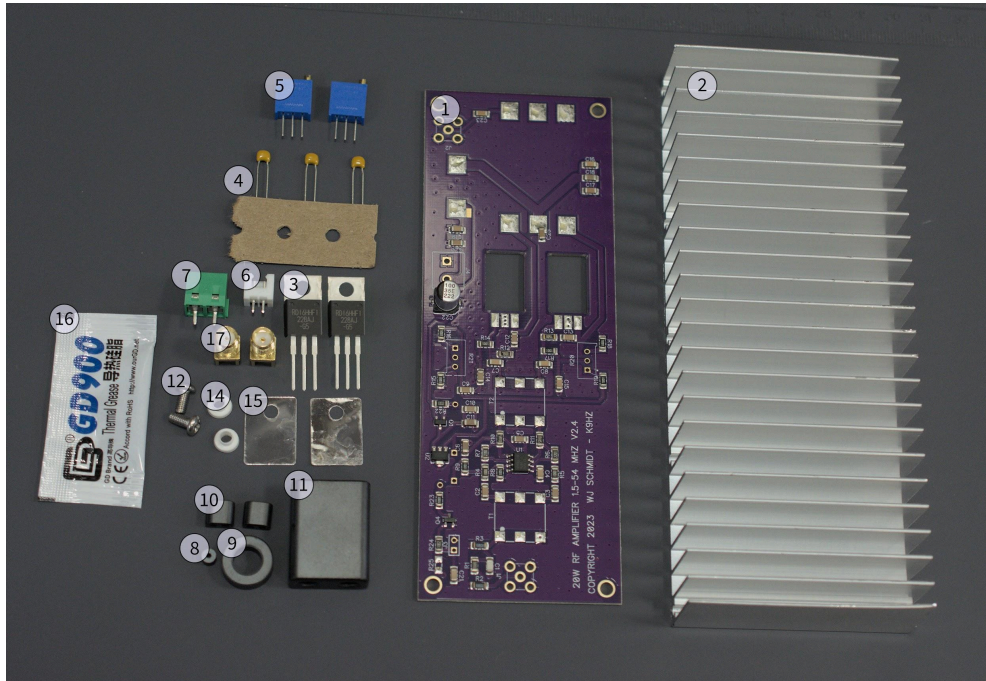


## K9HZ 20W Power Amplifier Assembly Manual



The K9HZ 20W Power Amplifier (PA) is a class AB2 HF amplifier intended for open source and homebrew transceivers such as the T41-EP SDT v12. With an input of 0dBm (1mW) and 12V DC, this amplifier produces 16W RMS continuously or 20W PEP in HF bands 160M-6M. The RD16HHF1 transistor finals are used quite conservatively, higher output powers are possible with minor adjustment (at the cost of reduced duty cycle).

### What's Included (Parts List)

1. (1) PCB (with SMD components pre-installed)
2. (1) Aluminum Heatsink (pre-machined)
3. (2) RD16HHF1 Transistors
4. (3) 100pF MLCC Capacitors
5. (2) 1kOhm Multi-Turn Potentiometers
6. (1) 2pin XH Socket
7. (1) 2pin Molex Block
8. (1) FB43 Ferrite Bead
9. (1) FT50-43 Toroid Core
10. (2) BN43-2402 Transformer Cores

11. (1) BN43-3312 Transformer Core
12. (6) 6mm M3 Stainless Steel Screws (2 pictured)
13. (4) M3 Stainless Steel Washers (not pictured)
14. (6) M3 Insulating Bushings
15. ~~(2) Ceramic TO-220 Insulation Pads~~ (note: **Part has been removed, insulators are not necessary due to the transistors used in the amplifier improving chip cooling.**)
16. (1) 0.5g Thermal Paste Packet
17. (2) SMA PCB Connectors
18. (90cm / 3') #30 Magnet Wire (not pictured)
19. (90cm / 3') #20 Silver-Plated PTFE Wire (not pictured)

Missing a part? Send an email to [justin@ai6ym.radio](mailto:justin@ai6ym.radio).

## You Will Need

1. [Soldering Station](#), hot air or separate heat gun optional but recommended.
2. [PCB Vise](#) or [Helping Hands](#)
3. [Jewelers Loupe](#)
4. [Solder](#) of your preference, 60/40 tin/lead is recommended.
5. [Flux Paste](#)
6. [Polyimide \(Kapton\) Tape](#)
7. [Solder Wick](#)
8. [Wire Cutters](#)
9. [Wire Strippers](#)
10. Sandpaper or [Hobby Knife](#) for stripping enamel wire
11. [Multimeter](#)
12. [Bench Power Supply](#) (minimum: 12V, 4A with current limiting function)
13. 5V Power Supply (batteries or second power supply)
14. [Signal Generator](#) and [Spectrum Analyzer](#)
15. [RF Attenuator](#) (minimum: 40dB, 20W rating)
16. [50ohm Dummy Load](#) (no required power rating)

## Safety Matters!



3

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!



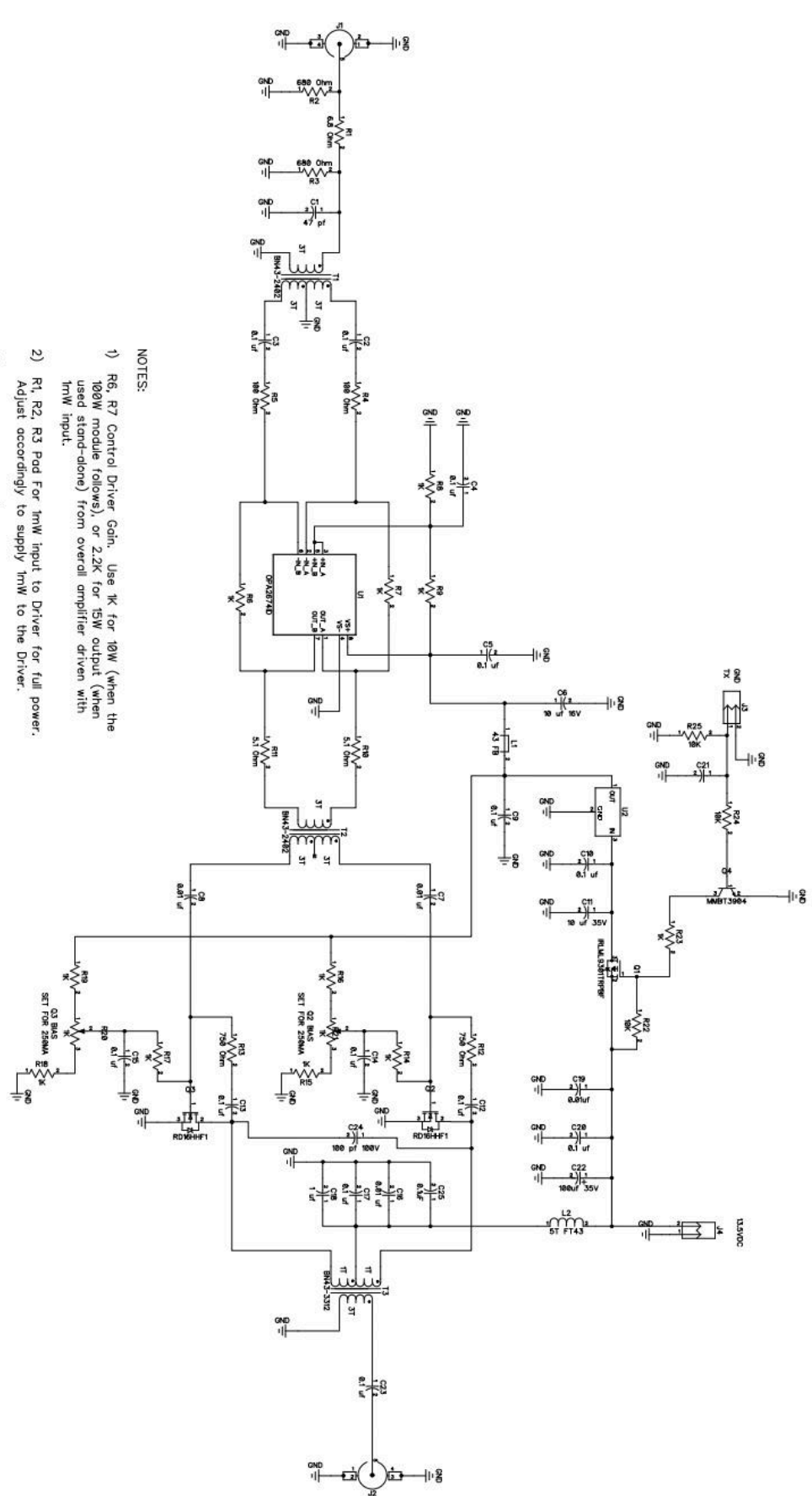
Fumes from heating the enamel coating on magnet wire can be dangerous.

Work in a well ventilated area!

