

## Product Review

# HF Signals BITX40 40-Meter SSB Transceiver Kit

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Until recently, the majority of low-power transceiver kits have operated on CW only, but the options for affordable SSB transceiver kits are few and far between, because of the more complex circuitry required to generate SSB. Enter the \$59 BITX40, a 7 W SSB transceiver for 40 meters built on a single PC board.

### A Bit of BITX History

Designed by Ashhar Farhan, VU2ESE, the BITX SSB transceiver design evolved from the S7C receiver described in *Experimental Methods in RF Design*.<sup>1</sup> The BITX design turns it into a *bidirectional* transceiver that uses the same basic signal path and circuit building blocks for transmit and receive by turning on the appropriate circuits for the direction of the signal. It was originally posted on the internet in 2003, as a means for Indian radio amateurs to get on the air using SSB with readily available and inexpensive components. Boards and kits were made available, the most recent of these being the BITX40v3 reviewed here and the more recently released  $\mu$ BITX, a multiband version.

The original BITX design used a voltage-controlled oscillator (VCO) for tuning, which, as with many analog variable frequency oscillators

<sup>1</sup>W. Hayward, W7ZOI; R. Campbell, KK7B, and B. Larkin, W7PUA, *Experimental Methods in RF Design* (Classic Reprint Edition). Available from your ARRL dealer, or from the ARRL Store, ARRL Item no. 1017. Telephone toll-free in the US 888-277-5289, or 860-594-0355, fax 860-594-0303; [www.arrl.org/shop/](http://www.arrl.org/shop/); [pubsales@arrl.org](mailto:pubsales@arrl.org).



(VFOs), was subject to instability and drift. In December 2016, a Raduino module was added to the BITX40. The Raduino offers the power of an Arduino Nano microprocessor, a liquid crystal display (LCD), and a highly stable Silicon Labs Si5351A digital clock generator. Even though the original BITX was designed to be hacked and modified, the addition of the Raduino changes the BITX40 from a simple 40-meter SSB kit into a full-blown SSB/Arduino experimental transceiver platform.

### Bottom Line

At \$59, the BITX40 is a good kit for someone transitioning from building simple kits to a more advanced, fully functional, low-power SSB transceiver. The Raduino module allows you to customize and modify the BITX40 at will.

### Unpacking the Box

Figure 1 shows the kit as delivered. The BITX40 transceiver board comes fully assembled, tested, and calibrated. All you have to do is some simple wiring of the external components, such as the Raduino module, potentiometers, a microphone element, connectors, and the like. Just about all the external components you need to complete the assembly are in the kit, including the Raduino and LCD display module. The only thing not included is a speaker, but just about any 8  $\Omega$  speaker will work fine.

The BITX40 does not come with an enclosure — that's left up to you. Builders have used 3D printed enclosures, cake pans, metal cigar boxes, and old satellite TV receiver boxes to house their finished BITX40 kits. I took the easy way out and purchased an enclosure and accessories kit designed for the BITX40 (see the sidebar, "INKITS Universal Case with Accessories").

## The BITX40 Board

The BITX40 board is nearly an all-transistor analog design. The only integrated circuit (IC) on the board is an LM386 audio amplifier. All the external components attach to the board using small plug-in keyed connectors, allowing for easy hookup and removal of the board for any modifications you may choose to make later.

While the specified output is 7 W, a separate power connector is provided for the power amplifier circuit, allowing you to apply up to 25 V. That increases the rated power output to 20 W, with only the addition of a larger heatsink on the MOSFET final amplifier.

Interestingly, the BITX40 does not directly support CW mode. It's strictly an SSB transceiver as it comes out of the box. Of course, it can be easily modified to allow for CW and digital modes (more on that in a bit). But, out of the box, it doesn't do CW — only lower sideband.

It's apparent that a lot of emphasis was placed on the receiver design. Along with a three-section band-pass filter, there's a four-crystal IF filter. Combined with the all-analog design, this provides very clean and crisp receive audio. The BITX is a bidirectional design, so the crystal filter is used for sideband suppression on transmit as well.

## The Raduino

The addition of the Raduino module is what makes the BITX40 a really fun kit to play with. Replacing the original analog VFO design with an Arduino Nano controlling an Si5351A clock generator chip provides the BITX40 with a more stable and accurate digital VFO, and it also offers the ability to add features — such as upper sideband, RIT, split-frequency operation, CW, dual VFOs, improved tuning capability, and much more — with simple firmware upgrades and minor hardware changes. A number

## INKITS Universal Case with Accessories

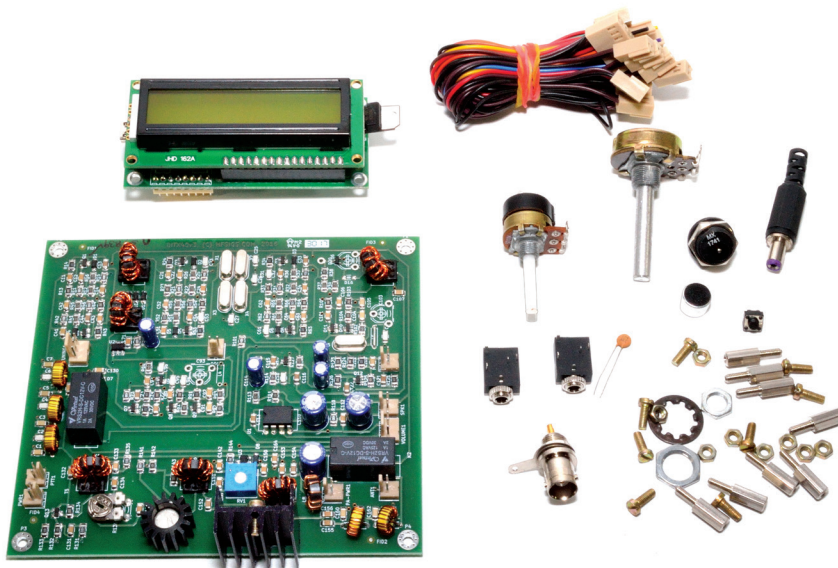
The BITX40 kit does not include an enclosure for the board, so you are on your own to come up with a suitable box. Because I am less mechanically inclined, I decided to purchase a pre-made enclosure from INKITS for \$24.99 plus shipping ([amateurradiokits.in](http://amateurradiokits.in)).

The aluminum case is available in several colors. While it is called a universal case, it is tailored for the BITX40 boards. It includes an accessories kit with the potentiometers, knobs, fuse holder, power switch, power connector, SO-239 coax connector, speaker, and hardware needed to mount the BITX40 board into the enclosure. The only thing that doesn't come in the accessories kit is a microphone connector.

It took a little bit of extra work to get my BITX40 board mounted and on the air. First, I received a momentary switch instead of a standard push-button on/off switch. A quick trip to the local auto parts store, and I had a nice power switch that fit the mounting hole perfectly. The holes for the tuning and volume potentiometers were just a little too small, so I had to drill them out. The opening for the LCD was also smaller than necessary, so I had to file the opening just a bit larger. This wasn't too bad, because the aluminum case is easy to work with. I also added a hole on the back for a headphone jack, along with holes for the function switch and CW key that I plan to use once I upgrade the firmware on the board to include these features.

