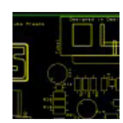
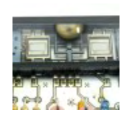
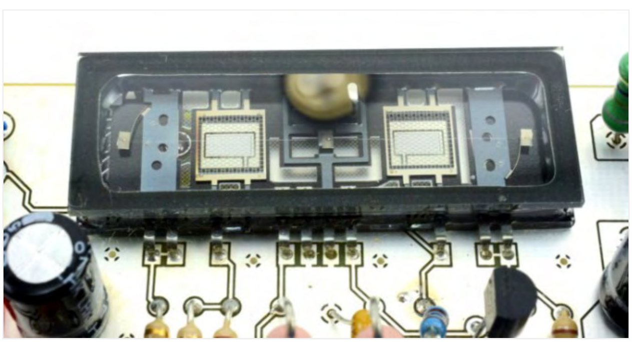
(/designspark/user/karlwoodward)

karlwoodward (/designspark/user/karlwoodward)





Design of a Korg Nutube Amplifier Part 1: Tube Basics



This is the first in a multi-part series exploring the design of a "guitar pedal" for amplification and distortion, going all the way from project start to a finished working design and making use of the Korg Nutube. We will be using only free design resources such as DesignSpark PCB (https://www.rs-online.com/designspark/pcb-software) so that it is easy to follow along and add your own touches to the design.

Why a guitar pedal?

A guitar pedal is the simplest and least restrictive amp we could pick. The term guitar covers so many devices that whatever effect is added, there would probably be a pedal to cover it.

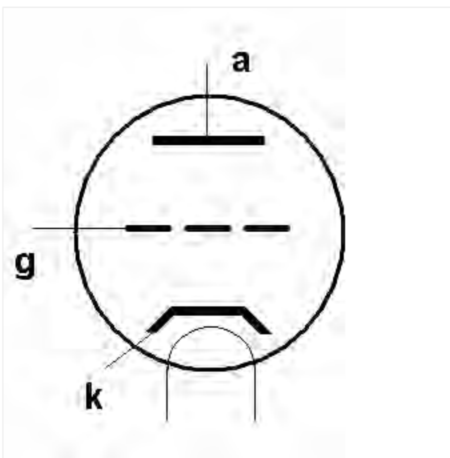
Also, not all guitar pedals have pedals — some simply amplify, some distort and some have a pedal to control the effect, whereas others a potentiometer. This leaves some leeway, allowing us to design around the device. While this may seem counter-intuitive, it will become useful later when we discuss some of the limitations of the amplification device.

Audiophiles love tubes

Sound and music are so subjective and something that would sound perfect to one person may sound awful to another. So it's quite unlikely that we'll come to a consensus regarding tubes vs. transistors. Tubes do change the sound as they amplify and it's often said the sound is "warmer". Without getting too deep in the rabbit hole this comes from many factors; some tube amplifiers add noise, while others have a low-frequency response and amplify the bass more than treble. Maybe it's simply the electrons are more angry in a tube than in a transistor, who knows!

Tubes are valves

Almost everyone has heard of a tube but may not know how they work. Just like semiconductors there are/were many types of valve, however, the staple was the triode and below is its symbol.



The triode is a simple device and likely much easier to understand than its modern replacements, transistors. It consists of three elements and you may recognise two of the names, anode and cathode:

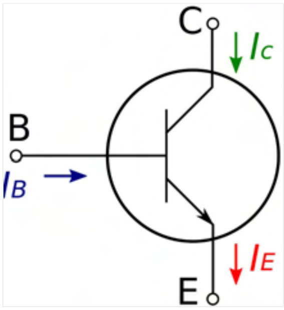
The cathode (k) also known as the filament, simply put is an electron source. In a hot cathode tube the electrons "boil off" — technically "thermionic emissions", but we like the image of very angry boiling electrons. This effect is created by heating the filament to very high temperatures (thousands of degrees), as it gives the electrons the energy to escape the work function of the metal in the cathode, or in other words "boil off". Coincidentally this is one of the reasons why old tubes get very warm and use lots of power.

The anode (a), also referred to as the plate, is where those boiled off electrons are accelerated to. This acceleration of electrons necessitates the plate is at a high potential of up to several hundred volts (or more in some cases). This anode/cathode arrangement was the design and is inherited from the first valves, the diode (yes it works the same as the silicon version).

The grid (g) is where things get interesting: by adjusting the voltage by a tiny amount on the grid with respect to the cathode, the electrons can be attracted or intercepted at the grid. This causes a much bigger change at the anode/plate, creating voltage amplification.

Voltage amplification vs. current amplification

Having got basic valve theory covered it's time to look at everyone's favourite amplification device of choice, the NPN transistor.



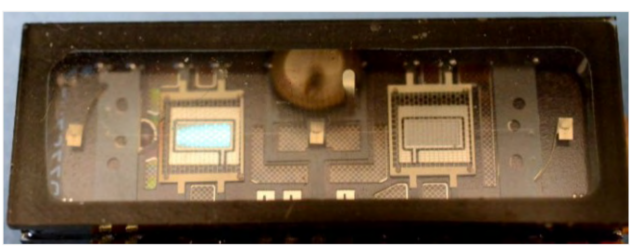
Note that while the end effect of these devices is similar — and in some ways their construction — they do not operate in the same way. The tube amplifier is a voltage amplification device and a MOSFET may be closer to a tube in actual function. A bipolar transistor is a current amplification device, which is subtly different.

In the case of the tube, if we apply a voltage at the gate the voltage at the plate will change by the gain multiplied by the input. I.e. Vp=Gain * Vg.

In the case of the NPN above, if we provide a voltage to the base it will act like a forward biased diode, rise to 0.6-0.7V, remain there and the base current will increase accordingly. If the source is not current limited the transistor will "pop" quite literally. This is why we have a base resistor which will limit this current. When we use a bipolar transistor amplifier we have to control the current into the base and vary this, not the voltage.

The gain again is quite simple and Ic= gain *Ib. Given a fixed impedance this can become a voltage (V=IR). This difference is an important one, not to be forgotten and means these circuits are not directly comparable. This is also one of the more tangible audiophile differences, driving your speakers via voltage will produce different characteristics than current.

So why tubes?



For the first time in a while (a long while) there is a new tube on the market, the Nutube (144-8943) (/designspark/purchase-product/1448943?cm_mmc=en-ds-_-web-_-ds%3Ainspiration%3Atechnology-hub%3Atechnology-lifestyle%3Adesign-of-a-korg-nutube-amplifier-part-1-tube-basics_bp-_-1448943) and (144-9016) (/designspark/purchase-product/1449016?cm_mmc=en-ds-_-web-_-ds%3Ainspiration%3Atechnology-hub%3Atechnology-lifestyle%3Adesign-of-a-korg-nutube-amplifier-part-1-tube-basics_bp-_-1449016). They aim to behave just like the triode, but without a few of the more problematic aspects of a standard triode. While the Nutube behaves like a pair of triodes, the construction is different. and more reminiscent of a Vacuum Fluorescent Display (VFD). There is a good reason for this and they are based on VFD technology.

A VFD is not a lot different to a tube; traditionally they would have a hot cathode, an anode/plate and a grid to control electron flow. The difference being there is a phosphor on the anode which glows when electrons bombard it. Noritake Itron Corp has found a way to create some gain during this process and hence the creation of the KORG Nutube.

In modern electronics, power has become a major concern and unlike the VFDs of old, the modern equivalents have adapted with the times and are very power efficient. The working voltages have dropped meaning the Nutube can work on as little as 5VDC, right up to 80VDC — although we wouldn't recommend going so high as creating that kind of voltage is tricky, dangerous and comes with a risk of shock. 12V would be a much more reasonable voltage to work with.

