Experiment 12 — Norton's Theorem

EL 111 - DC Fundamentals

By: Walter Banzhaf, E.K. Smith, and Winfield Young
University of Hartford
Ward College of Technology

Objectives:

1. For the student to be able to calculate the voltage across any one of several resistors in any circuit by using Norton's Theorem, and verify the results by measurements.
2. For the student to develop a constant current equivalent circuit, and to verify its validity by measurement.

Equipment and parts:

Meters:	Digital Multimeter (DMM); Milliammeter or Handheld MM such as the Agilent 971A
Power Supply:	Agilent E3631A DC power supply (0 to 20 V DC)
Resistors:	1.2 kΩ; 3.3 kΩ; 4.7 kΩ; 5.6 kΩ; 10 kΩ
Misc:	Component Board

Information:

Norton's Theorem can be used for two purposes: 1) to calculate the voltage across (or current through) any component in any circuit, or 2) to develop a constant current equivalent circuit which may be used to simplify the analysis of a complex circuit.

The steps used for Norton's Theorem are listed below:

Step 1 Remove the resistor (R) across which you desire to calculate the voltage. Label these terminals "a" and "b". Short these terminals together and determine the current that flows through this short. Call this short-circuit current I_n.

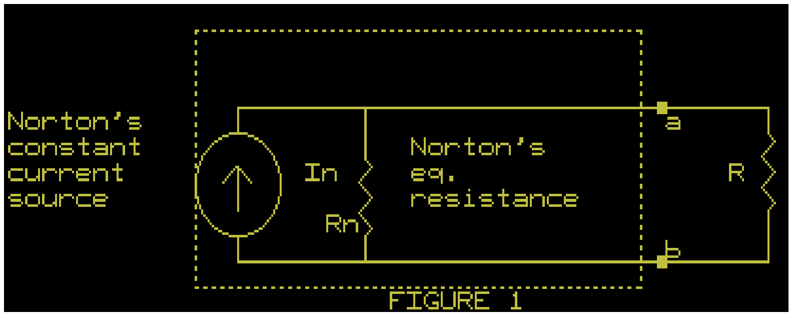
Step 2 With the terminal "opened" and sources replaced with their internal resistances (if any), calculate the resistance "looking back" from the open terminals. This resistance is R_n.

Step 3 The voltage you wish to calculate will be:

$$E = I_n\left(\frac{R_n R}{R_n + R}\right)$$

Where: I_n is from Step 1, R_n is from Step 2, and R is the value of the resistor removed in Step 1.

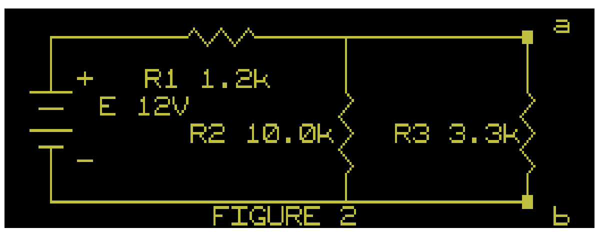
The constant current equivalent circuit is developed from the values calculated in the above steps. See Figure 1.



Procedure:

1. **The purpose of this procedure is for the student to practice the procedural steps of Norton's Theorem and compare the resultant calculations with measured values. Norton's Theorem will be used to find the voltage across R_3.**

   a) Connect the circuit of Figure 2.



   b) Measure the voltage across R_3 and the current through R_3. Record.

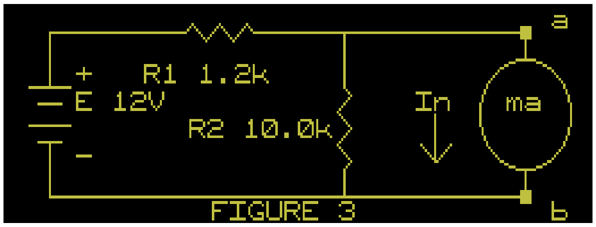
E_{R3} = ______(meas) I_{R3} = ____ (meas)

We will now use Norton's Theorem to calculate the voltage across R_3 by following the steps outlined on page one. SHOW ALL WORK in the space provided. Record the results of each step in the space provided.

   c) Step 1 Calculate (do not measure) the short-circuit current, I_n, when R_3 is replaced by a short circuit:

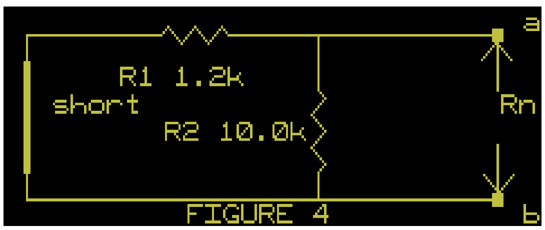
I_n = _______ (calc)

d) Connect the circuit of Figure 3 (this is the circuit of Figure 2, with R_3 removed and replaced by a short circuit, the ammeter). Make sure to use a current range higher than the calculated I_n above. This measurement is the "short-circuit" current.



