“The Challenger”

CW - SSB QRP Rig

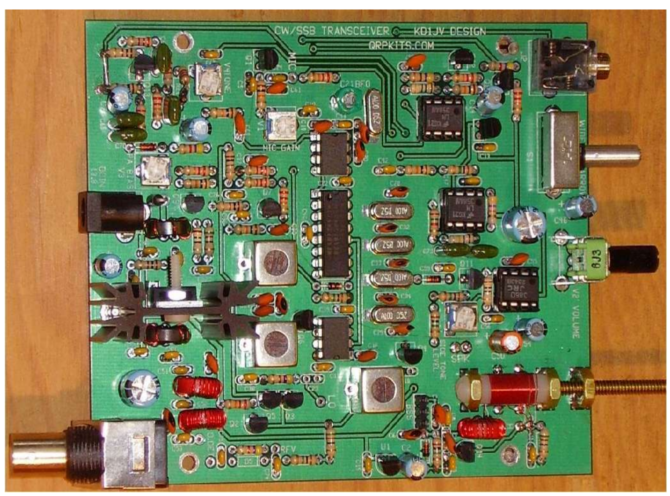
A KD1JV Design, kitted by qrpkits.com

This rig was designed to be entered into the ARRL “home brew challenge”. The results of the design contest won't be known for some time and it will be even longer before anything is published. We decided this was such a nice rig, it had to be kitted and made available as soon as possible. There's also the possibility the ARRL will choose some other design to win, so why take that chance?

The Challenger features both CW and SSB operation, the first rig kit in this price class to do so. The reasonably small size, low power consumption and nearly full band coverage of 40 meters makes this rig ideal for back up or emergency use.

Specifications:

Receiver sensitivity:	0.2 uV MSD typical
Audio output:	500 mw
Receiver current:	30 ma, no signal
Transmitter power out:	6 watts CW/pep typical at 13.8V supply
Transmitter spurs:	-50 dBc or better
Transmitter current:	900 ma at 6 watts CW output
SSB frequency response:	400 Hz to 2400 Hz
VFO drift:	From clod start, 200 Hz or less during 10 minute warm up.
Tuning rate:	About 13 kHz per knob revolution
Typical tuning range:	SSB: 7.280 to 7.150 MHz CW: 7.100 to 6.700 MHz
Power supply:	11 to 14 volts, 12.5 to 13.8 recommended.



Operation:

Front panel controls and jack.

Tuning:

This is a “backwards” tuning rig. Turning the tuning knob clockwise lowers the operating frequency. The only other thing to remember is that there is no stop when tuning counterclockwise. Be careful not to turn so far as to remove the tuning screw from the coil nuts.

Band Segment Select:

The tuning range of the PTO is about 130 kHz. In order to tune both the CW and SSB segments of the band, the PTO frequency is shifted using a set of SIP pins and a shorting plug. These are accessed from the bottom of the cabinet. When the center pin and the pin towards the center of the cabinet are shorted, the tuning range will be in the phone segment of the band. When the plug is moved to short the center pin and pin towards the outside of the cabinet, the tuning range will be in the CW segment of the band. Be aware that when in the CW band segment, the rig will tune about 30 kHz BELOW 7 MHz.

Volume:

Does this really need any explanation?

Wide/Narrow filter select:

This slide switch selects either the Wide (SSB mode) or Narrow CW audio filter. Using the CW filter significantly improves the selectivity of the receiver. Using the CW filter when in CW mode will help you match the other stations frequency, by making the tuning sharper. Ideally, the received CW note should match the rigs side tone frequency to exactly match the other stations frequency. Only people with perfect pitch can achieve this easily. The rest of us will have to rely on the CW filter to help us out.

MIC/KEY jack.

A single 3.5 mm stereo phone jack is used for both the microphone and PTT/CW key input. The MIC input is the sleeve of the plug and the PTT or CW key input is the tip. When a CW key with a mono phone plug is inserted into the jack, the rig will automatically switch to CW mode by enabling the keying of the CW tone oscillator.

Rear panel:

Antenna jack:

A standard BNC jack is used here.

DC IN jack:

12 to 14 volts DC at 1 amp minimum is connected here. A 5.5 mm x 2.1 mm barrel power plug will match the jack. A 2 amp fuse is recommended to be in line with the power supply.

Use of headphones:

Because there is no AGC or other audio level limiting in the rig, the use of headphones is not recommended. If you do wish to add a headphone jack, use one which will allow putting a 100 ohm or larger resistor in series with the headphones to help limit the maximum volume to a safe level.

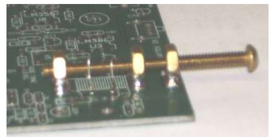
Parts list 40M CW/SSB RIG parts check list

	quantity	value			quantity	value	
	3	10 OHMS	All resistors 1/4W, 5%		2	4.7 p	NPO disk
	3	51 OHMS			3	22 p	NPO disk
	4	100 OHMS			5	33 p	NPO disk
	2	470 ohms			3	47 p	NPO disk
	1	1.5 K			1	68 p	NPO disk
	4	2.2 K			4	330 p	C0G multilayer
	4	4.7 K			1	680p	C0G multilayer
	7	10 K			9	1000p	disk
	8	22 K			27	.1 uF	X7R multilayer
	1	47 K			6	.022 uF	FILM
	1	100 K			5	1 uF/25V	Aluminum electrolytic
	6	1 MEG			2	10 uF/16v	Aluminum electrolytic
	4	10K trimmer			1	47uF/16	Aluminum electrolytic
	1	10K audio	PC mount, RA		2	330 uF/16	Aluminum electrolytic
					1	30 p trimmer	Green
	2	78L05	5V regulator				
	1	LM386	Audio amp		5	10.000 MHz	crystal
	2	LM358	Dual LP op amp		3	10.7 IF xformer	10 mm, brown slug
	1	74HC4053	Analog multiplexer		3	T37-2	Red
	2	SA602/612	Mixer/osc		2	FT37-43	black
	7	2N7000	TFET				
	4	2N4401	NPN, 500 ma		1	DPDT RA slide	
	1	2N4403	PNP, 600 ma		1	RT angle pc mount BNC	
	1	IRF510	Power MOSFET		1	3.5mm Stereo jack	
	1	J310	j-fet		1	nylon spacer	#6, 0.625” long Hex
	5	1N4148	Small signal		1	#6-1/4	Nylon screw
	1	1N5232B	5.1V zener		1	#4-32 ¼ nylon	
	1	1N5817	Schottky		3	#6-32 nuts	brass
	3	8 pin dip			1	#6-32	2” brass screw
					1	Heat sink	
	1	Speaker	2” dia low profile		4 feet	#32 wire	
	1	cabinet	5 x 5 x 1.5”		5 feet	#30 wire	
	1	Knob	1/2”		1 - #6-32	.25” round	
	1	SIP	shorting plug		1	Pwr jack	5.5 mm x 2.1 mm pin
	1	3 pin	SIP header		4	#4-32 1/4”	screws
	1	Circuit board			1	#4-32 nut	

Assembly: Please read through all the assembly instructions before starting!

