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EE 316-08
Electric Circuits & Electronics Design Lab

Lab 1: Circuits Review

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Lab Date: 01/26/2021

Lab Due: 01/26/2021

1. Introduction:

This lab simply covers the basics and reviews Ohm's law, and Kirchhoff's current and voltages laws. It also dives into using Thevenin Equivalent equations to solve a given circuit. Continually, this lab is pivotal in learning Multisim and understanding how to use its features to assist us in our lab.

2. Theoretical Analysis:

Using figure 1 below from the lab manual, we use mesh analysis to solve for branch currents, node voltages, loop currents, and branch voltages. We initially calculate them with the values as shown:

Vs = 5.0v
R1 = R2 = R3 = 100 ohms
R4 = R5 = 1000 ohms
R6 = R7 = 2200 ohms

After we run through the calculations the first time, we then go back and run them with a 10% increase on the resistors, and again with a 10% decrease on the resistors. The figure for calculation and tables with results follow:

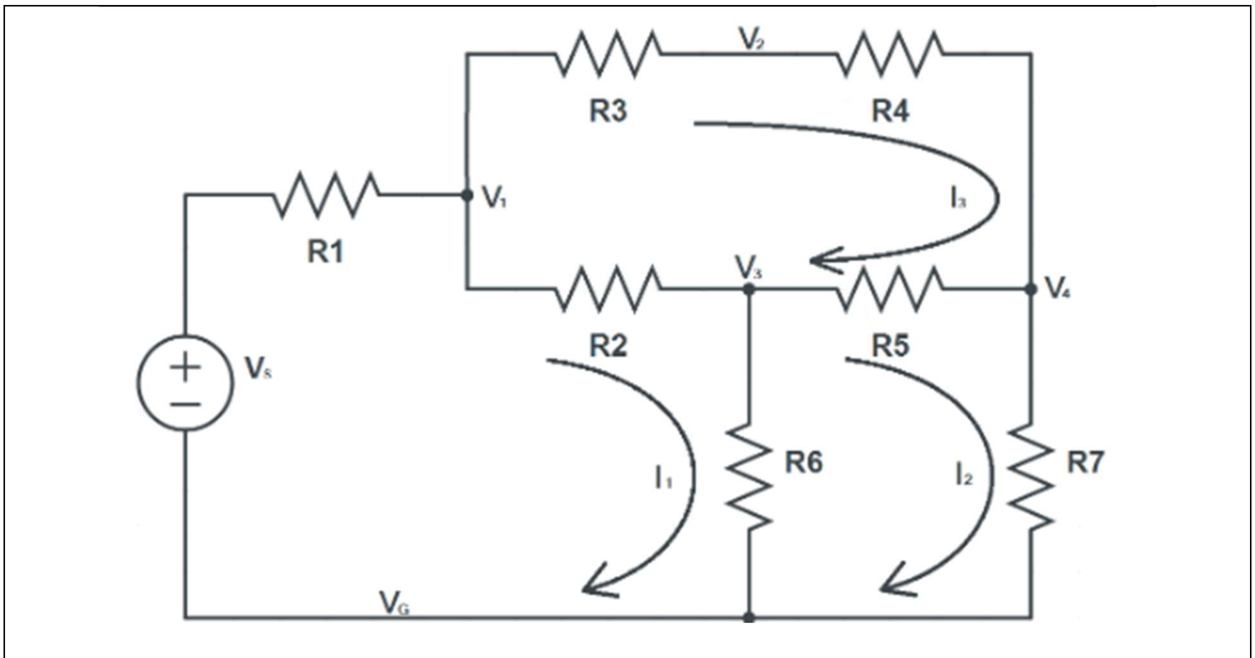


Figure 1: Circuit under analysis.

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 1: Calculations with Resistors at Nominal.

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 2: Calculations with a 10% decrease on all resistors.

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		

Table 3: Calculations with a 10% increase on all resistors.

3. Simulations:

The following simulations were all performed in multisim. This will not only prove our findings from our analysis of Figure one, but we will also develop more designs for Thevenin equivalent circuits and prove ohms law.

First, I will provide the simulation for figure 1 in terms of voltages and currents. I will place my findings in tables 4-6.

