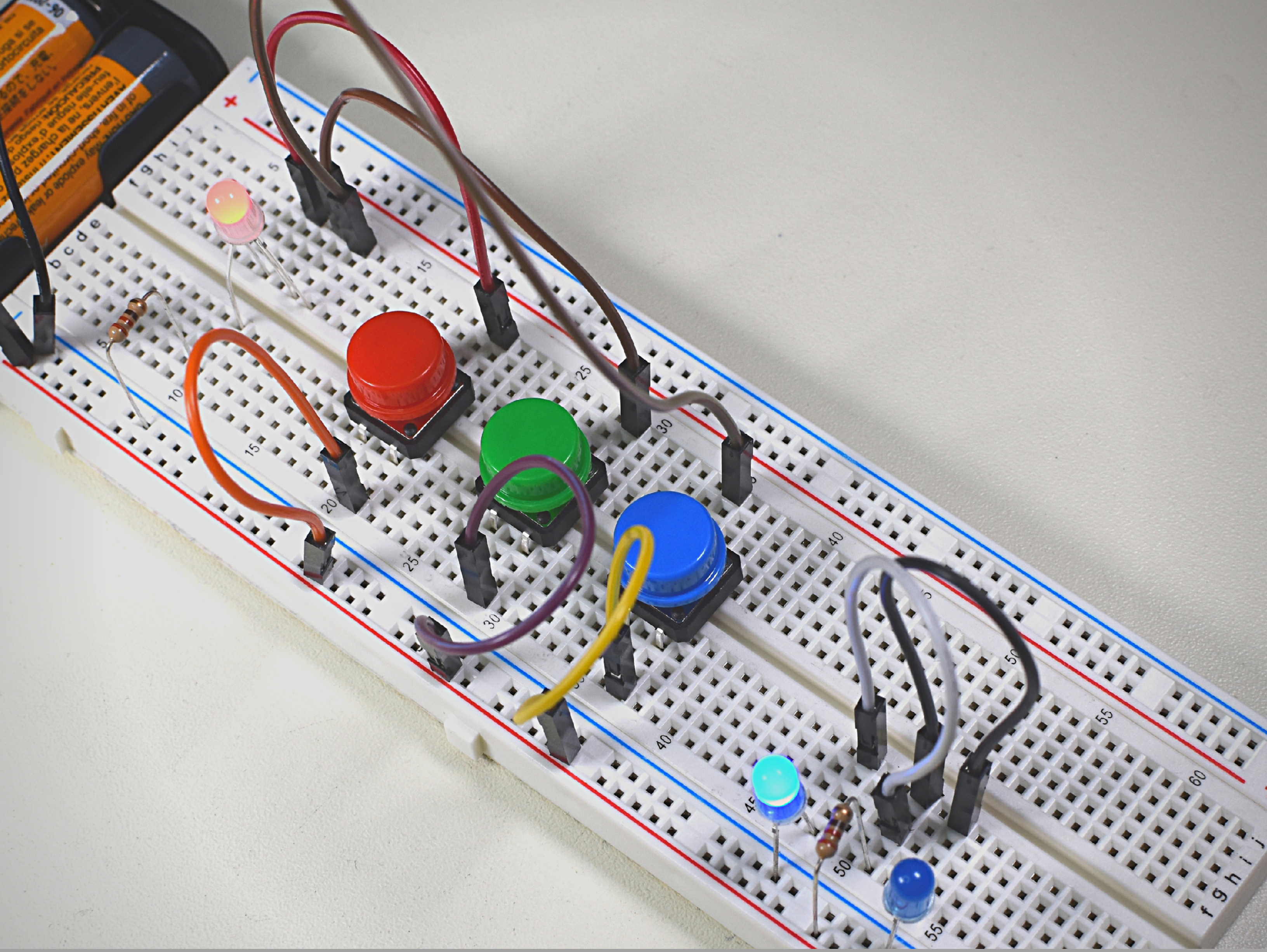

42 ELECTRONICS

INTRO TO CIRCUIT BUILDING

BY ERIC FEICKERT

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INTRO TO CIRCUIT BUILDING

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SERIES VS. PARALLEL CIRCUITS & OHM'S LAW

