

Lab01 - Resistors

Student Group

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Lab01 - Resistors

Challenge description

An automotive engineer is testing the electrical system of a passenger car. The vehicle has a **12 V battery**, interior lighting, a temperature sensor, and a rear window heater. During vehicle development, the engineer must verify electrical components using resistance measurements, Ohm's law, series and parallel circuits, Kirchhoff's laws, and the behavior of a non-linear load.

Resistance is defined by voltage and current:

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

A constant supply voltage is available for the experiment. This raises the following questions:

- How will the different values of U and I influence R ?
- How can the set of nodes help to understand the current flow?
- How will the voltage be affected from nonlinear resistors?

To answer these questions, different circuits are investigated: the Mesh-set, Set of nodes and a light bulb circuit for nonlinear resistors.

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Resistance measurement

Background Information

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 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.**

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

Experimental Tasks

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



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your left hand.

Tab. 1: Direct resistance measurement

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

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:

$R_{\text{serial}} =$



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

Tab. 2: Series and parallel connections

Indirect resistance measurement

Build the measuring circuit shown in [figure 1](#) for each of the three resistors and set the voltage on the



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power supply to $\sim 12 \text{ V}$.

Measure U_{n} [V] and I_{n} [mA]. Calculate R_{n}

Fig. 1: Indirect



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[k Ω] from these values.

Tab. 3: Indirect resistance measurement

Test Questions - Resistors

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



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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} :



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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 R_{2} ? $\frac{U_{\text{1}}}{U_{\text{2}}} =$

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



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enter the measured values in table 5.

Fig. 4: Node-set circuit

2 What is the relationship between currents I_{1} and I_{2} ? $\frac{I_{\text{1}}}{I_{\text{2}}} =$ 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:
 $I = \frac{U}{R_{\text{KP}}} =$

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 $R_{\text{L}} = 10 \text{ k}\Omega$, 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} :

$$R_{\text{i}} = R_{\text{1}} \parallel R_{\text{2}} = \frac{R_{\text{1}} \cdot R_{\text{2}}}{R_{\text{1}} + R_{\text{2}}}$$

Use the measured values of resistors R_{1} and R_{2} to calculate the internal resistance R_{i} of the voltage source: $R_{\text{i}} =$ $U_{\text{0}} =$

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: $P_L =$



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$$R_L \cdot I_2^2$$

Draw the equivalent voltage source of the voltage divider:

Fig. 5: Voltage divider

What would be the value of U_2 without R_L ?

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

Check the values by measuring:

$U_{2L, \text{Meas}}$:

$I_{2, \text{Meas}}$: 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



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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_s) and dynamic (or differential) resistance (r_d). 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



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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](#).



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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



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current values and enter them in [table 6](#).

Tab. 6: Values characteristic curve light bulb



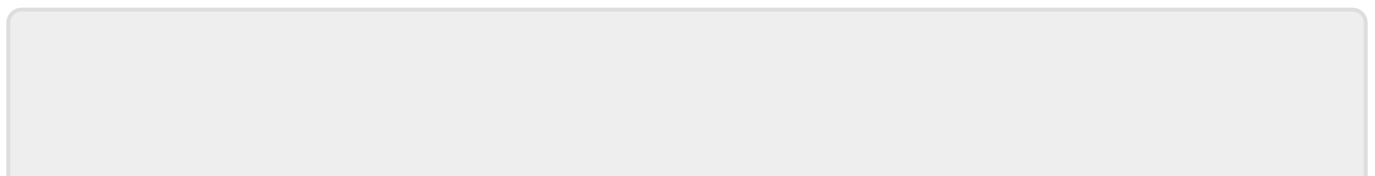
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Create the characteristic curve $I = f(U)$, s. [figure 9](#)

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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