I felt that the mounting method for the Raduino and LCD module was not secure enough for rough handling during portable operation, and that the Raduino could vibrate loose from the LCD. Using the standoffs included in the kit, I attached the LCD more firmly to the Raduino, and then mounted the whole assembly to the front of the enclosure.

As a finishing touch, I upgraded the tuning knob to a nicer one from my own parts supply. For those of us who prefer a pre-finished enclosure, the INKITS case is a nice option for the BITX40, and it looks great next to the big radios in my station.



**Figure 1** — The BITX40 kit includes an assembled and tested main PC board, a Raduino board with LCD display, and a handful of connectors and hardware items.

**Table 1**  
**HF Signals BITX40 SSB Transceiver Kit**

Manufacturer's Specifications	Measured in the ARRL Lab
Frequency coverage: Receive and transmit, 400 kHz segment of the 40-meter band.	Receive and transmit: 6.9895 to 7.5006 MHz.
Power requirements: +12 V dc at about 150 mA (receive) and 1 A (transmit).	At 13.8 V dc: Receive, maximum audio, no signal, 193 mA. Transmit, 1.15 A peak.
Mode: LSB.	As specified.
Receiver	Receiver Dynamic Testing
Sensitivity: Not specified.	Noise floor (MDS): -123 dBm.
Blocking gain compression dynamic range: Not specified.	20 kHz spacing, 101 dB.*
Reciprocal mixing dynamic range: Not specified.	Not measured.*
Third-order intermodulation distortion (IMD) dynamic range: Not specified.	78 dB.
Second-order intercept point: Not specified.	At 7.250 MHz, +59 dBm.
Receiver audio output: Not specified.	174 mW at 5.5% THD into 8 Ω. THD at 1 V <sub>RMS</sub> : 5.4%.
IF/audio response: Not specified.	Range at -6 dB points (bandwidth): LSB: 648 - 1,914 Hz (1,266 Hz).
Spurious and image rejection: Not specified.	IF rejection, 93 dB; image rejection, >133 dB.
Transmitter	Transmitter Dynamic Testing
Power output: 7 W PEP.	As specified at 13.8 V dc. 1.3 W RF output at 8 V dc.
Spurious-signal and harmonic suppression: Not specified.	44 dB (2nd harmonic). Meets FCC requirements.
Unwanted sideband and carrier suppression: Not specified.	Unwanted sideband, >70 dB. Carrier suppression, 43 dB.
Third-order IMD products: Not specified.	At 7 W PEP, 3rd/5th/7th/9th order: -25/-38/-48/-52 dBc.
Receive-transmit turnaround time (TX delay): Not specified.	1 ms.
Transmit-receive turnaround time: Not specified.	54 ms.
Size (height, width, depth): 1.5 × 4.8 × 2.4 inches, excluding protrusions. 3.5 × 6.6 × 8.0 inches, including protrusions. Weight: 2.1 pounds, including microphone.	
Second-order intercept points were determined using S-5 reference.	
*Due to filter bandwidth and the lack of AGC, the 5 and 2 kHz spacing tests could not be performed without receiver overload. ARRL Lab reciprocal mixing dynamic range tests are performed at 14 MHz. No low-noise 7 MHz test oscillator was available.	

of these modifications are already available online, along with customized versions of the Raduino firmware. Paired with the included two-line, 16-character LCD, customizable frequency and status display capability is added to the BITX40.

For more information, check out the official support website at [groups.io/g/bitx20](http://groups.io/g/bitx20) and other sites, including a Facebook group.

### Assembling the BITX40

Assembling the BITX40 in the enclosure only took two evenings. I spent more time fitting the various controls, switches, microphone/PTT, and antenna connectors into the enclosure than I did the actual wiring needed to complete the kit. The online instructions for wiring the kit are, for the most part, well written and easily followed. The only real confusion I had was when I got to

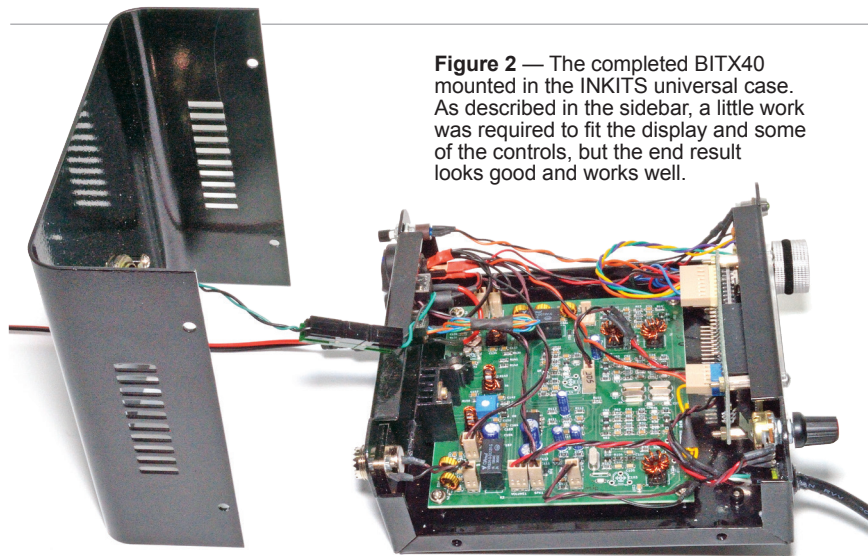
wiring up the tuning and volume potentiometers. The instructions call for you to connect wires to the “left” and “right” solder lugs on the potentiometers without explaining that this left and right orientation is as viewed from the front side of the potentiometer in question. Fortunately, the color photos accompanying the instructions solved the confusion in short order. Figure 2 shows the finished radio.

The BITX40 kit doesn't include what I would normally consider to be a microphone. Instead, the kit includes a small electret microphone element, and it's up to you to build your own holder. The documentation says you can use just about any microphone you want, including a standard PC-type microphone, but because I was building the kit for review, I chose to use the electret element to keep everything as original as possible. Unfortunately, I didn't have any old microphone shells laying around, so I used a small project box to hold the microphone element and PTT switch, and attached it to the board using an old microphone cable (see Figure 3).

### On the Air

The BITX40 worked the first time I powered it up. This is somewhat unusual for me, as I'm always making some kind of mistake along the way that I have to backtrack and troubleshoot. Not so with the BITX40 — it worked right out of the gate. After doing some basic testing on a dummy load, I hooked it up to my 40-meter dipole and started tuning around.

The tuning potentiometer takes some getting used to. The Raduino directly tunes about a 50 kHz portion of the 40-meter band. Turning the knob to either extreme initiates a 100 kHz auto-step tuning mode, known as *shuttle tuning*. It didn't take long to get used to this, although it would have been nice to have the auto-step tuning stop when I reached either end of the band.



**Figure 2** — The completed BITX40 mounted in the INKITS universal case. As described in the sidebar, a little work was required to fit the display and some of the controls, but the end result looks good and works well.

