CFT1 5-Band QRP CW Field Transceiver

By KM4CFT

Assembly Manual

In memory of Sherwin “Steve” Kayne.

My grandfather played a vital role in making me the person I am today and without his support I would have never pursued STEM and Amateur Radio. Although he never was licensed, he was a true elmer.

“The price of success is hard work, dedication to the job at hand, and the determination that whether we win or lose, we have applied the best of ourselves to the task at hand.”

- Vince Lombardi

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Overview

The CFT1 is a 5 Band, Compact Portable QRP CW Field Transceiver. It operates on the 40m, 30m, 20m, 17m, and 15m amateur radio bands. It features a ~5 watt class-D transmitter, message memory playback, iambic keyer (with paddle reverse), among other useful features.

The CFT1 was created by Jonathan, KM4CFT (age 25) with the field operator in mind, specifically for use in both Parks on the Air (POTA) and Summits on the Air (SOTA).

General Guidelines

This kit is designed to be an *intermediate* level kit and requires some level of skill with a soldering iron. It is assumed that the builder has a reasonable level of electrical knowledge.

All SMD components on this kit are already populated and the builder only will need to install the through hole components. Solder pads have been enlarged to make soldering easier where possible (exceptions include the 2x11 and 2x3 headers).

Make sure to have plenty of lighting and use magnification to inspect your work.

Something important: SAVE YOUR COMPONENT LEAD OFFCUTS! You will need them for grounding the cases of the 4 crystals!

Read this assembly manual carefully before doing any work on your kit! Failure to do so could lead to you making a mistake during assembly!

Tools/Equipment Required

There are some basic tools you will need to assemble the CFT1 along with some RF test equipment. For test equipment, there are multiple options listed.

Tools:

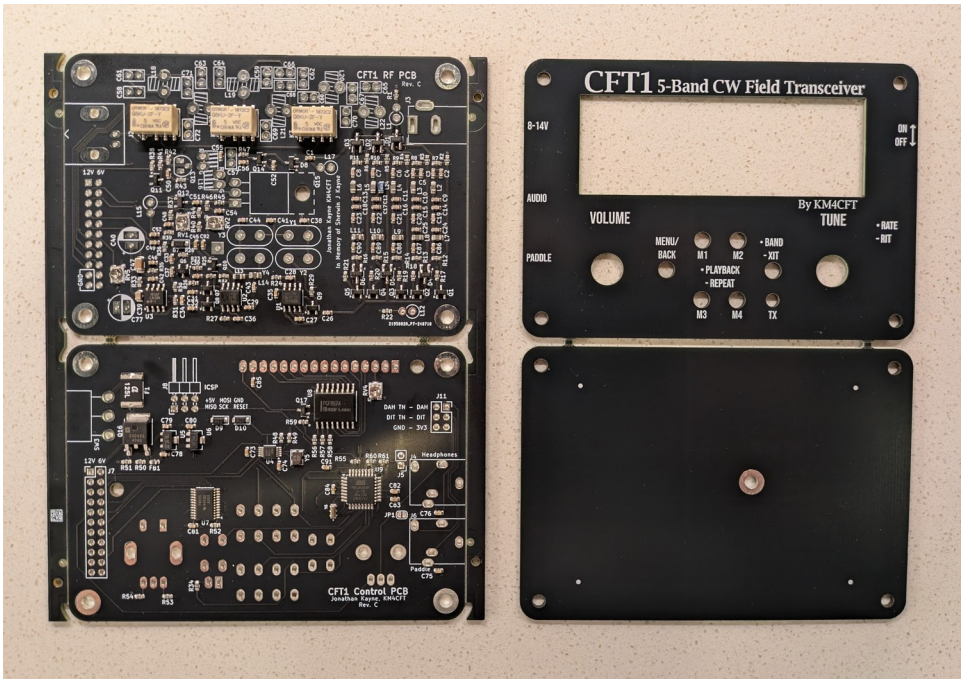
- Safety Glasses
- Soldering Iron
- Solder
- Flush Cutters
- Needle Nose Pliers
- Tweezers
- Screwdriver
- Magnifier
- Hobby Knife
- 2mm Allen Key
- (optional) file

Equipment:

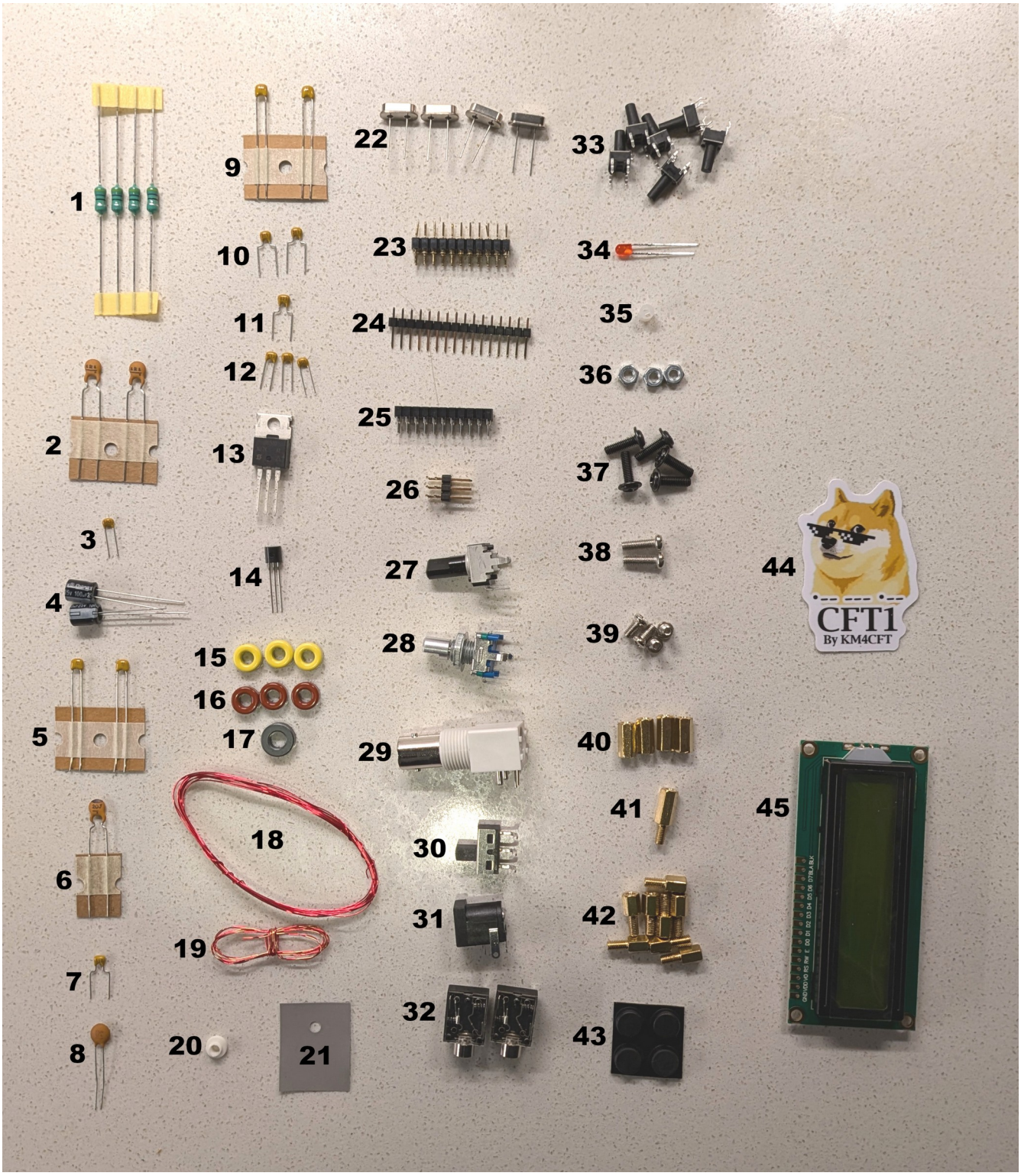
- Multimeter with Mini-grabber leads
- 12 volt power supply
- Watt meter capable of reading QRP levels
- Dummy Load
- RF receiver *(choose one of these options)*
  - Any HF radio with a CW mode
  - RTL SDR (can be found for about $20 on Amazon)
- RF signal Generator *(choose one of these options)*
  - TinySA Ultra (has built in generator)
  - Standard TinySA + 20dB RF Attenuator
  - Standard TinySA + Included Antenna
  - NanoVNA + short piece of wire (has a CW Tone generator)
  - HF Antenna + WWV
  - QRP HF radio transmitting into a dummy load

Parts List

PCBs:



Parts: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CFT1
By KM4CFT
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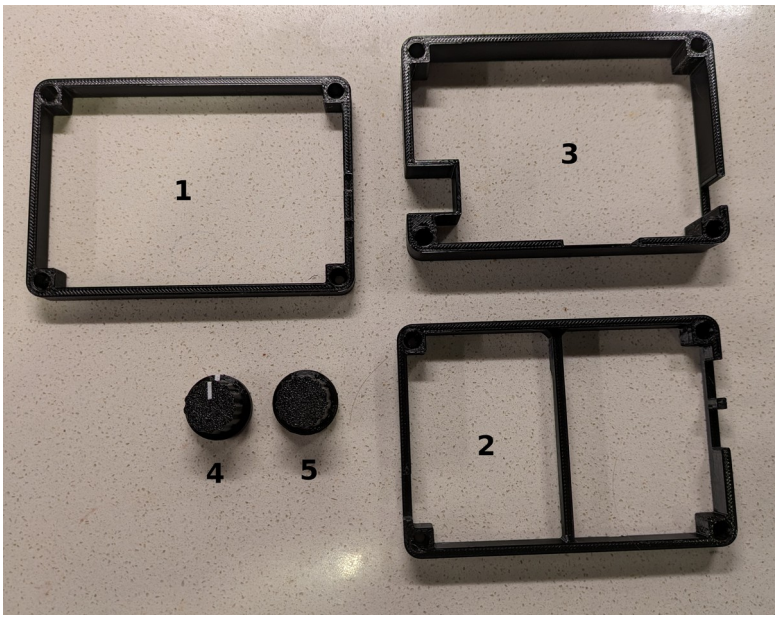
Number	Part	Qty/ Length	Number	Part	Qty/Length
1	47µH Inductor	4	24	1x16 Male Header	1
2	120pF (121) Cap	2	25	2x11 Female Header	1
3	68pF (68J) Cap	1	26	2x3 Right Angle Header	1
4	100µF Electrolytic Cap	2	27	1kΩ Potentiometer	1
5	150pF (151) Cap	2	28	Encoder	1
6	20pF (20J) Cap	1	29	BNC Connector	1
7	51pF (510) Cap	1	30	Slide Switch	1
8	100nF (104) Cap	1	31	5.5x2.1 Barrel Connector	1
9	180pF (181) Cap	2	32	3.5mm Headphone Socket	2
10	360pF (361) Cap	2	33	Tactile Switch	6
11	620pF (621) Cap	1	34	3mm LED	1
12	300pF (301) Cap	3	35	4.5mm LED Spacer	1
13	IRF510 MOSFET	1	36	M3 Hex Nut	3
14	MPS751 PNP	1	37	M3x10 Screw, Black	5
15	T30-6 Toroid	3	38	M3x10 Screw, Silver	2
16	T30-2 Toroid	3	39	M3x6 Screw	4
17	FT37-43 Toroid	1	40	M3x10 FF Hex Standoff	4
18	#28 Magnet Wire	6’	41	M3x10 MF Hex Standoff	1
19	Twisted Magnet Wire	12”	42	M3x6 MF Hex Standoff	8
20	TO220 Insulating Washer	1	43	Rubber Feet	4
21	TO220 Thermal Pad	1	44	CFT1 Sticker	1
22	4.9152 MHz Matched Crystal	4	45	LCD Screen	1
23	2x11 Male Header	1			

3D Printed Parts:



Number	Part
1	Top Perimeter
2	Center Perimeter*
3	Bottom Perimeter
4	Volume Knob
5	VFO Knob

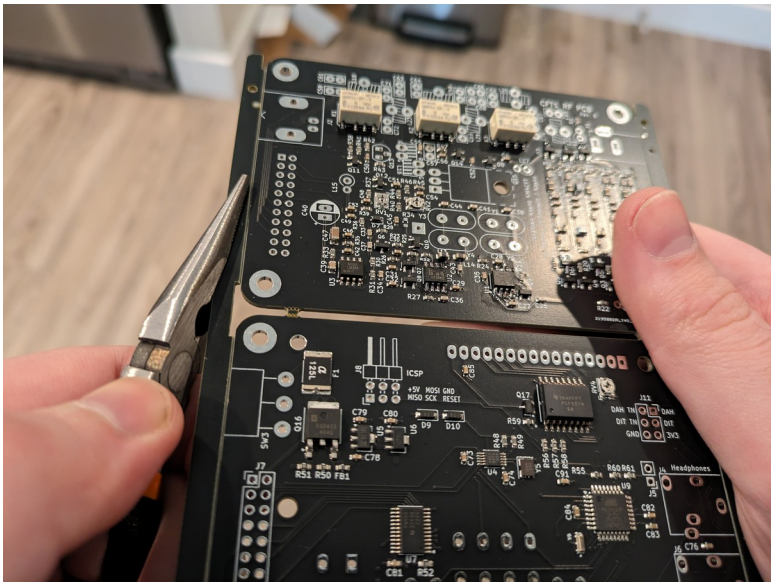
*This part contains a bridging move on the center bar. This means that the underside will look cosmetically ugly. It will be hidden inside the CFT1 so do not worry if it looks bad!

All parts are printed in PETG. You can print replacement parts by visiting printables.com and downloading the STL and STEP files there.

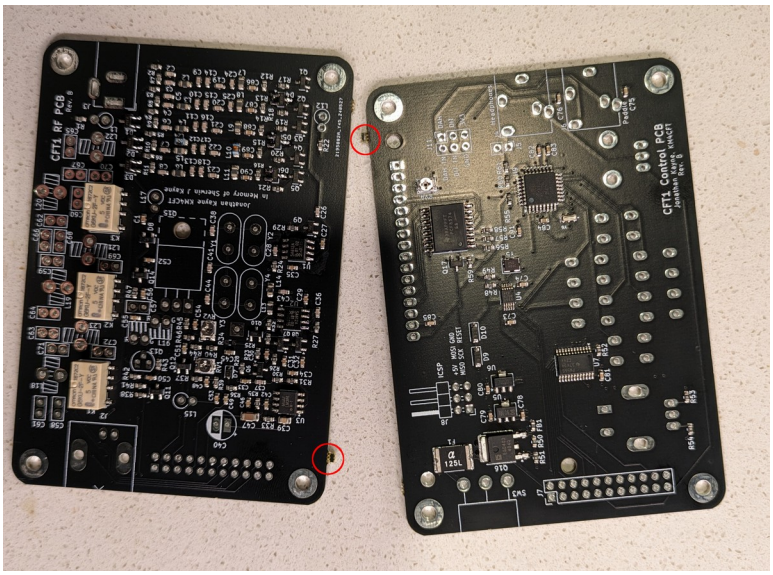
https://www.printables.com/model/963234-km4cft-cft1-5-band-cw-field-transceiver-printed-pa

Step 1: Break apart the PCBs

Using your needle nose pliers, carefully break away the two tabs on the side of the board.

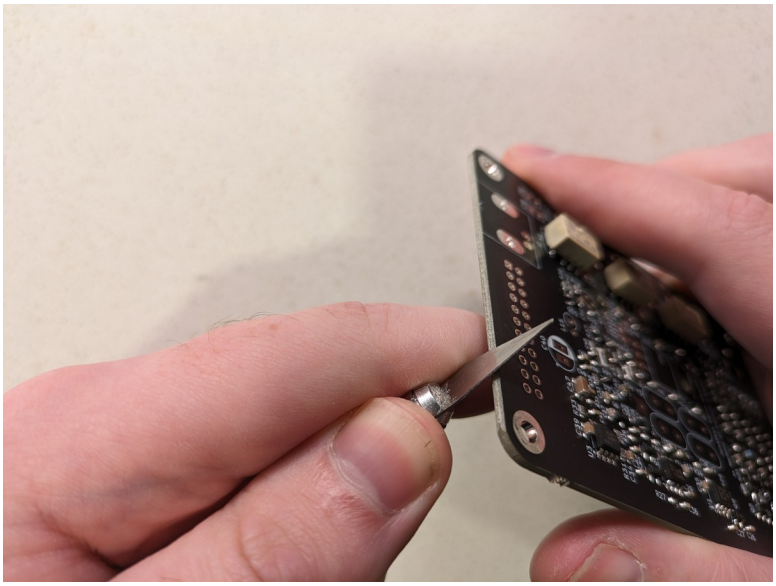


Next, separate the RF board from the Control board. There are two mousebite tabs that separate them and be sure to remove them.

