HOW TO MAKE CUSTOM METERS FROM SALVAGED PARTS

Surplus D'Arsonval movements are easily converted to special-purpose voltmeters and ammeters

BY PROF. ROBERT KOVAL

WITH the switch to digital logic and numeric readout devices in modern test equipment, the surplus market is becoming glutted with D'Arsonval meter movements. Actually, the availability of these parts is a boon to the electronics experimenter because the going prices for the movements are often only a small fraction of what he would have to pay if purchased from an industrial supply house.

Most surplus meter movements can be refurbished and custom designed to suit just about any metering need imaginable. The process is relatively simple.

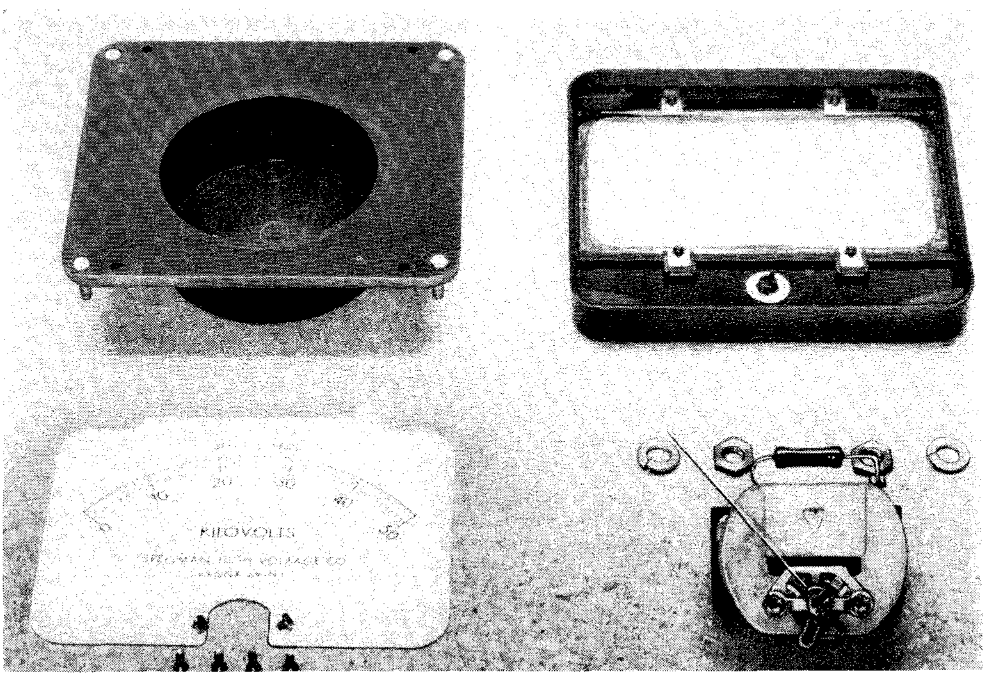
Preliminary Steps. Because the meter movement is from a surplus parts store, the first task is to clean away all dirt and other foreign matter from the case. This can be done with warm water and soap. For tough, greasy build-ups, try using some rubbing alcohol.

Once cleaned, carefully disassemble the movement (Fig. 1). Then inspect the movement to determine whether or not any resistors have been installed. Since you need only the basic movement for the next step, any resistors you find can be discarded.

Now, get out your VOM, a 2-megohm potentiometer, and a 1.5-volt dry cell with holder. Wire up the circuit shown in Fig. 2, but do not install the battery in its holder until after you adjust the pot for maximum resistance. Connect the battery and slowly adjust the setting of the pot to obtain exactly full-scale pointer deflection on the meter movement. (Note: Temporarily replace the old meter scale to locate the full-scale position.) Since the meter under test is in series with the VOM, both units carry the same magnitude of current. Hence, the VOM's reading is the full-scale current sensitivity of the meter movement.

At this point, the resistance of the meter

Fig. 1. The first step is to disassemble and clean the surplus meter.



