Metrology

Laboratory

THEME:

RESISTANCE MEASUREMENT

OBJECTIVES:

- to learn how to use an ohmmeter properly;
- to learn how to measure resistances of passive components properly;
- to learn how to calculate measurement errors and what are their sources.

EQUIPMENT:

- Components to be measured,
- Digital Multimeters,
- Analog Voltmeter,
- Analog Ammeter,
- Resistance Standard,
- DC Power Supply.

BACKGROUND:

The simplest method of resistance measurement is using directly an ohmmeter. The measured component must be connected to the ohmmeter as in Fig. 1. It is important to know that the component: cannot be connected into a circuit, must be passive and linear. To get the final result of measurement, one has to calculate the measurement limiting error using a proper formula for the digital or analog meter (according to the used ohmmeter).

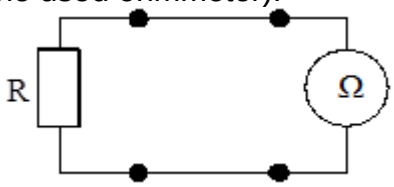

Fig. 1. Rresistance measurement using an ohmmeter

Another often used method for resistance measurement is the ammeter-voltmeter method (it is an indirect method), which has two variants: CVM – the circuit with correct voltage measurement (Fig. 2a) and CCM – the circuit with correct current measurement (Fig. 2b).

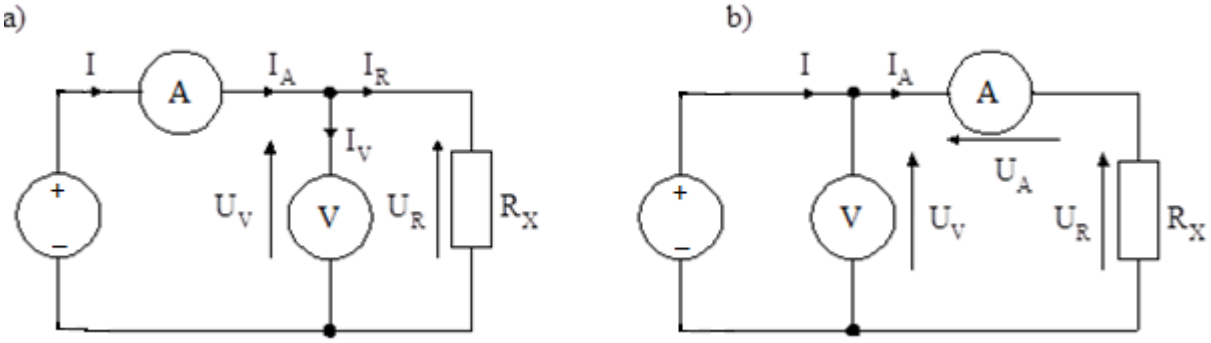

Fig. 2. The ammeter-voltmeter method of resistance measurement. The circuit with correct voltage measurement (a) and the circuit with correct current measurement (b).
R_V – internal voltmeter resistance, R_A – internal ammeter resistance.

For each circuit, the true value of resistance (R_x) is calculated from Ohm's law

$$R_X = \frac{U_R}{I_R}$$

One has to measure voltage and current first, using respectively a voltmeter and an ammeter, and then to use these values to calculate the measured value (R_m)

$$R_m = \frac{U_V}{I_A}$$

To calculate the limiting error of such measured value, expressions given below are used

$$\delta R_m = \delta U_V + \delta I_A; \qquad \Delta R_m = R_m \frac{\delta R_m}{100\%}$$

where δU_V, δI_A are the indication limiting errors of the voltmeter and ammeter.

Because real meters are used, they have impact on a circuit under the test. For CVM, one can see: $U_V=U_R$; $I_A=I_R+I_V$, and for CCM: $U_V=U_R+U_A$; $I_A=I_R$. Therefore for each circuit inequality $R_x \neq R_m$ holds, what means that the measurements are biased with the method error.

$$\Delta_m R = R_m - R_x, \qquad \delta_m R = \frac{R_m - R_x}{R_x}$$

Knowing about the existence of the method error, one has to calculate the so called correction factor $c = -\Delta_m R$, and then to add it to the measured value to get the corrected value (R_c)

$$R_c = R_m + c$$

The final formulas for the method errors are shown below:

for CCM $\quad \Delta_m R = R_A, \qquad \delta_m R = \frac{R_A}{R_m - R_A}$;

for CVM $\quad \Delta_m R = \frac{-R_m^2}{R_V - R_m}, \qquad \delta_m R = \frac{-R_m}{R_V}$.

As one can see, the above formulas point that the CCM circuit should be used for big resistances and the CVM one for small resistances. The threshold resistance for which the choice of the circuit doesn't matter is given as

$$R_{thr} = \sqrt{R_V R_A}$$

PROCEDURE:

1. Direct method of resistance measurement

Using the ohmmeter (Fig. 1) measure given linear and nonlinear resistors.

Calculate the errors for each measurement. Write down properly the results of measurements.

2. Indirect method of resistance measurement

Using the ammeter-voltmeter method measure given linear resistors. Do it with the both methods (CVM Fig. 3 or Fig. 2a, and CCM Fig. 4 or Fig 2b)

Calculate the resistances and errors for each measurement. Write down properly the results of measurements.

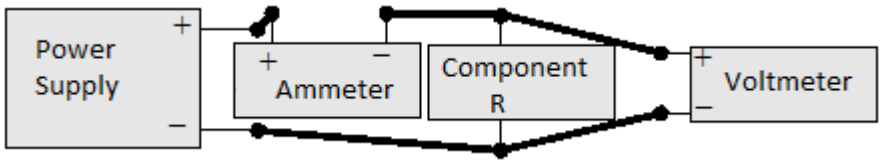

Fig. 3.

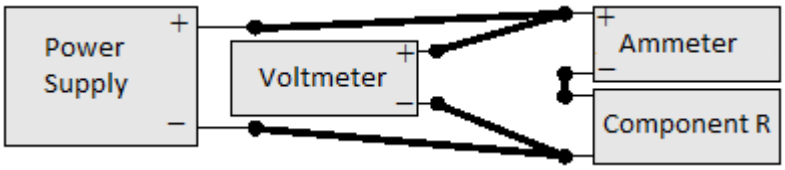

Fig. 4.