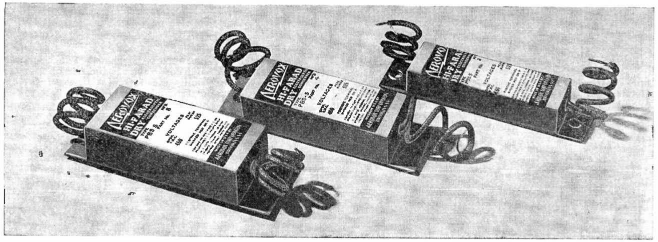

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Simple Methods of Measuring Resistance

By the Engineering Department, Aerovox Corporation

RADIO servicemen and experimenters frequently have occasion to measure the resistance of circuits or component parts. An instrument for this purpose should be simple, rapid in operation, have a wide range, be reasonably accurate, and, above all, it should be inexpensive. The equipment generally used meets these requirements fairly well. There is, however, a lack of understanding of the principles of operation as well as the cause of errors and how they can be avoided. The specification of the range of the instrument is usually vague and often meaningless. It is hoped to clear up many a mysterious point in the following article. It will also be shown how any voltmeter or milliammeter can be pressed into service to measure resistance. A chart is given which serves to find the required resistance from the meter reading; this chart will be valid for any kind of meter and for two different types of circuits.

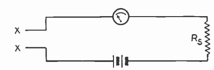

Fig. 1

THE "SERIES" CIRCUIT

The simplest type of circuit used for the measurement of resistance is shown in Fig. 1. It consists of a milliammeter, a resistance and a battery. In commercial instruments and in most other cases, the resistor has been given a value which is just right for making the milliammeter show full scale reading. This is done to get the greatest possible spreading of the resistance scale but it should be understood that it is not essential because the circuit can be used for resistance checking if the meter does not show full scale when the terminals X-X are shorted.

The procedure is as follows: the terminals X-X are shorted and the meter reading noted; let us call this reading m. The unknown resistance is connected between the terminals X-X and the reading is now n. The value of the unknown resistance is:

$$R = \frac{m - n}{n} Rs$$

Note that in the above reasoning there was no mention of the range of the milliammeter; and from the above paragraphs it should be clear that any meter, milliammeter or voltmeter can be used. The difference will be in the values of resistance it will measure most accurately, but any meter can be used and by the proper selection of the resistor Rs and the voltage of the battery, different resistance ranges can be obtained.

RESISTANCE SCALES

Special scales for the resistance ranges are made available by meter manufacturers. These scales are all made with the understanding that the reading m is full scale reading. They are made for various values of Rs, which really should be the value of the complete circuit including the resistance of the meter and of the battery. Now it can be shown mathematically, that the scales all resemble each other and the only difference between two scales, one of which is designed for a circuit having 1500 ohms resistance and one having 3000 ohms resistance, is that all values on the resistance scale of the second instrument are twice the corresponding values of the first.

Another peculiarity of the scale is that the value of the resistor Rs (in Fig. 1) plus the meter resistance, always appears at half scale reading. When ordering such a scale one orders by "center scale reading" and not by a range of from 0-100,000 ohms or any similar designation. Standard

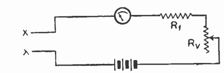

Fig. 2

scales generally have center scale readings of 1500, 3000, or 4500 ohms, or multiples of these values. This is done because of the prevalent use of 0-1 ma meters and standard batteries of 1.5 volt each.

WHAT IS THE RANGE OF THE INSTRUMENT?

Theoretically, any instrument of the kind illustrated in Fig. 1 has a range from zero to infinity. On both ends of the scale, however, it becomes impossible to obtain accurate readings. The greatest accuracy is to be had at the middle of the scale and it becomes less and less when approaching either end. The range of the meter should therefore be given by specifying the reading at half scale deflection and allowing a ratio of 1 to 10 or 1 to

20 either way. For instance, a resistance checker which has a center scale reading of 1500 ohms, can be used accurately for measuring values between 150 and 15000 ohms. Beyond these

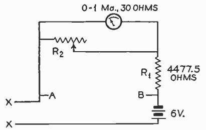

Fig. 3

limits errors become large. Some prefer to give the range of this instrument as from 75 to 30,000 ohms, thus allowing a ratio of 1 to 20 either way.

THE "ZERO ADJUSTER"

Compensating for variations in battery voltage is the cause of serious errors unless it is done properly. Fig. 2 shows the easiest way of doing it. A variable resistor, Rv is used in series with the resistor R1, the sum of the two being somewhat more than Rs in Fig. 1. If the voltage of the battery drops, the variable resistor is adjusted until full scale reading is again obtained. In doing so, the all-important "circuit resistance" has been changed and in order to be accurate, the scale should have this new resistance value at center scale reading. The result is that all measurements will be off by the same percentage.

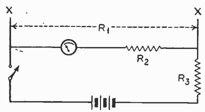

Fig. 4

If the battery voltage has dropped 10 per cent, the instrument will show all resistance values 10 per cent too high.

These errors can be made negligible when the zero adjuster is connected across the meter instead of in series with it. A suitable circuit is shown in Fig. 3. Instead of choosing the value of R1 so as to permit the meter to read full scale, the resistor is made smaller, so that approximately 20 percent more current flows than the meter can indicate. This extra current is passed around the meter through the variable shunt, R2. It is adjusted for full scale reading before testing resistors.