Before any parts are installed on the board, the nuts for the PTO coil are soldered in place. If this is not done now, it will be difficult to do later.

PTO nut installation:



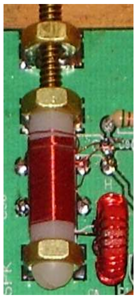
1. Clean any tarnish off edges of the nuts to make them easier to solder.
2. Thread the three brass nuts onto the brass screw.
3. Space the two nuts towards the end of the screw so that the nylon spacer fits between them with just a little wiggle room. Do not thread the spacer onto the screw, as it will melt when the nuts are soldered in place.
4. Position the third nut so it sits on the solder pad at the front edge of the board when the rear nuts are placed over their respective solder pad/nut outlines.
5. Clip two 1" long leads from a resistor (leaving enough on the resistor so you can use it latter) and from them into a "U". Use these "U" shaped leads to hold the nut/screw assembly in place on the board, using the pair of holes on either side of the screw. You can just fold over the leads on the bottom of the board or solder them in place. Crimp the leads against the screw for a more secure fit.
6. Make sure the screw is as square to the front edge of the board as you can manage.
7. Solder one side of the nut at the front edge of the board to the large solder pad. Before you solder the other side, recheck the alignment of the screw to make sure its still square to the board. Solder the two remaining nuts in place.
8. Once the nuts cool down, remove the leads holding down the screw and remove the screw. Proceed with the board assembly.

Winding L1, the PTO coil.

1. Thread the nylon spacer onto the brass screw and snug it up against the head of the screw. This will give you something to hold onto as you wind the coil. There are small holes drilled into one side of the spacer, one near each end of the spacer. If one of the holes is closer to the end of the spacer than the other, put the end of the spacer with the hole closest to that end at the head of the screw.
2. Locate the hole near the head of the screw and thread the end of the #32 wire into and though this hole and pull out about 1 inch, then loop it back through the hole. This will secure it in place.
3. Spin the screw/spacer with one hand, while guiding the wire by using your thumb and forefinger of the other hand. Try not to overlap turns and occasionally use a finger nail to snug up the turns against each other.
4. Its nearly impossible to keep track of the number of turns. Don't even try. Just fill up the space between the two holes. A few turns more or less won't matter.
5. When you get to the second hole, thread the remaining wire through it. Make a loop about 1 inch long and twist the wire together a few time near the spacer.
6. Continue winding five (5) more turns, in the same rotational direction as the main coil, then thread the wire end through the hole once more. This is the oscillator feedback winding.

Mounting the coil:

1. Remove the screw from the spacer.
2. Slide the spacer/coil assembly between the two nuts soldered to the board.
3. Thread the brass screw into the nuts and then into the spacer. If need be, rotate the spacer so the screw goes into it smoothly.
4. Insert the ¼" long #6 nylon screw into the nut at the rear of the coil. Again, rotate the spacer if needed to allow the screw to thread into it smoothly. If there is any play in the spacer between the nuts, snug the spacer up against the rear nut. This will keep it from spinning with the tuning screw.
5. Trim and tin the coil wire at the rear of the coil. Insert and solder this end into the hole just below the L2 label.
6. Trim and tin the loose wire end of the feedback winding. Insert this into the hole labeled "C" and solder.
7. Clip the wire forming the loop to separate the main L1 winding from the feedback winding. Tin these ends and use your ohm meter to identify which coil winding they are part of. Insert the wire end for the feedback winding into the hole labeled "H" and solder. Insert the wire end for the main L1 coil into the hole used to hold the screw in place when your were soldering the nuts in place.




Finished PTO coil mounted to board.

Board assembly:

Print a copy of the board layout on the next page for easy reference. The part values labeled in red. Experienced builders will need little more than this diagram to build the board. All parts, with the exception of the PA, are installed before any testing is done. Since component designation numbers are somewhat randomly located around the board, the board is divided into four quadrants. This will make locating where the part goes on the board easier when using the following part by part placement listing. You may also want to presort the parts according to type and value and place them in small bowls to keep them from getting lost. Parts are installed in the order of their height. The lowest profile parts are installed first, then progressively taller ones. After putting a part on the board, bent the leads slightly to one side so the don't fall out when you flip the board over to solder. Several parts can be installed before you start soldering.

Diodes:

There are 5 glass diodes. One of these is the 1N52228B zener diode. Identify this one first, (it has a pink sticker attached to one leg). Install the 1N5228B in location D4, in the lower left quadrant. Now install the remaining four 1N4148 diodes. D3 and D1 are located in the upper right quadrant, D5 in the lower right quadrant and D2 straddles the upper and lower right quadrants, just the the right of U7.

Resistors:

The resistor table is laid out in a four quadrant format. Locations in the quadrant are listed left to right, top to bottom. The color codes for several resistor values can be easily mistaken at a quick glance. In particular, be careful of 51 ohms (Green/Brown/Black) and 1 Meg ohms (Brown/Black/Green). These are VERY easy to mix up. Values which are in decade increments can also be confused, such as 470, 4.7K and 47K. So, take a good look at the colors before you solder the part in place! Leads are bent tight to the body of the resistor. Sometimes you have to help them a little with your needle nose pliers to make them sit flat on the board. Do not stand parts up off the board. There's no reason to do so and it looks bad.

