Electric Circuits & Electronics Design Lab

EE 316-03

Lab 1: Circuits Review

By:

Lab Section 316-03

Lab Date: 1/6/16

Lab Due: 1/13/16

Introduction:

The purpose of this lab is to review the core concepts of circuit theory and the basic concepts and techniques that will be used throughout this lab. Specifically we will examine Ohm's law, Kirchhoff's voltage and current laws, and Norton and Thevenin equivalents using theoretical analysis, simulations, and experimentation. This report will be broken down into five main sections. First we will consider the Theoretical analysis that would normally be done as part of the pre-lab. We will then examine the Multisim simulations that would also normally be discussed in the pre-lab. Next we turn to the physical circuits constructed on breadboards in the lab. Then, we will analyze and compare the results from all three prior sections. Finally, the report will conclude with a discussion of the meaning of the results.

Theoretical Analysis:

To begin, we considered the circuit given in Figure 1 using theoretical circuit analysis techniques, specifically mesh current analysis to find branch currents, node voltages, loop currents, and branch voltages. The assumptions made for component values are as follows:

V_s = 5.0 V

$R_1 = R_2 = R_3$ = 100 Ohms

$R_4 = R_5$ = 1000 Ohms

$R_6 = R_7$ = 2200 Ohms

The analysis was performed three times. The first time we assumed the resistors were the listed values. The second and third time, we assumed the resistors were ten percent above and below the nominal value respectively. The work for this analysis is attached in Appendix 1. The results of the analysis can be seen in Tables 1 through 3.

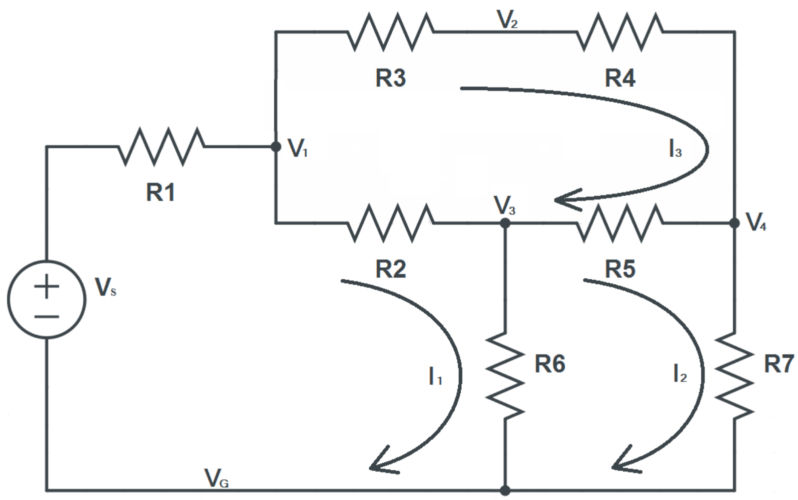


Figure 1: The Circuit Under Analysis

Table 1: Voltages and Currents with Resistors at Nominal

Branch Node or Loop #	Branch Voltages (V)	Branch Currents (mA)	Node Voltages (V)	Loop Currents (mA)
1	0.363	3.634	4.637	3.634
2	0.272	2.719	4.545	1.650
3	0.092	0.915	4.365	0.915
4	0.915	0.915	3.630	
5	0.735	0.735		
6	4.365	1.984		
7	3.630	1.650		

Table 2: Voltages and Currents with Resistors at -10%

Branch Node or Loop #	Branch Voltages (V)	Branch Currents (mA)	Node Voltages (V)	Loop Currents (mA)
1	0.363	4.038	4.637	4.038
2	0.272	3.021	4.545	1.833
3	0.092	1.017	4.365	1.017
4	0.915	1.017	3.630	
5	0.734	0.816		
6	4.366	2.205		
7	3.629	1.833		

Table 3: Voltages and Currents with Resistors at +10%

Branch Node or Loop #	Branch Voltages (V)	Branch Currents (mA)	Node Voltages (V)	Loop Currents (mA)
1	0.363	3.304	4.637	3.304
2	0.272	2.472	4.545	1.500
3	0.092	0.832	4.365	0.832
4	0.915	0.832	3.630	
5	0.735	0.668		
6	4.366	1.804		
7	3.630	1.500		

We next performed theoretical analysis on the circuit seen in Figure 2 to determine both its Norton and Thevenin equivalent circuits using the six steps outlined in the lab manual.

