Measuring current and voltage on resistors connected in parallel and series

Aim of the experiment

- Determine the total resistance of resistors connected in parallel
- Determine the total resistance of resistors connected in series

Foundations

Kirchhoff's laws and rules are of fundamental importance to the calculation of partial currents and voltages in branched electrical circuits:

- **Current law:**

  At every branch point the sum of the current strengths of the incoming current is the same as the sum of the current strengths of the outgoing currents.

- **Voltage law:**

  In every closed electrical circuit (loop) of a network the sum of the partial voltages on the lines (resistors, consumers) is the same as the sum of the voltages ("electromotive forces") of the power sources connected.

It is necessary to determine a sense of rotation for the loop. Currents that flow in this rotational direction, and voltages that cause currents which flow in the same direction, are to be considered positive and those counter to this are to be considered negative.

During the test the validity of Kirchhoff's laws is tested in electrical circuits with resistors connected in parallel or in series.

With the parallel connection of resistors R_1, R_2, ..., R_n the voltage U is the same at every branch. According to the current law the sum of the partial currents I_1, I_2, ..., I_n is the same as the total current through the resistors.

$$I = I_1 + I_2 + \ldots I_n \qquad (1)$$

This results in the following for the total resistance R:

$$\frac{1}{R} = \frac{I}{U} = \frac{I_1 + I_2 + \ldots I_n}{U} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots \frac{1}{R_n} \qquad (2)$$

With the series connection of resistors R_1, R_2, ..., R_n the current strength I is the same at every point in the electrical circuit. According to the voltage law the sum of the partial voltages U_1, U_2, ..., U_n at the resistors is the same as the voltage of the connected power sources.

$$U = U_1 + U_2 + \ldots U_n \qquad (3)$$

This results in the following for the total resistance R:

$$R = \frac{U}{I} = \frac{U_1 + U_2 + \ldots U_n}{I} = R_1 + R_2 + \ldots R_n \qquad (4)$$

The experiment is initially carried out with the parallel connection of various resistors, whereupon the total current and partial currents related to the resistors are measured. A total resistance is obtained from the measured values and compared with the theoretical value from the equation (2).

Subsequently the total current and the partial voltages are measured with the series connection of resistors. The total resistance is once again derived from the measured values and compared with the theoretical value from the equation (4).

Equipment

1 plug-in board DIN A4	576 74
1 STE resistor 220 Ω	577 36
1 STE resistor 330 Ω	577 38
1 STE resistor 470 Ω	577 40
1 STE resistor 1 kΩ	577 44
1 STE resistor 5,6 kΩ	577 53
1 STE resistor 10 kΩ	577 56
1 STE resistor 100 kΩ	577 68
1 set 10 bridging plugs	501 48
1 DC power supply, 0 to ±15 V	521 45
2 multimeter LD analog 20	531 120
3 pairs of cables, 50 cm, red / blue	501 45

Apparatus and method

The following is an example description of the setup of a parallel or series circuit with three different resistors. Setups with less, more or alternative resistors are also possible. It is therefore possible – for example by combining very low and very high resistances – to illustrate the influence of a measuring device.

CS 1007

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a) Parallel connection of resistors

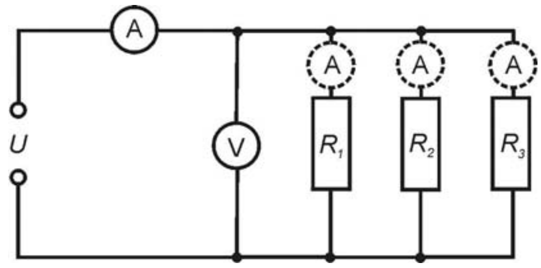

Fig. 1: Circuit diagram showing the parallel connection of resistors

Test equipment per Fig. 1. Initially use R_1 = 220 Ω, R_2 = 330 Ω and R_3 = 470 Ω as resistances.

- Switch on DC power supply.
- Set output voltage U = 10.0 V.
- Read and note down the total current strength I.
- Measure and note down the partial current strengths I_1, I_2 und I_3 in the loop with the resistors R_1, R_2 and R_3.

