1 Introduction to the Electrical Laboratory

Objective

This lab exercise serves as an introduction to the electrical laboratory. The fundamental circuit laws are introduces and practiced using a breadboard and analysis instruments.

Equipment

- DC Power Supply
- Digital Multimeter (DMM)
- Breadboard
- $1k\Omega$ to $10k\Omega$ Resistors
- Jumper Wires

Theory

An important principle in electrical circuits is Ohm's law. Ohm's law defines the relationship between Voltage, Current, and Resistance, as shown in Equation 1. If two variables are known, the third variable can be solved for.

$$V = I \times R \tag{1}$$

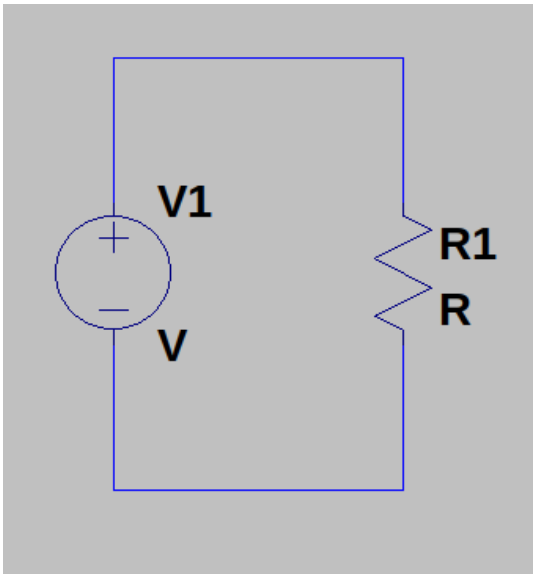

Figure 1: Circuit diagram with a voltage source (left) and resistor (right)

Where V represents the voltage potential in volts, I represents the current in Amps, and R represents the resistance in ohms (Ω). Note that ohms are commonly written as the greek letter Omega, Ω.

Another important principle is the Voltage Divider Rule (VDR). VDR defines how voltage drops over multiple resistors and how an output voltage can be created as a fraction of the input voltage, as shown in Equation 2. Figure 2 shows the voltage division circuit with V_{out} measured between the two series resistors.

$$V_{out} = \frac{R_2}{R_1 + R_2} \times V_{in} \tag{2}$$

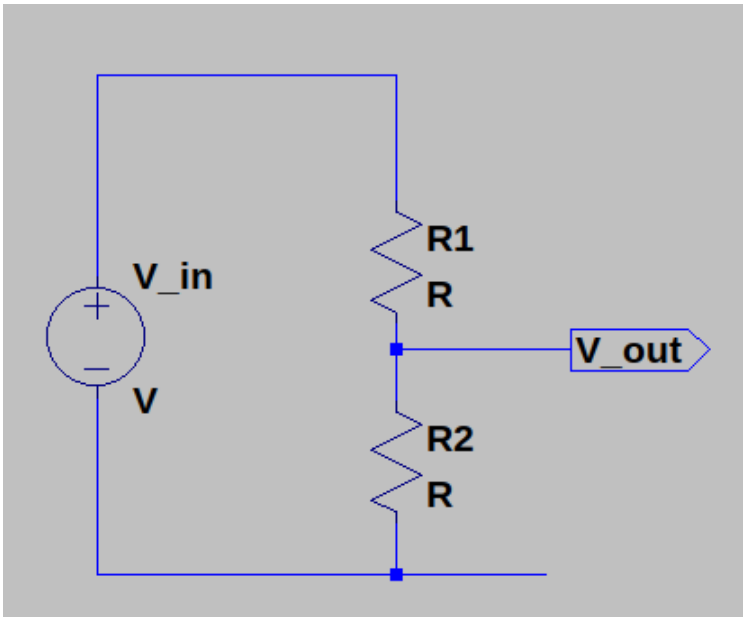

Figure 2: Circuit diagram of voltage divider rule with 2 in-series resistors

Procedure

1.1 Electrical Laboratory Safety

The electrical laboratory hosts a variety of hazards associated with electricity. When working in the electrical lab, a student must maintain awareness of the hazards present and address any concerns following the best practices outlined below. The effects of electric shock can range from a minor tingling, to burns, to cardiac arrest and death. Electricity may also produce sparks which pose a fire risk to nearby combustible items.

The following list summarizes the safety topics covered in this section, explained with more detail in subsequent paragraphs.

- No food or drink
- Shock/Electrocution hazard

- Bench setup - surge protector
- Emergency power shutoff
- Electrical fire hazards and A/B/C fire extinguisher
- Personal protective equipment - safety glasses for soldering/wire snipping

Food and drink are not allowed inside the laboratory. Liquid drinks pose and electrical shock risk when spilled. Generally, most drinks will conduct electricity and interact with circuitry, forming short circuits or causing other undesired effects.

