6SN7 Flea Amplifier PCB

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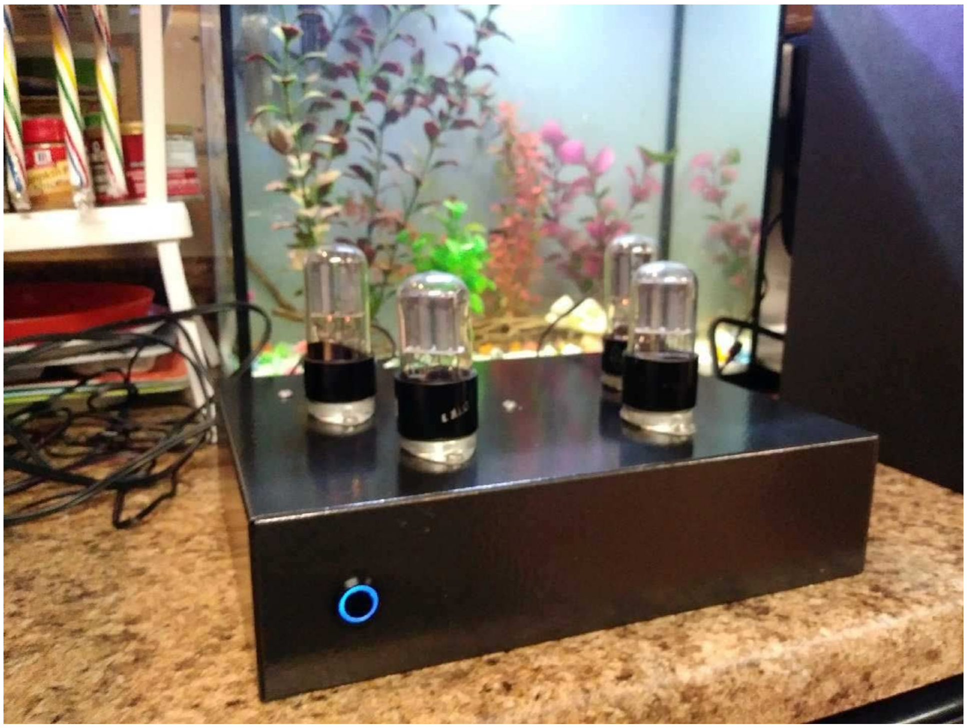


A picture of the original prototype of the Flea Amplifier, with Russian surplus 6N9S and 6N8S tubes installed.

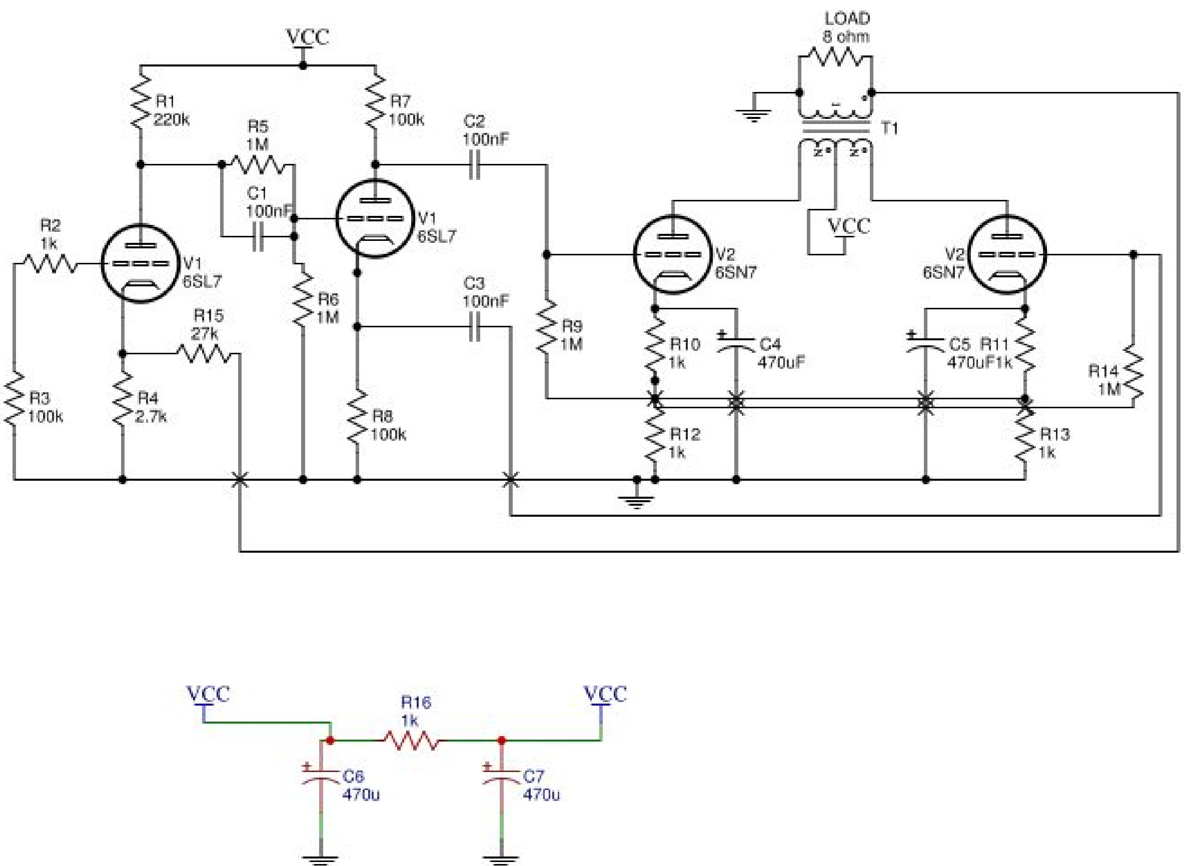
This PCB is intended to be used for the construction of a low power output, complete stereo amplifier on a single board, with minimal external circuitry. It has been set up to be moderately universal, and will simply require the addition of a suitable PSU, output transformers, and chassis, with the choice of input/output connectors being up to the end-user. Here are some basic design features-

1. **Self contained.** The complete amplifier circuitry(sans transformer) and associated signal components are built onto the PCB, for minimal offboard connections. Screw terminals are used to make installation easy and versatile. Simply build a PSU of your choice, add input/output jacks, and put it all together!
2. **Affordable, common parts are used.** No snake-oil or boutique, hard to acquire parts are used. Most everything can be purchased from "the usual places" for ease of gathering parts. Most of the parts (other than output transformers and tubes) can be purchased at places like Mouser and Digi-key. The tubes themselves work well even if you buy basic Russian equivalents from bulk-lots on Ebay, although fancier varieties will work too.
3. **No adjustments needed.** The amplifier has been designed as such that balanced/matched tubes are not required, and other than simply sorting a few

resistors (or using precision resistors) perfect balance is maintained without the use of adjustment pots, constant current sources/sinks, or any other active circuitry.