Lesson Overview

- ► Serial vs. Parallel Circuits
- ► Ohm's Law

Concepts to Review

- ► Breadboard Power, Rows and Columns (Lesson A-1)
- ► Connecting Battery to Breadboard (Lesson A-1)
- ► Building a Circuit with a Resistor and LED (Lesson A-2)
- ► LED Polarity, Forward Voltage (Vf) (Lesson A-2)

Materials Needed

- ❑ Breadboard Circuit from Lesson A-2, Activity #1
- ❑ 220-Ohm Resistor x1
- ❑ LED x1

LESSON A-3

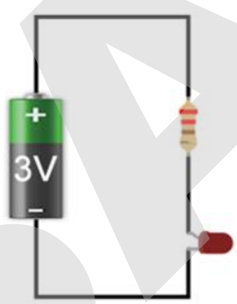
SERIES VS. PARALLEL CIRCUITS & OHM'S LAW

As you saw in the previous lesson, a circuit can be as simple as powering a single LED. However, in the real world, that's not a very useful application! You will generally see multiple components being powered by a single battery. For example, a remote control contains numerous switches, LEDs, and other components, all powered from a single battery. This lesson will dive into series vs. parallel circuits and teach you to power multiple component paths using a single battery.

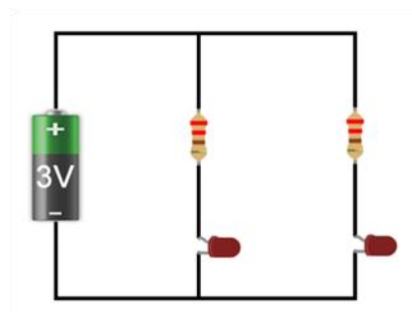
The circuit you built in the last lesson had a single path that ran from the anode (+) of the battery, through a resistor, through an LED, and then back to the cathode (-) of the battery. This is known as a series: one path of components running off the source battery.

But most projects or real-life applications would run in what's known as a parallel circuit. When running in parallel the current runs from the positive terminal of the battery, splits along multiple paths to power components, and then runs back to the negative terminal of the battery.

Circuit with components in series

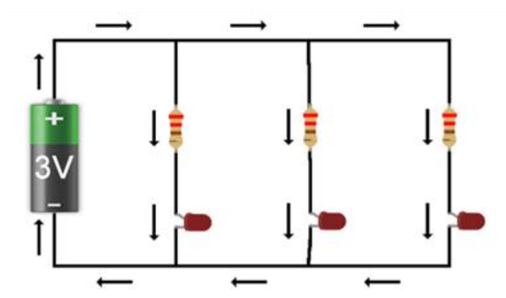


Circuit with two LED/resistor combinations running in parallel sharing the same power source

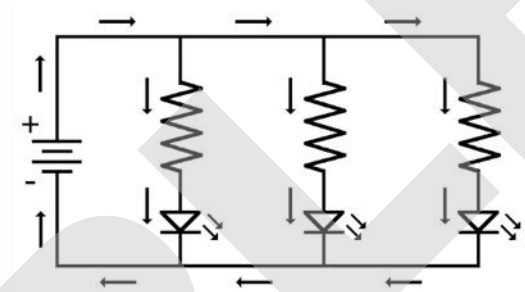


As you saw in Lesson A-2, Activity #2, there are some significant limitations to running serial circuits. Mainly that you would need a higher voltage battery to run anything more than a few simple components. Instead, circuits are normally run in parallel which allows the battery voltage to feed equally to all paths within the circuit. So, looking at Figure 3-1 (serial), with a 3-volt battery, 3-volts will feed resistor 1 and LED 1. In Figure 3-2 (parallel), a 3-volt battery will provide 3-volts of power to resistor 1 and LED 1 and 3-volts to resistor 2 and LED 2. Therefore, running circuits in parallel essentially makes the full battery voltage available across multiple paths.

Current flow in parallel components



Schematic equivalent



> **CAUTION!**
>
> Using parallel circuits to power multiple branches is convenient, however you must be careful to control current flowing through each branch using a resistor. Resistor 1 (R1) will only control current flowing through branch 1 including LED 1 (D1), while Resistor 2 (R2) is used to control current in branch 2. Without Resistor 2, branch 2 would have no current limit and the LED 2 (D2) could burn out due to excess current.