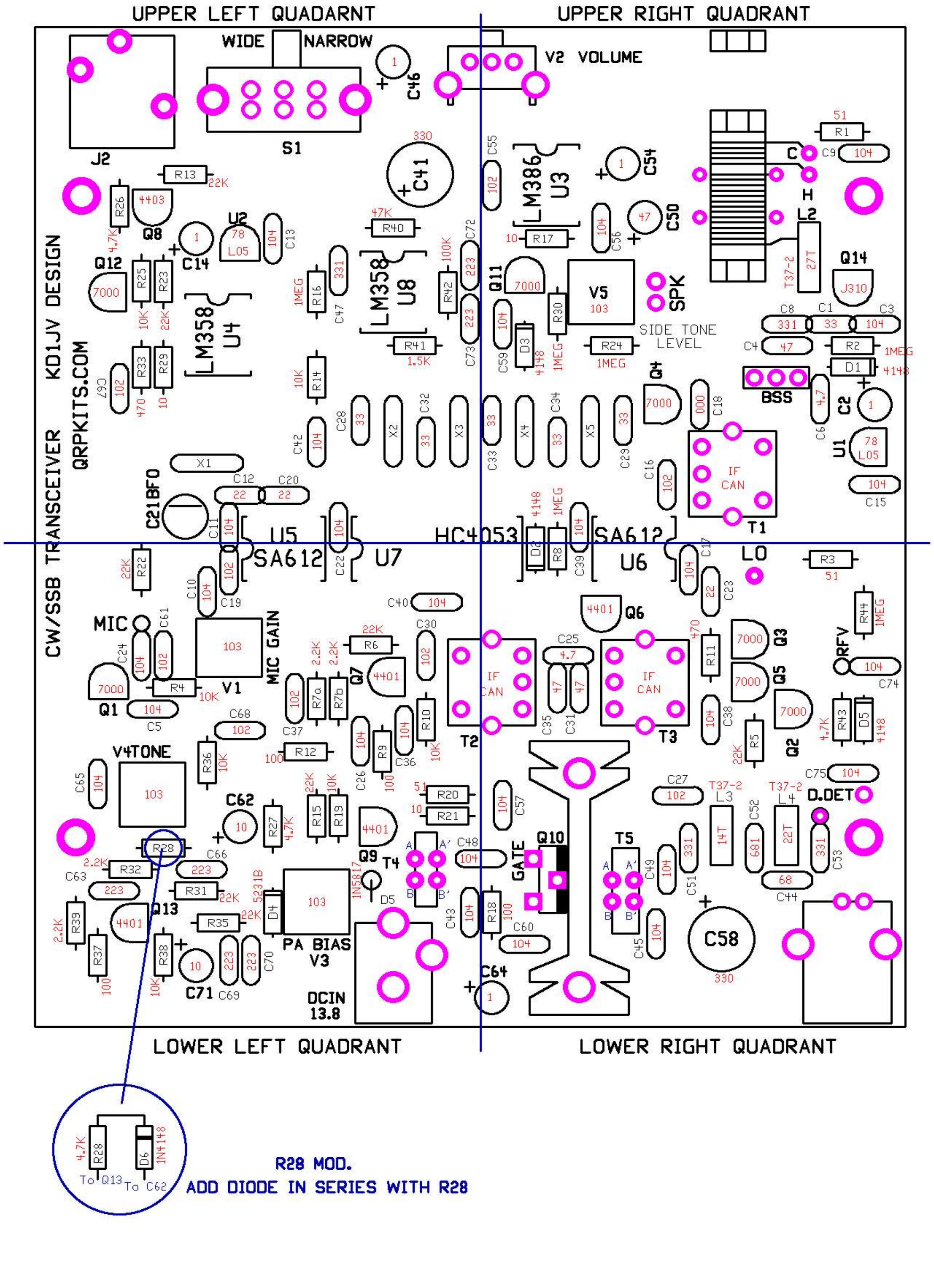
Small capacitors:

These are also listed in a table divided into quadrants.

Remaining parts:

The rest of the semiconductors, electrolytic caps and what ever else which is left are listed in a linear table with the quadrant it can be found in. Finding the locations of these parts will be easier, as there are less of them and most everything else has been installed.

Parts placement guide. Print out this page for easy reference while building the board.
NOTE: ground missing from C8, diode added in series with R28



Resistors

Quad(rant): U.L. -Upper Left, U.R. - Upper Right, L.L. -Lower Left, L.R.- Lower Right
All resistors ¼ watt carbon film, 5 % - last band gold.

	quad	***loc***	***value***	***Color code***			***qud***	***loc***	***value***	***Color code***
	U.L.	R13	22 K	RED/RED/ORG			U.R.	R1	51	GRN/BRN/BLK
	U.L.	R26	4.7 K	YEL/VOL/RED			U.R.	R17	10	BRN/BLK/BLK
	U.L.	R40	47 K	YEL/VOL/ORG			U.R.	R30	1 MEG	BRN/BLK/GRN
	U.L.	R25	10 K	BRN/BLK/ORG			U.R.	R24	1 MEG	BRN/BLK/GRN
	U.L.	R23	22 K	RED/RED/ORG			U.R.	R2	1 MEG	BRN/BLK/GRN
	U.L.	R16	1 MEG	BRN/BLK/GRN						
	U.L.	R42	100 K	BRN/BLK/YEL						
	U.L.	R33	470	YEL/VOL/BRN						
	U.L.	R29	10	BRN/BLK/BLK						
	U.L.	R41	1.5 K	BRN/GRN/RED						
	U.L.	R14	10 K	BRN/BLK/ORG						
	L.L.	R22	22 K	RED/RED/ORG			L.R.	R8	1 Meg	BRN/BLK/GRN
	L.L.	R6	22 K	RED/RED/ORG			L.R.	R3	51	GRN/BRN/BLK
	L.L.	R4	10 K	BRN/BLK/ORG			L.R.	R44	1 Meg	BRN/BLK/GRN
	L.L.	R7a	2.2 K	RED/RED/RED			L.R.	R11	470	YEL/VOL/BRN
	L.L.	R7b	2.2 K	RED/RED/RED			L.R.	R43	4.7 K	YEL/VOL/RED
	L.L.	R10	10 K	BRN/BLK/ORG			L.R.	R5	22 K	RED/RED/ORG
	L.L.	R9	100	BRN/BLK/BRN			L.R.	R18	100	BRN/BLK/BRN
	L.L.	R12	100	BRN/BLK/BRN						
	L.L.	R36	10 K	BRN/BLK/ORG						
	L.L.	R20	51	GRN/BRN/BLK						
	L.L.	R21	10	BRN/BLK/BLK						
	L.L.	R27	4.7 K	YEL/VOL/RED						
	L.L.	R15	22 K	RED/RED/ORG						
	L.L.	R19	10K	BRN/BLK/ORG						
	L.L.	R28	4.7 K	See note below						
	L.L.	R32	2.2 K	RED/RED/RED						
	L.L.	R31	22 K	RED/RED/ORG						
	L.L.	R39	2.2 K	RED/RED/RED						
	L.L.	R35	22 K	RED/RED/ORG						
	L.L.	R37	100	BRN/BLK/BRN						
	L.L.	R38	10 K	BRN/BLK/ORG						

R28 note: A diode needs to be added in series with R28. Cathode end connects to the resistor and anode end goes in R28 hole nearest C62/C66. See layout diagram.