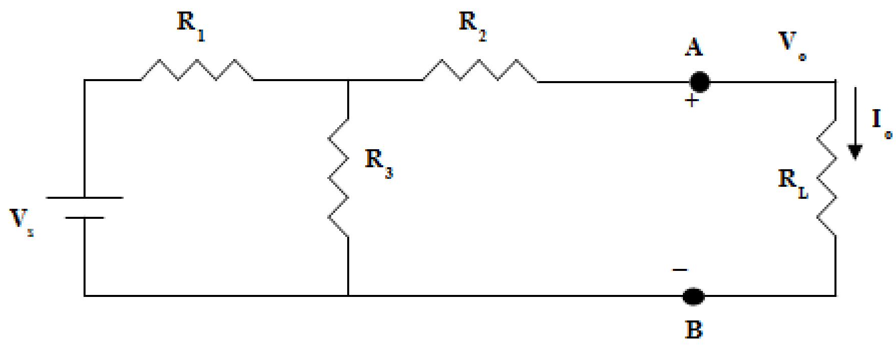


Figure 2: The Circuit to be Replaced with an Equivalent

We assumed the following about the values in the circuit:

V_s = 5.0 V

$R_1 = R_2 = R_3$ = 1000 Ohms

The work for finding both V_{oc} and I_{sc} and the sketches of the Thevenin and Norton circuits can be seen in Appendix 1. The calculated values are as follows:

V_{oc} = 2.5V

I_{sc} = 1.66mA

R_{th} = 1.5K Ω

Simulations:

For the next phase of the lab, we progressed from pencil and paper analysis to building and analyzing circuits in Multisim. We began in the same place as we did for the theoretical analysis, with the circuit in Figure 1. We used the same component values as before, again repeating the analysis at nominal and at plus and minus ten percent. The circuit created in Multisim can be seen in Figures 3 and 4, with Figure 3 showing voltage measurements and Figure 4 showing current readings. The values measured here are the same ones in the theoretical analysis. They are given for all three cases in Tables 4-6.

