

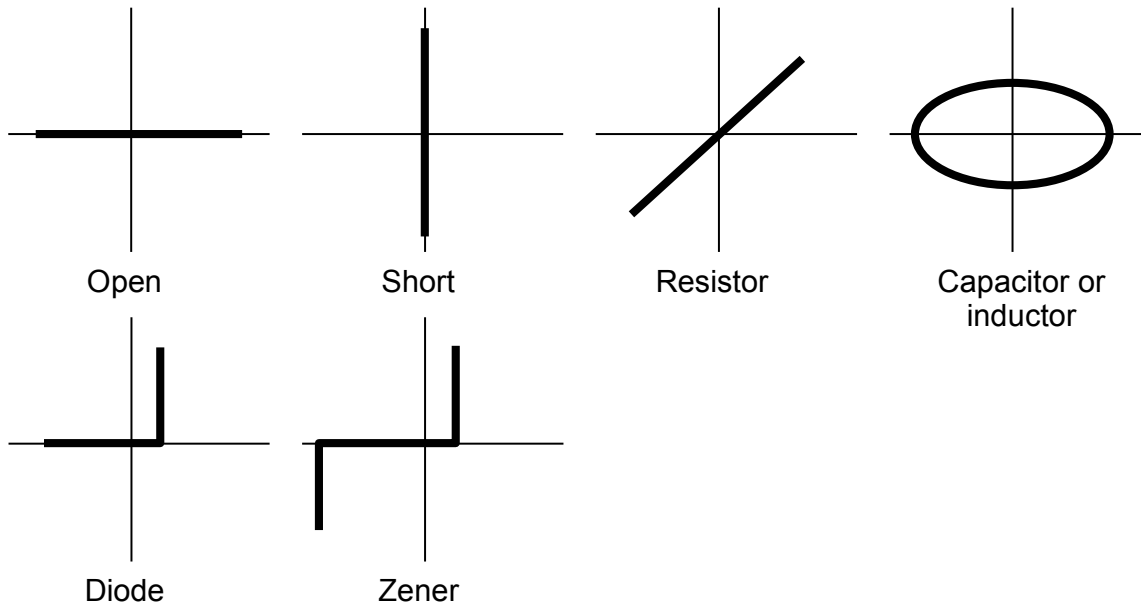
Octopus Tester

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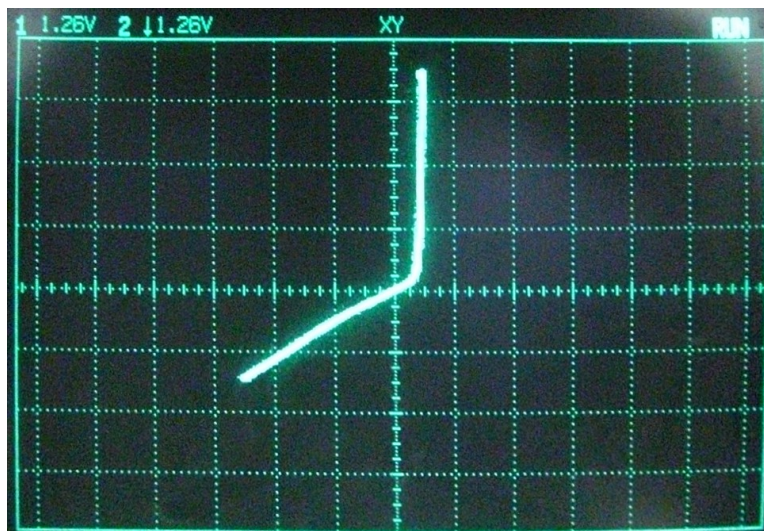
If you have an oscilloscope and you like fixing electrical things, a useful tool you can build is the Octopus tester. An added benefit is that it can be built from scrap you may already have.

This device probably got its name from the leads running all over the bench when you cobble one together. You can do a web search on "octopus tester" and you'll find lots of web pages with useful ideas.

The circuit provides a current-limited AC voltage to apply to components (and subcircuits) to test them with the circuit's power off. An oscilloscope is used to present the AC voltage along one axis and the current through the component on the vertical axis. This results in a current versus voltage $i(V)$ plot for the component. Typical patterns seen on the scope are:



The patterns for the inductor and capacitor are Lissajous patterns showing that the current leads or lags the voltage. In testing real circuits, you will often see combinations of these patterns. Here's one -- a signature of a diode in a sprinkler controller circuit:



You can see the slope of a resistor in the circuit, then the point where the diode turns on at around

half a volt (so it's a silicon diode, not surprisingly). Interestingly, a resistor next to this one showed a similar figure except the diode turn-on came at 2.5 volts and the turn-on point moved to the right, indicating a capacitor was charging. This is an example of a circuit giving a more complicated pattern than those illustrated above. A powerful troubleshooting tool is to compare these patterns on a suspect or non-working circuit with a working one. If any differences are seen, you immediately begin to suspect something that is involved in that subcircuit.

