Name/NetID: Teammate/NetID:

Section AB/BB: **0 1 2 3 4 5 6 7 8 9 A B C D E F (circle one)**

Experiment #3: Experimenting with Resistor Circuits

Laboratory Outline

In the coming weeks you will learn the fundamental concepts and how they map onto the behavior of real circuitry. The labs will help you apply common mathematical abstractions used in circuit theory to the physical devices and their interconnections. All electrical engineers speak a common language that they use to communicate ideas and design specifications. During the semester, you will learn some of the mathematical underpinnings of circuit theory in lecture. In the lab, you will learn how to use this knowledge to map the abstract circuit examples in lecture onto the behavior of physical devices. You will learn conditions in which the simple mathematical descriptions break down.

You will experiment with resistor networks (different configurations of resistors) to determine their behavior. You will reinforce DC measurement skills, experiment with the mathematical relationships between the voltages and currents in the circuits, and, perhaps most importantly, you will gain practice using a critical design-sharing visual language – the schematic.

Please use the Notes margin on the right for both notes to yourself about the experiment as well as for feedback to your TA on the quality or clarity of the lab procedure. Thanks!

Notes:

Common resistor Connections – Series and Parallel Connections

In lecture, you may already have been introduced to two common ways to connect resistors in a circuit – in *series* and in *parallel*. A series connection of resistors divides the voltage proportionally across a source. A parallel connection of resistors divides the current delivered by the source proportionally. Using these examples, you will be simultaneously exposed to the math, the schematic, and the physical layout of many resistor networks. Voltage measurements will enable you to understand basic relationships between the observed device behavior and the mathematical relations presented in lecture.

Series Connection

A series connection is a resistor network where the same CURRENT flows through each device. Let's build a simple series circuit.

- ✓ Build the circuit from the schematic of Figure 1 using $R_1 = R_2 = 1\ k\Omega$. The voltage V_S will be provided by the power supply you used last week – but DO NOT HOOK UP THE POWER YET. The + and – signs indicate the proper polarity of the power supply when you eventually hook it up. In later labs, devices like the diode, transistor, and all integrated circuits require that the power connected with the proper polarity or the operation of the circuit will be drastically altered.

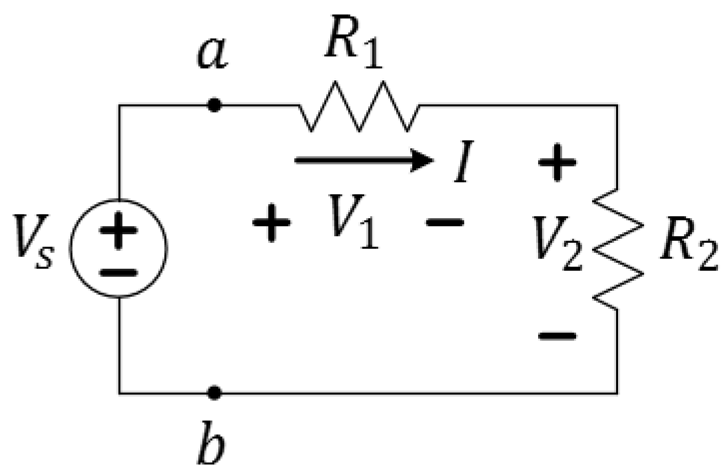


Figure 1: A series network of resistors.

Parallel Connection

A parallel connection applied to a resistor network is one where the same VOLTAGE appears across each device.

- ✓ Now build the parallel resistor network shown below somewhere else on your breadboard. Do not remove your series circuit. Again, start with $R_1 = R_2 = 1\ k\Omega$, and, again, do not connect the power source yet.

