

150 W Dummy Load

Build An Inexpensive 150W Dummy Load With Wattmeter

by

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The club (Milford Amateur Radio Club) that Al and I belong to had not done a club build until about a year ago when we did an antenna analyzer build. (November, 2017, *QST*.) At our hamfest, we discovered that there are a lot of other local hams who are interested in building projects. As a result, this past June we formed the Greater Cincinnati Builders Group (GCBG) and have a small knot of enthusiastic amateurs who share our passion for building amateur radio gear. It's an informal group without officers or monthly meetings; simply tied together through our common interest.



Figure 1. The dummy load display case.

The first build saw 28 members for the GCBG build the dummy load (DL) featured here. (See Figure 1.) It is essentially a less expensive version of the DL that is in my *Arduino Projects for Amateur Radio* book. The main difference is that the display is now a two-color OLED driven by an Arduino Nano microcontroller that plugs directly into the DL body. We've tested the DL at 200W for five minutes and, while you could probably cook French fries in the mineral oil, there was no damage to the DL. We have conservatively rated the DL at 150W.

If your club has never tried a club build, this would be a good first project for several reasons. First, everyone who puts a signal on the air should have, *and use*, a dummy load. With older equipment, there was a lot more knob-fiddling taking place each time you changed frequency. The max-and-min dance with the plate and grid controls of the old tube era made a DL a real necessity in the shack. While most modern transceivers minimize the tuning process, all of us have heard the clown who is whistling into his mike while he's messing around with "something" in his shack. Other "lids" nail a CW signal right on top of that rare DX station you just heard. A dummy load allows you to do whatever you feel you must, but the RF stays in your shack and isn't radiated to annoy the rest of us.

A second reason this is a good first project is because it can easily be built in a single session. The circuit is simple, as is the code that runs the DL. We have members who had never built anything before and they successfully completed the DL in a single afternoon. A third reason the DL is a good starting project is because it is fairly inexpensive. The cost should be under \$20, which might encourage those "on the fence" to take the plunge. We have made the source code and assembly manual for the build available and can be downloaded from our web site: HamRadioDesigns.com

The assembly manual contains a list of parts and suggested vendors from which to buy the components.

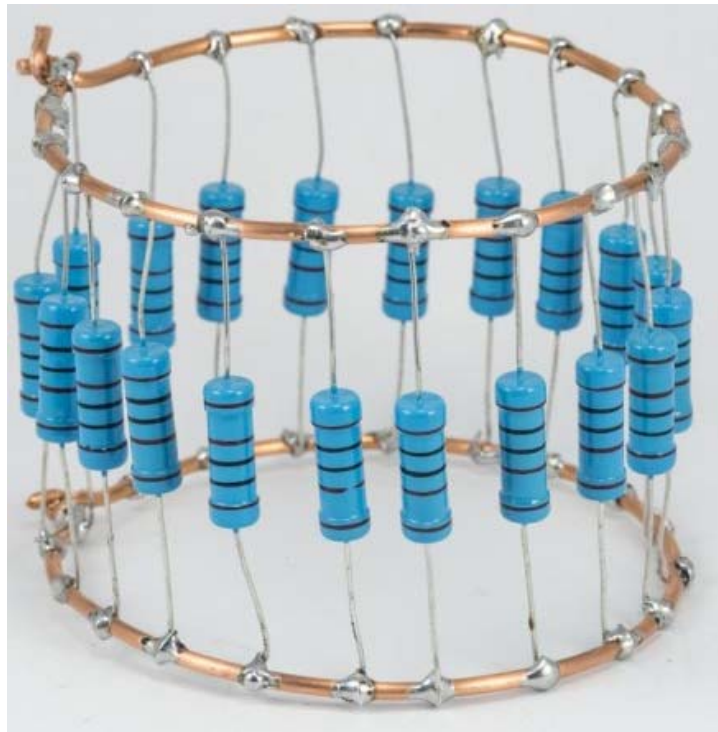


Figure 2. The DL resistor network.

The Resistor Network

The heart of the DL is constructed from 20 3W 1000 Ω (non-inductive) metal film resistors connected in parallel. Figure 2 shows the new version of the completed resistor network. The DL in the *Projects* book had the resistor network soldered between two brass sheets which were expensive and, in some cases, hard to find. This new version replaces those brass sheets with scrap wire stripped from standard 3-wire house

wiring. If you have a new housing develop going on somewhere near you, you can probably find scrap pieces of house wiring free for the asking.