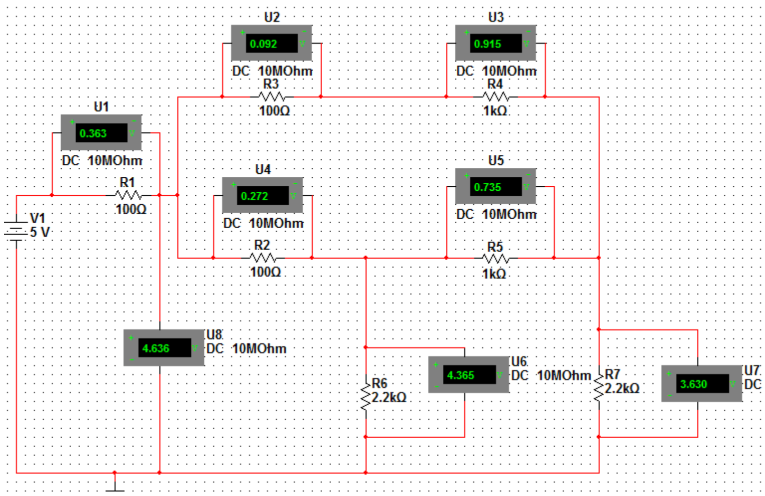


Figure 3: Voltage Readings at Nominal

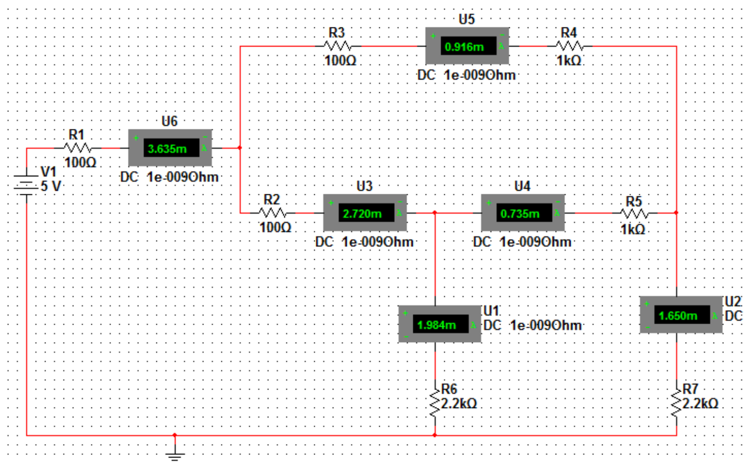


Figure 4: Current Readings at Nominal

Table 4: Simulated Values at Nominal

Branch Node or Loop #	Branch Voltages (V)	Branch Currents (mA)	Node Voltages (V)	Loop Currents (mA)
1	0.363	3.635	4.637	3.635
2	0.272	2.72	4.545	1.65
3	0.092	0.916	4.365	0.916
4	0.915	0.916	3.63	
5	0.735	0.735		
6	4.365	1.984		
7	3.63	1.65		

Table 5: Simulated Values with Resistors at -10%

Branch Node or Loop #	Branch Voltages (V)	Branch Currents (mA)	Node Voltages (V)	Loop Currents (mA)
1	0.363	4.039	4.637	4.039
2	0.272	3.021	4.547	1.833
3	0.090	1.017	4.365	1.017
4	0.915	1.017	3.630	
5	0.735	0.817		
6	4.365	2.204		
7	3.630	1.833		

Table 6: Simulated Values with Resistors at +10%

Branch Node or Loop #	Branch Voltages (V)	Branch Currents (mA)	Node Voltages (V)	Loop Currents (mA)
1	0.364	3.303	4.636	3.303
2	0.272	2.472	4.544	1.500
3	0.092	0.832	4.365	0.832
4	0.915	0.832	3.630	
5	0.735	0.669		
6	4.365	1.804		
7	3.630	1.500		

Next we considered the circuit in Figure 5, which we built in Multisim. Setting R_s at 100Ω and V_s at 5.0V we varied the value of the load resistor and recorded the value of the voltage across and current through the resistor. The circuit in Multisim can be seen in Figure 6 and the data collected can be seen in Table 7.

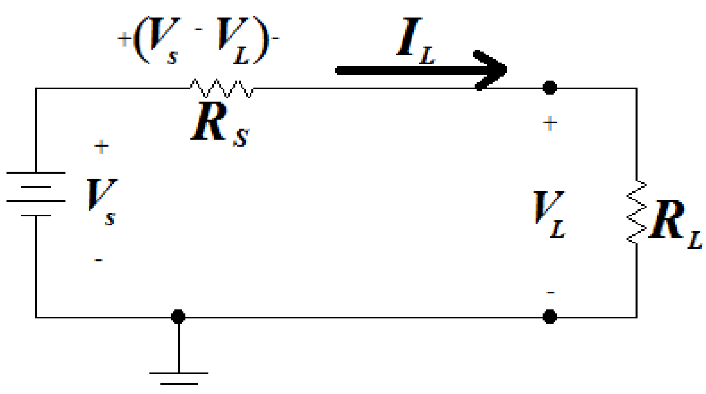


Figure 5: The Test Circuit

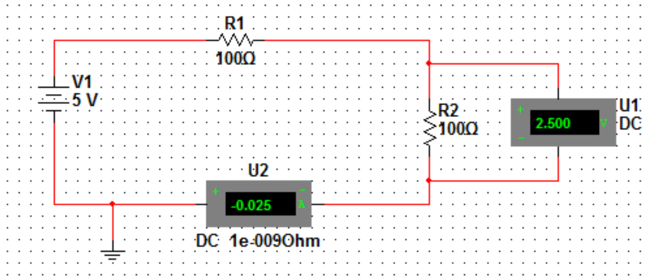


Figure 6: The Test Circuit in Multisim

Table 7: Multisim Data

RL	VL	IL A
10	0.455	0.045
20	0.833	0.042
40	1.429	0.036
70	2.059	0.029
100	2.500	0.025
150	3.000	0.020
200	3.333	0.017
300	3.750	0.013
500	4.167	0.008
1000	4.545	0.005

Finally, we repeated the analysis from the theoretical portion of the lab for Norton and Thevenin equivalent circuits, again using the circuit in Figure 2. Figures 7 and 8 show the measurements of open circuit voltage and short circuit current respectively.

