ENGG1100 Introduction to Engineering Design

Faculty of Engineering

The Chinese University of Hong Kong

Laboratory 3: Electronic Basic

Introduction

The basic elements of electronic circuits are VOLTAGE (V), CURRENT (I) and RESISTANCE (R). Voltage is the electrical pressure that forces electrons through a conductor, current is the rate at which the charges are flowing, and resistance is the tendency of the conductor to resist the current flow. Larger resistance means the current flowing through the conductor is reduced in magnitude (not speed) (Figure-3-1). Ohm's Law shows their relationship (Figure-3.2). Figure-3.3 is enhanced to show Ohm's Law with POWER.

A functional circuit is always a closed loop; the electric current flows from the positive terminal of the power source, through the electronic components and back to the negative terminal of the power source (electrons flow in the opposite direction of current, from the negative terminal to the positive terminal)(Figure-3.4).

To form an electronic circuit, there are many connection points to connect components, power sources, etc. Soldering and Printed Circuit Board are some practical solutions (actually the solution in our project). On the other hand, breadboard is another alternative that we use in the laboratory for quick prototyping and experiments.

After learning the relationship between voltage, current and resistance, 'Kirchhoff's Voltage Law' and 'Kirchhoff's Current Law' will be introduced in the following for circuit analysis.

https://en.wikipedia.org/wiki/Ohm%27s_law
https://en.wikipedia.org/wiki/Electric_current

Objectives

By completing this laboratory session, you should know/study

1. the characteristics of voltmeter, ammeter and ohmmeter;
2. a multimeter as a voltmeter, ammeter, ohmmeter and open-short checker;
3. the design/arrangement of breadboard;
4. how to fabricate circuits with a breadboard;
5. Ohm's Law with experiments;
6. Kirchhoff's Voltage and Current Laws;

Equipment

1. One functional breadboard (Figure-3.5);
2. One disassembled breadboard (Figure-3.7 and Figure-3.8);
3. One multimeter (Figure-3.9);
4. Four 3.9k ohm resistors (Figure-3.10);
5. One DC power supply (Figure-3.11);
6. Three wires for breadboard; and

\+ Printed Lab Sheet (Appendix-1).

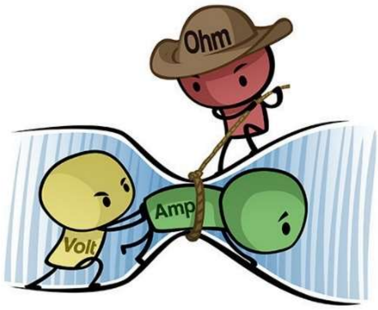


Figure-3.1: A good picture to show the relationship between voltage, current and resistance.
https://engineersforfuture.wordpress.com/2017/01/30/ohms-law/

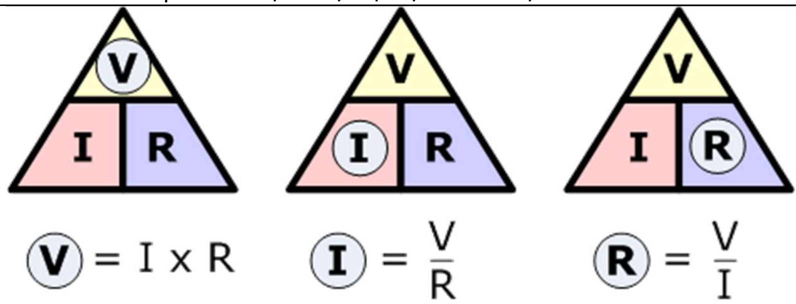


Figure-3.2: A good picture for memorizing Ohm's Law.
http://www.electronics-tutorials.ws/dccircuits/dcp_2.html

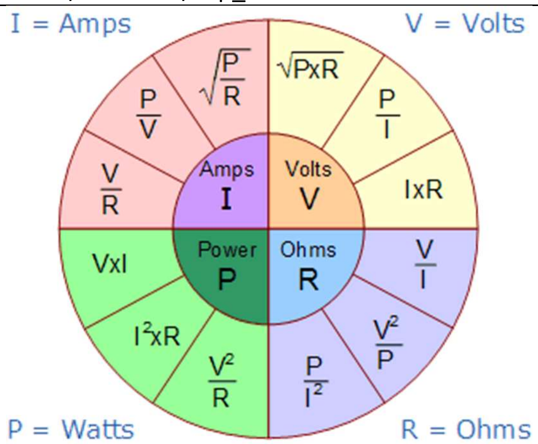


Figure-3.3: The relationship of Voltage, Current, Resistance and Power.
http://www.electronics-tutorials.ws/dccircuits/dcp_2.html

