Ohmmeter Reads To 300 Megohms

A novel circuit powered by the 117-volt line makes a wide-range, accurate, easily constructed ohmmeter for the technician

By JOHN T. BAILEY

The ohmmeter ranges are push-button-selected.

A NEW ohmmeter has been designed to meet all the needs of modern servicing and to avoid the limitations of certain common types. Its advantages are:

1. It is always ready for use at the snap of the switch—no waiting for tubes to heat up.
2. There are no batteries to run down or to compensate for because of reduced voltage due to age.
3. No zero adjusting is required when switching between ranges.
4. Maximum and minimum ranges are adequate for the most exacting servicing requirements.
5. It cannot burn out low-current tube filaments.
6. It is not affected by line-voltage fluctuations.
7. It is simple to use—just select the proper range.

The ordinary basic ohmmeter circuit of Fig. 1 consists of a series ar-

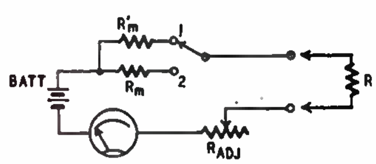

Fig. 1.—This is a standard ohmmeter circuit.

rangement of battery, meter, and resistance, with means for switching ranges and adjusting for zero balance. This simple circuit, regardless of range, theoretically reads from zero to infinity, but from the practical standpoint it falls far short of being a perfect solution. The highest value ordinarily marked on the meter scale is 200 times the mid-scale marking. The mid-scale value is equal to the total resistance of the series circuit with the terminals short-circuited. The total resistance is determined by the battery voltage and by the meter's current rating. For instance, using a 1-ma meter and a 20-volt battery would require a total resistance of 20 divided by .001 or 20,000 ohms. The meter scale would be calibrated from zero at the right to 20,000 ohms at mid-scale with a value of 200× 20,000 or 4 megohms at the left.

This scale is fairly open and easy to read from center to the right and compressed and increasingly hard to read to the left. However, with suitably overlapping ranges, this compressed scale is more serviceable than a linear one.

It is obvious from this example that the maximum range can be increased by using a higher-voltage battery, a more sensitive meter, or both. Each of these possibilities has its limitations. Larger batteries are expensive and bulky; microammeters are expensive and delicate.

The obvious solution is an a.c. power supply. In the ohmmeter shown in the photos, a 145-volt power source is used with a 100-microampere meter movement. The mid-scale reading is about 1.45 megohms, and a maximum reading of 300 megohms is obtained. Actually, the model shown has a maximum of 200 megohms indicated because of the difficulty in laying out the scale for good readability.

The power supply (Fig. 2) is a full-wave voltage doubler employing a pair of selenium rectifiers fed by a 1-to-1-ratio transformer. The transformer isolates the circuit from the power line so that there will be no danger of a short when probing in an a.c.-d.c. chassis.

The voltage-doubling circuit is required to produce a high enough starting voltage for the OD3/VR150 regulator tube, the constant voltage across which is used to energize the ohmmeter circuits. Note that all heat-generating components of the power supply are mounted above the chassis and cannot cause temperature errors in the measuring-circuit resistors, which are all mounted under the chassis.

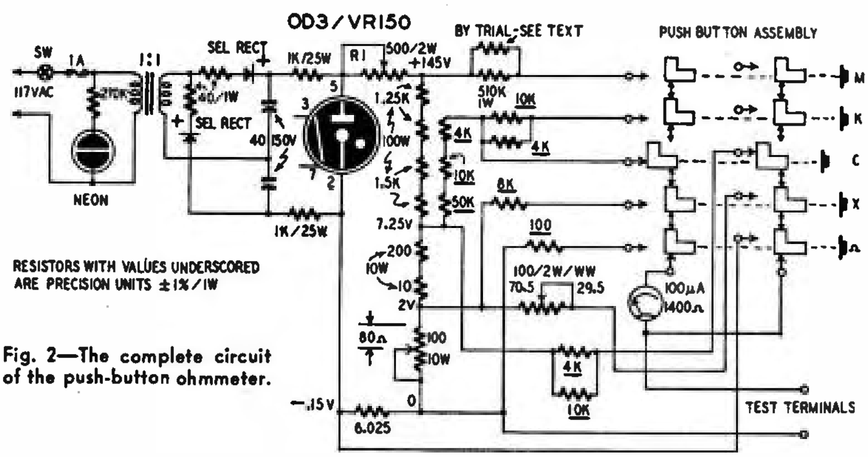

Fig. 2—The complete circuit of the push-button ohmmeter.

