

DIY "Butte" Solid-State Headphone Amplifier

Assembly instructions



What you need:

- The bare PCB (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")

The following are optional, but recommended:

- Needle-nose pliers
- Tweezers
- DMM (Digital Multimeter)

You also probably want some type of enclosure to package the completed amp in. You can use the one designed for it including an extruded aluminum housing and front/rear panels from pmillett.com (via eBay), or one of your own choosing.

To order the parts from Mouser, go to

<https://www.mouser.com/ProjectManager/ProjectDetail.aspx?AccessID=6f16d25474> and place an order. Alternatively, 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: **6f16d25474**.

The Mouser BOM includes all of the parts needed to build the Butte. 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 Mouser BOM may be out of stock. The BOM has some suggestions for alternate parts that can be used instead. 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.

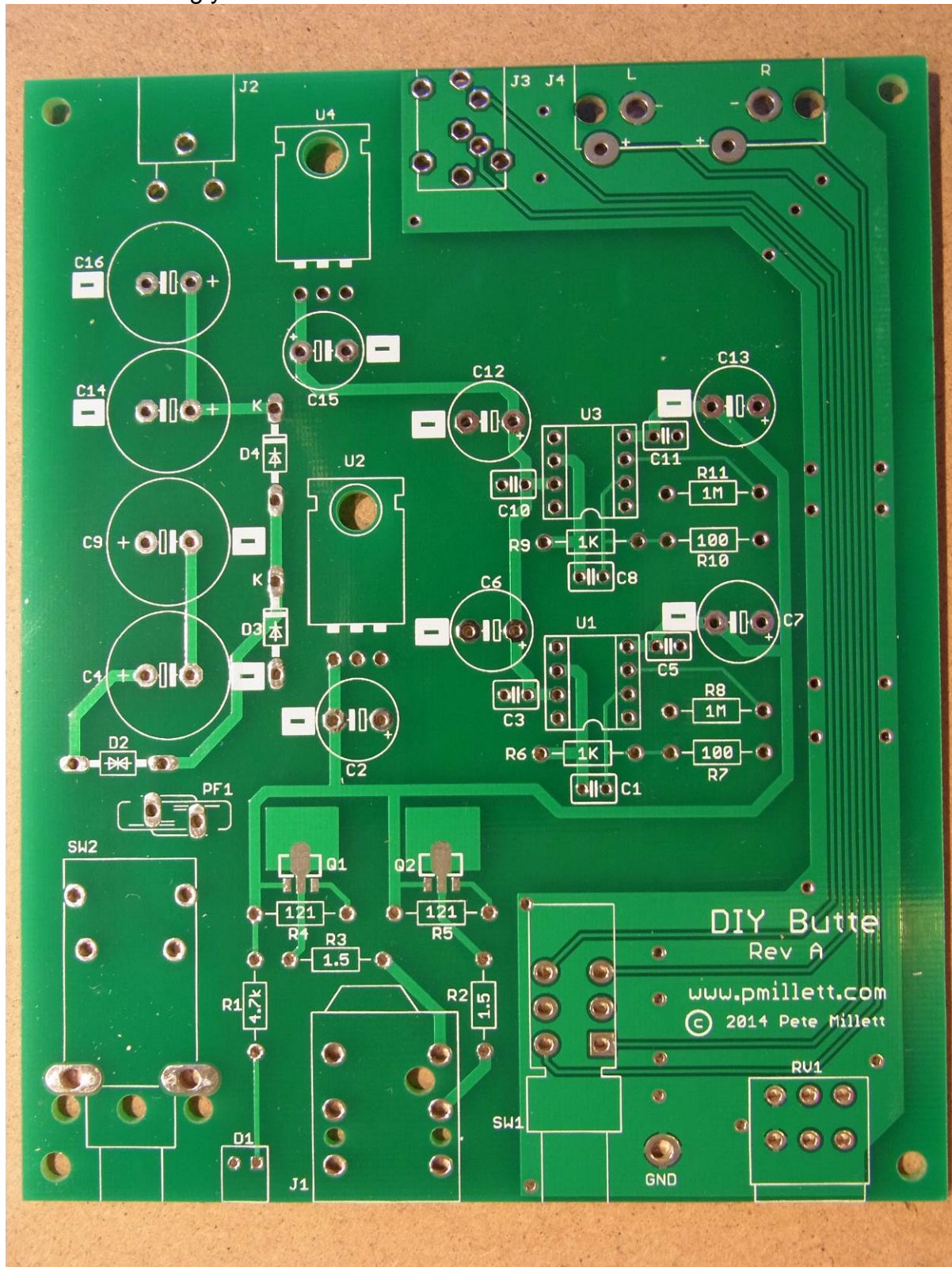
If you are new to soldering, it's highly recommended that you review one or more of the excellent on-line soldering tutorials. Just search "soldering tutorial" on the web and/or YouTube.

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:

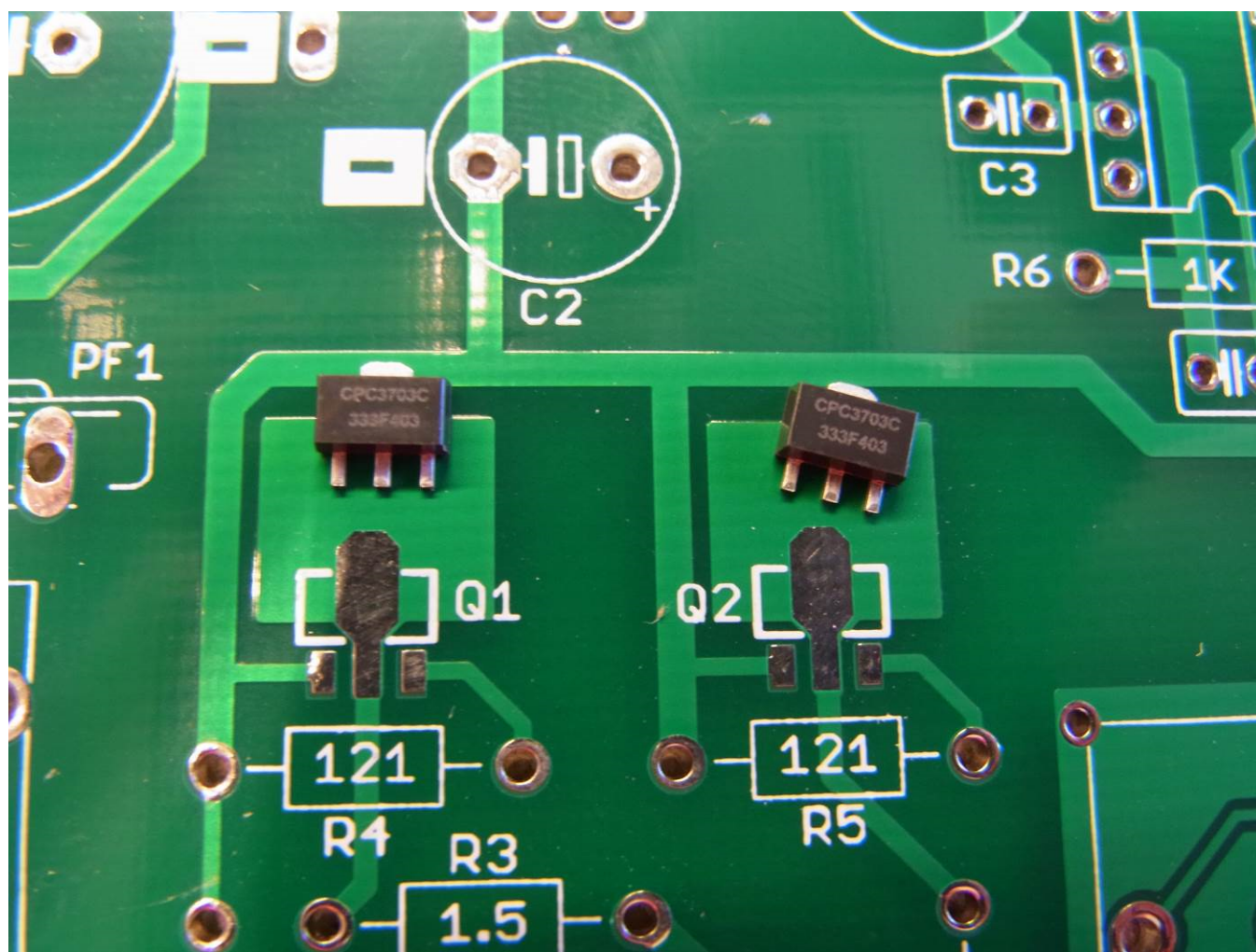


You'll see that each part has an outline silkscreened on the board, and a reference designator (name) next to it. Parts are numbered starting at the lower left, so you can expect to find resistor R1 somewhere near the lower left corner.

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 ("-" symbol for capacitors, and a bar and letter "K" for the cathode side of diodes).

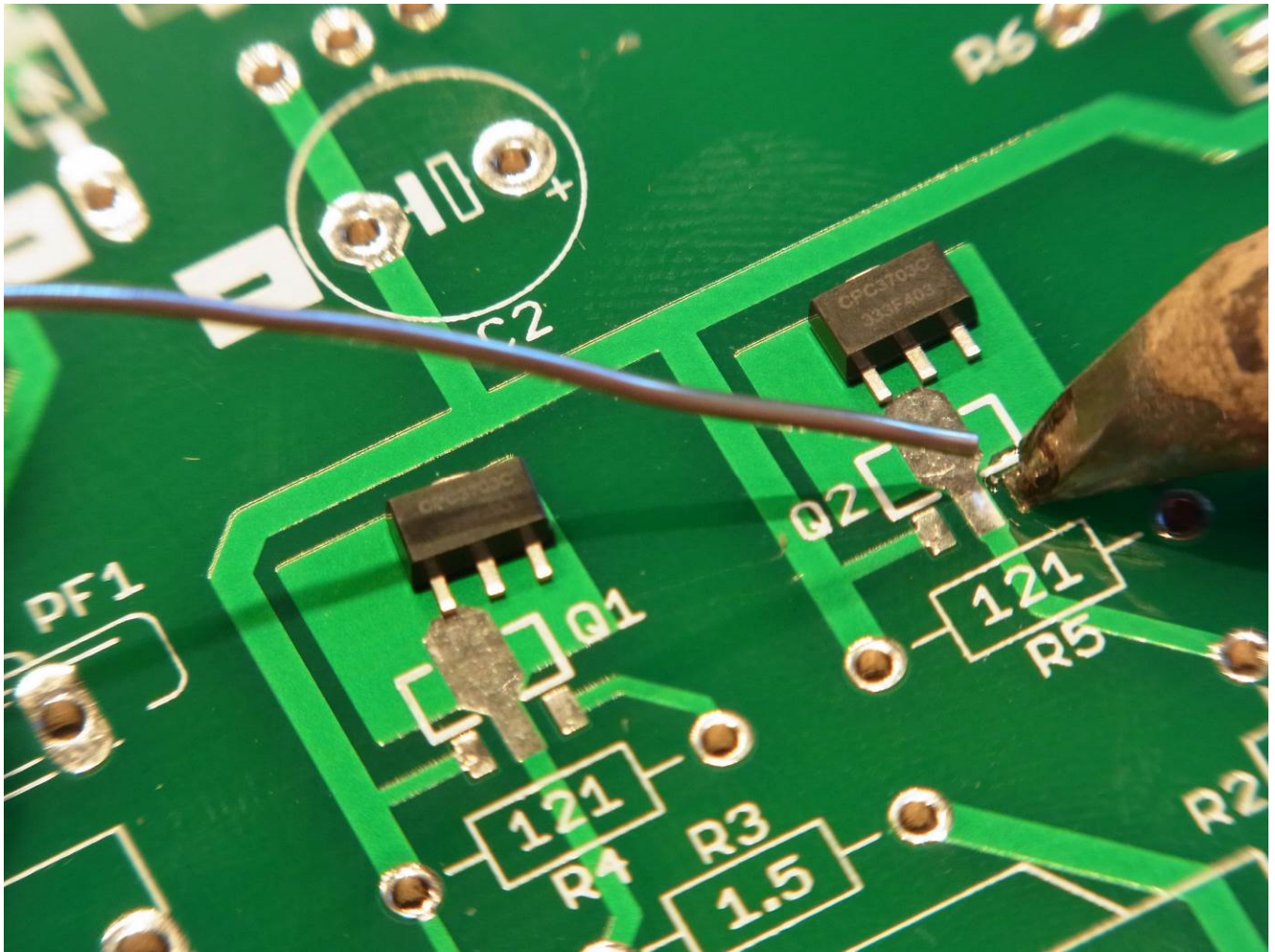
2. *OPTIONAL: Install Q1 and Q2*

Q1 and Q2 are the only surface-mount components on the PCB, so they deserve a little special attention, as they are installed differently than all the other parts.

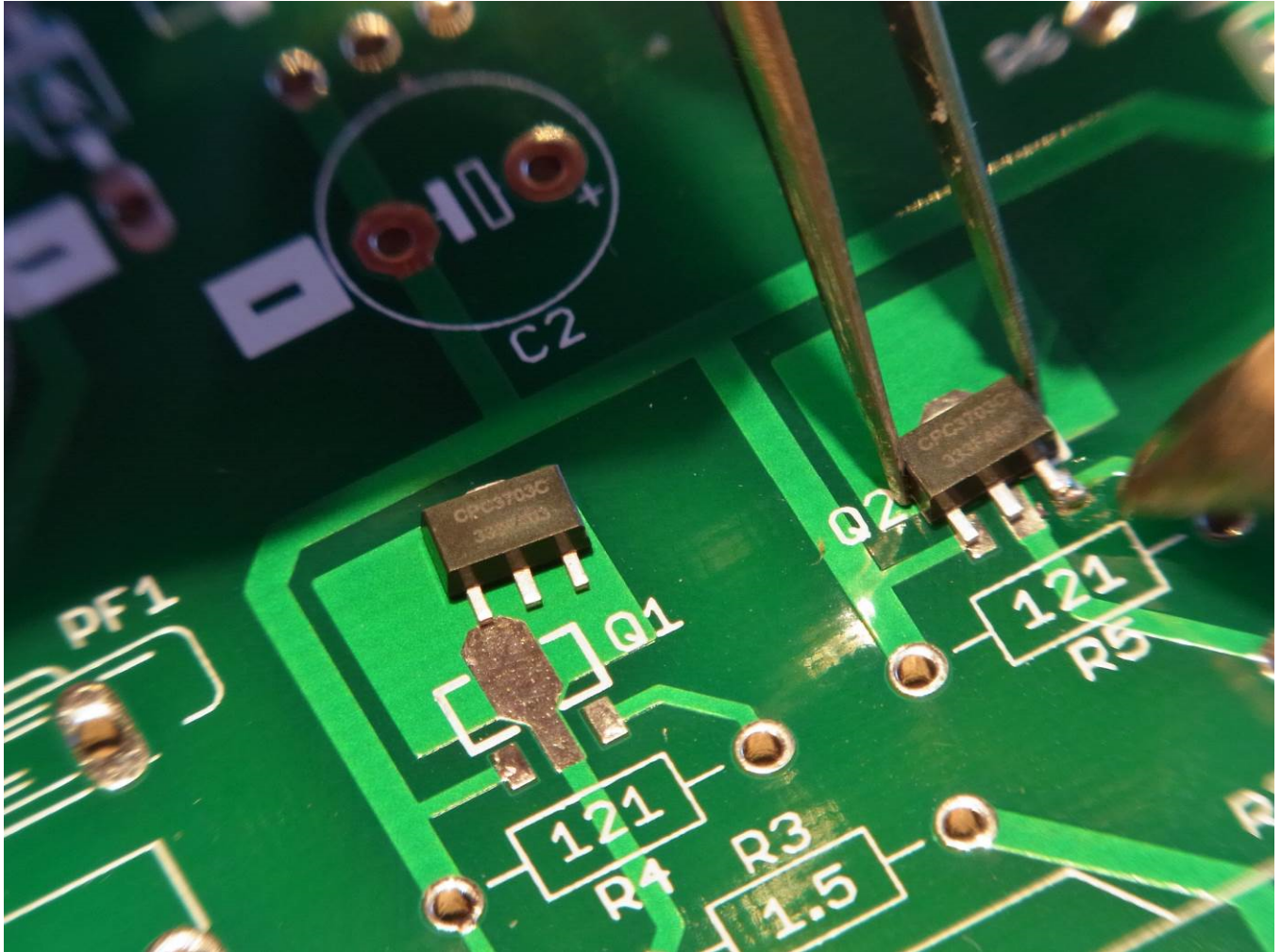


Note that these components are optional - you can leave them out if you want. They make a very small difference in the distortion spectra, and to be honest, it may be impossible to hear the difference with or without them. So if you want, leave them out for now - you can always add them later.

To hand solder the SMD components, first, add a little solder to one of the pads, like this:

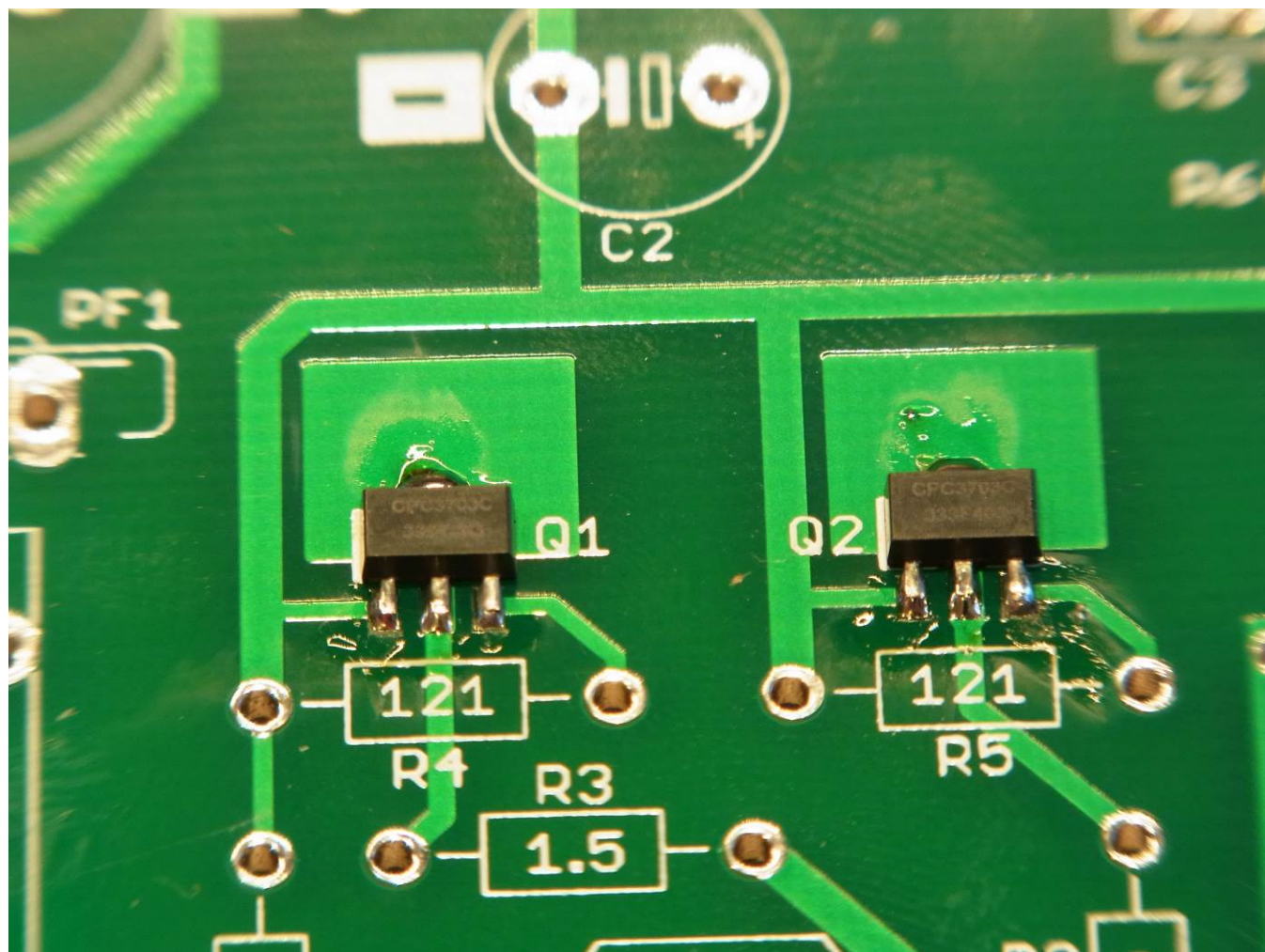


Next, using tweezers, a pair of needle-nose pliers, or your fingers (be careful!), slide the transistor onto the pads while holding the soldering iron on the pad at the same time:



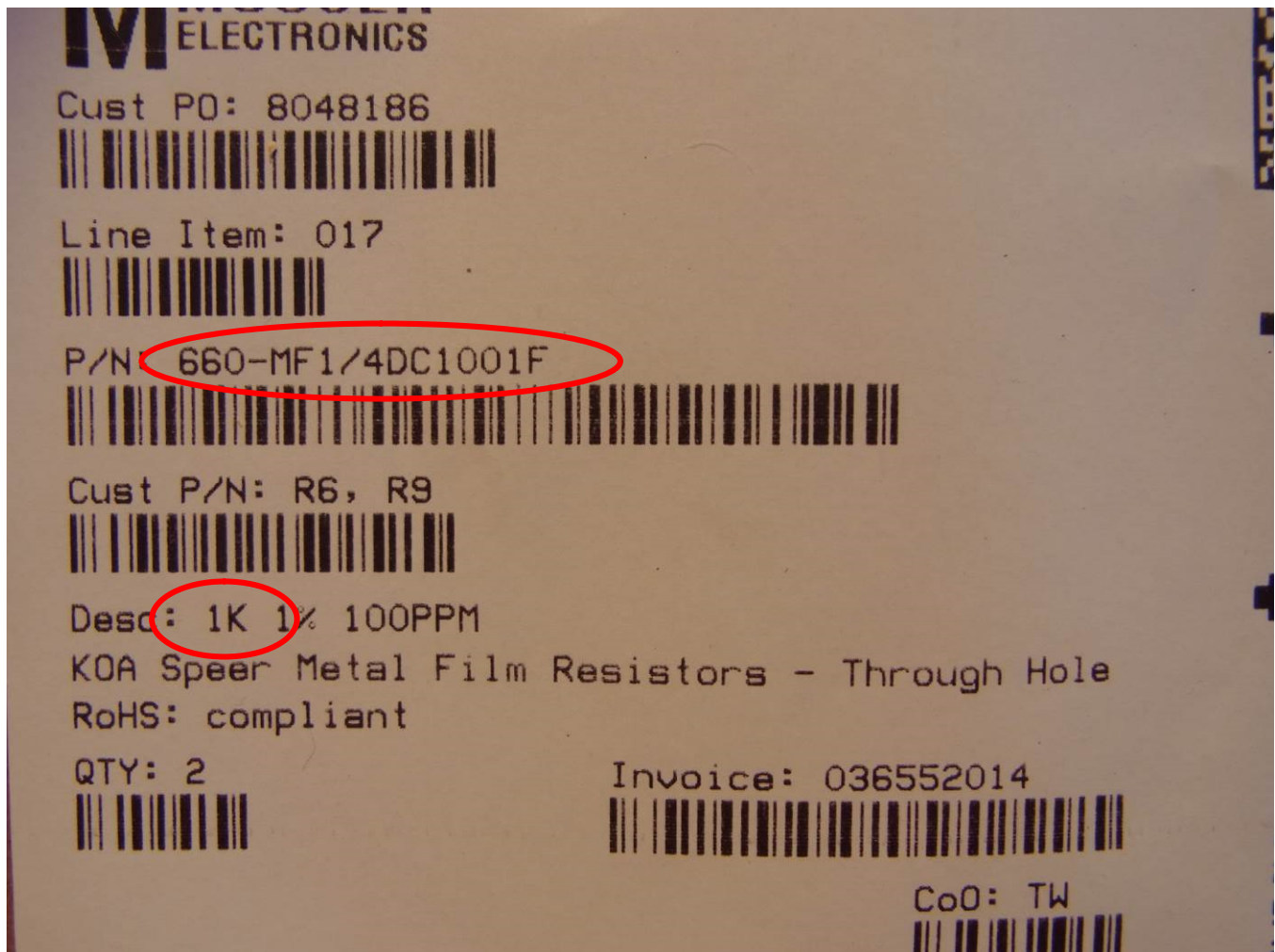
It's a little tricky. If you screw up and the part gets soldered in at a funny angle, heat the solder joint again and re-position it, until you have it close enough to hit all three pads.