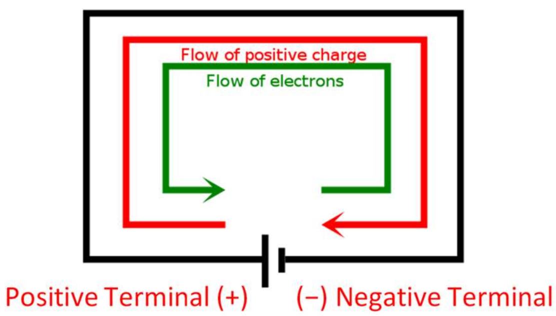


Figure-3.4: Circuit loop (Current flow and electron flow)
https://en.wikipedia.org/wiki/Electric_current#/media/File:Current_notation.svg

Experiment-3.1: Breadboard and open-short testing

Breadboard is a useful tool for forming temporary circuits as opposed to soldering. There are a lot of holes in matrix arrangement on the breadboard for component placement.
For the breadboard shown in Figure-3.5:

1. There are two/four large terminals (black, red, and other colors like green, yellow, white or blue, etc.), as shown on the left of the figure. They are not connected to the breadboard, and they are there for you to connect power or signal to the breadboard with extra wires.
2. In the matrix part, there are RED and BLACK (or blue) lines indicating the holes along the line form in ROWs and are connected together by metal at the back. (at the top and bottom of Figure-3.6).
3. Other holes between two groups of red and black lines are formed in COLUMNs and are connected together by metal. (One column is highlighted for illustration purpose at the center right of Figure-3.6.)

If you want to use breadboard to form a circuit, insert component pins (terminals) into suitable holes. Each group of holes is for the connection points in the circuit.
A disassembled breadboard is shown (in Figure-3.7 & Figure-3.8) to help you understand the backend connection patterns of the rows and columns.
It is easy to test an object with very low resistance using a multimeter in 'OPEN-SHORT testing'. We will use it to test our disassembled breadboard.