Factors in a Serial vs. Parallel Circuit

When working with circuits, it's helpful to understand the mathematical relationship between the battery voltage, current, and the amount of resistance your circuit will provide. For purposes of this course, you will only need to understand the mathematical equation known as Ohm's Law and how you would theoretically calculate this value. In later levels, you will learn the more complex math behind arriving at an exact value for any variable in the Ohm's Law equation which will allow you to design your own circuits.

First, here is a quick review of the definitions you learned in Lesson A-1:

- **VOLTAGE:** The difference in charge between two points, measured in volts; represented by V such as 1.5V or 3V.
- **CURRENT:** The rate at which charge is flowing, measured in Amperes or more commonly amps (A) or milliamps (mA) but this value will be represented by I in formulas. 1A equals 1000mA.
- **RESISTANCE:** A material's tendency to resist the flow of the current, measured in ohms; can be represented by Ω such as 100-ohms or 100Ω.
- Think of voltage as the potential ability to do work, current is how fast the work is being done, and resistance is anything keeping the work from being done faster.

We recommend you move to the Activities portion of the lesson and complete Activity #1 prior to reading through the remainder of this lesson.

Ohm's Law

The voltage, current, and resistance in a circuit are mathematically related. Ohm's Law can be used to determine the voltage, resistance, or current of any component in a circuit. If you have two out of the three values, you can calculate the third using:

$$V = I \times R$$ <u>or</u> Voltage = Current x Resistance

To use the formula, ensure that you convert all values to the following units:

- V is in volts
- R is in ohms
- I is in amps – Note: This is the most problematic unit as current is often in milliamps and must be converted before using it for Ohm's Law, so 10mA would become .010 amps in the formula

What if you need to solve for current or resistance? The formula can be manipulated to solve for these:

$I = V / R$ <u>or</u> $R = V / I$

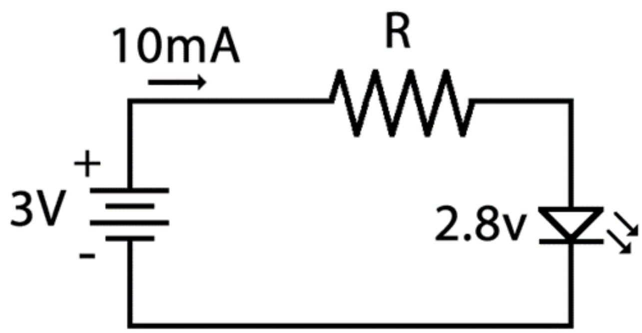
In future levels of this course, this formula will come in handy when selecting a resistor value to help limit current for an LED.

Note:

The following section is optional and skipping it will not keep you from completing the rest of this course. While calculating Ohm's Law is a useful exercise, this concept will be revisited in greater depth in future levels. What's important at this point is understanding that voltage, current, and resistance are mathematically related and calculating these values will be important once you move on to designing your own circuits.

Ohm's Law Calculation Example

Let's say you have an LED with a Vf of 2.8V, with a current limit of 10mA, and a supply voltage of 3-volts. The formula you would use is resistance equals the supply voltage minus the LED's forward voltage divided by the desired current in amps.



$$R = \frac{(Vsource - Vforward)}{Current}$$

$$R = \frac{(3 - 2.8)}{0.01}$$

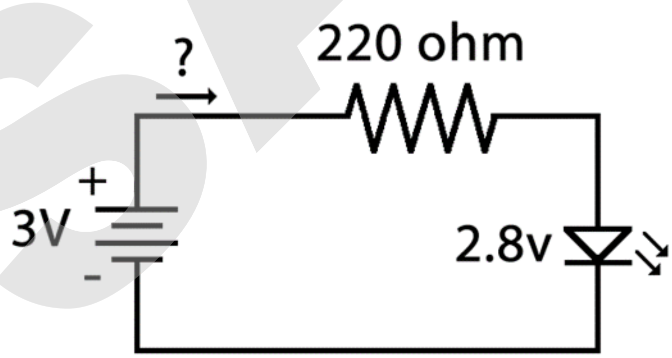
$$R = \frac{.2}{0.01}$$

$$R = 20 \text{ ohms}$$

Start by subtracting the LED Vf of 2.8 from the supply voltage of 3, and dividing that by 10mA or .010. This leaves you with .2 divided by .01 which equals 20 or 20-ohms. This means that with a supply voltage of 3-volts and an LED with a Vf of 2.8V, you would need a 20-ohm resistor to limit the current through the LED to 10mA.

