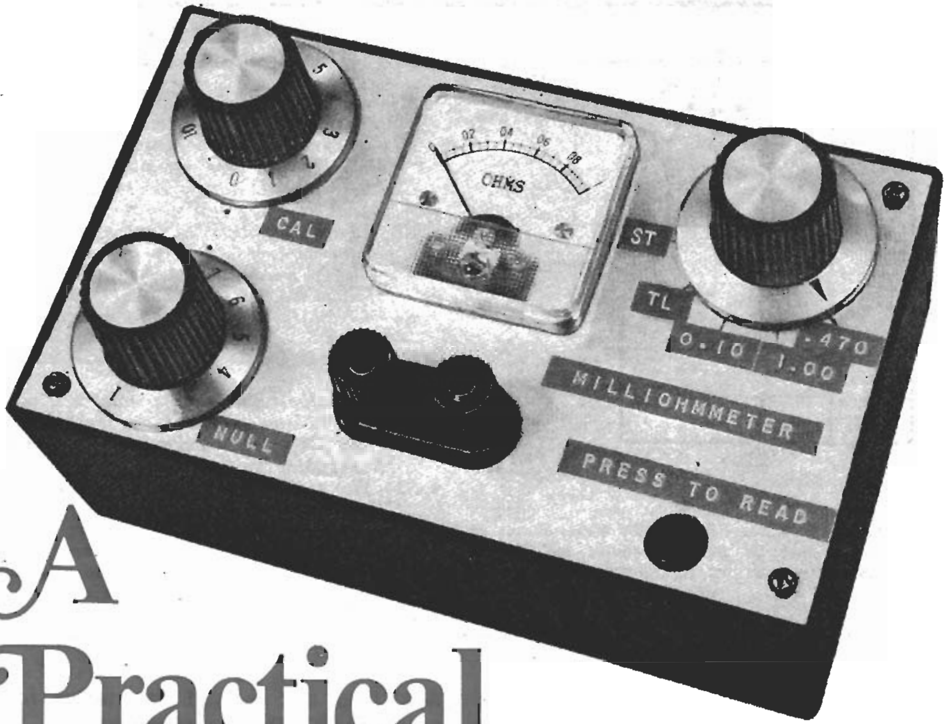

A Practical Expanded Scale Milliohmmeter

MEASURING THE ALMOST UNMEASURABLE

This test instrument was developed to measure what most electronic experimenters are inclined to think of as inconsequential resistances. However, the less than 1-ohm losses are important factors in detecting hi-fi ground loops, poor contacts in high amperage circuits, corrosion, etc. The circuit is a simple, easily balanced bridge. Provision is made in the instrument for long storage and battery protection.

CONVENTIONAL home and field-type VOM's are not designed to resolve accurately resistance readings between zero and one ohm. Even the very best multimeters employ a logarithmic scale, with 10 ohms as an average center-scale reading when the range switch is in the times-one position. And you need a very sharp eye, indeed, to differentiate between readings of, say, 0.27 and 0.05 ohms on a multitap transformer.

Commercially available milliohmmeters are

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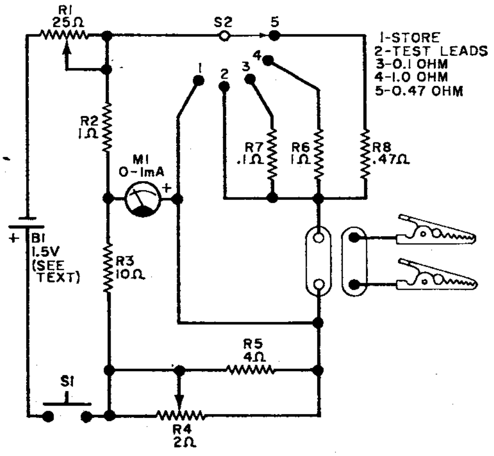


Fig. 1. Resistor R8 provides optional but very useful internal testing facility for checking calibration; S1 is momentary-action switch.

