Measuring with a multimeter

Work objective

Learning how to use a multimeter for measuring various electrical values of electronic components and circuits.

Readings

Access the following information sources to refresh your knowledge about electrical circuits.

https://en.wikipedia.org/wiki/Electrical_network
An electrical network is an interconnection of electrical components (e.g. batteries, resistors, inductors, capacitors, switches) or a model of such an interconnection, consisting of electrical elements (e.g. voltage sources, current sources, resistances, inductances, capacitances). An electrical circuit is a network consisting of a closed loop, giving a return path for the current.

https://en.wikipedia.org/wiki/Voltage
Voltage, electric potential difference, electric pressure or electric tension (denoted ΔV or ΔU) is the difference in electric potential energy between two points per unit electric charge. The voltage between two points is equal to the work done per unit of charge against a static electric field to move the charge between two points and is measured in units of volts (a joule per coulomb).

https://en.wikipedia.org/wiki/Electric_current
An electric current is a flow of electric charge. In electric circuits this charge is often carried by moving electrons in a wire. It can also be carried by ions in an electrolyte, or by both ions and electrons such as in a plasma. The SI unit for measuring an electric current is the ampere, which is the flow of electric charge across a surface at the rate of one coulomb per second.

https://en.wikipedia.org/wiki/Electrical_resistance_and_conductance
The electrical resistance of an electrical conductor is a measure of the difficulty to pass an electric current through that conductor. The inverse quantity is electrical conductance, the ease with which an electric current passes. The SI unit of electrical resistance is the ohm (Ω).

https://en.wikipedia.org/wiki/Ohm%27s_law
Ohm's law states that the current through a conductor between two points is directly proportional to the potential difference across the two points. Introducing the constant of proportionality, the resistance, one arrives at the usual mathematical equation that describes this relationship:

$$I = \frac{V}{R} \tag{1.1}$$

where I is the current through the conductor in units of amperes, V is the potential difference measured across the conductor in units of volts, and R is the resistance of the conductor in units of ohms. More specifically, Ohm's law states that the R in this relation is constant, independent of the current.

https://en.wikipedia.org/wiki/Series_and_parallel_circuits
The total resistance of **resistors in series** is equal to the sum of their individual resistances:

$$R_{series} = R_1 + R_2 + \cdots + R_n \tag{1.2}$$

The total resistance of **resistors in parallel** can be determined from the following equation:

$$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n} \tag{1.3}$$

For only two resistors in parallel, it results that

$$R_{parallel} = \frac{R_1 \cdot R_2}{R_1 + R_2} \tag{1.4}$$

The **current in a series circuit** is the same for all of elements,

$$I_{series} = I_1 = I_2 = \cdots = I_n \tag{1.5}$$

while the **total voltage is the sum of the elements' voltages**:

$$V_{series} = V_1 + V_2 + \cdots + V_n \tag{1.6}$$

The **current in a parallel circuit is the sum of the currents** passing through each element,

$$I_{parallel} = I_1 + I_2 + \cdots + I_n \tag{1.7}$$

while the **voltage in a parallel circuit** is the same for all of the elements:

$$V_{parallel} = V_1 = V_2 = \cdots = V_n \tag{1.8}$$

https://en.wikipedia.org/wiki/Electric_power
Electric power, like mechanical power, is the rate of doing work, measured in watts, and represented by the letter **P**. The electric power in watts produced by an electric current **I**, passing through an electric potential (voltage) difference of **V** is

$$P = V \cdot I = I^2 \cdot R = \frac{V^2}{R} \tag{1.9}$$

where **R** is the electrical resistance.

Using the multimeter

A multimeter or a multitester, also known as a VOM (Volt-Ohm meter or Volt-Ohm-milliammeter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter would include basic features such as the ability to measure voltage, current, and resistance (https://en.wikipedia.org/wiki/Multimeter).
The UT33D multimeter will be used during this laboratory work, its structure being presented in Fig. 1.1.
For further information about the UT33D multimeter, access
http://www.uni-trend.com/en/product/2014_0729_811.html
http://www.uni-trend.com/uploads/soft/wanyongbiao/UT33B.C.D-Manual-en.pdf

1. LCD Display
2. Hold Button
3. Display Backlight Button
4. Rotary Switch
5. COM Input Terminal
6. 10A Input Terminal
7. Other Input Terminals

Fig. 1.1: *The UT33D multimeter*

Take care about how the position of the rotary switch has to be set and about which terminals the multimeter's test leads have to be connected to, for various measurement types.

When making DC voltage, AC voltage, resistance or current (less than 10 A) measurements, the test leads have to be connected to the multimeter's **5** and **7** input terminals.

The position of the rotary switch depends on the type of the measurement:

- One of the V⎓ positions for DC voltage measurements (Fig. 1.2);
- One of the V~ positions for AC voltage measurements (Fig. 1.2);
- One of the **Ω** positions for resistance measurements (Fig. 1.3);
- One of the A⎓ positions for DC current measurements (Fig. 1.4).

The UT33D multimeter can not measure the alternative current.

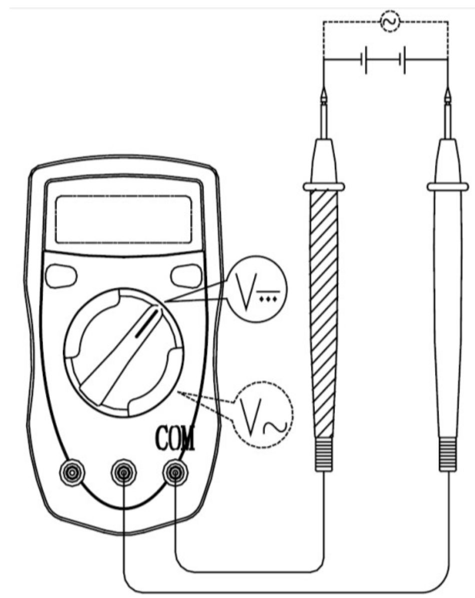

Fig. 1.2: *Rotary switch positions for voltage measurements*

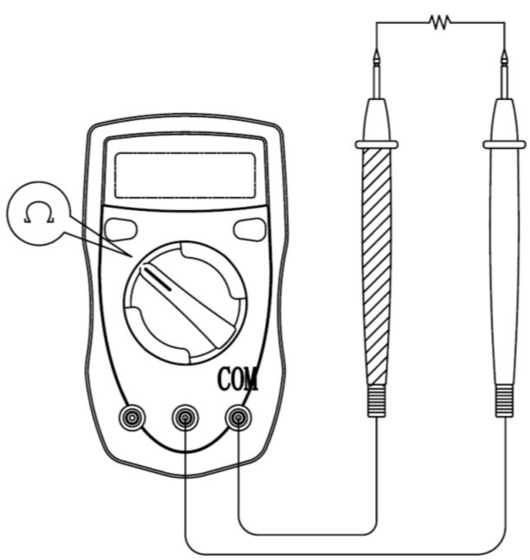

Fig. 1.3: *Rotary switch positions for resistance measurements*

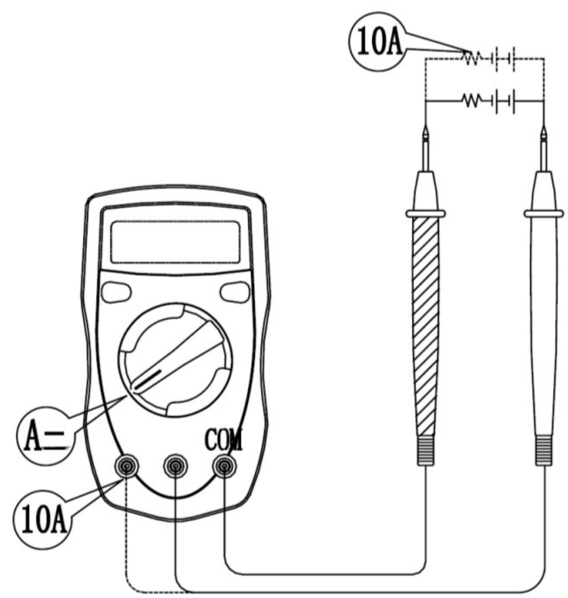

Fig. 1.4: *Rotary switch positions for current measurements*

Experimental setup

The experimental setup consists in two main sections: one for alternating (AC) voltage and current measurements and one for direct (DC) voltage and current measurements (Fig. 1.5).

