

PH102 Lab dc & rc Circuits

Introduction

In this experiment we will determine how voltages are distributed in resistor circuits according to Ohm's law, and explore series and parallel combinations of resistors.

Resistance is a measure of a device's ability to conduct electric current for a given potential difference. The higher the resistance, the lower the current for a given voltage. Resistors are passive electronic devices which have fixed values. Their relationship between current and voltage follows Ohm's Law:

$$V = IR \quad (1)$$

The SI unit of resistance is the ohm, $1 \Omega = 1 \text{ V/A}$. In general, the resistance can be calculated knowing the geometry of the device. For most practical devices, the resistor consists of a thin film or wire of a specific material with cross sectional area, A and length, l . The resistance is then given by:

$$R = \rho l/A \quad (2)$$

where ρ is a materials parameter called resistivity, measured in units of $\Omega\cdot\text{m}$. The schematic symbol for a resistor is shown at right.



As is the case for capacitors, there are two ways to connect resistors in an electronic circuit—series or parallel connection. In a series connection the components are connected at a single point, end to end as shown below:

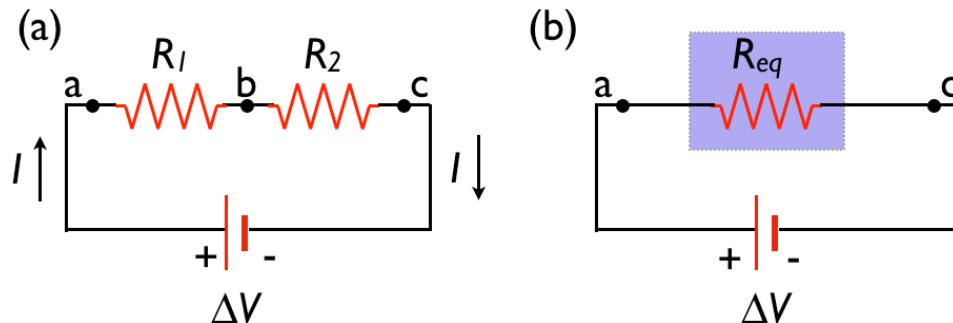


Figure 1: Series Resistors

For a series connection, the current through each resistor will be the same, and the voltage drops will together add up to the source voltage. We can find the equivalent resistance, R_{eq} , from

$$IR_{eq} = \Delta V = V_1 + V_2 = IR_1 + IR_2 \quad (3)$$

Thus

$$R_{eq} = R_1 + R_2 \quad (4)$$

In the parallel connection, the components are connected to each other at both ends as shown below:

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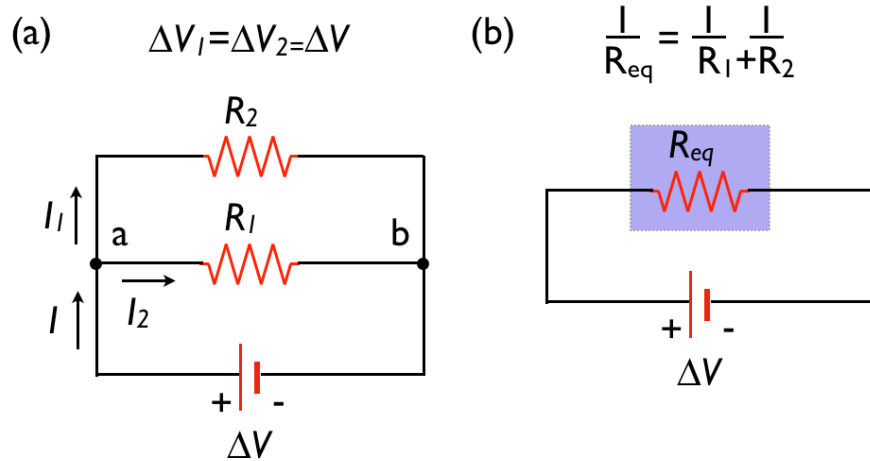


Figure 2: Parallel resistors

For a parallel connection, the voltage drops will be the same, but the two currents together will add up to the total current flowing out of the source. Then the equivalent resistance can be calculated by adding the currents:

$$V/R_{eq} = I = I_1 + I_2 = V/R_1 + V/R_2 \quad (5)$$

Thus

$$1/R_{eq} = 1/R_1 + 1/R_2 \quad (6)$$

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Checking your Bamalab box

At this point you should have connected your lab box and started the tutorial software.

