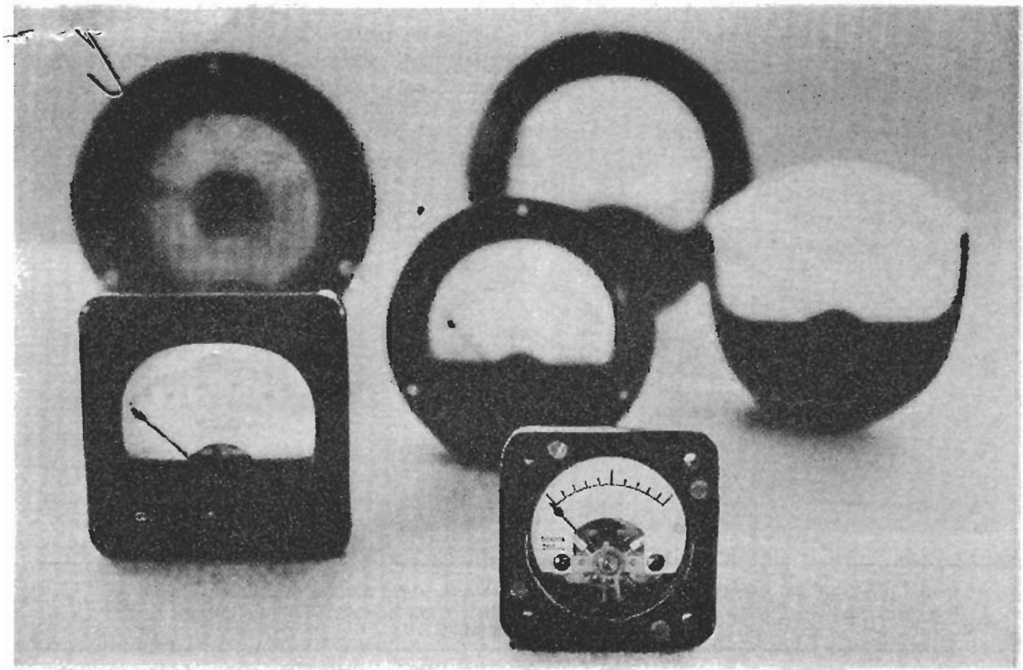


METERS: Let's Face Them

Why waste a meter, when all it may need is a brand-new face

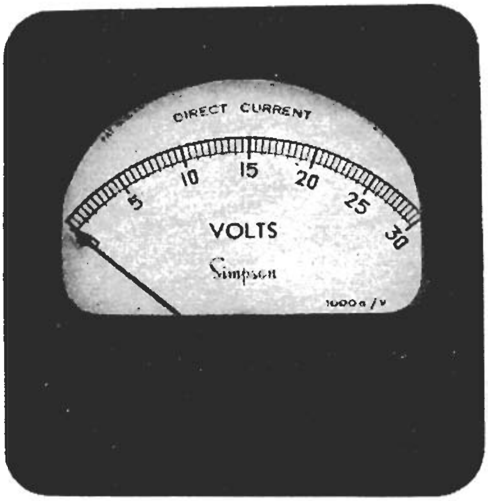
BY JESS W. SPEER, W6ELJ

HAVE YOU EVER started to build a project but had to stop because you needed a meter with a range you didn't have handy? If you're an average experimenter, situations like this probably crop up with annoying regularity. However, any technician, ham, or experimenter worthy of the name should be able to extricate himself from a simple meter problem.

Almost any D'Arsonval meter movement can be converted to suit virtually any current or voltage measuring requirement. The conversion described below is simple, inexpensive, and leaves the meter looking "made-to-order" for your projects. Just two steps are required: adding a multiplier or shunt to the basic meter movement, and reworking the meter scale to conform with the range needed. The whole job shouldn't take more than a couple of hours, even if you're a beginner at this sort of thing.

Meter Theory. All meters—regardless of how they are eventually used—are basically current-measuring devices. Generally, they are very sensitive, and if used to measure large currents, they must be shunted by a low-value resistor. The low-value shunt resistor will divert the greater part of the current away from the delicate low-current meter movement, thus altering the meter's current-indication range and protecting the movement.

Similarly, the voltage-measuring capability of a meter movement can be expanded many times if a suitably high-value multiplier resistor is connected in series with one of the meter's leads. The higher the resistance value of the mul-



In the photo at the left, the meter is shown before refacing it for the example explained in the text. The "after" view (right) shows the same meter refaced to a 0-150 mA current range.

tiplier, the greater will be the voltage-measuring range of the meter. Then, when the meter is connected to the circuit under test, the meter will indicate only the voltage drop caused by its own internal resistance.