Schematic

ZONE	REV	DESCRIPTION	DATE	APPROVED

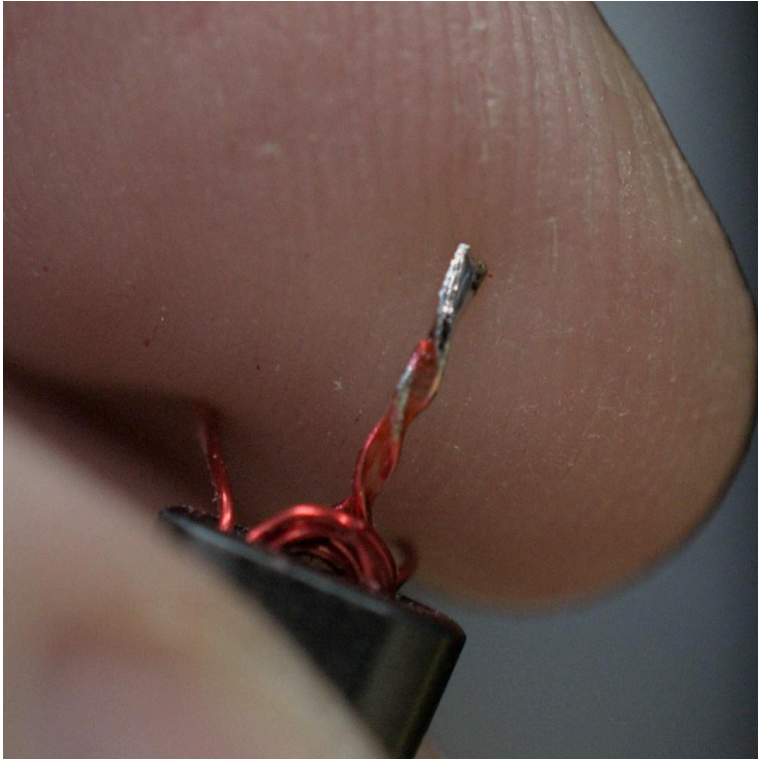
REVISIONS	DATE	APPROVED



- NOTES:
- 1) R6, R7 Control Driver Gain. Use K for 18W (when the 100W module follows), or 2.2K for 15W output (when used stand-alone) from overall amplifier driven with 1mV input.
  - 2) R1, R2, R3 Pod For 1mV input to Driver for full power. Adjust accordingly to supply 1mV to the Driver.
  - 3) L2 is 10 turns of #20 wire on a FT143 core.
  - 4) Set bias of 250ma for each RD16HHT1 at R20, R21.
  - 5) L1 is a wire with a small #43 bead or SMD equivalent.
  - 6) Amplifier response is +0/-0.1 from 1-54 kHz.
  - 7) Only install R25 for 12V+ PTT systems.

15WZ 20W 1-54 KHZ RF AMPLIFIER	
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DATE	REV
SEP 26 2023	2.4
SCALE	SHEET 1

## Input & Interstage Transformers



Wind the input transformer ( $T1$ ) from a BN43-2402 core and the provided #30 magnet wire. This transformer has a 3T (three turn) primary winding and a 6T center-tapped secondary winding. Starting with the secondary: cut two 10cm (4") lengths of #30 magnet wire. Strip about 1cm ( $\frac{3}{8}$ ") of insulation off one end of each length, twist these ends together and solder them.

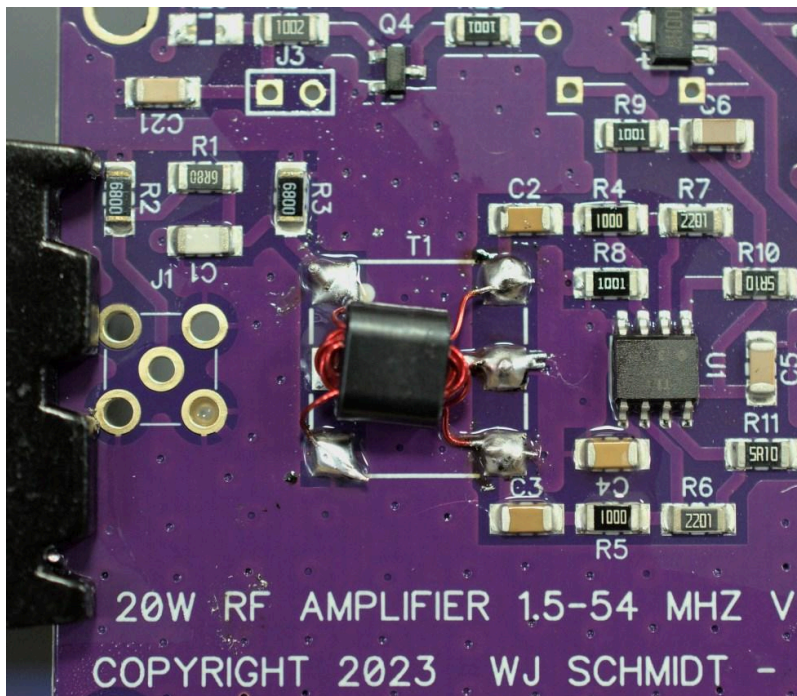
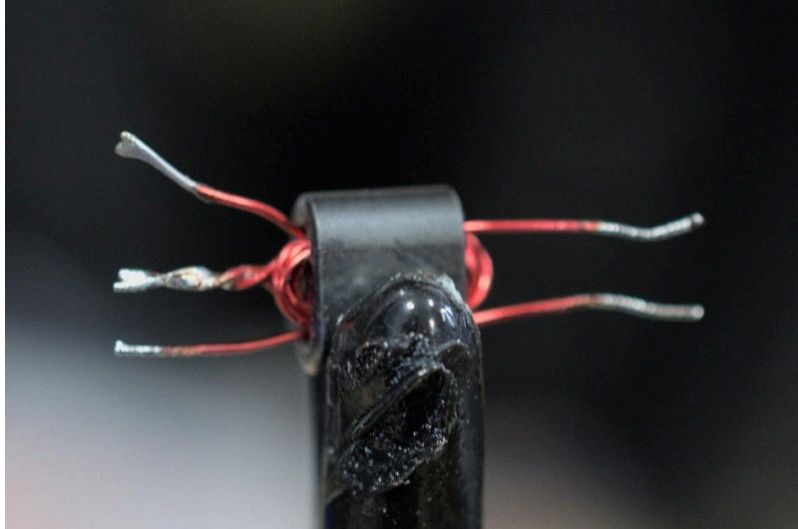
Pass the free ends of the joined wires into the BN43-2402 core (one wire in each side of the core). This forms 1T center-tapped winding ( $\frac{1}{2}$ T on each side). Wind

another  $2\frac{1}{2}$  turns with each wire to form the complete 6T center-tapped winding. Remember a pass through both sides of the transformer core counts as one turn.

Pro-Tip: Keep the winds tight to the core, pack them in with a soft object such as a toothpick. This will make the next winding much easier.

Cut another 10cm (4") length of wire and wind 3T starting on the opposite side of the transformer core.

Trim the ends of both windings to about 1cm ( $\frac{3}{8}$ ") and strip the enamel off of each end with a bit of sandpaper or a sharp knife. If using a knife be careful not to nick the copper wire. Verify conductivity on each winding before continuing. Each of the two windings should show near-zero resistance but there should be infinite (or several megohms of) resistance between the two windings.



Place T1 on the board with the primary winding on the left and secure it with a bit of tape. Use tweezers or small pliers to arrange the leads of the windings on their pads. Trim excess length as needed. Solder one lead to its pad and hold the end down with tweezers while the solder joint cools. Repeat for the remaining leads.

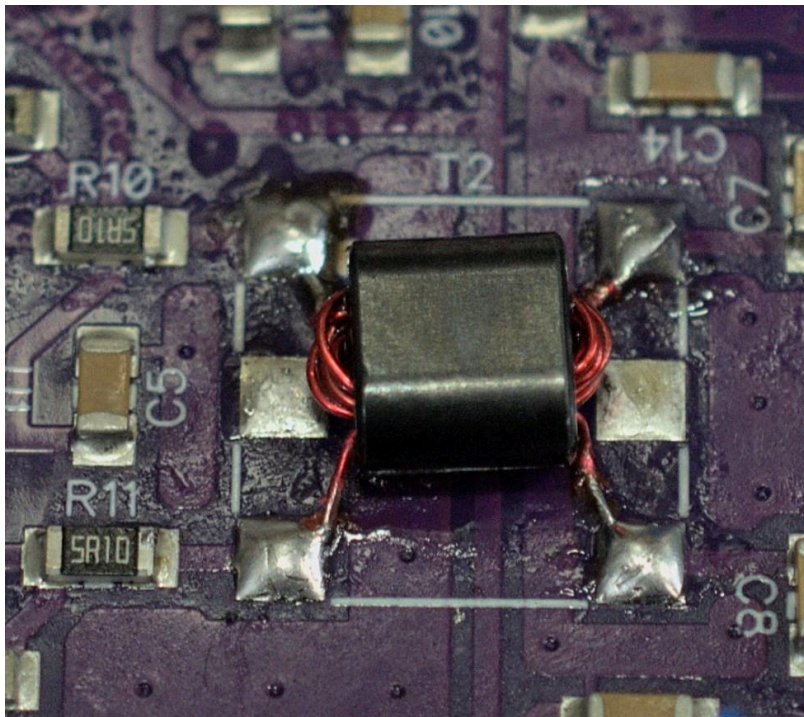
**Pro-Tip:** With one lead soldered it's easy to reposition the core if desired. Once more leads are soldered, moving the core will be difficult.

