Chapter Four

Measurement of Resistance

4.1 Introduction

The resistance is one of the most important electrical and electronic circuits elements. Its exists implicitly in the coils, transformers, transmission lines, …etc.

The choice of a suitable method of measurement of resistance depends on so many factors:

(i) The value of resistance to be measured.

(ii) The accuracy of measurement.

(iii) The condition of measurement.

(iv) The equipment available.

From the point of view of measurement, the resistances are classified as follows:

1- **Low resistance**: All resistances of the order 1 Ω and lower values come under this class. The Example of such resistances are: the armature and series winding of electrical machines, the resistance of ammeter shunt, …etc.

2- **Medium resistance**: This class includes all resistances of values between 1 Ω and 100 k Ω. Most of electricity apparatus used in practice have resistances within this limit.

3- **High resistance**: Resistances of 100 k Ω and above are termed as high resistances. The Examples may be the insulation resistance of cables, resistance of dielectric, …etc.

4.2 Measurement of low Resistance

Low resistance can be measured by one of the following methods:

1- Ammeter-Voltmeter method

The circuit diagram of this method is shown in Fig. (4.1)

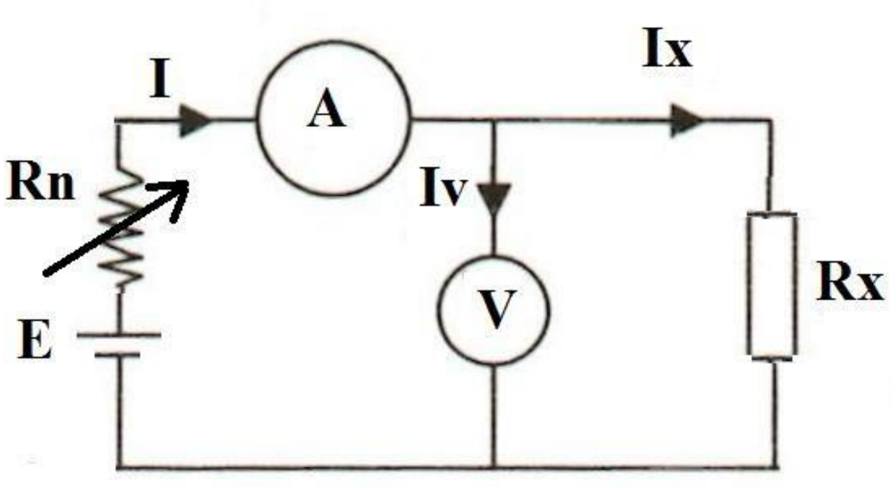


Fig (4.1) Ammeter voltmeter method for Low resistance measurement

Where,

R_x = is the resistance to be measured.

R_h = is a rheastat for current

The value of the unknown resistance R_x is measured as follows:

$$R_m = \frac{Valtmeter\ reading}{Ammeter\ reading}$$

Or

$$R_m = \frac{V}{I} \dots\dots\dots\dots\dots\dots\dots..(4.1)$$

but, $I = I_v + I_x$

$$\therefore\ R_m = \frac{V}{I_v + I_x} = \frac{V}{\frac{V}{R_V} + \frac{V}{R_x}} = \frac{1}{\frac{1}{R_V} + \frac{1}{R_x}}$$

$$\therefore R_m = \frac{R_x}{1 + \frac{R_x}{R_V}}$$

Where,

R_V = is the resistance of the voltmeter.

The percentage error can be calculated as follows:

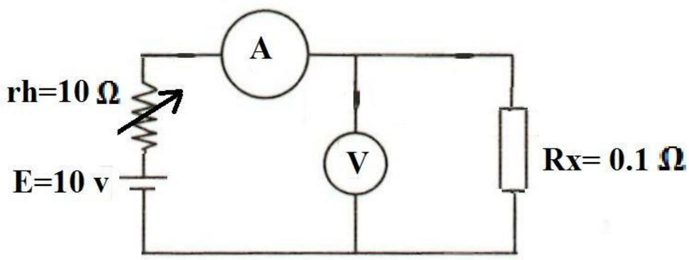
$$Error = \frac{|R_m - R_x|}{R_x} * 100\%$$

$$= \frac{\left|\frac{R_x}{1 + \frac{R_x}{R_v}} - R_x\right|}{R_x} * 100\%$$

$$= \left(\left|\frac{1}{1 + \frac{R_x}{R_v}} - 1\right|\right) * 100\% \ldots\ldots\ldots\ldots\ldots\ldots (4.3)$$

Example (4.1)

For the circuit shown in Figure below (1) derive an expression for the measured resistance and the percentage eroor (2) If the value of the resistance to be measured is 0.1 Ω and the voltmeter resistance is 5 k Ω, calculate the measured resistance and the value of percentage error.



