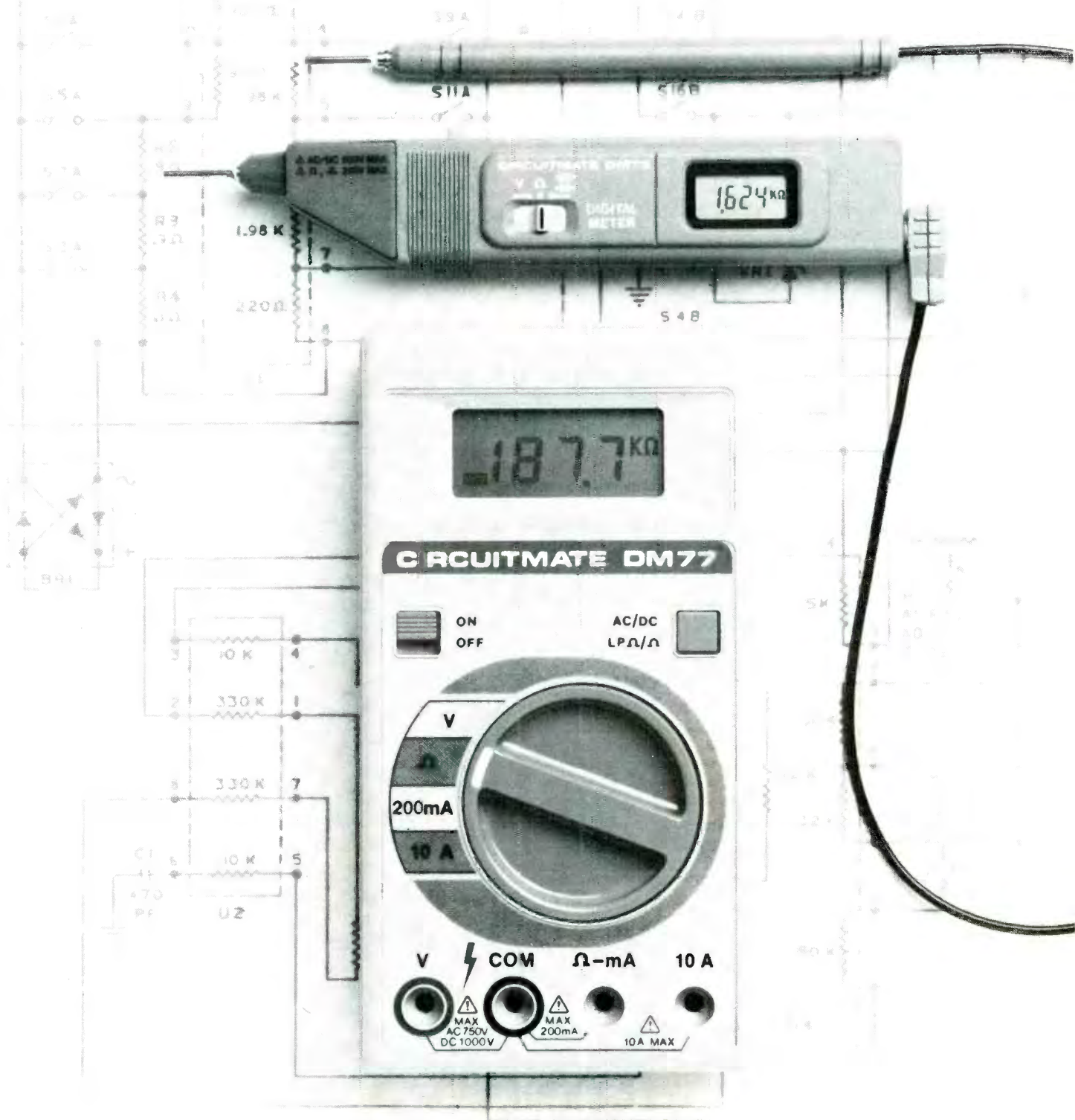# Using & Misusing Multimeters

Here are a host of tips on getting the most service out of a multimeter

By Gary McClellan*

A multimeter is probably the most useful electronic test instrument one can own. Use it properly, take good care of it, and it'll give you many years of circuit troubleshooting and other measurement applications. If you don't, however, you may get some unpleasant surprises, ranging from incorrect voltage and resistance readings to an inoperative tester; maybe even an electrical shock. To avoid these problems, it clearly pays to take some time to learn more about your multimeter. Here are some guidelines.