At this point, we should have a quick look at the design considerations/pros and cons of the Nutube.

The Nutube has the following benefits:

- Low power
- Safe operating voltages
- High reliability
- Small

It also has the following problems that must be considered: remember it's a VFD, not a power amp!

- Low gain
- High source impedance

Low gain

Comparing the KORG Nutube to a traditional triode like the 12AX7 its gain is pretty small; the 12AX7 typically has a gain of 100, whereas the Nutube has only around 5. This will limit the gain we have in a single Nutube to around 25 maximum (assuming no other factors and using both stages). This is likely enough for most purposes and will be fine for our pedal application.

High source impedance

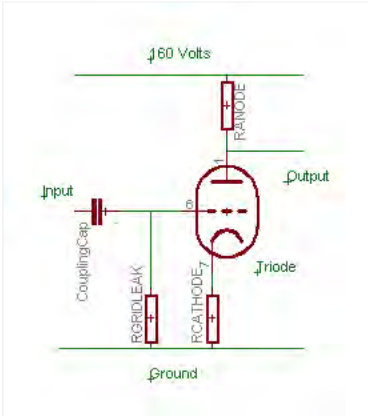
In addition to the low gain, the plate (anode) source impedance is around 300kOhms. This means that there is very little current available from the amplifier (e.g. 30-40uA level for 12V plate).

In comparison, the 12AX7 would be 62.5kOhms but with 250V plate voltage, leaving the drive around the mA level (at least 100 times more than the Nutube). Also since power = volts * current there power increase is a lot more than the Nutube can manage.

This makes the device unsuitable for most output drive stages without some form of buffer.

Next steps

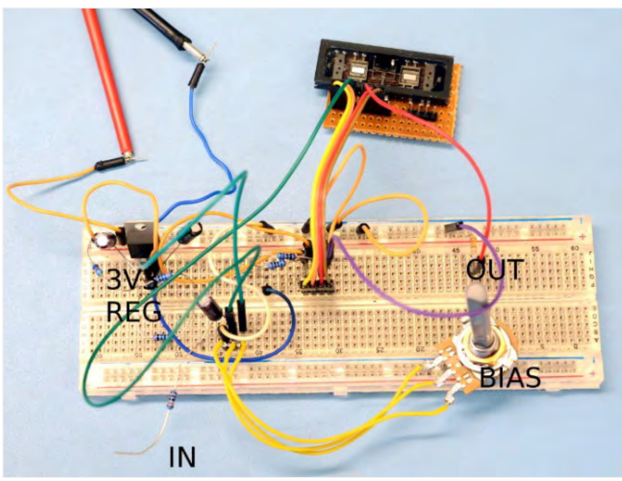
Now we have the fundamentals of tubes under our belts we need a basic amplifier circuit. Below is a typical triode circuit for a device such as the 12AX7, which would be a good starting point for our Nutube amplifier.



In the case of the Nutube, we have both ends of the cathode to connect. The cathode voltage should be 0.7V. Luckily for us in the Nutube datasheet, there is a reference schematic and it shows the cathode voltage being generated by connecting it to 3.3V via 150R. This means that the cathode is taking 17.3mA, which via Ohms law gives us a cathode resistance of around 40Ohms.

With this information, we can either leave the circuit as per the reference or create our own cathode driver. The default 300k anode resistor is probably a good start, but we'll look into further this as we progress with the design.

Finally, unlike the circuit above, the grid needs a bias and so placing a pot to 3v3 will allow us to bias the tube accordingly. Consider this pot as a variable bias voltage. From this, it's a simple task of breadboarding up the design for testing. Note that the bias current is quite high so this circuit must be a low(ish) impedance.



Final words

Having had a good look at both traditional tubes and the Nutube, we are in a good position to start looking at the amplifier design and other considerations — even building up a test circuit. If you are following along now would be a good time to get the scope out and look at the tube characteristics for a given input. At this point, it's a good time to say the dreaded words: ***to be continued….*** Next time we'll look at this basic circuit and what we need to do to turn this into a practical amplifier.

UPDATE: Part 2 is now available here... (https://www.rs-online.com/designspark/design-of-a-korg-nutube-amplifier-part-2-prototype)

See you next time.

Karl Woodward


(/designspark/user/karlwoodward)

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(/designspark/comments/8073/vote/up)
pde14
0
January 31, 2018 10:15

"A bipolar transistor is a current amplification device"
It is extraordinary how this myth continues to propagate. The fundamental equation of bipolar junction transistor operation is the Ebers-Moll equation which shows that collector current is a function of base-emitter voltage, The BJT is a voltage-controlled current source - this is based on the physics of the device and has been known since at least 1964 according to my $2 1964 copy of the GE transistor manual. Or see The Art of Electronics by Horowitz and Hill for a modern reference.
The myth of current control stems from the fact that in many transistors the base current is not negligible. This stems from manufacturing constraints, its not possible to make the base layer infinitely thin (although super-beta transistors get close at the expense of very low breakdown voltages).
An analogy would be making a triode using very thick wire for the grid. The grid current would then be non-negligible but the physics of the triode (anode current controlled by grid-cathode voltage) would be unchanged.
The BJT is not a current amplification device - the collector current is determined by the base-emitter voltage (physics of the device) and the base current is some small fraction of the collector current (manufacturing limitations). Collector current determines base current, not the other way round.

(/designspark/comments/8035/vote/up)
Rezzonics
0
January 22, 2018 10:00

If anybody is interested I tried to create Spice models for NuTube using Koren's model:
rezzonics.blogspot.fr/2017/05/korg-nutube-6p1-vs-12ax7-starved-tube.html (http://rezzonics.blogspot.fr/2017/05/korg-nutube-6p1-vs-12ax7-starved-tube.html)

(/designspark/comments/7901/vote/up)
DBell
0
January 5, 2018 11:33

A new tube, indeeed! Very interesting.
A couple comments about Part 1:
"Finally, unlike the circuit above, the grid needs a bias and so placing a pot to 3v3 will allow us to bias the tube accordingly."
Unlike the classic circuit, the NuTube requires a *positive* grid bias, which you can derive from 3V3, as stated. The classic triode (all the way back to Lee DeForest) requires a negative control grid bias, relative to the cathode. In the classic circuit quoted, that's derived by raising the cathode above ground, using RCATHODE.

(/designspark/comments/7743/vote/up)
PeterPan
0
November 21, 2017 08:56

I'm just finding out about the Korg Nutube device today, and I'm excited. For a while now I've wanted to build something like a push-pull output stage using triodes like 12AX7s, in order to take advantage of the transfer curve of a triode in a distortion pedal. This device would certainly make it more likely any experiments like that will successfully fit into a pedal size box! All I see for purchasing these devices here in that advertisements on the design-spark pages ar in UK currency. Has Designspark made these availble for USA purchase?

(/designspark/comments/7739/vote/up)
JohnAHind Moderated
0
November 20, 2017 15:22

I cannot help suspecting there is a lot of voodoo nonsense around valve amplifiers and vinyl recording ("angry electrons" indeed!). Is it not likely that the characteristic imperfections of these technologies simply trigger nostalgia? (Although personally, I prefer my music without hisses and pops.) I wonder has anyone tried measuring the transfer functions and noise characteristics and implementing them in a DSP? I bet that if you did that the audio snobs would be unable to tell the difference in a double-blind test! The feature could then simply be added at no cost as an optional software filter to any digital audio player.

I get the "steampunk" appeal of a traditional radio.

