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Product Review

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QRP Labs QCX CW Transceiver Kit

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I wouldn't expect a $50 CW transceiver kit to have many of the functions found on a typical desktop transceiver, but the QRP Labs QCX QRP transceiver kit surprised me with its capabilities. It's a single band, CW-only transceiver with 5 W output from a 13.8 V power supply, and it will operate from 7 to 16 V. The QCX can be built for 80, 60, 40, 30, 20, or 17 meters. With the optional GPS receiver board, the QCX can also be used for WSPR (Weak Signal Propagation Reporter) operation. A companion case, shown in the title photograph, is available.

The main 4 × 3.2 inch QCX printed circuit board uses through-hole components except for two surface-mount ICs that are pre-installed, and all controls are mounted on the board. No additional test equipment is required to build, align, and operate this CW transceiver.

The radio features two VFOs and RIT (receiver incremental tuning). Tuning rate is adjustable — 1 kHz, 500 Hz, 100 Hz, or 10 Hz. The transceiver can operate in semi-break-in or full-break-in (QSK), with solid-state switching for silent operation. The built-in CW keyer can operate in iambic mode A or B, as well as ultimatic and straight key modes. It has 12 message memories, and there's a CW decoder as well. An onboard microswitch can be used as a CW key in a pinch. CW offset and sidetone are adjustable. A battery monitor keeps an eye on supply voltage. In short, this little radio is packed with useful features.

Circuit Highlights

The final transistors operate very efficiently in class E and run cool enough with no heatsinks. However, transmitting into a high-SWR antenna system or without a load connected may damage the final amplifier stage. The transmitter includes a low-pass filter for harmonic suppression and a shaped CW envelope to remove key clicks.

An Si5351A integrated circuit acts as a synthesized VFO with a rotary encoder for tuning (the encoder is also used for menu selection). Control, keying, and other functions come from an ATmega328P microcontroller, which also feeds the two-line LCD. Built-in test equipment is used for alignment and troubleshooting.

Bottom Line

The QRP Labs QCX kit packs a surprisingly complete set of features into a small and inexpensive package. Assembly requires some time and patience, but the builder is rewarded with a 5 W CW transceiver that is a joy to use on the air.

Many low-power transceiver kits are based on an SA602, SA612, or similar integrated circuits that act as a conventional mixer. The less complex designs are direct conversion, while more complex designs use an intermediate frequency (IF), say 5 MHz, and add a crystal filter for selectivity.

The QCX receiver works on a different idea. Figure 1 is a simplified block diagram of the receiver section. The input signal goes through a band-pass filter and phase splitter into a Tayloe detector (a quadrature sampling detector).[1] The output of this stage is two channels of double-sideband audio. They are 90 degrees apart and referred to as *I* and *Q* channels. These are further amplified and sent to a phase shifter, so the phase difference between the two *I* streams and two *Q* streams is now increased by an

[1]Quite a bit of information on the quadrature sampling detector is available online. For example, see **www.youtube.com/watch?v=JuuKF1RFvBM**; **wparc.us/presentations/SDR-2-19-2013/Tayloe_mixer_x3a.pdf**, and **www.arrl.org/files/file/Technology/tis/info/pdf/020708qex013.pdf**.

