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Title: A 40 Meter CW/SSB Transceiver for the Homebrew Challenge
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A 40 Meter CW/SSB Transceiver for the Homebrew Challenge

This entry, the non-computer assisted winner, is a great fit to a backpack for portable operation.

Steven Weber, KD1JV

Meeting the $50 price goal for the ARRL Homebrew challenge turned out to be a little challenging. I didn't want to submit a "gutless wonder" that in theory would meet the specifications called for. If you're going to build a rig, it might as well be one that has a chance of actually making contacts. A few years ago I designed a fairly simple SSB rig for 75 meters. A quick "guess-timate" of the parts costs showed it would be a good candidate for this challenge

It took some creative thinking to get the costs down to within the objective and retain a good level of performance. Adding in the CW mode also complicated things a little. In the end, the goals were met and a really nice little SSB/CW QRP rig resulted.

Circuit Description — Overview

This transceiver is based on the classic Phillips SA602 receiver design. It's hard to say who first combined these two chips with a crystal filter to produce a simple HF receiver. For sure, the NE4040 rig of Dave Benson, K1SWL, and subsequent revisions helped popularize the concept.

My primary contribution to this basic design is the addition of an inexpensive CMOS analog multiplex chip to steer the signal flow direction through the crystal filter. This allows a single pair of SA602 mixers to be used as the receiver mixer and product detector while receiving, then as the balanced modulator and transmit mixer during transmit. To this basic transceiver "core," a VFO, audio and RF amplifiers, along with some TR switching was added, to produce a fully functional rig. There is nothing particularly special about these additional circuits.

Circuit Description — Details

Permeability Tuned Oscillator

The permeability tuned oscillator (PTO) uses a J310 JFET in a Hartley configuration. This is one of the simplest oscillator circuits and I found it to be the most stable by far. It isn't quite stable enough, however, to be used with modern digital modes such as RTTY and PSK31.

The frequency of the oscillator is tuned by a brass screw inserted into L1. This inductor is wound on a #6, nylon threaded spacer with 32 gauge wire. This makes a convenient coil form and has the advantage of stabilizing the tuning screw, because it is threaded. In order to limit the turns of wire on the spacer to a reasonable number, an additional inductor wound on a toroid core is used in series to provide the total inductance needed by the oscillator to operate at about 3 MHz.