Not all OD3/VR150 regulator tubes, even of the same manufacture, strike at the same voltage. Therefore it was decided to use 145 instead of 150 volts to power the ohmmeter. A 500-ohm rheostat R1 is connected between the tube and the ohmmeter circuit to absorb whatever difference exists between 145 volts and the voltage established by the regulator. This rheostat is adjusted from the front panel and, after it is once set, need not be touched unless tubes are changed. (It might be more tamper-proof if placed on the chassis. —*Editor*)

A bleeder made up of several series resistors is connected across the 145 volts so that lower voltages can be obtained for the lower ranges. This

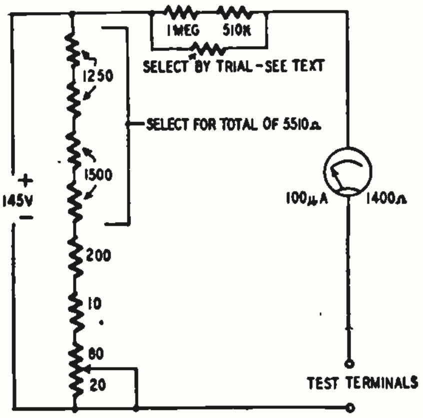

Fig. 3—High range is simple series circuit.

bleeder totals 5,800 ohms; 25 ma flows through it at all times. Except for the high range, it is important that this current be constant, so extra-heavy-wattage, wire-wound resistors are used, four in series, to make up the top 5,510-ohm section, so that the temperature rise will be small and will not change the resistance materially. These four resistors are mounted vertically under the chassis. Two are 1,250 ohms each, and the other two are 1,500 ohms each. Select these resistors carefully so that their total will be as close to 5,510 ohms as possible. The other sections of the bleeder consist of 210, 80, and 6,025

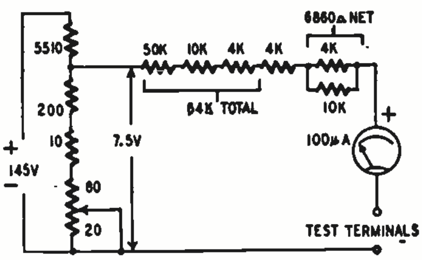

Fig. 4—The K range reads 1/20 of the M range.

ohms, all wire-wound. The latter may be home-made by winding the necessary length of enameled copper wire on a high-value carbon resistor.

The meter circuits

To describe the ohmmeter circuit, it is best to take one range at a time. Starting with the high or M range of 300 megohms, we have a simple series circuit, as shown in Fig. 3, with 145 volts d.c., a 100-microampere meter, and a multiplier. The multiplier value is 145 divided by .0001 or 1.45 megohms. From that value we must subtract the resistance of the meter and the effective internal resistance of the power supply. This is easiest to do by trial. Start with a 1.5-megohm multiplier consisting of 1-megohm and 510,000-ohm resistors in series. Then shunt this combination with a resistor of whatever value gives full-scale deflection with the ohmmeter test terminals shorted. An approximate value will be 4 or 5 megohms. Pay particular attention to getting this circuit exactly right because it later serves as a check on the calibration of the other ranges by acting as a voltmeter to check the 145-volt setting of the power-supply rheostat.

The second highest range (the K range) has the same calibration curve as the M range but reads 1/20 as much. This ratio provides good overlap. Since the M range reads 1.45 megohms at exact mid-scale, the K range must read 1.45/20 or 72,500 ohms at mid-scale. This is accomplished by another simple series circuit as shown in Fig. 4. The voltage is picked off at the 7.25-volt tap, making a multiplier of 72,500 ohms necessary. Subtracting the meter resistance (1,400 ohms for the meter used in this model) and disregarding the power-supply and bleeder resistances as negligible on this range, we find we need 71,100 ohms. If we break this down into 64,300 plus 6,800, we get a total of 71,100 and can use the 64,300-ohm section in the next range. Values of 64,300 and 6,800 ohms are not generally available in precision, wire-wound meter multipliers, but they can be approximated by combining standard multipliers. The 6,800 ohms (actually 6,860) is made up of a 4,000-ohm resistor in series with a 10,000- and 4,000-ohm shunt combination. The 64,300 value (actually 64,000) results from 50,000, 10,000 and 4,000 ohms in series. The difference between the actual and calculated values is less than 1% and therefore acceptable. Because of the substantial overlap and the difficulty in reading the crowded portion of the scale, this range was marked to only 500,000 ohms.