4. **Flexible design.** Want to build it with a different input/output tube? No problem! The noval version of the board will work with a variety of dual triodes for the gain/phase splitter stage, and without exotic parts or biasing schemes. The output stage can be built with an admittedly smaller variety of options, but there is still the possibility of increasing the power output by choosing higher power tubes and setting up the cathode resistance to suit.
5. **Good support available.** Want to try different parts values? Different input tubes? You can reach out to the designer directly via e-mail, or ask on the build thread. We will do our best to help you figure out if your idea will work.

Design overview and parts description/selection



Current schematic, to be replaced with better drawn version!!!

Circuit description

The circuit is a pretty simple affair, with a few enhancements that I managed to incorporate, otherwise it is pretty similar to a handful of amplifiers that have been reasonably well known over the years, such as Sy's Red Light District, Morgan Jones' Bevois Valley, and even the Dynaco Stereo 35. The differences in my implementation are mostly based on some ideas gleaned from John Broskie over at The TubeCAD journal, primarily concerning the biasing of the phase splitter, and the cross-coupled garter bias of the output stage.

The step network used in the biasing of the concertina has been seen in a few different places, such as Morgan Jones "Designing Valve Amplifiers", TubeCAD, and in the front end of Wavebourne's Pyramid Amplifier as well. The step network works to divide the DC voltage of the preceding gain stage to set a good bias point for the grid of the concertina splitter, and the capacitor across R5 shorts the AC signal directly to the grid, without this capacitor the signal would be attenuated along with the DC and be unnecessarily reduced. The alternative is to "self bias" the concertina, which works well, but keeps the concertina from following the gain stage as well as the step network does, and can have odd DC voltages during warmup.

Much debate has been had over who originally devised the garter bias scheme, with Alan Blumlein erroneously being given credit most often. I won't go into all that here, but after a bunch of successful long term testing, I think garter bias is a great way to go on low power builds. As one tube draws more current, the cross-coupling of the grid voltage causes the other tube to conduct less, which causes the grid voltage at the over-conducting tube to drop, stabilising voltage across each cathode resistor network, and equalising currents between the tubes much better than a single cathode resistor, or even individual cathode resistors. Not bad for the cost of two extra resistors!

This design was intended to specifically use my two favorite tubes, the 6SN7 and 6SL7. Both have very good linearity, and can still be had for reasonable prices. The Russian versions (6N8S and 6N9S, respectively) are cheap and work very well in this design. Due to the unbypassed cathode resistor in the gain stage, global negative feedback, garter-bias output stage, and concertina phase splitter, this amplifier will perform very consistently with the use of different types of tubes. This also means that super-expensive, fancy makes of tubes aren't really required, and tube rolling has little overall effect on the sound of the amplifier. The noval version will work with a wide variety of input tubes, and it is recommended that you choose parts to tailor the performance and operating points to a specific tube type. If using the Russian 6N1P for example, the same parts values as the 6SL7 can be used without any real parts changes, other than at times the cathode resistor in some circumstances. Other tube choices will require different parts values in most circumstances, and I intend to list some alternative loadouts later in this guide.

Parts Explanation

Parts values listed assume the standard 6SL7/6SN7 loadout, and an approximate 285-290v supply after power supply filtering. All parts can be installed on either side (with exception of C1 on the noval board, which must be installed on the bottom of the board) but the design intent is for the capacitors and terminal blocks to be installed on the bottom side of the board, and the silkscreen for these is on either side of the board. At this time the other components are only silkscreened on the top of the board, although the through-holes are plated for installation on either side.

R1- 220K. anode load resistors, a 1/4w part will work, I recommend a 1/2w or better, preferably 1W part. Could go lower to 150~180K if the cathode resistor is adjusted to give 50~60% of the supply voltage at the anode. A corresponding change in the feedback resistor may be required, but only if you are concerned about exact ratios. This is assuming the basic loadout of the 6SL7/6N9S preamp tubes, and runs them at pretty low current, which is how I prefer to run them. *For the noval Board and the 6N2P I use 100K*.

R2- 1K. Grid stopper. Anything from 220R~1500R will work, non critical. Might even be left out if using short interconnects. If using the noval board, high GM tubes (6922/6DJ8, 6BQ7, etc) will definitely need this part to be installed! I recommend using it for all builds unless you have a good reason not to. Carbon composition is the usual recommended style, but I use metal fim without issue.

R3- 100K. Grid leak. Also non critical. Just don't go too high. If using a control pot ahead of it, size it to be anywhere from six to ten times the value of the pot. I don't recommend going higher than maybe 250K to ground here, however due to grid capacitance. A 10K pot with a 100K resistor will work well.

R4- 2700R. Cathode resistor. Unbypassed. May need to adjust larger or smaller to get to a good operation point at the anode. 220K anode with 2700R cathode, and 27K~39K feedback resistor seems to work very well for me using the Russian 6N9S at around 285-300 volt supply. If higher plate voltage is desired, try a 3000~3300R resistor here. *For the noval Board and the 6N2P I use 1800R.*

R5- 1M and R5 1M5. 1/4W Step network. Sets bias for concertina splitter. **R5** is assumed to be 1M if the preceding plate voltage is 50% of the supply voltage. *Going forward* it may be best to use **1.5M for R5**, and adjust the cathode resistor **R4** of the previous stage for around 60~65% or so of the supply voltage to provide more symmetrical swing. I previously used 1M for R5, and I've changed to 1M5. *1M5 is my current recommendation.* The goal is to see 20~25% of the supply voltage at the cathode of the concertina either way, but it's not super critical at the signal levels we are seeing. Setting this so that from 20~30% of the first stage plate voltage across R7/R8 will also work, it's pretty flexible. Something like **1M for R5** and **680k for R6** will also work well.

C1- 100nF. coupling capacitor. This shorts the signal across R5 to allow a lower DC bias voltage, without reducing the AC signal. A quality polypropylene or polystyrene cap will do great here, and a 250V rating is plenty. I like axial lead types, but the board will also take 15mm lead spacing box types as well. You could go as low as 10nF here if you like, as we aren't making enough power to push much bass types of signal anyway. ***Install these before you install the tube sockets or you won't have room to solder them in!***

R7/R8- 100K. Concertina load resistors. Try to get these as closely matched as possible, this will ensure the best balance of drive signal. You can also go to a 68K~75K if that's what you have, but don't go much lower or performance will suffer. 1/4w is fine, I would even say that 1/8w would be fine in a pinch, but that's up to you. Buy a bunch and sort them out with a multimeter, preferably buy 1% or better precision resistors, and you will easily find a bunch that match to within .5%, which will be fine here.

C2/C3- 100nF. Coupling capacitors. Same advice as for C1. C1, C2, and C3 can all be identical for ease of sourcing parts. Ideally they would match pretty closely, but it isn't too critical here. Generally 10% tolerance parts will be close enough not to worry unless you're really anal about it.

