A600 v1.2

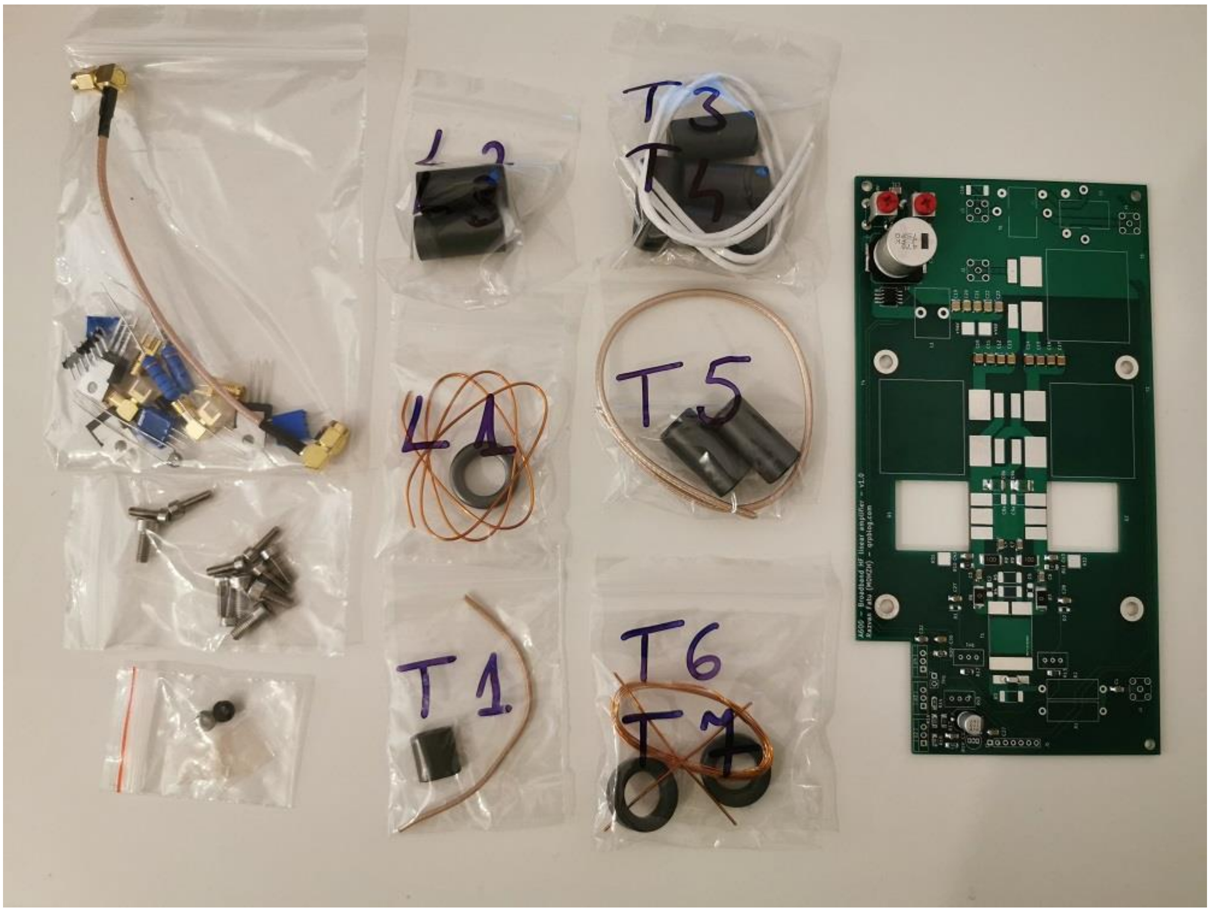
1.8-54MHz 600W amplifier kit

I designed, built and tested this in my spare time with little expectations, a lot of curiosity and a hope to make my small contribution to the Amateur Radio world. I trust you will enjoy putting this together and using it in the spirit of Amateur Radio.

If you have any issues, I'm just an email away.

Razvan (M0HZH) - razvan@qrpblog.com

The A600 v1.2 is a 600W 1.8MHz to 54MHz linear amplifier that uses low-cost but latest-technology LDMOS RF transistors. This shares the same PCB with the original v1.0 version (hence the v1.0 marking) but includes significant improvements in frequency coverage and performance. This is an Advanced level kit and assumes you have a good understanding of electronics.



To assemble this kit you will need the following tools & materials:

- soldering kit
- multimeter with a current range over 1A
- utility knife
- a short piece of RG-213 or similar coaxial cable
- electrical tape

For machining the copper heat spreader and heatsink:

- hand drill with speed control and 2.5mm (0.098") and 3.5mm (0.14") HSS drill bits
- tap wrench with 3mm (0.118") & 4mm (0.1575") HSS taps
- cutting fluid (I recommend lard - for example Monument White Tallow Medium)
- hexagonal (Allen) keys for tightening the bolts
- high-performance Thermal Interface Material (for best performance, Thermal Grizzly Conductonaut or similar liquid metal)
- regular thermal grease
- 3mm M3 PCB spacers (a stack of washers could be used)

To be able to test and then use the A600 on the air, you will need the following:

- a large heatsink to install the module on (0.1C/W is sufficient for normal use)
- a solid 48V/25A power supply
- a low pass filter for each band you plan to use this on
- circuitry that will switch the amplifier in/out of the circuit
- conductors, connectors as needed
- additional monitoring and protection circuitry is recommended.

Sensor Port

The Sensor Port (J5) is designed to interface with microcontrollers for measurement and control. Outputs are generally high impedance so it's recommended to use buffers (unitary gain opamps for example) if you want to drive any other types of circuitry than ADC inputs. It is highly recommended to use a ferrite choke on the cable that connects to J5 and decouple each signal with a 10nF ceramic capacitor to ground at the other end.

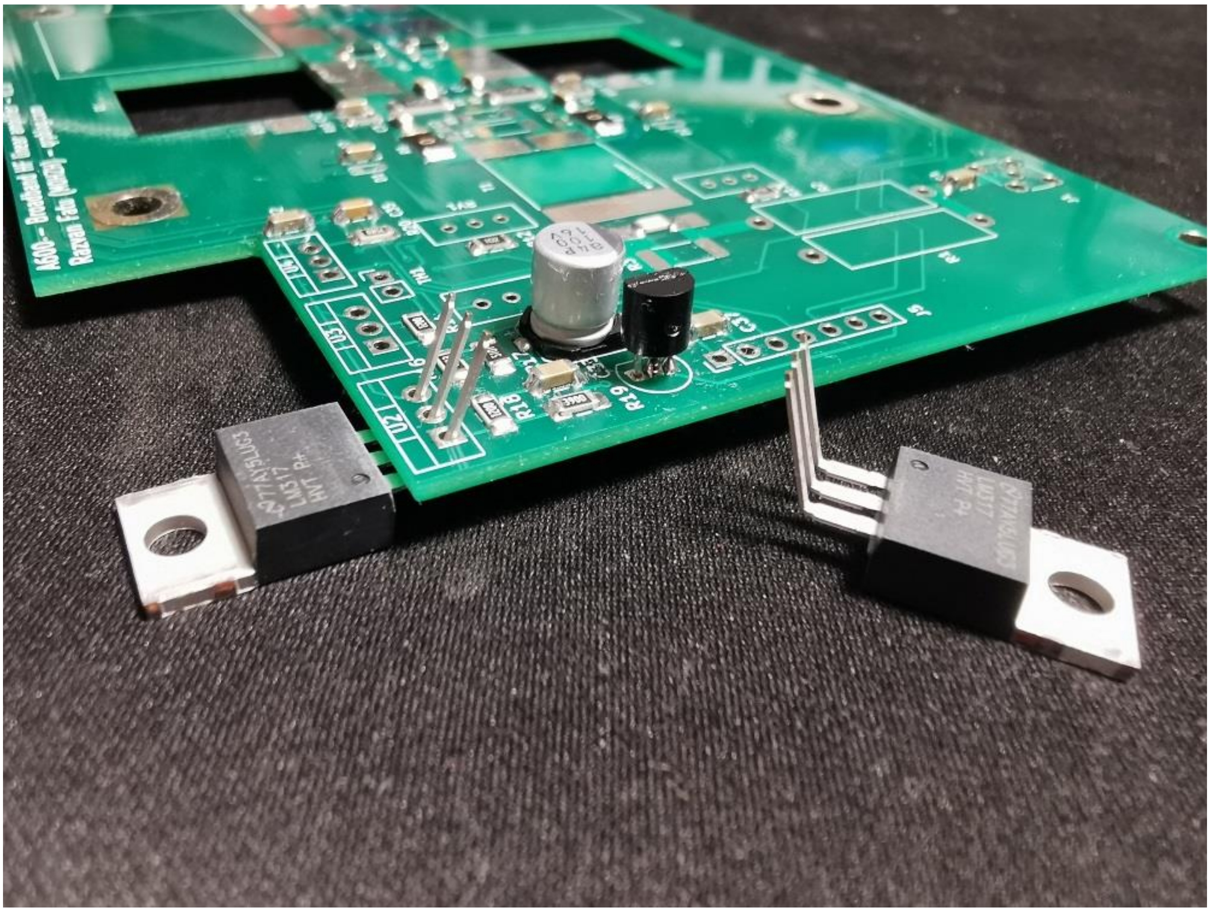
Pin	Name	Description
1	GND	Reference ground for measurements.
2	Vsense (output)	Voltage directly proportional to the PA Unit supply voltage, increases with approx. 0.0485V for every 1V at the supply. For 48V this pin should provide about 2.33V output.
3	Isense (output)	Voltage directly proportional to the PA Unit current draw. For zero current this pin sits around 2.67V and it increases with 0.066V for every 1A drained from the supply. See the ACS712ELCTR-30A-T datasheet for more information.
4	Vtemp (output)	Voltage directly proportional to the heatsink temperature. This output increases with 0.01V for every 1 Celsius degree. Expect 0.20 to 0.30V output for normal room temperature and 0.50V for the recommended thermal limit. See LM35D datasheet for more information.
5	REFsense (output)	Voltage proportional to the amplifier output reflected power square root. 3.70V for 600W.
6	FWDsense (output)	Voltage proportional to the amplifier output forward power square root. 3.70V for 600W.
7	BiasDisable (input)	Apply a positive voltage to this pin to reduce the power transistors' bias voltage. Around 1V should be enough to cancel the idle current completely; don't exceed 5V.

