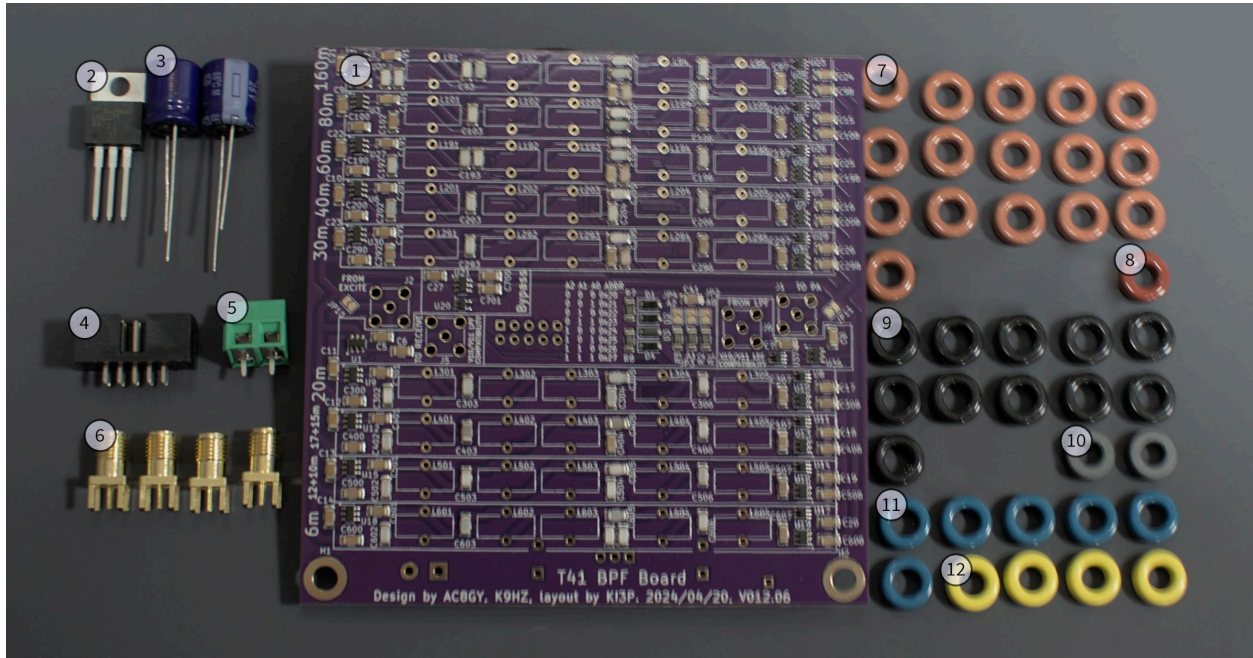


T41-EP SDT v12 BPF Module Assembly Manual



The T41 V12 BPF board filters out of band signals to prevent overloading the RF receive circuitry, and prevent amplification or transmission of spurious signals coming from the RF transmit circuitry.

A single MCP23017 provides control of onboard RF switches which enable specific filters or bypass filtering. RF switching is provided by dedicated IC switches on each side of each filter. The board has an on-board 3.3V regulator to power logic circuits and connects to I2C from the T41 main board over a 10-conductor ribbon cable. Power is provided from the T41 main board's 12V output.

What's Included (Parts List)

1. (1) BPF Board
2. (1) LM1117-3.3 Voltage Regulator
3. (2) 470uF Electrolytic Capacitors
4. (1) 2x5 IDC Box Header
5. (1) 2 pin Molex Terminal Block
6. (4) SMA PCB Connectors

7. (16) T37-0 Toroid Cores (Tan)
8. (1) T37-2 Toroid Core (Red)
9. (11) T37-10 Toroid Cores (Black)
10. (2) FT37-61 Toroid Cores (Grey / Unpainted)
11. (6) T37-1 Toroid Cores (Blue)
12. (4) T37-4 Toroid Cores (Yellow)
13. 14M (45') of #28 Magnet Wire (not pictured)

Missing a part? Send an email to justin@ai6ym.radio.

You Will Need

1. [Soldering Station](#), hot air or separate heat gun optional but recommended.
2. [Multimeter](#)
3. [PCB Vise](#) or [Helping Hands](#)
4. [Jewelers Loupe](#)
5. [Solder](#) of your preference, 60/40 tin/lead is recommended.
6. [Flux Paste](#)
7. [Polyimide \(Kapton\) Tape](#)
8. [Solder Wick](#)
9. [Wire Cutters](#)
10. Sandpaper or [hobby knife](#)
11. [Bench Vise](#) (optional)
12. [Crochet Hook](#) (optional)
13. [NanoVNA](#) (or comparable)

Safety Matters!



Soldering irons are hot. Everything they touch gets hot.

Have a fire extinguisher nearby!



Solder splatters. Your eyes are not easily replaceable.

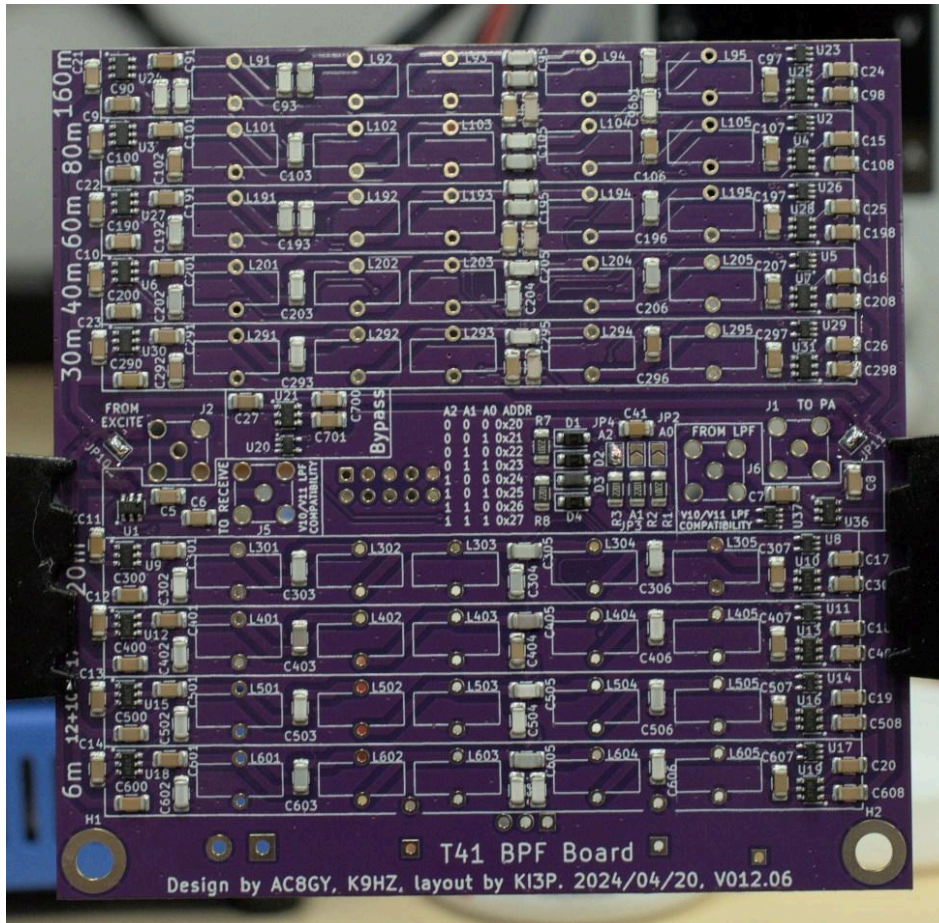
Wear your PPE!



Fumes from heating the enamel coating on magnet wire can be dangerous.

Work in a well ventilated area!

Signal & Address Jumpers



This board supports multiple use cases, this manual covers assembling for the primary transceiver of the T41 EP-SDT V12. For this use case we bridge the JP10, JP11, and A2 jumper positions with solder.

JP10 and JP11 bypass the switching circuitry which previous T41 versions (and the V12 second receiver option) need to switch between transmit and receive signal paths. A0, A1, and A2 set the MCP23017's I2C address.

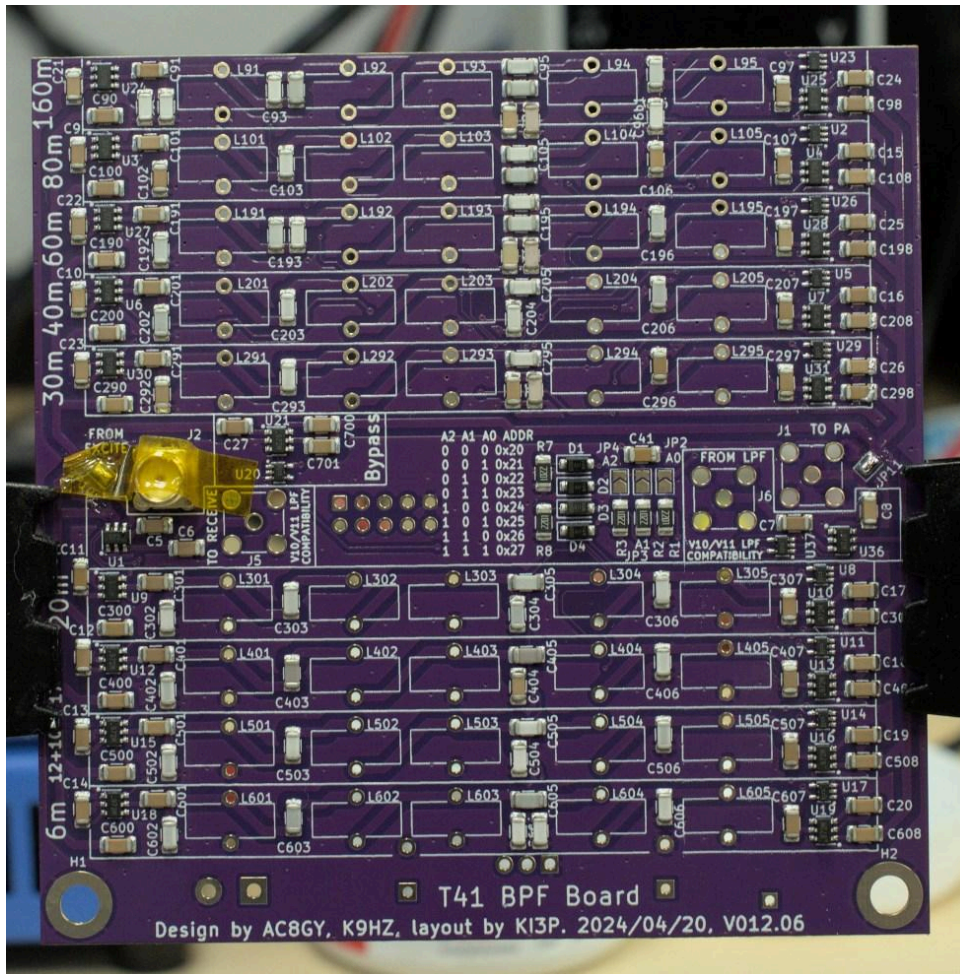
Note: If you're using this board as part of an upgrade to an older version of the T41, eg V10 or V11, or if you're building it for the second receiver option of the T41 V12 then DO NOT solder JP10 and JP11.

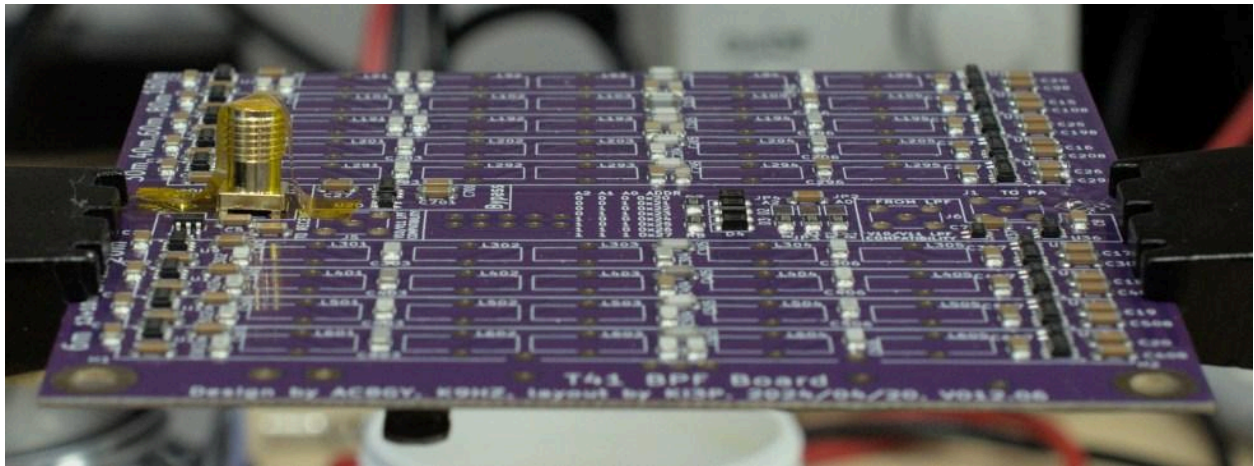
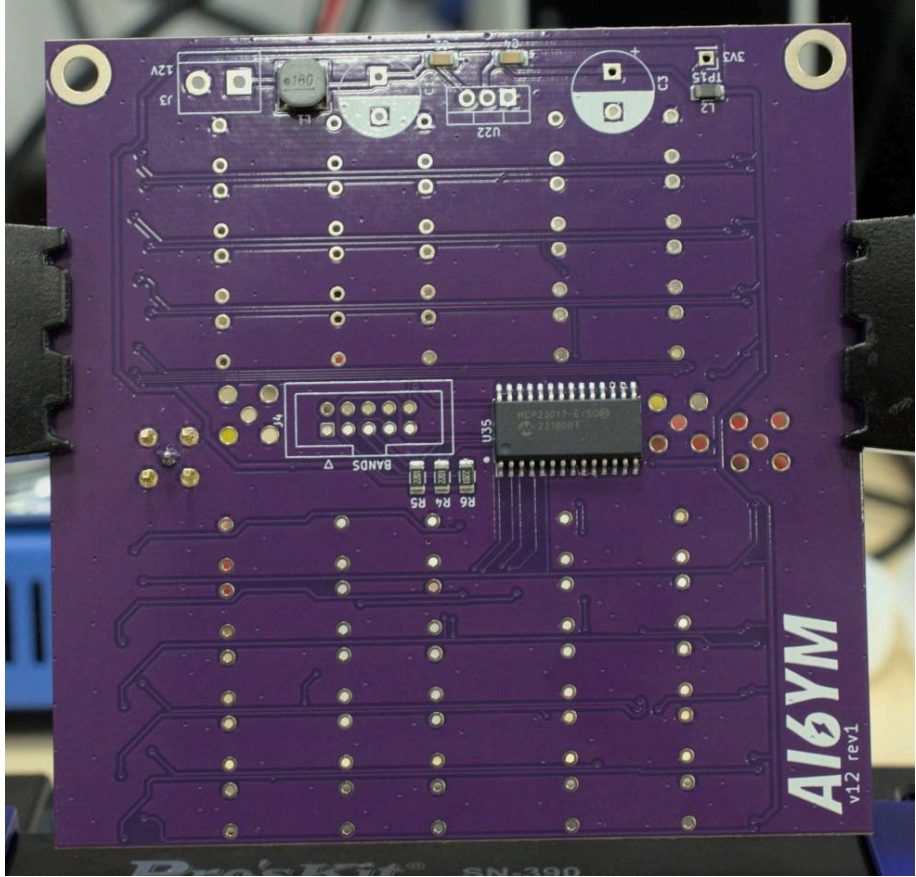
Also, for the second receiver option of the T41 V12, solder A2 and A1 to set the I2C address.

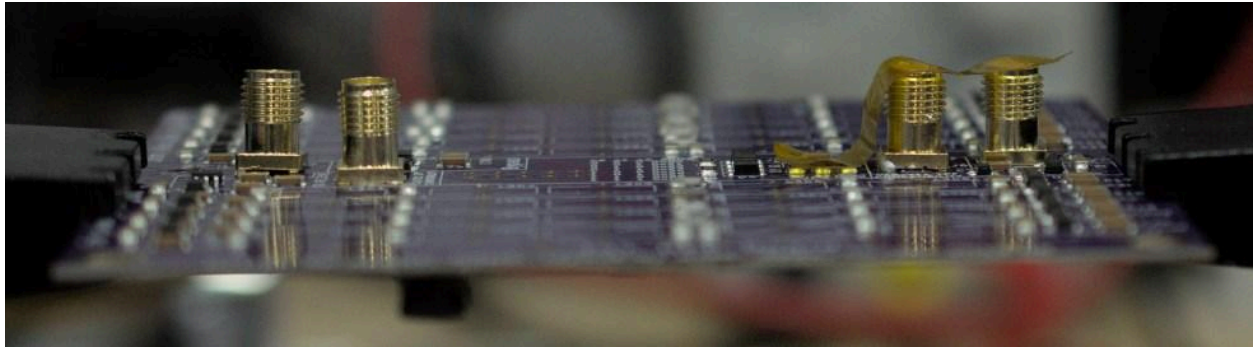
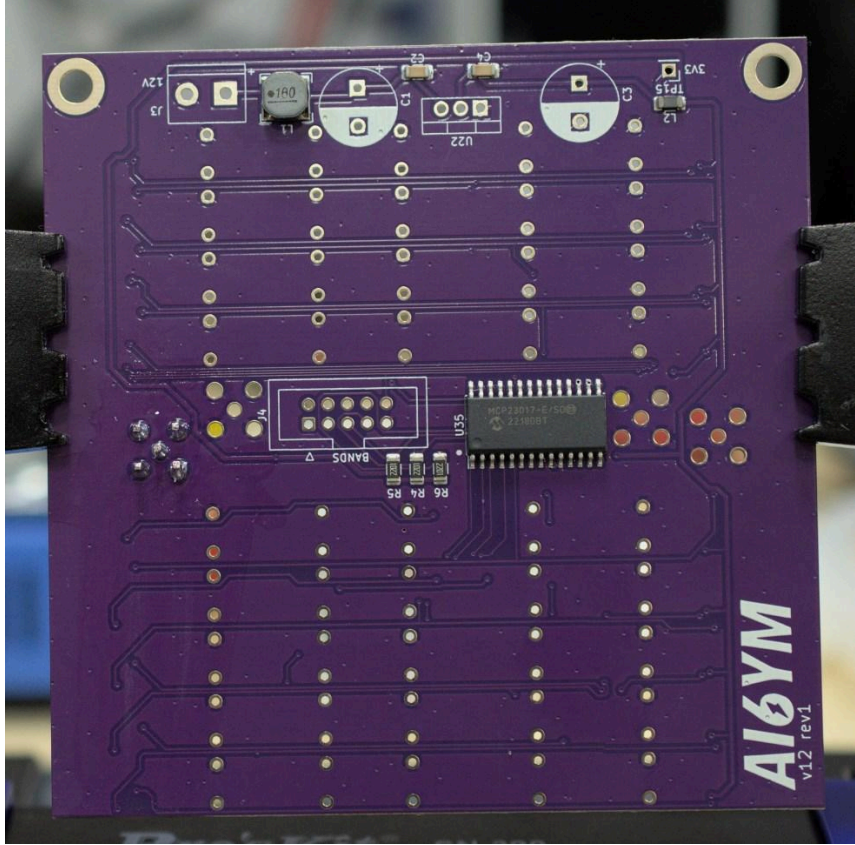
Addressing & Off Board Connectors

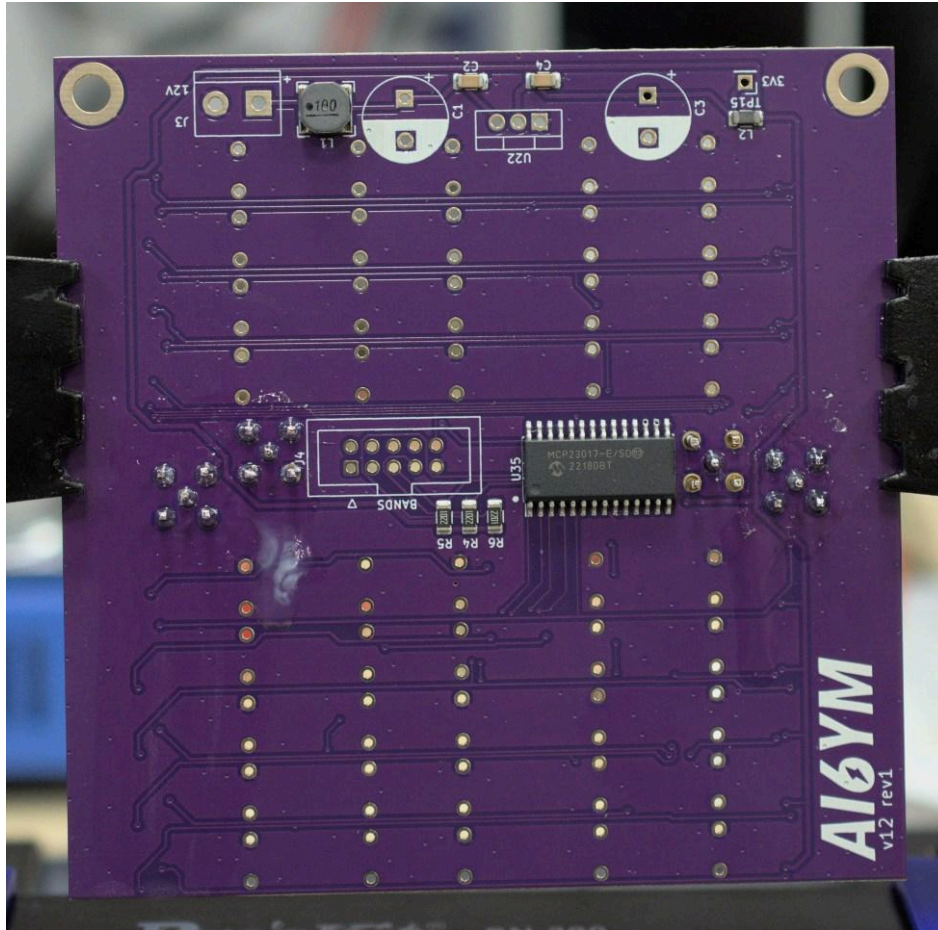
For the basic configuration, the V12 single receiver option, only the J1 (TO PA) and J2 (FROM EXCITE) are required. J5 and J6 are only required for the second receiver option or older versions of the T41. I'm soldering all four connectors in case I use this board for another purpose in the future.

Place the first SMA connector and secure it with a bit of tape. Solder the center pin and check the alignment of the connector. The connector should be straight up and down, sitting flat against the PCB. Once additional pins are soldered it will be difficult to correct misalignment, so double check before soldering more pins!





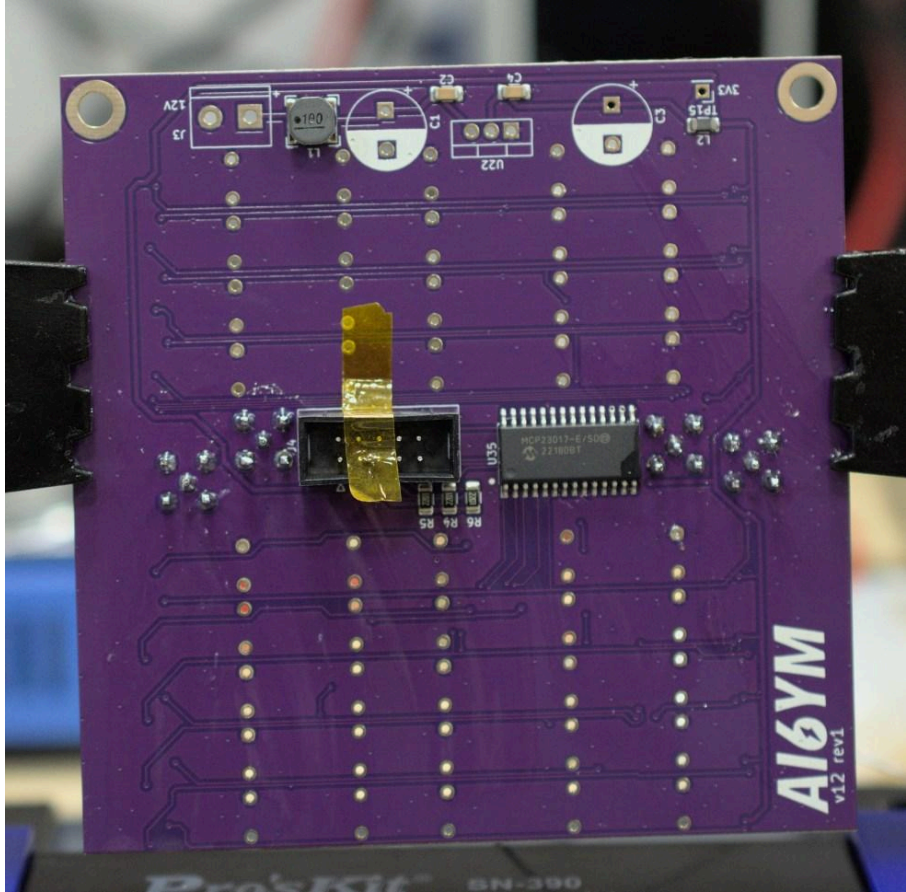




The photo above shows a slight misalignment of the connector at *J2* which I missed when building the board. This does not impact the performance of the board. Once your connector is aligned, solder the remaining (ground) pins.

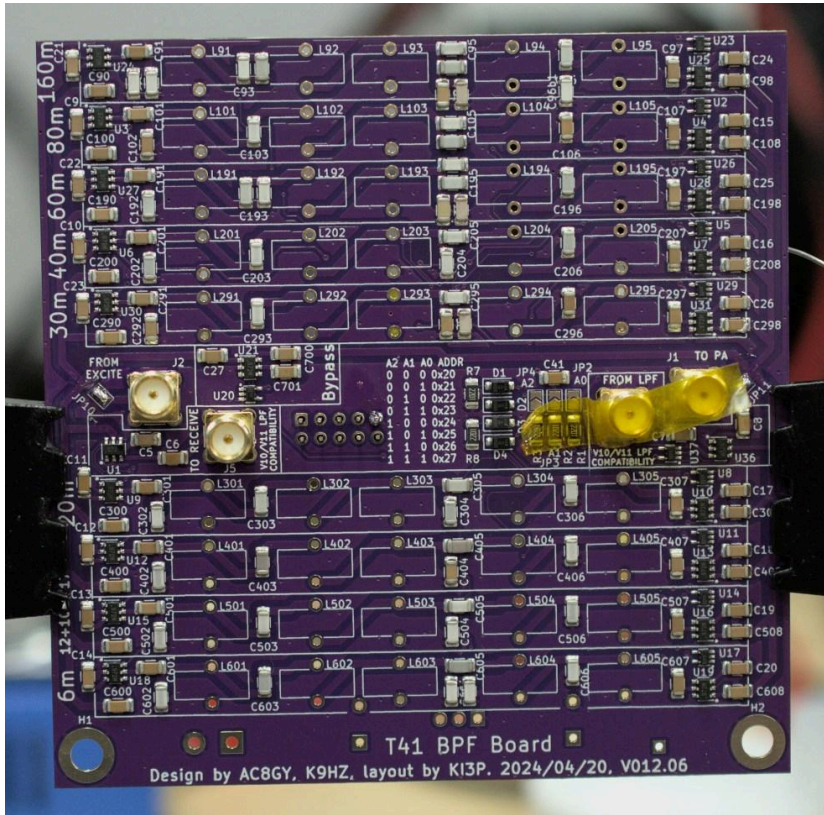
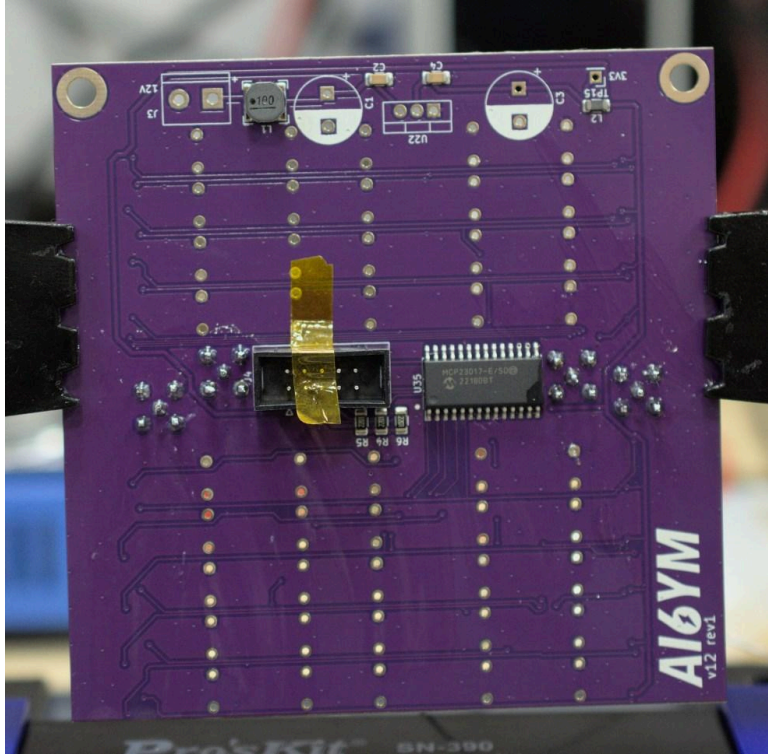
Pro Tip: Hot air and flux is very helpful, these connectors radiate heat away quickly which makes soldering difficult.

