1 and AC3 are connected to either end of the secondary winding of the mains transformer, and AC2 is connected to its centre tap. Each half of the dual opamp drives its own power MOSFET.
When power is first applied the reservoir capacitors are both discharged, and the parasitic diodes present in each MOSFET are put to positive use: through them the capacitors are initially charged to provide power for the opamp. Usually the circuit will be in normal operation after the first half-cycle of the mains.

Let us suppose for illustration that the input is connected to a transformer with two 12 V secondaries and a power rating of 50 VA, and that at the output of the circuit we connect a load of approximately 5 Ω.
Roughly speaking we would expect a rectified output voltage of approximately 15 V and an output current in the region of 3 A. The voltage divider formed by R3 and R4 will provide a reference voltage of 7.5 V.
Every 10 ms there will be a negative voltage peak either on AC1 or on AC3. If the voltage at the junction of R1 and R2 or at the junction of R5 and R6 is less than the 7.5 V reference, the output of the corresponding opamp will go high and the connected MOSFET will be turned on. P1 and P2 allow the point where the MOSFETs are turned on to be set individually in terms of the voltage difference between input and output. These voltages can be measured using an oscilloscope (a multimeter will not do the job!) between test points 1 and 2 and between test points 1 and 3.

With the component values given the threshold voltage can be set in the range 0 V to 375 mV in our example. In practice, with a 3 A load and using BUZ11 MOSFETs, a suitable threshold voltage is between 50 mV and 100 mV. Power losses



in the MOSFETs are only around 150 mW to 300 mW and so the devices do not need extra cooling. The potentiometers should not be set so that the MOSFETs conduct for longer than necessary, as this leads to brief short circuits of the input, audible as a humming of the transformer. It is best to start with the potentiometers adjusted to the centre of their travel.
D1 and D2 ensure that the inputs to the opamps never see excessive voltages of the wrong polarity. D3 and D4 protect the gates of the power MOSFETs.

With the components shown the active rectifier is suitable for output currents of up to around 5 A. The maximum transformer voltage is 15 V and so the output voltage is limited to about 20 V under load. With no load, a nominally 18 V transformer with poor regulation can give rise to DC voltages of over 32 V, exceeding IC1's maximum rating. Lower-impedance toroidal transformers with secondaries rated at up to 20 V (corresponding to 27 V at the output under load) work fine. The reservoir capacitors should be rated at at least twice the secondary voltage of the transformer. If more current is required (as is quite likely, since the circuit is designed for operation at low voltages) higher-power (lower 'on' resistance) FETs and larger smoothing capacitors are needed. Using the IRFZ48N and two 4700 µF electrolytics up to 10 A can be delivered with minimal losses. With a small piece of aluminium as a heatsink the FETs barely get warm. The printed circuit board tracks need to be reinforced with soldered wire links, and 6.3 A slow-blow fuses should be fitted for electrical safety.

Other dual opamp ICs besides the AD822 can be used. The author has also had good results using an original Texas Instruments TLC272. The outputs of this device can swing down to very nearly 0 V, which is essential in this circuit. Other suitable types include the OPA2244 and the better-known LM358N.

An Eagle layout file for the printed circuit board is available for free download from the *Elektor* website. The author would like to thank Hans-Jürgen Zons for his help in designing the printed circuit board.

(080499-I)

GPS Receiver

Thierry Duquesne

GPS has many other applications than just satnav in cars and other vehicles. It can also be used, for example, to note the position of a 'secret spot' for finding wild mushrooms out in the woodlands near your holiday chalet in Southern France…

Without seeking to compete with commercial GPS receivers, which employ powerful cartographic software to locate a vehicle or pedestrian in towns, our device quite simply lets us decode the GPS frames transmitted by the satellites and display the decoded latitude and longitude co-ordinates, which is enough information for finding where you are in the middle of a forest. Besides the cost (£ 65 or so) and the weight, the receiver described here is also interesting because of its powering, since it operates from just a simple 9 V battery, unlike commercial receivers that use a special built-in battery that's usually not removable.

Lastly, the system can very easily be incorporated into a mobile object like a robot etc.

Introduction to the GPS system

The Global Positioning System (GPS) is the main current worldwide satellite positioning system and the only one to be fully operational, while waiting for the European Galileo system. Set up by the US Defense Department in the 1960s, the system allows a person equipped with a receiver for the GPS frames to find out their position on the surface of the Earth. The first experimental satellite was launched in 1978, but the constellation of 24 satellites only really became operational in 1995.

Operating principle

The satellites send out electromagnetic waves that travel at the speed of light. Knowing this and the time the wave takes to arrive, it is possible to calculate the distance between satellite and receiver. To measure the time taken by the wave to reach it, the GPS receiver compares the transmission time (included in the signal) and reception time of the wave transmitted by the satellite. If the receiver has a clock that is perfectly synchronized with that of the satellites, three satellites are enough to determine the position in three dimensions by triangulation. However, if this is not the case, it takes four satellites to be able to resolve the clock issue and receive

Specifications:

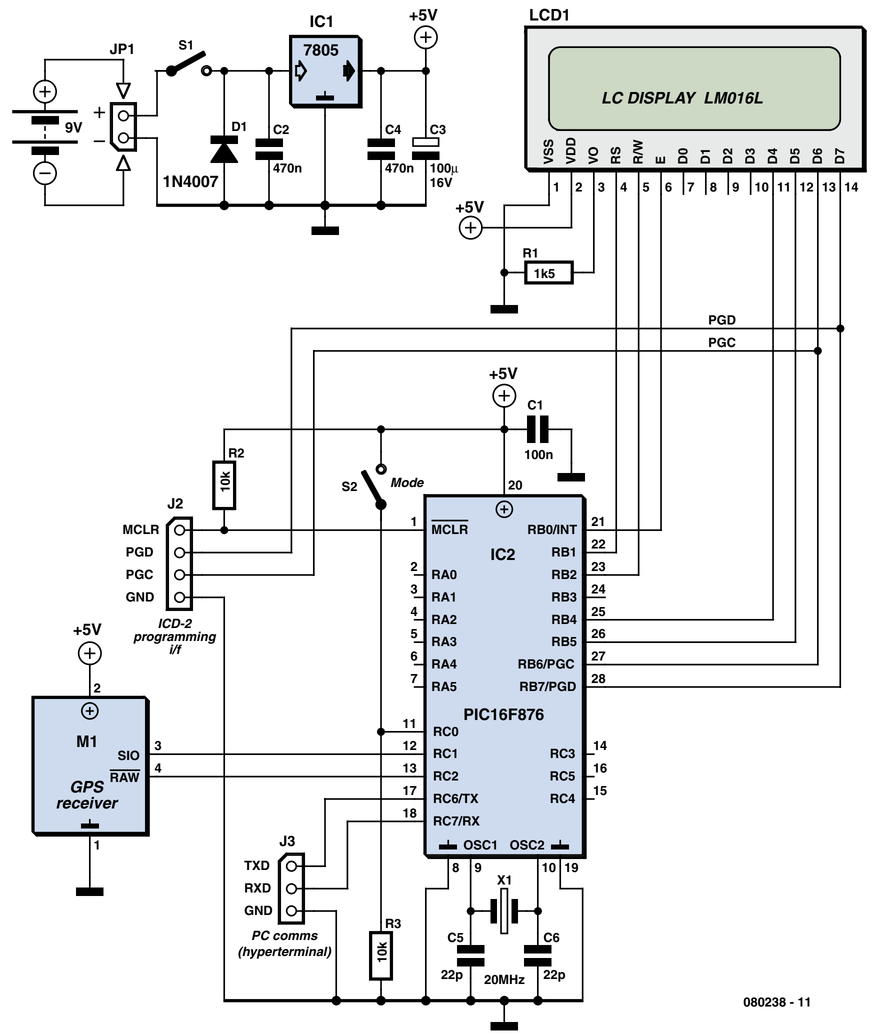
- Power supply: 5 V / 115 mA
- Built-in patch antenna
- System status display via red LED (flashing if the module is searching satellites for data acquisition and steady when at least three satellites have been successfully acquired)
- High sensitivity (–152 dBm for tracking, –139 dBm for acquisition)
- Rechargeable back-up battery for memory and real-time clock
- Position accuracy ±5 m and speed accuracy ±0.1 m/s
- Only four pins: 1 = GND 2 = +5 V Vcc 3 = serial communication: TTL, 8 data bits, no parity, 1 stop bit, uninverted (SIO: Serial Input Output) with 4,800 bps transmission 4 = mode selection (one single data

Displaying longitude and latitude information

There are three possible formats for displaying longitude and latitude data:

- 'GPS co-ordinates' format (degrees, minutes, and fractions of minutes) e.g.: 36°35.9159
- 'DDMMSS' format (degrees, minutes, seconds) e.g.: 36°35 54.95
- 'decimal' format e.g.: 36.5986°

The author normally uses the 'GPS co-ordinates' format display



the data correctly. A GPS can operate anywhere, just as long as it has an unobstructed view of the sky, 24 hours a day, 7 days a week. However, it's important to be aware that the position data may be incorrect in the presence of electromagnetic interference.

NMEA 0183 frames
Most GPS receivers provide data that can be used by other devices. The standard format is NMEA 0183 (National Marine & Electronics Association).

A NMEA 0183 frame is transmitted in the form of ASCII characters, at a rate of 4,800 baud. Each frame is preceded by '$', followed by the two letters 'GP' and three letters to identify the frame (most often GGA). Next come a certain number of comma-separated fields (making it possible to separate the various data).

To end, there is a checksum, preceded by the '*' symbol. This can be used to verify no errors have occurred during the transmission. One frame consists of a maximum of 82 characters. After that, it moves on to a new frame. Thus any microcontroller with a serial port can extract the data from the GPD module.

Here are a few examples of standard frames provided by the GPS module used in this article:

$GPGGA,170834,4124.8963,N,08151.6838,W,1,05,1.5,280.2,M,-34.0,M,,,*75 $GPGSA,A,3,19,28,14,18,27,22,31,39,,,,,1.7,1.0,1.3*34 $GPGSV,3,2,11,14,25,170,00,16,57,208,39,18,67,296,40,19,40,246,00*74 $GPRMC,220516,A,5133.82,N,00042.24,W,173.8,231.8,130694,004.2,W*70

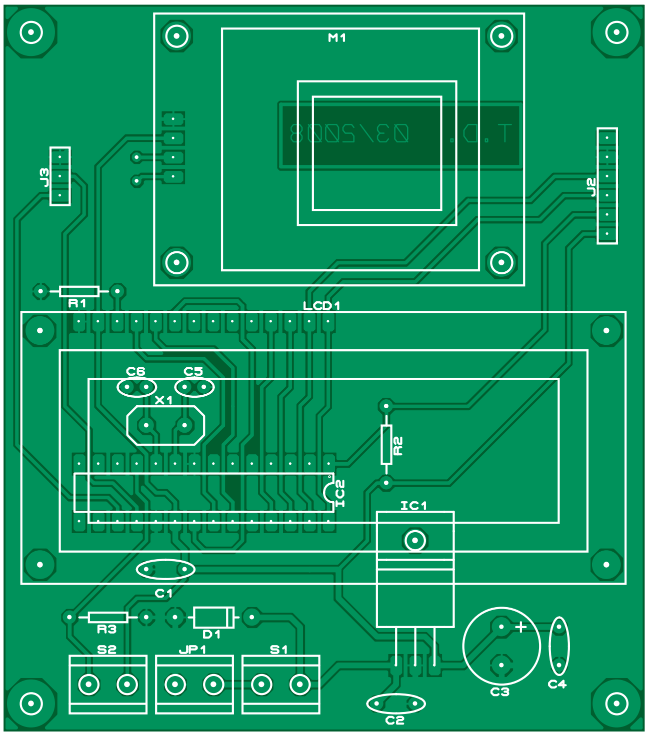
These strings of characters can be exploited to extract the wanted information, including for example the time, date, latitude, longitude, altitude, speed and direction of movement, and even the number of satellites being received or the validity of the received data.

The GPS receiver used is based on the integrated module offered by Parallax Inc. from the USA (or their local distributors).
Its principal characteristics are as follows:

- Reception of up to 12 satellites
- Data updated once per second
- 2 operating modes:

– Smart Mode: when the $\overline{\text{RAW}}$ pin is open-circuit (internally pulled up to logic high), the default 'Smart Mode' is enabled. In this case, the commands for receiving the special GPS data can be executed and the result returned. Each command is represented by one hexadecimal byte. Depending on the command, a certain number of data bytes will be returned. To send a command to the GPS receiver module, the user must first send the header characters '!GPS' (obviously without the quotes) followed by the specific command of their choice (for example, 0x02 to obtain the number of satellites being received) – in this instance, the receiver module would return one byte of data with the number of satellites.

– Raw Mode: When the $\overline{\text{RAW}}$ pin is forced low, the 'RAW Mode' is enabled, the module can then transmit the characters of the standard NMEA 0183 frames (GGA, GSV, GSA, and RMC), making it possible to use the raw GPS frames directly.



COMPONENTS LIST

Resistors
R1 = 1kΩ5
R2,R3 = 10kΩ

Capacitors
C1 = 100nF
C2,C4 = 470nF
C3 = 100µF 16V
C5,C6 = 22pF

Semiconductors
D1 = 1N4007
IC1 = 7805 (TO220 case)
IC2 = PIC16F876A (20 MHz), programmed with hex file from archive 080238-11.zip

Miscellaneous
X1 = 20 MHz quartz crystal (low profile)
JP1,S1,S2= 2-pin connector, 5mm lead pitch
J2 = 6-way SIL pinheader
J3 = 3-way SIL pinheader
K1 = connector for 9V battery
LCD1 = LCD, 2x16 characters, e.g. LM016L or equivalent
M1 = GPS receiver module type 28146 (Parallax Inc.)
PCB, ref. 080238-1 from www.thepcbshop.com

Certain devices, like engines, computers, and Wifi links, emit magnetic fields and interference that can prevent the module from receiving the required signals from the satellites and adversely effect its operation and performance. The acquisition time for a minimum of four satellites may take up to five minutes.

In the application described, we're going to be using the GPS module in 'smart mode'.

Electronics
Taking a look at the block diagram, we can see that our receiver revolves around a PIC16F876A microcontroller from Microchip Technology. Amongst its other tasks, it takes care of the transcoding and dialogue between the Parallax GPS receiver and the LCD display.
It's worth noting that the circuit has been

designed with two operating modes: you can either display just the geographical co-ordinates of latitude and longitude, or scroll through a whole mass of information (received frame validity, number of satellites received, date, GMT, altitude, latitude, longitude, and so on).

Powering is by way of a simple 9 V dry battery (or rechargeable), which connects to terminal block JP1. The 5 V supply voltage is generated by IC3, a 7805 regulator. Connector J3 allows dialogue with a PC via an RS-232 link (make provision for interfacing with a MAX232), while connector J2 allows programming of the PIC and in-circuit debugging thanks to the ICD2 marketed by Microchip.

The on/off switch S1 connects to the S1 terminal block on the board, the mode selection switch connects to the adjacent S2 terminal block.

PCB

It only takes a few minutes to build this circuit using the circuit board suggested here. The first step consists of soldering the small number of wire links, then the resistors, IC socket, unpolarized capacitors, and then the electrolytic capacitors, taking great care to observe correct polarity. Check for the presence of power on the correct pins of the IC socket. If everything is OK, next fit the programmed PIC (with the power off) into the socket, and finish by fitting the LCD display and the GPS module. The circuit should then work as soon as power is applied.

Selecting the display mode

By default, at power up the receiver displays the latitude and longitude co-ordinates. If you want to display more information, all you have to do is keep button S2 pressed as you power up the receiver.

(080238-I)

Downloads

The PCB artwork is available for free downloading from our website www.elektor.com; archive file 080238-1.zip.

The source code and .hex files for this project are also available from www.elektor.com; archive file 080238-11.zip.

Web Links

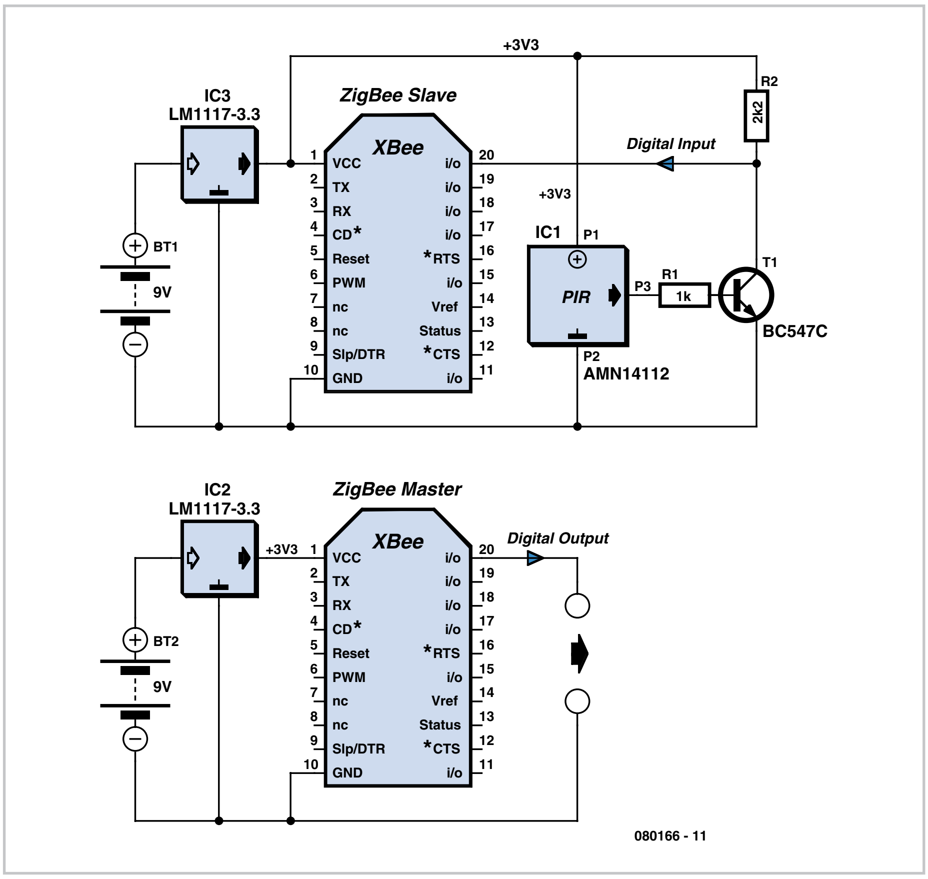
GPS 28146 manual:
www.parallax.com/Portals/0/Downloads/docs/prod/acc/GPSManualV1.1.pdf

PIC16F87XA data sheet:
ww1.microchip.com/downloads/en/DeviceDoc/39582b.pdf

ZigBee-based Wireless Motion Sensor

Sven van Vaerenbergh

It's easy put together a ZigBee wireless system if you use the XBee and XBee Pro modules. In this circuit, they are used to read the signal from a passive infrared PIR) motion sensor. This signal can be sent from one module to the other by using I/O Line Passing. A digital input signal on the DIO1 pin (pin 19) of module A can drive a digital output signal (DIO1) of module B. Similarly, an analogue input signal on AD0 of module A (pin 20) can control a PWM output signal of module B.



The 'master' module receives the sensor information from the 'slave' ZigBee modules. A single PIR sensor (type AMN14112) is connected to each slave. It has a digital output, a detection range of 10 metres, and an operating voltage of 5 V. As the ZigBee modules operate from 3.3 V, the lower supply voltage is obtained by using a 3.3-V regulator (type 1117) in combination with the circuit shown here.

The schematic diagram is simple and consists of only a few components: a 3.3-V voltage regulator with a 9-V battery, the module, the PIR sensor, and a transistor. The transistor pulls the digital input of the ZigBee module to ground when the PIR sensor detects motion. When the PIR sensor does not see anything, the transistor is cut off and the 3.3-V supply voltage is applied to the ZigBee module via a 2.2-kΩ pull-up resistor. Power is provided by the 9-V battery. This compact circuit can be built into a small case (so it can be placed in the garden, for example).

The modules are programmed using the X-CTU program. The data sheet for the

XBee modules is quite clear, and the commands are simple. The screenshot shows a terminal emulator with the settings for the transmitter module (with the connected PIR sensor).
Be sure to update the ZigBee command set to version 10A2 (v1.xA0*) when you are programming the modules, as otherwise you cannot include parameters with some of the commands and the module will not understand some of the commands.
Also be sure to perform a Read operation first when you update the firmware (from 1083 to 10A2). If you immediately perform a Write with the new version, you will lose communication with the module because the configured parameters will be overwritten.

The PIR transmitter module can be placed anywhere within a range of 30 metres from the receiver, such as in the garden. For a larger range, you can use the somewhat more expensive XBee Pro modules.

(080166-1)

Downloads

The source code and hex code for this design are available on www.elektor.com for free downloading; file # 080166-11.zip.

Master ZigBee code (receiver)

```
ATMY = 1 (Master address = 1)
ATDL = 0 (The address of the module it must receive data from is 0)
ATPL = 0 (Low power consumption)
ATIU = 1 (Disable transmission via UART)
ATBD = 3 (Set communication to 9600 baud)
ATD0 = 5 (Digital output on pin 20 of the module)
ATD1 = 5 (Digital output on pin 19 of the module)
ATIA = 0 (The master must change its outputs based on the slave with
   address 0. If ATIA = 0xFFFF, the master will change its outputs
   based on each received packet, independently of the address of
   the transmitter.)
ATWR (Save the settings in the flash memory)
```

Slave ZigBee code (transmitter)

```
ATMY = 1 (Slave address = 0)
ATDL = 0 (The address to which it must transmit is 1)
ATPL = 0 (Low power consumption)
ATIU = 1 (Disable transmission via UART)
ATBD = 3 (Set communication to 9600 baud)
ATD0 = 3 (Read the digital input signal on pin 20)
ATD1 = 3 (Read the digital input signal on pin 19)
ATIR = 14 (Sampling rate = 0x14)
ATWR (Save the settings in the flash memory)
```

Logic Goats

Rob Ives

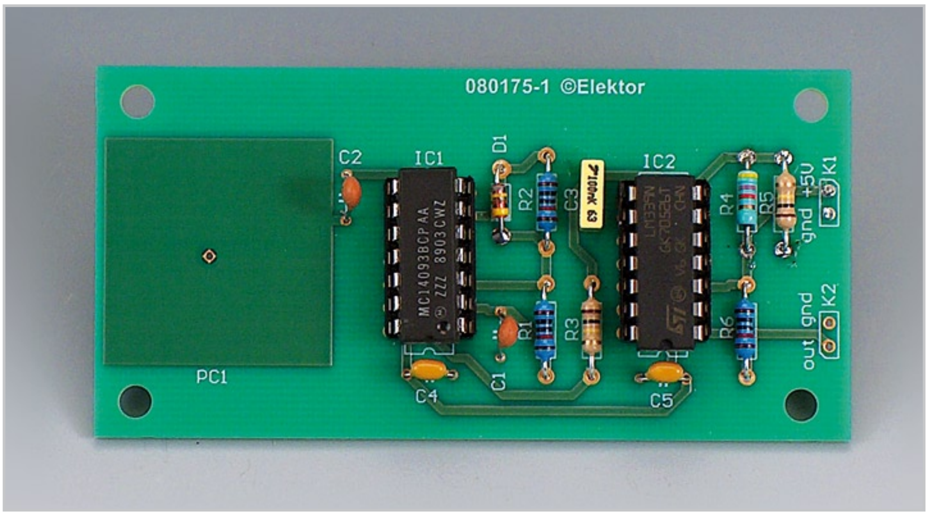
The central processing unit (CPU) at the heart of every computer or microcontroller system is basically a vast collection of microscopically small switches and logic gates. Unfortunately, the function of the logic gates in particular seems hard to grasp for the not too technically minded (or those who can't read simple tables).
Now, through the power of paper (cheap and generally available) these logic gates are available in goat form.
Properly constructed from the DIY guide the AND goat will nod its head only in you press the right button **and** the left button.
The OR goat, then, will nod its head in approval when the left button **or** the right button or **both** buttons are pressed.
The NOT goat, finally, gives a friendly nod of the head when the button is **not** pressed.
These models can be made from paper using delightfully designed cut-and-fold models you can download on the Flying Pig website. Suitable for age range 5 through 105 (some help may be required at the extremes).

(080482-I)

Web Link

www.flying-pig.co.uk/pagesv/logicgoat.html

Simple Capacitive Touch Sensor



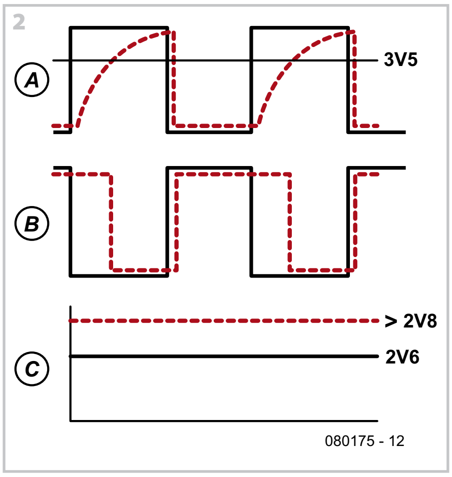
Wim Abuys

Capacitive touch sensors are based on the electrical capacitance of the human body. When, for example, a finger comes close to the sensor, it creates a capacitance to Earth with a value of 30 to 100 pF. This effect can be used for proximity detection and touch-controlled switching.

Capacitive switches have clear advantages compared to other types of touch switches (for example 50 Hz or 60 Hz detection or resistance detection), but are often more complex to implement. Manufacturers such as Microchip have in the past designed specialist ICs for this purpose. However, it is still possible to design a reliable capacitive detector and/or switch using only a limited number of standard components.
In this design we detect the change in the pulsewidth of the signal when the contact is touched. In **Figure 1** the following stages can be recognised, from left to right:

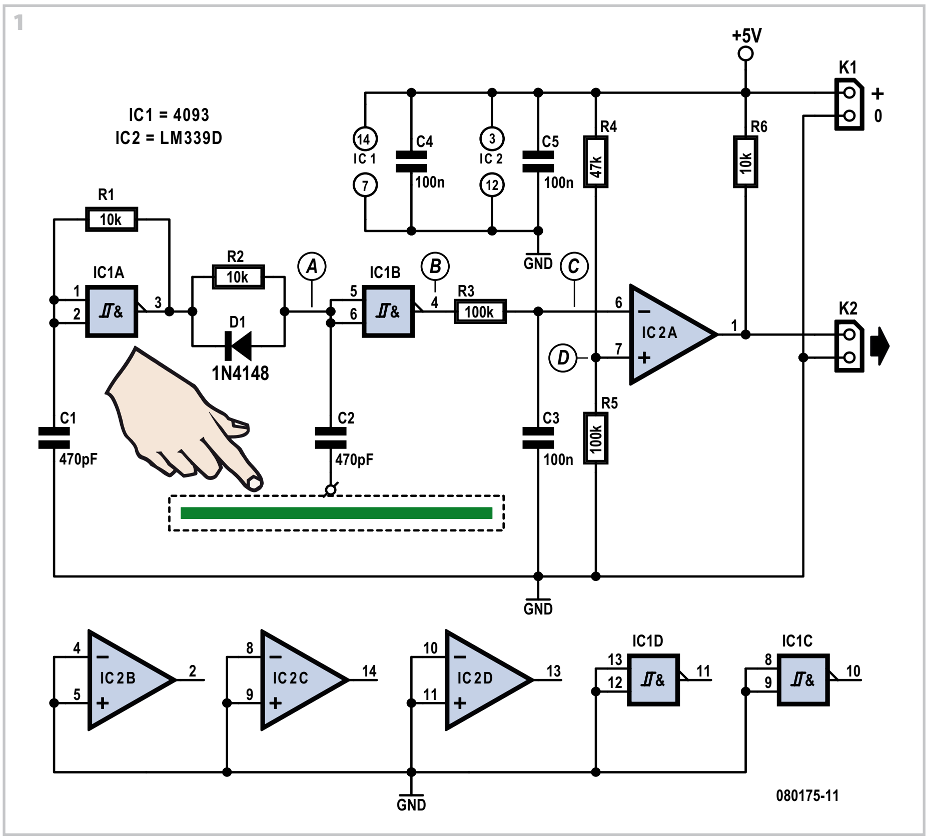
- a square-wave generator with a frequency of 300 kHz, using a Schmitt trigger IC (CD4093);
- an RC network with a flyback diode, followed by a Schmitt trigger/contact plate with an isolation capacitor of 470 pF;
- an RC network that converts the change in pulsewidth into a voltage. This voltage is about 2.9-3.2 V when the plate is touched (and 2.6 V when it isn't touched);
- an LM339 comparator is used to compare the voltage at point C with a reference voltage (D). The latter is set to about 2.8 V using a potential divider.

As long as the contact plate is touched the output of the circuit will be active. To make the operation of the circuit clearer we have



shown the signals at various points in **Figure 2**. The dotted line represents the signal when the plate is touched, the solid line when it isn't touched.
The reference voltage at D has to be set up once via potential divider R4/R5 (change the value of R4). The required value is strongly dependent on the surface area of the contact plate (this is usually a few square centimetres). Larger surfaces increase the capacitance and the voltage at C will therefore be greater when the plate isn't touched. The reference voltage at D should then be set closer to 3.4 V. The touch sensor can therefore also be made to work with larger areas (such as the complete metal enclosure of a device).

The circuit only works when a connection for higher frequencies (300 kHz) is made to Earth in some way. The circuit therefore doesn't work in battery-powered systems without a connection to Earth. In many systems without a direct connection to Earth there is sufficient parasitic capacitance to the mains Earth. In some cases it will be necessary to add an extra capacitor



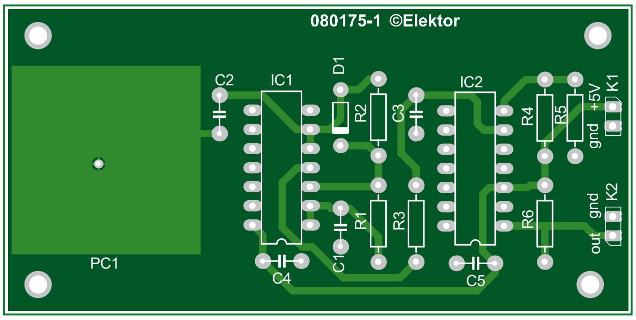
COMPONENTS LIST

Resistors
R1,R2,R6 = 10kΩ
R3,R5 = 100kΩ
R4 = 47kΩ

Capacitors
C1,C2 = 470pF
C3,C4,C5 = 100nF

Semicondcutors
D1 = 1N4148
IC1 = 4093
IC2 = LM339D

Miscellaneous
K1,K2 = 2-way pinheader
PCB, ref. 080175-1 from www.thepcbshop.com



between the mains Earth and the Ground of the circuit. To comply with safety regulations this capacitor should be rated for >3-4 kV (i.e. a Class Y capacitor).

The output signal can be used in various ways to switch on systems. The addition of an extra Schmitt trigger to the output is recommended in many cases, especially if the output connects to a digital input.

(080175-I)

Downloads
The layout for the printed circuit board is available from the Elektor Electronics website as a free download; ref. 080175-1.zip.

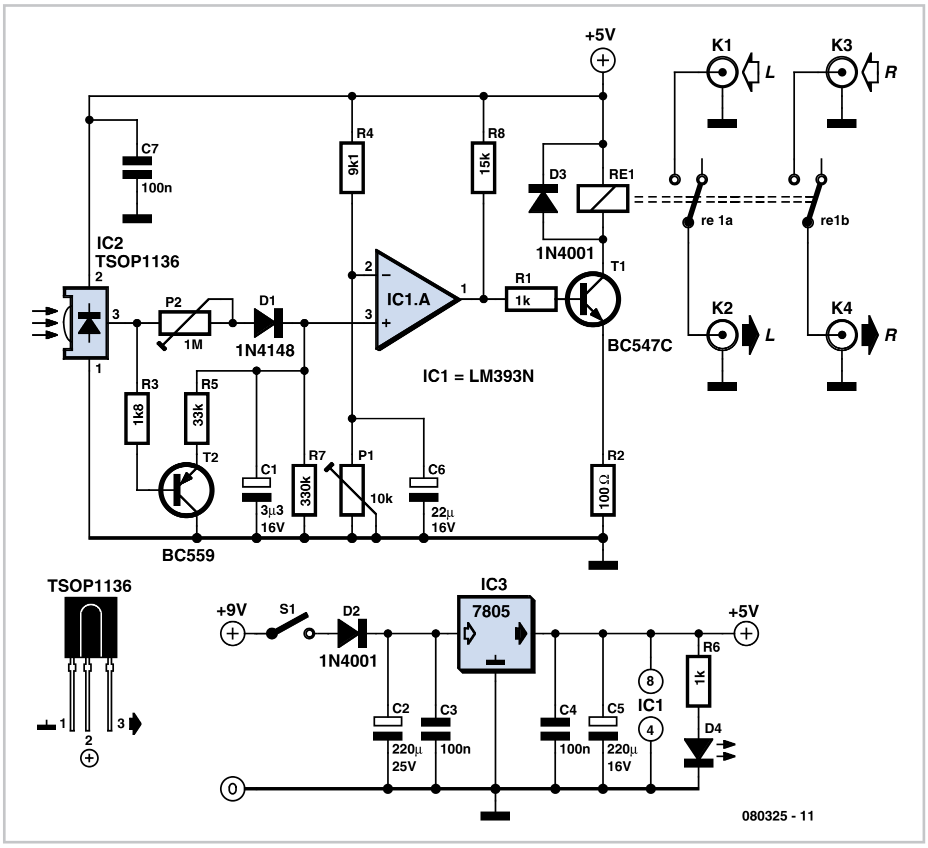
TV Muter

Michael Hölzl

Many households are still graced by tube-type television sets. If you want to connect one of these large tellies to your stereo system to improve the sound quality, this is usually not a problem because there are plenty of SCART to Cinch adapters available in accessory shops.

However, with some sets your pleasure is spoiled by the fact that the audio outputs of the SCART connector are not muted during channel switching. This can sometimes lead to nasty signal spikes, which can cause the loudspeakers of your stereo system to emit irritating popping and cracking noises. In such cases it is a good idea to fit your system with a mute circuit.

Fortunately, the right time to activate the mute circuit is defined by the fact that the happy zapper presses buttons on the remote control to switch channels, and the remote control emits IR signals. There are even inexpensive ready-made IR receiver modules available, such as the TSOP1136 used here, which produce trains of active-low pulses in response to such signals.



About the circuit: when no IR signal is present, a capacitor is charged via P2 and a diode. IC1 is a comparator that compares this IR voltage (applied to its non-inverting input on pin 3) to a voltage applied to its other input on pin 2. This reference voltage, which can be adjusted with P1, determines the switching threshold of the comparator. If IC2 receives an IR signal, T2 conducts, and as a result the voltage on C1 drops rapidly below the threshold level set by P1. This causes T1 to change from its previous 'on' state to the 'off' state. As a result, the relay drops out and the audio link to the stereo system is interrupted for the duration of the noise interval. It's all quite simple, as you can see.

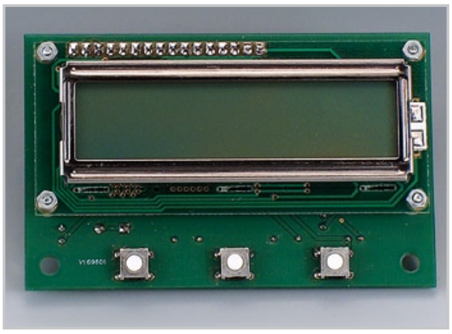
If you do not have a stabilised 5-V supply voltage available, you can use the circuit at the of the schematic diagram (with a 5-V voltage regulator) together with a simple (unstabilised) AC mains adapter that supplies a voltage in the range of 9 V to 12 V to the 7805 (IC3).

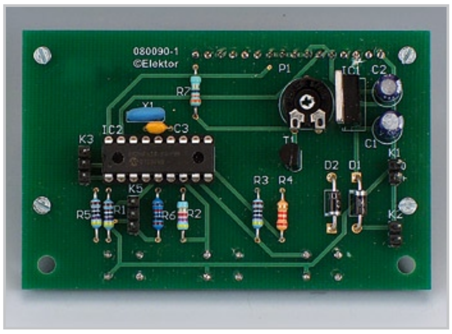
You can also use a relay with normally-closed contacts instead of normally-open contacts. In this case, simply swap the signals on pins 2 and 3 of IC1 so the relay pulls in when an IR signal is received instead of dropping out. This saves a bit of power because the relay is only energised during zapping. If you can't find any worthwhile use for the second comparator of IC1, it's a good idea to connect pin 6 to +5 V and pin 5 to ground.

To improve noise immunity, you should shield the IR sensor so it is not exposed directly to light from a fluorescent fixture.

(080325-1)

Universal Thermostat





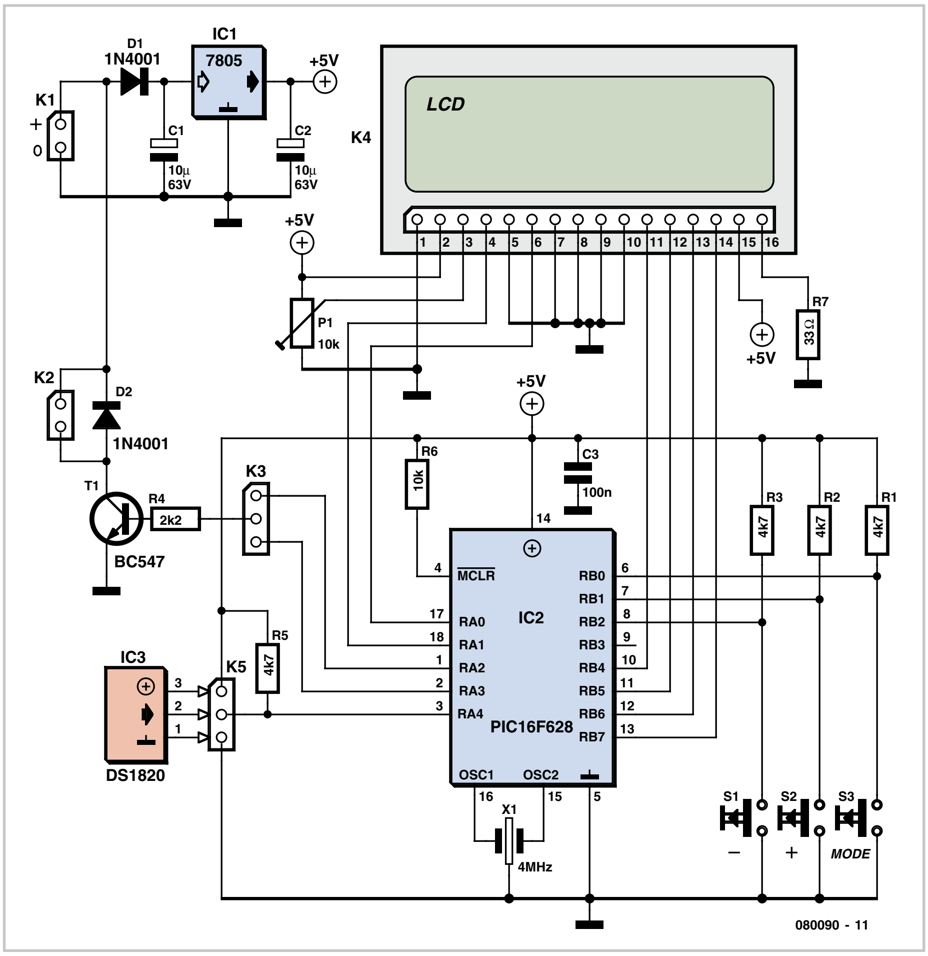
Ruud van Steenis

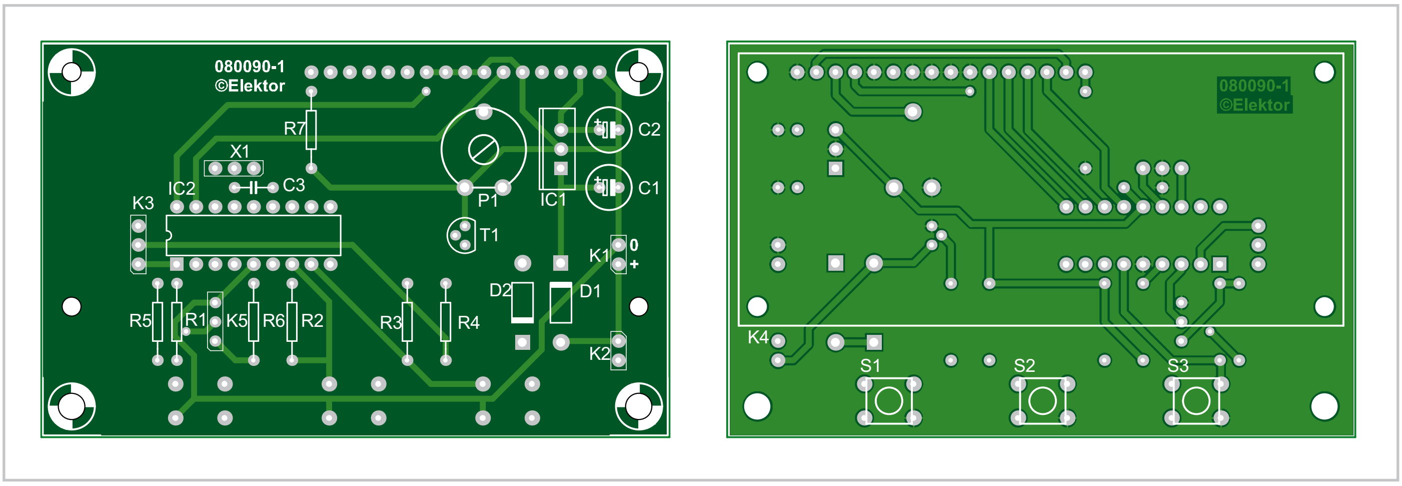
This circuit came about because of the dissatisfaction regarding the operation of the thermostat in a refrigerator. When using the built-in thermostat, it turned out that it was necessary to reduce the temperature setting in the summer in order to keep everything cold, compared to the setting in winter. This is probably as a result of a temperature sensor that is mounted too close to the cooling element, which means that phenomena such as thermal leaks and the average temperature in the fridge are not sufficiently accounted for in the control loop.

While designing the circuit for this electronic thermostat a decision was made to increase the control range so that it would also be suitable for other applications. Potential applications are the temperature control of a (living) room, heating of a flower box and obviously the etching tank!

The control range is adjustable from -25 °C to +75 °C in steps of 0.25 °C. The hysteresis is also adjustable. Hysteresis is the temperature error at which the system will turn on or off. A very small hysteresis results in a very stable temperature but has as disadvantage that the heating or cooling system turns on and off at a high rate, which generally leads to extra wear and tear in the compressor (cooling) or pump (heating). The hysteresis can be adjusted from 0.1 °C (very stable temperature) to 10 °C (practically no control at all...) in steps of 0.1 °C. The settings can be changed with 3 push buttons and the information is displayed on a 2×16 character LCD. The settings are stored in the EEPROM inside the PIC. During normal operation the LCD is used to display the actual temperature.

The main component in this circuit consists of a PIC 16F628. In addition to the aforementioned 2×16 character LC display, the





temperature sensor, type DS1820, also serves an important role in the circuit (connected to K5). Fortunately the DS1820 is already factory calibrated, so this saves us from a difficult task. A classic 7805-regulator and a common transistor pretty much complete the circuit. The clock source for the PIC is supplied by a 4 MHz ceramic resonator with built-in capacitors (Conrad Electronics order number 726406/726507).

There are two switching outputs from the PIC, one for cooling applications and another one when heating is called for. When cooling, the refrigeration system obviously has to be turned on when the temperature is too high, while when heating, the appropriate action needs to be taken when the temperature threatens to become too low. A jumper in this circuit makes the selection between cooling (jumper 2-3 on K3) and heating (jumper 1-2 on K3) possible.

When the circuit is turned on, the display shows 'TEMPERATURE' with underneath that the actual temperature in degrees Celsius. If the sensor is not connected then an error message will be displayed. By holding down the 'Mode' button until an asterisk appears, the text 'SET TEMPERATURE' appears and you can set the desired temperature in steps with the + and - buttons. By pressing the Mode-button again it is possible to set the desired hysteresis with the + and – buttons.

A hysteresis of 1 °C means that with a temperature setpoint of 20 °C and when heating, the output becomes active when the temperature drops below 19 °C (20–1), while everything turns off when the temperature reaches 21 °C (20+1).

To connect the circuit to external equipment a relay control (via K2) was chosen because of safety considerations. The transistor can easily handle currents up to 100 mA and a free-wheeling diode suppresses the back-emf from the relay coil. The power supply voltage can be selected based on the rated coil voltage of the relay that is used, 12 V, for example.

Keep in mind that when using this circuit to replace the thermostat in a fridge, the compressor motor which is to be controlled is directly connected to the mains and **a safe implementation of the complete circuit is therefore absolutely essential.**

If this circuit is used to heat, for example, a flower box, it can be useful to replace the switching transistor with a HEXFET. A prototype circuit with an IRFP3710, supplied a 12-V heating element with 1.5 A without any trouble at all, while the losses where so small that no heatsink was required. The 5-V output voltage from the PIC was in this case sufficient to turn the FET on properly.

The program in the 16F628 fills only about half of the available program memory space. Because there was no compelling need to program the whole thing in a particularly 'compact' way, the PicBasic Pro compiler was used for generating the hex file for the PIC.

Both the source file (1820THER.BAS) as well as the hex file to be programmed into the 16F628 (1820THER.HEX) are available free from the Elektor website as file number 080090-11.zip.

The source code is liberally commented, so that making changes (changing the temperature range, for example) is quite straightforward.

The temperature is initially set to 20 °C and the hysteresis to 2 °C.

For the sensor it is best if you use a 'plain' DS1820 and fit it with a length of 3-way ribbon cable. When using it with a refrigerator this has the advantage that the sensor cable can be easily routed to the outside because the rubber seal on the fridge door still closes sufficiently well to seal around the cable. Once the ribbon cable is connected to the DS1820, you can cover the sensor entirely with a thin layer of two-part epoxy glue and (before the glue has set) shrink a small length of heatshrink tubing around it. This gives a good, waterproof seal.

Alternatively you can buy a ready-made waterproof DS1820 sensor (for example Conrad Electronics # 184037/184052). These have, however, a type of telephone cable that is somewhat thicker than the ribbon cable.

(080090-I)

COMPONENTS LIST

Resistors
R1,R2,R3,R5 = 4kΩ7
R4 = 2kΩ2
R6 = 10kΩ
R7 = 33Ω
P1 = 10kΩ preset

Capacitor
C1,C2 = 10µF 63V
C3 = 100nF

Semiconductors
D1,D2 = 1N4001
T1 = BC547
IC1 = 7805
IC2 = PIC16F628-04/P (programmed, with software # 080090-11)

Miscellaneous
X1 = 4MHz ceramic resonator
S1...S3 = miniature push button
K1,K2 = 2-way pinheader
K3,K5 = 3-way pinheader
K4 = 16-way pinheader
DS1820 and 3-way ribbon cable
LCD with 2x16 characters
PCB #080090-1 from www.thepcbshop.com

Downloads

The source- and hex-code for this project, 080090-11.zip, as well as the layout for the PCB (080090-1.zip) are available as a free download from the Elektor website.

DTMF-controlled Home Appliance Switcher

Features

- Controls 6 high-power DC devices Five digits password security
- User-defined password
- Feedback to user by sounds
- Password and device status retained in EEPROM
- Device status on LED panel

Hesam Moshiri

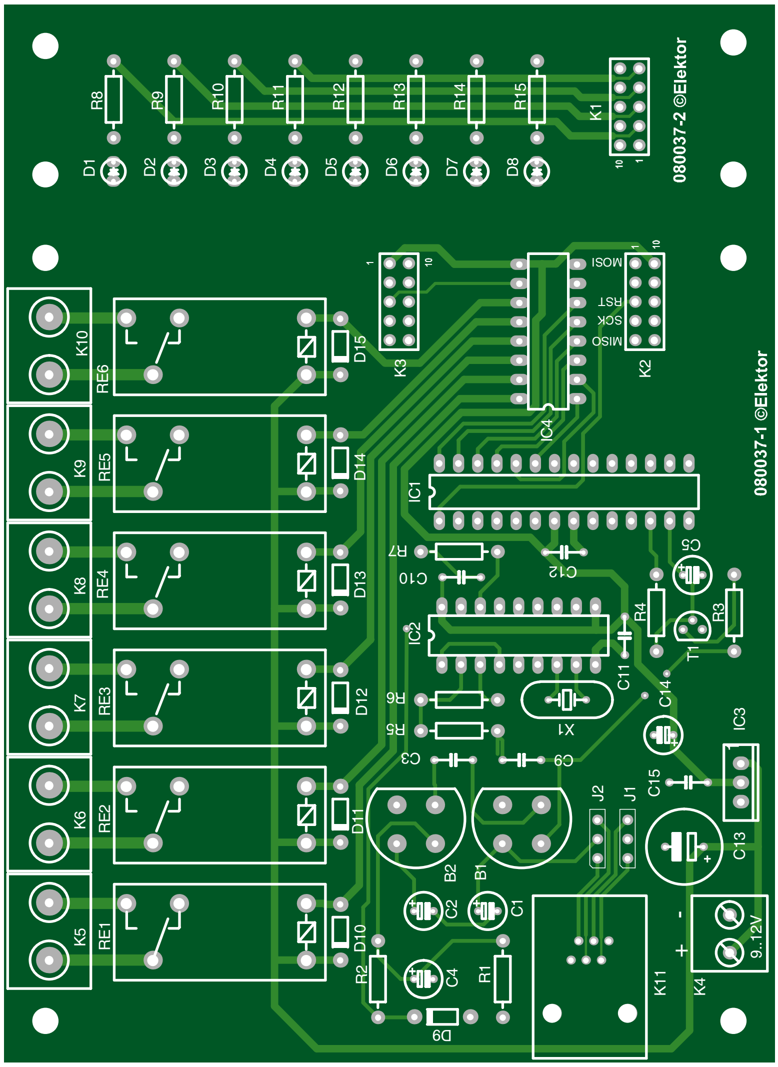
Caution. This circuit is not approved for connection to the public switched telephone network (PSTN).

Caution. Observe electrical safety precautions when connecting mains-operated loads to the circuit.

This circuit can be called using your mobile or a regular telephone set (with DTMF keys) and after passing some procedures, you can control DC-powered appliances installed in your home. Examples include the front door latch and the pump of a plant watering system.

You call the circuit and after three rings, it will answer your call and you will hear two little beeps. Next you enter your password. The default password for the circuit is: **12345**. Finish the password number with a hash (**#**) character. If your password is correct, you will hear two short beeps and you can control your devices or change a password. If you push the character * you will enter the password menu. Enter a new password using numbers (0-9) and with five digits length. Close off with a # at the end of the new password (e.g. 54321#). You will hear one long beep indicating that your new password is stored in memory and the circuit will disconnect the phone connection. If you do not push *, you can control your devices by entering pre-assigned numbers. For example, the number ‘1’ is for home front or rear door and every time you push it the door will open. Numbers 2-6 are for controlling five other devices. With every key push you change a device status and you will hear appropriate sounds that relate to the device status (see flowchart). After every command, the new device status will be stored in EEPROM. Once all devices have been controlled, simply hang up.

2



If the circuit is called but the user doesn’t enter any numbers, the circuit will hang up after 7 seconds. In all of these procedures, when you enter any number, the circuit

COMPONENTS LIST

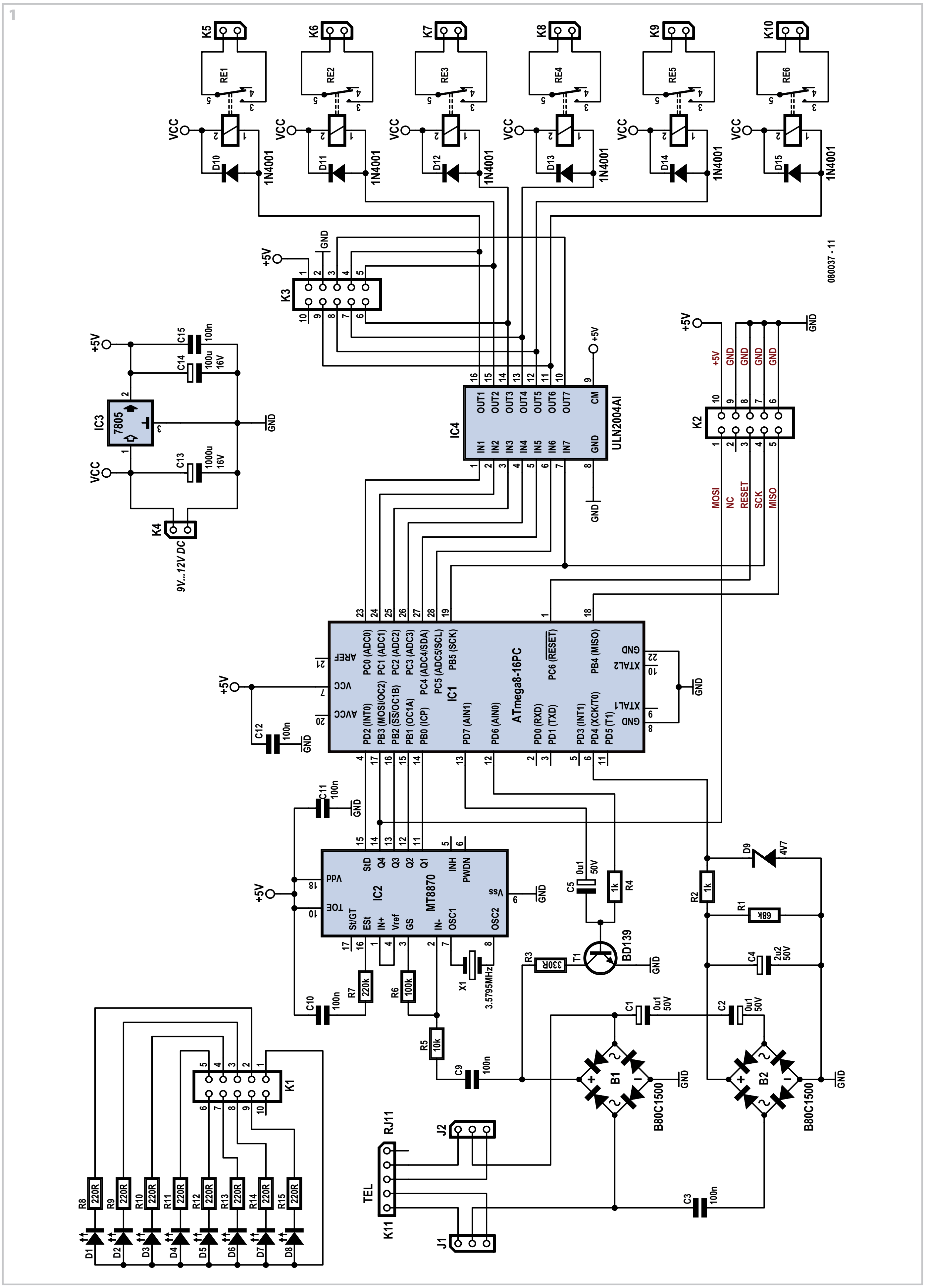
Resistors
R1 = 68kΩ
R2,R4 = 1kΩ
R3 = 330Ω
R5 = 10kΩ
R6 = 100kΩ
R7 = 220kΩ
R8-R15 = 220Ω

Capacitors
C1,C2,C3,C5,C9-C12,C15 = 100nF
C4 = 2µF2 40V radial
C13 = 1000µF 40V radial
C14 = 100µF 40V radial

Semiconductors
B1,B2 = B40C1500 (80Vpiv, 1.5A)
D1-D8 = LED, low current, 3mm
D9 = zener diode 4V7 400mW
D10-D15 = 1N4001
T1 = BD139
IC1 = Atmega8-16PC, programmed, Elektor Shop #080037-41
IC2 = MT8870
IC3 = 7805
IC4 = ULN2004

Miscellaneous
RE1-RE6 = 12V coil, e.g.V23057
X1 = 3.5795MHz quartz crystal
K1,K2,K3 = 10-way boxheader
K4 = PCB terminal block, lead pitch 5mm
K5-K10 = PCB terminal block, lead pitch 7.5mm
K11 = RJ11 connector, PCB mount, Hirose TM5RE1-64 (Digikey # H11257-ND)
J1,J2 = 3-way SIL pinheader with jumper
PCB, ref. 080037-1 from www.thepcbshop.com

1



IC1
ATmega8-16PC
IC2
MT8870
IC3
7805
IC4
ULN2004AI
K1
K2
K3
K4
9V...12V DC
RE1
RE2
RE3
RE4
RE5
RE6
1N4001
BD139
B80C1500
3.5795MHz
RJ11
TEL
K11
MOSI
NC
RESET
SCK
MISO
080037 - 11

will acknowledge reception with one short beep. Please wait briefly for the circuit to receive and process the number pressed.
A maximum of three wrong password entries is accepted. With every wrong password you enter, you will hear one long beep and if you enter a wrong password thrice, you will hear one long beep again and the circuit will hang up on you.
The circuit shows the status of all devices by its LED panel. D1 indicates the circuit power, D2 the answer status (ON: phone line is busy; OFF: phone line is free). The other LEDs indicate the status of the controlled devices (LED ON: device = ON, LED OFF: device = OFF).

The schematic diagram **Figure 1** has these main parts: power supply, ring detector, answering circuit, tone decoder, microcontroller, output relays and LED panel driver. The power supply includes IC3, C6, C7 and C8 producing the +5 V supply voltage for the circuit. The ring detector comprises B2, C1-C4, R1, R2 and D9. C1, C2 and C3 pick up the ring (AC) voltage of between 80 V and 100V, 25 Hz. B2 converts the ring voltage to DC. C4 serves for noise reduction and R1, R2 and D9 create a suitable voltage level at the PD4 pin of the microcontroller.
When you call the circuit, one +5 V ring pulse appears at the cathode D9. The answer circuit includes B1, C5, R4, R3 and T1. If you want the circuit to answer to one ring, put one resistor in parallel with the telephone line, reducing the line voltage to approximately 15 VDC and passing about 20 mA through the resistor. Answering the call implies driving T1 into saturation. Therefore the telephone line current will pass through R3. To hang up, T1 is switched off. The function of C5 is to inject a sound produced by the microcontroller. The DTMF tone decoder circuit includes R5, R6, R7, C9, C10, C11, X1 and IC2.

Table 1. ATmega8 programming settings

CKSEL0	0
CKSEL1	0
CKSEL2	1
CKSEL3	0
CKOPT	1

1: Unprogrammed, 0: Programmed

IC2 (an MT8870) is a DTMF tone decoder IC. It receives the DTMF tones via R5, R6 and C9. The corresponding binary data of each code appears on the Q1-Q4 pins. An incoming code is indicated by a rising edge on the STD pin. The event is fed to the INT0 pin of the microcontroller. A High level on the TOE pin of the MV8870 enables the outputs Q1-Q4. Here it is strapped to the +5 V rail.

The micro is an ATMega8 from Atmel. The final stage has a ULN2003 high voltage and high current Darlington transistor array IC, that easily copes with the relay and LED panel currents. Each output pin of this IC can drive up to 500 mA. The LED panel includes D1-D8 that indicate circuit activity and status of all devices. Caps C11 and C12 are included for noise reduction and it is to use multilayer capacitors ceramic for this purpose.

The PCB for the controller is shown in **Figure 2**. One PCB section comprises the main circuit the other is for the LED panel. The two PCBs are interconnected with a 10-way (2x5) IDC connector.
Once the circuit has been built up, the micro has to be programmed with the firmware hex file from free download archive **080037-11.zip** found on the Elektor website. The source code is also available: it was produced using MikroC from MikroElektronika.
Connect the 9-12 VDC mains adapter to J1. Next, program the microcontroller by means of the ISP socket, K2. Select an 8-MHz internal clock source for the micro by setting the fuse bits per **Table 1**. Don't forget to program both the Flash (filename.hex) and the EEPROM (filename.eep) file!
Connect your electrical appliances to the circuit observing all relevant electrical safety precautions. The EEPROM in the circuit ensures that settings are not lost after a reset or when a mains power interruption occurs.
Finally, we can calculate the security of the system. With a five-digit password, we have a 1 in 100,000 probability of hitting the correct code by chance, which seems adequate for such a simple system.

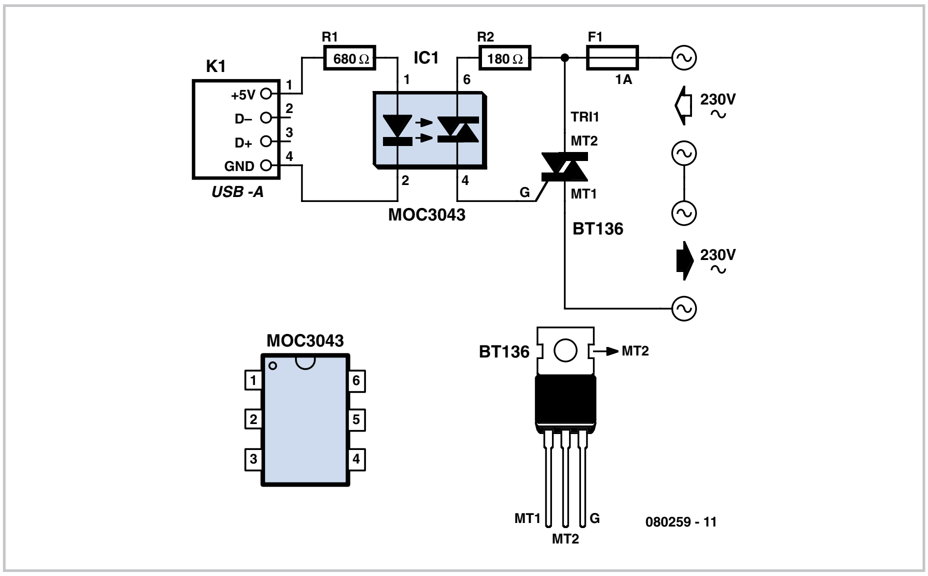
(080037-I)

USB Standby Killer

Wim Abuys

When turning a computer on and off, various peripherals (such as printers, screen, scanner, etc.) often have to be turned on and off as well. By using the 5-V supply voltage from the USB interface on the PC, all these peripherals can easily be switched on and off at the same time as the PC. This principle can also be used with other appliances that have a USB interface (such as modern TVs and radios).

This so-called 'USB-standby-killer' can be realised with just 5 components.
The USB output voltage provides for the activation of the triac opto-driver (MOC3043) which has zero-crossing detection. This, in turn, drives the TRIAC, type BT126.



The circuit shown is used by the author for switching loads with a total power of about 150 W and is protected with a 1-A fuse. The circuit can easily handle much larger loads however. In that case and/or when using a very inductive load a so-called snubber network is required across the triac. The value of the fuse will also need to be changed as appropriate.

The circuit can easily be built into a mains multi-way powerboard. Make sure you have good isolation between the USB and mains sections (refer to the Electrical Safety page published regularly in this magazine).

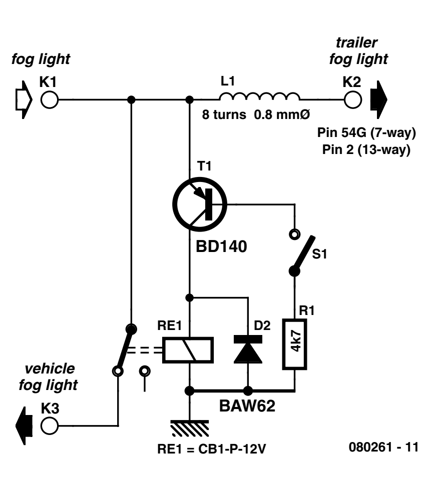
(080259-I)

Fog Lamp Switch

J. Geene

In most countries it is now mandatory or at least recommended to have a rear fog light on a trailer with the additional requirement that, when the trailer is coupled to the car, the rear fog light of the towing car has to be off. The circuit shown here is eminently suitable for this application.

The circuit is placed near the rear fog light of the car. The 12-V connection to the lamp has to be interrupted and is instead connected to relay contacts 30 and 87A (K1, K3). When the rear fog light is turned on it will continue to operate normally. If a trailer with fog light is now connected to the trailer connector (7- or 13-way, K2), a current will flow through L1. L1 is a coil with about 8 turns, wound around reed contact S1. S1 will close because of the current through L1, which in turn energises relay Re1 and the rear fog light of the car is switched off. The fog light of the trailer is on, obviously.



The size of L1 depends on reed contact S1. The fog lamp is 21 W, so at 12 V there is a current of 1.75 A. L1 is sized for a current between 1.0 and 1.5 A, so that it is certain that the contact closes. The wire size has to be about 0.8 mm. The relay Re1 is an automotive relay that is capable of switching the lamp current. The voltage drop across L1 is negligible.

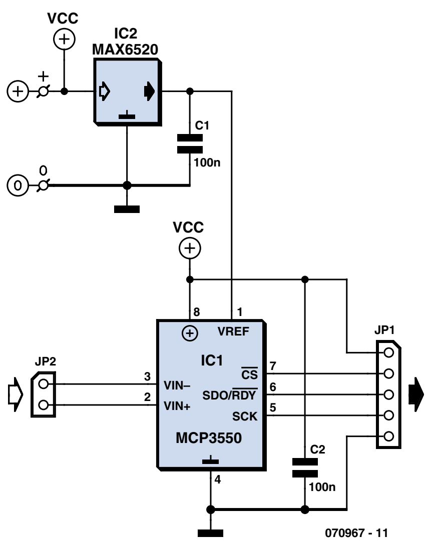
(080261-I)

22-bit A/D Converters

Steffen Graf

When accuracy matters more than speed, the MCP3550 series of analogue-to-digital converters from Microchip [1] is worth a look. They are ideal for accurately measuring DC voltages that only change slowly over time, offering an extremely high resolution of 22 bits while only drawing a paltry 150 µA from a 5 V power supply.

With the addition of a low power voltage reference such as the MAX6520 [2] as shown in the circuit diagram we have an ultra-precise analogue-to-digital converter with a total current consumption of around 0.2 mA, using only a minimum number of components. The conversion results are output using a serial interface that is easy to connect to the SPI port of a microcontroller. A file containing a printed circuit board layout for this design is available for free download from http://www.elektor.com.



Part	Notch frequency (Hz)	F_S (Hz)	Effective resolution (bit)
MCP3550-50	50	12.5	21.9
MCP3550-60	60	15	21.9
MCP3551	50 & 60	13.75	21.9
MCP3553	-	60	20.6

Microchip make four versions of these ICs. As the table shows, they differ in the frequency of the built-in notch filter, which is designed to help suppress mains hum. They also have different sample frequencies, as well as different effective resolutions.

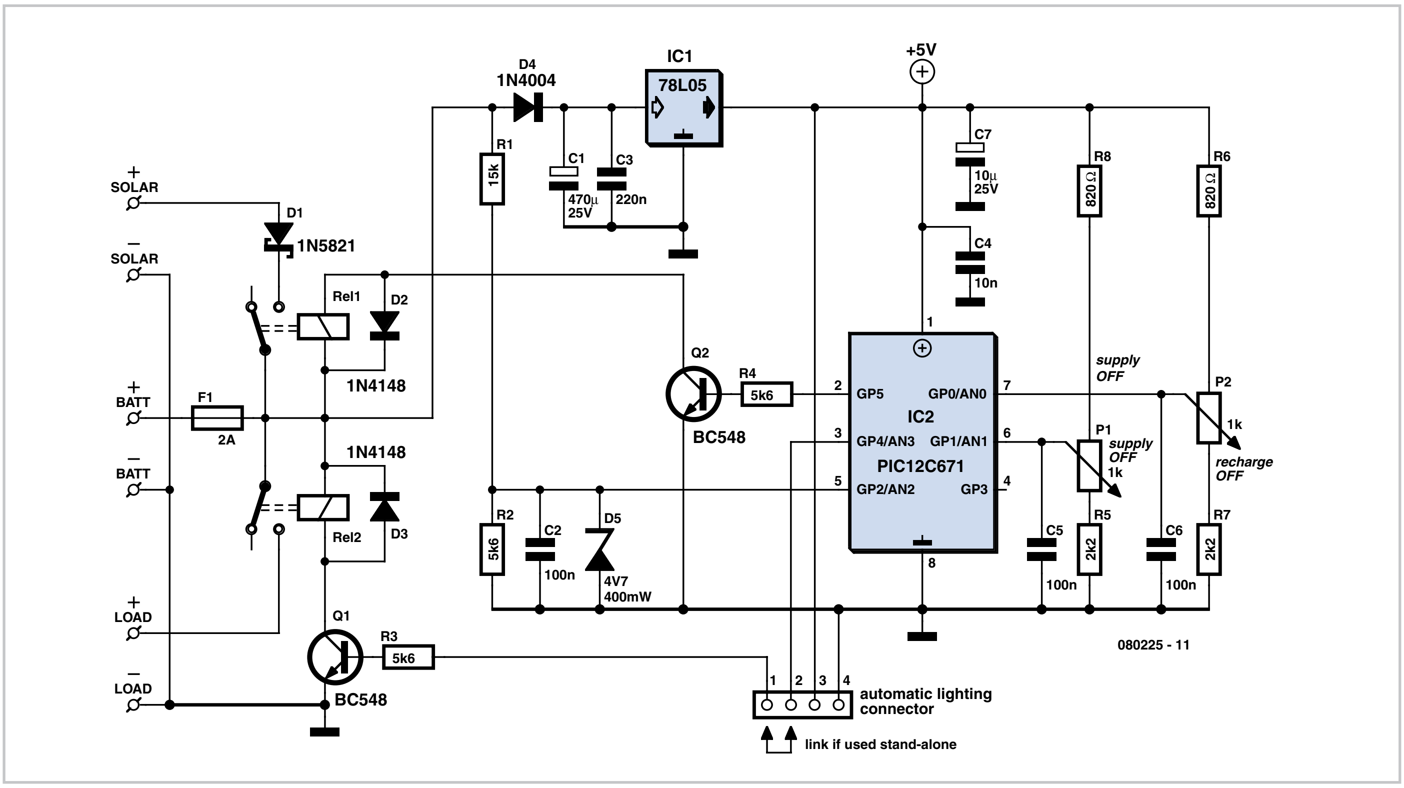
(070967-I)

Web Links

[1] http://ww1.microchip.com/downloads/en/DeviceDoc/21950d.pdf

[2] http://datasheets.maxim-ic.com/en/ds/MAX6520.pdf

Solar-powered Battery Charger



C. Tavernier

Long before the current fashion for sustainable development caused solar panels to blossom on roofs and terraces in non sun drenched areas of the world, numerous nomadic and Route 66 users were already using them on motor-homes or pleasure craft. In these situations, the primary rôle of a solar panel is not to sell power back to the local electricity board or utility, but to charge an array of batteries in our on the vehicle or craft to provide a source of electricity after dark.

Even though such an operation might appear trivial, all the more so if you look at certain 'charger' circuits, it really is nothing of the sort, if you're keen to look after your batteries. Even though it does work, the solution of wiring batteries, supplied load, and solar panels in parallel is far from being satisfactory in at least two situations, which we'll discuss below.

When the load powered by the batteries consumes little or nothing at all, and the batteries are already well charged, and it's also a sunny day, the batteries are in serious danger of being over-charged, which as everyone knows will severely shorten their life — and possibly your travel.
ling distance.

On the other hand, when the load powered by the batteries is drawing a lot of current and there is little or no sun, the batteries can end up completely discharged, which as it may turn out is just as detrimental to their life as over-charging.

Yet it takes only a handful of components to build our intelligent regulator, the circuit of which is given in **Figure 1**. It uses a PIC 12C671 microcontroller, which has the double advantage of being housed in an 8-pin DIL package and containing a multi-input analogue/digital converter (DAC).

Potential divider R6-P2-R7 feeds a discrete voltage level to AN0 to set the battery voltage at which charging should be stopped, to prevent any risk of over-charging. Potential divider R8-P1 and R5, feeding PIC analogue input line AN1, this time defines the battery voltage below which the load should be disconnected to avoid excessive discharge. In this way, a voltage window is created for the PIC to maintain in the interest of the battery's health and lifetime — and your peace of mind, of course.

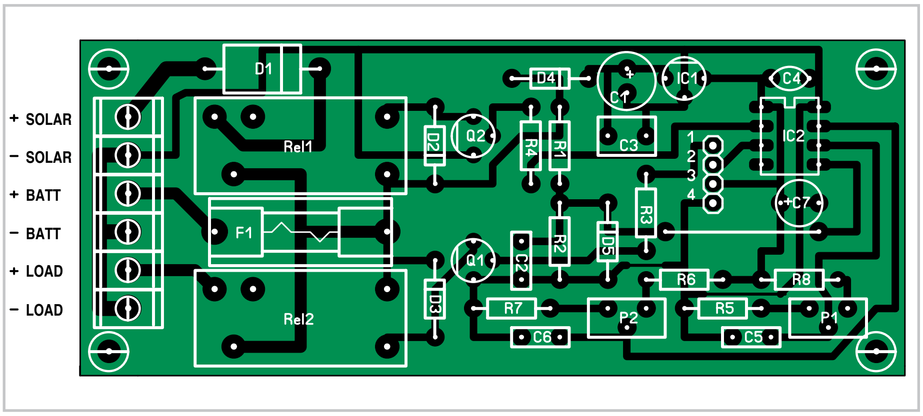
The voltage present at the battery terminals is measured via the potential divider – fixed this time – R1 and R2, feeding PIC port line AN2. Zener diode D5 protects the microcontroller from any spurious external voltage that might appear on the terminals of the solar panels – during thunderstorms, for example.

Depending on the above mentioned voltage thresholds, the circuit controls relays Re1 and Re2, via transistors T1 and T2. The first is used to connect the solar panels to the battery. Hence it is energized as long as the battery is not being over-charged, otherwise it is off. The second, T2, is used to connect the battery to the load being powered. So it is energized as long as the battery is not too deeply discharged, otherwise it is off.

Diode D1, which must be a Schottky type to minimize the forward voltage drop, avoids the battery discharging through the solar panel in periods of weak sunshine. A normal silicon diode in this position will have a too high forward drop (about 0.6-0.7 V) to ensure optimum results hence is not recommended.

Note the 4-pin connector at the bottom of the circuit diagram. This allows the present charger to be connected to the Solar-powered Automatic Lighting Module described elsewhere in this issue. If this module is not being used, all you need do is connect a jumper across pins 1 and 2, as indicated in the diagram.

To make this project easy to build, we've designed the PCB shown here. As usual, the copper track layout is contained in the free download available from the Elektor website. This PCB has been designed for 10 A Finder SPDT relays, which leaves plenty of freedom in terms of choice of panels and battery. When designing this charger, we



COMPONENTS LIST

Resistors
R1 = 15kΩ
R2-R4 = 5kΩ6
R5,R7 = 2kΩ2
R6,R8 = 820Ω
P1,P2 = 1kΩ potentiometer

Capacitors
C1 = 470 µF 25V
C2,C5,C6 = 100nF
C3 = 220nF
C4 = 10nF
C7 = 10µF 25 V

Semiconductors
D1= 1N5821
D2,D3 = 1N4148
D4 = 1N4004
D5 = zener diode 4V7 400mW
Q1,Q2 = BC548
IC1 = 78L05
IC2 = PIC12C671, programmed, see Downloads

Miscellaneous
Rel1,Rel2 = relay, 10A contact
F1 = fuse, 2A
4-way SIL pinheader
6 PCB terminal blocks, 5mm lead pitch
1 wire bridge
PCB, ref. 080225-I from www.thepcbshop.com

planned for a maximum battery current of 2 A, as indicated by the fuse value given, but there's nothing – apart, perhaps, from your wallet, for the cost of the battery and solar panels – to stop you from going higher.
The .hex file to be programmed into the PIC 12C671 is available free to download on the Elektor server, as well as from the author's own website (see end of article).
Once built, the project is elementary to adjust, and only requires a DC voltmeter and an adjustable PSU, even a very simple one. Do not connect any of the external elements to the charger, and replace the battery by your stabilized PSU set to 12 V, with a voltmeter across it.
Then increase the voltage to 14.5 V and adjust P2 so that Rel1 just drops out. Then reduce this voltage to confirm that Rel1 is energized again at around 12.8–13 V (depending on component tolerances).
Continue to reduce the voltage down to 10.5 V and then adjust P1 so that Rel2 drops out. Increase the voltage again to check that Rel2 is energized again around 12 V or just under. P1 and P2 do not interact, so it is easy to adjust them independently.
Lock the wipers of P1 and P2 with a little sealant and fit your project into a case, taking care to protect it from damp if it is to be used outdoors. A sealed electrical junction box is ideal for this, at a ridiculously cheap price.

(www.tavernier-c.com) (080225-I)

Downloads
The source code and .hex files for this project are available for free from www.elektor.com; file # 080225-11.zip.

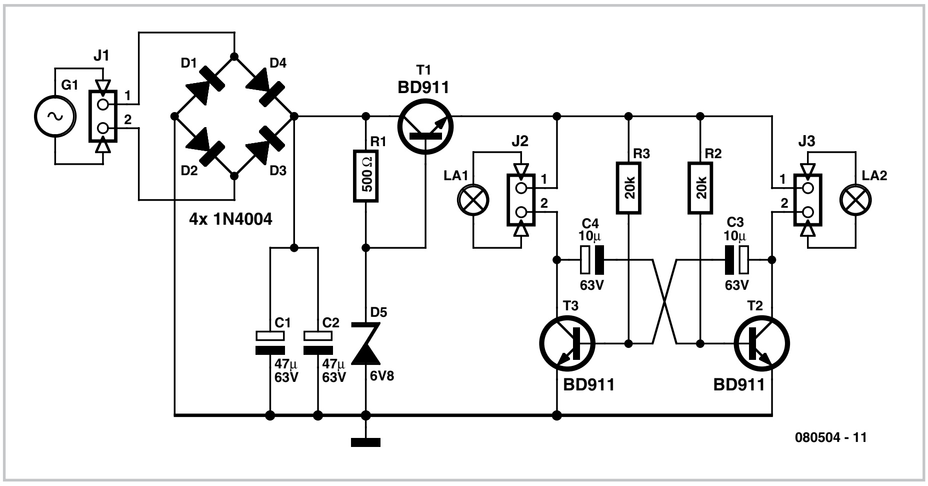
The PCB design is available for free download from our website www.elektor.com; file # 080225-1.zip

Simple LED Bike Light

Gatze Labordus

On my mountain bike I always used to have one of those well-known flashing LED lights from the highstreet shop. These often gave me trouble with flat batteries and lights that fell off. As an electronics student I thought: "this can be done better".
First I bought another front wheel, one which has a dynamo already built in the hub. This supplied a nice sine wave of 30 Vpp (at no load).
With this knowledge I designed a simple power supply. The transistors that are used are type BD911. These are a bit of an overkill, but there were plenty of these at my school, so that is why I used them. Something a little smaller will also work.
The power supply is connected to an astable multi-vibrator. This alternately drives the front light and the rear light. The frequency is determined by the RC time-constant of R3 and C3, and R2 and C4. This time can be calculated with the formula:

$$t = R3 \times C3 = 20 \times 10^3 \times 10 \times 10^{-6} = 0.2 \text{ s}$$



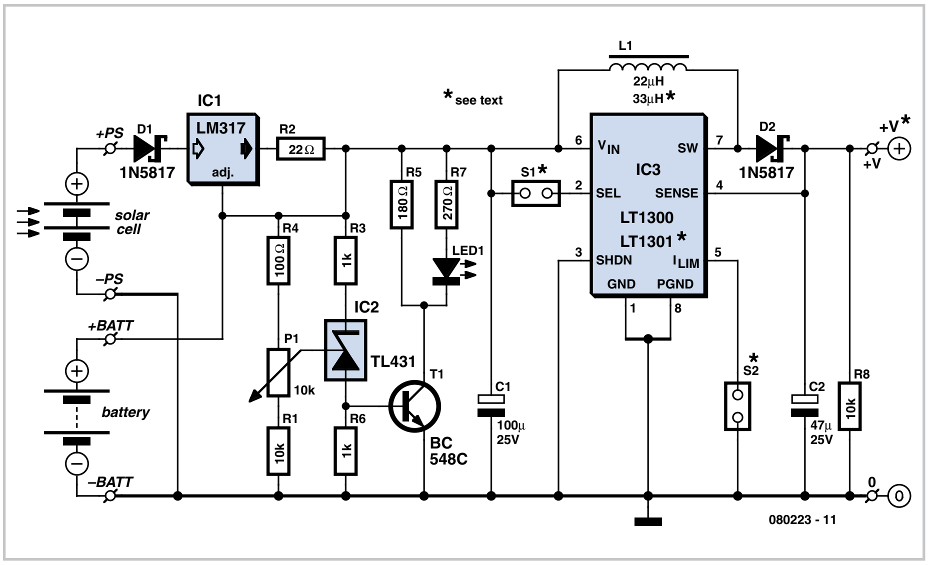
You can use a 22 kΩ (common value) for R2 and R3, that doesn't make much difference.
On a small piece of prototyping board are six LEDs with a voltage dropping resistor in series with each pair of LEDs. Such a PCB is used for both the front and the rear of the bike. Of course, you use white LEDs for the front and red ones for the rear. The PCB with the main circuit is mounted under the seat, where it is safe and has been working for more than a year now.
There are a few things I would change for the next revision. An on/off switch would be nice. And if the whole circuit was built with SMD parts it could be mounted near the front light. This would also be more convenient when routing the wiring. Now the cable from the dynamo goes all the way to the seat and from there to the front and rear lights.

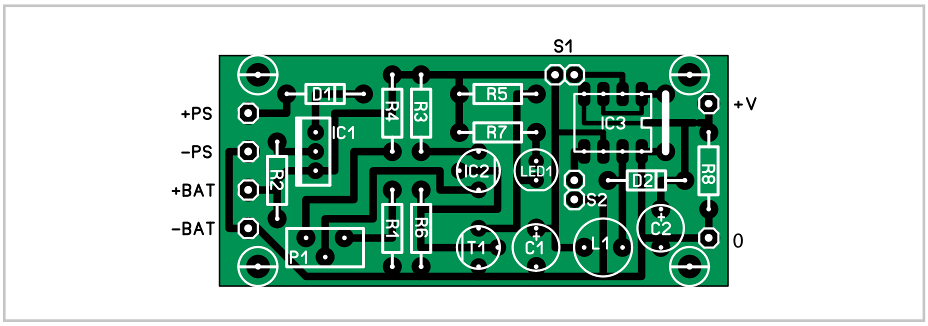
(080504-I)

Solar-powered Uninterruptible PSU

C. Tavernier

When you want to power an electronic device from solar panels, broadly speaking there are currently two approaches. The first, very conventional method (described elsewhere in this double issue) consists of employing a combination of solar panels (or an array), an automatic charger, and a battery (or an array). This combination then powers the device concerned, which has its own voltage regulating circuits. The second, which we are proposing in this project, consists of building a 'solar' PSU directly. It is of course based on the same concept as the one described above, but having been designed for this purpose right from the start, the elements it composes are integrated to a higher extent, leading to improved efficiency.
Our suggested circuit is intended to power a number of current electronic devices directly, and can provide three different voltages: 3.3 V, 5 V or 12 V, depending on component selection; all at a current of 400 mA, which can even be increased to 1 A if necessary (details below).
It's primarily based around IC3, a high-performance switching regulator from Linear Technology. Depending on whether you choose an LT1300 [1] or an LT1301 (*) [2] you will have a choice of two output voltages: 3.3 or 5 V for the former, and 5 or 12 V for the latter. For both ICs, the voltage is selected by fitting jumper S1 or not, as indicated in **Table 1**. Look carefully into the output voltages you will require and then select the appropriate ICs for the project.
When jumper S2 is fitted, the output current of these ICs is internally limited to 400 mA. It can be increased to 1 A by omitting the jumper, but we don't really recommend this as the rest of the circuit has been optimized for an output current from a few mA to 400 mA maximum.
The primary power source is the NiMH rechargeable battery pack, which in the





COMPONENTS LIST

Resistors
R1,R8 = 10kΩ
R2 = 22Ω
R3,R6 = 1kΩ
R4 = 100Ω
R5 = 180Ω
R7 = 270Ω
P1 = 10 kΩ potentiometer

Inductors
L1 = 22 µH (or 33 µH, see text)

Capacitors
C1 = 100µF 25V
C2 = 47µF 25V

Semiconductors
D1,D2 = 1N5817
T1 = BC548C
IC1 = LM317
IC2 = TL431
IC3 = LT1300 (or LT1301, see text)
LED1 = LED

Miscellaneous
S1,S2 = 2-way pinheader, lead pitch 2.54 mm, with jumper
6 solder pins
PCB, ref. 080223-1 from www.thepcbshop.com

case of the LT1300 will comprise two 1.2 V cells, or three cells in the case of the LT1301. The solar panel should be chosen to deliver a voltage of the order of 9 V at an output current of around 100 mA. Such panels are available commercially.
IC1 acts as a constant current charger to limit the current to around 60 mA. To avoid overcharging the battery in the event of low current draw by the device powered on the one hand and constant sunshine on the other, the circuitry around IC2 and T1 has been added. IC2 is just a variable zener which will turn on T1 harder as the voltage at the wiper of P1 increases. In this way, when the voltage at the battery terminals rises too high, as at the end of charging, T1 will be turned on harder and harder, bypassing part or all of the charging current to ground via R5 and R7, and lighting the LED as it does so. This is simply a contemporary variation of the traditional shunt voltage regulator.
The whole of the project fits easily onto a compact printed circuit board of which the component mounting plan reproduced here. The copper track layout is a free pdf download as usual. Building up the board should not present problems as there are no oddball components to solder or mount.

Table 1.

IC3	LT1300	LT1301
L1	22 µH	33 µH
S1 fitted	+V = +5 V	+V = +12 V
S1 absent	+V = +3.3 V	+V = +5 V
S2 fitted	I_{max} = 400 mA	I_{max} = 400 mA
S2 absent	I_{max} = 1 A	I_{max} = 1 A

An 8-pin DIL socket should be soldered in the IC3 position to allow fitting of one or the other of the intended ICs. If your usual retailer doesn't have them in stock, you should be able to obtain them from mail order suppliers, for example, from Farnell. Take care choosing the choke L1 (22 µH for the LT1300 or 33 µH for the LT1301). It must be able to handle a current of 800 mA without saturating, which is far from being the case with many ordinary moulded types. Our 22 µH one comes from Radiospares (RS Components) and is an ELC08D from Panasonic.
It is vital that diodes D1 and D2 are Schottky types, to minimize forward voltage drop, and in the case of D2, to be fast enough in terms of recovery. AA or even AAA 1.2 V batteries will be suitable, given the impressive capacity of current types on the market.
The circuit should work the moment it is powered; all that remains is to adjust potentiometer P1. To do this, temporarily disconnect the solar panel and batteries, replacing the latter with an adjustable stabilized power supply unit, across which you should also connect a voltmeter. If you are using the LT1300 version, i.e. with two 1.2 V cells, set your PSU to 3.2 volts and then adjust P1 to obtain definite illumination of the LED. If you use the LT1301 version (and hence three 1.2 V rechargeable cells), you'll need to set your PSU to 4.8 V and again adjust P1 till the LED lights.

(www.tavernier-c.com) (080223-I)

Web Links

[1] LT1300
www.linear.com/pc/downloadDocument.do?navId=H0,C1,C1003,C1042,C1035,P1449,D2742

[2] LT1301
www.linear.com/pc/downloadDocument.do?navId=H0,C1,C1003,C1042,C1031,C1060,P1450,D3451

Downloads

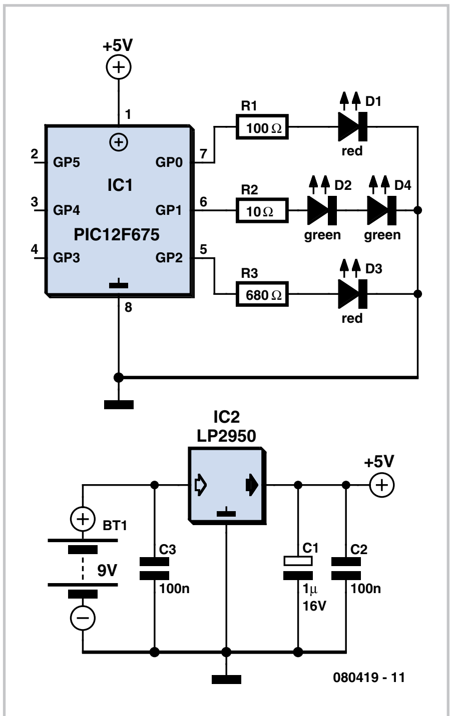
The PCB design for the project is available to download from the www.elektor.com; file # 080223-1.zip.

RGB Lights

Joseph A. Zamnit

The overall effect produced by this project is a glowing sequence of lights changing slowly from one colour to the next. The microcontroller cycles through randomly generated values of red, green and blue hues of light to produce a variety of nice colours.

The software implemented on the controller interpolates from one shade to another, each colour channel being treated independently. Light intensity is controlled by means of pulse width modulation (PWM) for each colour. A high frequency of approximately 60 Hz is used to modify the light intensity and eliminate any flicker that might arise.
One major problem that had to be overcome was unequal brightness of the LEDs used, the result of which is a tendency for one particular colour to dominate in the overall hue produced. It was found that



blue LEDs are perceived to have the largest intensity and green, the lowest. This was compensated for by using a large resistor for blue and a low resistor for green, together with two green diodes in series for higher green colour intensity. The values of the resistors may have to be tweaked to achieve the best balanced colour intensity. A diffused glow was achieved by cutting the lens of the ultra bright LEDs used and using a ping pong ball as a basic diffuser.
This very simple project is perfect for a rainy day and can be built in a couple of hours. Despite its simplicity it will produce a very interesting and glowing effect. Several units may be built and they will mix a variety of colours randomly.

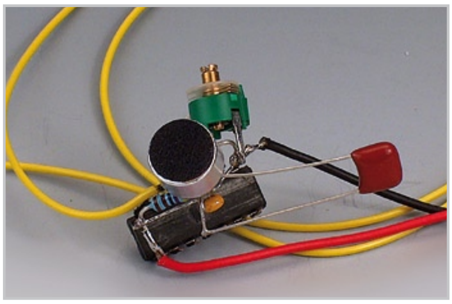
The source and hex code files for the PIC12F675 device are available as free download # 080419-11.zip from the Elektor website. The code was developed using CCS C.

(080419-I)

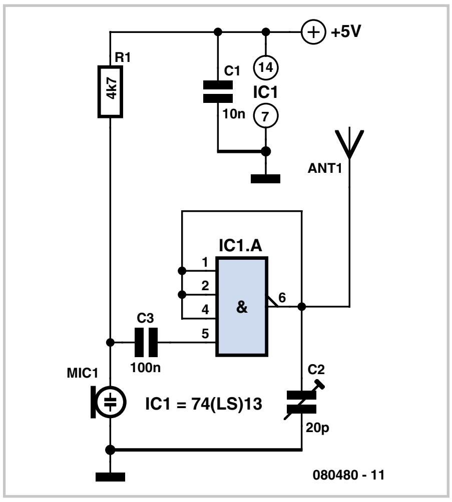
FM Microbug

Thijs Beckers

Although the idea has been around for a good while already, it’s still cute: a tiny circuit that you can hide just about anywhere for all sorts of eavesdropping activities. Fun for at work, but also usable as a babyphone. The basic necessities are a small microphone and a little transmitter. This can be realised using very simple resources.



This bug circuit operates in the normal VHF FM band and can thus be received using any ordinary radio. The schematic is based on a somewhat uncommon IC, the 74LS13, but with a bit of searching you can still manage to find one somewhere. The other five components (that’s all!) are all readily available. You might already have them in your parts drawer.



Here we use an electret capsule for the microphone. The necessary bias voltage is tapped off from the supply voltage via R1. If you use a crystal microphone instead, you can omit R1 and C3.
The microphone signal is fed to pin 5 of the IC. C2 is included to slightly improve the performance and sensitivity of the circuit. C1 serves to decouple the supply voltage so any spikes that may be present are suppressed. Just about any short length of wire makes a suitable antenna.

The circuit operates on the third harmonic at around 100 MHz. It takes a bit of experimenting to find the right frequency on the radio, but within a range of a few metres the circuit can even overpower signals from relatively powerful transmitters. Of course, this circuit is not entirely legal, so you shouldn’t try to boost the power too much. A range of 20 metres is certainly possible with the circuit as shown.

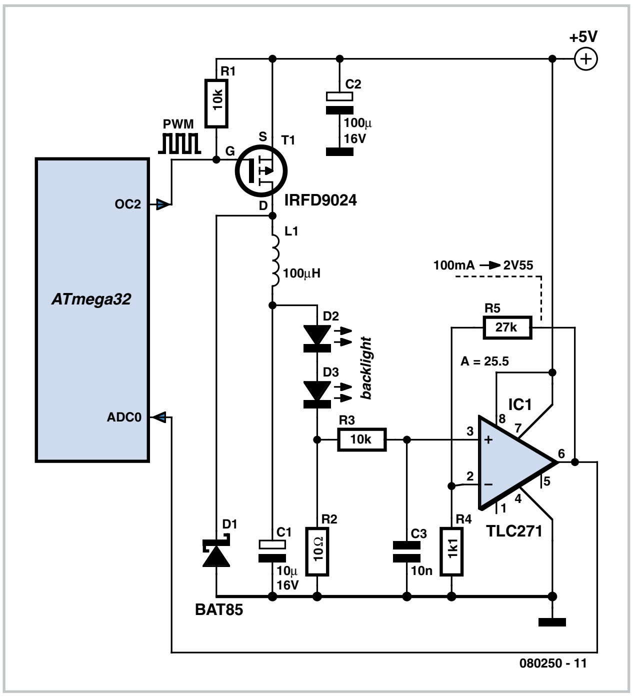
This very simple circuit is highly sensitive and somewhat prone to positive feedback, especially if you hold it in your hand. The best approach is to put it down somewhere and stay away from it; then it works fine. If you want to experiment with the circuit, feel free!

(080480-1)

Energy-efficient Backlight

Rainer Reusch

The backlights used in some LCD panels are not exactly economical: typical current draws of 20 mA to 100 mA are common. Normally the current is determined by a series resistor, which leads to additional power losses. It is considerably more efficient, if a little more complex, to use a switching regulator IC. Alternatively, it is often the case that driving the LCD panel is a microcontroller, which we can press into service to provide regulation in software. Fortunately, the regulation does not need to be exceptionally precise.



At the heart of our circuit is T1, a p-channel MOSFET, which is driven by an inverted (active low) pulse-width modulated signal from the microcontroller. Components D1, L1 and C1 form the remainder of the standard step-down switching regulator configuration. In the circuit diagram the LCD backlight is represented by two LEDs; the current flowing through these LEDs is measured by a shunt resistor, filtered, and finally amplified to a level suitable for input to the A/D converter in the microcontroller using an operational amplifier. R1 ensures that the transistor switches off completely when the microcontroller is reset (at which time all ports become inputs).
The circuit can be used with any microcontroller that can generate an inverted PWM signal at a frequency in the range 10 kHz to 100 kHz. We have developed a demonstration program and code module for the Atmel ATmega32

using GNU C. The source code can be downloaded from the *Elektor* website at http://www.elektor.com or from the author's site at http://reweb.fh-weingarten.de/elektor.

The program generates the PWM signal at 31.25 kHz (if the processor clock is 8 MHz) on the OC2 output (PD2) of the ATmega32 microcontroller. The pulse width can be adjusted in 256 steps. If the gain of the operational amplifier is 25.5 a current of 100 mA through the LEDs will correspond to a voltage of 2.55 V at the input to the A/D converter. The internal reference voltage of the ATmega32 is nominally 2.56 V, and so an LED current of 100 mA will lead to a ten-bit conversion result of 03FFh. It is sufficient to monitor only the top eight bits of this value, and depending on the error from the desired value, increment or decrement the pulse width of the PWM signal. This forms an integral controller.

As it stands, this solution cannot compete on simplicity with a series resistor. However, we can make some simplifications to the circuit by eliminating the regulation feedback loop. Dispense with the operational amplifier and surrounding circuitry, and have the software output a fixed PWM signal. This loses the ability of the circuit to compensate for part-to-part variation in the components and for temperature, but in practice such compensation is rarely necessary. The software also supports the simplified version of the circuit.

(080250-I)

SimpleProg

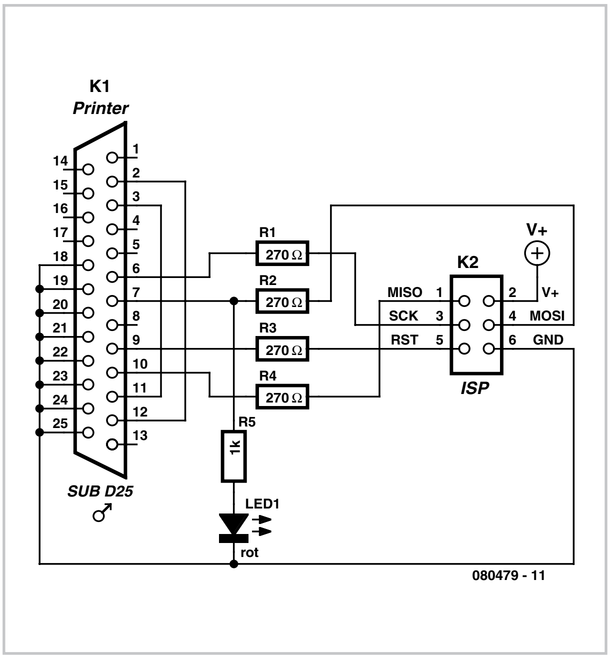
Easy ISP for AVR microcontrollers

Dr. Thomas Scherer

A trawl of the Internet will reveal no end of simple AVR microcontroller programmer designs for connection to the parallel port of a PC. Here at Elektor we have also published a few variations on this particular theme. One thing that is perhaps surprising is how different the various designs are from one another. One of the main reasons for the differences is that the programmers are intended for use with different AVR microcontroller development environments, although in some cases it is perhaps not always made as clear as it ought to be which one this is.

The circuit shown here was developed as part of the current Elektor AVR-ATM18 project series. Troubled by a nagging feeling that a circuit is not a proper circuit unless it contains at least one active component, the author added an LED to show when data transfer is occurring. In fact, this visual feedback is extremely helpful when troubleshooting, and is a worthwhile addition even if our aim is to make the simplest possible programmer.

Construction is very straightforward. The circuit can be built on a small piece of perforated board, using a flat cable with a 25-way sub-D plug crimped to one end and a 26-way IDC header crimped to the other to connect to the PC's parallel interface. The six-way ISP cable is plugged into a suitable box header on the perforated board. If six-way headers prove hard to get hold of, a ten-way type as shown in the photograph can be used instead with just the middle six pins wired.



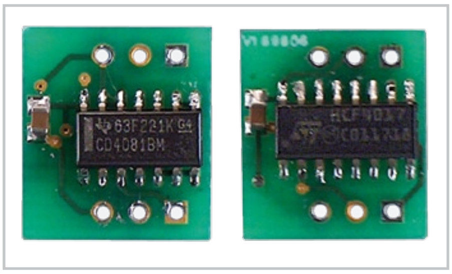
The programmer is compatible with the STK200 and STK300 from Kanda and will therefore work in conjunction with any program that offers those devices as options. It works perfectly with BASCOM [1], and Kanda also offers excellent (and free) programming software [2]. Observe that this unit uses 5 V signal levels. The target microcontroller should therefore also be powered from a 5 V supply, at least while it is being programmed.

(080479-I)

[1] BASCOM: http://www.mcselec.com

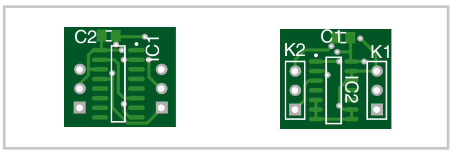
[2] http://www.kanda.com/avr-isp-software.html

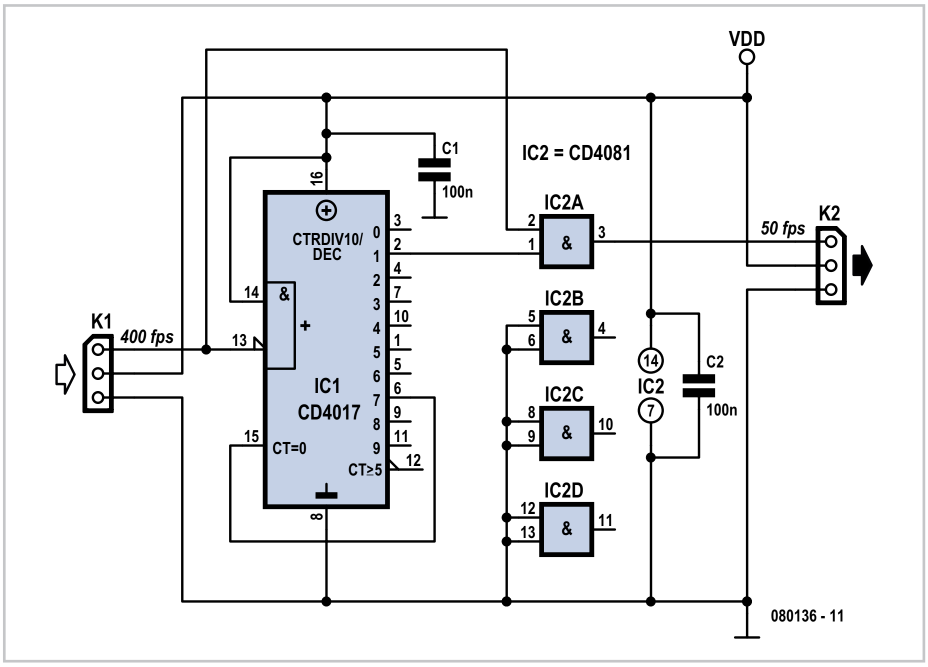
Radio Control Signal Frame-rate Divider



Mike Mobbs

Model radio-control equipment has evolved considerably over the years, and the humble servo has grown from the 1.5 ms at 50 fps (frames per second) format, to the more precise and powerful digital variety using, typically, 400 fps, and accessories such as helicopter gyros have evolved to make use of these improved servos. As a result, the later generations of gyros often only provide the 400 fps 'digital' signal, which is not suitable for use with the older 'analogue' servos. All is not lost, as this circuit allows only one frame in eight to reach the servo, replicating the 50 fps system. The prototype version was built using standard ICs, and sits neatly under the gyro (a CSM720 in the test setup) to provide the analogue output.





COMPONENTS LIST

C1 = 100nF
C2 = 100nF
IC1 = CD4017 (SMD)
IC2 = CD4081 (SMD)
K1 = 3-wire cable with 3-way socket
K2 = 3-wires cable with 3-pin plug
PCB, ref. 080136-1 from www.thepcbshop.com

The circuit uses a Type 4017 CMOS decade ring counter, which is clocked by the falling edge of the input via the CP1 (enable) pin, and reset by output 7. The first input pulse after reset sets output 1 high, which allows the next input pulse through to the output via a CMOS 4081 OR gate. Thus only one pulse in every eight is fed to the output. The use of negative logic to provide the AND function removes any risk of timing glitches, as the gating signal is established before the input pulse, and is stable for the duration of this pulse.