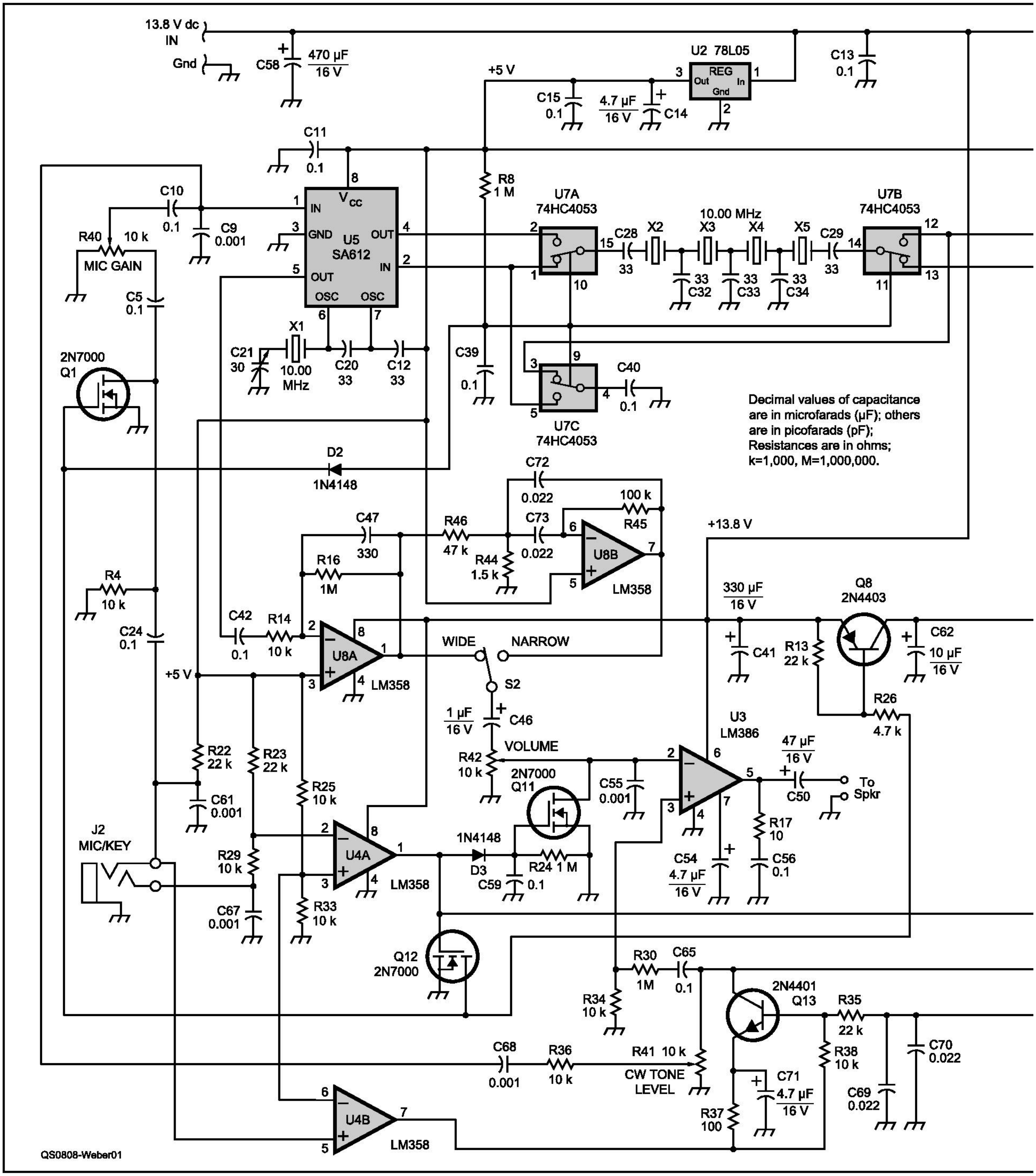
There isn't enough tuning range to cover the complete ITU Region 2 40 meter band, though for those outside the USA, that isn't much of a problem. The PTO has about a 130 kHz tuning range. To get the rig to work down in the US CW portion of the band, C4 is removed from the circuit. This increases the oscillator frequency and hence lowers the operating frequency. If you want to cover the entire 40 meter band, some means of switching the capacitor in and out of the circuit will have to be devised. I used single in-line package (SIP) header pins and a shorting plug. This is labeled BSS (band segment select) on the schematic and board layout.

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. The IF signal 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 bypass 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 FETs are used for additional bypassing of the mixer inputs. Because Q4 adds capacitance across the tuned input IF transformer, an additional capacitor to resonate the 10.7 MHz IF transformer to 7 MHz is not required. One is shown on the circuit diagram as 0 pF, 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 operational amplifier U4B, by a factor of 100 (40 dB) and feeds the VOLUME control, or optional audio CW fil-