1. Whether you're an old pro or just unwrapped your first multimeter, read the operator's manual that accompanies the instrument as carefully as possible. Besides the basic how-to-use-it information it contains, you may discover a bonus or two. For example, one manual for a multimeter I use shows you how to build a simple transistor tester accessory for it. Others I've read discuss testing a variety of components, and describe the use of helpful accessories such as high-voltage probes, r-f probes, and so on.

In addition to digesting the basics presented in a manufacturer's manual, it's a good idea to write useful information inside the front cover of the booklet that can help you with insurance in the event of a theft or if you lose the instrument. This should include the model number, serial number, purchase date and price.

2. Building upon what's in the manual, you should understand just what the multimeter's capabilities are. Not understanding this is the most common reason why users misuse their instruments. For example, if you tried to measure a 20-kHz ac signal on your meter, but didn't realize the manual indicated a 400-Hz ac re-

Beckman Industrial Corp., Brea, CA

sponse, your reading will be *wrong*! Doing this without thinking, you'll believe that there's a defect in the circuit, wasting troubleshooting time.

So the rule is: Know the limitations of your multimeter. Don't overload voltage and current ranges by applying too much voltage and current to the instrument. If you think you might exceed the DMM's ratings, use a high-voltage probe for the voltage ranges and an external high-current shunt for the current ranges. And never under any circumstances apply voltage to the ohms ranges! Though today's multimeters will withstand momentary overloads, there are limits to how much abuse they can withstand without damage, particularly the lower-priced models that have less extensive overload protection.

Here's an embarrassing story about what can happen if one ignores the operating limits of a meter. Some years ago I was troubleshooting a microwave oven with a new digital multimeter (DMM) having a 2000-volt dc range. So I figured the DMM would handle 2000 volts dc, naturally, and certainly the 1200 volts I expected from the oven. I connected the DMM to the oven's power supply, plugged in the ac cord, and pressed "cook." The oven hummed and, accompanied by a sharp cracking sound, the DMM expired permanently. What happened? A shorted rectifier inside the oven applied something like 1500 volts ac to the DMM! Had I read the manual I would have learned that the DMM couldn't handle over 1500 volts dc. Actually, it was exposed to about 4200 volts, peak-to-peak! The moral of this story is that when in any doubt whatsoever, expect more than the DMM can handle. Had I been careful and connected a high-voltage probe to the DMM, I'd have saved a $150 instrument from damage.

3. "Use your multimeter properly" is an obvious rule. But it's one that's often ignored, especially when you are pressed for time. The idea, of

course, is simple: Measure ac volts on ACV ranges, ac current on ACA ranges, dc volts on DVC ranges, dc current on DCA ranges, ohms on the Ohms ranges, and so on. This is plain common sense, but in practice it is easy to push the wrong button or plug the leads into the wrong jacks. The rotary range/function selector switch featured on some meters does a lot to make this operation exceptionally "goof proof," but no instrument is completely safe in this respect.

In practice, this rule is easy to remember if you get into the habit of setting the function and range switches *before* making any measurements. If you aren't sure of how large the measurement might be, set the range switch to the highest range and switch to lower ranges as necessary until you get a usable reading. Then connect the ground clip and make the measurement with the probe.

Two common abuses to multimeters are accidently measuring volts on the Ohms ranges and applying volts to the current ranges. With the Beckman Industrial HD100 DMM, the ohms ranges will withstand up to 600 volts DC or RMS AC without harm; this is exceptional protection for a DMM! Typically, modern multimeters can withstand 250 volts or less for very short periods of time, though some extend this range to 600 volts. Apply voltages above the extremes for an extended time period and you'll likely overheat protective resistors and diodes. As for applying voltages to current ranges, on most DMMs a fuse will blow, protecting expensive high-current resistors. However, voltage overloads may cause precision resistors to change value or damage an expensive IC chip if full meter protection is not incorporated into the instrument. As a result, expensive repairs or recalibration would be required!

