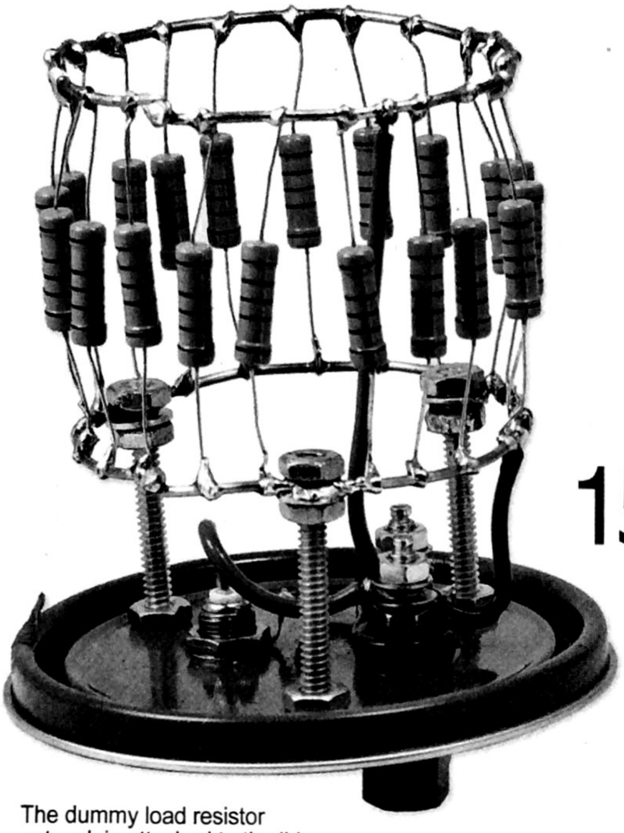

The dummy load resistor network is attached to the lid with brass bolts.

This project will find a home in every ham station, for whenever you're tuning on a band.

Build an Inexpensive 150 W Dummy Load with Wattmeter

Jack Purdum, W8TEE, and Al Peter, AC8GY

At our Milford Amateur Radio Club hamfest, we discovered that many local hams are interested in building projects. As a result, we formed the Greater Cincinnati Builders Group (GCBG) to share in each other's passion for building Amateur Radio gear. Twenty-eight members of the GCBG were able to build the dummy load (DL) described in this article.

It is essentially a less-expensive version of the DL that is in Jack's *Arduino Projects for Amateur Radio* book. Here, the display is a two-color OLED driven by an Arduino Nano microcontroller that plugs directly into the DL body (see Figure 1). We've tested the DL at 200 W for 5 minutes and, while you could probably cook French fries in the mineral oil, there was no damage to the DL. We conservatively rate the DL at 150 W.

Everyone should use a dummy load, especially with older equipment where a lot of knob-fiddling takes place each time you change frequency. This DL can easily be built in a single session. The circuit is simple, as is the code that runs the DL. The project is fairly inexpensive, at under $20.

You can download our source code and assembly manual from the **www.arrl.org/qst-in-depth** web page. The assembly manual contains a list of parts and suggested vendors for the components.

The Resistor Network

The dummy load is constructed from 20 non-inductive metal film resistors connected in parallel between two copper wire loops. Each resistor (see the lead photo) is 1,000 Ω at 3 W. In order for the resistor network to fit inside a quart can without touching any part of it, each wire loop is about 3 inches in diameter, spaced 2 inches apart. The resistors are wired in parallel, so the network looks like one large 50 Ω 60 W resistor. By bathing the resistor network in a quart of mineral oil, we increase its dissipation capability to more than 150 W. We use mineral oil rather than transformer (or other) oil because it is non-toxic.

Lay down two 14-inch-long pieces of #14 AWG wire about 2 inches apart on a work bench. Then solder the 20 resistors to the wires about ½ inch apart. Start the pattern at least 1 inch from the end of the two wires so you have enough of a pigtail left to twist/solder them together when you're done. Then loosely form the resistor network around a glass jar to make the 3-inch diameter circle.

