If you have ANY concerns about a lab procedure, contact your instructor before proceeding!

Series and Parallel Circuits
ECE 2100 Circuit Analysis Laboratory
28 May 2021

Equipment and Supplies

<table>
<thead>
<tr>
<th>Item</th>
<th>Supplier and Order Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breadboard</td>
<td>Jameco #2134993 (includes jumper kit not needed here)</td>
</tr>
<tr>
<td>LTspice® program</td>
<td>Available <a href="#">here</a></td>
</tr>
<tr>
<td>2.2kΩ 1/4W 5% resistor</td>
<td>From Jameco #691104</td>
</tr>
<tr>
<td>10kΩ 1/4W 5% resistor</td>
<td>From Jameco #690945</td>
</tr>
<tr>
<td>3.5 digit digital multimeter</td>
<td>Jameco #2230029</td>
</tr>
<tr>
<td>Minigrabber to Stackable Banana Test Leads 24 AWG</td>
<td>Jameco #198731</td>
</tr>
<tr>
<td>9V battery holder with switch and hookup wires</td>
<td>Jameco #2128067</td>
</tr>
<tr>
<td>9V battery</td>
<td></td>
</tr>
</tbody>
</table>

Learning Outcomes

Students will:
1. Use a breadboard to construct simple electric circuits;
2. Compute, simulate, and measure DC voltages and currents in series and parallel resistive electrical circuits;
3. Compute the error between hand analysis, experimental, and simulation results; and
4. Compute and measure the equivalent resistance of series and parallel-connected resistors.
Pre-Laboratory Assignment (STEPS 1-8)

1. Review the ECE 2100 Circuit Analysis Laboratory: Safety and Rules document.

2. Consider the circuit of Figure 1. Note that the voltage source Vdum has no effect on the circuit; it is used to measure Is=I(Vdum) in LTspice®.

   Compute the voltages and current of Table 1.
   Use the ‘hand analysis’ column of Table 1 to report your results.

3. Simulate the circuit of Figure 1 in LTspice® using a transient analysis. The terminals ‘A’ and ‘B’ were drawn using Draw->Circle and the Req arrow was created using Draw->Line. ‘Req’ is text. Nodes ‘1’, ‘2’, and ‘3’ were labelled using the node tool. Use the ‘simulation’ column of Table 1 to report your results.

4. Compute and record the equivalent resistance ‘seen’ by the source in Figure 1.

5. What is V4 in terms of the node voltages?

6. Consider the circuit of Figure 2. Compute the voltages and currents of Table 2.
   Use the ‘hand analysis’ column of Table 2 to report your results.

7. Compute and record the equivalent resistance ‘seen’ by the source in Figure 2.

8. Simulate the circuit of Figure 2 in LTspice® using a transient analysis.
   Use the ‘simulation’ column of Table 2 to report your results.
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![Series Circuit Diagram]

Figure 1. Series circuit

<table>
<thead>
<tr>
<th></th>
<th>hand analysis</th>
<th>simulation</th>
<th>% error (compared to hand analysis)</th>
<th>experimental</th>
<th>% error (compared to hand analysis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V(1) (node voltage)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V(2) (node voltage)</td>
<td></td>
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<tr>
<td>V(3) (node voltage)</td>
<td></td>
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</tr>
<tr>
<td>V4</td>
<td></td>
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<tr>
<td>V5</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Is</td>
<td></td>
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<td></td>
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</tbody>
</table>

Table 1. Series circuit data
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Figure 2. Parallel circuit

<table>
<thead>
<tr>
<th></th>
<th>hand analysis</th>
<th>simulation</th>
<th>% error (compared to hand analysis)</th>
<th>experimental</th>
<th>% error (compared to hand analysis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_d$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V(1)$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_2$</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Table 2. Parallel circuit data
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Procedure

**Series Circuit**

1. Put on your safety glasses and clear your work area.

2. **ENSURE THAT THE BATTERY HOLDER POWER SWITCH IS OFF.**

3. Construct the circuit of Figure 1 as shown in Figure 3.

4. **BEFORE TURNING ON BATTERY HOLDER POWER** remove the battery holder leads.
   
   Measure and record the resistance $R_{eq}$ between terminals A and B. Verify that the resistance between the power rails is about 12.2kΩ.