## Lab Notes: BITX40 40-Meter SSB Transceiver

*Bob Allison, WB1GCM,  
Assistant Laboratory Manager*

During testing, I noticed some unusual behavior when tuning. Each step is 50 Hz, but the dial resolution is 100 Hz. Tuning can be erratic if the dial stops right at the point of switching to the next 50 Hz. The 100 Hz digit sometimes flips back and forth between digits, and the tuned frequency does this too, but eventually I got the hang of it.

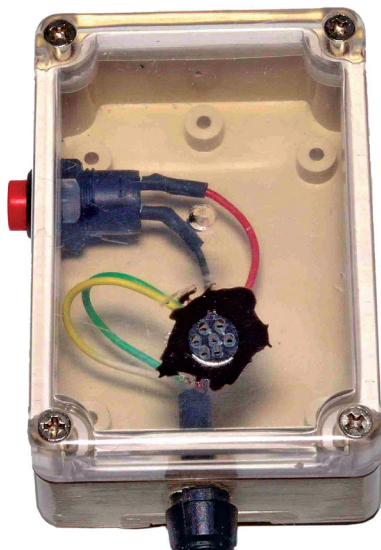
Sideband suppression is 43 dB below PEP — not the best, but not an issue. Two-tone transmit IMD tests showed the normal odd-order products, but with other harmonics mixed in. I adjusted the bias and the other drive level potentiometer to minimize the distortion products. The best setting for the bias (lowest IMD) was at the 100 mA increase of power consumption when the microphone button is pressed, as the manufacturer suggests.

BITX40, with a number of possible fixes posted online, but I could not find any definitive resolution. I was concerned that this sound was heard in the transmit audio, but after listening to the BITX40 on other receivers in my station, I heard no popping in the transmit audio. In fact, the transmit audio sounded rather good, considering the simple electret microphone element.

While band conditions weren't all that great, especially for low-power operation, I did manage to make a couple of contacts. I was pleased with the performance of the BITX40 on the air and received good reports on the signal and audio quality.

### Digital Modes on the BITX40

Using the factory-installed version 1.01 of the Raduino firmware, the BITX40 transmits and receives on lower sideband (LSB) only. Digital



**Figure 3** — The included condenser mic element mounted in a plastic project box with a PTT switch and cable. It's not pretty, but it sounds good.

One thing I noticed immediately was an audible clicking sound with each tuning step. This is apparently a known issue with the Raduino module, and not everyone is affected. There are a number of recommended simple modifications posted online to address this issue. I experienced this clicking sound whether I was running from a battery or a power supply. It's not all that objectionable, but I can see where it would become annoying over time. Because this is a known issue with a relatively easy solution, it would have been

nice to have the simple modification and components to resolve this issue included in the kit and instructions.

The thing that really jumped out at me was the receive audio. As advertised, it was crisp and clear, and it was very easy to tune in even weak signals. My ears generally don't do well with the noise on 40 meters, but I found the receive audio on the BITX40 to be easy to listen to. The audio output level is good, although when the gain was above  $\frac{3}{4}$ , the noise level rose significantly and the audio became distorted. This happened whether I used the speaker or headphones. The BITX40 doesn't have an AGC circuit, so you have to adjust the audio level manually between strong and weak signals.

While every BITX40 board is tested and calibrated before it is shipped, I found my board to be receiving and transmitting about 600 Hz high. I performed the simple calibration steps included in the wiring instructions and got it where it needed to be in a matter of minutes. As with tuning, the clicking noise was heard throughout the calibration process.

My homebrew microphone assembly worked well, although there was a loud popping noise in the speaker when the PTT was keyed. This is another known issue with the

modes, such as FT8 and JT65, use upper sideband (USB). Fortunately, a simple modification involving the removal of two capacitors and a firm-ware change can be made to the BITX40, allowing it to transmit and receive on upper sideband. For FT8 and JT65, you would also need to use a larger heatsink on the final output transistor. At 7 W out, the BITX40 would make an ideal radio for FT8 and JT65 operation.

### Final Notes

In looking through the code listing for the Raduino version 1.01 firmware, I discovered several features that were available but commented out and undocumented. These included dual VFOs, CW capability, and several other features I would like to know more about. In more recent versions of the Raduino firmware available online, these, along with other features, are available and well documented. I can see updating to one of these modified versions of the firm-ware in the not-so-distant future.

For the price, the BITX40 is a good SSB transceiver kit, especially for an “Arduino guy” or homebrewer such as me. The design philosophy behind the BITX40 and the Raduino module that encourages hacking and modification is hard to resist.



Visit <https://youtu.be/XX8dWS6b1Og> to see our review of the HF Signals BITX40 40-Meter SSB Transceiver Kit on YouTube.

In general, I was pleased with the construction and operation of the BITX40 out of the box. I can see where updating to a later version of the firmware and installing a few of the existing modules would add a lot of improvements and functionality. For example, the Raduino module allows the addition of a color TFT display and other enhancements that would make my BITX40 look extra nice and function as my primary digital mode transceiver on 40 meters.

As with any new product, changes occur after a unit has been evaluated. HF Signals reports that the BITX40 is now being shipped with

a rotary encoder in place of the tuning potentiometer. This would eliminate the need for “shuttle tuning” and offer a smoother and simpler method of tuning. They also recommend [github.com/amunters/bitx40](https://github.com/amunters/bitx40), managed by Allard Munters, PE1NWL, as the best collection of firmware upgrades for the BITX40. And finally, they emphasize that the BITX transceiver boards are fully open source, allowing anyone to copy, modify, and distribute radios based on any of the BITX designs.

*Manufacturer:* HF Signals, [www.hfsignals.com](http://www.hfsignals.com). Price: \$59 plus \$10 for DHL shipping from India.

## RigExpert AA-30.ZERO Antenna Analyzer Board

*Reviewed by Dave Cook, WA0TTN*  
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The RigExpert AA-30.ZERO is a fully functional vector impedance analyzer for 0.6 to 30 MHz on a compact printed circuit board. The device is basically a RigExpert AA-30 analyzer, but without the enclosure, display, and keypad. The user must supply a case and user interface of some sort. It can be used with a per-

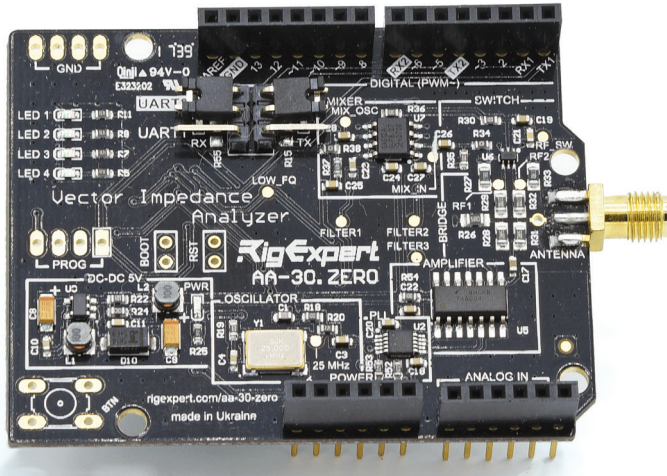
sonal computer or can be piggy-backed directly onto an Arduino microcontroller board. The AA-30.ZERO is very affordably priced and

### Bottom Line

The AA-30.ZERO board offers experimenters a way to build and customize an accurate and useful antenna analyzer for the HF bands.

can be used in a number of ways by the ham radio experimenter.