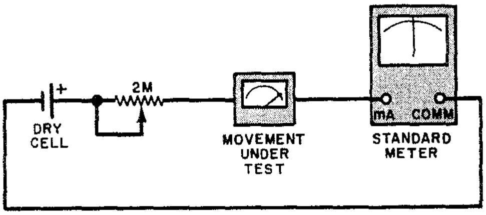


Fig. 2. Use this setup (with VOM and 1.5-V cell) to check movement's full-scale value.

movement (*Rm*) must be determined. Do *not* use an ohmmeter to measure the movement's resistance; the current supplied by the ohmmeter could easily damage the movement beyond repair. A method has been developed for calculating *Rm* using only the basic movement, two resistors of known value, and a 1.5-volt dry cell. The circuit hookup is shown in Fig. 3. Series resistor *Rser* should have a value large enough to permit *I1* to fall within the upper third of the scale. As a guide for choosing *Rser*, use Ohm's law. Assume the dry cell to be delivering 1.5 volts, and work this against the basic movement's full-scale current sensitivity. A fixed precision resistor would be ideal for *Rser*. The value of *Rsh* should be 1/10 or 1/20 the value of *Rser*. You can determine *I1* and *I2* from the meter's scales. Calculate *Rm* as follows:

$$Rm = \frac{Rser \times Rsh \times (I1 - I2)}{Rser \times I2 + Rsh\ (I2 - I1)}.$$

You now have enough information to custom-design a voltmeter or ammeter.

The Custom Voltmeter. It is usually convenient to customize a meter movement in such a manner that it retains the same numeric sequence on the original meter scales to obviate the necessity of relabeling the scales. However, this is not absolutely necessary if you do not mind the task of removing the old and applying new legends.

Since the meter movement shown in Fig. 1 has a numeral 50 at its full-scale index, let us design a voltmeter with a 0-5-volt range. Assume that 50 μA is needed to deflect the pointer to full scale and that *Rm* is 2090 ohms. To calculate the value of the multiplier resistor (*Rmult*) for any given voltage range (*Vr*), use the following equation:

$$Rmult = (Vr \times 1/Im) - Rm$$

In the equation, *Rm* is the basic movement's resistance (2090 ohms in our example), *Vr* is the voltage range desired (0-5 V full-scale), and 1/*Im* is the reciprocal of the current needed to obtain full-scale pointer deflection (1/0.000050). Hence, *Rmult* = (5 × 1/0.00005) − 2090 = 97,910 ohms.

As illustrated in the above example, a 97,910-ohm resistor will yield a 0-5-volt range when connected in series with the basic meter movement. To change ranges, simply substitute the desired full-scale figure for *Vr* in the equation. If you want multirange capability, calculate *Rmult* for each range desired and use a rotary switch for range selection.

Very likely, the value calculated for *Rmult* will not be readily available from the commercial selections listed. Do not let this deter you. It is a simple matter to arrange two or more resistors in series/parallel hookups to yield the required ohmic value. Alternatively, you can "trim" an ordinary carbon resistor to the proper resistance with the aid of a file (see Fig. 4). Select a fixed resistor of slightly lower value than required. For example, if you need 97,910

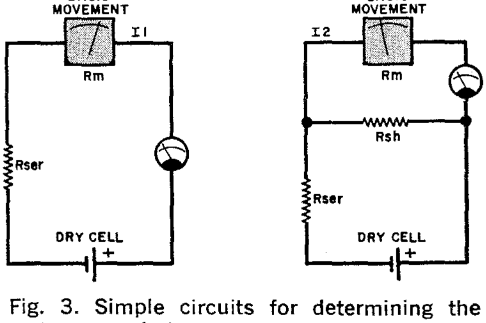


Fig. 3. Simple circuits for determining the resistance of the original meter movement.

