EEE 117L Laboratory – Network Analysis
Lab #2: Resistance, Voltage, and Current Measurements

Lab Day and Time: Wednesday, 1:30pm - 4:10pm

Group Number: # 03

Group Members: (Last Name, First Name)

Member #1: Algador, Vigomar Kim

Member #2: Chan, Casey

Member #3: Trinh, Bon

Total Score: /100

Work Breakdown Structure: It is important that every group member do their share of the work in these labs. Remember that you will receive no credit for the prelab if you did not contribute. Write in the Table provided below, which group member(s) contributed to the solution of each problem in the prelab. Also remember that only on prelab per group will be turned in to Canvas. If there was any group member that did not contribute, then write their name in the space provided below.

Problem Number	Group member(s) that worked on the problem.
Part I	Trinh, Bon Chan, Casey Algador, Vigomar Kim
Part IIA	Chan, Casey
Part IIB	Trinh, Bon
Part IIC	Algador, Vigomar Kim
Part IID	Trinh, Bon Chan, Casey Algador, Vigomar Kim
Part IIIA	Chan, Casey
Part IIIB	Trinh, Bon
Part IIIC	Algador, Vigomar Kim
Part IIID	Trinh, Bon Chan, Casey Algador, Vigomar Kim
Part IV	Trinh, Bon Chan, Casey Algador, Vigomar Kim

Absent member(s):____

General Instructions:

1) While working with your circuits, if you ever smell smoke or a funny smell, turn off the power to the circuit immediately. It is important to note that the Analog Discovery 2 (AD2) has a few protection protocols and will shut down all voltage sources if too much current is drawn, but is not impervious to damage due to misuse. Also make sure to also try to keep your work space clear from debris so as to avoid potential fire hazards. Similarly, do not keep your circuits powered for extended periods of time, as the components will become hotter as time goes on. If you must walk away from your circuit make sure the AD2 is powered off.

2) If you need extra pages in order to finish up the worksheet, make sure you add them to the end of the report, number them, and refer to those pages in the appropriate section.

3) Remember that to measure voltage, the digital multimeter (DMM) must be placed in parallel with the circuit element whose voltage you wish to measure. This is a non-invasive process in the sense that the circuit does not need to be altered to measure a desired voltage. However, to measure current, the DMM must be placed in series with the element whose current is to be measured. This is invasive, in the sense that a portion of the circuit must be disconnected in order to measure a desired current. Make sure to turn off power to the circuit before disconnecting any portion of the circuit.

4) If you need help with the PSpice simulations, refer to the tutorial from Purdue University that was listed in the syllabus:
https://engineering.purdue.edu/~ee255/lecturesupp_files/PSpice-Tutorial.pdf

Part I: Resistance Measurements Score: /20

There will be a total of five resistors, labeled R_1 through R_5, that will not only be used for this portion of the lab but also the remainder of experiments. It is typically good practice to gather all of the components of the circuits to be built and to experimentally measure their parameters of interest before you begin assembling your circuits. In the EEE 117L you will often be gathering resistors, capacitors, operational amplifiers, and wires. In the case of resistors and capacitors, you will find more often than not that the actual experimental values will be different than the intended or stated values, within a certain tolerance. Whenever we make predictions regarding the behavior of circuits based on theoretical equations is it important that we use the actual experimental values rather than the theoretical values in our calculations.