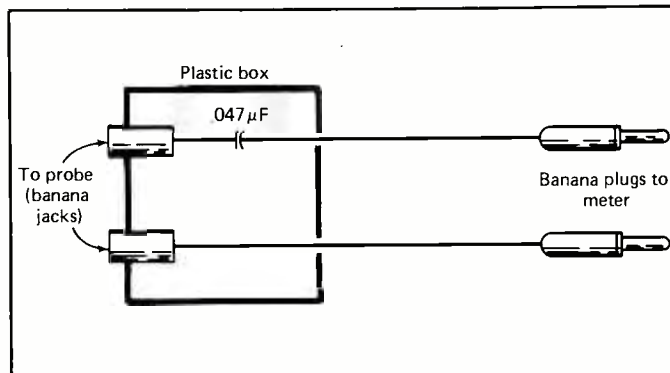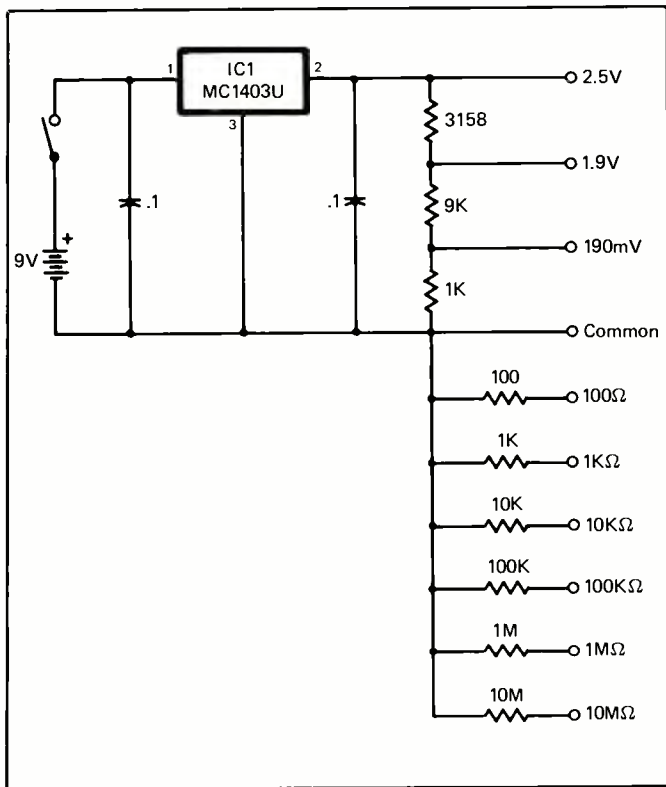**4.** You should always maintain equipment properly, of course. For example, if you don't replace test

Fig. 2. To eliminate any possibility of dc component from affecting an ac reading, it is a good idea to place a blocking capacitor (0.047 μF at 1600 volts) between the test leads and the input jacks of the multimeter. House the capacitor inside a plastic box to eliminate electrical shock hazards.

Fig. 1. Shown in this schematic diagram is a calibrator you can build to periodically check the condition of your multimeter's resistance and dc-voltage ranges. For best results, use only 1% or better tolerance resistors.

leads that have insulation you will expose yourself to the possiblity of an electrical shock. Don't discover defects the hard way.

Always check your test leads before using them. Look for cracks in wire insulation, especially where the wire enters probe and connector bodies. Replace broken connectors and probes immediately.

Keep your multimeter's case free of dirt and dust. If the case breaks, replace it promptly. A carrying case should be used for additional protection in any event. This will extend the life of the instrument, particularly if it gets rough handling.

If you goof and seriously overload your meter, check it to make certain it wasn't damaged by the overload. Check the overloaded range by measuring a few known voltages, currents, or resistances, and comparing the results. If different, repairs may be required. Note that faulty meters may seem to work properly, but

could actually be out of calibration. Should the meter indeed be damaged, tag it as such so that someone else in a service shop, school, or even at home won't use it unsuspectingly.

It is a good idea to have your multimeter calibrated periodically, even if it has not been overloaded. Generally, most quality DMMs used for professional work should be recalibrated yearly by the factory or an instrument service company that specializes in such work. When used in applications where accuracy is particularly critical, it may be necessary to recalibrate every six months.

You might want to build the simple calibrator (shown in Fig. 1) to check your meter periodically. With it you can check the key dc ranges and all Ohms ranges. For best results, obtain combinations of 1% precision resistors to match the values shown. Then measure the voltages and resistances with your calibrated multimeter and write them down for reference. Lat-

er, if there's any doubt about your instrument's accuracy, compare the values. If there is much difference, have the meter recalibrated.

