Series and Parallel Circuits  
ECE 2100 Circuit Analysis Laboratory  
5 October 2020

Equipment and Supplies

| LTspice® | Available here |

Learning Outcomes

Students will
1. Find and compare voltages, currents, and power from hand analyses and simulations of series and parallel-connected components.
2. Find and compare equivalent resistances from hand analyses and simulations of series and parallel-connected components.

Pre-Laboratory Assignment (STEPS 1-8)

Note: Typically, a laboratory safety quiz is completed at the beginning of the semester. Since this experiment is simulation only, the quiz will be completed at a later date. Lab power other than outlets for the computer and monitor will be switched off.

1. Bring a USB flash drive to store your work. Alternatively, you can store your files to a remote directory.

COVID-19 Safety

2. Complete the COVID screening questionnaire here PRIOR to coming to campus. If you are not able to come to campus as a result of this screening process, a makeup lab will be arranged.
3. Review the Bronco Student Pledge here.
4. You will be required to wipe down your keyboard, monitor, mouse, work area, and any contacted surfaces using a disinfecting wipe at the start and end of lab.
5. WASH YOUR HANDS immediately after lab.

Series and Parallel-Connected Elements

- Recall that circuit elements in SERIES share one node EXCLUSIVELY. Thus, the current THROUGH series-connected elements is the same.

- Recall that circuit elements in PARALLEL share BOTH nodes. Thus, the voltage ACROSS parallel-connected elements is the same.

6. Consider the series voltage divider circuit of Figure 1a.

   a. Derive an equation for voltage $V_{R1}$ in terms of $R_1, R_2, R_3, R_4,$ and $V_s$.  
   This is a voltage divider equation.  
   Repeat for voltages $V_{R2}, V_{R3},$ and $V_{R4}$.  

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Find these voltages for the specific values indicated in the Figure. Also find node voltages V(1), V(2), V(3), and V(4). 
**Use Table 1 to report these calculated results.**

b. Derive an equation for the ratio of \( V_s / I_s \) in terms of \( R_1, R_2, R_3, \) and \( R_4. \) This is the *equivalent resistance* \( R_{eq} \) ‘seen’ by the source \( V_s. \) Find this resistance for the specific values indicated in the Figure. 
**Use Table 1 to report this calculated result.**

7. Test Consider the series voltage divider circuit of Figure 1b.

a. Derive an equation for voltage \( V_{R1} \) in terms of \( R_1, R_2, \) and \( V_s. \) This is a voltage divider equation. Repeat for voltage \( V_{R2}. \)

Find these voltages for the specific values indicated in the Figure. Also find node voltages V(1) and V(2). 
**Use Table 2 to report these calculated results.**

b. Find the ratio of \( V_s / I_s \) in terms of \( R_1 \) and \( R_2. \) This is the *equivalent resistance* ‘seen’ \( R_{eq} \) by the source \( V_s. \) Find this resistance for the specific values indicated in the Figure. 
**Use Table 2 to present this calculated result.**

8. Consider the combination series/parallel circuit of Figure 2.

a. Derive an equation for current \( I_2 \) in terms of \( R_2, R_3, \) and \( I_s. \) This is a current divider equation. Repeat for \( I_3 \) in terms of \( R_2, R_3, \) and \( I_s. \)

b. Find these currents for the specific values indicated in the Figure. Also find node voltages V(1) and V(2). 
**Use Table 3 to report these calculated results.**

c. Derive a formula for the total resistance \( R_{eq} \) “seen by” \( V_s \) in terms of \( R_1, R_2, \) and \( R_3. \) Find this resistance for the specific values indicated in the Figure. 
**Use Table 3 to present this calculated result.**

d. Derive a formula for the current \( I_s \) in terms of \( R_1, R_2, \) and \( R_3, \) and \( V_s. \) Find this current for the specific values indicated in the Figure. 
**Use Table 3 to present this calculated result.**
Figure 1. Series circuits
<table>
<thead>
<tr>
<th></th>
<th>Calculated</th>
<th>Simulated</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{R1}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{R2}$</td>
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<tr>
<td>$V_{R3}$</td>
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<tr>
<td>$V_{R4}$</td>
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<tr>
<td>V(1)</td>
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<tr>
<td>V(2)</td>
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<td>V(3)</td>
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<td>V(4)</td>
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<td></td>
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<tr>
<td>$R_{eq}$</td>
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</table>

Table 1. Results for circuit of Figure 1(a)

<table>
<thead>
<tr>
<th></th>
<th>Calculated</th>
<th>Simulated</th>
<th>% Error</th>
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</thead>
<tbody>
<tr>
<td>$V_{R1}$</td>
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<tr>
<td>$V_{R2}$</td>
<td></td>
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<tr>
<td>V(1)</td>
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<tr>
<td>V(2)</td>
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<td></td>
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<tr>
<td>$R_{eq}$</td>
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</table>

Table 2. Results for circuit of Figure 1(b)
Figure 2. Combination series/parallel circuit

<table>
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<tbody>
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<tr>
<td>$I_3$</td>
<td></td>
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<tr>
<td>$V(1)$</td>
<td></td>
<td></td>
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<tr>
<td>$V(2)$</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>$R_{eq}$</td>
<td></td>
<td></td>
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<tr>
<td>$I_s$</td>
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</table>

Table 3. Results for circuit of Figure 2.
Procedures

1. Maintain social distancing during lab.

2. **Wipe down your keyboard, monitor, mouse, and work area with the provided disinfecting wipe.**

Part One

3. Use a transient analysis to simulate the circuit of Figure 1(a).
   Find all quantities of Table 1.
   For the percent error, use your calculated value as the reference.
   To find $R_{eq}$ plot $V_s/I_s$.

4. Change the analysis type to ‘DC Transfer’ with Output: V(4) and Source: Vs.
   Verify that running the simulation gives ‘\texttt{vs#Input\_impedance:}’ which is $R_{eq}$!
   ‘\texttt{Transfer\_function:}’ is the ratio of V(4) to $V_s$.

5. **Part Two**

6. Repeat steps 1-2 for Figure 1(b) and Table 2.
   Use V(2) as the `Output` for the ‘DC Transfer’ analysis.

Part 3

7. Repeat steps 1-2 for Figure 2 and Table 3.
   Use V(2) as the `Output` for the ‘DC Transfer’ analysis.

Clean-Up

3. Do not forget your USB stick.

4. **Wipe down your keyboard, monitor, mouse, work area, and any other contacted surfaces with the provided disinfecting wipe.**

5. **Wash your hands after lab.**

Analysis

1. Compute the power of each element of Figure 2. Check with LTspice®. Put results in a table and compute the error between each result using your calculated values as the reference. Is the conservation of energy principle satisfied?

2. Do the results of Table 2 satisfy KVL? Explain.

3. Do the results of Table 3 satisfy KCL? Explain.

4. Draw a circuit that has five resistors and a voltage source where none of the elements are in
series or parallel but **all** of the elements conduct a current.

**Credits and Copyright**

Adapted from material developed by current and former ECE faculty, including Professor Joseph Kelemen and Dr. Frank Severance. Simin Masihi and Masoud Panahi provided helpful feedback that was incorporated into this lab.

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