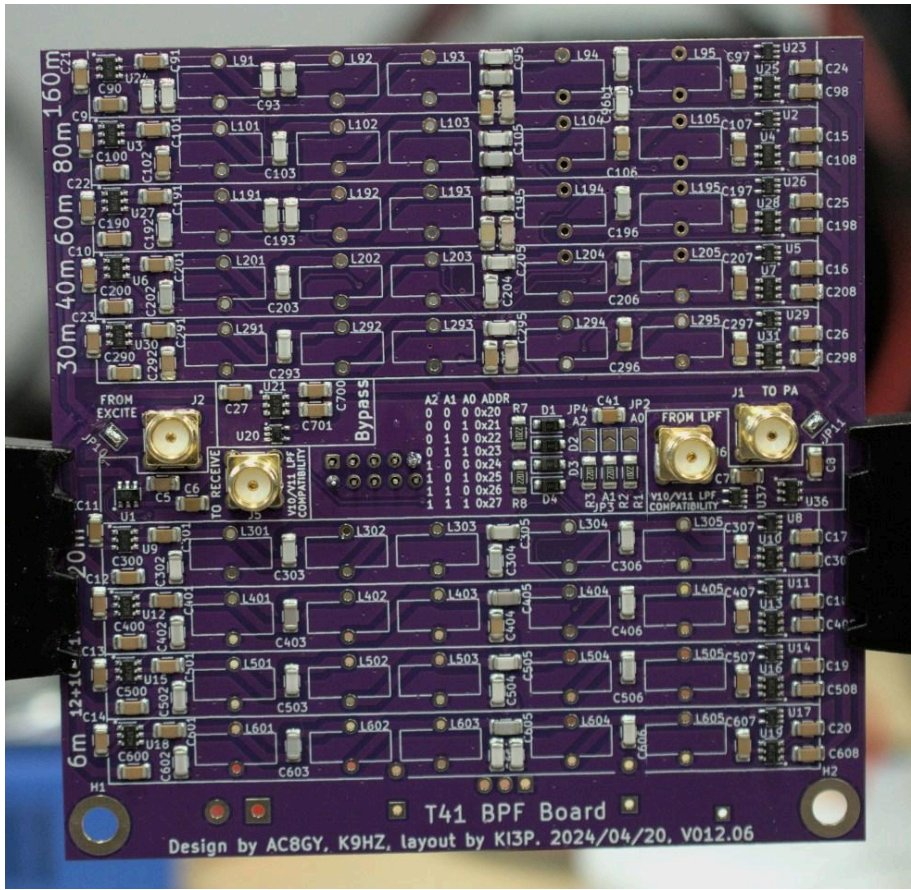
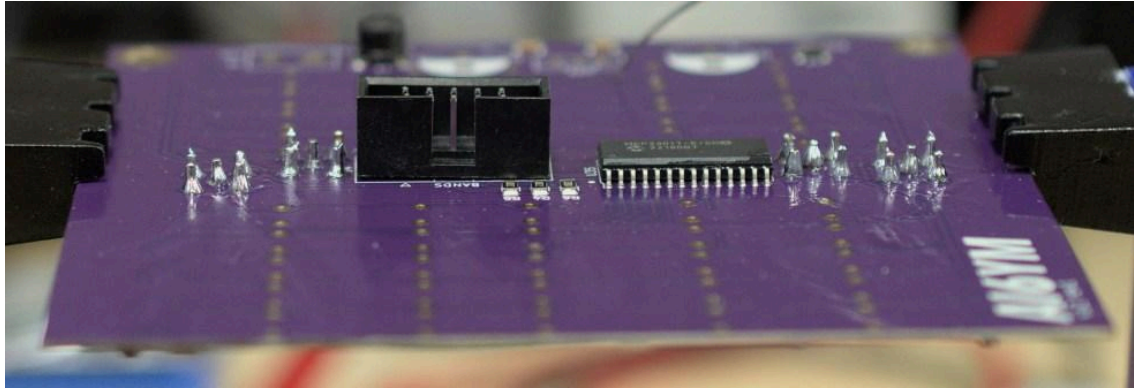
Repeat the process for the remaining connectors, feel free to skip assembly of connectors which you don't plan to use.

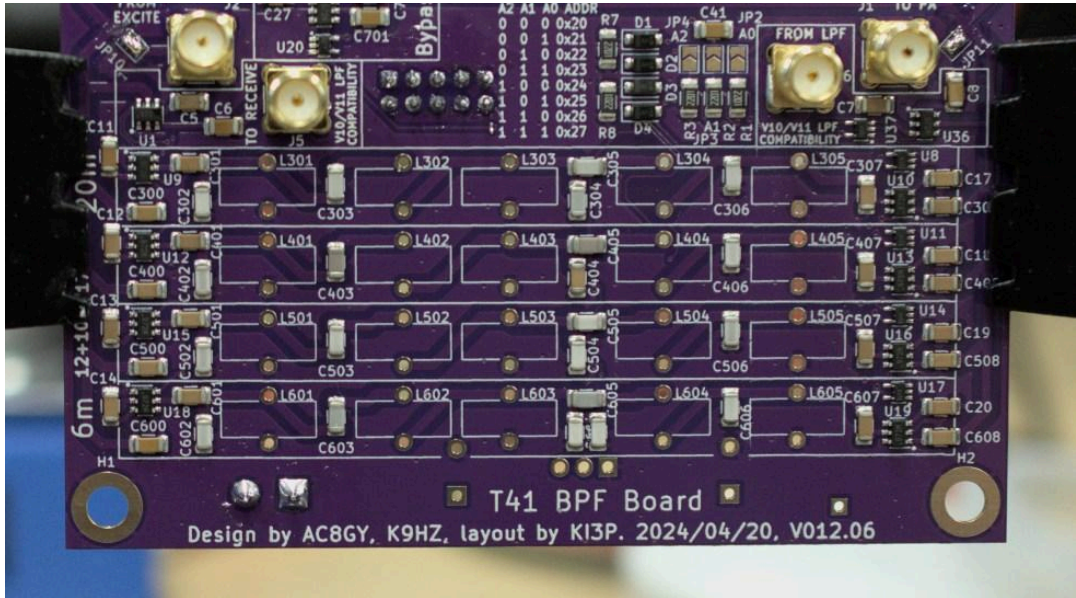
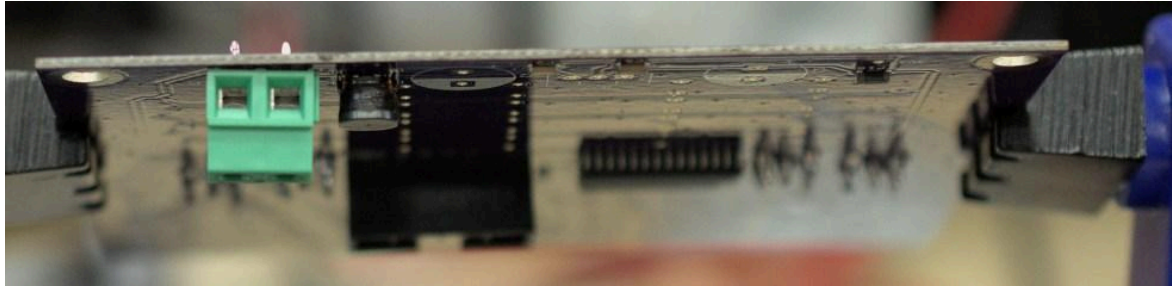
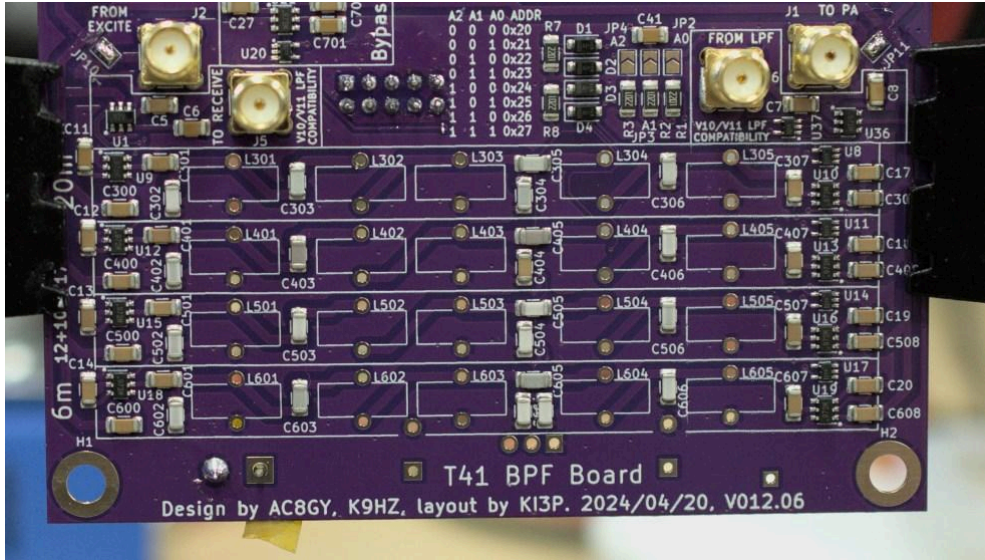


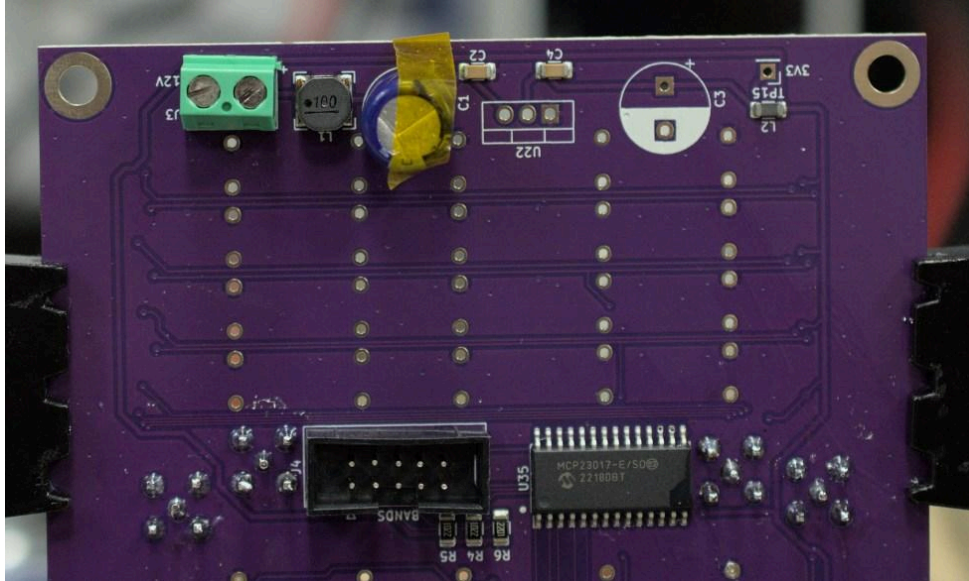
Next, place the IDC box header on the back of the board and secure it with a bit of tape.

Solder a single pin from the front of the board, check the alignment of the header, solder a pin on the opposite corner of the header, check the alignment again, and then solder the remaining pins.



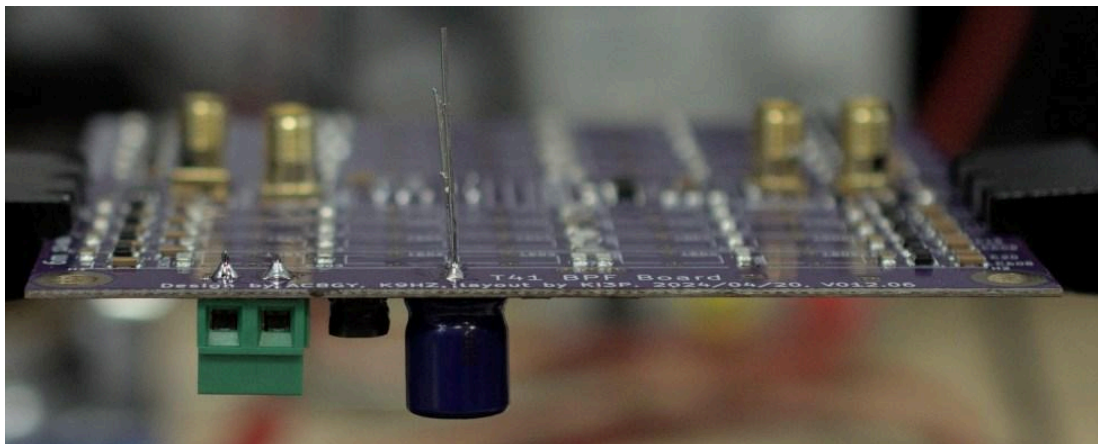


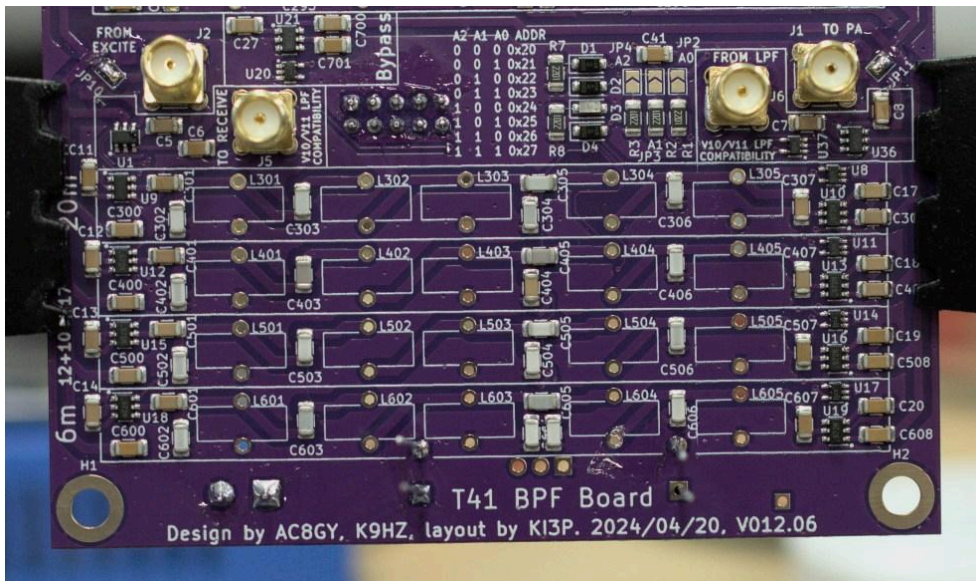
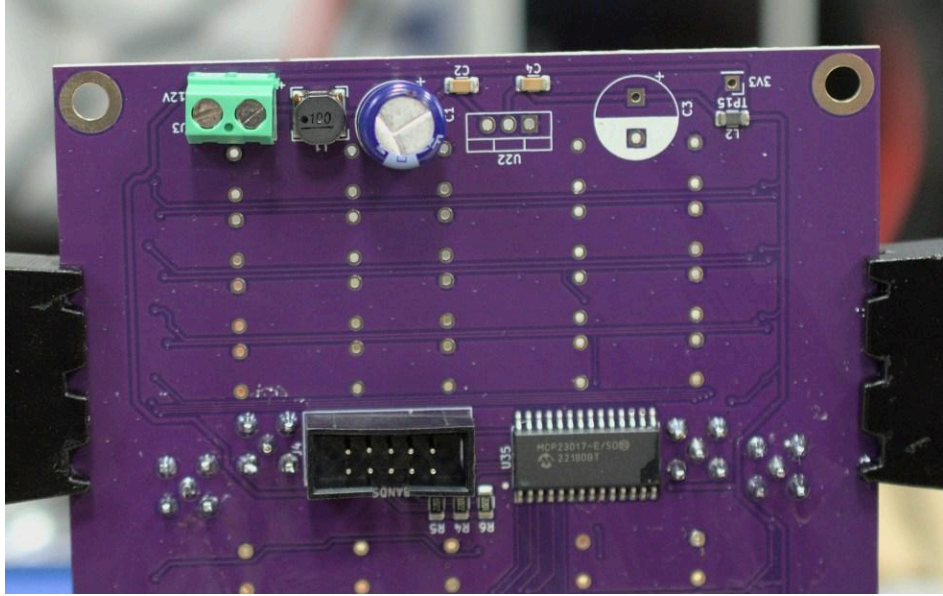


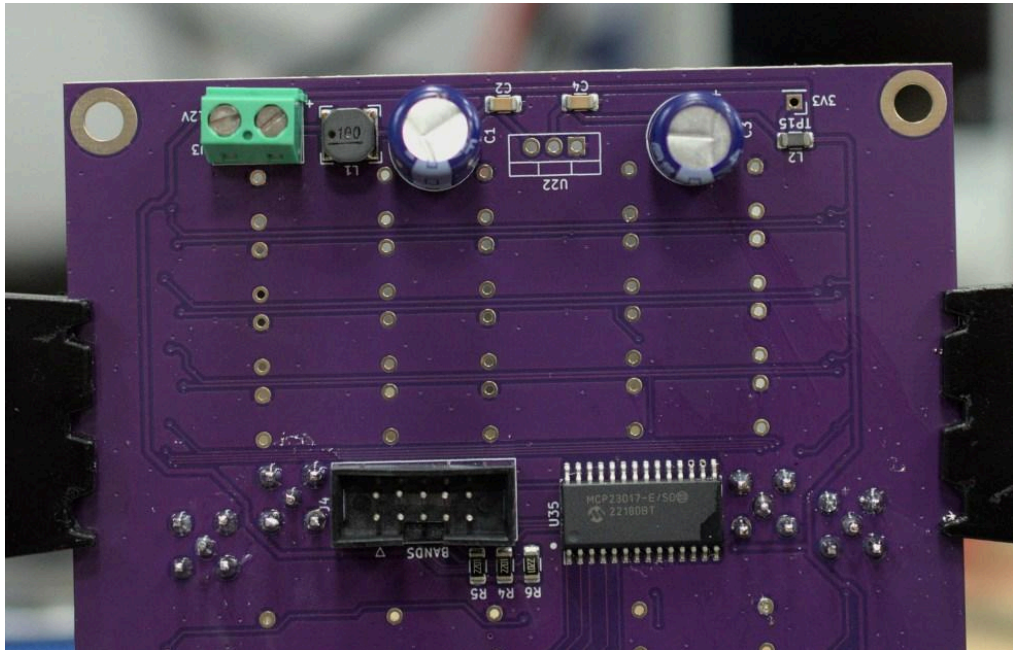
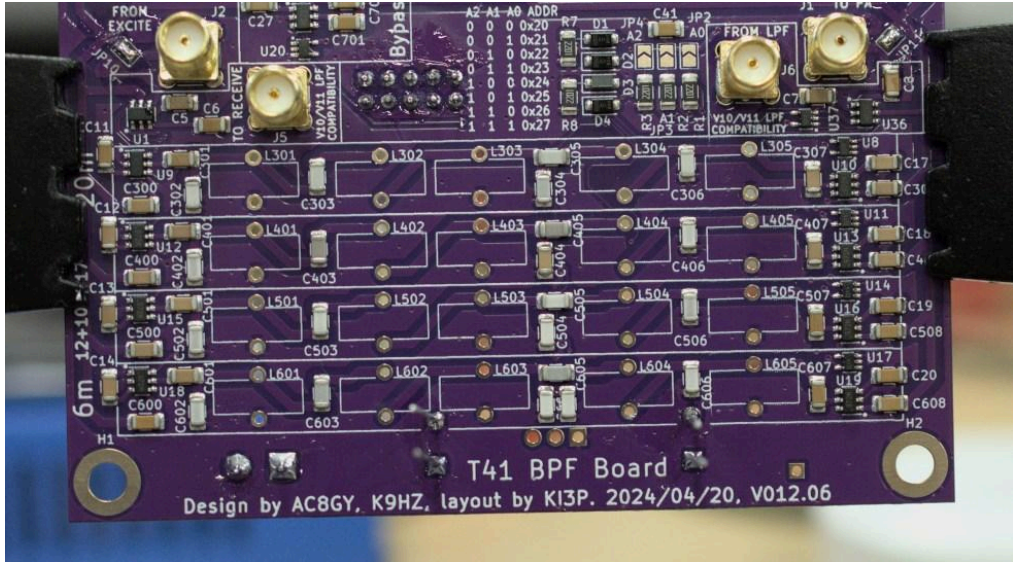


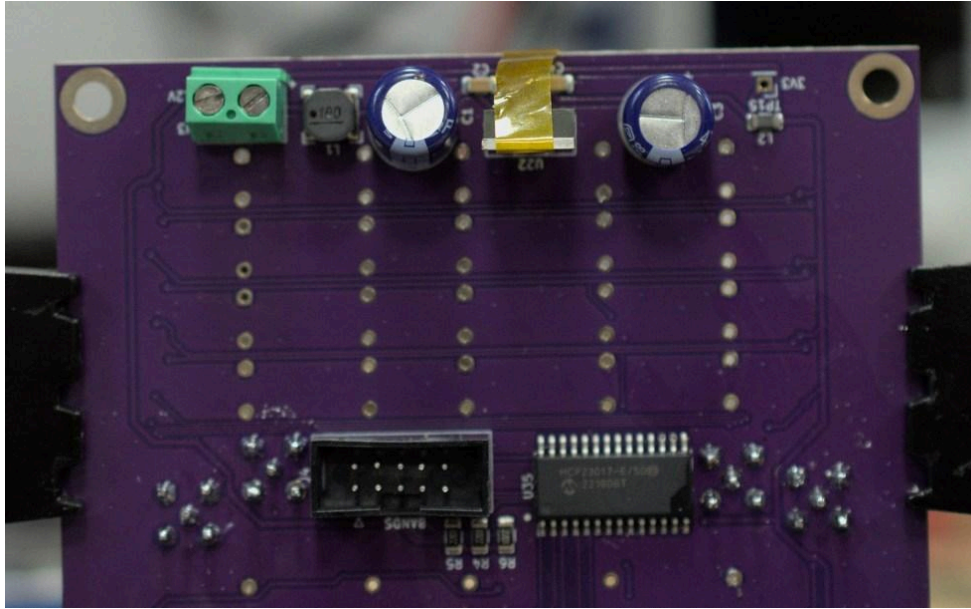
Place the first electrolytic capacitor on the back of the board and secure it with a bit of tape. Remember that the shorter leg, marked with a stripe on the capacitor's casing, goes through the hole marked in white on the silkscreen. The longer leg goes through the pin marked positive (+) on the silkscreen.

Solder one pin, check the capacitor is sitting flat on the board, and then solder the second pin. Repeat for the second capacitor.

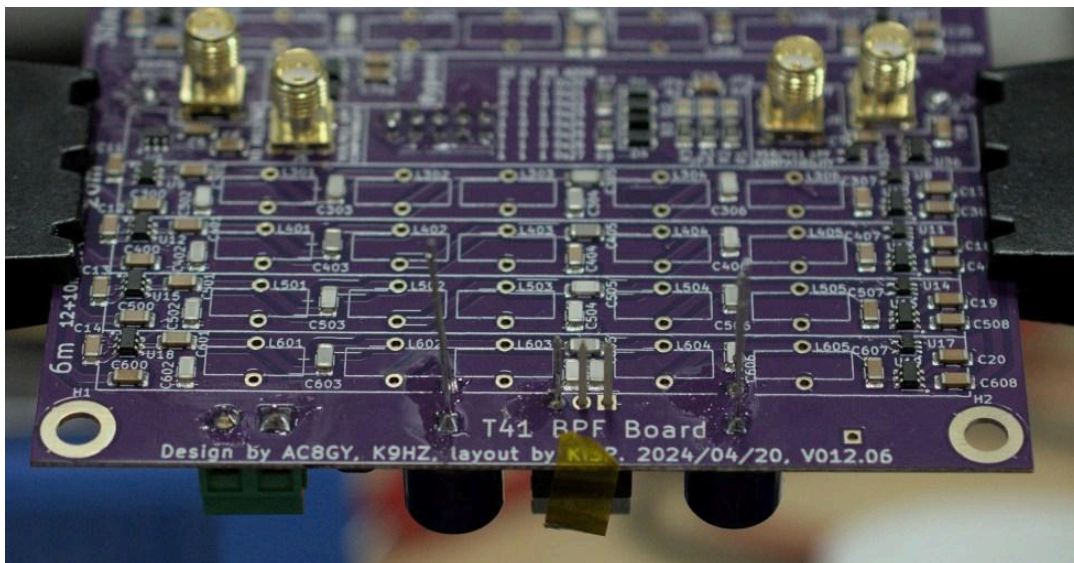


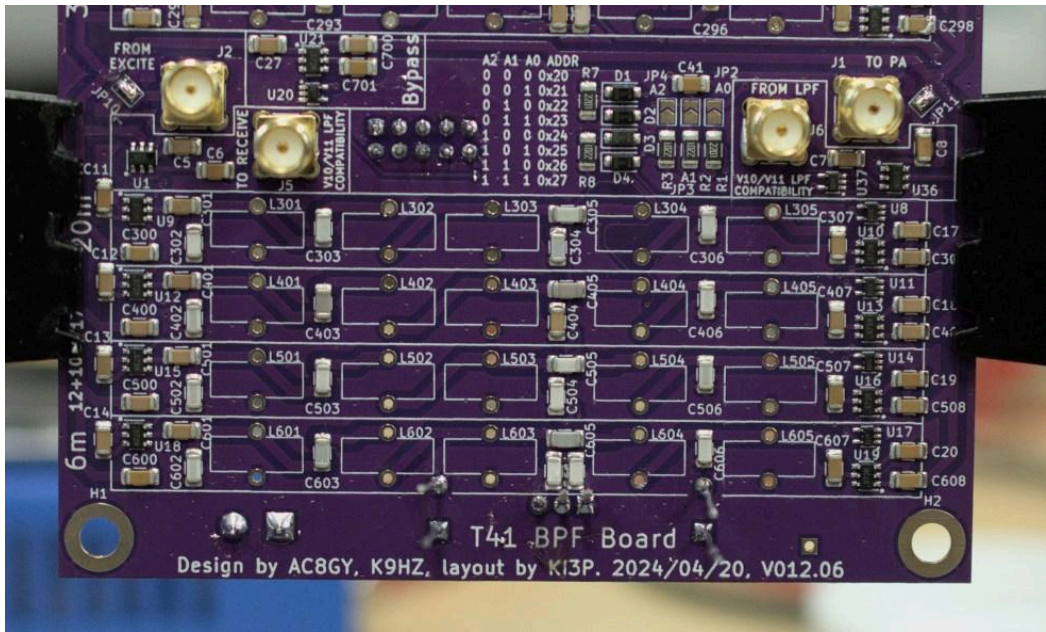
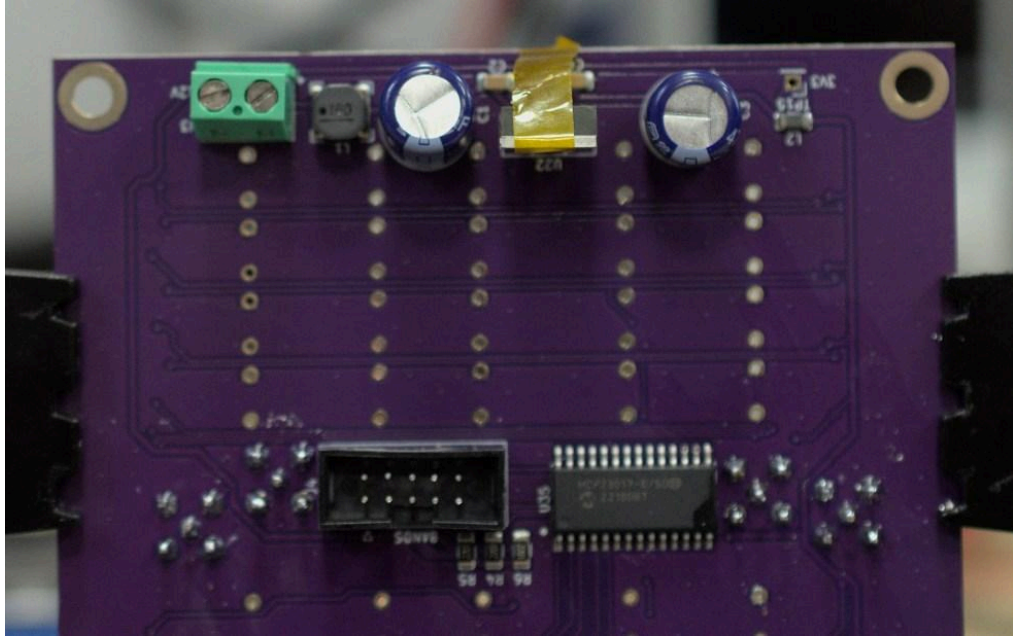