The AA-30.ZERO board arrives assembled and tested in a sealed anti-static bag along with a set of pins suitable for interfacing with an Arduino UNO or MEGA 2560 microcontroller. In my case, I chose to use stackable headers so that additional boards can be stacked on top of it (see Figure 4).



There are two options for using the AA-30.ZERO. One is to connect it to a TTL serial USB interface, which can then be plugged into a PC. The other option is to stack it directly onto an Arduino microcontroller using pins on the PC board. The first method is simplest. I bought a TTL UART serial converter module on eBay for about \$5. The serial module provides both power to the board and the serial transmit/receive signals needed to operate the AA-30.ZERO. RigExpert has a tutorial on their website show-

**Table 2**  
**RigExpert AA-30.ZERO**

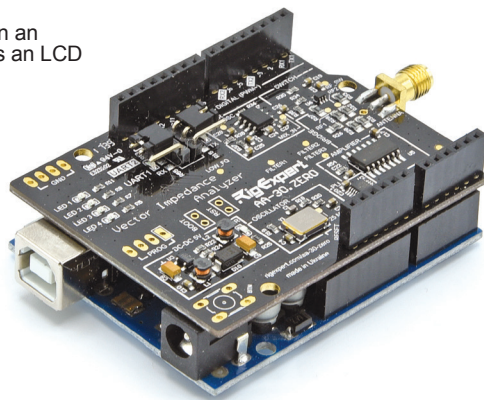
Manufacturer's Specifications	Measured in the ARRL Lab
Frequency range: 0.6 – 30 MHz.	As specified.
SWR measurable range: 1 to 100.	As specified.
Reference impedance for SWR measurement: For 25, 50, 75, and 100 Ω systems.	As specified.
Impedance accuracy: Not specified.	See measurements below.
Output power: +13 dBm, square wave.	As specified (20 mW).
Harmonic and spurious suppression: Not specified.	≥10 dB across entire frequency range.
Communication interface: Serial TTL at 38,400 bauds.	
Power requirements: USB powered, 5 V dc at 150 mA maximum.	
Dimensions (height, width, depth): 0.2 × 2.7 × 2.1 inches (board only, not including Arduino); weight: 3 oz.	

**ARRL Lab Impedance and SWR measurements with AA-30.ZERO and AntScope Software**

Load	Freq. (MHz)	AA-30.ZERO	Reference*	Load	Freq. (MHz)	AA-30.ZERO	Reference*
50 Ω (1:1 SWR)	3.5	49.7-j0.0 Ω (1.01:1), Z = 49.7 Ω	50+j0 Ω	200 Ω (4:1 SWR)	3.5	188.8-j19.9 Ω (3.82:1), Z = 189.8 Ω	201-j1.2 Ω
	14	49.6+j0.0 Ω (1.01:1), Z = 49.6 Ω	50+j0 Ω		14	176.6-j43.8 Ω (3.77:1), Z = 181.9 Ω	200-j4.8 Ω
	28	49.9+j0.2 Ω (1.00:1), Z = 49.9 Ω	50+j0 Ω		28	152-j60.8 Ω (3.58:1), Z = 163.7 Ω	200-j9.4 Ω
5 Ω (10:1 SWR)	3.5	5.2+j0.6 Ω (9.59:1), Z = 5.3 Ω	5.1+j0.0 Ω	400 Ω (8:1 SWR)	3.5	358.1-j54.3 Ω (7.33:1), Z = 362.2 Ω	400-j10 Ω
	14	5.9+j2.9 Ω (8.50:1), Z = 6.6 Ω	5.1+j0.2 Ω		14	325.7-j112.6 Ω (7.31:1), Z = 344.6 Ω	400-j17 Ω
	28	5.5+j3.3 Ω (9.15:1), Z = 6.4 Ω	5.1+j0.2 Ω		28	255.7-j164.2 Ω (7.28:1), Z = 303.9 Ω	389-j69 Ω
25 Ω (2:1 SWR)	3.5	25.1+j0.4 Ω (1.99:1), Z = 25.1 Ω	25.1+j0.2 Ω	50-j50 Ω	3.5	47.8-j45.0 Ω SWR: 2.44:1	50-j50 Ω
	14	25.1+j1.7 Ω (2.00:1), Z = 25.1 Ω	25.1+j0.4 Ω		14	43.9-j49.3 Ω SWR: 2.76:1	50-j50 Ω
	28	25.4+j2.1 Ω (1.97:1), Z = 25.5 Ω	25.1+j0.7 Ω		28	45.8-j44.9 Ω SWR: 2.49:1	50-j50 Ω
100 Ω (2:1 SWR)	3.5	99.8-j2.4 Ω (2.00:1), Z = 99.9 Ω	100-j0.2 Ω	50+j50 Ω	3.5	53.6+j49.1 Ω SWR: 2.50:1	50+j50 Ω
	14	99.2-j5.9 Ω (1.99:1), Z = 99.3 Ω	100-j0.9 Ω		14	57.3+j47.5 Ω SWR: 2.39:1	50+j50 Ω
	28	97.5-j9.7 Ω (1.98:1), Z = 98.0 Ω	100-j1.8 Ω		28	59.6+j48.8 Ω SWR: 2.45:1	50+j50 Ω

\*The SWR loads constructed in the ARRL Lab were measured on an Agilent 4291B impedance analyzer by ARRL Technical Advisor John Grebenkemper, KI6WX, for the reference measurements shown here. An Array Solutions precision termination was used for the 50 Ω tests. This termination has a wide frequency range.

**Figure 4** — The AA-30.ZERO stacked on an Arduino UNO. Additional boards, such as an LCD TFT display, can be stacked on top.



ing how to make the connections, and it also provides a download for their *AntScope* software for the PC.

### AntScope Software

The *AntScope* software is a very comprehensive analysis tool and makes it easy to verify the operation of the AA-30.ZERO. For some readers, this may be a sufficient solution for your antenna analysis needs without going further with integration with an Arduino microcontroller. Once downloaded and installed on your Windows computer, you configure *AntScope* by selecting the AA-30 analyzer as the measuring device, setting the COM port to the TTL UART serial converter port number, and the baud rate to 38,400. Note that you may receive the message on startup stating, “The firmware version is lower than 100. Some functions will not work.” This can be ignored because the program is properly communicating with the AA-30.ZERO.

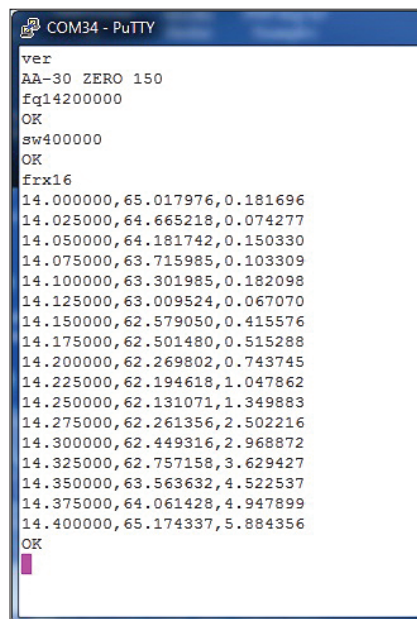
To make measurements, you can press the F9 key to set the center frequency, scan range, and number of samples. The program then commands the AA-30.ZERO to perform the scan and displays the results graphically. Figure 5 illustrates a full-band scan of my GAP Titan multiband vertical antenna.