A key point is that you typically hold two probes in your hand and probe the parts of the circuit. You look up at the scope's display, mentally evaluate the pattern, then go to the next component. This is fast -- you might spend a couple of seconds on each part. And, remember: you can make these comparisons even if you don't have a schematic of the circuit. Most things I've had to troubleshoot I haven't had a schematic.

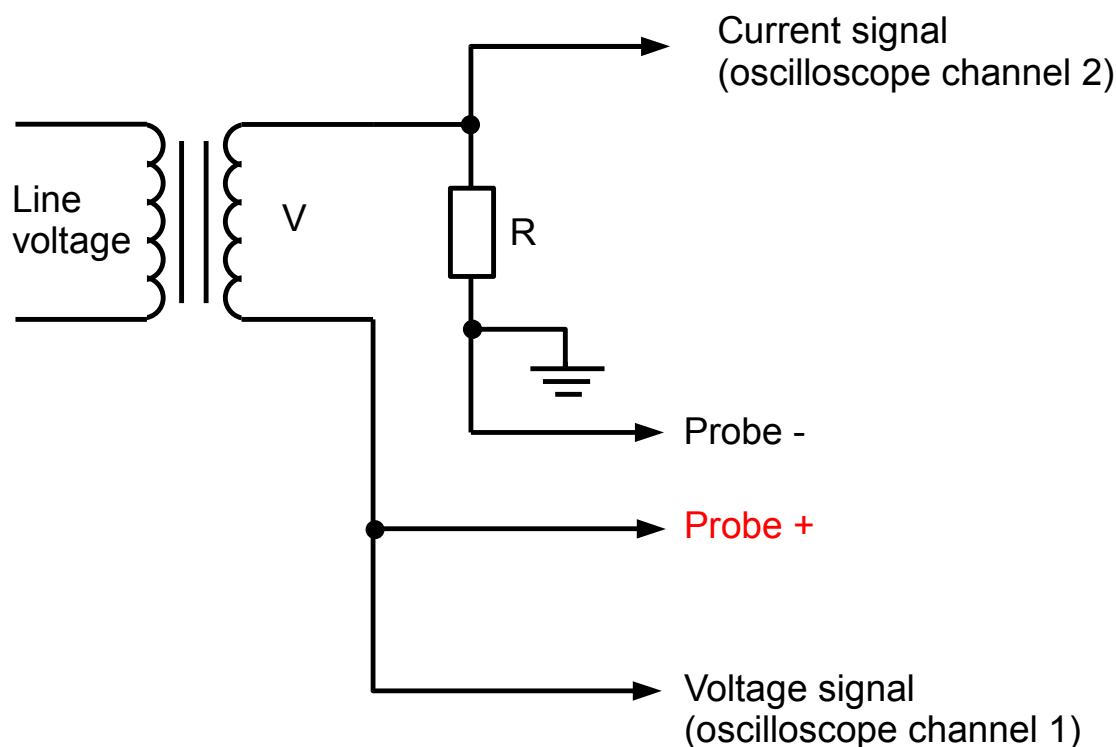
The basic test method of the Octopus was developed in the 1930's soon after the first commercial oscilloscopes appeared. A commercial instrument called the Huntron Tracker works on this principle and is still sold, but is priced out of reach of the typical hobbyist. I've not used a Huntron Tracker, but I suspect they are much nicer than the home-built variety, as they can change applied voltage range and frequencies, allowing you to test more components.

Some analog oscilloscopes have an Octopus tester built into them (one example is the B&K 2125A).

The method is sometimes called analog signature analysis. This contrasts to "digital signature analysis", which was made briefly popular by HP in the late 1970's with an instrument used to capture digital signatures from digital circuitry. However, it never became terribly popular as a troubleshooting technique because of the need to stimulate the circuitry in particular ways (I've read it's still occasionally used in niche applications). But analog signature analysis is still used frequently for troubleshooting.