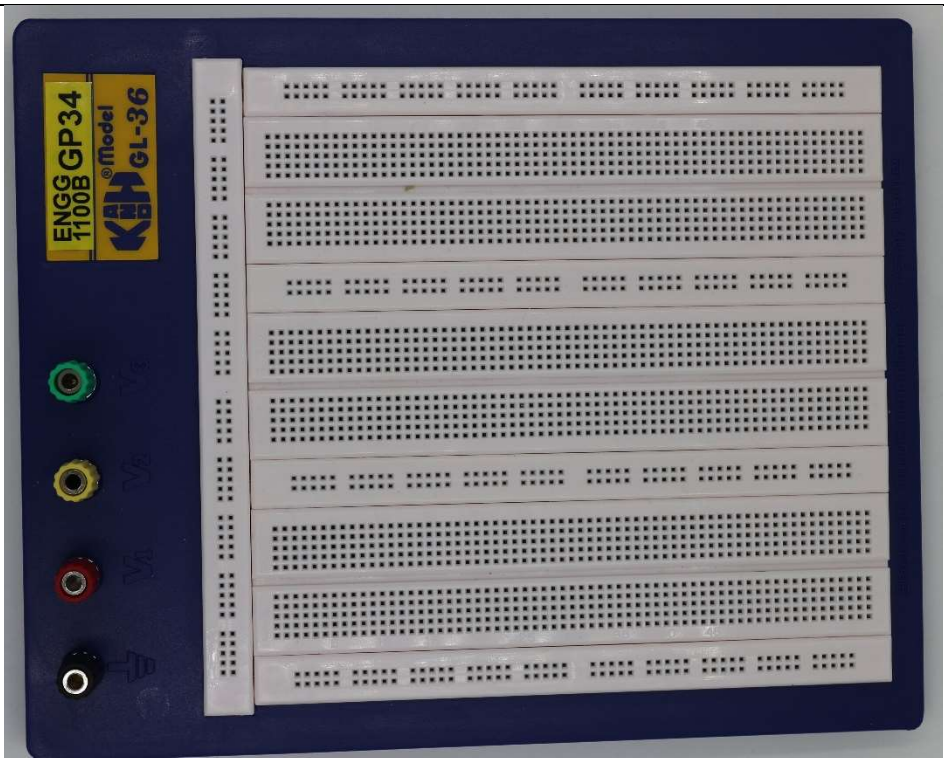


Figure-3.5: A breadboard

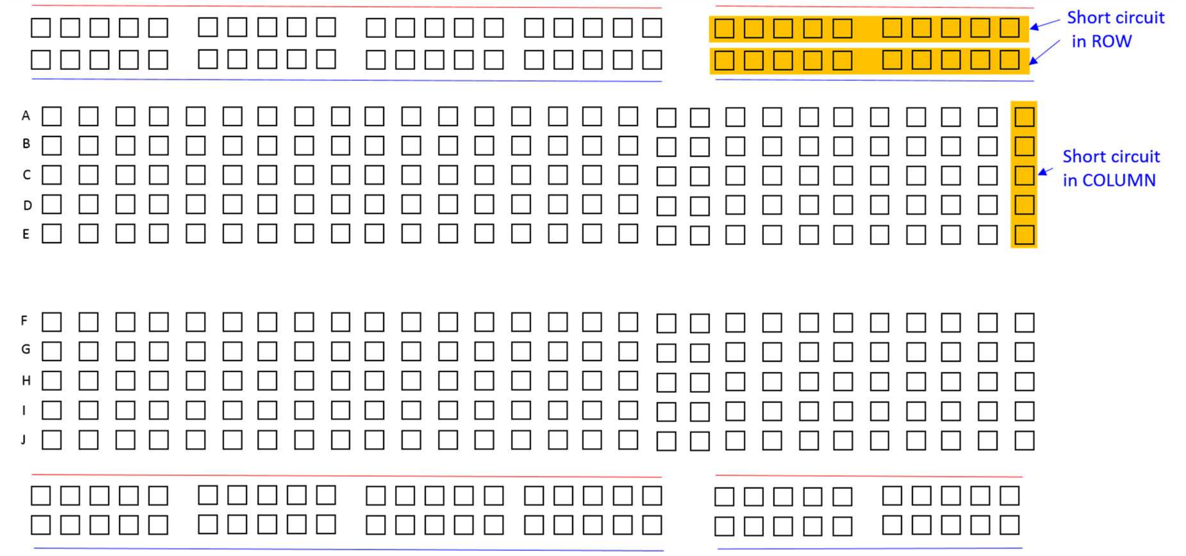


Figure-3.6: A part of breadboard

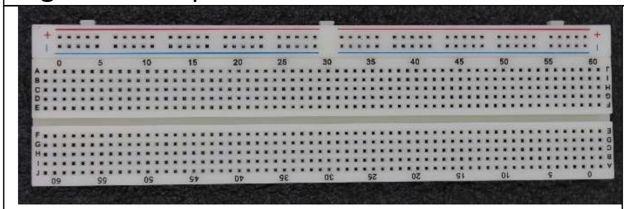


Figure-3.7: Top view of the disassembled breadboard.

Figure-3.8: Bottom view of the disassembled breadboard.

Figure-3.9: Multimeter (Note: different labs may use different models of multimeter but they shall be quite similar.)

Figure-3.10: 3.9k ohm resistors

Figure-3.11: DC Power Supply

Outcome:

1. To understand a breadboard design and internal arrangement.
2. To know how to use a multimeter for open-short testing.

Procedures

1. Insert a pair of probes (Figure-3.12) to the holes of the multimeter; RED probe to the hole with a ‘V’ mark, BLACK probe to the hole with a ‘COM’ mark. This is the same connection for i) OPEN-SHORT TEST, ii) ohmmeter and iii) voltmeter.
2. Turn ON the multimeter and <u>set to the BEEP sign’))) for OPEN-SHORT test</u>. The screen of the multimeter should show ‘OL’ (overload).
3. Connect two probe pins together; you should hear a ‘beep’ sound from the multimeter and the screen should show a small value with ohm. It means that two probe pins are <u>shorted</u> and a very small resistance between the two probes is being measured. Ask tutors for help if you cannot hear the ‘beep’ sound. Answer the questions in the Lab Sheet.
4. Measure the disassembled breadboard with ‘open-short test’ and complete the Lab Sheet by indicating the groups of connected holes (draw some lines to show which holes are connected together). **Hints: The metal stripes in the breadboard from bottom view can help you to understand breadboard design.**
5. Compare the functional and disassembled breadboards to understand the arrangement of holes on the breadboard, including the holes along the printed red and black lines on the breadboard.

Figure-3.12: The probes for multimeter.

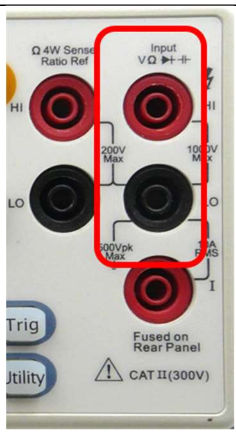
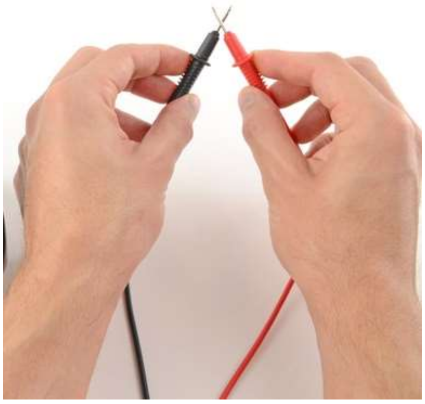


Figure-3.13: Insert the probes to the correct holes V (RED) and COM (BLACK)

 Figure-3.14: Shorting two probe pins together.	

