



COLLEGE OF ENGINEERING SUNY POLYTECHNIC INSTITUTE

ECE 260

Name: _____

Date: _____

Laboratory 5 – Thevenin and Norton Equivalent

Purpose: The purpose of this lab is to learn how to obtain a Thevenin Equivalent circuit by making measurements of the I-V (current-voltage) characteristics at a pair of terminals. Equivalent circuits are simplified versions of complex circuits that yield the same values and can therefore be used to make calculations about those circuits easier.

Equipment Required

- Breadboard and Variable Power supply
- Various resistors and potentiometer
- NI MultiSim Software

Learning Objectives

1. Discuss the purpose of equivalent circuits and provide examples of how they are used
2. Determine the Thevenin and Norton equivalent circuits for various circuit configurations
3. Use equivalent circuits to analyze the effect of changing load resistances
4. Identify the differences and similarities between Thevenin and Norton equivalent circuits.

Theory

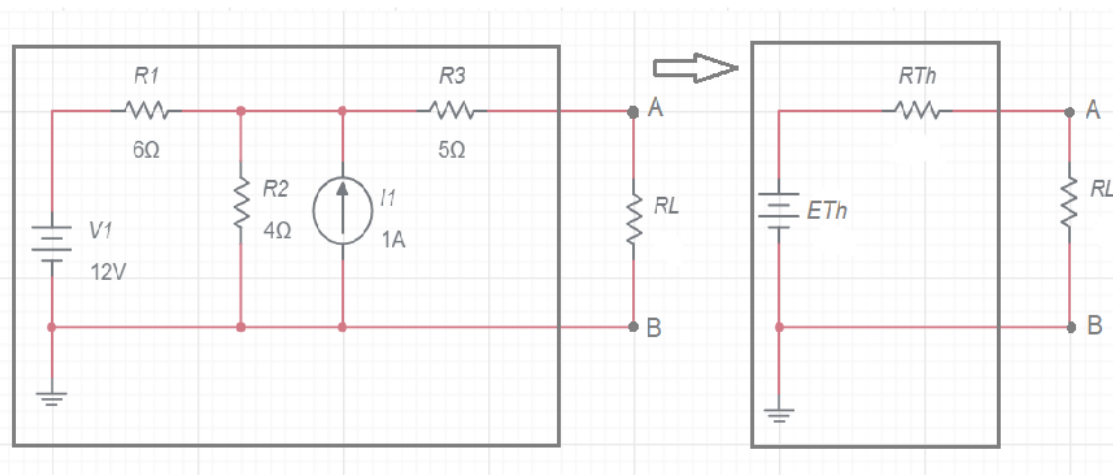


Figure 1

Thevenin equivalent circuits can be developed according to the following procedure:

1. Remove the part of the network through which the equivalent Thevenin's circuit will be analyzed (R_L , in the illustration above), and tag the network terminals where the removed element was located (A and B).
2. Calculate Thevenin's Resistance R_{TH} substituting all supplies by zero (current sources are replaced by open circuits and voltage sources are replaced by short circuits) and finding the resulting resistance between the two tagged terminals using an ohmmeter.

3. Calculate Thevenin's voltage V_{TH} , returning all power supply sources to their original settings and finding the voltage of the open circuit between the tagged terminals. Remove the load resistor R_L and measure the open circuit voltage
4. Draw Thevenin's equivalent circuit, adding the circuit part removed before. This step is indicated by placing the R_L resistor between the Thevenin equivalent circuit terminals.

Similar steps can be taken to find the Norton Equivalent Circuit. The first two steps to applying Norton's theorem are the same as for Thevenin analysis:

1. Remove the part of the network through which the equivalent Norton's circuit will be analyzed and tag the network terminals where the removed element was located.
2. Calculate Norton's resistance " R_N ," substituting all supplies by zero (current sources are replaced by open circuits and voltage sources are replaced by short circuits) and find the resulting resistance between the two tagged terminals.

