# *Hendricks QRP Kits*


# *Ft Tuthill 160*

3.5w to 5w DC CW Transceiver for 160m
Part 2 of 2

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# *Table of Contents*



# *List of Figures*

# Specifications

As measured from current prototypes, some variance in performance is expected from unit to unit.

### *Receiver*

**Tuning range:** Approximately 1.800 to 1.880+ MHz in two ranges

**Current Drain:** Approximately 30 ma @ 12v without optional Digital Dial

**Supply voltage range:** 12 to 13.8v

**Receiver bandwidth:** ~600 to 700 Hz bandwidth.

**MDS receiver sensitivity:** -116 dBm in a 700 Hz bandwidth

**Third order distortion** (IP3): +25 dBm

**Blocking Dynamic Range** (BDR): ~100 db (limited by the cw filter response)

**RIT tuning range**: Roughly + 2.5/-6.5 kHz from the transmit "spot" frequency

**Receiver Type:** DC receiver: Both sidebands (USB/LSB) are heard at the same time

### *Transmitter*

**Power Output**
~ 3.5w at 12v, ~5w at 13.8v

***Note: TX designed for CW type transmit duty cycle. Prolonged key down operation is not advised.***

## Building the Kit, cont

### *Installation of power sources (5v, 11v, 12v)*

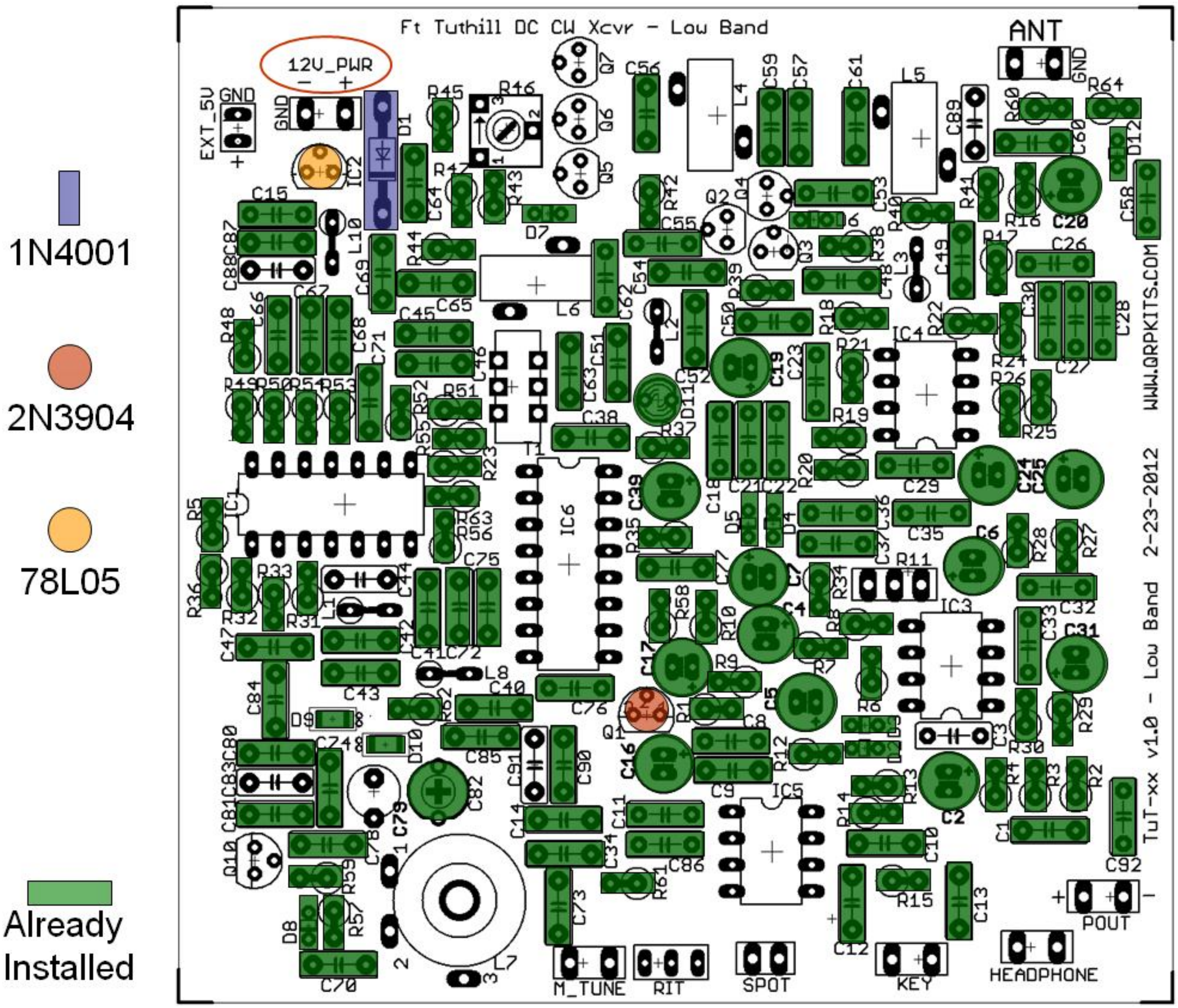



**Figure 1. Location of power source components**

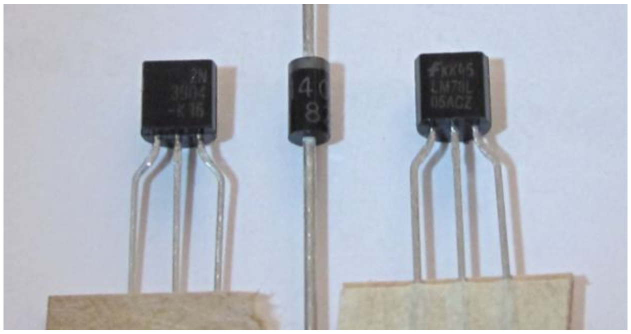



**Figure 2. Identification of 2N3904, 1N4001, and 78L05**

Install the large black 1N4001 diode. ☐ D1 – Save leads for temporary power connection below

Install the 2N3904 transistor ☐ Q1

Install the 78L05 ☐ IC2

Attach temporary power leads to the 12V_PWR terminal circled in red in the above diagram. The excess leas from the 1N4001 diode are thicker than normal and work well here.

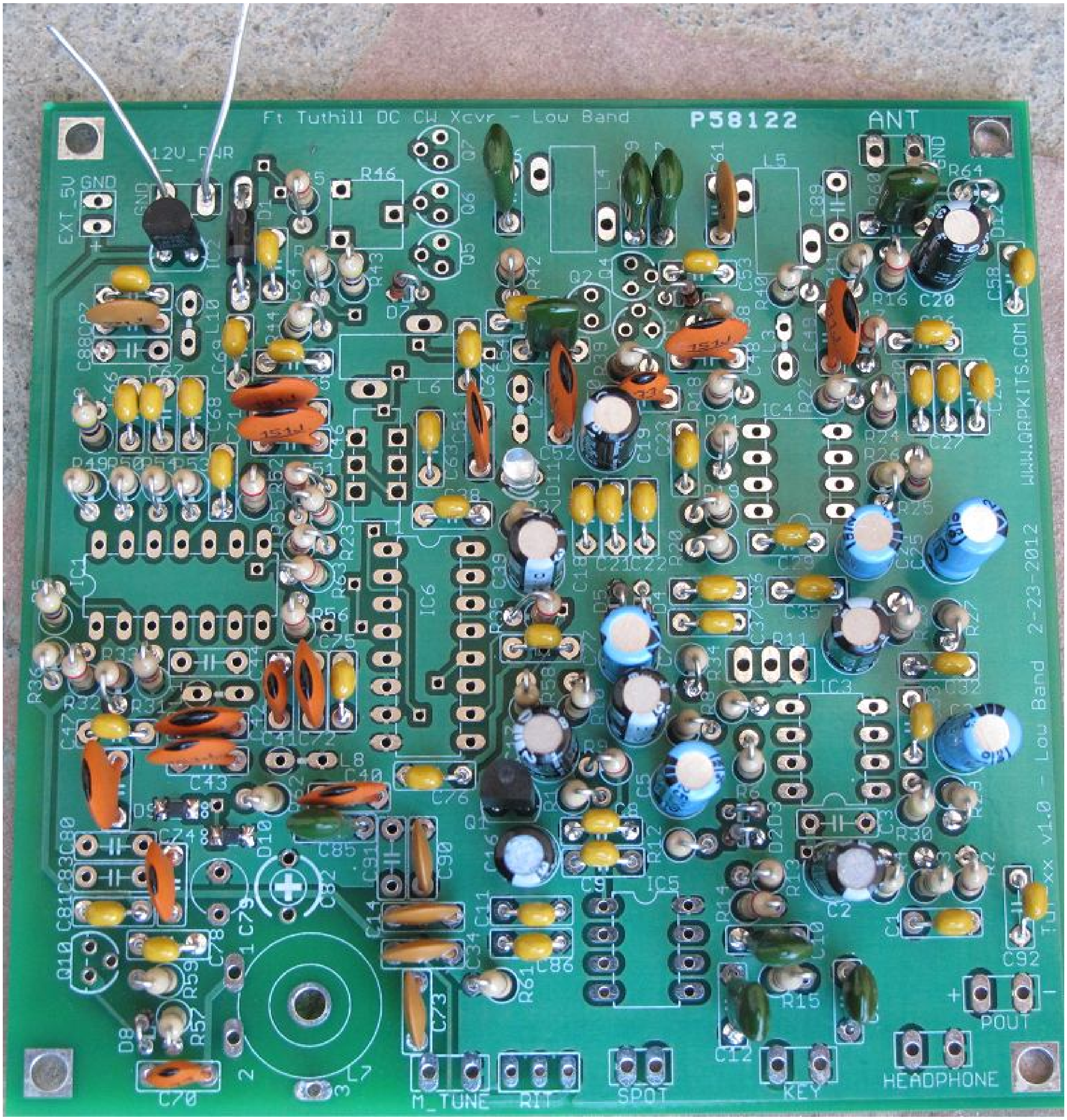



**Figure 3. Board with 12v, 11v, and 5v power sources installed**

## *Power Source Tests*

Connect a 12v power source. The following are a group of tests to be done:

☐ The LED on the board (D11) should light up blue.
☐ The current draw when connected to 12v battery will be in the **3** ma range.

The following are a series of DC checks on the pins of IC1, which is not installed yet. Use the bottom right mounting hole as a ground. All mounting holes are grounded except for the bottom left hole in the VFO area near Q10.

☐ pin 1: 5v This verifies that the 78L05 section is working.
☐ pin 2: 5v
☐ pin 4: 5v
☐ pin 6: 2.5v
☐ pin 8: 11.5v
☐ pin 11: 11.5v
☐ all the rest of the pins not listed above are 0 v or very near 0 v (pins 3, 5, 7, 9, 10, 12, 13, 14)

The following are a series of DC checks on the pins of IC4, a 8 pin IC near the top right of the board

☐ pin 1: 11v This verifies that the RX supply voltage filter section is working.

☐ ***Disconnect the 12v power source.***

## *Installation of ICs*

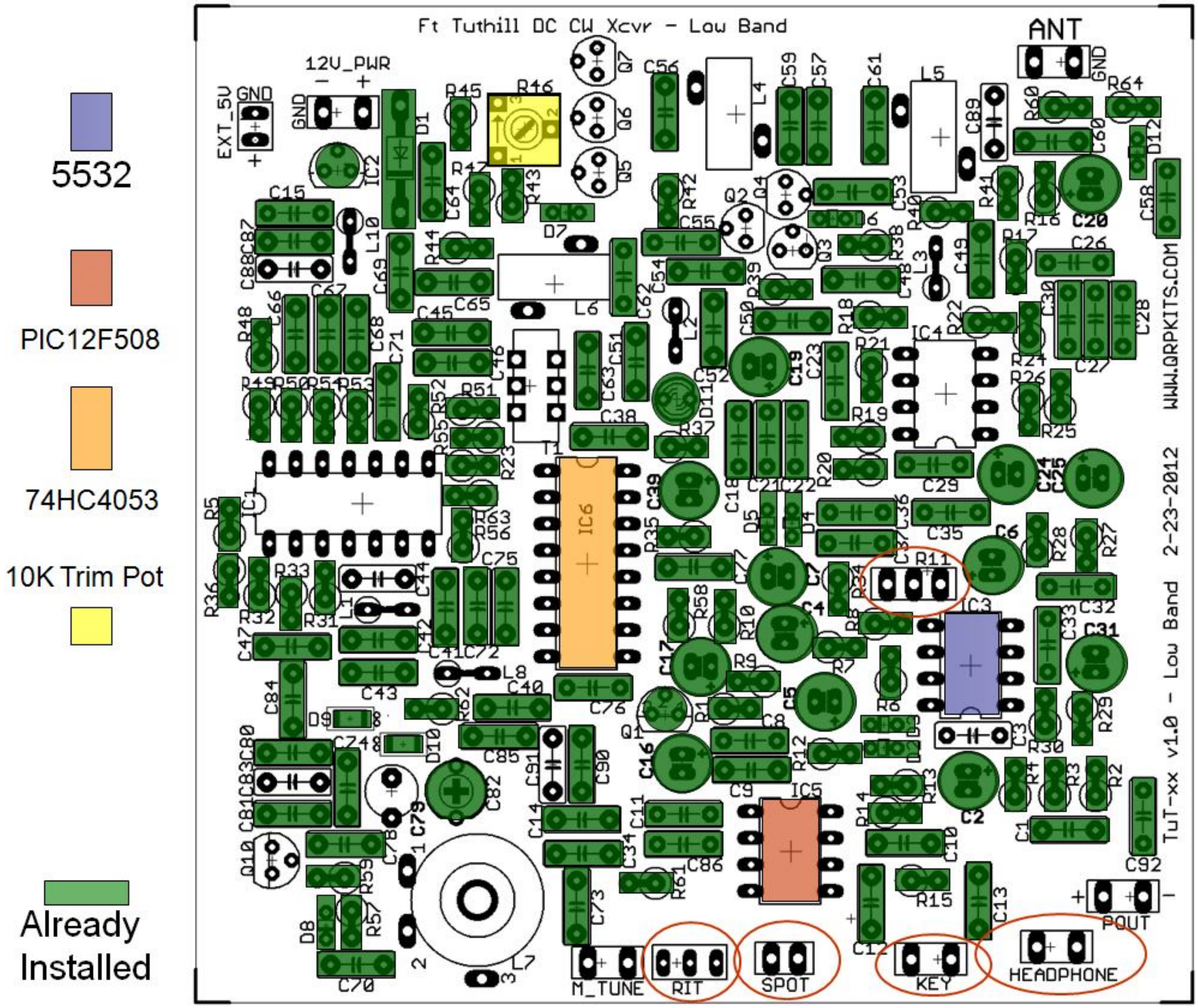



**Figure 4. Location of misc ICs plus R46 TX power adjust trim pot**

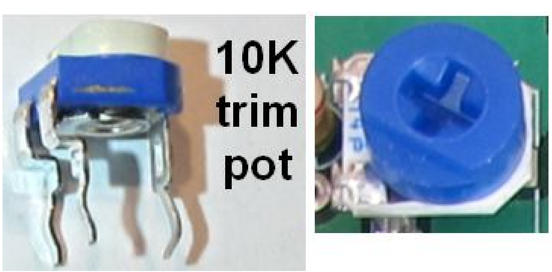



**Figure 5. Identification of 10K trim pot**

Install the 10K trimmer pot ☐ R46

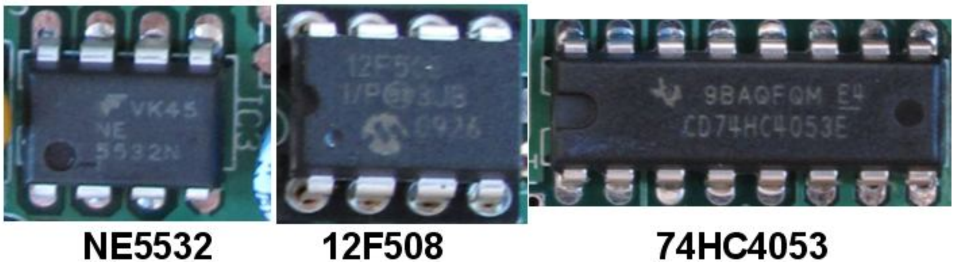



**Figure 6. Identification of NE5532, 12F508, and 74HC4053**

Install one of the two NE5532 op-amps ☐ IC3. ***Make sure the notch on the IC lines up with the notch on the board! Do not install backwards!***

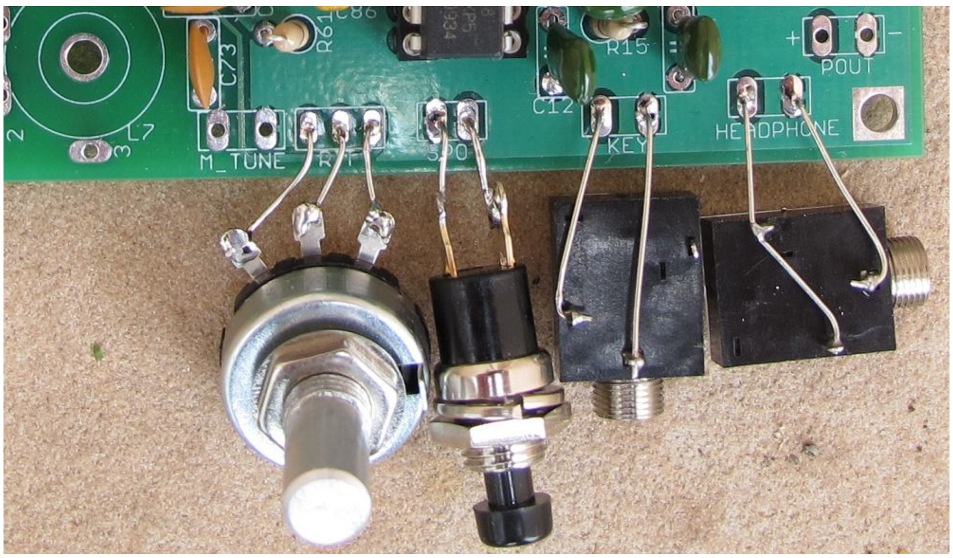



**Figure 7. Temporary installation of the 10K RIT pot, SPOT switch, KEY jack and Headphone jack**

☐ Temporarily add the headphone jack to the headphone output located in the bottom right corner of the board as shown above using scrap leads. Keep this temporary connection for the rest of the kit build.