Occasionally, components of your Bamalab box may stop functioning, or at least you may have reason to believe so. Fortunately, there is a simple procedure for verifying your Bamalab box. This procedure presumes that the previous stage - starting the software and verifying the USB connection - has been successfully completed.

Voltage input & output

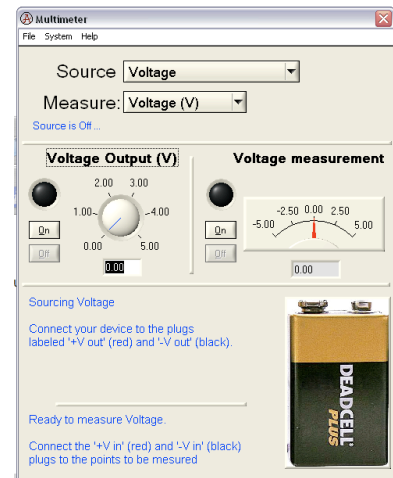
First, open the “multimeter” panel in the software. From the “Source” pulldown menu, select “Voltage,” and also select “Voltage” from the “Measure” pulldown menu. After performing each action, the middle portion of the window should change to reflect your choices, as shown at right.

Next, using two “banana” cables, **connect the voltage input and output together**. Do this by connecting “+V_{in}” on one side of the box to “+V_{out}” on the other side, and similarly connect “-V_{in}” to “-V_{out}.”

Now click the “on” button under “Voltage Output” portion of the screen. The circle just above the “on” button should now be green. Adjust the voltage output dial to some moderate value, perhaps 1.5 or 2V. You are now sourcing voltage from the V_{out} terminals.

In the “Voltage measurement” portion of the screen, click “on.” The circle above the “on” button should turn red. Now you are measuring the voltage at the V_{in} terminals, which are connected directly to the V_{out} terminals. **If everything is functioning properly, the voltage measurement should be very close to your output voltage.** Finally, change the voltage output dial to some new value (say, 3V). You should see the “voltage measurement” indicators change to follow the change in output, in real time.

Variations of 10-15% between output and input are tolerable. If the above is successful, your voltage sourcing and measuring are OK!



Current input and output

If you have just performed the previous step, turn off the voltage output and measurement. On the multimeter screen, elect to source and measure *current* now. The output and measurement regions of the screen should change after you do this.

Next, using two “banana” cables, connect the current input and output together. Do this by connecting “+I_{in}” on one side of the box to “+I_{out}” on the other side, and similarly connect “-I_{in}” to “-I_{out}.” **Operating the current source also requires you to flip a small switch on the side of the box.** Make sure this switch is set to “on.”

Now click the “on” button under “Current Output” portion of the screen. The circle just above the “on” button should now be green. Adjust the current output dial to some moderate value, perhaps 3 or 5mA. You are now sourcing current from the I_{out} terminals.

Next, in the “Current measurement” portion of the screen, click “on.” The circle above the “on” button should turn red. Now you are measuring the current passing through the I_{out} terminals, which are connected directly to the I_{out} terminals. **If everything is functioning properly, the current measurement should be very close to your output current.** Finally, change the current output dial to some new value (say, 2mA). You should see the “current measurement” indicators change to follow the change in output, in real time.

Variations of 10-15% between output and input are tolerable. If the above is successful, your current sourcing and measuring are OK!

