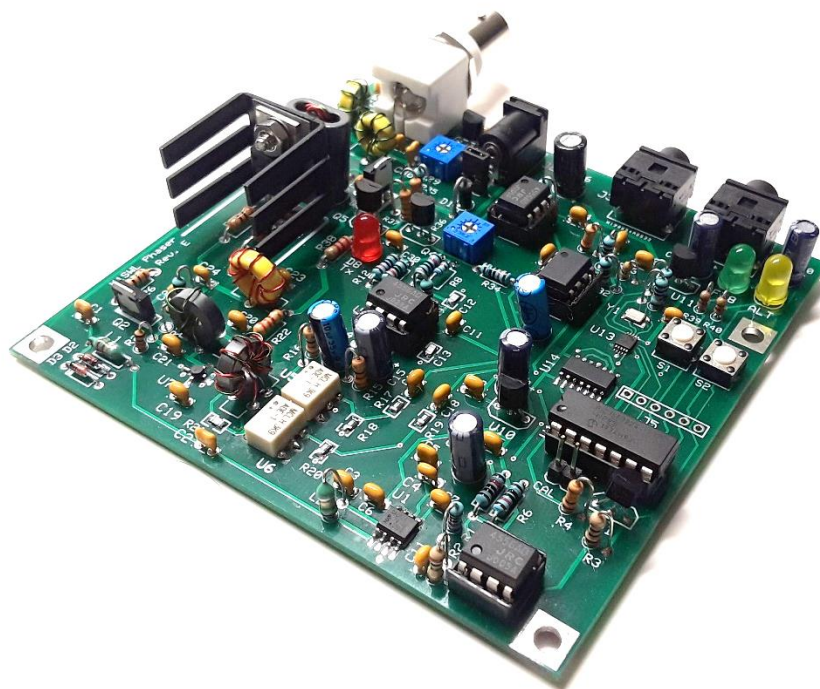


PHASER-15

Digital Mode Transceiver

*A single-board, 4-watt, Digital Mode SSB transceiver
for use on 15 or 10 meters*

by Dave Benson, K1SWL



INSTRUCTION MANUAL

(15M Version)

Revision E8

(December 2020)

Produced by Midnight Design Solutions

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Allows the Phaser instruction manual, when printed as a double-sided document, to show the Group Assembly Instructions on the left (the even page) with the corresponding Group Component Placement on the right (the odd page) ... like an open book. This avoids the need to flip pages when viewing corresponding pictorials.

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INTRODUCTION

The **Phaser Digital Transceiver™** is a single-board, 4-watt SSB radio specifically designed for using digital modes with computers running WSJT-X and FLDIGI applications. The **Phaser-15** is capable of transmitting and receiving on the 15M amateur band. This monoband transceiver is programmed to operate first at the popular FT8 frequencies, while a pushbutton entry shifts the operating frequency to an alternate frequency of the user's choice, initially provided at the JS8 'watering hole'. This ALT frequency may be easily reprogrammed to be anywhere in the HF spectrum, thus providing frequency flexibility to accommodate other digital modes such as PSK31, Feld Hell, Olivia, SSTV, etc. To ensure efficient use of spectrum in operation, the transmitter features an **adjustment-free phasing single-sideband (SSB) design**. The use of precision components provides unwanted sideband suppression in excess of 30 dB across its operating range, thus minimizing inadvertent QRM to other operators on the (unused) lower sideband. The use of SSB also eliminates the issue of out-of-phase signal cancellation at the Phaser's direct-conversion receiver. As such, it allows **Phaser** users to communicate with each other. This is a clear advantage over the use of 'entry-level' double-sideband (DSB) transceivers.

SPECIFICATIONS

Frequency coverage*:

Phaser-15 board: 21.074 MHz (FT8) and 21.078 MHz (JS8/Alt)

* FT8 frequency is hard-coded

* Alt frequency is soft-coded for JS8 mode, user reprogrammable

Transmit:

- 4 Watts maximum, 3.8 Watts typical
- Phasing SSB -- Upper sideband

Receive: MDS of -109 dBm

Frequency Calibration: 1-time

User Programmable 'Alt' frequency: 100 kHz to 30MHz, 100 Hz resolution

Adjustments: PA Bias, Tx Drive

DC Power: 12V nominal@ 130ma (Rx), 1A (Tx), center-positive 2.1mm coaxial plug. **15V max.**

Board Dimensions: 4.125" x 3.85" x 1.20"

Kits: Currently available for 15M and 10M. The 'Phaser' (no '-II') Kit is available for 160m, 80m, 60m 40m, 30m, 20m or 17m

Components:

- Virtually all through-hole parts for user assembly
- Employs 12 factory-installed surface mount parts,
- Two easy (*trust me!*) surface mount devices. They're 'huge'.

Enclosure Kits: Optionally available

PREPARATION FOR ASSEMBLY

Take a moment to carefully read this section, as it provides good “starting point” guidance that can be of great help in building the Phaser-15.

Tools & Supplies:

You’ll need the following tools and supplies for assembling the Phaser:

- [] Soldering iron – 20 to 40W, preferably thermostatically controlled
- [] Fine 60/40 (Pb/Sn) rosin core solder
- [] Diagonal cutters
- [] Needle-nose pliers
- [] Small flat- blade screwdriver
- [] Adhesive (Scotch®) tape
- [] Multimeter
- [] Clip leads (2)
- [] (Helpful) Close-up glasses or magnifier
- [] Operational Needs: Power supply, antenna, audio cables, computer and WSJT-X or FLDIGI apps

General Assembly Notes:

- **A number of components are polarity-sensitive.** This includes all semiconductor devices and diodes, and the five electrolytic capacitors. These are contained in antistatic envelopes.
- **Components these days are tiny!** In sunlight, one can read their printed values with +3.0 reading glasses. Most of the time, though, builders can benefit from using a 10-power eye loupe (costing about \$3-4 from DigiKey).
- **Assembly sequence:** These assembly instructions provide a step-by-step guide to successful construction of the Phaser-15. It is recommended that you follow the **six** grouped assembly sequences in order.
- **Schematic and Component Placement diagrams** are provided in Appendices 2 and 3, respectively. It is highly recommended to print a copy of this manual for reference during construction. As you build, you can check off each construction step as you complete them in order.
- **Further details** may be found in the grouped assembly sequences.

Parts Organization:

- Take some time to organize the parts provided and check them against the Parts List shown in Appendix 1. You may want to organize parts in a muffin tin or insert them into a sheet of Styrofoam® to keep them from disappearing... especially if you have a cat.
- To minimize the chance of static damage, keep ICs and semiconductors in the anti-static package until you’re ready to install them. As a practical matter, you don’t need an antistatic mat or ESD wrist strap. **Note:** You should try to avoid setting these components down on paper.
- The Phaser-15 parts kit has been thoughtfully prepared on a number of individually-bagged small cards containing all parts that will ultimately be attached to the printed circuit board. Now would be a good time to inventory the parts on these cards against the Parts List shown later in this manual in Appendix 1. If parts are missing in your kit, send an email to n2apb@midnightdesignsolutions.com and he will promptly provide shortages/replacements.

Phaser Parts:

Refer to the Parts List shown in Appendix 1 for inventorying all parts. *The illustrations below just show the kit organization and should not be used as a reference.*



As received, these two bags above contain the 9 cards shown below.
Stack 'em up in a small box, plastic drawer, etc to provide easy access to the parts when called for in the Instructions!

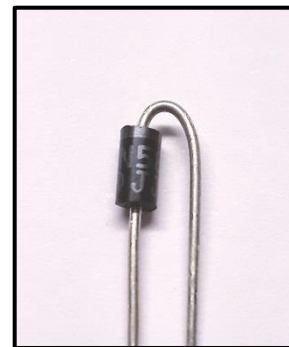
Phaser II Enameled Wire			Phaser II Semiconductors, 1 of 2			Phaser II Semiconductors, 2 of 2		
#28 AWG twisted-pair (red/grn), 8"	#26 AWG (red), 36"	#22 AWG (grn), 10"	D1	1N5818		Q5	2N3906	
			D2, D3	1N4148		Q6	NTD2955	
			D4	1N4756		U2, U3, U4	NJM4556	
			D5	Green LED		U5, U6	ADE-1 or ADE-1ASK	
			D6	Yellow LED		U8, U10	78L05	
			D7	Red LED		U11	78L33	
			Q1, Q4	2N4401		U9	LM393	
			Q2	2SC5706				
			Q3	RD06HVF1 FET				
REV. Midnight Design Solutions, N2APB E Design by K1SWL, Kitting by K3PEG			REV. Midnight Design Solutions, N2APB E Design by K1SWL, Kitting by K3PEG			REV. Midnight Design Solutions, N2APB E Design by K1SWL, Kitting by K3PEG		
Phaser II Resistors #1			Phaser II Resistors #2 & Inductors			Phaser II Connectors		
R37-A, R37-B	1.5 Ohm		R10, R29	10K Ohms pot. qty=2		Three 2-pin male headers	Snap from this 6-pin male header for CAL, PWR, TP1/TP2	
R26, R27	10 Ohms		R31	12K Ohms		DC Power Plug: J1	Two 2-pin female jumpers	
R15, R16	51 Ohms		R8	60.4K Ω 1%		3.5mm stereo jacks: J3, J4		
R3	100 Ohms		R2	1 Meg Ohms		DC Power Jack: J2		
R22	220 Ohms		Inductors	L3: FT37-43 (grey) 4 turns of #26 (red)		BNC RF Connector: J1		
R24, R25, R33, R36, R39, R40	1K Ω (1% tolerance)		L3 and T1	T1: FT37-43 (grey) 8 turns, bifilar, #28 (red/grn) twisted pair				
R38 (Taped down)	2.2K Ω		T2	BN43-202 Binocular core Pri: 2 T #27 (grn); Sec: 3 T #26 (red)				
R1, R4, R5 - R7, R9, R11 - R14, R23, R28, R30, R32, R34, R35, R41, R42	1K Ω (1% tolerance)							
REV. Midnight Design Solutions, N2APB E Design by K1SWL, Kitting by K3PEG			REV. Midnight Design Solutions, N2APB E Design by K1SWL, Kitting by K3PEG			REV. Midnight Design Solutions, N2APB E Design by K1SWL, Kitting by K3PEG		
Phaser II Miscellaneous			Phaser II Capacitors			Phaser II 15m band specific parts		
14-pin IC socket	Four 8-pin IC sockets		C5	10 pF		C1	15 pF	
S1, S2 push-btn switches	#4-40 screw, lock washer, and nut		C4, C10	33 pF		C2	27 pF	
Bumper, adhesive			C3, C6, C7, C14, C15, C18 - C24, C26, C27, C29, C34, C35, C38 - C42	0.1 μ F qty=22 (poly backed)		C33	39 pF	
			C8, C9, C11, C16 C17, C36, C43	10 μ F electrolytic		C25	120 pF	
			C37	22 μ F electrolytic		C30, C32	180 pF	
						C31	330 pF	
						L1, L2	2.2 μ H	
						U12: 16F1824		
						L5: T37-6 (yel) 11 turns of #26		
						L6: T37-6 (yel) 10 turns of #26		
REV. Midnight Design Solutions, N2APB E Design by K1SWL, Kitting by K3PEG			REV. Midnight Design Solutions, N2APB E Design by K1SWL, Kitting by K3PEG			REV. Midnight Design Solutions, N2APB E Design by K1SWL, Kitting by K3PEG		

GROUP 1 ASSEMBLY: Board Power

Refer to the diagram “Group 1 Component Placement” on the next page for reference to the location of components being installed here.