R9/R14- 1M. Output stage grid leaks. These can be as low as 220K really, but I like to keep them large to ease the load on the phase splitter. I usually use a 470K or a 1M here. Non critical as long as they aren't too small.

R10/R11/R12/R13- 1K. Cathode/Garter bias resistors. 1/8w will work here, but I would rather see a 1/4w or 1/2w part here. These should be very tightly matched as well, and done in pairs if you are unable to do them all per channel, IE, R10/11, and R12/13 should be closely matched so that side-by-side they track as best as possible. Buy a bunch and sort them out with a multimeter, preferably buy 1% or better precision resistors, and you will easily find a bunch that match to within .5%, which will be fine here. You can also go lower resistance here if you like, at the cost of higher dissipation in the output stage, 680-820R perhaps. Watch the max dissipation here though, and be sure to use "GTA/GTB" types if running them hot. Or, buy the cheap russian 6N8S and keep a few spares, they are very rugged and pretty long lasting.

C4/C5- 470uF. Bypass caps. Use a 25-35v part here, low ESR preferred. You can go lower in value to about 150uF without a noticeable lack of bass, but I wouldn't go lower than 220-330uF personally. Going up to 1000uF wouldn't hurt, but wouldn't be a huge benefit either unless it's parts on hand already. The board is set up for 5mm lead spacing.

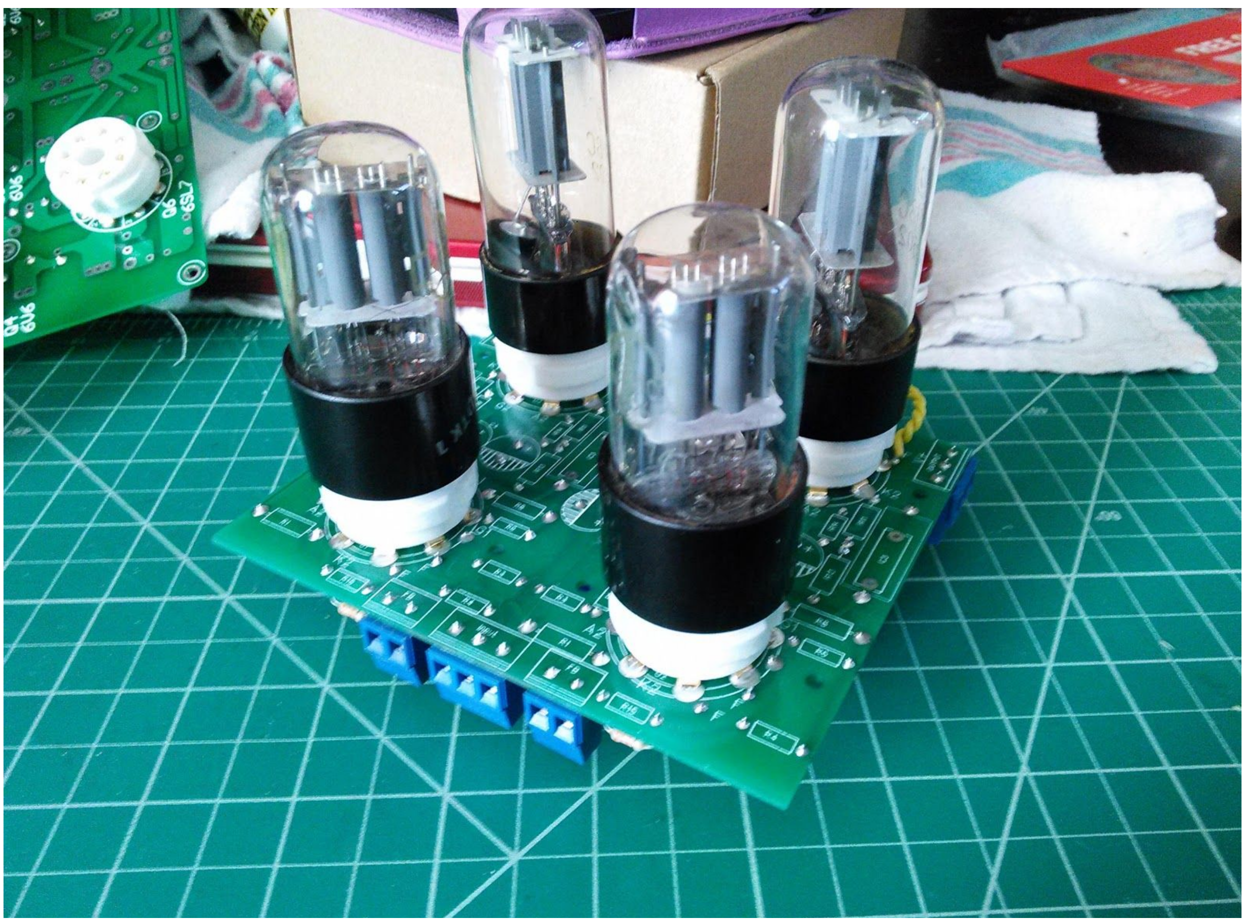
R15- 27K. Feedback resistor. Could go higher or lower to taste, or as needed to make up for lower output signal sources. Going higher than 47K doesn't seem to work as well as something around 22K~39K, with my personal favorite being 27K from what I've tried. *For the noval Board and the 6N2P I use anything from 18k to* .

