

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 $R_{\rm 1}$ (brown, green, orange), $R_{\rm 2}$ (yellow, violet, red), $R_{\rm 3}$ (red, violet, red) and the incandescent lamp $R_{\rm L}$. Also measure the approximate resistance $R_{\rm K}$ of your body from your right to

	R_1	R_2	R_3	R_L	R_K
nominal value					
measured value					

your left hand.

Tab. 1: Direct resistance measurement

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

What consequences can $R_{\rm K}$ have?

Now determine the series and parallel connections of resistors $R_{\rm 1}$, $R_{\rm 2}$ and $R_{\rm 3}$.

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

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

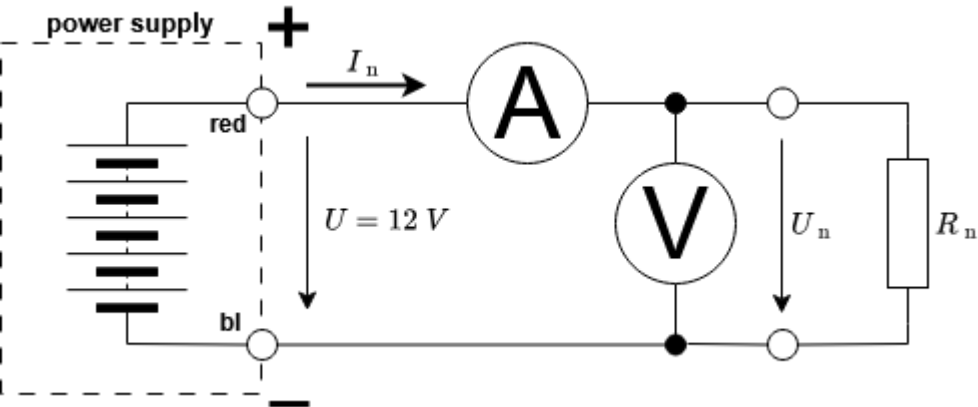


Fig. 1: Indirect resistance measurement Measure $U_{\rm n}$ [V] and $I_{\rm n}$ [mA]. Calculate $R_{\rm n}$ [$k\Omega$]

I_1	U_1	R_1	I_2	U_2	R_2	I_3	U_3	R_3

from these values.

Tab. 3: Indirect resistance measurement

Test Questions - Resistors

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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](#).

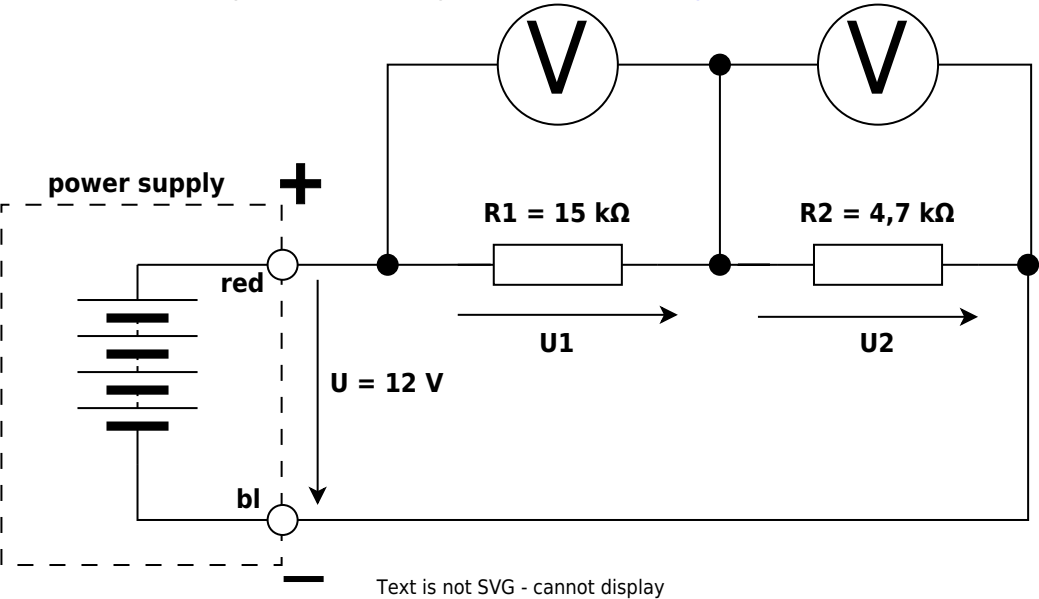


Fig. 2: Mesh-set Add the voltage arrows and measure U , U_{1} und U_{2} :