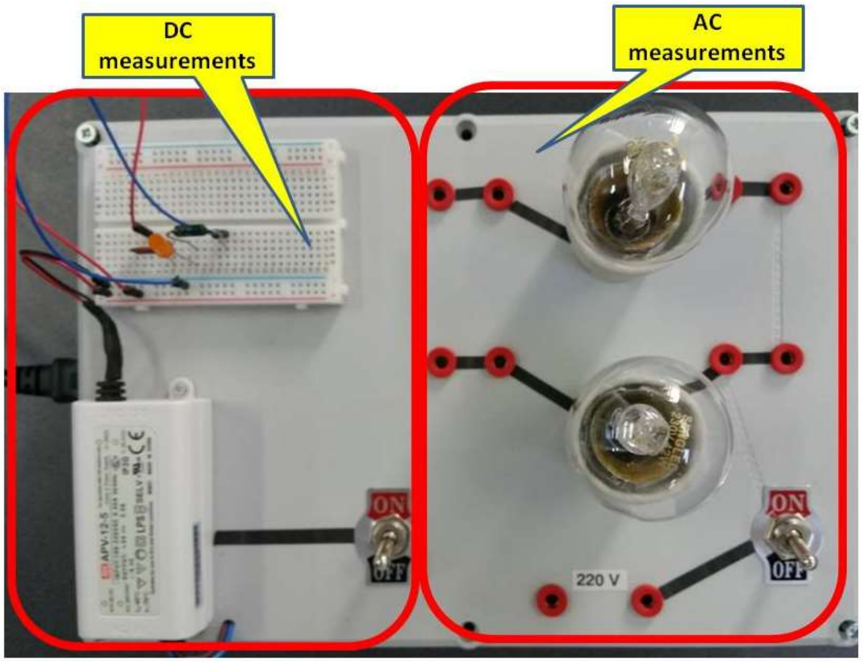

Fig. 1.5: *The main sections of the experimental setup*

The alternating voltage and current section (Fig. 1.6) consists in an AC source (220 V), two light bulbs (**LB1** and **LB2**), a switch and ten sockets (**Sk1** ... **Sk10**).

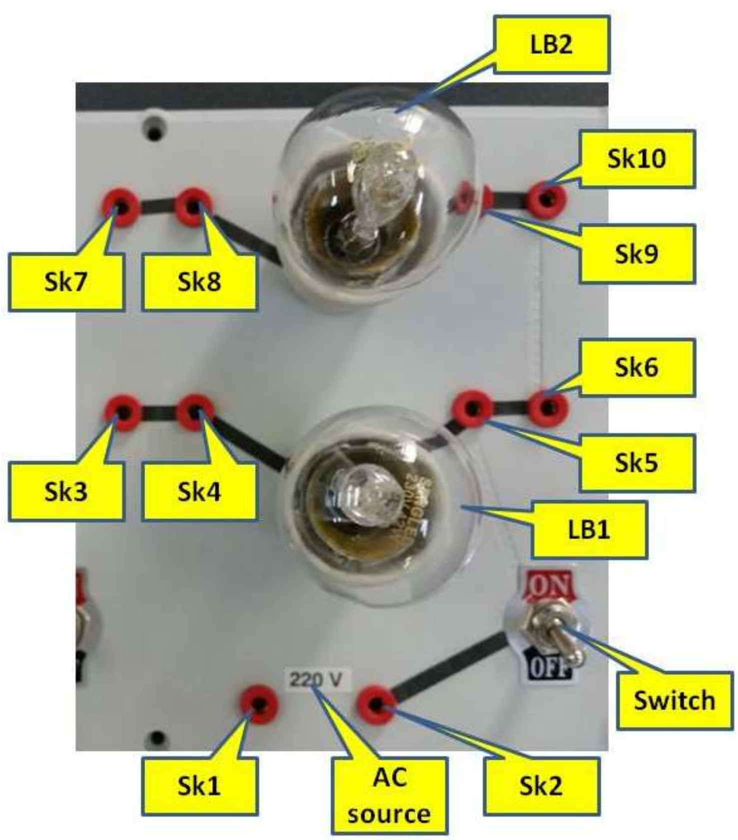

Fig. 1.6: *The components of the AC section*

The direct voltage and current section (Fig. 1.7) consists in a DC source (5 V), a prototyping breadboard and a switch.

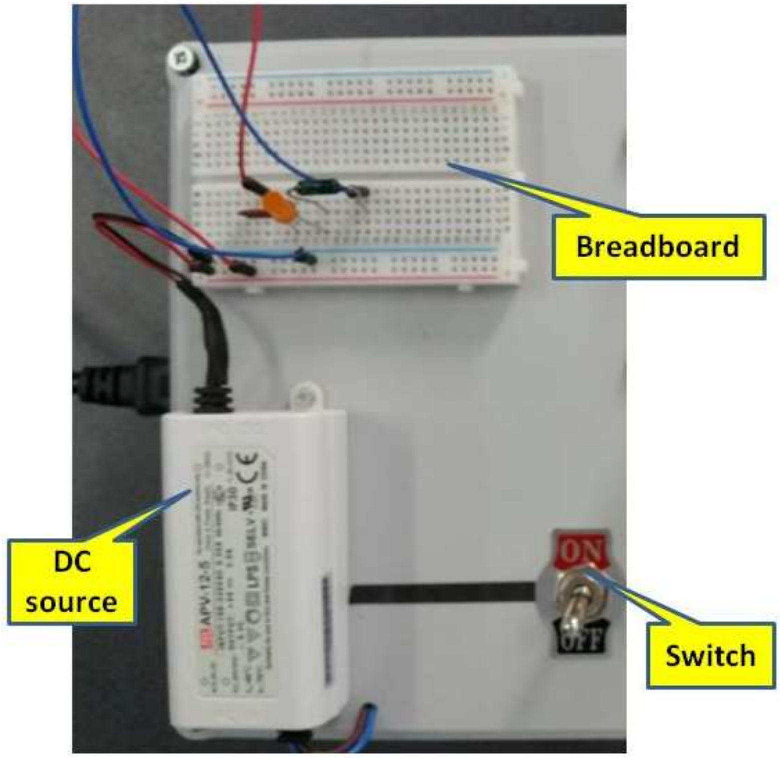

Fig. 1.7: *The components of the DC section*

The prototyping breadboard (Fig. 1.8) has:

- two central areas, each one having five columns (**a** ... **e** and **f** ... **j**) and 30 lines;
- two peripheral areas, each one having two columns, marked with red (**+**) and blue (**-**) stripes, and 25 lines on each column.

In the central areas, all the five pins on one line in an area are connected together.
For example, are connected together:

- the pins **a3**, **b3**, **c3**, **d3** and **e3**;
- the pins **f17**, **g17**, **h17**, **i17** and **j17**.

In the peripheral areas, all the pins on one column are connected together.
For example, the 25 pins along the red (**+**) stripe on the right side are all connected together.

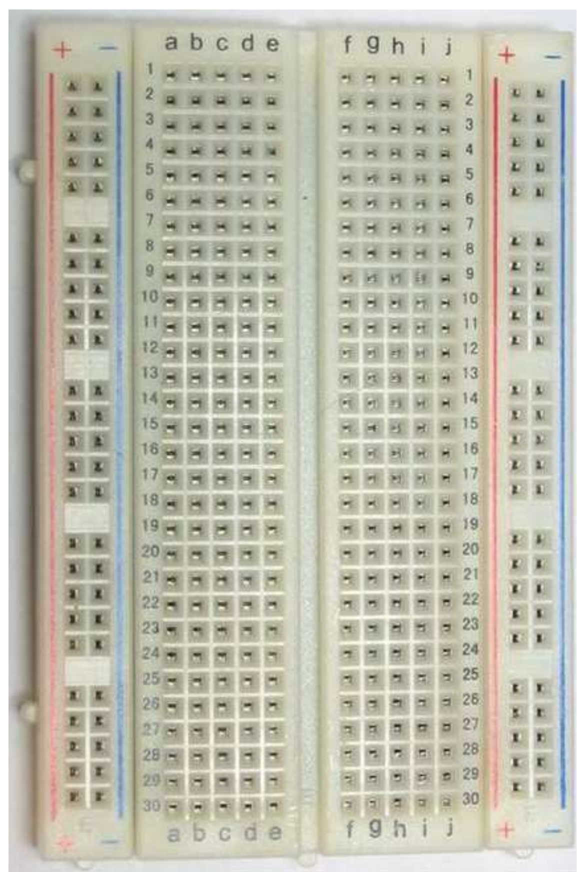

Fig. 1.8: *The prototyping breadboard*

Resistance measurements in the AC circuit

Put the multimeter's rotary switch in the **200 Ω** position. Connect the test leads to the **VΩmA** and the **COM** terminals (Fig. 1.9).

Fig. 1.9: *Rotary switch position and test leads connections*

Measure the resistance of the **LB1** light bulb by placing the multimeter's plugs in the **Sk4** and **Sk5** sockets (Fig. 1.10).

