

- Instructor Copy -

Series and Parallel Circuit Experiment

Worksheet V2

Objective: Explore how parallel circuits function and understand the relationship between voltage, current, and resistance in parallel connectivity. Compare these findings with those of series circuits to highlight the differences.

Materials Needed:

- Series and Parallel Circuits Magnetic Trainer
- A multimeter
- **Power Supply - Instructors: You can utilize the power supply that comes with the kit, or a bench top power supply.**

Safety Precautions:

- Always double-check the circuit connections before powering it on.
- Never handle electrical components with wet hands.
- Be mindful of the power supply voltage to avoid damaging the components or the multimeter.

Background

In a parallel circuit, all components are connected across the same two points, which creates multiple pathways for current to flow. This configuration ensures that the voltage across each branch of the circuit remains consistent. For reference, see Figure 2. In contrast, in a series circuit, as shown in Figure 1, components are connected end-to-end along a single path, and the voltage is divided among the components based on their resistance.

Observe that in Figure 1, which shows a series circuit, the voltage available before LED 1 is 12 V. However, after the current passes through LED 1, the voltage available at LED 2 drops to 8 V. In contrast, in Figure 2, which illustrates a parallel circuit, the voltage remains consistent at 12 V for both LED 1 and LED 2. This demonstrates that in parallel circuits, each component receives the same voltage regardless of the arrangement or number of other components.

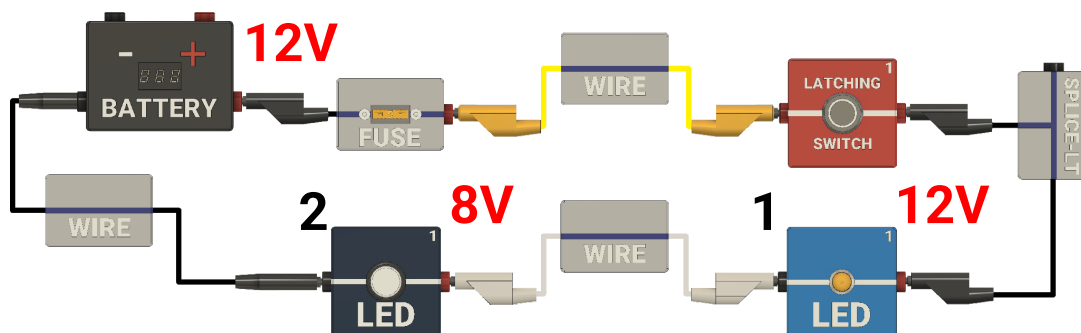


Figure 1: Voltage Measurement for a Series Circuit

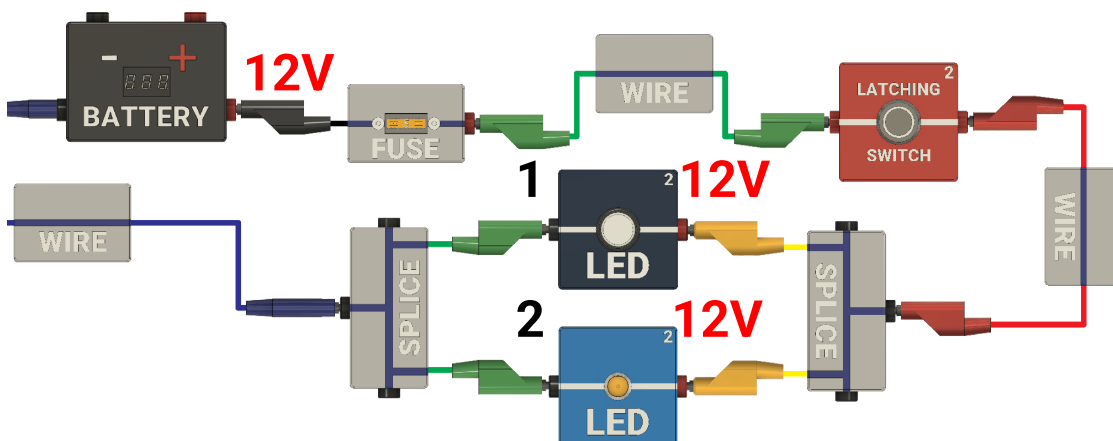
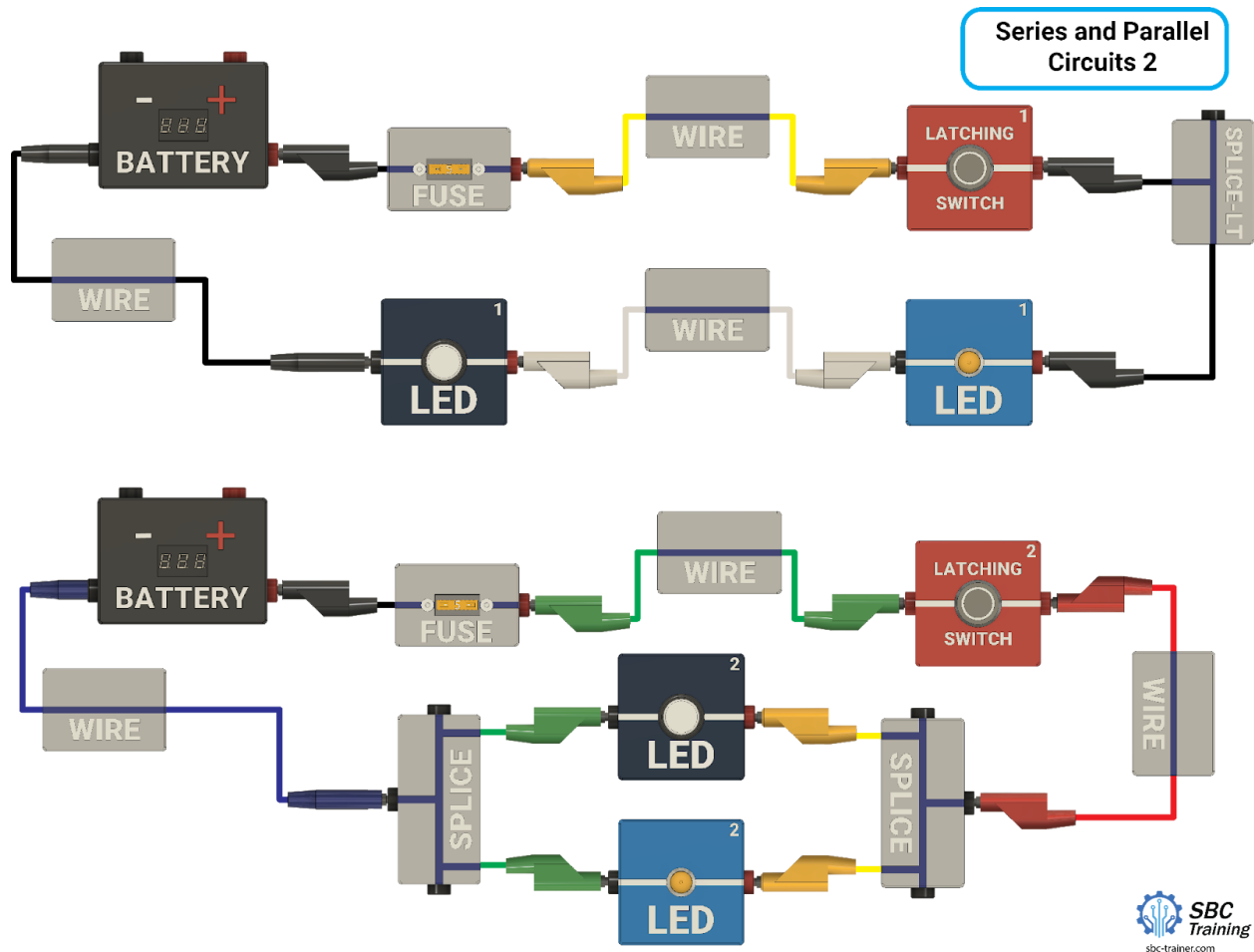


Figure 2: Voltage Measurement for a Parallel Circuit

Parallel Circuit LAB



Setup

Complete the following steps to set up for testing:

- Place all of the electrical nodes on the Series and Parallel Circuits Sheet

Measuring Voltage in a Series Circuit with LEDs

1. Set Up Your Multimeter:
 - a. Before you begin, make sure your multimeter is set to measure DC voltage.
2. Connect the POWER SUPPLY to each battery using the red and black POWER SUPPLY WIRES
 - a. Connect the POWER SUPPLY WIRES to the jacks of the POWER SUPPLY as shown in Figure 2
 - b. Attach one set of wires to the positive (red) and negative (black) terminals at the top of BATTERY, and connect another set to the positive (red) and negative (black) terminals at the top of the other BATTERY . See Figure 3



Figure 2: POWER SUPPLY Connection

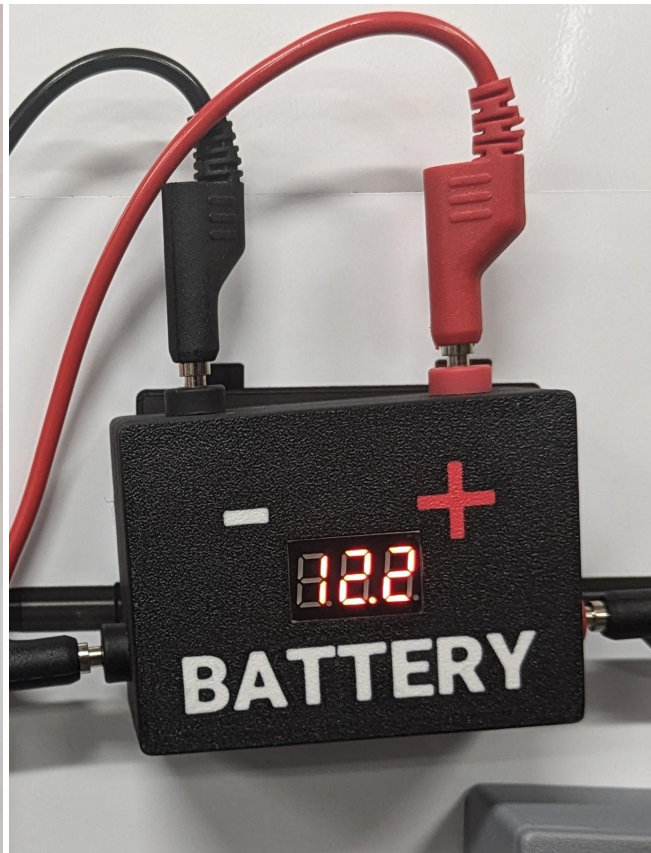


Figure 3: BATTERY Connection

3. Turn on the POWER SUPPLY by pushing up on the switch located at the top left side of the POWER SUPPLY
4. Ensure that the circuit is on by verifying that the LED is illuminated in both the TOP circuit and the bottom circuit
5. Measure Initial Voltage:

- a. Connect the multimeter probes to the BATTERY in the series circuit to measure the total voltage supplied to the circuit. This is your reference voltage. Compare to your value with that found on the small meter embedded in the BATTERY.. They should be similar
6. Measure Voltage Prior to small LED 1:
 - a. Place the multimeter's positive probe on the connection point just before the light blue small LED 1 (where the power enters small LED 1). See Figure 4
 - b. Place the negative probe on the negative terminal of the BATTERY in the circuit. Record this voltage.

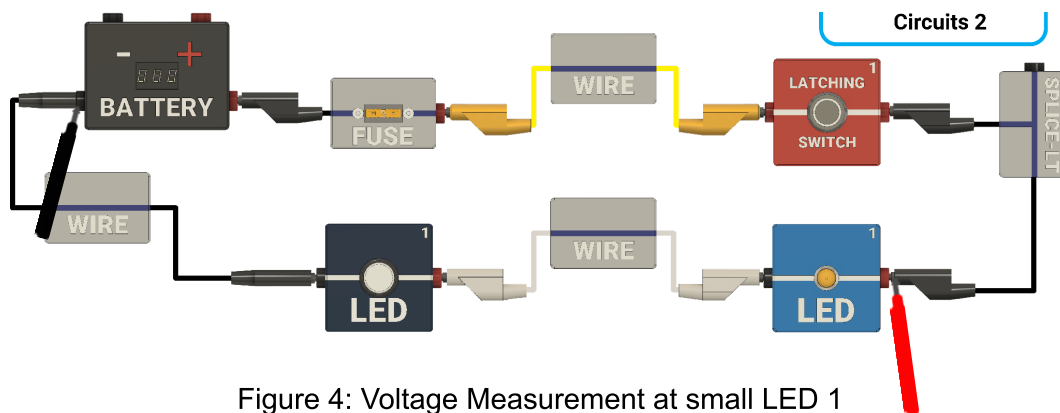


Figure 4: Voltage Measurement at small LED 1

Voltage Prior To small LED 1 _____12V_____

7. Measure Voltage Prior to large LED 1:

- Move the multimeter's positive probe to the connection point just before large LED 1 (after small LED 1 but before large LED 1). See Figure 5
- Keep the negative probe at the same negative terminal or ground. Record this voltage.

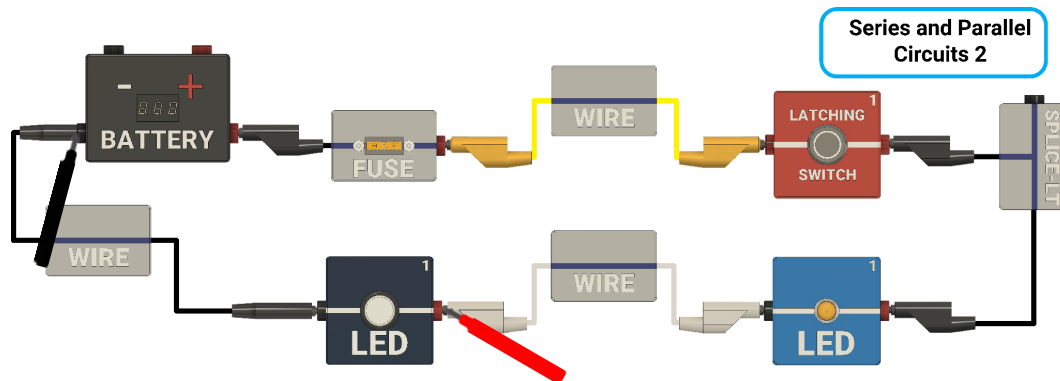


Figure 5: Voltage Measurement at large LED 1

Voltage Prior To large LED 1 ____8V____

Note:

These measurements will show you the voltage available at each point along the circuit, helping to identify how much voltage is dropped across each LED. The difference between the initial voltage and the voltage before each LED represents the cumulative voltage drop caused by the components preceding each measurement point.

Measuring Voltage in a Parallel Circuit with LEDs

8. Set Up Your Multimeter:
 - a. Before you begin, make sure your multimeter is set to measure DC voltage.
9. Measure Initial Voltage:
 - a. Connect the multimeter probes to the BATTERY in the parallel circuit to measure the total voltage supplied to the circuit. This is your reference voltage. Compare to your value with that found on the small meter embedded in the BATTERY. They should be similar
10. Measure Voltage Prior to Large LED 2:
 - a. Place the multimeter's positive probe on the connection point just before large LED 2. See Figure 6
 - b. Place the negative probe on the negative terminal of the BATTERY in the circuit. Record this voltage.

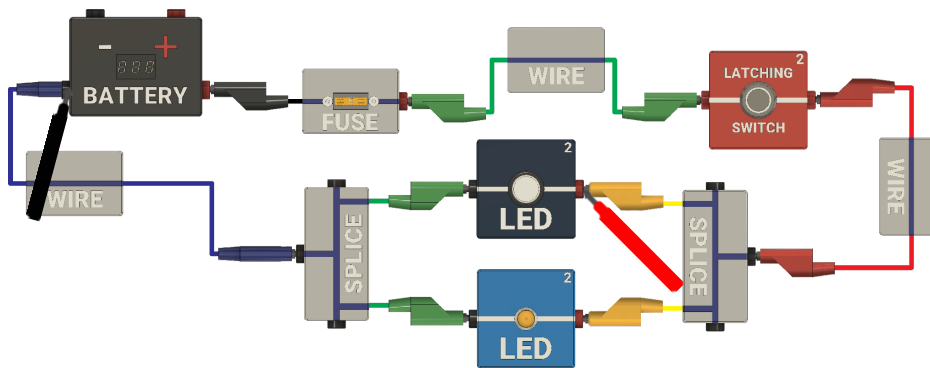


Figure 6: Voltage Measurement at large LED 2

Voltage Prior To Large LED 2 _____12V_____

11. Measure Voltage Prior to small LED 2:

- Move the multimeter's positive probe to the connection point just before small LED 2 See Figure 7
- Keep the negative probe at the same negative terminal of the BATTERY. Record this voltage.