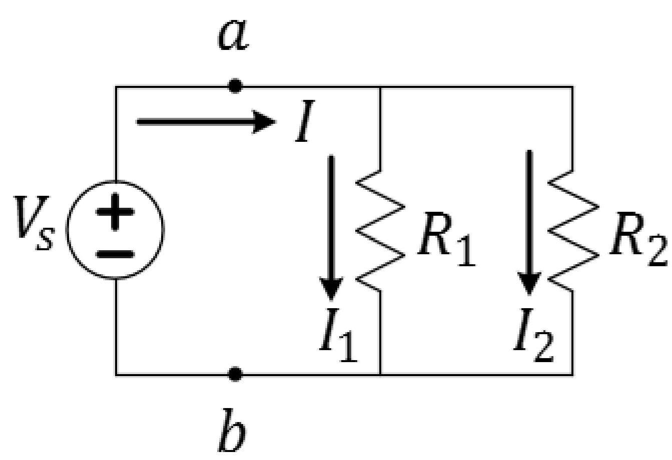


Figure 2: A parallel network of resistors.

Question 1: Measure the resistance of the resistor network, both series and parallel, by probing the circuit between points **a** and **b** and record the values. In lecture, you will call this value the equivalent resistance R_{EQ}. NOTE: The power supply must be disconnected to get a proper resistance measurement – this is why you were instructed to keep the power supply disconnected at first.

$R_{EQ} =$ (Series)	$R_{EQ} =$ (Parallel)

Notes:

- ✓ Finally, connect the power supply and set it to $5\ V$.
- ✓ Set up one of the DMMs to measure the value of I, the current that flows directly out of the power supply and labeled on the schematic above.

Question 2: Measure the current I in both circuits.

$I =$ (Series)	$I =$ (Parallel)

Question 3: Assume that the relationship between V_S, R_{EQ}, and I is linear. Use your measurements to determine the mathematical relationship among the three variables.

- ✓ **Remove the ammeter from the circuit.**

Notes:

The next three questions examine the relationship of the voltages across resistors connected in SERIES.

Question 4: Use the DMM to measure the voltage across each resistor in the Series Circuit and record the results in first empty row of the table below. Be sure to include V_S which is $5\ V$ for this initial measurement, the values of the resistors and the corresponding voltages.

V_S (in volts)	R_1 (Ω)	R_2 (Ω)	V_1 (in volts)	V_2 (in volts)	R_{EQ} (Ω)
5					
5					
5					
5					
5					
5					
5					
5					
5					

Table 1.

Question 5: Experiment with changing the resistor values R_1 and R_2 (R_1 need not equal R_2) to complete the table above. After every change measure the equivalent resistance R_{EQ} BEFORE hooking the resistors back up to the power supply and record its value along with the voltages across each resistor recording them in the same table. NOTE: Always choose values $> 1\ k\Omega$. In one of your resistor choices select resistor values that are orders of magnitude different – for example, one resistor might be $1\ k\Omega$ and the other $1\ M\Omega$. Also, for at least one choice of resistors, record two rows of data where the supply voltage, V_S, is varied instead.

Notes:

Question 6: Did you observe a trend between the voltages across each resistor and the relative resistances in the series network? Discuss. Pay attention to the next question as you draft your response.

Question 7: Using the data in the table find a relationship between the voltage across any individual resistor to the voltage V_S and a proportionality factor related to the individual resistances and the equivalent resistances.

The next three questions examine the relationship of the currents passing through resistors connected in PARALLEL .

- ✓ Determine the currents I_1 and I_2 in **one of two ways:**
  - Use the two DMMs as ammeters. This is a great way to gain experience in using the ammeter. If you choose to do this method, have the TA check your connections to reduce the possibility of blowing a fuse. Which is OK! But to minimize the risk have the TA take a look first.
  - Use Ohm's Law to compute the currents since $I = V/R$ is one form of the more recognized form $V = RI$.