Experiment-3.2: Ohm's law

Ohm's Law states the relationship among VOLTAGE, CURRENT and RESISTANCE. The circuit for the experiment is very simple (Figure-3.15); only a power source (voltage) and a resistor (resistance).

The power source (voltage source in this circuit) provides power and it has polarity. BLACK terminal is the reference point (0V, GND) and RED terminal is positive (higher voltage than the black terminal). Resistor has resistance and it is a non-polarized component.

All equipment and components have terminals (blue dots in Figure-3.16), we have to join them with some wires or solder them on a Printed Circuit Board (PCB). In this experiment, we will form the circuit with a breadboard step by step.

Before doing measurement, we should know the characteristics of voltmeter, ammeter and ohmmeter. Voltmeter is used to measure the voltage difference across two points (Figure-3.17 and 3.18). To prevent the current flows through the voltmeter to affect the measurement result, the internal resistance of voltmeter is very high (>10 Mohm). As a result, the leakage current flowing through the voltmeter is µA (micro-ampere) or nA (nano-ampere). Ammeter is used to measure the current flowing through a path, so it has to be placed in series with the path (Figure-3.19). Since it should not disrupt the original current flow in the path, ammeter behaves like a thick wire (i.e., very good conductor with very low internal resistance). Ohmmeter is used to measure the resistance of a component. It has a power source inside, and the internal resistor in ohmmeter can be changed for different ranges of resistance measurements. The ohmmeter will be damaged if it is used in a circuit that is powered.

Set the power supply with current limit to prevent from shorting the power supply output with high current accidentally. As shown in Figure-3.21, turn the current knob of the power supply 45 degrees clockwise from zero to set the current limit to around 500 mA.

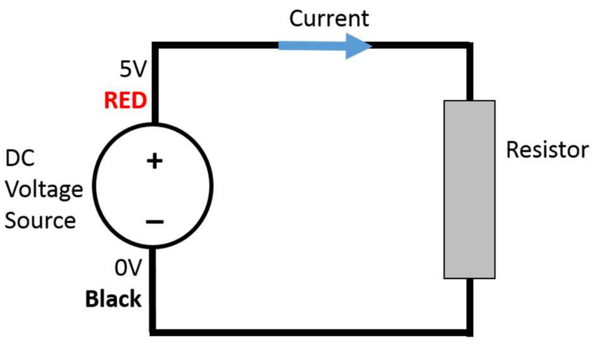


Figure-3-15: The circuit for this experiment.

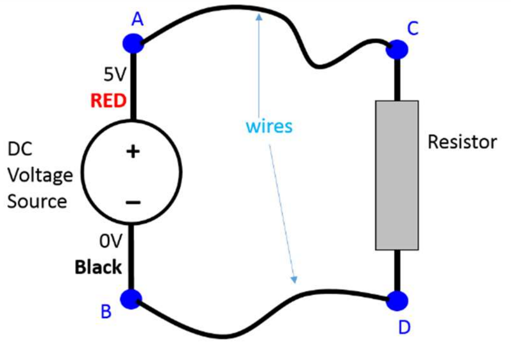


Figure-3.16: The circuit is marked with nodes.