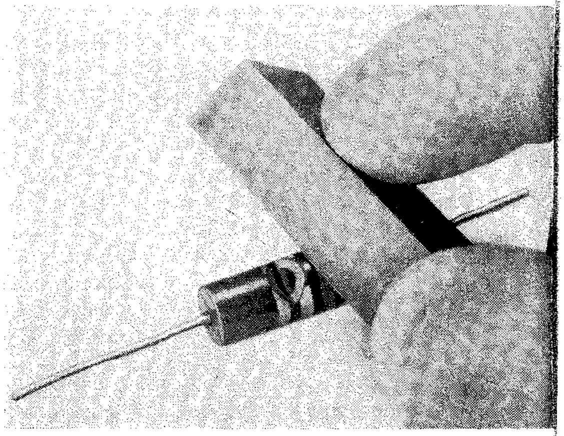


Fig. 4. The resistance of an ordinary carbon resistor can be trimmed by using a file.

ohms, a standard 91,000-ohm carbon resistor can be used. Use an ohmmeter to verify that it is indeed less than 97,910 ohms; a 10-percent tolerance resistor can go as high as 100,100 ohms, a useless figure for the trimming procedure.

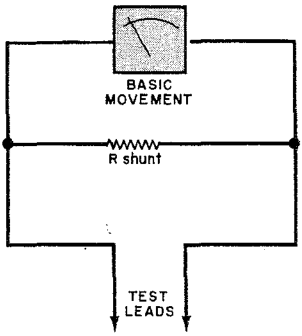


Fig. 5. The basic setup to be used for determining shunt resistor for an ammeter.

Use a resistance bridge or an ohmmeter to monitor your progress as you cut into the resistor with the corner of a triangular file. Work very carefully so as not to trim away too much of the composition resistance material and end up with a value too high for your needs. When the resistor is trimmed to the proper value, liberally coat the notch with coil dope to seal out moisture. This will assure a constant resistance under changing humidity conditions.

The multiplier resistor can be mounted inside or outside the meter's case. A tag indicating the range and units can then be affixed to the meter face. Make it large enough to completely cover the original legend.

The Custom Ammeter. A custom ammeter can be designed around the basic meter movement with much the same ease encountered when making the voltmeter. The basic hookup is shown in Fig. 5. The equation to use for determining the resistance of the shunt resistor is:

$$Rshunt = \frac{Rm \times Im}{Imax - Im}$$

Maximum current *Imax* is the desired full-scale current the meter is to indicate; *Im* is the current required to deflect the meter's pointer to full-scale; and *Rm* is the resistance of the basic movement.

Assume that you want a range of 0-50 mA and that *Rm* and *Im* remain the same as in the voltmeter example given above. Then, *Rshunt* would be equal to $(2090 \times 0.00005)/(0.05 - 0.00005)$, or 2.092 ohms. Again, if a different range or ranges are desired, the maximum current wanted would be inserted into the equation as *Imax*. A switching arrangement would be used to provide several ranges.

The value of *Rshunt* will normally be very low, sometimes on the order of only a fraction of an ohm. In cases where its value would be too low to be conveniently trimmed with a file, you will have to wind your own shunt resistors. Enamel-coated copper wire can be used as the resistive element, while the resistor form can be any high-value resistor (1 megohm will do). Wire gauges and the resistance they yield are given in the Table. A hand-wound shunt resistor assembly is shown in Fig. 6. After winding the wire onto the resistor body and soldering the wire's ends to the resistor's leads, coat the assembly with coil dope.

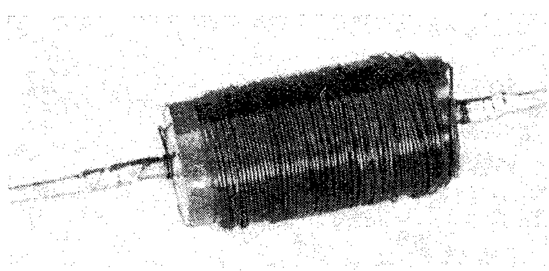


Fig. 6. A hand-wound shunt resistor. Next the assembly is protected with a coil dope.

As with the voltmeter, the ammeter's shunt resistor can be mounted inside or outside of the meter's case. Also, be sure to label the meter face with the range and unit for which it is designed. To check out your ammeter, connect it in series with a VOM and current source; both meters should indicate the same magnitude of current. ◈

RESISTANCE PER UNIT LENGTH OF COPPER WIRE AT 25° C

Gauge	Ohms per 1000 ft.	Gauge	Ohms per 1000 ft.
18	6.510	30	105.2
20	10.35	32	167.3
22	16.46	34	266.0
24	26.17	36	423.0
26	41.62	38	672.6
28	66.17	40	1069.0