

# A Wideband Dummy Load with a High-Accuracy Wattmeter

This inexpensive dummy load/Arduino-based wattmeter for 2 meters, 70 centimeters, and 23 centimeters is easy to build and performs like a commercial device.



The completed dummy load/wattmeter.

## Bob Fontana, AK3Y

In their November 2018 *QST* article “Build an Inexpensive 150 W Dummy Load with Wattmeter,” authors Jack Purdum, W8TEE, and Al Peter, AC8GY, designed and built an Arduino-based wattmeter with a dummy load that was limited to the HF through the lower VHF bands.

In “A High-Power Dummy Load for DC through VHF” in the August 2023 issue of *QST*, Stephen Werner, AG4W, used high-power flange-mounted resistors in a dummy load that could handle legal-limit power at up to 225 MHz.

My local FM repeater club recently decided to design a dummy load/wattmeter that covers 2 meters, 70 centimeters, and 23 centimeters. It had to accurately measure power levels from a few tens of milliwatts to 100 W, and it had to be compact enough to use for ARRL Field Day or other portable operations. Another desirable feature was the ability to use the same instrument in the VLF through HF spectrum, as several of us were also experimenting in the 630- and 2200-meter bands. A truly wideband device was of paramount interest. To achieve these requirements, it uses a

flange-mounted high-frequency/high-power resistor with a diode detector and an Arduino microcontroller. The associated software uses a few techniques to achieve very high accuracy, even at very low power levels.

## Flange-Mounted Resistors

Flange-mounted resistors typically use either a thin beryllium oxide (BeO) or thick aluminum nitride (AlN) film for the substrate material. Tantalum is often used as the resistive material. The mechanical and electrical properties are well controlled, resulting in superb high-frequency behavior — often well into the microwave range. Because of their thermal conductivity, these flange-mounted resistors can dissipate a lot of power despite being quite small. They are usually inexpensive, at less than \$5 for a 250 W unit. But before acquiring one, understand that beryllium is highly toxic. Don't ever open one of these devices.

## Design Concept

The dummy load/wattmeter consists of two printed circuit boards (PCBs): one for the wattmeter detection circuitry and another for the Arduino/display circuitry and interface. The detector board is flush mounted to a 45 × 60-millimeter aluminum heatsink, and the load

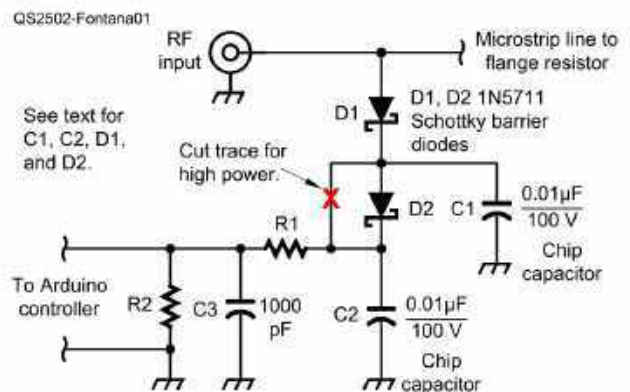


Figure 1 — The dummy load schematic.

