Lab01 - Resistors

Resistance measurement

Procedure for resistance measurement:

- Set the measuring device to resistance measurement
- Connect the resistance to be measured to the corresponding sockets on the measuring device (the measuring device sockets labeled COM and Ω
- Read the measured value

There are different types of resistance measurement:

- **direct** resistance measurement
- **indirect** resistance measurement

Direct resistance measurement

Determine the nominal and measured values of the resistance for R_1 (brown, green, orange), R_2 (yellow, violet, red), R_3 (red, violet, red) and the incandescent lamp R_L. Also measure the approximate resistance R_K of your body from your right to your left hand.

	R_1	R_2	R_3	R_L	R_K
nominal value					
measured value					

Tab. 1: Direct resistance measurement

How do you explain the deviation between $R_\mathrm{L,nominal}$ and $R_\mathrm{L,meas}$?

What consequences can R_K have?

Now determine the series and parallel connections of resistors R_1, R_2 and R_3.
Specify the formulas used:

$R_{\rm serial}$ =

$R_{\rm parallel}$ (= $R_{\rm a}$ || $R_{\rm b}$) =

	R1+R2	R1+R3	R2+R3	R1 || R2	R1 || R3	R2 || R3
calculated						
measured						

Tab. 2: Series and parallel connections

Indirect resistance measurement

The resistances can also be determined by measuring the current/voltage.

Ohm's law: In an electrical circuit, the current increases with increasing voltage and decreases with increasing resistance.

$$I = \frac{U}{R}$$

Build the measuring circuit shown in figure 1 for each of the three resistors and set the voltage on the power supply to $12 \ V$.

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Fig. 1: Indirect resistance measurement

Measure $U_{\rm n}$ [V] and $I_{\rm n}$ [mA]. Calculate $R_{\rm n}$ [kΩ] from these values.

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Tab. 3: Indirect resistance measurement

Mesh set

In every closed circuit and every mesh of the network, the sum of all voltages is zero!
Set the voltage on the power supply to 12 V and measure this voltage precisely using a multimeter. Set up the measuring circuit shown in figure 2.

Fig. 2: Mesh-set

Add the voltage arrows and measure U, U_1 und U_2:

Tab. 4: Mesh set voltage mesurement

What is the mesh set here?

Check the formula with the measured values:

The resistors R_1 and R_2 connected in series form a voltage divider. What is the ratio between the voltages U_1 and R_2?

$$\frac{U_1}{U_2} =$$

Set of nodes

At each junction point, the sum of all incoming and outgoing currents is equal to zero!
Set the voltage on the power supply to 12 V and measure the voltage accurately with a multimeter. In the first step, set up the measuring circuit shown in figure 3:

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Fig. 3: Node-set circuit 1

Draw the arrows for the directions of currents I_1 and I_2 in figure 4. The DC current measurement range must be set on both multimeter using the rotary switch. Then measure currents I_1 and I_2 and enter the measured values in table 5.

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Fig. 4: Node-set circuit 2

What is the relationship between currents I_1 and I_2?

$$\frac{I_1}{I_2} =$$

Switch the power supply back on and measure the current I. Enter its value in table 5.

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Tab. 5: Node set current mesurement

Determine the node set for node K and check its validity.

Using the measured values for resistors R_1, R_2, and R_3, calculate the total resistance $R_{\rm KP}$:

Using the calculated value $R_{\rm KP}$, check the measured value of the total current:

$$I = \frac{U}{R_{KP}} =$$

Voltage divider as voltage source

The voltage divider shown in figure 5 is in an unloaded state, as the entire current supplied by the power supply flows through the resistors R_1 and R_2 connected in series. A resistor parallel to R_2 loads the voltage divider. Set the voltage on the power supply to $12 ~\rm V$ and measure the exact voltage with a multimeter. Set up the measuring circuit shown in figure 5. For the connected load $R_{\rm L}$ = $10 ~\rm k\Omega$, the voltage divider represents a voltage source. Like any voltage source, it has a source voltage (also called the original voltage) U_0 and an internal resistance $R_{\rm i}$. The internal resistance of a voltage divider considered as a voltage source results from the parallel connection of the divider resistors R_1 and R_2:

$$R_i = R_1 || R_2 = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

Use the measured values of resistors R_1 and R_2 to calculate the internal resistance R_i of the voltage source:

$R_i =$

$U_0 =$

The power P_0 supplied by the power supply can be calculated using the following equation:

$$P_0 = U \cdot I_1$$

The power consumed by the load resistance can be determined using the following formula:

$$P_L = R_L \cdot {I_2}^2$$

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Fig. 5: Voltage divider

Draw the equivalent voltage source of the voltage divider:

What would be the value of U_2 without R_L?

$U_{2,zero} =$

Calculate $U_{2,\mathrm{L}}$ and I_2 for R_L = $10~\mathrm{k\Omega}$ using the values of the equivalent voltage source: (Provide formulas!)

$U_{2L}:$

$I_2:$

Check the values by measuring:

$U_{2L,Meas}:$

$I_{2,Meas}$:

Check the values using Kirchhoff's rules: (Provide formulas!)

U_{2L} :

I_2 :

Nonlinear resistors

All resistors examined so far are linear resistors, for which the characteristic curve $I = f(U)$ is a straight line, s. figure 6. The resistance value of a linear resistor is independent of the current I flowing through it or the applied voltage U.

Fig. 6: Characteristic curve of a linear resistor

With nonlinear resistors, there is no proportionality between current and voltage. The characteristic curve of such a resistor is shown in figure 7. With these resistors, we talk about static resistance (R) and dynamic (or differential) resistance (r). The static resistance is determined for a specific operating point: at a specific voltage, the current is read from the resistance characteristic curve.
The calculation is performed according to Ohm's law:

$$R = \frac{U}{I}$$

The differential resistance around the operating point is calculated from the current difference caused by a change in the applied voltage:

$$r = \frac{\Delta U}{\Delta I}$$

Fig. 7: Characteristic curve of a nonlinear resistor

A light bulb is examined as an example of a nonlinear resistor. Set up the measuring circuit shown in figure 8.

Fig. 8: Measuring circuit light bulb
Set the voltage on the power supply to the voltage values from table 6. Measure the corresponding current values and enter them in table 6.

Tab. 6: Values characteristic curve light bulb

Create the characteristic curve $I = f(U)$, s. figure 9

Fig. 9: Characteristic curve light bulb

Calculate the static resistance R at the operating point $U = 7.0 \text{ V}$:

Calculate the dynamic resistance r at the operating point $U = 7.0 \text{ V}$:

Compare the values with the values from table 1 (direct resistance measurement)

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