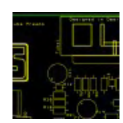
(/designspark/comments/7712/vote/up)
jeffhlrl
0
November 14, 2017 08:32

Hi Karl, your basic guide to the transistor is stretching the truth somewhat. Transistors are ALSO voltage operated devices, BUT base current flows as a result of that voltage, beta of hFE vary wildly with many operating parameters but the voltage operation is much more predictable over a large range of parameters and will allow you to realise much higher gain if you design for this. Adding a base resistor will help stop parasitic oscillations, but for an amplifier circuit will almost always add distortion. (So for a guitar amp that might be a plus...) As far as I know circuit simulators based on the SPICE softare use the voltage operation to perform simulations and use the Ebbers Moll equation and perhaps more modern derivatives rather than just the beta value. Yes, I accept that there are those circuits whose design and operation are purely based on beta, but that is a design choice rather than a fundamental facet of transistor operation. Ok, that said, these new valves look really cool :) Thanks for the article!

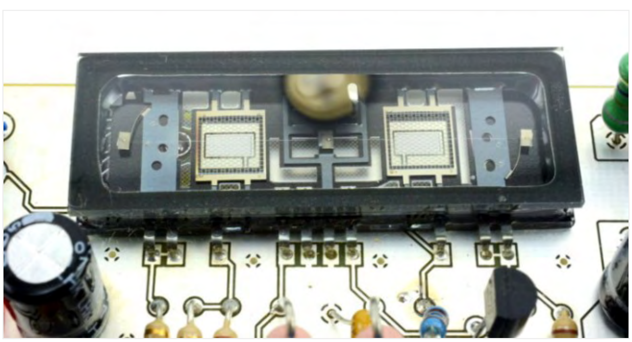
(/designspark/comments/7673/vote/up)
jskuhns
1
November 6, 2017 07:46

(/designspark/user/karlwoodward)

karlwoodward (/designspark/user/karlwoodward)



Design of a Korg Nutube Amplifier Part 2: Prototype

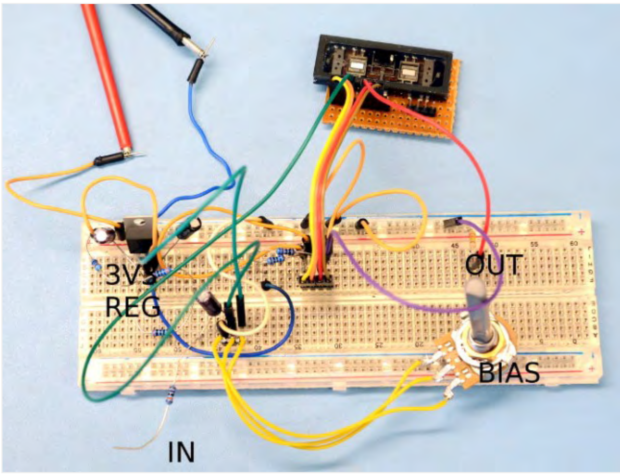


This is the second in a multi-part series looking at the design of a Nutube-based guitar pedal. The first provided an introduction to vacuum tubes and if you missed it you can find this in Part 1 (https://www.rs-online.com/designspark/design-of-a-korg-nutube-amplifier-part-1-tube-basics). We left off having started to look at amplifier design and building a small test circuit.

Minimum circuit

The circuit above is the bare minimum required for a single-stage Nutube amplifier. It consists of the following parts:

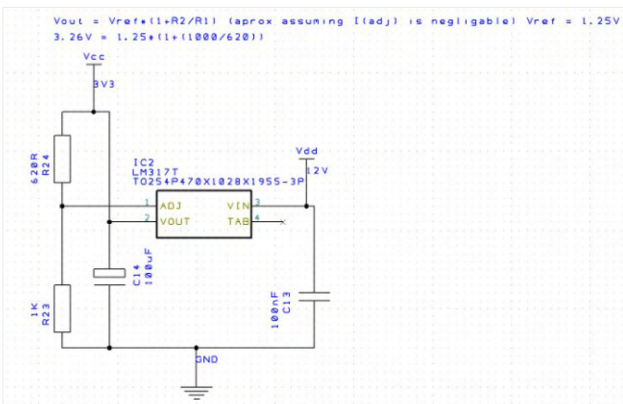
- A 3v3 regulator, in this case, an LM317T
- An input stage



Bias

An output pull-up resistor

A regulator is required



(Minimum LM317 Circuit, Excuse the reversed symbol!)

The Nutube requires a bias of around 2.5V and the filament needs 0.7V. The plate voltage is independent of this, so regardless of the operation voltage we need to provide these low voltage supplies.

Since the supplies are both low current (low mA) we can use a linear regulator, and just like the reference design, we can supply both of these from a single supply by resistively dividing it down.

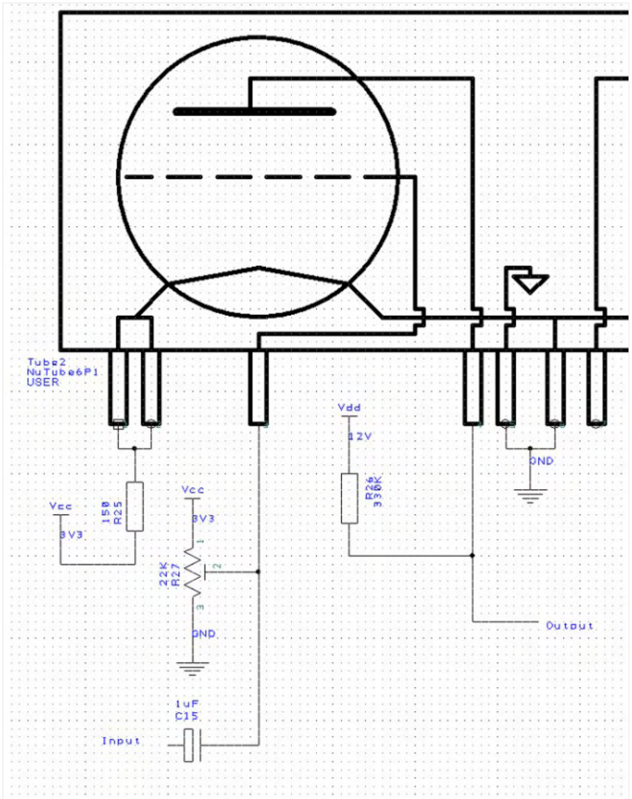
Without getting too deep into the design a linear regulator, they are not efficient and will create heat while dropping voltages. The equation is P=(Vin-Vout) * I. In other words: if the voltage drop or current is high, so is the power. Keep this in mind if adding additional circuity to the design and don't try taking Amps!

The advantage of using a linear regulator is it's simple and we can keep system noise down in comparison to a switching regulator, at the expense of additional power loss.

Passive input/output

The input stage is just a 1uF capacitor for AC coupling.

The bias is created by using a 22k potentiometer to allow adjustment. This will in effect provide a variable supply of 0V – 3.3V. The current available



from 22k is 150uA, which should be more than enough to provide the 6uA grid current.

The output is just a pull-up to the anode voltage (this will be the amp output voltage if the output is not AC coupled). The value of this pull-up can be adjusted to provide more output current, but it is important to stay within the power limit of the tube, which is 1.7mW.