"The dummy load is constructed from 20 non-inductive metal film resistors connected in parallel between two copper wire loops."

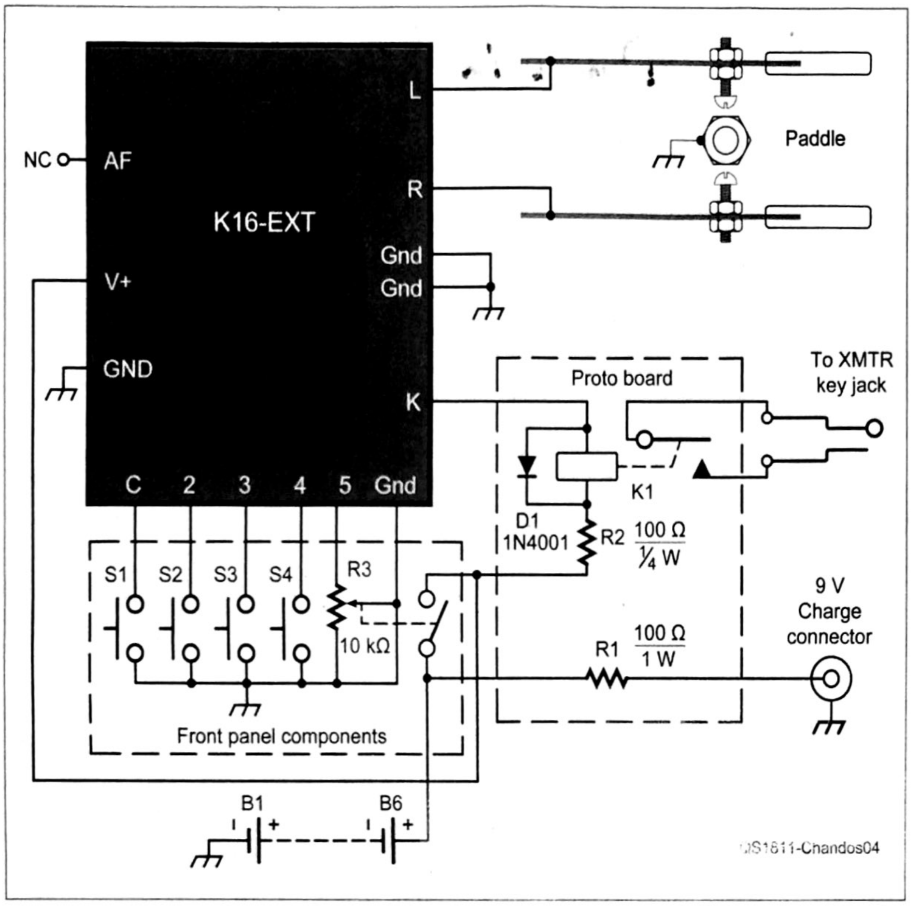

Figure 2 — Keyer schematic.
B1 – B6 — AA NiMH rechargeable batteries
D1 — 1N4001 diode
K1 — SRST reed relay, 5 V 20 mA coil
R1 — 100 Ω 1 W resistor
R2 — 100 Ω ¼ W resistor
R3 — 10 kΩ potentiometer with SPST switch
S1 – S4 — Momentary contact push-button switches

control for the keyer.[1] The module comes as a kit with a high-quality printed circuit board that has plated through holes and silk-screened component location information. Assembly was straightforward, taking less than an hour. This application requires several external components, as shown in the Figure 2 schematic. Potentiometer R3 controls the keying speed and the module is configured by switches S1 – S4.

I use the keyer with a number of transmitters, including vintage units with either cathode or grid-blocked keying, as well as modern units requiring logic levels. For this reason, I chose a reed relay K1 interface instead of the metal-oxide-semi-conductor field-effect transistor (MOSFET) interface provided by the kit. As a consequence, an internal battery power source is used. The 5 V reed relay requires 20 mA.