U	U_1	U_2

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](#):

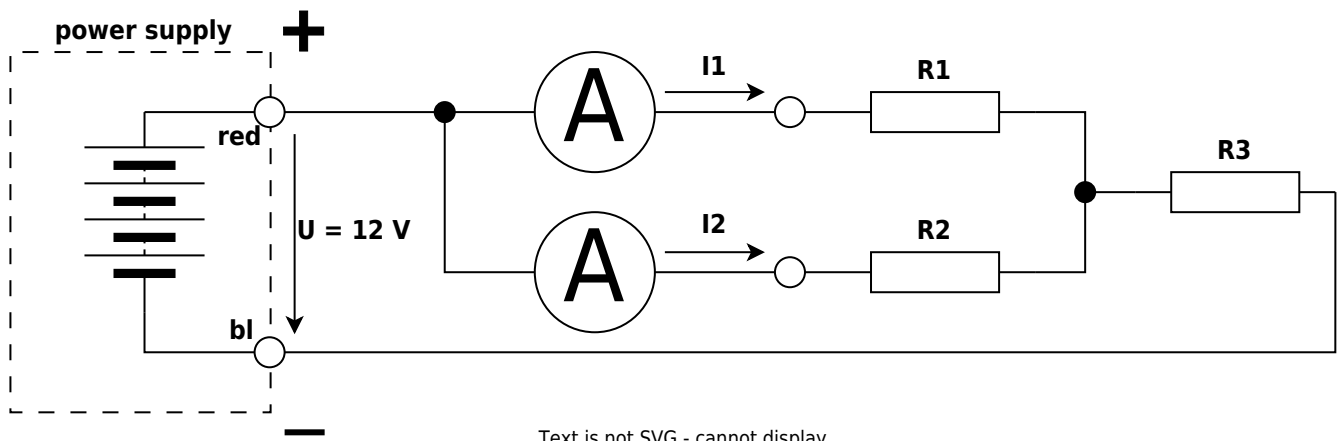


Fig. 3: Node-set circuit 1 Draw the arrows for the directions of currents I_1 and I_2 in figure 4. The DC current measurement range must be set on both multimeter using the rotary switch. Then measure currents I_1 and I_2 and enter the measured values in table 5.

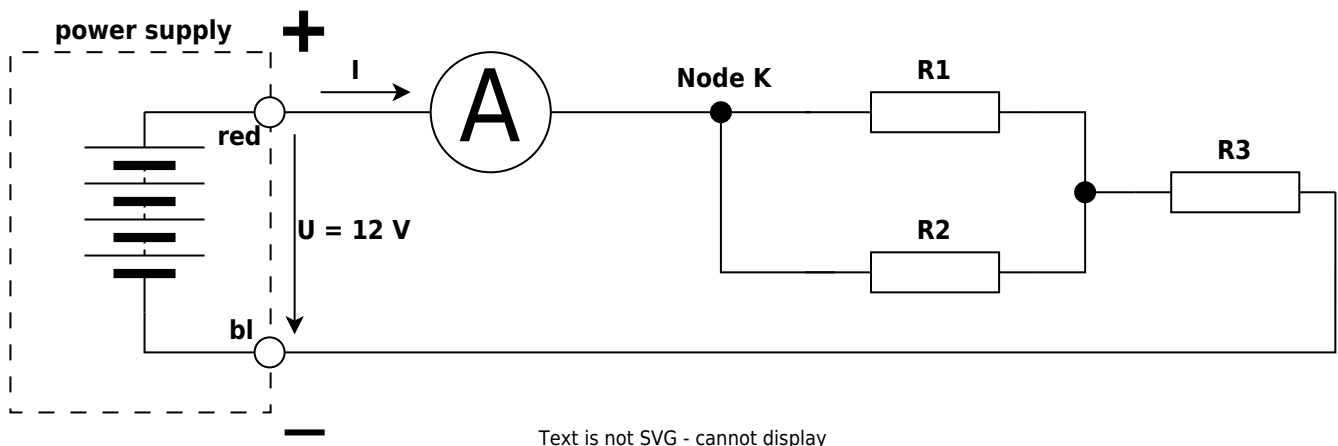


Fig. 4: Node-set circuit 2 What is the relationship between currents I_1 and I_2 ? $\frac{I_1}{I_2} =$ Switch the power supply back on and measure the current I . Enter its value in table 5.