☐ Connect a 12v power source and conduct the following tests:

☐ The current draw when connected to 12v battery will be in the **8.8** ma range.

The following are a series of DC checks on the pins of IC3: ☐ pin 8: 11.5v ☐ pin 7: 4.1v

☐ Attach headphones to the headphone jack and touch the middle hole of R11, located just above and to the left of IC3. A loud “hum” ought to be heard

☐ ***Disconnect the 12v power source.***

Install the timing processor, PIC12F508 ☐ IC5. ***Make sure the notch on the IC lines up with the notch on the board! Do not install backwards!*** It is optional to use an 8 pin socket for this IC.

☐ Connect a 12v power source and conduct the following tests:

☐ The current draw when connected to 12v battery will start in the **9.6-9.2** mA range until the V1 sign on is sent, then the current will drop to the **8.8** ma range, same as in the previous test.
☐ Listen in the headphones for the sidetone as the timing processor IC5 sends “V1” in CW about 3 seconds after the board is powered up

☐ ***Disconnect the 12v power source.***

Install the Mute/Detector/RIT analog gate 74HC4053 ☐ IC6. ***Make sure the notch on the IC lines up with the notch on the board! Do not install backwards!***

Temporarily install the RIT 10K panel mounted pot as shown above ☐ RIT
Temporarily install the spot switch as shown above ☐ SPOT
Temporarily install the key jack as shown above ☐ KEY

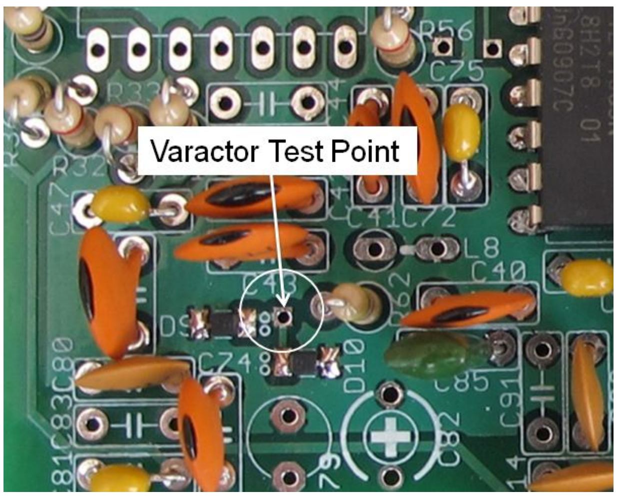



**Figure 8. Varactor test point for voltage measurements**

☐ Connect a 12v power source and conduct the following tests:

☐ The current draw when connected to 12v battery will be in the **9.8** ma range after “V1” is sent.
☐ Check RIT voltage across RIT diode D9/D10 at the test point shown above. Changing RIT pot will change diode voltage ranging from 1.2v with RIT pot all the way one direction to 5v with the RIT pot turned all the way the other direction..
☐ Press the “SPOT” button and hear a "tick" once a second.
☐ Measure the RIT diode voltage to be **2.6v** and make sure the RIT tuning pot has no effect on this voltage measurement. This is the TX tuning voltage which is fixed.

☐ Press the “SPOT” button again and "R" will be sent, and the diode voltage will be the RIT pot voltage again.

***Keep the RIT pot installed! It must be in place to have the VFO operate properly!***

☐ ***Disconnect the 12v power source.***

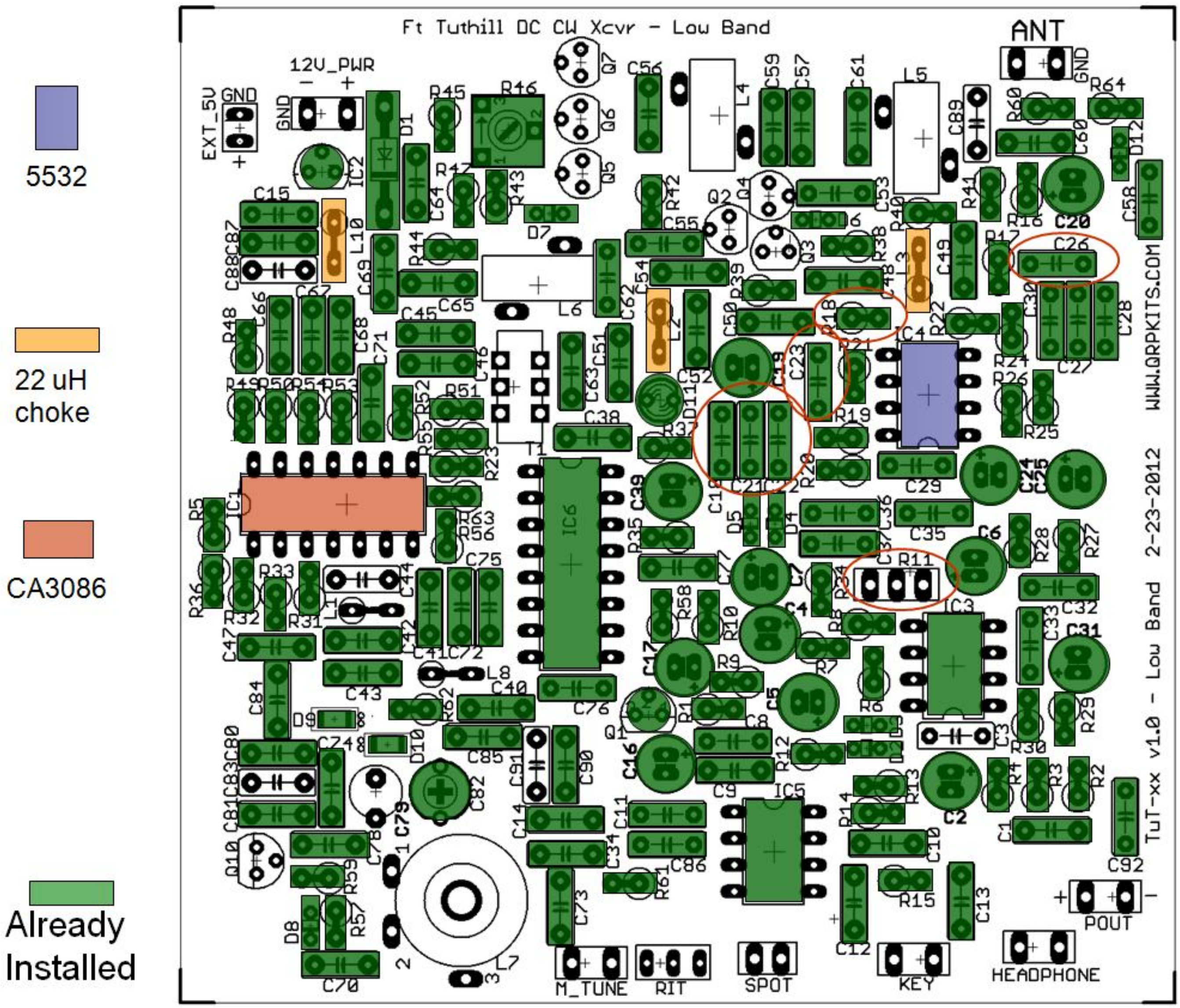



**Figure 9. Placement of IC1, IC4 and three of the six 22 uH chokes**

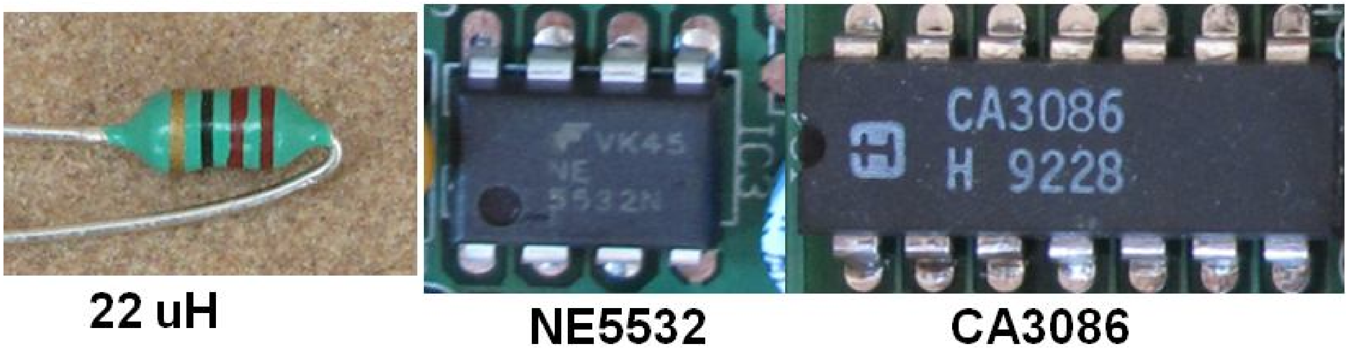



**Figure 10. Parts identification for the 22 uH choke, NE5532, and CA3086**

Install the op-amp, NE5532 ☐ IC4. ***Make sure the notch on the IC lines up with the notch on the board! Do not install backwards!***

Temporarily short the R11 pads (center and left). See the picture below. Keep this in place until the volume control pot is installed.

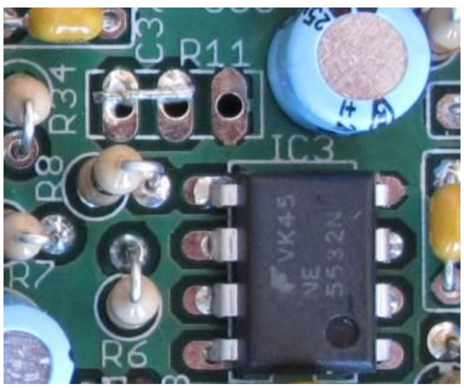



**Figure 11. R11 pads shorted for audio tests**

☐ Connect a 12v power source and conduct the following tests:

☐ The current draw when connected to 12v battery will be in the **16** ma range.
☐ Tapping yellow 0.1 caps C18, C21, C22, C23, C26 with a small screw driver should produce some noticeable microphonic clicks.
☐ Touch R18 just above IC4 should produce a loud hum

DC voltage checks on IC4:

☐ pin 1: 5v ☐ pin 7: 5v ☐ pin 8: 10.5v

☐ ***Disconnect the 12v power source.***

Install the transistor array, CA3086 ☐ IC1. ***Make sure the notch on the IC lines up with the notch on the board! Do not install backwards!***

☐ Connect a 12v power source and conduct the following tests:

☐ The current draw when connected to 12v battery will be in the **20.4** ma range.

DC voltage checks on IC1:

| | | | |
|---|---|---|---|
| ☐ pin 1: 5v | ☐ pin 2: 4.0v | ☐ pin 3: 3.25v | ☐ pin 4: 3.9v |
| ☐ pin 5: 3.25v | ☐ pin 6: 2.3v | ☐ pin 7: 1.5v | ☐ pin 8: 7.3v |
| ☐ pin 9: 0v | ☐ pin 10: 0v | ☐ pin 11: 11.3v | ☐ pin 12: 0v |
| ☐ pin 13: 0v | ☐ pin 14: 0. | | |

☐ ***Disconnect the 12v power source.***

Install 22 uH chokes ☐ L10, ☐ L2, ☐ L3

☐ Connect a 12v power source and conduct the following tests:

☐ Plug a straight key into the “KEY” jack and key the rig. The current will increase from **20.4** ma (not keyed) to **41** ma (keyed). The keying sidetone can be heard in the headphones.

☐ When keyed for more than 3 seconds, the transmitter sidetone can be heard going into “dotting” mode to protect the finals.