Then, solder the remaining leads. Put the soldering iron tip at the point where the lead touches the PCB pad, and apply a little solder. When you're done, it should look like this:



3. Install resistors R1-R11

Each bag of parts from Mouser looks like this:



Match the Mouser part number or the description with the parts on the BOM:

4 Resistor, 1/4W 1K

R4, R5, R6, R9

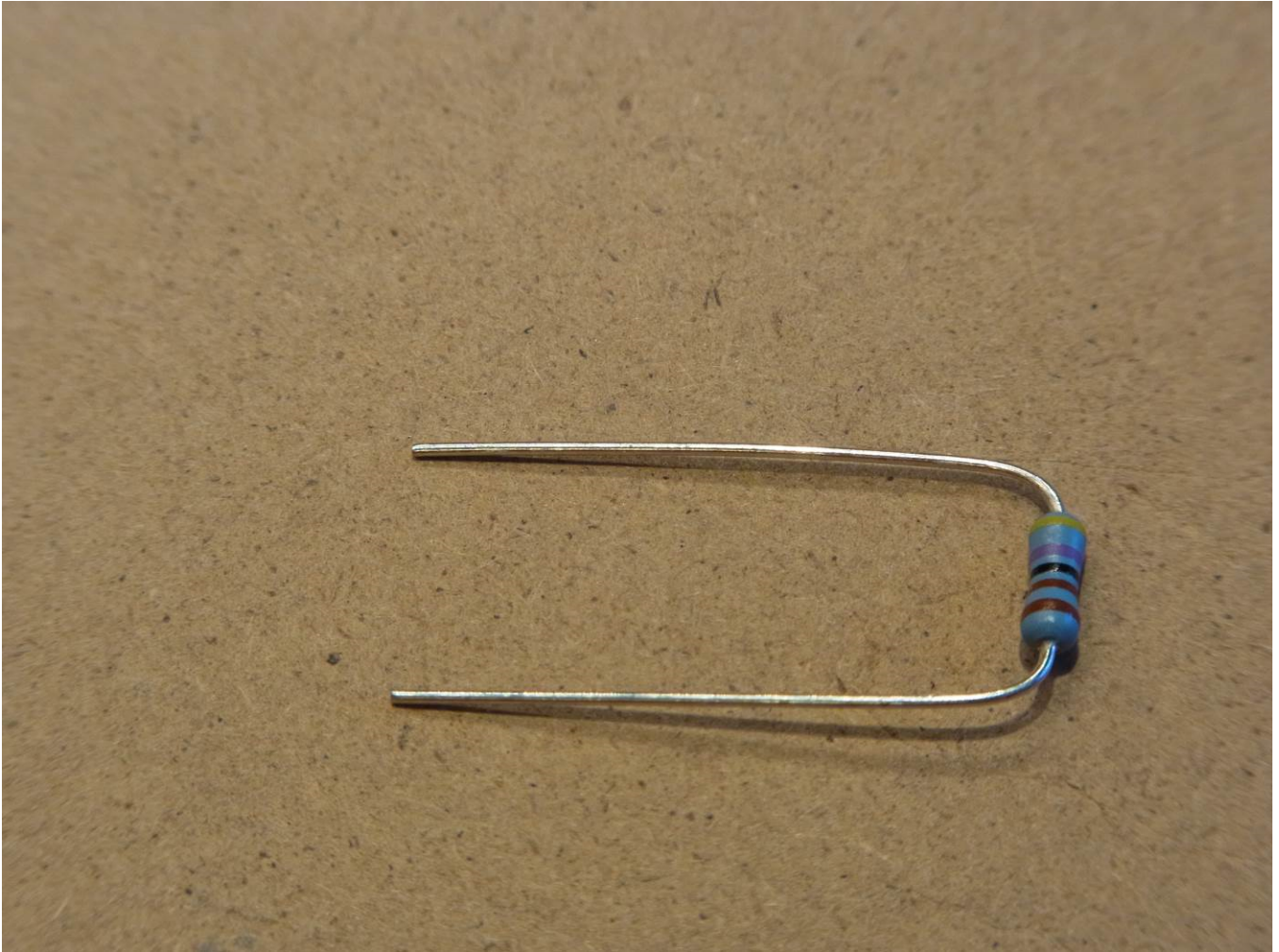
KOA

MF1/4DC1001F

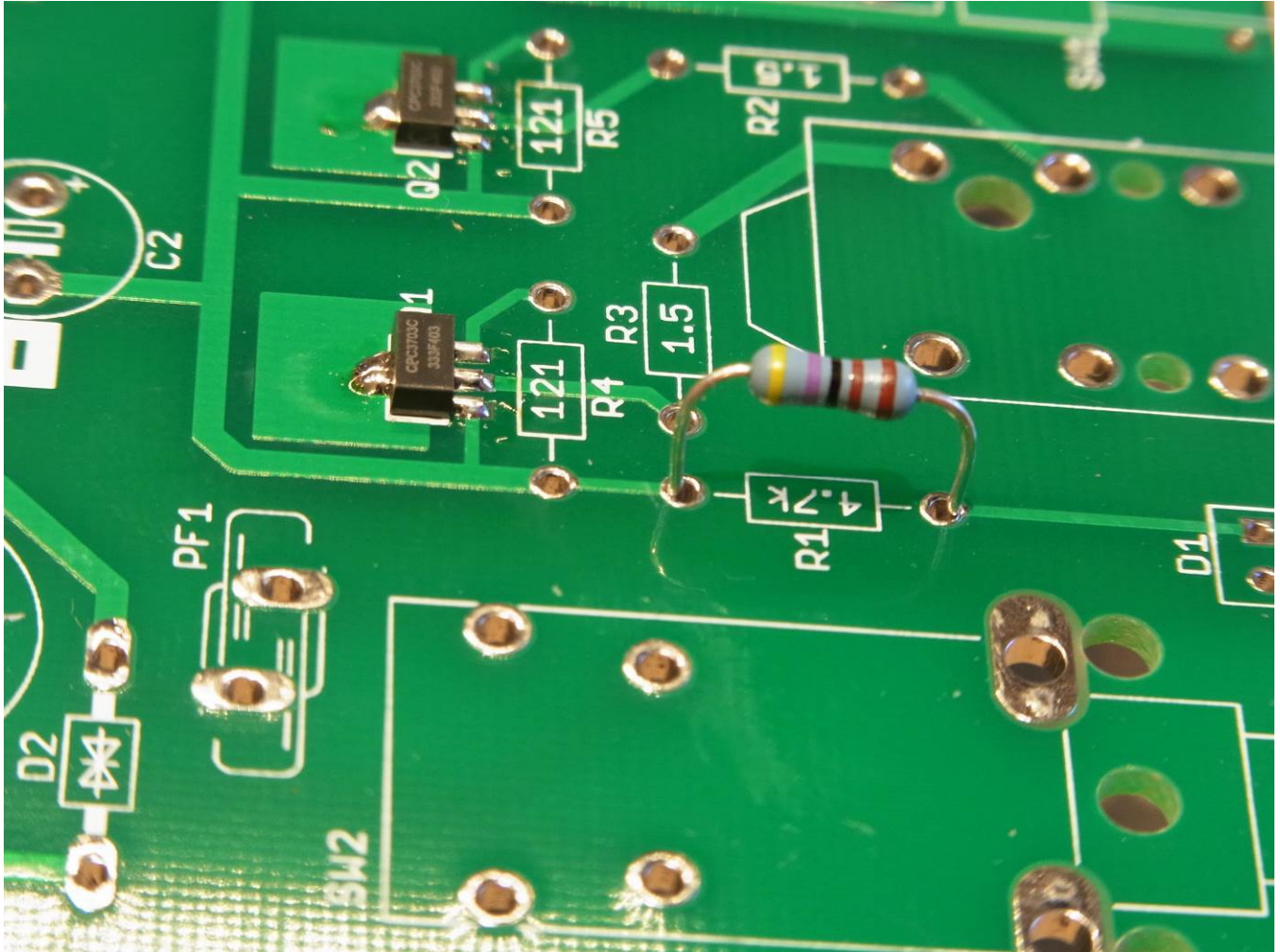
660-MF1/4DC1001F

So, for this particular part (a 1k resistor), it is installed at R4, R5, R6 and R9.

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:

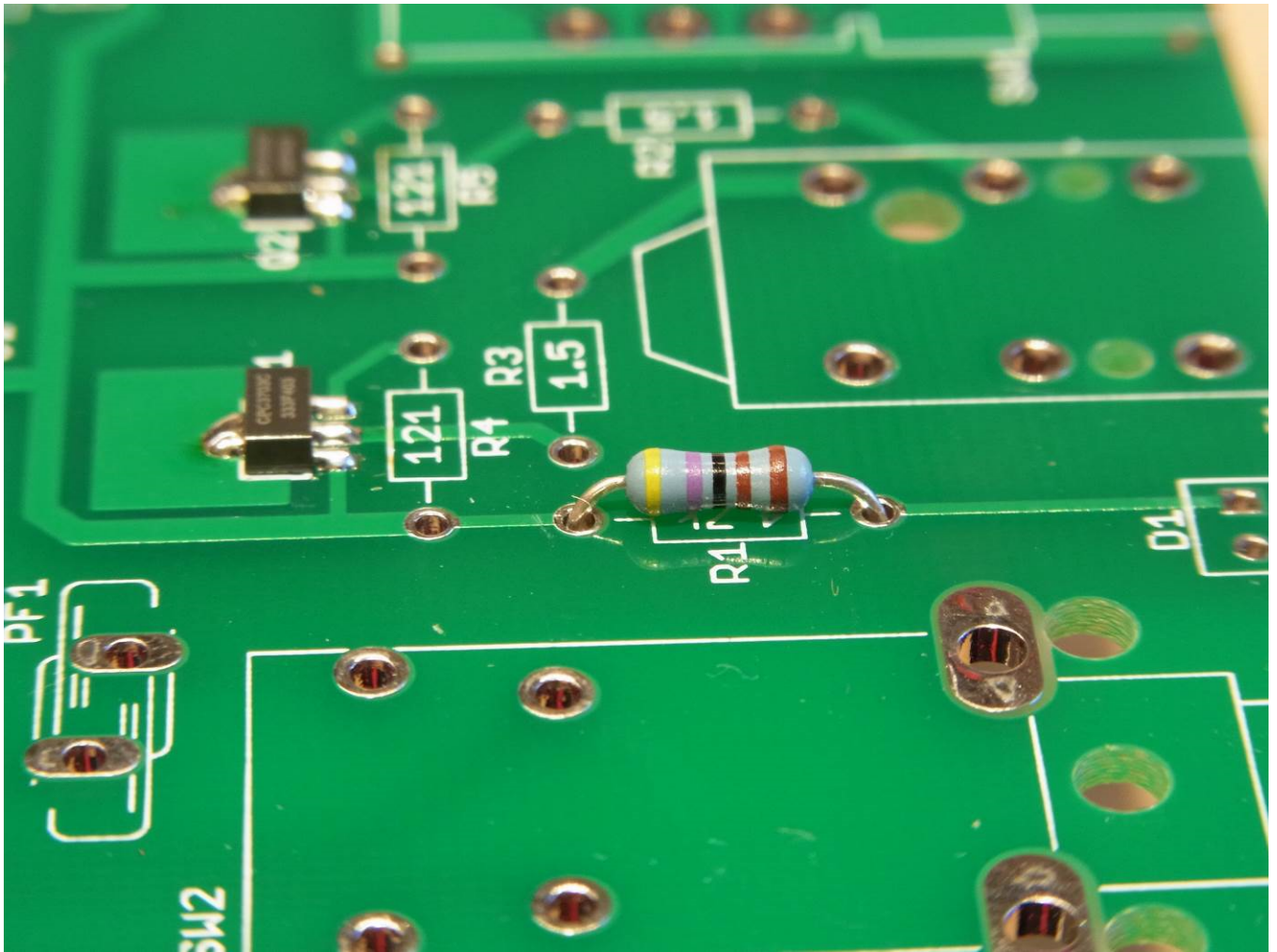


Next, insert them into the PCB in the appropriate spots (matching the reference designator on the bag, or on the BOM):

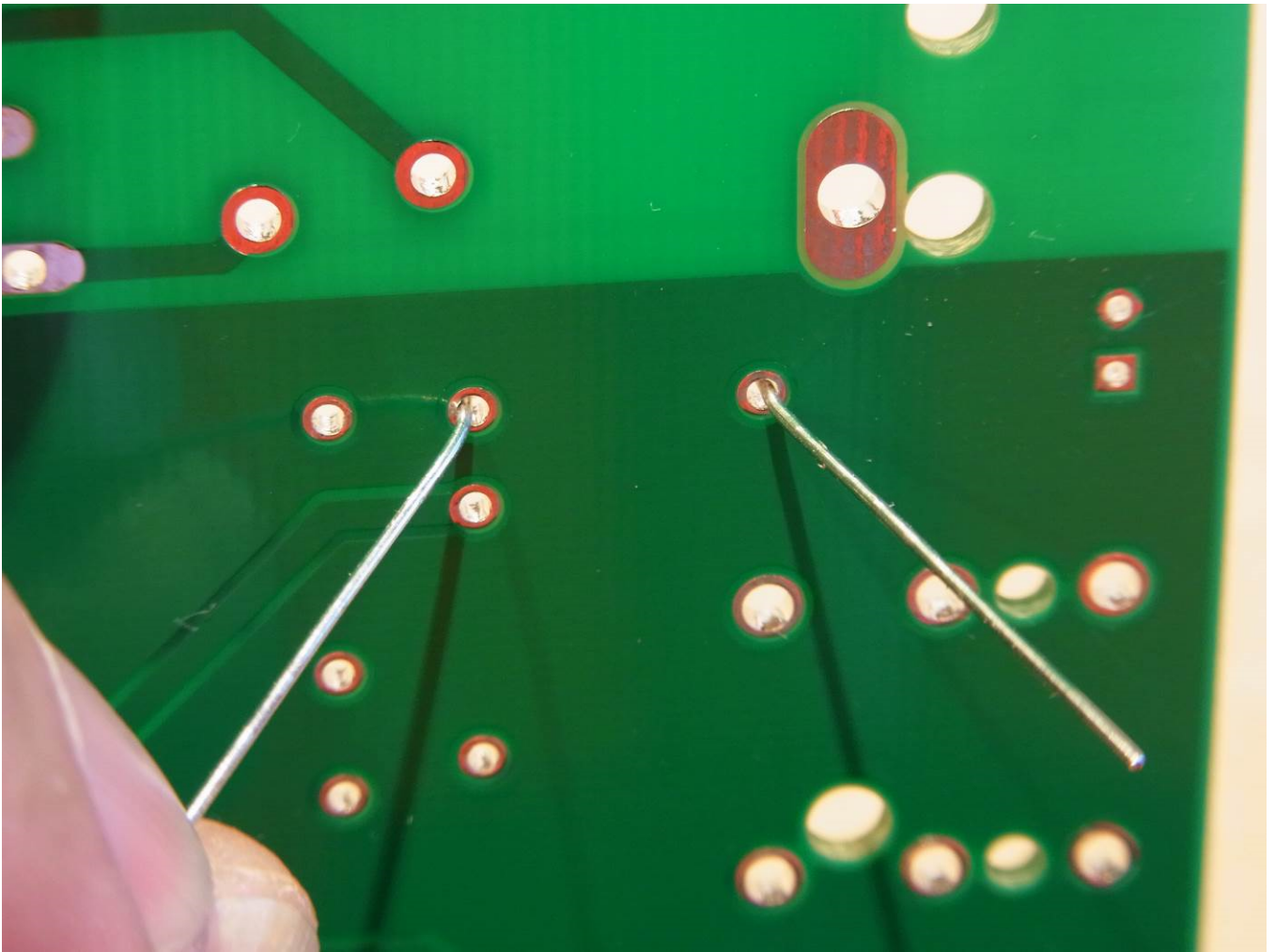


In addition to the reference designator, you can also see the resistance value is printed on the PCB. Note one difference: R4 and R5 say "121" on the PCB, but are actually 1k.

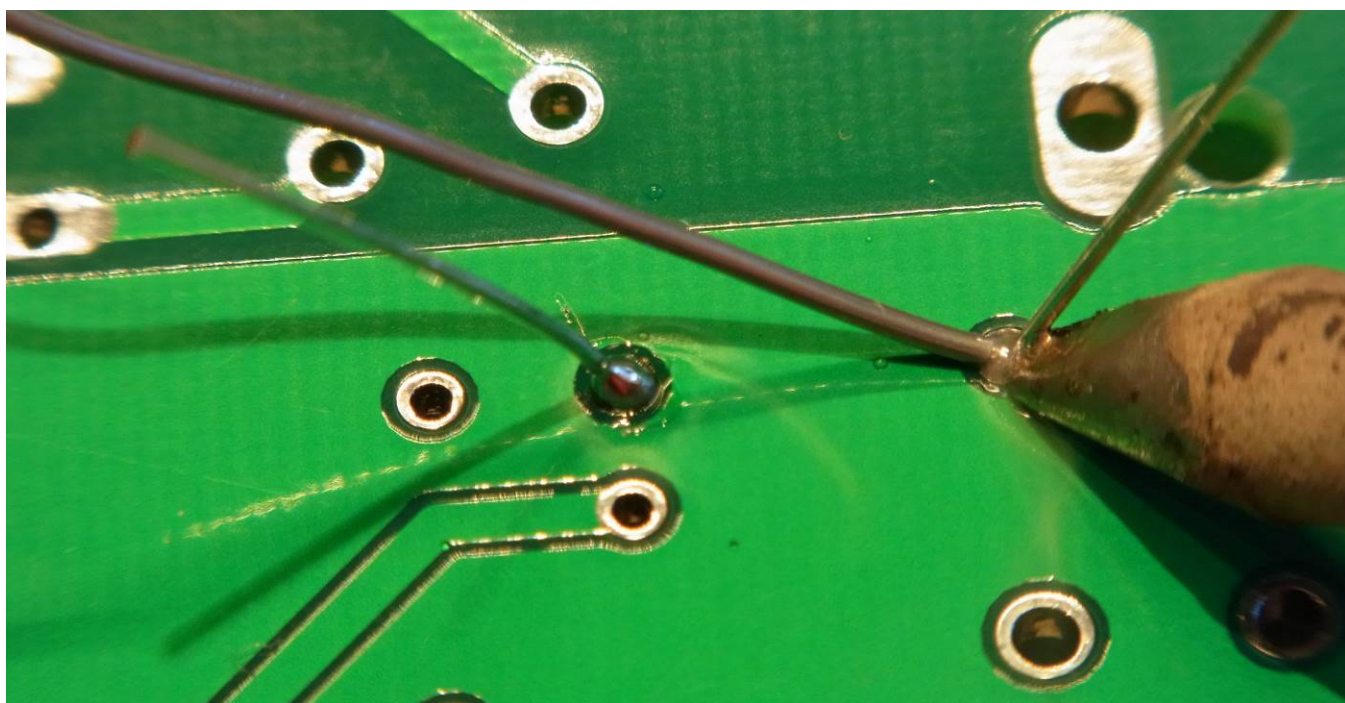
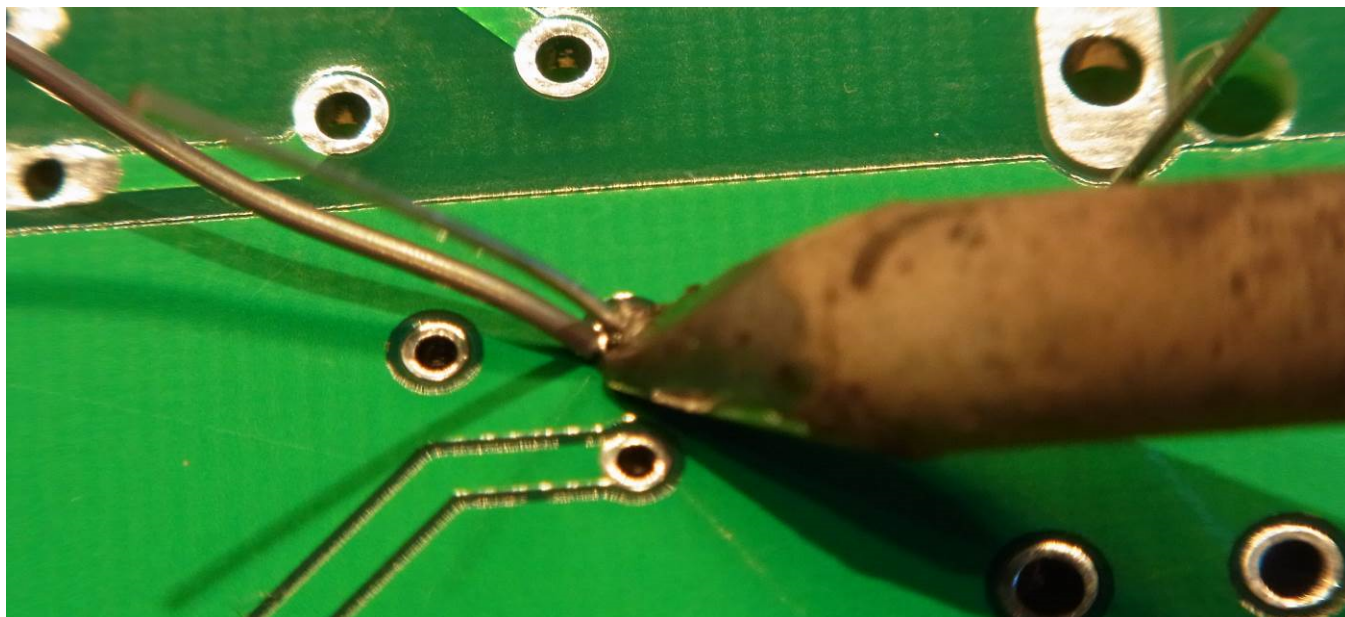
Push them down flush with the board:



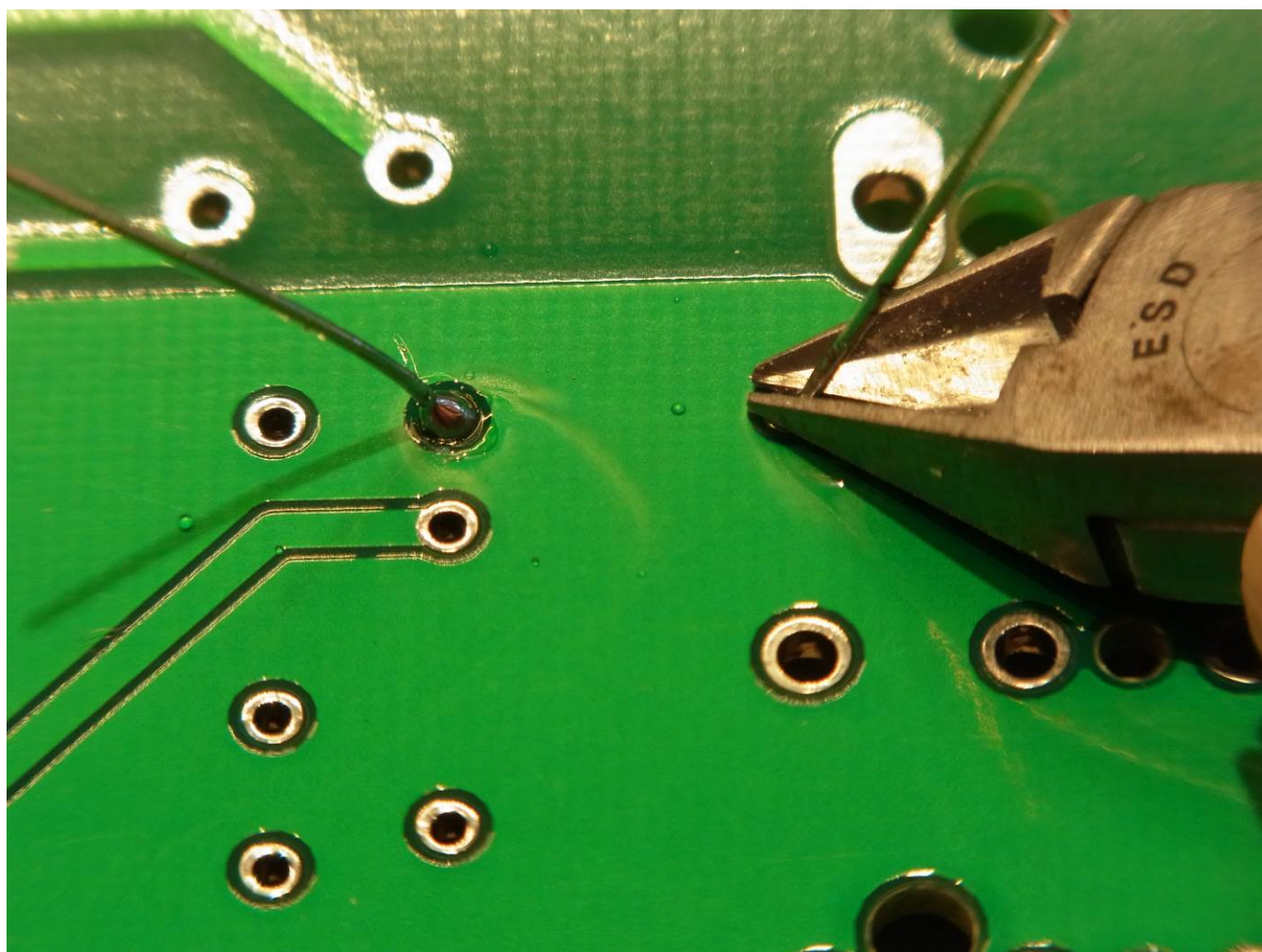
And bend the leads on the backside slightly:



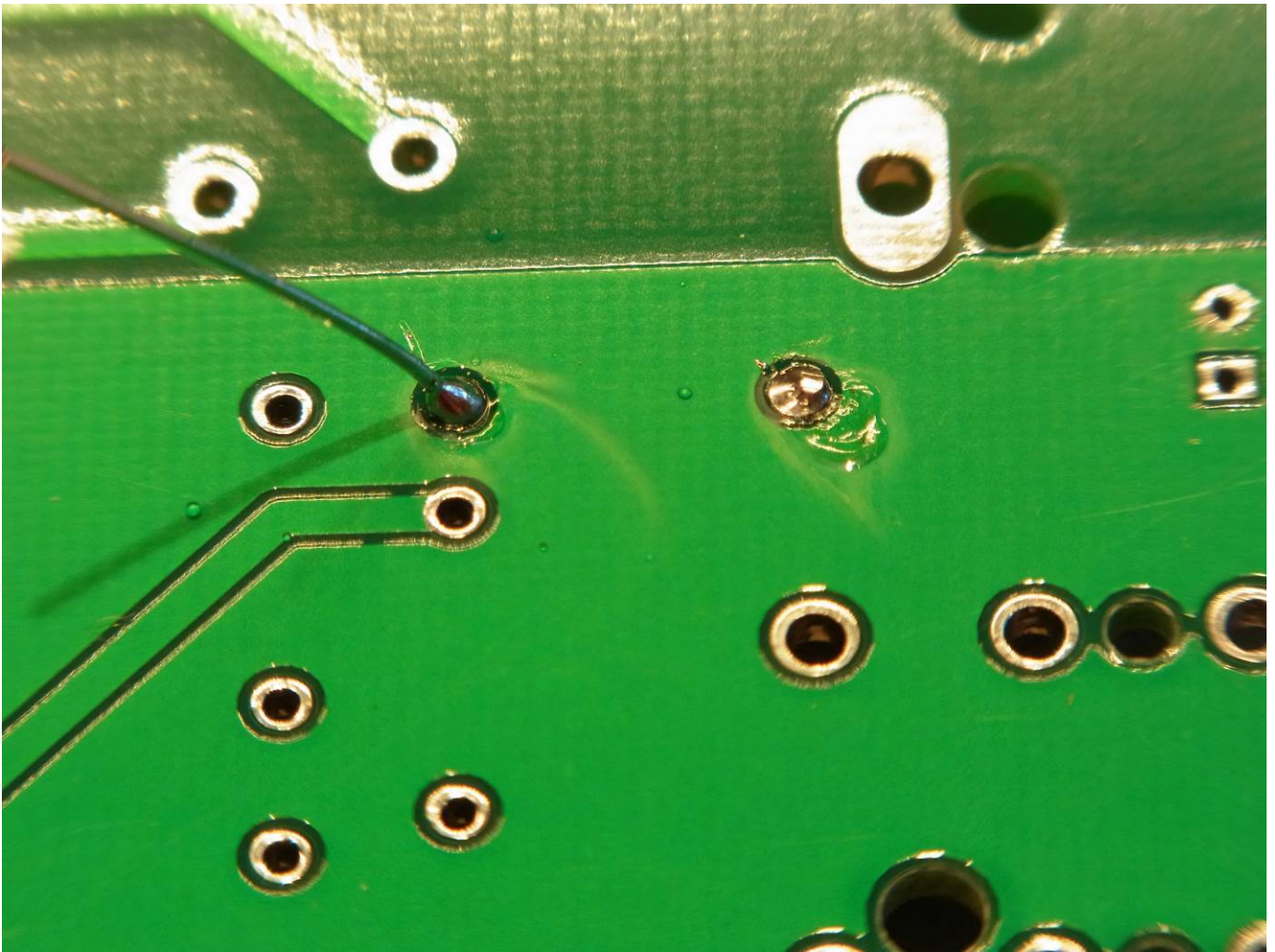
Next, solder the leads. Touch the soldering iron tip to both the pad and the lead, and apply a little solder:



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



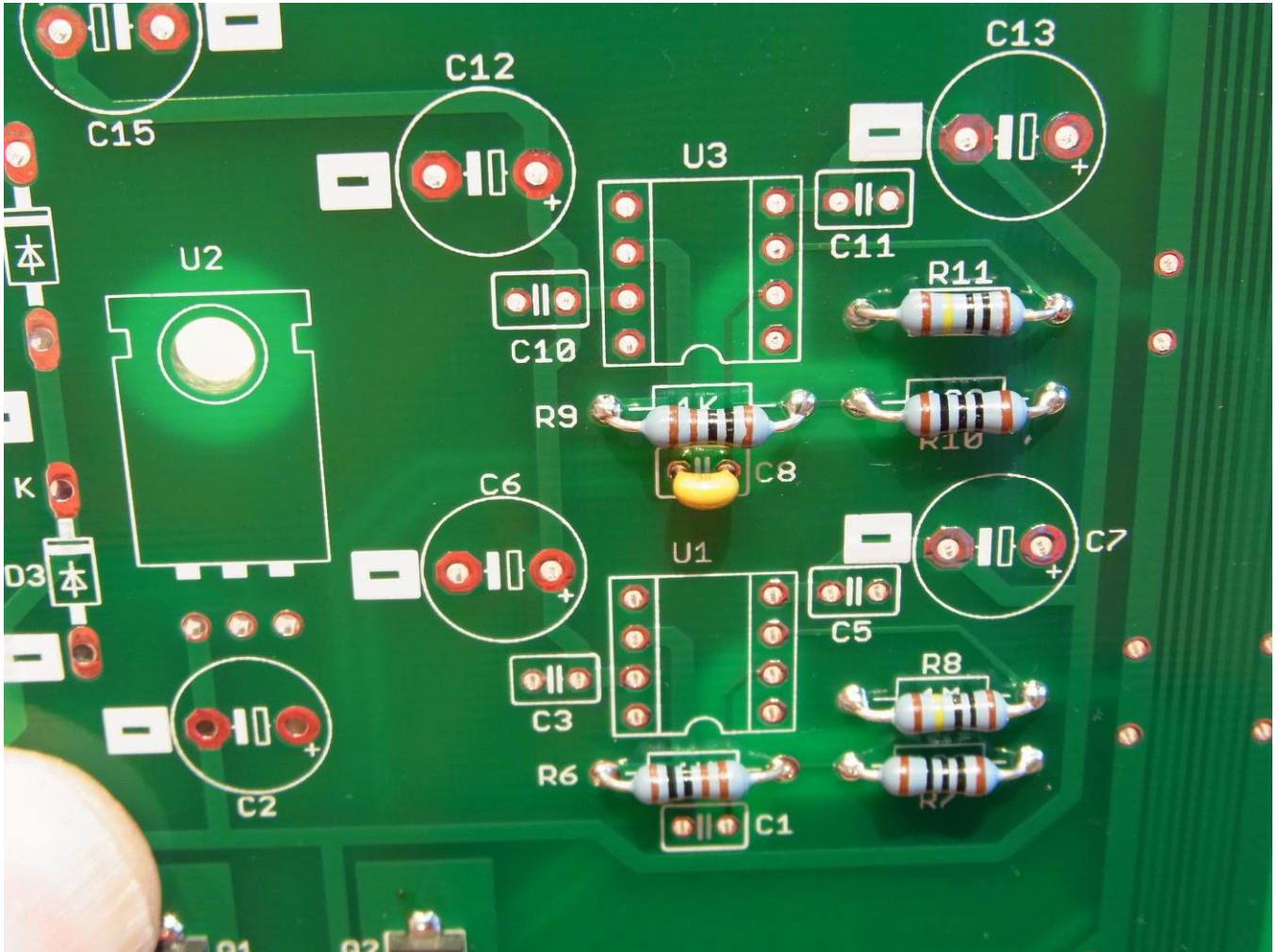
It should wind up looking like this:



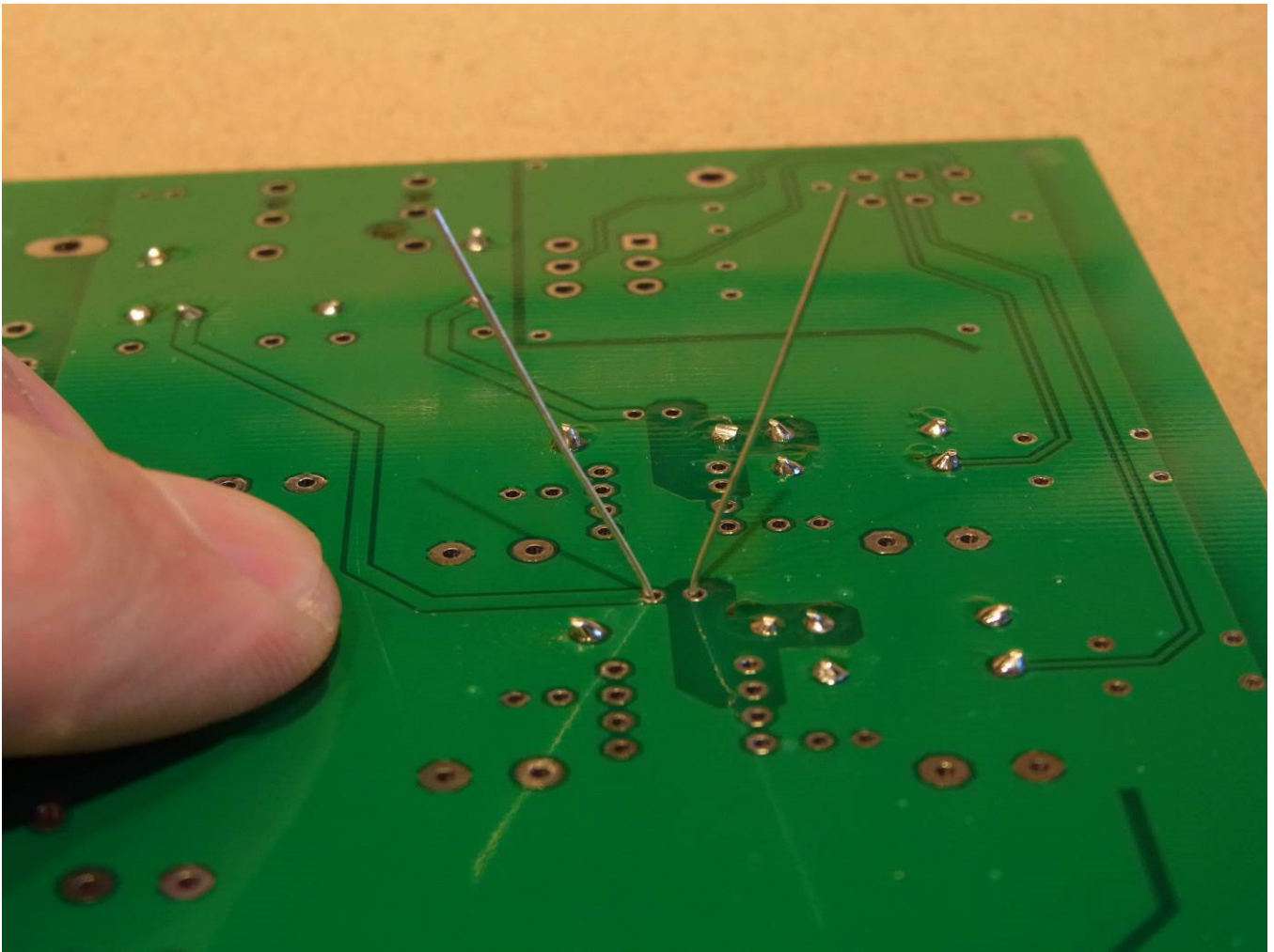
Now, repeat this process for all of the resistors (there are a total of 11 of them).

4. Install ceramic capacitors C1, C3, C5, C8, C10, and C11

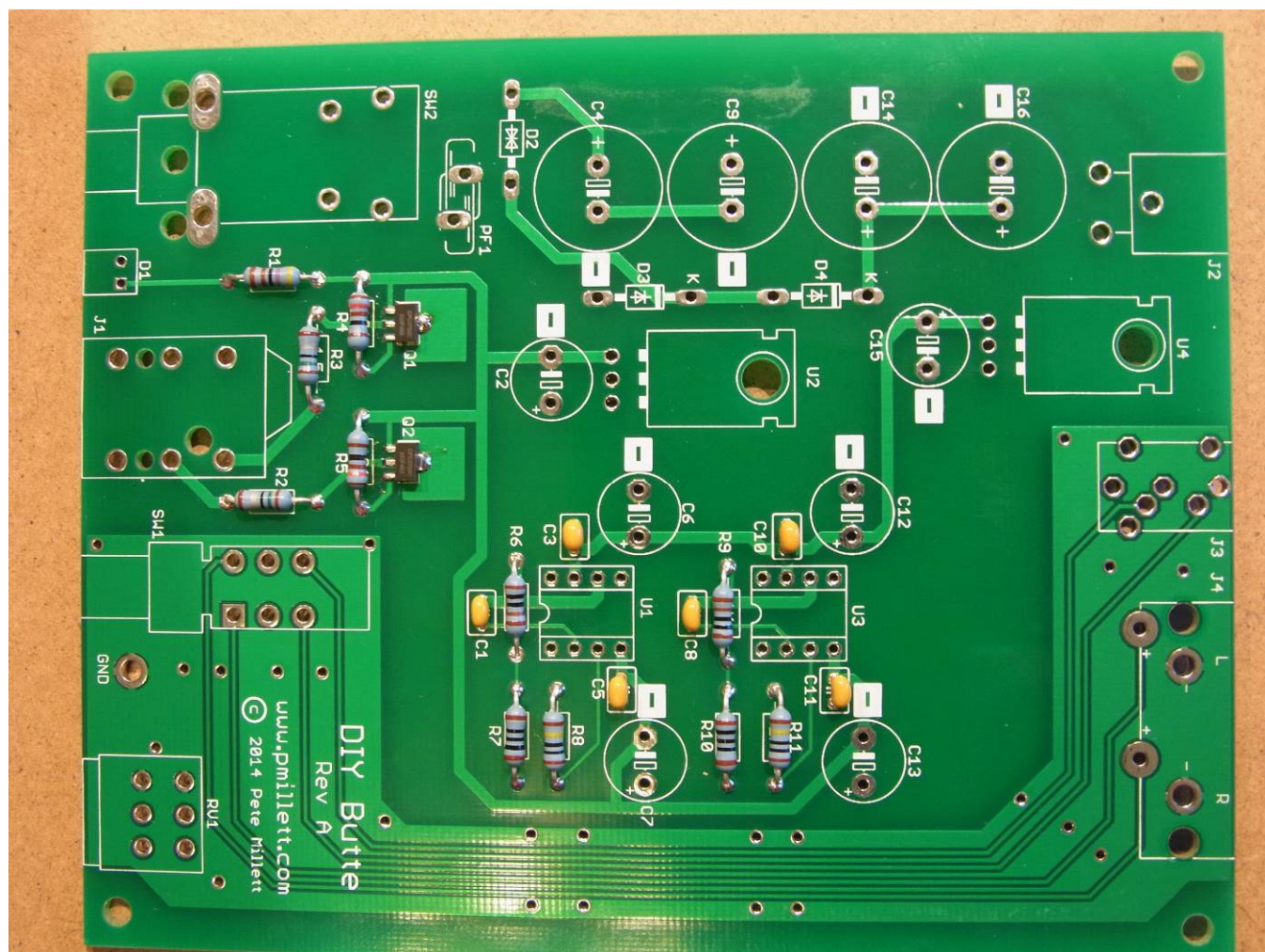
Next, install the small ceramic capacitors. (Note that the parts provided might be slightly different sizes or colors than those shown). These are small parts with the two lead wires sticking out one side, so you don't have to bend the leads before inserting them into the PCB:



As with the resistors, bend the leads and solder, then trim the excess lead wires:

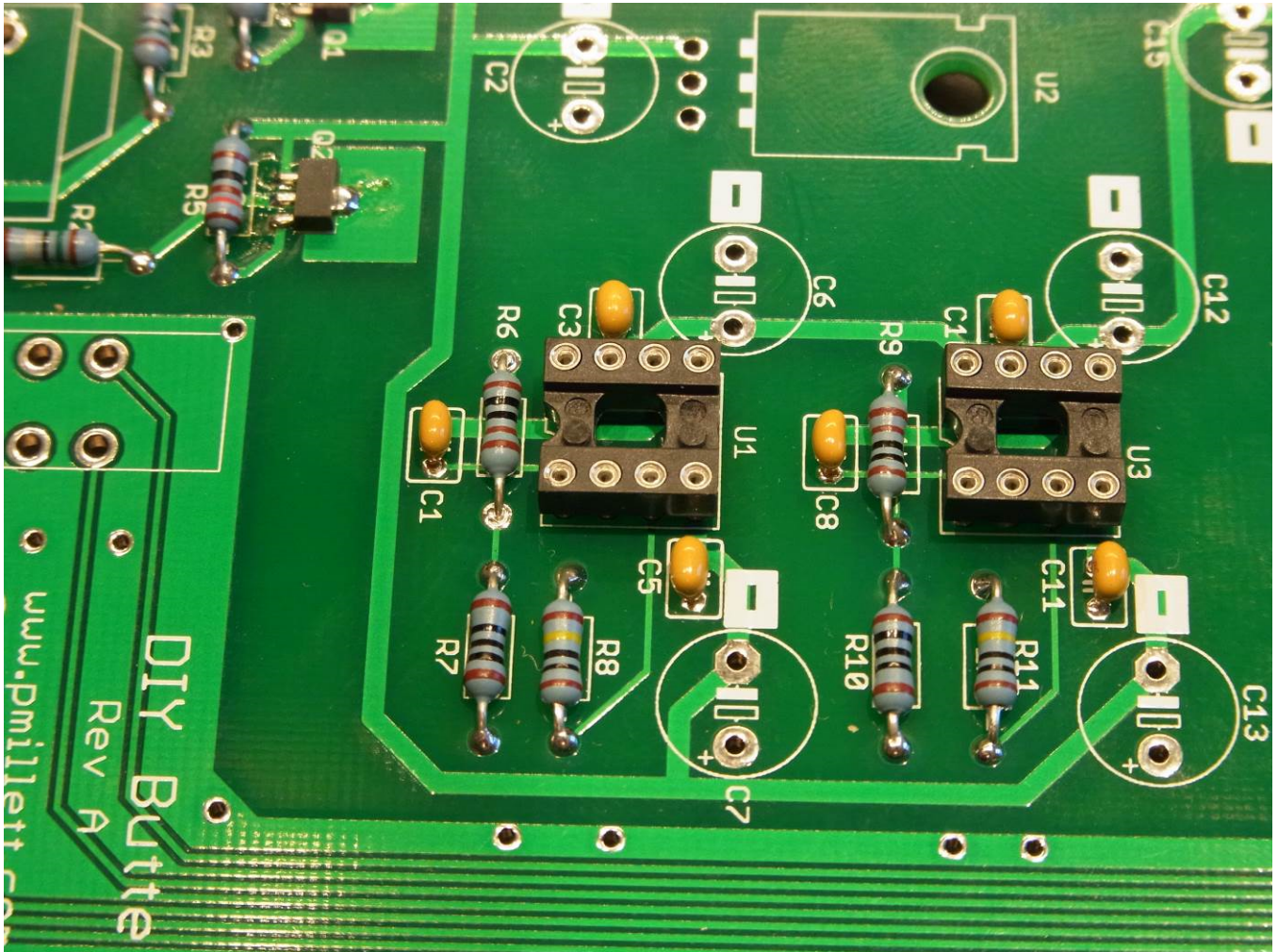


When you're done, the board should look like this:

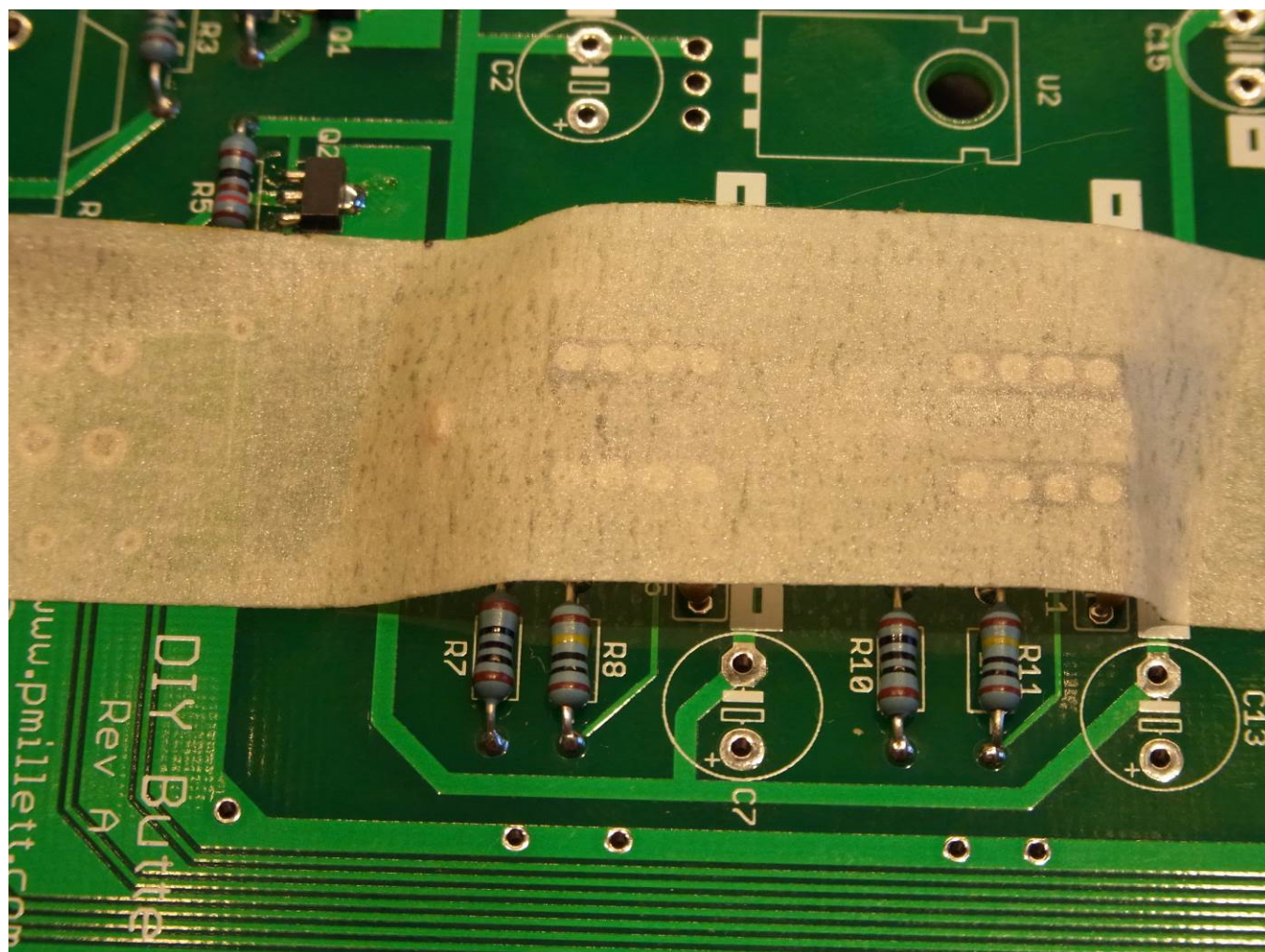


5. Install IC sockets

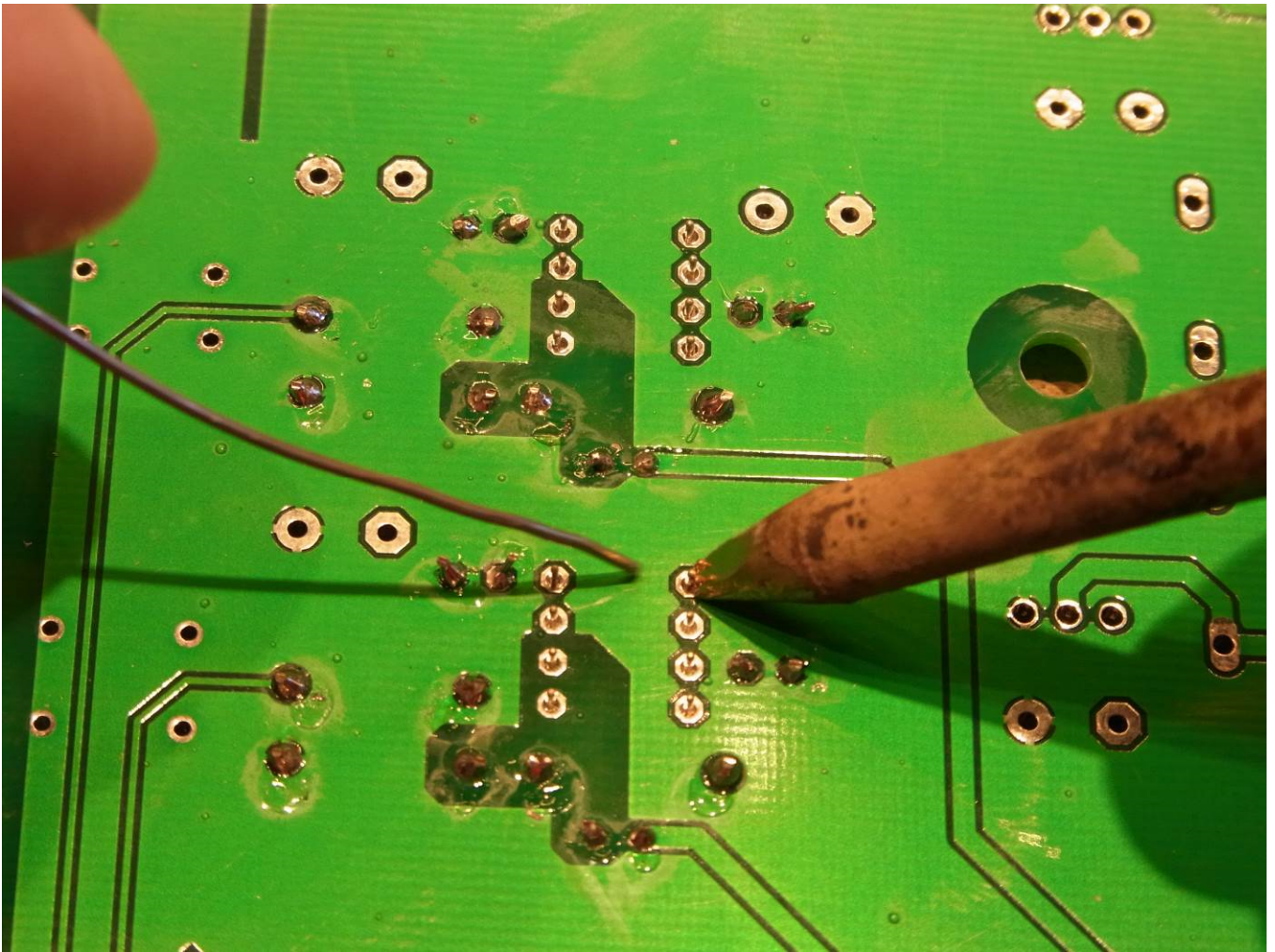
Two IC sockets are installed for the opamps, so you can change them to different ones if desired. Note the orientation of the sockets - there is a small notch to indicate pin 1, which is aligned with the PCB silkscreen:



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:

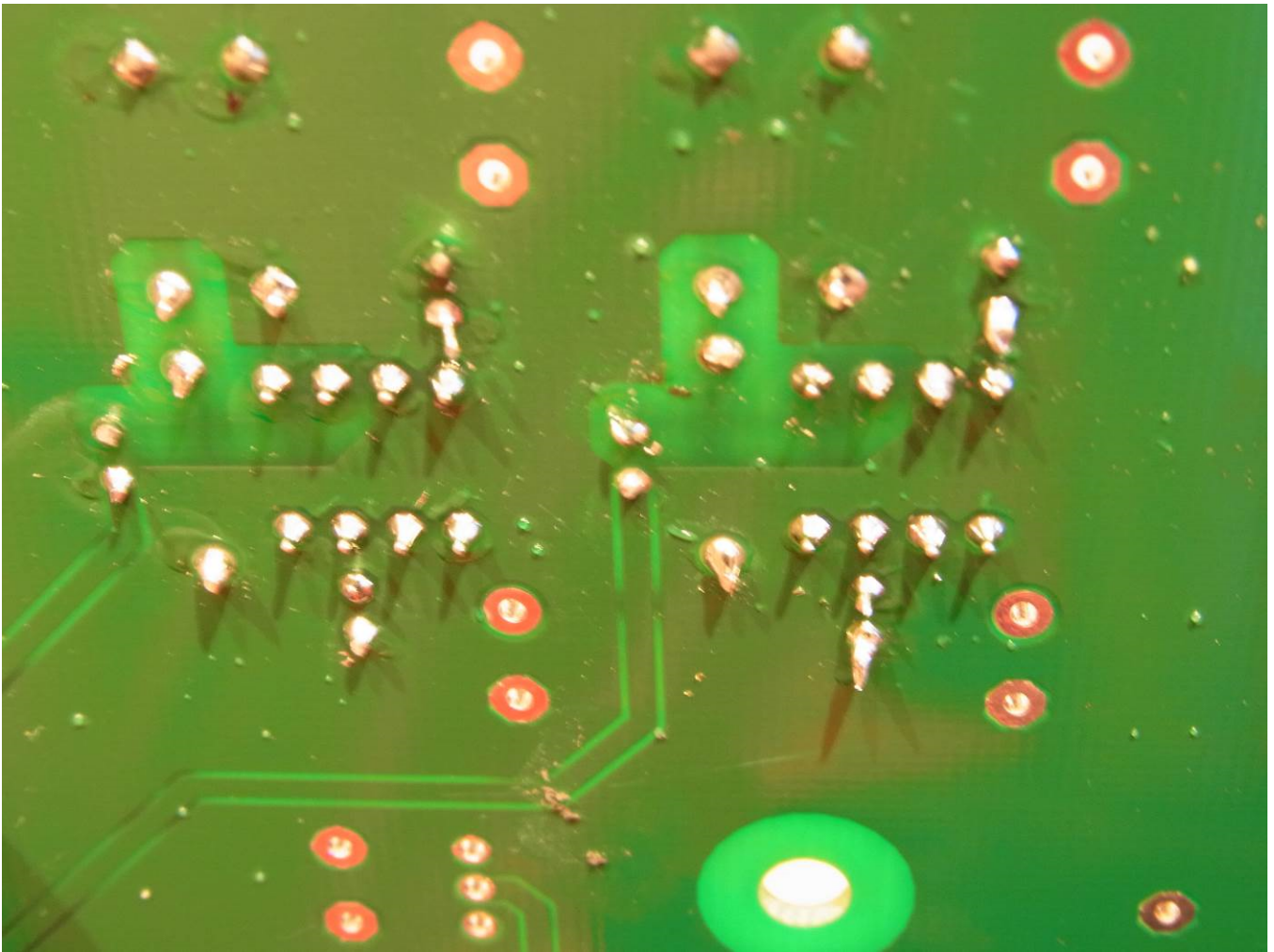


Flip the board over and solder the pins as before:



No trimming is needed.

It should look like this when you're done:

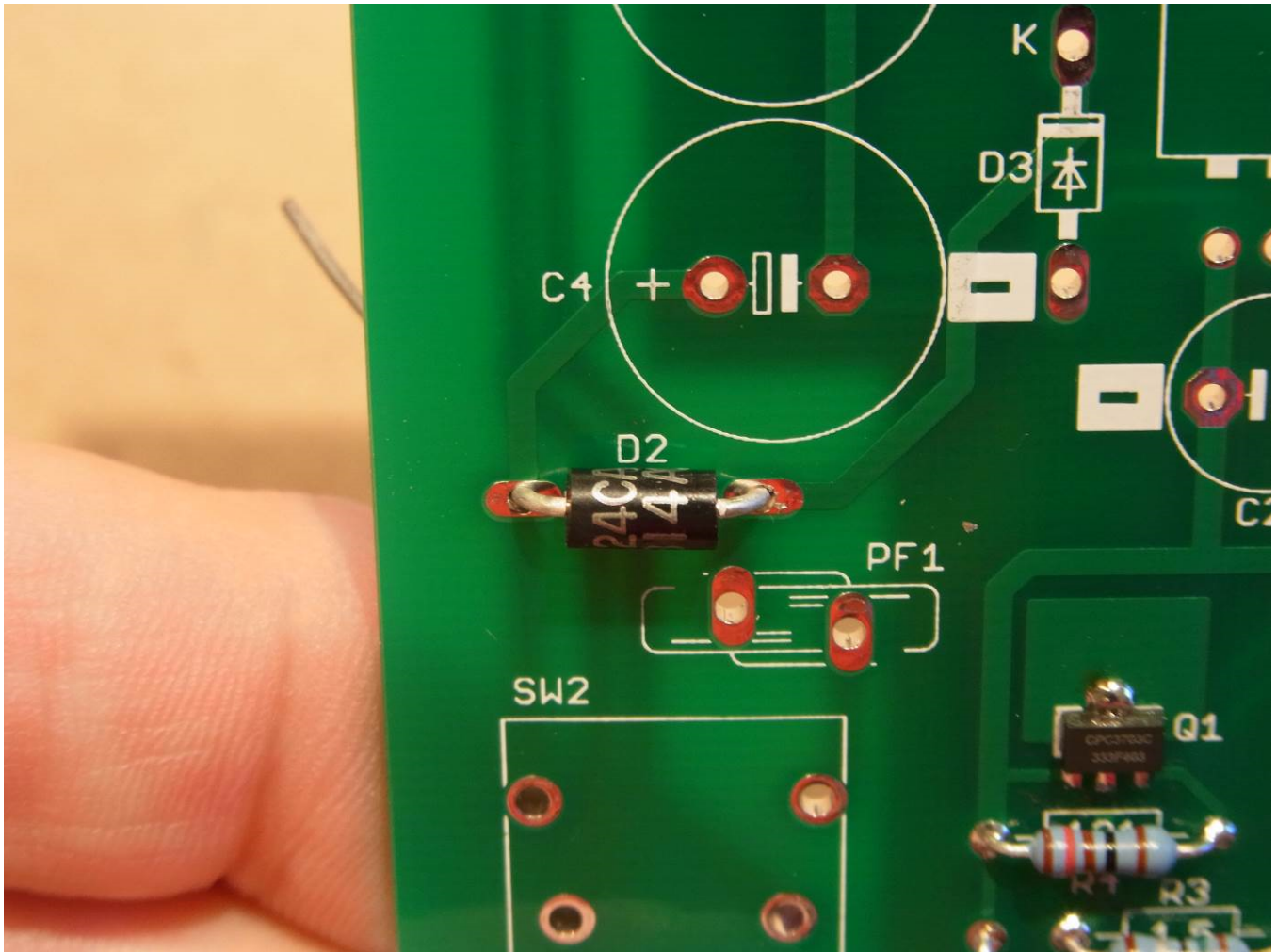


By the way, don't worry about the flux that gets splattered on the board when soldering. It's harmless...

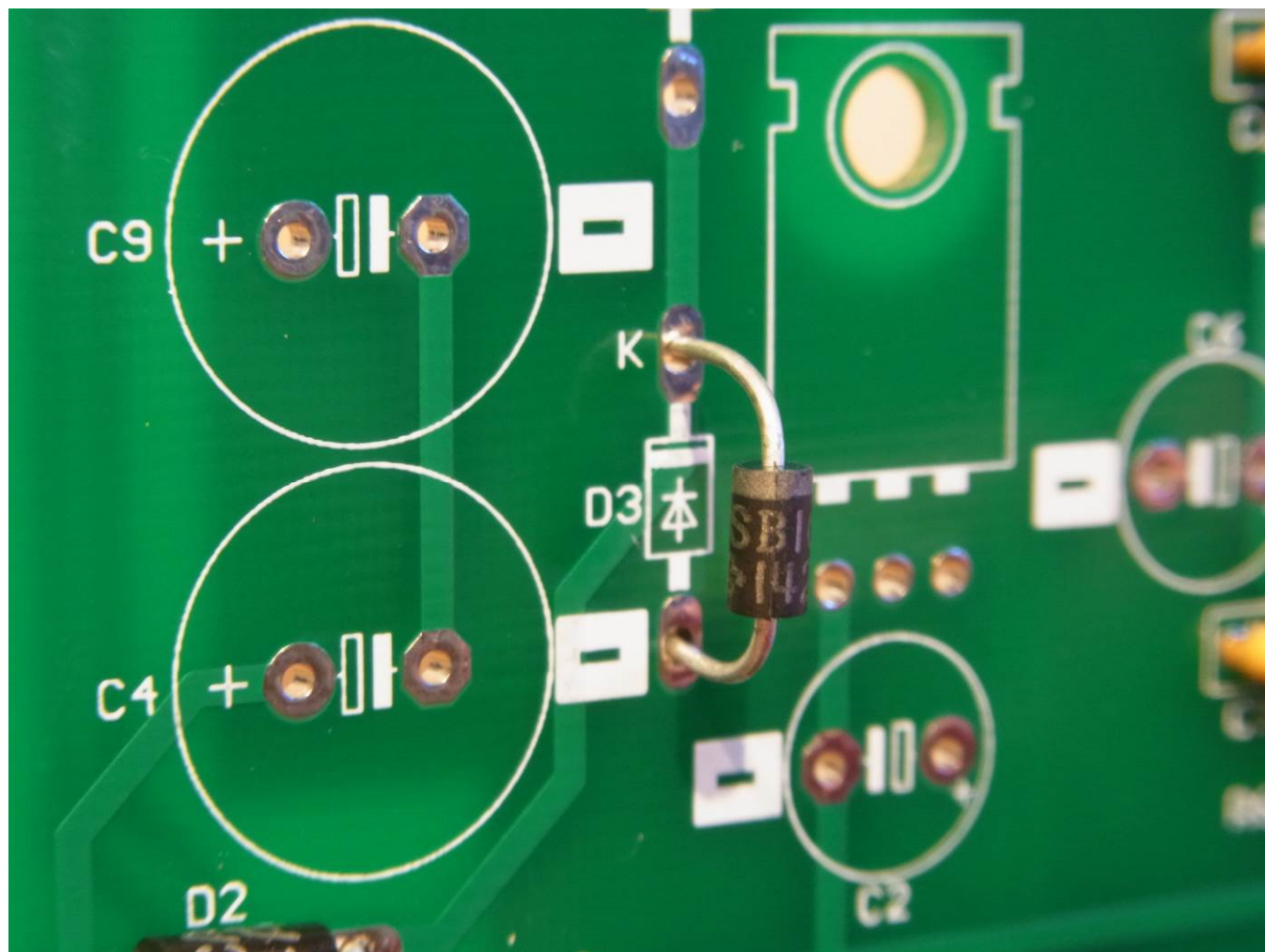
6. Install diodes D2, D3, and D4

These diodes are similar to resistors in appearance, generally black. Most 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.

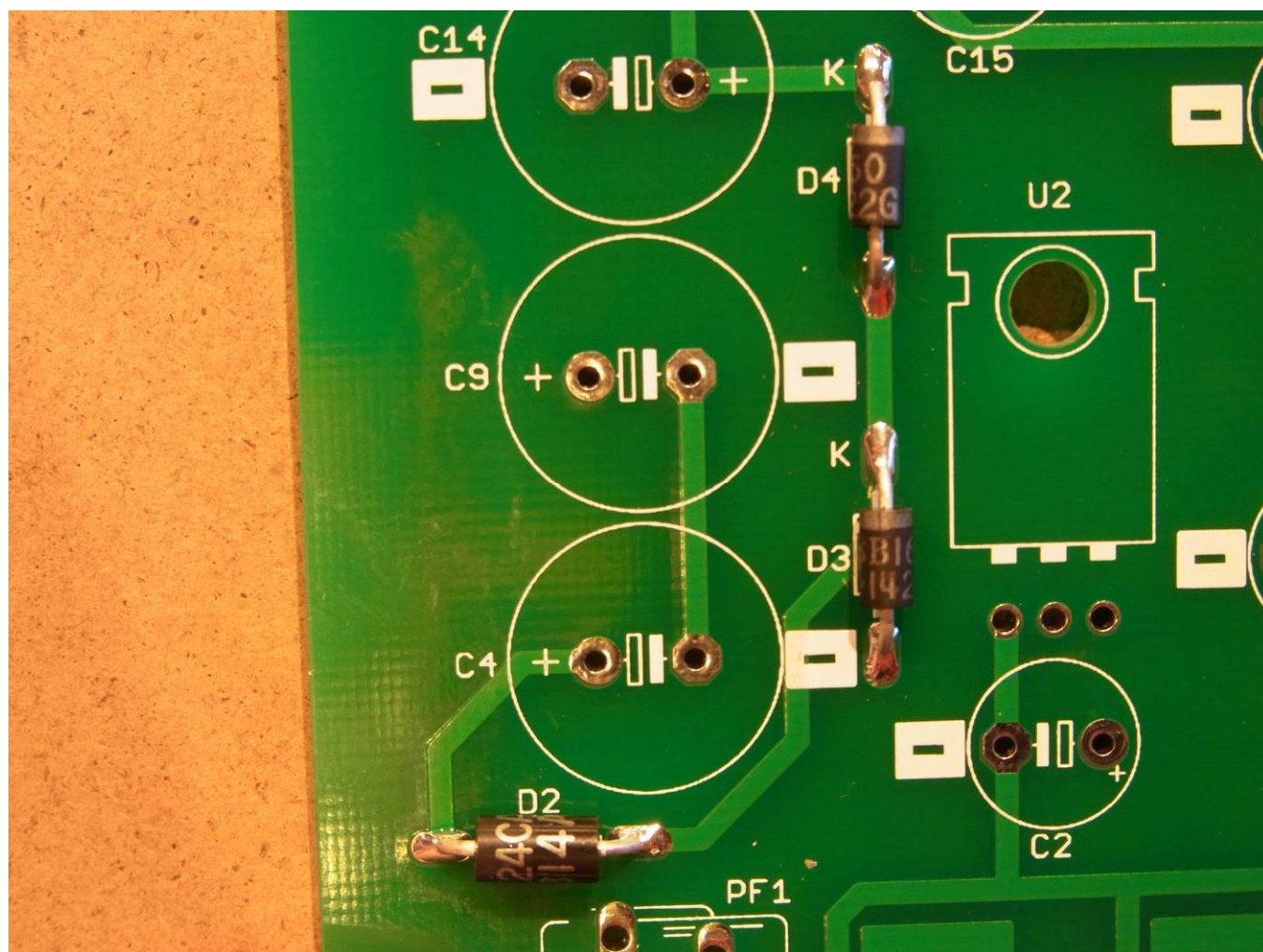
D2 is an exception to this rule - it is a bidirectional transient suppressor, so it can go in either way:



D3 and D4, however, need to be installed the right way. Note the diode has a band on one end that matches with the band on the PCB silkscreen, and also the letter "K" near that end:

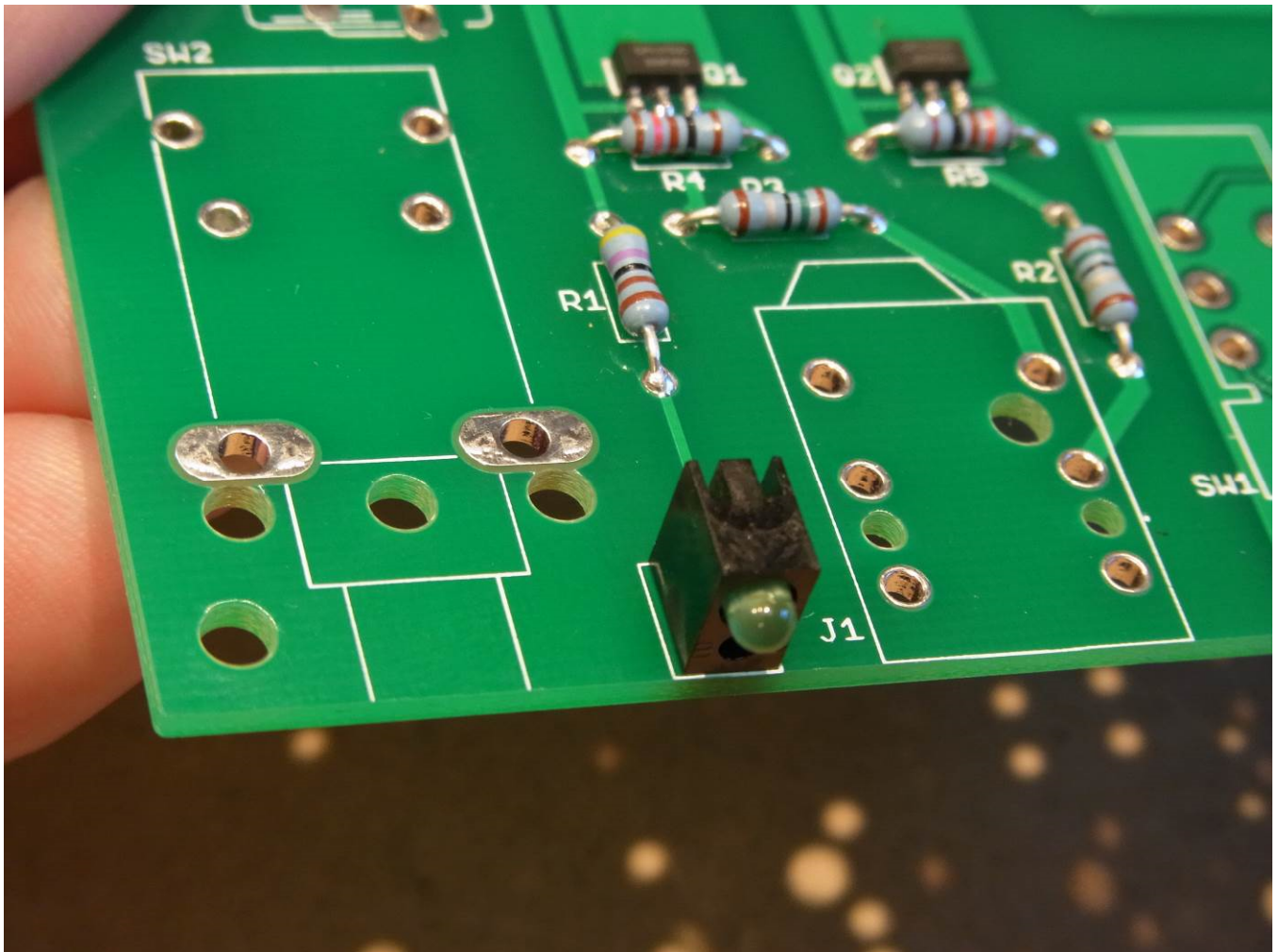


Solder them in place. Check again that they are in the right way by matching them to this photo:



7. Install the "power on" LED D1

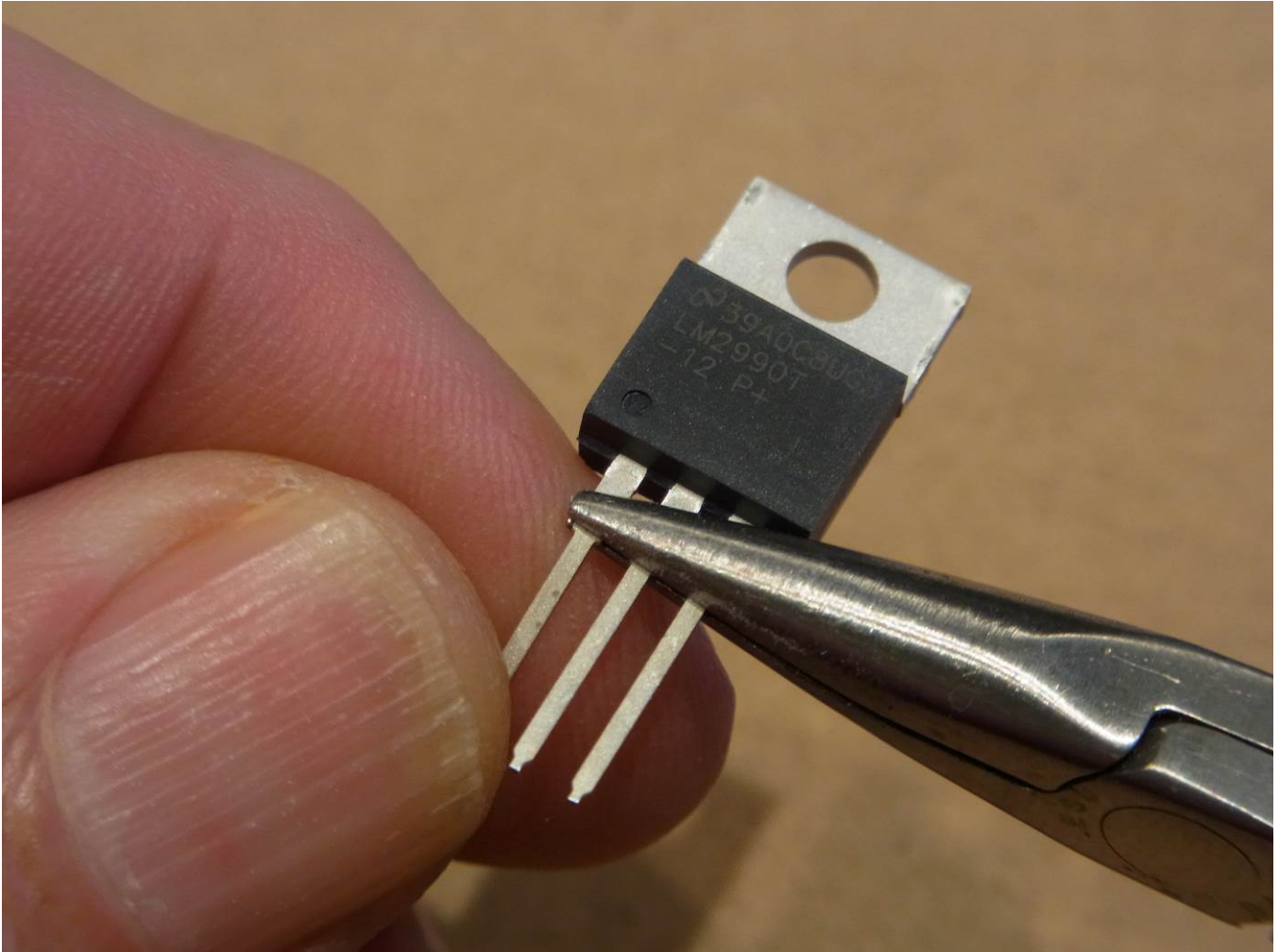
D1 is installed like the small capacitors. Just make sure it's pointed off the edge of the PCB!