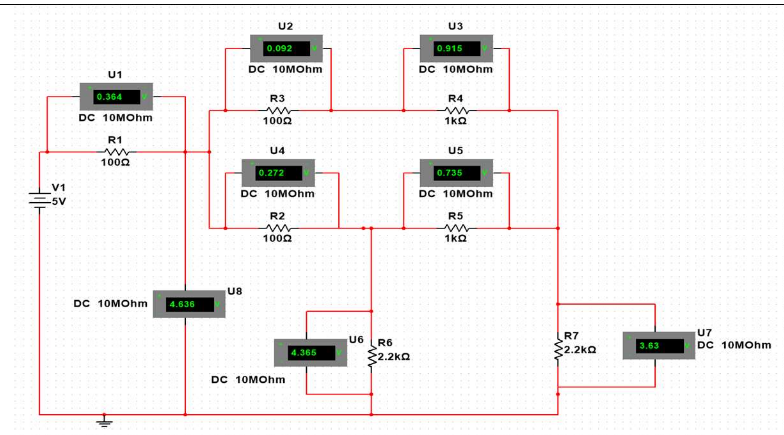


Figure 2: Simulation for figure 1, voltages

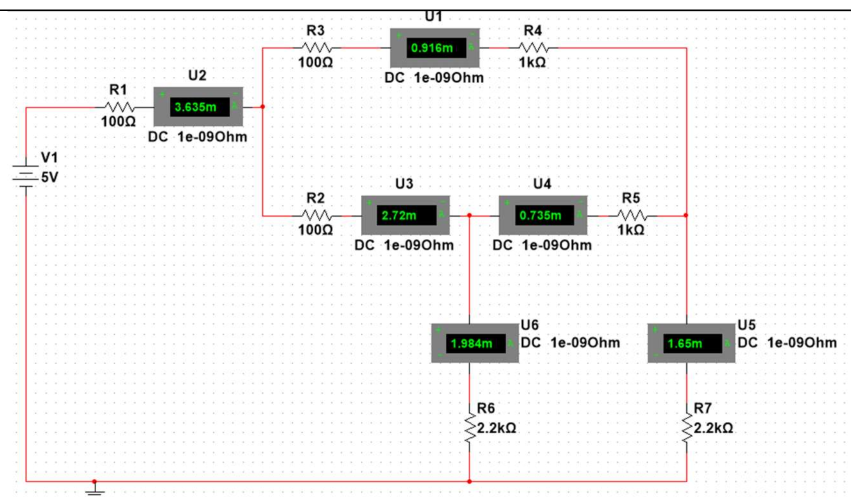


Figure 3: Simulation for figure 1, amperes

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 4: Calculations with Resistors at Nominal.

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 5: Calculations with a 10% decrease on all resistors.

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		

Table 6: Calculations with a 10% increase on all resistors.

As you can see, comparing the data from tables 1-3 and 4-6 shows that my hand calculations were accurate. You can see the handwritten portion in the appendix. Next, we will consider the circuit as shown in Figure 5. Building this in Multisim (see figure 6), we can see the results in table 7.

