Using the Multimeter

Figure 1. $8.95 $400

A multimeter is an essential electronics workbench tool. A wide variety of meters are available ranging in price from free to $400. The extra money gets you more features, a nicer interface and better precision. Most of the time the cheapies are just fine.

The reason these are called multimeters is they combine several functions into one box. At the very least you can measure current, voltage and resistance. In addition, you may find the ability to measure:

- Electrical continuity with a beep
- Diode and transistor voltage drop

- Transistor gain
- Transistor good/bad
- Temperature (needs special probe.)
- Frequency
- Capacitance
- Battery good/bad

The first thing you get when you spend more than $40 is automatic range selection. This is worth the money. Fancy meters also may include analog style displays (a bar graph), touch and hold measurements, min-max memory, and even a simple waveform display.

Controls and Connections

Figure 2.

Most meters are controlled by a single rotary switch. One of the positions on this switch is off, and you should use that to keep the battery from running down. Most digital meters will shut off if they are not used for a few minutes. You need to switch off and back to wake them up.

The switch chooses the type of test and range expected. If you try to test something that exceeds the chosen range, the meter will show **Overload** or something similar (maybe a 1 with no other digits). You want to use the lowest range that works for a test—this gives the best accuracy.

Meters are used with probes that (usually) plug into jacks on the front. One jack is labeled common, and will always be used with the black probe. There are usually at least two more jacks, and the red probe will be moved around for various tests. Most of the time the VΩmA jack will be used. The other standard jack is for high current measurements. The second meter in figure 1 has a fourth jack for low current measurements.

Figure 3.
Basic probes are simply pointed wires with handles. More elaborate probes will include detachable clips of various kinds. These are generally too fat to fit into tight spaces, so I prefer to use alligator clip leads clipped to the meter probe and the work. (I often solder extra wires onto circuit boards to give a convenient place to clamp.)

The Basic Measurements

Voltage
Voltage is easily the most common measurement you will make.

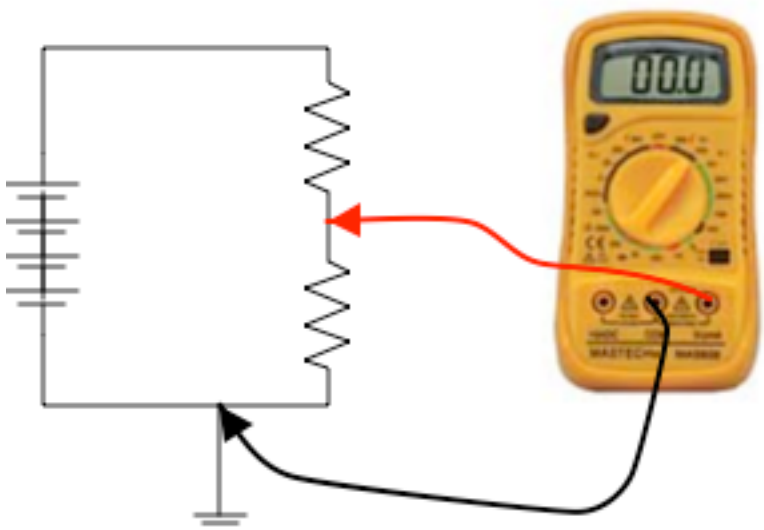

Figure 4.

Meters have two voltage tests, one for DC and one for AC. The labels might be a bit coy, such as V~ to mean AC. Either way, voltage measurements are taken parallel to the load as shown in figure 4. Put the red lead in the VΩmA jack and the black lead in common. The black lead is attached (or held) against a ground point, or the negative lead of the battery. The red lead is touched to the point of interest. If the red lead is more positive than the black lead, you will see the voltage as a number. If the red lead is more negative than the black lead, you will see a negative number. If the circuit is switched off, you will probably see 0.

Current

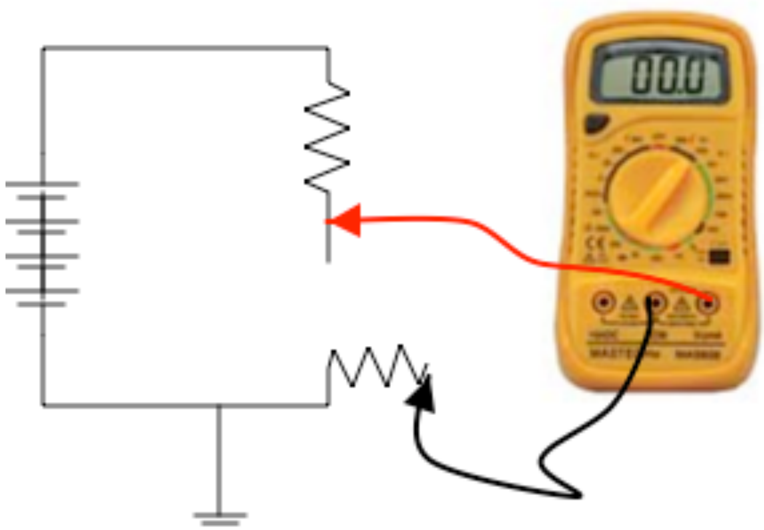

Figure 5.
Current measurements are taken in series with the circuit—in other words, the current flowing through the part of the circuit you want to test must also flow through the meter. Choose a current test and range before making the connections. Turn the power off before messing with the circuit. This is easy on a breadboard, but you will probably have to desolder something if you are working on a built circuit.