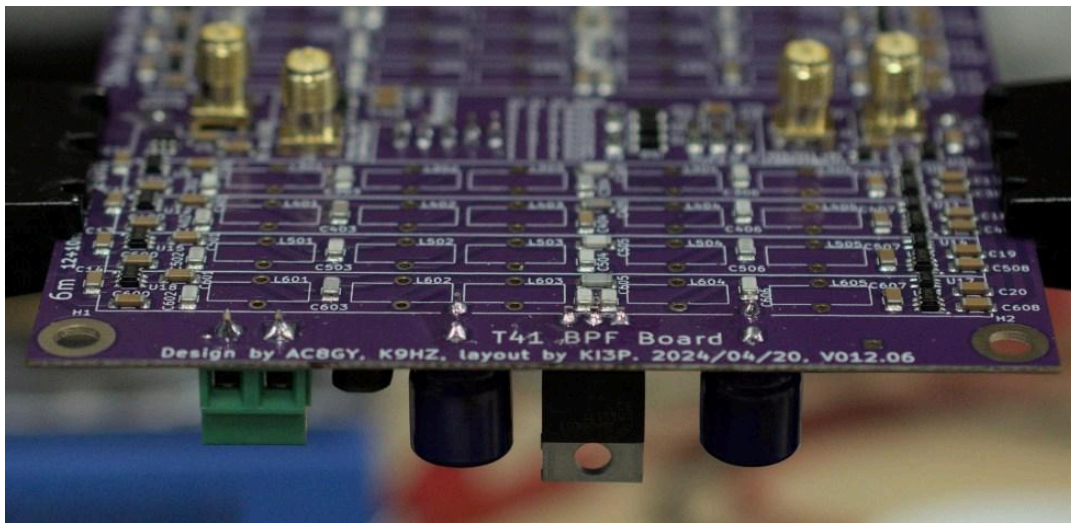
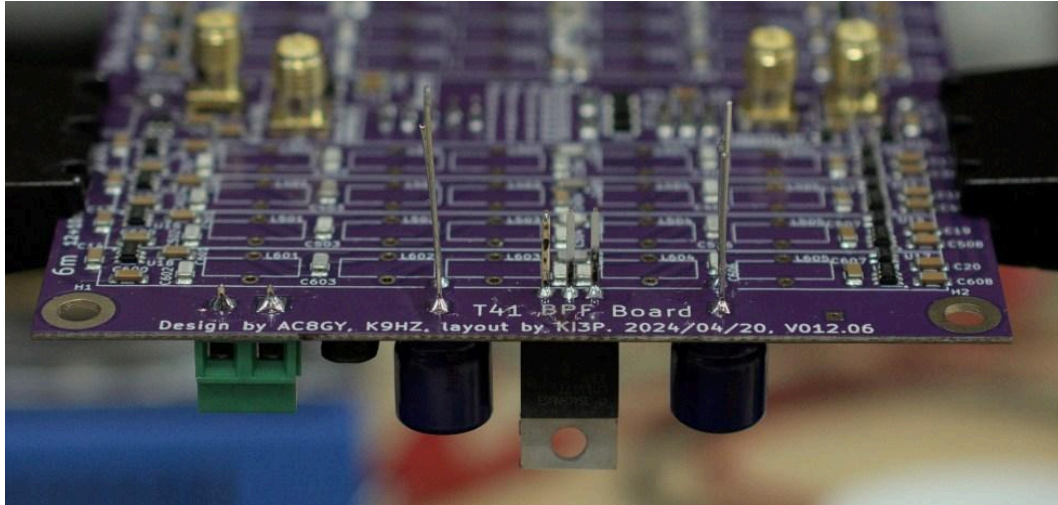




Place the voltage regulator, also on the back of the board, and secure it with a bit of tape. Solder one pin on the front side of the board, the left or right pin will be easier to solder because the center pin is connected to the tab which radiates heat away. Check alignment before soldering the remaining pins. Use hot air and flux if any pin is difficult to solder.







Trim the extra length from the capacitor and voltage regulator pins. This completes the control circuitry for the BPF board and we can move on to filters.

Prepare Your Inductors

Before you begin this process ask yourself if you can count, try to be objective. Are you sure? This process may show that you can't. Be prepared to accept that fact.

For a quick method of toroid winding check out my [tutorial on the twine lock method of toroid winding](#). Follow the table below, double check the turn count of every inductor, and keep the finished inductors organized.

Feel free to skip inductors for bands you don't plan to use. Keep in mind that the V12 RF Board doesn't actually support 160M yet and support may not be possible without rework or entirely new boards. I'm assembling all bands so my boards are the most capable they can be.

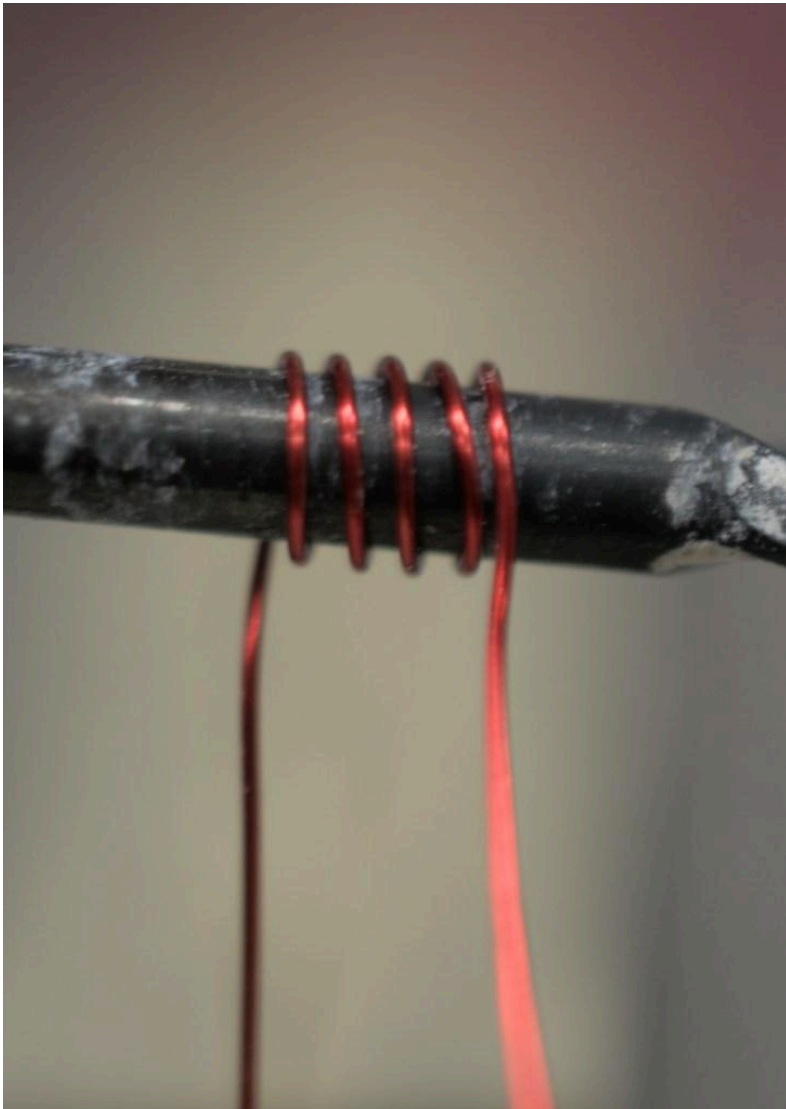
Band	Inductor	Toroid Core	Turns
160M	L091	T37-6 (Yellow)	25
	L092	FT37-61 (Unpainted)	15
	L093	T37-10 (Black)	20
	L094	FT37-61 (Unpainted)	15
	L095	T37-6 (Yellow)	25
80M	L101	T37-10 (Black)	18
	L102	T37-1 (Blue)	26

	L103	T37-0 (Tan)	30
	L104	T37-1 (Blue)	26
	L105	T37-10 (Black)	18
60M	L191	T37-10 (Black)	17
	L192	T37-1 (Blue)	25
	L193	T37-2 (Red)	9
	L194	T37-1 (Blue)	25
	L195	T37-10 (Black)	17
40M	L201	T37-0 (Tan)	29
	L202	T37-1 (Blue)	21

	L203	T37-0 (Tan)	22
	L204	T37-1 (Blue)	21
	L205	T37-0 (Tan)	29
30M	L291	T37-0 (Tan)	19
	L292	T37-10 (Black)	37
	L293	T37-0 (Tan)	11
	L294	T37-10 (Black)	37
	L295	T37-0 (Tan)	19
20M	L301	T37-0 (Tan)	18
	L302	T37-6 (Yellow)	26

	L303	T37-0 (Tan)	12
	L304	T37-6 (Yellow)	26
	L305	T37-0 (Tan)	18
17M / 15M	L401	T37-0 (Tan)	15
	L402	T37-10 (Black)	20
	L403	T37-0 (Tan)	12
	L404	T37-10 (Black)	20
	L405	T37-0 (Tan)	15
12M / 10M	L501	T37-0 (Tan)	14
	L502	T37-10 (Black)	18

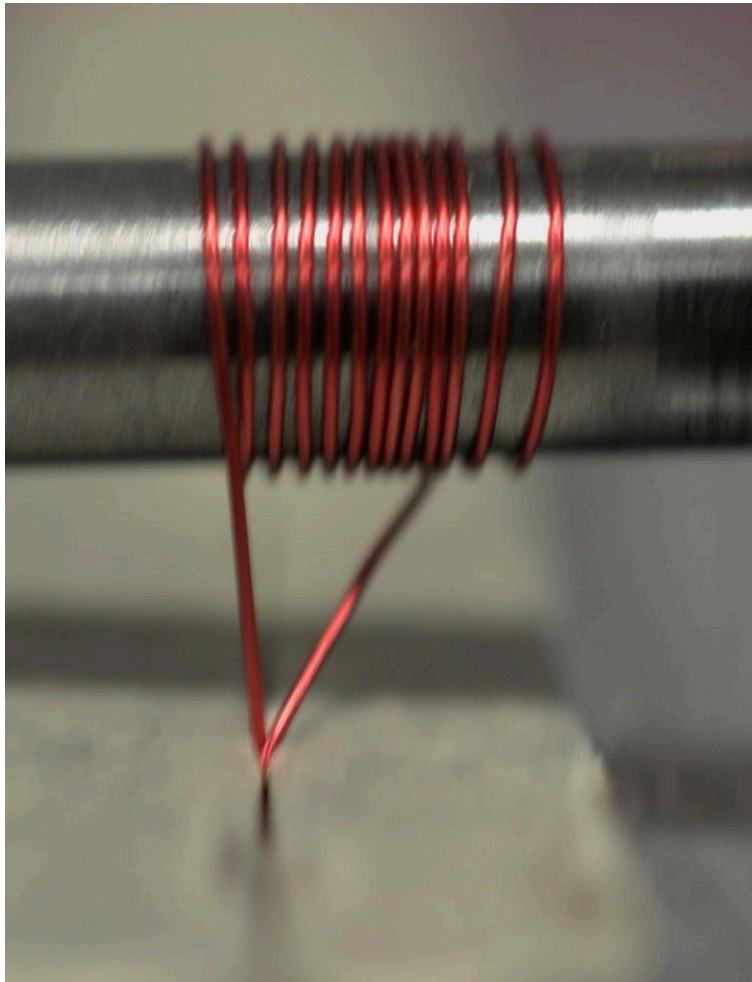
L503	T37-0 (Tan)	12
L504	T37-10 (Black)	18
L505	T37-0 (Tan)	14

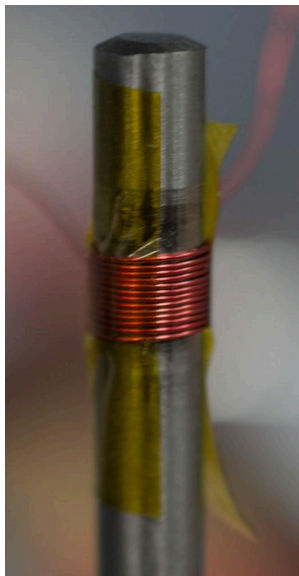
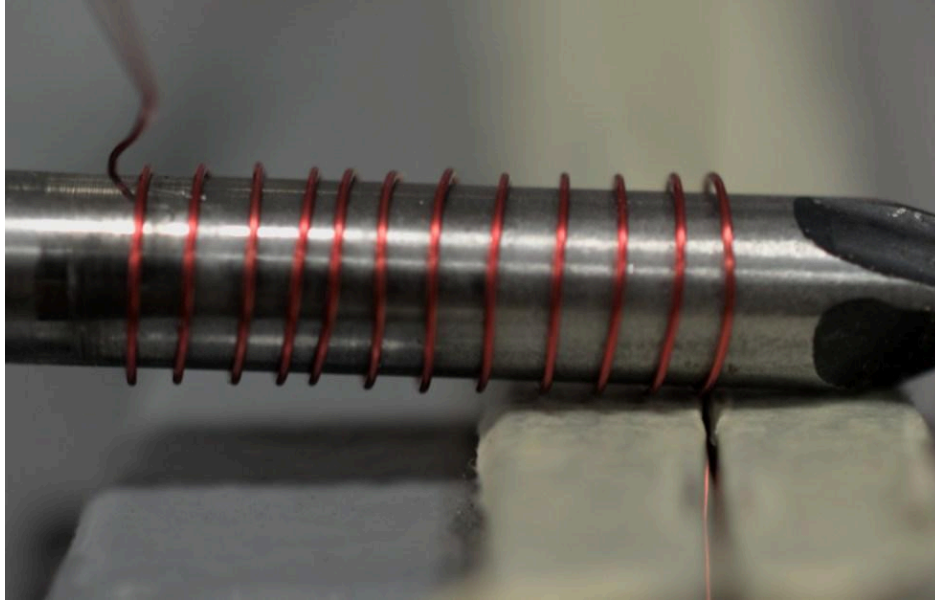


The 6M inductors are not included in the table above because that filter is built with air core inductors. For *L601*, *L603*, and *L605* use a dowel, drill bit, or other round object about 3mm

(1/8") in diameter. Wind a small bit of wire around the object and press squeeze the turns together tightly. Every pass over the top of your coil form is a turn. *L601* and *L605* are 5 turns, *L603* is 3 turns.

Wind *L602* and *L604* in a similar fashion with an 8mm (5/16") diameter form. Both of these inductors are 13 turns. Due to the number of turns these coils will try to spread out into a very long coil, secure the turns with a bit of tape to keep them together when removing the coil from the form. After a few minutes of resting, the tape can be removed and the turns will stay together relatively well.





For each inductor, double check the number of turns before trimming the excess wire to about 6mm (1/4") leads.

Note: The wire included in my kits is high-build, high-temperature enamel. This is a great choice for long-term durability but it makes stripping the enamel coating off the wire a bit more difficult. Heating the wire with your soldering iron will NOT be sufficient.

Strip the leads of each inductor by sanding lightly or scraping with a sharp blade. If using a blade be careful not to nick the copper wire which may cause it to break during assembly.

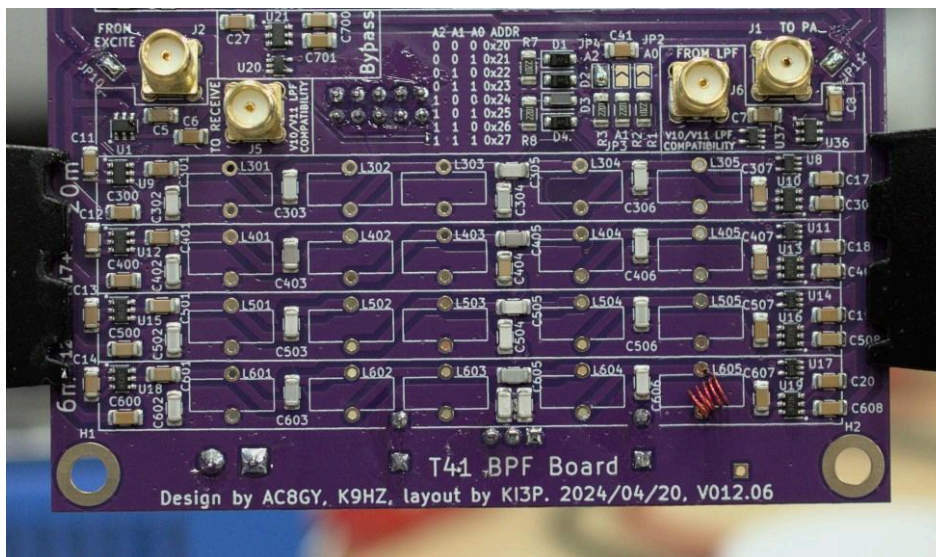
It's ok to rewind coils. I made several mistakes building this board and rewound several toroids. I've included extra wire in my kits for this purpose but additional wire is available inexpensively from many fine retailers.

Assembling & Tuning the Filters

For this build I've chosen to assemble, tune, and pot each filter individually. BPFs are sensitive to minor changes such as the position of turns on toroid cores, the spacing of turns on air cores, even just the position of each inductor relative to the board and each other. Adjusting filters is more difficult when the adjacent filters are also populated.

A BPF test sketch is available in my [GitHub repo](#). This sketch allows you to select each individual filter using the Teensy's serial connection for testing and tuning each filter with a NanoVNA.

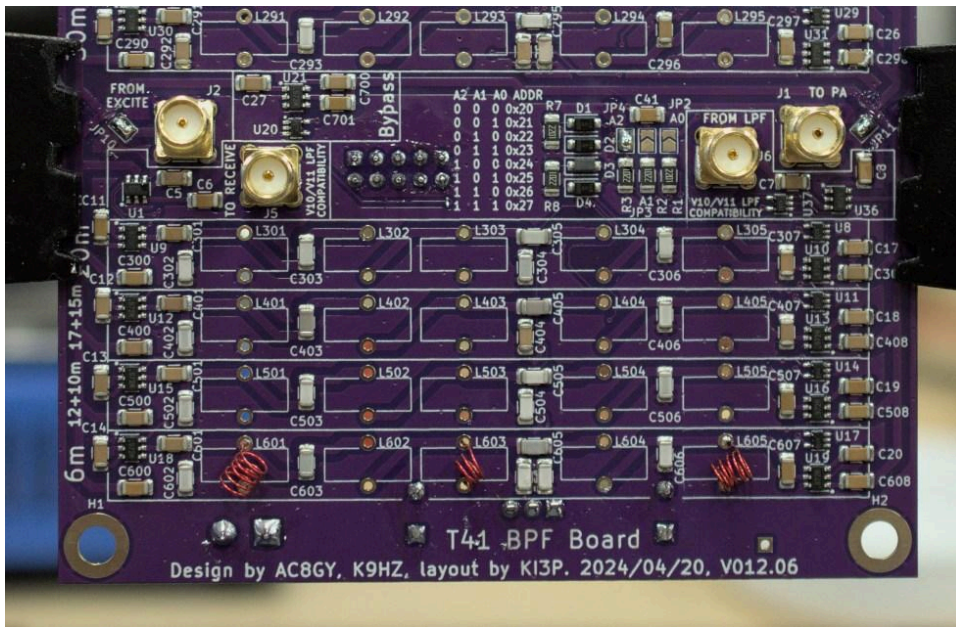
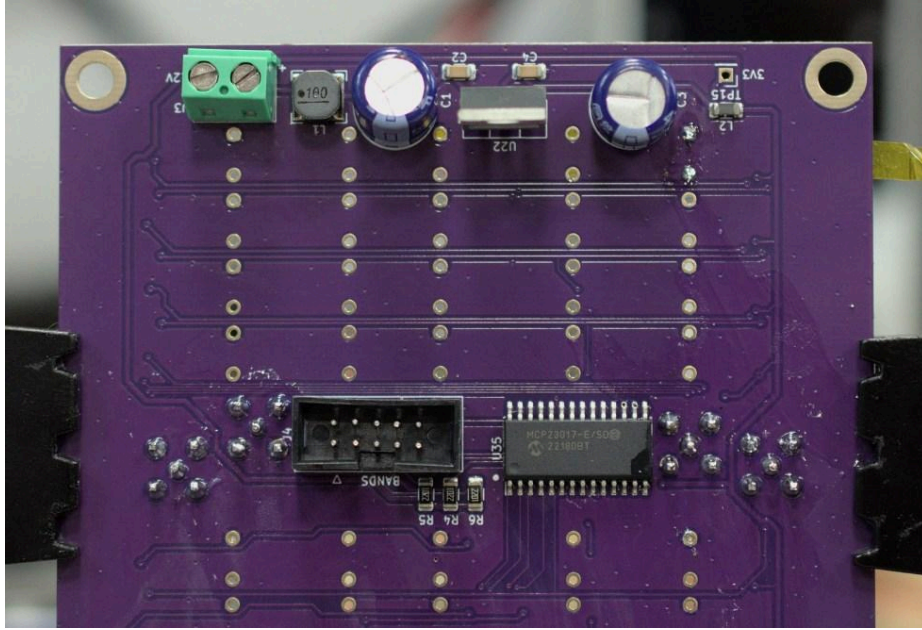
Start at the bottom of the board with the 6M filter and work your way up the board. Filters for the lower bands will be significantly simpler to tune.. Feel free to assemble the filters left-to-right or right-to-left, whichever is easier for you.

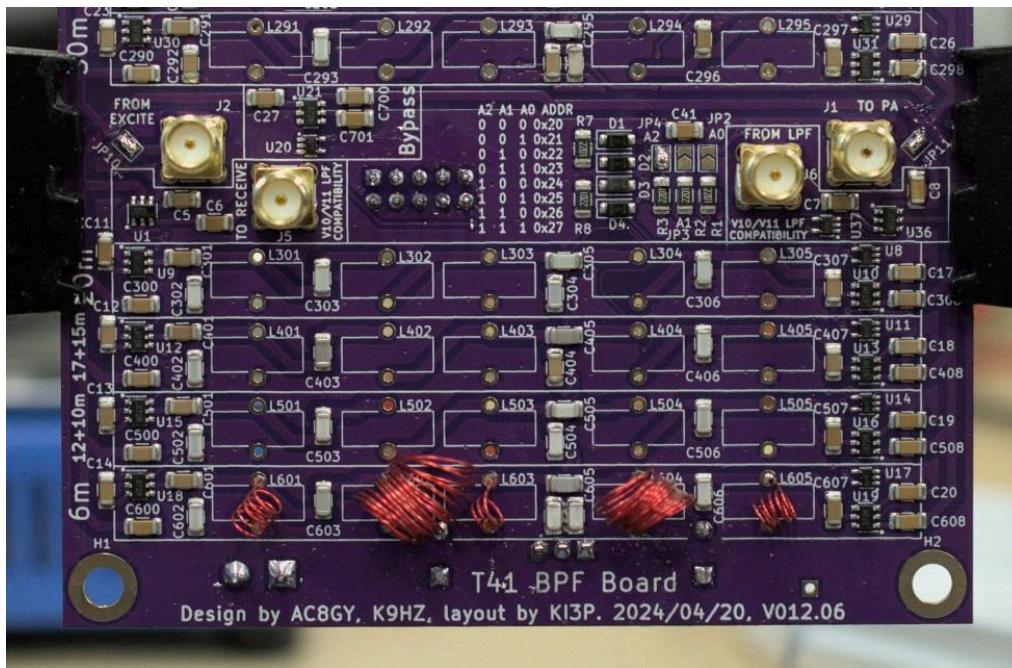
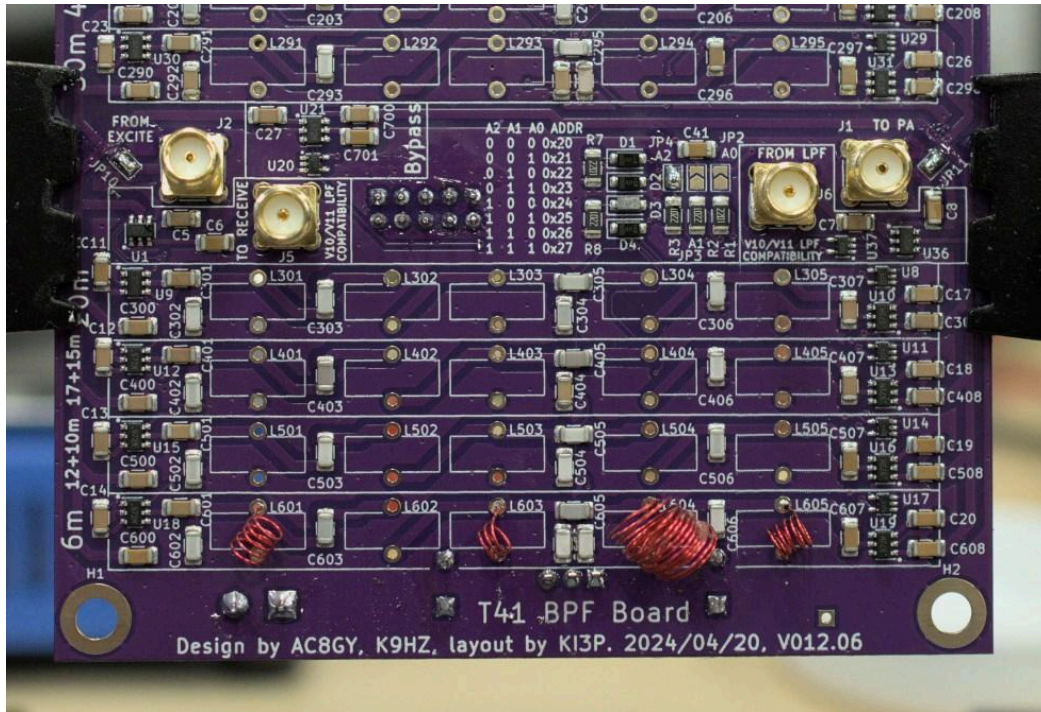


Place the first coil, secure with tape if necessary, solder one lead and then the other. Check for continuity across the solder joints before trimming the leads and moving on to the next inductor.