Finally, if your multimeter is ac powered, check the condition of the cord once in a while and replace it if damaged. Or if your instrument is battery powered, replace the battery promptly whenever the Low Battery indicator is displayed. I never experience such an indication, however, because I replace the batteries in all my instruments yearly, even if they are still good. You might want to do the same, as this reduces the chances of a battery expiring just when you need the instrument the most.

5. The first step in making any type of high-voltage measurement is to make sure that you have the right equipment to do the job. For voltages above 1000 volts dc or 750 volts ac, you should consider using a high-voltage probe with your multimeter. This probe attenuates the voltage by

100, making it easy to make measurements and protecting the DMM from overloads at the same time. A suitable one can be obtained at low cost from your electronics distributor or the DMM's manufacturer.

Be sure to use the right high-voltage probe with your multimeter, of course. These probes are designed to match standard input resistances, which may vary according to the model you have. Connect a probe designed for another input resistance, like one of those old 11-megohm VTVM probes, and a DMM will give you the wrong reading!

When making a high-voltage reading, always connect the ground clip to the circuit *first*. The set the DMM down so that you aren't holding it ¹ fore you touch the probe tip to ι..e circuit. It's a good idea, too, to place one hand behind your back when applying the probe. One can never be too careful.

With some high-voltage circuits, where the voltages are lethal, such as in microwave ovens, it is wise to modify the procedure a bit. Always turn off the power, then connect the ground clip and clip the probe to the circuit point. Stand back, then power the device and note the reading. When through, shut off the power before removing the probe.

6. You may be surprised to know that ac voltage and current measurements are often the toughest to make accurately with a typical multimeter. There are two major reasons for this: Waveshape and signal frequency.

The waveshape of an ac signal being measured is most critical, especially with less-expensive multimeters. DMMs are calibrated at the factory using a low-distortion sine wave. Therefore, for best accuracy, you must be measuring the same type of signal. In real life, however, this may not happen, so errors will creep into your ac measurements. How much error depends upon how distorted your signal is and the type of ac converter circuit in your meter. Most low-cost multimeters use an "average-responding" rectifier. This circuit may be as simple as a diode and two resistors or as fancy as an op amp and a few diodes. In practice, this simple circuitry is highly sensitive to waveshape and will give you consistently wrong readings from a distorted signal.

A better way to measure ac signals is with a True RMS (TRMS) multimeter. Circuits without these instruments use sophisticated averaging circuitry, usually contained inside a custom IC chip, and measure distorted waveforms with far greater accuracy than simpler average-responding circuits. Typical uses for a TRMS

Digital Vs. Analog Meters

Years ago, the VOM (volt-ohm-milliammeter) and the VTVM (vacuum-tube voltmeter) were the only choices one had when buying a multimeter. The VOM was popular, owing to its battery-powered portability, while the bulkier VTVM was chosen for its special measuring attributes where portability was not a consideration. Both use meter movements with "pointers" that move across calibrated scales. Both are analog-type meters, of course.

The electronic VTVM features higher input resistance than the VOM, thereby exhibiting less loading effect when taking measurements in a "live" circuit. Its lower input capacitance enables it to measure ac voltage at a higher frequency than the VOM can, too. Moreover, a more sensitive measuring capability, owed to its amplifier stages, makes measuring low voltages or resistances more accurate. On the other hand, a VOM is more stable, doesn't require warmup, and can measure current and decibels.

These differences evaporated, however, when solid-state VOMs were introduced a number of years ago. They combined the best attributes of both earlier instruments, while eliminating the need for tubes to warm up. VTMs quickly disappeared from the market, not surprisingly, being replaced by electronic models, while VOMs still linger on in the form of very-small, low-cost instruments.

Currently, digital multimeters (DMMs) are the most popular voltage and resistance test instruments. They earned this position for some very clear reasons. Firstly, scales don't have to be interpreted, as with analog instruments. Therefore, there's usually no eye strain or cerebral strain at all in reading a measurement value, since it's right there in familiar numeric form. Accurate readings are further enhanced due to the fact that there is no parallex error occuring from viewing a scale pointer at one angle or another. Little skill is needed, therefore, to use a DMM. Supporting this further, many DMMs have automatic range, overranging, and polarity features.

