# ECE 2100 Experiment II

# Thévenin and Norton Equivalents

**Introduction**

In this exercise we will try to verify Thévenin and Norton equivalents in the laboratory using actual components and sources. You will be asked to make calculations, and then to make measurements to verify that these calculations are valid.

This laboratory exercise is a study of equivalent circuits. Equivalent circuits are common throughout circuits and electronics. An equivalent circuit is used to replace another circuit, or part of a circuit, and is in some way simpler, easier to analyze, or more useful in that particular case. If the circuit that is substituted is truly equivalent, the behavior outside the equivalent circuit remains the same before and after the replacement. It is equivalent in no other sense, however, and the behavior *within* the equivalent circuit may be unrelated to the circuit it replaces.

## Research Question

## Can the theorem of Thevenin and Norton Equivalent Circuits be verified using actual circuit components in the laboratory?

## Components Required

¼ [W] resistors (number required in parentheses):

270[] (1) 8.2[k] (1) 3.9[k] (1)

470[] (1) 10[k] (3) 5.6[k] (1)

1[k] (3) 11[k] (1) 68[k] (1)

1.5[k] (1) 15[k] (1)

2.2[k] (2) 22[k] (2)

2.7[k] (1) 27[k] (1)

## Methods

## In this experiment we will make measurements necessary to find the Thevenin and Norton Equivalent Circuits at a specified pair of terminals for two different circuits. We will compare the measurement results to calculations of the Thevenin and Norton equivalents. In addition, we will measure the current through three load resistors connected to the circuit, and we will compare these currents with the currents predicted by the Equivalent circuits.

***Data***

## The data we collect will be the open circuit voltage and short circuit current needed to calculate the equivalent circuits. We will also measure load current through three resistors connected to the circuits.

***Data Analysis***

## We will use the theorem of Thevenin and Norton Equivalent Circuits to calculate the Thevenin and Norton Equivalents. Information on how to perform these calculations can be found in the *ECE 2100 NERD* folder available on the course website.

## Pre-Lab

## 1. Step 1. Calculate the Thevenin and Norton Equivalents for the circuit shown in Figure 1 following the instructions in that step.

## 2. Step 2. Calculate the currents expected by connecting resistors to Circuit 1, as described in Step 2.

## 3. Step 7. Calculate the Thevenin and Norton Equivalents for the circuit shown in Figure 2 following the instructions in that step.

## 4. Step 8. Calculate the currents expected by connecting resistors to Circuit 2, as described in Step 8.

## Procedure and Results

***Calculated Thevenin and Norton Equivalents: Circuit 1***

Step 1: Calculate the Thévenin and Norton Equivalents for the circuit shown in Figure 1 with respect to terminals a and b. Record your answers in the form of equivalent circuit diagrams, that is, draw and label the Thévenin voltage and resistance, and the Norton current and resistance, and clearly label the terminals a and b in each case.



**Figure 1:**  First of Two Circuits Used in the Experiment.

Step 2: Assume that resistors with values of 1[k], 2.2[k], and 10[k] are to be connected, one at a time, to **terminals a and b** in the circuit in Figure 1. Calculate the currents that would flow through each of these resistors and record these values in Table 1. In Step 6 you will measure these currents.

# **Table 1:** Current Measurement; Circuit 1

|  |  |  |  |
| --- | --- | --- | --- |
|  | 1[k] | 2.2[k] | 10[k] |
| calculated current |  |  |  |
| measured current |  |  |  |

***Measured Thevenin and Norton Equivalents: Circuit 1***

Step 3: Build the circuit in Figure 1 on your prototyping board. Measure the open circuit voltage and the short circuit current **between the terminals a and b**. Record your measurements in Table 2. Also, find the percent error between the measured values and the values calculated from part 1. Use the calculated values as a reference.

# **Table 2:** Open Circuit Voltage and Short Circuit Current; Circuit 1

|  |  |  |  |
| --- | --- | --- | --- |
|  | Measured values | Calculated from  part 1 | *%error* |
|  |  |  |  |
|  |  |  |  |

Step 4: Find the Thévenin and Norton equivalents for this circuit **using measurements** made in Step 3. Record your answers in the form of equivalent circuit diagrams.