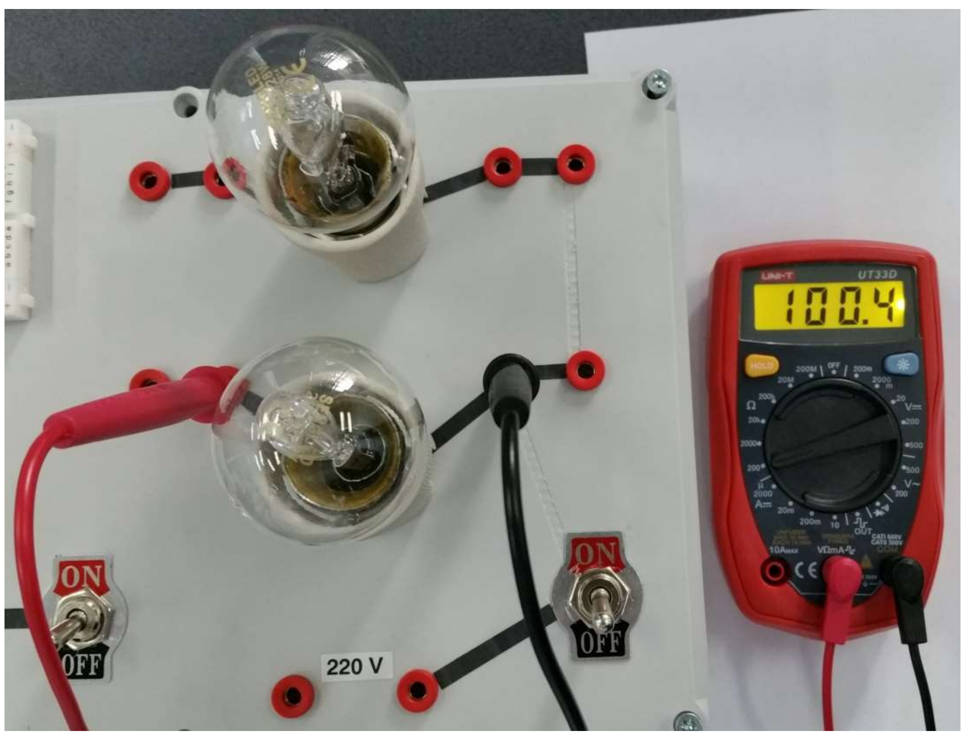

Fig. 1.10: *Measuring* ***LB1*** *resistance*

Measure the resistance of the **LB2** light bulb by placing the multimeter's plugs in the **Sk8** and **Sk9** sockets (Fig. 1.11).

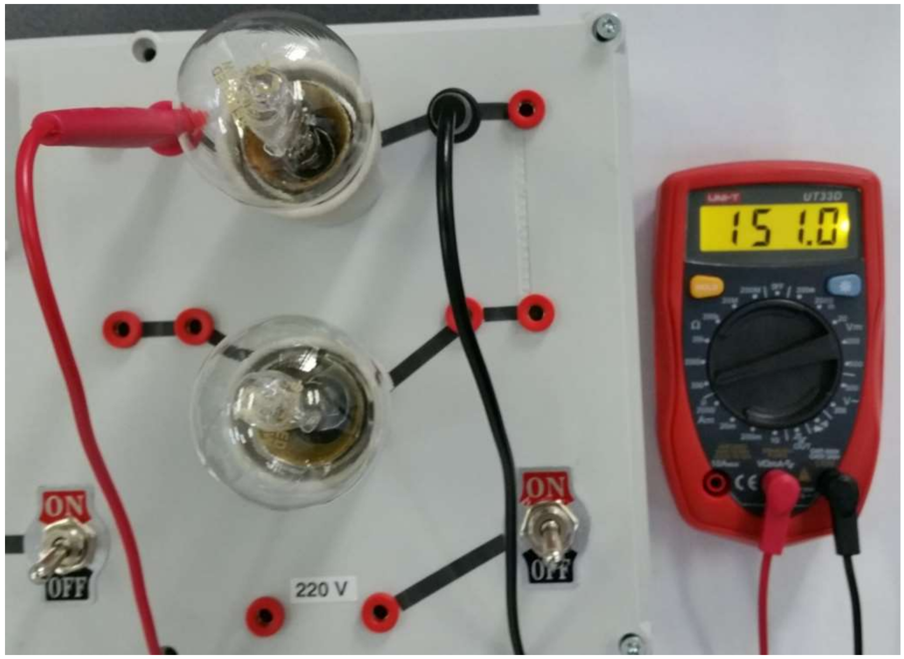

Fig. 1.11: *Measuring **LB2** resistance*

Connect the two light bulbs in a series circuit by connecting sockets **Sk6** and **Sk10**.
Measure the series circuit total resistance by placing the multimeter's plugs in the **Sk4** and **Sk7** sockets (Fig. 1.12).

Compare the measured value with that computed using Eq. (1.2).

Fig. 1.12: *Measuring the series circuit total resistance*

Connect the light bulbs in a parallel circuit by connecting **Sk4** with **Sk8** and **Sk5** with **Sk9** and then measure the circuit's total resistance by placing the multimeter's plugs in the **Sk3** and **Sk6** sockets or in the **Sk7** and **Sk10** sockets (Fig. 1.13).

Compare the measured value with that computed using Eq. (1.4).

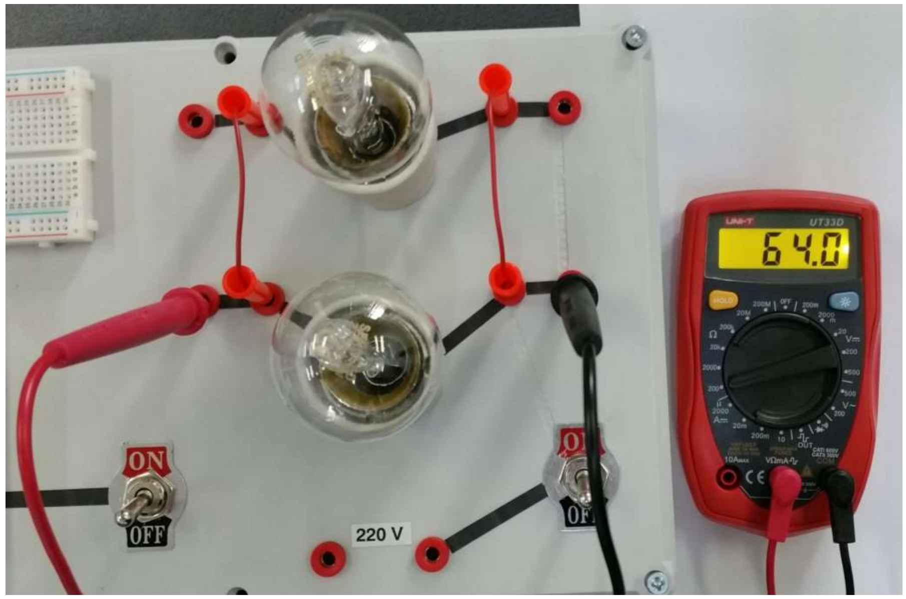

Fig. 1.13: *Measuring the parallel circuit total resistance*

Voltage measurements in the AC circuit

For measuring the voltage of the AC source (Fig. 1.14):

- Put the multimeter's rotary switch in the **500 V**~ position;
- Connect the test leads to the **VΩmA** and the **COM** terminals;
- Place the multimeter's plugs in the **Sk1** and **Sk2** sockets and push the switch in the **ON** position.

Check that the measured voltage is close to the 220 V expected value.

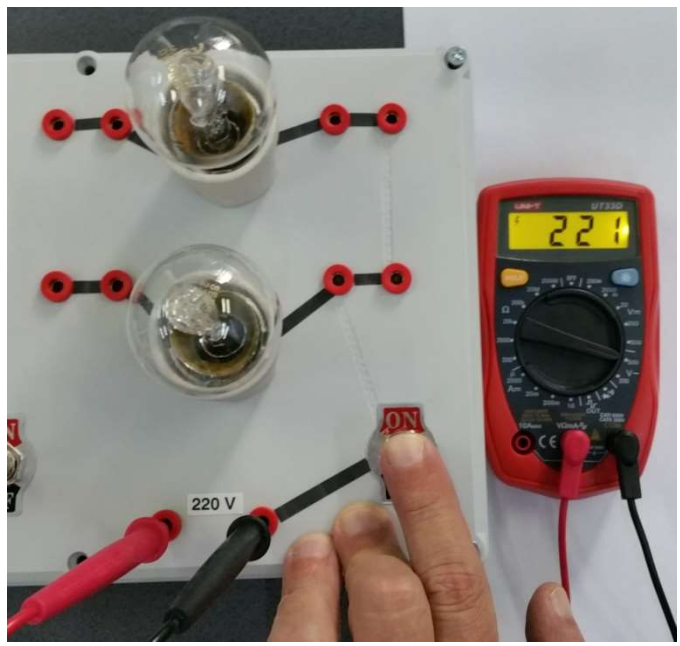

Fig. 1.14: *Measuring the voltage of the AC source*

To connect only light bulb **LB1** to the AC source, connect **Sk1** with **Sk4** and **Sk2** with **Sk5**.

For measuring the voltage across **LB1** (Fig. 1.15):

- Keep the multimeter's rotary switch in the **500 V~** position and the test leads connected to the **VΩmA** and the **COM** terminals;
- Place the multimeter's plugs in the **Sk3** and **Sk6** sockets and push the switch in the **ON** position.

