USING A Volt-Ohm Meter

Use this versatile tool to trace wires, troubleshoot water heaters and light switches, and even check your truck battery

by Rex Cauldwell

As an electrician, it would be impossible for me to identify or locate problems without my VOM (Volt/Ohm meter). It's so important I always carry two in my truck, one as a backup. The tool's versatility makes it invaluable for an electrician, but builders and remodelers can also use this tool to test for voltage, identify circuits, trace wires, and check out electrical problems on the job site. After you gain some proficiency with a VOM, you can sometimes identify solutions to electrical problems immediately. If you're not sure of the solution, you can at least determine whether an electrician should be called. Although you won't use it every day like I do, the VOM is a handy tool, and it's worth spending some time learning how to use it.

A good place to start is with some definitions. Voltage is the electrical pressure created by a power source, whether it's a flashlight battery or the utility company. Using a garden hose as an analogy, voltage would be equivalent to the pressure that forces the water through the hose.

Ohms are a measure of electrical resistance, which the VOM reads precisely. Again using the garden hose example, resistance would refer to the

Figure 1. Tone continuity test, water heater element. A properly functioning water heater element should produce a tone in a quality VOM when the probes are touched to the screw terminals. But getting a tone with one probe on the element and the other on the heater body most likely indicates that there's a cracked element shorting to the water. Failing either test means replacing the element.

diameter of the hose. The smaller the diameter, the greater the resistance and the less water (or electricity in a wire) that can get through it.

Buying a VOM

A high-quality professional meter costs several hundred dollars, but a basic one to satisfy the needs of most builders can easily be found for around $50. Really cheap models are available at consumer electronics stores, but those lack protective circuitry and will eventually fry when you check continuity or resistance with voltage present.

Analog vs. digital. Putting aside the various prices and levels of quality, there are two basic types of VOMs: analog and digital. The analog has a large meter that shows a collection of scales with various measurements behind an indicating needle. It has several drawbacks. First, you have to pick the right scale to get the proper voltage or resistance reading. And the ranging switch has to be turned to the approximate voltage or resistance before you measure. Also, looking at the scale from an angle can give you an inaccurate reading; plus, the numbers are tiny and tough to distinguish.

In general, analog meters are less expensive than digitals, but they are much harder to use. Very expensive and highly accurate analog VOMs for professionals are still available, but for the most part digital meters have replaced them.

Digital units, which I prefer, have varying features and prices. Lower-cost digital units have range selectors, just like the analog units, so you need to know the approximate voltage before you measure. I would rather spend the money for a higher-quality unit that does all the ranging automatically, like my Fluke model 25 (Fluke, Everett, Wash.; 800/443-5853, www.fluke.com). On an auto-ranging unit, all I have to do is place the probes across the points to be measured, and the unit gives me an instant voltage or resistance reading.

Features. Digital meters that cost less than $100 aren't always able to give instant readings because they have to count up to the voltage, which takes a few seconds. Also, low-cost digitals may not work properly in cold weather; if you're considering a purchase, be sure to check that out.

Another problem with low-cost digitals is that they frequently lack a built-in capacitor checking feature. Analog meters, even the cheapest, will check capacitors just by their design. If you need that capability, check for it before you buy. The meter's case should be made of a durable plastic because eventually you're going to drop it. Unless it's well made, with a shock-absorbing material, it will crack. Never buy a digital meter until you take it out of the box, install the batteries, and give it a try to make sure it works. While you're at it, verify that the meter gives an instant reading and isn't a count-up type.

When shopping for either type of meter, you should also take a good look at the probes. On lower-cost units, the probes are often so small and cheap that getting a reading when you insert them into a receptacle is nearly impossible. You'll get better probes with a high-quality meter. Probes as well as probe attachments can be purchased separately, but they're not universal. The most useful are insulated alligator clips that make a good connection and hold the wires, freeing up one of your hands. When buying probes or accessories separately, make sure they'll fit into the female connector slots on your meter.

Better-quality VOMs have a built-in tone continuity feature. I wouldn't buy one without it. The tone continuity feature energizes a speaker, sounding a tone when a circuit is completed, which is handy for many tasks. I'll describe how to make tone continuity tests later.

