

# 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  $\Omega$ )
- 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  $R_{L,nominal}$  and  $R_{L,meas}$ ?

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:

$$R_{\text{serial}} =$$

$$R_{\text{parallel}} (= R_a \parallel R_b) =$$

	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  $U_n$  [V] and  $I_n$  [mA]. Calculate  $R_n$  [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](#).



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Fig. 2: Mesh-set

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



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Tab. 4: Mesh set voltage measurement

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  $U_2$ ?

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

## 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 measurement

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  $R_{KP}$ :

Using the calculated value  $R_{KP}$ , 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 V and measure the exact voltage with a multimeter. Set up the measuring circuit shown in [figure 5](#). For the connected load  $R_L = 10 \text{ k}\Omega$ , 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  $R_i$ . 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  $U_{2,L}$  and  $I_2$  for  $R_L = 10 \text{ k}\Omega$  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  $U$ .



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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:

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



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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](#).



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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](#).



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Tab. 6: Values characteristic curve light bulb

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



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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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