Laboratory 2

Electrical Measurements, Use of Breadboards, and Ohm's Law

Objectives

- Become familiar with solderless breadboards
- Learn how to build circuits with the breadboards
- Introduce the use of ammeters and voltmeters
- Verify Ohm's law

Equipment and components

- 2x Digital multimeter with its manuals
- Power supply with its manual
- Breadboards
- Cables and connecting wires (as needed)
- Resistors 100 Ω, 270 Ω, 470 Ω, 680 Ω, 1 kΩ, 2.2 kΩ, 3.3 kΩ, 5.6 kΩ, 10 kΩ, 100 kΩ, 4.7 MΩ, 10 MΩ.
- 1xLight-emitting diode (LED)

Preliminary Work

1. **Read** the document "*Electrical Measurements*" available in the catcourses ("Files/Labs/").
2. **Read** the *Lab Procedure* (this document) to understand the tasks and steps that you will execute in the lab.
3. **Familiarize** yourself with the **principle of operation of a breadboard**, e.g., by watching the following video:
   https://www.youtube.com/watch?v=6WReFkfrUlk&ab_channel=ScienceBuddies

   A breadboard is a device for prototyping electric circuits. It is called solderless breadboard because the breadboard does not require soldering. It is reusable. This makes it easy to be used for creating temporary prototypes (protoboards).
   The picture below shows the structure of a typical breadboard.

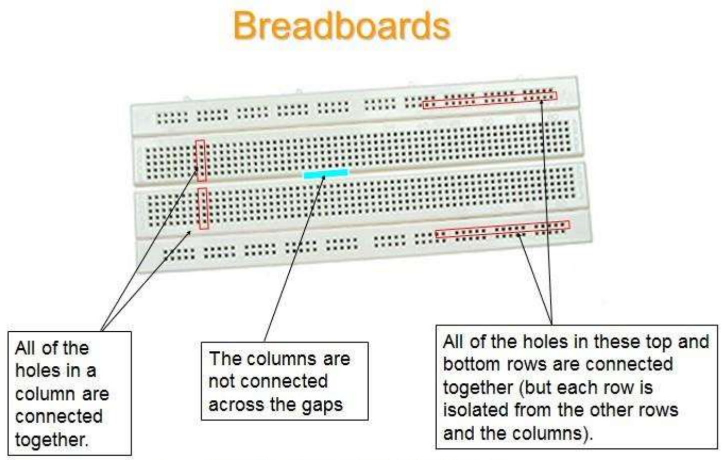
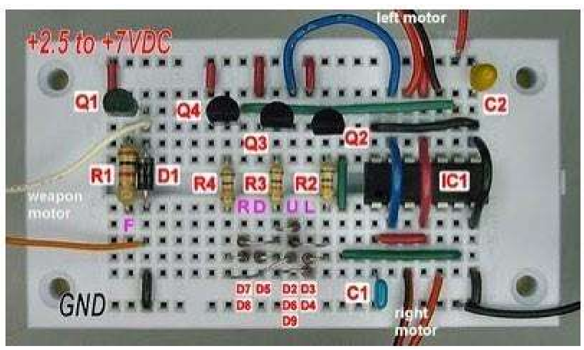
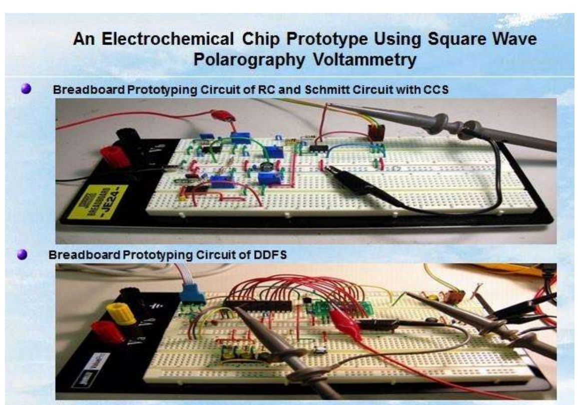


Image obtained from lectrures by Prof. David R. Jackson

Some good examples for circuit layouts on breadboards are shown below. You are encouraged to use the same design style. For example, the wires in red color are used to connect the positive terminals of power sources and the black wires for the negative terminals (called grounds). Use different colored wires to clearly indicate the different functionalities in a circuit. In addition, wire layouts should be clean and neat.