☐ ***Disconnect the 12v power source.***

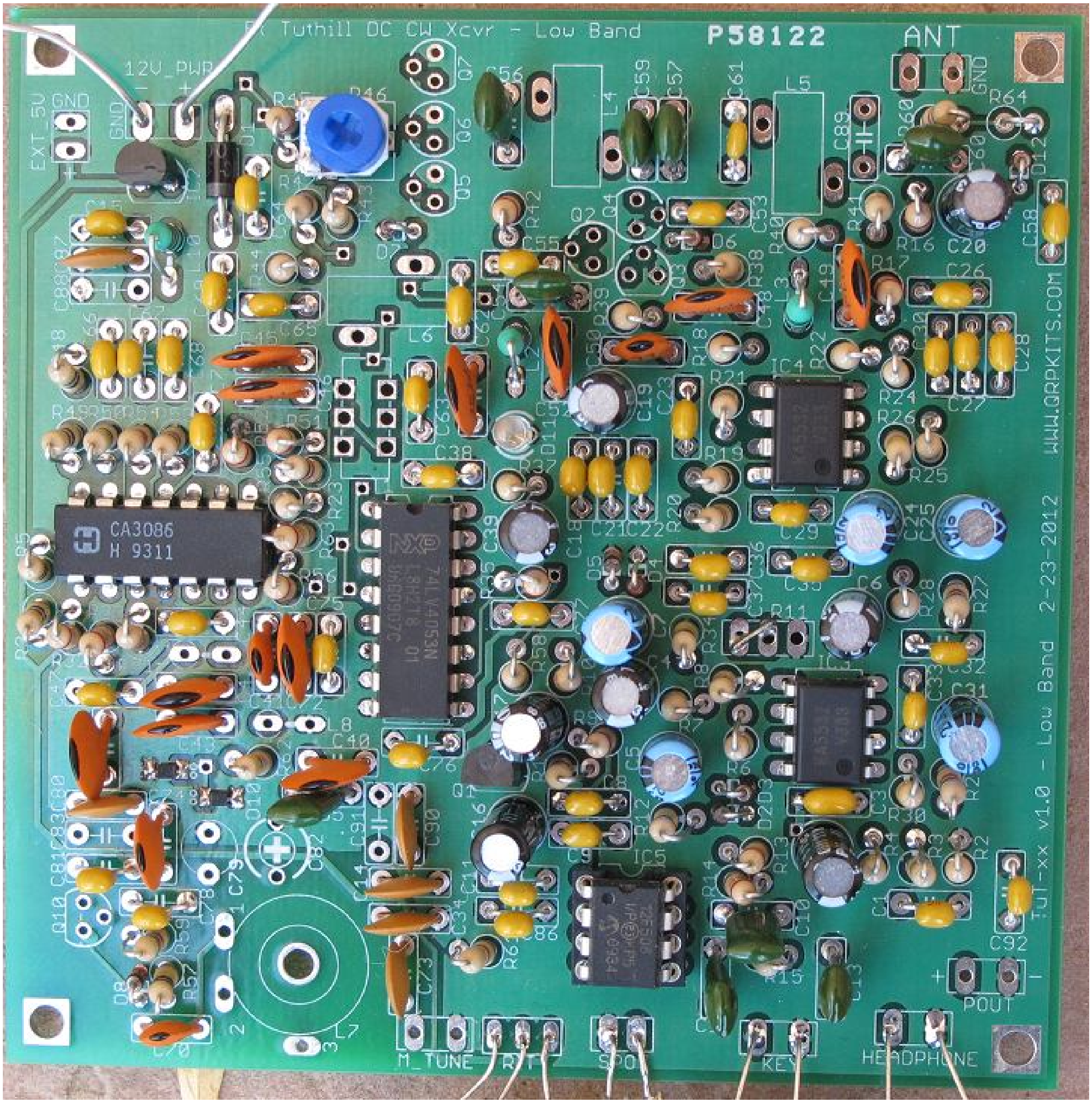



**Figure 12. Board with ICs installed.**

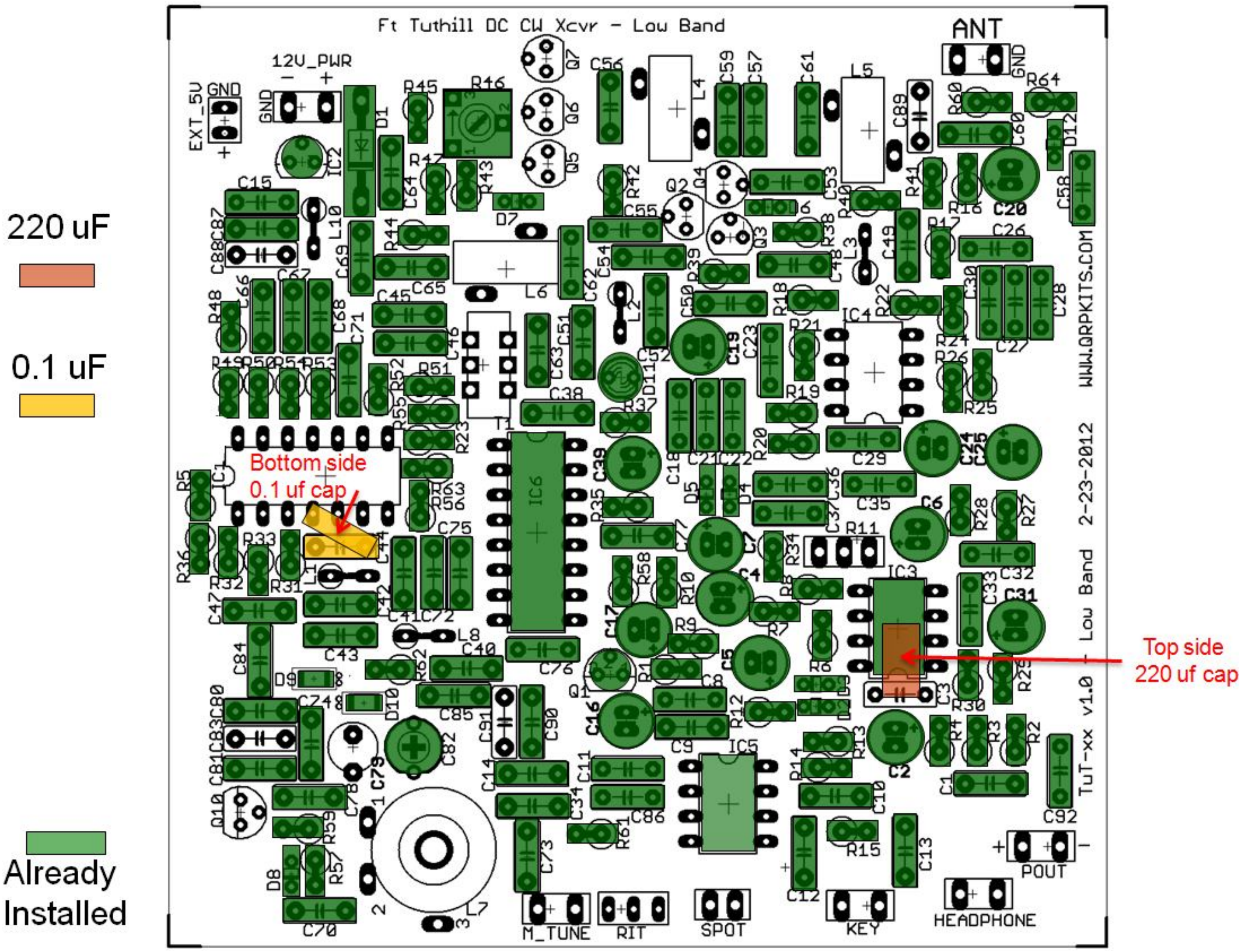



**Figure 13. Installation of bottom side 0.1 uf and top side C3/C44components**


**Figure 14. Lead forming and mounting for C3, the 220 uF cap.**

Form the leads for the 220 uF cap as shown. With the negative side up and the leads to the left, bend the leads down as shown. Install the ☐ 220 uF cap laying on top of IC3 as shown. ***Make sure to mount C3 with the polarity shown above!***

Install the 0.1 uF caps (marked “104”) ***but do not trim the leads on the bottom side*** ☐ C44. The leads for this 0.1 uF cap ***“untrimmed”*** will be used to help locate the mounting point of the other 0.1 uF cap on the bottom side of the board.

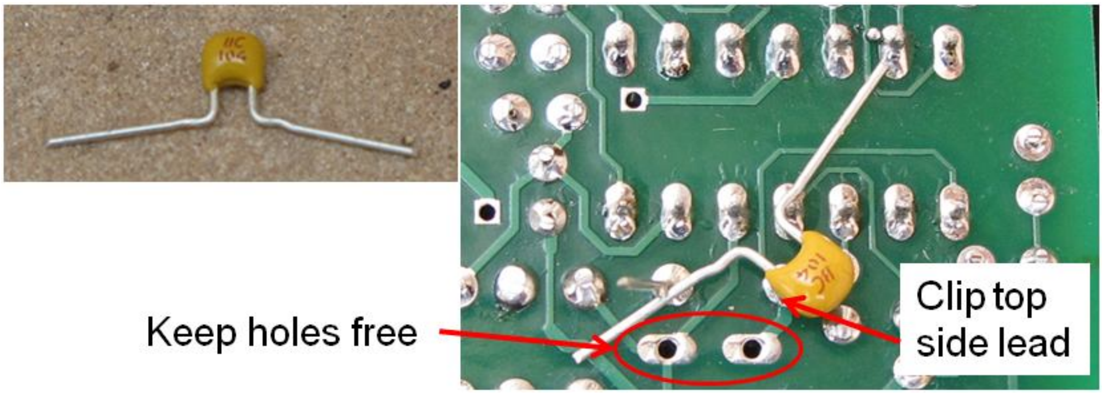



**Figure 15. Lead shaping of bottom side 0.1 uF (“104”) cap and “dry fit” mounting details**

Above picture shows a “dry fit of the 0.1 uF cap. It needs to be moved up to keep the hole for L1 free for later mounting. Install the ☐ 0.1 uF cap and trim all leads. ***Make sure the 0.1 uF cap leads do not short out against an unused pad!***

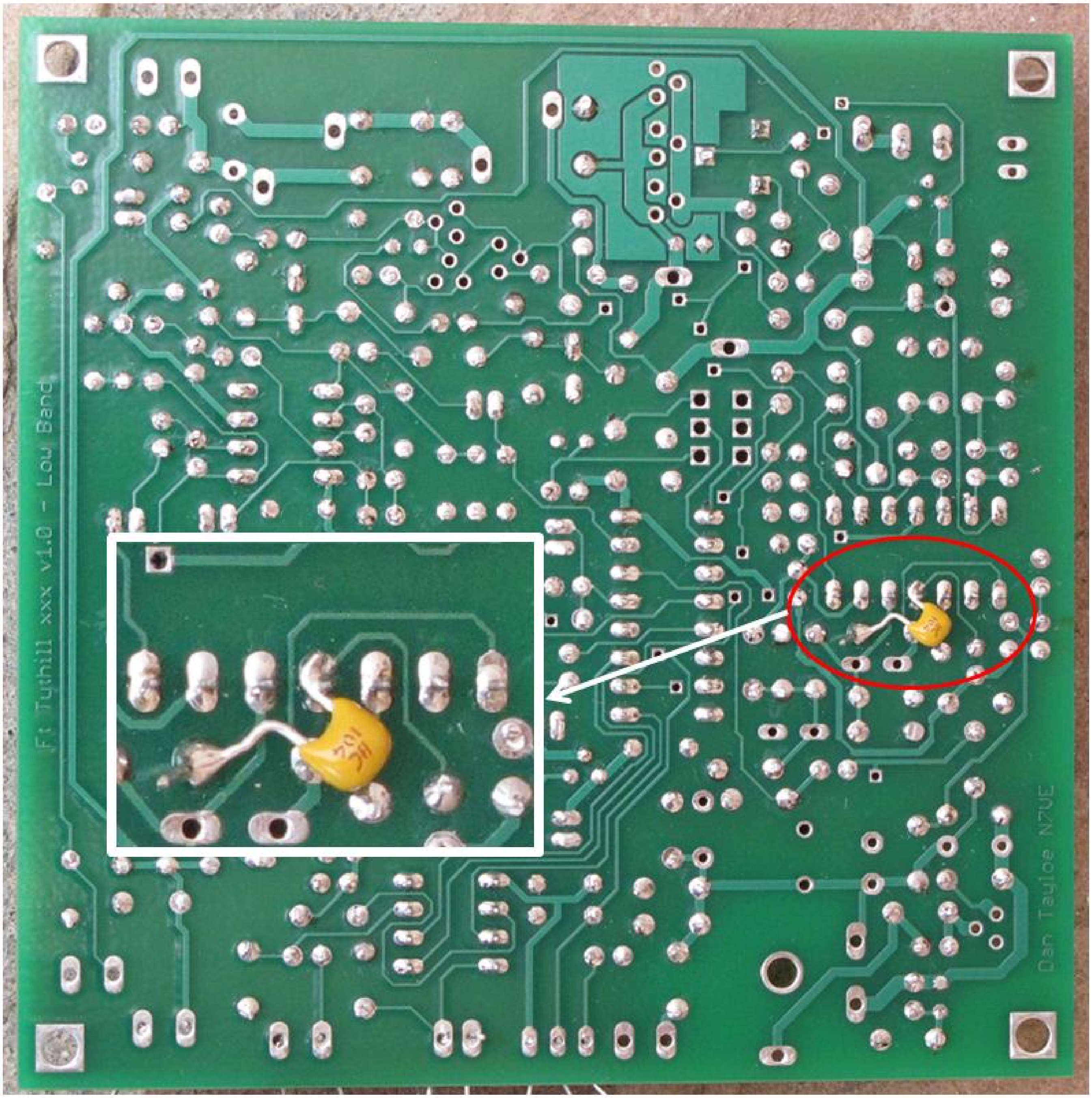



**Figure 16. Installation details of the 0.1 uF bottom side cap. Trim all leads when finished.**

## *Installation of VFO components*

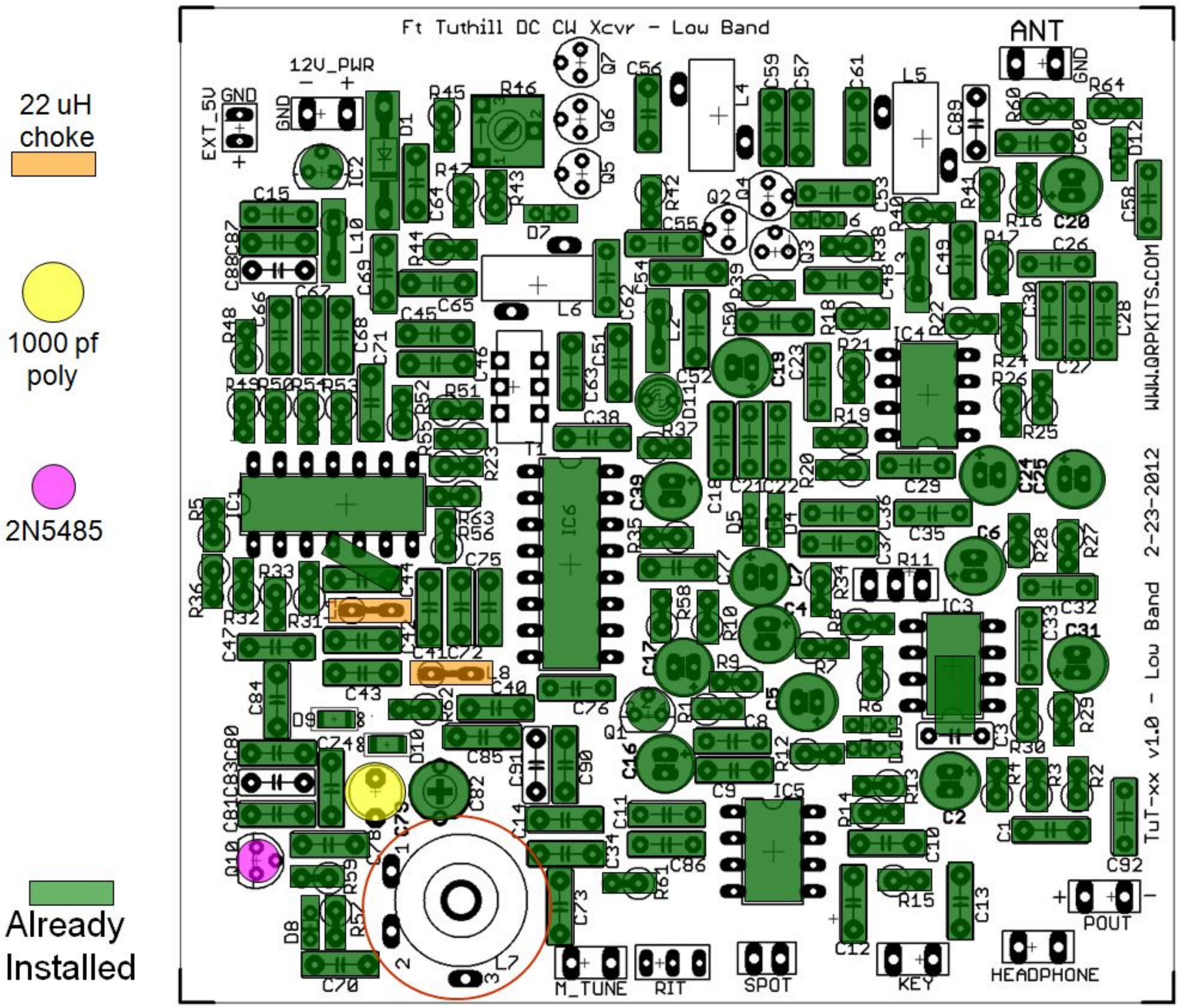



**Figure 17. Placement of VFO components**

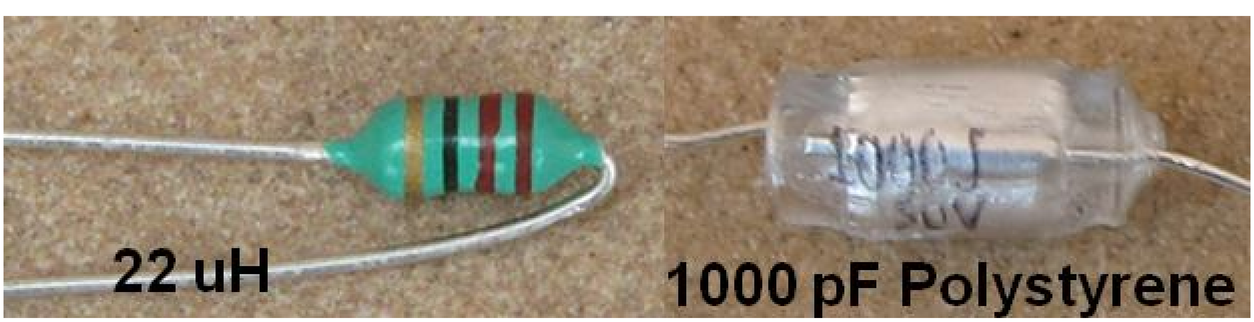



**Figure 18. Identification of 22 uH and 1000 pF poly**

Install 22 uH chokes ☐ L1, ☐ L8

Install 1000 pF polystyrene ☐ C79 - Note: mount the cap on end like a resistor.

Install 2N5485 ☐ Q10

Wind L7. See the pictures on the next page. This uses the largest red toroid (T50-2) core. This inductor requires 56 inches of #32 gauge wire, which is the finer of the two red spools of wire. This inductor needs a total of 88 turns which is composed of a 22 turn section, a tap, and a 66 turn section.

All the turns need to be wound side by side with no space between turns in order to fit on the core. The turns need to also be wound under tension so as to snug firmly to the core. Do not wind so tightly as to risk breaking the core. The thin wire ought to readily form itself to the surface of the core without a lot of tension.

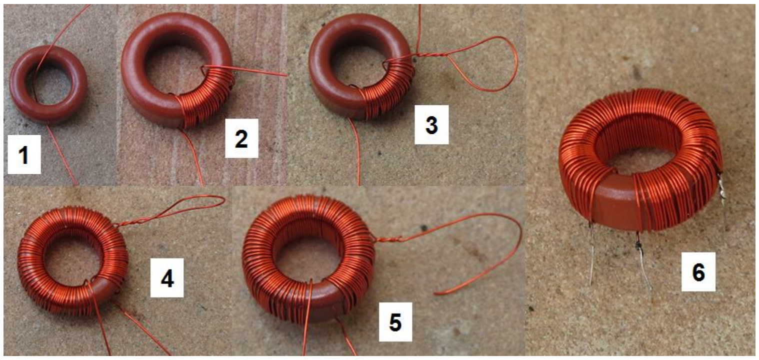



**Figure 19. Details on the construction of the VFO coil L7**

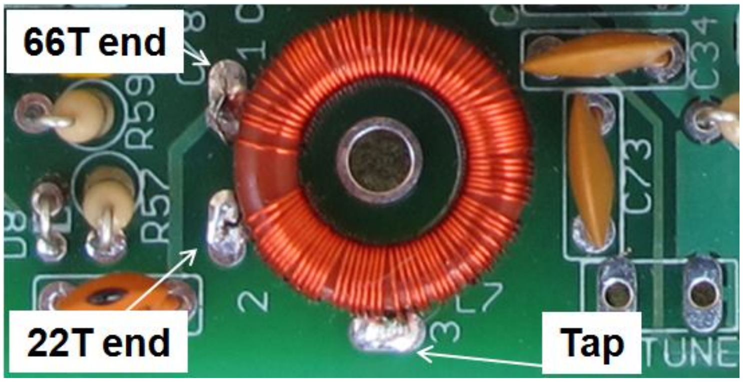



**Figure 20. Details on the mounting of VFO coil L7**

Please review the pictures above. The inductor is held in the left hand, and the right hand is used to wind the inductor. The first 22 turns are added counter-clockwise around the core through the bottom of the core. Every time the wire is passed through the center of the core counts as 1 turn. See “1 turn” in step 1 above. In order to fit on the core, all turns are wound “shoulder-to-shoulder” as close together as they can be wound. After the 22 turns are added (step 2), a small loop of wire is twisted together to provide the tap (step 3), and then 66 more turns are added (step 4).