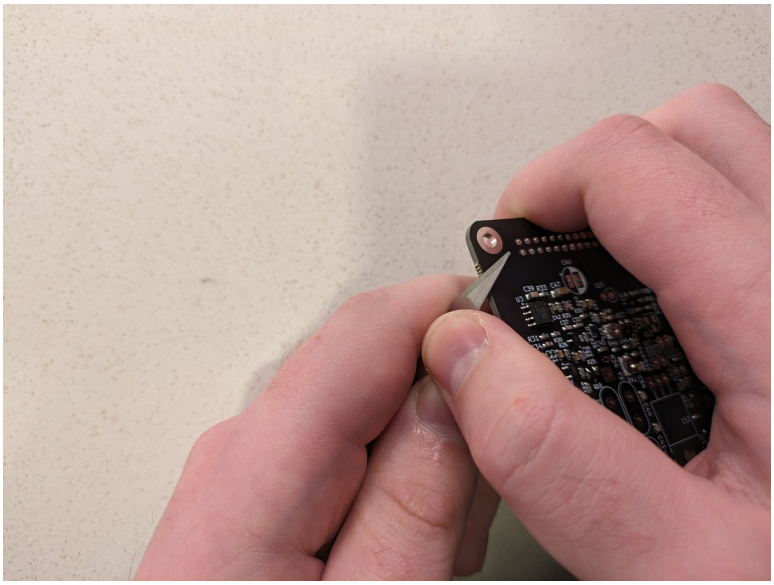


(If your kit came with the boards already separated, start here!)

Take your hobby knife and use it to gently scrape the sides of the boards. This should remove the roughness from the two tabs.



Using either the hobby knife or a file, smooth off the area where the mousebites are. Repeat this for the front and back panels.

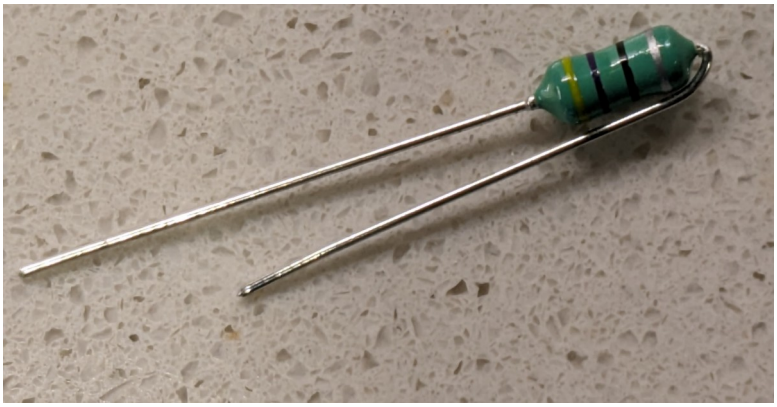


Repeat this process for the front and rear panels.

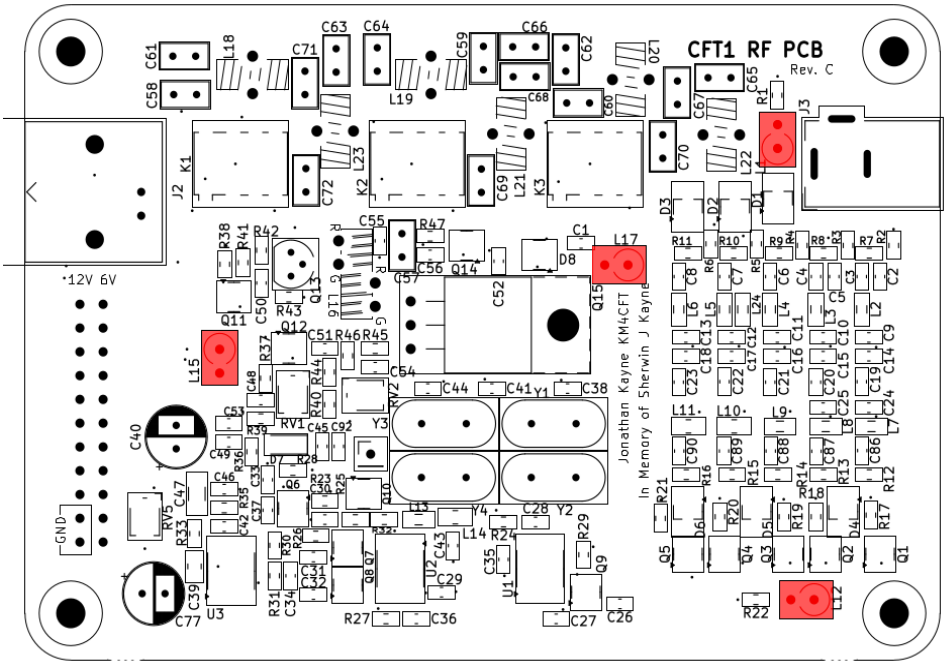
At this point, you have the two boards. For the first half of assembly we will focus on the RF board so you can put the control board off to the side for now! (The RF Board is the one with the three relays)

Step 2: Install the 4 Leaded Inductors

First, take the inductors and bend one of the ends around 180°. Next, Insert them into the two holes. Bend the leads on the other side at about a 30° angle so that they stay in place. Flip the boards over and solder them in place. Clip off the excess and remember to save them for later.

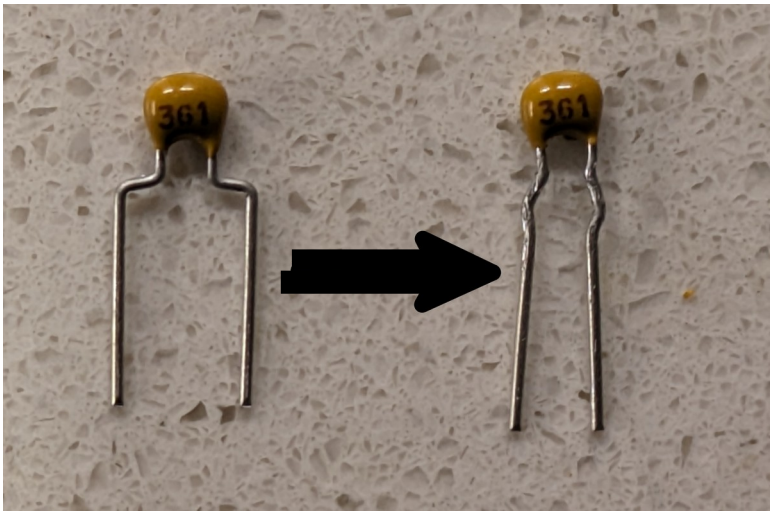


The four inductors are: L1, L12, L15 and L17

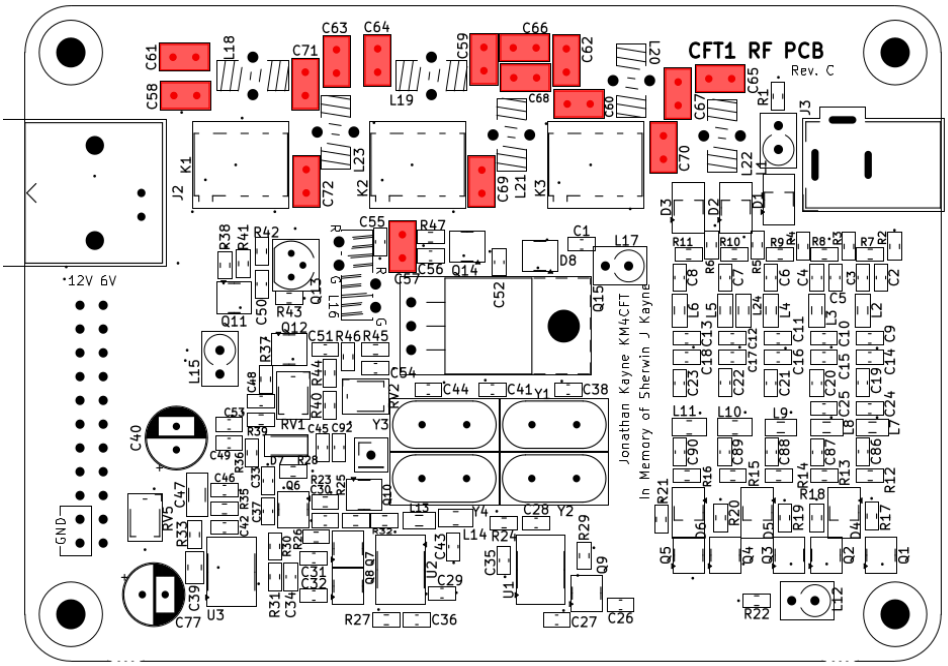


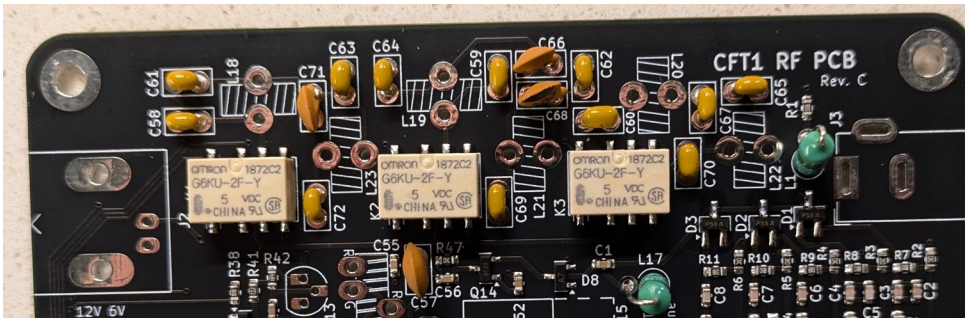
Step 3: Install 16 Ceramic Capacitors

The process for installing the ceramic capacitors is the same as in the previous step (except you don't need to bend the lead 180°) The capacitors might need the leads straightened out so that they fit neatly into the holes, so straighten them out using your needle nose pliers if needed.



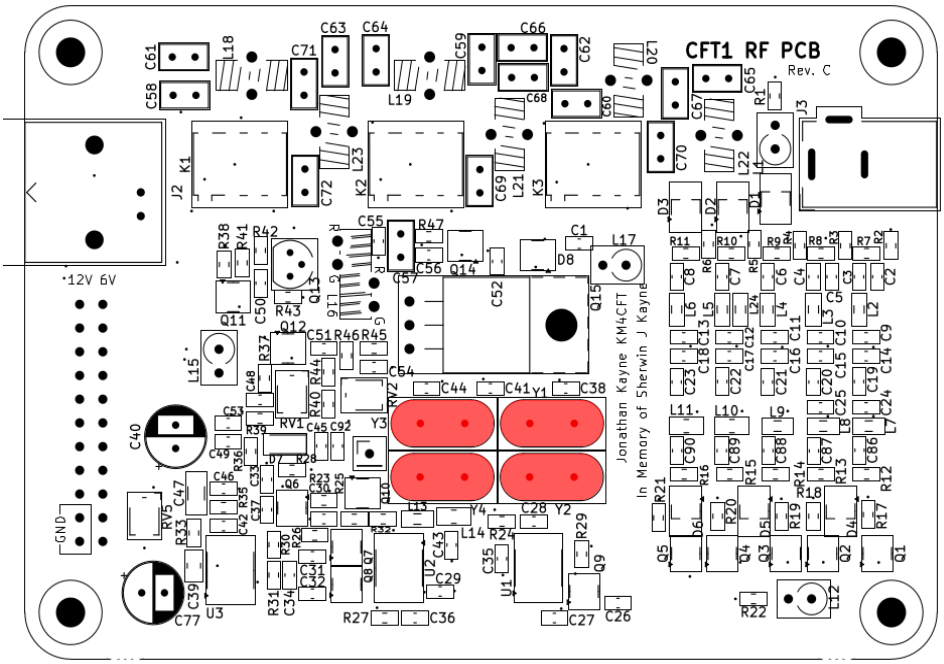
Item Number	Qty	Value	Label	Designator
8	1	100nF	104	C57
12	3	300pF	301	C58, C65, C72
9	2	180pF	181	C59, C69
5	2	150pF	151	C60, C70
10	2	360pF	361	C61, C64
3	1	68pF	680 or 68J	C62
11	1	620pF	621	C63
2	2	120pF	121	C66, C71
7	1	51pF	510 or 51J	C67
6	1	20pF	200 or 20J	C68


CFT1 RF PCB
Rev. C
12V 6V
GND
In Memory of Sherwin J Kayne
Jonathan Kayne KM4CFT


CFT1 RF PCB
Rev. C
12V 6V

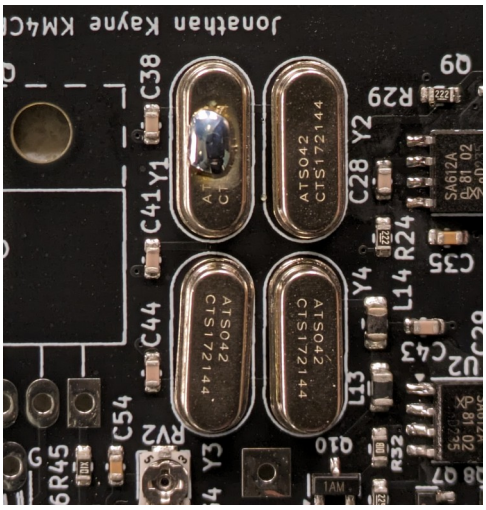
Step 4: Install the 4 Crystals

Take your 4 matched crystals and solder them in place just like in the previous step.

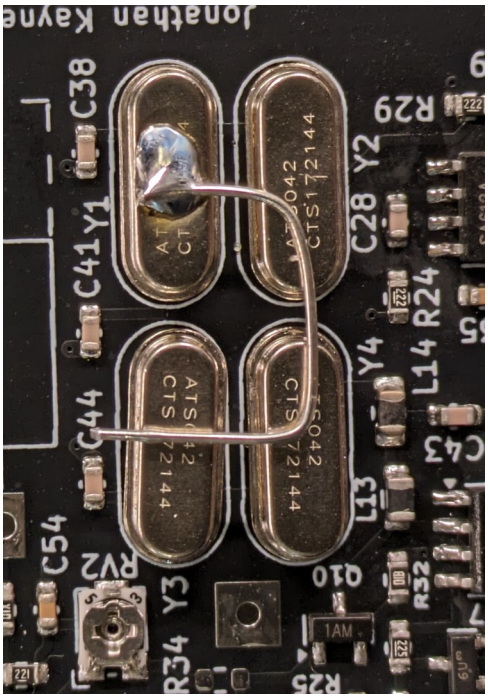


Next, we will take the clippings to properly ground the crystals. This will need to be done with a sense of urgency, as prolonged heat might damage the crystals.