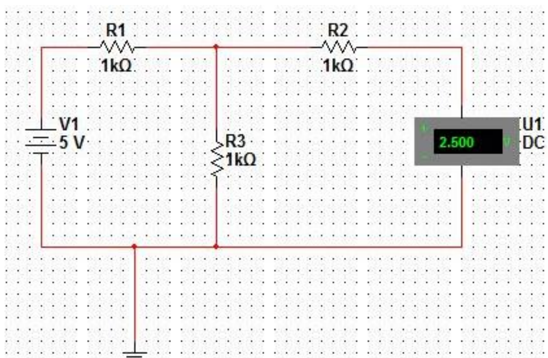


Figure 7: Open Circuit Voltage

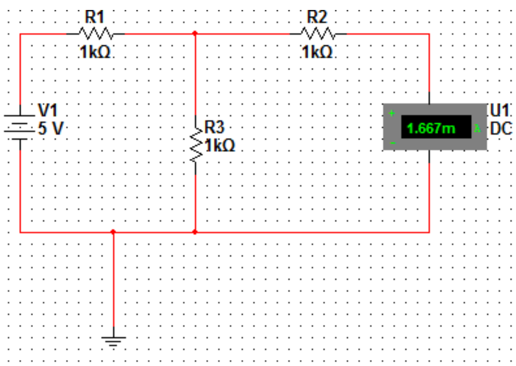


Figure 8: Short Circuit Current

Experimental:

For the last portion of the lab, we repeated prior portions of the lab work on a physical bread board to validate conceptual results. We started with the same circuit from Figure 1 we had already considered both theoretically and with simulations. This time, however, we only performed the analysis once, using only nominal values for components. The results can be seen in Table 8 of the results portion of this lab. Voltages were measured with a multi-meter placed on both ends of a resistor. Currents were measured by removing one end of a resistor and attaching it to one multi-meter and placing the other multi-meter lead at the point where the resistor was previously attached.

Next we built the circuit from Figure 5 on the breadboard and repeated the measurements from Multisim. The results can be seen in Table 9 of the results portion of this lab.

The final experimental step in this lab was creating a Thevenin equivalent for the circuit given in Figure 2. We first built the circuit on the breadboard and used the multi-meter to measure the open circuit voltage and short circuit current. Those values are given below.

V_{oc} = 2.528

I_{sc} = 1.64mA

R_{th} = 1.541K Ω

Using these values we were able to construct a Thevenin equivalent circuit using a 2.5 volt source and a 1.551K Ohm resistor in series with it. This circuit gave us the same open circuit voltage and short circuit current as the original circuit, but with only two components needed instead of four. We attempted to construct a Norton equivalent but were unable to do so due to a lack of a controlled low current source.

Results and Discussion:

The first two tables present the data previously discussed in the last portion of this lab. The values found here match closely with both the theoretical values and the simulated values. Discrepancies can be explained by tolerances in the parts used experimentally and tolerances on the multi-meter used to take the experimental readings.

Table 8: Simulated Values at Nominal

Branch Node or Loop #	Branch Voltages (V)	Branch Currents (mA)	Node Voltages (V)	Loop Currents (mA)
1	0.367	3.601	4.633	3.601
2	0.273	2.679	4.540	1.672
3	0.093	0.918	4.423	0.918
4	0.931	0.918	3.672	
5	0.750	0.742		
6	4.423	1.975		
7	3.672	1.672		

Table 9: Breadboard Data

RL	VL	IL A
10	0.347	0.042
20	0.858	0.039
40	1.455	0.034
70	2.091	0.028
100	2.864	0.024
150	3.256	0.019
200	3.376	0.016
300	3.797	0.012
500	4.220	0.008
1000	4.604	0.005

The results of the various portions of this lab confirm several key circuits concepts that will be discussed here. Those are Ohm's Law, Kirchoffs's Voltage and Current Laws, Thevenin equivalent circuits, and Norton equivalent circuits.