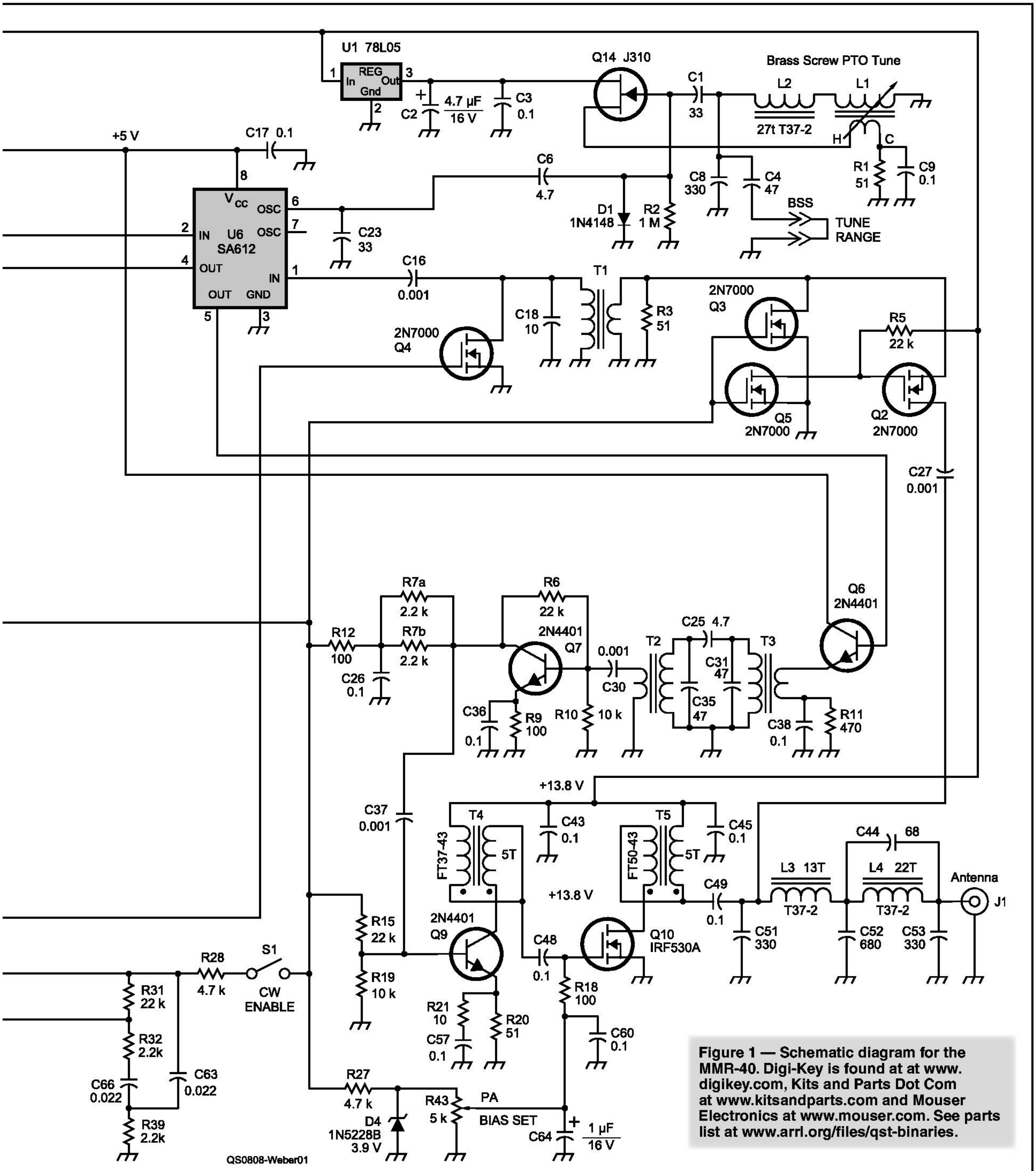


Figure 1 — Schematic diagram for the MMR-40. Digi-Key is found at at www.digikey.com, Kits and Parts Dot Com at www.kitsandparts.com and Mouser Electronics at www.mouser.com. See parts list at www.arrl.org/files/qst-binaries.

ters. U3, an LM386 audio amplifier, provides additional gain and drives the speaker. In CW mode, the CW sidetone is fed into pin 3 of U3, which provides a volume control independent side tone level to the speaker. Audio muting during transmit is performed by a 2N7000 FET, which simply shunts the input of the audio amplifier 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 Hz hum pick up. Trimmer R40 sets the audio level going into the U5 mixer, now being used as the balanced modulator. A common electret capacitor mic is used. The power required to run this mic is supplied by R22.

RF Driver and Power Amplifier

The transmit signal produced by the U6 mixer is buffered by emitter follower Q6 to drive the low input impedance of the IF transformer T3, used as part of the transmit band-pass filter. The output of the band-pass filter is taken from the secondary winding of T2 and then amplified by Q7 and Q9, to provide a signal large enough to drive the gate of the power amplifier, Q10.