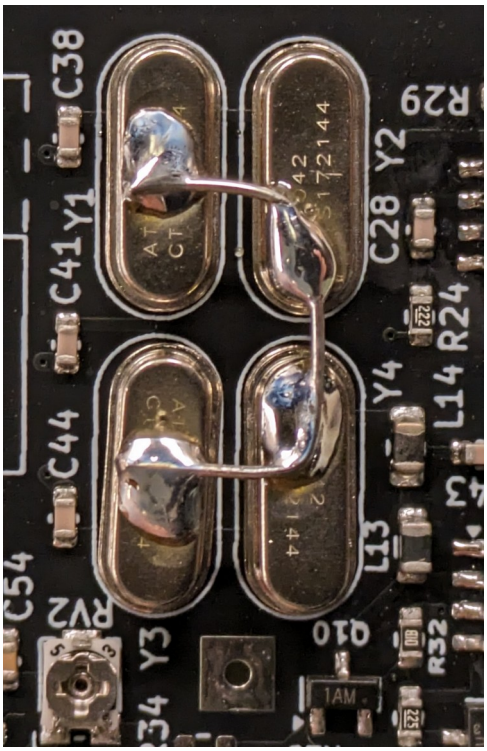
First, add a small blob of solder to one of the crystals



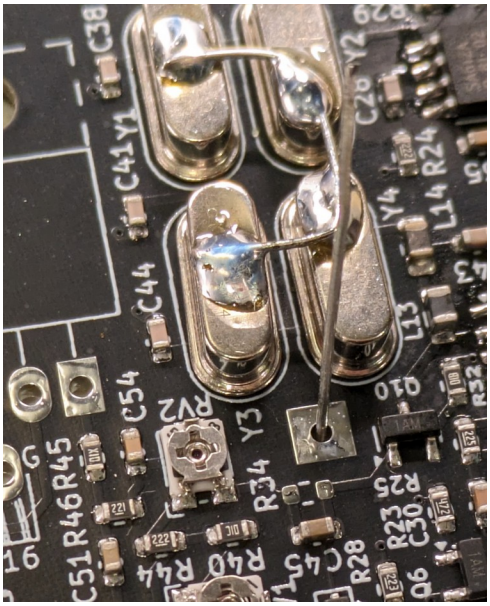
Next, use a lead trimming to bridge the crystals.



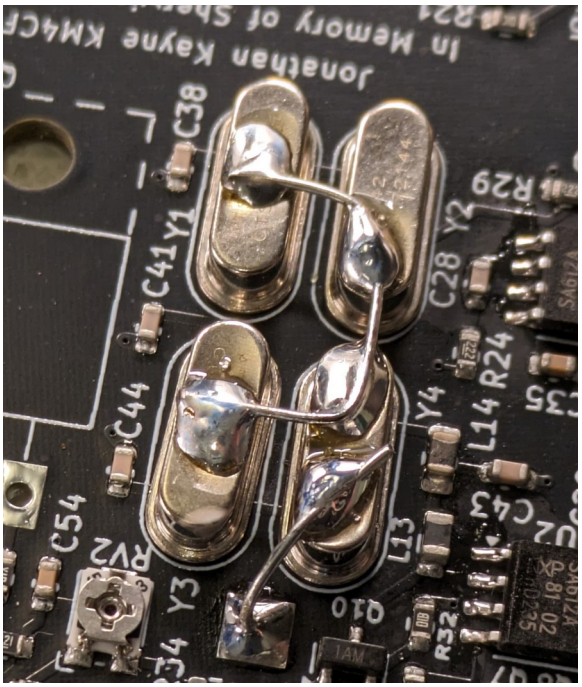
Repeat until all four crystals are connected.



Next, drop a trimming into the square pad and solder it in place (from the top).



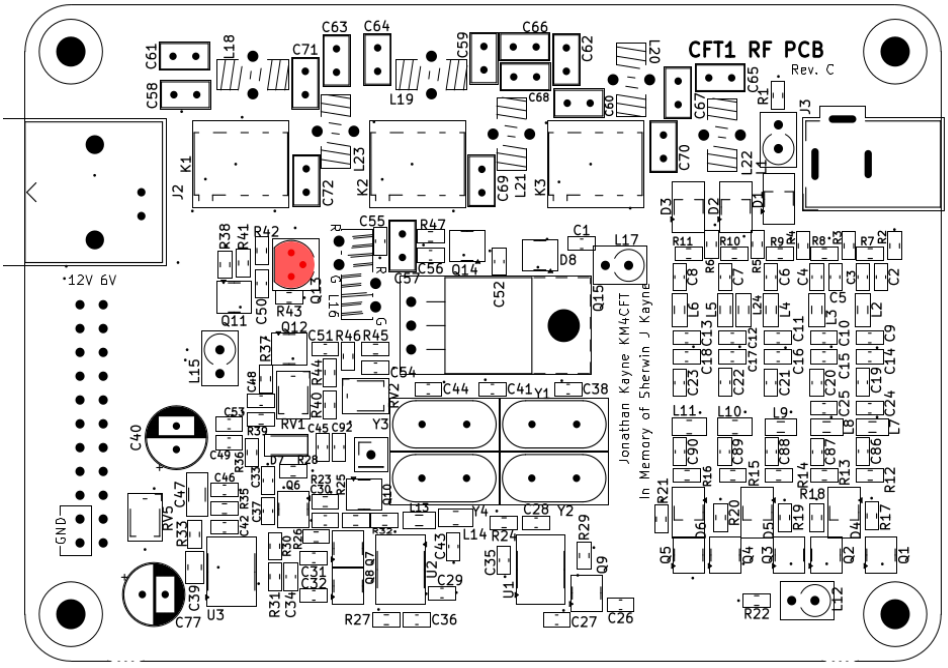
Finally, bend the wire so that you can solder the other end to the 4 crystals.



After this, you may discard any lead trimmings you currently have or in the future.

Step 5: Install the MPS751 PNP Transistor

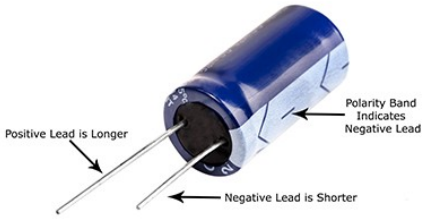
The MPS751 PNP Transistor will go into Q13. It is a TO-92 component so make sure that the flat side lines up with the flat indicated on the silkscreen!



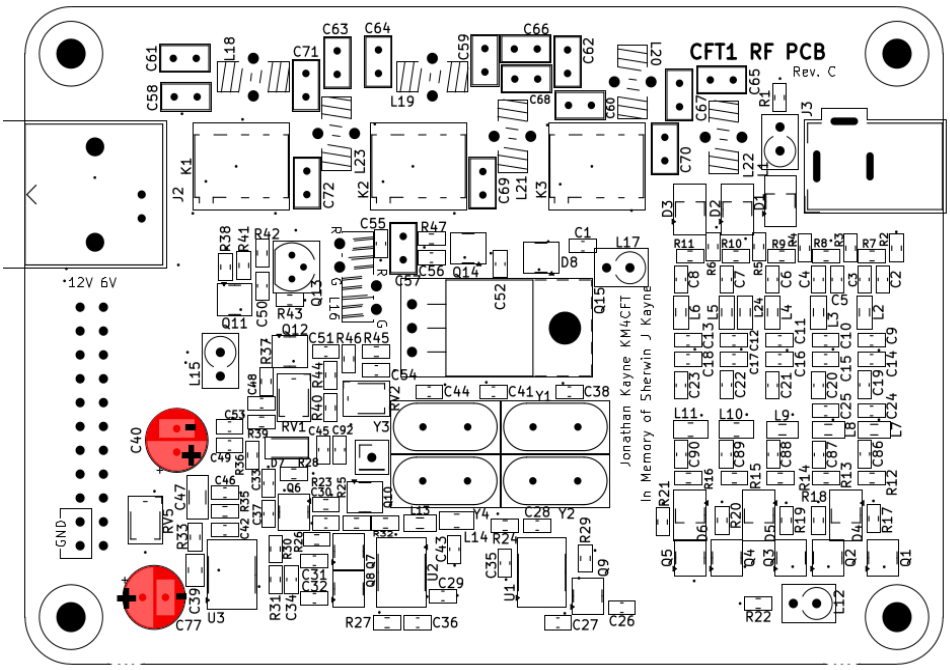
Step 6: Install Electrolytic Capacitors

The CFT1 has two 100µF Electrolytic Capacitors (C40 and C77) that need to be installed.

Electrolytic capacitors have a polarity that you *must* take note of. The polarity can be determined by the lead lengths. The longer lead is the positive. Furthermore, there is a stripe on the capacitor that indicates the negative terminal.

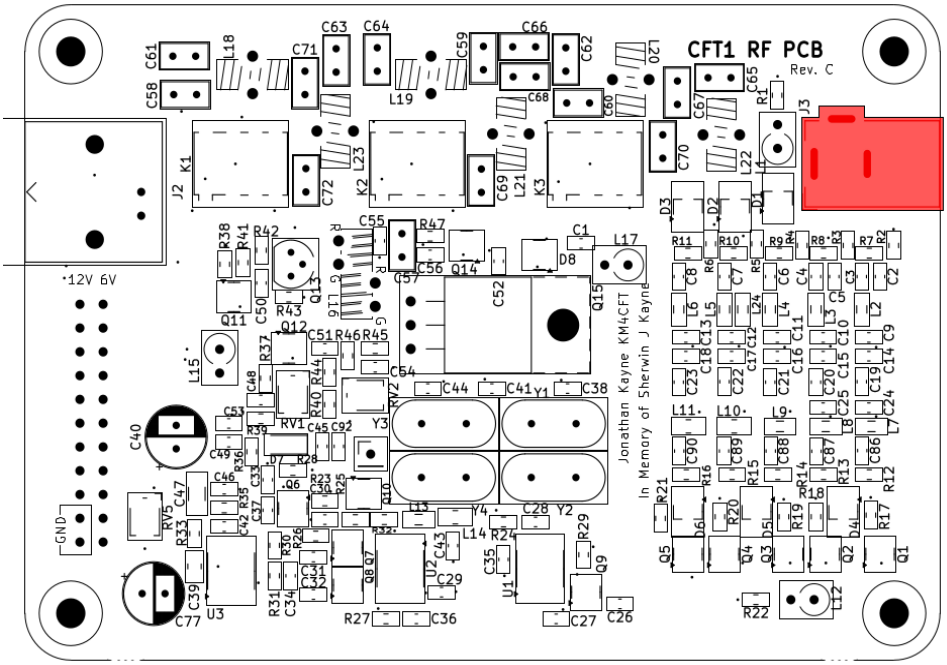


The longer (positive) lead goes where the plus sign is marked on the silkscreen. It is also indicated by the rectangular pad. The shorter (negative) goes where the white silkscreen is and has an oval shaped pad.



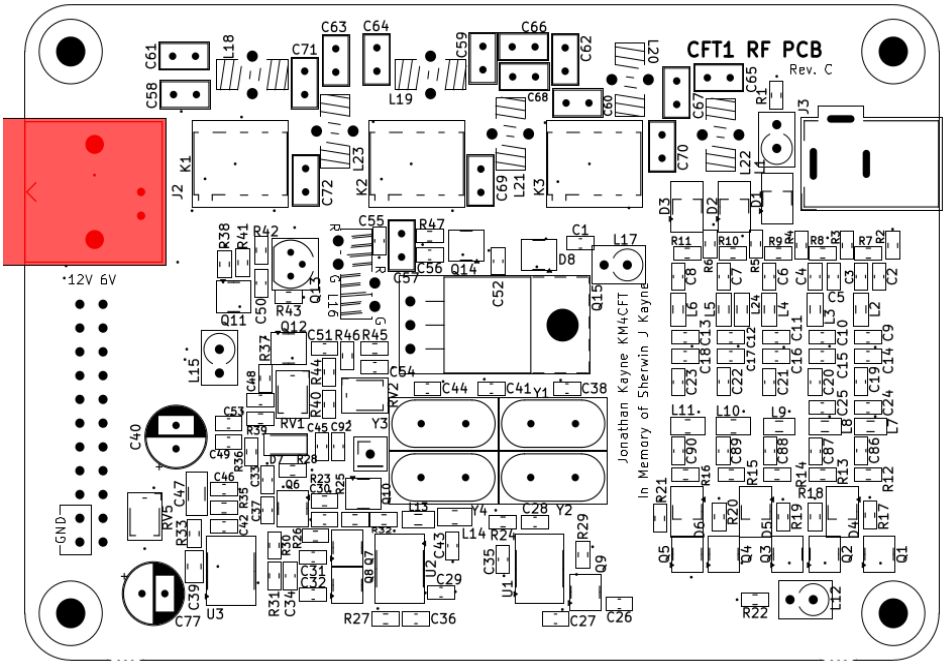
Step 7: Install the Barrel Jack

For this, we will want to ensure that the connector is perfectly straight. Drop in the barrel jack and solder the side tab in place. Check to see if it is properly aligned. If not, then be sure to adjust that. You can also use the 3D printed perimeter to verify that this is the case. Once aligned, solder the remaining 2 tabs.



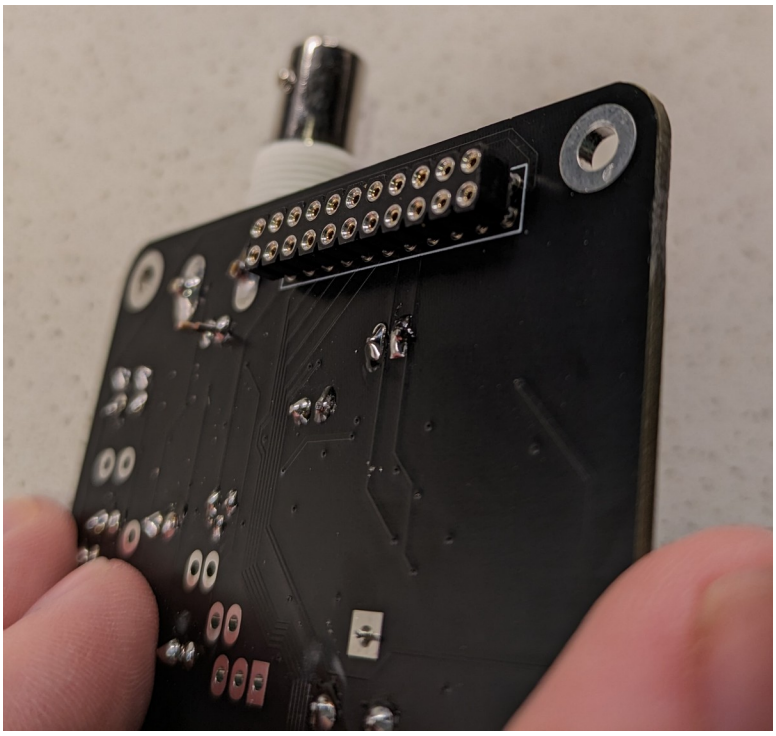
Step 8: Install the BNC Connector

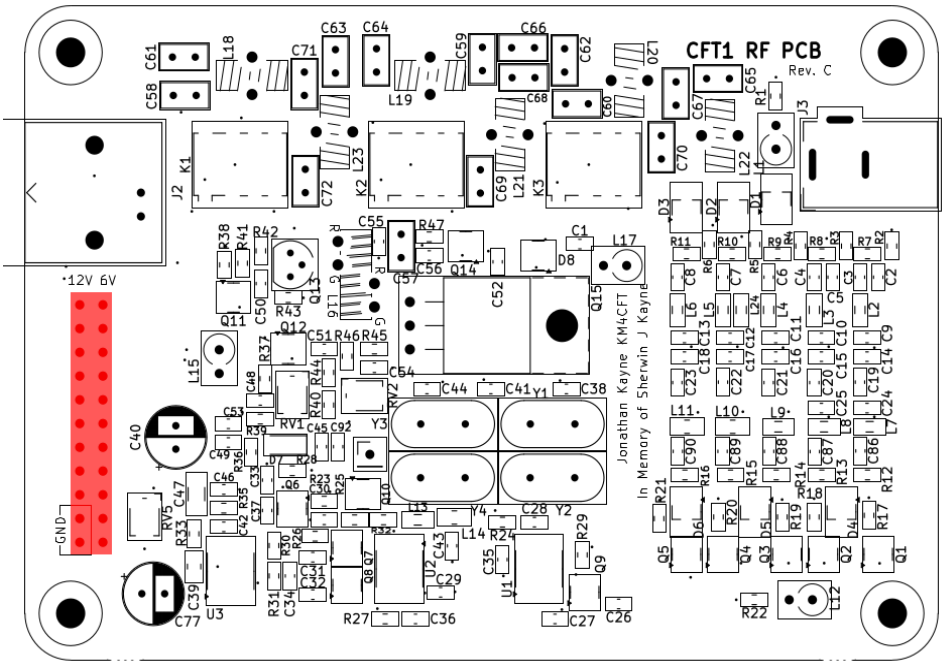
This should be performed just like the barrel jack. Solder the center pin (it should be the gold one). Make sure the connector is aligned properly, then solder the remaining pins.



