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EEEE 281 Experiment 3: Thévenin's Equivalent Circuit

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To: Section 2 TA: LJ Boone, Harrison Keats
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Lab Partner(s): N/A

Component	Percentage of Grade	Score	Comment
Report Formatting	20 %		
PSPICE: Setup Conditions	5 %		
PSPICE: Data and Figures	15 %		
PSPICE: Discussion of Simulation	15 %		
Hardware: Experimental Setup	10 %		
Hardware: Experimental Data and Tables	15 %		
Hardware: Discussion of Results	20 %		
Total Score:			
Graded By:			

Abstract

This laboratory exercise created a complex circuit were a Thevenin voltage and resistance was determined. To determine the equivalent voltage, a break was placed across the load resistor and the voltage was measured. The equivalent resistance was found by removing independent sources and placing a test source. The current through the test source will indicate the equivalent resistance in the Thevenin circuit. The ammeter in the multimeter was used to measure this current while the volt-meter was used to measure the break voltage.

1 Introduction and Theory

The scope of this experiment was to find the equivalent Thevenin circuit by measuring the break voltage and the current through a test source. A Thevenin circuit is one consisting of a voltage source and a resistor. According to Thevenin law, this circuit can represent any complex circuit with any configuration of current or voltage sources whether they be dependent or independent.

1.1 Theory: Circuit Topology

The circuit in question is one consisting of seven resistors. A list of parameters controls the value of each resistor. Four different variations of the circuit were designed to gain proper measurements in the simulations.

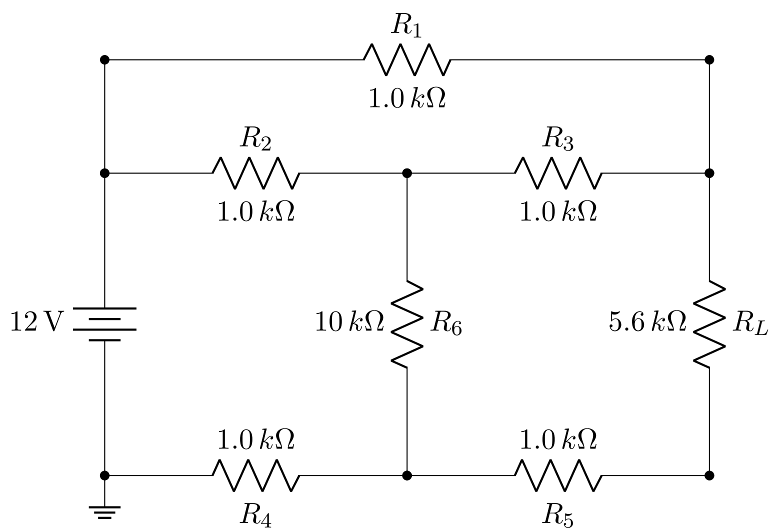

Figure 1.1.1: Circuit showing the ground, power-source, and load configuration

Figure 1.1 depicts the circuit in question. All resistors are $1.0\,k\Omega$ with the exception of R_6 which is $10\,k\Omega$ and the load resistor, R_L, is $5.6\,k\Omega$. A $12\,\mathrm{V}$ power source is connected to power the circuit.

1.2 Theory: PSPICE Simulation Summary

The PSPICE simulation began with a design of the circuit. The PSPICE setup used the libraries imported from the Circuits 1 library from the lab computer. The libraries were called **analog.olb**, **opamp.olb**, **source.olb**, and **special.olb**. The components used were "R/ANALOG" from the

analog.olb for the resistors, "VDC/SOURCE" from the **source.olb** for the voltage source and "O/CAPSYM" and "PARAMETER/SPECIAL" from the **special.olb** for ground.
A parameter list using the "PARAMETER/SPECIAL" component was used to allow the values of each resistor be easily changed. Rcommon controlled the value of every resistor apart from R_6 and R_L A resistor sweep was performed in the PSPICE so that the voltage across R_L could be measured for varying values of R_L. The slope of the curve would yield the Thevenin resistance while the intercept would represent the Thevenin voltage.