Finally, be sure that whichever meter you buy, analog or digital, cheap or expensive, has a built-in circuit for protecting the meter from voltage on the resistance scales. Without that feature, leaving it on a resistance or continuity ranging scale and putting the probes on a circuit that has voltage will kill it. Just like that. And you *will* do this — it's just a matter of time. If you're lucky, the meter will have a replaceable fuse; if not, it's time to buy another. A good-quality meter, like any other good tool, will pay for itself in time saved and long-term durability.

Figure 2. Tone continuity test, switch. With the probes on the terminals and the switch in the off position, there should be no tone. But when the switch is in the on position, a tone should be audible. No tone in either position or a tone in both positions means that the switch is faulty.

Tone Continuity Tests

Continuity testing involves checking the low-resistance path from one probe tip through the item being tested to the other probe tip. If the path is continuous, like an unbroken light bulb filament (and your meter is good enough), the buzzer within the VOM will sound. To test a light bulb, place one probe tip against the screw

shell of the bulb and the other against the center contact button. A tone signals that the bulb is good.

You can check a water heater element the same way. Start by removing the wires connected to the element's two screw terminals (first making sure the power is off). Place a probe tip on each terminal, and you should hear a tone. Then place one probe on one element terminal and the second on the tank's metal body; you should *not* hear a tone this time (see Figure 1, first page). Passing both tests means the first of the two elements is okay. To check the second element, repeat the tests.

Testing a simple two-terminal switch. Simple wall switches and trigger switches can be tested by placing the VOM's probes across the two terminals and operating the switch. All wires must be disconnected from the item under test; otherwise, electrons following another path could throw off the reading (Figure 2, previous page).

Tracing Wires

I use the tone continuity feature primarily for tracing wires. A perfect example is when I've forgotten which wire feeds a certain receptacle from a newly installed panel. Tracing a circuit starts by twisting the white and black wires together at the junction box. Back at the panel I check individual cables by touching the probes to the black and white wires there. When I touch the probes to the right cable in the panel box, I'll hear a tone. I double-check by untwisting the wires at the junction box; the tone should go away.

Sometimes I need to trace a single conductor. For example, I may need to know whether a red wire in a receptacle box is the same red wire in a junction box 40 feet away. To find out, I lengthen one of the probes by twisting an extra piece of wire around one of the leads. I take the other end of the wire and twist it around the red wire I'm testing in the box 40 feet away (the red wire only; if it's connected to other wires, I disconnect it) (Figure 3).

If I know that the wire is supposed to be continuous but it doesn't sound a tone, it may have been broken or cut somehow and is incapable of carrying current to the other end. Sometimes a drywall nail or screw will penetrate a wire and damage it. If I know the route the wire follows in the wall, I can sometimes locate the break by touching the second probe lead to the nails or screws along the wire's path. If a nail or screw has cut the wire and is still making contact, I'll get a tone when I touch the right one.

Resistance Testing

Another important use of a VOM is measuring the actual resistance of electrical devices. Electrical resistance refers to slowing or stopping the flow of electrons. The slowing of electrons is what creates the glow in your toaster and the heat that radiates from your electric baseboard. The resistance of the water heater element, previously checked for continuity, produces heat and transfers it to the water.

The resistance tester works much the same way as the continuity tester but has many calibrated networks within it to measure the exact amount of electron flow.

The VOM allows me to determine a water heater element's — or any heating element's — exact resistance in ohms. Placing the probe tips across a water heater element's two screw terminals (again with the power off and the wires disconnected) should give a