Small capacitors

Capacitor type: (M) multilayer, (F) film , (D) ceramic disk

	quad	LOC	Type/value	code			quad	LOC	Type/value	code
	U.L.	C13	(M) 0.1	104			U.R.	C9	(M) 0.1	104
	U.L.	C47	(M) 330 p	331			U.R.	C55	(D) 0.001	102
	U.L.	C72	(F) 0.022	223			U.R.	C56	(M) 0.1	104
	U.L.	C73	(F) 0.022	223			U.R.	C8	(M) 330 p	331 SEE NOTE
	U.L.	C67	(D) 0.001	102			U.R.	C1	(D) 33 p	33
	U.L.	C42	(M) 0.1	104			U.R.	C3	(M) 0.1	104
	U.L.	C28	(D) 33 p	33			U.R.	C59	(M) 0.1	104
	U.L.	C32	(D) 33 p	33			U.R.	C4	(D) 47 p	47
	U.L.	C12	(D) 22 p	22			U.R.	C33	(D) 33 p	33
	U.L.	C20	(D) 22 p	22			U.R.	C34	(D) 33 p	33
	U.L.	C11	(M) 0.1	104			U.R.	C29	(D) 33 p	33
	U.L.	C22	(M) 0.1	104			U.R	C18	(D) 22 p	22
							U.R.	C6	(D) 4.7 p	4.7
							U.R.	C16	(D) 0.001	102
							U.R	C15	(M) 0.1	104
							U.R	C39	(M) 0.1	104
							L.R.	C17	(M) 0.1	104
	L.L.	C19	(D) 0.001	102			L.R.	C23	Not used	
	L.L.	C10	(M) 0.1	104			L.R.	C25	(D) 4.7	4.7
	L.L.	C40	(M) 0.1	104			L.R	C35	(D) 47	47
	L.L.	C24	(M) 0.1	104			L.R	C31	(D) 47	47
	L.L.	C61	(D) 0.001	102			L.R.	C74	(M) 0.1	104
	L.L.	C30	(D) 0.001	102			L.R.	C38	(M) 0.1	104
	L.L.	C5	(M) 0.1	104			L.R.	C75	(M) 0.1	104
	L.L.	C37	(D) 0.001	102			L.R.	C57	(M) 0.1	104
	L.L.	C68	(D) 0.001	102			L.R.	C75	(M) 0.1	104
	L.L.	C26	(M) 0.1	104			L.R.	C27	(D) 0.001	102
	L.L.	C36	(M) 0.1	104			L.R.	C51	(M) 330 p	331
	L.L.	C65	(M) 0.1	104			L.R.	C52	(M) 680 p	681
	L.L.	C48	(M) 0.1	104			L.R.	C53	(M) 330 p	331
	L.L.	C66	(F) 0.022	223			L.R.	C49	(D) 0.1	104
	L.L.	C63	(F) 0.022	223			L.R.	C44	(D) 68 p	68
	L.L.	C43	(M) 0.1	104			L.R.	C60	(M) 0.1	104
	L.L.	C69	(F) 0.022	223			L.R	C45	(M) 0.1	104
	L.L.	C70	(F) 0.022	223						

C8 NOTE : before soldering ground end of cap, scrape solder mask off board, bend lead over and solder to ground plane.

	location	VALUE	QUADRANT	NOTES
	X1-2-3	10.000 MHz	U.L.	DO NOT STAND OFF BOARD, case will not short to pads.
	X4-5	10.000 MHz	U.R.	Cases can be soldered to pad below crystal, but is not required.
	U4-8-3	SOCKET	U.L. U.R.	ONLY THESE 3 IC's USE SOCKETS
	Q8	2N4403	U.L.	THERE ARE ONLY ONE OF THESE, DON'T MISTAKE IT FOR A 2N4401
	U2	78L05	U.L.	CENTER LEAD BENDS TOWARDS ROUND SIDE OF PACKAGE.
	Q12	2N7000	U.L.	These can be static sensitive.
	Q11	2N7000	U.R.	Use precautions if its cold and dry outside.
	Q14	J310	U.R.	
	Q4	2N7000	U.R.	
	U1	78L05	U.R.	SEE U2 NOTE
	Q1	2N7000	L.L.	
	Q7	2N4401	L.L.	
	Q9	2N4401	L.L.	
	Q13	2N4401	L.L	
	Q6	2N4401	L.R.	
	Q3	2N7000	L.R.	
	Q5	2N7000	L.R.	
	Q2	2N7000	L.R.	
	U5	SA602	CENTER	SOLDER DIRECT TO BOARD
	U7	74HC4053	CENTER	SAME AS ABOVE
	U6	SA602	CENTER	PIN 1 FACES OPPOSITE DIRECTION THAT OF U5 AND U7.
	V5	10K Trimmer	U.R.	
	V1-4-3	10K Trimmer	L.L.	
	C21	30 p trimmer	U.L.	Green, flat side towards line on outline
	C46-C14	1 uF / 25V	U.L.	LONG LEAD PLUS FOR ALL ELECTROLTICS
	C41	330 uF / 16V	U.L.	THIS CAP CAN EXPLODE IF INSTALLED BACKWARDS!
	C54-C2	1 uF / 25V	U.R.	
	C50	47 uF /16V	U.R.	
	C62-71	10 uF / 16V	L.L.	
	C64	1 uF / 25V	L.R.	
	C58	330 uF /16V	L.R.	SEE C41 NOTE
	T1-2-3	IF CANS	U.R. / L.R.	SOLDER THE MOUNTING TABS TOO.
	D6	1N5817	L.L.	CATHODE, (END WITH BAND) GOES INTO HOLE WITH CIRCLE OUTLINE.

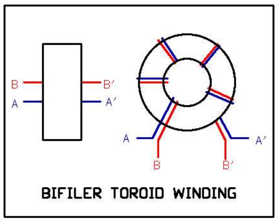
Assembly is now almost complete. Time to wind the coils, L2,3 and 4.

Toroid winding:

L2: Wind 27 turns (15" of the #30 wire) onto one of the red T37-2 toroid cores. Remember, a turn is each time the wire passes through the center of the core. Once done, trim and tin the leads and insert and solder into the L2 location.

L3 and L4: Wind 14 turns (9" of #30) on another red T37-2 core and mount in the L3 location. Wind 22 turns (12") on the remaining red core and mount in the L4 location.

