Lab 4: Thevenin Equivalent Circuits

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1. 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.

1.1 Equipment:

- Agilent E3631A DC Power Supply
- Agilent 34401A Digital Multimeter

2. Introduction

Any linear DC circuit as seen at a pair of terminals can be reduced to a practical voltage source (an ideal voltage source in series with a resistor). See Figure 1.

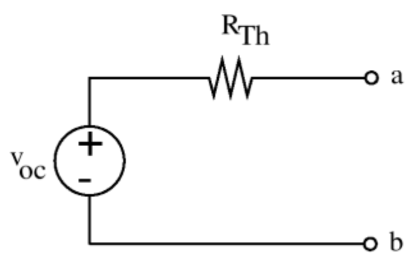

Figure 1: Thevenin Equivalent Circuit

In order to obtain the Thevenin Equivalent circuit, two quantities must be calculated or measured:

1. v_{oc}: The open circuit voltage drop from terminals a to b and

2. i_{sc}: The short circuit current from terminals a to b.

Once that values for v_{oc} and i_{sc} have been obtained, the Thevenin resistance R_{Th} can be determined from the relation

$$R_{Th} = \frac{v_{oc}}{i_{sc}} \qquad (1)$$

If the circuit contains **no dependent sources**, then R_{Th} may also be found by turning off all of the independent sources and using resistance reduction at terminals ab.

3. Experimental Procedure

You will build two circuits, calculate their Thevenin Equivalent circuit as seen at a pair of terminals, and then verify your analysis through measurements.

3.1 Circuit 1

1. Obtain four different valued resistors each with a value in the range 100 Ω - 1 k Ω. Randomly designate the resistors R_1, R_2, R_3, and R_4.

2. Measure and record the value of each resistor.

3. Build the circuit shown in Figure 2 on the breadboard mounted to the bench top, using the DC power supply as v_s. Once you have built the circuit, set the value of v_s to 1 V. Be sure to use the multimeter to make sure the terminal voltage produced by the power supply is as close to 1 V as you can get it.

4. Calculate the voltage drop from a to b (across R_4) using voltage division twice. Be sure to show all your work in your lab report.

5. Measure (and record) the voltage drop from a to b (across R_4).

6. Calculate the Thevenin Equivalent circuit as seen at terminals ab **without** R_4 present. You are calculating the the Thevenin Equivalent circuit as seen by R_4. Be sure to show all your work in your lab report.

7. Remove R_4 from your circuit. Measure v_{oc} and i_{sc} at terminals ab and calculate R_{Th}. Do your measurements agree with your theoretical analyses?

8. Dismantle your circuit. Obtain a 1 kΩ potentiometer (variable resistor) from the parts bin. There are several different drawers with potentiometers. Locate the drawer with the 1 kΩ label. Using the ohmmeter, adjust the resistance of the potentiometer to the value of R_{Th} you calculated in step 6.

9. Build the circuit shown in Figure 3 using the same resistor for R_4, the potentiometer for R_{Th}, and the DC power supply for v_{oc}. Adjust the terminal voltage of the power supply to the value of v_{oc} you calculated in step 6. Be sure to use the voltmeter to check this voltage!

10. Calculate the current through R_4 in Figure 3.

11. Measure the current through R_4. Do the calculated and measured values agree?

12. Measure the voltage across R_4. Does this value agree with your calculated value from step 4 and measured value from step 5?

13. Dismantle your circuit.

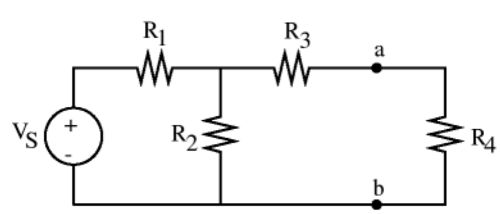

Figure 2: Circuit 1

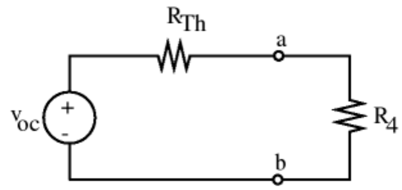

Figure 3: Thevenin Equivalent circuit connected to a load resistor

3.2 Circuit 2

1. Obtain five different valued resistors each with a value in the range 100 Ω - 1 k Ω. Randomly designate the resistors R_1, R_2, R_3, R_4, and R_5.

2. Measure and record the value of each resistor.

3. Build the circuit shown in Figure 4 on the breadboard mounted to the bench top, using the DC power supply as v_s. Once you have built the circuit, set the value of v_s to 1 V. Be sure to use the multimeter to make sure the terminal voltage of the power supply is as close to 1 V as you can get it.

4. Calculate the voltage drop from a to b (across R_4) using the node voltage method. Be sure to show all your work in your lab report.

5. Measure (and record) the voltage drop from a to b (across R_4).

6. Calculate the Thevenin Equivalent circuit as seen at terminals ab **without** R_4 present. You are calculating the Thevenin Equivalent circuit as seen by R_4. Be sure to show all your work in your lab report.

7. Remove R_4 from your circuit. Measure v_{oc} and i_{sc} at terminals ab and calculate R_{Th}. Do your measurements agree with your theoretical analyses?