The circuit

A minimal circuit is:



If the output of the transformer is V RMS volts, the circuit will apply a $2\sqrt{2} V$ peak-to-peak voltage across the unknown. Since 6.3 Vrms filament transformers are fairly common, they are often used

to construct an Octopus tester. The resistor R in ohms is used to limit the current through the component being probed, connected to the two points marked Probe. The short-circuit RMS current will be V/R . The RMS power dissipated by the resistor is V^2/R . These two relationships allow you to pick an appropriate value for R and its wattage rating.

You can, of course, build fancier versions; a web search will give numerous ideas. Most revolve around transformers with more voltage taps and rotary switches to select different values of R to get different short-circuit currents.

The transformer I used for mine was 7.0 Vrms center-tapped. This also gave me 3.5 Vrms. These conveniently gave me 5 volts and 10 volts zero-to-peak test voltages, making it easy to calibrate the horizontal axis of the scope. I decided I'd have 1 mArms of current in the 3.5 Vrms case and 10 mArms of current in the 7.0 Vrms case. This meant I needed 700 Ω and 3500 Ω resistors; I used a 680 Ω and 3470 Ω resistors, as they were what I had on-hand. I could have gotten closer, of course, by using a combination of resistors, but such accuracy is not needed for typical troubleshooting, so I didn't bother.

Here's a picture of the one I built:



This was made in an old box that already had the 6.3 VAC transformer mounted in it with a line cord; there were also four holes already drilled in the box, so I used them and adapted the rest as needed.

The leads were plugged into a digital multimeter set to measure current. At the 3.5 Vrms setting, the AC current was 1.02 mArms. At 7.0 Vrms, the current was 10.52 mArms.

Using the tool

The octopus tester is easy to use. Here's the procedure I use (for the 3.5 Vrms output voltage):

1. Connect the voltage output BNC terminal to channel 1 on the scope.
2. Connect the current output BNC terminal to channel 2 on the scope.
3. Set the Octopus to 3.5 VAC output.
4. Set the scope to XY mode.
5. Power on the tester.
6. You'll see a horizontal line. Set channel 1's gain to 1 V/div so that the line extends from -5 to +5

major divisions. Adjust position to center the line about the vertical axis.

7. Short the leads together to get a vertical line. Set channel 2's gain to 1.24 V/div so that the line extends from -4 to +4 major divisions. Adjust position to center the line about the horizontal axis.
8. Plug the probes into the box and start probing a circuit. Make sure the power to the circuit is off.

Uses

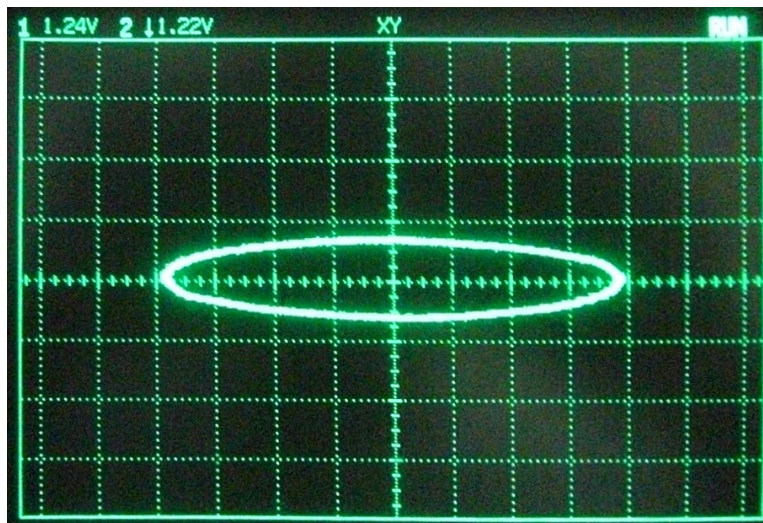
The Octopus is good for fast characterization and troubleshooting. Since I typically use it with my HP digital scope, I have the setup information stored in the internal registers. I recall the instrument setup, connect two BNC cables to the scope's channels 1 and 2, connect the two probes, turn the Octopus on, and I'm up and running. Only a scope like the B&K 2125A with the built-in Octopus tester is faster.

Just for the heck of it, I measured how long it took me to get set up to make these measurements. This involves grabbing two BNC coax cables, and getting the probes and their leads out of a drawer, connecting the leads, turning on the scope, and recalling the scope's setup. It took me 50 s to have everything up and running. Thus, I can be testing things in less than a minute. If I wanted to dedicate some probes and coax cables to the Octopus (I don't), then I'd be up and running in less than about 15 s, as that's the time it takes my HP 54601A scope to boot up.