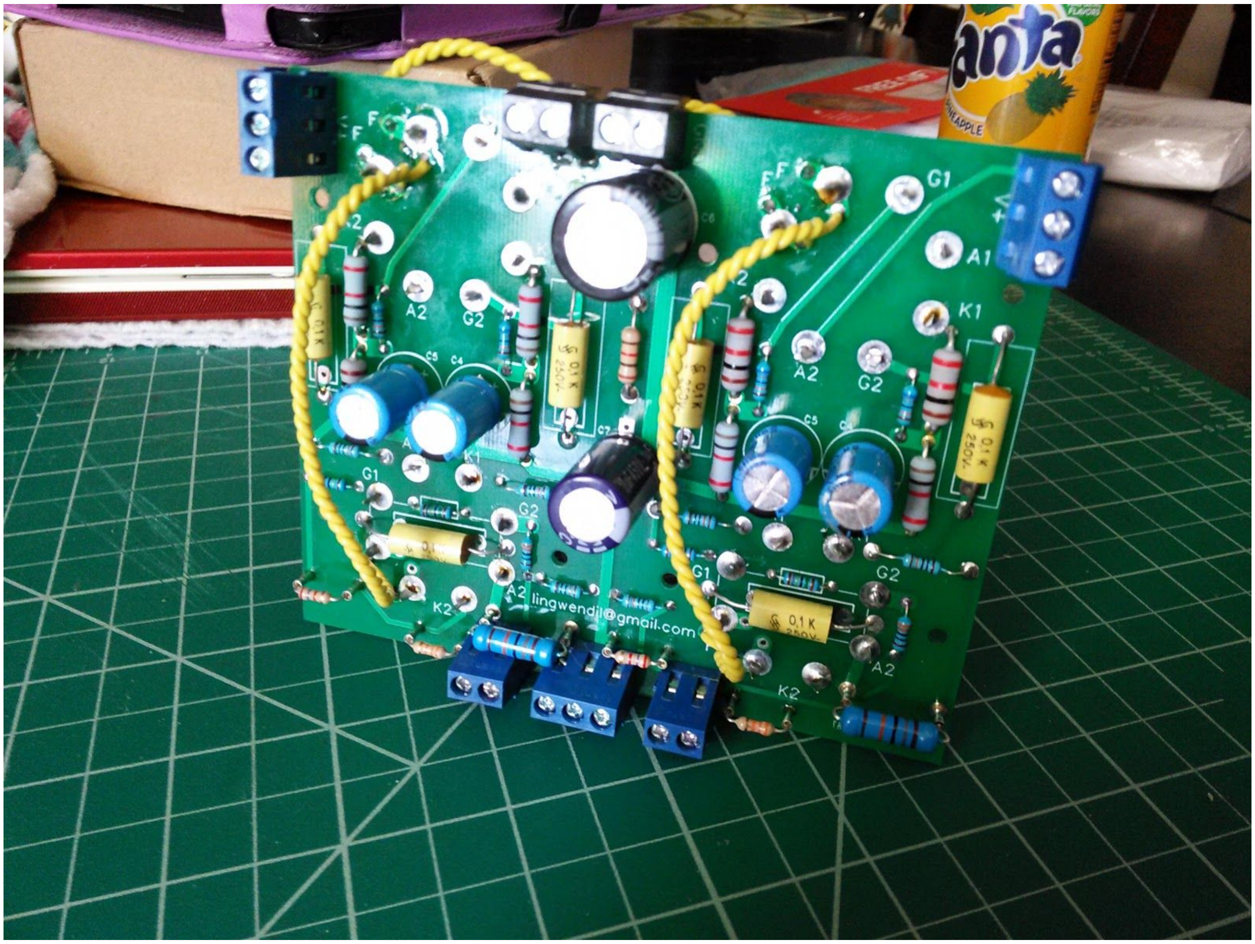
R16- 1K. Power supply filter resistor. Optional, depending on your choice of PSU. May or may not be needed in some applications. Might be replaced with a wire link if using a regulated supply. A basic 1/4W resistor will be fine unless dropping a lot of volts.

C6/C7- power capacitors. 47uF each on the schematic, but realistically you can run 10uF~22uF for C7, as the front end draws such low and constant current. May also be omitted in some applications. The board is set up for 5mm lead spacing on C5, or 6mm/7.5mm lead spacing on C6.

T1- Output transformer. This one's a bit tricky, and a bit of explanation is in order. In general, high impedance transformers can be a bit problematic, and can sometimes prematurely roll off the higher frequencies, especially if oversized for the application. It’s often better (for the transformer at least) to err on the side of *lower* impedance to minimise these losses. I use a 10VA power Toroid, with parallel connected 5 volt secondaries for the speaker winding, and the dual 120 volt primaries connected in series, with the connection being used as the center tap... Used this way it presents an approximate 17K plate-to-plate load, and with the addition of global NFB it has a very nice frequency response throughout the audio band. If using a conventional transformer, look for a 16K-35K reflected load. This is a little low impedance for the 6SN7 output tube, but gives good performance for the cost, and has a very warm and euphonic sound signature. It can easily be accomplished by using a standard EL84 or 6V6 output transformer from 8K-10K, and running twice the nominal load impedance on the secondary, IE, an 8 ohm load on a 4 ohm secondary. If not using feedback a higher load impedance is better than lower, but will give lower output. Ideally, one would run this to give as high a load impedance as possible up to around 32~35K if you wanted the utmost linearity, but run at the lower impedance you still get plenty of linearity up through about the 500mW Class A limit as designed. For instance, if running a 16 ohm (versus an 8 ohm) speaker with the Antek Toroid, power will drop to 750mW or so total, with vanishingly low distortion. If running very efficient speakers (or headphones) this may be a good option for some builders concerned about the highest possible linearity. For users that would like to use a conventional style transformer, a good choice may be the Edcor GXPP 12K:4, with an 8 ohm load on the 4 ohm tap for a ~24K load. This option has not yet been tested as of this writing.

Power supply- When built as originally designed with the 6SL7/6SN7, the total power draw is approximately 40mA total for the entire PCB/amplifier at idle, at around 285~290 volts. There is a companion PCB that will easily rectify and filter the voltage with a mosfet ripple filter, and allow an all-in-one solution to the high voltage portion, and this will work well off of a 240~260 volt AC transformer secondary. The original design is intended to use a 240VAC secondary, for a raw rectified voltage of 315~320 volts or so before filtering. If using a tube rectifier/choke style PSU I would recommend increasing the secondary voltage to 250VAC~260VAC to make up for rectifier voltage drop. For the filament supply, a 2P terminal block is provided on the edge of the board, and 2 amperes at 6.3 volts AC are drawn by the filaments. There are provisions on the board to allow wire to be jumped from socket-to-socket with tightly twisted wire to prevent hum. The prototype is dead silent with AC filament wiring on 91dB/W speakers, but for headphone use or super-efficient speakers DC heaters may be desired, and the wiring can easily be jumpered from socket-to-socket as needed and fed from the provided terminal block, for this option a separate DC supply will be required.