Notes:

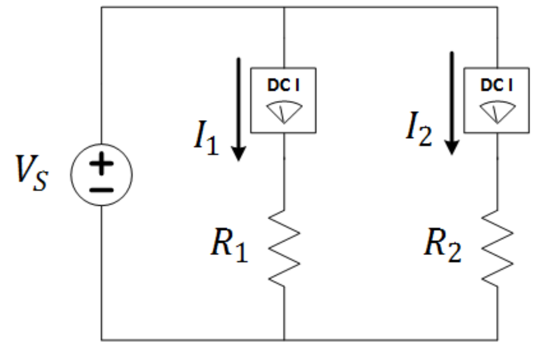


Figure 3: The ammeter must be in series with the element whose current is measured.

Question 8: Either measure or compute the currents I_1 and I_2 for the initial configuration where $V_S = 5\,V$ and both resistors are $1\,k\Omega$ and enter the values in the table below.

V_S (in volts)	R_1 (Ω)	R_2	I_1	I_2	R_{EQ}
5					
5					
5					
5					
5					
5					
5					
5					

Table 2.

Notes:

Question 9: Continue to experiment with changing the resistor values. Choose values $> 1\ k\Omega$ if you are *measuring* the currents. Measure or compute these currents and record the values in the same table. As with the Series configuration choose resistors that vary over orders of magnitude, though you don't need to vary the source voltage.

Question 10: Write your observations about how the currents flowing through each resistor varied as the relative resistances changed in the parallel network.

Question 11: Using the data in the table, find a relation between currents flowing through any individual resistor to the current, and a proportionality factor related to the individual resistances and the equivalent resistances.

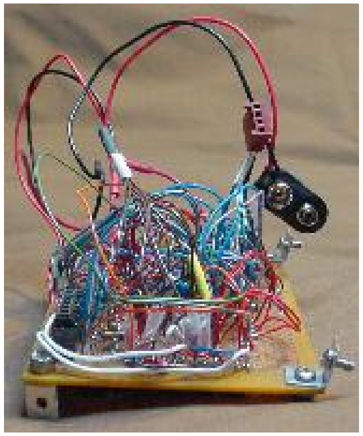
Reverse Engineering

To help develop proto-typing skills and the ability to build any circuit from a schematic there is nothing like trying to reverse engineer a circuit that has already been built.

- ✓ Build a rat's nest of a circuit made up of only resistors – you need not connect it to a power supply.
- ✓ Choose any two points and connect wires to them. Call these points A and B. They are equivalent to A and B in the Series and Parallel circuits indicating where a power supply was to be connected.
- ✓ Give the circuit to your partner or anyone else in your lab section. They must convert your circuit into a schematic so a few ground rules.
  - o The configuration must be a conducting circuit if connected to a power supply.
  - o No intentional mistakes…that is nothing tricky like breaking a wire and hiding the fact that it is broken.
  - o Unless the person you give the circuit to wants a challenge, use no more than 8 resistors.
  - o You may build the resistor network in such a way as to obscure the connectivity – be creative.

Question 12: Draw the schematic of the circuit that was given to you by another laboratory student. If (unintentional) errors exist, mark them and try to guess where the error was made or give it back and ask the person who constructed the network to fix it. For example, it is common to have two devices not be connected because the person building the circuit missed the proper hole on the breadboard.

Notes:



Example of the rat's nest approach to connectivity found at www.robotroom.com.

Depending on the application, this might actually be a better way to route the wires.

Notes:

Resistor/Source Connectivity

- ✓ Build the resistor network circuit using the schematic below using $R_1 = 1\ k\Omega,\ R_2 = 2.2\ k\Omega$, and $R_3 = 3.3\ k\Omega$. Do not connect the circuit to the power supply yet.

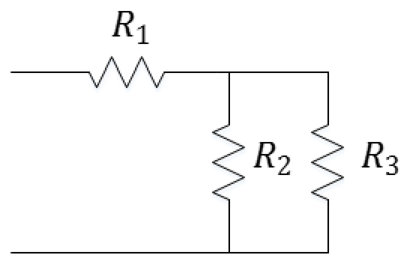


Figure 4: A more complex resistor network.

