Eye On Electronics

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DMMs offer improved convenience, durability and accuracy over the analog meters they've replaced in the shop. Their accuracy, often taken for granted, can be affected by several factors.

A gauge is good only if it's accurate. Studies have shown that instruments such as the digital multimeter are subject to at least three main categories of inaccuracy. The first is the measurement accuracy of the meter itself. The second is measurement error caused by poor gauging methods. The third comes from errors caused by using the wrong instrument or misinterpreting the data. With help from Fluke, Agilent and other makers of DMMs, here are some of the causes and cures for gauge measurement error.

The first place you'll encounter gauge accuracy issues is in a meter's spec sheet. To understand the accuracy specifications of a DMM, it helps to understand something about resolution, digits and counts. The *resolution* of a meter is a measure of how fine or precise a measurement it can make. The meter's range setting controls the span of the reading that can be made for the gauge setup. If the range is 0 to 10 volts and the resolution is .01 volt, then it should be possible to measure any voltage in that range, with the displayed value shown in .01-volt increments.

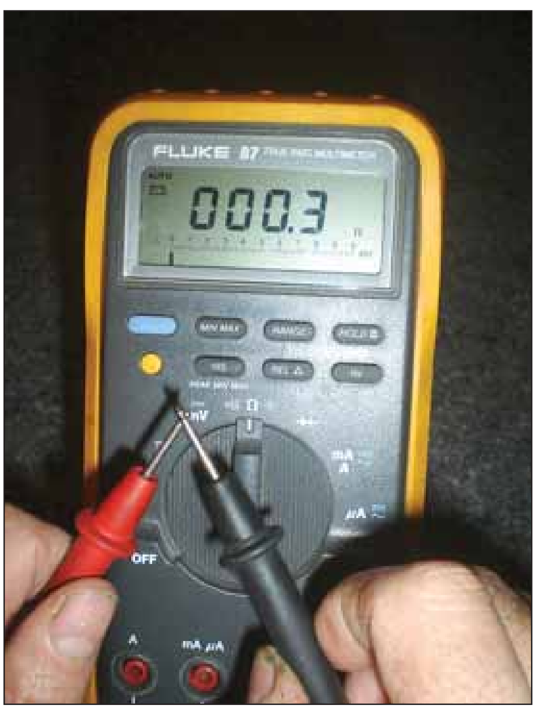

Photo: Mike Dale

Most resistance losses in the test leads of DMMs occur at the probe tips. These losses must be removed from the reading to ensure an accurate measurement.

The terms *digits* and *counts* are used to further describe a meter's resolution. General-use meters are typically said to have 3½ or 4½ digits of resolution. Their displays can show three or four digits that can range from 0 to 9, plus one digit that can only be a 1 or a blank. Taking the 3½-digit meter as an example, the highest reading it can display is 1999. The range switch places the decimal for you, while the function switch determines if it's amps, ohms or volts being measured.

Each of the numbers from 1 to 1999 represents a count of resolution. A 3½-digit meter has 1999 counts of resolution; a 4½-digit meter offers 19999 counts of resolution, based on its having one more digit in the display.

Electronic enhancements inside a meter can sometimes give higher resolutions than the number of digits would indicate. This depends on the range being used and is covered in the meter's owner's manual.

Knowing about digits and counts is useful in understanding the claims of DMM makers in terms of accuracy. According to Fluke, accuracy is the largest allowable error that will occur under specific operating conditions. This is expressed as a percentage of the reading plus added "counts" to reflect how the extreme right-hand digit might vary. If meter accuracy is stated to be ±1%, it means that a true 100-volt source will measure on the meter at between 99 and 101 volts. If the accuracy is stated at ±1% plus two counts, then the meter may actually read anywhere between 98.8 and 101.2 when the true reading is 100.00.

This is a good place to mention something about analog meters. Typically, these meters talk about accuracy in terms of full-scale reading. On the 100-volt scale, the accuracy might be within between 2 or 3 volts of the true reading. The catch is that if you're using the 0 to 100 range to make a measurement of about 10 volts, the 2- or 3-volt error could be 20% to 30% of the reading. With digital meters, the claimed accuracy is a percentage of the reading you actually see and not a percentage of the full-scale reading.

This is also a good place to caution you about digital readouts. Depending on the meter and the range setting being used, your meter may show two or more digits to the right of the deci-

continued on page 20

mal place. In fact, those digits may not mean anything. The accuracy of the meter is what the specification sheet says it is. In the example above, the true 100.00-volt source may actually read on the meter somewhere between 98.8 and 101.2. Don't be misled by a DMM reading of 99.2. At ±1%, the meter accuracy is very good, but it's not accurate to within a tenth of a volt.

DMMs are subject to calibration issues. All electronic components—and a DMM is full of them—are subject to some amount of drift. Precision lab meters are generally calibrated once per year. High-precision meters used in laboratories may be calibrated every 90 days.

For standard shop use, where accuracy of 1% or 2% is fine, you may never really need to have your meter professionally calibrated. If you become concerned about calibration, you can make a quick check by measuring a fresh AA cell at room temperature. If the reading you get is 1.5 volts, you should be good to go. You can do the same thing for the ohmmeter section, by buying a 1% tolerance resistor, making sure it's at room temperature and then measuring it with your meter. Remember, these are quick checks, not professional calibrations. They're intended as a way to give you confidence that your meter is as accurate as you need it to be.