8. Install voltage regulators U2 and U4

U2 and U4 are voltage regulator IC's in TO-220 packages. Note that although they look identical they aren't! Make certain you install them in the right locations. U2 is the negative regulator, LM2990 - U4 is positive, LM2940.

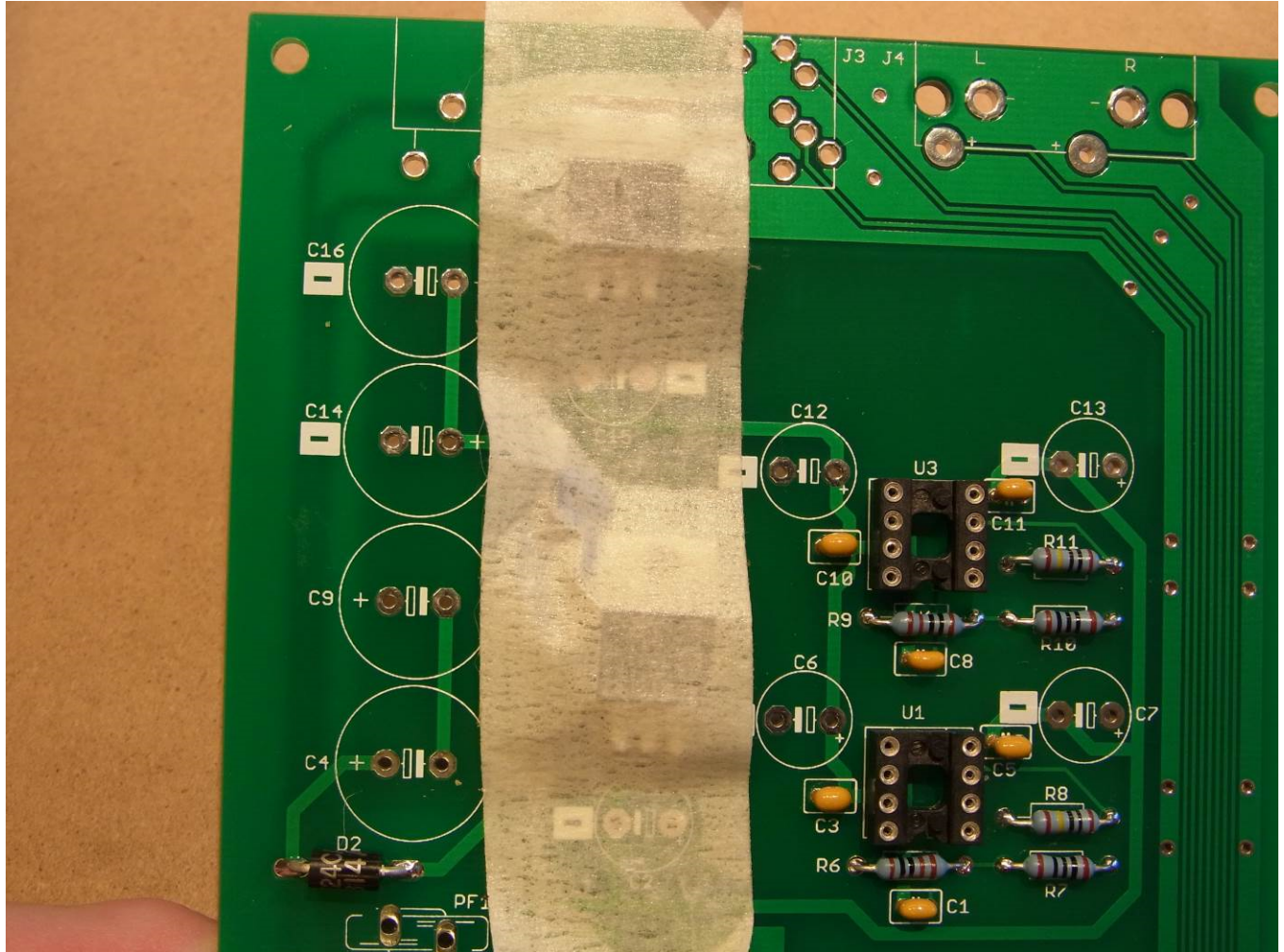
To install the ICs, the leads have to be bent at a right angle. When you do this you need to be careful to not bend them too close to the black plastic package, or you risk damaging the part. The best way to bend the leads is to use a pair of needle-nose pliers to hold the leads, but you can do it with your fingers alone if you are careful.



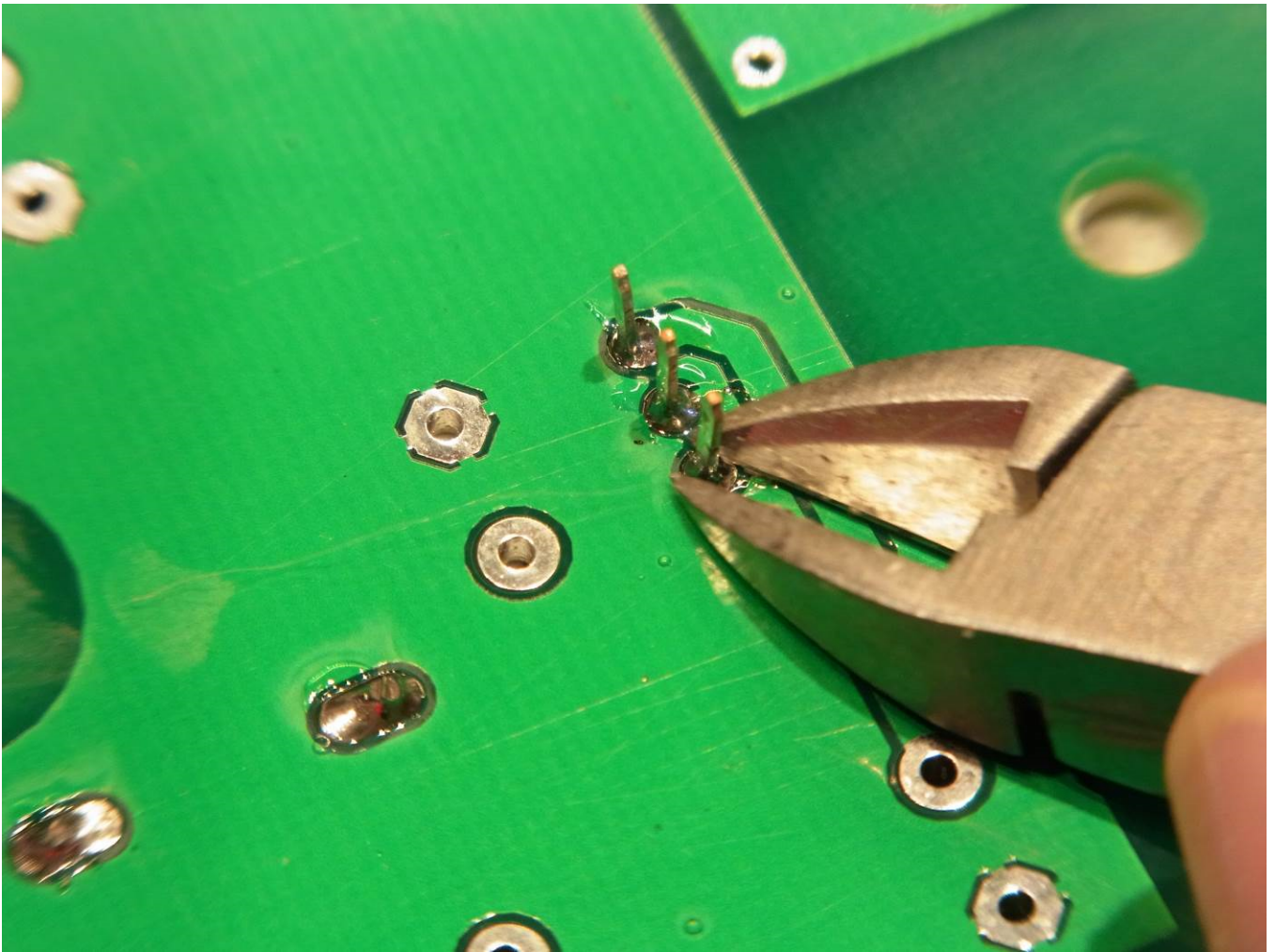
After bending, the parts should look like this:



Install them in the PCB. You may want to use tape to hold them in place while you solder. Make sure you have the right one in the right spot (U2 = LM2990, U4 = LM2940)!

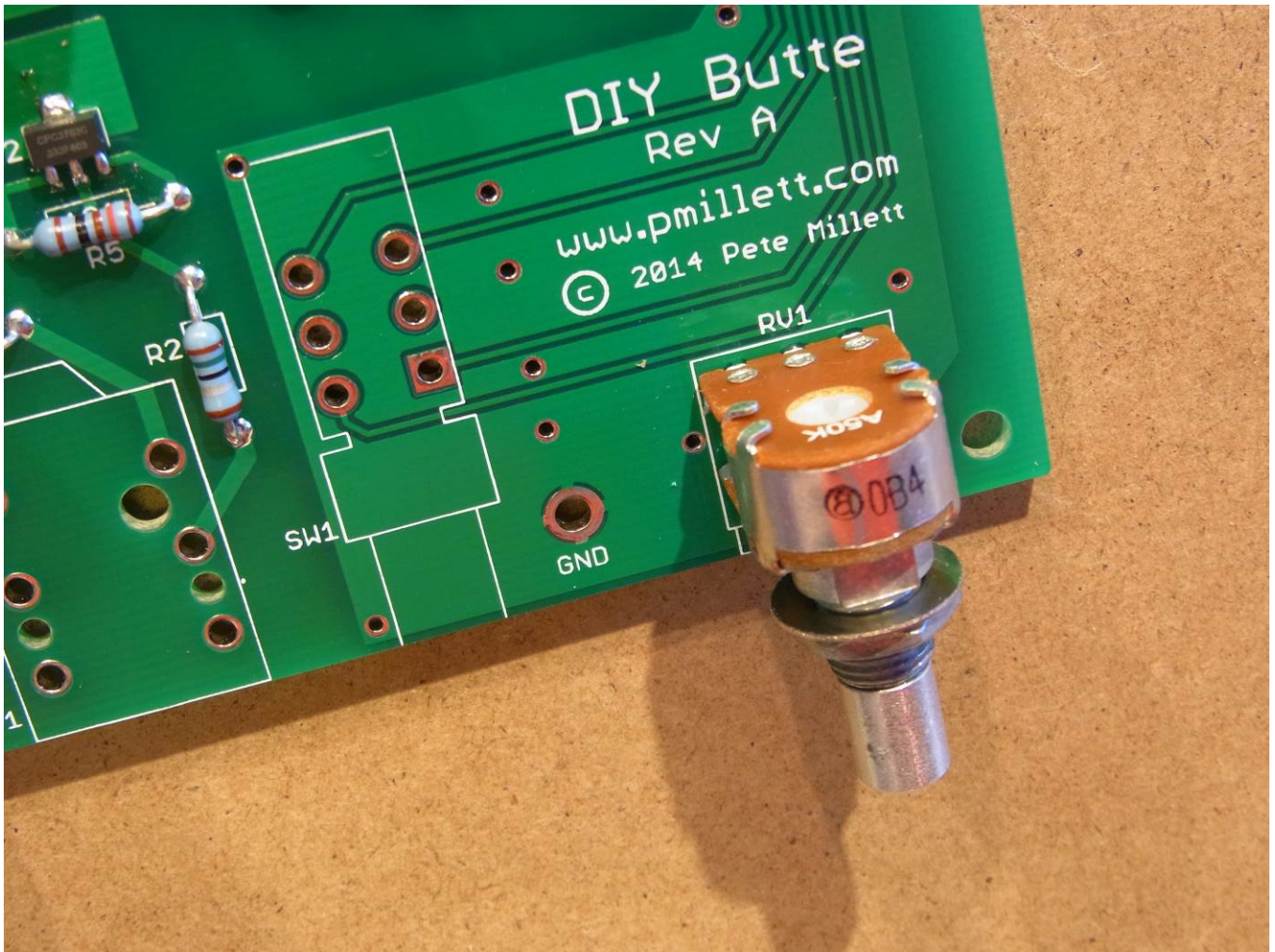


Solder the leads and clip off the excess:

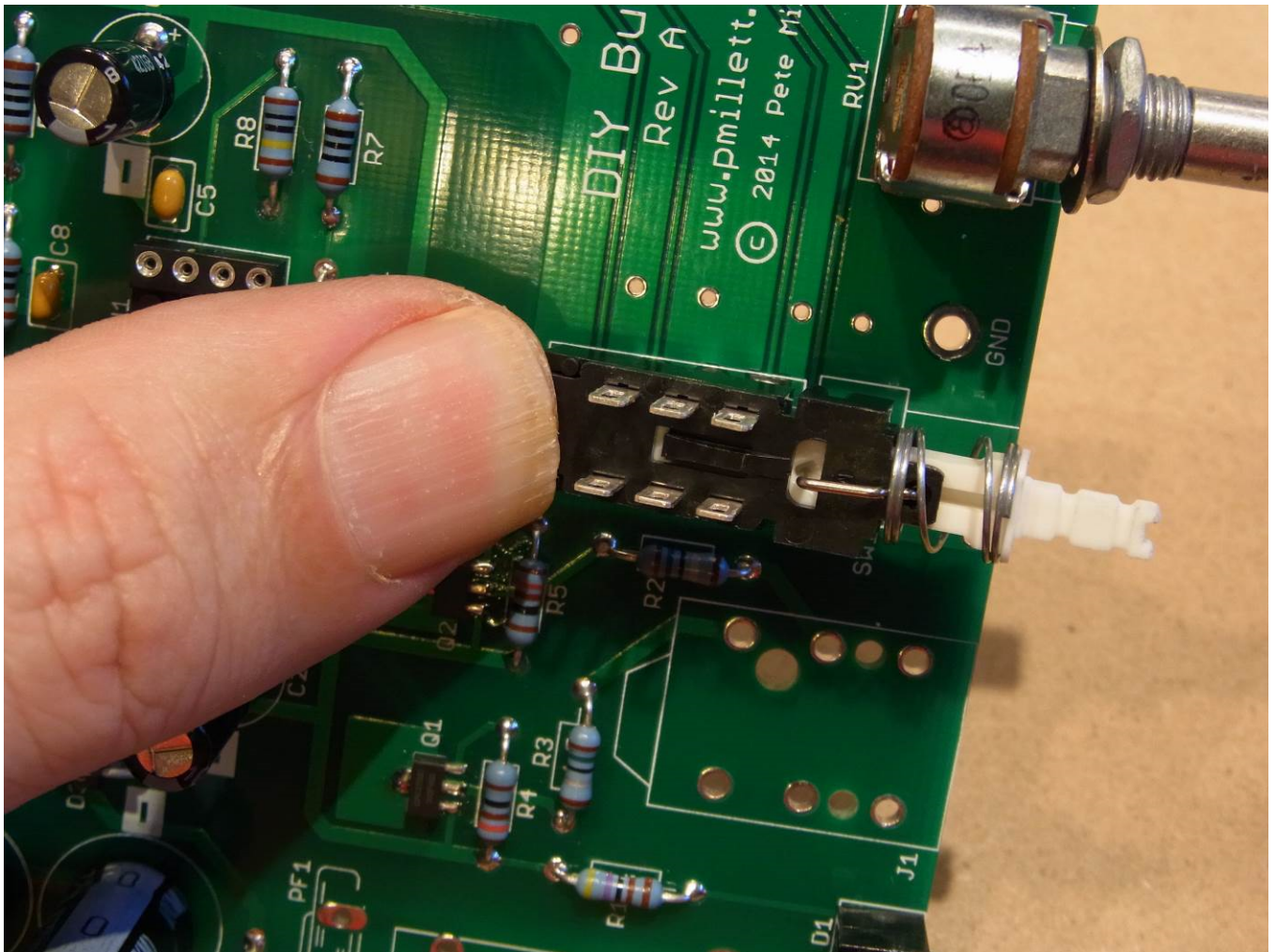


9. Install volume control RV1, headphone jack J1, and switches SW1 and SW2

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 to hold it in place while you solder them in:



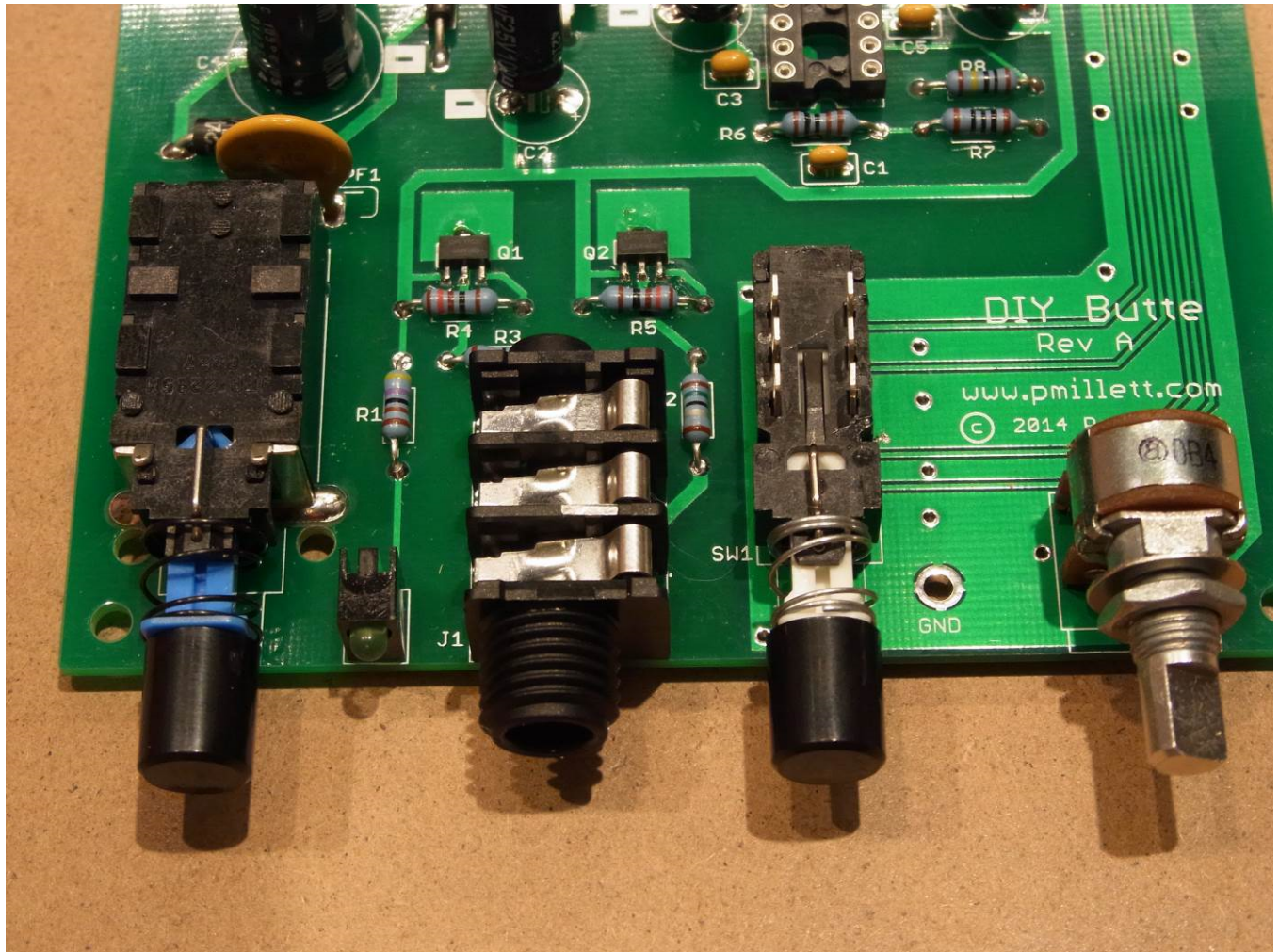
Make sure you have the parts seated all the way down on the PCB before fully soldering them in, or the parts won't align to the front panel. It's best to solder only one lead, then inspect the part to see if it is fully seated on the PCB. If not, heat the solder joint while pushing the part into the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



14. Install polyfuse PF1

Polyfuse PF1 is installed the same way as the small ceramic capacitors - insert it, bend the leads, solder, and trim.