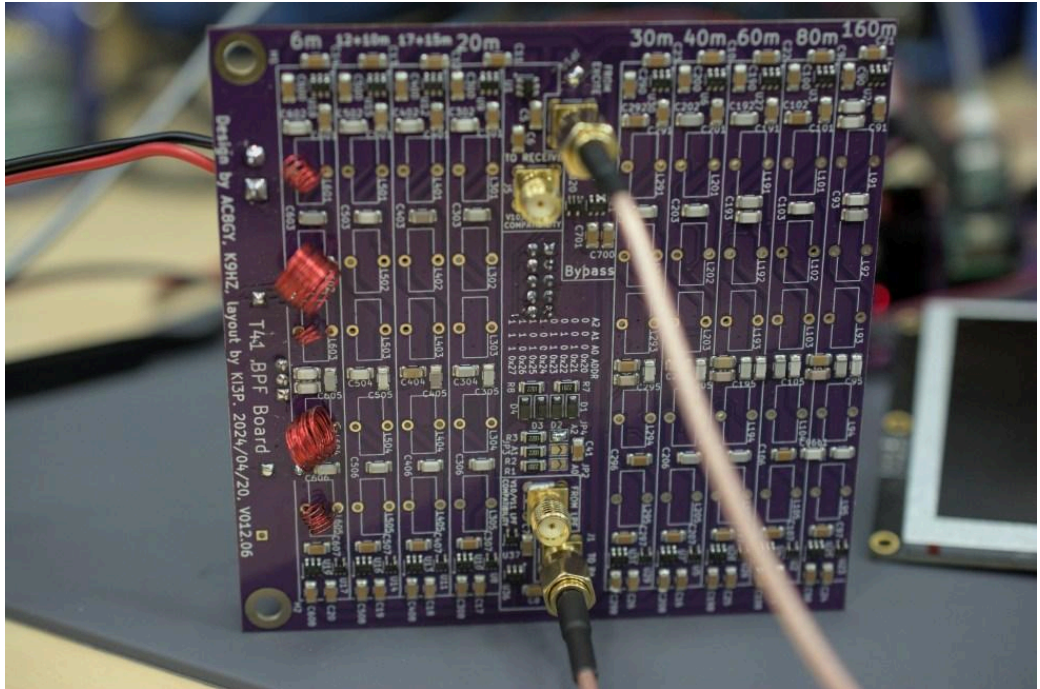
Caution: Be careful not to damage the power supply components with your soldering iron as you build the filter.

Pro Tip: Use a bit of extra heat (my iron is set to 370C / 700F) and a lot of flux to help break through the remaining enamel coating on the wire.



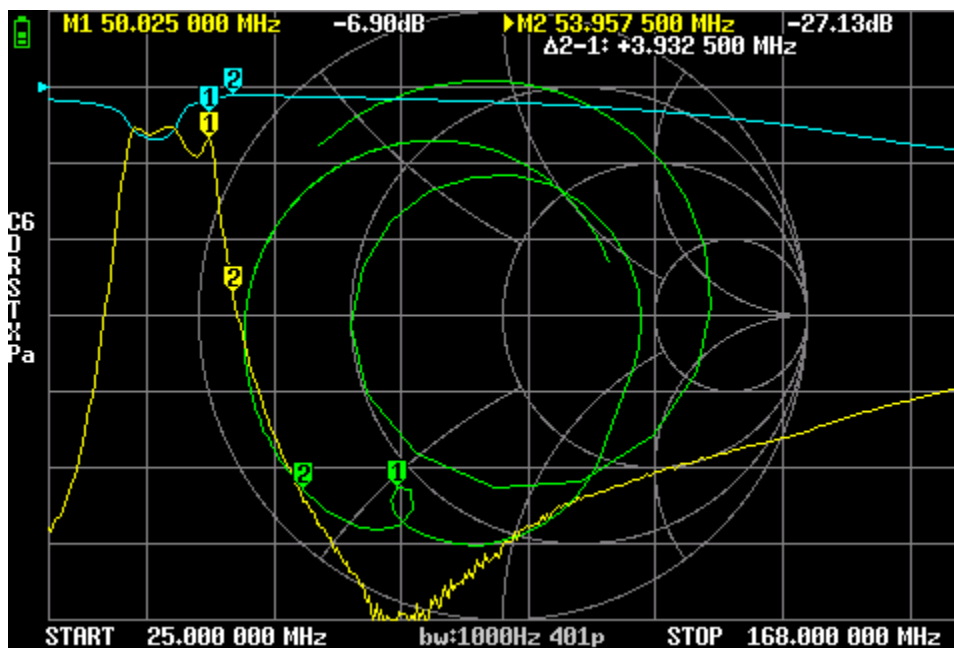
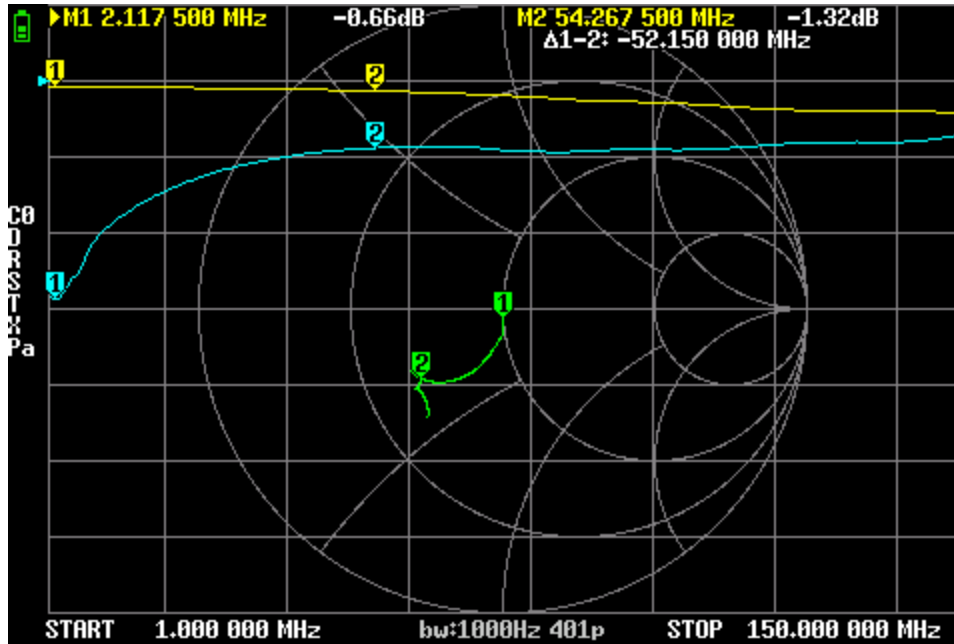


Before continuing to test and tune the 6M filter (or whichever filter you build first) connect this board to the main board and power it up with a current limiting supply. Total current draw will be somewhere under 0.35A at 13.8V. **DO NOT POWER THE BOARD FOR THE FIRST TIME WITH UNLIMITED CURRENT.**



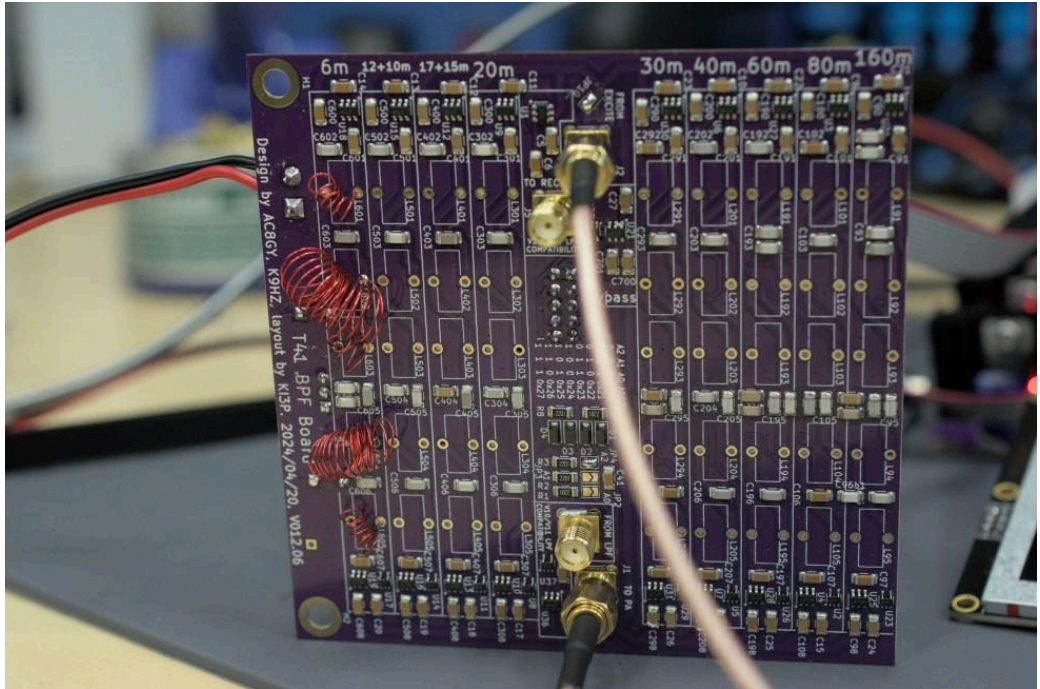
Now connect your main board and test equipment. Be sure your NanoVNA, or similar test equipment, has been calibrated for the frequency range you're measuring. I recommend testing filters from at least 0.5x their low cutoff frequency to at least 3.1x their high cutoff frequency using the maximum resolution possible. Remember that increased bandwidth will reduce resolution.

A good first test is to select the bypass option and measure S12 (energy passthrough) across the entire HF through 6M bands. Response should be essentially flat with a loss of under 1dB for most of the spectrum. Under 1.5dB is acceptable at 6M. Non-flat response or higher losses indicate something is wrong, likely with your cabling or test equipment.

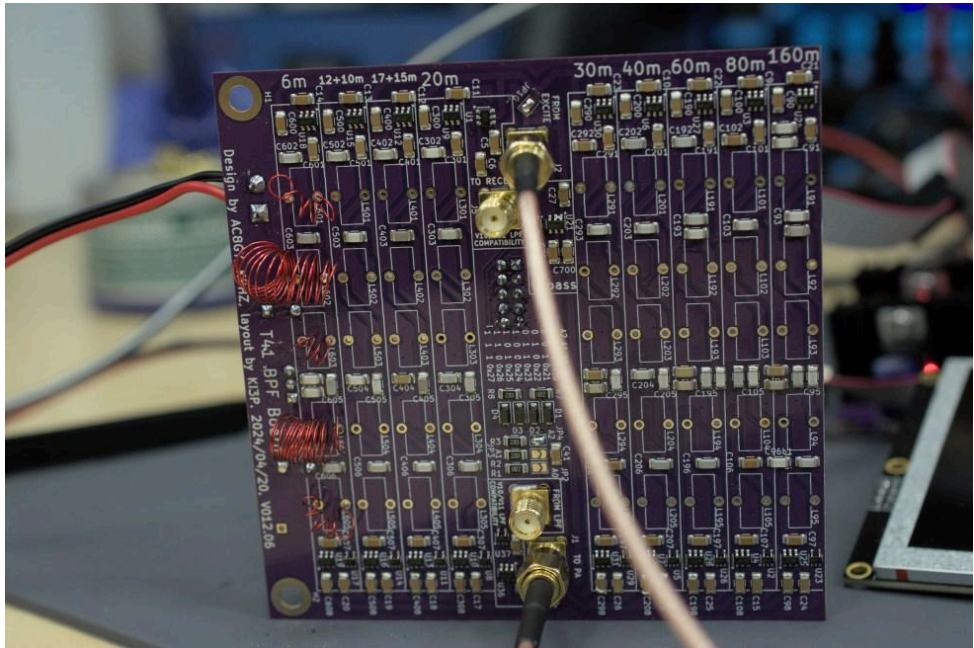


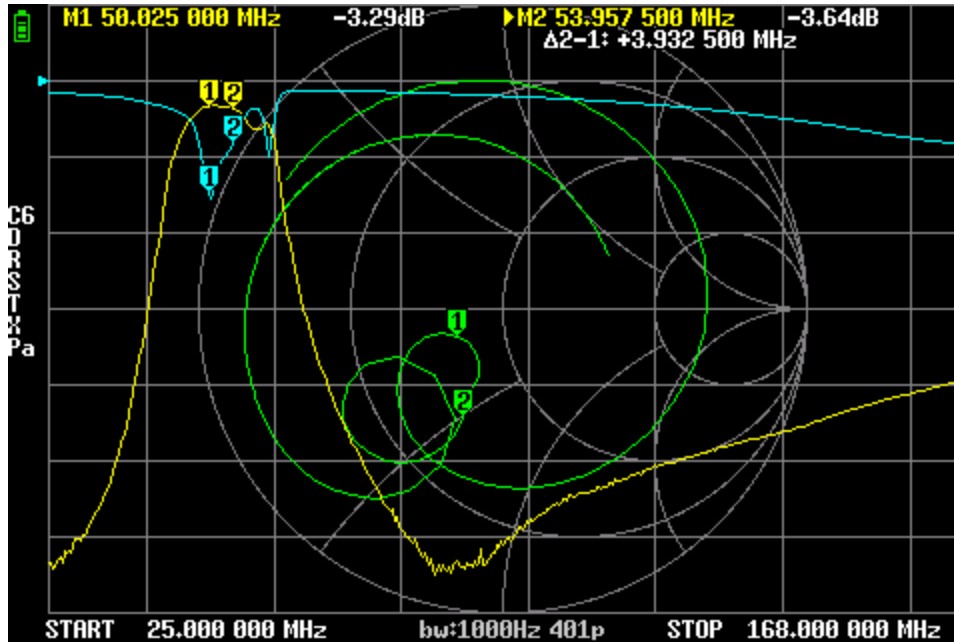
Next select the 6M filter (by entering “6” on the serial connection) and measure the performance of the filter.

The initial response of this filter isn’t good, but a response like this is not unexpected before tuning. Each inductor can be adjusted by pulling the turns apart or pushing them together. Adjust one inductor at a time and monitor the response, giving your VNA time to measure the new performance after each adjustment.



Once you've found the ideal configuration of one inductor, move on to the next. Keep in mind each adjustment affects the entire filter, you may need to go over each of the inductors multiple times to find the ideal filter.



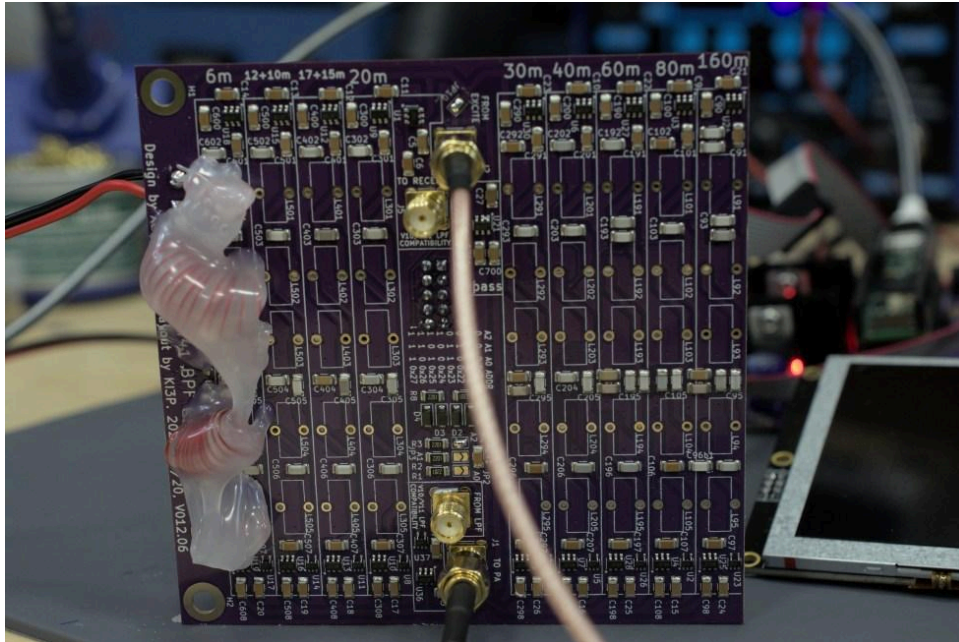


A good filter is flat in the passband or close to it, multiple peaks and rough shapes in the passband indicate a poorly tuned filter.

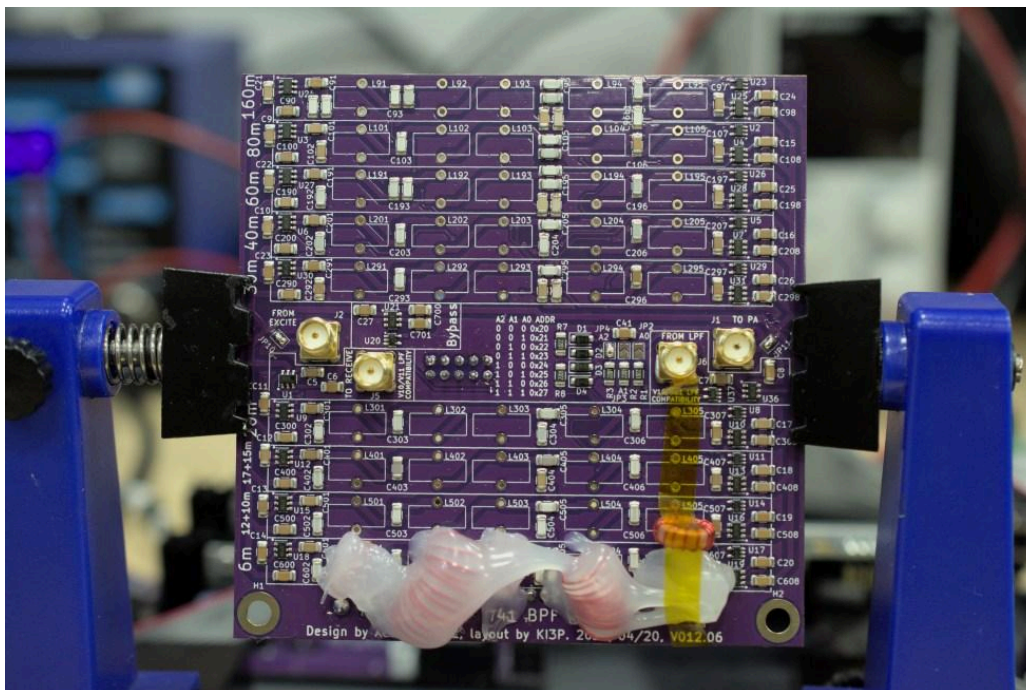
After several cycles of adjustments the filter response should stabilize. A loss under 3.5dB is good for the 6M filter.

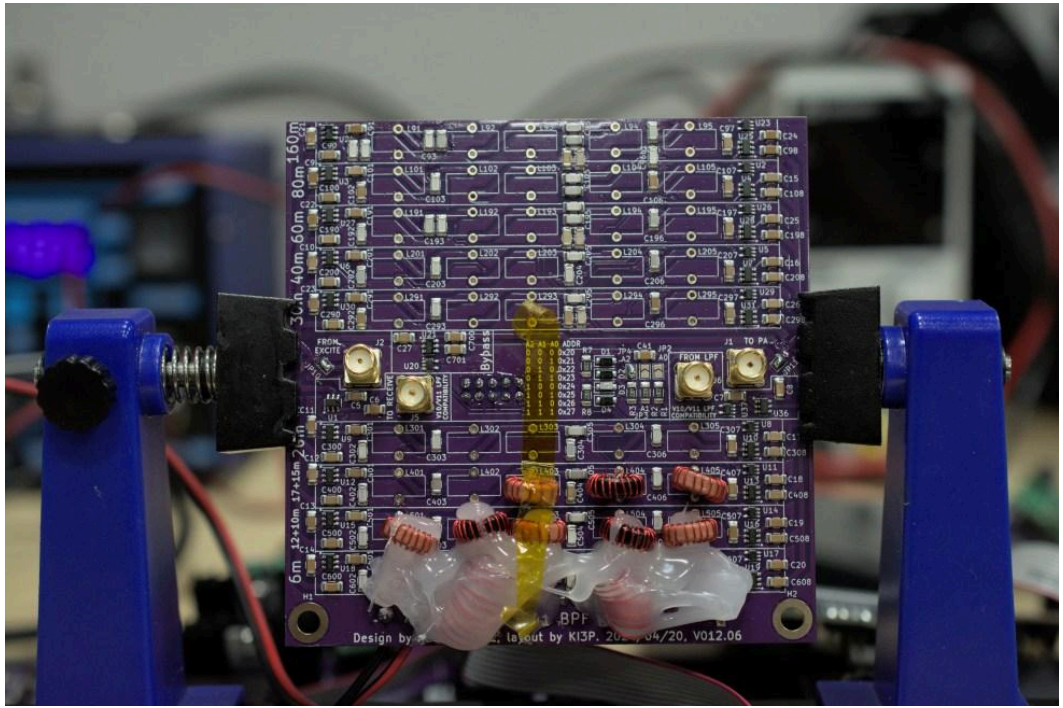
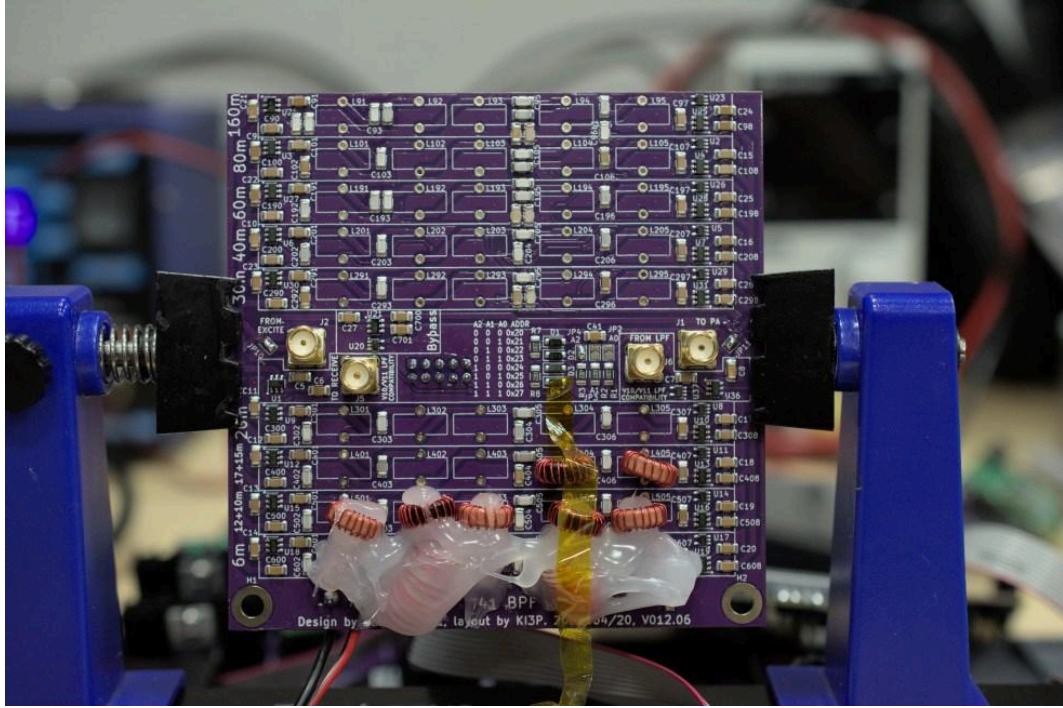
Before moving on these coils need to be secured. Any small bump will move the coils and detune the filter. Pot the coils with hot melt glue. Be gentle so you don't disturb your inductors!

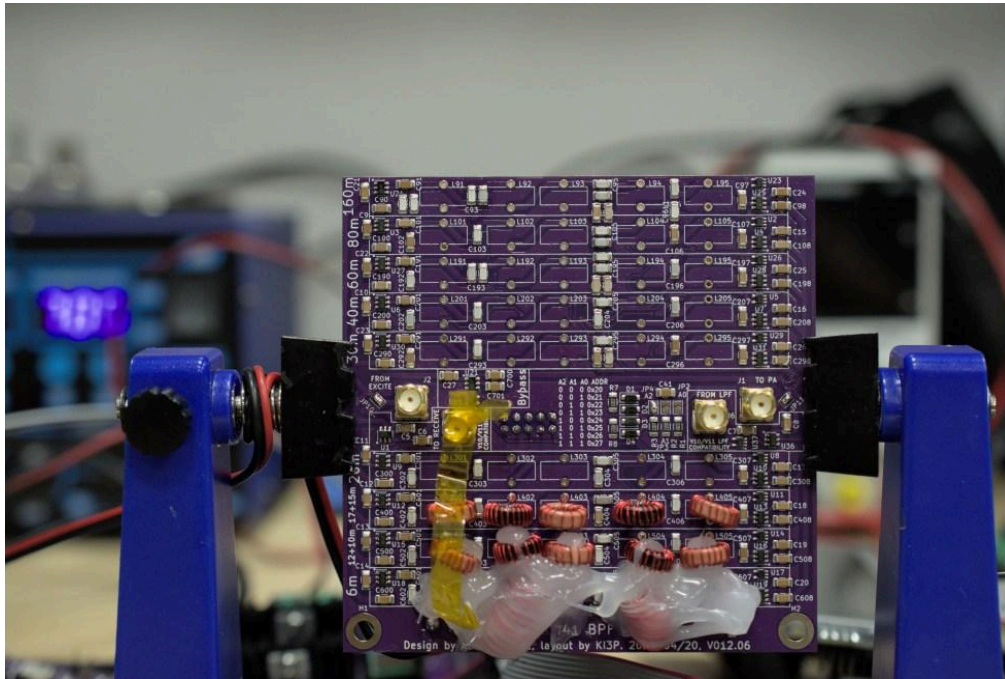
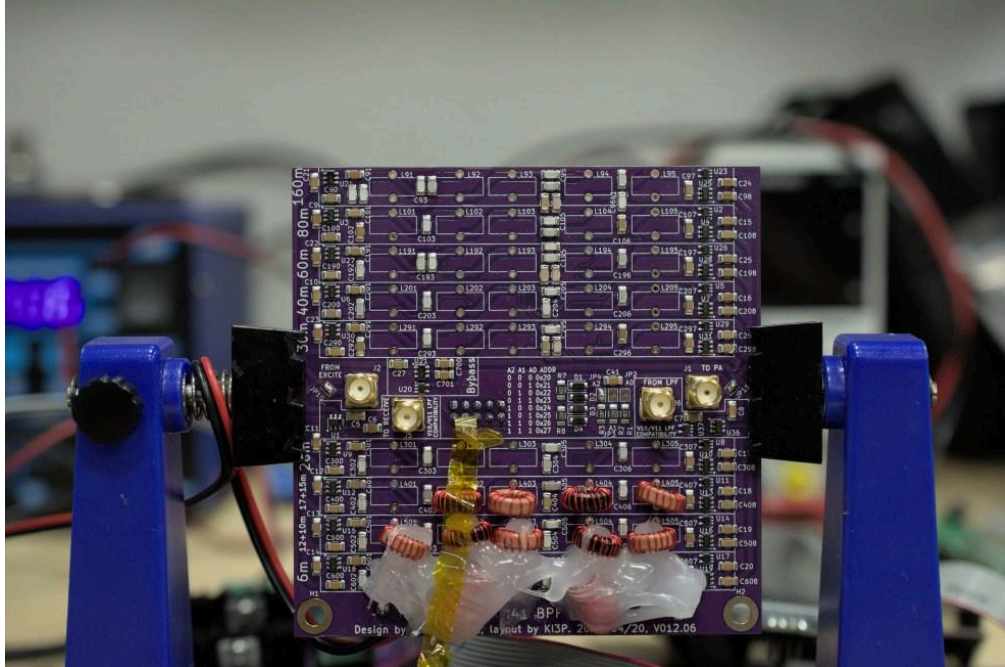
This looks like a mess but it works well and it's not going anywhere. Repeat for the next eight filters. Be sure to turn off the power supply and disconnect the BPF board from the main board before continuing.