Solder T1 to the board with the primary winding on the left (towards the input J1).

Wind the inter-stage transformer ( $T_2$ ) from the second BN43-2402 core and the provided #30 magnet wire. This transformer has a 3T primary winding and 6T secondary winding (without a center-tap). Starting with the secondary, cut a 15cm (6") length of wire and wind 6T on the transformer core. Cut a 10cm (4") length of wire and wind 3T on the opposite side of the transformer core.

Trim the ends of both windings to about 1cm ( $\frac{3}{8}$ ") and strip the enamel off of each end. Verify conductivity on each winding, but no conductivity between windings, before continuing.

Solder  $T_2$  to the board with the primary winding on the left.

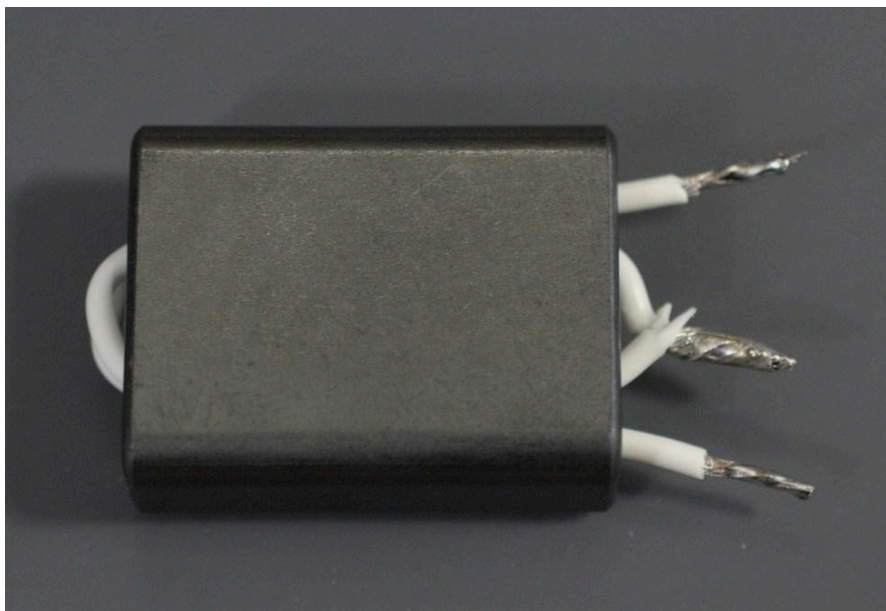


**Pro-Tip:** If you lose track of which side is the primary winding and which side is the secondary use an inductance (LC) meter to check each winding. The 3T primary will have a much lower inductance than the 6T secondary.

### Final Stage Transformer

Wind the final transformer ( $T_3$ ) from the provided #20 silver-coated PTFE wire. If you're not building from my kit #20 magnet wire is an

acceptable substitute.



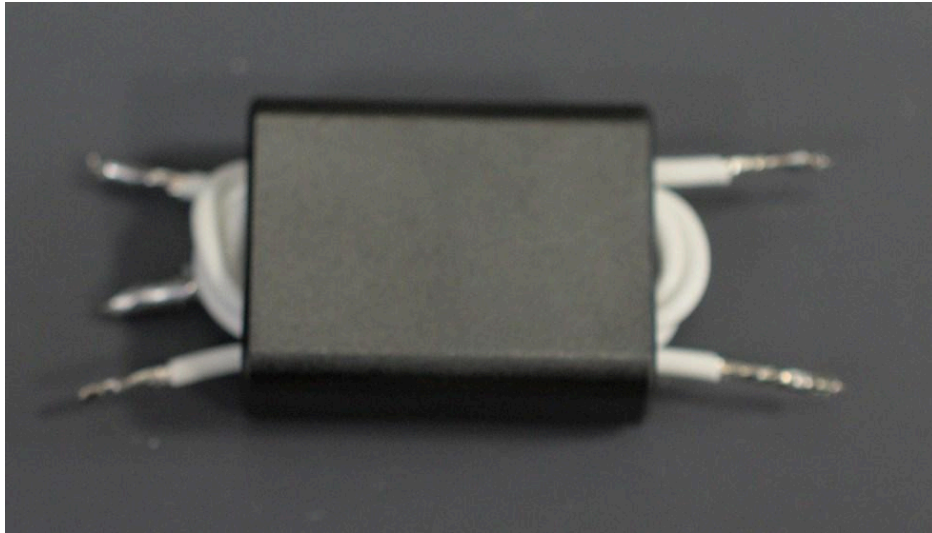
This transform has a 2T center-tapped primary winding and a 3T secondary winding. Starting with the primary winding, cut two 10cm (4") lengths of wire. Strip about 1cm ( $\frac{3}{8}$ ") from the one end of each length,

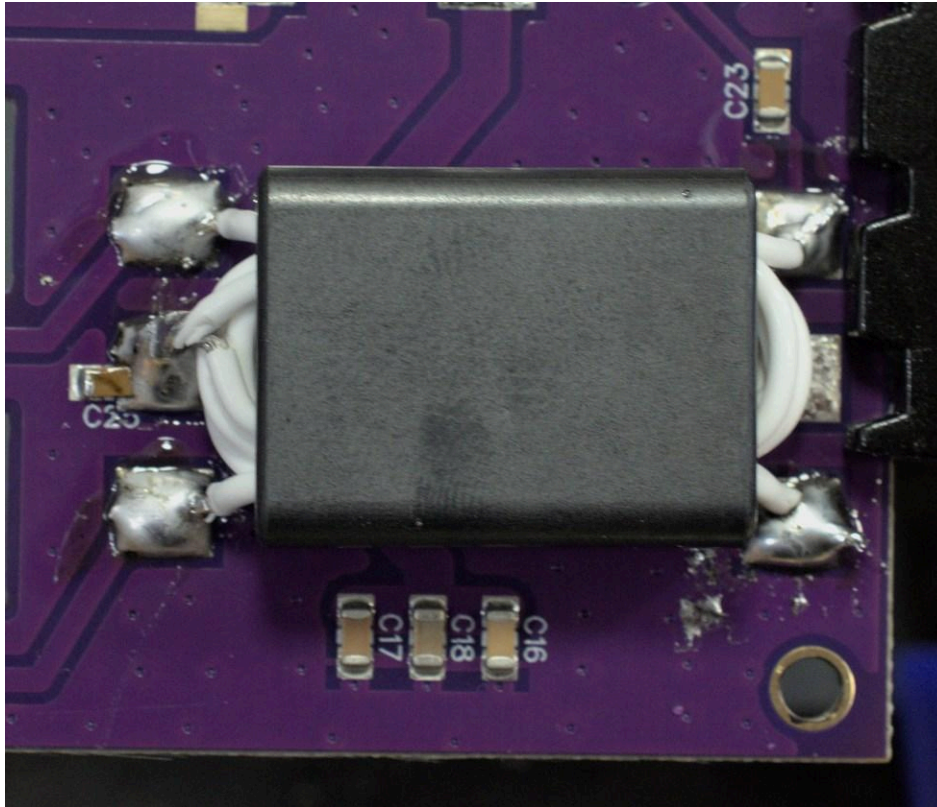
twist these ends together and solder them.

Pass the free ends of the joined wires into the BN43-3312 core (one wire in each side of the core). This forms 1T center-tapped winding ( $\frac{1}{2}$ T on each side). Pass each wire back through the core to complete the 2T center-tapped primary winding.

Cut a 30cm (12") length of wire for the secondary winding. Wind 3T on the opposite side of the transformer core.

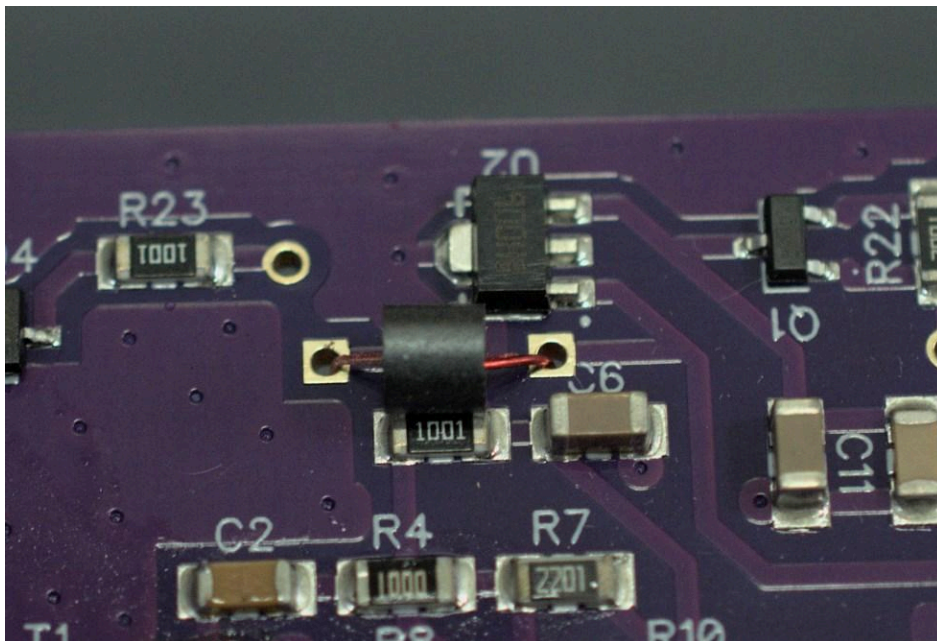
Trim the ends of each winding to about 1cm ( $\frac{3}{8}$ " ) and strip the ends of each winding. Twist the strands of each end together and tin them with solder. Check for continuity through each winding, and no continuity between windings, before continuing.