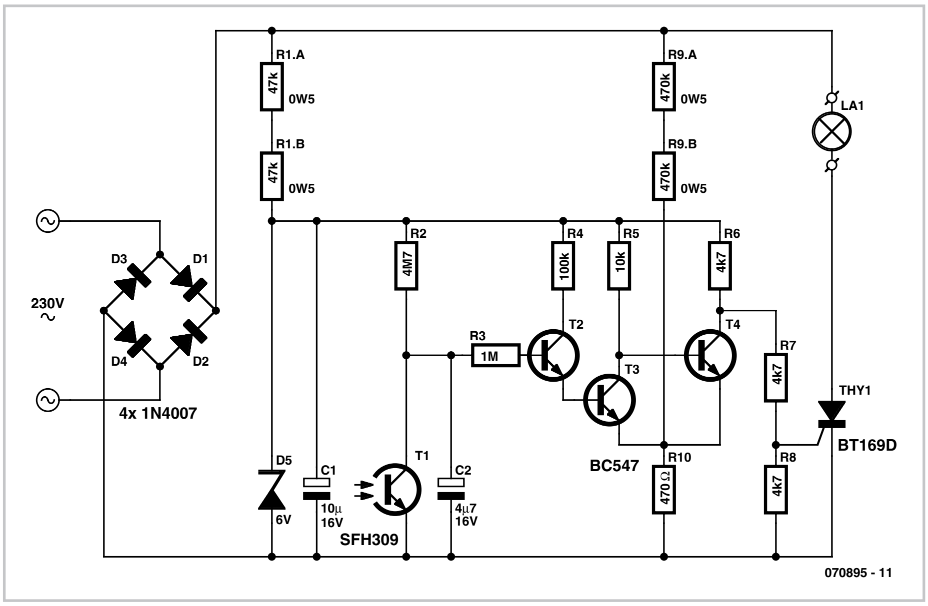
Other divider ratios can be used by choosing the relevant output for the reset.
A miniature PCB with SMD parts on it was designed for the converter to enable it to be incorporated into a model where space is always at a premium! The circuit is best encapsulated in heatshrink sleeving.

(080136-I)

FL Twilight Switch

Peter Herlitz

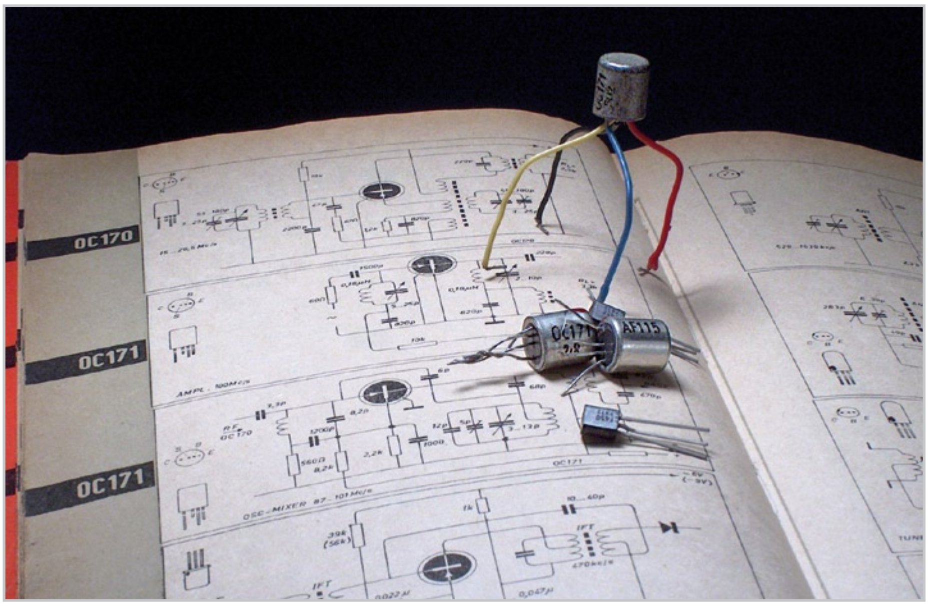
This light dimmer has been especially designed for use with fluorescent lamps (FLs). The circuit contains only a few components and can be built on a circuit board of only 2 by 3 cm if you use SMD components.
The mains voltage is rectified by D1 to D4 and this waveform goes to the in series connected fluorescent lamp and a thyristor. During the day the thyristor will not receive any gate current so that the lamp will remain off. At night the thyristor will receive a continuous gate current so that the fluorescent lamp stays fully on.
The light/dark detection circuit is built around T1 to T4. This part is fed directly from the rectified mains voltage via R1/D5/C1.
Photo transistor T1 measures the amount of ambient light. During the day, when there is sufficient light, T1 conducts. In that case T2 and T3 will block and T4 conducts so that the thyristor does not receive any current.

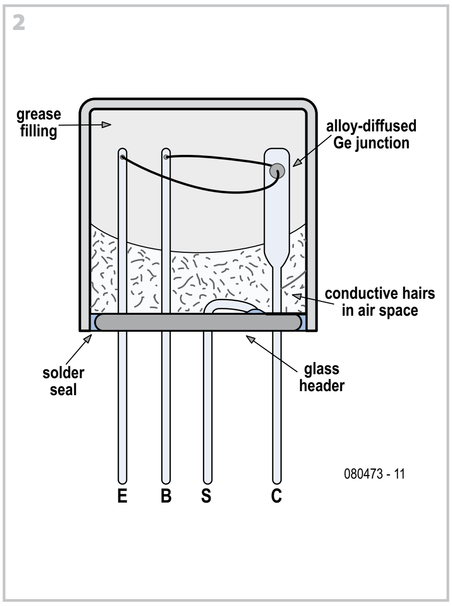


When dusk falls the voltage across electrolytic capacitor C2 increases. At some point this will become high enough so that T2 and T3 will conduct. T4 will not receive any base current any more and blocks, so that the thyristor will receive continuous gate current via voltage divider R6/R7/R8 and the lamp will light up. R9 and R10 provide for some hysteresis in the switching behaviour of T2 and T3, so that the circuit does not repeatedly turn on and off when dusk falls.
When building the circuit make sure that it is electrically safe, since it is directly connected to the mains voltage.

(070895-I)

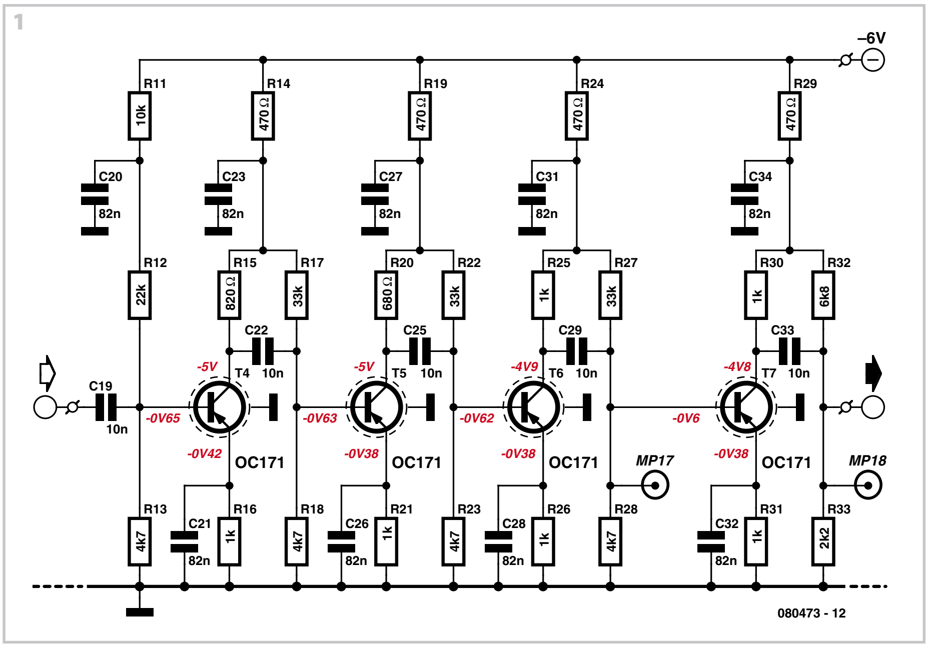
The OC171 Mystery (solved)





Jan Buiting, PE1CSI

The OC170 and OC171 transistors are germanium p-n-p alloy-diffused transistors in a TO-7 metal case. They were designed by Philips in the early 1960s as RF transistors with a (then spectacular) transition frequency of about 70 MHz. At the time, these devices marked a transition from the old 'grown alloy' to the new 'alloy-diffused' junction manufacturing, at the verge of the silicon age that was about to begin.
The OC170 and OC171 were a good success and got widespread use as RF and IF amplifiers, oscillators and mixers in early MW/LW portable radios as well as TV sets. When Philips phased out their 'OC' type prefix to comply with the Pro Electron semiconductor type designation system, successors of the OC170/171 called AF114, AF115, AF116 and AF117 appeared on the market. Both the OC and the AF devices carry a 'terrible secret' inside their TO-7 metal can.
If you switch on a 'dead' 1960s transistor radio containing one or more of the above mentioned trannies, try gently tapping them with a small screwdriver. In many cases the radio will crackle, burst to life or work intermittently and drop silent again after a while.
Surprisingly, unsoldering a suspect OC171 from the circuit and checking its junctions using an ohmmeter will not reveal faults in the junction proper. The device will also achieve its normal electrical specifications. However, an unexpected short-circuit may be measured between the shield wire (S) and the emitter or collector. In the 455 kHz IF amplifier shown in **Figure 1**, a domino-effect with all transistor biasing occurs if, say, the collector of the first OC171 is shorted to the shield, hence to ground. This was a practical case and a trigger to start a research.
In reference [1] Andrew Emmerson explains that these short-circuits are caused by microscopic conductive 'hairs' growing from the inside of the can in the air space under the grease filling (probably petroleum jelly or an early form of silicone grease). The phenomenon is illustrated in **Figure 2**. Typically the hairs will reach the emitter or collector wire. The nature of the growth is unknown; some suggest it's due to an electrochemical effect between the can metal and the wire metal, with the air and the slightest trace of acid in the grease interacting in the process. Others claim it's a 'Philips nasty' — a chemically engineered time bomb to generate sales of new radios. An even more unlikely suggestion is one of Philips' US competitors having supplied the grease through a sub-contractor 'in the plot'.
Interestingly, reference [2] confirms that the much dreaded 'Qual. Lab.' at Philips Semiconductors had expressed doubts about the use of a grease sealant around the diffused Ge junction used in OC17x and the later AF11x devices. It is not known if the air pocket beneath the grease filling is intentional or a production flaw.

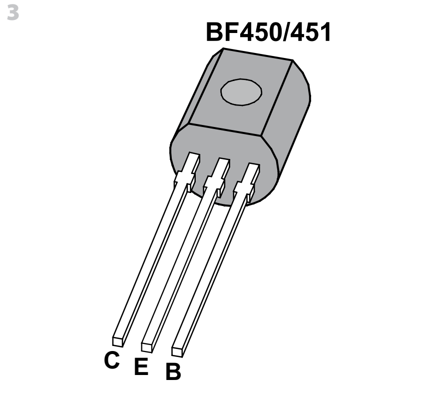


A well established trick applied by radio & TV service engineers was to cut the shield lead (S), isolating it from the circuit ground but if you were unlucky a hair would land between the E and B wires. Another disadvantage is the transistor case then being at the emitter or collector potential, causing RF radiation and the magical but unwanted 'hand effect' — the TO-7 is a relatively large case!

The hairs may be 'zapped' using a 47 µF electrolytic charged to about 50 V and connected between the S (shield) wire and the E, B and C wires twisted together. Although this method is good to retain the originality of your radio, the fault may occur again after some time as the hair growth continues.

Germanium transistors have a bias voltage of 0.2-0.3 V, so if an OC171 or one its siblings is replaced by a modern silicon p-n-p RF transistor like the BF450 or BF451 (**Figure 3**), resistors may have to be changed to get 0.6-0.7 V V_{B-E} bias levels in the circuit. Also, almost all silicon transistors will have a much higher transition frequency than the old 'geranium grot', so due attention should be given to RF decoupling and changed internal capacitances.

3



There is no point in buying NOS (new old stock) OC17x or AF11x transistors on EBay as the shiny devices you'll get will have the problem too.

Reportedly some audio transistors like the AC127, AC128, AC176, AC187 and AC188 also suffer from unwanted hair growth in invisible places.

(080473-I)

[1] Electronic Classics, Collecting, Restauration and Repair, Andrew Emmerson. ISBN 0-7506-3788-9.

[2] 50 Jaar Herkennen (Recognising 50 Years). Philips Semiconductors Nijmegen, C. van Anrooij, F. Geersten. H. Jacobs, P. Willemsen, G. de Wind (Editors). ISBN 90-90-17050-2.

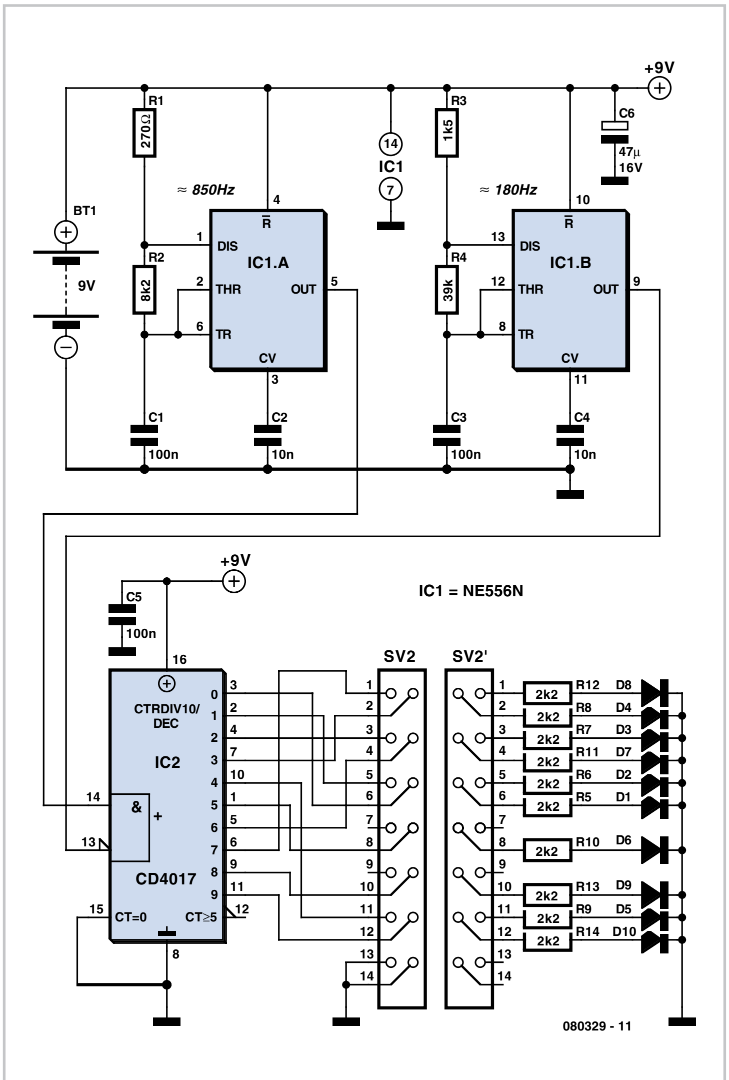
Pseudo-random Glitter

Hans-Jürgen Zons

A question recently asked on the Elektor website forum was how to make several white LEDs 'sparkle'. The helpful author has not only provided a useful suggestion (use a random effect), but also developed a suitable circuit and even designed a PCB layout. You can download the Eagle files for this from the Elektor website page for this article (www.elektor.com, archive # 080329-1.zip).

But first let's consider the basic question: artificial sparkling or glittering can best be simulated by having the different light sources switch on randomly at a particular frequency. Surprisingly enough, it is not all that easy to generate truly random sequences electronically. However, the electronic randomness does not necessarily have to be perfect for glitter applications. Patterns that appear to be random are sufficient for the desired visual impression.

Based on this principle, the author uses two 556 timer ICs to generate signals whose frequencies (850 Hz for IC1a and 180 Hz for IC1b) can be divided by each other without yielding an integer divisor. A decimal counter operated in an unconventional manner uses these two signals to produce a constantly pseudo-random pattern on its ten outputs, which repeats itself only very infrequently. This behaviour is obtained by applying the higher-frequency signal to the CLK input of counter IC2, with the CLK Inhibit input on pin 13 being driven by the lower-frequency signal. The result is 'genuine pseudo-random' blinking.



LEDs can be connected directly to the ten outputs, since a CMOS output can anyhow only supply a few milli-ampères. However, it is recommended to use series resistors (2.2 kΩ to 4.7 kΩ) to reduce the load on the IC outputs if the supply voltage is higher than 10 V. If you want to have more than ten LEDs glitter, you can naturally build several copies of this circuit.

(080329-1)

Microlight Fuel Gauge

Jean-Pierre Duval

Over the Internet, a microlight owner asked me to make him a fuel gauge for his ultra light aircraft. This seemed to me to offer various very interesting aspects, so I decided to take up the challenge.

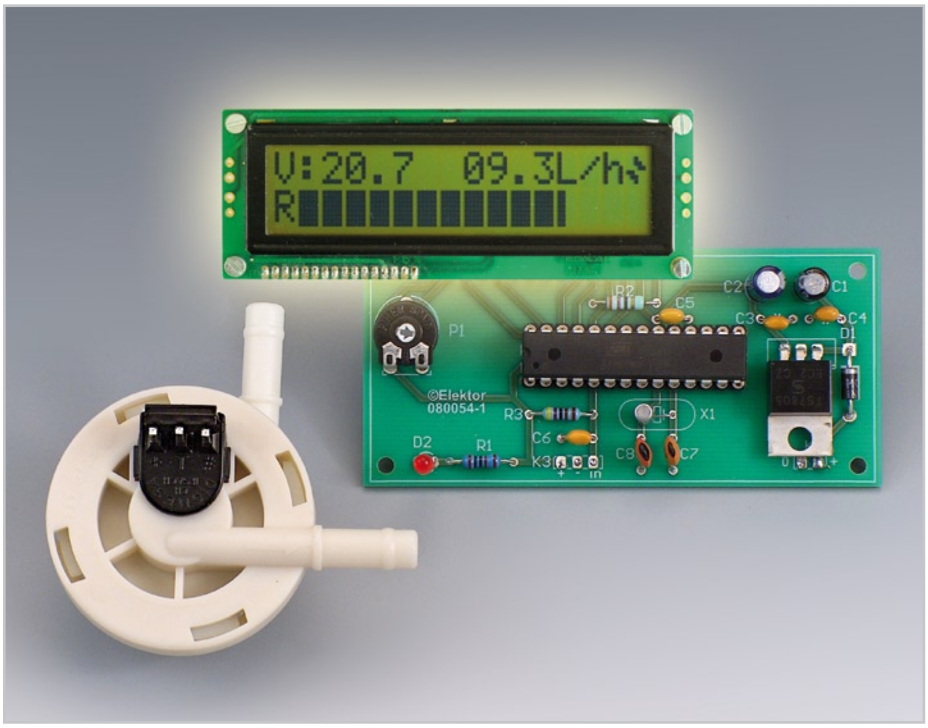
I started by gathering some basic information to define the specifications that would be required for this measuring instrument, so vital for any craft moving in the third dimension where a good supply of fuel is absolutely vital to prevent accidents and embarrassment. Here are the key details:

- a microlight always takes off with the fuel tank full;
- fuel consumption is usually between 7 and 9 litres/hour;
- it's important for the gauge to be perfectly readable in all circumstances, e.g. in the form of a bargraph;
- an indication of the amount of fuel remaining, expressed in litres;
- an indication of the instantaneous fuel consumption (l/h);
- it must be possible to have complete confidence in the gauge, so provision needs to be made for a warning in the event of it going wrong;
- for the transducer, we use the manufacturer's data (in this case Digmesa); for greater safety, all data used are taken at minimum values;
- two alerts need to be provided: 3.5 litres and 2 litres of fuel reserve remaining.

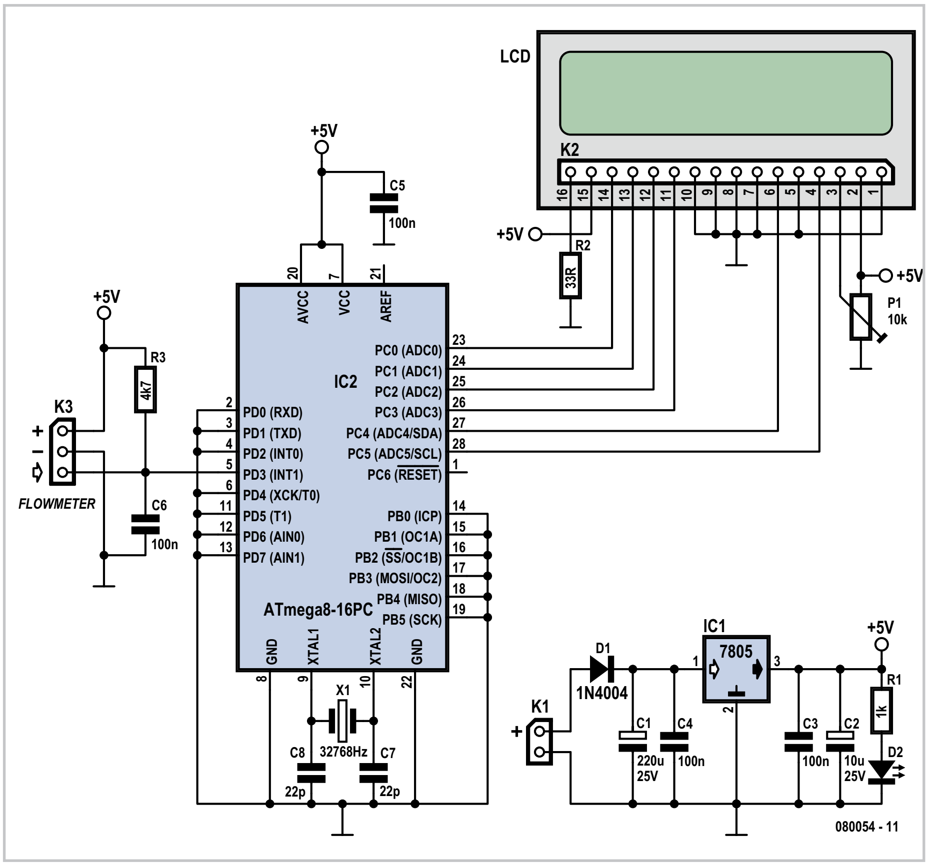
All these conditions are taken into account by the firmware – the program burned into the microprocessor – more than by the hardware, which can thus remain relatively simple.
Apart from the fuel flow sensor, an Atmel ATmega8 microcontroller, and the display, all it takes is a few capacitors and a very small number of resistors.

Time now to take a look at the circuit. Let's start with the power supply.

Totally conventional, we start out with the 12 V supplied by the battery, dropped to 5 V by a 7805 regulator. Upstream of this, a fuse, not shown on the circuit, protects the whole unit. Diode D1 protects the regulator against unintentional polarity reversal of the voltage at the power supply input. LED D2 indicates the presence of the output supply rail from the regulator IC1.



Now let's move on to the more interesting bit, which is the electronics of the virtual fuel gauge proper.
Leaving aside the microcontroller, the most important component in this project is the flow sensor. This is an FHKSC 932-8501 from Digmesa [1] & [2]. This detector can measure fluid flows from 0.03 to 2.0 l/min, equivalent to a range of 1.8 to 120 l/hr — more than sufficient for the application envis-



aged. Originally developed for measuring water flow in coffee machines, it is equally capable of measuring other fluids, as long as they are not too chemically aggressive (alcohols, petrol, wines, etc.). The ability to set the sensor port connections at different angles gives it unquestionable installation flexibility.

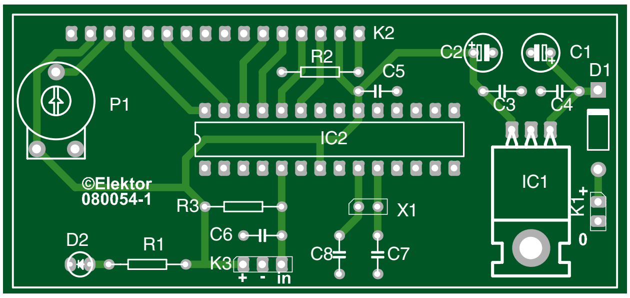
After that, we are interested in the (artificial) heart of the circuit — now it's time to get down to the really clever stuff.

The microcontroller used here, IC2, is an ATmega8 from the Atmel stable [3]. We shouldn't underestimate it — despite its name, this is a powerful component that we are far from pushing to its limits. It uses its internal 8 MHz oscillator to run the program and an external 32.768 kHz clock crystal to measure the instantaneous consumption. The crystal frequency is common, by the way, from the use in watches where it's one on the easiest ways of creating a stable source for seconds pulses.
This ATmega8 microcontroller has 24 I/O ports, of which we are only going to be using a few, for the following functions:
• six ports are used for the LCD display, i.e. almost the whole of port C (PC0–PC5);
• one INT1 port (PD.3) as an input for the pulses supplied by the flow sensor;
• two ports, PB.6 and PB.7, are devoted to the above mentioned clock crystal.

For Reset we use the microcontroller 'Brown-out' programmed via the microcontroller 'fuses'. 'Brown-out' defines the supply voltage level at which the program starts — in our case the minimum voltage is 2.7 V.
The Reset pin has an internal pull-up, so no external one is needed.
BASCOM Basic includes the tools needed to configure the fuses.
All unused ports are configured in the program as inputs, and from an electrical point of view are tied to ground on the board.

The liquid flow sensor produces very clean 5 V (TTL) pulses which trigger an interrupt (INT1) used to measure the engine's fuel consumption. Here, it is wired in accordance with the manufacturer's data (see [1]) www.digmesa.com, i.e. by adding a 4.7 kΩ pull-up resistor and a 100 nF capacitor between the signal output and ground (TTL-mode output).
Preset P1 allows adjustment of the LCD display contrast by adjusting the voltage V_{EE}.

The program is written in BASCOM BASIC, a powerful, economical programming language that's all the same very easy to implement. There is a free version available that is capable of producing up to 4 k of code [4].



COMPONENTS LIST

Resistors
R1 = 1kΩ
R2 = 33Ω
R3 = 4kΩ7
P1 = 10 kΩ preset

Capacitors
C1 = 220µF 25V
C2 = 10µF 25V
C3-C6 = 100nF
C7,C8 = 22pF

Semiconductors
D1 = 1N4004
D2 = LED, red
IC1 = 7805
IC2 = ATMEGA8, programmed with hex file from archive 080054-11.zip

Miscellaneous
X1 = 32.768 kHz quartz crystal
K1 = 2-way pinheader
K2 = 16-way SIL pinheader
K3 = 3-way pinheader
LCD, 2 x 16 characters with backlight, general purpose
F1 = flow meter, Digmesa type FHKSC 932-8501 (Conrad Electronics)
PCB, ref. 080054-1 from www.thepcbshop.com

The irreproachable operation of this fuel gauge relies on a plethora of arithmetic calculations going on inside the microcontroller. We'll describe the most important ones so that if necessary you can adapt the characteristics of this flowmeter so as to use it for other applications.
Let's suppose that our fuel tank has a capacity of 29 litres. If we assume that the sensor provides 1,800 pulses per litre (we measured over ten tanks and were at between 1,900 and 2,000 pulses per litre – in accordance with the manufacturer's data, but reduced down to 1,800); that gives us a maximum of:

$$1{,}800 \times 29 = 52{,}200 \text{ pulses}$$

for a completely full tank; in order to maintain a degree of safety margin (poorly-filled tank, leaks, and so on) we'll give ourselves a margin of 10%, and so will only count 48,000 pulses. Each pulse corresponds to 1,000/1,800, i.e. 0.555 ml.

The calculation of the instantaneous consumption expressed in litres/hour is a weighted value, recalculated every 10 seconds

The TIMER interrupt is used here in the Clock configuration to generate a very precise second value, so even with very low consumptions, the response is very close to the true value. The calculation of the volume remaining in the tank is performed by decrementing the amount consumed per unit of time from the volume remaining (see inset 'Procedure for calculating volume of fuel remaining').

All that remains to mention is the alert thresholds, at 3.5 and 2 litres, defined in the firmware. Again, if you want to adapt thee values to your personal requirements,

Procedure for calculating volume of fuel remaining:

Once again, the calculation is extremely simple :

If, at the outset, volume=48000

```
------interrupt routine------
rem    at each interrupt, the
   volume is decremented
DECR volume
--------display--------------
rem     after a formatting step
volume_remaining=volume
Tank = Str(volumeremaining)
Tank = Format(tank , “00.0”)
Locate 1 , 1 : Lcd “V:” ; Tank
```

do feel free to edit the microcontroller source code.
These calculations refer to the amount remaining; when one of the thresholds is reached, it causes the LCD display to blink at a fast rate.

One of the most interesting aspects of this project is the very customized way the display is used. It's worth taking a slightly closer look at it.
Some display tricks are used to display the values. The top line of our display (two lines of 16 characters) is used to show the numeric information about the volume remaining (V) and instantaneous consumption (l/h).

The character at the extreme right of this top line is a user character intended to symbolize the flowmeter. As long as the latter is working, this character changes shape, giving the impression of rotation. This is what we've called the 'operation indicator'.
In the measuring second, we make it change between two characters symbolizing the flowmeter. If the flowmeter isn't working, there is no variation in volume during the measuring period, and so this right-hand end character remains static.
Let's see now what the bottom line does. It's used to indicate the tank status in graphical form. When it is full, we will have 15 solid blocks to the right of the R (for 'Reservoir' = Tank).
The characters on the LCD display are each made up of an 8 row by 5 column matrix of pixels. To be able to display the gradual reduction in the amount of fuel available, we have created several special user characters. The solid block of 5 columns is part of the LCD display's own character set. We're going to create a block with just 4 columns, then one with 3, then 2, and then 1. After that, the block in question just goes blank.
Let's move on now to the calculations.
We have 15 characters, each with 5 columns, giving us 80 columns in all.
We have taken 48,000 as our starting point (allowing for our safety margin). Hence by division, 48,000/80 = 600. So, we can see that we need to lose one column every 600 pulses.

So we display the appropriate number and type of characters corresponding to the information to be displayed. In the photo of the display, the last character consists of two columns.

A printed circuit board was designed for this project. It's approximately the same size as the display, which can be mounted onto the board piggyback-fashion. The component layout needs no special mention. You should start with the smaller components, resistors, capacitors, headers, and diodes, finishing off with the socket for IC2. Don't fit the processor into its socket until you have first checked that the required voltage (5 V) is present on the relevant pins (7, 20, referenced to one of the pins connected to earth, 2,3 etc. refer to the circuit diagram).
It only remains to fit the flow sensor into the fluid (whatever it is) supply pipe. Header K3 is used for its supply and output signal. The LCD display connects to header K2. Take care to get it the right way round!

We're very curious to know what applications readers are going to find for the virtual gauge described here!

jeanpierre.duval2@orange.fr (080054-I)

Downloads

The source code and .hex files for this project, along with the board design are available on www.elektor.com. The respective file names are 080054-11.zip and 080054-1.zip.

Web Links

[1] Flow sensor source
www.digmesa.com/

[2] Flow sensor data sheet
www.digmesa.com/digmesa/upload/pdf/FHKSC/932-850xxxx_GB.pdf

[3] ATmega8 data sheet
www.atmel.com/dyn/resources/prod_documents/doc2486.pdf

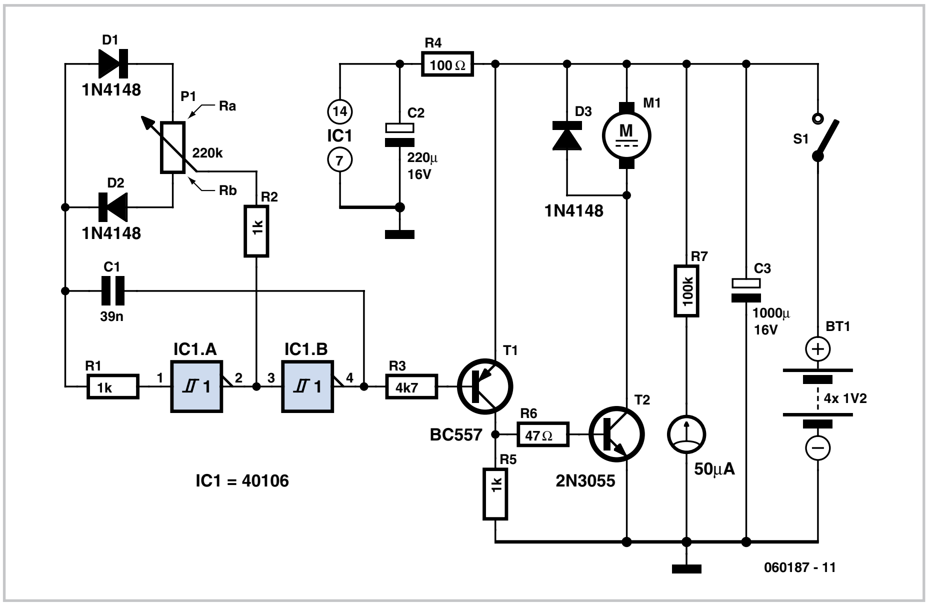
[4] BASCOM BASIC (MCS)
www.mcselec.com/index.php?option=com_docman&task=cat_view&gid=99&Itemid=54

PWM Control for Permanent Magnet Motors

Franz P. Zantis

DC motors with permanent magnets are widely used and popular among model builders. A particular characteristic of these motors is a large discrepancy between the startup torque and the nominal torque.

If a permanent magnet motor is to be powered from a DC supply and a constant, high torque is required at a variable operating speed, a pulsewidth modulator (PWM) of the type described here is needed.
We construct an astable multivibrator with the help of a couple of gates from a 40106 hex Schmitt trigger IC. The multivibrator has a mark-space ratio ('duty factor') that can be adjusted over a very wide range, independent of its operating frequency. Adjusting the potentiometer changes the

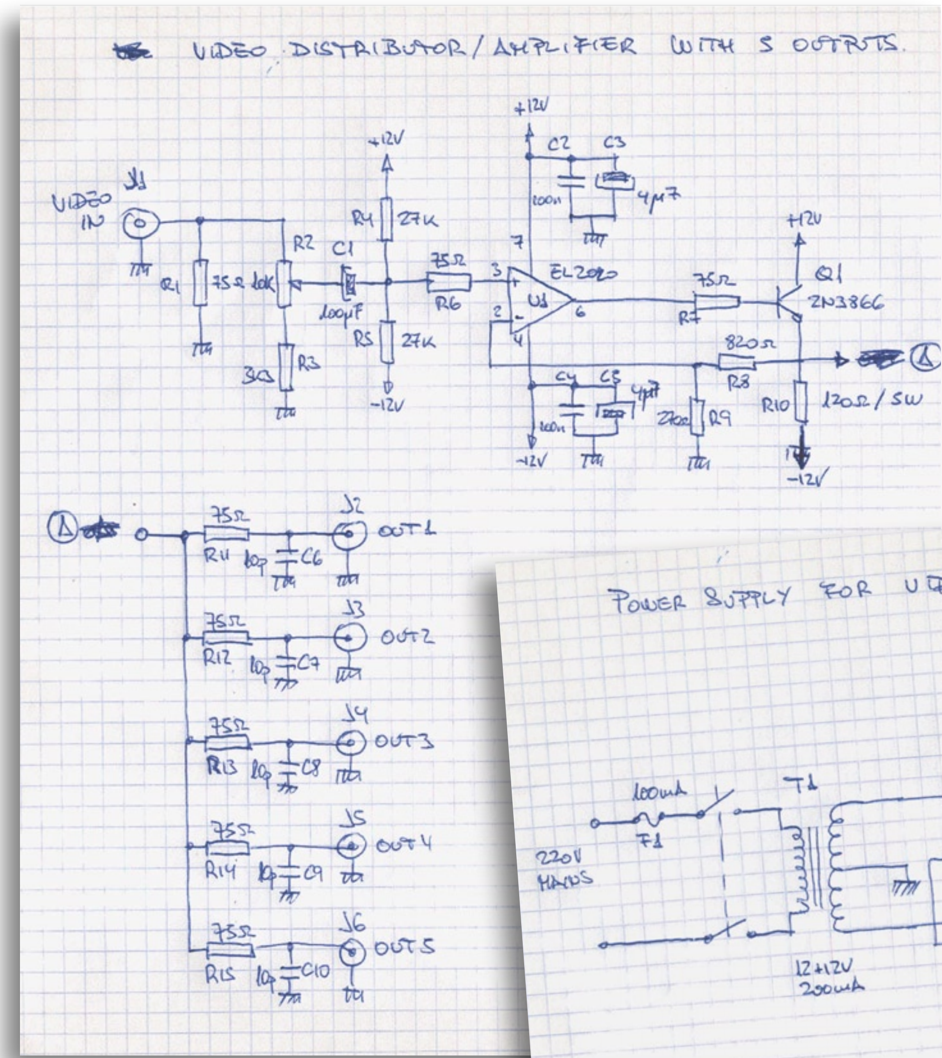


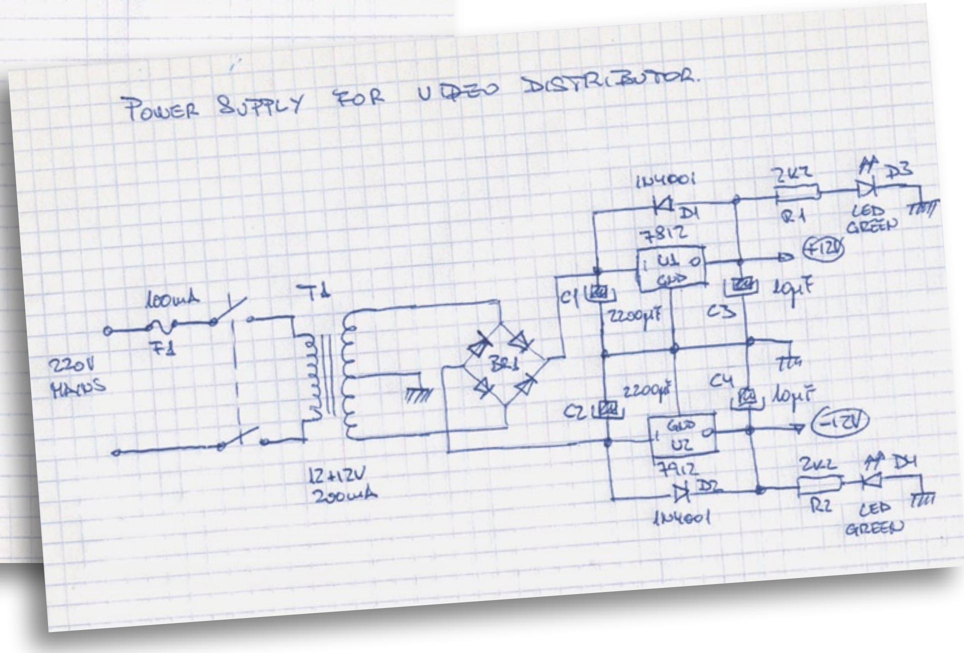
ratio between R_a and R_b, which together make up the total resistance of the potentiometer. Capacitor C1 is charged via R_b and is discharged via R_a. The corresponding mark-space ratio is present at the output of the oscillator on pin 4 of the 40106. The output high time is determined by R_a, while the output low time is determined by R_b. The oscillator frequency is constant at approximately 115 Hz. Transistor T1 provides current gain: when pin 4 of the 40106 is low, T1 turns on, and when the output is high, T1 is turned off. Sufficient current is available at the collector of this transistor to drive the base of the 2N3055 power transistor. R4 and C2 provide decoupling for the oscillator from the large currents switched by the power output stage. The moving-coil meter connected via R7 serves to monitor the state of the battery, which is useful when rechargeable cells are used. The circuit has been used by the author to drive a motor salvaged from an old cassette tape recorder. In this case the 2N3055 did not require a heatsink.

Interested readers will find that a search of the Internet turns up plenty of information on the theory and practice of driving DC motors using pulsewidth modulation.

(060187-I)

Five-output Video Distribution Amplifier





Eduardo Corral

Video fans and professionals in the field will find in this small signal distributor/amplifier an excellent ally when it's necessary to distribute a single video signal across several equipments. The circuit shown here should have a lot of applications.

Basically, the distribution amplifier takes the composite video signal from a video player (VCR) or a video generator (analogue output) and buffers it in such a way that it can be simultaneously applied to up to five different video equipment inputs, like monitors, TV sets, other VCRs and so on. For example, in a hall, the image produced by a central DVD player can be shown on five different TV screens with the sound reproduced through a separate amplifier.

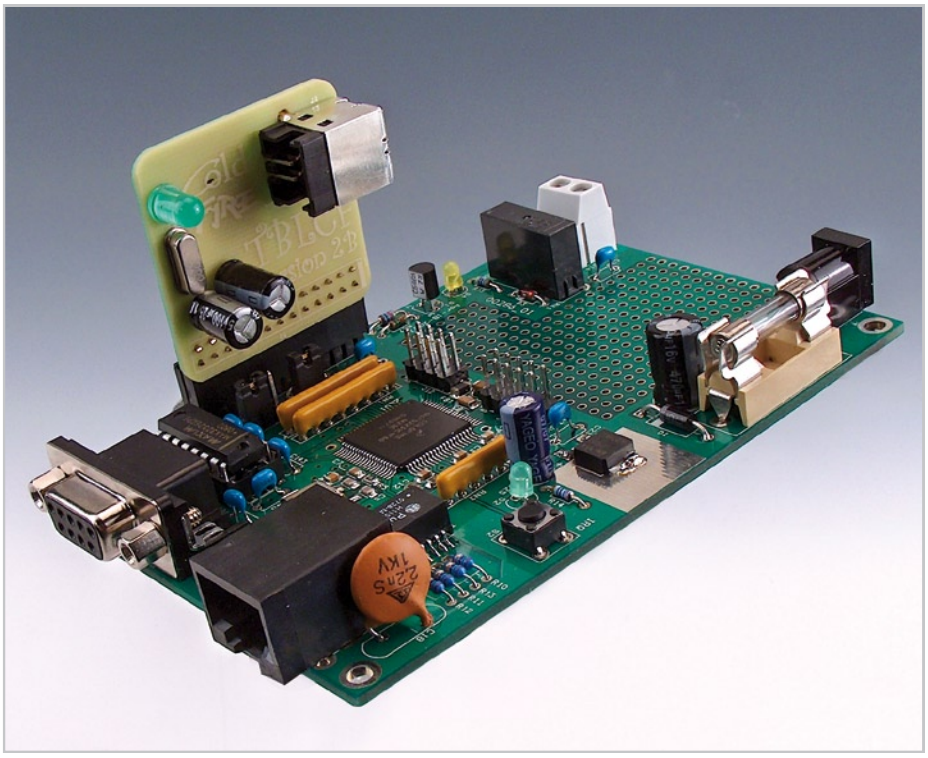
The circuit is based on the type EL2020 (or similar) operational amplifier which is marled by large bandwidth. The LL2020 amplifies the video signal applied to the input stage, with a gain adjustment range of ±6 dB. Output transistor Q1, a 2N3866, applies the video signal to the five outputs designed to drive loads with 75-Ω impedance.

The circuit requires a ±12 V symmetrical supply voltage, which can be obtained from a conventional power supply as shown by the schematic.

(080478-I)

Turbo BDM Lite ColdFire Interface

Luc Lemmens



In the April and May 2008 issues of Elektor the DigiButler was introduced, which is a simple, low-cost Home Automation Server built around the MCP52231, a ColdFire microcontroller made by Freescale. The two article instalments also mentioned Daniel Malik's Turbo BDM Lite ColdFire interface (TBLCF), a low-cost programming interface that is fully open source. Although we referred to the extensive TBLCF documentation, we didn't have enough time during the preparations of the DigiButler project to fully test this interface, and there wasn't an RoHS compliant replacement for the microcontroller in that circuit. This is now available, however, and may be obtained as a free sample via the Freescale website.

The software and firmware for the TBLCF can be found via the link at the end of this article, and tblcf_v10.zip is the file that we need. This can also be found as part of the free download (071102-11.zip) that we've added to the Elektor website. The .zip file contains a manual (manual_v14.pdf), which clearly explains how the drivers should be installed and how the controller for the interface should be programmed. It's just a matter of figuring out where the various files are stored.

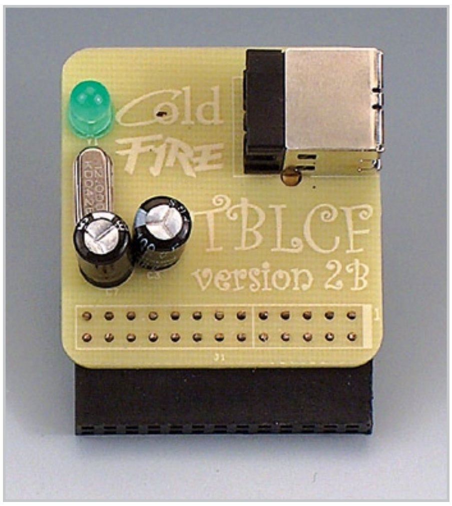
The USB drivers (page 13 of the manual) are contained in usb_drivers_v10.zip. Extract all the files from this .zip file into a new folder on the hard drive. You can then connect the interface to the PC, which should result in a message stating that a new hardware device has been found. If that doesn't happen it's a case of carefully checking all soldering on the TBLCF board. Note that the LED on the interface won't turn on yet at this stage. Next, follow the instructions given in the manual to install the drivers.
To program the firmware you need the files tblcf_bt.exe and tblcf.abs.s19. These can be found inside pc_binaries_v10.zip and tblcf_firmware_v04.zip\bin respectively. When the programming of the firmware has been completed Windows will start another procedure to install the new drivers, after which the PC has to be restarted. Once this has been done the LED on the TBLCF should be lit continuously if it has been correctly recognised by Windows. Whenever communications take place between the PC and the target system the LED flashes.
Adding the TBLCF to the CodeWarrior 6.3 IDE is clearly explained in the manual, and tblcf_gdi.dll can be found inside pc_binaries_v10.zip. The item 'Startup file' can be left blank.

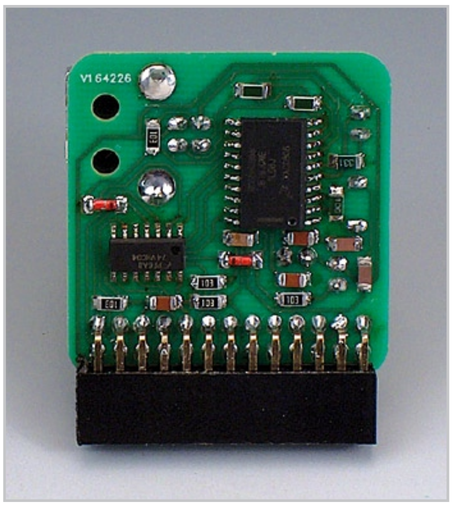
Up to this point the manual has held our hand through the installation process, but there is (as with the parallel programmer interface from the May issue) a section that requires extra attention: the settings for the flash programmer. From CodeWarrior, open the menu *Tools -> Flash Programmer*. Click on *Load Settings* and load the file setup.xml, which can be found in the folder DigiButler software\SW_Main_Board (see archive 071102-11.zip). Check that the *Target Processor* in this window is set to: 5223x. For the *Connection* choose TBLCF and make sure that the *target initialisation file* is M52235EVB_PnE.cfg. Then click on *Flash Configuration* and from the *Device* table select the CFM_MCF5220_25MHz. Then overwrite setup.xml using *Save Settings* to keep the new settings.

(080448-I)

Web Link

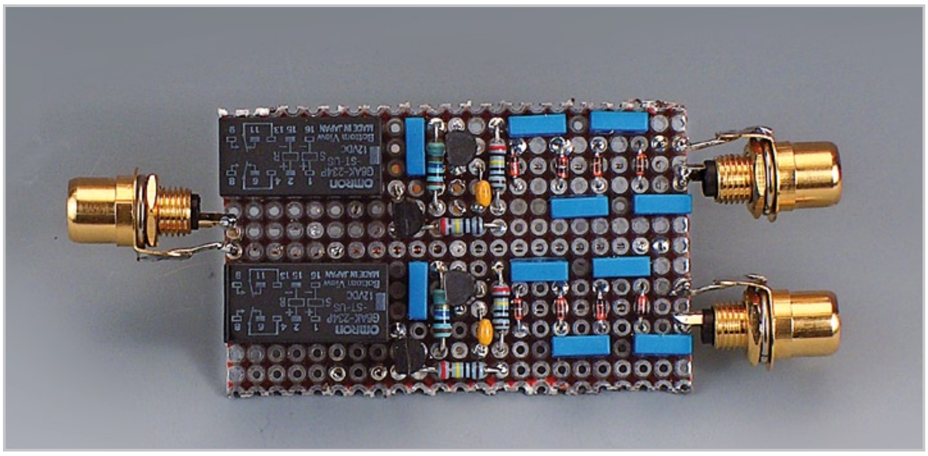
http://forums.freescale.com/freescale/board/message?board.id=CFCOMM&thread.id=624





Automatic S/PDIF Selector

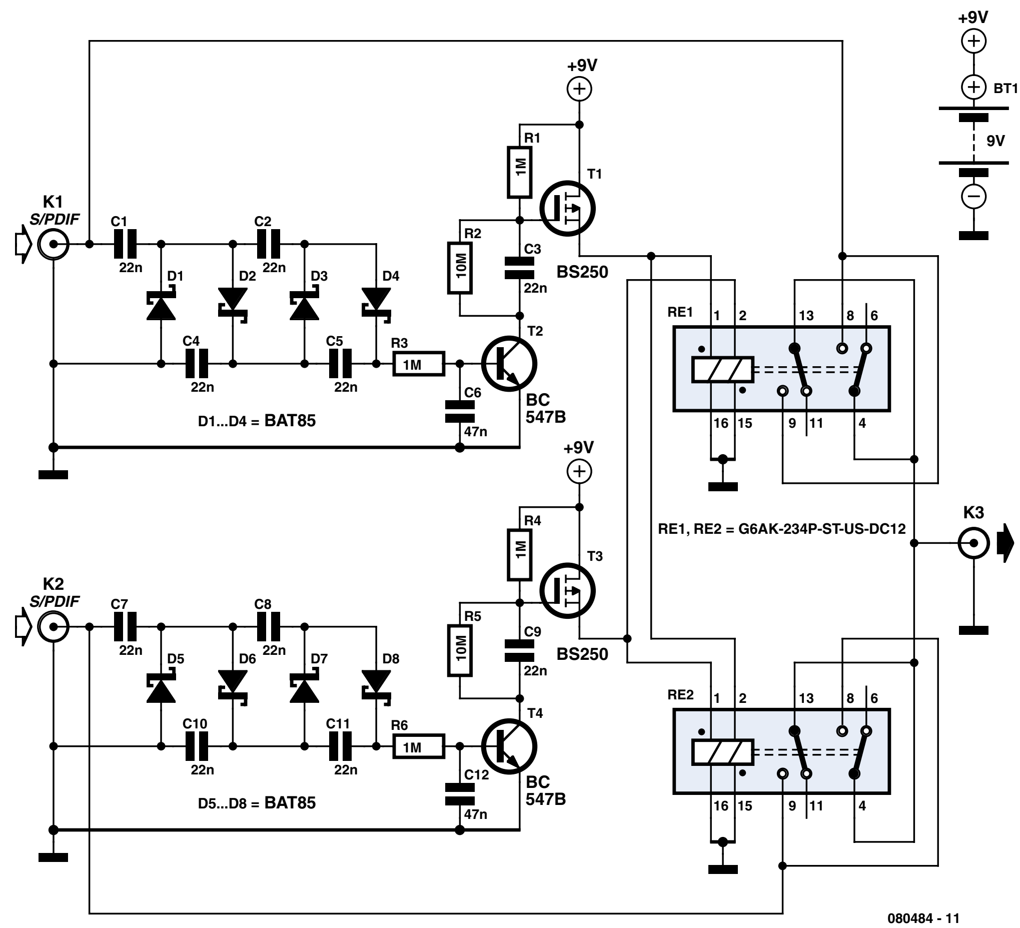
Ton Giesberts



These days there is an increasing number of devices that have a digital audio output, for example digital cable tuners, satellite receivers, DVD players/recorders or game consoles/computers. It is often the case that the existing receiver doesn't have enough coaxial S/PDIF inputs to accommodate all these devices, or the receiver is at the other side of the room from the TV and other equipment, and we'd rather not lay three or four separate S/PDIF cables along the skirting boards. This clever little circuit gets round these problems in an ingenious way. It doesn't need a mains supply nor does it have any external switches. The latter makes it possible to hide the device behind the equipment.

The circuit detects the appearance of a new S/PDIF signal on one of its two inputs and switches this to its output, so that only one connecting cable is required to connect two devices with S/PDIF outputs to the receiver. When several devices are turned on that output a continuous S/PDIF signal, the required device needs to be momentarily turned off and then on again to select it. It is relatively easy to expand the circuit with more inputs.

Because we wanted to avoid the use of a mains adaptor for this circuit we decided to make it battery-powered. For the design we therefore strived to keep the current consumption as low as possible. That meant that we didn't use buffer stages or comparators to detect the input signals. Instead we used bistable relays, which only require a short pulse to change their state, which is then latched.



When an S/PDIF signal appears on one of the inputs, a cascade circuit is used to derive a DC voltage from it. Because the nominal voltage of S/PDIF signals is only 0.5 V_{pp} (when terminated by 75 Ω), each input has a cascade stage with four diodes and four capacitors. The generated voltage then becomes twice the peak-to-peak value, which in this case results in nearly 1 V. In order to keep the threshold voltage as low as possible the cascade stage is loaded as little as possible, the capacitors are as small as possible and for the diodes we've used special Schottky types (BAT85).
This signal is then fed to a bipolar transistor that requires about 0.5 V to 0.6 V for it to conduct. A base resistor of 1 MΩ and a capacitor are used for interference suppression. The bipolar transistor drives a differentiator C3/R1 (C9/R4 for the other channel) to create a short pulse for the relay. The gate of the following P-channel MOSFET is momentarily connected to ground via capacitor C3 and transistor T2. This FET then drives the set-coil of one relay and the reset-coil of the other relay. The BS250 used here can switch a direct current of 250 mA without any problems, and has an even high peak-current capacity (up to 500 mA).

The number of inputs can be increased by adding more of these stages. Note that when there are more than two stages you need to connect each reset-coil via diodes (e.g. BAT85) to the FETs. In that way the voltage on the reset-coils doesn't end up at the set-coils of the other relays.
Depending on the type of relay used, you typically need about 15 mA to energise each coil. This means that the maximum possible number of inputs is much more than you're ever likely to need.
It is possible to use 12 V types for the relays. The G6A series made by Omron are guaranteed to switch at 8.4 V, for example the G6AK-234P-ST-US-DC12. The coil resistance is 800 Ω, which means that it requires only 11 mA. If you find you have some 'hesitant' relays when you're using more inputs and switch the relays via diodes, you can always use 5 V types. The switching current will then be higher, but in practice this has little effect on the battery life.
The current consumption of the circuit with signals present at both input is about 1.6 µA. This implies that the maximum theoretical battery life could be 35 years for a standard 9 V battery (500 mAh), which is much longer than its expected shelf life. Another option is to use three or four Lithium cells in series. These probably will give the circuit 'near-eternal life'.

(080484-I)

Phantom Supply for TV Antenna

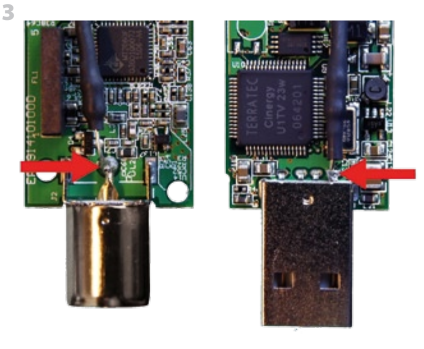
Dr. Thomas Scherer

The author gave his father-in-law a USB TV stick as a present. After experimenting with it for a little while, they concluded that the performance of the device when used with a passive antenna was very poor. An active antenna, unfortunately, requires an extra power supply, which is not really practical when used with a laptop. Reason enough, then, to solve the problem properly; and in any case the author wanted to try to shake off his unwanted reputation with his father-in-law as an amateur engineer!

The author took the USB stick home with him, with the idea of somehow or other adding the needed phantom power output to the device. Fortunately things turned out considerably simpler than he had expected.
As **Figure 1** shows, the stick is held together by a few screws, and so getting it apart is straightforward. So how does a phantom power supply work? Normally the antenna input is decoupled, as far as DC is concerned, from the main electronics by a capacitor. If we can somehow get 5 V onto the input in such a way that it does not short out the HF signal, we can provide a power supply to an active antenna. The current consumption of the amplifier in such an antenna is typically between 20 mA and 50 mA. This current (at +5 V) can easily be sourced from the computer's USB connector. If we connect this supply via a coil to the antenna input the problem is solved: the coil will present a high impedance to the high frequencies in the TV signal.

1


2

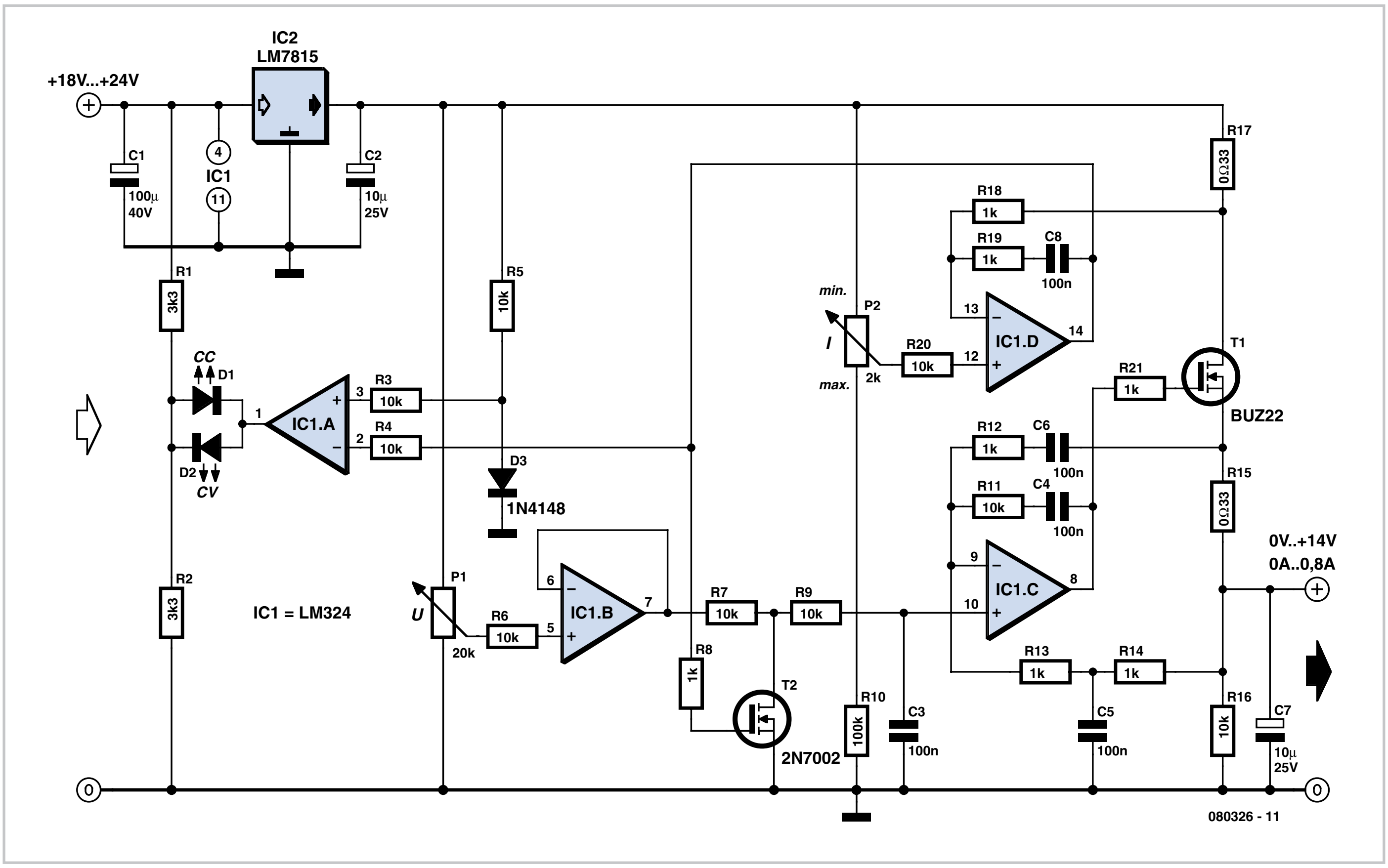

3


In order to make the antenna input short-circuit proof it is a good idea to add a 10 Ω metal film resistor in series with the coil. Using this type of resistor has the advantage that it will fail to an open circuit if overloaded for a prolonged period, and thus acts as a kind of fuse. The author used a 220 µH fixed inductor (any value above about 10 µH will do) with a DC resistance of 5.6 Ω. At a measured current draw of 30 mA the total voltage drop is around 0.5 V, which is entirely acceptable.
The two components were simply soldered together (**Figure 2**) and shrouded in heat-shrink tubing. The 'module' was then soldered into the USB stick: the red arrows in **Figure 3** show where the solder connections were made. The 5 V pin of the USB plug is opposite the ground pin, which in turn is easy to identify as it is electrically joined to the shield of the plug. The final construction is shown at the bottom of Figure 1.

The modification should work with all types of USB TV sticks: analogue tuners can benefit as much as digital tuners from an active antenna.

(080503-I)

Mini Bench Supply



Alexander Mumm

Every electronics engineer is familiar with the anxiety of the moment when power is first applied to a newly-built circuit, wondering whether hours of work are about to be destroyed in a puff of smoke. A high-quality power supply with an adjustable current limit function is an excellent aid to steadying the nerves.

Unfortunately power supplies with good regulation performance are expensive and homebrew construction is not always straightforward. Many of the 'laboratory power supplies' currently on the market are low-cost units based on switching regulators which, although certainly capable of delivering high currents, have rather poor ripple performance. Large output capacitors (which, in the case of a fault, will discharge into your circuit) and voltage overshoot are other problems.

The power supply described here is a simple unit, easily constructed from standard components. It is only suitable for small loads but otherwise has all the characteristics of its bigger brethren. Between 18 V and 24 V is applied to the input, for example from a laptop power supply. This avoids the need for an expensive transformer and accompanying smoothing. No negative supply is needed, but the output voltage is nevertheless adjustable down to 0 V.

A difficulty in the design of power supplies with current limiting is the shunt resistor needed to measure the output current, normally connected to a differential amplifier. Frequently in simple designs the amplifier is not powered from a regulated supply, which can lead to an unstable current regulation loop. This circuit avoids the difficulty by using a low-cost fixed voltage regulator to supply the feedback circuit with a stable voltage. This arrangement greatly simplifies current measurement and regulation.

To generate this intermediate supply voltage we use an LM7815. Its output passes through R17, which measures the output current, to MOSFET T1 which is driven by the voltage regulation opamp IC1C. Here R11 and C4 determine the bandwidth of the control loop, preventing oscillation at high frequencies. R15 ensures that capacitive loads with low effective resistance do not make the control loop unstable. The negative feedback of AC components of the current via R12 and C5 makes the circuit reliable even with a large capacitor at its output, and negative feedback of the DC component is via the low-pass filter formed by R14 and C6. This ensures that the voltage drop across R15 is correctly compensated for. C7 at the output provides a low impedance source for high-frequency loads, and R16 provides for the discharge of C17 when the set voltage is reduced with no load attached.

Current regulation is carried out by IC1D. Again to ensure stability, the bandwidth of the feedback loop is restricted by R19 and C8. If the voltage dropped across R17 exceeds the value set by P2, the current limit function comes into action and T2 begins to conduct. This in turn reduces the input voltage to the voltage regulation circuit until the desired current is reached. R7, R9 and C3 ensure that current regulation does not lead to output voltage overshoots and that resonance does not occur with inductive loads.

The controls of the power supply are all voltage-based. This means, for example, that P1 and P2 can be replaced by digital-to-analogue converters or digital potentiometers so that the whole unit can be

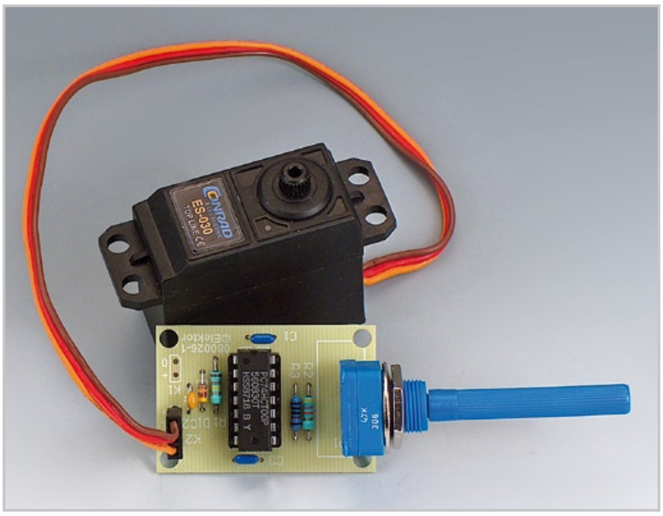
driven by a microcontroller. IC1B acts as a buffer to ensure that the dynamic characteristics of the circuit are not affected by the setting of P1.
IC1A is used as a comparator whose output is used to drive two LEDs that indicate whether the supply is in voltage regulation or current regulation mode. If D2 lights the supply is in constant voltage mode; if D1 lights it is in constant current mode, for example if the output has been short-circuited. The power supply thus boasts all the features of a top-class bench supply. IC1A and its surrounding circuitry can be dispensed with if the mode indication is not wanted.

A type LM324 operational amplifier is suggested as, in contrast to many other similar devices, it operates reliably with input voltages down to 0 V. Other rail-to-rail opamps could equally well be used. The particular n-channel MOSFET devices used are not critical: a BUZ21, IRF540, IRF542 or 2SK1428 could be used for T1, for example, and a BS170 could be used in place of the 2N7002. The capacitors should all be rated for a voltage of 35 V or higher, and R15 and R17 must be at least 0.5 W types. The fixed voltage regulator and T1 must both be equipped with an adequate heatsink. If they are mounted on the same heatsink, they must be isolated from it as the tabs of the two devices are at different potentials.

(080326-I)

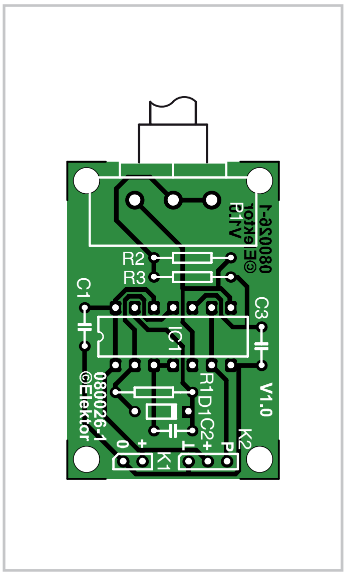
Servo Control

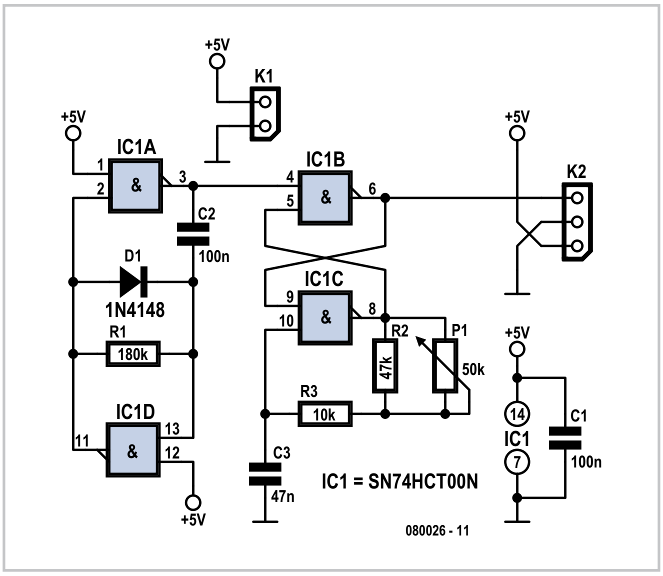
G. Baars



This circuit lets you control a servo in a simple way. It is built around a cheap and common logic IC. Together with a few resistors, capacitors and a diode this circuit can certainly be called simple and can be built on a small circuit board.
NAND gates IC1A and IC1D are used to build an oscillator which produces negative pulses with a repetition frequency of about 50 Hz. These very narrow pulses are used to toggle the output of the SR (set/reset) flipflop, which is built with gates IC.1B and IC.1C, every 20 ms. With every set-pulse the output of IC1C goes low, which causes C3 to be discharged via P1, after which the situation reverses. This results in a pulse at the output of IC1B, which repeats every 20 ms and the duration of which can be adjusted with P1. From experimenting with this circuit and an S3003 servo from Futaba it was observed that with a pulse duration of 1-2 ms it rotated through an angle of 90 degrees. However, by shortening the pulse duration a little more, to about 0.6 ms, there was a further 30 degrees of rotation. The component values in the circuit were chosen so that the pulse duration can be set from 0.6 to 2 ms with P1 and the total rotation amounts to about 120 degrees. Since the S3003 servo has a not inconsiderable torque of 4 kg·cm, at can be used, for example, to remote control the tuning capacitor of a so-called 'magnetic-loop' RF antenna.
The current consumption of the servo depends on the torque that needs to be delivered and varies from a few tens to several hundreds of milliamps.

(080026-I)





COMPONENTS LIST

Resistors:
R1 = 180kΩ
R2 = 47kΩ
R3 = 10kΩ
P1 = 50kΩ linear potentiometer

Capacitors
C1,C2 = 100nF
C3 = 47nF

Semiconductors
D1 = 1N4148
IC1 = 74HCT00

Miscellaneous
K1 = 2-way SIL pinheader
K2 = 3-way SIL pinheader
PCB, # 080026-1 from www.thepcbshop.com

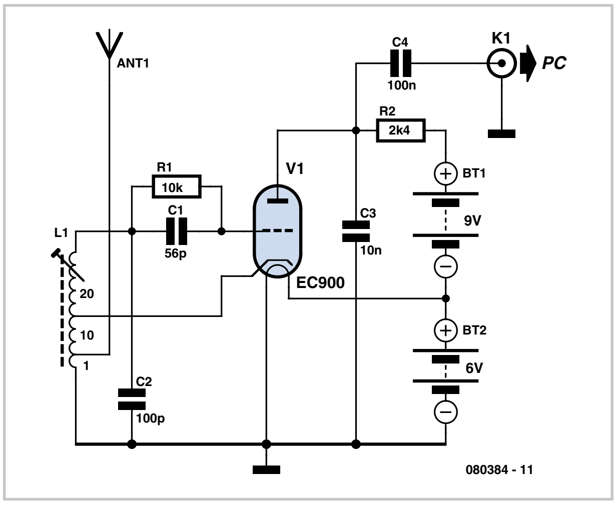
Software-defined Valve Radio

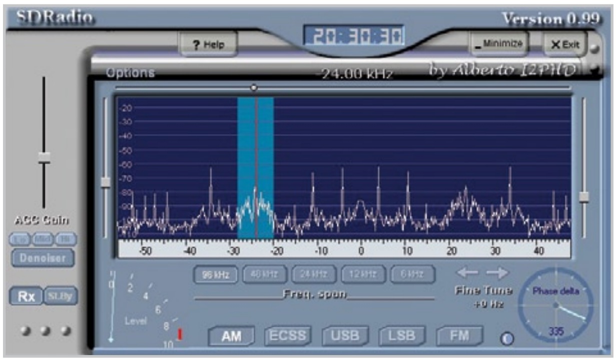
Burkhard Kainka

Software-defined radio (SDR) is all the rage. The idea is this: a very simple radio receiver is given top-of-the-range performance with the aid of a little software.

Even newer is SDVR (software-defined valve radio), where a single-valve radio is turned into a world receiver with some help from a PC. Power comes from four AA cells for the heaters, and a 9 V battery provides the anode supply.

The circuit is very simple: a PC900 (EC900) triode is used in a homodyne regenerative (Audion) configuration. Adjustment of the feedback is not necessary as the receiver always oscillates at high amplitude. A tuning capacitor can also be dispensed with as fine tuning is done in software. Coarse adjustment of the received band is possible by screwing the inductor core in and out. The receiver works in the 49 m band using a 30-turn coil on an 8 mm former.





The SDRadio program by Alberto (http://digilander.libero.it/i2phd/sdradio) is used as the decoder. The illustration shows an AM station being received. The sound card used (a USB Sound Blaster) has a sample rate of 96 kHz, giving a tuneable range of 48 kHz. In the illustration we can see three further transmissions.

A weakness of the receiver is that it only has one output channel. This means that each transmitter can be seen twice in the spectrum display, and there is no suppression of image frequencies as would be expected in a fully-featured SDR. Sometimes this can result in audible interference, in which case the only remedy is to tune to another transmitter. And if none of the channels appeals, you can simply move to another band with a twist of the screwdriver.

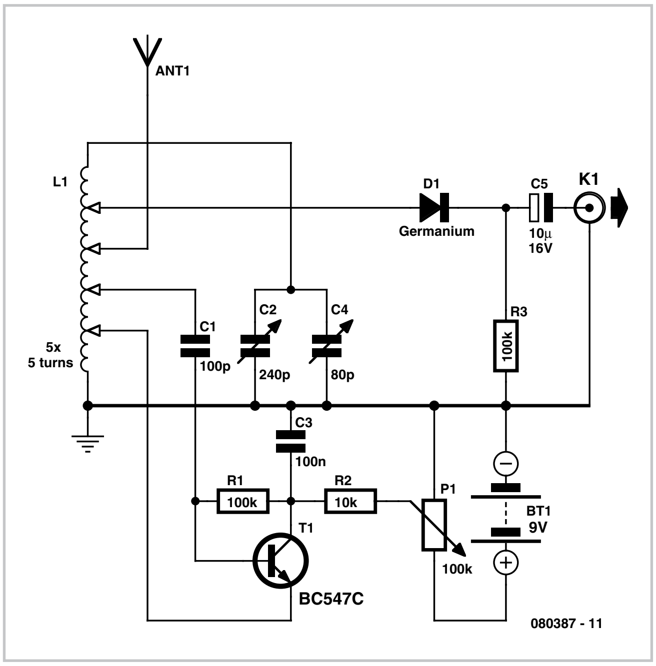
(080384-I)

Detector with Amplification

Burkhard Kainka

A simple shortwave radio detector is neither very sensitive nor very selective. However, with a little extra amplification we can improve the reception performance significantly.

The additional circuit is designed to compensate for the losses in the resonant circuit. A transistor is used to amplify the RF signal and feed it back into the resonant circuit. When the gain is set correctly we can make the amount of this feedback exactly equal to the losses. The resonant circuit is then critically damped and has a very high *Q* factor. Now we can separate transmissions that are just 10 kHz apart, and we can



tune in to very weak stations. The tuning capacitor used has two gangs of vanes with capacitances of 240 pF and 80 pF. These two gangs are connected in parallel to make a 320 pF variable capacitance. The air-cored inductor has 25 turns on a diameter of 10 mm, with taps at 5-turn intervals. The resonant circuit so formed is capable of covering the full shortwave band from 5 MHz to 25 MHz.

The shortwave detector can be connected to a power amplifier, or, for example, amplified PC loudspeakers. The antenna does not have to be very long: in experiments we used a one-metre length of wire. Tuning the radio involves adjusting the variable capacitor to bring in the station and then adjusting the gain of the feedback circuit for optimal output volume. If the potentiometer is turned up too far, the receiver will go into self-oscillation and become a mini-transmitter. At the optimal setting the sound quality is very pleasant and certainly no worse than many ordinary shortwave radios.

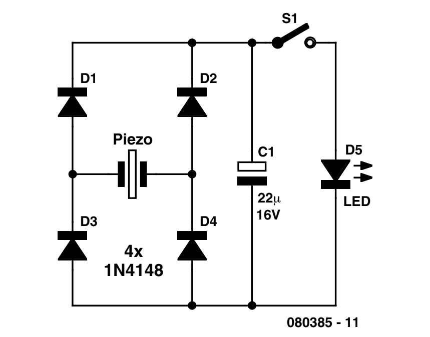
If you find shortwave detectors that use a battery and an amplifier a little new-fangled, you can get your fix of nostalgia by dispensing with the battery and connecting a crystal earpiece to the detector's output. The radio will of course also work without the feedback circuit, but with rather poorer performance.

(080387-I)

Piezo-powered Lamp

Burkhard Kainka

Energy is becoming ever more expensive, and some fresh ideas are needed. There are already human-powered devices on the market, most of which employ a dynamo to generate power. It is also possible to recover energy from a piezo crystal of the sort found, for example, in the loudspeakers in greetings cards. Making use of this device is relatively straightforward.



Piezo crystals can generate voltages of many tens of volts when given a firm enough prod with a finger to bend the baseplate. The charge moved, however, is relatively small and the crystal is effectively a capacitor with a capacitance of only around 20 nF to 50 nF. This means that we need larger-scale storage in the form of an electrolytic capacitor.

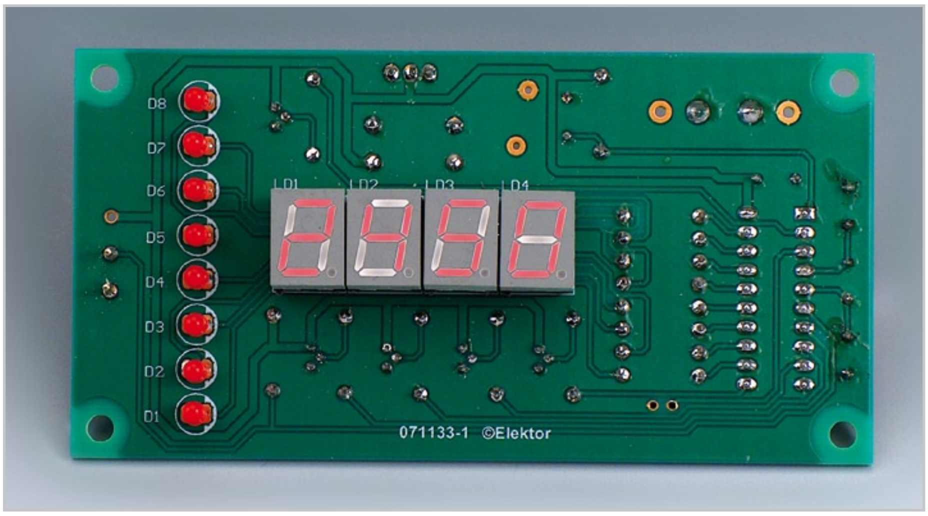
The piezo crystal can be treated as an alternating current source. We therefore need a rectifier and a reservoir capacitor. Pressing the metal surface of the transducer ten or twenty times with a finger will charge the electrolytic in steps to the point where it has enough charge to drive a LED. The circuit is a 'charge pump' in the full sense of the term.

When the button is pressed the electrolytic discharges into the LED, which emits a brief, but bright, flash of light.

(080385-I)

Digital Rev Counter for (Older) Diesels

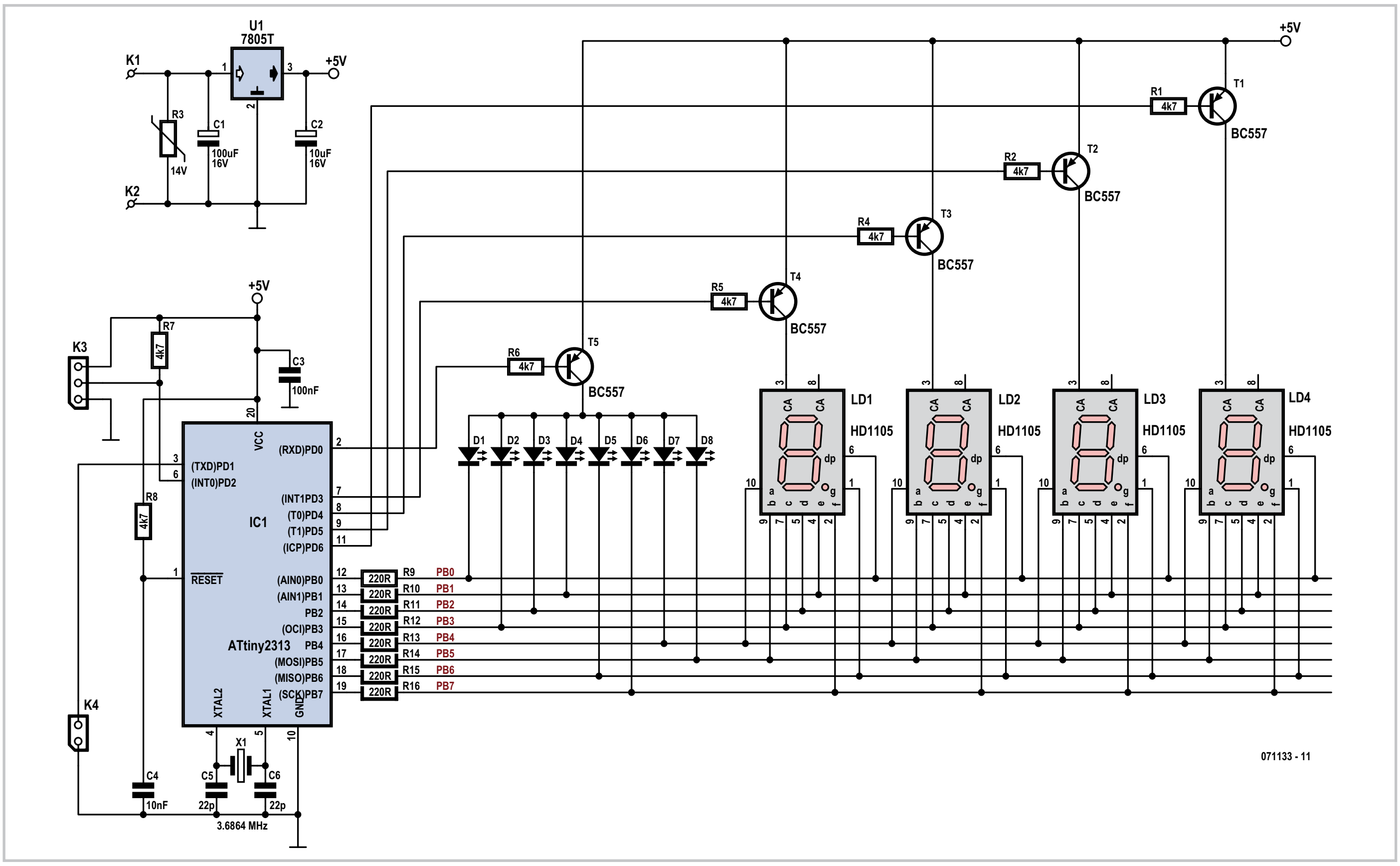
Romain Liévin



Current diesel vehicles are (practically) all fitted with a rev counter. But diesel-engined cars tend to 'last' longer than their counterparts with petrol engines, so it is more than likely that there are still a fair number of older diesel cars around without such an instrument for measuring engine speed. We're going to enable you to fit them with one.

On a petrol engine (motorbike or car), it's very easy to pick up pulses that reflect the engine revs. The number of articles that have appeared in Elektor are proof of this. Most circuits confine themselves to detecting the pulses generated by the ignition, either by magnetic coupling or directly, after shaping of an electrical signal. Since diesel engines by their very nature don't have spark plugs, an alternative method has to be found. Here, it takes the form of a logic Hall-effect sensor (UGN3140) that delivers a pulse every time a magnet passes in front of it. You could equally well use a reflective photodetector… The biggest difficulty lies in finding a spot to fit one or more magnets. The timing belt pulleys would be a good location, but the whole assembly is always protected by a cover. Diesel vehicles are often fitted with a vacuum pump for the brake servo system. This pump is connected to the camshaft via a belt. The ideal spot for fitting two magnets and the sensor! Why two magnets? Any good mechanic knows that a 4-stroke engine has to make two revolutions for each engine cycle. But the camshaft controls this cycle in just a single revolution, and hence it turns at half the engine speed. So using two magnets enables us to obtain the correct number of pulses.

As you can see, the circuit amounts to just a single IC, an AVR microcontroller from Atmel. Long gone are the days when it took no less than six ICs to produce even a two-digit a rev counter! What's more, using a microcontroller with a crystal-controlled clock makes it possible to dispense with any form of calibration. The microcontroller contains everything needed to count pulses, using its interrupt



input, and directly drive a multiplexed display, using its I/O lines that can sinking up to 20 mA. The display comprises four digits, to count from 60 to 9,999 revs. The bargraph is just a little gimmick that makes it easy to visualize engine acceleration or deceleration over a range of 1,000 rpm. It consists of eight LEDs, so offers a resolution of 125 rpm. To improve display accuracy, we recommend using two additional intermediate magnets (i.e. a total of four magnets on the camshaft). Because of the way the software has been designed (see software paragraph), the device needs at least one pulse every 0.5 second, i.e. 2 Hz, and hence a resolution of 120 rpm, which is not really enough and leads to an unstable display.

The Hall-effect sensor is connected to header K3.

Two additional magnets make it possible to increase the resolution to 60 rpm. The number of magnets fitted can be configured by means of the jumper fitted to header K4 (which may, as applicable take the form of a:

– no jumper = two magnets,
– jumper fitted = one magnet.

Not much needs be said about the power supply, except that:

– the regulator might need a heatsink, as the vehicle on-board voltage can reach 14 V, which represents a volts drop of 9 V with a current consumption of 30 mA, i.e. ≈ 0.3 W;
– the (vital) presence of a special car varistor to protect the regulator from voltage spikes. Otherwise, it's goodbye to the regulator the first time you start up!

This project requires relatively few resources, whence the use of a small microcontroller: the Atmel AT90S2313, which by now is an old faithful in Elektor. It has two timers, I/O lines capable of driving LEDs directly, and an interrupt input. The interrupt input is used to count pulses by incrementing a software pulse counter (cntH:cntL). The timer is set to generate an interrupt every 2.5 ms. This interrupt is used to:

– multiplex the display: each display is refreshed every 2.5 ms; hence the whole display is refreshed at a frequency of 80 Hz;
- increment a software counter up to 250 ms (= one tick).

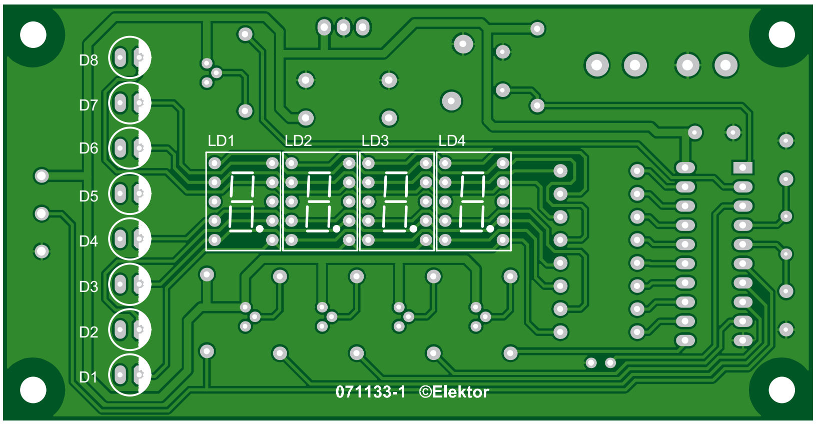
At each tick, the value of the pulse counter is stored alternately in counter 0 or counter 1. This tick is also used in the primary loop to trigger counter processing and display refresh. In the primary loop, counters 0 and 1 are added together to obtain the number of pulses seen during the last two consecutive 250 ms time slots, i.e. 0.5 s. This trick makes it possible to update the display more frequently (250 ms) without having to wait for the end of the measurement (0.5 s). This makes it possible to increase the speed of the digital chain without compromising accuracy. The remainder of the software consists of converting the number of pulses into rpm. Everything is implemented in integer arithmetic. Given that the measurement is performed over 0.5 s, the result has to be multiplied by two to obtain the frequency, and then by 60 to obtain a value in revs per minute.

All that then remains is to convert the binary result into a decimal value, which is achieved using Atmel's binary-to-BCD conversion routines (AVR204 Application Note). The most significant digit (MSD) is set to 0, and the result is then converted back to binary. This is a crafty method for calculating a remainder out of 1,000 (modulo) for the bargraph. This value then has to be divided by eight, as the bargraph has eight LEDs (coded by subtraction and a loop). The result is used as an index for a decimal-to-7-segment transcoding routine. As supplied, the software occupies about 75% of the program flash memory.

The software has been developed to work on an AT90S1200 or an AT90S2313. With a bit of luck it should also work on an AT90S1200, but although we haven't actually tried that, we're sure there are Atmel programming enthusiasts among our readers capable of doing it. Let us know!

The small inset schematic is that of a test generator specially designed for the rev counter.

(071133-I)



COMPONENTS LIST

Resistors
R1,R2,R4-R8 = 4kΩ7
R3 = S14K14 varistor
R9-R16 = 220Ω

Capacitors
C1 = 100µF 25V
C2 = 10µF 25V
C3 = 100nF
C4 = 10nF
C5,C6 = 22pF

Semiconductors
D1-D8 = LED, red, rectangular
LD1-LD4 = 7-segment LED display, common anode, e.g. HD1105
T1-T5 = BC557
IC1 = AT90S2313, programmed with hex file from archive 080238-11
IC2 = 7805T

Miscellaneous
X1 = 3.6864 MHz quartz crystal
K1,K2 = solder pin
K3 = 3-way pinheader
K4 = 2-way pinheader with jumper
UGN31 Hall-effect sensor
PCB, ref. 071133-1 from www.thepcbshop.com

Downloads

The PCB artwork file is available for free downloading from our website www.elektor.com; archive # (071133-1.zip.

The source code and .hex files for this project are also available from www.elektor.com; archive # 071133-11.zip.

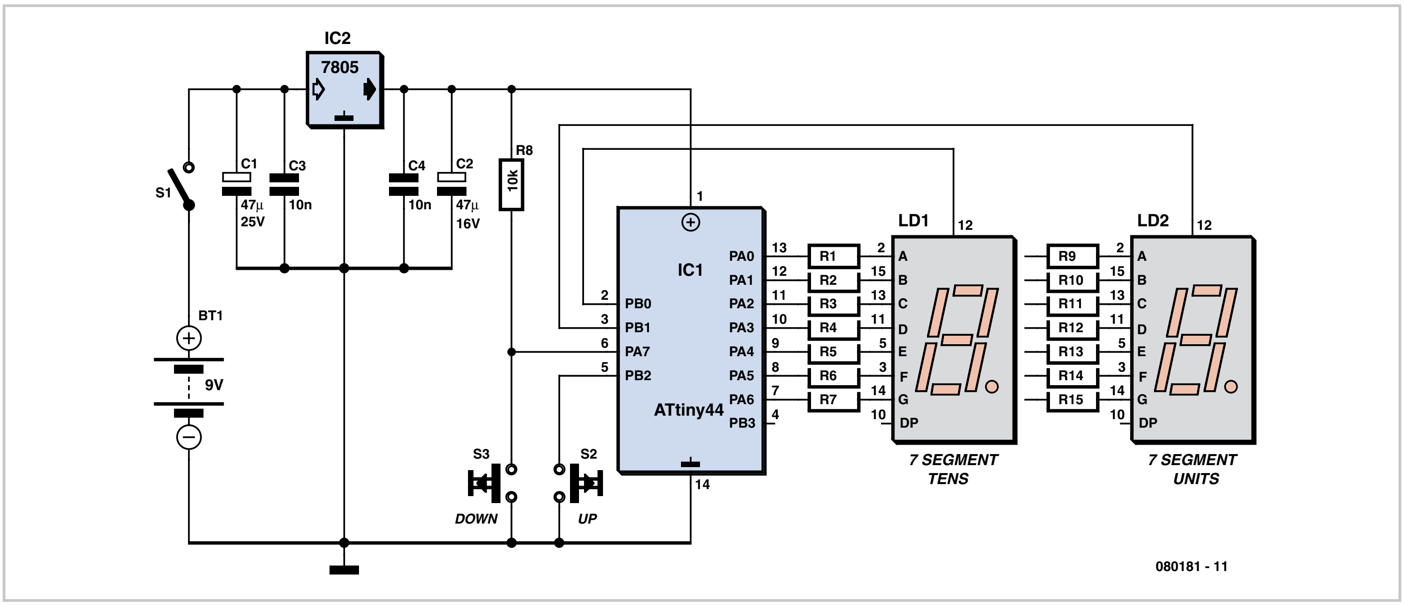
Web Links

AT90S2313 datasheet:
www.atmel.com/dyn/resources/prod_documents/doc0839.pdf

S14K14 varistor datasheet:
www.datasheetarchive.com/preview/3078060.html

UGN3140 Hall-effect sensor datasheet:
www.datasheetarchive.com/preview/3527952.html

Golf Tally



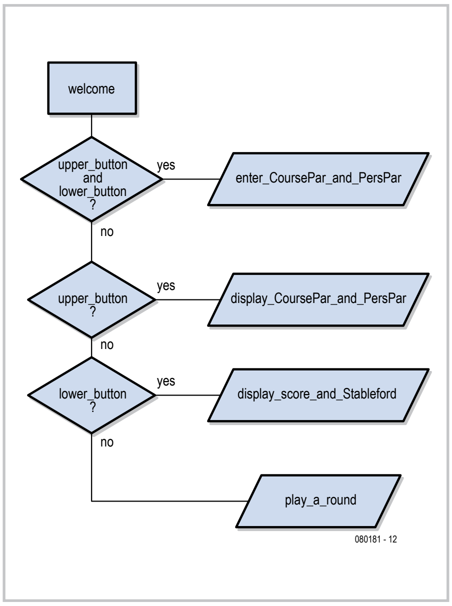
Stefan Hoffmann

For electronics enthusiasts building your own golf scorekeeper is a must (buying one is degrading – far too easy!). Then you can keep an eye on your total strokes on the course (and impress the other players naturally).

This example is based on an ATtiny44 microcontroller, equipped with just two seven-segment displays and two data entry keys (to minimise power needs).

The three EEPROM variables (18 arrays) used in the Bascom software are: CoursePar, the par for the course per hole, PersPar, for your personal score (par for the course plus handicap) and Score for the current total of strokes during the round. Since people play mainly at the same course and their handicap alters seldom (unfortunately far too seldom), the first two variables do not need to be entered into the EEPROM very often. Program source code and hex-file can be downloaded free of charge from www.elektor.com.

At the golf course for each round you enter the number of strokes made at each hole and save this as the third array. When you get to the 'debriefing' afterwards at the nineteenth hole you can display the par for the course, your personal score and number of strokes for each hole.



At power-up you need to set the user mode by pressing keys as follows:

1. S1 and S2 pressed:
Enter Par for the Course and Personal Score

2. S1 pressed:
Display Par for the Course and Personal Score

3. S2 pressed:
Display Score (number of strokes) and Stableford points

4. No key pressed:
Play a round – starts automatically, using the same mode as the last round.

The middle decimal point appears when the hole number is displayed; only the upper bar is shown for the CoursePar in the left-hand display with the corresponding Par figure in the right-hand display. When PersPar is shown the middle horizontal bar appears in the left-hand display, whilst the strokes total is indicated by the bottom bar. Stableford points are signified by three horizontal bars in the left-hand display.

The table gives a summary of the modes and the displays. It's a good idea to practise a bit before using the scorekeeper in earnest, if only to avoid irritation on the actual course…

(080181-1)

Inputs and displays

Input CoursePar and PersPar
Alternating input (press keys to increase or reduce): Hole/ CoursePar (e.g. 1.1 ‾5)

After 3 seconds next Hole

After the 18th Hole:

Alternating input (press keys to increase or reduce): Hole/PersPar (e.g. 1.3 –7)

After 3 seconds next Hole

Display CoursePar and PersPar
Alternating display: Hole/PersPar (e.g.1.1 ‾5

After the 18th Hole

Alternating display: Hole/PersPar (e.g. 1.3 –7)

Press keys for next/previous hole (in rotation)

Score and Stableford display
For each hole

Alternating display: Hole/Score (e.g. 1.1 _5)

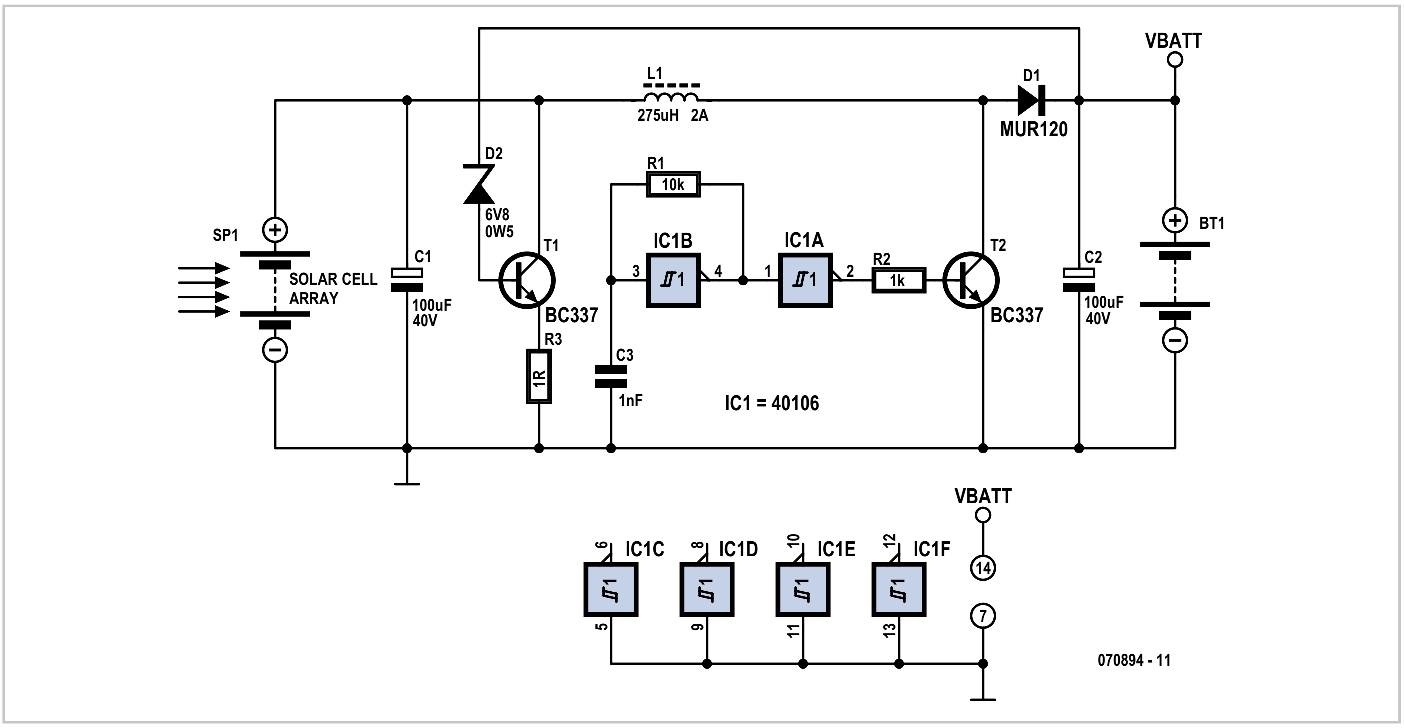
After the 18th Hole

Alternating display: Hole/Stableford points (e.g. 1.3 ≡ S2)

Play a round
Alternating display: Hole/Score (e.g. 1.1 _5)

Press keys to increase/decrease

Solar Cell Array Charger with Regulator



Lars Näs

This simple circuit can be used to charge batteries from a solar cell array. The circuit consists of an oscillator, a DC-DC step-up or 'boost' converter and a regulator that provides regulation of the output voltage.
The oscillator is built around a hex Schmitt trigger inverter IC, the 40106B, one resistor, R1, inserted between the input and the output of one of the gates in the 40106 to supply charge to C3. Depending on the values of resistor R1 and capacitor C3 you're using in the circuit, the oscillator will operate at different frequencies, but a frequency below 100 kHz is recommended. By consequence, the oscillator frequency should not exceed the maximum ripple frequency of capacitor C2 connected on the output. C2 should be an electrolytic capacitor with a DC working voltage larger than the desired output voltage. Besides, it should have a low ESR (equivalent series resistance).
IC1A is used as a buffer, ensuring that the oscillator sees a light, fairly constant load and so guaranteeing that the output frequency remains stable (within limits, of course). VCC of the Schmitt trigger can be connected directly to the battery charged, provided the charged battery voltage does not exceed the max. or min. limits of the Schmitt trigger's supply voltage. This ensures the Schmitt trigger can operate even if little power is obtained from the solar cell array.

When transistor T2 is turned on, (output from oscillator buffer IC1A is high), a collector current flows through inductor L1 which stores the energy as a magnetic field and creates a negative voltage V_{L1}. When transistor T2 is switched off, (output from oscillator buffer IC1A is low), the negative voltage V_{L1} switches polarity and adds to the voltage from the solar cell array. Consequently, current will now flow trough the inductor coil L1 via diode D1 to the load (capacitor C2 and possibly the battery), irrespective of the output voltage level. Capacitor C2 and/or the battery will then be charged. So, in the steady state the output voltage is higher than the input voltage and the coil voltage V_{L1} is negative, which leads to a linear drop in the current flowing through the coil. In this phase, energy is again transferred from the coils to the output. Transistor T2 is turned on again and the process is repeated. A type BC337 (or 2N2222) is suggested for T2 as it achieves a high switching frequency. Inductor L1 should have a saturation current larger than the peak current; have a core material like ferrite (i.e. high-frequency) and low-resistance. Diode D1 should be able to sustain a forward current larger than the maximum anticipated current from the source. It should also exhibit a small forward drop and a reverse voltage spec that's higher than the output voltage. If you can find an equivalent Schottky diode in the junk box, do feel free to use it.

The most important function of the shunt regulator around T1 is to protect the batteries from taking damage due to overcharging. Besides, it allows the output voltage to be regulated. Low-value resistor R3 is switched in parallel with the solar cell array by T1 so that the current from the solar cell array flows through it. Zener diode D2 is of course essential in this circuit as its zener voltage limits the output voltage when T1 should be turned on, connecting the solar cell array to ground via R3. In this way, there is no input voltage to the boost converter and the battery cannot be overcharged.

Sealed lead-acid (SLA) batteries with a liquid electrolyte produce gas when overcharged, which can ultimately result in damage to the battery. So, it's important to choose the right value for zener diode D2. Special lead-acid batteries for solar use are available, with improved charge-discharge cycle reliability and lower self-discharge than commercially-available automotive batteries.

Finally, never measure directly on the output without a load connected — the ripple current can damage your voltmeter (unless it's a 1948 AVO mk2).

(070894-I)

Web Link

www.electronicia.se

Assistance for BASCOM Programmers

Jochen Brüning

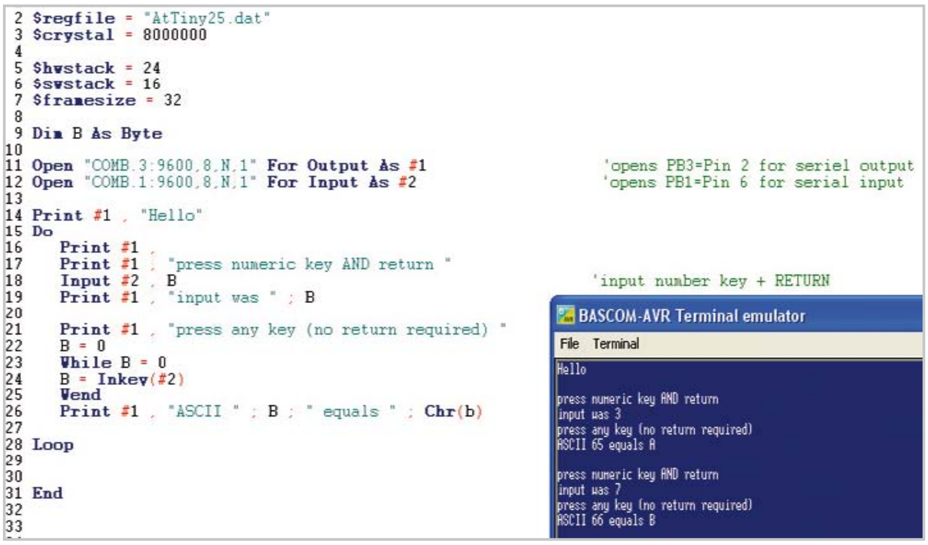
It is often useful to be able to display the values of certain variables or intermediate results during program execution when developing microcontroller software. This information can be invaluable especially when the program is not behaving entirely as you had anticipated.