Ohm's Law or V=I*R was born out by the analysis on the circuit given in Figure 5. Ohms law simply defines the relationship between voltage and current as being linear. When we plot the results from the simulation (as we have done in Figure 9), we see just that. The slope of this line is -100.76, meaning that as current increases voltage decreases. The x-intercept of this plot is 0.05 and the y-intercept is 5.0253.

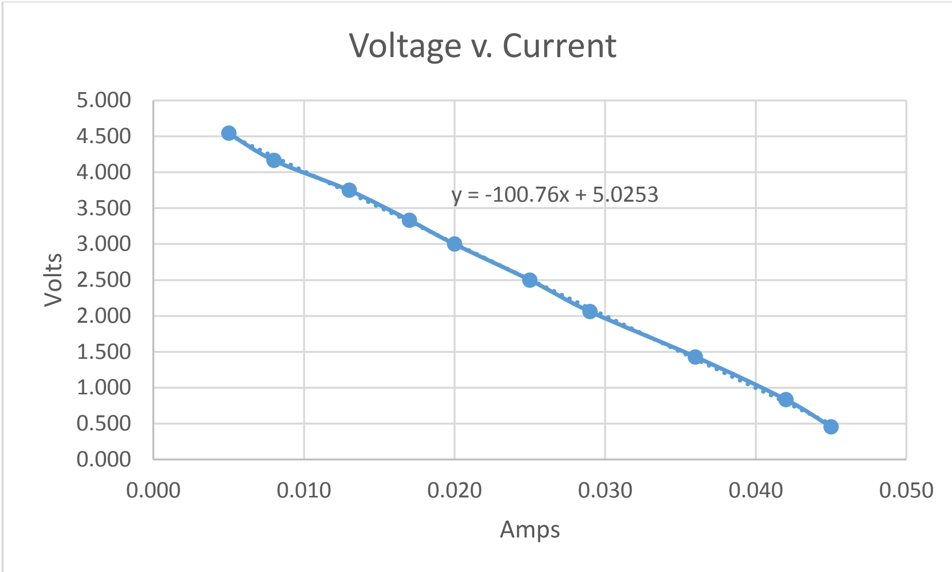


Figure 9: Voltage v. Current

Kirchoffs's Voltage Law states that the sum of the voltages around any closed loop in a circuit must be zero. Our analysis of the circuit in Figure 1 confirms this. If we look at any closed loop in that circuit, we can sum the voltages and they come out to be zero plus or minus a small margin of error.

Kirchoffs's Current Law states that the sum of currents entering and exiting any given node in a circuit must equal zero. If we again turn to the circuit in Figure 1, we can sum the currents entering any given node and see that they all come out to be zero.

We were also able to bear out Thevenin and Norton circuits. We found that these simpler circuits had the same open circuit voltage and short circuit current as the more complex circuits they are emulating. Thus using an equivalent allows for a much simpler circuit with the same functionality.

Conclusion:

As a whole, the results of the lab were closely in line with our expectations. There was virtually no discrepancies between the theoretical, simulation, and experimental results. All of the major circuits concepts we set out to prove were verified by the results of this lab. The lab also served as a useful introduction to the software and lab tools that will be used throughout this semester.

Appendix:

I_1: $5V - 100(I_1) - 100(I_1 - I_3) - 2200(I_1 - I_2) = 0$

$5 - 100I_1 - 100I_1 + 100I_3 - 2200I_1 + 2200I_2 = 0$

$-2400I_1 + 100I_3 + 2200I_2 = -5$

$2400I_1 - 2200I_2 - 100I_3 = 5$

I_2: $-2200(I_2 - I_1) - 1000(I_2 - I_3) - 2200(I_2) = 0$

$-2200I_2 + 2200I_1 - 1000I_2 + 1000I_3 - 2200I_2 = 0$

$-5400I_2 + 2200I_1 + 1000I_3 = 0$

I_3: $-100I_3 - 1000I_3 - 1000(I_3 - I_2) - 100(I_3 - I_1) = 0$

$-100I_3 - 1000I_3 - 1000I_3 + 1000I_2 - 100I_3 + 100I_1 = 0$

$-2200I_3 + 1000I_2 + 100I_1 = 0$

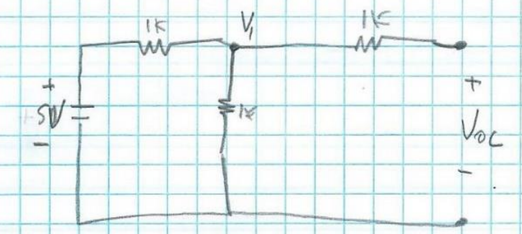
$$\begin{array}{c} \begin{array}{ccc} I_1 \quad & \quad I_2 \quad & \quad I_3 \end{array} \\ \left[\begin{array}{ccc|c} 2400 & -2200 & -100 & 5 \\ -2200 & -5400 & 1000 & 0 \\ 100 & 1000 & -2200 & 0 \end{array}\right] \end{array} \Rightarrow \begin{array}{l} I_1 = 3.634\ mA \\ I_2 = 1.650\ mA \\ I_3 = 0.915\ mA \end{array}$$

10% below nominal

$$\left[\begin{array}{ccc|c} 2160 & -1980 & -90 & 5 \\ 1980 & -4860 & 900 & 0 \\ 90 & 900 & -1980 & 0 \end{array}\right] \Rightarrow \begin{array}{l} I_1 = 4.038\ mA \\ I_2 = 1.833\ mA \\ I_3 = 1.017\ mA \end{array}$$

10% above nominal

$$\left[\begin{array}{ccc|c} 2640 & -2420 & -110 & 5 \\ -2420 & -5940 & 1100 & 0 \\ 110 & 1100 & -2420 & 0 \end{array}\right] \quad \begin{array}{l} I_1 = 3.304\ mA \\ I_2 = 1.500\ mA \\ I_3 = 0.832\ mA \end{array}$$



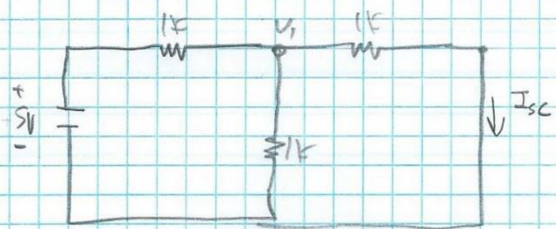
Nodal @ V_1: $\frac{V_1-5}{1k}+\frac{V_1}{1k}=0$

$$1k\left[\frac{V_1-5}{1k}+\frac{V_1}{1k}=0\right]$$

$$V_1-5+V_1=0$$

$$\frac{2V_1}{2}=\frac{5}{2} \qquad V_1=2.5V$$

$\underline{V_1=V_{OC}=2.5V}$



Nodal @ V_1: $\frac{V_1-5}{1k}+\frac{V_1}{1k}+\frac{V_1}{1k}=0$

$$1k\left[\frac{V_1-5}{1k}+\frac{V_1}{1k}+\frac{V_1}{1k}=0\right]$$

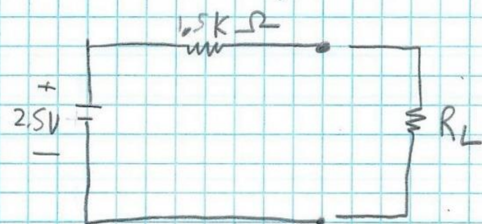
$$V_1-5+V_1+V_1=0$$

$$\frac{3V_1}{3}=\frac{5}{3} \qquad V_1=1.\overline{66}V$$

$$I_{SC}=\frac{V_1}{1k}=\frac{1.\overline{66}V}{1k}=\underline{1.\overline{66}mA}$$

$$R_{TH}=\frac{V_{OC}}{I_{SC}}=\frac{2.5V}{1.\overline{6}mA}=1{,}500\ \Omega$$

Thevenin equivalent



Norton Equivalent