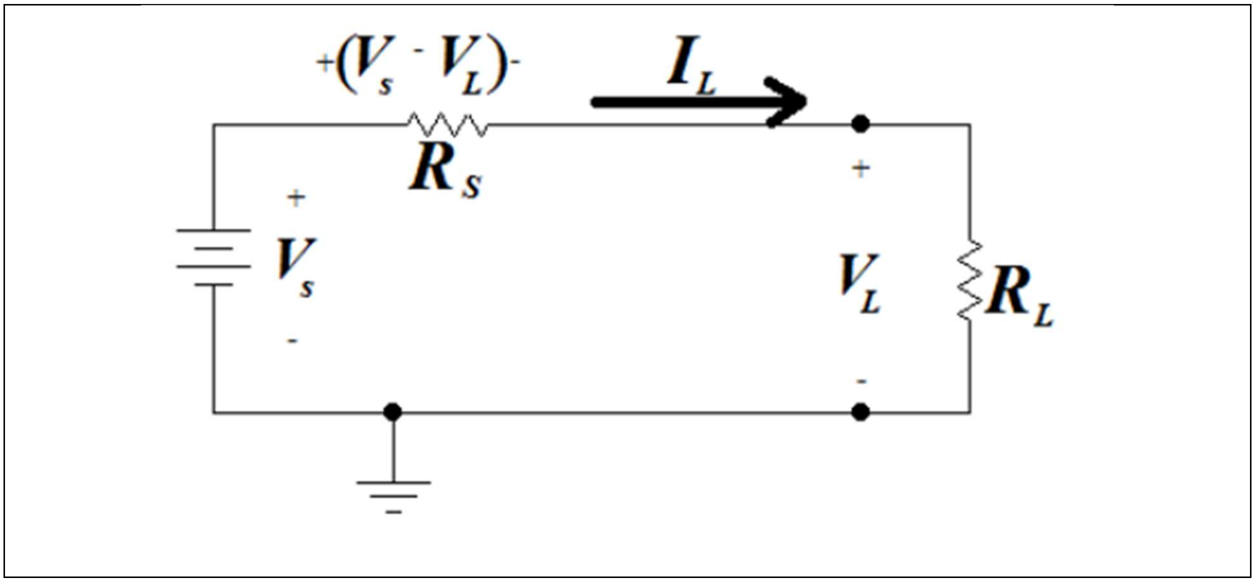


Figure 5: Test Circuit 1.4

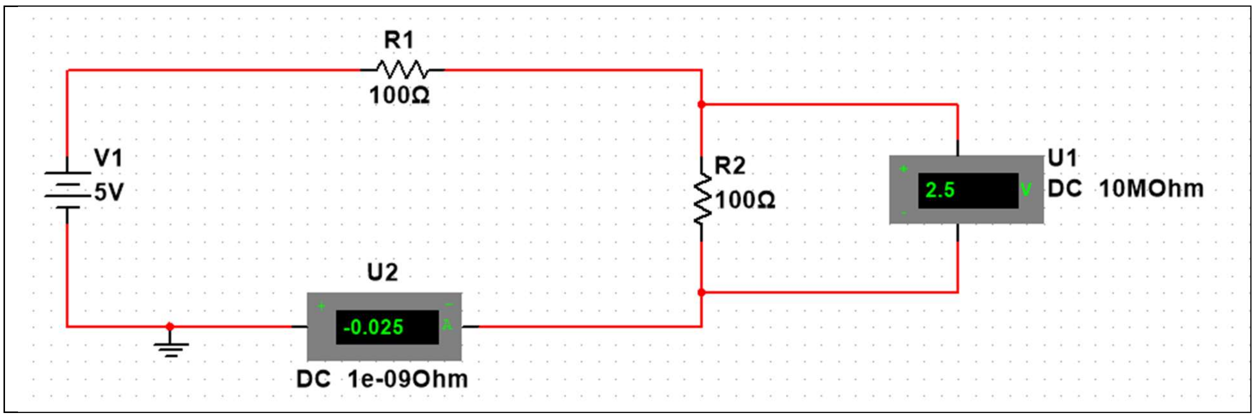
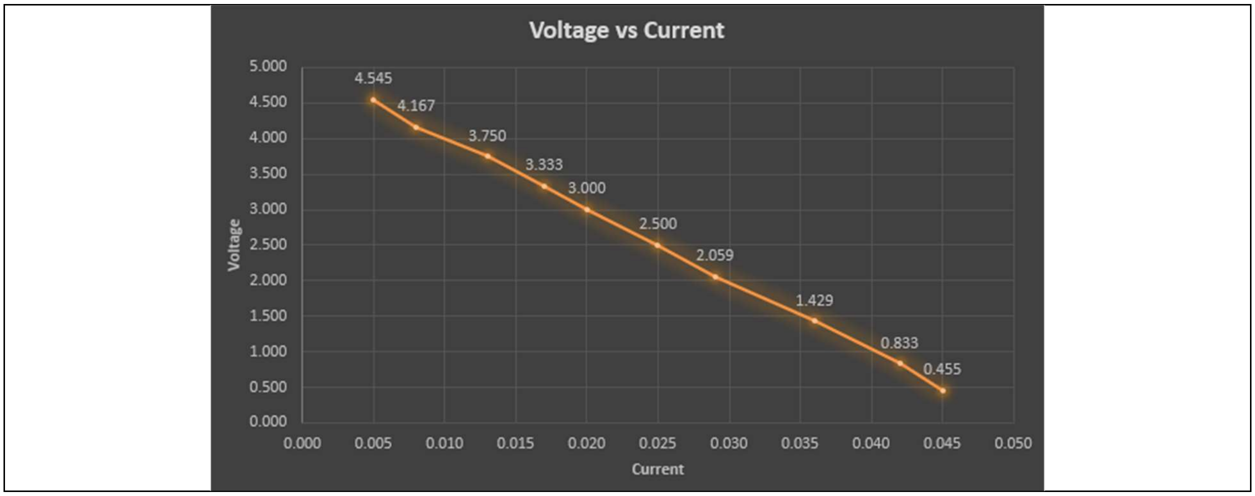


Figure 6: Figure 5 in Multisim

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

Table 1.7: Multisim data from the Multisim figure 6.



Plot 1: Voltage v Current for figure 6.

