EE 220/220L Circuits I (Fall 2019)
Laboratory 7 Thevenin and Norton Circuits

Background

The goal of this lab is to demonstrate the validity of Thevenin's and Norton's theorems. These theorems are useful for analyzing linear circuits by reducing them to a single independent source and resistor with respect to a pair of terminals where loads can be changed in and out.

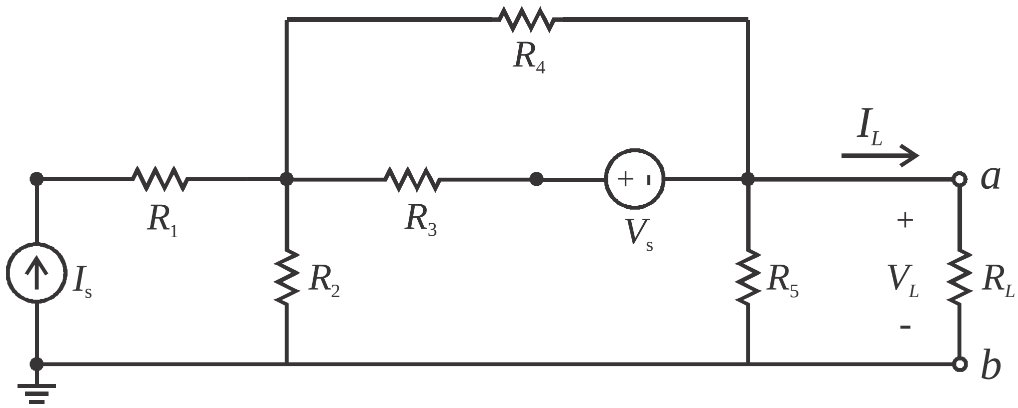

Figure 1 Circuit layout

Preliminary

We are interested in determining the power dissipated by a load resistor R_L connected between terminals *a* and *b* in the circuit shown above.

1) For $R_L = 100\ \Omega$, use circuit analysis (e.g., nodal or mesh analysis) to find the voltage V_L across and current I_L through the load resistor R_L in Figure 1. Given: $V_s = 20$ V, $I_s = 30$ mA, $R_1 = 220\ \Omega$, $R_2 = 470\ \Omega$, $R_3 = 680\ \Omega$, $R_4 = 330\ \Omega$, and $R_5 = 1.5\ \text{k}\Omega$. Then, calculate the power P_L dissipated by the load resistor. <u>SHOW ALL WORK IN LOGBOOK!</u>
2) Verify your results in step 1) using PSpice. Attach the PSpice circuit with voltage and current outputs displayed in the logbook with text showing EE 220L-xx, Lab #7, *your name*, *date*, & <u>description</u> of work.
3) Next, for the circuit shown in Fig. 1, remove R_L and calculate the equivalent resistance seen at terminals *a*-*b*. This equivalent resistance is the Thevenin (R_T) and Norton (R_N) equivalent resistances. Then, calculate the open circuit voltage $V_{oc} = V_T$ across terminals *a*-*b*. By source transformation, the Norton equivalent current $I_N = V_T / R_T$ [**<u>OR</u>** Calculate the short circuit current $I_{sc} = I_N$ flowing from terminal *a* to *b*. The Thevenin equivalent voltage $V_T = I_N * R_N$.] Draw fully labeled Thevenin and Norton equivalent circuits.
4) Verify your results in step 3) using PSpice. To get V_{oc}, replace R_L with an open circuit, simulate, display voltages, and print. [Hint: Delete R_L or set R_L equal to a large resistance, e.g., 10 GΩ.] To get I_{sc}, replace R_L with a short circuit, simulate, display currents, and print. [Hint: Set R_L equal to a very small resistance, e.g., 0.1 mΩ.] The equivalent resistance $R_{\text{eq}} = R_T = R_N = V_{oc} / I_{sc}$. Attach the PSpice circuits with voltage and current outputs displayed in logbook with text showing EE 220L-xx, Lab #7, *your name*, *date*, & <u>description</u>s of work.
5) Connect $R_L = 100\ \Omega$ to **both** the Thevenin <u>and</u> Norton equivalent circuits. Then, calculate V_L, I_L, and P_L for **both** equivalent circuits. Compare with results of parts 1) & 2).
6) Have the lab instructor or TA sign-off on your preliminary before you begin the experiment.