1.2.1 Theory: PSPICE Schematic Diagram

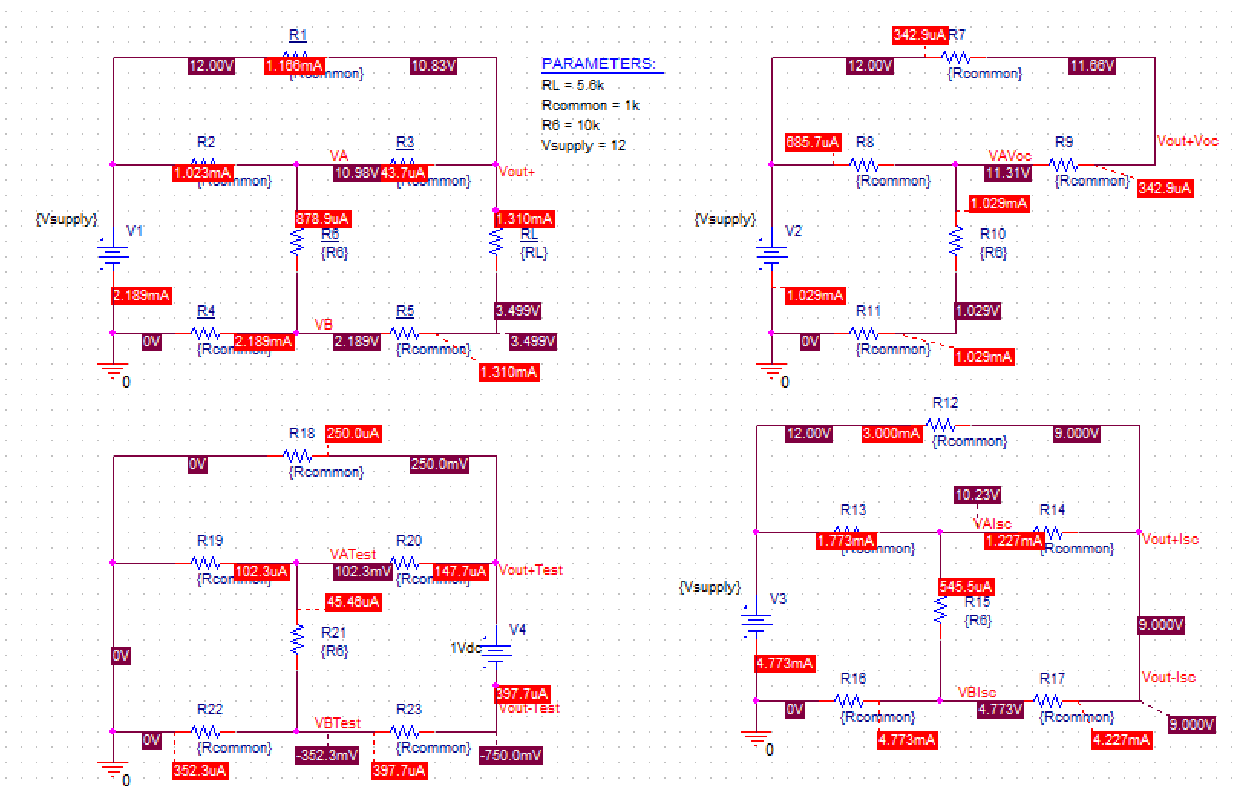

Figure 1.2.1: Screen shot of the PSPICE schematic with voltage markers.

The top left schematic is the full circuit. The top right shows the circuit needed to calculate the Thevenin voltage. A break can be seen where the load resistor was. The bottom left depicts a test source being added to the circuit with all of the independent power sources removed. This is used to find the equivalent resistance of the circuit. The final circuit is one were there is a short across the R_L to measure the current through the point when the resistance is $0\,\Omega$.

1.2.2 Theory: PSPICE Simulation Varying Load Circuit

Figure 1.2.2 shows the voltage curve as the resistor sweep simulation was calculated. A number of different resistance values were used to calculate the voltage across R_L.