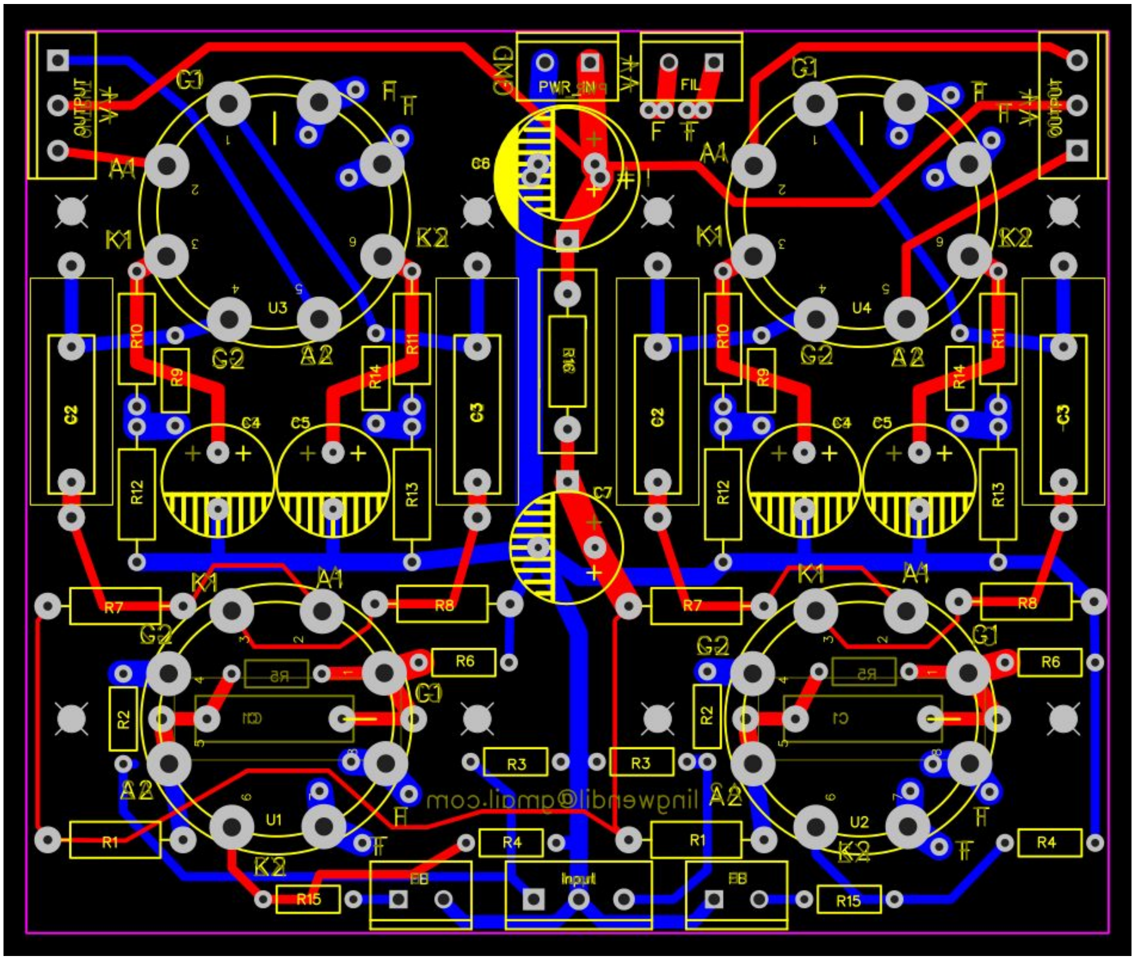


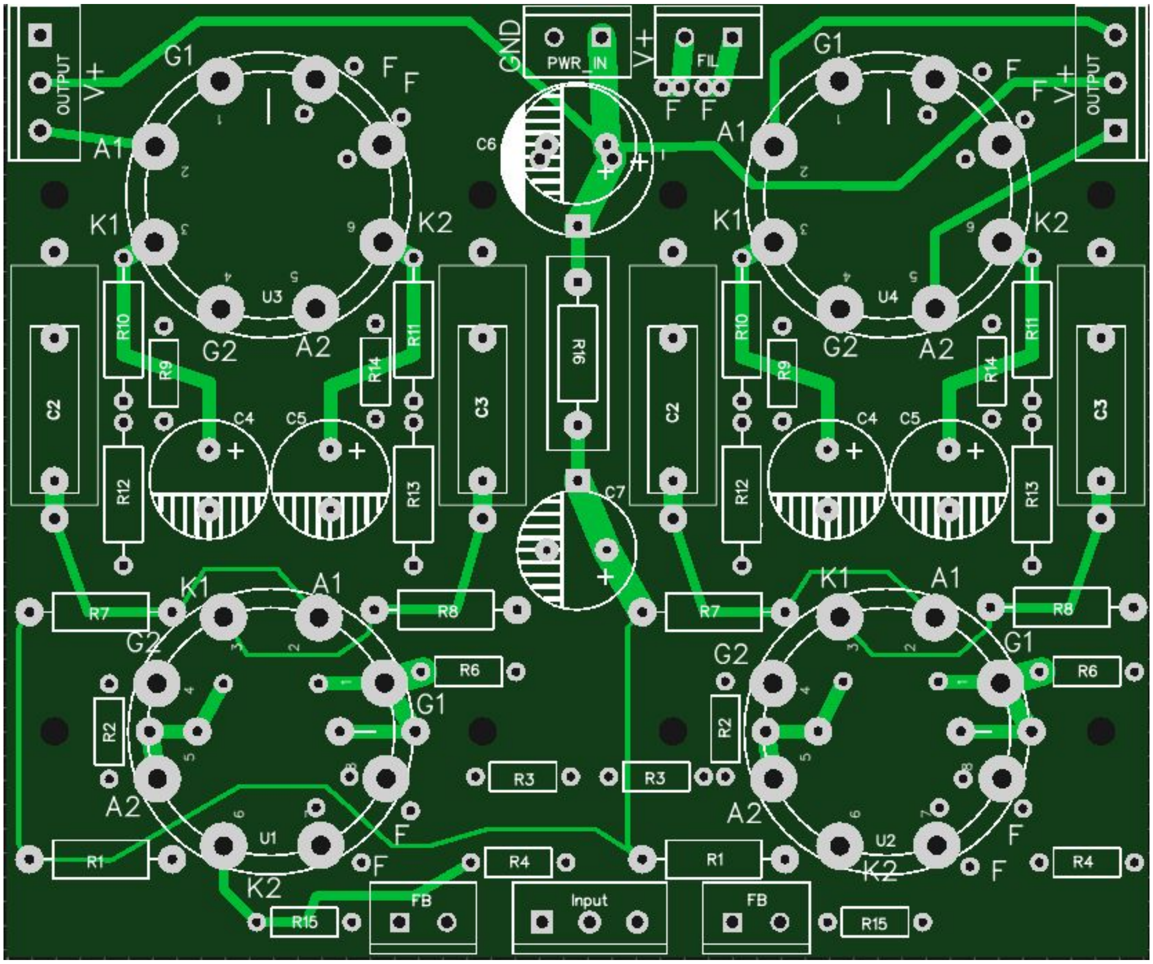


(Fully stuffed 6N9S/6N8S, First board release) Note the use of basic parts-box grade parts, nothing fancy here!

