The Editor of the Research Worker is always interested in receiving both favorable comments and adverse criticisms on the material featured in the Research Worker. Such comments help materially in the preparation of articles that will be of interest to the majority of readers.

If this article on Resistance Measurements has been of interest to you, your comments on it will be appreciated. If your comments are favorable other articles of a similar nature will be prepared from time to time. If you do not care for this type of article your criticisms will be welcome.

If there are any particular subjects dealing with the use of condensers and resistors in radio circuits that you would like to have discussed in these articles, please let us know and we will try to meet your needs with interesting and helpful articles on those subjects.

A CORRECTION.

It has been called to our attention by the Weston Electrical Instrument Co. that the data regarding the Weston microammeters and milliammeters given on page 2 of the January, 1930 issue is now incorrect in a number of instances due to changes made in the design of their instruments. These changes were made some time ago but were listed incorrectly due to the use of an obsolete catalog sheet in compiling the data for the Research Worker.

The corrections are as follows and it is suggested that Research Worker readers who are filing these papers for reference, make the necessary corrections.

The resistance of the 0-500 microammeter should be 55 ohms and that of the 0-800 milliammeter should be .125 ohms.

There are 50 scale divisions on the 0-500 microammeter and on the 0-10, 0-25, 0-50, 0-100 and 0-500 milliammeters.

There are 40 scale divisions on the 0-1, 0-2, 0-20, and 0-200 milliammeters.

There are 75 scale divisions on the 0-1.5, 0-15, and 0-150 milliammeters.

There are 60 scale divisions on the 0-300 milliammeter.

AEROVOX

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The AEROVOX Research Worker

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Vol. 3 March 1930 No. 3

A Simple and Efficient Ohmmeter for Resistance Measurements

By the Engineering Department, Aerovox Wireless Corp.

THERE are many instances in the process of designing, experimenting with and testing of radio receivers, amplifiers and power supply units, when it is very desirable to have some simple and efficient method for determining the resistance values of resistors, coils, chokes and other elements used in the setup.

The use of an ohmmeter in testing circuits is much more desirable than the phone and battery continuity tester since it gives much more information regarding circuit conditions.

The commercial direct-reading ohmmeters of course are suitable for such use and are used extensively by well-equipped laboratories but in many cases the cost of such instruments keeps them out of reach of the small experimenter and serviceman.

Fortunately it is possible to make such measurements with the ordinary testing instruments usually found in the experimenter's or serviceman's kit.

There are many different ways of making such resistance measurements but for the purpose of this article only the simplest, most efficient and accurate methods will be described.

The most common method used by experimenters in measuring the resistance of an instrument consists simply of a battery of known voltage connected in series with the unknown resistance and a current measuring instrument such as an ammeter or milliammeter. The resistance in the circuit can then be found by applying Ohm's Law which states that the resistance in ohms in a circuit is equal to the voltage in volts divided by the current in amperes. If low values of resistance are being measured and comparatively high accuracy

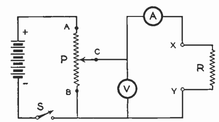

Fig. 1

is desired, the voltage must be accurately measured and the ammeter or milliammeter must also read the current accurately. Since the resistance of the ammeter or milliammeter also forms part of the circuit, its internal resistance must be subtracted from the result to find the actual value of resistance of the unit being measured.

This method is fairly simple and accurate but it has one drawback when many units are to be measured or speed is essential. This drawback lies in the fact that a calculation must be made for every resistance measurement.

This principle however has been applied in a very unique, and as far as we have been able to determine, an original manner by Mr. Joseph Calcaterra of the Aerovox Wireless Corporation for the rapid and accurate measurement of resistances, without the use of time consuming calculations.

The circuit used is shown in Fig. 1.

A potentiometer P of any suitable value but preferable of fairly high resistance such as 5,000 ohms is connected as shown in the circuit so that with the switches closed, any voltage within the limits of the battery can be applied to the external circuit consisting of the ammeter or milliammeter A and the test points X and Y.

The unknown resistor is connected between the test points X and Y. A voltmeter V is used to measure the voltage applied across the circuit consisting of the unknown resistor and the milliammeter.

The starting position of the movable arm C of the potentiometer P

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should always be at the B end of the resistance element so that as the arm is moved across the resistance element towards the A end, the voltage between the B and C terminals increases gradually. The negative terminal of the battery of course is connected to the B end of the resistance element of the potentiometer to obtain this action.

With switch S closed and a resistor R connected across the test points X and Y, the voltage as measured by the voltmeter will increase as the potentiometer arm is moved from its original position, near the B end of the potentiometer resistance element, towards the A end of the resistance element.

As the voltage applied across the circuit consisting of the milliammeter A and the resistor R increases, the current in the circuit increases and the milliammeter indicates a higher current as the voltage is increased.