Heatsink & cooling

For optimal cooling in normal conditions, the amplifier requires a heatsink that achieves around 0.1C/W thermal resistance. There are formulas that allow you to calculate the performance of a heatsink based on surface and air speed, but if the manufacturer doesn't provide that information it's best to follow the principle "bigger is better". If not sure, monitor the temperature pin output from the sensor port during tests to make sure this never goes above 50C.

The supplied copper heat spreader is meant to provide a better path for heat from the power transistors to the heatsink base, as well as a spacer that will keep the back area of the PCB away from the heatsink. The heat spreader will have to be in good contact with the heatsink over the whole contact area; it is recommended to check flatness and contact and adjust before installing if necessary. Because it's only 3mm thick and made of soft copper, the heat spreader could be further flattened with the right tools.

To drill copper and aluminum I recommend using good quality HSS drill bits, plenty of cutting fluid and a low drilling speed; this will avoid having drill bits stuck / broken. Place the PCB and U2, U3, U4, Q1 and Q2 in their position (for U2 / U3 / U4 you'll have to bend the pins like in the picture) to precisely mark the drilling holes.



For the 4 large holes (corresponding to the 4 corners of the heat spreader) use the 3.5mm (0.1378") HSS drill bit and then the 4mm (0.1575") tap (also with plenty of cutting fluid). The rest of the holes should be done with the 2.5mm (0.984") drill bit and the 3mm (0.1181") tap.

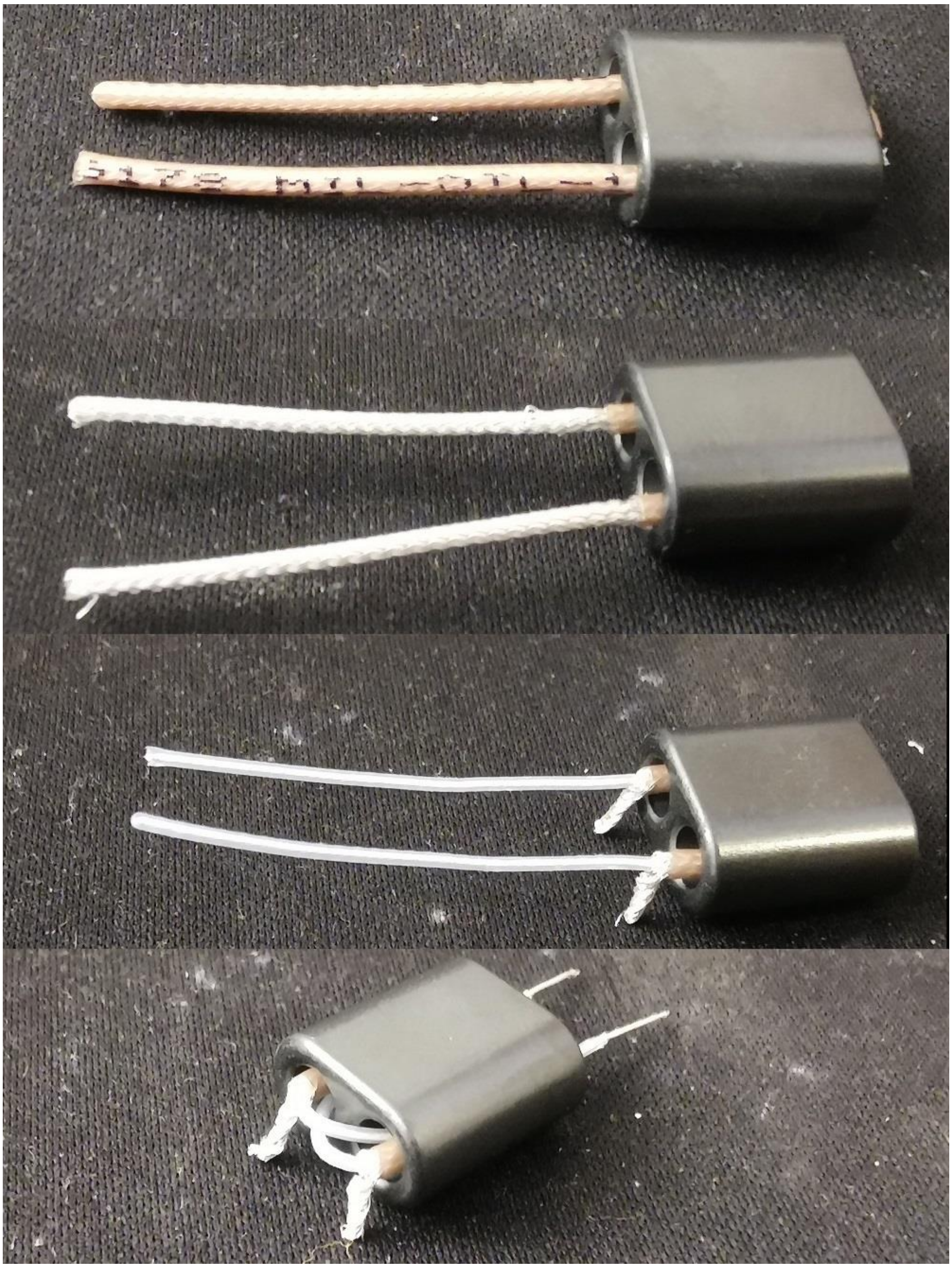
Bill Of Materials

Reference	Description	Value	Package	Code
PCB	Printed Circuit Board		190*100mm	v1.0
R29	Resistor	2k4	THT	MCMF006FF2401A50
R31	Resistor	560 / 3W	THT	ROX3SJ560R
R32	Resistor	560 / 3W	THT	ROX3SJ560R
TH1	Thermistor	1k		B57164K0102J000
RV1	Trimmer multiturn	1k	3296W	3296W-1-102LF
RV2	Trimmer multiturn	1k	3296W	3296W-1-102LF
RV3	Trimmer multiturn	10k	3296W	3296W-1-103LF
L1	Inductor, 8 turns	30uH	toroid	
T1	RF transformer, 2:1		binocular ferrite	
T3	RF transformer		2x ferrite tube	
T4	RF transformer		2x ferrite tube	
T5	RF transformer		2x ferrite tube	
T6	RF coupler, 33:1		toroid	
T7	RF coupler, 33:1		toroid	
U2	Voltage regulator		TO-220	LM317HVT
U3	Voltage regulator		TO-220	LM317HVT
U4	Temperature sensor		TO-220	LM35D
Q1	RF power transistor		TO-247	MRF300AN
Q2	RF power transistor		TO-247	MRF300BN
J1	Connector SMA PCB		angled	
J2	Connector SMA PCB		straight	
J3	Connector SMA PCB		straight	
J4	Connector SMA PCB		angled	
J5	Connector	7 pin		
JP1	Jumper cable		SMA-SMA	
TO-220 INS KIT	TO-220 Insulation kit	2x		
COPPER PLATE	Heat spreader			
M3	M3 bolts, stainless steel	8x 10mm	M3	
M4	M4 bolts, stainless steel	4x 10mm	M4	