T4 and T5 winding:



T4 and T5 are bifiler wound transformers. This simply means they use two wires of equal turns. Loop 8" of #30 wire and lightly twist it together. Wind the black FT37-43 core with five (5) turns. Snip off the end of the loop and tin all four wire ends. To work properly, the two ends of each wire has to be adjacent to each other on either side of the core. Use your ohmmeter once again to identify the two ends of one of the wires. If need be, move one of the ends so it is opposite the other when looking at the bottom of the core. See diagram. Now when the core is mounted on the board, the tracks will connect to the proper ends of the windings.

Last few parts:

The only things left to install are the phone jack, slide switch, volume control, power and BNC jack. Go ahead and install these parts now. Finish by inserting U4, U8 and U3 into their sockets. Q10 and the heat sink will be installed after the initial tests are done. SIP Pins. These three pins will be used for band segment selection of the PTO. They are installed with the long legs sticking out the bottom of the board. Later, a hole will be drilled into the bottom part of the cabinet so you can access these pins without taking the cabinet apart.

Testing and tune up:

At a minimum, you will need a DVM or multimeter, a shortwave radio capable of tuning down to 2 MHz, a QRP RF power meter and 50 ohm dummy load. A frequency counter and Oscilloscope would help immensely, should they be available to you.

Initial tests:

Before you apply power to the circuits, do a quick ohm meter check from the DC IN to ground and make sure there are no shorts there. You might see a momentary low resistance reading as the input filter caps charge up, but the resistance reading should quickly rise to infinite. If there is a short, find and remove it.

Now you can apply power to the board, 12 to 13.8 volts. First check to make sure there is 5 V, +/- 0.25 V, coming out of the two regulators, U1 and U2. Insert the tuning screw fully into the coil, then back it out a few turns. Insert the SIP shorting plug on the pins which ground the end of C4 so the PTO in the SSB portion of the band. Bring over the short wave radio, ideally one with a digital dial and if it has a BFO, thats even better. If you have a HF rig with general coverage, use that. Place the antenna near the PTO.

You should find the oscillator signal at about 2.85 MHz. If you have a frequency counter it can be connected to the pad labeled "LO", though this will shift the frequency slightly lower. If you can't find any signal from the oscillator, check the coil connections or it is possible the feedback coil leads are reversed. Once the PTO is working, remove the tuning screw. The frequency should shift down by about 130 kHz to about 2.72 MHz. The frequency can be fine tuned by changing the spacing of the wire on the L2 toroid. Try and set the PTO frequency to 7.150 MHz with the screw fully inserted into the coil. Bunching the turns close together will decrease the frequency, while spreading them apart will increase the frequency. It will be difficult to find the exact frequency using a typical AM only SW portable radio, due to its wide bandwidth. Greater accuracy would be archived with a HF rig with general coverage ability and used in the CW mode. For now, we just want to make sure we're tuning somewhere in the phone section of the band. For more precise adjustment of the frequency, you'll need to track down someone with a frequency counter or a communications quality HF receiver. Once the PTO frequency has been set, secure the L2 toroid to the board with a dab of hot glue. This will reduce micro phonic effects.

Now that the PTO Is working and tuning in the right area, connect a speaker to the SPK holes on the board. Turn the volume control up and you should hear some audio hiss. Give the BFO trimmer, C21, about a ¼ turn from its factory setting. Connect an antenna to the antenna jack, then tune around looking for an on air signal. Once you find one, adjust the slug in the top of T2 for best signal strength. Now tweak the BFO trimmer for best voice clarity (If your listening to a SSB station). You might have to re-tune the PTO slightly as you do this, as the two are somewhat interactive. Also check for image rejection. If you hear a signal on either side of zero beat, the BFO frequency is too low. Ideally, you want good voice clarity on the lower side band and good image rejection on the upper side band. Very strong signals such as those from a short wave broad cast station, will produce some noticeable signal on the opposite side band, even when the BFO is properly adjusted.

If all went well, you now have a functional receiver. If not, you have some trouble shooing ahead of you. If all you have is a DVM, about all you can do is check some voltages and do a careful visual inspection of your work. Often, this is enough to find where you went wrong. If not, try and find someone who has a signal generator and Oscilloscope for more in depth signal tracing.

Now for the transmitter sections.

An RF voltage detector is built into the board, located just above the RF output jack. This will be used to peak up the transmitter stages. Solder a resistor lead clipping into the hole labeled RFV. You can use a clip lead to connect this to your DVM or make a loop to slide the probe into. Clip the negative probe of the DVM to board ground, the most convent point is one of the board mounting holes. Solder a 3” length of hook up wire to the input of the diode detector (D.DET) to use as an input probe.

Connect the RF voltage probe to where the gate of Q11 will go, the junction of C50 and R23. Make sure you have the PTO Band Segment Selection shorting plug installed on the SIP pins to put the tuning in the SSB portion of the band and insert the tuning screw fully into the PTO coil.

Enable the CW tone generator by plugging in a straight key with a mono plug into the mic jack. You can also use a paddle, putting the rig in CW mode by closing the Dash paddle and keying the rig with the Dot paddle. Leave the CW tone level trimmer at its factory setting, which is midway. Key the transmitter and you should see some voltage from the RF probe. You should also hear the CW side tone from the speaker. This might be annoying after awhile, so you can disconnect the speaker for now or turn the level down with the side tone level trimmer.

Now adjust the transmit band pass filter, T3 and T4 for the maximum voltage from the probe. Tuning is somewhat interactive, so work back and forth a few times between the two transformers until you get the best results. You shouldn't have to turn the slugs much, adjust them slowly and a little at a time. Assuming a 13.8 volt supply, you should be able to peak the voltage to 4 or 5 volts.
Un-key the rig and turn the CW tone oscillator level trimmer to full counterclockwise. Key the rig again and the voltage from the RF probe should be zero. If not, there is carrier coming through the crystal filter. Slightly re-adjust the BFO trimmer so this voltage goes away. If the voltage goes up, your turning the trimmer the wrong way.

Remove power to the board, disconnect the RF probe and install the IRF-510 and heat sink. An insulator is not required between the tab of the '510 and the heat sink, as the anodizing is non conductive. However, a nylon screw is used for securing the '510 to the heat sink, so that if the nut should cut through the finish on the heat sink, no shorts to ground will occur.