Surprisingly, there isn't much in the way of tradeoffs. It's sometimes charged that a DMM's LCD display is difficult to read in dim light, which is true. But, then, so are meter scales. DMMs cannot function well in the face of rapidly changing values, but most users do not use a multimeter for this purpose. The same is true of measuring decibels, which DMMs cannot do. Relative cost of a DMM is higher than that of a VOM, but you get what you pay for. However, if you don't need very-high resolution, there are modestly priced DMMs available with better than 1% accuracy.

meter would be for servicing SCR motor speed controllers in industry, audio signals in the broadcast studio, and so on. Naturally, the TRMS circuit costs more, so the meter's overall price is higher. To users who need greater overall performance for their multimeters, the higher cost is certainly acceptable.

Probably the best approach when measuring ac signals where the waveform is unknown is to check it out first with an oscilloscope to get a rough reading (typical accuracy 3% to 5%). Then switch to the multimeter for a precise reading if the waveform looks like a clean sine wave.

Square waves can be measured with your multimeter if the frequency is low: a 5-volt square wave will read about half, or 2.5 volts, on most DMMs. This may be helpful if you are working on a digital circuit, and an oscilloscope isn't handy. Don't exceed the frequency limits, or the readings will be no good.

Also, the frequency of the ac signal being measured is important. Multimeters are very frequency-limited, and if you try to measure a signal above or below its limits you reading will be incorrect! To complicate things further, the frequency response will be different on the meter's other ac ranges, with the lowest ac range having the widest response. Thus, if you are measuring a signal on the lowest ac-volts range, and it is near the frequency limit, switching ranges will probably give different readings!

State-of-the-art DMMs often have frequency ranges of 45 Hz to 10 kHz on the lowest voltage range, while other designs or cheaper models may be restricted to 40 Hz or so. Check the frequency response limits in your operator's manual and be sure to stay well within them.

Did you know that audio signals are tough to measure on a digital multimeter, owing to its slow response time? To get maximum accuracy for digital readout, the cir-

cuitry is designed to make readings very slowly, at perhaps 1 to 2 readings a second. If your signal changes amplitudes more often than that, the DMM will make partial readings and display "garbage." Remember that your ac ranges give the best accuracy when measuring steady-state signals.

If you find it necessary to measure wide-amplitude-changing ac signals, such as audio and transducer outputs, it is usually better to use an oscilloscope or analog voltmeter. The same is true if you must measure signals whose frequencies exceed the range of the DMM. I keep a 10 MHz

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What Is A Half-Decade?

Numeric displays for digital multimeters are typically specified as having 3½- or 4½-decade capacity. Since each decade represents a power of 10, or another digit moving from right to left, you might think that a 3½-decade display can provide a maximum count of 4999 and a 4½-digit display a count of 49999. Though this could be the case when dealing with displays containing a half-decade, it almost never is for test instruments. In the case of the DMM (and many frequency/period counters), the half-decade in the display counts to only 1!

If a decade counts to only 1, why do manufacturers call it a *half*-decade? Isn't this misleading and a violation of the truth-in-advertising law? Technically speaking, it is misleading—but only if you don't understand what is implied by the term "half-decade." It's not a violation of the law, either, because the half-decade does more than just count to 1. It's also used to indicate polarity for dc voltages and currents.

To obtain the polarity-indicator function, the center horizontal segment of the display is turned on and off selectively to indicate negative and positive values, respectively. (Most DMMs with LED-type displays indicate only negative polarity with the minus sign. If the minus sign isn't present in the display, the

value being read is implied to be positive. Many LCD-type displays indicate both negative and positive values with minus and plus signs, respectively.) Since a single decade display does double duty as both a numeric and a polarity indicator, manufacturers early on adopted the convention of calling it a half-decade display. Interestingly, until a few years ago, a display that counted to only 1 with no polarity indication built into the system was referred to as a ¼-decade display.

In the early days of numeric-indicating digital test instruments, any decade that counted to only 1 used the 1 as an "overflow" indicator. Today's 1-count display/driver schemes are considerably more sophisticaded. When a 1 comes up in the display in the half-decade position, it's a true 1 and not just an arbitrary overflow (sometimes called an "overrange") indicator.

Built-in logic circuitry holds the 1 in the display until the value being measured exceeds the capacity of the display. At this point, the display either blanks out and is replaced by some indication that means the range limit has been exceeded, or the number in the display remains unchanged, with a separate indicator activated to inform the user that the display range has been exceeded.

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wide-band analog voltmeter handy for these occasional measurements.