Question 14: Measure the equivalent resistance – you have experience at this now – and record the value.

- ✓ Now add the power supply to the circuit set to $V_S = 5\ V$.

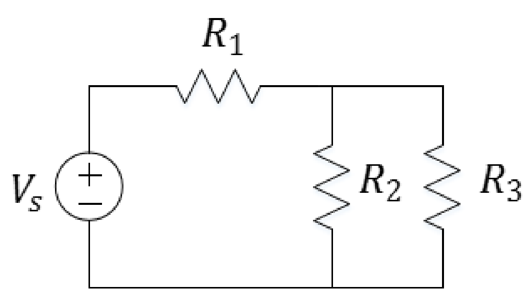


Figure 5: Adding power to the previous network.

Notes:

Question 15: Measure the voltages across each resistor and record them on the schematic in Figure 5, including the polarity by which they were measured.

- ✓ Disconnect the power supply, then reconfigure the resistor connections as shown in the figure below using the same resistors.

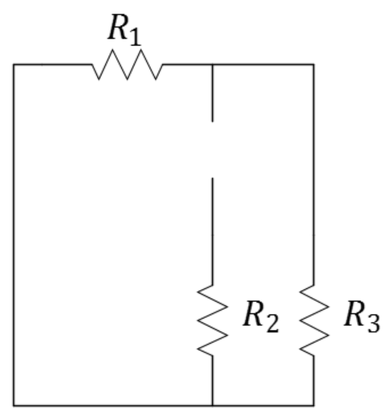


Figure 6: The same resistive network from a new "perspective".

Question 16: Measure the equivalent resistance of this modified resistor configuration using the Ohmmeter and record the value.

- ✓ Now add the power supply into the circuit set to $V_S = 5\ V$.

Notes:

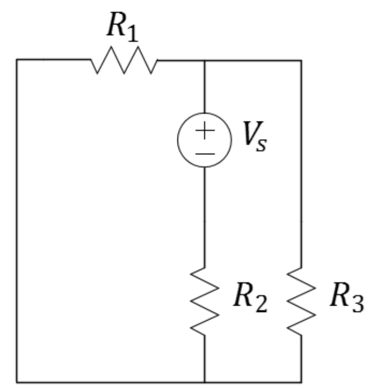


Figure 7: Adding power to the previous network.

Question 17: Measure the voltages across each resistor and record them on the schematic above, including the polarity by which they were measured.

Question 18: Did the voltages across each resistor remain the same or change when the location of the power supply changed? Explain.

What You Learned

This lab encouraged you to extend your skills in taking measurements and mapping each schematic – a visual representation of a circuit – to a physical circuit. The measurements you made were meant show you that, for simple resistor circuits, the relationships between the voltages and currents are linear thereby establishing an intuition that will help you to put the circuit laws you learn in lecture in context.

Notes:

Lab Report Rubric

The following rubric will be provided at the end of each lab procedure. As a final step in preparing your lab report, you will use this rubric to analyze your own performance.

Section	**Criterion**	**Comments:**
Experimental Setup and/or Design Description	Circuit Schematics are drawn neatly, accurately, and properly labeled. Decisions regarding experimental setup and design are clearly explained.	
Measurements	Tables include units and proper precision. Any *new device* introduced should be characterized using measurements!	
Computations	Computations performed on raw data are *explicitly* described and follow rules for significant figures.	
Analysis	Graphs have title, labels, units, scale, legend; Lines for curve-fitting appear in the graph when needed and parameters like the intercepts and the slope are labeled.	
Modeling	A mathematical model for the curve-fit graph allows for more abstract references to the device's behavior. The expected behavior is explained in the context of the graph.	
Conclusion	Conclusions are drawn from your experimental results to support the reason(s) for completing the experiment. Closes the loop on the Introduction.	
General Formatting	Answers to questions clearly labeled. The overall appearance of the report is professional.	
Self-assessment	This table has been thoughtfully completed.	