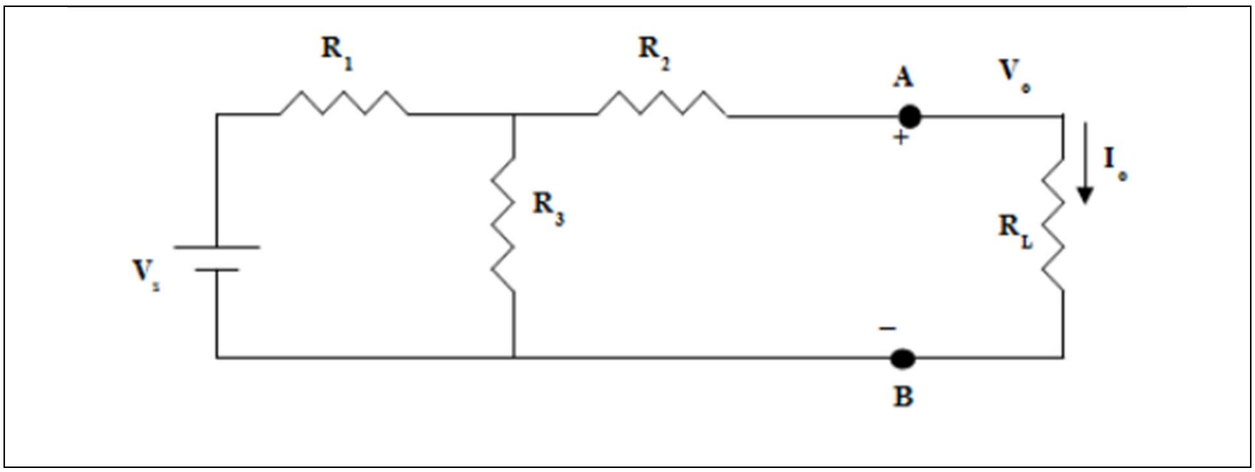
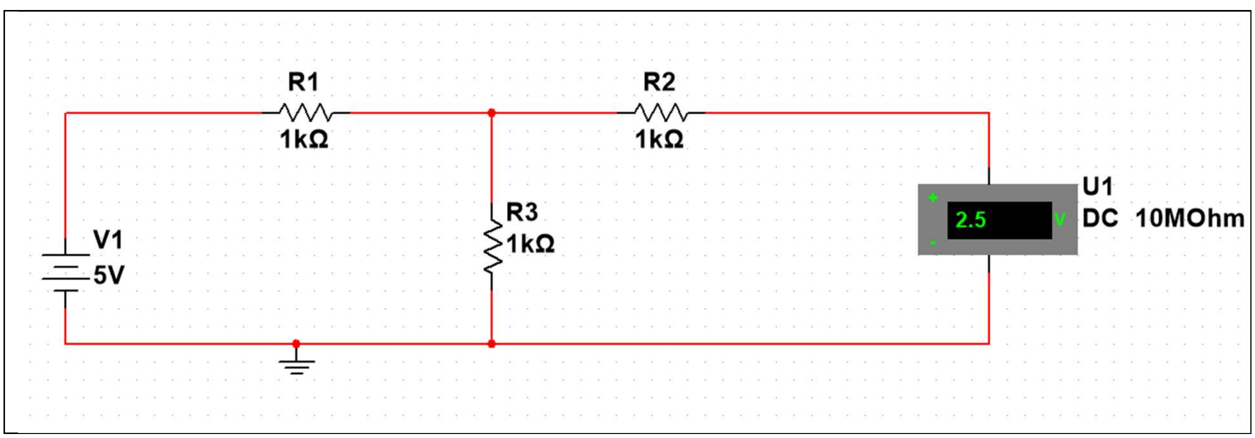


Figure 6: Test Circuit 1.5



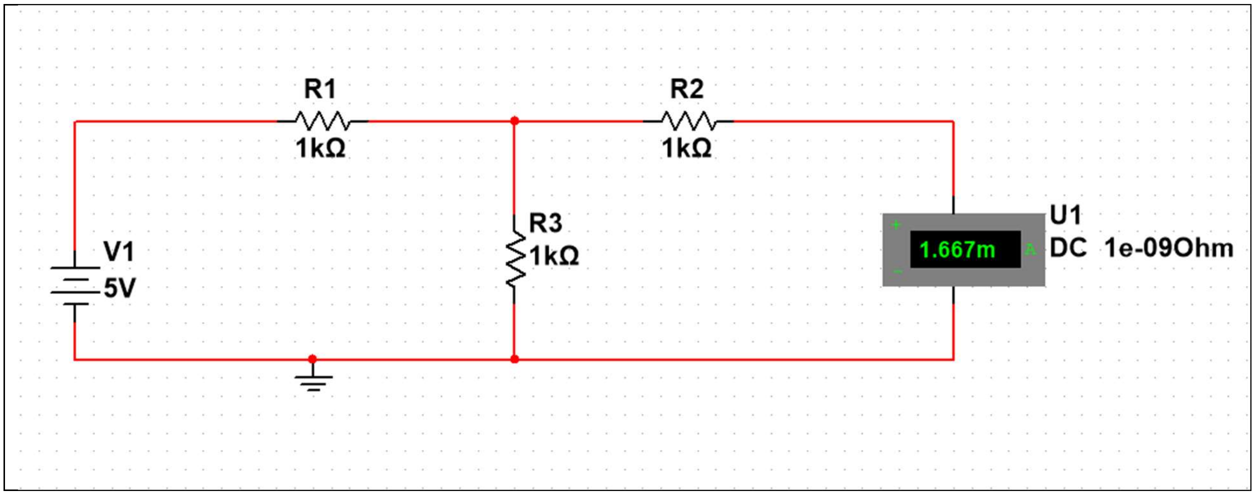


Figure 7: Figure 6 in Multisim, voltages and current calculation.