I	I_1	I_2

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:

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

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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 :

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

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: $P_L = R_L \cdot I_2^2$

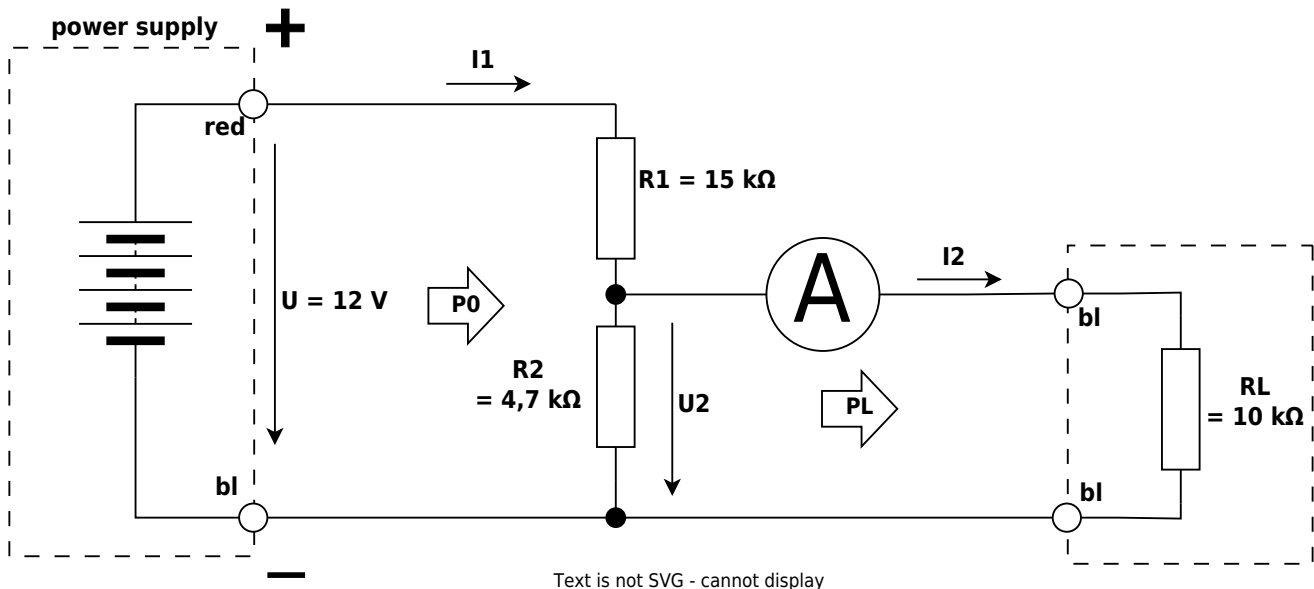


Fig. 5: Voltage divider

Draw the equivalent voltage source of the voltage divider:

What would be the value of U_2 without R_L ?

$U_{2,0} =$ 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:

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

$I_{2, \text{Meas}} :$ Check the values using Kirchhoff's rules: (Provide formulas!)

$U_{2L} :$ $I_2 :$

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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 .

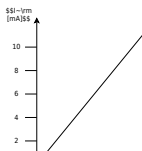


Fig. 6: Characteristic curve of a linear resistor

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](#).

U/V	0,5	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0
I/A									

Tab. 6: Values characteristic curve light bulb

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

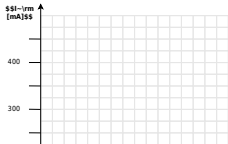


Fig. 9: Characteristic curve light bulb Calculate the static resistance R at the operating point $U = 7.0 \text{ V}$:

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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