Documentation

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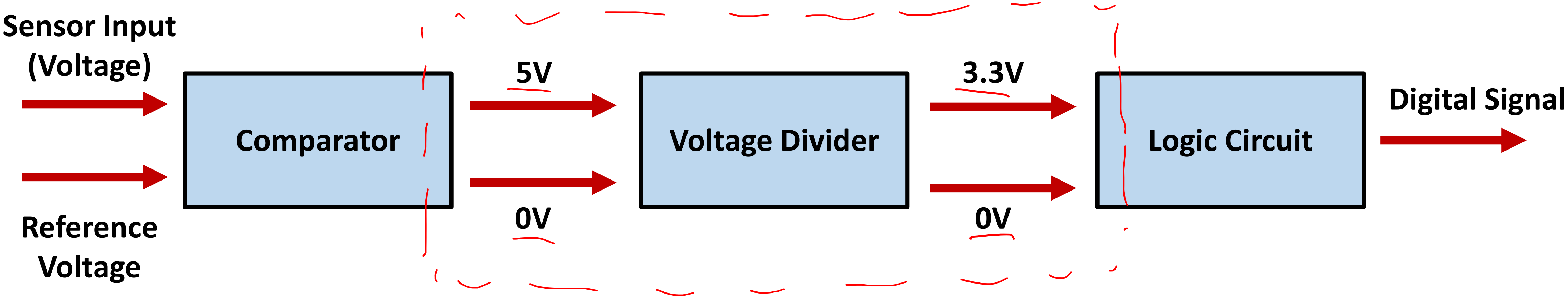
The Voltage Divider as a Circuit Component

Example: we have a sensor that outputs either 5V or 0V, but the (unspecified) logic circuit that acts on that input can only take inputs of 3.3V or 0V. What do we do?

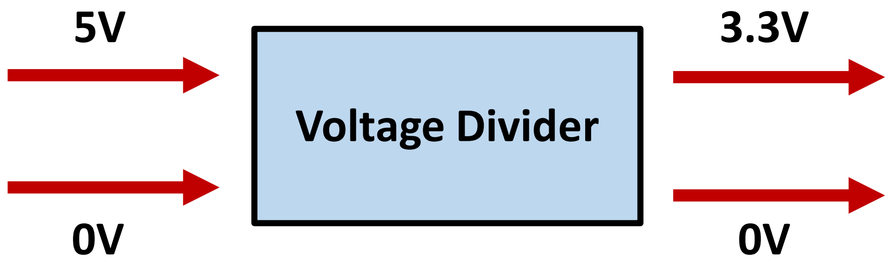
We'll use a voltage divider.

Let's draw a block diagram (required for omega labs!) of our system



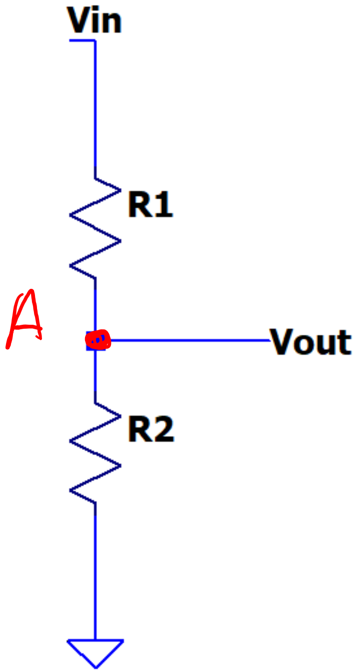
(See lecture notes from Class 03 for details on how to label block diagrams and all of your documentation for Proof of Concepts)

The Voltage Divider as a Circuit Component



How do we convert this block diagram into a circuit?

We know the input: 5V or 0V

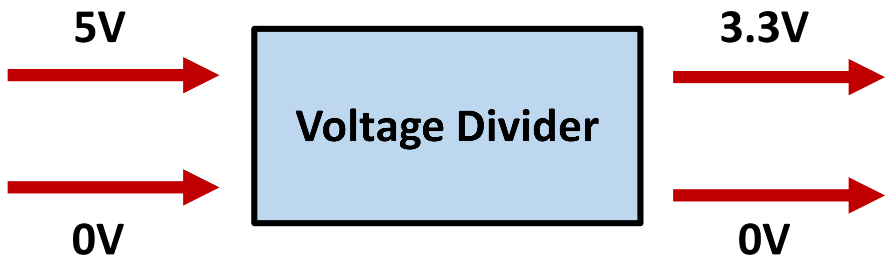


We know the output: 3.3V or 0V

And we know what a voltage divider looks like

How do we choose R1 and R2?

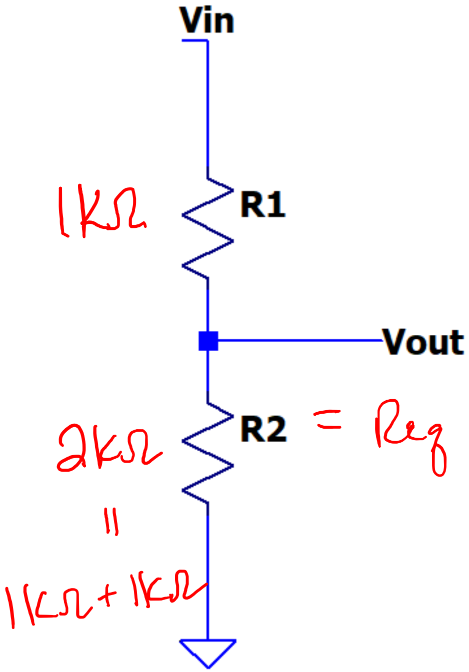
The Voltage Divider as a Circuit Component



Voltage Divider Equation:

$$V_{out} = V_{in} \frac{R_2}{R_1 + R_2}$$

3.3V 5V



$3.3V = 5V \cdot \frac{R_2}{R_1 + R_2} \rightarrow 3.3(R_1 + R_2) = 5R_2$

$3.3R_1 = 1.7R_2$

$\frac{3.3}{1.7} = \frac{R_2}{R_1} = 1.94$

↓ standard R value

Choose $R_1 = 1k\Omega$

↓

$R_2 = 1.94k\Omega \rightarrow 2k\Omega$ (2x 1kΩ R in series)

≈ $1k\Omega + 470\Omega + 470\Omega = 1940\Omega$

What do I need to submit for Lab01?

- If you are doing an **Alpha Lab**: **Proof of Concepts 1-6**
- If you are doing an **Omega Lab**: **Proof of Concepts 1-6**

Part A: Proof of Concepts List

1. Prove Ohm's Law, KCL, and KVL in a circuit.
2. Prove the concept of a voltage divider in a series circuit
3. Prove the concept of a how current flows in a series circuit (same current through R1 and R2 for example? Or different current?)
4. Prove the concept of voltage across a parallel circuit (same voltage? Or different….)
5. Prove the concept of a *current divider* in a parallel circuit. *Hint: Try to search for this equation online. Use other current calculations and a simulation to confirm!*

Part B: Proof of Concepts List

6. Prove the Concept of a voltage divider in your application. *In your discussion be sure to include if any failures occurred and speculate why they did. As an example, if you had trouble finding ways to accurately calculate values or simulate something, please state it.*

Proof of Concept #6

- **Alpha:** follow Lab01 instructions to build and test a circuit with a potentiometer
- **Omega:** show that your application uses a voltage divider as a functional component

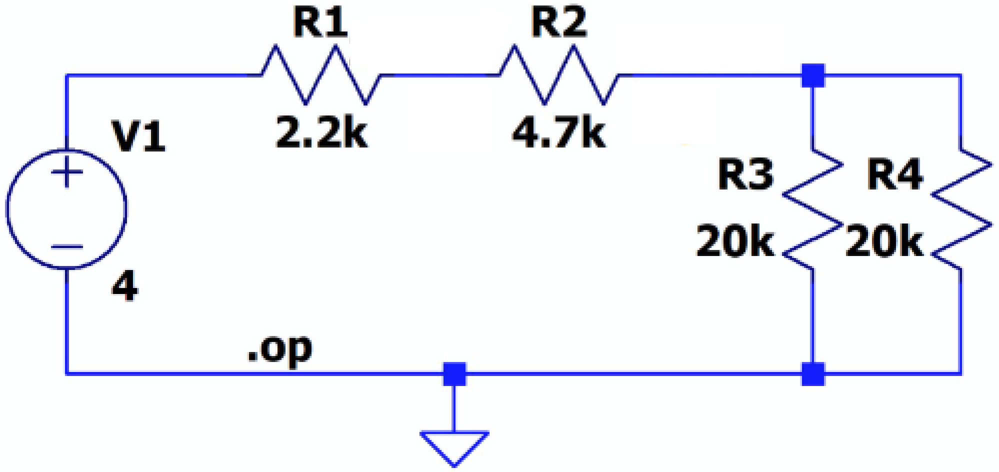
What is a Proof of Concept Again?

- You must demonstrate “this is right” for each concept. What does that mean?
    1. You must show/state what the concept is: building block
    2. You must show its proper function/behavior by hand calculations (*Analysis*).
    3. You must show its proper function/behavior via an LTSpice simulation. (*Simulation*)
    4. You must show its proper function/behavior via an experimental measurement. (*Experiment*)
    5. You must discuss your results.

- For full credit, you must show all five of these steps for each Proof of Concept (and the results should match, or you must explain why they do not). This answers “is this right?” and serves as documentation of your design process.

Example: Building Block

Kirchhoff's Voltage Law

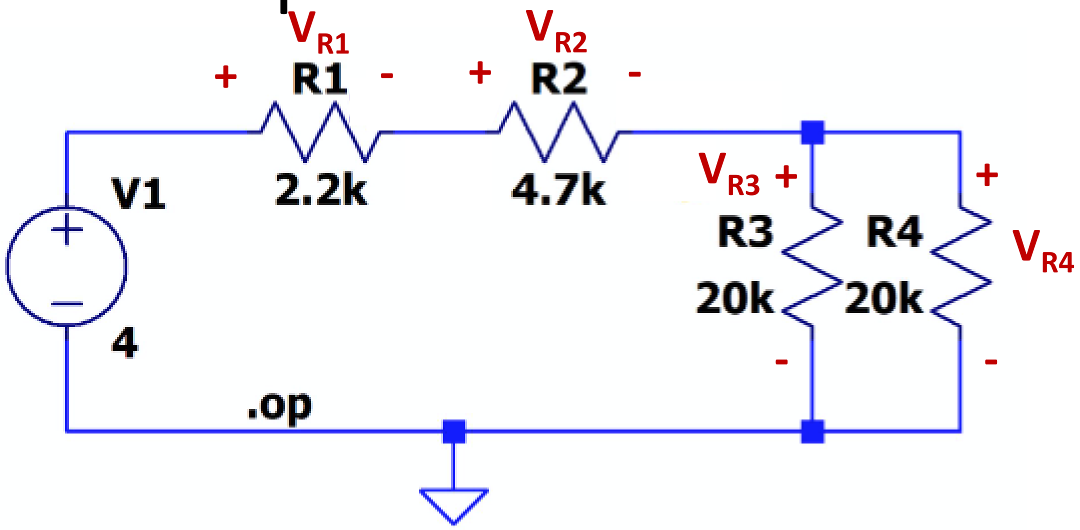


(Circuit for Proving KVL)

The sum of all voltages around a loop is zero

(Kirchhoff's Voltage Law)

Example: Mathematical Analysis



- Using circuit reduction, we can find the voltages across all resistors and currents through all resistors.
- Since R3 and R4 are in parallel we can combine them into an equivalent resistance R34:

$$R_{34} = R_3||R_4 = 20k\Omega||20k\Omega = 10k\Omega$$

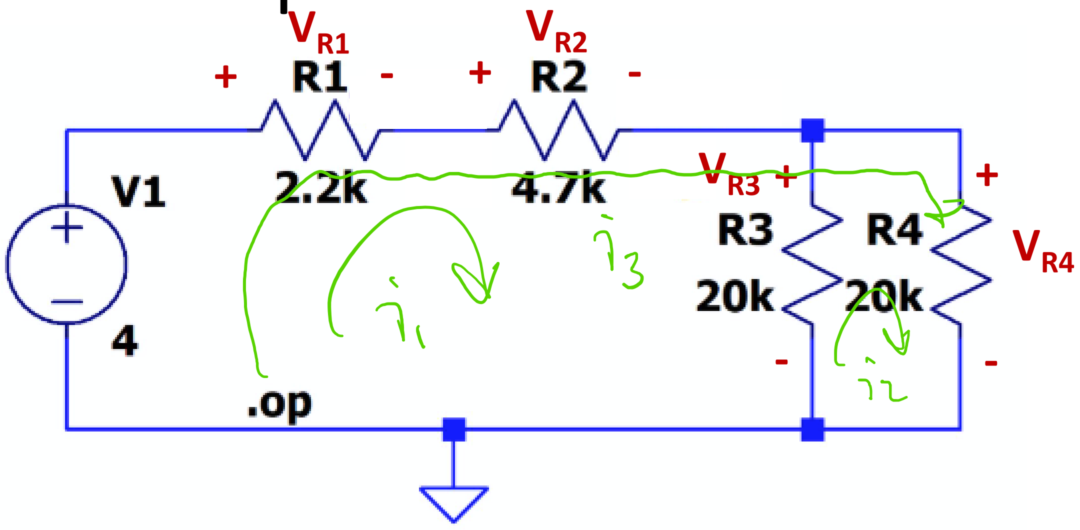
- Using the voltage divider equation, we can find the voltage across each of the resistors R1, R2 and R34.

$$V_{R1} = V_1 \frac{R_1}{R_1 + R_2 + R_{34}} = 4V \frac{2.2k\Omega}{2.2k\Omega + 4.7k\Omega + 10k\Omega} = 0.521V$$

$$V_{R2} = V_1 \frac{R_2}{R_1 + R_2 + R_{34}} = 4V \frac{4.7k\Omega}{2.2k\Omega + 4.7k\Omega + 10k\Omega} = 1.112V$$

$$V_{R34} = V_1 \frac{R_{34}}{R_1 + R_2 + R_{34}} = 4V \frac{10k\Omega}{2.2k\Omega + 4.7k\Omega + 10k\Omega} = 2.367V$$

Example: Mathematical Analysis



$$V_{R1} = 0.521V$$

$$V_{R2} = 1.112V$$

$$V_{R3} = V_{R4} = 2.367V$$

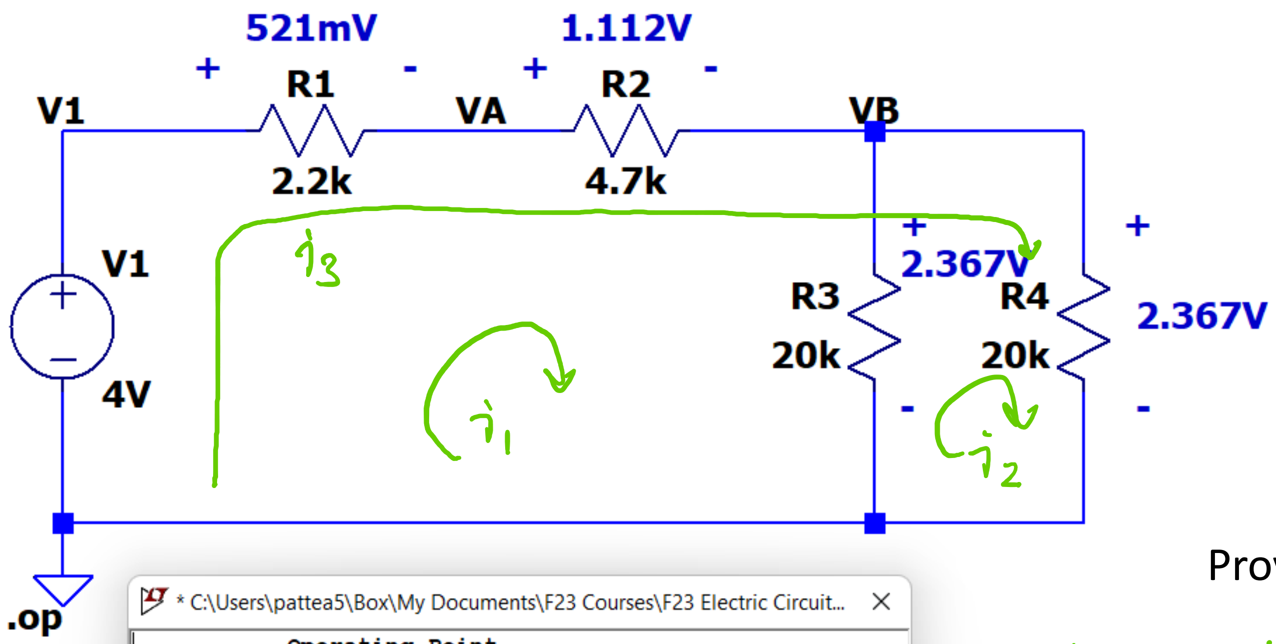
Proving that KVL holds in each of the loops:

1: $-4V + 0.521V + 1.112V + 2.367V = 0$ ✓

2: $-2.367V + 2.367V = 0$ ✓

3: $-4V + 0.521V + 1.112V + 2.367V = 0$ ✓

Example: Simulation




```
* C:\Users\pattea5\Box\My Documents\F23 Courses\F23 Electric Circuit...
       --- Operating Point ---

V(v1):          4               voltage
V(va):          3.47929         voltage
V(vb):          2.36686         voltage
I(R4):          -0.000118343    device_current
I(R3):          -0.000118343    device_current
I(R2):          -0.000236686    device_current
I(R1):          -0.000236686    device_current
I(V1):          -0.000236686    device_current
```

Comparison: Mathematical Analysis vs. Simulation

Voltage	Math. Analysis (V)	Simulation (V)
V_{R1}	0.521	0.521
V_{R2}	1.112	1.112
V_{R3}	2.367	2.367
V_{R4}	2.367	2.367

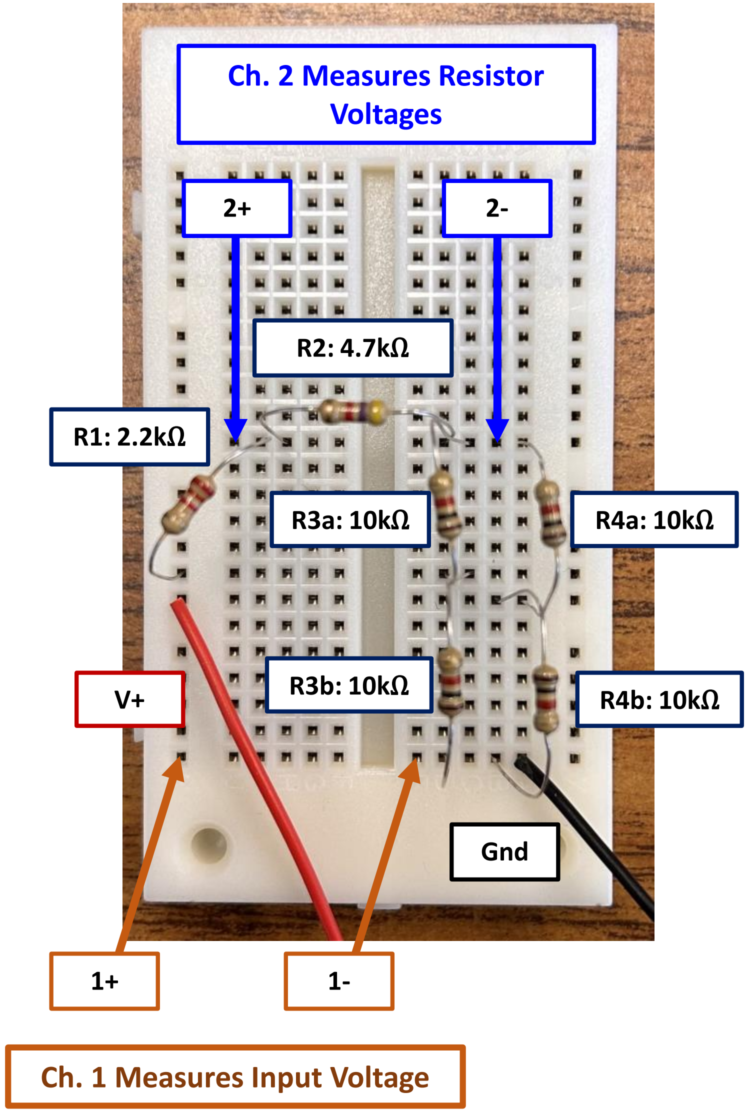
Proving that KVL holds in each of the loops:

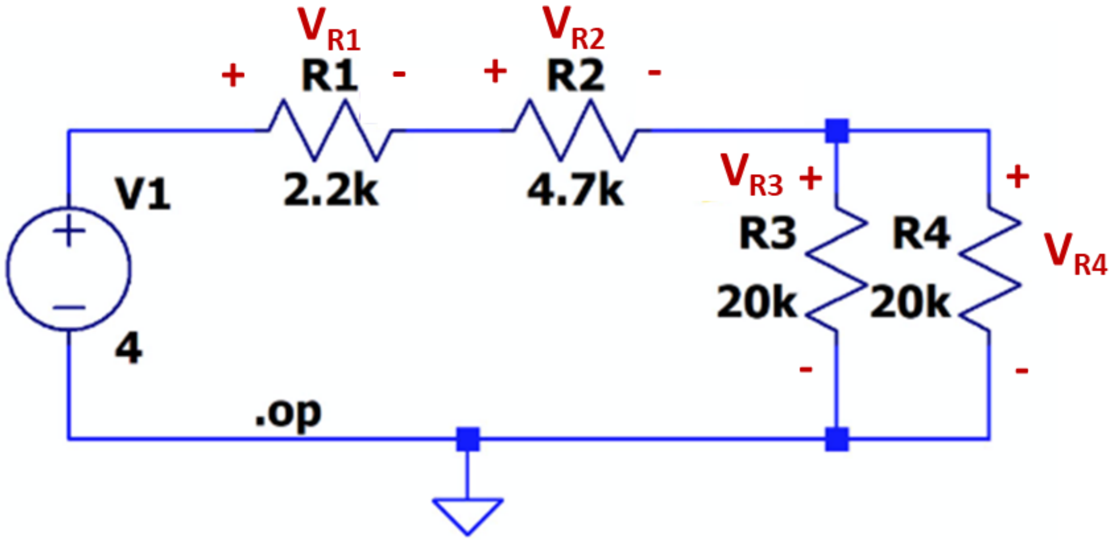
1: $-4V + 0.521V + 1.112V + 2.367V = 0$ ✓

2: $-2.367V + 2.367V = 0$ ✓

3: $-4V + 0.521V + 1.112V + 2.367V = 0$ ✓

Example: Experiment

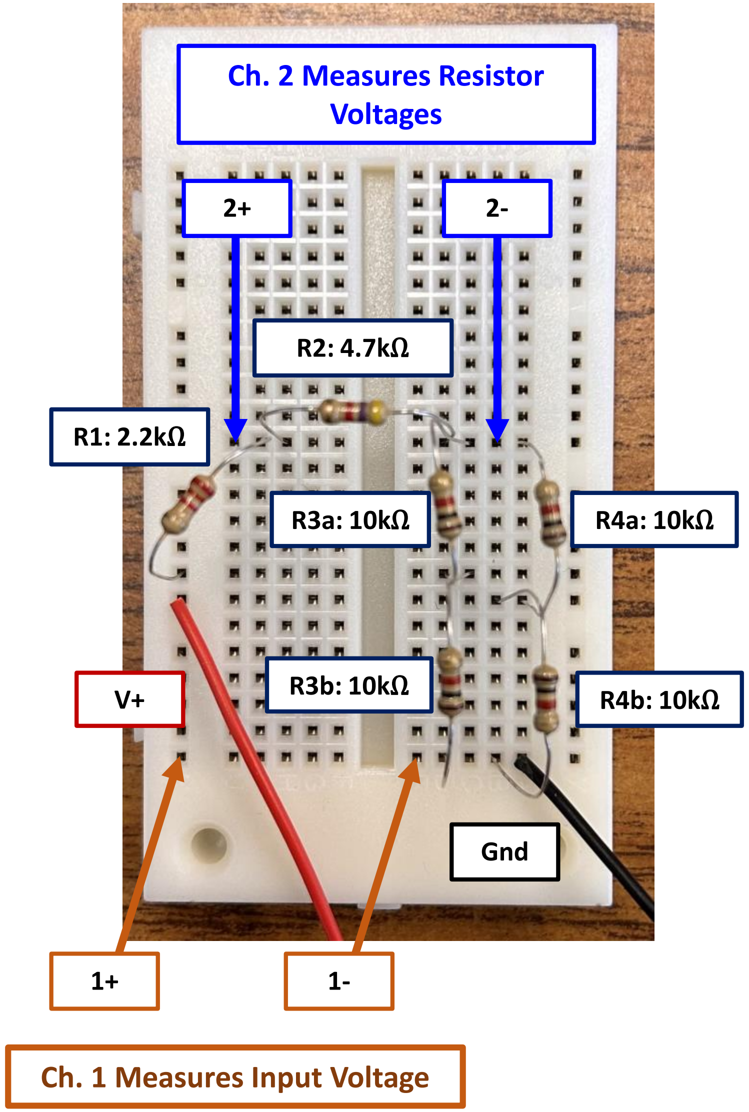


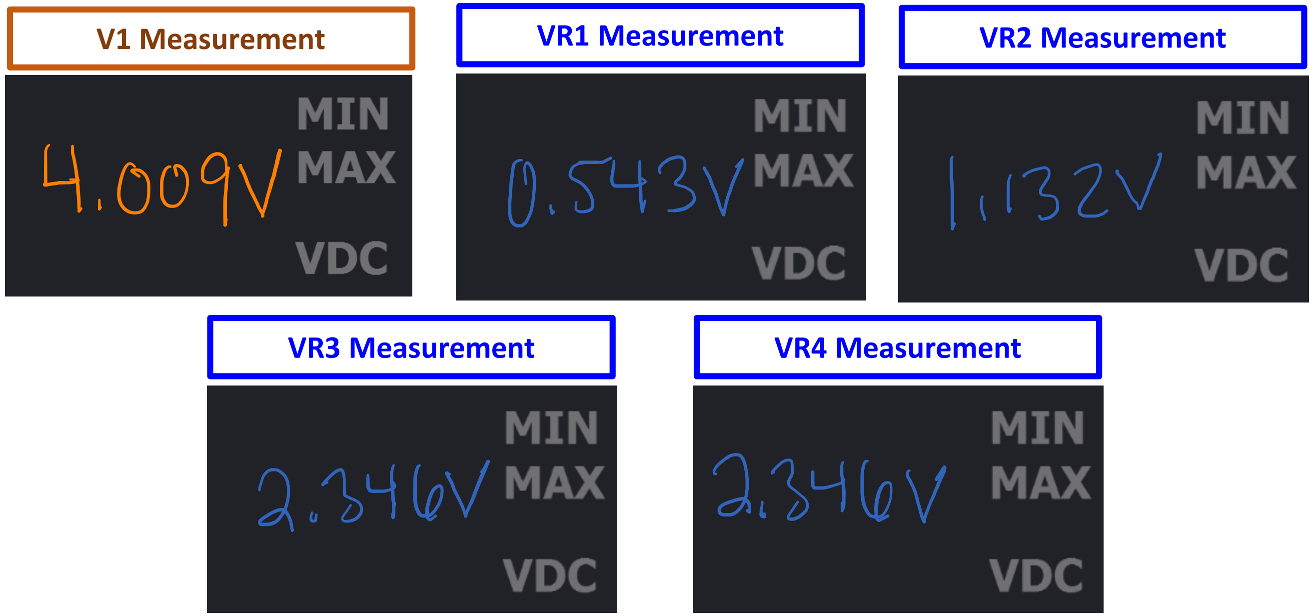


The circuit from the diagram above was built on a breadboard, as shown to the left. Since 20kΩ is not a standard resistor value, R3 and R4 were each implemented via 2, 10kΩ resistors in series (R3a & R3b; R4a & R4b).

Channel 1 was used to measure the DC input voltage V1, while Channel 2 was used to measure the resistor voltages VR1 – VR4.

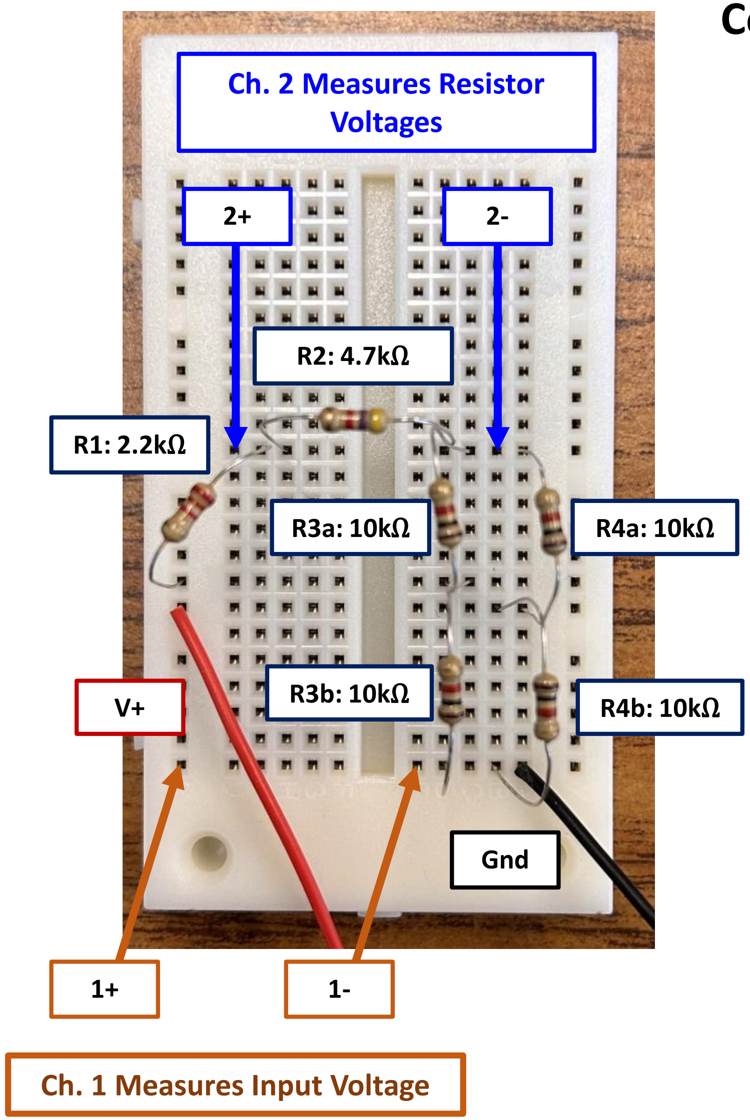
Example: Experiment





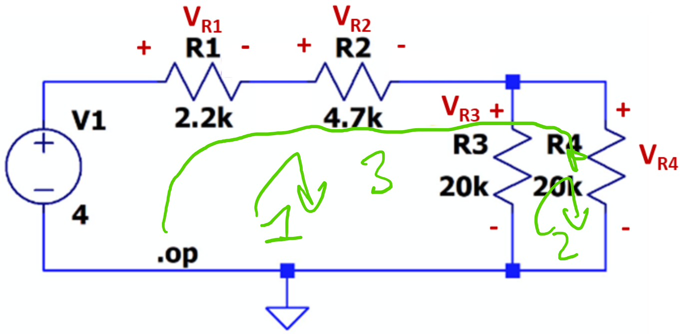
Voltage	Math. Analysis (V)	Simulation (V)	Expt. Measurement (V)
V_1	4	4	4.009
V_{R1}	0.521	0.521	0.543
V_{R2}	1.112	1.112	1.132
V_{R3}	2.367	2.367	2.346
V_{R4}	2.367	2.367	2.346

Example: Experiment



Comparison: Mathematical Analysis vs. Simulation vs. Experiment

Voltage	Math. Analysis (V)	Simulation (V)	Expt. Measurement (V)
V_1	4	4	4.009
V_{R1}	0.521	0.521	0.543
V_{R2}	1.112	1.112	1.132
V_{R3}	2.367	2.367	2.346
V_{R4}	2.367	2.367	2.346



Proving that KVL holds in each of the loops:

1: $-4.009V + 0.543V + 1.132 + 2.346 \approx 0.012V$

2: $-2.346V + 2.346V = 0V$

3: $-4.009V + 0.543V + 1.132 + 2.346 \approx 0.012V$

Example: Discussion

Circuit in General: While the voltages across the resistors of the circuit that were calculated via mathematical analysis and simulation match perfectly, experimental measurements varied slightly from those values. The input voltage V1 provided by the instrumentation board was not exactly 4V, but 4.009V, and the voltages across the resistors varied by up to 4.2% from the calculated values. Since the resistors I used in my circuit have a tolerance of 5%, this seems reasonable.

KVL: Although KVL was perfectly satisfied in both the mathematical analysis and simulation, experimental measurements showed that 12mV remained in loops 1 and 3 after summing all of the voltages. This extra 12mV is possibly accounted for if we included the resistance of the wires and breadboard traces that connect the elements, which we have assumed are zero.

How You'll be Graded for Proof of Concepts

Lab 01 Standards

1. I can simulate a simple voltage divider circuit using LTSpice.
2. I can calculate and simulate series and parallel resistances that I combine.
3. I can build and test a simple voltage divider circuit on a breadboard and measure using my instrumentation board.
4. Alpha: I can connect a potentiometer to the right pins in my circuit.
5. Alpha: I can setup up, simulate and interpret parametric analysis in a circuit.
6. Alpha: I can discuss real-world applications of a potentiometer.
7. Omega: I can create a circuit schematic using LTSpice for my design exploration.
8. Omega: I can make appropriate assumptions to simulate values for my design exploration.
9. Omega: I can discuss and identify areas where I get stuck, I don't quite understand, or require more information.
10. I can demonstrate "good failure" whenever applicable by providing accurate results in my experience and speculating what went wrong.
11. I can identify non-idealities or unexpected results and attempt to explain why they may exist.
12. I can answer for myself "Is this right?" by comparing mathematical calculations to simulation and experimental results.
13. I can show plots and diagrams that are easy to read, scaled correctly and clearly labeled.
14. I can use consistent variable labels and component values in mathematical calculation, simulation, and experimental results for easy comparison.
15. I can accurately answer conceptual questions found throughout the lab.

Where do I Submit Proof of Concepts?

- Remember, you need to do a full Proof of Concept for all 6 concepts in Lab01. Put all of them in a single document and upload it to the relevant Gradescope assignment. The template is on the course website under Course Resources and Documents/Lab Documents
- If you are doing an **Alpha Lab**, submit to

Lab01 Alpha - Proof of Concepts

Sep 14 at 10:00AM Oct 05 at 10:00AM
Late Due Date: Oct 09 at 10:00AM

- If you are doing an **Omega Lab**, submit to

Lab01 Omega - Proof of Concepts

Sep 14 at 10:00AM Oct 05 at 10:00AM
Late Due Date: Oct 09 at 10:00AM

What if I'm doing an Omega Exploration?

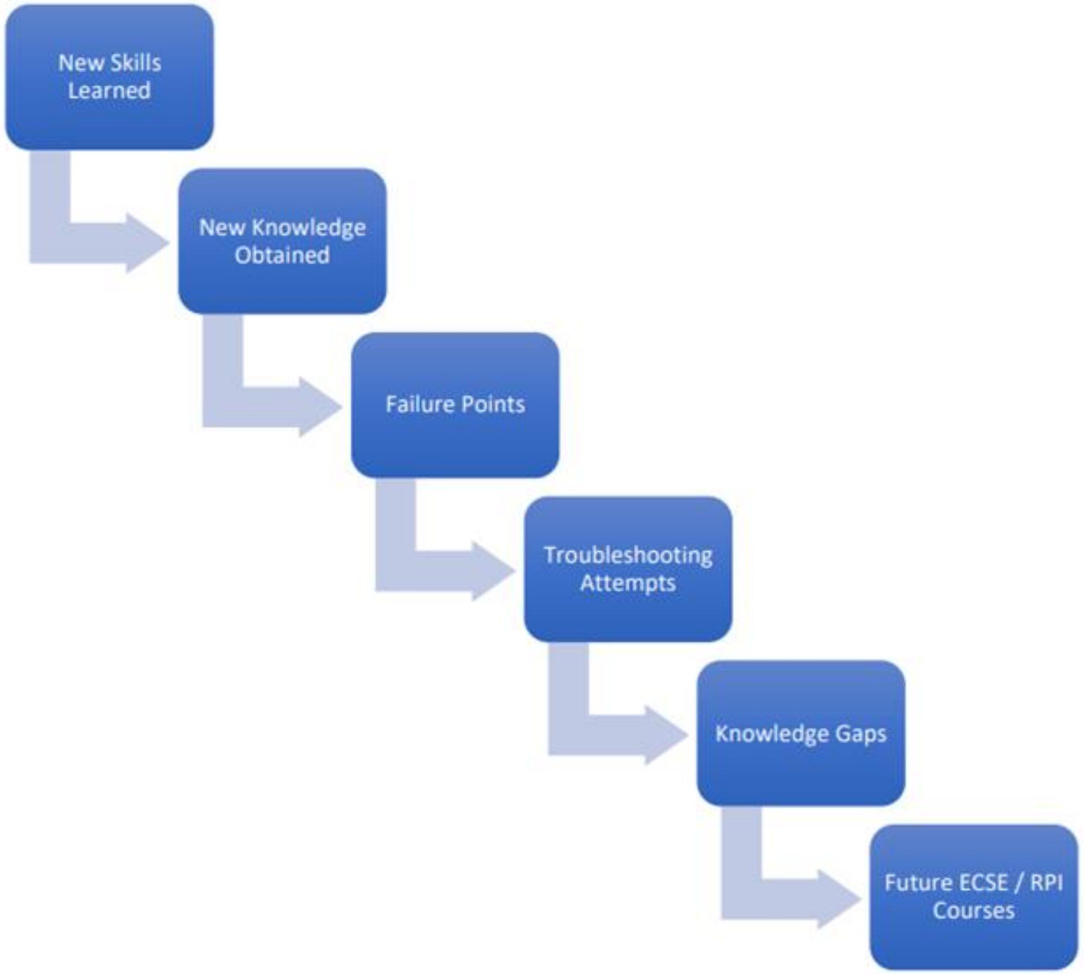
- You will also have to submit a **Presentation Video** and an **Exploration Map**
- The presentation video is a 5-minute video that includes all the elements listed to the right (this is how your presentation will be graded – 1 pt each)
- Presentation video guidelines are linked on the course webpage. Examples from last year.

Presentation Standards

1. I can explain the goal of the project and its scope within the course. (Over just one lab or across all labs)
2. I can present a high-level block diagram that represents the functional blocks of each part of my demonstration.
3. I can show calculations and, if needed, reasonable assumptions that helped me predict the correct function of my circuit.
4. I can show my simulated circuit and show important probe points to compare to my mathematic predictions
5. I can demonstrate the course concept as a working functional block or working experimental outcome.
6. I can show important functional blocks that work as expected OR attempt to explain why it failed through troubleshooting.
7. I can discuss design choices directly related to concepts I'm learning in Intro to ECSE.
8. I can briefly mention or discuss new knowledge obtained, design ideas OR design choices or ideas that are beyond the content of Intro to ECSE.
9. I can discuss plans for the next lab.
10. I can articulate at least ONE question based on my experience doing the Omega Exploration.

What if I'm doing an Omega Exploration?

- The **Exploration Map** documents your learning during your omega exploration.
- The exploration map template is linked on the course webpage
- An example can also be found on the course webpage



Where do I Submit my Video Presentation and Exploration Map?

- Submit the **Video Presentation** to

Lab01 Omega - Presentation Video

Sep 14 at 10:00AM Oct 05 at 10:00AM
Late Due Date: Oct 09 at 10:00AM

- Submit the **Exploration Map** to

Lab01 Omega - Exploration Map

Sep 14 at 10:00AM Oct 05 at 10:00AM
Late Due Date: Oct 09 at 10:00AM

So why bother with all of this?

Good documentation is ***vital*** as an engineer. It is:

1. A record of your work for your own reference.
2. A record of your work for others (to work from later).
3. Proof that you have followed proper design procedures.
4. Communication of your ideas to others.
5. A way to keep track of changes, improvements, bug fixes, defects, etc…
6. Required by your job.

Let’s look at some documentation. Is this good documentation? Open the “Is this Good Documentation?” link under Class 10’s resources. There is a Gradescope assignment with questions: “Class 10: Is this Good Documentation?” Work in groups of up to 5.

Due by Class 11

- MIDTERM QUIZ: WEDNESDAY 10/4, 6PM – 8PM IN SAGE 3303

- Gradescope submission for "Is this Good Documentation?" if you didn't finish during class.
- Watch the background videos under Class 11 and take notes.
- Attempt Problem Set 3 on Gradescope.

Midterm Quiz 1

MIDTERM QUIZ: WEDNESDAY 10/4, 6PM – 8PM IN SAGE 3303

Topics

- Basic circuit quantities and units (and metric prefixes)
- Circuit Analysis Technique #1: Circuit Reduction - Combining Resistors in Series and in Parallel
- Voltage dividers
- Circuit Analysis Technique #2: KCL/KVL/Ohm's Law
- Writing linear equations in matrix form (you do not have to solve them)
- Coming to class and attempting proof of skills

Link to Back Exams on Course Website

Policies

- Quizzes are open book and open notes
- Notes must be hand-written or printed out; no electronic devices will be permitted for use as reference during quizzes.
- Bringing printed out solutions to previous quizzes is not permitted.
- Non-communicating calculators are allowed.
- Students are not allowed to discuss/interact with anyone during the time they take the quiz.