The transmit power amplifier (PA) is an IRF530 power MOSFET. For linear operation, it requires a bias voltage of about 3 V. This is produced by a 3.9 V Zener diode for regulation with the exact bias voltage set by trimmer resistor R43. Bias is set so there is about 10 mA of PA current flow with no drive signal present.

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.

TR Switching

TR switching is controlled by operational amplifier U4A. The input to the noninverting input is set to a fixed 3 V by the resistor divider R25 and R33. 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. If the PTT or code key is closed, the voltage on the inverting input changes from 5 to near 0 V. The output of U4A now goes from its normally low state to a high state. Q12 is used to invert the polarity of the operational amplifier output, as both normally low and normally high states are needed for control.

Q1 is turned on, shunting audio from the microphone to ground in receive mode. 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 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.

During transmit, the output of U2B changes to high, Q1 is turned off, allowing audio from the microphone to pass into the balanced modulator. Q4 is turned on, bypassing the antenna input of the U8 IF mixer to ground. Q14 is also turned on, muting the audio output. Q2 and Q3 are 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 by the 1 μF capacitor, C64, at the gate input resistor because Q9 is turned on. This provides some wave shaping of the leading edge of a CW signal. When Q8 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 that 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.

CW Generation

The simplest way to make an 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. 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 that produces about a 600 Hz tone with the values shown.

CW operation is enabled by using a panel mounted slide switch to route the transmitter control voltage to the oscillator. To reduce costs, the mic jack is also used for the code key. The mic needs to be removed while using CW, so this works out. The PTT is wired to the tip of the plug, so a CW key with a standard mono plug can work.

Optional CW Audio Filter

Operating CW with only a SSB filter for selectivity can be annoying if there are other stations close by. There was room on the circuit board to squeeze in two audio band-pass filter stages to improve CW selectivity. The parts required for the filters are not included in calculating the cost of the rig, as they are not essential for its operation. It would be worth spending the extra couple of dollars to include these filters if you expect to use the rig much on CW.

KD1JV

Figure 2 — Details of the permeability tuned oscillator (PTO) tuning inductor. The PTO has about a 130 kHz tuning range, so a jumper is provided to move between CW and voice band segments.

A three position slide switch could be added to the front panel to select or bypass the filters. The first filter is relatively wide, with a Q of 3 and with a 600 Hz center frequency. This adds a little extra selectivity and might also be useful in SSB mode. The second filter is narrower with a Q of 5, also centered on 600 Hz for when you need even more selectivity to eliminate interference.

If responding to a CQ, you should try to match the tone received with the side tone frequency produced by the rig. This way, your frequency will match that of the other station. The addition of the CW audio filters help you match the other station's frequency by making the tuning shaper.

Construction and Test

This transceiver has been built using both "ugly construction" and on a PC board (shown in lead photo). Detailed construction, test and alignment instructions are provided on the *QST* binaries Web site.[1]

A complete kit, including a cabinet, is available from Hendricks Kits.[2] The instruction manual for the kit is worth taking a look at, no matter which method you use to build the rig. It is available for download from the Hendricks Web site. The kit manual includes information on interfacing the rig to a PC for digital mode operation.

Working with Low Power

By all definitions, this is a low power (QRP) rig. Five watts can be very effective while using CW mode. With voice, 5 W is a challenge. It's a lot harder for someone to copy a weak SSB signal than a weak CW signal. It helps to have the best antenna you can manage if you expect to work QRP sideband. Mostly, you have to be patient and persistent to make contacts. But that's the fun of it. Using 100 W is way too easy!

[1]**www.arrl.org/files/qst-binaries**.
[2]**www.qrpkits.com**.

Steve Weber, KD1JV, was first licensed in 1968 at the age of 15 and currently holds an Amateur Extra class license. Steve is well known in the low power (QRP) community as a prolific designer of kits and homebrew projects and is a member of the ARCI "QRP Hall of Fame" (2004). Steve can be contacted at 633 Champlain St, Berlin, NH 03570 or **kd1jv@ncia.net**. *He has a Web page at* **kd1jv.qrpradio.com**.