Applications using larger microcontrollers often already incorporate some form of liquid crystal display in the design so in this case it is reasonably easy to write a routine to display these intermediate values just for the purposes of program development. When your design uses one of the smaller microcontrollers like the ATtiny 25/45/85 series there are so few I/O pins available that it is impossible without additional hardware to provide a connection to an additional LCD even by using 4-bit addressing.

For designs using these tiny controllers the BASCOM programming environment can offer significant advantages; its compiler includes a software UART which provides a simple, flexible and 'reusable' solution to the problem by enabling data to be sent to and from the controller using its built-in terminal emulator program. It is only necessary to assign a single controller pin for the send and another for the receive serial data path. This approach gives far greater flexibility for the circuit layout when compared to microcontroller designs which use a hardware USART with its predefined pin assignments.

The connection between the controller and PC can be made using a USB port where it will be necessary to use a USB to TTL adapter cable like the one manufactured by FTDI and featured in the June 2008 edition of *Elektor* (page 48). An even simpler solution is to use the spare serial port (RS232) on the PC, it will only be necessary to convert the signals from the TTL levels required by the controller to the RS232 levels used by the PC.

A suitable circuit can be built using a MAX232 IC together with four capacitors. The author was able to make use of a cable taken from a redundant serial PC mouse. The 9-way D-type connector was fully encapsulated so it was necessary to solder the IC together with the capacitors into the cable and protect the circuit with



a length of heat-shrink sleeving. Details of the construction can be found in a PDF document which is available from the Elektor website.

The only additional software required by the controller are the OPEN instructions which are used to configure the software UART. This instruction sets parameters such as baud rate, parity and the number of stop bits for the serial communication channel. In addition it defines which controller pin is used for communications and also the data direction (send or receive). Two OPEN statements are therefore necessary; one to set up the transmitted data path and the other for the received data.

For example an instruction to configure data transfer from the controller to the terminal emulator:

```
Open „COMB.3:9600,8,N,1" For
   Output As #1
```

B.3 : indicates that port B.3 is used which is pin 2 of a ATtiny25 controller.

Output: indicates that data is sent from port B.3.

#1 : File handle, used in the following Print command.

Data can now be sent using the normal Print command:

```
Print #1 , „Hello" ;
   The variable to display
```

#1 : references the corresponding Open statement above

It is helpful to use a simple test program just to output some text. This will determine whether the parameters defined in the Open-statement and the terminal emulator (found under 'Tools' along the top of the screen or invoked with ctrl + t) are correctly configured and also if the cable is connected to the correct controller pin. There are different ways of sending variables to the controller; firstly it is necessary to use the Open statement to configure the Input and choose a different file handle (e.g. #2) in the Input or Inkey statements as in:

```
Open "COMB.1:9600,8,N,1" For
   Input As #2 'PB1 (=Pin 6 of the
   ATtiny25) for the serial input

Input #2 , Variable store      or

Variable store = Inkey(#2)
```

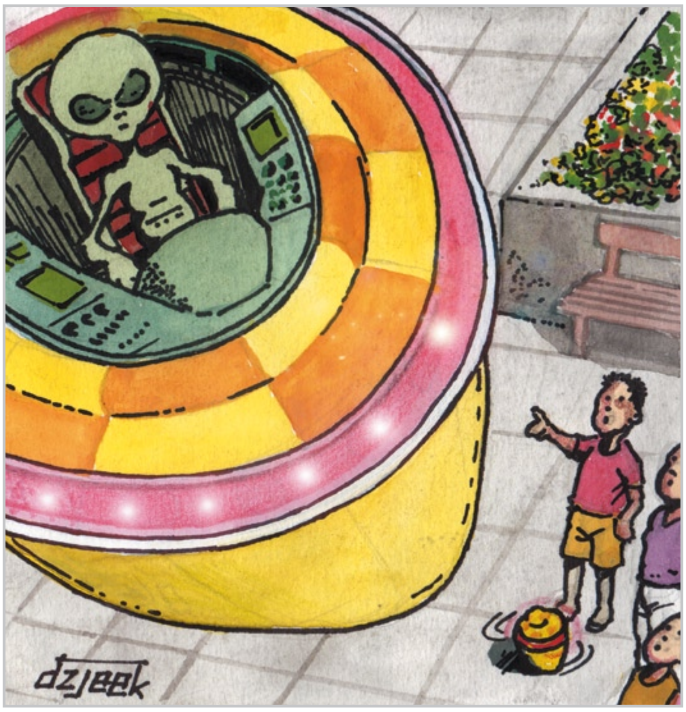
The input of data must be terminated with a RETURN. Inkey will return a value of 0 if there is no character waiting i.e. no key has been pressed. For further information refer to the BASCOM online help pages.

The screenshot shows a small test program listing together with the program output in the terminal emulator window. The hex file of this program is available for free download from the Elektor website, the file number is 080370-11.zip.

(080370e)

LED Spinning Top

Volker Ludwig DD0EU

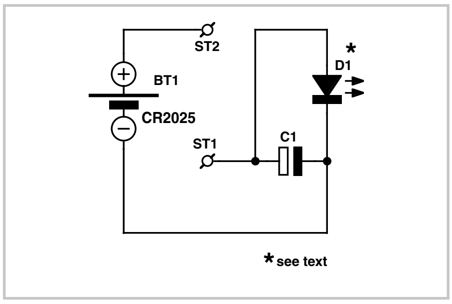


Commercially available plastic LED spinning tops consist of one or more LEDs powered from two button cells and activated using a switch actuated by centrifugal force. More elaborate devices, according to the author's research, also include a microcontroller to provide an ever-changing light display. It is entirely unacceptable, on both pedagogical and environmental grounds, that it is almost always impossible to replace the batteries without damaging the top. This gives us motivation enough to build or own version.

First of all a few craft skills are called for to turn up a wooden top on the lathe. If you feel slightly unwell at the thought of showing off your woodworking skills to your children, then the author (e-mail address email@dd0eu.de) is willing to help you out by supplying ready-made tops like the one illustrated here which, thanks to their long handle, spin very satisfyingly.

The circuit employs very few components and there is not a microcontroller in sight. The magic is down to the use of a high-brightness so-called 'rainbow LED' as mass produced for use in continuously-changing coloured 'mood' lights intended for domestic lighting applications. This device includes not only an RGB LED but also a control chip that causes it to change from colour to colour.

Normally this colour changing is too slow to make a pretty effect when the LED is mounted on a spinning top. However, there is an interesting effect that occurs when using these slowly changing LEDs as the smooth colour transitions are produced using pulse width modulation. When the top is spun quickly the pulses of light give



an attractive visual effect, as the author's photograph shows.

The circuit is very simple, with the main components being just the colour-changing LED and a 3 V button cell. It is important not to forget the centrifugal force switch, as otherwise the recipient of the toy may be rather disappointed to discover that the battery is flat!

In order to simplify construction still further, the author has designed a printed circuit board for the project. Once the board is populated the central hole provided can be used to locate it correctly over the handle of the top. The printed circuit board layout is available for download from http://www.elektor.com.

So that the top can be balanced correctly when construction is complete, it is important that it has no loose parts.

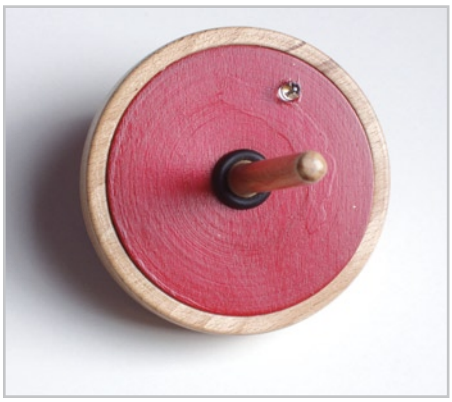
The two terminal pins ST1 and ST2 form the contacts for the centrifugal force switch. A sprung contact can be improvised by soldering one end of a spring salvaged from an old ballpoint pen (you may need to try more than one to find one that works) to one of the pins and a length of tinned copper wire to the other end of the spring. The wire and the other pin then form the switch contacts, which are closed when the top is spun (see the photograph).

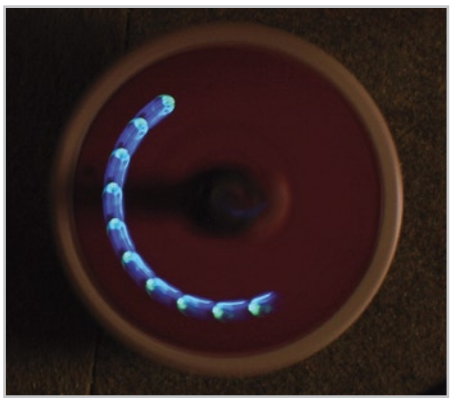
Things should be arranged so that there is a gap of about 1 mm between wire and pin when the top is stationary.

The bottom contact pad for the button cell can be made by soldering a small drawing pin in the middle of the battery holder area.

The counterweight is made from an M3x10 screw with nut and a 4 mm washer, which allows for a little adjustment to be made. If more weight proves necessary, further washers or nuts can be added.

(070916-I)





Cigarette-lighter Battery Charger

B. Broussas

This fine Summer's day, you've decided to go out for a breath of fresh air – but without wanting to give up your 'hi-tech toys' — whether it's your son's radio-controlled car, your daughter's MP3 player (all borrowed of course after due negotations), or your own favourite portable DVD player. All these appliances share the feature of usually operating on rechargeable batteries – which is of course no problem when the mains is at hand, as they all come with their own chargers.

But the problem gets a bit more complicated out in the country, and as Murphy's Law has it, that's always just the moment you find your batteries are flat or nearly so. If your car is parked nearby, we can suggest a solution in the form of this very simple project – and what's more, it will cost you practically nothing, since it uses mostly components that any good electronics enthusiast is likely to already have in a drawer or the junk box. Even if you did have to buy everything, the whole thing shouldn't cost more than about £ 10.

As **Figure 1** shows, it's a project that smacks of good old-fashioned – we almost said granddad's – electronics, as it doesn't use a microcontroller, nor even the slightest specialized integrated circuit (IC). In spite of this, it will look after your batteries, especially if you are reasonable about the charging time.

Whether they are old nicads (NiCd) – becoming extinct these days because of their many shortcomings and toxicity – or the omnipresent nickel-metal-hydrides (NiMH), these types of battery have to be charged at constant current. This charging current should be 10% of their rated capacity (printed on the label) for a normal or slow charge, or a maximum of 100% of their capacity, if you want a fast charge.

So, to recharge the NiMH or NiCd batteries in our various portable devices from a car battery – for that's what it's all about – all you have to do is build a constant current generator. To achieve this takes just two common or garden transistors, T2 and T3. The latter is turned on to a greater or lesser extent by way of R3 and T2. By virtue of the very principle of transistors, there cannot be more than about 0.6 V between the base and emitter of T2. If this voltage tends to drop, T2 will tend to turn off, which will then increase the conduction of T3 – and vice-versa. In other words, the base-emitter voltage of T2 will virtually always remain at 0.6 V.

Now this voltage is produced by the current passing through one of the resistors R4–R7, and hence also the battery to be charged. So it's easy to see that this current is quite simply given by $I_{ch} = 0.6 / R$ where I_{ch} is the desired charging current and R is one of the resistors R4–R7.

As T2 turns on (and hence the battery is charging), transistor T1 increasingly saturates. If this current drops too much, or falls to zero in the event of a poor contact or faulty battery, the LED goes out to indicate a problem. Diode D1 protects the circuit from possible reversed polarity of the battery being charged.

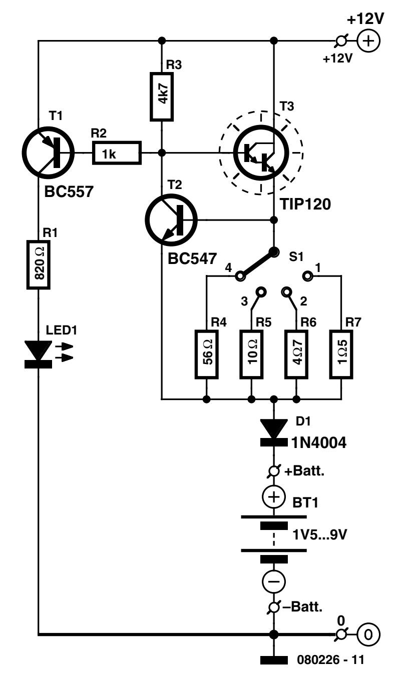
We have designed a small PCB for this project with provision for direct mounting of a rotary switch to be mounted, thereby reducing the wiring needed to nothing. This switch is Lorlin part no. PT6422/BMH and is available, for example, from Farnell under product ref. 1123675. However any other equivalent may be used if it can be adapted to the circuit board. In most case, that means installing some extra wires between the PCB and the switch pole and contacts. Transistor T2 may be required to dissipate quite a lot of heat for low-voltage batteries being charged at high currents, so space has been provided to fit it with a U-shaped heatsink. The various designed charging currents are 400, 130, 60, and 10 mA for positions 1–4 of the switch. The unavoidable voltage drop across T2 means the maximum voltage of the battery to be recharged cannot exceed 9.6 V.

If you want different charging currents from those designed, all you need do is simply replace one or other of R4–R7 by a resistor whose value has been calculated as above ($R = 0.6 / I_{ch}$) and whose power is given by $P = 0.36 / R$.

As a constant-current generator, the circuit is naturally protected against short-circuits, but do take care all the same if you increase the charging current too much not to exceed the maximum power dissipation in T3 (65 W) and more importantly, the power allowed by the small heatsink provided for on the PCB. A current of 500 mA seems to us a reasonable maximum value to not exceed. The value should cater for most NIMH and NiCd batteries if a few hours are allowed to charge them. But then it was a sunny day so that shouldn't be a serious concern.

(080226-I)

1



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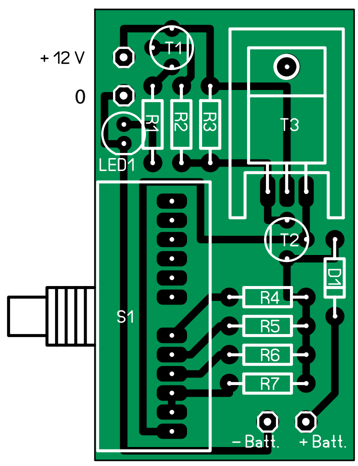


COMPONENTS LIST

Resistors

R1 = 820Ω
R2 = 1kΩ
R3 = 4kΩ7
R4 = 56Ω
R5 = 10Ω
R6 = 4Ω7
R7 = 1Ω5

Semiconductors

D1 = 1N4004
LED1 = LED, red
T1 = BC557
T2 = BC547
T3 = TIP20

Miscellaneous

S1 = 1-pole 4-way rotary switch (see text)
4 solder pins
2 9-V batteries
PCB, ref. 080226-1 from www.thepcbshop.com

Downloads

The PCB copper track and component mounting plan can be downloaded from www.elektor.com; file # 080226-1.zip

AlphaSudoku – supersize mind boggler

Puzzle designed by Claude Ghyselen

Elektor's Summer Circuits differing widely from the regular monthly editions, we thought it would make a nice change to publish a distinctly dissimilar type of puzzle this month, not just in regard of size but also complexity and diversity. We bet you've never seen one of these before and challenge you to solve it and enter a prize draw for an E-Blocks Professional starter kit and three Elektor Shop vouchers.

The method of solving the AlphaSudoku puzzle is basically the same as for a classic Sudoku, with some modifications! AlphaSudoku has a 25×25 cell structure and takes numbers 1 through 9 and letters A through P (i.e. including the letter 'O', hence the absence of the '0' in the numbers). The puzzle is essentially a (16×16) Alphadoku comprising nine classic (9×9) Sudokus using numbers 1 trough 9.
In AlphaSudoku, complete the diagram composed of 25×25 cells such that all letters A through P and all numbers 1 through 9 occur **only once** in every line, in every column and in every box (5×5; identified by a coloured outline). A number of clues are given in the puzzle and these represent the start situation. The nine embedded Sudokus have a background colour.
All correct entries received for the puzzle go into a draw for a main prize and three lesser prizes. All you need to do is send us the **combination of six numbers in the grey boxes**. The puzzle is also available as a **free download** from our website.

Solve AlphaSudoku and win!
Correct solutions received enter a prize draw for an **E-blocks Starter Kit Professional** worth **£ 249** and three **Elektor Electronics SHOP Vouchers** worth **£ 35.00 each.**
We believe these prizes should encourage all our readers to participate!

D	5		E	G	2			K	7		I	O			9	P		F		4	1		M	A
	1	I	6		8	A			E		H	F	L		2	K			4			5	9	3
		2	L		9	J	P		3	8			K		7		B		5		C			N
9			K		1	C	L	M	6	5	B	N		4	D		G			F		8		2
		H				B	G	I		2	J	P					N		1		E		7	
4	6	9	8	3			I	J		N		K	G	A	M	O			C			7		
	O			F	P					D					A		1			B	M	E		H
M		E	P	N		4			H	C				B	J				F	I	D			O
H	B	J	A				2		L						E								N	F
7					D	G			O		F	M			B	I	P	L	K	8			3	9
6	7			I	J	E	H				A	C	N	F		B	D	G		9	5	1		8
		P	O		I				D	J		5				4		7			G		K	
G	H	N			A			8	P	M						3			O	J	L			
A	K		M	J				1	N	E		9							L	H	O	D	P	C
1	8	5		2	F		M	C		P		D		I		H	K	E		3		6	4	
2	3	1	5	6		D					G	H	J		K	M	C		E	7		O	8	4
C	P	G	J	A	O	3			M	B	4				L	2			I		N		F	K
L			H		N		5		F	A	1			E	O				P	D	J	B		
		O	N							K	8		6	C					D	L	I		A	P
8	4			9							L	I		M	G		F		B	6		2		1
5	E	A			4		K	L	1	6	C			2	3	G	O					9		
K		8	2	M	7		F	G	9	1	E		D	3			I				P	C	H	J
			B	O	6	N	E	A	8	7				5	1		J	C	9		F		I	M
	9			1	3	P		B		4		G	I	8	5		A			O	7	K		6
F	D		3	7	C		J	H	5	9	M			P		N					4			L

Participate!
Please send your solution (the numbers in the grey boxes) by email to: editor@elektor.com.
Subject: alphasudoku 7-2008 (please copy exactly).

D	A	5	C	0	2	9	8	7	3	E	F	1	4	6	B
1	4	9	3	F	B	A	D	5	6	0	2	C	8	E	7
B	7	E	F	3	6	5	4	8	9	C	1	D	2	0	A
8	6	2	0	E	1	7	C	4	D	B	A	5	F	3	9
3	1	F	B	A	E	D	9	2	0	8	7	4	6	C	5
7	2	8	D	C	0	6	5	1	4	F	3	A	9	B	E
9	E	4	A	8	7	1	B	D	C	5	6	3	0	F	2
5	C	0	6	4	3	F	2	B	A	9	E	7	D	1	8
4	F	B	E	7	C	2	3	A	1	D	0	9	5	8	6
2	3	6	8	1	5	E	0	C	F	4	9	B	7	A	D
A	5	D	1	9	F	B	6	3	2	7	8	0	E	4	C
C	0	7	9	D	4	8	A	E	B	6	5	F	3	2	1
F	9	3	5	B	D	4	1	6	8	2	C	E	A	7	0
6	8	A	7	5	9	C	F	0	E	3	B	2	1	D	4
E	D	C	2	6	A	0	7	F	5	1	4	8	B	9	3
0	B	1	4	2	8	3	E	9	7	A	D	6	C	5	F

Include with your solution: **full name and street address.**

Alternatively, by fax or post to:

Elektor Hexadoku
Regus Brentford
1000, Great West Road
Brentford TW8 9HH
United Kingdom.
Fax (+44) 208 2614447

The closing date is **1 September 2008.**

The competition is not open to employees of Elektor International Media, its business partners and/or associated publishing houses.

Prize winners
The solution of the May 2008 Hexadoku is: **36815**.

The **E-blocks Starter Kit Professional** goes to: Lee Archer (UK).

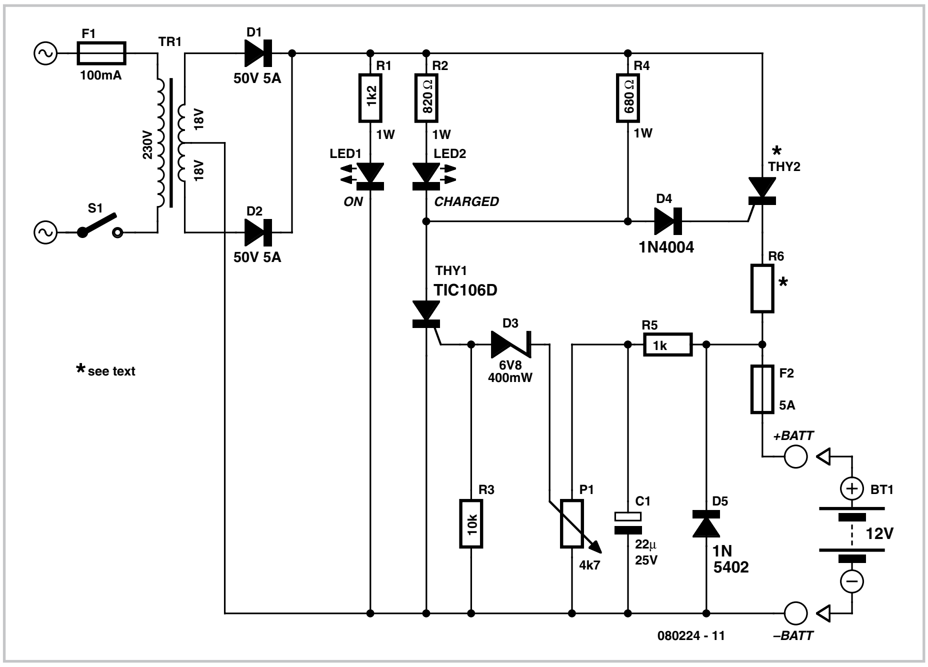
An **Elektor SHOP voucher** worth £ 35.00 goes to Theis Borg (DK); Barry Cook (UK); David Chester (USA).

Congratulations everybody!

(080463-I)

Automatic Car Battery Charger

C. Tavernier



A Summer Circuits edition on 'all things outdoors' — good, but what of all the battery-powered circuits that remains indoors? Once the fine weather starts, the family car tends to remain increasingly in the garage – which is as beneficial to the owner, his/her bank account and the air that we breathe as it helps — to an extent to — reduce CO_2 emissions. However, when we come to want to use the trusty vehicle again, it often happens that the battery shows serious, deeply worrying signs of being flat, sometimes to the point of preventing the engine from starting altogether. Push-starting is no longer recommended or even possible with modern cars, so a topped up battery is highly appreciated.

The solution of leaving an off-the-shelf charger permanently connected is not generally satisfactory, unless you're lucky enough to have an 'electronic' one. The majority of dirt cheap ordinary chargers don't include any regulation circuitry and so will over-charge a vehicle battery if you're unwise enough to leave it permanently connected.

So our proposed project is to build a charger that can act as both a standard charger, and a float charger that you can leave permanently connected without the slightest risk to your battery or fear of over-charging. What's more, it doesn't use any 'exotic' components and is ridiculously cheap.

Let's have a look at the circuit diagram. The voltage supplied by our charger's transformer is rectified by diodes D1 and D2 but is not smoothed. Strange as it may seem, this is vital for it to work properly, because as a result the rectified voltage consists of a succession of sinewave half-cycles, and hence falls to zero 100 times per second.

When thyristor THY2 is conducting, the battery is effectively charged, the charging current being limited only by resistor R6, which has to be calculated as shown below. This thyristor is triggered via resistor R4 for each half-cycle of the mains, except when thyristor THY1 is itself triggered. In that event, THY2 turns off the first time its supply voltage drops to zero, and no further current can reach the battery.

The voltage at the battery terminals is sampled by R5 and smoothed by C1 before turning on THY1 or not via P1 and D3. As long as this voltage is lower than a certain threshold, determined by the setting of P1 and corresponding to a battery that is not yet fully charged, THY1 is not triggered and so leaves THY2 conducting for all the mains half-cycles.

When the voltage at the battery terminals is high enough, THY1 is triggered and thus prevents THY2 from being triggered. This phenomenon is not in fact quite as clear-cut as we have just described, but takes place very progressively, so as it approaches full charge, the battery's average charging current gradually reduces automatically, eventually stopping completely once the fully-charged voltage has been reached.

LED1 acts as a charging indicator, while LED2 lights more when THY1 is being triggered frequently, thereby acting as a fully charged indicator.

Three components of the circuit proposed here need to be selected according to the characteristics you want your charger to have; these are R6, THY2, and TR1. R6 needs to be calculated according to the maximum charging current you want, from: R6 = 16 / I where I is the current expressed in amps. Warning! Given the value of the other elements in the circuit (D1, D2, TR1, and the fuse), do not exceed 5 A. The power dissipated in R6 can be calculated from P_{R6} =

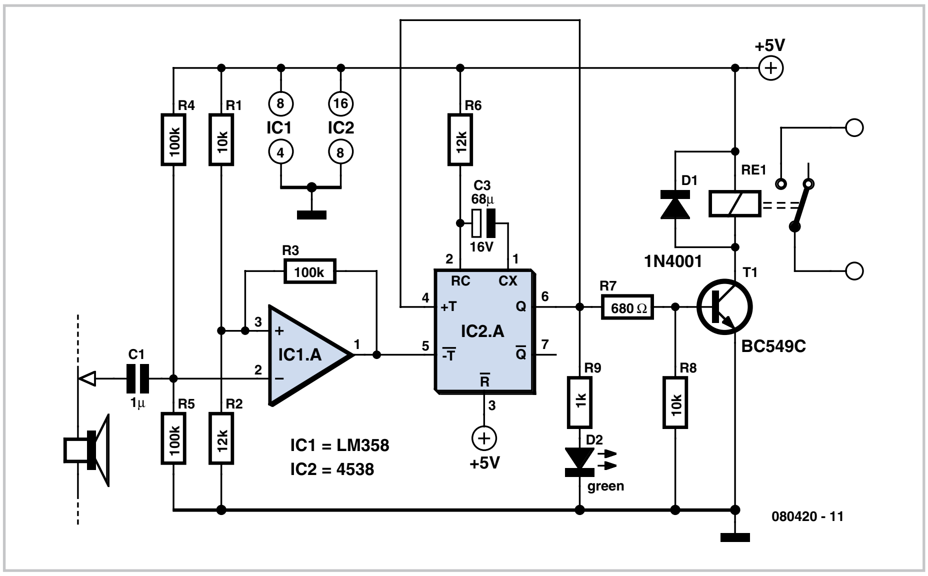
36 / R6 with P expressed in watts and R6 in ohms, of course.
Thyristor THY2 should be a 100-V type (or more) rated at 1½ to 2 times the desired maximum charging current.
And lastly the transformer, which should have a power in VA given by: $P = 18 \times 1.2 \times I$ where I is the maximum desired charging current, expressed in amps.
The only adjustment to be made concerns pot P1 and will require access to a well-charged battery. Connect it to the charger output and replace the 5-A fuse with an ammeter – preferably an old analogue type, better able to respond to average currents than certain modern digital types. Then adjust potentiometer P1 to obtain a current of around 100 mA.
Later on, when you have the opportunity to charge a very flat battery, you will be able to fine-tune this adjustment by tweaking P1 to obtain a charging current close to the maximum you have set by means of R6. You'll need to find a compromise setting between the float charging current, which mustn't exceed around 100 mA, and this maximum current.
Whatever the accuracy of your adjustment, you can be reassured that your battery will be treated better by this project than by many of its non-electronic counterparts to be found in the shops.

(www.tavernier-c.com) (080224-I)

Auto-off for Audio Gear

Joseph Zamnit

A good way to spend a relaxing afternoon is to be in a quiet place with just the right amount of sun or shade, drinks within reach and listening to your favourite songs on MP3 or CD. You doze off and by the time you wake up again the audio equipment has dropped silent due to flat batteries. What a pity!



The simple circuit shown can prevent this embarrassing situation by de-actuating a relay when no audio signal is detected for about two seconds.
The circuit consists of a sensitive LM358 based comparator, IC1A, which keeps monostable IC2A (a 4538) triggered as long as an audio signal is detected at the input. Via coupling capacitor C1 the circuit takes its input signal from the 'hot' side of the loudspeaker or headphones in your audio gear. The monostable will time out 2 s after being triggered, the delay being determined by R6 and C3.

(080420-I)

LED Switching Regulator

Jean Claude Feltes

On the author's bench lay two ICs, waiting to be tried out: an LM3404 switching regulator (only available in a surface mount package, unfortunately), and a U2352 PWM IC. Together they could be used to make a small dimmer for LEDs. As in the case of the 'Dimmable LED lamp' elsewhere in this issue we use a 6 V lead-acid battery as our source of energy, and a Luxeon 3 W LED as our light source. V_{CC} therefore lies between a minimum of around 5.4 V and a maximum of around 7.2 V.

The right-hand part of the circuit shows the switching regulator, which reduces the voltage from the 6 V lead-acid battery to the 4 V required by the high-power LED. As the voltage is reduced the current must increase, and so less current flows through the input power connections than does through the LED.

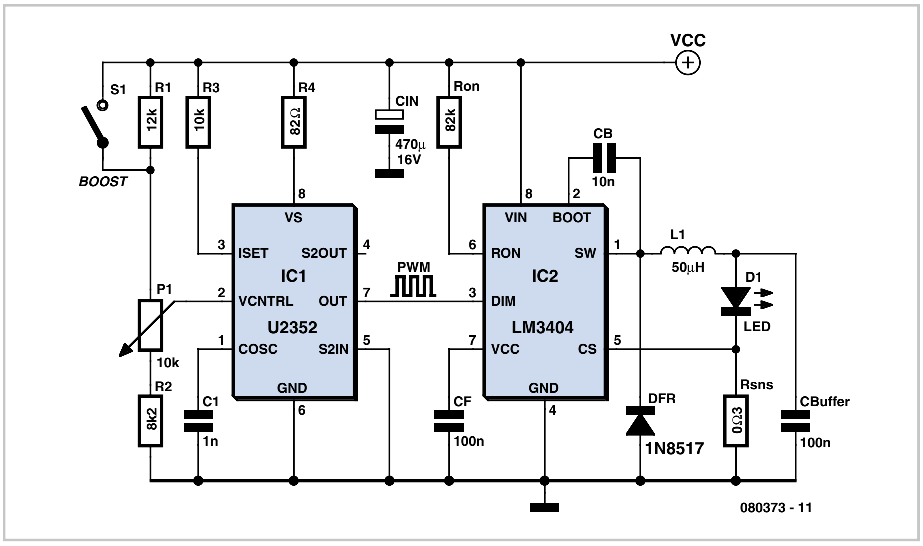
The LM3404 includes all the necessary control electronics along with a MOSFET switch. The voltage across resistor R_{sns} (CS, pin 5 of IC2) is proportional to the LED current and is compared against an internal reference of 200 mV. If the voltage falls below 200 mV the MOSFET is turned on for a fixed time t_{ON}. During this period the current through the inductor and the LED rises in an essentially linear fashion.

Time t_{ON} is determined by R_{ON} and the input voltage V_{IN}:

$t_{ON} = 0.134\ (R_{ON}/V_{IN})\ \mu s = 1.83\ \mu s$
(where R_{ON} is in kΩ and V_{IN} in V).

After this time period has expired the MOSFET is turned off and an approximately linearly-falling current flows through the flyback diode and the LED until U_{sns}, the voltage across R_{sns}, reaches 200 mV, whereupon a new cycle begins. While the MOSFET is off no current flows in the supply to the regulator. The minimum off time is 0.3 µs.

Ripple current is inversely proportional to the inductance and to the switching frequency. During t_{ON} the current rises linearly and the voltage across the coil is
$U_L = U_{IN} – U_{LED} – U_{SNS} = 1.8$ V.
Hence
$U_L = L(\Delta I_{LED}/\Delta t)$.
With $\Delta t = t_{ON}$ we obtain a ripple current of 66 mA.
When the current reaches its lowest value the voltage across R_{sns} is 200 mV. The average value of the current is one half of the ripple current greater.
With $R_{sns} = 0.3\ \Omega$ the average current is given by
$I_{avg} = 200\ \text{mV}/300\ \text{m}\Omega + 66\ \text{mA}/2 = 700$ mA.
This is around the maximum permitted value for a 3 W LED.
The LED current can be adjusted by changing R_{sns}, for which we can use a twisted length of resistance wire. More elegantly, we can use the PWM IC to drive the DIM input of the switching regulator.



The U2352 can generate a PWM signal adjustable from 0 % to 100 % using a minimum of external components. The basic frequency of the internal triangle wave oscillator is set by C1 to around 10 kHz:
$f_{osc} = 55/(C_{osc} \cdot V_s)$
(where f_{osc} is in kHz, C_{osc} in nF and V_s in V).
The triangle wave voltage is compared against a reference voltage set by P1, and at the output of the comparator we have our PWM signal.

The signal passes through some internal control logic before reaching the output of the device to protect the output from overload. Since we do not require this function it is disabled by taking pin 5 to ground and pin 3 to V_{CC} via R3. It is not clear from the datasheet whether resistor R4 is strictly necessary for internal voltage stabilisation.

The PWM signal is taken from the output of the U2352 to the DIM input of the LM3404 and imposes a 10 kHz pulse-width modulation on the light produced. The ‘Boost’ switch (or pushbutton) forces the PWM output high and thus the LED to maximum brightness.

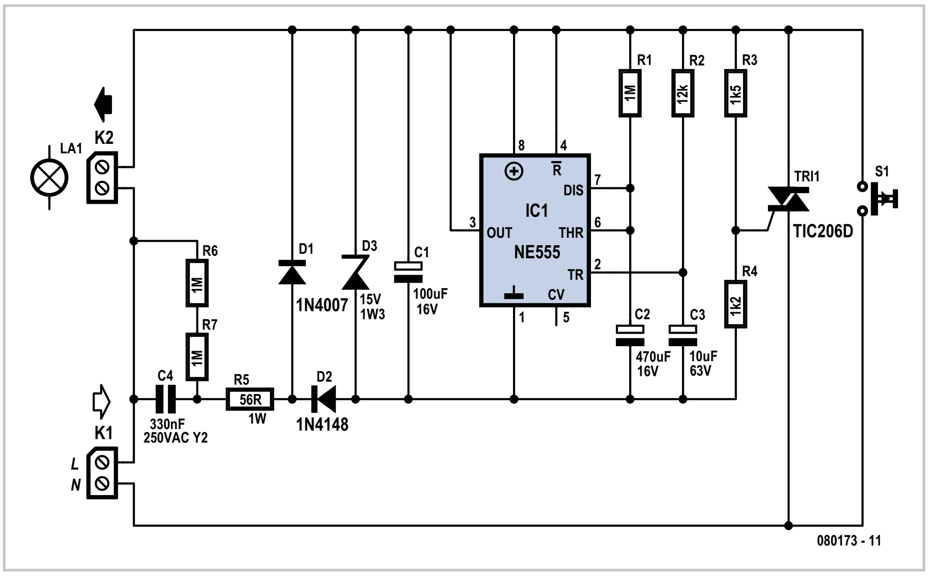
(jean-claude.feltes@education.lu) (080373-I)

Lighting Governor

Peter Jansen

This circuit is very handy as a timer circuit for a lamp, for lighting a staircase, for example, but can also be used as indicator for the front doorbell. A significant advantage of this circuit is that the circuit draws almost no current when in the inactive state.

The circuit is activated with push button (S1), after which IC5 (a 555 timer IC) starts to count down the set time. During this time the triac continues to conduct and the lamp is turned on. The ‘on’ time of the lamp is on is determined by the combination of R1 and C2 and can be changed as required by your application or personal preference.



R2 and C3 have been added because the 555 expects a ‘negative’ pulse at its trigger input. When the power supply is turned on, C3 holds the TR input of the 555 Low for a short time, which triggers the timer IC. Depending on the exact type (brand) of 555, the value of C4 (330 nF) may have to be changed to ensure a high enough power supply voltage when in the active state. Note also that you shouldn't use a 'too heavy' version of the triac. The circuit will drive at the most just a little more than 5 mA into the gate of the triac. The circuit worked properly when tested with a TIC206 and the slightly bigger TIC216.

When selecting push button S1, take into account the switching current of the lamp. The switch must be able to handle that safely.

In the event of a defective part, a 15-V zener diode is connected across the power supply for protection (D3). R6 and R7 have been added so that C4 will be discharged. In this way no dangerous voltage can remain when the circuit is unplugged. When large values for C2 are used, such as the 470 µF shown here, a good quality capacitor is required for C4. Any potential leakage resistance will then have no influence on the set time. Because of an inferior capacitor in our prototype the time was considerably longer than expected...

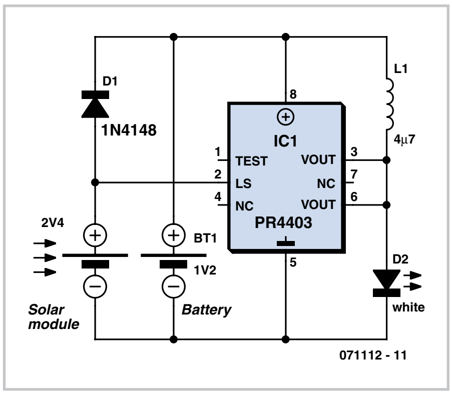
(080173-I)

Solar Lamp using the PR4403

Burkhard Kainka

The PR4403 is an enhanced cousin of the PR4402 40 mA LED driver. It has an extra input called LS which can be taken low to turn the LED on. This makes it very easy to build an automatic LED lamp using a rechargeable battery and a solar module.

The LS input is connected directly to the solar cell, which allows the module to be used as a light sensor at the same time as it charges the battery via a diode. When darkness falls so does the voltage across the solar module: when it is below a threshold value the PR4403 switches on. During the day the battery is charged and, with the LED off, the driver only draws 100 µA.



At night the energy stored in the battery is released into the LED. In contrast to similar designs, here we can make do with a single 1.2 V cell.

The PR4403 is available in an SO-8 package with a lead pitch of 1.27 mm. The other components are a 1N4148 diode (or a Schottky 1N5819) and a 4.7 µH choke.

Pin 2 is the LS enable input, connected directly to the solar module. According to the datasheet, it is possible to connect a series resistor at this point (typ. 1.2 M) to increase the effective threshold voltage. The LED will then turn on slightly earlier in the evening before it is not completely dark.

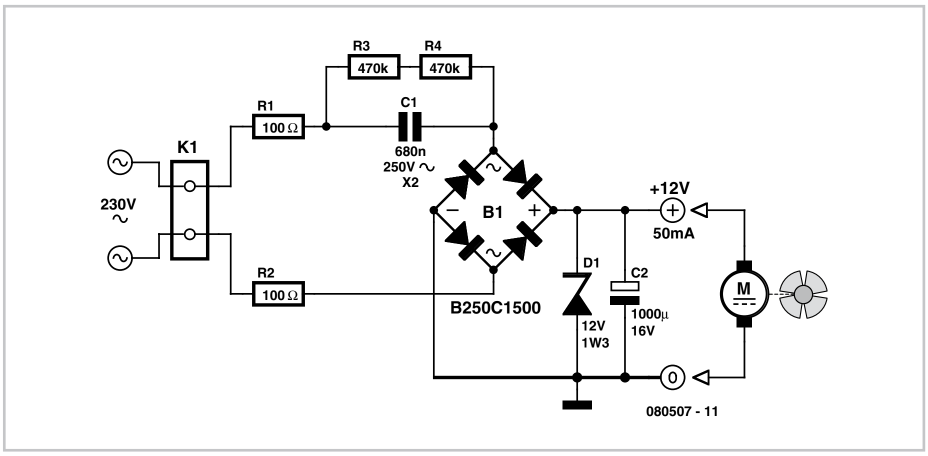
Pins 3 and 6 of the device must be connected together and together form the output of the circuit.

(071112-I)

12V Fan Directly on 230 V

Ton Giesberts

This circuit idea is certainly not new, but when it comes to making a trade-off between using a small, short-circuit proof transformer or a capacitive voltage divider (directly from 230 V mains voltage) as the power supply for a fan, it can come in very handy. If forced cooling is an afterthought and the available options are limited then perhaps there is no other choice. At low currents a capacitive divider requires less space than a small, short-circuit proof transformer.



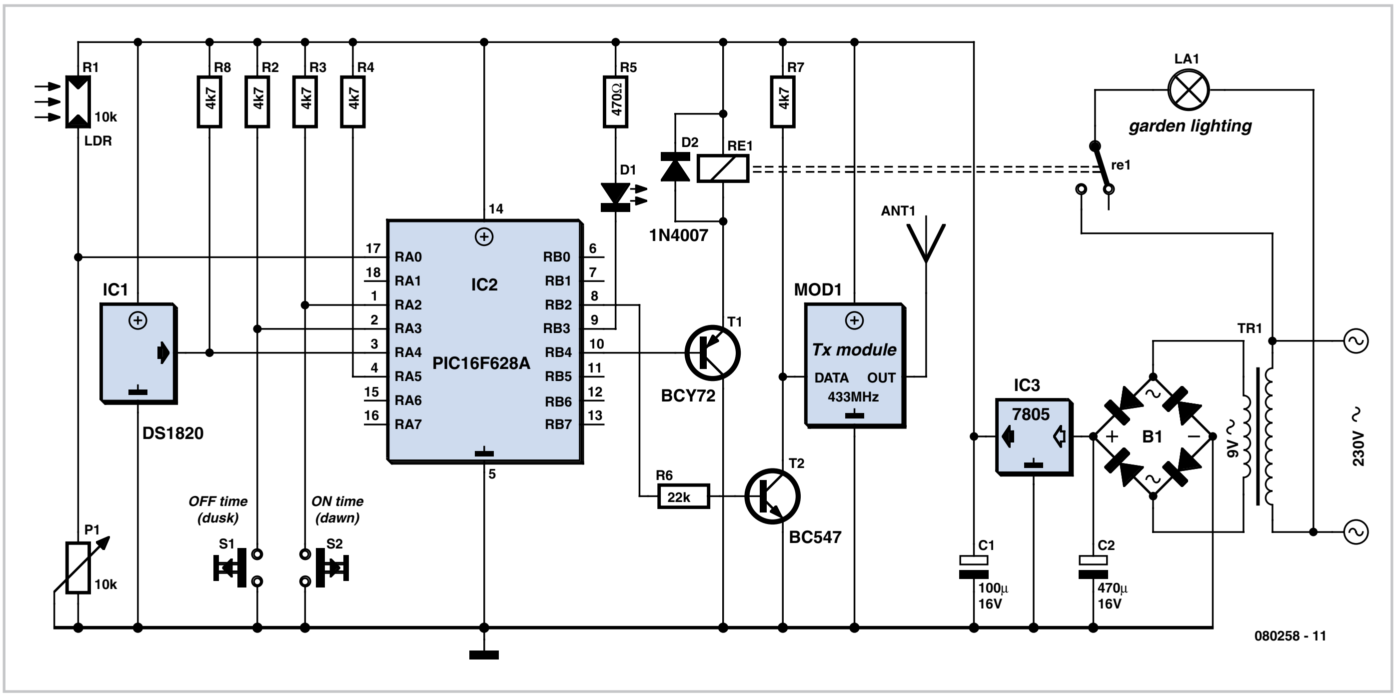
R1 and R2 are added to limit the inrush current into power supply capacitor C2 when switching on. Because the maximum rated operating voltage of resistors on hand is often not known, we choose to have two resistors for the current limit. The same is true for the discharge resistors R3 and R4 for C1. If the circuit is connected to a mains plug then it is not allowed that a dangerous voltage remains on the plug, hence R3 and R4.

Capacitor C1 determines the maximum current that can be supplied. Above that maximum the power supply acts as a current source. If the current is less then zener diode D1 limits the maximum voltage and dissipates the remainder of the power.
It is best to choose the value of C1 based in the maximum expected current. As a rule of thumb, start with the mains voltage when calculating C1. The 12 V output voltage, the diode forward voltage drops in B1 and the voltage drop across R1 and R2 can be neglected for simplicity. The calculated value is then rounded to the nearest E-12 value.

The impedance of the capacitor at 50 Hz is 1 / (2π50C). If, for example, we want to be able to supply 50 mA, then the required impedance is 4600 Ω (230 V/50 mA). The value for the capacitor is then 692 nF. This then becomes 680 nF when rounded. To compensate for mains voltage variations and the neglected voltage drops you could potentially choose the next higher E-12 value. You could also create the required capacitance with two smaller capacitors. This could also be necessary depending on the shape of the available space. It is best to choose for C1 a type of capacitor that has been designed for mains voltage applications (an X2 type, for example).

(080507-I)

Outside Light Controller



Wim de Jong

This controller turns on the outside lights as soon as it becomes dark and then turns the lighting off at a set time, so that the lights are not burning needlessly all night long.
It is also possible to automatically turn the lights on again in the morning at another preset time. Then once it is light enough outside they turn off again.

You could obtain this functionality with an LDR and a switching time clock. The LDR senses when it is dark enough and the clock can turn the lights off again at a preset time, and the other way around.
To keep the design simple and cheap, a different solution was chosen for this switching clock. A normal clock needs to be set initially and perhaps again periodically as the clock drifts after a while. In addition, a display is required to set this clock, plus a few push buttons.
Here a different approach is taken. Starting with the fact that an LDR can detect the sunrise and sunset and that the sun 'loops' around in 24 hours, we can use this knowledge as an alternative method for determining the time. This clock does not need to be set. The solar clock is born.
The controller is built around a PIC16F628A, which runs from its internal RC oscillator at 4 MHz.
When sunrise is detected, a counter is started, this counter keeps running until the following sunrise (reset).
At sunset, the current value of the counter is stored in the variable 'zontot'. So after sunset the time can be determined with the formula:

time = counter - zontot/2

This design has two pushbuttons to set the switching times; 'Evening off' (S1) and 'Morning on' (S2). The push buttons can only be operated after sunset and before sunrise.
If in the evening (after sunset, the garden light are on) button S1 is pushed, the lights will from now on go off at this particular time. When button S2 is pressed in the morning before sunrise, the lights, from now on, will turn on at this time and continue to be on until sunrise.

These times are stored in the EEPROM inside the PIC so that they are not lost when the supply voltage is removed.
The DS1820 temperature sensor shown in the schematic and the 433-MHz transmitter (a cheap transmit/receive module from Conrad Electronics) are optional. These can be used to measure the outside temperature and send it to a receiver in the house. This outside temperature is sent as a byte once every minute and at a baud rate of 1200 bits/s (8 bits, no parity) with a resolution of half a degree. –2=–1°, 0=0°, 2=1° etc.
Sensor and transmitter can be omitted without any problems if this functionality is not required.

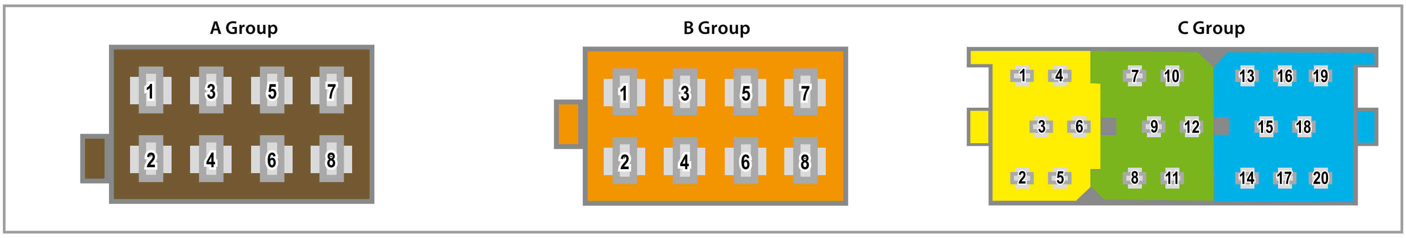
The adjustment procedure is as follows. Set the potentiometer so that the LED is on when it is dark and off when it is light. Leave the circuit alone for a 24-hour period so that the controller can synchronise with the daily sun cycle.
After that you can use the two pushbuttons to set the switching times.

(080258-I)

Downloads

The source and hex code files for this project are available as a free download from www.elektor.com; file # 080258-11.zip.

ISO Standard for Car Radios



A Group	Power Supply	
1	RPM pulse	A pulsed RPM signal is used to maintain a constant volume level or to operate a navigation system. This is also known as SCV (Speed Controlled Volume) or GALA (Geschwindigkeits-Abhängige Lautstärke-Anpassung).
2	Remote control / ground / telephone mute	Mutes the audio output of the radio. This requires a hands-free kit that pulls pin 2 to ground during a telephone call.
3	Remote control	Strongly brand-dependent.
4	Constant 12 V in; orange (yellow)	Constantly connected to the +12-V terminal of the battery. Memory settings (stations, tone and time) are thus retained when the radio is switched off.
5	Switched 12 V out / antenna remote, blue	The motor-driven antenna is extended when 12 V is present on this pin. It can also be used to switch accessories such as amplifiers or sound processors.
6	Lighting, yellow/black	12 V must be present on this pin to illuminate the buttons of the radio and allow the display to be dimmed.
7	Switched 12 V in, red	The radio can be switched on if 12 V is present on pin 7 (via the ignition switch).
8	Ground, black (brown)	Connection to the chassis and thus to the negative terminal of the battery.

The assignments of pins 1 to 3 may be swapped, depending on the make or brand. Pin 3 is sometimes used for a brand-specific bus signal.
The assignments of pins 4 and 7 are often swapped (for example, by VW, Audi and Opel).
In recent VW models, pin 5 is used as a supplementary connection for constant +12 V. This means that if you install a different radio, you must disable this connection, as otherwise the new radio will have a short life.

B Group	Loudspeakers
1	Right rear +, blue
2	Right rear –, blue/black
3	Right front +, grey
4	Right front –, grey/black
5	Left front +, green
6	Left front –, green/black
7	Left rear +, brown
8	Left rear –, brown/black

C Group	Extensions
1	Line out, left rear
2	Line out, ground
3	Line out, right rear
4	Line out, left front
5	Antenna/remote 12 V out
6	Line out, right front
7... 10	Brand/make dependent
11	Phone in
12	Phone in, ground
13	CD ID
14	Brand/make dependent
15	Ground
16	Constant +12 V
17	Switched +12 V
18	CD changer line-in ground
19	CD changer line in, left
20	CD changer line in, right

The assignments of pins 1–6 are always as described here. However, recent Becker radios use pin 6 for the subwoofer output. Manufacturers can use the remaining pins as they see fit.

Giel Dols

A standard for the audio connections of car radios has been generated in order to avoid having every car manufacturer devise its own solution to this common and recurrent issue. This standard has now been adopted by the International Organization for Standardization (ISO). The mechanical construction, dimensions and shape are clearly specified, at least in principle. Here we have to say 'in principle' because some manufacturers cannot resist the temptation to arrange the signals on the connectors according to their own ideas.

The classic examples of this are Audi, Opel and VW, which practically make a tradition of exchanging the terminals for the constant supply voltage and switched voltage. As a result, if you connect a new radio it will behave in a very irritating manner: every time you switch off the ignition and remove the key, all your settings will be lost. As a result, most car radio manufacturers provide a simple way to swap these connections in the cabling.
The tables clearly show which signals are assigned to the various pins of the connectors (or how they should be assigned).
It is thus very much recommended to use a multimeter to check whether everything is connected as it should be, especially for the connections in the 'A' group.

(080471-1)

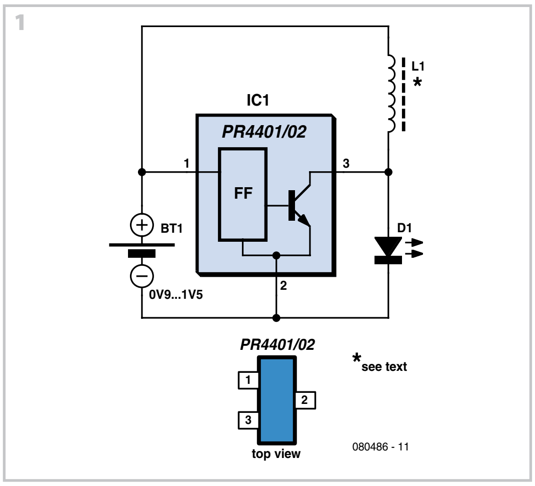
PR4401/02 off the Beaten Track

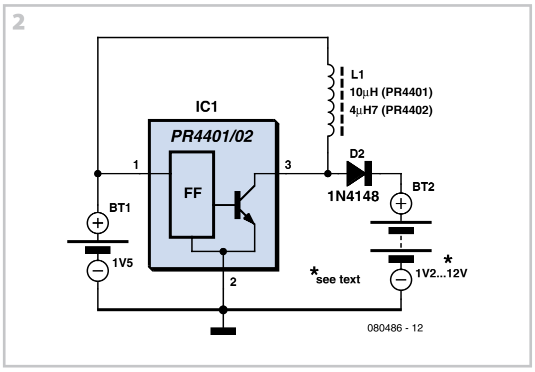
Ernst Krempelsauer & Burkhard Kainka

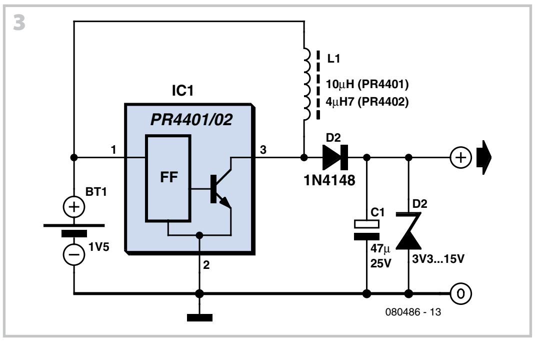
The well-known PR4401 and PR4402 LED drivers from PREMA have enjoyed great popularity as a result of their low cost, tiny physical size, and ready availability. The device is a switching regulator that is specifically designed for driving white LEDs from a single dry or rechargeable cell. The only external component required is a small inductor (see **Figure 1**). For maximum output power a 10 µH inductor is needed in the case of the PR4401, and 4.7 µH in the case of the PR4402. With an input voltage of between 0.9 V and 1.5 V the PR4401 can then deliver a current of up to 23 mA into the white LED connected to its output; the PR4402 can manage currents as high as 40 mA. Other current-delivery applications besides driving LEDs are also possible, of course. For example, the LED can be replaced by a string of between one and ten NiMH cells in series plus a series diode (see **Figure 2**). The cells will then be charged at a current of up to 23 mA (PR4401) or up to 40 mA (PR4402).

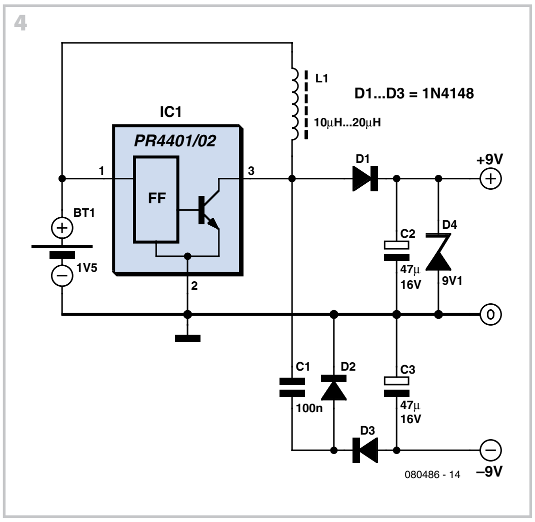
The output of the switching regulator behaves as a kind of constant power source, always delivering (with the coil values suggested above) around 70 mW (PR4401) or 140 mW (PR4402) into the connected load. When charging NiMH cells the current will be at its maximum value given above when up to three cells are connected (3.6 V), and with more cells (that is, with a higher total battery voltage) the current will fall. With ten cells (12 V) the current flow to the battery is just 6 mA (PR4401) or 12 mA (PR4402).

The ICs are less suitable for applications where the load characteristics are not constant. The lower the load, the higher the output voltage, and with an open-circuit output an internal zener diode limits the output voltage to approximately 18 V. This diode therefore effectively replaces the missing load and dissipates the power output by the regulator. If the output voltage is limited to a lower value using an external zener diode then the regulator will deliver all the output power not taken by the load into the diode. The upshot of all this is that the lower the load, the poorer the efficiency of the circuit.









Applications of this attractive device as a voltage source are also worth a quick look. For example, you might be looking for an application for the printed circuit board, with PR4401 IC and coil ready fitted, that came free with the September 2007 issue of *Elektor*.

Figure 3 shows the circuit of a simple voltage regulator using a PR4401 or PR4402. The zener diode voltage is chosen according to the wanted output voltage, between 3 V and 15 V. These voltages can be generated from a single NiMH or alkaline cell (1.2 V or 1.5 V), which, for example, allows you to replace the expensive 12 V batteries found in some instruments and in remote controls for garage door openers. The maximum output current from the voltage regulator can be calculated as follows:

$$I_{max} = P_{max}/U_Z$$

P_{max} is 70 mW (PR4401) or 140 mW (PR4402) and U_Z is the zener voltage, which is equal to the output voltage. The circuit is most efficient when the output current is near to I_{max}. If necessary, I_{max} can be reduced by using a higher-valued inductor to match it better to the required output load. To a reasonable approximation, doubling the inductance will halve the maximum output current.

We can also use a LED driver to generate a symmetrical supply from a single NiMH or alkaline cell. **Figure 4** shows a practical example generating +9 V and –9 V. Because of the additional diode in the negative arm of the circuit, the negative output is about 0.7 V lower in magnitude than the positive. In our prototype, where we used a 15 µH inductor and a 1.5 V cell voltage, we obtained the measured output voltages of +9 V and –8.3 V (with no load), and +8.6 V and –7.9 V (with a 2.2 kΩ load, simulating the 4 mA current draw of a typical opamp circuit).

The current drawn from the 1.5 V cell was 50 mA in the no-load case and 80 mA in the 2.2 kΩ load case.

(080486-I)

Luxeon Logic

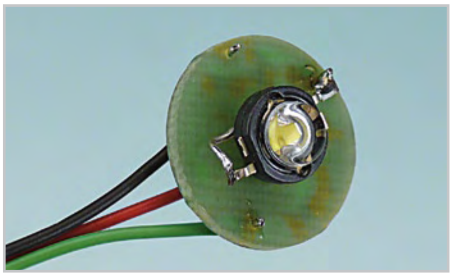
Brightness control for LED flashlights

Oliver Micic (Germany)

The small super-bright Luxeon LEDs from Philips are suitable for many applications, including small but handy (that is, bright) pocket torches. However, you don't always need maximum brightness, so it would be nice to have a simple brightness control. After giving this question a bit of thought, the author designed the circuit described here. An ATtiny microcontroller enables convenient one-button operation. Three brightness levels can be selected by pressing the button one to three times in succession, and pressing it yet again switches the LED off. In this state the ATtiny enters sleep mode with a current consumption of around 1.2 µA.

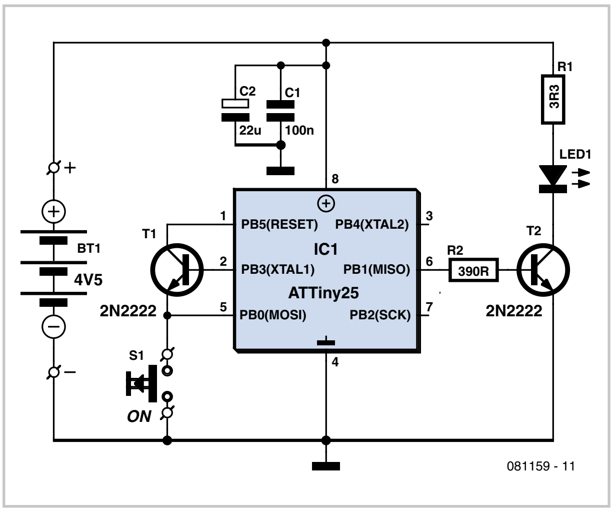
The current consumption rises to around 12 mA in normal operation, plus the current through the LEDs. At 4.5 V, the currents measured by the author at the three brightness settings were 50 mA, 97 mA, and 244 mA.

The LED current can be set to other levels by adjusting the value of R1 in the circuit, although the maximum operating current of the LED should not exceed 350 mA. If you want to use more than one LED, you will have to use a different transistor type, since the maximum rated current of the 2N2222 is 600 mA.



Features

- Three selectable brightness levels
- One-button operation
- Microcontroller control circuit
- Current consumption in sleep mode only 1.2 µA



With regard to the quite simple circuit, we can mention that it lacks a crystal because the clock is provided by the internal 8-MHz oscillator of the ATtiny microcontroller. The firmware [1] is written in BASCOM and works with PWM control using the internal clock divider (1:8). If any changes are made, this should be maintained to ensure that the firmware runs at 1 MHz, which reduces the current consumption.

A suitable small PCB is available via the Elektor website, and as usual the layout can be downloaded free of charge [1]. The author [2] designed a round PCB that fits nicely in a pocket flashlight with three AA batteries.

(081159-I)

Internet Links

[1] www.elektor-usa.com/081159

[2] www.dg7xo.de

Downloads

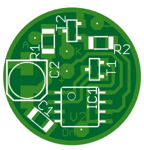
081159-1: PCB design (.pdf), from [1]

081159-11: Source code and hex files, from [1]

Product

081159-41: ATtiny25 microcontroller, ready programmed

COMPONENT LIST



Resistors
R1 = 3Ω3 (1206)
R2 = 390Ω (1206)

Capacitors
C1 = 100nF (1206)
C2 = 22µF 10V (SMD)

Semiconductors
T1,T2 = 2N2222 (SOT-23)
IC1 = ATtiny25-20SU (SOT-8)
LED1 = Luxeon LED, 1W (SMD), white

Miscellaneous
Pushbutton
PCB # 081159-1 [1]

Preamplifier for RF Sweep Generator

Gert Baars (The Netherlands)

The RF sweep frequency generator ('wobbulator') published in the October 2008 issue of Elektor has a receiver option that allows the instrument to be used as a direct-conversion receiver. This receiver does however have a noise floor of only –80 dBm, which really should have been −-107 dBm to obtain a sensitivity of 1 µV. So, for a good receiver some more gain is required. A wideband amplifier, however, generates a lot of additional noise as well and as a consequence will not result in much of an improvement.

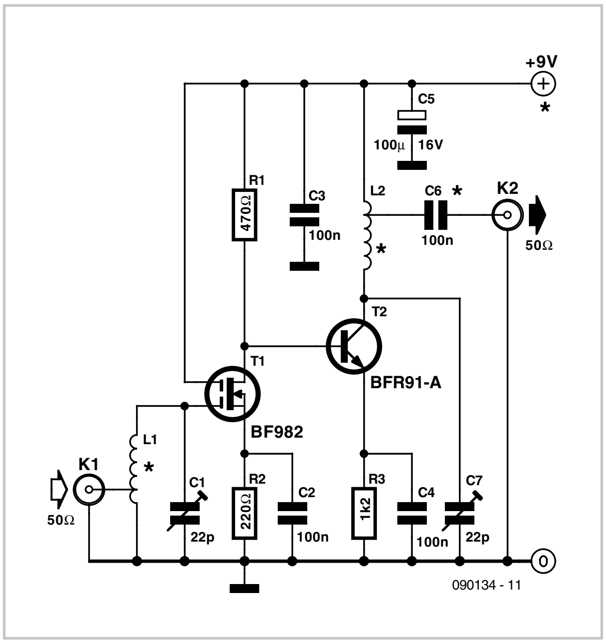
As an experiment, the author developed a selective receiver with a bandwidth of about 4 MHz. Because a gain of at least 35 dB is required, the preamplifier consists of two amplifying elements.

The input amplifier is designed around a dual-gate MOSFET, type BF982. This component produces relatively little noise but provides a lot of gain. The output stage uses a BFR91A for some additional gain.

Preamplifiers where both the gate and the drain are tuned often struggle with feedback via their internal capacitance. Here, the drain circuit has a relatively low impedance, which prevents this from happening. In the prototype that was tested, the input and output are located at right angles with respect to each other to prevent inductive coupling (see photo). Despite the high gain, the amplifier was perfectly stable even without any shielding.

The two air-cored coils in the circuit both consist of 4 turns and have an internal diameter of 6 mm, made from AWG #18 (1-mm) diameter silvered copper wire and with a tap after 1 turn.

The amplifier is mainly intended for the 144 MHz amateur band, but with other coils can also be used for the FM broadcast band, for example.



FM detection is achieved by tuning near the edge of the IF filter. At an offset of 15 kHz this is only a few dB lower than at the centre of the pass-band, so that damping is not noticeable. The measured sensitivity in the 2 m band was about 1 µV (6 dB).

A good antenna always contributes to the reception, of course. A wideband (scanner) outdoor antenna will give good results. Adding this wobbulator/receiver option results in a nice monitor receiver. By setting the scan frequencies of the spectrum analyzer to 144 and 148 MHz (or 146 MHz where applicable), any signal within this range is directly visible. When a signal is detected it is merely a case of clicking the scan stop button and then clicking on the signal in the display window using the right mouse button. After this, the receiver switches directly to this frequency and you can listen to the signal. You can subsequently resume the scanning so that you can continue to look for other signals.

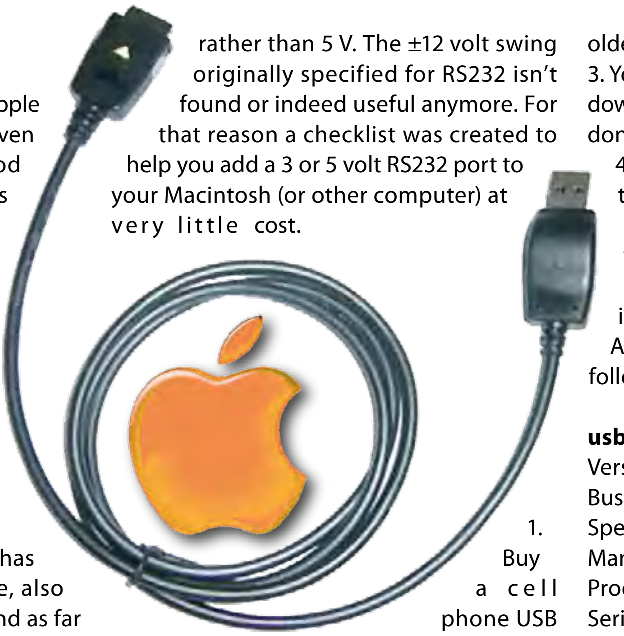
For narrowband FM detection you need to select the FMN button in the window for the receiver and this then provides the required offset for the edge detection at 25 kHz bandwidth. This value is adjustable via the 'setting' menu (default is 12,500 Hz) and can be changed experimentally for best results.

To power the circuit you can use a 9-V battery. It is also possible to power the amplifier directly from the RF sweep generator, if output capacitor C6 is replaced with a link; in the 'options' menu you will then have to select the option 'use probe'.

(090134-I)

Cheap Serial Port for the Mac

Gerrit Polder (The Netherlands)



Many people would agree that the Apple Macintosh is a fantastic computer. Even so, it's been less popular for a good while amongst electronics engineers and enthusiasts. Of course there was a good reason for this: Apple was one of the first companies that left out the ever so useful RS232 port. And not only on their notebooks (sorry, MacBooks!), they also left them out from their desktop computers. It's been a good 10 years since Apple started delivering those beautiful, futuristic iMacs in a range of colors, but unfortunately without an RS232 port.

However, times change and Apple has steadily increased its market share, also amongst electronics enthusiasts. And as far as 'the other brands' are concerned, there is virtually no laptop made nowadays that does come with an RS232 port.

The RS232 port is still considered very useful by many electronics-minded people though. These days microcontroller circuits that employ ersatz-RS232 often work at 3 V rather than 5 V. The ±12 volt swing originally specified for RS232 isn't found or indeed useful anymore. For that reason a checklist was created to help you add a 3 or 5 volt RS232 port to your Macintosh (or other computer) at very little cost.

1. Buy a cell phone USB cable from a shop or via the Internet from Hong Kong; it shouldn't cost a lot.

2. Look at [2] for the pinout of the plug. It will tell you what connections are used by RS232 and what the operating voltage is. This will be 3 volts for most modern cell phones; for older models it is usually 5 volts.

3. You will usually get some software for Windows with the cable — if you can use it you're done. Congratulations!

4. Mac users have to do a bit more work though. Connect the cable to the computer and have a look in the System Profiler (Applications/Utilities) under Hardware/USB to see what type of interface it is.

As an example, you could see the following:

usb data cable:

Version:	1.00
Bus Power (mA):	500
Speed:	Up to 12 Mb/sec
Manufacturer:	Silicon Labs
Product ID:	0x10c5
Serial Number:	0001
Vendor ID:	0x10ab

5. You can see from this that you have a 'Silicon Labs' interface. From the website of this company [1] you download the CP210x USB to UART Bridge Virtual COM Port (VCP) driver for Mac OS X.

6. The driver is installed by double-clicking on the SLAB_USBtoUART Installer.
7. Unfortunately, the standard Product and Vendor ID of this driver do not correspond with those of the GSM cable, but that is easily rectified. The Product and Vendor ID that discovered in step 4 can be included in the file: */System/Library/Extensions/SLAB_USBtoUART.kext/Contents/Info.plist*. All that's left to do is to type a few instructions to load the driver.
8. Open a terminal session and type:
$ sudo kextload /System/Library/Extensions/SLAB_USBtoUART.kext
$ touch /System/Library/Extensions
*$ ls -al /dev/tty.SLAB**

If all went well you should see something like this:

crw-rw-rw- 1 root wheel 9, 8 Oct 18 08:32 /dev/tty.SLAB_USBtoUART

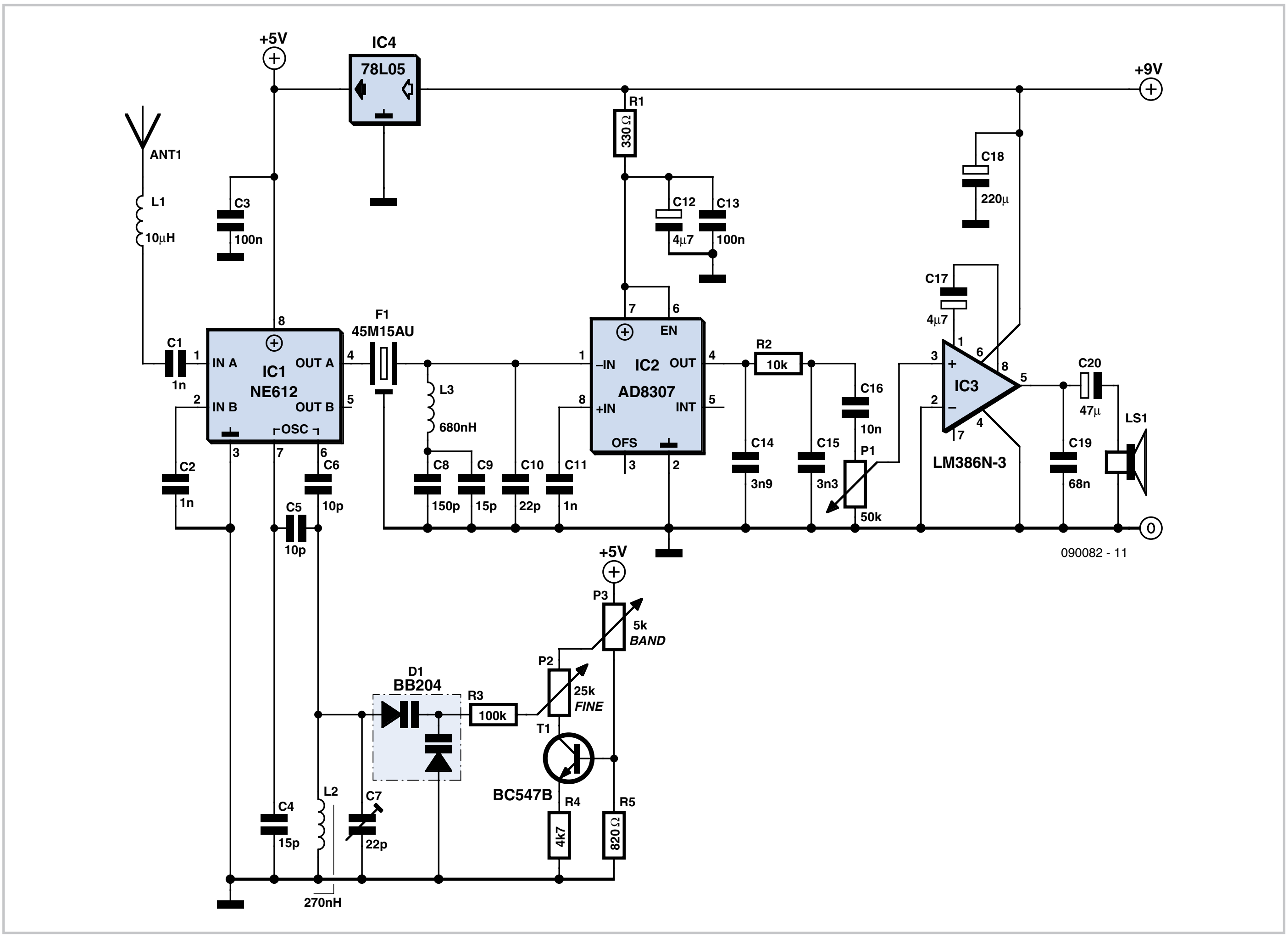
as proof that the new COM port is available.

(090092-I)

Internet Links

[1] www.silabs.com
[2] http://pinouts.ru

0–18 MHz Receiver



Gert Baars (The Netherlands)

The receiver shown in the schematic has some characteristics not unlike those of the so-called 'world band receivers' from the old days, which could usually receive LW, MW and SW up to about 20 MHz in AM and which were crammed with transistors. Because of the 'low-budget' character of this circuit it forgoes a tuning scale/indicator and the design has been kept as simple as possible. Nevertheless, the name 'Mini World Receiver' would not be inappropriate for this design.

In the RF bands up to 30 MHz, the majority of stations can actually be found below 18 MHz. It is possible to make a receiver for this with a relatively simple circuit. The simplicity of the circuit is therefore its primary strength, but that does not mean that the results are poor. The receiver is a single superheterodyne with the salient characteristic that the receiving range from DC to 18 MHz can be tuned in a singe range.

The circuit uses a high intermediate frequency (IF). This makes the image frequency large, so that its suppression is very easy, which contributes to the simplicity of the circuit. This also means that the ratio between the highest and lowest required VFO frequencies remains small as well.

The circuit starts with a NE612 mixer IC (IC1), which also contains an oscillator. The oscillator is a Colpitts type and is tuned here using a dual-varicap diode (D1). The Mixer is followed by a crystal filter which has a center frequency of 45 MHz and a bandwidth of 15 kHz. This bandwidth is a little large for AM, but the advantage of the filter type 45M15AU that is used here, is that it is reasonably if not favorably priced.

With an IF of 45 MHz and a receiving range from DC to 18 MHz, the VCO frequency therefore has to be IF+F0 = 45 to 63 MHz. The image frequency is now 90 MHz higher than the desired receiver frequency, at 90–108 MHz. A single coil in series with the antenna provides sufficient suppression at these frequencies. It really cannot be any simpler.
After the IF filter follows an LC combination which suppresses the fundamental frequency of the IF filter (45M15AU is a 3rd overtone type) and increases the damping. A logarithmic detector was chosen for the IF amplifier. The advantage is mainly the small number of external components that are required for this. The detector is an AD8307 (IC2) and has a sensitivity of about –75 dBm, which works out to about 40 μV. Together with the gain of the mixer (around 17 dB) the sensitivity of the receiver ends up at about 5 μV. Because of the logarithmic characters of the detector, an AGC (automatic gain control) is not necessary. A simple RC filter subsequently provides some additional fundamental frequency and noise suppression.

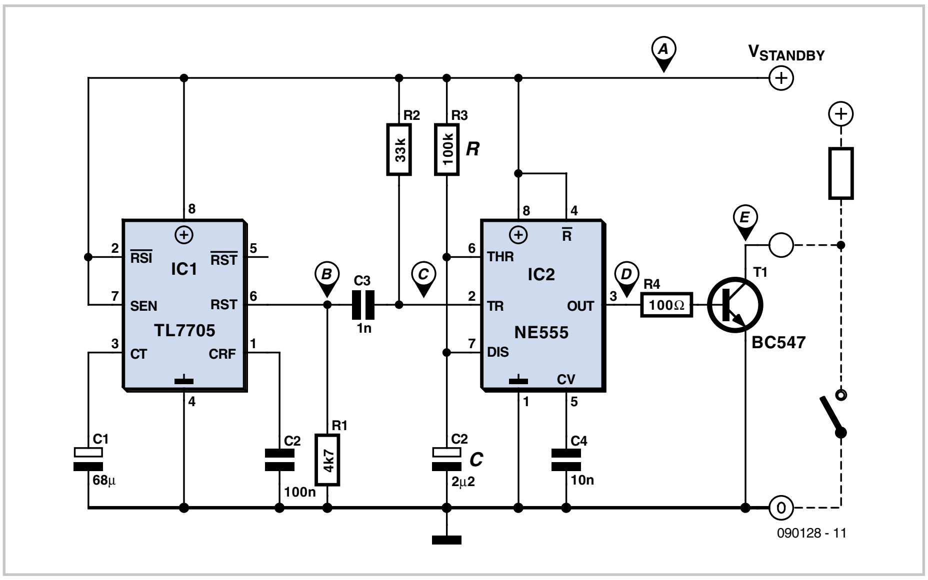
The AF amplifier follows this filter and is configured for a gain of approximately 200. This is enough to drive a speaker so that it exceeds the ambient noise. If necessary the volume can be adjusted with P1.
To tune such a large frequency range it is certainly preferable to use a multiturn potentiometer. Because of the low-budget character of this design, a circuit around two potentiometers is used instead. A transistor configured as a current source provides a constant voltage of about 1 volt across the 'Fine' tuning potentiometer (P2). The 'Band' potentiometer (P3) has a negligible effect on the voltage across the 'Fine' potentiometer, but it does allow the voltage at both extremes to be changed. In this way the 'Band' control can be used to select a window within which the 'Fine' potentiometer is used for the actual tuning. The ratio is about 1 to 5. If you prefer a ratio of, say, 1 to 10, you can increase the emitter resistor R4 from 4.7 kohms to 10 kohms.
Because the VFO has to be stable, only the power supply to the mixer/VFO IC has been regulated. The power supply voltage to the AD8307 has been reduced with a resistor to a safe value, while the AF amplifier is powered directly from the battery. The current consumption of the circuit without a signal is less than 20 mA and with good audible audio about 50 mA. The circuit continues to work well with power supply voltages down to about 6.5 volts. This means that a 9 V battery will last extra long.

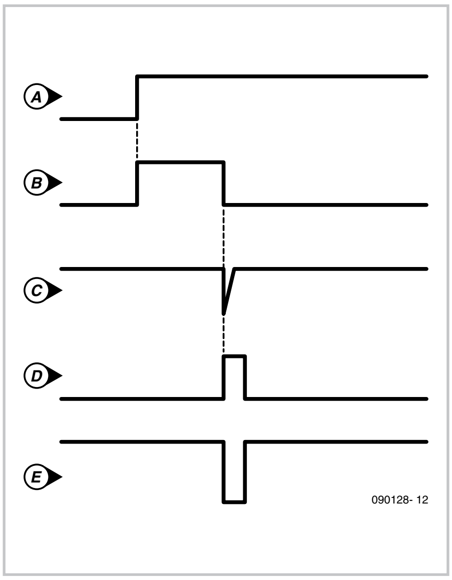
Calibration of the circuit is simple. The tuning potentiometers have to be set to the lowest frequency first. Use trimmer capacitor C7 to find a point where AC power line hum becomes audible. Here the receiver frequency is at 0 Hz. Optionally you can also tune to a strong longwave station as the lowest receiver frequency.

As a minimum a simple telescoping antenna with a length of about 2 feet is required, which makes the receiver eminently suitable for portable use. With such an antenna dozens of broadcast and amateur stations are audible, particularly during the evening when propagation becomes favorable. Although a wire antenna with a length of 20 to 60 feet does increase the signal strength, particularly during the day, you'll find that it is not strictly necessary.

(090082-I)

Start-up Aid for PCs





Egbert Jan van den Bussche (The Netherlands)

Since one of the servers owned by the author would not start up by itself after a power failure this little circuit was designed to perform that task.

The older PC that concerned did have a standby state, but no matching BIOS setting that allows it to start up unattended. Although a +5 V standby supply voltage is available, you always have to push a button for a short time to start the computer up again. Modern PCs often do have the option in the BIOS which makes an automatic start after a power outage possible. After building in the accompanying circuit, the PC starts after about a second. Incidentally, the pushbutton still functions as before.

The circuit is built around two golden oldies: a NE555 as single-shot pulse generator and a

TL7705 reset generator. The reset generator will generate a pulse of about 1 second after the supply voltage appears. The RC circuit between the TL7705 and the NE555 provides a small trigger pulse during the falling edge of the 1 second pulse. The NE555 reacts to this by generating a nice pulse of 1.1*RC*. During that time the output transistor bridges the above mentioned pushbutton switch of the PC, so it will start obediently.

Other applications that require a short duration contact after the power supply returns are of course also possible.

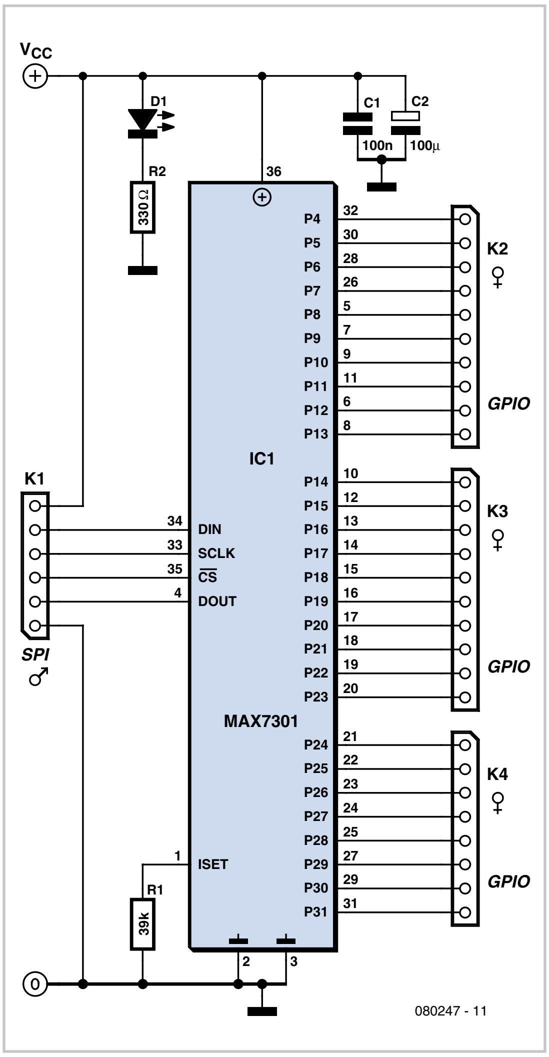
(090128-I)

Port Expander

Steffen Graf (Germany)

It can sometimes happen that even when using the largest version of a microcontroller for a particular design application there are just not enough I/O port pins to handle all the inputs and outputs. This can be the case when for example several LCDs are driven in parallel or when it is necessary to input values from aa large number of switches and pushbuttons.

The circuit shown here solves the problem using the I/O port expander IC type MAX7301 from Maxim [1]. This device can be powered from a supply between 2.5 V and 5 V which makes it suitable for use with both 3.3 V and 5 V controllers (the value of resistor shown as R2 is suitable operation from a 3.3 V supply).
The port expander uses the SPI interface so it only requires four microcontroller pins: Data In, Data Out, Clock and Slave Select. Many microcontrollers have an SPI interface already implemented on-chip but if not it should be relatively easy to implement the function in software. We have sacrificed four pins on the interface but this port expander now gives us 28 general purpose I/O pins (GPIOs) which can be configured as either inputs (with or without pull-ups) or outputs. Providing the microcontroller is fast enough the GPIOs can be switched at a rate of 26 MHz.



The project page of this article [2] includes full listings (in the form of a small C library) of the author's software implementation. This allow the ports to be configured as inputs or outputs and the value of the input port pins to be read or output pins to be set.

The instruction
`io_max7301(0xF, Portpins);`
selects port pins used as outputs. A macro expression such as PCONF8_11 is used for Portpins to refer to port pins 8 to 11. The instruction
`io_max7301(0x0, Portpins);`
configures port pins as inputs. To output data from the port pins use
`set_max7301(data, Portpins);`
where *data* = binary data. And the instruction
`data = get_max7301(Portpins);`
reads the binary value of input data.

(080247-I)

Internet Links

[1] http://datasheets.maxim-ic.com/en/ds/MAX7301.pdf

[2] www.elektor-usa.com/080247

Download

Software

080247-11 source code, from [2]

Slow Glow

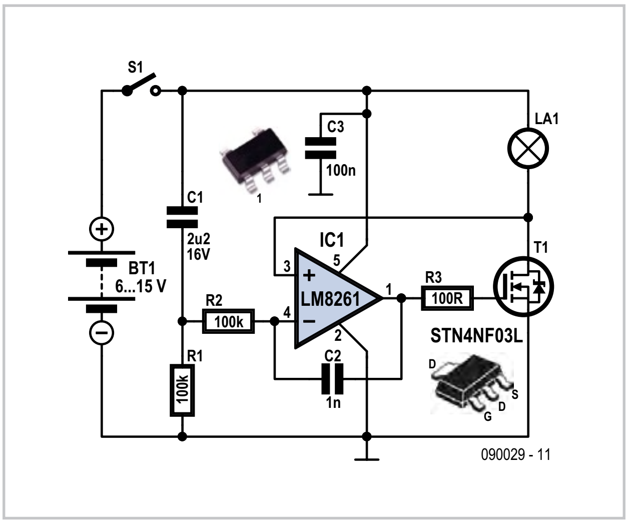
Dirk Visser (The Netherlands)

There are many different ways in which a lamp can be made to light up gradually. This circuit presents one of them. What is special about this circuit is that it can be turned into a power potentiometer with only a small modification.

Slow Glow operates as follows: the instant the circuit is turned on, the inverting input of the opamp is at the same voltage as the inverting input, which is equal to the supply voltage. However, C1 will slowly charge up, which causes the voltage on the inverting input to drop. This voltage therefore looks like an inverted RC charging curve. The reduction of this voltage causes the output voltage of IC1 to increase, and T1 is driven open harder. This in turn causes the voltage across the lamp to follow the shape of an RC charging curve, and the use of a transistor means that a large current can be supplied.

When it comes to the choice of op amp you have to keep in mind its common mode range. In this circuit it needs to be equal to the full supply voltage. As a voltage follower the need is therefore for a rail-to-rail opamp. An LM8261 was picked mainly because it

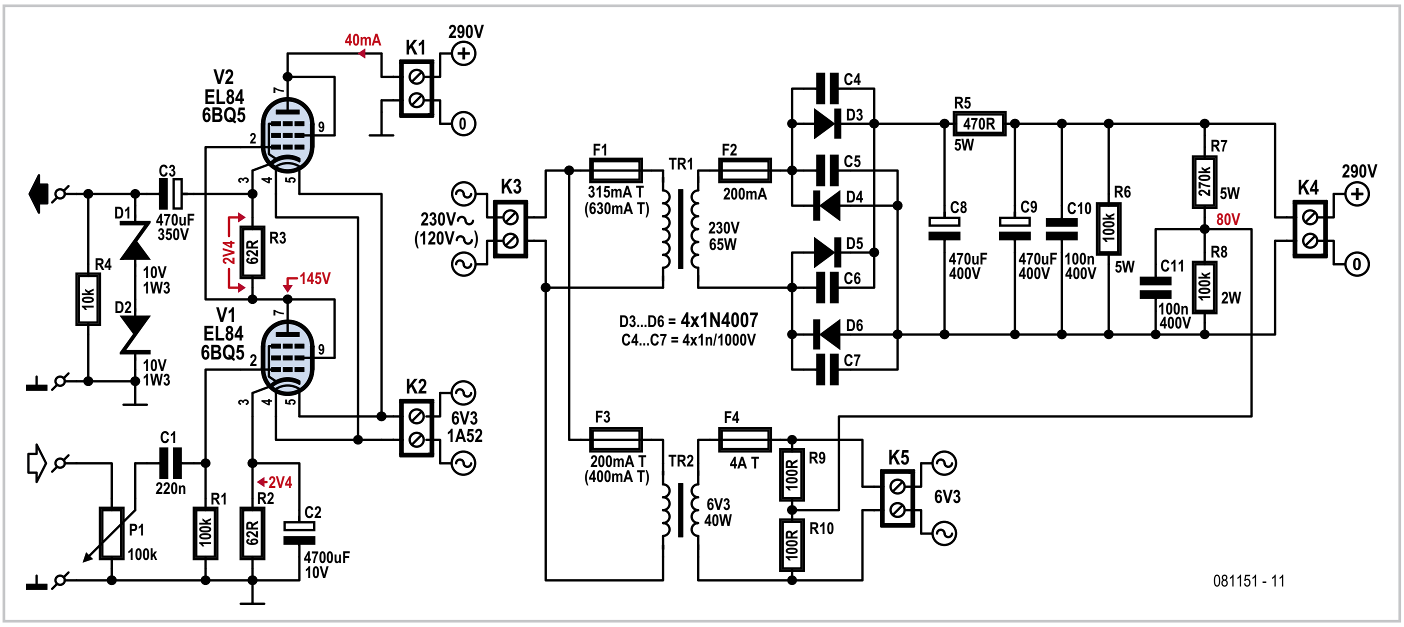
combines an exceptionally small package (SOT23-5, 2.92 x 2.84 mm) with an equally exceptional supply voltage range of 2.7 V to 30 V. There are very few rail-to-rail opamps offering such a large supply voltage range. The opamp has been decoupled with C3 because of its speed (GBWP: 21 MHz). The speed isn't critical in this case though. R3 is connected in series with the MOSFET to prevent spurious oscillations from occurring.
It stands to reason that this circuit is best built using SMD components. C1 can be obtained in an 0805 package (ceramic multilayer) and all other parts are also available in SMD packages. For the MOSFET we found an SOT-223 variant made by ST, the STN4NF03L. It can switch more than 6 A, which is impressive considering its dimensions (7 x 6.5 mm). If more power is needed than the maximum dissipation of 3.3 W (at 25 °C) permits, there is no problem if a bigger FET is used (for example, one in a larger D2PAK package). There is a large number of FETs available in this type of package that can cope with significantly higher currents and power.
The circuit can also be used with normal 12 V halogen lighting if a bit of cooling and a TO-220 package is used. With the values used for R1 and C1 the transistor needs to dissipate the maximum power for only just over a tenth of a second. This power is obviously dependent on the type of lamp connected up. The gate-source voltage of the MOSFET determines the permissible supply voltage range. The absolute maximum value here is 16 V, and there is also a minimum voltage required to obtain a low channel resistance (<0.05 Ω at U_{GS} = 5 V). Hence the supply voltage range for this circuit is 6 to 15 V and a 16 V rated type for C1 is sufficient.



When C1 and R1 are replaced with a potentiometer (with the slider connected to R2), the whole circuit behaves much like a potentiometer, but one with very large output power. The MOSFET is driven by IC1 such that a balance exists between the inputs of the op amp. The voltage at the drain therefore becomes equal to the voltage at the wiper of the potentiometer.

(090029-I)

SRPP Headphone Amplifier



Martin Louw Kristoffersen (Denmark)

Mention tube amplifiers and many designers go depressive instantly over the thought of a suitable output transformer. The part will be in the history books forever as esoteric, bulky and expensive because, it says, it is designed and manufactured for a specific tube constellation and output power. There exist thick books on tube output transformers, as well as gurus lecturing on them and winding them by hand. However, with some concessions to distortion (but keeping a lot of money in your pocket) a circuit configuration known as SRPP (series regulated push-pull) allows a low-power tube amplifier to be built that does not require the infamous output transformer. SRPP is normally used for pre-amplifier stages only, employing two triodes in what looks like a cascade arrangement.

Here we propose the use of two EL84 (6BQ5) power pentodes in triode SRPP configuration. The reasons for using the EL84 (6CA5) are mainly that it's cheap, widely available and forgiving of the odd overload condition. Here, two of these tubes are SRPP'd into an amplifier that's sure to reproduce that 'warm thermionic sound' so much in demand these days.

Before describing the circuit operation, it must be mentioned that construction of this circuit must not be attempted unless you have experience in working with tubes at high voltages, or can rely on the advice and assistance of an 'old hand'. As a safety measure, two anti-series connected zener diodes are fitted at the amplifier output. These devices protect the output (i.e. your headphones and ears) against possibly dangerous voltages at switch-on, or when output capacitor C3 breaks down.
The power supply is dimensioned for two channels, i.e. a stereo version of the amplifier. The values in brackets are for Elektor readers on 120 V AC networks. Note the doubled values of fuses F1 and F3 in the AC primary circuits. The PSU is a conventional design, possibly with the exception of the 6.3 V heater voltage being raised to a level of about +80 V through voltage divider R7-R8. This is done to prevent exceeding the maximum cathode-heater voltage specified for the EL84 (6CA5). R6 is a bleeder resistor emptying the reservoir capacitors C8 and C9 in a quick but controlled manner when the amplifier is switched off. Rectifier diodes D3–D6 each have an anti-rattle capacitor across them.

In the amplifier, assuming the tubes used have roughly the same emission, the half-voltage level of about +145 V exists at the junction of the anode of V1 and the control grid of V2. The SRPP is no exception to the rule that high quality, (preferably) new capacitors are essential not just for reproducibility and sound fidelity, but also for safety.

(081151-I)

Easy LEGO Robotics Set Up

Tilo Gockel (Germany)

At the beginning of 2006 the Danish company LEGO introduced the NXT programmable brick into their 'Robotics Invention System'. Many schools and universities all over the world have since recognized this as an ideal tool to introduce the concepts of software and hardware design. Spare parts or additional components for the system can be purchased from on-line auction sites or ordered from the LEGO web shop [1].
If you are planning to invest in the system for a child, teenager or even for your own personal use you should be aware that you may encounter some issues when first installing the software. The problems can occur on machines running Windows XP or Vista because the software is not officially supported. The following tips will be helpful and should solve the main problems you are likely to come across.

First off, try installing the software on the supplied CD as suggested in the manual. With any luck it will be successful. Choose 'complete installation' option and then tick Quicktime 2.1 option and not the Quicktime 3.0 and DirectX 6.1. It is likely that there is a more up to date version of DirectX already installed on your machine. It is important to specify Quicktime 2.1; more recent versions are not recognized!
In some cases the computer may now 'hang' when it tries to execute probe.exe, if this is the case then it is necessary to make a few changes to the installation:

1. Uninstall the LEGO software (Program files / LEGO MINDSTORMS / ... / uninstall)
2. Uninstall all versions of Quicktime (Start / Control Panel / Add or Remove Programs / right click on Quicktime)
3. Re-install the LEGO software selecting Quicktime 2.1.
4. Start / Control Panel / System / click 'Advanced' tab / Performance click 'Settings' / click 'Advanced' tab / Now on 'Virtual memory' reduce the size to 384 MB.

Step 4 is important, otherwise Quicktime reports that there is too little memory available and does not even start — a somewhat curious bug.

Now a change is necessary to the start icon for Mindstorms; right click on the LEGO Mindstorms desktop icon and select 'Properties', now click the Shortcut tab and change the 'Start in' path from 'C:\Program\LEGO MINDSTORMS\probe.exe' to 'C:\Program\LEGO MINDSTORMS'. Occasionally a problem will occur with the Windows installer service (error 1281) which causes the computer to hang. To get round this you can either reboot before each new installation or you can manually stop the installer by going to Start / Control panel / Administrative tools / Services / right click Windows Installer and click on the service status box 'Stop'. Now run the software by clicking on the desktop LEGO icon (make sure that the CD is in the computer's CD drive). Installing the older LEGO Robotics Invention Version 1.0 can sometimes generate a problem with the screen Display Properties; a solution to the problem can be found at [2].

Some practical tips for newcomers to the LEGO system: communications between the brick and the IR transmitter can be disrupted by strong external light sources such as table lamps and fluorescent lighting. A green LED on the IR transmitter indicates that the communication was successful. When it is anticipated that the system will not be used for a period of time don't forget to remove the battery from the IR transmitter station.
The IR tower needs a serial port but newer computers do not usually have this type of port, in this case try a USB — infrared transmitter dongle these can be found on Internet auction sites and retail at relatively low prices. Alternatively an even cheaper solution is a USB to RS232 interface (e.g. the USB2 Serial USB 1.1 from Reichelt in Germany).
Several alternative programming environments have been developed for the LEGO system and for more adventurous projects like those described in [3] it is better to use a high-level compiled language rather than the LEGO graphic programming environment which comes bundled with the controller. A good choice is the free NQC (Not Quite C) cross compiler [4] which uses a C-like syntax.

(081129-I)

Internet Links

[1] http://shop.lego.com/ByCatalog
http://www.lego.com/education/school
[2] www.crynwr.com/cgi-bin/ezmlm-cgi/7/21888
[3] www.tik.ee.ethz.ch/tik/education/lectures/PPS/mindstorms/#finished
www.informatik.uni-kiel.de/rtsys/lego-mindstorms/projekte/#c1798
www.youtube.com/results?search_type=&search_query=lego+mindstorms&aq=f
[4] http://bricxcc.sourceforge.net/nqc/

Pseudo Fan

Dr. Thomas Scherer (Germany)

The aim of this circuit is to trick a so-called 'intelligent' fan controller that a fan is connected to it when it is not. This may sound like madness, yet there is method in it.

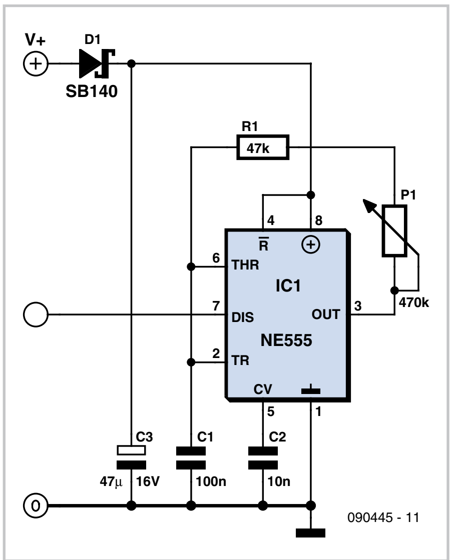
The author was so pleased with his small private server (a network attached storage, or NAS, device) that he recommended it to a friend. The friend had found a good source of low-cost SSDs (solid state disks) and replaced the spinning hard disks with semiconductor memory, with the aim of saving power. With the drives replaced, it became apparent that there was an opportunity to make the unit quieter still. Since the SSDs only dissipated a total of 5 W, surely it would be possible to disconnect the noisy internal 60 mm fan?

Characteristics

- simulates a fan of any size(!)
- pseudo-rotation frequency adjustable from 15 Hz to 150 Hz
- current consumption less than 5 mA
- operating voltage from 4 V to 15 V
- low noise!

Unfortunately it was never going to be that easy. The moment the fan was disconnected an annoying buzzer started to sound continuously: the electronics in the NAS box does not just control the fan speed to maintain a reasonable temperature inside the unit, it also checks that the fan is indeed spinning. If the controller thinks the fan has stopped, it sounds the alarm. The author was called in to see if he could solve the problem.

It immediately became clear that the fan had a standard three-pin connector. The cable carried a voltage of between +5 V to +12 V on the red wire and ground on the black wire; on the yellow wire the fan produced a square-wave signal with a frequency of about 35 Hz. To fool the controller into thinking that the fan is turning we simply needed to generate a square wave!



Old hands will no doubt be able to guess what comes next: the 555 timer, one of the best-selling ICs ever, is ideal for this task. It can cope with the range of supply voltages, and conveniently features a traditional open-collector output.

The circuit diagram contains no great surprises. Rather than using the standard astable configuration of the device, the frequency-determining resistance (comprising the series connection of R1 and P1) is wired to pin 3, which is normally used as the output. This has the twin advantages of leaving pin 7 free to use as an open-collector output and of giving a 50 % duty cycle. With the component values suggested the output frequency can be adjusted from approximately 15 Hz to approximately 150 Hz, which should be more than enough for any application.

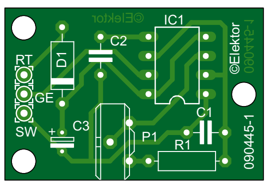
It is of course possible to build a simple circuit like this on a small piece of prototyping board. However, a much more professional look can be achieved using the printed circuit board we have designed for the job. The layout file can, as usual, be found on the Elektor website on the pages accompanying this article [1].

The pseudo-fan is of course not limited to being used in small servers. It is becoming more and more popular to build PCs that are quiet, especially if they are to be used as media centers. This means using passive cooling wherever possible. Unfortunately in some cases the BIOS throws its spanner in the works by not allowing the fan rotation sensors on the motherboard to be disabled individually. The pseudo-fan provides a simple and quick solution to this problem and avoids complicated BIOS patches. Some fans use a four-wire cable, and these too can be 'virtualized' using this circuit by ignoring the fourth wire and connecting the remaining three in the way described above.

If it will not be necessary to adjust the pseudo-fan speed P1 can be replaced by a wire link and R1 chosen appropriately. The frequency is then given by $f = 1.44 / (2 \times R1 \times C1)$.

(090445-I)

COMPONENT LIST



Resistors
R1 = 47kΩ
P1 = 470kΩ, small, upright

Capacitors
C1 = 100nF
C2 = 10nF
C3 = 47µF 16V

Semiconductors
D1 = SB140 (Schottky diode)
IC1 = NE555

Miscellaneous
Branched cable with 3-way plug
PCB # 090445-1

Internet Link

[1] www.elektor.com/090445

Download

090445-1: PCB design (.pdf), from [1]

Programmable Nokia RTTTL Player

Sajjad Moosavi (Iran)

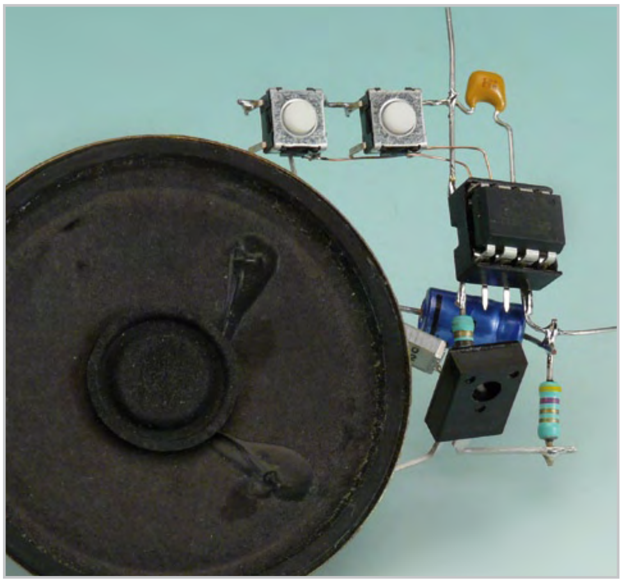
This circuit is an easy way to play monophonic music as you may remember it (fondly or not) sounding from those good old Nokia 3310 cell phones. The circuit can be used in applications like doorbells, phone ringers, bike horns or any other alarm circuit — waves of recognition and cell phone wistfulness in the audience guaranteed!

Monophonic music is made of some notes in a specific order with a given duration for each note. These notes are selected from a range specified in the **table** shown here. Nokia developed a programming language to transfer monophonic music to its cellphones and called it RTTTL, for Ringing Tone Text Transfer Language.