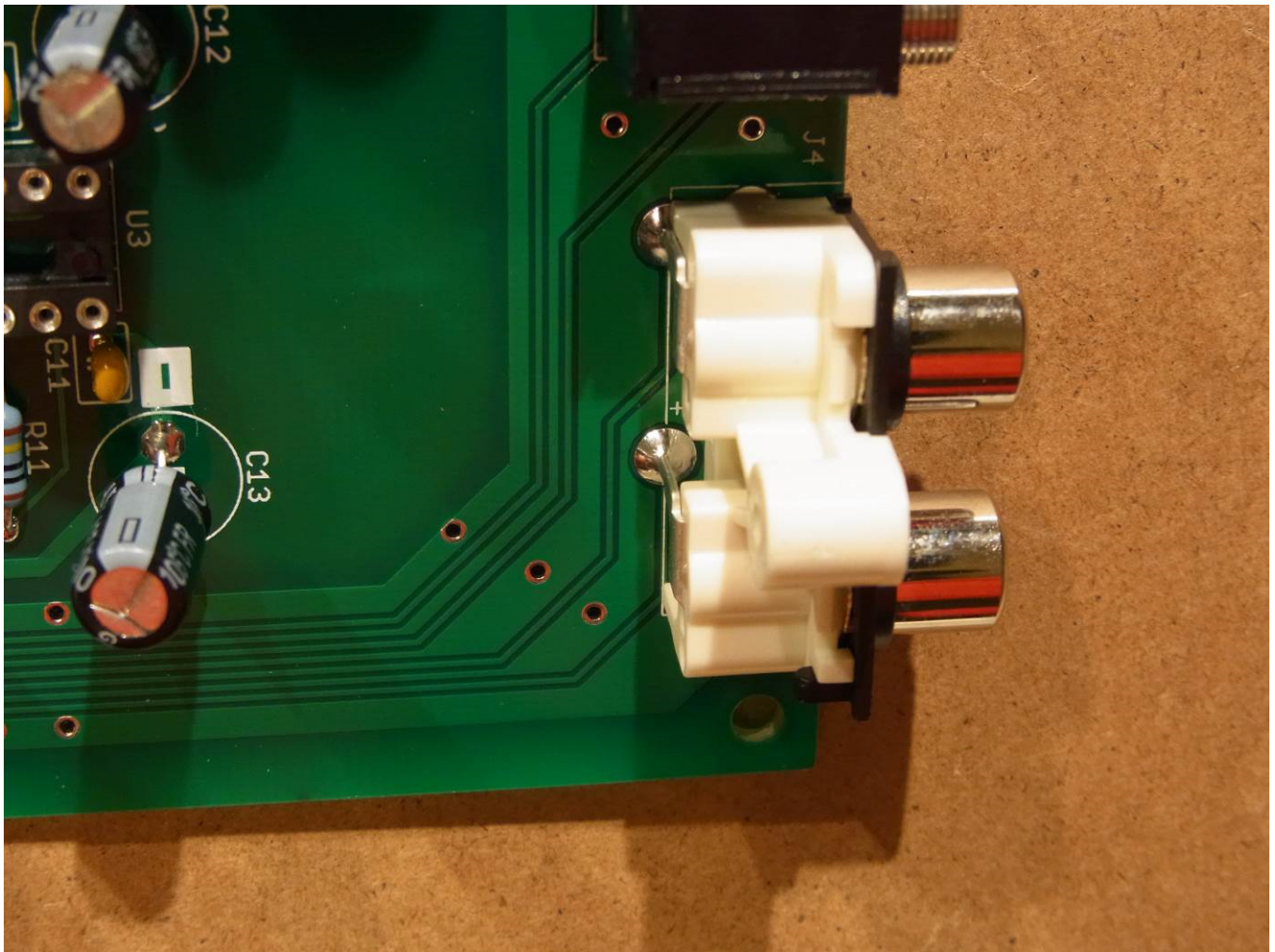
When you are done with these the board should look like this:

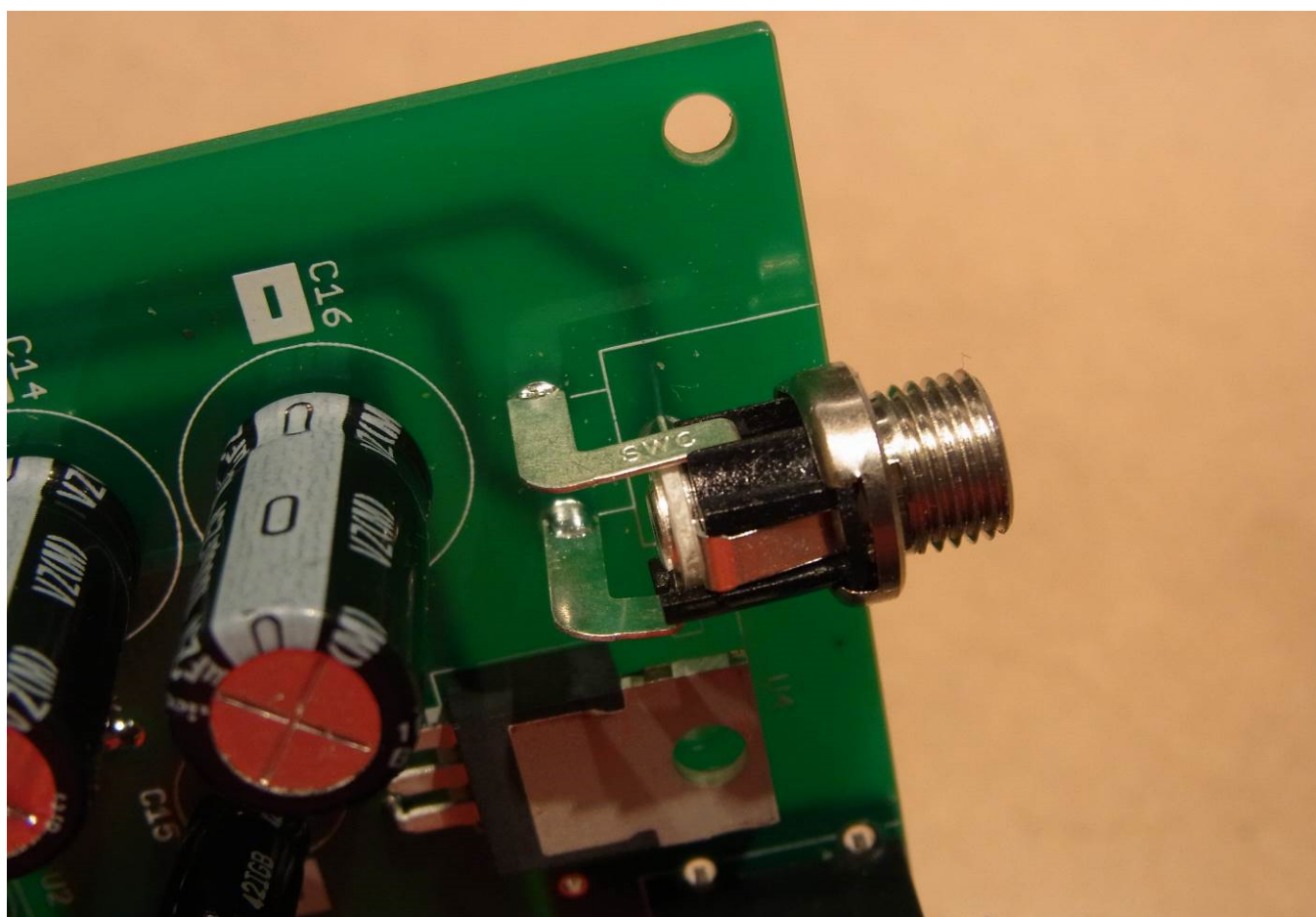
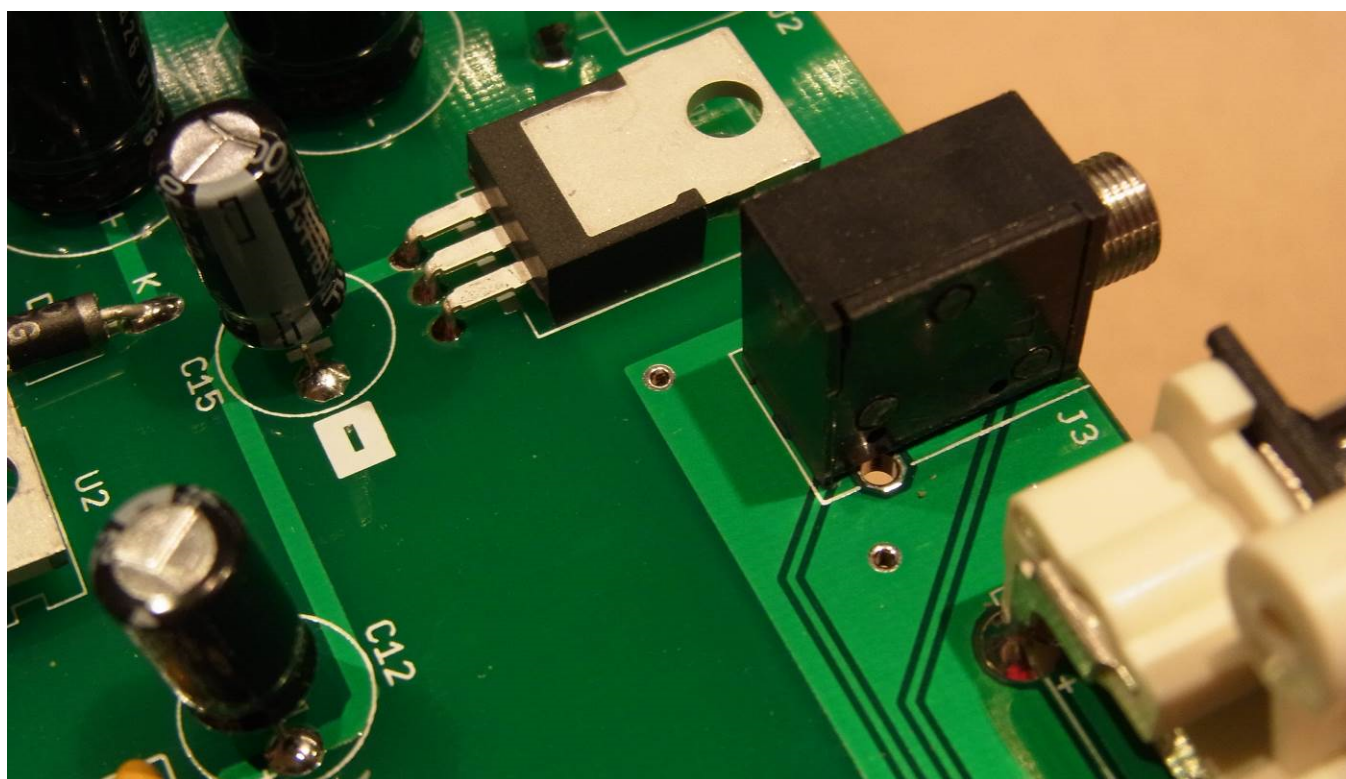


15. Install power jack J2 and input jacks J3 and J4

Install the jacks on the rear edge of the PCB. J2 and J4 snap into the PCB, but J3 may need to be held in with tape when you solder it in. Don't worry if the part supplied for J3 doesn't use all the holes in the PCB - the PCB is designed to accommodate several different connectors, so the jack may not have all the leads that there are holes for.

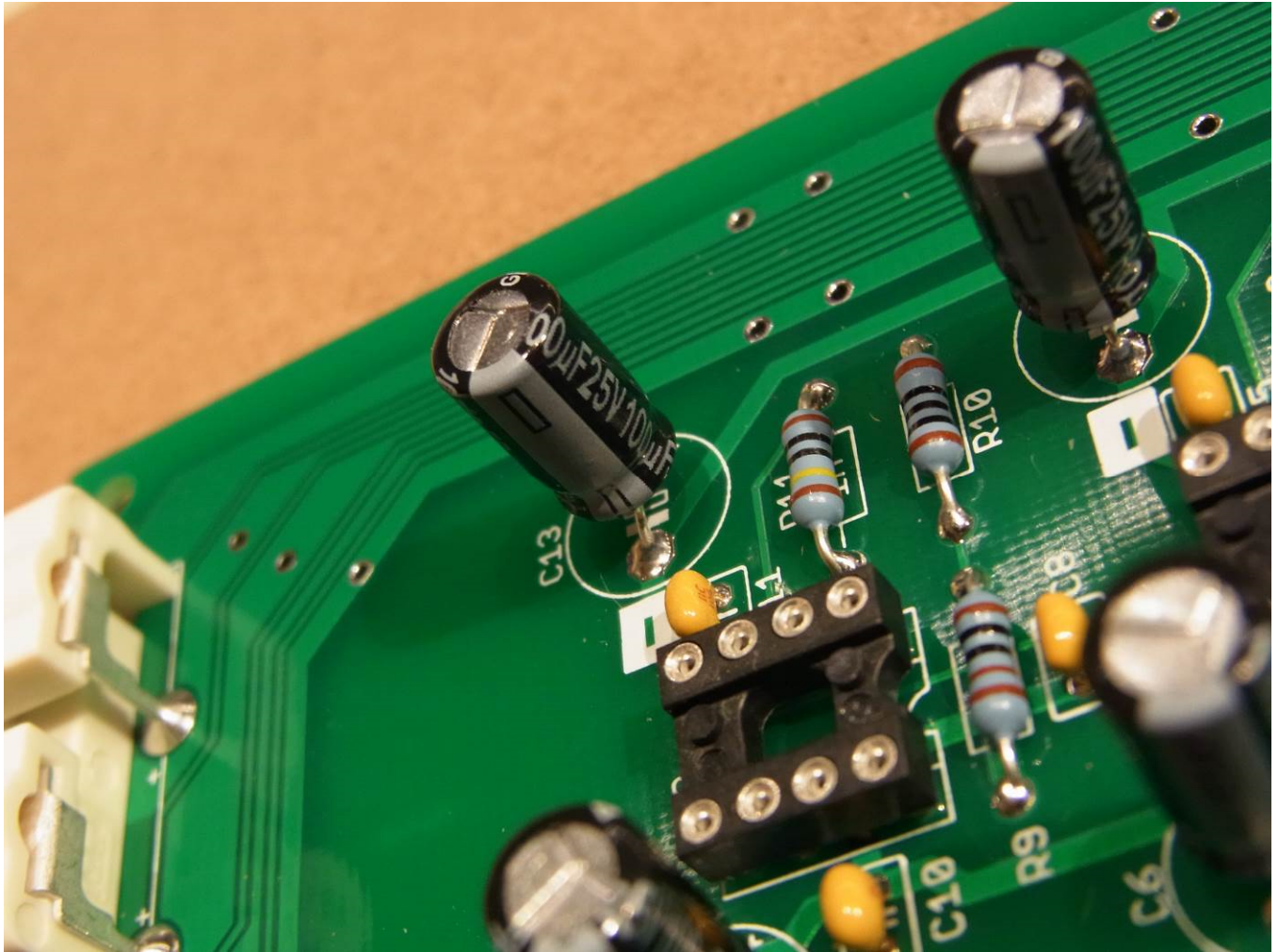
As before, make sure the parts are fully seated on the PCB before completely soldering them in!





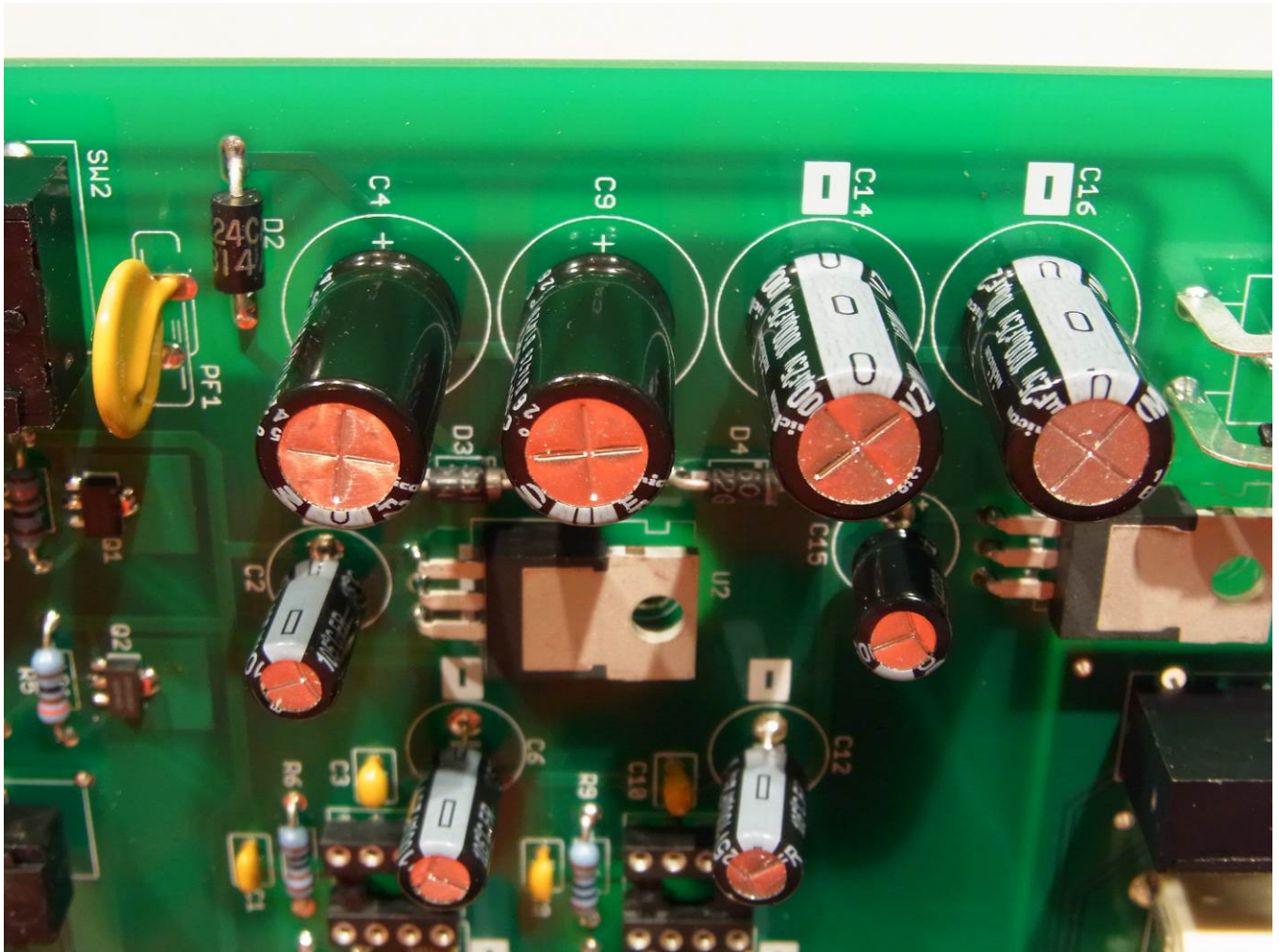
16. Install small electrolytic capacitors C2, C6, C7, C12, C13, and C15

Install the smaller electrolytic capacitors. be VERY careful that they are installed the correct way - the PCB has a prominent "-" marking that needs to align with the stripe and "-" symbol on the capacitors. Insert them, bend the leads, solder and trim as before. Check again that the orientation is correct:



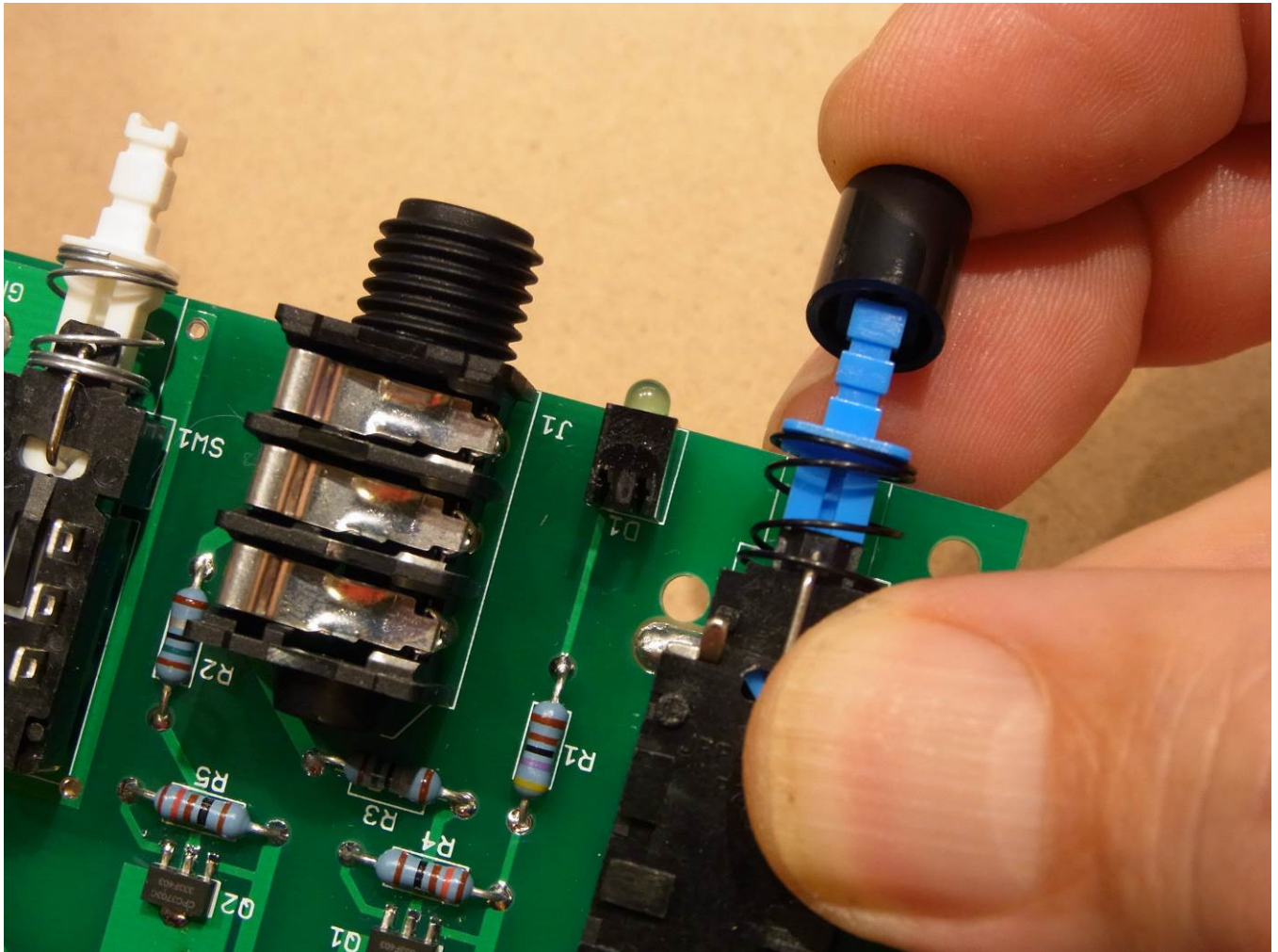
17. Install large electrolytic capacitors C4, C9, C14, and C16

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



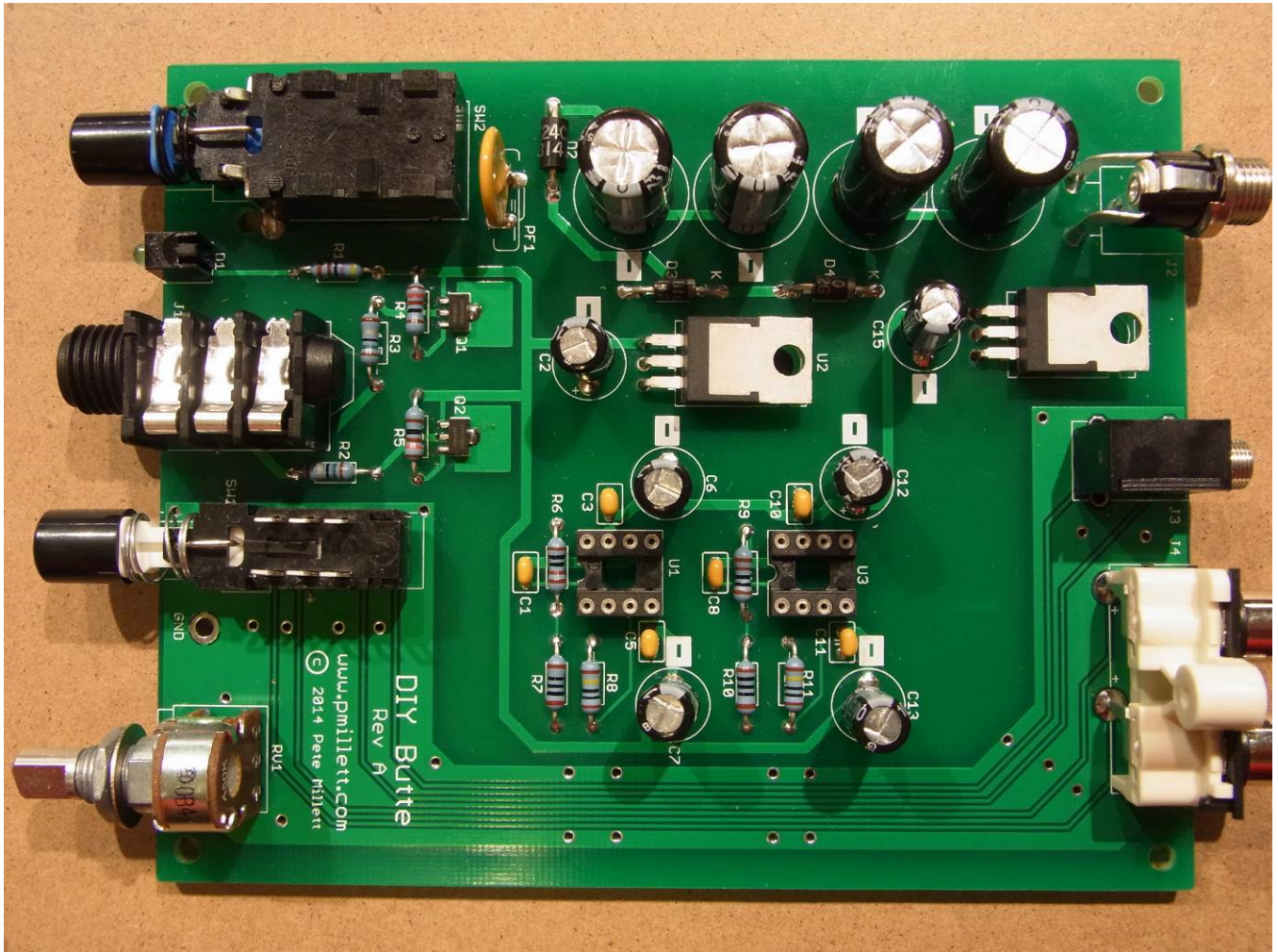
18. Install the pushbutton caps

There are two plastic caps that are installed on the power and input switches. Simply pop them into place by pressing in:



19. 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:



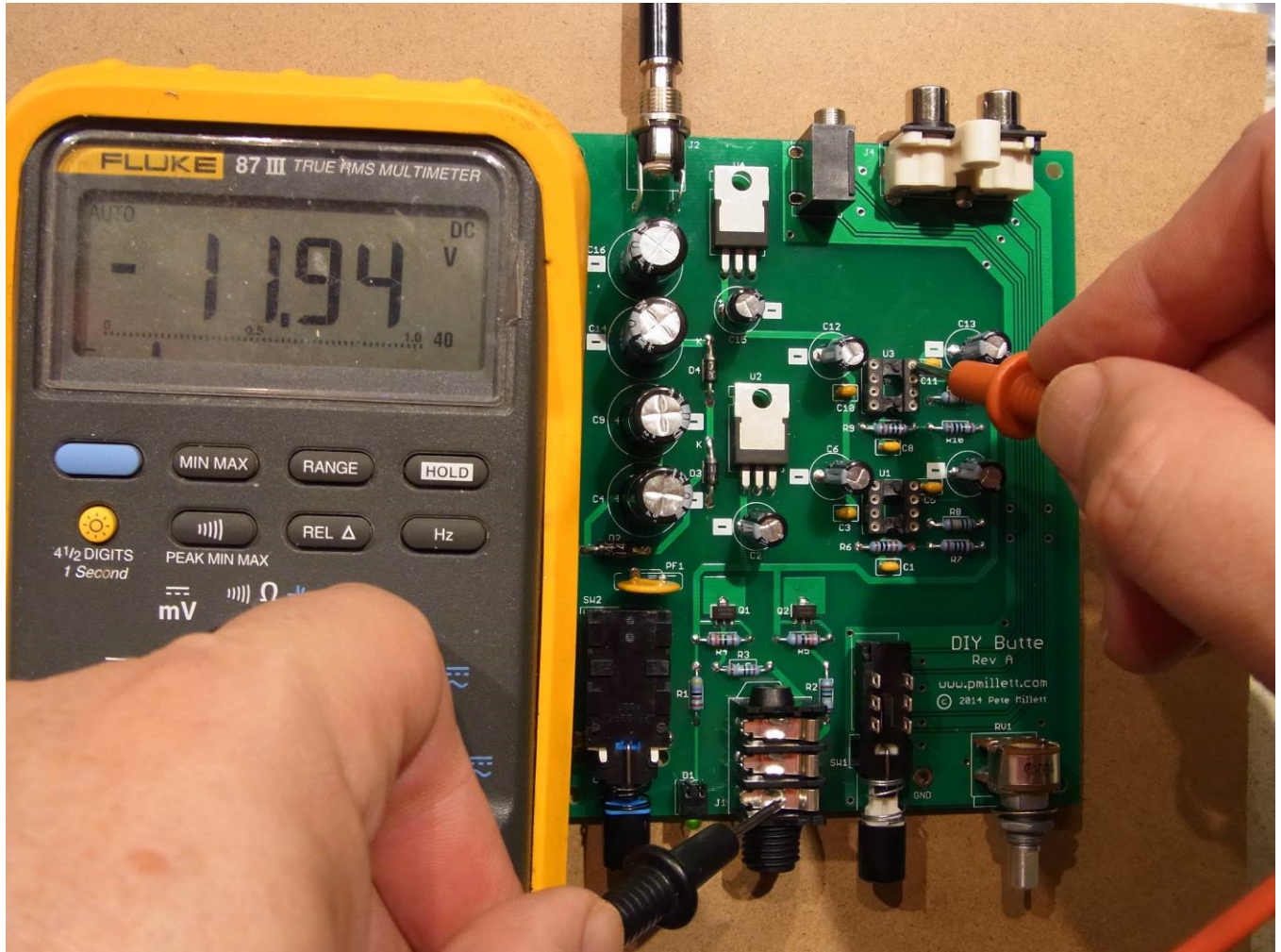
20. Power supply voltage test

If you have access to a DMM (Digital Multimeter), you can do a simple test before installing the opamps to make sure that the power supply is operating correctly.

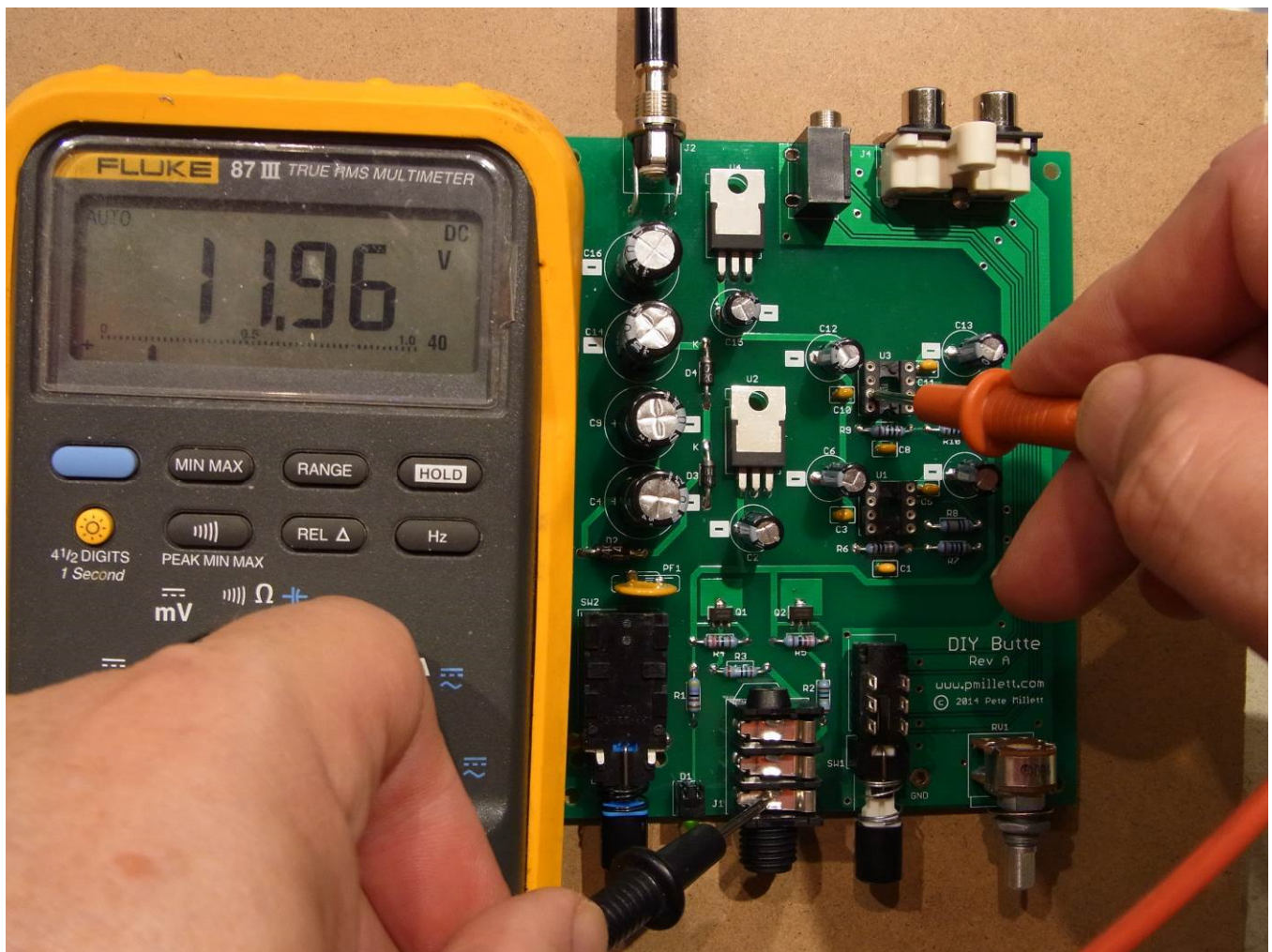
First, make sure the board is sitting on a non-conductive (not metal!) surface, so nothing on the back gets shorted. Wood, or a magazine or stack of paper works fine.

To do this test, plug the AC adapter into the board, and plug the adapter into the wall. Push in the power switch. The power LED should light up - if not, unplug it and go back and re-inspect; something must be unsoldered or incorrectly installed!

Assuming the LED is on, set the DMM to read DC volts, and hold the negative (black) and positive (red) leads as shown below. You should get a reading around -12V (+/- 0.2V is fine):



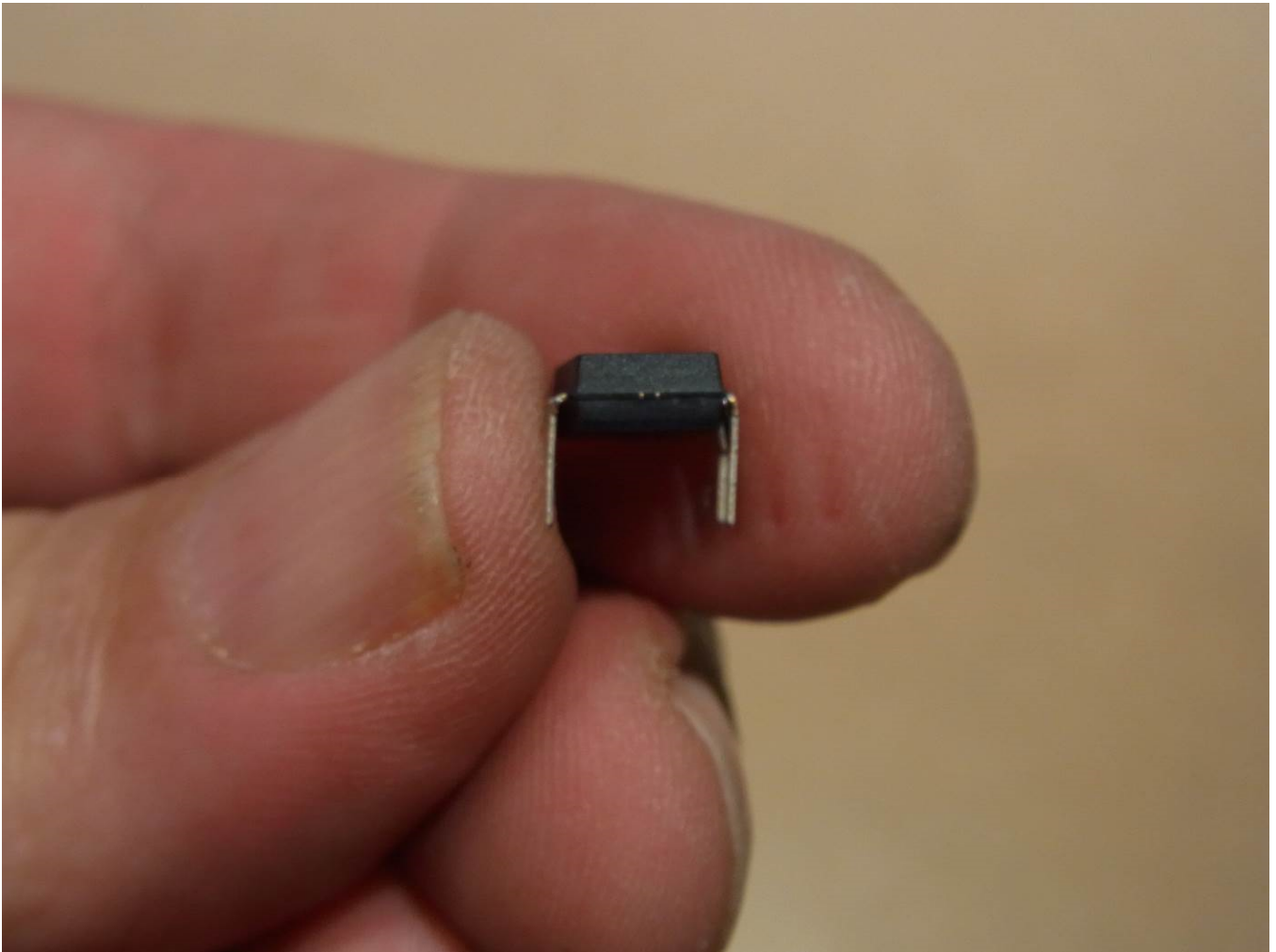
Next, move the positive (red) lead as shown below, and verify a reading of +12V or so:



If either reading is off, unplug and go back and check you work!

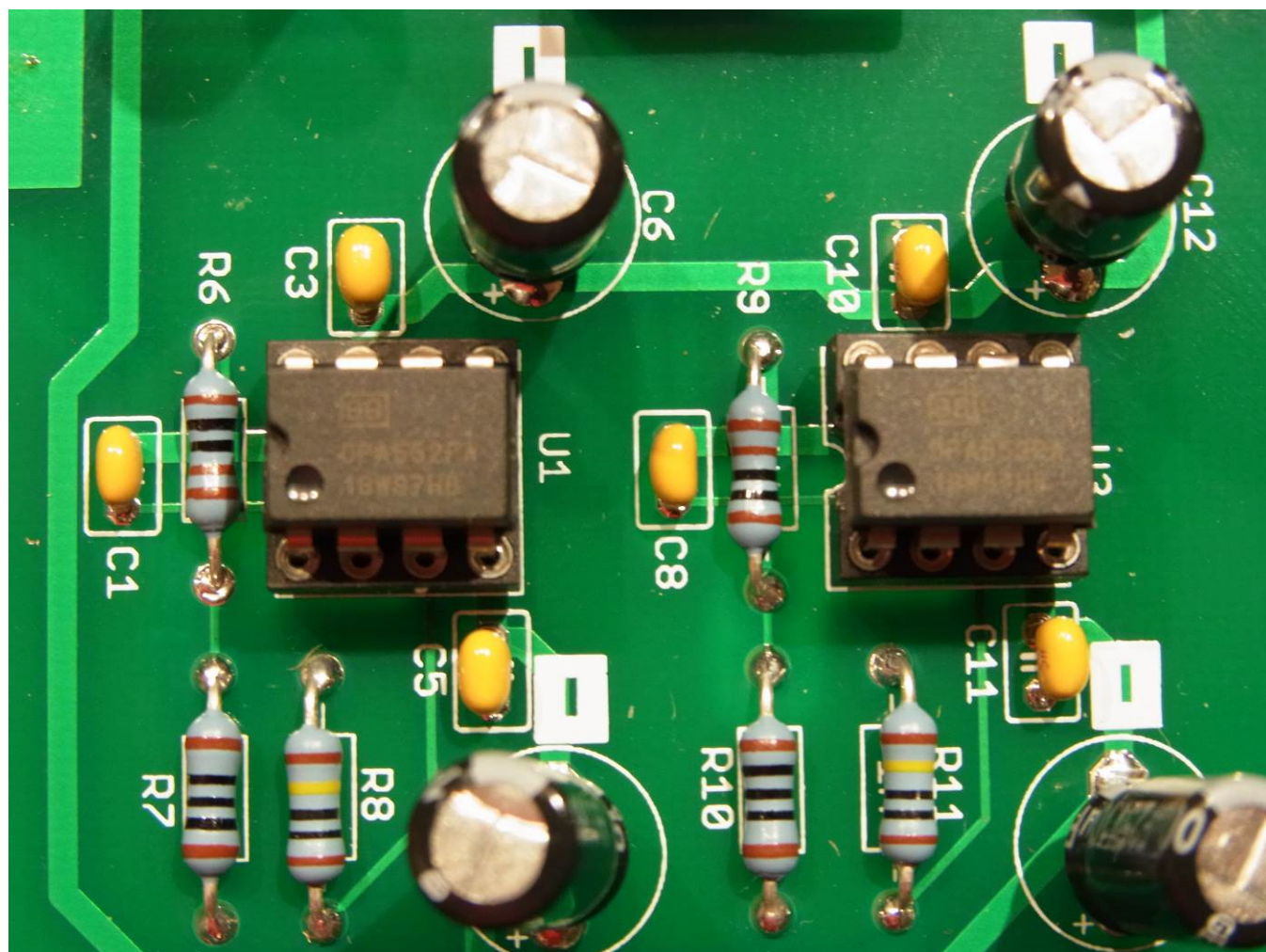
21. Install the opamps U1 and U3 into the sockets

Now, plug the opamp ICs into their sockets. You will 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.

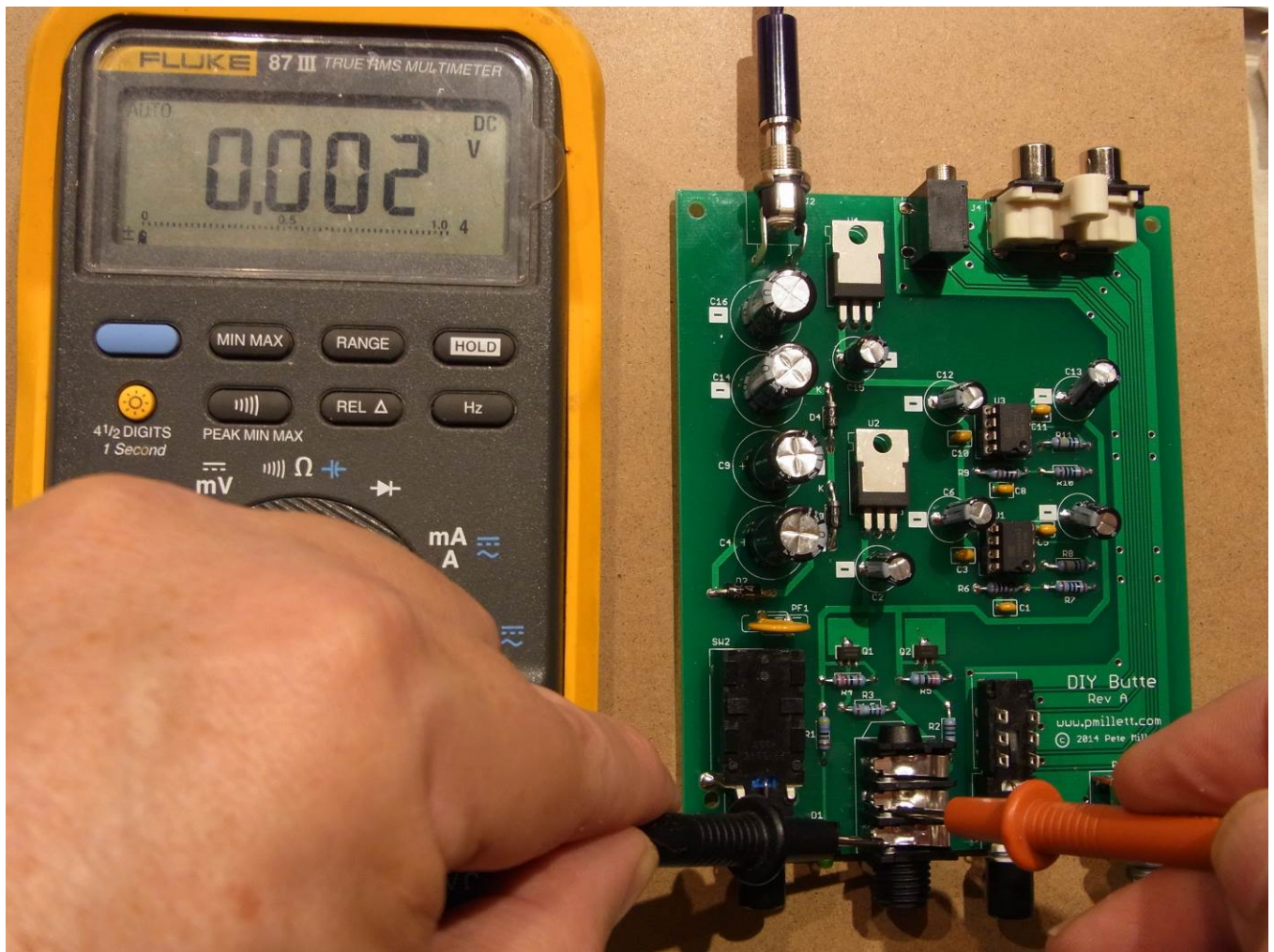
They should look like this - double-check the orientation to match the photo:

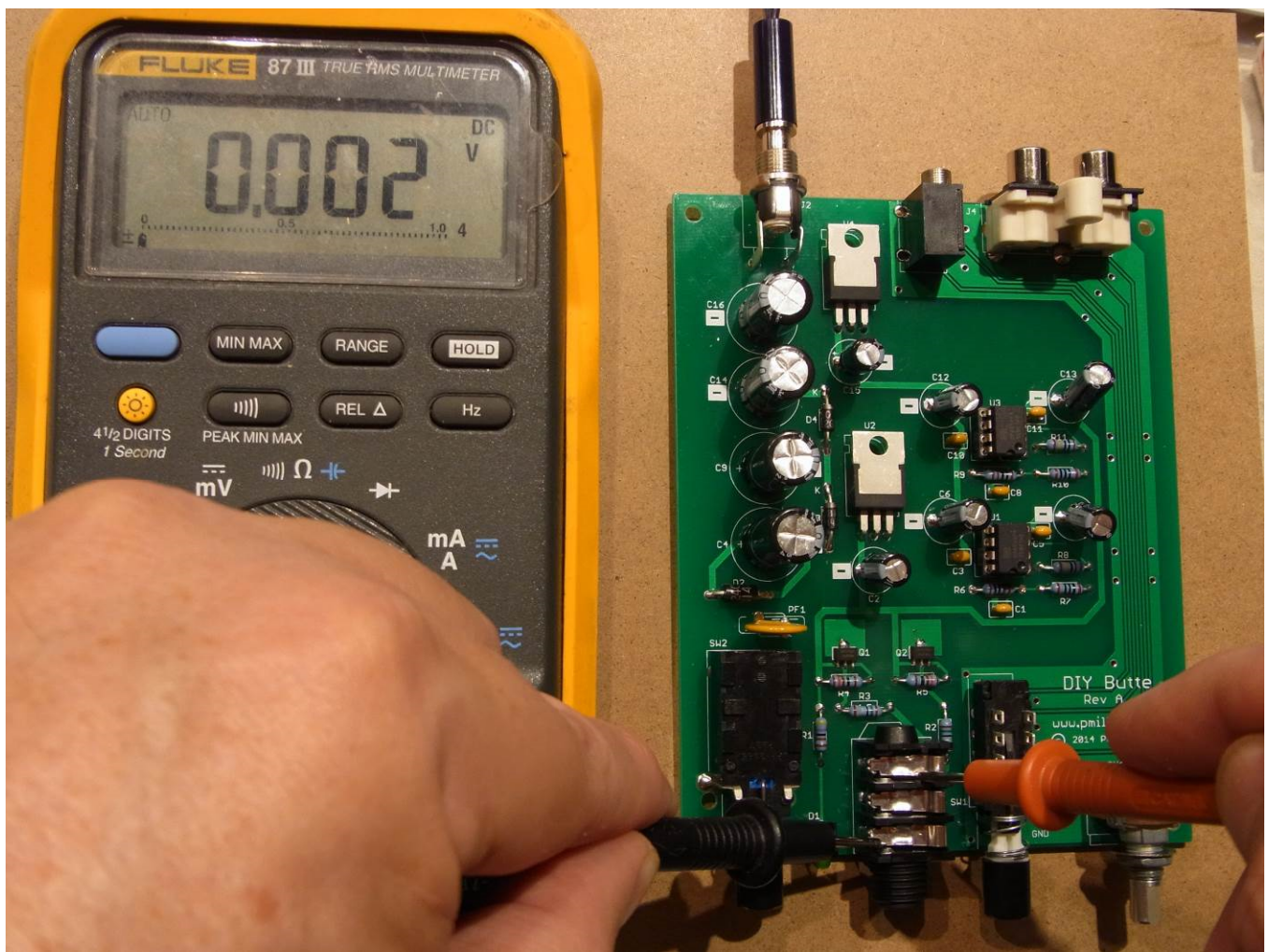


22. Output offset test

Again, if you have access to a DMM, perform this check to make sure everything is OK with the build. This checks to make sure that there isn't any DC offset on the amp outputs. DC offset will cause nasty pops and could even damage your headphones!

Set the DMM to measure DC volts, and position the leads of the DMM as shown in the two photos below. You should measure something close to 0 volts. Anything more than about 100mV (0.1V) is a problem. You should go back and inspect everything.





23. Listen!

At this point, all checks out. Plug the amp into a music source, either through J3 (1/8" jack) or J4 (RCA jacks). Select which input you want using SW1.

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!

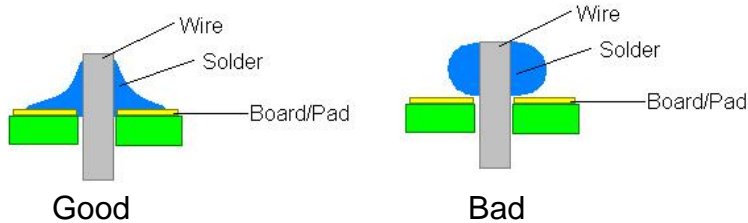
You can buy the enclosure designed for the amp from pml1.com via eBay (stores.ebay.com/pml1.com). Or you can design and build your own. There is a mechanical drawing at the end of this document to assist you in designing a case.