Test setup

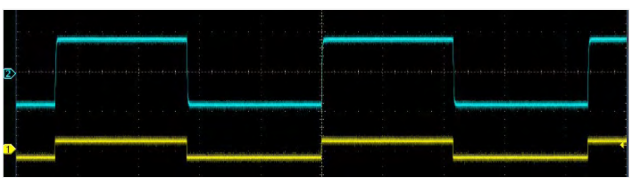
To test the circuit we used an older sine wave generator we have, however living in the age of the Arduino you could simply build your own using an Arduino Due (http://uk.rs-online.com/web/p/processor-microcontroller-development-kits/7697412/) by following this (https://www.arduino.cc/en/Tutorial/DueSimpleWaveformGenerator) tutorial. You will not be able to tell much of what's going on with just a multimeter, so at this point, it would help if you had access to an oscilloscope.

The first thing we need to do is to adjust the bias so that it sits at around 2.5V, by adjusting the pot a DVM can be used for this.

Following this, we inject a sine wave of around 200mV (quite a reasonable figure for a guitar pickup). As can be seen in the plot above, the Nutube is amplifying by around 3.5 times. This is to be expected since 5 times is a maximum and less is likely due to the load we are providing creating a potential divider….. But we have no load, or do we?

We are using an oscilloscope to measure the output and the equivalent circuit of the oscilloscope will end up being a resistor to ground of 1M impedance. This is only 3x the anode resistance so it will have a significant effect. This will need addressing in the final circuit as we cannot rely on a 1Meg (or more) input impedance in the device attached to our output.

Next, we can try a few other waveforms: a much higher frequency sine and a square wave (pretty nasty for an amp).



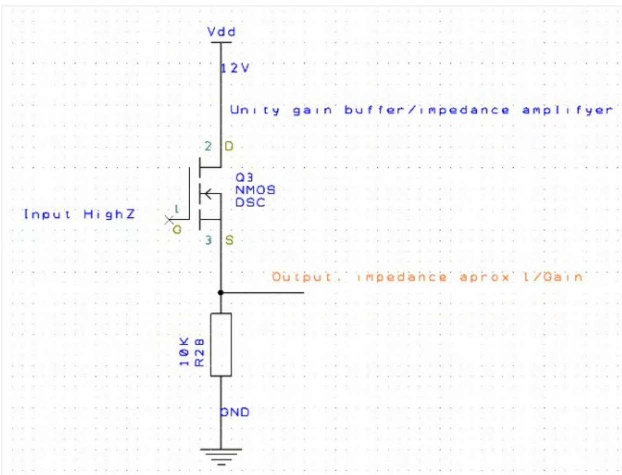
The high-frequency wave doesn't look to be attenuated or distorted (visually anyway), so the Nutube is doing a good job and has sufficient bandwidth for audio at least. The square wave is interesting as it gives us an indication of the stability of the amplifier; the very sharp start/stop edges can be used to check something called step response. A stable or over damped system will not overshoot in such a case. The Nutube is definitely on the over-damped side of the equation. This is a good thing and should help produce a "sound effect" which will change the tone of the audio.

Finally, we should test the maximum input before we hit distortion. In this case around 1Vpk-pk. Any more than this and the output starts to “clip” and will distort (this may actually be the desired effect). The good news is we can change this clipping threshold by adjusting the bias voltage.

Next steps

At this point, we are almost ready for committing to CAD. We need to consider the output impedance and possibly the input too. Although if we are being fed by another device it will be expecting a 10k impedance, which we are not too far from using a 22k bias pot.

The output would benefit from some form of unity gain amplifier (https://en.wikipedia.org/wiki/Buffer_amplifier), which could be an op-amp or a simple FET/BJT circuit that will simply change from a high impedance to a low(er) impedance output. This output impedance may also be a concern for the cascading of two amplifiers, so AC coupling will be required.



We may want to try some audio through the design, although the breadboard is pretty noisy so we may not get exactly what we expect out of it. In addition, at this point, it would be a good idea to test out some unity gain output amplifiers too.

Final words

Having tested our Nutube and gained confidence in the circuit, this is a good point to break off and add the words, **to be continued next time**. If you are impatient, at this point building a stripboard circuit is quite possible and by the end of the next post, we will be at a point where we can commit to CAD and get a prototype built.

Read 'Design of a Korg Nutube: Part 3' now... (https://www.rs-online.com/designspark/design-of-a-korg-nutube-amplifier-part-3-pcb-computer-aided-design)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(/designspark/comments/7740/vote/up)
dave oxborrow Moderated
0
November 20, 2017 15:22

I have read with great interest this article using this new type of valve. Apart from low power requirement, low operating voltages and compact size, I don't think it has a lot going for it. The gain is very low by any standards and the output voltage swing is only a volt or so. As a part-time muso, builder and repairer on many guitar amps over a period of more than 30 years, you can make a simple all conventional valve based amp with around 15 watts of power and a great sound
using those antiquated things we call valves. Part of the sound of a serious musician-friendly amp is choosing the right operating points for the valves and the frequency response of the tone controls.

(/designspark/comments/7738/vote/up)
B-DOG Moderated
0
November 20, 2017 15:23

Forgive a naive question. I need an amplifier and#wa wondering if this could be used as a "normal" amplifier leaving out any guitar-specific. I am obviously not well versed in Analogue electronics. I do like the idea of a valve amplifier though.

karlwoodward Moderated

November 21, 2017 15:33

@B-DOG It should be ok, you may need to put a " impedance buffer" up front depending on your source impedance. The design in this series is not going to be overly guitar specific but we are designing a mono amplifier.

(/designspark/comments/7710/vote/up)
amonteiro
0
November 13, 2017 11:52

I have been building overdrive/distortion mechanisms since I starting playing with electronics (and electric guitars). This includes amplifying with different types and amounts of non-linearity using transistors, operational amplifiers (OA) with diodes, leds and mixed, and also more recently using digital signal processing.
It is always difficult to summarize something about this theme but my general understanding is that tubes sound well because they do not amplify linearly.
There is almost always some degree of distortion, subtle at low levels and getting more and more noticeable IN A GRADUAL MANNER, as you increase the drive.
So, one interesting thing to do with this tube is to drive it into non-linear zones perhaps with an OA, from light to high overdrive.
The biasing can play an interesting role in making the output more or less asymmetric.

The rest is filtering: before the nonlinear element, to get an approximately even level throughout the notes range a guitar; and after, to control the amount of high frequency in the spectrum generated by distortion. But there would be so much to say about the filtering alone...

Rezzonics

January 22, 2018 09:48

@amonteiro I think that tube distortion is pleasing to the ears because they have predominantly even harmonics, which musically correspond to the same note, one o more octaves higher, while odd harmonics are out of tune. The soft and asymmetric clipping contribute to this type of distortion more pleasant to the ears.

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karlwoodward (/designspark/user/karlwoodward)

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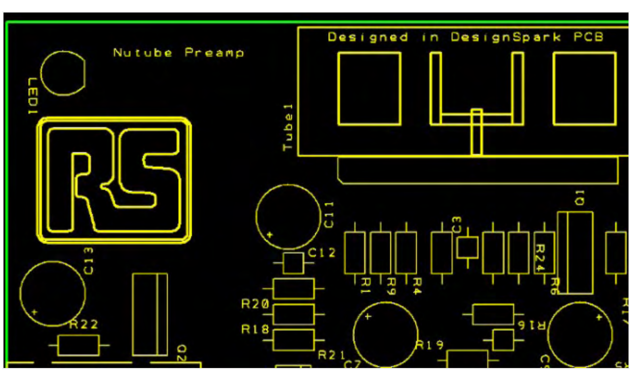
Design of a Korg Nutube Amplifier Part 3: PCB Computer Aided Design



This is the third post in a series about creating a guitar pedal style amplifier. Last time in Part 2 (https://www.rs-online.com/designspark/design-of-a-korg-nutube-amplifier-part-2-prototype) we took a look at creating a breadboard prototype. Following which we probably have enough data to commit a circuit design to CAD.