Experiment

1) After measuring the resistors (including R_L), build the circuit shown in Figure 1. Remember to set the current and voltage sources with the power supply connected to the complete circuit. Measure and record V_S, I_S, V_L, and I_L. Then, calculate the power P_L dissipated by the load resistor. Record all results (including resistor and source values) in a table.
2) Next, experimentally determine the Thevenin and Norton equivalent circuits for the circuit shown in Figure 1. **Remember the current source must be checked and re-set whenever the circuit is changed** (e.g., R_L is removed or changed).
   a) Remove R_L, then measure and record the open circuit voltage $V_{oc,\text{meas}}$ (i.e., $V_{T,\text{meas}}$) across terminals *a-b*.
   b) Remove R_L and replace with short circuit (i.e., ammeter). Measure and record short circuit current $I_{sc,\text{meas}}$ (i.e., $I_{N,\text{meas}}$) from terminal *a* to *b*. Compute $R_{\text{eq,meas1}} = V_{oc,\text{meas}} / I_{sc,\text{meas}}$.
   c) Measure and record the equivalent resistance $R_{\text{eq,meas2}}$ (i.e., $R_T = R_N$) with ohmmeter. [Hint: Disconnect the voltage source & replace with a wire (i.e., short circuit) and disconnect the current source (i.e., open circuit).] How does $R_{\text{eq,meas1}}$ compare with $R_{\text{eq,meas2}}$?
   d) Record analytic and experimental results for V_T, I_N, and $R_{\text{eq}} = R_T = R_N$ (both) in a table. Table format- variable name in first column, calculated values in second column, measured values in third column, and percent difference in the fourth column.
3) Based on the results of part 2), build the Thevenin equivalent circuit. I.e., set voltage source equal to $V_{T,\text{meas}}$ and come up with a resistor or resistor combination close to $R_{T,\text{meas2}}$ to connect in series (sketch your resistor/resistor combination). Measure and record $V_{T,\text{exp}}$ and $R_{T,\text{exp}}$. Then, successively measure & connect load resistances of 150 Ω, 1 kΩ, and R_T. Measure V_L and I_L (use to get measured P_L) for each R_L.
4) Have the lab instructor or a TA sign-off on your data.

Analysis and Conclusions

- Using the <u>experimental</u> Thevenin equivalent circuit (i.e., $V_{T,\text{exp}}$ and $R_{T,\text{exp}}$), calculate V_L, I_L, and P_L when R_L = 150 Ω, 1 kΩ, and R_T. Put results in a single table with the experimental results of part 3). Table format: column 1 nominal R_L, column 2 measured R_L, column 3 calculated V_L, column 4 measured V_L, column 5 calculated I_L, column 6 measured I_L, column 7 calculated P_L, and column 8 measured P_L.
- On a single graph, use **Matlab** to plot load power P_L (mW) versus load resistance R_L (Ω) for both the analytical (**solid line**) and experimental (**individual dots**) cases. For the analytic trace, use $V_{T,\text{exp}}$ and $R_{T,\text{exp}}$ values in your equation for P_L. Use enough data points (i.e., R_L values) to achieve a smooth line [as a suggestion make step size $\Delta R_L \le 50\ \Omega$]. Make the horizontal ($R_L$) axis go from 0 to 1500 Ω. Label results using a legend. Insert both graph and m-file (include EE 220L-xx, Lab #7, *your name*, *date*, & description of work in comment lines) in logbook. Keeping in mind the maximum power transfer theorem, comment on the results shown by the graph.
- Analyze the data and discuss the results. Explain differences between measured and calculated/predicted values.