The ZZRX-40 Direct Conversion 40 Meter Receiver

Source your own parts or buy the kit — either way, it's a fun project!

Craig Johnson, AA0ZZ

While experimenting with one of the ubiquitous receiver designs that use an NE602 mixer and LM376 audio amplifier, I was amazed at how well they performed with so few components. There are many ways to make them "better," and builders differentiate their own designs. Our club had been looking for simple projects for our build-a-thons. The project described here could be interesting for the many fairly new builders in the club.

The ZZRX-40 receiver doesn't break any new ground. It packages some ideas that have been around since shortly after the NE602 was introduced by Signetics in the 1980s. Pairing the NE602 and LM386 has inspired many receiver and transceiver designs.[1, 2, 3]

Design Strategy

One of my prime design requirements was to design a project that worked "right out of the box," with no adjustments or tweaks. Okay, if you are using the VFO option, you may want to tweak the variable capacitor to make the tuning start at the bottom edge of the 40 meter band. However, if you use the jumpers to select the crystal-controlled oscillator at first, you just connect an antenna and headphones, apply power, and you will start to hear signals. That's sure to bring big smiles to the faces of first-time builders and old-timers alike — as it did at our club build-a-thon. "Hey, I built this, and it works!"

The ZZRX-40 is interesting because of the unusual enclosure. The builder solders PCB boards together, which gives the case a homebrewed, but polished look, seen in the lead image and in Figure 1. The corners are notched to assist in board alignment, so it takes just a few minutes to make a nice case.

As you can see in the circuit diagram in Figure 2, this is a bare-bones, direct-conversion radio. The front-end filter is deliberately wide so it doesn't need any tuning coil or capacitor adjustments.

Using the ZZRX-40

Apply 9 to 13 V from a battery or power supply to J1, or connect a four-cell 6 V battery pack to header HDR3. Connect an antenna to J2 and headphones to J3. Turn R1 clockwise to maximum volume, and if you are using the crystal-controlled VFO, you should hear signals immediately. Turn the tuning potentiometer R2 to pull the crystal frequency a few kilohertz on each side of its nominal frequency.

If you selected the VFO in header HDR4, advance the tuning knob clockwise about ⅓ of the way up from minimum. This should be approximately 7.0 MHz. Tuning is very sensitive, but you should be able to receive CW, SSB, and AM signals.

Tuning CW Signals

As you tune in CW signals in a DC (direct conversion) receiver such as this, the sound will be equally strong on the lower and upper sides of center zero-beat. It may sound strange if you are accustomed to listening to CW signals with one sideband suppressed, as they usually are in modern receivers. This is done to minimize interference from nearby stations. Many direct conversion receivers such as this ZZRX receiver do not have circuitry to suppress one sideband or the other, so you hear them both as you tune across the signal. There really isn't a convention for which side to listen to for CW stations. Some suppressed-sideband receivers use the lower side of zero-beat and others use the upper side. Some of these CW receivers allow you to change from one side to the other. They usually refer to the two sides as

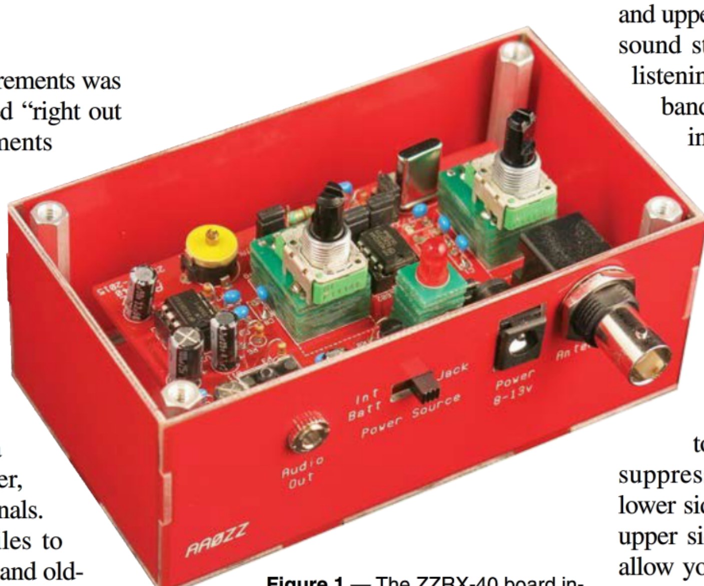


Figure 1 — The ZZRX-40 board inside a box constructed from PCBs.