Computer-Aided Design

Long gone are the days of drawing PCBs using sticky tape or a pen; yes this was the way in the distant past. However, the modern way is to use a computer program to create both schematics and then a PCB from these schematics. Just like your favourite word processing app, there are many CAD programs out there.

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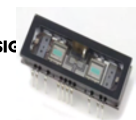

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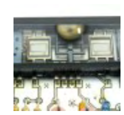
karlwoodward



Design of a Korg Nutube Amplifier Part 2: Prototype

karlwoodward

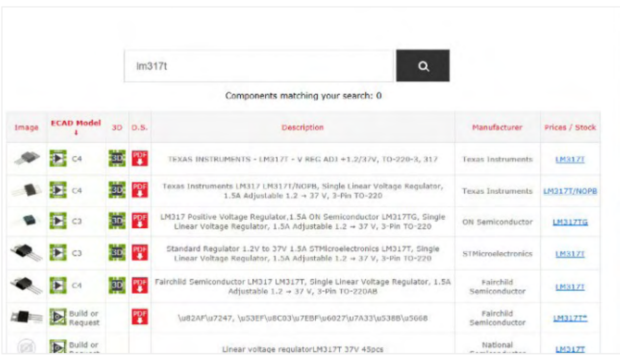
There are CAD programs that are quite eye-wateringly expensive (the price of a high-end car) and requiring a reasonable amount of training and experience to use, down to completely free versions that can again need training or be simple to use. In our case, we will use the free DesignSpark PCB (https://www.rs-online.com/designspark/pcb-software).

Having used quite a few CAD packages over the years I would say that most have a similar system and operation. DesignSpark PCB is no different and felt quite familiar and intuitive, plus there are also many excellent tutorials that help fill gaps in knowledge.

As with most CAD processes, we will need to go through a few stages: schematic capture, part creation and final layout.

Part creation

One of the great features is that footprints and symbols are provided for a good proportion of the RS catalogue, with a system in place that can help create footprints for some of those that do not. Below is an example: we did not have an LM317T part or footprint, so we followed a link in DesignSpark PCB to http://rs.componentsearchengine.com/ (http://rs.componentsearchengine.com/) to create both schematic and layout symbol/footprints.



lm317t

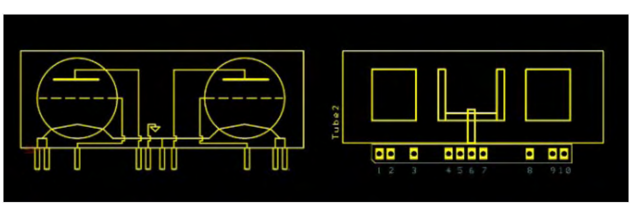
Components matching your search: 0

Image	ECAD Model	3D	D.S.	Description	Manufacturer	Prices / Stock
	C4	3D	PDF	TEXAS INSTRUMENTS - LM317T - V REG ADJ +1.2/37V, TO-220-3, 317	Texas Instruments	LM317T
	C4	3D	PDF	Texas Instruments LM317 LM317T/NOPB, Single Linear Voltage Regulator, 1.5A Adjustable 1.2 → 37 V, 3-Pin TO-220	Texas Instruments	LM317T/NOPB
	C3	3D	PDF	LM317 Positive Voltage Regulator,1.5A ON Semiconductor LM317TG, Single Linear Voltage Regulator, 1.5A Adjustable 1.2 → 37 V, 3-Pin TO-220	ON Semiconductor	LM317TG
	C3	3D	PDF	Standard Regulator 1.2V to 37V 1.5A STMicroelectronics LM317T, Single Linear Voltage Regulator, 1.5A Adjustable 1.2 → 37 V, 3-Pin TO-220	STMicroelectronics	LM317T
	C4	3D	PDF	Fairchild Semiconductor LM317 LM317T, Single Linear Voltage Regulator, 1.5A Adjustable 1.2 → 37 V, 3-Pin TO-220AB	Fairchild Semiconductor	LM317T
	Build or Request		PDF	\u82AF\u7247, \u53EF\u8C03\u7EBF\u6027\u7A33\u538B\u5668	Fairchild Semiconductor	LM317T*
	Build or			Linear voltage regulatorLM317T 37V 45pcs	National	LM317T

As can be seen above there are several parts available. If we wished to make one to match the Fairchild LM317T we could click build/request and follow the guides giving a part within a few minutes.

It would be remiss at this point if we did not point out that, while this is a great feature, a lot of these parts are unverified and therefore not guaranteed to be entirely error free. This is far from unique and would be true of any unknown library — even with the most expensive CAD packages. So as with any CAD library and even those you make yourself — maybe especially those you make yourself — verify!

If you want a custom or specific CAD cell, there is no better solution than creating one from scratch. There are several tutorials (https://www.youtube.com/watch?v=MCWYwkxlOs0) out there and once you get the hang of it you can start creating some exotic CAD cells.



Schematic capture

If you have read the previous articles in this series you may have noted that the schematics previously shown were from CAD packages, most of which were created in DesignSpark PCB. Given there are several excellent

Design of a Korg Nutube Amplifier Part 4: Build and

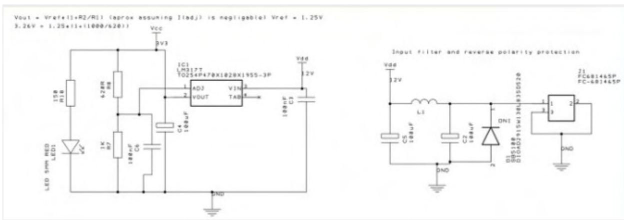
karlwoodward

Design of a Korg Nutube Amplifier Part 5: Finishing

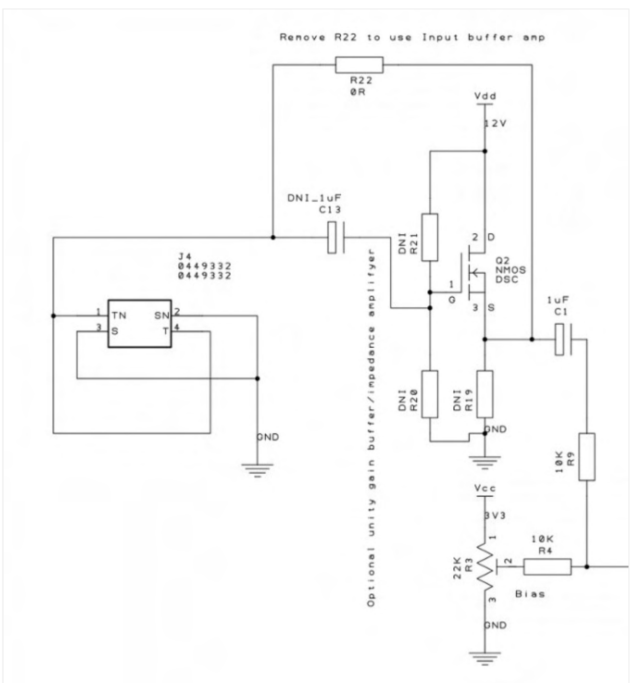
Andrew Back

tutorials (https://designspark.zendesk.com/hc/en-us/sections/202625509) on how to get started, we will not cover how to use the package and instead just the results we get from it.