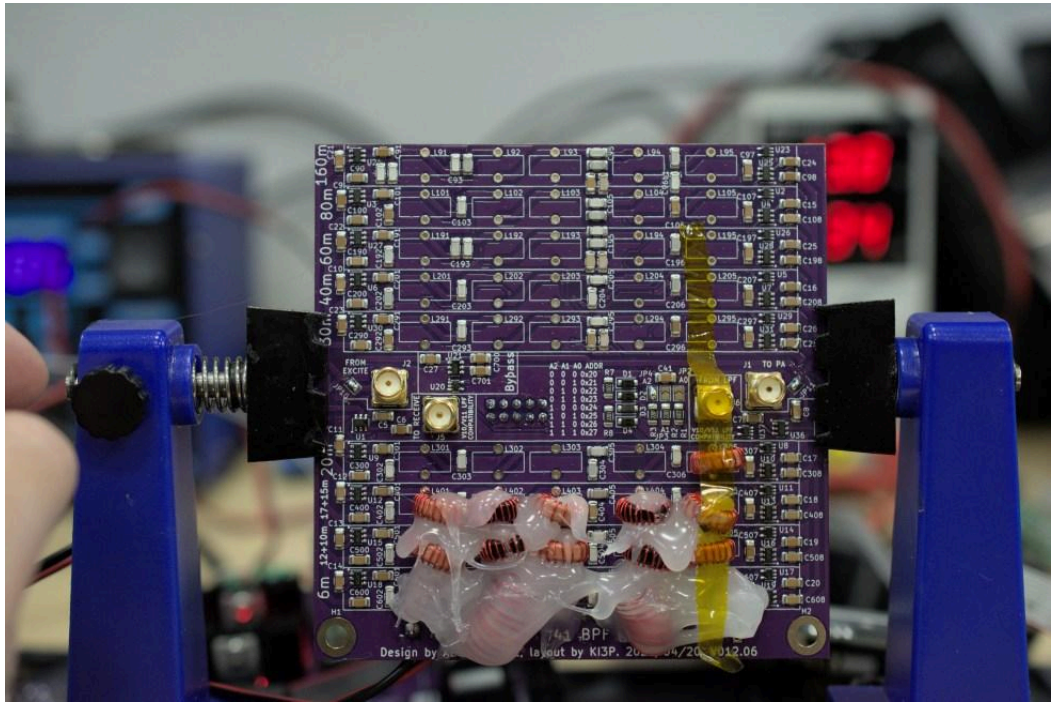
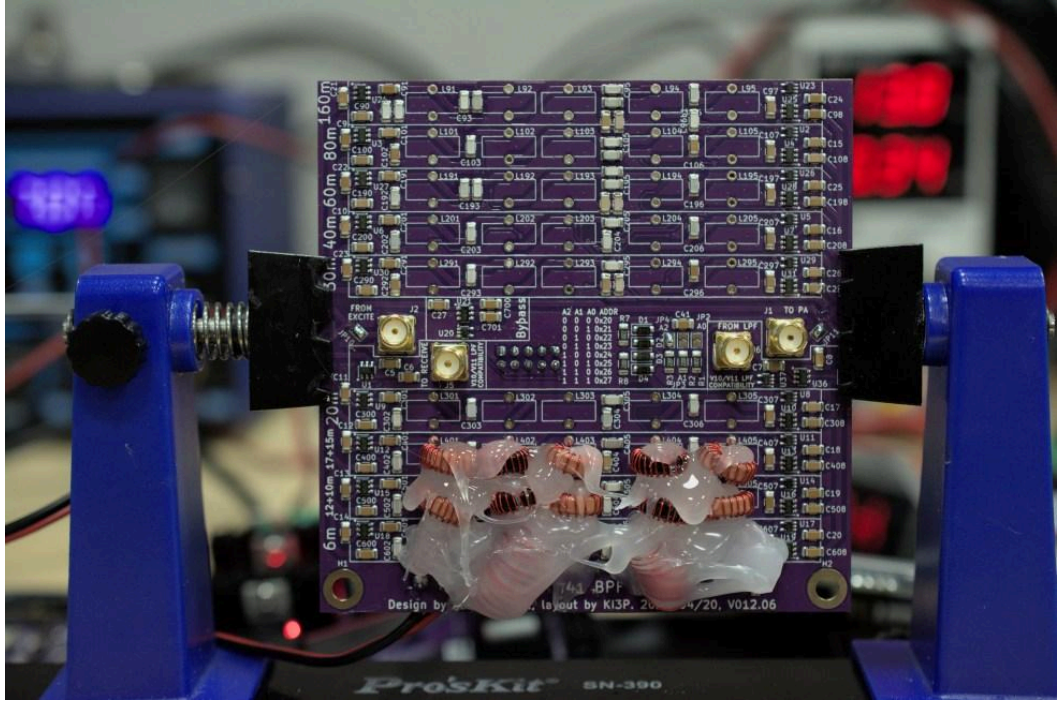


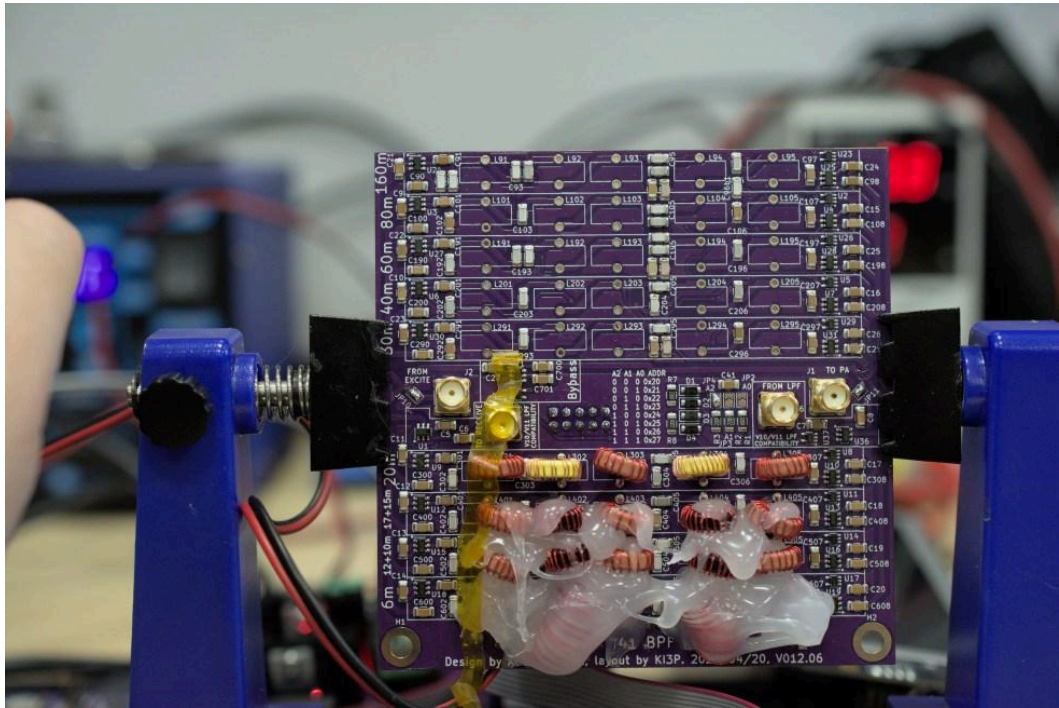
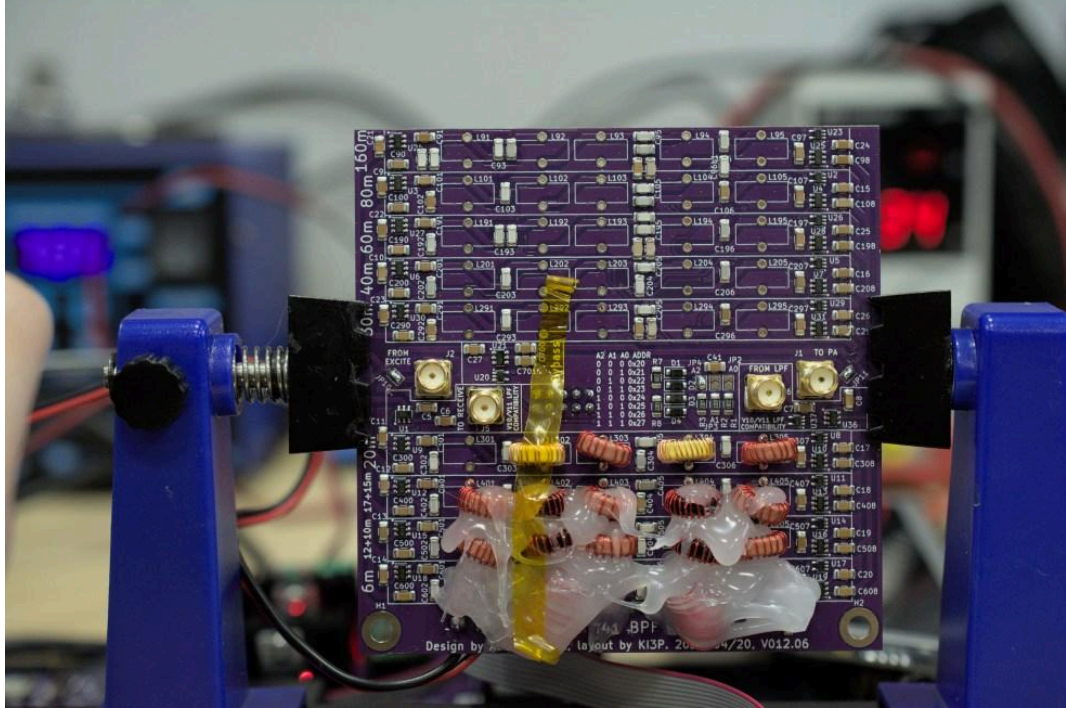
Toroidal inductors can be tuned by squeezing coils together around the core or spreading them out. There's quite a bit of play in the coils for the higher bands. Test and tune each filter before potting it with hot melt glue to prevent movement. Losses of around 3.5dB are good for this type of filter, better performance is possible for the lower bands.

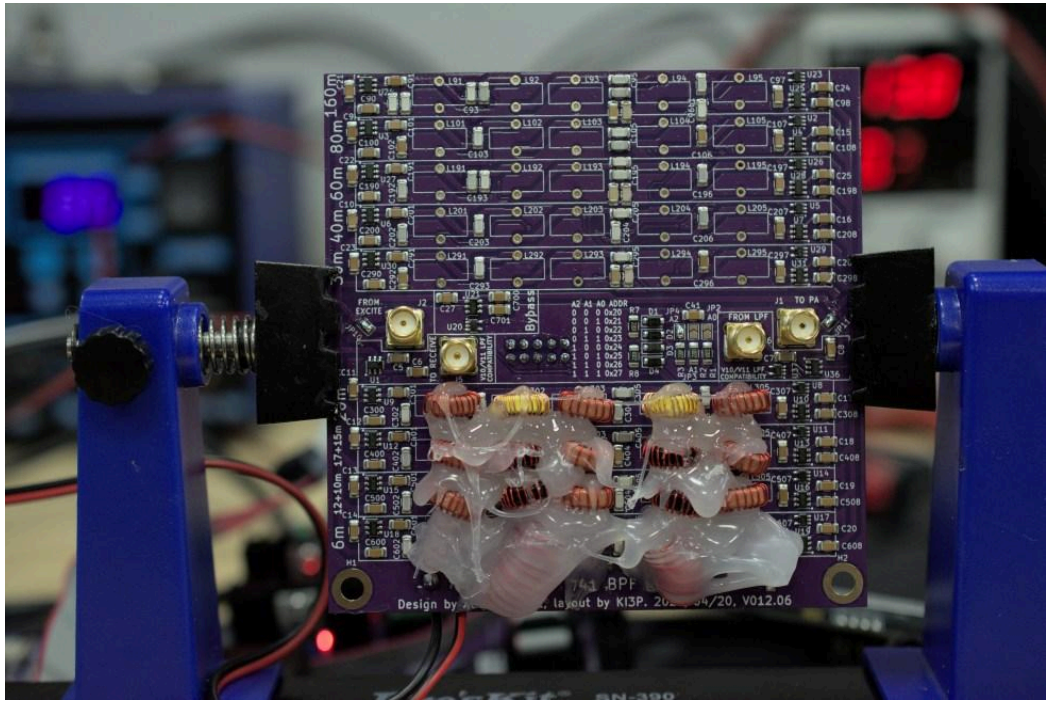
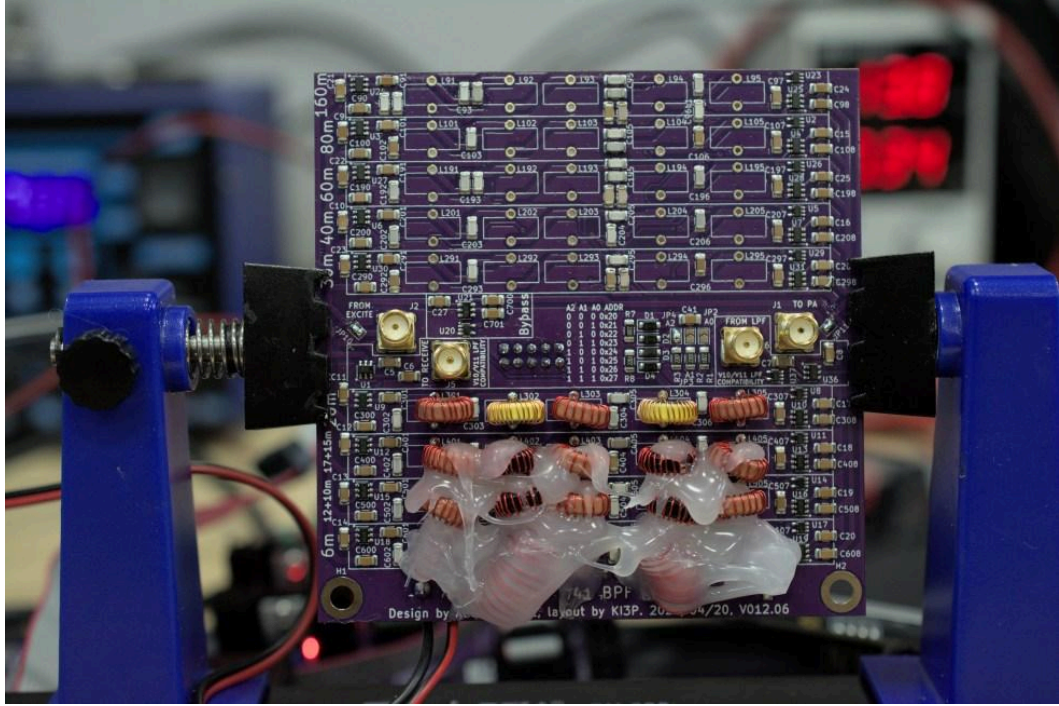


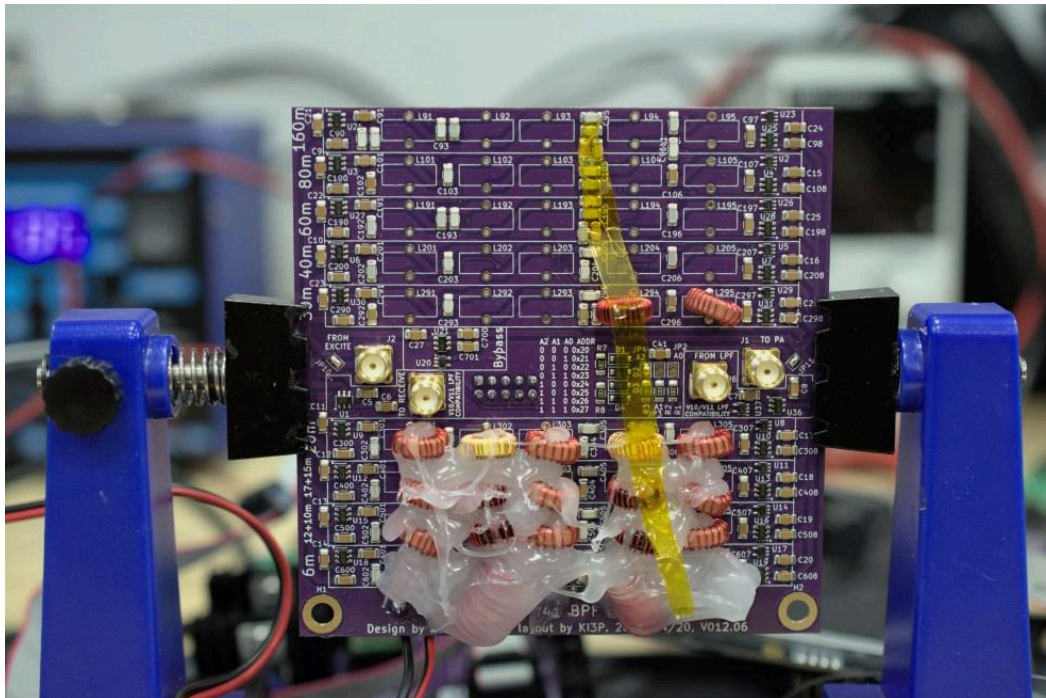
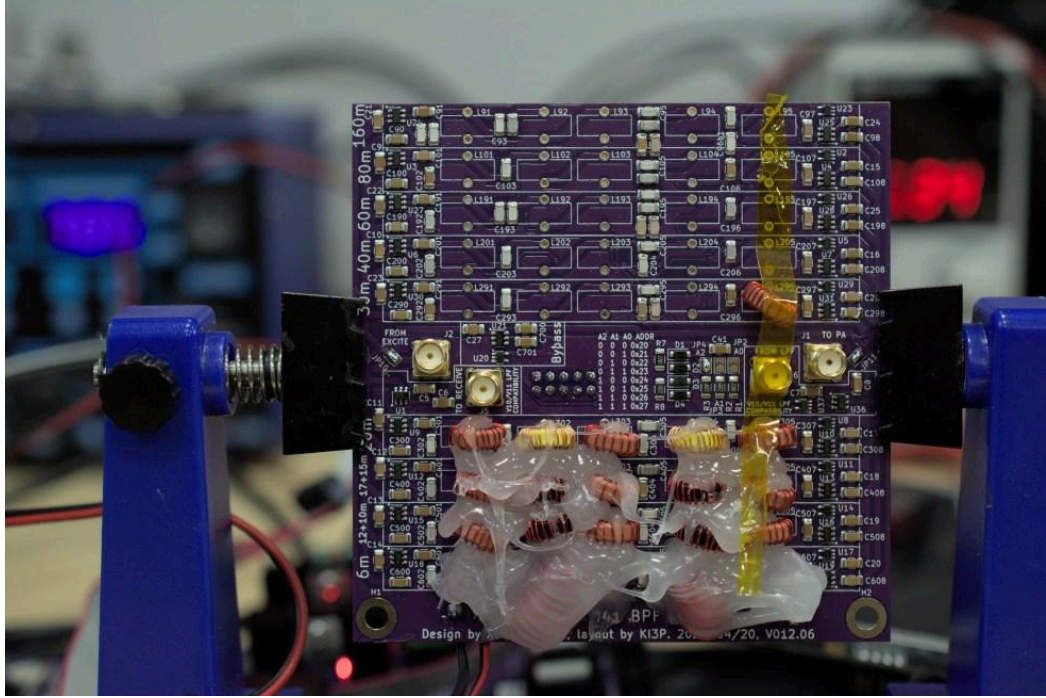


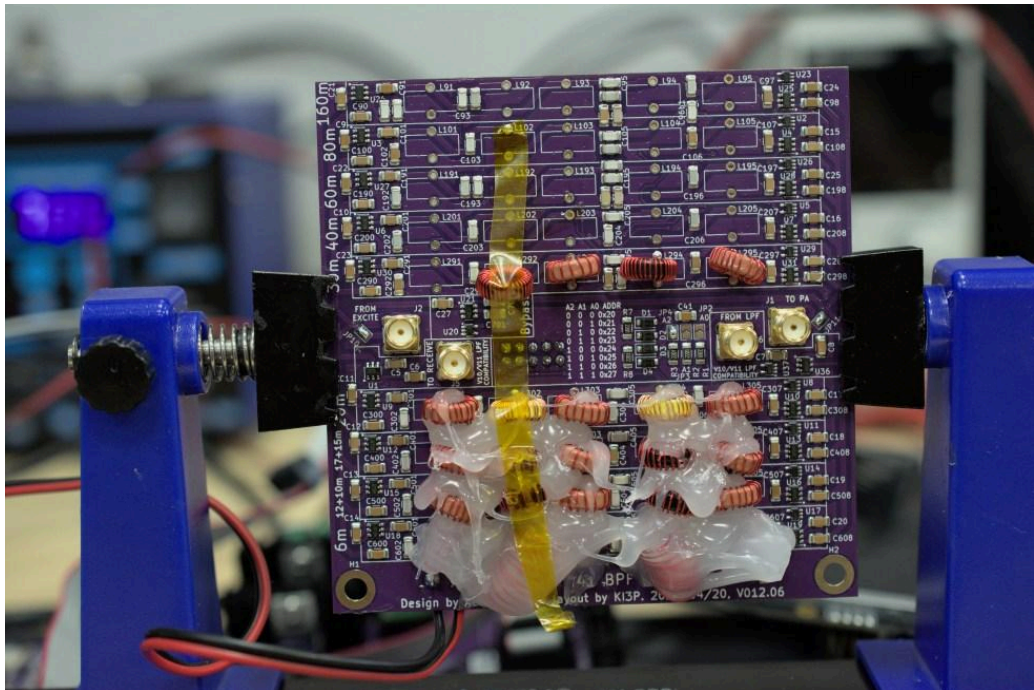
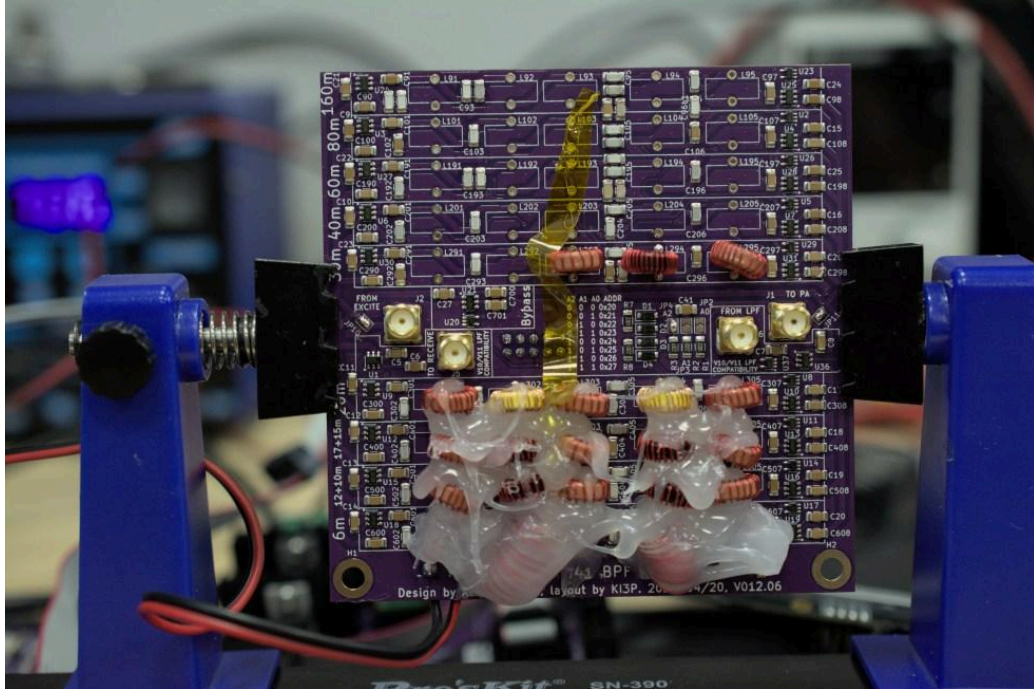


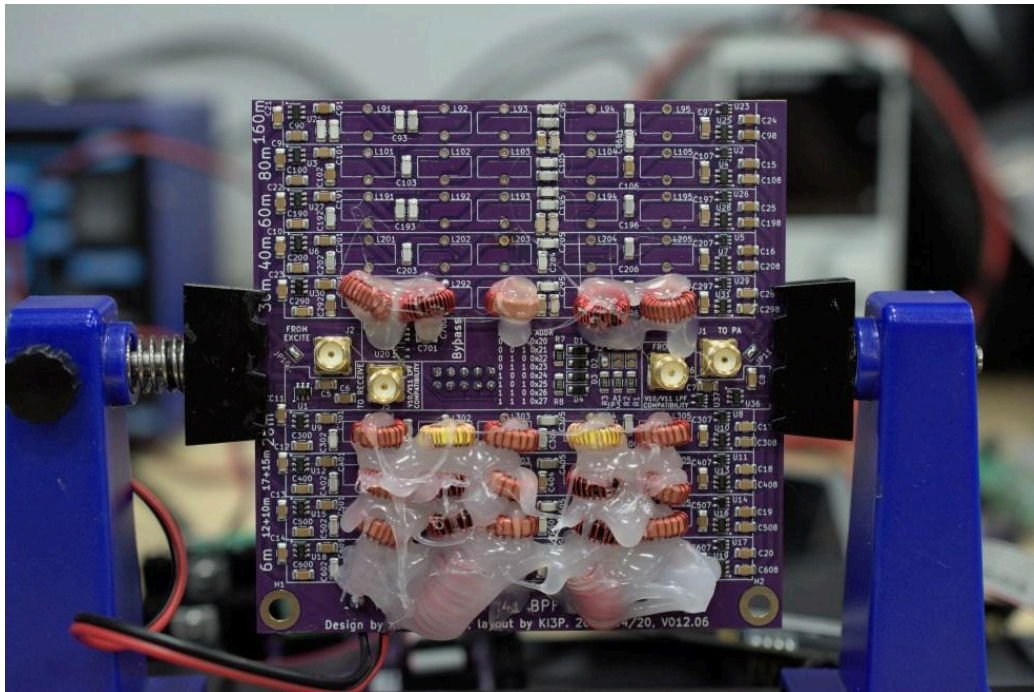
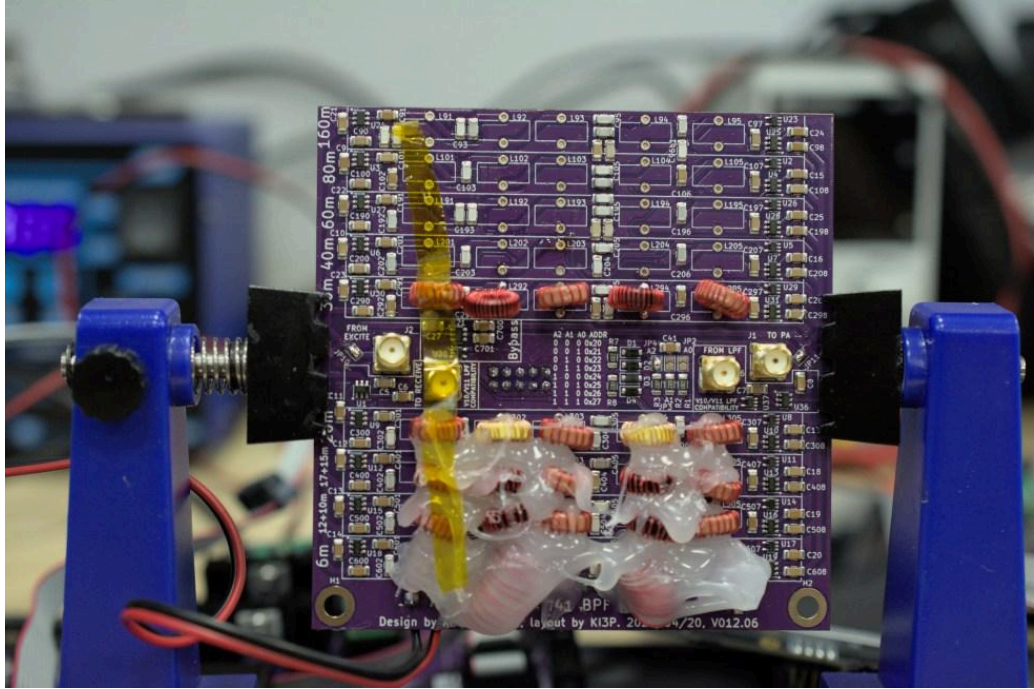


