

# A Simple High-Frequency Communications Receiver



## James Forkin, WA3TFS

I had to take a new approach for this 40-meter transceiver project, as many of my favorite components are no longer available as through-hole parts. Tiny surface-mount devices (SMD) and components are difficult for many builders to handle. Two modules I used for this project do have SMDs, but they are pre-assembled and just plug into the circuit board. This article explains the receiver portion of my transceiver project (see the lead photo). This receiver can also be built to receive 160 or 80 meters, but will require changes to the input band-pass filter.

Frequency control is based on an off-the-shelf DDS module and an Arduino Nano microprocessor. I also selected a 1.44-inch color LED display, but you can easily substitute a 1.8-inch display.

This elegantly designed radio includes a microcomputer controller.

The adjustable bandwidth crystal filter has a good response for AM, SSB, and CW signals, and is a unique feature for this design. This filter uses three 9 MHz crystals and some varactor diodes to control the bandwidth. A fourth 9 MHz crystal is used in an oscillator to generate the beat frequency oscillator (BFO) injection. Frequency stability is excellent. [Note: This receiver is designed for lower sideband (LSB) only, so it is not suitable for most digital modes, including FT4 and FT8, which require the use of upper sideband. — Ed.] Double-balanced diode mixers are used for front-end mixing and detection of the received signals.

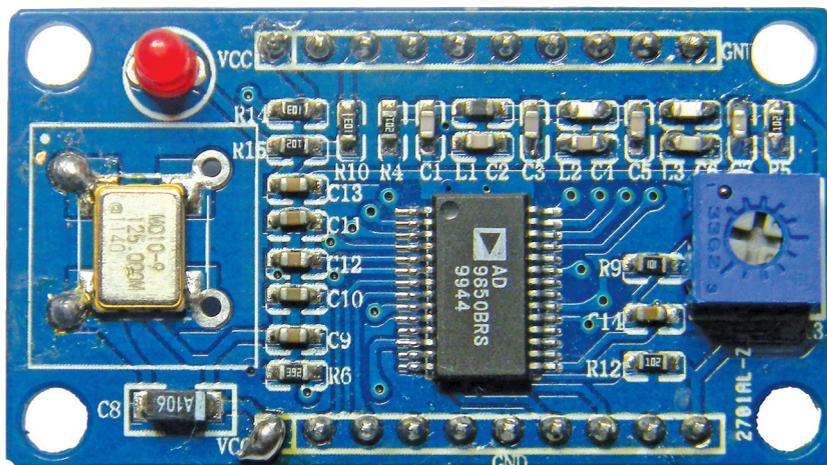


Figure 1 — The DDS module.

## Circuit Design

The full receiver schematic, parts layout, input band-pass filter, and other details are on the *QST* in Depth web page, at [www.arrl.org/qst-in-depth](http://www.arrl.org/qst-in-depth). An antenna connects to a broadband single-stage RF preamplifier and then to a multi-stage band-pass filter designed for the 40-meter band (7.0 MHz to 7.3 MHz). You must wind three toroidal coils for this filter on T37-2 toroid cores. The inductors for the preamp and the two IF stages are bifilar windings on FT37-43 toroid cores. The required number of turns is noted on the schematic. To use this receiver on another band, you need only substitute components in this section to incorporate values for that band. Refer to *The ARRL Handbook* for filter design details.

The software on the *QST* in Depth web page supports not only the 40-meter band, but other bands as well. The usable bandwidth of the receiver is limited by the front-end band-pass filter parameters. I found that I needed to add a broadcast band rejection filter at the antenna input; the design for this filter is also on the *QST* in Depth web page.

Output from the input band-pass filter feeds the RF input of an SRA-1 or SBL-1 double-balanced diode mixer. This type of mixer does not overload easily. Local oscillator RF from the DDS module (see Figure 1) is fed to the local oscillator (LO) input of the mixer. The LO frequency is 9 MHz above the desired receive frequency. For example, tuning to 7150 kHz requires an LO frequency of 16,150 kHz.