Use your digital multimeter (DMM) to measure the experimental resistance of all of the resistors to be used and compare these values to the theoretical values as read off of the color code. For a detailed explanation of the color codes used for resistors refer to the following article found in Wikipedia, https://en.wikipedia.org/wiki/Electronic_color_code. The comparison should be given as a percent difference and can be calculated using equation (1) shown below. Do the actual values of all of the resistors fall within the tolerances printed on the last color band of the resistors? Use the following Table 1 to record your answers.

$$\%Difference = \left|\frac{R_{theoretical} - R_{experimental}}{R_{theoretical}}\right| \times 100\% \qquad (1)$$

Resistor	Theoretical Resistance	Experimental Resistance	% Difference	Tolerance (Yes/No)
R_1	100 kΩ	98.5 kΩ	1.5 %	YES
R_2	300 kΩ	298 kΩ	0.67 %	YES
R_3	2 kΩ	1.979 kΩ	1.05 %	YES
R_4	1 kΩ	0.999 kΩ	0.1 %	YES
R_5	3 kΩ	2.971 kΩ	0.97 %	YES

Table 1. Resistance Measurements

Part II: Voltage Measurements Total Score: /30

All of the calculations, simulations, and experiments in this section will be based on the circuit shown in Figure 1, shown below. Note that this is a classic, simple voltage divider.

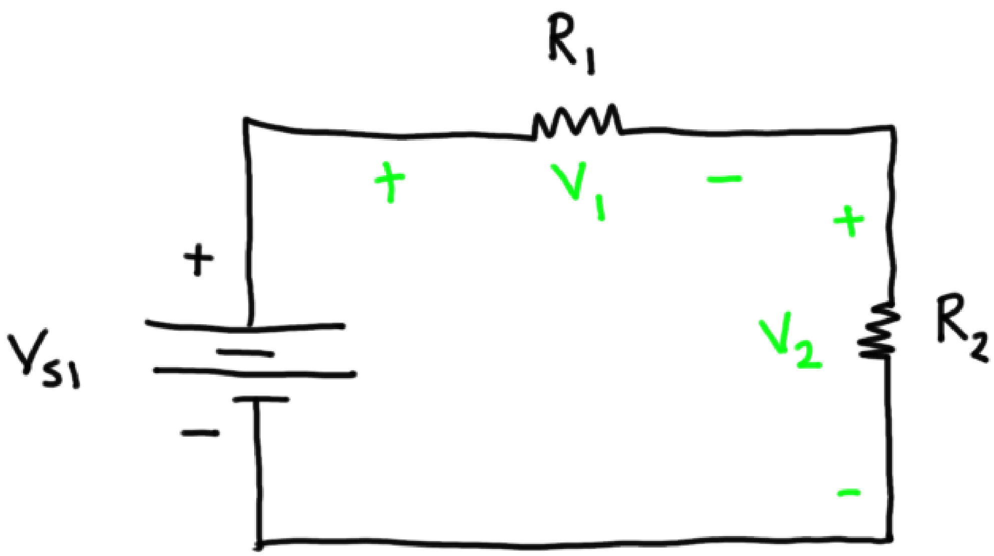


Figure 1. Voltage Measurements Circuit

A. Hand Calculation of Theoretical Value Score: /10

In the prelab you should have been able to calculate the voltages V_1 and V_2 in terms of V_{s1}, R_1 and R_2 in equation form. Using those equations, the value of $V_{s1} = 2.0\ V$ which will be experimentally set, and the measured values of R_1 and R_2 obtained from Part I of this experiment, to calculate the theoretical values of V_1 and V_2 numerically. Make sure to show all your work, including units.