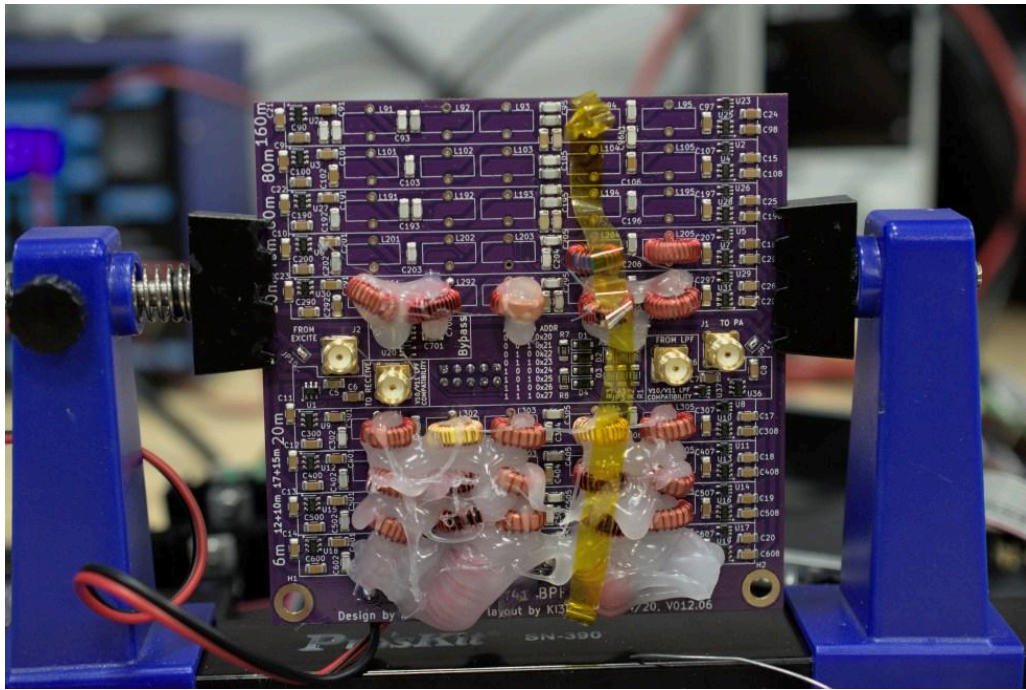
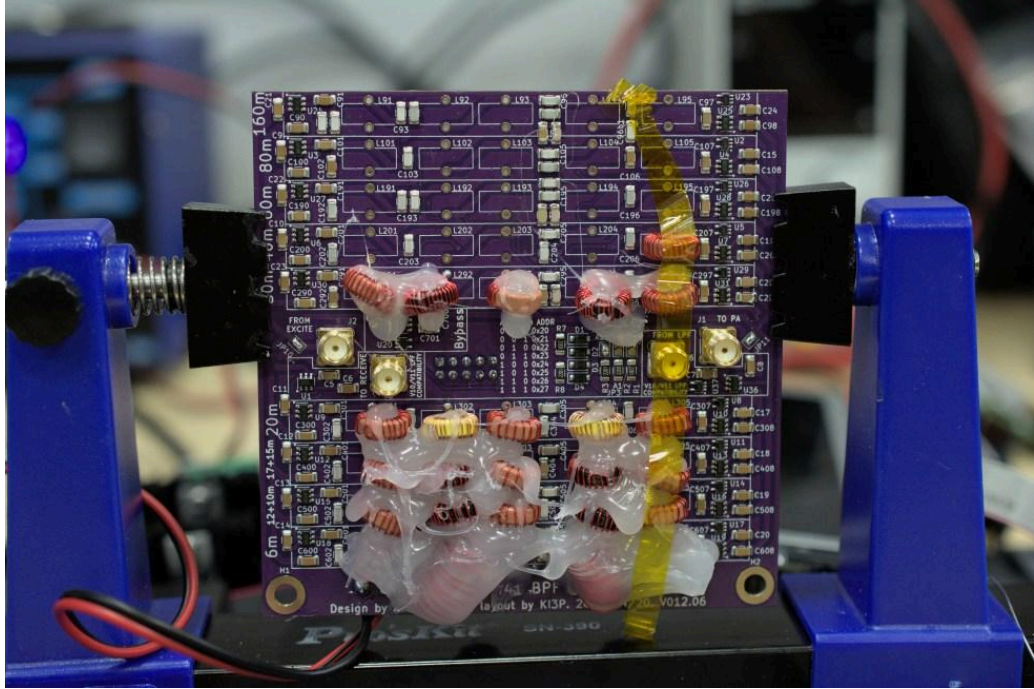


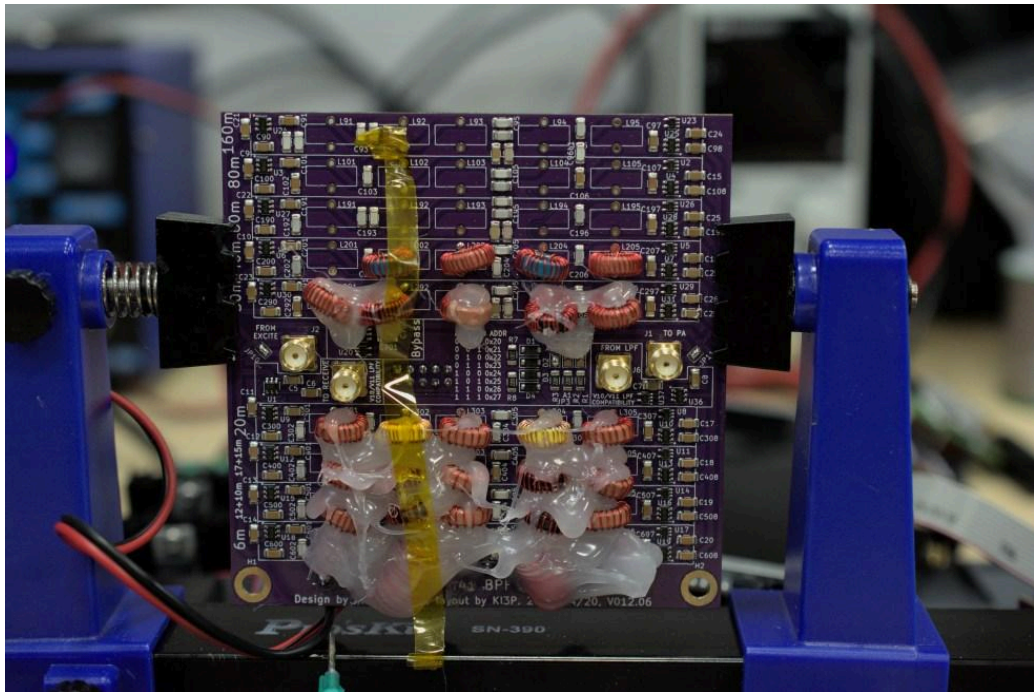
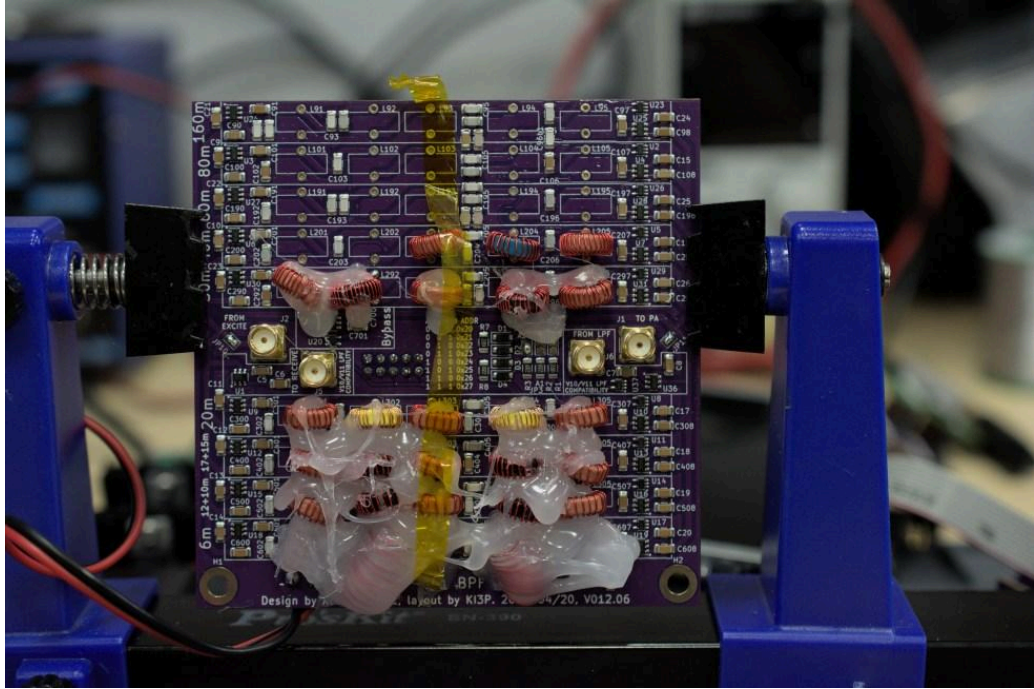


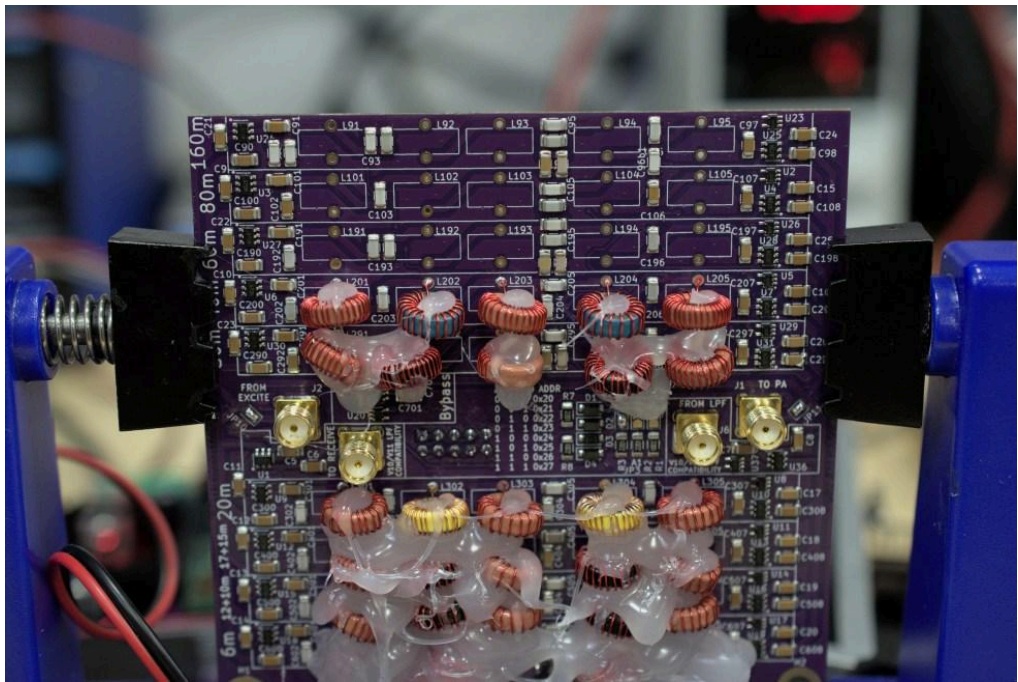
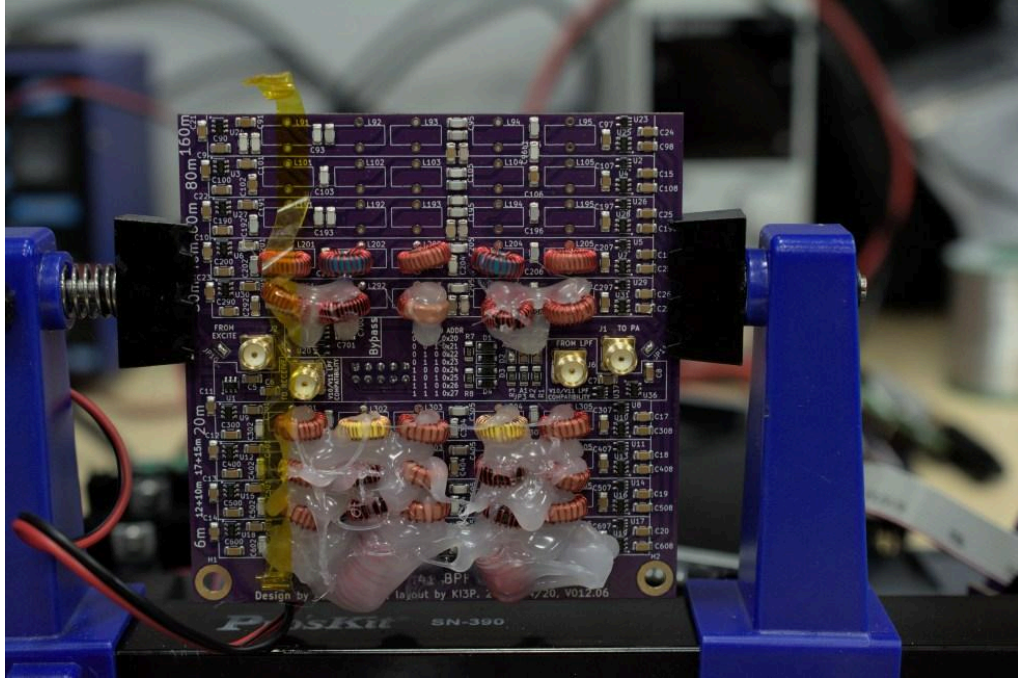


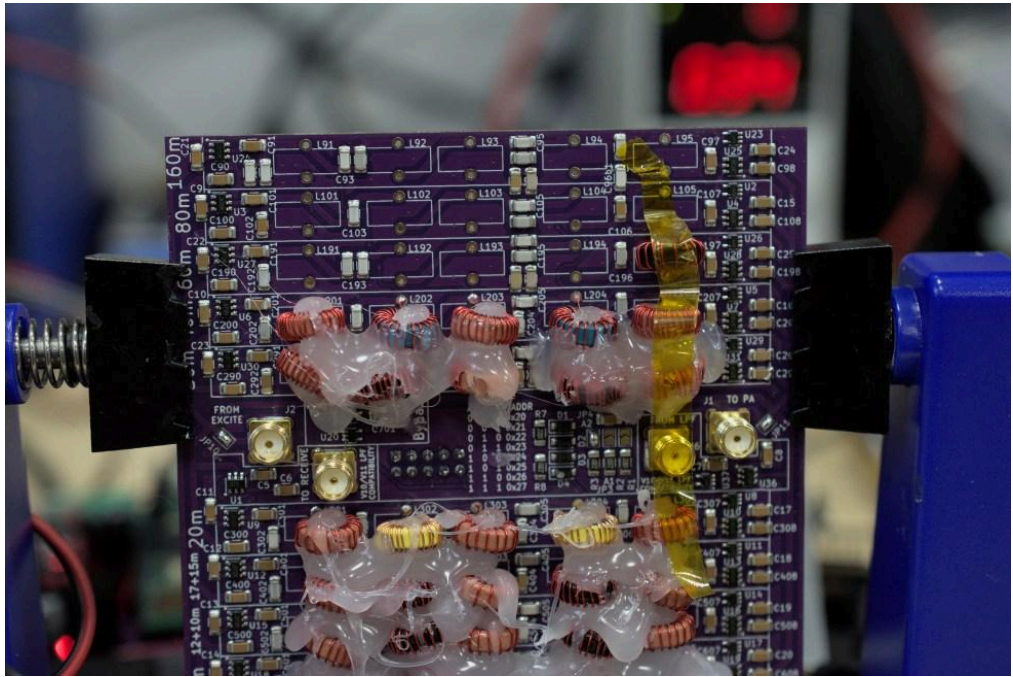
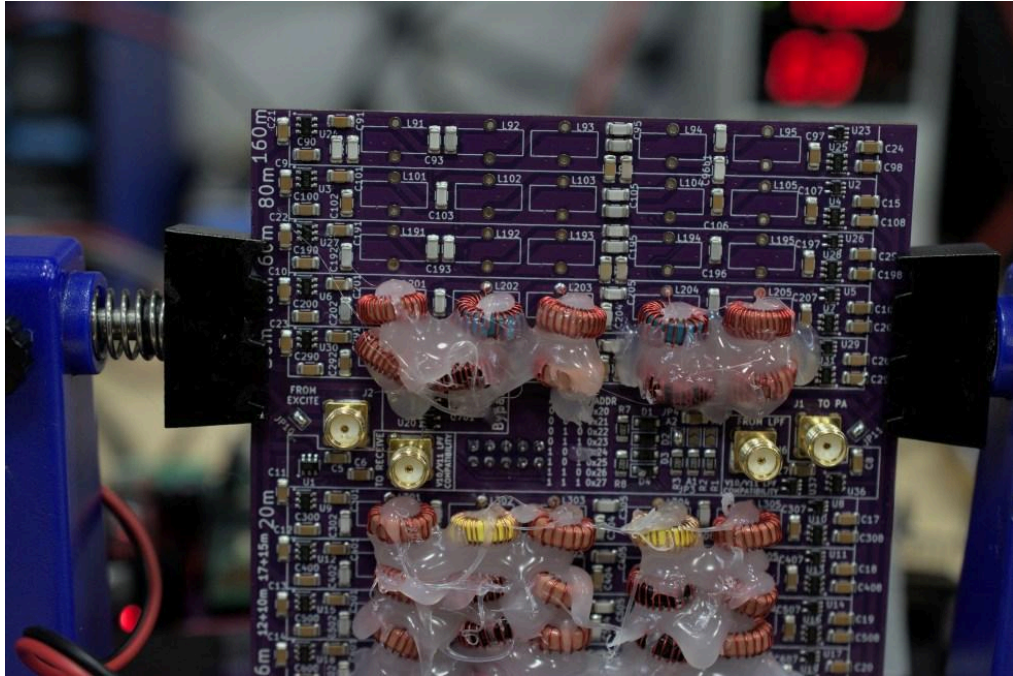


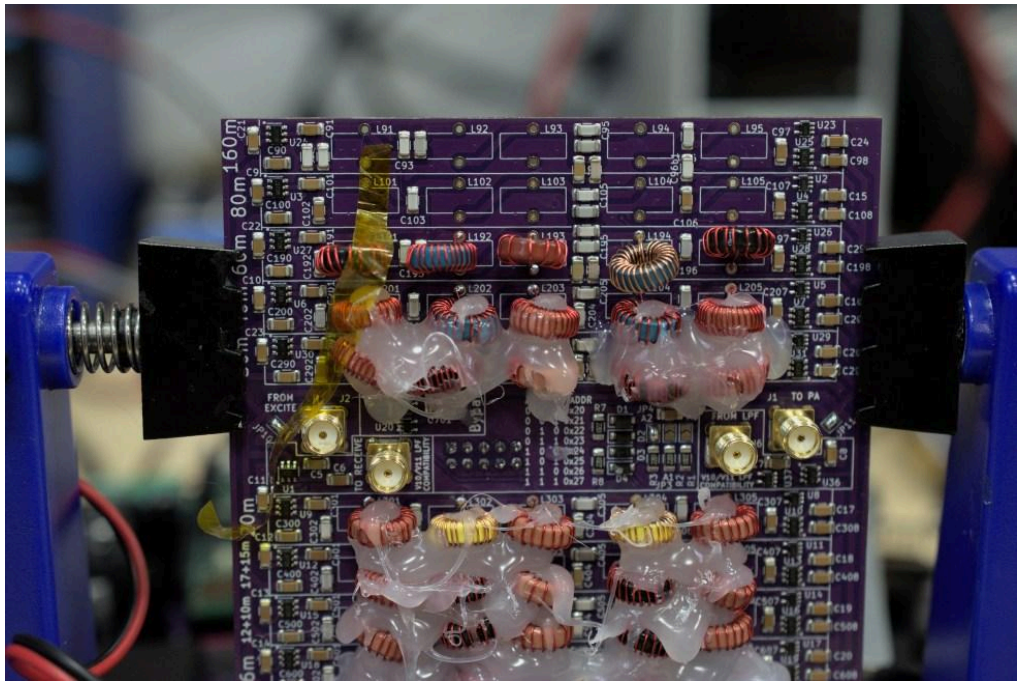
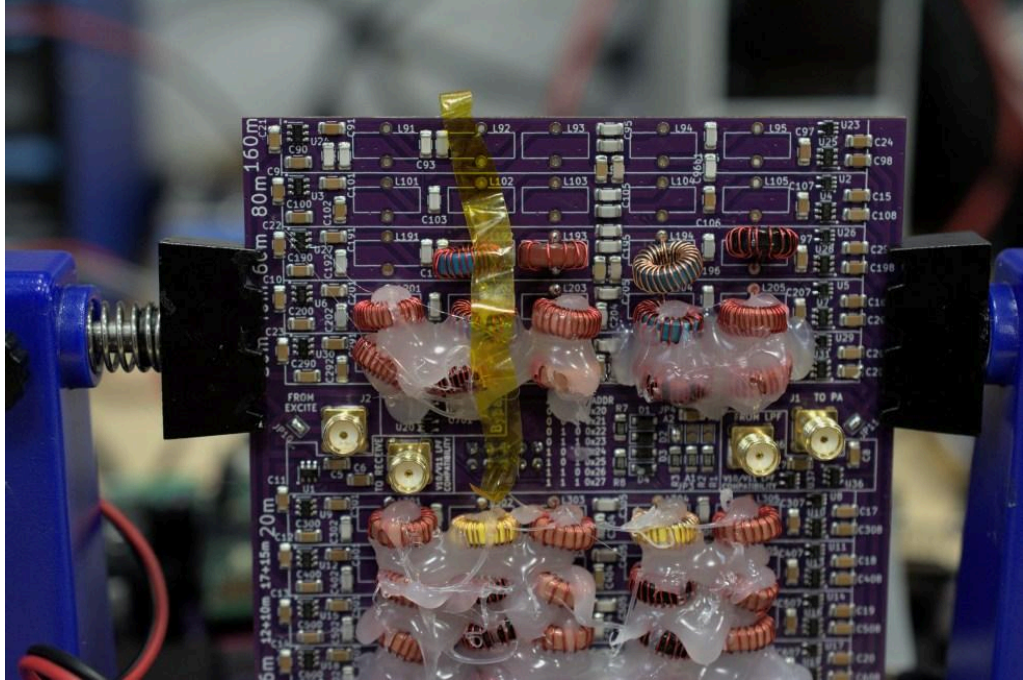


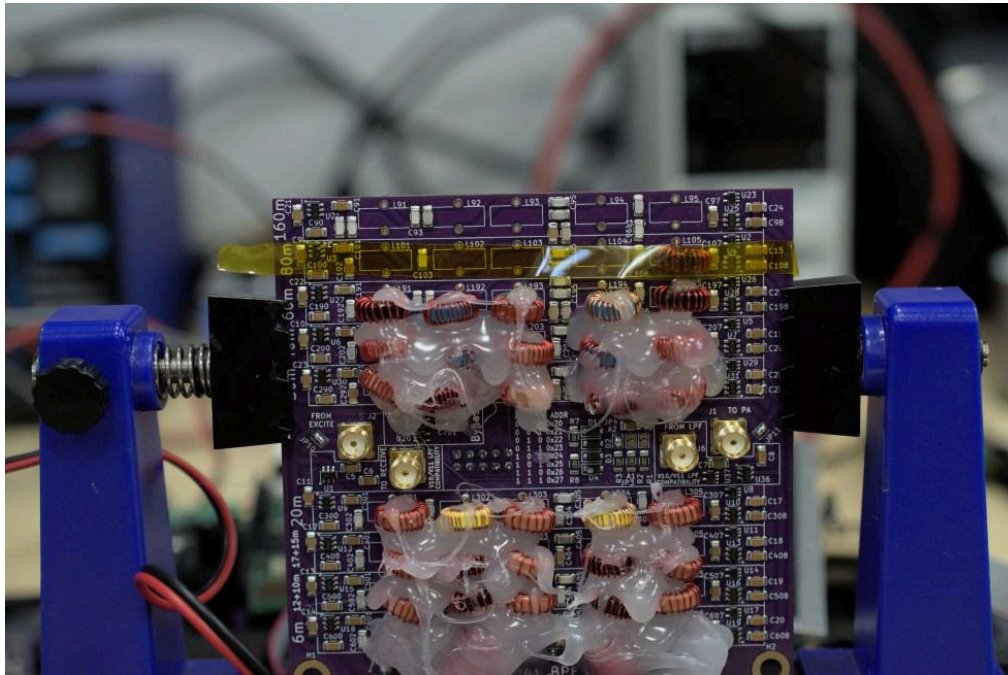
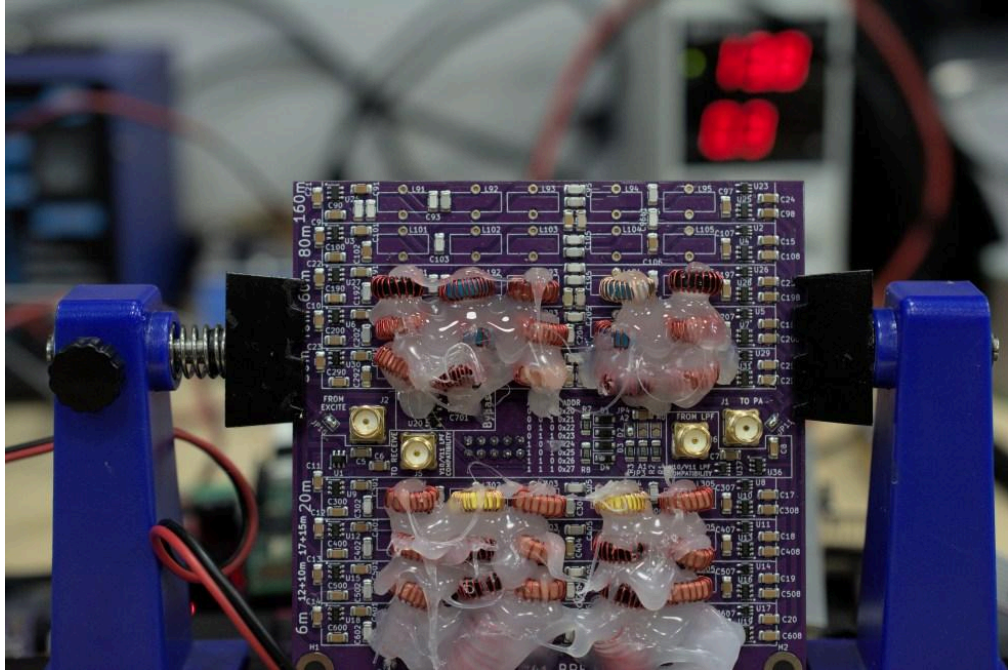