10mA is well below the limit of 20mA, however LEDs need very little current to turn on so it's best to go as low as possible. Later in this course, you will power the breadboard using the Raspberry Pi. Since the Raspberry Pi is a small computer, it can only output a limited amount of current, so keeping the LED current to a minimum is a good idea.

Use Ohm's Law to determine how much current the LED is allowed when we use a 220 -ohm resistor and a 3-volt supply.

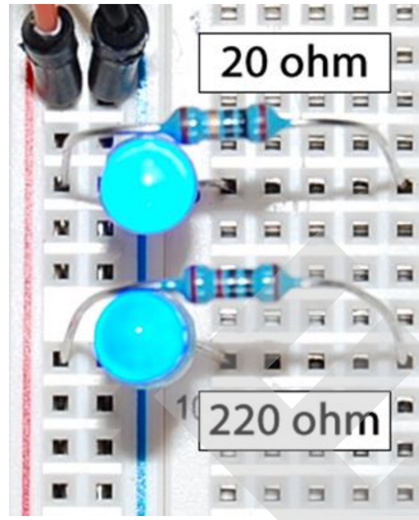


$$I = \frac{(Vsource - Vforward)}{Resistor}$$

$$I = \frac{(3 - 2.8)}{220}$$

$$I = \frac{.2}{220}$$

$$I = .0009$$



Using this formula, a 220-ohm limits the LED current to .0009 amps or .9mA. Comparatively, a 20-ohm resistor would limit the LED current to .010 amps or 10mA.

This means that if your voltage source was only able to supply 10mA of current, you could power a single LED with a 20-ohm resistor or you could power 11 LEDs using 220-ohm resistors.

There is not much LED brightness difference between the two, so limiting the current as much as possible is the better option, especially when powering LEDs using the Raspberry Pi.

As you can see from this photo, the 20-ohm resistor powering the LED at 10mA is only marginally brighter than the 220-ohm resistor powering the LED at .9mA. Unless your application requires an extremely bright LED that needs a lot of current, you can normally get away with powering LEDs using very little current.

Don't worry if you don't quite understand the math. You will not need this equation for the remainder of this course and you will revisit this concept in future levels. The goal is for you to understand that voltage, current, and resistance are mathematically related, and that the equation can be used when designing circuits.

Note:

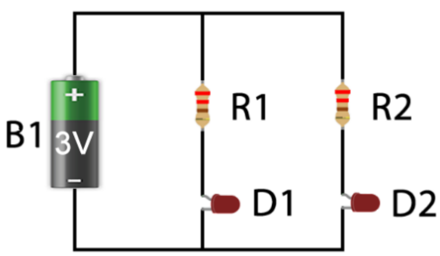
If you wish to dive deeper into Ohm's Law and the math involved, visit this webpage: www.42electronics.com/level-a-resources

LESSON A-3

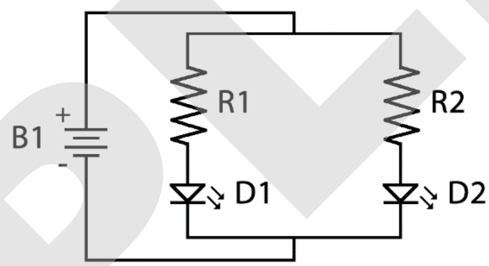
ACTIVITY #1:
BUILD A PARALLEL CIRCUIT

As in the previous lesson, below you will find the schematic for this project, for your review in future lessons. In this activity, you will add a second LED and resistor combination in parallel with the first.