$$V_1 = \frac{V_S R_1}{R_1+R_2}$$

$$= \frac{(2.0\ V)\ (100\ k\Omega)}{100\ k\Omega + 300\ k\Omega} = 0.5\text{V}$$

$$V_2 = \frac{V_S R_2}{R_1+R_2}$$

$$= \frac{(2.0\ V)\ (300\ k\Omega)}{100\ k\Omega + 300\ k\Omega} = 1.5\text{V}$$

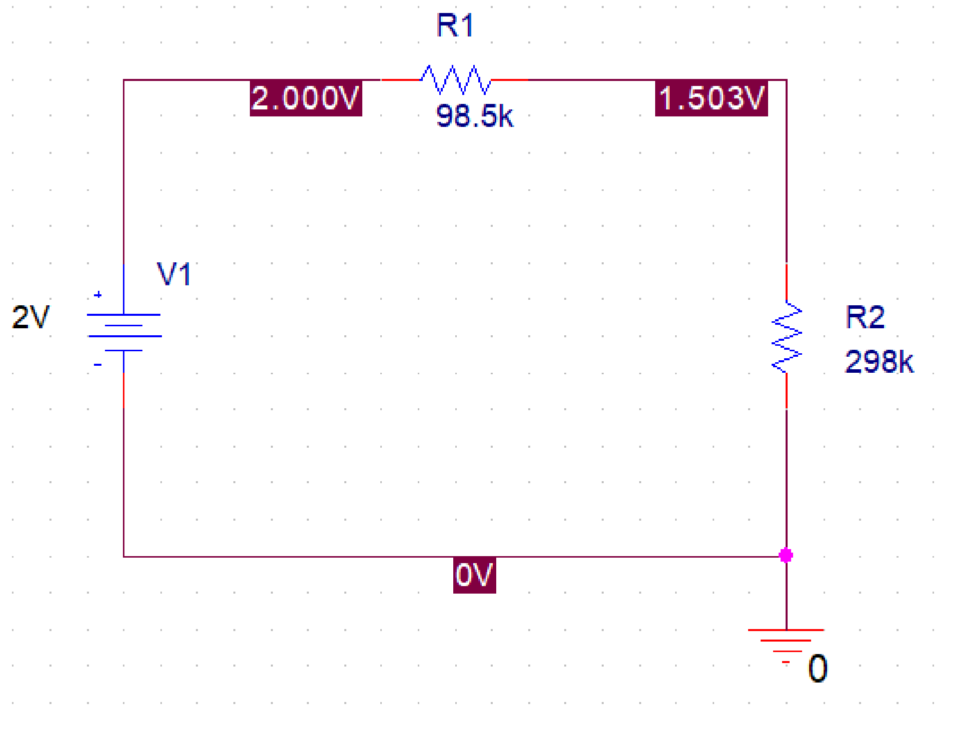
Answers:

$V_1 = 0.5$ V $V_2 = 1.5$ V

B. Simulated Values Score: /10

Using PSpice simulates the circuit shown in Figure 1. Use the experimental values for V_{s1}, R_1, and R_2 in the simulation. Using the "snipping tool" create a picture of the circuit after the simulation has been run and paste it below. Keep in mind that part of your grade here will be determined by (a) how neat your circuit has been created in the workspace and (b) the clarity of the elements in the simulation, i.e. can you clearly see everything relevant.

Simulation Result:



Use the values of the voltages in the simulation to calculate the voltages V_1 and V_2.

Answers:

$V_1 = 0.497$ V

$V_2 = 1.503$ V

C. Experimental Values and Comparisons Score: /10

Assemble the circuit shown in Figure 1 using your breadboard and resistors. Use the positive voltage supply from the Analog Discovery 2 (AD2) to provide it with power. Using your digital multimeter (DMM) measure the voltages V_1, V_2, and V_{s1} and record them in the Table 2 shown below. Fill in the rest of the table using the values of the voltages obtained from parts A and B of this experiment to compare them.

Voltage	Theoretical Voltage	Simulated Voltage	Experimental Voltage
V_{s1}	2.0 V	2.0 V	2.0 V
V_1	0.5 V	0.497 V	0.492 V
V_2	1.5 V	1.503 V	1.491 V

Table 2. Voltage Measurements

D. Questions

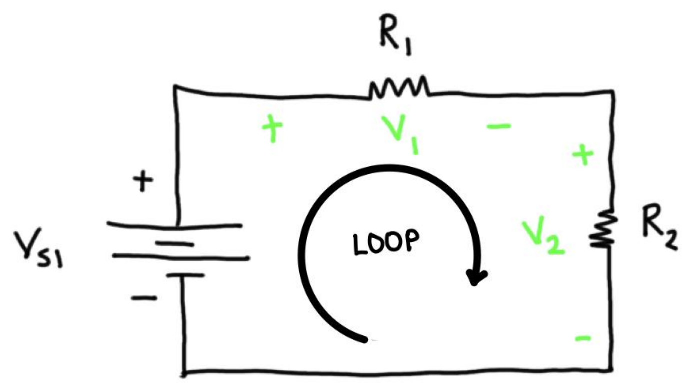


Figure 2. Verification of Kirchhoff's Voltage Law (KVL)