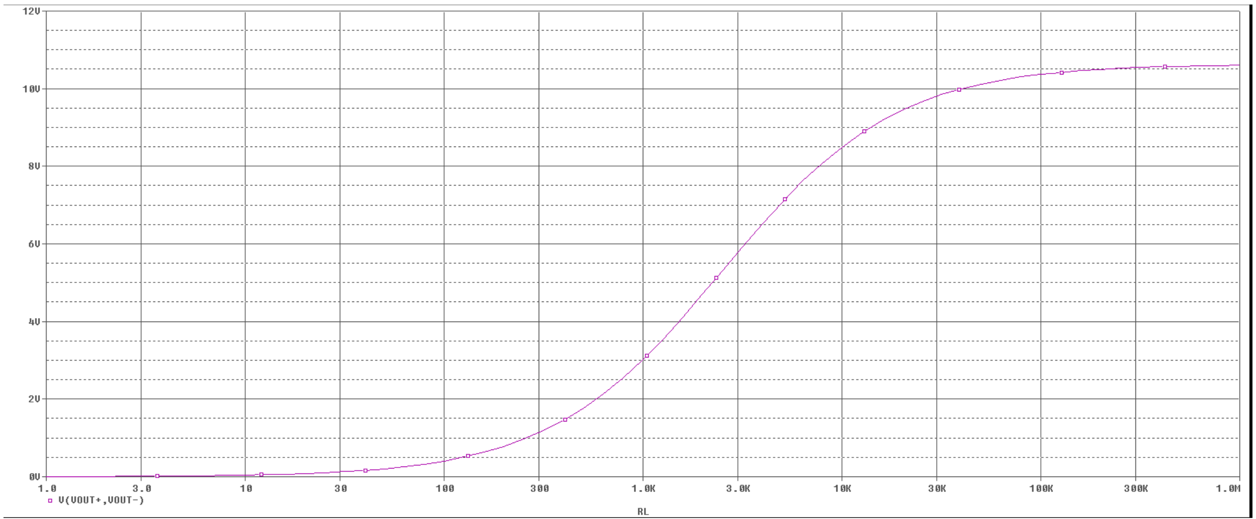

Figure 1.2.2: Screen shot of the PSPICE resistor sweep simulation.

Table 1: Variable Load PSPICE test results

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V_{th} (V)	R_{th} (Ω)
10.629	2514.3

By graphing the voltage vs current, number of qualities about the circuit can be gained from the linear progression that is generated.
The regression in Figure 1.2.3 shows a line with the equation:

$$y = -2514x + 10.6 \qquad\qquad R^2 = 1 \tag{1.2.1}$$

The align of this line indicates the Thevenin resistance while the Y-intercept is the Thevenin voltage. This is because when the current is zero, the circuit has a break therefore the voltage across R_L is the Thevenin voltage. The slope of the graph is the negative of the Thevenin resistance because we are graphing V vs $-I$ therefore the slope can be seen as $-R = \frac{V}{-I}$.

1.2.3 Theory: PSPICE Simulation Open Circuit/Short Circuit Test

The open circuit test in Figure 1.2.1 (top-right), is generated by creating a break in the circuit where the load resistor (R_L) is found. This also effectively removes R_5 as it is in series with this break and therefore no current is passing through it and no voltage drop can be measured across it. In the bottom right of Figure 1.2.1, the short circuit test can be seen. Here a wire is placed across R_L and the current is measured through the wire.
Table 2 shows the R_{th} calculations when the voltage across the load is measured with a break and the current through the load is measured with a short. The results agree with the PSPICE simulation.