There are a number of very useful display options, including SWR, complex impedance, and even a Smith chart. See the PDF instruction manual included with the *AntScope* program for additional information.

The ARRL Lab tested the AA-30.ZERO and *AntScope* with various loads, and the results are shown in Table 2. The Lab’s test loads are built into coaxial cable connectors that are attached to the analyzer’s antenna connector. RigExpert notes that when measuring a load connected to the analyzer via a coaxial cable and/or several adapters, the measurement accuracy could be influenced by the connecting cable.

### Testing with a Terminal Program

You can also command the AA-30.ZERO interactively, using a terminal program such as *PuTTY*. Using *PuTTY* as our example, set the terminal to serial mode, set the COM port to that of the USB serial interface, and set the baud rate to 38,400.

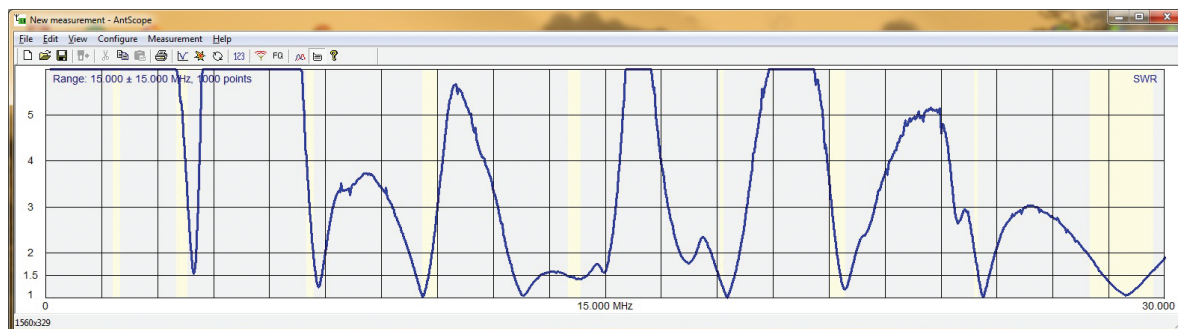


**Figure 6** — The results of a scan request using the *PuTTY* terminal program to communicate with the AA-30.ZERO.

Then in the terminal options, enable local echo and local editing so that you will be able to view the commands as you type them. Following the sequence of commands in Figure 6, you should see the raw results of the scan request.

### Connecting to an Arduino

For those who enjoy tinkering with software, connecting the AA-30.ZERO to an Arduino microcontroller gives you the option for creating your own custom antenna analyzer. There are several ways to connect the board to an Arduino. The first, and the default as the board is config-



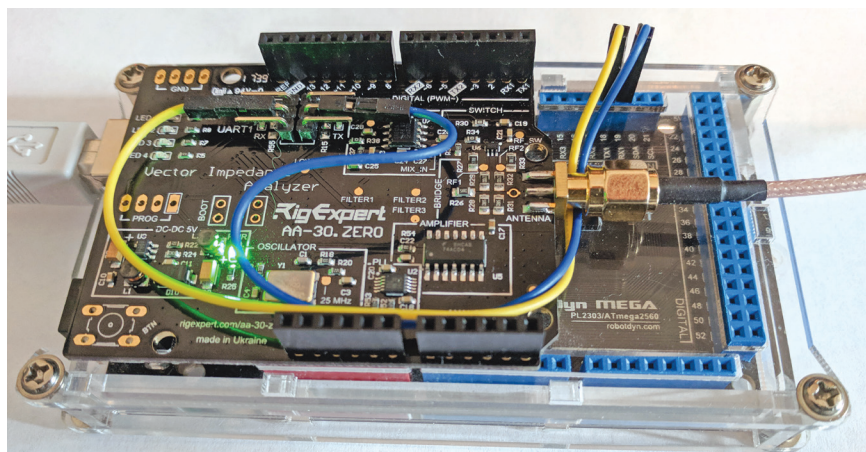
**Figure 5** — A 0 to 30 MHz scan of a GAP Titan multiband vertical antenna using the AA-30.ZERO and *AntScope* software. Each division is 1.5 MHz. Note the resonances (low SWR) in the various amateur bands.

## Arduino Considerations

There are a few considerations when implementing your own antenna analyzer with an Arduino and the AA-30.ZERO:

- The serial I/O baud rate is fixed at 38,400 baud. This is because the board was designed for use with the Arduino SoftwareSerial library, which has a maximum operating speed of 57,600 baud on a standard UNO microcontroller. This speed was chosen as a conservative setting.
- If used with the MEGA 2560, be aware that it supports SoftwareSerial only on certain pins, which can be found in the Arduino SoftwareSerial documentation. However, the MEGA does provide three additional hardware serial ports as an alternative to using the SoftwareSerial library.

- When the AA-30.ZERO is commanded to start the analysis measurement, it sends the response out in one continuous stream. Your Arduino application must be prepared to accept this stream of data and buffer it if necessary. Because there is no flow control implemented in the AA-30.ZERO, consider reducing additional data processing until this data burst is completed.
- The AA-30.ZERO draws up to 150 mA, so you need to consider this current requirement, if stacking boards powered only by the Arduino microcontroller's power regulator. I originally built my ZERO with headers, thinking that I could stack an LCD TFT display on top, but unfortunately, the total power consumption was just too much for the Arduino power regulator. Other options are to provide an external 5 V supply to the entire system, or to provide separate power to the Arduino, display, and the AA-30.ZERO board.



**Figure 7** — The author's AA-30.ZERO mounted on an Arduino MEGA 2560. The blue and yellow wires connect the two serial I/O lines on the AA-30.ZERO board to the auxiliary Serial1 port supported by the MEGA.

ured, is to access the serial communications via the digital Pins 4 (TX) and 7 (RX) using the Arduino SoftwareSerial library.

Another option is to relocate the jumpers on the board to connect the serial lines to the digital Pins 0 (TX) and 1 (RX). This option precludes the use of the Arduino serial port for use with the Arduino IDE (programming software) and for debugging, but if you have a “headless” Arduino project, it allows you to use the Arduino's hardware serial port.

Yet another option, which is how I configured my AA-30.ZERO, is to remove the UART selection jumpers

entirely, and install two sets of pins on the board where there are solder pads originally placed for a DPDT switch. This allows you to select either the UART1 or UART2 interfaces using pin jumpers, or to bring the serial lines off the board entirely for a custom hookup. I chose to do most of my testing on an Arduino MEGA 2560, which is much faster and has more memory than an UNO. For the MEGA, I brought the two serial I/O lines off the AA-30.ZERO board to connect to the auxiliary Serial1 port supported by the MEGA, as shown in Figure 7. See the sidebar, “Arduino Considerations,” for more information.