Check that the measured voltage is close to the 220 V expected value.

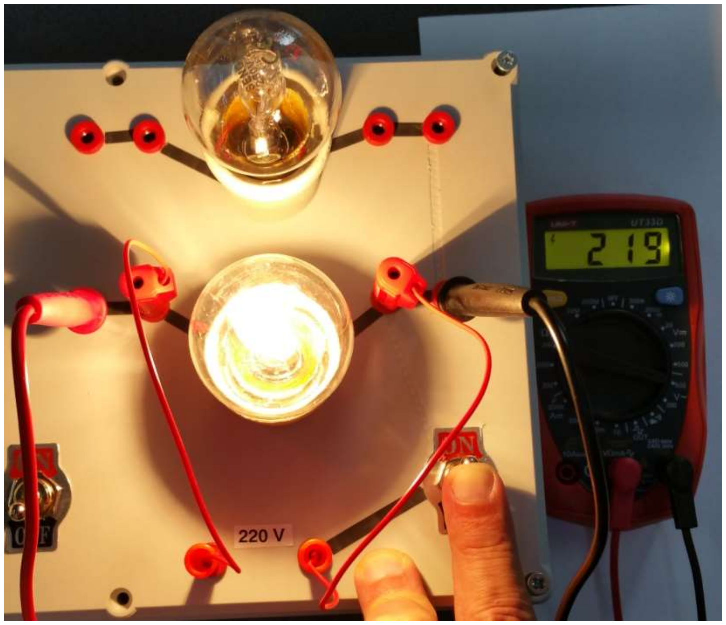

Fig. 1.15: *Measuring the voltage across **LB1** powered alone*

To connect only light bulb **LB2** to the AC source, connect **Sk1** with **Sk8** and **Sk2** with **Sk9**.

For measuring the voltage across **LB2** (Fig. 1.16):

- Keep the multimeter's rotary switch in the **500 V~** position and the test leads connected to the **VΩmA** and the **COM** terminals;
- Place the multimeter's plugs in the **Sk7** and **Sk10** sockets and push the switch in the **ON** position.

Check that the measured voltage is close to the 220 V expected value.

Fig. 1.16: *Measuring the voltage across **LB2** powered alone*

Connect the light bulbs in a series circuit by connecting **Sk1** with **Sk3**, **Sk10** with **Sk6** and **Sk2** with **Sk7**.

For measuring the voltage across the series circuit (Fig. 1.17):

- Keep the multimeter's rotary switch in the **500 V~** position and the test leads connected to the **VΩmA** and the **COM** terminals;
- Place the multimeter's plugs in the **Sk4** and **Sk8** sockets and push the switch in the **ON** position.

Check that the measured voltage is close to the 220 V expected value.

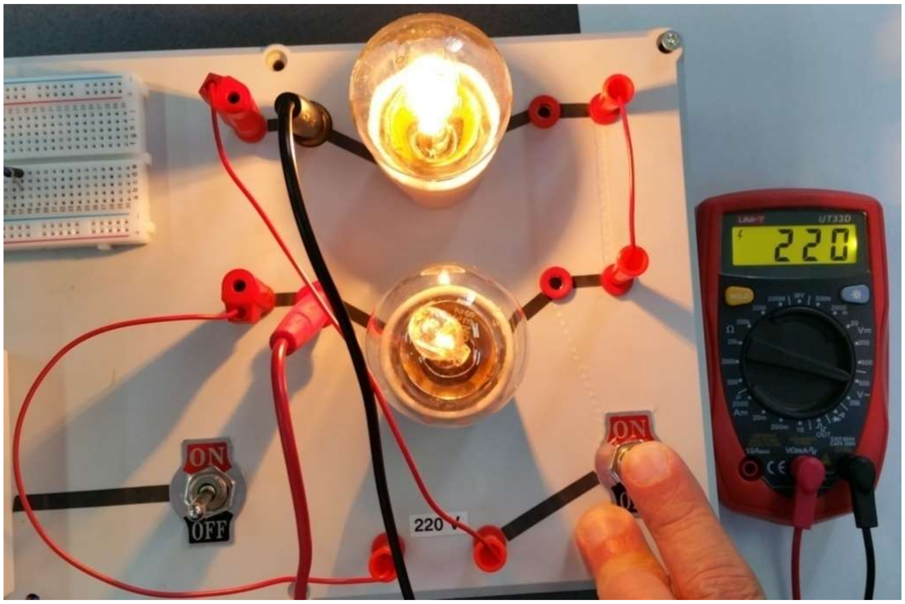

Fig. 1.17: *Measuring the voltage across the whole series circuit*

For measuring the voltage across **LB1** (Fig. 1.18):

- Keep the multimeter's rotary switch in the **500 V~** position and the test leads connected to the **VΩmA** and the **COM** terminals;
- Place the multimeter's plugs in the **Sk4** and **Sk5** sockets and push the switch in the **ON** position.

Mark the measured value as U_1.

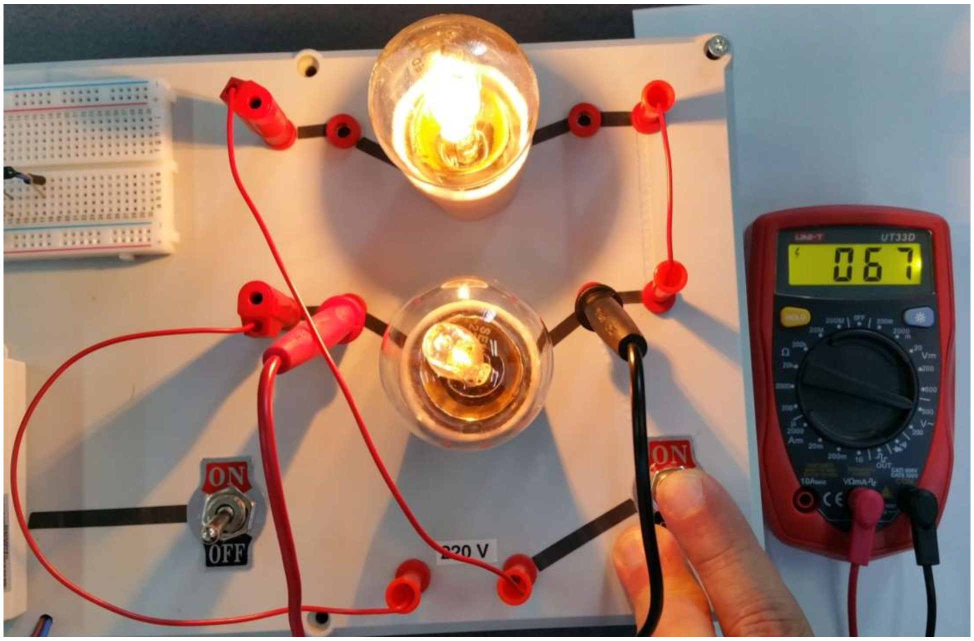

Fig. 1.18: *Measuring the voltage across **LB1** in a series circuit*

For measuring the voltage across **LB2** (Fig. 1.19):

- Keep the multimeter's rotary switch in the **500 V~** position and the test leads connected to the **VΩmA** and the **COM** terminals;
- Place the multimeter's plugs in the **Sk8** and **Sk9** sockets and push the switch in the **ON** position.

Mark the measured value as $\mathbf{U_2}$.

Check Eq. 1.6.

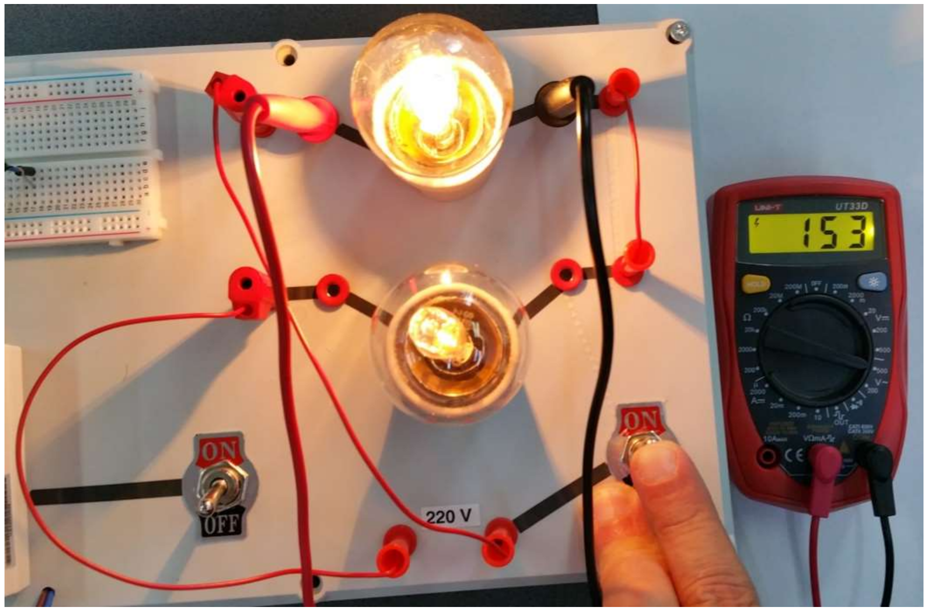

Fig. 1.19: *Measuring the voltage across* ***LB2*** *in a series circuit*

Connect the light bulbs in a parallel circuit by connecting **Sk1** with **Sk3**, **Sk4** with **Sk4**, **Sk9** with **Sk5** and **Sk6** with **Sk2**. Take care that, in **Sk3** and **Sk6**, you will have to insert the plugs having an extra socket.