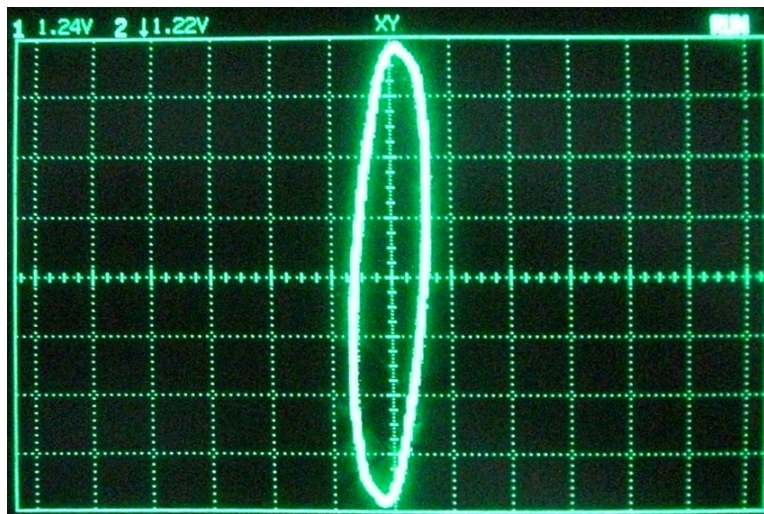
Sample traces

Here are some sample traces. The horizontal gain was set at 1.25 V/div and the vertical direction was 250 μ A/div. After taking these pictures, I realized it made more sense to set the horizontal gain to 1 V/div; this gives me almost 5 divisions on either side of zero -- and makes it easier to read off voltages. When I use the 7 Vrms output, I set the horizontal gain to 2 V/div.

Here's a 100 nF capacitor:

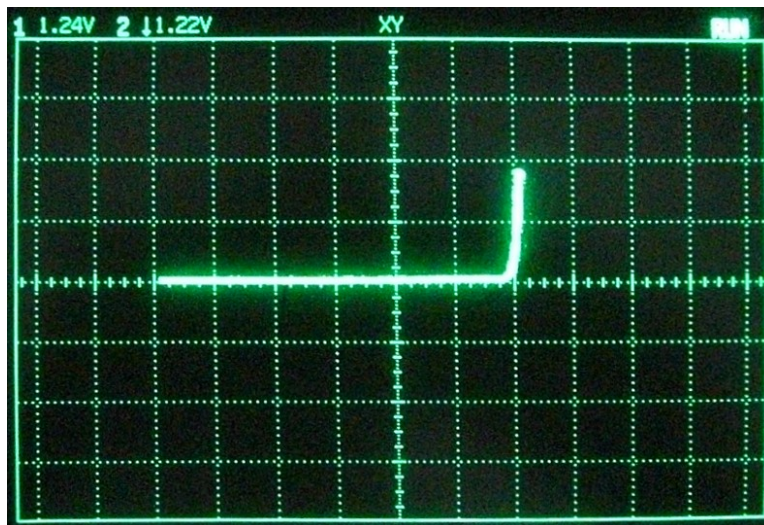


A 520 mH inductance (part of a transformer):



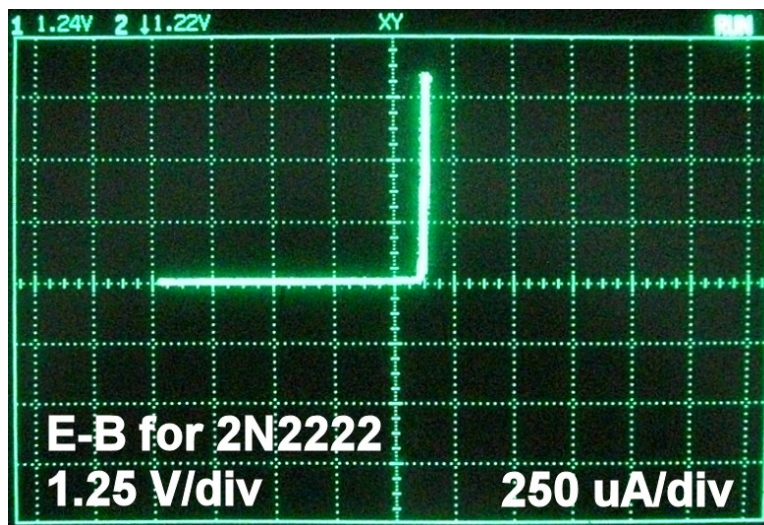
Note there's a slight lean to the right of the ellipse; this is because of the winding resistance. From the slope, I'd estimate it to be on the order of $50\ \Omega$; it was $45\ \Omega$ when measured with a DMM.