Each laboratory is equipped with an emergency shut-off switch located near the entrance of the room. The shut-off switch should be used in the event of a serious electrical fault. Students must be aware of the evacuation plan in the event of a fire present or fire alarm. Before evacuating, ensure that all equipment is shut off. Only class A/B/C dry powder fire extinguishers and CO2 fire extinguishers are rated for putting out electrical fires. The fires are extinguished by replacing the available oxygen present with non-flammable powder or gas.

Each lab bench is equipped with a surge protector outlet strip which will automatically trip under conditions that exceed its current limit. After every lab session, all equipment should be unplugged from the outlets.

Personal protective equipment (PPE) is the term for the set of equipment used to protect a lab user from hazards. In the electrical lab, safety glasses must be used when soldering to protect the eyes from splashes of molten solder. Safety glasses are also worn when clipping wire leads and small components. Clipped wire ends can shoot from the wire clippers with surprising speed and pose a serious threat to one's eyes.

1.1.1 Best Practices

- No food or drink in the laboratory
- Inspect equipment for visible damage or frayed wires and report to the instructor with any concerns
- Keep the bench clear of unnecessary items
- Keep equipment and components organized at the bench
- Return all equipment to its storage location when finished
- Ensure that yourself or lab partners are clear of exposed contacts before powering on any equipment

1.2 Power Supply and Metering

All electrical circuits require a source of electricity. In the lab, direct current (DC) electricity is sourced from a DC power supply. Many laboratory DC power supplies will have variable configurations that can limit the amount of voltage or current can be delivered to the circuit. DC refers to the constant voltage supplied and subsequent unidirectional flow of electrical current. Alternating current (AC) sources supply voltage that changes periodically at a fixed frequency, subsequently changing the direction of electrical current every half-cycle.

Locate a DC power supply and bring to bench. **Examine the power supply and record the make and model to be included in the lab report.**

Another common test instrument is the digital multimeter (DMM). The DMM is a device that has functionality of measuring multiple aspects of an electrical circuit. The DMM includes an ohmmeter for measuring resistance, a voltmeter for measuring voltage, and an ammeter for measuring current.

Locate a DMM and bring back to bench. **Examine the DMM and record the make and model for the lab report.**

Turn on the DMM and use the interface to change between the different operating modes: voltmeter, ohmmeter, and ammeter.

Many DMMs will automatically adjust the measurement scale depending on the measured values. However, some DMM will require that the scale is adjusted manually. When performing a measurement with the DMM, use your best judgement (along with theory) to select the scale that will represent the measurement. For example, if the expected measured voltage is 5 Volts, then the scale should be adjusted up to 10 Volts so the measurement can accurately be represented.

1.3 Breadboard Circuit

Breadboards are plastic boards with holes for connecting components to quickly build and prototype circuits. The holes on the breadboard form connections as shown in Figure 3, representing the electrical connections formed by the internal metal bus. On most breadboards, the outer buses are commonly used for power delivery and label "+" or "-" for positive and negative voltage, respectively.

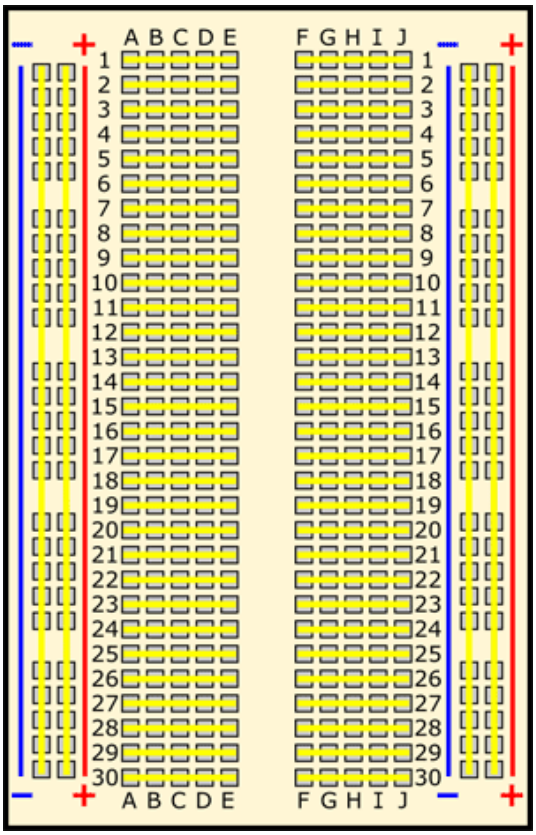

Figure 3: Breadboard inner connections. Source: `https://www.sciencebuddies.org/image-credit?id=7326`

The following exercises will walk through the operation of the DMM for analyzing resistance, voltage, and current in a circuit.