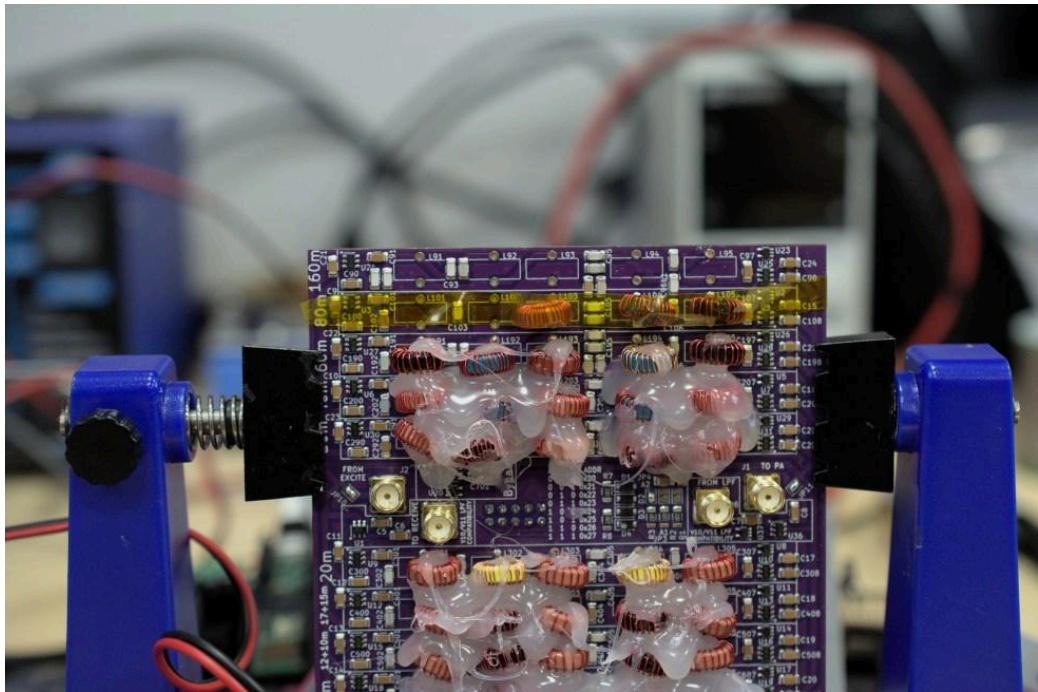
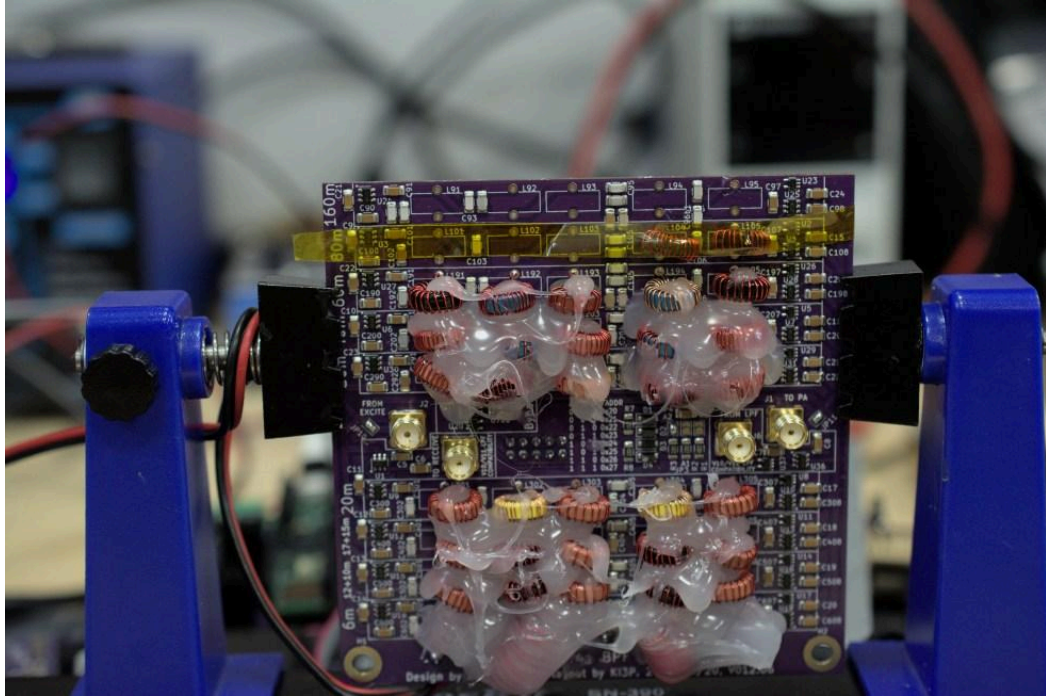


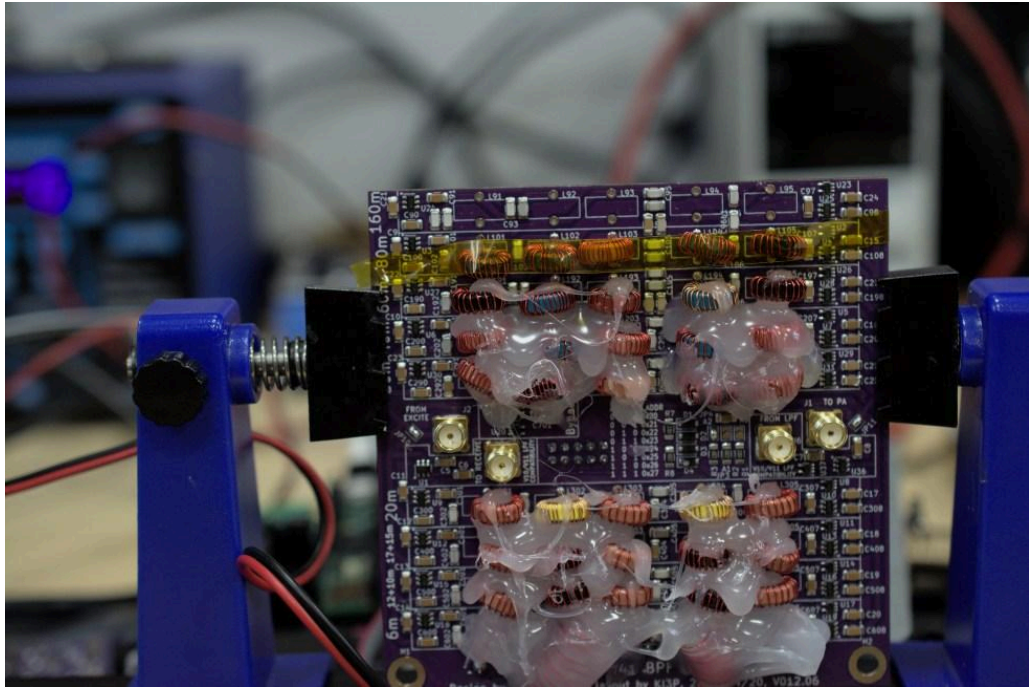
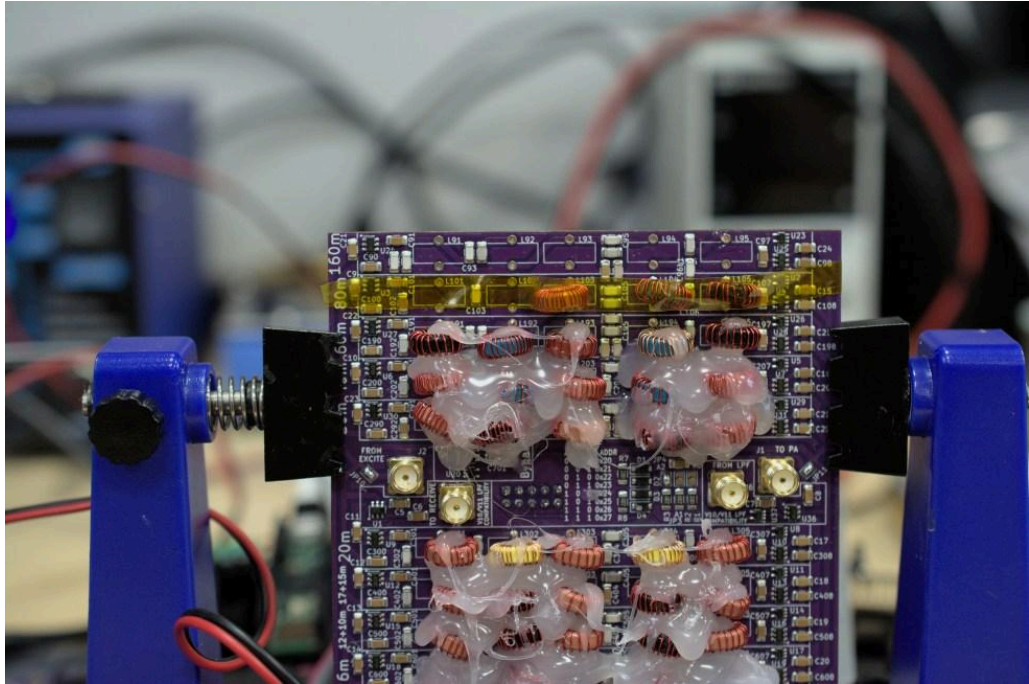


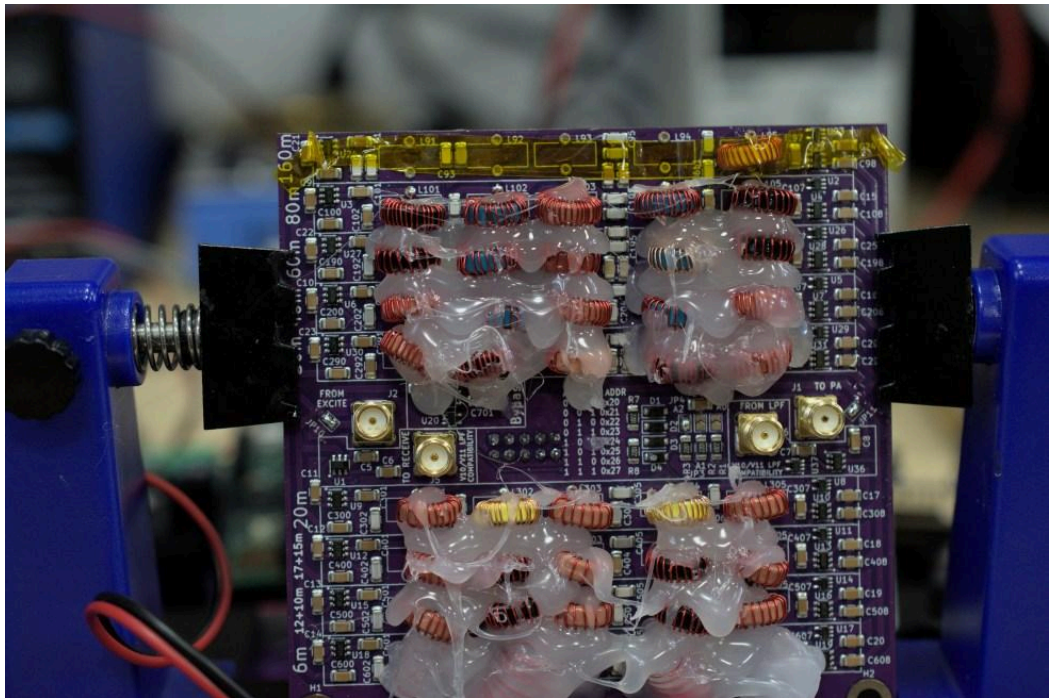
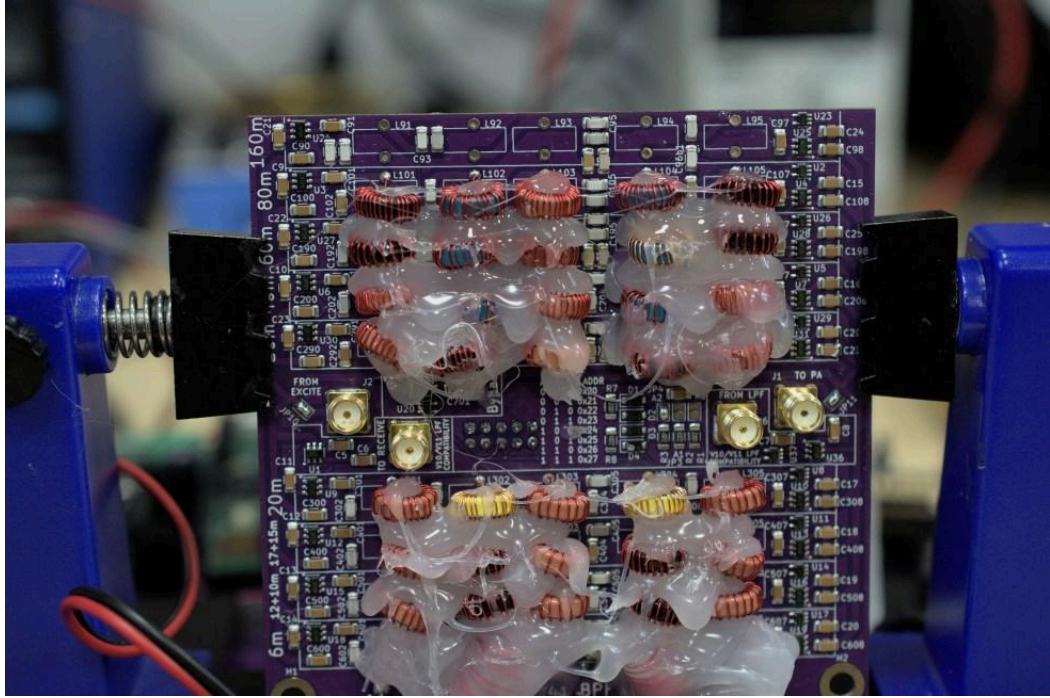


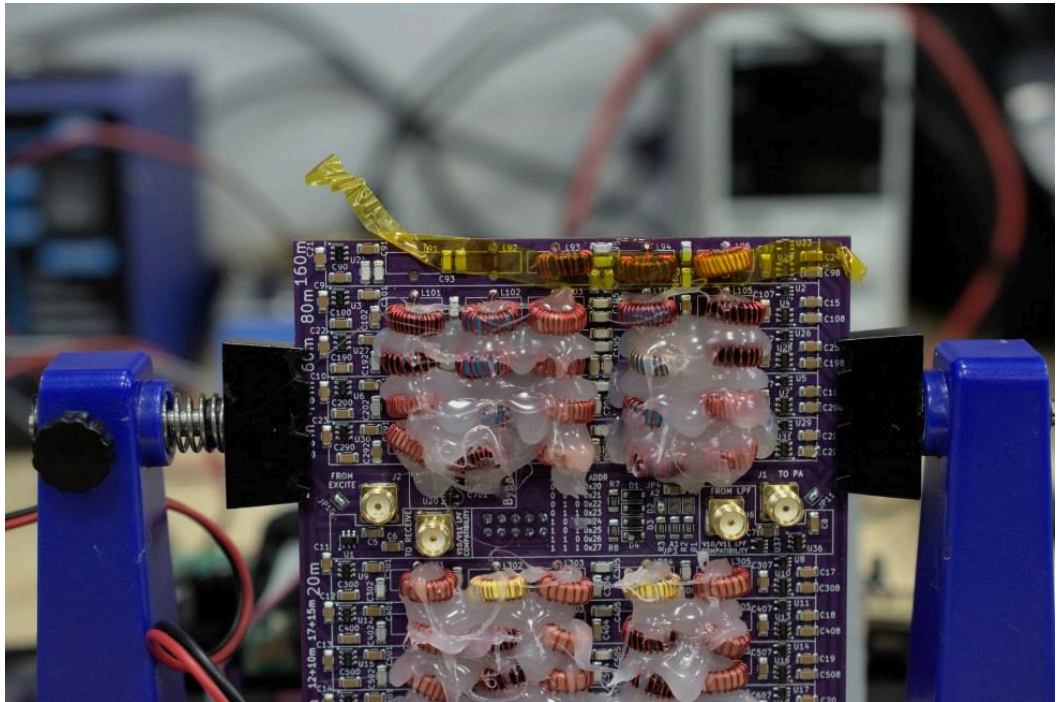
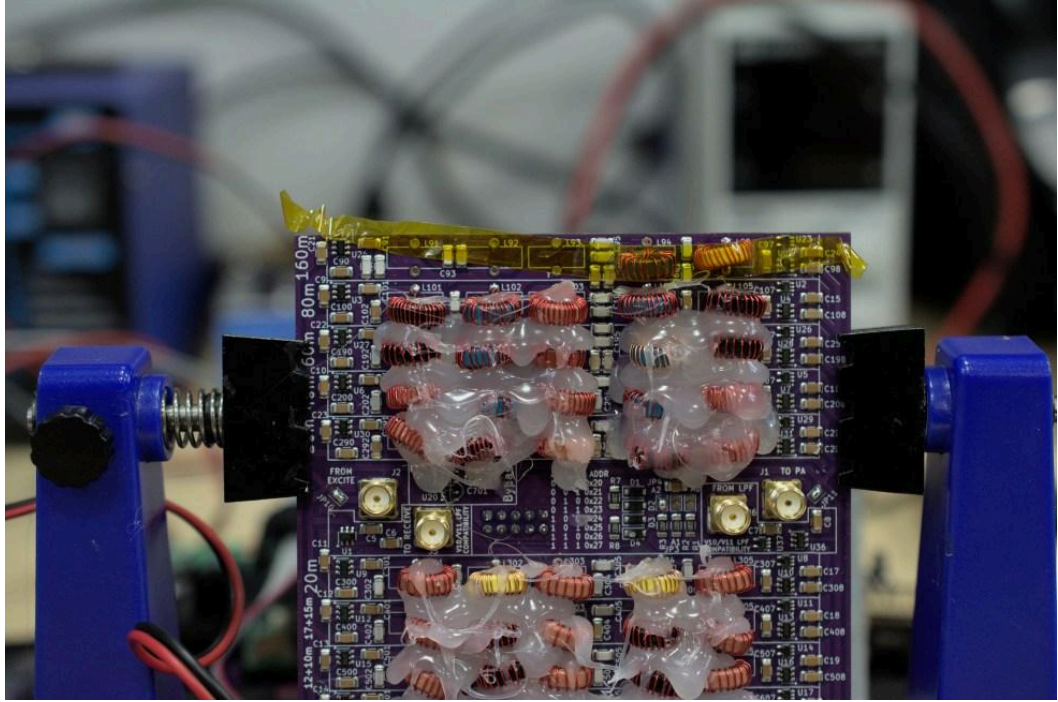


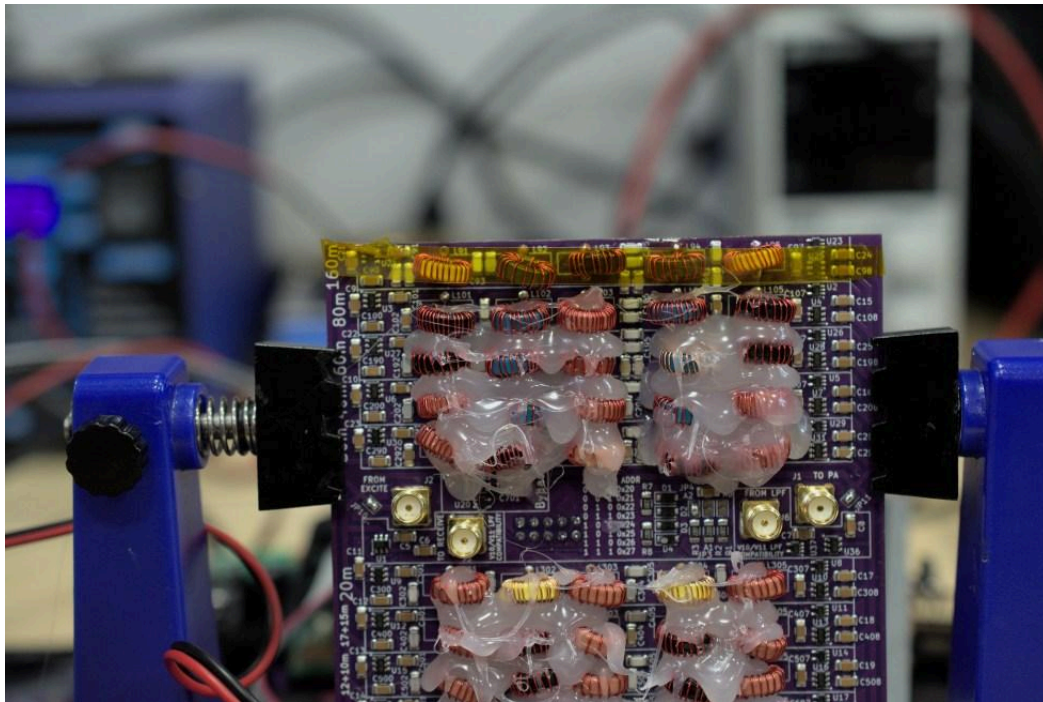
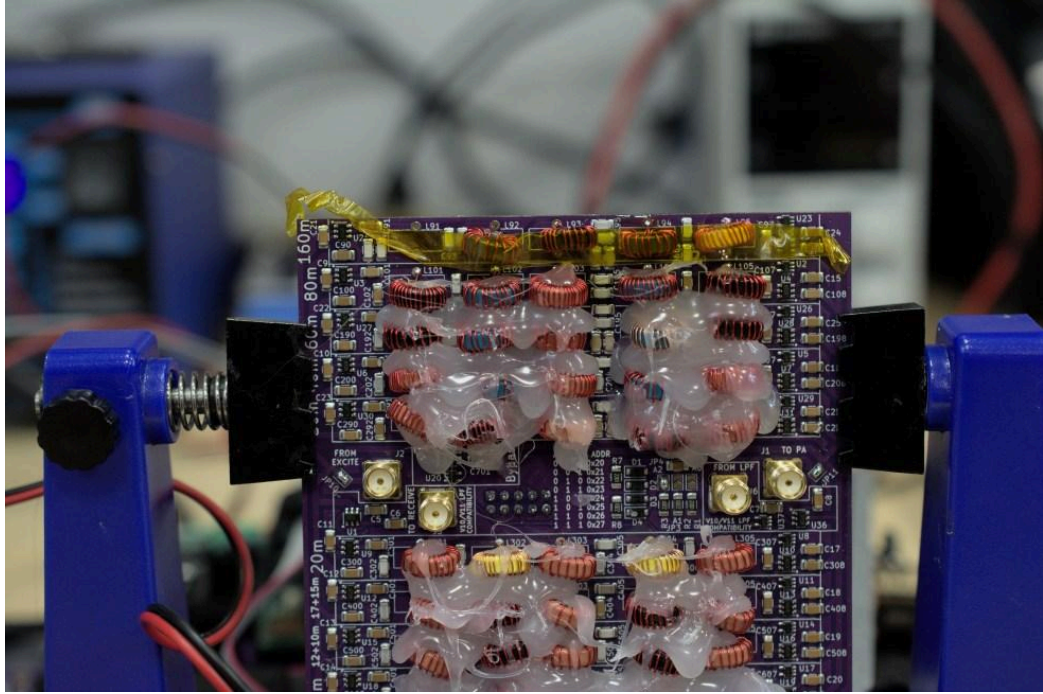


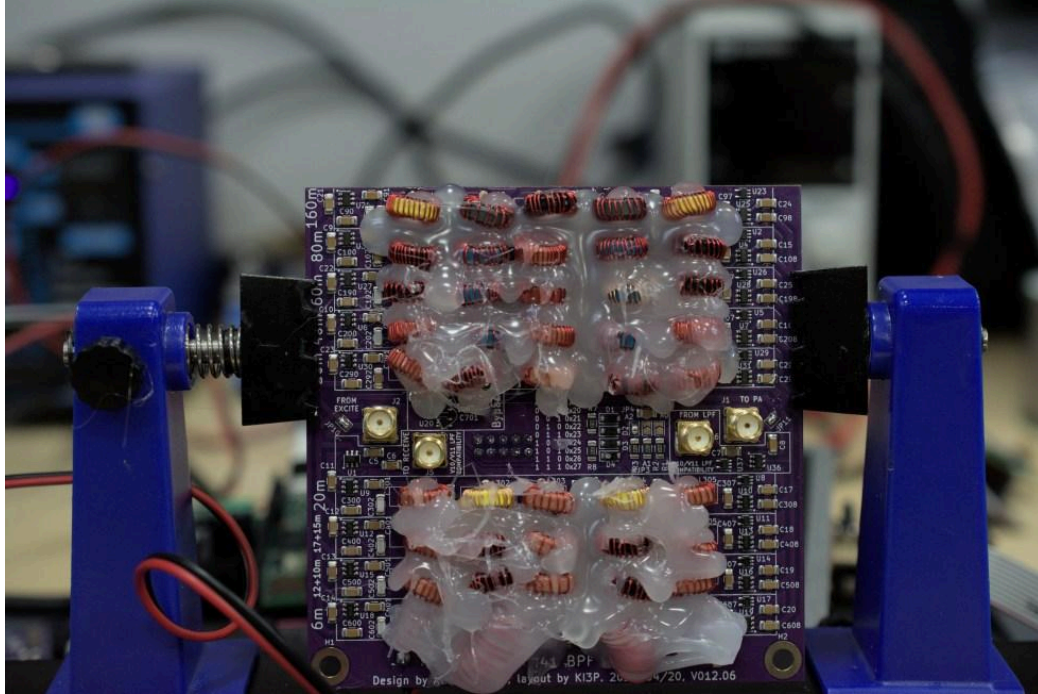




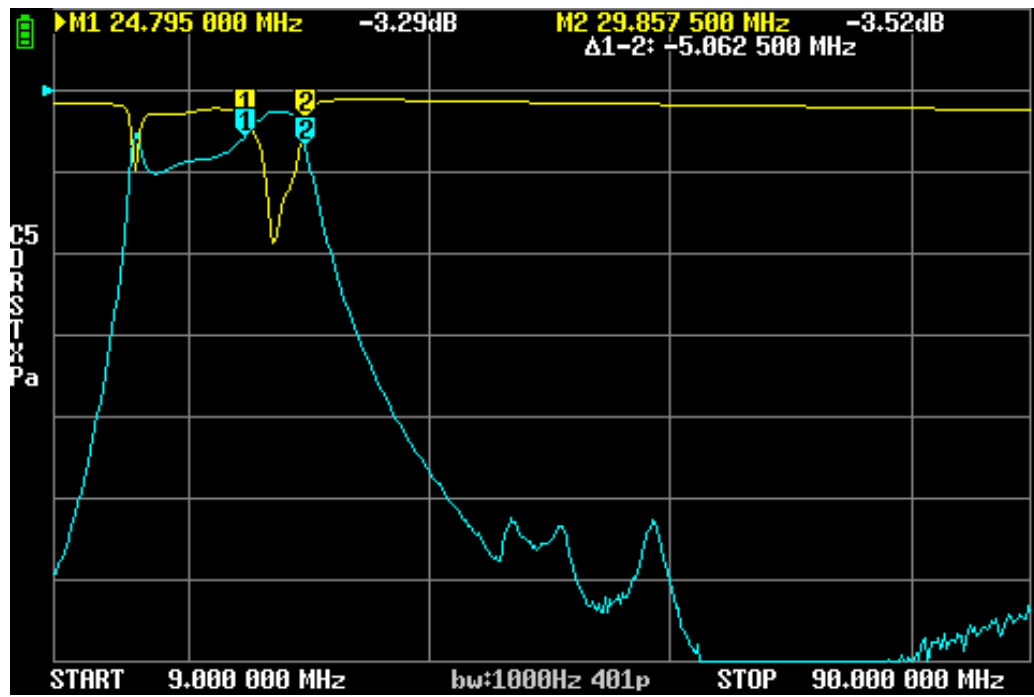
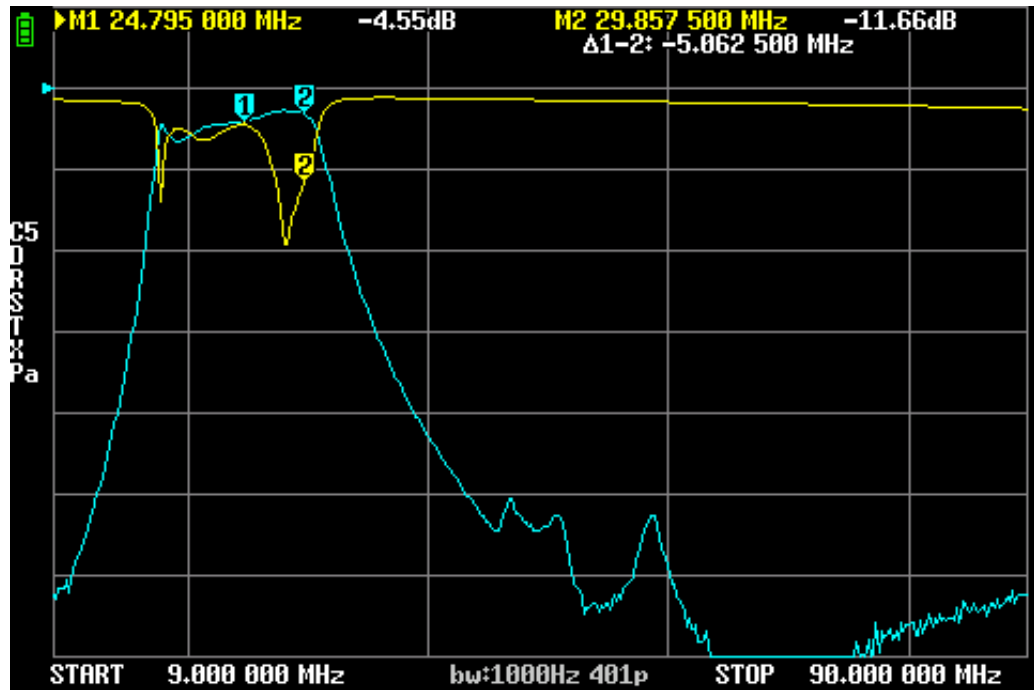