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 thorough the schematic, and check voltages to isolate the problem. If you are a newbie, you might need to solicit help from somebody.

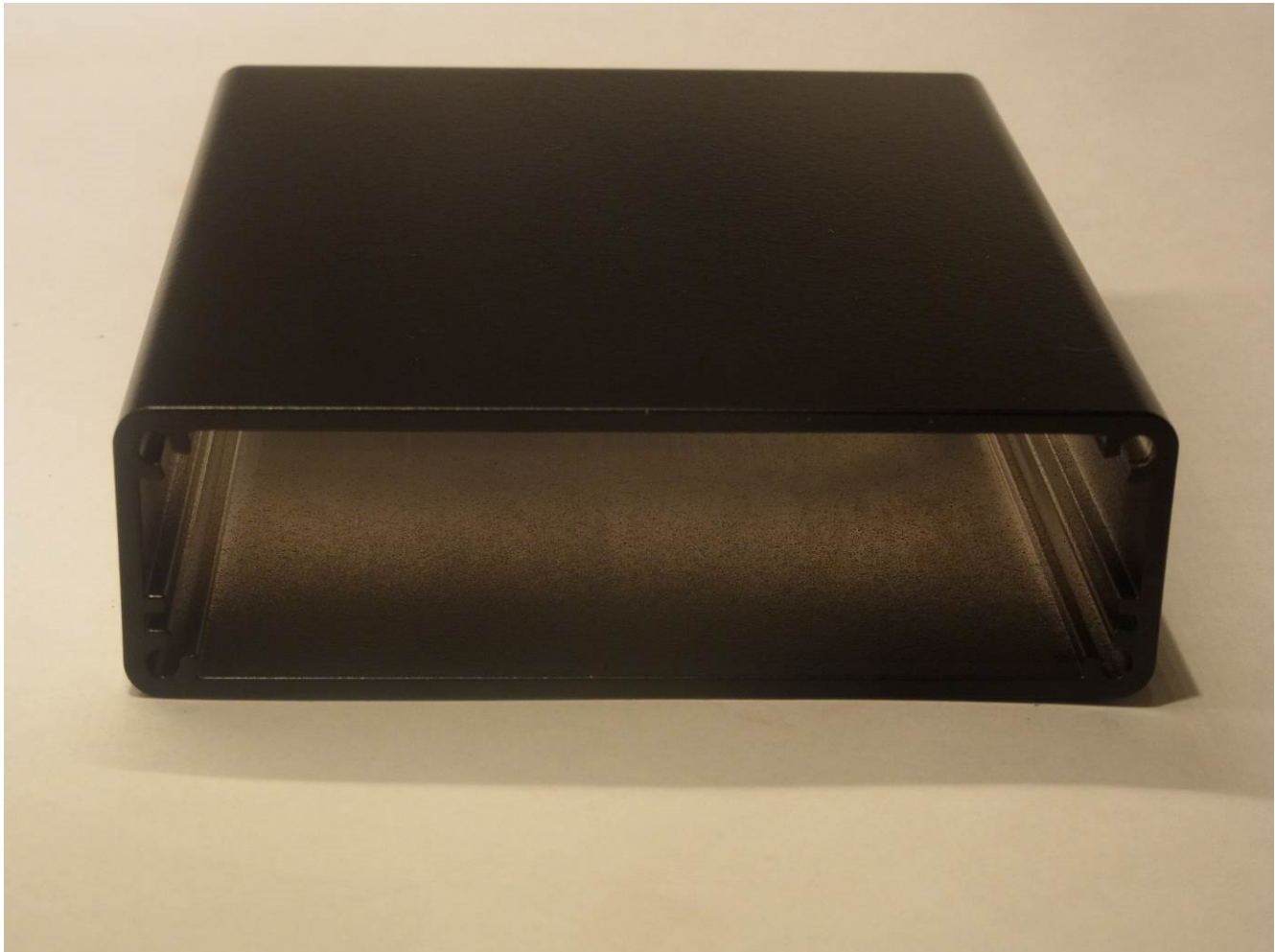
Using the Enclosure

If you want an easy way to package the amp, you can put a complete metal enclosure to go with the PCB. Here's what it looks like all packaged up:



1. Remove the screws & remove the panels

The enclosure ships with the front and rear panels attached. Inside is a small bag with adhesive feet and a screw that fasten the RCA jack. If you bought the PCB and enclosure together, the PCB will be inside as well.

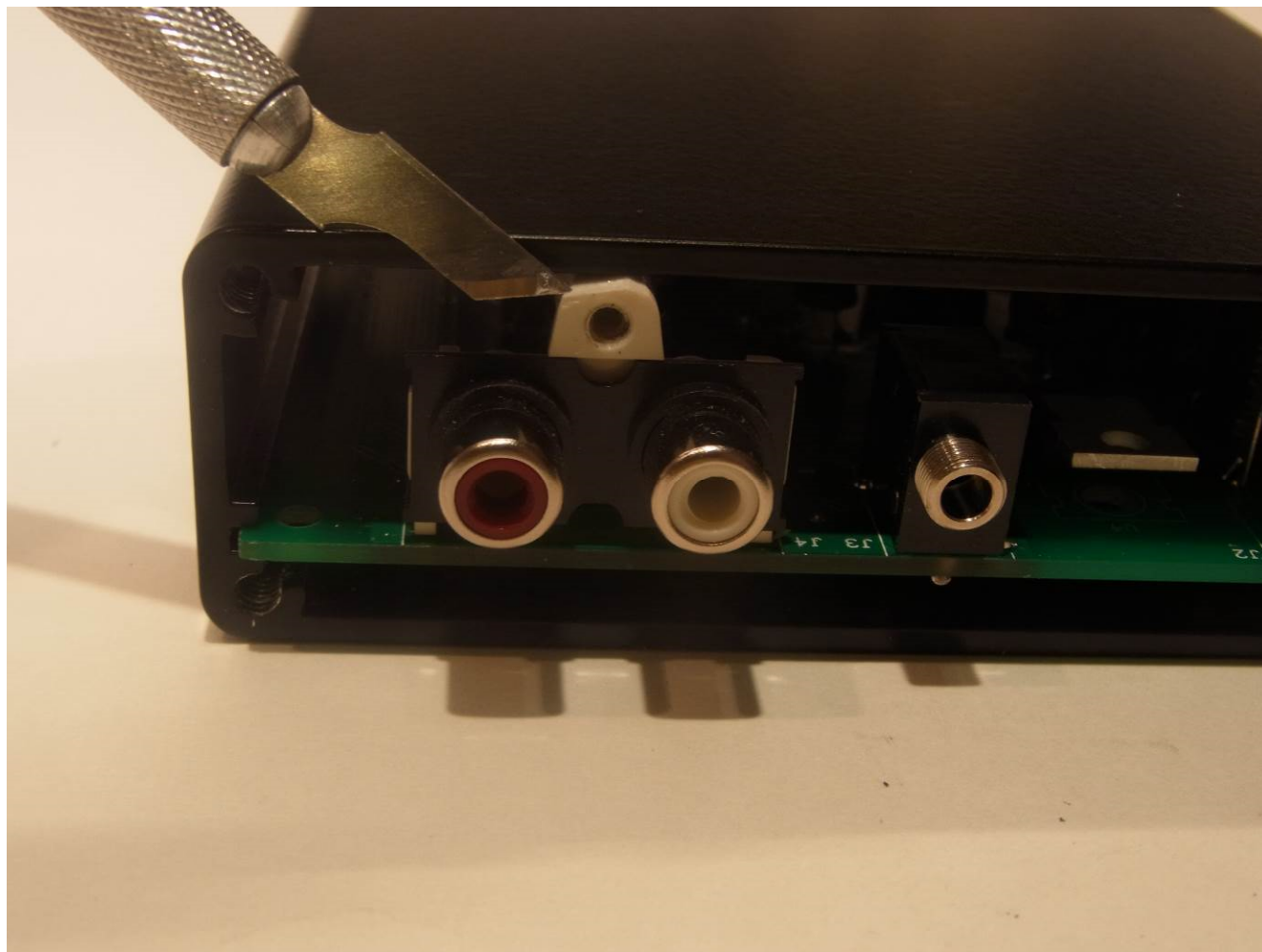


2. Slide the finished (and tested!) PCB assembly into the case

There are card guides molded into the case. Simply slide the board into the case.



You may need to trim the RCA jack a little - it is a very tight fit and it might be best to use a knife or wire cutter to trim just a little off, so it slides in easier.



3. *Place the rear panel*

Place the rear panel onto the PCB components. Make sure the plastic part of the RCA connector goes into the holes.



Put in two screws to hold the rear panel in place, but don't tighten them all the way yet.



4. *Place the rear panel*

Place the front panel in the same way as the rear. Put in two screws but leave them loose.



The LED needs to fit into the small hole. Be careful - you might need to push the LED one way or another to get it to fit.



5. *Install panel nuts for the power jack, pot, and headphone jack*

Next, install the nuts on the power jack (rear panel)...



and headphone jack (front panel)...



...and volume control (front panel). These don't need to be very tight - finger tight is fine. Especially the volume control nut - if you tighten it too much you can bend the volume control off of the PCB.



6. Put in the rest of the screws, and attach the RCA jack

Put the remaining panel screws in place and tighten them all.

Use the small screw provided with the enclosure to fasten the RCA jack to the rear panel. Not too tight, the plastic is easy to strip!



7. Install the rubber feet

There are 4 adhesive rubber feet provided with the enclosure. Peel them from the backing and stick them to the bottom of the enclosure near the corners.



8. *Install the volume knob*

The volume knob is just pushed onto the shaft. But it is REALLY hard to remove, so don't install it until everything else is done and tested!



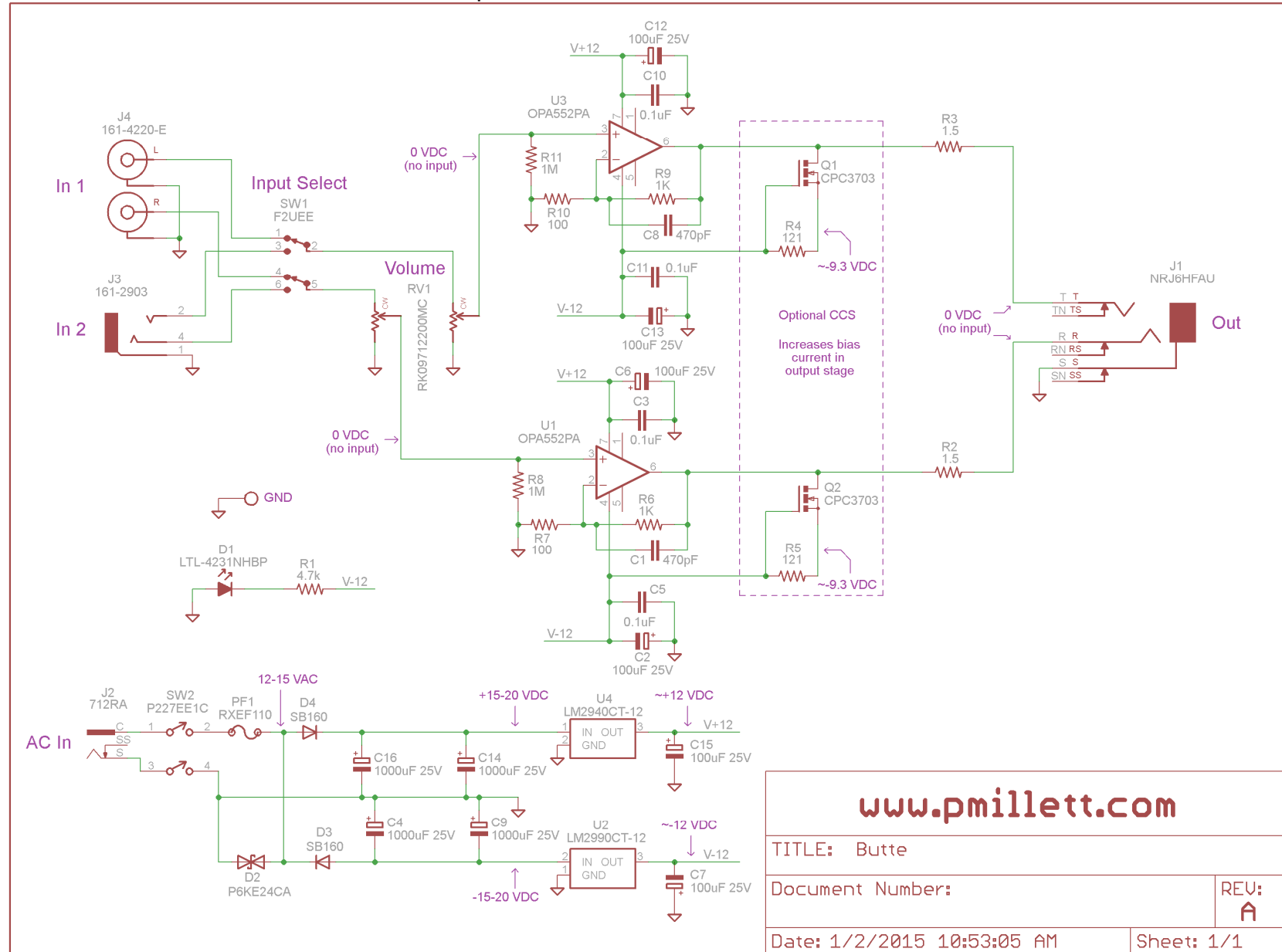
Appendix 1: Bill of Materials (Parts List, or BOM)

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

Qty	Description	Ref. Des	Manuf.	Manuf. PN	Mouser PN	Cost Ea	Cost Ext	Alternate Mouser PN	Notes
2	Capacitor, 470pF NPO ceramic 0.1" LS	C1, C8	Vishay	K471J15C0GF53L2	594-K471J15C0GF53L2	\$ 0.10	\$ 0.20	594-K471J15C0GF5TL2	
6	Capacitor, 100uF 25V electrolytic, 5mm LS 8.5mm dia	C2, C6, C7, C12, C13, C15	Panasonic	EEU-FR1E101B	667-EEU-FR1E101B	\$ 0.44	\$ 2.64	667-EEU-FR1J101LB	
4	Capacitor, 0.1uF X7R ceramic 0.1" LS	C3, C5, C10, C11	Vishay	K104K15X7RF53L2	594-K104K15X7RF53L2	\$ 0.10	\$ 0.40	594-K104K15X7RF5TL2	
4	Capacitor, 1000uF 25V electrolytic, 5mm LS 13mm dia	C4, C9, C14, C16	Nichicon	UVY1E102MPD	647-UVY1E102MPD	\$ 0.32	\$ 1.28	647-UVK1E102MPD	
1	LED, 3mm right angle	D1	Lite-On	LTL-4231NHBP	859-LTL-4231NHBP	\$ 0.20	\$ 0.20	696-SSF-LXH103GD	You can use other colors if you want
1	TVS Diode, 24V 600W bidirectional DO-15/DO-204	D2	Vishay	P6KE24CA-E3/54	625-P6KE24CA-E3	\$ 0.59	\$ 0.59	576-P6KE24CA	Make sure you get bidirectional (CA) not uni (A)
2	Schottky diode, 60V 1A DO-41	D3, D4	Vishay	SB160-E3/54	625-SB160-E3	\$ 0.13	\$ 0.26	512-SB160	
1	Jack, 1/4" TRS phone	J1	Neutrik	NRJ6HF	550-20311	\$ 0.59	\$ 0.59	550-20311AU	Alternate is gold plated
1	Nut for phone jack	at J1	Neutrik	NRJ-NUT-B	550-1005	\$ 0.14	\$ 0.14	550-1002	Alternate is metal
1	Jack, 2.1mm power	J2	Switchcraft	722RA	502-722RA	\$ 2.80	\$ 2.80	502-L722RA	
1	Jack, 3.5mm TRS phone	J3	Kycon	STX-3150-5C	806-STX-3150-5C	\$ 1.51	\$ 1.51	502-35RAPC2BV4	
1	Jack, horizontal dual RCA	J4	Kobiconn	161-4218-E	161-4218-E	\$ 0.81	\$ 0.81	161-4220-E	Alternate is gold plated
1	PTC Fuse, 1A	PF1	Tyco	RXEF110	650-RXEF110	\$ 0.38	\$ 0.38	650-RXEF110K	
2	Depletion-mode N-channel MOSFET	Q1, Q2	ixys	CPC3703C	849-CPC3703C	\$ 0.83	\$ 1.66	689-DN3525N8-G	
1	Resistor, 1/4W 4.7k	R1	KOA	MF1/4DC4701F	660-MF1/4DC4701F	\$ 0.12	\$ 0.12	71-CCF554K75FKE36	
2	Resistor, 1/4W 1.5 ohm	R2, R3	KOA	MF1/4DC1R50F	660-MF1/4DC1R50F	\$ 0.12	\$ 0.24	603-MFR-25FBF52-1R5	
4	Resistor, 1/4W 1K	R4, R5, R6, R9	KOA	MF1/4DC1001F	660-MF1/4DC1001F	\$ 0.12	\$ 0.48	71-CCF551K00FKE36	
2	Resistor, 1/4W 100 ohm	R7, R10	KOA	MF1/4DC1000F	660-MF1/4DC1000F	\$ 0.12	\$ 0.24	71-CCF55100RFKE36	
2	Resistor, 1/4W 1M	R8, R11	KOA	MF1/4DC1004F	660-MF1/4DC1004F	\$ 0.12	\$ 0.24	71-CCF551M00FKE36	
1	Pot, 10k stereo audio	RV1	Alpha	RV122F-20-15F-A10K	313-1240F-10K	\$ 3.16	\$ 3.16	RV122F-20-15F-A50K	
1	Knob, 6mm shaft	at RV1	Eagle Plastic	450-BA761	450-BA761	\$ 0.60	\$ 0.60	450-BA261	You can use a different one
1	Switch, DPDT latching push	SW1	C&K	F2UEE	611-F2UEE	\$ 1.66	\$ 1.66	611-F2UEEAU	Alternate is gold plated
1	Switch, DPST power push	SW2	E-switch	P227EE1CXC	612-P227EE1CXC	\$ 2.72	\$ 2.72	611-NE1845EE	
2	Cap, pushbutton	at SW1, SW2	C&K	21125	611-21125	\$ 0.49	\$ 0.98	612-TAG-BK	You can use different colors
2	Opamp, high current	U1, U3	TI	OPA552PA	595-OPA552PA	\$ 5.04	\$ 10.08	595-OPA551PA	Many other choices - see website
2	Socket, 8-pin DIP	at U1, U3	Mill-Max	110-99-308-41-001000	575-199308	\$ 0.27	\$ 0.54	575-144308	Optional, but a good idea
1	Linear regulator, -12V TO-220	U2	TI	LM2990T-12/NOPB	926-LM2990T-12/NOPB	\$ 3.22	\$ 3.22	926-LM79M12CT/NOPB	
1	Linear regulator, +12V TO-220	U4	TI	LM2940CT-12/NOPB	926-LM2940CT-12/NOPB	\$ 1.64	\$ 1.64	863-MC78M12CTG	
1	AC adapter 12VAC 500mA - 1A 2.1mm plug	none	Triad	WAU12-1000	553-WAU12-1000	\$16.68	\$ 16.68	553-WAU12-500	Need different adapter for non-US use
1	PC Board					\$20.00	\$ 20.00		stores.ebay.com/pmillett
	Total						\$ 76.06		

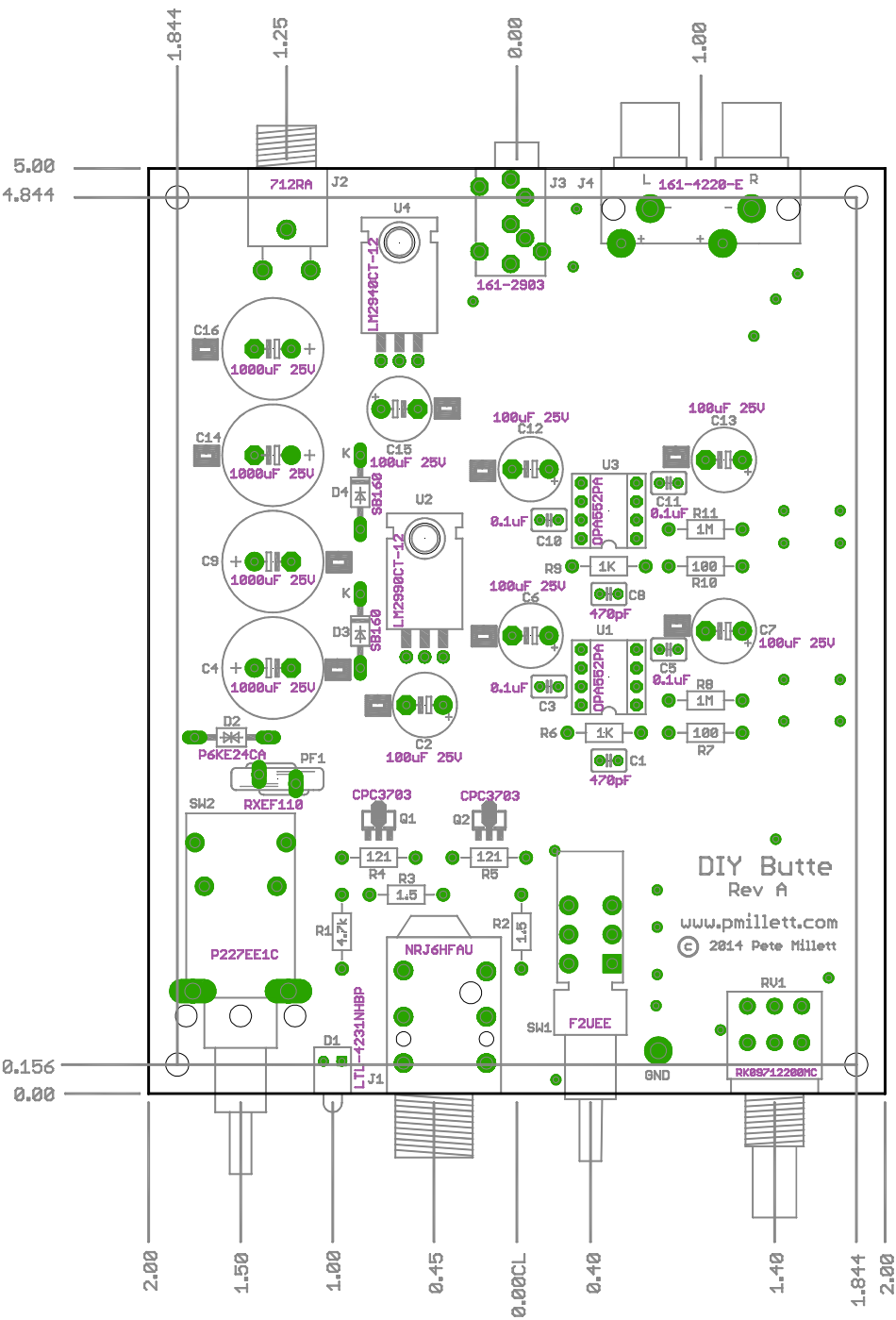
Appendix 2: Schematic

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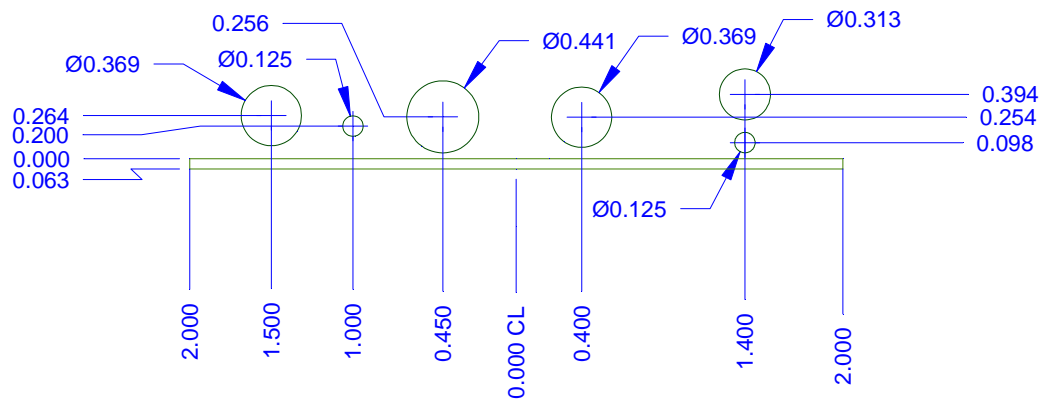


Appendix 3: Mechanical Drawings

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



Front Components



Rear Components