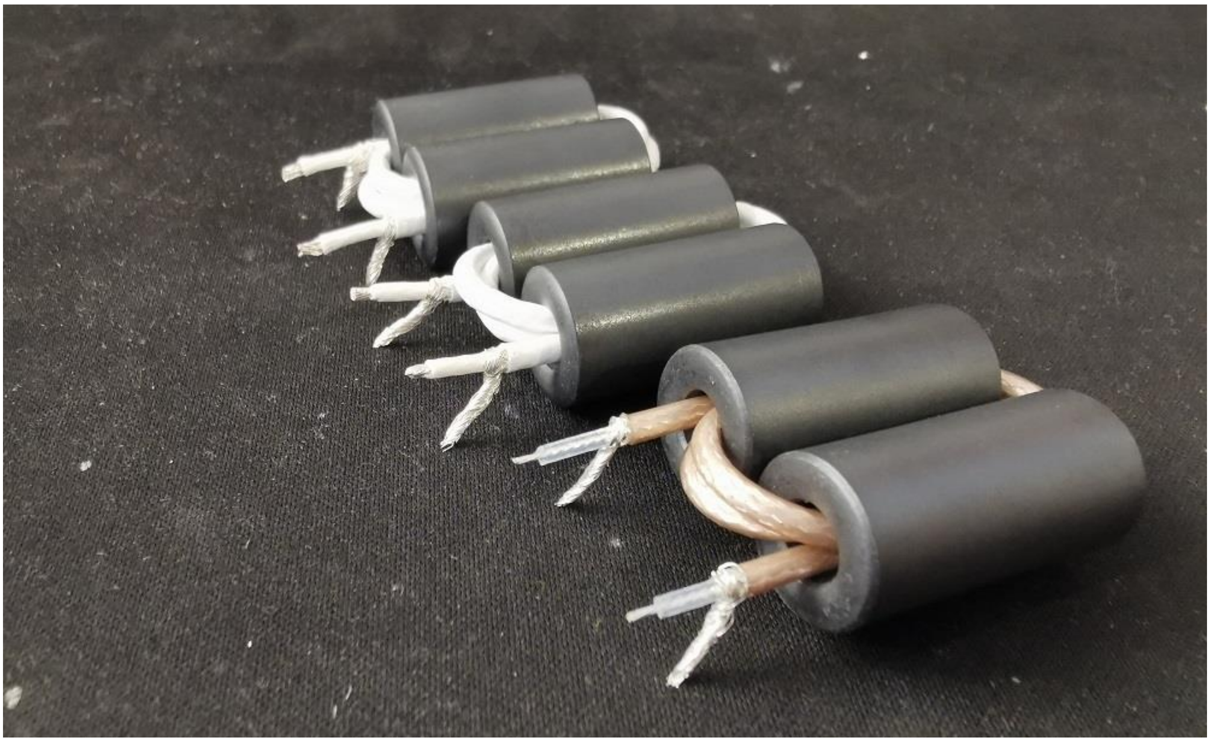
Assemble parts

Some of the parts supplied in this kit require assembly before they can be installed.

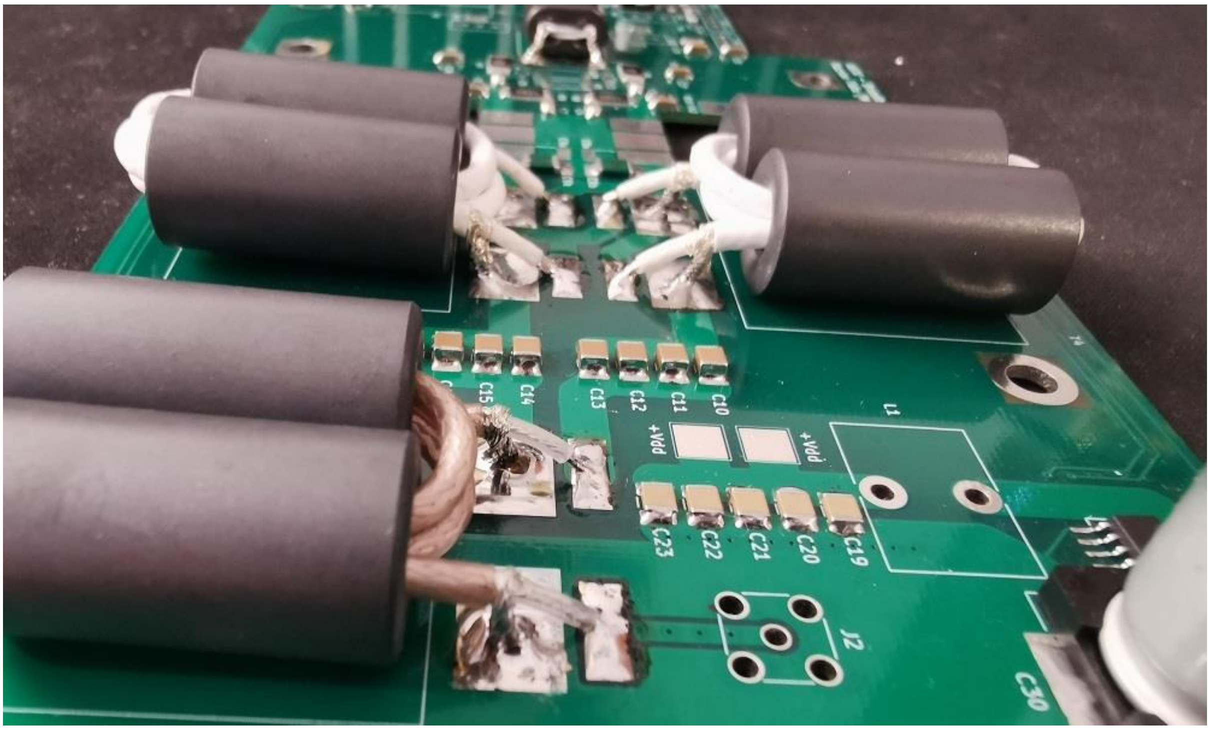
T1 - 2:1 turns ratio transformer with coaxial cable. Wind one turn of coaxial cable through the ferrite core so both ends come out on the same side in equal lengths. With the utility knife, carefully remove the external jacket off both the ends hanging out, remove the shielding and cut most of it, leaving only ~1cm (1/4 inch) on each side. Take the two insulated center conductors and pass them through the core one more time, so they come out on the opposite side. You should end up with something like in the picture:



T3, T4 & T5 - 3 turns coaxial on two large ferrite cores. T3/T4 coax and ferrite cores have different specs than T5 so make sure you don't mix them. Wind the supplied coaxial cable so it passes 3 times through each of the two cores. With the utility knife remove the outer jacket over the last 1cm (1/2 inch) at each end, remove the shielding over the last 5mm (1/4 inch) and carefully cut the insulation to expose the tip of the central wire.

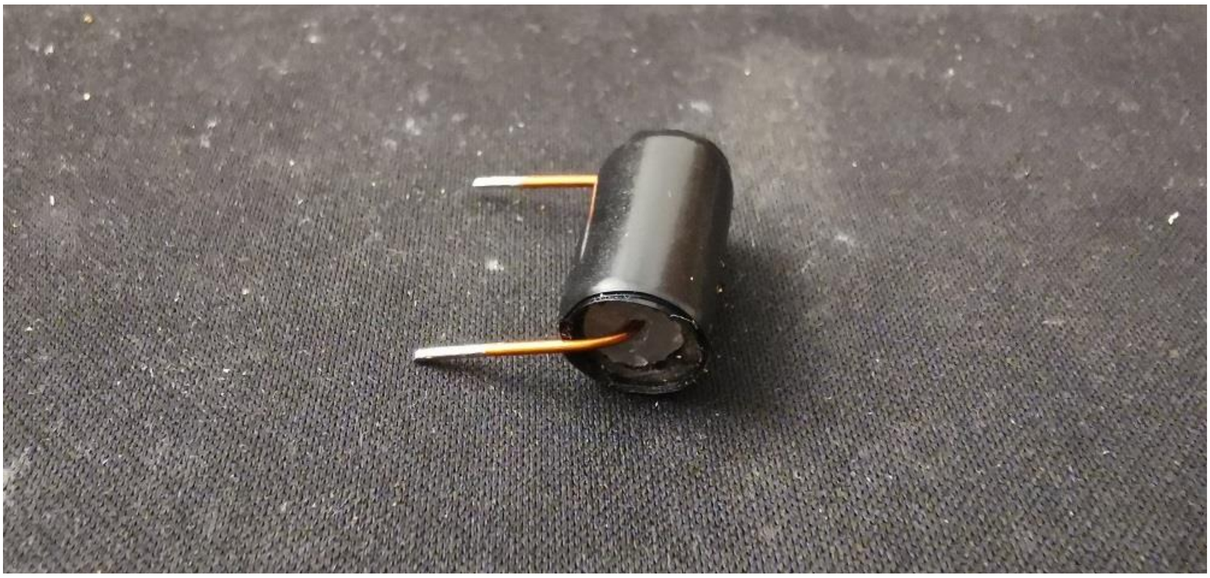


Quicky coat in solder the exposed shielding and the central wire and then solder in place. Do not heat more than necessary as it may damage the coaxial cable.