If the current expected is larger than an amp, use the high current jack[1]. Which lead is connected where is not particularly important, but the sign will tell you the current direction.

It is far, far better to calculate current than test it. Usually if there is too much current somewhere, components will smoke and the test is too late. Current testing is best done before circuits are built, finding out how much current salvaged motors need and the like.

[1] If you get this wrong, you can kiss your meter goodbye. Or at least you will have to replace a fuse.

Resistance

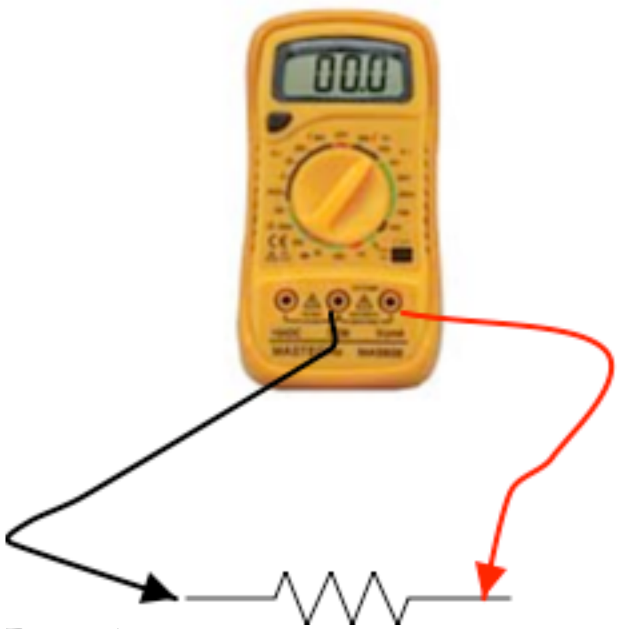

Figure 6.

Resistance is tested out of circuit. If you try to read the resistance of a part while it is in the circuit, you may be fooled by unnoticed parallel paths. If you do check the resistance of an in circuit part, turn the power off.

The main exception is testing our solder connections. When things look dodgy, I check the resistance between parts that are supposed to connect. The reading should be 0 or a very small number.

Things to watch out for

With manual range meters, it easy to get confused and be off by a decade. The number listed as the range is the full scale value. A reading of 1.00 on the 2000mV range is one volt. The same reading on the 200mV scale is 0.1 volts. Usually the first digit can only be 0 or 1, so the biggest reading you can see is 1.99. This is why I like to spend the extra bucks for an auto ranging meter. These will move the decimal place and show the correct unit in the display.

The error of these meters is a percentage of the full scale value. So if you make a measurement on the 2000mV range of a meter with 1% error, it could be off as much as 20 mV. This is significant if the reading is 40mV. Always use the smallest range that will fit.

Make sure you get a good tight fit between the probe and circuit. The same things that confound soldering will make the meter inaccurate. This is especially a problem if the solder process has left traces covered in flux or burned gunk. Use the tip of the probe to scratch a shiny spot.

Be careful about what you touch with the probe. I once destroyed a $500 amplifier by shorting an output transistor with a meter probe. It went into cascade failure and literally burst into flames[2]. If you are working on a board that translates Arduino output to 12V for motors, you can do the same on a smaller but equally devastating scale. Always pick a large target for the probe—if there is a component connected to an ic pin, touch the component lead, not the pin. If you have to work in an extremely crowded area, slip a bit of insulation over the probe so only the point of the tip is showing.

Do not attempt to measure current coming out of the wall. That's a ticket for an ambulance ride. If you need to measure power draw or lamp current, get a meter designed for the purpose, such as a clamp-on ammeter. If you want to check your house or car wiring, get a power probe.

Figure 7

[2] Sort of the way James Bond takes out the bad guy's computer, but in slow motion.