For measuring the voltage across **LB1** (Fig. 1.20):

- Keep the multimeter's rotary switch in the **500 V~** position and the test leads connected to the **VΩmA** and the **COM** terminals;
- Place the multimeter's plugs in the extra sockets of the plugs already connected to **Sk3** and **Sk6** and push the switch in the **ON** position.

Check that the measured voltage is close to the 220 V expected value.

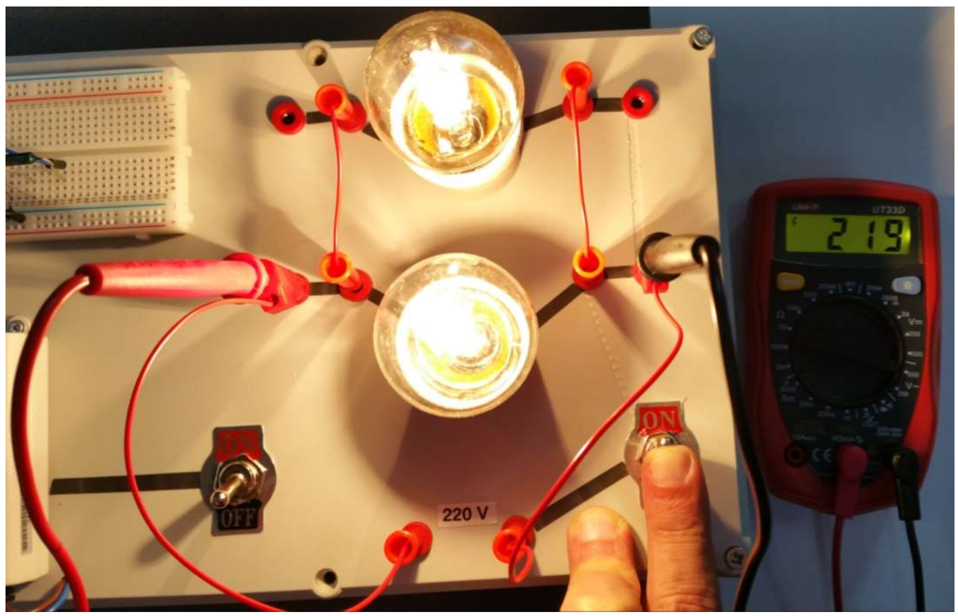

Fig. 1.20: *Measuring the voltage across* ***LB1*** *in a parallel circuit*

For measuring the voltage across **LB2** (Fig. 1.21):

- Keep the multimeter's rotary switch in the **500 V**~ position and the test leads connected to the **VΩmA** and the **COM** terminals;
- Place the multimeter's plugs in the **Sk7** and **Sk10** sockets and push the switch in the **ON** position.

Check that the measured voltage is close to the 220 V expected value.

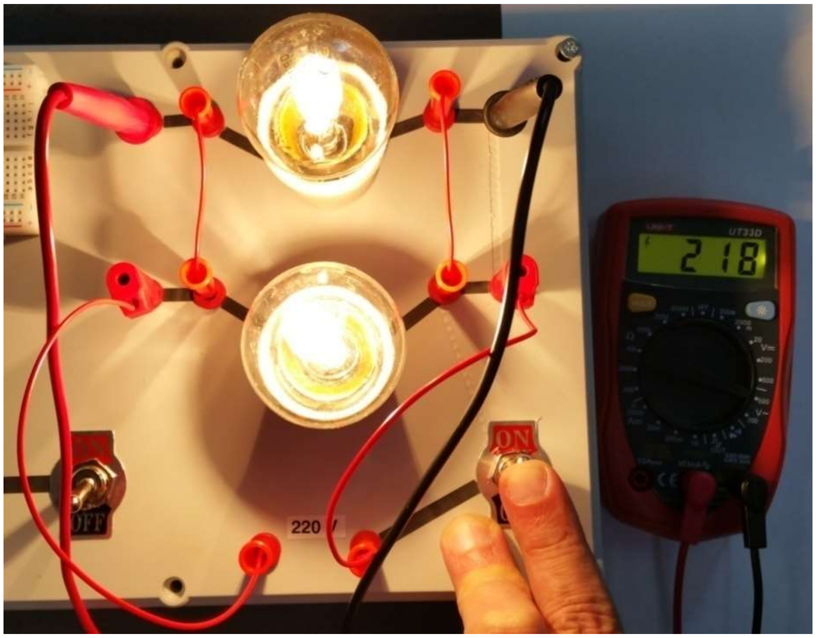

Fig. 1.21: *Measuring the voltage across* ***LB2*** *in a parallel circuit*

DC circuit measurements

For measuring the DC power source voltage (Fig. 1.22):

- Make sure that the lead wires from the DC power source are connected to a pair of pins from the **+** and **–** columns of a breadboard's peripheral area;
- Connect two wires to some pins on the same **+** and **–** columns;
- Put the multimeter's rotary switch in the **20** V ⎓ position;
- Connect the multimeter's test leads to the **VΩmA** and the **COM** terminals;
- Keep the contact between the multimeter's test leads and the two wires connected to the **+** and **–** columns.

Check that the measured voltage is close to the 5 V expected value.

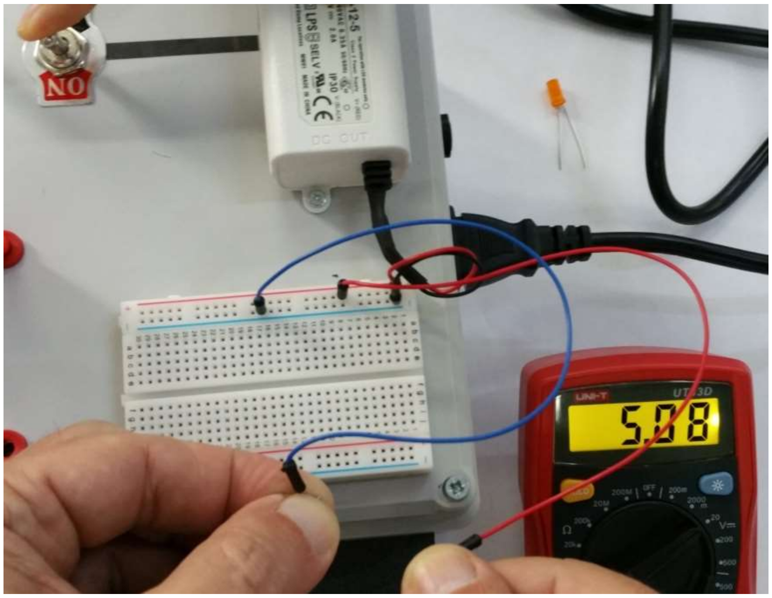

Fig. 1.22: *Measuring the DC power source voltage*

For measuring the separate resistance of each of two provided resistors (Fig. 1.23):

- Keep the multimeter's test leads connected to the **VΩmA** and the **COM** terminals;
- Put the multimeter's rotary switch in the **2000 Ω** position;
- Keep the contact between the multimeter's test leads and the resistor's terminals.

Mark the two measured resistance values with $\mathbf{R_1}$ and $\mathbf{R_2}$.

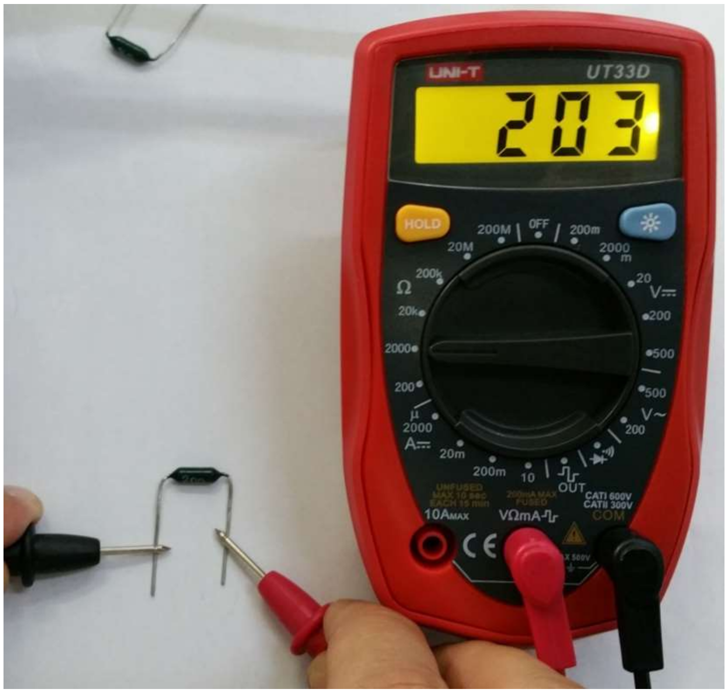

Fig. 1.23: *Measuring the resistance of one resistor*

Place the two resistors on the breadboard for connecting them in a series circuit.