After all 88 turns are wound (22 + 66), cut the loop (step 5) and tin all three leads (step 6). On the tap make sure that the “twisted” portion is tined as well. If the twist is soldered correctly, an ohm meter will show a short from the “start” lead to the “end” lead.

The 22 turn “start” end and the tap are tinned and mounted through holes 2 (the 22 turn end) and 3 (the tap), while the ***66 turn end is soldered to the top of the board to hole 1***. The VFO frequency will start out low, typically by 3 or 4 turns, and this 66 turn end is the side where turns will need to be removed in order to raise the frequency to 1.840 MHz at a rate of roughly 20 KHz per turn from its low starting frequency of around 1.75 MHz. The VFO will be tuned at the end of the assembly.

***Make sure the RIT pot is in place! It is necessary to have the VFO operate properly.***

☐ Connect a 12v power source and conduct the following tests:

☐ The current draw when connected to 12v battery will be in the **29** ma range.

☐ ***Disconnect the 12v power source.***

## *Installation of TX Finals/RX front end components*

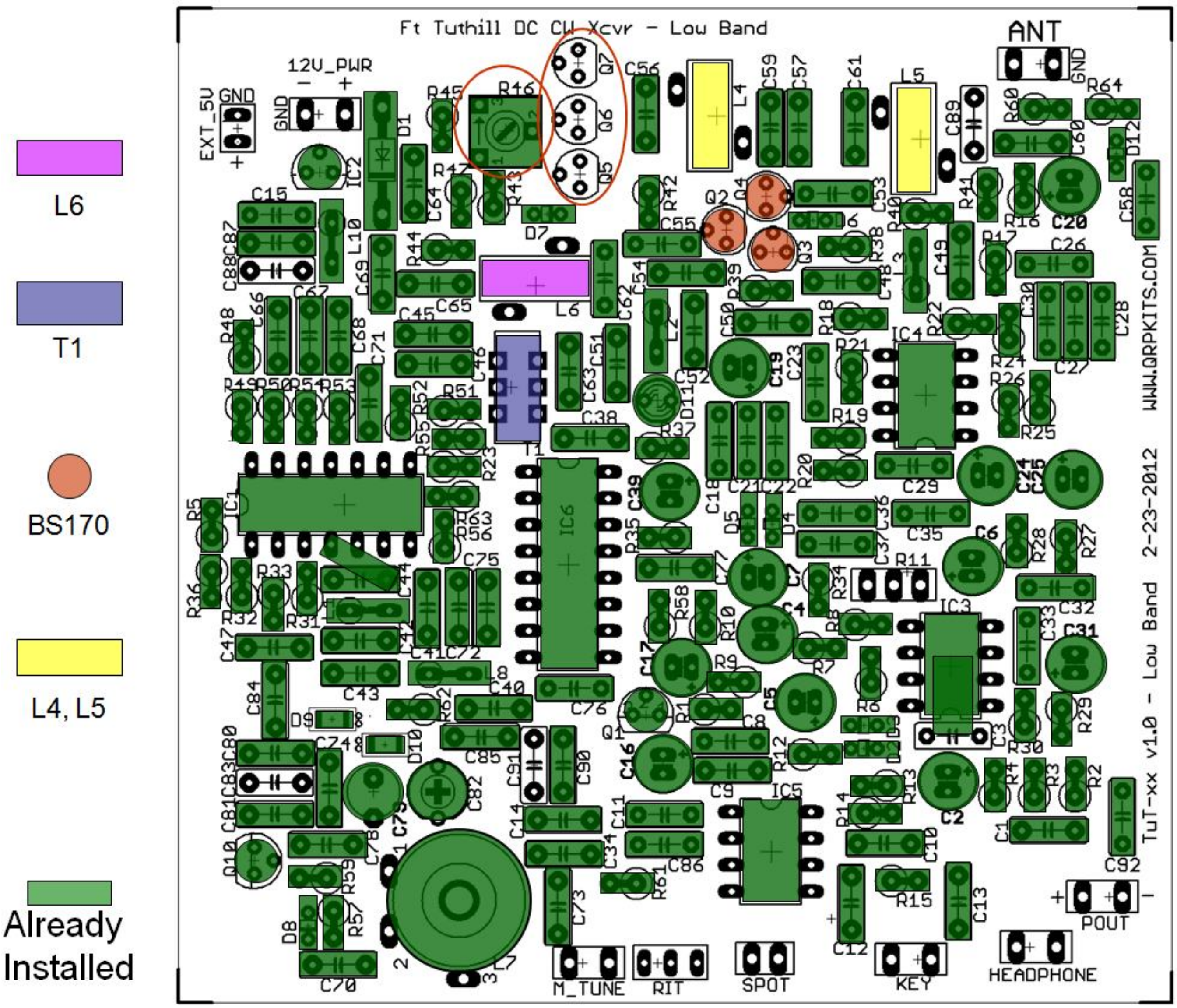



**Figure 21. Placement of the TX final and last receiver front end components**

Preparation of the wire used for T1:

☐ Take 18" of each of the three large #28 gauge wire, Red, Green, and Gold. Do not use the small fine red wire.

☐ Place the three wires together and knot the end as shown in 1) below.

☐ Place the knot in a drill chuck and tighten the drill chuck on the knot as shown in 2) below.

☐ Hold the far end of the wire taut as shown in 3) below

☐ Use the drill to twist the wire as shown in 4) below.  The number of twists per inch is not very important.

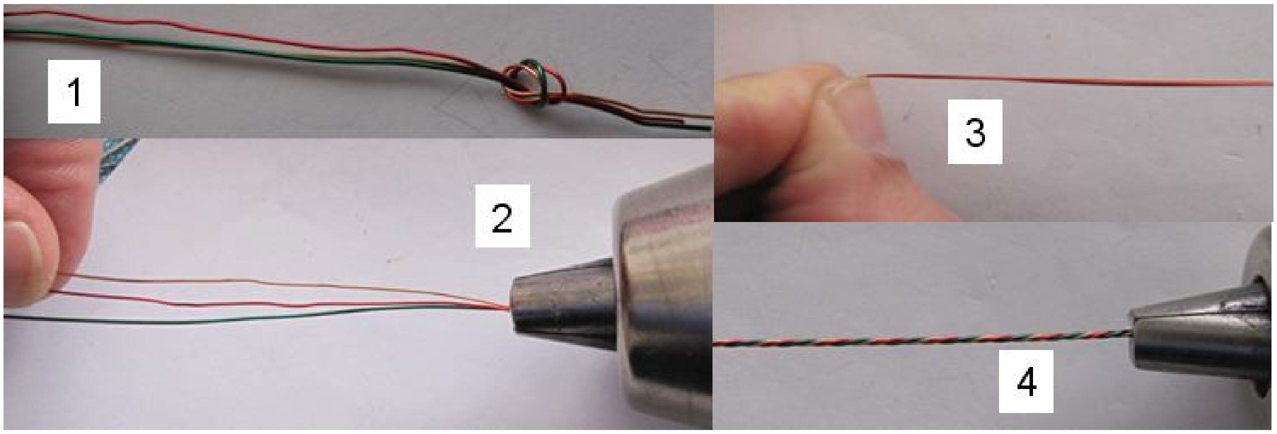



**Figure 22.  Wire preparation for the wire used in T1**

☐ Take the twisted wire prepared above and wrap 11 turns on a FT37-43 core as shown in 1) below. The FT37-43 is the only core that is not colored red on one side

☐ Trim of the excess wire allowing room for soldering the leads as shown in 2) below

☐ Untwist the wire and arrange them in color pairs as shown in 3) below.  Pair the like colors as shown.

☐ Tin all six wires up to the bottom edge of the FT37-43 core.  Keep the color pairs together as shown in 3 below!

The holes in the board for T1 have six holes arranged as three sets of two as shown below the top two holes are for one color pair (both red wires for example), the middle two holes are for the second color pair (both green for example), while the bottom two holes are for the third color pair (both gold wires for example).

☐  Mount the core in the board vertically with the wire pairs lined up top, middle, and bottom.  The color order is not important as long as the same colors are kept together in pairs.

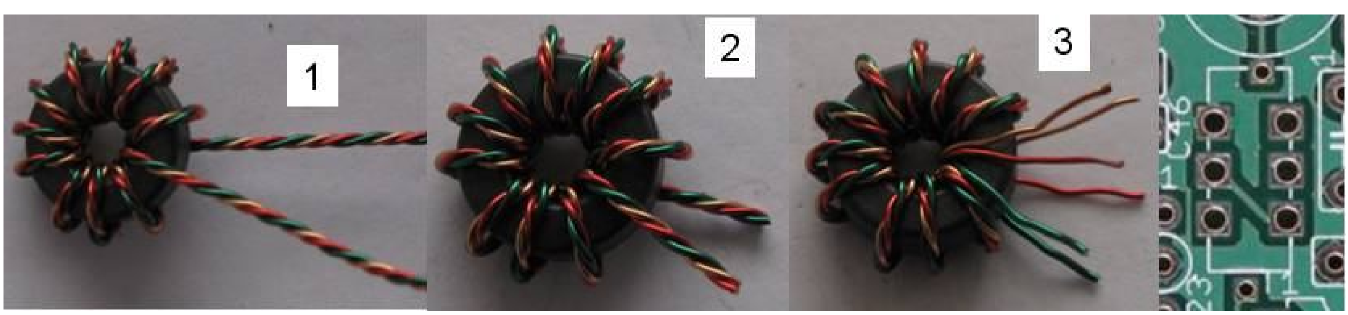



**Figure 23.  Preparation of T1 and picture of the PCB holes for T1**

Prepare L6 using a T37-6 core (red colored), and a 16” length of the larger red # 28 gauge wire as shown below. The coil needs ***31 turns***. **These turns need to wound right next to each on the core in order to fit.** Remember, the first pass through the center of the core counts as turn # 1. The holes in the PC board assume L5 is wound in a certain way. The lead pattern assumes that each turn is added from the ***bottom*** side of the core, and that the turns are added in a ***counter-clockwise*** direction around the core.

Tin the leads up to the core edge as shown above. The pads to L6 are oval shaped and are labeled 1, 2, and 3. ***Do not use the square feed though pads!*** Mount L6 vertically as shown below. **Install ☐ L6.**

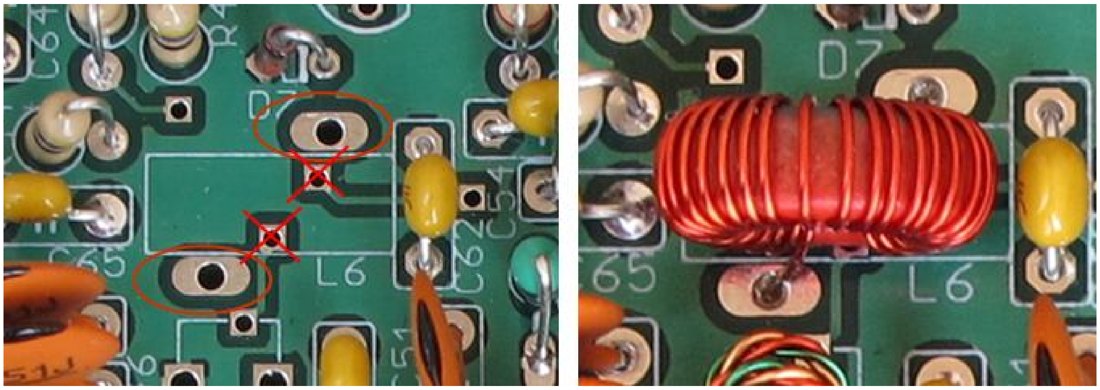



**Figure 24. L6 pads identified. Use oval pads, not square holes**

Install Antenna switch BS170 transistors ☐ Q2, ☐ Q3, and ☐ Q4

☐ Using the larger red enamel wire (#28 gauge), take 14” of the wire and wind L5 with **26 turns** of wire on to a red T37-2 core. **These turns need to wound right next to each on the core in order to fit.** Remember, the first pass through the center of the core counts as turn # 1. The holes in the PC board assume L5 is wound in a certain way. The lead pattern assumes that each turn is added from the ***bottom*** side of the core, and that the turns are added in a ***counter-clockwise*** direction around the core.

☐ Tin the leads up to the edge of the core and mount L5 vertically as shown below.

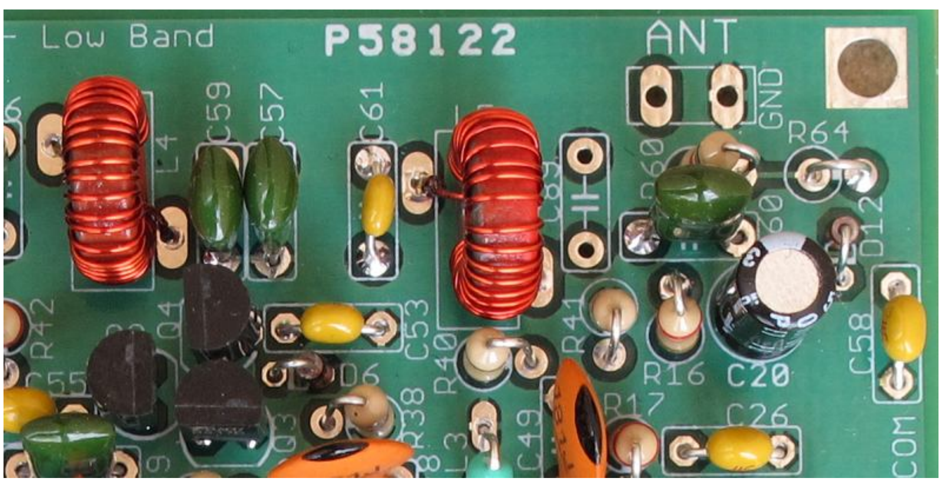



**Figure 25. L4 and L5 mount vertically**

☐ Using the larger red # 28 gauge wire, wind L4 with **27 turns** of wire on to a red T37-2 core using 14" of wire. **These turns need to wound right next to each on the core in order to fit.** Remember, the first pass through the center of the core counts as turn # 1. Like L5, the holes in the PC board assume L4 is wound in a certain way. The lead pattern assumes that each turn is added from the ***bottom*** side of the core, and that the turns are added in a ***counter-clockwise*** direction around the core.

☐ Tin the leads up to the edge of the core and mount L4 vertically as shown above.

## *Transmitter LPF Tests*

It is really common to have connection problems with enamel wire when it is soldered to the PC board. A simple check to make sure each toroid is soldered in properly is to take an ohm meter to the pads on each end of the coil and make sure there is a short.

The following tests are specifically testing L4 and L5.

☐ Take an ohm meter and measure across the antenna terminals. If all is well, this should read as an open. If it does not, check for shorts in the L4 and L5 area.

☐ Also take an ohm meter and measure from the antenna input to the pad of L4 next to C56. This should show a short (0 ohms or very close to it) and verifies that L4, and L5 are all connected properly in series.

Now only the finals need to be added to finish the PC board. However, at this point, it is time to roughly set the frequency of the VFO.

## *VFO alignment*

***The RIT pot must be in place for the VFO to operate properly!***

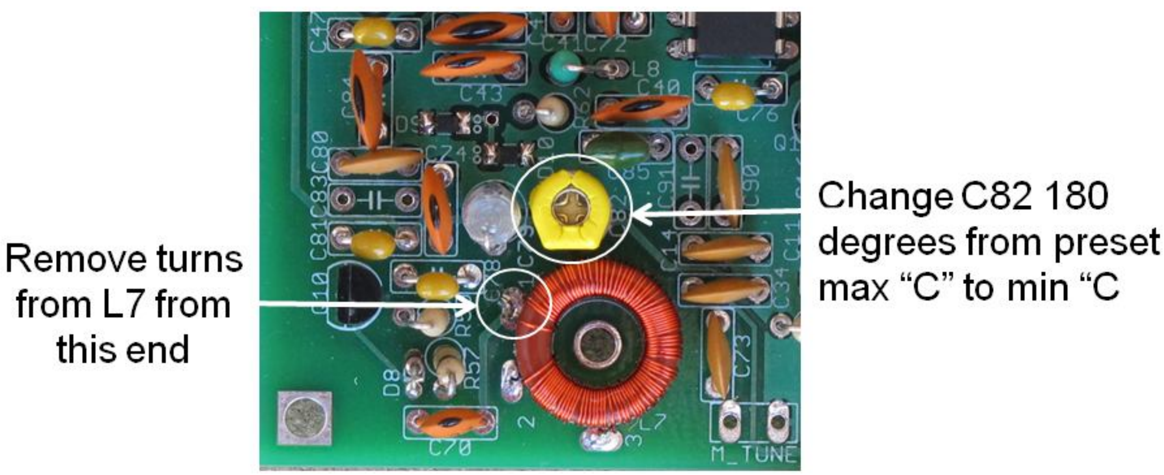



**Figure 26. View of VFO area including trim cap C82 and L7**

First look at C82, the trim cap. The metal slots in it form the pointer of an arrow. Note the direction of this arrow. This trim cap comes preset from the factory at maximum “C”. Rotate the direction of the “arrow” by 180 degrees (1/2 turn) so that the trim cap is at minimum “C”.

