General Guidelines:
- Record data and observations carefully for each lab measurement and experiment.
- You must obtain Lab. Assistant's signature on each page of your lab data before leaving the lab. Signed pages must be included in the report.
- Make sure you understand the experiment procedure before executing it. You must obtain enough data to complete the various parts of the procedure.
- Request Lab Assistant's help to verify your circuit before turning on the power supplies and generators.
- Please operate the equipment in a reasonable manner. Avoid power supply short circuits. Report failures to the Lab. Assistant.

<table>
<thead>
<tr>
<th>Parts:</th>
<th>Equipment:</th>
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<tbody>
<tr>
<td>- Resistors as needed</td>
<td>- Breadboard</td>
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<tr>
<td></td>
<td>- Digital Multimeter (DMM)</td>
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<td></td>
<td>- Frequency Counter</td>
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<td>- Signal Generator</td>
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<td>- Oscilloscope</td>
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Objective:
The objective of this session is to verify the application of Kirchoff’s laws to simple circuits through laboratory measurements.

Tool Description:

**Breadboards / Prototyping boards (Proto-boards)**
Solderless breadboards are the most typical option to prototype electronic circuits. A prototype is an initial real implementation of a circuit. It is used to evaluate a design and test actual performance under certain test conditions. Breadboards usually consist of a rectangular plastic enclosure. On the surface of a breadboard, there are many holes for plugging in components (refer to Fig.1).

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![Figure 1. Typical Breadboard](Image)
The breadboard consists of metal strips running underneath the enclosure as shown in Fig. 2. These strips are used as interconnection points (nodes) to build circuits. They can be accessed through the appropriate holes.

![Fig. 2. Breadboard Internal Connections](image)

The horizontal strips shown in Fig. 2 are often used for power supply voltages (i.e. V+, GND) and the vertical strips are for the components.

**Design and Simulation:**
1. Design 2 voltage divider and 2 current divider circuits using a 6-volt source and:
   a. Two different resistors.
   b. Two equal resistors.

   Make sure the resistor values selected in (a, b) and their associated currents correspond to power levels below the maximum resistor power rating (1/4 W typical).

2. Design a non-series parallel (bridge) circuit similar to the circuit in Fig. P1.39 of the Textbook. Substitute the power supply with 6-volts and the resistors as follows: 3 _ 2.2 K_, 6 _ 4.7 K_ and 4 _ 3.3 K_. Select values of R₁ and R₂ such that \( i > 0 \) mA. Find R₁ and R₂ to obtain \( i = 0 \) mA. Is it possible to find more than 1 set of values \{ R₁, R₂ \} that satisfy this condition?

In this laboratory experiment, you will build a total of five circuits.

Using the values of the voltmeter and ammeter internal resistance that you measured in Lab 1, use PSpice to simulate the four circuits and compare the results to the theoretical and measured values. Do not forget to draw the circuits with the nodes labeled as they were coded in PSpice.

**Procedure:**

**I. Experiment - Voltage Divider**
1. Obtain resistors for your designed values from the parts bin. If you do not find the exact values, recalculate the (theoretical) associated currents and voltages and include them in your report.

2. Measure the resistor values using the multimeter as an ohmmeter.

3. Build the voltage divider circuit using the resistors on a lab breadboard.

4. Set the power supply to 6V. Use the voltmeter to ensure the proper setting.

5. Using the voltmeter, measure the voltage across each resistor. Record these values, as always, and verify Kirchhoff's Voltage Law (KVL).

6. Comment on the accuracy of measurements made considering the internal resistance of the voltmeter.

7. Create a table presenting theoretical and measured voltages along with percent error. Consider whether your theoretical values for the voltages across each resistor should include the effect of the voltmeter internal resistance. **Important Note:** When you are calculating percent error, you should avoid cases in which the theoretical value is zero.
since the percent error is meaningless. To calculate percent error between theoretical and experimental verification of KVL, use the source voltage as the reference. For example, in the measurements made in this section, the theoretical value (and measured value!) for the voltage across the supply is 6V. The measured value is the same as the theoretical value because you used the voltmeter to set the power supply voltage to 6V. To obtain the KVL measured voltage, you can add the voltage across resistors. Compare with 6V.

8. Repeat the procedure for the equal-value resistors voltage divider.

9. Perform step 8 for 2 resistors of 10 MΩ each. In this case, do you need to include the effect of the voltmeter?

II. Experiment - Current Divider

1. Obtain resistors for your designed values from the parts bin. If you do not find the exact values, recalculate the (theoretical) associated currents and voltages and include them in your report.

2. Measure the resistor values using the multimeter as an ohmmeter.

3. Build the current divider circuit using the resistors on a lab breadboard.

4. Set the power supply to 6V. Use the voltmeter to ensure the proper setting.

5. Measure the voltage across the resistors. Record this value.

6. Configure the multimeter to measure current. Remember that this requires two things: Remove the terminal of the red probe from the voltage/resistance measuring receptacle and insert it in the current measuring receptacle on the front panel of the multimeter. Then press the DC current button, also on the front panel of the multimeter.

7. Measure the current through the 6V source. Remember that you have to break the circuit and insert the ammeter in series with the 6V source to allow the current to flow through the ammeter.

8. Measure the current through each resistor.


10. Repeat the procedure for the equal-value resistors divider circuit.

11. Repeat the procedure for the equal-value resistor current divider with 2 resistors of 10_ each. NOTE: Before you perform the measurements for this current divider, place a 10K_ resistor in series with the current divider in order to avoid exceeding the resistors power rating. Make sure you record the voltages across the series 10K_ resistor and the voltage of the current divider. Verify Kirchhoff's Voltage Law (KVL).

12. Comment on the accuracy of the current measurements made (consider the internal resistance of the ammeter).
III. Experiment – Bridge Circuit

1. Obtain resistors close to your designed values from the parts bin. If you do not find the exact values, recalculate the (theoretical) associated currents and voltages and include them in your report.

2. Measure the resistor values using the multimeter as an ohmmeter.

3. Build the bridge circuit using the resistors on a lab breadboard.

4. Set the power supply to 6V. Use the voltmeter to ensure the proper setting.

5. Measure the voltage across each resistor. Record these values.

6. Configure the multimeter to measure current. Remember that this requires two things: Remove the terminal of the red probe from the voltage/resistance measuring receptacle and insert it in the current measuring receptacle on the front panel of the multimeter. Then press the DC current button, also on the front panel of the multimeter.

7. Measure the current i. Remember that you have to break the circuit and insert the ammeter in series with the 3.3K to allow the current to flow through the ammeter.


9. Repeat the procedure for all the designed values for the bridge circuit.