1.3.1 Voltmeter Operation

The voltmeter is used to measure the potential difference between two terminals and measured in Volts.

1. Acquire the following items: DMM, DC power supply.
2. Turn on power supply and set to 5 Volts.
3. Change DMM to voltmeter operation, and set scale to AUTO or 1-Volt range.
4. Carefully connect the negative power supply terminal with the negative DMM probe, then connect the positive terminal to the positive DMM probe.
5. **Record the voltage displayed on the DC power supply.**
6. **Record the voltage displayed on the DMM voltmeter.**
7. Disconnect the probes from both terminal. Shut down the power supply.

1.3.2 Ohmmeter Operation

The ohmmeter is a device that measures the resistance across a component. Resistors are electrical components the resist the flow of electricity. Through-hole resistors are cylindrical components with metal leads from either end. They are indicated as through-hole because they are fitted to circuits by feeding the leads through a hole where the connection is formed. These types of resistors are marked with color codes that describe the rated resistance value of the resistor. Use the following figure to identify resistor values by their color code.

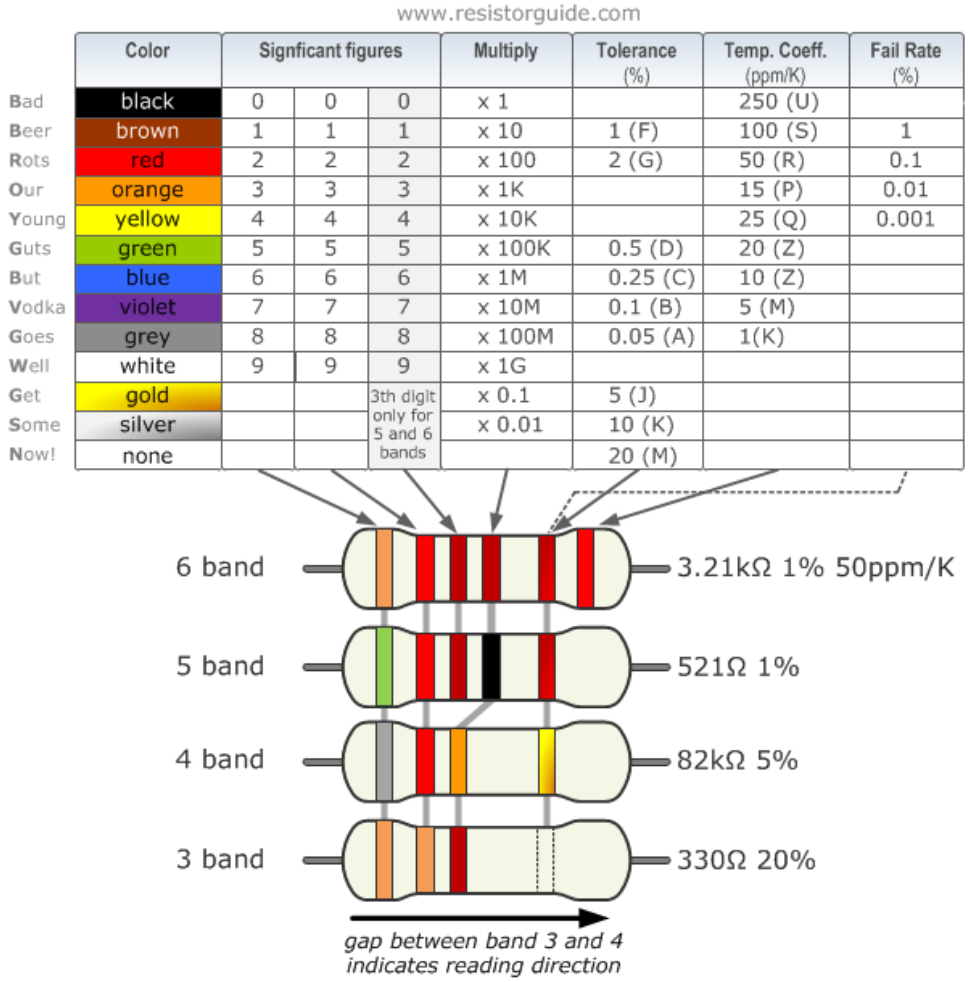

Figure 4: Source: `https://eepower.com/resistor-guide/resistor-standards-and-codes/resistor-color-code/#`

1. Acquire the following items: DMM, breadboard, 2 resistors rated between $1k\Omega$ to $10k\Omega$, jumper wires

2. Verify the resistance using the color-coded bands. **Record the rated resistance**

value.