Step 9: Install the 2x11 Pinsocket

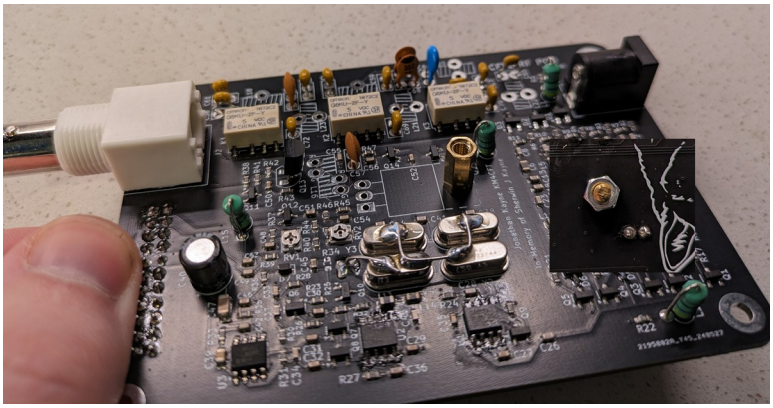
The 2x11 pinsocket is a *female* connector, and is soldered to the **Bottom** side of the board. The pads are small to be careful and double check to make sure you have a good solder joint and no solder bridging!

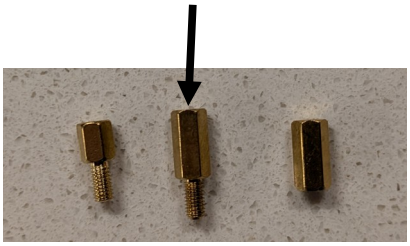




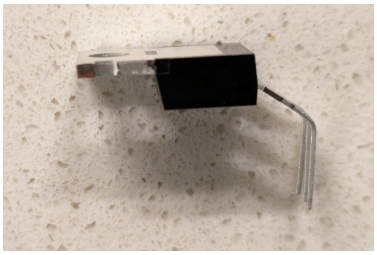
Step 10: Install the IRF510 MOSFET

Special care must be taken for this step. First, take a M3x10mm Male/Female Hex Standoff and secure it to the PCB with an M3 nut.

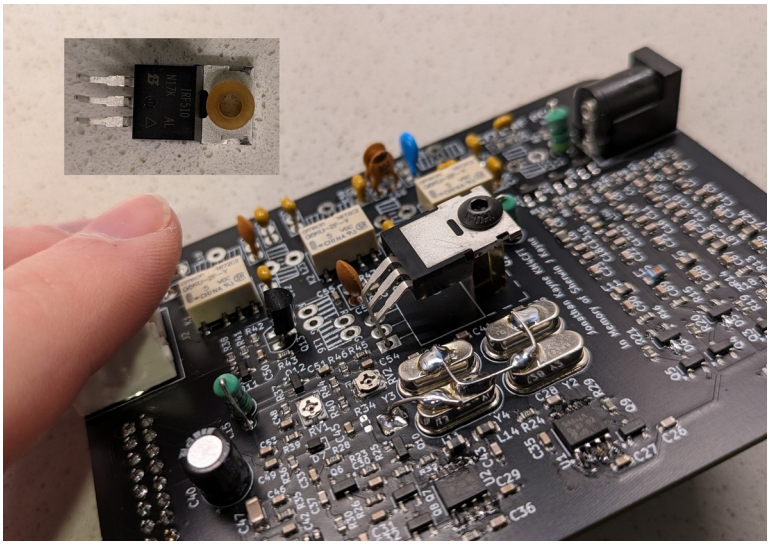




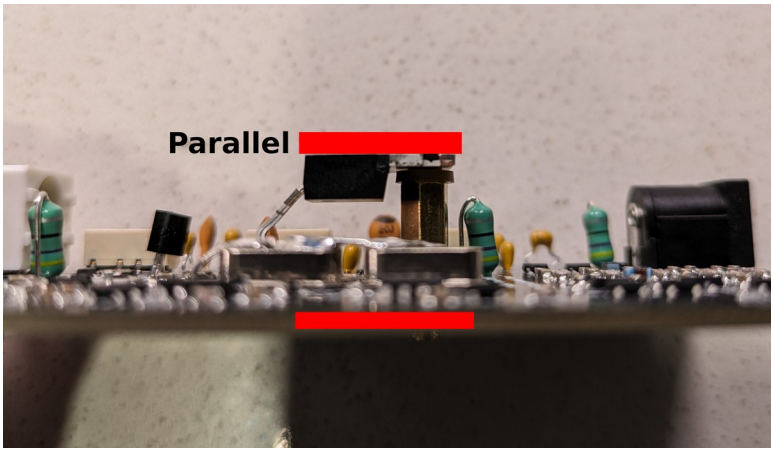
Next, bend the leads of the IRF510 MOSFET as shown in the following picture:



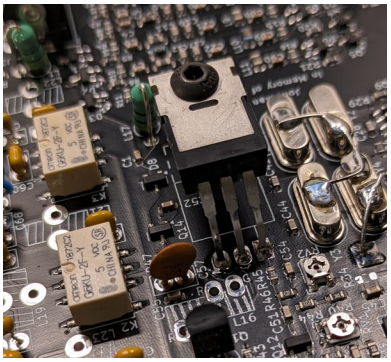
Next, take the plastic insulator/grommet and secure the IRF510 to the standoff with an M3x6 screw. While doing so, try to fit the pins into their holes. (note: grommet and screw might be different color than what is pictured)

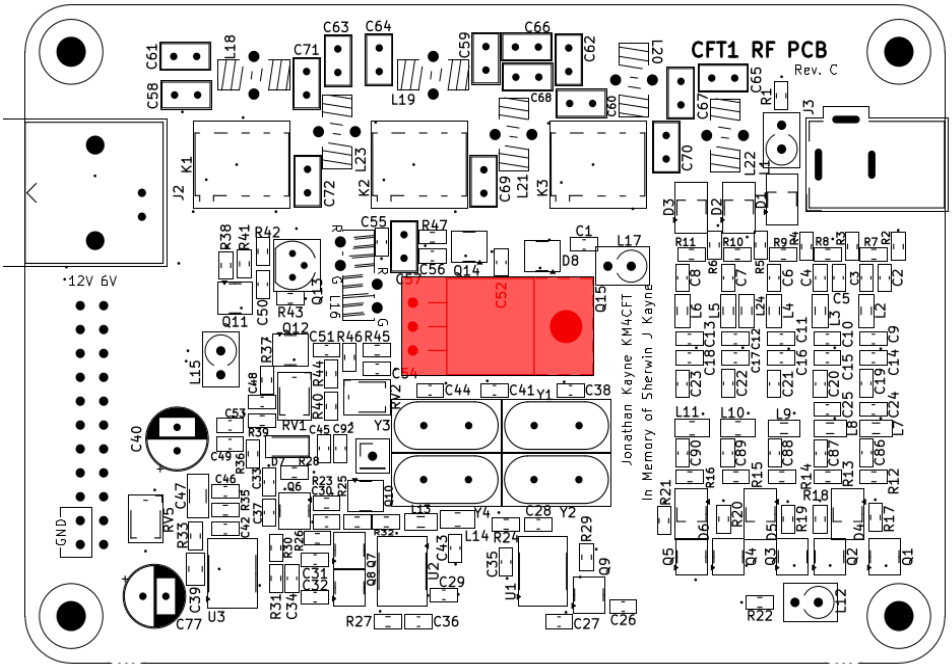


Make sure that the flat of the IRF510 is perfectly parallel to the PCB so that it will make thermal contact with the back plate heatsink later!



Solder the 3 terminals in place.





Step 11: Wind and Install the 6 Toroidal Inductors

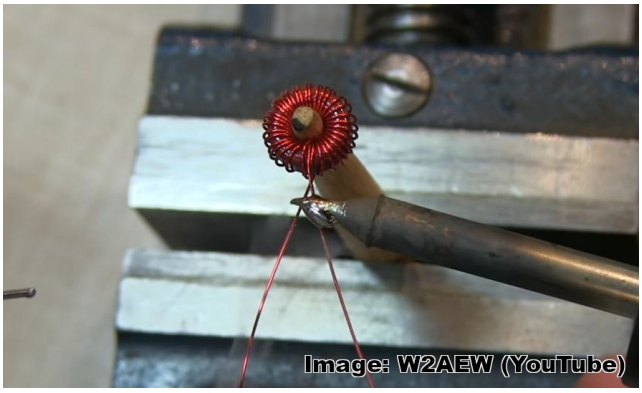
Now onto everyone's favorite part of assembly, winding toroids!

Winding toroids may seem daunting to some, but I assure you it isn't that bad. All you need to remember is every time the wire passes through the center of the toroid, it counts as a turn. You will want to cut the wire to the length indicated in the table and wind the number of turns also indicated. Once you have completed the number of turns specified, go ahead and count it again just to be safe (measure twice, cut once… or *count* twice, *solder* once if you will)

Be sure to evenly spread out your turns so that you have the correct amount of inductance!

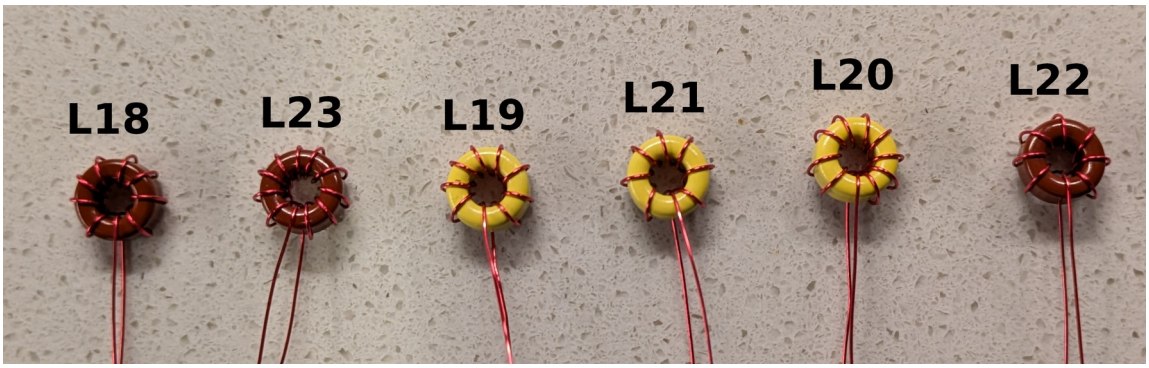
To strip away the enamel you have multiple options. A popular way is to scrape away the enamel with a hobby knife or some fine grit sandpaper. Alternatively, you can use a blob of solder to burn off the enamel. Personally, I think that the use of solder is the most effective way since it also pre-tins the the wire for you!

Ensure that you strip the enamel within a quarter to eighth inch of the toroid otherwise you won't be soldering bare wire when you stick the wire through the board!

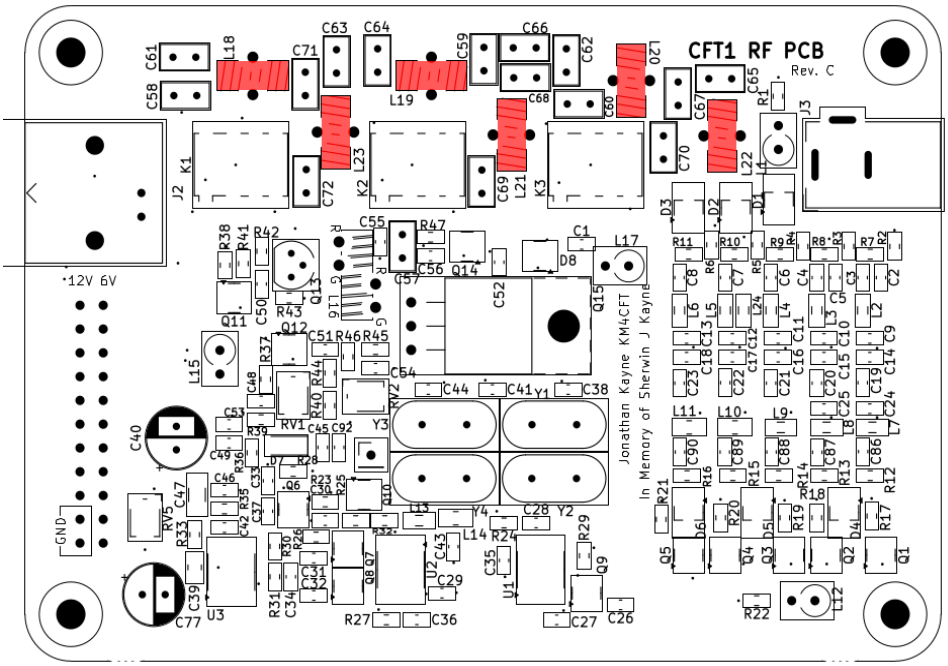


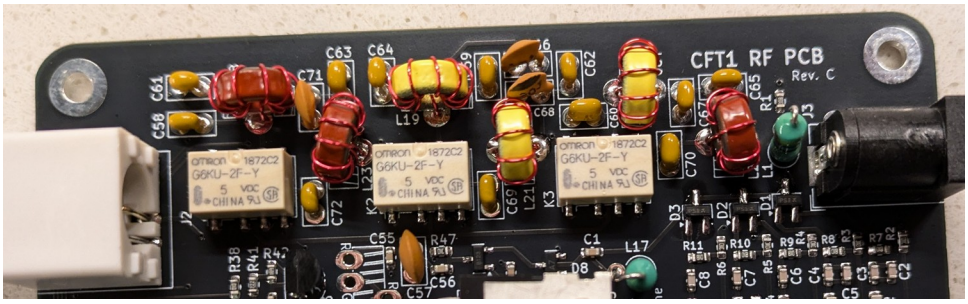
If you have not already done so, I highly recommend watching video #151 By W2AEW on YouTube. It will walk you through how to properly wind a toroidal inductor. (see QR code for direct link)

Designator	Core	Inductance	Wire Length	Turns
L18	T30-2 (red)	350nH	8”	9
L23	T30-2 (red)	520nH	10”	11
L19	T30-6 (yellow)	290nH	8”	9
L21	T30-6 (yellow)	230nH	8”	8
L20	T30-6 (yellow)	360nH	10”	10
L22	T30-2 (red)	275nH	8”	8



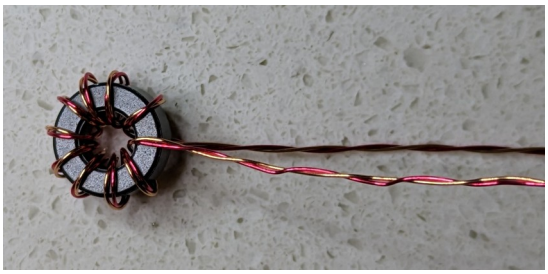
When you solder these inductors to the board, let the molten solder remain on the pad for about 10 seconds just to make extra sure that you strip away any remaining enamel. **This is an incredibly common mistake people make by not doing so!**


CFT1 RF PCB
Rev. C
12V 6V
GND
In Memory of Sherwin J Kayne
Jonathan Kayne KM4CFT


CFT1 RF PCB
Rev. C

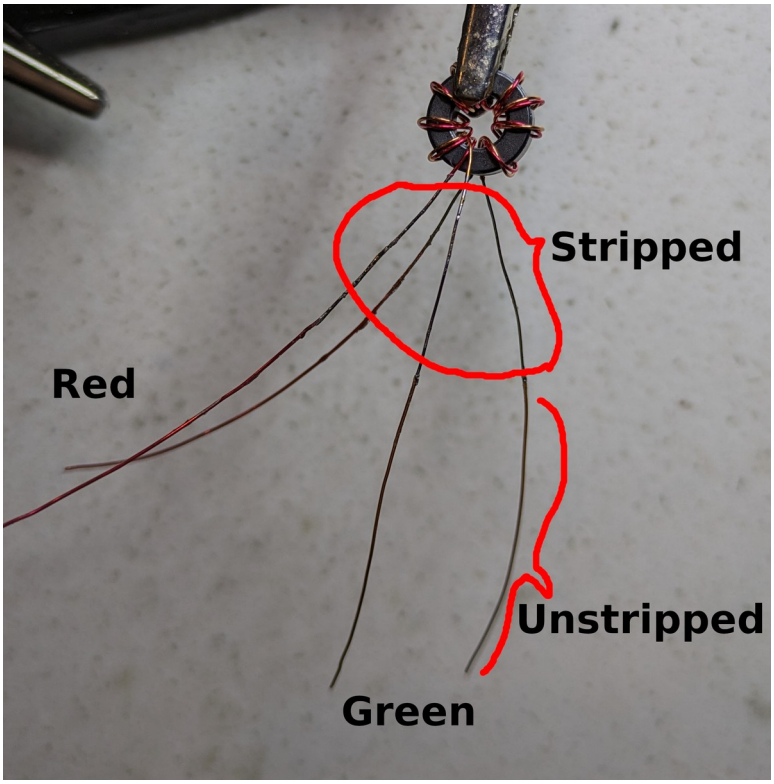
Step 12: Wind and Install the Bifilar Transformer

In the kit there is a 12” piece of twisted magnet wire. The wire comes pre-twisted to make it easier for the builder. To make the transformer, simply take the FT37-43 toroid (the gray one) and wind 10 turns around the toroid.