NOTE: The location of components installed in this assembly group are shown with either a **green dot** (for the ceramic capacitors) or a yellow dot (for all others).

- [] **IC Sockets:** Install the four (4) 8-pin IC sockets and the 14-pin IC socket. Tape each of these sockets down on the top side of the board to hold them in place before soldering. Observe the orientation as shown on the silkscreen (i.e., the printing on the board). Ensure that all socket leads protrude through the board before soldering. It's helpful to solder a pair of opposite corner-pins and check to make sure the sockets are solidly seated on top of the board. Retouch as needed.
- [] **2-pin header:** Using diagonal cutters, snap a section of 2 segments off the supplied 6-pin header strip. Install this 2-pin strip at the location in front of J2.
- [] **2-pin jumper:** Place a 2-pin jumper on the header just installed.
- [] **Remaining header pins:** Snap and install remaining header pins at ‘CAL’ (2 pins) and ‘TP1 TP2’ (2 pins). Install a short piece of clipped resistor lead at TP3. Have it stick up about 3/8” above the board for use in a later measurement.
- [] **J2:** Install DC power connector J2. It may be helpful to tape it down before turning the board over to solder.
- [] **D1:** To install diode D1 vertically, bend the lead on the BANDED end of the 1N5818 (or SB130) so the component forms a ‘hairpin’ shape. Install the component with the body of the component oriented as shown in the photo. The diode’s body is closest to the male header and jumper installed in the previous step.
- [] **0.1 uF ceramic capacitors:** Install 22 0.1 uF capacitors (marked as ‘104’) at the locations shown on the next page. These locations are shown in **green**. They are:
C3, C6, C7, C14, C15, C18, C19, C20, C21, C22, C23, C24, C26, C27, C29, C34, C35, C38, C39, C40, C41 and C42.
- [] **U8, U10:** Install the 78L05 3-pin ICs (U8 and U10), matching their orientation to that of the silkscreen outline. The ‘flat’ side faces the rear of the board.
- [] **U11:** Install the 3-pin 78L33 (or KY5033) regulator at U11, again matching its orientation to that of the silkscreen outline.
- [] **C9, C43:** Install the 10 uF electrolytic caps at C9 and C43. These and all other electrolytic capacitors are polarity-sensitive. In each case, the longer lead must be installed nearest the ‘+’ sign on the silkscreen legend. Double-check to ensure that the negative side of the capacitor (marked with a -) is facing away from the ‘+’ sign on the silkscreen.
- [] **C37:** Install the 220 uF electrolytic cap at C37, again observing polarity.



TEST #1: Basic Power

- Apply 12V power through jack J2. (The center pin is positive.)
- With your multimeter ground clip attached to any of the board mounting holes, measure for 5V at pin 8 of the U2 pin socket.
- Then measure for 3.3V at pin 1 of the U12 IC socket.
- Do not proceed until you see these voltages, as the rest of the components depend on these voltages for proper operation.
- Remove power before proceeding to the next assembly group.



GROUP 2 ASSEMBLY: T-R Switching

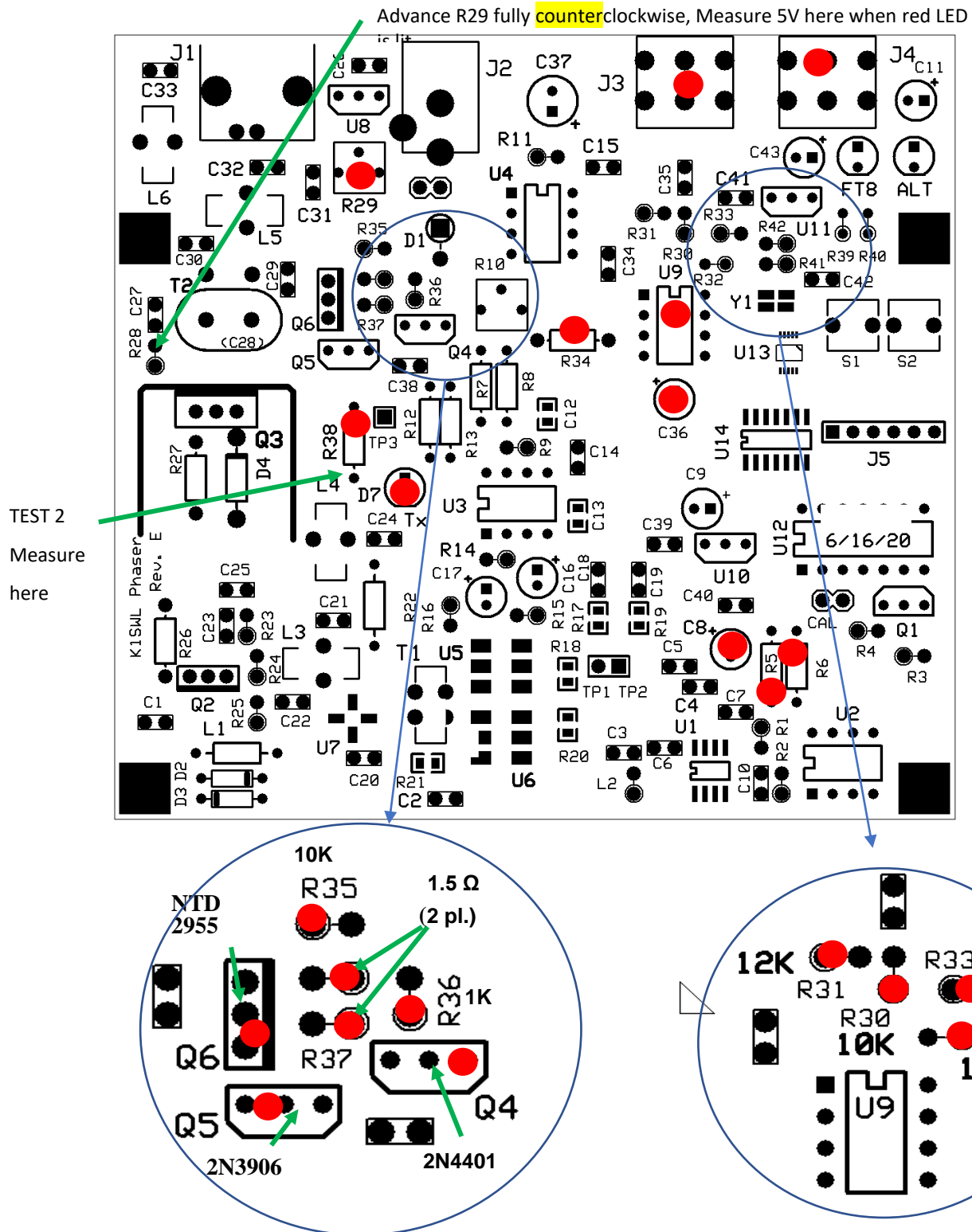
This assembly group installs the T-R switching logic. Component locations are indicated with **red** dots in the diagram on the next page.

- [] **J3, J4:** Install 3.5mm audio connectors at J3 and J4.
- [] **R5, R6, R30, R32, R34 and R35:** Install 10K resistors (brn-blk-blk-red-brown) resistors at R5, R6, R30, R32, R34 and R35.
- [] **C8, C36:** Install two 10 uF electrolytic caps, at C8 and C36. This and all other electrolytic capacitors are polarity-sensitive. In each case, the longer lead must be installed nearest the '+' sign on the silkscreen legend. Again, double-check the polarity before soldering.
- [] **R31:** Install the 12K (brown-red-orange-gold) resistor at R31.
- [] **R33, R36:** Install 1K (brown-blk-red-gold) resistors at R33 and R36.
- [] **R37A, R37B.** Install the two 1.5 ohm resistors (brown-green-gold-gold at R37A and R37B.
- [] **R29 (10K pot):** Install a 10K ohm trim pot (blue) at R29. *[NOTE: Some kits may be supplied with a slightly larger trim pot which will require bending the leads to fit into the pads on the pc board. See Appendix 9 for guidance.]*
- [] **Transistor Q4:** Install a 2N4401 3-pin device at Q4. Observe orientation of the device's flat edge. Take care not to overheat solid-state devices.
- [] **Transistor Q5:** Install the 2N3906 3-pin device at Q5. Observe orientation of the device's flat edge.
- [] **Transistor Q6:** Install the NTD2955 3-pin device at Q6. Observe orientation of the device's metal tab as shown in the illustration. *The metal tab faces to the right.*
- [] **R38:** Install a 2.2K (red-red-red-gold) resistor at R38.
- [] **D7:** Install the red LED at D7. The flat edge of the device faces the 'D7' silkscreen legend. (This corresponds to the shorter of D7's two wire leads.) *Install D7 high above the board if you're using it later for the enclosure kit.*
- [] **Integrated Circuit U9:** Insert the LM393 8-pin IC in the socket at U9. Observe orientation of pin 1, as marked with a small dot or cutout at the pin 1 edge of the device.

TEST #2: T-R Switching

- Upon completion of this group, you can connect the 12V power source again to J2 and a cable from your computer audio output at J3.
- Launch the WSJT-X software on your computer. (See "Quick Start" in Appendix 4.)
- Click on the 'TUNE' button in the WSJT-X app and verify that the 'Tx' LED turns on.
- **Turn R29 fully left (CCW)** and verify the presence of 5V on the top pad of R28.
Once this is verified, return R29 to the fully right (CW) position again!
- Click on the 'TUNE' button again and verify that the LED turns off.
- Do not proceed until you see these voltages, as the rest of the components depend on these voltages for proper operation. **NOTE:** If this test fails, make sure that sufficient sound-card audio is being supplied to J3. The minimum signal level for switching this voltage is roughly 150 mV at J3 on a multimeter's **AC voltage** scale.
- Remove power before proceeding to the next assembly group.

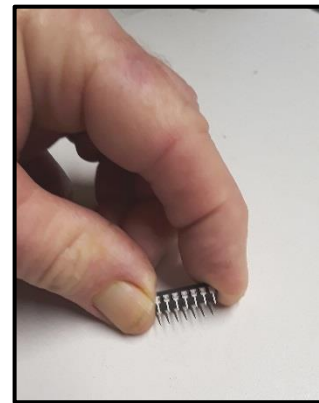
Group 2 Component Placement



GROUP 3 ASSEMBLY: Local Oscillator

This assembly group installs the local oscillator function. Component locations are indicated with **red** dots in the diagram on the next page.

- [] **Green LED:** Install the Green LED (D5) at the board location labeled 'FT8'. Ensure that the longer lead (the anode) is installed toward the rear (top) of the board. The shorter lead (the cathode) is identifiable by its proximity to the 'flat' on the otherwise-round base of the diode body. *(It may be difficult to see this flat.)*
- [] **Yellow LED:** Install the Yellow LED (D6) at the board location labeled 'ALT'. (Same caution about orientation.)
- [] **R39, R40(1K):** Install two 1K ohm resistors (brn-blk-red-gold) at R39 and R40.
- [] **R41, R42(10K):** Install two 10K resistors (brn-blk-blk-red-brown) at R41 and R42.
- [] **S1, S2:** Install tactile switches S1 and S2.
- [] **Integrated Circuit U12:** Install 14-pin IC U12 (PIC16F1824). This device is polarity-sensitive. The dot and/or notch at one end of the device must face to the left as you are viewing the 'U12' designator. You may need to bend the IC pins gently inward to mate with the socket. The best approach is to push the IC down on each side separately using a hard surface to bend one 7-pin row at a time. Once you've installed the IC, ensure that all leads are seated in the socket.