The third or C range is carried out to 20,000 ohms and reads 3,000 ohms at mid-scale. The circuit is shown in Fig. 5. The 7.5-volt tap and the 64,000-ohm multiplier section of the K range are used, plus a shunt resistor of 2,860 ohms. This shunt resistor is a parallel combination of 10,000 and 4,000 ohms.

The fourth or X range of Fig. 6 uses the same calibration as the C range and is 1/20th of it, reading 1,000 ohms maximum and 150 ohms at mid-scale. The 2-volt tap is used with an 8,000-ohm series resistor and a 70.5-ohm shunt. The 70.5-ohm resistor should be a wire-wound one with an adjustable slide.

The fifth or low range is different from the others and can be seen in Fig. 7. It is typical of low-range scales in that it reads backward. The meter is deflected to full scale with terminals open. The resistance to be measured is connected as a shunt across the meter, causing the meter to back up. The unusual part about this design is that it reads only 6 ohms at mid-scale, and a low reading of .05 ohms is possible. When we consider that the resistance of a pair of test leads is about this much, we realize that this range is more than adequate for low-resistance service in measuring coils, for instance. Another very important feature of this low range is that it is impossible to pass more than 25 ma through the resistance being measured. Most back-up-type, low-range ohmmeters pass considerable current, some as high as 300 ma, and almost all pass enough to burn out the filaments of a subminiature or hearing-aid tube. With this circuit there is no danger.

Fig. 2 shows that the ohmmeter uses

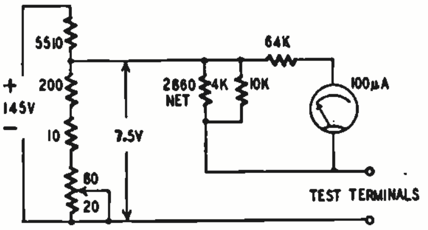

Fig. 5—C range has a 20,000-ohm maximum.

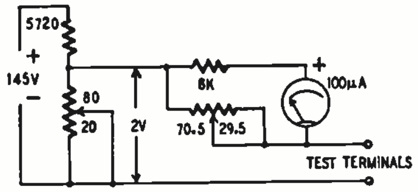

Fig. 6—X range reads 150 ohms at mid-scale.

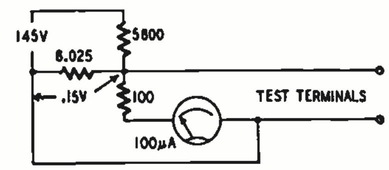

Fig. 7—Low-range scale reads left to right.

a push-button transfer switch for selecting the various ranges. This transfer feature is necessary to prevent damaging the meter if more than one button is held in at the same time. The usual type of push-button assembly used on home receivers, it is readily available. The best-quality switch must be used or else its own leakage resistance will cause error on the high range. A simple two-gang, five-position rotary switch could be substituted.

Calibration of the ohmmeter is relatively simple. The scale divisions are calculated using the formula: scale reading (assuming a 100-division scale) $=100-(100R/R+R_m)$. R is the resistance being measured and R_m is the meter-circuit resistance, both values expressed in the same units. For example on the high range, a 500,000-ohm resistor being tested would read $100-(100\times.5/.5+1.45)=74.36$ divisions on a 100-division scale or almost three-fourths of full scale. Additional points are calculated in the same manner.

When carefully constructed and calibrated, this ohmmeter will prove a valuable piece of test equipment in any service shop or laboratory. In service in the author's laboratory for over a year now, it still retains its original accuracy.

MATERIALS FOR OHMMETER

Resistors: 1—100, 3—4,000, 1—8,000, 3—10,000, 1—50,000 ohms, 1 watt, precision (± 1%); 2—40, 1—270 000, 1—510,000 ohms, 1—1 megohm, 1 watt; 1—10, 1—200 ohms, 10 watts; 1—1,000 ohms, 25 watts; 2—1,250, 2—1,500 ohms, 100 watts; 1—500-ohm, 2-watt rheostat; 1—100 ohms, 2 watts, adjustable; 1—100 ohms, 10 watts, adjustable.
Miscellaneous: 2—40-μf, 150-volt electrolytic capacitors; 1—1-to-1-ratio power transformer; 2—5-plate selenium rectifiers; 1—neon lamp; 1—1-ampere fuse assembly; 1—OD3/VR150 tube; 1—100-μa meter with internal resistance of 1,400 ohms; 1—2-gang, 5-button, transfer-type push-button assembly; 1—s.p.s.t. toggle switch; case, hardware etc