   If the resistance is correct reinsert battery holder leads and place DMM in a voltage measurement mode. *Do not proceed until the resistance is correct.*

5. Turn on battery holder power.
   
   Measure the voltages of Table 1 and put results in that table in the ‘experimental column’. **Turn off battery holder power.**

6. **ENSURE THAT BATTERY HOLDER POWER SWITCH IS OFF.**

7. Place DMM in a current measurement mode and insert into the circuit as shown in Figure 4. **REMEMBER THAT AN AMMETER IS A SHORT. IT MUST BE IN SERIES AS SHOWN.**

8. **DOUBLE CHECK YOUR WIRING** and then turn on battery holder power.
   
   Measure the current of Table 1 and put result in that table in the ‘experimental column’. **Turn off battery holder power.**
   
   Return DMM to voltage measurement mode.
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Figure 3. Circuit of Figure 1 constructed using a breadboard. Voltage V4 is being measured. The orange jumper wire will be replaced with an ammeter to measure Is in Figure 4. Your resistor values are different.

Figure 4. Measuring Is using an ammeter. The ammeter is placed IN SERIES. Your resistor values are different.
Parallel Circuit

9. ENSURE THAT THE BATTERY HOLDER POWER SWITCH IS OFF.

10. Construct the circuit of Figure 2 as shown in Figure 5.

11. BEFORE TURNING ON BATTERY HOLDER POWER remove the battery holder leads.

Measure and record the resistance $R_{eq}$ between terminals A and B.
Verify that the resistance between the power rails is about 1.8kΩ.

If the resistance is correct reinsert battery holder leads and place DMM in a voltage measurement mode. *Do not proceed until the resistance is correct.*

12. Place DMM in a voltage measurement mode.
    Turn on battery holder power.
    Measure the voltages of Table 2 and put results in that table in the ‘experimental column’.
    **Turn off battery holder power.**

13. ENSURE THAT BATTERY HOLDER POWER SWITCH IS OFF.

14. Place DMM in a current measurement mode and insert into the circuit as shown in Figure 6 to measure $I_1$. **REMEMBER THAT AN AMMETER IS A SHORT.** IT MUST BE IN SERIES AS SHOWN. The ammeter REPLACES the orange jumper.

15. Turn on battery holder power.
    Measure $I_1$.
    Place result in Table 2.
    **Turn off battery holder power.**

    **Return DMM to voltage measurement mode.**
    Replace the orange jumper.

16. ENSURE THAT BATTERY HOLDER POWER SWITCH IS OFF.

17. Place DMM in a current measurement mode and insert into the circuit to measure $I_2$. **REMEMBER THAT AN AMMETER IS A SHORT.** IT MUST BE IN SERIES. Thus the yellow jumper is replaced with the ammeter.

18. Turn on battery holder power.
    Measure $I_2$.
    Place result in Table 2.
    **Turn off battery holder power.**

    **Return DMM to voltage measurement mode.**
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Figure 5. Circuit of Figure 2 constructed using a breadboard. Voltage $V_s$ is being measured. Note that the lead of one resistor is used to probe the circuit ground. Since only one lead is being used that resistor has no effect on the circuit. The orange jumper wire will be replaced with an ammeter to measure $I_s$ in Figure 6. Your resistor values are different.

Figure 6. Measuring $I_1$ using an ammeter. Measure $I_2$ by reinserting the orange jumper and replacing the yellow jumper with the ammeter in a similar manner. Your resistor values are different.
19. Disassemble the circuit and stow away components. Be sure that your DMM is in a voltage measurement mode and is OFF.

20. Ensure that the battery holder leads and battery terminals will not be inadvertently connected together by wires, metallic tools, etc. during storage.

21. Wash your hands when done.

**Analysis**

1. Why is the resistance expected to be about 12kΩ in Procedure 4?

2. Why is the resistance expected to be about 1.8kΩ in Procedure 11?

3. Using your measured values of Vs, R1, and R2, redo Table 1 and explain changes in the error percentages.

4. Using your measured values of Vs, R1, and R2, redo Table 2 and explain changes in the error percentages.

**Credits and Copyright**

Adapted from material developed by current and former ECE faculty, including J. Kelemen and F. Severance. Modified based on input from ECE laboratory instructors, particularly M. El Yabroudi, S. Hajian, and S. Masihi. S. Durbin contributed to the development of this laboratory.

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