Solder T3 to the board with the center-tapped primary on the left.

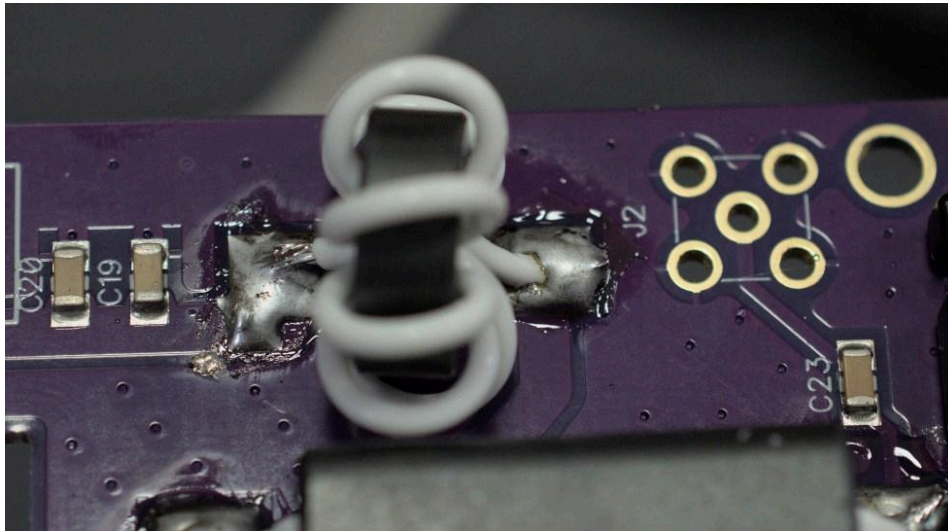
## Inductors



Use the ferrite bead and a small piece of #30 magnet wire or the cutoff from a leaded component to form  $L1$ . Simply pass the wire or cutoff through the bead, strip the ends, and pass through the board.  $L1$  is placed under  $U2$  and above  $C6$  on the upper-left side of the board. The position is not marked. Secure the bead to the board with a bit of tape and solder both ends from the back side of the board. Check for continuity across the joints then trim any excess length from the ends of the wire.

Use the FT50-43 toroid core and the included #20 wire to form  $L2$ . If you're not building from my kit #20 magnet wire is an acceptable substitute. Cut a 40cm (16") length of wire and wind 7T around the core. If you plan to use the amplifier mostly on lower bands (160M and 80M) wind 10T instead, this will reduce performance over 30MHz (10M and 6M bands).

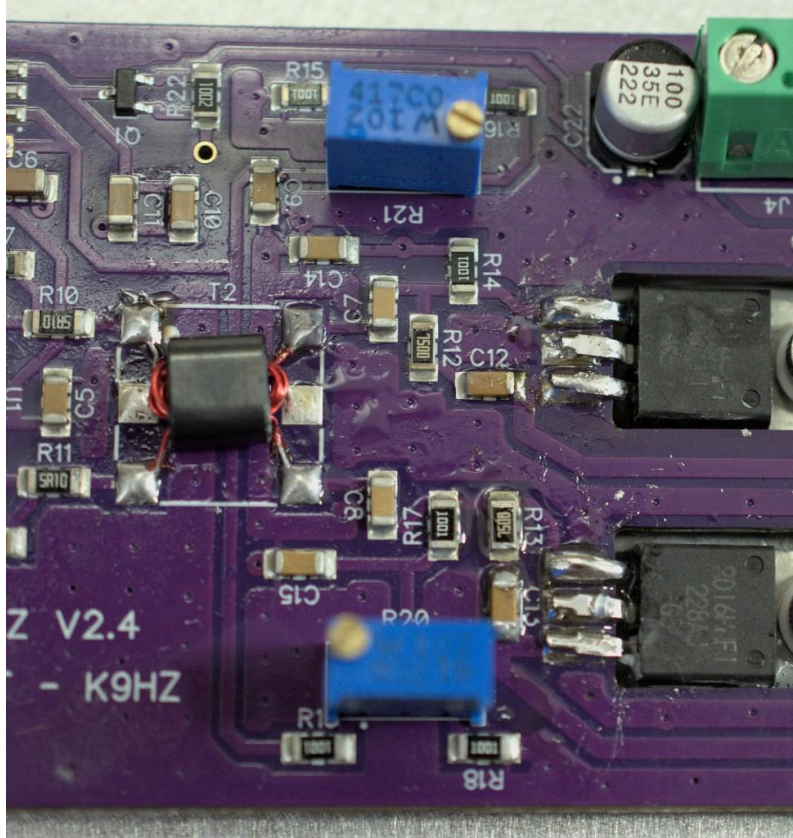
Trim and strip the ends of the inductor. Twist the strands of each end together and tin them with solder. Check for continuity through the winding before soldering  $L2$  to the board (on the upper-right corner near  $J2$ ).



## Trim Pots

The two trimmer potentiometers are  $R20$  and  $R21$ . For each of these components place the part on the board with the adjustment screw facing the interior of the board. Secure with a bit of tape and solder one pin from the back side of the board. Check alignment of the part before soldering the remaining pins. Trim excess length from the pins to prevent shorts to the heatsink in later steps. Repeat for the second trim pot.

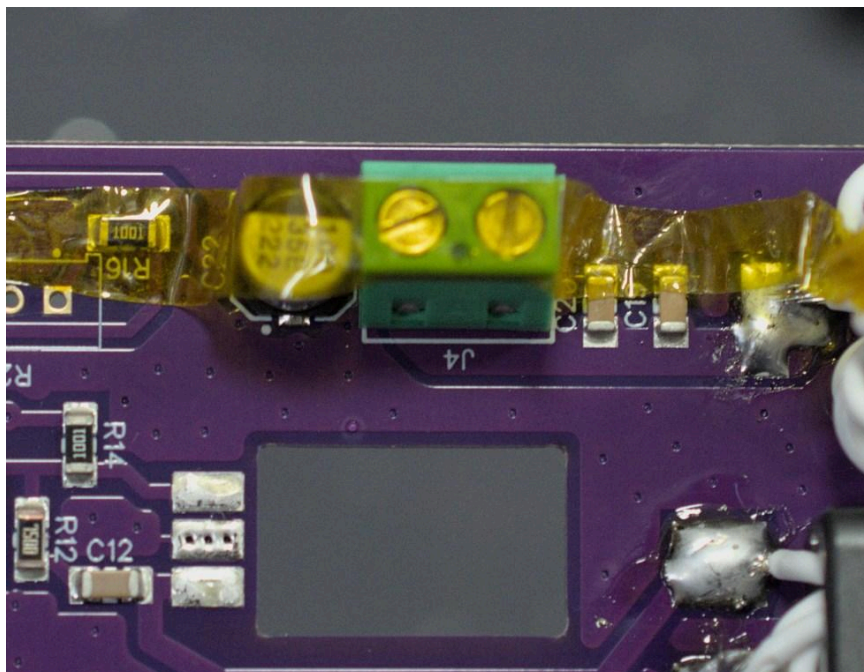
Note: If either of these components is soldered backward there is no need to remove it and correct the placement. The adjustment of the potentiometer will simply be backward (in later steps where turning clockwise (CW) or counterclockwise (CCW) simply reverse the instruction).