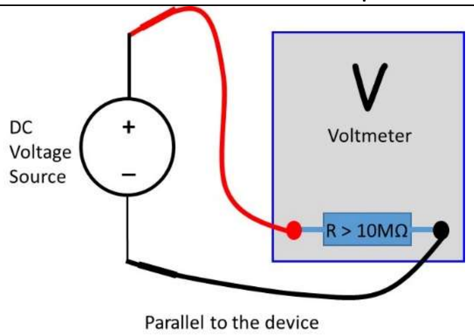


Figure-3.17: Measuring voltage of a voltage source

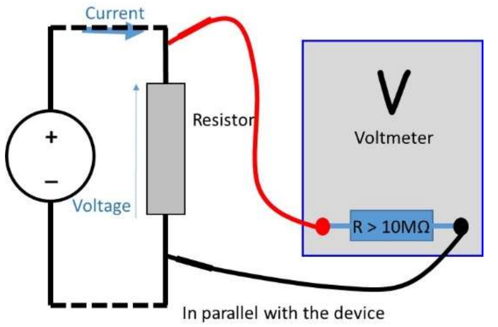


Figure-3.18: Measuring voltage across a device with a voltmeter

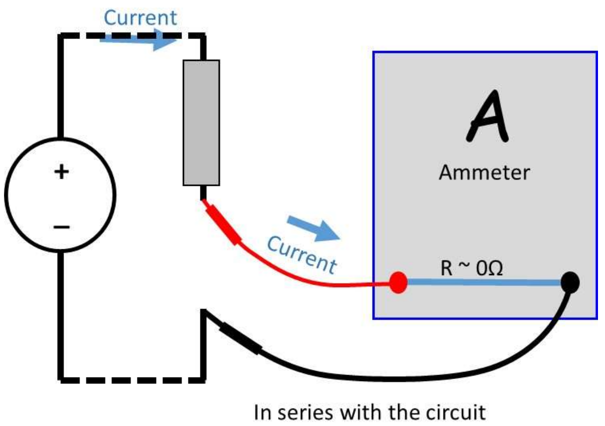


Figure-3.19: Place ammeter in series the circuit

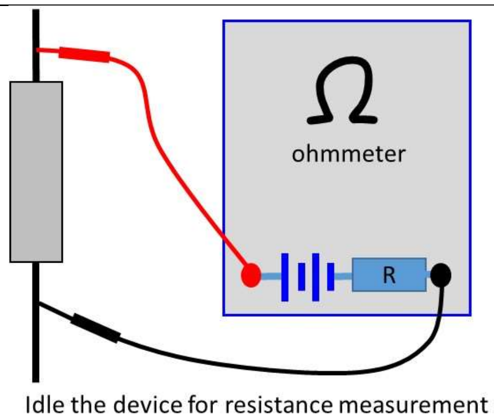


Figure-3.20: Idle the component (i.e., power supply is turned off) during resistance measurement.

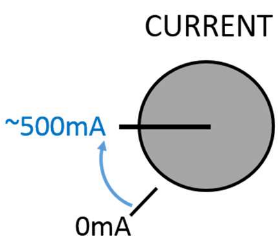


Figure-3.21: Set the power supply with 500mA current limit.

Outcome:

1. To measure RESISTANCE, VOLTAGE and CURRENT with multimeter.
2. To build a circuit with a breadboard.
3. To know the connection of voltmeter, ammeter and ohmmeter.
4. To verify Ohm's Law with experiment.

Procedures

1. Disconnect from the power supply. Turn ON the power supply. Set the voltage to 5V. And set the output current limit to around 500 mA as shown in Figure-3.21. Power OFF the power supply with the POWER switch.
2. Connect the power supply outputs POSITIVE (+) and NEGATIVE (-) to the breadboard with cables or wires. Insert one 3.9k ohm resistor to the breadboard as shown in Figure-3.22. With reference to Figure-3.16, there should be four groups (A, B, C and D) of holes on the breadboard (Refer to your measured results in experiment-3.1 procedure-4).
3. Connect the groups of holes (nodes) A and C together, and B and D together with wires to form two new nodes AC and BD (Figure-3.23). The formed circuit on the breadboard is the same as the one in Figure-3.16.
4. <u>Set the multimeter for DC voltage measurement</u>: Insert the RED probe to the hole marked 'V'. Insert the BLACK probe into the hole marked 'COM'. Set the function to $V_{\overline{---}}^{\,}{}_{DC}$ sign.
5. Power ON the power supply. Measure the voltage difference **across the power supply** and **across the resistor** as shown in Figure-3.24 and Figure-3.25. (Refer to experiment-3.1 procedure-1 for voltmeter setting.)
6. Power OFF the power supply. <u>Set the multimeter to DC ammeter</u>: Insert RED probe to 'µA, mA, A' hole. Insert BLACK probe to 'COM' hole. And set the function to $I_{\overline{---}}^{\,}{}_{DC}$ sign. **<u>Power OFF the power supply before modifying your circuit is very important. The components will be damaged in case of any short circuit or incorrect connection.</u>**
7. Replace the wire that is connecting node-A and node-C with an ammeter. Measure the current flowing through the ammeter. **Note that you should RESTORE the previous original connection(s) after each current measurement!**
8. Calculate the resistance of the circuit with Ohm's Law.
9. Power OFF the power supply. Take out the resistor from the breadboard and measure it with ohmmeter (set the multimeter function to Ω) as shown in Figure-3.20.
10. Calculate the power consumed by the resistor.
11. Conclude your measured current and calculated current. Why are they the same?