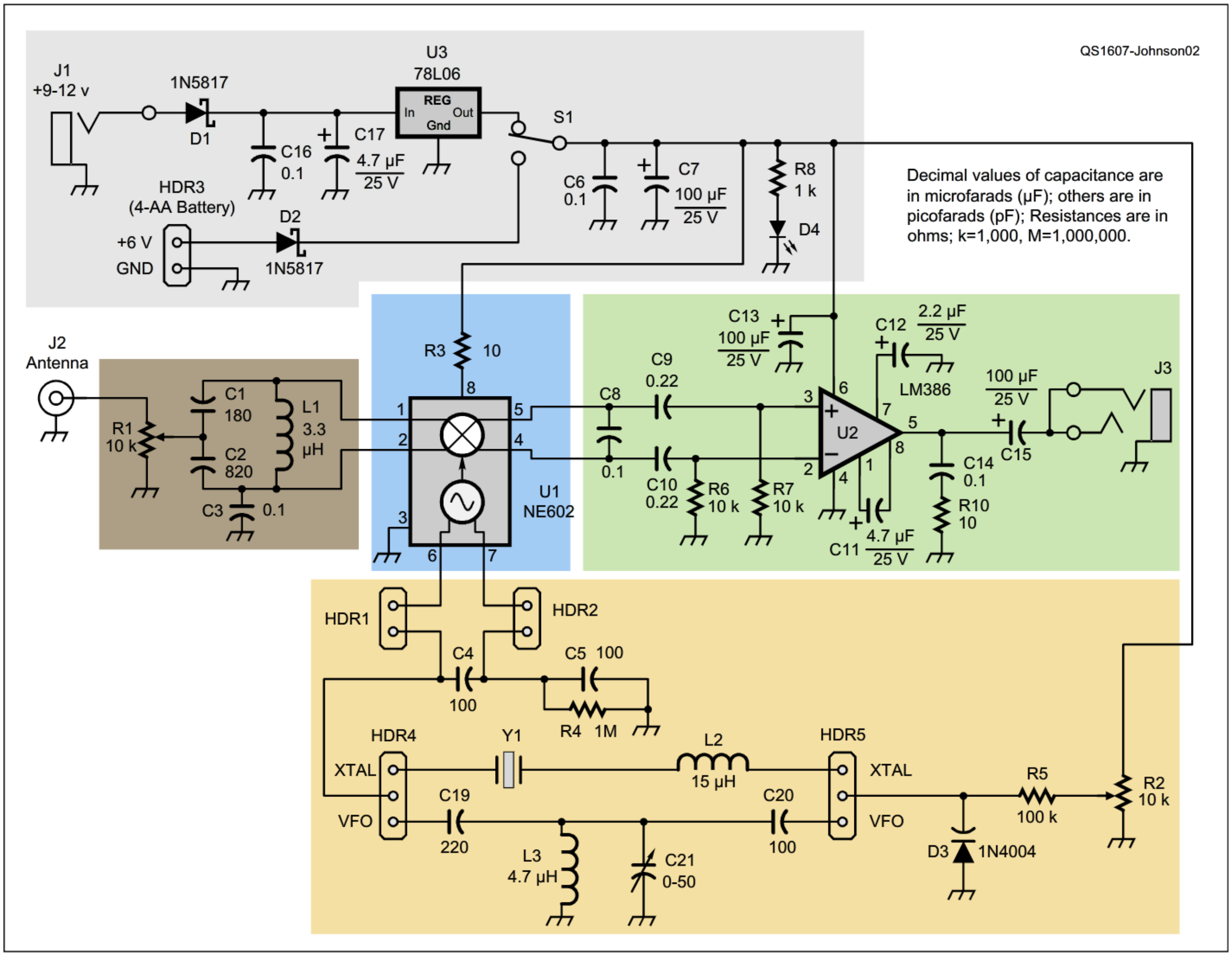


Figure 2 — Schematic diagram of the ZZRX-40 receiver.