At any setting of the potentiometer arm, the resistance in the circuit (resistance of R plus the resistance of the milliammeter) is equal to the voltage (as read on voltmeter V) divided by the current in amperes (as read on the milliammeter A).

To take a concrete instance, let us suppose that a milliammeter having a range of 0 to 1 milliampere and an internal resistance of 27 ohms such as a Weston Type 301 milliammeter or a Jewel Pattern 88, 0 to 1 milliammeter having a resistance of 30 ohms is used as the current measuring instrument at A. If points X and Y were connected together, forming a shortcircuit across resistor R, the only resistance in the external circuit across which the voltmeter V is connected, would be the resistance of the milliammeter and the negligible resistance of the connecting wires.

With the Weston milliammeter having a resistance of 27 ohms, a voltage of .027 volts, 27 (ohms) times .001 (ampere) would be required to give a full scale deflection of the milliammeter without any other resistance in the circuit. With the Jewel milliammeter, a voltage of .03 volts would be required.

Now if the total resistance in the external circuit, consisting of the milliammeter resistance and the resistance R were 1,000 ohms, a full scale deflection of 1 milliampere would be obtained with a voltage of 1 volt (1,000 times .001) across the circuit.

With 5,000 ohms in the circuit, full scale deflection would be obtained with 5 volts (5,000 times .001) across the circuit.

It is easy to see that with a 0 to 1 milliammeter at A, the resistance in the circuit is directly proportional to the voltage applied in the circuit and when the voltage is adjusted by means of the potentiometer so that a full scale deflection (1 milliampere) is obtained, the resistance in the circuit in ohms, is equal to 1,000 times the voltage reading.

Here then is a very simple and accurate method of measuring resistance which involves nothing more than the adjustment of a potentiometer to the point where the reading on the milliammeter is full scale or 1 milliampere and then multiplying the voltage reading by 1,000, surely a very simple calculation.

The range of the instrument is limited only by the voltage of the battery and the ranges of the voltmeter and milliammeter and these of course can be varied almost at will, to give many interesting applications.

With a 0 to 1 milliammeter at A the circuit may be considered to have characteristics of 1,000 ohms per volt because the resistance in the circuit when the potentiometer is adjusted for full scale deflection of 1 milliampere at A is 1,000 ohms per volt.

It is interesting to note that the ohms per volt characteristics of this type of circuit for ammeters and milliammeters of different ranges is as follows:

0 to 1 ampere .... 1 ohm per volt
0 to .1 ampere (100 ma.) .... 10 ohms per volt
0 to .01 ampere (10 ma.) .... 100 ohms per volt
0 to .001 ampere (1 ma.) .... 1,000 ohms per volt
0 to .0001 ampere (.1 ma.) .... 10,000 ohms per volt
0 to .00001 ampere (.01 ma.) .... 100,000 ohms per volt

When using ammeters of higher than 0 to 1 ampere ranges, the ohms per volt characteristics will be as follows:

0 to 10 ampere .... 1 ohm per volt
0 to 100 ampere .... .01 ohm per volt

When using any of the above ammeters or milliammeters, the range of resistances that can be measured is limited only by the voltage of the battery and the range of the voltmeter.

The accuracy of the reading is limited only by the accuracy of the instruments.

The most important advantages of this type of arrangement for measuring resistances over that in which a battery and a milliammeter which has been calibrated to read in ohms are that the scale readings

RANGE OF AMMETER	0-100 AMP.	0-10 AMP.	0-1 AMP.	0-100 MA.	0-10 MA.	0-1 MA.	0-100 MICRO-AMP.	0-10 MICRO-AMP.
OHMS PER VOLT	.01	.1	1	10	100	1,000	10,000	100,000
MAX. VOLT.	MAXIMUM MEASURABLE RESISTANCE VALUES IN OHMS							
1.5	.015	.15	1.5	15	150	1,500	15,000	150,000
2.0	.02	.2	2.0	20	200	2,000	20,000	200,000
4.0	.04	.4	4.0	40	400	4,000	40,000	400,000
4.5	.045	.45	4.5	45	450	4,500	45,000	450,000
6.0	.06	.6	6.0	60	600	6,000	60,000	600,000
22.5	.225	2.25	22.5	225	2,250	22,250	225,000	2,250,000
45.0	.45	4.5	45.0	450	4,500	45,000	450,000	4,500,000
90.0	.90	9.0	90.0	900	9,000	90,000	900,000	9,000,000

Fig. 2

are not crowded but are equally spaced for equal increases in resistance and that the accuracy of the readings is not affected by variations in the voltage of the battery.

In the milliammeter type of direct reading ohmmeter, consisting of a battery, a milliammeter and a high resistance of a value such as to give full scale deflection when no external resistor is connected in the circuit, the accuracy on measuring high resistance values is poor due to the crowding of the divisions on the high resistance reading end of the scale.