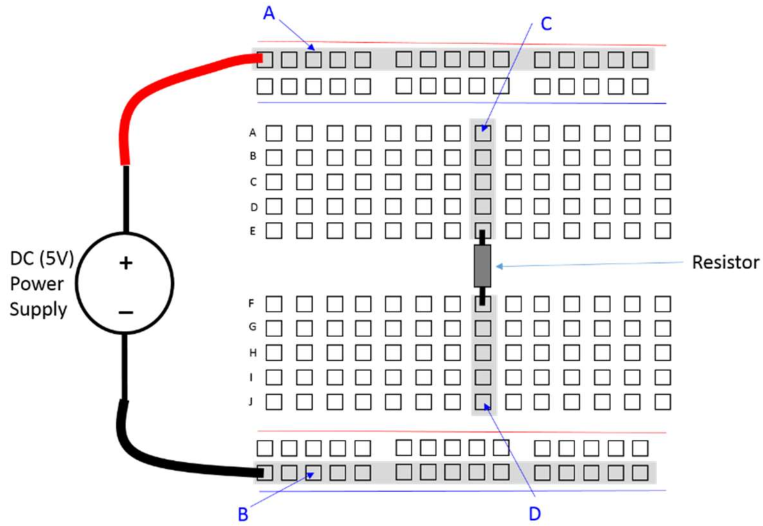


Figure-3.22: Place the power supply and a resistor on the breadboard

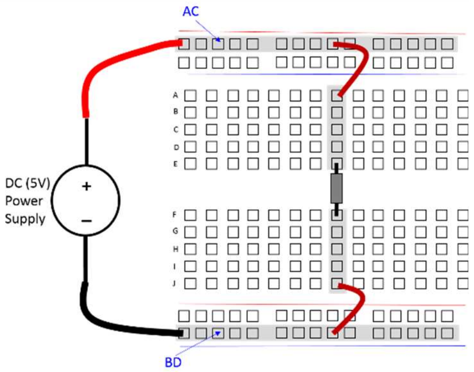


Figure-3.23: Build Figure-3.16 circuit on the breadboard.

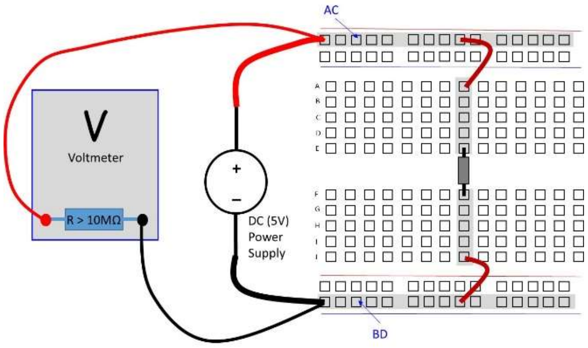


Figure-3.24: Measure the voltage across the power supply voltage.

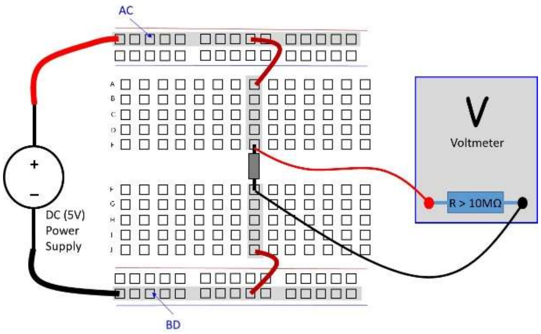


Figure-3.25: Measure the voltage across the resistor

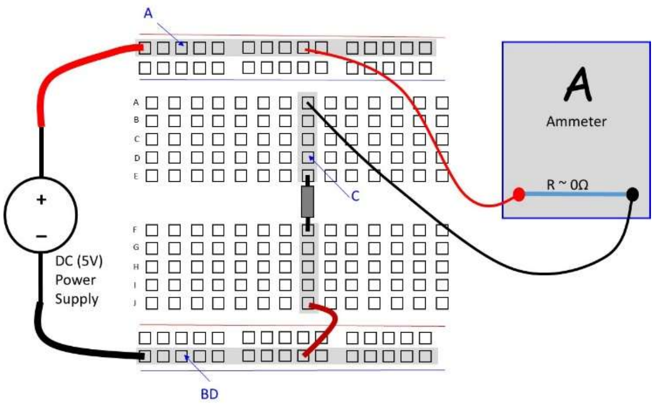


Figure-3.26: Measure the current of the circuit

Experiment-3.3: Kirchhoff's Voltage Law

'**The sum of all voltages around a loop is equal to zero**' is the definition of Kirchhoff's Voltage Law. The circuit of this experiment is simple. It contains one power supply and two resistors.

Students are assumed to know how to set the power supply with current limit, to use power supply with correct procedure, to set the multimeter as a voltmeter, ammeter and ohmmeter, and to use them for voltage, current and resistance measurements. Please review experiment-3.2 if you are not completely clear about them.