The power source is a stack of six NiMH AA rechargeable cells, mounted in a holder with a 9 V battery-style snap connector. The battery capacity provides approximately 6 months of operation without recharging.

Construction

The construction details are evident in Figure 1. Thin pieces of aluminum were bent in a vise for the front and back covers, and were attached to the wooden base with #4 wood screws. The front panel contains the four momentary contact switches and the speed control pot with its integral power on/off switch. The rear panel includes the transmitter interface cable and a jack to allow battery charging.

A small piece of prototype board is used for the reed relay K1 and its associated circuitry D1, R2 along with a current limiting resistor R1 for battery charging. The battery B1 – B6 is charged using a 9 V wall-wart voltage source. To determine when the battery is fully charged, the source is removed and the battery terminal voltage monitored via the charging connector. A terminal voltage of 8.35 V indicates full charge.

The kit and the prototyping board are fastened to the wooden base using #4 wood screws and nylon spacers. An aluminum strap secures the battery pack to the base. Finally, another piece of shop-fashioned aluminum forms the keyer cover, as shown in the lead photo.

Conclusion

After several months of operation, there have been no problems with the contact between the brass bolts and aluminum post. Although the battery charging method is less than optimal, it has proven satisfactory. The unit is heavy enough so that movement during operation is not a problem. In any case, I glued sheet cork to the bottom of the wooden base for increased friction on the operating table. My granddaughter loves to play with the keyer and has christened it "The Beep Box," for obvious reasons.

[1]P. Danzer, N1II, "Hamcrafters K16 Keyer Kit," Product Review, *QST*, Feb. 2017, pp. 64 – 65. Manual available from **www.hamcrafters2.com/files/k16man_R09.pdf**.

Photos by the author.

Amateur Extra-class licensee Ronald Chandos, W7ITR, has been licensed since 1952. He has a BS in physics from Cal State Long Beach. In 2001, Ron retired from Motorola Government Group after a 41-year career in aerospace. He has eight patents in the areas of computer architecture, cryptography, and satellite communications. Ron enjoys restoring and operating vintage boatanchors and military equipment, with a station consisting of four generations of equipment. His other interests include astronomy and woodworking.

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Next, mount the resistor network to the lid of the can. We designed a template (see Figure 2) for drilling the holes in the lid of the can. The ¾-inch spacing between points A – A is fairly critical as that is the spacing required for the two-terminal banana binding post seen in Figure 1. The 7⁄16-inch diameter holes at C points are for the 1½-inch-long brass bolts that hold the resistor network in place. The distance between each C hole is 2⅛ inches. The B hole is for the coax connector that will be used for the RF feed to the DL. Some of our builders used a connector meant to mate with a PL259 RF connector, while most preferred a BNC connector. The size of B depends on your choice of the antenna connector. The small plus sign (+) on the template is the approximate center of the lid.

Figure 1 — The RF power display mounts atop the can using banana plugs.

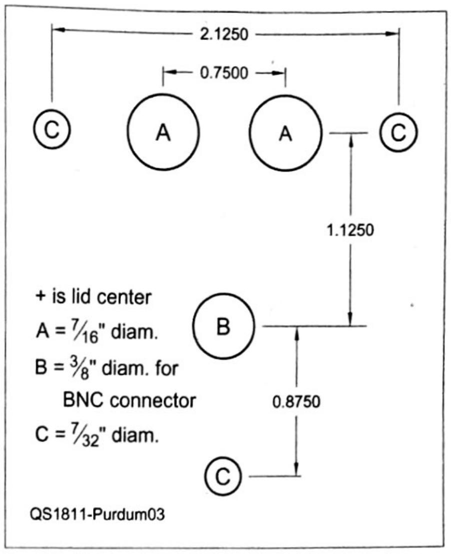

Figure 2 — The can lid template used for drilling holes.

The metal used to make the quart can lid is pretty thin and can tear if you are not careful when drilling the template holes. For that reason, draw the template on a piece of wood that fits "inside" the can's rim. Now place the lid between that piece of wood and a piece of scrap wood, clamp in place, and drill the holes. This should prevent you from tearing the lid while drilling the template holes.