A table showing the various resistance ranges which can be covered with ammeters of ranges of from 0 to 10 microamperes (0 to .00001 ampere) up to ammeters of 0 to 100 amperes when used with batteries of the values indicated is shown in Fig. 2. In each case of course, the range of the voltmeter should be high enough to read the maximum voltage of the battery being used, and should preferably be of the high resistance type.

It is also important to remember that the battery should be of sufficient capacity to furnish the amount of current used in the test. Thus while large size dry batteries can furnish currents of higher than 10 amperes for a very short time, such a drain is harmful to the battery.

In such cases it is best to use storage batteries.

The ohms per volt characteristics of any given ammeter or milliammeter when used in this connection is obtained by using the reciprocal of the maximum reading of the meter in amperes. Thus for a 0 to 100 ampere ammeter, the reciprocal is 1/100 or .01.

For a 0 to 1 milliammeter, the highest scale reading is 1 milliampere or .001. The reciprocal of .001 is 1/.001 or 1,000, so that a 0 to 1 milliammeter has a characteristic of 1,000 ohms per volt when used in this way.

If a 0 to 1.5 milliammeter is available, it can be used as a 0 to 1 milliammeter by setting the potentiometer until the reading on the milliammeter is one miliampere and reading the voltage at that point when the multiplier by which the voltage reading must be multiplied to find the resistance is the same as that of 0 to 1 milliammeter, namely 1,000 ohms per volt. If the full scale reading is desired then the multiplier is found by taking the reciprocal of .0015 ampere (1.5 milliampere) or 1/.0015 which equals 666.66 ohms per volt. The difficulty of using this odd number as a multiplier brings out the importance of using the 1, 10, 100, etc. readings of the milliammeters or ammeters used in such an ohmmeter, which greatly simplify the calculations.

In using this type of ohmmeter, it will be found that greatest accuracy will be obtained when the range of the voltmeter is such that

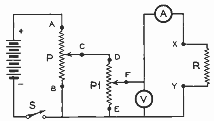

Fig. 3

the voltmeter reading, when the full scale deflection is obtained on the ammeter, is near the maximum reading of the voltmeter. In other words the lowest range voltmeter possible to cover the voltage should be used, since in that case the voltage can be read more accurately.

An example will make this point clear. If an ohmmeter of the type we have been describing, using a 0 to 1 milliammeter as the current measuring instrument is being used to measure a resistance of 4,500 ohms, the voltage reading with a full scale deflection of 1 milliampere will be 4.5 volts. If a 5-volt voltmeter is used, having its scale calibrated in tenths of a volt, this reading can be made very accurately. However if a high range voltmeter, such as a 0 to 250 voltmeter is used, which is calibrated in 5-volt divisions, it would be difficult to get a very accurate reading.

A good plan is to use a high-voltage battery and high range voltmeter to get an approximate idea of the voltage that will be required to obtain a full scale deflection, and then use a voltmeter of the desired low range that will just about cover the reading that is expected.

Of course it is not necessary to use a large number of milliammeters and voltmeters for this purpose, since it is possible to use multi-range voltmeters and milliammeters or to use multipliers in connection with a milliammeter and voltmeter.

This setup can be made permanent by mounting the required voltmeter, milliammeter, multipliers and potentiometer in a case or on a panel, with binding posts by means of which the battery and the unknown resistor may be connected in. It is also possible to keep the expense at a minimum by merely mounting the potentiometer, switch and binding posts and pin jacks so that the arrangement can be connected up quickly for use simply by plugging the meters into the pin jacks provided for them and connecting the battery to the terminals provided. It is important in connecting the battery that proper polarity connections be observed, since if the battery terminals are reversed, and the potentiometer is set for maximum voltage at the start instead of at zero voltage, the high voltage, if the resistance connected in the circuit is small may cause a current to flow through the circuit that may be high enough to burn out the milliammeter.

The 0 to 1, 0 to 10 and 0 to 100 milliammeters will cover the range of resistance values usually encountered in practice with a high degree of accuracy.

When a very fine adjustment of voltage, not obtainable with the ordinary wire wound potentiometer, is desired, a compound potentiometer consisting of two potentiometers connected as shown in Fig. 3 can be employed, potentiometer P1 acting as a vernier for potentiometer P.

With this type of arrangement it is not necessary to change batteries in order to get a close adjustment of voltage. All that is necessary is to set the movable arm of potentiometer P1, slightly below terminal D of its resistance element so that the voltage reading can be shifted slightly each way. Then the movable arm of potentiometer P can be moved gradually from its starting point at the B end of its resistance element, toward the A end of the resistance element.

The final close adjustment can be made by adjusting the movable arm of potentiometer P1.

A number of other interesting and useful ways of making resistance measurements will be described in detail in the next issue of the Research Worker.