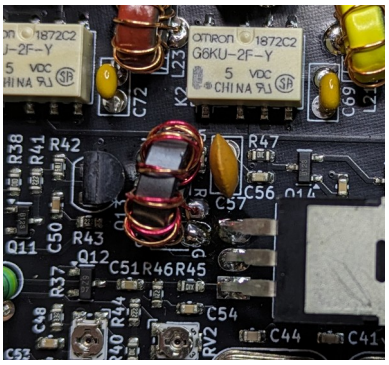


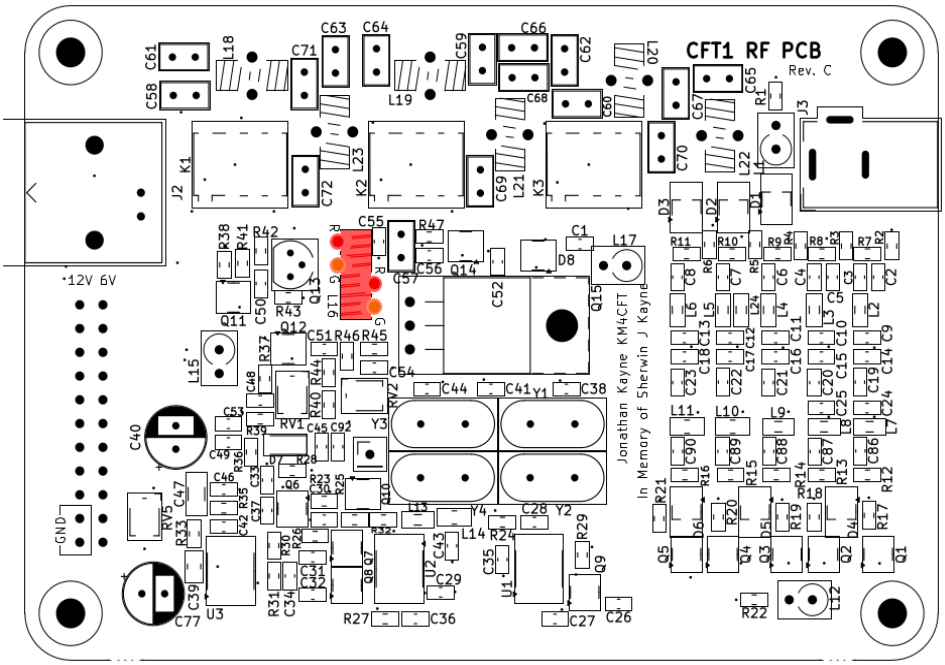
You will notice that there are two colors of magnet wire in the twist. One is red and the other is green. To make things super simple, the red wire goes in the hole marked with an ‘R’ and the green goes in the hole marked ‘G’ on L16.

Prior to inserting the wire use a blob of solder to partially strip away the enamel. I recommend leaving the last ¼” of the wire ends alone so that you still have the color indicator for inserting and double checking that you matched them to the right hole.



Once you have double checked that you have the wires in the correct holes, solder them in place (remembering to let the solder stay molten for 10 seconds just to be safe) then trim off the excess.

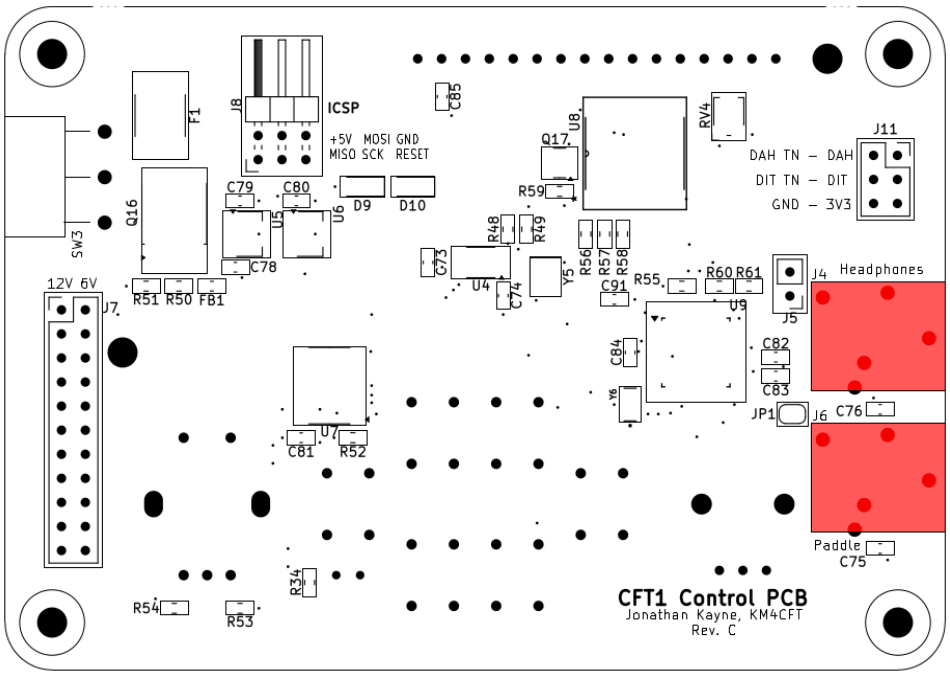


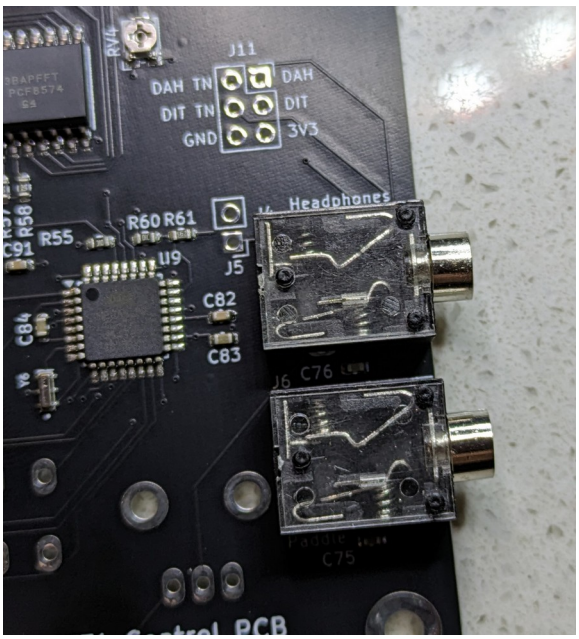


At this point, you have finished assembly of the RF boards for now!

Step 13: Install the two 3.5mm Jacks

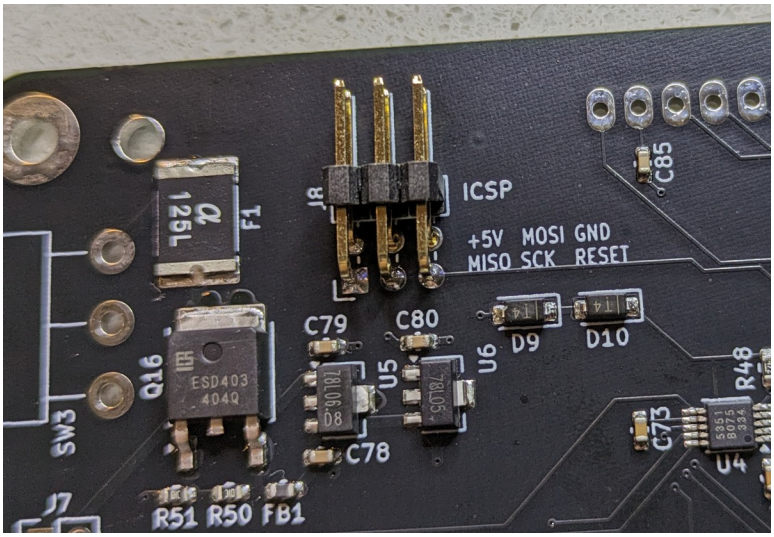
Take out the Control board. You will want to install the two 3.5mm audio jacks onto the board. Solder a single pad then verify that the jack is properly aligned and flat with the board prior to soldering the remaining pads.

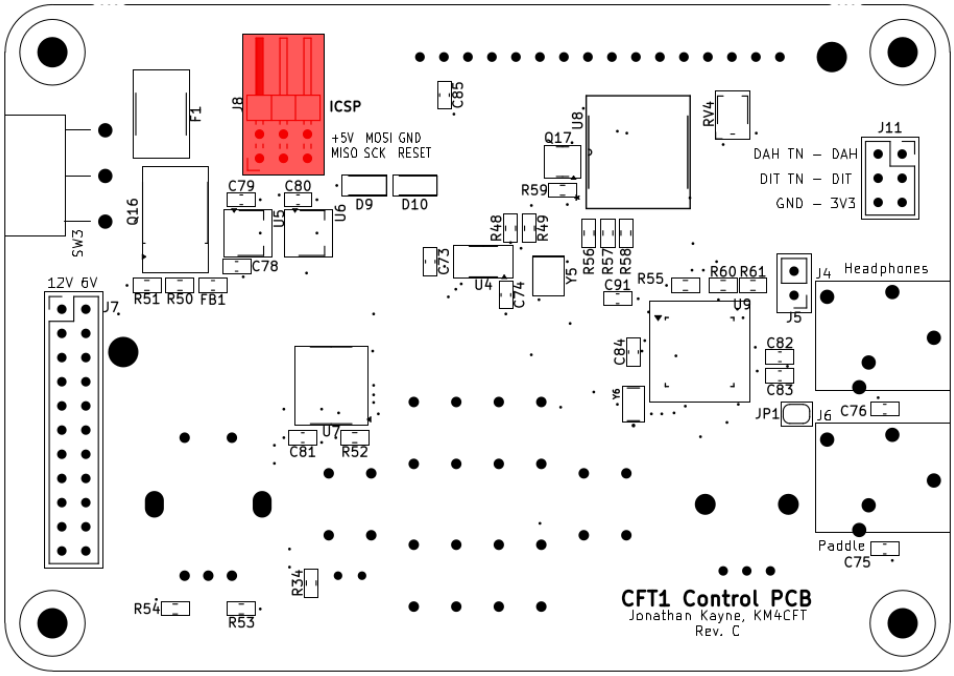




Step 14: Install the 2x3 Right Angle Header

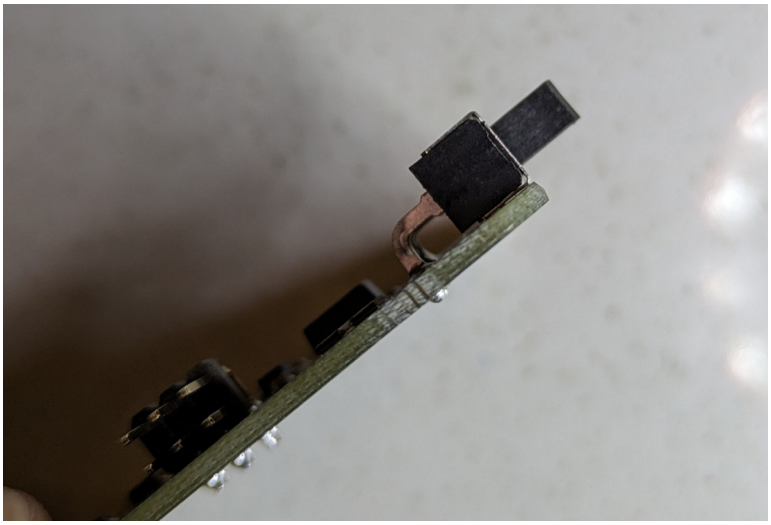
Next, we will want to install the 2x3 right angle male header. This is for the programmer in case you need to update the firmware or load your own custom firmware onto the board. Just like before, solder a single pin, make sure it is properly aligned, then solder the remaining 5 pins.

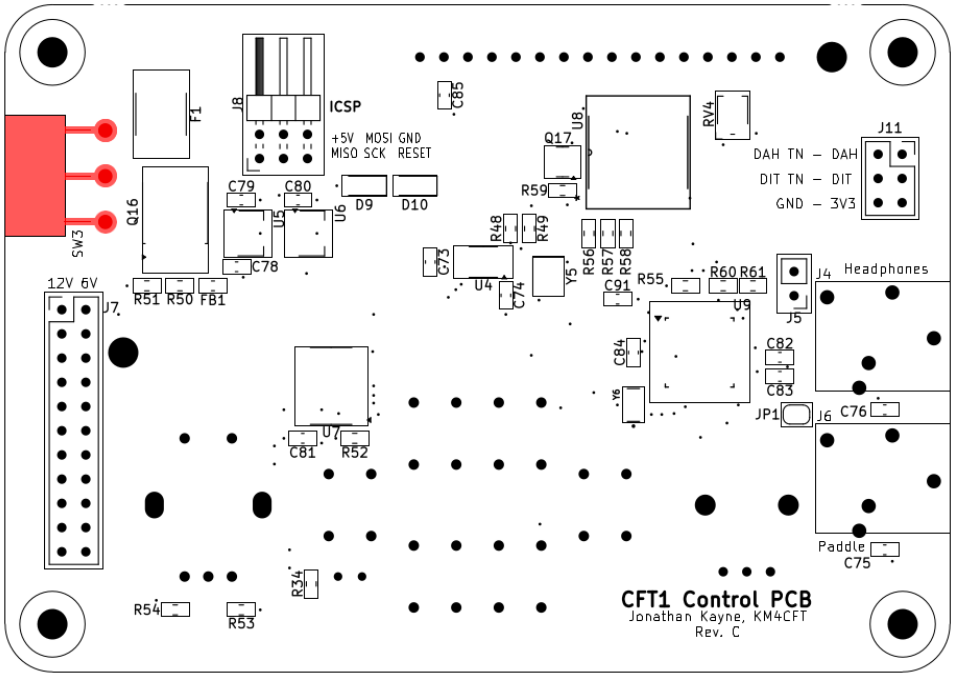




Step 15: Install the Power Switch

Take out the slide switch and solder one pin in place. Make sure it is perfectly flat against the board then solder the remaining two pins.