In order for the resistor network to fit inside a quart can, each wire loop needs to be about 3" in diameter, spaced about 2" apart. These dimensions allow the resistor network to easily fit inside the quart can without touching any part of it. Because the resistors are wired in parallel, the network ends up looking like one large 50Ω, 60W resistor. By bathing the resistor network in a quart of mineral oil, we increase its ability to absorb power to more than 150W. We use mineral oil rather than transformer (or other) oil because it is non-toxic.

If you do the math, two pieces of 14 gauge wire about 14" long should be laid down on a work bench 2" apart. Then solder the 20 resistors to the wire, about 0.50" inches apart. Start the pattern at least 1" from the end of the two wires so you have enough of a pigtail left to twist/solder them together when you're done. You could then loosely form the resistor network around a glass jar to form the 3" diameter circle. You get the idea...

The next task is to mount the resistor network to the lid of the can. We designed a template for drilling the holes in the can, as seen in Figure 3. The spacing between points A-A (0.75") is fairly critical as that is the spacing required for the two-terminal banana binding post seen in Figure 1. The holes at points C are for bolts that hold the resistor network in place. Hole B is for the coax connector that will be used for the RF feed to the DL. We had some builders use a connector meant to mate with a PL259 RF connector while most preferred a BNC connector. Your call, but the size of B is influenced by your choice of the antenna connector. The small plus sign (+) on the template is the approximate center of the lid.

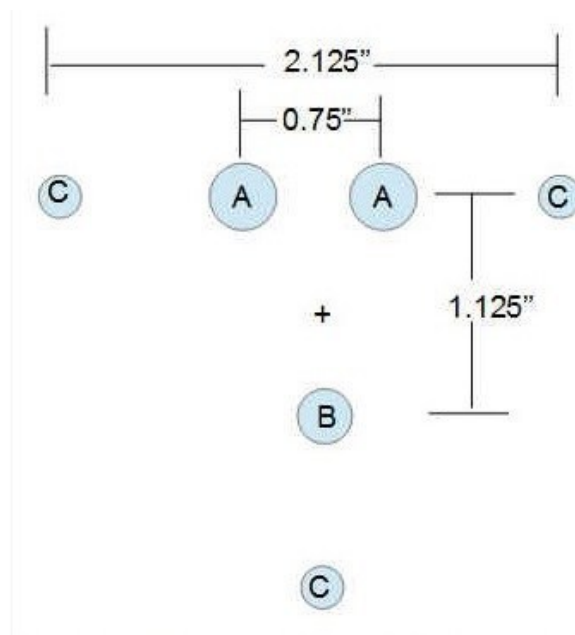


Figure 3. The can lid template.

Note that the metal used to make the quart can is pretty cheap and will "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.

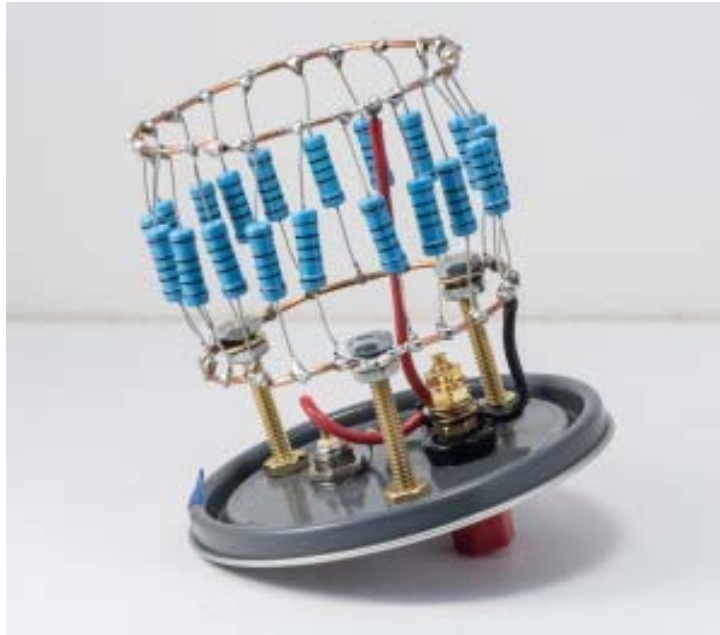


Figure 4. Mounting the resistor network.

