Superposition and Thevenin's Theorem

ECE 2100 Circuit Analysis Laboratory
version 7 October 2021

Equipment and Supplies

variable DC voltage sources
digital multimeter
breadboard
resistors (1/4W) 1kΩ 5.6kΩ (2) 10kΩ (2)
variable resistor

Pre-Laboratory Assignment (STEPS 1-7)

SUPERPOSITION THEOREM

1. Consider the circuit of Figure 1. Using a hand analysis, find node voltage 3 (with respect to ground of course) for three cases:

   a. V1=5V and V2=0V;

   b. V1=0V and V2=10V;

   c. V1=5V and V2=10V.

   Verify the superposition theorem using your results from steps a, b, and c.
   Enter results into Table 1 "analysis" column.

2. Repeat pre-laboratory step 1 using LTspice®.
   Enter results into Table 1 "simulated" column.
   Compare simulation results to your hand analysis results. They must closely agree.

THEVENIN'S THEOREM

3. Consider the circuit of Figure 2. Use nodal analysis and LTspice® to find V_{AB}=V(out) for R_L=5.6kΩ and R_L=10kΩ. Enter results into Table 2 "Nodal Analysis" section.

4. Find the Thevenin equivalent circuit "looking into" nodes A and B; that is, find the Thevenin equivalent of the circuit "seen" by R_L using hand analysis. Be sure to draw the Thevenin equivalent circuit in your notebook.

5. Find the Thevenin equivalent circuit using LTspice® as follows:

   a. Set R_L=100MegΩ; note that R_L is now effectively an open circuit.

b. Find V_{TH} by using a .op simulation command.

c. Find R_{TH} by using a .tf simulation command as shown.
   R_{TH} is the value listed as the circuit "output_impedance."

6. Use your Thevenin equivalent circuit to find V_{AB} for R_L=5.6kΩ and R_L=10kΩ by hand analysis. Enter results into Table 2 "Thevenin's Theorem" section.

7. Draw your Thevenin equivalent circuit in LTspice® and connect R_L=5.6kΩ then R_L=10kΩ. Thus your circuit will consist of V_{TH} in series with R_{TH} and R_L. Find V_{AB} using LTspice® and enter into Table 2 "Thevenin's Theorem" section.

8. Your nodal analysis and Thevenin's Theorem results must match.

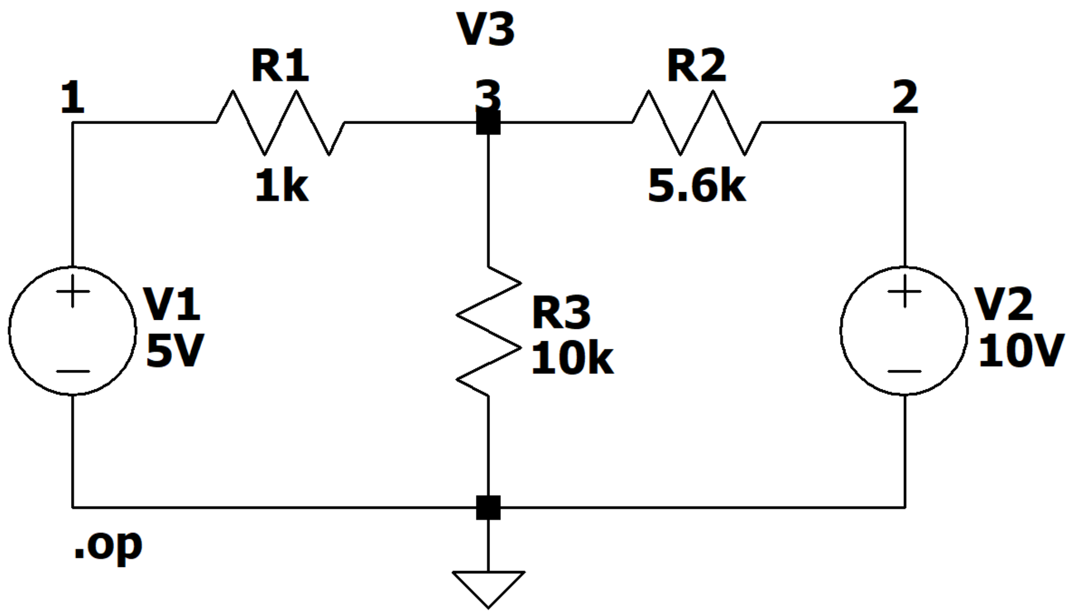

Figure 1. Circuit with Two Sources

case	analysis V_3	simulated V_3	experimental V_3	% error (simulated vs. analysis)	% error (experimental vs. analysis)
a					
b					
c					

