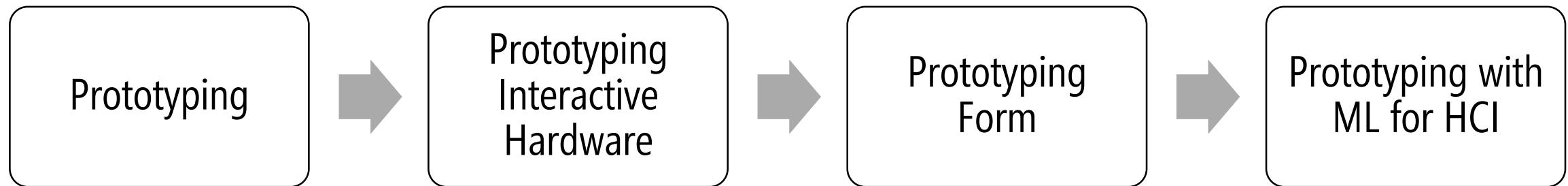


PHYSICAL COMPUTING 1: CIRCUITS

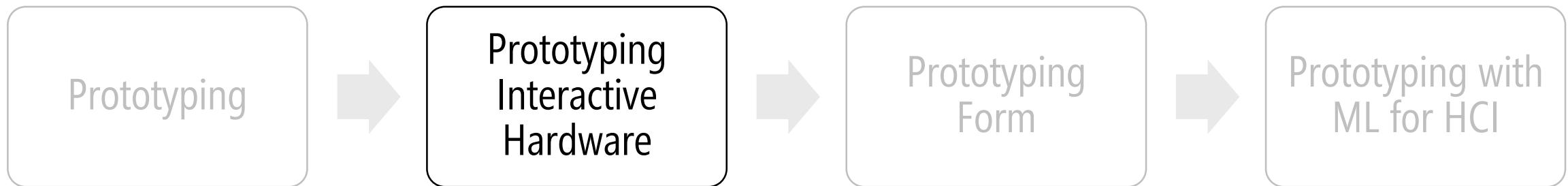
CSE 599 Prototyping Interactive Systems | Lecture 2 | Oct 1

Jon Froehlich • Liang He (TA)

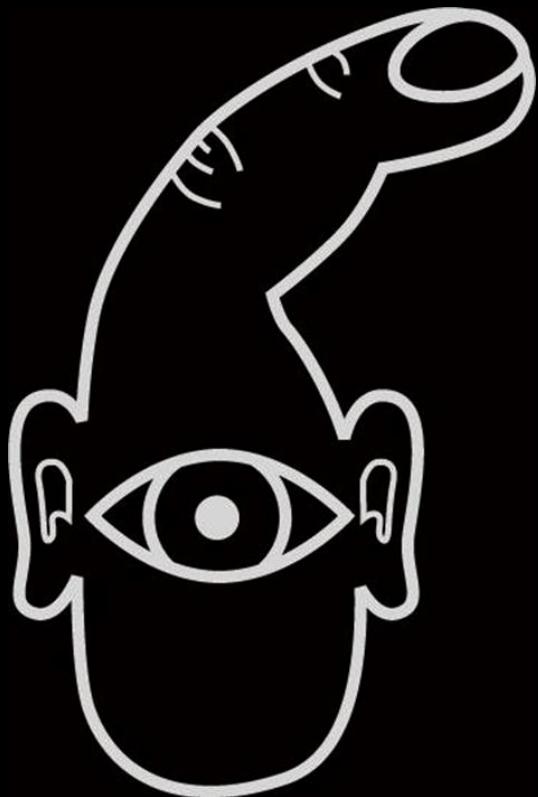
COURSE CURRICULUM



COURSE CURRICULUM



How the computer has traditionally seen us...



One of the most sweeping — and unintended — transformations that the **desktop computing paradigm** has brought about is the extent to which the **physical performance of work has homogenized**. For certain activities, such as writing this paper, the keyboard interaction paradigm appropriately leverages our bimanual dexterity. But, with a keyboard and mouse interface, **the use of our bodies** for writing a paper is the same as for editing photographs. And playing music. And communicating with friends and family. And anything else that one might want computation for.

Scott Klemmer, Bjoern Hartmann, Leila Takayama

From: *How Bodies Matter: Five Themes for Interaction Design*

DIS, 2006

The image shows the first page of a research paper. At the top right, it says "How Bodies Matter: Five Themes for Interaction Design". Below that is the author information: "Scott R. Klemmer, Bjoern Hartmann, Stanford University CHI Group, Computer Science Department, Stanford, CA 94304-2205, USA". To the right of the authors is a small portrait photo. The main title "How Bodies Matter" is in large, bold, black font. Below the title, the subtitle "Five Themes for Interaction Design" is in a smaller, regular black font. Underneath that, the acronym "DIS" is in a bold black font. The rest of the page contains dense, small black text, likely the abstract and introduction of the paper.

One of the most sweeping — and unintended — transformations that the **desktop computing paradigm** has brought about is the extent to which the **physical performance of work has homogenized**. For certain activities, such as writing this paper, the keyboard interaction paradigm appropriately leverages our bimanual dexterity. But, with a keyboard and mouse interface, **the use of our bodies** for writing a paper is the same as for editing photographs. And playing music. And communicating with friends and family. And anything else that one might want computation for.

Scott Klemmer, Bjoern Hartmann, Leila Takayama

From: *How Bodies Matter: Five Themes for Interaction Design*

DIS, 2006

How Bodies Matter: Five Themes for Interaction Design

Lilia Takayama
Stanford University CHIME Lab
Stanford, CA 94301-2650 USA
<http://chime.stanford.edu>

ABSTRACT
The desktop computing paradigm has a central role in shaping how we approach the world, understanding of the world, and how we interact with the world. This paradigm is based on a physical metaphor: time, psychology, knowledge, and physiology. It is a metaphor that has been used to describe the desktop computing paradigm since its inception. In this paper, we argue that the desktop computing paradigm is no longer appropriate for the needs of modern users. We propose five new themes for interaction design that are specifically designed to address the needs of modern users. These themes are: 1) the body as a tool for creating user interfaces; 2) the body as a tool for interacting with the environment; 3) the body as a tool for interacting with other people; 4) the body as a tool for interacting with the world; and 5) the body as a tool for interacting with the self.

Author Keywords
Interaction design, affordances, embodiment, perception, cognition, action, time, psychology, knowledge, physiology.

ACM Classification Keywords
H.5.1. User/Machine Systems: Interaction design
H.5.2. Information interfaces and presentation: User interface—theory and methods

INTRODUCTION
The desktop computing paradigm is one of the central themes of computer science. It is a metaphor that has been used to describe the desktop computing paradigm since its inception. In this paper, we argue that the desktop computing paradigm is no longer appropriate for the needs of modern users. We propose five new themes for interaction design that are specifically designed to address the needs of modern users. These themes are: 1) the body as a tool for creating user interfaces; 2) the body as a tool for interacting with the environment; 3) the body as a tool for interacting with other people; 4) the body as a tool for interacting with the world; and 5) the body as a tool for interacting with the self.

ACKNOWLEDGMENTS
This research was funded by grants from the National Science Foundation, the National Institutes of Health, and the National Institute of Standards and Technology. We would like to thank the anonymous reviewers for their valuable feedback. We also would like to thank the members of the CHIME lab for their support and encouragement.

REFERENCES
The references in this paper are as follows:
[1] Scott R. Klemmer, Bjoern Hartmann, and Leila Takayama. 2006. How Bodies Matter: Five Themes for Interaction Design. In Proceedings of the Conference on Designing Interactive Systems (DIS 2006), San Jose, CA, USA, June 26-29, 2006, Lilia Takayama, Ed., pp. 1-10. ACM, New York, NY, USA, ISBN 1-59593-331-9, DOI 10.1145/1138577.1138587.
[2] George Lakoff and Mark Johnson. 1980. Metaphors We Live By. University of Chicago Press, Chicago, IL, USA.

THROUGH DISCUSSION
The discussion phase of the conference aims to facilitate open exchange of ideas and perspectives. We invite participants to share their thoughts and experiences related to the theme of the conference. The discussion phase will allow for sharing, discussing, and reflecting on the various themes presented in the conference. The discussion phase will also provide an opportunity for participants to ask questions and receive answers from the speakers and other participants. The discussion phase will also provide an opportunity for participants to share their own experiences and perspectives related to the theme of the conference.

DISCUSSION
The discussion phase of the conference aims to facilitate open exchange of ideas and perspectives. We invite participants to share their thoughts and experiences related to the theme of the conference. The discussion phase will allow for sharing, discussing, and reflecting on the various themes presented in the conference. The discussion phase will also provide an opportunity for participants to ask questions and receive answers from the speakers and other participants. The discussion phase will also provide an opportunity for participants to share their own experiences and perspectives related to the theme of the conference.

And, of course, this is now **changing**... which is very exciting!





amazon







LEARNING OBJECTIVES

In this module, we are going to learn **how to prototype** these rich, **interactive experiences** that **embed computation** in **artifacts**.

We will cover theories, techniques, and tools!



RESOURCES

GREAT RESOURCES FOR THIS MODULE

[Physical Computing @ ITP/NYU](#)

Online video series

Jeff Feddersen & Tom Igoe, ITP at NYU

Over 100 extremely high-quality teaching videos about circuits, & Arduino

[Adafruit's Learn Arduino Series](#)

Online tutorial series

Simon Monk, Author

A nice intro series to key circuit and Arduino concepts.

[Sparkfun's Tutorials](#)

Online tutorial series

A nice intro series to key circuit and Arduino concepts.

[Exploring Arduino](#)

Book

Jeremy Blum, Author

There are lots of Arduino books and this is one of the best imo

[Make: Electronics](#)

Book

Charles Platt, Author

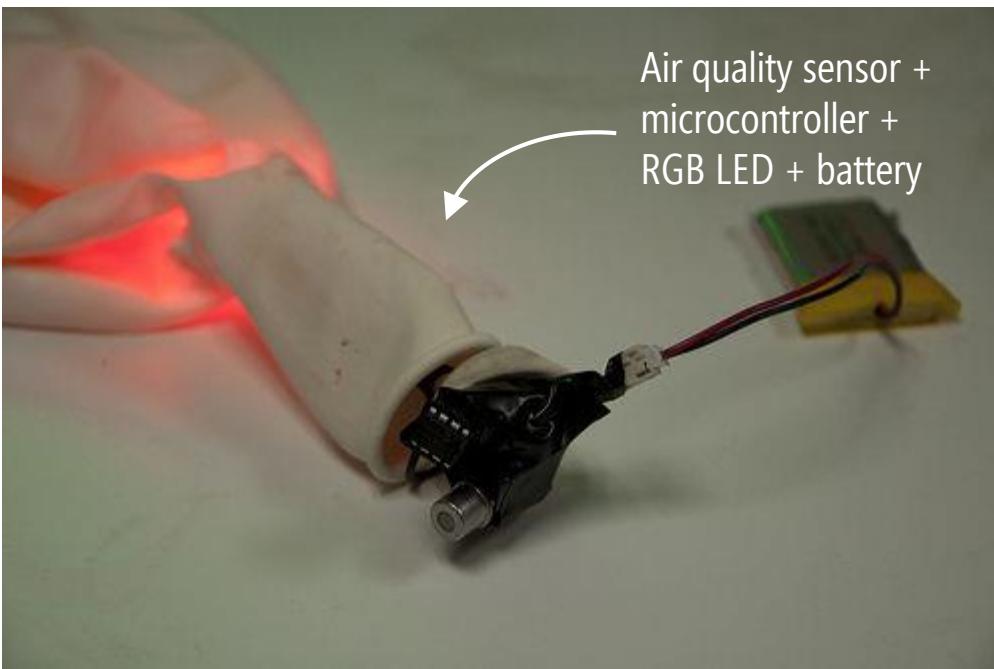
There are lots of introductory books to electronics, this is one of the best

Here are some **example projects** that—by the end of the quarter—you will have the skills to build yourself.

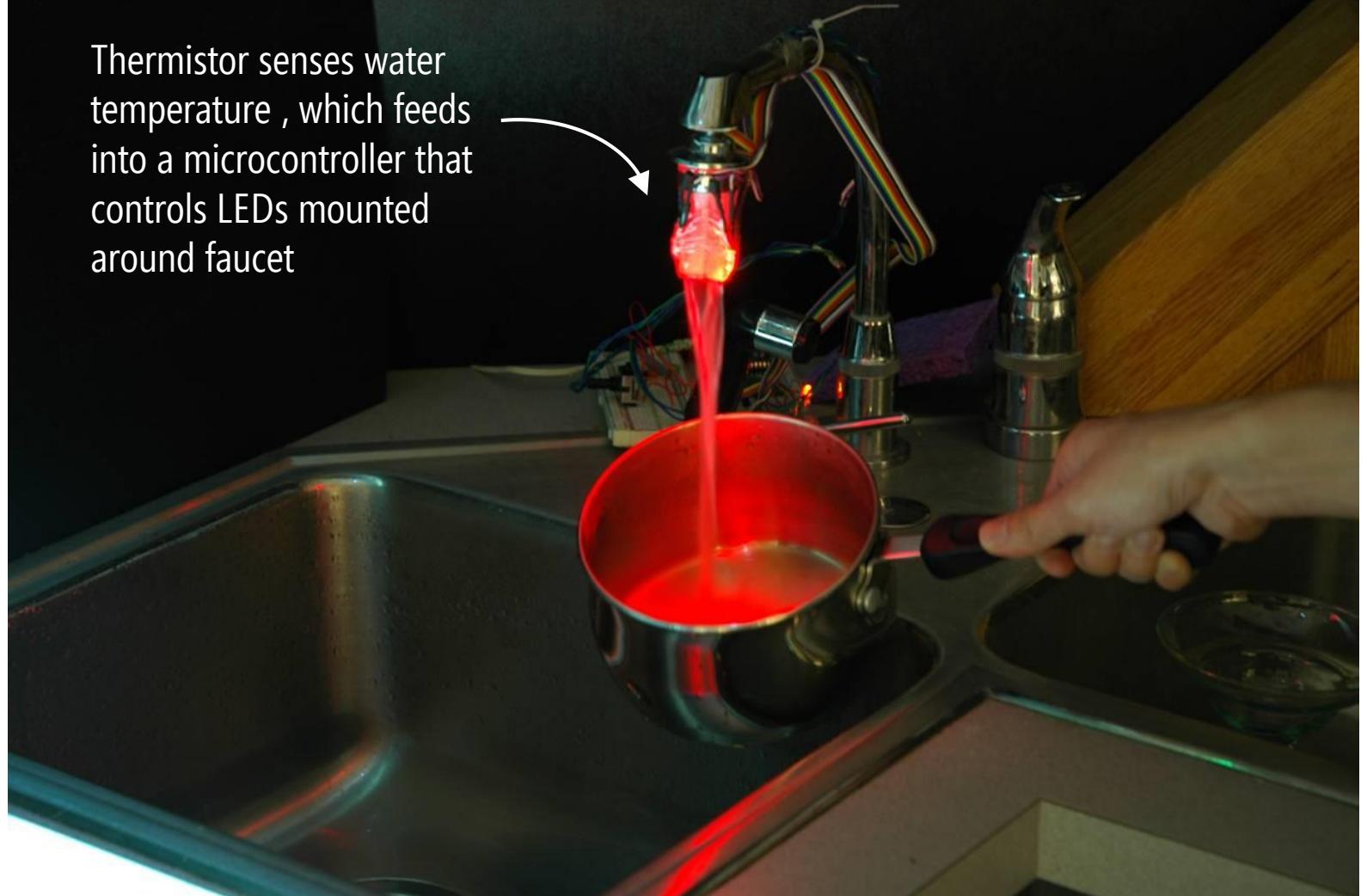
PHYSICAL COMPUTING PROTOTYPE EXAMPLES
AMBIENT AIR POLLUTION SENSORS



Kuznetsov *et al.*, Red Balloon, Green Balloon, Sensors in the Sky, *UbiComp2011*

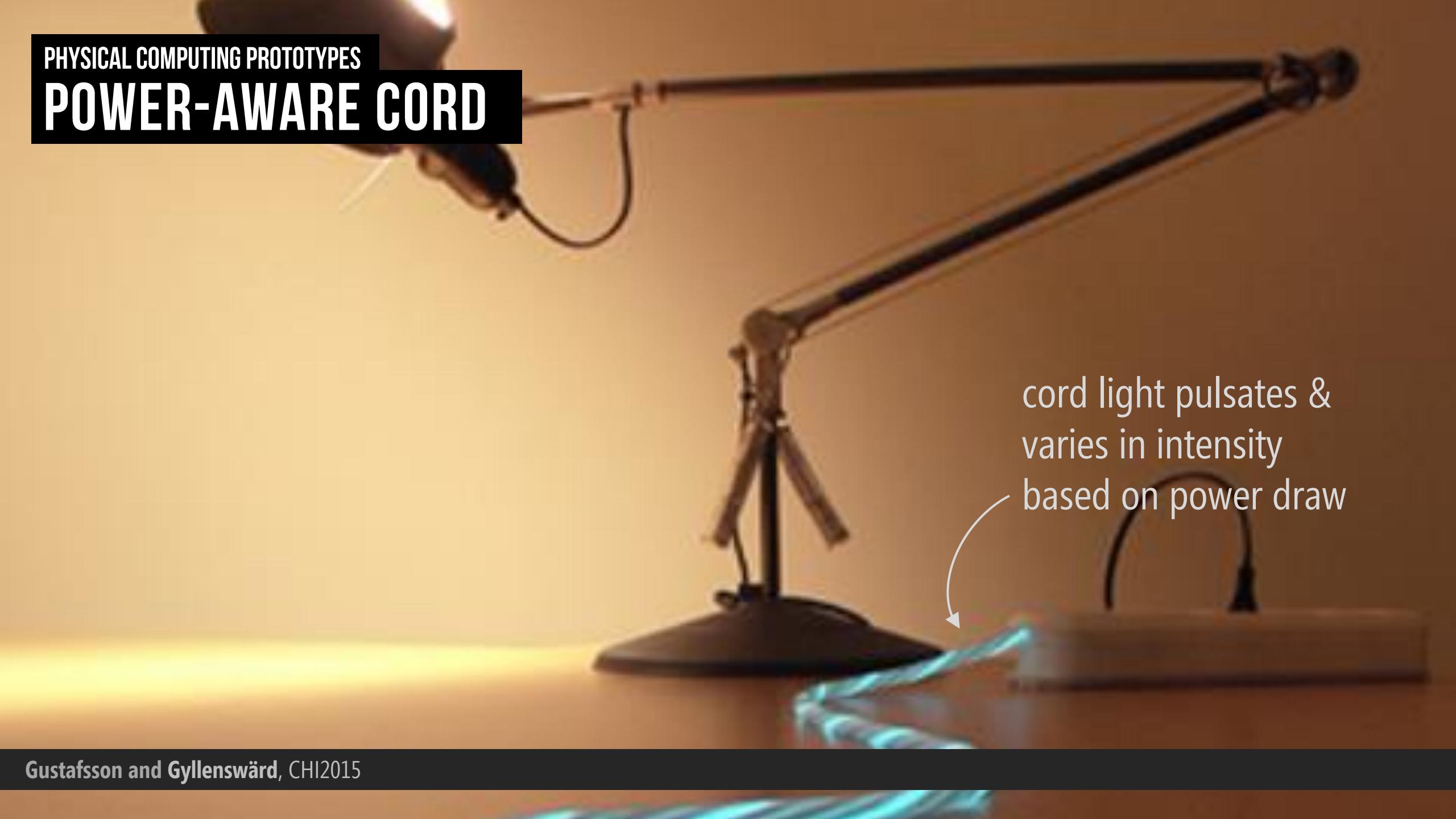


PHYSICAL COMPUTING PROTOTYPES HEATSINK



PHYSICAL COMPUTING PROTOTYPES

POWER-AWARE CORD

A photograph of a power cord prototype. The cord is black with a glowing blue and green pattern along its length. It is connected to a vintage-style desk lamp with a flexible gooseneck arm. The lamp is mounted on a dark base. A curved white arrow points from the text to the glowing section of the cord.

cord light pulsates &
varies in intensity
based on power draw

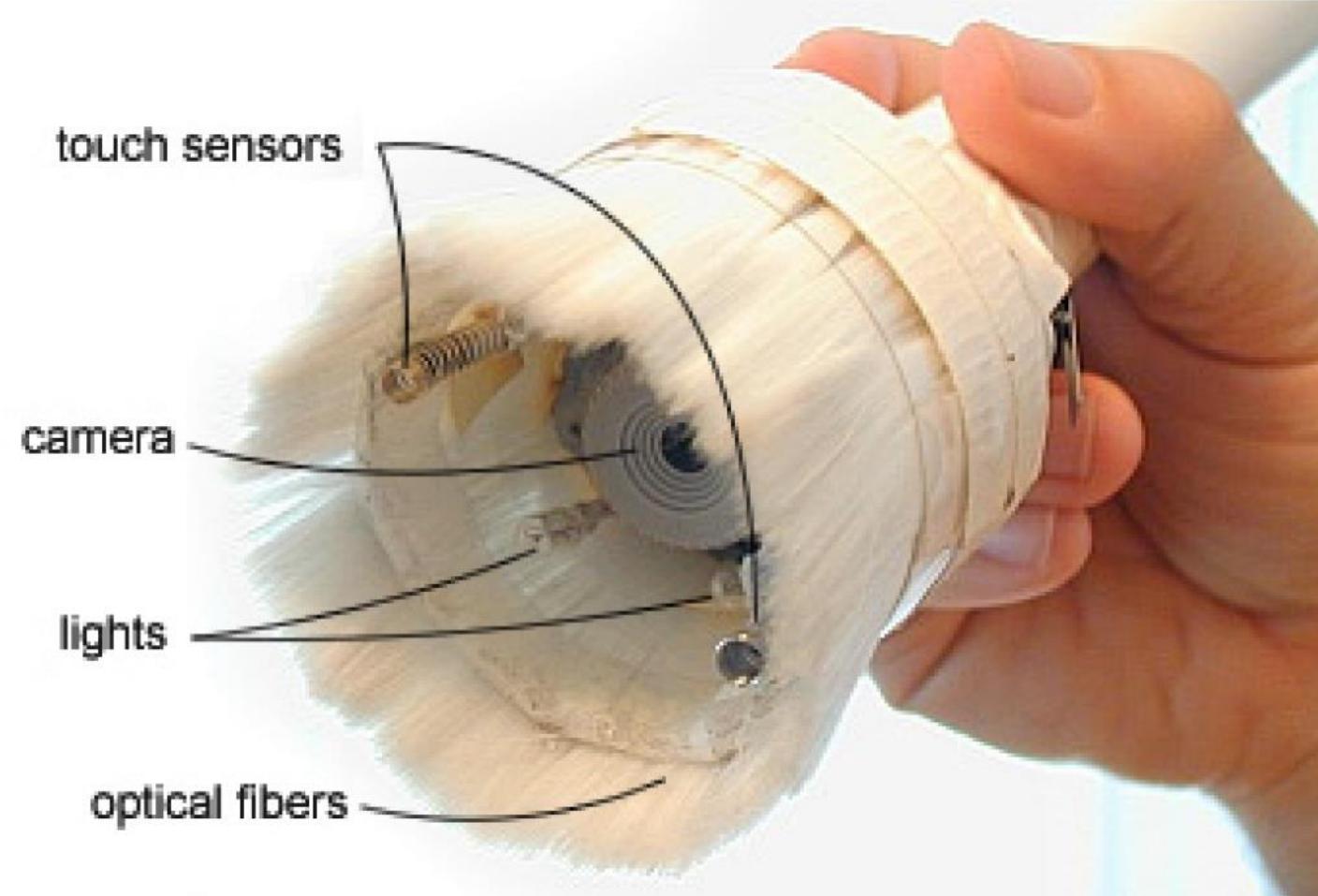
PHYSICAL COMPUTING PROTOTYPES

I/O BRUSH: DRAWING WITH EVERYDAY OBJECTS





I/O BRUSH: DRAWING WITH EVERYDAY OBJECTS



PHYSICAL COMPUTING PROTOTYPES

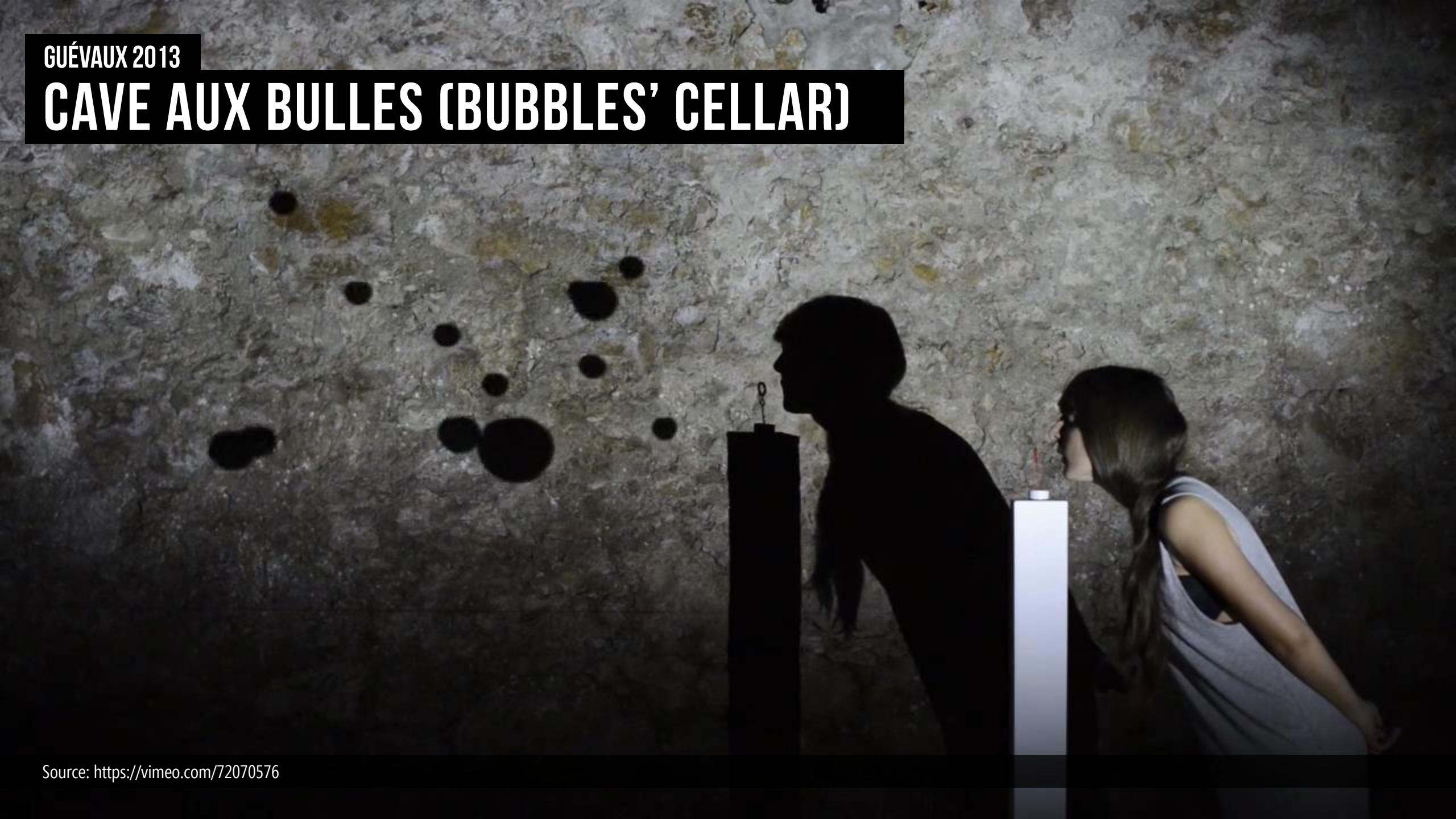
CUSTOM INPUT CONTROLLER: INTERACTIVE BEACH BALL





GUÉVAUX 2013

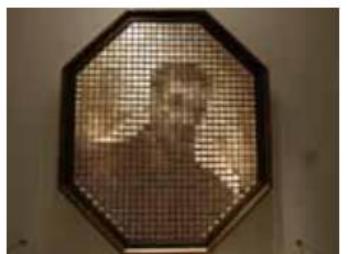
CAVE AUX BULLES (BUBBLES' CELLAR)





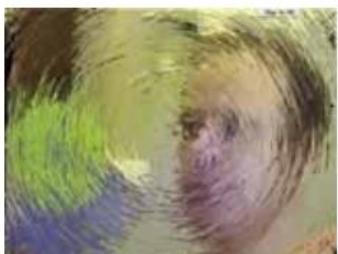
DANIEL ROZIN INTERACTIVE ART | Works| About | Contact

Mechanical Mirrors



Wooden Mirror

Software Mirrors



Mirror Number 2

Video Painting



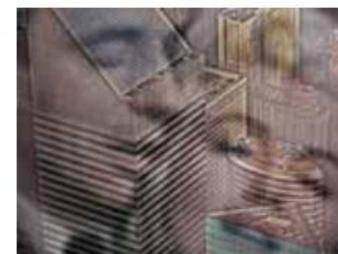
Easel

Glass Sculptures



Broken-Mirror

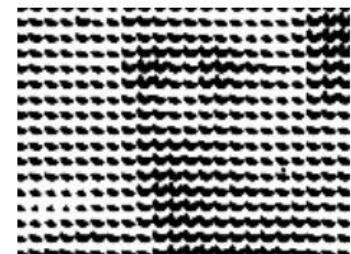
Proxxi Prints



Yves-Merilyn/Skyline



Trash Mirror



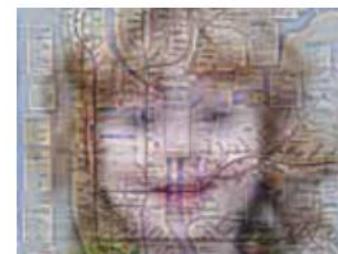
mirror5.html



Paint-Cam



Self Centered Mirror



Yonatan/Subway Map



Shiny Balls Mirror



Mirror Number 6



Origin Of Species



Yulie



Sharon / West Bank

PHYSICAL COMPUTING PROTOTYPES

INTERACTIVE WOODEN MIRROR (1990)



Designer: Daniel Rozin, <https://youtu.be/BZysu9QcceM>



Course Project

Published

Edit

⋮

Related

Speed

Overview

For your course projects, you will design and build a novel **physical interactive computing experience** using signal processing + machine learning, fabrication, and Arduino. My hope is that you can use the course project to work on your research (and to simply scratch a long-standing itch that you've had).