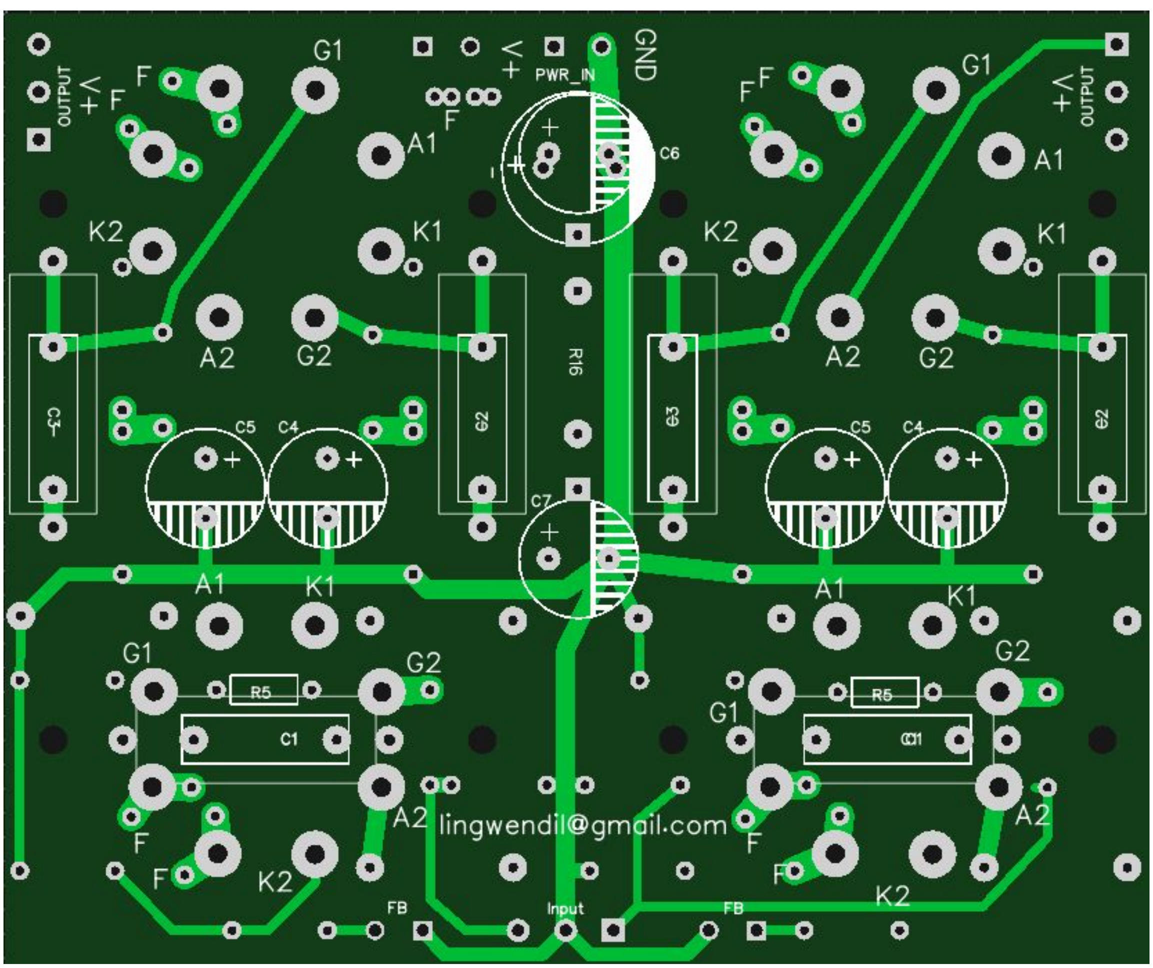
What follows is the multilayer, top, and bottom views of the PCBs for reference. This may be useful to allow you to familiarise yourself with them boards before assembly, and to ensure all parts are oriented correctly.