Output from the mixer (IF) connects directly to the input of the multi-stage adjustable bandwidth crystal filter. When a control voltage is applied to the crystal

bandwidth control, the bandwidth of the filter will change from approximately 1 kHz to 4 kHz. Ideally, the three crystals should be exactly on the same frequency, however, a slight variation in frequency will minimally change the response. The varactor diodes will not be exactly the same either, and this variation will affect the overall response. Leaded varactor diodes may be difficult to find. I located them on eBay.

Some 330  $\Omega$  resistors terminate both the input and output of the crystal filter. This value is not critical, but changes to this value will affect the roll-off characteristics and the in-band ripple of the filter response. A lower resistance will increase filter roll-off rate but also increase ripple level within the passband.

Output from the filter couples to a two-stage IF amplifier using two 2N3904 transistors. Each RF amplifier stage requires a bifilar wound coil. Wind them on FT37-43 toroid cores exactly like the band-pass filter coils, but wind two wires at the same time. It will be easy to identify the windings if you use two different colored wires. My printed circuit board (PCB) layout is marked **R** and **G** to indicate red and green wires. The proper connections are handled by the PCB, so just connect the start windings on one side and the end windings on the opposite side. The schematic indicates the required number of turns.

The gain of the second amplifier stage is controlled from the front panel. I did not incorporate an automatic gain control (AGC) circuit in this design. AGC could be added at this control point if desired. Higher voltage (up to 12 V) applied here increases gain and lower voltage decreases gain.

The second stage of the IF amplifier is coupled to a second double-balanced diode mixer at the RF input. A 2N3904 transistor oscillator and a 9 MHz crystal supply the LO injection. Adjustable capacitor C25 allows frequency adjustment. This is the only adjust-

**The full receiver schematic and other details are on the *QST* in Depth web page, at [www.arrl.org/qst-in-depth](http://www.arrl.org/qst-in-depth).**

ment required in the receiver. Frequency can be adjusted using another calibrated receiver, a frequency counter, or even by ear for best sounding SSB phone signal. The IF output from the mixer connects to a single-stage 2N3904 transistor audio preamp, and then to a 10 kΩ volume control. An LM386 audio amplifier configured for a gain of 200 completes the audio chain.

## Software

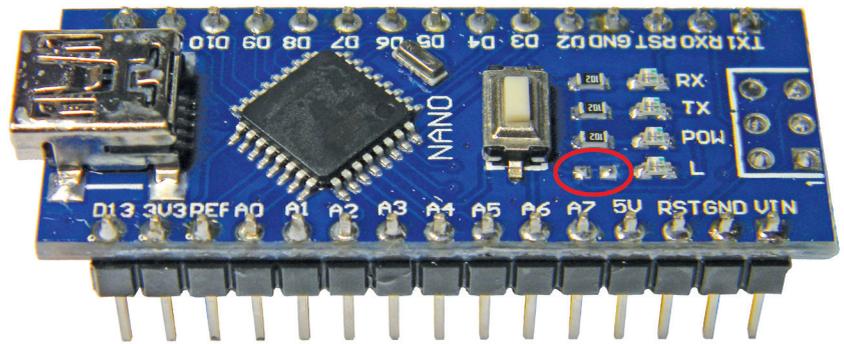
Tuning, frequency control, and display are all handled by software loaded onto the Arduino Nano. I selected this microprocessor because it has enough capacity to support the application and it is inexpensive. I used a Nano and DDS module in my previous project, “Super Simple 6-Meter SDR Transceiver,” in the March 2019 issue of *QST*. Download the software for programming this Arduino device and compile and load the control software before the receiver will function. Full instructions are available on the Arduino website.