For the signal processing + machine learning portion, you can (and should) use off-the-shelf libraries or cloud APIs. For example, if you're working with sound, you could use the [Minim](#) ↗ library (for Processing) or [Librosa](#) ↗ (for Python), for computer vision, you could use [Google's Vision AI API](#) ↗ or [Microsoft's Cognitive Services API](#) ↗. Here are some other examples:

- The major cloud companies each provide their own ML services, including [Microsoft](#) ↗, [Amazon](#) ↗, and [Google](#) ↗
- [Google AI, On-Device, Real-Time Hand Tracking with MediaPipe](#) ↗
- [Real-time Human Pose Estimation in the Browser with TensorFlow.js](#) ↗
- [RunwayML, Machine Learning for Creators](#) ↗

You are welcome to purchase and/or use any additional devices/components to support your idea (e.g., utilize your own smartphone or purchase an RGB LED matrix). I also have some available components like a few WiFi-enabled Arduinos, ~20 Microsoft Kinects, ~3 Microsoft HoloLenses, ~10 Android phones, etc.

This prompt is intentionally open-ended to allow you to focus on your own interests, aspirational growth areas, and to enable you to work on something related to your research.

Arduinos, ~20 Microsoft Kinects, ~5 Microsoft HoloLenses, ~10 Android phones, etc.

This prompt is intentionally open-ended to allow you to focus on your own interests, aspirational growth areas, and to enable you to work on something related to your research.

Timeline

- [Project Pitches](#) due Tues, Oct 8, 2019
- Project Proposal due Tues, Oct 22, 2019
- Project Check-In 1 due Tues, Nov 26, 2019
- Project Check-In 2 due Thurs, Dec 5, 2019
- Final Projects due Wed, Dec 11th with live demo at showcase event

Deliverables

- A [Hackster.io](#), [Instructables](#), [Arduino Project Hub](#), or other public post (email us for permission) describing your design and how to build it
- A link to your **github repository** with source code, design files, etc.
- A **video overview of your design** posted to YouTube, Vimeo, or some other cloud service (we will not accept uploaded mp4s directly to Canvas). The video can be unlisted or public (your choice).
- A **live, interactive demo** on Dec 11, 2019 at our showcase event. You can also show your video in the background. The showcase is from 4:30-6:20PM in Sieg 322 (our studio!). (Note: we may change this depending on how many students sign up for the course).

Project Pitches

Published

Edit

⋮

Please read the [Final Project assignment](#) first then loop back to read the project pitch assignment.

Project Pitches

For your pitches, you must submit:

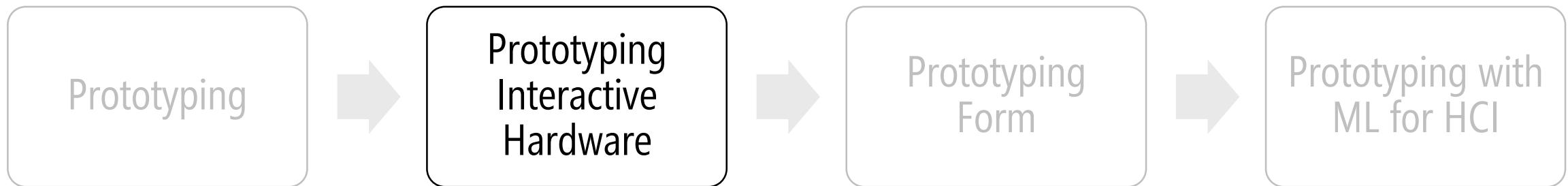
- A **brainstorm sheet or sheets** (can be scanned from paper or born digitally) enumerating at least 10 different project ideas (at least 1-3 sentences per idea of explanation). Focus on a *breadth of ideas*.
- You will also **downselect** to your top **two favorite ideas**. For those two ideas, we would like you to write 1-2 paragraphs explaining the idea (with sketches, if you'd like), why it is interesting, how it fulfills the design prompt, and feasibility for completion (key challenges, timeline, etc.). Unlike the brainstorm sheet, we would like these paragraphs **written digitally**.

The TA and I will review all of the downselected ideas and help you reflect on possible pursuits. We will also spend in-class time to share ideas.

Points 2

Submitting a text entry box or a file upload

COURSE CURRICULUM



TODAY'S LEARNING GOALS

What is a **circuit, voltage, current, and resistance**

What is a **resistor** and how to use it

What is an **LED** and how to use it (e.g., polarity, current limiting resistor)

What is **Ohm's Law** and why is it useful?

Series vs. **parallel** resistive circuit configurations

What is a **breadboard** and how to use it

How to **read a datasheet**

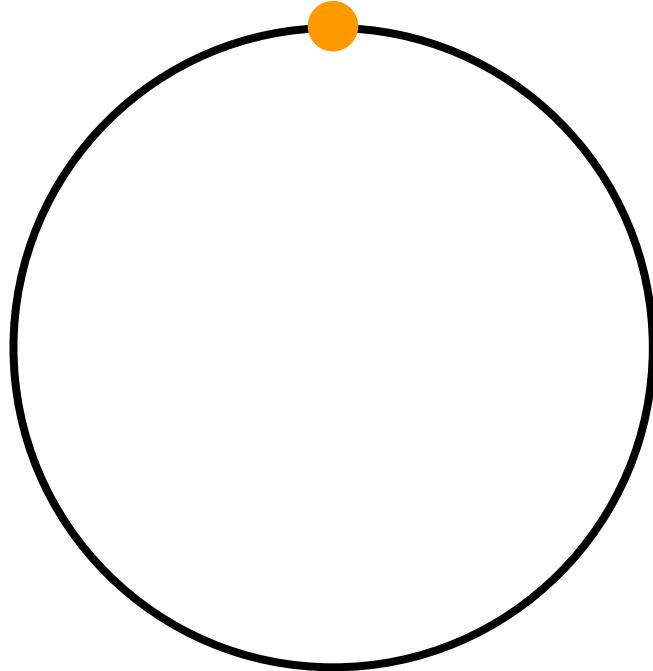


ARE YOU READY?!

CIRCUITS

WHAT IS A CIRCUIT?

WHAT IS A CIRCUIT?



cir·cut [noun]

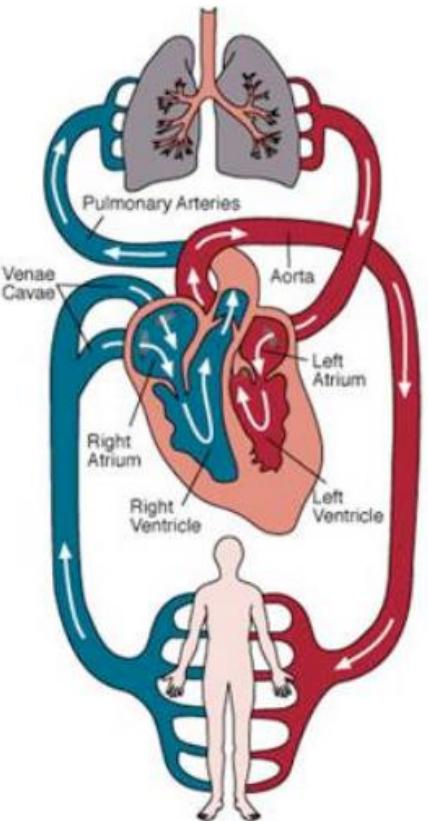
A route that starts and finishes at the same place.

- Oxford Dictionary

CIRCUITS

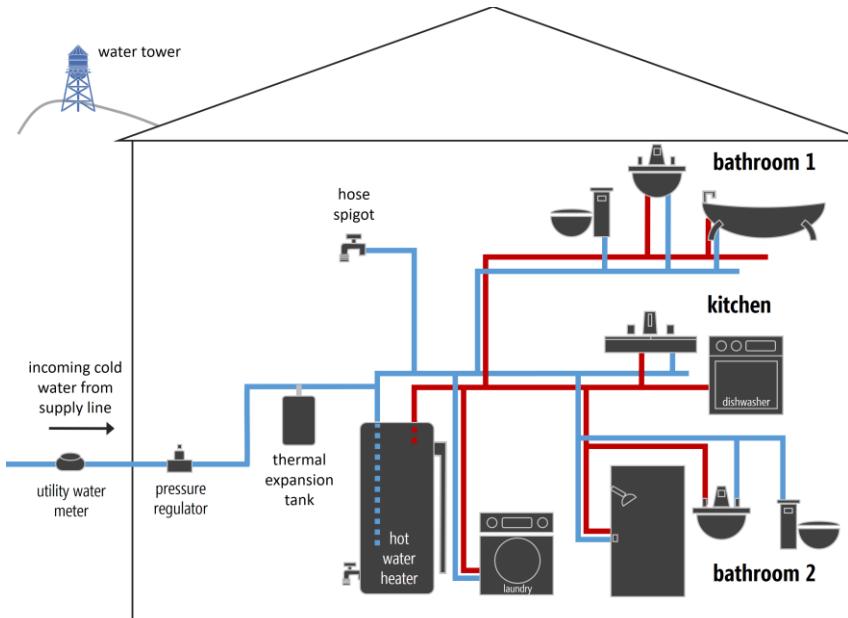
SOME EXAMPLE CIRCUITS

HUMAN CIRCULATORY SYSTEM



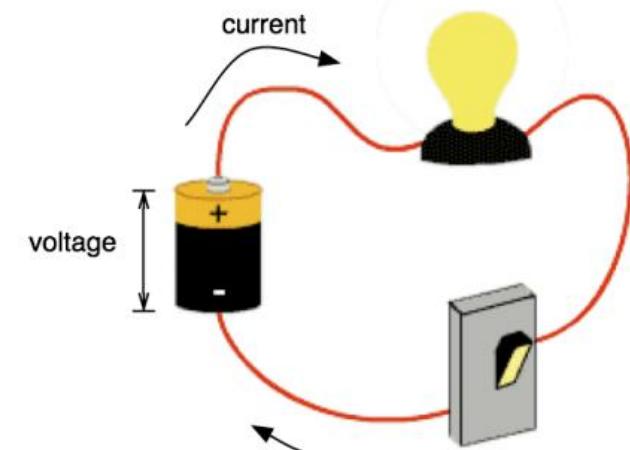
Heart pumps, blood flows

WATER PLUMBING SYSTEM



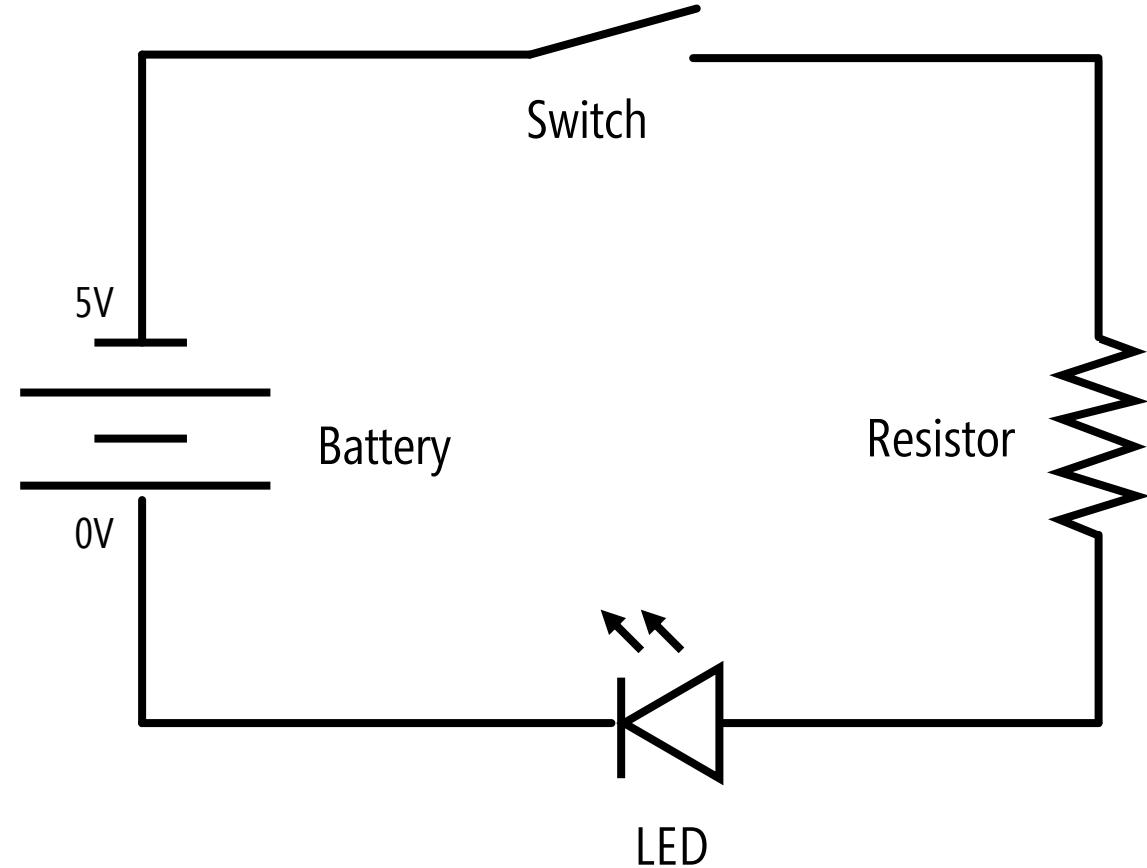
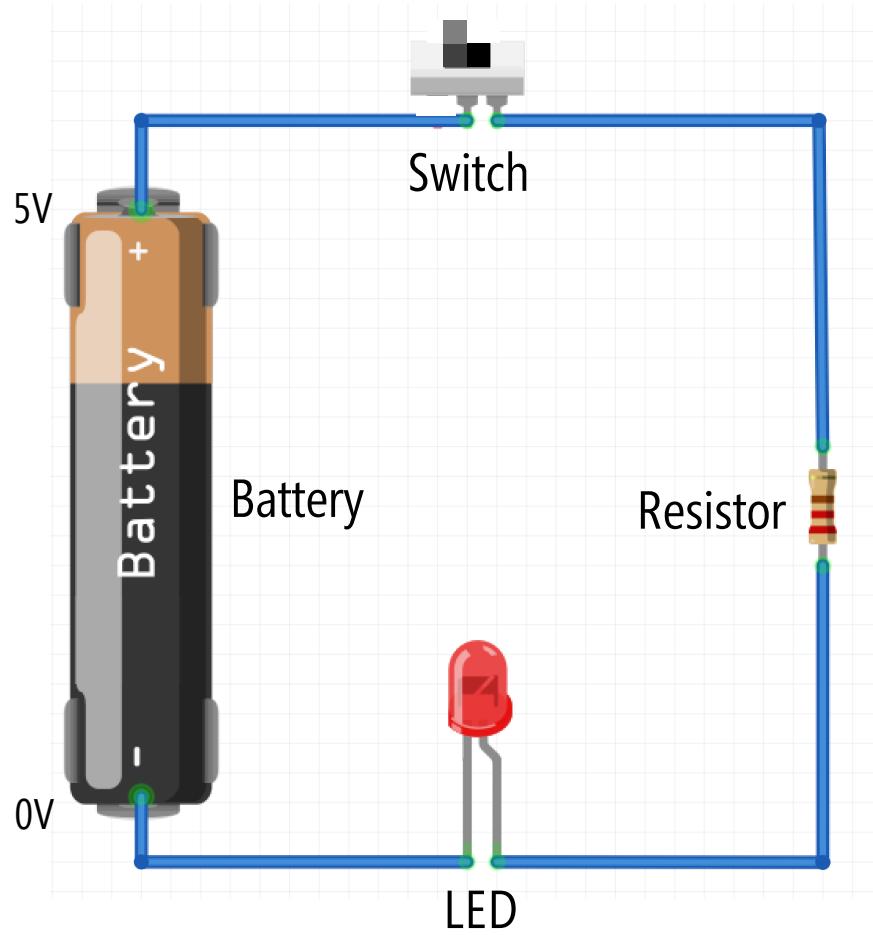
Water pressure pushes, water flows

ELECTRICAL CIRCUITS

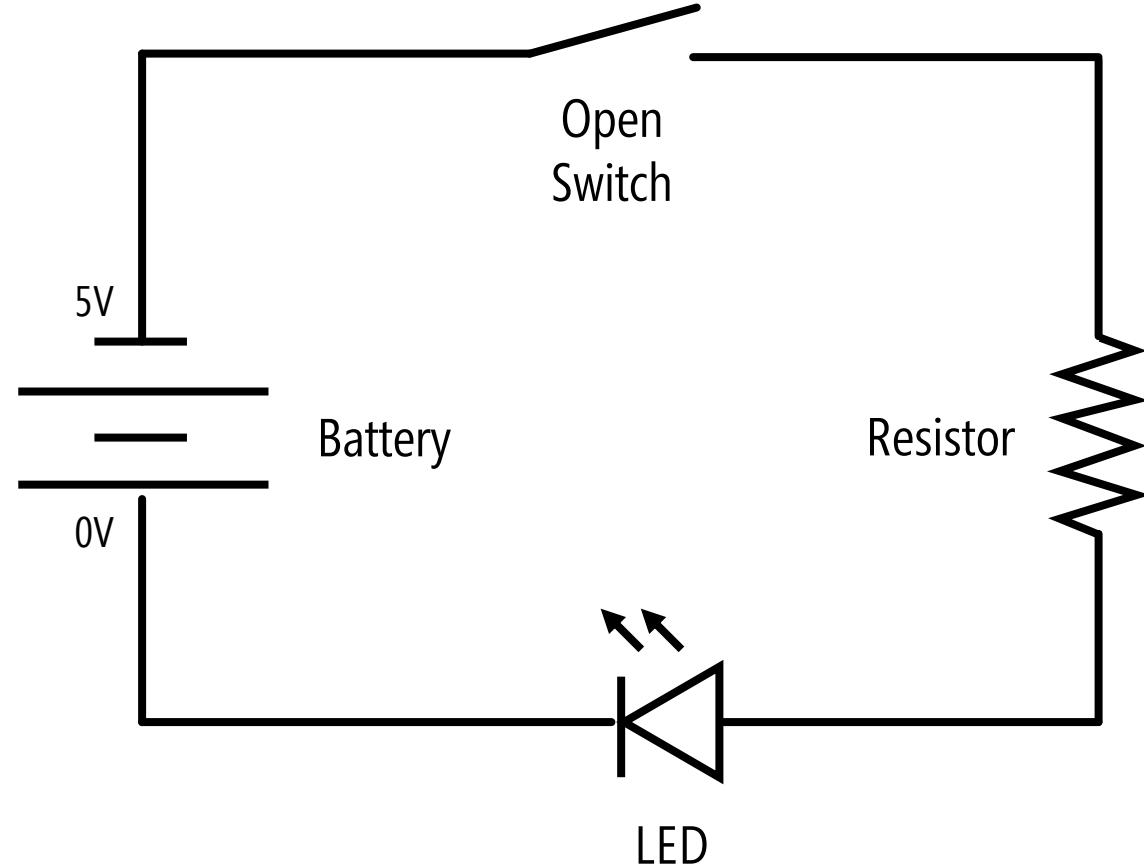
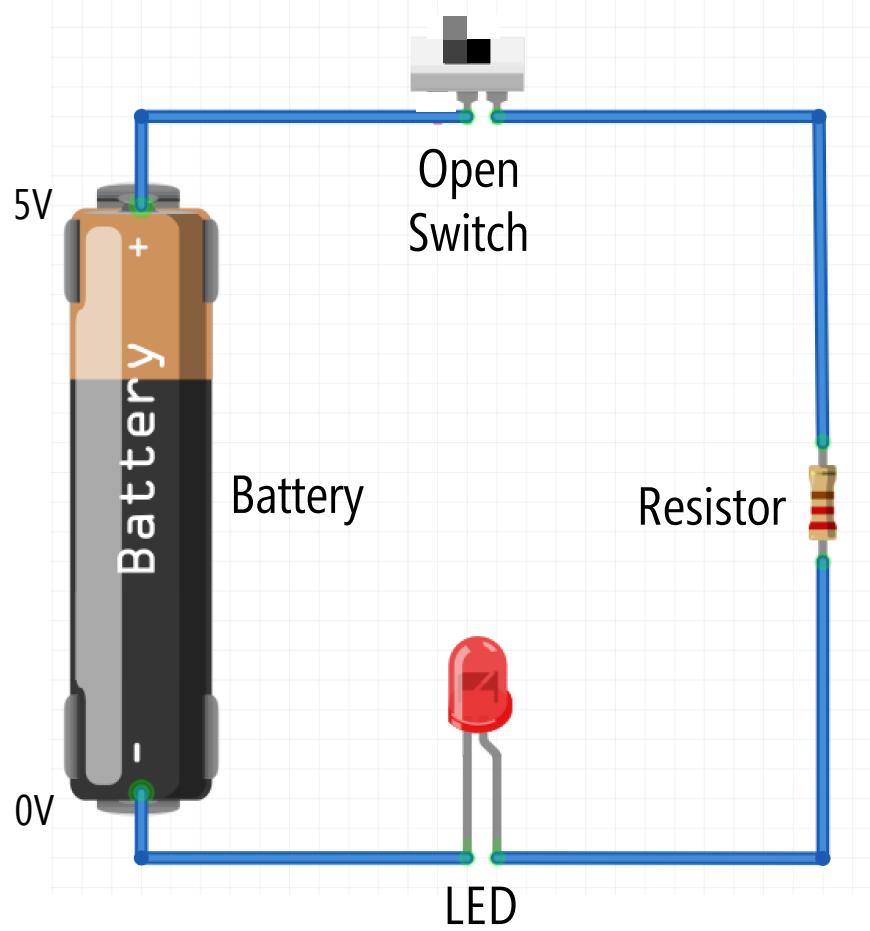


Voltage pushes, current flows

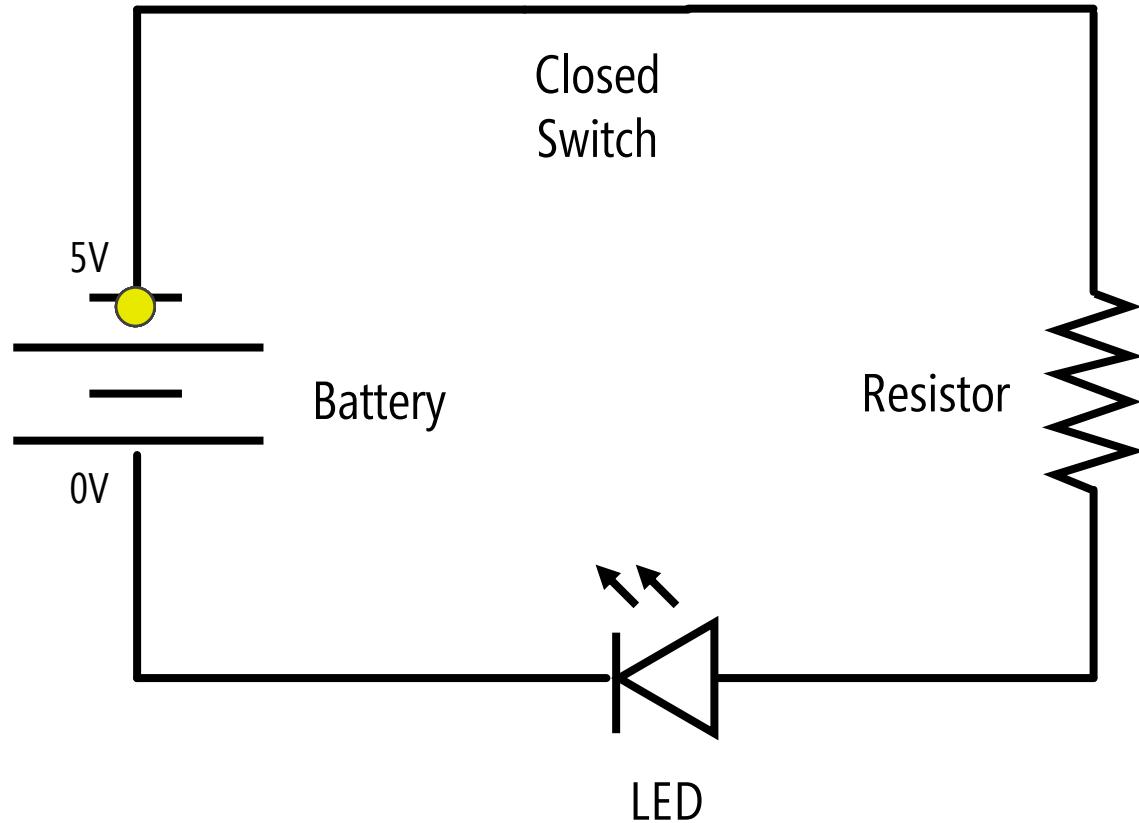
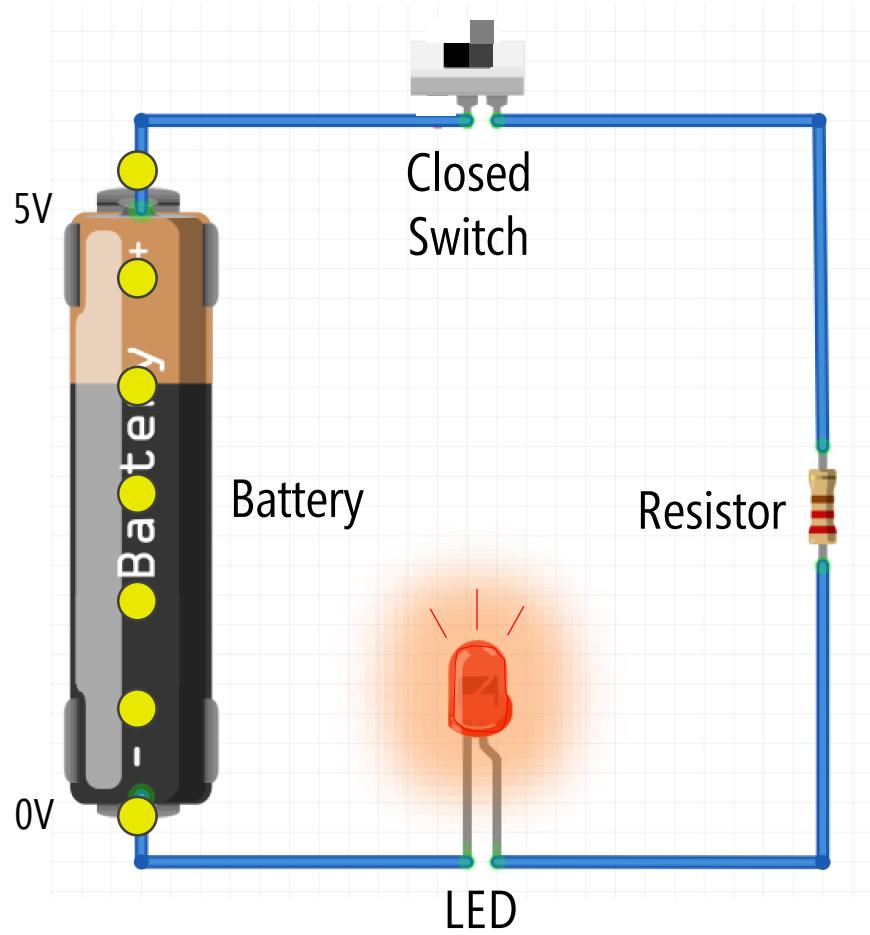
PICTORIAL VS. SCHEMATIC CIRCUIT DIAGRAMS