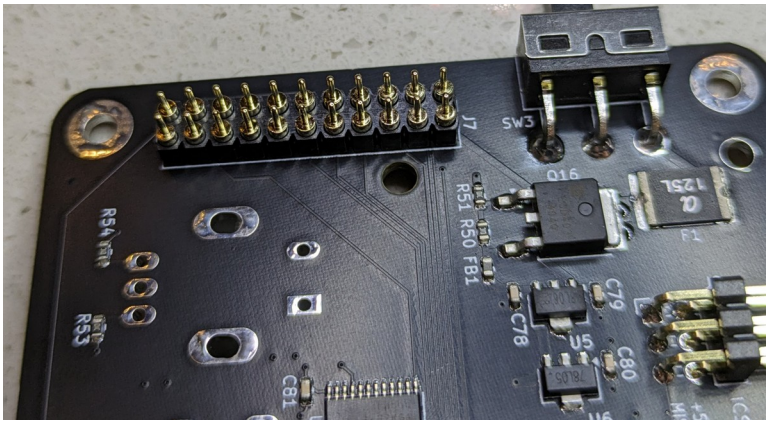


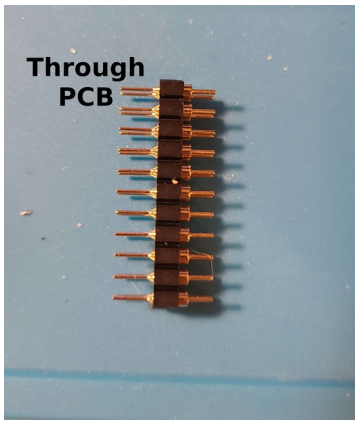


Step 16: Install the 2x11 Pinheader

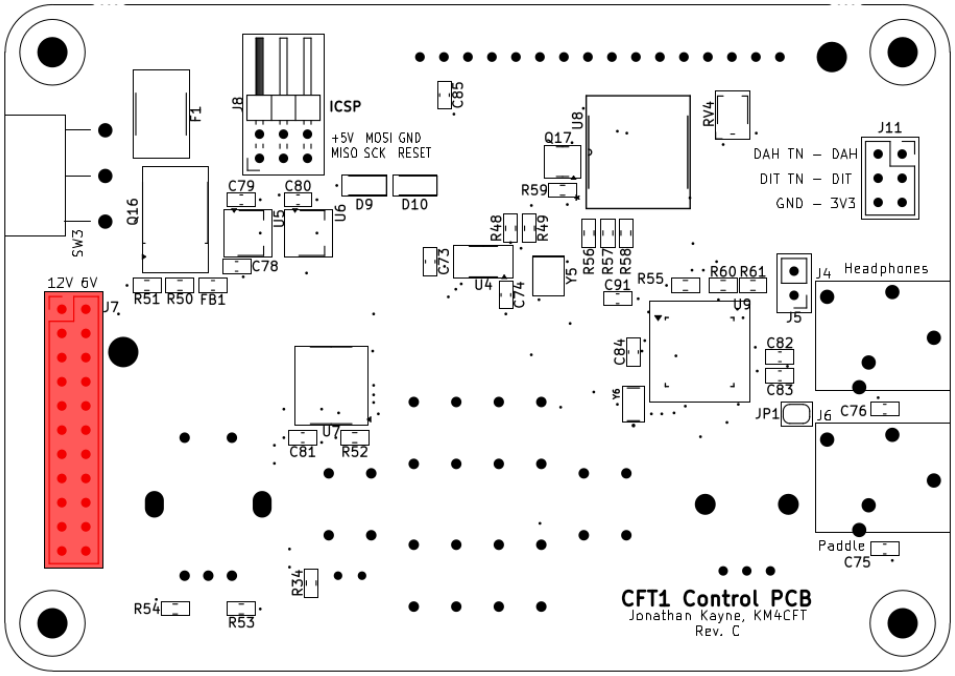
This is the *male* header and will be soldered onto the top side of the board. The pads are small so make sure you get a complete solder joint and don't have any solder bridges!

When you solder this, the end opposite of the metal shoulder will go through the board like its shown in the picture:





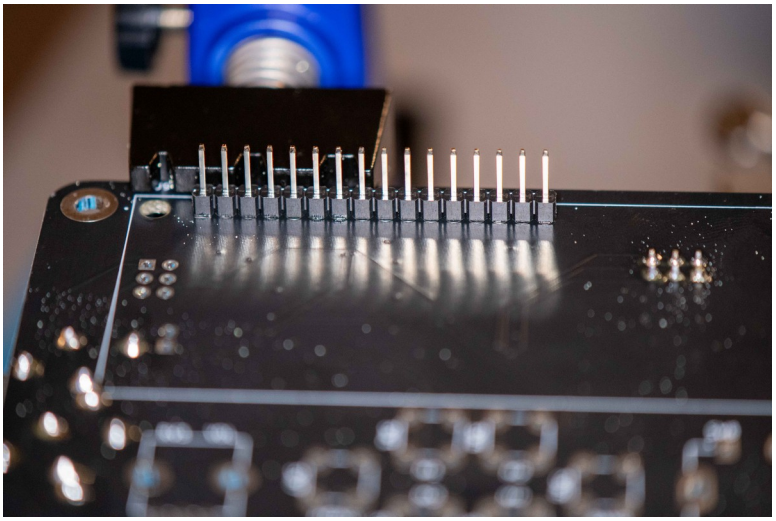
On the opposite side, use your flush cutters to trim the leads flush. Be careful because the leads have a tendency to go flying! (SAFETY GLASSES!!!)



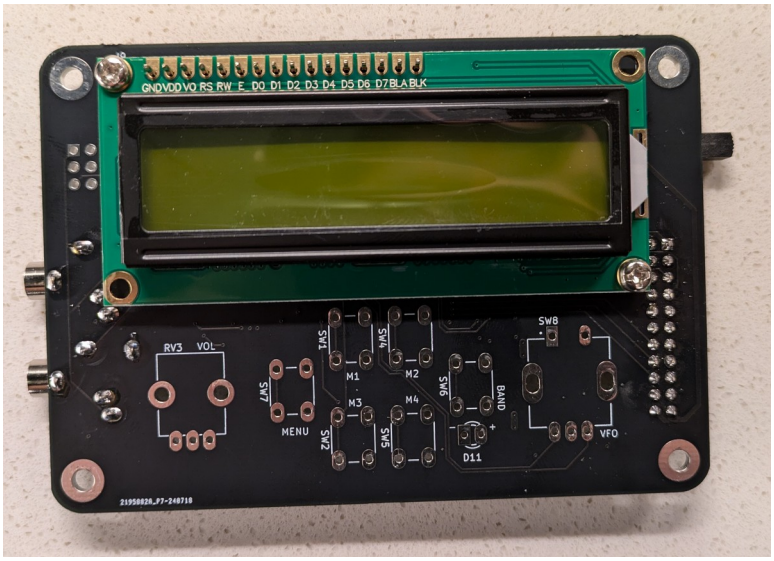
Step 17: Install the LCD Screen

For steps 17-21, we will be soldering components to the **BOTTOM** side of the board. Please keep this in mind!

First, we need to take the 1x16 male header and solder it to the bottom side of the board. Solder a single pin then use your fingers to make sure it is properly aligned. The shorter side of the header goes through the board as shown in the following picture. Once aligned, solder the remaining 15 pins.

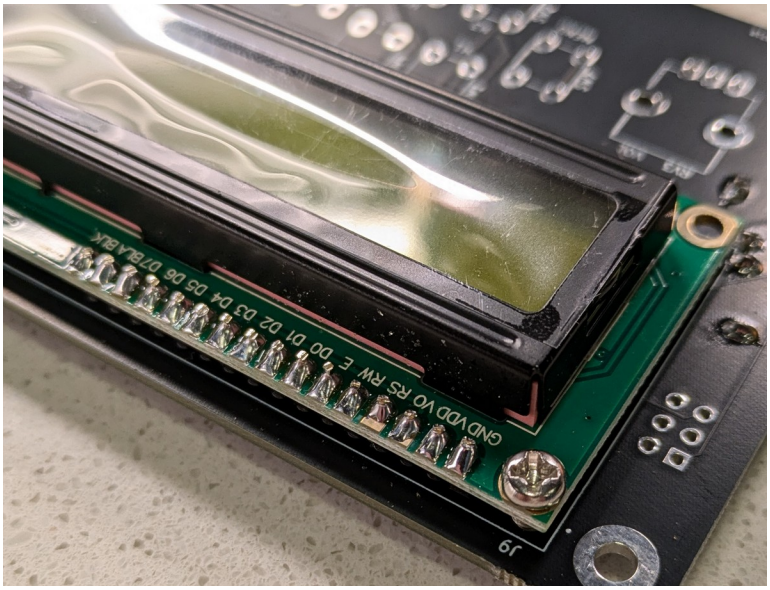


Next, take out the LCD screen and drop it in place. Secure it to the board with 2 **M3x10 silver screws** (item number 38) and M3 nuts. There is no spacer between the LCD and the Control PCB so **do NOT over-tighten the screws!**



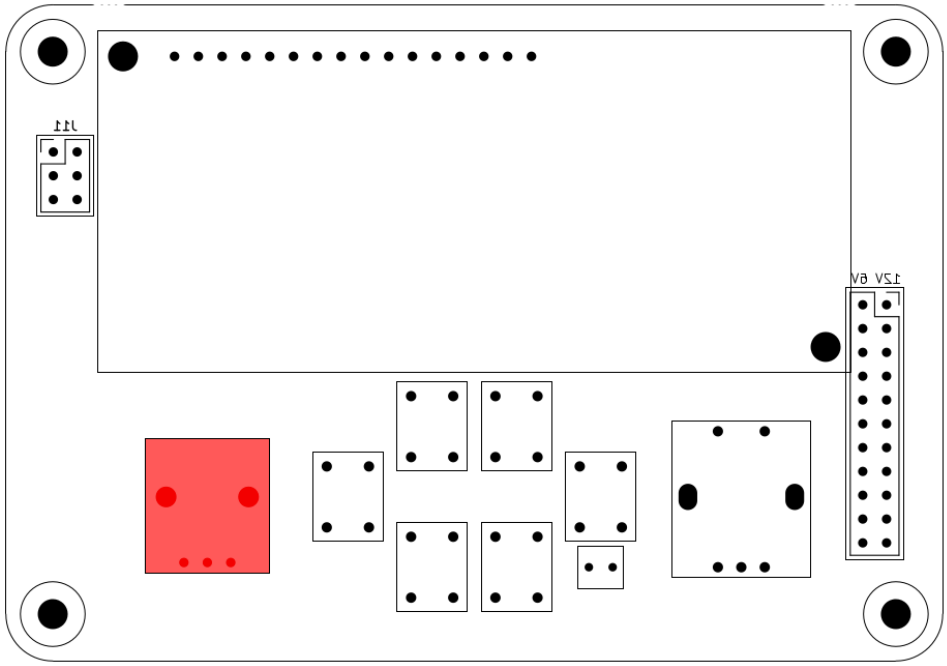
Next, solder the 16 pins to the LCD module.

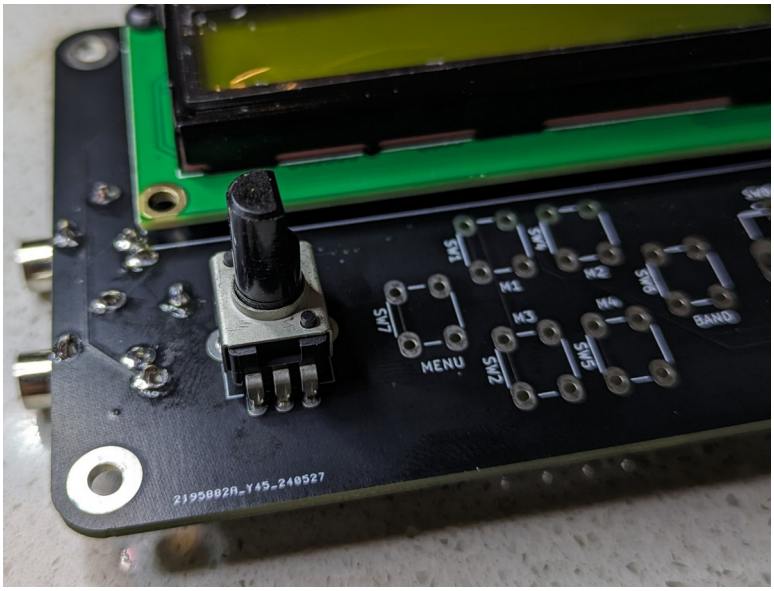
Finally, use your flush cutters to trim the connector. Be careful because the leads have a tendency to go flying! (SAFETY GLASSES!!!)



Step 18: Install the Volume Potentiometer

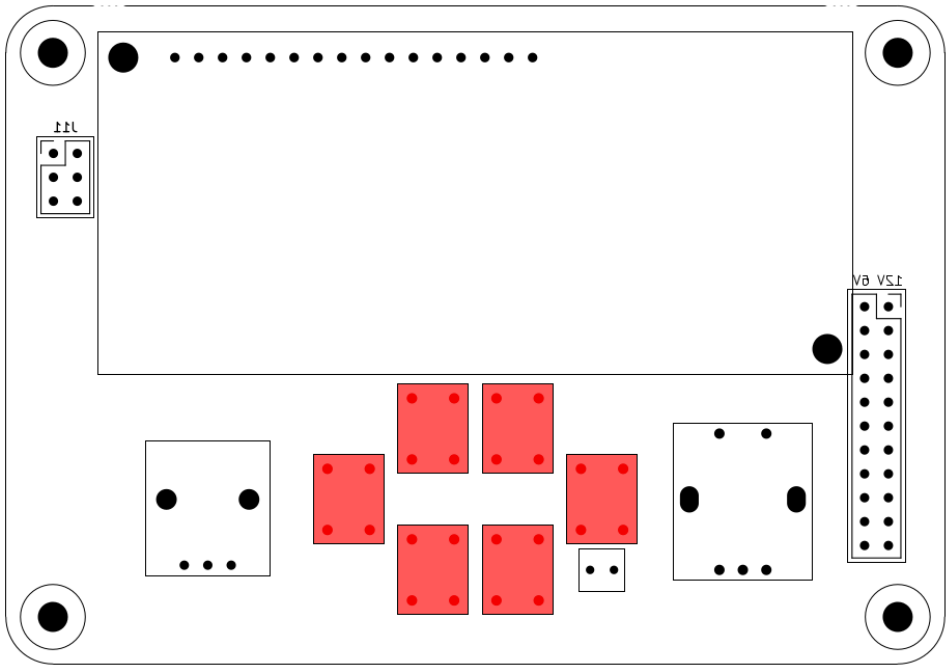
The volume potentiometer is the component with the black shaft. Install it on the bottom side of the board and solder it in place!

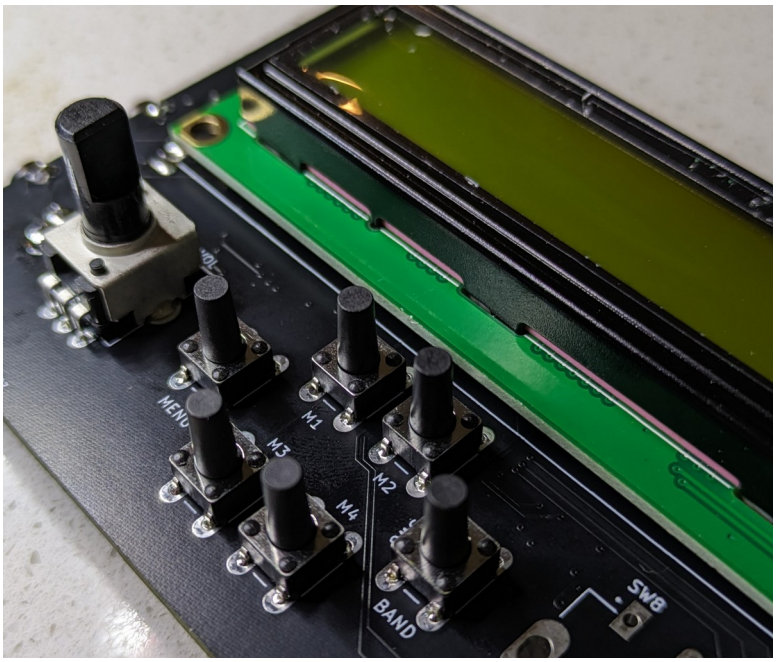




Step 19: Install the 6 Tactile Buttons

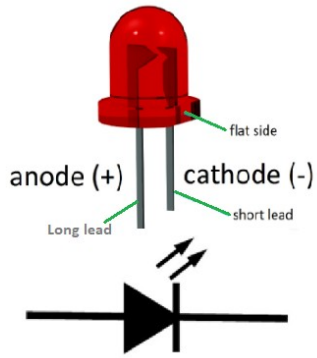
Take the 6 tactile switches and install them onto the bottom side of the board. Make sure they are properly aligned and not crooked otherwise they might not align with the front panel! Solder them all in place.