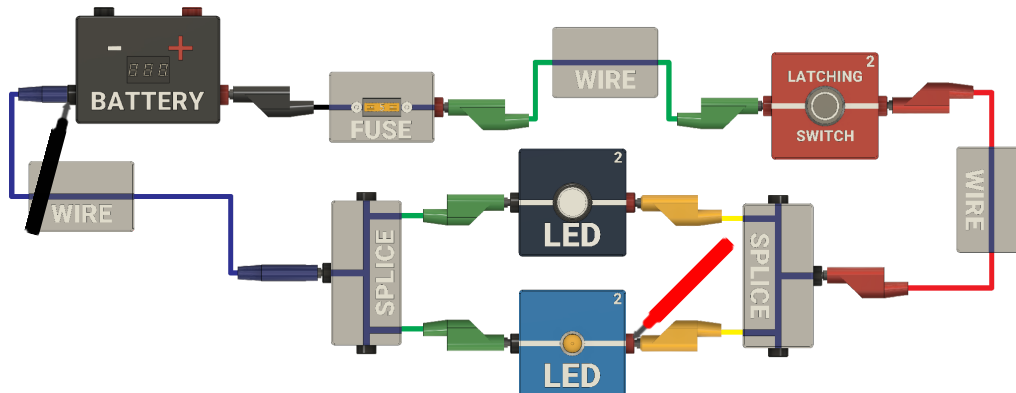


Figure 7: Voltage Measurement at small LED 2

Voltage Prior To small LED 2 ____ **12V** ____

Comparing Voltage Across LEDs in Series and Parallel Circuits

When observing the voltage at small LED 1 and large LED 1 in a series circuit, you will notice that the voltage decreases from one LED to the next. This decrease occurs because each component in a series circuit uses a portion of the voltage from the source, leading to a progressive voltage drop along the circuit.

In contrast, when you measure the voltage across small LED 2 and large LED 2 in a parallel circuit, you should see that the voltage remains consistent at each LED and matches the source voltage. This consistency is due to the nature of parallel circuits, where each component is directly connected to the voltage source. Therefore, the voltage across each LED in a parallel circuit is not affected by other LEDs and stays equal to the total voltage supplied by the source.

12. How does the voltage distribution in a series circuit compare to a parallel circuit?
- a. In a series circuit, the voltage is the same across all components, whereas in a parallel circuit, it varies.
 - b. In a series circuit, the voltage varies across each component, while in a parallel circuit, it remains constant across each component.
 - c. Both series and parallel circuits distribute voltage equally across all components.
 - d. Neither circuit type allows voltage to remain constant across components.
13. If the voltage source provides 12V, what is the voltage across each component in a parallel circuit?
- a. It depends on the number of components.
 - b. Each component receives a fraction of the total voltage.
 - c. Each component receives the full 12V.
 - d. The voltage is 0V across each component.

Understanding the Impact of an Open in Series and Parallel Circuits

An "open" in an electrical circuit refers to a break or gap in the conducting path through which current flows. This interruption can significantly affect the operation of the circuit, and its impact varies dramatically between series and parallel configurations.

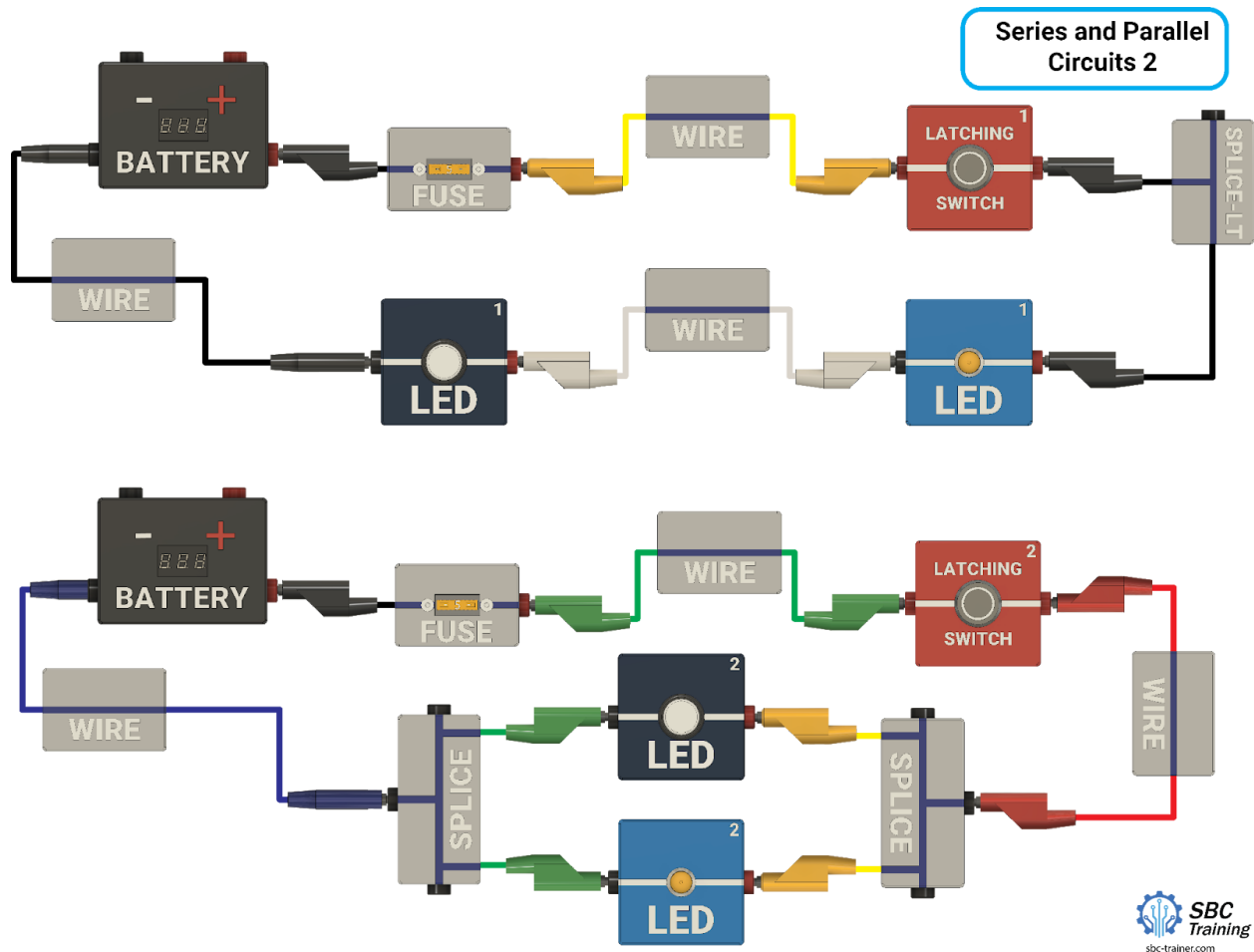
Open in a Series Circuit:

- **Effect on the Circuit:** In a series circuit, an open will stop the entire flow of current because there is only one path for the current to travel. If any part of this path is broken, it creates an open circuit, and no electrical current can flow through any of the components.
- **Practical Example:** Consider a string of old-style Christmas lights wired in series. If one bulb fails and creates an open circuit, the entire string of lights will go out because the path for current flow is interrupted.

Open in a Parallel Circuit:

- **Effect on the Circuit:** In a parallel circuit, an open in one branch only affects that specific branch; other branches will continue to operate normally because they provide alternative paths for the current. This is due to each branch being independently connected to the power source.
- **Practical Example:** In a house, multiple appliances are connected in parallel to the main electrical system. If one appliance breaks down and its circuit opens, it does not affect the operation of other appliances, which will continue to function because each has its own direct path to the power source.