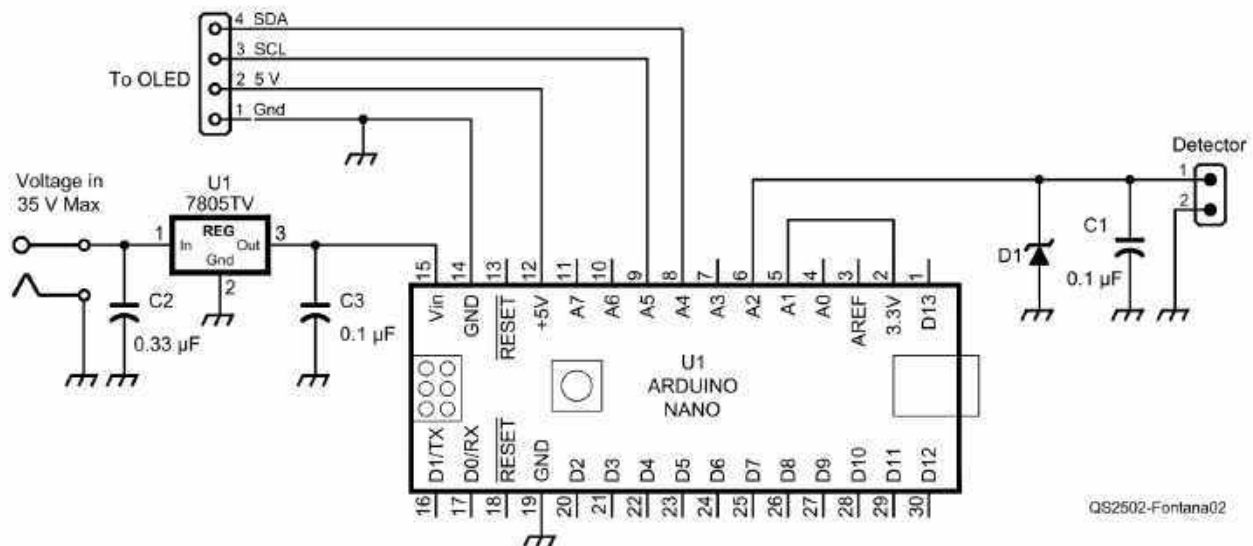


Figure 2 — The Arduino controller and display schematic.

resistor is also mounted on the heatsink. The PCB construction allows for the use of 50  $\Omega$  microstrip interconnects, which results in a wide frequency response. The Arduino-based wattmeter portion of the project incorporates automatic calibration of the resistor-divider network using the on-board 3.3 V reference voltage. The resistor-divider network limits the detector voltage into the Arduino's analog inputs. More detailed descriptions of the calibration techniques used and the associated software design can be found at [www.arri.org/qst-in-depth](http://www.arri.org/qst-in-depth). There, you will also find the Gerber files for the detector circuitry and Arduino-based controller PCBs.

### Circuit Details

The schematics for the two PCBs are shown in Figures 1 and 2. The assembled PCBs are shown in Figures 3

and 4. The complete parts list for the two boards and pictures of the bare PCBs are shown at [www.arri.org/qst-in-depth](http://www.arri.org/qst-in-depth).

The flange-mounted power resistor mounts to the heatsink using thermal compound. A short length of 50  $\Omega$  microstrip connects it to the SMA input connector. Because the heatsink is small, operation at 100 W should probably be limited to no longer than 1 minute. For higher power levels, or for longer transmit durations, you can flip the unit so that the heatsink is on top. If you flip the unit, you must also flip the OLED display. This requires a couple of lines of code change. Add the line "display.setRotation(2);" after each instance of "display.clearDisplay();"

The completed assembly is shown in Figure 5, which demonstrates the power from a Baofeng UV-5R being



Figure 3 — The assembled dummy load/detector.

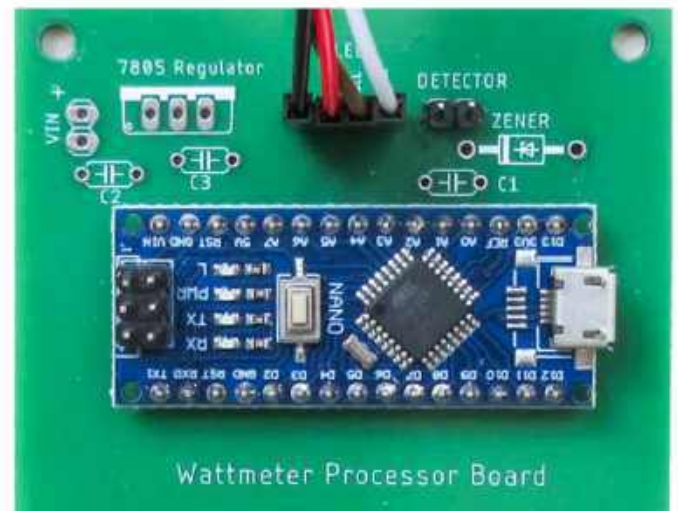
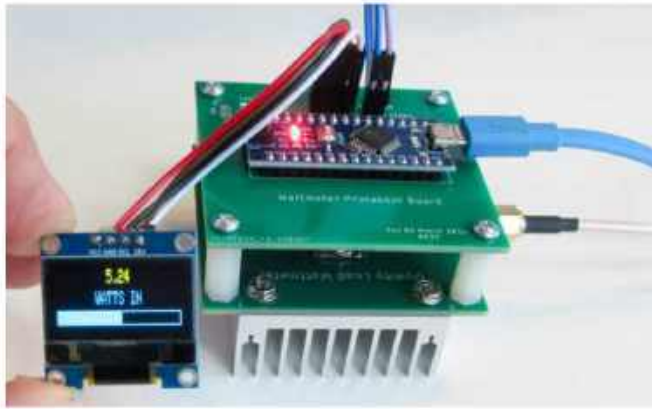


Figure 4 — The assembled Arduino controller.