The lid assembly should resemble that shown in the lead photo. Brass bolts and brass washers are used to hold the resistor network as they take soldering much better than stainless-steel hardware does. The assembly manual provides the details on the wiring. A thin film of silicone sealant around the holes and banana terminal block prevents the mineral oil from leaking out.

The Circuit

Figure 3 shows the circuit wiring for the DL. The small OLED display is controlled by an Arduino Nano. We buy these five at a time on the internet for about $3 each. The OLED is a small (0.96-inch) 128 × 64 display and uses the SPI interface, which minimizes the number of connections between the OLED and the Nano. Our display supports two colors and costs about $4. Cheaper displays are available, but make sure the display supports the SPI/I2C interface. Many suppliers are willing to give small discounts on quantity orders for group purchases.

In Figure 3, R3 is the resistor network built earlier and shown in the lead photo. D1 is a BAV21 diode. While the exact type is not critical, the diode is subject to some healthy RF, so it should have a voltage rating of at least 250 V. It rectifies the RF from the resistor network and feeds the R1 and R2 voltage divider. The junction of these two resistors is connected to the Arduino Nano analog Pin A1. The Nano can tolerate voltages only between 0 V and 5 V on an analog pin. The voltage divider keeps the voltage into A1 within safe limits. R1 and R2 can be ¼ W resistors. C1, a 250 to 500 V disc ceramic capacitor, helps average the rectified

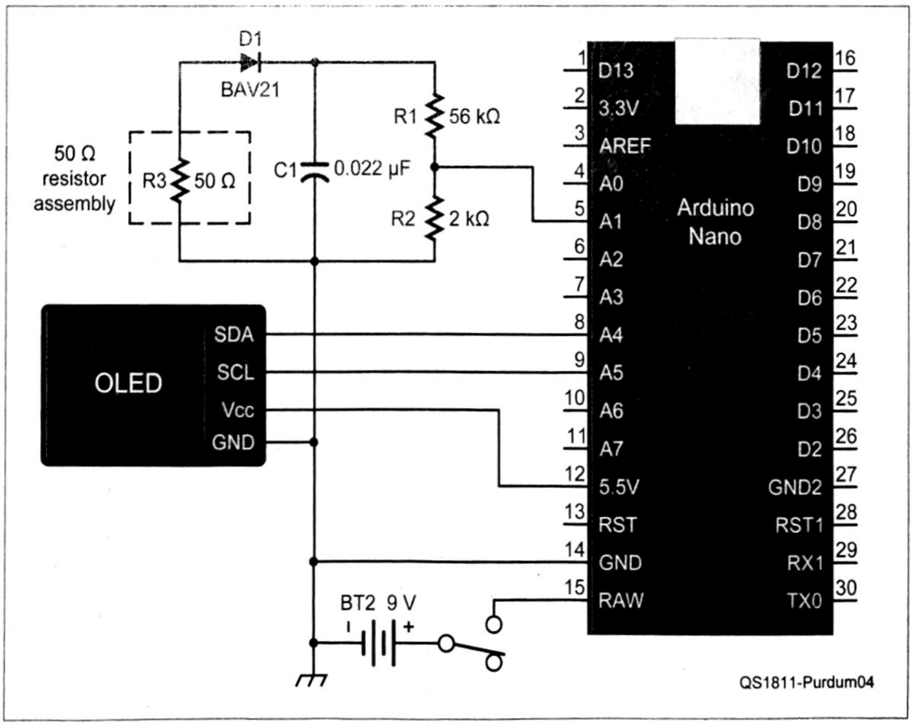

Figure 3 — The circuit diagram for the dummy load.

RF voltage from D1 to produce a clean dc voltage. The rest of the circuit shows how the 9 V battery power is routed through the SPDT switch to the Nano and OLED.