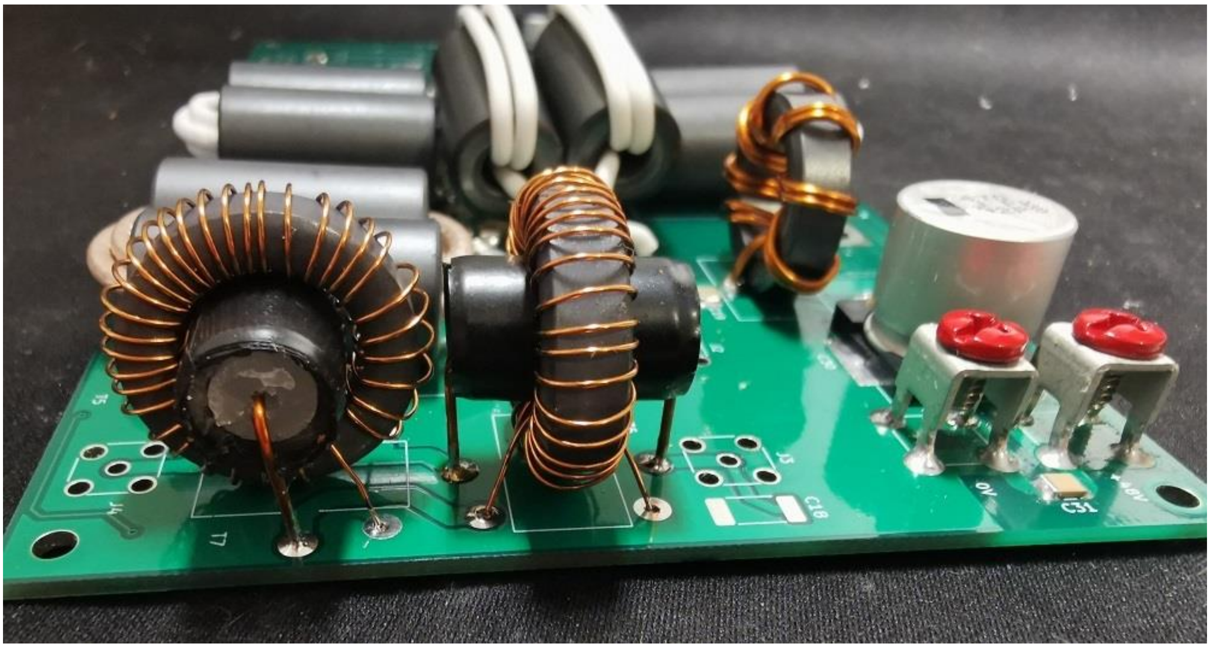


T6 & T7 - 33 turns on toroid with one central wire. Pay extra attention to symmetry with these two transformers, as it may affect forward & reflected power measurement in the higher frequencies. First, wind 33 turns of the thin wire on the toroid, as equally spaced as possible and making sure they cover about 90% of the toroid. Carefully scrape the insulation off the wire ends with the utility knife and coat in solder.

For the second step, you will need some electrical tape and small piece of RG-213 or similar coaxial cable to make the central spacer. Cut a piece of 1.5cm (around 5/8 inch) coaxial cable and remove the shielding and the central wire. Cover the central insulation with a few layers of electrical tape to make sure it's not loose inside the outer jacket. Apply a few extra layers of electrical tape on the outer jacket as well, to make sure it is a snug fit inside the toroid. Pass the thick copper wire through the central spacer, bend it at 90 degrees where it comes out, scrape the insulation off the ends and cover in solder.



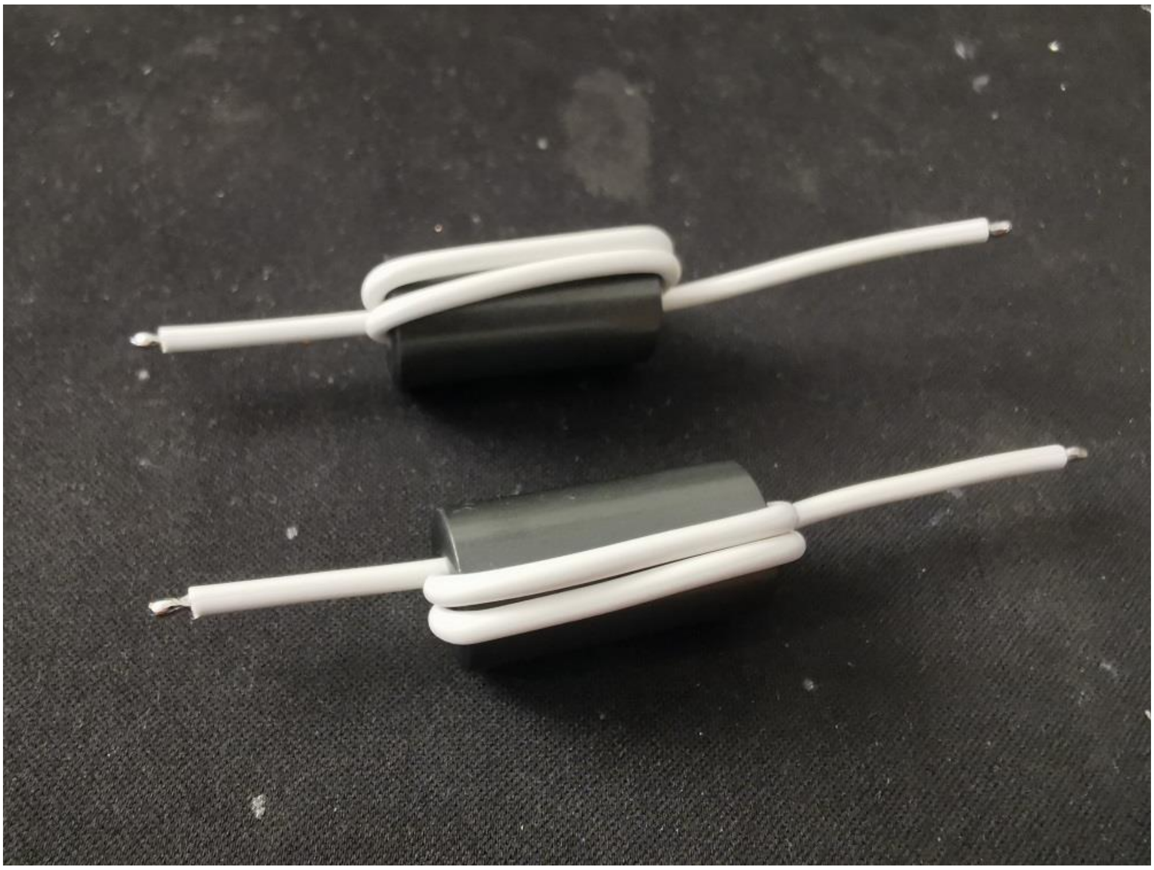
Install on the board as in the picture, trying to have the toroid not touch the PCB.



