INCREASE YOUR ANALOG METER'S RANGE

Adding the right shunt to your meter's circuit will extend its measuring range

BY JOHN BAILEY

IN AN analog meter, dc current flowing through a meter coil creates a magnetic field that works against the field of a fixed magnet. The resulting force causes the meter coil to rotate, moving the meter needle, which is attached to the coil, upscale. If too much current flows through the meter coil, the magnetic field may be so strong that the meter needle actually wraps itself around the upper limit stop. Thus, each meter has a built-in upper current limit (its range) to prevent such accidental damage. If you want to use a meter at a current value that is higher than its limit, you must use a meter shunt.

A meter shunt is actually a resistor that "shunts" excessive current around the meter movement. As the higher current flows through the shunt, the voltage drop across it (E = IR) is applied to the meter coil. The resistive shunt must be designed so that, at the maximum desired current flow, the voltage generated across the shunt will cause a current flow (I = E/R) within the meter coil to allow its pointer to just reach the top of its scale. Thus, by proper selection of the shunt resistance, a meter with almost any current rating can be used to measure almost any desired current. All that has to be changed is the meter scale.

The range of a milliammeter can be increased to almost any value by using a shunt whose resistance is calculated from $R_s = R_m/[(\text{new range}/\text{meter range})-1]$ where R_s is the shunt resistance and R_m is the meter resistance. For example, to

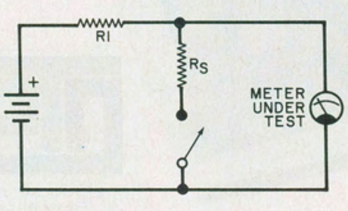

Fig. 1. Circuit for determining meter resistance using two precision resistors.

increase the range of a 1-mA, 50-ohm meter to measure 20 mA, $R_s = 50/[(20/1)-1] = 50/19 = 2.6316$ ohms.

Determining Meter Resistance. If the meter resistance is not known, you may be able to measure it using the resistance function of a DMM. However, the measuring voltage of most DMMs may be high enough to drive a sensitive analog meter off scale. *Do not* use a VOM because there is normally too much voltage across their probe tips. Besides, the accuracy of a typical VOM is not good enough for this type of measurement.

The well-known procedure of shunting the meter being measured with a resistor of such value that a normal full-scale deflection is reduced to half-scale deflection (thus making the meter resistance equal to the shunting value) is basically sound; but it requires an adjustable constant-current source. Even if such a source were available, the value of the shunting resistor would have to be measured with a bridge.

Fortunately, there is a relatively simple and easy way to determine the resistance of a meter. All you need is a low-voltage battery and two precision resistors. The circuit required is shown in Fig. 1. Precision (1%) resistor $R1$ is selected to produce a little less than full-scale deflection (battery voltage is not important). Note this deflection and call it "A." The meter is then shunted with another precision resistor R_s selected to produce a deflection of approximately half scale. This deflection is noted as "B." Solve for R' using $R' = R_s[(A-B)/B]$. Enter R' into $R_m = (R1 \times R')/(R1-R')$ to determine meter resistance. For example, assume a 1-mA meter and a 1.5-V dry cell. Then $R1$ was selected as 1580 ohms and it produced a deflection of 0.92 mA ("A"). Similarly, R_s was selected as 51.1 ohms and it produced a deflection of 0.47 mA ("B").

Thus, $R' = [51.1(0.92–0.47)]/0.47 = 48.93$ ohms. The meter resistance is determined by calculating $R_m = (1580 \times 48.93)/(1580 - 48.93) = 50.49$ ohms.

Making a Shunt. For noncritical applications, a shunt is formed by scramble winding a length of enameled copper wire on a high-value resistor body which serves as a form with axial leads. The wire gauge and length are found from a Wire Table that covers gauge and resistance/foot.

It has been customary to wind on slightly more wire than was needed according to calculations and then to remove turns until the exact value was reached. However, there is a slight problem in this approach.

When the shunt wire is soldered to the resistor leads, the temperature of the wire, and the associated resistor body/leads may increase the total resistance due to the positive temperature coefficient of the wire. In conjunction with this, usually insufficient time was allowed for the wire and resistor to cool down to room temperature before removing any turns. This resulted in the shunt appearing to have too much resistance, so more turns than necessary were removed. Then, when the shunt had cooled, it was found to have too low a value.

However, there is a way to "tweak" the shunt resistance to the correct value while it is connected to the meter with which it will be used.

Start by using the wire table to determine the gauge and length of wire whose resistance is slightly *less* than that required for the shunt. This is found using the first equation in this article. Do not wind this wire on the resistor body at this time. Instead, use the setup shown in Fig. 2. Solder a heavy-gauge wire (large enough so that its resistance will be negligible) to each end of the length of magnet wire, and connect the other ends across the meter to be shunted.

Adjust the current calibration potentiometer until the desired current flows through the series circuit as indicated on the calibration meter. The meter to be shunted should display a slightly lower indication due to the slightly smaller shunt.

Grip one end of the heavy-gauge shunt lead in a bench vise, and the other soldered end in a pliers. Make sure that there are no kinks in the shunt wire as it may break in the next step.

While observing the meter-to-be-shunted indications, gently pull the wire using the pliers. The wire will stretch with a soft "give" feeling and its resistance will increase. Keep stretching the shunt wire until the meter to be shunted produces the desired indication (via the calibration meter). It may be necessary to readjust the calibration meter depending on how much disparity there was between the two meter deflections when the process was started.

To illustrate stretching versus resistance, a 5-foot length of #34 gauge wire was stretched 18″ as its resistance increased 40% approximately linearly. This amount of stretch should not be used, but it does show what happens during a wire stretch.

Shunt Example. Assume a 1-mA meter is to be shunted so that its new full-scale value will be 20 mA. The meter resistance (using the equations in this article) was found to be 50.49 ohms. The value of the shunt was found to be 2.657 ohms. A wire table showed that #36-gauge wire has 423 ohms per 1000 feet (0.423 ohms/foot). Therefore, 6.31 feet produces 2.67 ohms. Six feet was selected to produce 2.538 ohms, slightly less than the calculated value.

Using the circuit of Fig. 2, the wire was stretched until the shunted meter indicated exactly full scale when the calibration meter indicated 20 mA.

The wire was then scramble wound on a 1000-ohm (any high value will do), half-watt resistor body with the ends of the shunt wire soldered to the resistor body axial leads. The completed shunt was then installed on the meter, and the meter scale re-calibrated. ◇

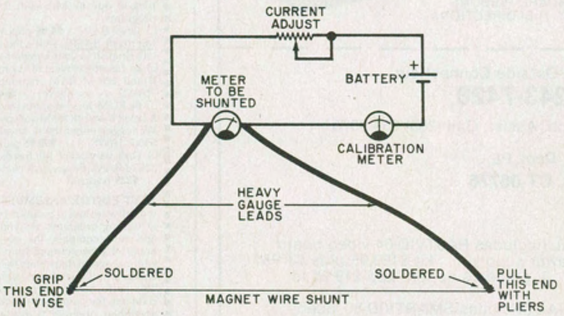

Fig. 2. Heavy-gauge leads are used to reduce any resistance between the meter and the shunt to be stretched. Do not stretch the magnet wire shunt to the breaking point.