First, we need power. For our design, we decided to go with a 12V “brick”, but this could easily be a 9V battery (it won't last very long) or 18-24V laptop supply. While the circuit we have designed should work to 40Vdc; the parts we are using have an upper limit and we chose capacitors carefully as overvoltage on electrolytic capacitors can result in rather drastic consequences. Another point of caution with higher voltages is the regulator will get hotter, due to the reasons discussed last time (https://www.rs-online.com/designspark/design-of-a-korg-nutube-amplifier-part-2-prototype).

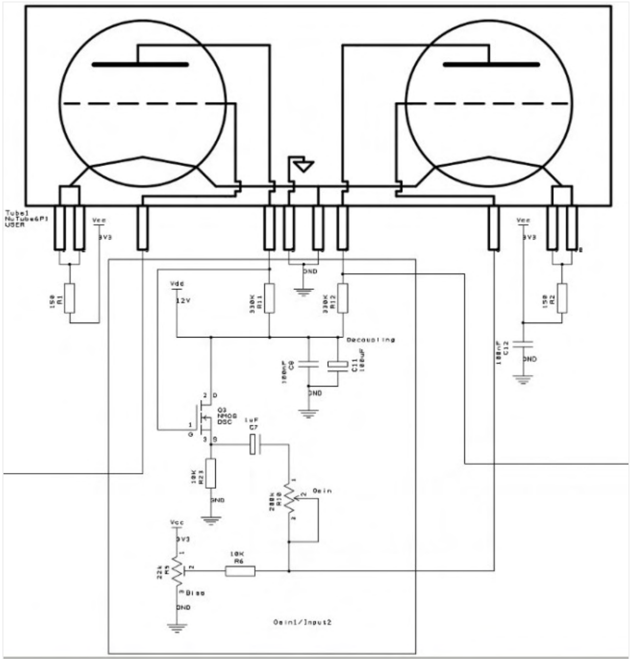


We also added a small CLC filter on the power input. With a large diode for reverse voltage protection, this will rely on either an external fuse or the plug top/power brick current limiting but should save the tube and design in the event of accidental power reversal. We would not advise use with a 12V battery without a fuse, for example.



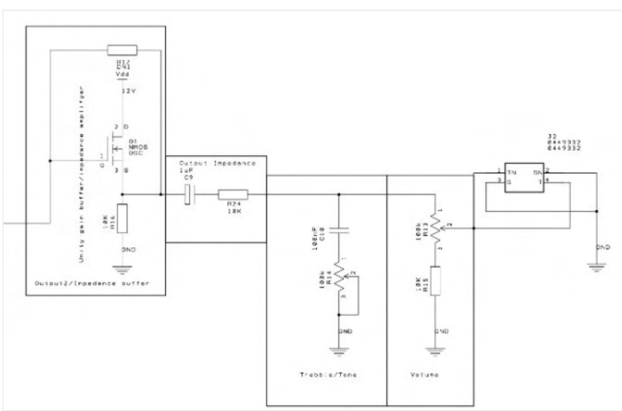
The input circuit looks complicated, but if you ignore the DNI (Do Not Insert) impedance buffer at the input, there is only a short in R22, a capacitor in C1 and 10k series impedance, before the bias which is also buffered by 10k. These 10k resistors provide a little current limiting from the variable supply created by the potentiometer a.k.a. “pot” (this is close to 0R once set to limits).

We have left the buffer out as we assume our source to be another pedal and therefore low impedance, but if you wish to have a high impedance input just fit the impedance buffer.



To cascade the amplifiers (for additional gain) we have added an impedance buffer. Since the Nutube has such a high output impedance it struggles to drive the second Nutube without a little impedance trickery.

We've also added the first in our 3 control pots here; acting like a variable resistor this pot effectively allows us to remove the gain from the first amplifier or add it to the second resulting in around 5-25 times gain from a pair of tubes.



For our output we have another impedance buffer to guarantee a low output impedance, AC coupling to remove the bias induced by the tubes — which also has an output impedance adjustment resistor set by R24 (we used 10k because we had some already) — and followed by two adjustment controls.

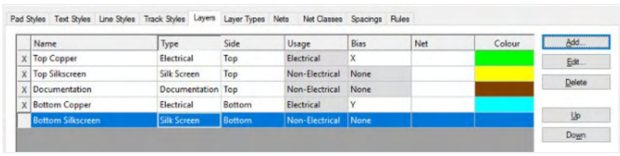
The first control is an RC filter, which will allow us to remove HF by varying degrees. With R14 at 100k there is little effect from the tone circuit, however, as R14 drops the circuit becomes more dominant and will attenuate the output more, especially higher frequencies. By altering C18 this roll-off can be adjusted to suit and the smaller C18 is the higher the frequency before the effect becomes dominant.

Finally, a volume control which effectively divides down the output from 1/11 to 11/1. When the wiper is at pin 1 of R13 the output has 110k to gnd and a 10k source impedance (loud); when the wiper is at pin 3 the output has 110k source impedance and 10k to gnd (quite).

CAD Layout

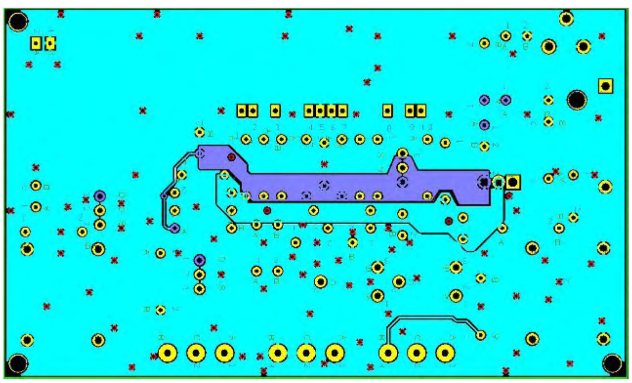
CAD layout has many methods and pitfalls, with each engineer having their own methods and styles. A key to success is to floor plan correctly before you start, as knowing where everything is going to go helps a lot and will make the CAD layout easier. Use of the "rats nest" can help here, but the first design is going to be daunting.

The very first thing to do is think where the boards are to be made since this will influence the layers, track and gap parts and vias used. Different PCB fabricators have different ability's and technology's they can deal with, so this is a key step that should be not be ignored.



Getting everything placed before routing is a good strategy for smaller boards. Sometimes this is not possible but it can help.

Another item commonly missed from designs is probably the most important nets of all, ground and power. It is often put in as an afterthought or thin track, whereas the impedance of the ground plane is key to keeping the system noise down and in the case of the amplifier, keeping noise out of the amp. To this extent we allocated most (as much as possible) of layer 2 of our PCB to ground. This will keep everything common and gnd induced noise low.



The use of "polys" can help. The design shown above is using these flooded copper areas extensively to give a reliable and low impedance supply. Use caution however, as these floods do add a lot of complexity to the design and require some lateral thinking during the layout and floor planning. Close to our hearts, being Yorkshire born and bred, is the side benefit: a board being near 100% copper means less waste as less copper is etched off, resulting in get more copper for your money.

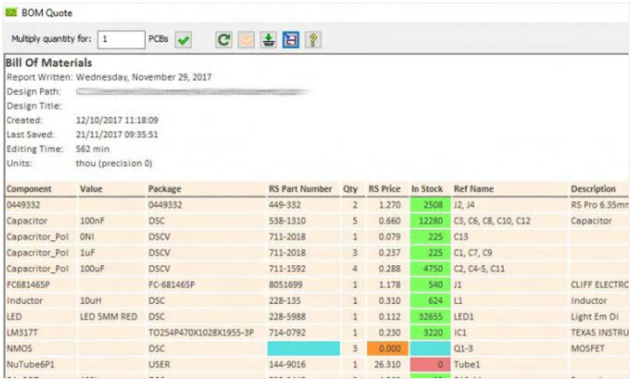
Ordering PCBs

Having routed and placed your parts there are three things left to do:

- Create your manufacturing files in the format required (Gerber most likely)
- Check check and check again everything, including the Gerbers!
- Submit these files to the PCB fab of your choice. DesignSpark PCB has a link for one which is convenient but there are much more out there.