Analog meters

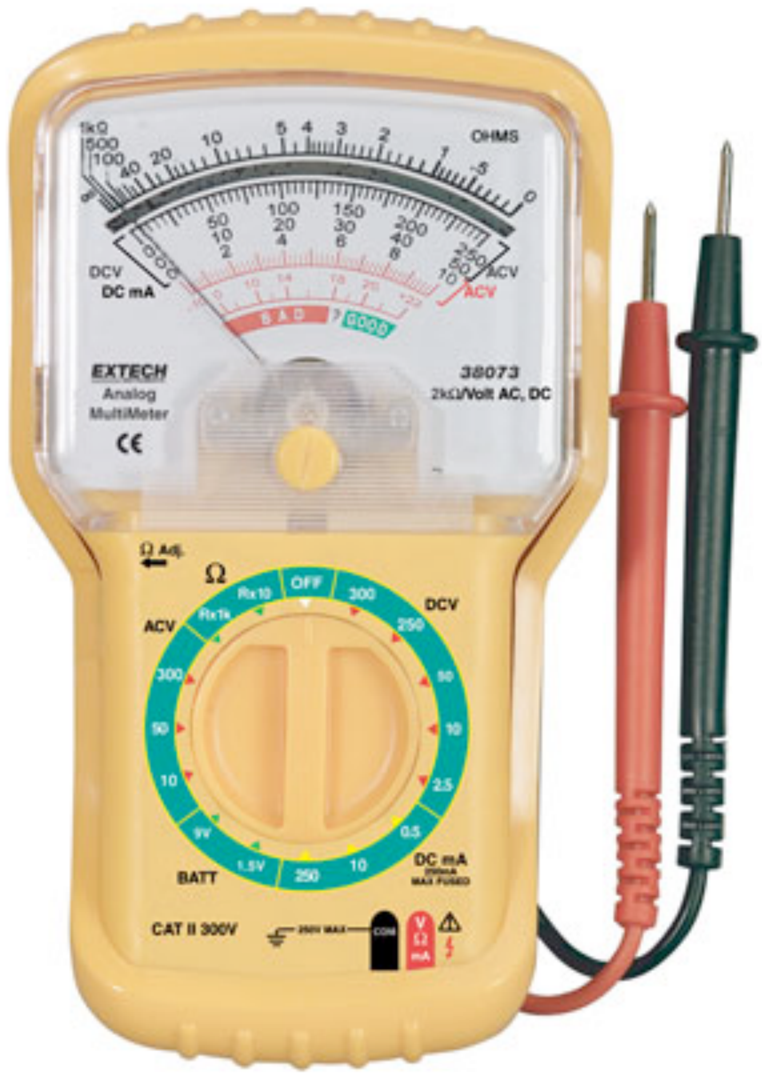

Figure 8.

Digital meters are wonderful, but there are times I miss the old fashioned needle meters. Analog meters are best when you are trying to tweak a value with a trimpot or dial, because they respond faster and more smoothly than digital meters.

The difficult thing about analog meters is the multiple ranges printed on the face—there is a scale for each range. On the meter in figure 7 there are scales for 10, 50 and 250, and it is not immediately obvious that you read the 50V scale when using the 300V range. (Even the manual is unclear on this.)

To get an accurate reading, you must look directly into the meter. Since the needle is above the scale, if you look from the side the needle will line up with the wrong number. Good meters have a mirror on the scale to help line up[3].

[3] Not that analog meters are all that accurate. The cheapies are accurate to 5% of full scale. If you need precise measurement, get a digital meter.

Some analog meters have a dB scale—this is useful if you work with audio circuits. You should shop around for one that has the dB on the top instead of squeezed in at the bottom. Audio measurements are only accurate in the telephone frequency range, around 1000Hz. You can't use this kind of meter for frequency response tests. This is true of digital meters also. If you need to measure broadband audio, be prepared to spend some serious bucks for a test set such as the one in figure 9. These include precision signal generators as well as highly accurate test meters. Prices start around $600.

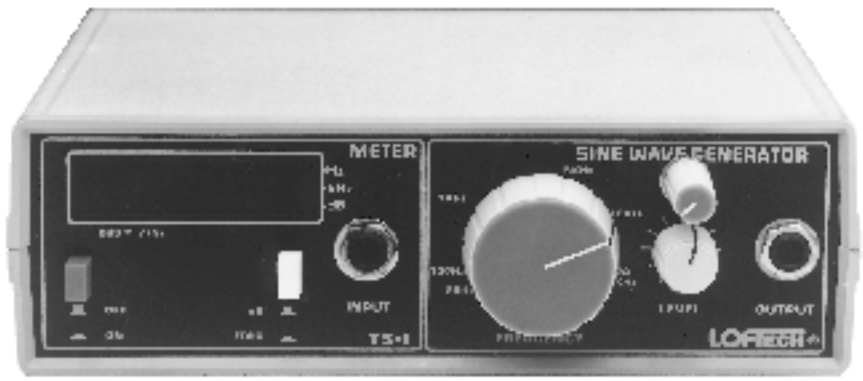

Figure 9.