The simplest way to do this is to get a signal generator, like a DDS VFO, and use it to feed an insulated wire that is placed close to T1. If a signal generator is used, set it to a relatively large signal level such as -10 dBm. Now sweep the signal generator from 1.7 to 1.85 MHz until the signal generator signal is heard. You may need to search around a bit depending on exactly how many turns have actually been placed on L7. It is easy to be off by one or two turns either way out of 88 total.

In all of my prototypes, all VFOs came up at around 1.75 MHz. The VFO is course tuned by removing turns from the 66 turn side of L7. Each turn removed raises the frequency by about 20 KHz. 1.75 MHz is 50 kHz too low, so I typically had to remove 3 turns to get the VFO above 1.8 MHz. If the final tuning range is to be 1800 kHz to 1837 kHz (37 kHz tuning range), this course adjustment must end up just above the high end of the desired tuning range or 1837 kHz.

Since the VFO is really operating at 1/3$^{rd}$ the operating frequency, you can listen for the VFO on an AM pocket radio in the 540 to 600 KHz range (600 KHz x 3 = 1.8 MHz) and double check if the VFO is running and where it is.

Assuming 20 KHz per turn, determine where the receiver is tuned to, how many turns need to be removed to get to where you need to go, and remove one fewer than that many turns. If for example, you want to get to 1837 kHz, and the receiver is currently receiving a signal at 1730 kHz. This is a difference of 107 kHz which means that removing 5 turns at 20 KHz per turn will get the VFO above 1837 kHz. Start by removing one less or two turns (in this example). These extra turns are removed from L7 at the end indicated by the figure above. This lead is soldered to the top of its pad to make it easier to unsolder and reattach when finished. Remove the two turn3, cut off the excess wire, tin the wire and re-solder it to the top of the pad. Now double check the received frequency by sweeping the signal generator around until it is again heard in the receiver. Double check one more time to see if one or more turns need to be removed and remove these excess turns. Cut off the extra wire, re-tin the lead, and solder it down to the top of pad 1 of L7.

At this point, the trimmer cap C82 can be used to provide fine frequency adjustments to place the VFO right where it is desired. It has an adjustment range of about 20 KHz, which is a bit more tuning range than removing a turn. Remember that the main tune capacitor has not yet been added to the board, so the final frequency will be a bit lower with the main tune capacitor than without it.

When the surface the receiver is on is bumped, a bit of “twang” might be heard in the receiver due to some vibration of L7. If this is the case, it might be desirable to use a **small** amount of ***hot candle wax or hot glue*** to stick the coil to the surface of the PCB. An alternative might also be to use a ***nylon 4-40 screw (1”), a nylon washer, and a nylon nut.*** 6-32 nylon hardware will work also. These nylon components can be found at Ace Hardware or other hardware stores.

***Do not use glues to cement L7 into place!*** Some glues will ruin the operation of the VFO (like Gorilla Glue, Super glue, or J B Weld). Do not risk this. Please stick with either candle wax, hot glue, or nylon hardware (nylon screw, nylon washer and nylon nut) to stabilize L7 if it does have a vibration problem.

If you do not have a signal source like a signal generator or a DDS VFO, two other alternatives are:

1) Use a frequency counter, coupling the counter to the square feed through point right next to the 74HC4053 (IC6) pin 1 using a 10 to 22 pF capacitor. If a frequency counter is added to the kit, this is the recommended pick off point for the counter. The frequency allows the receiver frequency to be measured directly.

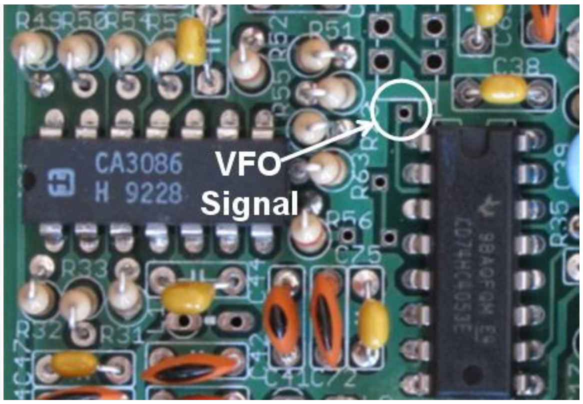



**Figure 27. Suggested VFO pick off point shown**

2) Use a second 160m receiver to listen for the VFO using a section of insulated wire (18"?) placed near L8 which is in the VFO area. Remove one turn at a time from L7, listening for the VFO in the 1800 to 1850 kHz area. This last method will work assuming the VFO is running properly. Using a very short wire will make sure that all other signals on the band will be very weak, while the tripled VFO signal form L8 should be very strong. You will be able to tell that this signal is from the TUT-160 by moving the wire closer or further to L8. When you do this, the strength of the signal should change dramatically if this is indeed a signal from the VFO.

***One small note on VFO stability.*** For best drift performance, I have found that VFOs need to be "broken in" for best VFO stability. I suggest leaving the rig on continuously for at least three days to accomplish this.

Now that the receiver has been roughly set to the proper frequency, the finals can be installed.

**Install three BSS170 transistors, ☐ Q5, ☐ Q6 and ☐ Q7.**

**☐ Set the TX power control trim pot R46 *half way*.** This gives a bit less than full power setting for the transmitter. In the transmitting test below, this pot can be used to increase the output power to the maximum capable. At full power the transmitter passes the FCC requirement for spectral purity with all harmonic typically being at least 50 dB down. In my prototype, half way set the power output to about

2.5v (16v peak) when using 12v, while setting to maximum gave 4w or 20v peak.  See the following section for testing and measuring the output power.

## ***Transmitter Tests***

A connection can be made to the antenna jack ("ANT" at the top right of the board) to allow a quick test of the transmitter before the board is placed in a case. The transmitter output power is fixed. With a supply voltage of 12 V, the kit should deliver approximately **3.6 to 4w** of output power into a 50 ohm dummy load. The kit is designed to deliver over 5w when a 13.8v supply is used.   The current drain is approximately **760 mA at 12V.** 5w is the nominal output power. There is expected to be some power variation from kit to kit.

The output power can be tested by measuring the voltage across the pads marked "POUT" (power output) near the headphone outputs.  This voltage is a simple peak detector that is only guaranteed to work properly when the rig is transmitting into a 50 ohm dummy load.  A 50 ohm dummy load provides the proper DC return to make this output work correctly.  Many antennas do not have a DC return path, so this output may not work properly when connected to a real antenna.

When transmitting into a dummy load, the output power can be calculated using the measured peak RF voltage from the following equation which is designed for using peak voltage into a 50 ohm load:

Power = V*V/(2*R) = V*V/100

Thus, 3.6w corresponds to a peak voltage of 19v, 4w corresponds to 20v and 5w corresponds to 22.3v. Using a 12v supply, the output power should be in the 3.5 to 4w range.  R46 can be varied to adjust the output power to these maximum limits.

***This peak power detector is simply used as a check to make sure the transmitter is working correctly into a dummy load.  In order to do this, a diode is connected to the antenna which can cause undesired mixing products from out of band RF signals.  Thus the wire loop installed at R64 near the antenna output needs to be cut after this power check verification is performed.***

This transmitter is not designed for continuous key down operation, although it could likely survive such operation into a good 50 ohm load due to its high efficiency (the finals are approximately 72% efficient). At 5w of RF output, the finals are using about 7w of DC power, and each of the three BS170s are rated at 800 mW each. Thus, this is about 660 mW of heat per device.

The V2 PICF508 firmware has a "dotting" mode that kicks in after about three seconds of continuous key down to protect the finals from potential overheating. This reduces the TX to 1/3rd duty cycle to allow longer antenna tune up cycles not to overheat the transmitter.

The transmitter will survive transmitting for a brief time into an open load. However, prolonged transmission into an open load will burn up the BS170 finals.

Remove the temporary connections for the power, the RIT pot, the key jack, the spot switch, the headphone jack, antenna jack and the temporary short on the volume control R11 (middle right between the two 8 pin IC3 and IC4 ICs).

**The kit is now ready to be placed into the case.**

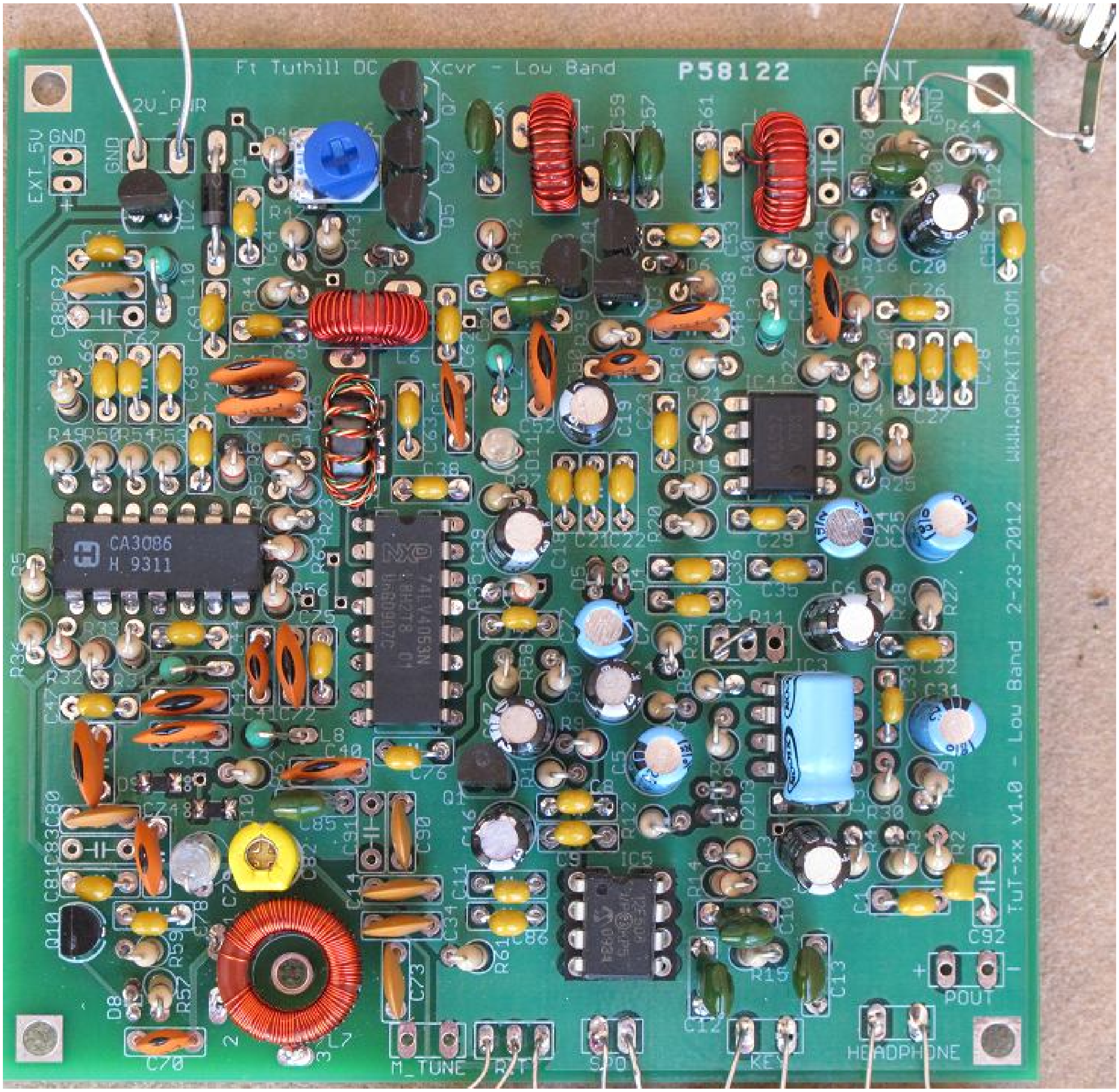


**Figure 28. Finished PCB. Cut loop at R64 when testing is done.**

## *Placing the Kit into a Case*

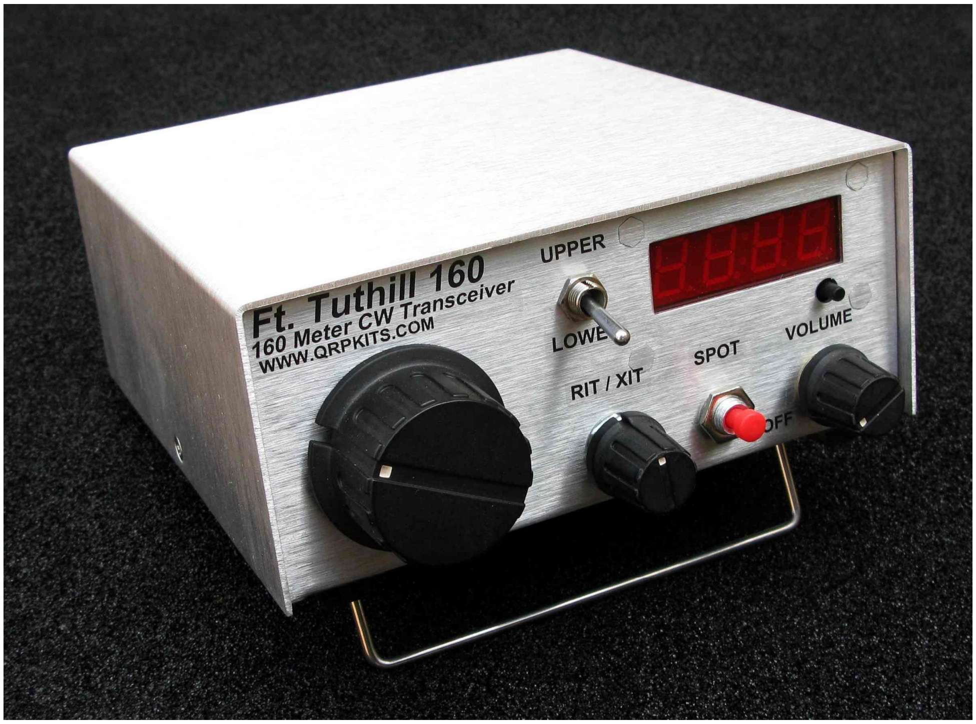



**Figure 29. Front panel view with decals applied and optional Digital Dial frequency counter**


**Figure 30. Rear panel view with decals applied**

The above pictures show the labeling for the 160m version.

## *Chassis Preparation*

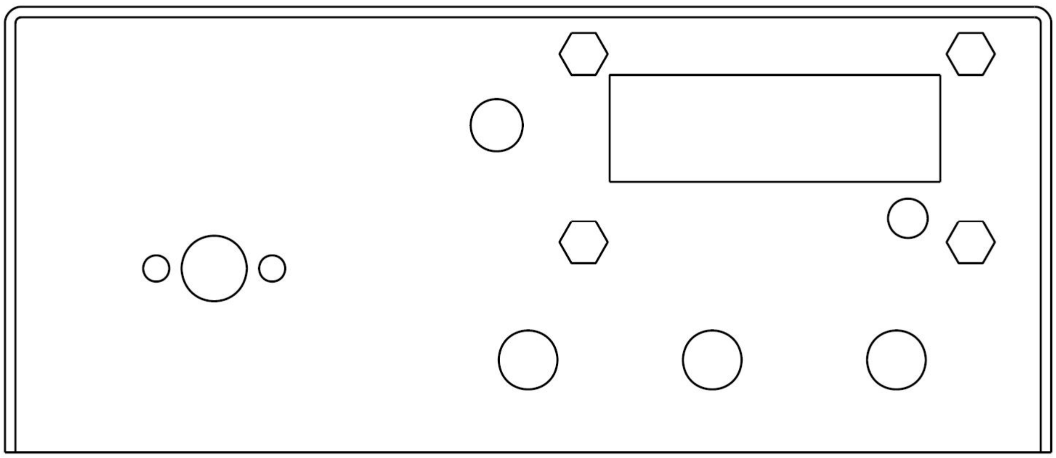


**Figure 31. Drawing of the front panel before controls are mounted**

The chassis supplied is furnished in a brushed aluminum finish. You may choose to leave it as is, or paint it. If you choose to paint the chassis, after cleaning thoroughly, we recommend a primer coat, sanded lightly, and then a finish coat in the color of your choice. If you chose to use the supplied decals, it is best to keep the front and rear panel, light in color, so there is contrast between the black decals and your painted surface. You can paint the cover the same color, or a contrasting color of your choice.