Using the calculations from figure 7, we can see that the Thevenin equivalent resistance for figure 8 will be 1.5kohm

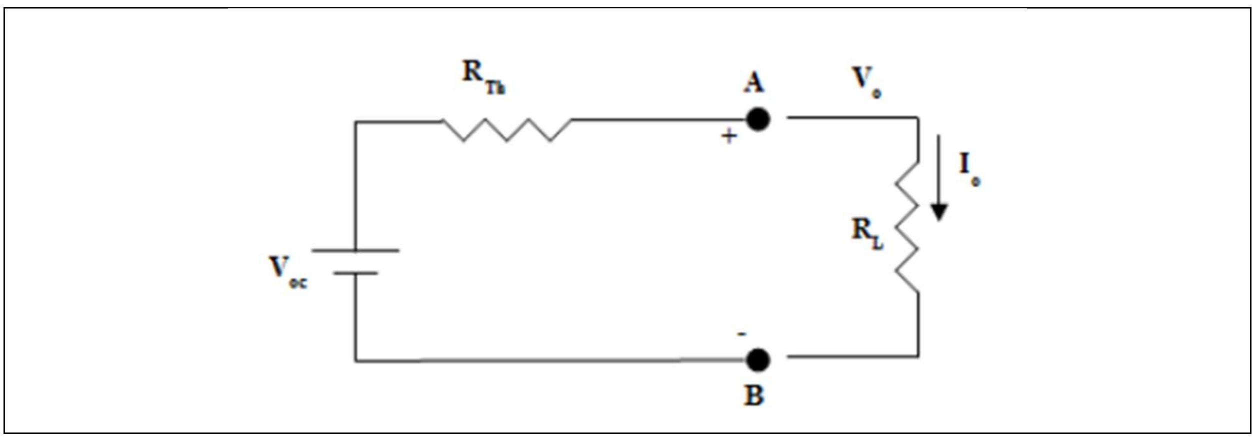


Figure 8: Test Circuit 1.6

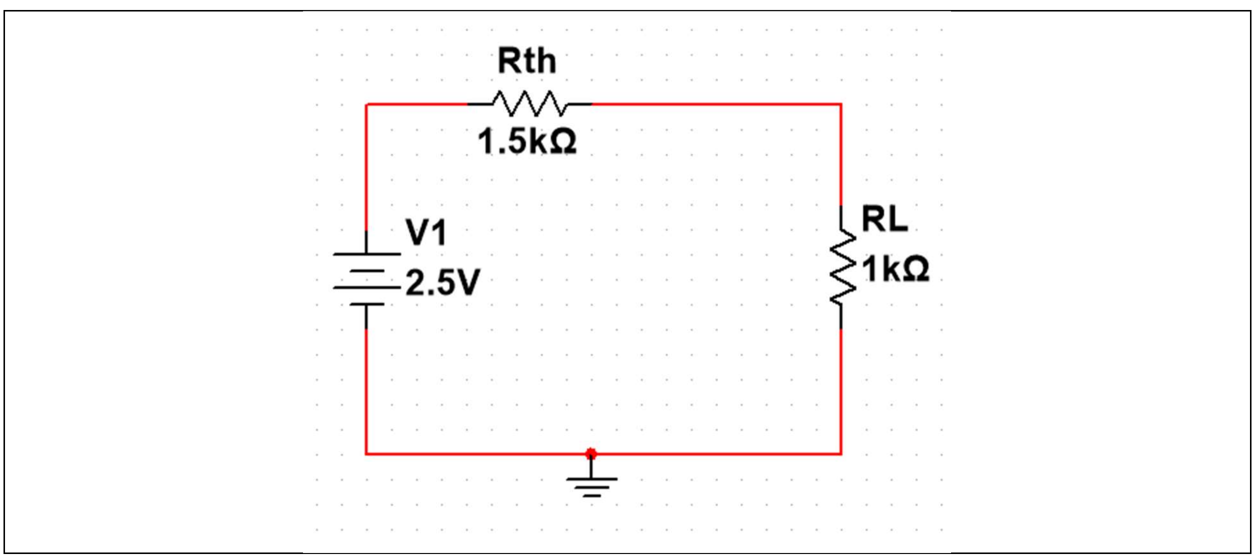


Figure 9: Figure 8 in Multisim, Thevenin equivalent circuit for the calculations from Figure 7.