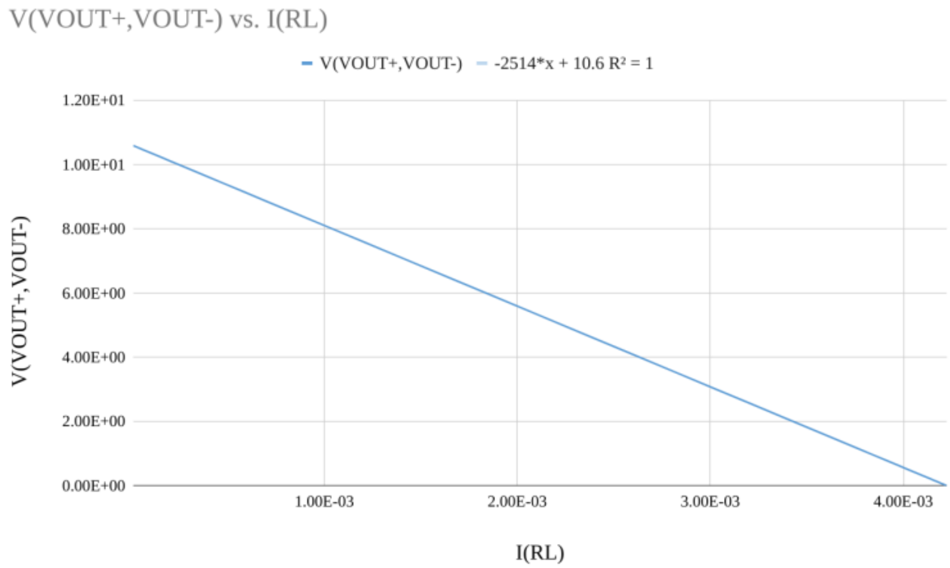

Figure 1.2.3: Linear regression of V_L vs R_L

Table 2: PSPICE Open/Short Test Table

V_{th} (V)	I_{sc} (mA)	R_{th} (Ω)
10.629	4.227	2515.02

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1.2.4 Theory: PSPICE Simulation Test Signal Method

In the bottom left of Figure 1.2.1 the test signal can be seen. Here the circuit is altered by removing all of the independent sources. Voltage sources become wires and current sources become breaks. The load resistor is replace by a voltage source with a chosen voltage. 1 V is chosen for this test source.

Table 3: R_{th} from Test Signal.

Test Signal (V)	V_{R5} (V)	$I_{\text{Test Signal}}$ (mA)	R_{th} (Ω)
1.0	.3977	0.3977	2514.5

Using the test signal method, the R_{th} value was calculated to be very close to that of the other method. These two measurements agree.

2 Hardware Experiment: Results and Discussion

In the hardware portion of this experiment, the Thevenin voltage and Resistance were measured using various methods. A graph was created to mimick the resistor sweep done in PSPICE.

2.1 Equipment Used in the Laboratory

PSPICE Capture CIS was used to create the circuit and the perform the simulation. The DC Power Supply shown in Table 4 was used in the hardware portion to power the circuit. The multimeter shown was used to measure the voltage and resistances across each of the resistors.

Table 4: Equipment/Software required for Lab 3.

Item	Tool	Room
Simulation	OrCAD Capture CIS	09-3200
DC Power Supply	Agilent E3631A	09-3200
Multimeter	Agilent 34401A	09-3200

2.2 Hardware Results/Discsussion Resistor Values

Table 5 shows the experimentally determined resistor values for each of the resistors used in the circuit. All of the resistors were in an acceptable range from the rated $5.6\,k\Omega$ value.

Table 5: Resistors used in the laboratory.

Resistor	Exp. Value (kΩ)
R_1	0.983
R_2	0.983
R_3	0.987
R_4	0.981
R_5	0.982
R_6	9.95

2.3 Hardware Results: Open/Short Extraction

Table 6: Hardware Open/Short Test Table

V_{th} (V)	I_{sc} (mA)	R_{th} (Ω)
10.475	4.547	2303.7

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To determine the Thevenin voltage and resistance using the open/short circuit test, the load resistor was removed from the circuits. Using the 12 V source a multimeter measuring voltage was placed across the load resistor terminals. Next, the fuse on the multimeter was changed to be used as an ammeter. The ammeter terminals were placed inside the nodes where R_L attached. The measured values were recorded in Table 6. A Thevenin resistance was calculated using Ohm's Law. These results agree with the simulation. The value is around 200 Ω lower than the simulated value because most of the experimental resistors were slightely under their rated values.

2.4 Hardware Results: Direct Measurement of R_{th}

The direct method of R_{th} is done by shorting the connection between the power source terminals and using the mutlimeter to measure the resistance across the load terminals.

Table 7: R_{th} direct measurement table

R_{th} (kΩ)	$2.360\,k\Omega$

Table 7 shows the results of the direct measurement. These results agree with the simulation and the open/short circuit test.

2.5 Hardware Results: Test Signal Extraction

The test signal is a method used to determine the Thevenin resistance. By removing the independent sources, only the Thevenin resistor is kept in the circuit and therefore by placing a source of our choosing, the resistance can be determined. The test signal is placed across the load and then the current through the source is determined. To easily find this current, the voltage across the resistor in series with the source can be measured, in this case R_5 was used.

Table 8: R_{th} from Test Signal.