If you choose to leave the brushed aluminum finish, the PEM standoffs for the Digital Dial are installed after the chassis is grained, so it will be necessary to use a small piece of emery paper to blend in the small hex imprint of the PEM standoffs. Finish the grain in the same direction (horizontally) as the surrounding finish. Our display pictures on the web site show the chassis prepared in this method. This would be the coolest option, in the sun, if you are using the radio outdoors.

## *Decal installation*

If the plain aluminum look is desired, the decals will need to be applied before the kit is mounted inside the chassis, because several light coats clear spray will be needed to protect the decals, and all the hardware needs to be removed before doing the spraying. It may be best to temporarily loosely attach controls and knobs in order to better see where to place the decals. Again, remove the hardware before applying the clear coat.

If the case is going to be painted, the painting also needs to be done before the controls, main PCB, or Digital Dial is added. When painting the cases, three ***light*** coats of enamel paint seems to work well. Wait an hour between coats. With each coat, the paint will be extremely soft and easily damaged. If you damage a painted surface, use steel wool to strip off all the paint and start all over. When done with the third coat, place the painted case in the oven at 180 to 200 degrees F for two hours. Place it on a middle rack with a pan above and below it to protect it from direct heat. Two hours at this heat will harden the paint nicely. A picture of a painted case is shown below. When you paint the case top, make sure to also paint the underside back from the edge by 0.5". As you can see in the pictures below, some of the underside of the case top overlaps with the bottom and is visible.


**Figure 32. Picture of decal locations on the front and back panels (painted case)**

The decals are applied the same as model decals. Cut around each group of text or symbols you wish to apply. It doesn't have to be perfect as the background film is transparent. Apply the decals before you mount anything to the chassis. Use the above picture to get the correct spacing around the holes and cutouts, as it is very easy to do a great decal installation and have a portion covered up with a knob

**Thoroughly clean the surface of the panel to remove any oils or contamination. We have found that moving the decals into position on bare aluminum chassis is difficult, due to the brushed surface, so we advise pre-coating the chassis with the Krylon clear before applying the decals, and then, after as well.**

Trim around the decal. After trimming, place the decal in a bowl of lukewarm water, with a small drop of dish soap to reduce the surface tension, for 10-15 seconds. Using tweezers, handle carefully to avoid tearing. Start to slide the decal off to the side of the backing paper, and place the unsupported edge of the decal close to the final location. Hold the edge of the decal against the panel, with your finger, and slide the paper out from under the decal. You can slide the decal around to the right position, as it will float slightly on the film of water. Use a knife point or something sharp to do this. When in position, hold the edge of the decal with your finger and gently squeegee excess water out from under the decal with a tissue or paper towel. Work from the center, to both sides. Remove any bubbles by blotting or wiping gently to the sides. Do this for each decal, and take your time. Allow to set overnight, or speed drying by placing near a fan for a few of hours. When dry, spray two **light** coats of matte finish, Krylon, clear to seal and protect the decals, and allow to dry in between coats. ***Using a first coat that is too heavy can cause the decals to shift. Keep the first coat light!*** All decals come with two complete sets, in case you mess up a decal.

## *Connecting Jacks, Button, and Controls to the Case*

Whether or not a Digital Dial is purchased, the red plastic bezel needs to be installed on the front panel. Place the bezel on the front panel mounting posts for the Digital Dial and mark with a felt pin exactly how much plastic needs to be removed to get the bezel to fit over the posts and around the Digital Dial push button hole. The picture below shows the bezel as trimmed with a pair of scissors using square cutouts.

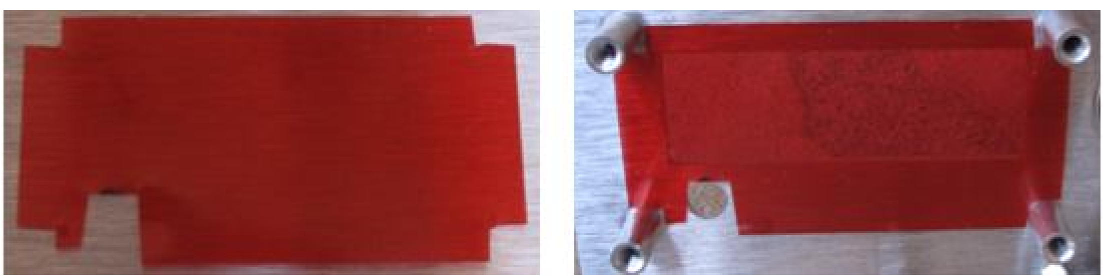


**Figure 33. Trimmed red plastic bezel and shown mounted in place**

When the Digital Dial is used, the bezel does not need to be secured as the mounting of the Digital Dial behind it and the bezel cut outs around the mounting posts seem to hold it into place. If a Digital Dial is not in place, it is suggested that a rigid piece of cardboard (such as from the box the kit came in) be placed behind the bezel (cut to match the bezel and its cut outs). The backing should then be taped into place using scotch tape.

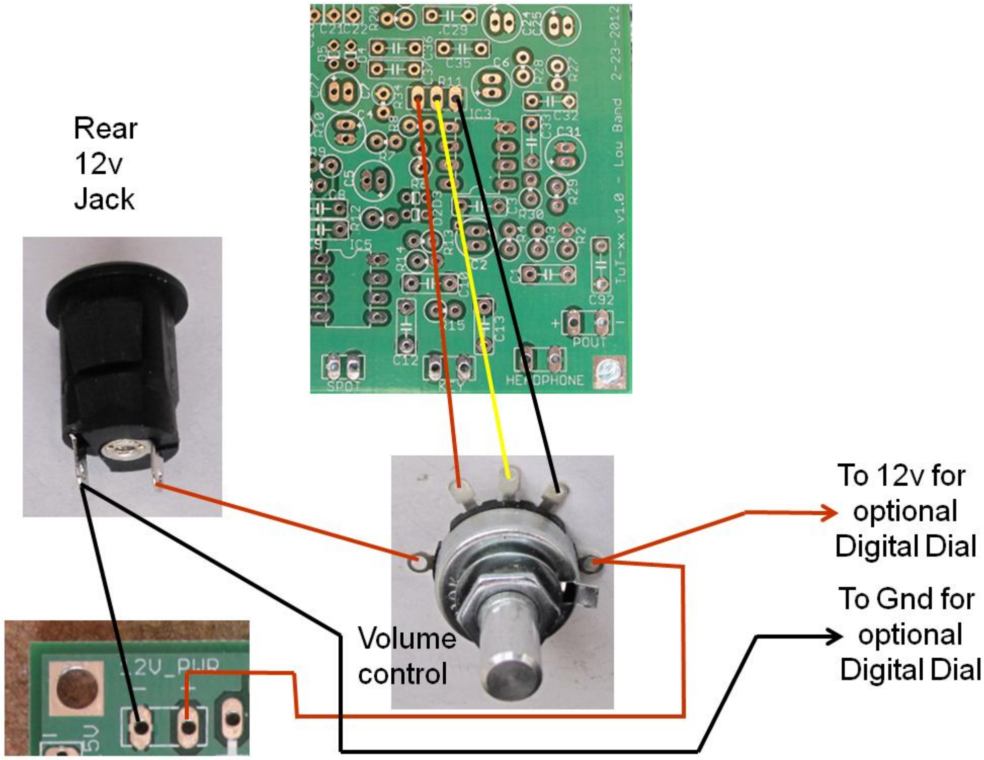



**Figure 34. Visualization of 12 V power jack, volume control and Digital Dial connections**

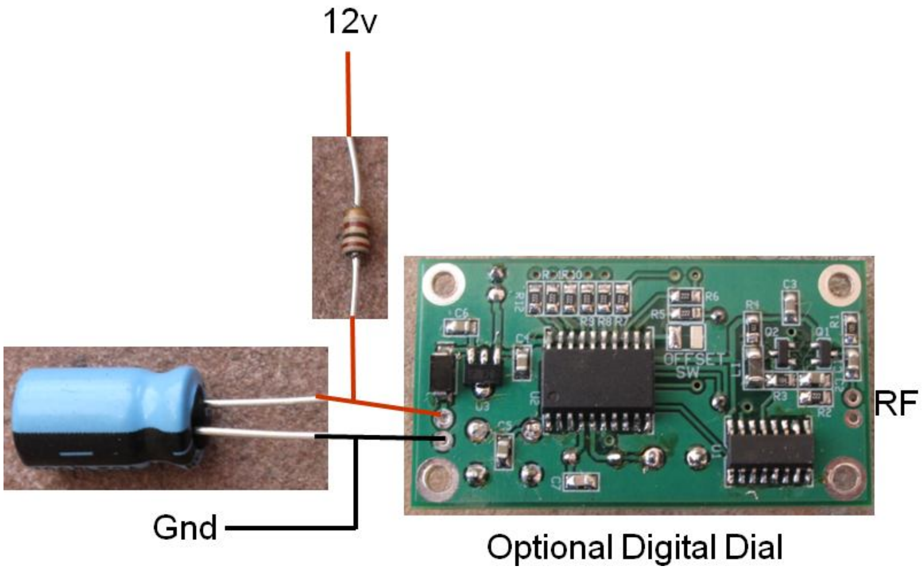



**Figure 35. Optional digital dial and additional 12 V filtering, 100 ohm and 220 uF cap**

See the following pictures for the next three steps:

First, mount the optional digital dial to the case (bezel and PCB).

Add the 220 uF cap and 100 ohm (brown/black/brown) resistor as illustrated in pictures both above and below. Notice that the 220 uF capacitor has to be bent backwards to stay inside the case and also be mounted to leave room to connect the 100 ohm resistor. Note the 220 uF cap was shifted to the side to make room for the 100 ohm resistor. ***The polarity of the 220 uF cap is important!*** Mount it stripe down as shown.

Next mount power jack to rear panel. The center lug is the +12v, the lug to the right is the ground terminal. ***Mount as shown below.***

Next mount volume control front panel. Note that if the digital dial is used, the three top lugs must be bent down. ***Make sure the volume control is installed with the power switch tab horizontal (as shown!) to prevent the 12 V power from shorting to the case!***

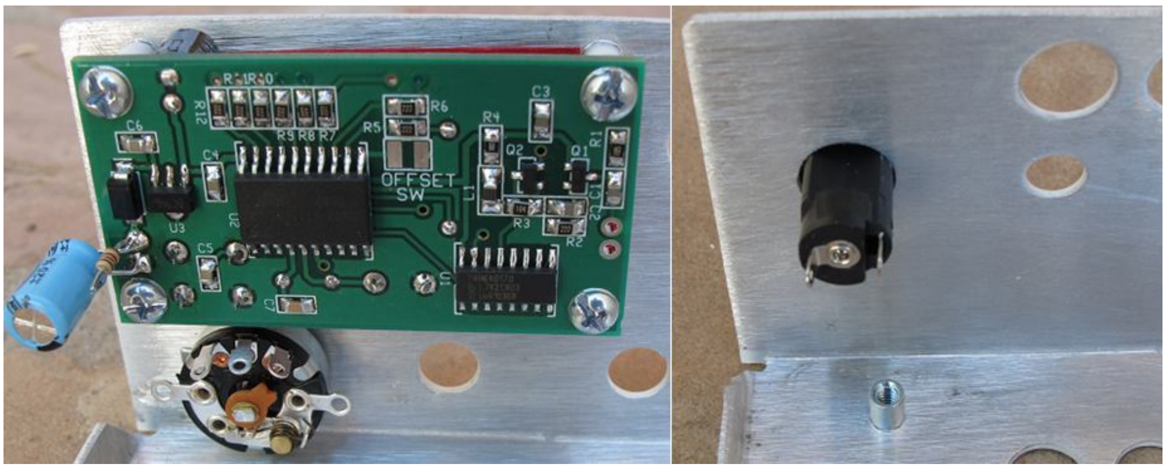


**Figure 36. Optional Digit Dial, Volume control and 12v power jack mounted**

See the following picture for the next steps:

Next wire volume control wires to the bottom side of the PCB – 3" of tri-filer twisted wire (Green-Red-Gold) left over from the winding of T1. I lost my left over wire, so the picture shows show twisted # 32 red wire, all the same color.

Next add power wires to top side of the PCB (1 ¼" hookup wire on the 12v ground side, 9 ½" of hookup wire on the +12v side)

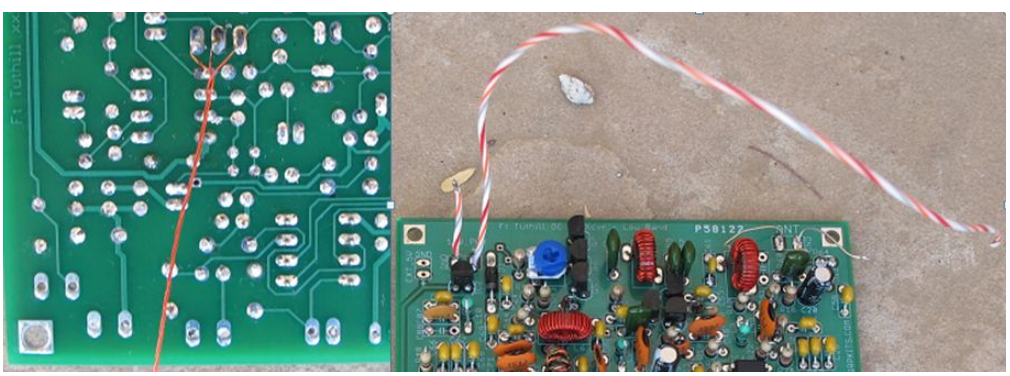
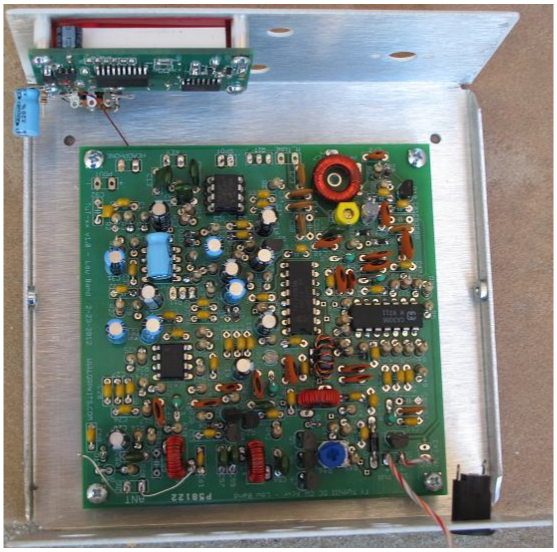


**Figure 37. 3" R11 volume control wires on bottom, short ground and long 12v wires on top**

Mount the PCB in the case using four 4-40 screws.  Mount the VFO coil as shown towards the front panel as shown below.



***All rear connections (power, key, and headphone jack) should be routed around the outside of the standoffs (not under the VFO!) and the left edge of the board (the CA3086 edge) in order to keep them away from the transmitter power amplifier and antenna connection.***

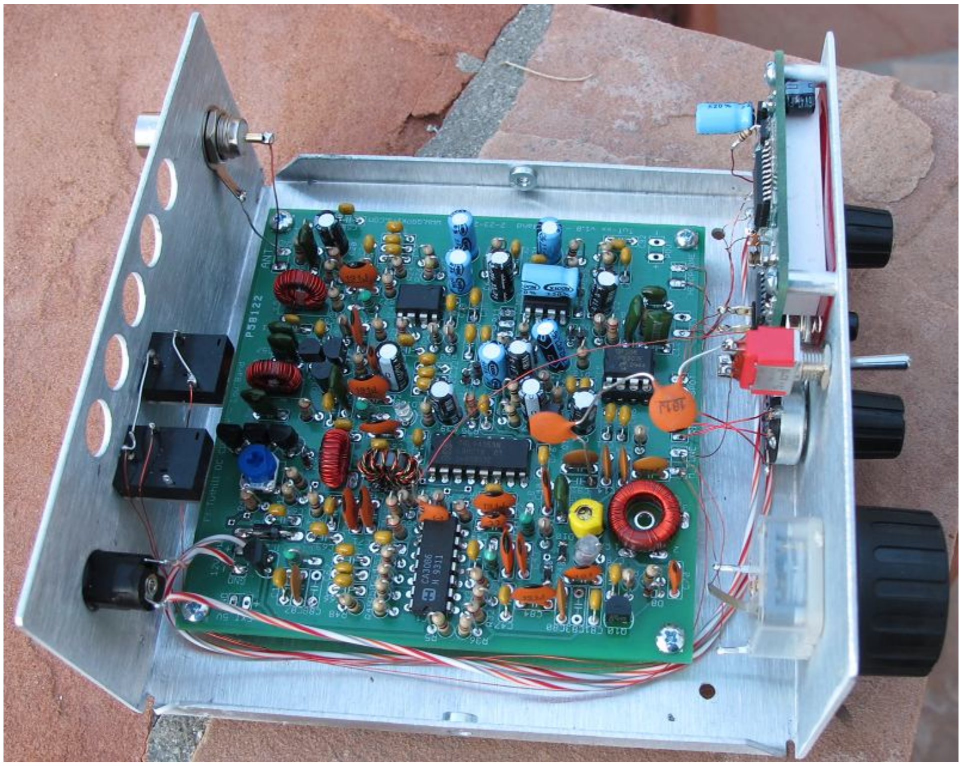


**Figure 38. Route all rear panel wiring along the 12v power/VFO side as shown**

Connect as shown in the picture below:

Wire the PCB ground to the power jack

Wire the PCB 12v power to the volume control switch

Wire the 12v jack to the other side of the volume control switch using 7 ¼" of hookup wire.