Step 5: Measure the Thévenin resistance by connecting an ohmmeter at terminals a, b - **but see the note below first!**  Record your answer in the table below. Find the percent error between this measurement and the value obtained from calculations of the open-circuit voltage and short-circuit current. Use the calculated value as a reference.

To find the equivalent resistance you need to "deactivate" the independent sources in your circuit. Be careful here! Turning the power supply off may not give you the results you expect, because the output of the power supply does not behave like a short circuit when its power is removed. Another likely suggestion is to turn the input voltage from the power supply to zero. However, if it does not go to exactly zero, it will behave as a source in the circuit. This will cause errors in your ohmmeter reading. **The proper procedure here is to remove the power supply from the circuit and replace the connection with a wire (short circuit).** But again, be careful! ***Do not short the output of the DC power supply***; this can damage the supply.

# **Table 3:** Thévenin Resistance for circuit 1

|  |  |  |  |
| --- | --- | --- | --- |
|  | Measured in  part 5 | Obtained from Calculated | *%error* |
| Thévenin  resistance |  |  |  |

Step 6: Connect a 1[k] resistor **between terminals a and** b in the circuit of Figure 1, and measure the current through it. Repeat this step using a 2.2[k] resistor and a 10[k] resistor. Record your measurements in Table 1.

***Calculated Thevenin and Norton Equivalents: Circuit 2***

Step 7: Calculate the Thévenin and Norton Equivalents for the circuit in Figure 2 with respect to terminals a and b. Record your answers in the form of equivalent circuit diagrams.



Figure 2: Second Circuit Used in this Experiment

Step 8: Assume that resistors with values of 1[k], 2.2[k], and 10[k] are to be connected **between terminals a and b** in the circuit in Figure 2, one at a time. Calculate the currents that would flow through each of these resistors and record these values in Table 4. In Step 12 you will measure these currents.

# **Table 4:** Current Measurement; Circuit 2

|  |  |  |  |
| --- | --- | --- | --- |
|  | 1[k] | 2.2[k] | 10[k] |
| Calculated current |  |  |  |
| Measured current |  |  |  |

***Measured Thevenin and Norton Equivalents: Circuit 2***

Step 9: Build the circuit in Figure 2 on your prototyping board. Note in particular the power supplies and be sure that both of them are "floating" with respect to ground. (To be *floating* means that neither side of the supply is connected to ground.) Measure the open-circuit voltage and the short-circuit current between terminals a and b using your multimeter. Record your measurements in Table 5. Also, find the percent difference between the measured values and the values calculated from the circuit of part 7. Use the calculated values as a reference.

# **Table 5:** Open Circuit Voltage and Short Circuit Current; Circuit 2

|  |  |  |  |
| --- | --- | --- | --- |
|  | Measured values | Calculated from  Step 7 | *%error* |
|  |  |  |  |
|  |  |  |  |

Step 10: Find the Thévenin and Norton equivalents for this circuit using your measurements in Step 9. Record your answers in the form of equivalent circuit diagrams.

Step 11: Measure the Thévenin resistance using the ohmmeter (see the description in Step 5 as to how to do this). Record your answer in the table below. Find the percent error between this measurement and the value obtained from calculations of the open circuit voltage and short circuit current. Use the calculated value as a reference.

# **Table 6:** Thévenin Resistance; Circuit 2

|  |  |  |  |
| --- | --- | --- | --- |
|  | Measured in  part 5 | Obtained from calculated *vOC*, *iSC* | *%error* |
| Thévenin  resistance |  |  |  |

Step 12: Connect a 1[k] resistor **between terminals a and b** and measure the current through it. Repeat this step using a 2.2[k] resistor and a 10[k] resistor. Record your measurements in Table 4.

# **Conclusions**

1. There are always some errors involved in making measurements. The important thing is to be able to recognize when the errors are in a reasonable range and when they are not. Are your errors reasonable? Explain your answer in terms of the percent errors generated in this lab.

2. How does the characterization of the circuit as a Thévenin or Norton's equivalent simplify the prediction of the response of a circuit?

3. Consider an AC wall plug. Is it better to model this source as a Thévenin equivalent or as a Norton Equivalent? Explain why.

4. Again consider an AC wall plug. Is this source more like an ideal voltage source or like an ideal current source? Explain why.