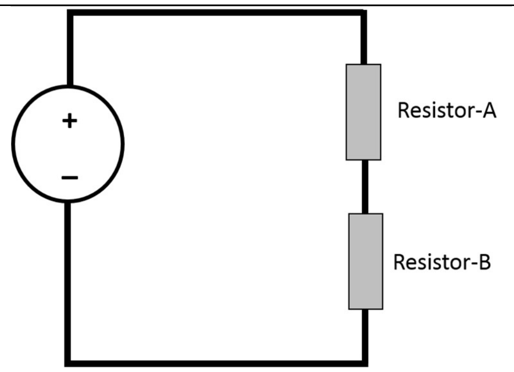


Figure-3.27: The circuit for Kirchhoff's Voltage Law

Outcome:

1. To verify Kirchhoff's Voltage Law with experiment.

Procedures

1. Power OFF the power supply. Build the circuit in Figure-3.27 on the breadboard as shown in Figure-3.28.
2. Power ON the power supply. Measure the voltages across the power supply, Resistor-A and Resistor-B.
3. Conclude your measured results with Kirchhoff's Voltage Law.

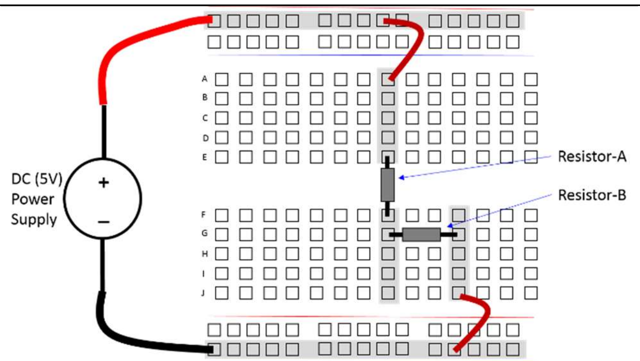


Figure-3.28: The component placements for Kirchhoff's Voltage Law test

Experiment-3.4: Kirchhoff's Current Law

'At any node (junction) in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node' is the definition of Kirchhoff's Current Law. The circuit of this experiment is simple, too. It contains one power supply, three resistors and their joined node-X.

Students are assumed to know how to set the power supply with current limit, to use power supply with correct procedure, to set the multimeter as a voltmeter, ammeter and ohmmeter, and to use them for voltage, current and resistance measurements. Please review experiment-3.2 if you are not completely clear about them.

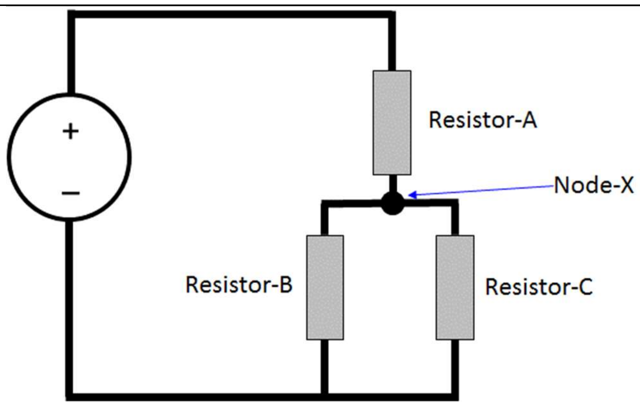


Figure-3.29: The circuit for Kirchhoff's Current Law

Outcome:

1. To verify Kirchhoff's Current Law with experiment.

Procedures

1. Power OFF the power supply. Build the circuit in Figure-3.29 on the breadboard as shown in Figure-3.30.
2. Power ON the power supply. Measure the currents through Resistor-A, Resistor-B and Resistor-C. **Note that you should RESTORE the previous original connection(s) after each current measurement!**
3. Conclude your measured results with Kirchhoff's Current Law.