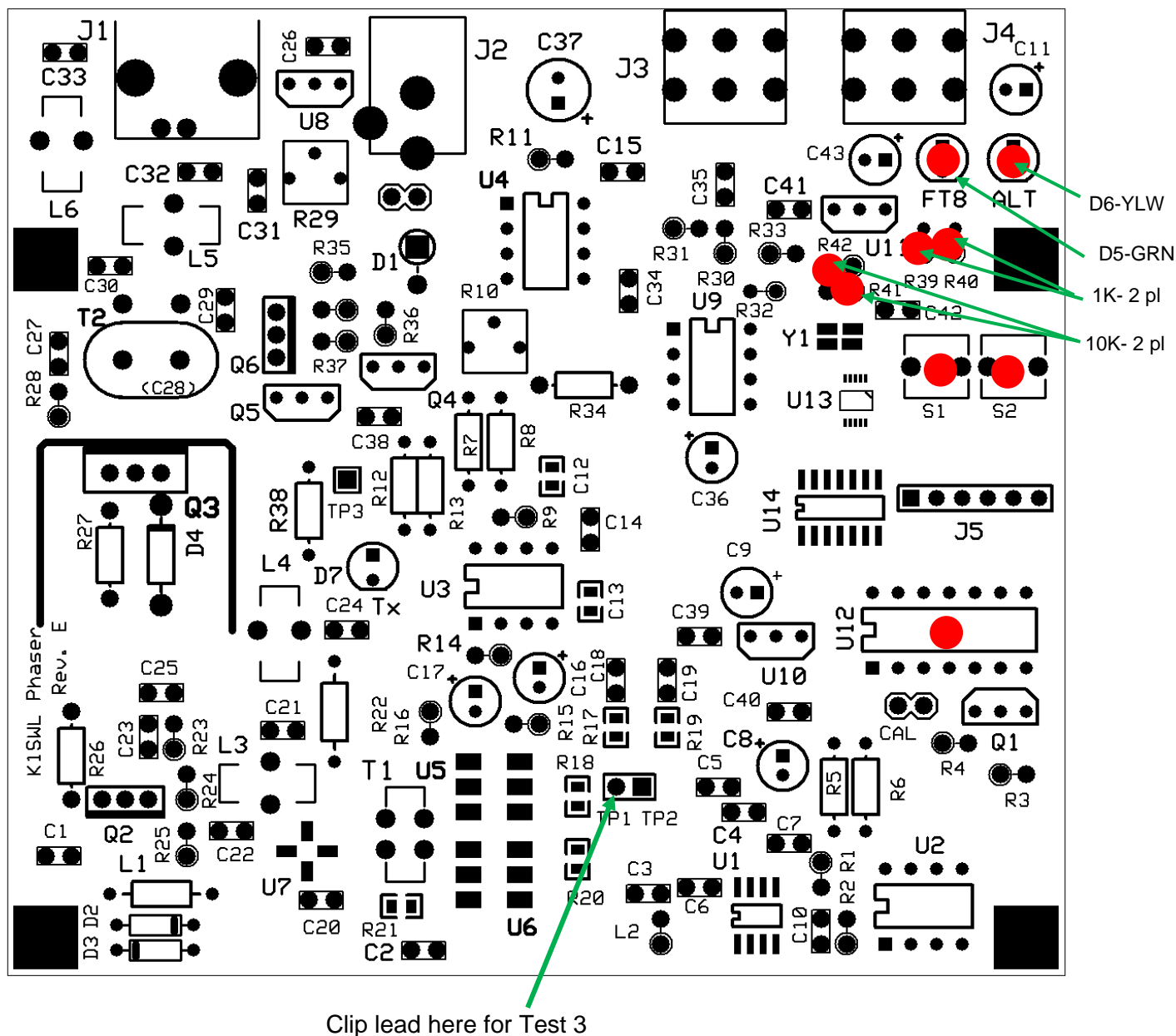
TEST #3

Connect a 12V power source to J2 and verify that the green 'FT8' LED illuminates. Connect a clip lead to TP1 or TP2 - **but not both**. Leave the other end of the clip lead free. You should be able to hear a steady carrier on your 'big rig' at 21074.0 kHz. Note: The frequency may be off by as much as 1 kHz. Refer to the 'Adjustment/Calibration' section of these Instructions for calibration.

If the green LED does not light, check for: (1) R41 and R42 soldered in properly; (2) U10 inserted and oriented properly; and (3) green and yellow LEDs oriented with flat side toward the 'FT8' and 'ALT' silkscreen legends. If green LED still not illuminating contact us for further assistance. Do not proceed further with assembly until this is resolved.

Remove 12V power from J2.

Group 3 Component Placement



GROUP 4 ASSEMBLY: Receiver

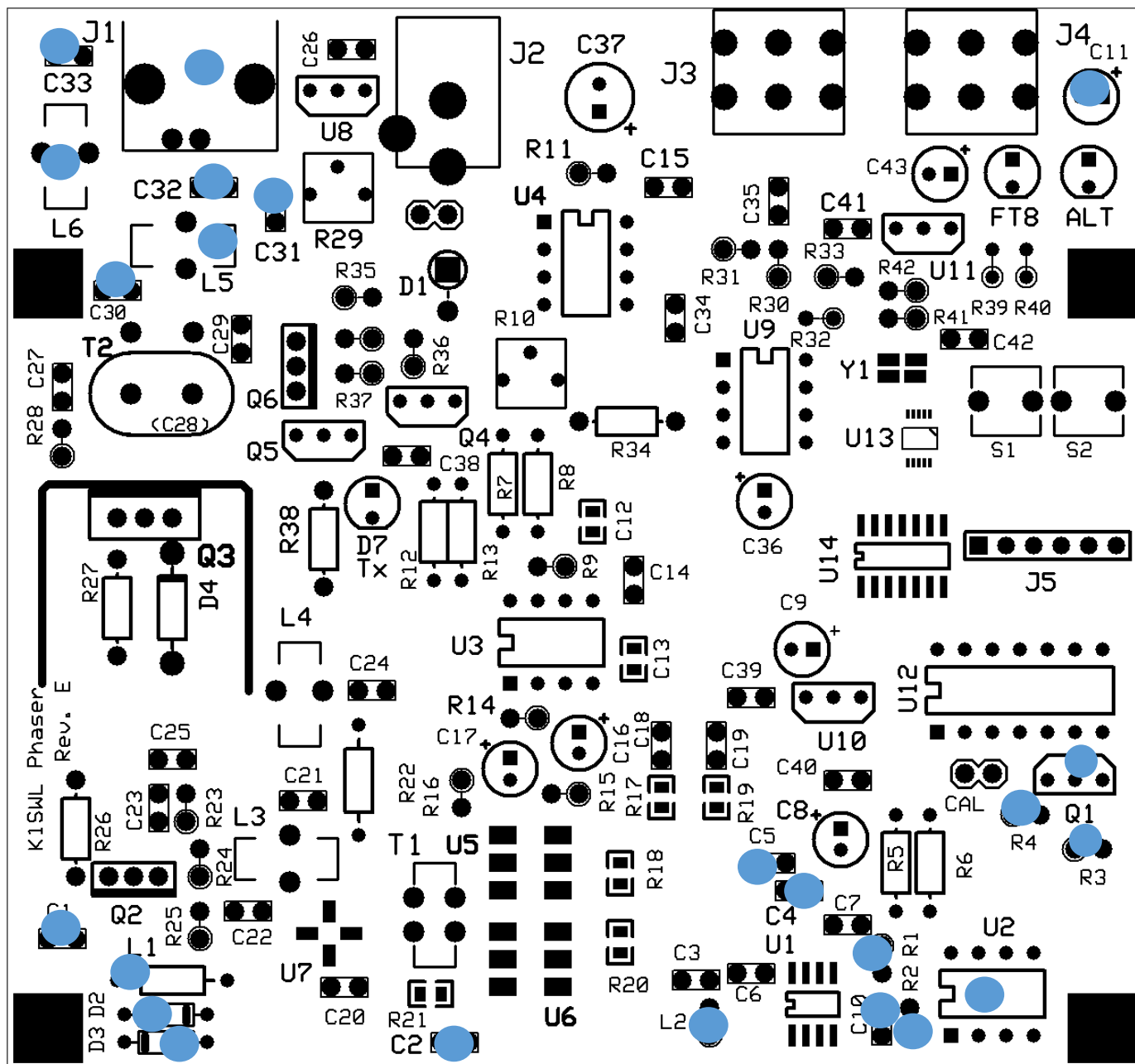
This assembly group installs the Phaser's receiver components. *See next page for component placement, as indicated by blue dots.*

- [] **C1 (15 pF):** Install a 15 pF (marked as '150' or '15J') capacitor at C1.
- [] **D2, D3 (1N4148):** Install 1N4148 diodes (small, glass bodies) at D2 and D3. Match their orientations as shown on the silkscreen.
- [] **C2 (27 pF):** Install a 27 pF (marked as '270' or '27J') capacitor at C2.
- [] **C5(10 pF):** Install a 10 pF (marked as '100' or '10J') capacitor at C5.
- [] **C4,C10 (33 pF):** Install a 33 pF (marked as '330' or '33J') capacitors at C4 and C10.
- [] **L1, L2 (2.2 uH):** Install 2.2 uH RF Chokes (red-red-gold-gold/silver) at L1 and L2. The RF chokes are slight larger in diameter than the ¼W resistors and are more tapered at the ends of the body. **Caution:** Avoid sharp bends in the leads right where they leave the body, as this may damage the component.
- [] **R1, R4 (10K resistor):** Install 10K (brn-blk-blk-red-brown) resistors at R1 and R4.
- [] **R2 (1M resistor):** Install a 1M (brn-black-grn-gold) resistor at R2.
- [] **R3 (100-ohm):** Install a 100-ohm (brn-black-brn-gold) resistor at R3.
- [] **C11 (10 uF):** Install a 10uF electrolytic capacitor at C11.
- [] **Q1 (2N4401):** Install a 2N4401 transistor at Q1, matching its outline to that of the silkscreen.
- [] **C31 (330 pF):** Install the 330 pF ('331') capacitor at C31.
- [] **C30, C32 (180 pF):** Install the 180 pF ('181') capacitors at C30 and C32.
- [] **C33 (39 pF):** Install the 39 pF ('39J') capacitor at C33.
- [] **U2 (NJM4556):** Install an NJM4556 8-pin IC at U2. The notch or dot on the case must face to the left.
- [] **L5 (T37-6 Toroid):** Cut an 10" length of #26 red magnet wire and wind **11 turns** on a T37-6 (yellow) toroid. Prepare the leads and install at L5. **See Appendix 8 for guidelines on winding toroids.**
- [] **L6 (T37-6 Toroid):** Cut an 9" length of #26 red magnet wire and wind **10 turns** on a T37-6 (yellow) toroid. Prepare the leads and install at L6. **See Appendix 8 for guidelines on winding toroids.**
- [] **BNC (J1):** Install the BNC connector at J1. Solder all connections. The two 'press-fit' leads are not used electrically but they provide mechanical stability

Test 4: Receiving FT8 Signals

When this assembly group is complete, the Phaser-15 receiver should be operational. Refer to the Quick-Start section of these instructions for hookup and operating guidance.