## Initial Testing

A simple way to test the AA-30.ZERO mounted on an Arduino microcontroller is to load the “serial repeater” project available on the RigExpert website. This Arduino sketch (program) simply reads commands from the serial port, sends them to the AA-30.ZERO, and then echoes the response back to the serial port. You can load this sketch using the Arduino IDE, test it interactively, then exit the IDE and connect to the Arduino serial port using the *AntScope* program for more comprehensive testing. At this point, you're ready to develop your own Arduino programs.

## Data Analysis

The AA-30.ZERO delivers complex impedance measurements. Unlike a simple SWR measurement, the complex measurements are most suitable for plotting on a Smith chart. This could be presented on a graphical display, or the SWR curves can be computed and displayed. However, the equivalent SWR is easily computed using the following formulas:

$$SWR = \frac{1 + |\rho|}{1 - |\rho|}$$

and

$$|\rho| = \sqrt{\frac{(R_1 - R_0)^2 + X_1^2}{(R_1 + R_0)^2 + X_1^2}}$$

where

$R_1$  = the measured load resistance

$X_1$  = the measured load reactance

$R_0$  = the characteristic impedance of the antenna, for example, 50  $\Omega$ .

More information about these formulas, transmission line measurements, and calculations can be found in the “Transmission Lines” chapter of *The ARRL Handbook* (Sections 20.1.2 and 20.1.3 in the 2018 and 2019 editions).

## Conclusion

The most compelling feature of the AA-30.ZERO is that it requires only four connections: +5 V, ground, and TTL-level serial TX/RX. It can be built into just about any computer or microprocessor project, such as a Raspberry Pi, which can be connected via the USB serial adapter. It can also be connected via the serial I/O port on its GPIO connector for a direct connection. See the *QST* in Depth website ([www.arrl.org/qst-in-depth](http://www.arrl.org/qst-in-depth)) for an example Arduino

sketch and for more information about using the AA-30.ZERO with a Raspberry Pi.

The AA-30.ZERO requires only simple commands and parsing of the responses to build an extraordinarily capable and customizable vector network analyzer at a modest price.

*Manufacturer:* RigExpert Ukraine Ltd., Kyiv, Ukraine; [www.rigexpert.com](http://www.rigexpert.com). Available from many US dealers. Price: AA-30.ZERO, \$85 (board only).

# Lights for the Workbench

Reviewed by Paul Danzer, N111  
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I spend a lot of time at my workbench, assembling small printed circuit boards with tiny components and narrow pin spacing. Good lighting is essential to see well enough to solder accurately and prevent cold solder joints or solder bridges. Old-fashioned 60 or 75 W incandescent bulbs were fine in the past, but today there are many other choices.

## Bulb Specifications

For many years, light bulbs were rated in watts — 60, 75, 100, and so on — which suggested a certain brightness. Today’s bulbs are usually rated in *lumens* to describe the amount of light that is radiated. Table 3 summarizes published values comparing the two types of ratings. There are many such tables on the internet with slightly different val-

ues, but Table 3 gives an idea of what to expect.

The lumen is a measure of the total amount of light given out, but just as with antennas, an important characteristic is where the light is concentrated. That’s where another specification — *lux* — is helpful. The conversion is 1 lux equals 1 lumen over 1 square meter. As with antenna gain, for a given lumen value, the lux value will be higher if the bulb’s *beamwidth* is narrow. That means that a specific area will be illuminated brighter with a narrow beamwidth

(high lux value) than with a wide beamwidth (low lux value). The lux value is not often given, but you may see a specification for beamwidth.

Another consideration is *color* — not red, blue, or green, but a rating of the bulb’s spectrum. The color is specified in two ways: bulb color temperature and use. Table 4 lists the three typical color descriptions (different sources have slightly different definitions and numbers). A daylight bulb is probably best for a workbench.

## Classic Workbench Lamps

First we’ll look at two very common, classic workbench lights. The lamp shown in Figure 8 uses a circular 22 W cool white fluorescent bulb around the circumference of a 5-inch-diameter, 1.75 $\times$  magnifier. This combination is commonly used in industry for inspection and offers a good way to read tiny labels on parts or check soldering quality on a PC

### Bottom Line

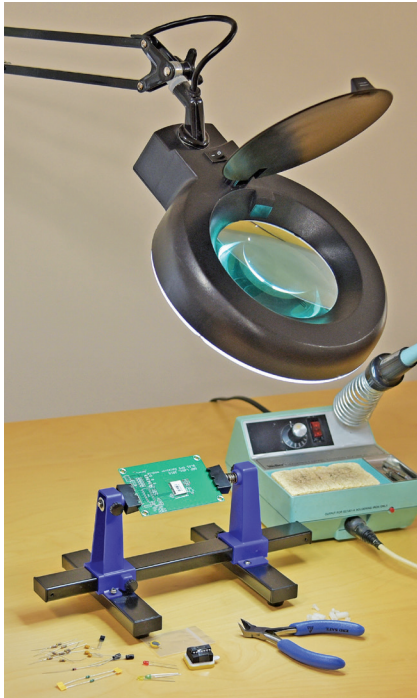
Good lighting is very important for today’s workbench, especially if you are working with small components and a densely populated PC board. There are many choices available, but some block access or provide insufficient light to the work space.

**Table 3**  
Lumens and Watts

Lumens	Incandescent Watts
400 – 500	40
650 – 850	60
1,000 – 1,400	75
1,400 – 1,700	100
2,700	150

**Table 4**  
Bulb Light Color and Temperature

Bulb Temperature (Kelvins, K)	Description	Typical Use
2,400 – 3,000	Soft white	Living room, pleasant surroundings
3,500 – 4,100	Bright white	Kitchen, work spaces
4,800 – 6,500	Daylight	Detail work, workbench



**Figure 8** — The fluorescent light and magnifying lens is good for examining circuit boards, but often gets in the way if you want to solder or do other things under the magnifying lens.

board. These lamps do have a drawback. When you place a circuit board or other project under the lamp, close enough that the work is in focus in the magnifier, the light fixture is usually too close to allow you to use a soldering iron under it.

The lamp shown in Figure 9 can be found in many sizes and colors, with clip-on, vise-type, or weighted bases. There is usually a sticker inside giving limits of 60 to 100 W for an incandescent bulb. Quite often the bell-shaped housing gets in the way when you're trying to work on a circuit, and you may find yourself readjusting the reflector position for best illumination.