Physical circuit



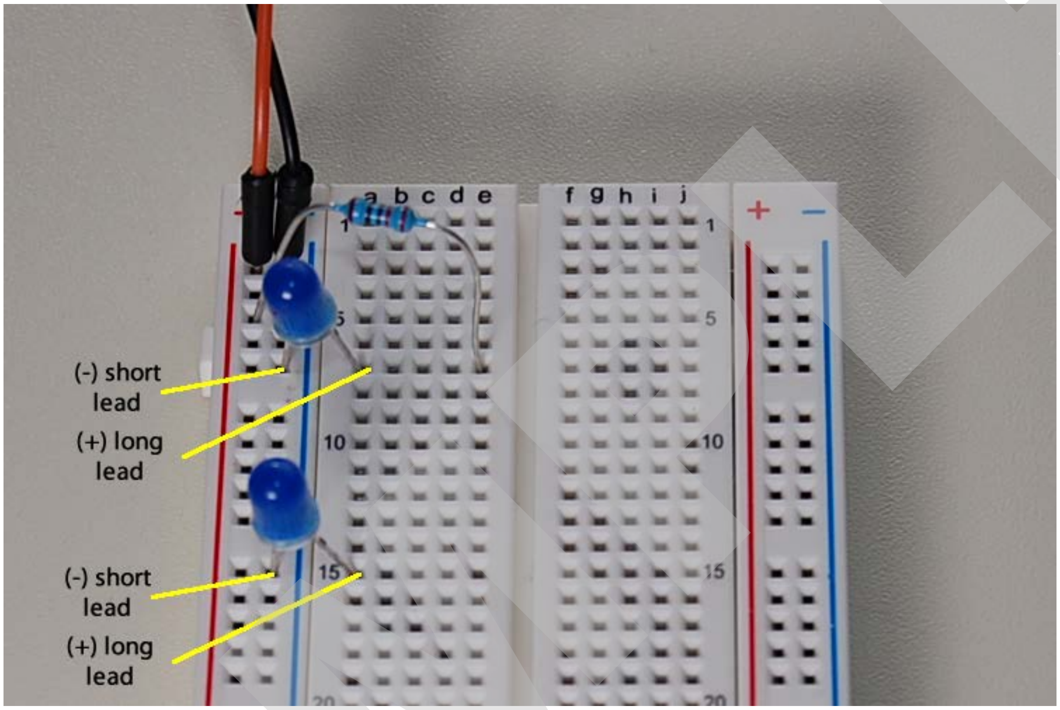
Schematic Diagram



Step #1

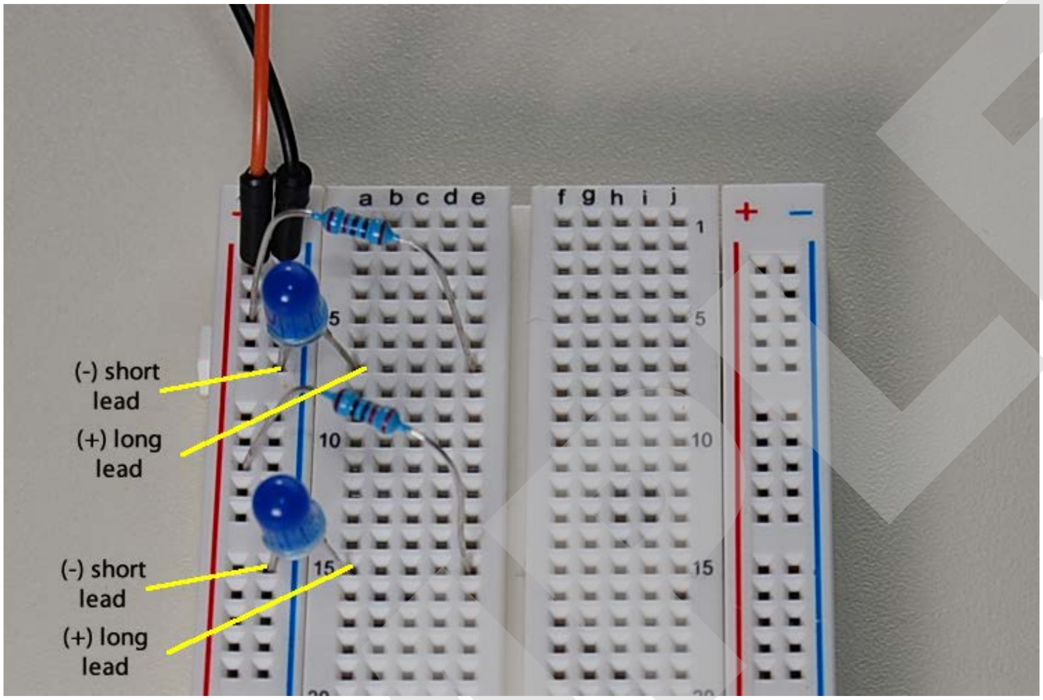
If it's not still built on your breadboard, construct the circuit from Lesson A-2, Activity #1 and then you may proceed with the activity for this lesson.