Note that $R_{TH} = R_N$. The final two steps are different:

3. Calculate Norton's current " I_N ," returning all power supply sources to their original settings and finding the short circuit current between the tagged terminals. (In all cases, keep in mind that the current has to be measured using an ammeter between the pair of terminals tagged in step one.)
4. Draw Norton's equivalent circuit, adding the circuit part you removed before.

Applications of Equivalent Circuits

Equivalent circuits are used for quickly analyzing complex circuits. Norton circuits are well-suited to simplifying parallel circuits, while Thevenin's theorem applies best to series circuits. Some of the advantages offered by both theorems are:

- Both theorems allow the determination of any given voltage or current in a linear network with one, two, or any number of power supplies.
- Both theorems allow the analysis of a specific part of a network, substituting the remaining network with an equivalent circuit.

Equivalent circuits are helpful for calculating current and voltage across load resistors, which are subject to change across multiple trials or use cases. Equivalent circuits are often used to expedite calculations regarding power circuits that support loads such as light bulbs and appliances.

Another real-world application of equivalent circuits is in determining the maximum power transfer between two circuits.

In addition, each type of circuit can also be used to help calculate the other, as they are mathematically related:

$$R_{Th} = R_N$$

$$V_{Th} = I_N R_N$$

$$I_N = \frac{V_{Th}}{R_{Th}}$$

When performing either type of analysis, it is sometimes easiest to calculate the values for the other method and convert them using the appropriate equation.

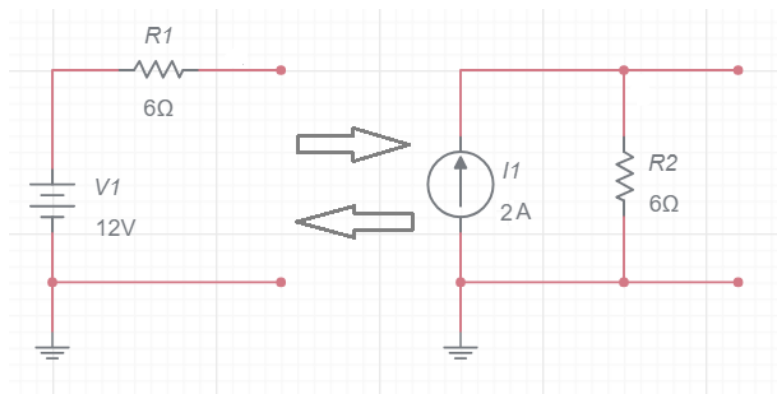


Figure 2

When you are exploring the applications of equivalent circuits, it is important to understand their limitations, as well. The greatest drawback of the both theorems is that they only apply to linear circuits, and most circuits behave linearly only within a specific range of values.

Questions:

With a complex circuit including multiple voltage sources and several resistors. According to Thevenin's theorem, the circuit can be replaced with an equivalent circuit with the following:

- a) A series circuit with voltage source and resistor
- b) A parallel circuit with voltage source and resistor
- c) A series circuit with current source and resistor

The purpose of equivalent circuits is to help us

- a) Make and design simple, two-component circuits
- b) Understand Norton's theorem
- c) Analyze complex circuits more quickly and easily
- d) Avoid having to analyze parallel circuits

Which statement is UNTRUE of Thevenin equivalent circuits?

- a) They allow you to isolate specific components by abstracting out the rest of a circuit
- b) They are closely related to Norton equivalents but Thevenin circuits use a current instead of a voltage source
- c) They are often used to make calculations for power circuits with variable loads
- d) They do not necessarily apply to circuits with non-linear components

Which equation relating to Thevenin and Norton circuits is TRUE?