Open in Series vs Parallel Circuit LAB



Setup

Complete the following steps to set up for testing:

- Place all of the electrical nodes on the Series and Parallel Circuits Sheet

Measuring Voltage in a Series Circuit with LEDs

1. Set Up Your Multimeter:
 - a. Before you begin, make sure your multimeter is set to measure DC voltage.
2. Connect the POWER SUPPLY to each battery using the red and black POWER SUPPLY WIRES
 - a. Connect the POWER SUPPLY WIRES to the jacks of the POWER SUPPLY as shown in Figure 2
 - b. Attach one set of wires to the positive (red) and negative (black) terminals at the top of the BATTERY, and connect another set to the positive (red) and negative (black) terminals at the top of the other BATTERY . See Figure 3

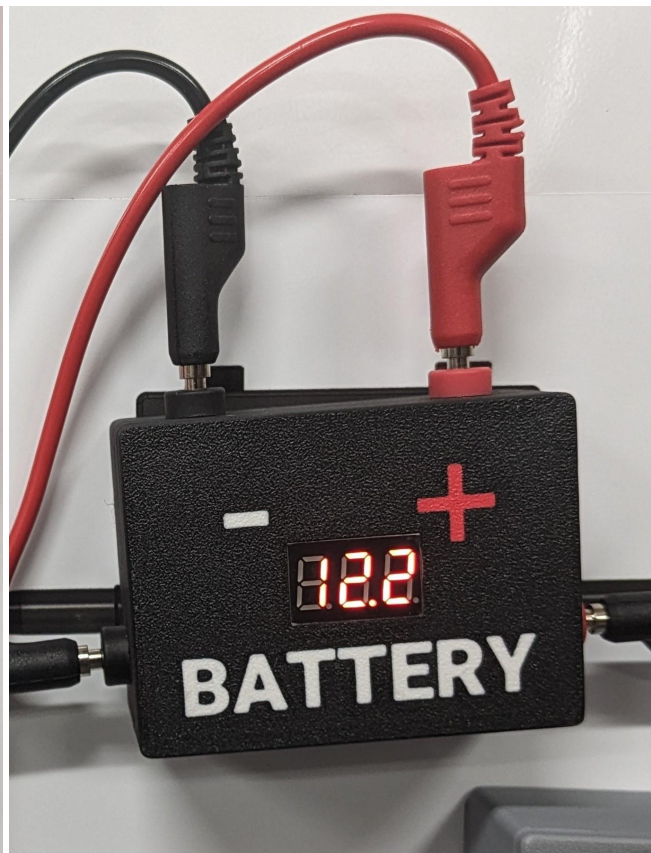


Figure 2: POWER SUPPLY Connection

Figure 3: BATTERY Connection

3. Turn on the POWER SUPPLY by pushing up on the switch located at the top left side of the POWER SUPPLY
4. Ensure that the circuit is on by verifying that the LED is illuminated in both the TOP circuit and the bottom circuit:
5. Disconnect the white WIRE connecting the two LEDs in the series circuit
6. Observe and record the results

Series circuit open results ____The circuit does not function at all____

7. Remove the top large LED 2 of the parallel circuit
8. Observe and record the results

Parallel circuit open results ____The small LED 2 is still working__

9. What happens if there is an open in one component of a series circuit?
 - a. The current in the entire circuit stops. **Correct**
 - b. The current bypasses the open component and continues to flow.
 - c. The voltage across the circuit increases.
 - d. Only the component with the open stops working, while others continue to function.
10. How does an open in one branch of a parallel circuit affect the other branches?
 - a. All branches stop functioning because the current cannot flow.
 - b. Other branches are not affected and continue to function normally. **Correct**
 - c. The voltage across the entire circuit drops significantly.
 - d. The current increases in the remaining functioning branches.

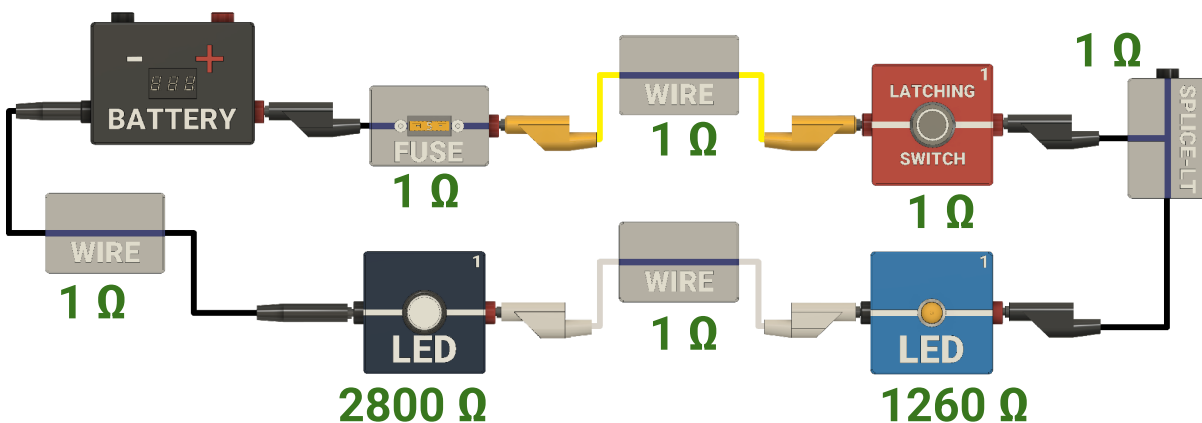
Calculating Total Resistance in a Parallel Circuit

In a parallel circuit, each component is connected directly to the voltage source, causing the voltage across each component to be the same. However, the resistance behaves differently from in a series circuit.

In a series circuit, the total resistance is the sum of the resistances of each component along the circuit. This is because the components are connected end-to-end, and the current must pass through each component sequentially. Therefore, you simply add up the resistance of each individual component to determine the total resistance.

The formula for total resistance in a parallel circuit reflects the division of current across the paths:

$$R_{total} = R_1 + R_2 + ... R_n$$



Total Circuit Resistance = $4066\ \Omega$

Figure 9: Total Circuit Resistance in a Series Circuit

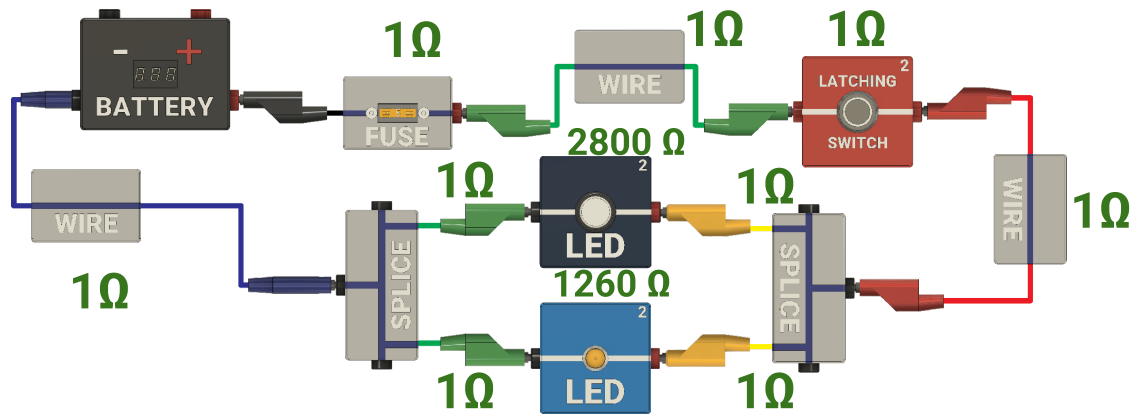
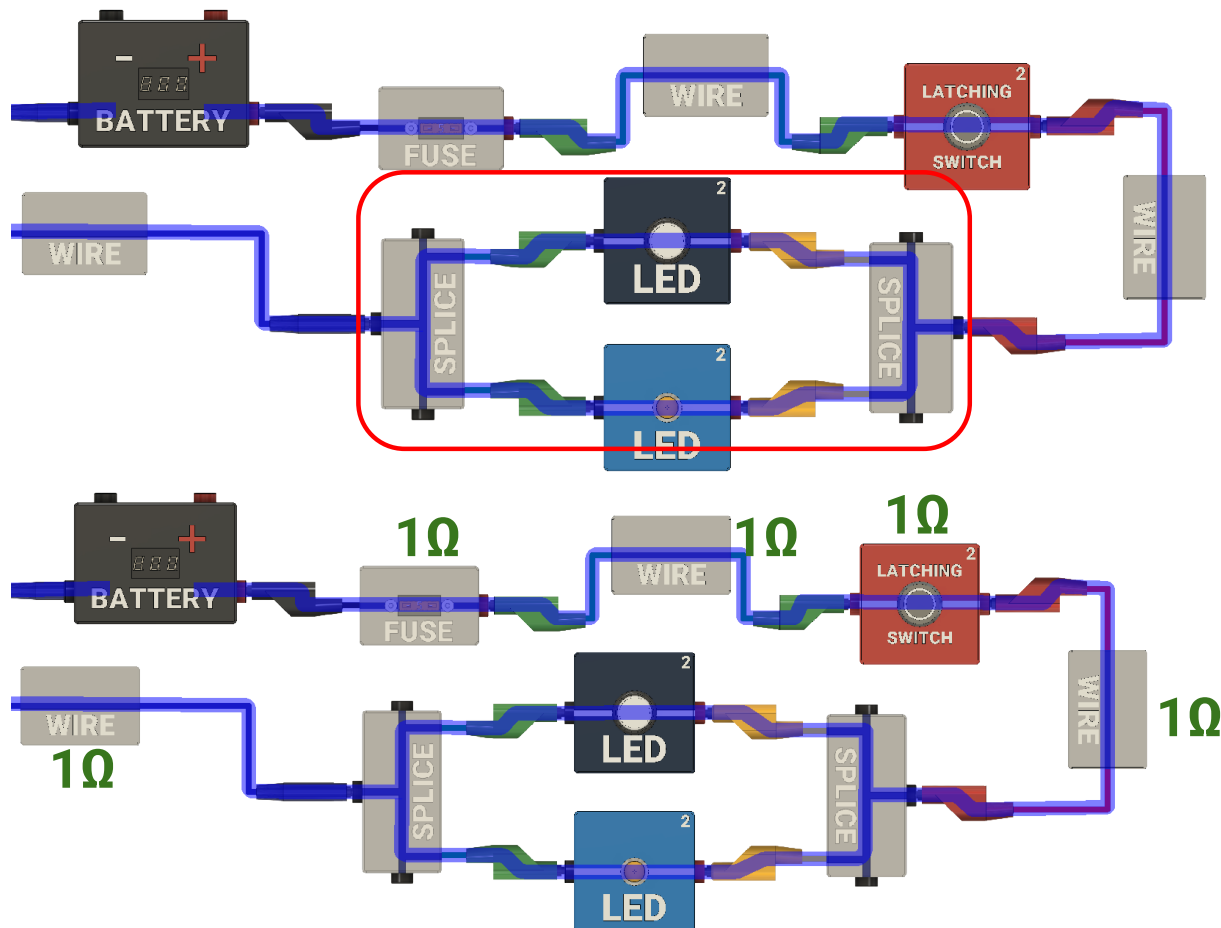