Current measuring meters are always connected in *series* with the circuit under test. Conversely, a voltmeter is connected in *parallel* with the test circuit.

The accuracy of any meter measurement depends on the sensitivity and accuracy of the movement and the tolerance of the shunt or multiplier resistors. In some cases (such as vacuum-tube grid circuits where current flow is very small), a very high-input-impedance voltmeter is required to prevent loading down the circuit and causing inaccurate readings. However, most experimental circuits do not require a high-impedance voltmeter, nor must the readings be exact. For this reason, meters capable of making many useful measurements can be improvised without resorting to complicated mathematics.

Reworking the Meter Scale. Take a hypothetical case where a 0-150 mA meter is needed but the only meter available is calibrated for 0-30 volts d.c. This is a fortunate accident since the meter scale is divided into six major divisions, each separated by ten minor increments (see photos). Thus each individual increment will divide the desired range into 2.5-mA steps, with the major divisions indicating, 25, 50, 75, 100, 125, and 150 mA, respectively. The major divisions simplify scalar readings.

To rework the scale, carefully remove the movement from its case and the two screws that anchor the scale plate in place. Then delicately slide the plate from under the meter pointer, taking care to avoid bending the pointer. Set the movement aside, and place the scale plate on a clean, flat surface.

Next, remove the original numbers and the word VOLTS from the plate with an ordinary typewriter eraser (or carefully scrape them away with a sharp knife if you can't get good results with the eraser), but leave the divided scale intact.

When all traces of the numerals and letters are removed, use a suitable size "Letraset" or "Prestype" lettering kit to renumber the major scale divisions as shown. When transferring the characters from the lettering sheet, place the sheet of type over the scale with the characters oriented as they would normally be read. Also, keep the numbers equidistant to lend a professional appearance to the job. For example, with two-digit numbers, the scale mark should separate the two numbers; with three-digit numbers, the central numeral should align with the scale mark.

After renumbering the scale, transfer the word MILLIAMPERES or the symbol mA to the position from which you removed the word VOLTS. Now, remove the multiplier resistor that may be connected to the meter terminals, anchor the scale plate back in place, and reassemble the meter.

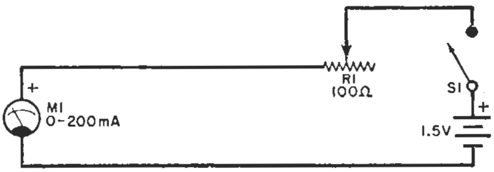


Fig. 1. Simple current-limiter test setup is essential to finding value of shunt resistance needed.

The Meter Shunt. The resistance of the shunt needed for a current-measuring meter can be determined mathematically if you know the internal resistance of the movement. However, a simple trial-and-error technique is usually a lot quicker and just as accurate.

First, breadboard a circuit like that shown schematically in Fig. 1. Meter *M1* in the diagram is a basic 200-mA movement, or it can be a VOM set to read current on a range nearest (but above) 150 mA for our hypothetical example. Set potentiometer *R1* for maximum resistance, and close *S1*. Then adjust *R1* so that *M1* reads exactly 150 mA. Open *S1*, and remove *M1* from the circuit, but be careful not to disturb the setting of *R1*.

Since a trial-and-error technique of arriving at the value of the shunt is to be employed, an arbitrary length of magnet wire should be selected. If you use #24 or #22 wire, start with a 24" length. Be sure the wire size you select is capable of handling the current it must shunt away from the meter. For example, use #24 wire for shunts that must handle 500 mA or less. For up to 900 mA, #22 wire can be used but for greater current-handling capability, a larger size wire must be selected from the "Copper Wire Table" in the *Radio Amateur's Handbook*. When selecting the wire to use, restrict yourself to high quality "Formvar" or "Nylcad" enameled wire.

After cutting the wire to its arbitrary length, scrape away 1" of insulation from each end, and connect the bared ends to the terminals of the meter you are converting. Insert the meter in place of *M1* in the circuit, and close *S1*. If the pointer deflects less than full-scale, a longer wire is needed; if the pointer swings off the upper end of the scale, use a shorter wire.