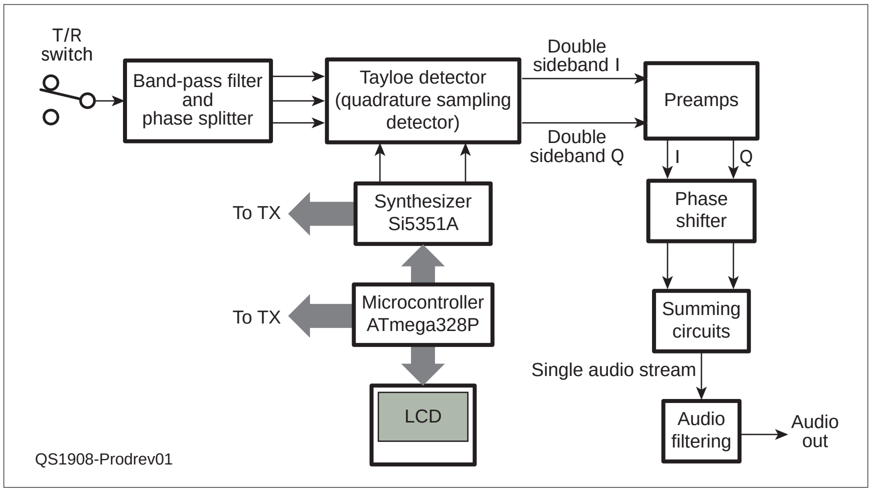

Figure 1 — Signal flow is from top left to bottom right. The two double-sideband detected signals are combined into one audio signal.

additional 90 degrees. When summed, one sideband is nulled out by the resulting 180-degree difference, and one sideband is increased in amplitude by having a zero-degree difference.

The circuit must be adjusted to make the relative amplitude identical and 90-degree phase shifts accurate. This is accomplished in a brief setup procedure using test signals and a display built into the QCX. Performance, as measured in the ARRL Lab, is given in Table 1 and Figures 2 and 3.

Building the Kit

I recommend that a prospective builder gain experience with simpler kits before tackling this one. There are quite a few parts to install, including several toroids to be wound. Assembly is straightforward, with an excellent set of well-illustrated instructions, but you will be making more than 280 soldered joints on a densely packed PC board.

The assembly instructions are available online. Documentation includes a block diagram, a full schematic diagram, and a full-page wiring diagram showing all interconnects. Stage-by-stage explanations clearly describe the function of circuit elements.

I learned a new trick from the instructions. If you have to remove a component, clearing the solder holes can be challenging. The instructions suggest using a pointed wooden toothpick. As you heat the hole to remove the remaining solder, the wood will not carry away the heat, and you can just shove it through the hole.

Parts are inserted in order of height — the ones closest to the board go in first. Each group of parts has its own illustration, with the locations of the parts to be inserted highlighted in red. Figure 4 shows part of an illustration accompanying a step for inserting 16 capacitors. To make sure you have not skipped anything, put a black pencil dot on the red-coded component after you install it. When you are finished with that step, look for any red components without black dots.

Preparation is Key

The instructions are clear and straightforward, but there are a few things you can do ahead of time to make assembly go smoothly. Use a multimeter or good magnifier to identify the resistor and capacitor values. Watch for two inductors that look like resistors — L5 and L6. Switches S2 and S3 are rectangular, so care must be taken to install them correctly. The instructions tell you to make sure the 28-pin socket lays flat on the board. You can either follow the hints in the text or tape it down before soldering it in place.

There are several places where you have to make a decision. If you intend to mount the finished transceiver in your own enclosure, you may not want to mount the controls on the PC board. When you get to the point of installing the pushbuttons, jump ahead to the section on wiring the controls off the board to see what works best with your enclosure.

QRP Labs offers an optional QLG1 GPS receiver for WSPR operation. While building the transceiver, another decision point is the connection of the cable to the GPS unit, if you plan to incorporate one. (See the notes later in this review about how the GPS cable works with the companion enclosure.)

To complete the assembly, you have to wind five toroidal cores. Three are used for the transmitter low-pass filter and one for the transmitter class-E resonant circuit. How to wind them is well covered in the directions.

The fifth toroid is the receiver input phase splitter/band-pass filter transformer. It has three small windings and one large winding. The large winding with an associated capacitor is resonant on the band you selected for your unit. If you are building a 40-meter unit, there may not be enough room for the full transformer winding. (This is also true for the 80-meter unit.) The instructions tell you that it is okay to overlap turns to fit on the toroid. However, you need room for the three smaller windings. I wound the three small windings first and then the large winding, thus ensuring there was enough room for the small windings. A later posting on the QCX online discussion group said it was okay to do the large winding first, and then install the smaller windings on top.