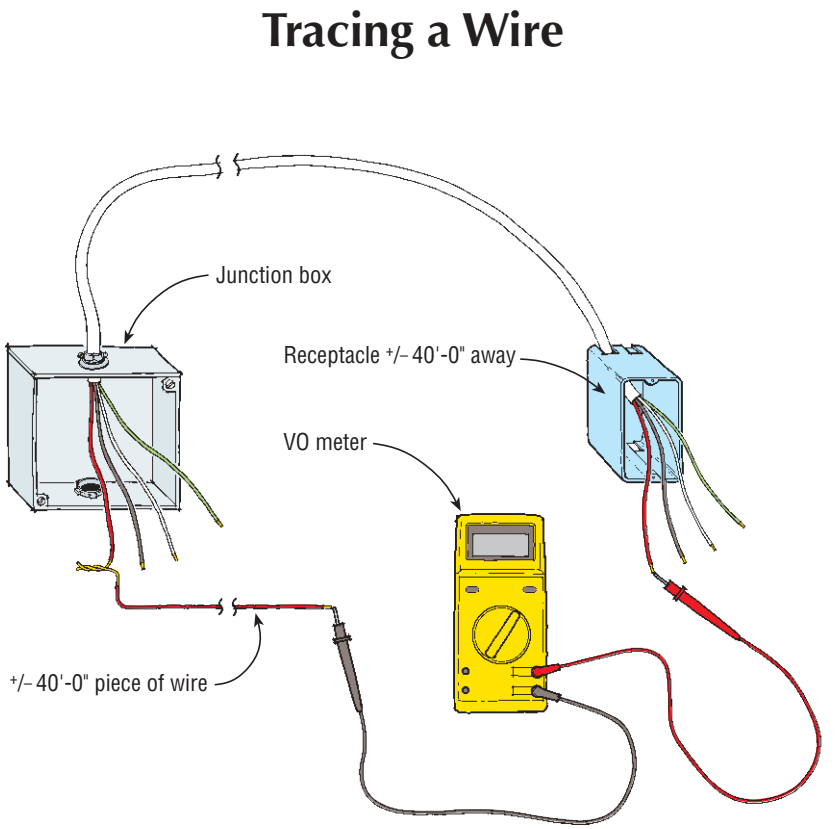

Figure 3. Tone continuity test, tracing a wire. Lengthening a probe with an extra piece of wire allows you to trace a single conductor between two locations. A tone means the wire is continuous.

Figure 4. Resistance test, water heater element. A reading of about 13 ohms (4,500 watt/240 element) indicates that this water heater element is functioning correctly.

Figure 5. Testing DC voltage, car battery. Reversing polarity causes the needle to fly off the scale in the opposite direction on an analog meter, or read in the negative on a digital unit (left). Reversing the probes will give an accurate measurement (right).

reading of about 13 ohms. My autoranging unit will give a direct reading immediately, instead of requiring me to select from several scales. In the case of a water heater, I'd use the Rx1 setting. This test is actually two tests at once. First, I'm doing a continuity test without a tone; second, I'm determining the element's actual resistance (Figure 4).

Sometimes a manufacturer indicates what its product resistance should read before it's considered unserviceable. A submersible pump, for example, should read the highest resistance possible from the windings to the motor frame. This resistance is called infinity (∞), which translated means that there should be an infinite amount of resistance preventing the electrons that power the pump motor from flowing to the motor frame. Over time, lightning surges can break down the resistance from the windings to the frame, and eventually the pump may not be worth reinserting into the well. If I get a reading of less than 5,000 ohms, I recommend a new pump.

Transformers like the one that converts 120 volts to 24 volts for the doorbell can also be tested by measuring their resistance. A transformer has two leads on each side; after turning off the power, I place the probes across either the input or the output leads (on Rx1). Generally, any indication means that the transformer is functioning.

Testing DC Voltage

Measuring voltage is the next most common use of a VOM. It can measure both DC and AC voltage. Probably the most likely DC measurement you might check would be that of your car or truck's battery voltage. Anything less than 12 volts with the engine off would indicate a shorted cell. You could also check whether the alternator is getting enough voltage to the battery. With the engine running at 2,500 rpm, it should measure about 14.2 volts across the battery. For both of these checks, I simply put the VOM on DC voltage and place the probes across the battery terminals. DC voltage has polarity: positive and negative — the same as indicated on flashlight batteries. When measuring DC voltage, you should try to match the polarity of the item being tested (battery or whatever) to the polarity of the meter's probes indicated on the VOM (Figure 5).