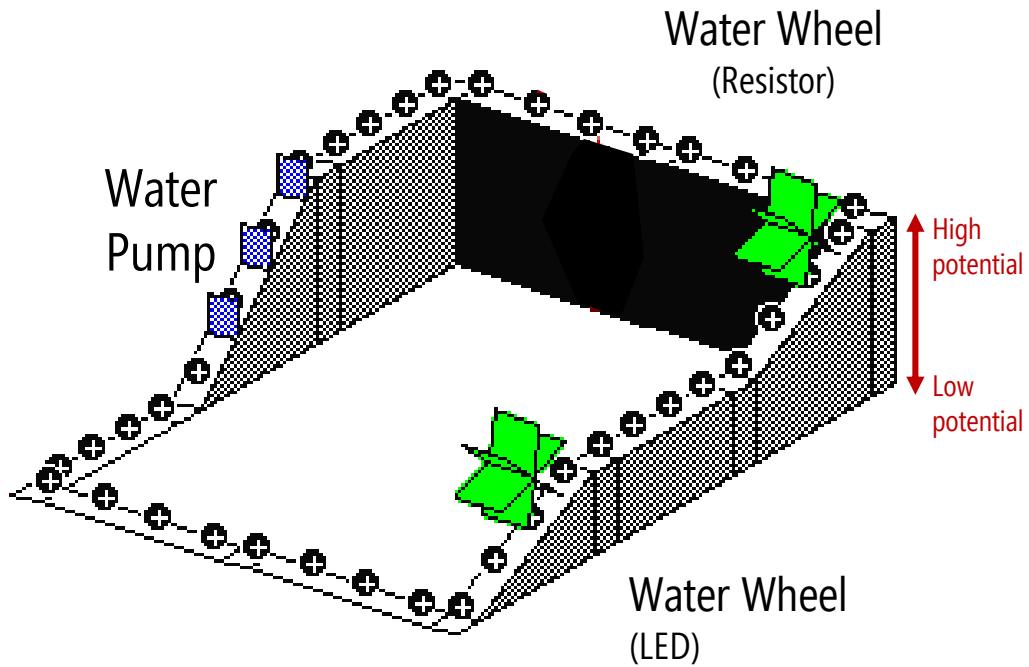
OPEN CIRCUIT: NO CURRENT FLOWING



CLOSED CIRCUIT: CURRENT FLOWING

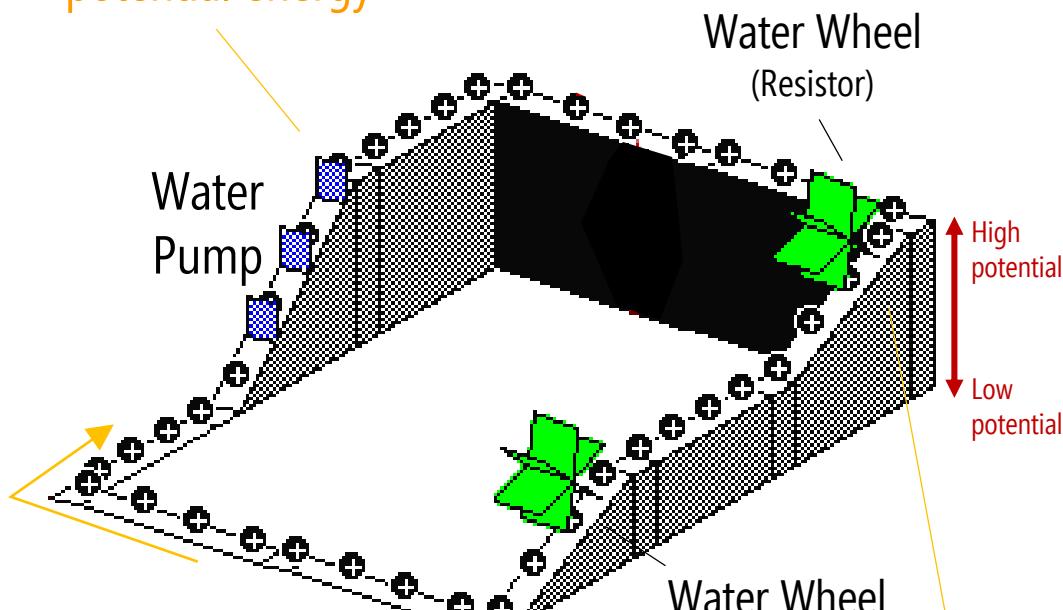


ELECTRIC CIRCUITS: WATER ANALOGY



ELECTRIC CIRCUITS: WATER ANALOGY

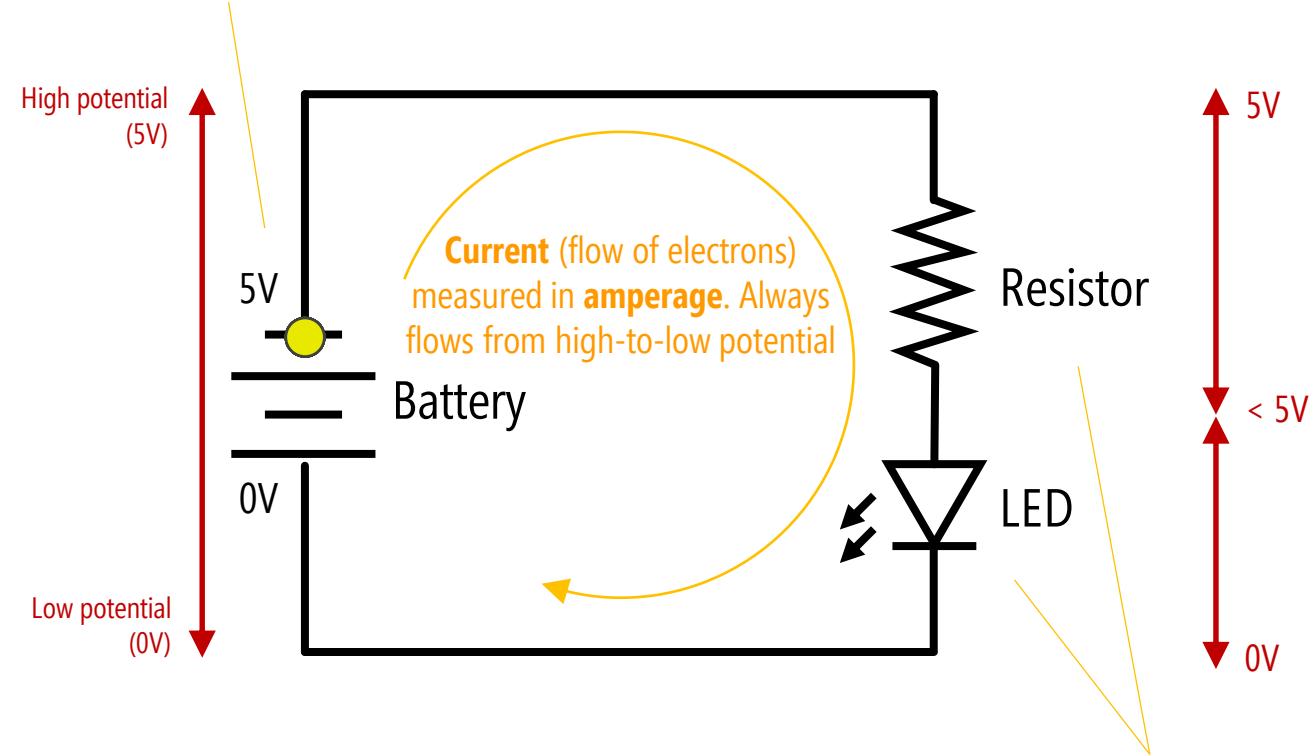
Water pump increases potential energy



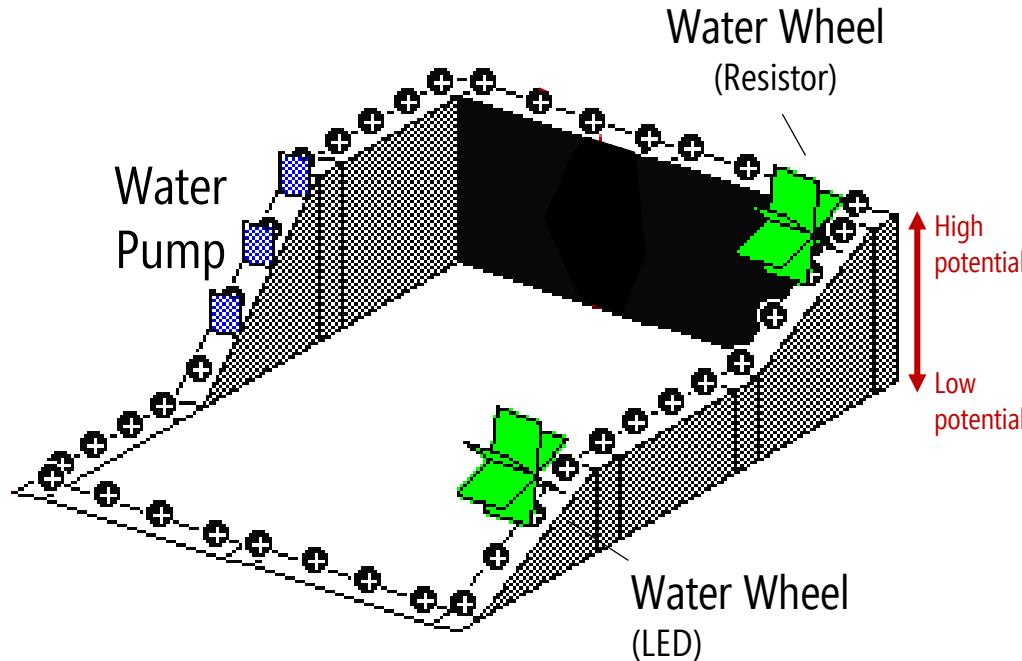
Water flow (e.g., gallons/min). Always flows from high-to-low potential.

Water turning wheel takes work thus reducing force

Battery provides force to move electrons (measured in **voltage**)



Resistor and LED use energy (as heat & light), which reduces **voltage**



water pressure [wä-dər 'pre-SHər] | measured in *pounds per square inch (psi)*

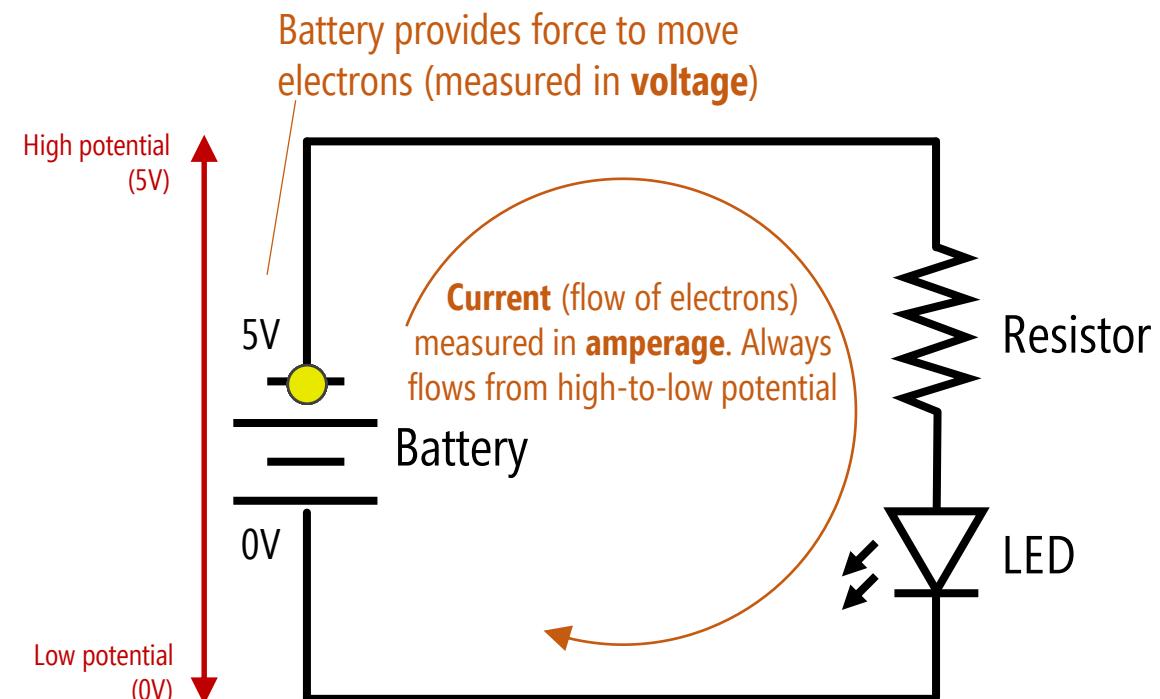
Pressure pushes water molecules from high pressure to low pressure. Gravity (or other external forces) can also move water from high potential to low potential.

flow [flō] | measured in *gallons/second (or liters/second)*

Flow is a measurement of the amount of water through a medium over time. Current always flows from highest potential to lowest.

pipe size [pīp sīz] | measured in *inches or meters*

Water flow directly corresponds to pipe size. The larger the pipe, the more flow.



voltage [vohl-tij] | measured in *joules/coulomb or volts (V)*

Voltage pushes electrons in a circuit using an electromotive force (EMF) from high potential to low potential.

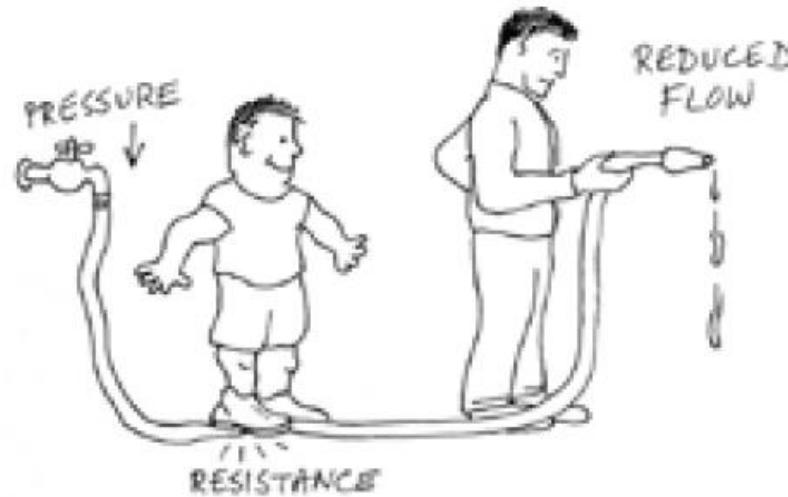
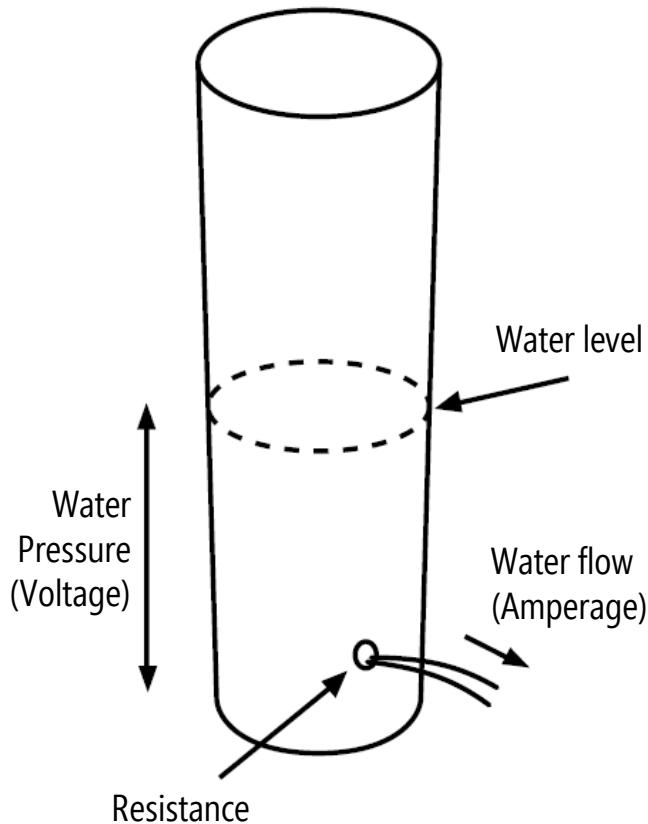
current [kur-uhnt] | measured in *coulombs/sec or amps (I)*

Electric current is the flow of charge through a wire/conductor. Current always flows from highest potential (voltage) to lowest.

resistance [ri-zis-tuhns] | measured in *ohms (Ω)*

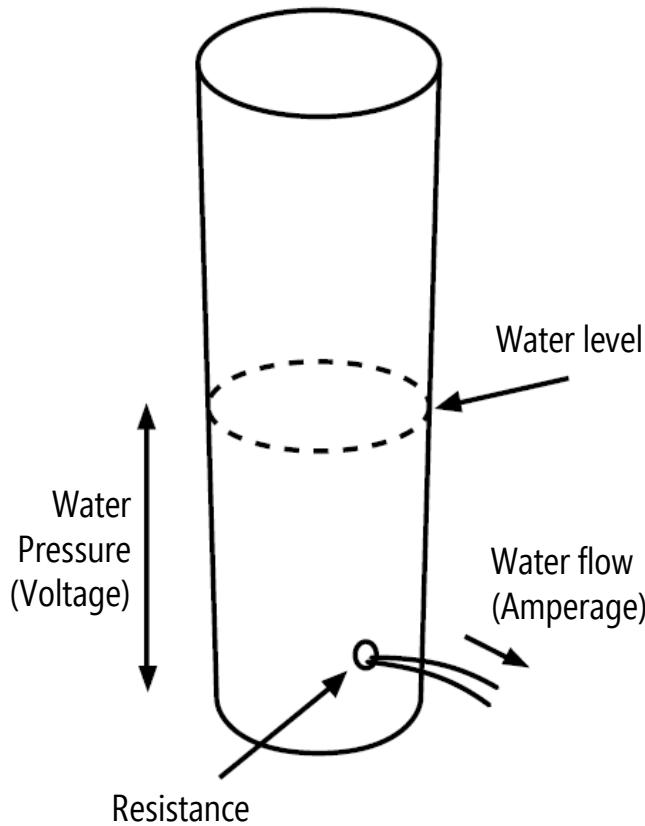
A material's tendency to resist the flow of charge (current). The higher the resistance, the less current.

ELECTRIC CIRCUITS: WATER ANALOGY 2

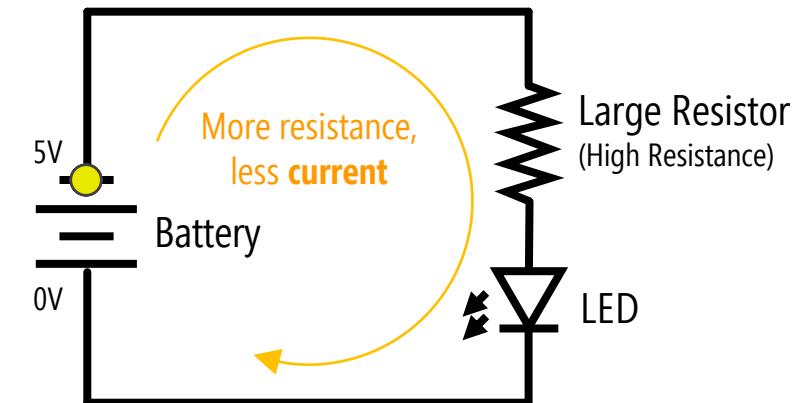
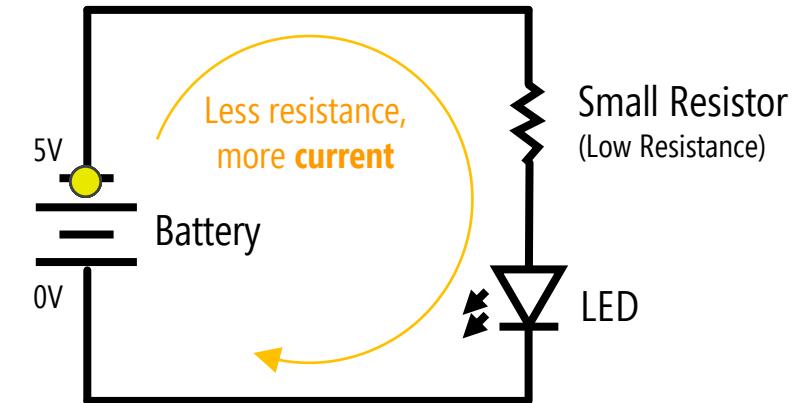


Increase resistance, reduce flow

ELECTRIC CIRCUITS: WATER ANALOGY 2

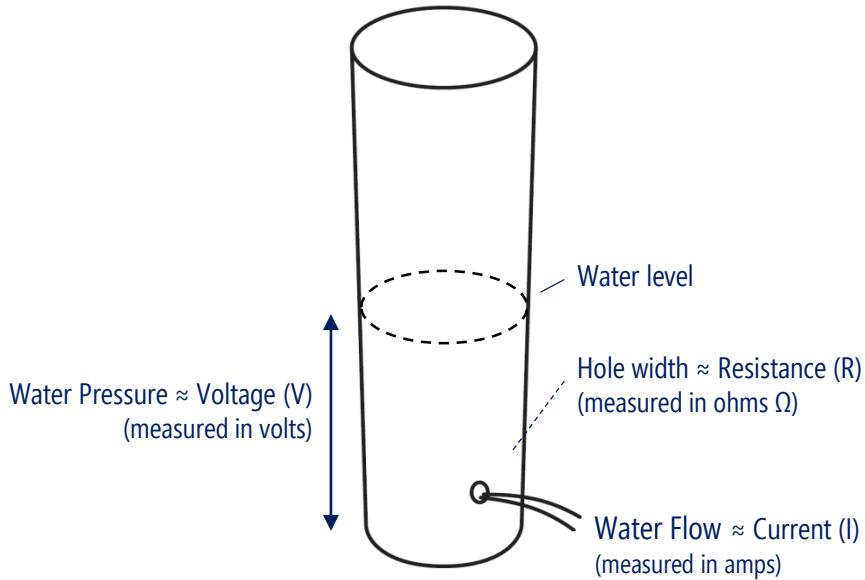


Increase resistance, reduce flow

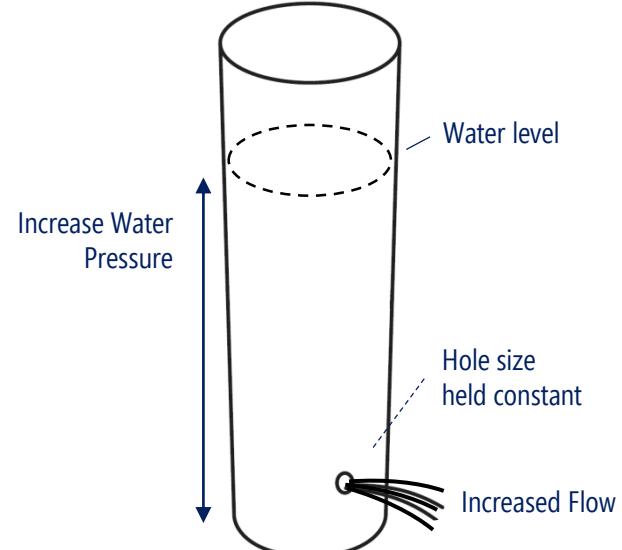


TWO WAYS TO INCREASE CURRENT

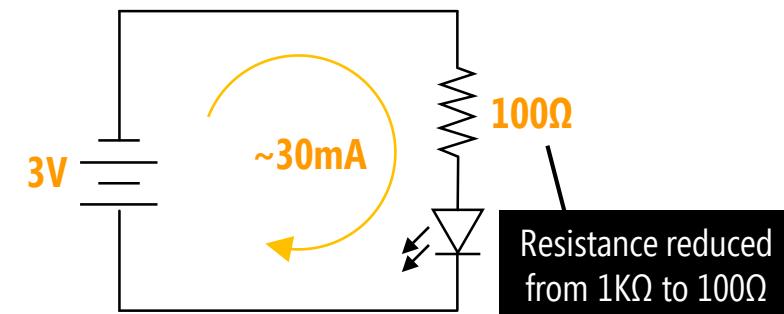
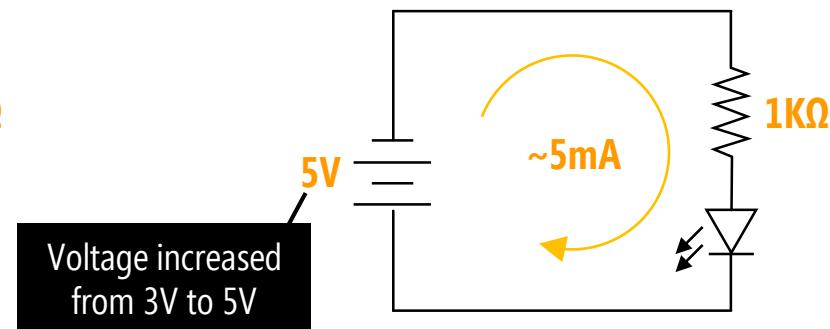
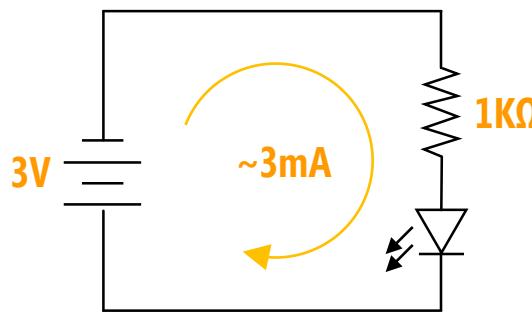
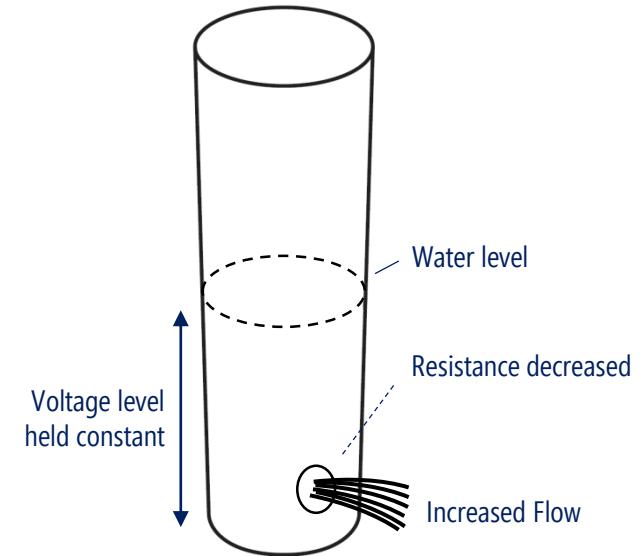
Base Circuit



1. Increase Voltage

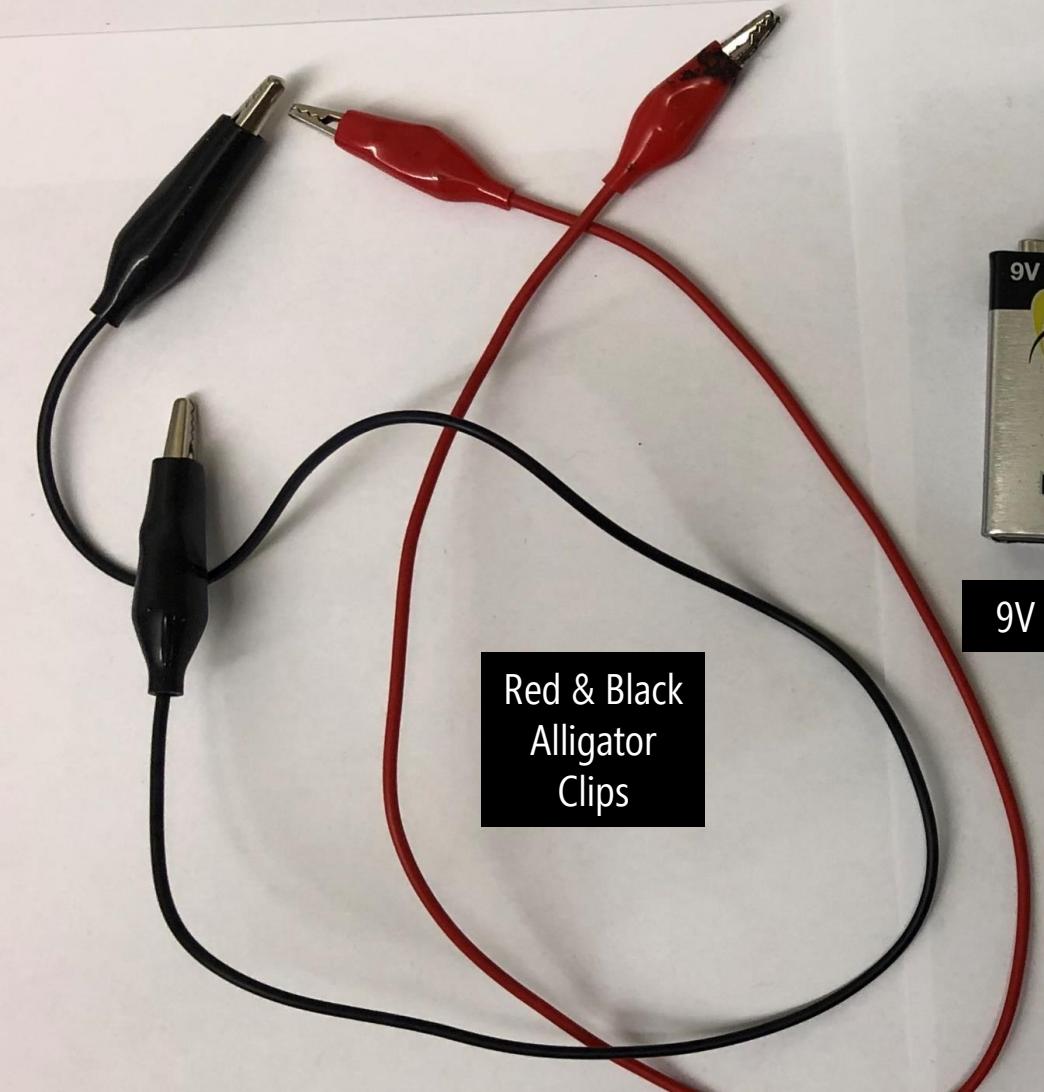


2. Decrease Resistance



ACTIVITY

BUILD YOUR FIRST CIRCUIT: RESISTOR + LED



Red & Black
Alligator
Clips



9V Battery



2.2K Ω Resistor



Red LED

ACTIVITY

BUILD YOUR FIRST CIRCUIT: RESISTOR + LED

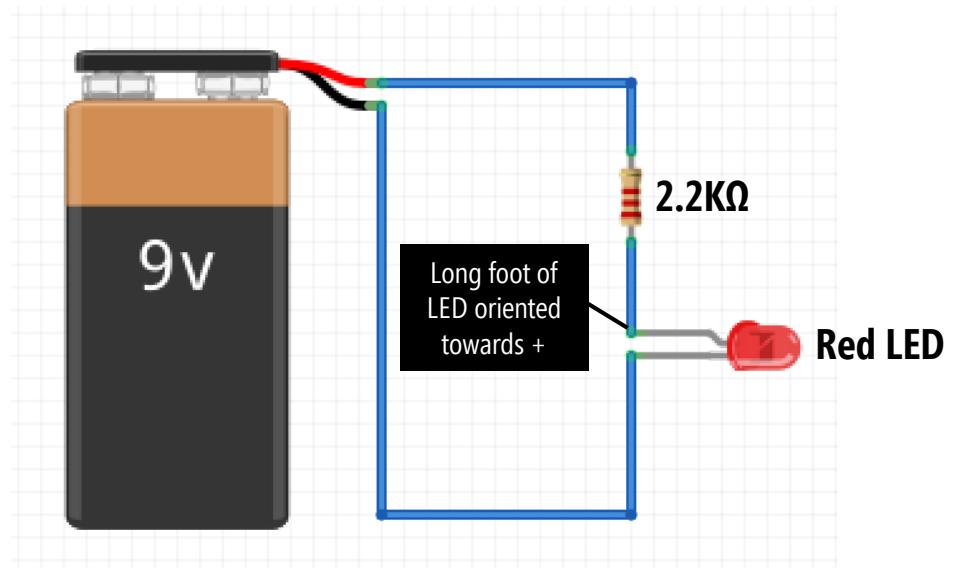
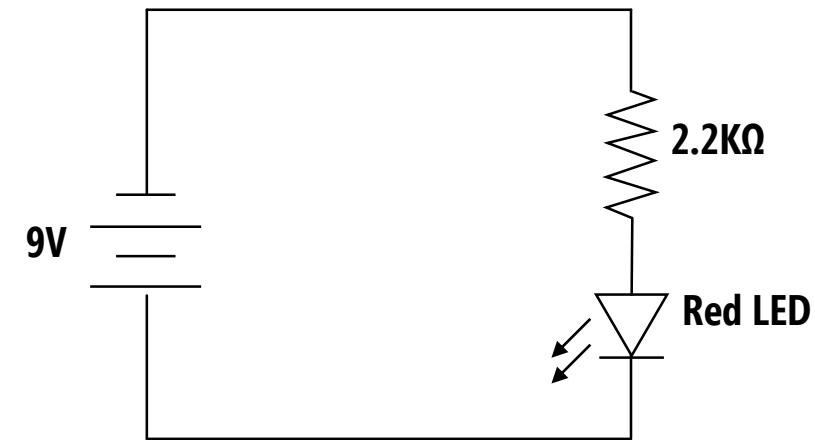


DIAGRAM VIEW



SCHEMATIC VIEW

ACTIVITY

BUILD YOUR FIRST CIRCUIT: RESISTOR + LED

How do I make these diagrams?