Alignment and Test

Everything you need to align and test the QCX is built into the unit, and three pages in the instructions detail the step-by-step alignment procedure. Built-in test equipment includes a voltmeter, power meter, frequency

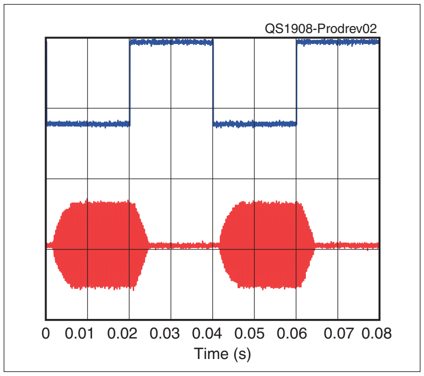

Figure 2 — CW keying waveform for the QRP Labs QCX 40 showing the first two dits using external keying. Equivalent keying speed is 60 WPM. The upper trace is the actual key closure; the lower trace is the RF envelope. (Note that the first key closure starts at the left edge of the figure.) Horizontal divisions are 10 ms. The transceiver was being operated at 5 W output on the 7 MHz band.

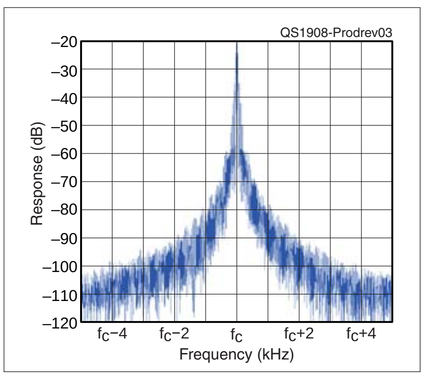

Figure 3 — Spectral display of the QRP Labs QCX 40 transmitter during keying sideband testing. Equivalent keying speed is 60 WPM using external keying. Spectrum analyzer resolution bandwidth is 10 Hz, and the sweep time is 30 seconds. The transmitter was being operated at 5 W PEP output on the 7 MHz band, and this plot shows the transmitter output ±5 kHz from the carrier. The reference level is 0 dBc, and the vertical scale is in dB.

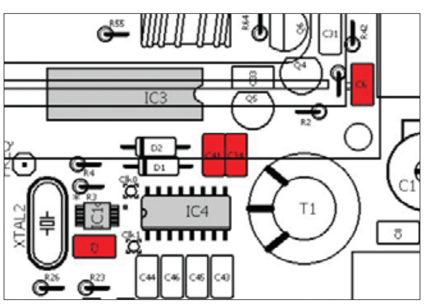

Figure 4 — Part of a figure from the instructions that shows where capacitors are mounted, as indicated by the red coloring.

Table 1
QRP Labs QCX-40, serial number n/a

Manufacturer's Specifications	Measured in the ARRL Lab
Frequency coverage: 40-meter amateur band.	Receive and transmit, as specified.*
Power requirements: 7 V dc minimum to 16 V dc maximum.	At 13.8 V dc: Receive, 123 mA; transmit 682 mA.
Modes of operation: CW; WSPR is available with the optional GPS receiver installed.	As specified.
Receiver	**Receiver Dynamic Testing**
Sensitivity: Not specified.	Noise floor (MDS): –128 dBm at 7 MHz.
Noise figure: Not specified.	7 MHz, 19 dB.
Blocking gain compression dynamic range: Not specified.	Blocking gain compression dynamic range: 20 kHz offset, 131 dB; 5/2 kHz offset, 111/103 dB.
Reciprocal mixing dynamic range: Not specified.	Not measured. Low-noise 7 MHz oscillator not available.