Group 4 Component Placement



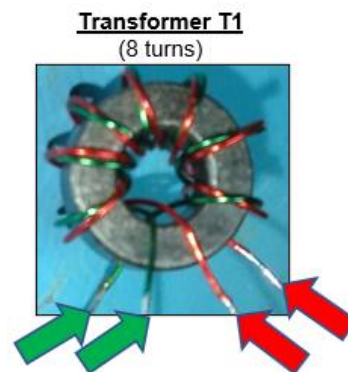
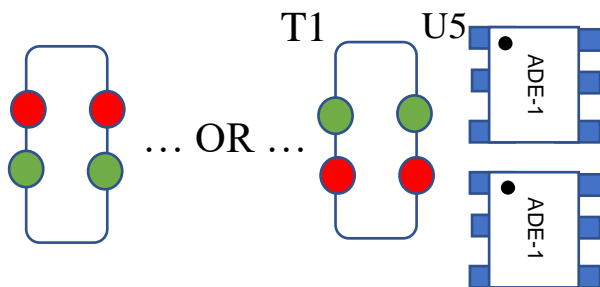
GROUP 5 ASSEMBLY: SSB Phasing

This assembly group installs the SSB phasing components. See next page for component placement, with **red** (10K ohm) and **orange** dots indicating component locations.

- [] **R8 (60.4K):** Install the 60.4K 1%-tolerance (blue-black-yellow-red-gold) resistor at R8.
- [] **R7, R9, R11, R12, R13, R14 (10K):** Install 10K (brn-blk-blk-red-brn) resistors. These are highlighted in **red** on the next page.
- [] **R10 (Trimmer):** Install the 10K trim pot (blue, 3 leads) at R10. *[NOTE: Some kits may be supplied with a slightly larger trim pot which will require bending the leads to fit into the pads on the pc board. See Appendix 9 for guidance.]*
- [] **U3, U4 (NJM4556):** Install NJM4556 8-pin ICs at U3 and U4. The notch or dot on the case must face as shown in the component placement diagram (next page).
- [] **R15, R16 (51 ohm 5%):** Install 51 ohm 5% resistors (green-brown-blk-gold) at R15 and R16.
- [] **C16, C17 (10 uF):** Install the two remaining 10 uF capacitors at C16 and C17.
- [] **R22 (220 ohms)** Install the 220 ohm 5% resistor (red-red-brn-gold) at R22.
- [] **U5, U6 (ADE-1)** Install the two 6-lead ICs at U5 and U6. Proceed as follows: Add a little solder to one of the corner pads for U5. While holding the ADE-1 with the pin 1 'dot' oriented as shown below, tack that corner down. Retouch as needed until the ADE-1 is straight and centered on the PCB pads. Solder the remaining IC leads to the PCB pads. Repeat for the second ADE-1 device (U6).
- [] **T1 (Toroid FT37-43):** Wind 8 turns of the #28 red/green twisted-pair wire on the FT37-43 toroid form (gray, 0.37"-dia). Take extra care to avoid scrambled turns. Prepare the leads as described next. Refer to Appendix 8 "Winding Toroids."

Two leads of a given color must be arranged to one side of the finished toroid. The two remaining leads must be grouped to the other side of the toroid. This is illustrated in the photo to the right.

Now, install the toroid at T1 in either orientation as shown below.

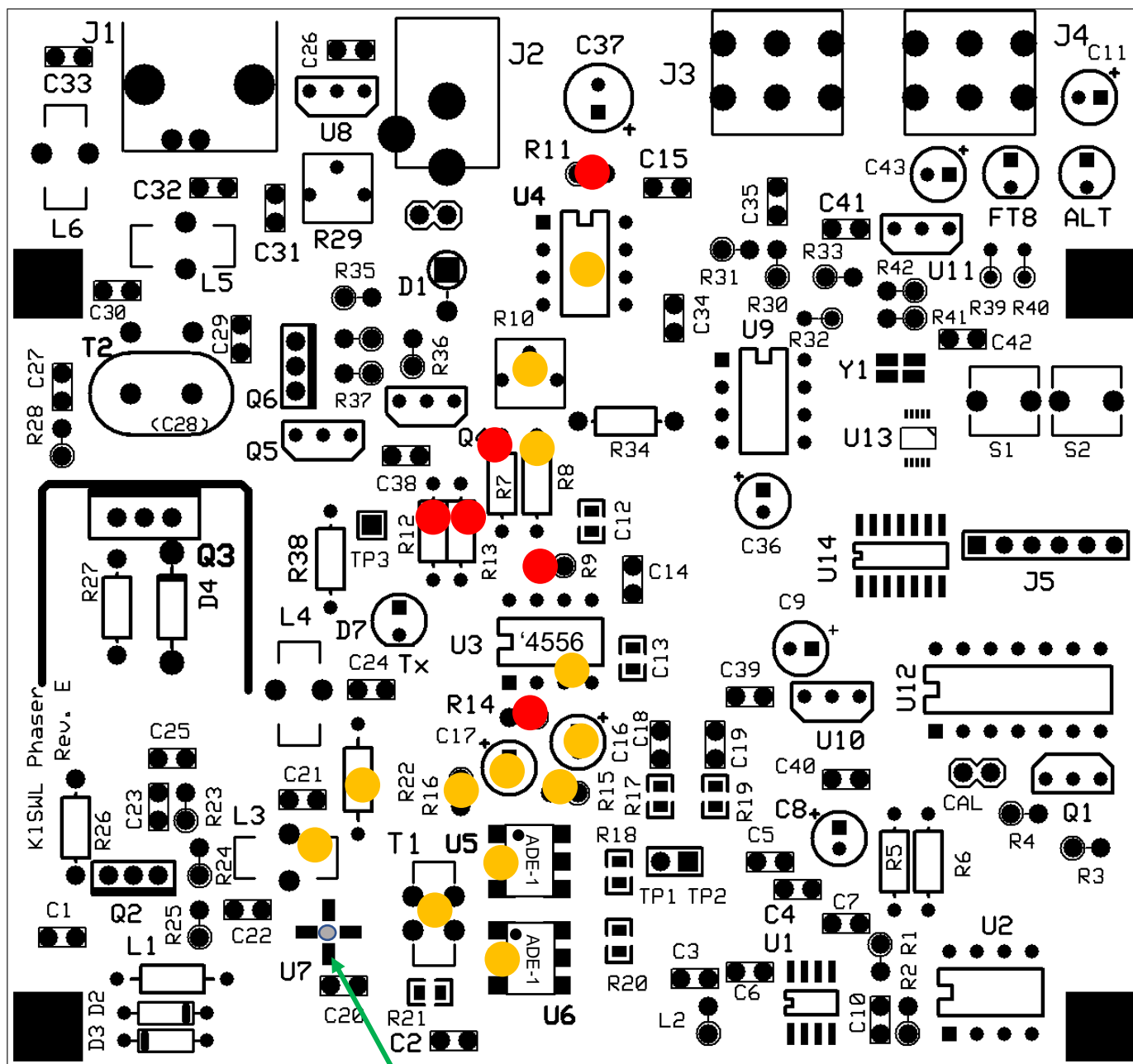


- [] **L3 (FT37-43 Toroid)** Using 4" of #26 red magnet wire, wind four (4) turns on the remaining FT37-43 toroid. Prepare the leads as before and install.

Test 5: Listening for the transmitter signal

Apply 12V power via J2 and audio via J3. Command WSJT-X to "TUNE". (See 'Quick-Start'.) Probe the U7 lead shown on the next page - this serves as an impromptu 'antenna'. As you tune across the operating frequency with your 'big rig', you'll note that one sideband is much stronger than the other. The unwanted lower sideband should be 30-35 dB weaker. (This test is pretty subjective, and receiver overload may complicate things. You're looking for a difference in the upper and lower sideband levels.)

Group 5 Component Placement



Test 5: Probe here

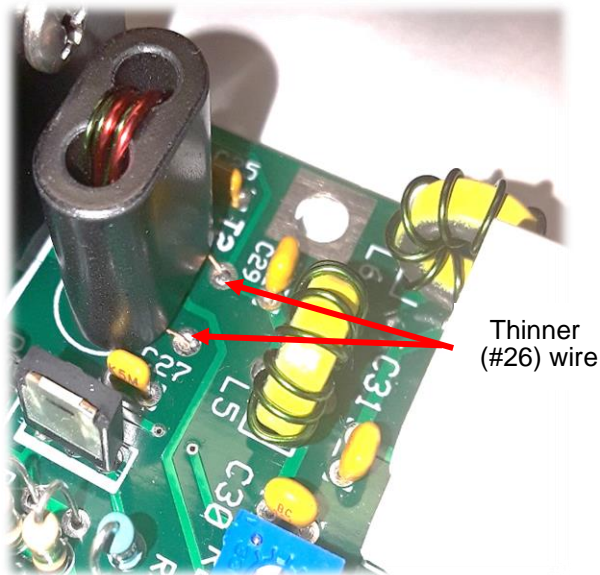
GROUP 6 ASSEMBLY: Transmitter Strip

This assembly group installs the Transmitter strip, whereby the mixer output is amplified and sent to the antenna jack.

- [] **R23, R28 (10K ohm)** Install the two remaining 10K (brn-blk-blk-red-brn) resistors at R23 and R28.
 - [] **R24, R25 (1K):** Install the remaining (2) 1K resistors (brown-blk-red-gold) at R24 and R25.
 - [] **R26, R27 (10-ohm):** Install the (2) 10-ohm resistors (brown-blk-blk-gold) at R26 and R27
 - [] **C25 (120 pF):** Install the 120 pF capacitor ('121') at C25.
 - [] **L4 (T37-6 Toroid):** Using 12" of #26 red magnet wire, wind 12 turns on the T37-6 (yellow) toroid. Prepare the leads as before and install at L4.
 - [] **D4 (1N4756):** Install the 1N4756 diode (glass, larger body) at D4. Match the banded end to that shown on the silkscreen.
 - [] **Q2 (2SC5706):** Install the 2SC5706 transistor at Q2. Make sure the tab on the device matches the orientation shown on the silkscreen
 - [] **T2 (Binocular core BN43-202):** Using the 8" length of #22 magnet wire, wind two (2) turns on the core. **See Appendix 8 for details.** Bend one of the two wire leads at a 90-degree angle. Draw the turns tight as you go.
 - [] Using 10" of #26 magnet wire, wind 3 turns on the same binocular core. Start the wire into the same hole that the bent lead uses and proceed from there. When complete, trim all four wires to ½" length and prepare the leads for installation.
- The two heavier wires install within the silkscreen outline for T2. The two lighter-gauge wires install toward the rear-facing L5 as illustrated below left.

[] Q3 Assembly (RD06HVF1):

- [] Insert the supplied 4-40 screw into the heat sink as shown below.
- [] Place the thermal pad down over the screw.
- [] Set the Q3 device on the screw.
Caution: Static Sensitive Device
- [] Add the #4 lockwasher, 4-40 nut and tighten firmly.