Using Figure 2, define a loop and determine whether KVL is satisfied experimentally. Show your work below.

$$-V_s + V_1 + V_2 = 0$$

$$-2.0V + 0.497V + 1.503V = 0$$

$$0 = 0$$

Part III: Current Measurements **Total Score: /30**

All of the calculations, simulations, and experiments in this section will be based on the circuit shown in Figure 2, shown below. Note that the portion of the circuit that contains R_4 and R_5 is a classic current divider.

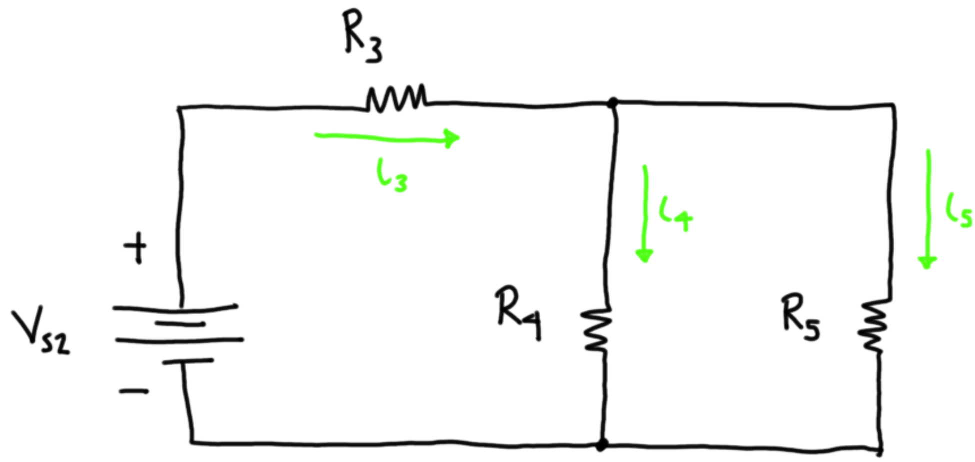


Figure 3. Current Measurements Circuit

A. Hand Calculation of Theoretical Values Score: /10

In the prelab you should have been able to calculate the currents i_3, i_4, and i_5 in terms of V_{s2}, R_3, R_4, and R_5 in equation form. Using those equations, the value of $V_{s2} = 5.0\ V$ which will be experimentally set, and the measured values of R_3, R_4, and R_5 obtained from Part I of this experiment, calculate the theoretical values i_3, i_4, and i_5 numerically. Make sure to show all your work, including units.

Answers: (You most likely will have to add a page to the end of the report to justify ALL your work).

$$i_3 = \frac{V_s(R_4+R_5)}{R_3R_4+R_3R_5+R_4R_5} = \frac{(5.0\ V)(1\ k\Omega + 3\ k\Omega)}{(2k\Omega)(1k\Omega)+(2k\Omega)(3k\Omega)+(1k\Omega)(3k\Omega)} = 1.818 \text{ x } 10^{-3}\text{A} = 1.818 \text{ mA}$$