Next Steps

PCB's ordered, we need to kit the BOM (Bill Of Materials). DesignSpark PCB has a link for this and if the parts are set-up correctly it can be ordered directly from the PCB package.



BOM Quote

Multiply quantity for: 1 PCBs

Bill Of Materials

Report Written: Wednesday, November 29, 2017
Design Path:
Design Title:
Created: 12/10/2017 11:18:09
Last Saved: 21/11/2017 09:35:51
Editing Time: 562 min
Units: thou (precision 0)

Component	Value	Package	RS Part Number	Qty	RS Price	In Stock	Ref Name	Description
0449332		0449332	449-332	2	1.270	2508	J2, J4	RS Pro 6.35mn
Capacitor	100nF	DSC	538-1310	5	0.660	12280	C3, C6, C8, C10, C12	Capacitor
Capacritor_Pol	0NI	DSCV	711-2018	1	0.079	225	C13	
Capacritor_Pol	1uF	DSCV	711-2018	3	0.237	225	C1, C7, C9	
Capacritor_Pol	100uF	DSCV	711-1592	4	0.288	4750	C2, C4-5, C11	
FC681465P		FC-681465P	8051699	1	1.178	540	J1	CLIFF ELECTRC
Inductor	10uH	DSC	228-135	1	0.310	624	L1	Inductor
LED	LED 5MM RED	DSC	228-5988	1	0.112	32655	LED1	Light Em Di
LM317T		TO254P470X1028X1955-3P	714-0792	1	0.230	3220	IC1	TEXAS INSTRU
NMOS		DSC		3	0.000		Q1-3	MOSFET
NuTube6P1		USER	144-9016	1	26.310	0	Tube1	

It will then be a waiting game to see if the PCB we just designed works, or if it's a bust!

Next time we'll build up this PCB and check our circuits work. There may be a slight issue, given our guitar playing experience is somewhat lacking and so we may have to cheat and order a 3.5mm – ¼ inch cable.

Karl Woodward

(/designspark/user/karlwoodward)

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Karl is a design engineer with over a decade of experience in high speed digital design and technical project leadership i

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(/designspark/comments/8038/vote/up)
Rezzonics
0
January 22, 2018 09:50

I used 24V in my design, because this is the voltage required to get at least 25W on a Class-D amplifier, this provides a bit more gain, which is 14dB at +12V and 17dB at +30V: rezzonics.blogspot.fr/2017/09/korg-nutube-6p1-vs-12ax7-tube-hybrid.html (http://rezzonics.blogspot.fr/2017/09/korg-nutube-6p1-vs-12ax7-tube-hybrid.html)

(/designspark/comments/7916/vote/up)
DavidH18
0
January 8, 2018 08:55

Hi Karl,
Thanks so much for posting this series and all the explanation. I picked up a NuTube in Akihabara (Tokyo) last month in the hopes of making an interesting guitar pedal so your article series is great. I have been building along and have built something very similar to your design on breadboard. I have just played my guitar through it so I'm pleased it works. Some things I have noticed with my adaptation

(probably due to things I've messed up):
- I'm running on 9V because that is standard guitar pedal voltage
- A high pitched whistling sound
- The guitar sounds a little muffled
I look forward to your next installment with interest!
Thanks once again. David


(/designspark/user/karlwoodward)

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WATCH (/DESIGNSPARK/CONTENT/8449/WATCH)

Design of a Korg Nutube Amplifier Part 4: Build and Test

This is the penultimate post in our series about creating a guitar pedal style amplifier with the Korg Nutubes. We previously left off with ordering PCBs and the nerve-racking wait associated with it. Due to the somewhat unreliable nature of the Mark 1 Human, everyone gets a PCB wrong now and again and it's that certain knowledge that causes those sleepless nights. This tension is also the reason it's so exciting the day PCBs arrive and we had already ordered a kit of parts to build up our amplifier, so we set straight to work on this.

The build

Building up the circuit was a case of soldering the through-hole parts. This is somewhat of a novelty since as design engineers we spend most of our time soldering metallic dust onto pads we cannot see — otherwise known as surface mount components. Having been a while since we soldered up a circuit that you can see with the naked eye, it was a rather therapeutic hour.

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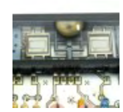
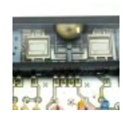


Design of a Korg Nutube Amplifier Part 2: Prototype

karlwoodward



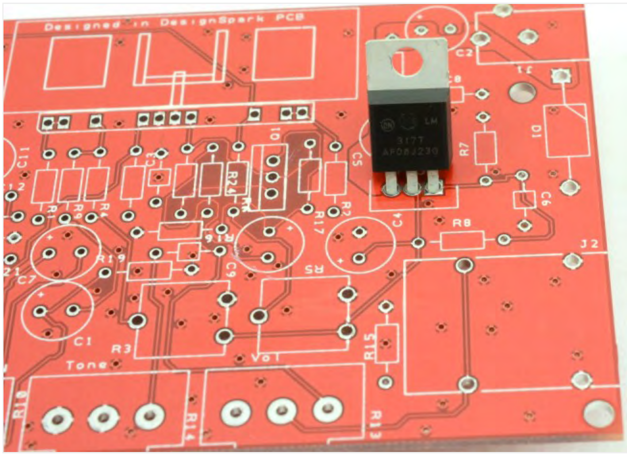
Design of a Korg Nutube Amplifier Part 3: PCB

karlwoodward

Design of a Korg Nutube Amplifier Part 5: Finishing

Andrew Back

The good news is the CAD cells look great: the Nutube fits perfectly, as do the FETs, pots and connectors. The TO220 LM317 is a little on the large side and ideally could do with smaller pads, however, it's far from the end of the world!



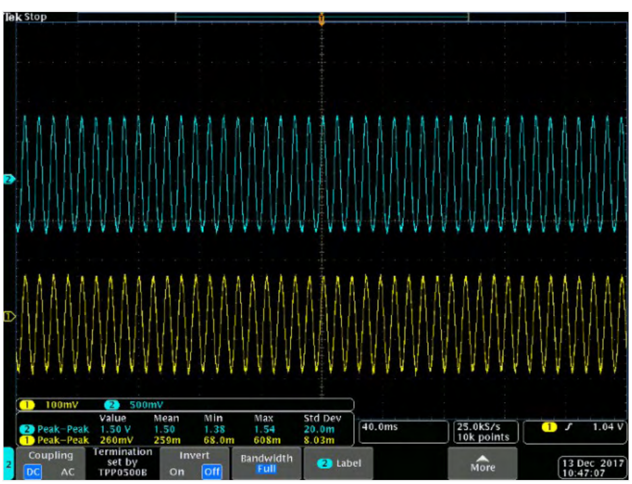
Build done, it's time to power up the design.

Testing

One thing that is often neglected and is quite possibly the most important part of a design is the test — quality testing is what sets apart a project from a design. We've already done quite a bit of testing in Part 2 (https://www.rs-online.com/designspark/design-of-a-korg-nutube-amplifier-part-2-prototype), so let's start by checking these waveforms and that both our build and PCB are performing as expected.

Before we get started we must adjust the bias to around 2.5V, just like we did in Part 2. It's best to not connect the circuit and use a DVM for this. The 22k pots are set to 50% out of the factory which will give 1.5V Bias which is not enough.