Table 1. Results Table

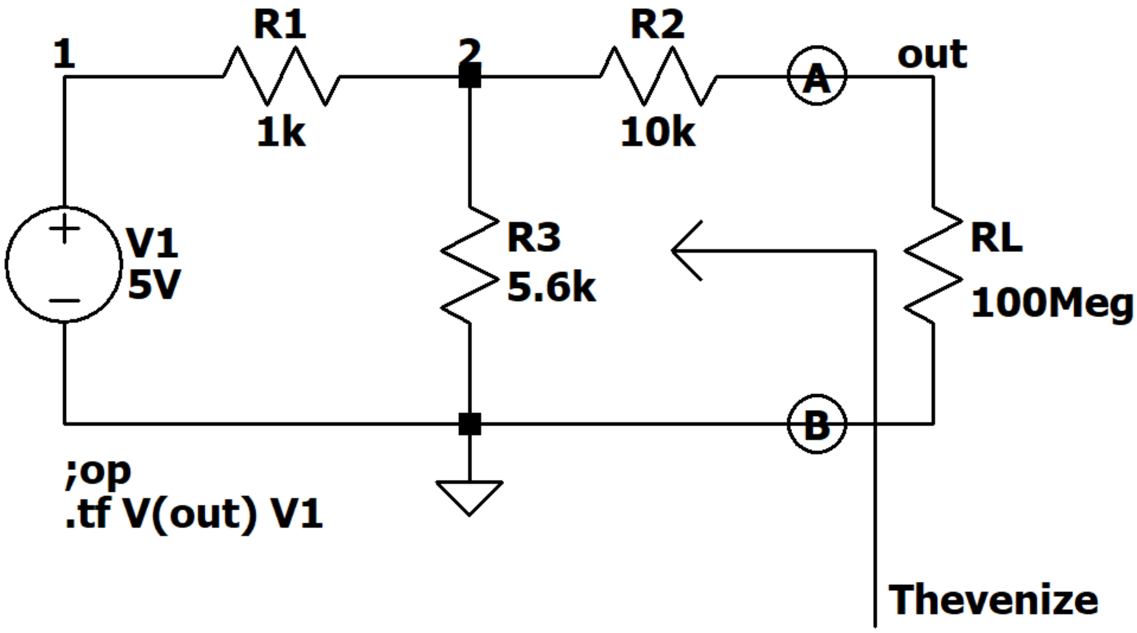

Figure 2. Resistive Circuit

R_L	**analysis V_{AB}**	**simulated V_{AB}**	**experimental V_{AB}**	**% error (simulated vs. analysis)**	**% error (experimental vs. analysis)**
Nodal Analysis					
5.6kΩ					
10kΩ					
Thevenin's Theorem					
5.6kΩ					
10kΩ					

Table 2. Results Table

Procedures

SUPERPOSITION THEOREM

1. Construct the circuit of Figure 1. Use current-limited supplies for V1 and V2 and set current limits as close to 1mA as possible.

2. Measure node voltage V(3) for the three cases of Table 1 and enter results.

3. Turn off power supply.

4. Compute experimental errors. Do not proceed unless your measurements closely match hand analysis and simulation results.

5. Explain how the work of laboratory procedure step 2 provides an experimental example of the superposition theorem.

THEVENIN'S THEOREM

Measurement of R_{TH} and V_{TH}

6. Construct the circuit of Figure 2 without V1 and R_L. Place a short where V1 would be connected. Measure the resistance between terminals A and B. This is R_{TH}.
   Compare to your pre-lab result.
   Return DMM to voltage measurement mode.

7. Remove short and connect V1: use a current-limited supply for V1 and set current limit to as close to 1mA as possible.

8. Enable power supply output and measure V_{AB}. This is V_{TH}. Compare to your pre-lab result.

9. Turn off power supply.

10. Do not proceed unless your measurements of R_{TH} and V_{TH} closely match hand analysis and simulation results.

Direct Measurement of V(out)

11. Measure V_{AB} for the Table 2 R_L values and enter results in the "Nodal Analysis" section.

12. Turn off power supply.

13. Compute experimental errors. Do not proceed unless your measurements closely match hand analysis and simulation results.

Measurement of V(out) Using Thevenin Equivalent Circuit

14. Construct the Thevenin equivalent of the circuit of Figure 2 using a variable resistor to

realize R_{TH}. Measure and record V_{AB} for each value of R_L in Table 2 "Thevenin's Theorem" section.

15. Turn off power supply.

16. Do not proceed unless your measurements closely match hand analysis and simulation results.

17. Explain how the results of laboratory procedures step 11 provide an experimental example of Thevenin's theorem.

Analysis

1. For a **fixed** R_{TH} and variable R_L maximum power is transferred from V_{TH} when $R_L=R_{TH}$. Use the circuit of Figure 2 and LTspice® to show that the converse is not true; that is, show that maximum power is not transferred from V_{TH} when $R_{TH}=R_L$ for a **fixed** R_L and variable R_{TH}. What value of R_{TH} results in maximum power transfer if R_L is fixed?

Credits and Copyright

Adapted from material developed by current and former ECE faculty, including Professor Joseph Kelemen and Frank L. Severance. Thanks to Juan Ramirez for improvement to this lab.