8. Dismantle your circuit. Obtain a 1 kΩ potentiometer (variable resistor). Using the ohmmeter, adjust the resistance of the potentiometer to the value of R_{Th} you calculated in step 6.

9. Build the circuit shown in Figure 3 using the same resistor for R_4, the potentiometer for R_{Th}, and the DC power supply for v_{oc}. Adjust the terminal voltage of the power supply to the value of v_{oc} you calculated in step 6. Be sure to use the voltmeter to check this voltage!

10. Calculate the current through R_4 in Figure 3.

11. Measure the current through R_4. Do the calculated and measured values agree?

12. Measure the voltage across R_4. Does this value agree with your calculated value from step 4 and measured value from step 5?

13. Dismantle your circuit.

14. Return the resistors to the **proper** drawers in the parts cabinet.

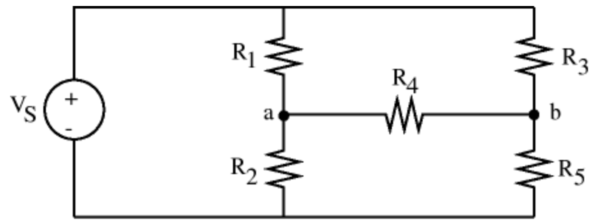

Figure 4: Circuit 2

PSpice (to be done outside of lab)

Read Section 3-9.2 *Small-Signal Transfer Function* in Rashid which explains how to use the .tf control line. The syntax of the .tf control line is:

.tf outputvar inputsrc

Circuit 1 (with the load resistance R4 replaced by a dummy resistance Rdummy) is shown in Figure 5 with the nodes labeled for PSpice. If the .tf control line

.tf v(3) vs

is used, PSpice will produce the input resistance as seen by the voltage source v_s, the output resistance (Thevenin resistance at terminals ab), and the voltage gain from v_s to v_{ab}. For example, if the following code is executed with PSpice:

```
*Theveninl.cir
Vs 1 0 10
Rl 1 2 750
R2 0 2 1200
R3 3 2 1000
R4 3 0 1000Meg
.tran 2.0 2.0
.tf v(3) Vs
.probe
.end
```

then the file Thevenin.out will contain:

```
****   SMALL-SIGNAL CHARACTERISTICS

       V(3)/Vs =  6.154E-01

       INPUT RESISTANCE AT Vs = 1.950E+03

       OUTPUT RESISTANCE AT V(3) = 1.462E+03
```

The simulated value of the open circuit voltage v_{oc} is the voltage gain times the input voltage or v_{oc} = (0.6154)*(10) = 6.154 V. The simulated value of the Thevenin resistance R_{Th} is the output resistance (R_{Th} = 1.462 kΩ) which is easily verified by analysis.

Use PSpice to simulate the four following circuits.

1. Circuit 1 with R_4 present.

2. Circuit 1 with R_4 replaced with a large *dummy* resistor. Use the .tf control line to obtain the Thevenin Equivalent circuit parameters.

3. Circuit 2 with R_4 present.

4. Circuit 2 with R_4 replaced with a large *dummy* resistor. Use the .tf control line to obtain the Thevenin Equivalent circuit parameters.

Compare in detail your theoretical, measured, and simulated results.

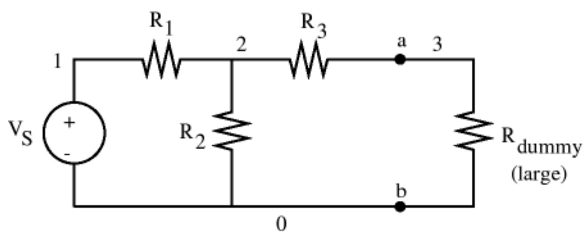

Figure 5: Circuit 1 with nodes labeled for PSpice

5. Questions

Answer the following questions in your lab report.

1. What is meant by the word "equivalent" in Thevenin Equivalent circuits?

2. Explain why R_{dummy} is needed in the PSpice simulations. Why not just take R_4 out of the circuit and simulate the resulting circuit?

3. Why is it that making R_{dummy} "large" produces accurate simulation results? How large must R_{dummy} be in order to produce accurate simulation results?

4. What is the practical value of Thevenin Equivalent circuits? Give several practical applications in which Thevenin Equivalent circuits are used.

5. As you have seen, the Thevenin Equivalent of a circuit can be obtained by calculating/measuring two I-V values: v_{oc} and i_{sc}. Often, it is not practical to measure the short circuit current. Can you imagine trying to measure i_{sc} for a car battery? Suppose you wanted to obtain the Thevenin Equivalent of a circuit by making two measurements, neither of which involves measuring i_{sc}. You measure v_{oc} and then place a 1 kΩ resistor across the terminals and measure the voltage drop across the resistor. Do you have enough information from these two measurements to obtain the Thevenin Equivalent circuit? Justify your answer in detail.

6. Suppose you have two boxes in front of you. One box contains a Thevenin Equivalent (voltage source inseries with a resistor) and the other box contains a Norton Equivalent (current source in parallel with a resistor). Each box has a pair of terminals available for measurement. You cannot open the boxes. You may make any electrical measurements at the terminals. You also have access to the outside surface of the boxes. Can you determine which box contains the Thevenin Equivalent and which box contains the Norton Equivalent? Or is it impossible to determine which circuit is in which box? Justify your answer in detail.