First, we adjust all of the control pots from the 50% level, setting both gain and volume to max, and the tone to min.



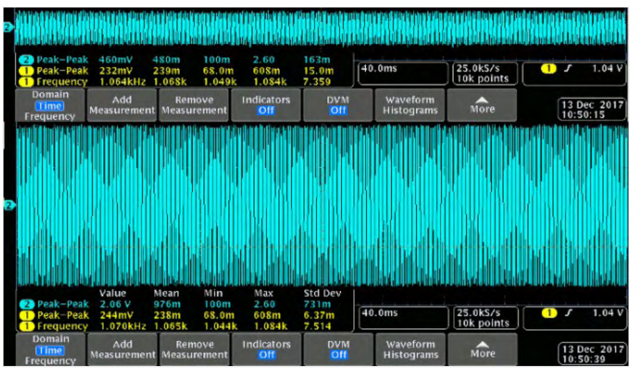
Looks like the amplifier is working!

The output is around 6 times the input, which is acceptable for a distortion pedal. We are not running the tubes for maximum gain; the 10k resistors R9/R4 and R10(lowR in the case above)/R6 will be acting like a pot down to the inputs and changing these to a higher value should increase gain if desired, but note there needs to be sufficient plate current for operation.

One thing to note here, there is some slight distortion to the output, we found playing with the bias can help.

By adjusting the bias to around 2V we can remove the distortion, but as previously noted in Part 2, this may be a desired effect and we can play with this once we get to using the device.

Next the tone circuit.



The image above shows min to max adjustment of the tone circuit @ 1kHz. This should have a profound effect on the audio and make the bass far more prominent.

Finally, we need to know the max/min input to output gain.

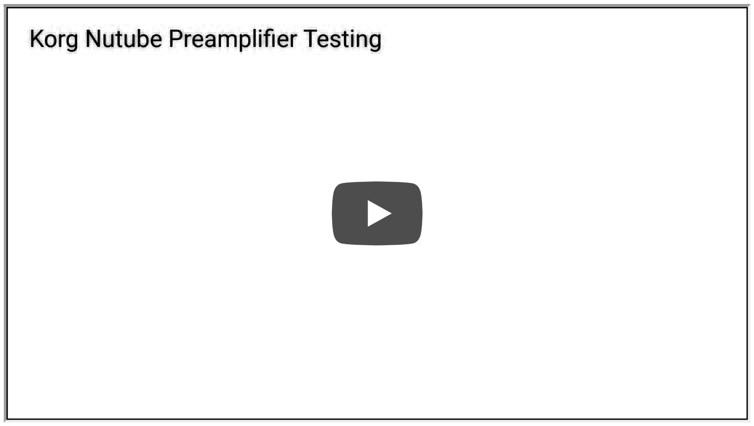
From this, we can see we don't have quite as much gain as the first prototype (this had around 10 total), but there is plenty of adjustment. At the minimum gain and volume, we get an attenuation of 0.2 i.e. 1/5'th of the input. At the maximum settings, we get around 8-9 times the input signal, which is plenty for the purposes of a "distortion pedal".

We also checked the impulse response using a square wave, again the system erred on the over-damped side, which is excellent. However, we neglected the most important thing: does it work for a guitar…

At this point, we have to admit we have no idea how to play a guitar, so it's time to cheat. We have a phone and YouTube with plenty of excellent guitar solos on there. We need a cable from 3.5mm stereo to 6.25mm mono these are relatively common.

Next, we needed to check the peak-to-peak output of the phone and luckily it had an output of 0.2V pk-pk at max volume, which is roughly that of a guitar pedal!

All that is left is to test.



Further adjustments

Throughout this series, we've been discussing options for expansion and improvement. The tone circuit, for example, can be adjusted by changing C10 to 47nF. This would increase the cut-off response. By changing R6 and R4 to a higher impedance gain could be improved. Adding the input impedance amplifier Q2, C13 & R19, the input impedance would be less critical and a high impedance output would be attenuated less.

Given two of these circuits, this design could become a nice pre-amplifier for a transistor stereo.

Alternatively, using a single stage could give a similar effect for a stereo application but with a single tube.

Final words

Being an engineer from the age of transistors it's been a blast working with something so different. In some ways the humble valve is so much better than a transistor — two words: it glows! The four-year-old in us all loves things that glow.

Hopefully, this series has given some insight into the inner workings of a valve amplifier and inspired new projects. For those who would like to try building their own, the DesignSpark PCB database, Gerbers and a bill of materials can be found on GitHub (https://github.com/DesignSparkrs/nutube-preamplifier).

Read the final part in the series on building a custom-case enclosure and storage case now. (https://www.rs-online.com/designspark/design-of-a-korg-nutube-amplifier-part-5-finishing-touches)

Karl Woodward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(/designspark/comments/8075/vote/up)
laundryman
0
January 31, 2018 15:20

Discrete components! Valves! 1/4" jacks! Absolutely outstanding. It brings back my days of youth. Projects like this enable understanding of first principles of electronics and physics, and much more fun than programming a PIC!
Bring them on! I wonder if the sound gets better as the tube gets run in? Like the old Marshall amps.

(/designspark/comments/8070/vote/up)
jdhebenton
0
January 31, 2018 08:42

A good project with a pretty specialised device. A technical comparison of how different amplifier types behave when turned up to 11 would be really interesting. The youtube reviews of the Ibanez Screamer - a formerly solid state guitar pedal that's now gone NuTube - by guys who can play their guitars at youtu.be/QU0rFqPNr0Q (https://youtu.be/QU0rFqPNr0Q) and youtu.be/aD_0byuj0I8 (https://youtu.be/aD_0byuj0I8) are really interesting, if lacking electronic detail!

(/designspark/comments/7931/vote/up)
danielleoh
0
January 9, 2018 08:37

I like this project because it introduces me to a new technology. I agree though, that I would love to hear this thing cranked up to eleven so I can hear its overdrive characteristics; scream, baby, scream!

(/designspark/comments/7929/vote/up)
amonteiro
1
January 8, 2018 14:04
(/designspark/comments/7929/vote/down)

I don't want to look negative but, to make a relatively linear pré-amp for acoustic guitar is something much easier with an operational amplifirer.
Where I think this device coul be very interesting was not addressed in this case. It would be a design where the non-linear characteristics of the nutube could shine.
For that, it should be designed an overdrive pedal, for electric guitar (not acoustic) perhaps with an op-amp as a first stage, with variable gain, to drive the nutube from linear to highly distorted.
In overdrive pedals filters are usually used to control/shape de amount of high order harmonics created by distortion. That should also be part of such a pedal.
At last, the output should be connected to a guitar amplifier (clean channel).

Only in this kind of scenario the potential of this devices could be analised.
I have designed several guitar pedals and a full DSP amplifier, and I am a guitar player. So, I will be very glad to share my expertise in the matter if someone wants.
a.monteiro2007@gmail.com

(/designspark/comments/7928/vote/up)
mike_haben
0
January 8, 2018 13:53

Nice demo, but (as I'm sure all the bedroom guitarists were hoping to hear), what nice warm crunchy sounds do you get when it's overdriven? Surely the main point of a tube pre-amp is to create a "Marshall-in-a-matchbox"? Go on, turn it up to 11...

(/designspark/comments/7921/vote/up)
lastwinj
0
January 8, 2018 10:28

yes

(/designspark/comments/7919/vote/up)
Cryangardner
0
January 8, 2018 08:56

Is it possible to use this as a preamp and send it to a power amp to drive a guitar speaker?