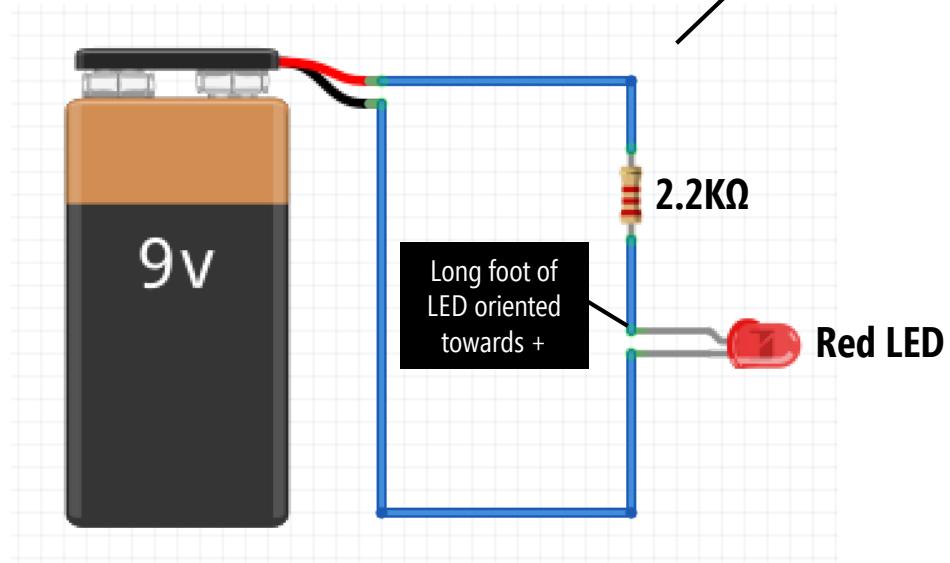
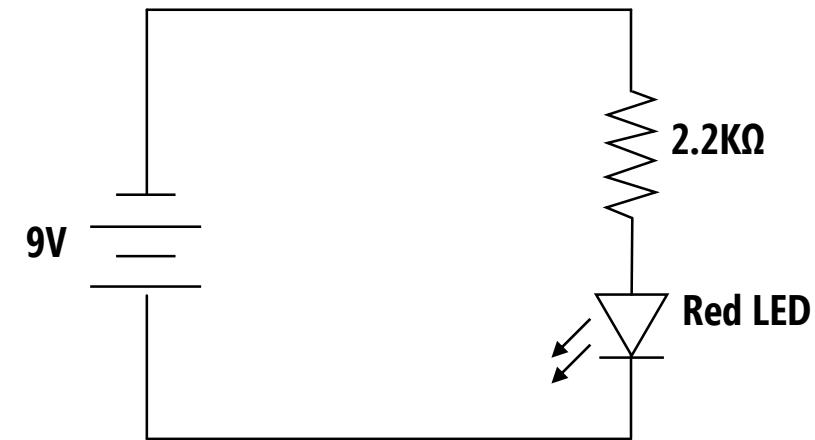


DIAGRAM VIEW



SCHEMATIC VIEW

BUILDING CIRCUIT DIAGRAMS IN FRITZING

How do I make these diagrams?

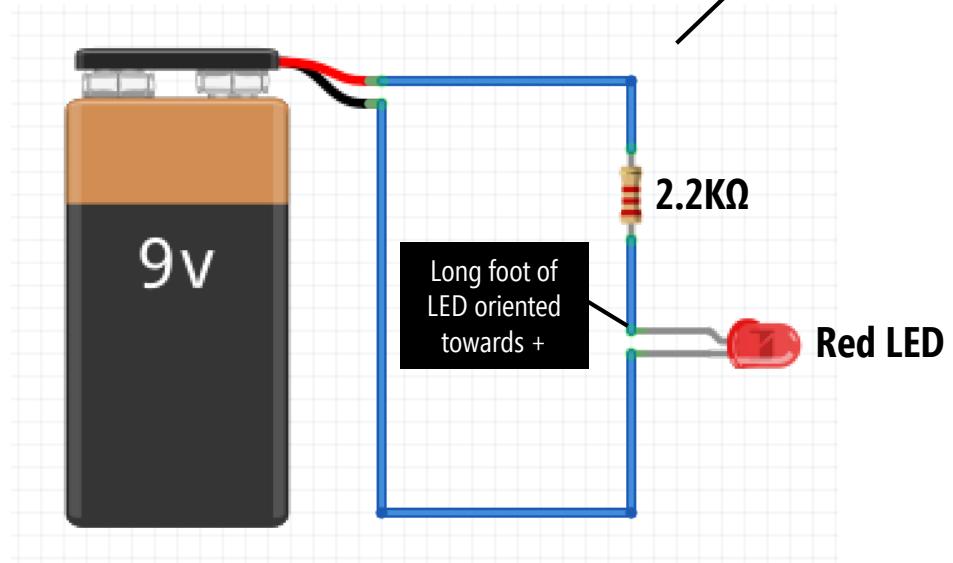
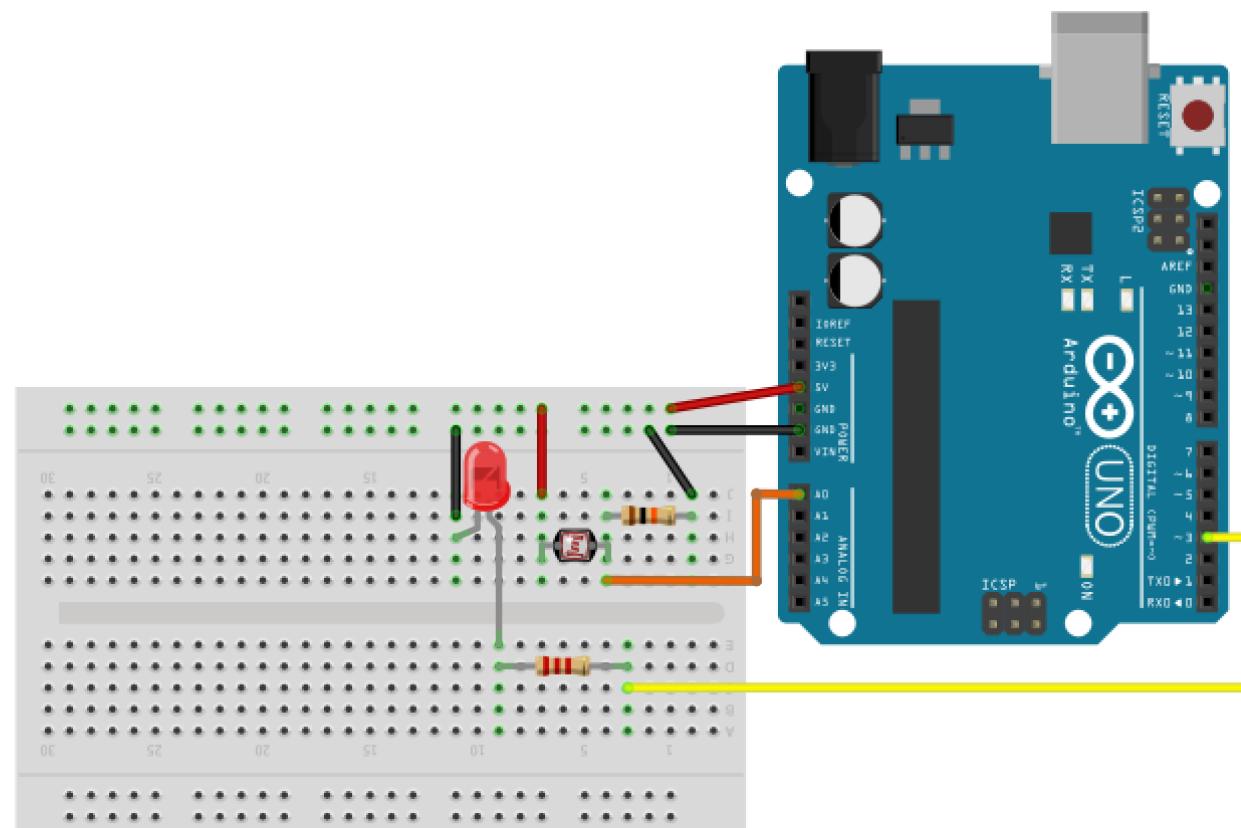


DIAGRAM VIEW



[File](#) [Edit](#) [Part](#) [View](#) [Window](#) [Routing](#) [Help](#)[Welcome](#)[Breadboard](#)[Schematic](#)[PCB](#)[Code](#)

Parts



Core Parts

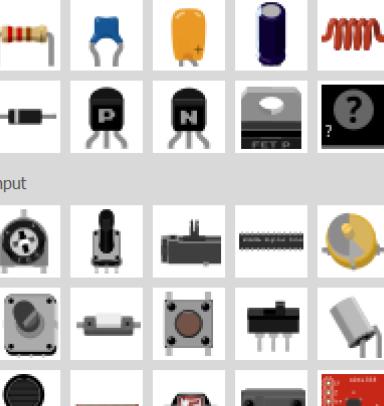
CORE

MINE

INPUT

seeed

intel



Inspector



fritzing



Add a note



Rotate



Flip

Routing completed



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May 13, 2019

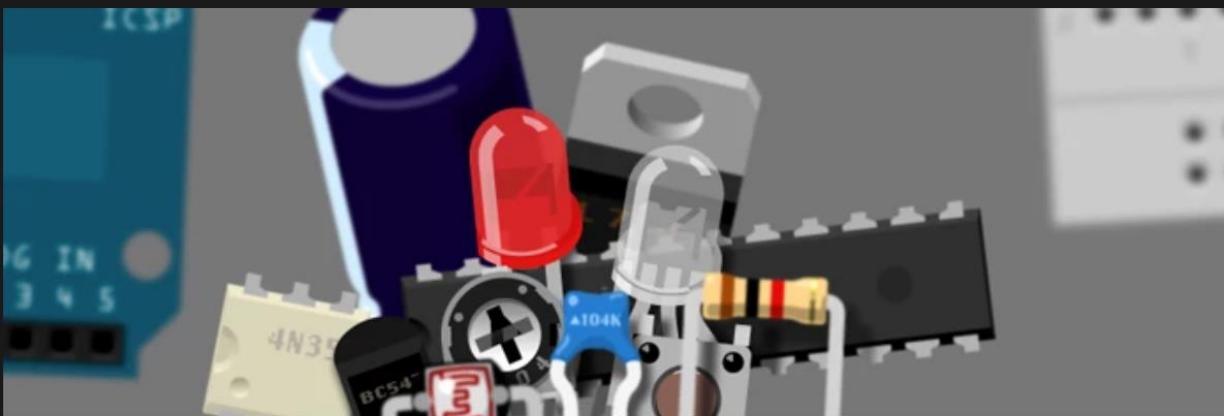
THE FUTURE OF FRITZING IS MURKY AT BEST

by: Brian Benchoff

[f](#) [t](#) [g+](#)

64 Comments

February 14, 2019



Fritzing is a very nice Open Source design tool for PCBs, electrical sketches, and schematics for designers and artists to move from a prototype to real hardware. Over the years, we've seen fantastic projects built with Fritzing. Fritzing has been the subject of books, lectures, and educational courses, and the impact of Fritzing has been huge. Open up a book on electronics from O'Reilly, and you'll probably see a schematic or drawing created in Fritzing.

However, and there's always a however, Fritzing is in trouble. [The project is giving every appearance of having died](#). You can't register on the site, you can't update parts, the official site lacks HTTPS, the Twitter



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AUTODESK®
TINKERCAD®



Code

Start Simulation

DIAGRAMS

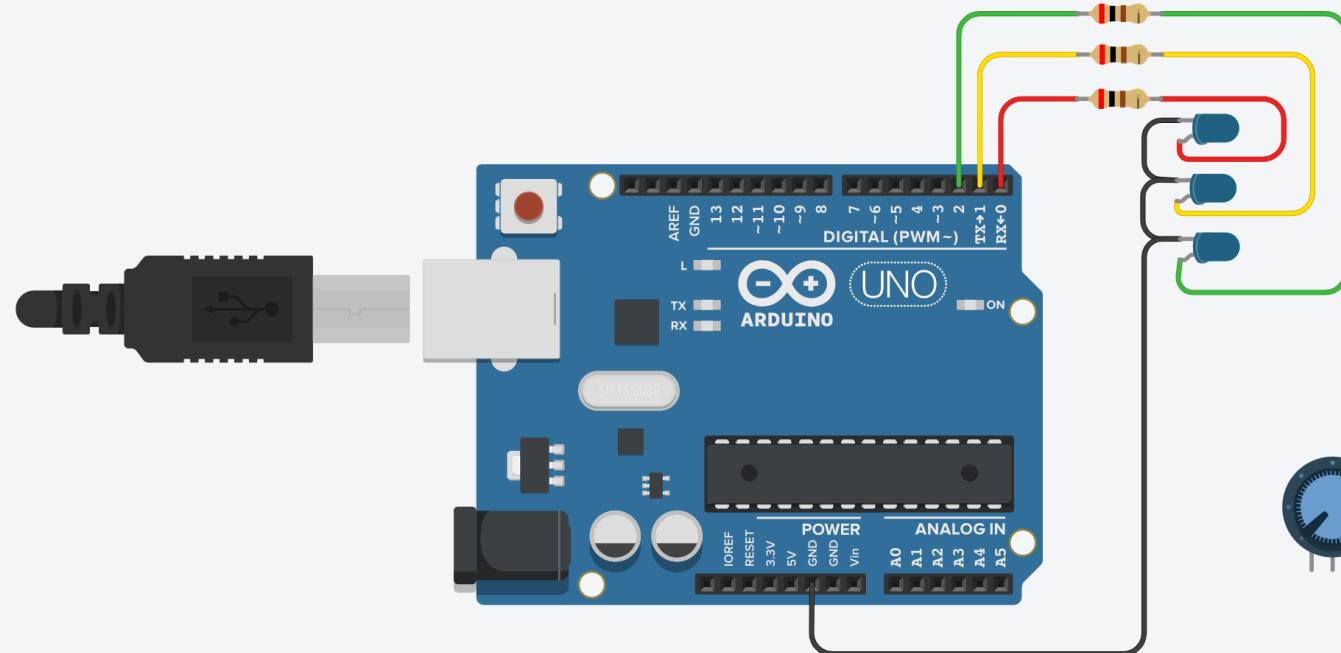
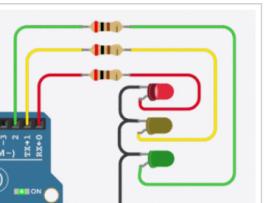
Cor

Your
blinking.

Continue Tinkering

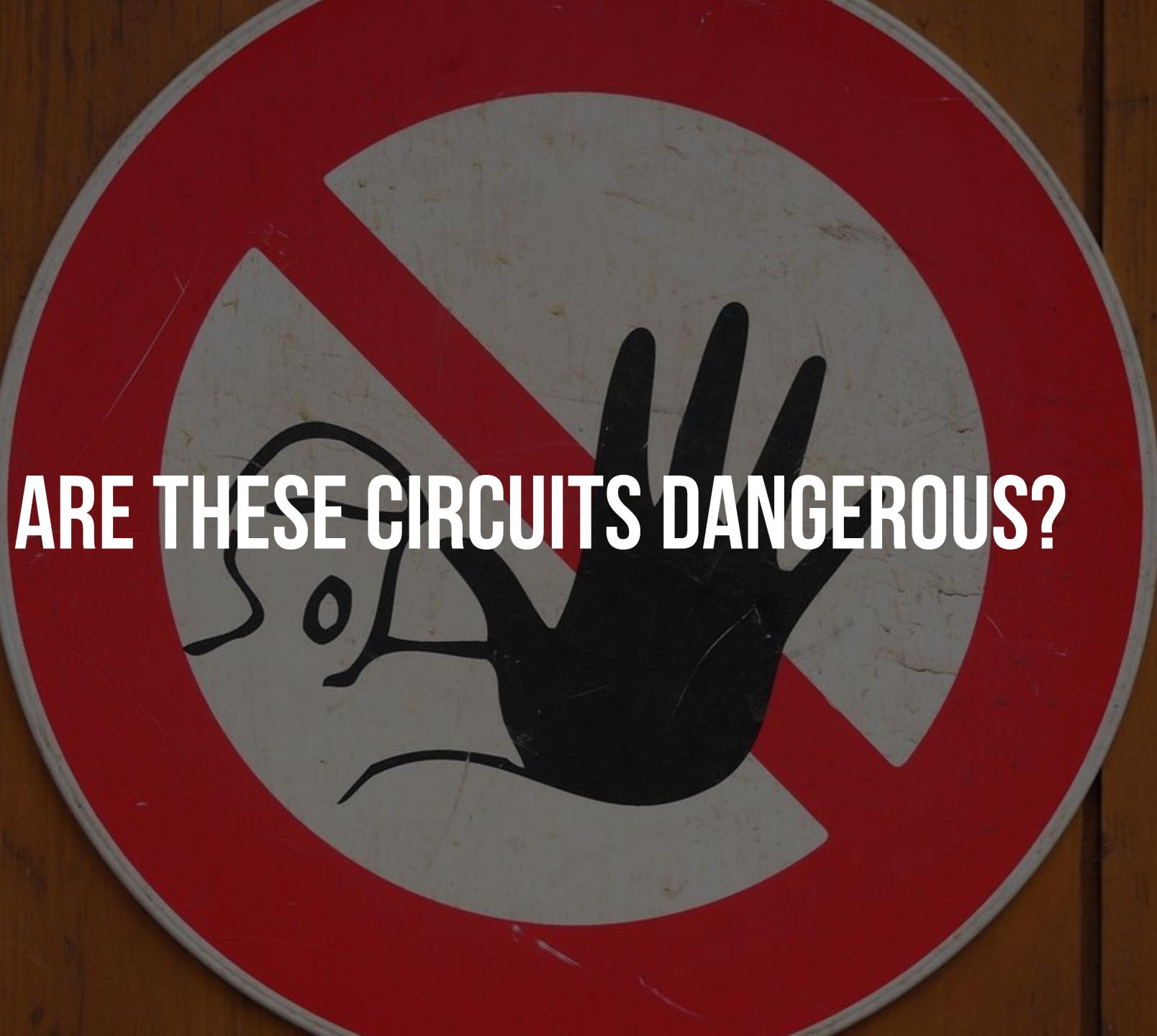
- You can also change the color of your wires. Try selecting different components in this design and see what properties you can change.
- What happens to the brightness of the LEDs when you edit the resistance of the resistor it's attached to? The resistor helps reduce current in the circuit so that the LED does not exceed its maximum rated current.
- In later tutorials, you'll learn how to program an Arduino to make your designs interactive. If you want to take a peek at the code that's running your traffic lights, click the Code Editor button in the toolbar.

Continue onto the next lesson to learn how to wire up components in Circuits.



Reset

Done



ARE THESE CIRCUITS DANGEROUS?

DANGEROUS CURRENT LEVELS



DC Current	Probable effect on human body
1 - 5 mA	Tingling sensation
5 - 10 mA	Pain
10 - 20 mA	Involuntary muscle contractions
20 - 100 mA	Paralysis, heart stoppage

Current can be **dangerous—high current (amperage)** is what can kill you or cause tissue damage. To get high amperage, you need high voltage and low resistance.

CURRENTS IN PERSPECTIVE

It's useful to have some idea of typical current draws when working with electronics.



Microwave



Low-Power Microchip



Toaster



SmartPhone



Typical LED



100W lightbulb



Laptop



Lightening Strike

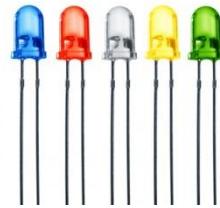
What do you think draws
the **most current**?

CURRENTS IN PERSPECTIVE

It's useful to have some idea of typical current draws when working with electronics.



Low-Power Microchip
A few μA or pA



Typical LED
Draws 20mA



SmartPhone
Draws ~200mA loading a webpage



100W lightbulb
Draws about 1A



Laptop
Draws ~2-3A



Toaster
Draws about 7-10A



Microwave
Draws 8-13A



Lightening Strike
Around 1000A

DANGEROUS CURRENT LEVELS



DC Current	Probable effect on human body
1 - 5 mA	Tingling sensation
5 - 10 mA	Pain
10 - 20 mA	Involuntary muscle contractions
20 - 100 mA	Paralysis, heart stoppage

The NIOSH states "Under dry conditions, the **resistance offered by the human body may be as high as 100,000 Ohms**. Wet or broken skin may drop the body's resistance to 1,000 Ohms," adding that "high-voltage electrical energy quickly breaks down human skin, reducing the human body's resistance to 500 Ohms."

We'll be (mostly) working with **3.3V** and **5V DC**. Imagine your skin has $\sim 50\text{K}\Omega$ resistance, with 5V, that's **0.0001 amps** or **0.1 mA**, which is well within the safe range. Whew!

ACTIVITY

BUILD YOUR FIRST CIRCUIT: RESISTOR + LED

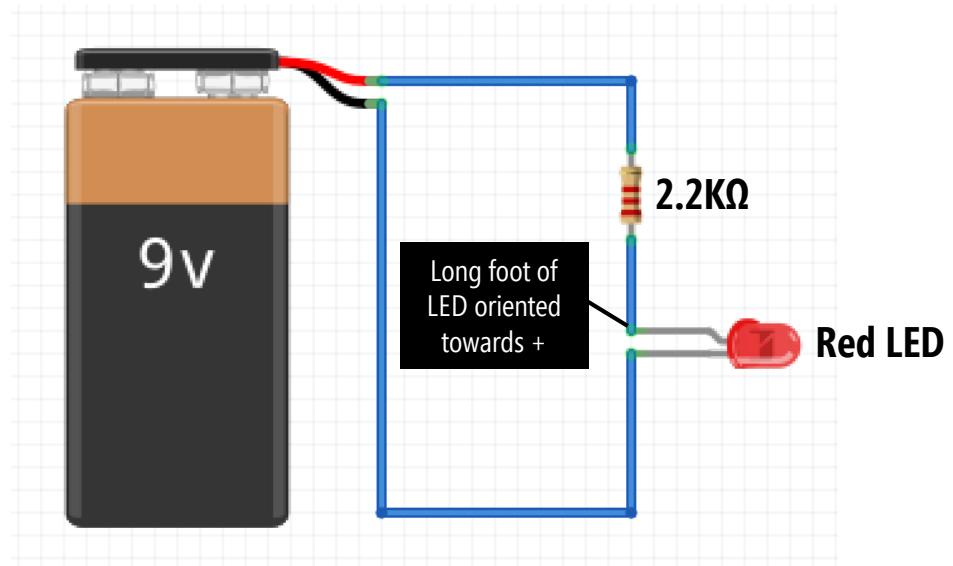
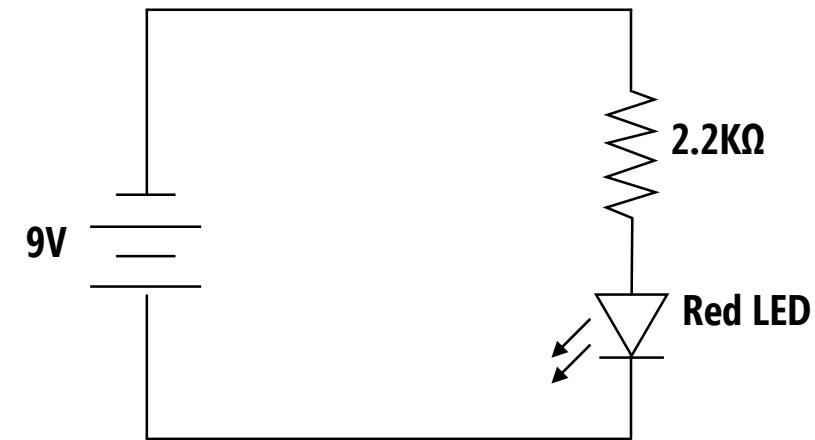


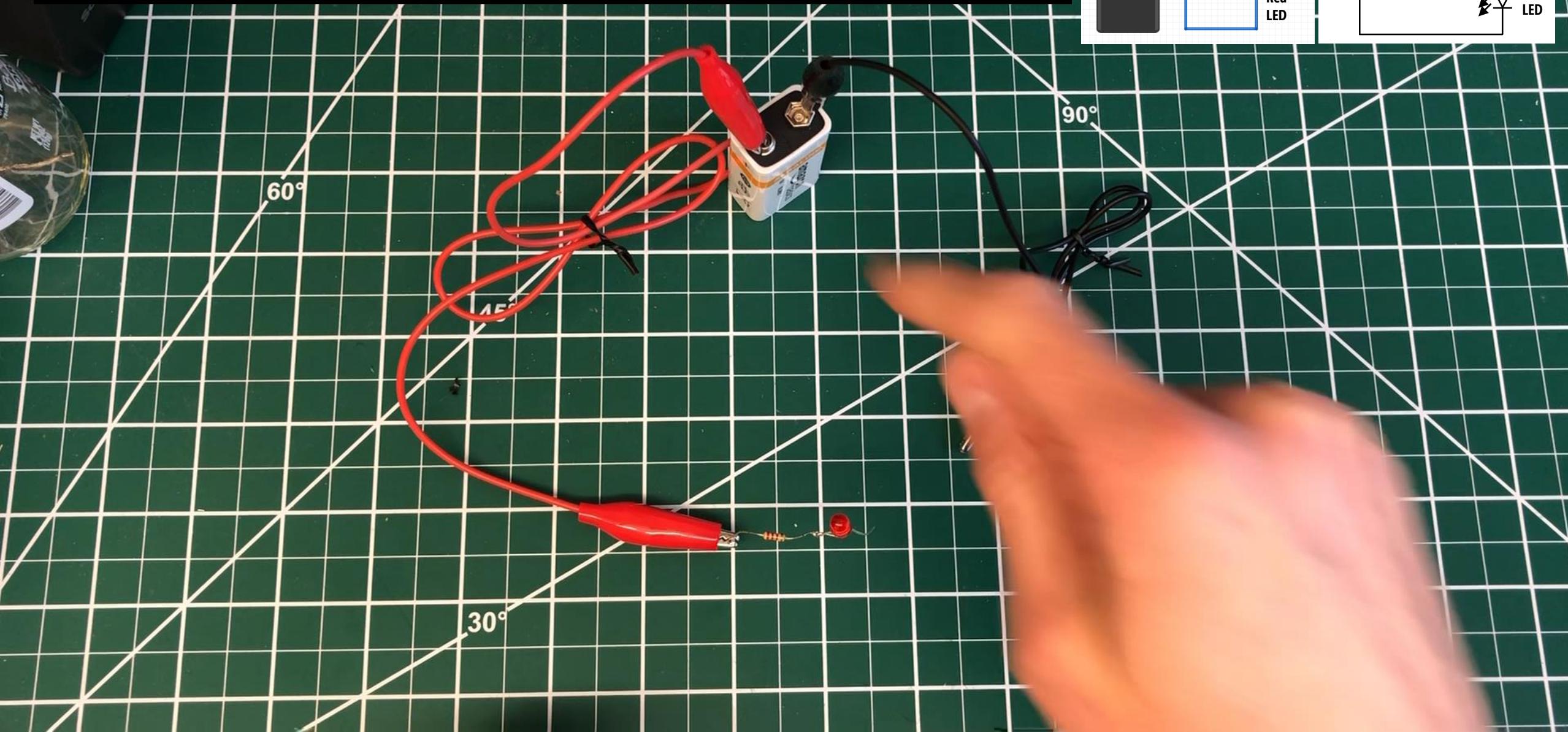
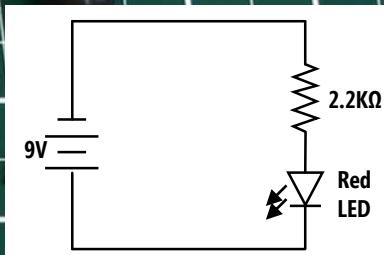
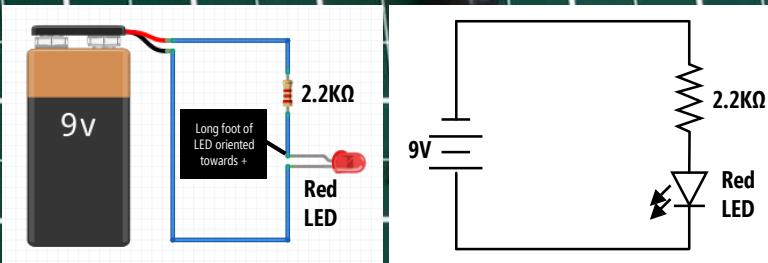
DIAGRAM VIEW



SCHEMATIC VIEW

ACTIVITY

BUILD YOUR FIRST CIRCUIT: RESISTOR + LED



A woman with long, dark hair is captured mid-dive into a dark blue ocean. She is wearing a black one-piece swimsuit. Her body is arched, and her head is above the surface, creating a spray of water. The background consists of the textured surface of the ocean.