Wire the optional digital dial to the volume control switch

Wire up the volume control as shown in the earlier volume control pictorial.  Use an ohm meter to match up volume control wires with R11 pads.

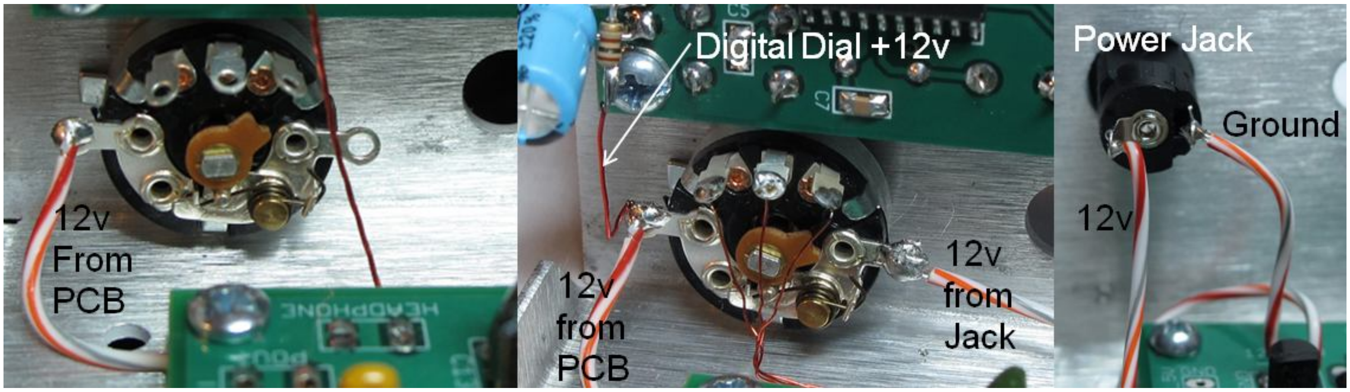



**Figure 39. 12v wiring from PCB to Volume switch to Power jack plus optional Digital Dial power connection**

Add RIT pot as shown below.

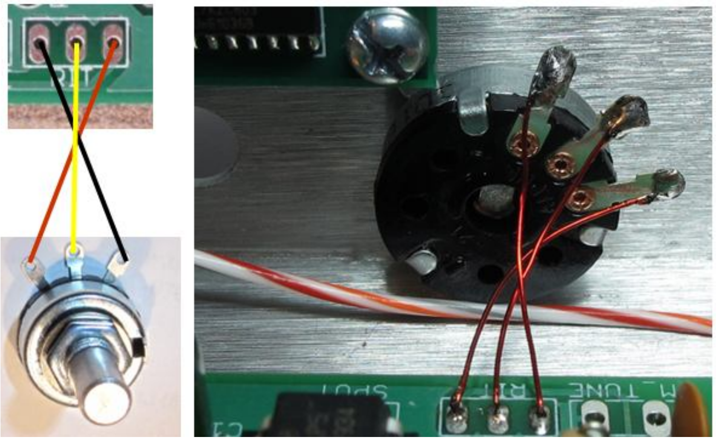


**Figure 40.  Visualization of RIT pot connection and view of connected pot**

Connect 12v to the rear power jack and make sure that turning the volume control "on" and "off" causes the optional Digital Dial to light up and the blue LED on the PCB to also light up.

Add headphone and keyer jacks as shown below.

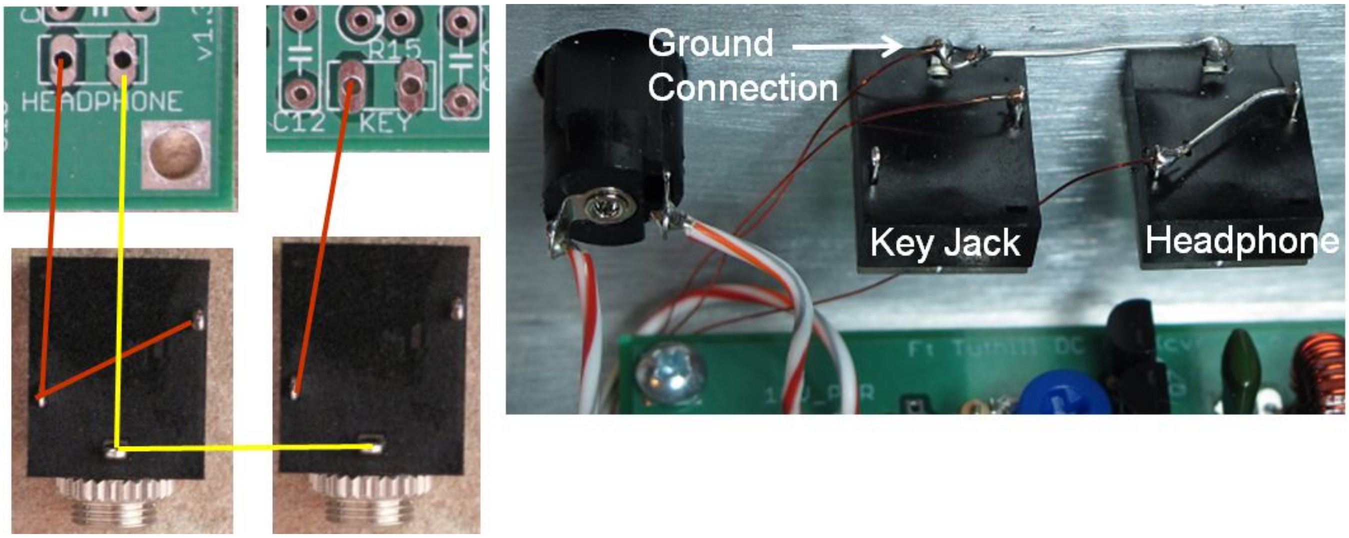



**Figure 41. Visualization of Key and Headphone Connections, rear panel connections**


**Figure 42. Key and Headphone PCB connections**

Run a quick test by plugging in a pair of headphones, turning on the power and listening for the cw sign on.

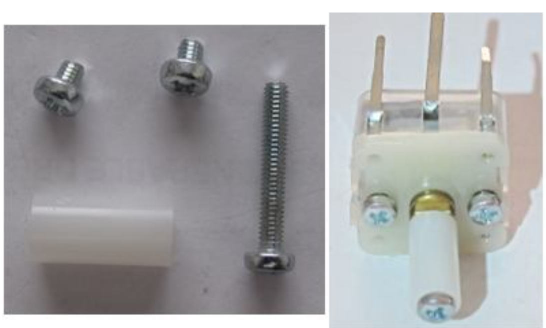


**Figure 43. Mounting hardware for the main tune capacitor**

The above picture shows the main tune capacitor with its mounting hardware. The long screw is used to attach the ¼” nylon sleeve to the main tune shaft so that a normal ¼” shaft knob can be used to tune the receiver*. If the small mounting screws are added to the tuning capacitor before it is mounted to a front* *panel, beware that tightening the screws can cause them to go to deep into the capacitor body and damage the interior of the capacitor.* Once mounted on a front panel, this will not be a problem.

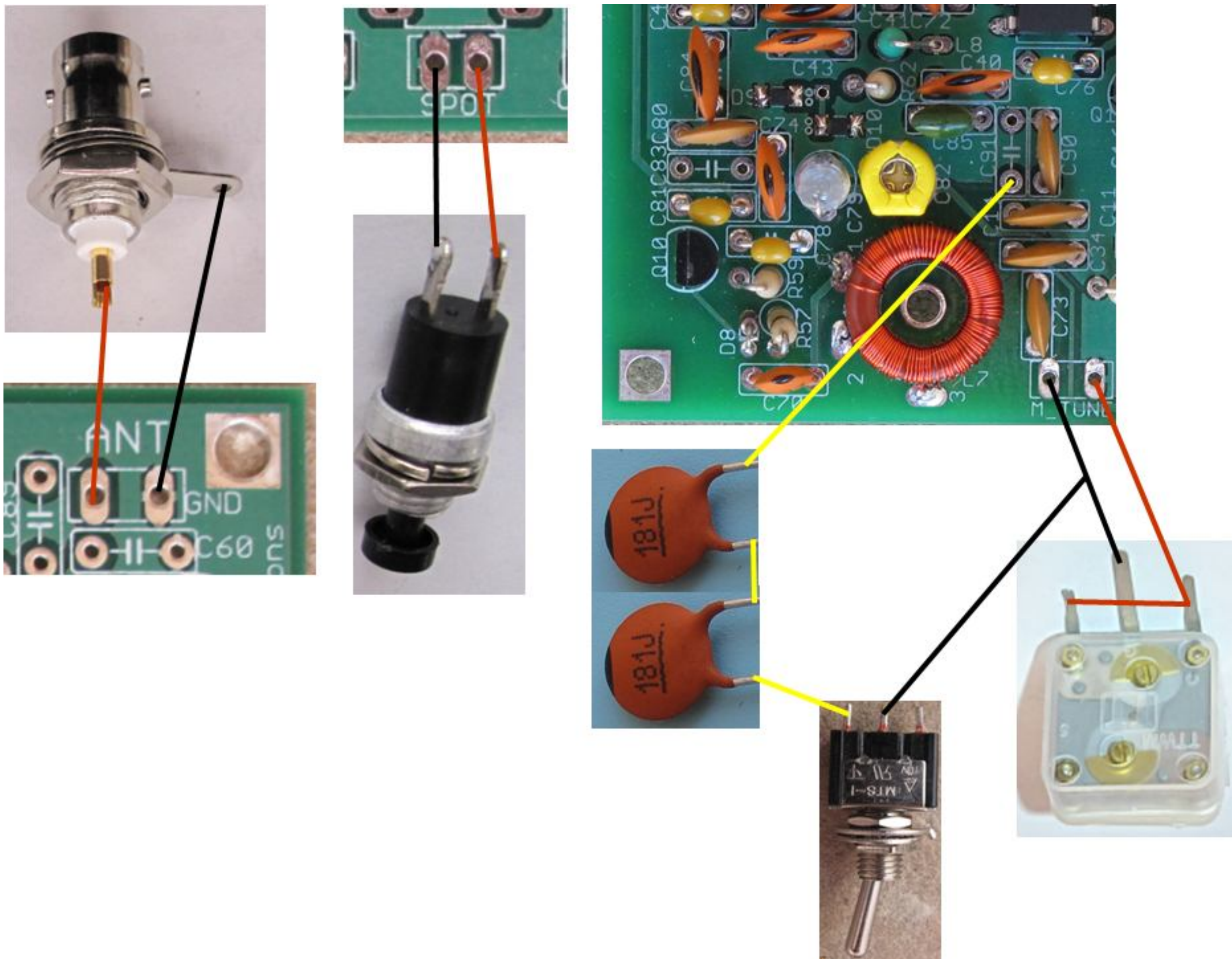



**Figure 44. Connection of main tune capacitor and Hi/Low band Switch, Spot, and Antenna**

Add Antenna jack, spot switch, main tune cap and high/low band switch as shown above and below.

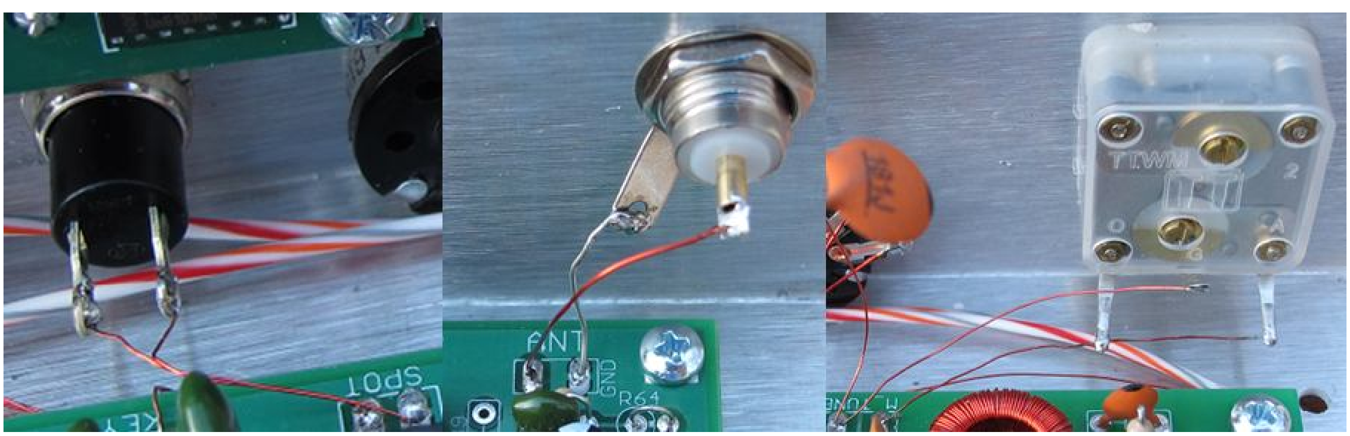



**Figure 45. Wiring of spot switch, antenna jack and main tuning polyvaricon cap.**

***Note: when wiring both the range switch and the main tuning polyvaricon cap, it is very important to make sure the ground connections are (black lines in Figure 44) connected as shown***. If the ground connections for both the main tune and band switch are not wired properly, placing your hand near the main tune knob or band switch handle will move the receiver frequency.

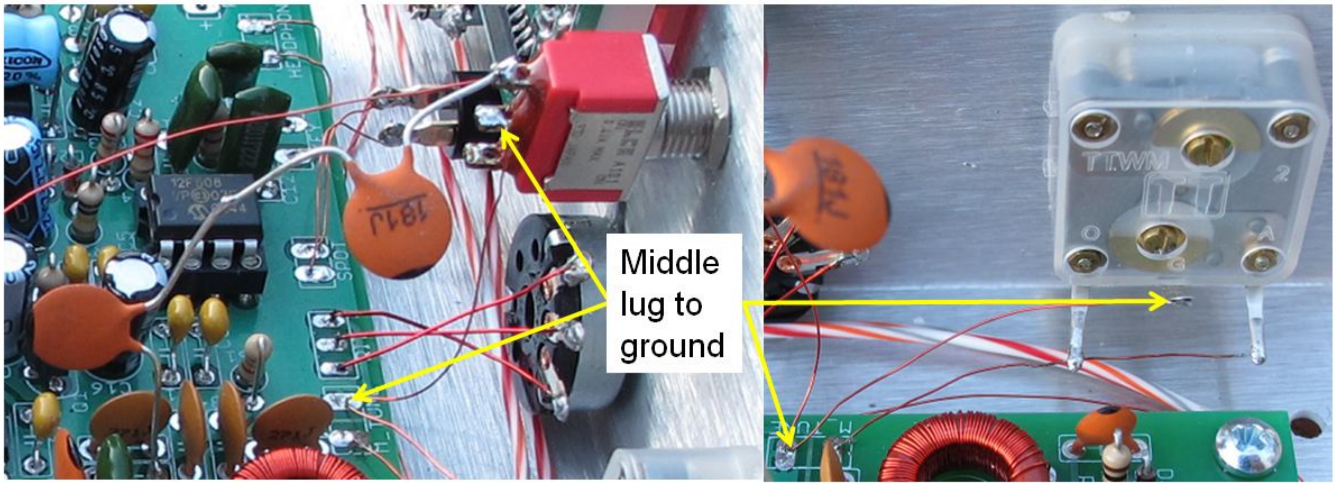



**Figure 46. Make sure the right terminals are connected to the right PCB ground pad.**

Connect the high/low band switch and two series 180 pf (marked 181 as shown) as shown above and in Figure 44.

This kit uses a 1.5" main tuning knob. 44 kHz of total tuning range in a half turn if a 1.5" knob seemed to work well, so the kit has been designed to operate in two tuning ranges of 44 KHz. This is nominally 1.800 to 18.044 for the bottom tuning range. The upper tuning range switches 90 pF (2x 180 pf in series) into and out of the circuit. 90 pF provides ~37 KHz of offset between the high band and low band. Thus, this configuration would cover ~1.830 to 1.880 MHz.