Arduino programming software required to program the Arduino Nano microprocessor can be downloaded from [www.arduino.cc/en/Main/Software](http://www.arduino.cc/en/Main/Software). An inexpensive 1.44-inch diagonal LCD display module shows the receive frequency. A 1.8-inch LCD may be substituted, but requires more front panel space. Control software, `single_band_rcvr_R2_180.ino`, for the 1.8-inch display, and `single_band_rcvr_R2_144.ino` for the 1.44-inch display, are available on the *QST* in Depth web page and at [www.wa3tfs.com](http://www.wa3tfs.com).

Two low-cost encoders are connected to the microprocessor. One tunes the DDS module by way of the Nano for the desired receive frequency, and the other selects the tuning rate per step. Both incorporate a pushbutton switch function. Pushing the step encoder will switch the frequency step size to 100 Hz. The tune switch will return the receiver to 7150.000 kHz. The software handles the 9 MHz offset for the LO.

I decided to also add a notch filter function by incorporating the notch filter section from my article, “WA3TFS Audio Notch Filter and Clipper,” published in the August 2015 issue of *QST*.

The receiver may be mounted in any enclosure you desire. The lead photo shows a simple cabinet constructed from wood and acrylic plastic.



**Figure 2** — Remove the circled resistor from the Nano board to disable the LED.

## Tuning, frequency control, and display are all handled by software loaded onto the Arduino Nano microprocessor.

## Controls

Controls necessary for the receiver consist of two encoders, a volume control (10 kΩ recommended), a 10 kΩ RF gain control, and a bandwidth control (also 10 kΩ). 12 V power is internally regulated to 5 V by IC2, an on-board linear regulator, for powering the Nano and DDS modules. There is room to use a small heatsink on this part if desired. All parts on the board are easy-to-assemble through-hole components. The two modules containing surface-mount parts are pre-assembled and simply plug into the board. The rear panel requires a 12 V power connection, speaker jack, and an RF antenna connector of your choice. I used a BNC style for this project.

I designed a double-sided PCB to make this project easy to duplicate. The board measures 6.3 × 3.95 inches. The design lends itself for use as a stand-alone HF receiver or as the receiver section of a transceiver. The components necessary to assemble the circuit board are listed in a file on the *QST* in Depth web page.

## Initial Setup

You must remove a resistor on the Nano board for it to function correctly (see Figure 2). Just heat one end of the resistor with a soldering iron and remove it. Program the Nano microprocessor by downloading the software, compiling it, and uploading it to the Nano using the Arduino software. Be sure to use the

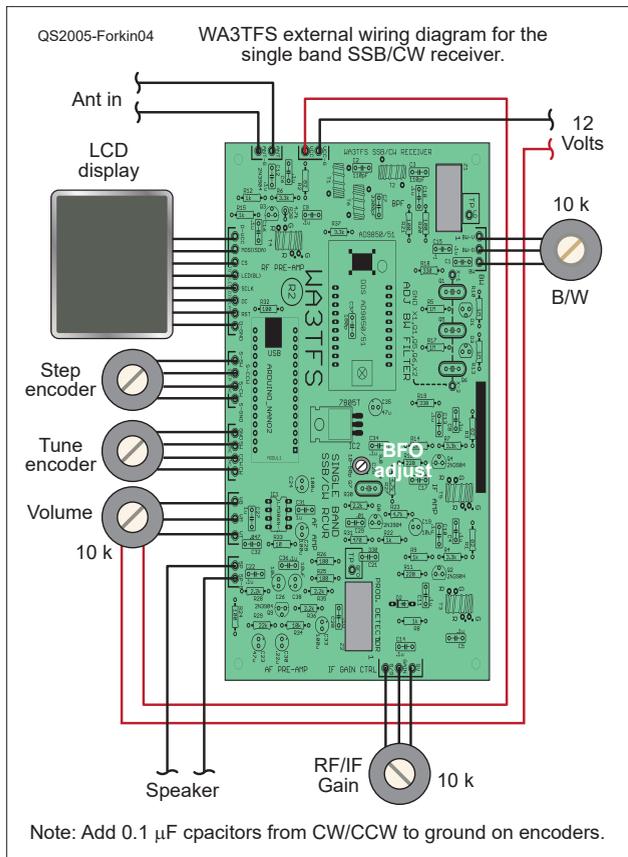


Figure 3 — The wiring external to the PCB.