Figure 10: Total Resistance in a parallel circuit

In a parallel circuit, components are connected across the same two points, creating multiple paths for the current. This arrangement means that the voltage across each component is the same, but the current can split and travel through multiple branches. The formula for total resistance in a parallel circuit reflects the division of current across the paths:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}$$

This configuration reduces the overall resistance because each resistor in parallel provides an additional path for the current to flow, thereby decreasing the circuit's total resistance. Even if one path (resistor) offers significant resistance, others help carry the load, effectively making it easier for the current to pass through the circuit compared to a single path in a series setup.



Step 1: Total of Series part of circuit = 5Ω

Figure 11: Total Resistance of Series part of circuit

Step 1: Break the circuit into section that are only series circuits

- The blue lines in the top part of Figure 11 show that there is only one path for current to enter the component and one path for the current to leave the component except for the region outlined in red. The components outside the red box are in series and we can just sum them up
- The red box in the middle will be addressed next

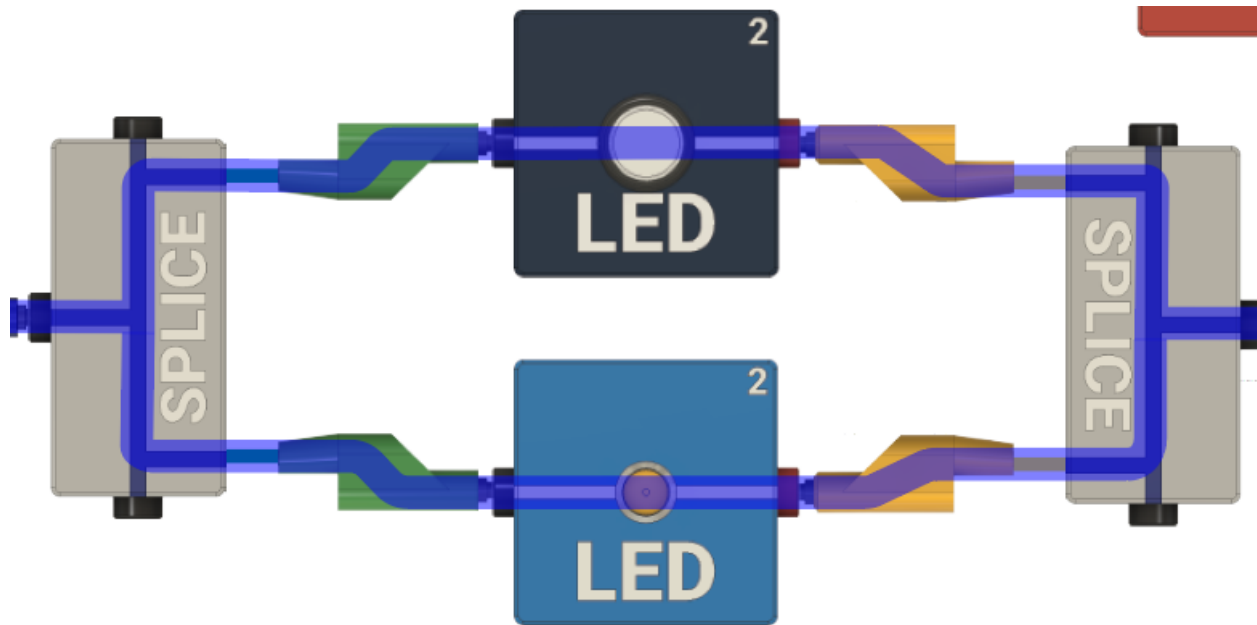


Figure 12: Two paths for current to flow in a parallel circuit

Analyzing Current Paths in Figure 12

In Figure 12, observe that the current can follow two distinct paths after leaving the SPLICE. It can flow either through the top LED or through the bottom LED. Specifically:

- **Top Path:** The current flows out of the SPLICE, travels through the yellow wire, passes through the top LED, and returns via the green wire.
- **Bottom Path:** A similar current path exists at the bottom, where current exits the SPLICE, moves through another yellow wire, flows through the bottom LED, and returns through a different green wire.

Calculating Total Resistance:

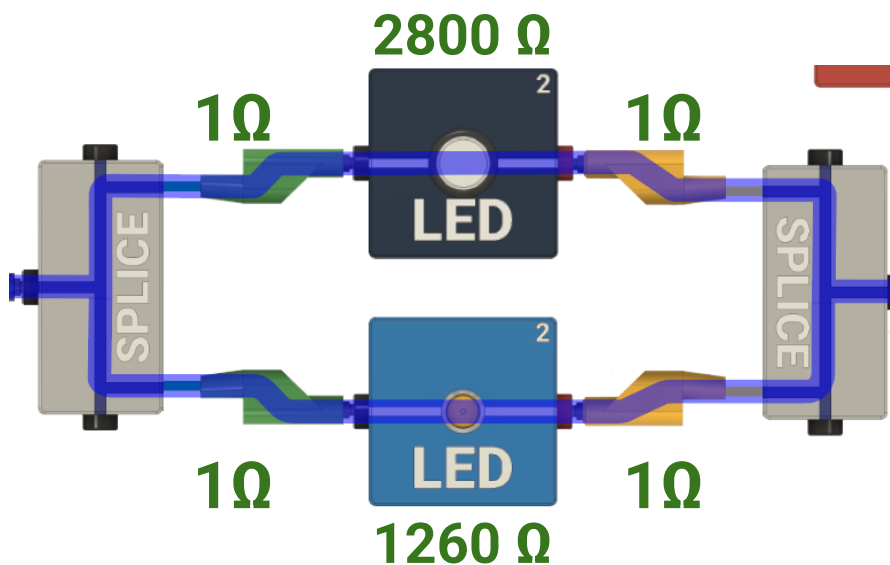
To accurately determine the total resistance for each path, we must account for the resistance of each component along the way. This includes:

- The resistance of the yellow wire,
- The resistance of the LED,
- The resistance of the green wire.