Sources of measurement error are unique to the type of measurement being made and the range being used. One source of measurement error that all DMMs face is in the test leads. The leads themselves are usually made of a very pure copper that has been made into as many as 30 fine strands of wire so the leads are as flexible as possible. To keep the copper from oxidizing inside the insulation, it's often plated with tin. Despite the effort that goes into making the wire for high-quality leads, there are at least four interfaces per lead between the electronics of the meter and the actual test points—the points where the wire connects to the probes and to the meter plugs, and the points where the meter plugs interface with the meter and the test probes connect to the device being tested.

The net result is that between the copper losses and the lead connections, there is some amount of resistance in the leads and probe connections. This test lead resistance can amount to .2 to .5 ohm. Because the meter includes this resistance in the overall measurement, it effectively becomes a source of gauge error.

A perfect example of where this becomes an issue is in the resistance checks done to test an ignition coil. The primary should read approximately .5 ohm. If the gauge error adds .5 ohm to the real reading, then an answer of 1.0 ohm for the coil primary would be what the meter would display.

Further possible error may come from the contact resistance between the test probes of the DMM and the contacts of the coil. Human error also comes into play here in how the test leads are applied and how much pressure is used to hold them in place.

When you add all of this together, the potential error in measuring the primary resistance could actually be larger than the correct reading. Test lead losses also can affect low-level voltage and current readings. In gauge reliability studies, it has been stated that the error must be less than 20% of the tolerance, with the goal that it should be less than 10%.

Zeroing Feature

There are a number of possible solutions to the problem of test lead losses. Fluke's Model 88 automotive meter, for example, has a zero button. Holding the end of the meter probes together, then holding the zero button until the meter zeros cancels out the resistance losses in the leads but doesn't eliminate the resistance between the probes and the coil itself.

If your meter doesn't have a zeroing feature, you can hold the leads together, wait until the measurement stabilizes, then deduct that amount from the meter reading when you make the test.

The temperature of the device under test can also lead to measurement error. The secondary of an ignition coil might read something around 10,000 to 12,000 ohms at room temperature. Since the resistance of copper wire varies with temperature, the same coil will measure differently if it's either very hot or very cold. A similar but opposite problem can happen when using a DMM to measure the value of high-temperature-coefficient devices like thermistors. The test current applied by the meter can result in some internal heating of the device, and thus the value will continue to change the longer the leads are applied.

As if there wasn't enough to worry about already, there are other possible sources of error that can come from the test leads. Most test leads are about 30 in. long. Coincidently, that's about the same length as a vehicle's radio antenna! If you think about it, test leads do look a lot like antennas leading into the instrument.

The frequency of the noise that can get into a meter this way is related to the length of the test leads. How much noise can enter depends on the coupling between the antenna and the amplitude of the source of the radio frequency noise. Some meters have built-in capacitors from the input to ground that are of the right size to shuffle true high-frequency noise off to ground before it can affect meter accuracy.

You're most likely to see this problem in voltage measurements. The key to minimizing this problem is to keep the meter and its cables away from vehicle noise generators such as the ignition system, alternator and starter. Cell phone transmitters and even CB radios in transmit mode can affect meter measurements. Large magnetic fields such as those found near the battery power cable to the starter during cranking can also affect meter readings if the meter's leads pick up the field.

DMMs intended for automotive use often include features for the measurement of time-dependent voltages such as AC, pulse width modulation and duty cycle. There are possible sources of gauge error in those types of measurements that you need to be aware of. Most AC meters are accurate within the range of 50 to 500Hz. The meter may respond to higher frequencies, but accuracy will suffer.

On the AC setting, the meter is expecting to see uniform sine waves of a constant frequency and amplitude. The average responding type of AC meter will give you a reading of the average voltage seen. If the sine wave is not of a pure shape, the average responding me-

continued on page 67

continued from page 20

ter will give you an inaccurately low reading. True RMS meters, on the other hand, are more expensive and work by measuring the heating value of the waveform. This value depends on the area under the sine wave curve. Waveforms that are not sine wave shaped can fool an average responding meter into giving you an incorrect reading.

There are two ways to measure current with a DMM. One is to place the ammeter in series with the current flow. This will give the most accurate measurement, but it does require breaking the path of current flow for meter insertion. The clamp-type inductive probe circles around the conductor carrying the current and uses a Hall cell to measure the amplitude of the magnetic field created around the wire by the current flow. The clamp-type probe measurement is somewhat less accurate than a series measurement, but is hugely more convenient. It's also safer in terms of circuit integrity and not disturbing wires and connections.

Probably the most significant source of gauge error is in choosing the wrong instrument to make the measurement with in the first place, or in failing to understand what the reading is really trying to tell you.

Because many technicians have only a DMM, makers offer instructions on how to measure the resistance of the coils found in starters, alternators and ignition coils. The first problem is that the resistance of the coils in these devices is low (typical coil primary resistance of .5 ohm) and subject to the significant gauge measurement error mentioned above.

More important is for you to understand that the purpose and function of the coils is inductive in nature, and to then choose the right instrument to measure the performance of the coil. In this case, the best way is to monitor the current ramp with an oscilloscope. The resistance readings may give the impression the coil is okay, when in fact it's not.

You can see that there are lots of possible ways to make measurement errors. Your best defense is a good set of leads and a quality meter that's capable of making the measurements you need. M