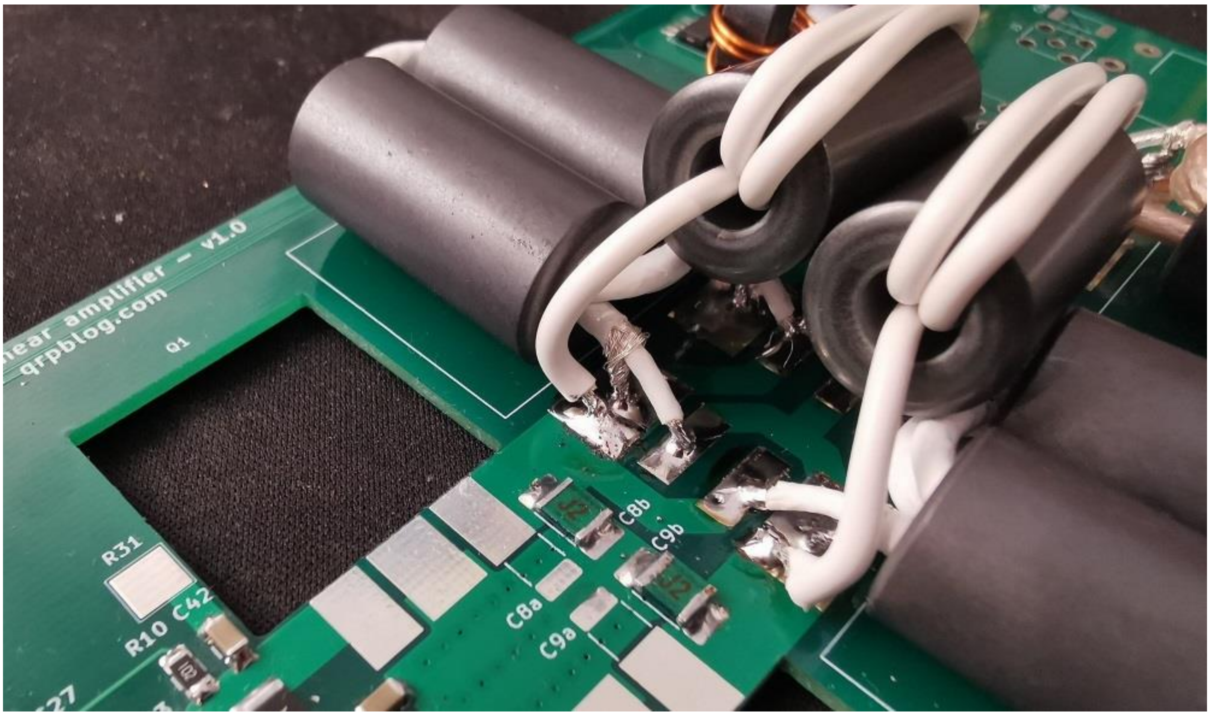
L1 - 8 turns bifilar on toroid. Cut the supplied wire in two equal lengths and wind the two wires together on the toroid; it should be enough for 8 turns, with a bit to spare. With the utility knife scrape the insulation from the wire ends.

Make sure you apply a clean layer of solder coating, install L1 as in the picture and solder in place.

L2 & L3 - 3 turns on large ferrite bead. Wind the supplied wire so it passes 3 times through the ferrite core. Use the utility knife to remove about 5mm (1/4 inch) of wire jacket, coat with solder.

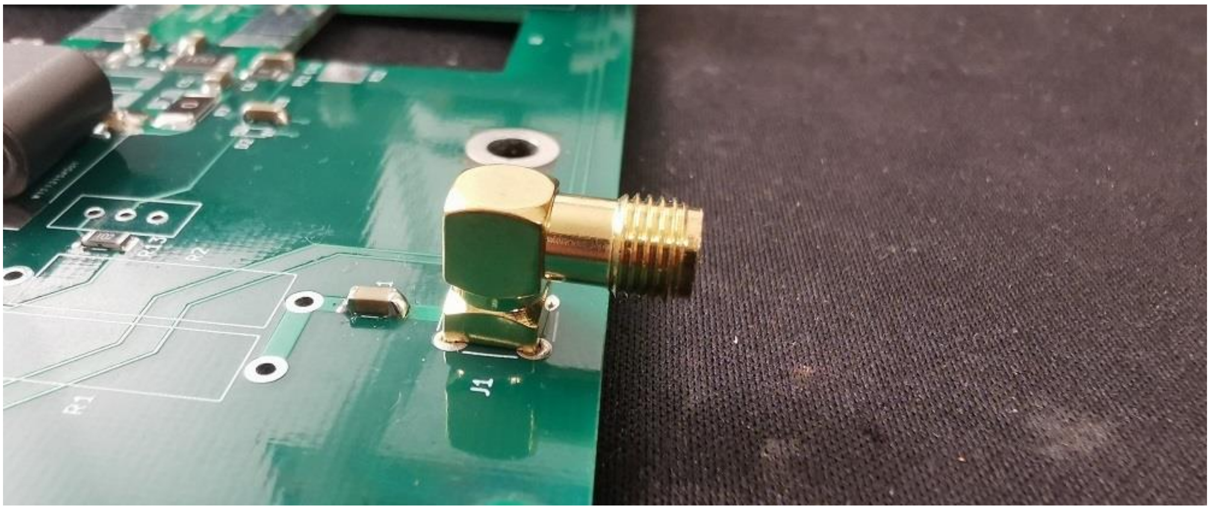


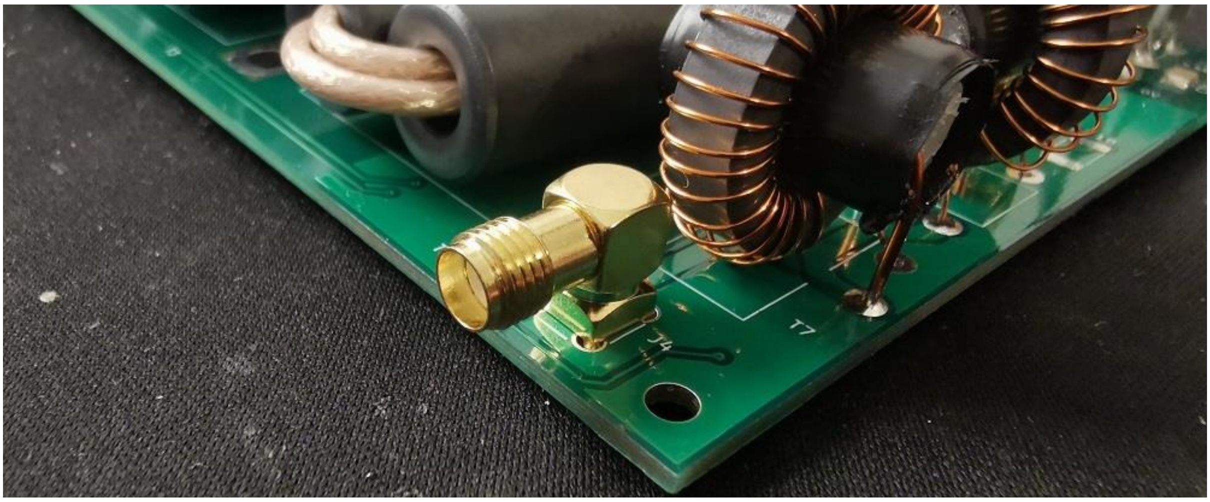
Solder in place as seen in the pictures.



Install & adjustment

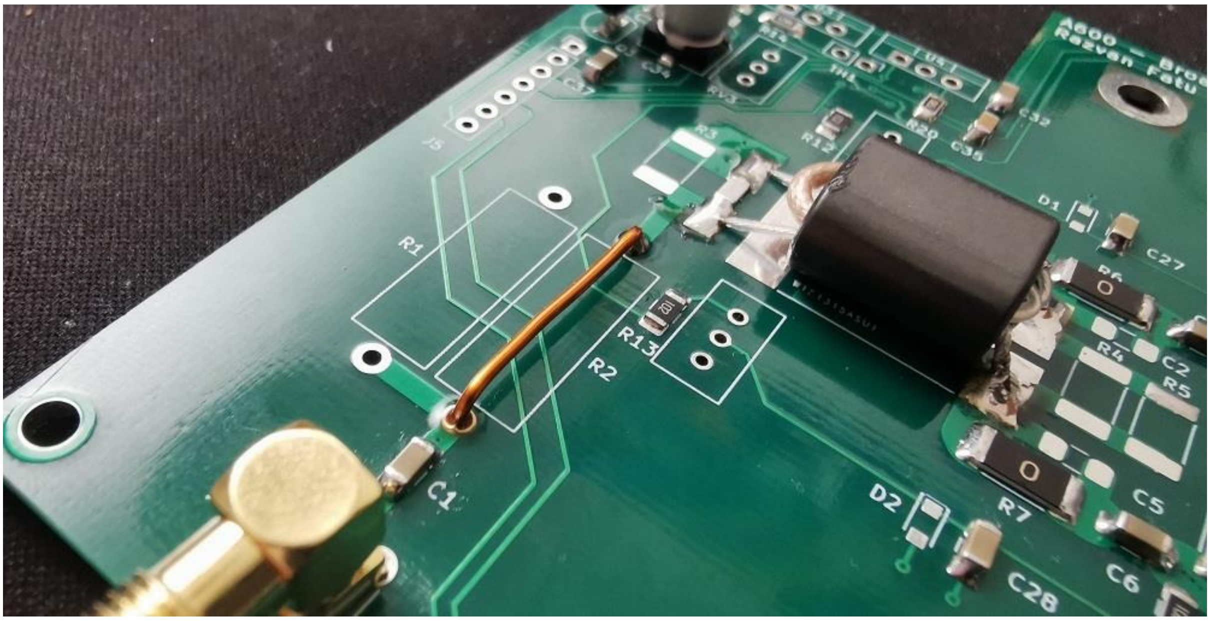
There are 2 straight and 2 angled SMA connectors in the kit, you can choose which to use where for J1, J2 J3 and J4; pay attention to clearance on the underside.