C1 — Capacitor, 180 pF
C2 — Capacitor, 820 pF
C3, C6, C8, C14, C16 — Capacitor, 0.1 µF
C4 — Capacitor, 100 pF
C5 — Capacitor, 100 pF
C7, C13, C15 — Capacitor, 100 µF
C9, C10 — Capacitor, 0.22 µF
C11, C17 — Capacitor, 4.7 µF
C12 — Capacitor, 2.2 µF
C18 — (Not used)
C19 — Capacitor, 220 pF
C20 — Capacitor, 100 pF
C21 — Trimmer capacitor, 0 – 50 pF
D1, D2 — Diode, 1N5817
D3 — Diode, 1N4004
D4 — LED, red
HDR1 – HDR3 — Two-pin header
HDR4, HDR5 — Three-pin header
J1 — Power socket, dc
J2 — RF socket, BNC
J3 — Audio jack
L1 — Inductor, 3.3 µH
L2 — Inductor, 15 µH
L3 — Inductor, 4.7 µH
R1, R2 — 10 kΩ potentiometer
R3 — Resistor, 10 Ω
R4 — Resistor, 1 MΩ
R5 — Resistor, 100 kΩ
R6, R7 — Resistor, 10 kΩ
R8 — Resistor, 1 kΩ
R9 — (Not used)
R10 — Resistor, 10 Ω
U1 — RF IC, NE602
U2 — Audio amplifier IC, LM386N-1
U3 — Regulator IC, 78L06
Y1 — Quartz crystal, user choice, 40 meter band

CW and CW-Reverse. For CW signals in the ZZRX, listening to either side of zero-beat is possible, and both will be nearly the same volume. If one side or the other experiences interference from a nearby station, you can just move a little and listen to the other side.

Tuning SSB Signals

SSB signals tuned with the ZZRX will also be equally strong on the LSB and USB sides. This may sound strange if you are accustomed to listening to SSB signals on a receiver that suppresses one sideband. The ZZRX receiver is a direct conversion receiver, so it doesn't have circuitry to suppress one of the sidebands. You hear both of them. Suppressing one side or the other is done in receivers to minimize interference from nearby stations. An SSB transmitter only transmits one of the sidebands for efficiency reasons. By convention, SSB stations on the 40 meter band use LSB for voice transmission. In many modern receivers, when set to receive the correct-by-convention sideband, the signal will be intelligible on the correct sideband. With this DC receiver, as you advance upward in frequency you will hear the SSB stations start high in tone and go lower. As you continue to advance the frequency, the tones of the SSB station reach a low point and then start to get higher again. The first side you heard (lowest frequency) was the UPPER sideband and the second side (higher frequency) is the LOWER sideband. I know, this is counter-intuitive, but technically correct. [Readers may find the *QST* article "About SSB," by Ward Silver, N0AX, helpful.[4] — *Ed.*] In the 40 meter band, because of the convention, you will find the SSB speech to be unintelligible on the USB side and intelligible on the LSB side.

Theory of Operation

Figure 3 shows a block diagram of the basic DC receiver. The RF signal from the antenna passes through a broad front-end filter, then downconverts in a mixer to base-band audio. An audio amplifier and audio filter signal amplify the signal and reproduce it on the speaker.

Front-End Filter

The signal from the antenna passes via the BNC connector J2 (see Figure 2) to a gain control potentiometer R1, then to a simple RF band-pass filter (C1, C2, and L1), which is also an impedance transformer. The capacitive divide circuit transforms the antenna impedance to the 1500 Ω input impedance of the NE602. The band-pass filter was designed with a low Q and is centered on 7 MHz. Unlike a sharper (higher Q) filter, this design does not require any front-end tuning adjustments.