Using the circuit from in Lesson A-2, Activity #1 as a starting point, you will first add a second LED. Insert the anode of the LED into A15 and the cathode of a second LED into N1-15.



Step #2

Because the second LED you just added is functioning in parallel with the first, you will need to add a second resistor to control the flow of current. Connect a second 220-ohm resistor between P1-11 and E15.



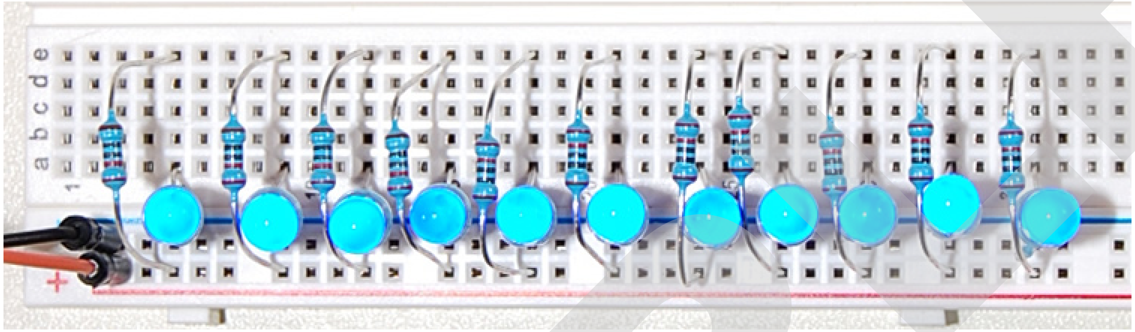
Step #3

Take a moment to track with your eye how the current flows in this circuit and ensure you understand the path from battery positive, through the components, and back to battery negative:

- Positive of the battery to P1-3 powers the positive power rail
- Current splits into two separate paths:
  - P1-5 through the first resistor to E7, across row 7 to A7, into the first LED, and out to N1-7
  - P1-11 through the second resistor to E15, across row 15 to A15, into the second LED, and out to N1-15
- Paths merge at the negative power rail and flow through N1-3 to negative of the battery

Step #4

If desired, you may continue to add the other resistors and LEDs in this kit to the circuit, in parallel, following the same pattern. The number of resistors and LEDs included in this kit are safe additions to this circuit. However, if you are working with additional components beyond what is included in this kit, keep in mind that current is not an infinite resource and you will eventually exceed the maximum current output rating of your power source. This is particularly true when you work with the Raspberry Pi in later lessons.



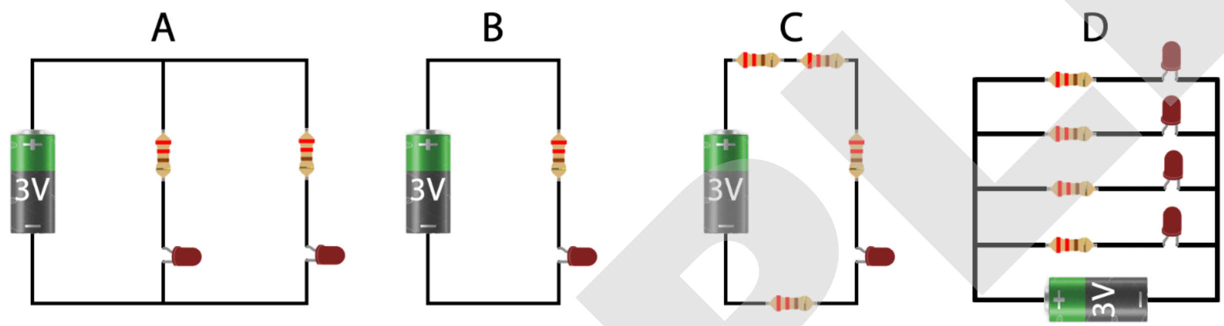
Step #5

Disassemble the circuit and return the components to the kit in preparation for the next lesson.

LESSON A-3

QUESTIONS FOR UNDERSTANDING

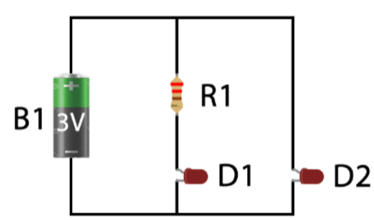
1. Here are some images of series and parallel circuits. Label each circuit as series or parallel.