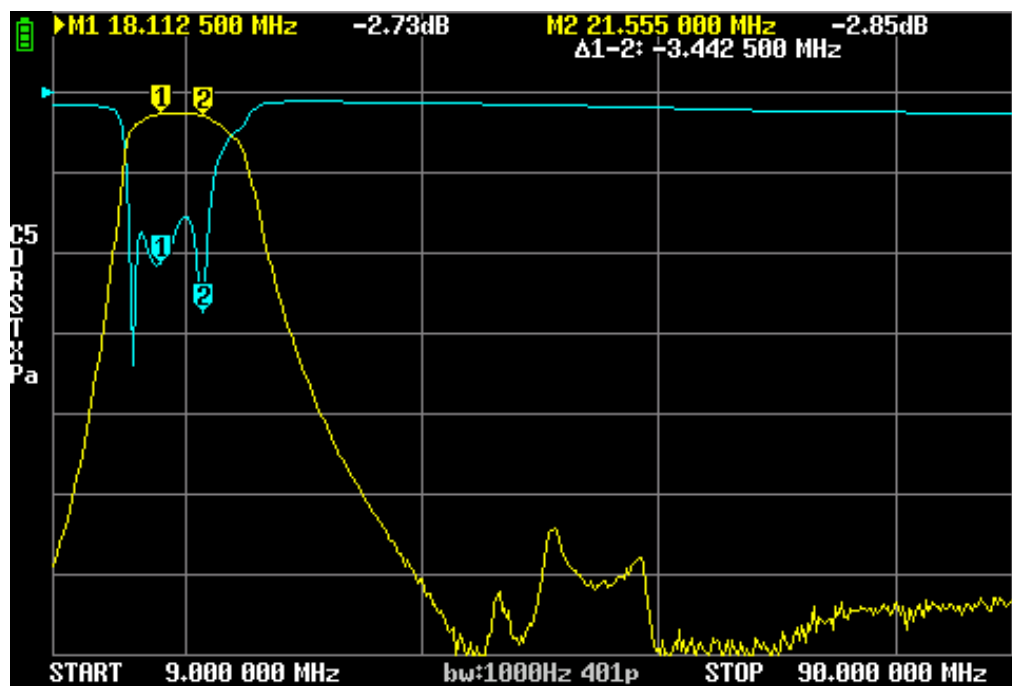
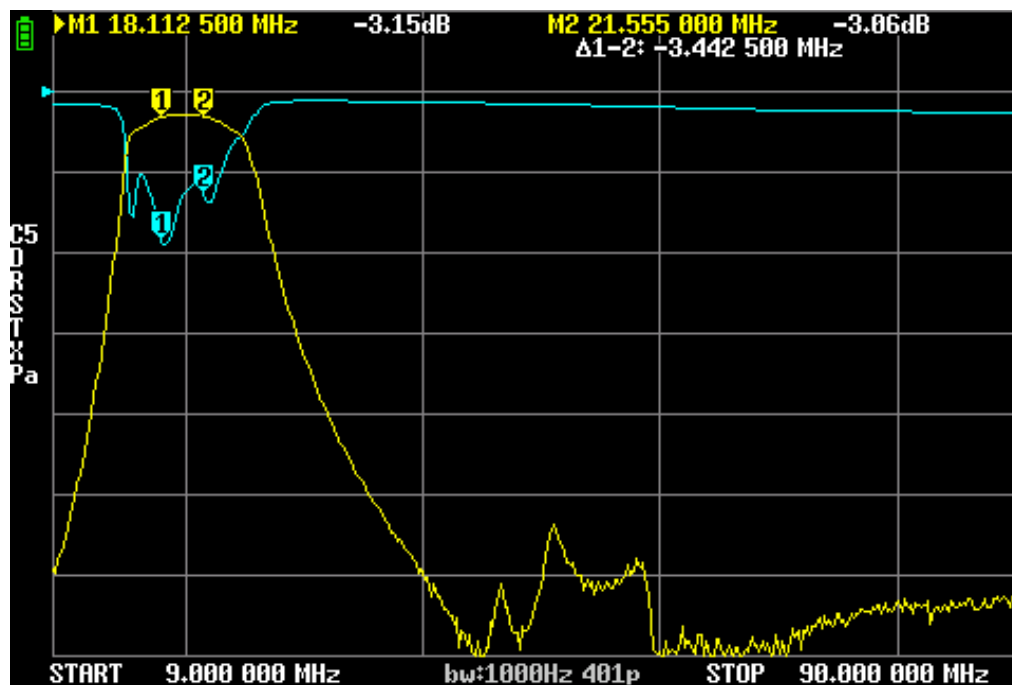


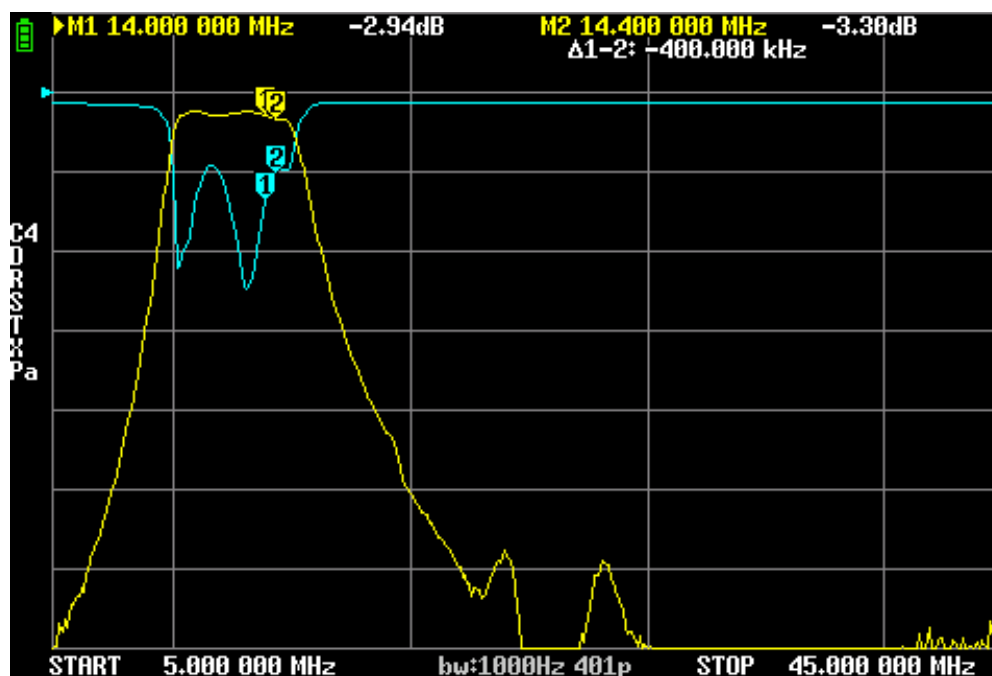
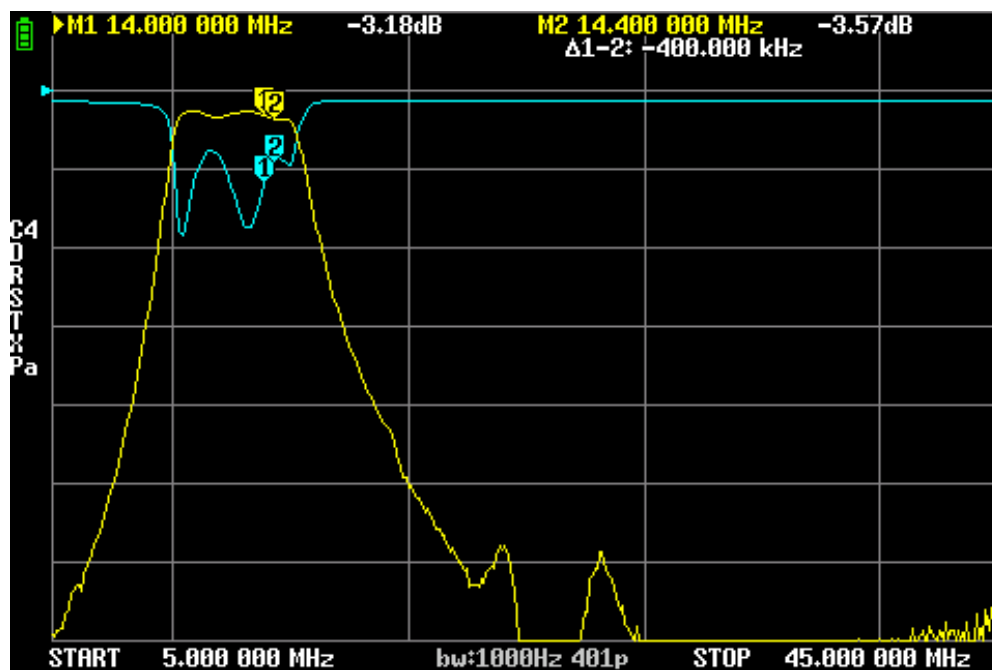


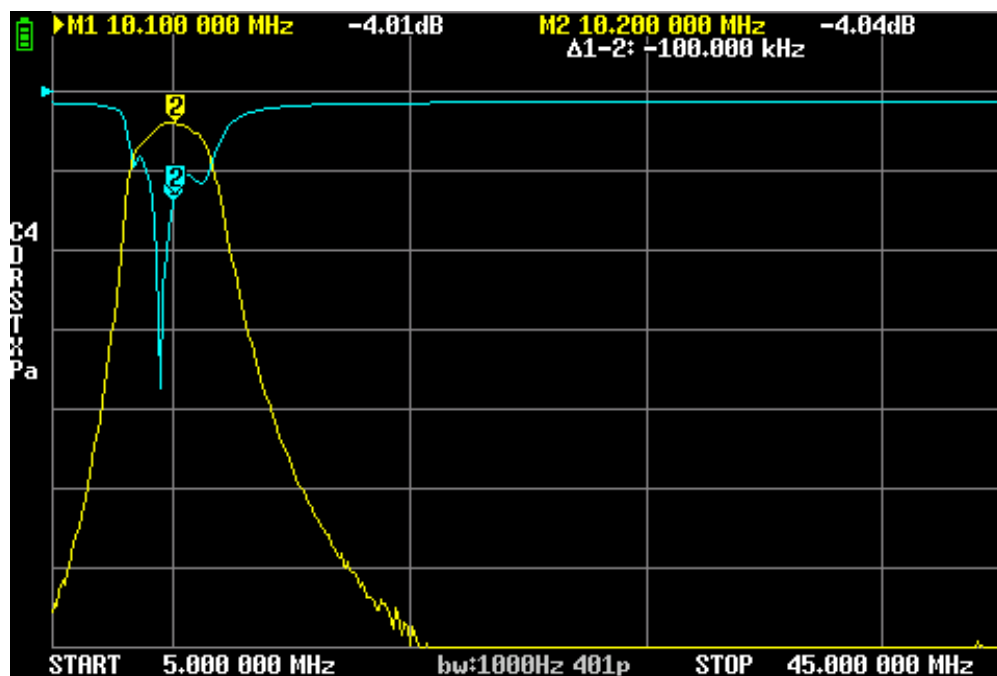
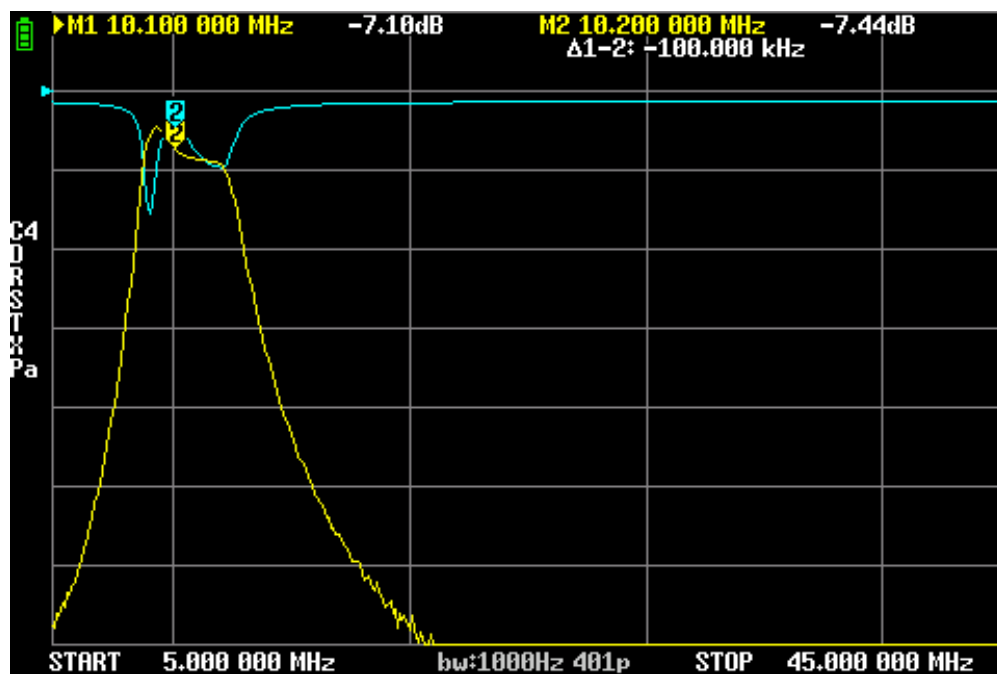


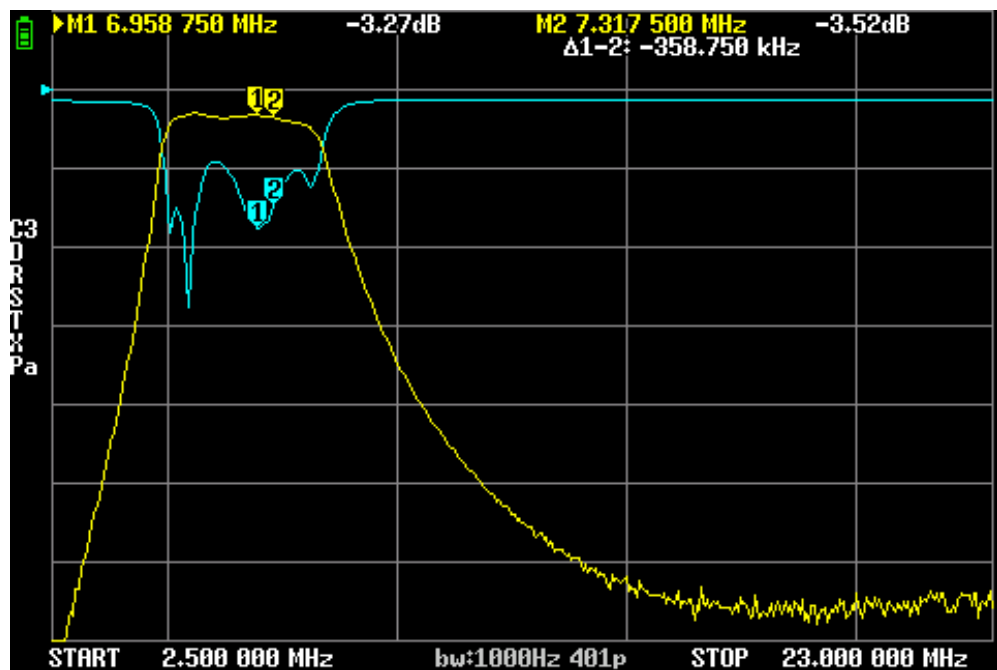
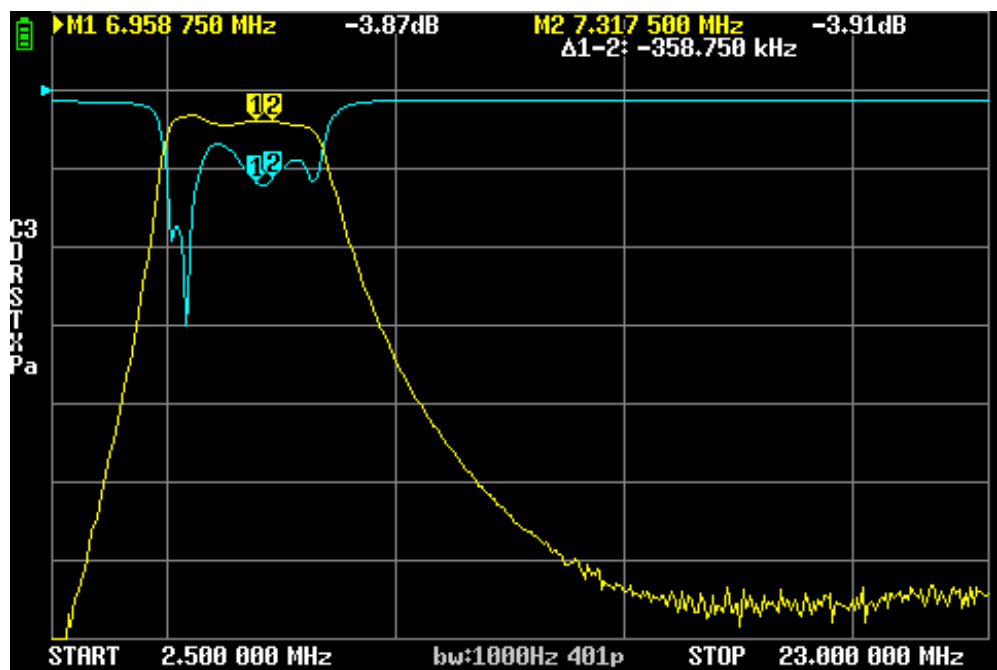
As you move to the lower band filters less tuning will be necessary and in some cases little tuning will be possible. The gallery below shows the initial performance of each of my filters and the performance which was achieved with tuning. Some bands are better than others but all are acceptable to me. Practically speaking this is about as good as these filters can get without reworking the capacitors on each board.

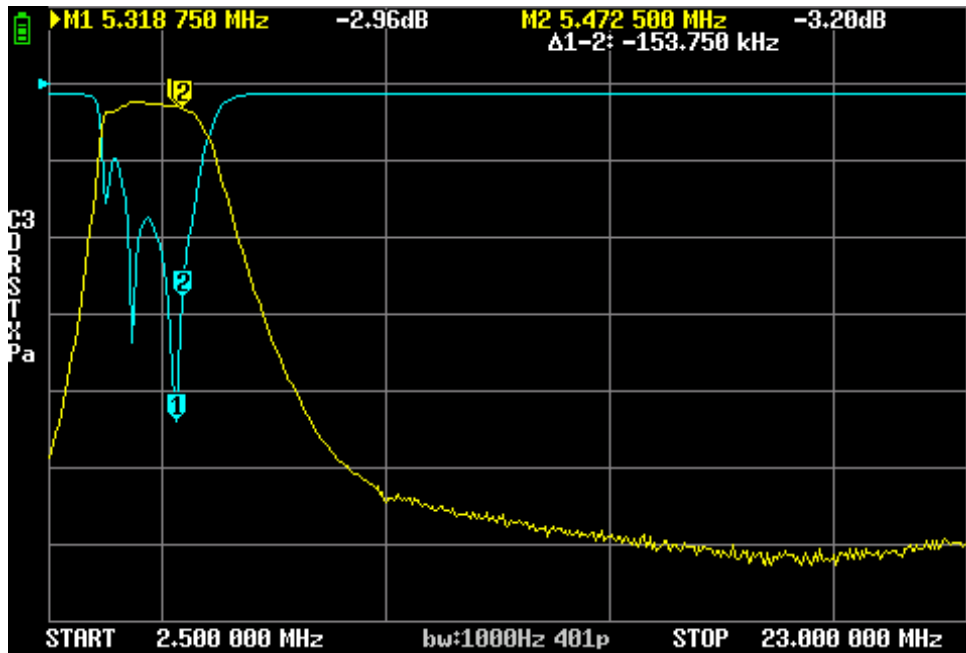
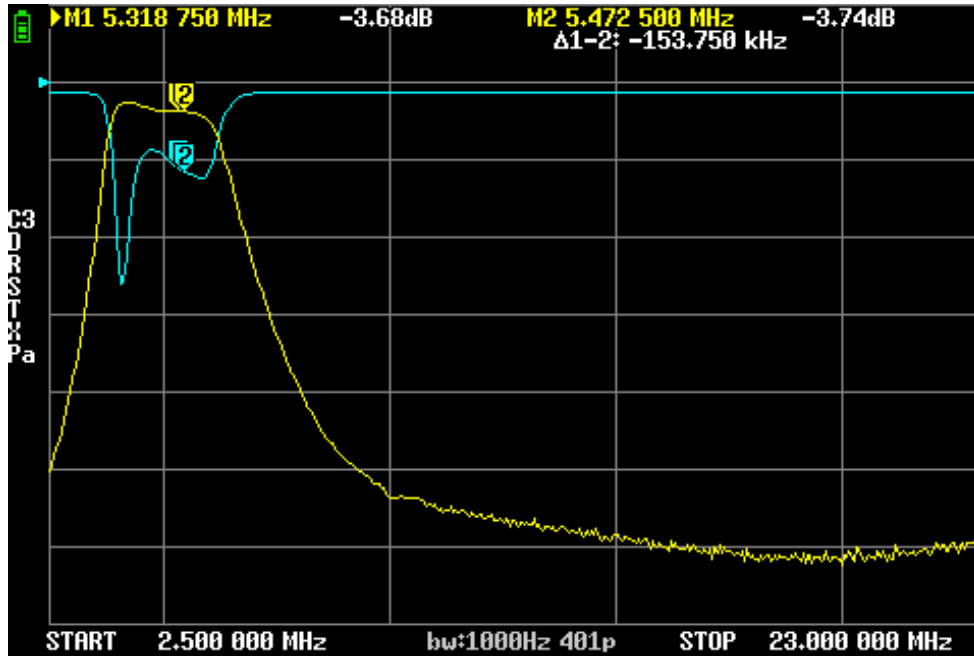


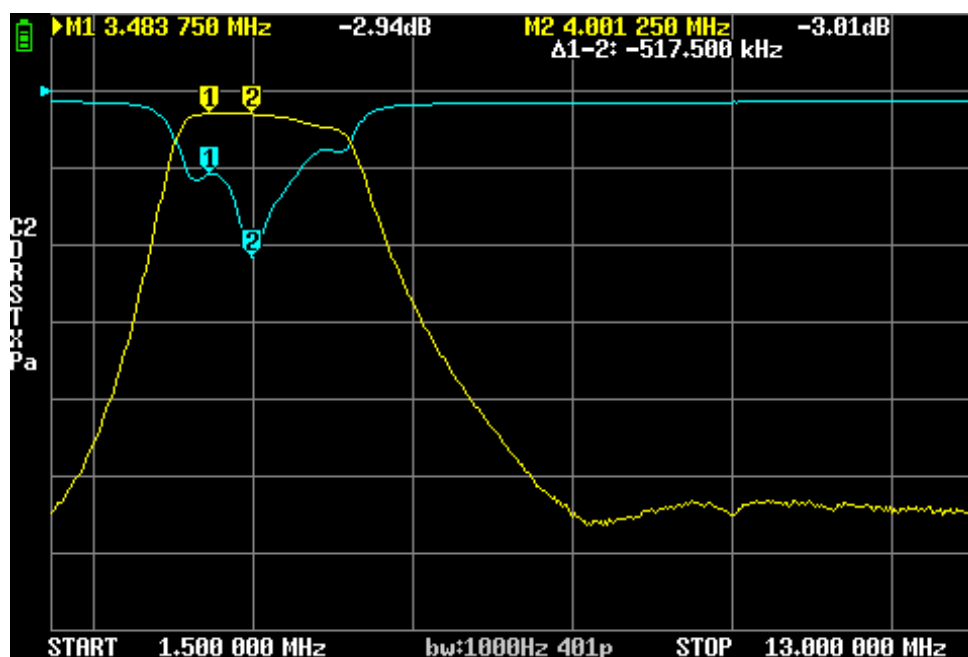
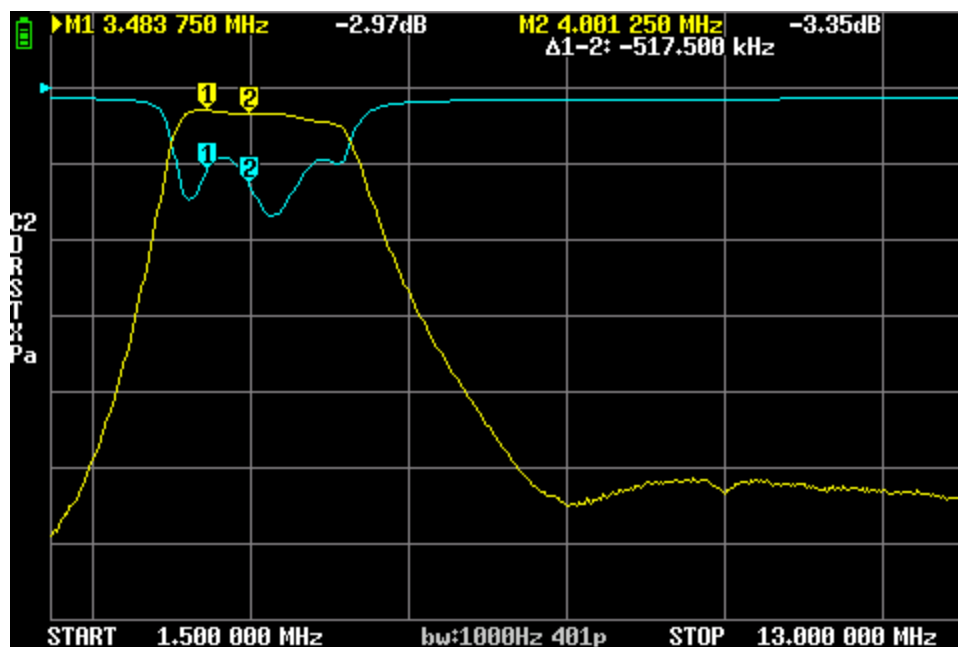


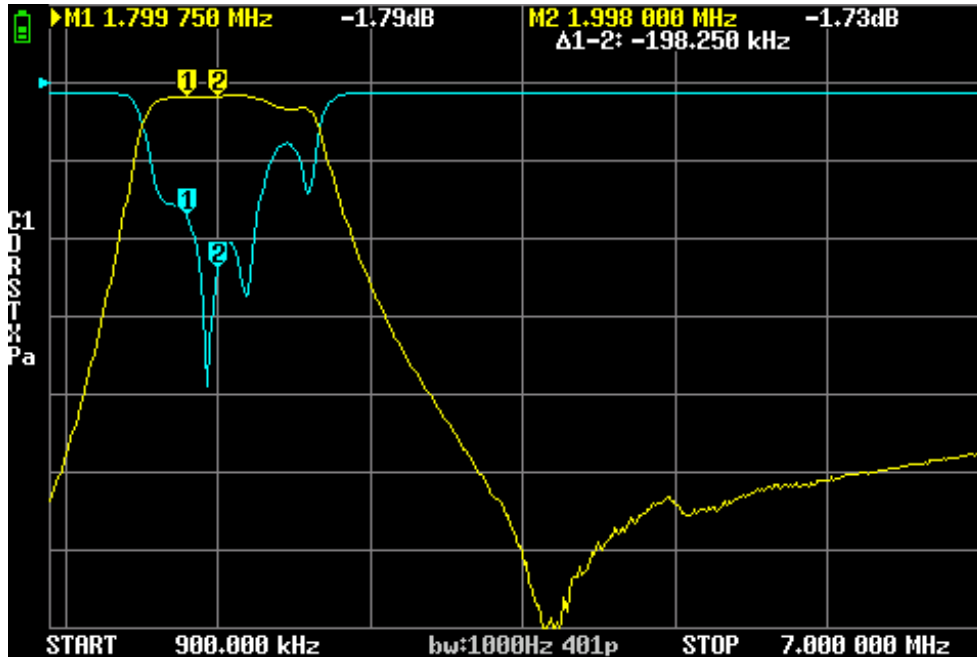












Finishing Up

That's it for this board, it can take a long time to build because testing and tuning needs to be done during assembly, but the result is a great set of BPFs for the T41 or any HF radio project. If your board is anything like mine it's covered in flux residue and desperately needs to be cleaned. Use isopropanol to clean the board thoroughly, I soaked mine a while and gave it multiple cycles of rinsing, gently scrubbing, soaking, and rinsing again.

The process of potting the inductors with hot melt glue is a bit unsightly but can be improved if desired.

Turn your heat gun to a low setting (120C / 250F or so) and use the airflow to gently shape the glue. This method can melt the glue into air pockets and more thoroughly secure each inductor, in addition to improving the appearance of the board.

WARNING: Use LOW heat and be patient. Using higher heat can move the SMD components and cause malfunctions or damage. Repairing components buried under hot glue is very, very unpleasant.

