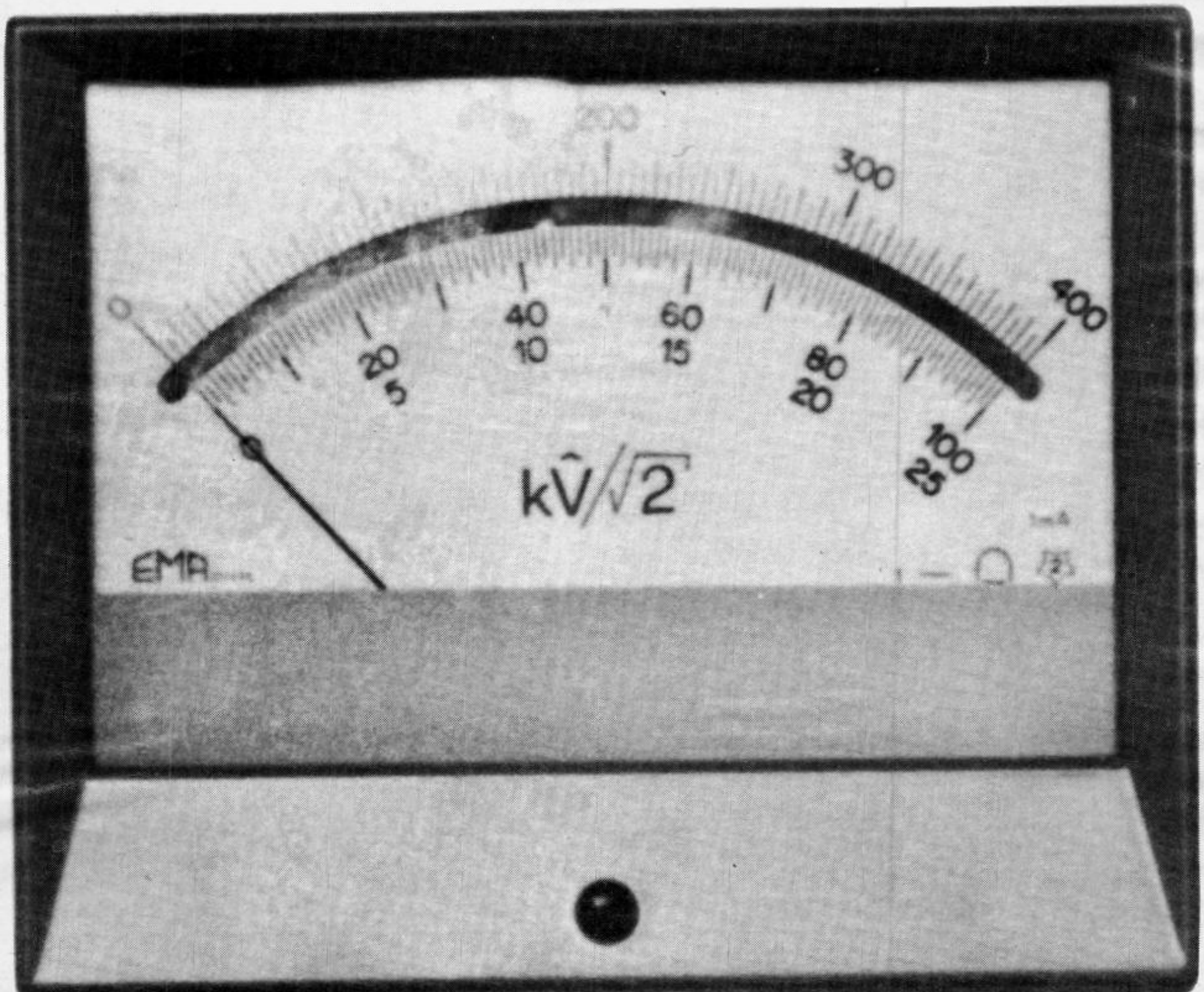
Surplus Meters



Surplus stores often have a collection of various analogue meters. Here's how to adapt them to your own uses.