Add these resistances together to find the total resistance for each path:

- Top Path Total Resistance: Add the resistances of the top yellow wire, the top LED, and the top green wire. As noted in Figure 13, the combined resistance totals 2802 ohms.
- Bottom Path Total Resistance: Similarly, for the bottom path, add the resistances of the bottom yellow wire, the bottom LED, and the bottom green wire. This path has a total resistance of 1262 ohms.

This approach ensures that we account for all resistance factors in each part of the circuit, providing a comprehensive understanding of how resistance impacts current flow through different routes.



Top circuit resistance = $1\Omega + 2800\Omega + 1\Omega = 2802\Omega$

Bottom circuit resistance = $1\Omega + 1260\Omega + 1\Omega = 1262\Omega$

Figure 13: Total resistance for top and bottom circuit

Step 2. Calculate the parallel resistance

- With the total resistances for both the top and bottom paths established, we can proceed to calculate the overall resistance of this part of the circuit using the formula for resistors in parallel.

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}$$

- Assign the total resistance of the top path as R1
 - R1 is 2802 ohms
- Assign the total resistance of the bottom path as R2
 - R2 is 1262 ohms

$$\frac{1}{R_{total}} = \frac{1}{2802} + \frac{1}{1262}$$

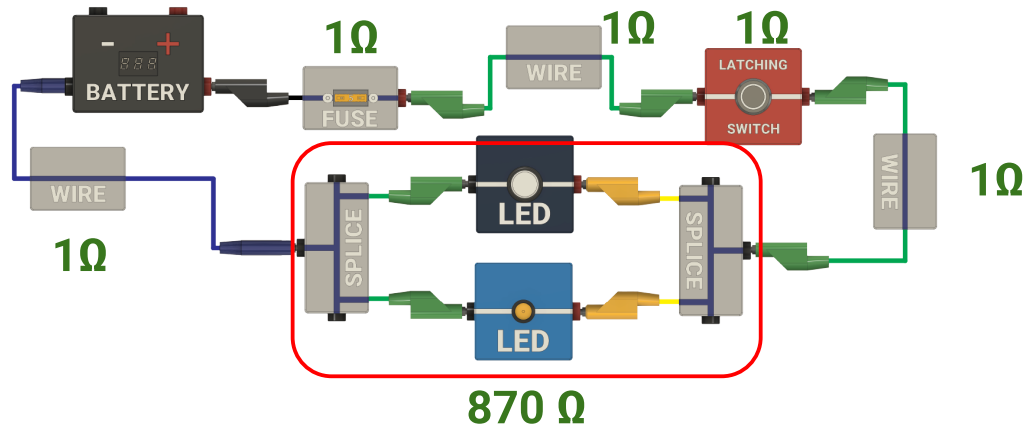
- Use a calculator to sum determine the value

$$\frac{1}{R_{total}} = 0.001149$$

- The 1/x function on most calculators will find the reciprocal of 0.001149

$$R_{total} = \sim 870$$

Step 3. Add the remaining resistance values



Step 3: Total resistance of the circuit = 875 Ω

Figure 14: Total Resistance of Series part of circuit

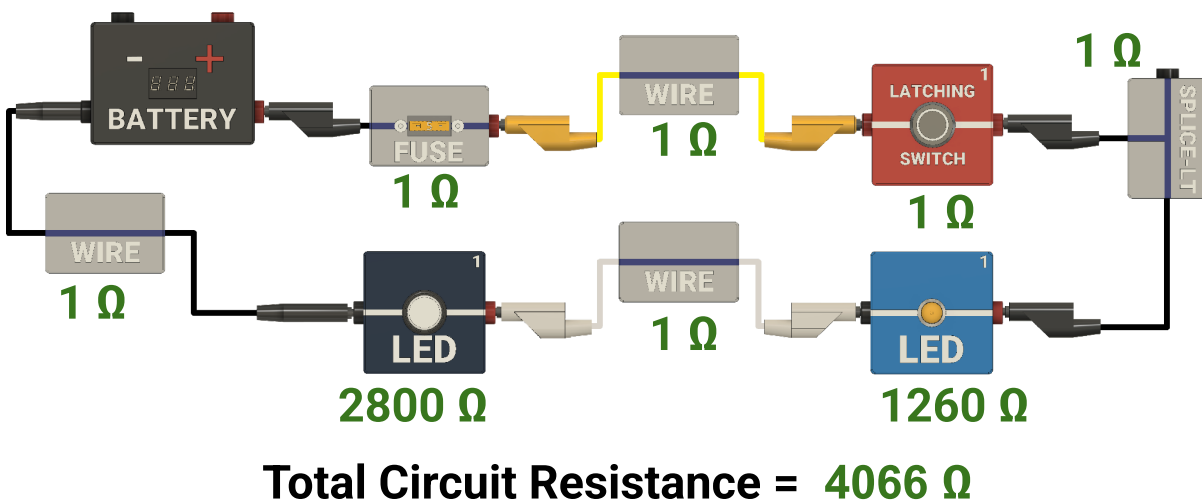


Figure 15: Total Circuit Resistance in a Series Circuit

Purpose of Calculating Total Resistance in Parallel Circuits

The primary reason we delve into the calculations for total resistance in parallel circuits isn't just to practice our math skills, but to demonstrate and confirm a crucial electrical principle:

- **The total resistance of a parallel circuit is always less than the resistance of the smallest resistor within that circuit.**
- **Using essentially the same components in a series circuit results in a much higher total resistance**

Why This Concept Matters:

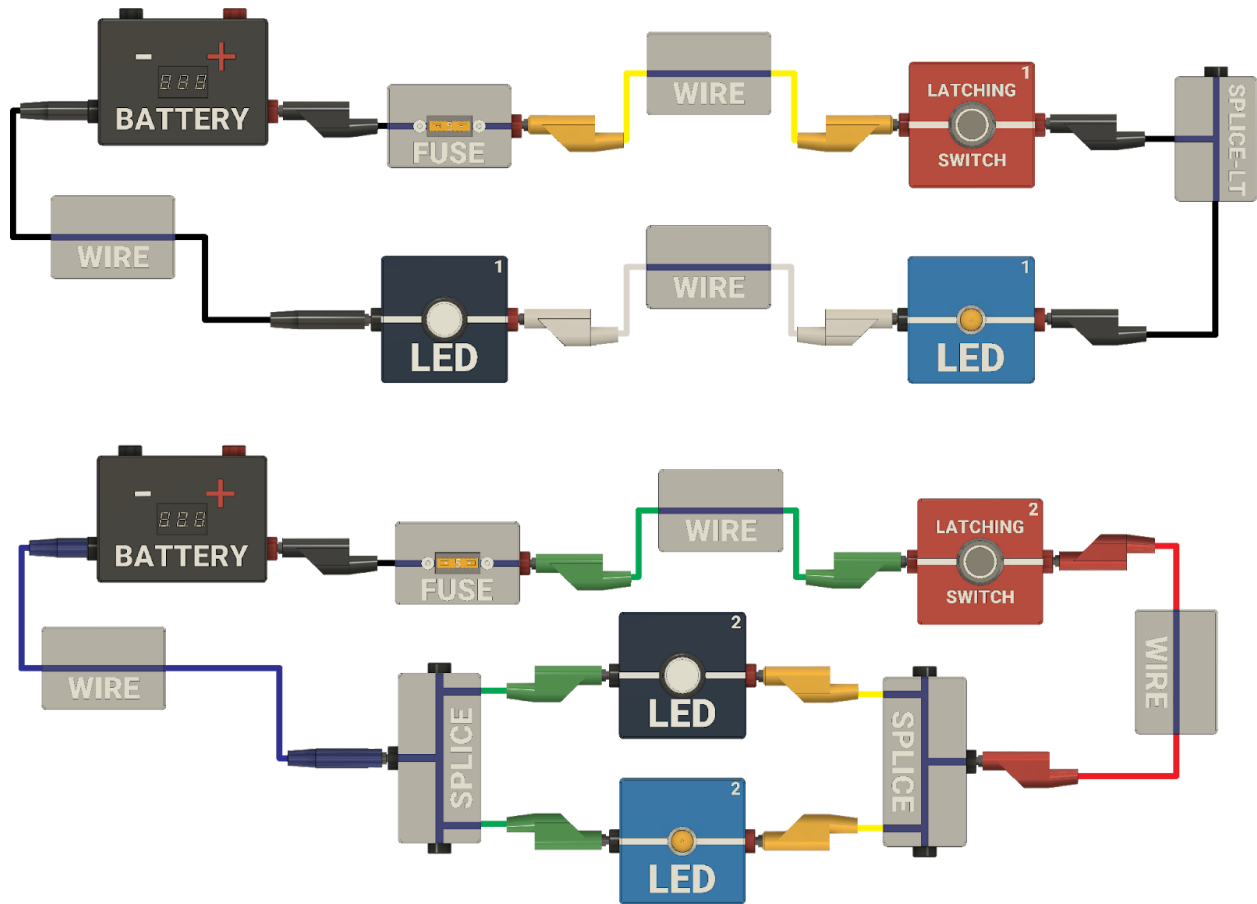
In practical terms, this principle is vital in many applications, such as in the design of electronic devices, electrical power systems, and circuits in automotive and aerospace industries. Engineers and technicians use this knowledge to optimize circuit performance, ensure safety, and maintain efficiency in systems where consistent electrical output is critical.

Understanding that adding more resistors in parallel reduces the overall resistance allows us to predict how adding or removing components affects a circuit. This is crucial for troubleshooting and improving existing designs, where managing load and distribution of current can enhance functionality and durability.

Why Resistance Decreases in Parallel:

When components are connected in parallel, each additional branch provides a new path for the current to travel. The more paths available, the less resistance the current encounters overall. This is akin to water flowing through multiple pipes simultaneously—the overall resistance to flow decreases as more pathways are available. Therefore, the total resistance in a parallel circuit will always be less than the resistance of the smallest resistor in that circuit and certainly less than the cumulative resistance in a series circuit of the same components.

Current Calculations in a Parallel and Series Circuit



Setup

Complete the following steps to set up for testing:

- Place all of the electrical nodes on the Series and Parallel Circuits Sheet

Calculating total resistance using Ohm's Law

1. Set the multimeter to measure DC Amperage
2. Connect the POWER SUPPLY to each battery using the red and black POWER SUPPLY WIRES
 - a. Connect the POWER SUPPLY WIRES to the jacks of the POWER SUPPLY as shown in Figure 2
 - b. Attach one set of wires to the positive (red) and negative (black) terminals at the top of the BATTERY , and connect another set to the positive (red) and negative (black) terminals at the top of the other BATTERY . See Figure 3

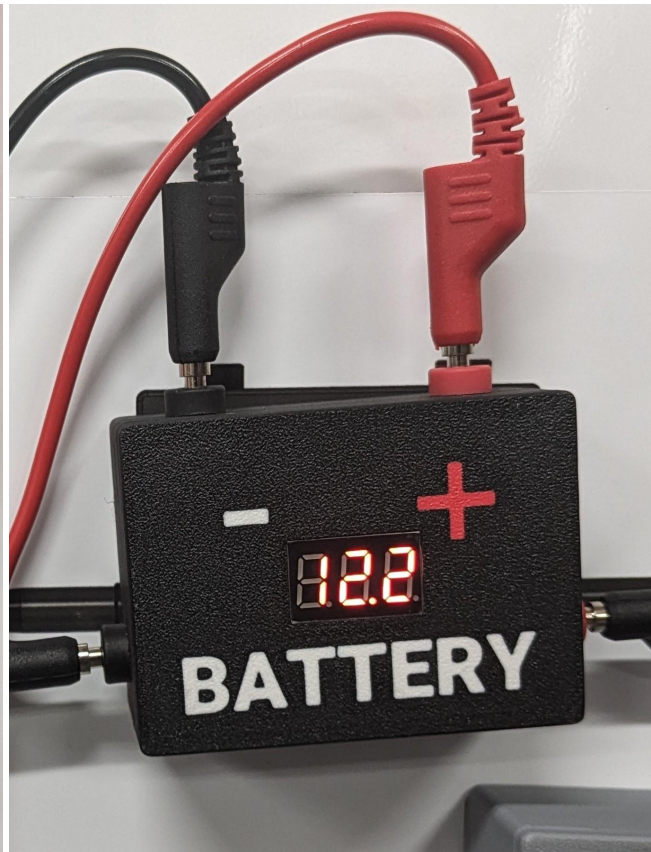


Figure 2: POWER SUPPLY Connection

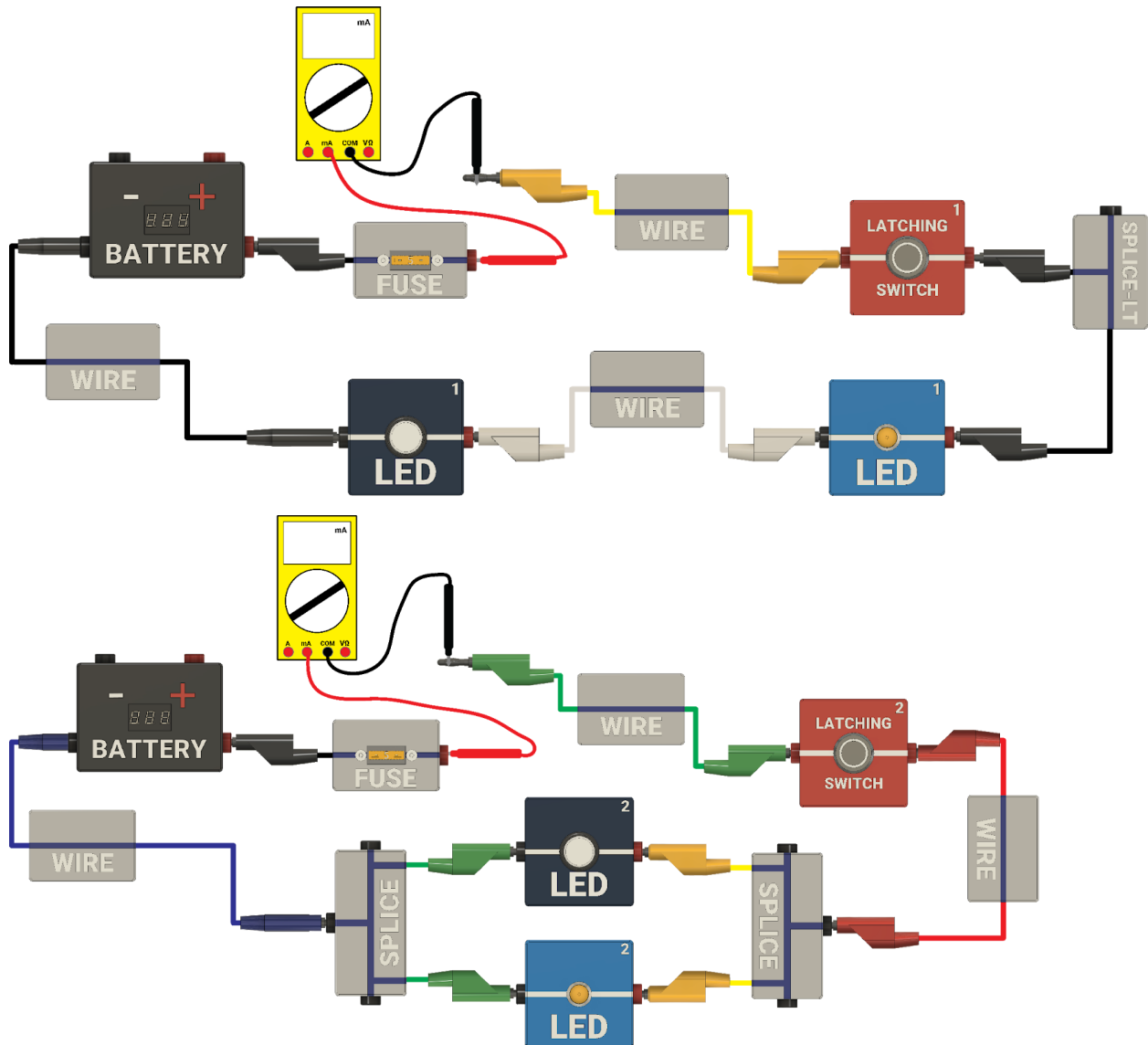
Figure 3: BATTERY Connection

3. Turn on the POWER SUPPLY by pushing up on the switch located at the top left side of the POWER SUPPLY
4. Ensure that the circuit is on by verifying that the LED is illuminated in both the TOP circuit and the bottom circuit
5. Unplug the yellow wire going into the fuse of the top series circuit
6. Unplug the green wire going into the fuse of the bottom parallel circuit
7. Review figure the series circuit below before proceeding
8. Place the red meter lead in the red jack of the top circuit fuse