Another lesser-known problem with measuring ac signals is when a dc voltage is present. For example, the output from a power supply rectifier may contain many volts of dc plus some ac ripple. With some DMMs, particularly early models, both voltages will be read at once. This can be quite a surprise if you were to measure power supply ripple and get a reading greater than the supply voltage! If you have this problem, the cure is to connect a 0.047-μF, 1600-volt dc blocking capacitor in series with the input, as shown in Fig. 2. Note that if your work is confined to solid-state applications, you can probably get by with a 200-volt dc capacitor.

And finally, don't forget that ac measurements are especially susceptible to hum and noise pickup. If you are measuring low-level signals in a high-impedance circuit, simply touching the hot lead or moving it around may affect the reading. The cure is to use a shielded cable with appropriate connectors for these measurements.

7. Let's move on to dc voltage and current measurements. These measurements are among the simplest and most troublefree you can make, yet there are pitfalls to avoid. Consider the following:

Like ac measurements, the voltage or current you are measuring must be steady. If it changes your DMM readings will "bounce around" and cause confusion. After all, it is hard to trust a multimeter that keeps giving different readings! The solution is to use an oscilloscope or analog voltmeter, accepting a loss of accuracy.

Any ac or noise components on the dc signal will cause errors, as they combine with the desired signal and are therefore also measured. Some multimeters are better than others at rejecting these signals. If you need greater rejection of annoying ac or noise components, look for a meter

with higher Common Mode Rejection Ratio (CMRR) and Normal Mode Rejection Ratio (NMRR) specifications.

8. In a pinch, the measurement of noisy signals can be improved two ways. First, try connecting a 0.1-μF polyester capacitor across the input jacks. Or if your meter is ac/battery powered, switch to battery operation. Sometimes the absence of line-induced noise does the trick, allowing greater accuracy.

9. Ohms measurements can be affected by three different factors:

Voltage appearing on the circuit being checked for resistance is a problem, naturally. This is especially true with circuit capacitors, which set up a current flow in the circuit that adds or subtracts from the current source in the multimeter. As a result, you get the wrong reading. A tipoff of a "live" circuit is when you get an overrange indication (circuit is powered) or a changing reading (voltage being bled off by the meter).

Solid-state devices can conduct current and, thus, throw off your readings. Most modern multimeters have "low-power" ohms provisions, which applies roughtly 0.5-volt maximum to the circuit. Consequently, those widely used silicon devices won't turn on, thereby giving you a more accurate picture of the circuit's resistances. Of course, if you have an older multimeter that doesn't have low-power ohms, or if you work with germanium devices, it will be necessary to unsolder parts before making any measurements.

Often, the 20-megohm range of your multimeter will be senstitive to noise pickup. Touching the leads or moving them around may affect your reading quite a bit. This is caused by the high-impedance, hum-sensitive circuitry and low currents used on this range. If you have this problem, one way to reduce it is to use shielded leads. Another way is to connect a 0.1-μF polyester capacitor across the test-lead input jacks.

10. Let's round up our discussion with some brief thoughts on DMM use. Did you know that DMMs generate r-f signals? How much signal and at what frequencies depends upon the make and model of the instrument. The signal is strongest on the leads when the instrument is set for the lowest dc voltage range.

I discovered this fact when I was working on a communications receiver. A broadband buzzing sound appeared in the speaker whenever the DMM was placed on the upturned chassis. Moreover, some DMMs can be influenced by strong signals from nearby transmitters. As a result, it pays to be wary of any readings made in this environment, as r-f pickup through the leads and case can throw off your readings. Many manufacturers today internally shield the DMM circuitry to reduce r-f pickup.

Digital circuitry using CMOS logic requires special care when being tested with a multimeter. Always ground one probe to the circuit before touching any inputs; that way any static charge carried by the instrument will not pass through any IC inputs, damaging parts. Also be careful when using the Ohms position to locate "stuck" lines, or lines shorted to power or ground by a bad IC. Removing the bad IC may cause the DMM to apply full voltage to an IC input, damaging the part. Admittedly, this situation is unlikely with modern instruments having low-power ohms ranges, but older multimeters may apply enough voltage and current to cause damage.

Some applications, such as receiver alignment, require an instrument that shows voltage trends clearly. A DMM won't do the job, as the display updates too slowly. Additionally, you must remember the last reading displayed before it changes. In this case, an analog type meter or an oscilloscope should be used. I use a high-quality FET multimeter for these applications, so analog meters aren't dead yet, are they? **ME**