When the lid construction is completed, it should look similar to that shown in Figure 4. Brass bolts and washers are used to hold the resistor network as they take soldering much better than stainless steel hardware. (The assembly manual provides the details on the wiring shown in Figure 4.) A thin film of silicon sealant around the holes and banana terminal.

The Circuit

Figure 5 shows the circuit that is used 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. Our experience with clones has been very good. The OLED is a small (0.96") 128x64 display and used the SPI interface. This interface minimizes the number of connections between the OLED and the Nano. We chose a display that supports two colors at a cost of about \$4 each. Cheaper displays are available, but make sure it supports the SPI/I2C interface. Also, don't be afraid to write to your parts supplier if you are buying for a group. Most are willing to give small discounts on quantity orders.

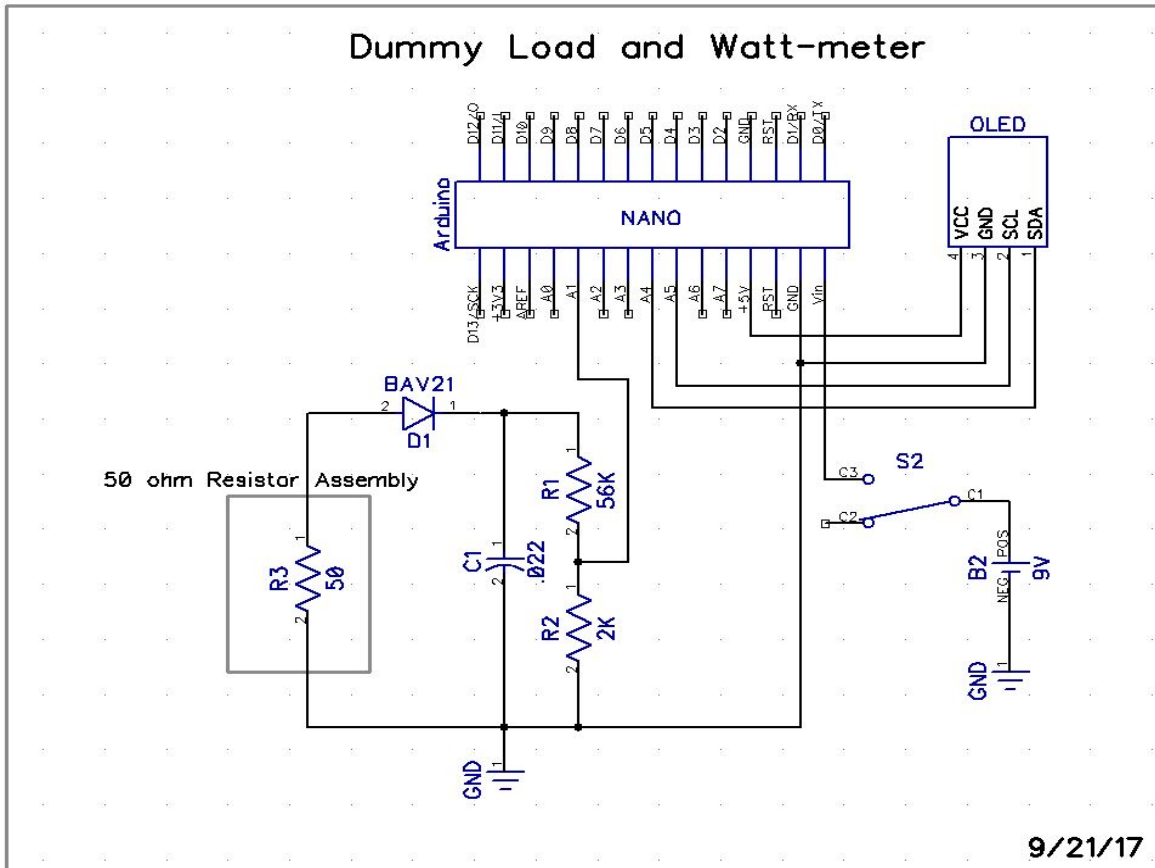


Figure 5. Circuit diagram for DL.