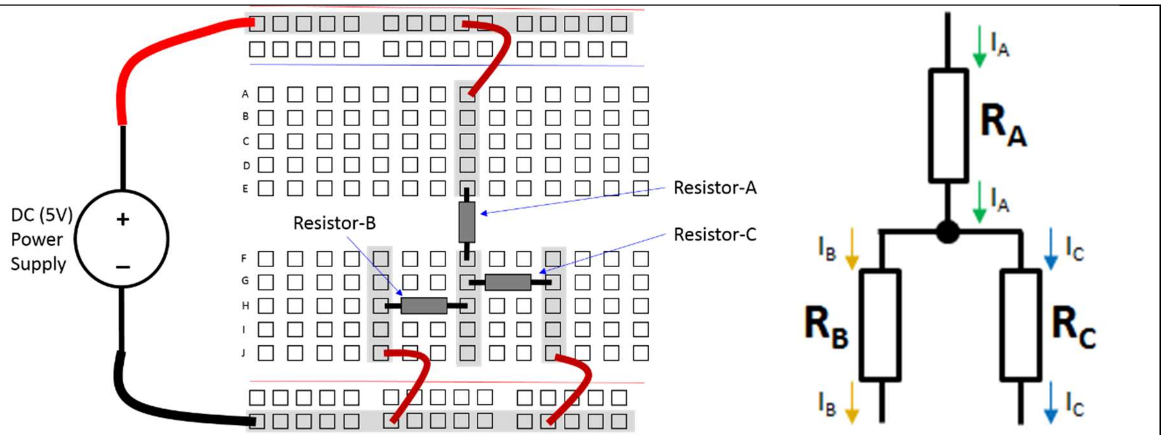


Figure-3.30: The component placements for Kirchhoff's current law test

Group Number: ____________________________

Student Name 1: ___________________________ **Student ID 1:** ____________________

Student Name 2: ___________________________ **Student ID 2:** ____________________

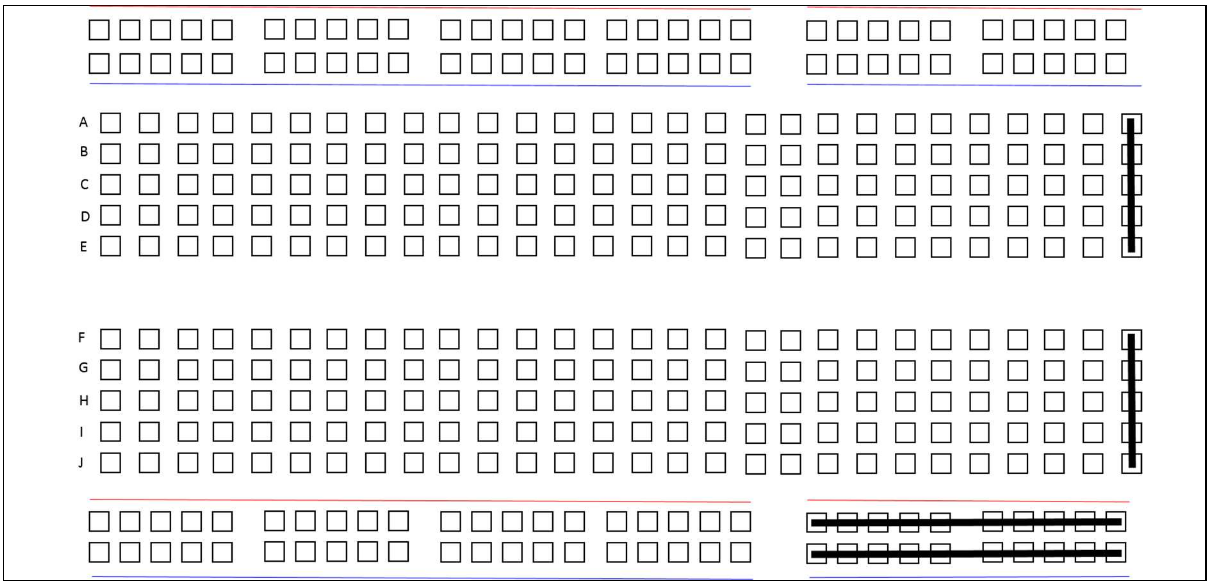
Appendix-1: Lab Sheet

Experiment-3.1

(1) The meaning of hearing a 'beep' sound from the multimeter in open-short mode measurement: ________________.

(2) The meaning of no 'beep' sound from the multimeter in open-short mode measurement: ________________.

(3) The arrangement of the breadboard.



(4) Conclusion:

Experiment-3.2

Procedure-5:

Voltage across the power supply: _____________.

Voltage across the resistor: ______________.

Procedure-7:

Current through the resistor: ____________.

Procedure-8:

Calculated resistance: _________________.

Procedure-9:

Measured resistance: _______________.

Procedure-10:

Calculated power consumed on the resistor: _______________.

Procedure-11:

Conclusion:

Group Number: ___________________________

Student Name 1: __________________________ **Student ID 1:** ____________________

Student Name 2: __________________________ **Student ID 2:** ____________________

Experiment-3.3

Procedure-2:

Voltage across the power supply: _______________.

Voltage across Resistor-A: _______________.

Voltage across Resistor-B: _______________.

Procedure-3:

Conclusion:

Experiment-3.4

Procedure-2:

Current through Resistor-A: _______________.

Current through Resistor-B: _______________.

Current through Resistor-C: _______________.

Procedure-3:

Conclusion: