

"NuHybrid" Solid-State Headphone Amplifier

Assembly instructions

What you need:

- The bare PCB plus Korg Nutube 6P1 (from pmillett.com via eBay)
- The parts (from Mouser)
- A soldering iron and solder (Tin/Lead 63/37 is the easiest to work with - lead-free solder is more difficult)
- Wire cutters ("diagonal cutters")
- DMM (Digital Multimeter)

The following are optional, but recommended:

- Needle-nose pliers

To order the parts from Mouser, go to

<http://www.mouser.com/ProjectManager/ProjectDetail.aspx?AccessID=b68a30231c>, or go to the "Tools" page at <http://www.mouser.com/Tools/Tools.aspx> and enter this access code in "Cart Sharing" towards the bottom of the page: [b68a30231c](#)

The Mouser BOM includes all of the parts needed to build the NuHybrid except for the PCB and the Korg Nutube, which are available from <http://stores.ebay.com/pmillett>. You can also refer to the bill of materials at the end of this document for additional info.

Occasionally one of the parts on the BOM may be out of stock. The BOM has some suggestions for alternate parts that can be used instead, as well as alternate parts that are available from Digi-Key. Note that the Mouser BOM may be updated from time to time as parts become difficult to source.

When assembling, keep the BOM and schematic handy, in case you have any questions about what parts go where.

It is assumed that the builder has some basic electronics knowledge, like knowing which end of the soldering iron to hold in the hand, and hopefully some experience building electronics. However, this is a very easy project and is suitable for a first-time builder.

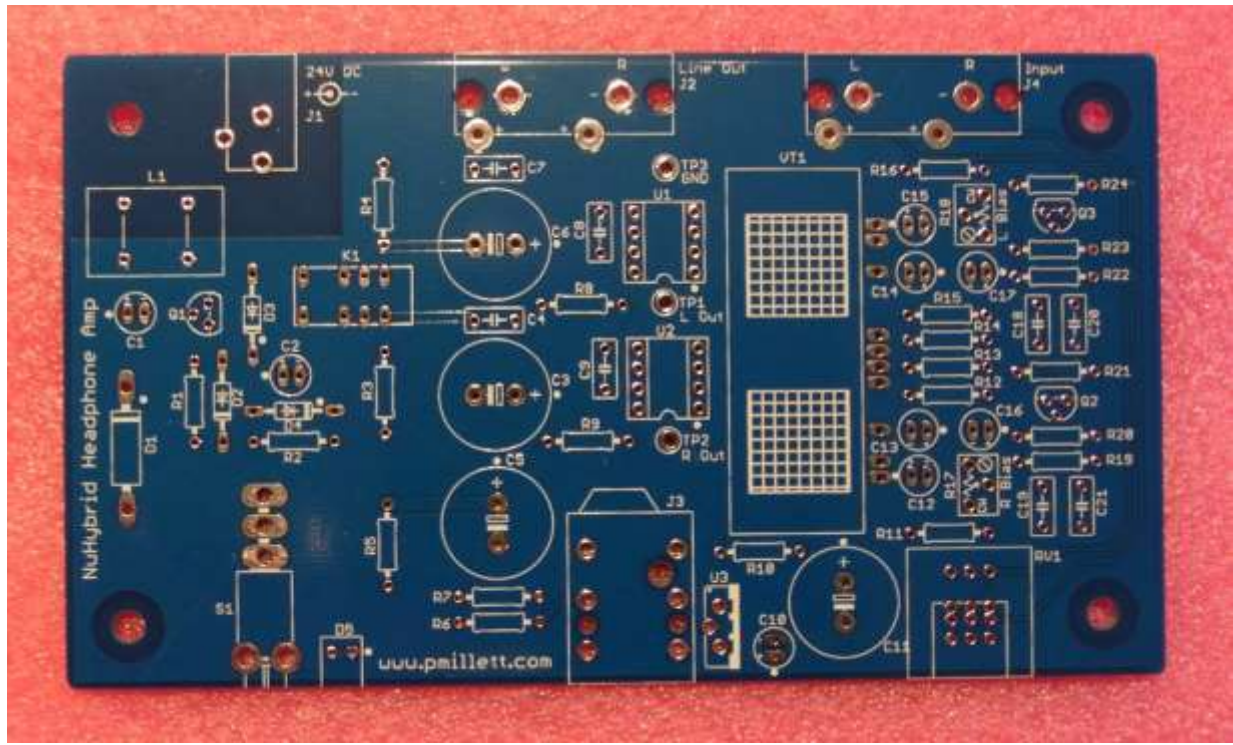
If you are new to soldering, it's highly recommended that you review one or more of the excellent on-line soldering tutorials. Just search "soldering tutorial" on the web and/or YouTube.

There is nothing sacred about the order that is listed for assembly. It can be convenient to build starting with low-profile components, and work your way up to taller parts, so it's easier to solder on the board backside. That is the way the instructions read. But you can install parts in any order you want.

PCB Assembly

Step 1. Introduction

Start with familiarizing yourself with the bare PC board:



You'll see that each part has an outline silkscreened on the board, and a reference designator (name) next to it. Parts are numbered starting at the lower left, so you can expect to find resistor R1 somewhere near the lower left corner.

Some parts, like resistors, have no polarity and can be installed in either orientation. Others, like diodes and electrolytic capacitors, need to be installed in a particular direction. These parts have the orientation clearly marked on the silkscreen with a dot for the positive terminal for capacitors, and a bar and dot for the cathode side of diodes.

2. Install resistors

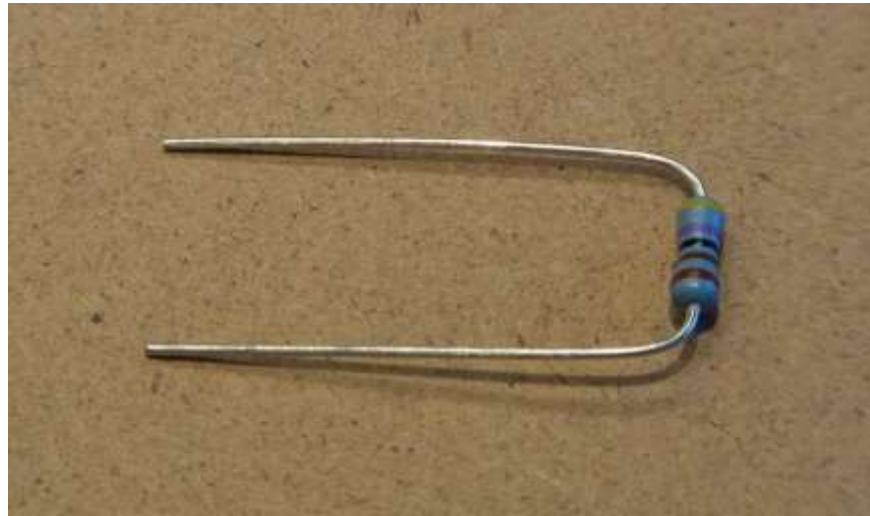
Each bag of parts from Mouser looks like this:



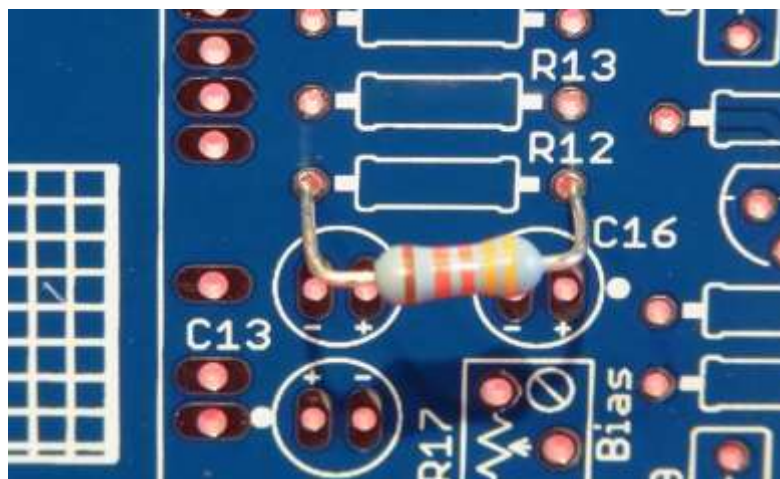
Match the Mouser part number or the description with the parts on the BOM. In this case, you will see that 33.2k resistors are installed at R12 and R15.

Note that the resistors may be different colors.

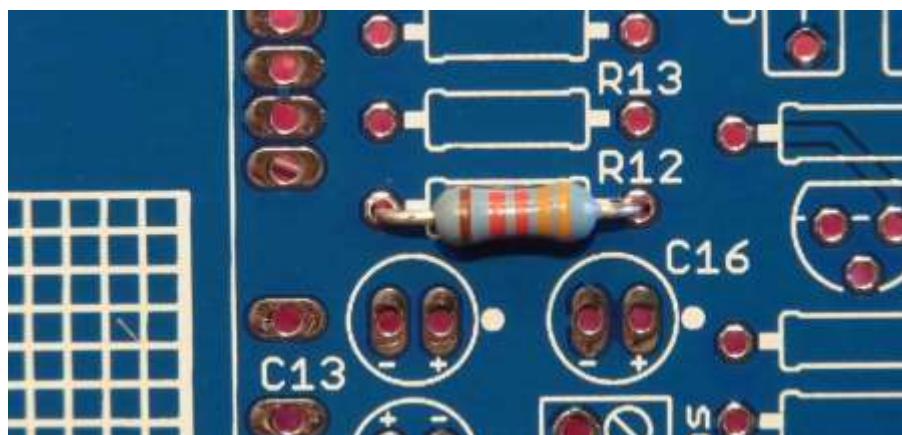
In no particular order, install the resistors. After you remove them from the bag, you'll need to bend the leads (you can just use your fingers) so they look like this:



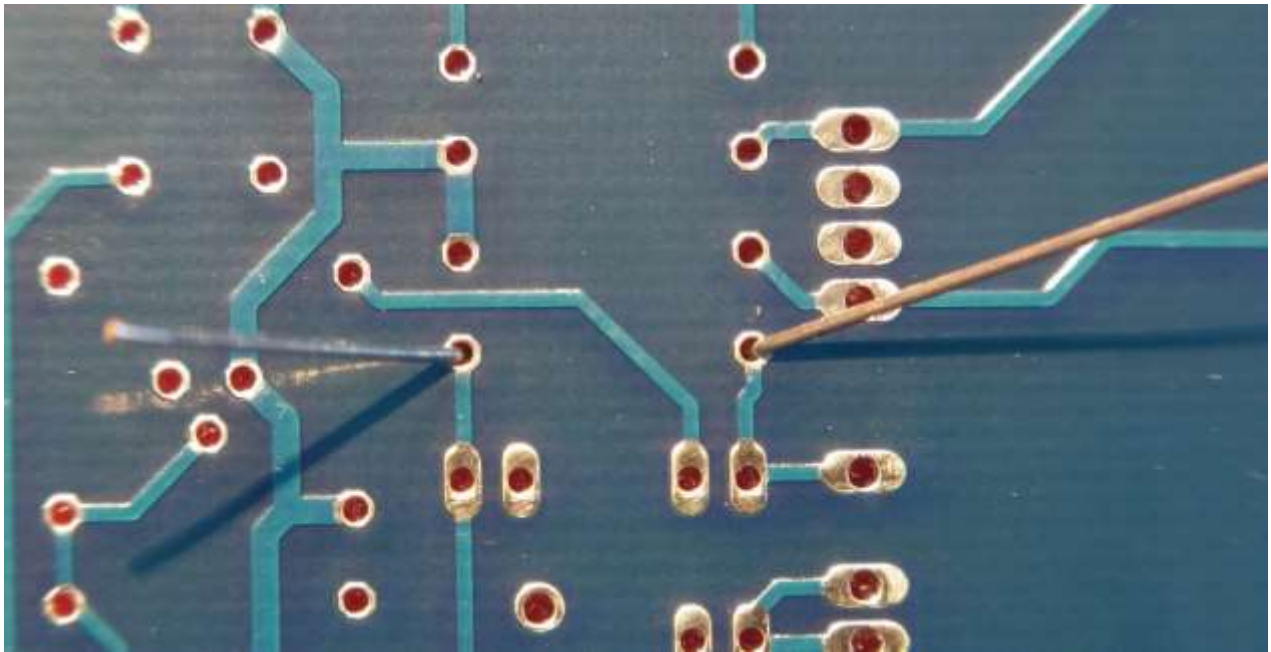
Next, insert them into the PCB in the appropriate spots:



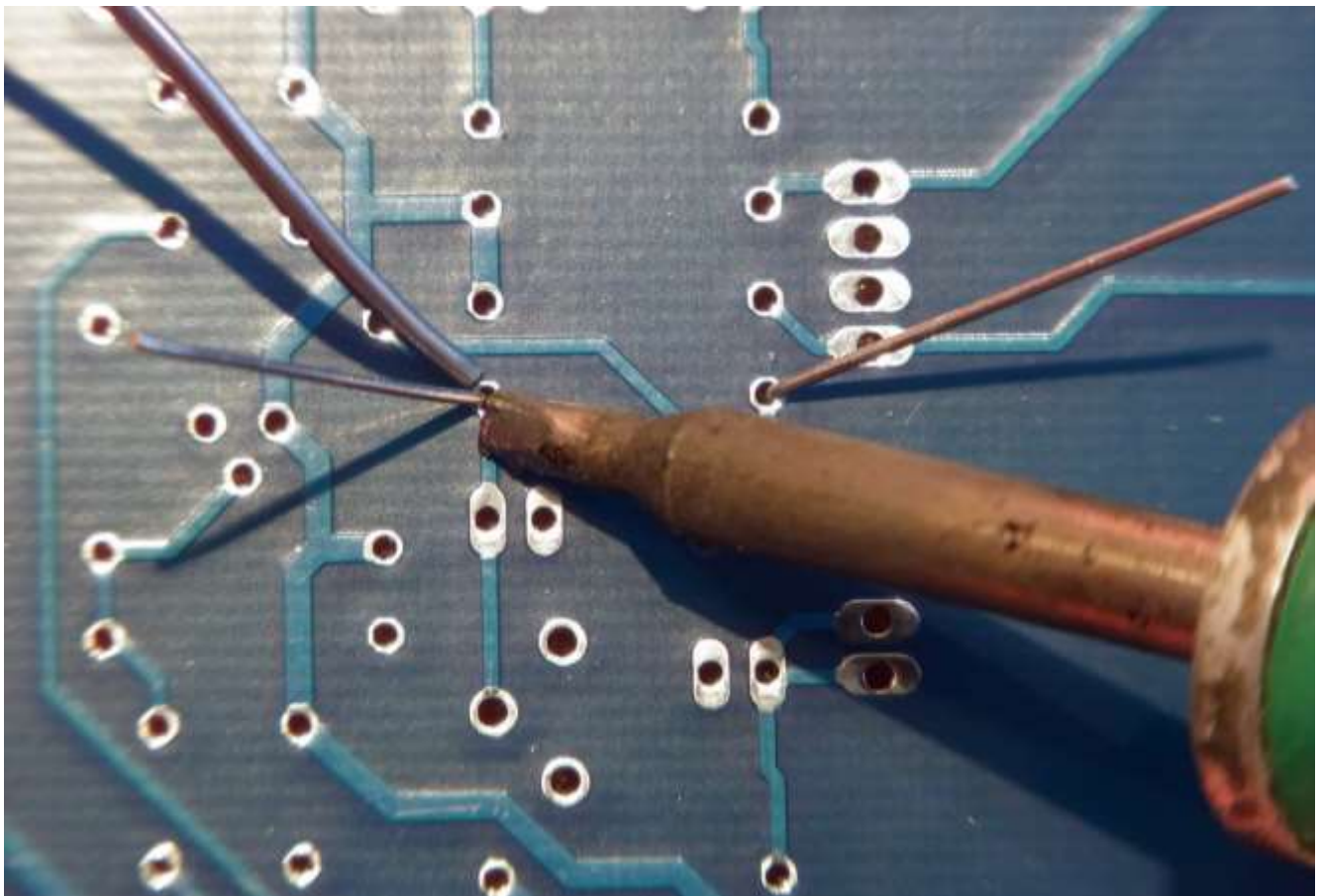
Push them down flush with the board:

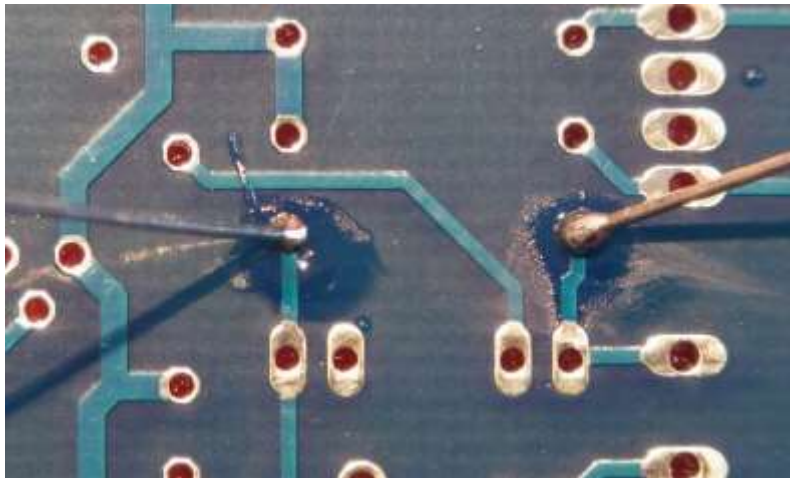
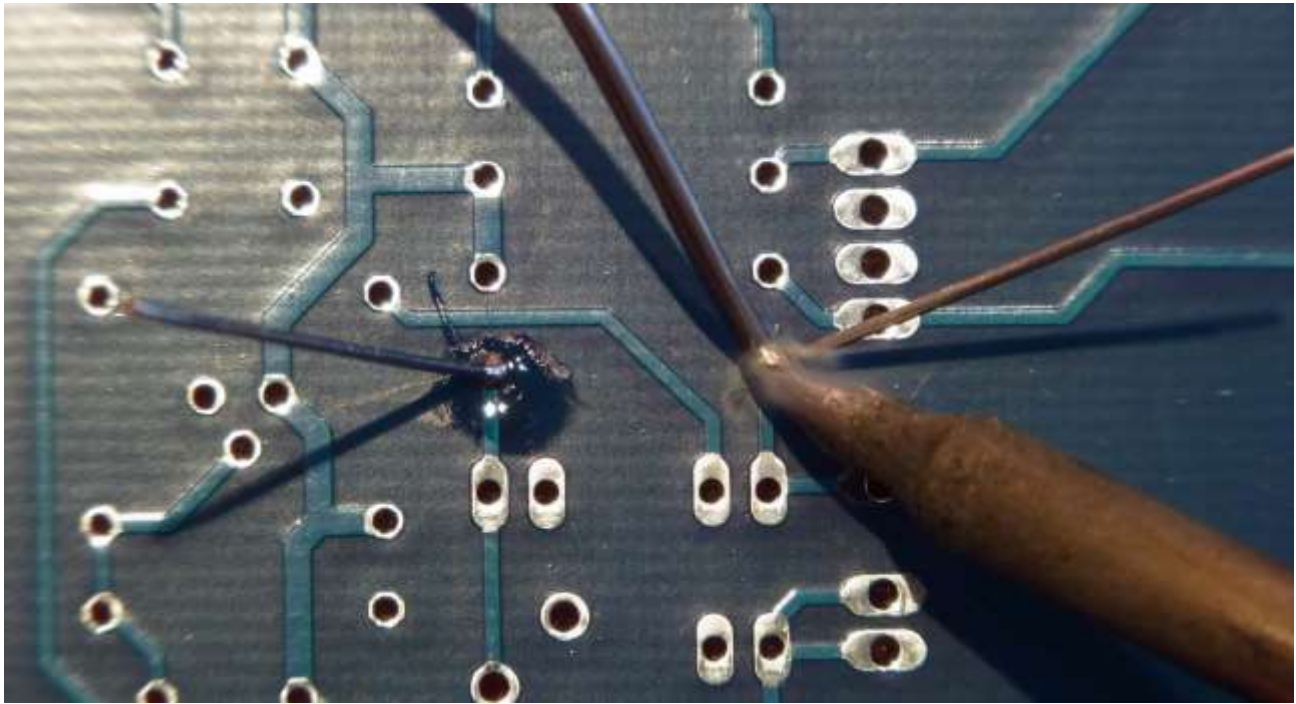


And bend the leads on the backside slightly:

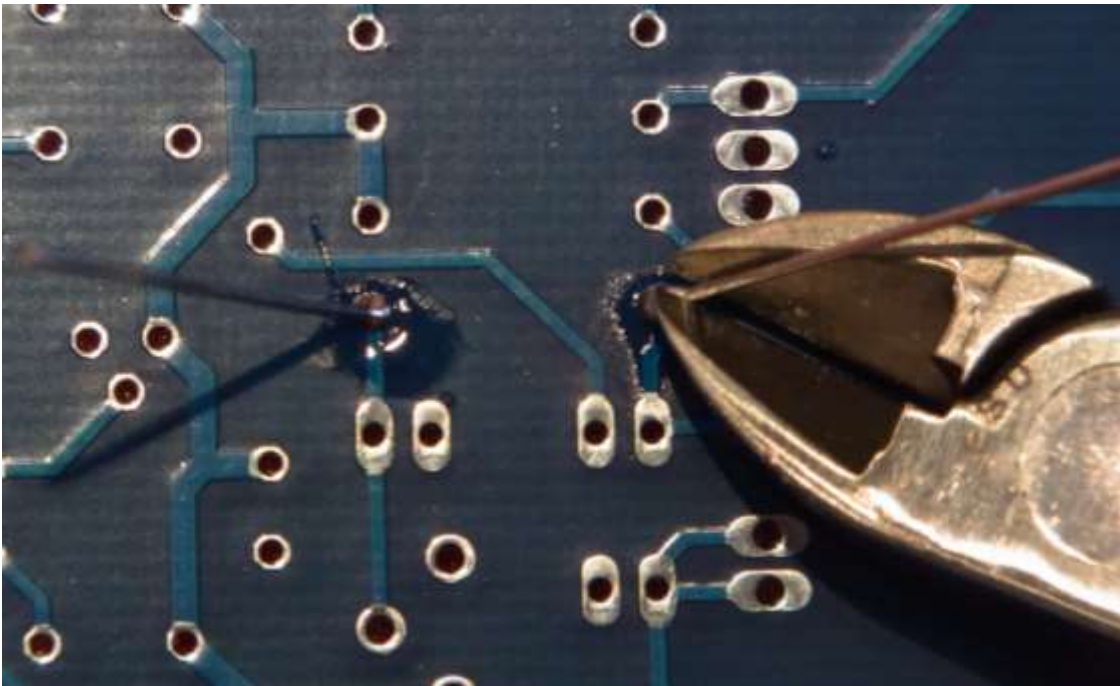


Next, solder the leads. Touch the soldering iron tip to both the pad and the lead, and apply a little solder:





Next, using wire cutters ("diagonal cutters"), trim the excess wire leads:

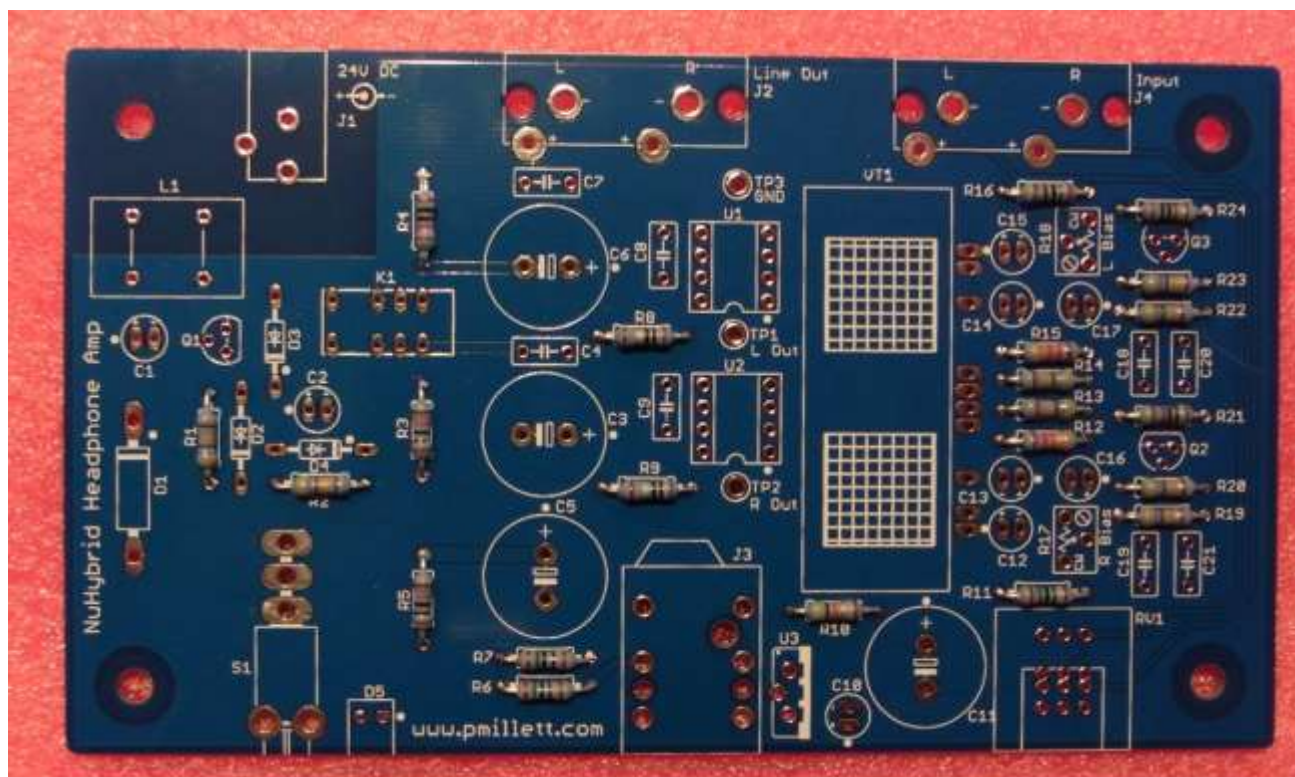


It should wind up looking like this:



Now, repeat this process for all of the resistors.

When you're done, the board should look like this:



2. Install diodes

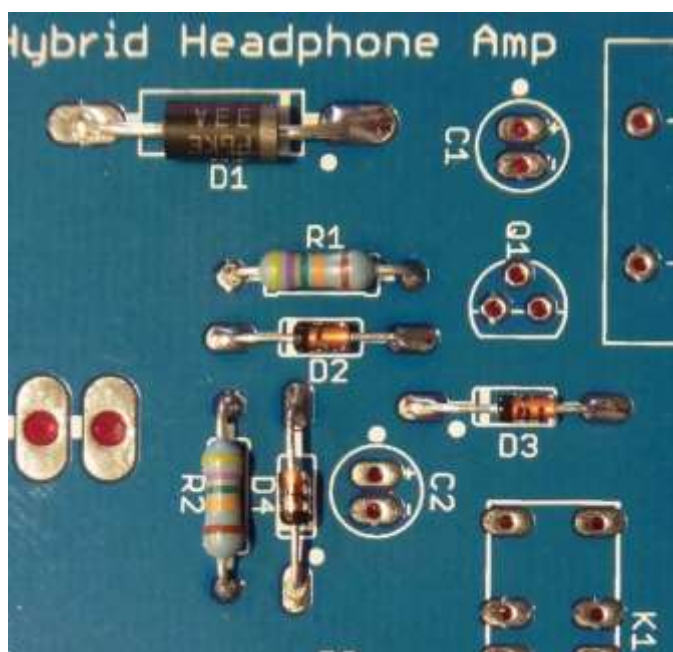
The diodes are installed the same way as the resistors.

Diodes need to be installed in the correct orientation, so be careful and double-check to make sure they are pointed the right way before soldering.

Note the diodes have a band on one end that matches with the band on the PCB silkscreen, and the PCB also has a dot near that end.

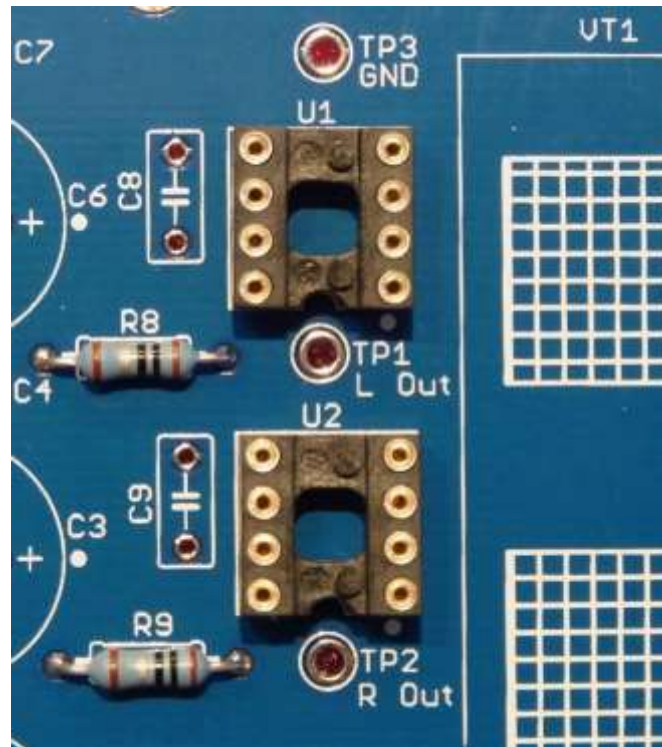
Be careful, as the two 1N4148 diodes (D3 and D4) look virtually identical to the 1N5245B Zener diode (D2)!

As with the resistors, bend the leads and solder, then trim the excess lead wires. Check again that they are in the right way by matching them to this photo:

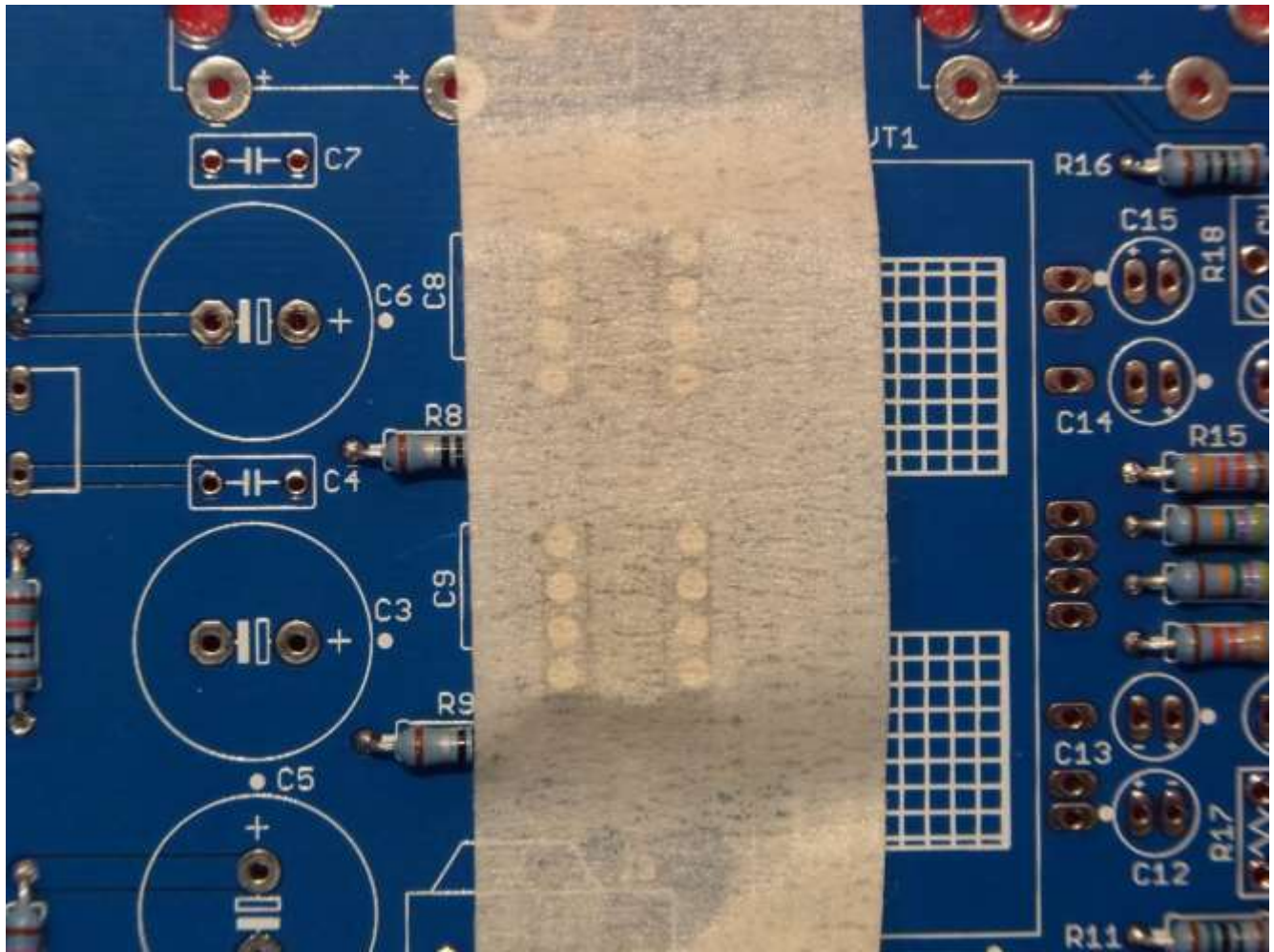


3. Install IC sockets

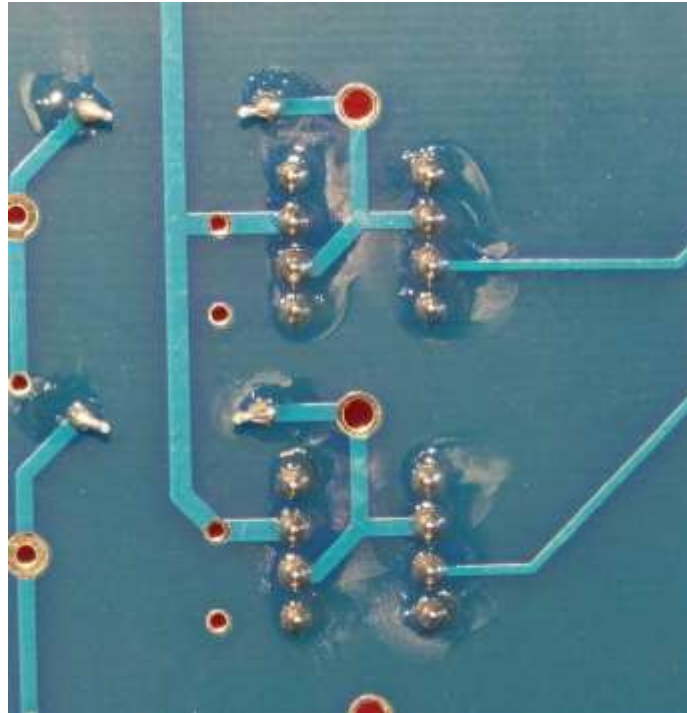
Two IC sockets are installed for the opamps, so you can change them to different ones if desired. Note the orientation of the sockets - there is a small notch to indicate pin 1, which is aligned with the PCB silkscreen:



The IC sockets are soldered in as before, but since they have short pins that cannot be bent, they somehow need to be held in place while you solder the pins. If you are dexterous you can hold them with one finger while soldering, or just use a piece of tape:



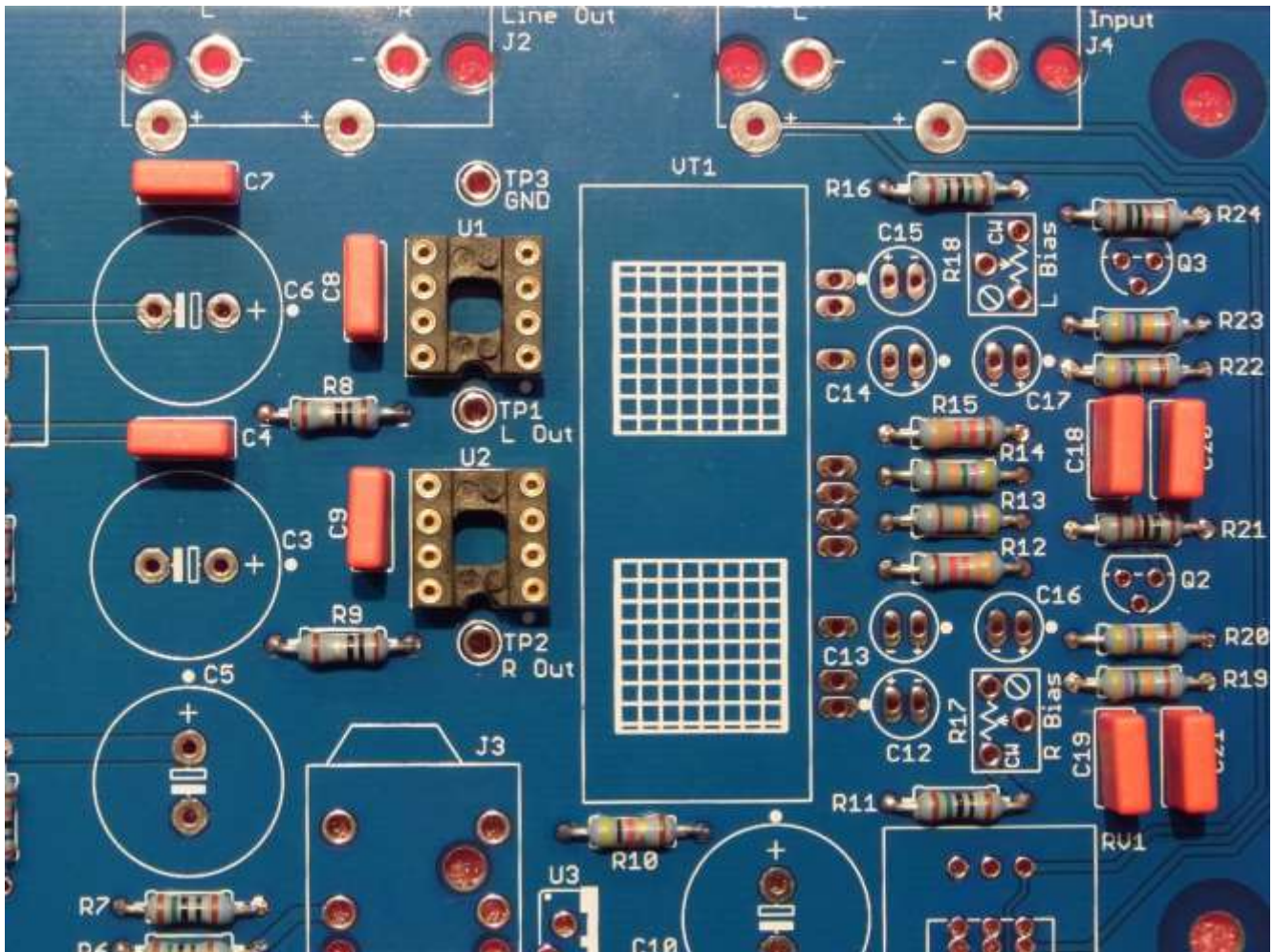
Flip the board over and solder the pins as before. No trimming is needed. It should look like this when you're done:



By the way, don't worry about the flux that gets splattered on the board when soldering. It's harmless...

4. Install film capacitors

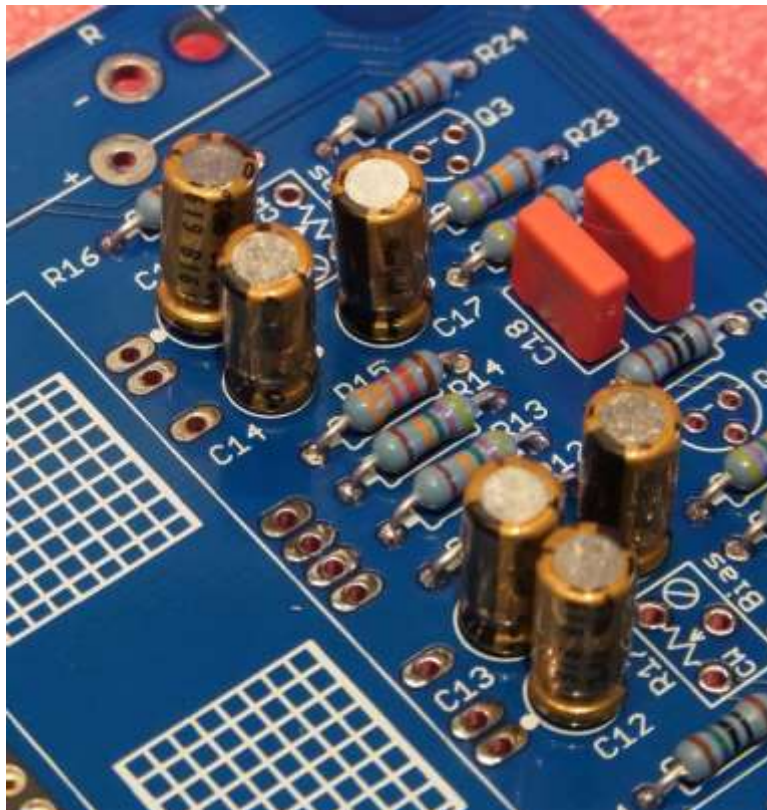
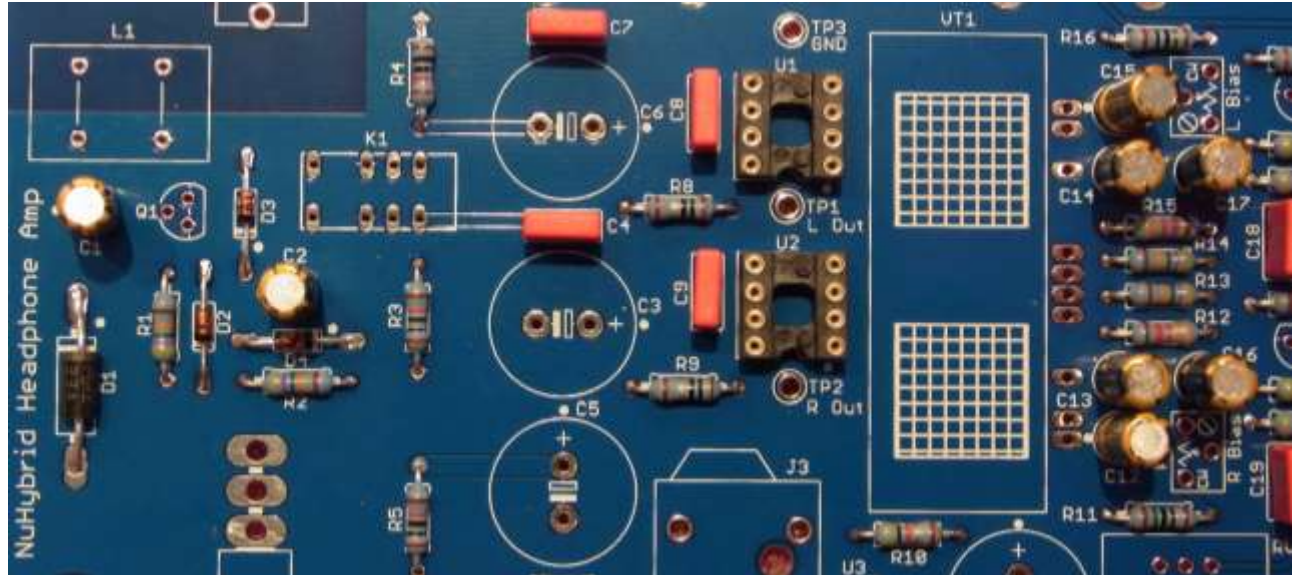
Next, install the film capacitors. (Note that the parts provided might be slightly different sizes or colors than those shown). These are small parts with the two lead wires sticking out one side, so you don't have to bend the leads before inserting them into the PCB:



Bend the leads over a bit to hold them in the board, solder, and trim the excess.

5. Install the small electrolytic capacitors

Install the smaller electrolytic capacitors. Be VERY careful that they are installed the correct way - the PCB has a dot marking the positive terminal of the capacitors. The longer lead wire is the positive terminal. Note that on the capacitor body, only the negative side is labeled – so the other side is positive. Insert them, bend the leads, solder and trim as before. Check again that the orientation is correct:



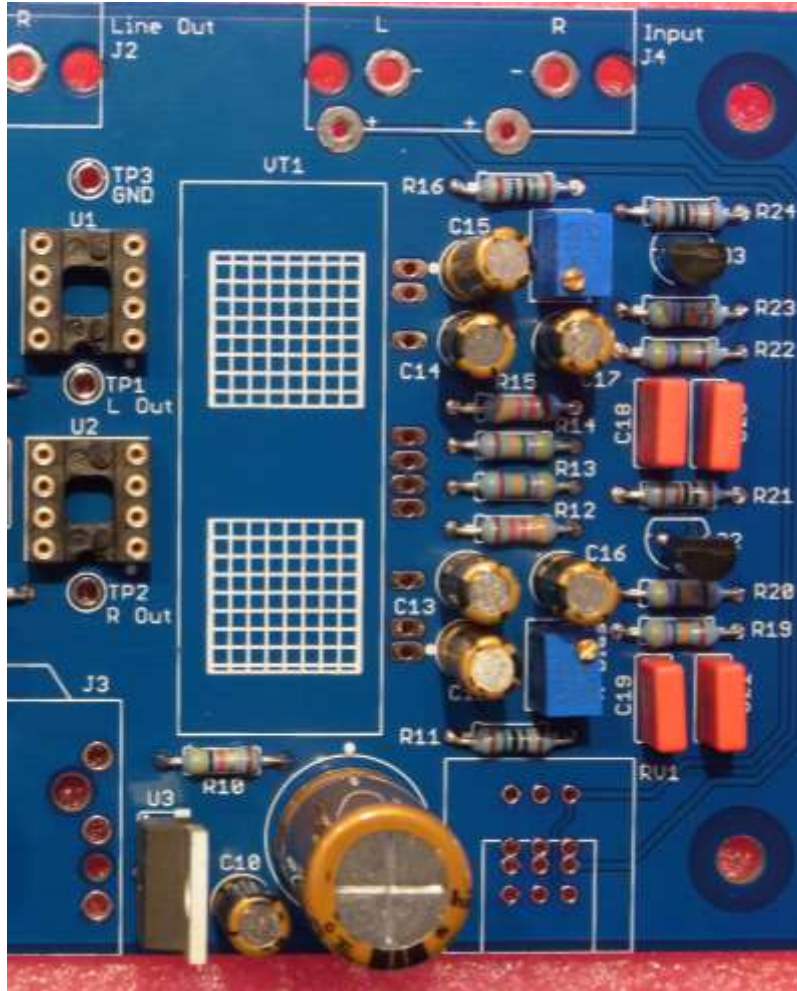
6. Install large electrolytic capacitors

Install the four larger electrolytic capacitors, the same way as the smaller:



7. Install the bias adjust trim pots, transistors and voltage regulator

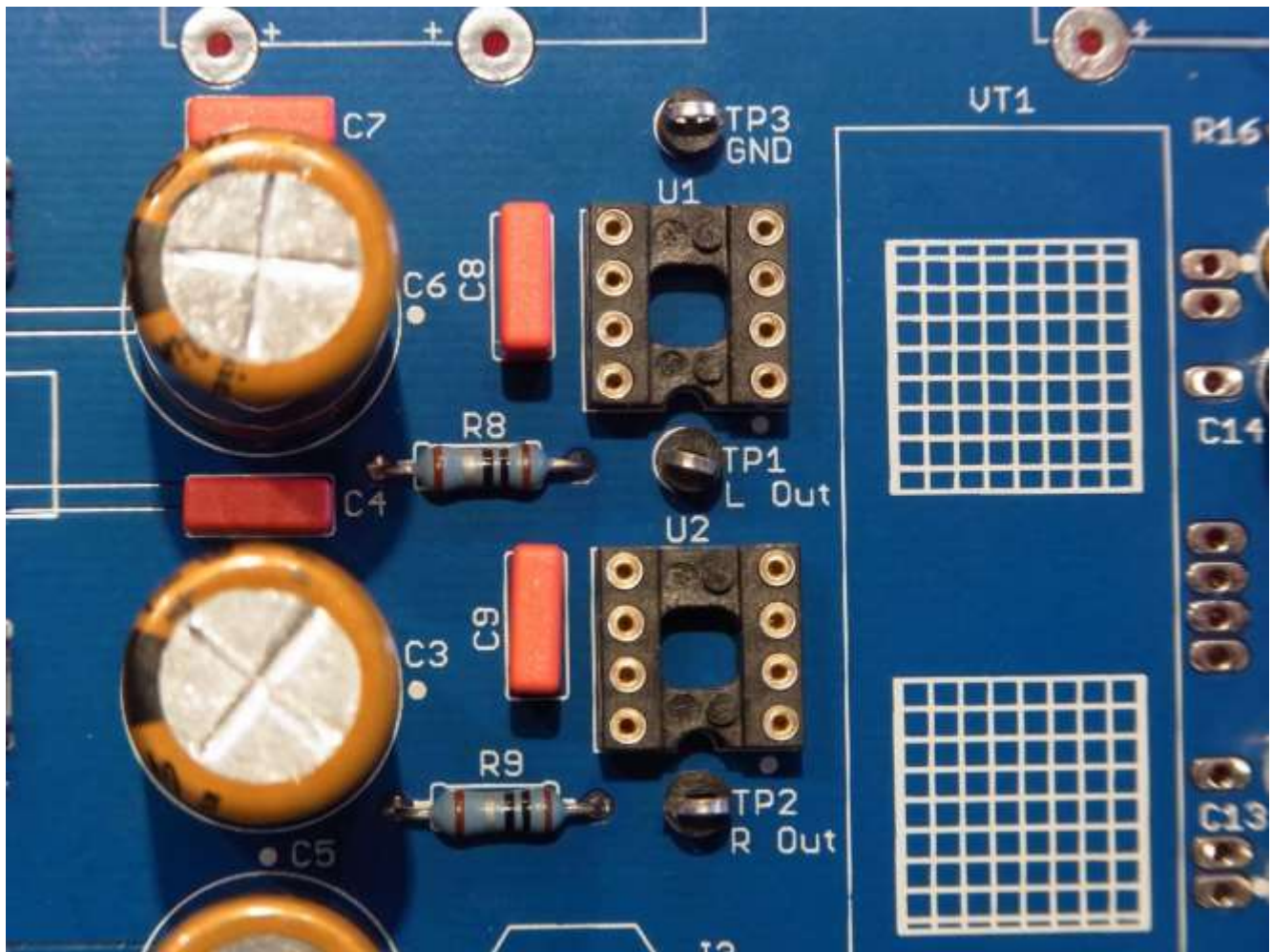
Install the bias adjust pots (R17 & R18), three small transistors (Q1, Q2, and Q3) and a voltage regulator IC (U3). Note that Q1 is a 2N7000 MOSFET, and Q2 & Q3 are 2N3904 NPN transistors – they look almost the same, but you can read the part number on the device. You need to slightly bend the leads of the transistors and voltage regulator then push them into the PCB. Bend the leads slightly on the back, solder, and trim the leads.



(Note that Q1 isn't visible in this photo – it is off to the left).

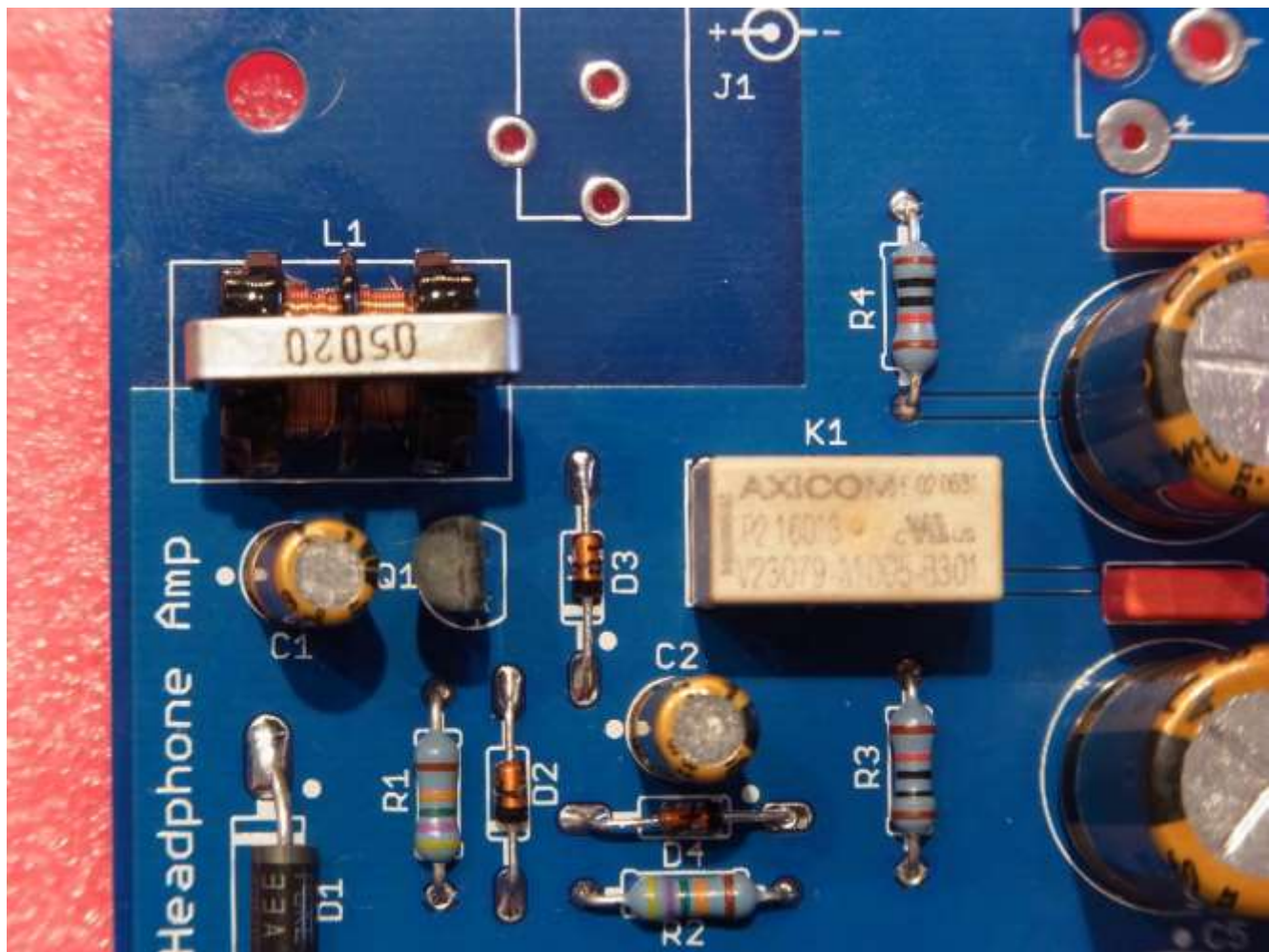
8. Install the test points

There are three small test points installed near the opamps. Insert them and solder.



9. Install the relay K1 and common mode inductor L1

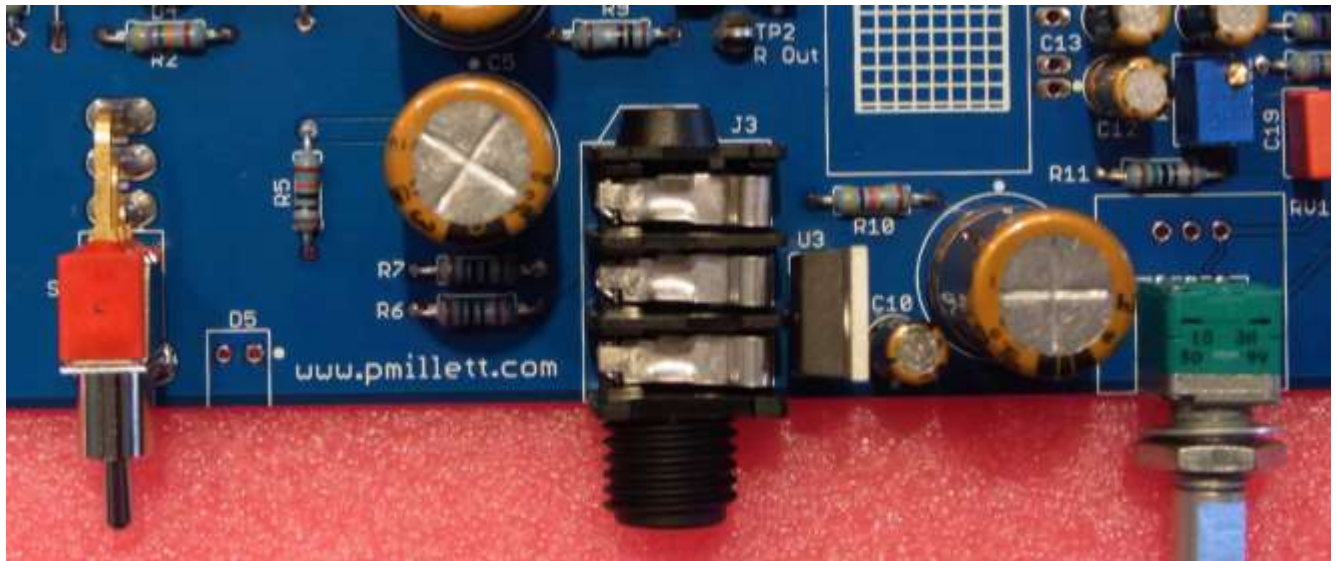
Just place them – the relay will only go in one way, and the inductor works either direction – bend the leads a bit, solder, and trim the excess leads.



Note that the relay may be a different color...

10. Install volume control RV1, headphone jack J3, and switch S1

These parts are simply inserted into the PCB and soldered. Some may snap into the PCB and stay put, and some you may need to use tape or your fingers to hold it in place while you solder them in:

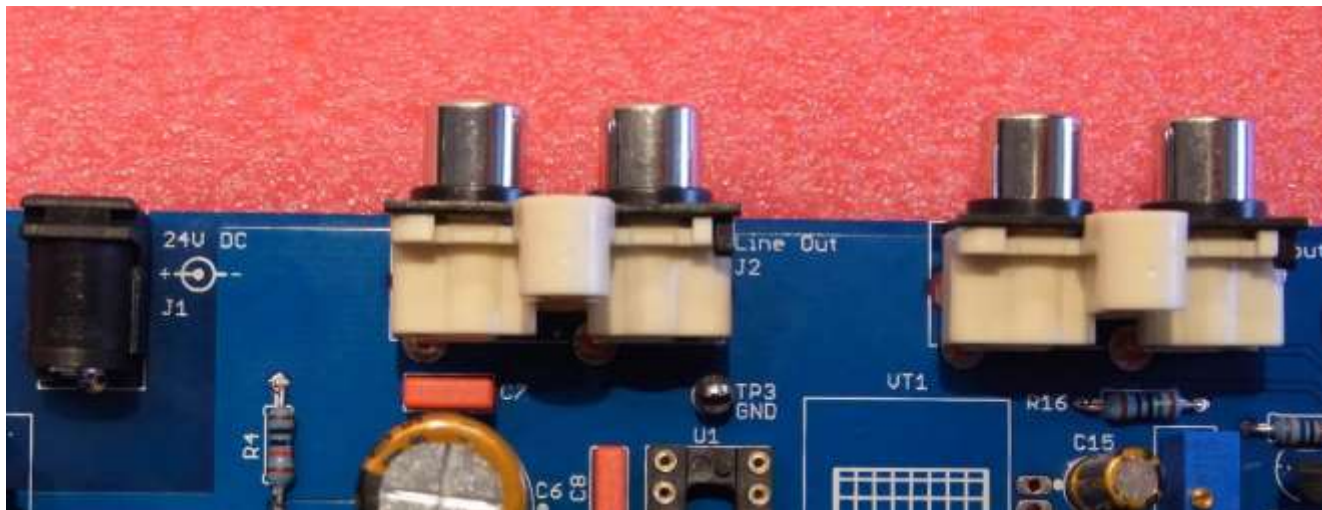


Make sure you have the parts seated all the way down on the PCB before fully soldering them in. It's best to solder only one lead, then inspect the part to see if it is fully seated on the PCB. If not, heat the solder joint while pushing the part into the PCB.

11. Install power jack J1, input jack J4, and line out jack J2

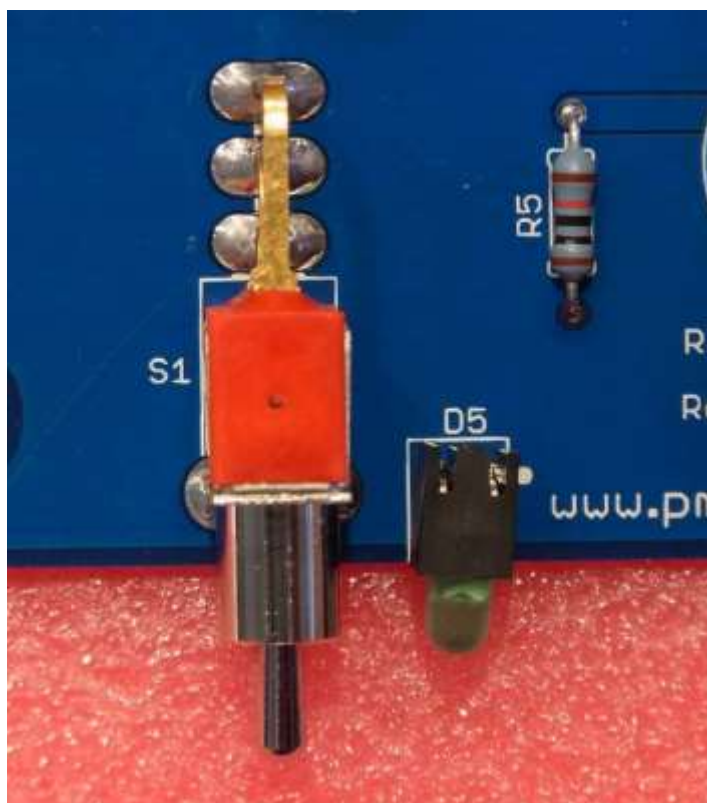
Install the jacks on the rear edge of the PCB. J2 and J4 snap into the PCB, but J1 may need to be held in with tape (or your fingers) when you solder it in.

As before, make sure the parts are fully seated on the PCB before completely soldering them in!



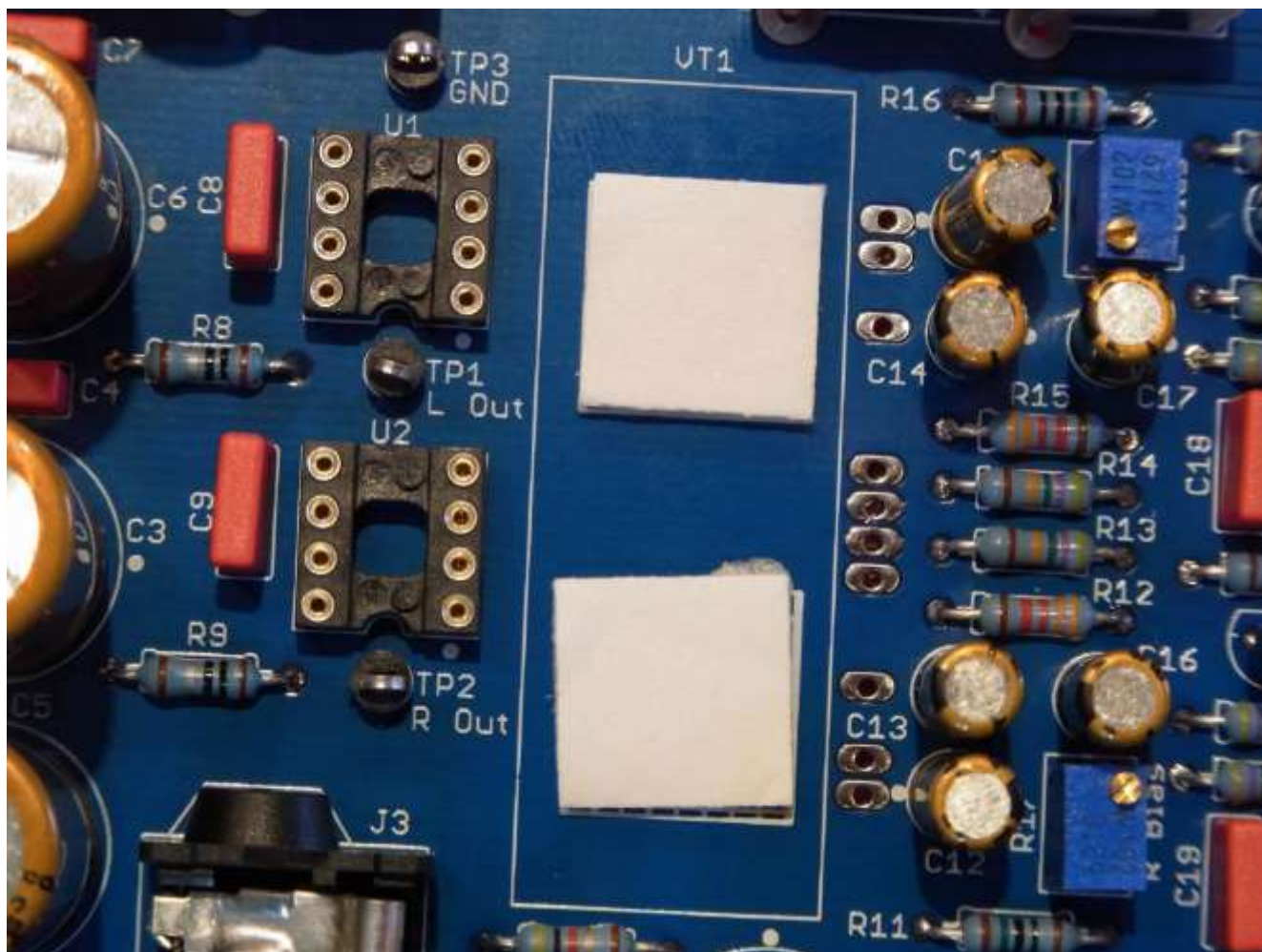
12. Install the "power on" LED D5

The LED is installed like the small capacitors. Just make sure it's pointed off the edge of the PCB!



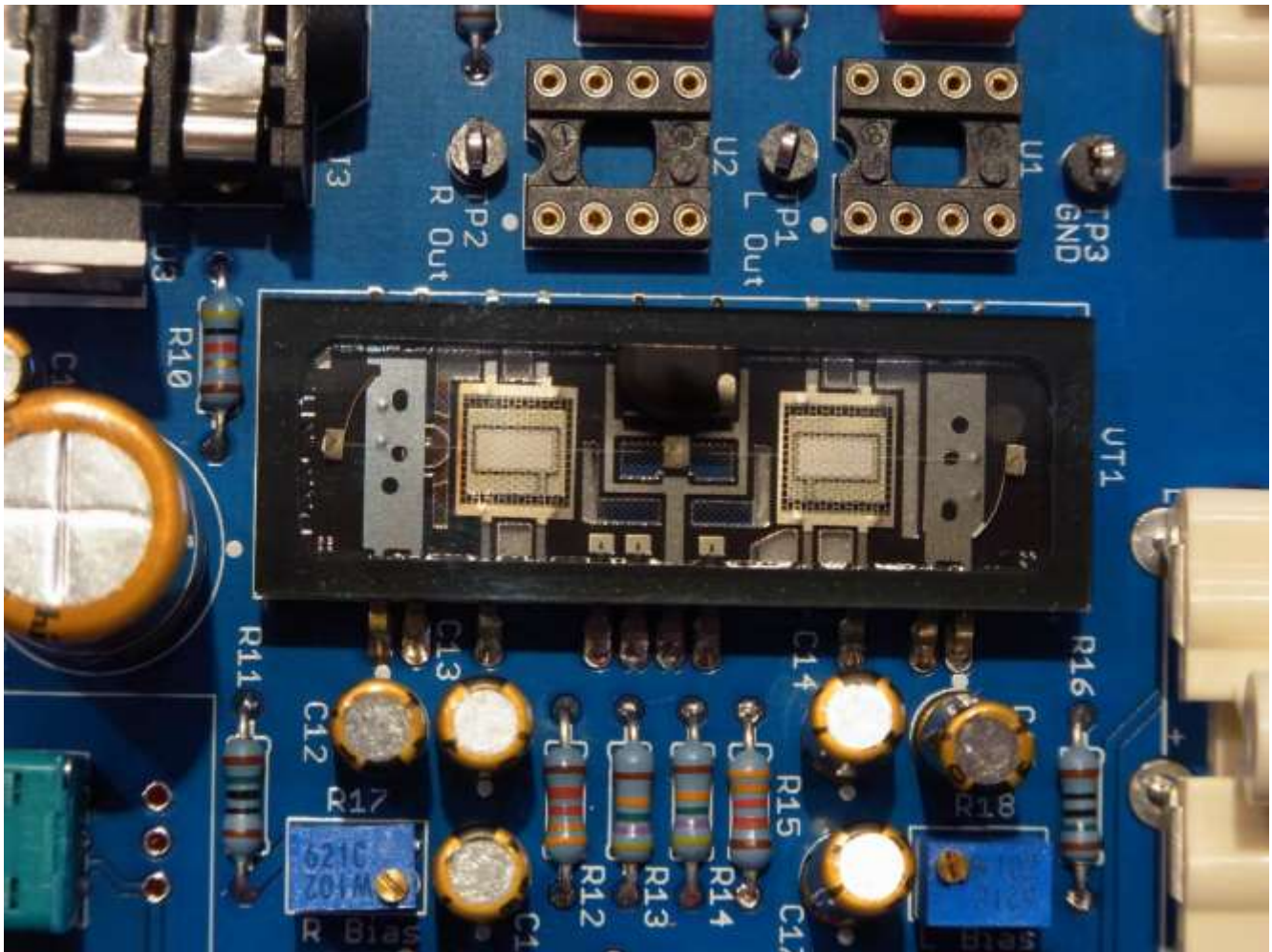
13. Install the Nutube

Last part! First, peel the backing off of the two squares of double-stick foam tape (these are supplied with the PCB and Nutube), and apply them to the PCB in the area indicated on the silkscreen:



The foam tape holds the Nutube in place.

Next, remove the backing from the top of the tape to expose the adhesive. CAREFULLY insert the Nutube into the PCB and press it onto the tape. The pins are very soft and fragile, so go slow, and be careful not to bend the pins. Solder the pins.