By David Thomson

SOME KIND of electrical measuring device is fundamental to all serious experimentation with electronics. Many readers probably own a volt - ohm -milliammeter (which I shall refer to as a VOM), costing anywhere from $10 to $150 or so. This article will dig into the construction of the meter "movement" itself, which may help you to repair that old VOM instead of buying a new one, or perhaps to make use of some cheap surplus meters for your next project.

The d'Arsonval meter movement used in most cheaper VOM's has been around for 100 years or so with very little change. It consists of a needle attached to a coil of wire pivoted so it can rotate in the field of a strong permanent magnet. Current is passed into the coil through the springs which also serve to hold it at "zero" when no current is present. Notice that I mention current, not voltage. This type of meter actually measures current, and to make it read volts, watts, degrees celsius or revolutions per minute depends upon external circuitry. The same goes for measurements of AC (alternating current or voltage).

Principles Of Operation

Two important properties of any meter movement are full-scale current and full-scale voltage drop. These refer to the current which must flow through the coil of the movement to make the needle point to the maximum reading on the scale, and the corresponding voltage across the meter movement terminals at that time.

The ideal meter movement would have a low-resistance coil, a low full-scale current, low full-scale voltage drop, low friction in the pivots and low cost. A real meter may have one or more of these qualities, but not all. For example, a low full-scale current may be achieved by increasing the number of turns of wire in the coil. However, this will increase the resistance (and voltage drop) as well as the weight. To reduce weight, we would prefer to use finer wire for the coil, which increases resistance again. A low friction suspension helps to reduce full-scale current but adds to the cost. That is why you cannot pick a meter movement at random and expect external circuitry to make it do what you want.

Now let's look at the "external circuitry", which for DC measurements consists of resistors connected in series of "shunt" (parallel) with the meter movement. Two examples should clarify what is required.

Suppose we have two identical meter movements, and for ease of calculation let's assume that each has a coil resistance of 50 ohms and a full-scale deflection current of 1 mA. The voltage across the terminals of the movement at full-scale deflection will be 50 millivolts, that is, 50 Ohms X 1 mA = 50 mV (see Table 1).

Voltmeter On The Cheap

Let's use one movement to build a voltmeter which reads 10 V at full-scale. All that we need add is one resistor in series with the movement to limit the current:

10 V / 1 mA = 10 K ohms

To be precise, we might expect to subtract the coil resistance of 50 ohms and look for a resistor of 9950 ohms, to connect to the meter movement as shown in Figure 1. In real life, you won't find a 9950 ohm resistor, but 10 K is close enough. Commercial resistors are rated at 5%, 10% or 20% "tolerance", that is, the best 10 K resistor you can buy off the shelf (5% tolerance) may be anywhere between 9500 and 10500 ohms, and the completed meter will be accurate within .5 V.

"Sensitivity", measured in "ohms per volt," is an important property of a voltmeter because it indicates how much effect the use of that meter will have upon the circuit being measured. Our meter will have a sensitivity of 1 K ohms per volt; this is a function of the meter movement itself, no matter what series resistor we use.

1 V / 1 mA = 1 K ohm per volt

A sensitivity of 20 K ohms per volt (50 micro-amps full scale) is about the best you will find in a D'arsonval meter, unless you are lucky enough to find a "taut band suspension" meter. These may have a full-scale current as low as 1 micro-amp!

Thoughts

Let's use the second meter movement to build an ammeter with a full-scale deflection of one ampere.

Since the meter movement itself cannot carry such a large current, we will provide a parallel path called a "shunt" to carry most of the current — 999 mA, to be exact (see Figure 2). Using Ohm's Law again, the shunt resistor should have a value of:

50 mV / 999 mA = .05005 ohm

You can't buy that in your neighbourhood store, but you may find it at an electrical supplier under the name of "1 Amp 50 mV shunt". For other than 50 mV, a standard value, there is no chance. A cheaper solution (why pay more for the shunt than you paid for the meter?) is to build your own shunt. From wire tables, we can find out the resistance in ohms per 1000 feet of any gauge of copper wire we may have on hand. The trick is to be sure you know what gauge it is. If you have a choice, choose a gauge which will make the shunt wire about one foot long. And if the wire is not insulated or enamelled, it will have to be wound very carefully so the loops do not touch.