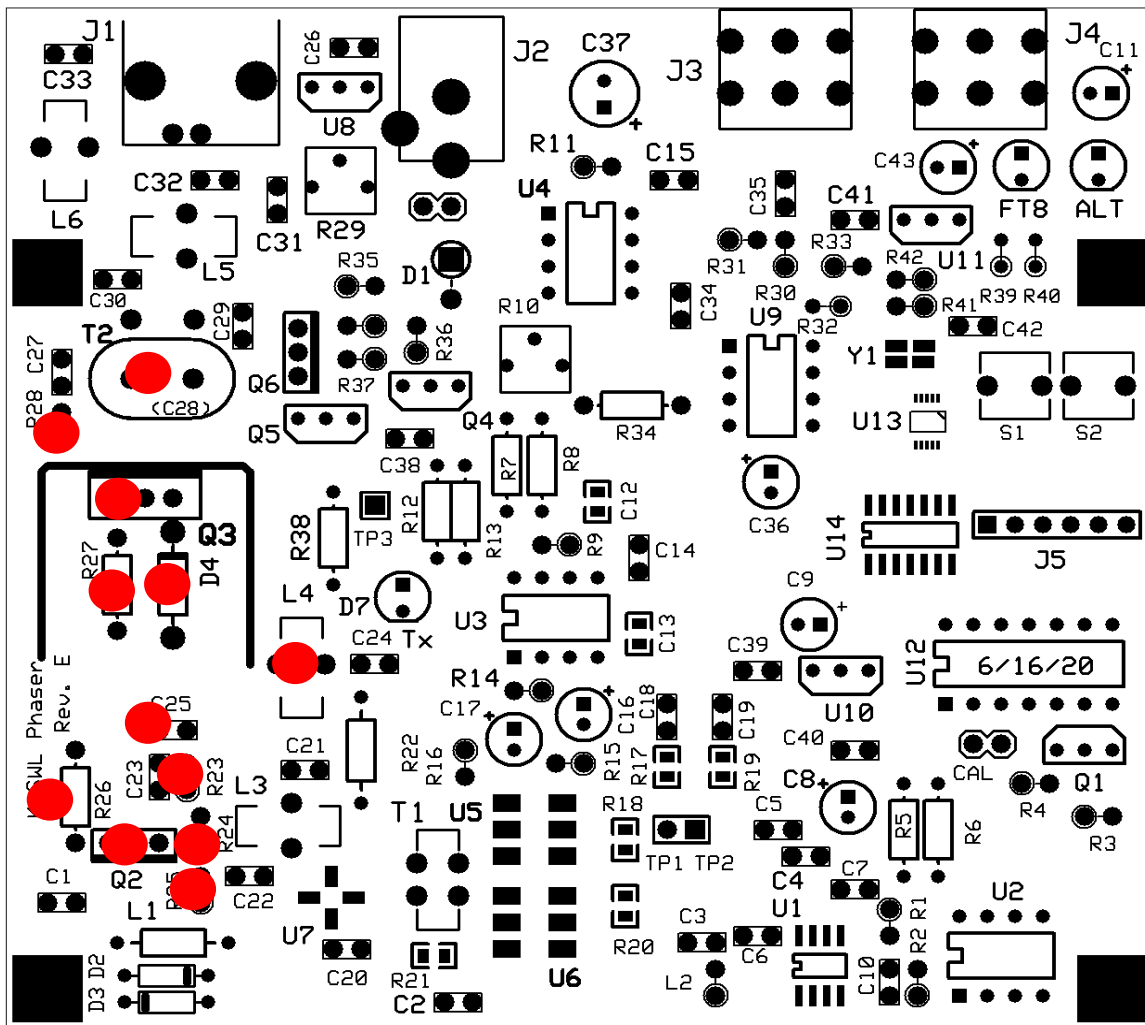


- [] Install the Q3 assembly.
- [] Turn R10 and R29 fully clockwise.

This completes the assembly of the Phaser-15 board kit!

We recommend cleaning the flux residue from the underside of the circuit board. You may use cotton swabs dipped in acetone (a hardware store item). It does a great job removing the flux. *Do not use nail polish remover for this job as it may contain oil or other ingredients.*

Group 6 Component Placement



APPENDIX 1: Parts List (for the Phaser-15)

Quantity	Ref. Designator	Description	Notes & Markings
----------	-----------------	-------------	------------------

Capacitors:

1	C5	10 pF	'100' or '10J'
2	C4, C10	33 pF	'33' or '33J'
22	C3, C6, C7, C14, C15, C18, C19, C20, C21, C22, C23, C24, C26, C27, C29, C34, C35, C38, C39, C40, C41, C42	0.1 uF	'104'
7	C8, C9, C11, C16, C17, C36, C43	10 uF	Polarized
1	C37	220 uF	Polarized

Resistors are $\pm 5\%$ tolerance $\frac{1}{4}$ watt unless otherwise noted:

2	R37-A, R37-B	1.5 ohm	Brown-grn-gold-gold
2	R26, R27	10 ohm	Brown-black-black-gold
2	R15, R16	51 ohm	Green-brown-black-gold
1	R3	100 ohm	Brown-black-brown-gold
1	R22	220 ohm	Red-red-brn-gold
6	R24, R25, R33, R36, R39, R40	1K ohm	Small- on cut tape Brown-black-red-gold
1	R38	2.2K ohm	Red-red-red-gold
18	R1, R4, R5, R6, R7, R9, R11, R12, R13, R14, R23, R28, R30, R32, R34, R35, R41, R42	10K 1%	Brown-blk-blk-red-brown)
2	R10, R29	10K	Potentiometer, Blue, 3 leads
1	R31	12K	Brown-red-orange-gold
1	R8	60.4K 1%	Small Blu-blk-ylw-red-brown
1	R2	1M ohm	Brown-black-grn-gold

Connectors:

2	CAL, Power	2-pin male header, 0.1"	
2	CAL, Power	2-pin female jumper	
1	P1	Power plug, 2.1mm x 2.5mm	
1	J1	BNC jack, right-angle mount	
1	J2	DC power jack	
2	J3, J4	Audio jacks, 3.5mm 3-cond.	

1	L3	FT37-43 toroid, 4 turns #26 magnet wire	Dark grey
1	T1	FT37-43 toroid, 8 turns bifilar, red/green #28 twisted pair <i>See Group 5 for details.</i>	Dark grey
1	T2	BN43-202 Binocular core (Flat, 2 holes) <i>See Group 6 for details.</i>	Primary: 2 turns #22 magnet wire Secondary: 3 turns #26 magnet wire.

Semiconductors:

1	D1	1N5818 or SB130	Black body
2	D2, D3	1N4148	Glass body, small
1	D4	1N4756	Glass body
1	D5	Green LED	
1	D6	Yellow LED	
1	D7	Red LED	
2	Q1, Q4	2N4401	TO-92, 3 leads
1	Q2	2SC5706	3 leads, small, w/ tab
1	Q3	RD06HVF1	3 leads, large
1	Q5	2N3906	TO-92, 3 leads
1	Q6	NTD2955	TO-92, 3 leads, small , metal tab
3	U2, U3, U4	NJM4556	8-pin DIP IC
2	U5, U6	ADE-1 or ADE-1ASK	6-lead flat-pack
2	U8, U10	78L05	TO-92, 3 leads
1	U11	78L33 or KY5033	TO-92, 3 leads
1	U9	LM393	8-pin DIP IC
1	U12	16F1824	14-pin DIP IC

Miscellaneous:

1	--	14-pin IC socket	
4	--	8-pin IC socket	
2	S1, S2	tactile pushbutton switch	
1	--	Thermal pad	19.1MMX12.7MM GRAY
1	--	Heat sink	HS104-1
1	--	#4-40 x 3/8" screw	
1	--	#4-40 tooth lockwasher	
1	--	#4-40 hex nut	
1	--	Header strip, 6-pin	

INSTRUCTION MANUAL (for 15m)

1	--	#28 red/green twisted pair	8", pre-twisted
1	--	#26 magnet wire	36" length
1	--	#22 magnet wire	8" length
4	--	bumper, adhesive	clear plastic, place in corners of pcb

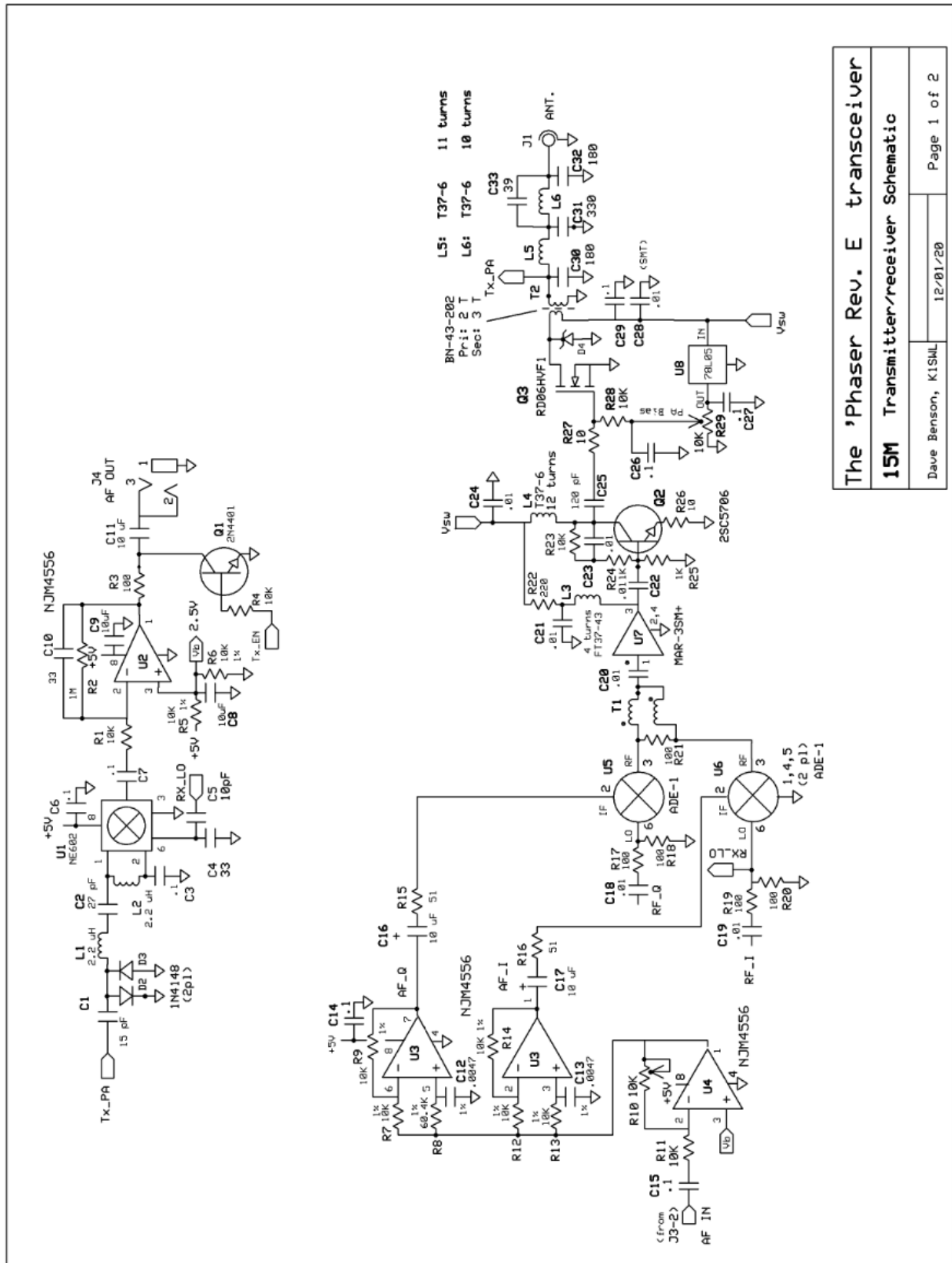
PCB (with pre-installed parts):

1	--	PCB	4" x 4" (approx)
2	C12, C13	4700 pF 1%	(pre-installed)
5	R17, R18, R19, R20, R21	100 ohm 0805 SMT	(pre-installed)
1	U7	MAR-3SM+	(pre-installed)
1	U13	Si5351	(pre-installed)
1	U14	74ACT74	(pre-installed)
1	Y1	25.000 MHz	(pre-installed)
1	U1	SA612AD	(pre-installed)

15 meter-specific parts

1	C1	15 pF	'150' or '15J'
1	C2	27 pF	'270' or '27J'
1	C33	39 pF	'390' or '39J'
1	C25	120 pF	'121'
2	C30, C32	180 pF	'181'
1	C31	330 pF	'331'
2	L1, L2	2.2 uH RF choke	Red-red-gold-gold/silver
1	L4	T37-6 toroid, 12 turns #26 wire	(yellow)
1	L5	T37-6 toroid, 11 turns #26 wire	(yellow). See group 4 instructions
1	L6	T37-6 toroid. 10 turns #26 wire.	(yellow. See group 4 instructions

APPENDIX 2a: Phaser-15 Schematic: (1 of 2)



The 'Phaser Rev. E transceiver

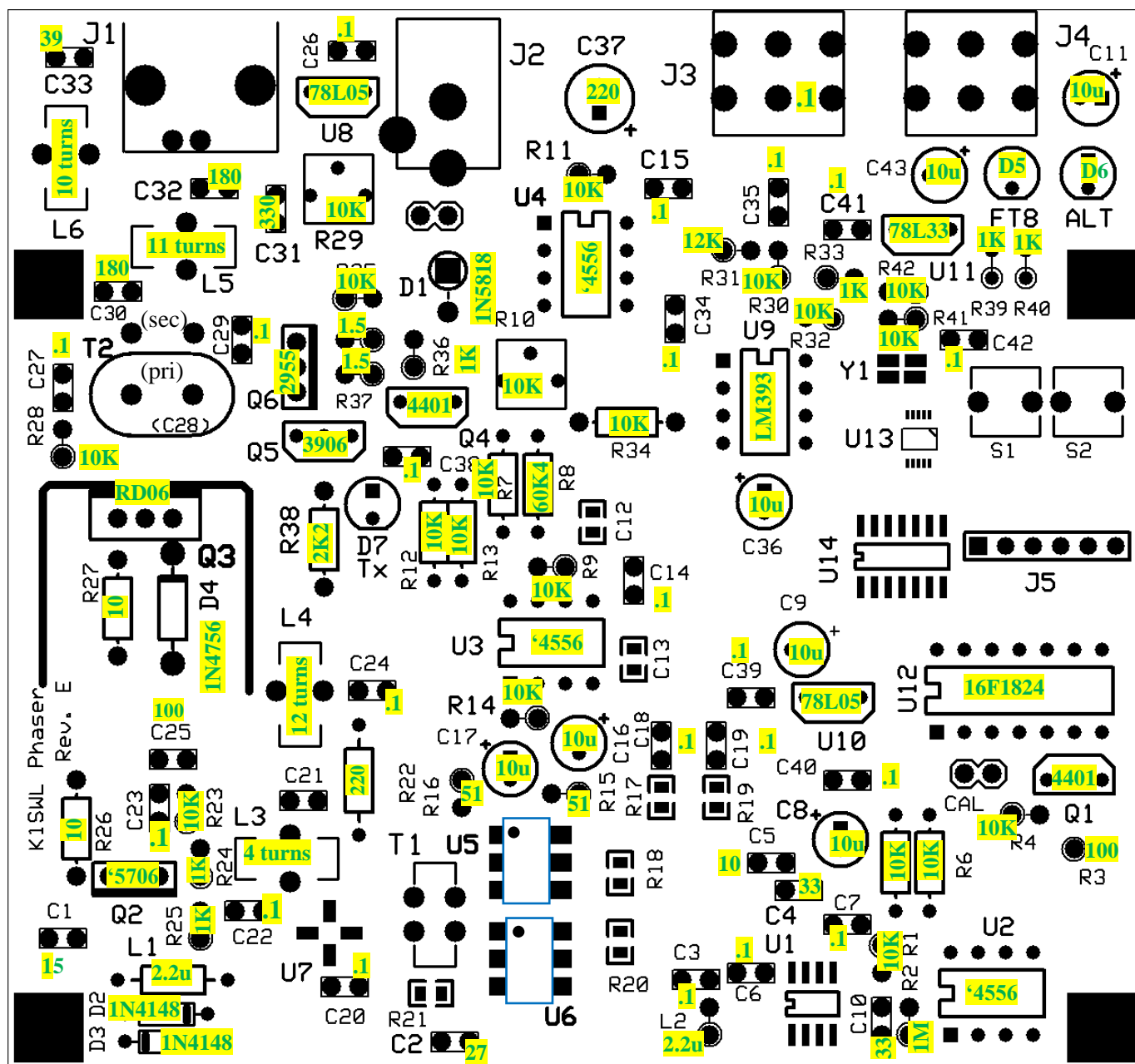
15M Transmitter/receiver Schematic

Page 1 of 2

12/01/20

Dave Benson, K1SWL





APPENDIX 4: ‘Quick-Start’ Operation Guide

FT8 operation is based on a computer software application called WSJT-X. This application is available in Windows, Mac and Linux versions. Here’s a link to the definitive Guide to get you started:

<http://www.physics.princeton.edu/pulsar/K1JT/wsjsx-doc/wsjsx-main-2.0.0.html>

Getting on the air with WSJT-X isn’t difficult. The process follows this sequence:

- Download and Install WSJT-X
- Enter your Call sign and Grid Square into a setup dialog box
- Select from several operating options

These steps are well documented in the online ‘Helps’ available from the URL above, and especially in the “FT8 Hinson Tips” guide at https://g4ifb.com/FT8_Hinson_tips_for_HF_DXers.pdf

FT8 relies on fairly accurate timekeeping. Transmissions follow a 15-second pattern, starting at the beginning of the 15-second interval. Transmissions last for 13 seconds. Following a transmission, users are receiving for the next 15-second frame. During the receiving period, your computer is gathering all signals within the receiver passband for 13 seconds. In the remaining 2 seconds, your computer is analyzing the received content and displays decoded text on the left side of the WSJT-X display screen.

To be successful with FT8, you need to ensure that your computer timekeeping is accurate. The Windows timekeeping (for instance) is probably not adequate. The WSJT-X guide recommends an application, and we use ‘Dimension4’ software. It’s free.

<http://www.thinkman.com/dimension4/download.htm>

The software lists a multitude of timekeeping providers. Chose a publicly-available one near you. You’ll also need to choose how often the program syncs your computer. Every 20-30 minutes should be fine.

The need for accurate timekeeping often confounds newcomers to this mode. If you’re seeing good signals and clear FT8 traces.... but no decodes – make sure your timekeeping application is running. *Tip: There’s an option to make the time-syncing a startup task, so it’s always running in the background.*

System Set-up with the Phaser-40 SSB FT8 Transceiver:

Connect to the Phaser as shown in the diagram below.

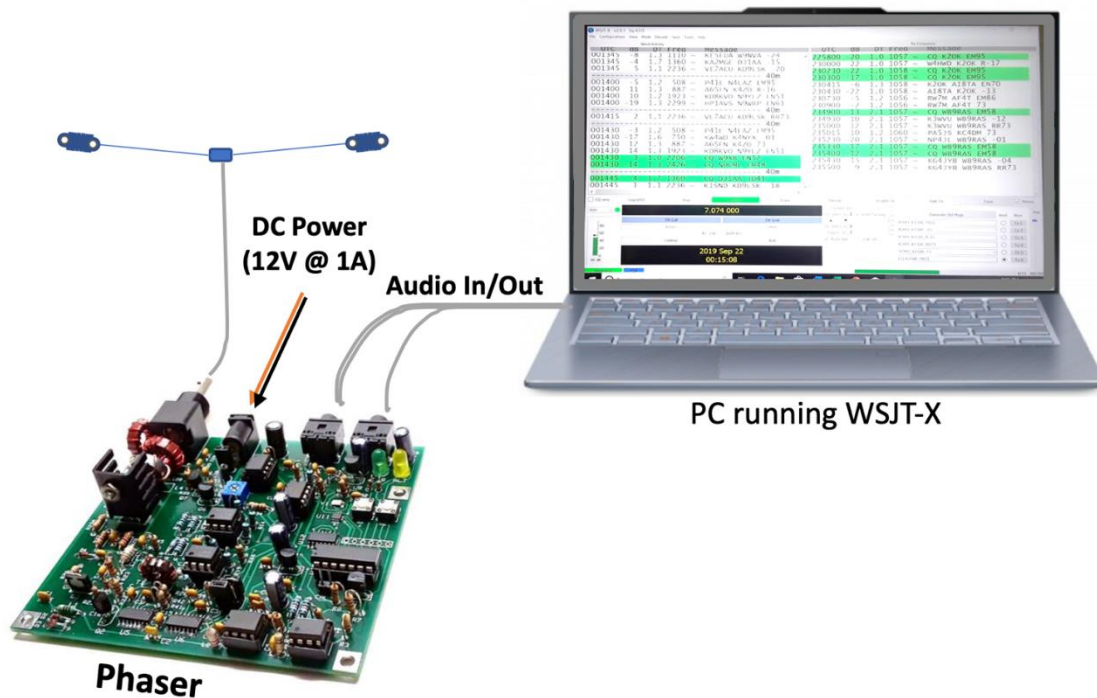


Figure 4: Connecting the Phaser Board to a Computer

Audio Cables -- Be sure the audio cables are going to the correct I/O jacks on your computer. Phaser **J3** connects to your computer's **MIC** input. **J4** connects to your computer's **headphone/speaker** output.

Power Supply – Use a sufficiently capable supply to power the Phaser board. Oftentimes, ac adapters (e.g., ‘wall-warts’) do not have good regulation at their current rating, and the transmitted signal will suffer if there is low voltage or AC ripple.

Antenna – The Phaser is expecting to see a matched, 50-ohm antenna feedline at the BNC port. Use a tuned antenna or a pre-adjusted antenna tuning unit (ATU).

