Laboratory Assignment #2: Thévenin and Norton Equivalent Circuits
Spring 2008

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.

Parts: Equipment:
- Resistors as needed
- Breadboard
- Digital Multimeter (DMM)
- Signal Generator
- Oscilloscope

Objective:
The objective of this session is to practically verify the existence of Thévenin and Norton equivalents for simple circuits through laboratory measurements.

Background:
Ideal and practical sources
Voltage and current sources used in laboratory are not ideal. Ideal voltage sources have zero series resistance and ideal current sources have an infinite parallel input resistance. The absence of any resistors implies that there is no internal power dissipation. In turn when we look at the ideal voltage source (Thevenin circuit without a resistor), we note that if we short circuit the output, the predicted output current is infinitely large, a very non-practical result. In the Norton case (current source without a resistor), the open circuit output voltage will be infinitely large. We then have a circuit that will have a voltage breakdown if we don’t provide a load at the output. Practical sources have some finite resistance associated with them. The function generators in the laboratory have internal resistances of 50 or 600 Ohms, depending on the model. Thevenin and Norton theorems allow us to model the function generator used in lab as follows:

For both circuits we have added loads that draw the same load current, $I_L$, but the loads need not be otherwise specified at this time. For many applications these circuits can represent complicated
circuits that are effectively in a black box that we cannot open and investigate. In this case we
cannot distinguish between a Norton and a Thevenin circuit by studying its current-voltage output
characteristic. The two circuits above will have identical output current and voltage regardless of
the load type:
\[ V_{out} = V_T - I_T R_T = (I_N - I_L) R_T \]
Here to satisfy the equivalence of terms:
\[ V_T = I_N R_N, \]
\[ R_T = R_N = V_{oc}/I_{sc} \]
where \( V_{oc} \) is the open-circuit voltage and \( I_{sc} \) is the short circuit current as shown in Fig.1.

**Measuring Thevenin and Norton Equivalent Circuit Parameters:**
Because both circuits are assumed to be linear, measuring two operating points on the \( V_{output} vs. I_L \)
relationship allows us to measure the circuit parameters. Convenient points are the open circuit
voltage and the short circuit current output. These work from the theoretical point of view but not
necessarily from an experimental point of view. Never try to measure the short circuit current of a
regulated voltage supply or the open circuit voltage of a regulated current supply.

**Prelab:**
1- Why shouldn’t you do a direct measurement of the short circuit current of a regulated voltage
supply, or the open circuit voltage of a regulated current supply? (Hint: *What happens when you
short a voltage source?*)
2- Shown in Fig.2 is a plot of the I-V characteristics of the accompanying circuit (Black Box).

**Figure 1. Norton and Thévenin equivalent circuits**

**Figure 2. Black box and I-V characteristic**

a) Evaluate the parameters \( I_N, V_T, \) and \( R_T \) of the black box.
b) Draw the Thevenin and Norton equivalent circuits for the black box.

The plot in Fig. 2 is called the load line. Potting the load line to measure the Thevenin and Norton
equivalent circuits is referred to as the load line method. This method allows the characterization
of the equivalent circuits without having to physically apply a short or an open at the load. For
example, if one needs to determine the Norton equivalent circuit of a voltage source, shorting the
output is not an option. A short at the output would draw too much current resulting in a blown fuse.

3- In Fig. 3, $R_S$ and $V_S$ represent the Thevenin equivalent circuit of some black box.

![Figure 3](image)

The “black box” is loaded with a resistor $R_U$:

a) Find $R_U$ such that $V_U = V_S/2$.

b) Find the power, $P_U$, dissipated in $R_U$.

c) For an arbitrary value of $R_U$, find $P_U$ as a function of $V_S$, $R_S$, and $R_U$.

d) From (c), for what value of $R_U$ will $P_U$ be maximum?

e) Compare the answers from (a) and (d).

4- For the circuit in Fig. 4:

![Figure 4](image)

When you try to analyze a complex circuit as in Fig. 4, if you are interested mainly in the circuit seen by the output load, you can solve for the behavior of two simpler circuits instead, one for no load (Thevenin), and one for a short circuit load (Norton). Draw these circuits. How many node equations will you need for each circuit? Could any of the circuit elements be omitted without affecting the Thevenin or Norton equivalent resistance? If so, why?

a) Find the Thevenin equivalent circuit seen by the load resistor $R_{Load}$ (i.e. calculate $V_T$ and $R_T$).

b) Find the Norton equivalent circuit ($I_N$ and $R_N$) seen by $R_{Load}$.

c) Draw the Thevenin and Norton equivalent circuits using the values calculated in (a) & (b).
d) Calculate $V_L$ and $I_L$.
e) Use PSPICE to verify your answers.

**Circuit Lab Experimental Procedure:**

**I. Thevenin and Norton Equivalents**

Set up the circuit in Fig. 4:

1. Measure the current ($I_L$), through $R_{Load}$, and the voltage ($V_L$), across $R_{Load}$.

2. Find the Thevenin equivalent circuit seen by $R_{Load}$ (i.e., the equivalent circuit between nodes a and b with $R_{Load}$ removed from the circuit). To get the equivalent circuit, follow these steps:
   a) Remove $R_{Load}$ from the circuit.
   b) Measure $V_{ab}$ (open circuit voltage = Thevenin Voltage = $V_T$).
   c) Set the voltage source to zero volts, and use the ohmmeter to measure the equivalent resistance between nodes a & b (This is the Thevenin Resistance = $R_T$).
   d) Can $R_T$ be determined using only the measurements in (1) and (2b)? How? (Hint: Prelab)

3. Find the Norton equivalent circuit seen by $R_{Load}$. For this part, DO NOT physically apply a short to measure $I_{SC} = I_N$. Instead, use the load line method (prelab problem #2) to measure $I_{SC} = I_N$. This works as follows:
   a) Set the potentiometer to the original load value and connect it between nodes a & b.
   b) Vary the potentiometer, and measure the voltage ($V_P$) across it, and the current ($I_P$) through it.
   c) Obtain five data points (preferably having uniform voltage spacing between them) and plot $V_P$ vs. $I_P$ (similar to the graph in prelab problem #2).
   d) From the plot in (c), find $I_N$, $V_T$, and $R_T$. Or, you can measure $I_P$ and $R_P$ instead of $I_P$ and $V_P$. This can be easier to handle in lab. Why?

4. Compare the results from part (3) to the results from part (2).

**II. Thevenin Circuit Evaluation**

1. Set up the circuit in Fig. 5. (Use the values measured in step I.2 for $V_T$ and $R_T$).

2. Measure the voltage $V_{RL}$, and the current $I_{RL}$.

![Figure 5](image)

3. Compare $V_{RL}$ and $I_{RL}$ to those measured in step I.1.

**Conclusion:**

- Discuss your results and compare ALL your lab data to calculated results.
- Give percentage deviations between your calculated and experimental data.
- Explain any deviations that you find.
- Comment on Thevenin and Norton equivalent circuits.