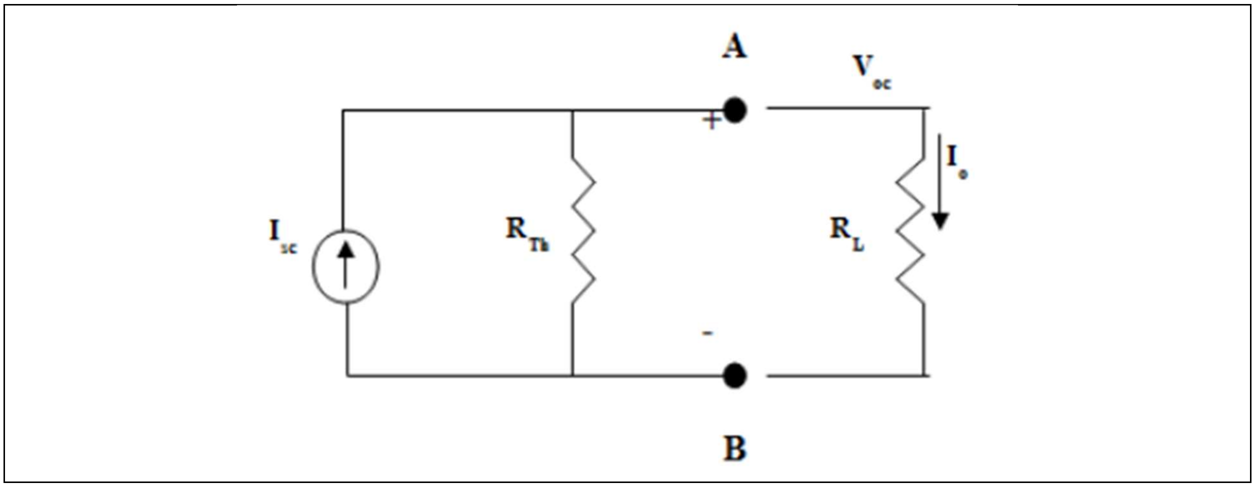


Figure 10: Test Circuit 1.7

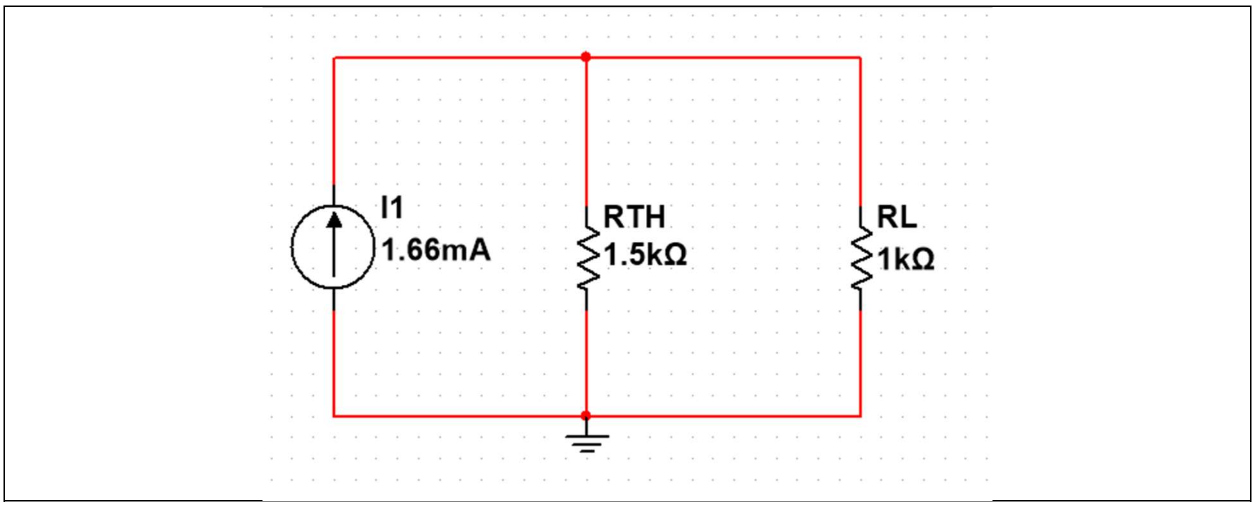


Figure 11: Figure 10 in Multisim, Norton equivalent circuit.

~~4. Experimental:~~

We were not instructed to provide experimental results for this lab, see the following screenshot.

Summary

- Lab 1 Report & Pre-lab 2 are due on Tuesday 26th January 2021 by midnight.
- Analyze circuit in Fig. 1.3 under 3 assumptions – all resistors are exact value, 10% above the exact values, and 10% below the exact values.
  - Hands calculations
  - Simulations
  - ~~Experimental results~~
- Analyze circuit in Fig. 1.4 – Fig. 1.7
  - Simulations
  - ~~Experimental results~~

5. Results and Discussion:

This lab set out to introduce, review, and prove Ohm's law, Kirchoff's Current Law, and Kirchoff's voltage law. First, we look at figure 5 which covers ohm's law. This law essentially states that the relationship between current and voltage is linear, see Plot 1. Next, we look at Kirchoff's current and voltage laws both represented and proven by our first circuit displayed in figure 1. If you sum all the voltages in the closed loop circuit, within a small margin it sums to zero. Similarly, for the current law, we can see that they also sum to zero when looking at the nodes. Lastly, we used Thevenin and Norton circuits that provided us with similar results to their much more complicated circuits they were emulating.