Solution

(1) The expression for R_m and error can be derived as above

(2) $R_m = \frac{R_x}{1+\frac{R_x}{R_v}} = \frac{0.1}{1+\frac{0.1}{5000}} = 0.099998\,\Omega$

$$Error = \frac{|R_m - R_x|}{R_x} = \frac{|0.99998 - 0.1|}{0.1} * 100\% = 0.002\%$$

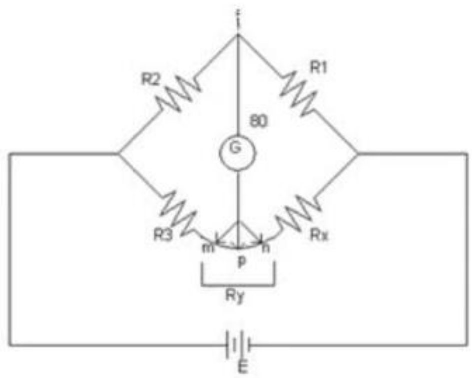
Note: Error can also be calculated by Eq. (4.3)

2-Kelvin's Double Bridge Method

The kelvin's double bridge is one of the best available bridge for the précis measurement of low resistances. The term double bridge is used because the circuit contains a second set of ratio arms.

The provision, in this bridge, has been made to eliminate the errors due to contact and lead resistances. The connection of this bridge

ب- قنطرة كلفن Kelvin Bridge:



Ry تمثل مقاومة السلك الموصل بين **Rx** و **R3** .

$$R_y = R_{np} + R_{mp}$$

$$\frac{R_{np}}{R_{mp}} = \frac{R_1}{R_2}$$

$$R_X + R_{np} = \frac{R_1}{R_2}(R_3 + R_{mp}) = \frac{R_1}{R_2}R_3 + \frac{R_1}{R_2}R_{mp}$$

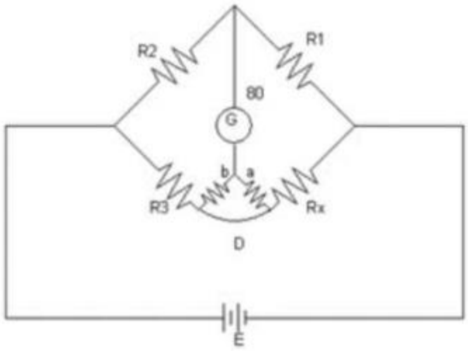
$$R_X = \frac{R_1 R_2}{R_3}$$

قنطرة كلفن المزدوجة Kelvin Double Bridge:

$$(\frac{R_1}{R_2} - \frac{a}{b})$$

$$R_X = \frac{R_1 R3}{R_2} + \frac{bRy}{a+b+Ry}(\frac{R_1}{R_2} - \frac{a}{b})$$

$$(\frac{R_1}{R_2} = \frac{a}{b})$$



$$R_X = \frac{R_1 \; R_3}{R_2}$$

....

Exam / The kelvin double bridge is balanced at the following values

a= 100.31 Ω , b=200 Ω, Ry = 700 µΩ

R1= 100.24 Ω, R2=200 Ω, R3=100.03 µΩ

احسب Rx ..

$$R_x = \frac{R_1 R3}{R_2} + \frac{bRy}{a+b+Ry}(\frac{R_1}{R_2} - \frac{a}{b})$$

$$R_x = \frac{100.24 * 100.03 * 10^{-6}}{200} + \frac{200 * 700 * 10^{-6}}{100.31 + 200 + 700 * 10^{-6}}(\frac{100.24}{200} - \frac{100.31}{200})$$

R_X = 49.97 µΩ

Exam / The kelvin double bridge is balanced at the following values
b=1000.6 Ω
R2=100 Ω
Ry=0.1Ω
R3=0.00377Ω
Calculate
1-the value Rx When the second term of the equation is neglected,
2-the value Rx by using the full equation

solution

$$R_X = \frac{100 * 0.00377}{100} = 0.00377\Omega$$

$$R_x = \frac{100 * 0.00377}{100} + \frac{1000.6 * 0.1}{99.92 + 1000.6 + 0.1}\left(\frac{100}{100} - \frac{99.92}{1000.6}\right)$$

R_X = 0.0856 Ω