

Construction project:

Multi-purpose preamp board

Need to amplify or process an audio signal? This universal board design may be the answer – it will accommodate almost any circuit requiring a dual op-amp and power supply.

by ROB EVANS

How often have you found yourself scanning through data books or back issues of EA, searching for the audio circuit you require? This can be quite a time consuming process, particularly when an appropriate printed circuit board (PCB) has to be designed from scratch or modified from an existing layout.

To avoid this inconvenience, we have designed a multi-purpose PCB that allows for a wide variety of component positions around a standard dual op-amp. This lets us assign the one universal PCB to a diverse range of circuit configurations, by simply rearranging the component positions.

As an example of some of the common applications, six circuits have been developed and tested, and are presented here with matching component overlays. Also, a number of power supply alternatives may be accommodated on the PCB, and are presented in a similar manner.

So, to build the circuit that you require, it's simply a matter of selecting the op-amp design, nominating the type of power supply, and installing the components as shown in the overlays. If the circuit is not one of the six presented, only a little planning is needed to arrange the component positions correctly.

Suitable op-amps

Although a similar, universal PCB could have been designed for a quad or single op-amp, the dual configuration was found to be the best compromise

between complexity and versatility.

A single op-amp board does not allow us to easily add a following stage for extra processing, or another identical stage for stereo applications. Conversely, the PCB design for a versatile quad op-amp circuit would be physically too large for many applications.

Another factor in favour of the dual op-amp is the wide range of devices to choose from, all with the same pin-out. This allows us to consider the price versus performance aspect of the op-amp for each application. They range from dual versions of the ubiquitous uA741, to the high performance LM833 and NE5532 devices.

The LM833 is of particular interest, since it is a relative newcomer to the audio arena and offers very high performance – not unlike the popular NE5534 single op-amp. However, the LM833 is a dual op-amp and costs only slightly more than the NE5534 – that adds up to excellent value for money. This IC was tested in a couple of our more demanding circuits, and found to produce impressive results.

Naturally, ICs such as the humble LM1458/4558 are quite suitable for the published circuits, and cost around one third the price of the LM833. These will deliver quite respectable results, particularly in the circuits configured for a low voltage gain. Also, much the same applies for the common TL072 dual JFET op-amp, which offers a very low input bias current and low-noise performance at around two thirds the price of an LM833.

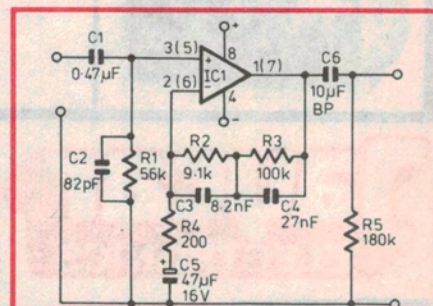
So there we have it. Select a suitable IC, the style of power supply you want, and position the components to create the circuit that you require. The six circuits shown here are mainly preamps, with a tone control and mixing stage thrown in for good measure. However, with a little imagination, this universal PCB will easily accommodate many other two op-amp configurations.

RIAA phono preamp

This stage is designed to amplify and equalise (to the standard RIAA curve) signals from a standard 'moving magnet' type magnetic phono cartridge.

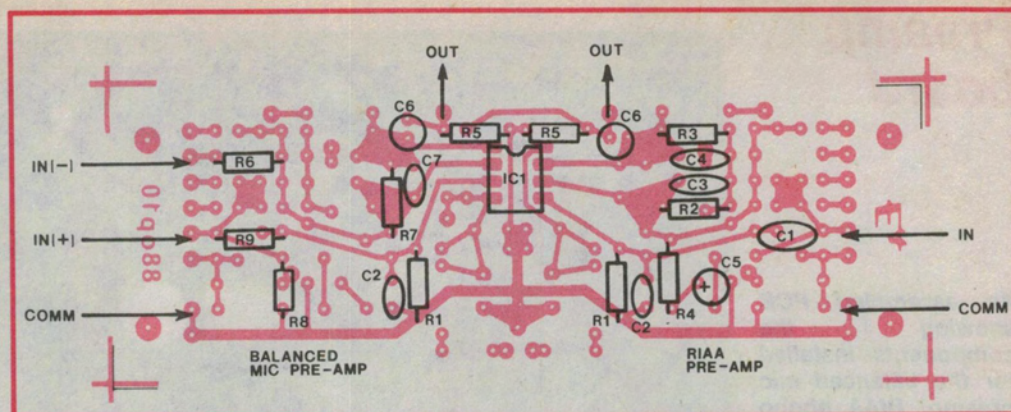
Despite the simple appearance of this design, it is capable of excellent performance when configured around an IC such as the LM833. In fact, our prototype delivered signal to noise ratio and distortion figures of 88dB and 0.008% respectively, when connected to power supply '1'.