These lamps have a standard socket that will accept newer bulbs, such as an 18 W LED bulb. One example, made by CREE, is rated at 1,600 lumens and a color temperature of 2,600 K (soft white). While the large reflector might still get in your way, at



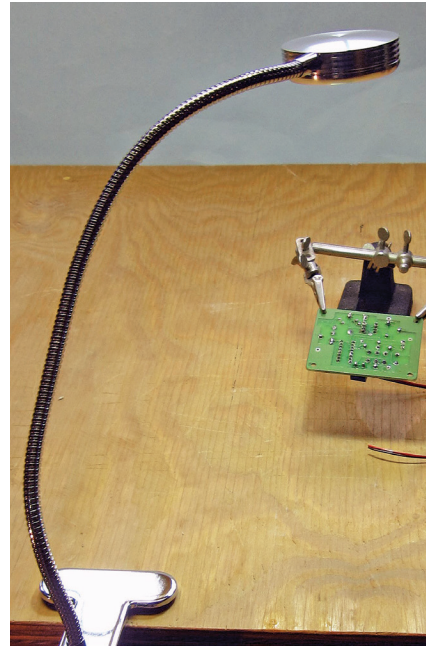
**Figure 9** — This flexible light fixture can accept most common base bulbs, not just the incandescent ones it was originally designed for. A modern LED spotlight is a good choice.

18 W the bulb runs cool. Of course, similar bulbs are available from many manufacturers.

Another good choice is an LED spotlight bulb. One model from Ecosmart is rated at 5,000 K (daylight) and 470 lumens. That sounds low, but the beamwidth is so narrow (resulting in a high lux value) that you might find it too bright. You could remove the reflector from the fixture, because the reflector plays no part in the bulb performance. By contrast, a 45 W incandescent flood light, the same physical size as the LED unit, gives off 385 lumens, runs hot, and is rated as soft white.

### More Modern Designs

I picked a few new-style LED light fixtures to see how they perform on the workbench. These are representative of the many choices available from stores and online vendors.

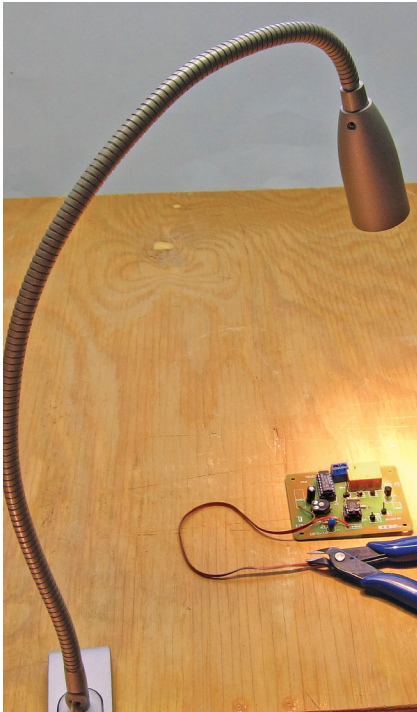


**Figure 10** — The mounting lip for this small head light is bigger than the light head.

Figure 10 shows the Simple Designs LD2000-CHR High Power LED Clip Light. I found mine online at [www.homedepot.com](http://www.homedepot.com) for about \$20, and it's available from a number of other online vendors. I picked it for its "High Power" name, small head, and spring-clip mount. The flexible gooseneck is about 20 inches long, and the head with the light is about 3 inches in diameter. It is rated at 320 lumens and a color temperature of 3,000/6,000 K. While not disputing the published specifications, this physically attractive unit did not put enough light on the bench to be useful for me.

The Artkalia Morpheia LED desk lamp, shown in Figure 11, is another flexible lamp with a small head (1½ inch diameter) and a 12-inch, flexible gooseneck. The mounting hardware offers several configurations. I bought the lamp at [www.lowes.com](http://www.lowes.com) for about \$50. At press time, it was no longer available at Lowes, but Amazon and several other vendors still made it available.

The lumen rating is 120, relatively low because the unit uses only one LED, but the beamwidth is specified

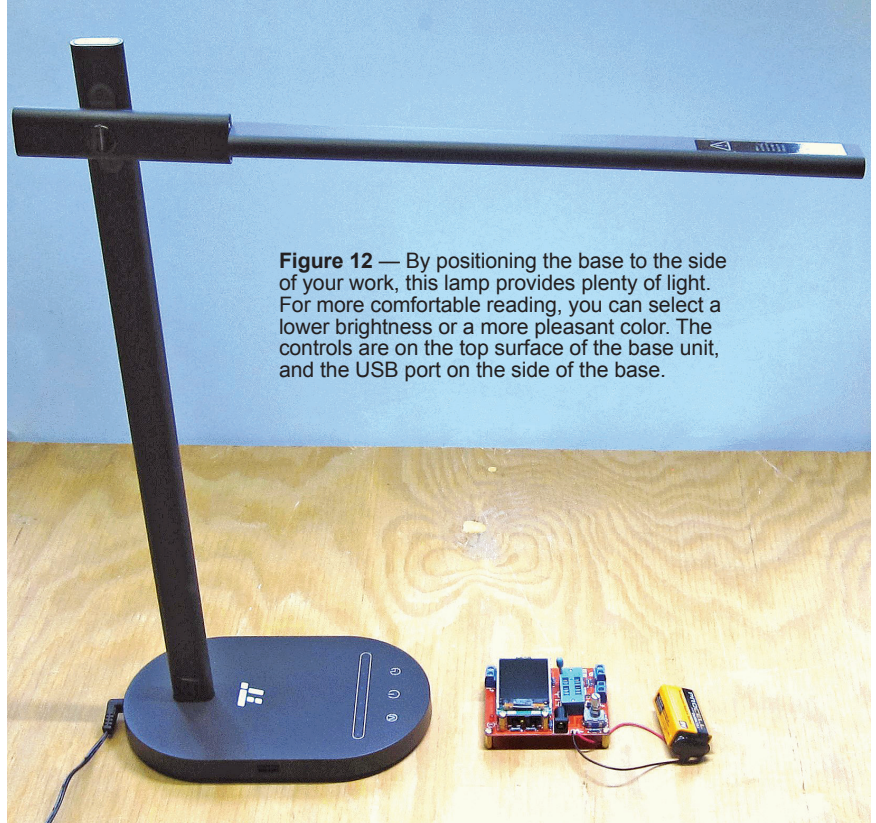


**Figure 11** — Both vise-type and screw-in-type mounts are included in this LED light. The head is small, but to get enough light from it, you have to position it very close to the work area.

at 15 degrees. Specified color temperature is 3,000 K. I hoped that the narrow beamwidth would provide a decent lux value, but unfortunately, it did not give off enough light to be useful on my workbench.

I found the TaoTronics TT-DL030 LED Desk Lamp, shown in Figure 12, on Amazon for about \$35, and it's available from other online vendors as well. Finally success! The intensity is adjustable. At maximum output, the lamp is rated at 1,500 lux when positioned about 16 inches from the lamp head to the work surface. It comes with five selectable color temperatures from 2,800 to 6,500 K. Positioned over your workspace, it gives you room to work and more than enough light for today's circuits.

On the base unit, there is an adjustable intensity control and three touch-sensitive areas. One area is the **ON/OFF** switch, the second is the color temperature selector, and the



**Figure 12** — By positioning the base to the side of your work, this lamp provides plenty of light. For more comfortable reading, you can select a lower brightness or a more pleasant color. The controls are on the top surface of the base unit, and the USB port on the side of the base.