Mixer

The NE602 (U1) has been the workhorse mixer for receivers, transmitters, and transceivers since it was introduced in the 1980s. It performs well, but it has limitations — mainly its dynamic range. It provides a signal gain of 18 dB, and has a local oscillator (LO) that can be tuned with a crystal or tank circuit. It can also act as a buffer for an external VFO or signal generator. Mixing an LO with an incoming RF signal of slightly different frequency, say 600 Hz higher, produces an audio tone of 600 Hz.

Table 1
LO Frequency and Varactor DC Voltage

Frequency	Voltage on D3
7.000 MHz	0.0 V
7.348 MHz	6.0 V

Local Oscillator

The ZZRX standard configuration uses a crystal-controlled oscillator. The crystal oscillator is configured with a fixed inductor and a 1N4004 diode D3 used as a voltage-controlled capacitor (varactor) in series with the crystal. The crystal frequency is changed by a few kilohertz as the voltage applied to the varactor is varied by turning the knob on tuning potentiometer R2.

The ZZRX crystal oscillator can be changed into a VFO by altering two jumpers, HDR4 and HDR5. Now, series inductor L2 is replaced with inductor L3 that resonates with the varactor capacitor D3. C20 decouples the dc tuning voltage from ground via L3.

This very simple VFO is made from a few inexpensive components. Using a 1N4004 as a varactor tuning element limits the capacitance range to approximately 35 pF to 15 pF as the voltage changes from 0 V to 6 V (see Table 1). Tuning is very sensitive. Trimmer capacitor C21 sets the lower limit of the 40 meter band. You can do this with a frequency counter connected to the top end of resistor R4, or by listening for the ZZRX LO signal in a nearby receiver. Potentiometer R2 should be turned completely counterclockwise when setting the lower frequency limit.

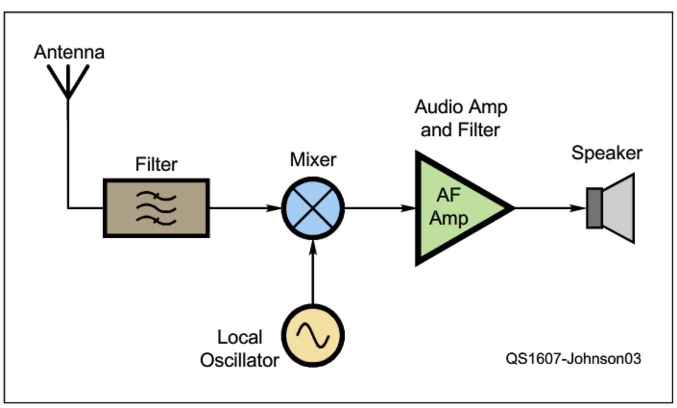
Using an External VFO or Signal Generator

The two 2-pin headers HDR1 and HDR2 have jumpers to select the built-in crystal-controlled oscillator or the simple VFO. If you want to use an alternate VFO or a signal generator, remove both jumpers and inject your VFO signal into the U1 side pin of HDR1.

Audio Amplifier

Amplifier U1, the LM386N-1, is configured, with C11 between Pins 1 and 8, to provide a gain of 200. It also provides some filtering that blocks signals above 300 kHz. The series combination of C14 and R10 provide additional audio filtering.

Figure 3 — Block diagram of the simple direct conversion receiver.