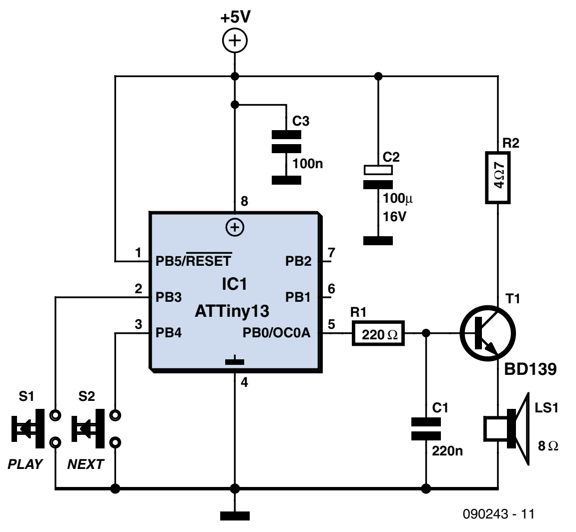
Looking at the table, each note has a different frequency according to selected octave. An octave is the interval between two points where the frequency at the second point is twice the frequency of the first. So to select a specific note in this table, you specify its column and row like A4 (220 Hz) or A#7 (1864.7 Hz). Two successive notes in the table differ by a factor of exactly the 12th root of 2 (approximately 1.059). For example: E6 (1318.8) = D#6 (1244.8) × 1.059 Hz.

After selecting the note, the next issue is its duration, i.e. how long it should sound. In contemporary music you will typically observe see the following basic note durations 1/1, 1/2, 1/4, 1/8th, 1/16th. A *Whole Note*, a.k.a. '1/1' or *semibreve*, is typically equal to four beats in 4/4 time. A *Beat* is the basic time unit of a piece of music. The real duration of a beat is related to *Tempo*. *Tempo* or *BPM* (beats per minute) is the speed of a given piece and specifies how many beats should be played in a minute.

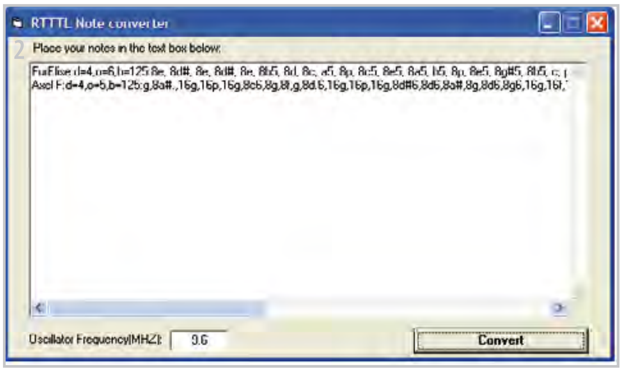
The RTTTL format is a string divided into three sections: name, default value, and data. The name section consists of a string describing the name of the ringtone. The default value section is a set of values separated by commas. It describes certain defaults which should be adhered to during the execution of the ringtone. Possible names are: d (duration), b (tempo), o (octave).



1



2



The data section consists of a set of character strings separated by commas, where each string contains a duration, note, octave and optional dotting (which increases the duration of the note by one half). For example here is RTTTL ringtone for the famous *Für Elise* piece:

FurElise:d=4,o=6,b=125:8e, 8d#, 8e, 8d#, 8e, 8b5, 8d, 8c, a5, 8p, 8c5, 8e5, 8a5, b5, 8p, 8e5, 8g#5, 8b5, c, p, 8e5, 8e, 8d#, 8e, 8d#, 8e, 8b5, 8d, 8c, a5, 8p, 8c5, 8e5, 8a5, b5, 8p, 8e5, 8c, 8b5, 2a5

The string consists of three parts separated by colons. The first part is the song name, 'FurElise' (apologies from Mr ASCII to the Beethoven Heritage for the non-umlauted *u*). The second part contains the defaults, with 'd=4' meaning that each note without a duration specification is by default a quarter note, 'o=6' setting the default octave, and 'b=125' defining the tempo. The third part comprises the notes proper. Each note is separated by a comma and includes, in sequence: a duration specification, a standard music note (as shown in first column of the table) and an octave specification. If no duration or octave specification is present, the default applies.

The circuit shown in **Figure 1** contains an ATtiny13 microcontroller programmed to read the RTTTL format (with some modification), store strings in its program memory and generate notes in the form of square waves. The note frequencies are read from a table stored in memory and durations will be calculated in the program. The commonly used octaves 3 through 7 (110 Hz – 3323.7 Hz) can be played by this circuit.

The microcontroller is an 8-pin ATtiny13 Atmel microcontroller employing its internal oscillator. The music signal generated at the PB0 pin applied to a simple emitter follower circuit that's open to your improvements in terms of filtering and amplification. Also, because the program puts a low demand on CPU use and resources, you can make the free microcontroller I/O ports do other jobs. The microcontroller's 1 KB program memory is good for storing about 20 songs. Other microcontrollers with larger memories may be used to be able to store more songs. As a minimum hardware requirement, the micro should have an 8-bit timer with compare/match capability.

The microcontroller must first be programmed with the firmware for the proj-

	Octave								
Note	1	2	3	4	5	6	7	8	9
A	27.5	55.0	110.0	220.0	440.0	880.0	1760.0	3520.0	7040.0
A#/Bb	29.1	58.3	116.5	233.1	466.2	932.4	1864.7	3729.4	7458.9
B	30.9	61.7	123.5	247.0	493.9	987.8	1975.7	3951.3	7902.7
C	32.7	65.4	130.8	261.6	523.3	1046.6	2093.2	4186.5	8372.9
C#/Db	34.6	69.3	138.6	277.2	554.4	1108.8	2217.7	4435.5	8871.1
D	36.7	73.4	146.8	293.7	587.4	1174.8	2349.7	4699.5	9398.9
D#/Eb	38.9	77.8	155.6	311.2	622.4	1244.8	2489.5	4979.1	9958.1
E	41.2	82.4	164.9	329.7	659.4	1318.8	2637.7	5275.3	10550.6
F	43.7	87.3	174.7	349.3	698.7	1397.3	2794.6	5589.2	11178.4
F#/Gb	46.2	92.5	185.1	370.1	740.2	1480.4	2960.8	5921.8	11843.5
G	49.0	98.0	196.1	392.1	784.3	1568.2	3137.1	6274.1	12548.2
G#/Ab	51.9	103.9	207.7	415.5	830.9	1661.9	3323.7	6647.4	13294.8

ect. The programming procedure comprises these steps:

1. Convert your favorite RTTTL format songs using the 'Converter' utility.
2. Compile the ASM file using an AVR assembler like the one provided with Atmel AVRStudio.
3. Write the HEX file to the microcontroller using a suitable device programmer.

In the first step, use the 'Converter' software shown in **Figure 2**. This utility was developed using Visual Basic which runs under Windows operating systems. Paste or type the song data and specify the clock frequency of the microcontroller in Megahertz, then press the 'Convert' button. Note that the ATtiny13 micro uses its 9.6 MHz internal oscillator. The software converts the songs and copies them to a file called 'ringtones.inc'. Next, Assemble the 'rtttl.asm' file with 'ringtones.inc' using an AVR assembler. The assembler outputs are two main files, 'rtttl.hex' and 'rtttl.eep'. These files should be written to the microcontroller's program memory (or EEPROM) using a serial or parallel programmer.

(090243-I)

Downloads & Product

Programmed Controller

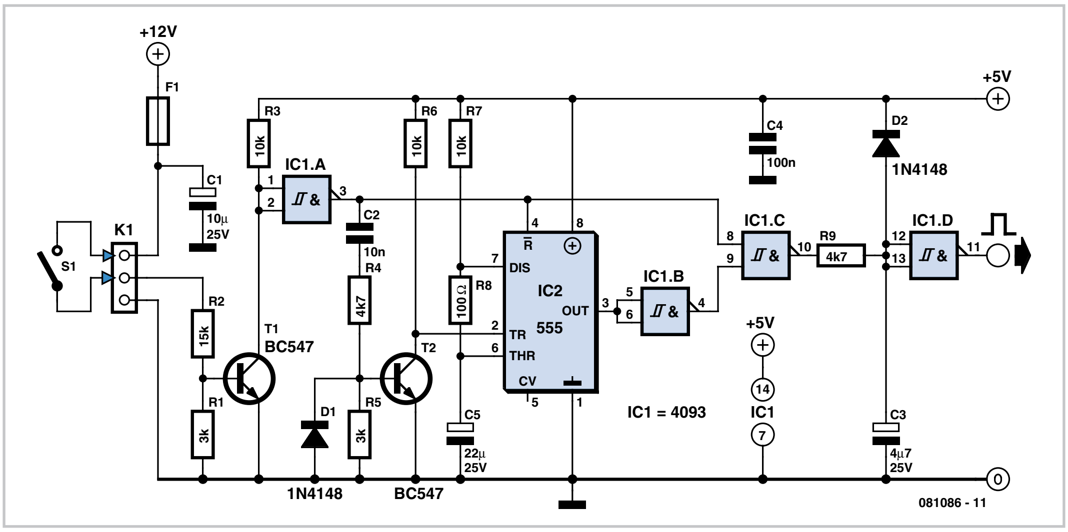
Order code: 090243-41 (plays 'Popcorn' song only).

Software

File: 090243-11.zip (free download). Content: ATtiny13 source & hex files; 'Converter' utility; location: www.elektor-usa.com/090305

Switching Delay

Thorsten Steurich (Germany)



The circuit described here was designed as an addition to a remotely-controlled garage door opener. The problem was that a brief burst of interference, arising from a thunderstorm or an AC line spike, was enough to trigger the mechanism, and the author found this a nuisance. The effect of the circuit is to enable the output from the receiver module only when a relatively long pulse (more than about 0.5 s) is received. The circuit can of course also be used in other similar situations, such as electrically-powered shutters, alarms and the like.

At the heart of the circuit is NAND gate IC1.C. The output of the circuit (after inverter IC1.D) only goes high when both inputs to IC1.C are at a high level. When the circuit is triggered T1 conducts, and the output of inverter IC1.A, and hence also pin 8 of IC1.C, go high. If we now arrange things so that for a preset time the other input to IC1.C remains low, the trigger signal will not be propagated to the output until this period has elapsed. In the case of the author's garage door opener, this will only happen if the button on the transmitter is held down.

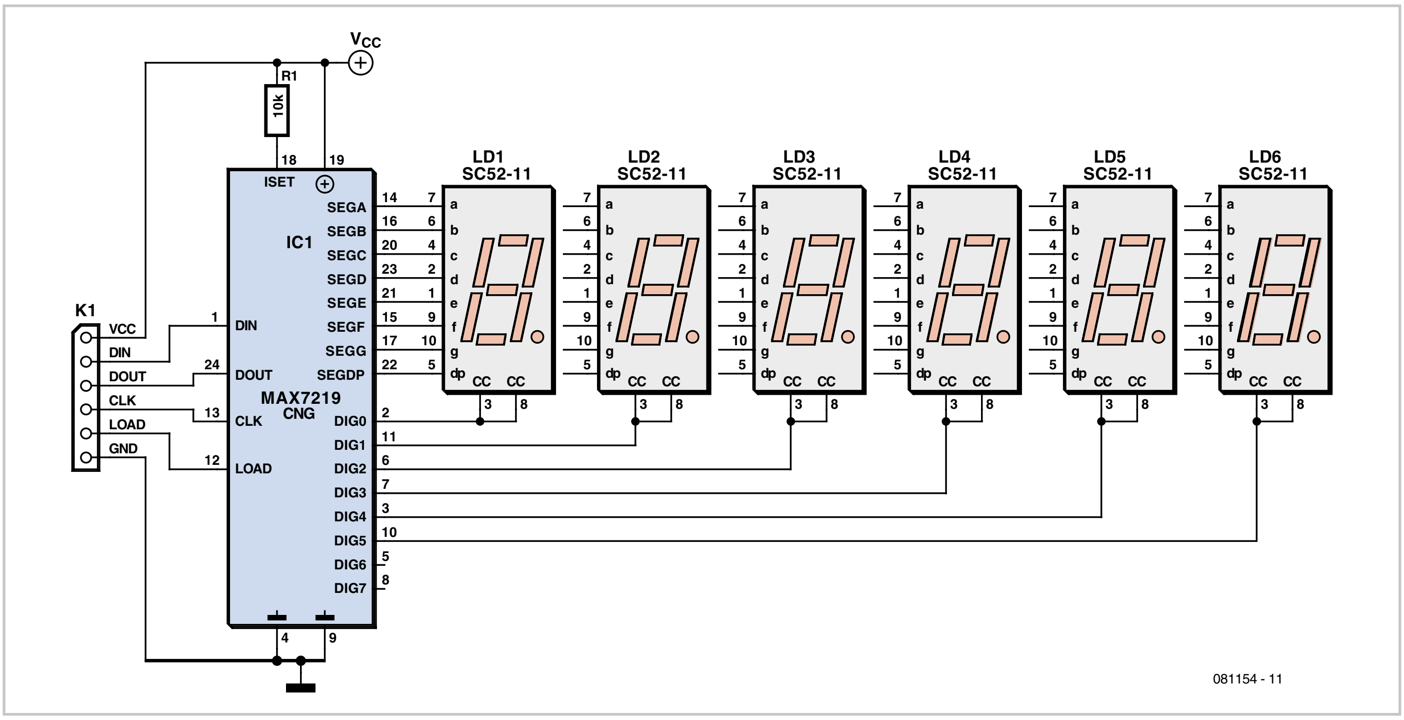
The 555 timer is used to generate the delayed gating signal for IC1.C. It is wired as a monostable multivibrator in a similar fashion to the arrangement in the ‘Economy Timer’ circuit elsewhere in this issue. When the circuit is triggered T2 will briefly conduct as a result of the positive edge at the output of IC1.A. This triggers the 555 timer: its output will go high, and thus pin 9 of IC1.C will go low. Because of the propagation delays through the components a very short low pulse will appear at the output of IC1.C when the circuit is triggered. The RC combination at the input to IC1.D ensures that this does not affect the output.

When the period of timer IC2, as determined by R7 and C5, expires its output returns low. This allows the input signal to pass through IC1.C. If the button on the remote control has been released before the timer expires, no signal will pass to the output.

When the trigger signal is removed the output of IC1.A goes low, which resets the timer: the 555’s reset input, like its trigger input, is active low. The circuit is now again in its quiescent state.

(081086-I)

Six-digit Display with SPI Port



Characteristics

- six-digit seven-segment display
- just two components, plus display modules
- driven using software SPI emulation
- C driver routines easily adapted to any type of microcontroller

Uwe Altenburg (Germany)

There is no essential difference between a seven-segment display and seven individual LEDs with either their cathodes or their anodes connected together. Often the display will be driven by a microcontroller, and when several digits are wanted, they are usually driven in a multiplexed fashion. This involves connecting together each segment in a given position across the digits, with each of the seven common segment lines (plus decimal point) being driven by an output port pin of the microcontroller via a series resistor. Each digit also requires a transistor, which again needs an output port pin to drive it. For a six-digit display, this means a total of fourteen output port pins: almost two whole ports on an 8-bit microcontroller.

Maxim offers a solution to this problem in the MAX7219. The device is controlled over an SPI port, requiring just four I/O pins on the microcontroller. It can drive up to eight individual seven-segment displays. Contrary to popular belief, multiplexing the displays does not reduce overall power consumption: although each digit is only driven briefly the LED current must be correspondingly increased in order to achieve the same average brightness. According to the device’s datasheet the MAX7219 can deliver up to 500 mA per digit. The rapidly changing current draw can cause interference to the microcontroller’s power supply if adequate decoupling is not provided.

An advantage of the MAX7219 is that neither series resistors nor drive transistors are required. Only one external resistor is needed, which is used to set the segment current for all the digits. Since it is also possible to adjust the segment current over the SPI port, a fixed 10 kΩ resistor is suitable.

The small printed circuit board is designed to accept Kingbright SC52-11 common cathode display modules, which have a digit height of 13.2 mm. The display is available in a range of colors. If you wish to modify the board layout to suit a different display, the Eagle file is available for download from the web pages for this article [1].

A special feature of the MAX7219 is the ability to cascade multiple devices, allowing several display boards to be driven from a single microcontroller. No extra I/O pins are required on the microcontroller as the data bits are shifted through the chain of devices: the output DOUT of one module is connected to the DIN input of the next, and the LOAD and CLK signals are wired in parallel.

How do we program the device? The MAX7219 contains 16 internal registers that can be serially addressed and written to. Each seven-segment display is configured using a separate 16 bit message, where bits 0 to 7 carry the data to be displayed and bits 8 to 11 carry the register address. Bits 12 to 15 are not used.

Each bit is clocked into the device on the rising edge of the CLK signal. While the data bits are being transmitted the LOAD signal must remain low; when it goes high the message is written to the addressed register. It is not necessary for the microcontroller to have dedicated SPI hardware: a low data rate is adequate in almost all cases and so the necessary waveforms can be generated in software. The author has written suitable routines in C [1], which are easily adapted for any type of microcontroller. The routine SendCmd() is responsible for 'bit banging' the I/O ports to generate the SPI signals.

A couple of the MAX7219's registers require initialization. The mode register determines whether the internal BCD-to-seven-segment decoder is used or whether the data stored in the registers correspond directly to segment patterns. The latter option is more general but requires the use of a look-up table in the driver: in the author's source code this array is called Segments. A further register sets the total number of digits to be driven; and finally the segment current must be set and the display enabled. Once everything is initialized the digit registers can be written to using the function UpdateDisplay().

The display module is also supported by the M16C TinyBrick [2] described in the March 2009 issue of Elektor. A simple example program can be downloaded from the project website, showing how easy it is to control the display using the built-in BASIC interpreter.

(081154-I)

Internet Links

[1] www.elektor-usa.com/081154

[2] www.elektor-usa.com/080719

Downloads

081154-1: PCB layout (.pdf), from [1].

081154-11: source code, from [1].

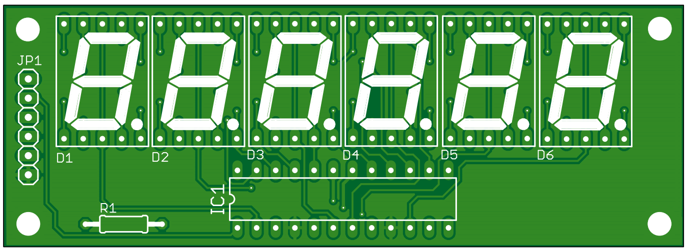
CAD files, from [1].

COMPONENT LIST

Resistors
R1 = 10kΩ

Semiconductors
D1–D6 = SC52-11 (Kingbright)
IC1 = MAX7219CNG

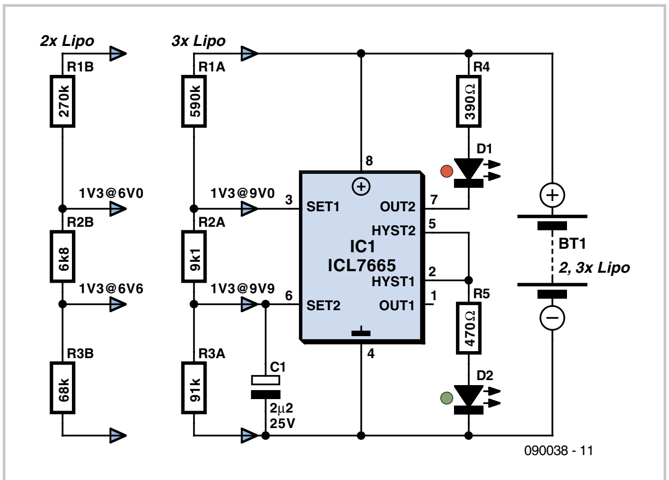
Miscellaneous
JP1 = 6-way pinheader
PCB # 081154-1 [1]



LiPo Monitor

Werner Ludwig (Germany)

The LiPo Monitor simplifies voltage monitoring of Lithium Polymer (LiPo) batteries during use. You clearly want to avoid discharging them too far and another thing on your wish list should be a warning when the permitted limit of safe discharge is approaching. A green LED remains on for all the time that the battery voltage remains adequate. If the volts drop as far as the terminal voltage level, a red LED lights to signal that further use (and discharge) of the battery will be harmful and not allowed. Before this happens, in the lower but still OK voltage range, both LEDs illuminate to warn that the end is nigh. The circuit is particularly suitable for monitoring the LiPo propulsion batteries of radio control models that are used primarily in short range operation, such as indoor model helicopters.



The ICL7665 device used in this circuit contains two comparators plus an internal 1.3 V voltage reference. Each comparator has two outputs, OUT and HYST. This enables you to monitor each of the two inputs SET1 and SET2 for over and under-voltage.

OUT1 is an inverting output, whereas the other three are non-inverting. The maximum current is 25 mA per output. OUT1 and OUT2 are current sinks (open-drain outputs of N-channel MOSFETS, source to ground). HYST1 and HYST2 are current sources (open-drain outputs of P-channel MOSFETS, source to $+U_B$). The truth table shown below provides information on the switching behaviour of the ICL7665.

The two comparators in the LiPo Monitor form a window discriminator (voltage

ICL7665 Truth Table		
SET1/SET2	OUT1/OUT2	HYST1/HYST2
USET1 > 1.3 V	OUT1 = ON = LOW	HYST1 = ON = HIGH
USET1 < 1.3 V	OUT1 = OFF = high-impedance	HYST1 = OFF = high-impedance
USET2 > 1.3 V	OUT2 = OFF = high-impedance	HYST2 = ON = HIGH
USET2 < 1.3 V	OUT2 = ON = LOW	HYST2 = OFF = high-impedance

range sensor). The battery voltage under observation is applied, via a voltage divider, to both of the inputs. The voltage dividers in this circuit are designed for situations using two or three LiPo cells and are arranged so that the warning range, in which both LEDs light together, lies between 3.0 and 3.3 volts per cell. This makes for timely charging and avoids deep discharge of propulsion batteries.

(090038-I)

Internet Link

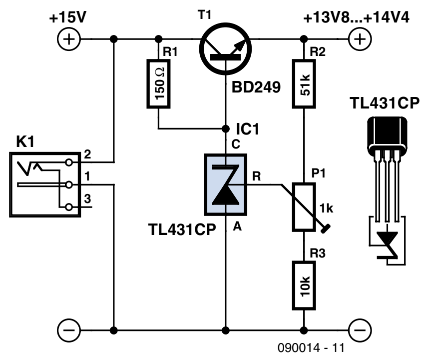
http://datasheets.maxim-ic.com/en/ds/ICL7665.pdf

Low-drop Series Regulator using a TL431

Lars Krüger (Germany)

Like the author you may keep some 12 V lead-acid batteries (such as the sealed gel cell type) in stock until you come to need them. A simple way of charging them is to hook up a small unregulated 15 V 'wall wart' power supply. This can easily lead to overcharging, though, because the off-load voltage is really too high. The remedy is a small but precise series regulator using just six components, which is connected directly between the power pack and the battery (see schematic) and doesn't need any heatsink.

The circuit is adequatele proof against short



circuits (min. 10 seconds), with a voltage drop of typically no more than 1 V across the collector-emitter path of the transistor.

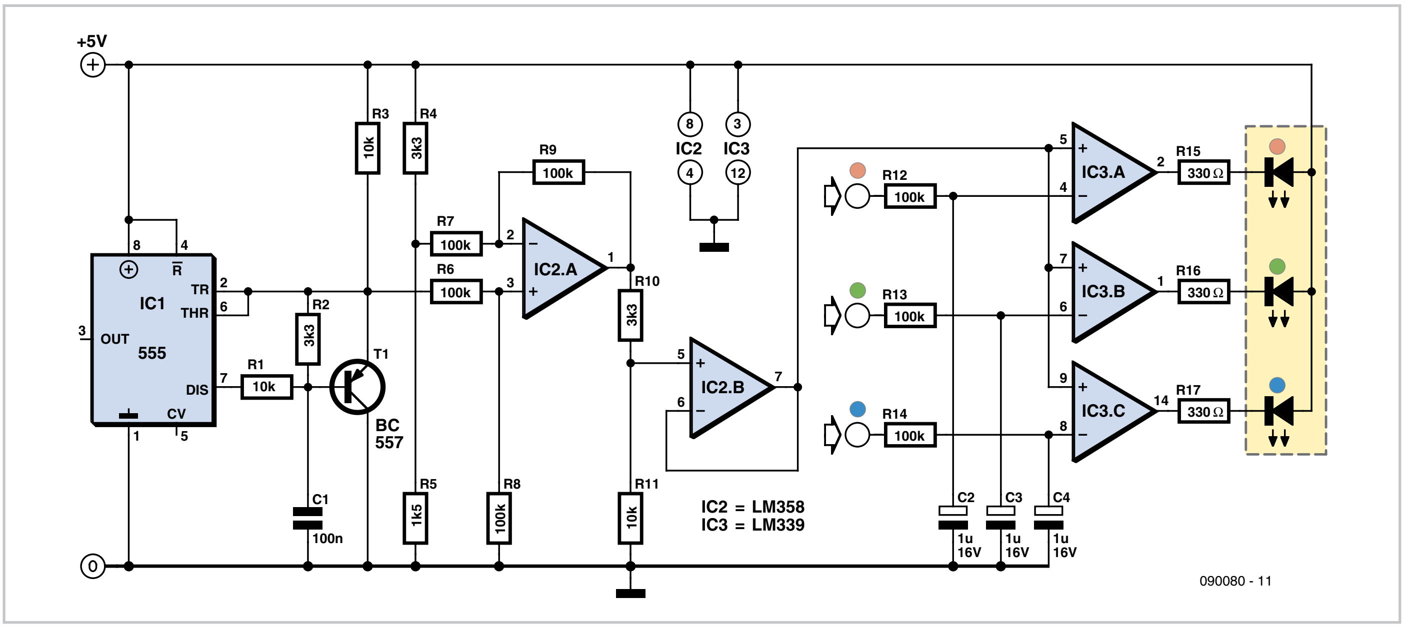
For the voltage source you can use any transformer power supply from around 12 V to 15 V delivering a maximum of 0.5 A. By providing a heatsink for T1 and reducing the value of R1 you can also redesign the circuit for higher currents.

(090014-I)

Internet Link

http://focus.ti.com/lit/ds/symlink/tl431.pdf

VGA Background Lighting



Heino Peters (The Netherlands)

More and more people are using a PC (conventional or notebook) to view films. The VGA output can be used to provide a matching 'Ambilight' effect for this. If you restrict yourself to a single RGB LED, you can also draw the power for this circuit from the VGA connector, along with the RGB signals.

The following pins of the 15-way VGA connector (three rows of five pins) are used for this circuit:

Pin 1: Red video signal
Pin 2: Green video signal
Pin 3: Blue video signal
Pin 5: GND
Pin 9: +5 V

The video signals for the red, green and blue channels are available at the RGB outputs. These signals have an amplitude of 1 to 1.35 V, and they output the screen imagery at the rate of dozens of frames per second. This produces the visible image on the screen. The circuit described here drives an RGB LED according to the average values of each of these three signals. Of course, this is not a full-fledged 'Ambilight' system, but the RGB LED will produce a nice green light during a rugby match or an orange hue if a sunset is shown on the screen.
A sawtooth generator is built around IC1 and T1. It supplies a nice sawtooth signal to opamp IC2a via R6. The frequency of the sawtooth signal is approximately 850 Hz, and its amplitude ranges from 1.6 to 3.4 V. IC2A subtracts approximately 1.6 V from this due to voltage divider R4/R5. After this, voltage divider R10/R11 reduces the peak value of the sawtooth to around 1.35 V. The resulting sawtooth signal is buffered by IC2b and used to drive the three comparators in IC3. The level of the red video signal is averaged by the R12/C2 network. IC3a constantly compares the previously generated sawtooth signal with the average value of the red video signal. If the image has a high red content, the output of IC3a will be logic Low a good deal of the time, while with a low red content it will be Low less often. This comparator circuit thus implements a PWM driver for the red LED. The same arrangement is used for the green and blue channels.

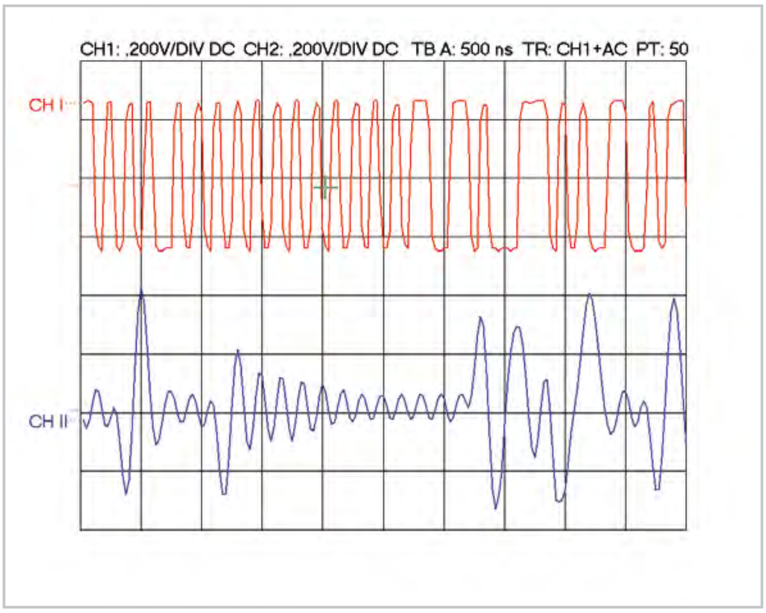
Note that with a notebook computer you always have to enable the VGA first, usually by pressing Fn-F5. If you use a desktop or tower PC, you can tap off the video signals from an adapter connected between the video cable and the monitor.
You can also use several LEDs or a LED strip (available from Ikea and other sources) in place of a single RGB LED. In this case you will need an external power supply for the LEDs, but the control circuit can still be powered from the PC. If you use multiple LEDs or a LED strip, connect the cathodes (negative leads) of the LEDs to the comparator outputs of IC3 as shown on the schematic diagram, and connect all the anodes (positive leads) to the external power supply. Resistors R15–R17 are often already integrated in the LED strip. There's no harm in using an external supply with a higher working voltage, such as 12 V. Remember to connect the ground terminal of the external supply to the ground of the control circuit.

IC3 can handle a current of 15 mA on each output. If this is not enough, swap the connections to the inverting and non-inverting inputs of the three comparators in IC3 and connect their outputs to the bases of three BC547 transistors. Connect a 10-kΩ resistor between each base and the positive supply line (+5 V). Connect the emitter of each transistor to ground, and connect the collector to the LED strip. A BC547 can switch up to 100 mA with this arrangement, and a BC517 can handle up to 500 mA.

(090080-I)

Wireless S/PDIF Connection

Ton Giesberts (Elektor Labs)



A question came to mind after the 'Hi-fi Wireless Headset' article was published in the December 2008 issue of Elektor: why don't we design a wireless S/PDIF connection? This would of course have been a very useful option (the modules in question digitise an analogue signal in the transmitter, which is then converted back to analogue by the receiver).

The idea is therefore to create a digital (in other words, lossless) connection between two devices. As a compromise we could have added an S/PDIF input to the transmitter mentioned above. However, in that case the D/A converter in the receiver would mainly determine the quality of the analog signal, and that was something we didn't want.

Amongst lots of other things, a possible solution was found on the Internet, which we wanted to try out in practice. It concerns the use of wireless audio/video modules to transfer the signal. However, no use is made of the audio section of the modules! The S/PDIF signal is connected directly to the video input of the transmitter, without modification or any extra circuitry! At the video output of the receiver you then have a copy of the S/PDIF signal — well, that is the theory.

The bandwidth of the modules we used is just enough to transfer the digital signal from a CD. We tested this with a Gigavideo 30 made by Marmitek. This is a somewhat older version, and equivalent devices shouldn't cost much more than a few tens of dollars.
To reliably transfer an S/PDIF signal from a CD player you need a bandwidth of at least 6 MHz. The minimum pulse width of an S/PDIF signal of 44.1 kHz is 177 ns. The video bandwidth of 5.5 MHz (this depends very much on the quality of the modules used) seems to be sufficient to create a usable link.

The shape of the signal at the output of the receiver no longer consists of a tidy square wave, but looks more like a sine wave. This is of course the result of the limited bandwidth available. Everything will be fine as long as the zero crossing points (or original pulse edges) haven't shifted with respect to each other. This is because an S/PDIF receiver retrieves the clock signal from the input signal with the help of a PLL circuit.

Because the edges are less steep, the receiver will be more susceptible to noise and some jitter could occur. If the edges start shifting with respect to each other it is likely that the PLL can no longer cope with the signal. The quality of the connection is therefore not as good as that provided by a coaxial cable, but for those of you who don't want to lay a cable, between two floors for example, this is obviously a cheap alternative!

Something that should also be taken into account is that walls can significantly reduce the maximum distance between the transmitter and receiver. In our lab are two areas that are partially divided by a 1-metre (3 feet) thick brick wall. When this wall was between the transmitter and receiver the maximum range was reduced to barely two metres (6.5 ft).

We decided to test the circuit with an S/PDIF signal with a sample frequency of 96 kHz (DVD with 24-bit audio). The minimum pulse width for this signal is only 81 ns. This would seem to be too short to be transferred reliably by the modules. The oscillogram shows the signal at the input of the transmitter (top waveform) and the output from the receiver. This shows clearly how the shorter pulses are attenuated (the bottom waveform has been delayed by about 440 ns compared with the top one).

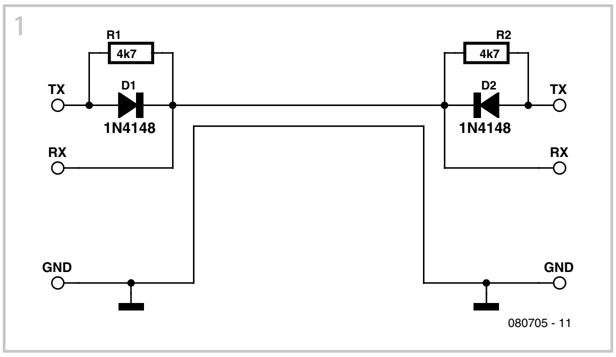
We tried adding a frequency dependent amplifier to compensate for the restricted bandwidth, but the amplitude of the attenuated pulses could not be increased enough without affecting the phase of the pulses. We found out that the S/PDIF receiver just couldn't cope with this 'improved' signal at all.

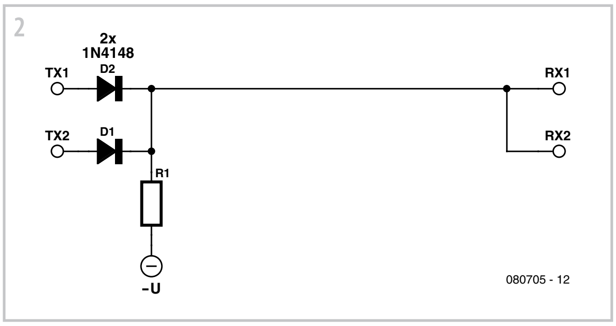
(081034-I)

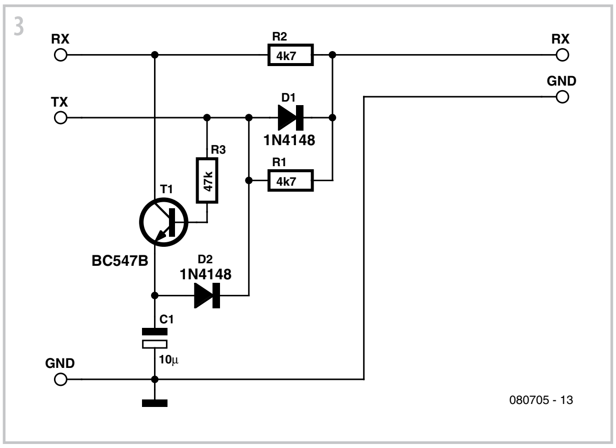
One Wire RS-232 Half Duplex

Andreas Grün (Germany)

Traditional RS-232 communication needs one transmit line (TXD or TX) and one receive line (RXD or RX) and a Ground return line. The setup allows a full-duplex communication; however many applications are using only half-duplex transmissions, as protocols often rely on a transmit/acknowledge scheme.
With a simple circuit as shown in **Figure 1** this is achieved using only two wires (including Ground). This circuit is designed to work with a 'real' RS-232 interface (i.e. using positive voltage for logic 0s and negative voltage for logic 1s), but by reversing the diodes it also works on TTL based serial interfaces often used in microcontroller designs (where 0 V = logic 0; 5 V = logic 1). The circuit needs no additional voltage supply, no external power and no auxiliary voltages from other RS-232 pins (RTS/CTS or DTR/DSR).
Although not obvious at a first glance, the diodes and resistors form a logic AND gate equivalent to the one in **Figure 2** with the output connected to both receiver inputs. The default (idle) output is logic 1 (negative voltage) so the gate's output follows the level of the active transmitter. The idle transmitter also provides the negative auxiliary voltage –U in Figure 2. Because both receivers are connected to one line, this circuit



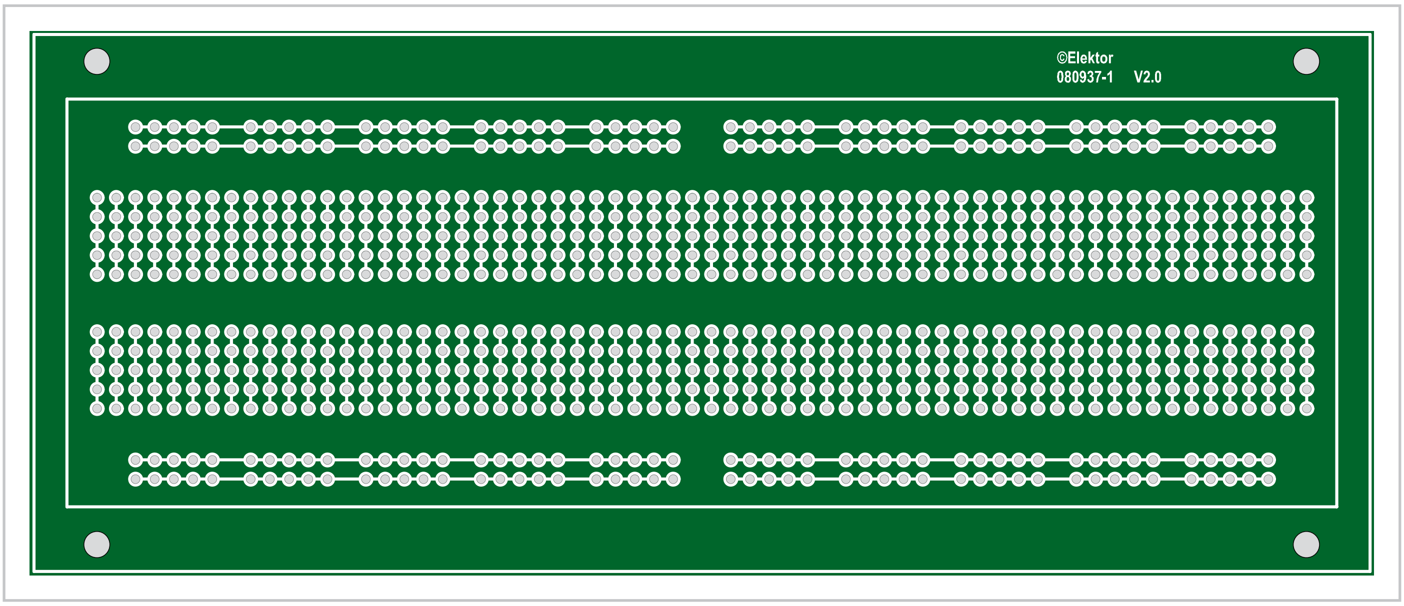




generates a local echo of the transmitted characters into the sender's receiver section. If this is not acceptable, a more complex circuit like the one shown in **Figure 3** is needed (only one side shown). This circuit needs no additional voltage supply either. In this circuit the transmitter pulls its associated receiver to logic 1 (i.e. negative voltage) by a transistor (any standard NPN type) when actively sending a logic 0 (i.e. positive voltage) but keeps the receiver 'open' for the other transmitter when idle (logic 1). Here a negative auxiliary voltage is necessary which is generated by D2 and C1. Due to the start bit of serial transmissions, the transmission line is at logic 1 for at least one bit period per character. The output impedance of most common RS-232 drivers is sufficient to keep the voltage at C1 at the necessary level.
Note: Some RS-232 converters have quite low input impedance; the values shown for the resistors should work in the majority of cases, but adjustments may be necessary. In case of extremely low input impedance the receiving input of the sender may show large voltage variations between 1s and 0s. As long as the voltage is below –3V at any time these variations may be ignored.

(080705-I)

Breadboard/Perfboard Combo



Based on an idea from Luc Heylen (Belgium)

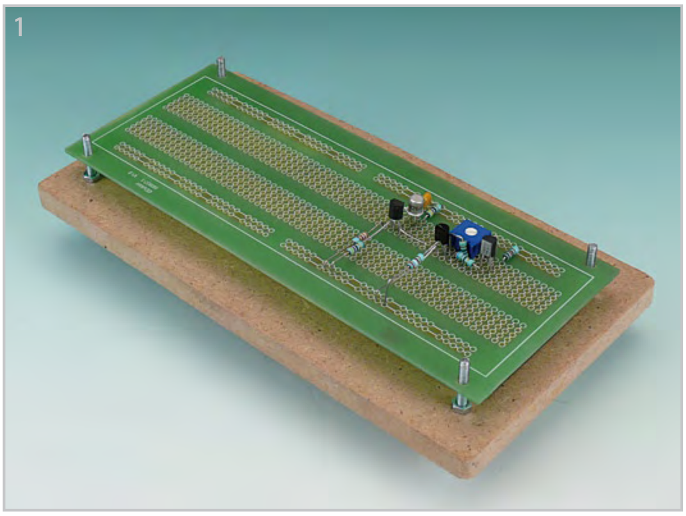
Electronic hobbyists and engineers often use breadboards to experiment with small circuits. A breadboard consists of a thick strip of plastic with an array of holes and embedded metal contact strips that interconnect individual rows of holes. A few long rows extending over the entire length are located along the sides; they can be used for supply voltages. With this arrangement of holes and strips, you can plug all sorts of electronic components (including ICs) into the breadboard and build a circuit by interconnecting them as desired with short lengths of wire. Of course, we don't have to explain this to most of our readers, since they have probably used a breadboard occasionally.

The advantage of a breadboard is that you can try out different ideas to your heart's content without having to use a soldering iron every time you make a change. It's also a lot easier to see what you're doing than when you build a circuit on a piece of perfboard, where the wiring on the copper side can quickly turn into a rat's nest that isn't so easy to sort out when you want to make changes.

Of course, breadboards also have their disadvantages. They can't be used for RF circuitry, which is something you always have to consider. The spring contacts also tend to wear or weaken over time, which can lead to poor connections. Despite these disadvantages, breadboards are especially convenient and affordable tools for electronic designers.

If you do a lot of work with a breadboard, you are often faced with the problem that after you have managed to build and test a circuit that works the way it should, you have to take it all apart and rebuild it on a piece of perfboard because the circuit has to be used somewhere right away. In such cases, leaving the circuit in its breadboard form is not a long-term option.

The person who thought up the idea described here, who is a fervent breadboard user, encountered this problem regularly and came up with the following solution. Make a printed circuit board with the same layout, hole spacing and interconnections as a standard breadboard. Secure this PCB on top of the breadboard, and then plug the components and interconnecting wires through the holes in the PCB, mounting them the same way as you would normally do with the breadboard (**Photo 1**). Use slightly longer component leads and wire ends than usual, due to the extra thickness of the PCB. Fit ICs in sockets with extra-long pins (wire-wrap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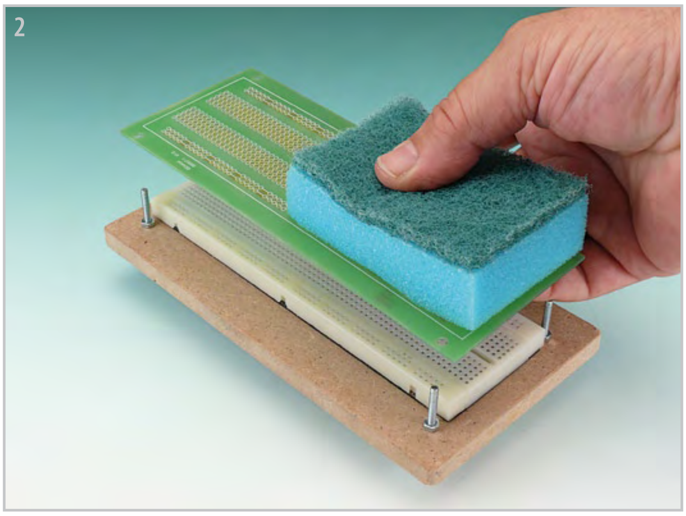

2

pins). In a circuit built using this arrangement, the contact strips in the breadboard provide the interconnections, so there's no need for soldering.

Once the circuit is finished and works the way it should, you don't have to rebuild it before you can use it somewhere else. Press a sponge or a bag filled with styrofoam particles on top of the circuit (**Photo 2**) and clamp it securely in place (**Photo 3**). After this, you can pull the PCB with the components free from the breadboard, turn it over, and then trim all the leads protruding from the copper side and solder them in place (**Photo 4**). The interconnections are exactly the same as on the breadboard.

To make it easy to work with this combination of a breadboard and a PCB, it's a good idea to mount the breadboard on a piece of wood with four long M3 screws arranged to fit exactly through the corner holes of the printed circuit board. This way you can mount the PCB precisely and securely on top of the breadboard.
For the breadboard, we used a type SD12N from Velleman [1], which is carried by a number of electronics retailers. Note that other types of breadboards may have different dimensions or contact arrangements, which means that they cannot be used with the PCB layout shown here.

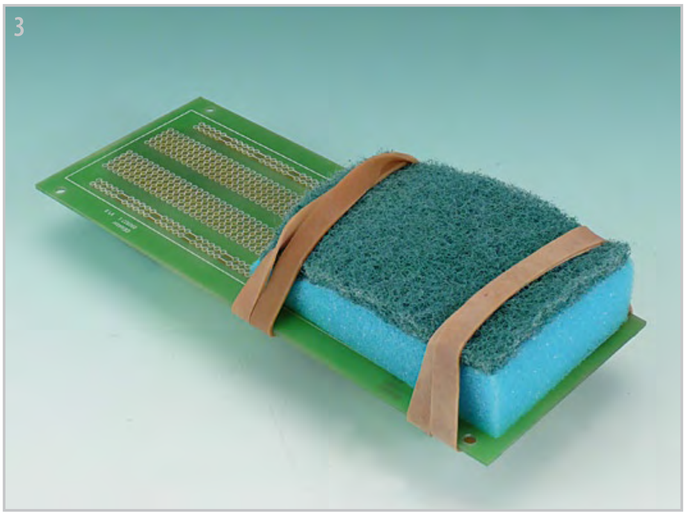
(080937-I)

Internet Link

[1] www.velleman.be/nl/en/product/view/?id=40573

Download

080937-1: PCB layout (.pdf), from www.elektor-usa.com/080937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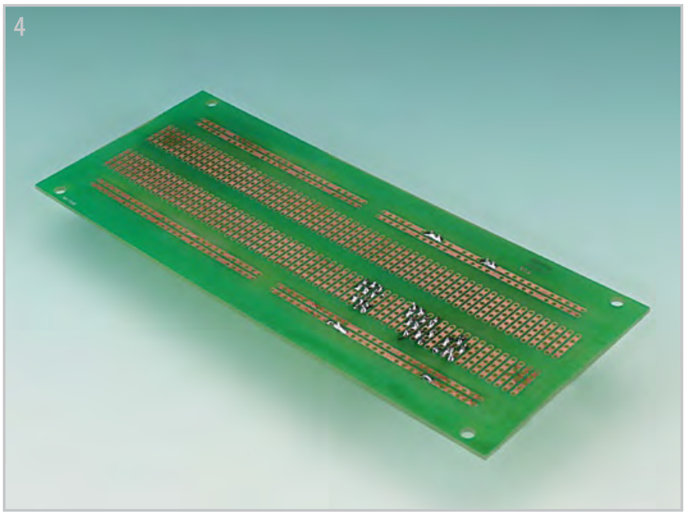
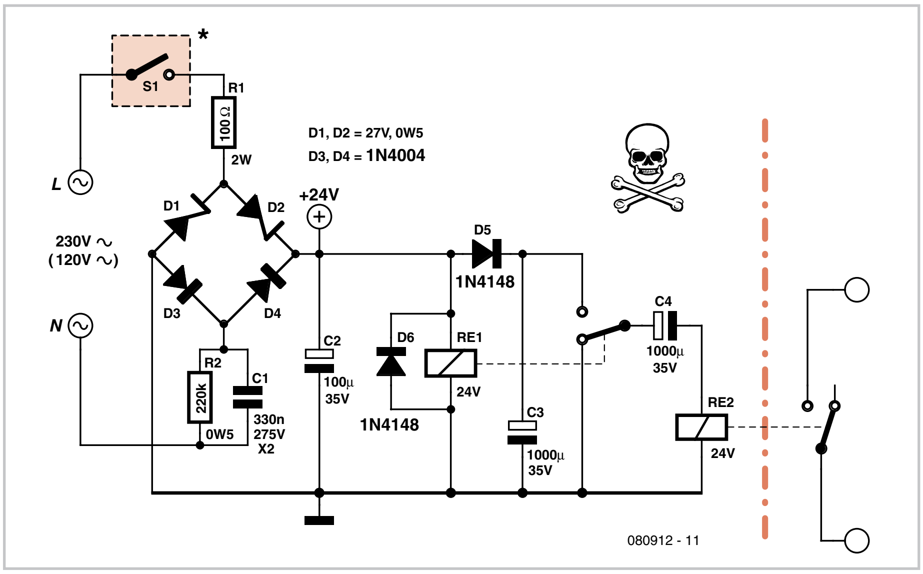

4

Momentary Action with a Wireless Switch

Matthias Haselberger (Germany)

Many different types of wireless switch modules with a relay for switching AC power loads are commercially available. However, some applications require a short On or Off pulse, such as is provided by a momentary-action (pushbutton) switch. Here we describe a solution that simulates a pushbutton switch with a standard wireless switch. A supplementary circuit converts the switch module into a remotely controllable momentary-action switch.
In the supplementary circuit, S1 is the switching contact of the relay in the wireless switch module. This contact energises a 24-V power supply connected directly to the AC power outlet, consisting of a bridge rectifier (D1–D4) with a series resistor (R1), a series capacitor (C1), and a charging capacitor (C2). The two Zener diodes in the bridge rectifier (D1 and D2) limit the DC voltage on C2 to approximately 24 V.
When the wireless switch module closes contact S1, 24 VDC is applied to the coil of relay RE1, which closes. At the same time, capacitor C3 charges via D5. When the contact of RE1 switches, capacitor C4 provides the charging current for C3. The charging current flows through the coil of RE2, which remains actuated as long as the current is sufficiently large. The current decreases as the voltage on C4 rises, with the result that RE2 drops out and the contact of RE2 (the 'momentary' contact) opens again.

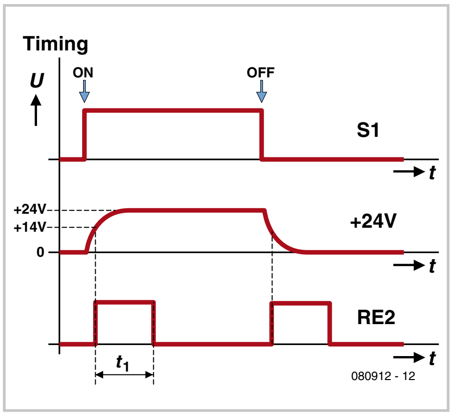


S1 opens when the relay in the wireless switch module is de-energized, which causes RE1 to drop out shortly afterward and connect capacitor C4 to ground. The capacitor discharges through the coil of RE2, causing its 'momentary' contact to be actuated again. The timing diagram shows the switch-on and switch-off sequences of the wireless switch (S1 contact).

The duration of the 'button press' (engagement time of RE2) depends on the capacitance of C3 and C4. The equation $Q = C \times U = I \times t$ can be used to calculate suitable capacitor values for a specific hold time (t_1 in the timing diagram) with a given relay current. The value shown in the circuit diagram (1000 µF) corresponds to a hold time of 1 second with a relay current (holding current I_H) of 10 mA:

$C = I_H \times t_1 / U = (0.01\ \text{A}) \times (1\ \text{s}) / 10\ \text{V} = 1000\ \mu\text{F}$.

A reed relay cannot be used for RE2 because the voltage across the coil reverses. This also

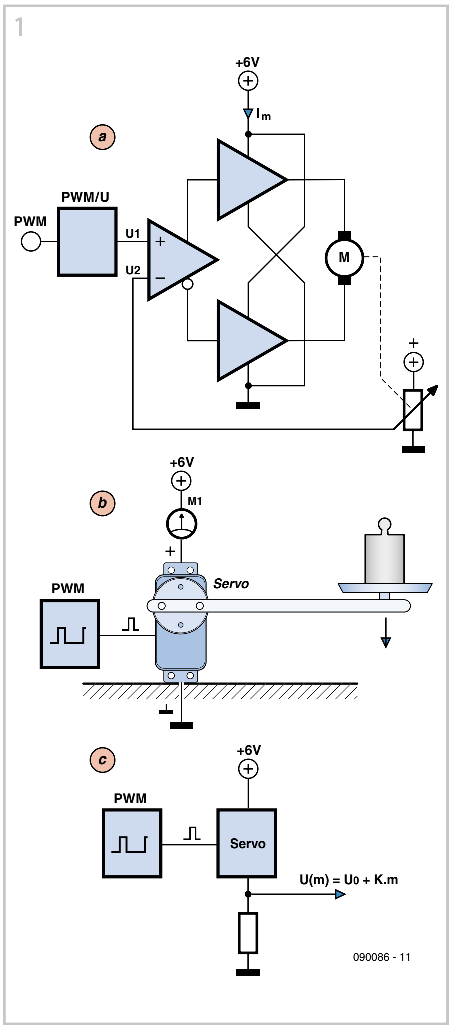


means that a free-wheeling diode cannot be used, but it is anyhow not necessary due to the slow discharge of C4. RE2 should be a 'Class II' relay (such as the Omron G6D-1A-ASI 24DC) to provide adequate insulation of the switch contact. RE1 does not have to be a Class II relay. Due to the presence of AC power line voltage, R1 and R2 must have a rated working voltage of 250 V (150 V), although they can also be formed from two resistors with half this rated working voltage connected in series, each with half of the specified power rating. In this case, R1 consists of two 47 Ω / 1 W resistors and R2 of two 100 kΩ / 0.25 W resistors. Readers on 120 VAC 60 Hz AC networks should change C1 into 680 nF.

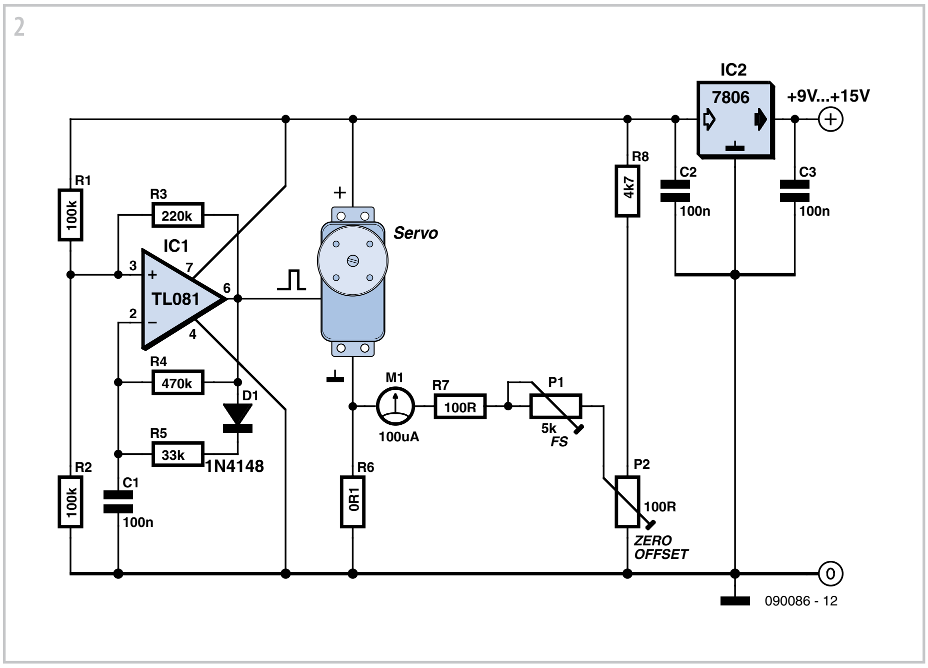
The circuit can be fitted in a plastic enclosure with an integrated AC power plug, which can easily be plugged into the wireless switch module. The contact of RE2 can then be fed out to a terminal strip as a floating contact. For adequate AC isolation, a safety clearance of at least 6 mm (air and creepage paths) to other conductors must be maintained, in addition to using a Class II relay.

(080912_1)

Servo Scales



Gert Baars (The Netherlands)



With a bit of adeptness, you can build an electronic scales based on a servo motor. Depending on the type of servo you use, it can measure weights of up to around 10 pounds (just under 5 kilograms) with reasonable accuracy.

If you examine the operating principle of a servo motor in more detail (**Figure 1a**), you can see that in simple terms, it consists of a control loop that uses a potentiometer to convert the motor position to a voltage that is compared to the voltage from a PWM converter. Based in this information, the motor is rotated so that its measured position corresponds to the desired position (U2 = U1).

As can be seen from **Figure 1**, all you need for a scales based on a servo motor is a square-wave oscillator that supplies a signal at a constant frequency of around 50 Hz with a fixed duty cycle of approximately 10%. This defines a fixed setting for the position of the motor axle. If a mechanical force tries to rotate the motor axle in this situation, the servo control loop adjusts the drive signal to the motor to counteract the rotational force. The motor thus has to supply an opposing force, and that costs power, with the result that the current through the motor increases. With a type RS-2 servo, this current can rise to as much as 1 A, while the quiescent current is no more than a few dozen milliampères. If you attach an arm to the motor axle and fit it with a weighing pan, and then connect an ammeter in the servo supply line, you have a sort of simple electronic scales. The scales can be calibrated using a reference weight, with the length of the arm set to produce a certain amount of current with a certain weight, such as 0.25 A with 1 lb. Two pounds would then draw 0.5 A, and so on.

The scales can also generate a voltage output if you measure the voltage across a sense resistor in series with the ground lead of the servo (**Figure 1c**). Due to the quiescent current consumption of the servo motor with no load, this voltage is not zero with no weight on the scales, but it is low compared with the value with a certain amount of weight. Naturally, this offset can be compensated by using an instrumentation amplifier. This increases the accuracy, and you could even consider equipping the scales with a digital readout.

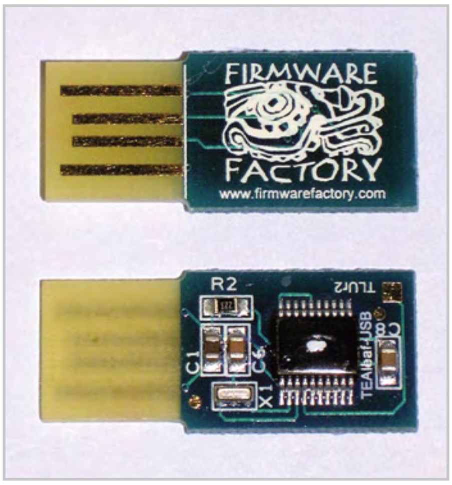
Figure 2 shows a simple finished version with a PWM oscillator and analog readout. The two potentiometers can be used to adjust the offset and weighing range. The length of the scale arm multiplies the torsion on the servo motor due to the weight. Doubling the arm length reduces the weighing range by half and thus doubles the accuracy, but it also increases the zero offset due to the weight of the arm. In practice, an arm length of around 10 cm (4 inches) proved to be a good compromise.

(090086-I)

Driver Free USB

Richard Hoptroff (United Kingdom)

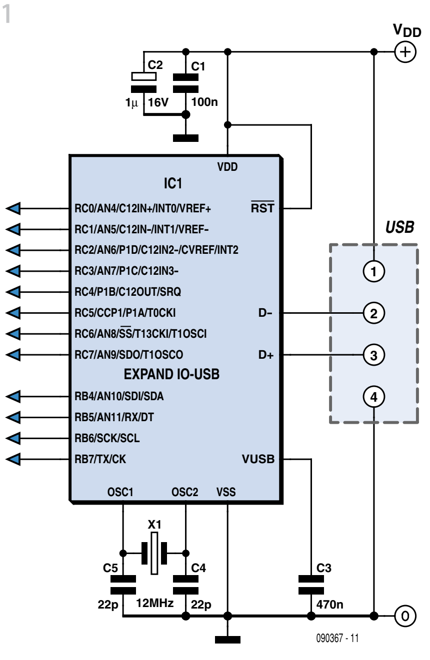
USB (universal serial bus) was supposed to solve a lot of problems when connecting devices to PCs, but in many ways it's still a bit of a pain in the plughole. Typically, each new device needs a new driver to be installed. Often, a COM port then gets assigned, and you have to find out from the operating system what the COM port number is. And with some products, that COM port number can change if you plug it into a different socket!



A sneaky way round the driver problem is to use the Human Interface Device (HID), as used by mice and keyboards, or the Mass Storage Device (MSD) interface, as used by flash drives. This is because just about all the flavors of Windows, Mac and Linux operating systems available today have HID and MSD drivers pre-loaded. HexWax Ltd. have adopted this approach for their driver-free USB chip sets. Their USB to UART, SPI and I²C bridges use the HID interface and their embedded file system and data logger chips use the MSD interface.

A particularly flexible friend is called 'expandIO-USB'. As its name suggests, it is an I/O expander with a USB interface. But that's a modest description, considering its analog-to-digital inputs, interrupts, PWM, comparators, counters, timers, SPI, I²C, UNI/O, etc. The USB interface is designed so that all the programming is done on the PC rather than on the chip, which saves a lot of development time.

1



For example, to measure the analog voltage on AN6, you send the following 4-byte command from the PC (*0x* prefix denotes hexadecimal):

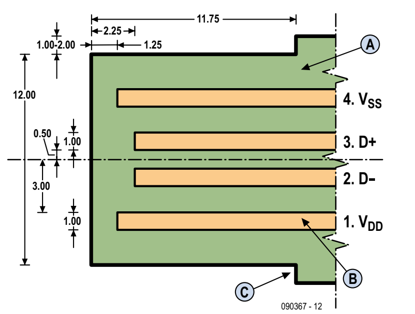
0x96 0x06 0x00 0x00

The chip takes the measurement and reports the result as a 4-byte response: *0x96 0x06 0x02 0x36*.

In this example, the voltage measured is 5 V × *0x0236* ÷ *0x03FF* = 2.76 volts. Similarly, the following command exchanges three bytes with a slave SPI device:

0xAF 0x03 0x45 0x67 0x00. Command: Send *0x45 0x67 0x00* to slave.

2



0xAF 0x03 0x00 0x00 0x89. Response: Slave sent *0x00 0x00 0x89*.

The commands are sent using the operating system's HID interface, which is very similar to reading and writing to a file. Example source code is provided at [1].

In the basic circuit of the driver, **Figure 1**, only a crystal and filter capacitors are required in addition to the 'expandIO-USB' chip also described in some detail at [1]. Although it is available as a through-hole device, the surface mount version has the advantage that it is small enough for 'dongle'-style applications as shown in **Figure 2**. Surface mount USB plugs can be quite difficult to source, but an elegant, zero-cost solution exists. You can design one into the printed circuit board itself, so long as you don't mind a PCB 2.0–2.20 mm thick including tracks (arrow 'A' in Figure 2) for the dimensions. For best reliability, the PCB contacts ('B') should be plated with hard gold flash (0.25-1.27 µm) over nickel (2.6-5.0 µm). Finally, shoulders ('C') are required to prevent over-insertion force. The overall PCB width should be 16.00 mm or less.

(090367-I)

Internet Link

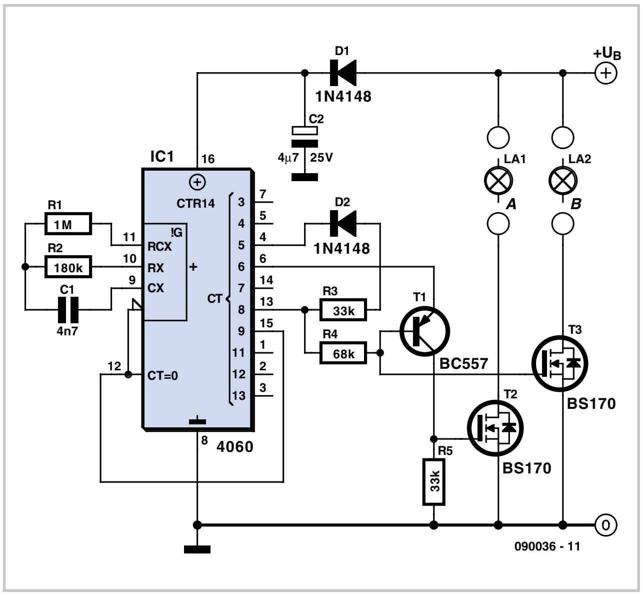
[1] www.hexwax.com

Lighting Up Model Aircraft

Werner Ludwig (Germany)

This circuit provides aircraft modellers with extremely realistic beacon and marker lights at minimum outlay. The project's Strobe output (A) provides four brief pulses repeated periodically for the wing (white strobe) lights. In addition the Beacon output (B) gives a double pulse to drive a red LED for indicating the aircraft's active operational status. On the prototype this is usually a red rotating beacon known as an Anti-Collision Light (ACL). The circuit is equally useful for road vehicle modelers, who can use it to flash headlights and blue emergency lights.

All signals are generated by a 4060



14-stage binary counter and some minimal output selection logic. Cycle time is determined by the way the internal oscillator is configured (resistor and capacitor on pins 9/10) and can be varied within quite broad limits. High-efficiency LEDs are your first choice for the indicators connected to the Beacon and Strobe outputs (remember to fit series resistors appropriate to the operating voltage Ub and the current specified for the LED used).

The sample circuit is for operating voltages between 5 and 12 V. Current flow through the two BS170 FET devices must not exceed 500 mA.

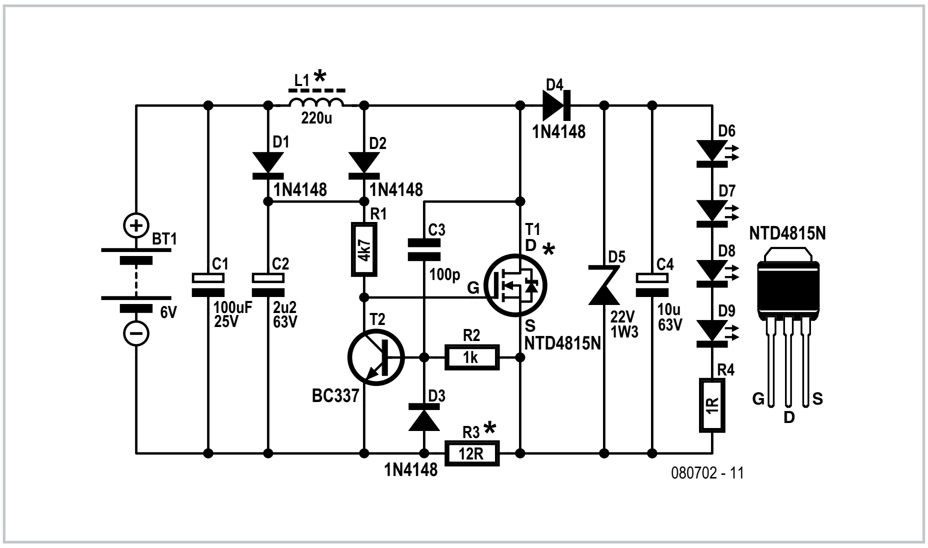
(090036-I)

LED Bicycle Lights

Ian Field (United Kingdom)

Before getting started an acknowledgement is due, the circuit presented here uses an ingenious method of controlling a flyback converter by the voltage developed on a current sensing resistor; this was published by Andrew Armstrong in the July 1992 issue of ETI magazine.

The reworked circuit is quite simple. At the instant that power is applied only a small current flows to charge C4 so insufficient voltage is developed on R3 to switch T2 on. Also, D1 allows C2 to charge from the 6 V battery, so R1 feeds enough voltage to switch on T1 — this shunts the voltage across L1 and the current in it starts to rise. At a certain point the current which returns via R3 will develop sufficient voltage to switch on T2 which shunts the gate voltage to T1 causing it to switch off, initiating the flyback voltage from L1. The flyback pulse forces a current around the circuit, charging C4 and feeding the LEDs. As the return current is via the current sensing resistor R3, this keeps T2 turned on and T1 turned off, so the flyback phase is not clamped until it has given up all its energy. Capacitor C3 provides positive feedback to ensure reliable oscillation and sharpen up the switching edges. Components D1, D2 & C2 form a bootstrap boost circuit for the MOSFET gate, although it is logic level it only guarantees the stated $R_{D\text{-}S(on)}$ at a V_g level of about 8 V — by happy coincidence the combined V_f of



four ultrabright red LEDs is about 8.8 V and this is the value that the output is normally clamped to.

There are some notes on the components specified. For position T1 an n-channel MOSFET with a very low $R_{D\text{-}S(on)}$ of 15 mΩ (at 10 V) Is suggested, although its high I_D rating (35 A) is not strictly necessary. Purists may wish to use Schottky barrier diodes for D2 and D4, but a quick look at the data sheet for the popular BAT85 shows that with a T_{rr} of 4 ns it is not actually any faster than the 1N4148. It is doubtful whether the lower V_f would make any noticeable difference.
Zener diode D5 has been included as a safety measure in case the output should ever find itself open circuit. The flyback converter can develop a quite impressive voltage when run without load and would have no difficulty damaging the MOSFET. If a higher voltage MOSFET is used then C4 could easily fall prey to excessive voltage if the lead to the LED breaks. In the final working prototype D5 was a 1.3-watt 22-volt zener, but any value between 18 and 24 V is fine. Bear in mind that with four white LEDs on the output the voltage will be somewhere in the region of 13 V.
L1 is a 9 mm diameter 0.56 A 220 µH inductor with a low DC resistance (Farnell # 8094837); don't even think about using those small axial lead inductors disguised as resistors — even the fat ones last only a few seconds before failing with shorted turns.
On R3, this resistor is selected depending on the configuration of LEDs. A value of 20 mA is fairly typical for 5 mm LEDs, on this basis four red LEDs will need about 12 Ω; five red LEDs about 10 Ω, and four white LEDs about 6.8 Ω. Resistor R4 (1 Ω 1%) is provided to use as a temporary connection for the LEDs' negative lead so the volt drop can be measured to indicate the current flowing during setting the correct LED current by adjusting R3.
The efficiency of the circuit depends on the LED current, which also determines to some extent the switching frequency. At 10 mA (4 white LEDs) 170 kHz was measured on the prototype — and that's about the maximum normal electrolytic capacitors are able to withstand. If more current is drawn (e.g. three white LEDs at 30 mA) then the switching frequency drops to about 130 kHz and the efficiency rises to around 75%.

The circuit is simple enough to construct on stripboard, which can be built as a single or double unit to suit whatever lamp housings are ready to hand. The double unit should fit comfortably in a 2x D cell compartment and the single board is only a whisker bigger than a single C cell.

Suggested lamp housings are the Ever Ready and the Ultralight but there should be many others that can be modified to house the stripboard. In many cases the hole for the bulb will need 4 notches cut with a round file so that the LEDs can be pushed far enough through. These can be secured in place with a spot of hot melt glue.

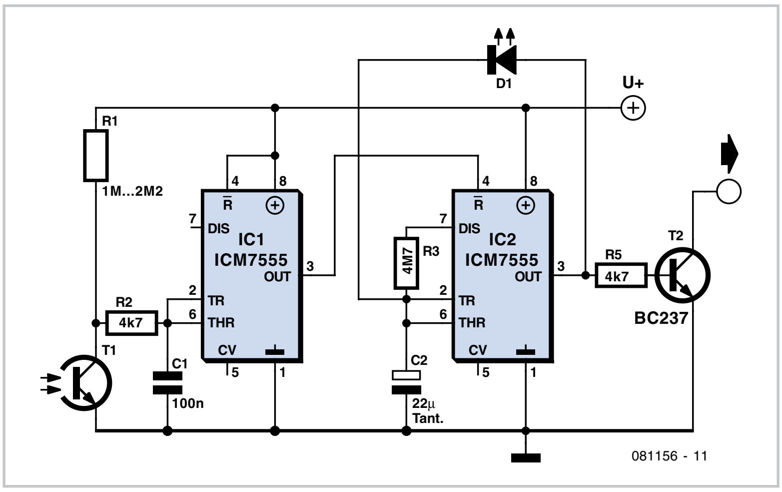
The battery and switch box can be surprisingly challenging, the unit built for a family member went on a bicycle with a wire basket so it was easy to bolt a Maplin ABS project box to that. With only the tubular frame to fix things onto, it's not so easy. The author's battery box for the present project is an old Halfords lamp — the one that drops into a U shaped plastic clip that does nothing to deter thieves, but it's far more secure when cut down to make a battery box and clamped to the handlebar with a jubilee clip. It easily holds a 6 V 1.3 Ah SLA battery from Maplin but any nominal 6 V type can be used as per individual preference. Deep discharging should be prevented.

Please Note. Bicycle lighting is subject to legal restrictions, traffic laws and, additionally in some countries, type approval.

(080702-I)

Remote Washing Machine Alert

Götz Ringmann (Germany)



It is often the case these days that the washing machine and tumble dryer are installed in an outbuilding or corner of a garage. This not only makes the kitchen a much quieter place but also leaves room for a dish washer and gives additional cupboard space. The problem now is how to tell when the wash cycle is finished. In bad weather you don't want to make too many fruitless trips down the garden path just to check if the wash cycle is finished. The author was faced with this problem when he remembered a spare wireless door chime he had. With a few additional components and a phototransistor to passively detect when the washing machine's 'end' LED comes on, the problem was solved.

C1 smoothes out any fluctuations in the LED light output (they are often driven by a multiplex signal) producing a more stable DC voltage to inputs 2 and 6 of IC1. The circuit is battery powered so the CMOS version of the familiar 555 timer is used for IC1 and IC2. The output of IC1 (pin 3) keeps IC2 reset (pin 4) held Low while there is no light falling on T1. When the wash cycle is finished the LED lights, causing T1 to conduct and the voltage on C1 starts to fall. Changing the value of R1 will increase sensitivity if the LED is not bright enough.
When the voltage on C1 falls below 1/3 of the supply voltage IC1 switches its output (pin 3) High, removing the reset from IC2. T2 conducts and LED D1 is now lit, supplying current to charge C2. When the voltage across C2 reaches 2/3 supply IC2 switches its output Low and C2 is now discharged by pin 7 via R3. The discharge time is roughly one minute before the transistor is again switched on. The process repeats as long as light is falling on T1.

Transistor T2 is a general-purpose small signal NPN type. The open collector output is wired directly in parallel with the bell push (which still functions if the transistor is not switched on). Ensure that transistor output is wired to the correct bell push terminal (not the side connected to the negative battery terminal).

Each timer consumes about 60 µA quiescent and the circuit can be powered from the transmitter battery. Alternatively a 9 V battery can be substituted; it has much greater capacity than the original mini 12 V battery fitted in the bell push.
Before you start construction, check the range of the wireless doorbell to make sure the signal reaches from the washing machine to wherever the bell will be fitted.

(081156)

Freezer Trick

Reuben Posthuma (New Zealand)

There are a number of explanations to why putting devices in the freezer often repairs them. Firstly, cooling PCBs down to freezer-level temperatures can often repair dry joints, because of the effects of expansion/contraction due to temperature change. Although the wholesome effect of a night in the freezer may be temporary, it may help you track down rare or otherwise elusive errors in circuits.
Secondly, with rechargeable batteries on boards, the cold temperatures basically cause the cell(s) to do a complete discharge cycle,

which effectively resets corrupted memory by causing a complete 'factory' reset to be performed.

Thirdly, the low temperatures can (sort of) rejuvenate the chemicals in the battery, which results in a 'good as new' battery!

Although any or all of the above explanations may be refuted scientifically, the 'he who dares, wins' approach prevails. In other words, no harm in giving it a try.

Be sure to use good quality plastic bags to securely package circuit boards, components or batteries before putting them into the freezer. This will eliminate any risk of contaminating foodstuffs.

(090205)

LEDify It!

Mobile 3-watt LED Lamp

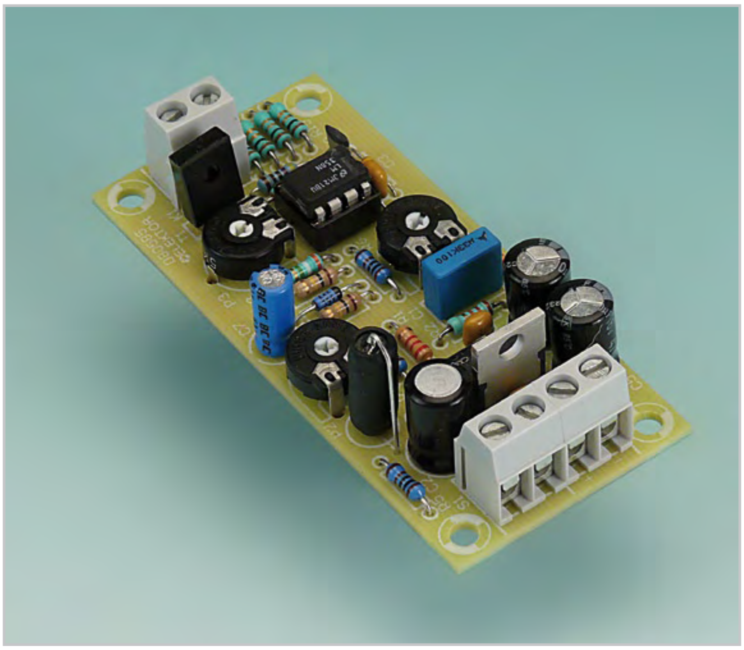
Jürgen Stannieder (Germany)

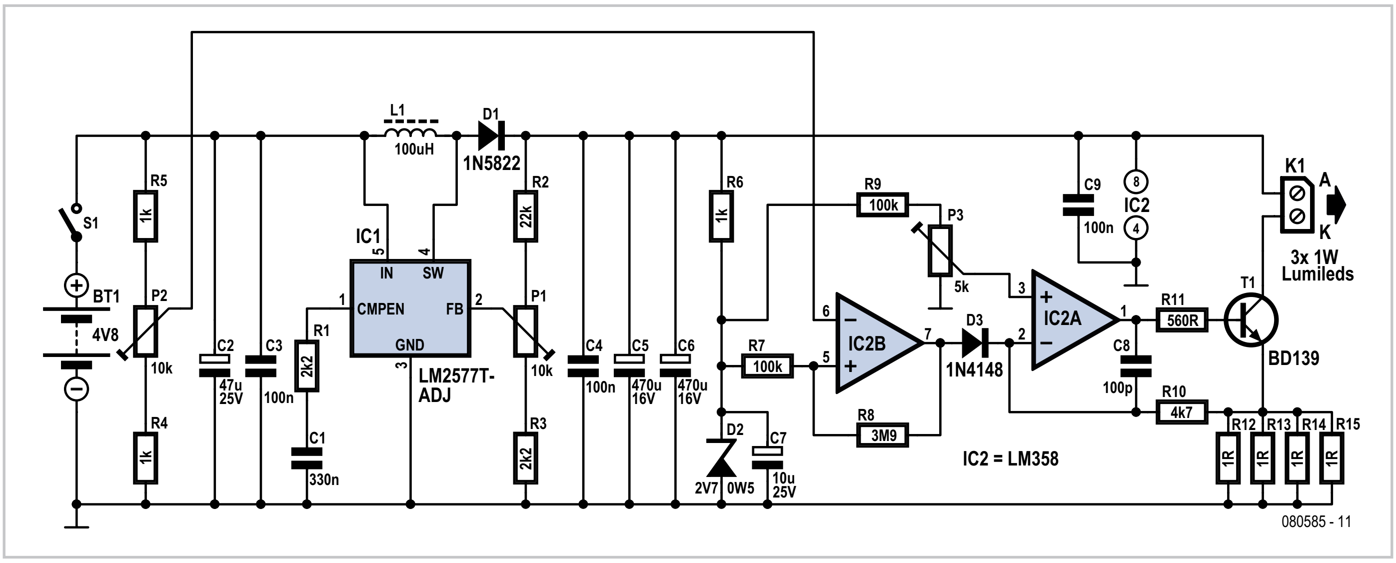
A traditional hand-held flashlight could hardly be described as a cutting-edge piece of technology; in fact it's probably the exact opposite, circuits don't come much simpler! Text books have for years used a battery, light bulb and switch to describe just what a circuit is. We are also aware of the shortcomings of the filament lamp; the light dims as the battery discharges and occasionally you need to replace a burned-out bulb. Why not treat an old flashlight to a 21st century make-over? Replace the bulb with more efficient LEDs, the 5 mm 70 mW types will not be very illuminating but 1-watt white LEDs are now reasonably priced.

It's not quite as simple as removing the bulb and replacing it with an LED. Unlike a filament bulb an LED exhibits differential resistance i.e. its resistance depends on the applied voltage. It is necessary to supply it with a constant current. This can be achieved (approximately) by using a series resistor but power loss in the resistor reduces efficiency. Also, light output will decrease as the battery voltage sinks. The LEDify design solves both these problems: firstly, a switching regulator reduces losses and maintains a constant light output as the battery voltage falls. Secondly, an adjustable constant current source maintains stable operating conditions for the LEDs.
The LM2577T-ADJ step-up voltage regulator [1] forms the centre point of the design. Together with coil L1 and the flywheel diode D1 it boosts the input voltage from 4.8 V up to 10 to 12 V. The 4.8 V input is provided by four NiMH rechargeable batteries connected in series while the 10 to 12 V output is used to power three series connected white

Features

- Three 1 W LEDs powered from 4.8 V
- Efficiency > 80 %
- Light output independent of battery voltage
- Battery deep-discharge protection





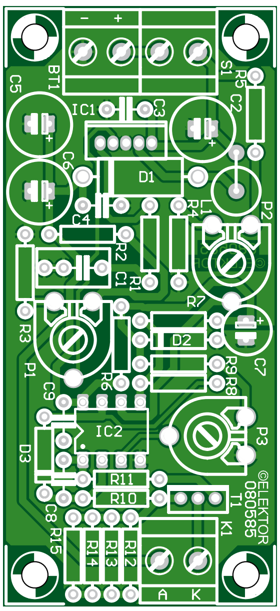
LEDs. One half of the dual op amp IC2 forms an adjustable current source while the other half switches the light off when the supply voltage sinks too low to avoid discharging the cells too much.

IC2A is configured to generate a constant current. Zener D2 supplies a reference 2.7 V at its cathode which is divided by the R9/P3 network to supply an adjustable voltage of 0 to 128 mV to the non-inverting input of IC2A. IC2A controls T1 so that the voltage at its inverting input, produced by the voltage drop across the resistors R12 to R15, is the same as at its non-inverting input. The adjustment range of P3 produces a current of between 0 and almost 0.5 A through the 0.25 Ω resistor formed by the four parallel 1 Ω resistors. The typical operating current of a 1-watt LED is around 350 mA, this produces a voltage of 88 mV across the four parallel resistors. With the LM358 even with the input at zero there will be an output voltage of 0.6 V so with P3 at a minimum a few milliamps will still be flowing through the LEDs.

The LEDs are turned off when the battery voltage falls too low, IC2B comparing a proportion of the battery voltage via P2 with the reference voltage on D2. If the battery voltage is below the reference voltage the output of IC2B will go high and the current source IC2A will be switched off. The circuit still draws a few milliamps when under-voltage is triggered so a good lower threshold to set is around 1 V per cell. With four cells P2 should be adjusted so that the LEDs switch off when the battery voltage falls below 4 V.

The adjustment range on P2 produces a voltage of around 3 V to over 10 V. Although four cells are shown in the diagram the circuit can accommodate anything from three to six. Do not use more than six cells when driving three LEDs in series, the input voltage would produce excessive dissipation in IC1 which can result in the battery voltage being applied directly to L1 and D1. The voltage step-up function of IC1 ensures that the cathode of D1 is at a higher voltage than the anode so D1 is not conducting. When the IC output switches, energy stored in L1 is converted into a higher voltage but lower current passing through D1 and then stored on capacitors C5 and C6. The 52 kHz switching frequency gives a stable output voltage with very little ripple.

IC1 reads the feedback voltage measured



COMPONENT LIST

Resistors
R1,R3 = 2kΩ2
R2 = 22kΩ
R4,R5,R6 = 1kΩ
R7,R9 = 100kΩ
R8 = 3MΩ9
R10 = 4kΩ7
R11 = 560Ω
R12,R13,R14,R15 = 1Ω
P1,P2 = 10kΩ preset, miniature, horizontal
P3 = 5kΩ preset, miniature, horizontal

Capacitors
C1 = 330nF MKT lead pitch 5mm or 7.5mm
C2 = 47µF 25V radial, lead pitch 2.5mm, ø max. 8.5mm
C3,C4,C9 = 100nF ceramic, lead pitch 5mm
C5,C6 = 470µF 16V radial, lead pitch 2.5mm, ø max. 8.5 mm
C7 = 10µF 63V radial, lead pitch 2.5mm, ø max. 6.5 mm
C8 = 100pF ceramic, lead pitch 5mm

Inductor
L1 = 100µH axial, upright mounting, suggested types: 5800-101 (Bourns) rated 0.63A/0.2Ω (Digi-Key # M8290-ND), B82111EC25 (Epcos) rated at 1A/0.65Ω (Farnell # 9752102) or MESC-101 (Fastron) rated at 1A/0.65 Ω (Reichelt # MESC 100µ)

Semiconductors
D1 = 1N5822
D2 = 2V7 0W5 zener diode
D3 = 1N4148
T1 = BD139
IC1 = LM2577T-ADJ (TO-220-5 case, straight pins)
IC2 = LM358 (DIP-8)

Miscellaneous
K1,S1,BT1 = 2-way PCB terminal block, lead pitch 5mm
S1 = single-pole on/off switch
BT1 = holder for 4 NiMH batteries*
3 pcs 1-watt power LED
PCB # 080585-1

* see text

at pin 2 and compares it with a reference of 1.23 V. It adjusts the peak switch current accordingly to maintain a constant output voltage. The divider chain formed by R2, R3 and P1 allow the output voltage to be varied between 3.5 V and 19 V. A typical 1 W LED has a forward voltage drop of around 3.25 V. Three LEDs in series gives 9.75 V, when the voltage drop across T1 and R12 to R15 are added to this we get 10 V. The adjustment range of P1 is sufficient to cater for LEDs with a forward voltage drop of up to 4.0 V.

In the Elektor lab we measured a supply current of 0.87 A from the 4.8 V battery pack giving a current through the LEDs of 0.35 A. Using 2000 mAh rechargeables you can expect a full battery pack to last for more than two hours. The circuit efficiency is over 82 % with a 4.8 V battery pack and around 89 % with a 5.6 V battery.

The set up procedure for the completed circuit is simple. Using an adjustable power supply set the output voltage to 4.8 V. Connect three LEDs in series to the anode and cathode (A, K) contacts of K1 and adjust P1 so that the voltage measured between the A connection of K1 and ground is 12 V. Now set the current by adjusting P3 until 88 mV is measured across resistors R12 to R15. To operate the circuit at optimum efficiency reduce the 12 V supply by adjusting P1, check that a constant 88 mV is maintained across R12 to R15, if it starts to fall then you have set P1 too low. Lastly adjust P2 so that the LEDs turn off when the supply drops below 4 V. Should the LEDs not light at all check that P2 has not been set too high.

(080585-I)

Internet Links

[1] www.national.com/mpf/LM/LM2577.html

[2] www.elektor-usa.com/080585

Download

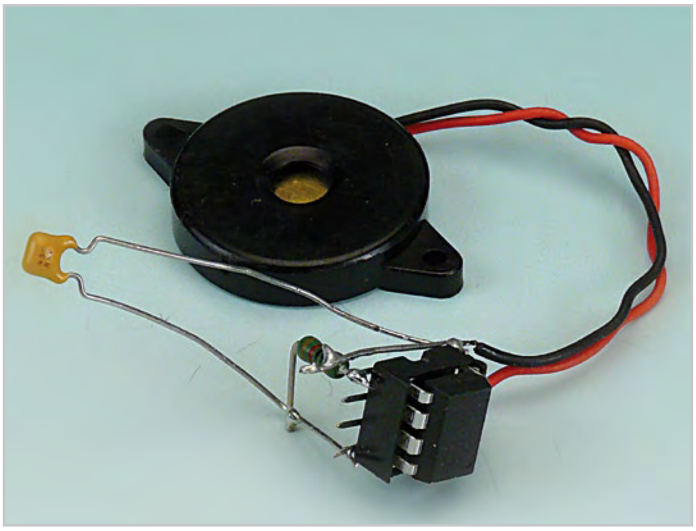
PCB

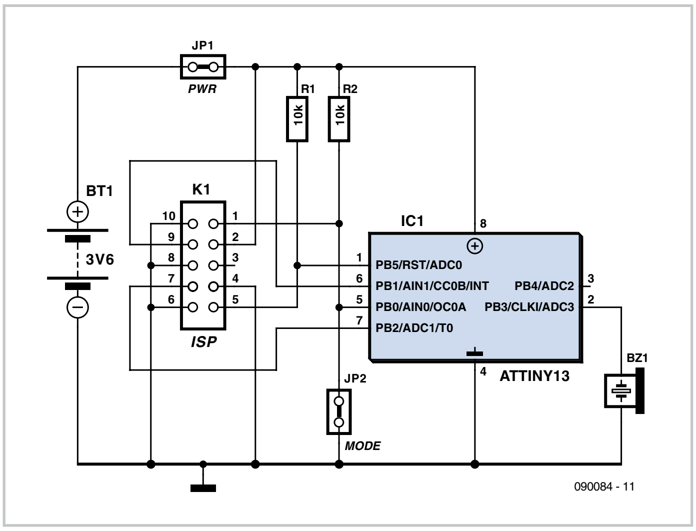
080585-1 PCB layout (.pdf), from [2]

Annoy-a-Tron

Tolunay Gül (The Netherlands)

The idea for this circuit came from the website www.thinkgeek.com [1]. The author thought that it could be made better and simpler. A search on the Internet didn't get any results so the next logical step was to design something himself. With the help of a small AVR microcontroller from the spares box and a buzzer the experimenting could begin.
The circuit consists of little more than the AVR micro, a buzzer and an ISP header to program the code into the microcontroller. Apart from two resistors, a jumper to select the mode and an on/off switch, the circuit just needs a battery. The author used an old battery from a Nokia mobile phone because it had a large capacity, but was still fairly small. In principle a small button cell and a holder will suffice as well, and possibly even some solar cells from an old calculator could work.





The mode switch is used to choose between normal mode and a test mode. In the latter mode the Annoy-a-Tron will beep constantly. In normal mode the tone generator creates irritating beeps with a random pause of 10 to 500 seconds between successive beeps.

The controller obviously needs a program written for it. As is usual for BASCOM-AVR the code starts with a regfile that states which AVR is used. This is followed by the Xtal/internal oscillator choice. Next come the software and hardware stack, the frame size and the configuration settings. First portb.3 is configured as an output and given the name 'speaker'. Then the variable 'seconds' is defined as a 'word' type.

When the AVR is turned on it first comes to an endless loop. In this it checks if the mode jumper is in place or not. If it's not in place (a logic '1' caused by the pull-up resistor) the micro jumps to sub1. Here it comes to an endless loop again. Within this loop it creates a constant beeping noise.

When the mode jumper is put in place and the power is removed from the circuit and then reapplied (a reset), the controller once more comes to an endless loop. However, this time it sees a '0' because the jumper pulls the I/O pin to a low level. This causes the program to jump to sub2. This is again an endless loop, which immediately generates a beep. It then generates a random number from 0 to 50, adds one to it and stores it in the variable 'seconds'. The number in 'seconds' is then multiplied by 10 to obtain a longer pause before the next beep. The program then waits for the required number of seconds before jumping back to the beginning of the loop.

The circuit can be easily built on a piece of stripboard. Alternatively, an SMD board could be designed, which means that the resulting circuit could be made very small. The software can be downloaded from the Elektor website [2].

(090084)

Internet Links

[1] www.thinkgeek.com/gadgets/electronic/8c52

[2] www.elektor-usa.com/090084

Download

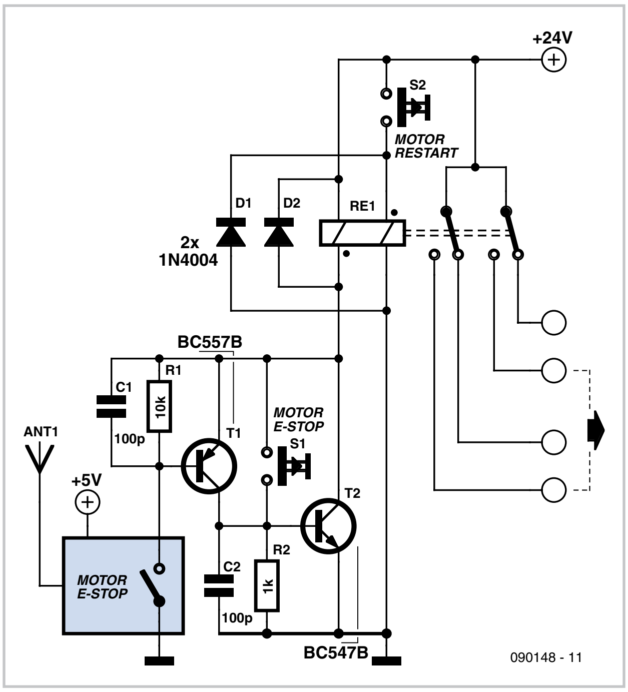
090084-11: source code and hex files, from [2]

Simple Wireless and Wired Emergency Stop System

Jacquelin K. Stroble (USA)

This circuit allows a cheap or discarded wireless doorbell set (i.e. transmitter and receiver unit) to be used as a remote emergency stop on a high-power electrical motor or motor controller system.

When the button on the wireless doorbell unit is pressed, the resulting 0 V signal from the receiver unit ('motor E-Stop') causes pnp transistor T1 to be turned on. Via transistor T2, latching relay Re1 then changes state. The same is achieved when the wired Motor E-Stop button, S1, is pressed. The reset button, S2, must be pressed to reverse the state of the latching relay.
The choice of T1 and T2 is not critical — they are general purpose, low voltage pnp and npn switching transistors respectively, for which many equivalents exist.



As an EMC precaution, small capacitors (100 pF) are fitted across base resistors R1 and R2, preventing the motor from being shut down by external electrical noise and interference. The set and reset coils of the latching relay each have a flyback diode to prevent back-emf peaks damaging T1 and T2. The contacts of the latching relay can be used to switch a more powerful relay, or a motor driver.

(090148-I)

Desulphater for Car Batteries

Christian Tavernier (France)

Even if you take great care of your car or motorbike battery, you're bound to have noticed that its life is considerably shorter than the high purchase price and sales pitch probably led you to expect. Of course there are several reasons for this, and high on the list is the phenomenon of slow but inevitable sulphating of the plates. To understand properly what this involves, we need to look at a bit of chemistry.

A lead/acid battery exploits a chemical reaction which is written as follows, when discharging:

Pb + 2H2SO4 + PbO2 —> PbSO4 + 2H2O + PbSO4

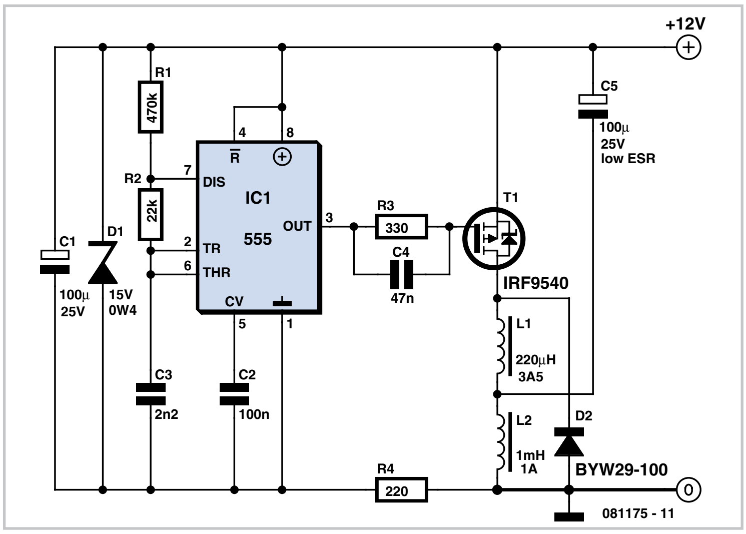
This indicates that, in contact with sulphuric acid, the porous lead of one plate and the porous lead dioxide of the other are both converted into lead sulphate and water. During charging, the following reverse chemical reaction occurs:

$PbSO_4 + 2H_2O + PbSO_4 \longrightarrow Pb + 2H_2SO_4 + PbO_2$

This time, the electric current being passed converts the lead sulphate and water into lead, lead dioxide, and sulphuric acid. In theory, the reaction is totally reversible, which is why a battery can be charged and discharged a great many times.

Unfortunately, with the passing of time and successive charge/discharge cycles, the second reaction, i.e. the one that converts the lead sulphate back into lead, becomes incomplete, and leaves some lead sulphate on the surface of the battery plates. As this is a poor conductor, it tends to get thicker in places where it has started to collect, and unfortunately this phenomenon of sulphating, for that's what it's called, is cumulative and gets worse and worse as time goes by.
Once a battery has got badly sulphated beyond a certain point, no standard charging process is able to recover it. What happens is that, because the lead sulphate Is a poor conductor, the battery's Internal resistance Increases, which In turn reduces the charging current, and thereby the effectiveness of the

charging chemical reaction; this in turn leaves even more lead sulphate on the plates… and so it goes on, in a vicious circle. There is a chemical process that makes it possible to eliminate the lead sulphate from a battery before it's too late, but it's a tricky operation and uses highly corrosive chemicals that are dangerous to handle. What's more, many of the batteries sold these days are sealed and so it's impossible to gain access to their electrolyte without damaging them.



The project we're suggesting here lets you desulphate your battery electronically — and the sooner you start doing it, the more effective the process will be. It is based on research carried out in the United States, which showed conclusively that if you apply short, high-amplitude pulses to the battery, the resulting ionic agitation produced at the battery electrodes gradually breaks up the lead sulphate crystals. Even if you're a bit sceptical about the effectiveness of this process, you can try it out for yourself without any great financial risk, as the circuit required is simple and cheap. Nothing ventured, nothing gained!

The circuit used is very similar to the one currently to be found in the United States, where this type of desulphating process is popular as well as widespread. Apart from a few details, it's pretty much like a 'boost' type switch-mode power supply unit (SMPSU) — i.e. one that steps up the input voltage. IC1 is wired as an astable multivibrator running at a frequency of the order of a kilohertz and generates very short mark/space (on/off) ratio pulses at its output.

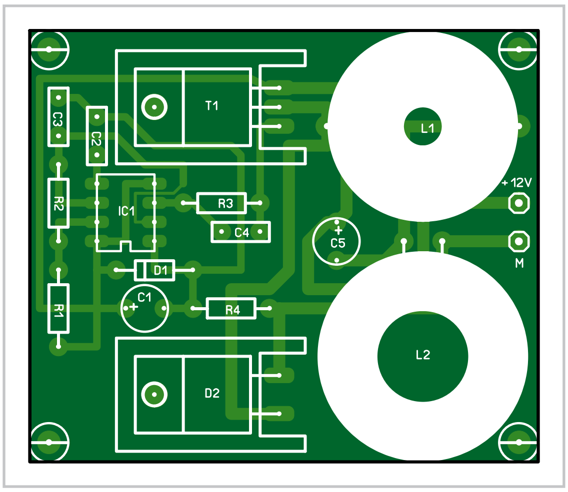
When T1 is turned off by the level of these pulses, capacitor C5 is able to charge up to the battery voltage through inductor L2. When T1 turns back on again, which happens for only a very short time, given the mark/space ratio of the pulses, capacitor C5 discharges abruptly via T1 and L1. When T1 then turns off again, the inductor L1 means that the discharge current can't stop instantly. So it is obliged to pass through the battery via diode D2.

With a high-quality capacitor for C5 (meaning a device with a low ESR) and a short connection in heavy-gauge wire from the circuit, we can push a peak current of some 5 to 10 A through the battery. Despite this, the power consumption of the circuit is still fairly low, of the order of 40 mA, because of the very low mark/space ratio of the signals produced.

Construction shouldn't be any problem, especially if you use the printed circuit board design suggested [1], but for optimum performance, you do need to pay careful attention in choosing the components.

The inductors used must not be changed. They are available, for example, from Radiospares (RS Components) as part numbers 228-422 (L1) and 334-9207 (L2). Diode D2 is a readily-available type and should only be replaced if this is unavoidable, and then only by an ultra-fast device. Capacitor C5 must be a low series resistance type, such as those intended for switch-mode power supplies. As can be seen from the component overlay of the PCB designed by Elektor Labs, T1 and D2 are fitted with small U-shaped heatsinks designed to take TO-220 packages.

It is advisable to install the circuit into an earthed metal case, as it generates quite severe electromagnetic interference that it's best not to allow to radiate out as it is likely to upset the operation of other equipment. EMC regulations and recommendations apply here.



The battery connection must be made using short wires, of at least 2.5-3.0 mm^2 gauge (AWG # 12-13), securely connected to the battery terminals, since for the process to be effective, it's important to minimize any series resistance between the circuit and the battery. If necessary, it can be left permanently connected.

Some writers and pundits advise connecting a charger (even a low output one) to the battery at the same time, to avoid the circuit's discharging the battery in the long term. But we would not recommend doing so, since the charger's relatively low output impedance distorts the pulses produced by the circuit and hence diminishes its effectiveness.

Caution / Safety Notice

If you use this desulphater directly on your vehicle battery, remember to disconnect at least one of the connections to the battery, as the parallel impedance of the many devices that stay permanently powered in modern cars once again diminish the effectiveness of the system.