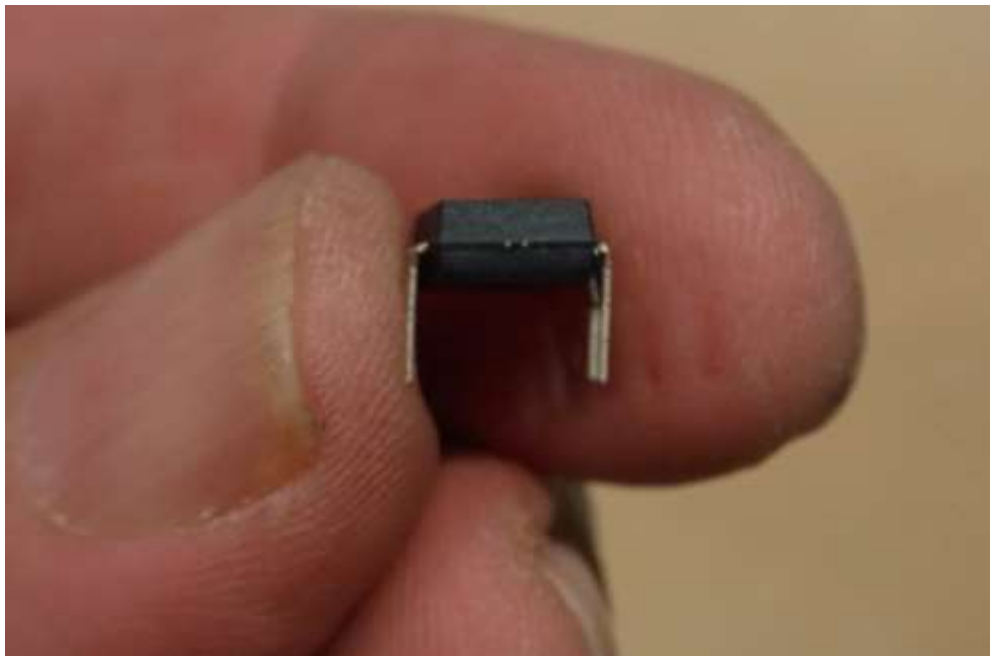
12. Inspection

Before you plug the opamps into their sockets, first do a thorough visual inspection of the PCB. Make sure all the parts are soldered in, and all are oriented correctly. Match it to the photo below:



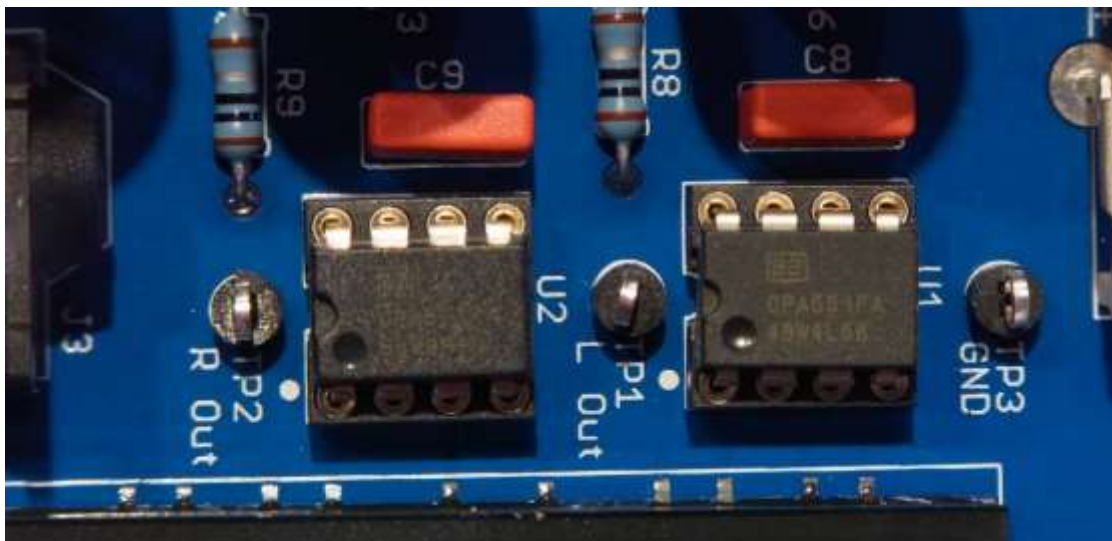
13. Install the opamps U1 and U2 into the sockets

Now, plug the opamp ICs into their sockets. You may need to gently bend the leads together so they are parallel to fit the socket:



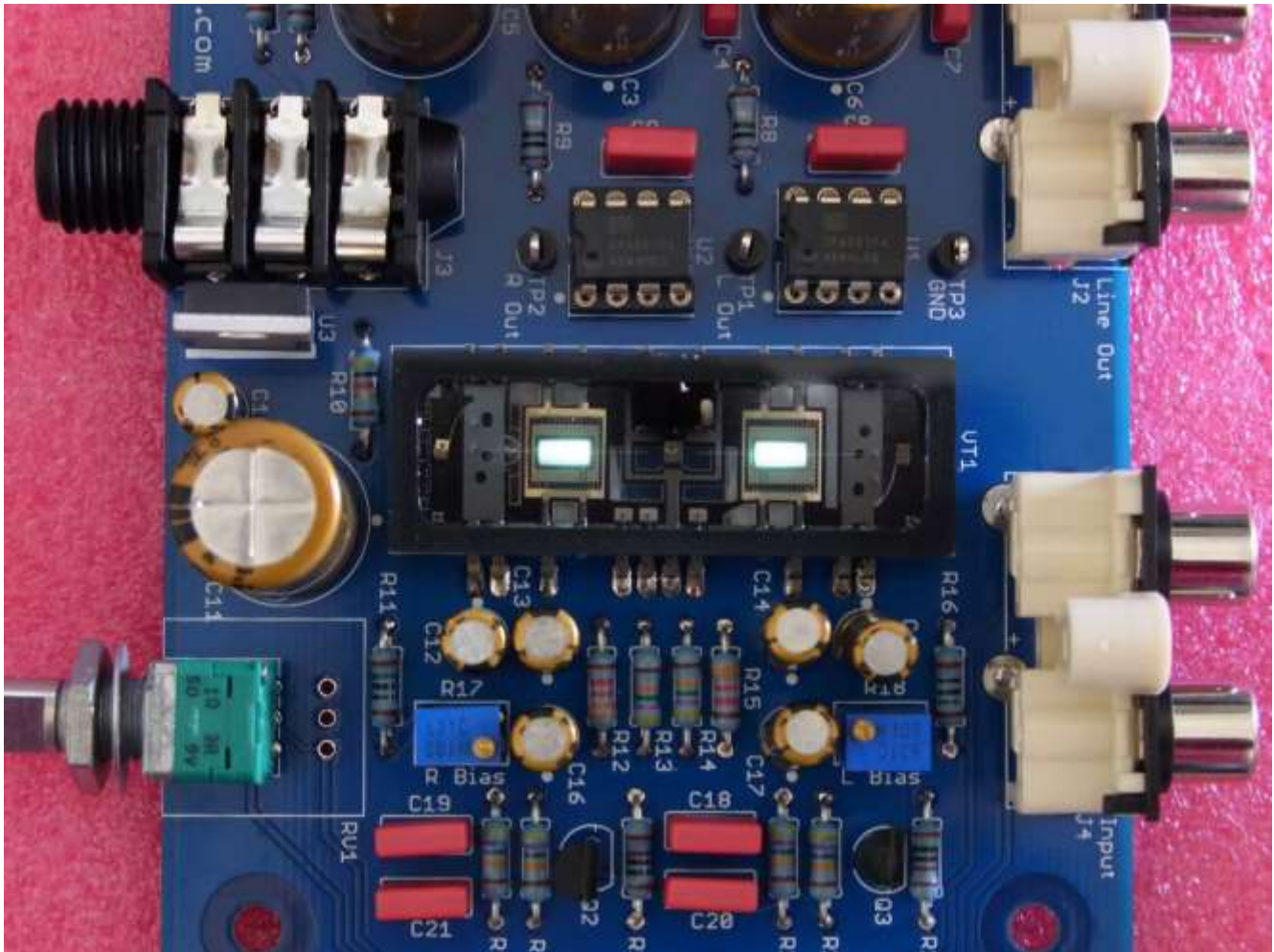
Then press them into the sockets. Make sure you align pin 1 with the notch on the sockets, and the notch on the PCB silkscreen! Be careful that the leads don't get bent! If they do, pull the IC out of the socket and straighten the leads, and try again.

They should look like this - double-check the orientation to match the photo:



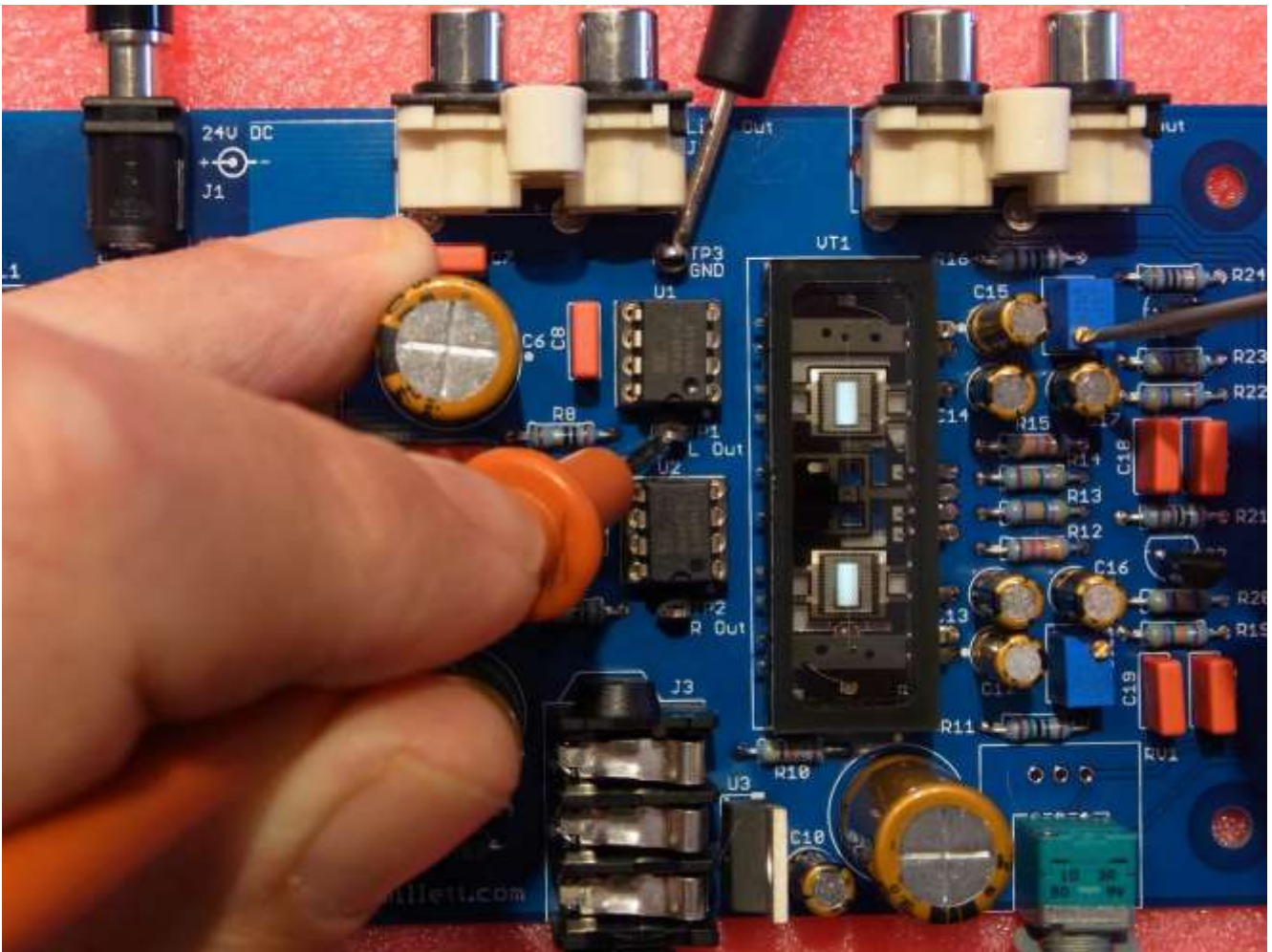
14. Power-on test

Verify that your power adapter is 24V DC (check the label). Connect it to the power jack on the board, and plug it in. Flip the power switch on (on is up). The power LED should light, and you should see a bluish-white glow from the Nutube triodes – if not, unplug the power, and go back and check to make sure everything is soldered in correctly!



15. Output bias adjustment

Set the DMM to measure DC volts, and position the leads of the DMM on TP1 and TP3 as shown in the photo below. Adjust R18, the “L Bias” potentiometer, to get a reading of about 11V.