In Figure 5, R3 is the resistor network built earlier. 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 250V or more. Its purpose is to rectify the RF coming from the resistor network, which can then be fed into the voltage divider formed by R1 and R2. The junction of these two resistors is connected to the Arduino Nano analog pin, A1. The Nano can only tolerate voltages between 0V and 5V on an analog pin. Because the voltage coming from D1 may exceed 5V, the voltage divider created by R1 and R2 keeps the voltage going into A1 within safe limits. The current coming into the voltage divider is fairly small, so 1/4W resistors are fine for R1 and R2. C1 helps average the rectified RF voltage from D1 to produce a clean DC voltage. We used a 500V disc ceramic for C1; probably overkill, but they were cheap and available. The rest of the circuit shows how the 9V battery power is routed through the SPDT switch and 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
https://github.com/adafruit/Adafruit_SSD1306
<Adafruit_SSD1306.h>//
<![if
!supportLineBreakNewLine]>
<![endif]>
```

Again, 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. Figure 6 shows the OLED connections during testing.

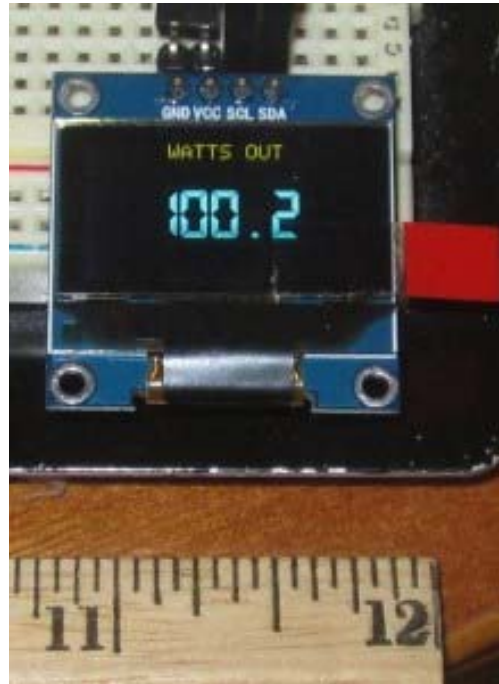


Figure 6. OLED connections.

Circuit Components

Because of the low parts count, we simply used a small piece (2" x 1.35") of prototype perf board (0.1" pitch) to hold the circuitry. The 4-pin header at the top of Figure 7 is where the 4 pins of the OLED are plugged into the board. Also note that the Nano has a mini USB connector onboard. You can buy the Arduino Nano Pro Mini for less than the Nano, but the Pro Mini version does not have the USB connector. It's worth the extra dollar or so to have the USB connector as it simplifies programming the Nano considerably.

Mounting of the remaining components is not critical, but we elected to mount them near the upper-right corner of the board. The wiring of the few components between the OLED display and the Nano is explained in considerable detail in the assembly manual, along with numerous photos. Figure 7 shows how our board looks from the bottom side of the board, which is where the connecting wires are placed. Your layout may well vary depending on the size and shape of your case. Figure 8 shows how we mounted the 9V battery in the case along with its power switch and the banana posts that plug into the banana connector shown in Figure 4.

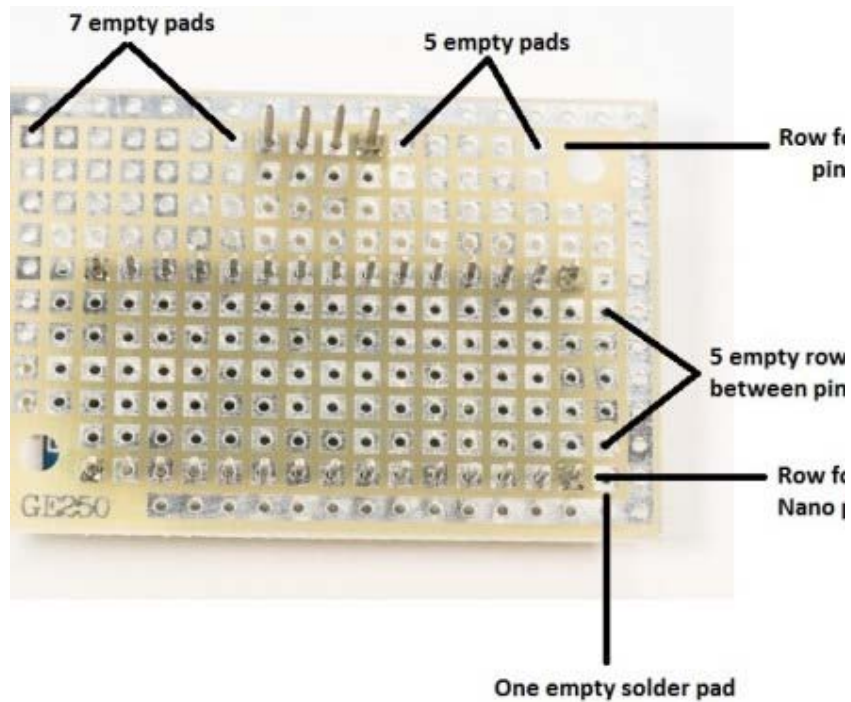


Figure 7. View from the bottom of the circuit board.

AI used a 3D printer to fashion a custom faceplate in several different colors that is a perfect fit for the OLED and the perf board. He is making the STL (3D print) file available to anyone who wishes to use it. Again, the assembly manual has many additional photos to help guide you in the construction process.



Figure 8. Positioning the Battery

Mounting the Resistor Network

Before putting the assembly in the can it is a good idea to test the resistor network. First, carefully inspect the 40+ solder joints to make sure you did not miss one or that there are no cold-solder joints. Once you are satisfied, check the resistance of the network without the Watt-meter attached. It should read quite close to 50 ohms (49.8 to 50.2 ohms). If you get 52 or higher, one of the resistors is still not soldered. Re-do any questionable connections.

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

That's it! 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

Now we are ready to test the DL. Because you know the resistor network is good, the next job is to test the display electronics. Turn the DL on and look for the splash screen followed by a "0.00" display reading. Now hook up the DL to your transmitter and send some power to it on 20 or 40 M. Set your power level pretty low to start; perhaps 5 to 10W. If the transmitter has a SWR readout, it should indicate "1" or very close to that value. If all is OK, send the DL some more RF power, and the Watt meter should read pretty close to the transmitter power level. Try increasing the power levels and watch the reading go up. Remember, the DL is only good to 150W, so keep it away from your kilowatt rig. If there is a problem, check all of the connections for opens or shorts.

Calibrating

While the DL comes nominally calibrated, you may wish to fine tune your DL to account for tolerances in the components. Calibration is very easy. First, beg or borrow an in-line Watt-meter, if you don't already have one. Fellow hams in your club may have one or your a high school or university physics lab may let you use theirs. Then send a fairly high power level to the DL, preferably between 50 and 100 watts. Read the reference power level and the DL reading. Divide the reference level by the DL reading. That is your correction factor.

For example, suppose your reference meter shows a value of 80W and the OLED shows 76W with the same input power. Your correction factor is:

$$\text{CorrectionFactor} = 80 / 76 = 1.052632$$

There is no reason to carry the fractional component past 6 decimal places because the Arduino compiler's *float* data type has, at most, 7 digits of precision. To fine tune the DL reading, you have to be able to 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 CALIBRATIONOFFSET8.9763
```