6. Conclusion:

The findings from this lab helped to prove Kirchoff's voltage and current laws as well as ohm's law. Also, the use of Thevenin and Norton circuits makes solving a very complex circuit much easier, even in Multisim. Continually, this lab was extremely helpful in providing an introduction into Multisim and other tools that will be helpful in the long run. Lastly, from using Multisim to give us accurate results to solving the circuits by hand, this lab followed through on its purpose.

7. Appendix:

Theoretical Analysis

Referring to Figure 1.3, calculate the circuit's Branch Voltages, Branch Currents, Node Voltages, and Loop Currents with the following assumptions. (Note: Mesh Analysis may be useful here.)

1. First assume all the resistors are exact (i.e. a 10 ohm resistor is exactly 10 ohms).
2. Then assume all resistors are 10% above the exact values.
3. Then assume all resistors are 10% below the exact values.

Record all your data in tabular format similar to Table 1.1. Let the exact values of source voltage and resistors be defined by the following values:

Vs = 5.0V
R1 = R2 = R3 = 100
R4 = R5 = 1 K
R6 = R7 = 2.2 K

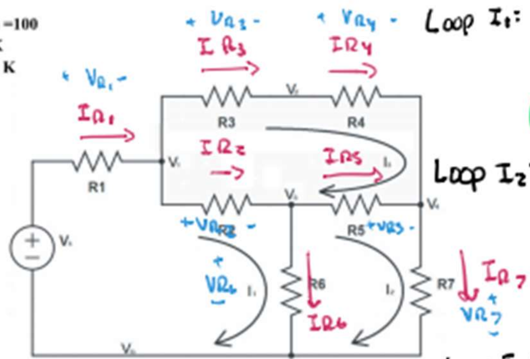


Figure 1.3

Loop I_1: $R_1 I_1 + R_2(I_1 - I_3) + R_6(I_1 - I_2) - 5 = 0$

$R_1 I_1 + R_2 I_1 - R_2 I_3 + R_6 I_1 - R_6 I_2 = 5$

$(R_1 + R_2 + R_6) I_1 - R_6 I_2 - R_2 I_3 = 5$

Loop I_2: $R_6(I_2 - I_1) + R_5(I_2 - I_3) + R_7 I_2 = 0$

$R_6 I_2 - R_6 I_1 + R_5 I_2 - R_5 I_3 + R_7 I_2 = 0$

$(R_6 + R_5 + R_7) I_2 - R_6 I_1 - R_5 I_3 = 0$

Loop I_3: $R_3 I_3 + R_4 I_3 + R_5 I_3 - R_5 I_2 + R_2 I_3 - R_2 I_1 = 0$

$-R_2 I_1 - R_5 I_2 + (R_2 + R_3 + R_4 + R_5) I_3 = 0$

$$\left.\begin{array}{l} (R_1 + R_2 + R_6) I_1 - R_6 I_2 - R_2 I_3 = 5 \\ -R_6 I_1 + (R_6 + R_5 + R_7) I_2 - R_5 I_3 = 0 \\ -R_2 I_1 - R_5 I_2 + (R_2 + R_3 + R_4 + R_5) I_3 = 0 \end{array}\right\} \begin{bmatrix} R_1+R_2+R_6 & -R_6 & -R_2 \\ -R_6 & R_5+R_6+R_7 & -R_5 \\ -R_2 & -R_5 & R_2+R_3+R_4+R_5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 5 \\ 0 \\ 0 \end{bmatrix}$$

Plug in Resistor values / 100

$$\left[\begin{array}{ccc|c} 24 & -22 & -1 & .05 \\ -22 & 54 & -10 & 0 \\ -1 & -10 & 22 & 0 \end{array}\right] \longrightarrow \left[\begin{array}{ccc|c} 1 & 0 & 0 & 0.003634 \\ 0 & 1 & 0 & 0.00165 \\ 0 & 0 & 1 & 0.0009152 \end{array}\right] \longrightarrow \begin{array}{l} I_1 = .003634A \\ I_2 = .00165A \\ I_3 = .0009152A \end{array}$$