Source: http://electronics-sarath.blogspot.com/2010/05/how-breadboard-can-connect-components.html



Source: "An Electrochemical Chip Prototype Using Square Wave Polarography Voltammetry" (Master thesis, Yan Shi)

Lab Procedure

Note: Use the provided solderless breadboard and proper components when making measurements. If you are not sure about your circuit connections, ask the lab instructor to check the circuit before turning on the power.

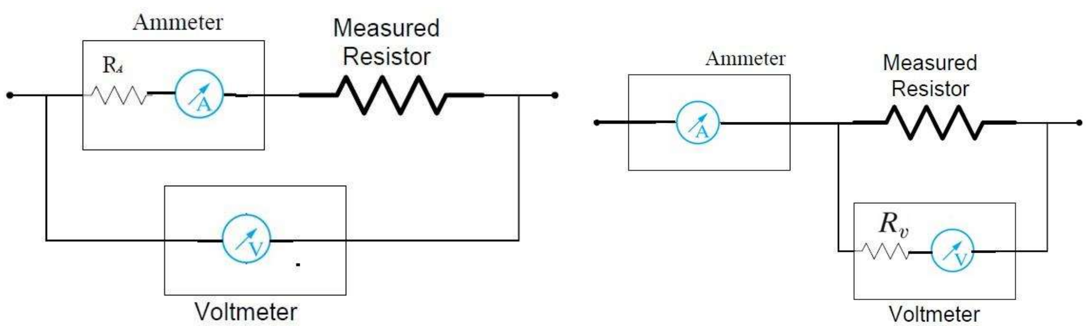
PART A

1. Set one multimeter as an **ammeter** and set another multimeter as a **voltmeter**. Then, measure the internal resistances of the ammeter and voltmeter. Write down your results in the table below.

Internal Resistances of the Ammeter and Voltmeter

Internal resistance of the Ammeter (Ω)	Internal resistance of Voltmeter (kΩ)
.991 Ω	1 MΩ

2. Pick two resistors rated at 1kΩ and 100 kΩ. Employ the two circuit configurations (a) and (b) shown below one at a time for each resistor.
   - Set the DC power supply to 10 V and it connect in parallel to circuit a)
   - Measure the voltage and current; write down your results in the table below
   - Repeat the measurements with the power supply connected in parallel to circuit b)
   - Compute the resistor value based on the measurements
   - What are the % errors between the measured and rated value of each resistor? (The necessary formulas for these calculations are given in the "Electrical Measurements" file); write down your results in the table below



(a) (b)

Resistor = 1kΩ

	Measured Voltage	Measured Current	Rated Resistance	Computed Resistance	% Error
Configuration (a)	9.99V	7.3mA	1kΩ	1.368kΩ	36.8%
Configuration (b)	9.93 V	7.17mA	1kΩ	1.38k Ω	38%

Resistor = 100kΩ

	Measured Voltage	Measured Current	Rated Resistance	Computed Resistance	% Error
Configuration (a)	9.98V	98.2µA	100 kΩ	101.63kΩ	1.63%
Configuration (b)	9.93A	108 µA	100 kΩ	91.94kΩ	8.062%

- Why should the ammeter be connected in series with the resistor and the voltmeter connected in parallel with the resistor shown in the two configurations? Explain.

Voltmeter has a high internal resistance which when connected in series will distribue the current that is flowing through the circuit; such is known as the loading effect

- Which circuit configuration provides more accurate results for each resistor?

Circuit B for voltmeter is parallel not distributing current flow.

PART B

3. Pick a resistor with a rated resistance value of 2.2 kΩ.

4. Set the output voltage of the DC power supply to 2 V (suggestion: check output voltage of the power supply with a voltmeter before connecting it to the circuit).
   - Consider the two configurations shown in step 2. Construct the circuits and measure the currents in the resistor and the voltages cross it. Write down your results in the table below.
   - Repeat the same measurements for output voltage 4 V, 6V, 8V …, 20 V and Write down your results in the table below.
   - Plot V-I characteristic (voltage is on vertical axis) of the resistor based on your results.

