Wrocaw University of Science and Technology

ELECTRIONIC MEASUREMENTS
LABORATORY REPORT

Chair of Electronic and Photonic Metrology
ELECTRIONIC MEASUREMENTS LABORATORY

Theme of class: RESISTANCE MEASUREMENT

Group no: 1

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1 Introduction

1.1 Theory

Resistance can be measured using two methods: direct or indirect. To take a direct measurement, the measured component must be connected to the ohmmeter as shown in Fig. 1. The component cannot be connected to a circuit, and must be passive and linear. The final result is obtained by calculating the limiting error and applying it to the measured value.

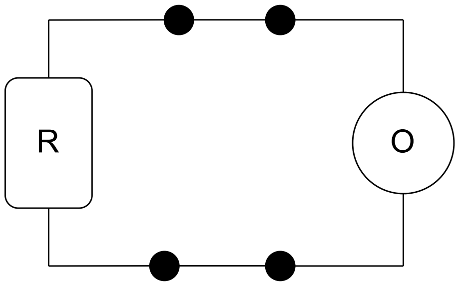

Figure 1: Direct resistance measurement schematic

1.2 Equipment

The following devices were used during the laboratory:

- digital meter: UT803;
- linear resistor;
- diode resistor.

2 Experiment

2.1 Direct resistance measurement

For direct measurements, we used linear resistors (R_2, R_4) and a diode (D). Measurements were taken for three different ranges and both polarities. Tab. 1 shows all of the measurements along with the final results.

R_x	$R_m[]$	$R_r[]$	Accuracy	$\Delta_{res}[]$	$\Delta R[]$	$\delta R[]$	$R \pm \Delta R[]$
Positive polarity							
R_2	424.4	600	$0.8 + 3$	0.1	3.6952	0.870688	424.4 ± 3.7
R_4	OL	600	$0.8 + 3$	0.1			
D	OL	600	$0.8 + 3$	0.1			
R_2	420	60000	$0.5 + 2$	10	22.1	5.261905	420 ± 23
R_4	2650	60000	$0.5 + 2$	10	33.25	1.254717	2650 ± 34
D	OL	60000	$0.5 + 2$	10			
R_2	400	600000	$0.5 + 2$	100	202	50.5	400 ± 202
R_4	2600	600000	$0.5 + 2$	100	213	8.192308	2600 ± 213
D	OL	600000	$0.5 + 2$	100			
Negative polarity							
R_2	424.4	600	$0.8 + 3$	0.1	3.6952	0.870688	424.4 ± 3.7
R_4	OL	600	$0.8 + 3$	0.1			
D	OL	600	$0.8 + 3$	0.1			
R_2	420	60000	$0.5 + 2$	10	22.1	5.261905	420 ± 23
R_4	2650	60000	$0.5 + 2$	10	33.25	1.254717	2650 ± 34
D	42.69	60000	$0.5 + 2$	10	20.21345	47.349379	42.69 ± 20.22
R_2	400	600000	$0.5 + 2$	100	202	50.5	400 ± 202
R_4	2600	600000	$0.5 + 2$	100	213	8.192308	2600 ± 213
D	178400	600000	$0.5 + 2$	100	1092	0.612108	178400 ± 1092

Table 1: Direct resistance measurements (for: R_m – measured resistance, R_r – range, Accuracy: $\pm$ (a of reading + n – number of uncertain digits), Δ_{res} – resolution, $\Delta R, \delta R$ – limiting error)

Example calculations for $R_r = 600\,\Omega$ (R_2, positive polarity) are shown in the equations below.

$$\Delta R = \frac{a}{100} \cdot R_m + n \cdot \Delta_{res} = \frac{0.8}{100} \cdot 424.4\,\Omega + 3 \cdot 0.1\,\Omega = 3.6952\,\Omega \tag{1}$$

$$\delta R = \frac{\Delta R}{R_m} \cdot 100 = \frac{3.6952\,\Omega}{424.4\,\Omega} \cdot 100 \approx 0.870688 \tag{2}$$

2.2 Indirect resistance measurement

2.2.1 Digital

For indirect measurements, we used two digital meters and resistor standard. Measurements were taken for 8 different ranges using CVM and CCM methods

Example calculations

$$V = \frac{\alpha \cdot V_r}{\alpha_{max}} = \frac{39.5 \cdot 7.5\,\mathrm{V}}{75} = 3.95\,\mathrm{V} \tag{3}$$

Rx	V	V_r	Acc	ΔV	δV
30	4.892	6	0.3%+2	0.01668	0.3408830744
100	4.896	6	0.3%+2	0.01669	0.3408496732
300	4.897	6	0.3%+2	0.01669	0.3408413314
1000	4.898	6	0.3%+2	0.01669	0.3408329931
3000	4.899	6	0.3%+2	0.01670	0.3408246581
10000	4.899	6	0.3%+2	0.01670	0.3408246581
30000	4.899	6	0.3%+2	0.01670	0.3408246581
100000	4.899	6	0.3%+2	0.01670	0.3408246581

Table 2: Indirect resistance measurements for $E \sim 4.8\,\mathrm{V}$ (R_x – true value for resistance, V – measured voltage,V_r – range, ΔV – absolute error, δV – relative error)

I	Ir	Acc	ΔI	δI	R_m
136.909	1000	0.1+0.01	0.236909	0.1730412172	35.73176343
42.7542	100	0.05+0.005	0.0527542	0.1233895149	114.5150652
15.7777	100	0.05+0.005	0.0257777	0.1633805941	310.3747695
4.42445	10	0.05+0.02	0.00542445	0.1226016793	1107.030252
1.55186	10	0.05+0.02	0.00255186	0.1644388025	3156.856933
0.48787	10	0.05+0.02	0.00148787	0.3049726362	10041.60945
0.16289	10	0.05+0.02	0.00116289	0.7139112284	30075.51108
0.04875	10	0.05+0.02	0.00104875	2.151282051	100492.3077

Table 3: (I – circuit current, Ir – range, ΔI – absolute error, δI – relative error, R_m – measured value)

ΔR	δR	R_m +- ΔR	R_V	R_A
6952.729034	0.5139242916		10	0.0001
24667.25518	0.4642391882		10	0.001
61555.19102	0.5042219256		10	0.001
238875.1465	0.4634346724		10	0.01
624794.227	0.5052634606		10	0.01
1554916.618	0.6457972942		10	0.01
2851473.195	1.054735887		10	0.01
4032423.945	2.492106709		10	0.01

Table 4: (ΔR – absolute error, δR – relative error, R_V – internal voltmeter resistance, R_A – internal ammeter resistance)

$$\Delta V = \frac{0.3}{100} \cdot V + 2 \cdot 0.001 = \frac{0.3}{100} \cdot 4.896 + 2 \cdot 0.001 = 0.016\,69\,\mathrm{V} \tag{4}$$

$$\delta V = \frac{\Delta V}{V} \cdot 100 = \frac{0.01669}{4.892} \cdot 100 \approx 0.3408830744 \tag{5}$$

$$R_m = \frac{U_r}{I_r} = \frac{4.896\,\mathrm{V}}{42.7542\,\mathrm{mA}} = 114.515\,065\,2\,\Omega \tag{6}$$

$$\delta_m R = \delta I + \delta V = -0.340\,849\,673\,2\,\% + 0.123\,389\,514\,9\,\% = -0.464\,239\,188\,2\,\% \tag{7}$$

ΔmR	δmR	c	R_c	$R_c + -\Delta R$
0.0001	0.000002798638249	-0.0001	35.73166343	
0.001	0.000008732551747	-0.001	114.5140652	
0.001	0.000003221921755	-0.001	310.3737695	
0.01	0.000009033258406	-0.01	1107.020252	
0.01	0.00000316771773	-0.01	3156.846933	
0.01	0.0000009958572889	-0.01	10041.59945	
0.01	0.0000003324965384	-0.01	30075.50108	
0.01	0.00000009951011401	-0.01	100492.2977	

Table 5: ($\Delta mR-$ systematic error, $\delta mR-$ relative error c - correction factor R_c- calculated resistance)

$$\delta_m R = -\frac{R_A}{R_m - R_A} = -\frac{0.001\,\Omega}{114.515\,065\,2\,\Omega + 0.001\,\Omega} \approx 0.000008732551747 \tag{8}$$

$$c = -\Delta_m R = -(0.001\,\Omega) = -0.001\,\Omega \tag{9}$$

$$R_c = R_m + c = 114.515\,065\,2\,\Omega + 0.001\,\Omega = 114.514\,065\,2\,\Omega \tag{10}$$

3 Conclusion

During this laboratory we practiced measuring DC current and learned how the internal resistance of a meter affects the circuit. To be thorough, we tried both direct and indirect methods of measurements.

Both experiments showed us that the internal meter resistance can introduce measurement errors. When the meters internal resistance was lower than the circuits, the device was functioning properly and the systematic error had very small values. However, when the circuit's resistance dropped below the meter's, the results became unreliable and lay far outside the expected set of values, sometimes even with the systematic error added. This was caused by the meter losing its primary function and blocking the current from flowing through. Thus, when high precision is desired, measurements should taken on circuits with a much higher resistance than that of the meter.