Some people have complained that SMA connectors "don't look like they could handle 600W". The manufacturer specifies them for at least 600W up to 1GHz and some industrial manufacturers like Hilberling use them exclusively in their 1kW+ HF/VHF amplifiers, but if you're not comfortable with this you can solder coax cables directly to the PCB instead of the SMA connectors.

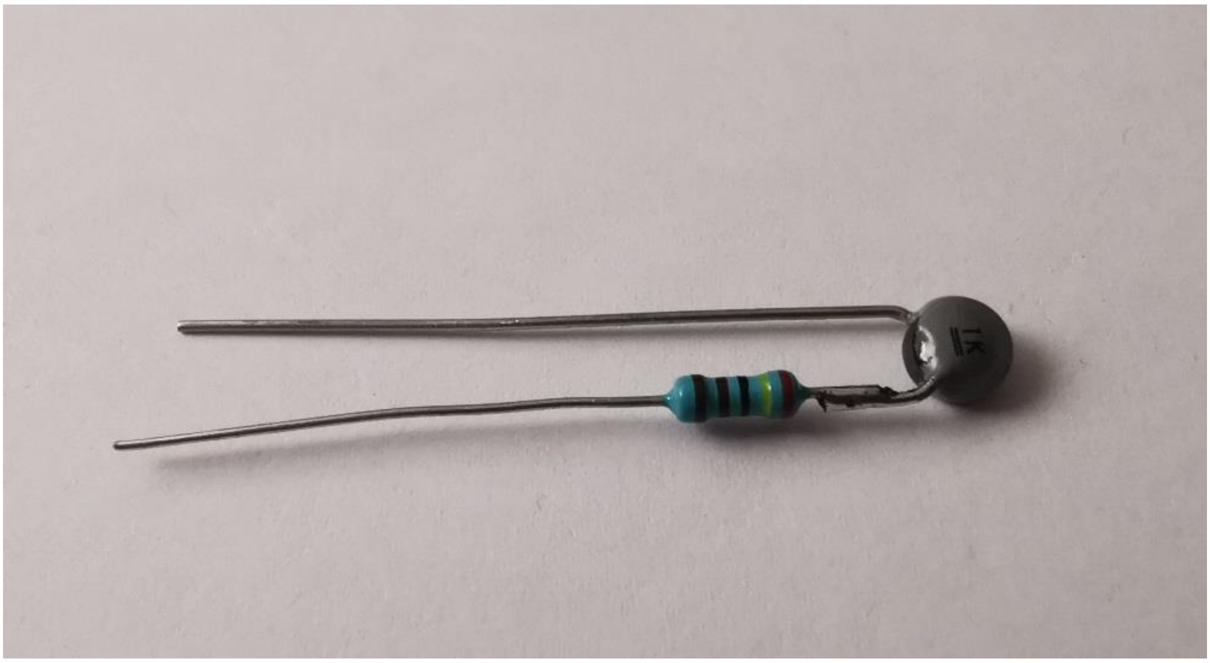
If you intend to drive the amplifier with more than 5W but less than 20W, the PCB board has 3 positions (R1, R2 and R3) where a suitable Pi attenuator can be installed.

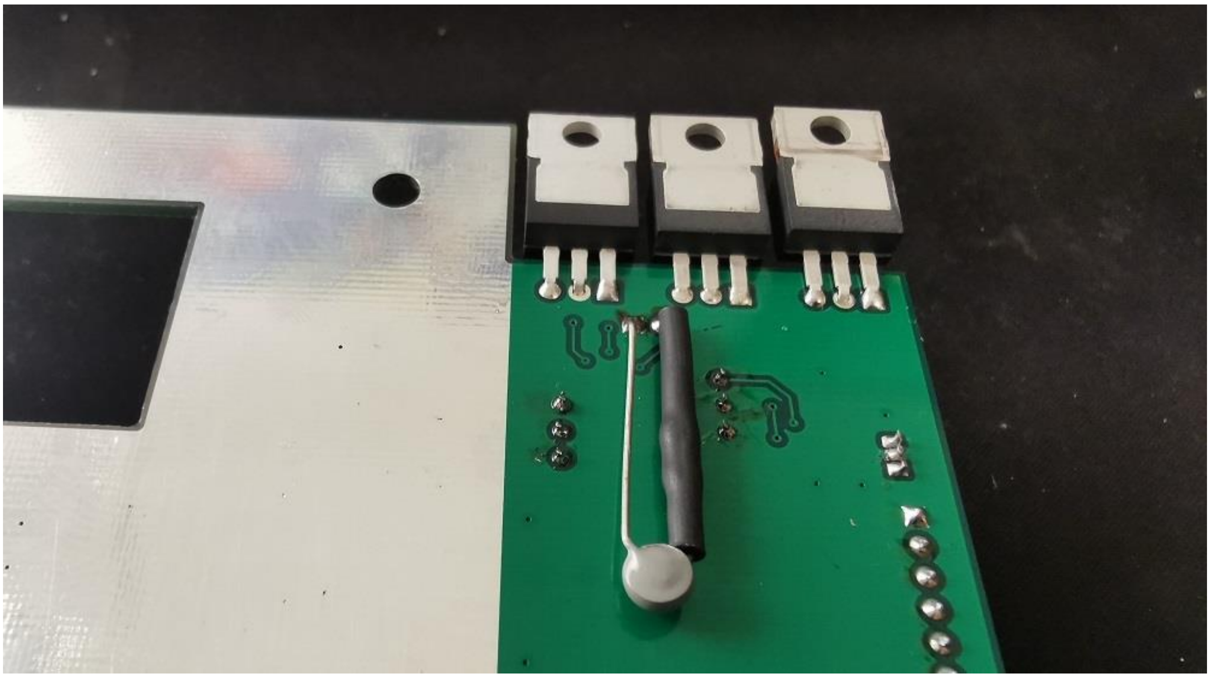


R1 and R2 can fit 3W resistors (2 or 3 can be stacked in each position for more power handling) and R3 is a 2512 SMD resistor typically rated at 1W, so keep that in mind when you design your attenuator. If you have less than 5W drive or you plan to use an off-board attentuator, just install the straight wire in place of R2. No need to worry about its inductance as the capacitor at T1's input cancels it.

Next, install the three (blue) multiturn trimmers RV1 (1k), RV2 (1k) and RV3 (10k) (see a picture further down in this document).

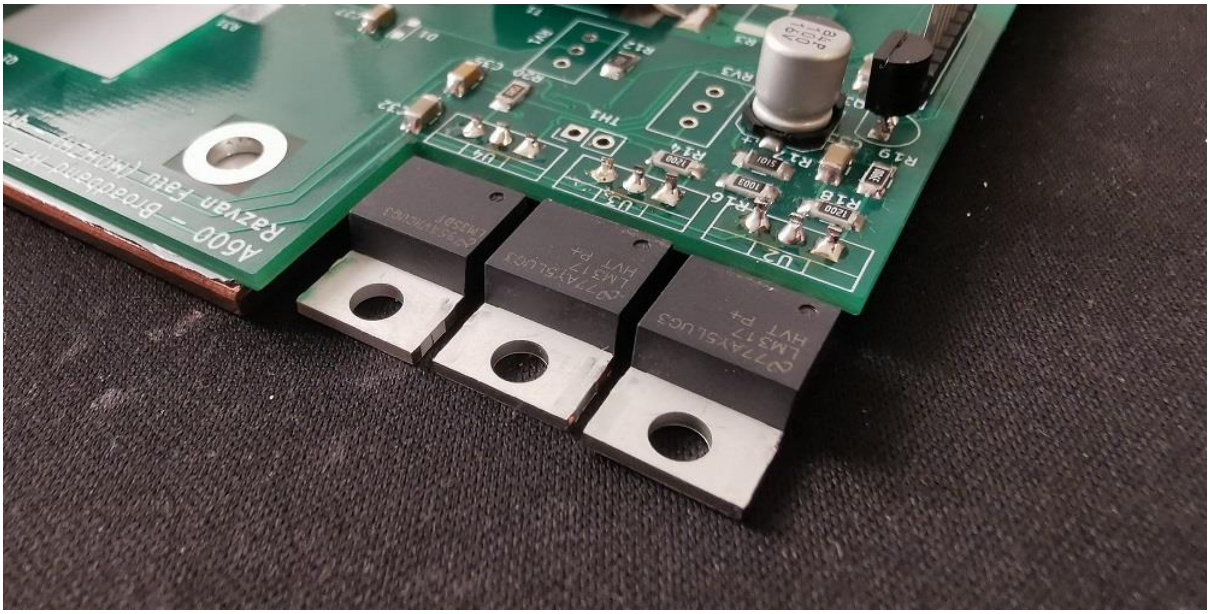
The TH1 thermistor (grey disc) and R29 (2k4 resistor) are meant to be installed in series and connected to the TH1 position. The thermistor should be in as close contact to the heatsink as possible for best idle current stability. One suggestion is to have them on the back of the PCB like in the picture below, so TH1 is touching the heatsink while being gently pressed by the PCB. A drop of non electrically conductive thermal paste can help.