Results based on Configuration (a) for 2.2 kΩ

Power Supply Setting (V)	Current Measured	Voltage Measured	Computed Resistance
2	0.66 mA	2.04V	3.091kΩ
4	1.31 mA	4.02V	3.076kΩ
6	1.94 mA	5.93V	3.077kΩ
8	2.65 mA	8.14V	3.072kΩ
10	3.29 mA	10.08V	3.064kΩ
12	3.91 mA	11.99V	3.066kΩ
14	4.61 mA	14.12V	3.063kΩ
16	5.25 mA	16.07V	3.055kΩ
18	5.91 mA	18.04V	3.052kΩ
20	6.58 mA	20V	3.04kΩ

Results based on Configuration (b) for 2.2 kΩ

Power Supply Setting (V)	Current Measured	Voltage Measured	Computed resistance
2	0.65 mA	1.96V	3.046kΩ
4	1.33 mA	4.06 V	3.057kΩ
6	1.98 mA	6.05V	3.056kΩ
8	2.62mA	8.62 V	3.052kΩ
10	3.29 mA	10.02V	3.046 kΩ
12	3.95 mA	12.05V	3.051kΩ
14	4.59mA	14.01 V	3.052kΩ
16	5.28mA	16.05V	3.040kΩ
18	5.91mA	17.96 V	3.039kΩ
20	6.61mA	19.94V	3.02kΩ

Which configuration can provide more accurate measurement? Why? (hint: check the internal resistances of your voltmeters and ammeters)

Data for part B have a more consistent trend in data w/ no jump in value.

5. Pick another resistor with a rated resistance value of 10 kΩ.
6. Repeat step 4. Compare and discuss the two plots you obtained.

Results based on Configuration (a) for 10 kΩ

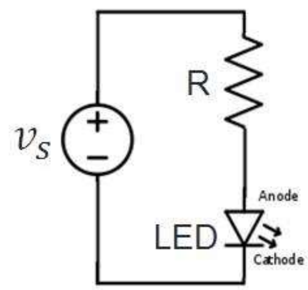
Power Supply Setting (V)	Current Measured	Voltage Measured	Computed resistance
2	0.15mA	2.03V	13.537kΩ
4	0.29mA	4.05V	13.966kΩ
6	0.42mA	6.04V	14.047kΩ
8	0.57mA	8.03V	14.088kΩ
10	0.72mA	10.07V	13.986kΩ
12	0.87mA	12.06V	13.862kΩ
14	1.02mA	14.04V	13.765kΩ
16	1.16mA	16.15V	13.922kΩ
18	1.13mA	18.11V	13.824kΩ
20	1.44mA	19.99V	13.882kΩ

Results based on Configuration (b) for 10 kΩ

Power Supply Setting (V)	Current Measured	Voltage Measured	Computed resistance
2	0.15 mA	2.04V	13.600 kΩ
4	0.29 mA	4.05V	13.966kΩ
6	0.43mA	5.98V	13.907kΩ
8	0.58mA	8.02V	13.828kΩ
10	0.73mA	10.05V	13.767kΩ
12	0.87 mA	12.07V	13.874kΩ
14	1.02 mA	14.1V	13.74kΩ
16	1.17mA	16.04V	13.786kΩ
18	1.31 mA	18.06V	13.709kΩ
20	1.46mA	19.99V	13.692kΩ

PART C

7. Construct the circuit below on your breadboard with a resistor of $1\ k\Omega$ and a Light-emitting diode (LED). A LED emits light when current flows through it. A LED has two terminal, one is named anode, the other the cathode.
   - the LED's anode should be connected to the terminal of the resistor
   - the LED's cathode should be connected to the negative terminal of the power supply



8. Set the DC power supply to the values shown in the table below (suggestion: use the voltmeter to check the output of the power supply). Measure the current in the LED and the voltages cross it. Write down your results in the table below. Plot V-I characteristic (voltage is on vertical axis) of the LED based on your results

Power Supply Setting (V)	Current Measured	Voltage Measured	Computed Resistance
1	1 µA	1.04V	1.04 kΩ
2	0.23mA	1.71V	7.435 kΩ
4	1.6 mA	1.78V	1.113 kΩ
6	3.03mA	1.81V	0.597 kΩ
8	4.45mA	1.83V	0.411 kΩ
10	5.89mA	1.85V	0.314 kΩ
12	7.3mA	1.86V	0.255 kΩ
14	8.72mA	1.88V	0.216 kΩ
18	11.73mA	1.9V	0.162 kΩ

Are the V-I graphs you obtained from steps 4 and 8 different? Explain it. Which element is linear? The resistor or the LED?

The graph for step 4-8 shows that the same linear relationship; however, the graph for step 8 is different, for there is a slight dip within the graph. Furthermore, the one value that stayed consistent through the experiments were the resistance.

Questions and conclusions

- Summarize your findings and explanations in response to the questions posed in this lab instructions.