Octal Board



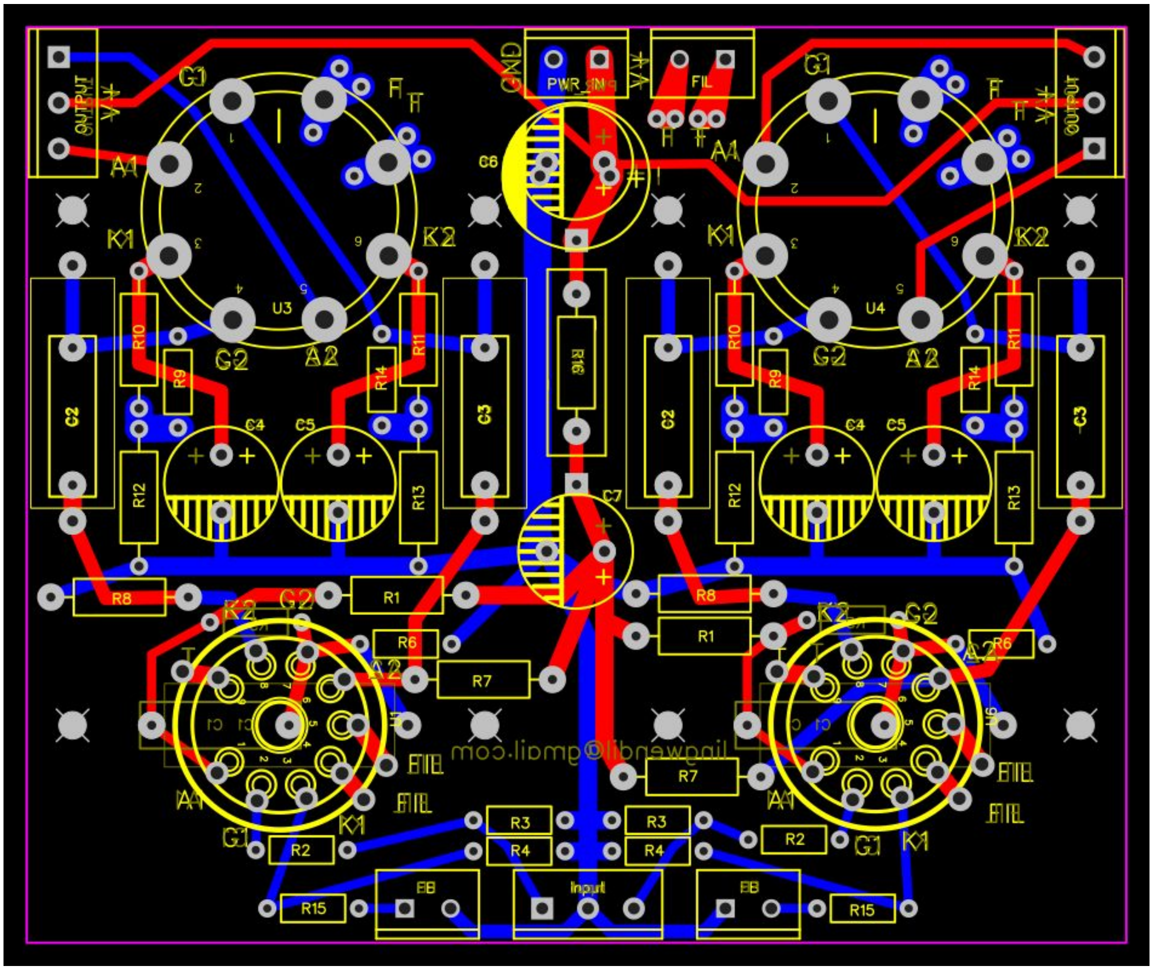


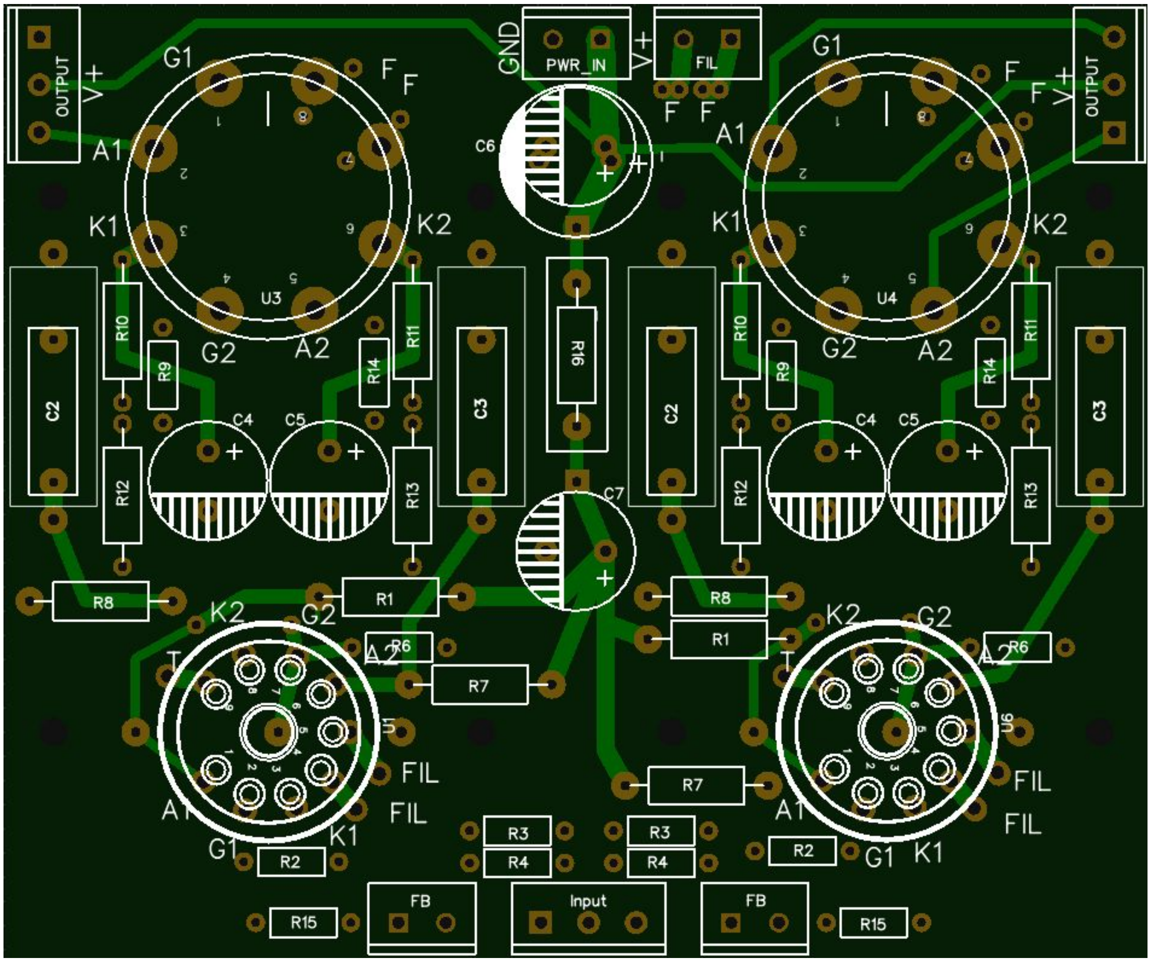
OUTPUT
V+
GND
PWR_IN
FIL
G1
A1
K1
K2
G2
A2
F
U1
U2
U3
U4
C2
C3
C4
C5
C6
C7
R1
R2
R3
R4
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
FB
Input



OUTPUT
V+
GND
PWR_IN
G1
A1
K1
K2
G2
A2
F
C1
C2
C3
C4
C5
C6
C7
R5
R16
FB
Input
lingwendil@gmail.com

Noval board




OUTPUT
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U3
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GND
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C6
R10
R9
R11
R14
R16
C2
C3
C4
C5
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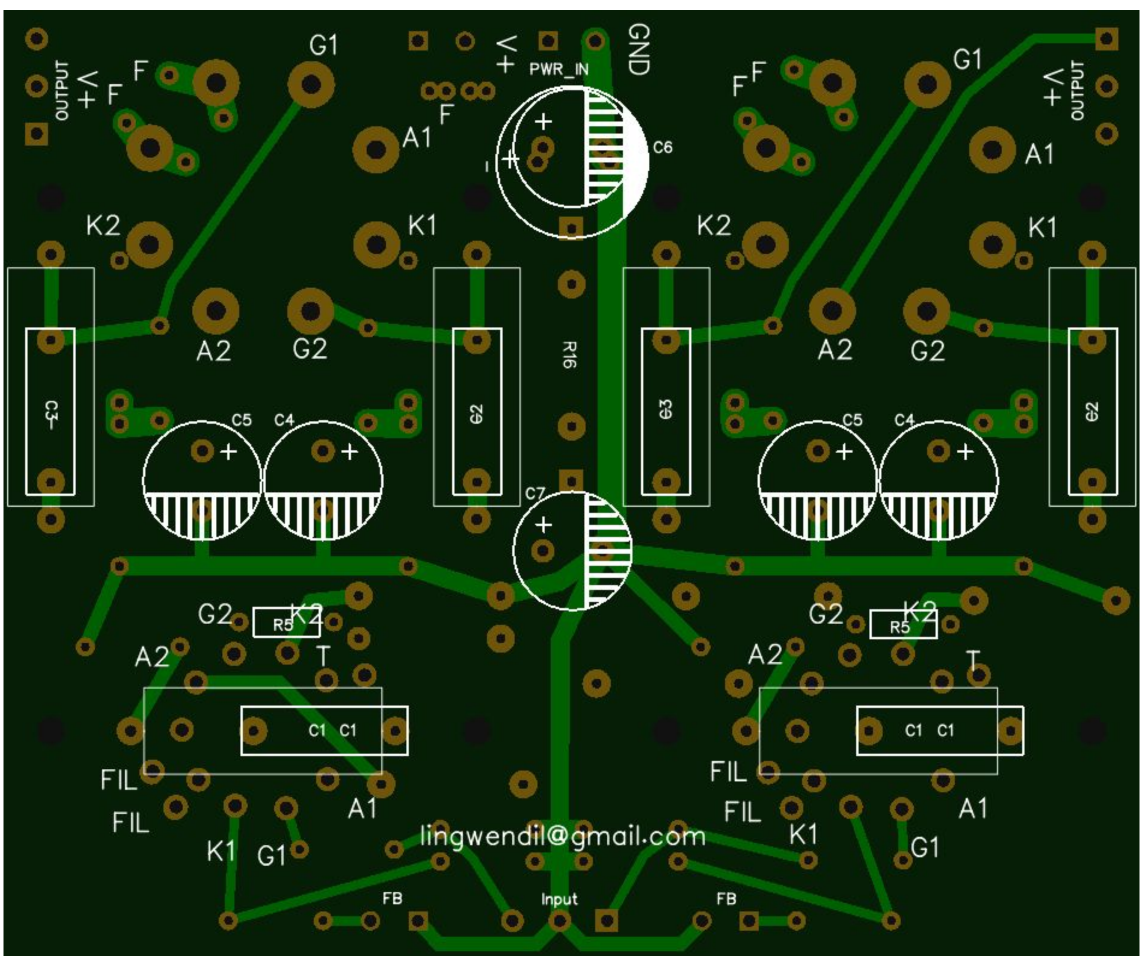
Input