Connect an amp meter in series with the power supply. Most DVMs have a 200 ma and 20 amp scale. Use the 20 amp scale, as the lower current scales are fuse protected and we can easily exceed 200 ma if not careful. Further, it is highly recommended to have a 2 amp fuse in series with the power supply to the board. **Also connect a RF power meter and 50 ohm dummy load to the antenna jack.**

1. Re-apply power to the board.
2. Turn the CW tone oscillator off by adjusting the V4 level trimmer fully counter clockwise. If your using a paddle, you can use the dot paddle to key the transmitter, but don't enable the tone oscillator by keeping the Dash paddle open.
3. Key the transmitter. Note the current being drawn by the board, which should be 90 to 100 ma.
4. Slowly turn up the PA bias voltage with V3, until the current increases by 10 to 20 ma. Be careful not to go much past this, as the bias voltage can quickly get to the point where the IRF-510 is fully turned on. At this point, it will draw as much current as the supply will deliver – that is until something fries! Thats why its important to have that 2 amp fuse in line and a box of spares handy!

Once the PA idle current is set, un-key the transmitter. Key the transmitter again and increase the CW tone level until the RF power output stops increasing. This should occur at between ½ and ¾ of a turn from full counter clockwise. Full power output with a 13.8V supply should be 4 watts or greater. Best power output can be tweaked by adjusting the spacing of the turns on the L2 and L3 LPF toroids. You will probably find the best power output is when the turns are somewhat bunched close together, instead of evenly space around the core. This adjustment can make a significant change in power output. With a little adjustment of these coils, full power output will be between 6 and 7 watts with a 13.8V supply. If you monitor both power output and supply current, you can also adjust the LPF coils to give the best PA efficiency. Try and find the point at which you get the most power output with the least amount of supply current. This should occur when the supply current is about 900 ma.

If you don't have a QRP RF power meter, the diode detector can be used instead. There is a hole just below the D.DET input which connects to the antenna jack. Put a short jumper between these holes to measure RF output voltage. Power output is approximately V*V / 100, assuming an dummy load very close to 50 ohms.

Power output will not be constant across the tuning range of the PTO and between the SSB and CW band segments. This is due to a change in PTO signal amplitude due to the brass screw. The band width of the transmitter band pass filter also reduces power output as the frequency moves from the center frequency it was peaked out. This effect will be more pronounced below the center frequency of the filter. Therefore, power output will be fairly constant over the voice segment of the band and fall off as much as a few watts at the low end of the CW segment. That is why power output should be peaked near the center of the band, 7.150 MHz.

Microphone gain:

Setting the mike gain control is a little tricker. Too much gain and the signal will flat top and distort. Too little gain and you will not have full modulation along with low power output. Start with the V1 trimmer set about 1/3d up from full counterclockwise. The best way to set the gain is to look at the transmitted signal with a 'Scope. Pictures of what a properly modulated signal should look like can be found in the ARRL handbooks. The next best option is to use a SSB receiver to listen to the signal and hear how it sounds. Be sure to use headphones with the monitor receiver and transmit into a dummy load. The exact setting depends on the sensitivity of the microphone and how loud you talk. If your like me, you probably talk louder into a mike than face to face to another person. Just one of those things. If you have no way to look or listen to the signal, leave the setting at mid scale and try to get on air reports for fine adjustment. (Maybe with a local ham you can coordinate with over a 2 meter repeter)

Mounting the board in the cabinet:

First, you will need to make a hole in the bottom cover plate to access the band select pins. The bottom cover is the one with the screw holes for securing the two half's together. Drill a hole 2.00” from the front edge of the cover and 1.125” from the right hand side. (looking at the cover from the outside). Elongate the hole with a hobby knife or file so you can easily access the pins and shorting plug.

100% scale drill templates are included in this instruction manual's software folder for drilling the front and rear panels. Open these files with MS paint and print. Most bit mapped file viewing programs will not print to scale, as they fit to page. The drill templates are viewed from the outside of the cabinet. The power connector has to stick through the panel a little, so you will have to square up the hole a little bigger than the outside edges of the connector.

Speaker:

A drill template to make a nice hole pattern for the speaker is also included. The center hole for the speaker should be located 2.5” from the front end of the cabinet top and 2.00” from the right side. Tape the drill diagram to the top of the lid and drill 1/16” guide holes through the paper at each hole center. Then remove the guide and drill the full sized holes. If you use the guide to simply put center punch dings in the plastic and then remove the template, the center punch dings will be very difficult to see in the black plastic.

Once the holes have been drilled and the hole edges de-burred, Center the speaker over the hole pattern and attach it to be lid by running a bead of hot glue along the edge. But first, only tack the speaker in place in a couple of spots and make sure the cover fits without the speaker hitting anything.

Putting the knob on the tuning screw:

A round, ¼" diameter plated brass spacer is supplied to put on the tuning screw so the knob will fit without wobbling. First, you will have to cut down the length of the screw so it doesn't stick out too far from the front panel when fully inserted into the coil. The quickest and easiest way of cutting the screw is with a Dremal cut off wheel. Its advised to use eye protection when doing this, as the wheel can shatter easily. A dust mask in also a good idea. Cut the screw about 1/2" from the head of the screw, producing a threaded rod 1 1/2" long. The spacer can be soldered to the end of the what is not a threaded rod, but remove some of the nickel plating off the end first, or you'll have a hard time getting the solder to stick to the spacer.

Microphone:

You will have to make or adapt a microphone to use with this rig. A common, inexpensive Electret mike cartridge is used. The simplest solution is to adapt an old CB mike. These come in two flavors, the dynamic and electret. The dynamics are often bad, as the cartridge can be damaged by abuse. These mikes often have a spot for an electret cartridge molded into the housing.

The mike for this rig has to be wired so its always under power. CB mikes wire the cartridge through the PTT switch, so this will have to be rewired. Remove the DIN plug on the end of the cord and wire up a 3.5 mm stereo plug, so that the mike connects to the sleeve (this is generally the yellow wire) and the PTT is connected to the tip (usually the red wire).

Making your own microphone:

This is easy enough to do. An electret cartridge can be salvaged from any number of sources. An old cordless phone or answering machine is the first place to look. Or you could go to your favorite discount department store and look for one of those cheap "hands free" cell phone adapters and pull it out of there. While at the department store, pick up a 99 cent pair of earbuds for the cord.

Once you have the electret cartridge, all you need is a normally open push button switch and something to mount them in. A half sized Altiods tin would work and make a cute little mike. If you use the full sized standard tin, there would be room to add a battery and a audio speech clipper for improved audio punch.

Another option is to use a block of wood and a dowel to make a desk mike. Lots of opportunity here to be creative.