Now, multiply the *CALIBRATIONOFFSET* number by *CorrectionFactor*:

$$\text{CALIBRATIONOFFSET} = 8.9763 * 1.052632 = 9.44873$$

and change the symbolic constant to the new value:

```
#define CALIBRATIONOFFSET9.44873
```

Recompile and up-load 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 ref 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 is pretty simple and doesn't need much in the way of comments. The code does not rely on a single reading of the power level. Instead, the code samples the power input 30 times (as determined by the variable named *ITERATIONS*) by reading the A1 analog pin (i.e., *SENSORPIN*). This allows us to construct an average power reading. The average is used because the power being applied could be changing because of tuning by the user or environmental factors (e.g., the oil getting hotter). The one second delay at the bottom of the code loop is done to reduce flickering which is introduced when the display is updated. The flickering cannot be completely avoided, but the delay makes it less noticeable.

The rest of the code should be pretty easy to understand.

Conclusion

We think this is a great build project for a club because:

- 1) it's useful,
- 2) it's easy to build, even for beginners, and
- 3) it's inexpensive to build.

A DL is one piece of equipment every shack should have and that you should use whenever you are tuning on a band. If you have an antenna switch, connect one post to the DL. That way, a quick flip of the switch and you can tune to your heart's content without affecting other hams on the air. You can also use it to check the power level you are running. If you're using a 100W transceiver in a QRP environment or contest, this provides a quick way to make sure you're settings are correct and you're playing by the rules. We hope you will use this DL often in your shack to not only monitor the power output from your rig, but also to limit radiating power during any tune-up procedures you might use.