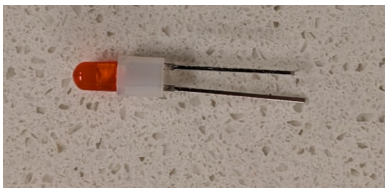


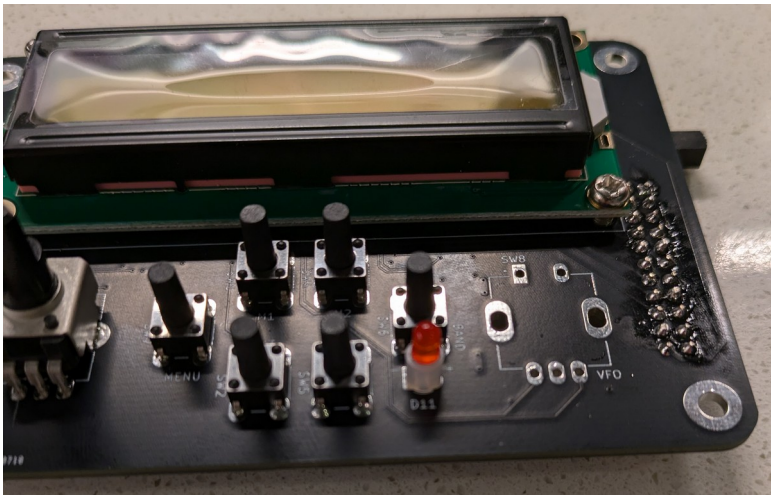
Step 20: Install the LED

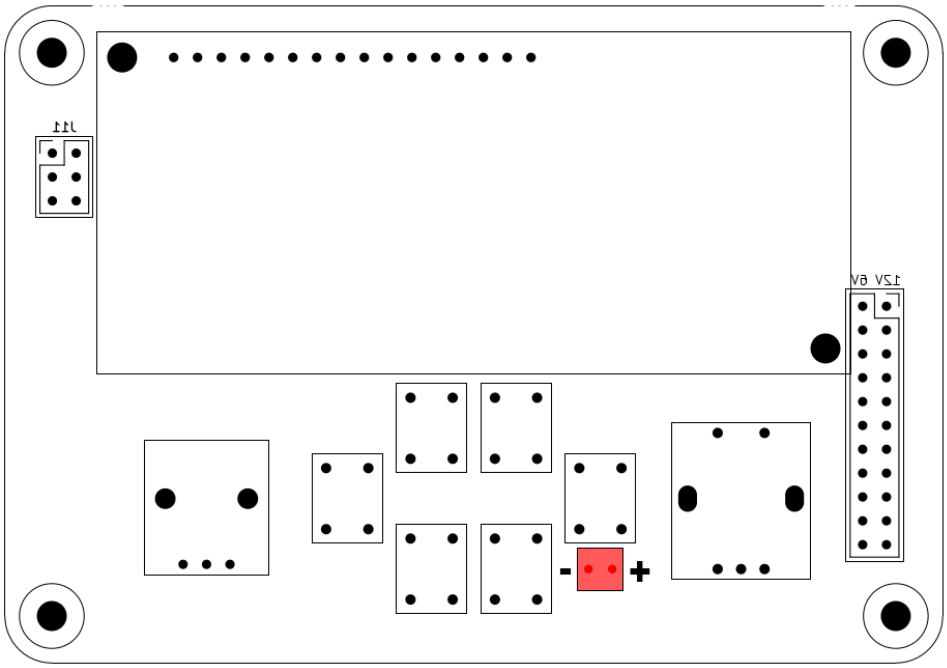
Take out both the LED and 4.5mm LED Spacer. Just like with the Electrolytic Capacitors, the LED is polarized. The polarity can be found by observing both the lead length and the flat. The cathode, or negative terminal has a flat marking on the casing and is the shorter of the two leads.



Slide the LED through the spacer holes and orient it so that you get the polarity correct. The correct polarity is marked on the PCB, and can also be determined by the pad shapes. The oval one is positive and the rectangular one is negative. Solder it in place and cut the excess leads.

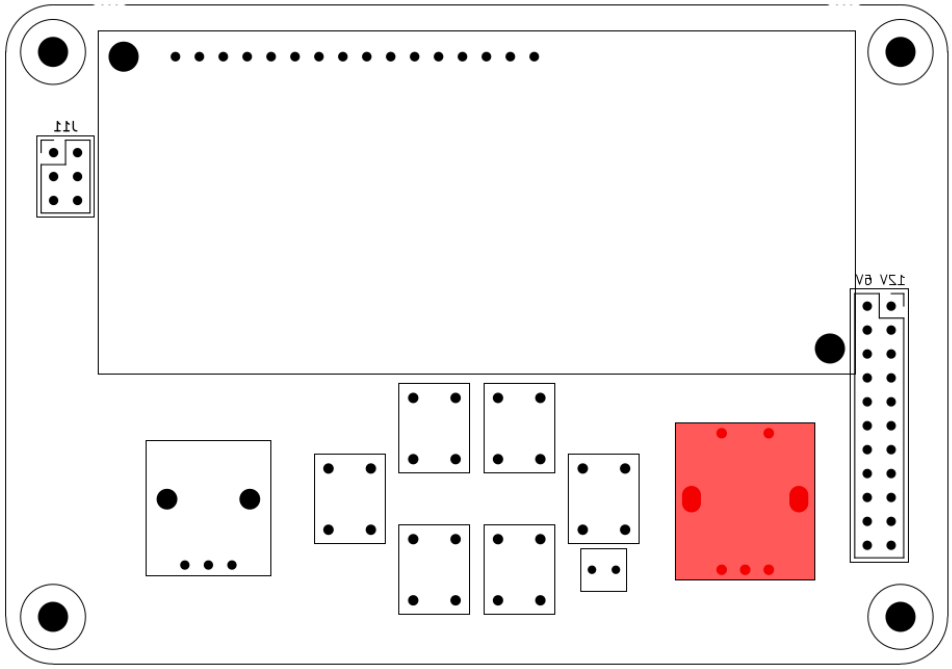





J11
12V 6V
-
+

Step 21: Install the Encoder

Next take the Rotary Encoder (the metal shaft) and install it on the bottom side of the board. Solder it in place.



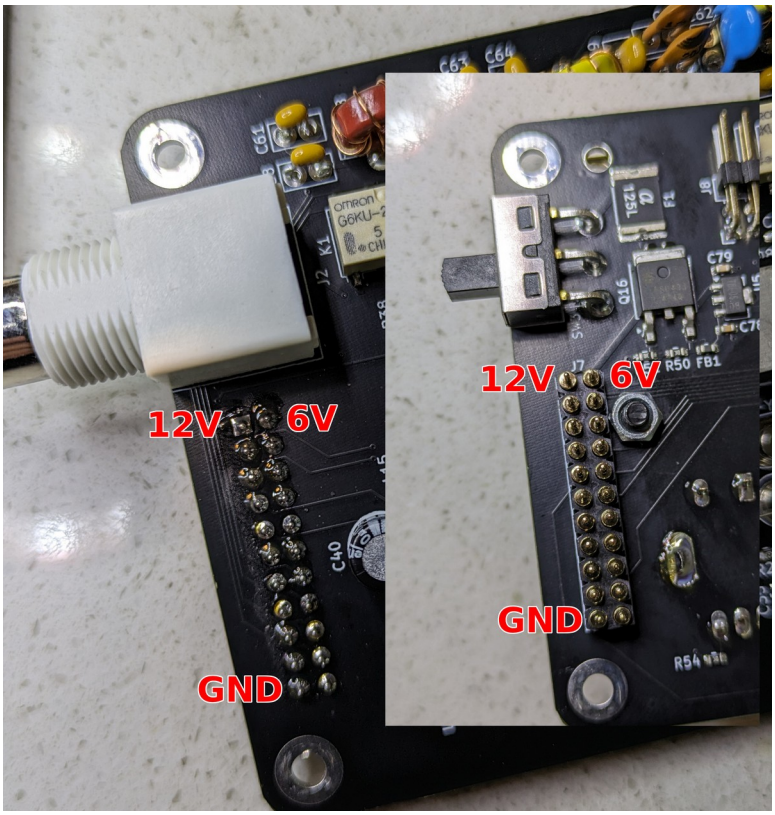
Go ahead and remove the nut and washer from the encoder and set it aside for later.

With that, you have finished soldering your CFT1!

Step 22: Electrical Check

Before we apply power, we need to check a few things to make sure there aren't any issues with the board. Carefully inspect the boards with plenty of light and magnification to make sure there aren't any bad solder joints or solder bridges.

After you do this, take out your multimeter and check that there aren't any shorts between any supply lines and ground. You can see the pinout of each board here:

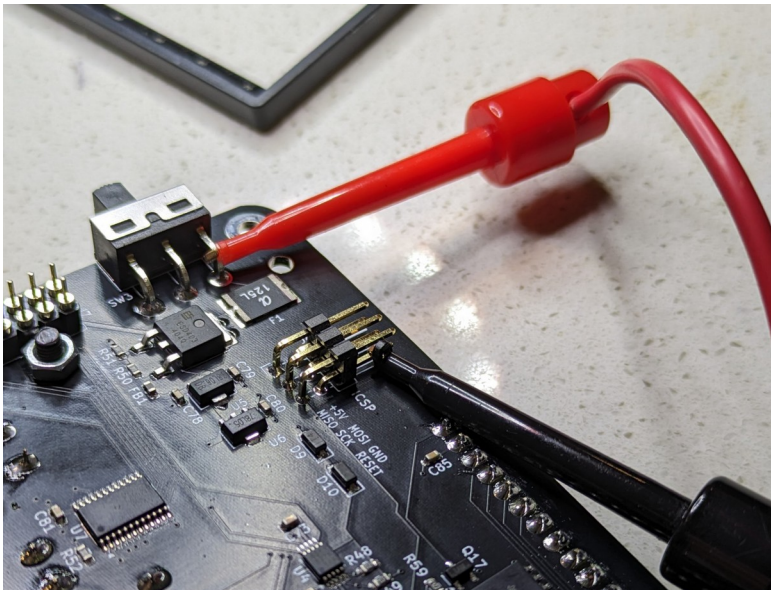


The resistance between pins should be approximately these values:

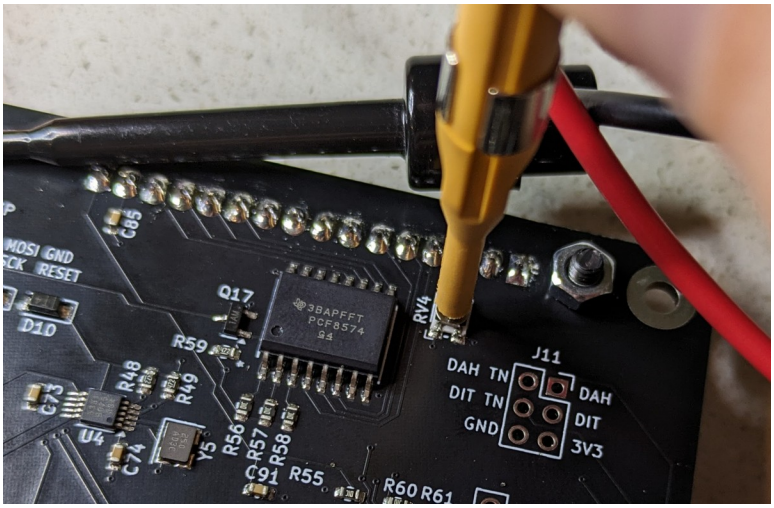
Board	Pin A	Pin B	Resistance
RF	12V	GND	1-15MΩ
RF	6V	GND	1-15MΩ
RF	12V	6V	1-15MΩ
Control	12V	GND	5-10kΩ
Control	6V	GND	1-4kΩ
Control	12V	6V	5-15kΩ

Step 23: Initial Power up; Set LCD Contrast

For this, you will need to attach power using some mini-grabbers. Apply 12v to the following pins:



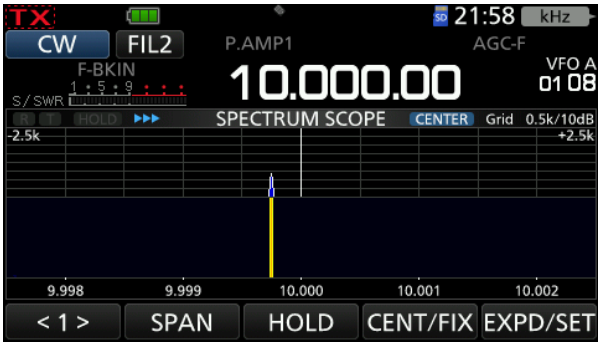
The LCD screen should come on. During boot-up it will briefly turn off then back on. Once this happens, use a small Phillip's head screwdriver to adjust the contrast by turning RV4. You will most likely need to turn it clockwise to do so.



Step 24: Set 10 MHz Calibration

To perform this calibration, you will need either a frequency counter or another receiver. It is preferable to have a receiver with a spectrum display so you can see where the frequency is. This will be shown using an IC-705 but an inexpensive option that would also work well is an RTL SDR which can be purchased inexpensively for about $20.

First, enter the calibration menu and select the “10 MHz Ref” adjustment. (access by pressing the menu button, rotating the encoder counterclockwise and pressing the knob once to enter the calibration menu) Short press to edit this item. You should see “100 Hz” on the display. Place the antenna of your receiver near the bottom-right of the CFT1 for best reception. (AKA near the male 2x11 pinheader) If your receiver has a Pre-Amp, I recommend using it.



In the above image, you can see that the reference signal is *lower* than we want. In this situation, we want to *decrease* the reference value. If the reference was higher than we want, we would want to increase the reference value. Once we get this as close as possible, press the VFO knob to confirm, then long-press the VFO knob again to go into 1 Hz adjustment and then we can fine tune to 10 MHz.

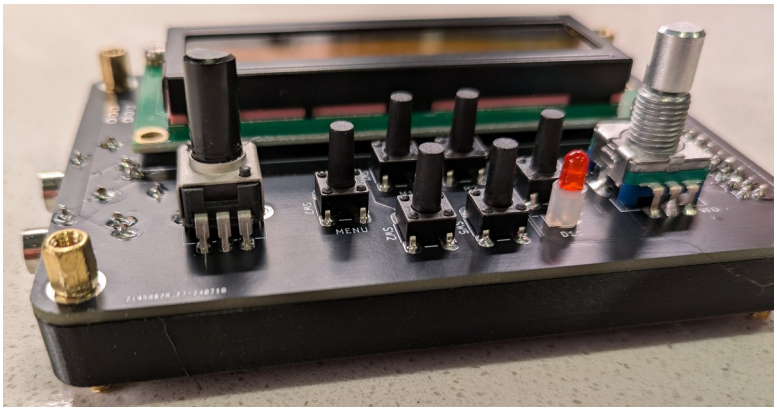
Some radios have a “spot” feature that lets you play a sidetone while receiving. This can be particularly helpful with fine tuning the 10 MHz reference since it allows you to “zero-beat” your received signal and essentially getting the si5351 within 1 Hz of 10 MHz. (You will hear a “wowowow” sound as you get closer to zero-beat) A good technique to do this without a spot feature is to use a smartphone or computer to playback a tone (I recommend 700 Hz). They can be found easily on YouTube if you cannot find an online tool.

Once you are done calibrating this, it is recommended you power cycle the radio after exiting the CAL Menu. Go ahead and disconnect power to the radio.