Trouble shooting:

Hopefully, you won't have to any trouble shooting. If you do have to, remember that the most common reasons a kit does not work the first time are soldering problems and misplaced components. Therefore, many problems can be found simply by doing a very careful visual inspection of your workmanship. The chances of having bad parts is slim, unless they were damaged during installation. The 2N7000 are somewhat sensitive to static discharge. IC's can be damaged if put in backwards or in the wrong location, though some of them will survive this.

It you have problems, it is helpful to narrow down the area to look at the most closely. Often it is easier to determine which circuits are working properly first. Start with the audio circuits and work towards the antenna. The voltage tables shown below might help identifying problem areas.

First checks:

- Power supplies. Verify proper supply voltage to the board and output of 5 volt regulators;
- Check PTO oscillator for operation and proper output frequency
- Check BFO oscillator for proper operation. A general coverage HF receiver can be used for verifying the oscillator operation if nothing more suitable is available.

Voltage tables:
Voltages measured with 13.8 volt supply connected. There can be some variation in the voltages you measure do to loading of the particular DVM or voltmeter you use and part to part tolerances, in particular the voltage regulators. Only be concerned if the voltages are significantly different than those shown. Pin 5, U4 voltage depends on characteristics of Electret mike element used.

Pin#	***U3***	***U4 Rx***	***U4 Tx***	***U8***	***U5/6***			***U8 Rx***	***U8 Tx***
Pin 1	1.35	0	12.2	5.0	1.40			1.40	1.40
Pin 2	0	5.0	0	5.0	1.40			3.22	3.22
Pin 3	0	0.11	0.11	5.0	0			1.38	1.38
Pin 4	0	0	0	0	3.58			1.38	1.38
Pin 5	6.71	4-2	4-2	5.0	3.78			1.40	1.40
Pin 6	13.53	0.22	0.22	5.0	5.0			0	0
Pin 7	6.58	12.15	12.15	5.0	4.54			0	0
Pin 8	1.35	13.53	13.53	13.53	5.0			0	0
		CW mode					Pin 9	4.55	0
Pin 1		0	12.2				Pin10	4.55	0
Pin 2		5.0	0				Pin 11	4.55	0
Pin 3		0.22	0.22				Pin 12	1.38	1.38
Pin 4		0	0				Pin 13	3.8	3.8
Pin 5		0	0				Pin 14	3.32	1.4
Pin 6		0.11	0.11				Pin 15	1.4	3.32
Pin 7		0	0.63				Pin 16	5.0	5.0
Pin 8		13.53	13.53						

Transistors:

	C Rx	***B Rx***	***E Rx***		***C Tx***	***B Tx***	***E Tx***	
Q6	5.0	3.8	3.2		5.0	3.8	3.2	
Q8	0	13.5	13.5		13.2	12.7	13.5	
Q7	0	0	0		5.0	1.4	0.7	
Q9	13.53	0	0		13.53	2.8	2.1	

Fets

	D Rx	***G Rx***	***S Rx***		***D Tx***	***G Tx***	***S Tx***	
Q1	0	13.53	0		0	0	0	
Q2	0	13.53	0		0	0	0	
Q3	0	0	0		0	13.5	0	
Q5	13.5	0	0		0	13.5	0	
Q4	0	0	0		0	13.5	0	
Q12	13.5	0	0		0	12.52	0	
Q14	5.0	0	0.57		5.0	0	0.57	

Circuit description

The circuits can be divided up into several functional blocks:

1. Permeability Tuned Oscillator (PTO) – used for frequency tuning
2. SSB detector / generator and IF mixer
3. Audio stages
4. RF driver and power output amplifiers
5. T/R switching
6. CW generation

PTO:

The Permeability Tuned Oscillator (PTO) use a J310 j-fet in a Hartley configuration. This is one of the simplest oscillator circuits one can choose from and I found it to be the most stable by far. However, it might not be quite stable enough to be used with digital modes such as RTTY and PSK-31. Though if the software supports AFC, it might just work if transmissions are kept short.

The frequency of the oscillator is tuned by using a brass screw inserted into the L1 coil. The coil is wound on a # 6, Nylon threaded spacer with # 32 wire. This makes a convenient coil form and has the advantage of stabilizing the tuning screw, due to the fact it is threaded. In order to limit the number of turns of wire on the spacer to a reasonable amount, an additional inductor wound on a toroid core is used in series to provide the total amount of inductance needed by the oscillator to operate at about 3 MHz. The brass screw used for tuning causes the inductance of the PTO coil to decrease as it is inserted into the coil. This of course, causes the frequency of the oscillator to increase. The mixing scheme of this transceiver is such that increasing the VFO frequency decreases the operating frequency. This results in “backward tuning” of the rig. Clockwise rotation of the tuning knob lowers the operating frequency instead of rising it.

There isn't enough tuning range to cover the complete region 2 40 meter band, though for those outside the USA, that isn't much of a problem. The PTO has about a 130 kHz tuning range. To get the rig to work down in the CW portion of the band, C4 is removed from the circuit. This increases the oscillator frequency and hence lowers the operating frequency of the rig. If you want to cover the entire 40 M band, some means of switching the capacitor in and out of the the circuit will have to be devised. I used SIP header pins and a shorting plug. This is labeled “BSS” (Band Segment Select) on the schematic and board layout. Using a toggle or slide switch might increase drift of the PTO. Output from the oscillator is taken from the gate of the j-fet through a small value capacitor. A dedicated 5 volt regulator is used to supply power to the oscillator. The oscillator has a few 100 Hz initial warm up drift, then settles down nicely.

SSB detector / generator and IF mixer:

This section of the circuit is comprised of two SA602 mixers, a crystal filter and a 74HC4053 analog multiplexer to switch the filter between the inputs and outputs of the mixers. During receive, U6 is used to combine an input signal coming into the rig from the antenna with the Local Oscillator frequency (generated by the PTO) to produce the IF (Intermediate Frequency) of 10.000 MHz. The IF is routed to the crystal filter through one section of the 74HC4053 analog switch. Another section of the 'HC4053 routes the output of the crystal filter to the input of the product detector mixer, U5. The filtered IF is mixed with the BFO, which uses the internal oscillator section of the mixer, to produce an audio signal.

During transmit, the signal path between the two mixers is reversed. An audio signal is applied to the input of U5, which now acts as a balanced modulator. The output of the mixer is a signal which is the sum and difference of the audio frequency applied to the input and the BFO oscillator. This is double sideband modulation. To produce single sideband modulation, the signal must pass through the crystal filter, which removes one of the sidebands and any residual carrier. In the case of this filter, lower sideband is passed and the upper sideband is removed. The 'HC4053 switches now route the signal from the output of U5, through the crystal filter and into the input of U6. U6 combines the IF with the LO to produce a signal in the 40 meter band.

