

HFpacker–Amplifier Project Manual



(Manual version: Sept. 2003)

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and volunteers



Introduction

Welcome all builders to the homebrew Hfpacker-Amp Project. This project and your efforts will provide you with a 2 watt input to 35 watt output linear amplifier for use with QRP SSB/CW transmitters on the amateur bands 160 through 10 meters and which can be powered from a 12 volt DC supply. The design is a good balance between output power, physical size and battery power consumption. The completed amplifier will reward the builder with a clean, more powerful output signal for a QRP rig when radio conditions become marginal.

This project is not a beginner's project and requires a medium skill level to complete it successfully. Builders require soldering, hand tool, basic electronics and component identification skills. This project manual is not included with the project parts in order to keep costs to a minimum. Instead it is available as a PDF document file from <http://www.hfprojects.com>. The manual is produced in landscape format to allow more readable text per screen. This manual provides all you will need to successfully complete the amplifier project, however, some additional PDF files are provided at the above website for those interested in seeing more pictures of the project at various stages of construction.

The genesis of this circuit is fully described in the 2001 ARRL Handbook and in reprint articles from the ARRL. If you are an ARRL member, you can view the amplifier articles on-line at: <http://www.arrl.org/members-only/tis/info/pdf/9903040.pdf> and <http://www.arrl.org/members-only/tis/info/pdf/9903043.pdf>. Full design credit is given to Mike Kossor, WA2EBY. This amplifier project comprises three printed circuit board *modules*: an RF amplifier module containing the MOSFETs, a switch-mode power supply module which converts 12VDC to 24VDC and a bandpass

filter module. The amplifier module is mounted to the inside bottom of the chassis box and its MOSFETs are attached to a heat sink. The power supply board is fastened above the amplifier board, while the filter board is mounted vertically along one side end of the chassis.

Circuit Details

The amplifier module is a push-pull design, biased for Class AB linear operation and uses low-cost power MOSFETs in its output stage. Maximum efficiency is at 10 MHz and develops over 70 watts input. QRP transmitter RF input is first sensed, which trips a relay, feeding RF through an RF attenuator pad. The signal is then applied to the primary of T3 via an input impedance-matching network consisting of L2. T3 is a 1:1 balun that splits the RF signal into two outputs 180 degrees out of phase. One of these signals is applied by C3 to Q1's gate. The other signal is routed via C8 to Q2's gate. The drains of Q1 and Q2 are connected to the primary of output transformer T1, where the two signals are recombined in phase to produce a single output. T1 also provides impedance transformation from the low output impedance of the MOSFETs to the 50Ω antenna port. DC power is provided to the drains of Q1 and Q2 by phase-reversal choke, T2. This is a very effective method to provide power to Q1 and Q2 while presenting a high impedance to the RF signal over a broad range of frequencies. The drain chokes for Q1 and Q2 are wound on the same core, and the phase of one of the chokes is reversed. C7 increases the bandwidth of impedance transformation provided by T1, especially at 21 MHz. The 5 V bias supply voltage is derived from a 78L05 regulator. Bypass capacitors C5, C6, C10 and C11 remove RF voltages from the bias supply voltage. Gate bias for Q1 and Q2 is controlled independently. VR1 adjusts Q1's gate-bias voltage via R1 and L1. VR2 works similarly for Q2 via R5 and L3. At low

frequencies, the amplifier's input impedance is essentially equal to the series value of R1 and R5. L1 and L3 improve the input-impedance match at higher frequencies. The low value of series resistance provided by R1 and R5 also reduces the Q.

The switch-mode power supply module plugs into the top of the amplifier board and boosts the nominal 13.6VDC input to 24VDC at 4-5 amperes during voice peaks. The power supply is normally off unless commanded to be on by the TR Relay, which senses RF, so that during receive or standby its standby current is very low. There is a 10 mA current draw when power supply is off, 80.0 mA current draw when power supply is on and 5A current draw when the amplifier is keyed by a transceiver for power output of 35 watts. The circuit is reverse polarity and overcurrent protected. In the transmit mode, the power supply develops 24VDC at J3. The voltage output measured at TP3 is controlled by U1, an LT1270 switching regulator. The output voltage is sensed back at pin 2 from the voltage divider R4 and R7. U2 is an IPS511 device which provides short-circuit protection and zero volts out when the power supply is off. An internal current limit of 5A is continually monitored by U2. In the event of over-current, the output voltage drops to zero. The U2 device purposely goes into a thermal shutdown and has a temperature hysteresis time delay before attempting to supply current again. A toggle switch connected to J5 can place the MOSFET amplifier in the tune and/or standby modes when toggle switch is closed. A closed toggle switch position inhibits DC output and the amplifier is thus off. With an open toggle switch the Hfpacker-Amplifier is on.

The filter module board attaches to one internal side of the chassis with a 6 position rotary switch. It has 6 low-pass filters covering the amateur bands 160 through 10 meters for bandpass filtering. These filters suppress harmonic output and comply with FCC regulations. Frequency selection is made using SW4, a 2-pole, 6-position rotary switch.

Specifications

| | |
|-------------------|--|
| Size | 5.1 x 3 x 3.3" (LWD, including heat sink) |
| Weight | less than ¼ lb. |
| Supply voltage | 8.5 to 15 VDC (13.8V nominal); reverse-polarity protection; internal self-resetting fuse |
| Current drain, | |
| Standby | less than 10 mA |
| Transmit | 8-9 A at 35-40 Watts |
| Filter Selection | 6-position rotary switch |
| Frequencies | 160, 80, 40, 30-20, 17-15, 12-10 meters |
| Control | Standby/Operate toggle switch |
| Input | BNC 50 ohm |
| Output | SO239 50 ohm |
| Power cable | 2-pin inline quick-disconnect |
| Drive requirement | 2.5 watts RF (with internal 4 dB pad) |
| Power output | 35 watts RF 160 – 10 meters |
| Duty cycle | Designed for intermittent SSB service |
| Forced air | 100% |
| Intermittent | 50% |
| Spurious products | -40 dB or better @ 35 watts |
| Harmonic content | -45 dB or better @ 35 watts |
| Load tolerance | 2:1 or better SWR recommended |
| T-R delay | approximately 10ms |
| Control | RF sensing T-R relay |
| Voltage Booster | 12 to 24 VDC buck-boost switching regulator is activated to power the MOSFET amplifier while transmitting. |

Specifications above assume a 13.8 VDC supply and 50-ohm load at the antenna.

Preparation

The most important preparation step before building is to completely and thoroughly read this manual. This will familiarize you with the project, its circuitry, building requirements and components.

There are six steps in the Hfpacker-Amplifier assembly process:

1. Chassis and Heat Sink preparation
2. RF amplifier board assembly
3. Power supply board assembly
4. Filter board assembly
5. Interconnect cables and Chassis assembly
6. Bias adjustment and Testing

After reading this document and prior to assembly you should do an inventory of parts (Appendix A). In the unlikely event that you appear to have missing parts, duplicates or wrong parts please first double check for the parts in *all* bags, recheck the inventory and if this fails please contact the project organizers. This might also be the time to re-acquaint yourself with how to identify resistors and capacitors by the standard codings (Appendix E), if you have forgotten.

Construction Techniques

It is a fact that 90-95% of problems with completed electronics/radio kits are due to either component misplacement or soldering faults. We cannot stress highly enough the importance of double checking component installation before soldering and then good soldering technique in order to have a working amplifier at the end of this project. Other builder faults are active component damage due to over-heating and damage to circuit board pads and tracks caused by poor desoldering, too high a wattage of soldering

iron or carelessness. It is very rare to have initially faulty components or printed circuit boards (PCBs).

Good Soldering Technique

- use a 12-25 watt soldering iron with a clean, non-corroded, well-tinned, fine tip
- keep the tip clean by frequently rubbing it along a wet sponge
- keep the tip tinned
- ensure all circuit board pads and component leads are clean (not a problem with this project because boards and components are new)
- ensure the soldering iron tip is at its working temperature and is in contact simultaneously with both surfaces to be soldered (the pad and the component)
- let the contact zones heat before applying only electronics grade rosin cored solder (usually 3-6 seconds will do)
- apply the solder to the two surfaces (not the iron tip) and only enough solder to coat both surfaces
- ensure that the joint does not move after you remove the soldering iron tip and until the solder has solidified
- the resultant good solder joint should be shiny, in perfect contact with pad and wire and often has a concave upwards appearance
- special care for toroid coils: the toroids and inductors you will wind and solder in this project use enamel coated magnet wire. You must remove this insulation coating at the ends of the wires prior to soldering. Two techniques are: 1) use a small butane cigarette lighter to burn off the insulation material or 2) take a large drop of hot solder on your soldering iron tip and run the wire end through the hot solder blob to remove the insulation (this may not work with low wattage irons). Other methods such as using sandpaper or a razor knife will work but you may damage the wire or the toroid windings if you are not careful.

Suggested Tools

- 12-25 watt electronics soldering iron, electronics grade solder, iron stand and sponge
- desoldering braid and/or desoldering pump or bulb
- fine needle nose pliers, small fine wire cutters, wire stripper
- hobby drill and small drill bits, electric drill and drill bits, drill punch or awl, reamer
- drill bits: #60, #43, 1/16, 1/8, 3/16, 1/4, 5/16, 3/8, 5/8, 1" (last two may be boring bits, punches or reamer)
- 4-40 NC size tap with tap handle
- small screwdrivers including jewelers screwdrivers, small file
- multi-meter, scissors, tape or glue stick, ruler, test leads
- 50 ohm 35 watt dummy load, 50 ohm resistors

Component Installation

For each component, our word “*Install*” always means:

1. Pick the correct part to start with – in the assembly notes that follow we often provide a part number only. You must match this part number with the correct component using the parts lists (Appendix A). Some parts may be in bags other than their own module bags.
2. Insert the component into the correct PCB position. Refer to the PCB component outline (silkscreen) and Appendix D for the filter module.
3. Orient it correctly, following the PC board outline. This is vital for active components, electrolytic and tantalum capacitors and diodes. Also, it is good practice to mount resistors and capacitors in identical orientations (for resistors normally read color code left to right in same direction as the silkscreen on the PC board). This makes component checks easier.
4. Install all low profile components first: usually resistors, capacitors, diodes, then electrolytics and active components.
5. Resistors should be mounted about 1/8” above the board.

6. Mount all capacitors, relays and connectors as flush to the board as possible.
7. Bend the wires of the components at the bottom side slightly outwards in order to hold the component in place for soldering.
8. Solder as per techniques described above.
9. Trim excess wire leads.
10. Mark off each installation step in sequence as you complete it, in the box provided (e.g.).
11. Warnings and important points are posted with a ⓘ symbol.

Winding Toroids

To wind a toroidal inductor, pull the correct wire length through the toroid core center, dividing the wire length in half. Wrap half the turns with one wire end and then wrap the remaining turns with the other end, in the direction shown in Figure 1. Each pass through the center of the core counts as one turn (e.g., in Figure 1 there are 3 turns). After winding, the turns should be evenly spaced around most of the core, leaving a small (about 30°) gap between the first and last turns (i.e. about 85% of the circumference of the toroidal core should contain evenly spaced wire turns). You must then remove the insulation coating the ends of the two toroid wire ends using techniques described above.



Figure 1

Care of the IRF-510 MOSFET's

MOSFETs are susceptible to electrostatic discharge damage (ESD). It is important to use proper grounding techniques while handling the amp circuit board and the MOSFETs in particular. While working with MOSFETs you should wear a grounding strap and have an antistatic mat at your feet. At the very least you should frequently ground your hands to the nearest ground point. The IRF510 is a good compromise MOSFET that will work up to 30

MHz but has poor thermal characteristics of 3.5°C/Watt. When used in intermittent SSB and CW service forced-air cooling is not required. Tuning time with full power should be limited to less than 30 seconds with 1-2 minutes between cycles to prevent. Operating at 24VDC does not press the MOSFET to their limits. The Sil-Pad TO220 mounting kit has excellent thermal performance and provides a greaseless thermal interface between the MOSFET and the heatsink. Users report that this amplifier can be safely used for contest CW operation without further cooling. For PSK/RTTY forced air cooling is necessary or a reduction of power by reducing the input drive.

Chassis and Heat Sink Preparations

It is recommended that the builder start by preparing the chassis and heat sink before assembly of the circuit board modules because alignment of the MOSFETs requires that the chassis heat sink holes and heat sink taps have been prepared beforehand. Also, seating of the filter board requires that the chassis holes have been drilled.

Templates for drilling chassis holes and for drilling and tapping of the heat sink are located in Appendix B. These are CAD drawings which are exactly to scale in this document.

- ❑ Print out the Appendix B template pages, ensuring that printer settings are such that the pages are printed *as shown* (i.e. no “fit to page”, nor scales other than 100%).
- ❑ Check your printout scaling by measuring the templates with a ruler and comparing those to the measurements shown on each drawing.

Heat Sink Modification

- ❑ Cut out the heat sink template with scissors and paste or tape it to the back of the heat sink.
- ❑ Start the holes with a hole punch, awl or pick and then drill the six marked holes with a pilot (small sharp bit). A Dremel with a #60 bit will do, or a regular hand drill with a 1/16” bit. A drill press will enable better alignment, but is not necessary.
- ❑ Enlarge the six holes with a #43 drill bit, just to the point where the bit comes through the fins of the heat sink.
- ❑ Tap thread the holes using a 4-40 thread hand tap. Tap at least 1/8” deep. If you feel resistance back off the tap to remove cuttings. Oil on the tap and in the hole will help.

- ❑ Test the threads with a 4-40 bolt or spacer. Be careful when threading these into the heat sink. You do not want to break off any threads.
- ❑ File the edges of the holes lightly to remove burrs.

Chassis Holes Drilling

- ❑ Cut out the chassis templates with scissors and paste or tape them onto their appropriate positions on the aluminum chassis. See example in Figure 2 and note below.



Figure 2. Using a template for drilling

- ❑ ⓘ It is vital that the builder position the end panel templates correctly, in relation to the off-center large heat sink mount holes as shown above. The orientation is shown in Figure 2 and Appendix B templates and must be followed exactly.
- ❑ Drill all the marked holes on the chassis templates with a pilot

(small sharp bit), after using a pick or drill punch to start the hole. A Dremel with a #60 bit will do, or a regular hand drill with a 1/16" bit.

Drill the holes out to the size as listed on the drawings. If you do not have 5/8" and 1" bits for the larger holes use a reamer, boring bit or chassis punch.

File the edges of the holes lightly to remove burrs.

MOSFET Amplifier Module Board Assembly

Install resistors R1 through R7.

__R1 __R5: 27Ω, ½ W (red, viol, blk)

__R2: 24Ω, 1 W (red, yel, blk)

__R3 __R4: 220Ω, 1W (red, red, brn)

__R6: 1.2K, ¼ W (brn, red, red)

__R7: 4.7K, ¼ W (ylw, viol, red)

Install ceramic disc capacitors C1, C3, C4, C5, C6, C8, C9, C10 and C11 (all 0.1 uF (104)).

__C1 __C3 __C4 __C5 __C6

__C8 __C9 __C10 __C11

Install C14 (0.01uF, 103).

Install C12 and C15 (.001uF, 102).

Install C7 (47pF).

Install C2, a radial electrolytic capacitor (10uF). This cap is polarized. Insert + lead in the square pad at C2 outline on. The + lead is longest.

Install dip molded capacitor C13 (2.2uF), also polarized.

Install diodes D1 and D3 (1N4148). The black ring on the diode is the cathode. Form the diode leads with approximately 3/16-inch lead on each side of the body. Use a pair of needle-nose pliers and make a 90-degree bend. The white line on the PCB outline is the cathode end. D3 needs to be mounted towards the edge of the board to clear the connector jack J4, installed later.

Install diode D2 (1N4004). The cathode band on the diode aligns with the white stripe of the component outline.

Install potentiometers VR1 and VR2. Rotate both potentiometers until they are centered in the middle of their operating range (in order to assist in correct placement). The pot will stand up off the board resting on the shoulders of the leads. Make sure it is flush on all three leads. Install VR1, VR2 to PC board with blue arrow pointed directly towards the IRF-510 MOSFET silkscreen positions.

ⓘ Using a small bladed screwdriver, now turn both pots fully clockwise. This will be the starting position when adjusting the MOSFET transistor bias later. Fully clockwise places the wiper of the potentiometer at ground or zero bias voltage.

Install K1. Make certain the pins are straight. Two pins on the end of the relay are spaced further apart from the other pins. Orient the relay to align with the pattern on the board. Insert the relay and ensure that all 8 leads are visible on the solder side. Solder one corner pin making sure relay is flush to the board. Press down on the relay while quickly re-heating the pin just soldered to ensure relay is flush to the board. Solder the remaining pins.

Install U1 (7805). Spread the leads of the IC just slightly to match the hole pattern on the board. Ensure the flat of the IC matches the flat of the component outline. The body of U1 should be spaced about 1/4 inch away from the board.

Install J6 (5-pin connector). Ensure connector is flush against the board and perpendicular. Solder one pin. Inspect alignment. Re-flow the soldered pin for final position. Solder the remaining pins.

Install J1 (3-pin connector), as above.

Install Q3 (2N5089). Spread the leads of the transistor just slightly to match the hole pattern on the board. Ensure that the flat of the transistor matches the flat of the component outline. Q3 should be spaced about 1/4 inch away from the board.

Install TP1, TP2, TP3. Orient the wire of the test points in the same direction for consistency.

Install J2, J3, J4, J5. Orient the board with the relay viewed in the lower right corner. The locking ramps of J3 (Ant) and J5

(Filter-B) are on the left, next to the relay. J2 (Filter-A) has its locking ramp to the left, while J4 (Xcvr) has the locking ramp to the right.

❑ Install two 3/4 inch x .187 round spacers on the left side of the board at the inside set of holes on the left edge of the circuit board. Use two nylon washers and 4-40 x 3/16 inch screws attached from the backside.

❑ Install temporarily two 3/4 inch hex male/female threaded spacers. Use two 4-40 nuts on the backside to retain the spacers. The nuts will later be replaced with threaded spacers attached to the chassis when the amplifier is placed on the chassis.

T1 Transformer Construction

T1 has a primary and secondary winding on the BN-43 3312 balun core (the large 2 hole ferrite core). Use the #20 AWG Teflon covered wire to construct T1. See Figure 3 (left side) for a photo of a completed T1.



Figure 3. Photos of T1, T2 and T3

❑ Prepare two wires. The first *primary* wire is 6 1/2 inches long. The second *secondary* wire is 10 inches long. The primary will be two loops while the secondary will be three full loops.

❑ Run the primary wire through first. Make sure to keep the wires from crossing over and unnecessarily blocking the wiring tube. When you complete running the primary winding you should have two wire ends sticking out one end of the balun tube.

❑ Mark the primary side by putting a dab of fingernail polish on the core.

❑ Run the secondary wires through. Be careful to organize the path the wire takes so as to not block the wiring path. It may appear difficult to pass the last wire through the tube but it can be done. After you complete the windings, you will have primary wires on one end and secondary wires on the other end.

❑ Strip the wires within 1/4 inch of the tube hole.

❑ Place the primary wires on the right side of the rectangle near capacitor C7 on the amplifier PCB. The secondary wires go to the left side of the rectangle near J2.

❑ Feed the primary wires into the board and pull them up tight into the holes. You should not have any strands of wires showing when you pull the wire tight into the hole. Solder the primary wires.

❑ Feed the secondary wires into the board and pull them up tight into the holes. A tiny bit of solder right at the very tip end of the strands will hold them together as you push them through the holes. Solder the secondary wires.

❑ Position the transformer over the T1 outline. The transformer is now suspended by the four wires and hovering possibly 1/8 inch above the board. Press the transformer down to the board. The leads will hold the transformer in this position.

T2 Transformer Construction

T2 uses two stacked FT-50-43 cores and has ten bifilar turns of #22 wire. See center of Figure 3.

❑ Measure and cut two #22 wires, each 15 inches long. Twist

these two wires together, with about 4 twists per inch.

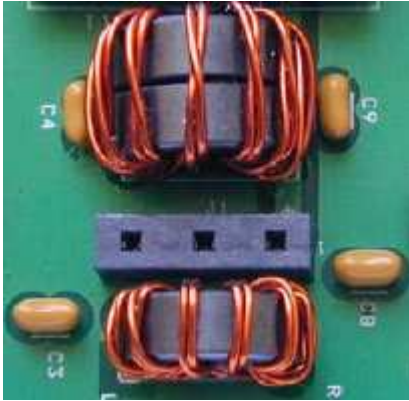


Figure 4. T2 and T3

- ❑ Pass the twisted wire through the center of the two cores. Find the center of the wire and bend around the cores in a U shape. Hold one half wire set steady and wind the other wire half through the center of the cores 5 times.
- ❑ Pass the remaining wire end through the center 5 more times. You now have a total of ten (10) turns through the center of the cores.
- ❑ Equally distribute the windings on the cores.
- ❑ Unravel the twists on the wire ends.
- ❑ Trim these ends so that only 3/8-inch leads remain.
- ❑ Use a butane cigarette lighter, hot blob of solder, sandpaper, emery board or small file to remove the enamel from the 4 wires. Tin these leads.
- ❑ Use an ohmmeter to determine the two windings. On the schematic diagram (Appendix C) the first winding is labeled pins 1 and 2 (there should be zero ohms reading between pins 1 and 2). The second winding is labeled pins 3 and 4 (zero ohms reading between pins 3 and 4). Make certain the two windings are not shorted. The circuit board has a square pad identifying lead 1 of the transformer.
- ❑ Lay the board flat in front of you with T1 at the top. TP1 should be in your upper left corner.
- ❑ Viewing the windings of T2 orient T2 so the wires run vertically

through the cores on the board. When oriented in this position, T2 will fit the component outline. See Figures 4 and 5.

With the PCB oriented such that T1 is in the left hand corner then Lead 1 is upper right, with square pad, Lead 2 is lower right, Lead 3 is upper left and Lead 4 is lower left.

- ❑ Put the 4 leads through the board and snug up T2 tight to the board. Solder. Inspect your joints to make certain that solder flows onto the wire and into the holes.

T3 Transformer Construction

T3 uses one FT-50-43 core and has ten (10) bifilar turns of #24 wire.

- ❑ Measure and cut two #24 wires, each 11 inches long. Twist these two wires together with about 4 twists per inch.
- ❑ Wind 10 turns exactly as explained in the section above for transformer T2.
- ❑ Equally distribute the windings on the core. Unravel the twist on the remaining ends of the wires. Trim these ends so that only 3/8-inch leads remain.
- ❑ Remove the enamel insulation (see “Soldering Techniques”) from the 4 wire ends. Tin the leads thoroughly.
- ❑ Use an ohmmeter to determine the two windings. The first winding is labeled pins 1 and 2 (there should be a zero ohms reading between pins 1 and 2). The second winding is labeled pins 3 and 4 (zero ohms reading between pins 3 and 4). Make certain the two windings are not shorted. The circuit board has a square pad identifying lead 1 of the transformer.
- ❑ Lay the board flat in front of you with T1 at the top. TP1 should be in your upper left corner. Viewing the windings of T3 now, orient T3 so the wires run vertically through the cores on the board. When oriented in this position, T3 will fit the component outline.
- ❑ Orient the PCB oriented such that T1 is in the left hand corner:

lead 1 is lower left with the square pad, lead 2 is upper left, lead 3 is lower right and lead 4 is upper right.

☐ Put the 4 leads through the board and snug up T3 tight to the

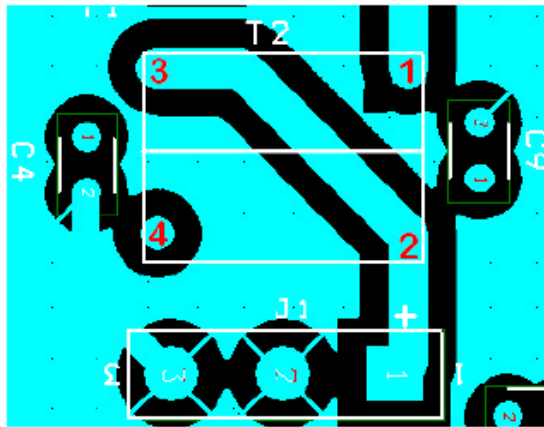


Figure 5. T2 soldering positions on PCB.

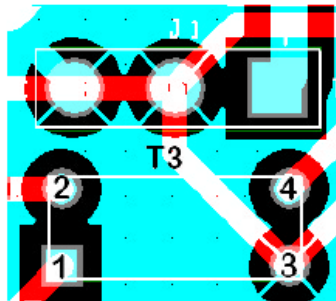


Figure 6. T3 PCB position.

board. Solder. Inspect your joints to make certain that solder flows onto the wire and into the holes. It will take a little more heat to flow pin 3 since it is the ground plane.

Inductors Assembly

NOTE ⓘ: Frequent questions concerning 10 or 9 1/2 inductor turns are answered in Figure 7. The next series of steps fabricate L1, L2 and L3 using #24 enameled transformer wire. L1 and L3 have 9 1/2 turns of #24 close wound on a 0.25 inch ID. These two inductors are identical in size and are formed by wrapping the turns over the shaft of a 1/4 inch drill bit.

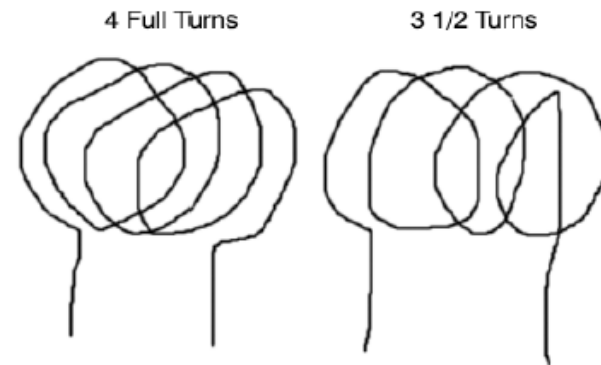


Figure 7. Counting inductor turns.

☐ Cut two 12 inch lengths of #24 AWG enameled magnet wire. Wrap each wire around a 1/4" drill bit shaft 10 times to make two separate inductors. By wrapping the wire around the shaft 10 times you will get 9 turns. The last turn arcs only 1/2 turn before entering the circuit board.

☐ Trim the excess leads to 3/16 inch. Burn or scrape the insulation off the ends of the wires, tin with solder and insert into the circuit board. The wires poking through on the circuit side should be adjusted to protrude only about 1/8 inch. Solder.

☐ Align the inductors directly over the L1 and L3 outline on the board using tweezers. The windings should remain close wound.

☐ Cut a 4-inch length of #24 AWG enameled magnet wire. L2 has

3 ½ turns of #24 close wound on a 0.19 inch ID. Form the inductor by wrapping the turns over the body of a .187 aluminum spacer. Wrap the wire around the spacer 4 times. Trim the excess leads to 3/16 inch. Burn or scrape the insulation off the ends of the wires, tin with solder and insert into the circuit board. Solder.

Adjust the inductor position to be directly over the L2 outline on the board. The windings should remain close wound.

MOSFET Installation

ⓘ Be aware that the sensitivity of a MOSFET's gate makes them vulnerable to damage by ESD. If possible, use a soldering iron with a grounded tip. It is recommended the builder wear a wrist strap and use an anti-static mat. At the very least, you should frequently ground your hands to the nearest ground point.

Attach four .187 x .25 inch male/female spacers temporarily on the bottom side of the circuit board with four 4-40 nuts. The male/female spacers are in the chassis parts bag.

Install the MOSFET's *under* the circuit board. Bend the leads 90 degrees up (away from the mounting surface of the MOSFET) about 0.2 inch away from the body. Push the leads up through the pads on the circuit board.

Locate the heat sink. You will use it temporarily to set the spacing of the MOSFETs from the back side of the circuit board.

Ensure the MOSFET is flat against the heat sink with the circuit board sitting on the spacers and flat on top of the heat sink. Note also, that the thickness of the chassis (0.06 inch) needs to be accounted for. Sandwich the chassis and heat sink together to get the proper spacing.

Solder the leads from the component side of the board. Do not bend the leads. Trim the leads flush with the board after soldering.

Center the hole in the tab of MOSFET with the access hole on the circuit board. You can adjust the MOSFET position slightly by placing the end of small file through the holes to leverage the movement.

The MOSFETs will be secured to the heat sink during final chassis assembly.

Power Supply Module Board Assembly

This power supply module is revision 2.0 and includes a revised VOX circuit to eliminate voice clipping.

Install all resistors:

__R2: 1.0Ω ¼ W (brn, blk, gold)

__R3 __R9 __R12 __R15: 4.7K ¼ W (ylw, viol, red)

__R4 __R14: 22K ¼ W (red, red, orn)

__R5 __R8: 100K ¼ W (brn, blk, ylw)

__R6 __R7: 1.2K ¼ W (brn, red, red)

__R16: 2.7K ¼ W (red, viol, red)

Install capacitors __C6, __C7, __C8. Observe the lead with the + mark on C8. The + lead goes to the hole with the + symbol (square pad).

Install D1 (RL251). The silver band of the diode aligns with the white stripe of the component outline.

Install __D3, __D5 (1N4148). The black bands of the diodes align with the white stripe of the component outline.

Install __D6, __D7 (1N753A). The color bands of these zener diodes align with the white stripe of the component outline.

Install inductor L2 (brn, blk, gld). Install flush with board.

Install U1. This part requires that the leads be formed in a specific way. It is advisable to work on a static free pad with a ground strap to your wrist. You will note that the leads are pre-bent in a stagger configuration for vertical mounting. However, we are going to mount the device flush against the board. The first step is to straighten the leads so they are all flat. Holding the tab in one

hand and with a pair on needlenose pliers in the other, squeeze the five leads about 1/4 inch from the body. All 5 leads should now be flat. Hold U1 near its PCB outline position. Notice that leads 2 and 4 will have a shorter bend than leads 1, 3 and 5. A recessed dimple marks pin 1 on the device that will go into the square pad hole. Pins 2 and 4 are bent at a right-angle 1/8 inch from the body. Temporarily place the part on the board with pins 2 and 4 through the board. Observe where pins 1, 3 and 5 need to be bent to go through their pads. Insert the 5 leads through the holes.



Figure 8. Mount position of U1.

❑ Insert a TO-220 thermal conductor pad under U1 (these are rectangle shaped pad material that has thermal conducting and electrical insulating properties. They are gray or pink in color on a peel-n-stick backing. Handle with needle-nose pliers to prevent contamination of the pad). Align the pad with the mounting hole. Place 4-40 screw from the backside through the board and through the tab of the device. Place an internal tooth washer over the threads. Fasten a 4-40 nut and tighten the component to the board. Make certain while tightening that the body is flush against the thermal pad and the board and that the leads are not under strain when in final position. The leads should be parallel with the device and then down through the board. It is only necessary to trim leads 2 and 4 on the backside so that all 5 lead tips stick slightly through the board. An insulating shoulder washer is not needed for the screw since the potential of the tab and the board is ground. Solder.

See U1 in Figure 8 (middle of photo

- ❑ Install TP1, TP2, TP3, TP4. Orient the wire of the test points in the same direction for consistency.
- ❑ Install CB1 (Thermal Circuit Breaker- a yellow lozenge-like component). Bend the leads at a right angle so the component will lie flat on the board (see Figure 8, left side of photo). On the backside, bend the leads in opposite directions to hold the component in place.
- ❑ Install TABS at J1, J2. Flush mount. Tack one lead. Make certain the tab is perpendicular to the board. Repeat for the other tab.
- ❑ Install J5 (TUNE). This is a 2-pin friction lock header. Place the friction lock to the outside. Solder one pin. Ensure header is flush with board. Reheat connection if necessary.
- ❑ Install J6 (TEST), as above.
- ❑ Install Q2, Q3 (2N5089) transistors. Spread the leads of the transistors just slightly to match the hole pattern on the board. Make certain that the flat of the transistor matches the flat of the component outline. Q2 and Q3 should be spaced about 1/4 inch away from the board.
- ❑ Install Q1 (2N3906) transistor, as above.
- ❑ Install electrolytic capacitors: __C2, __C3, __C5, __C9, __C24, __C25 .
The positive leads are longest. Insert these leads in square pads marked (+).
- ❑ Install C4 (330uF). The positive lead is longest. Insert in square pad marked (+) and solder flush.
- ❑ Install L1 (50uH). Flush mount to the board.
- ❑ Install U2 (IPS511). This is a 5-lead TO220 device. Pin 1 goes to the square pad. The leads are initially straight. You must slope pins 2 and 4 forward so the device will match the component footprint on the board. The device stands up off the board about 1/8 inch.
- ❑ Install D2 (SR860) vertically and matching the component footprint on board. Push the part in until it stands up off the board about 1/8 inch.
- ❑ Insert J3 and J4 on the back side of the circuit board. Before

mounting J3 carefully trim its leads by ¼ “ so they match 5 pin header J5.

Install D4, the red LED. This LED is supplied with long stranded wire leads for easier mounting of the LED to the chassis. You will have to trim these leads to a convenient length.

Plug the power supply module on top of the amplifier module and test for fit and alignment.

Visit: <http://www.hfprojects.com> and download PictureGallery.pdf to see Header J3 and J4 and the power supply as mounted above the amp module.

Filter Module Board Assembly

The assembly of the filter module PCB comprises 7 steps:

1. wind and prepare all the toroids
2. install the silver mica capacitors
3. install all the toroids
4. install the rotary switch
5. perform a continuity test
6. construct the coax cable interconnects
7. install the coax cable interconnects

i It is important that the above steps be done in order. It is also suggested that the builder refer to Appendix D for toroid and capacitor placement positions, because the solder pads on this board are very close together and components are soldered to both sides of this PCB.

Toroids Construction

Wind L1: cut 15" piece of 24 ga. enameled wire, select BLUE T50-1 core, wind 21 turns. Used on 160 meters.

Wind L2: cut 15" piece of 24 ga. enameled wire, select BLUE

T50-1 core, wind 21 turns. Used on 160 meters.

Wind L3: cut 9" piece of 24 ga. enameled wire, select RED T50-2 core, wind 9 turns. Used on 30-20 meters.

Wind L4: cut 8" piece of 24 ga. enameled wire, select RED T50-2 core, wind 8 turns. Used on 30-20 meters.

Wind L5: cut 7" piece of 24 ga. enameled wire, select RED T50-2 core, wind 7 turns. Used on 30-20 meters.

Wind L6: cut 15" piece of 24 ga. enameled wire, select RED T50-2 core, wind 21 turns. Used on 80 meters.

Wind L7: cut 15" piece of 24 ga. enameled wire, select RED T50-2 core, wind 21 turns. Used on 80 meters.

Wind L8: cut 11" piece of 24 ga. enameled wire, select BLACK T50-10 core, wind 11 turns. Used on 80 meters.

Wind L9: cut 10" piece of 24 ga. enameled wire, select BLACK T50-10 core, wind 10 turns. Used on 17-15 meters.

Wind L10: cut 13" piece of 24 ga. enameled wire, select RED T50-2 core, wind 16 turns, Used on 40 meters.

Wind L11: cut 13" piece of 24 ga. enameled wire, select RED T50-2 core, wind 16 turns. Used on 40 meters.

Wind L12: cut 10" piece of 24 ga. enameled wire, select BLACK T50-10 core, wind 9 turns. Used on 12-10 meters.

Wind L13: cut 9" piece of 24 ga. enameled wire, select BLACK T50-10 core, wind 8 turns. Used on 12-10 meters

For all toroids:

Verify the # of turns are correct, equally spaced and occupy about 85% of the core's circumference.

Cut the tail of the toroid leads to about 1/2 inch long.

Remove completely the enamel insulation from the leads to within 1/8 inch of the core. Use a butane lighter to burn it off or a blob of hot solder to aid in removal of the enamel, or scrape it off carefully with a file or sandpaper.

Do not yet install these toroid inductors. Installation is *after* installation of the capacitors on the bottom side of the circuit board.

- __C11 1200 pF (1200)
- __C21 470 pF (470)
- __C22 820 pF (820)

Bottom-side Capacitor Assembly

All but three of the silver mica capacitors are installed on the bottom side of the filter PCB. See Appendix D for a parts placement diagram.

☐ Capacitors are installed from top to bottom and from right to left. Push the capacitor through and flush with the board. Bend the leads at a very slight angle and cut the leads short. Solder one lead, making sure capacitor is still flush with the board and then solder the other lead. Trim the residual leads short as possible.

☐ Install in order :

- __C23 470 pF (470)
- __C13 1200 pF (1200)
- __C9 220 pF (220)
- __C8 220 pF (220)
- __C2 150 pF (150)
- __C1 27 pF (27)
- __C14 12 pF (12)
- __C7 100 pF (100)
- __C19 10 pF (10)
- __C16 150 pF (150)
- __C20 33 pF (33)
- __C24 82 pF (82)
- __C25 150 pF (150)
- __C17 220 pF (220)
- __C26 68 pF (68)
- __C18 100 pF (100)
- __C10 47 pF (47)
- __C3 120 pF (120)
- __C15 39 pF (39)
- __C12 1800 pF (1800)

Top-side Toroid Assembly

Figure 9 is a photo of the toroids and some capacitors mounted on the top layer of the filter module circuit board. Appendix D also has a good parts placement diagram. The builder should refer to both in order to assist in correct toroid installation. In order to remove excess toroid leads in confined areas where wire cutters cannot be positioned properly grasp the end of the soldered toroid lead with long-nose pliers. Slowly bend the lead back and forth until it breaks off.

☐ Install toroids in the following order, proceed from left to right and from top to bottom along the PCB:

- __L3 (red, 9 turns)
 - __L4 (red, 8 turns)
 - __L8 (black, 11 turns)
 - __L2 (blue, 21 turns)
 - __L12 (black, 9 turns)
 - __L7 (red, 21 turns)
 - __L11 (red, 16 turns)
 - __L10 (red, 16 turns)
 - __L6 (red, 21 turns)
 - __L1 (blue, 21 turns)
 - __L13 (black, 8 turns)
 - __L9 (black, 10 turns)
 - __L5 (red, 7 turns)
- ☐ Install the remaining silver mica capacitors on the top layer:
- __C5 2700 pF (2700)
 - __C6 1500 pF (1500)
 - __C4 1500 pF (1500)

Rotary Switch Installation

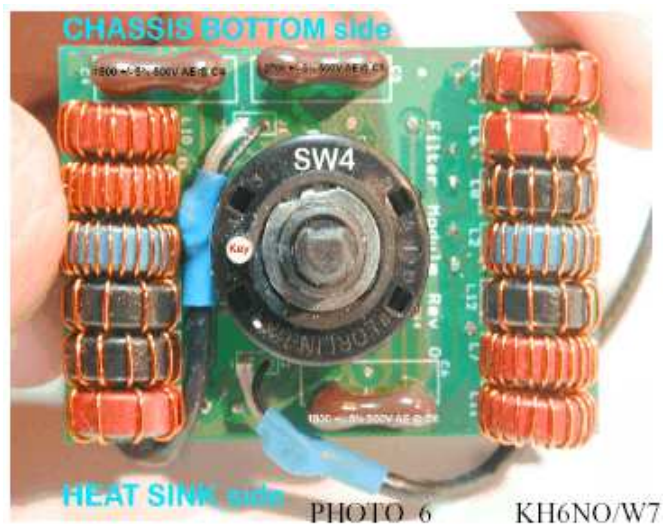


Figure 9. Installation of SW4.

Figures 9 and 10 assist with correct rotary switch (SW4) installation. Note that along the top rim of the switch, close to the shaft, is a small round circular protuberance, called a key (shown and marked in read as “key” in Figure 9). This key *must* be on the top-side of the PCB closest to the side with the 6 toroids, not the 7 toroids (Figure 9). The toroid (upper side) of this filter board will face towards the metal chassis. One red toroid is seen directly below the silver mica capacitor C4 (labeled as 1500 +/- 5% 500V AE, Figure 9, upper left). This is the same upper left position shown in Figure 10, illustrating how the filter board is to be positioned within the chassis.

- ❑ Mount SW4 by itself, onto the chassis *first*.
- ❑ Place thin cardboard pieces on both sides of toroids to evenly space filter board away from metal chassis until the pins from SW4 barely protruded through the filter board.

- ❑ Position the filter assembly board against the SW4 pins, as square as possible using metal sides of chassis as a guide.
- ❑ Solder the filter board to the contact pins of SW4.
- ❑ Use a small round needle file on both SW4 chassis holes to assist with squaring of the filter assembly board, if necessary.
- ❑ Note in Figure 9 the two coax cables, which will be constructed and mounted in the next section. It is now recommended that those cables are attached to J1 and J2 on the *back side* of the filter board, not the front side as shown in figure 9.

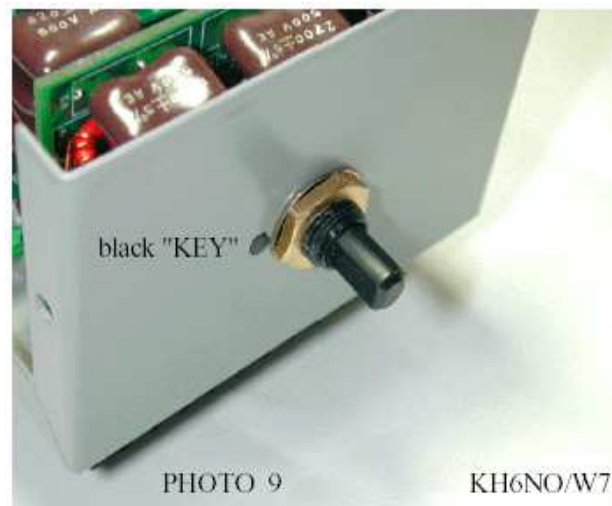


Figure 10. Filter board and SW4 position on chassis.

Toroid Continuity/Short Tests

- ❗ In this section we will use an ohmmeter to assure the builder of toroid continuity and that there are no shorts to ground on the toroids, which could destroy Q1 and Q2 amplifier MOSFETs when the amplifier is powered up.
- ❑ Connect multimeter between J1, pin 1 and J2, pin 1 on filter

board. Zero ohms must be read as SW4 (the rotary band switch) is switched through all 6 positions.

- ❑ If your meter does not read zero ohms, check the filter schematic to see which toroids are installed in that particular switch position. Re-flow the associated toroid solder joints, or remove and re-work that toroid.
- ❑ Connect multimeter between pins 1 and 2 of J1 on filter board. There should be no reading, that is no shorts to ground as SW4 is rotated through its 6 positions. Any shorts must be repaired.

Filter Module Coax Cable Interconnects

In this section we will construct two RG-174U coaxial cable interconnects, which connect the filter board to the amplifier board.

- ❑ Cut two 6-inch lengths of RG-174 coax. Strip ½ inch insulation back on each end, comb out the braid flat, trim the braid to 1/8 inch long.
- ❑ Cut 2 lengths of #24 AWG black hookup wire each 1 inch long. Strip 1/8 inch insulation from the end of each wire. Tin all wire ends. These small wires will be soldered onto the outer coax shield braid and made into pigtailed for easier connection to the crimp terminals of the friction lock headers (Appendix B).
- ❑ Solder one end of each of the above 1 inch lengths of #24 stranded black hookup wire to each coaxial cable braid end. Fold the wire over and then double back in a U-shape and solder the other end to the braid.
- ❑ Cover with 3/8-inch length of 1/4 inch shrink tubing. Shrink the tubing with a heat source.
- ❑ Remove 1/8-inch insulation from the pigtailed black wire ends and tin with solder.

The next steps are to attach the locking ramp housing (Molex connectors) to one end of each coax cable. These will attach to the RF amp board. Please refer to Appendix B “View of Lock Ramp

Housing” and “View of Wire Attached to Crimp Terminal” in order understand how these Molex connectors work, before proceeding.

- ❑ Attach two crimp terminals to each of the center and braid conductors on one end of each coax cable. Note the little barb on the crimp terminal. This barb, when the connector is correctly assembled, snaps into place within the housing. Tin the wire and place it within the crimp connector trough area. Use needle nose pliers to bend the metal tabs around the wire. Solder with minimal solder. Form any remaining tabs around the wire and the insulation. Insert the pin into the brown Molex housing with the barb visible in the slot: the center conductor goes to pin 1 in each case. It should click into place and you should then not be able to pull it out of the housing.
- ❑ Solder the free ends of each coaxial cable to the capacitor side (back side) of filter board at J1 and J2. The center conductor is soldered on the right side of J1 and J2 as you look at the back of the board with the top of the board oriented correctly. You will have to refer to the front-side J1 and J2 outlines as there are no outlines on the back side of the filter board.
- ❑ Although we are not at chassis assembly stage yet, observe how the friction lock headers are installed on the MOSFET Amplifier board. Orient board with relay in upper left when viewing the component side. On J3 (Ant), J5 (Filter-B), and J2 (Filter-A) pin 1 is up. On J4 (XCVR), pin 1 is down.

Chassis Assembly

Install Filter Board, Switch, Coax Connectors and Heat Sink

- ❑ If not already installed, install the filter board to the chassis end

panel as per Figure 10. Dress its coax cable interconnects so as to not interfere with other assemblies.

❑ Attach two 6 inch lengths of black #24 AWG stranded hookup wire to the SPST toggle switch. Twist the wires about 5 twists per inch. Strip 1/8-inch insulation from each end and tin the wires lightly.

❑ Solder the wires to the terminals of the SPST toggle switch.

❑ Install the SPST toggle switch in the 1/4 inch diameter hole.

Orient the switch so the bat handle moves horizontally on the panel. The switch is in the closed position when the bat handle is toward the center of the panel. Tighten the panel nut securely.

❑ Connect the two switch wires to Molex crimp terminals and insert into the Molex locking ramp housing. This cable will plug into TUNE on the Power Supply Module. It does not matter which wire is in the left or right locking ramp housing.

❑ Install the BNC jack in the 3/8-inch hole on the chassis connector panel. Tighten the nut securely.

❑ Install the SO239 jack in the 5/8-inch hole and secure with two 4-40 screws, internal tooth lock washers and 4-40 nuts. Orient the connector so the open side of the center pin is accessible for soldering.

❑ Place the heat sink on the outside of the bottom of the chassis. Attach the heat sink to the bottom of the chassis with four male/female threaded stand off terminals (.187 x .25 inch).

❑ Make certain that the MOSFET mounting holes are free from sharp edges that might puncture through the MOSFET insulators, which will be installed next.

Mounting the MOSFETs and Amp Board

❑ Take precautions against ESD.

❑ Place a TO-220 thermal conductive insulation material pad on the mounting surface of both MOSFETs. Align the pads such that they cover the metal surface with the hole of the device and the insulator centered.

❑ Mount the MOSFETs to the heat sink through the chassis holes with two 4-40 screws (do not use lock washers).

❑ Make a final alignment of the MOSFET mounting hole over the threaded hole of the heat sink.

❑ *If* alignment is poor, re-solder the MOSFET leads on the amp board to relieve any sideways pressure from mis-alignment.

❑ Place a fiber shoulder washer on a 4-40 x 3/16-inch screw. The shoulder is towards the end of the thread so that when it is inserted into the mounting tab of the MOSFET device, the screw is insulated from the MOSFET. A magnetic screwdriver makes it easier to insert the screws. Tighten the MOSFETs to the heat sink.

❑ Attach the MOSFET Amp board to the chassis 4-40 spacers with two 3/16 inch 4-40 screws at one end and two 3/4 inch threaded hex spacers at the end, near the relay.

❑ Measure with an ohmmeter to ensure there is no short circuit from the MOSFETs to the chassis:

1. Connect one ohmmeter lead to the chassis.
2. Connect other lead sequentially to all MOSFET solder connections on the board. The reading should be infinite resistance or very high megohms.

A low ohms reading indicates a short circuit from the board to chassis. If you get a short, ensure that the MOSFET is properly insulated from the chassis and heat sink.

Chassis Coax Cable Interconnects

In this section we construct two chassis coaxial cable interconnect assemblies in exactly the same manner as we did in the “Filter Module Cable Assemblies” above. Please refer to that section for methodology. These two coax cables will be used to connect the BNC RF in jack to J4 on the amp board and to connect the SO-239 RF out jack to J3 on the amp board.

❑ Prepare two 5-inch lengths of RG-174 coax cable exactly as per “filter module cable assemblies” section above

❑ Note in Figure 11 how the J4 cable center conductor is towards

top side of the amp board while J3 center conductor is towards the bottom side of the amp board. J4 goes to the BNC jack and J3 to the SO-239 jack.



Figure 11. Placement of J2, J3, J4 and J5 coax connectors.

- ❑ Plug in a RG-174 cable assembly to J3 (ANT). The cable assembly has crimp terminals and a locking ramp housing. Solder the center conductor of the RG-174 cable to the center pin of the SO-239 connector. The shield wire of this cable should have a ring terminal attached. Put the ring terminal under the top mounting screw of the SO-239 connector. Use a 4-40 screw, lock washer and nut. Tighten securely. Use a 4-inch nylon cable tie to physically secure the cable body to the ring terminal. This will provide strain relief for the center conductor of the cable.
- ❑ Plug in a RG-174 cable assembly to J4 (XCVR). The cable assembly has crimp terminals and a locking ramp housing. Solder the center conductor of the RG-174 cable to the center pin of the BNC connector. Solder the shield wire of the RG-174 cable to the other BNC terminal.
- ❑ Plug coax cable interconnect “Filter A”, which is attached to J1 on the filter board into the Molex connector J2 on the amplifier

board. Insert the center conductor into the locking ramp housings to mate with pin 1 on the board. Insert connector. Dress cable as shown in Figure 11. Note location of the center conductor.

- ❑ Plug coax cable interconnect “Filter B”, which is attached to J2 on the filter board into the Molex connector J5 on the amplifier board. Insert the center conductor into the locking ramp housings to mate with pin 1 on the board. Insert connector. Dress cable as shown in Figure 11. Note location of the center conductor.
- ❑ Uncertainties concerning coaxial cable installation and orientation can be overcome by referring to Figure 11, the schematic diagrams (Appendix C) and the PictureGallery.pdf file at the website.

Install Power Supply Module and 12VDC Power Cord

See Figure 12 for details.

- ❑ Install the power supply module board on top of the amplifier board using four 4-40 screws. Ensure that connectors power supply and amplifier board connectors J3-J1 and J4-J6 mate correctly under the board and that none of the coax cable assemblies are pinched.
- ❑ Insert a rubber grommet into the 5/16-inch hole on end panel.
- ❑ Cut the black and red power cable in half.
- ❑ Run the power cord through the grommet into the chassis interior.
- ❑ Strip 3/8-inch insulation from each wire end.
- ❑ Crimp insulated crimp-on terminals on the two wires.
- ❑ Plug terminals to the 1/4 inch wide power input tabs on the power supply module: the red wire goes on J1 (PWR+) and the black wire goes on J2 (GND).
- ❑ Put a service loop in the wire around C9. Use a 4-inch cable tie to make a strain relief at the grommet (Figure 12).

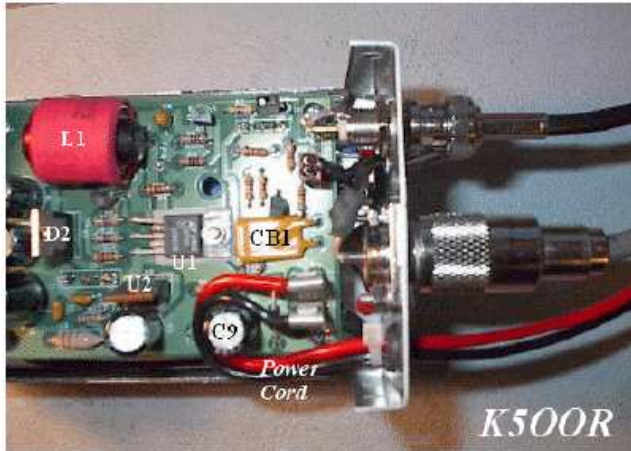


Figure 12. Detail of power cord and cables.

Testing and Alignment

For this exercise the builder will require the following:

- a small flat bladed screwdriver for potentiometer adjustments
- larger flat blade screw driver for case screws
- multimeter to measure volts, ohms and amperes
- dummy load to handle 35 watts
- 50 ohm terminators (50 ohm ¼ W resistors in parallel with the BNC and SO239 jacks will suffice)
- test leads
- 12VDC, 9A power source
- cable to connect 12v power source to the power cable.

Power Supply Module Tests

- Set the multimeter to measure DC voltage.
- Monitor TP3 (+) and TP2 (-) with multimeter.
- Jumper J6 (Test).
- Connect the power cable to 12VDC while observing the meter

and the power supply. Measure 24 volts (+/- 0.5V).

An unsuccessful test will require a thorough check of components, component placement, connectors and solder joints on the power supply module.

MOSFET Amplifier Bias Adjustment

- ⓘ Ensure that the two potentiometers (VR1, VR2) are both in the fully clockwise position. Failure to do so can lead to excess current in the MOSFETs and their consequent failure.
- Measure resistance between J1 pin 1 (+) to J1 pin 2 (-) on the amp board. The reading should be very high or infinite.
- Terminate both BNC input and SO239 output with 50 ohms (50Ω, ¼ W resistors will suffice).
- Plug the power supply module on to the MOSFET amplifier board.
- Make certain the cables to the filter board are not in the way or pinched between the transformers below and the board above.
- Ensure that J3 (male 3 pin header) and J4 (male 5 pin header) on circuit side of power supply board are correctly plugged in to J1 (female 3 pin connector) and J6 (female 5 pin connector) on the MOSFET amplifier board.
- Tighten four (4) power supply hold down screws.
- Put the multimeter in series with the power source and the power cable in order to measure current. Plug in 12VDC power. The T-R relay will click closed for about 1 second then it will open again.
- Measure in-line current of ____ mA. (11.48 mA reference current). Unplug power.
- Measure voltage from TP2 on the power supply module to the VOUT pin of U1 on the MOSFET amplifier board. U1 is located close to the 5-pin board-to-board connector. Capacitor C1 is just to the right of U1. Plug-in power again. The reading should be 5VDC (+/- 0.1 VDC). ____ VDC. Unplug power.

- Put the meter in series with the power source and the power cable to measure current. Connect the test clips from pin 1 to pin 2 of J6 (TEST) on the power supply module. This will activate the power supply. Plug it in.
- Allow 30 seconds for current stabilization. Record the quiescent (idle) current. _____ mA, (60.2 mA reference quiescent current). The T-R relay will click closed. Unplug power.
- Measure voltage from TP2 (-) to TP3 (+). Voltage measures about 24VDC. _____ VDC. Unplug power.
- Put the meter in series from the power source to the power cable to measure current.
- Allow 30 seconds time for current stabilization.
- Pass a small blade screwdriver through one of the BIAS access holes after a stable reading has been obtained. Monitor the current very carefully. Turn the potentiometer counterclockwise slowly until you see the current begin to increase. Increase the current for 10 mA additional current. Keep tweaking the reading for the target current equaling quiescent + 10mA. For example, if the reading is 60.2 mA, adjust BIAS pot for 70.2 mA.
- Turn the other bias pot counterclockwise to increase the current by 10mA. If the reading is 70.2 mA, adjust BIAS pot for 80.2 mA.

You are now finished setting the bias for both MOSFETs. The total current should be 20mA above the quiescent (80.2 mA reference). Do not attempt to run more bias current than 10 mA for each MOSFET device.

Final Tests

- Ensure that the QRP transmitter you will be using with the Hfpacker-Amp has an RF power output of about 2.5 watts or less. If more than 2.5 watts, the RF attenuation pad resistors (R2, R3, R4) on the amplifier module board will have to be changed accordingly. See the RF amplifier module schematic, Appendix C, which has an input attenuator table.
- Connect a 35 watt, 50 ohm dummy load to the SO-239 jack,

preferably also with an inline wattmeter. (A homebrew dummy load can easily be constructed with appropriate high wattage parallel resistors mounted in a small container with mineral oil, e.g. 4 – 200Ω, 10 W resistors in parallel).

- Connect your QRP transmitter to the BNC jack.
- Connect the amp power cable to a 11.5-14VDC, 9A power source.
- Place SW1 in the standby position.
- Key your transmitter and check for approximately 35 watts output on each band during voice peaks and for a clean sounding signal on a nearby receiver.
- No output power on any band suggests power supply or chassis interconnect problems.
- Significantly inconsistent watts out dependent upon the band you choose suggests problems with the filter module.
- Consistently poor output across all bands suggests problems with the amplifier module.

Any problems encountered need to be traced back to their likely module using standard troubleshooting techniques, along with studying the schematics in Appendix C. Assistance is also available at the user forums at <http://www.hfprojects.com>.

End Panels Silkscreen

As a final touch to this project the builder may choose to add silkscreen end panels. They are provided in Appendix B. Further ideas for enhancement of the chassis are provided in PictureGallery.pdf at <http://www.hfprojects.com> and in the user forums at the same website.

Appendix A – Parts Lists

① The parts for the Hfpacker-Amp come in sorted zip-lock bags labeled for each module they *generally* pertain to. Sometimes however, to minimize the number of items in each bag and to reduce the labor of our volunteer sorters, *certain parts may be placed in other bags*. Volunteers will *attempt* to ensure each bag contains only parts for that module. If you appear to be missing parts please double-check *all* bags. A check box column is provided in the following Parts Lists in order to assist with inventory.

| Appendix A | CHASSIS MODULE PARTS LIST | | | |
|-------------------|---|------------------------|-------------|-------------------------------------|
| Designator | Description | Reference | QTY. | <input checked="" type="checkbox"/> |
| Misc. | Enclosure, Project Aluminum Box 5 1/4 x 3 x 2 1/8 | Chassis | 1 | |
| Misc. | Heat Sink, 4.6 x 2.4 inches | Chassis | 1 | |
| Misc. | Spacer, Threaded Keystone male / female .187 x .250 | Chassis | 4 | |
| Misc. | Washer, Shoulder # 4 | Chassis | 2 | |
| Misc. | Pad, Thermal Conductor for TO-220 | Chassis and PS modules | 3 | |
| Misc. | Connector, BNC (female) Panel Mount | Chassis | 1 | |
| Misc. | Connector, SO239 (female) Panel Mount | Chassis | 1 | |
| Misc. | Grommet, Rubber 1/4 inch ID | Chassis | 1 | |
| Misc. | Disconnect, Polarized Quick -12", 2-pin 16 ga. wire | Chassis | 1 | |
| Misc. | Terminal, "FLAG shaped" (female) .250 22-18 ga. | Chassis | 2 | |
| Misc. | LED, Panel w/wires | Chassis | 1 | |
| Misc. | Knob, 1.04"D x 0.62"H | Chassis | 1 | |
| Misc. | Switch SPST Toggle | Chassis | 1 | |
| Misc. | Cable Tie, Nylon 4 inch | Chassis | 2 | |
| Misc. | Terminal, Ring #4 | Chassis | 2 | |
| Misc. | Crimp Terminal, Molex 538-08-50-0114 | Chassis | 6 | |
| Misc. | Locking Ramp Housing, 2P Molex 538-22-01-2027 | Chassis | 3 | |
| Misc. | Coax Cable, RG-174 566-8216-100 | Chassis | 12 in. | |
| Misc. | Heat Shrink tubing, 1/4" | Chassis | 3 in. | |
| Misc. | Wire, Hookup #24 AWG stranded, black | Chassis | 12 in. | |
| Misc. | Nut, 4-40 small pattern 2 | Chassis | 2 | |
| Misc. | Screw, 4-40 x 5/16th and/or 3/8 inch | Chassis | 6 | |
| Misc. | Washer, 4-40 internal tooth LOCK2 | Chassis | 2 | |
| Misc. | Core, FB-24 77 Ferrite??? | Chassis | 2 | |
| Misc. | Crimp Terminal, Molex 538-08-50-0114 | Filter module | 4 | |
| Misc. | Locking Ramp Housing, 2P Molex 538-22-01-2027 | Filter module | 2 | |
| Misc. | Coax Cable, RG-174 566-8216-100 | Filter module | 12 in. | |
| Misc. | Wire, Hookup #24 AWG stranded, black | Filter module | 12 in. | |
| Misc. | Nut, 4-40 small pattern | PS module | 1 | |
| Misc. | Screw, 4-40 x 3/8th inch (Binder Head) | PS module | 1 | |
| Misc. | Washer, 4-40 internal tooth LOCK | PS module | 1 | |
| Misc. | Nut, 4-40 small pattern (temp use) | Amplifier module | 4 | |
| Misc. | Screw, 4-40 x 5/16 inch | Amplifier module | 2 | |

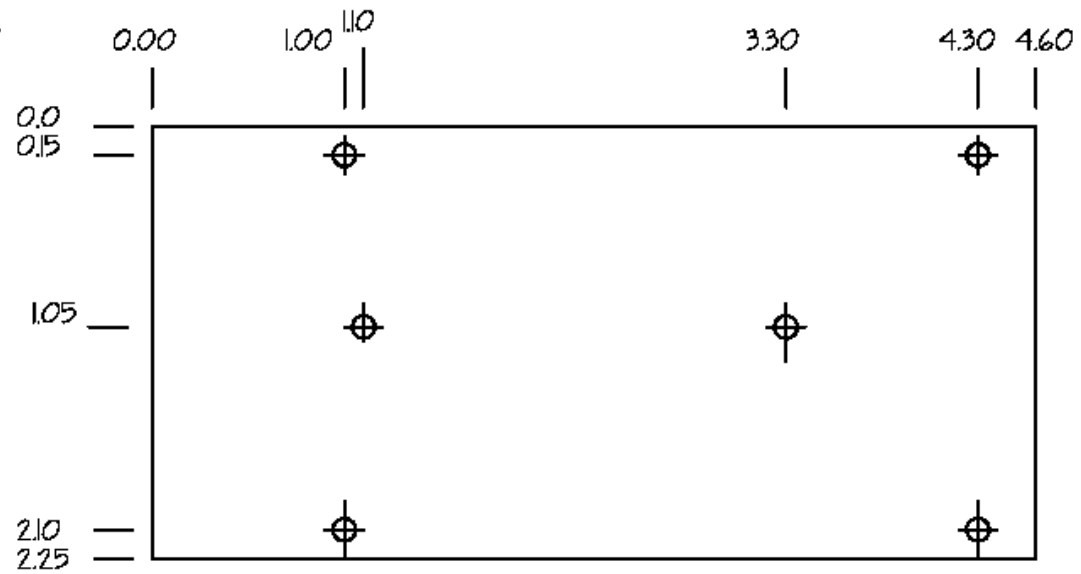
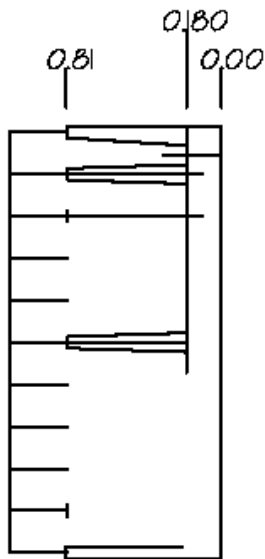
| Appendix A | AMPLIFIER MODULE PARTS LIST | (continued) | <input checked="" type="checkbox"/> |
|--------------------------------------|--|--------------------|-------------------------------------|
| Designator | Description | QTY. | |
| C1, C3, C4, C5, C6, C8, C9, C10, C11 | Capacitor, 0.1uF, 100V, 10% | 9 | |
| C2 | Capacitor, 10uF, 35V, radial | 1 | |
| C7 | Capacitor, 47pF, 500V (470) | 1 | |
| C12, C15 | Capacitor, 0.001uF, 50V, 10% | 2 | |
| C13 | Capacitor, 2.2uF, 25V | 1 | |
| C14 | Capacitor, 0.01uF, 100V, 10% | 1 | |
| D1, D3 | Diode, 1N4148 | 2 | |
| D2 | Diode, 1N4004 1A 400V | 1 | |
| J1 | Connector, 3 pin female, 0.2" PPSS-03-01-T-S | 1 | |
| J2, J3, J4, J5 | Header, friction lock 2 CKT male, 0.100 | 4 | |
| J6 | Connector, 5 pin female, SSW-105-02-S-S | 1 | |
| K1 | Relay, DPDT, MR82-12USR | 1 | |
| L1, L3 | Coil (to be wound by builder), 9 1/2T #24AWG 0.25 ID ??? | 2 | |
| L2 | Coil (to be wound by builder), 3 1/2T #24AWG 0.19 ID ??? | 1 | |
| Misc. | Printed circuit board for amp module | 1 | |
| Misc. | Spacer, aluminum RND threaded .187 x .750 in. | 2 | |
| Misc. | Washer, nylon or plastic #4 | 2 | |
| Misc. | Standoff, HEX male/female threaded .750 x 4-40 | 2 | |
| Misc. | Wire, #24 AWG magnet wire | 60 in. | |
| Misc. | Wire, #20 AWG teflon covered | 18 in. | |
| Misc. | Wire, #22 AWG magnet wire | 36 in. | |
| Misc. | Nut, 4-40 small pattern (temp use) | 4 | |
| Misc. | Screw, 4-40 x 5/16 inch | 2 | |
| Q1, Q2 | IRF-510 MOSFET (static sensitive!) | 2 | |
| Q3 | Transistor, 2N5089 | 1 | |
| R1, R5 | Resistor, 27Ω, ½ W (red, viol, blk) | 2 | |
| R2 | Resistor, 24Ω, 1W (red, yel, blk) | 1 | |
| R3, R4 | Resistor, 220Ω, 1W (red, red, brn) | 2 | |
| R6 | Resistor, 1.2K, ¼ W (brn, red, red) | 1 | |
| R7 | Resistor, 4.7K, ¼ W (yel, viol, red) | 1 | |
| T1 | Core, balun BN-43-3312 (2 holes) | 1 | |
| T2, T3 | Core, FT50-43 ferrite | 5 | |
| TP1, TP2, TP3 | Test Point, glass bead insulated (white) | 3 | |

| Appendix A | AMPLIFIER MODULE PARTS LIST | (continued) | |
|-------------------|---------------------------------------|--------------------|--|
| U1 | Regulator, LM78L05ACZ, 5 volts | 1 | |
| VR1, VR2 | Resistor, variable potentiometer, 10K | 2 | |

| Appendix A | POWER SUPPLY MODULE PARTS LIST | | |
|-------------------|--|-------------|-------------------------------------|
| Designator | Description | QTY. | <input checked="" type="checkbox"/> |
| C2, C3, C5, C9 | Capacitor, 100uF 50V, low ESR | 4 | |
| C4 | Capacitor, 330uF 50V, low ESR | 1 | |
| C6, C7 | Capacitor, 0.1uF 100V | 2 | |
| C8 | Capacitor, 1uF 25V | 1 | |
| C24, C25 | Capacitor, electrolytics, 10uF, 16V | 2 | |
| CB1 | Circuit breaker, 16V, 7A hold, 11.9A trip (yellow lozenge) | 1 | |
| D1 | Diode, RL-250, 251 or 252 | 1 | |
| D2 | Diode, Schottky, Rectron SR860 | 1 | |
| D3, D5 | Diode, signal, 1N4148 | 2 | |
| D4 | LED Diode, red, panel mount with wires | 1 | |
| D6, D7 | Diode, zener 6.2V, 1N753A | 2 | |
| J1, J2 | Terminal, "tab" shaped male, 0.25" (pc board mount) | 2 | |
| J3 | Header, 3 pin male 0.2" pitch , Samtec | 1 | |
| J4 | Header, 5 pin male 0.1" pitch , Samtec | 1 | |
| J5, J6 | Header, friction lock, 2 CKT male, 0.100, Molex | 2 | |
| L1 | Inductor, 50 uH, radial high current, Dale/Vishay | 1 | |
| L2 | Inductor, 1 uH, 4A (brown, black, gold) | 1 | |
| Misc. | Printed circuit board for power supply module | 1 | |
| Misc. | Nut, 4-40, small pattern | 1 | |
| Misc. | Screw, 4-40 x 3/16" (binder head) | 1 | |
| Misc. | Washer, 4-40 internal tooth lock | 1 | |
| Misc. | Thermal conductor pad for TO-220 | 1 | |
| Q1 | Transistor, 2N3906 | 1 | |
| Q2, Q3 | Transistor, 2N5089 | 2 | |
| R2 | Resistor, 1.0Ω, ¼ W, 5% (brn, blk, gld) | 1 | |
| R3, R9, R12, R15 | Resistor, 4.7K, ¼ W, 5% (ylw, viol, red) | 4 | |
| R4, R14 | Resistor, 22K, ¼ W, 5% (red, red, orn) | 2 | |
| R5, R8 | Resistor, 100K, ¼ W, 5% (brn, blk, ylw) | 2 | |
| R6, R7 | Resistor, 1.2K, ¼ W, 5% (brn, red, red) | 2 | |
| R16 | Resistor, 2.7K, ¼ W, 5% (red, viol, red) | 1 | |
| TP1,TP2,TP3,TP4 | Test points, glass insulated (white) | 4 | |
| U1 | IC, LT1270ACT, 10A power switch regulator, TO-220 | 1 | |
| U2 | IC, IPS511-ND, power MOSFET switch | 1 | |

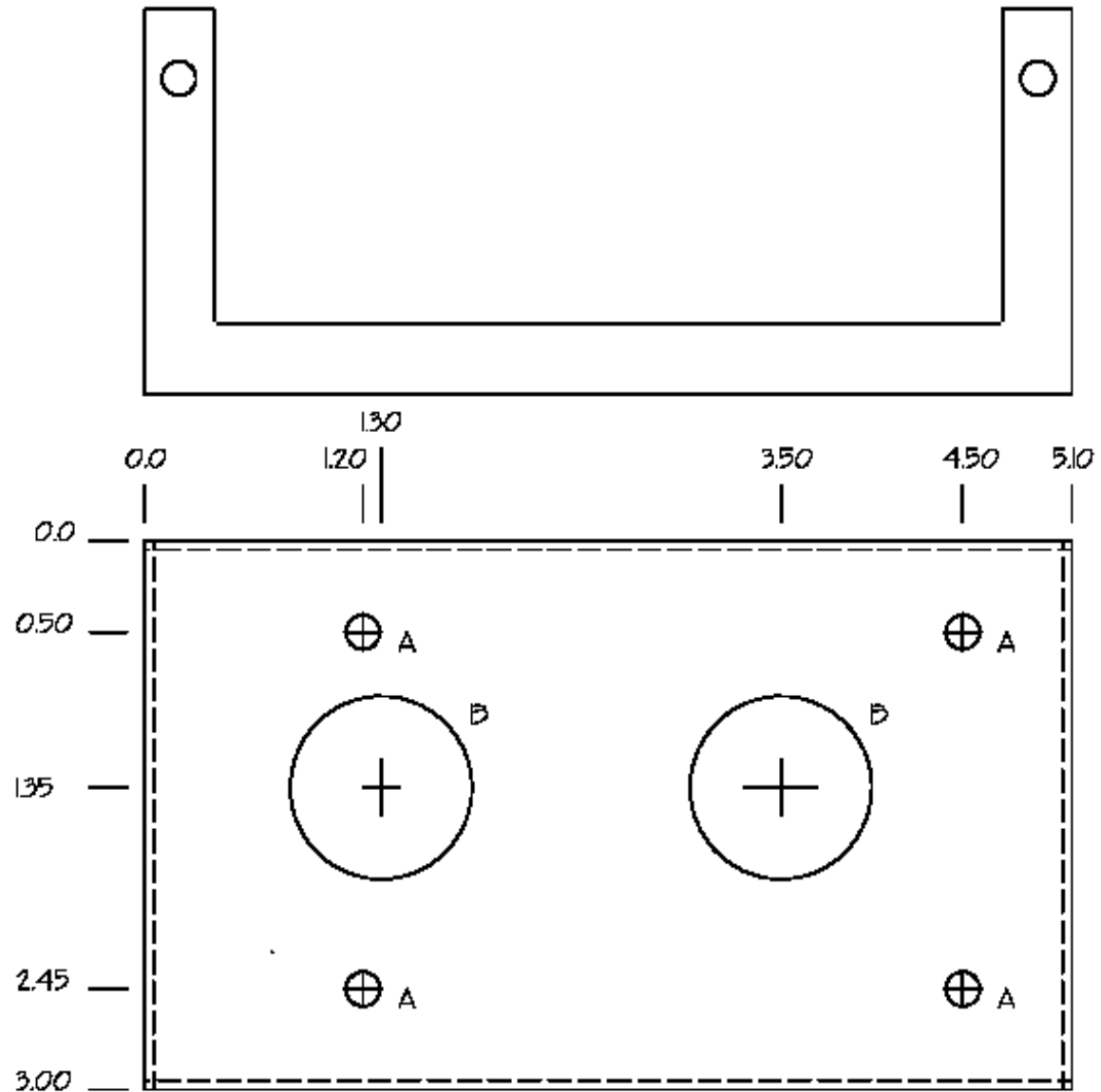
| Appendix A | FILTER MODULE PARTS LIST | | |
|------------------------------|---|-------------|-------------------------------------|
| Designator | Description | QTY. | <input checked="" type="checkbox"/> |
| C1 | Capacitor, 27pF, 500V, silver mica | 1 | |
| C2, C16, C25 | Capacitor, 150pF, 500V, silver mica | 3 | |
| C3 | Capacitor, 120pF, 500V, silver mica | 1 | |
| C4, C6 | Capacitor, 1500pF, 500V, silver mica | 2 | |
| C5 | Capacitor, 2700pF, 500V, silver mica | 1 | |
| C7, C18 | Capacitor, 100pF, 500V, silver mica | 2 | |
| C8, C9, C17 | Capacitor, 220pF, 500V, silver mica | 3 | |
| C10 | Capacitor, 47pF, 500V, silver mica | 1 | |
| C11, C13 | Capacitor, 1200pF, 500V, silver mica | 2 | |
| C12 | Capacitor, 1800pF, 500V, silver mica | 1 | |
| C14 | Capacitor, 12pF, 500V, silver mica | 1 | |
| C15 | Capacitor, 39pF, 500V, silver mica | 1 | |
| C19 | Capacitor, 10pF, 500V, silver mica | 1 | |
| C20 | Capacitor, 33pF, 500V, silver mica | 1 | |
| C21, C23 | Capacitor, 470pF, 500V, silver mica | 2 | |
| C22 | Capacitor, 820pF, 500V, silver mica | 1 | |
| C24 | Capacitor, 82pF, 500V, silver mica | 1 | |
| C26 | Capacitor, 68pF, 500V, silver mica | 1 | |
| L1, L2 | Toroid core, T50-1 (blue) | 2 | |
| L3, L4, L5, L6, L7, L10, L11 | Toroid core, T50-2 (red) | 7 | |
| L8, L9, L12, L13 | Toroid core, T50-10 (black) | 4 | |
| Misc. | Printed circuit board for filter module | 1 | |
| Misc. | Wire, #24 AWG magnet wire | 19.5' | |
| Misc. | Crimp terminal, Molex 538-08-50-0114 | 4 | |
| Misc. | Lock Ramp Housing, 2P, Molex 538-22-01-2027 | 2 | |
| Misc. | Coax cable, RG-174 | 12 in. | |
| Misc. | Heat shrink tubing, 1/4" | 1.5" | |
| Misc. | Wire, #24 AWG, hookup, stranded, black | 12" | |
| SW4 | Switch, rotary, 6 position, 10WA175 | 1 | |

Appendix B – Templates

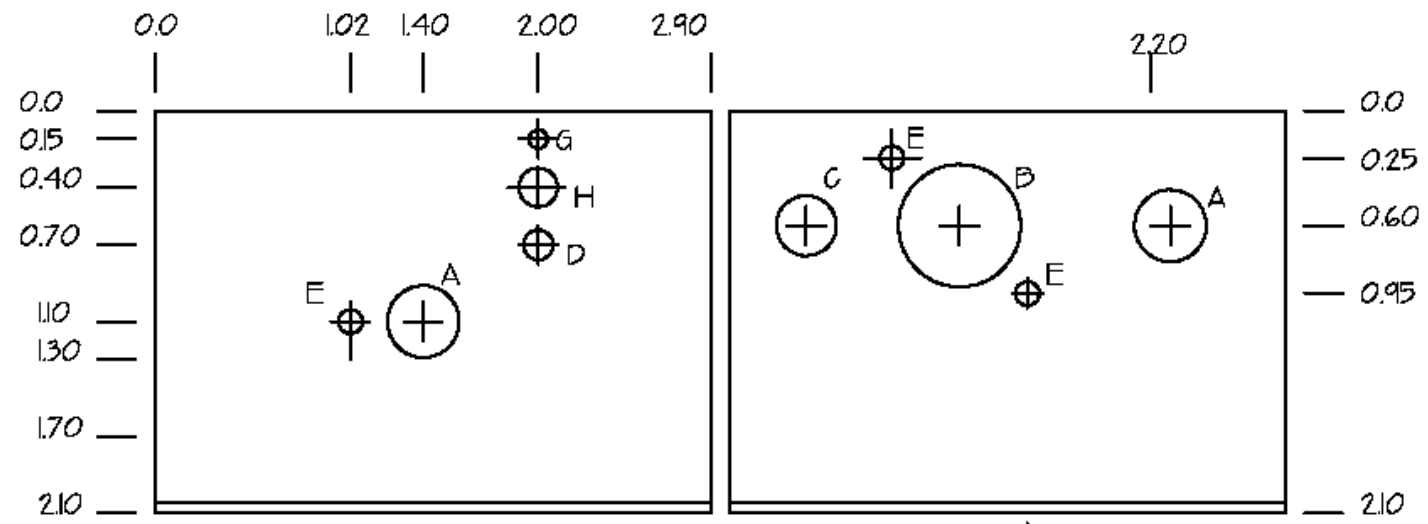


MATERIAL: HEAT SINK: AAVID 646903B0460

DRILL 6 HOLES AND TAP FOR 4-40 SCREW

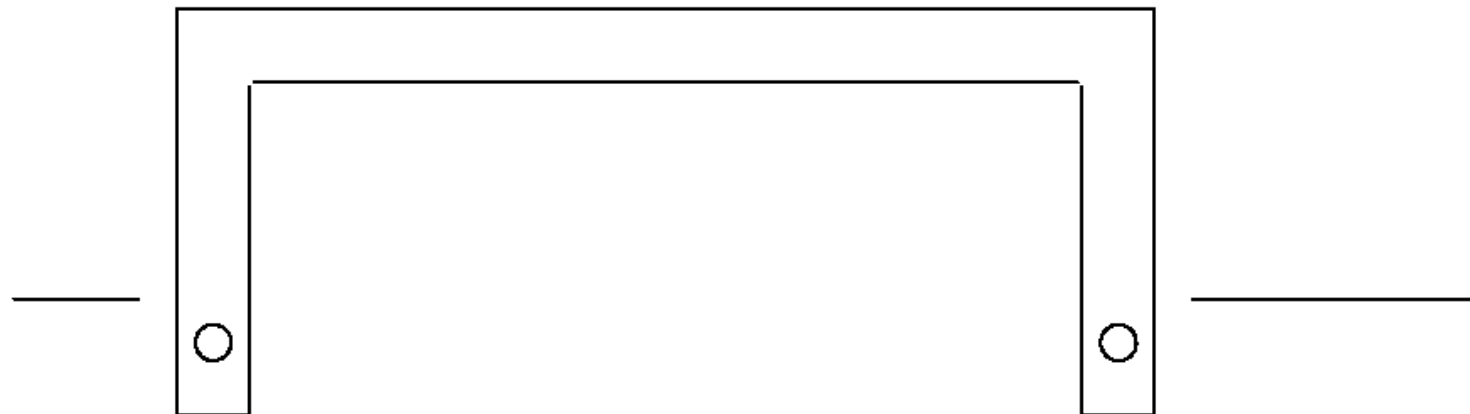
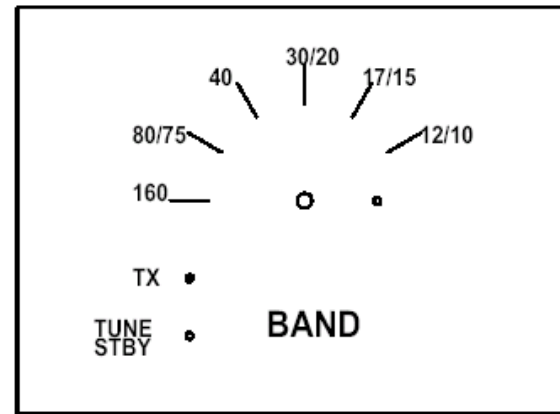
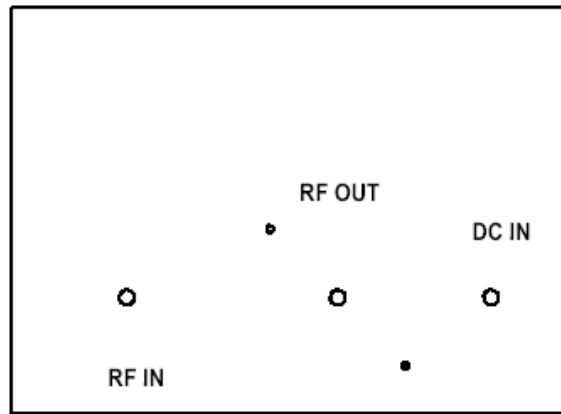


MATERIAL: RADIOSHACK ALUMINUM PROJECT ENCLOSURE 270-238
 A - 4 HOLES 3/16 INCH DIA. B-2 HOLES 1 INCH DIA.
 TOP VIEW VER 1.0

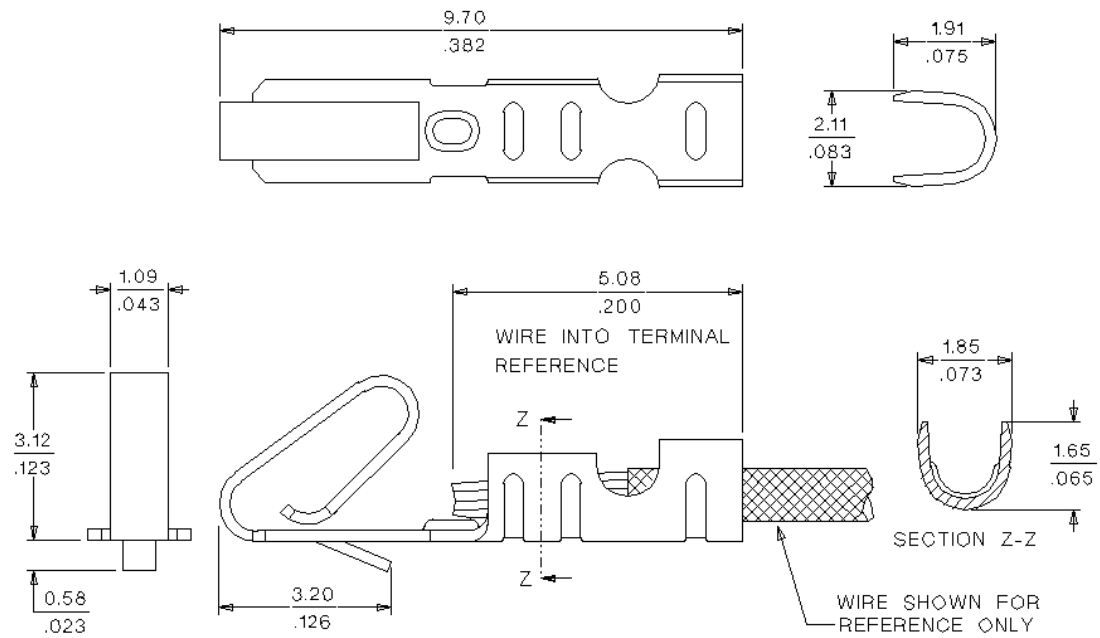


A-3/8 inch DIA. B-5/8 inch DIA.
 C-5/16 inch DIA. D-5/32 inch DIA.
 E-1/8 inch DIA. F- (deleted)
 G-7/64 inch DIA. H- 7/32 inch DIA.

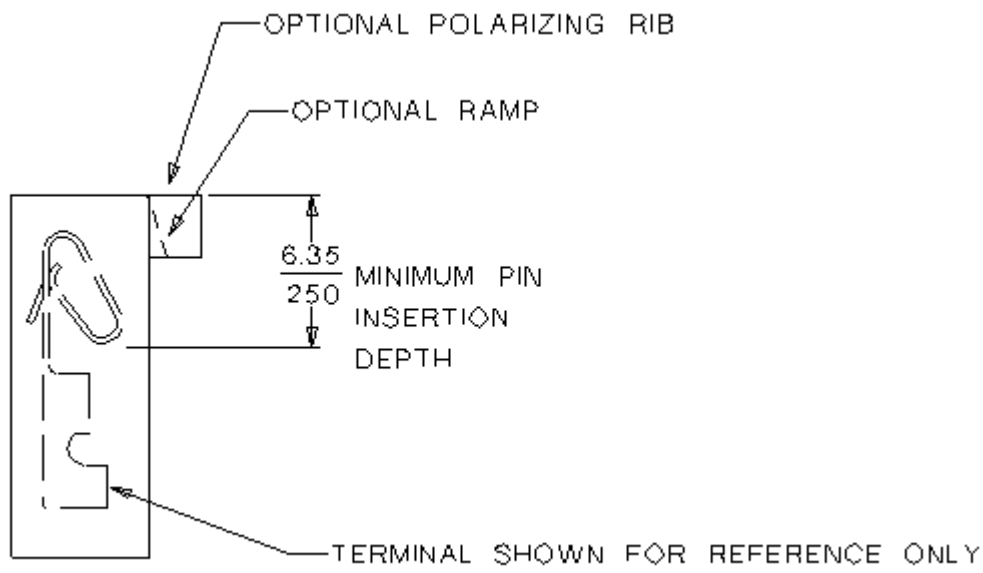
MATERIAL: LMB JIFFY BOX 537-J-880



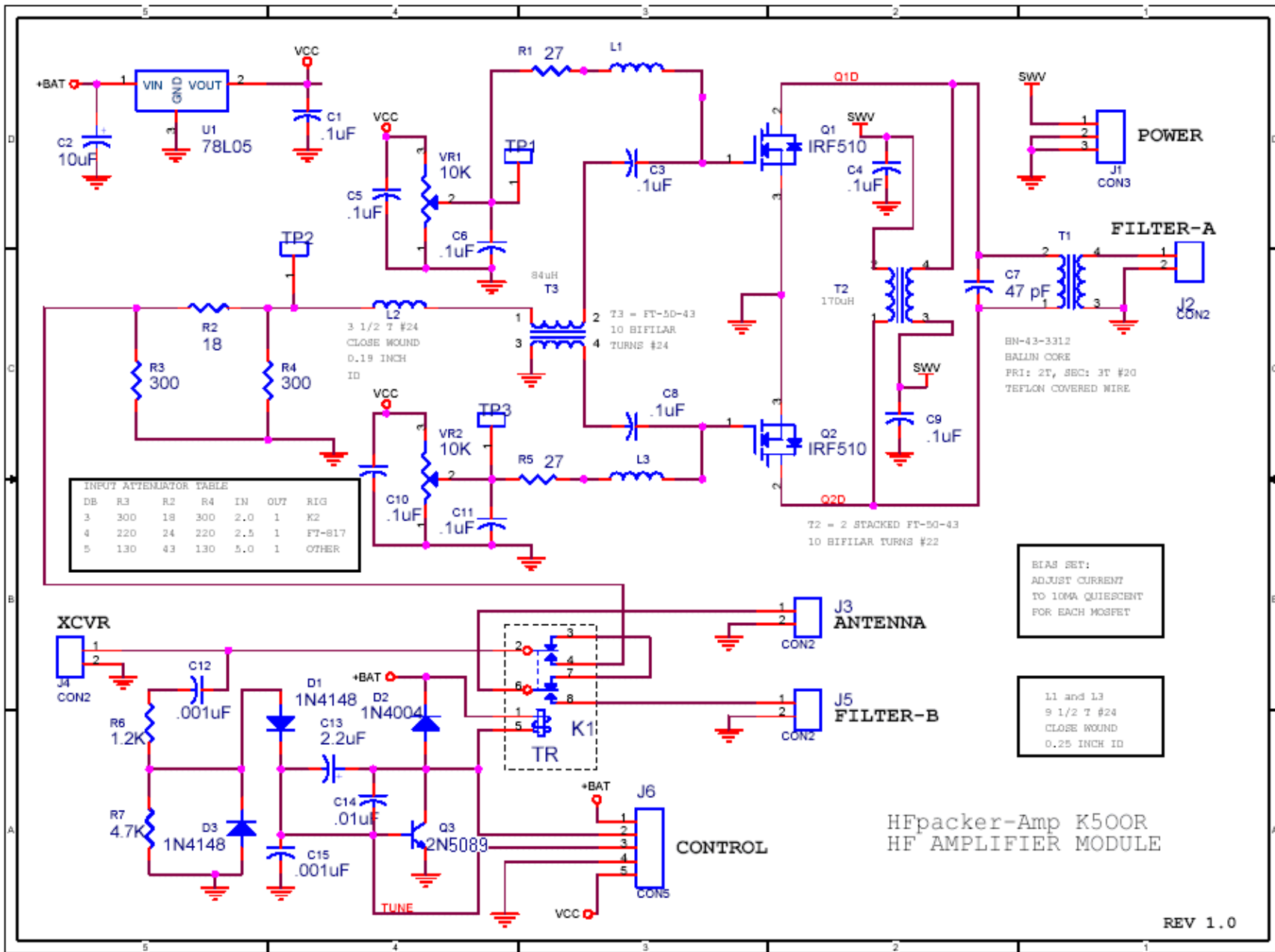
View of Molex Crimp Terminal with wire attached

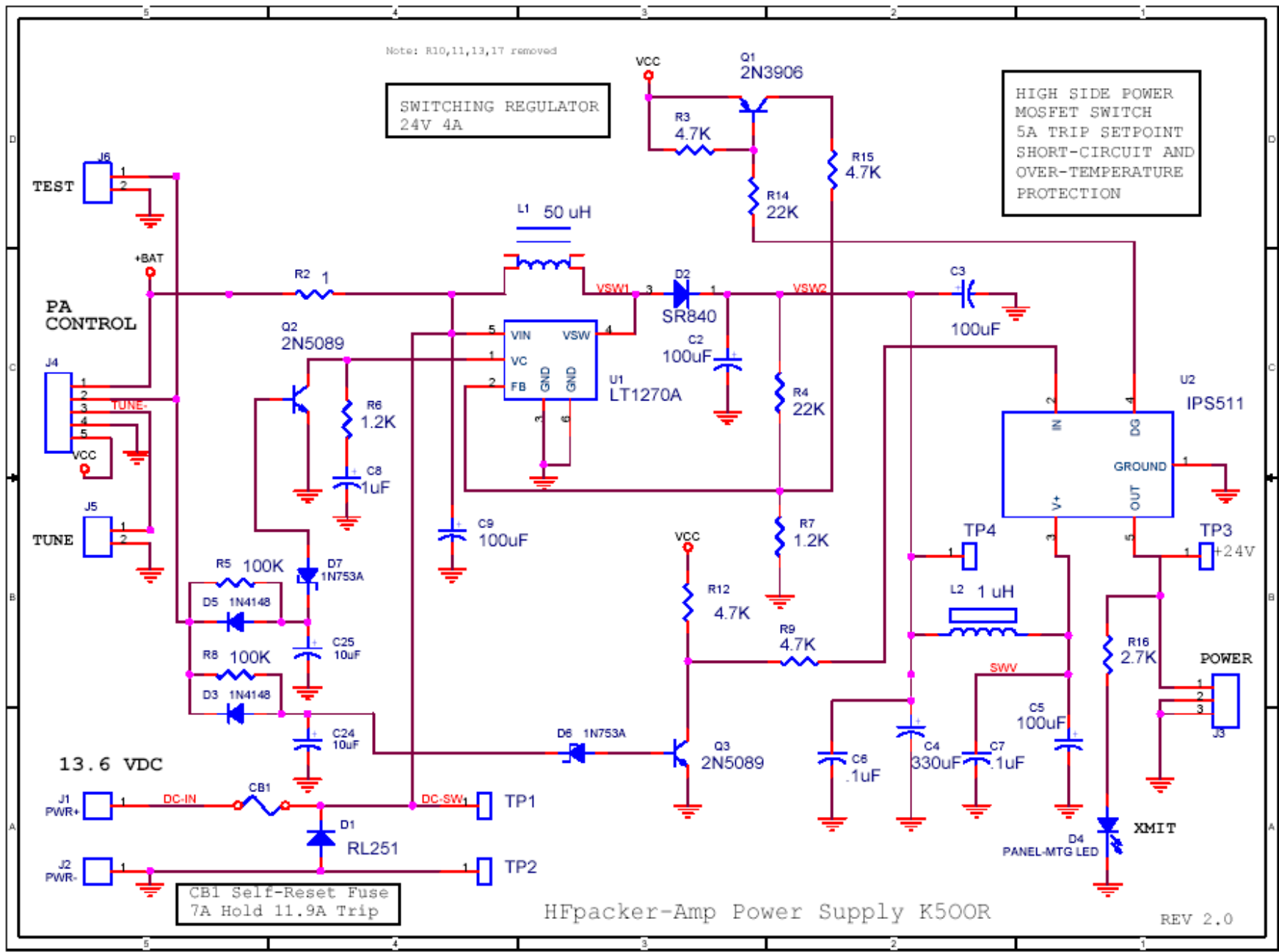


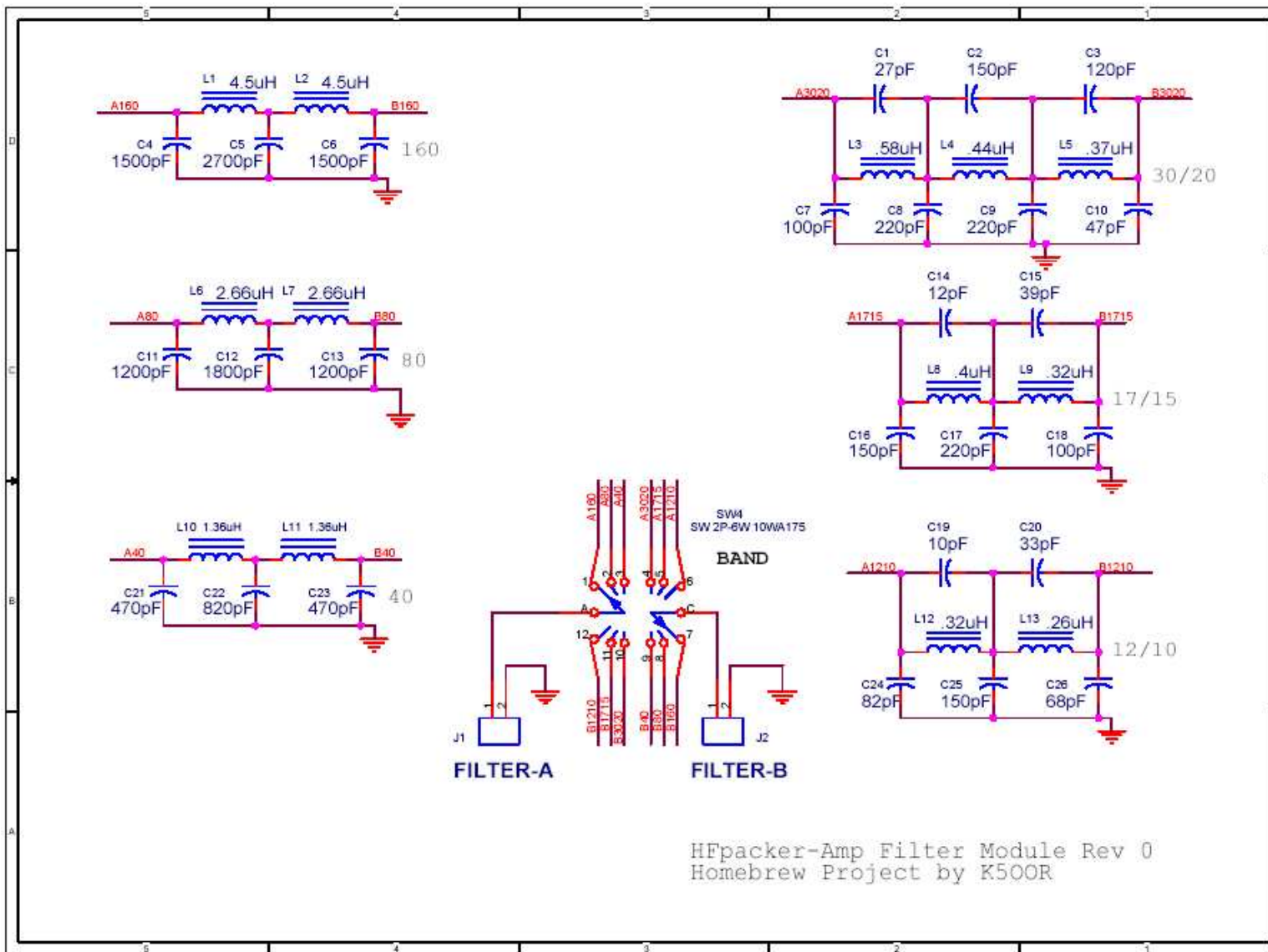
View of Molex Lock Ramp Housing with terminal inside



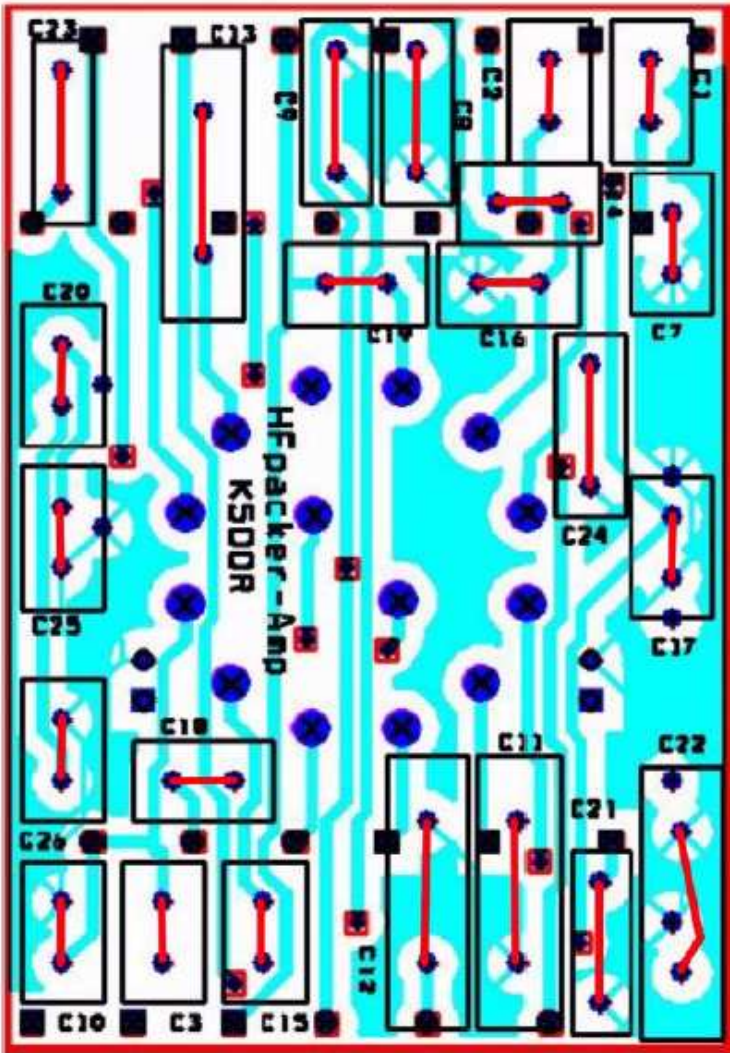
Appendix C: Schematics



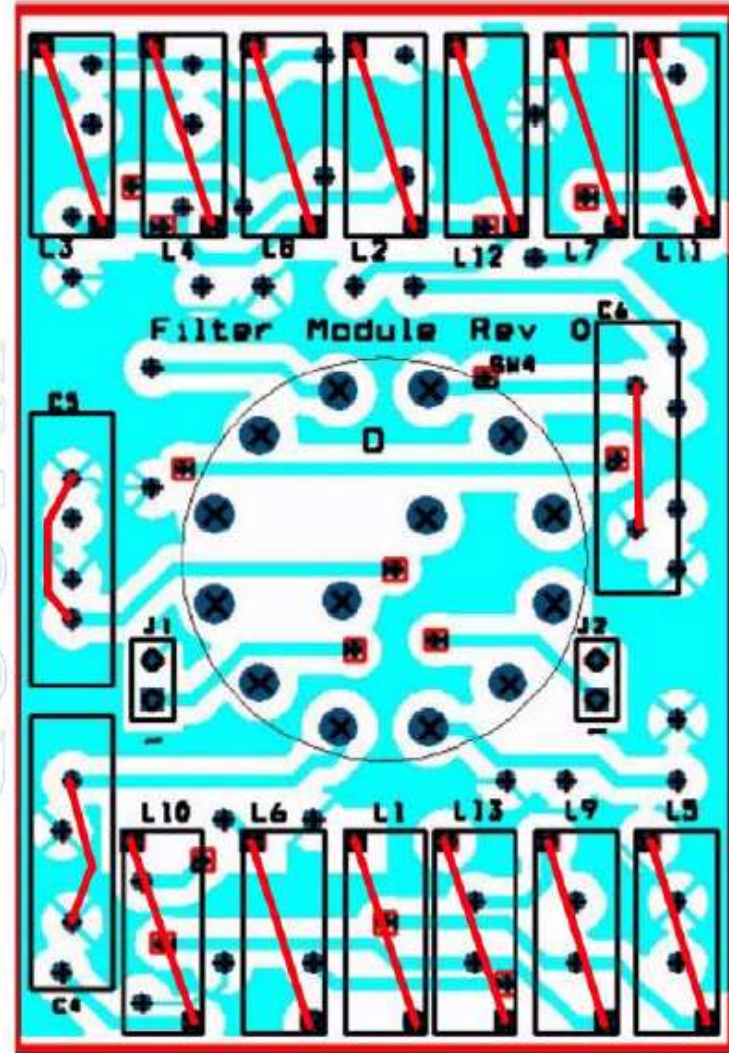




Filter Board -- Capacitor Installation

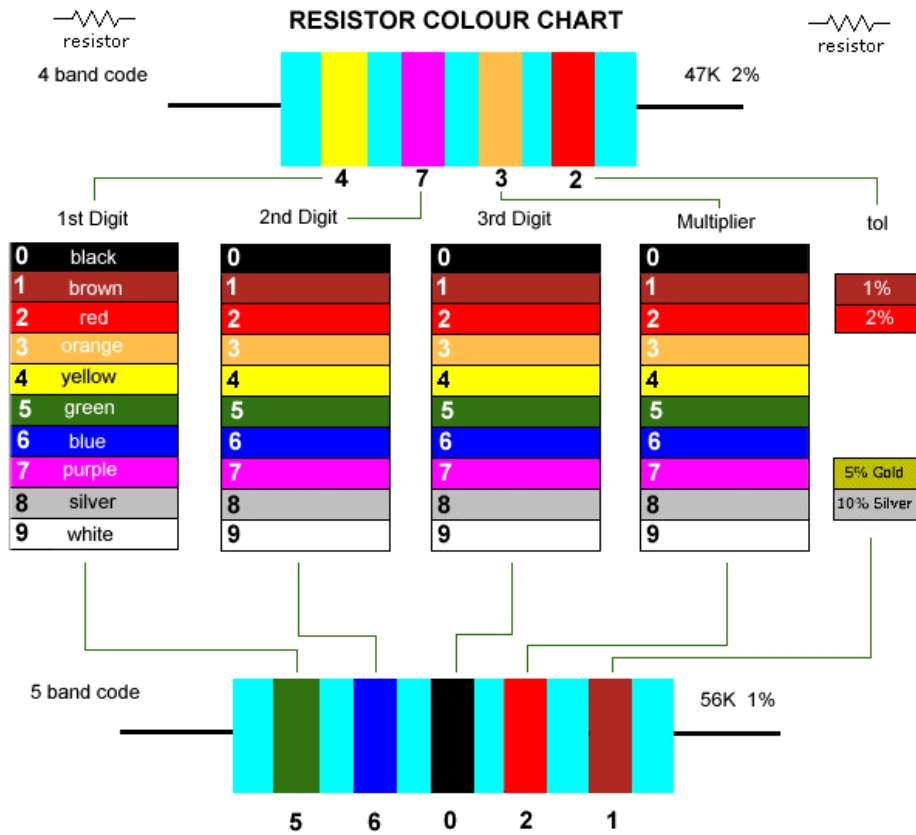


Filter Board - Toroid / Capacitor Installation



Appendix D: Filter PCB Component Placement

Appendix E: Resistor and Capacitor Identification



Identifying Capacitors

Small-value fixed capacitors (such as the silver mica capacitors for the filter module) are usually marked with one, two, or three digits and no decimal point. If one or two digits are used, that is always the value in *picofarads* (pF). If there are three digits, the third digit is a multiplier. For example, a capacitor marked "330" would be 33 pF (33 with a multiplier of 0). Similarly, "151" would be 150 pF, and "102" would be 1000 pF (or .001 μ F). Fixed capacitors with values of 1000 pF or higher often use a decimal point in the value, such as .001 or .02. This is the value in *microfarads* (μ F).