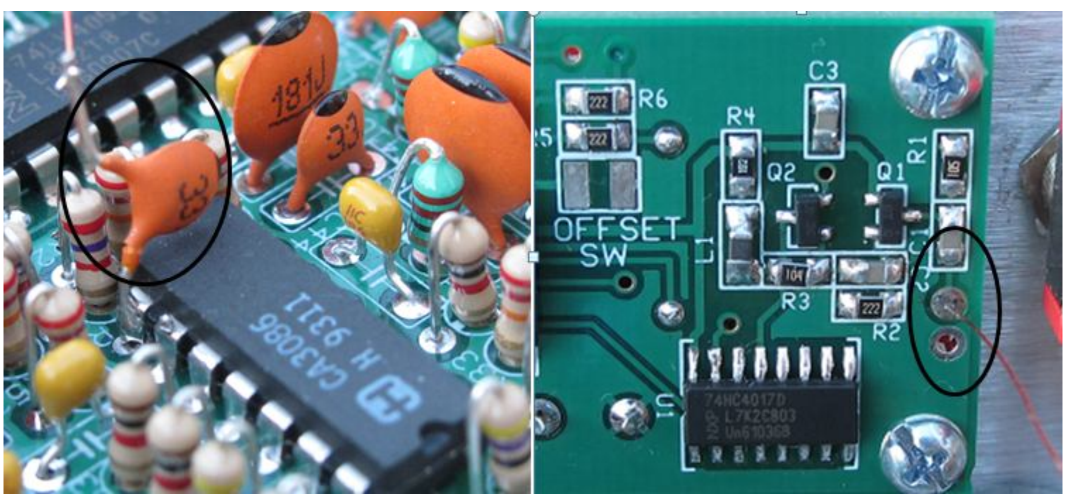



**Figure 47. Connecting RF to optional Digital Dial frequency counter**

The last thing to connect is to feed the RF to Digital Dial.  For this optional connection, a 33 pF capacitor is attached as shown above to pin 8 of the CA3086 chip.  A piece of # 32 wire is then used to connect the other end of the 33 pf cap to the RF input of the digital dial as shown above.

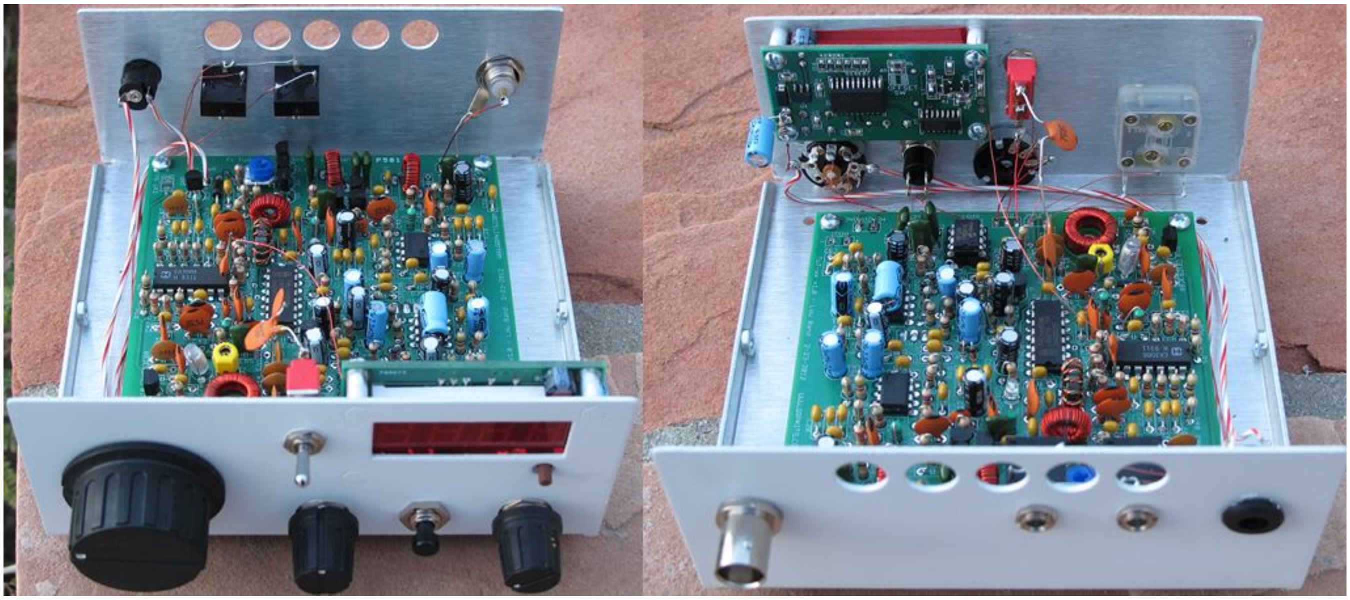


**Figure 48.  Front panel/back panel view before adding decals.  Painted case shown.**

## *Final frequency tweaks*

After the kit is placed into the chassis, final frequency adjustments to the VFO can be made.

Adjusting the VFO involves switching the Hi/Lo band switch to the low side and then adjusting the lowest frequency of that range to be 1.800 MHz.  Earlier sections covered how to tune the VFO.  Most of these adjustments will involve compressing or spreading the turns on the VFO coil L7.  Earlier, C82, the trim cap, was set to its minimum value.  We want to use as little of C82 as possible.  Trim caps such as C82 can degrade the stability of the VFO, so it should be used as little as possible, keeping near its minimum value.

If adjusting L7 cannot get the VFO to 1.800 at the bottom end of the low range, removing a turn of L7 will raise the frequency by ~20 KHz.  Removing a turn from the pad 1 side of L7 should be considered only if spreading the turns on L7 fails and the frequency is too low.

At this point, we are done and the transceiver is ready for use.

## Optional additions to the kit include a QRP Kits (www.qrpkits.com) digital dial frequency counter and an internal keyer kit.  The supplied key jack can be wired for either a straight key or a dual paddle

# A few tips on using the transceiver

## *How "spot" and RIT works*

First a description on how the RIT and "spot" works. The VFO has two varactor diodes, D9 and D10 that are used to provide offset tuning to the VFO. The blue LED is used as a kind of 2.8v shunt voltage regulator. During ***transmit***, the VFO varactors are supplied this ***fixed 2.8v voltage*** via one of the three analog SPDT switches in the 74HC4053. This sets the transmit frequency somewhat mid way (2.8v) in the 1.25 to 5v varactor tuning voltage range.

In other simple rigs, this "mid range" TX voltage is normally just set using two resistors as a simple voltage divider off the 5v supply. However, the use of the blue LED is used to stabilize (regulate) any small voltages changes out of the 5v regulator. The voltage out of the 5v regulators can shift a bit as the current demands changes and the input supply voltages droop on transmit. These transmit voltage variations in the 5v supply has caused TX "chirp" on some rig designs in the past. The use of the blue LED, providing enhanced 2.8v regulation is just additional insurance against TX chirp.

Recapping, the 2.8v from the blue LED sets the TX varactor voltage to mid tuning range. When the rig is ***receiving***, the varactors are fed a ***variable voltage from the RIT pot*** which allows the varactor voltage to be set anywhere between 1.2 and 5v. Since the RIT voltage can be set either above or below the fixed 2.8v used by the transmitter, the receiver can be tuned higher than the transmitter frequency (2.8 to 5v) or lower than the transmit frequency (1.2v to 2.8v). There is roughly 2.5 kHz of tuning range on one side of the TX frequency and 6.5 kHz on the other, so things are not exactly centered.

When you press the "spot" switch, the timing processor (the PIC12F508) switches the 2.8v blue LED voltage into the varactor diodes and sends a brief short "beep" once a second to remind you that you are in the "spot" mode. At this point the receiver is set dead on the transmit frequency. In the "spot" mode, if you zero beat another stations (i.e., reduce the frequency of his tone until it goes to zero Hz), when you transmit, you should be sending exactly on his frequency. In the "spot" mode, the RIT pot does nothing as it is disconnected from the varactors.

When you are in the "spot" mode, and you are hearing 1 second brief beeps, if you press the "spot" a second time, an "R" will be sent and the fixed 2.8v TX voltage will be replaced with the variable RIT pot voltage. At that point, you can vary the RIT knob, and you will notice that you can tune the station that you zero beated in the "spot" mode to a comfortable listening tone (like 600 Hz) in ***two places*** in the RIT tuning range. ***Note where these two places are***. RIT will normally be set to one of these two positions. One of the two positions is listening ***above*** your transmit frequency (+600 Hz?), and the other one is listening ***below*** your transmit frequency (-600 Hz?). As you tune across the band and hear a station you want to work, you will need to use one of these two RIT positions to place the TX directly on top of his signal. However, only one of two positions will place the TX in the right spot, and that depends on whether you are listening to a signal above or below your TX frequency.

Figuring out which RIT offset to use takes a little bit of practice. Practice tuning across the band and checking if you have the RIT set right. When tuning across the band from the low side of 80m to the high side of 80m, you probably want to listen on one side of zero beat for the arriving station as it moves from a high frequency to a listenable 600 Hz. When moving from a high 160m frequency to a low

160m frequency and you hear an arriving station moving from high frequency to a listenable 600 Hz, you will want to use the other RIT tuning point. When you don't know what to do, use "spot" to zero beat the station, then undo "spot" and use the RIT to tune to a listenable tone.

Play with things for a while and I think you will get the hang of knowing if you are listening to the station on the right side so that your TX signal will be in the right place. When in doubt, "spot".

## *Using RIT to escape QRM*

Now if you are in a QSO with a station, and another station pops up and QRMs you, this could be a station on the opposite sideband of the sideband you are listening to. If this is the case, you can get rid of the station by quickly flipping the RIT from one sideband tuning spot to the other. Remember above I suggested you note where the two 600 Hz points are on your RIT tuning range. If you flip from the one position to the other, your transmitter frequency will not have moved. In addition, the signal you are listening tune will be at the same pitch as before. However, your opposite sideband will have moved quite a bit and if the interfering signal was on the opposite sideband he will be gone. Now, in doing this you may have moved a different interfering signal to the new opposite sideband position, but at least you have options.

If the interfering signal was in the sideband that you were using, changing to the opposite sideband by using the RIT knob will not get rid of him, but something else will happen. If the interferer was higher in frequency than the station you were listening to, he will now be lower in frequency than the station you were listening to. Likewise if he was lower infrequency before, he will be higher in frequency afterwards. The receiver filtering is designed to attenuate low frequency signals. This was primarily aimed at reducing any potential 60 or 120 Hz hum. However, if an interfering signal is on the low frequency side of the station you are listening to or if it can be moved to the low frequency side by flipping sideband settings on the RIT, you do have the option of adjusting the RIT such that the interferer is closer to zero beat, thus attenuating him. The desired signal might be lower than what you would normally listen to, but QRM reduction is always a good thing.

Like I said, tune across the band, play with the RIT, and see what flipping from one sideband to the other using RIT does in separating two signals from each other. ***It is good to have options!***

## *What RIT setting to use when calling "CQ"*

In a lot of simple QRP transceivers, the "RIT" RX/TX offset is fixed to ~ 600 Hz.

In this transceiver, the TX frequency offset is fixed, and the receiver frequency is variable due to the RIT offset tuning. If you are going to call CQ, you need to set the RIT knob at one of the two 600 Hz offset points (+/- for personal preference) so that when someone answers dead on your calling frequency, you will hear them at your preferred pitch.

The way you figure out where these two offsets are in your RIT tuning range is to find a signal on the band and "spot" him. By this I mean you turn on the spot mode by pressing the "spot" button, at which time you will hear a brief “beep” once a second to let you know that “spot” mode is active. In the “spot” mode, tune the target signal with the main tuning knob (the RIT does nothing in the spot mode) so that its signal tone goes all the way down to 0 Hz. Now undo the “spot” mode by pressing the spot button again (you will hear a cw “R” to let you know the spot is canceled). Now tune the RIT knob and find the two points where the signal is at a comfortable receiving tone. Remember these two points on the RIT dial. Mark them if you need to.

Now that you know where these two RIT tuning points are on your RIT tuning range, when you call CQ, set the RIT to one of these two points. It does not matter which of the two offsets you use. If someone then answers your CQ dead on your calling frequency, he will end up at the tone offset that you want. The fact that most folks answering you do not know how to respond exactly on your frequency means that you may want to touch up the RIT setting to get the responding station at your preferred received CW pitch.

Unless you specifically want to work a station with a split offset (like a DX station), you should normally have your RIT set to one of the two offsets identified above. After a QSO has begun, the RIT can be tweaked to set a station which is not exactly at your desired pitch to the pitch you want.

## *How to work a station using split frequency*

Someone might want to give QRP DX hunting a shot. What I would suggest is to use the "spot" function on a hound that gets the attention of the DX station (or at least ***close*** to where the last worked station was), and then use the RIT to tune to the DX station himself. That lets you hear the DX (via the RIT) with your transmitter set up near where the DX station has picked up a recent contact.

The range of the RIT is limited, >1.8 kHz, so a Fox working a 1 kHz split is at the edge of the RIT range. If you like a 600 Hz cw pitch, then you can readily work a station with up to a 1.2 kHz split. The 1.2 kHz offset assumes the worst case of listening to the target station on the opposite side of your transmit frequency (1200 + 600 = 1800 Hz). If you listen to the target station on the side of the station as your transmit frequency, the desired 600 Hz offset can instead be used to hear the target station even further away. Using this scheme, the largest offset that can be used is 1800 + 600 or 2400 Hz.

## *“Key down” transmitter protection mode*

The "dotting" function has nothing to do with RIT. When you key down too long, nominally 3 seconds, the transmitter will start sending a string of dots just to keep the heat down on the final. If your cat bumps your key and your transmitter is left going all day, your finals will not over heat, and everyone on the band will probably know it is just a TUT160 stuck key down. If this mode did not exist, you might come back to a puddle of plastic for finals and this is one simple mechanism to keep that from happening. When you are tuning up the antenna and the TX goes into dotting mode, you can stop TX dotting mode by letting up on the key up for a second, which resets the 3 second timer.

## *“V1” sign on message*

“V1” is sent when the receiver is turned on. This primarily tells you that the software version in the PIC12F508 is version 1 of the software. If the software is ever changed, the next version will report “V2”. The sign on is used as a debugging diagnostic during the build to let the builder know that the chip and the last stage of the audio amplifier is operating as expected. If the software version were to ever change, this would let you know which software version you have.

When you turn on the receiver, it seems to take quite a while (~3 seconds) for the “V1” message to be sent. This is because it takes some time for the bias on the op-amps to charge up via their R/C bias network, and if the “V1” were sent any earlier, it simply would not be heard.

In the build it was suggested that the PIC12F508 be socketed. This is because there might be upgrades to the software in the future that you may or may not be interested in. The best IC sockets use round “machined” pins rather than flat, stamped, leaf spring pins. ICs have been known to work their way out of the inexpensive leaf spring type sockets.

## *A note on headphone sensitivity*

You will not get any more volume out than you had in the testing phase of the receiver as the volume was wired to run wide open.

I have a variety of headphones. The least sensitive commonly available headphones have a sensitivity of ***90 dB SPL/mW*** although I have seen some as low as ***86 dB SPL/mW***. Middle of the road headphones have a sensitivity of ***100 to 106 dB SPL/mW***. High sensitivity headphones (these tend to be ear buds) are in the ***108 to 112 dB SPL/mW***.

My bottom of the line Koss over the ear headphones fall into the 90 dB range and they do indeed sound weak. I have some old Radio Shack "on the ear" types in the 104 dB range and they sound great. I have not tried my Koss "the plug" ear bud types (112 dB), but they would be hotter yet. Notice that "medium" performance headphones will be ~ 14 dB louder than low performance headphones. This is a big difference. Also note that there is a ***26 dB span*** between the least sensitive headphones and the best ear buds. That is a very big difference.

Bottom line is that great magnets seem to be necessary for reasonable headphone performance. Inexpensive magnetics seem to produce insensitive headphones.

I would suggest going to Best Buy or Wal-Mart and checking the specifications of various headphones. I notice that some headphones cheat and specify xx dB SPL ***per 1 volt*** (I have seen 116 dB), which is not at all the same scale as xx dB SPL***/mW***. It just a way to make 102 dB SPL/mW headphones appear much better than they really are. Let the buyer beware.

***If your receiver audio output seems way low, find a headphone that you like in the 102+ dB range and you will be surprised how much more audio you get out of the receiver.***

If you don’t like using headphone, get a computer speaker set. These are relatively inexpensive and have a built in audio amplifier. Not all amplified speakers are RF proof through. 5w is not a lot of power, but I would suggest buying from a local store so that you can return them if they don’t work out.

## *Rig problems: Howling Receiver – The HSOD*

In building my prototypes, I have accidentally shorted out the 11v filtered supply provided by Q1, a 2N3904. When this happens, the supply voltage on IC4 goes low (check pin 8), much lower than 11v (like 5v or so). At that point, the IC4 will oscillate producing a “howl” in the receiver audio.

The receiver howling/dead TX is a classic symptom that Q1 is now toast. It is very easy to do and I have managed this twice now across my multiple prototypes. With no 11v, there is no RX and the receiver audio howls. I call it the Howling Squeal of Death (HSOD), kind of like the Microsoft Windows BSOD (Blue Screen of Death).

Q1 was designed as a separate transistor from the CA3086 package specifically so it can be easily replaced just in case this particular problem happens. A 2N2222, 2N4401, another 2N3904, or most any generic NPN transistor will work for Q1 as long as you keep the pin out the same.

Simply replace Q1 and you are good to go. It is a problem that seems much worse than it actually is and is relatively easy to fix.

## *Toroids – The most common problem*

The most common kit problem is the enamel wire on the toroid cores and getting them soldered in place properly. All toroids have a start and an end, and the simplest check to to place an ohm meter from the pad of the start to the pad of the end and make sure that the ohm meter shows a short between the two points. If there is no short, remove the toroid, re-tin the leads, and reinstall the toroid.