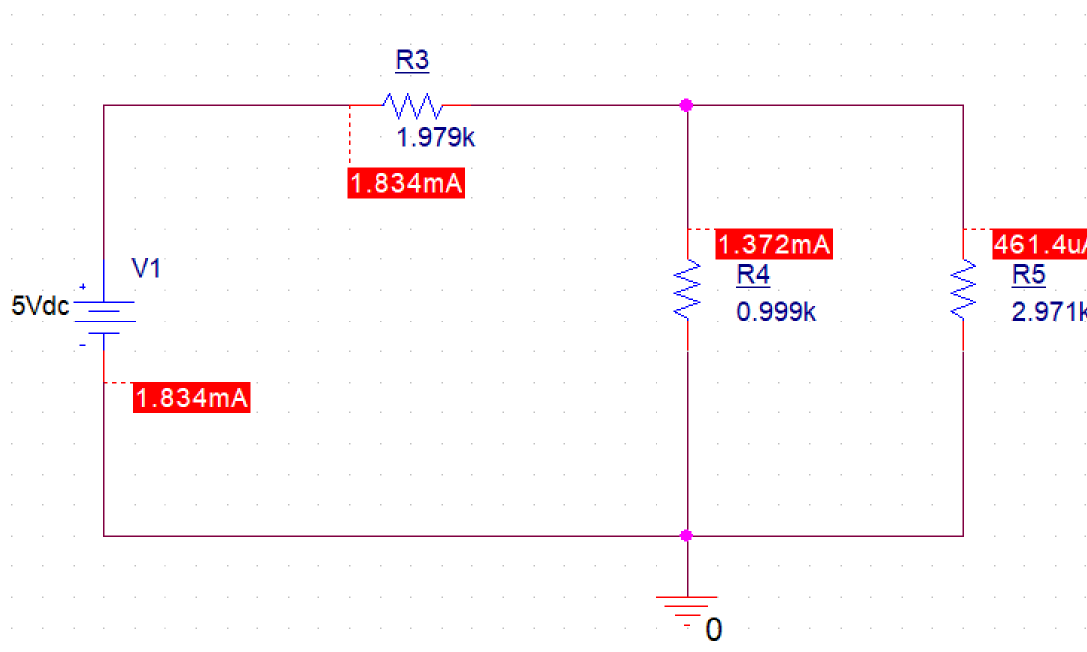
$$i_4 = \frac{V_s(R_4+R_5)}{R_3R_4+R_3R_5+R_4R_5} = \frac{(5.0\ V)(3\ k\Omega)}{(2k\Omega)(1k\Omega)+(2k\Omega)(3k\Omega)+(1k\Omega)(3k\Omega)} = 1.364 \text{ x } 10^{-3}\text{A} = 1.364 \text{ mA}$$

$$i_5 = \frac{V_s(R_4+R_5)}{R_3R_4+R_3R_5+R_4R_5} = \frac{(5.0\ V)(1\ k\Omega)}{(2k\Omega)(1k\Omega)+(2k\Omega)(3k\Omega)+(1k\Omega)(3k\Omega)} = 4.545 \text{ x } 10^{-4}\text{A} = 0.4545 \text{ mA}$$

B. Simulated Values Score: /10

Using PSpice simulate the circuit shown in Figure 3. Use the experimental values for V_{s2}, R_3, R_4, and R_5 in the simulation. Using the "snipping tool" create a picture of the circuit after the simulation has been run and paste it below. Keep in mind that part of your grade here will be determined by (a) how neat your circuit has been created in the workspace and (b) the clarity of the elements in the simulation, i.e. can you clearly see everything relevant.

Simulation Result:



Use the values of the currents in the simulation and identify the currents i_3, i_4, and i_5.

Answers:

i_3 = 1.834 mA

i_4 = 1.372 mA

i_5 = 0.461 mA

C. Experimental Values and Comparisons Score: /10

Assemble the circuit shown in Figure 3 using your breadboard and resistors. Use the positive voltage supply from the Analog Discovery 2 (AD2) to provide it with power. Using your digital multimeter (DMM) measure the currents i_3, i_4, and i_5 and record them in the Table 3 shown below. Fill in the rest of the table using the values of the voltages obtained from parts A and B of this experiment to compare them.