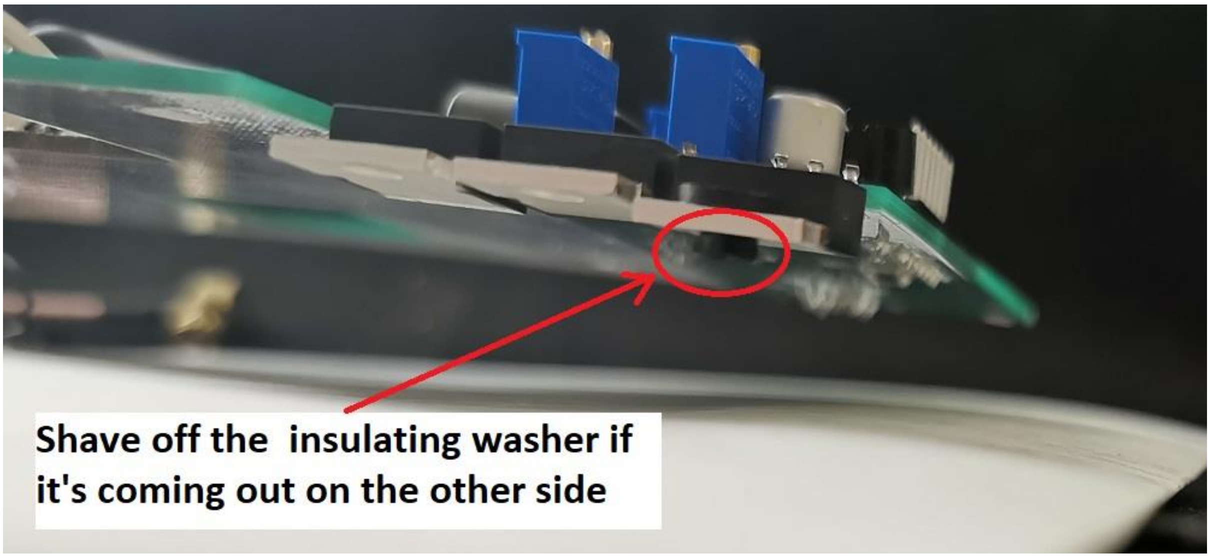


At this stage, place the PCB on the heatsink and check there is no protrusion on the back that could touch the heatsink, except TH1. Pay close attention to where L1, T6, T7 come through the board on the back as their traces carry a lot of energy. Remember there is only 3mm of spacing, provided by the copper heat spreader.

With the PCB board temporarily bolted to the heat spreader & heatsink with the 4x M4 bolts, place U2 (LM317HVT), U3 (LM317HVT) and U4 (LM35D) in their position and solder their legs; cut any excess length.



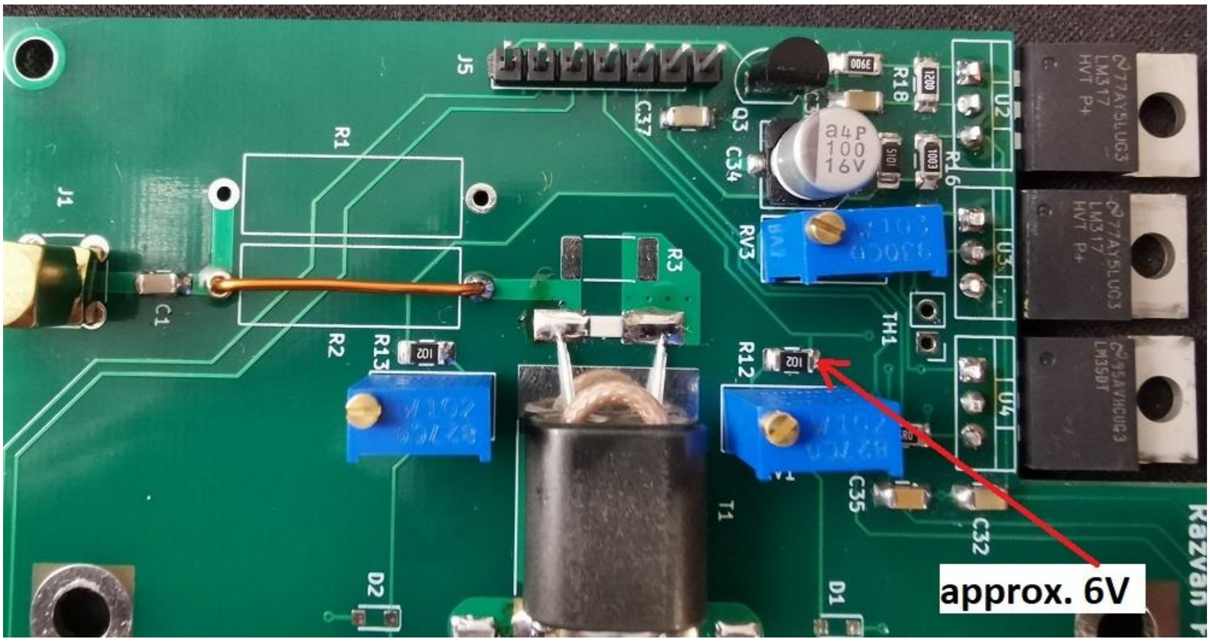
Remove the bolts holding down the PCB to prepare the assembly for permanent mounting. Clean the surfaces thoroughly (soapy water & sponge, wash with plenty of water, wipe with an alcohol-soaked cloth and leave to dry) and apply sufficient thermal grease on the copper heat spreader and on U2, U3 and U4. For U2 and U3 you will need to use the insulating mounting kit (mica sheet and plastic washer). If the washer is too long and comes out on the other side of the IC tab, make sure to shave it off with the utility blade so it's level.



Place the heat spreader on the heatsink and the PCB on top of the heat spreader and screw down the four M4 bolts and then the three M3 bolts for U2, U3 and U4.

Do not install Q1 and Q2 yet !

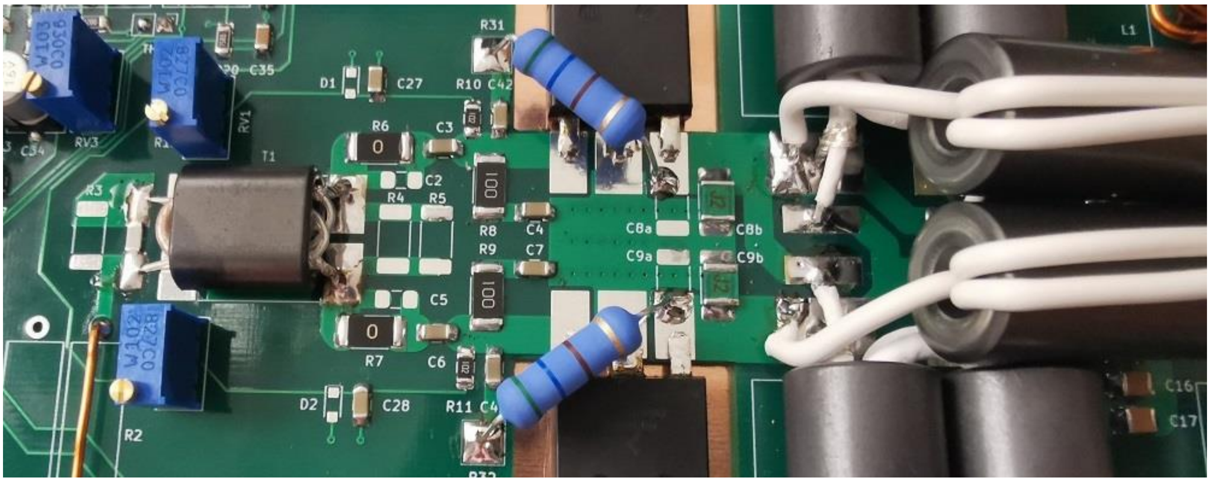
At this point you can apply the +48V to the board through a multimeter on the current range. After the initial surge, the current draw should be around 40mA. Adjust RV3 until the voltage at the upper side of R12 is around 6.0V.



Measuring the voltage at the Gate pad for Q1, adjust RV1 until the voltage is around 2.2V and do the same for RV2 while measuring the Gate tab of Q2.