ARRL Lab Two-Tone IMD Testing

Band	*Spacing*	*Measured IMD Level*	*Measured Input Level*	*IMD DR*
7 MHz	20 kHz	–128 dBm	–28 dBm	100 dB
		–97 dBm	–14 dBm	
		–60 dBm	0 dBm	
7 MHz	5 kHz	–128 dBm	–48 dBm	80 dB
		–97 dBm	–28 dBm	
		–21 dBm	0 dBm	
7 MHz	2 kHz	–128 dBm	–57 dBm	71 dB
		–97 dBm	–39 dBm	
		–20 dBm	0 dBm	

Second-order intercept point: Not specified.	14 MHz, +49 dBm.
IF/audio response: Not specified.	Range at –6 dB points: 640 – 890 Hz (350 Hz); Equivalent Rectangular BW, 289 Hz.
Receive processing delay time: Not specified.	4 ms.
Transmitter	**Transmitter Dynamic Testing**
Power output: 3 – 5 W depending on supply voltage.	0.16 W at 7 V dc; 2.3 W at 10 V dc; 3.5 W at 12 V dc; 4.9 W at 14 V dc; 6.4 W at 16 V dc.
Spurious-signal and harmonic suppression: >50 dB.	54 dB. Meets FCC emission standards.
CW keyer speed range: Not specified.	1 to 104 WPM, iambic A and B.
CW keying characteristics: Not specified.	See Figures 2 and 3.
Transmit-receive turnaround time: Not specified.	S-9 signal, 22 ms.
Transmit phase noise: Not specified.	See "Lab Notes."

Size (height, width, depth, incl. protrusions): 2.3 × 5.2 × 3.8 inches. Weight, 9.6 oz.

Second-order intercept point was determined using S-5 reference.

*The QCX can be built for 80, 60, 40, 30, 20, or 17 meters. 40-meter version tested. Transmitter is capable of transmitting outside of the 40-meter band. See "Lab Notes."

counter (up to 8 MHz), and signal generator (3.5 kHz to 200 MHz). It's best to connect a 50 Ω dummy load to the antenna jack during the alignment steps.

After choosing the band and frequency, you want to maximize receiver gain, so the first step uses the signal generator to peak the input resonant circuit. A clear set of pictures show how to tell the trimmer capacitor is in its proper range or at the end of its adjustments.

The next three steps adjust the I/Q balance and the phase shift for the best unwanted sideband cancelation. These three steps are repeated for minimum output on the built-in LCD. Then you are finished!

Remember to reconnect the antenna after alignment. If you accidently transmit without an antenna or dummy load, you may overheat the final stage transistors.

Using the Enclosure

Once you have the PC boards assembled, you can use the QCX as-is and show it off to visitors or at the local club. If you do want to package it, a good choice is the companion metal enclosure sold by BaMaTech in Germany (**www.bamatech.net**). The front panel is an attractive printed film overlay on the metal case top, but you have to take care not to scratch the film. Figure 5 shows the completed unit, with the LCD plugged in and installed in the case.

The case comes with all parts needed to mount the QCX board, as well as rubber feet and a small Allen wrench needed for the knob extenders. On the right side of the bottom section is an opening for the optional QRP Labs QLG1 GPS unit connecting cable. Note that once you have closed the case, you cannot disconnect or reconnect the cable without disassembling the enclosure top — which is more than a few minutes of work. If you are not going to connect the QCX to the GPS unit, a cover for the small access opening and two mounting screws are included.

Operation

As noted earlier, the final stage of the transmitter runs class E, which is very efficient. You can damage it by connecting the QCX to a high-SWR load or, more likely, forgetting to connect the transmission line entirely.

When you first apply power, you will most likely be in the CW mode on a single frequency, ready to go. Section

Figure 5 — The finished QCX PC board with the two-line LCD plugged in on top and installed in the BaMaTech case. The power connector is toward the top left edge and the BNC RF output on the top right edge. The left-hand knob is the volume control, and the right-hand multipurpose knob changes frequency and makes menu selections.