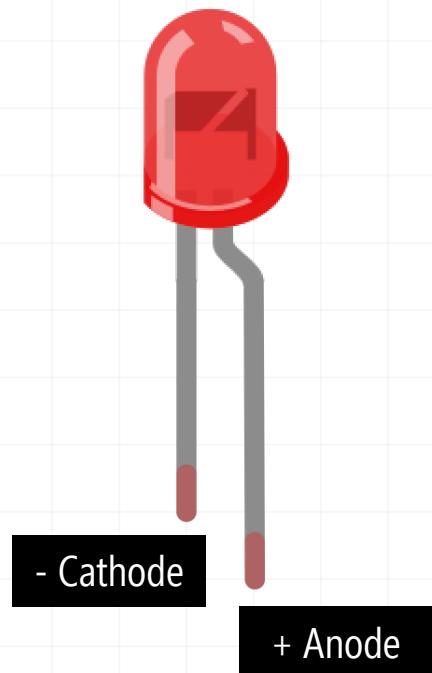
LET'S DIVE INTO WHAT WE BUILT HERE 😊



LEDS AND HOW TO USE THEM

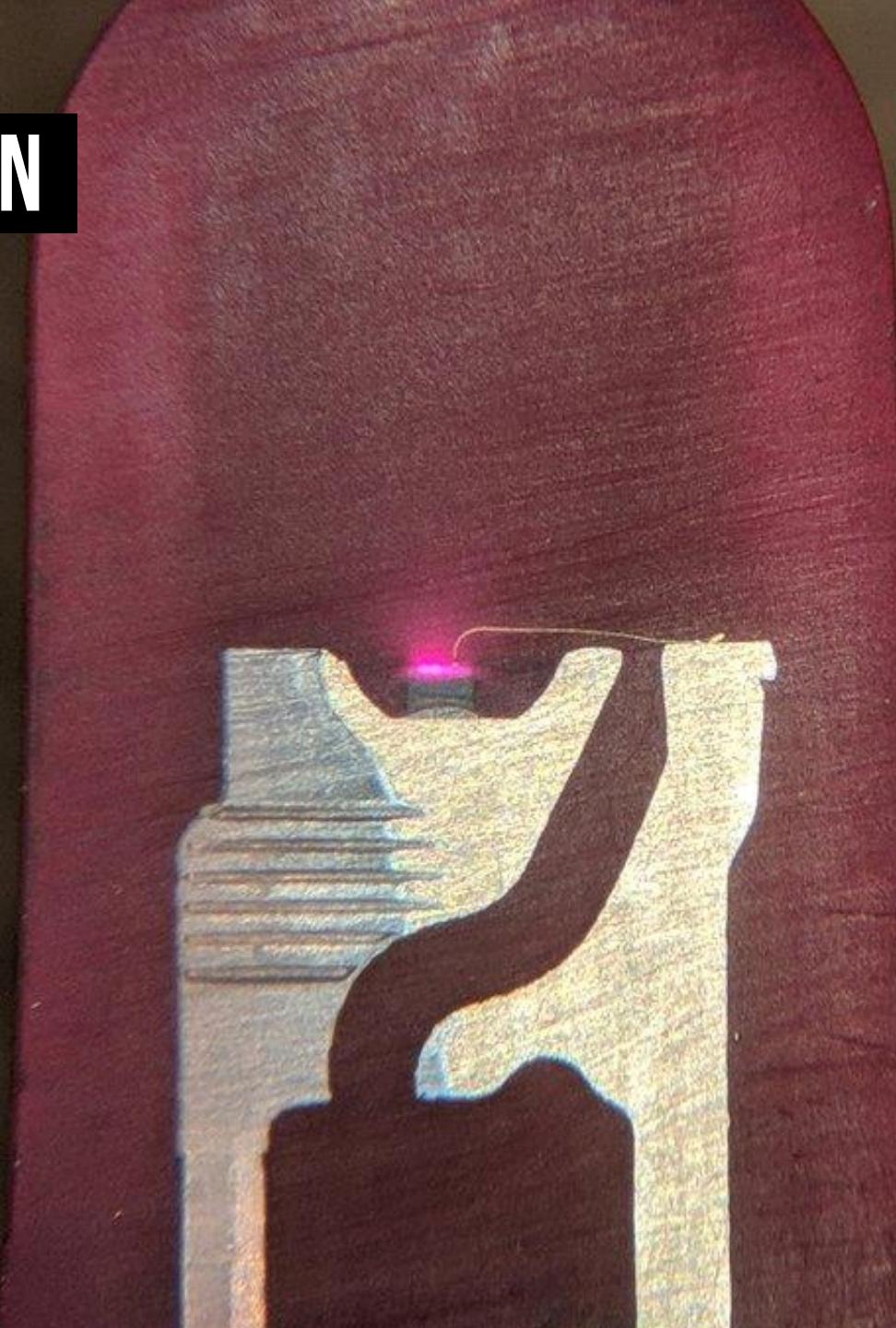
WHAT IS A LIGHT-EMITTING DIODE (LED)?

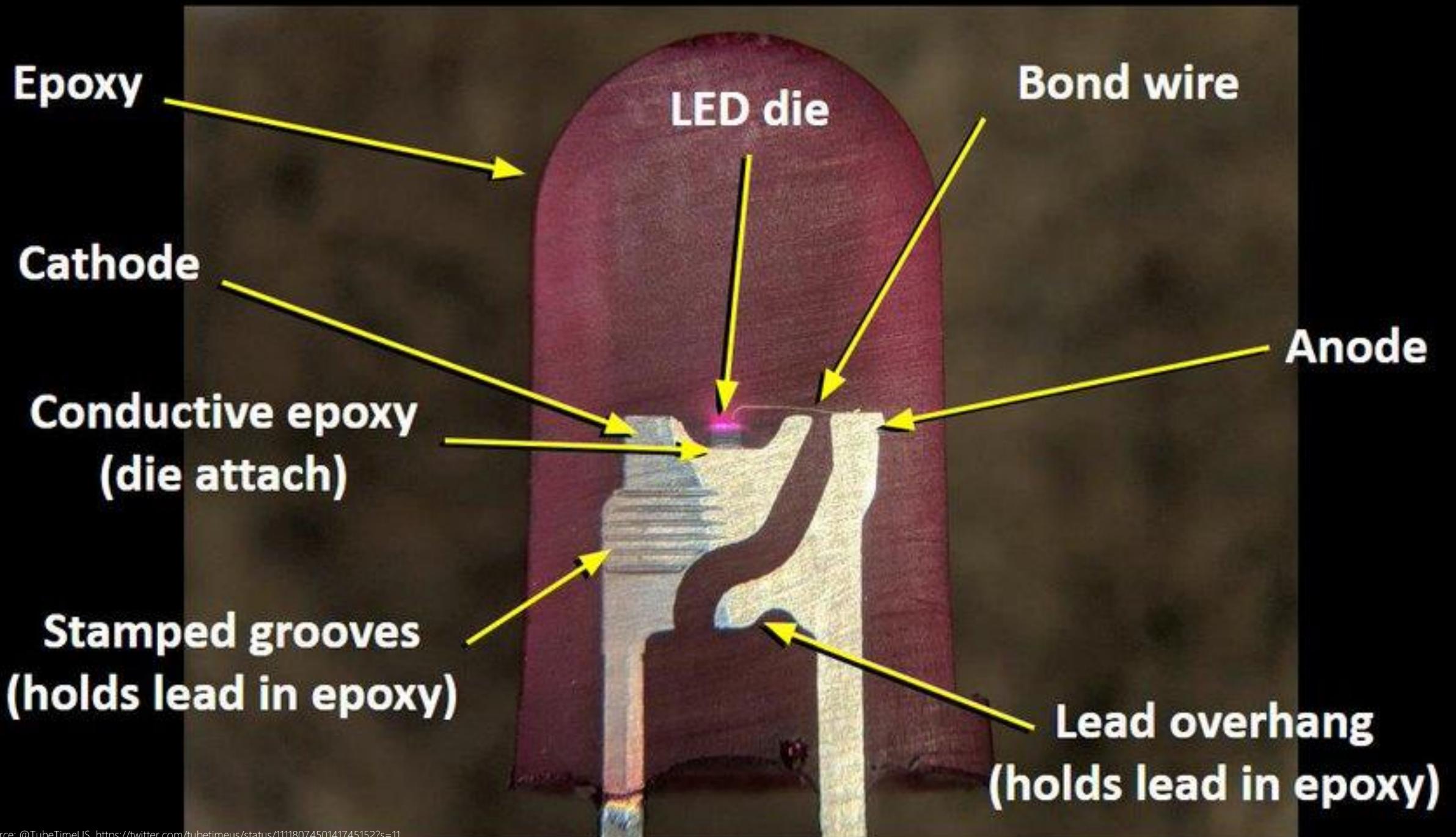
LEDs emit light when certain voltage and current requirements are met.



LEDS

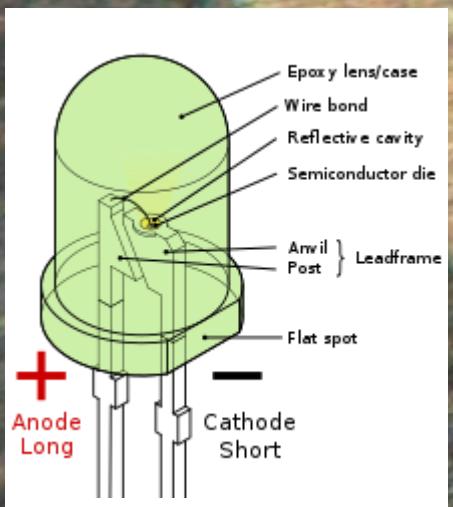
LED CROSS SECTION





LEDS

LED DIE CLOSE UP



Tube Time @TubeTimeUS · Mar 29

the metal cathode has a cup shape because it also acts as the reflector.

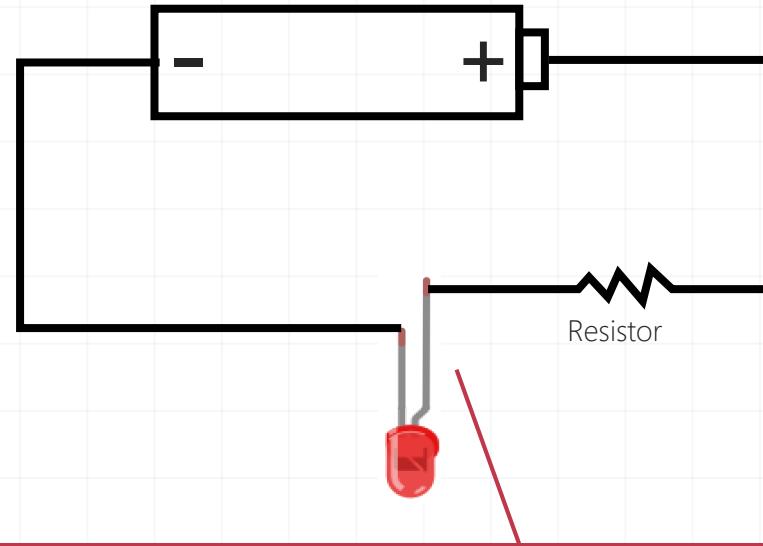
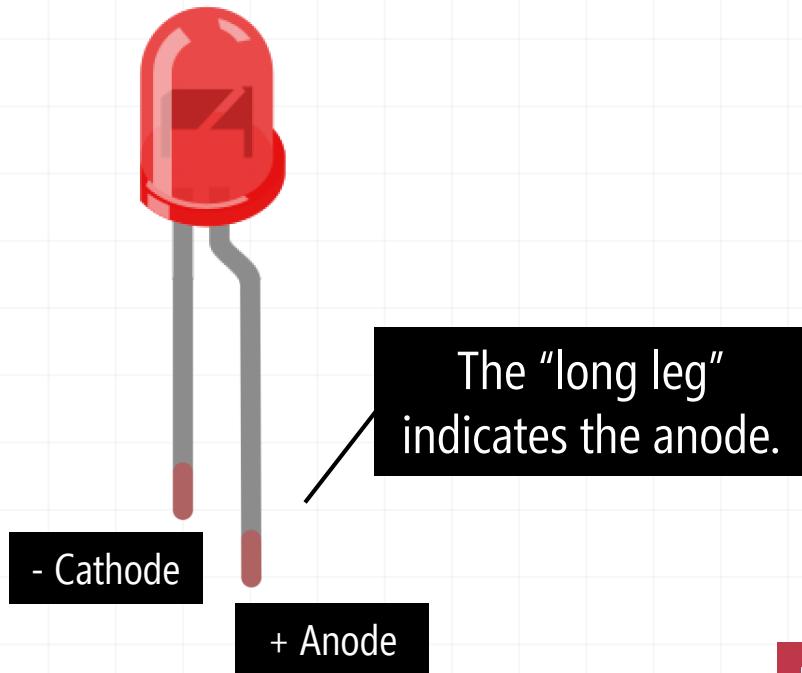
2

3

80

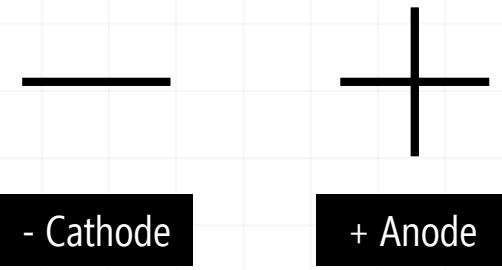
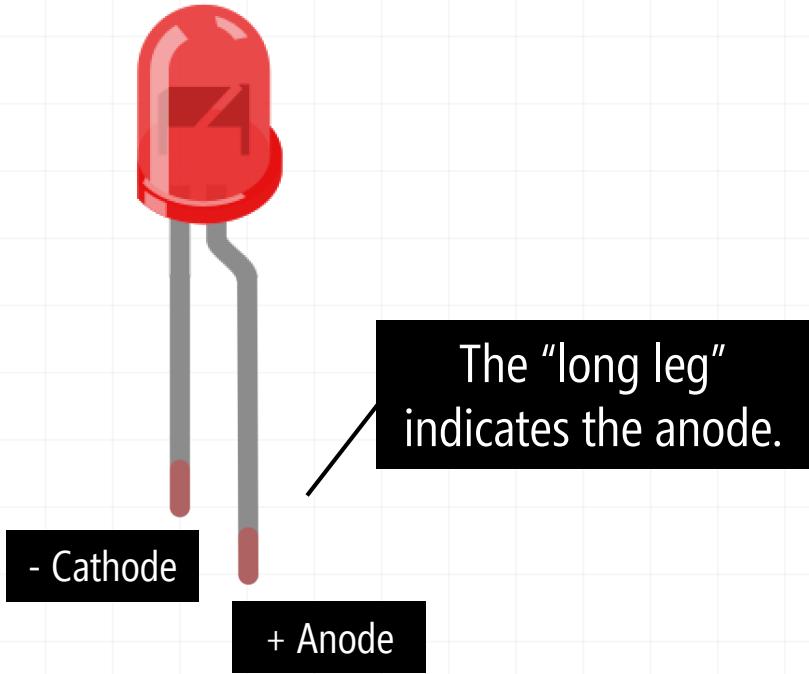
↑

LIGHT-EMITTING DIODES (LEDS): 2 THINGS

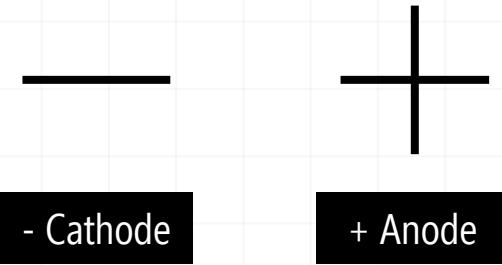
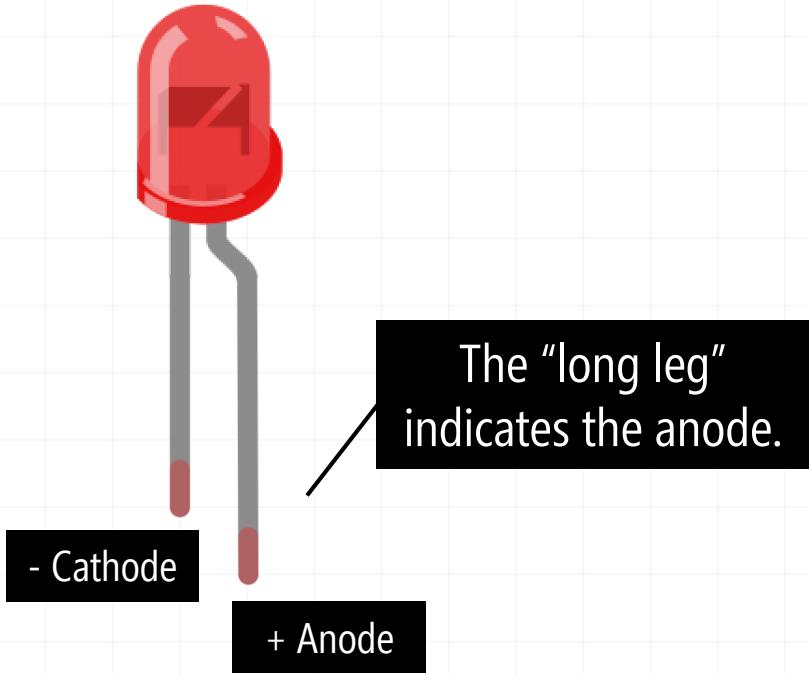


First: Unlike resistors, LEDs have **polarity**. They only allow current to flow in one direction. The long leg (the anode) must be connected towards positive supply voltage.

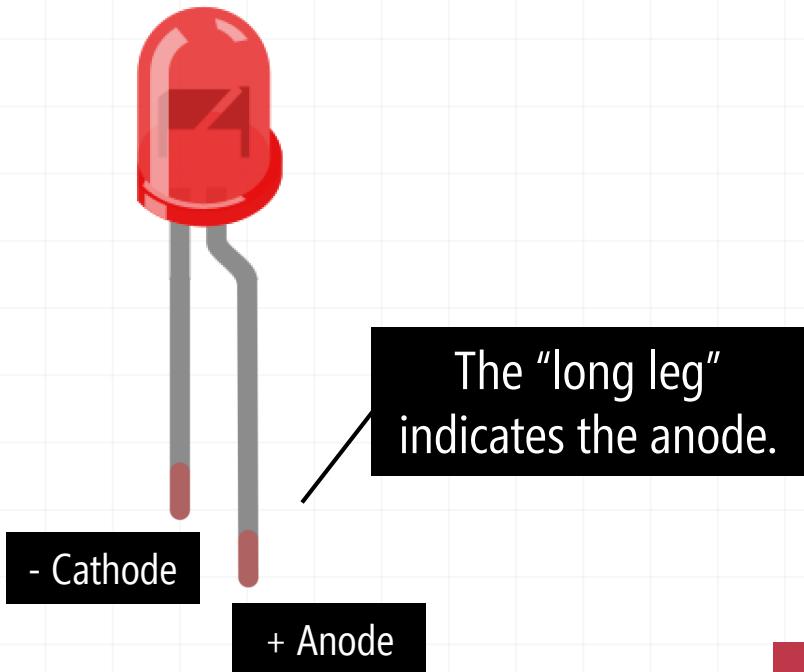
LONG LEG MNEMONIC



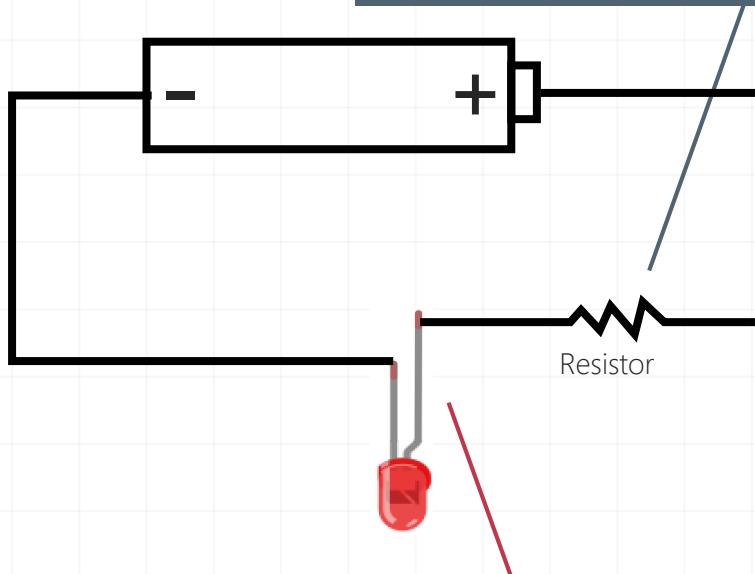
LONG LEG MNEMONIC



LIGHT-EMITTING DIODES (LEDS): 2 THINGS

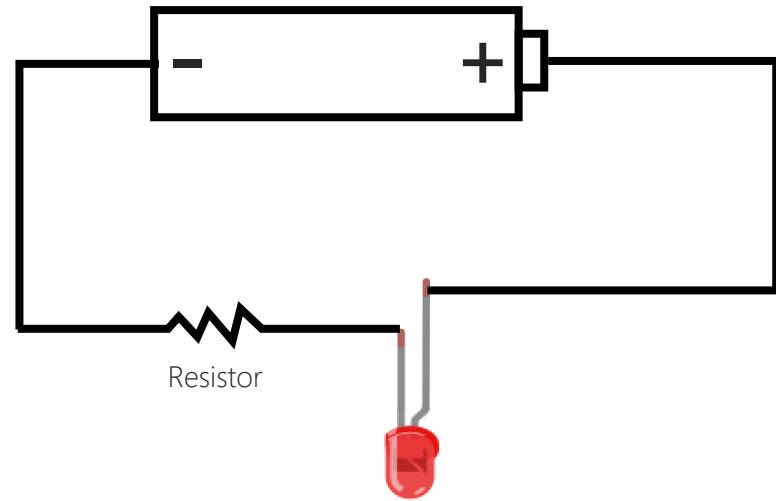
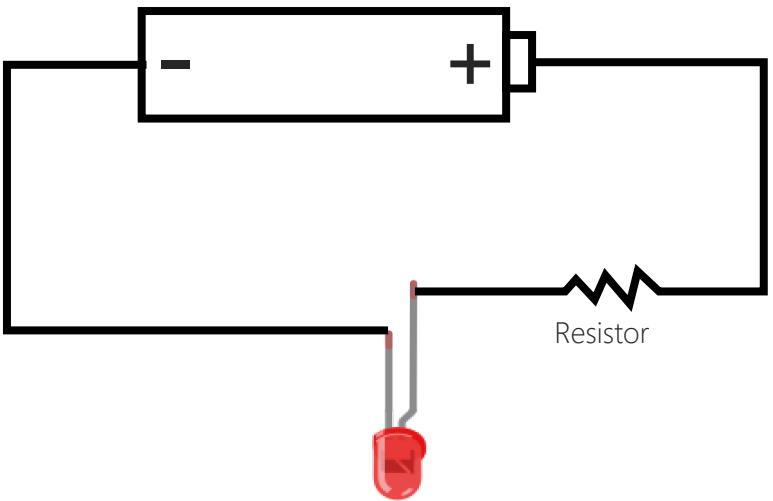


First: Unlike resistors, LEDs have **polarity**. They only allow current to flow in one direction. The long leg (the anode) must be connected towards positive supply voltage.



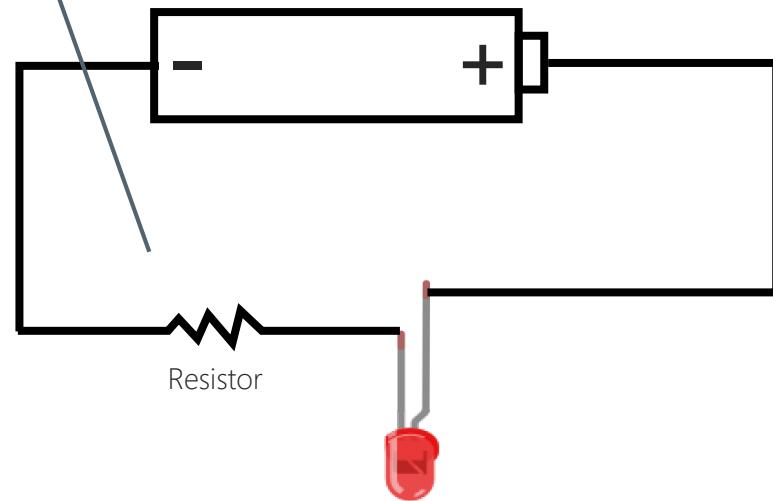
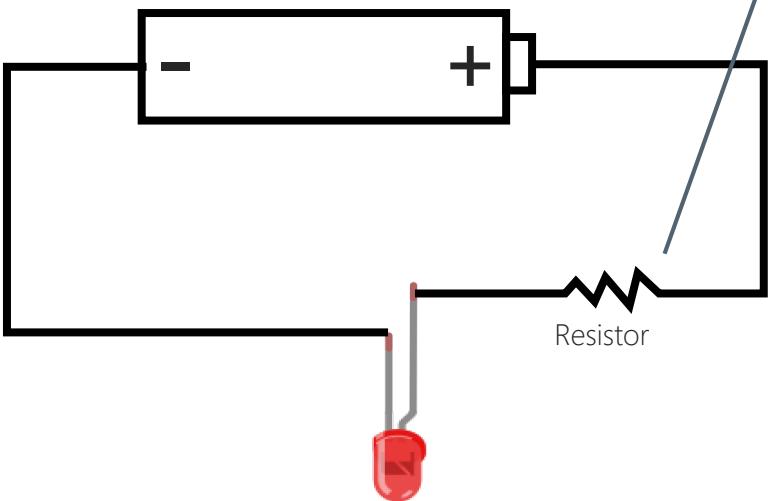
Second: LEDs require **current limiting resistors**. Do not hook up an LED directly to a power source without a resistor or the LED could burn out.

WHERE DO I PUT THE RESISTOR? BEFORE OR AFTER LED?



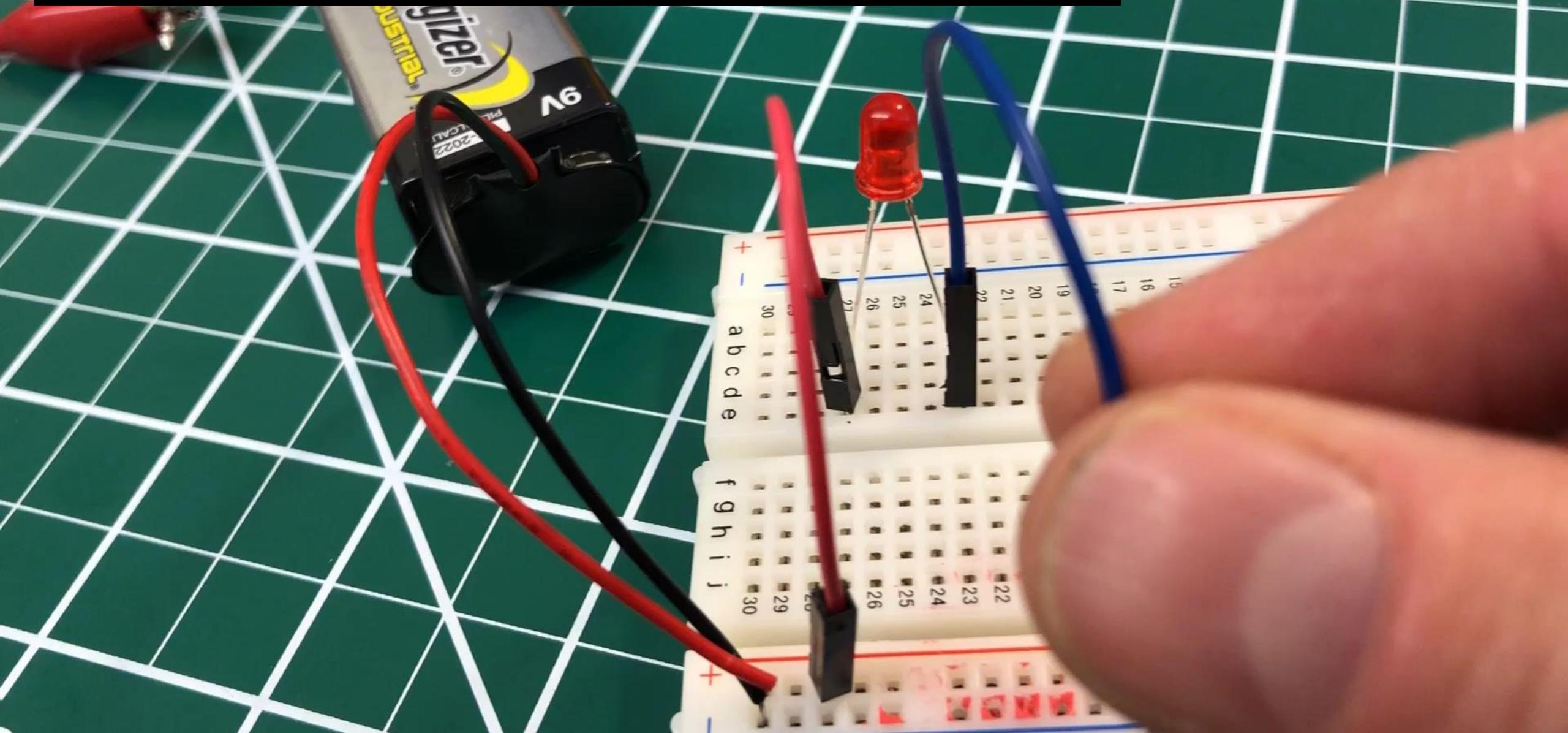
WHERE DO I PUT THE RESISTOR? BEFORE OR AFTER LED?