### RF Interference from Lamps

Today's bulbs and fixtures most often have a power supply built in to drive the LED or other modern bulb. Despite FCC requirements limiting radiation from these power supplies, sometimes their emissions are strong enough to cause severe interference to nearby receivers. ARRL Lab Engineer Mike Gruber, W1MG, described this problem in "Light Bulbs and RFI — A Closer Look" (in the October 2013 issue of *QST*, pp. 42 – 45). Even with complaints and petitions to the FCC since then, the problem still exists. Sometimes the package will claim compliance, but that's not always the reality. The potential for interference is one more reason to make sure you can return any light bulb or lamp if you discover it radiates so badly that it interferes with your operating.

third is a timer. Power to the unit is supplied by a wall transformer that plugs into the base of the lamp. Pressing the timer area provides an automatic shutoff after one hour.

In addition, this lamp has a USB port. At first glance, you might wonder about the usefulness of a USB port on a workbench light, but today more and more equipment comes with the need to plug into a USB port for either operation or charging. You can also use it as a convenient 5 V dc

supply at 1 A, if you cut apart a USB cable.

### RF Interference Tests

I tested each of the bulbs and lamps for RF interference with my ham equipment. The first test used my main HF transceiver, about 10 feet away. This radio feeds a short length of coaxial cable, then a shielded balun, and finally ladder line to the antenna outside. The second test was with a portable consumer short-wave radio, unshielded, in a plastic

case with a 24-inch-long whip antenna. I tuned both of these radios across the HF bands from 80 through 10 meters, listening for interference from the lamps. Finally, I used a 2-meter handheld radio with the squelch off to listen for noise on VHF.

Neither the CREE LED lamp nor the Ecosmart LED spotlight put out HF or VHF noise detectable from more than an inch or two away from the bulb. The same was true for the Simple Designs and Artkalia LED desk lamps. Only the TaoTronics unit

put out a small amount of RF noise, detectable with the consumer radio when its whip antenna was as much as 5 inches away. In summary, interference with your receiver would not be a consideration for any of the bulbs or lamps tested here.

### Other Choices

In the January 2017 issue of *QST*, I reviewed the Carson Optical Pro Series Magnifying Visor with LED Light. The single light was very good for filling in shadowed places when I was working. Carried to the next

step, a headband-mounted light will do a good job in providing a spotlight on your project. Make sure the light can tilt, so you don't have to bend your neck to get the light on the subject.

Local stores and online vendors offer a wide variety of lights that might be a good addition to your workbench. Before buying anything, however, check the vendor's return policy. On your workbench, the results may be different from what you're expecting based on the manufacturer's description and specifications.

# NTE Electronics Heat-Shrink Self-Solder Butt Splice Connectors

*Reviewed by Mark Wilson, K1RO*  
QST Product Review Editor  
k1ro@arrl.org

Recently, DX Engineering announced the availability of some new butt connectors for splicing wire. Made by NTE Electronics, these connectors incorporate a low-temperature solder ring, waterproof hot-melt adhesive, and a transparent heat-shrink sleeve. They are installed with a heat gun and don't require crimping or soldering.

Connectors are available for four wire sizes: 26 – 24 AWG (NTE part no. 76-HISBC26); 22 – 18 AWG (76-HISBC22); 16 – 14 AWG (76-HISBC16), and 12 – 10 AWG (76-HISBC12). They come in packages of 50 and 100 and are color-coded for the different sizes.

I first tried the 12 – 10 AWG size to splice the power lead for a 13.8 V dc transceiver. I stripped the wires to the dimensions shown on the package and inserted the ends in the connector. At first, I had some trouble holding both ends of the wire and the connector in place while operating



### Bottom Line

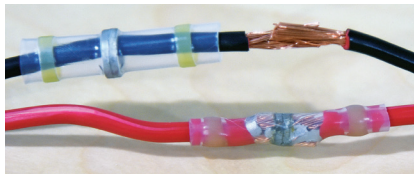
These NTE connectors require just a heat gun to make a secure, weatherproof connection without crimping or soldering.

the heat gun. After watching a YouTube video from DX Engineering, I learned that it works a lot better if you push the ends of the wires together so that the wire strands intertwine, as shown in Figure 13.

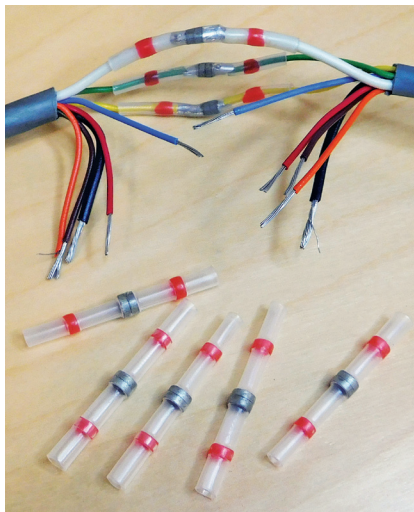
The spec sheet indicates that the solder starts to melt at 138 °C (280 °F). The heat gun I used is adjustable from 100 – 1,100 °F, so I picked a medium setting. The heat-shrink sleeve started shrinking right away, but it took a while for the solder to melt. At first, I was worried about heating the tubing too much, but eventually, the solder melted and the sleeve was still intact. I removed the heat and held the wire still until the solder cooled, making a good electrical connection. I tried tugging on the ends of the wire, and found that it was a good mechanical connection as well.

Next, I tried the 22 – 18 AWG size connectors with an eight-conductor rotator cable (see Figure 14). With the smaller connector and wire, the solder melted a lot more quickly.

There may be a situation in which you need to splice some wires where there is no ac power for a heat gun. I tried using the hot air tip with my Steinel TS-600 butane soldering iron,



**Figure 13** — The 12 – 10 AWG size connectors. Note how the strands are intertwined on the black wire.



**Figure 14** — Splicing a rotator cable with the 22 – 18 AWG size connectors.

and it worked just fine with both sizes of connectors. Actually, the narrow nozzle was easier to work with than the heat gun. I was able to first concentrate on melting the solder, and then finish shrinking the ends of the tubing. DX Engineering recommends using a reducing nozzle with a regular heat gun to better focus hot air on the solder ring, but I didn't have one for my heat gun.

*Manufacturer:* NTE Electronics, 44 Farrand St., Bloomfield, NJ 07003; [www.nteinc.com](http://www.nteinc.com). Available from DX Engineering ([www.dxengineering.com](http://www.dxengineering.com)) and other sources. Price: \$30 – \$47 for a pack of 50; \$59 – \$93 for a pack of 100 (varies by size).

## Strays

### Looking for QSLs

I am looking for QSL cards from W9NAA (Rose Tech Radio Club of Terre Haute, Indiana) and W9NVH (Herman Moench). If you have any to sell or donate contact me, C. Gidding, KC9UNL, at [curtstamp@aol.com](mailto:curtstamp@aol.com).

## New Products

### Third Hand Come-Along Tool

The Third Hand Come-Along tool can be used for pulling cables and wires behind furniture or taming tie-down straps that the wind seems to be blowing in the wrong direction. It is also handy for pulling tools to you when in tight spaces. Made with PVC and 95-pound-test paracord, it comes with a snap hook plus a 10-inch pressure loop strap for handling bulky items. For more information, or to order, visit [www.3rdhandtool.com](http://www.3rdhandtool.com). Price: \$9.50.