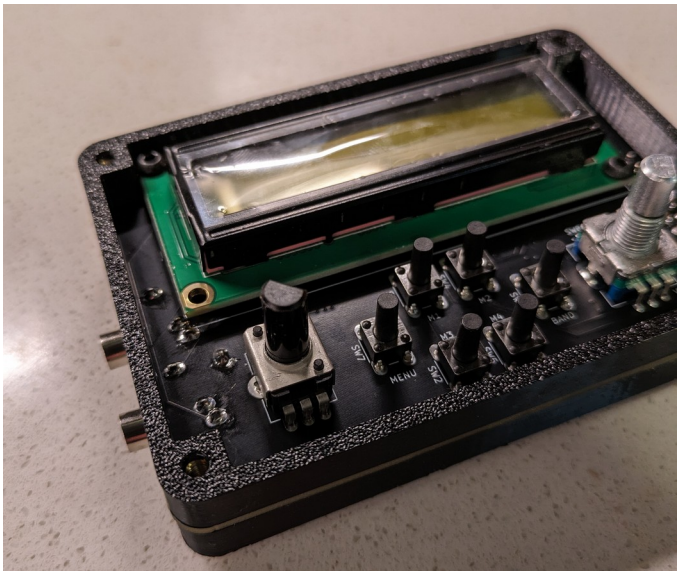
Step 25: Install Front Plate

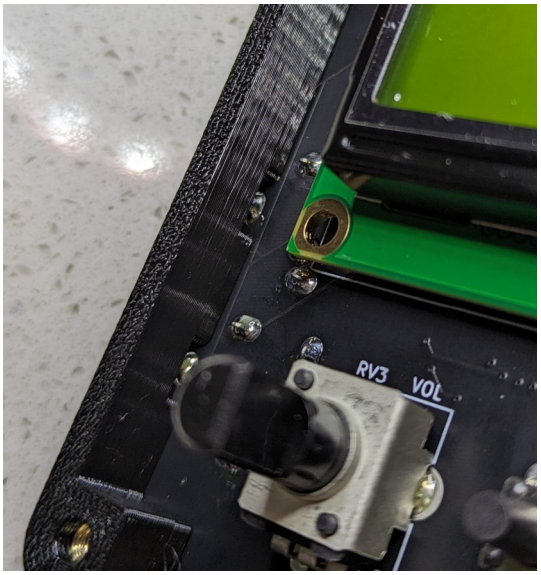
The CFT1 uses three 3D printed perimeter pieces that go in between the PCBs in a configuration similar to an ice cream sandwich. Take 4 of the M3x6mm Male/Female Hex Standoffs and push them into the center 3D Printed perimeter (the one with 3 notches):

Next, push the center print onto the control PCB. You might have to press a little bit to get it to fit in place, but be careful otherwise you might break the 3D print! Secure it to the board with the remaining 4 M3x6mm Male/Female Hex Standoffs:



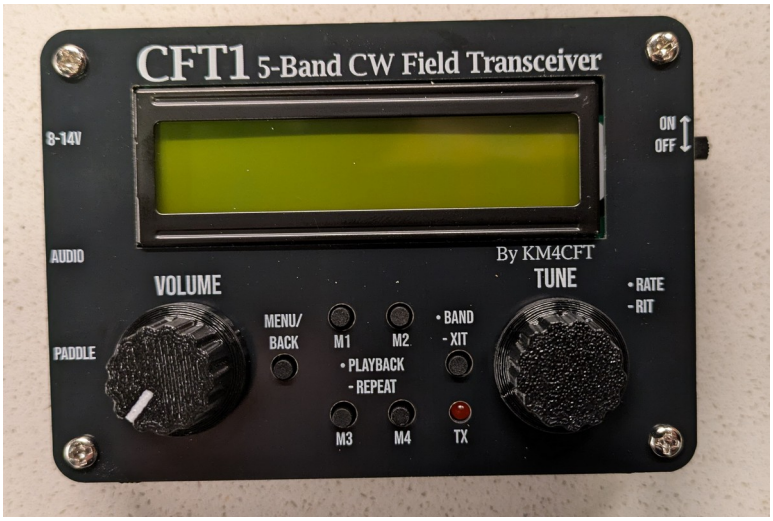
Next, take the front 3D printed perimeter (no notches) and press it into place. Note that there are 2 small cutouts that align with the two pads of the 3.5mm headphone jacks.





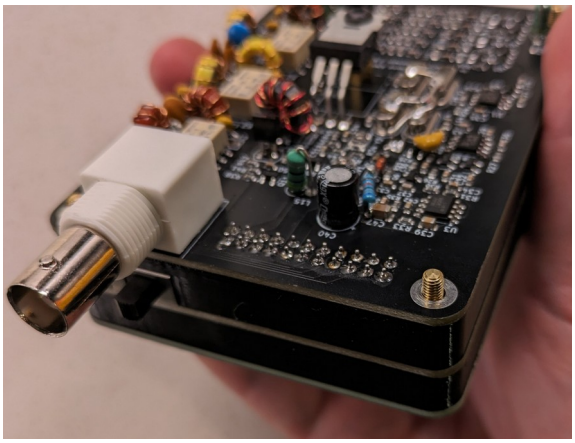
Next, take the front PCB panel and drop it into place. The cutout for the LCD screen might not fit perfectly. If it doesn't, use a file to enlarge the cutout until it does fit. Use the washer and nut to secure the rotary encoder in place. Remove the M3x6 screw that is temporarily holding the IRF510 to the standoff on the RF board. Also remove the nut and washer from the VFO encoder (if you haven't already). Fasten the panel to the assembly with four M3x6 screws, and the washer/nut from the encoder. Do not over-tighten the nut and washer.

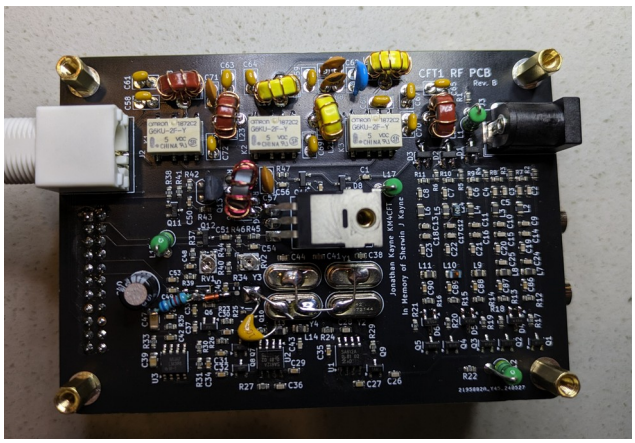
Finally, take the two knobs and press them onto the encoder and volume potentiometer. The one with the white stripe is for the volume potentiometer.



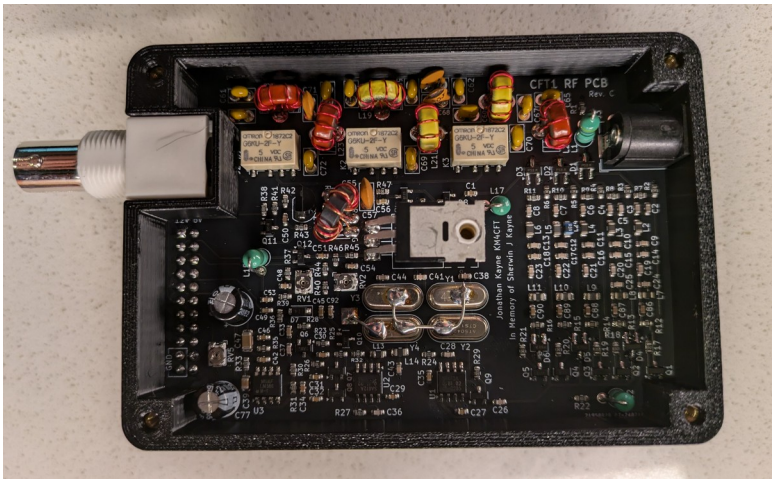
Step 26: Put the Boards Together!

Take your RF board and press it into place. The connectors are a tight fit so keep that in mind! Secure it with 4 of the M3x10mm Female/Female Hex standoffs.





Finally, take the bottom perimeter 3D print and press it into place (the one with 2 slots)



Step 27: Calibrate the IF Frequency

To calibrate the IF frequency we will need some sort of signal generator. Apply power through the barrel connector and turn on the radio.

You will want to make it so that you can hear a tone. This can be done by either injecting a -90 dBm tone into the radio or by using another QRP radio transmitting into a dummy load. The nanoVNA has an option to generate a CW tone as well, and is effective if you attach Port 0 to a short piece of wire and set the radio nearby. Finally, you can use WWV as a reference too. (TinySA Ultra: Use -90 dBm, Standard TinySA: Use with an attenuator or use the included antenna and output -30 dBm with it next to the BNC connector)

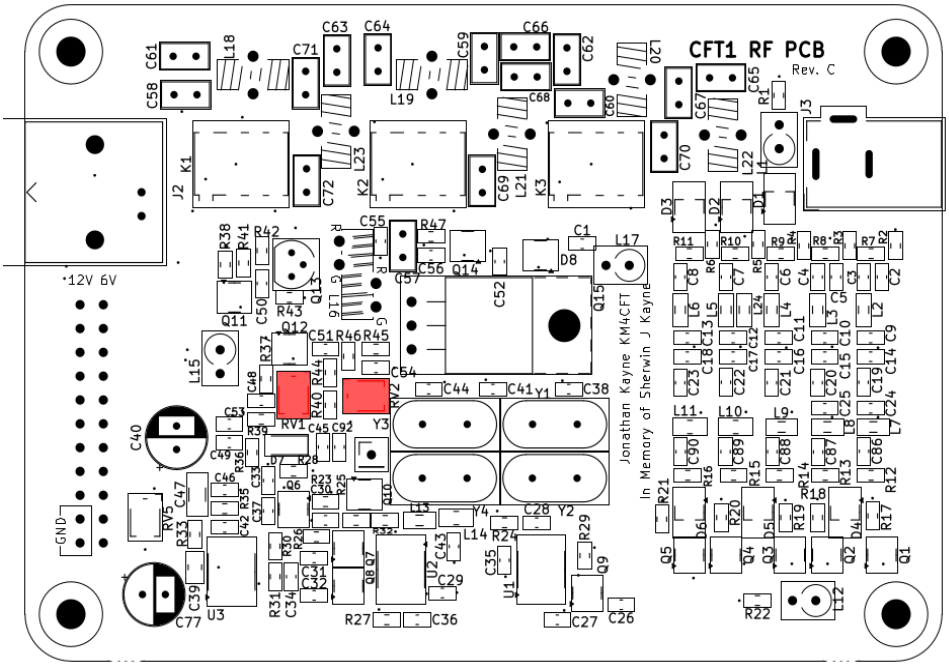
You should now hear a tone through your headphones. Enable RIT by long-pressing the VFO knob, and adjust the RIT value up and down to see if you can get an increase in volume. This will likely happen between ±0.10. This will give you an idea of if you need to raise or lower the IF value.

Lets say for example that you find that the audio peaks at +0.03. This means you should **raise** the IF value by 30 Hz. Disable RIT by long-pressing the VFO knob again then go into the calibration menu and adjust the IF Frequency value. As you do so, you should hear the audio getting louder. Accept the value by pressing the VFO knob to save the setting.

Step 28: Calibrate the PA

This is an incredibly important step so read this section carefully and follow the directions exactly. Failure to do so could lead to you damaging your radio!

There are two trimmer potentiometers on the RF board. RV1 sets the power level while RV2 sets the PA drive level.



Make sure you are using a 12 volt power supply when performing this procedure. Using 13.8 volts is okay, but you will need to adjust RV1 accordingly.

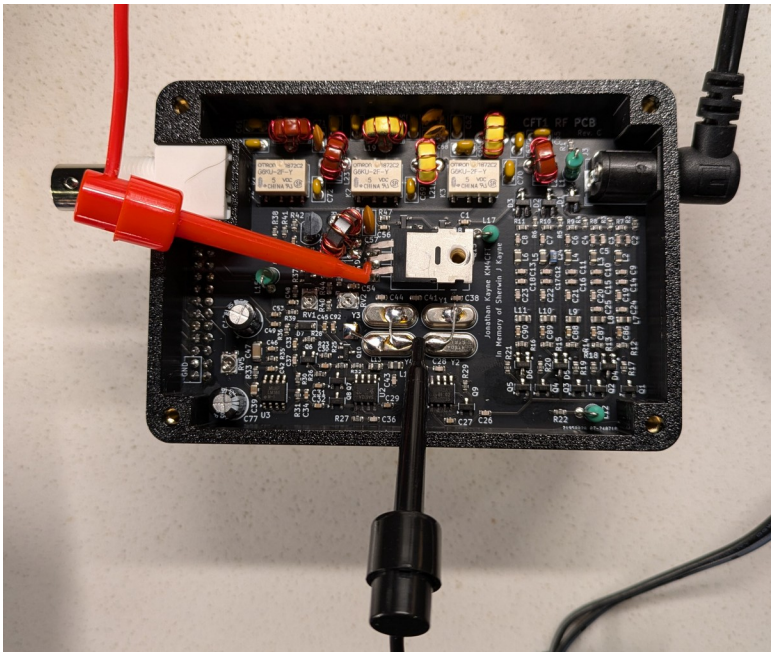
First, turn both RV1 and RV2 fully clockwise. Next, connect a paddle and either put the radio in “Straight Mono” or “Straight Stereo” depending on what key you have. Hook your radio to an RF Power Meter and dummy load.

Make sure the band is set to 20 meters (14-14.1 MHz)

Go into the Calibration menu and change the “PA Osc” setting from Enable to Disable.

Take your multimeter and clip the positive lead to the Gate of the IRF510 (the one connected to the rectangular pad) and clip the negative lead to Ground. The leads on top of

the four crystals can be used for this. Ensure you aren't shorting the IRF510 with the positive lead.

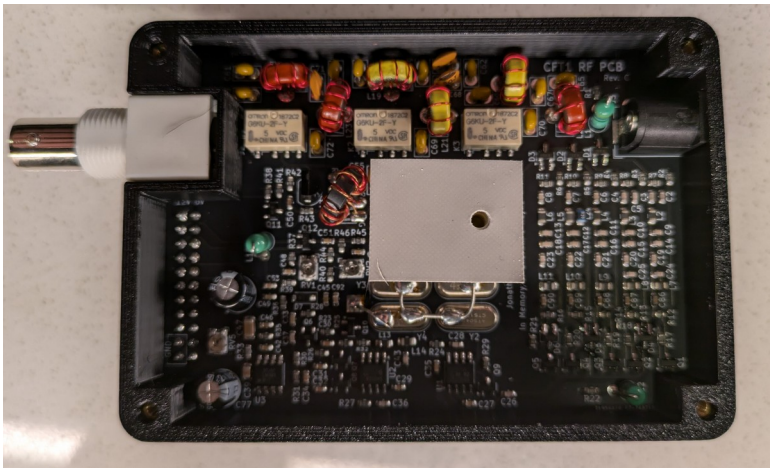


Next press down your paddle to turn on the PA. You will want to adjust RV2 such that you read between 2 and 2.5 volts at the gate of the IRF510. (For best results, I recommend between 2.3 and 2.4v) Once you do, disconnect the multimeter from the radio and change back the *PA Osc* setting from Disable to Enable.

Now, press the paddle down and adjust RV1 so that you see 5 watts coming out of the radio. You will want to transmit in 5 second bursts since the IRF510 isn't connected to a heatsink! If you are using a 13.8v power supply then you can optionally set the power level between 5.5 and 6 watts instead.

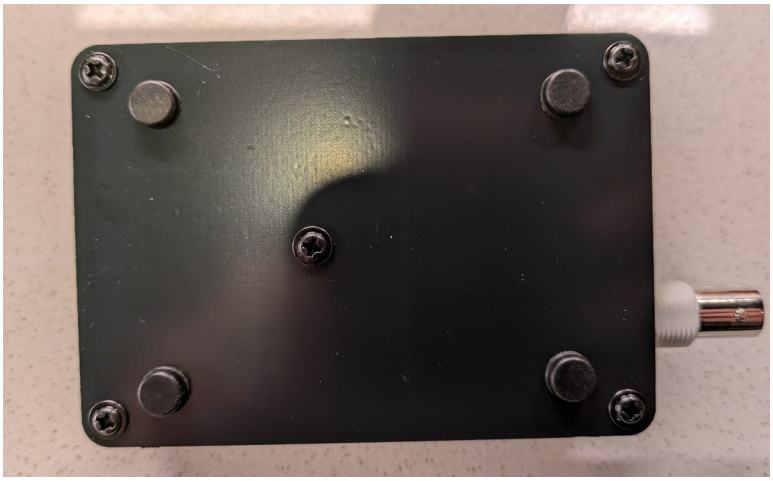
Step 29: Close up the Transceiver

Take the thermal pad and place it on top of the IRF510, aligning up the holes.



Take the cover and place it on top and re-fasten the M3x10 screw to the IRF510. Use 4 more M3x10 screws to secure the back plate to the radio.

Finally take the four rubber feet and secure them to the radio. There are four dots on the plate to help you align the feet.



Congratulations! You have completed assembly of your new CFT1 transceiver! Please refer to the owner's manual for more information on how to use your new radio. 72!