For measuring the total resistance of the serial circuit (Fig. 1.24):

- Keep the multimeter's test leads connected to the **VΩmA** and the **COM** terminals;
- Keep the multimeter's rotary switch in the **2000 Ω** position;
- Keep the contact between the multimeter's test leads and the circuit's external terminals.

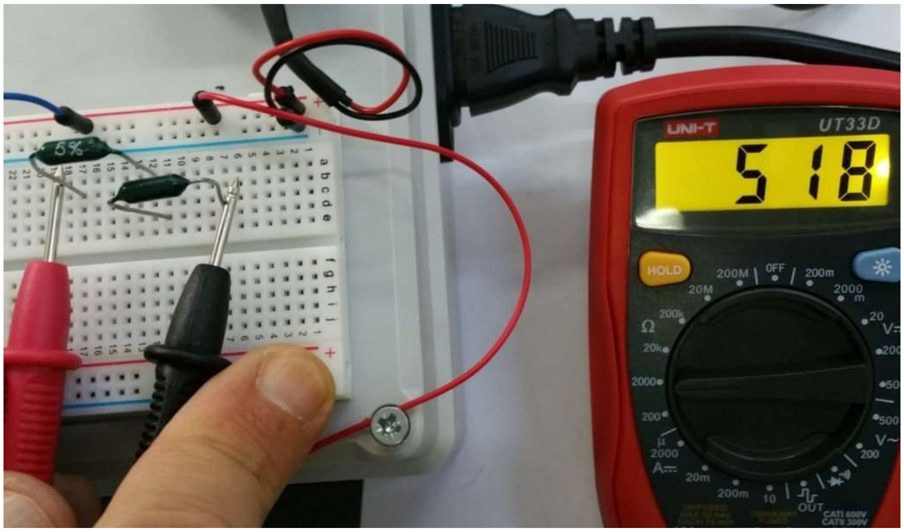

Fig. 1.24: *Measuring the total resistance of the serial circuit*

Check Eq. 1.2.

For measuring the voltage across the serial circuit (Fig. 1.25):

- Keep the multimeter's test leads connected to the **VΩmA** and the **COM** terminals;
- Put the multimeter's rotary switch in the **20** V⎓ position;
- Keep the contact between the multimeter's test leads and the circuit's external terminals;
- Push the switch in the **ON** position.

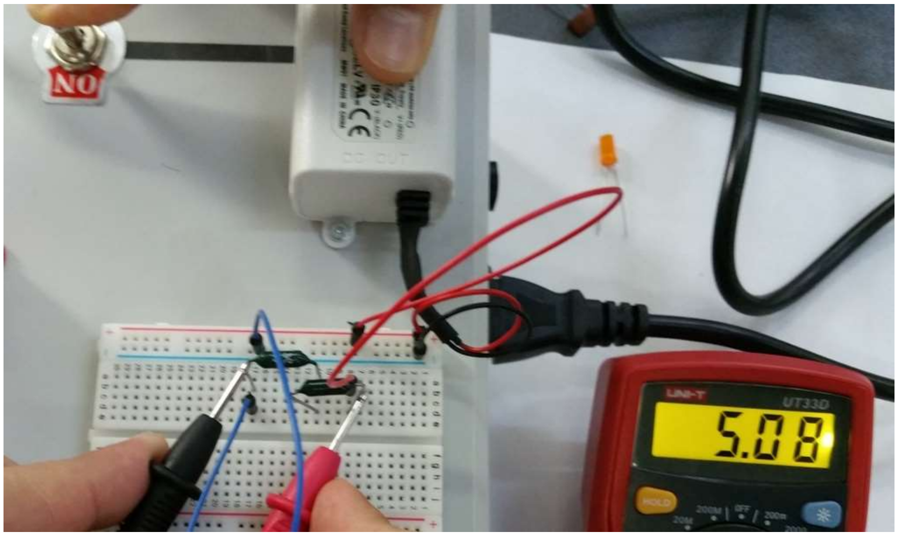

Fig. 1.25: *Measuring the voltage across the serial circuit*

Check that the measured voltage is close to the 5 V expected value.

For measuring the voltage across the first resistor (Fig. 1.26):

- Keep the multimeter's test leads connected to the **VΩmA** and the **COM** terminals;
- Keep the multimeter's rotary switch in the **20** V⎓ position;
- Keep the contact between the multimeter's test leads and the first resistor's terminals;
- Push the switch in the **ON** position.

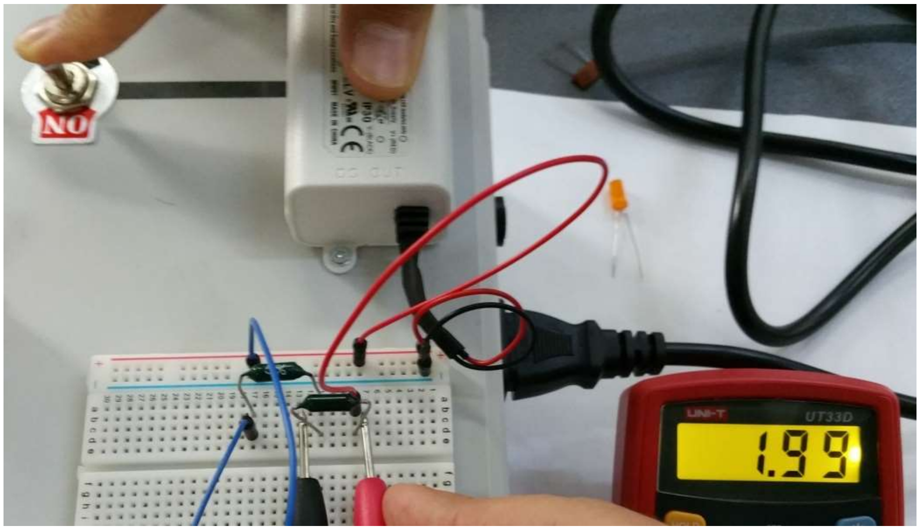

Fig. 1.26: *Measuring the voltage across the first resistor in a serial circuit*

Mark the measured voltage value with $\mathbf{U_1}$.

Perform the same operations for measuring the voltage across the second resistor (Fig. 1.27) and mark the measured voltage value with **U_2**.

Check that the sum of the voltages measured across the two resistors equals the total voltage across the series circuit (Eq. 1.6)

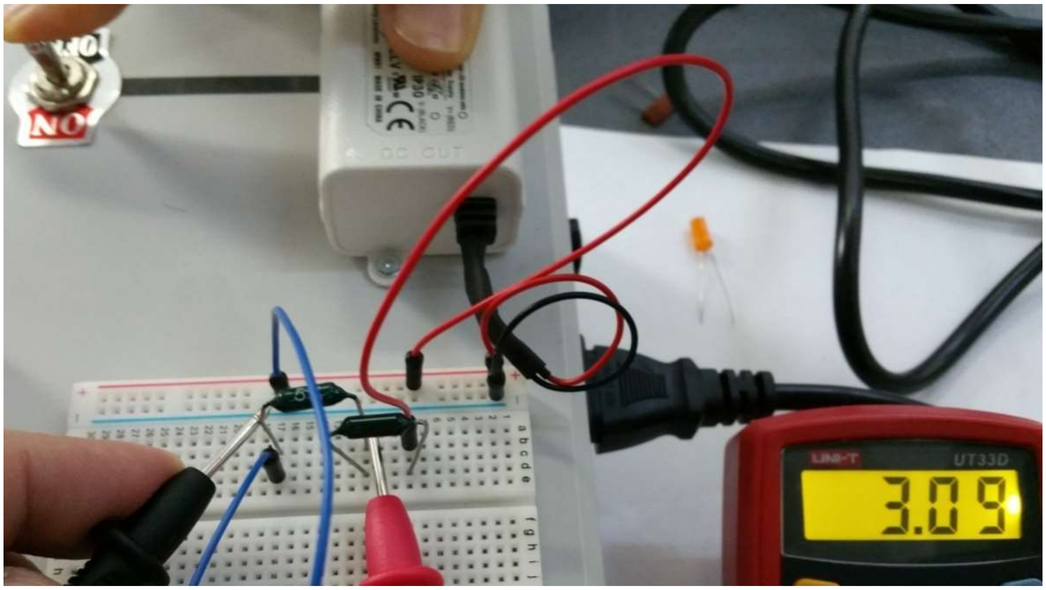

Fig. 1.27: *Measuring the voltage across the second resistor in a serial circuit*

For measuring the current, the multimeter has to be inserted in the electric circuit, in series with the other components.