3. Connect 1 resistor to the breadboard.
4. Jump the positive bus to one end of the resistor, and jump the negative bus to the other end.
5. Select the ohmmeter mode of the DMM.
6. Use the DMM probes and connect each to either end of the resistor.
7. **Record the measured resistance value displayed on the DMM.**
8. Connect the second resistor in-series with the first resistor, as shown in Figure 2.
9. Use the DMM probes and measure the total resistance over both resistors, **record the result.**

1.3.3 Ammeter Operation

CAUTION: Ammeters are equipped with single-use fuses that open the circuit in the event of current overdraw. **NEVER ALLOW THE AMMETER TO SHORT-CIRCUIT A POWER SUPPLY.**

Ammeters are used to measure current through a circuit. They must be connected in-series with the circuit element to be measured. Current must flow through the ammeter for it to be measured. For this reason, special attention should be given to avoid putting large amounts of current through the ammeter.

1. Acquire the following items: DMM, breadboard, 2 resistors rated between $1k\Omega$ to $10k\Omega$, jumper wires
2. Change the DMM to ammeter mode.
3. Configure the DC power supply to about 5 volts.
4. Using the same breadboard and resistor from the previous exercise, add jumper wire connection from the positive bus to the positive terminal of the DC power supply.
5. Replace the negative bus connection with a connection one end of the DMM ammeter. This puts the ammeter in-series with the resistor. Use the circuit diagram in Figure 5 for reference.
6. The current will begin to flow when the other end of the DMM ammeter is connected to the negative terminal of the DC power supply.
7. **Record the measured current.**

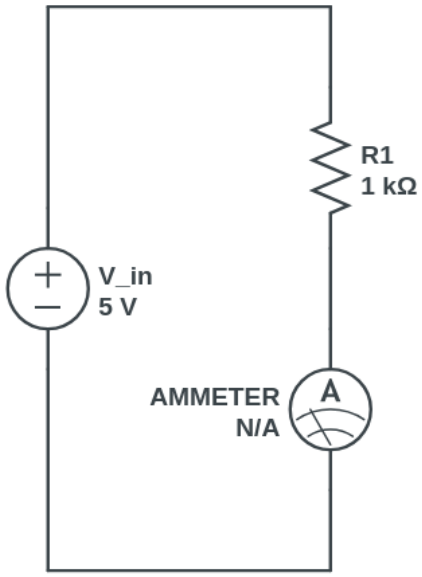

Figure 5: Ammeter operation

1.3.4 Voltage Divider Circuit

The voltage divider circuit demonstrates how series resistors affect the voltage over the entire circuit, and produce an output voltage that is a fraction of the input.

1. Construct the voltage divider circuit as shown in Figure 6. Use the resistors from the previous exercises. **Record the resistor values for R_1 and R_2.**
2. Configure the DC power supply to 5 Volts and power the circuit.
3. Use the DMM as a voltmeter and measure the voltage drop over R_2. **Record the result.**

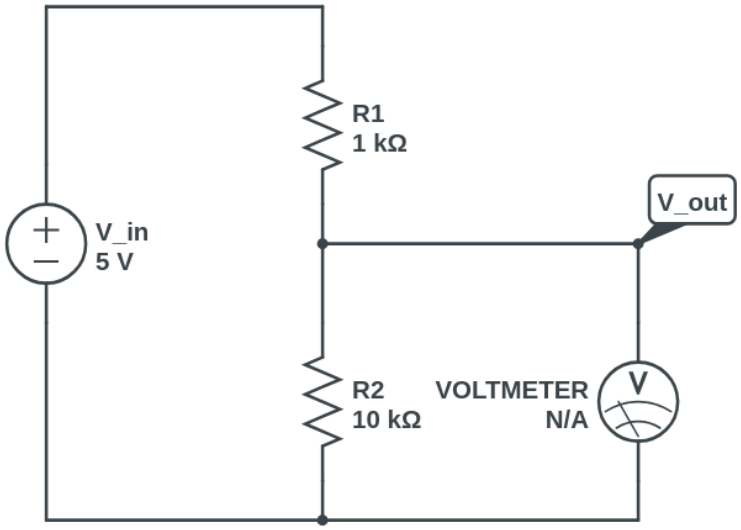

Figure 6: Voltmeter opeation for VDR

REMINDER: Make sure to shut down all equipment.. when finished and return items to their storage locations.

Questions

1. Where is the shut-off switch located in your laboratory? Record the building and room number.
2. Choose three of the best practices for electrical lab safety and extrapolate on why they should be followed.
3. What effect to total resistance was observed when adding the second resistor in-series with the first resistor?
4. Using Ohm's law, find the expected current based on the rated resistance and the DC power supply reported voltage. Compare this result to the measured current.
5. Using Ohm's law, find the expected current based on the measured resistance and the measured voltage. Compare this result to the measure current.
6. Use voltage divider rule to calculate the expected value of V_{out} based on the measured resistance and measured input voltage. Compare this result to the measured value of V_{out}.