Although the circuit diagram of the RIAA preamp shows the use of close tolerance resistors, an alternative range of standard preferred values is listed in the parts table. With these values, the preamp will track the RIAA curve with only a little less accuracy than the close tolerance version such as our test circuit, which followed within ± 0.5 dB.



This simple RIAA phono preamp is capable of excellent performance when used with a high quality op-amp.

Component overlay for the balanced mic preamp (left hand side of PCB) and RIAA preamp (right hand side of PCB).



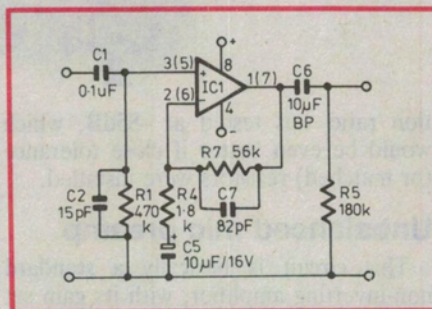
The circuit itself has a mid-band (1kHz) voltage gain of about 35dB, and a frequency response set to the RIAA curve by R2, R3, C3 and C4. The response is rolled-off at very low frequencies by the combination of R4 and C5, and C1 and R1, while any extraneous high frequencies from the source signal are limited by C2.

The low frequency gain of this circuit is set to about 55dB by the combination of R2, R3, and R4, reaching this peak level at about 30Hz. This leaves the circuit very susceptible to mains hum interference, which may dominate the background noise. In fact, if a high quality op-amp is used, the noise performance tends to be limited by the hum alone, which in turn depends on the power supply and shielding around the PCB.

NAB tape preamp

An NAB tape preamp is designed to amplify and equalise the low level signals from the playback head of a tape recorder. The basic circuit configuration is identical to the RIAA preamp, with the exception of the frequency selective feedback network. This network, comprising of R3, R4, R7 and C3 sets the equalisation curve to the NAB tape playback standard.

This response curve heavily boosts the low frequencies (+35dB) in the same manner as the RIAA equalisation, and



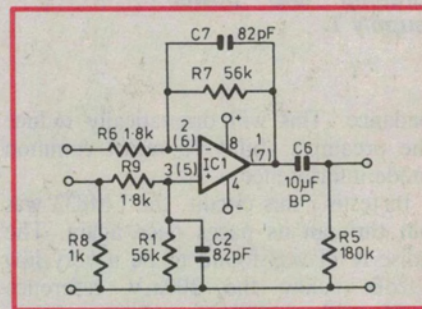
The circuit for a tape head playback amplifier which follows the NAB equalisation curve.

care must be taken with circuit shielding and the prevention of power supply ripple.

Balanced mic preamp

In effect, this circuit is simply a high gain subtracting amplifier. One of the anti-phase signals from a balanced microphone is applied to the inverting input, while the other is applied to the non-inverting input of the op-amp IC1, at R6 and R9/8 respectively. Since these signals are out of phase, they will be amplified by the op-amp, while any signals common to both inputs (such as electrical interference) will be subtracted or rejected.

The gain at each input is matched when R7 is the same value as R1, and R9 is that of R6, and may be calculated



A simple high performance balanced mic preamp based around a subtracting amplifier. Note the input impedance matching resistor R8.

using standard gain equations. However, when calculating the gain at the non-inverting input, the inverting input should be considered to be grounded.

In our circuit, R8 pads the impedance of the non-inverting input down to that of the inverting input, which may be calculated by the equation:

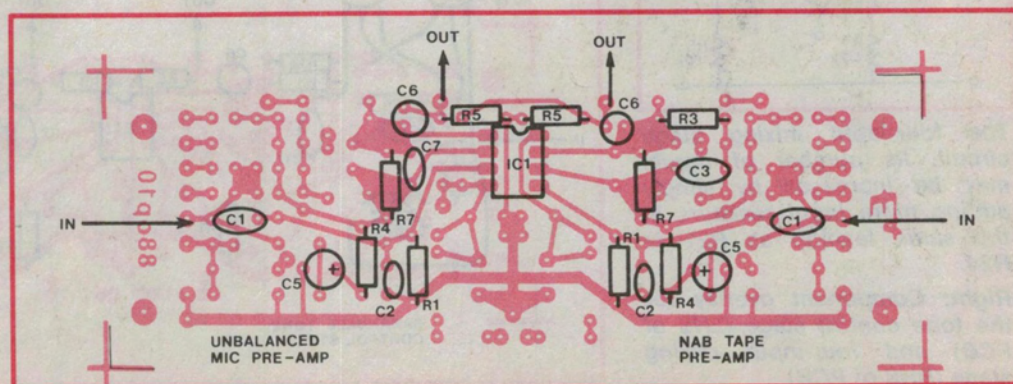
$$R_{in} = R_6 / (1 + A_{tt}) = 914 \text{ ohms}$$

where: $A_{tt} = R_1 / (R_1 + R_9)$

Therefore, to correctly pad the non-inverting input, R8 should have a value of 929 ohms, or the preferred value of 1k ohms.

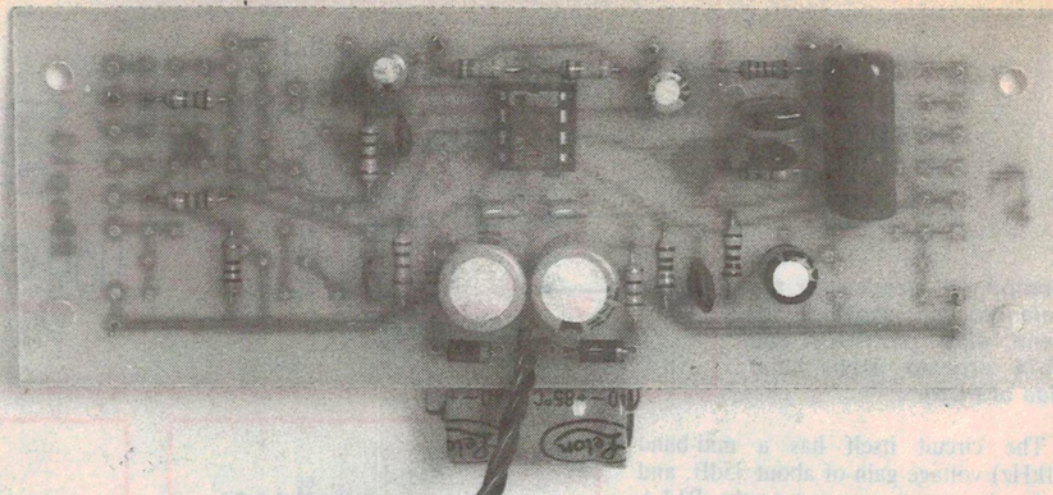
The above calculation is important if this preamp is to be truly 'balanced', since differing impedances at the two inputs will unbalance the signal source – which invariably has some output im-

Component overlay for the unbalanced mic preamp (LHS of PCB) and NAB tape preamp (RHS of PCB).



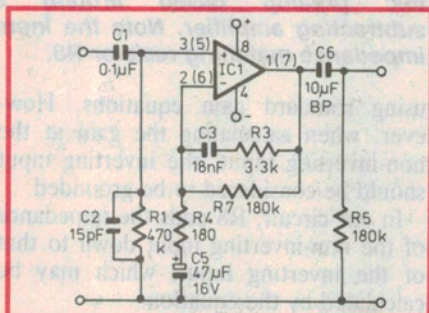
Preamp board

An assembled PCB showing the components installed for the balanced mic preamp, RIAA phono preamp and power supply 1.

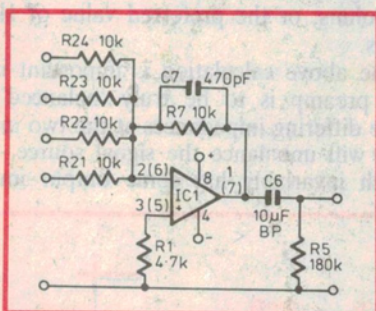


pedance. This will dramatically reduce the preamp's ability to reject common mode interference.

In testing this circuit, the LM833 was put through its paces once again. The noise level was found to be a very low -92dB below the 100mV reference level, with a distortion figure of less than 0.01%. The common mode rejection



The unbalanced mic preamp is based around a standard non-inverting op-amp stage, with the input impedance set by R1.



The four-input mixing stage circuit. Its number of inputs may be increased by simply adding more input resistors in the same fashion as R21 to R24.

Right: Component overlay for the tone control stage (LHS of PCB) and four-input mixing stage (RHS of PCB).

tion ratio was tested at -85dB, which would be even better if close tolerance (or matched) resistors were installed.

Unbalanced mic preamp

This circuit is basically a standard non-inverting amplifier, with its gain set to about 30dB by R7 and R4. It has a relatively high input impedance of about 470k as set by R1, which allows it to be used with high or low impedance microphones. Naturally, this circuit could be used wherever a high input impedance, high gain stage is required.

To reduce the sub-sonic signals generated by microphone handling noise, the low frequency response is limited to about 19Hz by the filtering action of R4 and C5. Conversely, the high frequency response is restricted by the capacitors C7 and (depending upon the source impedance) C2.

Mixing stage

This stage is a standard virtual earth summing amplifier, and is used to add

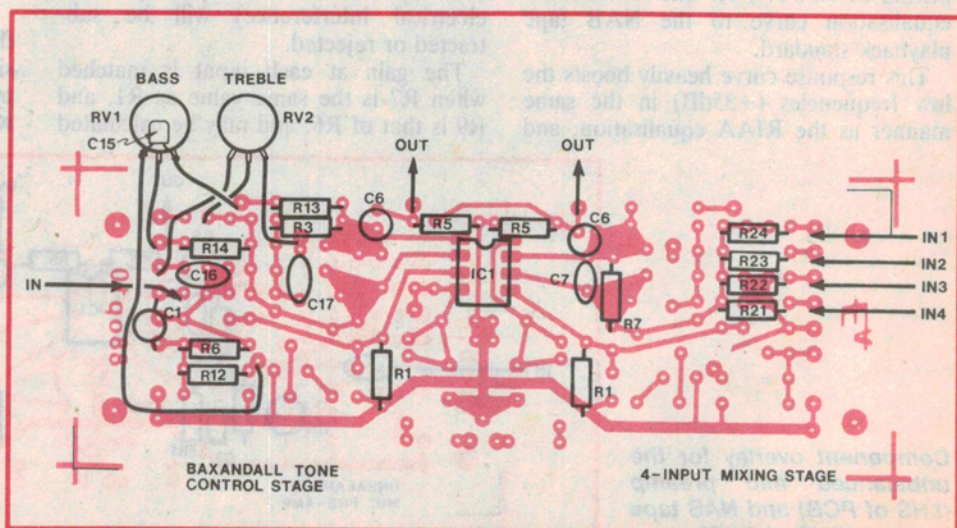
(or mix) a number of inputs to produce a single result. For example, a series of microphone preamps may be mixed together in this stage, and the output used to drive a power amp or other signal processors.

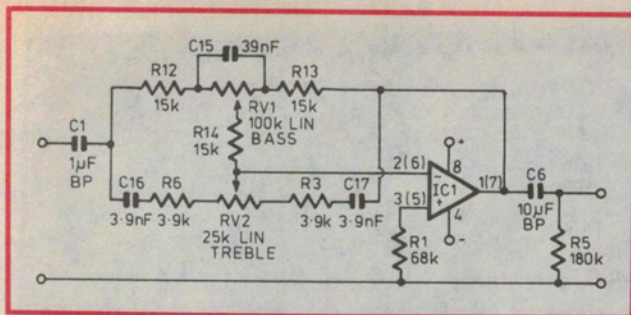
The gain for each input is set by its series resistor (in this case R21 to R24) divided by the feedback resistor R7. The gain of the whole stage may be varied by simply replacing R7 with a suitable potentiometer. Again, the high frequency response is restricted by C7 and the op-amp input currents matched by the addition of R1.

Tone control stage

A Baxandall type tone control stage uses two distinct feedback networks around an inverting amplifier, one for low frequency (Bass) adjustment, and the other for high (Treble) frequencies.

The Treble network is composed of R3, R6, C16, C17 and RV2, and may be regarded as open circuit at low frequencies, due to the high impedance of C16 and C17. However, at high fre-





Left: The tone control circuit uses the familiar Baxandall feedback network to control the level of bass and treble frequencies.

quencies the stage may be regarded as a normal inverting amplifier, with a series input 'resistor' comprised of C16, R6 and one section of RV2. Since the feedback 'resistor' is formed by C17, R3 and the remaining section of RV2, the gain of this stage will depend upon the ratio of these two 'resistors'. As may be seen from the circuit, this ratio is determined by the 'Treble' potentiometer RV2.

The Bass network of this stage is formed by R12, R13, C15 and RV1, and may be analysed in a similar manner to the Treble network. The series input 'resistor' in this case is comprised of R12 and one section of RV1, while the feedback 'resistor' is R13 and the remaining section of RV1. Once again, the ratio of these resistors is determined by the level potentiometer RV1, which is bypassed at high frequencies by C15. The additional resistor R14 is included to reduce the loading effects between the two networks.

Power supplies

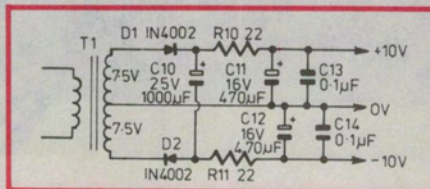
All of the above circuits require a split, or dual rail power supply between about ± 5 volts and ± 15 volts when used with most op-amps. We have elected to use power supplies delivering ± 10 volts, with the exception of the battery based power supply (number 4). This will supply about ± 4.5 volts, which may be a little low for op-amps such as the LM833, which have a minimum recommended rail supply of ± 5 volts. But in practice, we have found that this device will perform quite satisfactorily from the lower voltage.

The type of power supply chosen for the selected audio circuit will depend upon the availability of a suitable voltage source (AC or DC), and the final application. The described power supplies should cover most situations.

Power supply 1

This supply employs a transformer with two secondary windings, or a centre tapped single winding. Each section is half wave rectified (by D1 and D2), and applied to a filter network consisting of R10, R11, and C10 to C14.

The positive supply rail is filtered by



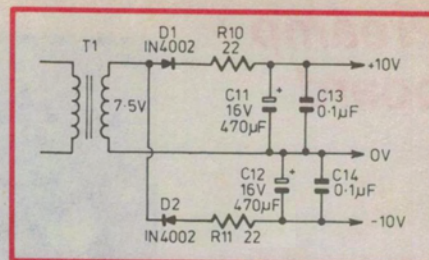
Power supply 1 configuration: Note the addition of C10 to provide additional filtering for the more sensitive circuits.

R10 and C11, with C13 providing a high frequency bypass to ensure the op-amp's stability. The negative rail is similarly treated by R11, C12 and C14. To reduce output ripple, C10 has been included as extra filtering between the supply rails, which acts as further reservoir between half cycles.

If the final unit is to be mains powered and housed in a separate case, a transformer with a split (or dual) secondary should be used with this power supply configuration. However, if the circuit board is to be installed into an existing piece of equipment, this configuration may be supplied from a spare split winding of the equipment's existing power transformer.

Power supply 2

The rectifying and filtering process of this supply is identical to that of power supply 1, with the exception of the transformer configuration - only a sin-



Power supply 2 configuration: This arrangement will suit an AC plugpack style of transformer.

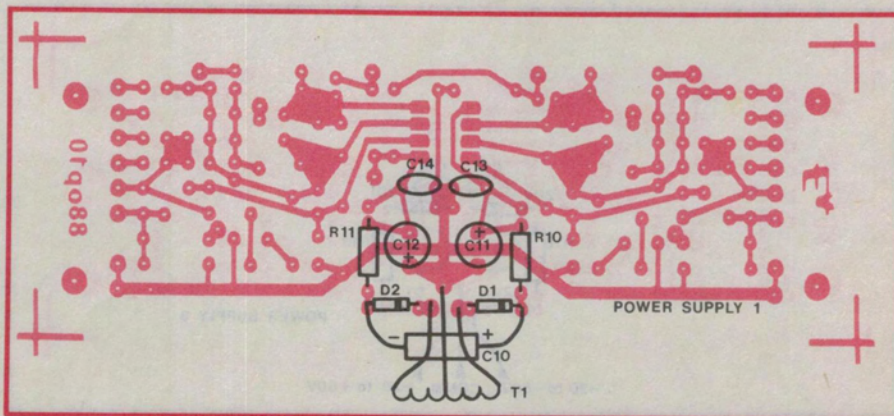
gle winding is required. In this case each alternate half cycle is rectified to produce the two supply rails. Since the half cycles are passed to each rail in an alternate fashion, the extra filter capacitor (C10) of power supply 1 will provide no extra benefit, and has not been included.

This power supply configuration is the logical choice when only a single transformer winding is available, such as the AC output of a plugpack. However, the ripple content may be a little high for heavily equalised, high gain circuits such as the RIAA and NAB preamps. In this situation, another configuration should be used or additional filtering included.

Power supply 3

A typical application of the described circuits may be to install a preamp or tone control stage into an existing audio amplifier. In this case, a spare transformer winding is unlikely to be available, and the amplifier's DC supply rails must be used to power the circuit board. For this situation power supply 3 is required.

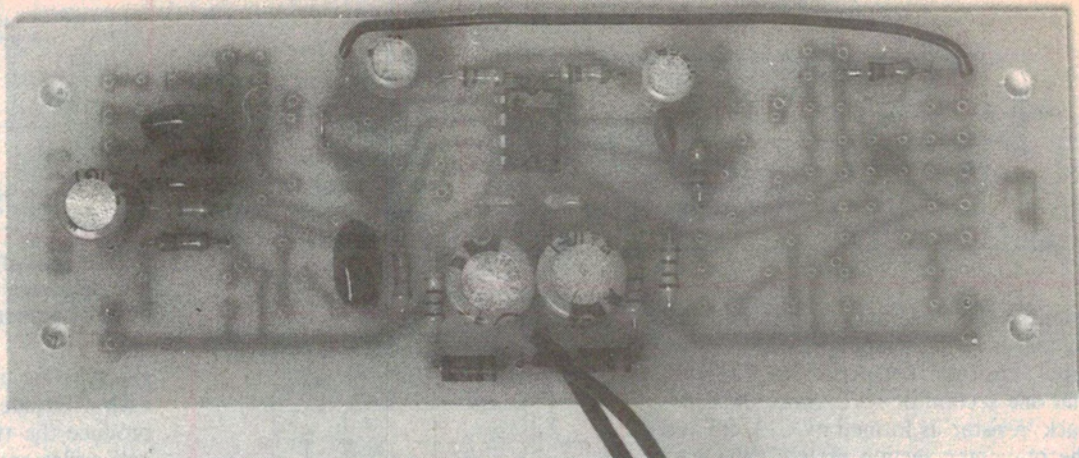
Each half of this supply is composed of a standard zener diode regulator circuit (R10, R11, ZD1 and ZD2), with output filtering as previously described. The two diodes (D1 and D2) are in-



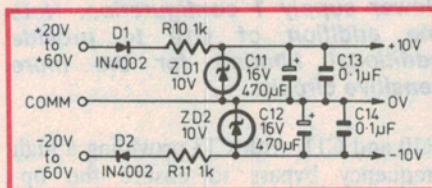
Component overlay for Power supply 1: Note that C10 is mounted on the underside (copper side) of the PCB.

Preamp board

An example of the PCB used in other applications. The LHS is arranged as a second order low-pass filter, while the RHS is a unity gain inverting amplifier.



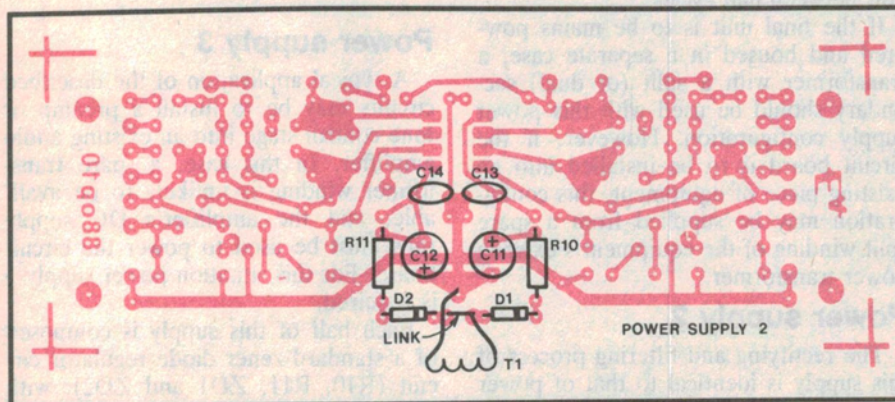
cluded to prevent the output voltage from being rapidly discharged by the collapsing source voltage, which occurs when the amplifier is turned off. Consequently, the preamp's supply voltage is maintained until the power amp has shut down, which in turn prevents any discharging transients (from the preamp) from being transferred to the loudspeakers. In effect, this is a de-thump facility.



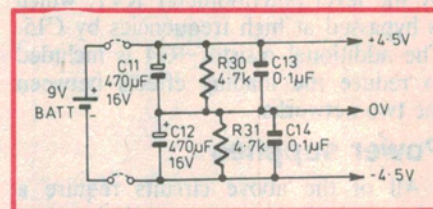
Power supply 3 configuration: This arrangement will produce a stable low voltage supply from existing higher voltage rails.

Power supply 4

Where a low cost portable design is required, this circuit may be used to generate a pseudo balanced power supply of ± 4.5 volts. In most audio circuits, virtually all of the power supply current flows from the positive rail to the negative rail, with very little DC current flowing in the common or zero-volt line. In fact, this line is more of an



Above: The component overlay for Power supply 2.

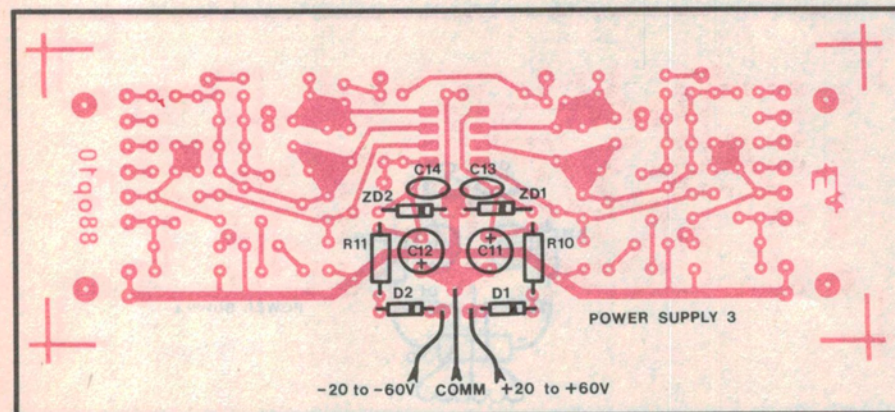


Power supply 4 configuration: This single battery arrangement produces a pseudo zero-volt line by the voltage divider action of R30 and R31.

AC reference and is held to a low impedance by the action of C11 and C12, which allows the DC referencing resistors (R30 and R31) to be a reasonably high value. The aim of course, is to keep the battery current consumption to a minimum.

For a higher supply rail and increased output headroom, two 9 volt batteries may be wired in series, with their centre connection taken to the zero-volt line. In this case, R30 and R31 may be omitted.

When using one battery or any other single DC source, the negative side of this source may be tied to ground or the common connection of other circuitry. In this situation the input and output of our circuit is biased at half of the supply rail, and must be AC coupled to the other circuitry. The resistor which establishes the DC potential at the output



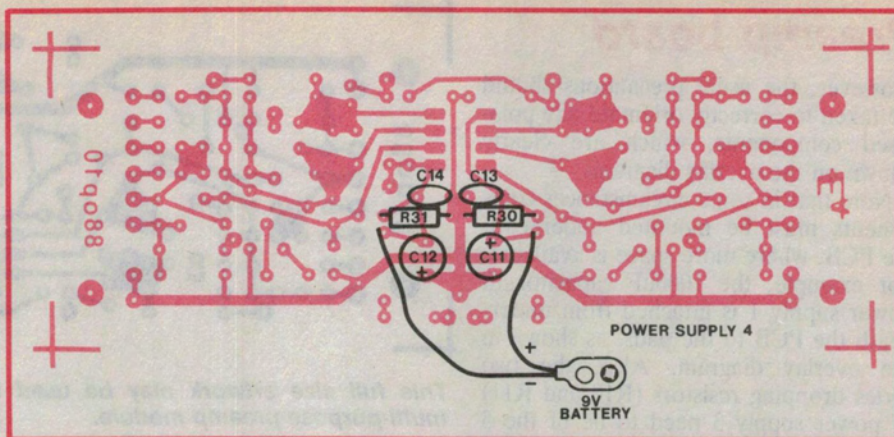
Component overlay for power supply 3: Note that for supply voltages above 35 volts, R10 and R11 should be 5 watt types and mount underneath the PCB.

(R5) is normally returned to the common line, as shown in the component overlays. In the above circumstances, this resistor should now be connected to the negative rail (now the common point) via the alternative pads on the PCB.

Construction

Once the components have been selected for the chosen audio stage/power supply combination, and the PCB checked for any etching anomalies, the construction may begin.

Assembling selected components on the PCB is quite straightforward, and there should be little difficulty in constructing any of the described circuits.



Component overlay for power supply 4. See text for the alternative connections when using two batteries.

PARTS LIST

All versions

- 1 PCB code 880p10, 125 x 45mm
- 1 dual op-amp, LM833 or similar
- 1 10uF 50V bipolar electrolytic
- 1 180k 1/4W resistor

RIAA preamp

Resistors

- (1/4 watt, 5%): 1 x 56k
- (1/4 watt, 1%): 1 x 200 ohms (R4), 1 x 9.1k (R2), 1 x 100k (R3)
- Alternative resistors (1/4 watt, 5%): 1 x 390 ohms (R4), 1 x 18k (R2), 1 x 220k (R3)

Capacitors

- 1 47uF 16V PC-mount electrolytic
- 1 0.47uF metallised polyester
- 1 27nF metallised polyester (C4), alternative: 15nF
- 1 8.2nF metallised polyester (C3), alternative: 3.9nF
- 1 82pF ceramic

NAB preamp

Resistors (all 1/4W, 5%)

- 1 x 180 ohms, 1 x 3.3k, 1 x 180k, 1 x 470k

Capacitors

- 1 47uF 16V PC-mount electrolytic
- 1 0.1uF metallised polyester
- 1 18nF metallised polyester
- 1 15pF ceramic

Balanced mic preamp

Resistors (all 1/4W, 5%)

- 1 x 1k, 2 x 1.8k, 2 x 56k

Capacitors

- 2 x 82pF ceramics

Unbalanced mic preamp

Resistors (all 1/4W, 5%)

- 1 x 1.8k, 1 x 56k, 1 x 470k

Capacitors

- 1 10uF 16V PC-mount electrolytic
- 1 0.1uF metallised polyester
- 1 15pF ceramic

Mixing stage

Resistors (all 1/4W, 5%)

- 1 x 4.7k, 5 x 10k

Capacitors

- 1 470pF ceramic

Tone control stage

Resistors (all 1/4W, 5%)

- 2 x 3.9k, 3 x 15k, 1 x 68k

Potentiometers

- 1 x 25k linear, 1 x 100k linear

Capacitors

- 1 1uF 50V bipolar electrolytic
- 1 39nF metallised polyester
- 2 3.9nF metallised polyester

Power supply 1

- 1 transformer, 7.5-0-7.5V AC at 150mA (or similar)

Resistors

- 2 x 22 ohm, 1/4 watt 5%

Capacitors

- 1 1000uF 25V axial-mount electrolytic
- 2 470uF 16V PC-mount electrolytics
- 2 0.1uF monolithic ceramics

Semiconductors

- 2 1N4002 diodes

Power supply 2

- 1 transformer or AC plug pack, 7.5V AC at 200mA or similar

Resistors

- 2 x 22 ohm, 1/4 watt 5%

Capacitors

- 2 470uF 16V PC-mount electrolytics
- 2 0.1uF monolithic ceramics

Semiconductors

- 2 1N4002 diodes

Power supply 3

Resistors

- 2 x 22 ohm, 1/4 watt 5%
- 2 x 1k, 1 or 5 watts (see text)

Capacitors

- 2 470uF 16V PC-mount electrolytics
- 2 0.1uF monolithic ceramics

Semiconductors

- 2 1N4002 diodes
- 2 10V 1 watt zener diodes

Power supply 4

Resistors

- 2 x 4.7k ohm, 1/4 watt 5%

Capacitors

- 2 470uF 16V PC-mount electrolytics
- 2 0.1uF monolithic ceramics

Preamp board

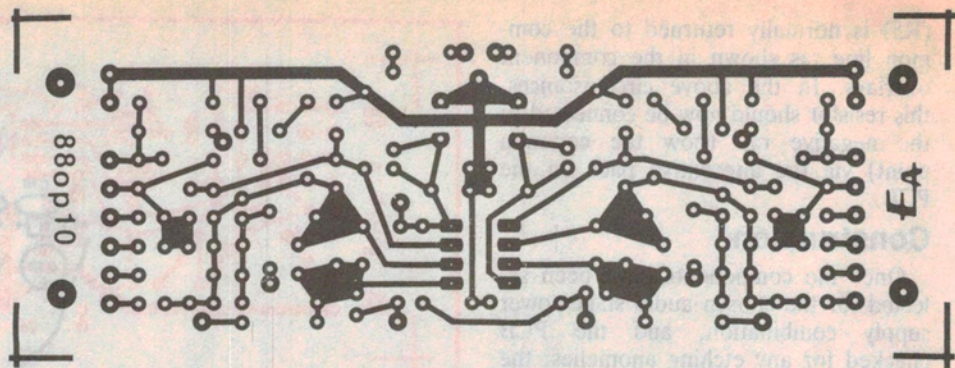
However, the usual precautions should be taken to correctly orientate any polarised components, which are clearly shown on the overlay diagrams.

Note that in some circumstances components must be mounted underneath the PCB, where more space is available. For example, the 1000uF capacitor in power supply 1 is attached from underneath the PCB to the pads, as shown in the overlay diagram. Also, the two series dropping resistors (R10 and R11) of power supply 3 need to be of the 5 watt type for source voltages above about 35 volts, and need to be mounted underneath the PCB.

If the available components are too large or small for the indicated positions, there will usually be an alternative pad position to suit the spacing of this component. In fact, it is quite easy to chop and change the layout of a given design to suit most physical requirements. Such are the joys of a multi-purpose PCB!

Component changes

Although the described circuits have been tested with the component values as shown, the performance parameters



This full size artwork may be used to etch your own PC boards for the multi-purpose preamp module.

may be modified quite easily. By using standard op-amp equations and noting the text for each of these circuits, alternative components may be calculated to satisfy most requirements.

Depending upon the associated circuitry, many of these circuits may be direct coupled by omitting the input and output capacitors. However, bear in mind that the input bias current of a typical bi-polar op-amp (such as the LM833), will produce a slight *positive* offset voltage at its input terminals. Also the output will tend to compensate by sitting at a slightly *negative* potential.

These small offsets may be used to advantage if the circuit does not have to cope with external DC levels. That is, the more expensive bipolar style capacitors may be replaced with standard polarised electrolytics, and biased with these offset voltages in mind.

So there it is, a universal function block that should have many times the number of applications we have shown. There's no doubt it will be popping up in the future for other two op-amp circuit requirements. In fact, the PCB has been designed with active filters in mind – a subject we have not recently covered...yet!