Lab Notes: QRP Labs QCX Transceiver Kit

Bob Allison, WB1GCM, ARRL Laboratory Assistant Manager

Paul, N1II, initially built an 80-meter QCX kit. Testing in the ARRL Lab revealed a second harmonic 37 dB below the fundamental. To be compliant with FCC Part 97 standards, 43 dB of harmonic and spurious emission is required. The 80-meter QCX also generated noticeable key clicks. We contacted Hans Summers, GØUPL, at QRP Labs. Hans discovered that the CW rise time was too fast, generating key clicks, and changed the values of C31, R41, and R42 in the MPS751 keying circuit. He also fixed a bug in the firmware. These changes were made in production, and modification information for earlier kits is available on the QRP Labs website. At press time, Hans had determined that our 80-meter QCX had a defective MPS751 in the keying circuit but had not found out why the harmonic suppression was less than expected.

We obtained a 40-meter version of the QCX, and the test results in Table 1 are based on that unit. It has 54 dB of harmonic and spurious emission suppression, more than enough to meet FCC standards. It also has adequate keying waveform shaping to prevent key clicks and wide keying sidebands. Transmitted phase noise is low, better than –135 dBc at 10 and 50 kHz from the carrier.

The 40-meter QCX transceiver is an overall good performer. It has more than enough sensitivity for 40-meter operation and does a good job with strong adjacent signals, although a strong station (say, S-9 + 40 dB) that is 2 kHz away from the tuned frequency will be heard weakly, bleeding through the filter.

Of interest to field operators who have experienced a failing battery, this little transceiver will keep receiving and transmitting all the way down to a supply voltage of 7 V dc, although the output power is really low at that voltage.

Although the QCX-40 has a 7 MHz band-pass filter, it will transmit on other bands. Do not do this — the harmonics will exceed FCC requirements. Instead, get a QCX with the appropriate filter for the band you're interested in.

4 in the menu selects keyer mode, speed, and sidetone settings. From here, go to menu section 3, **VFO**, to set the rest of the operating conditions. This little transceiver allows you to set and vary a host of functions, just like many full-size tabletop radios.

If there is no sign of power output, before breaking out the test equipment, first go to menu item 6.2 and check that the mode selected is CW. Next, go to menu item 4.7 and see that the code practice setting, which inhibits transmission, is set to off.

Toward the end of the assembly manual is a cheat sheet with some basic instructions on how to use the RIT, change the tuning rate, and a few other common operating functions. In my case, I could not wait to try out the QCX, so I just chose a comfortable keyer speed and started operating. After using it a while, I forgot I was not on my 100 W tabletop rig.

The next day, I was able to try out more of the available functions. The CW decoder worked, but not surprisingly, it was sensitive to the selected speed. I contacted two DX stations who were using split-frequency operation without difficulty. There is no AGC and there is plenty of audio, so you might have to ride the volume control as you tune across the band. I left the CW offset and sidetone frequencies at the default settings but turned down the sidetone volume a bit. In summary, this little unit functions as a capable single-band CW transceiver at an amazing size and cost.

Support

QRP Labs has sold thousands of these kits, and if you have a question, help is readily available. A great resource is the online group at **groups.io/g/QRPLabs**. You can also seek support by using a link from the QRP Labs website. Responses to questions are often emailed back within 24 hours. Several videos and a number of helpful newsletters and documents may be accessed from the QRP Labs website as well.

Next month, we'll take a look at the companion QLG1 GPS receiver kit, WSPR operation, and the optional dummy load kit.

Manufacturer: QRP Labs, Mugla, Turkey; **www.qrp-labs.com**. Price: QCX kit (specify band), $49. Built and tested units are occasionally available at $89. Postal service airmail shipping to the US typically takes 2 – 3 weeks and starts at $7. The enclosure kit is available from BaMaTech in Germany (**www.bamatech.net**) for about $36 plus about $8 shipping (varies with the current Euro exchange rate).