2. Why would you use parallel circuits instead of keeping all components in series?

3. What is the formula for Ohms Law?

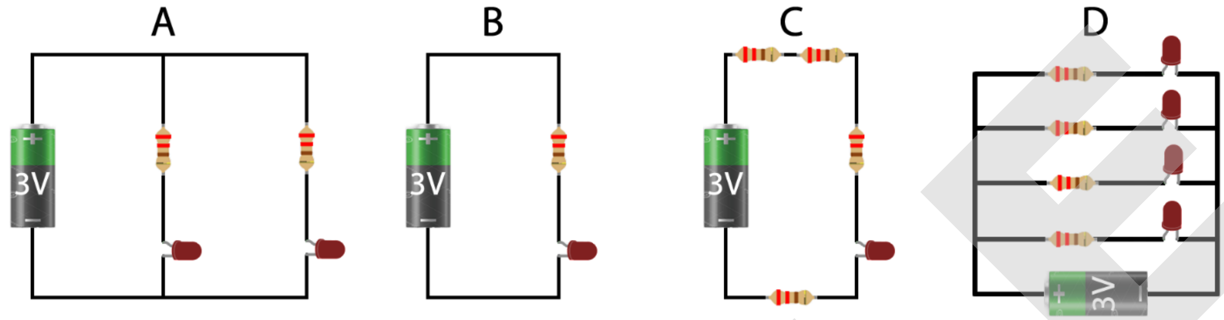
4. In this circuit, Resistor 1 is connected between the battery positive and LED 1. Will Resistor 1 in this configuration limit the current flowing through LED 2?



Answers Can be Found on the Next Page

Answers

1. **Here are some images of series and parallel circuits. Label each circuit as series or parallel.**



ANSWER: A: Parallel, B: Series, C: Series, D: Parallel

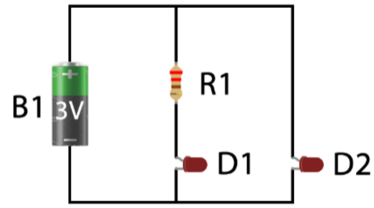
2. **Why would you use parallel circuits instead of keeping all components in series?**

ANSWER: A parallel circuit allows the voltage from the battery to be used equally across all paths in the circuit. So, a 3V battery will provide 3V to path 1, 3V to path 2, etc. This allows you to run multiple components on a single low-powered battery. Running multiple components on a series circuit will generally require a higher voltage battery to account for the Vf (forward voltage) required by certain components.

3. **What is the formula for Ohms Law?**

ANSWER: V = I x R <u>or</u> Voltage = Current x Resistance

4. **In this circuit, Resistor 1 is connected between the battery positive and LED 1. Will Resistor 1 in this configuration limit the current flowing through LED 2?**



ANSWER: No, Resistor 1 will only limit the current flowing along the path between battery positive, LED 1, and battery negative. The path containing LED 2 will require its own resistor (Resistor 2) to limit the current flowing through LED 2.

INTRO TO CIRCUIT BUILDING

Scope and Sequence

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- What is Electricity?
    - Static Electricity vs. Current Electricity
    - Voltage, Current, and Resistance
- What is a Circuit?
    - Short Circuits
    - Open Circuits vs. Complete Circuits
- Circuit Components
    - Batteries
        - Anode vs. Cathode
    - Breadboards
        - Soldered Circuits vs. Breadboard Circuits
        - Breadboard Connections and Power
- Activity: Powering Breadboard Connections

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- Resistors
  - How Resistors Work
  - Using Resistors to Build Circuits
  - Calculating Resistance Value
- Light Emitting Diode
  - How LEDs Work
  - LED Polarity
  - Pairing Resistors and LEDs
- Calculating Forward Voltage
- Activities
  - Activity #1: Build a Circuit to Illuminate an LED
  - Activity #2: Build a Series Circuit

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Series vs. Parallel Circuits and Ohm's Law

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  - Resistor Use in Parallel Circuits
  - Understanding Voltage, Resistance, and Current in Serial vs. Parallel Circuits
- Ohm's Law
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  - Size and Type of Jumper Wire
  - Spacing Components to Avoid Short Circuits
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Introduction to Components: Switches

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