$I_{R_1} = I_1 = 3.634A$

$I_{R_2} = I_1 - I_3 = 2.719mA$

$I_{R_3} = I_3 = .9152mA$

$I_{R_4} = I_3 = .9152mA$

$I_{R_5} = I_2 - I_3 = .735mA$

$I_{R_6} = I_1 - I_2 = 1.984mA$

$I_{R_7} = 1.65mA$

$V_{R_1} = I_{R_1} R_1 = .36v$

$V_{R_2} = I_{R_2} R_2 = .27v$

$V_{R_3} = I_{R_3} R_3 = .09v$

$V_{R_4} = I_{R_4} R_4 = .91v$

$V_{R_5} = I_{R_5} R_5 = .73v$

$V_{R_6} = I_{R_6} R_6 = 4.37v$

$V_{R_7} = I_{R_7} R_7 = 3.64v$

$V_1 = 5 - V_1 (I_{R_1})(R_1) = 4.64v$

$V_2 = V_1 - V_2 = I_{R_3} R_3 = 4.55v$

$V_3 = V_1 - V_3 = I_{R_2} R_2 = 4.37v$

$V_4 = V_3 - V_4 = I_{R_5} R_5 = 3.64v$

+10% Resistor Values $R_6 = R_7 = 2420$ | $R_1 = R_2 = R_3 = 110$

$R_4 = R_5 = 1100$

$$\left[\begin{array}{ccc|c} 2690 & -2420 & -110 & 5 \\ -110 & 5440 & -1100 & 0 \\ -110 & -1100 & 2420 & 0 \end{array}\right] \longrightarrow \left[\begin{array}{ccc|c} 1 & 0 & 0 & 4.038 \\ 0 & 1 & 0 & 1.833 \\ 0 & 0 & 1 & 1.017 \end{array}\right] \longrightarrow \begin{array}{l} I_1 = 4.038 \text{ mA} \\ I_2 = 1.833 \text{ mA} \\ I_3 = 1.017 \text{ mA} \end{array}$$

$I_{R_1} = I_1 = 4.038$

$I_{R_2} = I_1 - I_3 = 3.021$

$I_{R_3} = I_3 = 1.017$

$I_{R_4} = I_3 = 1.017$

$I_{R_5} = I_2 - I_3 = 0.816$

$I_{R_6} = I_1 - I_2 = 2.205$

$I_{R_7} = 1.833$

$V_{R_1} = I_{R_1} R_1 = .36v$

$V_{R_2} = I_{R_2} R_2 = .27v$

$V_{R_3} = I_{R_3} R_3 = .09v$

$V_{R_4} = I_{R_4} R_4 = .91v$

$V_{R_5} = I_{R_5} R_5 = .73v$

$V_{R_6} = I_{R_6} R_6 = 4.37v$

$V_{R_7} = I_{R_7} R_7 = 3.64v$

$V_1 = 5 - V_1 (I_{R_1})(R_1) = 4.64v$

$V_2 = V_1 - V_2 = I_{R_3} R_3 = 4.55v$

$V_3 = V_1 - V_3 = I_{R_2} R_2 = 4.37v$

$V_4 = V_3 - V_4 = I_{R_5} R_5 = 3.64v$

−10% Resistor values $R_6 = R_7 = 1980$ | $R_1 = R_2 = R_3 = 90$

$R_4 = R_5 = 900$

$$\left[\begin{array}{ccc|c} 2160 & -1980 & -90 & 5 \\ -1980 & 4860 & -900 & 0 \\ -90 & -900 & 1980 & 0 \end{array}\right] \longrightarrow \left[\begin{array}{ccc|c} 1 & 0 & 0 & 3.304 \\ 0 & 1 & 0 & 1.300 \\ 0 & 0 & 1 & 0.832 \end{array}\right] \longrightarrow \begin{array}{l} I_1 = 3.304 \text{ mA} \\ I_2 = 1.300 \text{ mA} \\ I_3 = 0.832 \text{ mA} \end{array}$$

mA ↓

$I_{R_1} = I_1 = 3.307$

$I_{R_2} = I_1 - I_3 = 2.472$

$I_{R_3} = I_3 = 0.832$

$I_{R_4} = I_3 = 0.832$

$I_{R_5} = I_2 - I_3 = 0.668$

$I_{R_6} = I_1 - I_2 = 1.804$

$I_{R_7} = 1.50$

$V_{R_1} = I_{R_1} R_1 = .36v$

$V_{R_2} = I_{R_2} R_2 = .27v$

$V_{R_3} = I_{R_3} R_3 = .09v$

$V_{R_4} = I_{R_4} R_4 = .91v$

$V_{R_5} = I_{R_5} R_5 = .73v$

$V_{R_6} = I_{R_6} R_6 = 4.37v$

$V_{R_7} = I_{R_7} R_7 = 3.64v$

$V_1 = 5 - V_1 (I_{R_1})(R_1) = 4.64v$

$V_2 = V_1 - V_2 = I_{R_3} R_3 = 4.55v$

$V_3 = V_1 - V_3 = I_{R_2} R_2 = 4.37v$

$V_4 = V_3 - V_4 = I_{R_5} R_5 = 3.64v$

Figure A1: Hand calculations for solving Figure 1.