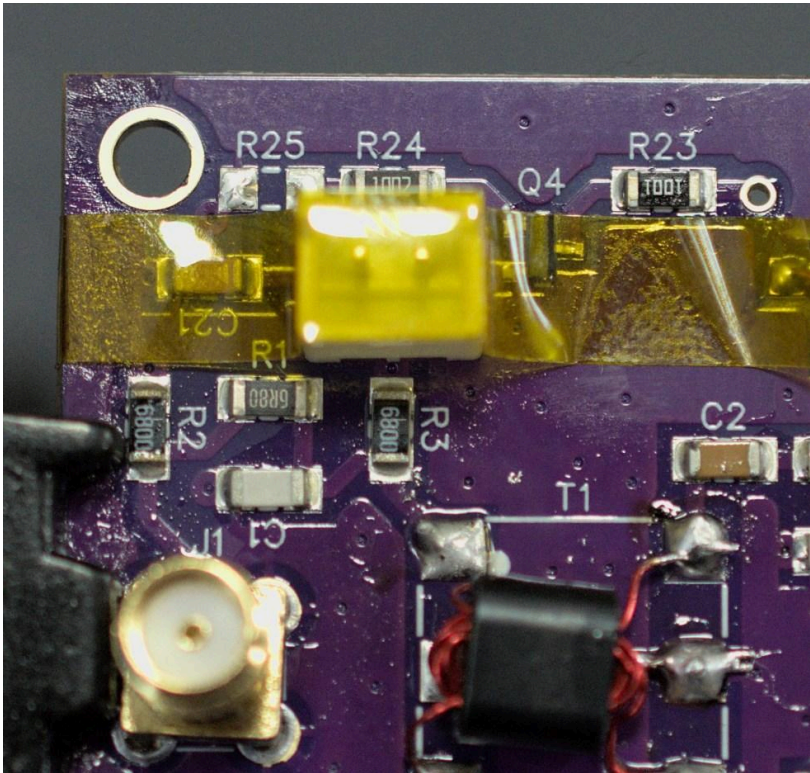
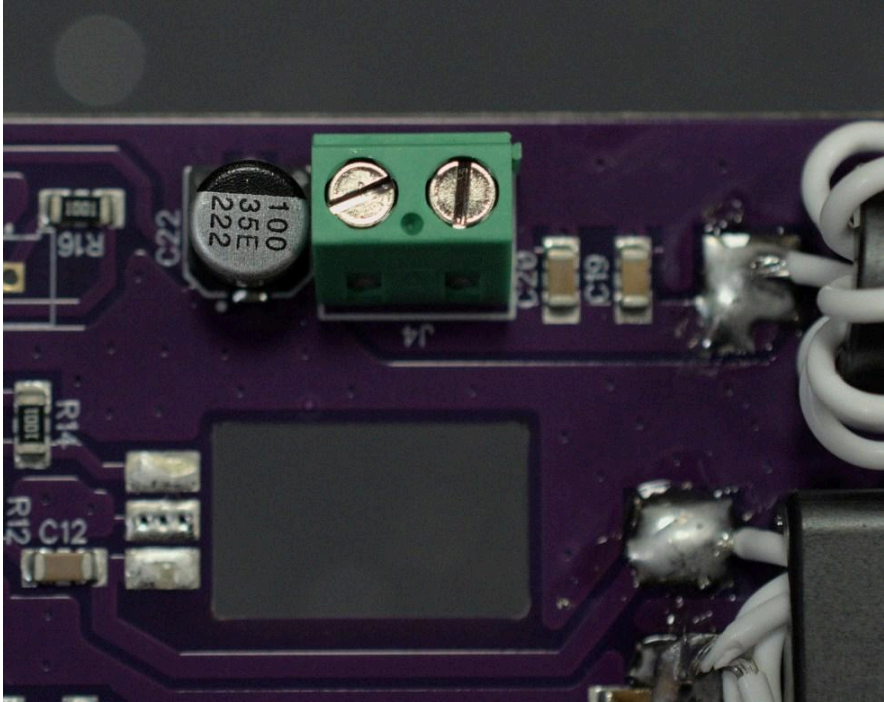


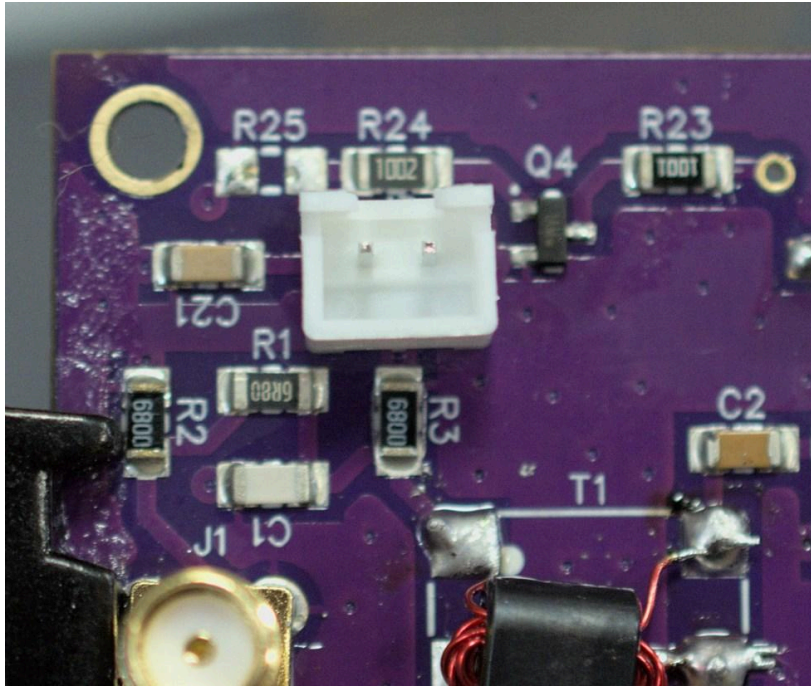
## Power & PTT

Place the 2pin molex block on the board at *J4* and secure it with a bit of tape. Note its polarity with a permanent marker to ease testing and final connection. Solder one pin from the back side of the board, check alignment of the part, and then solder the second pin.

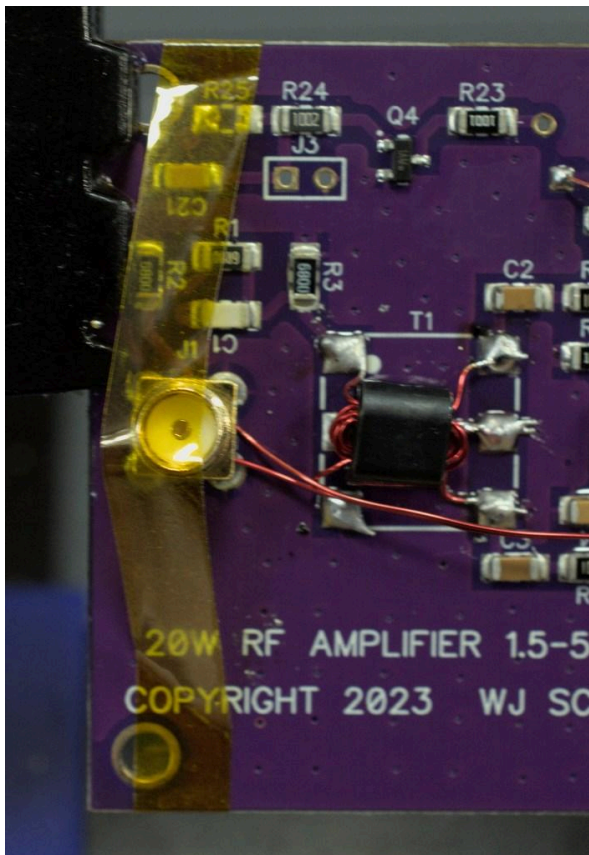
Place the 2pin XH socket at *J3* and secure it with a bit of tape. Be sure the clip side (the cutout in the plastic box) is facing up (away from the center of the board). Solder one pin from the back side of the board, check alignment of the part, and then solder the second pin.