- a) $R_N / R_{TH} = V_{Th}$
- b) $I_{TH} = I_N$
- c) $V_{TH} = I_N / R_N$
- d) $V_{TH} = I_N \times R_{TH}$

Procedure

Thevenin Equivalent

1. Here you will compare current flowing through a load resistor, for various resistances, both for a complex circuit as well as for its Thevenin equivalent. You will use Ohm's Law and then Thevenin circuit analysis to theoretically determine these values.

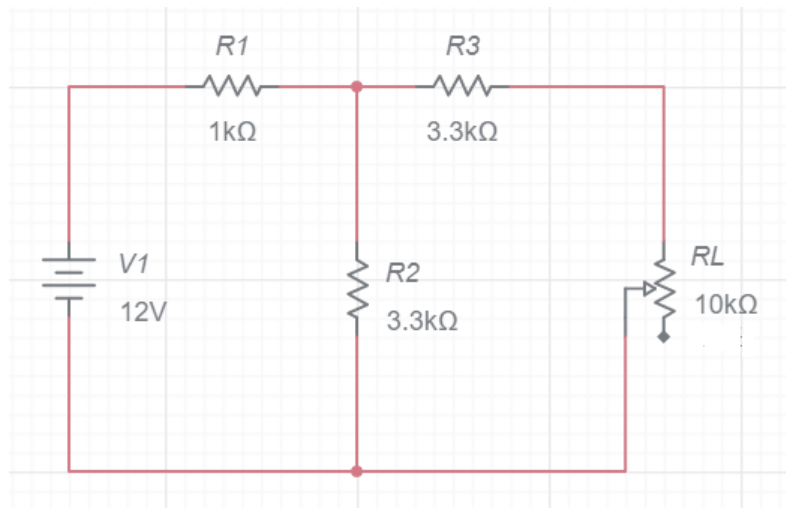


Figure 3

- a. For the circuit shown, use Ohm's Law to calculate the current flowing through R_L for load resistance values of $1\text{k}\Omega$, $4.7\text{ k}\Omega$, and $10\text{ k}\Omega$. Record the calculated values in Table 1.
- b. Calculate the Thevenin Equivalent circuit using the steps described above.
 - i. What was the Thevenin resistance you found while developing your equivalent circuit?
 - ii. What was the Thevenin voltage you found while developing your equivalent circuit?
- c. Determine the current for each load resistance once more, this time by using Thevenin equivalent circuit you found in the previous step. Record the calculated values in Table 1.

Table 1

R_L Resistance ($\text{k}\Omega$)	Calculate Current I (mA) using Ohm's Law	Calculate Current I (mA) Using Thevenin's Theorem
1		
4.7		
10		

2. Here you will build an Equivalent Circuit both on a breadboard and using MultiSim (**be sure to include the Multisim circuit when you hand in your report**) . You will construct a complex circuit and measure the current across a load resistor for various resistance values

- a. Construct the circuit shown in Figure 3. Start with a load resistance of $1\text{ k}\Omega$ to start.
- b. Connect the proper multimeters to the circuit to make the necessary measurements
- c. From the instruments tab, open the following instruments:

- Digital Multimeter (DMM)
 - Variable Power Supply, 0-15 VDC
- d. Set the variable power supply to 12 V.
 - e. Measure the current flowing through R_L using the DMM
 - f. Record your measurements in the table below

Table 2

R_L Resistance ($k\Omega$)	Measured Current (mA) Original Circuit
1	
4.7	
10	

3. Change the load resistance and measure the current flowing through R_L again
 - a. Change the R_L value to 4.7 $k\Omega$ by replacing the 1 $k\Omega$ R_L resistor. This will model a variable load resistance
 - b. Measure the current flowing through R_L
 - c. Record the resulting current value in Table 2
 - d. Repeat with an R_L value of 10 $k\Omega$
4. Now you will build a simplified Thevenin equivalent circuit of the one you just analyzed and then measure the current for various load resistances
 - a. Set the Thevenin resistor to the calculated Thevenin resistance (R_{TH}).
 - b. Connect the Thevenin equivalent circuit as shown in Figure 1. Set the variable power supply voltage value to the calculated V_{TH} . Begin with an R_L of 1 $k\Omega$.
 - c. Measure the current flowing through the load resistor, R_L as you did in the original circuit.
 - d. Record your measurements in Table 3
5. Change the load resistance and measure the current again
 - a. Change the value of R_L value to 4.7 $k\Omega$ by replacing the 1 $k\Omega$ resistor
 - b. Measure the current flowing through R_L
 - c. Record the measurement value in Table 3
 - d. Repeat for a load resistance of 10 $k\Omega$. Record your results