9. Place the black meter lead on the banana plug of the yello wire that you disconnected
10. Record the amperage measured for top circuit.
11. Repeat the amperage measurement for the bottom circuit following the illustration of the parallel circuit with the meter

Top Series Circuit Amperage: 2.6 A

Bottom Parallel Circuit Amperage: 14.4 A



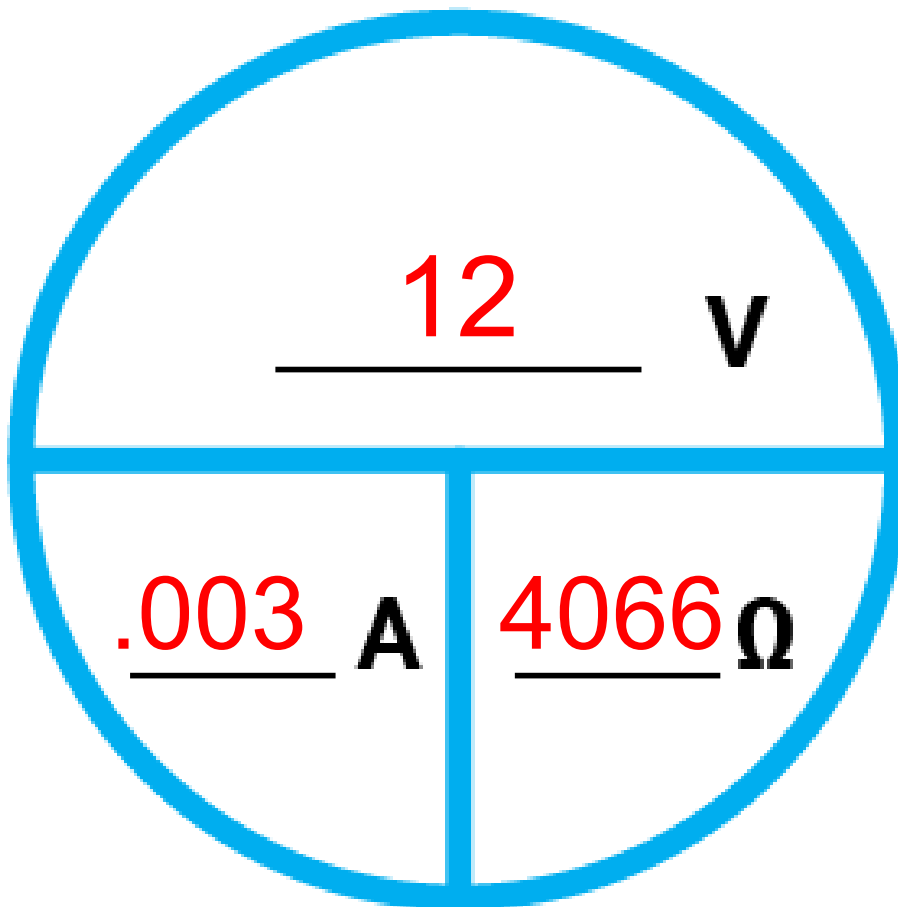
Calculations

1. Refer to the Ohm's Law Circle below to calculate the TOTAL RESISTANCE in the top Series circuit. Use the voltage measurement from the BATTERY and the current measurement from the circuit for your calculation.

Note on Discrepancies:

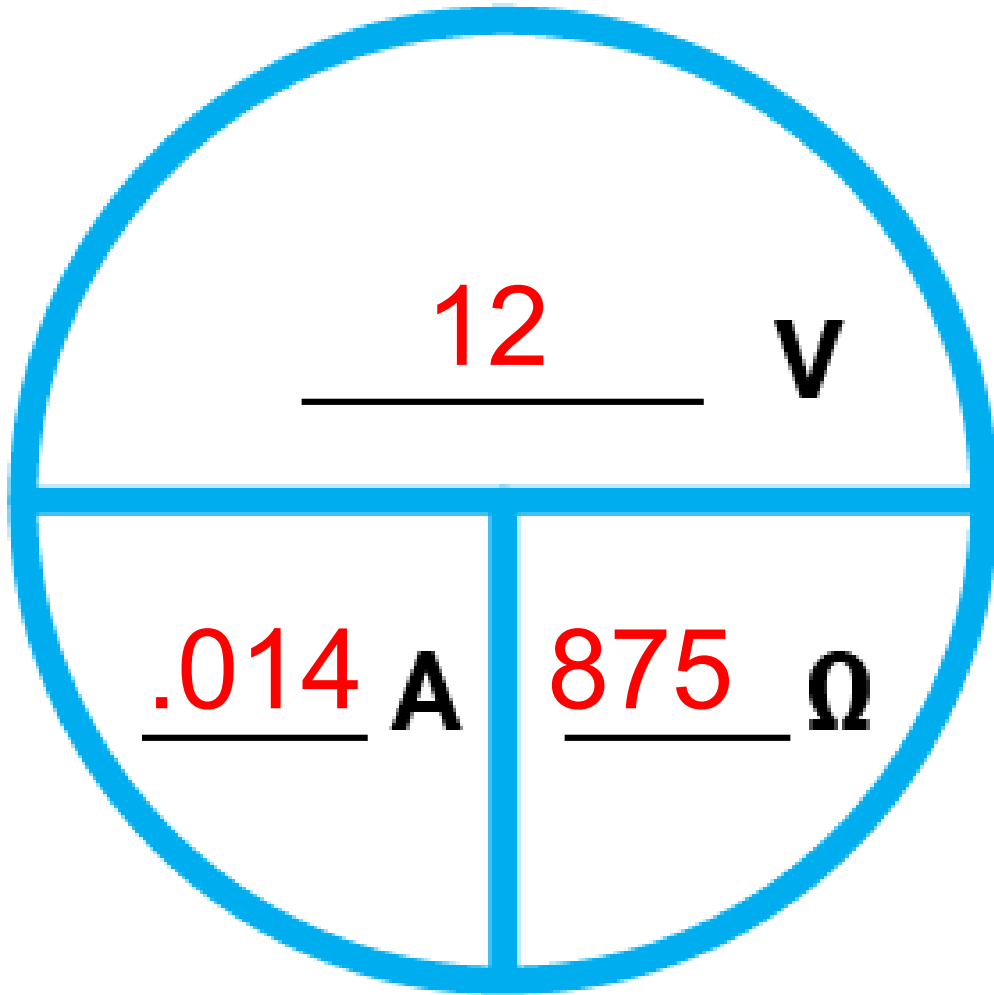
You might notice that the calculated total resistance doesn't exactly match the measured resistance. This discrepancy can occur due to the heat generated when current flows through wires and components. Heat tends to increase the resistance of these components, which in turn can reduce the current flow.

However, components like LEDs typically generate less heat when activated, leading to a less pronounced change in resistance compared to other electrical elements. Therefore, the impact of heat on the resistance of LEDs may not be as significant, affecting the current to a lesser extent.



Total Resistance Calculation Top Series Circuit

2. Refer to the Ohm's Law Circle below to calculate the TOTAL RESISTANCE in the bottom parallel circuit. Use the voltage measurement from the BATTERY and the current measurement from the circuit for your calculation.



Total Resistance Calculation Bottom Parallel Circuit

3. Which circuit has the highest current?
 - a. Top circuit
 - b. Bottom circuit **Correct**
4. Which circuit has the highest total resistance?
 - a. Top circuit **Correct**
 - b. Bottom circuit
5. If the voltage in the circuit is the same what can be said about the relationship between the total resistance in a circuit and current? **(SELECT ALL THAT APPLY)**
 - a. As the total resistance in the circuit increases the current decreases **Correct**
 - b. As the total resistance in the circuit decreases the current decreases
 - c. As the total resistance in the circuit increases the current increases
 - d. As the total resistance in the circuit decreases the current increases **Correct**
 - e. There is not a relationship between the total resistance and current in the circuit
6. If three resistors—10 ohms, 20 ohms, and 30 ohms—are connected in parallel, which of the following is true about the total resistance of the circuit?
 - a. It is less than 10 ohms but greater than 5 ohms. **Correct**
 - b. It is more than 30 ohms.
 - c. It is equal to the sum of all resistors.
 - d. It is exactly 10 ohms.