I_n = ____________ (meas)

e) **Step 2:** Refer to Figure 4, which is Figure 2 with R3 removed and the 12 V source replaced by a short circuit (a dead voltage source). Calculate R_{TH} in Figure 4, **showing all work.**



R_n = _____ (calc)

f) Connect the circuit of Figure 4. Use the DMM to measure R_n. This measurement is the "back resistance" = Norton resistance = R_n.

R_n = _________ (meas)

g) **Step 3:** Use Norton's Theorem (Ohm's Law) to calculate the voltage across R_3, E_{R3}.

$$E_{R3} = I_n\left(\frac{R_n R_3}{R_n + R_3}\right)$$

E_{R3} = __________

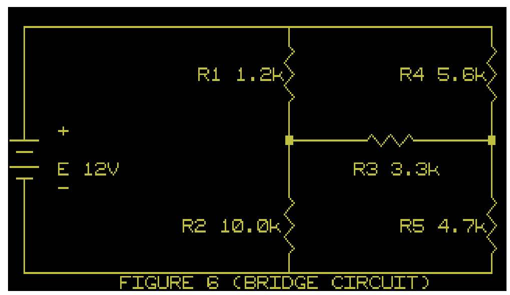
h) Compare the measured voltage from step b) with the calculated voltage in step g) above. If they are not close, do both over again until the error is found.

i) Draw below a schematic diagram of the Norton's Theorem equivalent circuit and label all values. (If a constant current source were available, this circuit could be connected to verify that this circuit would give the same results for E_{R3} as in the original circuit.) This is Figure 5.

Figure 5, Norton's constant current equivalent circuit.

2. **In this procedure, the student will connect a bridge circuit. E_{R3} will be measured. Norton's Theorem will then be used to calculate E_{R3}. Use the same steps as in Procedure 1.**

a) Connect the circuit of Figure 6.

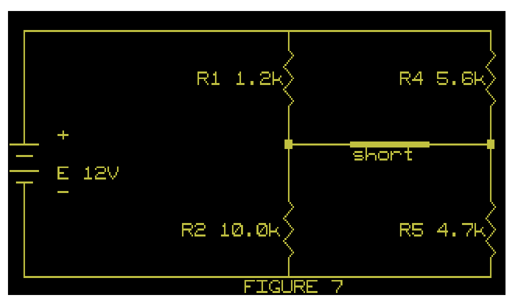


b) Measure the voltage across R_3.

E_{R3} = _________ (meas)

c) Now we will use Norton's Theorem to calculate the voltage across R_3 by making a Norton equivalent circuit, replacing the 12 V source, R_1, R_2, R_4 and R_5, with a Norton equivalent circuit. This requires that we calculate I_n and R_n. Refer to Figure 7. **Show all your work**.

Step 1: Calculate I_n, the current through the short in Figure 7.



I_n = ______________ (calc)

d) Now we will find out if the calculated I_n is correct. Connect the circuit of Figure 7. Replace the "short" with the milliammeter or handheld (which have very low resistance) and measure I_n.

I_n = __________ (meas)

e) **Step 2:** Refer to Figure 8, which is Figure 6 with R3 removed and the 12 V source replaced by a short circuit (a dead voltage source). Calculate R_n in Figure 8, **showing all work.**

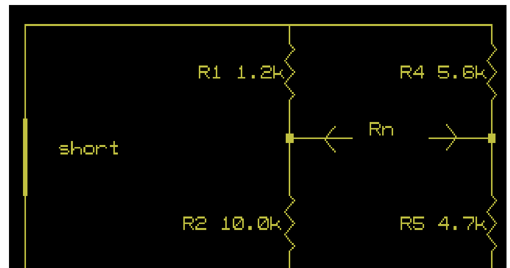


FIGURE 8

R_n = __________ (calc)

f) Now we will find out if the calculated R_n is correct. Connect the circuit of Figure 8. Use the DMM to measure R_n.

R_n = __________ (meas)

g) **Step 3:** Use Norton's Theorem (Ohm's Law) to calculate the voltage across R_3, E_{R3}.

$$E_{R3} = I_n \left(\frac{R_n R_3}{R_n + R_3} \right)$$

E_{R3} = __________

h) Compare measured voltage from Step 2 with the calculated voltage in step 3 above. If they are not reasonable close, do both over again until the error is found.

i) Draw below Figure 9, the Norton's Theorem equivalent circuit.

Figure 9, Norton's Theorem equivalent circuit.