(081175-I)

COMPONENT LIST

Resistors
R1 = 470kΩ
R2 = 22kΩ
R3 = 330Ω
R4 = 220Ω

Capacitors
C1 = 100µF 25 V
C2 = 100nF
C3 = 2nF2
C4 = 47nF
C5 = 100µF 25 V, low ESR

Semiconductors
D1 = 15 V 0.4 W zener diode
D2 = BYW29-100
IC1 = NE555
T1 = IRF9540

Inductors
L1 = 220µF 3.5A
L1 = 1mH 1A

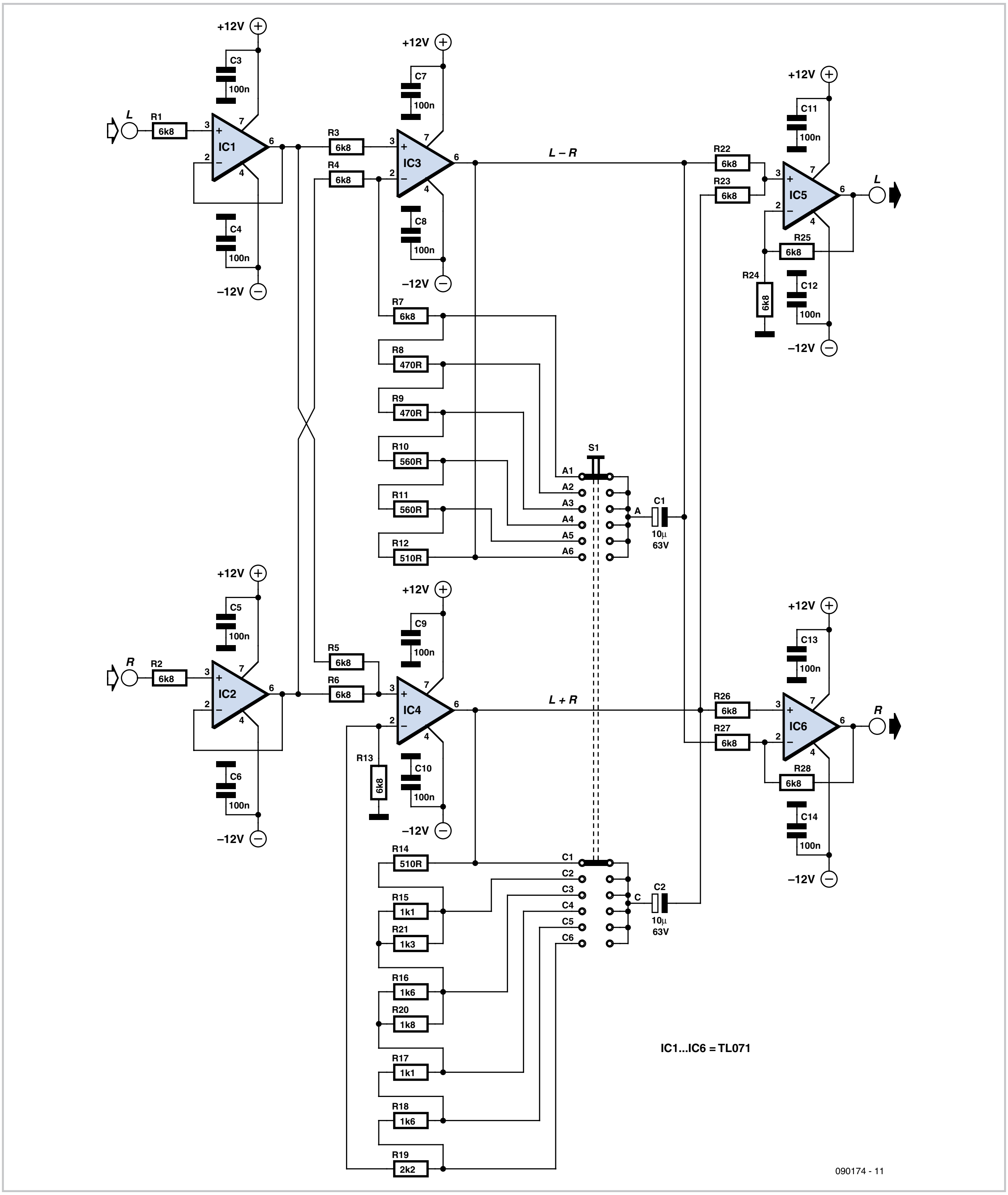
Internet Link
[1] www.elektor-usa.com/081175

Download
081175-1: PCB layout (.pdf), from [1]

Stereo Widening

Huub Smits (The Netherlands)

Although the principle is quite old, ‘widening’ of the sound image is still done these days in many portable devices, ghettoblasters and PC loudspeakers, even though it is usually called something else in these applications. To generate the stereo image, the left channel also contains part of the sound from the right channel, shifted a little in phase compared to the right channel. The same is true for the right channel, where the signal from the left



channel is slightly shifted in phase. To make the stereo image 'wider', you can amplify the difference signals of both channels.

To do this you generate a sum- and a difference signal from the left and right channels. With a couple of opamps you can realise a 'left+right' signal and a 'left-right' signal. So the (left–right) signal needs to be made stronger with respect to the (left+right) signal. Expressed as a formula:

(L+R) + (L–R) = 2L and (L+R) – (L–R) = 2R

With a suitable circuit, the left signal in the left channel is increased and the right signal is decreased. Similarly, in the right channel the right signal is increased if the left signal reduces. To maintain a constant volume, we also have to make sure that the total signal strength remains the same.

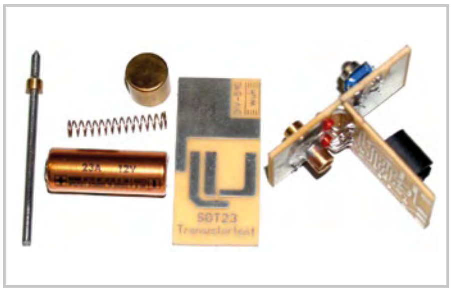
From the schematic you can see how this problem was solved. IC1 and IC2 are the input buffers. After the buffer, the left and right signals are combined with the other channel respectively. IC3 generates the (L–R) signal and IC4 the (L+R) signal. With two times six resistors and a multi-position switch, the amount of the effect can be adjusted. The values of resistors R7–R12 and R14–R21 are selected such that the total volume remains about the same when changing the switch. IC5 and IC6 generate the final left and right signal from the (L+R) and (L–R) signals.
For additional protection, electrolytic coupling capacitors of 10 µF 16 V can be added to the inputs and outputs. Each of the inputs of IC1 and IC2 will then also need a 10 kΩ resistor to ground, otherwise the opamp outputs will run up against power supply rail.

The power supply requires a symmetrical voltage of ±12 V. This voltage can usually be found in an existing amplifier, so normally there is no need to build a special power supply.

(090174-I)

SMD Transistor Tester

Ludwig Libertin (Austria)



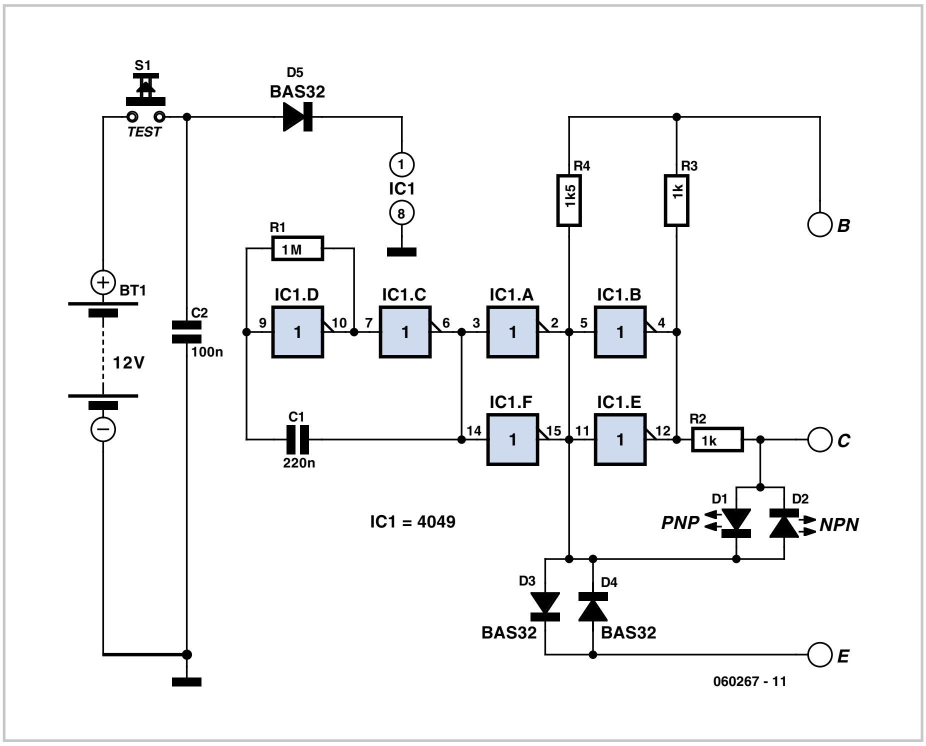
The article 'SMD Soldering Aid' by Gert Baars in the December 2005 issue of *Elektor* [1] was the original inspiration for a truly 'electromechanical' version of this design for a transistor tester for SMD transistors in SOT23 case outline. However, Gert's strip metal construction method was not chosen and instead an alternative design was created out of strips of soldered PCB material. Glassfiber epoxy resin PCB material cannot compare with strip metal for springiness so the spring from a discarded ballpoint pen was used, which provides adequate clamping pressure. The key advantage of this choice of materials is that the TUT (transistor under test) is pressed hard onto three PCB tracks that lead directly to sockets into which a conventional transistor tester can be plugged. It really is this simple (without any soldering) to check whether the TUT is flaky or worth keeping for reuse.

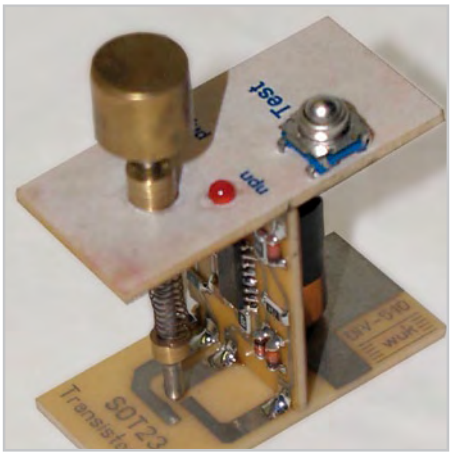
The actual procedure for using this SMD transistor tester is no different from checking out transistors that have wire leads. In most cases all you are interested in is whether the TUT is dead or alive and also if it is of the NPN or PNP variety. This much you can discover without the need to hook up an external transistor (and the extra bother).

No sooner said than done. The result is a project that's equally useful as a simple 'test connector' hook-up for the TUT and as a simple transistor tester. The very minimalist circuit consists of a CD4049 (CMOS HEX inverter/buffer) and a few additional components — naturally all in SMD form factor. IC1.D and IC1.C together with R1 and C1 form a squarewave generator with a frequency of around 2 Hz. This drives inverters IC1.A and IC1.F (connected in parallel for higher output current), which in turn feed IC1.B and IC1.E. If no transistor under test is connected, LEDs D1 and D2 will both flash together in anti-phase and half the operating voltage will be present at base connection B.
Now insert a transistor in the test device: both LEDs flashing indicate an open circuit,

Features

- Standalone SMD transistor tester
- Identifies defective transistors
- Distinguishes NPN from PNP



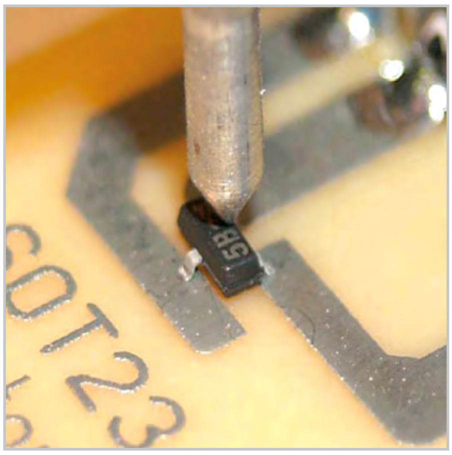


in other words the transistor is defective. An internal short circuit (connection between C and E) is indicated by the two LEDs glowing dimly. A functional NPN transistor conducts only when the voltage on C is higher than on E. LED D1 Is now short-circuited and only D2 flashes. In similar fashion only D1 flashes for a PNP device. The circuit draws only 10 mA or so and using pushbutton S1 for operation means that the battery will have a very long life.

The type GP23A 12 V battery is an integral part of the mechanical structure and is clamped between the upper and lower printed circuit boards. A small section sawn from a piece of plastic pipe is used as a *de facto* battery clip glues to the vertical printed circuit board improves stability (**2**). The nail-like metal pin is passed through a small ring of brass soldered to the upper PCB.

To simplify the task of replicating the PCBs the author has made the layout files of the three small PCBs available on the article's web page [2]. To use these you will not need the full version of the Sprint Layout software, as you can open the files just as well with the free Viewer programme [3].

(060267)



Internet Links

[1] www.elektor.com/magazines/2005/december/smd-soldering-aid.57995.lynkx

[2] www.elektor-usa.com/060267

[3] www.abacom-online.de/html/dateien/demos/splan-viewer60.exe

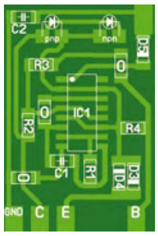
COMPONENT LIST

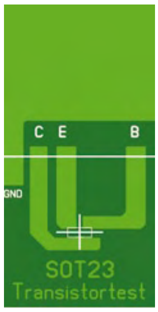
Resistors
R1 = 1MΩ
R2 = 1kΩ
R3, R4 = 10kΩ

Capacitors
C1 = 220nF
C2 = 100nF

Semiconductors
D1, D2 = LED, 3 mm
D3, D4 = BAS32
IC1 = 4049 (SO16)

Miscellaneous
S1 = pushbutton, push to make
12 V battery GP23A
Mechanical parts as described
PCBs (see text)



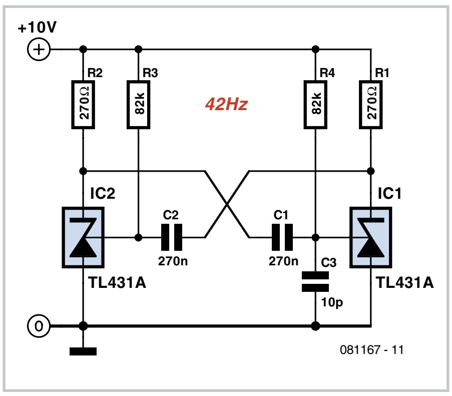


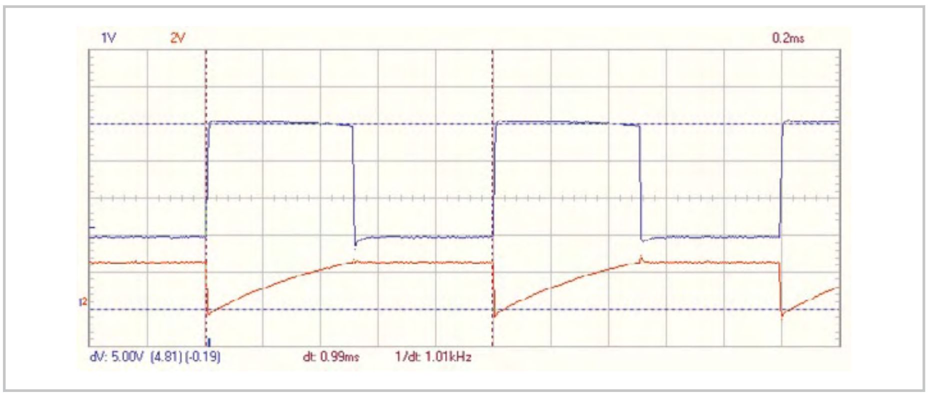
TL431 Multivibrator

Gilles Clément (France)

Oscillators have a certain appeal to electronics enthusiasts. They're rather 'alive' because there's something 'beating' inside them, isn't there?

Here the TL431 'super zener', an easily-sourced standard device, is made to oscillate. It's a 3-pin IC: cathode, anode, and ref. input. An op amp compares V_{ref} with an internal 2.5 V reference and drives a bipolar transistor that 'shorts' the cathode to the anode. So the cathode voltage V_k has two stable states: $V_k = V_{supply}$ if $V_{ref} < 2.5$ V and $V_k = 2$ V (the V_{ce} of the transistor) if $V_{ref} > 2.5$ V. A bit like a transistor that works with voltage instead of current, so with a little effort it should be possible to force it to oscillate between





these two states.
If two TL431s are wired as an astable multivibrator you'll find that it works! But actually, it ought not to, since the op amp's V+ input is unable to sink the capacitor charging current! So, how does it work then?
In fact, the current passes via a stray internal diode between V_{ref} and the cathode (which is certainly noted on some data sheets like [1], but not on all of them).

This was checked using the excellent (and free) LTspice simulator [2]. The frequency is defined by R and C (and of course the supply voltage). It gives a very good squarewave (see scope trace) up to around 50 kHz. The signal is much better than using bipolar transistors. However, the low voltage stays at 2 V, but this can be solved by using a FET on the output, or by using similar ICs with lower reference voltages like for example the TLV431 (threshold 1.24 V) or the ZXRE060 (threshold 0.6 V).

The 10 pF capacitor C3 is only there to make the LTspice simulation start up correctly; it's not needed in the real circuit, which makes use of natural asymmetries.
The author's LTspice model is available for free download from [3].

(081167-I)

Internet Links

[1] www.datasheetcatalog.org/datasheet/calogic/TL431.PDF

[2] www.linear.com/designtools/software/#Spice

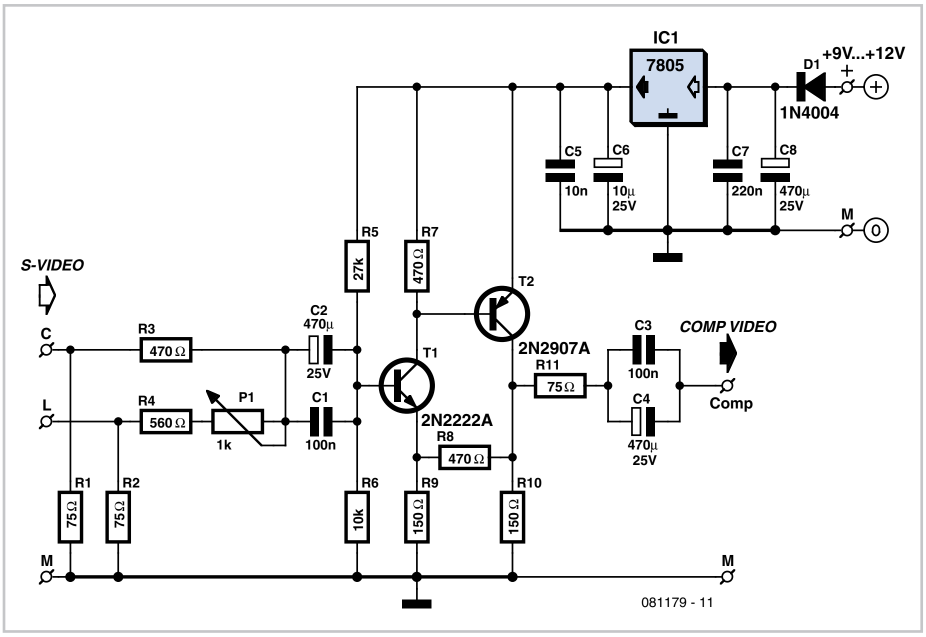
[3] www.elektor-usa.com/081167

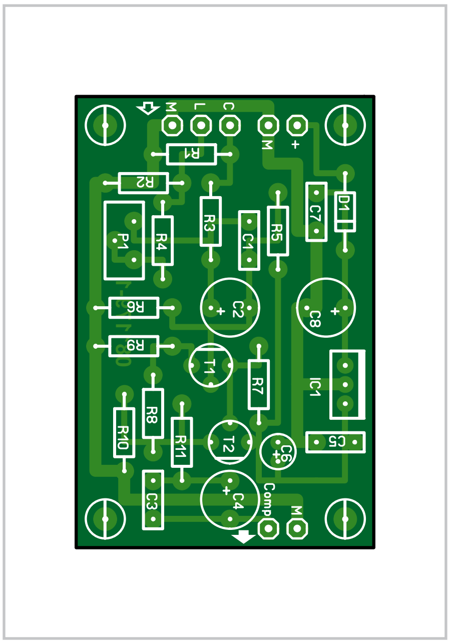
S-video Converter

Christian Tavernier (France)

With the astonishingly rapid growth in the market for flat-screen TVs and high-definition TV, many CRT television sets have been consigned to the attic, even though many of them were still working perfectly and could have been used as spare sets in a bedroom or another room, for example. Although all current flat-screen receivers have very comprehensive facilities and include digital inputs via DVI or HDMI connectors and analog inputs in S-video format, this was unfortunately not the case with the CRT televisions that were being sold only a few short years ago, which were more often than not fitted with only composite video inputs, either directly or via their SCART socket. The converter we are suggesting building, very simple since it only uses two transistor, lets you convert any S-video signal into a composite signal and so will perhaps enable you to give a new lease of life to your old CRT television.

The principle of S-video is very simple, as it merely consists of carrying the chrominance and luminance information, which form the basis of all color video signals, over separate channels. In composite video, by contrast, both these signals are combined over a single path, and the resulting inevitable interferences between them degrade the appearance of the image being reproduced. Fortunately, the components of an S-video signal, whether in the SECAM, PAL, or even NTSC standards, are almost the same as the ones found in a composite signal of the same standard. So it's going to be relatively simple to combine them in order to reconstitute the composite video signal that our CRT television is expecting to see. In order for this recombination to be correct, there is just one constraining factor to be taken into account, concerning the respective levels of the components, as the chrominance one is only half the amplitude of the luminance one.





Our circuit picks up the component signals on the two standardized pins of the 4-pin mini-DIN socket normally used for S-video (also known as an Ushiden socket), taking care to maintain the 75 Ω impedance via R1 and R2. The mixing of the two signals is then taken care of by R3, R4, and P1; the latter lets you adjust the respective levels of the two component signals exactly.

The two transistors that come next are wired in such a way as to create a wideband ampli-

fier, the gain of which is set to 3 by the ratio between R8 and R9. Combining the input components has had the effect of dividing the overall amplitude of the video signal by a factor of 1.5, and the output impedance matching resistor is going to divide the signal in half again (once the signal is terminated at the input of the destination equipment), all of which adds up to a total attenuation of 2×1.5, corresponding to the make-up gain we have designed into our amplifier. In this way, inserting our converter into a video chain will have no effect on the level of the signals passing through it.
The composite video output passes via 75 Ω resistor R11 in order to match the circuit's output impedance to the input impedance of the composite video input on the device to which it is connected. At both input and output, note the parallel combinations of C1 / C2 and C3 / C4, so that the video signals, with a frequency range extending from a few tens of Hz to several MHz, can pass through these capacitors under the best possible conditions.
If we want to avoid unwanted color or brightness variations, it is vital to power the circuit from a stabilized supply, achieved here by using a standard 3-pin regulator IC to provide a 5 V rail for the circuit. So the project can be powered from a 'plug-top' AC adaptor that gives 9 to 12 V at 100 mA or so. Diode D1 is there just to protect against any accidental inversion of the PSU polarity that might possibly occur.

The circuit itself is very easy and construction shouldn't present any difficulties. It can be built on the PCB we suggest [1] or on a piece of prototyping board, but in either case, we recommend using fiberglass board, because of the high frequencies involved in the video signals.

If you want your converter to follow the proper standard in terms of connectors, you'll want to use a female 4-pin mini DIN S-video socket for the input and a female phono socket (a yellow one, for the purists!) for the output. As for the power supply, all you'll need is a simple jack to suit the AC adaptor unit you've chosen.
The circuit should work right away, and all that you then have to do is to adjust the preset P1 so as to obtain a composite video signal that gives correct contrast and saturation on the TV receiver you are using.

(081179-I)

COMPONENT LIST

Resistors
R1,R2,R11 = 75Ω
R3,R7,R8 = 470Ω
R4 = 560Ω
R5 = 27kΩ
R6 = 10kΩ
R9,R10 = 150Ω

Capacitors
C1, C3 = 100nF
C2, C4, C8 = 470µF 25V
C5 = 10nF
C6 = 10µF 25V
C7 = 220nF

Semiconductors
D1 = 1N4004
T1 = 2N2222A
T2 = 2N2907A
IC1 = 7805

Miscellaneous
4-pin mini DIN connector
Cinch connector (yellow)
DC supply connector

Internet Link
[1] www.elektor-usa.com/081179

Download
081179-1: PCB layout (.pdf), from [1].

SSR 2.0

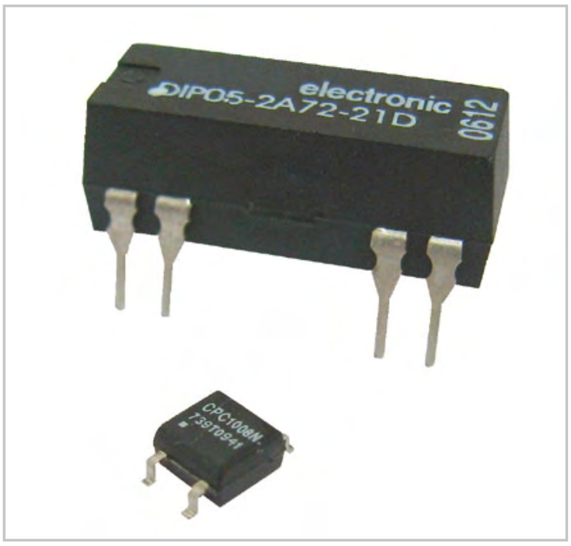
OptoMOS semiconductor relays

Fredi Krüger **(Germany)**

OptoMOS or PhotoMOS relays are something of a special category. Looking at a block diagram the device falls somewhere between an optocoupler and a conventional SSR (Solid State Relay).

To compare technologies the input signal to a standard analog optocoupler modulates the light of an LED. The light induces a current in an isolated phototransistor or Darlington. The output current from this type of device is relatively small (a few milliamps) and is approximately proportional to the input signal.

Solid state relays by comparison have a similar input LED but this time the light is used to trigger a built-in triac or thyristor. They are used to switch AC loads and some variants include circuitry to ensure switching occurs as the AC passes through zero. This reduces switching EMI but also makes them unsuitable for phase control applications.

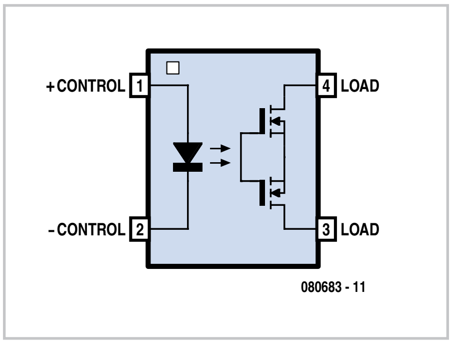


Conventional mechanical relays have been around for years. They switch both AC and DC supplies and can be designed to handle high current and voltage. Standard semiconductor relays can switch high current and high voltage loads but are not suitable for DC supplies and cannot be switched at high frequency.
Taking a closer look at the block diagram of a typical modern optoMOS relay shows an LED at the input as in the a normal optocoupler, but this time the light is used to switch two complementary photo MOSFETs which form a bidirectional switch. This bidirectional configuration is capable of switching both AC and DC supplies at speeds of around 1 ms. Most of the major IC manufacturers produce their own versions and amongst those stocked by one supplier include NEC (PS7141-2B), International Rectifier (PVN012APbF), Clare (LBB110) and Vishay Semiconductors (LH1502BB). The characteristics of these devices

range from a maximum load current from 50 mA to 10 A with a voltage range from 20 V up to 2 kV. The switch resistance can be as low as a few mΩ to 100 Ω and the input control current ranges from around 2 mA to 10 mA depending on the type of relay. Some other manufacturers are Toshiba, Fairchild, Aromat (NAiS), Panasonic, Sharp, Cosmo and Avago. Some of the advantages of OptoMOS relays are:

- Small package outline — also in SMD!
- Long service life
- No contact wear
- No contact bounce
- No generation of EMI
- High switching speed
- Insensitivity to vibration
- Insensitivity to magnetic fields
- No magnetic field emission
- Low control power requirements

There are several different package outlines including one with eight relays in the same



package. When choosing a relay for a particular application the description will include the specification 'X form Y'. X is a number indicating how many switches are in the package and Y indicates the type of contact: 'B' = normally closed while 'A' = normally open. Some of these relays have both normally open and normally closed in the same package, useful for making a changeover switch.
In the Elektor labs we took a look at the TLP4227G-2 from Toshiba. This 8-pin version is described as '2 form B', i.e. two normally closed relays. The contacts are capable of switching 350 V at 150 mA. Without any current flowing in the LED the device is on and we measured an output resistance of 15 Ω. With an LED current of 0.5 mA the resistance starts increasing and at around 0.9 mA it rises sharply giving an off resistance of around 300 MΩ.

The FOD3180 is another variant from Fairchild; it is a high speed MOSFET gate driver optocoupler which has additional load supply voltage connections. It is capable of switching 2 A at 250 KHz. At this speed it is necessary to take precautions to suppress EMI generation generated in the load.

(080683-I)

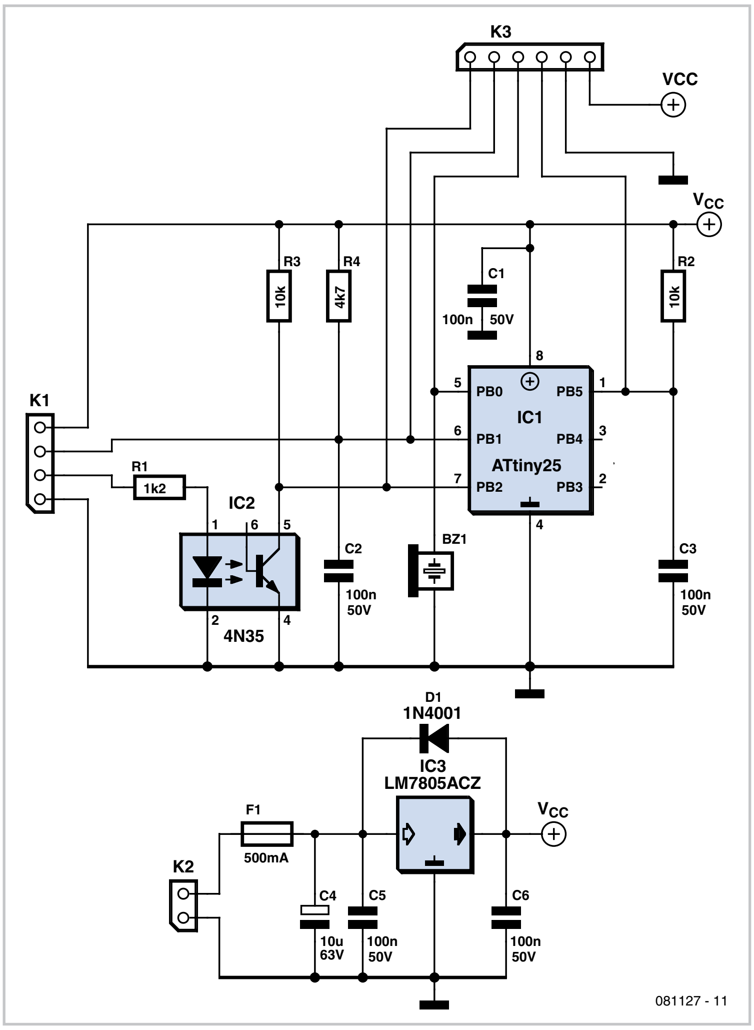
Internet link

www.toshiba.com/taec/components2/Datasheet_Sync//214/4495.pdf

Speed Control

Mark Donners (The Netherlands)

The author went for a ride in a rental Citroen a while ago. This car had a nice gadget onboard that the author was unable to find available as a separate accessory. In such cases, there's only one option for an electronics enthusiast: do it yourself!
The device in question monitors how fast you are driving. An alarm sounds if you go faster than the preset speed. This gives the driver good control over how fast he actually drives. You can regard it as a pseudo cruise control.
This circuit is built around an Atmel ATtiny25 microcontroller, which has all the features necessary for achieving the desired objective. The microcontroller operates at 1 MHz using a clock signal generated by an internal oscillator. The desired speed is set by a pushbutton switch connected between pins 3 and 1 of connector K1, which is connected to input PB1 of the microcontroller.
The idea is that the driver should push the button when the car reaches the desired speed detec-



tion limit. After this speed has been 'stored' via input PB1, the microcontroller will generate an acoustic alarm if the set speed is exceeded. It produces two short beeps if the speed is slightly higher than the set value, or a long, loud beep if the speed is significantly higher.
The speed is measured via pin 2 of connector K1. Optical isolation with IC2 protects the PB2 input of the microcontroller against excessively high voltages. You can tap off the speed input signal of the car speedometer for this purpose, or you can fit a magnet and reed relay to the driveshaft or an axle.
The firmware is written in C and assembled using Codevision. All the firmware does is to monitor the speed input signal using an interrupt-driven routine. The signal is monitored by measuring the interval between two successive pulses: the shorter this interval, the higher the speed. If the set speed level is exceeded, an

alarm signal is generated. You can use connector K3 to program the microcontroller (1 = SCK; 2 = MISO; 3 = MOSI, 4 = $\overline{\text{RESET}}$). Information about available speed signals in different makes of cars is found on the Internet, for example, at [2].

Caution. Tapping off or altering the speed signal generated by a vehicle for use on public roads may be illegal and/or void manufacturer's warranties.

(081127-I)

Internet Links

[1] www.elektor-usa.com/081127

[2] http://koti.mbnet.fi/jylhami/trip/speedsignal.pdf

Download

081127-11: source code and hex code, from [1].

Four-component Missing-pulse Detector

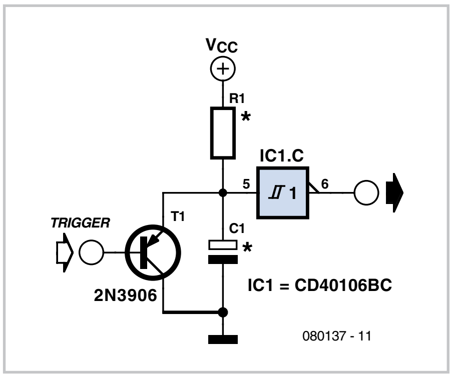
Lars Näs (Sweden)

A missing-pulse detector is a 'one-shot' triggered device that is continuously retriggered by incoming pulses before a predefined timing cycle is completed. At room temperature, the positive-going threshold voltage (V_{th+}) for the CD40106BC hex Schmitt trigger IC falls in the range of 60% to 86% of its supply voltage (V_{cc}: 5 V–15 V). If we also take into account that capacitor C1 takes a time constant defined as R1×C1 [seconds] to reach 63% of its full charge voltage, the constant is roughly the time C1 takes to charge up to the level V_{th+}, thus changing the logic state of pin 6 on IC1.C.

Based on the above assumption, if a pulse train with a High-level period shorter than

T = R1C1 [s]

is present on the base of T1, this pnp transistor will remain in the cutoff state. This allows



R1 to charge up capacitor C1, but not sufficiently to reach the positive voltage threshold set at input pin 5 of the gate. Consequently Schmitt trigger output pin 6 will remain High. For a retriggered pulse period of 3 seconds (or 0.3Hz) you'd use R1 = 330 kΩ and C1 = 10 µF.

Now, if the High-level pulse duration on the base of transistor T1 is longer than T, the transistor will remain cut off, but the capacitor will charge until V_{th+} is reached and the output pin 6 of the Schmitt trigger gate will change to logic Low.

When no pulse (i.e. a logic Low state) is present on the base of T1, the transistor is driven into saturation. This allows C1 to instantly discharge, setting up the initial conditions for the next pulse.

The trigger signal can for instance be supplied by a Hall-Effect switch set up to measure if a wheel with a magnet is rotating or not.

This circuit uses one gate in the CD40106BC, leaving the other gates free for use for other purposes. Do take into account that CD40106 devices from different manufacturers or production batches may have slightly different threshold voltages, which requires the calculated value of T to be adapted carefully to match the specifications of the gate used.

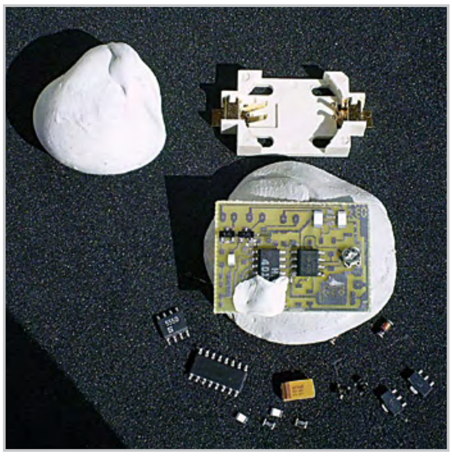
(080137-I)

Hassle-free Placement of SMD Components

Leo Szumylowycz (Germany)

Gadgets can be very useful to assist the task of placing components in printed circuit boards. Some people clamp the PCB in a small vice, either the vacuum-fixing variety (with a sucker) or the type that clamps to the edge of the workbench, or else they use one of those 'third hand' devices with several crocodile clips. But none of these is much help when you are dealing with surface mount (SMD) components. Even the steadiest hand is of little use if just the smallest slip causes the PCB to jump out of the croc clips. In this kind of operation you cannot steady your hands on the work surface and they soon get tired.

The author has discovered a better, albeit unconventional, solution: a substance like modeling clay that is sold for cleaning the



gummy mess out of the metal type letters on traditional typewriters (yes, some people do still use these good old machines). This substance is sold in specialist stationery shops but if you can't find it, a good substitute is Blu-Tack adhesive putty (or one of the several similar products), which you can buy in strips, square or small pads. You'll need to knead it in your hands a while for this kind of assembly work.

Once you have softened a lump to a suitably elastic consistency, you can press it onto the actual work preparation area and place the printed circuit board on top (see photo). The underlay should be rectangular or circular, about 20 to 25 cm (8 to 10 inches) across. This approach enables you to maneuver the SMD printed circuit board into the best position at any time during the parts placement process and fix it firmly in place with both hands. Using a conductive material for this underlay enables it to be earthed for discharging any static electricity charge. Many mousepads are suitable for this purpose, used with the conducting surface uppermost.

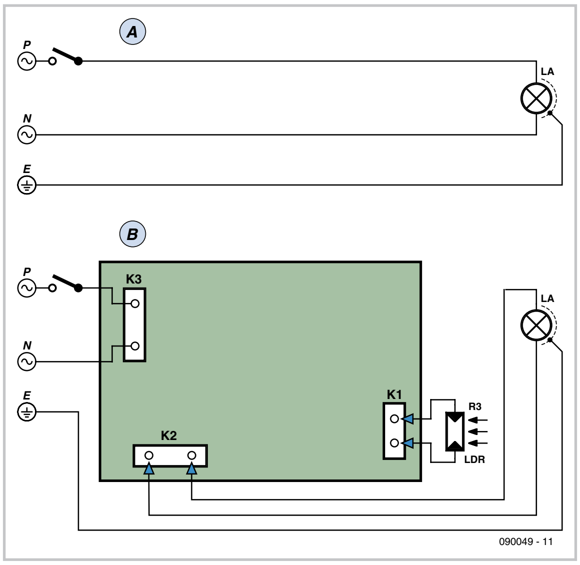
Instead of Blu-Tack you could use other materials such as Plasticine or even chewing gum, although the author has not tested these personally. Here practitioners will state that SMD printed circuits boards can also be populated using double sided sticky tape. Blu-Tack has the advantage, however, that you can use it to fix individual components onto the PCB tidily and 'squarely' before soldering, leaving both hands free for the actual soldering.

(090368-I)

Daylight Switch

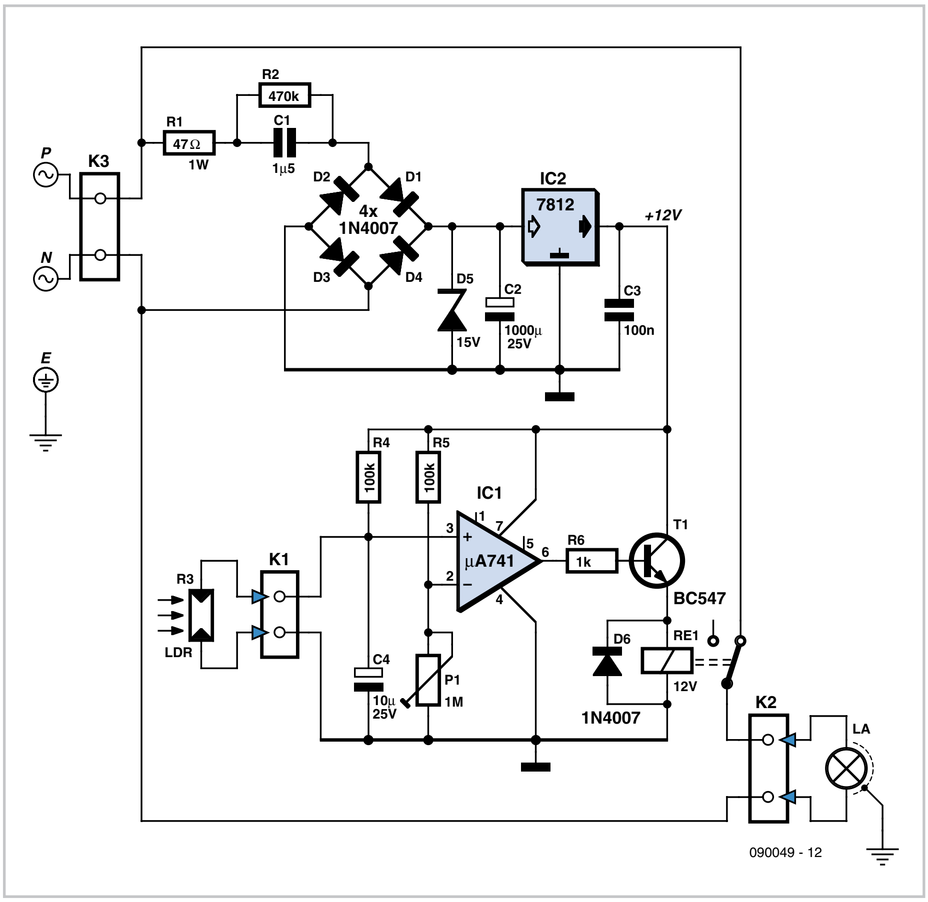
Mickael Bulet (France)

This project was originally designed for lighting up an illuminated sign for a wine-grower. The sign was originally controlled by a simple time-switch, which had to be reprogrammed every day to avoid the sign's lighting up while it was still daylight. This is time-consuming, and can lead to wastage of electricity and other resources. A better solution would be an automatic switch capable of detecting the transition between daylight and night-time. In addition to that fundamental requirement, the specifications also demanded a very compact unit that would be easy to install and not require major modifications to the existing electrical installation.



The project described here is compact enough, fitting into an 80×80 mm (internal dimensions) IP55 junction box, for example, the Plexo® range from Legrand. It is easy to install; all you have to do is cut into the cable leading to the light and wire it in series. The circuit is AC powered, without using a transformer. The impedance of a capacitor is used to drop the 230 VAC (or 120 VAC) power voltage and limit the current. Resistor R1 protects the capacitor (C1) against surge currents when power is applied at lighting-up time, and R2 ensures that it is discharged at turn-off. Readers on 120 VAC, 60 Hz networks should change component values as follows: R1 = 2x 100 Ω in parallel (stacked) or 1x 47 Ω, 2 watts; C1 = 2.2 µF. Also note P = phase, N= neutral, P (PE) = protective earth.

Rectification is achieved using a bridge rectifier, which makes it possible to double



COMPONENT LIST

Resistors

R1 = 47Ω 1W
R2 = 470kΩ
R3 = LDR
R4, R5 = 100kΩ
R6 =1kΩ
P1 = 1MΩ multiturn preset, vertical

Capacitors

C1 = 1µF5 400V MKT
C2 = 1000µF 25V axial
C3 = 100nF LCC 63V
C4 = 10µF 25V radial

Semiconductors

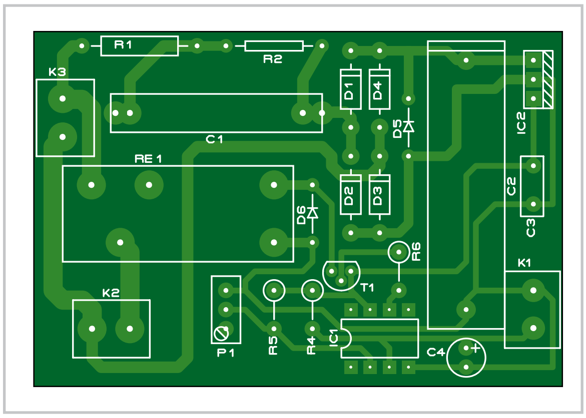
D1–D4, 6 = 1N4007
D5 = 15V 1.3W zener diode
T1 = BC547 or equivalent
IC1 = µA741 or equivalent
IC2 = 7812, or low-drop equivalent

Miscellaneous

RE1 = relay, 12V coil, 1x 10A, 250V c/o contact
K1,K2,K3 = 2-way PCB terminal block, 5mm (0.2") lead pitch
Type IP55 electricity junction box, internal dimensions 80 x 80 mm (3.15" x 3.15") e.g. plexo LEGRAND # 922-06
20 mm length of electricity conduit, diam. 20 mm (0.8")

the usable current compared with the conventional rectification often encountered in this sort of power supply. A zener diode of around 15 V (minimum, as the 12 V regulator needs to be allowed enough headroom to do its job properly) limits the voltage in the first instance; it is then smoothed by C2, then more accurately regulated by IC2 and finally decoupled by C3. The stable 12 V supply is required above all for the voltage divider that acts as a reference for the comparator.

The darkness is detected by an LDR, which in conjunction with R4 forms a voltage divider, the output voltage of which is inversely proportional to the intensity of the light falling on the LDR. Capacitor C4 absorbs rapid changes in this voltage, in order to avoid unwanted triggering. R5 and P1 form a voltage divider for the comparator (IC1) reference voltage — this is what determines the threshold for the light to be turned on. When the voltage on pin 3 of IC2 is higher than the voltage on pin 2, the comparator activates the relay via T1, and the sign is lit up.



A printed circuit board has been designed (the design is available free from [1]) to make building the switch easier. Don't forget to tin the tracks switched by relay RE1 so they can carry as much current as possible to the light to be controlled. In some cases, it may be necessary to beef up the tracks with pieces of solid copper wire.

The circuit fits into a sealed IP55 box, like an electricity junction box, for example. Drill a hole in the lid of the box to allow the leads to pass through from the LDR, which you will need to glue to the lid. In front of the LDR, fit a piece of 20 mm diameter plastic conduit about 20 mm long as a shield, so that the LDR won't be affected by the light coming from the light you are trying to control. Install the switch as far away as possible from the light it is operating, to avoid ending up with a flasher!

Last of all, adjust P1 for the light level at which you want the relay to switch on.

Caution / Notice

When you're handling the circuit for testing etc., be really careful to avoid getting a shock, as there is live AC voltage present over most of the PCB. Never connect the circuit's internal ground rail to the protective earth (E/PE) line.

(090049-I)

Internet link

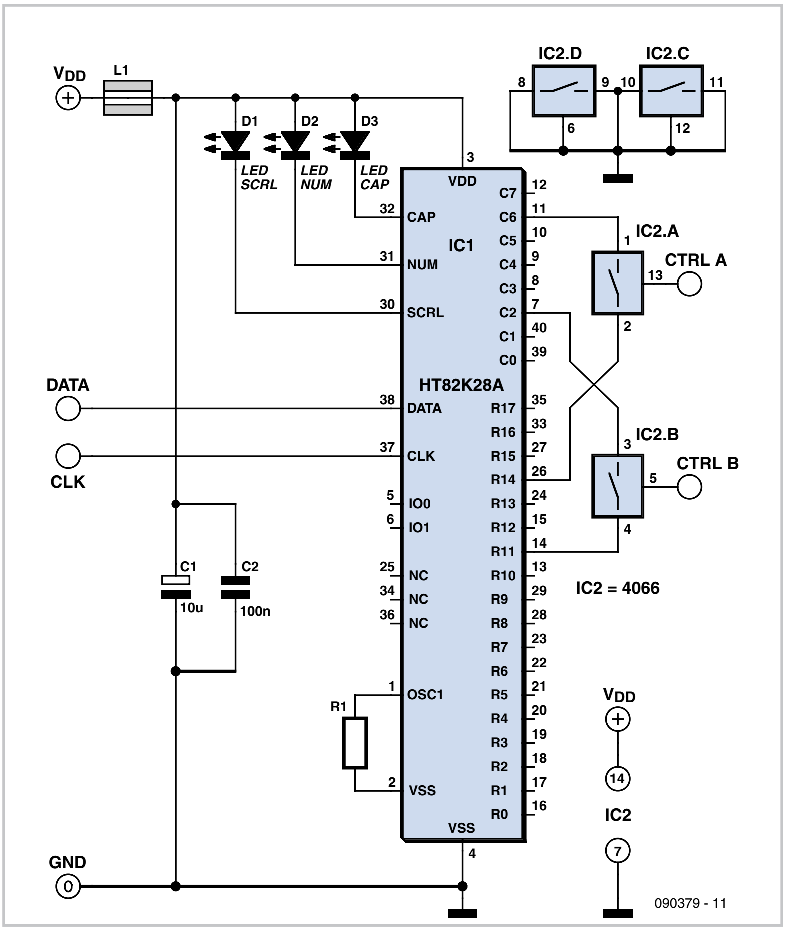
[1] www.elektor-usa.com/090049

Control Interface via PC Keyboard

Jacob Gestman Geradts (France)

One of the more difficult aspects when making a control or security system that uses a PC (a burglar alarm using a PC, for example), is the connection of the sensors to the computer. In addition to typically requiring specialist interface expansion boards, the writing of the program that includes interrupts is often also an insurmountable obstacle. But when only a simple system is concerned consisting of, for example, four light barriers or, if need be, trip wires giving a digital on/off signal when uninvited guests enter, then a much cheaper but nevertheless effective interface is possible.

For this interface we use an (old) computer keyboard. This contains as many switches as there are keys.



These switches are scanned many times per second in a matrix in order to detect the potential press of a key. The number of columns is usually eight (C0–C7 in the schematic); the number of rows varies for each type of keyboard and can range from 14 to 18 (R0–R17 with the HT82K28A keyboard encoder mentioned in the example). To each switch there is a single column- and a single row connection.

The intention of the circuit is that sensor A will 'push' the letter A, when it senses something. This requires tracing the keyboard wiring to figure out which column and which row is connected to the A key. One of the four analog switches from the familiar CD4066 CMOS IC is then connected between these two connections; that is, in parallel with the mechanical A key on the keyboard. When the Control-A input of the

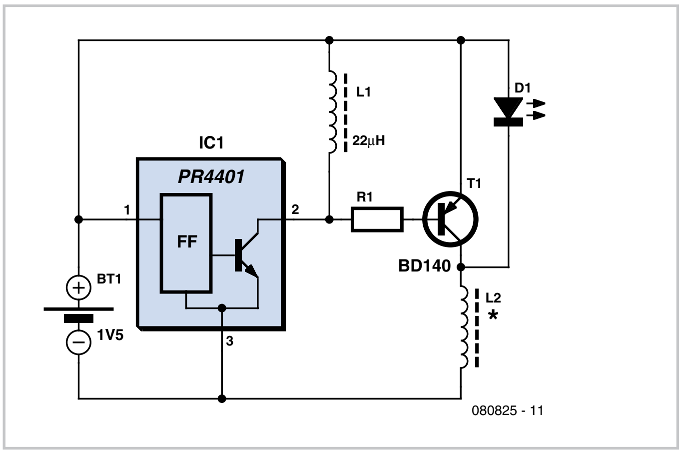
CD4066 is activated by sensor A, the letter A will be sent to the computer by the keyboard. The PC can then act appropriately, for example by entering the alarm phase.

The system is not limited to (burglar) detection using a PC. The remote control of a TV set or other electronic devices can also be operated with a 4066 in the same way; for example to scan through a number of TV channels in a cyclical fashion. To do this, you could, for example, shunt the 'next channel' button using one of the 4066 switches, which itself is activated by a 1-Hz square wave generator.

In the schematic only switches A and B of the CD4066 are connected to the keyboard. You can, of course, use all four of the switches and if you need more than four you can use multiple CD4066 ICs. The indicated wiring between the keyboard IC and the 4066 is an example only, and each 'typed' letter has to be determined by the user for the specific keyboard that is used. It is important that each CD4066 switch is always connected between a row- and a column connection. The output signal from the sensors has to be suitable for the CD4066 and the power supply voltage of 5 volts used by the keyboard. The power supply for the CD4066 may be obtained from the keyboard.

(090379-I)

PR4401 1-Watt LED Driver



T.A. Babu (India)

The PR4401 chip from Prema can be used to drive an LED directly, but not a high-power LED like one of the popular 1-watt types currently available on the market. The circuit shows that the drive signal at the V_{out} terminal of the PR4401 chip (pin 2) turns a medium-power PNP switching transistor (T1) on and off. When T1 is switched into conduction, inductor L1 is charged. When T1 is switched off, the inductor discharges its stored energy through the LED during flyback with enough current to allow a one-watt LED to light up at nominal brightness.
During the 'on' time of transistor T1, the current through inductor L2 ramps up linearly to a peak value as expressed by.

$$I_{L2(pk)} = [(V_{batt} - V_{CEsat(T1)}) \times T_{on}] / L2$$

where $V_{CEsat(T1)}$ is the collector-to-emitter saturation voltage of T1 (here, a type BD140 is suggested).

During T1's 'off' time, the inductor voltage reverses, forward-biasing the LED and discharging through it at a constant voltage roughly equal to the forward voltage of the LED, while its current ramps down to zero. Because this cycle repeats at a high rate, the LED appears to be always on, its brightness depending on the device's average current, which is proportional to the peak value. The LED current is roughly a triangular pulse with a peak current approximately equal to the inductor's current because of the finite turn-off time of T1. The estimated average current may be calculated from

$$I_{LED(avg)} = 1/2 \times I_{L2peak} \times [T_{dis} / (T_{on} + T_{off})]$$

Where T_{dis} is the discharge time of inductor L2 through the LED. The LED's brightness can be increased or decreased by varying the inductance of L2. In practice, any value between 10 and 56 µH will work just fine. The inductor current increases on each cycle until T1 goes out of saturation, hence a small resistance (R1) is required at the base of T1. Without the 'stopper resistor', the final current goes out of control due to the DC gain of T1. A transistor with a high DC current gain and low collector-to-emitter saturation voltage is the best choice if you want to tweak the circuit for efficiency. Regarding L2, make sure the peak current through it is below the saturation level.

(080825-I)

TurboGrafx-16 (PC-Engine) RGB Amplifier

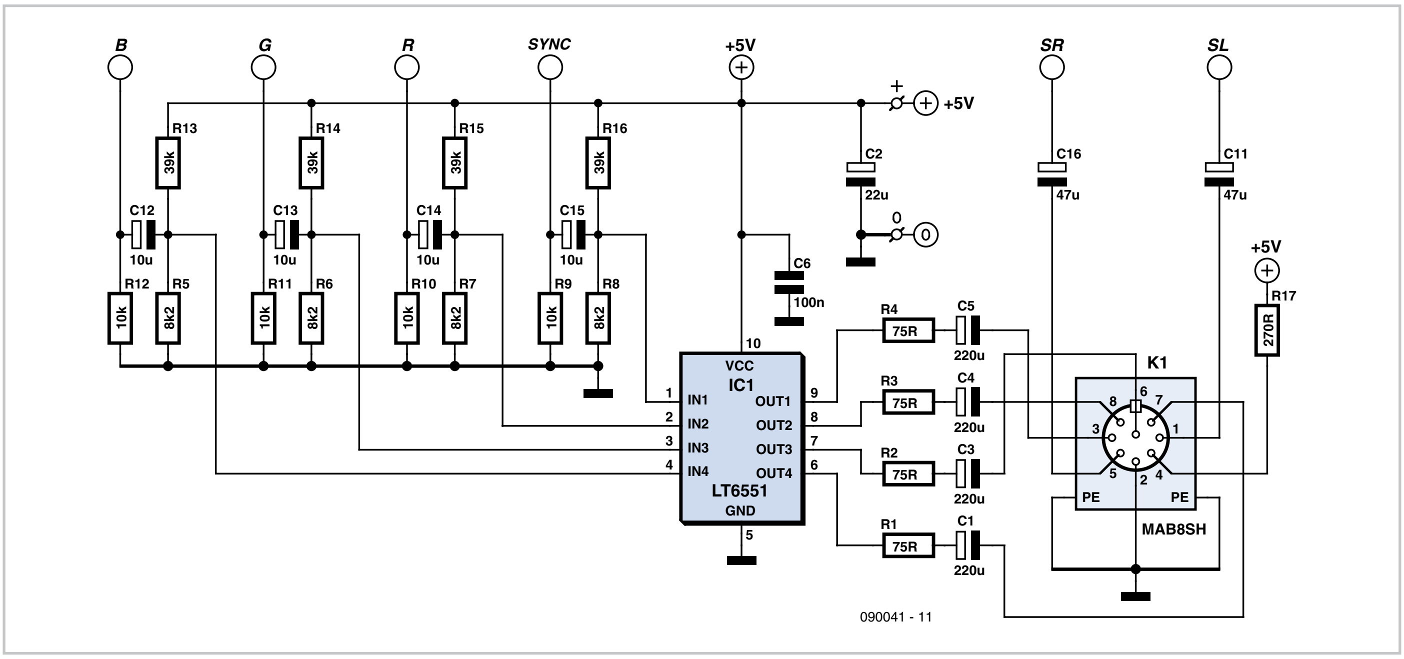
Marco Bettiol (France)

The PC-Engine, also marketed under the name TurboGrafx-16 [1] is an 8-bit games console made by NEC/Hudson Soft which appeared in Japan in 1987. In terms of units sold, for some time it exceeded Nintendo and its famous Famicom (NES in Europe). Despite this success, it was never officially distributed in Europe. Sodipeng was the only company to market it, but it remained a pretty well kept secret.

Nowadays, people who want to play again with this excellent machine are faced with a problem of incompatibility of the video signals, as the PC-Engine's NTSC video output may not be compatible with some PAL/SECAM television sets. The only way to be able to use this console and obtain a color picture is to connect directly to the HUC6260 video processor which provides the red, green, and blue primary signals plus sync. As luck would have it, these signals are directly available on the machine's rear expansion port. This port also provides the left and right audio signals, along with a 5 Vdc power rail. Even though the RGB signals are at the standard level of 0.7 V p-p, they still can't be fed to the TV set directly, as the HUC6260 is not capable of driving into a 75 Ω load. This is where you get out our soldering iron, oscilloscope, and calculator!

The principle of this circuit is very simple and is based around a single IC, the LT6551 from Linear Technology. The package contains four independent video amplifiers with a fixed gain of 6 dB. This IC is available in MSOP format, which means the overall size of the circuit can be kept down. The RGB + sync signals are picked up directly from the expansion port.

The input impedance of the circuit is set at 10 kΩ so as not to overload the HUC6260. R9 for the sync circuit, R10, 11, and 12 for the RGB. Next, we need to eliminate the 3.6 V DC component and set the RGB signals at a more suitable level. If the signal were to be amplified as is, the amplifier would be bound to saturate. So the choice of a proper level is vital in order not to distort the reproduction of the image being amplified. Capacitors C12–C16 provide coupling, and only the wanted AC component of the signal passes on to the next stage.



SCART socket wiring [2]

Ground	4, 5, 9, 13, 17, 18, 21, (14)
R	15
G	11
B	7
Video/Sync	20
Audio Left	6
Audio Right	2
RGB switching	16

PC-Engine expansion port (resembles DIN 41612) [3]

A1	Audio Left
C1	Audio Right
C2, 20	ground
A2, 21	+5 V dc
A23	Red
B23	Green
C23	Blue
C22	sync

This AC signal needs to be fixed or 'clamped' to an optimum level. The specifications of the LT6551 offer an input range from 0 to 2.5 V maximum with a 5 V supply (see data sheet). R5/R13 and the three other identical pairs of resistors create voltage dividers. By choosing the values of 8.2 kΩ and 39 kΩ, you obtain an operating point around 0.86 V. A little calculation just to check: 0.7 V plus 0.86 V gives a maximum input signal of 1.56 V.
It's important to choose the coupling capacitor value correctly, according to the value of these resistors. Together, they form a high-pass filter that attenuates the lower frequencies of the wanted signal. As a rule-of-thumb, you need to calculate this filter in such a way as to set the cut-off frequency at one tenth of the lowest frequency to be passed, which in this case is 30 Hz, the NTSC frame rate (25 Hz for PAL/SECAM). So let's take 30 Hz as the cut-off frequency. The formula for the cut-off frequency of a first-order filter $f_c = 1/(2\pi RC)$ gives C = 3.9 µF (with R = R5//R13 = 6,775 Ω and f_c = 3 Hz) and so you'll choose the slightly higher value close to this: 4.7 µF for example.
The LT6551 amplifies the video signal by a factor of two (+6 dB) and so we find at its output terminals a signal of 1.4 V, together with a DC component. A capacitor (C1, C3, C4, C5) removes this unwanted DC component and the output impedance is set to the standard value of 75 Ω by a resistor (R1–R4). This 75 Ω output impedance is effectively in series with the 75 Ω impedance of the TV set's input stage, which divides the voltage by two, bringing the video signal back down to its standard value of 0.7 V. And that's why we need to use an amplifier with a gain of 6 dB.
An 8-pin DIN socket carries the RGB + sync signals. The sound signals are filtered of any DC component and the RGB switching signal needed by the SCART input is also provided. All that remains is to make up the cable with the correct pin-outs.
This little project helps us remember that video games can generate very serious activities, and that in electronics nothing is ever chosen by chance. Enjoy your gaming!

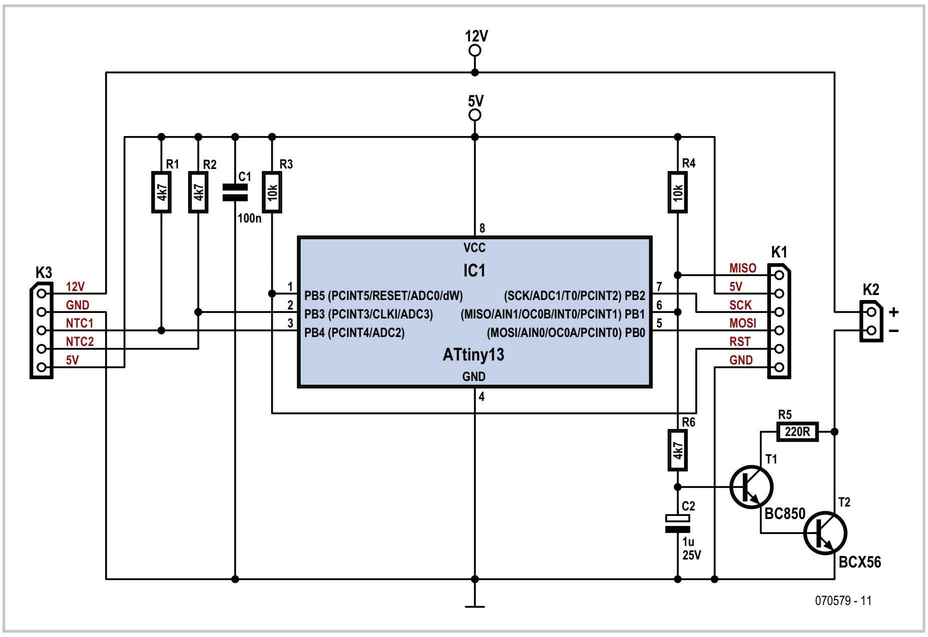
(090041-I)

Internet links

[1] http://en.wikipedia.org/wiki/PC-Engine
[2] http://en.wikipedia.org/wiki/SCART
[3] http://www.gamesx.com/misctech/pcebp.php

Fan Speed Controller

Andreas Vogel (Germany)



Anyone who uses a computer for long periods will appreciate the benefits of a silent PC. Quite a few websites now sell computer accessories specifically designed to make your desktop run more quietly. The CPU fan is often the main culprit in a noisy PC; in many cases it can be replaced by a large passive heat sink to dissipate the heat more efficiently. The heat sink fins are arranged to make optimum use of air blown through the case by the power supply fan.

The specification of Intel's ATX type PC form factor even suggests that the cooling air should be used in this way but to be successful on modern machines it is necessary to pay careful attention to a number of factors. Firstly it is important to use a processor which has the lowest possible power consumption (especially in idle mode), the lower cost 45 nm technology chips are a good place to start here. Secondly it is important to pay attention to the air flow in the case to ensure that it is ducted efficiently from the PSU through the passive CPU heat sink. The main drawback with this setup is that fan speed is only controlled by the temperature of the PSU, not the processor.

The solution of course is to install a new fan speed controller and fit a temperature sensor to the CPU heat sink. The controller senses the air temperature in the PSU as well as the processor heat sink and adjusts the fan speed according to the warmest reading. This approach ensures that everything remains cool.
With this in mind the author built this versatile fan speed controller using little more than a small microcontroller, a few transistors and two NTC thermistors. The main circuit element IC1 is an 8-pin 8-bit ATtiny13 microcontroller from Atmel. This controller has more than enough 10-bit resolution analog inputs for the job.
The circuit diagram is not so complicated: Two thermistors are connected between NTC1 and NTC2 of K3 and ground. Together with R1 and R2 they form two voltage divider networks. The voltages produced at NTC1 and NTC2 are proportional to the measured temperatures. These are sampled by the analog inputs ADC2 and ADC3 of the microcontroller. The controller will select one of ten fan speed settings depending on the measured values of temperature. The higher of the two temperature readings will always be used. The output from pin 6 is a pulse modulated waveform to control fan speed. The output Darlington configuration of T1/T2 drives the fan from the PWM waveform integrated by R6/C2. This low pass network filters out the 15 Hz fundamental of the PWM output signal to reduce any PWM noise generated in the fan windings.

The power connections to 12 V and 5 V on K3 can be supplied from an unused floppy disk drive or spare hard disk power cable. K1 provides the connection for the in-circuit programming cable for the microcontroller. R4 should ensure that the fan is switched on if the microcontroller hangs or a fault occurs.
The circuit is so simple that it can comfortably fit on a square of perforated stripboard and housed in a small plastic enclosure. Fix one of the thermistors onto the heat sink (doesn't matter which one but make sure it is electrically insulated from the heat sink). The other thermistor can be positioned in the air flow from the PSU so that air can pass freely around it. The PSU fan can now be connected to the new fan speed controller. Some fans have a built-in thermistor which regulates the fan speed autonomously. In this case remove the thermistor and replace it with a fixed resistor to make sure it runs at full speed (try 1 kΩ).
The firmware for IC1 is written in assembly language and would also run in principle on other variants of the ATtiny microcontroller family.

(070579-I)

Download & Product

Programmed controller

070579-41 Controller ATtiny13

Software

070579-11: source code and hex files, from www.elektor-USA.com/070579

Power-up/down Sequencer

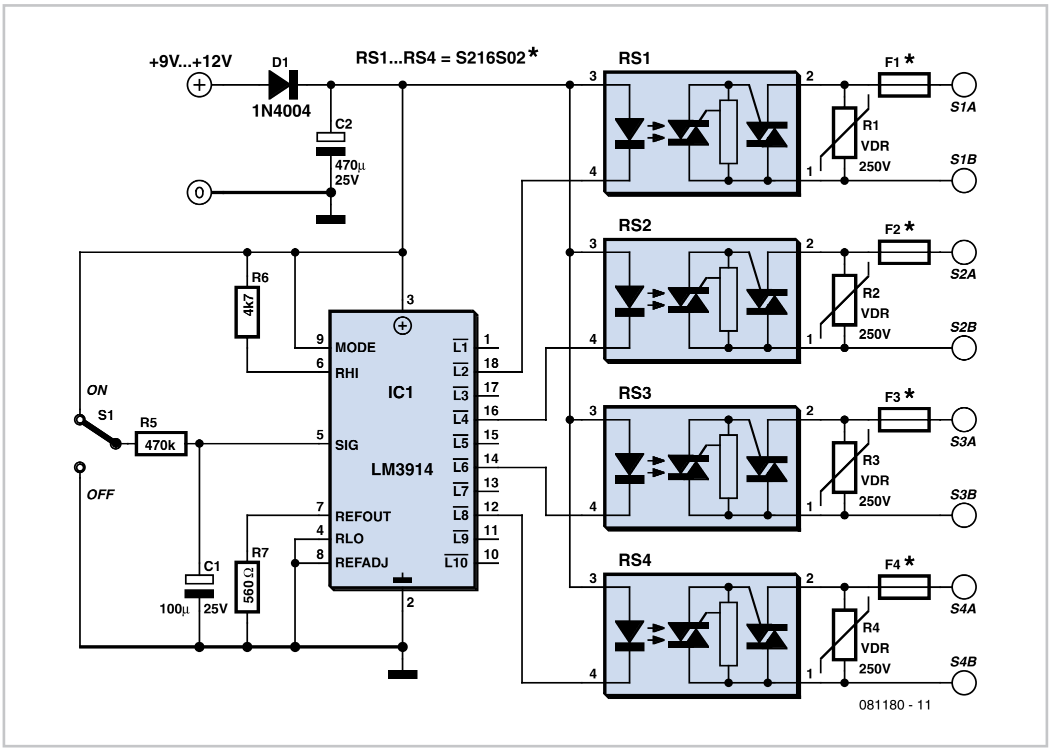
Christian Tavernier (France)

Whether you're talking about a home cinema or a computer system, it's very often the case that the various elements of the system have to be turned on or off in a quite specific order, or at least, automatically. Constructing this sort of automation system is well within the capability of any electronics enthusiast worthy of the name, but in this 'all-digital' age, most of the circuits of this type to be found in amateur electronics magazines or websites use a microcontroller. Even though that is indeed a logical solution (in more ways than one!), and you might even say the easiest one, it does pose problems for all those people who don't (yet) have the facilities for programming these types of IC. So we decided to offer you now an approach that's very different, as it only uses a simple, cheap, commonly-available analog integrated circuit, which of course doesn't have to be programmed. Our project in fact uses as it's 'brain' an LM3914, a familiar IC from National Semiconductors, usually used for driving LED VU (volume unit) meters.

Before taking a look at the circuit for our project, let's just remind ourselves that the IC has one analog input and ten outputs intended for driving LEDs. It can operate in 'point' mode, where the LEDs light up in turn, from first to last, depending on the input voltage, but only one LED is lit at any given time. Alternatively it can operate in 'bar' mode (this is the mode normally used for VU meters), and in this case, the LEDs light up one after the other, in such a way as to create a strip of light (bar) that is longer or shorter according to the input voltage. This is the mode selected for the LM3914 in the circuit described in some detail below.

So as to be able to control the AC powered equipment our sequencer is intended to manage, we are using solid-state relays — four, in our example, though you can reduce or increase this number, up to a maximum of ten. Since the input devices in solid-state relays are LEDs, they can be driven directly by the LM3914 outputs, since that's exactly what they're designed for. As only four relays are available, these are spread across outputs L2, L4, L6, and L8, but you can choose any arrangement you like to suit the number of relays you want to use.

Resistor R7 connected to pin 7 of the LM3914 sets the current fed to the LEDs by the LM3914 outputs. Here, it's been set to 20 mA, since that is the value expected by the solid-state relays chosen. The input voltage applied to pin 5 of the LM3914 is none other than the voltage present across capacitor C1 — and this is where the circuit is ingenious. When the switch is set to 'on', C1 charges slowly through R5, and the LEDs of the solid-state relays on the outputs light one after another as this voltage increases; in this way, the units being controlled are powered up in the order you've chosen. To power-down, all you have to do is flip the switch so that C1 discharges through R5, and the LEDs go out in the reverse order to that in which they were lit, in turn powering down the units connected



to the solid-state relays. Easy, isn't it?
If you're not happy with the sequence speed, all you need do is increase or reduce the value of R5 in order to alter the speed one way or the other.

The circuit needs to be powered from a voltage of around 9 to 12 V, which doesn't even need to be stabilized. A simple 'plug-top', 'wall wart' or 'battery eliminator' unit will be perfect, just as long as it is capable of supplying enough current to power all the LEDs. As the LED current is set by R7 to 20 mA per LED, it'll be easy for you to work out the current required, according to the number of solid-state relays you're using.

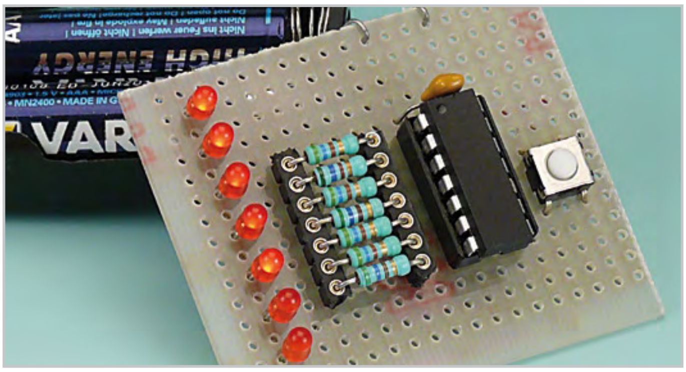
In our prototype the type S216S02 relays from Sharp were used, mainly because they proved readily available by mail order. They also have the advantage of being compact, and their switching capacity of 16 A means you can dispense with a heatsink if you're using them for a computer or home cinema system, where the current drawn by the various units can be expected to remain under 1 A. These solid-state relays must be protected by a fuse, the rating of which needs to be selected according to the current drawn by the devices being powered.

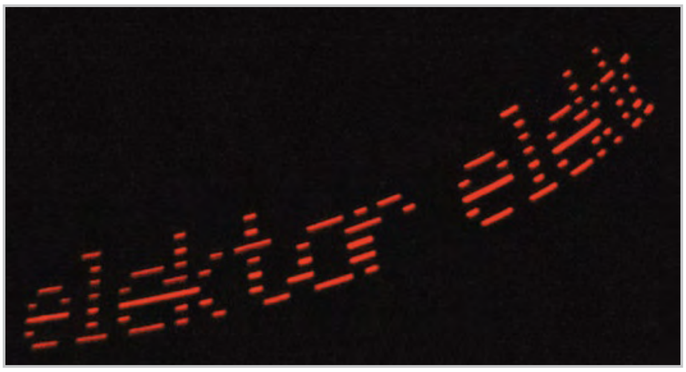
Also note the presence across the relay terminals of a VDR, also known as a GeMOV or SiOV, intended to protect them from any spurious voltage spikes. You can use any type that's intended for operation on 250 VAC without any problem. The values of fuses F1 to F4 are of course going to depend on the load being protected.

Construction of the circuit shouldn't present any particular difficulty, but as the solid-state relays are connected directly to AC power, it is essential to install it in a fully-insulated case; the case can also be used to mount the power outlet sockets controlled by the circuit. Note that sockets are female components.
Let's just end this description with the sole restriction imposed by our circuit — but it's very easy to comply with, given the intended use. In order to remain triggered, the solid-state relays must carry a minimum holding current, which is 50 mA in the case of the devices we've selected. In practical terms, this just means that each of the devices powered by our sequencer must draw at least 50 mA, or in other words roughly 12 VA at 230 VAC, or 25 VA at 120 VAC.

(081180-I)

Floating Message

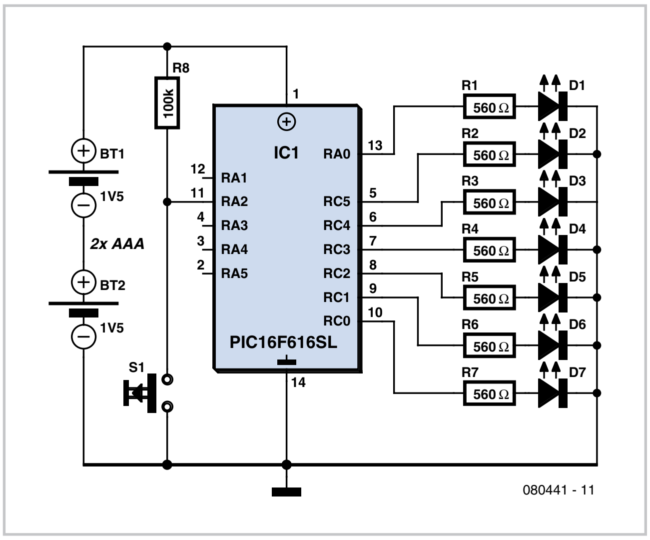




Ludovic Voltz (France)

This project lets you display a message floating in the air using just seven LEDs, a microcontroller, and the movement of your arm. How can that be possible?

The human eye and brain can't resolve a moving object, and the same applies to anything that changes rapidly. It is by exploiting this shortcoming (or capacity, depending on which way you look at it!) that we are able to see videos and all types of footage, clips, visual effects and so on, on the many screens around us.



When the images on the screen appear at a rate of at least 24 per second, humans can no longer make them out as individual images and perceive the result as a moving object. It's this 'persistence of vision' that the author has exploited in creating this project.
The characters of the message to be displayed use a very common 7 line × 5 column character style. The columns are displayed sequentially by the seven LEDs arranged in a column: first column 1, then 2, and so on up to 5. If the LEDs are moved on slightly before displaying the next column, the eye thinks it is seeing the whole character. The LEDs flash at a frequency of the order of 200 Hz, and so all you have to do is move the circuit around to see the message appear as if it were floating in mid air. Here's a little gadget that will amuse young and old alike on summer evenings.

For simplicity and compactness, this project uses a PIC16F616 microcontroller from Microchip, capable of working off no more than 2 V. This allows the circuit to be powered from two AAA rechargeable batteries (2 × 1.2 V), a good compromise between battery life and the space taken up. What's more, this solution is environmentally-friendly, as the batteries can be recharged, unlike CR2035 button cells, for example.

The messages are created with the help of an Excel file, where all you have to do is fill in the cells with 0's or 1's according to the character you want to display. This file then directly gives the hex code for the corresponding constant. Naturally, this file is available in the download accompanying this article [1].

Using the circuit is as simple as its operating principle. A brief press of the button starts the sequence for displaying the word. Then all you have to do is synchronize your movements with pressing the button. In order to be able to read the word properly, it's best to repeat the operation more than once. You can store several words in the PIC's Flash memory (up to the limit of its capacity, of course). To move on to the next word, you must press the button for at least 0.6 s. The reproduction will be clearer if the background lighting is low.

(080441-I)

Internet Link

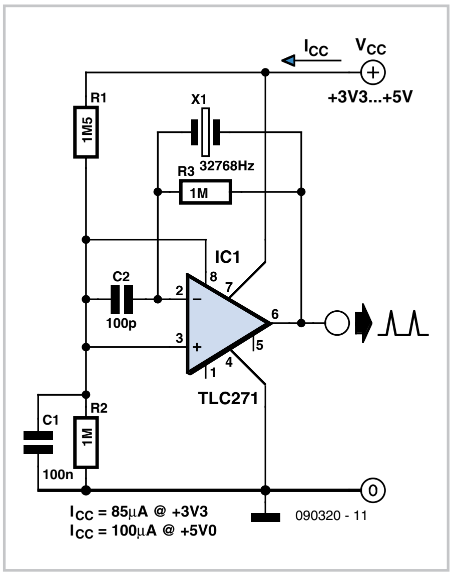
[1] www.elektor-usa.com/080441

Micropower Crystal Oscillator

Rainer Reusch (Germany)

Crystal oscillators for digital circuits are normally built as Pierce oscillators with an inverter. The inverter operates as a linear amplifier and thus requires extra current. But you can also build a crystal oscillator using an operational amplifier (op amp for short)! If a very low frequency is involved, for instance 32.768 kHz (commonly used for clocks), you can get away with a comparatively 'slow' micro power op amp.

In the sample circuit shown a widely available TLC271 is used. On pin 8 we have the opportunity to set the 'bias mode', with three choices ranging between fast operation with higher current consumption and slower operation at low current. For our clock crystal the middle setting will suit us fine. Pin 8 is therefore connected to the voltage divider R1/R2. The current consumption of the entire circuit is impressively modest and at 5 V this is just 56 µA! The oscillator also functions astoundingly well at 3.3 V. At the same time the current drops to a more battery-friendly 41 µA. A prototype built in the Elektor Labs produced the slightly higher values indicated in the circuit diagram.



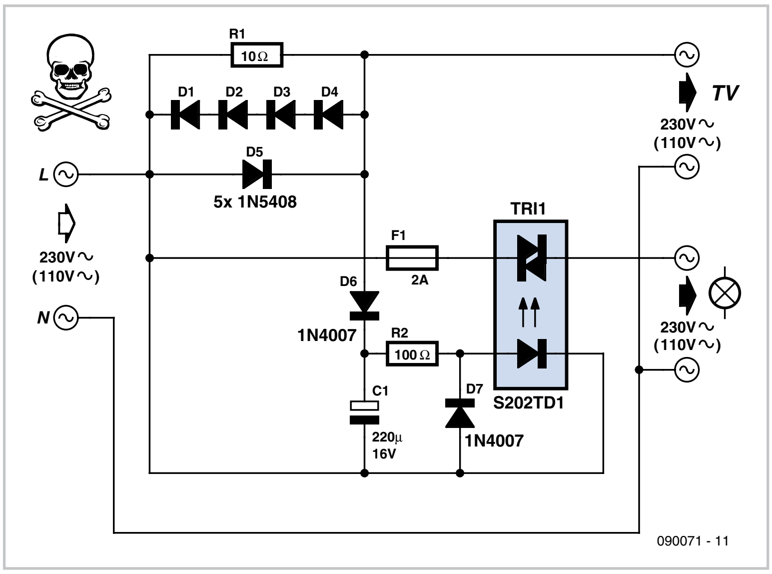
The output signal delivered by this circuit has admittedly scant similarity to a square wave. Nevertheless some cosmetic surgery will tidy this up, with treatment in the Schmitt trigger following. To save current (naturally) we use a CMOS device such as the 74HC14.

(090320-I)

Automatic TV Lighting Switch

Piet Germing (The Netherlands)

The author is the happy owner of a television set with built-in Ambilight lighting in the living room. Unfortunately, the television set in the bedroom lacks this feature. To make up for this, the author attached a small lamp to the wall to provide background lighting, This makes watching television a good deal more enjoyable, but it's not the ideal solution. Although the TV set can be switched off with the remote control, you still have to get out of bed to switch off the lamp.



Consequently, the author devised this automatic lighting switch that switches the background light on and off along with the TV set. The entire circuit is fitted in series with the AC power cable of the TV set, so there's no need to tinker with the set.

It works as follows: R1 senses the current drawn by the TV set. It has a maximum value of 50 mA in standby mode, rising to around 500 mA when the set is operating. The voltage across R1 is limited by D5 during negative half-cycles and by D1–D4 during positive half-cycles. The voltage across these four diodes charges capacitor C1 via D6 during positive half-cycles. This voltage drives the internal

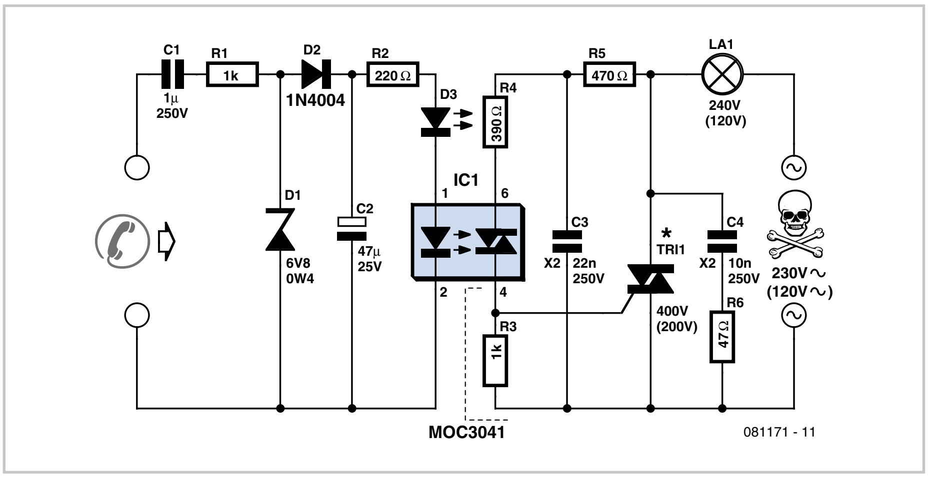
LED of solid-state switch TRI1 via R2, which causes the internal triac to conduct and pass the mains voltage to the lamp.
Diode D7 is not absolutely necessary, but it is recommended because the LED in the solid-state switch is not especially robust and cannot handle reverse polarization. Fuse F1 protects the solid-state switch against overloads.
The value of used here (10 Ω) for resistor R1 works nicely with an 82-cm (32 inch) LCD screen. With smaller sets having lower power consumption, the value of R1 can be increased to 22 or 33 Ω, in which case you should use a 3-watt type. Avoid using an excessively high resistance, as otherwise TRI1 will switch on when the TV set is in standby mode.
Some TV sets have a half-wave rectifier in the power supply, which places an unbalanced load on the AC power outlet. If the set only draws current on negative half-cycles, the circuit won't work properly. In countries with reversible AC power plugs you can correct the problem by simply reversing the plug.
Compared with normal triacs, optically coupled solid-state relays have poor resistance to high switch-on currents (inrush currents). For this reason, you should be careful with older-model TV sets with picture tubes (due to demagnetization circuits). If the relay fails, it usually fails shorted, with the result that the TV background light remains on all the time.
If you build this circuit on a piece of perfboard, you must remove all the copper next to conductors and components carrying mains voltage. Use PCB terminal blocks with a spacing of 7.5 mm. This way the separation between the connections on the solder side will also be 3 mm. If you fit the entire arrangement as a Class II device, all parts of the circuit at AC line potential must have a separation of at least 6 mm from any metal enclosure or electrically conductive exterior parts that can be touched. Local/national electrical safety regulations may dominate however.

(090071-I)

Phone Ring Repeater

Christian Tavernier (France)

Even though cordless phones have invaded our homes and offices, you don't always have them at hand, and as their ringtones are usually very much quieter than the old rotary-dial-type analog phones, it can happen that you miss a call you've been waiting for while you've been going about your daily business. Until quite recently, you could still find remote ringers that could be plugged into any standard phone socket in order to have an additional ringer, but it seems as if these accessories are currently being phased out as everyone is 'going cordless'. So we decided to suggest something better, with this phone ring repeater that makes it possible to control any device connected to the AC power outlet using the ringtone available on any subscriber line, and naturally, with all the guarantees of safety and isolation that are of course rightly expected. So it's capable of driving a ringer, or indeed even a high-powered sounder to alert you when you are in the garden, for example; but it is equally able to light a lamp for a 'silent ring' so as to avoid waking a sleeping baby or elderly person.
This circuit has been designed to be compatible with all phone systems the author is aware of and also to be totally stand-alone. What's more, the circuit can be connected to the phone system without any danger — though in some countries, it is prohibited to connect non-approved devices to the public switched telephone network (PSTN). Check local regulations in this respect.
In order to understand the principle of it, we just need to remember that the ringtone present on a phone installation is an alternating voltage, whose amplitude and frequency vary somewhat between countries, but always with comparable orders of magnitude except in the case of exchange systems used in large companies. However, when the line is quiescent or a call is in progress, it carries only a direct voltage. Capacitor C1 makes it possible to pick off just the AC ringing voltage, which is then rectified by D2 and amplitude-limited by D1. The resulting DC voltage



charges capacitor C2, which makes it possible to light LED D3 as well as the LED in the optocoupler IC1. This is no ordinary optocoupler, but is in fact an AC power zero-crossing detecting opto-triac, which allows us to control the chosen load while generating no, or less, interference, which would not be the case using a standard opto-triac.
The output triac it contains is not powerful enough to drive a load directly connected to the mains, so it is used to drive the trigger of triac TRI1, which is a totally standard 400 V device, rated at x amps, where x is chosen to suit the maximum power of the load you want to control using this circuit.
Resistors and capacitors R5 and C3 on the one hand, and R6 and C4 on the other help, serve to suppress the switching transients, which are already inherently low because of the AC zero-crossing switching provided by IC1.
Construction is not at all difficult, but does require a few precautions in choosing some of the components. First of all, capacitor C1 must be an MKT type, mylar or equivalent, with a 250 V operating voltage because of the relatively high amplitude of the ringing voltage. For safety reasons, it is essential that capacitors C3 and C4 are self-healing types intended for AC power use at 250 VAC. These capacitors are generally known as Class X or X2 capacitors.
As for the triac, it should have a 400 V operating voltage (but see below for users on 120 VAC power) and maximum current slightly greater than the maximum current drawn by

the load being driven. As this will usually be a sounder or a common lamp, a 2 A type will usually be more than adequate in most situations. As the circuit can be expected to operate for short periods only, there is no need to mount the triac on a heatsink.
One final important point: as the right-hand part of the circuit is connected directly to AC power, it is vital to fit this inside a fully-insulated housing, for obvious safety reasons. Make sure you cannot touch any part when the circuit is in use.

The circuit should work at once and without any problems, but if you notice that D3 doesn't light up fully, and hence incorrect or erratic triggering of the triac, because of too low a ringing voltage, all you need to put things to rights is reduce the value of resistor R1.

The circuit as shown was dimensioned for operation from 230 VAC power. Readers on 120 V AC power should modify the following component values: R4 = 180 Ω; R5 = 220 Ω; TRI = 200 V model; IC1 = MOC3031. Optionally, C3 and C4 may be rated at 120 VAC.

(081171-I)

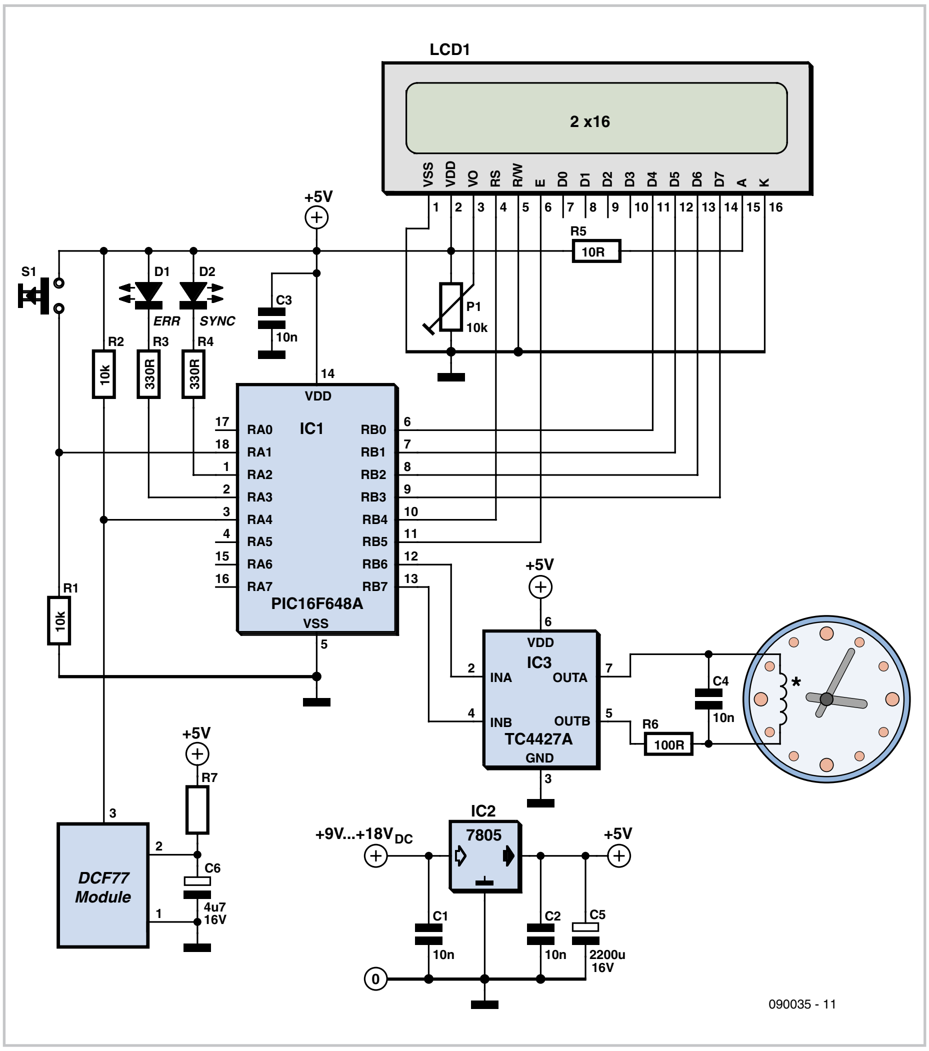
Pulse Clock Driver with DCF Synchronization

Hans Oostwal (The Netherlands)

Sometimes you can pick up a nice office clock or station clock at a bargain price. To ensure that these clocks all show the same time inside an organization such as the railway system and avoid hassles with changing between winter time and summer time or replacing empty batteries, these clocks are normally connected to a clock pulse network that is driven by a master clock or radio signal. The master clock generates a pulse every minute, with successive pulses having opposite polarity.

If you want to use a clock of this sort, you naturally want it to keep good time. This is handled by the circuit described here, which offers the following features:

- it is synchronised to the DCF77 time reference signal at 77.5 kHz (from Mainflingen, Germany) so the time is always correct;
- it is inexpensive – by using a microcontroller (in this case a PIC16F648A), the circuit requires only a few components, and it can easily be assembled on a piece of perfboard;
- it generates pulses at one-minute intervals with alternating polarity;
- it also shows the time and date on an alphanumeric LCD module;
- automatic switching between winter and summer time;
- time data is backed up in case of power failure (stored in PIC EEPROM).



When using a clock of this sort, note that some models have jumpers that can be fitted or removed to configure the clock for different working voltages. If you have this type of clock, select the lowest voltage (usually 24 V). Based on the author's experience, clocks from the Dutch PTT (former postal and telecommunication authority) also work OK at 12 V.

Figure 1 shows the schematic diagram of the hardware. The circuit is built around a PIC16F648A clocked by its internal 4-MHz oscillator. A standard two-row LCD (HD44780 compatible) is connected to the microcontroller to display operating instructions or the date and time.
The circuit can be powered from an AC mains adapter that supplies a DC voltage in the range of 9 to 18 V. A voltage regulator (IC2) generates a stable 5-V supply voltage for the electronics from this. The supply voltage from the adapter is connected directly to the TI4427A MOSFET driver IC that drives the clock coil. This driver IC has a operating voltage range of 4.5 to 18 V and a maximum rated output current of 500 mA (1.5 A peak). This is adequate for most clocks. If you need more current, you can add a transistor or relay to the output stage. The clock coil has a fairly high inductance, so the supply voltage has extensive decoupling in the form of several ceramic capacitors (C1–C4) and an electrolytic capacitor (C5).
A DCF77 receiver/decoder module from Con-

rad Electronics (p/n 641138) provides the time reference signal. It is also powered by the 7805 voltage regulator. The non-inverted output of this module is connected to port RA4 of the microcontroller. As reception of the long-wave signal from the DCF transmitter may not be good in some locations, especially if you fit the circuit in a metal enclosure, it is advisable to fit the DCF module in a separate plastic box that can be placed a certain distance away from the clock.
The source code of the software is written in Flowcode 3 Pro and is available free on the Elektor website for downloading (item number 090035-11). It is based on the software for the E-Blocks DCF clock published in the December 2007 issue (075094-11). The original software has been adapted to this application and extended with code that generates a pulse signal on ports B6 and B7 with a period of 1 minute and alternating pulse polarity.
Pushbutton switch S1 is used for most of the operator functions. This button is connected to port A1 and has several functions:

- if S1 is not pressed when the power is switched on, the microcontroller executes a warm start. This is the normal situation. In the event of a power failure, the analog time and the polarity are saved in EEPROM, and they are restored after the next warm start;

- if S1 is pressed when the power is switched on, a cold start is executed. This must be done the first time the circuit is used (see below for more information);

- if S1 is pressed during normal operation, the variables 'a_hrXX' and 'a_minuteXX' are shown on the display, which enables the user to set the analog clock.

In order to synchronize the analog clock to the digital clock, the analog clock must first be set to exactly 12 o'clock. If you have a clock that can only be operated electrically, which means it does not have any mechanism (such as a knob) to set the time manually, you can hold S1 pressed after the cold start to cause the circuit to generate a continuous series of clock pulses. Release S1 when the clock reaches exactly 12 o'clock. If you have a clock that can be set manually, first set it to 12 o'clock and then switch on power to the circuit with S1 held pressed. Release S1 when the message 'cold start… done' appears on the LCD. If the DCF signal is being received properly, the date and time will be shown on the display after a few minutes and the analog clock will be set to the right time.

If the time shown by the analog clock differs from the time shown on the LCD by one minute, the polarity of the pulses does not match the state of the stepper motor in the clock. This can be corrected by first setting the clock to the right time and then swapping the two leads. This action must be completed within one minute.

(090035-I)

Internet Link

[1] www.elektor-usa.com/090035

Product

090035-41: Programmed PIC

Download

090035-11: Flowcode (.fcf) and hex files, from [1]

Frequency and Time Reference with ATtiny2313

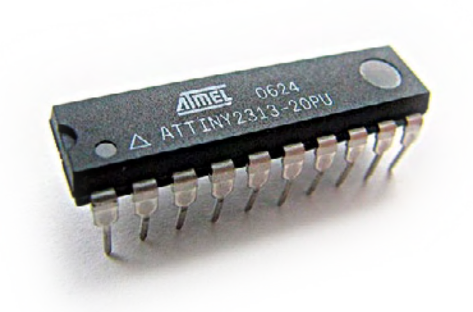
Vladimir Mitrovic (Croatia)

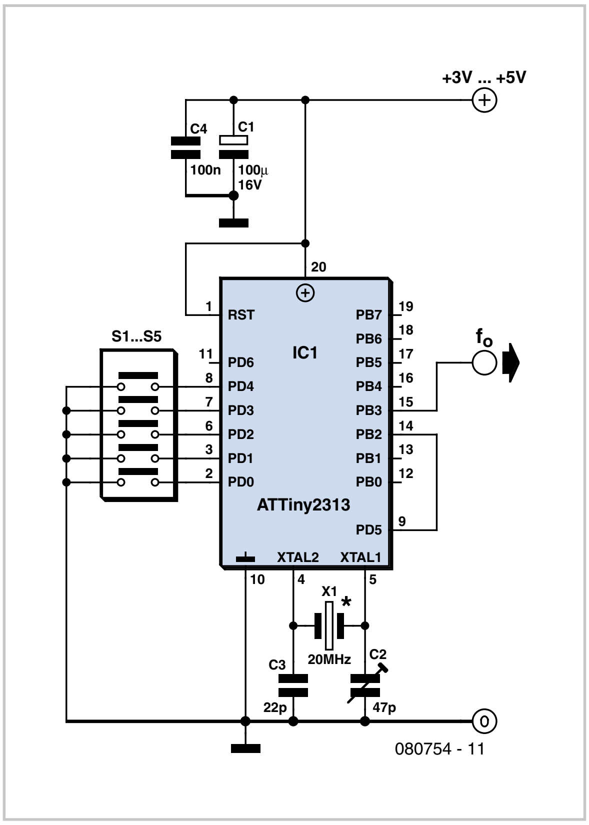
In this project an AVR microcontroller type ATtiny2313 acts as a variable frequency divider, giving a sequence of very stable reference frequencies with a 50% duty cycle and covering a frequency range of 0.1 Hz – 4 MHz in 1, 2, 4 or 8 steps. The circuit is very simple because everything is done inside the microcontroller. In the program 31 different frequencies are predefined and may be selected by switches S1–S5 according to **Table 1**.

The ATtiny2313 has two timers/counters: 16-bit Timer/Counter1 and 8-bit Timer/Counter0, both offering various modes of operation. The 'Clear Timer on Compare Match' (CTC) mode is the most appropriate for generating a waveform output. In CTC mode Timer/Counter1 counts the system clock or external pulses up to the value given in the OCR1A (Compare1A) register. When the counter value matches the OCR1A value the counter is cleared to zero and the OC1A pin (PB3) toggles. In CTC mode Timer/Counter0 counts the system clock or external pulses up to the value given in the OCR0A register. When the counter value matches the OCR0A value, the counter is cleared to zero and the OC0A pin (PB2) toggles. Division factors up to 2 x 65536 (for Timer1) or 2 x 256 (for Timer0) can be obtained by setting appropriate values in the OCR1A and OCR0A registers. Besides by the timer division factor, an output frequency is also determined by the system clock, the system clock prescaler (1-2-4-8-16-32-64-128-256) and the timer prescaler (1-8-64-256-1024). In this design, an 8 MHz or a 20 MHz crystal may be used in position X1 (20 MHz shown in circuit diagram) but not indiscriminately because matching firmware should reside in the ATtiny.

There are obviously several appropriate settings for producing a given frequency. As the system clock and the system clock prescaler setting determine the overall current consumption as well (lower frequency = lower consumption), we will always choose the lowest possible CPU clock. Assuming X1 = 8 MHz, for the 1 Hz to 4 MHz frequency range, only Timer/Counter1 is used. It counts the (prescaled) system clock pulses and the output frequency may be calculated from:

f = 8,000,000 / [2 × system_clock_prescale × (1 + OCR1A_value)]





For the lower frequencies, 8-bit Timer/Counter0 is used as an additional prescaler (division factor: 10) between the prescaled system clock and Timer/Counter1. The latter is set in the counter mode and now counts pulses at the Timer/Counter0 output pin OC0A (PB2); hence, the OC0A pin (PB2) and the external input pin T1 (PD5) are interconnected. The output frequency can be calculated as:

f = 8,000,000 / [2 × system_clock_prescale × (1 + OCR1A_value × 2 × (1+OCR0A_value)]

The program, which was written in BascomAVR, constantly monitors switches S1–S5. It is available as a free download [1]. If any change in the switch settings occurs, the 'Set_f' subroutine is called to set a new frequency. The subroutine will stop timers, reconfigure them, set proper values in various registers to obtain the proper division factor and restart the timers. The values for the registers are written in three tables.

1. 'Clock_prescale_table' contains the values in the range of 1 to 256 (only values 2^n are allowed) which will be used to calculate the proper value for the Clock Prescale Register, CLKPR.

2. 'Ocr1a_table' contains the values in the range of 1 to 65535 which will be used to calculate the proper value for the Timer/Counter1 Output Compare Register OCR1A. Only values 5^n (1, 5, 25, 125, 625, 3125 and 15625) are used in this design. A zero (0) entry denotes that Timer/Counter1 is stopped for this frequency. Note that the value in the table is decremented by 1 before being written into the OCR1A.

3. 'Ocr0a_table' contains the values in the range of 1 to 255 that will be used to calculate the proper value for the Timer/Counter0 Output Compare Register OCR0A. Only values 0 and 5 are used in this design: a '0' entry denotes that the Timer/Counter0 is stopped for this frequency, while '5' produces division of the system clock by 10. If even lower frequencies are needed, other type-5^n values (25 and 125) can be used to produce division factors of 100 and 1000. Note that the value in the table is decremented by 1 before being written into the OCR0A.

The *Fref_ATtiny2313_Elektor_8MHz.bas* program should be compiled and the resulting hex code programmed into the ATtiny2313 microcontroller before first use. Be sure to set the Flash Fuse bits to the proper value for an external crystal resonator (CKSEL3...0 = 1111) because the internal RC Oscillator is selected by default. The hex file for 8 MHz is also available straight away in the download at [1]. A variable capacitor C2 is provided to tune a crystal frequency to exactly 8.000 MHz, if

possible. If you are satisfied with the crystal's accuracy, replace C2 with a fixed capacitor. Set the configuration switches according to Table 1 to obtain the wanted frequency.
Powered at 3 V, the 8-MHz version of the frequency reference may still be used with most logical families running at 5 V: CMOS, LSTTL, HC, HCT and so on. However, be careful and do not allow any current to flow from 5 V powered circuits back into the microcontroller through the PB3 pin. This could cause battery charging through the microcontroller's clamping diodes with unpredictable results for both the battery and the microcontroller. If such a risk exists, connect a 3 V zener diode between PB3 and GND to effectively limit the voltage to a safe value. Caution: ready-programmed device **080754-41** from the Elektor Shop is programmed for the 20-MHz configuration and does not work down to 3 V.

Raising the supply voltage to 5 V will approximately double the supply current to 15 mA (max.), but it will also allow you to raise the clock frequency to 20 MHz and obtain some higher frequencies from the circuit. If current consumption is not an issue, you may contemplate the use of a precision quartz oscillator to drive the microcontroller.

The program *Fref_ATtiny2313_Elektor_20MHz.bas* will produce reference frequencies in the 0.001 Hz – 10 MHz frequency range in steps of 1, 2 or 5. The main difference with the 8 MHz program is that the timer prescaler for Timer/Counter0 is used here in order to produce frequencies under 0.01 Hz. A table called "Timer0_prescale_table" is added to the program. It contains values '0' (if Timer/Counter0 is not used), '1' (if it is used but not prescaled) or '8' (if it is used and prescaled by the factor of 8).

The frequencies supplied by the 20 MHz version are given in **Table 2**. The two lowest frequencies, marked by an asterisk (*) in the table, could not be obtained exactly, but the division error is well under the crystal tolerance and therefore may be totally neglected.

(080754-I)

Internet Link

[1] www.elektor-usa.com/080754

Downloads & Products

Programmed Controller

080754-41 ATtiny2313, ready programmed, 20 MHz configuration

Software

080754-11 Source and hex files for 8 MHz and 20 MHz, from [1]

Table 1. DIP switch settings for X1 = 8 MHz

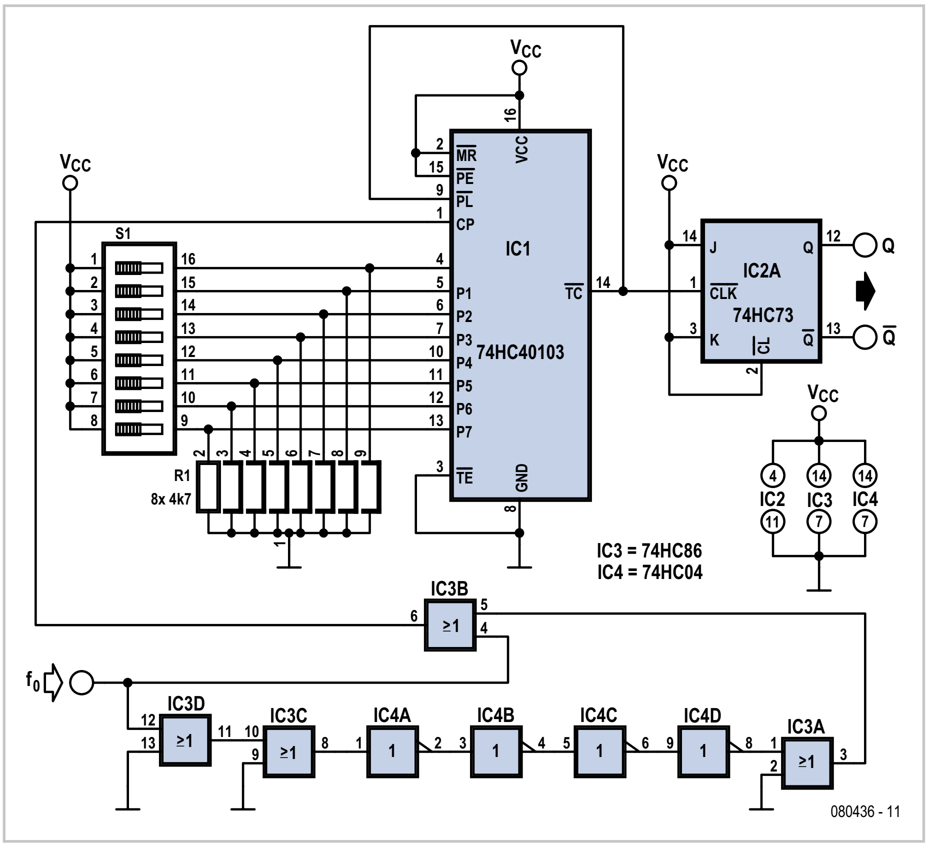
S5	S4	S3	S2	S1	PD4…PD0	Output freq.	
on	on	on	on	on	00000	4	MHz
on	on	on	on	off	00001	2	MHz
on	on	on	off	on	00010	1	MHz
on	on	on	off	off	00011	800	kHz
on	on	off	on	on	00100	400	kHz
on	on	off	on	off	00101	200	kHz
on	on	off	off	on	00110	100	kHz
on	on	off	off	off	00111	80	kHz
on	off	on	on	on	01000	40	kHz
on	off	on	on	off	01001	20	kHz
on	off	on	off	on	01010	10	kHz
on	off	on	off	off	01011	8	kHz
on	off	off	on	on	01100	4	kHz
on	off	off	on	off	01101	2	kHz
on	off	off	off	on	01110	1	kHz
on	off	off	off	off	01111	800	Hz
off	on	on	on	on	10000	400	Hz
off	on	on	on	off	10001	200	Hz
off	on	on	off	on	10010	100	Hz
off	on	on	off	off	10011	80	Hz
off	on	off	on	on	10100	40	Hz
off	on	off	on	off	10101	20	Hz
off	on	off	off	on	10110	10	Hz
off	on	off	off	off	10111	8	Hz
off	off	on	on	on	11000	4	Hz
off	off	on	on	off	11001	2	Hz
off	off	on	off	on	11010	1	Hz
off	off	on	off	off	11011	0.8	Hz
off	off	off	on	on	11100	0.4	Hz
off	off	off	on	off	11101	0.2	Hz
off	off	off	off	on	11110	0.1	Hz
off	off	off	off	off	11111	standby	

Table 2. DIP switch settings for X1 = 20 MHz

S5	S4	S3	S2	S1	PD4…PD0	Output freq.	
on	on	on	on	on	00000	10	MHz
on	on	on	on	off	00001	5	MHz
on	on	on	off	on	00010	2	MHz
on	on	on	off	off	00011	1	MHz
on	on	off	on	on	00100	500	kHz
on	on	off	on	off	00101	200	kHz
on	on	off	off	on	00110	100	kHz
on	on	off	off	off	00111	50	kHz
on	off	on	on	on	01000	20	kHz
on	off	on	on	off	01001	10	kHz
on	off	on	off	on	01010	5	kHz
on	off	on	off	off	01011	2	kHz
on	off	off	on	on	01100	1	kHz
on	off	off	on	off	01101	500	Hz
on	off	off	off	on	01110	200	Hz
on	off	off	off	off	01111	100	Hz
off	on	on	on	on	10000	50	Hz
off	on	on	on	off	10001	20	Hz
off	on	on	off	on	10010	10	Hz
off	on	on	off	off	10011	5	Hz
off	on	off	on	on	10100	2	Hz
off	on	off	on	off	10101	1	Hz
off	on	off	off	on	10110	0.5	Hz
off	on	off	off	off	10111	0.2	Hz
off	off	on	on	on	11000	0.1	Hz
off	off	on	on	off	11001	0.05	Hz
off	off	on	off	on	11010	0.02	Hz
off	off	on	off	off	11011	0.01	Hz
off	off	off	on	on	11100	0.005	Hz
off	off	off	on	off	11101	0.002	Hz*
off	off	off	off	on	11110	0.001	Hz*
off	off	off	off	off	11111	standby	

Frequency Divider with 50% Duty Cycle

Roland Heimann (Germany)



In digital circuit design, especially in microprocessor or measuring applications, it is often necessary to produce a clock signal by dividing down a master clock. The 4-chip solution suggested here is very versatile; it takes a 50% duty cycle input clock and outputs a 50% duty cycle clock selectable (via an 8-way DIP switch) for every divisor from 1 to 255.

The most complex chip in this design is IC1, an 8-bit down-counter which is 'programmed' by the binary value set up on the eight DIP switches. An edge detector circuit made up of IC3 and IC4 produces a pulse at every rising and falling edge of the input clock f_0. Each time the counter reaches zero a flip flop is toggled to produce a 50:50 mark/space ratio output signal.

It does not matter if the gates used in the edge detector circuit are inverting or non-inverting; the only important points are that the correct number of gates are used and the delay time produced by each gate. The total propagation delay through seven HC type gates will be enough to generate a pulse of sufficient width to reliably clock the counter. Propagation delay is the time taken for a signal at a gate's input pin to affect the output, and this is given in the data sheet. The edge detector produces a pulse on both the positive and negative edges of the input clock signal.

The down-counter decrements its value each time it receives a clock impulse on CP. Whenever the counter reaches zero the terminal count pin ($\overline{TC}$) generates a negative pulse, reloading the counter (via parallel load $\overline{PL}$) with the binary switch setting. The counter continues counting down from this value.

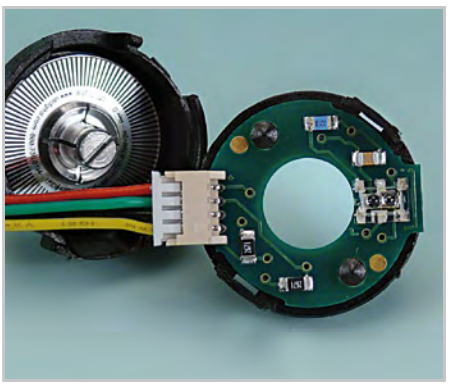
The JK flip flop IC3 is configured as a toggle type flip flop (both inputs J and K wired to a '1') the outputs Q and $\overline{Q}$ change state (toggle) on each rising edge of the $\overline{TC}$ output of IC1.

The DIP switches are used to set up the division ratio, to divide the clock by 23 for example, set the DIP switches to the binary value of 23 i.e. 00010111 (setting P4, P2, P1 and P0 to High).

(080436-I)

PIC Detects Rotation Direction

Lionel Grassin (France)

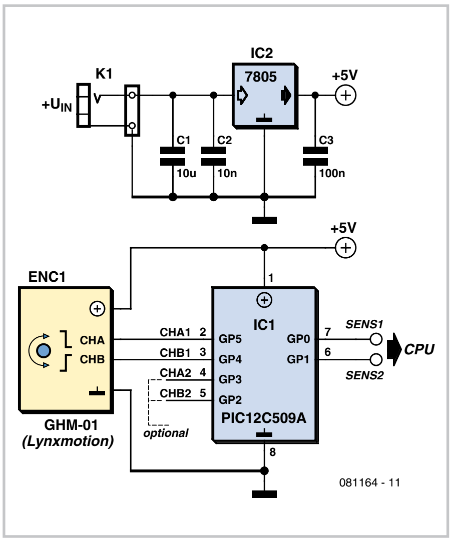


In the field of robotics, along with many other applications involving a motor (printers, for example), it is often necessary to measure a motor's speed and acceleration or direction of rotation. One simple technique is to fit a quadrature encoder to the shaft of the motor to be monitored. A quadrature encoder (see photo) is a device that produces two square-wave signals 90° apart as it turns. The direction in which the encoder rotates determines which of these two signals is in advance (compared with the other), thereby making it possible to detect the rotation direction.

An algorithm for detecting the rotation direction doesn't need to be complicated, but it does need to be fast enough to be able to follow high speeds and speed variations. This can be achieved using program-

mable logic (FPGA, GAL, PAL, etc.), but the author wanted to use a small, cheap microcontroller. He opted for the PIC12C509A from Microchip, an 8-pin microcontroller with six I/Os. Two inputs and one output are all the rotation direction sensor needs, so the little PIC is able to handle two quadrature encoders at the same time.

The algorithm developed by the author operates asynchronously, which ensures a very wide operating range, dependent on the capabilities of the microcontroller. The algorithm loop time is 20 µs for a PIC12C50X using the internal 4 MHz clock, so it is theoretically possible to follow a pulse signal of up to 50 kHz. This corresponds to a speed of 3,000 rpm for a motor fitted with a quadrature encoder giving 1024 pulses per rotation.



And all this for two motors/encoders at the same time! You can find all the details of the algorithm — and more — on the (French) website of the Fribotte team to which the author belongs [1].

The program (source code and hexadecimal file) is available on free download from the web page for this article [2].

(081164-I)

Internet Links

[1] http://fribotte.free.fr/bdtech/detectsens/detect-sens.html

[2] www.elektor-usa.com/081164

Download

081164-11: source code and hex file, from [2]

Vocal Adaptor for Bass Guitar Amp

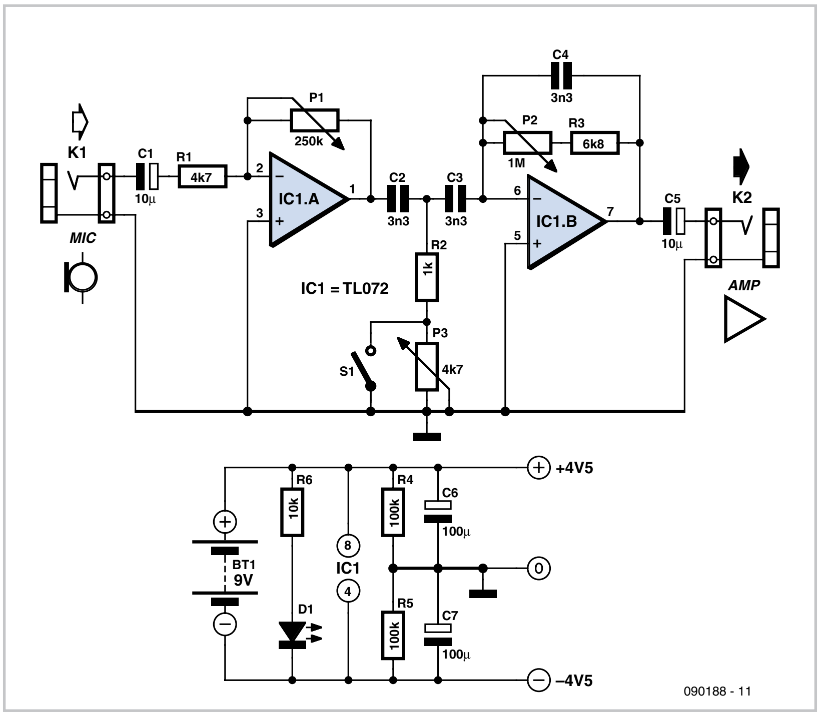
Jérémie Hinterreiter (France)

These days, music is a major hobby for the young — and not-so-young. Lots of people enjoy making music, and more and more dream of showing off their talents on stage. But one of the major problems often encountered is the cost of musical equipment. How many amateur music groups sing through an amp borrowed from a guitarist or bass player?

This is where the technical problems arise — not in terms of the .25" (6.3 mm) jack, but in terms of the sound quality (the words are barely understandable) and volume (the amp seems to produce fewer decibels than for a guitar). What's more, unpredictable feedback may cause damage to the speakers and is very unpleasant on the ear. This cheap little easy-to-build project can help solve these technical problems.

A guitar (or bass guitar) amplifier is designed first and foremost to reproduce the sound of the guitar or bass as faithfully as possible. The frequency response of the amp doesn't need to be as wide or as flat as in hi-fi (particularly at the high end), and so this sort of amplifier won't permit faithful reproduction of the voice. If you build an adaptor to compensate for the amp's limited frequency response by amplifying in advance the frequencies that are then attenuated by the amp, it's possible to improve the quality of the vocal sound. That's just what this circuit attempts to do.

The adaptor is built around the TL072CN low-noise dual FET op amp, which offers good value for money. The NE5532 can be used with almost the same sound quality, but at (slightly) higher cost. The circuit breaks down into two stages. The first stage is used to match the input impedance and amplify the microphone signal. For a small 15 W guitar or bass amplifier, the achievable gain is about 100 (gain = P1/R1). For more powerful amplifiers, the gain can be reduced to around 50 by adjusting P1.



The second stage amplifies the band of frequencies (adjustable using P2 and P3) that are attenuated by the guitar amp, so as to be able to reproduce the (lead) singer's voice as clearly, distinctly, and accurately as possible. To refine the adaptor and tailor it to your amplifier and speaker, don't be afraid to experiment with the component values and the type of capacitors.

The circuit can readily be powered using a 9 V battery, thanks to the voltage divider R4/R5 which converts it into a symmetrical ±4.5 V supply.

(080188-I)

Guitar Pick-up Tone Extender

David Clark (United Kingdom)

This design extends the basic sonic possibilities of an electric guitar without the use of any electronic 'effects'. The expanded number of tone possibilities is brought about by mixing continuously-variable amounts of the output from each of the guitar's pick-ups, along with switching the phase of each pick-up. This effectively gives an infinite range of tones as opposed to the five available for a normally switched set-up. This is not a project for the faint-hearted, however; it involves modifying the wiring to the guitar's pick-up coils and switches, and possibly the scratch-plate itself, depending on the chosen location for the replacement for the standard 0.25-inch (6.3-mm) jack connector. Use of a cheap 'copy'-style guitar is recommended!

The standard 'Stratocaster'-style guitar features three pick-ups and a five-way switch that allows the player to select one of the following combinations:

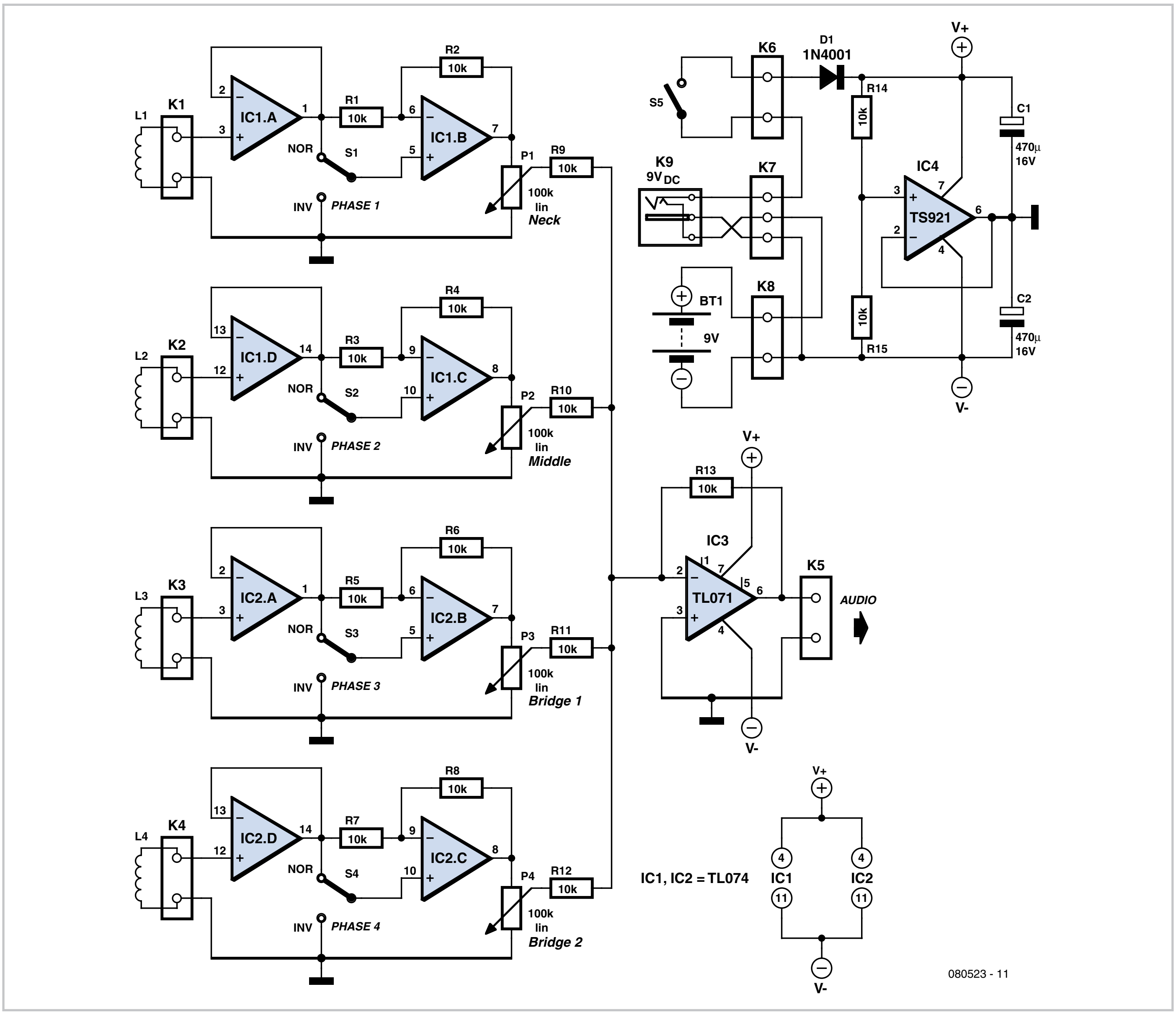
- neck pick-up
- neck and middle pick-up in parallel
- middle pick-up
- middle and bridge pick-up in parallel
- bridge pick-up

Guitarists eager to find new sounds from their instrument sometimes alter the wiring and add other switches to this arrangement, but this is of course not a flexible arrangement, and certainly not something that could be altered mid-performance playing for a crowd, no matter if a dozen or so in a downtown bar or 40 k at Woodstock v. 2.1.1!

This project allows up to four pick-ups to be employed, since the bridge pick-up on a 'Stratocaster' is often a so-called 'humbucker' type, which can be split into two independent pick-ups, shown here as Bridge 1 (L3) and Bridge 2 (L4).

The really intrepid among you may decide to build the circuitry in SMD and incorporate a tiny board into the guitar. However, having four switches and four pots on the guitar may be too much of a good thing.

The alternative is to wire the guitar pick-ups individually to



a 9-pin sub-D type connector that is added either to the guitar body or its scratchplate. The connector is linked to the input sub-D connector on the control unit via a long 'straight-through' serial interface computer cable. The Tone Extender circuitry may be built in a Vero style box, of which an example is shown in the photograph. Connection from the unit to an unmodified guitar amplifier is via a standard guitar lead.

Each pick-up section consists of two opamps from a TL074 package, one inverter (e.g. IC1.A) and one buffer (e.g. IC1.B). Each has a normal/invert switch (NOR/INV, e.g. S1) to select the phase of the signal component, and a 100-kΩ linear law potentiometer at its output to set the desired level. The output signals of all four opamp sections are summed by IC3 (a TL071) which provides a suitably low output impedance to drive the guitar amplifier.

Opamp IC4 splits the supply voltage obtained from 9 V (6LR22) battery BT1 into symmetrical rails V+ and V–. Alternatively, a battery eliminator with a regulated output voltage of 9 V DC may be connected to K9, when the battery is automatically disconnected.

Whatever method of construction is chosen, the unit effectively provides the guitarist interested in experimenting with unusual pick-up configurations a flexible way of quickly setting up and trying probably all possible variations, without having to get out the soldering iron and hard-wire each new idea. As such it should be an invaluable aid to allowing all manner of sonic possibilities to be realized.

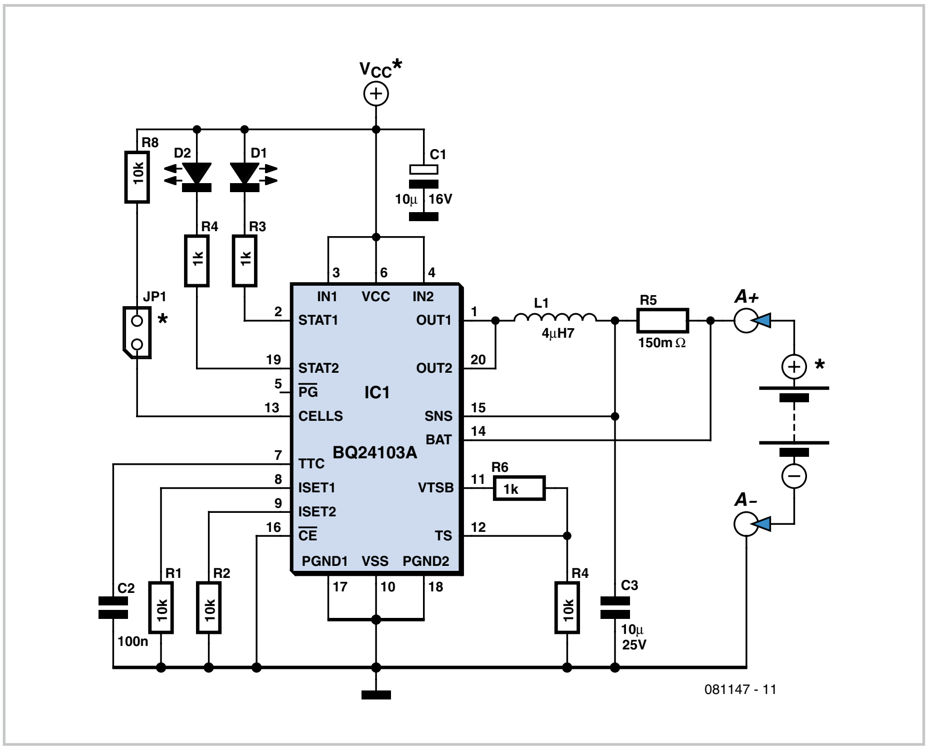
(080523-I)

Lithium Battery Charger using BQ24103

Steffen Graf (Germany)

The BQ24013 is a simple-to-use charge controller suitable for use with lithium-ion and lithium-polymer batteries. A major advantage it has is that it includes integrated power MOSFETs capable of working with charge currents of up to 2 A. Its switching frequency is high, at 1.1 MHz, and so only a small external coil is needed. In comparison to linear charging circuits the switching topology offers a much higher degree of efficiency.

A further benefit is that it is capable of charging battery packs consisting of either a single cell or of two cells wired in series. Two LEDs indicate when the battery is being charged (D1 lights) and when the battery is fully charged (D2 lights). The charge current is set by the choice of external resistors [1]. There are three currents to set: the initial (precharge) current, the charge current and the charge termination current. With the component values given the precharge current is 67 mA, the charge current is 667 mA and the termination current is also 67 mA.



The IC of course ensures that the charging process is carried out correctly and in particular that the maximum permissible cell voltage is never exceeded: this is extremely important for lithium chemistry cells. Even more important is to note that jumper JP1 should be fitted **only in the case where two cells are being charged**. When charging a single cell the jumper must **not** be fitted, or there is a risk of **explosion** or **fire** as the charging voltage will be too high.

The minimum supply voltage for charging a single cell is 5 V; for charging two cells it is 9 V. According to its datasheet, the IC is specified for supply voltages of up to 16 V. Unfortunately the IC is only available in a QFN20 package, which is rather tricky to solder. In compensation, the tiny package does make it possible to build a complete 2 A charging circuit on less than 2.5 cm² of printed circuit board.

For the prototype, with a charging current of 670 mA, we selected for L1 a 4.7 µH inductor with a DC resistance (DCR) of 0.082 Ω (82 mΩ) rated for a current (DCI) of 1.72 A. If a charge current of up to 2 A is wanted, an inductor with a DCR of less than 0.025 Ω (25 mΩ) and a current rating of 4 A or more should be chosen. For R5 we used a Vishay 150 mΩ SMD resistor in an 0805 package (available, for example, from Farnell), and for C3 a ceramic barrier-layer capacitor with a working voltage of 25 V. If an electrolytic capacitor is used it must have a very low ESR.

An overview of the various versions of the IC that are available can be found at [2]. For our prototype we used a type BQ24103A.

(081147-I)

Internet Links

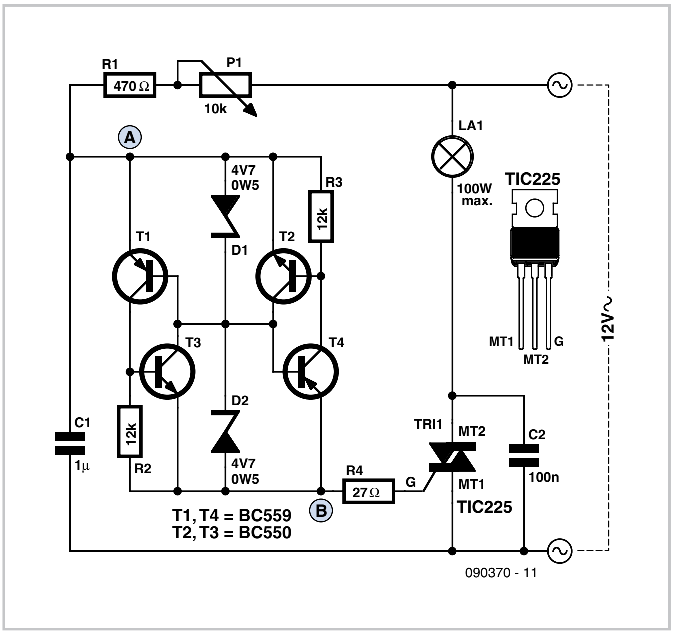
[1] www.ti.com/lit/gpn/bq24103a

[2] http://focus.ti.com/docs/prod/folders/print/bq24103a.html

12 V AC Dimmer

Peter Jansen (The Netherlands)

The circuit described here is derived from a conventional design for a simple lamp dimmer, as you can see if you imagine a diac connected between points A and B. The difference between this circuit and a normal diac circuit is that a diac circuit won't work at 12 V. This is the fault of the diac. Most diacs have a trigger voltage in the range of 30 to 40V, so they can't work at 12 V, which means the dimmer also can't work.



The portion of the circuit between points A and B acts like a diac with a trigger voltage of approximately 5.5 V. The network formed by R1, P1 and C1 generates a phase shift relative to the supply voltage. The 'diac equivalent' circuit outputs a phase-shifted trigger pulse to the triac on each positive and negative half-cycle of the sinusoidal AC voltage.

This works as follows. First consider the positive half of the sine wave. C1 charges when the voltage starts to rise, with a time constant determined by C1, R1 and P1. T1 does not start conducting right away. It waits until the voltage across D2 reaches 4.7 V and the Zener diode starts to conduct. Then current starts to flow, driving T1 and T3 into conduction. This produces a pulse at point B. The same principle applies to the negative half of the sine wave, in this case with D1, T2 and T4 as the key players.

The trigger angle can be adjusted with P1 over a range of approximately 15 degrees to 90 degrees. C2 provides a certain amount of noise decoupling. Depending on the load, the triac may need a heat sink. You can use practically any desired transistors; the types indicated here are only examples. If the circuit does not dim far enough, you can change the value of P1 to 25 kΩ. This allows the trigger angle to be increased to 135 degrees.

Note: this circuit works fine with normal transformers, but **not** with 'electronic' transformers.

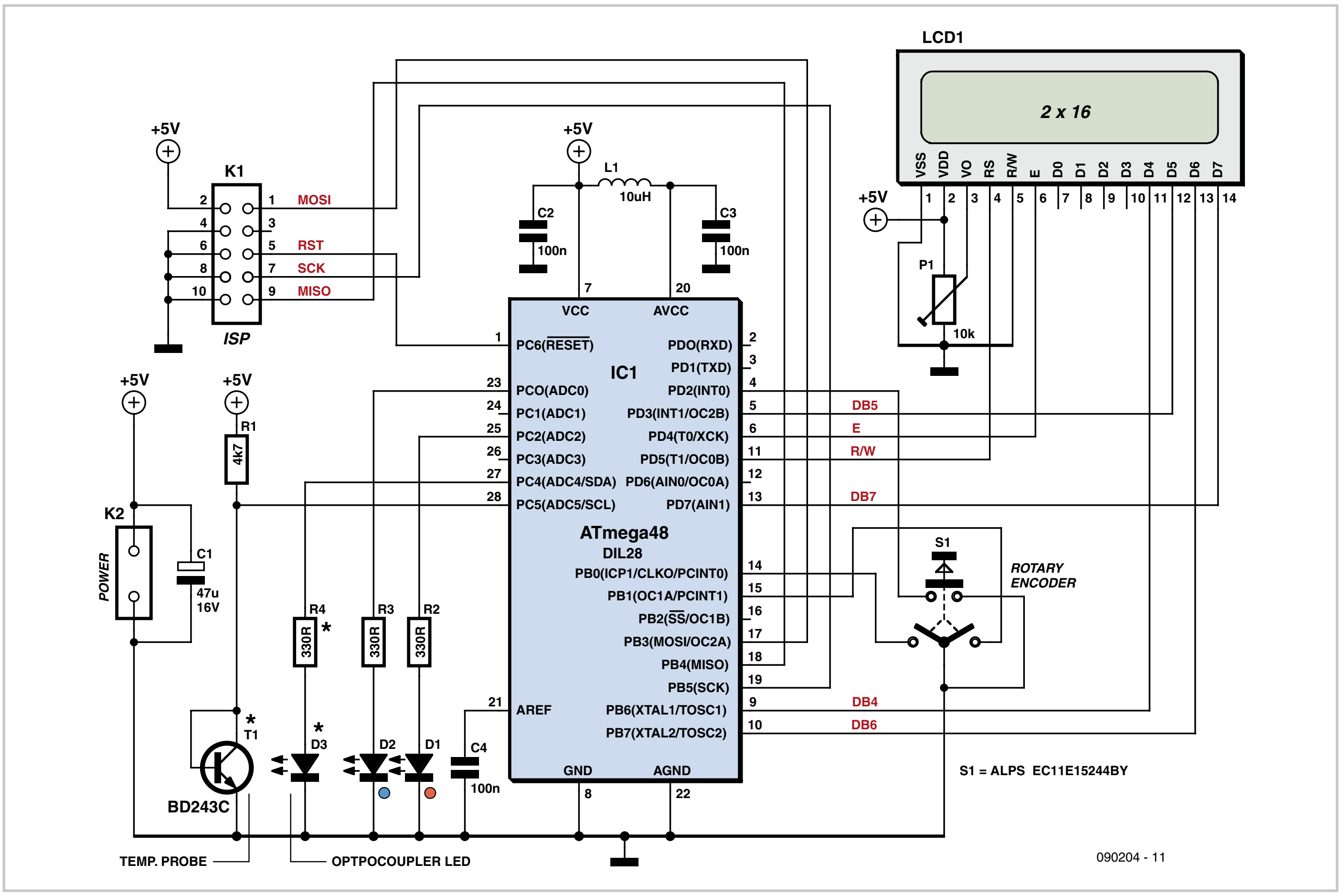
(090370-I)

Simple Temperature Measurement and Control

Jochen Brüning (Germany)

The circuit described here and its accompanying BASCOM software arose from the need to control the temperature in a laminator. The laminator does include its own temperature controller, but it was not suitable for the author's purposes (making printed circuit boards using a thermal transfer method [1]). The result (see circuit diagram) is based around an ATmega48 microcontroller with a 2-by-16 LCD panel and a rotary encoder. The base-emitter junction of an ordinary NPN power transistor in a TO220 package is used as the temperature sensor. Although this technique is not often seen, it is far from new: decades ago Elektor published a digital thermometer design with an NPN transistor pressed into service as the sensor. The approach has the advantage of a wide linear temperature range from –50 °C to +150 °C and the TO220 package is particularly convenient because it has a handy fixing hole and heatsink to allow good thermal contact. Note that the heatsink is electrically connected to the collector of the transistor, so it may be necessary to use an insulating washer.

The BD243C is wired as a diode by connecting



its collector and base together and powered from the 5 V rail via a 4.7 kΩ resistor. A current of approximately 1 mA therefore flows through the diode. The voltage across the diode has a reasonably constant negative temperature coefficient of around –2 mV/K, and so the plot of voltage against temperature is reasonably straight. The voltage is measured using the ATmega48's internal A/D converter using input ADC5 on pin 28. A point to note is that we can use the 1.1 V internal reference voltage to obtain good precision when converting the diode voltage drop, which is around 0.6 V. Not all AVR-series microcontrollers have the 1.1 V internal reference for the A/D converter, which should be borne in mind if modifying the design to use a different microcontroller.

The set point for temperature control is entered using the rotary encoder in one degree steps. Turn the encoder to the right to increase the set point, to the left to decrease it. It is possible to set upper and lower thresholds for switching. If the rotary encoder has a pushbutton function, this can be used to select between setting the upper and lower thresholds; if not, a separate button must be fitted.

The display consists of the LCD panel and two LEDs. The upper line of the LCD shows the measured temperature and the lower line shows the current set point (upper and lower temperature switching thresholds). P1 adjusts the contrast of the LCD.

The two LEDs show the state of the controller at a glance. If the blue LED (D2) is lit, the temperature is too low (below the lower switching threshold); if the red LED (D1) is lit, the temperature is too high (above the upper switching threshold); and if both LEDs are lit the temperature is just right (between the lower and upper switching thresholds).

Since at least one LED is always lit there is no need for a power indicator LED.

The output of the controller is the logic level on pin 27 (PC4). The author used this to drive a solid state relay (SSR) in his application which in turn controlled the heating element in the laminator. The circuit diagram shows this as LED D3, which is intended to represent the LED in the optocoupler in the SSR.

ISP connector K1 is optional and can be dispensed with if a ready-programmed microcontroller is used (see 'Downloads and products'). It will then not be possible to calibrate the temperature reading, as this can only be done in the software using the ISP interface. However, for many one-off applications it will be sufficient to determine the upper and lower switching thresholds experimentally, including compensation for any error in the temperature measurement.

Details of the control process can be found by inspecting the BASCOM source code. Calibration of the temperature measurement, as mentioned above, is done by directly modifying the software. Remove the comment characters (') from lines 105 to 107 of the program, and comment out lines 108 to 110 by adding a single inverted comma at the start of each. The display will now show the conversion results from the A/D converter in the ATmega48. Immerse the sensor in a mixture of ice and water and wait until the reading stabilizes. Note down the conversion result (or take a number of results and average them for better accuracy). Now immerse the sensor in boiling water and repeat the procedure. Replace the number 546 in line 86 of the source code with the conversion result for the ice-water mixture. Now subtract the conversion result for boiling water from the ice-water result and divide by 100: substitute the answer for the value 2.460 in line 87 of the source code.

As indicated at the start, we assume in this calibration that the conversion result versus temperature relationship is linear. We can write this in the form $y = mx + c$, where c is the A/D conversion result at 0 °C (the intercept of the A/D conversion result axis) and m is the (negative) slope of the base-emitter junction voltage-temperature characteristic, calculated by dividing the difference between the conversion results at 0 °C and 100 °C by 100. These two numbers allow you map any conversion result into a corresponding temperature.

(090204-I)

Internet Links

[1] http://thomaspfeifer.net/direct_toner_pcb.htm

[2] www.elektor-usa.com/090204

Download

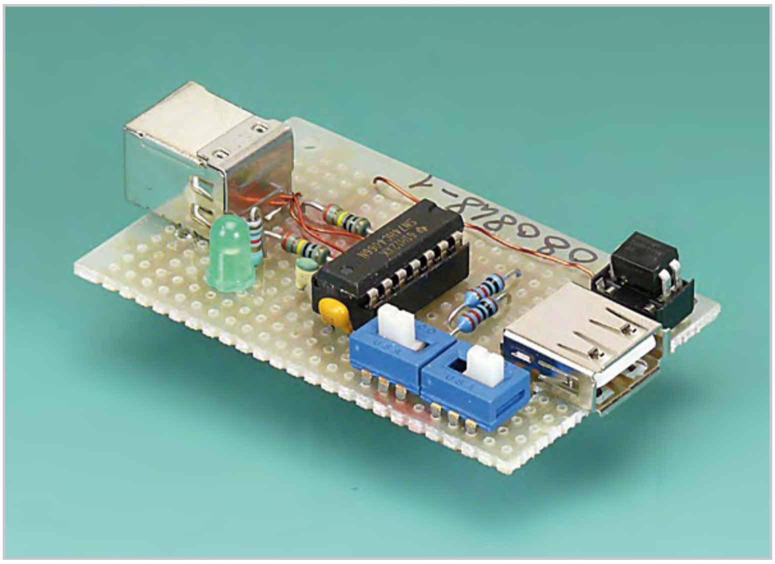
090204-11: source code files, from [2].

Product

090204-41: ready-programmed ATmega48 microcontroller.

USB Switch

Rainer Reusch (Germany)



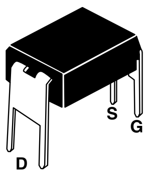
Anyone experimenting or developing USB ported peripheral hardware soon becomes irritated by the need to disconnect and connect the plug in order to re-establish communication with the PC. This process is necessary for example each time the peripheral equipment is reset or a new version of the firmware is installed. As well as tiresome it eventually leads to excessive contact wear in the USB connector. The answer is to build this electronic isolator which disconnects the peripheral device at the touch of a button. This is guaranteed to reduce any physical wear and tear and restore calm once again to the workplace.

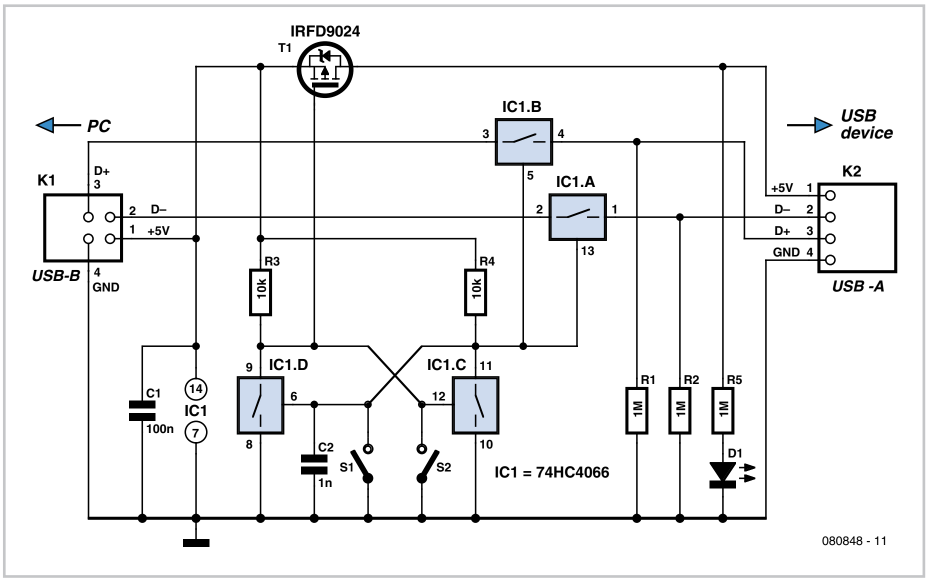
The circuit uses a quad analog switch type 74HC4066. Two of the switches in the package are used to isolate the data path. The remaining two are used in a classic bistable flip-flop configuration which is normally built using transistors. A power MOSFET switches the power supply current to the USB device. Capacitor C2 ensures that the flip flop always powers-up in a defined state when plugged into the USB socket ('B' in the diagram). The peripheral device connected to USB socket 'A' will therefore always be 'not connected' until pushbutton S2 is pressed. This flips the bistable, turning on both analog gates in the data lines and switching the MOSFET on. The PC now recognizes the USB device. Pressing S1 disconnects the device.
The circuit does not sequence the connections as a physical USB connector does; the power supply connection strips are slightly longer than the two inner data carrying strips to ensure the peripheral receives power before the data signals are connected. The electronic switch does not suffer from the same contact problems as the physical connector so these measures are not required in the circuit. The simple circuit can quite easily be constructed on a small square of perforated stripboard. The design uses the 74HC(T)4066 type analog switch, these have better characteristics compared to the standard 4066 device. The USB switch is suitable for both low-speed (1.5 MBit/s) and full-speed (12 MBit/s) USB ports applications but the properties of the analog switches and perf-board construction will not support hi-speed (480 MBit/s) USB operation.

The IRFD9024 MOSFET can pass a current of up to 500 mA to the peripheral device without any problem.

(080848-I)

IRFD9024



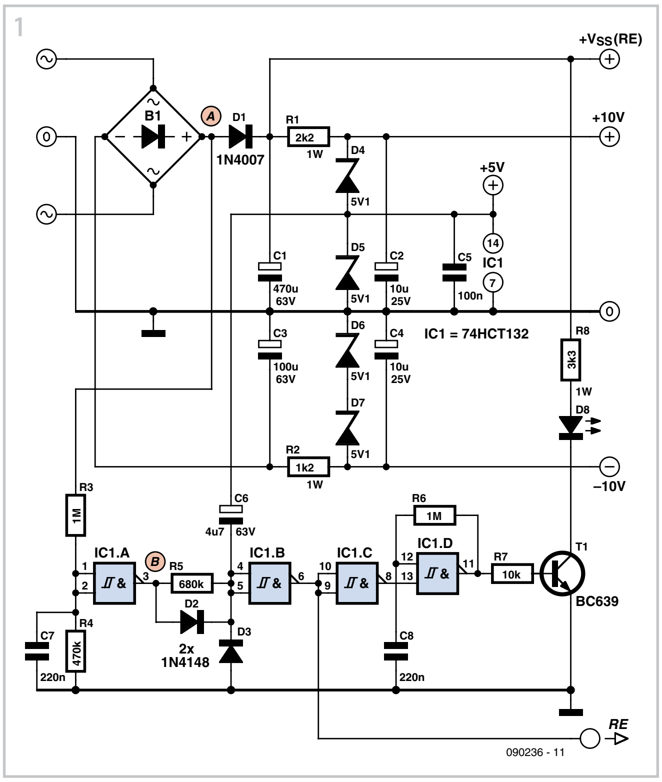


Load Protection for Audio Amplifiers

Joseph Kreutz (Germany)

In order to be effective, any protection device connected between an audio amplifier output and the speakers needs to connect the load only after a few seconds' delay, disconnect it immediately the AC supply is turned off, and prevent any high-level DC component from being able to damage the loudspeakers. As the circuit suggested here can readily be 'grafted' onto any existing circuit, it merits the title 'universal'. The circuit diagrams in **Figures 1** and **2** relate to a prototype fitted to an amplifier producing 50 W into 8 Ω, with a ±35 V power supply. This circuit can be readily adapted to other supply voltages, and hence to other audio power outputs. The appropriate values for R1, R2, R8, R15, and R19, along with the operating voltages for C1 and C3 and the choice of semiconductors D9, D10, T1, T2, and T3 are given in **Table 1**.

1



Circuit operation is simple: when the amplifier is turned on, the voltage at the junction of bridge rectifier B1 and diode D1 quickly charges capacitor C7 via resistor R3. Capacitor C7 avoids mains zero crossings causing spurious triggering. When the upper threshold voltage of IC1a is reached, its output goes low. At this moment, C6 is gradually charged via R5, and once the voltage across it reaches the required value, IC1b output goes high and turns relays RE1 and RE2 on via transistors T2 and T3. This process produces a delay of around 5 s. In order for us to be certain that IC1b output starts off low, the initial voltage across C6 must be zero. So this capacitor is connected directly to the +5 V rail. This circuit works by determining voltage thresholds: this means that we need to choose an SN74HCT132 quad Schmitt NAND gate for IC1.

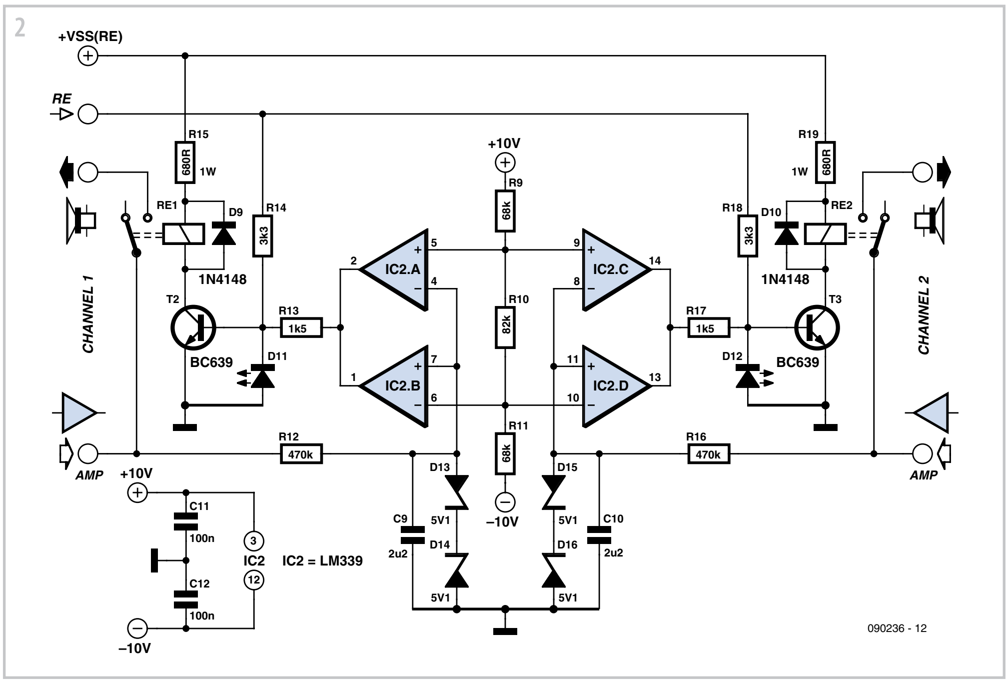
Gate IC1c inverts the relay control signal and feeds it to one input of IC1d, which then operates as an oscillator, making LED D8 flash at around 4 or 5 Hz during the delay period.

As soon as the relay control signal goes high and the relays turn on, the IC1d oscillator is disabled and LED remains constantly lit. The LED is powered directly from the HT rail across C1, and 3.3kΩ resistor R8 limits the current through it to 10 mA. As shown in **Table 1**, the value of R8 depends on the supply voltage and hence on the power of the amplifier to which the protection circuit is to be connected.

As soon as the AC power is turned off, IC1a output goes high and capacitor C6 discharges rapidly through D2, which then causes IC1b output to go low and the relays RE1 and RE2 to turn off almost immediately. So the amplifier load is isolated instantly and the circuit re-armed so as to produce the required delay next time AC line power is applied.

Detection of any DC component is performed by IC2, an LM339 quad comparator. The networks C9/R12 and C10/R16 act as low-pass filters: they attenuate the audio signal very heavily, but if any DC voltage is present on the amplifier output, it will be fed to IC2's comparator inputs. If it exceeds ± 3.75 V, at least one of the comparators will output a 'low' signal, and thus turn off the corresponding relay control transistor. The load will remain isolated as long as the fault condition continues. This signal will also cause current to flow in the LEDs D11 or D12, indicating that the protection has been activated. Zener diodes D13 to D16 provide over-voltage protection for the comparator inputs. It's wise to make sure that R12 and R16 are indeed correctly connected to the amplifier outputs and not to the relay contacts feeding the loudspeakers.

2



The choice of relays is not really critical: any

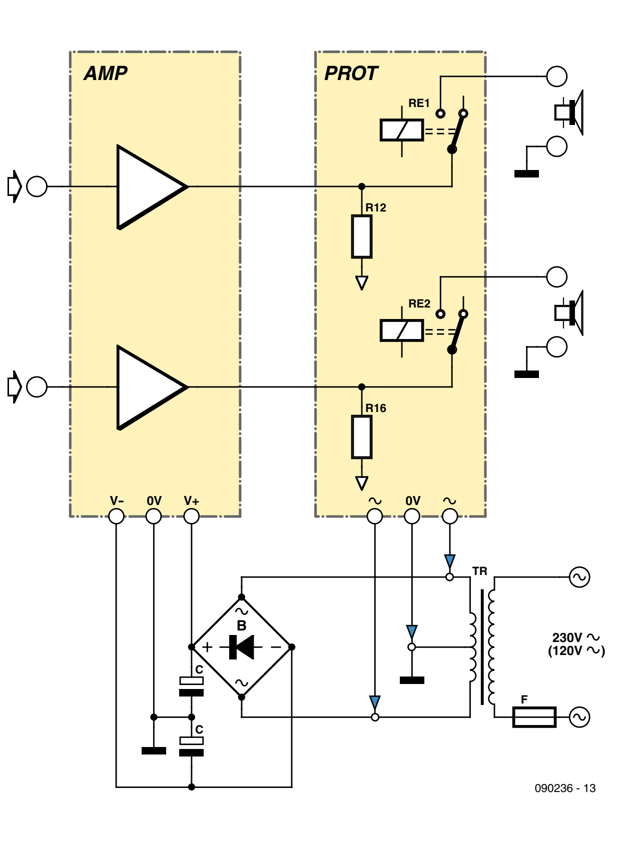
Table 1. Stereo (2-channel) amplifier

Supply voltage [V]	27	35	47	56	64	70	76
Power into 4 Ω [W]	50	100	200	300	400	500	600
Power into 8 Ω [W]	25	50	100	150	200	250	300
Working voltage for C1 (470 µF) & C3 (100 µF) [V]	40	63	63	80	80	100	100
Value for R1	1k8, 0,25 W	2k2, 1 W	3k3, 1 W	4k7, 1 W	4k7, 1 W	5k6, 1 W	5k6, 1 W
Value for R2	820 Ω, 1 W	1k2, 1 W	1k8, 1 W	2k2, 2 W	2k7, 2 W	2k7, 2 W	3k3, 2 W
Value for R3	2k7, 0,25 W	3k3, 1 W	4k7, 1 W	5k6, 1 W	6k8, 1 W	8k2, 1 W	8k2, 1 W
Value for R15 & R19 (*)	-	680 Ω, 1 W	1k2, 1 W	1k8, 1 W	2k2, 1 W	2k7, 2 W	2k7, 2 W
D9 et D10	1N4148	1N4148	1N4148	1N4148	1N4148	BAV21	BAV21
T1, T2, T3	BC639	BC639	BC639	BC639	BC639	2N5551	2N5551
* for 24 V relays drawing a current in the region of 15 mA.							

type that has a high enough breaking capacity, works from 24 V, and only needs around 15–25 mA to drive it will do. The relays fitted to the prototype are RT 314024 ones made by the Austrian company Schrack [1]. They can switch 16 A, which is enough for amplifiers with pretty reasonable powers. The prototype is fitted to a 50 W per channel stereo amplifier, whose 35 V supply voltage is higher than the relays' rated operating voltage. So it was necessary to fit series resistors R15 and R19 in order to drop the excess 11 V. As the relay coil resistance is 1,450 Ω, these series resistors need to be 680 Ω and rated for a dissipation of 1 W. Naturally, the value of R15 and R19 depends on the type of relay chosen and the amplifier's supply voltage, as shown in **Table 1**. However, the value isn't critical, as the relays are pretty tolerant about their operating voltage. Besides, it's easy enough to find out the resistance of a relay coil: just measure it with an ohmmeter!

It's essential to pick up the power

3



for the circuit directly from the amplifier's power transformer terminals, before the rectifier and smoothing capacitors, as shown in the connection diagram in **Figure 3**. This voltage is rectified by bridge rectifier B1 and applied via D1 to the 470 µF smoothing capacitor C1. The power for the relays and LED D8 is taken from directly across this capacitor. Diode D1 allows capacitor C1 to be isolated as soon as the AC line power goes off: so when the amplifier is turned off, there is zero voltage at IC1a input , and the relays are guaranteed to be off. The +10 V and +5 V rails are regulated by zeners D4 and D5, while D6 and D7 stabilize the –10 V rail feeding IC2. Using two zeners in series limits the power each of them has to dissipate.

It is perfectly simple to extend the circuit for 5+1 or 7+1 channel audio systems, as used on an increasing number of computers. And it's all the more advisable because the sound cards often produce erratic signals when the computer

Table 2. System with 5+1 or 7+1 channels

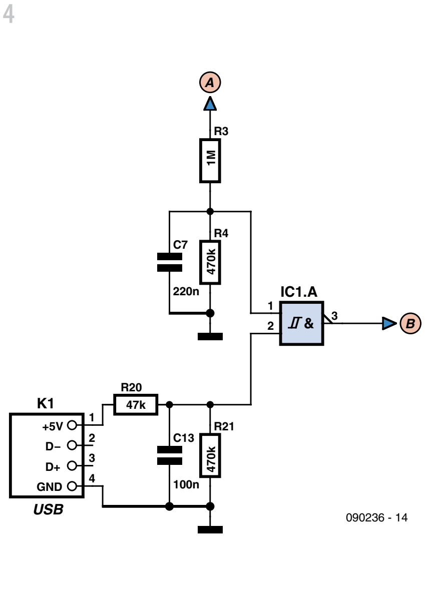
Supply voltage [V]	27	35	47	56	64	70	76
Power into 4 Ω [W]	50	100	200	300	400	500	600
Power into 8 Ω [W]	25	50	100	150	200	250	300
Working voltage for C1 (2200 µF) & C3 (470 µF) [V]	40	63	63	80	80	100	100
Value for R1	820 Ω, 1 W	1k2, 1 W	1k8, 1 W	2k2, 2 W	2k7, 2 W	2k7, 2 W	3k3, 2 W
Value for R2	270 Ω, 2 W	390 Ω, 2 W	560 Ω, 5 W	680 Ω, 5 W	820 Ω, 5 W	820 Ω, 10 W	1k, 10 W
Value for R3	2k7, 1 W	3k3, 1 W	4k7, 1 W	5k6, 1 W	6k8, 1 W	8k2, 2 W	8k2, 2 W
Value for R15 et R19 (*)	-	680 Ω, 1 W	1k2, 1 W	1k8, 1 W	2k2, 1 W	2k7, 2 W	2k7, 2 W
D4 - D7	BZV85C5V1 or 5V1 device capable of dissipating 1 W						
D9 & D10	1N4148	1N4148	1N4148	1N4148	1N4148	BAV21	BAV21
T1, T2, T3	BC639	BC639	BC639	BC639	BC639	2N5551	2N5551
* for 24 V relays drawing a current in the region of 15 mA.							

is powered up or down, which when amplified can be at best unpleasant, and at worst, damaging for the loudspeakers.

As shown in **Figure 4**, the +5 V supply rail present on the computer's USB bus is applied to one of the inputs of gate IC1a, the other input being used to check the presence of the amplifier supply voltage. So both the computer and the amplifier have to be running for the speakers to be connected after a 5-second delay. The 100 nF capacitor C13 avoids unwanted triggering. Turning off the computer or the amplifier disconnects the speakers immediately.

The **Figure 1** delay circuit, modified as per the circuit in **Figure 4**, is common to all channels, and provides the relay control signal for them all. But the DC component switching and protection unit shown in **Figure 2** has

4



to be repeated 3 or 4 times, so as to be able to control the number of channels in the system. Refer to **Table 2** for the component values for a protection circuit for a 5+1 or 7+1 channel system. The modifications mainly affect the following points:

- The values of R1 and R2 are reduced, but their dissipation increased, as shown in **Table 2**;
- C1 and C3 are also increased to 2,200 µF and 470 µF respectively;
- Zener diodes D4 to D7 change to type BZV85C5V1 or equivalent, capable of dissipating 1 W.

(090236-I)

Internet Link

[1] www.schrack.com

Impact Clock

G. van Zeijts (The Netherlands)

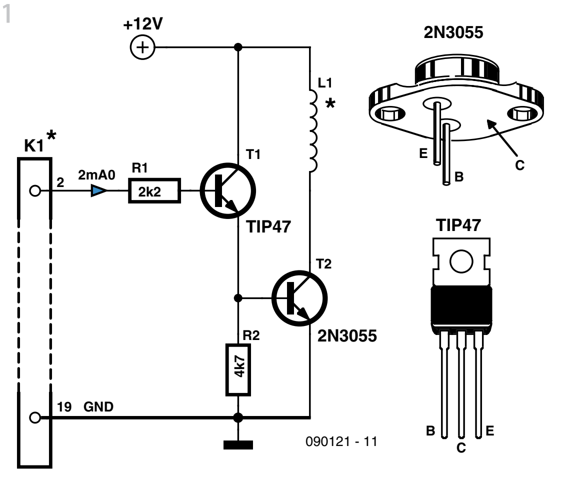
The read/write heads of a hard disk drive are moved back and forth over the magnetic platters by a linear motor. This motor consists of a coil that moves in a strong magnetic field, combined with some sophisticated electronics that drives it such that the read/write heads are quickly positioned to the desired location.

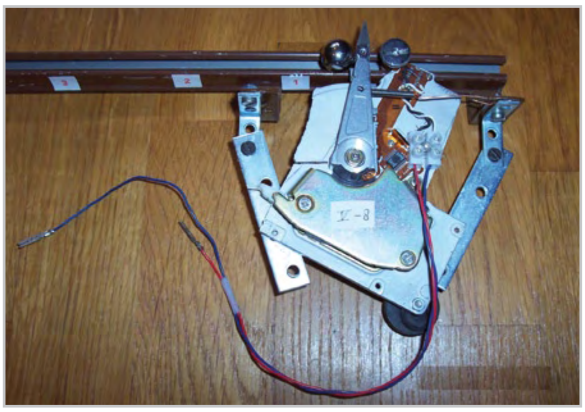
By now enough hard disk drives have crashed that every enthusiast should have no trouble getting his or her hands on one and using it for other purposes.

As the head motor has a fairly long stroke and can supply considerable force, we used it in this project to build a special sort of clock.

If you simply apply a DC voltage to the coil, the arm jumps from one end to the other one with a bang. If you reverse the polarity of the voltage, the arm moves in the opposite direction. The voltage applied to the coil can be controlled by a PC with the aid of a Darlington circuit (**Figure 1**). We used one of the pins of the Centronics port on the computer (K1 in the schematic drawing) to drive the circuit. Here the control signal is provided by pin 2 of the Centronics connector, which cor-

1





responds to bit 0 of port H378. Pin 19 (ground) is tied to the ground line of the control circuit. Use a hefty AC power adapter for the power supply; it must be able to deliver at least 2 A.

The mechanical design of the clock is rather unusual. It consists of a length of curtain rail arranged at an oblique angle, along which a steel ball from a ball bearing can be propelled upward and roll back down under its own weight. If the ball is struck by a blow whose strength depends on the time of day, it will travel for a certain distance along the curtain rail. By observing the motion of the ball, you can read the time (approximately) from an hours scale marked along the length of the rail. The previously mentioned head motor from a discarded hard disk drive is used to generate the impact on the ball. The ball rests against the arm of the motor when it is at its lowest point on the rail. The computer calculates the force of the impact and drives the motor for a certain length of time.

The program for the clock is written in Visual Basic and has a simple design. The software is extensively documented.

Now for some practical details on the clock:

- Rail length approx. 160 cm (5′ 5″)
- Height difference (top/bottom) approx. 10 cm (5″)
- Ball diameter 17 mm (11/16″)
- Head motor coil resistance 5–15 Ω (depending on hard disk model)
- Coil voltage 5–12 V (depending on coil resistance)

The hours scale on the rail must be determined experimentally after first adjusting the impact for 12.00 h so the ball nearly reaches the highest point of the rail.

(090121-I)

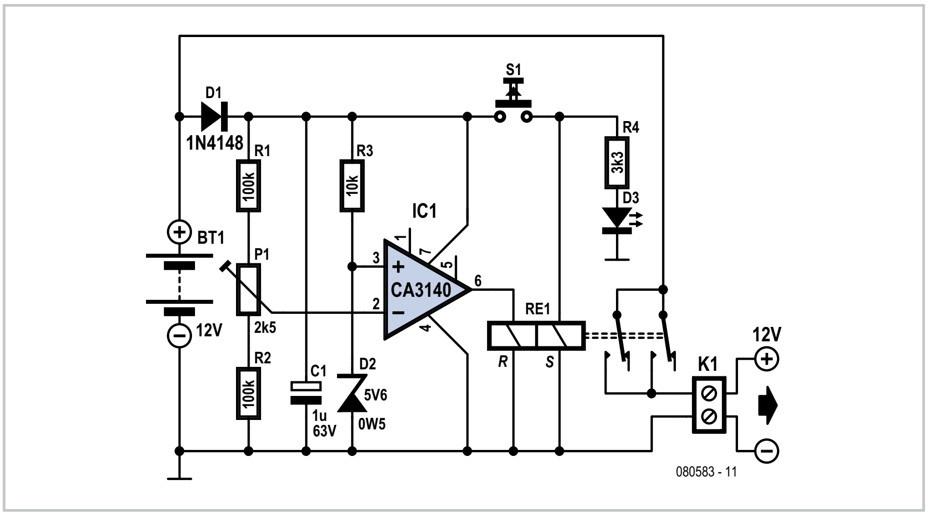
Download

090121-11: Visual Basic program, from www.elektor-

Lead Acid Battery Protector

Jürgen Stannieder (Germany)

The circuit described here can be used to ensure that a 12 V sealed lead acid (SLA) gel battery isn't discharged too deeply. The principal part of the circuit is a bistable relay, which is driven by the output of an op amp.



The battery voltage is first reduced via D1, R1, P1 and R2, and then continuously compared with a reference voltage set up by diode D2. When the battery discharges too much and its terminal voltage drops below the level set by P1, the output of the opamp becomes High, which causes the relay to toggle. This in turn isolates the load from the battery. The battery can be reconnected via S1 once the battery has been replaced or recharged.

The relay used in the prototype is a 5 V bistable type made by Omron (G6AK-234P-ST-US 5 VDC). The two windings of the relay each have a resistance of 139 Ω (for the RAL-D 5 W-K made by Fujitsu this is 167 Ω). When the battery voltage starts to become too low and the relay is being reset the current consumption of the circuit is about 45 mA. Shortly after the load has been disconnected, when the battery voltage rises above the reference voltage again, the reset coil will no longer be powered and the current consumption drops back to about 2.5 mA.

The range of P1 has intentionally been kept small. With a reference voltage of 5.6 V (D2) and a voltage drop of 0.64 V across D1, the circuit reacts within a voltage span of 11.5 V and 11.8 V. This range is obviously dependent on the zener diode used and the tolerance.

For a greater span you can use a larger value for P1 without any problems. With the potentiometer at its mid setting the circuit switches at about 11.6 V.

(080583-I)

Automatic Curtain Opener

Ton Smits (The Netherlands)

This circuit can be used with a timer clock to open and close curtains or (vertical) Venetian blinds. The curtain or blind is driven by an electric motor with a reduction gearbox fitted to the control mechanism of the curtain or blind. This circuit is ideal for giving your home an occupied appearance while you are away on holiday or for some other reason. In the author's house, this arrangement has provided several years of trouble-free service on a number of windows fitted with Venetian blinds.
The original design was a simple relay circuit with pushbuttons for opening and closing and reed switches acting as limit switches. The mechanical drive is provided by a small DC motor with a reduction gearbox and pulley (all from Conrad Electronics).
It was later modified to work automatically with a timer clock. The timer operates a small 230-VAC (or 120-VAC) relay with a change-over contact. Thanks to the two timers, the motor stops after a few seconds if one of the reed switches is missed due to a mechanical defect.
The circuit works as follows (see Figure 1).
In the quiescent state, relays RE1–RE3 are de-energized and the motor is stopped.
Open the blind:
When the timer clock applies power to the 230-V (120-V) relay RE3, the voltage at the junction of C1 and R1 goes high. IC1 (a 555) then receives a trigger pulse on pin 2, which causes its output (pin 3) to go High and energize RE1, which in turn causes the motor to start running. When the magnet reaches reed switch S1 ('Open'), the 555 is reset. If the reed switch does not operate for some reason, the relay is de-energized anyhow when the monostable times out (time delay = 1.1 RC; approximately 5 seconds).
Close the blind:
The timer clock removes power from RE3, which causes a trigger pulse to be applied to

the other 555 timer (IC2) via R5 and C4. Now the motor starts running in the other direction. The rest of the operation is the same as described above for opening the blind.

Diodes D2 and D5 prevent the outputs of the 555 ICs from being pulled negative when the relay is de-energized, which could otherwise cause the timer ICs to malfunction.

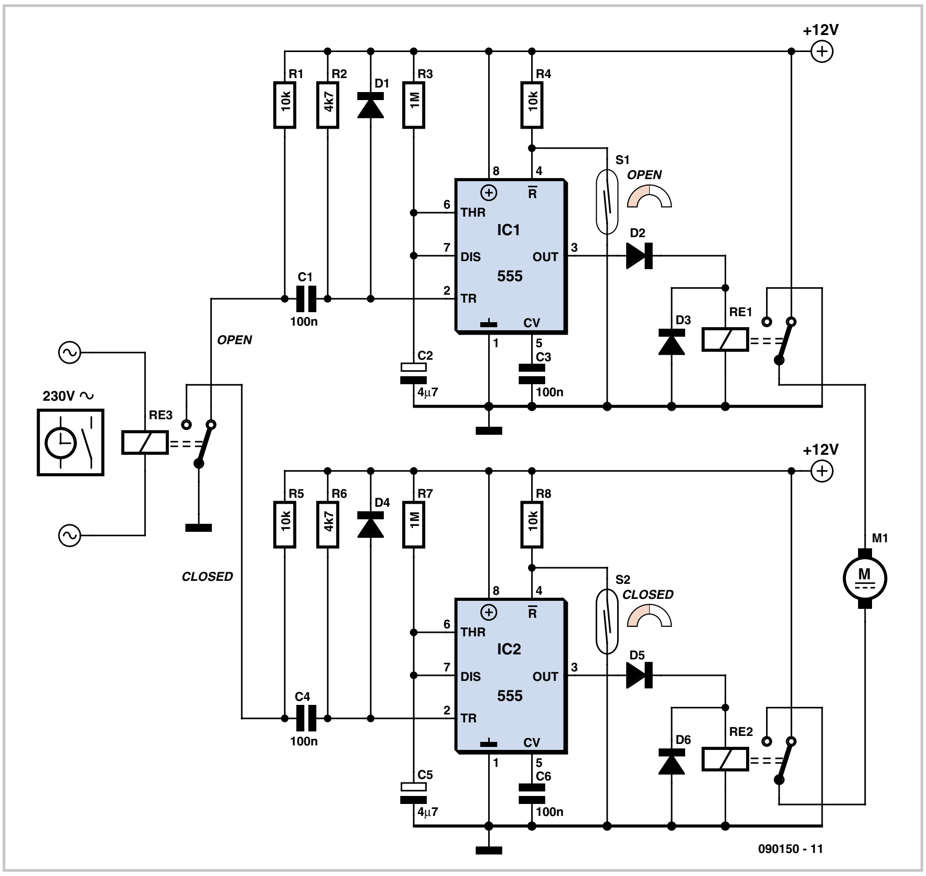
All components of the mechanical drive come from Conrad Electronics [2]: a motor with a reduction gearbox (type RB32, order number 221936) and a pulley (V-belt pulley, order number 238341) on the output shaft. An O-ring is fitted to the pulley to provide sufficient friction with the drive chain of the Venetian blind. The magnet for actuating the reed switches is a rod magnet with a hole in the middle (order number 503659), and the chain of the Venetian blind is fed through this hole.

(090150-I)

Internet Links

[1] www.elektor-usa.com/090150

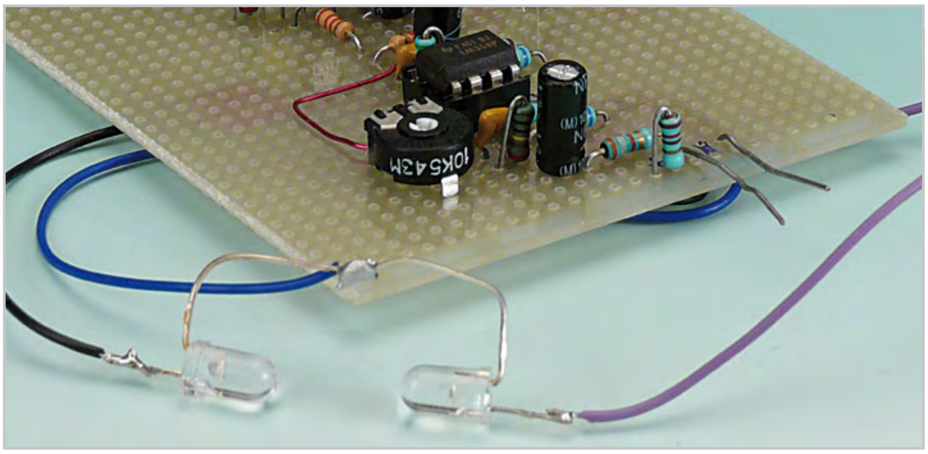
[2] www1.conrad-uk.com



Stress-o-Meter

Markus Bindhammer (Germany)

The common meaning of the term 'stress' is distinctly different from what specialists understand by the term, and even they disagree with each other. The Wikipedia entry for this term [1] gives an impression of its complexity. Consequently, it's a good question whether it is even possible to measure stress. However, it is certainly possible to measure how our bodies respond to stress.
No matter whether something is especially pleasant or instead triggers anxiety or aggression, if there is a strong stimulus, our bodies are prepared to act accordingly. Jumping for joy, fleeing, and attacking all cost a lot of energy. One the many consequences is thus an increase in the heart rate, which is probably the most easily measured response to stress.
The resting heart rate of a healthy person is around 50 to 100 beats per minute (bpm). A person's pulse can be measured either electrically with an ECG instrument or by sensing the periodic variation in blood flow through the body tissue. The first method requires electrical contact between electrodes and the skin, which is not especially advisable for



DIY electronics. By contrast, the variation in blood flow can easily be sensed using light transmission, since the absorption of the transmitted light depends on the blood flow. Ear lobes and fingertips are especially suitable for light transmission measurements.
The author converted an ordinary plastic clothespin into a finger or ear clip. To do so, he first drilled a 5-mm hole in each arm of the clip and then glued an IR LED (type SFH487) in one hole and a phototransistor (type SFH309FA) in the other hole (see drawing). A bright red LED or even a white LED can be used in place of the IR LED. It's even possible to use an LDR as the photosensor. Ready-made clips are also available commercially as medical accessories (expensive) or accessories for ergometers and similar sports equipment (inexpensive).
With a 5-V supply, the current through the IR LED is around 30 mA. The sensor signal (with its small voltage variations) passes through a high-pass filter (C1/R3), which removes slow drift, to the non-inverting input of opamp

IC1a. The combination of C2 and R5 forms a low-pass filter that decouples high-frequency noise. IC1a amplifies the signal in the passband, which is centred at 100 bpm, by a factor of 100. A similar combination of filter and amplifier is built around IC1b, in this case with a gain of 500. The LM348 dual opamp is especially suitable for this circuit because it can handle small-signal inputs close to 0 V, even when powered from a single-ended supply. The overall gain of the two stages can be adjusted with P1. The output of IC1b drives T2 and T3 in parallel, so D2 blinks at the same rate as the variation in blood flow through the ear or finger between D1 and T1.

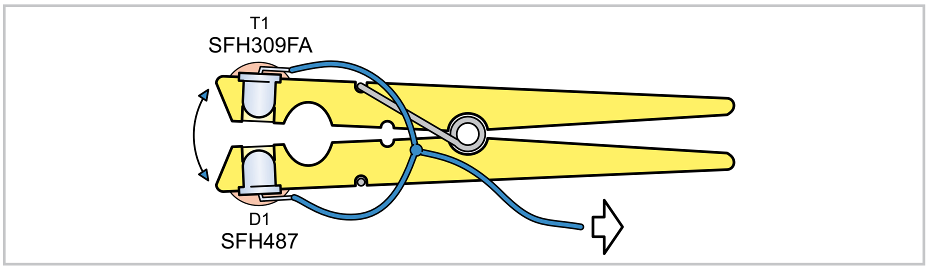
The 'excess rate', or stress, is indicated by IC2, a conventional 555 timer IC. Transistor T3 shorts out capacitor C6 when D2 is on. This resets the internal flip-flop of the 555 and causes pin 3 to go High, which in turn causes D4 to light up. When D2 is off, C6 can charge via R12. If the charging interval is long enough for the voltage on C6 to rise to two-thirds of the supply voltage, the output of the 555 changes state, LED D4 goes dark, and D3 flashes briefly. This means that the user's pulse rate is low as long as D3 blinks periodically. C6 and R12 are dimensioned such that D3 remains dark at heart rates above 100 bpm.

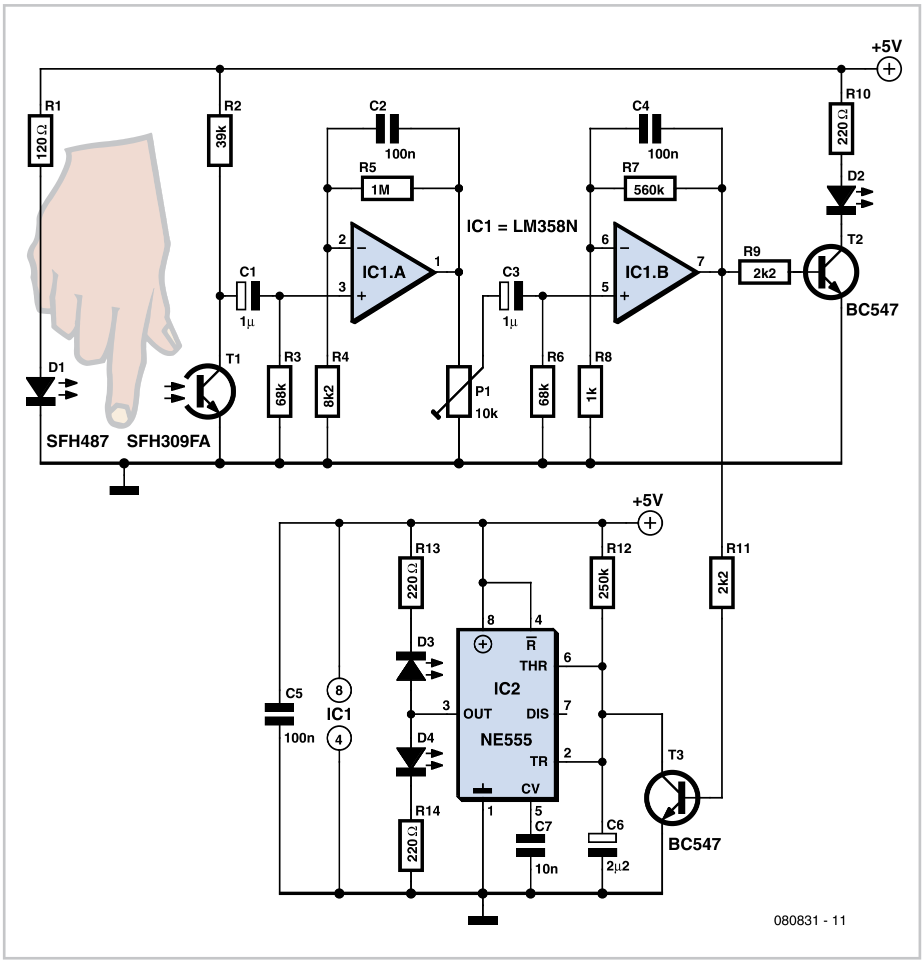
For safety reasons, an AC power adaptor should not be used as the power source. The circuit works properly with a supply voltage of 4.5 to 7 V, so a set of four alkaline, NiCd or NiMH cells forms a perfectly adequate power source.

(080831-I)

Internet Link

[1] http://en.wikipedia.org/wiki/Stress





Powering a Second Hard Drive

Leo Szumylowycz (Germany)

Just about every hands-on computer builder knows the problem: you've acquired an extra hard drive or cooling fan but there are no spare cables or connectors to power these additional components inside the computer case. In situations like this splitter cables, also called Y-cables, can be a blessing. But what if you don't have one of these to hand and the local computer shop is closed? There's only one thing for it — DIY! As tasks go, splicing in an extra cable is not particularly difficult, as long as you have sharp eyesight. All you need is a second power cable and a choc block terminal strip and the job's done. It works adequately (for a while) but it doesn't look particularly attractive, reliable or professional.

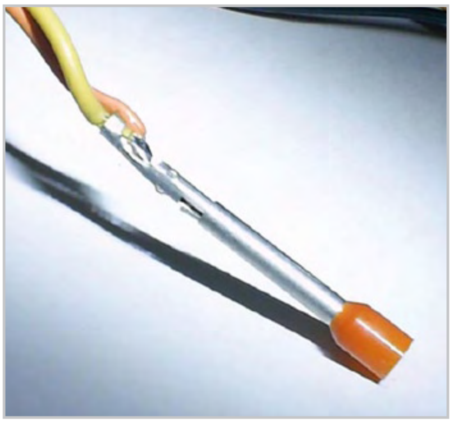
A more elegant solution would be to solder the new power cable direct to the corresponding connector of the existing device. Elegant, yes, but not particularly straightforward, since the power supply rails are seldom easy to get at, whilst the metal pins of individual power connectors are of course buried inside their plastic shell.

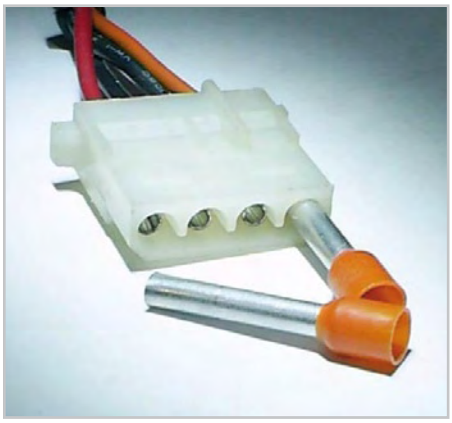
A little trick involving the sleeves that go on the ends of wires will enable you to extract the pins as far out of the retaining mount as needed to solder onto the rear of these pins additional wires for the accessory device you wish to install.

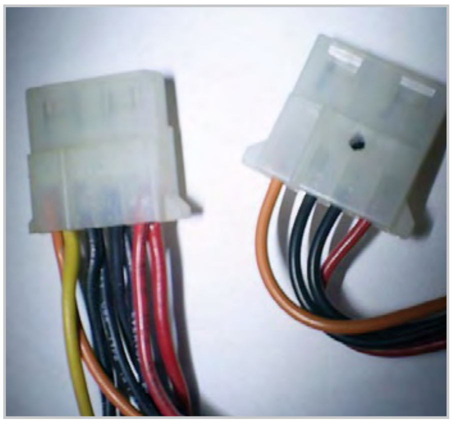
We need two types of sleeves, 4 mm (0.16") for the plugs and 6 mm (0.24") for the sockets.

First of all the contact on the cable is pressed hard into the plastic retainer to ensure the restraint spring grips cleanly and fully.

Next we attach wire sleeves to the pin that we are extracting and push it carefully and slowly into the plastic retainer as far as the latch and end stop. Just before this point is reached you will feel some resistance, with a click sound heard after you have overcome







the pressure. Exactly as this click is heard you need to remove the wire in question, with its pin, from behind out of the plastic housing. If this doesn't work exactly as desired, it can help to twist the sleeve around while you are pulling. Normally you can release about four pins using one sleeve. For assured reliability, however, it is recommended to use several sleeves.

The free ends of the additional cable should be soldered (using great care and as little solder as possible, as shown in the photo) to corresponding pins close up against the existing cable. Any unwanted solder blobs are best removed with desoldering braid (solder wick). Finally we need to bend the contact springs gently outwards and press each pin back into its right position. You will find the longer sizes of sleeve are easier to handle, also that the individual parts of the connectors move around more easily if you spray them first with contact lubricant.

(090201-I)

Two-button Digital Lock

Francis Perrenoud (Thailand)

Now here's a digital lock unlike any other, as it has only two buttons instead of the usual numeric keypad. The way it works is as simple as its keypad. Button S1 is used to enter the digits of the secret code in a pulsed fashion — i.e. the number of times you press the button is determined by the digit to be entered. A dial telephone uses the same type of coding (now maybe there's an idea?). Press four times for a 4, nine times for a 9, etc. Pressing button S2 indicates the end of a digit. For example, to enter the code 4105, press S1 four times, then press S2, then S1 once, S2 once, then without pressing S1 at all, press S2 again, then finally S1 five times and S2 once to finish. If the code is correct, the green LED D1 lights for 2 seconds and the relay is energized for 2 seconds. If the code is wrong, the red LED D2 lights for 2 seconds, and the relay is not energized.

To change the code, fit a jumper to J1 and enter the current code. When the green LED D1 has flashed twice, enter the new 4-digit code. D1 will flash three times and you will need to confirm the new code. If this confirmation is correct, D1 will flash four times. If the red LED D2 flashes four times, something's wrong and you'll need to start all over again. To finish the operation, remove the jumper and turn the power off and on again — the digital lock is now ready for use with the new code.

The software can be found on the web page for the project [1]. Don't forget to erase the microcontroller's EEPROM memory before programming it, so you can be sure that the default code is 1234 and not something unknown that was left behind in the EEPROM.

A little exercise for our readers: convert this project into a single-button digital lock — for example, by using a long press on S1 instead of pressing S2 to detect the end of a digit.

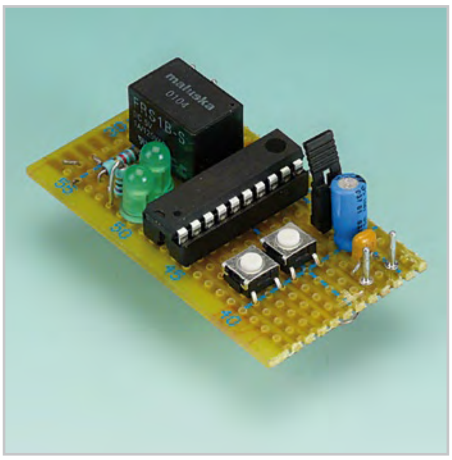
(090127-I)

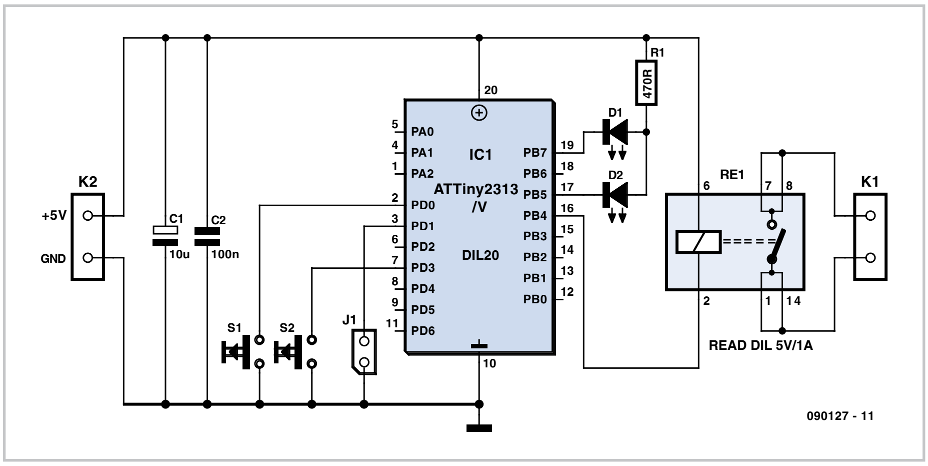
Internet Link

[1] www.elektor-usa.com/090127

Download

090127-11: source codes and hex file, from [1].





Wireless Baby Monitor

Wolfgang Papke (Germany)
Ton Giesberts (Elektor Labs)

Walkie-talkies (also known as handheld or PMR, Personal Mobile Radio) can be bought at low prices even from department stores, and they can be operated without a licence in many countries. Considering the low cost, such a set would be very suitable for use as a wireless baby monitor, with the addition of several external components. These are connected to the jack sockets for an external loudspeaker/microphone and an external PTT (Push-To-Talk) switch, which are often found on these devices.

The walkie-talkie with the extra electronics and microphone is placed in the baby's room. When the PTT switch on the other walkie-talkie is actuated for about a second the 'baby' walkie-talkie produces a series of tones, which the external electronics can detect. This then activates its own PTT switch for about 5 seconds, so it switches over to transmit. During this time the other device can hear what the external microphone picks up.

Figure 1 shows the circuit that the author designed for this. It has been designed specifically for a Tevion 3000 PMR sold some time ago by Aldi. This type of PMR has a combined jack socket that includes all the required connections.

The voltage present on the PTT connector is used to generate the supply voltage for the circuit via R3, D1 and C1/C2. When the loudspeaker output presents a series of tones (when the PTT switch on the other walkie-talkie is held down), it causes T1 to conduct. This also turns on T2 and T3, so that the external microphone is connected to ground. The resulting current that flows through the microphone should be sufficient to activate the PTT circuit in the walkie-talkie, causing it to transmit. If the external microphone doesn't draw sufficient current, a resistor (R8) should be connected in parallel. Some experimentation with the value of this resistor may be required. If you want to make use of the internal microphone then R8 should be replaced with a wire link.

When the walkie-talkie switches to transmit the built-in amplifier stops producing a signal and T1 turns off. However, since electrolytic capacitor C3 has been charged up in the mean time, transistors T2 and T3 will keep conducting for several seconds until C3 has been almost discharged via R4.

In the Elektor labs a simpler version with the same functionality (**Figure 2**) has been designed for use with a cheaper PMR set that can be obtained from Conrad Electronics (PMR Pocket Comm Active Pair, order number 930444). These walkie-talkies have separate jack sockets for the LS/Mic and PTT connections.

When there is a call a series of tones is produced that is used to turn on T1 via R3. T1 then activates the PTT function and the microphone amplifier is turned on. However, it's not just the audio signal that is used, but also the DC offset produced when the internal output stage is turned on. Both the internal as well as external loudspeaker are driven via an output capacitor of 100 µF. When there is a call it charges up via R3 and the base-emitter junction of T1. If the walkie-talkie is called often there would be a danger that the output capacitor would remain charged and the DC offset of the audio signal would no longer be sufficient to turn on T1. To prevent this, D1 is connected in reverse across the base-emitter junction of T1, providing a discharge path for the output capacitor. To keep the circuit active for a minimum amount of time the microphone voltage is used to provide an extra base current. This is done by charging C1 via R1. When the transmitter is turned off the microphone and R2/

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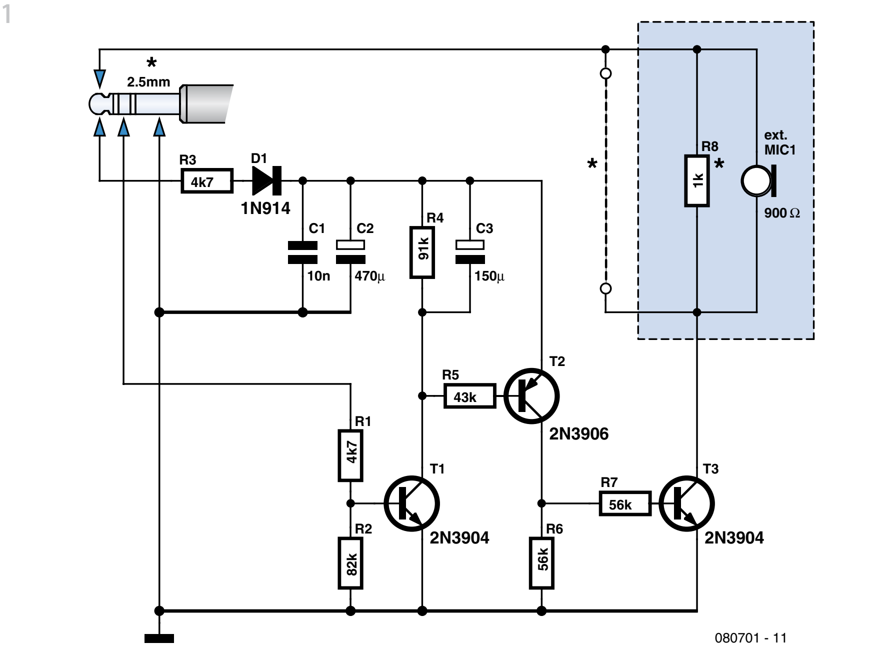
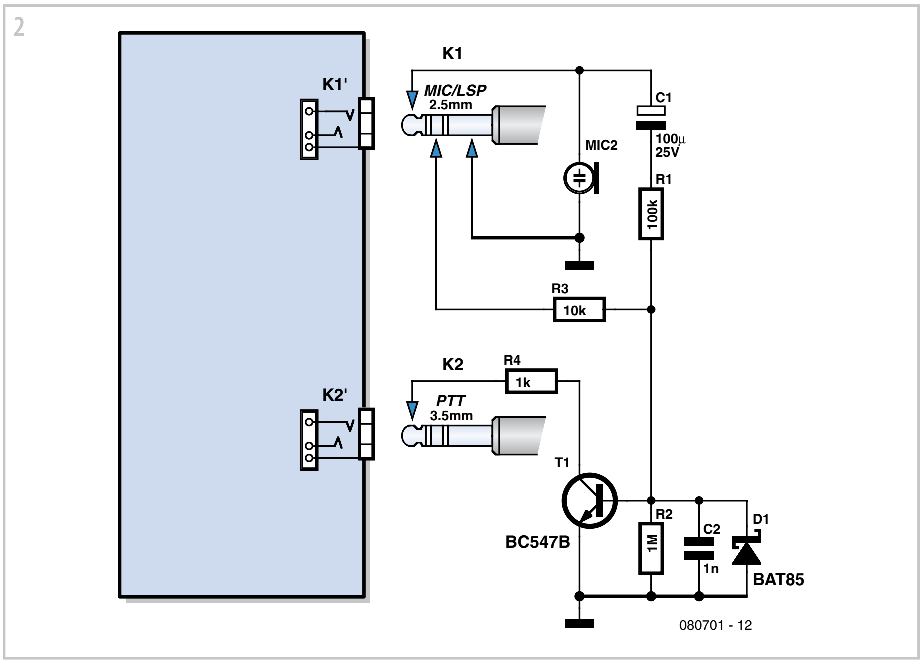


D1 provide a discharge path for the capacitor. C2 ensures that the circuit won't react to spikes caused by interference. As can be seen from the second circuit diagram, use is made of two connectors, a 2.5 mm jack plug for an external headset and a 3.5 mm plug for the PTT function. These connectors are particular to the walkie-talkies we used here. With other types of walkie-talkie you should first check the connection details of the connectors before you connect the circuit up.

When the circuit is used as a baby monitor you should check that the microphone you're using can pick up all the sounds. In our case the microphone didn't appear to be very sensitive. The microphone amplifier has probably been designed for a voice that is near the PMR unit. When used as a baby monitor the microphone should therefore be positioned as close to the baby as possible.

(080701-I)

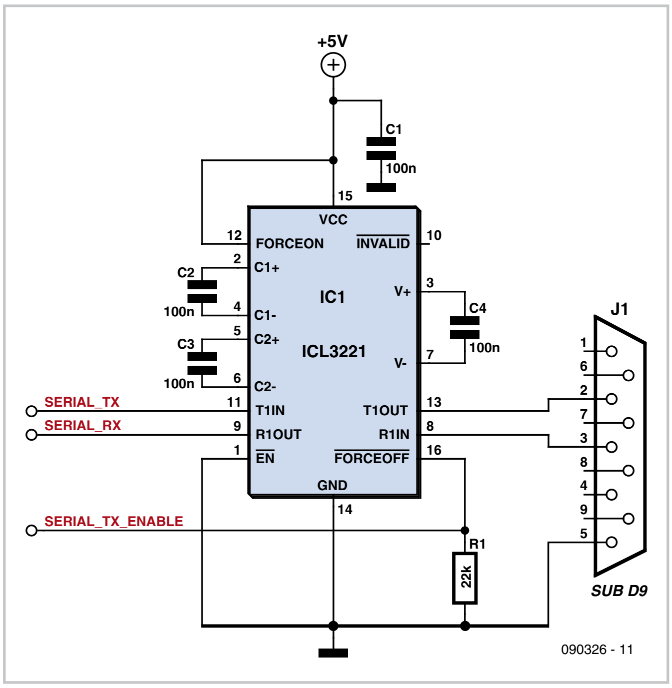


Network RS232

Marcos Agra-Trillo (United Kingdom)

With an ever increasing number of off the shelf electronic modules and boards available at low prices, designers are inclined to use these instead of making all their electronics from scratch. In many cases this makes sense as developing say, a PID motor controller or a GPS receiver from scratch requires considerable skill, time and effort. A surprising number of modules still have an interface based on RS232. No wonder, as RS232 is easy implemented on a microcontroller with two I/O pins and a line driver such as the MAX232. In the case where the master is a PC, the serial port is relatively easy to access on both Windows and Linux. Usually modules implement a text terminal interface that decodes single line commands with arguments and generate a reply like this:

```
Tx: cmd arg0 arg1 ... argX/n
Rx: cmd arg0 arg1 ... argX/n
replyline0/n
replyline1/n
...
replylineY/n
```



A complication occurs when there are a number of RS232 modules in a project, as each requires a serial interface at the master. A hardware solution in the form of an RS232 multiplexer would be a solution but wouldn't it be nice to get this functionality for free!
By deviating from the original aim of RS232 as a point-to-point link, we can have an RS232 network in which all the modules share both transmit and receive lines to one master interface. All modules operate at the same speed, start and stop bits with no flow control. When idle, all the modules are listening for commands from the master and have their transmitters disabled. Each module is configured with an identifier consisting of a number that the master sends as a single line (e.g. '2/n' selects module 2). If a module receives an identifier that matches its own, it is selected and can decode commands and drive its transmitter for the duration of the reply. Conversely, if the identifier does not match it must not decode commands and ensure its transmitter remains disabled.

In addition to some firmware support, the RS232 driver electronics must be able to tri-state the transmitter while keeping the receiver operational. Sadly, the classic MAX232 driver is unsuitable but the ICL3321 and MAX242 are possible candidates for our purpose. These have low-power shutdown modes that power-down the charge pump and transmitters but keep the receivers enabled for monitoring RS232 activity.
The number of modules in your RS232 network is limited by the (nominal) 5 kΩ pull-down at the receiver input of the line driver device. Multiple modules increase the loading

on this signal, reducing the maximum operating speed and cable length. Using the circuit shown here, running an application with five modules at 9,600 bps located within 3 feet of each other did not present any problem.

Modules need a means of enabling the network mode and setting the unique identifier. This can be done via switches, jumpers or, if I/O pins are scarce, by storing the configuration in the user EEPROM/Flash provided by many microcontrollers. If the latter is done, it is reasonable to assume the module will only be configured with normal RS232. Special configuration commands can then be provided that are always decoded irrespective of the identifier match.
It is unlikely that commercially available modules can be tweaked to support 'network' RS232 unless the vendor has used a suitable RS232 line driver and is prepared to provide the firmware code. However, it is possible to implement on DYI modules and perhaps module designers can take note and enhance the functionality of their future designs.

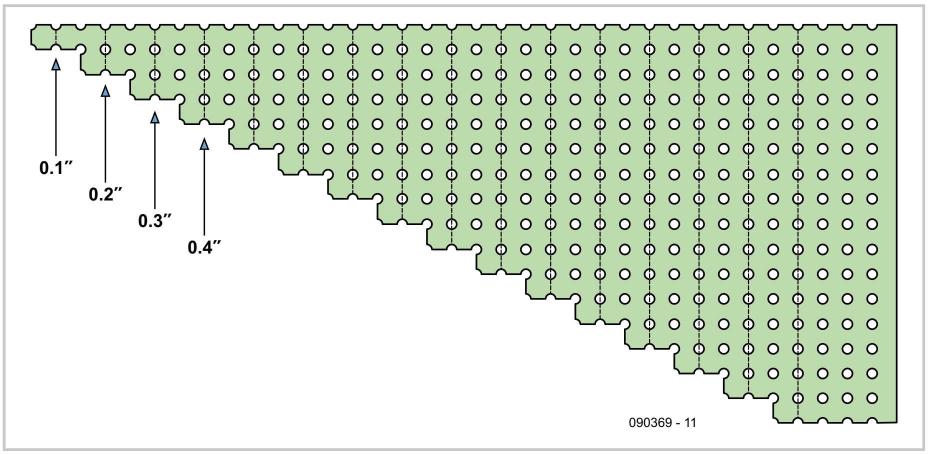
(090326-I)

Simple Wire Link Bender

Louter van der Kolk (The Netherlands)

When you want to mount components on a PCB or a piece of prototyping board, you not only want to do this quickly, but also tidily. The bending of really tidy wire links with the correct pitch is often a tedious chore. The following is a handy aid for doing this.

Using a small piece of 0.1 inch (2.54 mm) prototyping board, you can very easily make a handy bending jig for wire links. With a jigsaw, cut the piece of prototyping board into a staircase shape as shown in the drawing. You can make it as big as you need. Make sure that the horizontal cuts are slightly towards the outside with respect to the holes, so that clear indentations remain in the horizontal sections.



Bending a wire link is now very easy: choose the desired pitch on the jig (dashed line), take a piece of wire and fold it sharply around the indentations corresponding to the selected pitch. A neat wire link is the result, with exactly the right pitch and ready for soldering tightly into the PCB or prototyping board. With close-fitting wire links the board looks much better and they are also mounted much more quickly.
Tof course he bender is also suitable for resistors with leads.

(090369-I)

Single-cell Power Supply

Harald Broghammer (Germany)

Many modern electronic devices and microcontroller-based circuits need a 5 V or 3.3 V power supply. It is important that these voltages are constant and so a regulator of some kind is essential, including in battery-powered devices. The simplest approach is to select a (perhaps rechargeable) battery whose voltage is rather higher than that required by the circuit and use an ordinary linear voltage regulator. Unfortunately this solution is rather wasteful of precious energy and space: for a 5 V circuit at least six NiCd or NiMH cells would be required.

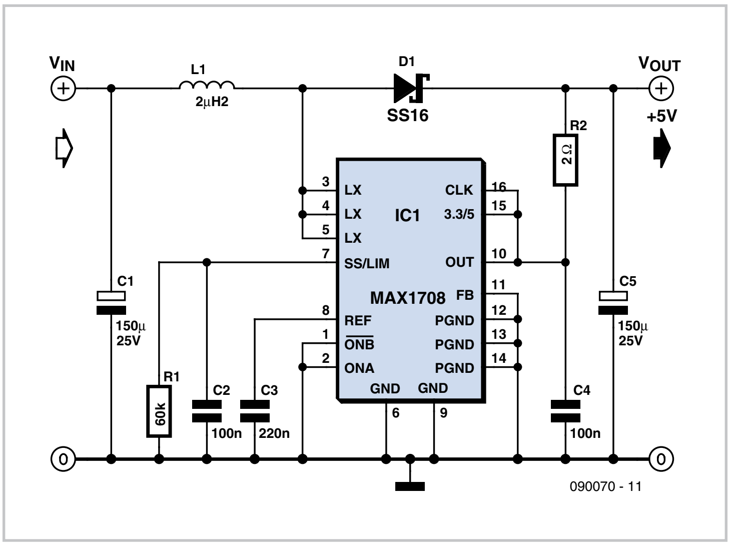
Both these disadvantages can be tackled using a little modern electronics. A good way to minimize energy losses is to use a switching regulator, and if we use a regulator with a step-up topology then we can simultaneously reduce the number of cells needed to power the circuit. Fortunately it is not too difficult to design a step-up converter suitable for use in portable equipment as the semiconductor manufacturers make a wide range of devices aimed at exactly this kind of application. The Maxim MAX1708 is one example. It is capable of accepting an input voltage anywhere in the range from 0.7 V to 5 V, and with the help of just five external capacitors, one resistor, a diode and a coil, can generate a fixed output voltage of 3.3 V or 5 V. With two extra resistors the output voltage can be set to any desired value between 2.5 V and 5.5 V.

Characteristics

- Input voltage from 0.7 V to 5 V
- Output voltage from 2.5 V to 5.5 V
- Maximum output current 2 A
- Can run from a single cell

The technical details of this integrated circuit can be found on the manufacturer's website [1], and the full datasheet is available for download. An important feature of the device is that it includes an internal reference and integrated power switching MOSFET, capable of handling currents of up to 5 A. It is, for example, possible to convert 2 V at 5 A at the input to the circuit into 5 V at 2 A at the output, making it feasible to build a 5 V regulated supply powered from just

two NiCd or NiMH cells. With a single cell the maximum possible current at 5 V would be reduced to around 1 A.
The example circuit shown here is configured for an output voltage of 5 V. The capacitor connected to pin 7 of the IC enables the 'soft start' feature. R2 provides current limiting at slightly more than 1 A. For maximum output current R2 can be dispensed with. Pins 1 and 2 are control inputs that allow the device to be shut down. To configure the device for 3.3 V output, simply connect pin 15 to ground.



tron PISR series, is needed. A fundamental limitation of the step-up converter is that the input voltage must be lower than the output voltage. For example, it is not possible to use a 3.7 V lithium-polymer cell (with a terminal voltage of 4.1 V fully charged) at the input and expect to be able to generate a 3.3 V output, as diode D1 would be permanently conducting. On the other hand, there is no difficulty in generating a 5 V output from a lithium-polymer cell.

(090070-I)

The coil and diode need to be selected carefully, and depend on the required current output. To minimize losses D1 must be a Schottky type: for a 1 A output current the SB140 is a suitable choice. For L1 a fixed power inductor, for example from the Fas-

Internet Link

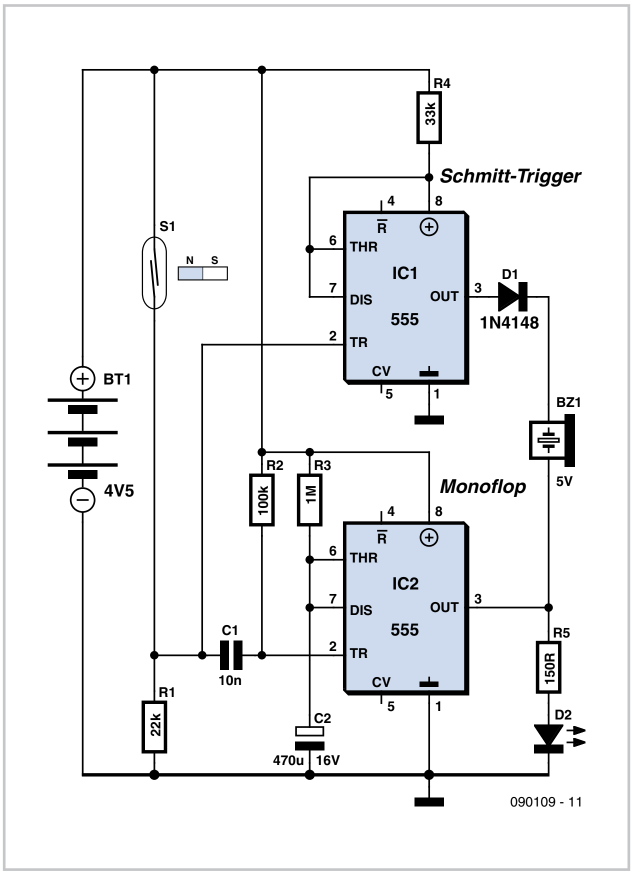
[1] www.maxim-ic.com/quick_view2.cfm/qv_pk/3053

Economy Timer

Stefan Hoffmann (Germany)

Windows should be opened only a few minutes for ventilation, and due to the risk of break-ins, you shouldn't leave windows open for hours on end or when nobody is at home.