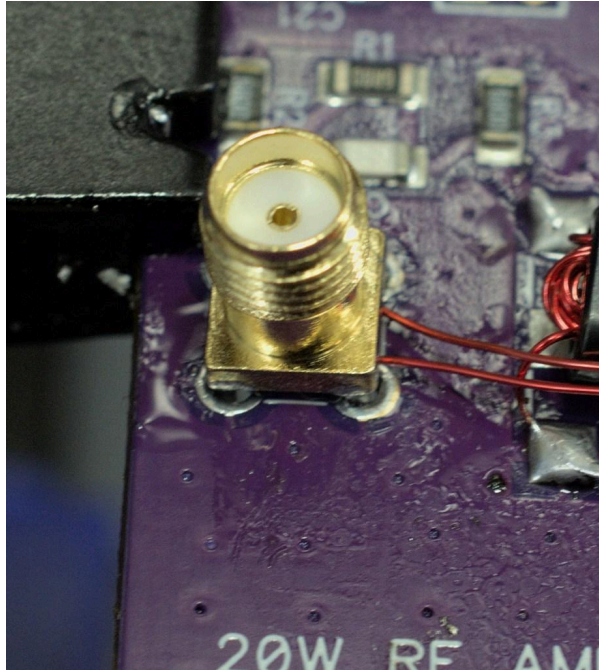






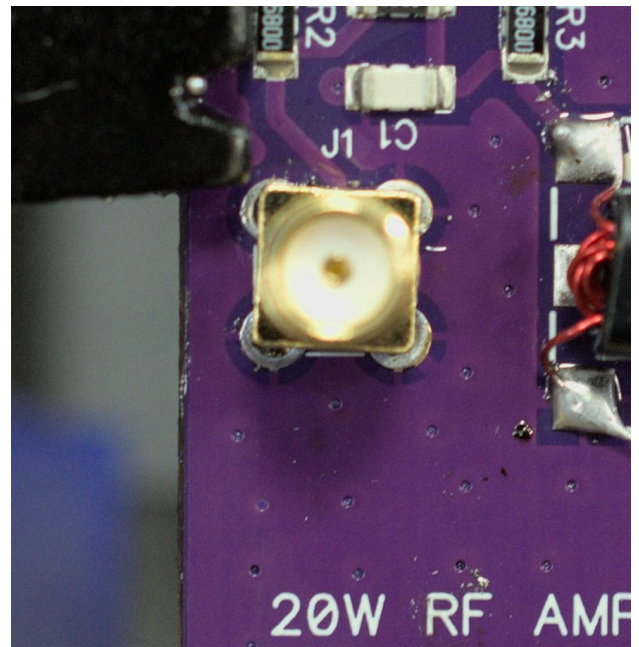
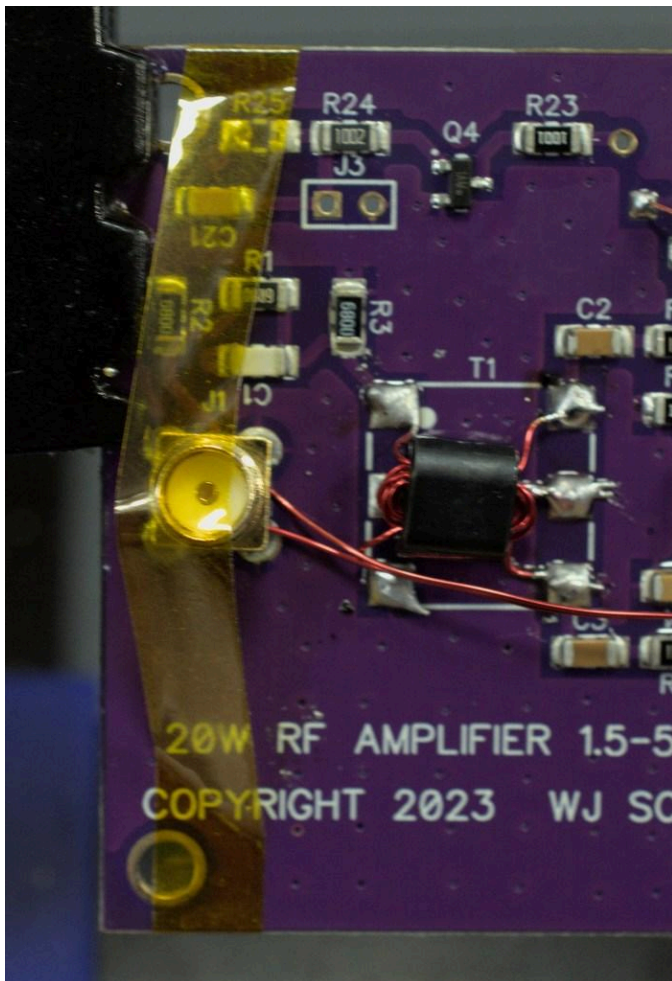
RF Input & Output

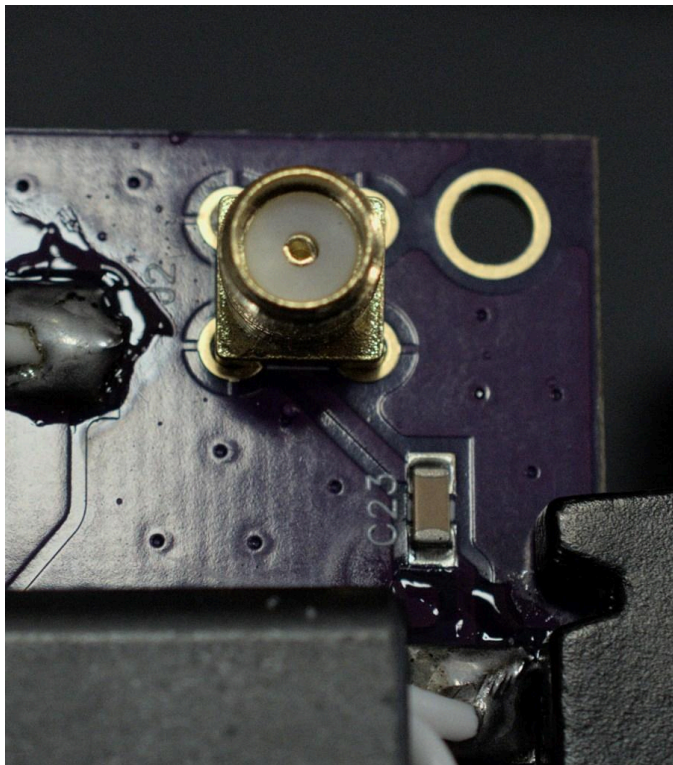
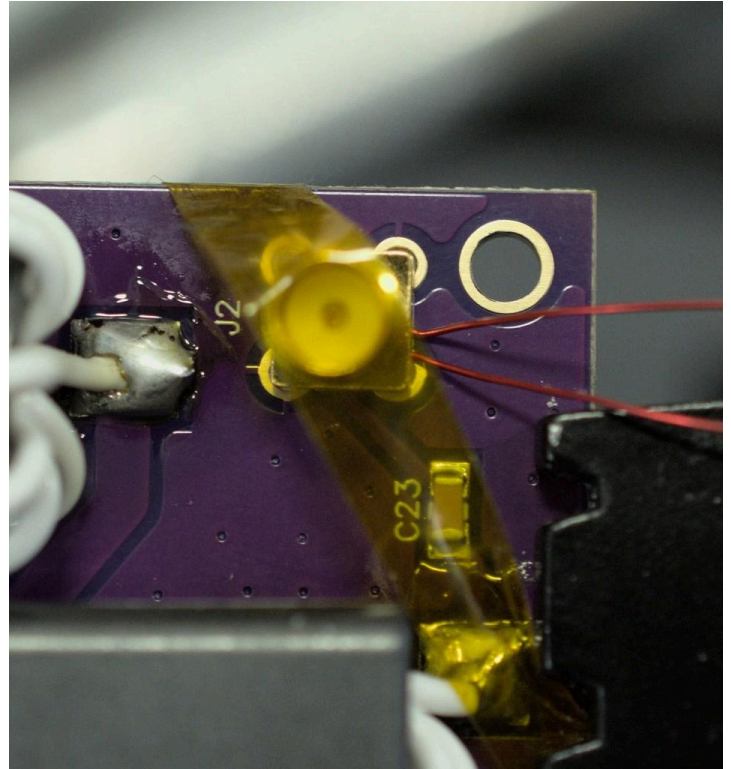
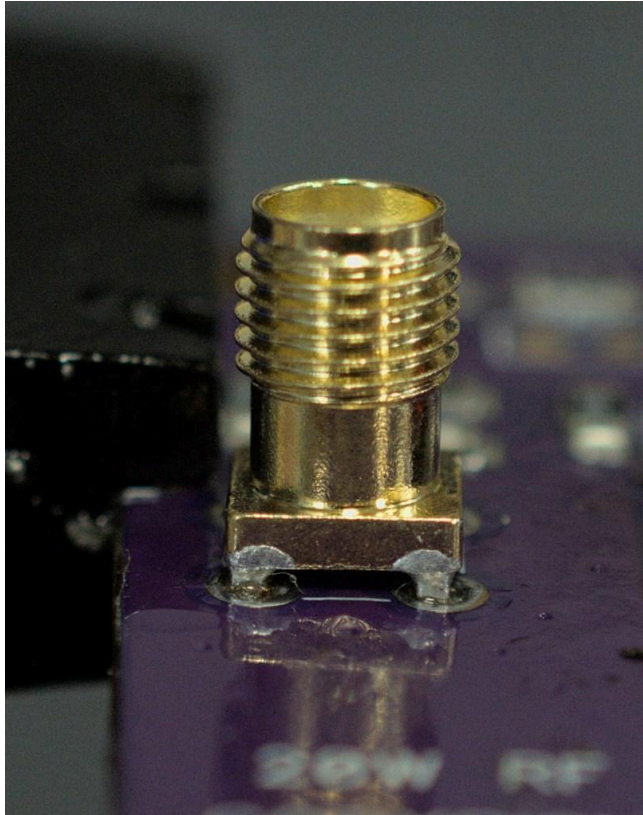




Input RF is connected through *J1* and the output is routed through *J2*. The current revision of this PCB has a small flaw – the pad for the center pin of the SMA connectors is a bit too large and so it can short to the case. To prevent this place a small spacer, such as a piece of #30 wire under the connector when placing it on the board. This creates a small gap and prevents the short. Be sure the spacer is long enough that you can pull it out after soldering.

Place one SMA connector, with the spacer under it as described above, and secure it with tape. Solder the pins from the back, using heat and flux as necessary, and then remove the spacer. The connector may be slightly misaligned due to the spacer but this will not impact performance. Repeat for the second connector.