PARTS LIST

B1—Three 1.5-volt AA cells connected in parallel
M1—0-1-mA, 50-ohm meter movement (Monarch No. PMC6S or similar)
R1—25-ohm, 5-watt wire-wound potentiometer (Mallory No. VW25 or similar)
R2,R6—1-ohm, 2-watt, 5% tolerance wirewound resistor
R3—10-ohm, 2-watt, 5% tolerance wirewound resistor
R4—2-ohm, 5-watt wirewound potentiometer (Mallory No. VW2 or similar)
R5—4-ohm, 1.5-watt, 5% tolerance wirewound resistor
R7—0.1-ohm, 2-watt, 5% tolerance wirewound resistor
R8—0.47-ohm, 2-watt, 5% tolerance wirewound resistor (optional, see text)
S1—Spst pin-plunger momentary-action switch (Robertshaw No. 1MD1-1A)
S2—Five-position, non-shorting rotary switch (Mallory No. 3215J or similar)
Misc.—Five-way binding post pair; banana plug pair; Keystone No. 171 three-AA-cell holder; control knobs; chassis box; hookup wire; epoxy cement; solder; etc.

expensive instruments, costing $175 and more. However, with modern solid-state equipment in which biasing resistors in the 0-1-ohm range are common, a milliohmmeter is almost a must for measuring such values. By eliminating unnecessary ranges and maintaining accuracy to within practical limits, it is possible to build a milliohmmeter for less than $18.

The milliohmmeter described in this article has two very useful ranges—0-1 ohm and 0-0.1 ohm. The scale is very nearly linear (it would take very expensive and elaborate equipment to show that it is not), but is actually a tiny portion of a logarithmic curve, expanded to cover the full swing of the meter pointer.

Theory of Circuit Design. As shown in Fig. 1, the circuit of the milliohmmeter consists of a resistive bridge, one side of which is made up of the test leads (and resistance being measured). Closing *S1* causes current to flow from *B1* via *R1* to the bridge.

With *S2* in position 2 and the test leads shorted together, *R4* is adjusted to ten times the lead resistance, balancing the 1:10 ratio of the *R2-R3* side of the bridge. The meter will now indicate zero, regardless of the setting of *R1*. If the test leads are disconnected, with *S1* closed, the bridge will be heavily unbalanced in a direction such that current will flow from *R2* through the meter to *R4*, swinging the meter pointer off-scale.

For calibration purposes, *S2* must be switched to *R6* for the 1-ohm range or *R7* for the 0.1-ohm range. If *S2* is in position 3, *R7* is placed in series with the test leads, unbalancing the bridge circuit and moving the meter pointer by an amount determined by calibration potentiometer *R1*. Potentiometer *R1* is then adjusted to produce a full-scale pointer deflection.

Setting *S2* to position 2 and placing a 0.1-ohm resistor across the leads will also cause a full-scale deflection of the meter pointer (assuming that the setting of *R1* remains undisturbed). Hence, it is possible to compare the standard internal resistances of *R6* and *R7* with the values of resistance being measured and obtain direct readings in ohms.

Resistor *R5* is used to smooth the operation of *R4* and help balance the bridge. An optional feature of the circuit is *R8* which provides a useful internal resistance for checking calibration.

Construction. Assembling the milliohmmeter should present no problems, since there is nothing critical about the circuit. As shown in Fig. 2, all components, except the battery bank and its holder, mount directly to the front panel. To simplify mounting, a hard-