Repeat the test section for other resistance values.

b) Series connection of resistors

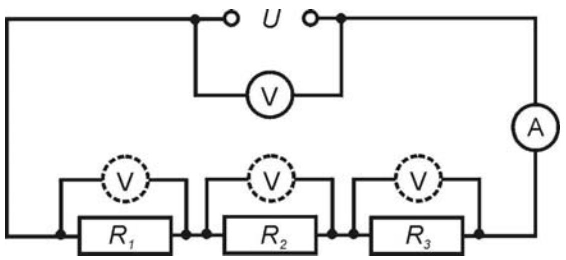

Fig. 2: Circuit diagram showing the series connection of resistors

Test equipment per Fig. 2. Initially use R_1 = 220 Ω, R_2 = 330 Ω and R_3 = 470 Ω as resistances.

- Switch on DC power supply.
- Set output voltage U = 10.0 V.
- Read and note down the current strength I.
- Also measure and note partial voltages U_1, U_2 and U_3 at each of the resistors R_1, R_2 and R_3.

Repeat the test section for other resistance values.

Measurement examples and evaluation:

a) Parallel connection of resistors

Measurement 1: R_1 = 220 Ω, R_2 = 330 Ω, R_3 = 470 Ω
Voltage U = 10.0 V

i	$\frac{R_i}{\Omega}$	$\frac{I_i}{\text{mA}}$	$\frac{R_i \cdot I_i}{\text{V}}$
1	220	43	9.5
2	330	31	10.2
3	470	22	10.3

Total current strength: I = 96 mA

$I_1 + I_2 + I_3$ = 96 mA

Total resistance: $R = \frac{U}{I}$ = 104 Ω

$$\frac{1}{R_{theo}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = 9.7 \cdot 10^{-3} \frac{1}{\Omega} \text{ or } R_{theo} = 103\ \Omega$$

Measurement 2: R_1 = 1.0 kΩ, R_2 = 5.6 kΩ, R_3 = 10 kΩ
Voltage U = 10.0 V

i	$\frac{R_i}{\text{k}\Omega}$	$\frac{I_i}{\text{mA}}$	$\frac{R_i \cdot I_i}{\text{V}}$
1	1.0	9.8	9.8
2	5.6	1.8	10.1
3	10	0.97	9.7

Total current strength: I = 13 mA

$I_1 + I_2 + I_3$ = 12.6 mA

Total resistance $R = \frac{U}{I}$ = 0.77 kΩ

$$\frac{1}{R_{theo}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = 1.3 \cdot 10^{-3} \frac{1}{\Omega} \text{ or } R_{theo} = 0.78\ \text{k}\Omega$$

In both measurements the total current strength is obtained from the sum of the measured partial currents. The current law is hereby fulfilled. The partial voltages $R_i \cdot I_i$ are the same as the total voltage U. The experimentally ascertained total resistance equates to the theoretical value R_{theo} calculated from the individual resistances.

b) Series connection of resistors

Measurement 1: R_1 = 220 Ω, R_2 = 330 Ω, R_3 = 470 Ω

Voltage U = 10.0 V

Current strength I = 9.7 mA

Total resistance $R = \frac{U}{I}$ = 1.03 kΩ

i	$\frac{R_i}{\Omega}$	$\frac{U_i}{\text{V}}$	$\frac{U_i / R_i}{\text{mA}}$
1	220	2.1	9.5
2	330	3.2	9.7
3	470	4.6	9.8
Σ	1020	9.9	—

Measurement 2: R_1 = 1.0 kΩ, R_2 = 5.6 kΩ, R_3 = 10 kΩ

Voltage U = 10.0 V

Current strength I = 0.60 mA

Total resistance $R = \frac{U}{I}$ = 16.7 kΩ

i	$\frac{R_i}{\text{k}\Omega}$	$\frac{U_i}{\text{V}}$	$\frac{U_i / R_i}{\text{mA}}$
1	1.0	0.58	0.58
2	5.6	3.3	0.59
3	10	5.9	0.59
Σ	16.6	9.8	—

In both measurements the total voltage is obtained from the sum of the partial voltages. The voltage law is hereby fulfilled. The experimentally ascertained total resistance concurs with the sum of the individual resistances and the current strength U_i/R_i through the individual resistors the total current I.

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