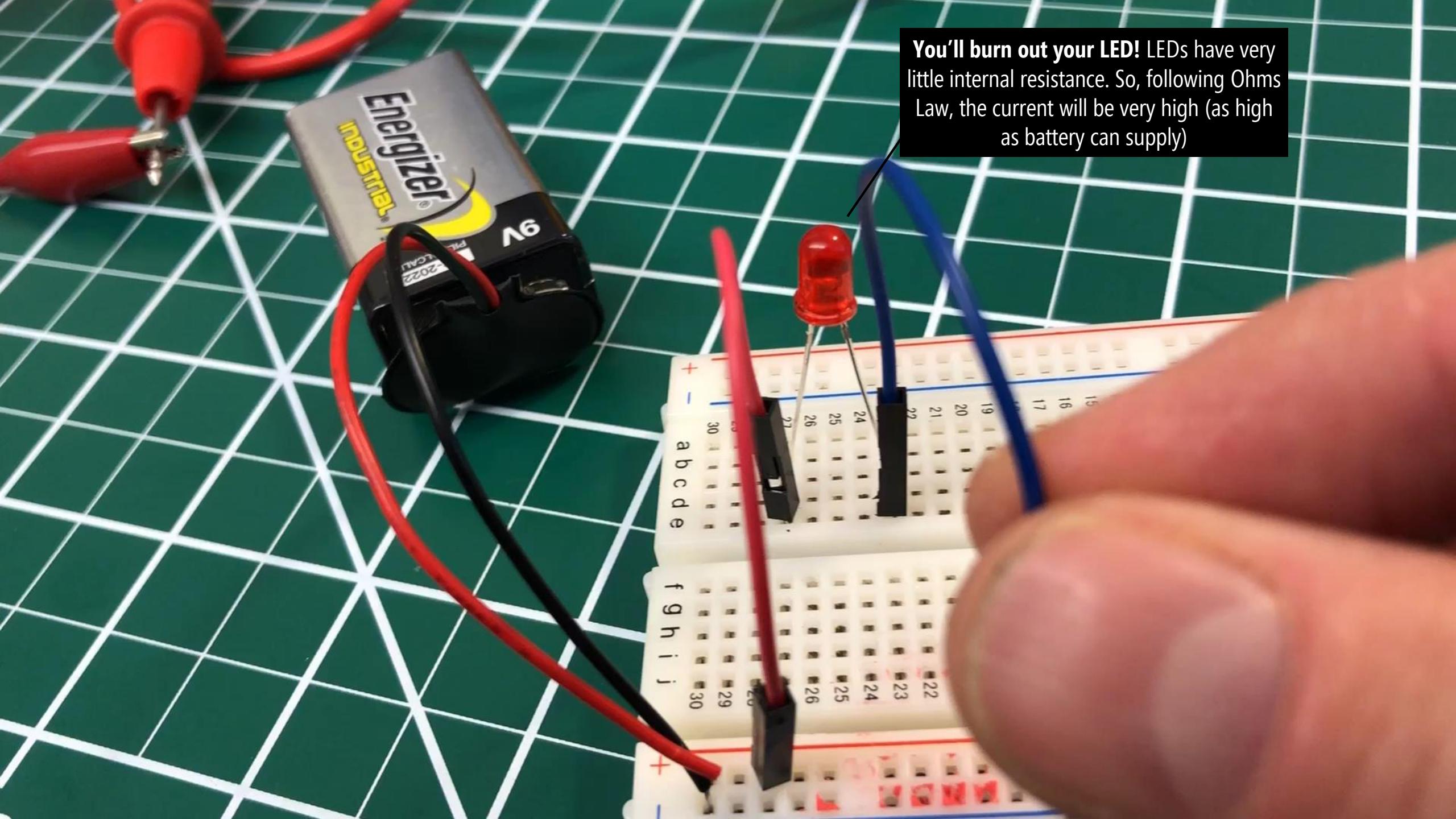
The current limiting resistor can be on either side of the LED (this can be shown with Ohm's Law, which we will soon learn about)



USING LEDs

WHAT HAPPENS IF YOU FORGET THE RESISTOR

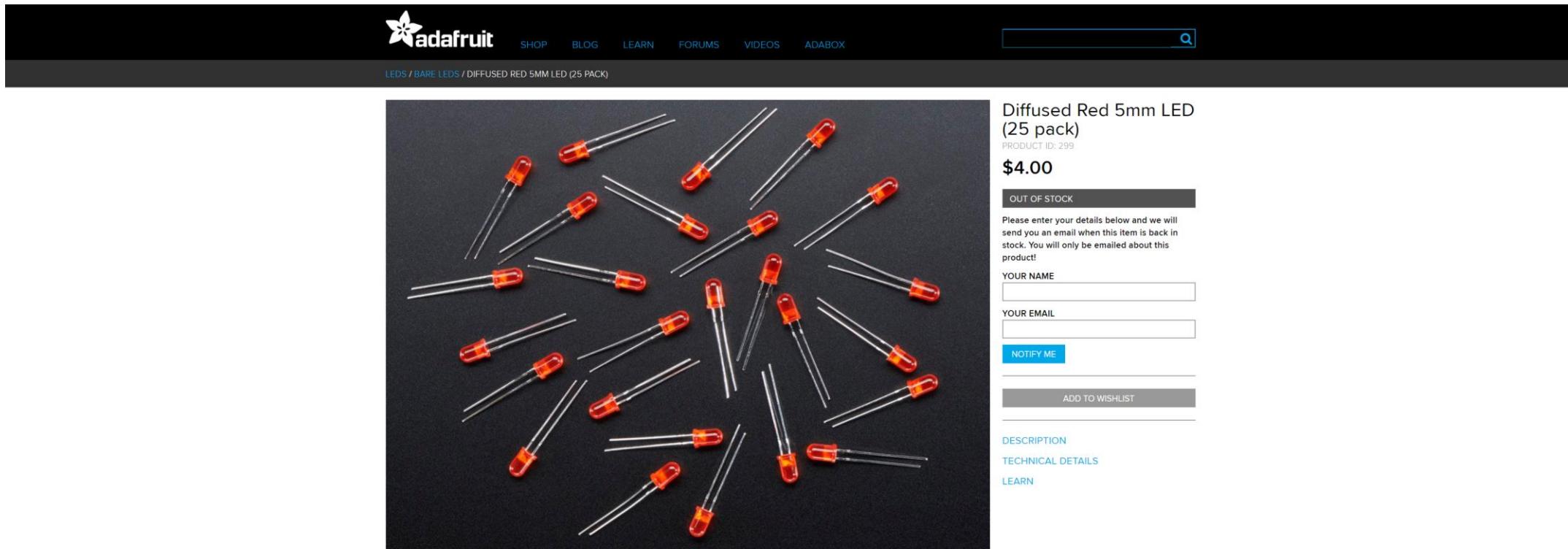




You'll burn out your LED! LEDs have very little internal resistance. So, following Ohms Law, the current will be very high (as high as battery can supply)

DIODES: FORWARD VOLTAGE

A diode (including an LED) won't allow current through unless a **forward voltage** condition is met. The LED's datasheet will tell you what this is (e.g., 1.8-2.5V). Let's use another water analogy.



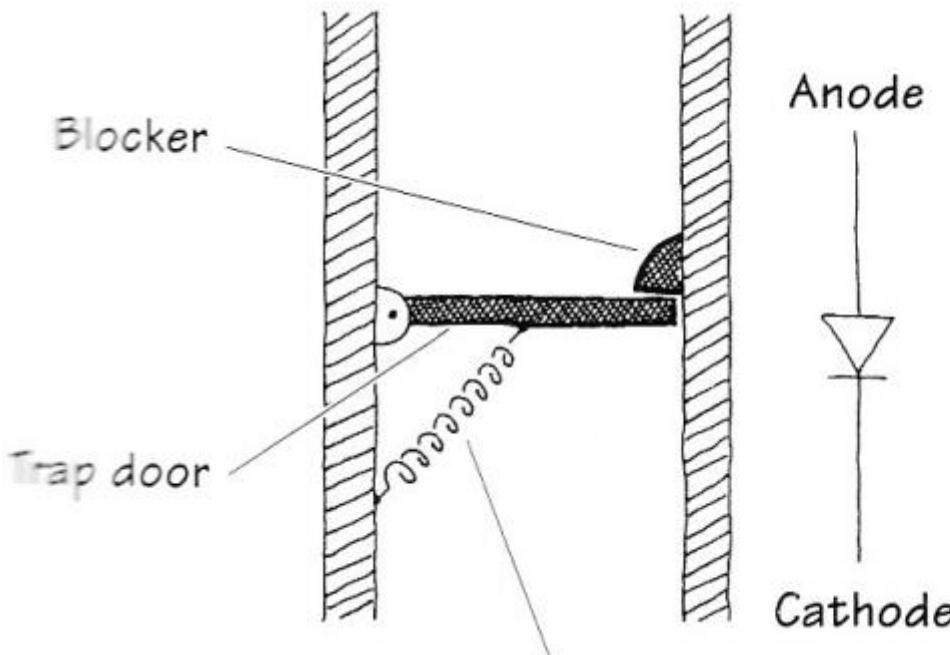
DESCRIPTION

Need some indicators? We are big fans of these diffused red LEDs, in fact we use them exclusively in our kits. They are fairly bright so they can be seen in daytime, and from any angle. They go easily into a breadboard and will add that extra zing to your project.

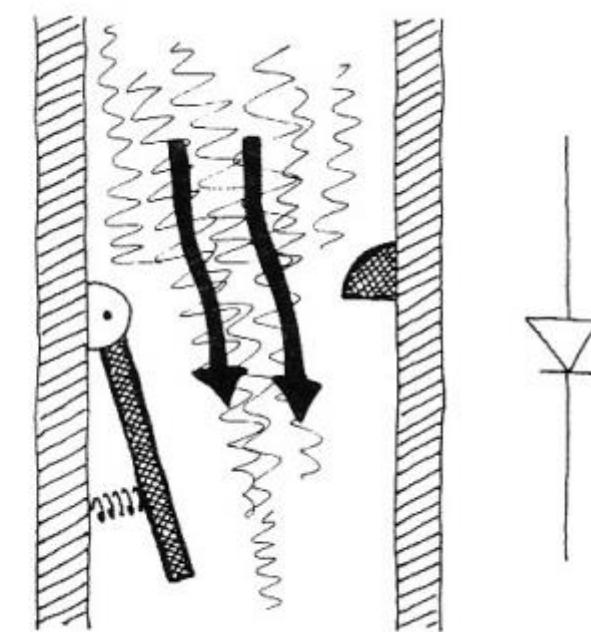
- Pack of 25 diffused red LEDs
- 5mm diameter
- 1.85-2.5V Forward Voltage, at 20mA current
- Datasheet

DIODES: FORWARD VOLTAGE

A diode (including an LED) won't allow current through unless a **forward voltage** condition is met. The LED datasheet will tell you what this is (e.g., 1.8-2.5V). Let's use another water analogy.



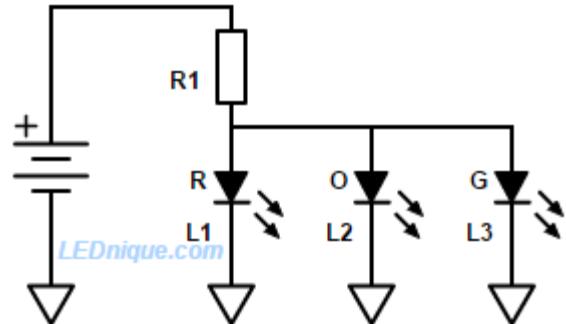
Imagine this trap door won't open unless a certain water pressure threshold is met (this is the forward voltage).



Once the threshold is met, the trap door opens and water (current) passes through.

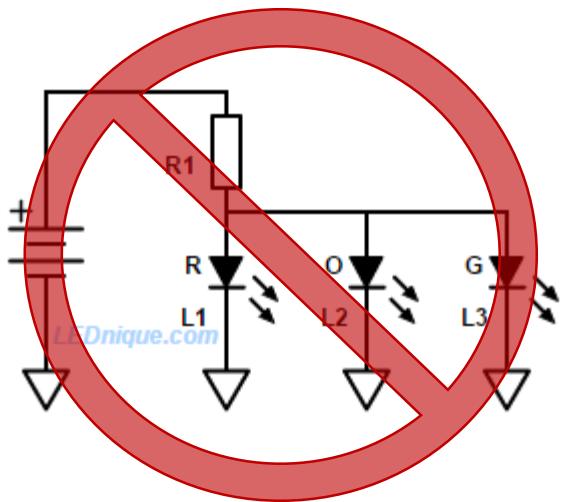
HOW DO I HOOK UP MULTIPLE LEDS?

One Resistor, LEDs in Parallel



HOW DO I HOOK UP MULTIPLE LEDS?

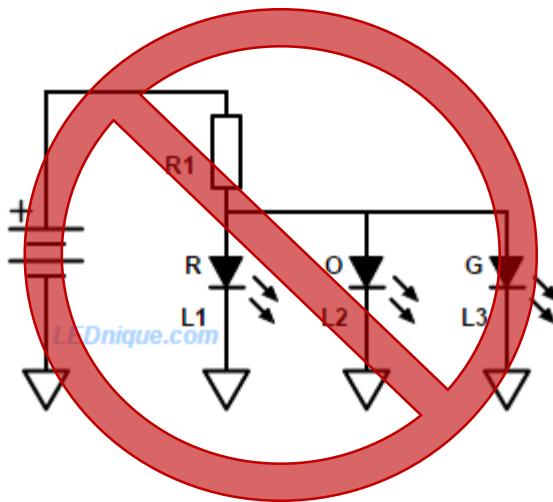
One Resistor, LEDs in Parallel



Though tempting, don't do this. In this configuration, some LEDs will receive far more current than others—which will wear (or blow) them out

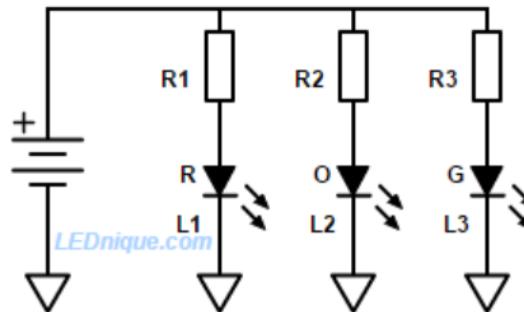
HOW DO I HOOK UP MULTIPLE LEDs?

One Resistor, LEDs in Parallel



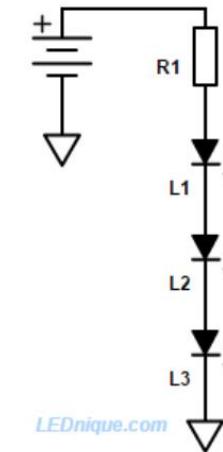
Though tempting, don't do this. In this configuration, some LEDs will receive far more current than others—which will wear (or blow) them out

Multiple Resistors, LEDs in Parallel

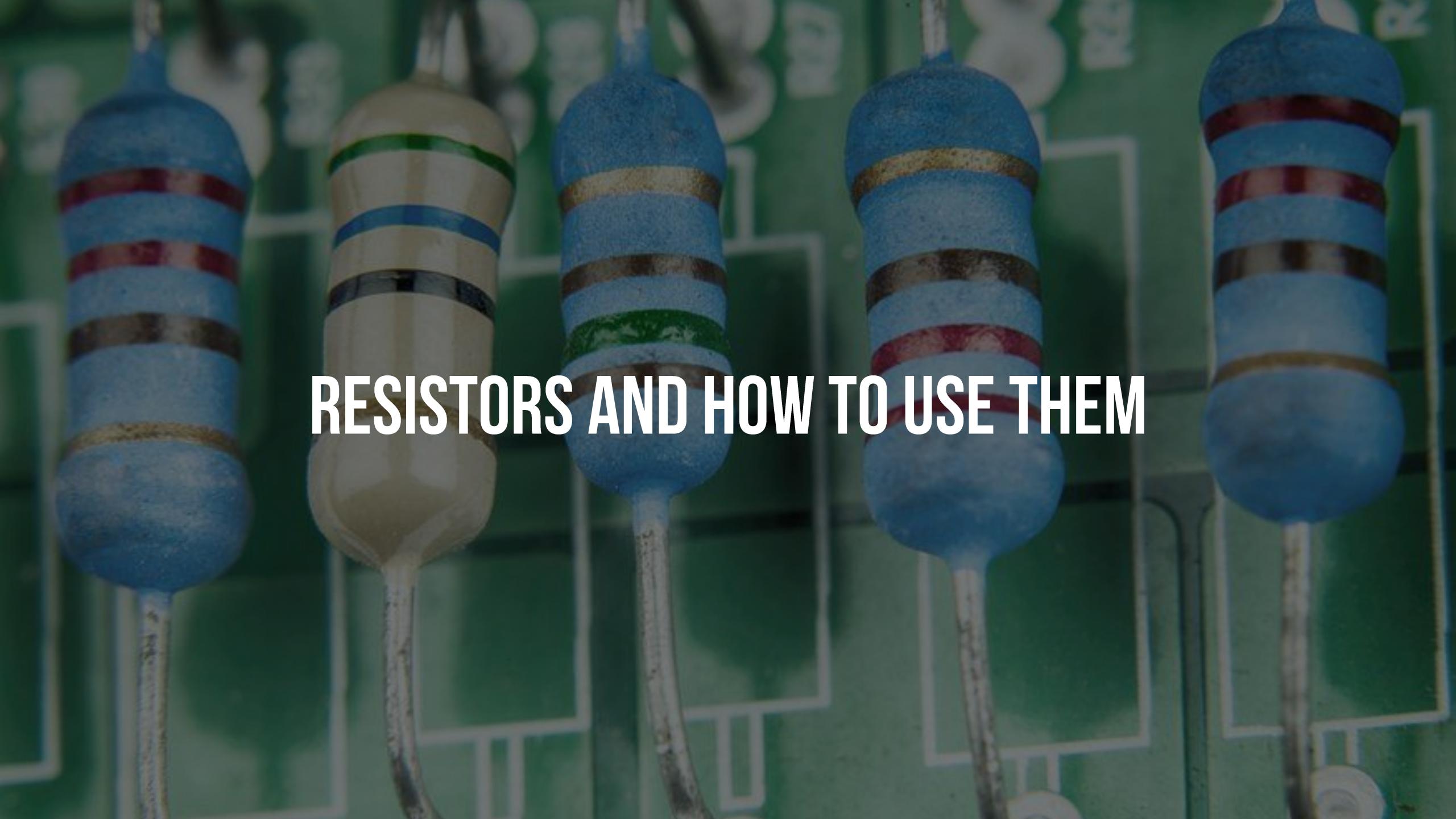


Instead, add in a current limiting resistor for each LED in parallel. This “current hogging” by the LED with the lowest forward voltage.

One Resistor, LEDs in Series



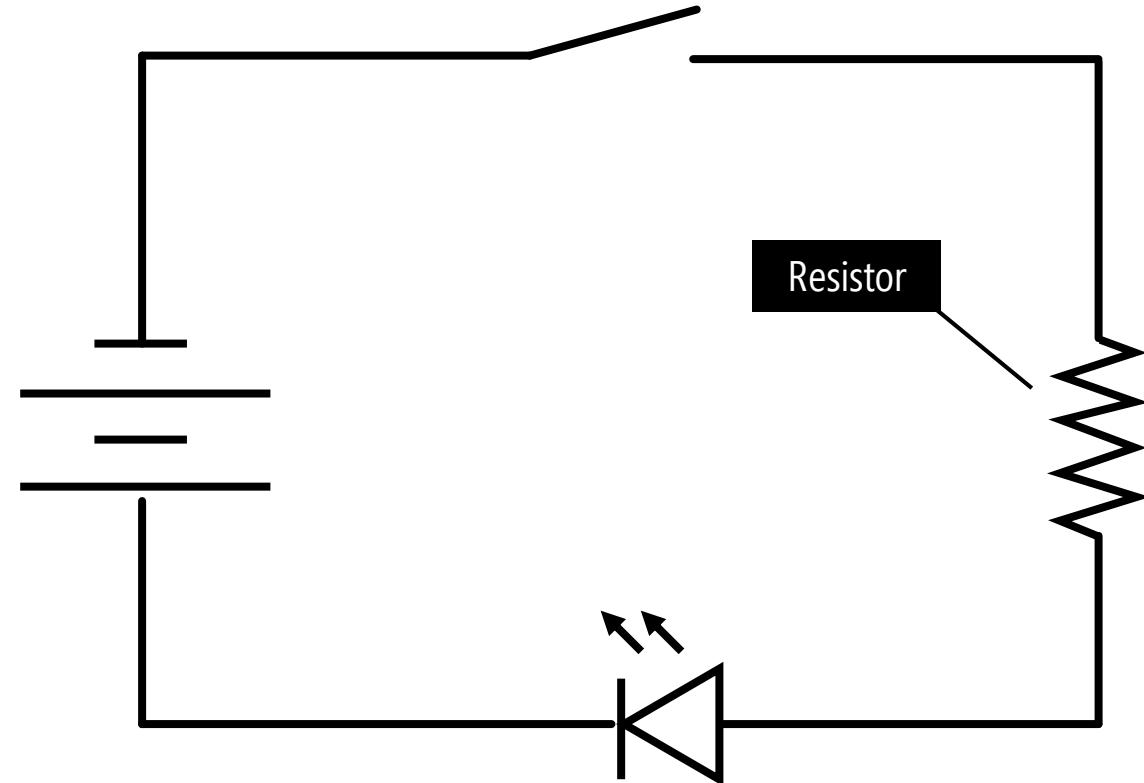
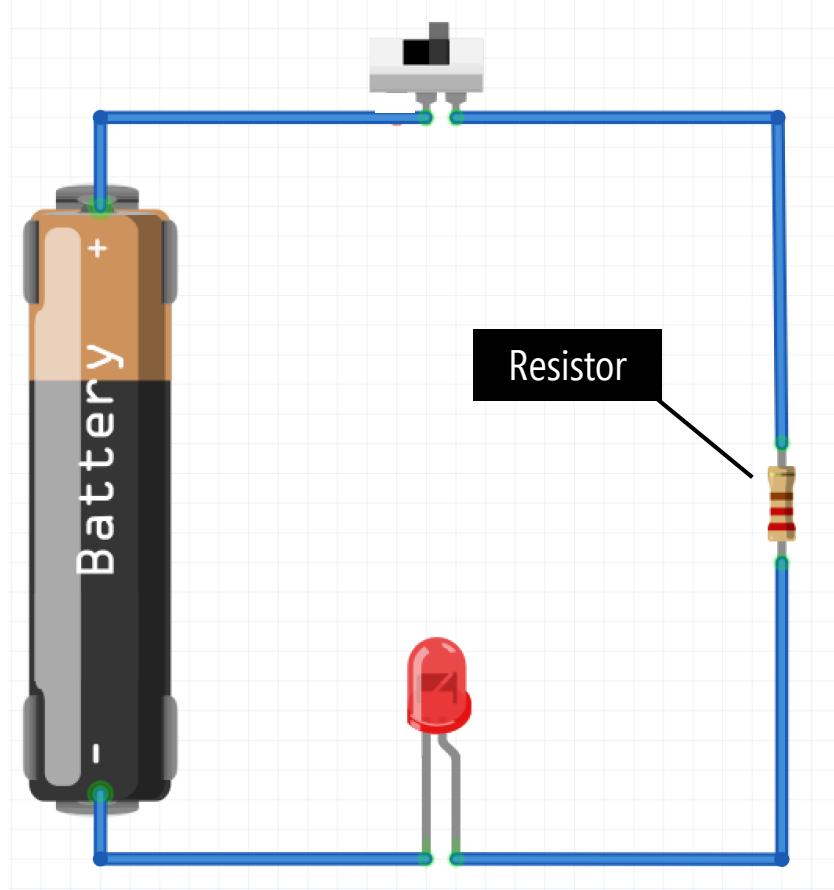
If the supply voltage is adequate, you can hook up the LEDs in series with a single current limiting resistor (here, all LEDs will have the same current).



RESISTORS AND HOW TO USE THEM

RESISTORS

WHAT IS A RESISTOR?



RESISTORS

WHAT IS A RESISTOR?

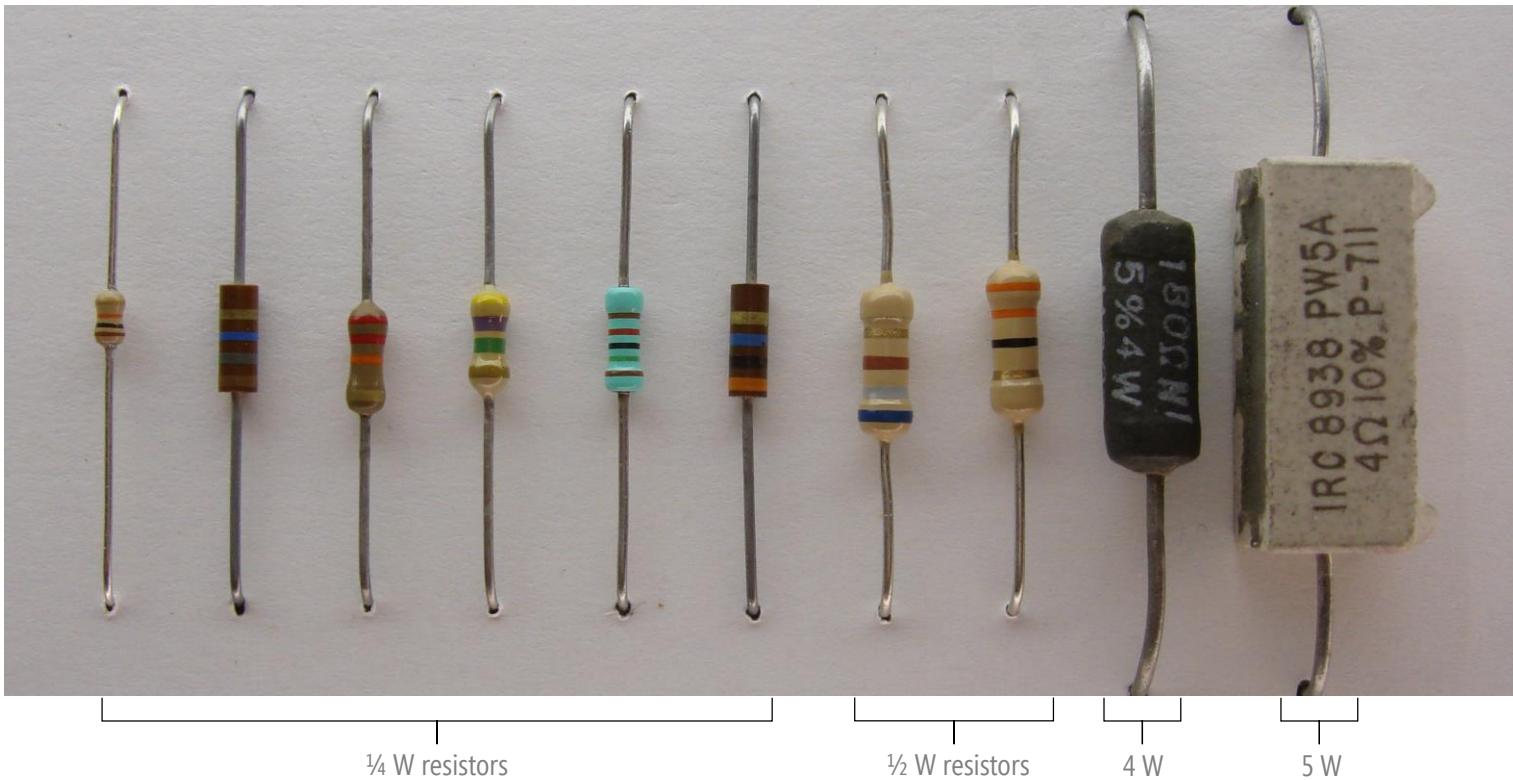
American-Style Symbol



International-Style Symbol



Resistors limit the flow of electrons through a circuit by converting electrical energy to thermal energy (heat).



Resistors have no polarity so you can put them into a circuit in either orientation.