This circuit detects when a window is open (it can also be used with a door), indicates that the window is open by means of a red LED or a blinking LED, and emits a loud acoustic signal from an intermittent electronic buzzer to remind you to close the window.
The active components consist of a pair of type 555 timer ICs. Switch S1 is a reed switch that is attached to the window frame, and when the window is closed the switch is closed by a magnet attached to the window casement.
When the window is closed, the reed switch connects resistor R1 to the 4.5-V supply voltage. If the window is opened, S1 opens as well and the voltage on R1 drops immediately to 0 V. As a result, the trigger input of IC2 is briefly pulled to ground via C1.
IC2 is wired as a monostable flip-flop, and it is triggered by this pulse. After C1 charges, the supply voltage is again present at the trigger input of the monostable flip-flop (via R2). This



prevents retriggering and allows the monostable to time out normally.
The red LED or blinking LED (user option; select the value of the series resistor accordingly) indicates that the timer is running (pin 3 is logic High). The output of the second 555 IC, which configured as a Schmitt trigger, also goes High when its trigger input is pulled to ground. As a result, the DC buzzer connected between the outputs of the two 555 ICs is not energized because both outputs are High.
If the window is closed within the time interval determined by the R3/C2 network, the output of the Schmitt trigger returns to the Low state. If the output of IC2 is still High, diode D1 prevents any current from flowing through the DC buzzer. After the monostable times out, the outputs of both 555 ICs are Low and the buzzer remains silent.
Things are different if the window is still open when the monostable times out. The Schmitt trigger output remains High, but the monostable output goes Low. As a result, a positive voltage is applied to the buzzer, and it generates an acoustic signal until the window is closed. As befits an intermittent buzzer, it generates an intermittent signal.
The time-out interval of the monostable can be calculated reasonably accurately with the formula

$t = 1.1 \times C2 \times R3$

With the indicated component values (1 MΩ and 470 µF), the alarm sounds after approximately nine minutes if the window is still open.
Instead of the reed switch, you can use a light-dependent resistor (LDR) to detect the light from the refrigerator lamp. If you replace R1 with a trimpot and adjust it so that the monostable is triggered when the refrigerator lamp goes on (when the refrigerator door is opened), after the monostable times out the buzzer will remind you to close the refrigerator door (which is often left open). A nice side effect here is that you can use this circuit to definitively answer the age-old question of whether that refrigerator lamp actually goes off when the fridge door is closed ;-).

(090109-I)

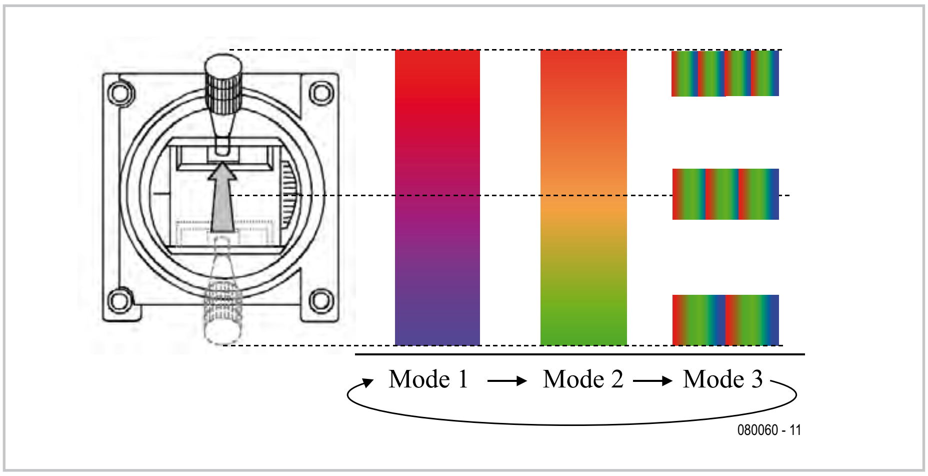
Full-color Night-flight Illumination

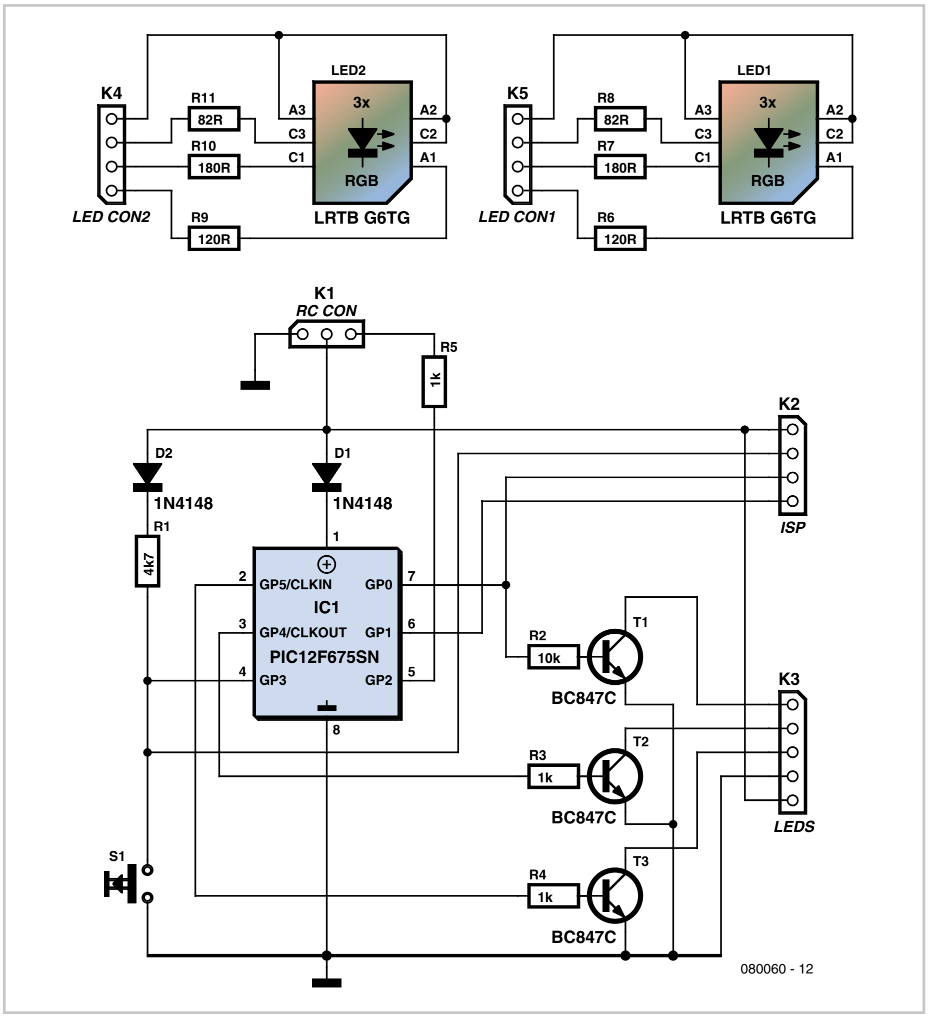
Steffen Schütte (Germany)

There are various types of night-time illumination available for model aircraft. The circuit described here is special in that it allows the color of the RGB LED that is used to be controlled remotely. The circuit can be connected to a spare receiver output channel or in parallel with a channel already in use for other purposes. The color of the RGB LED changes according to the servo position for the selected channel and according to the selected mode of operation.

Characteristics

- Supply voltage: 4.8 V (4.5 V to 5.5 V)
- Maximum current for each output: 150 mA
- Maximum current per LED module: 150 mA (50 mA per color)
- Operating modes: 3
- Servo range: ±100 %
- Dimensions (prototype): 32 mm x 25 mm x 7 mm
- Controller weight: 5 g
- LED module weight: 0.7 g





At the heart of the circuit is a PIC12F675 microcontroller (IC1), which is connected to one output channel of the radio receiver: this allows it to measure the corresponding servo position. Depending on its operating mode, the microcontroller generates pulse-width modulated waveforms on three outputs, which in turn drive the connected RGB LED (or LEDs) via transistors T1 to T3 to produce a range of colors. The other main components are the mode button S1 and a four-way connector (K2) used for in-system programming (ISP) of the microcontroller. D1 and D2 are required to prevent a connected radio receiver from interfering with the programming operation.

In contrast to the simplicity of the hardware, the software running in the microcontroller is rather complex. Commented source code is available for free download from the project page at www.elektor-usa.com. The most important parts of the program are the initialisation code, the interrupt routine and the main loop.

The interrupt routine is triggered by a level change on the input port pin connected to the radio receiver. It tests whether the edge is rising or falling: if rising, Timer1 is set to zero to allow the time to the following falling edge to be measured. The pulse width corresponds to the servo position and is output by the receiver every 20 ms. The 20 ms timebase derived from the receiver signal is also used to orchestrate the polling of the mode button. When the mode button is pressed (the input port pin going from High to Low) the device changes mode.
If the device is not in continuously-changing mode the new color for the RGB LED is calculated in the interrupt routine by calling the routine 'calcResult'. If the device is in continuously-changing mode the relevant calculations are performed in the main loop.
Pressing S1 cycles through the following operation modes (see also the accompanying figure). In mode 1 the color changes from blue (minimum servo position) to red (maximum position). A press of S1 advances to mode 2, where the color changes similarly from green to red. A further press enters mode 3, where the color changes continuously, with the speed of the change depending on the servo position. Finally, pressing the button once more returns to mode 1. The most recently used mode is stored in the microcontroller's EEPROM while power is not applied.
When power is applied to the receiver the channel that has been selected for use must be set to its minimum position. This is because the circuit uses the initial value of the pulse width to 'learn' the minimum position. If the channel is not set to its minimum position, the device will never fully reach the color red (in modes 1 and 2) or the maximum possible color-changing speed (in mode 3).

The upper part of the circuit diagram shows how the RGB LED can be connected to connector K3. It is possible to connect multiple LED units in parallel. An extra pin on K3 is taken to ground in order to allow permanently-lit LEDs to be connected alongside the RGB LEDs. It is of course necessary to keep within the maximum permissible current draw from the receiver or battery eliminator circuit (BEC).

(080060-I)

Download

080060-11: source code and hex files, from www.elektor-usa.com/080060

Product

080060-41: ready-programmed PIC12F675 microcontroller

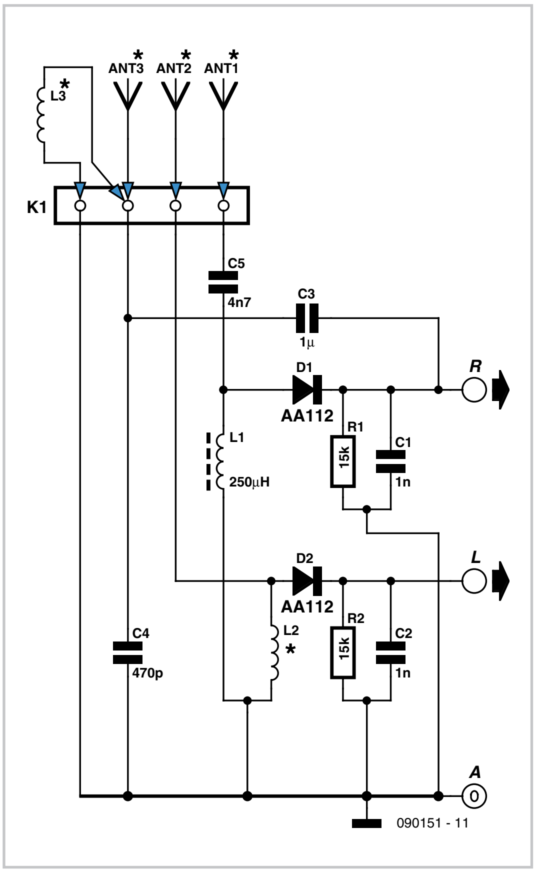
Smoggy

use your Walkman to detect electrosmog

Tony Ruepp (Germany)

Even if your good old (Sony) Walkman sees little use nowadays it would be a shame to get rid of it altogether. The more so when just removing the tape head would allow the built-in audio amplifier to become an outstanding electrosmog detector for a variety of purposes.

Looking at the schematic, readers with RF experience will have no difficulty in recognizing the diodes and coils of the two detector-receivers, which serve to capture and demodulate RF signals. With its coil of four turns (L2) one receiver covers the higher frequency range of the electromagnetic waves, whilst the second detector takes care of the lower frequency range. For this reason a coil with a greater number of turns is required: L1 is an RF choke of about 250 µH. The precise value is not critical and it could equally be 220 µH or 330 µH.



The outputs of both detector-receivers are connected to the cables disconnected previously from the tape heads, feeding the right and left channel inputs to the Walkman's audio amplifier. Please note here that the screening of the tape head cable does not have to be absolutely identical to the ground connection of the amplifier circuitry. As we are dealing with a stereo amplifier, we are listening into both channels and thus both RF ranges at the same time.

One channel of the amplifier can also be used to demodulate low-frequency magnetic alternating fields via a capacitor (C3) bypassing diode D1 and connecting either a third coil (L3, for instance; a telephone recording adapter) as the pickup device or else a long piece of wire for acquiring low frequency AC electrical fields. Sources like this are discernible mainly by a distinct 60 Hz (or 50 Hz) humming in the earphones.

Predicting what you may hear down to the very last detail is difficult, since every locality has its own, individual interference sources. Nevertheless, with practice users will succeed in identifying these interference sources by their particular audio characteristics.

To sum up, four different 'sensors' can be connected to the inputs of this circuit: ANT1 (approx. 50 cm long whip antenna), ANT2 (3.5 cm short stub antenna), ANT3 (approx. 1 m long wire antenna for low frequency electrical fields) and a coil for magnetic fields. Finally, two more tips:

1. Use only ‘good old’ germanium diodes for D1 and D2. Sensitivity will be much reduced if silicon diodes are used, as these have a higher threshold voltage.

2. Smoggy does not provide an absolute indication of field strength and even more so cannot provide any guidance whether anything it detects might be harmful. Its function is to detect electromagnetic signals and compare their relative magnitude.

(090151-I)

Solar-driven Moisture Detector

Christian Tavernier (France)

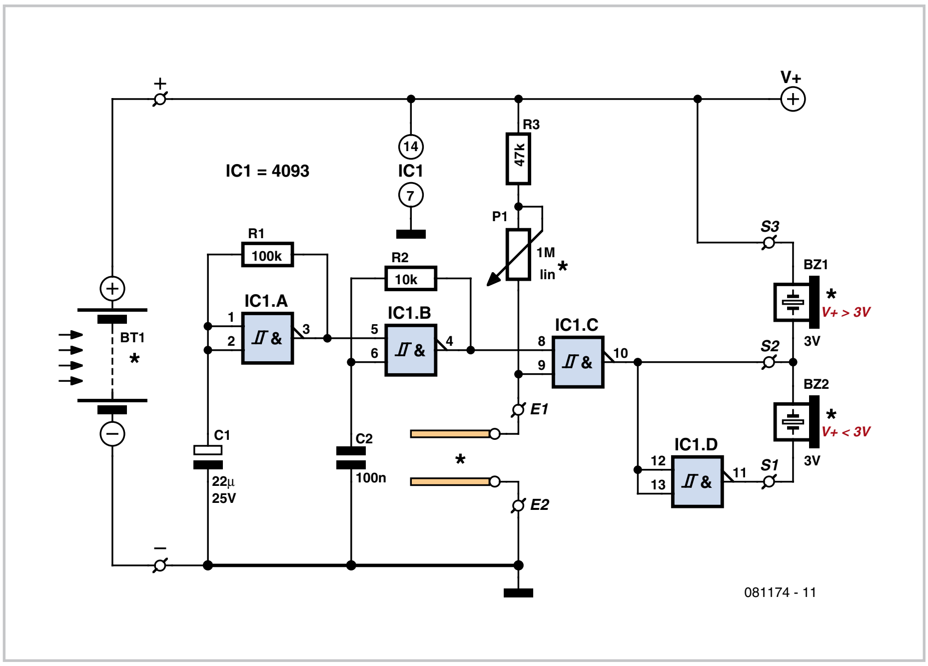
When we think of solar cells or panels, what springs to mind immediately is producing power — only natural, given the primary purposes of such devices; but we don’t necessarily think of using them in applications where the fact they don’t produce power in the absence of light may actually be useful. Yet this is just the case in the project discussed here.

The project, then, is intended for detecting moisture here on Earth using solar power. It’s primarily aimed it at those of you who like to brighten up their house or flat with pot plants, but are afraid of inadvertently letting them die of thirst.

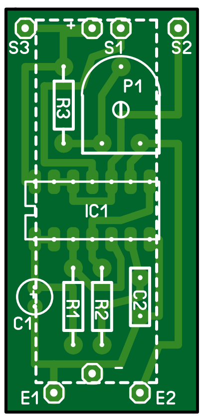
Using its two electrodes, formed from two stiff pieces of bare copper wire, it can be stuck into the pot of any plant you want to monitor. As long as the plant isn’t thirsty, i.e. the soil in the pot is moist enough, it will just sit there and do nothing at all. But when the soil dries out below a certain threshold (which you can adjust to suit the soil used and the plant being monitored), it starts ‘squealing’ to tell you it is time to give the poor plant a drink.

But so that your husband/wife/girlfriend/boyfriend (as applicable!) won’t throw your plant out of the window because the detector has started squealing in the middle of the night, we obviously want it to work only during the day. This is where the solar cell comes in handy: on the one hand, it is used to power the circuit, making it totally stand-alone; and on the other, the lack of power produced when in darkness means the circuit is automatically silenced at night.

Once we’ve adopted this principle, the circuit is remarkably simple, using just a single 4093 CMOS logic chip, which contains four 2-input Schmitt trigger NAND gates.



The first gate, IC1a, is wired as a very low frequency astable oscillator. When its output is at logic high, which occurs at regular intervals, it enables IC1b, which is also wired as an astable oscillator, but this time at an audible frequency. The signal from IC1b then has to pass through IC1c, which can only happen if E1 and E2 are not connected, allowing the corresponding input to be pulled up to logic High. You will have realized that E1 and E2 are the electrodes stuck into the soil and so will not be connected if the latter is not sufficiently conductive, i.e. when it starts to dry out. The threshold at which gate IC1c turns on is obviously adjustable using P1.



COMPONENT LIST

Resistors
R1 = 100kΩ
R2 = 10kΩ
R3 = 47kΩ
P1 = 1MΩ linear potentiometer

Capacitors
C1 = 22µF 25V
C2 = 100nF

Semiconductors
IC1 = 4093

Miscellaneous
Solar cell (see text)
Piezo buzzer
2 copper wire electrodes
PCB no. 081174-I

Depending on whether or not the circuit is supplied from a voltage greater or less than 3 V — which depends on the solar cell used, as we'll be seeing in a moment — the piezo sounder can be connected either directly between IC1c output and the positive supply, or between the outputs of IC1c and IC1d, which is wired as a simple inverter and so enables you to double the output voltage.

The circuit is very simple to build, and you can just as easily use the suggested board design [1] or build it on a piece of prototyping board. The sounder used must of course be one without built-in electronics, as here it is just being used as a simple transducer. If it's a large-diameter flat type, you could, for example, glue it onto the casing of IC1, while if it's a small-diameter type with rigid pins, it can be soldered directly onto the end of the PCB where its connection pads are located.
As for the solar cell, for the prototype Solems devices were used, available for example from Selectronic France [2]; these are marked with a very simple 3-figure code in the form NN/LL/WW, where NN is the number of elements in the cell (each element producing around 0.5 V), LL is the length of the cell, and WW the width, in mm. Equivalent cells from other suppliers may work equally well though.
Although in theory standard CMOS logic ICs only work above 3 V, the majority of those we tried in our circuit did actually work with a lot less, which means that if you're on a tight budget (or have a lot of plants to monitor!), you can use the cheapest cells, part no. 05/048/016.
If your budget is a little higher, and you don't want to bother selecting the 4093 CMOS ICs, go for a 07/048/016, or better still a 07/048/032, which will allow the circuit to work under excellent conditions as soon as the illumination reaches around 1,000 lux. You can also cannibalize such cells from solar-powered garden lights, which can often be found at giveaway prices in the big DIY stores.
Given the size of the suggested PCB, the Solems cells can be soldered directly onto the copper side of it. But when connecting the cell up, do take care to be very quick soldering the leads to the two silvered pads at each end of it. They are actually metallized directly onto the glass of the cell and so are pretty fragile.
As soon as the cell is connected, if the two electrodes E1 and E2 are 'in mid-air', the circuit should start 'squealing', as long as it is getting enough light. You can then solder two stiff copper wires onto E1 and E2 (e.g. stripped offcuts of 1.5 mm^2 / AWG16 domestic wiring cable) and spike the circuit into the plant you want to monitor. Then all you have to do is adjust P1 so that the circuit cries for help when the soil has reached the level of dryness you have chosen.

If the frequency of the sound produced doesn't suit you, you can change it by increasing or reducing C2 and/or R2. Likewise, if you don't like its repeat frequency, you can change that by adjusting C1 and/or R1.

(081174-I)

Internet Links

[1] www.elektor-usa.com/081174

[2] www.selectronic.fr

Download

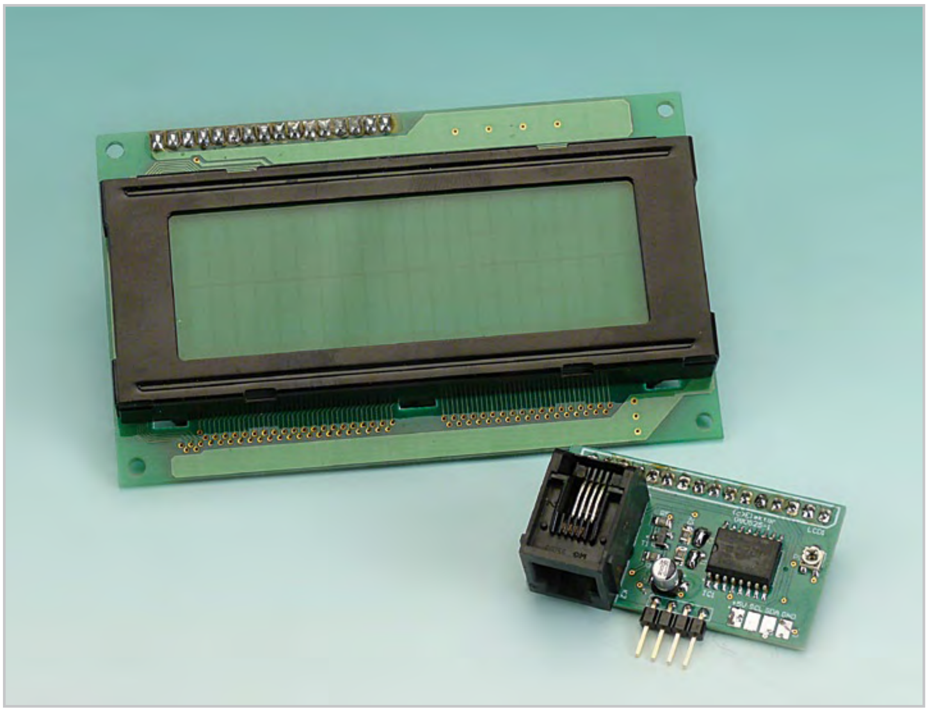
081174-1 PCB layout (.pdf), from [1]

I²C Display

R. Pretzenbacher (Austria)

Pretty graphical simulators are all very well when developing circuits using microcontrollers, but sometimes there is no substitute for a proper display connected to real hardware. LCD panels based on the Hitachi HD44780 controller are popular as they are cheap and, at least in principle, easy to use. Unfortunately they require a large number of control signals, which in turn means bulky cables and losing the use of many of the microcontroller's I/O pins.

Here we present a solution to the problem in just three characters: I²C!

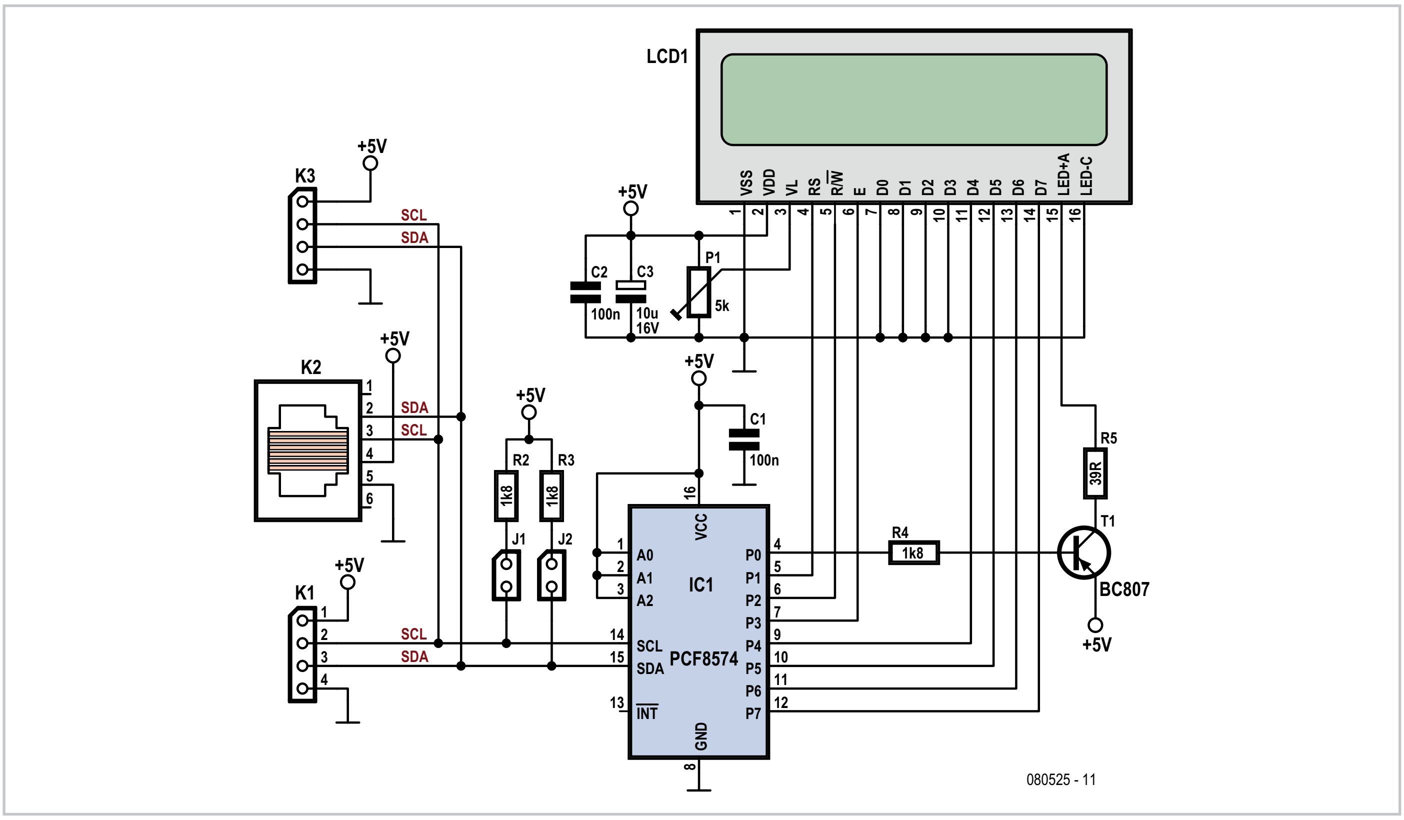


Characteristics

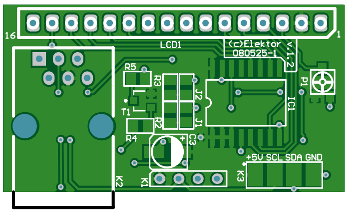
- Universal LCD module for microcontrollers
- Requires just two I/O port pins
- Multiple displays on one I²C bus
- Simple to use with AVR firmware

With the addition of just one extra chip to bridge the gap between the I²C bus and the LCD panel's parallel interface, we can make a universal display module on a simple compact printed circuit board. Besides ground and +5 V power, the module needs just two control lines from the host microcontroller system: SCL and SDA. This makes the job of interfacing to a display much more straightforward. The Hitachi controller can be operated in its 'four-bit mode', where only four data lines are connected along with three control signals: 'E', 'R/W' and 'RS'. And now we come to the elegant part of this design: rather than using a microcontroller to drive these seven lines we use a simple I²C bus port expander device offering eight I/O pins. This even leaves us one spare output which we can use to switch the LCD's backlight (or any other LED) on and off.

We selected the PCF8574, which is available in



COMPONENT LIST



Resistors
P1 = 5kΩ, SMD (Murata)
R2,R3,R4 = 1kΩ8, SMD 0805
R5 = 39Ω, SMD 0805 (see text)

Capacitors
C1,C2 = 100nF, SMD 0805
C3 = 10µF 16V, SMD (Vishay), diam. 4mm

Semiconductors
IC1 = PCF8574 (PCF8574A) (see text)
T1 = BC807, SMD SOT23

Miscellaneous
LCD with HD44780 compatible controller
K1 = 4-way SIL pinheader, lead pitch 0.1" (2.54mm)
K2 = RJ11 socket, PCB mount
K3 = solder islands
J1,J2 = 2-way pinheader with jumper, 0.1" lead pitch
20-way pinheader, 0.1" pitch, for LCD connection
PCB # 080525-1

two variants. The variants differ in the regions of the I²C address space to which they can be configured to respond: see [2]. As shown the circuit is arranged so that the device responds to he highest address in its range: in the case of the PCF8574 this address is 0x4E and in the case of the PCF8574A the address is 0x7E. Using these two chips it is possible to make two display modules that can be connected to the same I²C bus simultaneously without address conflict and without any modifications to the circuit. If it is desired to use one of the other seven possible device addresses (for example if there is a conflict with another I²C device on the same bus) the wiring of the address bits (pins 1 to 3) needs to be changed appropriately.

The circuit itself is straightforward. The signals from the port expander are taken directly to the pins of the LCD panel, with the exception of output P0 which controls the backlight via PNP driver transistor T1. The value of R5 must be chosen according to the current rating of the backlight, which can be determined from the LCD panel's datasheet. The value of 39 Ω shown is suitable for a typical one-line panel with a rated LED current of 30 mA. Preset P1 is used to adjust the display contrast: frequently the display is only visible over a narrow range of contrast settings. Jumpers J1 and J2 enable the standard pull-up resistors on the SCL and SDA lines: there should only be one pair of such pull-up resistors over the whole bus. The printed circuit board offers a range of possibilities for connection to the bus: header K1, RJ11 socket K2 and solder pads K3.

To simplify using the display the author has written driver software in C, suitable for use with AVR microcontrollers. As usual this is available from the *Elektor* web page for this article [1] and can of course be modified to suit your own requirements. The software is divided into three parts as follows.

1) I²C functions
(may be modified to suit particular AVR microcontrollers)

• i2cInit	initialize I²C master
• i2cCheck	test whether a slave is responding
• i2cSend	send data over the I²C bus
• i2cReceive	read data over the I²C bus

2) Low-level display functions
(not normally used in applications)

• whNibb	send data nibble to display: call twice to send a byte
• rdsyB	read status byte from display (for example, to determine if the display is busy)
• cntrB	send control byte to display (for example, to shift the display left or right)
• dataB	send data byte to display
• wBusy	test whether display is busy

Control byte constants
(for use with 'cntrB')

• dshr	0b00011100	// shift display one position to the right
• dshl	0b00011000	// shift display one position to the left
• curon	0b00001110	// cursor on
• curoff	0b00001100	// cursor off
• curblk	0b00001111	// cursor blinks

3) User-level display functions
(for use in applications)

• Ddisp	write character at current cursor position
• DClear	clear display
• Dpos	set cursor position
• Dinit	initialize display
• DBcd2	output a two-digit BCD value
• DHexByte	output a byte in hexadecimal
• DWord	output an unsigned 16-bit value
• DLong	output an unsigned 31-bit value
• DInt	output a signed 16-bit value

The user-level functions can be changed as required without needing to know the low-level details of how the display is driven.

(080525-I)

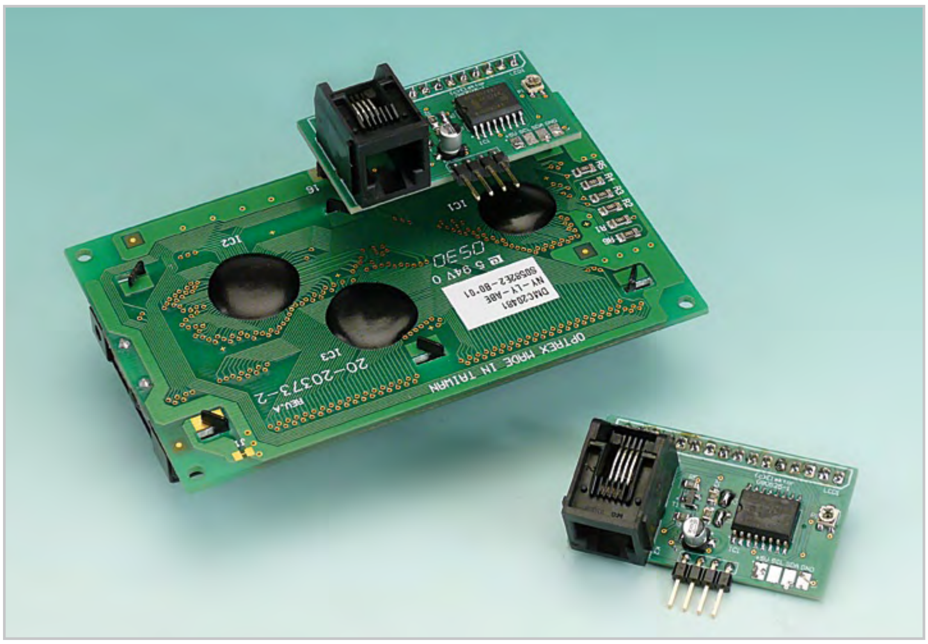
Internet Links

[1 www.elektor-usa.com/080525

[2] www.nxp.com/acrobat_download/datasheets/PCF8574_4.pdf

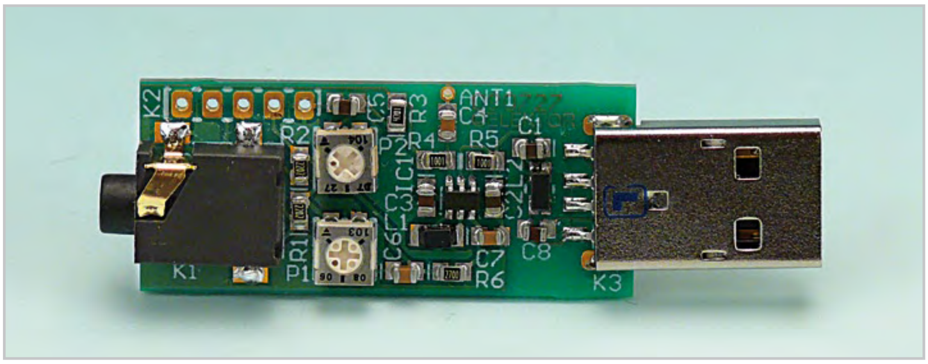
Downloads
080525-1: PCB layout (.pdf), from [1]

080525-11: source code files, from [1]



FM Audio Transmitter

Design: Mathieu Coustans (France)



When the author started thinking about this project he had a simple VHF FM transmitter in mind that could be used to play audio files from an MP3 player or computer on a standard VHF FM radio. The circuit shouldn't use any coils that would have to be wound at home, as is often the case with other FM transmitter designs, because it would add an unwanted level of complexity to the project. Such an FM transmitter can be used to listen to your own music throughout your home. There is also an advantage when you use this transmitter in the car, as there is no need for a separate input to the car stereo to play back the music files from your MP3 player.

To keep the circuit simple as well as compact, it was decided to use a chip made by Maxim Integrated Products, the MAX2606 [1]. This IC from the MAX2605-MAX2609 series has been specifically designed for low-noise RF applications with a fixed frequency. The VCO (Voltage Controlled Oscillator) in this IC uses a Colpitts oscillator circuit. The variable-capacitance (varicap) diode and feedback capacitors for the tuning have also been integrated on this chip, so that you only need an external inductor to fix the central oscillator frequency. It is possible to fine-tune the frequency by varying the voltage to the varicap. Not much is demanded of the inductor, a type with a relatively low *Q* factor (35 to 40) is sufficient according to Maxim. The supply voltage to the IC should be between 2.7 and 5.5 V, the current consumption is between 2 and 4 mA. With values like these it seemed a good idea to supply the circuit with power from a USB port. A common-mode choke is connected in series with the USB connections in order to avoid interference between the circuit and the PC supply. There is not much else to the circuit. The stereo signal connected to K1 is combined via R1 and R2 and is then passed via volume control P1 to the Tune input of IC1, where it causes the carrier wave to be frequency modulated. Filter R6/C7 is used to restrict the bandwidth of the audio signal. The setting of the frequency (across the whole VHF FM broadcast band) is done with P2, which is connected to the 5 V supply voltage.

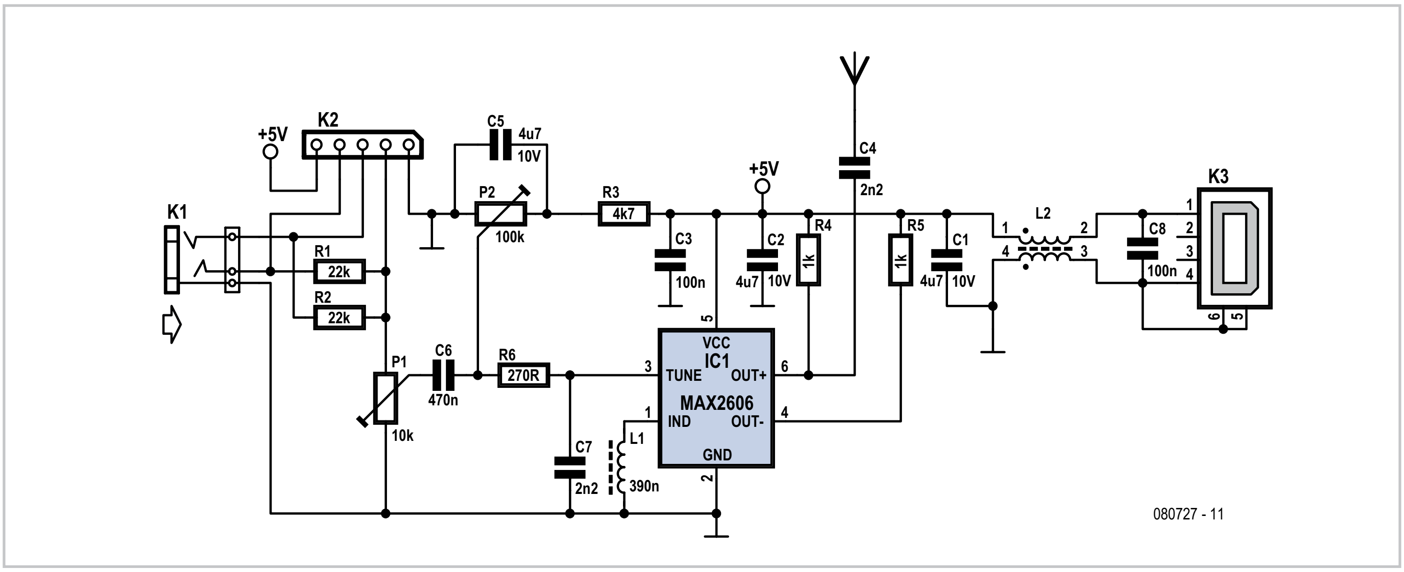
Specifications

- Easy to build thanks to the use of a MAX2606
- Can be powered from a USB port on a computer
- Current consumption of just 2 to 4 mA, supply voltage of 2.7 to 5.5 V
- Can be expanded with a pre-emphasis circuit

The PCB designed in the Elektor Labs uses resistors and capacitors with 0805 SMD packaging. The size of the board is only 41.2 x 17.9 mm, which is practically dongle-sized. For the antenna an almost straight copper track has been placed at the edge of the board. In practice we achieved a range of about 6 metres (18 feet) with this. There is also room for a 5-way SIL header on the board. Here we find the inputs to the 3.5 mm jack plug, the input to P1 and the supply voltage. The latter permits the circuit to be powered independently from an AC power outlet, via for example three AA batteries or a Lithium button cell. Inductor L1 in the prototype is a type made by Murata that has a fairly high *Q* factor: minimum 60 at 100 MHz.

Take care when you solder filter choke L2, since the connections on both sides are very close together. The supply voltage is connected to this, so make sure that you don't short out the USB supply! Use a resistance meter to check that there is no short between the two supply connectors before connecting the circuit to a USB port on a computer or to the batteries.

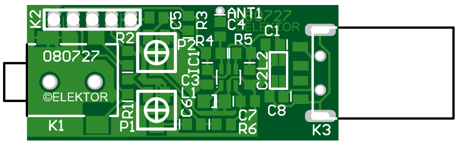
P1 has the opposite effect to what you would expect (clockwise reduces the volume), because this made the board layout much easier. The deviation and audio bandwidth varies with the setting of P1. The maximum sensitivity of the audio input is fairly



COMPONENT LIST

Resistors (all SMD 0805)
R1,R2 = 22kΩ
R3 = 4kΩ7
R4,R5 = 1kΩ
R6 = 270Ω
P1 = 10kΩ preset, SMD (TS53YJ103MR10 Vishay Sfernice, Farnell # 1557933)
P2 = 100kΩ preset, SMD(TS53YJ104MR10 Vishay Sfernice, Farnell # 1557934)

Capacitors (all SMD 0805)
C1,C2,C5 = 4µF7 10V
C3,C8 = 100nF



C4,C7 = 2nF2
C6 = 470nF

Inductors
L1 = 390nF, SMD 1206 (LQH31HNR39K03L Murata, Farnell # 1515418)
L2 = 2200Ω @ 100MHz, SMD, common-mode choke, 1206 type(DLW31SN222SQ2L Murata, Farnell # 1515599)

Semiconductors
IC1 = MAX2606EUT+, SMD SOT23-6 (Maxim Integrated Products)

Miscellaneous
K1 = 3.5mm stereo audio jack SMD (SJ1-3513-SMT CUI Inc, DIGI-Key # CP1-3513SJCT-ND)
K2 = 5-pin header (only required in combination wsith 090305-I pre-emphasis circuit)
K3 = USB connector type A, SMD (2410 07 Lumberg, Farnell # 1308875)

large. With P1 set to its maximum level, a stereo input of 10 mV_{rms} is sufficient for the sound on the radio to remain clear. This also depends on the setting of the VCO. With a higher tuning voltage the input signal may be almost twice as large (see VCO tuning curve in the data sheet). Above that level some audible distortion becomes apparent. If the attenuation can't be easily set by P1, you can increase the values of R1 and R2 without any problems.

Measurements with an RF analyzer showed that the third harmonic had a strong presence in the transmitted spectrum (about 10 dB below the fundamental frequency). This should really have been much lower. With a low-impedance source connected to both inputs the bandwidth varies from 13.1 kHz (P1 at maximum) to 57 kHz (with the wiper of P1 set to 1/10).

In this circuit the pre-emphasis of the input is missing. Radios in Europe have a built-in de-emphasis network of 50 µs (75 µs in the US). The sound from the radio will therefore sound noticeably muffled. To correct this, and also to stop a stereo receiver from mistakenly reacting to a 19 kHz component in the audio signal, an enhancement circuit Is published elsewhere in this issue (Pre-emphasis for FM Transmitter, also with a PCB).

Notice. The use of a VHF FM transmitter, even a low power device like the one described here, is subject to radio regulations and may not be legal in all countries.

(080727)

Internet Links
[1] http://datasheets.maxim-ic.com/en/ds/MAX2605-MAX2609.pdf

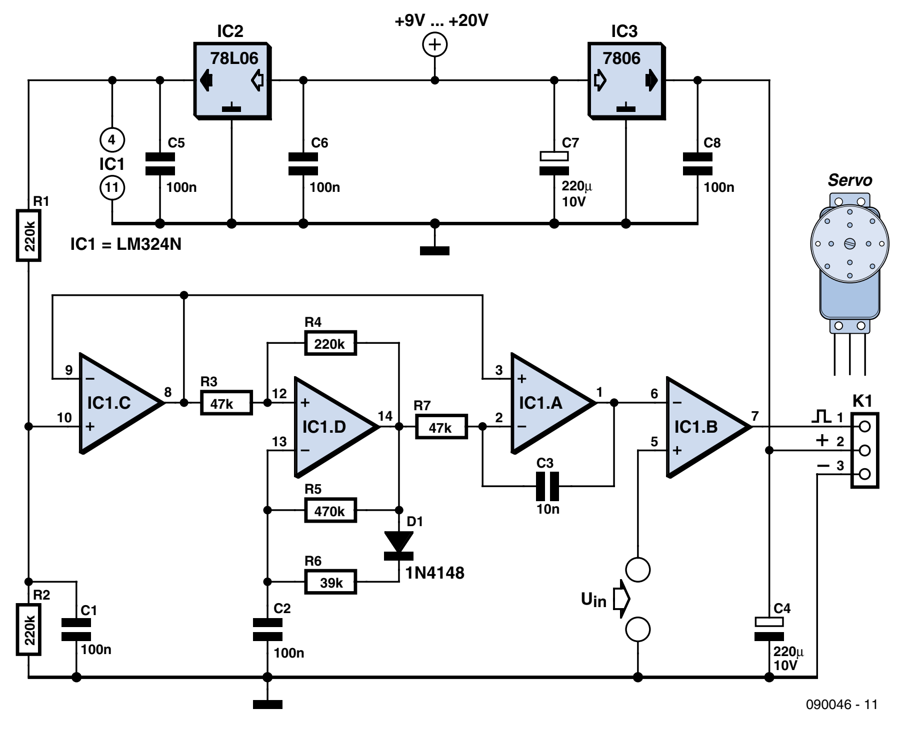
[2] www.elektor-usa.com/080727

Download
080727-1 PCB layout (.pdf), from [2]

Servo Driver

Gert Baars (The Netherlands)

When it comes to driving a servo you typically have to send a PWM signal to the servo input. The frequency of this signal is about 50 Hz and the duty cycle is variable. The duty cycle is usually between about 5 and 10%, corresponding with a pulse width of about 1 to 2 ms. The conversion of a resistance value into a PWM signal is fairly straightforward when a variable RC time constant circuit is used. Converting a voltage into a PWM signal is a bit more difficult, but it does offer some useful advantages.



When the position of a servo can be controlled via a voltage, it can be implemented via a potentiometer acting as a voltage divider. However, you could also use the output of a sensor such as a Hall sensor, an LDR or an NTC. That way you could easily create a feedback loop that takes account of the position, light intensity or the temperature, and use this to control the servo. This can in turn be used to open or close a gas or water valve, for example. The circuit can therefore be said to be reasonably versatile.

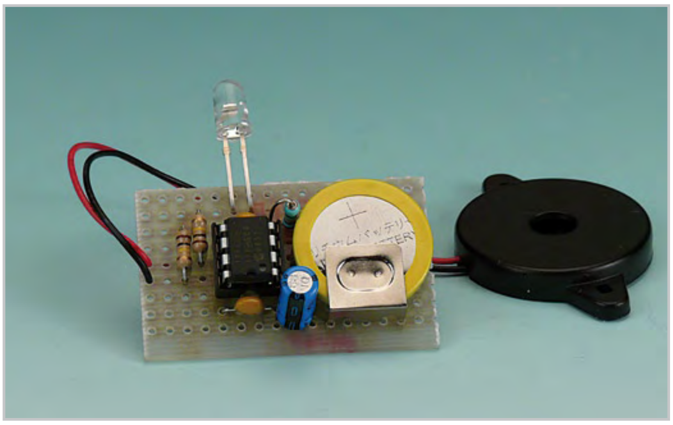
There are special purpose PWM modulator ICs available, but it's just as easy to use a quad op amp such as an LM324. In the circuit op amp C is configured to output a bias signal of half the supply voltage. Op amp D is set up as a square-wave oscillator, with its frequency set to about 50 Hz, which is the frequency required by the servo. The duty cycle is fixed and set to a value slightly higher than the maximum 10%.

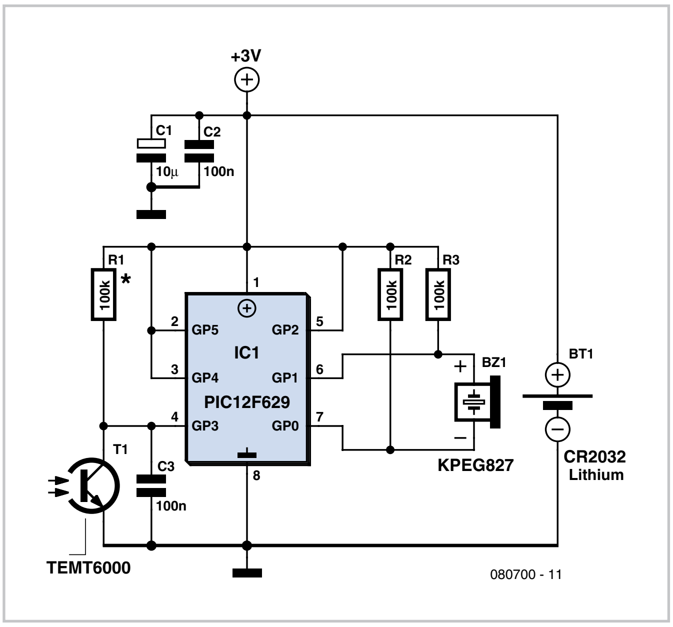
This is followed by an integrator that changes the waveform of the pulse into a triangular form. Op amp B is configured as a comparator that compares this triangular wave with the DC voltage U_{in}. The output of the comparator is a PWM signal that is suitable to drive the servo directly. The frequency is about 50 Hz and the duty cycle can be varied from just under 5% to a good 10% when U_{in} varies from 0.5 to 4 V. The servo, an RS-2 in our prototype, reacts to this with an angular rotation of about 200 degrees. The transfer function in this case is therefore 200 / (4–0.5) = 57 degrees per volt.

(090046)

Chill Out Loud

Andrew Denham (United Kingdom)





Everyone knows that when the refrigerator door is casually closed it sometimes bounces open again just a little. Enough to put the fridge light on, but that's often un-noticeable even at night unless one looks closely. After a day out, you may come home to sour milk and dodgy chicken. After several mornings with debatable milk, the author decided that something would have to be done, and came up with this little gizmo. The light in his fridge always comes on even with a 2 mm door opening, so that's a promising place to start.

The TEMT6000 phototransistor device from Vishay will 'see' visible light, and is both cheap and readily available. It has negligible dark current and can sink a few µA happily. Since a battery powered device is required, the current for the entire circuit has to be as low as possible. A PIC with 'sleep' mode is a good choice, and the 12F629 fits the bill nicely: small, cheap, easily obtained, with an internal RC oscillator on board, and up to five I/O pins as well.

According to the PIC12F629 datasheet [1] all pins have to be set as inputs and pulled high for best low power operation, and every peripheral in use will add some drain. Since the unit is permanently powered from a battery, there is no need for brown-out protection. No A/D or comparators are required, and no watchdog timer either, allowing the lowest power settings in Sleep mode to be exploited. Typical current here is shown as 1.2 nA with a guaranteed maximum of 770 nA at a 3 V supply, reducing to 700 nA at 2 V.

The type CR2032/1HF Lithium cell has a rated capacity of 230 mAh and a nominal voltage of 3 V [2]. On this basis with the typical current in sleep mode the battery would last over 250 years, or effectively for its shelf life, so a CR2032 with tags is worth soldering in to a PCB. Even at the maximum Sleep current, it would last for over 30 years — certainly longer than the fridge! One advantage of a Lithium battery is its long shelf life, and an ability to deliver power at low temperatures.

An obvious choice to make a squawk is a piezo sounder, again cheap and easily obtained. This can be driven from the PIC directly across two ports and will withstand 3 V_{p-p} drive easily. After some testing, a Kingstate KPEG827 [3] proved a worthy candidate. It makes sufficient racket at 3 V drive from about 2.0 kHz to about 4.5 kHz.

The PIC program was developed using MikroElektronika products only: a fully paid up MikroBasic compiler and the BigPIC 4 board. However the final program is so small that it can be compiled using the free version of MikroBasic (free up to 2 K of code, download at [4]).

For the simple reason of ease, the PIC used is the 8-pin DIL version. This can be re-programmed easily using a simple DIL socket adapter. ICP is OK if you have to use SMD but the socket takes up a lot of room and negates the purpose of SMD in the first place on a very small PCB. I used the PicFlash2 programmer again from MikroE, but could have used the on-board EasyPIC4 programmer. The source code used is available free from the Elektor website [5].

The timer will work with anything that can pull the GPIO.3 input Low and hold it Low, so could be used with bi-metallic temperatures sensor, or the software adapted to read a One-Wire temperature sensor. It could also be used to sense over- or under-voltage etc. with some adaptation. The delay before the alarm sounds is adjustable from about 1 to 255 seconds in software.

One word of warning: there are many PIC pro-

grammers out there. If you use other than the MikroE programmer with the code from the Elektor website, make certain that the PIC oscillator configuration is correct. Not all software reads the Configuration correctly; it needs to be set for INT RC OSC, with GPIO.4 and GPIO.5 as I/O. Anything else will stop the oscillator and may damage the PIC! Some programmers need these parameters to be set manually before blowing the chip. In case of doubt, consult the source code listing.
After some tweaking with the port settings, the sample chip consumed an estimated 0.02 µA in Sleep mode. Once triggered the unit consumes about 500 µA for the timer period of 1 minute, then about double that once the sounder is operating. This is well under the maximum current for the cell used (10 mA max. pulsed) and would bleat for about 10 days with a fresh battery, which hopefully will never happen. With a fridge opened say 20 times a day for less than a minute, the battery life expectancy reduces to about 9 years, still a reasonable longevity.
The photograph shows a prototype built on a small piece of perfboard by Elektor Labs. Here the ambient light sensor is a type TEPT5600 (which looks like a UV LED). As opposed to TEMT6000, the TEPT5600 has to be pointed directly to the light source due to its narrower 'viewing angle'. It also requires the value of R1 to be doubled (approximately).
Even on perfboard the circuit is compact enough to be fitted in a small ABS case, preferably one with a battery compartment because that's the ideal place for the sounder. A small hole in the end should allow the sensor to 'see' the light. This hole was filled with clear epoxy resin to act as a window without allowing too much moisture into the case. The latter was achieved by fixing tape over the inside then filling the hole flush. It was then allowed to set whilst the box was fixed upright. The circuit board may be fixed in place with a little hot melt glue. The unit could be mounted to the fridge wall using double-sided adhesive foam strip or Velcro, but space allowing it may equally sit on the shelf.
To start the microcontroller for the first time, or when the battery is replaced, the fridge door should be closed or the sensor covered. Once the sensor detects light, it takes 60 seconds before the alarm sounds. When in the fridge with the door closed (or the sensor covered) the unit goes back to sleep… peace!
Of course the fridge does have to have a light that works or the unit will think it is in the dark all the time.

(080700-I)

Internet Links

[1] http://ww1.microchip.com/downloads/en/devicedoc/41190c.pdf

[2] www.panasonic.com/industrial/battery/oem/images/pdf/Panasonic_Lithium_CR2032_CR2330.pdf

[3] www.farnell.com/datasheets/16396.pdf

[4] www.mikroe.com

[5] www.elektor-usa.com/080700

Downloads & Products

Programmed Controller

080700-41: programmed PIC12F629.

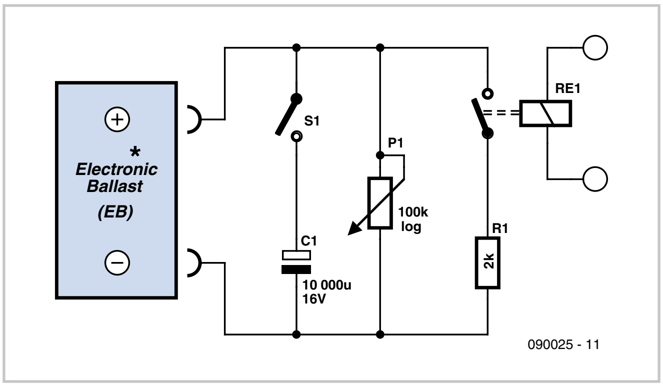
Software

080700-11.zip: MikroBasic source code and hex files, from [5].

Dimmable Aquarium Light with Simulated Sunrise and Sunset

Jürgen Ollig (Germany)

Electronic ballasts (EBs) for fluorescent lamps, also known as electronic control gear (ECG), have advantages over their conventional cousins: higher efficiency, flicker-free start-up, no 50 Hz (60 Hz) flicker and longer tube life. Moreover, they allow the light to be dimmed. Suitable EBs with a 1–10 V analog control interface are available from all the usual manufacturers, including Osram and Philips. An internet search for 'dimmable EB' will turn up a large number of on-line sales outlets for the devices. For the purposes of this circuit EBs with a digital interface (known as DALI, for Digital Addressable Lighting Interface) are not suitable.



Osram provides an excellent technical description of the 1–10 V interface on their website at [1]. The interface provides an interference-proof DC voltage of up to 10 V, which, when loaded, delivers an essentially constant current of 0.6 mA: in other words, it is a constant current source with an open-circuit voltage of 10 V. If a resistor is connected across the interface then the lower its value, the lower will be the voltage across it, and this controls the dimming of the connected lamp. When the control input is open circuit and the voltage across it is 10 V, the lamp is driven at full brightness (100 % of nominal power). If the control input is shorted the control gear dims the lamp to 3 % of nominal power. Between 3 % and 100 % the behavior of the controller is logarithmic.
The very simple circuit described here to drive the interface has several features that will be of particular interest to aquarium owners.
The circuit is connected across the control input of the EB and therefore the control voltage appears across it. The brightness of the tube can be adjusted using P1. S1 allows electrolytic capacitor C1 to be connected across P1: the charge current (0.6 mA) is very small and the capacitor very large (10000 µF) and so it charges very slowly. This means that the voltage across it, and hence the brightness of the fluorescent tube, will increase only slowly. The larger the value of C1, the slower the rate of brightness increase; with the suggested value the simulated sunrise takes around 12 minutes to complete. As can be seen, the circuit does not need its own power supply. When the EB is switched off C1 discharges into P1 (assuming S1 is closed); when it is next switched on the brightness of the tube will rise slowly as before.
An optional extra is the circuit consisting of relay RE1 and resistor R1. If the contacts of

RE1 close C1 will be slowly discharged into R1. The control voltage will fall gradually and the tube will slowly dim. The larger the value of R1, the slower the simulated sunset will be. When the contacts of RE1 are closed the value of R1 will also affect the maximum brightness that can be achieved by adjusting P1: the greater the value of R1, the higher the maximum brightness.

One possible arrangement is to plug the aquarium light into one timeswitch and drive RE1 from a mains adaptor plugged into a second timeswitch. The relay contact is made to close say 30 minutes before the first timeswitch turns the aquarium light off. When the simulated sunset is complete the relay contact can be allowed to open again.

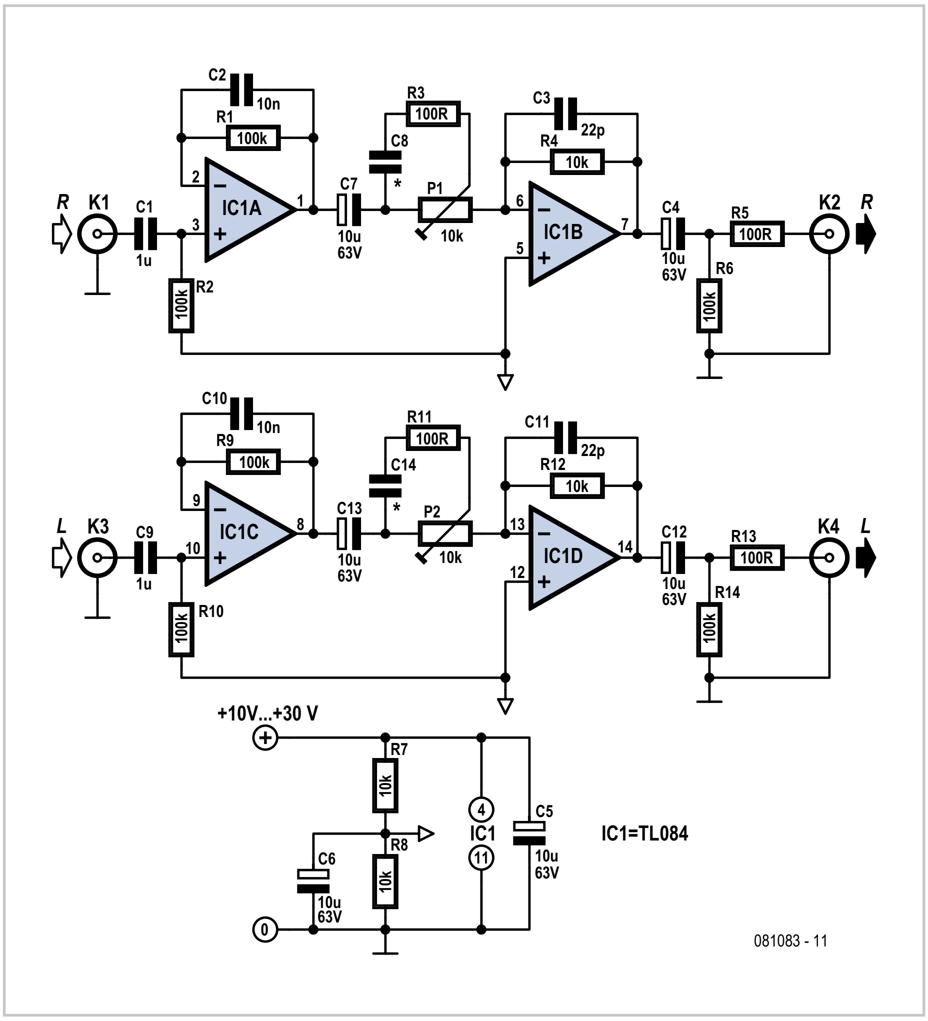
(090025-I)

Internet Link

[1] http://www.osram.co.uk/_global/pdf/Professional/ECG_%26_LMS/ECG_for_FL_and_CFL/QUICKTRONIC_DIM_Technical_Guide130T003GB.pdf

Audio Source Enhancer

Thorsten Steurich (Germany)



Vinyl or CD: which has the better sound? It's a question still hotly debated among audiophiles everywhere. We will try to shed a little light on what lies behind the question and look at a simple circuit that can significantly enhance the sound from a CD player.

Sometimes, on first hearing a new low- to mid-range CD player, the sound is not altogether convincing when compared to a record player. It is worth looking at the recording and replay processes as a whole for both CDs and records to see why this might be. Assuming that we start from the same source, or master recording, of a given piece of music, the differences are broadly as follows.

Records and CDs use very different recording technologies. For records the signal first undergoes pre-emphasis similar to that used in FM radio, where the higher frequency components of the signal are amplified. The resulting signal is cut into the lacquer master disc that will be used for pressing. Unlike CD manufacture, this is an entirely analogue process, and it introduces a phase shift into the signal. To compensate for the pre-emphasis the preamplifier in a record player includes a de-emphasis (or 'RIAA') filter which attenuates the higher frequency components. The purpose of pre-emphasis is to improve the overall signal-to-noise ratio of the signal as played back, reducing hiss and crackle. De-emphasis introduces further phase shifts, and as a result the final signal is rather different from that produced by a CD player. The processing involved in CD manufacture and playback can be entirely digital (in the case of 'DDD' recordings) and phase errors are reduced practically to zero.

The circuit shown here uses a quad opamp (two opamps per channel) to produce 'record-like' phase shifts. In the author's experience low- and mid-range CD players tend to have greatly attenuated output at higher frequencies, and the circuit therefore also offers the facility to boost these components to taste. The value of capacitors C8 and C14 may be anywhere between 100 pF and 10 nF according to the frequency response desired. At the low-frequency end the response is more than adequate, thanks to the large coupling capacitors used. The circuit also functions as a buffer or impedance converter, which can help to reduce the effect of cable capacitances. With CD players that have an output impedance of 1 kΩ or more the difference between cheap cables and more expensive low-capacitance cables can be noticeable. This circuit has an output impedance of just 100 Ω and so cheaper cables should normally be more than adequate.

The circuit can of course also be used with other digital audio sources such as minidisc players, hard disk recorders, DAB tuners, digital terrestrial and satellite television receivers and so on. The supply voltage can be anywhere from 10 V to 30 V. It will often be possible to take power from the CD player's own

supply; if not, a separate AC power adaptor can be used.
The output signal for each channel is inverted (i.e., is subjected to a 180 degree phase shift) by the second opamp (IC1.B and IC1.D). This does not affect the operation of the circuit. By changing the value of feedback resistors R4 (for IC1.B) and R12 (for IC1.D) the overall gain of the circuit can be adjusted so that the output level matches that of other components in the audio system.

(081083-I)

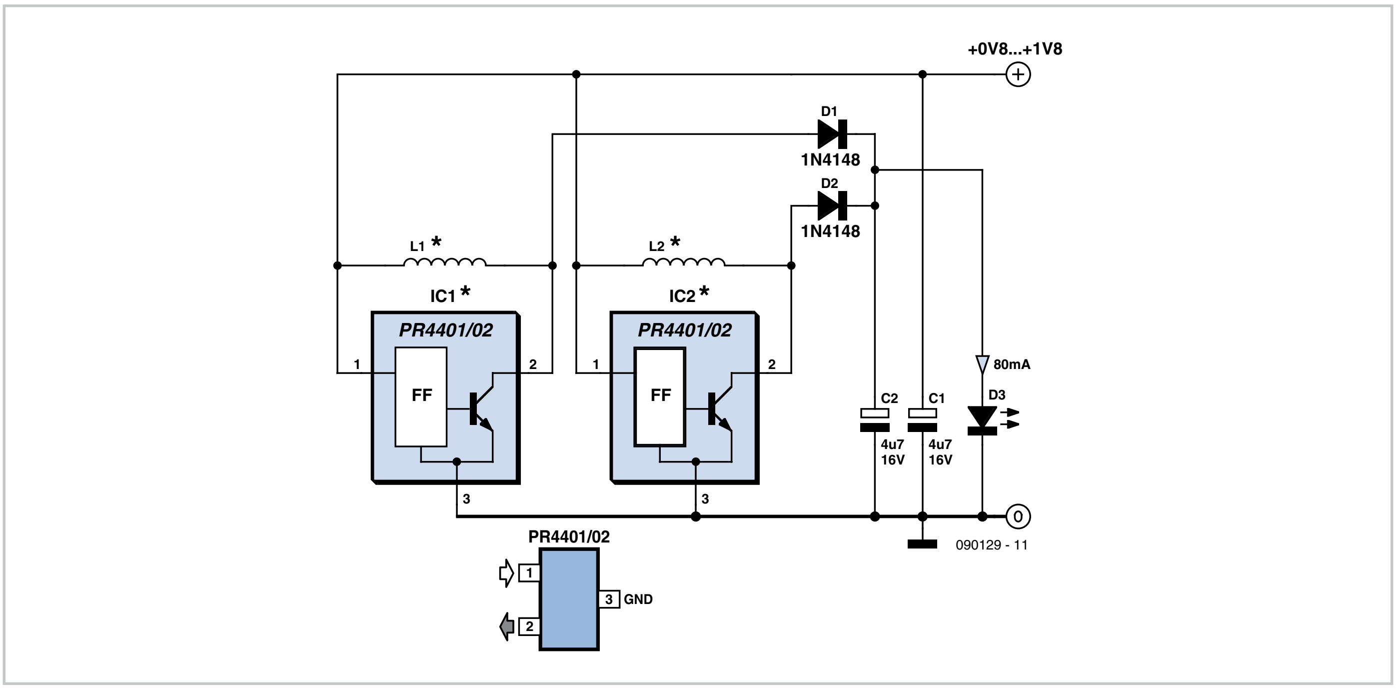
Doubling Up with the PR4401/02

Leo Szumylowycz (Germany)

Among the many interesting applications for the PR4401/02 devices from Prema, some have already appeared in the 2008 edition of Elektor Summer Circuits. Over and above their unbeatable performance, dependable operating range from 0.8 V upwards and minimal reliance on peripheral components all we might ask for might be greater output current, in order to be able to fully exploit a 4-chip LED with 80 mA. It would be handy too if one could replace the 9 V 'block' batteries used in the more sophisticated LCD multimeters. With the fully tested circuit presented here both problems can now be eliminated.

In the schematic shown two of these ICs are connected in parallel via diodes to a single charge capacitor. If the need arises you can connect even more of these ICs in parallel in the same way.
The value of inductance required is calculated in the same way as for standard applications of the IC; 10 µH for the PR4401 with a current of 20 mA and 4.7 µH for the PR4402 with a current of 40 mA.
To power an 80 mA LED with a single 1.5 V battery the circuit shown needs to be equipped with PR4402s and 4.7 µH inductors. If you feel like constructing the entire project with SMDs, you will need SMD tantalum electrolytics (4.7 µF, 35 V) of style 'A' for C1 and C2 plus SMD inductors such as Murata LQH3C-4.7µH for L1 and L2 (available from RS Components, Farnell and Anglia Components).

(090129-I)

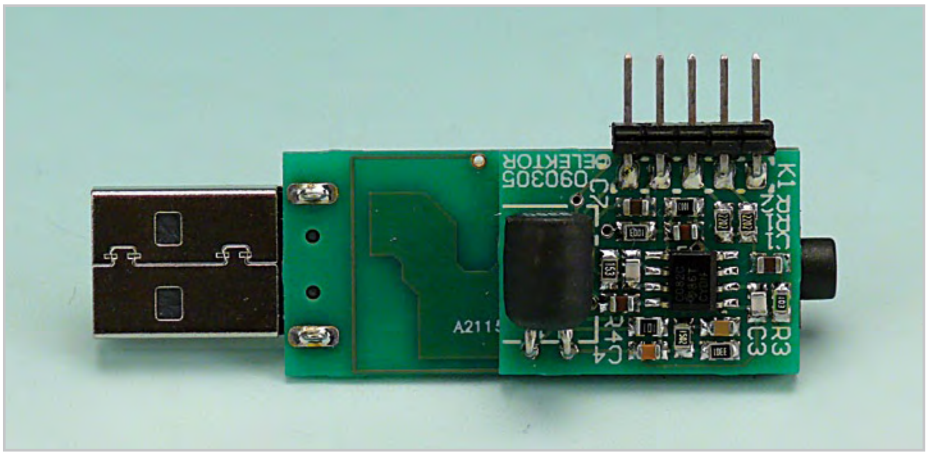


Pre-emphasis for FM Transmitter

Ton Giesberts (Elektor Labs)

Specifications

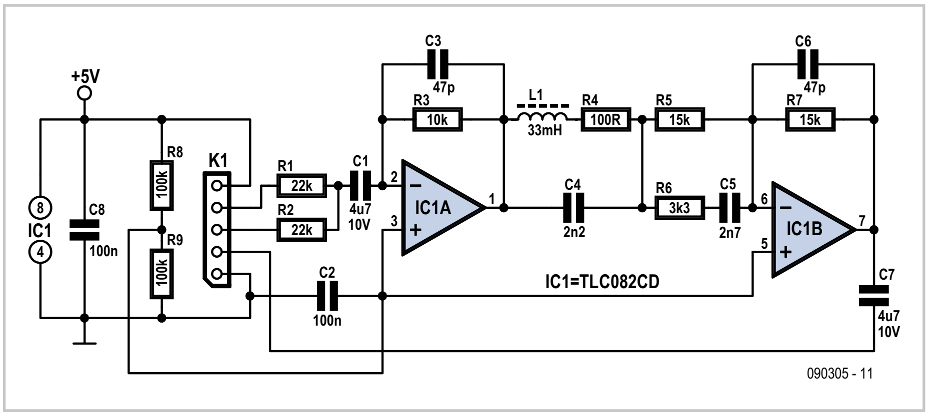
- Correction network for FM Transmitter 080727
- Also includes a 19-kHz filter
- Current consumption of 3 mA

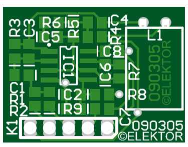


This circuit was specially designed to be used with the FM Audio Transmitter found elsewhere in this issue, but it can also be useful as an addition to other transmitters.
The circuit uses a dual op amp. The first op amp (IC1A) functions as a mixer and a buffer for the following correction network. The input sensitivity can be adjusted with the help of R3 (a lower value reduces the sensitivity). The 50 µs correction for the pre-emphasis is carried out by C5 and R6. IC1B buffers the signal before it is fed to the transmitter via K1.

Since the FM transmitter is a mono version, a 19 kHz filter has been included to prevent a stereo FM receiver from mistakenly switching to stereo mode due to the presence of 19 kHz components in the received signal. Any signals around 19 kHz are blocked with the help of a simple tuned circuit (L1/C4). R4 ensures that the *Q* isn't too large. Due to tolerances you may find that the frequency can deviate from 19 kHz (in our prototype the resonance frequency was closer to 20 kHz). In view of the value of the inductor, a through-hole version has been used for this (see component list).
Without the parallel circuit the crossover point of the correction network is about 16.7 kHz. This is more than enough for audio via VHF FM. The addition of the parallel circuit causes the amplitude around 10 kHz to increase a little, and the –3 dB point is then reached at 13.5 kHz. In the prototype this cut-off point was about 1 kHz higher due to component tolerances.
The board designed for this circuit has been kept as small as possible through the use of SMDs for most components. The dimensions of the FM transmitter board also played a part here. To make it easier to connect this circuit to the transmitter board, a connector was included on this board. The supply voltage and audio signals are carried via this connector. The board has been designed in such a way that it can either be mounted behind the FM transmitter or alongside it.

When the pre-emphasis board is used R1 and R2 should be removed from the transmitter board. When the circuit is mounted behind the transmitter board it was found that the FM signal strength was clearly reduced, so it would be better if a length of wire was used as aerial and connected to the transmitter board (it just so happens there is a via next to C4).
To measure the effect of the pre-emphasis circuit we first measured the frequency response of the output of a small radio. The result of this can be seen in the graph (1 = without pre-emphasis, 2 = with pre-emphasis). It can be clearly seen that the higher frequency components are attenuated by the de-emphasis filter in the radio. When the pre-emphasis circuit is connected to the transmitter the result is an almost flat response above 1 kHz. The 'bump' around 100 Hz is caused by a type of bass-boost in the radio to improve





COMPONENT LIST

Resistors (all SMD 0805)
R1,R2 = 22kΩ
R3 = 10kΩ
R4 = 100Ω
R5,R7 = 15kΩ (24kΩ for 75 µs)
R6 = 3kΩ3 (3kΩ6 for 75 µs)
R8, R9 = 100kΩ

Capacitors
C1,C7 = 4µF7 10V
C2,C8 = 100nF
C3,C6 = 47pF
C4 = 2nF2
C5 = 2nF7

Inductors
L1 = 33mH, e.g. 22R336C Murata Power Solutions (Farnell # 1077046)

Semiconductors
IC1 = TLC082CD SO8 (Farnell # 8453713)

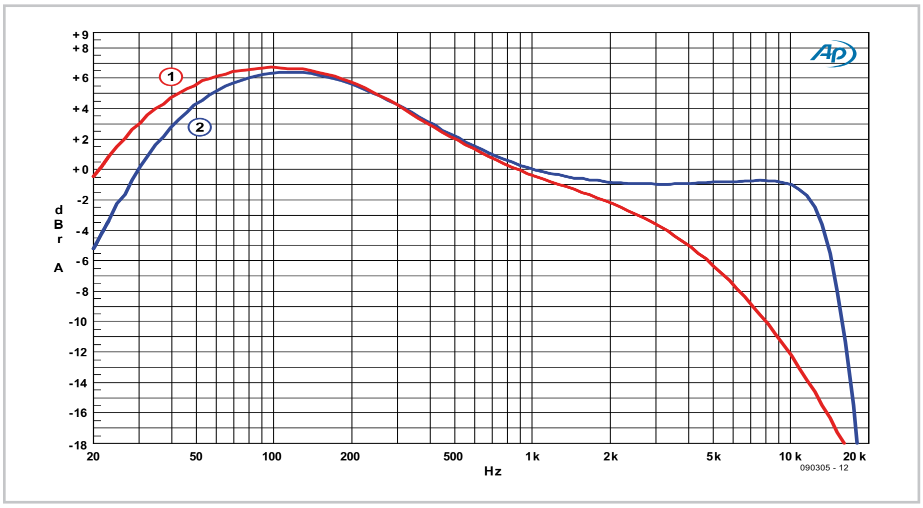
the quality of the sound. The low cut-off point has risen slightly due to the inclusion of two extra coupling capacitors in the pre-emphasis circuit, but in practice this will be hardly noticeable. The current consumption of the transmitter is increased by this circuit from 2 to just over 5 mA.

The component values in the circuit diagram are for 50 µs pre-emphasis. For adaptations to 75 µs as used in the USA and other countries, please refer to the parts list.

(090305)

Download

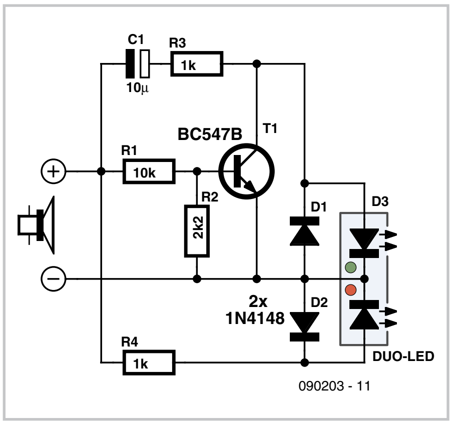
090305-1: PCB layout (.pdf), from www.elektor-usa.com/090305



Sensitive Audio Power Meter

Michiel Ter Burg (The Netherlands)

As a follow-up to the simple audio power meter described in [1], the author has developed a more sensitive version. In practice, you rarely use more than 1 watt of audio power in a normal living-room environment. The only time most people use more is at a party when they want to show how loud their stereo system is, in which case peaks of more than 10 W are not uncommon.
With this circuit, the dual LED starts to light up green at around 0.1 watt into 8 ohms (0.2 watt into 4 ohms). Naturally, this depends on the specific type of LED that is used. Here it is essential to use a low-current type. The capacitor is first charged via D1 and then discharged



via the green LED. This voltage-doubler effect increases the sensitivity of the circuit. Above a level of 1 watt, the transistor limits the current through the green LED and the red LED conducts enough to produce an orange hue. The red color predominates above 5 watts.
Of course, you can also use two separate, 'normal' LEDs. However, this arrangement cannot generate an orange hue. For any testing that may be necessary, you should use a generator with a DC-coupled output. If there is a capacitor in the output path, it can cause misleading results.

(090203-I)

Reference

[1] Simple Audio Power Meter, Elektor July & August 2008.

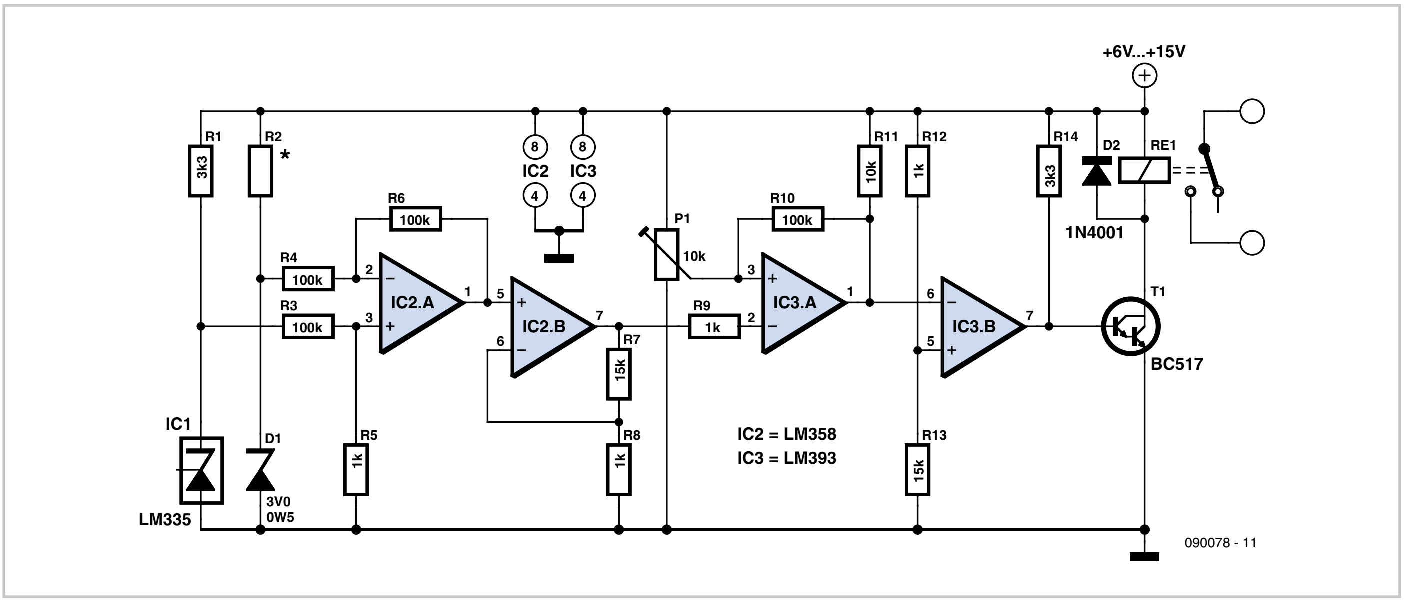
Bathroom Fan Controller

Heino Peters (The Netherlands)

Many bathrooms are fitted with a fan to vent excess humidity while someone is showering. This fan can be connected to the light switch, but then it runs even if you only want to brush your teeth. A better solution is to equip the fan with a humidity sensor. A disadvantage of this approach is that by the time the humidity sensor switches on the fan, the room is already too humid.

Consequently, we decided to build a circuit that operates by sensing the temperature of the hot water line to the shower. The fan runs as soon as the water line becomes hot. It continues to run for a few minutes after the line cools down, so that you have considerably fewer problems with humidity in the bathroom without having the fan run for no reason. Naturally, this is only possible if you can fit a temperature sensor somewhere on the hot water line and the line does not become warm if hot water is used somewhere else.

We use an LM335 as the temperature sensor. It generates an output voltage of 10 mV per Kelvin. The output voltage is 3.03 V at 30 °C, 3.13 V at 40 °C, 3.23 V at 50 °C, and so on. We want to have the fan switch on at a temperature somewhere between 40 and 50 °C (approx. 100–150 °F). To do this accurately, we first use the opamps in IC2 to improve the control range. Otherwise we would have an unstable circuit because the voltage differences at the output of IC1 are relatively small.
IC2a subtracts a voltage of exactly 3.0 V from the output voltage of IC1. It uses Zener diode D1 for this purpose, so this is not dependent on the value of the supply voltage. The value of R2 must be selected according to the actual supply voltage so that the current through D1 is approximately 5 mA. It is 600 Ω with a 6-V supply (560 Ω is also okay), or 2400 Ω (2.2 kΩ) with a 15-V supply. If you have to choose between two values, use the lower value.



IC2b amplifies the output voltage of IC2a by a factor of 16 ((R7 + R8) ÷ R8). As a result, the voltage at the output of IC2b is 0.48 V at 30 °C, 2.08 V at 40 °C (104 °F), and 3.68 V at 50 °C (122 °F). Comparator IC3a compares this voltage to a reference voltage set by P1. Due to variations resulting from the tolerances of the resistor values, the setting of P1 is best determined experimentally. A voltage of 2.5 V on the wiper should be a good starting point (in theory, this corresponds to 42.6 °C). When the water line is warm enough, the output of IC3 goes Low.

R10 provides hysteresis at the output of IC3a by pulling the voltage on the wiper of the setting potentiometer down a bit when the output of IC3a goes Low. IC3b acts as an inverter so that relay Re1 is energized via T1, which causes the fan to start running. After the water line cools down, the relay is de-energized and the fan stops. If this happens too quickly, you can reduce the value of R11 (to 33 kΩ, for example). This increases the hysteresis.

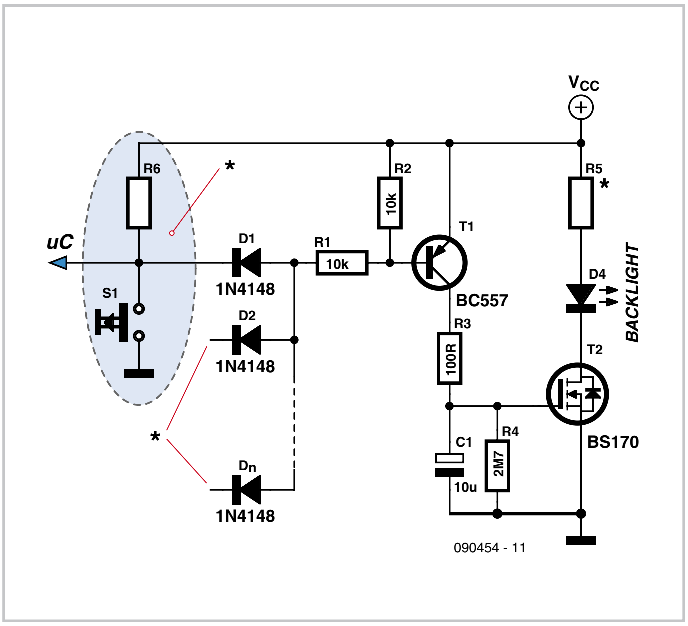
The circuit does not draw much current, and the supply voltage is non-critical. A charging adapter from a discarded cell phone can thus be used to power the circuit. If the supply voltage drops slightly when the relay is energised, this will not create any problem. In this case the voltage on the wiper of P1 will also drop slightly, which provides a bit more hysteresis on IC3a.

(090078-I)

Backlight Delay

Clemens Valens (Elektor France)

Lots of devices are fitted with a liquid crystal display (LCD). Now LCD implies backlighting — that rather useful option that enables us to read the message being displayed! For devices where there's no need to read the display continuously, the backlight doesn't need to stay lit up all the time — several seconds is often all you need to read the display. This saves a little power and lengthens the life of the backlight. Devices fitted with an LCD also have a processor, and so it's possible to employ a function to control the backlight directly from within the processor software. But sometimes it's not possible to implement this sort of function within the microcontroller, because all the controller's pins are already in use, or because you don't have the source codes or tools needed to modify the software. The circuit described here has been designed for just such cases.



A device using an LCD usually has at least one button that, in most cases, pulls one of the microcontroller inputs down to 0 V when it is pressed. If no such button exists, one can always be added. We can use the signal from this button to control the backlight. As soon as the button is pressed, the backlight is activated, then extinguished a few seconds later by the timer. Using an OR gate, it's possible to use several different buttons to trigger the timer.

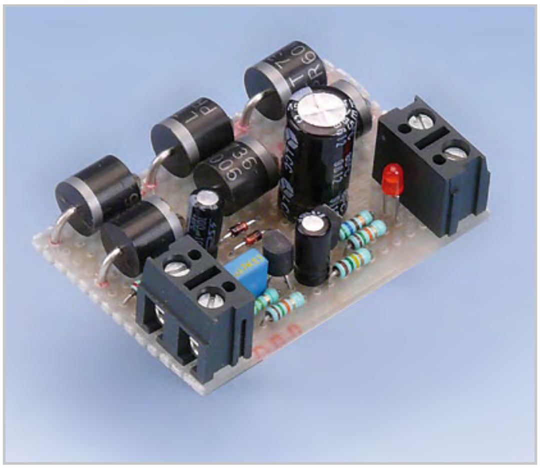
It doesn't take many components to build a timer like this. The OR gate consists of a pull-up resistor R1+R2 and as many diodes as there are buttons. Thanks to these diodes, transistor T1 conducts while the button is pressed, and hence capacitor C1 is charged, the MOSFET T2 conducts, and the backlight comes on. Because R3 has a very low value, capacitor C1 charges very rapidly, so even a very brief press of one of the buttons is enough to trigger the timer. Once the button is released, T1 turns off, and C1 then discharges slowly through R4 alone, since T2 has a very high input impedance. When T2's gate voltage falls low enough, it turns off and the backlight goes out. The time the backlight stays lit after all the buttons have been released is roughly R4 (Ω) × C1 (F) seconds.

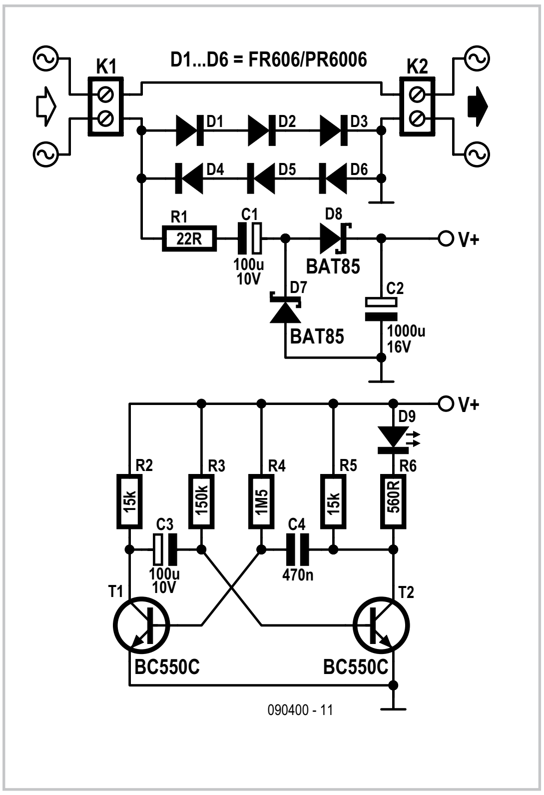
Of course, this circuit can be used for other applications too, and can be used to switch things other than an LED — for example, a relay. The value of R5 depends on the load being switched. For an LED running off a 5 V supply, a value of around 300 Ω will be about right.

(090454-I)

Power On Indicator

Ton Giesberts (Elektor Labs)





Some types of electronic equipment do not provide any indication that they are actually on when they are switched on. This situation can occur when the backlight of a display is switched off. In addition, the otherwise mandatory mains power indicator is not required with equipment that consumes less than 10 watts. As a result, you can easily forget to switch off such equipment. If you want to know whether equipment is still drawing power from the AC outlet, or if you want to have an indication that the equipment is switched on without having to modify the equipment, this circuit provides a solution.

One way to detect AC power current and generate a reasonably constant voltage independent of the load is to connect a string of diodes wired in reverse parallel in series with one of the AC supply leads. Here we selected diodes rated at 6 A that can handle a non-repetitive peak current of 200 A. The peak current rating is important in connection with switch-on currents. An advantage of the selected diodes is that their voltage drop increases at high currents (to 1.2 V at 6 A). This means that you can roughly estimate the power consumption from the brightness of the LED (at very low power levels).

The voltage across the diodes serves as the supply voltage for the LED driver. To increase the sensitivity of the circuit, a cascade circuit (voltage doubler) consisting of C1, D7, D8 and C2 is used to double the voltage from D1–D6. Another benefit of this arrangement is that both halve-waves of the AC current are used. We use Schottky diodes in the cascade circuit to minimise the voltage losses.

The LED driver is designed to operate the LED in blinking mode. This increases the amount of current that can flow though the LED when it is on, so the brightness is adequate even with small loads. We chose a duty cycle of approximately 5 seconds off and 0.5 second on. If we assume a current of 2 mA for good brightness with a low-current LED and we can tolerate a 1-V drop in the supply voltage, the smoothing capacitor (C2) must have a value of 1000 µF. We use an astable multivibrator built around two transistors to implement a high-efficiency LED flasher. It is dimensioned to minimise the drive current of the transistors. The average current consumption is approximately 0.5 mA with a supply voltage of 3 V (2.7 mA when the LED is on; 0.2 mA when it is off). C4 and R4 determine the on time of the LED (0.5 to 0.6 s, depending on the supply voltage). The LED off time is determined by C3 and R3 and is slightly less than 5 seconds. The theoretical value is R × C × ln2, but the actual value differs slightly due to the low supply voltage and the selected component values.

Diodes D1-D6 do not have to be special high-voltage diodes; the reverse voltage is only a couple of volts here due the reverse-parallel arrangement. This voltage drop is negligible compared to the value of the AC line voltage. The only thing you have to pay attention to is the maximum load. Diodes with a higher current rating must be used above 1 kW. In addition, the diodes may require cooling at such high power levels.

Measurements on D1–D6 indicate that the voltage drop across each diode is approximately 0.4 V at a current of 1 mA. Our aim was to have the circuit give a reasonable indication at current levels of 1 mA and higher, and we succeeded nicely. However, it is essential to use a good low-current LED.

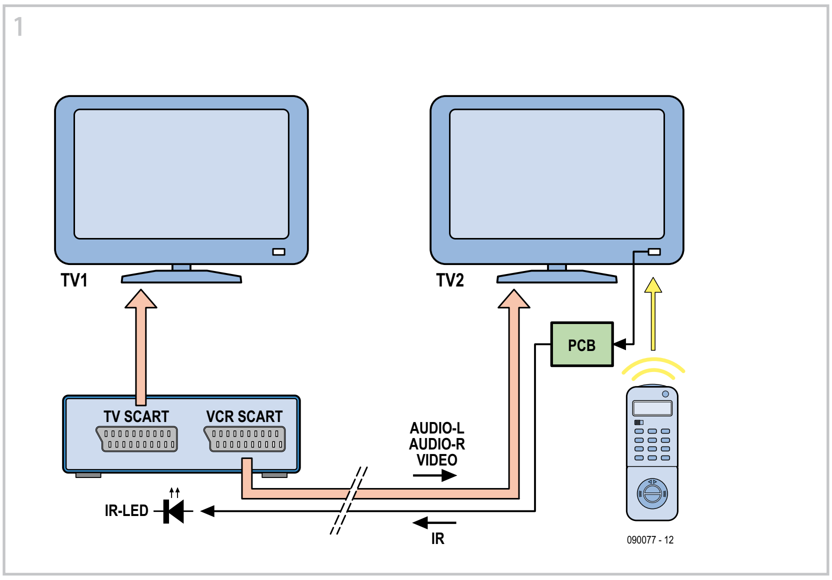
Caution: the entire circuit is at AC line potential. Never work on the circuit with the mains cable plugged in. The best enclosure for the circuit is a small, translucent box with the same color as the LED. Use reliable strain reliefs for the mains cables entering and leaving the box (connected to a junction box, for example). The LED insulation does not meet the requirements of any defined insulation class, so it must be fitted such that it cannot be touched, which means it cannot protrude from the enclosure.

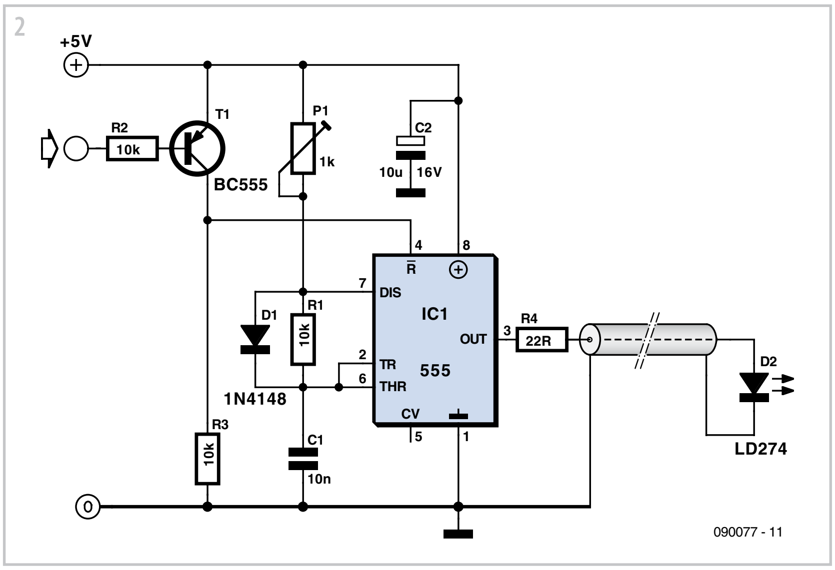
(090400-I)

Two TV Sets on a Single Receiver

Heino Peters (The Netherlands)

With the advent of digital television, it's often necessary to use a separate receiver. If you have several television sets in your house, you have to buy a digital receiver (and accompanying subscription) for each set. The solution described here lets you watch television in two or more places in your home using a single digital receiver, while allowing the digital receiver to be controlled from both locations. The circuit needed for this is powered from one of the two television sets (see **Figure 1**).

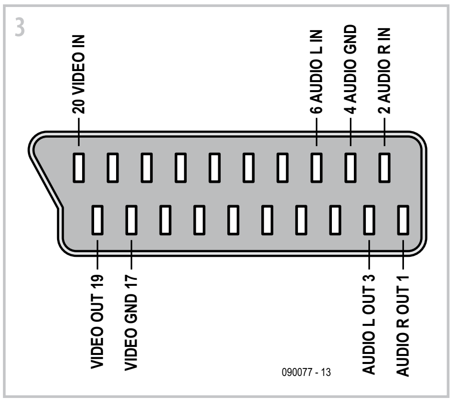




You'll need a length of four-way shielded cable (such as Conrad Electronics # 606502) for the connection between the digital receiver and the second TV set. Two shielded conductors are used to transmit the audio signals (L and R) from the receiver to the second TV set, another one is used to transmit the video signal, and the last one is used to transmit the remote control signal from the remote control for the second TV set to the digital receiver located next to the first TV set. The infrared sensor of the second TV set receives the signal from the remote control unit for the digital receiver and sends it via a small circuit to an IR LED aimed at the infrared sensor of the digital receiver near the first TV set. With this arrangement, it's convenient to buy a second (programmable) remote control unit so you don't have to carry the original remote control unit of the digital receiver back and forth all the time.

Most digital receivers have two SCART connectors for connecting a television set and a video recorder. The second SCART connector can be used quite nicely for the signals to be sent to the second TV set (see the connection diagram in **Figure 3**). If this connector is already in use, you can always take the audio and video signals from the Cinch connectors (if present).

The circuit necessary for converting the infrared signal received by the second TV set into a new signal for driving the infrared LED at the digital receiver location is shown in **Figure 2**).

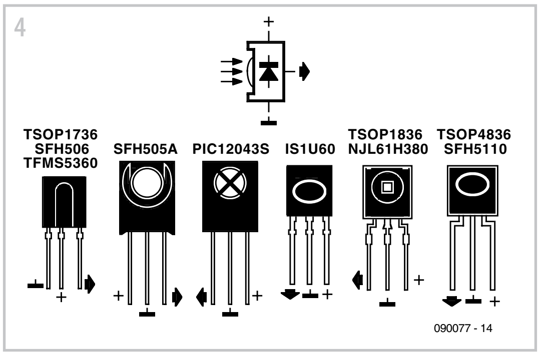


The infrared signal from the remote control unit consists of short pulse trains of modulated infrared light. The modulation frequency varies from one brand to the next and lies in the range of 30 to 56 kHz (B&O, different as always, uses 455 kHz). Frequencies in the 36–40 kHz range are most often used in practice. The modulation frequency of an infrared sensor is usually indicated in its type number. For example, the TSOP1736 responds to IR light modulated at 36 kHz, the TSOP1738 likes 38 kHz, and so on. **Figure 4** shows a few IR receivers and their pinouts. Infrared sensors also have adequate sensitivity to other frequencies close to their design frequency. Consequently, we assume a modulation frequency of 38 kHz here, which covers the full range from 36 to 40 kHz. The IR receiver demodulates the infrared signal. The demodulated signal forms the input to our circuit, which uses it to generate a new modulated signal for the IR LED located next to the digital receiver.

The author opened up his second TV set (watch out for possible sources of high voltage inside the set!) in order to use the set's built-in IR receiver and tap off power for the modulator circuit. However, you can also fit the circuit with its own IR receiver and use a separate power supply (AC power adapter).

The output signal of the IR receiver is used to trigger an astable multivibrator built around our old friend, a 555 timer IC. The data line of the IR sensor is High in the quiescent state and goes Low when it receives an modulated IR signal. As the Reset input of the 555 responds to an active-low signal, an inverter is built around T1, R2 and R3. The modulation frequency for IR LED D2 is set to approximately 38 kHz by P1, R1 and C1. Diode D1 allows the duty cycle of the output signal to be less than 50%, which cannot be achieved otherwise. The rise time of the oscillator signal on the Threshold input of the 555 is set by P1 and C1, while the fall time is set by R1 and C1.

The ratio of P1 to R1 determines the duty cycle, which is approximately 30% in this case. With a 5-V supply voltage, P1 is set to 1 kΩ, but it must reduced to a lower value (around 500 Ω) with a lower supply voltage. If possible, use an oscilloscope to adjust the oscillator frequency to 38 kHz (period: 26.3 µs). To generate a test signal at the 555 output, temporarily connect the circuit input to ground.



Place IR LED D2 in front of the digital receiver so it shines on the receiver's IR sensor. Use the screen of the fourth shielded conductor of the cable between the receiver and TV2 for the negative lead of D2. Resistor R4 is dimensioned for a current of around 100 mA through the IR LED. If you use a 3.3-V supply voltage, R4 must be reduced to 3.3 Ω.

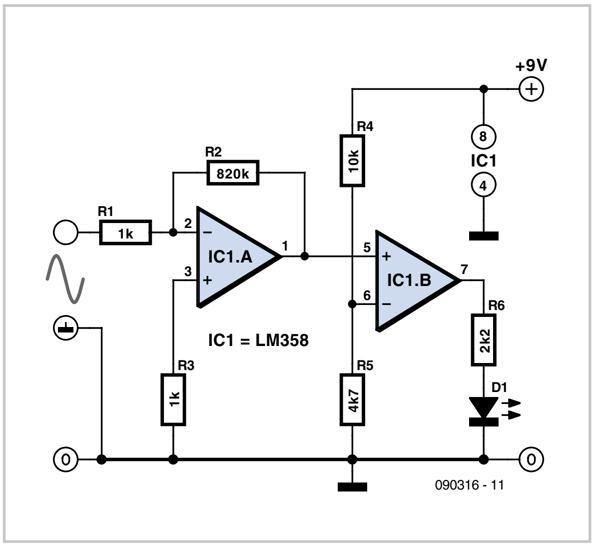
You can also use this circuit for the remote control of audio or video equipment located inside a closed cabinet.

(090077-I)

Tester for Inductive Sensors

Hugo Stiers (Belgium)

This tester uses a LED to indicate whether an inductive sensor is generating a signal. It can be used to test the inductive sensors used in ABS and EBS systems in cars, with engine camshafts and flywheels, and so on.
The circuit is built around an LM358 dual opamp IC. The weak signal coming from the sensor (when the wheel is turning slowly, for example) is an alternating voltage. The first opamp, which is wired here as an inverting amplifier, amplifies the negative half-cycles of this signal by a factor of 820. The second opamp is wired as a comparator and causes the red LED to blink regularly.



In order to judge the quality of the signal from the sensor, you must turn the wheel very slowly. If the red LED blinks, this means that the sensor is generating a signal and the distance between the sensor and the pole wheel (gear wheel) is set correctly. If the distance (air gap) is too large, the sensor will not generate a signal when the wheel is turned slowly, with the result that the LED will remain dark, but it will generate a signal if the wheel is turned faster and the LED will thus start blinking. Irregularities in the blinking rate can be caused by dirt on the sensor or damage to the pole wheel (gear wheel).

If you connect an oscilloscope to the LED with the engine running, you will see a square-wave signal with a pattern matching the teeth of the gear wheel, with a frequency equal to the frequency of the AC signal generated by the sensor.
You can also use this tester to check the polarity of the connecting leads. To do this, first dismount the sensor and then move it away from a metallic object. The LED will go on or off while the sensor is moving. If you now reverse the lead connections, the LED should do exactly the opposite as before when the sensor is moved the same way.

The circuit has been tested extensively in several workshops on various vehicles, and it works faultlessly.

The author has also connected the tester to sensors on running engines, such as the camshaft and flywheel sensors of a Volvo truck (D13 A engine). With the camshaft sensor, the LED blinks when the engine is being cranked for starting, but once the engine starts running you can't see the LED blinking any more due to the high blinking rate.