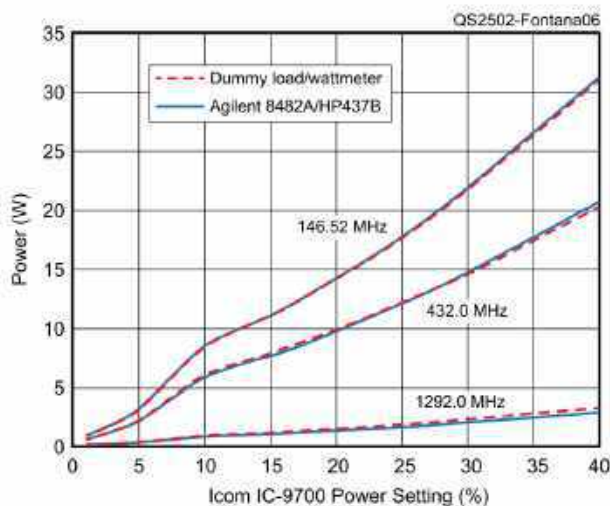
**Figure 5** — The assembled and unpackaged dummy load/wattmeter.

measured at 146.52 MHz. The software provides an adaptive bar graph display so that changes in power level can be observed both numerically and graphically — the latter is useful for tuning applications. The lead photo shows the dummy load/wattmeter packaged in a 3D-printed case. The 3D STL files are included at [www.arrl.org/qst-in-depth](http://www.arrl.org/qst-in-depth).

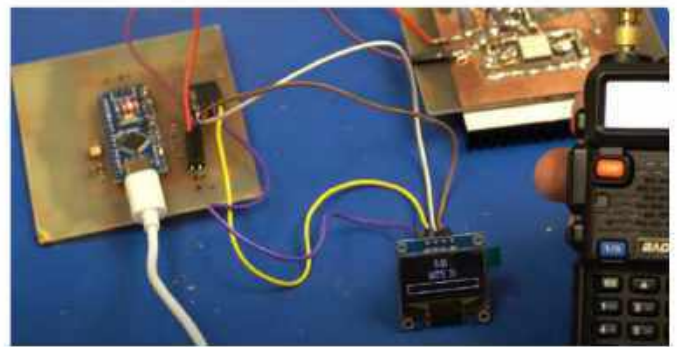
### Performance and Recap

The measured standing wave ratio was less than 2.0:1 to 1360 MHz and less than 1.5:1 from dc to 755 MHz. Using my Icom IC-9700 as a signal source, I compared this unit to an Agilent 8482A power sensor and HP437B power display on 2 meters, 70 centimeters, and 23 centimeters. The results are shown in Figure 6.

You can see how close the two setups compare, down to the tens of milliwatts (the minimum readable signal level for this unit is approximately 5 mW). On 2 meters, the worst-case error was 1.6% (0.069 dB). On 70 centi-



**Figure 6** — A power measurement comparison between the dummy load/wattmeter described in this article and the commercial Agilent 8482A sensor.



Click here to watch ARRL Lab Digital RF Engineer John McAuliffe, W1DRF, take you along as he builds a wattmeter.

meters, the worst-case error was 3.3% (0.14 dB), and on 23 centimeters, it was 9.9% (0.41 dB). However, keep in mind that the Agilent 8482A sensor element has specifications for only  $\pm 1.6\%$ , and the HP437B power sensor can add another  $\pm 1.5\%$  variation.

This article describes a field-portable dummy load/wattmeter that can be used from dc to the 23-centimeter band with an accuracy rivaling that of expensive Agilent test equipment. With the ability to measure power levels down to 10 mW, the unit is ideal for QRP and QRPP operations as well.

### See QST in Depth for More!

Visit [www.arrl.org/qst-in-depth](http://www.arrl.org/qst-in-depth) for the following supplementary materials and updates:

- ✓ Calibration techniques for the resistor-divider network and associated software design
- ✓ Gerber files for the detector circuitry and Arduino-based controller PCBs
- ✓ Complete parts lists for the dummy load PCB and the wattmeter PCB
- ✓ Pictures of the bare PCBs
- ✓ STL files for the device's 3D-printed case

All photos provided by the author.

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