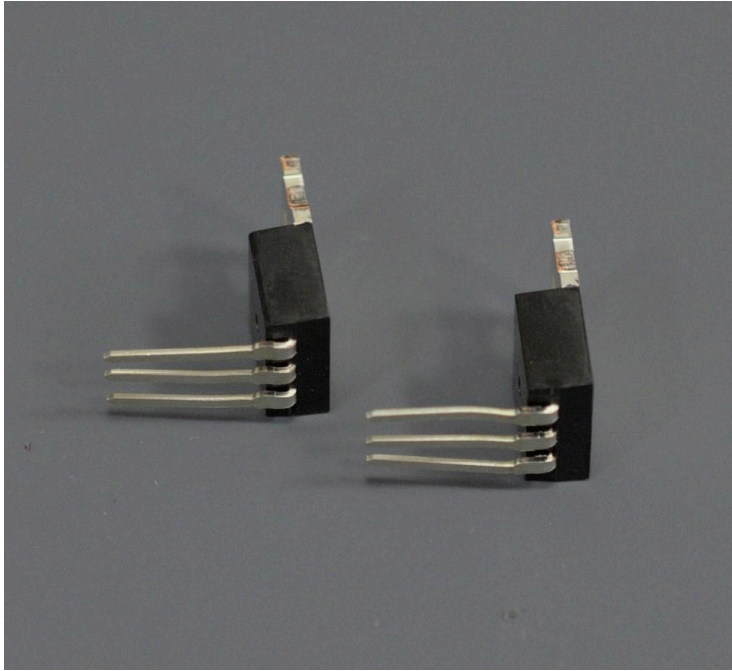




## Final Stage Transistors

Pro-Tip: At this stage the board is nearly complete. Test for shorts between  $V_{cc}$  and  $Gnd$  by placing your multimeter probes on the two power input terminals. Your meter should read infinite resistance (or several megaohms, if you have a very sensitive meter).

Bend the pins of each RD16HHF1 transistor up (away from the tab). Be careful to bend the pins in the correct



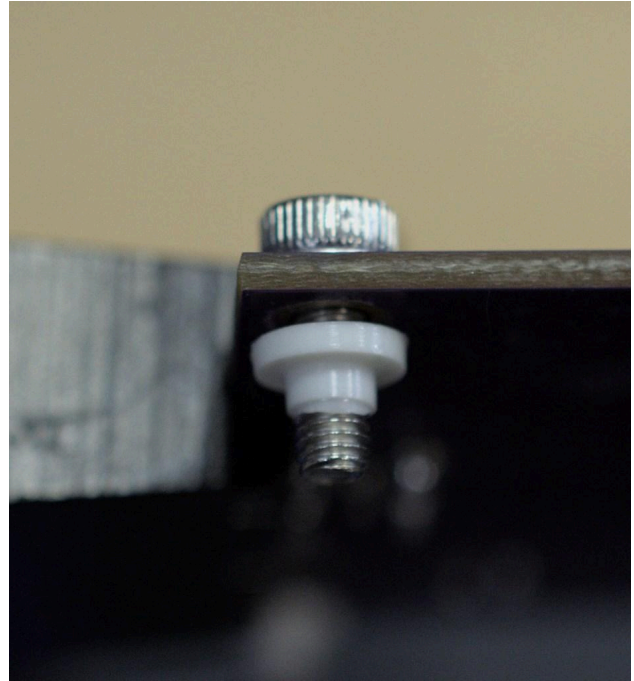
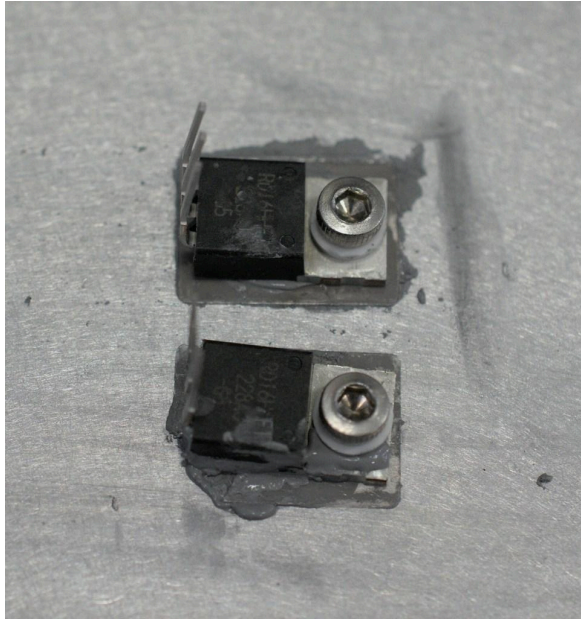
direction, if you bend them the wrong direction and attempt to correct your mistake the pins will break off.

The final stage transistors must be secured to the heatsink with thermal paste applied for adequate cooling. Place a small amount of thermal paste to the metal back of each transistor and spread it out a bit. Securing the transistors to the heatsink (in future steps) will further spread the paste.

Place one of the insulating bushings on an M3 screw and pass it through the front of the transistor. Thread the screw into one of the pre-drilled and tapped holes near the center of the heatsink. Do not tighten the screw yet, the transistor should be allowed to move a bit. Repeat for the second transistor.

Clean off excess thermal paste as needed or desired.

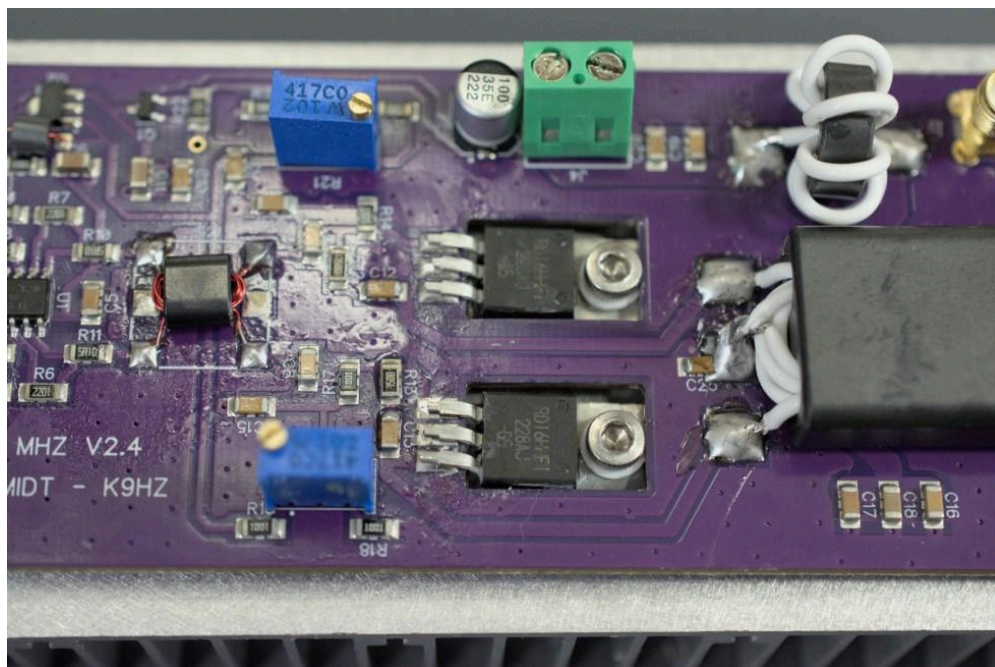
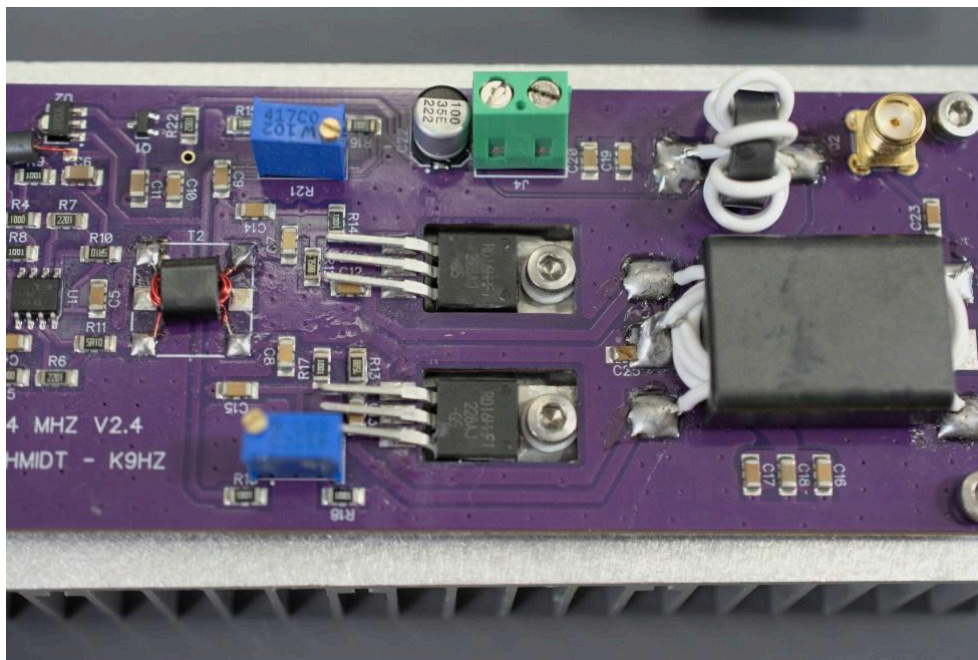
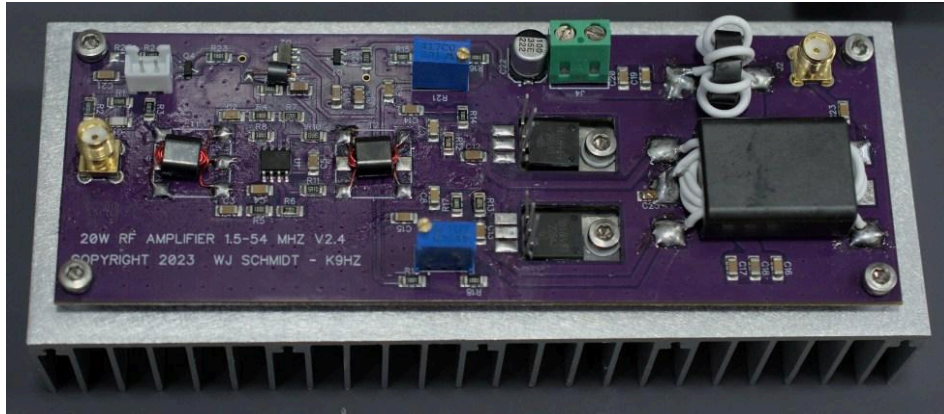
**Pro-Tip: If you plan on installing this amplifier in a case do it now! A plastic / nonmetallic case needs holes cut out for the transistors to make contact with the heatsink. That changes the position of bends in their leads for later steps. Metal cases aren't an issue, but you'll need thermal paste between the case and heatsink.**