Test Signal (V)	V_{R5} (V)	$I_{R5} = i_{test}$ (mA)	R_{th} (Ω)
1.0	0.426	0.426	2347.4

A 1 V test source was used for simplicity. The results shown in Table 8 agree with the previous measurements and the simulations. If the test source was changed to 3 V, the results would not change because the current i_{test} would change accordingly which would result in the same R_{th} value to be calculated.

2.6 Hardware Results: Varying Load Extraction

The varying load experiment is similar to the resistor sweep. The load resistor was changed for multiple valued resistors and the voltage across the load was measured. A current was calculated and then graphed.

Table 9: Variable load resistor Table. Use Ohm's Law to determine the load current (I_L)

Resistor	Exp. Value (kΩ)	V_{RL} (V)	I_L (A)
R_{L1}	120	0.512	0.00426
R_{L2}	390	1.500	0.00385
R_{L3}	2.20k	5.101	0.00223
R_{L4}	4.70k	7.010	0.00149
R_{L5}	5.60k	7.379	0.00132
R_{L6}	8.20k	8.160	0.000995
R_{L7}	15.0k	9.070	0.000605
R_{L8}	18.0k	9.275	0.000515

The values shown in Table 9 where used to generate a graph and a linear regression.

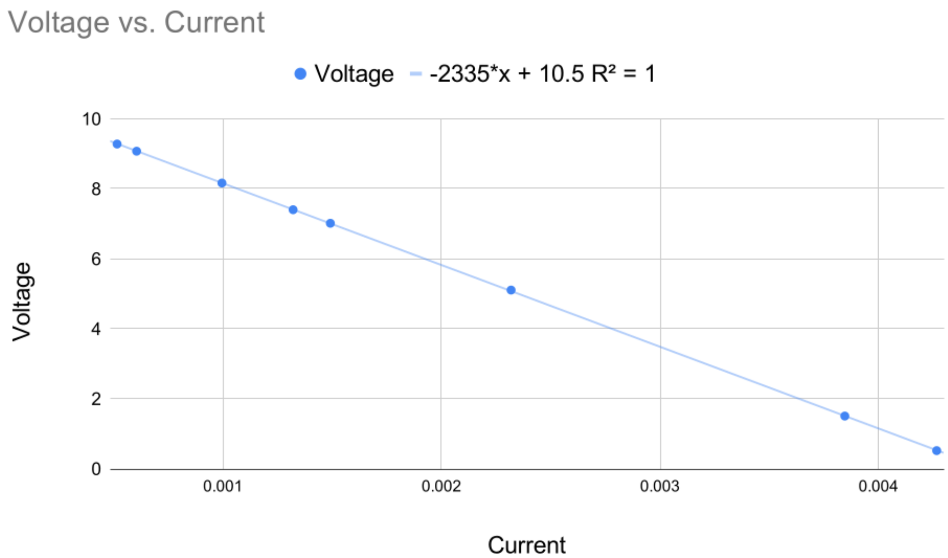

Figure 2.6.1: Linear regression of V_{RL} vs I_L

Figure 2.6.1 is a graph of Table 9 where current is on the X-axis and voltage on the Y. The Y-intercept is the Thevenin voltage because that is where the circuit has a break. The slope of the the line is the measured Thevenin resistance. The value $2335\,\Omega$ agrees with the previous experiments and the simulations.

3 Conclusion

This laboratory experiment attempted to prove the validity of Thevenin's Theory that any complex circuit could be simplified relative to a load component where the load is in series with a voltage source and a resistor. The lab started with simulations of the circuit in which the voltage across the break of the load was measured as well as the current through the short. Also, a test source was placed instead of a resistor on the load as an alternative method for determining the Thevenin resistance. A resistor sweep was conducted where the voltage across a varying resistor was measured from $1\,\Omega$ to $1\,M\Omega$. In the hardware portion, the simulations were conducted on a breadboard. A break voltage and short current were measured along with a direct measurement of the Thevenin resistance. A $1\,V$ test source was also used to determine this resistance. Finally, a resistor sweep was conducted where eight different resistors were used as the load elements and the voltage across them were measured and graphed. This laboratory experiment validates Thevenin's Theorem experimentally because the calcuated value is relatively close to the simulated value. The relative different can be attributed to the slight variance from the rated resistance. These differences collectively caused an experimentally determined Thevenin resistance to be around 200Ω lower than the simulated resistance.

4 Acknowledgments

- wikibooks.org helped with the LaTeX code.
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References

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