A blue LED with a DMM-measured forward voltage of 2.55 V:

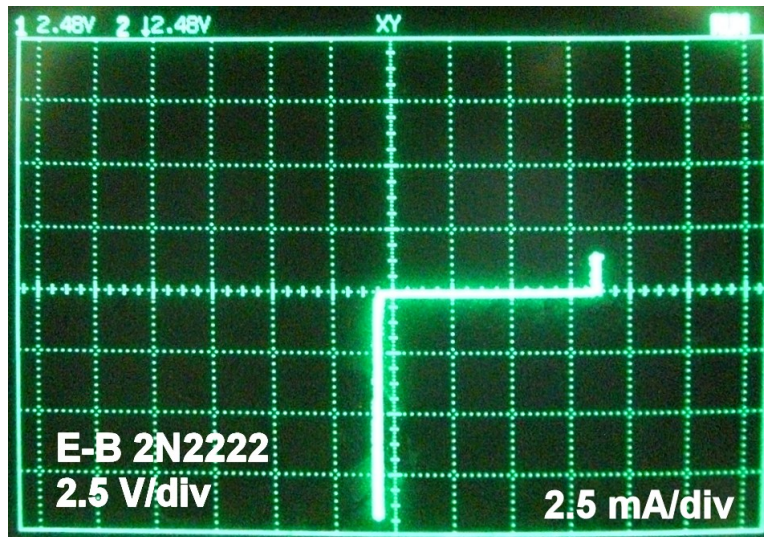


Note the knee of the curve at 2 div or 2.5 V.

Here's a 2N2222 transistor. The first picture is the emitter-base junction:



The manuals will tell you that this trace should look like a zener diode. Here's a trace with the 10 V zero-to-peak stimulation:



The leads were reversed from the previous picture. In addition, the current in the vertical direction should really be 2.6 mA/div because the current was measured at 10.6 mA, but 2.5 mA is a little easier to remember.

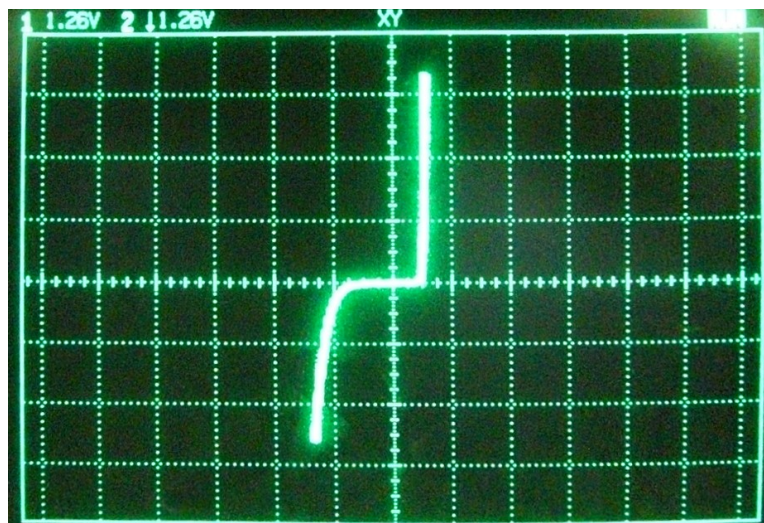
Because you can identify the polarities of the signals, you can identify all the leads and the polarity of an unknown bipolar transistor.

Here's the emitter-collector with the Octopus changed to 7 Vrms:



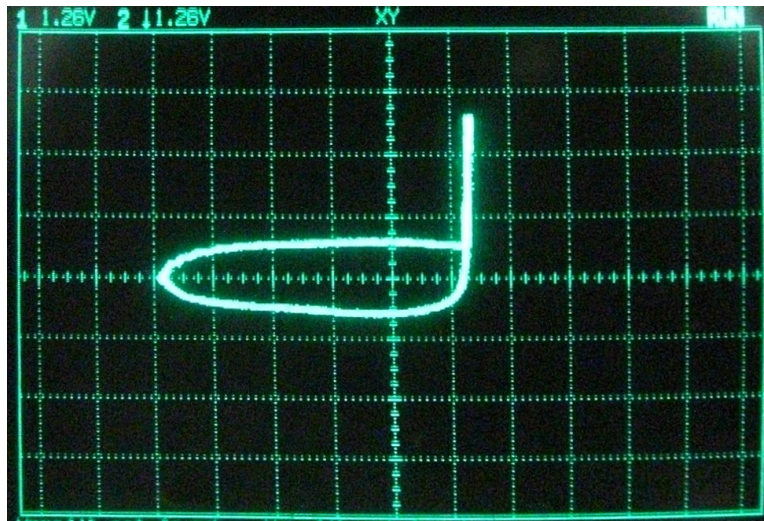
Apparently Huntron made a model that was sold by Tektronix called the TR201. It was without a display, as the typical Tek user would already have a scope. It came with a good manual (Tek part number 071-0114-01) that explains the details of using such a tool. If you're interested in building your own Octopus, it will likely be worth your time tracking down a copy (I found a copy on the web somewhere).

Here's a 3.3 V 1 W zener diode:



The zener was labeled by the seller as 3.3 V, but it's only reaching about 1.5 V for its reverse breakdown voltage.

As a last example, here's the signature of a 100 nF capacitor in parallel with a red LED:



I mentally call this a "golf club" because it looks like a golf putter. It demonstrates a composite type of signal that can be seen when testing real circuits.

Other examples of use

With a set of probes, an easy thing to do with the Octopus is to quickly identify the pins of a relay. The coil pins show up as an inductor. Once you've identified the coil, you can then identify the NC and NO contacts by powering the relay coil. For example, I have a PCB relay that's sealed in an opaque container and there are no markings for the pins; the model number contains "12V", leading me to believe it's a 12 volt relay. I identified the coil leads, then measured the resistance between these leads at $123\ \Omega$. That would put the DC current at about 0.1 A. I measured it at 90 mA when 12 V was applied and this actuated the relay correctly. Using the Octopus, I then identified the common, NO, and NC terminals. While I could have done this identification with an ohmmeter, the Octopus has the advantage of unambiguously identifying the coil through its elliptical signature. A normally open contact with an internal resistance could look like a coil, although I know this is stretching assumptions a bit far.

Another quickie use during troubleshooting is when you have a line-powered device that doesn't operate. The first check is to put the Octopus on the power line input leads and operate the power switch. If the device has a transformer, then you should see the signature of the primary winding of that transformer. If there's no movement, you know there's a problem is in the power supply end. An open, for example, might be indicating a blown fuse.

One of the most powerful uses of the Octopus is comparing a known-good item to a suspect one. I have a line-powered heater that I use in my computer room in the winter. I stopped using it last winter because it started smelling like something was burning. Fortunately, we had another identical heater. A quick comparison of the two heaters by putting the Octopus' leads on the power cord showed that the 5 position switch (Off, Fan, Lo, Med, Hi) had distinct problems. The fan motor's elliptical shape wasn't seen in the fan position and the other positions had bad noise problems (the good fan just showed low resistances). The ellipse from the fan also was able to tell me that the thermostat was working because as I turned it, the ellipse changed to a horizontal line (an open circuit). The comparison in the other positions told me the switch had gone bad, so I salvaged parts and tossed the rest out. Note this didn't require me knowing anything about how the device worked (although I had a good idea of how it was constructed, as it was a simple device). Total troubleshooting time was under a minute.

On the sprinkler controller board mentioned above, there were three CD4051 CMOS 16 pin DIP chips that are 8 channel MUX chips. Each chip had a decoupling capacitor dedicated to it and it was easy to identify the power leads of the chip because they had the same signature as the decoupling capacitor. Of course, this could be verified by consulting a data sheet, but the point is that the

Octopus can give you clues about things without knowing the circuit. Another feature of the Octopus is that I could put the probe on one pin, then drag it along the pins on the other side of the chip to see the variations in behavior. The point is that these are fast tests and can help you spot out-of-the-ordinary behavior.

Summary

The Octopus tester applies an AC current-limited voltage to a component or circuit and plots this voltage against the current on an oscilloscope set to XY mode operation. Since our brains are fast at recognizing patterns, the Octopus test patterns can be used to identify the behavior of a circuit or component. Comparing a circuit's behavior to a known-good circuit can tell you whether the suspect circuit is working correctly. Since you only need to look at the scope for a few seconds, you can test lots of components and circuits quickly to help you troubleshoot non-working circuits.

If you have an oscilloscope and you occasionally need to troubleshoot electrical things, building a simple Octopus circuit will make a lot of sense -- they are cheap to build and easy to use.