(090316I-I)

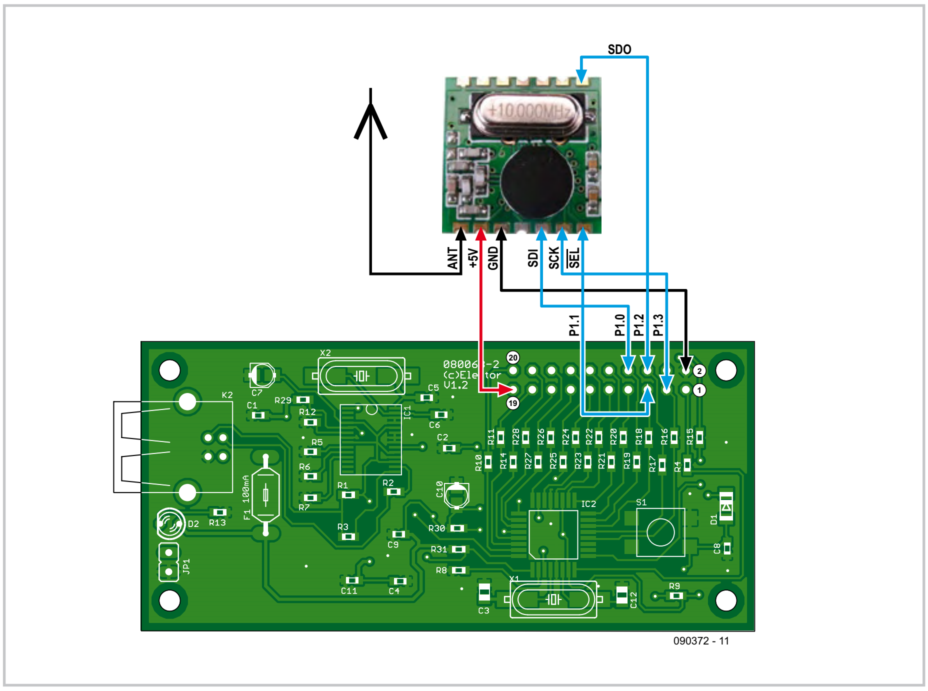
USB Radio Terminal

Rainer Schuster (Germany)

In the January 2009 issue of *Elektor* we saw how straightforward it is to connect a low-cost RFM12 868 MHz ISM (licence-free) radio module to an ATmega microcontroller. Simple example listings in BASCOM demonstrated how to communicate data using the modules [1].

The 'USB radio terminal' circuit described here connects an RFM12 radio module to the R8C/13 microcontroller board used in the 'Transistor Curve Tracer' project described in the February 2009 issue [2]. The populated board, complete with USB interface connec-

tor, is available from the *Elektor* shop.
The circuit can be used to transfer data (for example from a PC terminal emulator program) wirelessly to another microcontroller and vice versa. Of course, the remote microcontroller also needs to be equipped with a radio module.
As ready-made and tested boards are available (even the radio module is available from *Elektor* [3]) building the circuit does not present any great difficulty. All that is necessary is to connect a total of six pins of K1 on the R8C/13 microcontroller board to pins on the radio module. The 5 V and ground pins are connected directly to their namesakes so that the radio module draws its power from the microcontroller board. The SPI port on the radio module is driven from port pins P1.0 to P1.3 on the microcontroller: see the 'circuit diagram'.
The microcontroller module will receive its power over the USB cable when it is connected to a PC.
The author has written R8C firmware in C, available for download in source or hex format from the *Elektor* website. The C source can be edited and compiled using the 'High Performance Embedded Workshop' IDE by Renesas [2], and further information is available from the R8C pages of the Elektor website [4]. The Motorola hex file can be downloaded over the USB port using the Flash Development Toolkit [2][4]. To enter programming mode jumper JP1 must be fitted on the microcontroller board and the reset button pressed briefly. After programming is complete, don't forget to remove the jumper and press the reset button again.
The firmware mostly consists of the BASCOM routines written by Burkhard Kainka [1], modified and converted into C. Extra functions have been added to handle the UART1 interface, which is connected to the USB interface chip.
On the transmit side, the program waits for characters to arrive over the USB port and stores them in an intermediate buffer. When



the sequence <CR> <LF> is received the line of characters is sent to the radio module transmitter using a special protocol.

On the receive side, the program waits for characters from the radio module receiver. When the <STX> control code ('start of text', 0x02) is received, the subsequent characters are buffered until the stop code <ETX> ('end of text', 0x03) is received. The transmitted message includes a trailing checksum, so the complete sequence of characters is <STX> <string> <checksum> <ETX>. If the checksum is correct, it, along with the <STX> and <ETX> characters, is discarded, <CR> <LF> is appended, and the resulting string sent out over the USB port to the PC.

Of course, strings and commands can be sent over the radio link to other applications. In some cases the protocol will have to be adapted. In particular, because of the limited available RAM on the R8C/13 (1 kB) the intermediate buffer is only 200 bytes long. This should be adequate for most uses.

As configured, the software uses a data transfer rate of 9600 baud with 8 data bits, 1 stop bit, no parity and no handshake. The terminal program (for example, Hyperterminal) must be configured to match these settings.

(090372-I)

Internet Links

[1] www.elektor-usa.com/071125

[2] www.elektor-usa.com/080068

[3] www.elektor-usa.com/090372

[4] www.elektor.com/service/r8c---information.78378.lynkx

Products

071125-71: 868 MHz radio module, populated and tested, available via [3]

080068-91: R8C microcontroller board, populated and tested, available via [3]

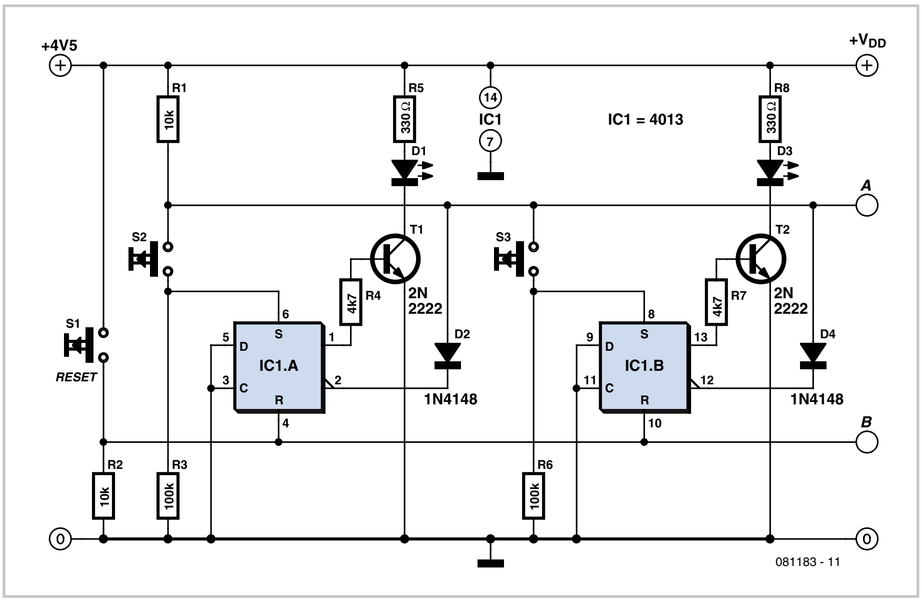
Going for Gold

Joseph Kopff (France)

The title refers to a popular TV game show where the contestants each have a big button. The gameshow host asks a question and the first contestant to press their button makes an illuminated indicator light up on their desk. The other contestants' buttons are automatically inhibited, so that everyone can see who was the first contestant to press their button, and so is allowed to answer the question. The project described here shows how to build a similar sort of refereeing device yourself, using simple resources and without needing a microcontroller, which is pretty rare these days! The basic circuit is for just two contestants, but the modular design means it can easily be expanded.

The diagram shows three buttons: S2 and S3 are the buttons for the two contestants, S1 is the button for the host, which allows them to reset the circuit before each fresh question. The 'brains' of the circuit is IC1, a 4013 dual D-type flip-flop, of which only the Set and Reset inputs are used here. This circuit can handle quite a wide supply voltage range, from 3 to 15 V, and so the project can easily be run off

a 4.5 V battery pack (the power consumption is minimal).
IC1 is armed by pressing S1 (reset). In this state, the non-inverting outputs (pins 1 and 13) are at 0 and the inverting outputs (pins 12 and 12) are at 1. Hence line A is pulled high by R1, since diodes D2 and D4 are not biased on. If contestant 1 presses button S2, the non-inverting output of flip-flop IC1a goes to logic 1, and LED D1 lights via T1 to indicate that contestant 1 has pressed the button. At the same time, the flip-flop's inverting output goes to logic 0, making diode D2 conduct. Line A is now pulled down to 0, and consequently contestant 2's button S3 can no longer trigger the second flip-flop. The reverse happens if it is contestant 2 who presses their button S3 first.



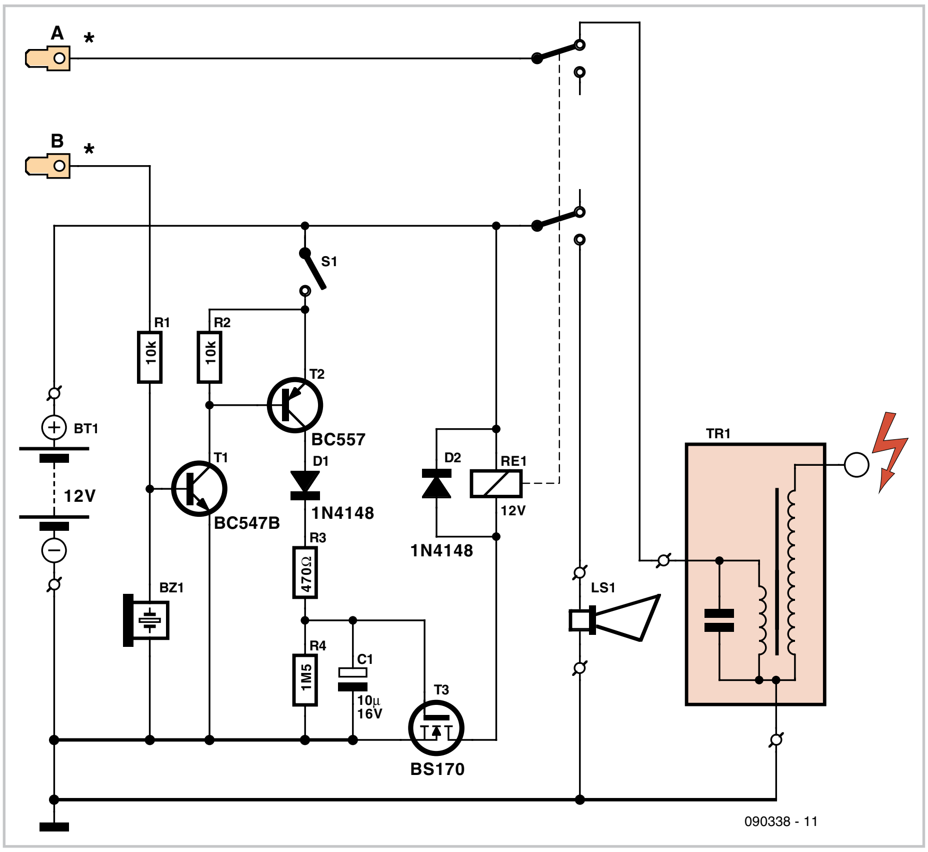
The circuit can be extended to 4 or 6 contestants (or even more) by adding a second or third (or more) 4013 IC. All you have to do is repeat the circuit (minus R1, R2, and S1) and connect to the A, B, Vdd, and 0 V lines on the right-hand side.

(081183-I)

Cut-rate Motorbike Alarm

T.A. Babu (India)

Motorbikes are often a target for thieves. Here is an alarm that's loud, cheap and simple to build. Arming and disarming the alarm is done with a hidden switch, S1. This tiny circuit does not unduly load the battery, as it draws very little current in the standby condition.
To activate the alarm, turn or press the hidden switch S1 to the 'on' position. If anyone attempts to start the motorbike, +12 volts from the ignition switch (connected to 'B') causes transistor T1 to conduct and switch on T2. The siren (LS1) then sounds for about 20 seconds, the period being determined by FET T3 wired as a monostable timer. The siren is a high-power ready-made piezo horn of the self-oscillating type.
Another piezoelectric component in the circuit has a different purpose — Bz1 detects attempts to tamper with the vehicle, or move it without starting the engine. The piezo transducer element should be mounted in such a way as to faithfully pick up vibration from the motorbike frame due to tampering.
One set of contacts on relay RE1 is used to effectively disconnect the ignition coil to prevent the bike from functioning when someone tries to steal it. Usually, there is a wire running from the alternator (point A) to the ignition coil (TR1), which has to be routed through the N/C (normally closed) contact of the relay. The hidden switch S1 is preferably a miniature type or its electrical equivalent. To deactivate the alarm, the hidden switch should be flipped to the 'off' position to disable the movement sensor and the siren driver/timer circuit when the ignition key is turned… by the lawful owner!



(090338-I)

Digital Sweep and Sinewave Generator

with direct frequency entry

Wilfried Wätzig (Germany)

The Parallax SX28-based ‘Frequency Response Sweep Oscillator’ project published in the April 2008 issue of *Elektor* inspired the author to develop a similar circuit based on the ATmega48 microcontroller. As it turns out, the ATmega-based circuit is nearly as capable as the original.
An important characteristic of the design is the maximum direct digital synthesis (DDS) sample rate that can be achieved when generating a sinewave. The specifications are comparable:

SX28 design: f_{DDS} = 50 MHz / 28 cycles = 1.78 MHz
ATmega48 design: f_{DDS} = 25 MHz / 18 cycles = 1.39 MHz

At 25 MHz, the ATmega48 is somewhat overclocked in this circuit. The maximum specified clock frequency according to the datasheet is 20 MHz. In practice, however, this does not seem to lead to problems.
The other important part of the circuit is the digital-to-analog converter (DAC) connected to Port D of the microcontroller. This takes the form of an *R-2R* network and can approximate a sinewave with a sample rate of 1.39 MHz. The digital values are read from a look-up table.
A passive sixth-order Butterworth low-pass filter with a corner frequency of 500 kHz is used to smooth the DAC output. This is particularly necessary at higher frequencies.

The user interface is principally provided via a twelve-button telephone-style keypad. In sweep mode the four rows of buttons (1-2-3, 4-5-6, 7-8-9 and *-0-#) are used to adjust the marker frequency up and down in coarse or fine steps.
In sinewave generation mode the desired frequency is entered directly on the keypad in Hertz. For example, to enter 12 kHz, type ‘*12000#’. The usable frequency range runs from around 10 Hz to 500 kHz.
In order to ensure that a clean output signal is produced the timer interrupt is disabled during sinewave generation. If a button is pressed a pin change interrupt is triggered which enables the timer so that a new frequency value can be entered.

The sinewave frequency accuracy and stability are determined by the quality of the 25 MHz crystal. There may also be a small error in absolute frequency resulting from rounding errors in the calculation of the DDS phase accumulator increment value.

The DDS phase accumulator increment value is derived from a set of values stored in a look-up table:

increment = *freq* * 2^{24} * cycles / f_{osc}

for freq = 2^k, k = 0 to 19. The total increment value is calculated to 24 bits of precision.

The main features of the unit are listed in the text box, and the functions of switches S1 to S3 are given in **Table 1**.
The digital outputs on Port B are protected from short circuits by series resistors. The amplitude of the sinewave output can be set between 0 V_{PP} and 4.5 V_{PP} using P1.

The ATmega48 chip can be programmed using the 10-way ISP interface connector provided. The firmware for this project was written in assembler using the Atmel AVR Studio 4 development system, version 4.14. The project files (source code and hex) are available for free download from the Elektor website [1]. The zip file also includes a screenshot showing the fuse settings required for the microcontroller in AVR Studio 4. As an alternative to the program-it-yourself route, ready-programmed microcontrollers are available from the Elektor Shop.

(080577-I)

Characteristics

Digital sweep function:

- Frequency ranges: 100 Hz to 100 000 Hz or 50 Hz to 15 000 Hz,
- logarithmic scale with 256 steps
- 2 sweep rates: 0.2 ms or 0.4 ms per frequency value
  (phase accumulator increment value changed every 0.2 ms or 0.4 ms)

Outputs in sweep mode:

- sine output
- marker frequency (rectangular wave)
- marker position pulse
- trigger pulse at start of each sweep

Digital sinewave operation:

- Direct frequency entry in Hertz via keypad
- Format: ‘*’ = start of entry
  digit(s) 0 to 9
  ‘#’ = end of entry, start sinewave generator

Outputs in sinewave mode:

- sine output (0 V_{PP} to 4.5 V_{PP})
- frequency/marker pulse (rectangular wave)

Internet Link

[1] www.elektor-usa.com/080577

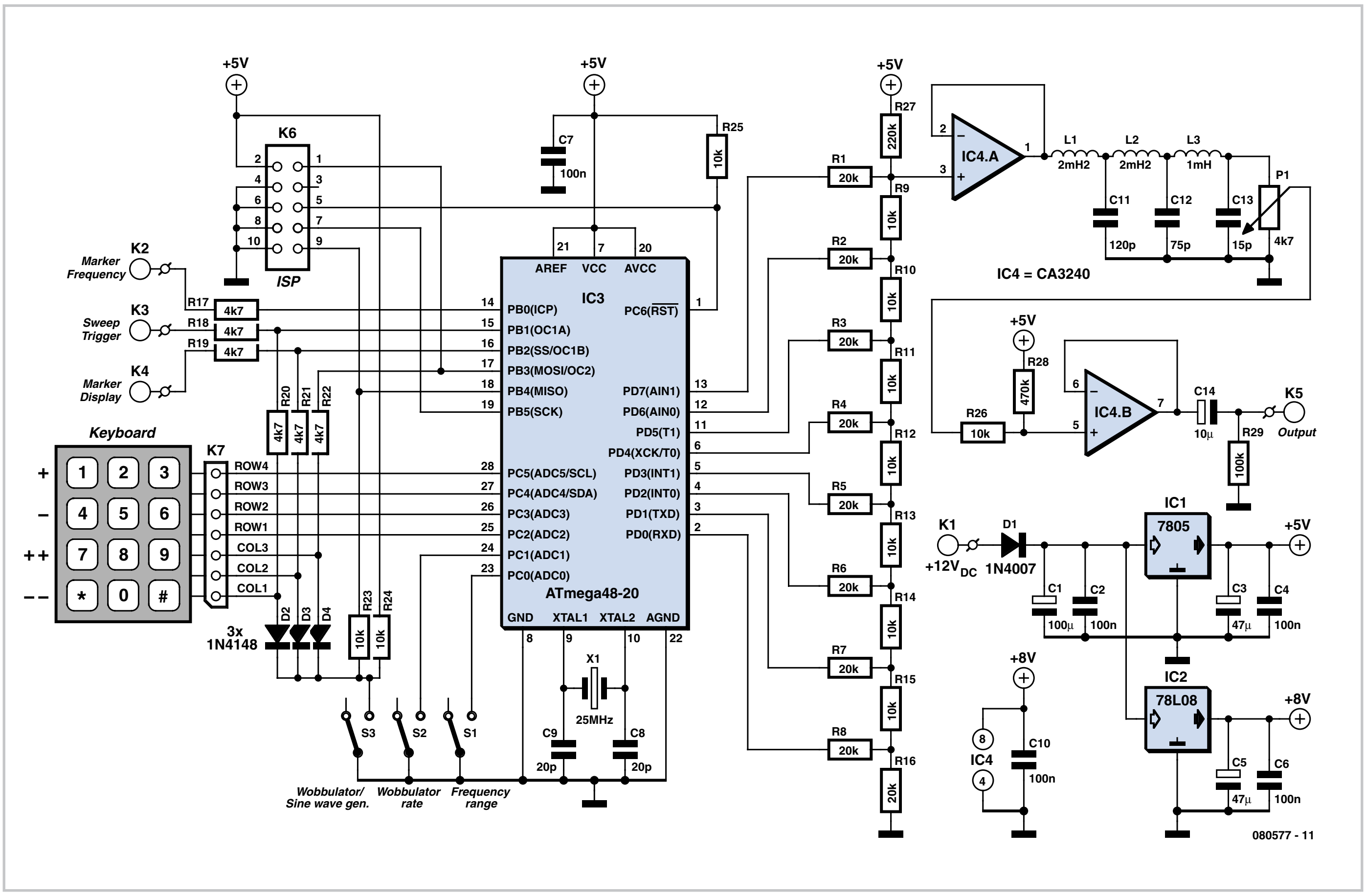
Downloads and products

080577-41: ready-programmed ATmega48 microcontroller

080577-11: source code and hex files, from www.elektor.com/080577

Table 1. Function of switches S1 to S3

	Open	Closed
S1 (frequency sweep range)	50 Hz to 15 kHz	100 Hz to 100 kHz
S2 (sweep rate)	0.2 ms	0.4 ms
S3 (sinewave/sweep output)	sinewave output	sweep output

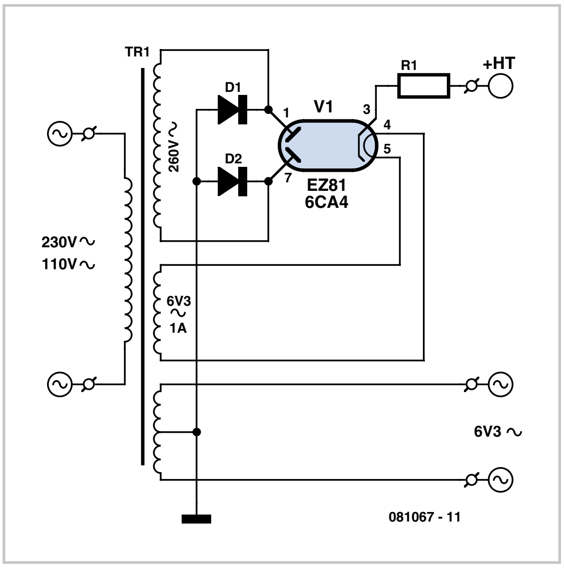


Guitar Amplifier PSU

Malcolm Watts (New Zealand)

Tubes (thermionic valves) have never departed from the amplified instrument scene and the majority of guitarists, including very young ones, wouldn't use anything else. Some diehards think that the H.T. (high tension) rectifier should also be a piece of glassware and some manufacturers are still producing amplifiers incorporating one. The nett effect is really that a rectifier tube acts as a relatively effective heat-dissipating resistor, causing the HT rail to sag as output signal loading increases, generating a compressive characteristic which is fundamentally added distortion ('crunch').

The traditional arrangement uses a centre-tapped HT winding on the power transformer but this has a number of drawbacks for an adequately rated core size including increased voltage stress, small wire size and a poor utilization of the available winding window.



The example arrangement shown here reduces both of these problems and for a given core increases the current delivery capability of the winding by allowing the use of a heavier wire gauge. Normally some resistance is added in series to each anode to limit peak cathode current to minimise cathode-stripping during the high current pulses delivered to the input filter capacitor at each voltage peak. Even if one includes such resistance (and a single resistor in series with the cathode or winding achieves the same end albeit with double the device dissipation) the benefits to the transformer of reduced voltage stress and increased wire insulation thickness (which scales with wire diameter) along with decreased heating in the windings, are obvious.

Alternatively, a smaller winding window (reduced core size) may be employed without diminishing power-handling capacity.

The circuit shown here should is typically intended for the amplifier preamp and phase splitter stages. Due to the use of the EZ81 (6CA4) tube its maximum output current is about 100 mA. Higher currents call for a more powerful rectifier tube and diodes to match.

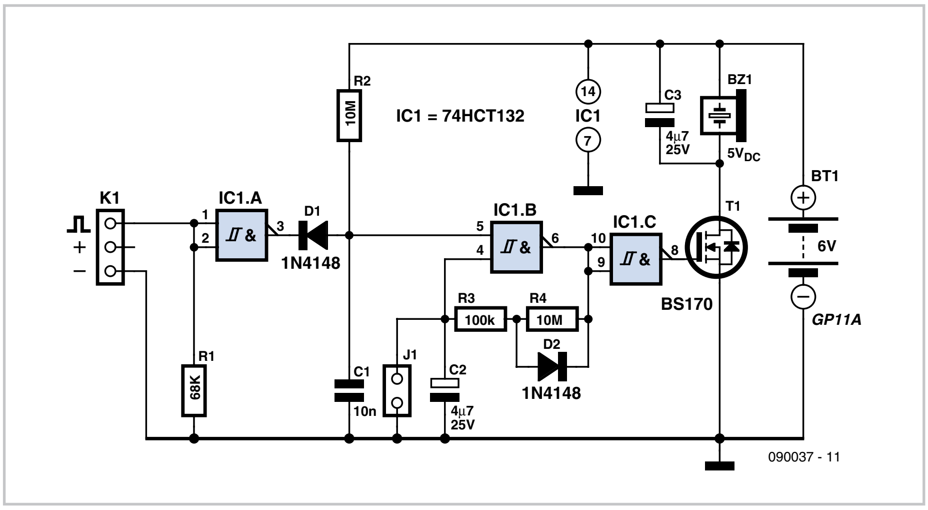
(081067-I)

Acoustic Distress Beacon

Werner Ludwig (Germany)

An ELT (Emergency Locator Transmitter, also known as a distress beacon) is an emergency radio transmitter that is activated either manually or automatically by a crash sensor to aid the detection and location of aircraft in distress. This acoustic ELT project is intended for radio-control (RC) model aircraft, which every now and then decide to go their own way and disappear into the undergrowth.

The audio locating device described here enables model aircraft that have landed 'off limits' to be found again and employs its own independent power supply. The small camera battery shown in the circuit activates an acoustic sounder when radio contact is lost and produces a short signal tone (bleep) every ten seconds for more than 25 hours. Current consumption in standby and passive (with jumper J1 set) modes is negligible. The timing generator for the alarm tone is the Schmitt trigger AND-gate IC1.B; its asymmetric duty cycle drives a 5 V DC sounder via



MOSFET transistor T1. All the time that the RC receiver output is delivering positive pulses, the oscillator is blocked by IC1.A and diode D1. Setting jumper J1 parallel to C2 also disables the oscillator and serves to 'disarm' the distress beacon.

(090037-I)

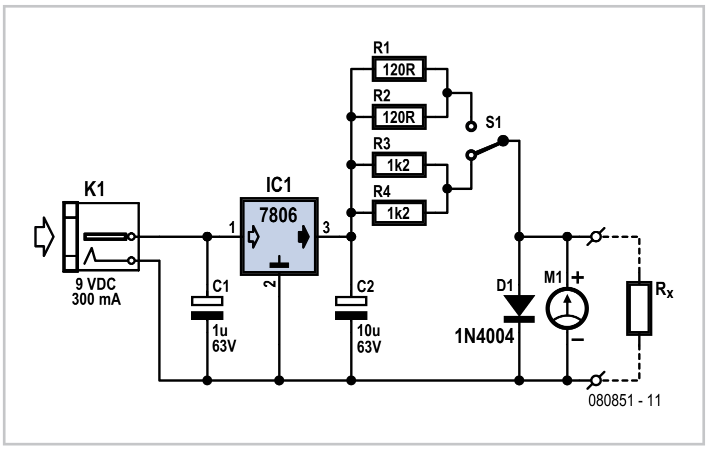
Internet Link

http://en.wikipedia.org/wiki/Emergency_Position-Indicating_Radio_Beacon

Measuring Milliohms with a Multimeter

Klaus Bertholdt (Germany)

Low values of resistance can be troublesome especially when large currents flow through them. A current of, say, 10 A passing through a terminal with a contact resistance of 50 mΩ will produce a voltage difference of 0.5 V. This resulting power loss of five watts is dissipated in the termination and can give rise to a dangerously high temperature which may degrade insulation around the wires.



Measuring low values of resistance is not easy. Low cost multimeters do not include a milliohm measurement range and specialist equipment is expensive. The simple circuit described here allows milliohm measurements to be made safely on a standard multimeter. The circuit consists of little more than a 6 V voltage regulator and a mains adapter capable of supplying around 300 mA at 9 to 12 V.

The circuit supplies a fixed current output of 100 mA or 10 mA selected by switch S1. This connects either the 60 Ω or 600 Ω resistor into the constant current generator circuit. The resistor values are produced by paralleling two identical resistors; 120 Ω and 1.2 kΩ from the E12 standard resistor range. Two test leads with probes are used to deliver current to the test resistance. The resultant voltage drop is measured by the multimeter (M1).

With the test current set to100 mA a measurement of 1 mV indicates a resistance of 10 mΩ. At 10 mA (with S1 in the position shown in the diagram) a measurement of 1 mV indicates a resistance of 100 mΩ while 0.1 mV is equal to 1 mΩ. Diode D1 protects the meter from too high an input voltage.
With the voltmeter connected as shown in the diagram it measures not only the voltage drop across R_X but also that produced by the resistance of the test leads, and probes. To make a true measurement, first touch the probes close together on the same lead of the test resistance and note the reading, now place the probes across the test resistance and note the reading again. The first reading measures just the test leads and probes while the second includes the resistance R_X. Subtract the first measurement from the second to get the value of R_X.

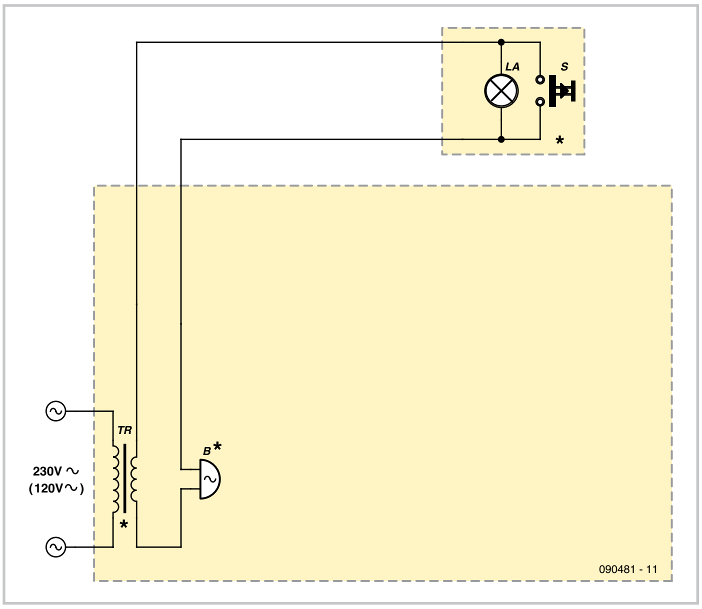
The accuracy of the measurements are influenced by the contact resistance of switch S1, the precision of resistors R1 to R4, the 6 V supply level and of course the accuracy of the measuring voltmeter.

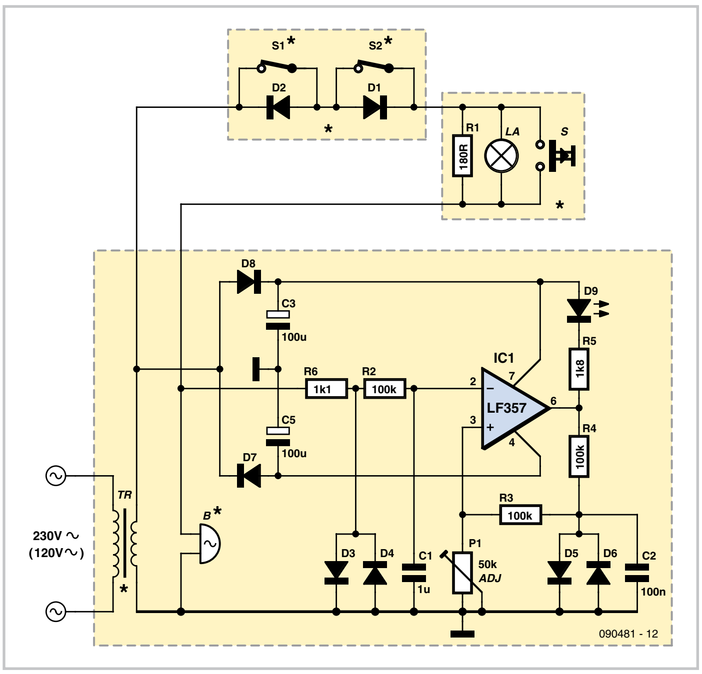
For optimum decoupling C1 should be fitted as close as possible to pin1 of IC1. An additional electrolytic capacitor of around 500 µF can be used at the input to the circuit if the input voltage from the AC power adapter exhibits excessive ripple.

(080851)

Snail Mail Detector

Philippe Temporelli (France)





Since his letter-box is outdoors and quite some way from the house, the author was looking for a simple means of knowing if the postman had been without having to go outside (contrary to popular belief, the weather isn't always fine in the South of France). Circuits for this kind of 'remote detection' come up regularly, but always involve running cables between the letter-box and the detection circuit in the house. Seeking to avoid running any extra cables, the author had the idea of using the existing cables going to the doorbell, conveniently located adjacent to his letter-box.

The letter-box has two doors: one on the street side for the postman, and one on the garden side for collecting the post. A microswitch is fitted to the street-side door, to light an indicator in the house showing that the postman has been. A second microswitch is fitted to the door on the garden side, to turn off the indicator once the post has been collected. The only difficulty then remains to connect these detectors to a remote circuit in the house that remembers whether the postman's been or not.

The idea was to use the alternating half-cycles of the AC signal on the cable going to the doorbell to transmit the information, according to the following logic:

- Both half-cycles present: no change in the status of the mail detector.
- An interruption (even brief) of one half-cycle: indicator lights permanently.
- An interruption (even brief) of the other half-cycle: the indicator goes out.

Note that the signal is tapped off across the doorbell coil via R6 and the pair of diodes connected in inverse-parallel (to limit the signal, particularly when the bell is rung). The signal is then filtered by R2/C1, before being used by IC1, which is wired as a comparator with hysteresis. The trigger threshold is adjusted by P1, using a pair of inverse-parallel diodes as a voltage reference (positive or negative according to the output state):
For the detection to work, there has to be continuity in the bell-push circuit — this is generally ensured by the little lamp illuminating the bell-push. Resistor R1 is added just in case the lamp is blown or not present.
To keep things simple, the circuit is powered directly from the doorbell transformer itself (8 V secondary). The author managed to fit the little circuit within the doorbell unit, with the LED poking through a hole in the casing so it is readily visible in the hall of his house.

(090481-I)

DMX Transmitter

Gerald Weis (Austria)

Lighting effects are always popular at special events, whether large or small. For example, a spotlight with a moving head can be used to project a company logo or other image on the wall or ceiling. These special-effect light sources are controlled by the widely use DMX protocol [1], for which many PC-based programs are available. However, providing some sort of PC and setting up the USB and DMX hardware involves a certain amount of extra effort and expense. Consequently, the author built a small stand-alone DMX transmitter that can easily be configured using three buttons.

The entire circuit is based on a Texas Instruments MSP430F2112 microcontroller, along with an SN65HVD10QD RS485 transceiver IC from the same manufacturer (note: both ICs can be obtained from TI as samples).

In addition, it requires a small circuit board, a female XLR connector, three pushbutton switches, and a few resistors and capacitors. The circuitry around the MSP430 (including the JTAG port) is standard. More information about the microcontroller is available on the Web [2]. The schematic diagram shows a quartz crystal, but it can be omitted if desired because the MSP430 has an internal oscillator. If you use the internal oscillator, it's important to adjust the frequency precisely using resistor R6 = R_{OSC} (also shown in the schematic diagram). The microcontroller data sheet [3] lists the appropriate values. To check the frequency of the internal oscillator, it should be fed out to an I/O pin and measured.

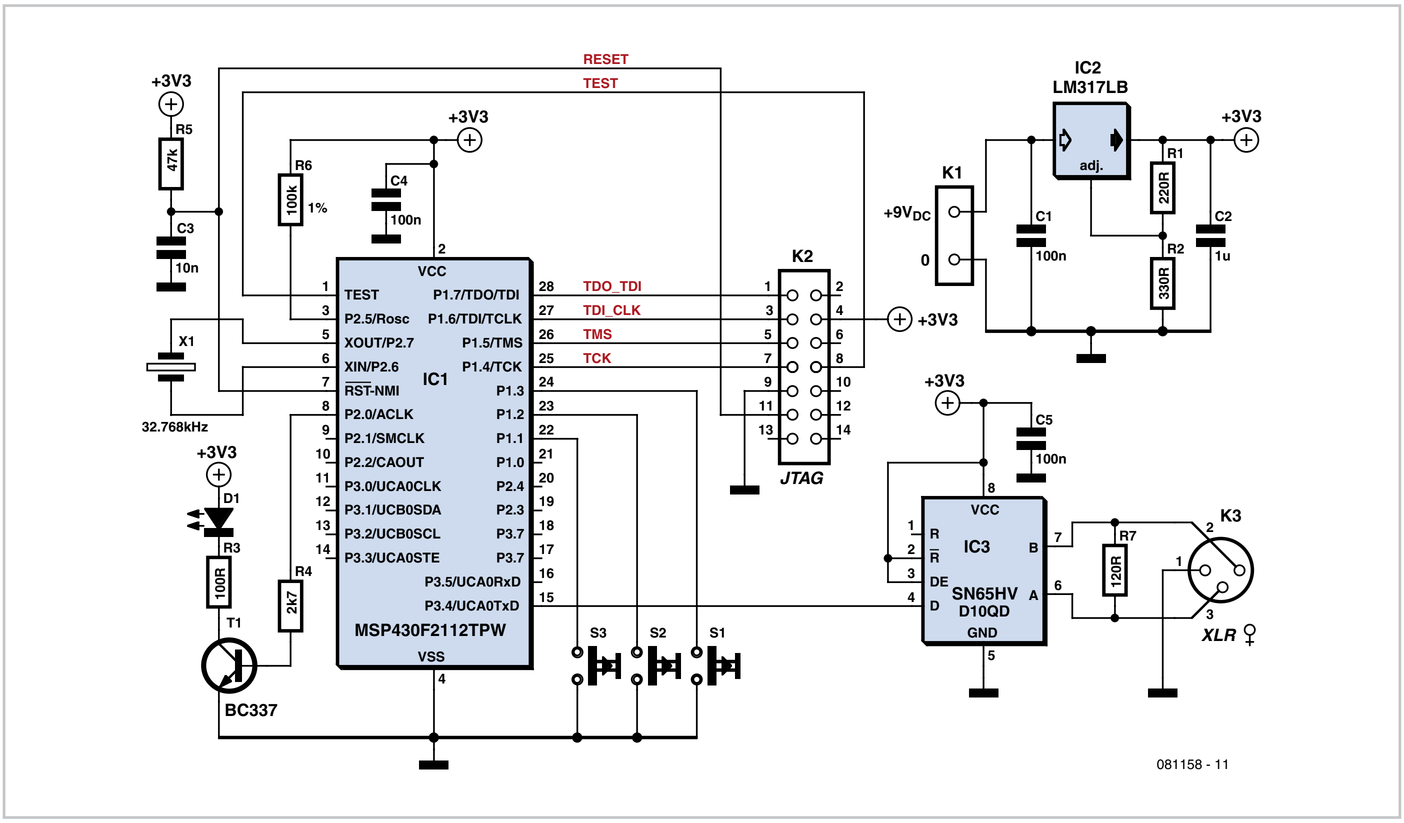
A LED that indicates that the transmitter is operating is driven via port pin P2.0. Extensive information on the DMX driver (IC3) and its circuitry is available on the Web [4].

The author wrote the firmware for the microcontroller, which must be adapted to the actual DMX device that is used. The author's C source file for this project can be downloaded from the Elektor website [5]. IAR Kick-start Edition, which can also be downloaded from the Elektor website [6], can be used as the development environment.

The code for initializing the serial interface is also shown on the TI website. The program transmits 25 DMX channels at once. Interrupts are used to handle pushbutton input and transmit the DMX data. In the author's example software, one button is configured for the tilt motion of the Futurelight MH-640 moving head unit, while the other two buttons are unused.

As with every project, this one also has room for improvement. If you use the internal oscillator of the MSP430, the DMX bus may not operate at the right speed if the temperature changes. However, this could be compensated by measuring the temperature with the temperature diode in the MPS340 and making suitable adjustments. A display would also be a nice addition. Anyone who is interested in expanding on the current design is welcome to contact the author [7].

(081158-I)



Internet Links

[1] http://en.wikipedia.org/wiki/DMX512-A

[2] www.ti.com

[3] http://focus.ti.com/lit/ds/symlink/msp430f2112.pdf

[4] http://focus.ti.com/docs/prod/folders/print/sn65hvd10.html

[5] www.elektor-usa.com/081158

[6] www.elektor-usa.com/081041

[7] hihi85@gmx.at

Download

Software

081158-11: source code files, from [5]

Single Lithium Cell Charger

Steffen Graf (Germany)

Using the BQ24002 from Texas Instruments it is possible to build a simple and small charger module for single lithium-ion (Li-ion) cells. The device is available in a SSOP20 package and so does not require heroic assembly and soldering skills.

Individual cells are becoming available from the main catalog suppliers, but a much cheaper option is to rescue cells from defunct notebook batteries. In most cases only a couple of cells are faulty and the others can still look forward to a long and useful life. A single cell is ideal for any equipment that needs a 3.3 V power supply, and will generally give a good operating life. The charger circuit requires a 5 V input, which can readily be obtained from a USB port or from any 5 V power supply.

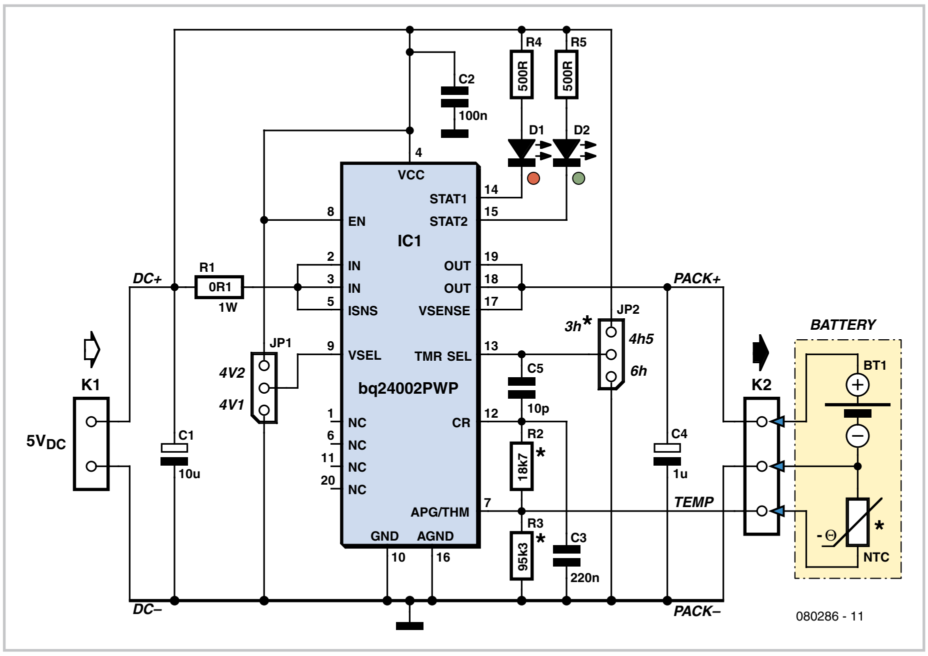
Characteristics

- Designed for a single Li-ion cell
- Suitable for all lithium chemistry cells with a final voltage of 4.1 V or 4.2 V (lithium-cobalt, lithium-manganese and lithium-polymer)
- Configurable 4.1 V or 4.2 V final voltage
- Input voltage from 4.5 V to 10 V (depending on charge current)
- Charge current up to 1.2 A
- Charge current configurable via shunt resistor
- Linear regulator topology
- Precharge function for deeply-discharged cells
- Charge status indicated by two LEDs
- Two package options: SSOP20 or QFN

The charge process begins with a trickle charge current. When the cell terminal voltage is sufficiently high the charger switches to a higher constant charge current. Charging is terminated when the cell voltage reaches a preset limit (the 'final voltage'). The charger described here is suitable for cells with a final voltage of 4.1 V or 4.2 V, configured using jumper JP1: pin 9 is taken to ground to select 4.1 V or to V_{CC} to select 4.2 V.

It is important **never** to exceed the maximum permissible cell voltage: if in doubt, **consult the manufacturer's specifications for the definitive value**.

The charge current is determined and monitored by input shunt resistor R1. A value of 0.1 Ω gives a charge current I_L of 1 A: the general formula is $I_L = 0.1\ V / R1$. In this example, the input voltage should be no greater than 5.3 V to ensure that the maximum allowable power dissipation of the IC is not exceeded. With a charge current of 0.5 A (R1 = 0.2 Ω), the maximum allowable input voltage is 7.6 V. The circuit offers a charge time limit and cell temperature monitoring. The charge time limit is set using JP2. If the jumper is not fitted charging will always stop within three hours, even if the cell has not reached its final voltage. If the jumper is fitted to pull pin 13 to V_{CC} (the supply voltage) the time limit is four and a half hours, and if pin 13 is pulled to ground the time limit is six hours. If the final voltage is reached early, charging will of course cease before expiry of the time limit. The LEDs allow the charge process to be monitored. Red LED D1 lights during charging and flashes to indicate that a fault has been detected. When the cell is more than 90 % charged the red LED is extinguished and the green LED lights.



Pin 7 (APG/THM) is the input to a window comparator with a lower threshold of 0.56 V and an upper threshold of 1.5 V. If the voltage on this pin is over 1.5 V or below 0.56 V the IC regards this as a fault and aborts the charging process. Charging can only occur if the voltage on the pin lies between the two thresholds. The window comparator can be used either to monitor the IC's supply voltage or to monitor the temperature of the lithium cell. In the circuit shown we have used the input in a temperature monitoring configuration: the voltage on pin 7 is determined by a voltage divider comprising R2, R3 and an NTC thermistor, which is arranged to sense the temperature of the lithium cell and which is wired in parallel with R3 via connector K2. Pin 12 (CR) carries a reference voltage of 2.85 V; so that charging is possible under normal conditions the thermistor and the voltage divider of which it forms a part must be dimensioned so that the voltage on pin 7 lies within the comparator's voltage window when the cell is running at a safe temperature. The values shown for R2 and R3 will allow charging as long as the resistance of the thermistor lies between 4.8 kΩ (upper temperature limit) and 26.6 kΩ (lower temperature limit). Using a typical 10 kΩ thermistor (such as the Vishay 2381 640 63103) this means that charging will occur as long as the cell temperature is between approximately 5 °C and approximately 43 °C. A 12 kΩ thermistor from the same series gives an upper limit of 48 °C: this is the arrangement used in Texas Instruments' evaluation module [1].

Formulae are given in the datasheet [2] to help with the calculation of component values in the voltage divider. Alternatively, the TempSense Designer software [3] can be used: it offers a graphical user interface and a number of other features.

(080286)

Internet Links

[1] http://focus.ti.com/lit/ug/sluu113/sluu113.pdf

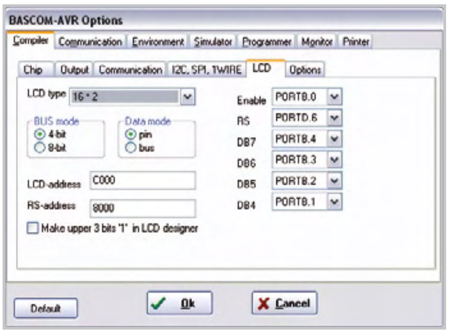
[2] http://focus.ti.com/lit/ds/slus462e/slus462e.pdf

[3] http://focus.ti.com/docs/prod/folders/print/bq24002.html

Long Duration Timer using ATtiny2313

Jürgen Stannieder (Germany)

This timer circuit is designed to switch on a 12 V load in a solar-powered installation for a preset period at the press of a button. When the period has expired a latching relay disconnects both the load and the controller circuit from the 12 V supply. The length of the period can be configured by making suitable changes to the microcontroller's source code.



When button S1 is pressed a voltage appears across relay coil L1, and the relay switches the load on. Since the relay is a latching type, it remains in this state when the button is released. There is now a supply to the 78L05 voltage regulator (a low-dropout type such as the LP2950CZ-5.0 may also be used) and the microcontroller is powered up. In the microcontroller the timer program runs until the configured time interval has elapsed. Around 90 % of the way through the time period LED D2 lights as a warning that the load will shortly be switched off, and this time can also of course be configured by changing the software.

When the full time interval has elapsed the microcontroller sets an output (pin 7) high, which triggers the CNY 17-3 optocoupler and in turn drives relay coil L2. The relay returns to its initial state, disconnecting the load as well as the controller (which is also powered via the relay contact) from the 12 V supply.

The author used a miniature 16-by-2 LCD panel type HMC16223SG in his prototype, measuring just 52 mm by 20 mm. It is of course possible to use any standard LCD module that uses an HD44780-compatible controller. Note that P1 is used to adjust the contrast of the LCD: if the display appears blank it is worth checking the contrast setting before suspecting a more serious problem! If desired, the LCD can be dispensed with, along with the corresponding parts of the source code.

The upper line of the LCD shows the total time period, in seconds, for which the software is configured, while the lower line shows the time, in seconds, since the button was pressed.

The screendump shows the LCD settings under BASCOM-AVR. The source code for the program is available for download at [1].

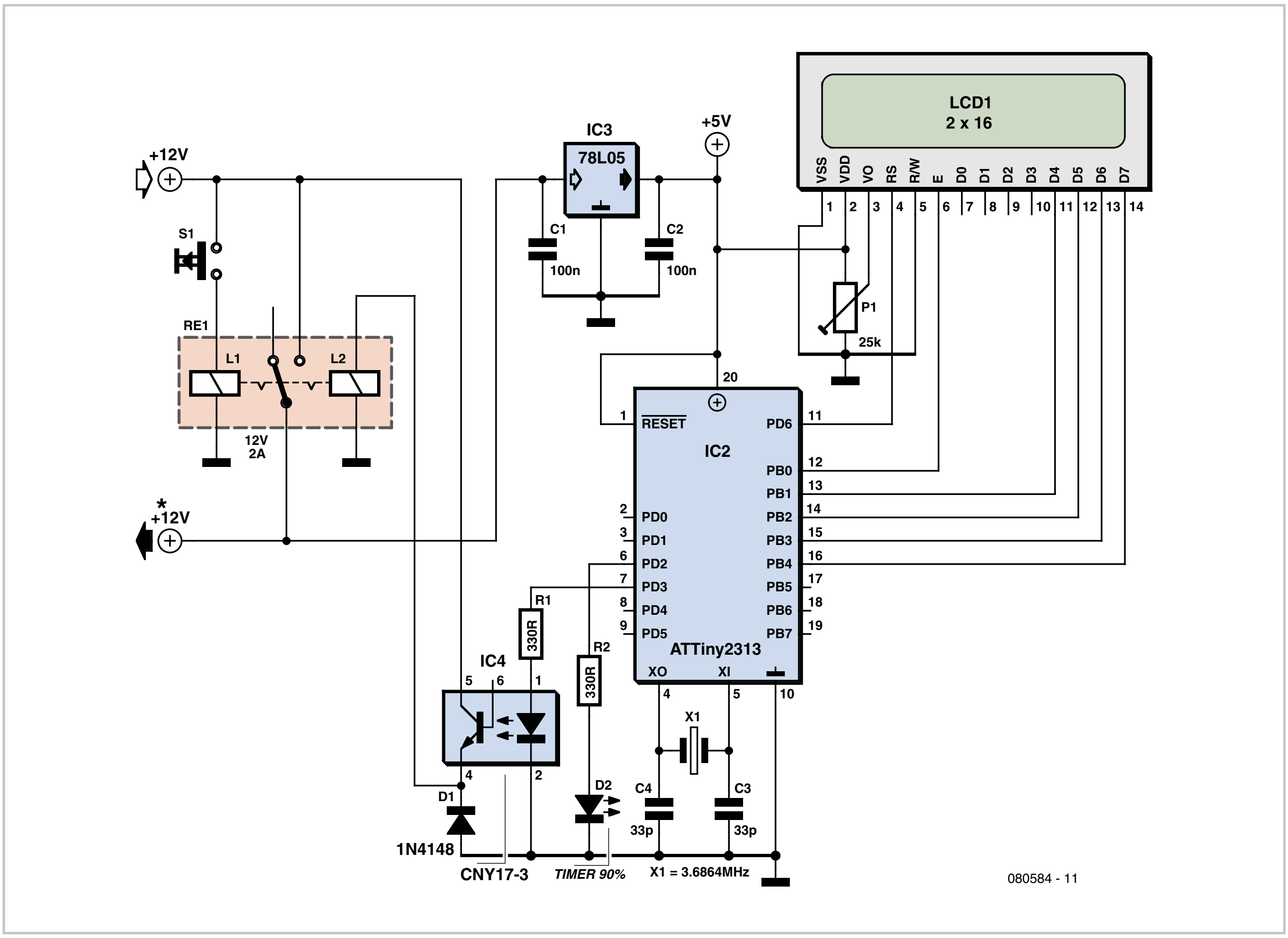
(080584-I)

Internet link

[1] www.elektor-usa.com/080584

Download

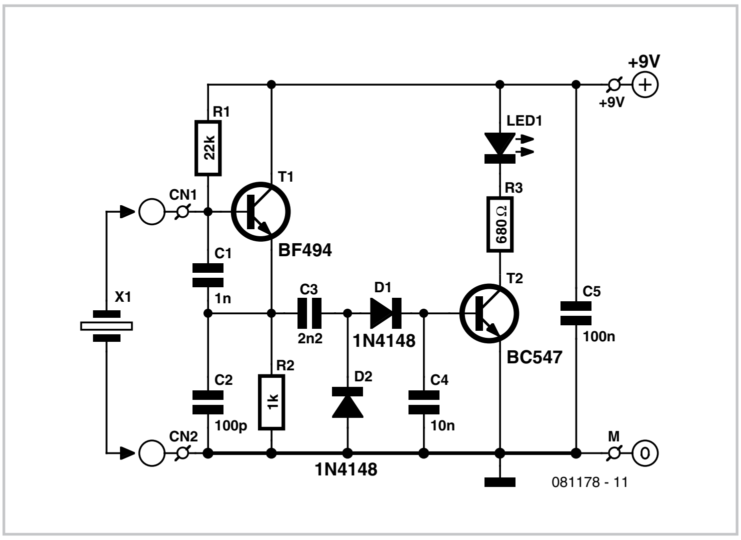
080584-11: source code, from [1]



Quartz Crystal Tester

Christian Tavernier (France)

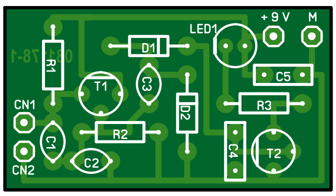
Although most passive components are usually fairly easy to test, the proper functioning of a quartz crystal cannot be checked using any standard measuring instrument. A quartz crystal is actually a very simple device in principle, since all it consists of is a slice of quartz, accurately cut, of course, held between two metal electrodes, or with metallic contacts deposited on it to serve the same purpose. But sadly, owing to its being made like this, an ohmmeter or capacitance meter will not measure anything across a crystal, since it will have a resistance of several megohms (MΩ) and a stray capacitance of only a few picofarads (pF) — regardless of whether it's working or not. So the only solution available to us is to fit the crystal into a circuit, i.e. an oscillator, and see if it oscillates or not. This is just what our tester does — and at a ridiculously low cost.



As the frequencies of the crystals we deal with may cover a very wide range — the vast majority of them will be typically between 1 MHz and 50 MHz — we need to build an oscillator that will be capable of working over a very wide frequency range. This task is given to transistor T1, which is arranged as an aperiodic oscillator — i.e. it is not tuned to any particular frequency. If you are familiar with this type of oscillator circuit, you'll note that the feedback capacitor C1 has an unusually high value, which enables this circuit to cope with almost any type of crystal with a frequency between 1 and 50 MHz.

So if the crystal is good enough, a pseudo-sinewave signal at the crystal's fundamental frequency will be present at the emitter of T1. This signal is rectified by D2 and charges capacitor C4 via D1. As soon as the voltage across this reaches a high enough value, transistor T2 turns on and lights the LED in its collector circuit, thereby indicating that the crystal is usable.

Clearly, because of its operating principle, this circuit doesn't let us check the actual operating frequency of the crystal, but experience shows that, when a crystal is faulty, it will fail to oscillate at all, but that when it does oscillate, it will do so at the frequency for which it was made, or one of its harmonics (see below). If it's important for you to measure this frequency, you can connect a frequency meter or oscilloscope across resistor R2.



The circuit itself is very simply and can be built on the little dedicated PCB whose design we have suggested for you [1], or on a piece of prototyping board (perfboard, Veroboard etc.). In either case, it is essential for the base material to be fiberglass and not paxolin, because of the high frequencies that may be involved.

To achieve the connection to the crystal to be tested, two HC6/U and HC18/U sockets can be soldered in parallel to accommodate crystals using these pin-out formats. Crystals that have wire leadouts can easily be connected to one or other of these two sockets.

The power supply is provided by a source of 9 V. A simple 9 V PP3 battery is ideal, given the circuit's low power consumption and above all the fact that it's only ever used for a relatively short time.

As previously explained, the circuit works for any crystal with a frequency between 1 and 50 MHz — i.e. virtually all the crystals on the market. It's important to appreciate that, even though you do find crystals marked with frequencies higher than 50 MHz, they rarely actually operate directly at this frequency, which is in fact the harmonic frequency to which the oscillator in which they are fitted needs to be tuned. So their fundamental oscillating frequency is in fact normally below 50 MHz, by a ratio of 2 or 3, depending on which harmonic (or overtone) is to be used. The reason for this curious way of going about things lies in the manufacturing technology for these devices, which requires the slice of quartz to be finer and finer as the actual operating frequency (or 'fundamental frequency') is increased. And so, if they try and go too high with direct oscillation at the fundamental frequency, the slice becomes so fragile that it may break all of its own accord.

(081178-I)

COMPONENT LIST

Resistors
R1 = 22kΩ
R2 = 1 Ω
R3 = 880Ω

Capacitors
C1 = 1nF
C2 = 100pF
C3 = 2nF2
C4 = 10nF
C5 = 100nF

Semiconductors
D1, D2 = 1N4148
T1 = BF494
T2 = BC547
LED1 = LED

Miscellaneous
Socket for HC6/U and/or HC 18/U type xtal

Internet Link
[1] www.elektor-usa.com/081178

Download
PCB
081178-1: PCB layout (.pdf), from [1].

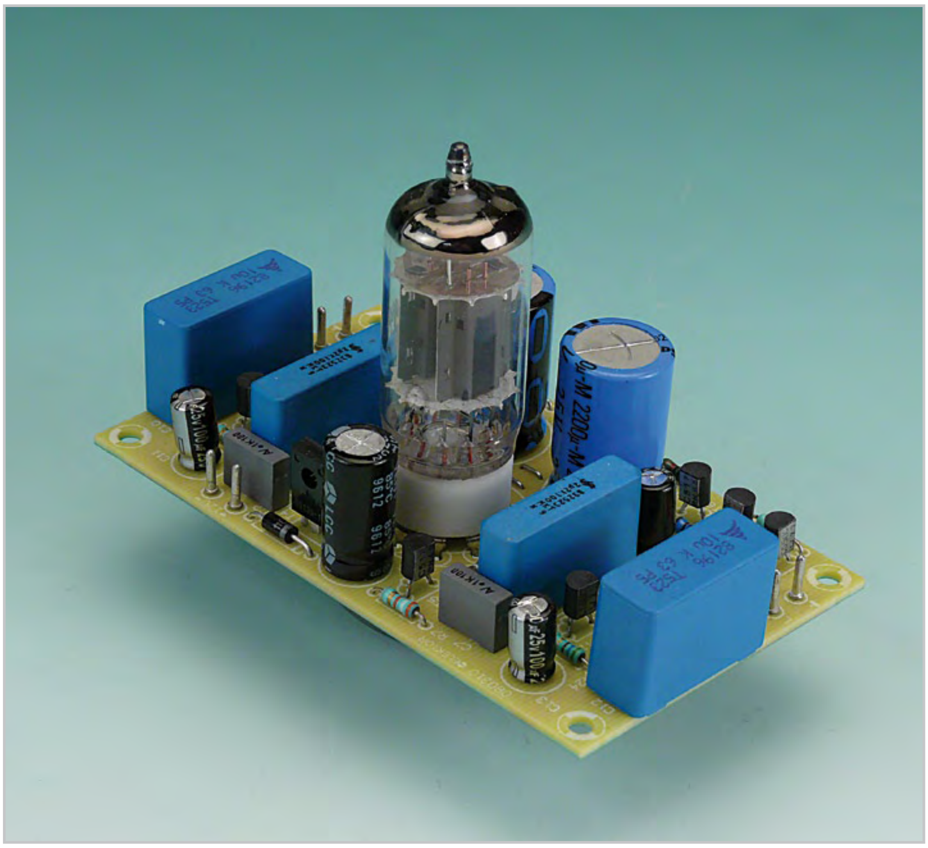
Improved Hybrid HeadPhone Amplifier

Tuck Choy, PhD (Singapore)

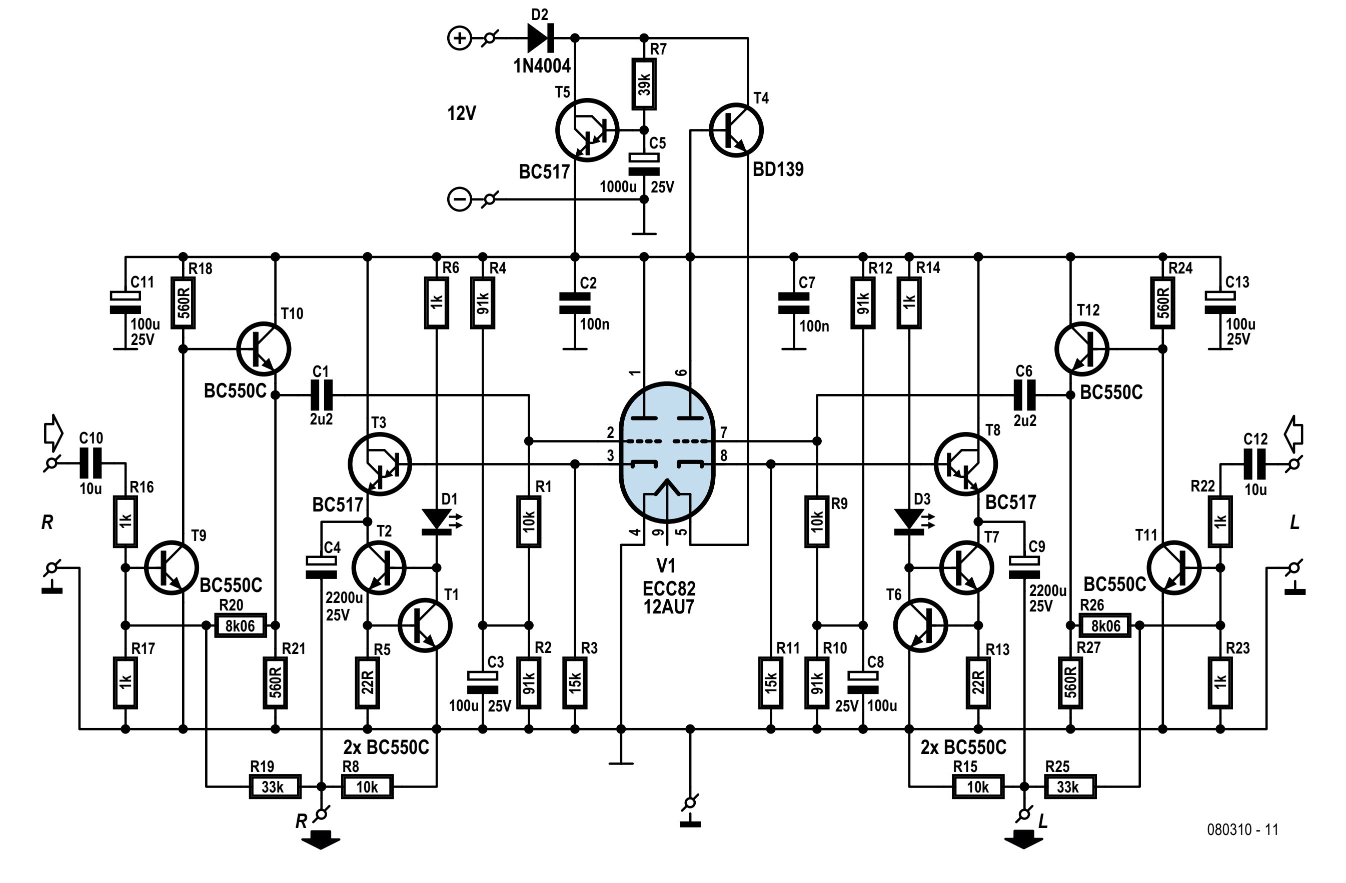
Jeff Macaulay's excellent single tube ECC82/12AU7 'Hybrid Headphone Amp' (HHA) published in [1] spurred the author to implement some modifications culminating mainly in an additional input preamp. The resulting project was then slightly reworked in the Elektor Audio Labs and the result is shown here, along with a PCB design to Elektor standards.

Specifications

- Warm up time: min. 30 minutes
- Load impedance: 33 Ω
- Supply voltage: 12.1 VDC
- Current consumption: 235 mA
- Gain (33 Ω load): 4.5
- Max. output voltage: 730 mV
  (THD = 3%, clipping audible)
- THD + N: 0.13 % (1 mW/1 kHz/B = 80 kHz)
- S/N: 87 dB (ref. 1 mW, B = 22 kHz)
- Bandwidth: 17 Hz – 3.5 MHz (at 1 mW)
- Output impedance: 2 Ω
- DC output voltage: 1 mV (33 Ω load)
  3 mV (150 Ω load)



1



The original HHA was designed for line inputs of the order of 1 V_{rms} and an output impedance of about 35 ohms. Unfortunately there do not seem to be hard and fast international standards for headphone output levels or impedances. Higher end headphones such as the AKG type K601 (impedance 125 ohms) and K701 (impedance 62 ohms), coupled a hi-fi preamplifier system like the author's Rega Mira (which supplies only 600 mV_{rms} out) resulted in a compromized dynamic range and low loudness performance especially on older CD recordings.

Initial experiments with modifying the BC517 Darlington output of the HHA were rather unsuccessful. The low anode current from the tube requires this specialized gain stage and any efforts to boost the output seems to modify the system from a tube based amplifier into a transistor one and the resulting audio performance was also not encouraging. The main problem with the original HHA is both its strength and weakness, as the unity-gain tube cathode follower does not offer any voltage gain in the first place. The low noise and distortion due to the tube is no doubt offered by its low anode voltage and hence low noise and distortion characteristics.

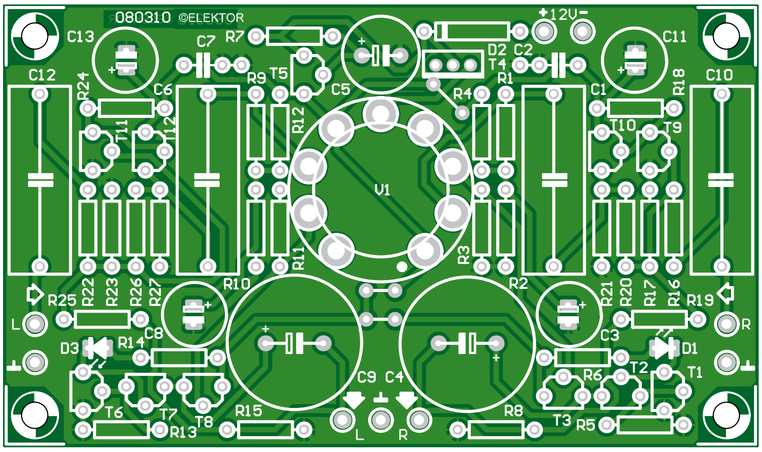
Referring to the circuit diagram in **Figure 1** a stereo amp is shown, as opposed to a monoblock for the original HHA. The hunt for a suitable input voltage amplifier to slightly boost the voltage gain resulted in the use of a dual BC550C inverting shunt feedback amplifier with a voltage gain of about 8. Being an inverting amplifier it conveniently allows some negative feedback (about 3%) to be introduced using 33 kΩ resistor R19 (R25). The feedback causes a direct voltage of a few millivolts at the amplifier outputs, and the **Specifications** listed here were obtained with feedback in place. Without feedback, the outputs carry no direct voltage. The negative feedback feature was found quite useful such as with the AKG K701 to further boost performance, but this is a rather subjective feature you might like to experiment with for yourself. Capacitor C1 (C6) gives the circuit a reasonable specification for its low-frequency roll-off.

In the prototype of the amplifier, the ECC82/12AU7 required about 15 minutes of warming up before normal operation was obtained. This is due to the relatively low heater voltage of about 9.4 V from the BD139 series pass element. The functions of T5/C5 and T4 are explained in some depth in the original article.

The single-sided circuit board design shown in **Figure 2** allows a stereo amplifier to be built. The copper track layout for making your own PCB can be downloaded free of charge from the project webpage. You'll notice that the solder side of the board has large copper fill areas to maximise the ground plane surface, which helps to keep noise and all sorts of interference down to a minimum. The tube socket has a rather spacious footprint as well as large holes to allow sockets from different suppliers to be used.

(080310-I)

2



Measurement data

Voltages measured w.r.t. circuit ground	
T1/T6 base	0.7 V
T2/T7 base	1.4 V
T3/T8 base	3.8 V
T3/T8 Emitter	2.8 V
ECC82 grid	4 V
T10/T12 Emitter	6.2 V
T9/T11Base	0.67 V
ECC82 anodes	10 V
ECC82 pin 5	9.4 V
D2 (across device)	0.8 V
T5 VCE	1.3 V
R6/R14 (across device)	6.85 V

Component List

Resistors

R1,R8,R9,R15 = 10kΩ
R2,R4,R10,R12 = 91kΩ (E96: 90kΩ9)
R3,R11 = 15kΩ
R5,R13 = 22Ω
R6,R14,R16,R17,R22,R23 = 1kΩ
R7 = 39kΩ
R18,R21,R24,R27 = 560Ω
R19,R25 = 33kΩ
R20,R26 = 8kΩ06

Capacitors

C1,C6 = 2µF2 100V, lead pitch 22.5mm (WxL = 10 x 26 mm abs. max.)
C10,C12 = 10µF 63V, lead pitch 22.5mm (WxL = 10 x 26 mm abs. max.)
C2,C7 = 100nF, MKT, lead pitch 5mm or 7.5mm
C3,C8,C11,C13 = 100µF 25V, lead pitch 2.5mm, diam. 8.5 mm max.
C4,C9 = 2200µF 25V, lead pitch 7.5mm, diam. 18mm max.
C5 = 1000 µF 25V, lead pitch 5mm, diam. 10 mm max.

Semiconductors

D1,D3 = red LED
D2 = 1N4004
T1,T2,T6,T7,T9,T10,T11,T12 = BC550C
T3,T5,T8 = BC517
T4 = BD139

Miscellaneous

V1 = ECC82 or 12AU7
9-pin ('Noval') PCB mount socket, e.g. Conrad Electronics # 120529
PCB, # 080310-1 from www.thepcbshop.com

Reference

[1] Hybrid Headphone Amp, Elektor July & August 2006; www.elektor.com/050347

Downloads & Products

PCB design

No. 080310-1 (.pdf) at www.elektor-usa.com/080310

Braitenberg Robot

Abraham Vreugdenhil (The Netherlands)

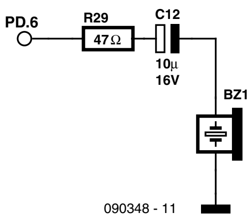
In 1984 Valentino Braitenberg published a nice demonstration to show the behavior of robots. The question is: what IS behavior or what do we THINK behavior is. This demonstration uses simple robotic vehicles, each of which contains a very simple program. Each robotic vehicle has two driven wheels and two light sensors at the front. These sensors look towards the front and each drive a motor. The robots also have a bumper to sense whether they have hit anything. This can be either a wall or another robot. Now, in the simplest form of the robotic vehicle, the left front light sensor is connected with the right rear wheel. Likewise the right front light sensor is connected to the left rear wheel. If we now place the robotic vehicle in a space with a light source, the robotic vehicle will move towards the light source.

There are, however, also vehicles where the left front sensor is connected to the left rear wheel and the right front sensor to the right rear wheel. Such a robotic vehicle will avoid a light source instead. Now, suppose you have multiple light sources which are repeatedly turned on and off, as well as multiple robotic vehicles with different behaviors, what will happen? You will first see that all the light seekers go towards the light source and all the light avoiders move away. When the light sources subsequently move, all the robots will spring into action and this results in new activity. If you're an outsider or you do not know in advance what sort of program is contained in the robotic vehicles, then it is nice to discuss what is happening here. People have the tendency to attribute various kinds of human behavior to certain devices and robots. This one is 'aggressive', the other 'evasive' or passive. Whole discussions are started based on a few robotic vehicles driving around with each ultimately containing a very simple program. Perhaps this says more about the method of thinking or the behavior of the spectators then it does about the behavior of the robotic vehicles themselves.

How can this experiment be repeated in a simple way? You need a number of small and cheap robots that can easily be programmed and changed to suit your needs. A few years ago the company Arexx [2] introduced a trim robot construction kit onto the market, the Asuro. This robot is available from Conrad Electronics [3], among others. The Asuro contains an Atmel ATmega processor with a built-in hex loader. You can write programs for the Asuro in C or (simpler) in Bascom [4]. Using an IR interface (with the supplied RS232 IR transceiver) the hex program can be sent to the Asuro. A USB IR transceiver is also available.

The Asuro also has an experimenting board available. Here the board is used for three purposes. You connect two bumper supports, mount two light sensors and finally add a piezo-element (according to **Figure 1**). For the light sensors on the experimenting board you use the two IR diodes normally mounted underneath the Asuro (these are T9 and T10). Fit these with a little plastic tube.

On the expansion board you use the connections for the red LED D11 to connect the piezo element. To distinguish between the different robotic vehicles you give each a different colour by wrapping the battery compartment in paper of different colours. You can also give each robotic vehicle an unique number internally. While driving around the robots can continuously transmit their behavior, i.e. decisions via the IR transceiver. If you mount an IR transceiver above the 'playing field' you can follow everything the robots 'do' on the computer.



The program, written by the author for this purpose, can be downloaded from the Elektor website [1]. A general overview of what the program does is given here. After it starts up it first waits for a second in the INIT routine. If a bumper is pushed during this time, the light seeking behavior is activated. If the bumper is not pushed then the behavior will be light avoiding. After a short beep it waits to check whether the number of the robot has be changed or not. This is done by pushing the bumper a number of times. If not, the EEPROM is checked to see if it already contains a number. If a valid entry is found then that number will be used, otherwise the number 10 is used. The main loop consists of three parts: a bumper part (A), a light avoiding/seeking part (B) and a random component (C).

The program is written in Bascom AVR. For more information refer to the program listing (download # 090348-11). The Bascom AVR generated hex file is transferred to the Asuro using the Flash.exe program supplied with the Asuro. You can then start again, determine the behavior by pushing the bumper, followed by entering a number by pushing the bumper a few times and the Braitenberg-Vehicle is on its way. Get ready for long discussions on what these robots are doing and what behavior is taking place.

To produce the random light changes on the playing field, the author designed a circuit with a 98C2051 and a few solid-state relays, which ensures that four incandescent lamps at the side of the playing field light up in different combinations every 25 seconds. This effect ensures that the robotic vehicles will continue to search and avoid.

(090348-I)

Internet Links

[1] www.elektor-usa.com/090348

[2] www.arexx.com

[3] www.conrad-int.com

[4] www.mcselec.com

Download

Software

090348-11: Bascom and hex file, from [1]

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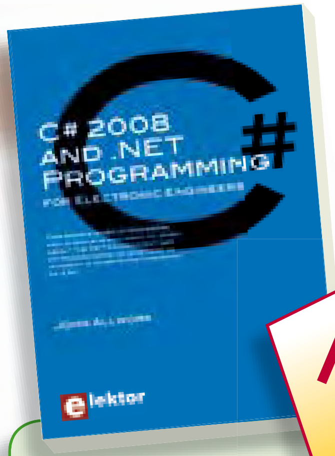

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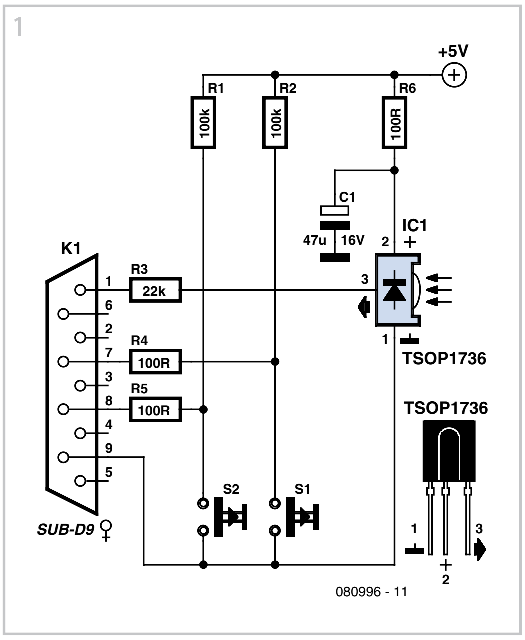
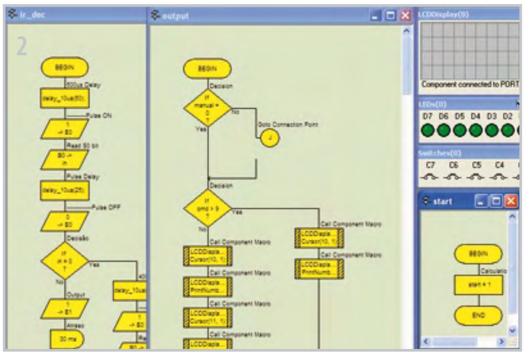
An E-Blocks IR RC5 Decoder

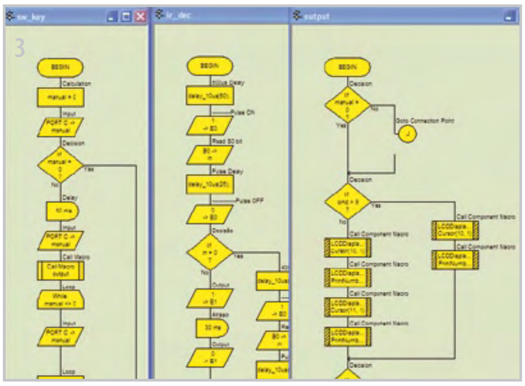
José Basilio Carvalho (Portugal)

The infrared (IR) decoder described here was designed to enable an Elektor E-Blocks development system [1] to process commands from RC5 (compatible) remote controls typically used for Philips audio/video equipment. The E-blocks complement consists of

1 x PICmicro USB Multiprogrammer EB-006 with 4 MHz xtal;
1 x EB-007 (8 push to make switches) connected to PORTC;
1 x *EB-005 imitation LCD board (16x4)* connected to PORTA;
1 x EB-004 LED board or 8-Relay board connected to PORTD;
1 x EB-004 LED board connected to PORTE (or just one LED and a 470 Ω resistor on RE1).







The original EB-005 E-Block has a 16x2 LCD. For the purpose of this project, an EB-005 was reverse-engineered and replicated on prototyping board and wired to accommodate a 4x16 LCD. The home made board has a SIL socket strip that also accepts 16x1 and 16x2 LCDs, all of which were found to be pin compatible. Photos of the author's DYI EB-005 are available at [2]. The proposed IR decoder board is connected to PORTB.

Once fully debugged and tested in terms of hardware and software, an E-blocks system may be 'undressed' and replicated as a stand-alone circuit with just the basic elements and running firmware. In most cases, the circuit boils down to no more than a (PIC) micro with some I/O devices around it like switches, sensors, relays and LEDs. If changes or extensions are required, you build up the E-blocks constellation again, do whatever is necessary to get it all to work, save the new .fcf and make the system blow a fresh PIC for inserting into the stand-alone system.

Here the PIC16F877microcontroller runs at 4 MHz to decode signals matching the Philips RC5 protocol. The complete E-Blocks layout can be used to test remote controls with suspected faults, and to switch 8 devices using a 'known good' control. The address and command decimal values appear on a 16x4 LCD display. The decoder proper (**Figure 1**) is just a standard application circuit of the TSOP1736 IR decoder IC with some components around it for connectivity with the E-blocks PORTA (based on sub-D connectors).

Keys 1 to 8 of the remote are used to control eight bits of PORTD individually, switching on or off any AC or DC devices by way of an 8-way relay board or similar. The Standby key is used to switch all eight outputs on and off. There are also eight push-to-make switches to manually toggle the state of any output. By pressing switch 1 and 2 at the same time you switch all outputs on or off. The state of the outputs is shown on the LC display. Bits 6 and 7 of PORTB are used to select the address mode of the output control; 00 =TV, 01 = VCR, 10 = SAT, 11 = Hi-Fi.

The program was designed with Flowcode, the graphical software design utility for E-blocks. A part of it is shown in **Figure 2**. The resulting .fcf file is available free of charge from the Elektor website [2].

The main flowchart allocates the LC display to PORTA, initialises ports, reads the state of bits 6 and 7 into variable 'mode', enables RB0/INT interrupts and starts a loop.

A 1 to 0 transition on the RB0/INT pin will call the 'start' macro, which is only used to set a variable and call the 'ir_dec' macro. Inside the 'ir_dec' macro, some delays are present to read RB0 near the end of the S1 bit, as well as during the start and second half of the S2 bit. If they are '010', the signal is recognised as coming from a valid RC5 remote control. Some more delays effectively skip the toggle bit (not used here) and start to read the five address bits and six command bits into the 'adr' and 'cmd' variables respectively. During the 'ir_dec' macro, 14 300-µs pulses are generated on the RE0 pin to enable an oscilloscope to show detailed timing of the RC5 preamble and address/command bits.

After a successful IR decoding, the 'ir_dec' macro calls the 'output' macro. Inside the 'output' macro the display shows address and command values in decimal notation, compares 'adr' and 'mode' variables to validate the device mode used, and sends the value of the 'cmd' variable to PORTD, displaying the output state in binary.

A blinking LED on the RE1 pin reveals the activity of any non-RC5 remote controls (like Sony, Panasonic, etc.). The main loop also calls the 'sw_key' macro to read PORTC switches to control the PORTD outputs manually.

(080996-I)

Internet Links

[1] www.elektor.com/eblocks
[2] www.elektor-usa.com/080996

Downloads

Software

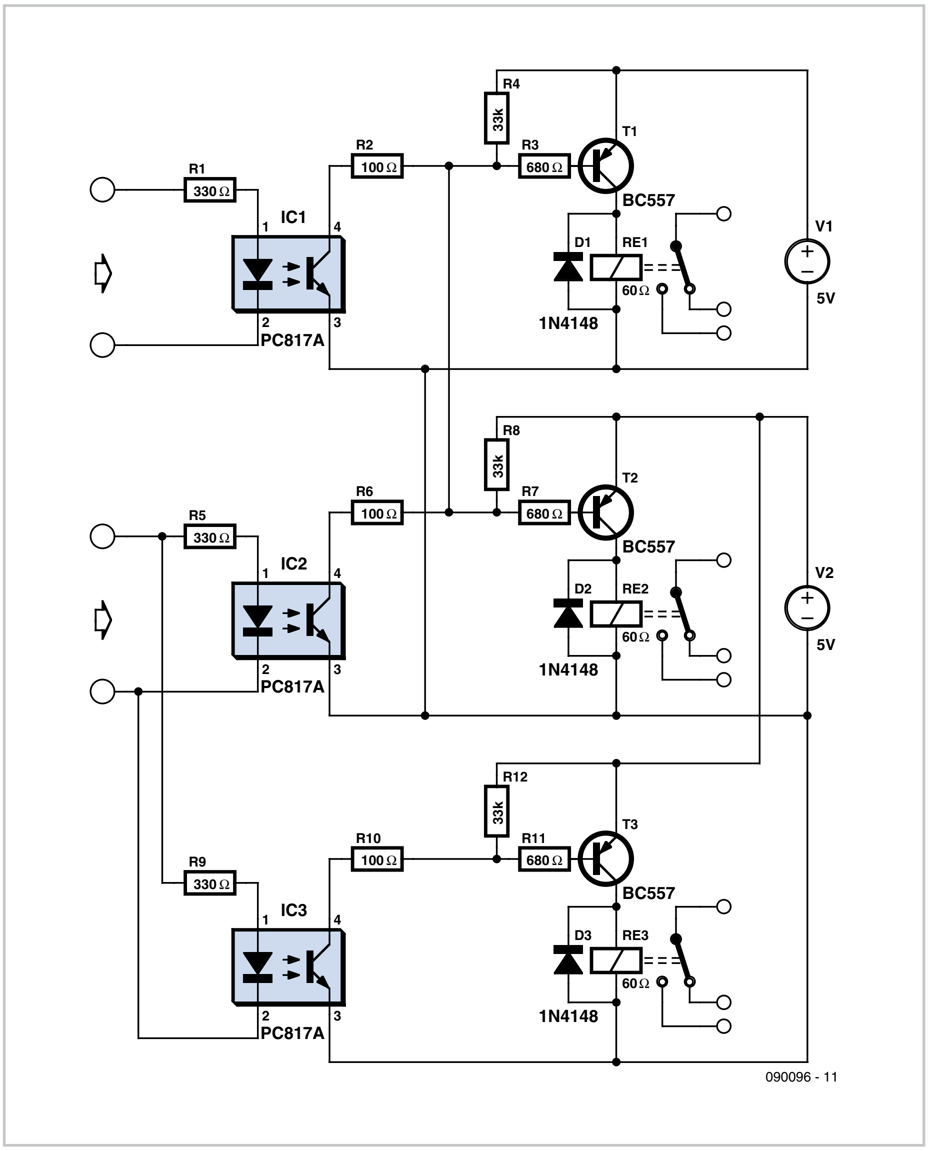
080996-11.zip: Flowcode (.fcf) file, from [2]

Supplementary Information

080996-12.zip: Photos of DIY EB-005, from [2]

Remote Control for Network Devices

Werner Rabl (Germany)



Many devices connected to a local area network (LAN) are left on continuously, even when they are not needed, including DSL and cable modems, routers, wireless access points, networked hard drives, printer servers and printers. The power consumption of all these devices can add up to a considerable fraction of one's electricity bill. With the simple circuit described here we can ensure that all these devices are only powered up when at least one selected host device (such as a PC or a streaming media client) is turned on. We insert a relay in the AC line supply to the devices whose power is to be switched, along with a driver circuit controlled from the host device over a two-wire bus. Optocouplers provide galvanic isolation. One way to implement the bus is to use the spare pair of conductors that is often available in the existing LAN cable.

The circuit diagram shows an example configuration where there are two controlling host devices (a streaming media client and a PC) and three network devices (a DSL router, a networked hard drive and a networked printer). We will assume that all the media files are held on the networked hard drive. The DSL router (to provide an internet connection) and the hard drive are to be powered up when either the PC or the media client is powered up; the printer only when the PC is powered up.

We can think of the devices as being in two groups, the first group consisting of the DSL router and the hard drive, the second just the printer. An optocoupler is powered from each of the controlling host devices: these ensure that the devices are isolated from one another and from the rest of the circuit. The relay circuit, located close to the networked devices, is controlled from the outputs of the optocouplers. The relay circuits are powered from (efficient) AC adaptors: modified cell phone chargers do an admirable job.

In the circuit shown a 5 V supply from the controlling devices is used to drive each optocoupler. Host 1 (the streaming client) drives optocoupler IC1, host 2 (the PC) drives optocouplers IC2 and IC3.

Optocouplers IC1 and IC2 both control the networked devices in group 1: networked device 1 is the DSL router, switched by relay RE1, and networked device 2 is the hard drive, switched by relay RE2.

Optocoupler IC3 controls the networked device in group 2, namely the printer. This is switched by relay RE3.

The connections between the optocouplers and the relay stages can be thought of as a kind of bus for each group of devices. The devices in a given group can be switched on by simply shorting its bus, and this gives an easy way to test the set-up. Resistors R2, R6 and R10 at the collectors of the transistors in the optocouplers protect them in case power should accidentally be applied to the bus.

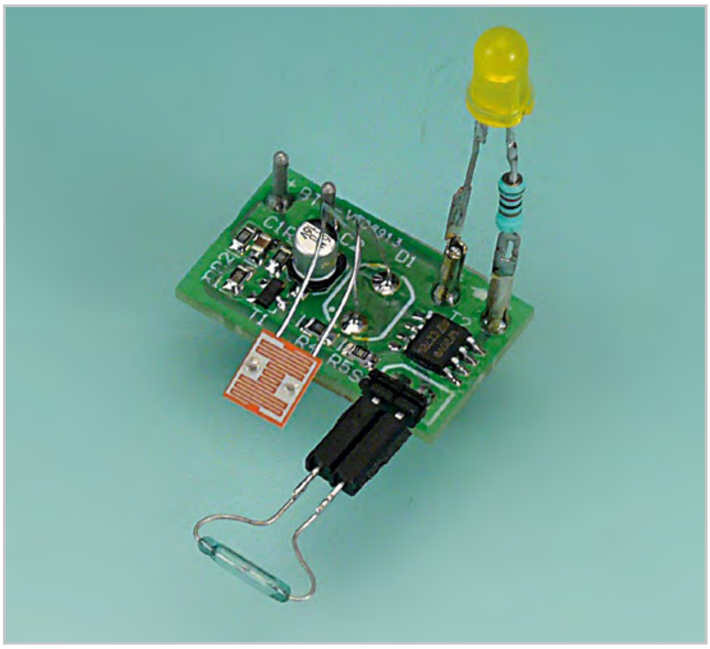
The supply voltages V1 and V2 shown in the example circuit diagram are derived from the AC power adaptors as mentioned above and are used to power the relays. We have assumed that the networked hard drive and the printer are located near to one another, and so it is possible to use a single AC power adaptor to provide both voltages. Another possibility would be to add a third wire to the bus to carry power: this would allow all relays, wherever they were located, to be powered from a single supply.

It is worth noting that network attached storage (NAS) devices such as networked hard drives normally require an orderly shutdown process before power is removed. Devices that use Ximeta's NDAS technology do not suffer from this problem.

(090096-I)

Automatic Bicycle Light

Ludwig Libertin (Austria)

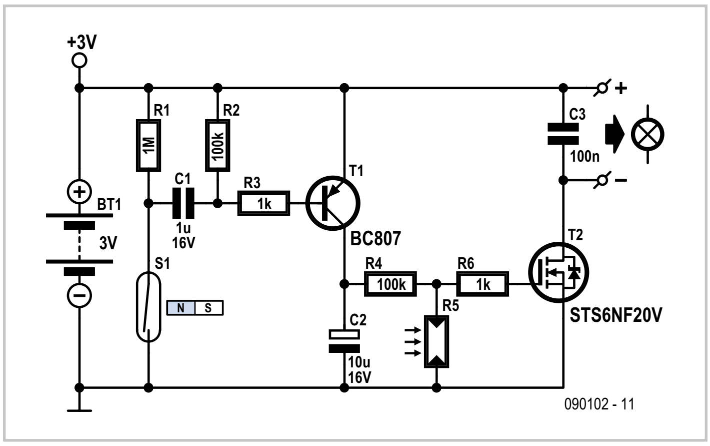


This automatic bicycle light makes cycling in the dark much easier (although you still need to pedal of course). The circuit takes the ambient light level into account and only turns on the light when it becomes dark. The light is turned off when no cycling has taken place for over a minute or if it becomes light again. The biggest advantage of this circuit is that it has no manual controls. This way you can never 'forget' to turn the light on or off. This makes it ideal for children and those of a forgetful disposition.

To detect when the bicycle is used (in other words, when the wheels turn), the circuit uses a reed switch (S1), mounted on the frame close to the wheel. A small magnet is fixed to the spokes (similar to that used with most bicycle speedometers), which closes the reed switch once for every revolution of the wheel. Whilst the wheel turns, pulses are fed to the base of T1 via C1. This charges a small electrolytic capacitor (C2). When it is dark enough and the LDR therefore has a high resistance, T2 starts conducting and the lamp is turned on. With every revolution of the wheel C2 is charged up again. The charge in C2 ensures that T2 keeps conducting for about a minute after the wheel stops turning. Almost any type of light can be connected to the output of the circuit.

With a supply voltage of 3V the quiescent current when the reed switch is open is just 0.14 µA. When the magnet happens to be in a position such that S1 is closed, the current is 3 µA. In either case there is no problem using batteries to supply the circuit. The supply voltage can be anywhere from 3 to 12 V, depending on the type of lamp that is connected. Since it is likely that the circuit will be mounted inside a bicycle light it is important to keep an eye on its dimensions. The board has therefore been kept very compact and use has been made of SMD components. Most of them come in an 0805 package. C2 comes in a so-called chip version. The board is single-sided with the top also acting as the solder side.

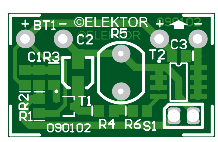
The print outline for the LDR (R5) isn't exactly the same as that of the outline of the LDR mentioned in the component list. The outline is more a general one because there is quite a variety of different LDR packages on the market. It is therefore possible to use another type of LDR, if for example the light threshold isn't quite right. The LDR may also be mounted on the other side of the board, but that depends on how the board is mounted inside the light.



For the MOSFET there are also many alternatives available, such as the FDS6064N3 made by Fairchild, the SI4864DY made by Vishay Siliconix, the IRF7404 made by IRF or the NTMS4N01R2G made by ONSEMI. The reed switch also comes in many different shapes and sizes; some of them are even waterproof and come with the wires already attached.

For the supply connection and the connection to the lamp you can either use PCB pins or solder the wires directly onto the board. The soldered ends of the pins can be shortened slightly so that they don't stick out from the bottom of the board. This reduces the chance of shorts with any metal parts of the light.

Do take care when you use a dynamo to power the circuit — the alternating voltage must first be rectified! The same applies to hub dynamos, which often also output an alternating voltage.



COMPONENT LIST

Resistors
R1 = 1MΩ (SMD 0805)
R2,R4 = 100kΩ (SMD 0805)
R3,R6 = 1kΩ (SMD 0805)
R5 = LDR e.g. FW150 Conrad Electronics # 183547

Capacitors
C1 = 1µF 16V (SMD 0805)
C2 = 10µF 16V (SMD chip type)
C3 = 100nF (SMD 0805)

Semiconductors
T1 = BC807 (SMD SOT23)
T2 = STS6NF20V (SMD SO8)

Miscellaneous
S1 = reed switch (not on board) + 2-way right angle pinheader
BT1 = 3–12V (see text)

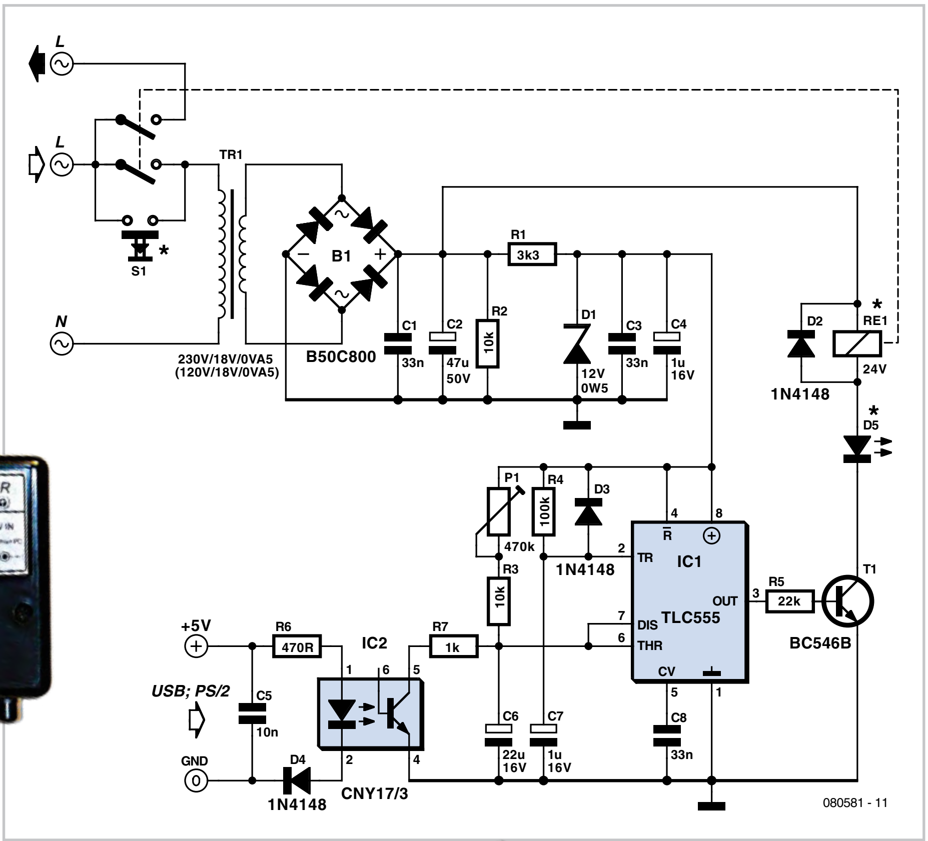
Please Note. Bicycle lighting is subject to legal restrictions, traffic laws and, additionally in some countries, type approval.

(090102-I)

Download
090102-1 PCB layout (.pdf), from www.elektor-usa.com/090102

PC Power Saver

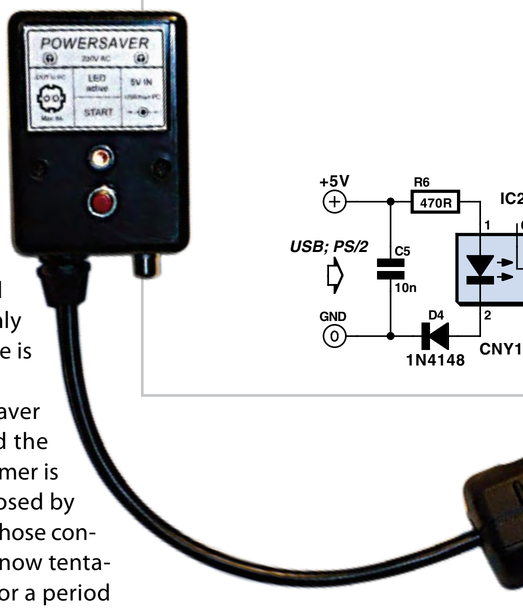
Wolfgang Gscheidle (Germany)



This circuit is designed to help minimise the quiescent power consumption of PCs and notebooks, using just our old friend the 555 timer and a relay as the main components. The circuit itself dissipates around 0.5 W in operation (that is, when the connected PC is on); when switched off (with the relay not energized) the total power draw is precisely zero.

A prerequisite for the circuit is a PC or note book with a USB or PS/2 keyboard socket that is powered only when the PC is on.

The power saver can be used to switch PCs or even whole multi-way extension blocks. The unit can be built into an ordinary AC power adaptor (which must have an earth pin!) as the photograph of the author's prototype shows. The PC is plugged in to the socket at the output of the power saver unit, and an extra connection is made to the control input of the unit from a PS/2 (keyboard or mouse) socket or USB port. Only the 5 V supply line of the interface is used.



When button S1 on the power saver is pressed the unit turns on, and the monostable formed by the 555 timer is triggered via the network composed by R4 and C7. This drives relay RE1, whose contacts close. The connected PC is now tentatively powered up via the relay for a period determined by P1 (approximately in the range from 5 s to 10 s).

If, during this interval, the PC fails to indicate that it is alive by supplying 5 V from its USB or PS/2 connector (that is, if you do not switch it on), the monostable period will expire, the relay will drop out and any connected device will be powered down. No further current will be drawn from the supply, and, of course, it will not be possible to turn the PC on. Whenever you want to turn the PC on, you must always press the button on the power saver shortly beforehand.

If, however, 5 V is delivered by the PC to the input of optocoupler IC2 before the monostable times out (which will be the case if the PC is switched on during that period), the transistor in the optocoupler will conduct and discharge capacitor C6. The monostable will now remain triggered and the relay will remain energized until the PC is switched off and power disappears from its USB or PS/2 interface. Then, after the monostable time period expires, the relay will drop out and the power saver will disconnect itself from the AC. There is no need to switch anything else off: just shut down the system and the power saver will take care of the rest. It is also possible to leave the machine as it updates its software, and the power saver will do its job shortly after the machine shuts down.

Power for the unit itself is obtained using a simple supply circuit based around a miniature transformer. Alternatively, a 12 V AC power adaptor can be used, as long as a relay with a 12 V coil voltage is used for RE1. In his prototype the author used a relay with a 24 V coil connected as shown directly to the positive side of reservoir capacitor C2, the 555 being powered from 12 V regulated from that supply using R1 and D1. A fixed resistor can of course be used in place of P1 if desired. If the adjustment range of P1 is not sufficient (for example if the PC powers up very slowly) the monostable period can be increased by using a larger capacitor at C6.

The relay must have at least two normally-open (or changeover) contacts rated at at least 8 A. The contact in parallel with S1 is used to supply power to the device itself, and the other contact carries all the current for the connected PC or for the extension lead to which the PC and peripherals are connected.

Pushbutton S1 **must be rated for 230 VAC (US: 120 VAC) operation**: this is no place to make economies. The coil current for the relay flows through LED D5, which must therefore be a 20 mA type. If a low-current LED is used, a 120 Ω resistor can be connected in parallel with it to carry the remaining current. The Fujitsu FTR-F1CL024R relay used in the author's prototype has a rated coil current of 16.7 mA.

Optocoupler IC2 provides isolation between the circuit and the PC, and is protected from reverse polarity connection by diode D4.

The power saver should be built into an insulated enclosure and great care should be taken to ensure that there is proper isolation between components and wires carrying the mains voltage and the other parts of the circuit. In particular, the connection to the PC and associated components (R6, C5, D4 and IC2) should be carefully arranged with at least a 6 mm gap between them and any part of the circuit at AC line potential.

(080581-I)

entered into the grid, defining the starting point for you.
If you can solve this puzzle, there are some nice prizes to be won. All you have to do is send us the **five figures** in yellow, reading from **top to bottom**.
The puzzle is also available as a **free download** from the Elektor website.

6	8	1	0	7	D	4	5	B	2	E	3	A	C	9	F
D	C	9	F	8	B	0	3	4	5	A	1	7	2	6	E
2	A	3	5	E	F	C	9	0	8	7	6	B	D	1	4
B	4	7	E	2	A	6	1	F	D	C	9	8	3	0	5
E	5	4	D	0	7	2	A	3	9	1	B	6	8	F	C
7	2	F	8	C	6	3	E	A	0	5	4	9	B	D	1
0	6	B	C	9	4	1	F	8	7	D	E	3	5	2	A
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9	E	8	B	4	1	A	2	5	F	6	D	C	0	7	3
A	1	C	4	3	0	D	7	E	B	8	2	F	9	5	6
F	0	D	3	5	C	E	6	1	A	9	7	2	4	8	B
5	7	2	6	F	9	8	B	C	3	4	0	E	1	A	D
8	9	E	2	1	5	7	C	6	4	B	A	D	F	3	0
4	D	5	7	A	3	B	8	9	C	0	F	1	6	E	2
C	F	6	1	D	2	9	0	7	E	3	5	4	A	B	8
3	B	0	A	6	E	F	4	D	1	2	8	5	7	C	9

Solve Hexamurai and win!
Correct solutions received from the entire Elektor readership automatically enter a prize draw for an E-blocks Starter Kit Professional worth US$ 425.00 (rrp) and three Elektor Electronics SHOP Vouchers worth US$ 55.00. We believe these prizes should encourage all our readers to participate!

Participate!
Please send your solution (the numbers in the grey boxes) by email to hexadoku@elektor-usa.com

Subject: **hexamurai 07-2009 (**please copy exactly).

Include with your solution: **full name and street address.**

Alternatively, by fax or post to:
Elektor Hexadoku
PO Box 876
Peterborough NH 03458-0876
USA
Fax: 603-924-9467

The closing date is
1 September 2009.

The competition is not open to employees of Elektor International Media, its business partners and/or associated publishing houses.

Prize winners
The solution of the May 2009 Hexadoku is: **857C9**.
The **E-blocks Starter Kit Professional** goes to: Marcel Delomenede (France).
An **Elektor SHOP voucher** goes to: Adrian Bradshaw (UK); Thomas Raith (Germany); Heinz-Dieter Richter (Germany).

Congratulations everybody!

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