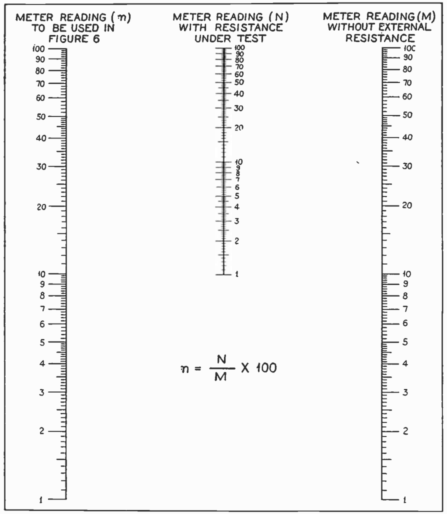

Fig. 5

GETTING MULTIPLE RANGES

The above resistance checker would be accurate only from 450 to 45000 ohms and no doubt readers wish to extend that range both up and down. (It should be understood that the usual calibrated dial is calibrated somewhat beyond these limits, but the range becomes too crowded to be accurate). The range can be extended upwards by adding resistance to R1 and to add a corresponding amount to the battery. For instance, by adding 9 times 4500 ohms (40500 ohms) in series with R1 and adding nine times 6 volts (54 volts) to the battery, all values of the scale are multiplied by ten. The instrument now reads from 4500 to 450,000 ohms. Similarly, by shunting (connecting between A and B in Fig. 3) the whole circuit with a resistance of 500 ohms (1/9 or 4500) the range becomes lower and all meter readings should be divided by 10. The same process can be repeated.

THE SHUNT CIRCUIT

A second circuit, often used in radio work is shown in Fig. 4. Here, the meter is placed in series with an adjustable resistor and the unknown circuit is connected across the meter or across the meter and a small resistor R2. The circuit under measurement then acts as a shunt on the meter and the needle will fall back depending on the size of the shunt. If we again call the first reading m (without the shunt) and the reading with the unknown resistor as a shunt n, the value of the unknown resistor is given by

$$R = \frac{n}{m-n} R1$$

where R1 is the sum of the meter resistance plus the series resistor R2, if any. The equation greatly resembles that for the series circuit. When two

scales are made up, one according to each equation and both having the same center scale reading, they will be mirror views of each other.

The circuit is usually employed for low ranges, because the meter resistance is generally low. Placing a 30 ohms 0-1 ma meter in series with 4500 ohms and a 4.5 volt battery, would give a range from 1/20th of 30 to 20 times 30 or from 1.5 to 600 ohms.

The equation given above will not be valid unless the series resistor R3 is large compared to R1, or center scale reading. Therefore, in the above example, 4500 ohms and 4.5 volts were chosen rather than 1500 ohms and 1.5 volt.

make it indicate full scale or nearly full scale, when the circuit is closed, employing the circuit of Fig. 1. If the meter in question is a voltmeter, the multiplier will serve as the resistor Rs in Fig. 1 and the instrument has to be connected in series with a battery within its measuring range. The unknown resistance can be found by calculation. A similar procedure can be followed with the parallel circuit of Fig. 4.

USE OF THE CHARTS

Figs. 5 and 6 are charts designed to eliminate all calculations for those who do not have their resistance meter calibrated. Fig. 6 is to be used bottom of the chart. The circuit, B, of Fig. 6 requires the use of the scale along the top of the chart for the meter deflection.

The graph is direct reading for values of Rm+Rs of from 10 to 100 ohms; for values beyond these limits, all values along the vertical and horizontal scales should be multiplied by the same number, 10, 100, etc.

Fig. 5 is designed for those who are using a meter, battery and resistance in any emergency and may not have the meter show full scale deflection when X-X is shorted in circuit A or open in circuit B. Find the meter reading M without the un-

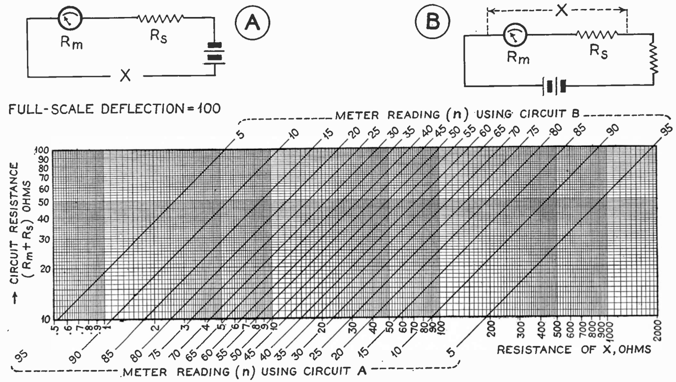

Fig. 6

As a zero adjuster, R3 can be made variable or rather a part of it should be variable. The example quoted could employ a fixed 4000 ohm resistor and a 1000 ohm variable one in series with it.

USING ANY METER AS RESISTANCE METER

The foregoing is a sufficient introduction to the use of any meter as resistance checker, if no calibrated meter is handy. The instructions are: place the instrument in series with a battery and sufficient resistance to for any resistance checker which shows full scale reading before the unknown resistor is connected. It is used as follows: Assuming that the circuit resistance is known, check the unknown resistance and get the reading n on the meter. Along the vertical scale of Fig. 6, find the value of the circuit resistance (Rm+Rs), follow the horizontal line to the right until it intersects the slanting line representing the meter reading. Moving downward at this crossing, read the value of the resistance on the horizontal scale below. When the circuit of A (Fig. 6) is used, the meter reading should be entered from the known resistor, and the reading N with the resistor in the circuit. Lay a straight edge along the corresponding values N on the middle scale and M on the left hand scale of Fig. 5. The intersection with the left hand scale shows the value n to be used in Fig. 6.

If the circuit resistance is not known, it may be found by "measuring" a standard resistor and working the problem backwards, entering Fig. 6 with this value on the horizontal scale and finding Rm+Rs on the vertical scale.