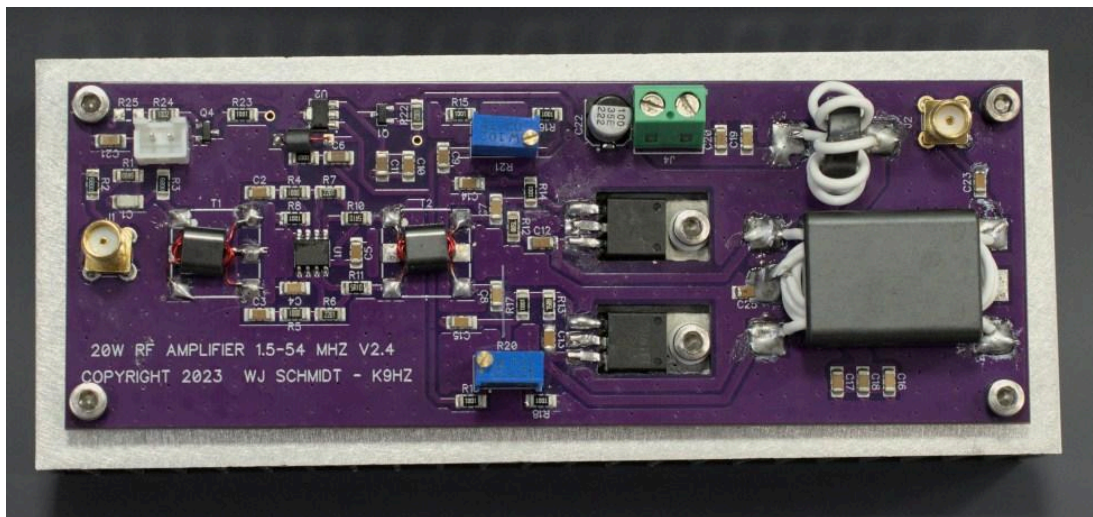
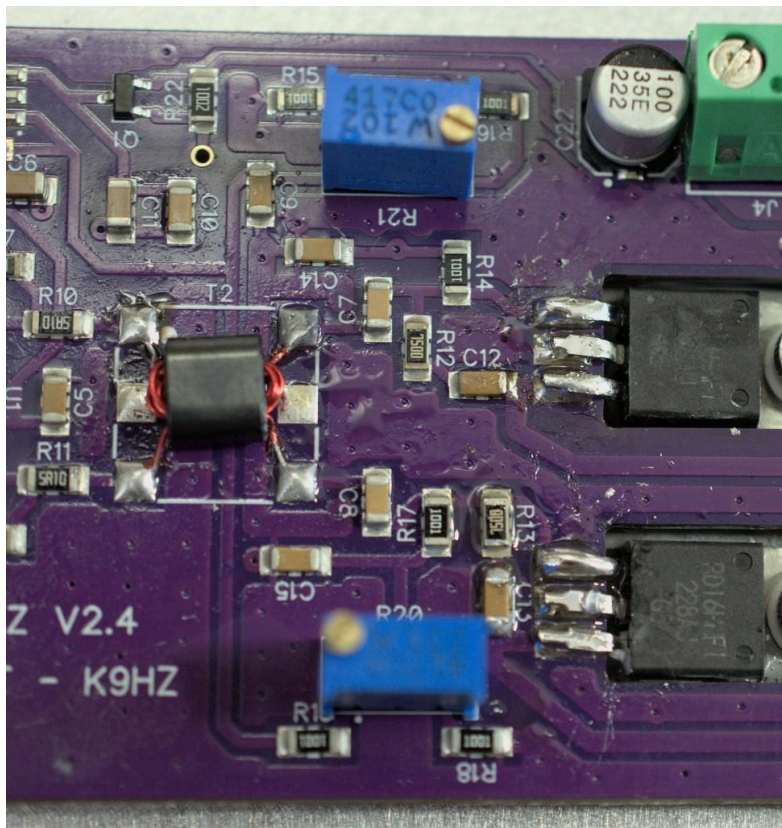


Place an M3 screw and washer through each corner of the board and place an insulating bushing on the screw from the back side of the board. This creates a small gap allowing the board to be secured to the heatsink without any of the components contacting the heatsink and causing a short circuit.

Place the board on the heatsink, align the transistors with the holes in the board so that they pass through, and then secure the board to the heatsink by tightening the screw on each corner.

Bend the pins of each transistor forward onto the pads on the board. Trim the excess length and press the pins firmly onto the pads. Align the transistor so that its pins are directly over the pads and not crossing / touching multiple pads. Solder one pin, double check the alignment, and then solder the remaining pins. The center pin will require extra heat and flux since it is being cooled by the tab and heatsink. After soldering, tighten the M3 screw and repeat for the second transistor.





Testing & Tuning

Power Up Test

Set your bench power supply to 12V with the current limit set to zero. Connect power to the board. Connect a dummy load to the output, if you have a second dummy load connect it to the input.

Adjust R20 and R21 fully clockwise (CW). The provided trim pots click when they are rotated to the end of either position.

Slowly increase the current limit on your power supply. The full voltage should be reached with <50mA power draw (depending on your power supply you may see a load of 0mA). Any load over 50mA should be treated with suspicion.

Test the voltages at each RD16HHF1 transistor. The gate pin (left / top) should read 0V, source (center) should read 0V, and drain (right / bottom) should read about 12V.

Apply 5V on the left pin of the XH connector (J3). This is the PTT connection. Now the gate pin of each transistor should read about 3V. Switching the 5V at PTT on and off should turn this voltage on and off.

## Bias & Tuning

With the board powered up and PTT on (5V at the left pin of J3). Slowly adjust R20 counterclockwise (CCW) until the current draw increases by 250mA from the initial reading. Slowly adjust R21 CCW for an additional increase of 250mA. Release PTT and power down the board.

Connect a frequency source with a level of 0dBm (1mW) or less. The NanoVNA is a good choice for this (connect port 1 / S11 of the NanoVNA to the input SMA on the amplifier). Connect a spectrum analyzer to the output SMA through a 40dB attenuator which is rated for at least 20W. TinySA is a good choice.

Pro-Tip: You can use the NanoVNA as your spectrum analyzer, but you won't be able to see the harmonic content. The 40dB attenuator must be placed between the amplifier's output and port 2 / S12 on the NanoVNA.

Cheap-Ham Tip: If you don't have a 40dB attenuator with a 20W rating you can chain attenuators. A 10dB attenuator with a 20W rating will reduce the power to 2W. Additional attenuators with lower power ratings can then be used to reach a total attenuation of 40dB. These smaller attenuators are, of course, much less expensive.

With this setup take whatever readings you would like. You can measure gain, output power, SWR, harmonic content, etc. The NanoVNA is generating a -10dBm signal while the amplifier will accept up to 0dBm, be sure to factor this into your measurements.

Three 100pF ceramic capacitors have been provided to tune performance of the amplifier. These capacitors may be placed across the primary winding of T3. In general adding capacitance at that point will improve performance on the lower bands, at the expense of the higher bands.

Based on my test results, I did not add any capacitors, but I encourage you to test the effect of adding one or more capacitors, they can always be removed if the performance is better without them.

## Finishing Up

Clean up your board as necessary or desired, and test performance as much as you'd like.

My test results showed a gain of ~52dB from 160M through 15M. Gain was 3dB down at 10M and 8dB down at 6M. That's a bit better than I expected since it means a -10dBm input will produce the full 16W rated output. By calibrating the output power of your T41 (or other radio) to compensate for the lower performance on higher bands you can achieve the full 16W output on all bands.

This amplifier is quite conservatively rated, the final stage transistors are theoretically capable of about 30W output up to 30MHz. The recommended configuration of the amplifier described in this manual ensures stable and efficient operation with 100% duty cycle.