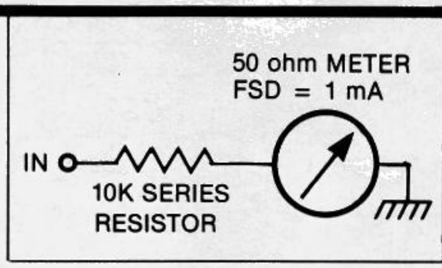


Fig. 1. A 0 to 10V voltmeter from a 1 mA meter movement.

Refer to Table 2 for the next step, which is the calculation of the length of the shunt wire. (A "mil" is 1/1000 inch, that's .001).

Let's say you have bought a spool of No. 30 (30 gauge) wire-wrap wire for your shunt. From the table, you will need:

(.05005 ÷ 103.2) x 1000 x 12

which works out to 5.82 inches.

Use an ordinary resistor as a form for your shunt; pick one at least ten times the final resistance of the shunt, and a physically suitable size. Wind the shunt wire around the form and solder both ends to the resistor leads.

For greater precision in your final product, you may want to read Reference 1, which suggests a way of calibrating your meter against a second meter which you are sure is correct. That may be hard to do where currents of one or more amperes are involved; it all depends on the contents of your junk box. With patience, you can set surprising accuracy from surplus equipment, which is often of high quality, but if the meter is just a means to some other end, don't spend too much time building it.

Notice that for voltage measurements requiring high sensitivity, the full-scale current requirement of the meter movement is critical; for current measurement, the full-scale voltage drop is critical. A typical VOM is a compromise, which may not work too well on low voltages or currents over about 250 mA.

If sensitivity is important to you, read up on simple DC amplifiers (you might try Reference 2, although I have not built that project yet). It is undoubtedly cheaper than stalking the perfect meter movement.

Shopping For A Used Meter

A few suggestions, not necessarily in order of importance:

Look for small print in a corner face stating FSD = 1 mA (full scale deflection = 1 milliamp) or 001DCMA, which also appears to mean 1 mA, or FS = 200*u*A (the *u* is really a Greek "mu" meaning "micro" or 1 millionth), and if you are lucky, coil resistance in ohms. If FSD is less than 1 mA, assume the resistance is over 100 ohms.

If you can't find these figures, look at the meter scale. If it is calibrated in a milli-volts or milli- or micro-amps, that *may* apply to the meter movement itself. If calibrated in amperes, it very likely has an FSD of 50 millivolts; it may even be labelled "use 50 mV shunt". If calibrated in volts, who knows?

Look at the face and consider how easy it will be to make it look good on your project. For example, changing a 0-500 scale to read 0-5 is easy; buy some white correcting fluid and cover the zeros!

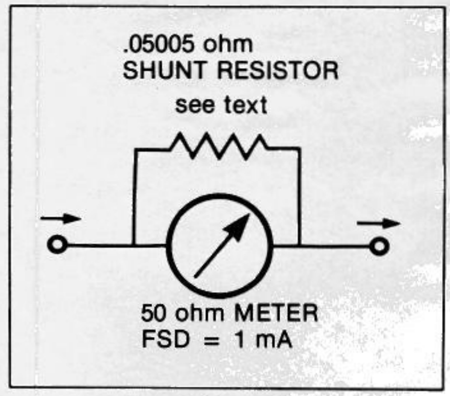


Fig. 2. A 0 to 1 A ammeter from the same movement.

Do not be too pessimistic about the funny scales which are printed on the surplus meters you find. With some patience and care, you can re-design the face of the meter to read whatever you want. I suspect the ones that are calibrated in gallons or feet above sea level are slightly cheaper because people who have not read this article don't know how to make use of them. So you are at a definite advantage! However, taking apart a meter to give it a new face must be done with care. It is very easy to bend or break the needle, bend a spring or lose a tiny screw which you can't replace. If you have more thumbs than fingers, you might be better advised to let it be, unless it was *very* cheap. I once had a perfectly good battery charger for my car which had a meter calibrated in "knots"!

Although the advent of micro-electronics has given us alternative ways of making precise measurements, the basic d'Arsonval meter still has a fascination for the experimenter. And if your budget is limited, surplus meters can give you more for less money.