The data (**SDA**) and clock (**SCL**) lines from the OLED are connected to the Nano analog pins A4 and A5, respectively. These are the standard interface pins used by most Nano software libraries. The software uses two non-standard libraries:

```
#include <Adafruit_GFX.h>
//

https://github.com/
adafruit/Adafruit-GFX-
Library

#include <Adafruit_
SSD1306.h> //

https://github.com/
adafruit/Adafruit_SSD1306
```

All **#INCLUDE** preprocessor directives to the compiler that use non-standard libraries have a comment that tells you where to go on the internet to download the library.

Circuit Components

Because of the low parts count, we used a small 2 × 1.35 inch piece of prototype 0.1-inch pitch perforated circuit (PC) board to hold the circuitry. Figure 4 shows the Nano positioned on the PC board. The four-pin header at the top of Figure 4 is where the four pins of the OLED are plugged into the board. Also note that the Nano has a mini USB connector onboard. It's worth the extra cost to have the USB connector, as it simplifies programming the Nano considerably.

Mounting of the remaining components is not critical. The wiring of the few components between the OLED display and the Nano is explained in considerable detail in the assembly manual.

Figure 5 shows how we mounted the 9 V battery in the case along with its power switch and the banana posts that plug into the banana connector shown in Figure 1. Al used a 3D printer to fashion a custom faceplate in several different colors that is a perfect fit for the OLED and the PC board. He is making the 3D-print STL file available to anyone who wishes to use it.

Mounting the Resistor Network

Test the resistor network before putting the assembly in the can. Carefully inspect solder joints to make sure you did not miss [illegible] that there are no cold [illegible] Check the resistance [illegible] without the wattmeter attached. It should read with 0.2 Ω of 50 Ω. If you get 52 Ω or higher, one of the resistors is still not soldered. Re-solder any questionable connections.

> *"Test the resistor network before putting the assembly in the can."*

To prevent leakage, liberally apply silicone caulk to all of the areas inside the lid that have been drilled. Don't forget inside the RF connector. Some RF connectors can provide an internal leakage path for the oil.

Fill the can with a quart of mineral oil and you're done. Don't overfill the can — remember that the resistor network will displace some of the oil.

First-Time Use

Next, test the display electronics. Turn the DL on and look for the splash screen followed by a "0.00" display reading. Hook up the DL to your transmitter and send some power to it on the 20- or 40-meter band. Set your power level pretty low to start; perhaps 5 to 10 W. If the transmitter has an SWR readout, it should indicate very close to 1:1. If all is okay, send the DL some more RF power, and the wattmeter should read close to the transmitter power level. Try increasing the power levels and watch the reading go up.

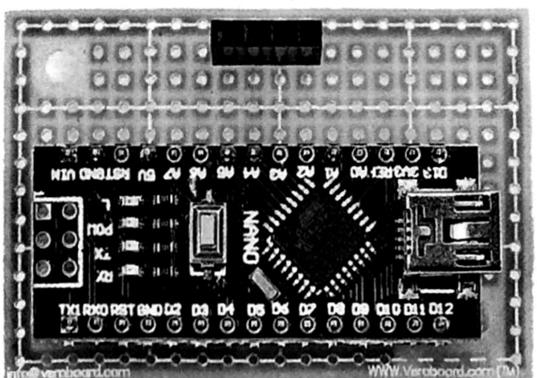

Figure 4 — The Arduino Nano and OLED header are mounted on a PC board.

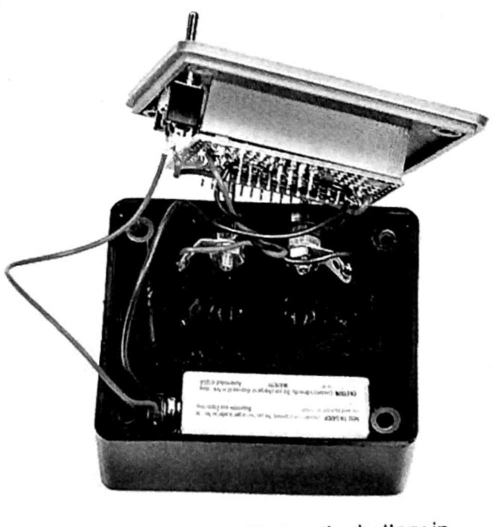

Figure 5 — Positioning the battery in the wattmeter housing.