For example, for measuring the current passing through one resistor, the multimeter's test leads and the wires have to connected like in Fig. 1.28.

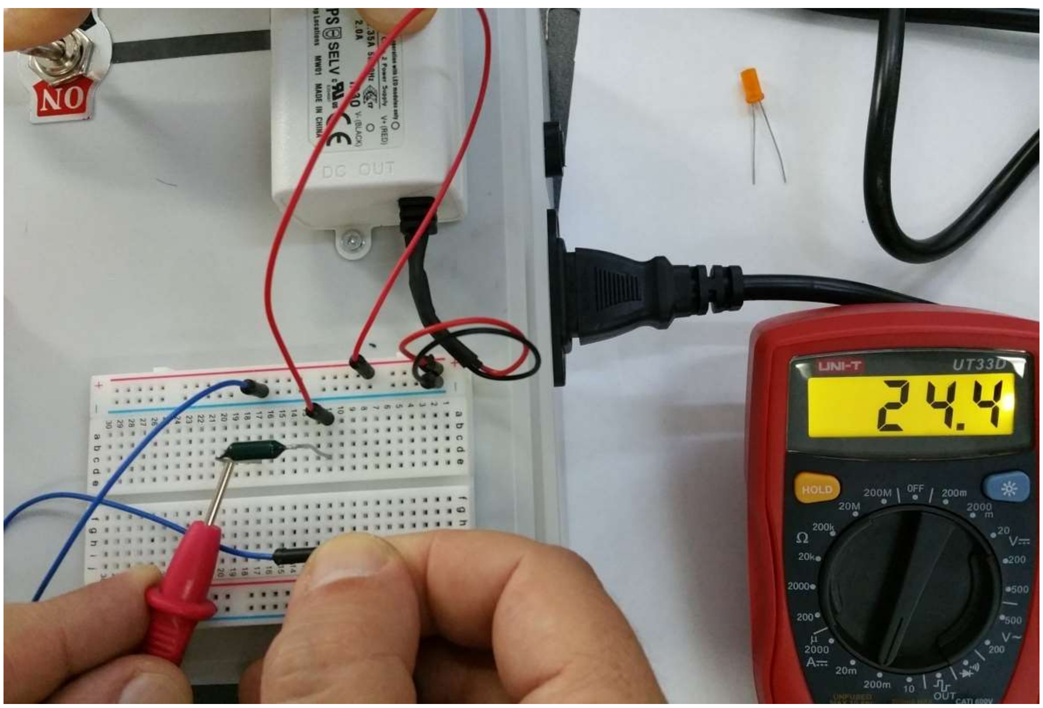

Fig. 1.28: *Measuring the current passing through one resistor*

For measuring the current passing through the series circuit (Fig. 1.29):

- Keep the multimeter's test leads connected to the **VΩmA** and the **COM** terminals;
- Put the multimeter's rotary switch in the **200 mA ⎓** position;
- Keep the contact between one of the multimeter's test leads and the wire connected to the breadboard's **–** column;
- Keep the contact between the other multimeter's test lead and the free terminal of the second resistor;
- Push the switch in the **ON** position.

Check the measured value of the current against those of the total voltage across the series circuit and total resistance of the series circuit.

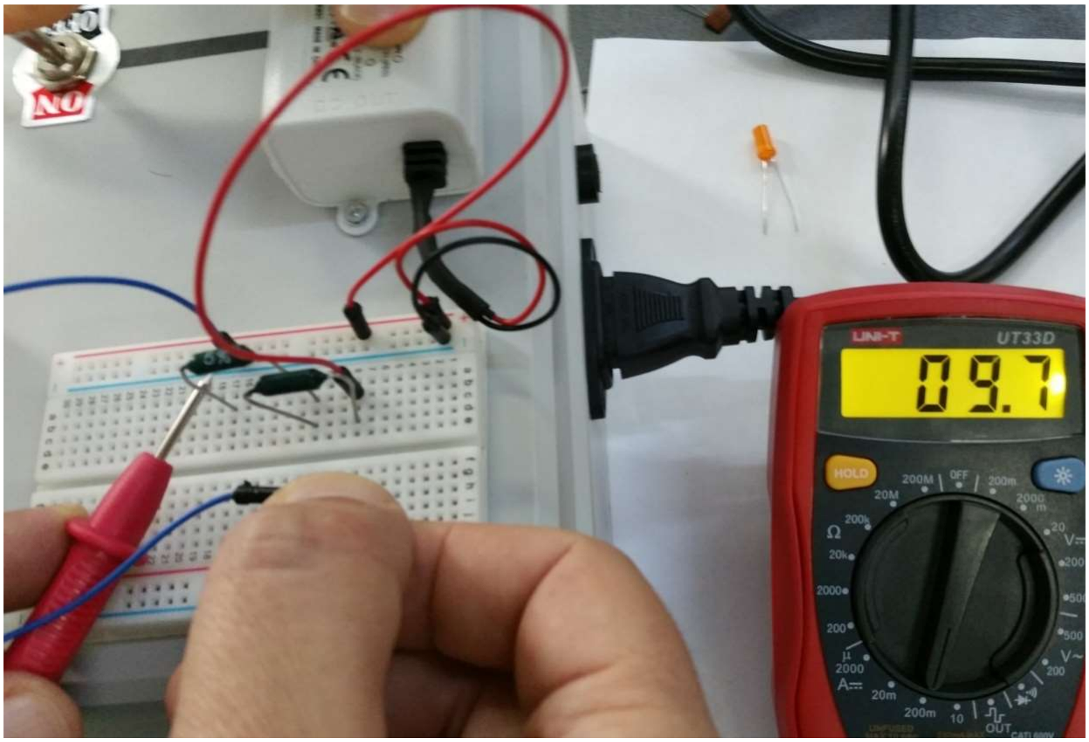

***Fig. 1.29:** Measuring the current passing through the whole series circuit*

Place the two resistors on the breadboard for connecting them in a parallel circuit.

For measuring the total resistance of the parallel circuit (Fig. 1.30):

- Keep the multimeter's test leads connected to the **VΩmA** and the **COM** terminals;
- Put the multimeter's rotary switch in the **2000 Ω** position;
- Keep the contact between the multimeter's test leads and the circuit's external terminals.

Check Eq. 1.4.

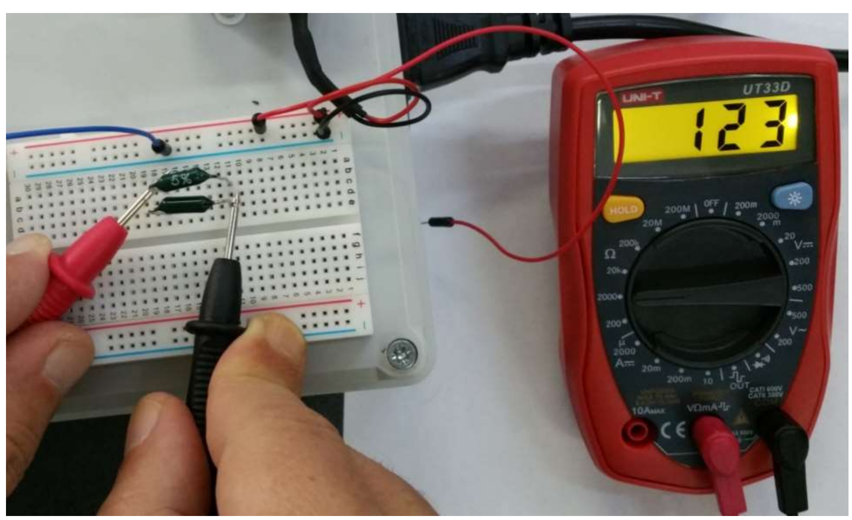

***Fig. 1.30:** Measuring the total resistance of the parallel circuit*

For measuring the voltage across the parallel circuit (Fig. 1.31):

- Keep the multimeter's test leads connected to the **VΩmA** and the **COM** terminals;
- Put the multimeter's rotary switch in the **20** V⎓ position;
- Keep the contact between the multimeter's test leads and the circuit's external terminals;
- Push the switch in the **ON** position.