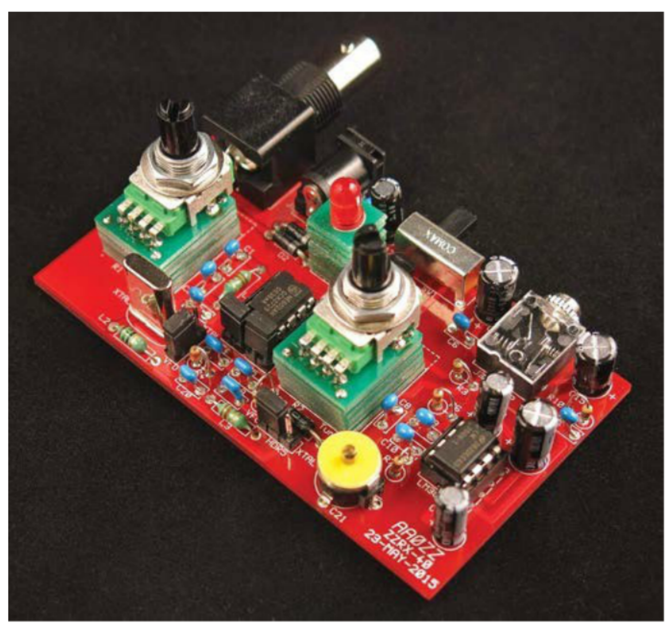


Figure 4 — A completed ZZRX-40 circuit board.

Additional Help for Build-a-Thons

A complete illustrated theory of operation, user manual, and printed circuit board template image are on the *QST* in Depth web page.[5] I would like to thank Wes Hayward, W7ZOI, for his helpful suggestions in the final tweaks of the schematic part values. For up-to-date details and further documentation about this project, please see my web page, **www.aa0zz.com**. Boards, parts, and enclosures are available from the Four States QRP Group, at **www.4sqrp.com/zzrx40.php**.

Notes

[1]W. Hayward, W7ZOI; R. Campbell, KK7B; B. Larkin, W7PUI, *Experimental Methods in RF Design*, available from ARRL, Item no. 9239 available from your ARRL dealer, or from the ARRL Store. Telephone toll-free in the US 888-277-5289, or 860-594-0355, fax 860-594-0303; **www.arrl.org/shop/**; **pubsales@arrl.org**.

[2]J. Dillon, WA3RNC, "The Neophyte Receiver," *QST*, Feb 1988, pp 14 – 18.

[3]S. Bornstein, K8IDN, "The MRX-40 Mini Receiver," *QST*, Sep 1997, pp 59 – 60.

[4]H. Ward Silver, N0AX, "About SSB," *QST* Jan 2016, pp 51 – 54.

[5]**www.arrl.org/qst-in-depth**

Photos courtesy of the author.

Craig Johnson, AA0ZZ, was licensed in 1964 at the age of 14. He credits ham radio with sparking his interest in electronics and pointing him toward a career in electrical engineering. He received a Bachelors degree in Electrical Engineering, and later an MBA. Craig lives in St Paul, Minnesota. He worked for Unisys for 35 years on the design and development of large, mainframe computers and operating system software, then switched to working with microprocessor hardware as well as software development. He holds seven US patents related to computer hardware and software. Craig loves to explore the overlap between computers and Amateur Radio that came about with the advent of microprocessors. He developed many projects using microprocessors, especially for frequency synthesis (DDS and PLL) in VFOs. He greatly enjoys helping others to understand how to use microprocessors in their own projects. Craig enjoys CW, operating QRP, DXing, and contesting, but he is happiest when he is tinkering, building, or experimenting with new designs, circuits, and software. You can reach him at 4745 Kent St, Shoreview, MN 55126, or at **aa0zz@arrl.net**.

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Strays

The Faces Behind Logbook of The World

ARRL's Logbook of The World Study Committee meets every month by teleconference, but once per quarter they convene at ARRL Headquarters in Newington, Connecticut to review the status of the world's most widely used electronic QSL system. Shown here at their May 3 meeting, from left to right: Doug Haney; Rick Murphy, K1MU; ARRL Field Services and Radiosport Department Manager Dave Patton, NN1N; ARRL Field Services and Radiosport Department Assistant Manager Norm Fusaro, W3IZ; ARRL Information Technology Manager Michael Keane, K1MK; ARRL First Vice President Greg Widin, K0GW; Dave Bernstein, AA6YQ, and ARRL Chief Financial Officer Barry Shelley, N1VXY (seated). Not shown: ARRL Principal Web Development Engineer Dennis Budd, K3DGB; ARRL Treasurer Rick Niswander, K7GM, and ARRL Roanoke Division Director Jim Boehner, N2ZZ.