The third analog switch section of the 'HC4053 is used to switch a by-pass capacitor between input pins on U5 and U6 which need to be at RF ground depending on the direction the mixer is being used for at the time. Two 2N7000 T-FETS are used for additional by-passing of the mixer inputs. During receive, Q1 AC shorts the audio input to U5 to ground, preventing noise pick up, which can show up in the received audio output. During transmit, Q4 AC shorts the antenna side input of U6 to ground, ensuring any transmit signal which might leak past the QSK switch stays out of the mixer. Because Q4 adds capacitance across the tuned input IF transformer, an additional cap to resonate the 10.7 IF transformer to 7 MHz is not required. One is shown on the circuit diagram as 0 p, in case one wants to modify the rig to work on 75 meters.

Audio stages:

During receive, the audio signal produced by U5 is amplified using op amp U4b, by a factor of 100 (10 dB) and feeds the volume control or the CW audio band pass filter. U3, a LM386 audio amplifier provides additional gain and drives the speaker. In CW mode, the CW side tone is feed into pin 3 of U3, which provides a volume control independent side tone level to the speaker. Side tone level is controlled by a trimmer, V5. Audio muting during transmit is done with a 2N7000 T-FET, which simply shunts the input to the audio amp to ground. An R/C delay on the gate slows down the turn off time. This allows the transmitter time to fully decay to zero output and gives switching transits time to settle down, which would otherwise result in audio “thumps” and clicks.

During voice transmit, audio from the microphone goes through a simple R/C high pass filter to reduce or eliminate 60 cycle hum pick up. The V1 trimmer sets the audio level going into the U5 mixer, now being used as the balanced modulator. A common Electret capacitor mike is used. Power is required to run this type of mike, and is supplied by R22.

RF Driver and power amplifier:

The transmit signal produced by the U6 mixer is buffered by an emitter follower, Q6 to drive the low input impedance of the T4 IF transformer used as part of the transmit band pass filter. Two IF transformers are connected “back to back” to form a double tuned circuit. IF transformers are used here instead of toroid coils and trimmer caps. The metal can of the transformer provides good shielding, it takes up less space than a separate toroid with capacitor trimmer and is easier to ensure it will peak at the desired frequency. The output of the band pass filter is taken from the secondary winding of T3 and then amplified by Q7. The signal is further amplified by the driver stage, Q10 to provide a signal large enough to drive the gate of the power amplifier.

The PA is a IRF-510 power MOSFET. For linear operation, it requires a bias voltage of about 3 volts. This is produced by a 3.9V zener diode for regulation with the exact bias voltage needed being set by a trimmer resistor. Bias is set so there is about 10 ma of current flowing into the PA when no drive signal is present.

The output of the PA is coupled to a Low Pass Filter (LPF) which removes harmonics and ensures proper spectral purity of the output signal. C45 connected across L3 forms a trap at the second harmonic frequency. This significantly improves the second harmonic rejection and improves PA efficiency, over what is normally achieved using a 5 pole filter. The inductance of the two coils used in the LPF are not equal, as is normally the case for this type of filter. The values were optimized to provide some impedance matching between the PA output impedance and the load. This also increases power output and PA efficiency.

T/R switching:

T/R switching is controlled by the op amp U2b. The input to the non-inverting input is set to a fixed 3 volts, by the resistor divider R28 and R38. The inverting input is also connected to a resistor divider, but this time with unequal values and the ground end connected to a PTT or code key. When the PTT or code key is closed, the voltage on the inverting input changes from 6 volts to 1.9 volts. The output of U2b now goes from its normally low state to a high state. Q12 is used to invert the polarity of the op amp output, as both normally low and normally high states are needed for control.

When in the normally low state for receive, Q1 is turned on, shunting audio from the microphone to ground. Q4 is turned off, allowing signals from the antenna to pass into the U6 mixer. Q14 is also turned off, allowing audio to pass into the audio amp. Q9 is turned off, so there is no voltage is going to the transmitter amplifier stages. Finally, Q2 is on, while Q3 is off, allowing signals from the antenna to pass into the receiver input transformer.

When the output of U2b changes to the high transmit state, Q1 is turned off, allowing audio from the microphone to pass into the balanced modulator, Q4 is turned on, by-passing the antenna input of the U8 IF mixer to ground, Q14 is turned on, muting the audio output, Q2 is turned off and Q3 is turned off, isolating the receiver input transformer from the transmitter output signal. Q9 is turned on, supplying power to the transmit amplifiers and PA bias circuit. The PA bias voltage is delayed when Q9 is turned on by the 1 uF cap, C64 at the gate input resistor. This provides some wave shaping of the leading edge of a CW signal. When Q8 is turns off, C62 continues to supply voltage to the transmitter circuits as it discharges, providing tailing edge wave shaping to a CW signal.

The switch direction control pins for the 74HC4053 are connected to an R/C delay circuit and turned on and off through an isolating diode which is connected back to the output of U2b. When the rig goes into transmit, the control pins are pulled low through the diode. This causes the switches to immediately switch to the transmit configuration. When the rig switches back to receive, C39 in combination with R11 delays the switching back to the receive configuration by a few milliseconds. This ensures that the transmit signal is still being generated as the transmit amplifiers ramp down. This is important when CW mode is being used so that proper CW wave shape generation is produced.

CW generation:

The simplest way to make a SSB rig operate CW is to use a tone oscillator connected to the audio input. A single audio tone will produce a single output frequency. Otherwise, the BFO frequency would have to be shifted during transmit so that the carrier now falls into the pass band of the crystal filter, instead of being filtered out as it normally is for SSB operation. Shifting the BFO can be a little complicated and since we need a tone oscillator for side tone anyway, we might as well use that. The tone oscillator is a “twin T” configuration and produces about a 600 Hz tone with the values shown.

CW operation is enabled by simply plugging a mono plug into the microphone jack. This grounds the resistor supplying voltage to the mike element. An op amp senses that this voltage is at ground potential and causes its output to go from a normally high state to a low state. This output is connected to the emitter and base resistor of the tone oscillator. Now, when the transmitter is keyed, the full keyed supply voltage for the transmitter circuits appears across the tone oscillator, turning it on. A diode had to be added in series with the collector resistor for the tone oscillator transistor. This keeps the voltage coming from the op amp from back feeding through the bias resistors and transistor diode junctions into the keyed transmitter voltage line and tuning on the QSK fets.

Schematic