Mentally calculate the final length of wire needed for the shunt, using the meter indication as a gauge. For example, if the 24" length of wire produces only a ⅔-scale deflection, the final length should be about 36" (plus about 6" to allow for trimming purposes). The process is a bit tricky if the pointer has moved beyond the upper limit of the scale. In this case, snip away about an inch of wire at a time until the pointer swings slightly beyond the full-scale deflection point. (Remember, when using this cut-and-try technique, *S1* must be open at all times when the shunt wire is not connected to the meter terminals.)

Now, double the wire in the center, and wind it over the body of a 500,000-ohm (or larger), 1-watt resistor, as shown in Fig. 2. The two ends of the wire, wound in the same direction as shown, will make the shunt non-inductive. But if the inductance of the shunt is unimportant, just wind the wire in one direction from end to end. (In cases where bulk winding of the wire is large,

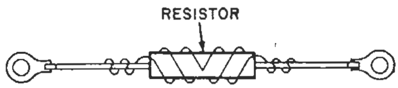


Fig. 2. Correct method of winding a noninductive shunt, winding from center to ends, is shown here.

glue ½″-¾″ diameter pieces of cardboard or plastic on each side of the resistor body to prevent the wire from slipping off.) Affix solder lugs to the resistor leads as shown, but don't solder the shunt wire in place.

Connect the shunt to the meter's terminals, close *S1*, and use the trial-and-error technique until the wire yields an exact 150-mA deflection of the meter pointer. (Do not readjust *R1*.) Finally, to check linearity, insert the converted meter in a circuit like that shown in Fig. 3. Meter *M1* is the converted meter, and *M2* is any other meter capable of measuring 150 mA or more. Potentiometer *R1* should have a value of 100 ohms or greater.

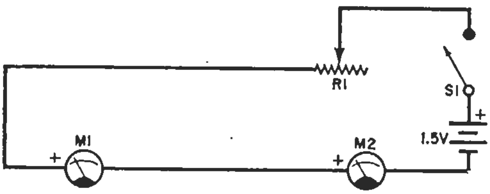


Fig. 3. When checking linearity of converted meter, pointers of both meters should move proportionally.

Close *S1* and vary the setting of *R1* while observing the meters. Both meters should indicate essentially the same reading, point-for-point, over the entire range of the converted meter. After this is done, solder the shunt wire's ends to the resistor leads.

Voltmeter Range Multipliers. Most meter sensitivities—either in microamperes, milliamperes, or ohms/volt—are stamped somewhere on the meter. However, if a meter's basic sensitivity is not indicated, the circuit shown in Fig. 3 can be used to determine it. The process used is comparison, in which case, *M1* should be a basic 1- or 2-mA meter, and the value of *R1* should be increased accordingly.

If a meter's sensitivity is expressed as 1000 ohms/volt, the movement has a full scale sensitivity of 1 mA (determined by Ohm's law where $I = E/R = 1/1000 = 1mA$). Once the approximate voltage level to be measured and the current required for full-scale meter deflection are known, the multiplier resistance value can be determined by dividing the meter sensitivity in amperes into the desired full-scale voltage (in volts) range.

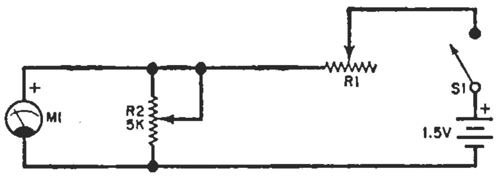


Fig. 4. This circuit is used to determine the internal resistance of any unknown meter movement.

Assuming that a 0-1 mA movement is to be used to measure 100 volts, the multiplier resistor would be 100,000 ohms. The multiplier resistor is then connected in series with one of the meter's terminals.

For very accurate measurements, the internal resistance of the meter must be determined, then subtracted from the value calculated for the multiplier resistor. (Use the circuit in Fig. 4 to determine the internal resistance of the meter. Potentiometer *R1* is 100 ohms. Simply adjust *R1*—with *R2* disconnected—until *M1* indicates exactly full scale. Connect *R2* and adjust it until *M1* indicates exactly half-scale. Disconnect the power from the circuit, remove *R2* without upsetting its setting, and measure the resistance of *R2*. This measured resistance is equal to the internal resistance of the meter.)

For accuracy, precision wire-wound resistors of 1% tolerance or better should be used. However, in most cases, resistors with a 5% tolerance will suffice.

With the conversion techniques described in the foregoing, it is easy to see that almost any meter can be reworked to suit your needs. Both the techniques employed and equipment needed are simple enough to understand and use even by a novice to electronics —much less to someone with extensive experience in fabricating projects. —30—