‘Mic’ Setting on Computer – The receive audio being sent to the computer is fairly strong and you will need to reduce the computer ‘mic’ input level to a near-minimum setting. Open your computer's 'Control Panel' and make the following selections in sequence: 'Hardware and Sound' ... 'Sound' ... 'Manage Audio Devices' ... 'Recording' ... 'Microphone' 'Levels'. *[This sequence may vary somewhat with different operating systems.]* Adjust the slider to have the WSJT receive level bar indicator read approximately ‘40’ when your antenna is connected to the board. (See lower-left corner of Fig 5 below for this indicator.)

‘Speaker/Volume’ Setting on Computer – The computer ‘speaker’ slider sets the audio level delivered to the Phaser board, and together with the ‘Pwr’ sliderbar on the WSJT-X control screen, it serves as the RF ‘power adjust’. A good setting to use as a starting point is mid-scale on both of these controls.

WSJT-X will ask you to specify a radio during setup. Select ‘NONE’.

If your computer has a single 4-pin jack instead of separate ‘mic in’ and speaker/headset jacks, there’s a ready solution. There are several Y-adapters available:

- Do a search on ‘audio splitter for headphones and mic’.

You want one with a male 4-pin plug and two female 3-pin jacks. They run \$5-\$10 everywhere in the universe except New Jersey. Amazon has them.

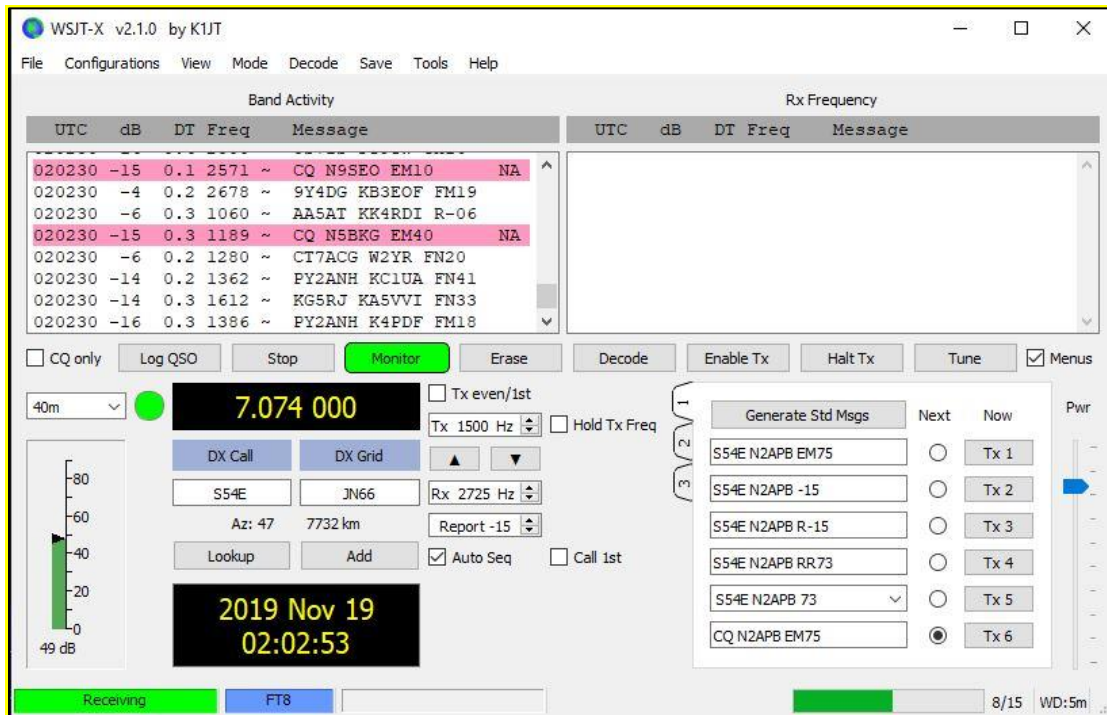


Figure 5: Sample view of WSJT-X control screen

APPENDIX 5: Adjustment/Calibration

There's not much to it! Except for when adjusting the blue trim pots. 'Backwards' trim pots were supplied in the kits such that you will need to **turn left (CCW) to increase the power and bias levels; and correspondingly turn right (CW) to decrease the levels.** We apologize for this counter-intuitive parts anomaly.

Adjustment:

- Turn trim pots R10 and R29 fully to the right, or CLOCKWISE (CW). **← IMPORTANT!**
- Connect cables to J1 through J4 as described in the previous section (Appendix 4). Open the WSJT-X application on your computer.
NOTE: This step assumes you have an SWR/power meter between the Phaser-15 and the antenna or dummy load.
- Set the WSJT-X 'Pwr' slider (lower right corner of display) to minimum.
- Click on the 'TUNE' button on your computer's display monitor. Advance the Pwr slider until the red Tx LED turns on. Advance the Pwr slider further to within 5-10% of full-scale.

Click the TUNE button on and off a few times to verify that the computer's audio is reliably detected by the Phaser.

It's tempting to set the Power slider to maximum, but there's a reason not to: Your computer's sound card output may have noticeable distortion content at its maximum setting. It's best to run the sound card output at a moderate level to keep your on-the-air signal as clean as possible.

Connect one end of a clip lead to the positive (red) probe on your multimeter. Connect the other end of the clip lead to D1's wire loop. Connect a second clip lead to TP3 - its other end goes to the negative (black) probe on your multimeter.

Click on the 'TUNE' button and measure the resulting DC voltage. This is the voltage across the current sense resistors. *I get about .06 volts, which is .06V/0.75 ohms, or 80 mA.*

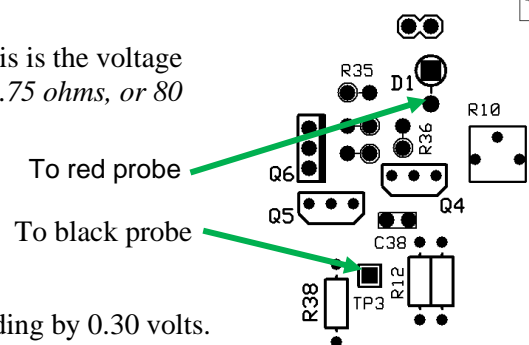
Record your result: _____ Volts

Add 0.30V to the result _____ Volts

Turn the trimpot R29 **left (CCW) to increase** the **bias voltage** reading by 0.30 volts. *In my case, that's 0.36 Volts.* This increase corresponds to a 400 mA idling current on the PA device.

Uncheck the TUNE button to let the Driver and PA cool if necessary

- With TUNE selected, **turn trim pot R10 left (CCW) to increase** the **output power** reading to 3 Watts into a 50-ohm load or matched antenna. This yields the cleanest possible signal quality. Further advances on R10 will yield 3.8 Watts, but that's the threshold at which signal quality deteriorates.
- Click on 'TUNE' again to end the test.




Calibration:

Apply 12 volts DC via J2. The other cables are not needed.

Install the remaining 2-pin jumper at 'CAL' (just below U10, the 14-pin DIP IC). This puts the logic in Frequency Calibration mode.

If you have a frequency counter:

-  Connect a probe to TP1 and observe the displayed frequency. **Caution:** Make sure you're not shorting TP1 and TP2 together
- Pressing S1 lowers the operating frequency and pressing S2 raises the frequency. Adjust the frequency to 28074.00 kHz. There's plenty of time to perform this adjustment. The longer you hold a switch down, the further the frequency will move. NOTE: During the interval when the logic is updating the Si5351, that device's output is turned off. The result is that the frequency will read somewhat low. Wait several seconds after releasing S1 or S2 to let the reading stabilize.

No frequency counter?

- Set your 'big rig' to 21074.00 kHz and connect a clip lead to TP1 (same caution as above.) Leave the other end of the clip lead free. You should be able to hear a steady carrier from the Phaser. Adjust frequency with S1 and S2 until the carrier's pitch matches that of your big rig's (key-down) sidetone.
- **No 'big-rig'?**
 - Install all cables to the Phaser as described in the previous section (Quick-Start). You should see the characteristic waterfall traces of FT8 signals. Adjust frequency with S1 and S2 until significant activity starts at about 500 Hz on the WSJT-X waterfall display. There'll be more activity during nighttime hours.
 - Once you've set the frequency by any of the methods above, remove the jumper from the 'CAL' location. This commands the logic to store the adjusted frequency in non-volatile memory and the Phaser returns to normal operation. This calibration should not need to be repeated.

APPENDIX 6: Theory of Operation

Receiver: The receiver input is supplied from a connection ('Tx PA') on the collector side of the low-pass filter. The combination of C1 and L1 provides a fairly broad peak at 21 MHz for a measure of selectivity. C2 and L2 provide an impedance step-up, with L2 also providing equal DC biases to the receiver mixer inputs. An SA612 (U1) provides the mixer function. *When signals are mixed with another signal, the resulting product includes sum and difference frequencies. We're interested in the difference frequency; in this case, audio.*

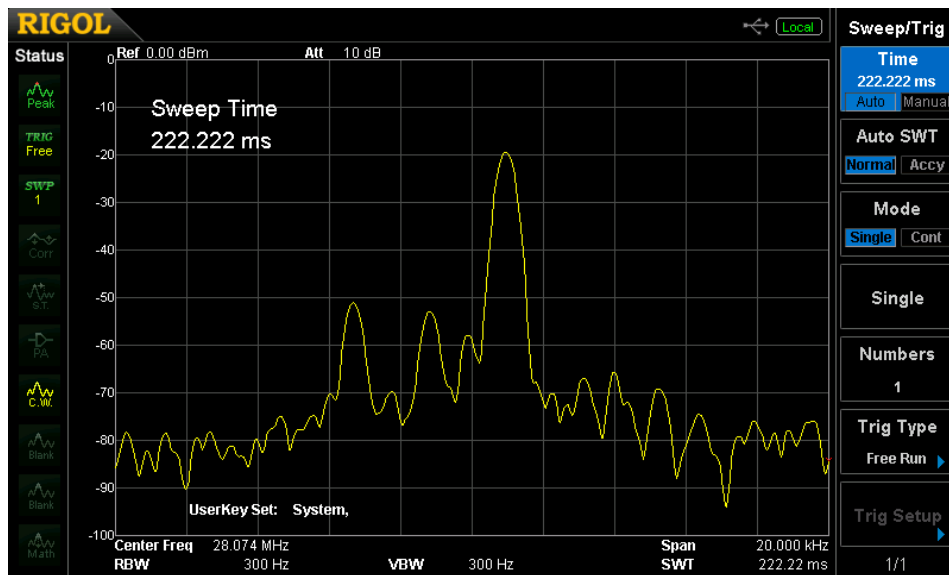
The resulting audio is amplified by a gain of 100 (40 dB) in a single section of U1. Note that the output level is quite low. *The audio level is inadequate for headphone use but is perfectly adequate for a sound card's microphone input.*

Transmitter: The frequency source for both transmitting and receiving is a Silicon Labs Si5351 (U11). This IC outputs a 3V square wave at four times the operating frequency. Two flip-flops comprising U12 divide the frequency by a factor of 4 and provide a reference phase ('I') and a quadrature phase ('Q') delayed 90 degrees from the reference.

U3 is a dual op-amp whose two audio outputs are separated in phase by a nominal 90 degrees. U4 and adjustment pot R10 set the signal level applied to the transmit strip. *This adjustment allows setting the output power without needing to tinker with the WSJT-X sound card settings. This ensures reliable T-R operation even at very low power levels, should you choose to do that.*

The two sets of audio signals, 0 degrees ('I') and 90 degrees ('Q'), are applied to the 'IF' ports of diode-ring mixers U5 and U6. The RF inputs to these devices are fed to the LO ports of these devices inputs and are also in quadrature. The outputs of U5 and U6 each comprise a double-sideband waveform. The two signals are combined by T1 to form a single-sideband signal. The two pairs of sidebands add (upper sideband) and cancel (lower sideband).