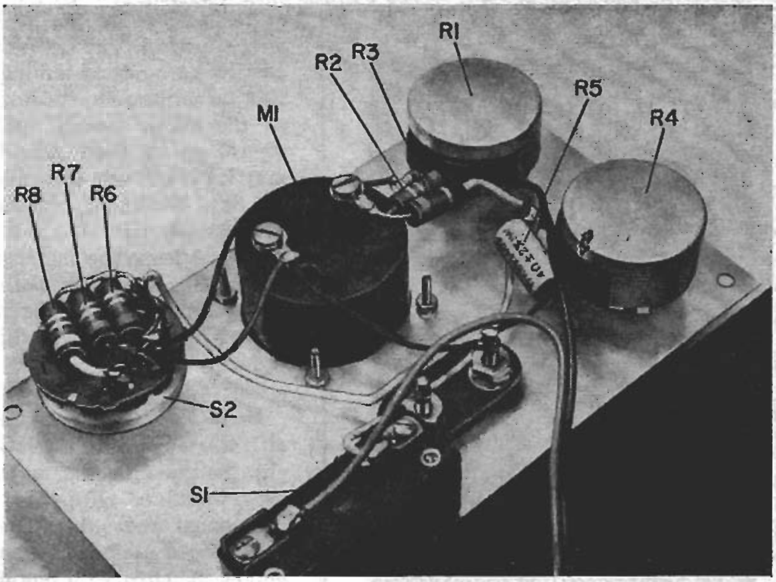
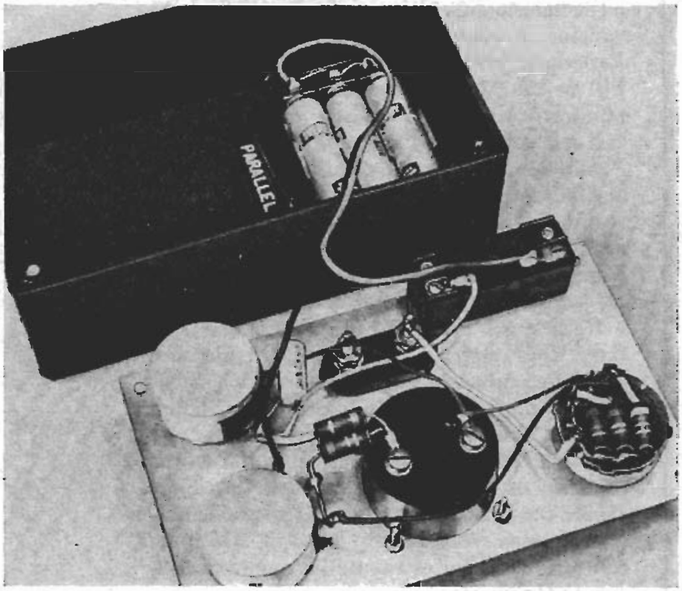


Fig. 2. The simplicity of the circuit allows all components to connect directly to the control and meter lugs.



The battery supply for the circuit is mounted in place with the aid of three AA-cell holders and machine hardware.

set epoxy cement bonding is used between the top of the housing of switch *S1* and front panel and between the battery holder bank and case. The meter movement, binding posts, function switch (*S2*), and potentiometers fasten in place with the hardware supplied.

Since there are only a few components, wiring by the point-to-point method is easy. Note, however, that the bank of three batteries that make up *B1* must be connected in *parallel* with each other. Also, when mounting the binding posts, make absolutely certain that both are insulated from the front panel.

Once the circuit is wired up as illustrated in Fig. 2, assemble the case. Now, make your test leads. Probe-type leads are useless for the milliohmmeter. What are needed for the test ends of the cables are strong spring-loaded clips that will lock solidly onto the leads of the components under test. This is necessary because in dealing with resistance measurements in the fraction of an ohm range, contact resistance becomes an important factor in accurate calibration and test readings.

It is not necessary to use any special type of test lead cable, nor are the lengths of the cables critical. The instrument is designed so that, in zero-adjust nulling and full-scale deflection calibration, the test leads become part of the bridge circuit and are "nulled out" regardless of their specific resistances. (It may seem strange that you have to consider test lead resistance, but the meter will easily demonstrate that if a null is obtained using only one lead, the meter will indicate half-scale deflection with both leads—and after calibration will give the resistance in milliohms of the lead not used in the nulling procedure!)

How To Use. First, short together the alligator clips on the test leads. It is best to clip the leads together in the same manner as they would be clipped to the leads of the component under test. This will assure good contact resistance. If you merely hold together the clips with one hand, you will find adjustments difficult to make because of the varying pressure you exert on the clips. Especially noticeable on the 0.1-ohm range will be the "jumpy" movement of the meter pointer.

Next, set *R1* to maximum resistance and *S2* to the TEST LEADS position. Depress *S1* and adjust null control *R4* for a zero meter reading. Then release *S1* and set *S2* to the desired range position. Again, depress *S1*. Now, adjust the setting of calibration control *R1* for a full-scale pointer deflection.

Release *S1*. Set *S2* to the TEST LEADS position. Your meter is now ready to measure resistance values in the range for which it was calibrated.

When storing the milliohmmeter away, set *S2* to the STORE position. This minimizes the chances of damage or off-scale readings should the PRESS-TO-TEST switch be accidentally depressed. As with any type of electronic equipment, batteries should be removed altogether for prolonged storage.

Aside from checking the values of less-than-one-ohm resistors, the milliohmmeter is a handy item to have available for other tests. It can be used to check corrosion in automotive wiring connections, a serious source of IR losses even if only a few milliohms of resistance is involved. Other uses include troubleshooting motors, generators, and starters, measuring the cold resistance of incandescent light bulbs, winding bias and motor control resistors from hookup wire, and checking for resistance in power distribution systems and ground circuits. —30—