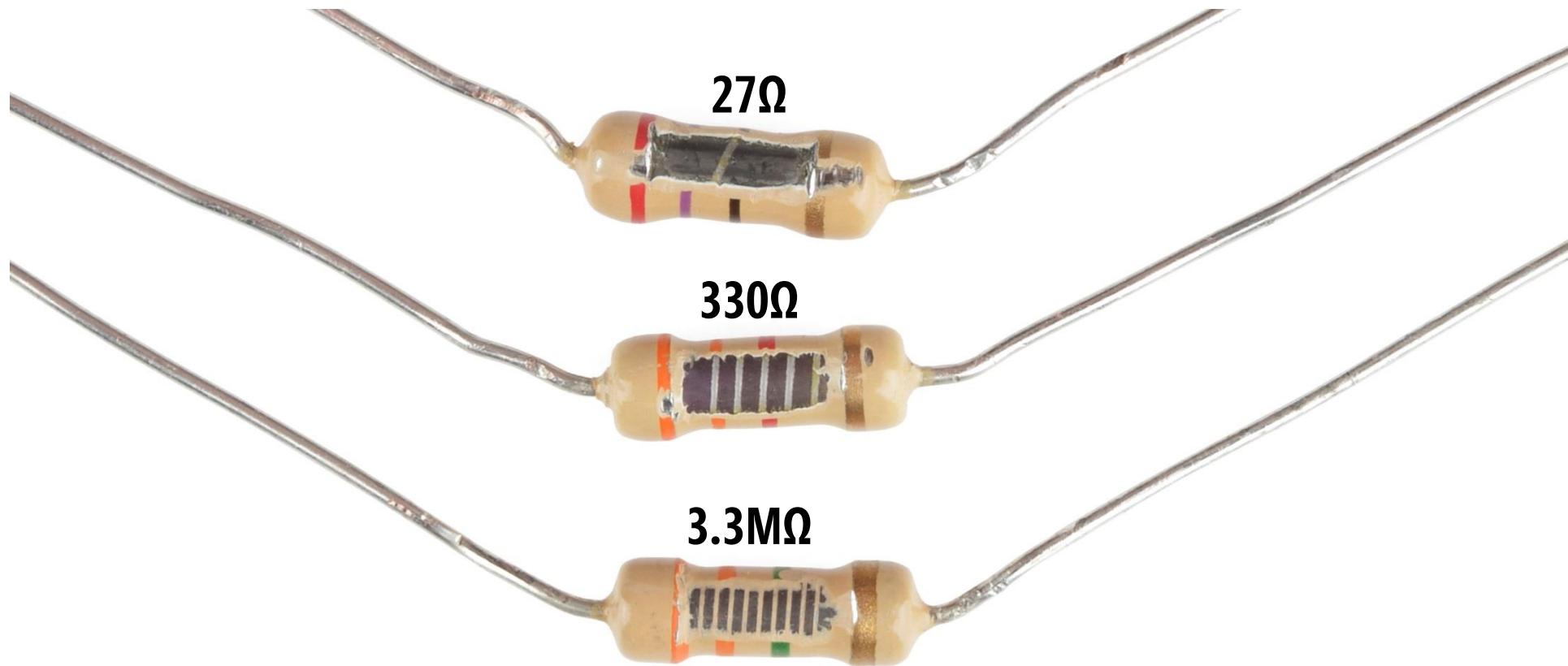
Resistors are characterized by their **resistance value (in Ohms or Ω)** and their **maximum power capacity (in Watts)**, which is the maximum rate at which they can convert electrical energy to thermal energy.

All conductive elements—even a copper wire—**have resistance.**
Resistors are carefully built to have specific resistances.

RESISTORS

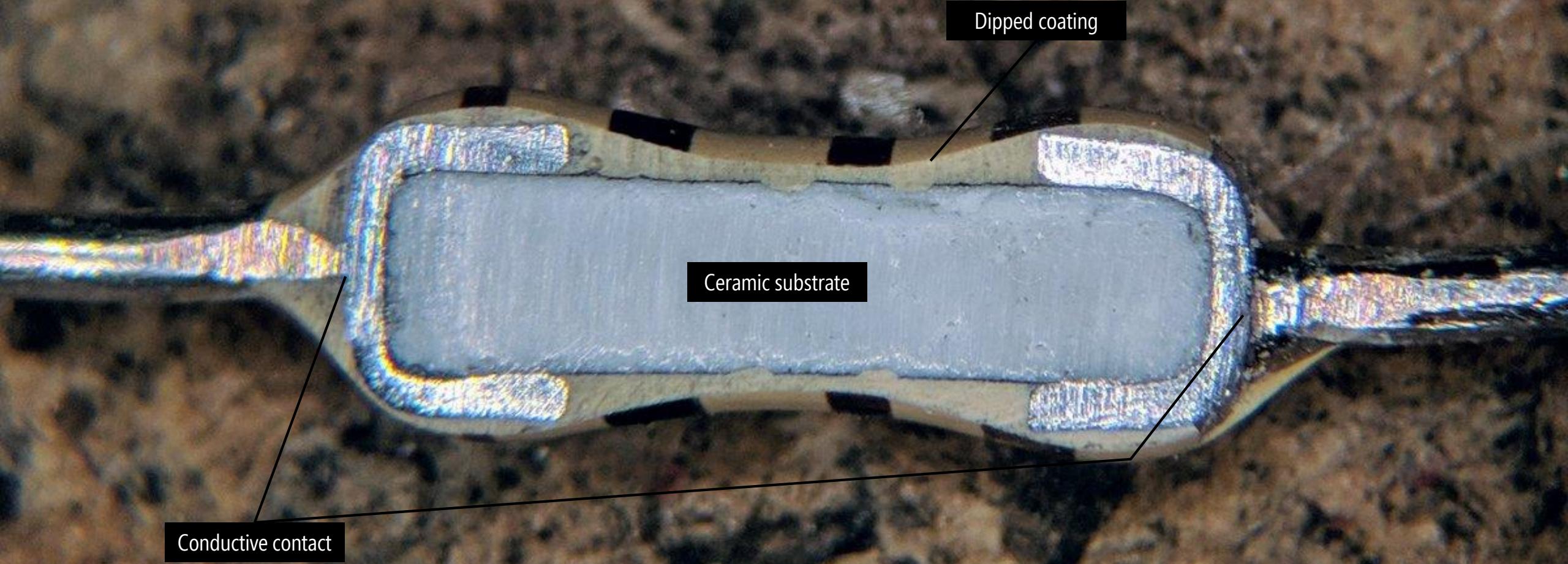
RESISTOR COMPOSITION

Resistors are composed of a thin film of conductive material wrapped around an insulating material. The more wraps, the higher resistance.



RESISTORS

RESISTOR CROSS SECTION

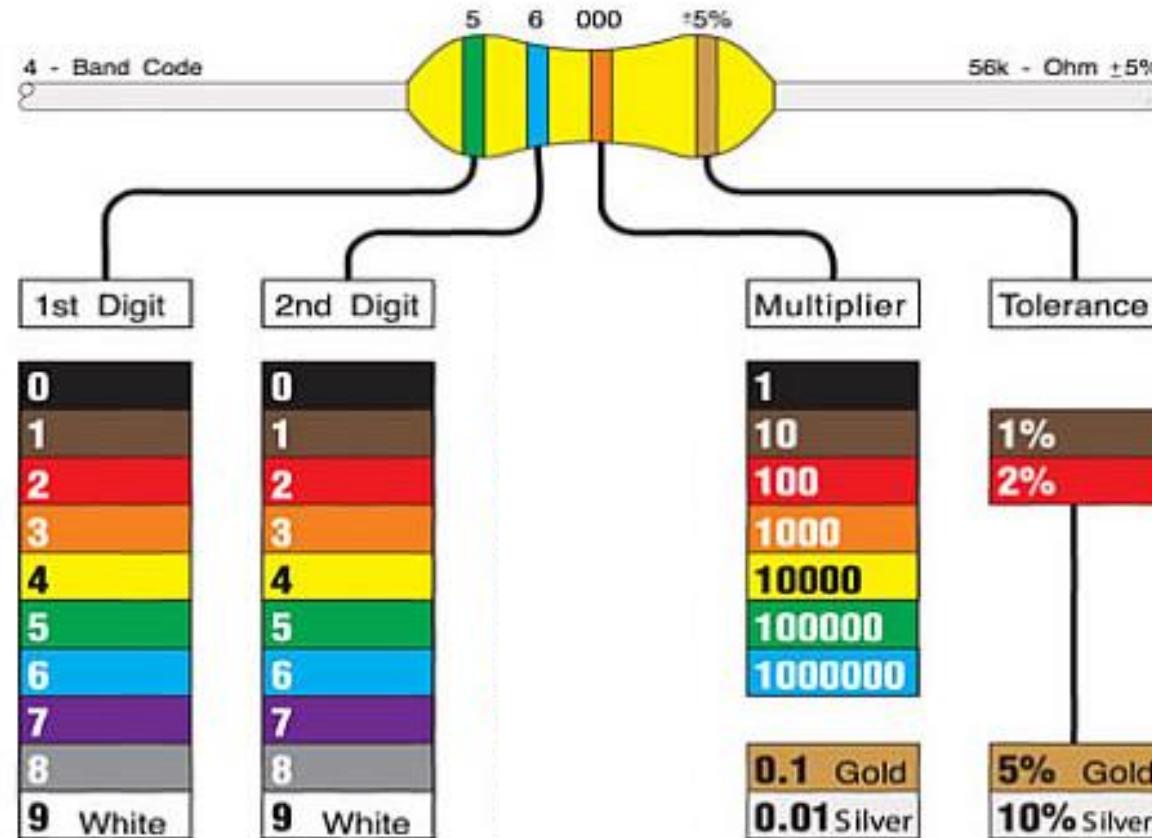


RESISTORS

READING A RESISTOR'S VALUE

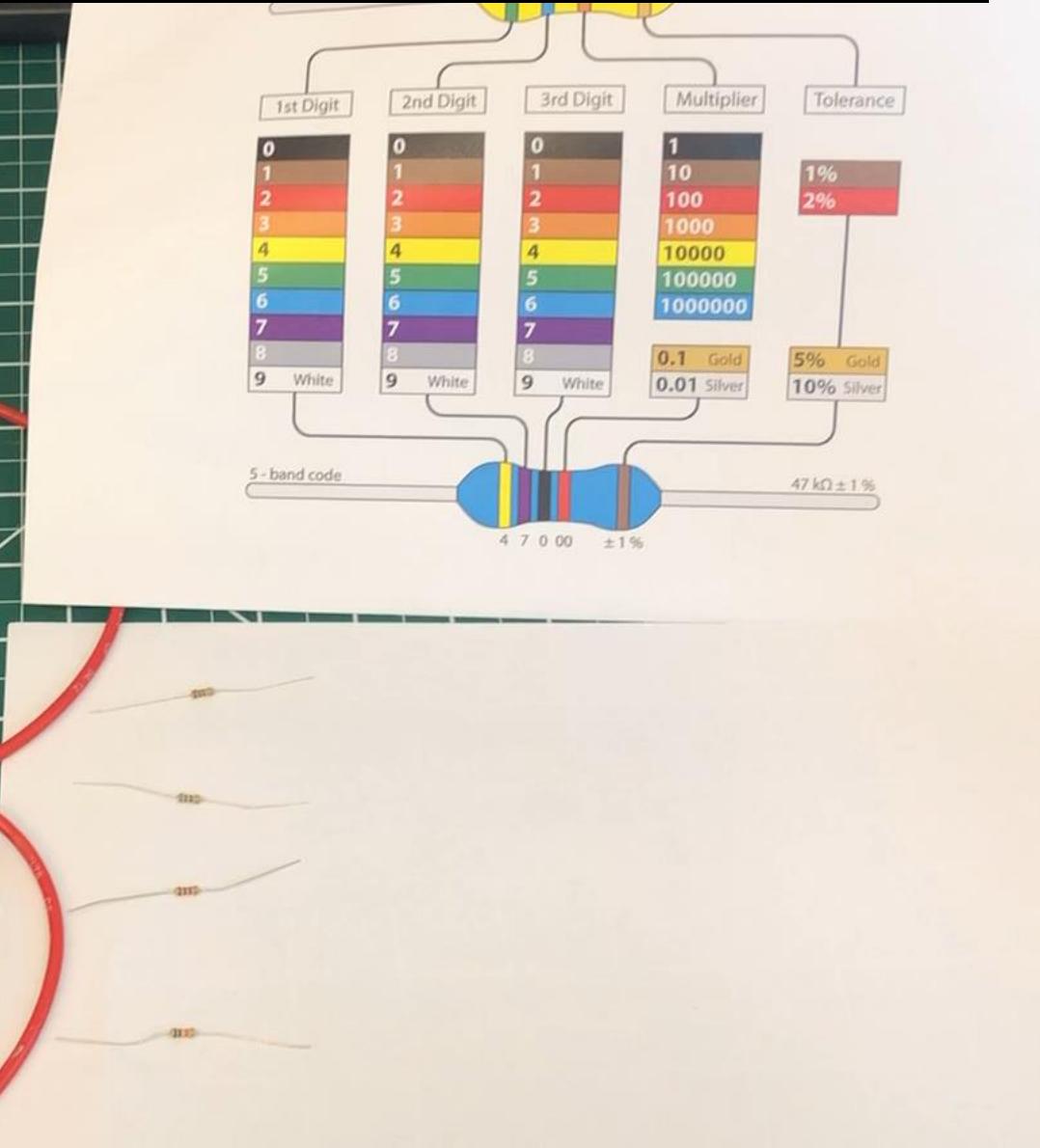
Resistors have color-coded stripes indicating their resistance value

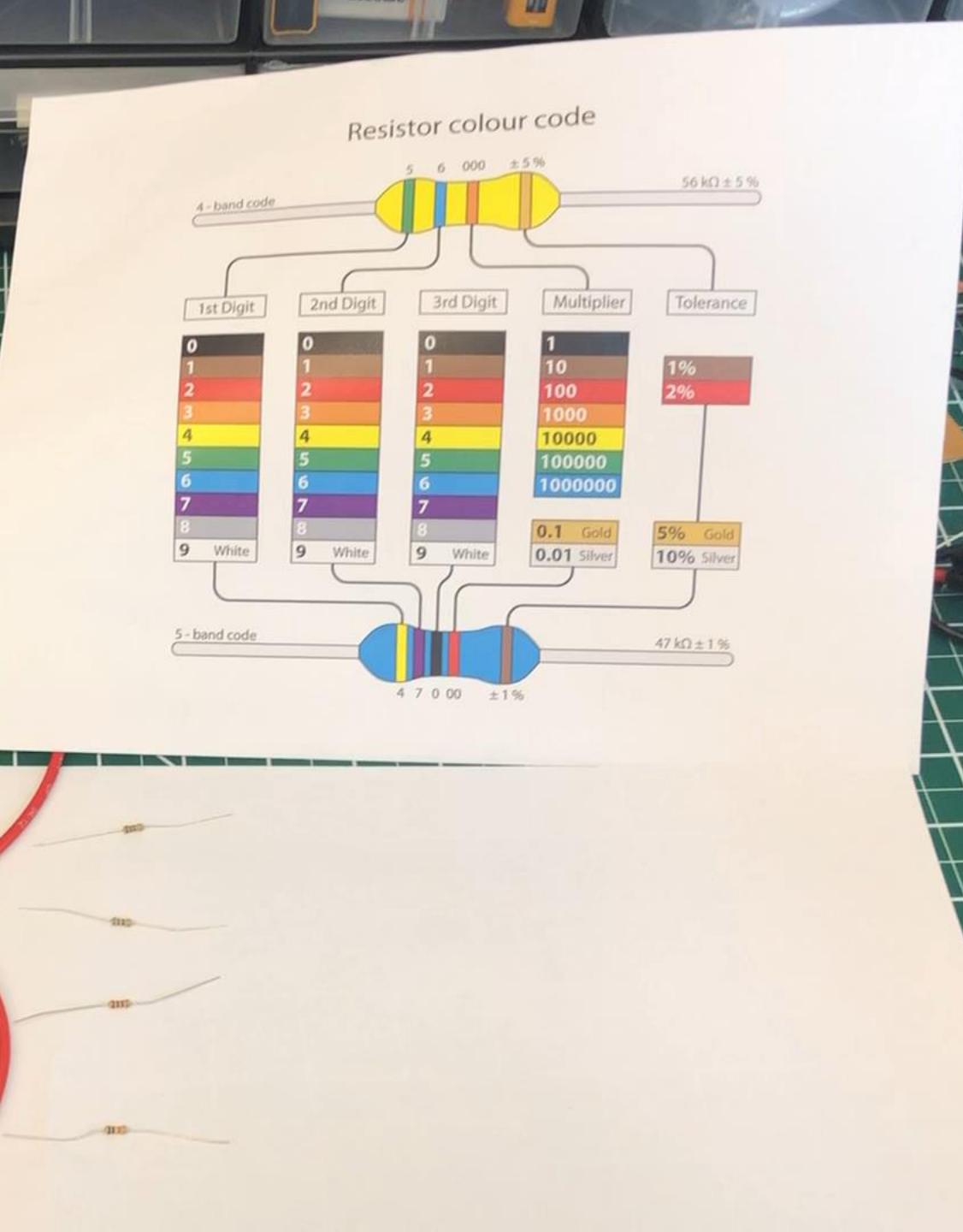
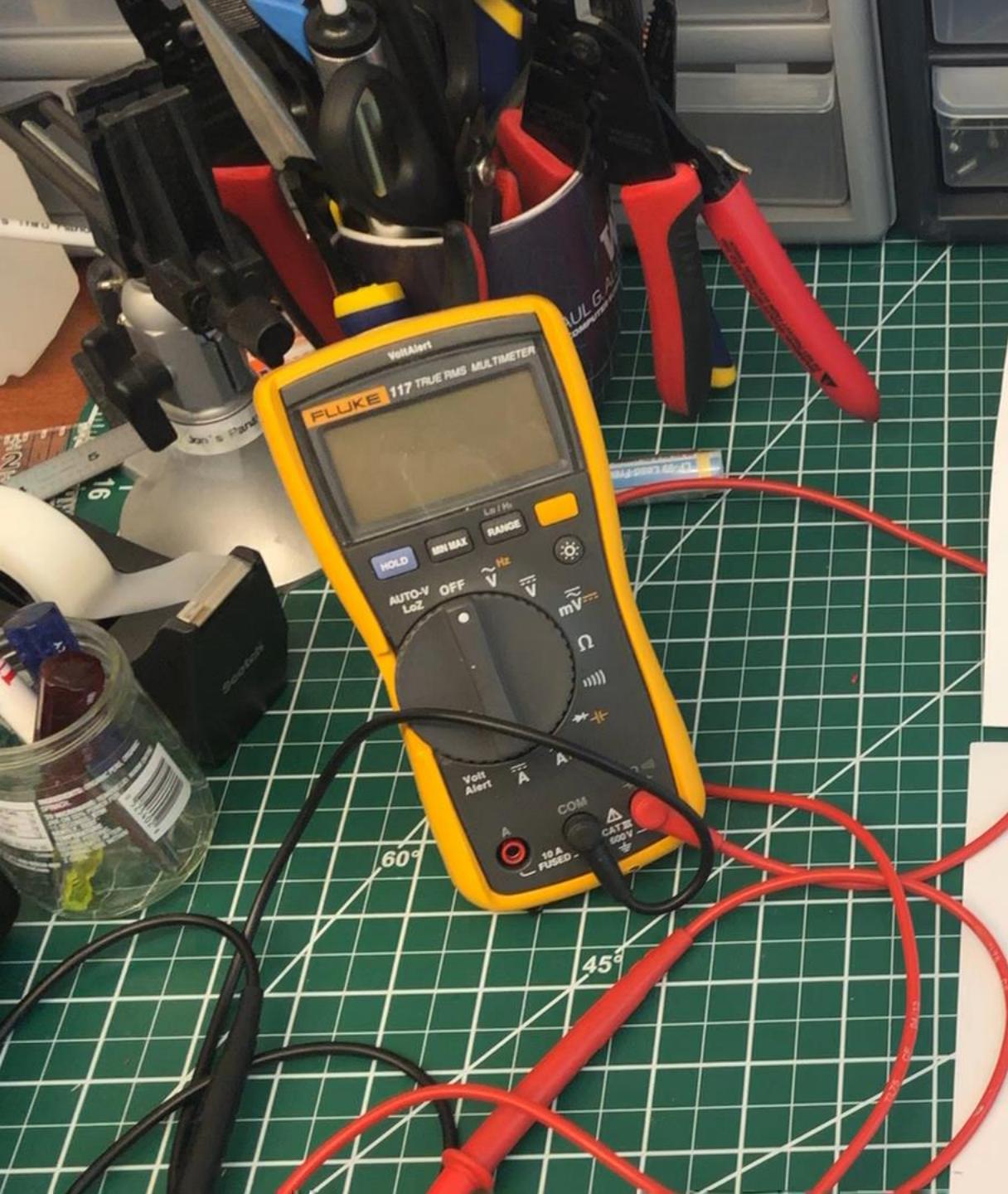
The tolerance stripe is always gold (5%) or silver (10%), which enables you to orient the resistor to read left-to-right



RESISTORS

READING A RESISTOR'S VALUE FROM THE COLOR BANDS

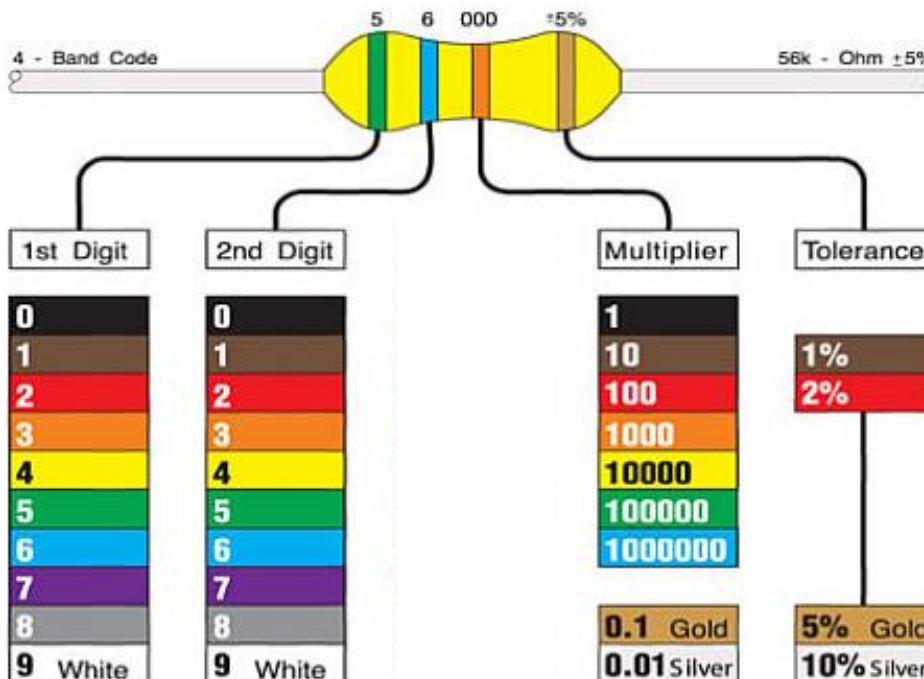




RESISTORS

EXERCISE: READING A RESISTOR'S VALUE

Resistors have color-coded stripes indicating their resistance value



What is the value of this resistor?

Red, red, brown



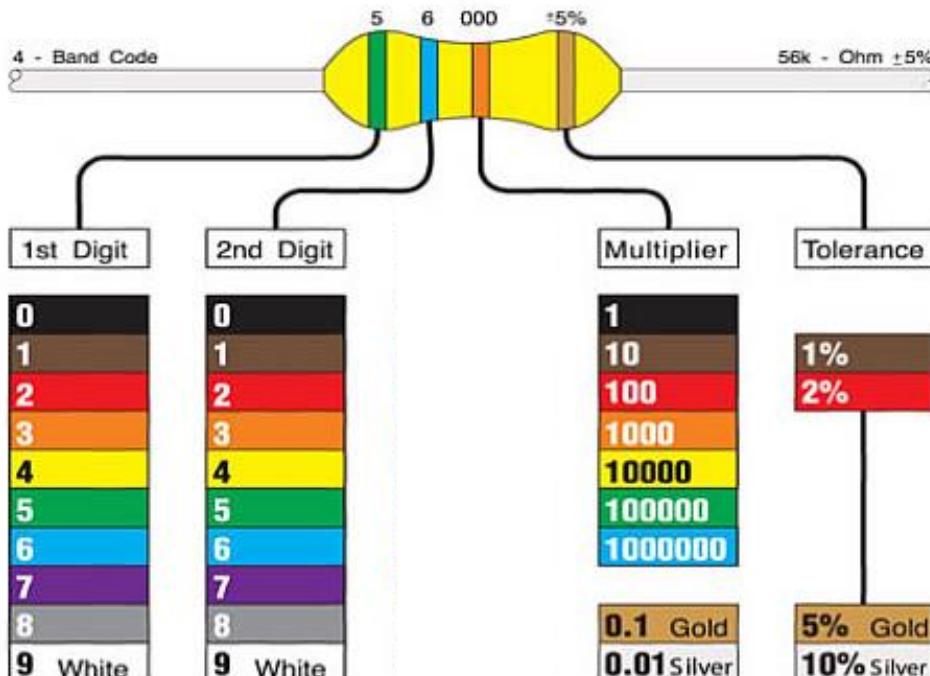
What is the value of this resistor?

Brown, black, orange



RESISTORS

READING A RESISTOR'S VALUE



What is the value of this resistor? 220Ω

Red, red, brown= 2, 2, 10 = $22 * 10 = 220\Omega$



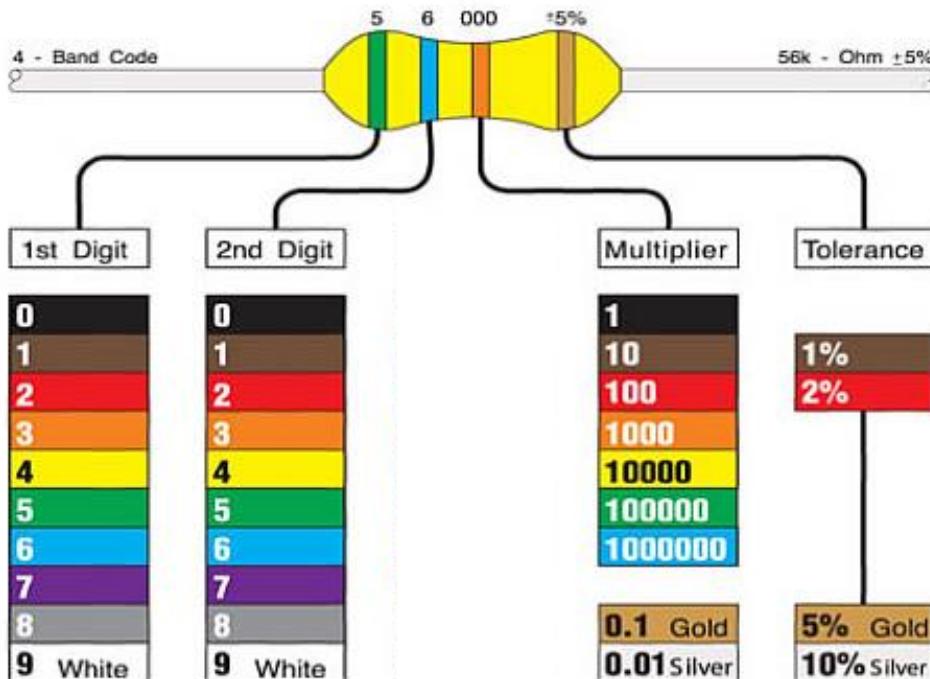
What is the value of this resistor?

Brown, black, orange, gold



RESISTORS

READING A RESISTOR'S VALUE



What is the value of this resistor? **220Ω**

Red, red, brown= 2, 2, 10 = $22 * 10 = 220\Omega$



What is the value of this resistor? **10,000Ω or 10KΩ**

Brown, black, orange, gold = 1, 0, 1000 = $10 * 1000 = 10K\Omega$



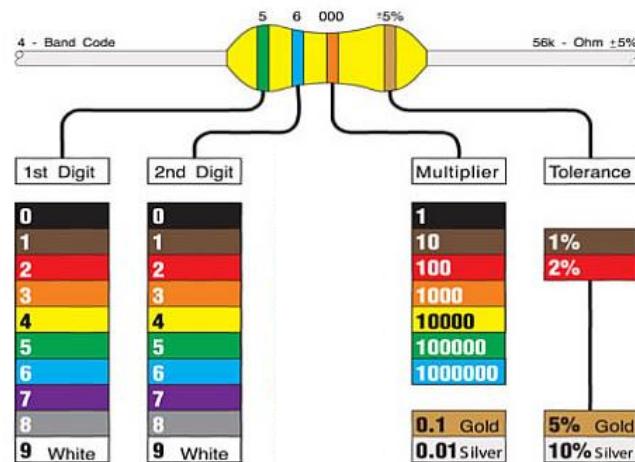
RESISTORS

READING A RESISTOR: THREE STRATEGIES



1. Keep Your Resistors Organized

I typically buy the SparkFun Resistor Kit, which comes organized by resistor value. We purchased ~10 of these for the studio.