Voltage	Theoretical Voltage	Simulated Voltage	Experimental Voltage
V_{s2}	5.0 V	5.0 V	5.0 V
Current	Theoretical Current	Simulated Current	Experimental Current
i_3	1.818 mA	1.834 mA	1.828 mA
i_4	1.364 mA	1.372 mA	1.367 mA
i_5	0.4545 mA	0.461 mA	0.460 mA

Table 3. Current Measurements

D. Questions

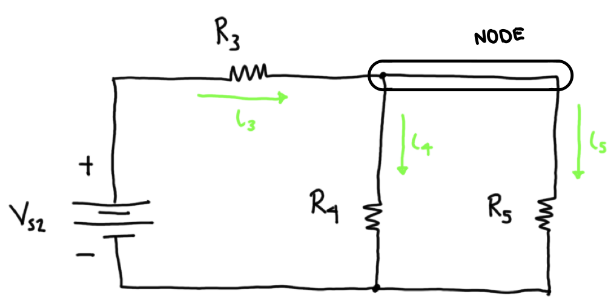
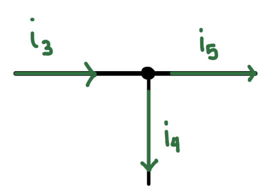


Figure 4. Verification of Kirchhoff's Current Law (KCL)

Using Figure 4, circle and label a node with three elements and determine whether KCL is satisfied experimentally. (Hint: there is only one node for which you have all of the experimental data, so choose wisely). Show your work below.



$i_3 - i_4 - i_5 = 0$ $\quad\quad$ $i_3 = i_4 + i_5$

(1.828mA) - (1.367mA) - (0.460mA) = 0

0.001mA = 0 $\longrightarrow$ **0.001mA ≈ 0**

Part IV. Conclusion Total Score: /20

Explain as a group in a few paragraphs what you learned from this lab and these experiments. Some of the topics that you should cover are, for example: What did you find easy to do? What challenges did you encounter? Was it difficult to assemble the circuits? Did your experimental results match with your predictions with both the hand calculations and simulations? If there were differences, were they acceptable? Did you find it difficult to work in a group? Write the conclusion as if you were writing an English essay. This is an important portion of the lab, so make sure to do a good and thorough job.

The first part of the laboratory determines the tolerance for each resistor showing how close the actual resistance is to the theoretical resistance. This is a very important starting point in being able to have accurate values for the next steps of the laboratory. Assembling the circuit was not difficult since we followed along with the in-class demonstration. In the second part of the laboratory, we focused on determining the voltage in each resistor using three different procedures. First, we use hand calculation using the theoretical values which would help us to assume the results for the experimental part. For the second procedure, we are required to use the PSpice simulation to determine the voltage. It was easy for us to simulate the circuit on PSpice since we got the experience from lab one. We found it easy to measure the resistors to get the experimental values for voltage. For the third procedure, we used equipment such as the breadboard, resistors, and digital multimeter to measure the voltage. Given the diagram, it was easy to set up the resistors in the breadboard and we were able to measure the voltage pretty quickly. Based on our table, we were able to observe the values for theoretical, simulated, and the experimental are very close with less than 1 difference.

For the third part of the laboratory, we are required to measure the current. Similarly to part two of the laboratory, we did three procedures. The challenging part that we encountered was trying to measure the actual current. It was confusing to set up the resistors knowing which end of the resistor had to be disconnected from the breadboard, and knowing which test probes had to be connected to which resistor. We had to connect four different test probes to measure the current, so that took some time for us to figure out. When verifying the experimental values for the voltages, KVL was satisfied since it equalled zero. The experimental values for the KCL values were off by 0.001 mA, but it is at an acceptable value.

We did not find it difficult for us to work in a group. We were all able to get along with each other. During lab time, we were working efficiently and using the time wisely. We were able to divide the tasks equally. One of us was building the circuit, one was taking the readings of the current and voltage, and the other was recording the data. We are all accessible outside of class and able to communicate with each other.