Remember, the DL is good to only 150 W. If there is a problem, check all of the connections for opens or shorts.

Calibrating

The DL comes nominally calibrated, but you may wish to fine-tune your DL. Calibration is very easy. First, obtain an in-line wattmeter. Then, send a fairly high power level, 50 to 100 W, to the DL. Read the reference power level and the DL reading. Divide the reference level by the DL reading. That is your correction factor.

For example, if your reference meter shows 80 W and the OLED shows 76 W, your correction factor is **CORRECTIONFACTOR** = 80/76 = 1.052632.

To fine-tune the DL reading, you must make changes to the DL source code. Open the DL source code file in the Arduino IDE and look for the line that has the following directive:

```
#define CALIBRATIONOFFSET
8.9763
```

Now, multiply the **CALIBRATIONOFFSET** number by CorrectionFactor: **CALIBRATIONOFFSET** = 8.9763 × 1.052632 = 9.44874 and change the symbolic constant to the new value:

```
#define CALIBRATIONOFFSET
9.44874
```

Recompile and upload the new code. Do another trial — your display value for power should be very close now. If it is worse, check to see if you divided the reference level by the DL reading and try again.

The Dummy Load Code

The code for the dummy load is available as part of the download, and is also printed in the assembly manual. The code samples the power input 30 times — as determined by the variable named **ITERATIONS** — by reading the A1 **SENSORPIN** analog pin. This allows us to construct an average power reading. We used an average because the applied power could be changing due to tuning by the user or environmental factors, like the oil getting hotter. The 1-second delay at the bottom of the code loop is done to reduce flickering when the display is updated.

Conclusion

Dummy loads should be used whenever you are tuning on a band. If you have an antenna switch, connect one port to the DL. That way, with a quick flip of the switch, you can tune to your heart's content without affecting other hams on the air. It can also be useful if you're using a 100 W transceiver in a low-power environment or a contest as a quick way to make sure your settings are correct and that you're playing by the rules. This 150 W dummy load is a great club build project because it's useful, easy to build, and inexpensive.

"With a quick flip of the switch, you can tune to your heart's content without affecting other hams on the air."

Photos by the authors.

ARRL Life Member Dr. Jack Purdum, W8TEE, has been licensed continuously since 1954. He had his own software company from 1977 to 1994, specializing in programming tools, including an MS-DOS C compiler. Jack retired from Purdue University's College of Technology, where he taught various programming courses. He has written dozens of magazine and journal articles, along with 18 programming texts, including *Arduino Projects for Amateur Radio* and *Beginning C for Arduino*. He is Vice President of the Milford Ohio Amateur Radio Club and co-founder of the Greater Cincinnati Builders Group. You can reach Jack at **jjpurdum@yahoo.com**.

Al Peter, AC8GY, has a background in physics and mechanical engineering. He has been a ham since 2010, and an electronics builder-experimenter since the 1960s. Al was founder and CEO of a major engineering consulting and software company specializing in CAD and related software, and has extensive computer and software experience. He designed and built Arduino MCU-related projects for Amateur Radio. His projects include an add-on board for the uBITX, a high-performance Arduino-based signal generator, a scalar network analyzer, and various economical high-function tools for the ham shack. Al's interests include photography, woodworking, and fly fishing. He is co-founder of the Greater Cincinnati Builders Group. You can reach Al at **afp.ac8gy@gmail.com**.

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Feedback

In Figure 4 of the September 2018 Product Review of the Goal Zero Yeti 400 Lithium Portable Power Station (pp. 40 – 42), the label for the vertical axis should read "Voltage Divided by 10." The plot shows –200 to +200 V. *(Thanks Ted Cohen, N4XX)*