Table 3

R_L Resistance (kΩ)	Measured Current (mA) Thevenin Equivalent Circuit
1	
4.7	
10	

Analysis

These questions will help you review and interpret the concepts learned in this lab.

In your own words, what is a Thevenin equivalent circuit? What are its components? What is it used for?

When the two circuit analysis methods are compared, in what cases should we use Ohm's Law and in which should we use Thevenin's theorem?

How similar are your values for the original circuit and for the Thevenin equivalent? Are your measured values consistent with your calculated ones? If not, why do you think that is?

Norton Equivalent (you don't need to build this circuit, just perform the analysis)

1. Here you will compare current flowing through a load resistor, for various resistances, for a complex circuit as well as for its Norton equivalent. You will use Ohm's Law and then Norton circuit analysis to theoretically determine these values.

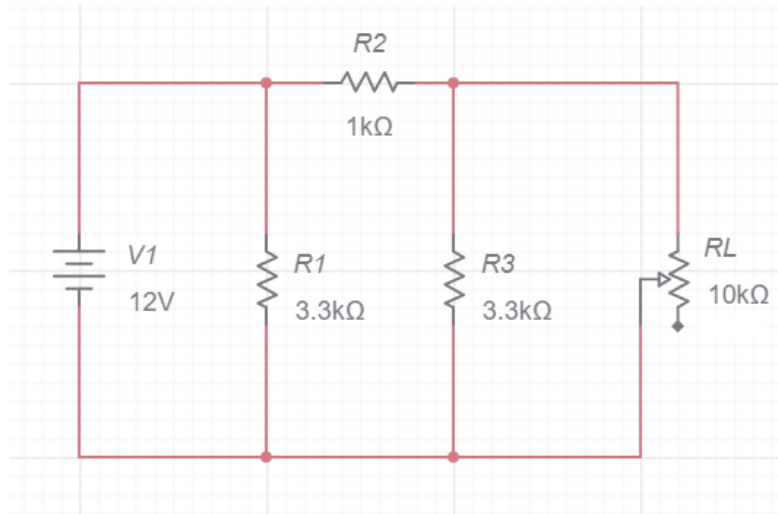


Figure 6

- a. For the circuit shown, use Ohm's Law to calculate the current flowing through R_L for load resistance values of 1kΩ, 4.7 kΩ, and 10 kΩ. Record the calculated values in Table 4.
- b. Determine the current for each load resistance once more, this time by using Norton Theorem to develop an equivalent circuit. Record the calculated values in Table 4.

Table 4

R_L Resistance (kΩ)	Calculate Current I (mA) using Ohm's Law	Calculate Current I (mA) Using Norton's Theorem
1		
4.7		
10		

What was the Norton resistance and current you found while developing your equivalent circuit?

Analysis

These questions will help you review and interpret the concepts learned in this lab. In your own words, describe Norton's Theorem. How is Norton's theorem limited its applications?

Are the values for the original circuit in this section similar to the values for its equivalent? Do your measured values align with your calculated ones? If not, why do you think that is?

How are Norton's Theorem and Thevenin's theorem related?

How is Norton equivalent circuit different from a Thevenin equivalent circuit?

What kind of equivalent circuit did you build in both implementation stages?

Record any observations related to Thevenin's theorem, Norton's theorem, or their applications that you have not yet noted.