Suppression of the unwanted sideband was measured as 34 dB-or-better over an audio frequency range of 800-2800 Hz.



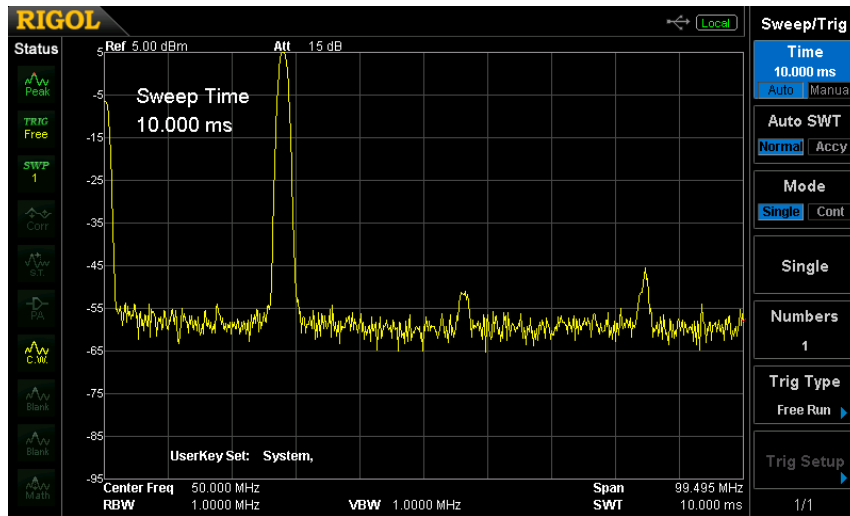
Transmitted 1-kHz USB tone at 3.2 Watts out.

Note suppression of both carrier and opposite sideband.
(The carrier frequency is at the center graticule and is 38 dB down. The unwanted (lower) sideband is down 34 dB.

The peak to the left of the lower sideband is an Intermodulation Distortion (IMD) product and is down 32 dB. This is typical of linear (SSB) transmitters.

Measurements were taken with a Rigol DSA705 Spectrum Analyzer. Lower tone-frequency suppression can be expected to be worse and was not evaluated below 800 Hz. The phasing network design is from Experimental Methods for RF Design, Figure 9.48. This network was scaled up in frequency for the Phaser by reducing the values of capacitors C12 and C13.

A Monolithic Microwave IC (MMIC) amplifies the SSB signal by ~12 dB, and feedback amplifier Q2 provides further gain to drive the PA stage. Collector choke L3 and associated capacitor C25 form an L-network. This transforms the stage's 200-ohm design value to the lower 20-ohm nominal input impedance of the PA stage. The PA stage collector impedance is designed for 22 ohms. T2's 2:3 turns ratio provides a 2.25:1 impedance step-up to 50 ohms. The output low-pass filter cleans up the PA waveform to reduce harmonic content. Capacitor C25 provides a notch in the filter's 2nd harmonic response. This allows the relatively-simple low-pass filter to meet FCC/EU standards for spectral purity.



Logic: The controller IC (U10) is a PIC 16F1824 running on an internal 16 MHz clock. Upon application of power, the PIC initializes the Si5351 to the FT8 operating frequency. In normal operation it's in a polling loop looking for closures on frequency-select switches S1 and S2. Upon sensing a closure, it re-initializes the Si5351 to the appropriate frequency and illuminates the corresponding discrete LED.

Transmit/Receive switching is done by sensing the presence of audio from the computer sound card. An LM393 comparator output shorts capacitor C36 to ground for audio input signals greater than 450 mV p-p. The second comparator section is used solely as an inverter and turns Q4 and Q6 on to serve as a bias source for transmit operation.

Frequency Calibration: The PIC controller polls the 'CAL' input and detects when the user puts a jumper in place. The controller then enters a process of changing the Si5351 reference signal slightly based on the user's pressing the S1 and S2 to decrease or increase (respectively) the operating frequency. The frequency correction is stored in non-volatile memory upon removal of the CAL jumper. This is a one-time procedure. See 'Adjustment/ Calibration' (Appendix 5).

APPENDIX 7: User-Programmable ALT Frequency Entry

The ALT frequency may be programmed to be anywhere in the HF spectrum. This supports other digital operating modes and the use of the Si5351A as a general-purpose signal source.

Here's how to program the ALT frequency:

- 1) Press and hold the FT8 pushbutton during power-up.
- 2) Upon releasing the pushbutton, the FT8 LED blinks on and off TWO times.
- 3) Enter any 6-digit frequency (i.e., five kilohertz digits and the 100-Hz digit) between 00100 and 30000. For example, enter '2 1 0 9 4 6' for 21,094.6 kHz. *NOTE: The 6th digit better enables one to program the ALT frequency for use with digital modes like WSPR.*

Digit entry procedure:

- a) Use the FT8 and Alt pushbuttons to enter the frequency using Morse characters. Press the FT8 pushbutton for a DIT and the Alt pushbutton for a DAH;
 - b) Enter Morse elements at any speed and element spacing. 'Slow is good'; and
 - c) After each DIT is entered, notice the FT8 LED blink on and off ONCE;
After each DAH is entered, notice the Alt LED blink on and off ONCE.
- 7) After six digits are entered the Phaser will:
- a) Blink the Alt LED on-and-off THREE times;
 - b) Save the new frequency in EEPROM for future use (as the Alt frequency); and
 - c) Illuminate the ALT LED to indicate that this new frequency is in effect. *Operation of the FT8 frequency is unchanged.*

If there is an error during entry of the Alt Frequency, the Phaser will blink the Alt LED continuously until power is removed, at which point you may try again.

APPENDIX 8: Winding Toroids

A properly-wound toroid is shown at right.

- **Each time the wire goes through the hole it counts as a turn**
- **The windings are tight.** Pull the wire taut after each turn comes over the outer edge of the core.

and please... no scrambled turns!



GOOD TOROID!

- **Doublecheck the turns count.** *I do this by bumping a fingernail over each turn.* When the number of turns is correct, cut the leads to a length of 3/8" (1cm).
- **Strip the leads** by scraping with a small knife to remove the insulation. *(Despite the manufacturer's claims, the insulation will probably not melt when you apply a soldering iron.)*
- **Once the leads are prepared, make sure the turns are evenly spaced on the toroid form.** *If the leads are bunched together, the inductance will be too high. This results in low power output.*



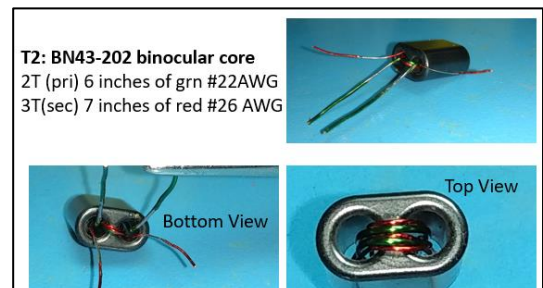
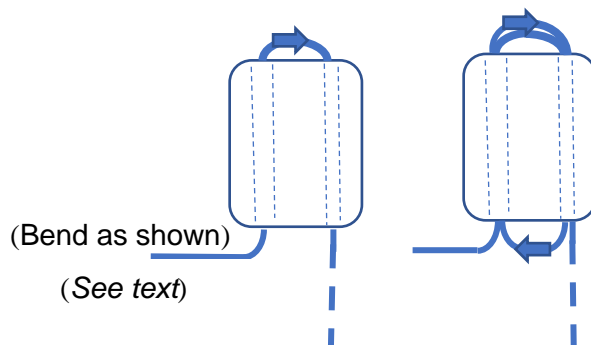
BAD TOROID!

(bad bad toroid!)

WINDING BINOCULAR CORES:

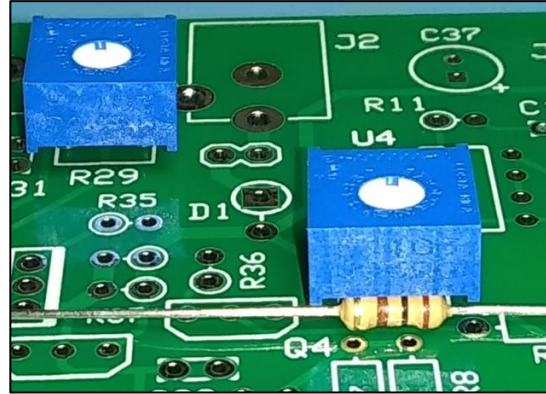
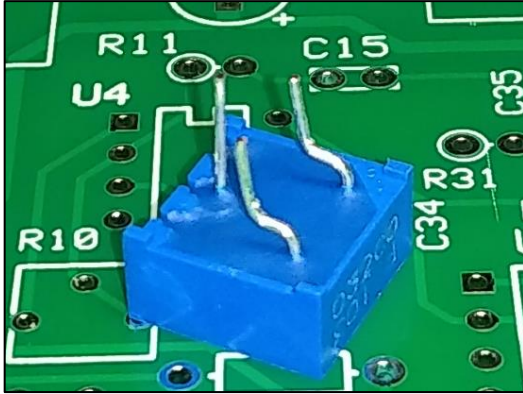
Easy!

One turn on a Binocular core:



APPENDIX 9: Bending Leads for R10 and R29

Some kits may have a larger blue trim pot supplied for R10 and R29. If this is so for your kit, you will need to bend the leads in order to fit them into their pads on the pc board, as shown below. (The trim pots will be raised off the pc board a little bit as illustrated by the axial lead resistor, but this is okay.)



CREDITS

Concept, Design, Prototyping, Documentation ... *Dave Benson, K1SWL*

Microcontroller Software ... *Craig Johnson, AA0ZZ*

Kitting ... *Larry Przyborowski, K3PEG*

Productization, Documentation, Financing, Sales, Website, Support ... *George Heron, N2APB*

DOCUMENT REVISION HISTORY

Rev E1 - Initial Release.

Rev E2 - Correction for 6-pin header (not 7-pin) and creating TP3 with a piece of scrap wire.
Also corrected discrepancy on turns count for L5 (11 turns) and L6 (10 turns). The text now matches the Parts List and Schematic.

Rev E3 - Discovered our trimpots turn in reverse to normal, so needed to adjust the ADJUSTMENT section on page 30.
(See red text.)

Rev E4 - Clarified language for Test 2 and Test 3.

Rev E5 - Added KY5033 part number as option for the 3.3V regulator in Group 1. Also simplified and clarified Test 2 procedure and the Group 2 Component Placement diagram.

Rev E6 - Corrected text in Test 2 description. Updated schematic (pg 2, Logic) for correct 1.5-ohm resistors R37A/B.
Added some pics of a binocular transformer on page 35 and a pic of our actual 8-turn transformer T1 on page 16.

Rev E7 - Corrected text in Adjustments (page 30) to correctly state: “Advance the Pwr slider until the red Tx LED turns on.” (We are not yet using the voltage on TP3 at this point.)

Rev E8 - Corrected frequency to “21074.0” in the Test section on page 12.