version of the software that corresponds to the LCD size you're using for the project. You'll need to format the data to download to the LCD properly. Do this before mounting the Nano onto the circuit board. It will be powered by the USB connection during programming. When successfully programmed, mount it onto the circuit board. The proper orientation is shown on the circuit board.

After you have completed the assembly and checked the interconnection wiring external to the PCB (see Figure 3) to the volume, gain, and bandwidth controls and the two encoders, it's time to start up the receiver, laid out in steps on the *QST* in Depth web page. After that, the receiver is ready to use and no further adjustments are needed. You will find it useful for listening to SSB, CW, and AM signals.

The adjustable bandwidth allows copy under crowded conditions and the audio output is adequate for any situation. The bright display is readable under most lighting conditions. For best operation, set the audio gain to a wanted level and adjust the RF gain as necessary.

I have circuit boards available and a limited number of partial kits. The kits include a circuit board, crystals, diode mixers, and varactor diodes. The parts list specifies all required components to complete the assembly. Visit my website ([www.wa3tfs.com](http://www.wa3tfs.com)) for details.

James Forkin, WA3TFS, learned code as a Boy Scout while working on his Eagle rank. He was licensed as a Novice (WH6HOC) in 1971 while stationed in Hawaii with the US Army. He made his first contact from there, reaching Alaska using a homebrew 5 W transmitter and vertical antenna on 15 meters. Jim retired as an electronics design engineer after 35 years of developing analog and digital products. He specialized in electro-mechanical design and EMI suppression techniques. Jim has been designing and building amateur radio devices since he was first licensed. You can find some of his projects at [www.wa3tfs.com](http://www.wa3tfs.com). He has published articles in *QST* and *Ham Radio Magazine*. He is active on 40- and 20-meter SSB using homebrew transceivers. You can contact Jim at [jforkin@verizon.net](mailto:jforkin@verizon.net).

For updates to this article, see the *QST* Feedback page at [www.arrrl.org/feedback](http://www.arrrl.org/feedback).

## VOTE

If you enjoyed this article, cast your vote at [www.arrrl.org/cover-plaque-poll](http://www.arrrl.org/cover-plaque-poll)

## Digital *NCJ* and *QEX* — Two New ARRL Member Benefits Coming Soon!

Beginning in late April, *The National Contest Journal*, better known as *NCJ*, and *QEX*, a magazine devoted to design and experimentation, will become available in digital format to all ARRL members *at no extra charge*. (Print editions of *NCJ* and *QEX* will remain available exclusively to paid subscribers.)

Both ARRL magazines have been favorites among select audiences for decades. Subscribers to *NCJ* enjoy in-depth articles about the competitive side of amateur radio, while *QEX* readers experience technical material written at a higher level than one would ordinarily find in *QST*.

If you read *QST* and our new *On the Air* magazines through the ARRL Magazines app on your iOS or Android device, you'll soon discover that the app has added the May/June issues of *NCJ* and *QEX*. You will also be able to read *NCJ* and *QEX* on your desktop or laptop computers. Unlike the printed versions of these magazines, the digital versions of *NCJ* and *QEX* will appear in color and contain "live" internet links.

Watch for announcements in the coming days on the ARRL website ([www.arrrl.org](http://www.arrrl.org)), in the *ARRL Letter*, and on ARRL social media such as Facebook, Twitter, and Instagram.

Now you have four magazines for your reading pleasure, just by being a member of ARRL!