Remove +48V supply and install Q1 (MRF300AN) and Q2 (MRF300BN). Their legs would have to be cut as in the picture to be able to fit. If you chose a liquid metal thermal interface, make sure you apply a thin layer on both the copper side and the back of the transistors. Tighten the bolts first and solder the legs afterwards, so there is minimal mechanical stress to the solder connections.

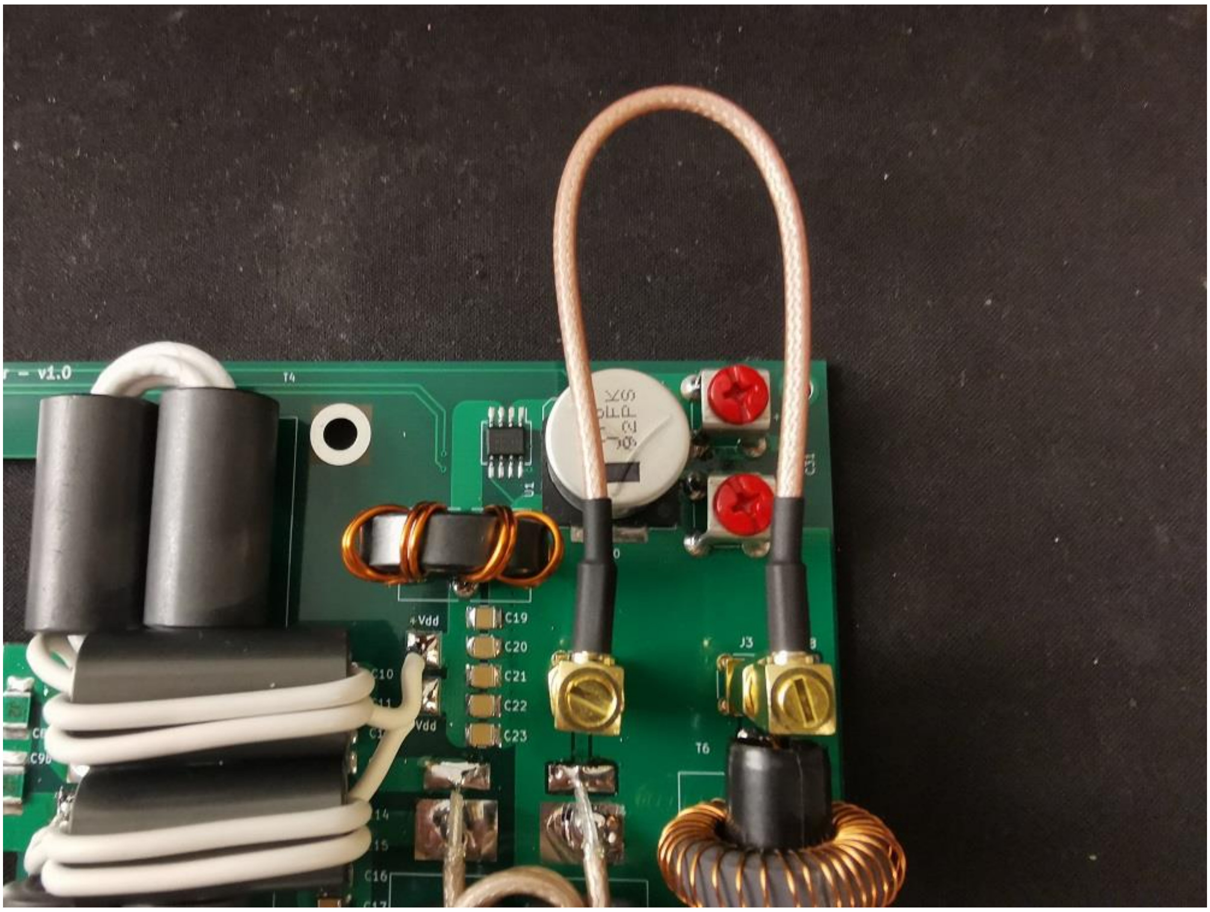
Once that's done you can install the last parts, R31 & R32 (the large 560ohm / 3W resistors) as in the picture.



Now you can apply +48V again to the board and monitor current, which should still be around 40mA. Slowly turn RV1 so the Gate voltage increases until the total board current has increased by 200mA (for example to 240mA if the initial drain was 40mA). Do the same for RV2 until the current has increased by another 200mA.

Setting idle current

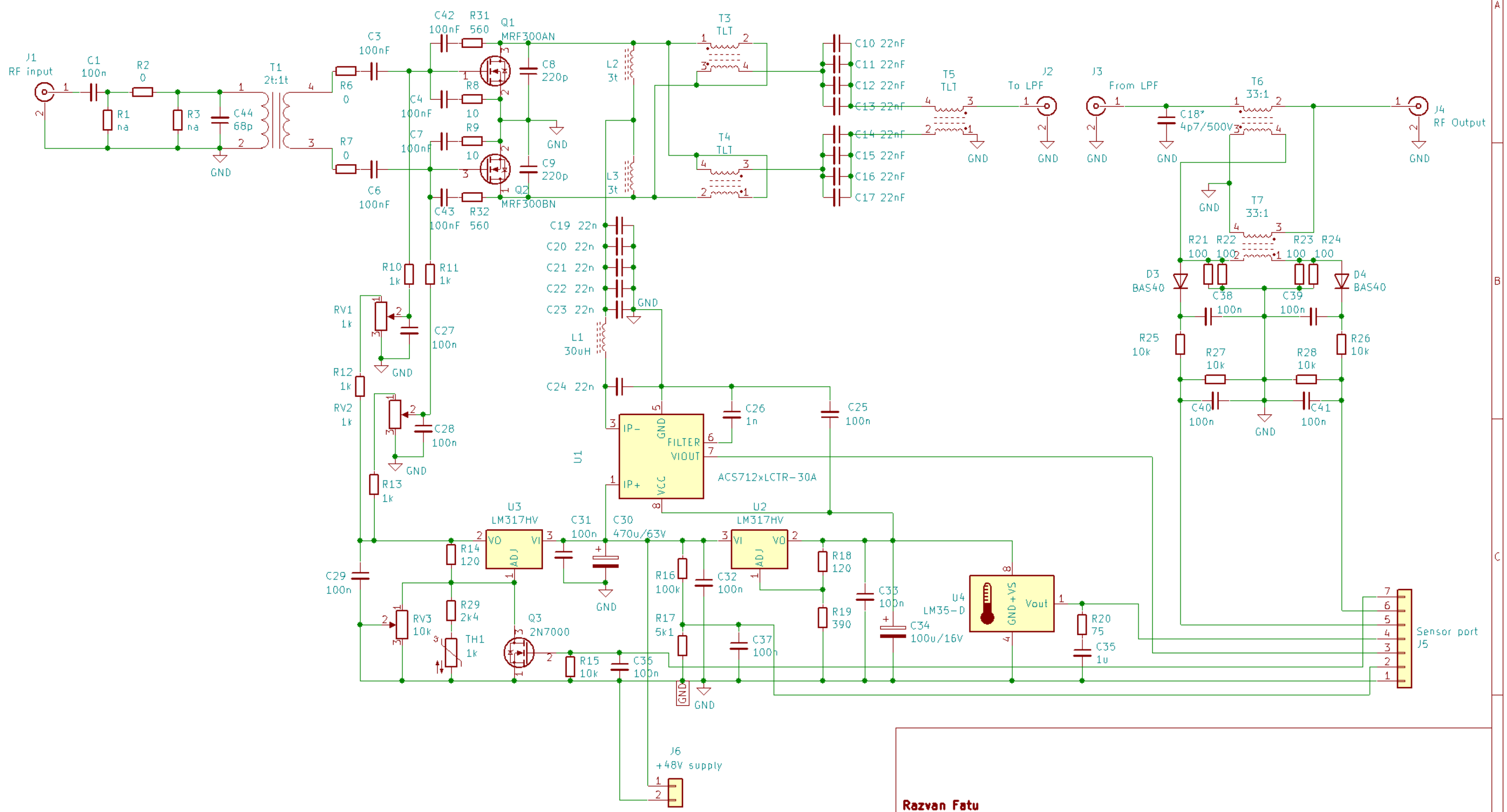
Install the jumper cable between J2 and J3 and connect the amplifier's output to a dummy load.



Slowly turn RV1 so the Gate voltage increases until the total board current has increased by 200mA (for example to 240mA if the initial drain was 40mA). Do the same for RV2 until the current has increase by another 200mA.

From now on, you can test with RF drive, carefully measuring output power, drain current and heatsink temperature.

Never exceed 5-6W of drive to the amplifier as this will damage the power transistors.



Razvan Fatu

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