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Experiment I: Series resistors

This laboratory uses the tutorial software and hardware you were introduced to last time.

- Connect two resistors in series by stacking the “banana” plugs.
- Connect one side of one resistor to the “+Iout” terminal on the black “Labjack” box, and the other side of the second resistor to “-Iout”. Do this such that current can go into one resistor, through the second, and back to the source.
- Flip the switch on the side of the box to the “on” position. No current is flowing yet.
- Connect *one of your resistors only* “+Vin” and “-Vin” terminals. The +Vin connection should be on the same side of the resistor as the +Iout connection. The idea is to measure the voltage drop across only one resistor at a time.
- In the tutorial software, choose “Voltage vs. Current”

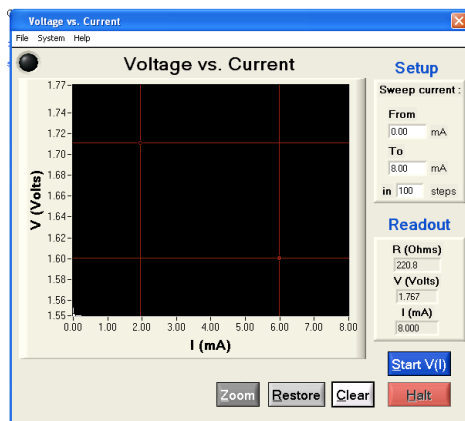


Figure 3: The voltage *vs.* current panel.

- Sweep the current from zero to a few mA, until you generate a nice straight-line characteristic. From the “File” menu, save your data.
- In Excel, plot the data as “X-Y scatter” and add a (linear) trendline. Print this plot (properly labeled).
- From your trendline, record the slope of your line and the resistance.

$$\text{Slope} = \text{_____ V/A} \qquad R_1 = \text{_____ } \Omega$$

- repeat parts e-g for your second resistor.

$$\text{Slope} = \text{_____ V/A} \qquad R_2 = \text{_____ } \Omega$$

- repeat parts e-g while measuring the voltage across *both resistors at once*

$$\text{Slope} = \text{_____ V/A} \qquad R_{eq} = \text{_____ } \Omega$$

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How well does your data support the rule for combining series resistors?

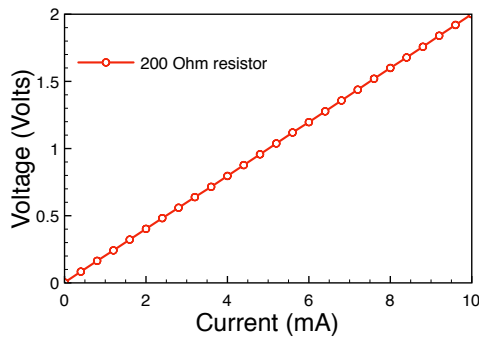


Figure 4: Example Voltage-Current plot.

Experiment II: Parallel Resistors

- Using the same two resistors from Experiment I, now connect them in parallel.
- repeat parts e-g above while measuring the voltage across both resistors.

$$\text{Slope} = \text{_____ V/A} \quad R_{\text{eq}} = \text{_____ } \Omega$$

Given the values of R_1 and R_2 from Experiment I, how well does your data support the rule for combining parallel resistors?

Experiment III: LEDs

- Connect your LED as you connected the resistors, and produce a $V(I)$ curve for the orientation that lights up the LED. Note the LED color and maximum voltage and turn in your plot.

$$\text{color} = \text{_____} \quad V_{\text{max}} = \text{_____ V}$$

- Now use **voltage sourcing** as you did in the last lab, and produce a $I(V)$ curve for your LED. Note the threshold voltage. **What happens at the threshold voltage? Why is there no threshold current?**

$$\text{threshold V} = \text{_____ V}$$

When you are finished:

- Turn the switch on the side of the box “off.”
- Straighten up your components and wires
- Turn in a hard copy of your report and **your plots**