Move the positive lead to TP2, and adjust R17 (“R Bias”) to get about 11V again.

If you cannot adjust the pot to get to 11V, unplug power and go back and check everything again.

Note that you can experiment with this setting to change the sound of the amp. There will be no harm to the amp in setting this wherever you like.

23. Listen!

At this point, all checks out. Plug the amp into a music source, headphones into the output, and listen.

Note that the power-on mute circuit will not turn on the headphones for about 5-10 seconds after power is turned on. This avoids a big “thump” as the amp powers up.

24. Package the amp

Since there are no hazardous voltages, it's perfectly OK to listen to the amp in a "bare board" configuration. You need to be very careful that the board doesn't sit down on anything metal, or you risk causing a short and damaging something!

The BOM includes a plastic case that the PCB will fit into. The screws provided with the enclosure are used to secure the board. If you prefer, you can package the amp into some other enclosure as well.

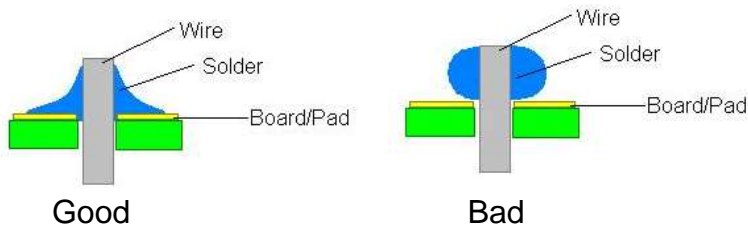
Oh, and the volume control knob provided in the BOM just pushes on to the volume control shaft. Don't put it on until you have everything done, though, as it is VERY hard to pull off once it's in place!



Troubleshooting

If the amp doesn't work, there is a 95% chance that there is a solder problem, either an open joint or shorted leads.

Go back and inspect all of the solder joints one by one. If any look suspect, re-heat them with the soldering iron. It is common for novice soldiers to get solder on the exposed lead, but not flow the solder onto the PCB pads. The joints should look like little volcanoes, with a solder "fillet" from the lead to the pad.



If there is a big blob of solder, remove the excess using solder braid, or heating it and whacking the board against a table (gently!).

If the solder is good, the next most likely issue is that a component is installed incorrectly. This can mean a part is installed the wrong orientation, or a part is installed in the wrong place. Look over the board. Sometimes it helps to have somebody else inspect it - often you will overlook the same error over and over again, when somebody else will spot it right away!

It is very unlikely that a component is defective when shipped. However, parts can get damaged if they are installed incorrectly and power is applied. That's why it is VERY important to check the assembly BEFORE applying power!

If you have some electronics experience, you should be able to go through the schematic, and check voltages to isolate the problem. If you are a newbie, you might need to solicit help from somebody.

Appendix 1: Bill of Materials (Parts List, or BOM)

You can also download this in .XLS or .PDF form from www.pmillett.com.

1 K1	NEC-Tokin KEMET	EC2-24NJ	551-EC2-24NJ	655-V23079A1005B301	399-11037-5-ND	PCB Low Signal Relays - PCB 24VDC NON-LATCH	\$ 2.43	\$ 2.43	
1 L1	Kemet	SU9V-05020	80-SU9V-05020	963-TLF9UA202WR54K1	399-10721-ND	Common Mode Chokes / Filters 0.5amp 2mH	\$ 0.90	\$ 0.90	
1 Q1	Fairchild Semiconductor	2N7000	512-2N7000	689-2N7000-G	2N7000FS-ND	MOSFET N-CHANNEL 60V 200mA	\$ 0.37	\$ 0.37	
2 Q2, Q3	Fairchild Semiconductor	2N3904	512-2N3904BU	610-2N3904	2N3904FS-ND	BJT NPN Transistor General Purpose	\$ 0.17	\$ 0.34	
8 R1, R2, R13, R14, R19, R20, R22, R23	KOA Speer	MF1/4DC4753F	660-MF1/4DC4753F	603-MFR-25FBF52-475K	475KXBK-ND	Through Hole Metal Film Resistors - 1/4W 475K ohm 1%	\$ 0.12	\$ 0.96	
2 R12, R15	KOA Speer	MF1/4DC3322F	660-MF1/4DC3322F	603-MFR-25FBF52-33K2	33.2KXBK-ND	Through Hole Metal Film Resistors - 1/4W 33.2K ohm 1%	\$ 0.12	\$ 0.24	
3 R5, R21, R24	KOA Speer	MF1/4DC1002F	660-MF1/4DC1002F	603-MFR-25FBF52-10K	10.0KXBK-ND	Through Hole Metal Film Resistors - 1/4W 10K ohm 1%	\$ 0.12	\$ 0.36	
2 R8, R9	KOA Speer	MF1/4DC1R00F	660-MF1/4DC1R00F	603-MFR-25FBF52-1R	1.0QBK-ND	Through Hole Metal Film Resistors - 1/4W 1 ohm 1%	\$ 0.10	\$ 0.20	
1 R10	KOA Speer	MF1/4DC40R2F	660-MF1/4DC40R2F	603-MFR-25FBF52-40R2	40.2XBK-ND	Through Hole Metal Film Resistors - 1/4W 40.2 ohm 1%	\$ 0.12	\$ 0.12	
2 R3, R4	KOA Speer	MF1/4DC1001F	660-MF1/4DC1001F	603-MFR-25FBF52-1K	1.00KXBK-ND	Through Hole Metal Film Resistors - 1/4W 1K ohm 1%	\$ 0.12	\$ 0.24	
4 R6, R7, R11, R16	KOA Speer	MF1/4DC1500F	660-MF1/4DC1500F	603-MFR-25FBF52-150	150XBK-ND	Through Hole Metal Film Resistors - 1/4W 150ohms 1%	\$ 0.12	\$ 0.48	
2 R17, R18	Bourns	PV37W102C01B00	81-PV37W102C01B00	858-64WR1KLF	490-2969-ND	Through Hole Trimmer Resistors - 1.0Kohms 6mm SQ	\$ 2.08	\$ 4.16	
1 RV1	ALPS	RK09712200HA	688-RK09712200HA	652-PTD902-2015FA103	PTD902-2015F-A103-ND	Potentiometers 10 KOHms Dual Audio	\$ 1.63	\$ 1.63	Upgrade:TKD 2CP601-10K (Parts Connexion)
1 S1	E-Switch	100SP1T2B4M7RE	612-100-A2472	108-0020-EVX	EG2364-ND	Toggle Switches ON-ON SPDT R/A	\$ 3.29	\$ 3.29	
3 TP1, TP2, TP3	Keystone Electronics	5006	534-5006	534-5007	36-5006-ND	PCB Test Point Black 0.063	\$ 0.32	\$ 0.96	Optional
2 U1, U2	Texas Instruments	OPA551PA	595-OPA551PA		OPA551PA-ND	High Current Opamp	\$ 5.12	\$ 10.24	Possible to use others
1 U3	Texas Instruments	UA78M33CKCS	998-MIC2940A-3.3WT	296-21633-5-ND	576-1134-ND	LDO Voltage Regulator 3.3V TO-220	\$ 0.90	\$ 0.90	
2 At U1, U2	Mill-Max	110-41-308-41-001000	575-11041308410010	575-113308	ED90515-ND	IC Socket 8 pin	\$ 0.76	\$ 1.52	
1 Case	Serpac	051-I-BLACK	635-051-I-B		SR051-IB-ND	Enclosures, Boxes, & Cases 3.26X5.63X.91 BK	\$ 6.88	\$ 6.88	Or build your own
1 AC Adapter	Mean Well	GST25U24-P1J	709-GST25U24-P1J		T1073-P5P-ND	Wall Mount AC Adapters 25W 24V	\$ 12.67	\$ 12.67	
1 Knob	Davies Molding	1230-J	5164-1230-J	450-BA361		Control Knob 6mm Flat to 4.5mm	\$ 0.94	\$ 0.94	Or use other, shaft is 6mm
1 PCB + Nutube 6P1	pmillett.com					Blank PCB plus Korg Nutube 6P1	\$ 50.00	\$ 50.00	

Italic = similar part

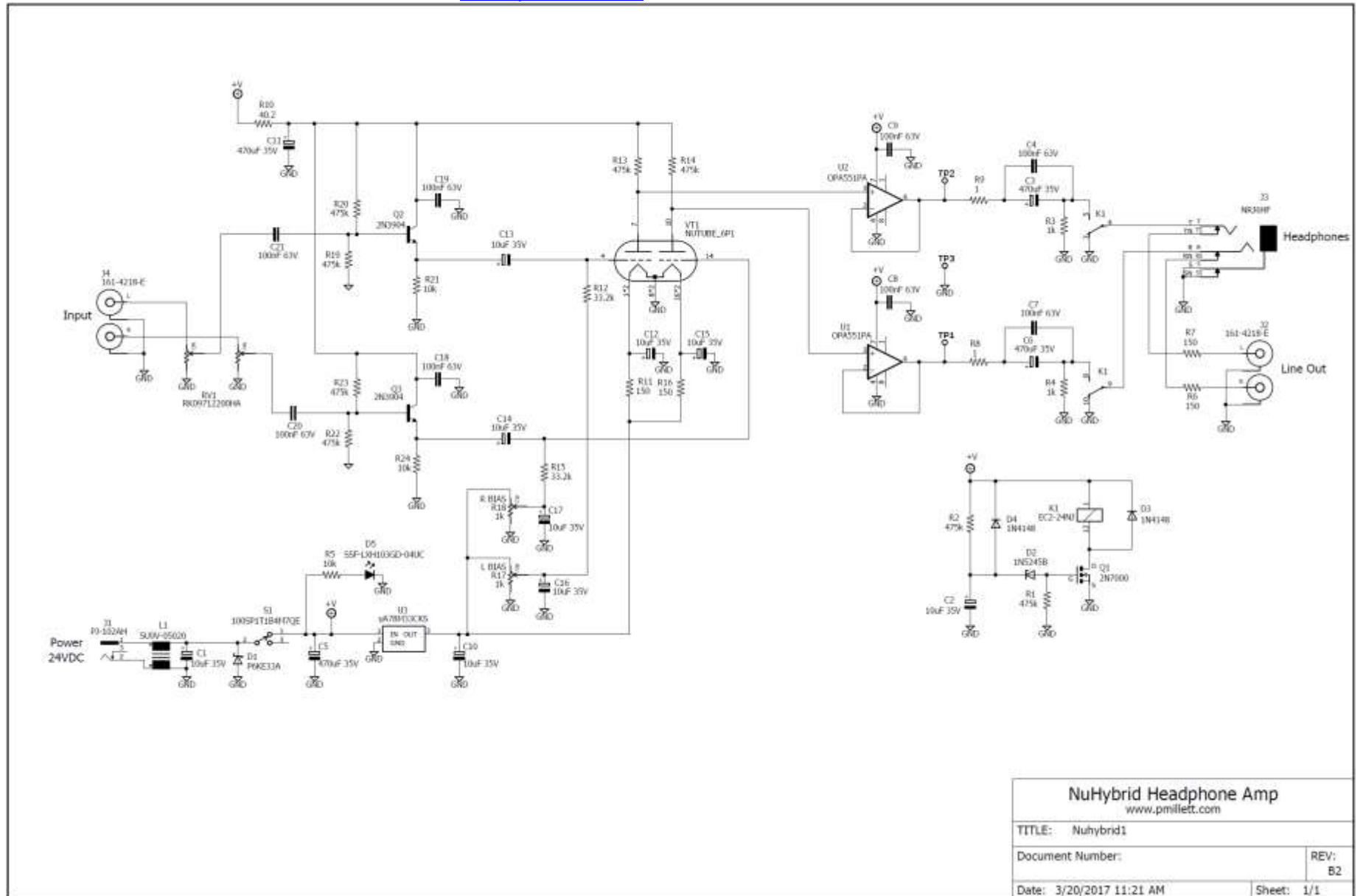
Italic = similar part

Total

\$ 114.27

Appendix 2: Schematic

You can also download this in .PDF form from www.pmillett.com



Appendix 3: Mechanical Drawing

You can also download a .DXF or .PDF file at www.pmillett.com.