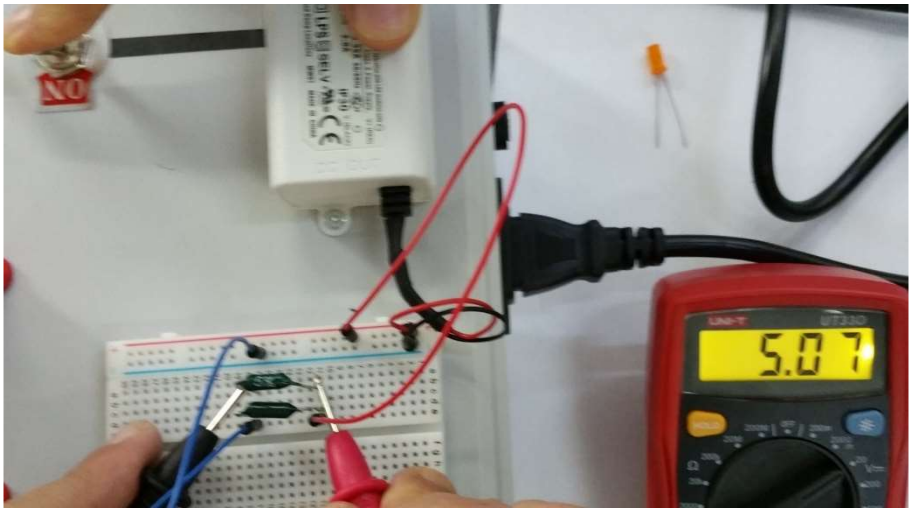

Fig. 1.31: *Measuring the voltage across the parallel circuit*

Check that the measured voltage is close to the 5 V expected value.

For measuring the current through the whole parallel circuit (Fig. 1.32):

- Keep the multimeter's test leads connected to the **VΩmA** and the **COM** terminals;
- Put the multimeter's rotary switch in the **200 mA**⎓ position;
- Keep the contact between one of the multimeter's test leads and the wire connected to the breadboard's **–** column;
- Keep the contact between the other multimeter's test lead and a terminal of one resistor;
- Push the switch in the **ON** position.

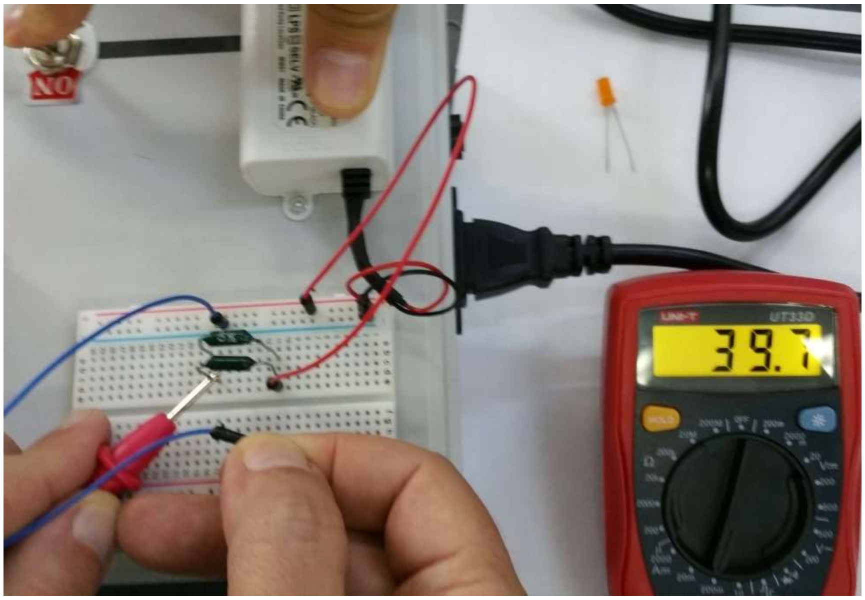

Fig. 1.32: *Measuring the current through the whole parallel circuit, using the first resistor*

Check the measured value of the current against those of the total voltage across the parallel circuit and total resistance of the parallel circuit.

Check that the same measured value of the current through the whole parallel circuit is obtained if the second multimeter's test lead is connected to the terminal of the other resistor (Fig. 1.33).

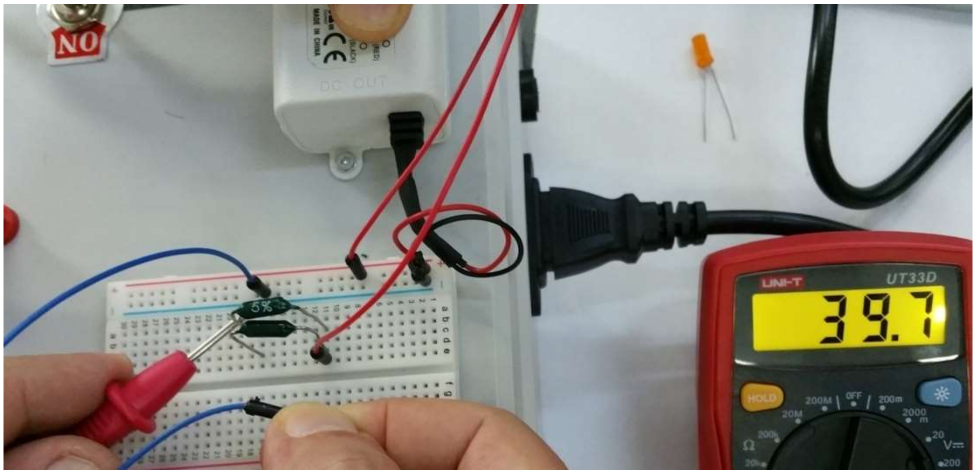

Fig. 1.33: *Measuring the current through the whole parallel circuit, using the second resistor*

Connect the wires for inserting the multimeter in the circuit branch of the first resistor, for measuring the current passing through it (Fig. 1.34).

Check the measured value of the current against those of the total voltage across the parallel circuit and resistance of the first resistor.

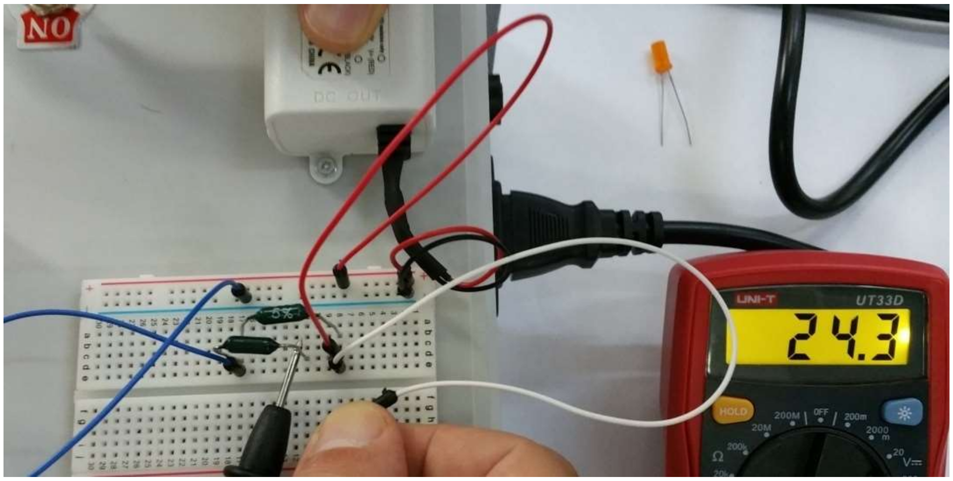

Fig. 1.34: *Measuring the current through the first resistor in a parallel circuit*

Connect the wires for inserting the multimeter in the circuit branch of the second resistor, for measuring the current passing through it (Fig. 1.35).

Check the measured value of the current against those of the total voltage across the parallel circuit and resistance of the first resistor.

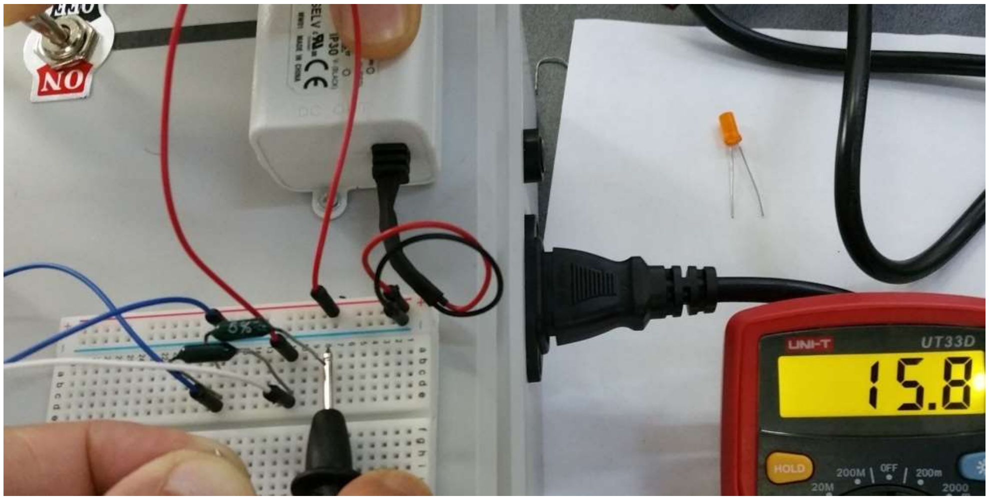

Fig. 1.35: *Measuring the current through the second resistor in a parallel circuit*