Testing AC Voltage

For electricians, determining AC voltages is the most common use of a VOM. I use it to verify the absence of voltage before working on a circuit, to determine whether something is 120 or 240 volts, to check for abnormally low or high voltage in a residence, and to see if a transformer is producing the correct voltage (Figure 6, next page). I can also use it for more advanced voltage checks. For example, we all know that if we go to a receptacle and measure across the plug-in terminals, we should get approximately 120 volts. And if you have a

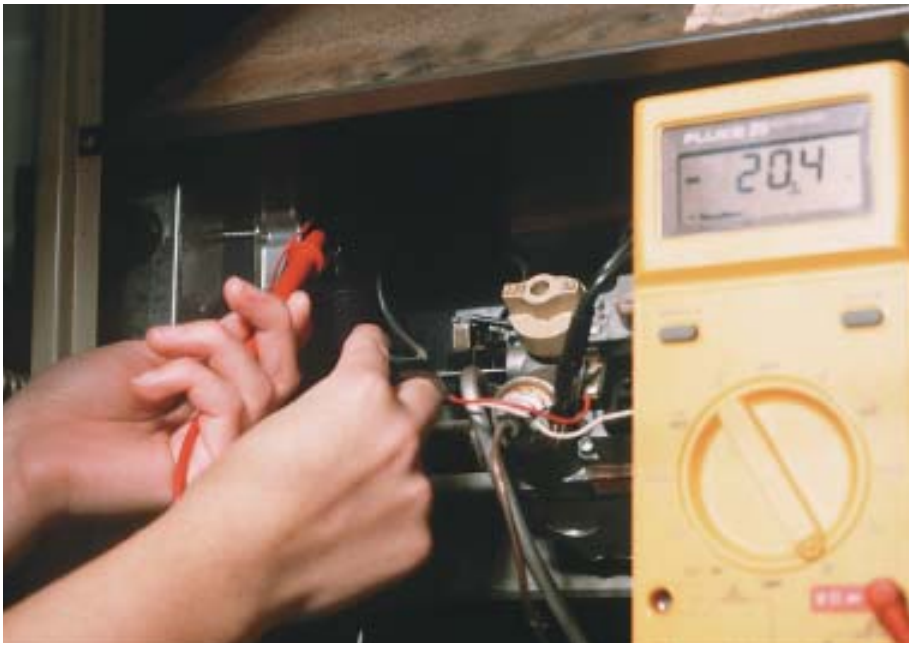

Figure 6. Testing AC voltage, transformer. The transformer inside this furnace changes the 120-volt AC to 24 volts for the gas valve and thermostat. With the power off and the meter set on Rx1, any measurement usually indicates that the transformer is working.

ground terminal on the receptacle, you should get 120 volts from the short terminal to the ground terminal as well. If you don't get that, either the grounding circuit is broken or the receptacle is wired incorrectly (Figure 7).

Remember, no appliances or fixtures should be plugged into a circuit that's undergoing a voltage test. Remember, too, that when a probe tip touches a hot wire, the probe tip also becomes hot. Measuring voltages, since it has to be done with the circuit energized, is very dangerous and is best left to a professional.

Checking Capacitors

Another, more advanced use of a VOM is to check capacitors. Capacitors are electrical components that store electrons, and they are a critical part of many electronic appliances. You'll find a capacitor in the control box of a submersible pump. It gives the pump an extra kick during startup, helping it to get up to speed. Lightning surges often destroy capacitors, but, fortunately, it's easy to check whether they're working. Put the VOM across the capacitor's two terminals with the ranging dial on Rx1. The VOM will provide the electrons to charge up the capacitor, which will be indicated by the VOM's needle swinging from one side of the dial to the other. If nothing happens, reverse the probes and try again. If you reverse one more time and there is still no needle activity, the capacitor is bad.

Be Careful

Misusing a VOM can be dangerous; in fact, it can kill you. Let the professionals make the hot high-voltage AC measurements — they're trained and insured for it. Amateurs can use the meter for the low-voltage, continuity, and resistance checks without excessive risk.

***Rex Cauldwell** is a Master Electrician and Plumber and the owner of Little Mountain Electric and Plumbing in Rocky Mount, Va.*

Figure 7. Testing AC voltage, ground check. After the ground wire has been disconnected at the panel, this receptacle still shows voltage present because the neutral and ground wires are making contact somewhere in the circuit. Sometimes the wiring is done this way intentionally (although it's illegal) so that when a cheap plug-in tester is used, the receptacle appears to be properly grounded.