OUTPUT
V+
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G1
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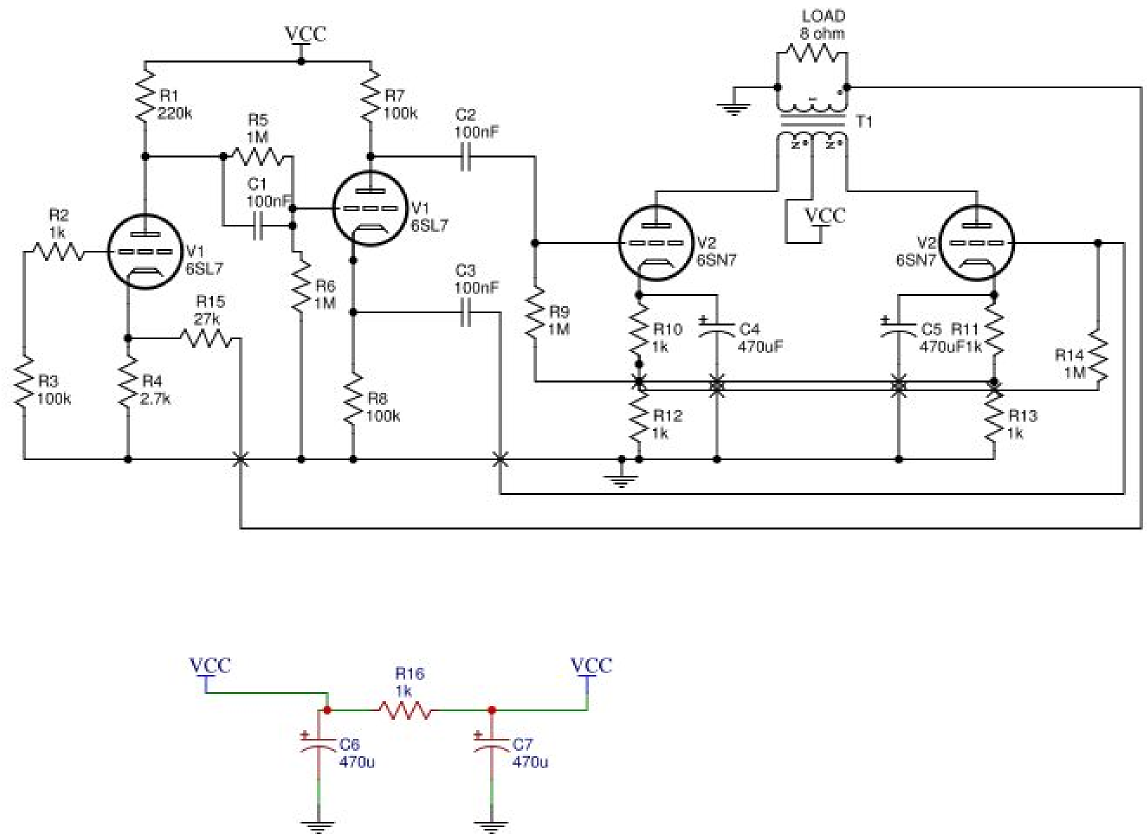
K2
K1
A2
G2
PWR_IN
GND
C6
R16
C3
C2
C5
C4
C7
R5
T
C1
FIL
lingwendil@gmail.com
FB
Input

Bill of materials

Note at this time each channel has the same parts designations on the PCB, that will change in future revisions to make things more clear IE, R1R/R1L, etc. All resistors assumed to be 1% or better metal film parts.

qty	***Part name***	***description***	***Rating and notes***
2	*R1*	*220k input anode resistor*	*½ watt or better is recommended, metal film or oxide. Higher wattage if using 6N1P, 6DJ8, etc*
2	*R2*	*1k input grid stopper*	*1/8 watt or better, carbon comp preferred.*
2	*R3*	*100K input grid leak*	*1/8 watt or better, different value not critical.*
2	*R4*	*2700R input cathode resistor*	*1/8 watt or better.*
2	*R5*	*1.5M step network resistor*	*1/8 watt or better.*
2	*R6*	*1M step network resistor*	*1/8 watt or better.*
4	*R7, R8*	*100k concertina resistors*	*1/4w or better, 1/2wor better if using 6N1p or similar tubes. Match these in pairs for each channel for the best balance from the phase splitter!*
4	*R9, R14*	*1M output stage grid leaks*	*1/8 watt or better, can go smaller if you keep it 10x the resistance of R7/R8.*
8	*R10, R11, R12, R13*	*1k output cathode resistors*	*1/8 watt or better, match these as close as possible in quads per channel for best DC balance!*
2	*R15*	*2700R input feedback resistor*	*1/8 watt or better.*
1	*R16*	*1k power supply filter resistor*	*1/4 watt or better, higher wattage and resistance if needing to drop higher voltage.*
6	*C1,C2, C3*	*100nF coupling capacitor*	*Rated for at least the maximum supply voltage to be used. For most cases 350 volts is plenty. Metal film or polypropylene such as MKP is recommended. 28mm hole spacing for axial lead or 10mm lead spacing if using radial/box type caps.*
4	*C4, C5*	*470uF cathode bypass*	*25-35 volts, low ESR preferred. Can increase to 1000uF if desired.*
2	*C6, C7*	*47uF power supply capacitors*	*Rated for at least the maximum supply voltage to be used. For most cases 350 volts is plenty.*
2	*T1*	*Output transformer*	*See notes at beginning of guide*
4	*socket*	*PCB mount noval (9 pin)*	
3	*terminal*	*3 pin screw terminal*	*250VAC rated, 5mm lead spacing*
4	*terminal*	*2 pin screw terminal*	*250VAC rated, 5mm lead spacing*



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Date: 2018-05-10		Sheet: 1/1
EasyEDA V5.4.12	Drawn By: Lingwendil	