2. Resistor Chart (or from Memory)

Obviously, you can also use a resistor chart (or your memory) but you still have to find the resistor you're looking for! ☺



3. Use a Multimeter

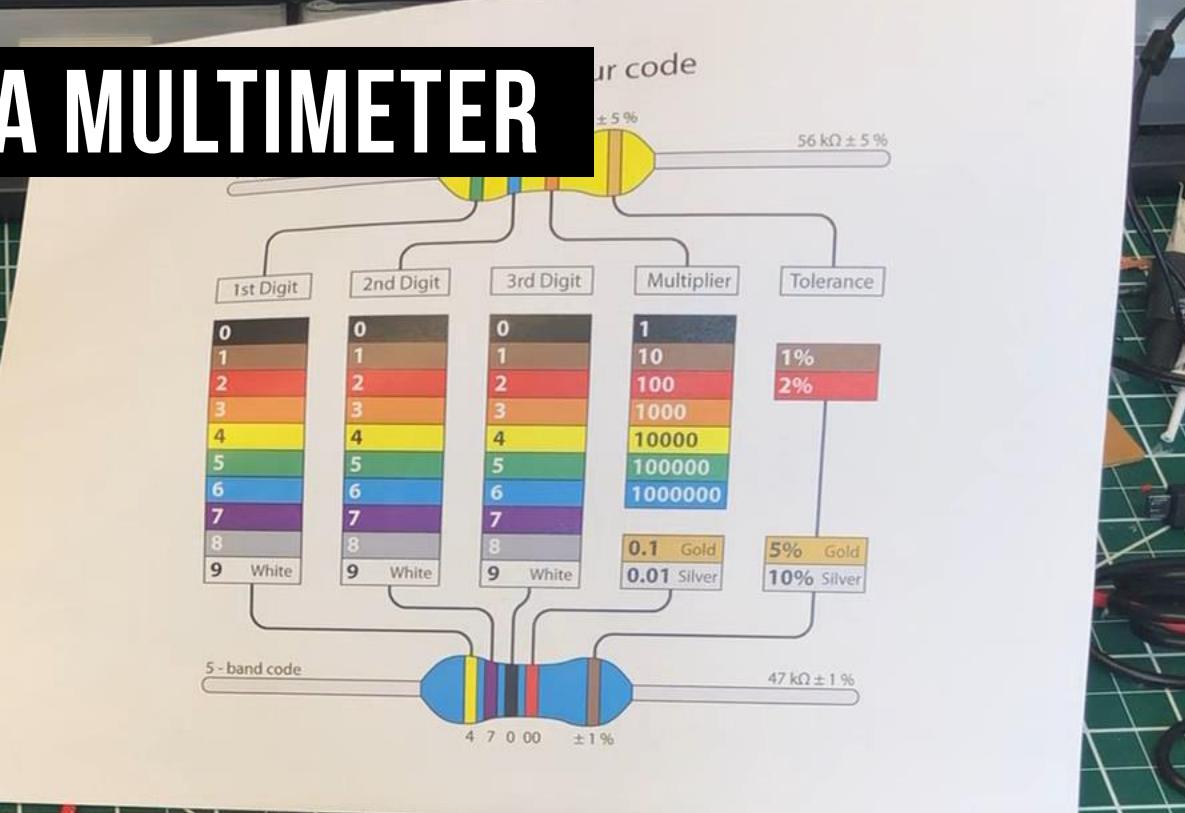
Make sure that the resistor is not connected to anything else and switch the multimeter to its resistance measurement setting

FASTEST

SLOWEST

RESISTORS

MEASURING A RESISTOR WITH A MULTIMETER



BROWN BLACK BROWN
1 0 × 10 = 100Ω

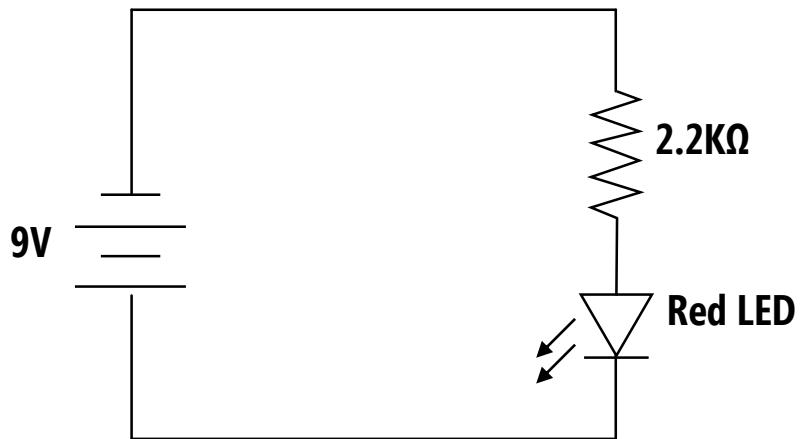
BLUE GRAY BROWN
6 8 × 10 = 680Ω

RED RED RED
2 2 × 100 = 2,200Ω 2.2kΩ

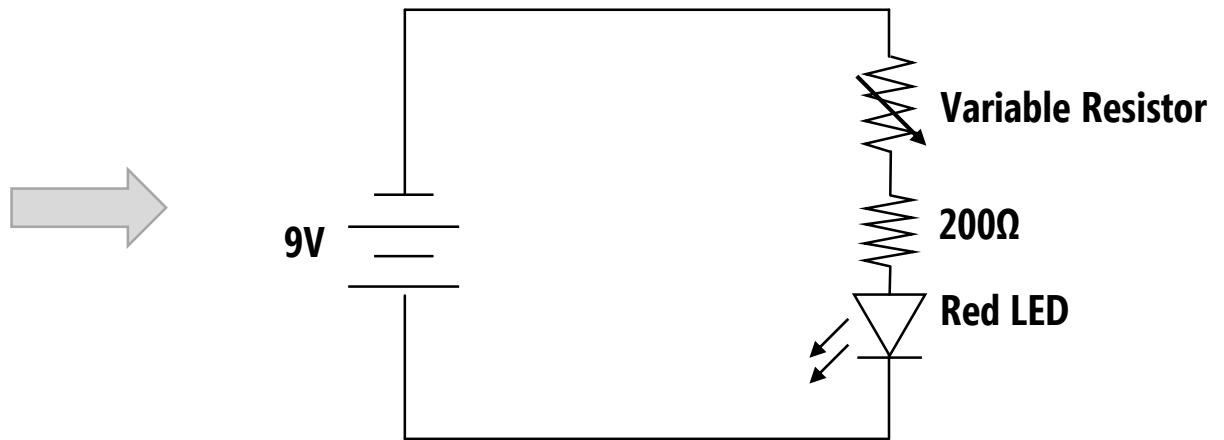
BROWN BLACK ORANGE
1 0 × 1,000 = 10,000Ω 10kΩ

ACTIVITY

BUILD YOUR 2ND CIRCUIT: VARIABLE RESISTOR + LED



BEFORE



NEW

ACTIVITY

A DIY VARIABLE RESISTOR

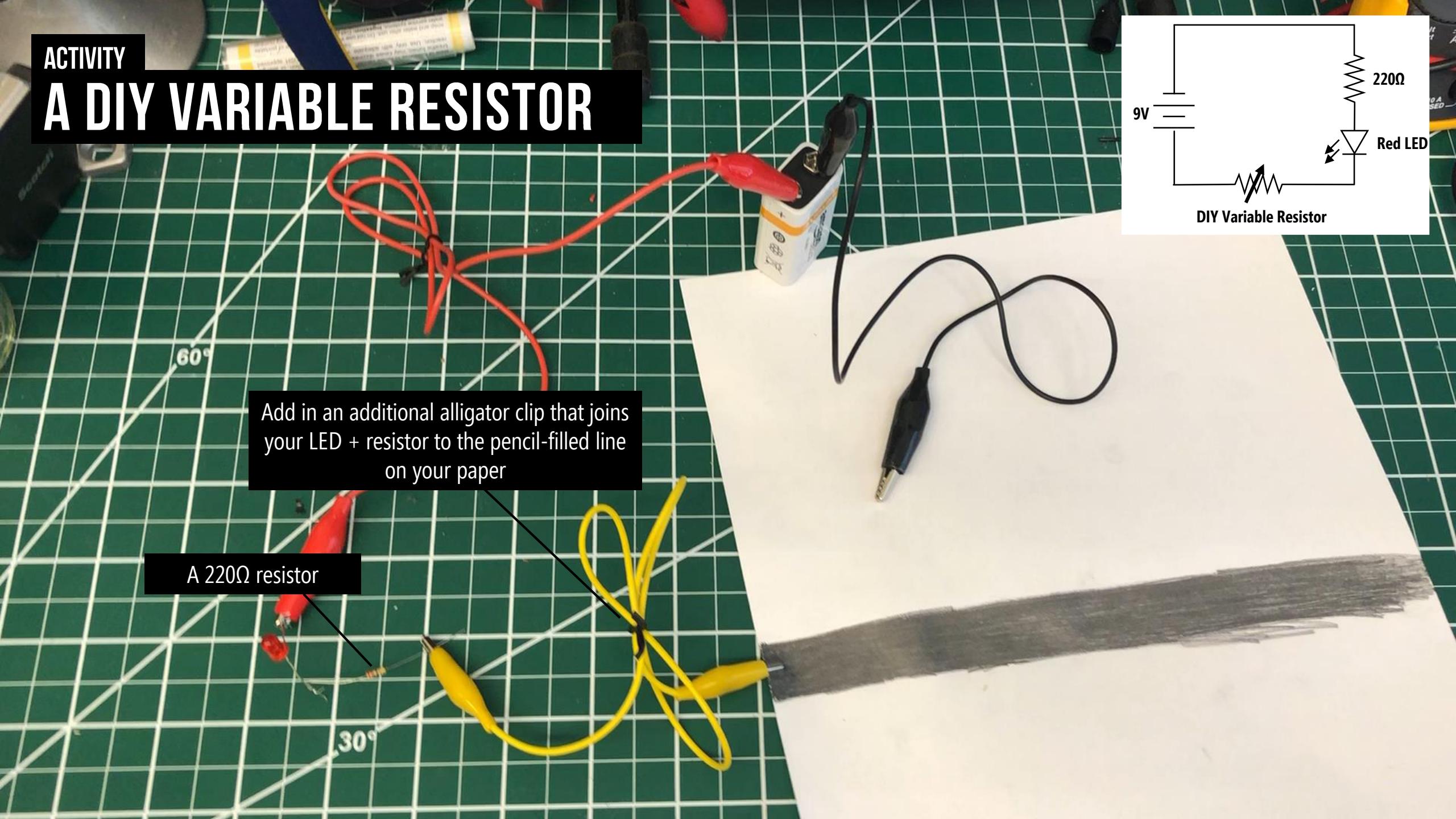
Make something that looks like this. Press hard. The more graphite, the better!

Pencil "lead" is
conductive!



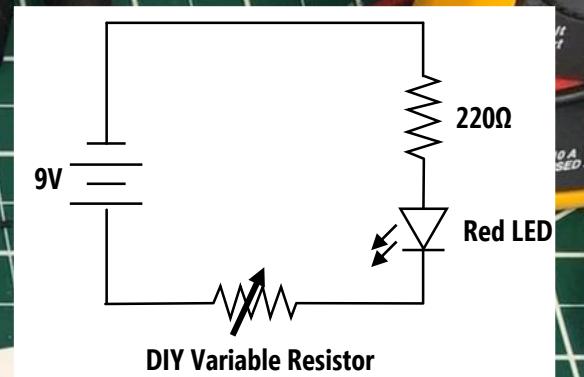
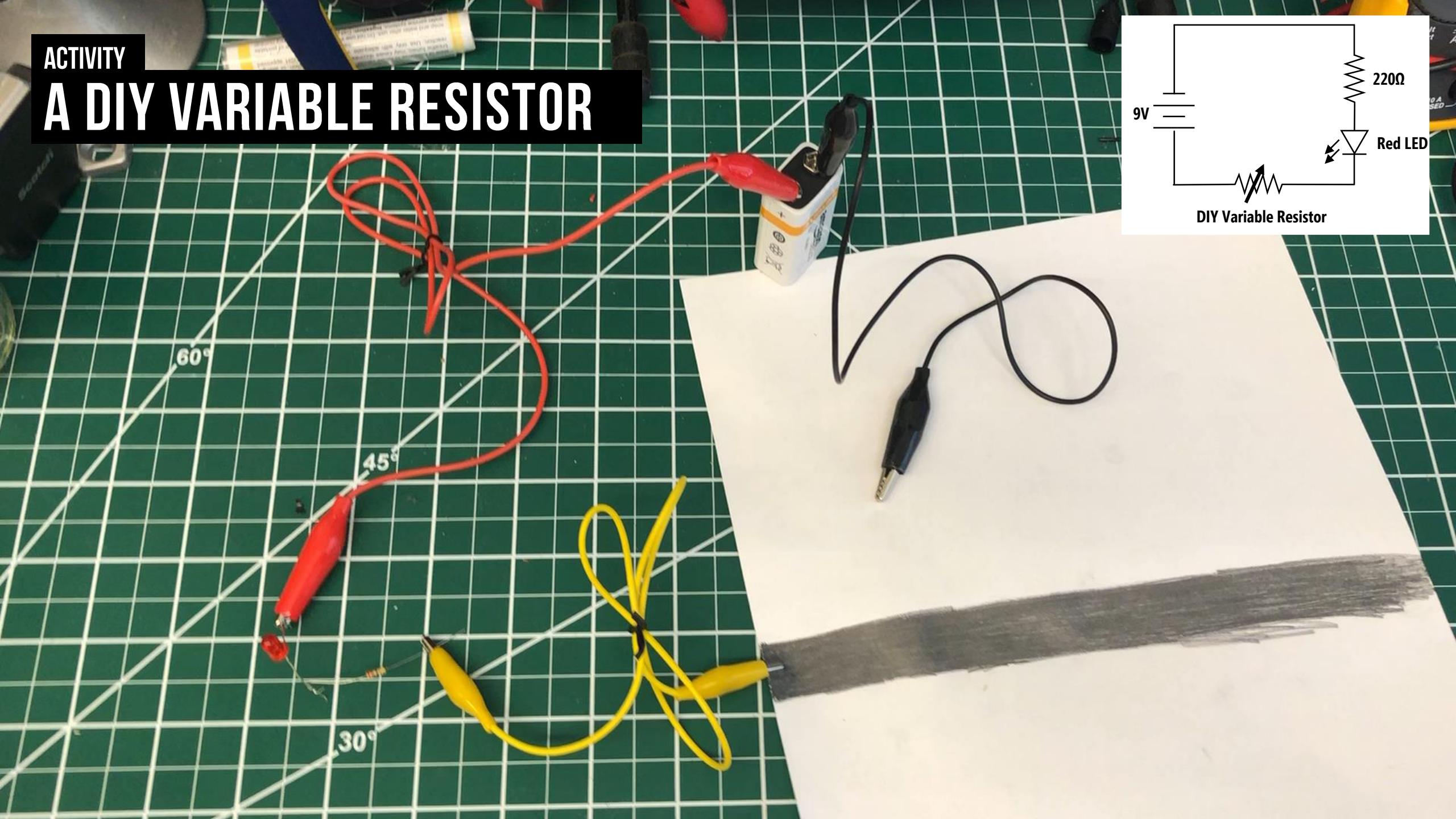
ACTIVITY

A DIY VARIABLE RESISTOR



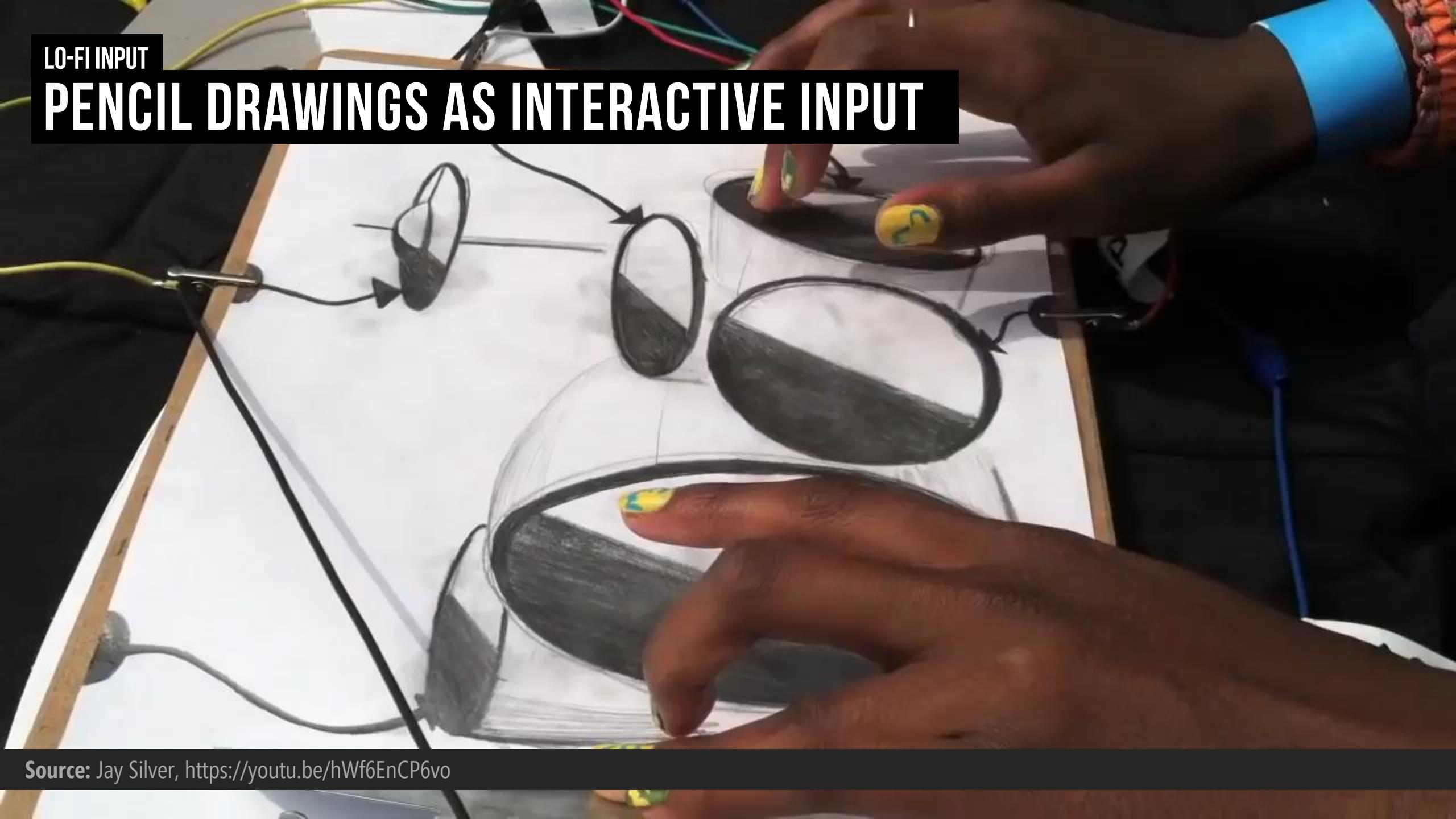
ACTIVITY

A DIY VARIABLE RESISTOR



LO-FI INPUT

PENCIL DRAWINGS AS INTERACTIVE INPUT



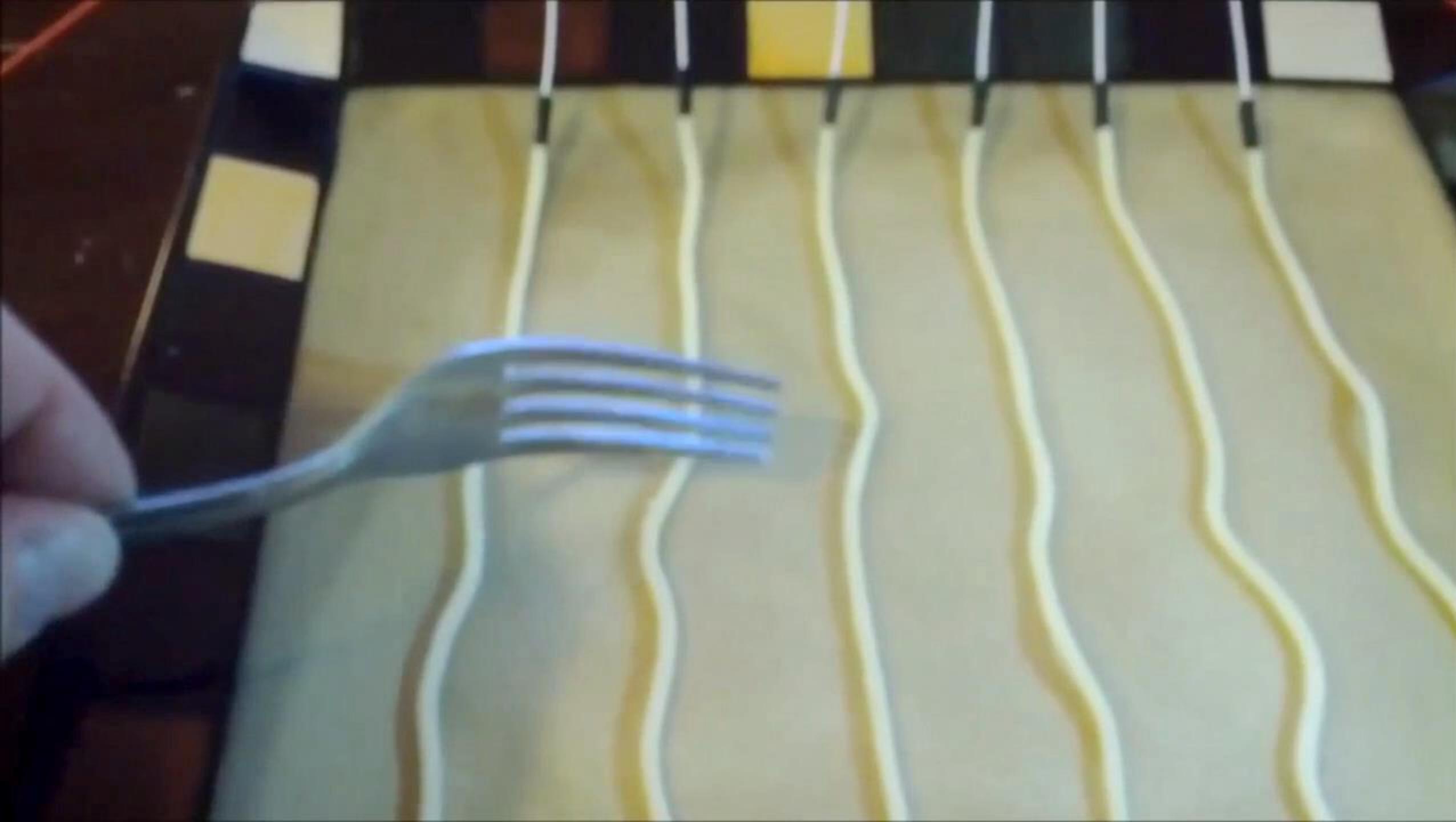
Source: Jay Silver, <https://youtu.be/hWf6EnCP6vo>

LO-FI INPUT

PENCIL DRAWINGS AS INTERACTIVE INPUT



Richard Johnson, CMSC838f student, 2014



VARIABLE RESISTORS

LOTS OF DIFFERENT KINDS OF VARIABLE RESISTORS



Potentiometer 10k; \$0.95*



Touch Membrane
Potentiometer; \$12.95



Photocell (aka photodetector
or photo resistor); \$1.50



Thermistor 10k; \$0.75



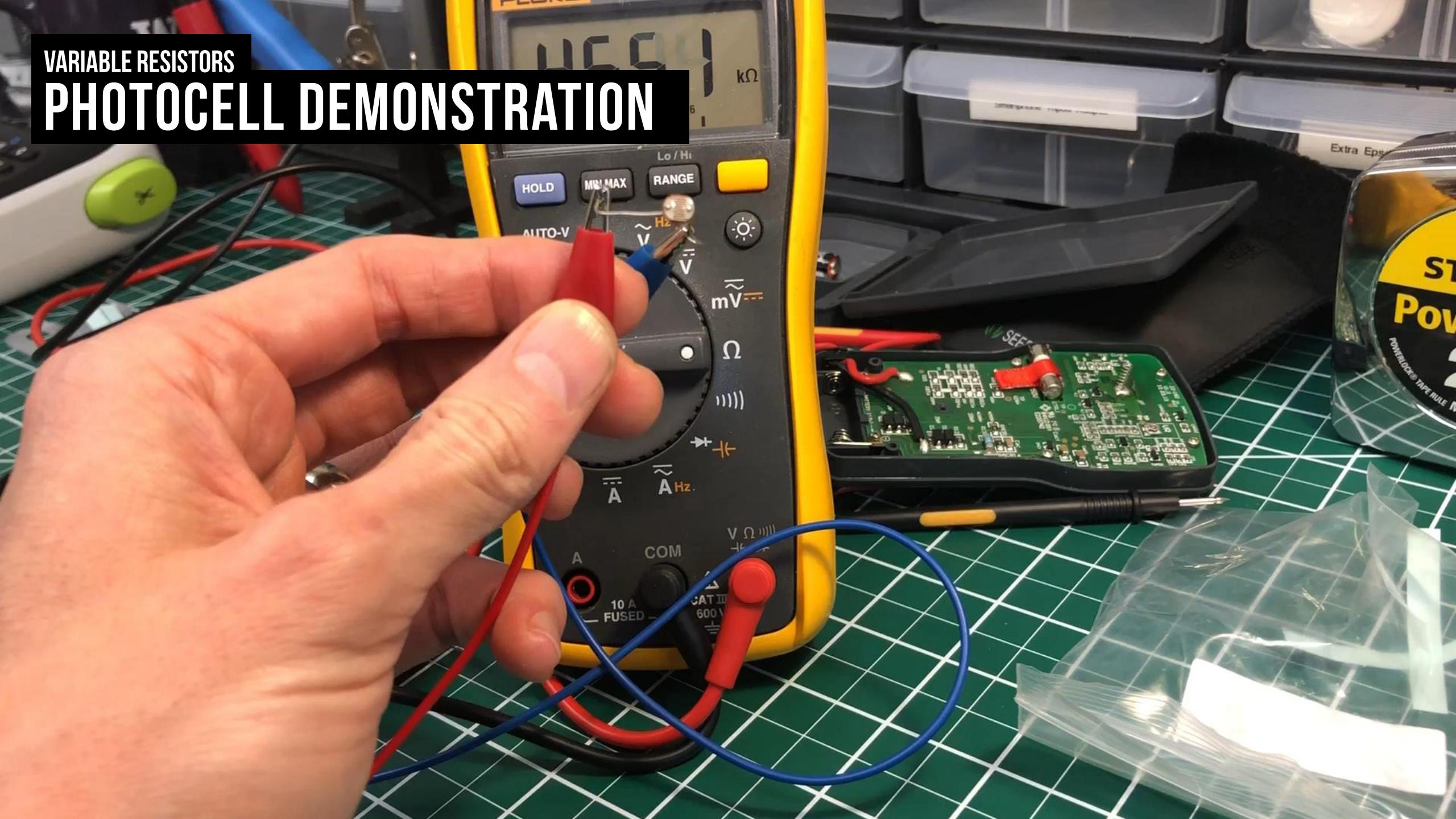
Force Resistive Sensor
0.5"; \$6.95

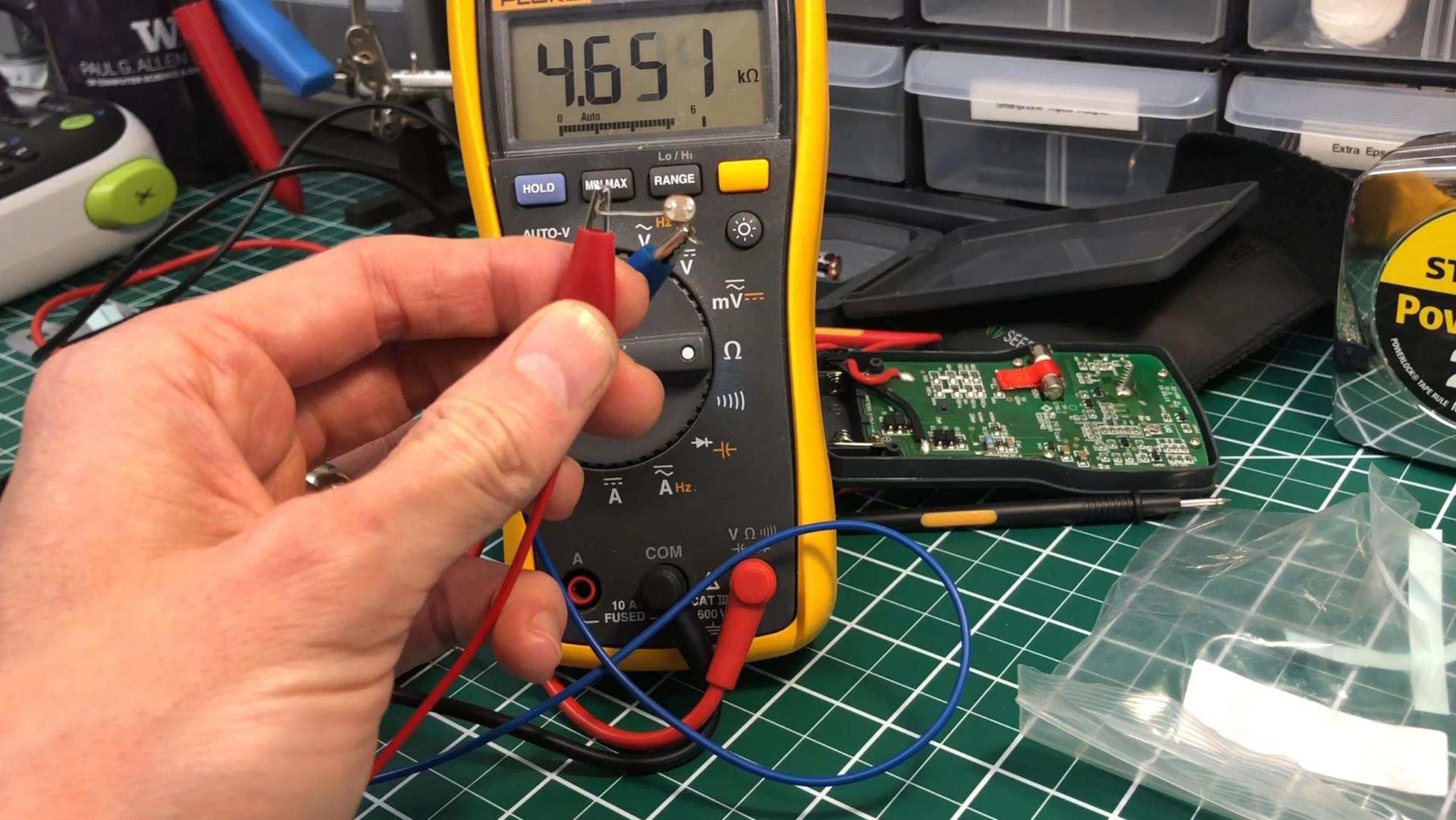


Flex Sensor 4.5"; \$12.95

VARIABLE RESISTORS

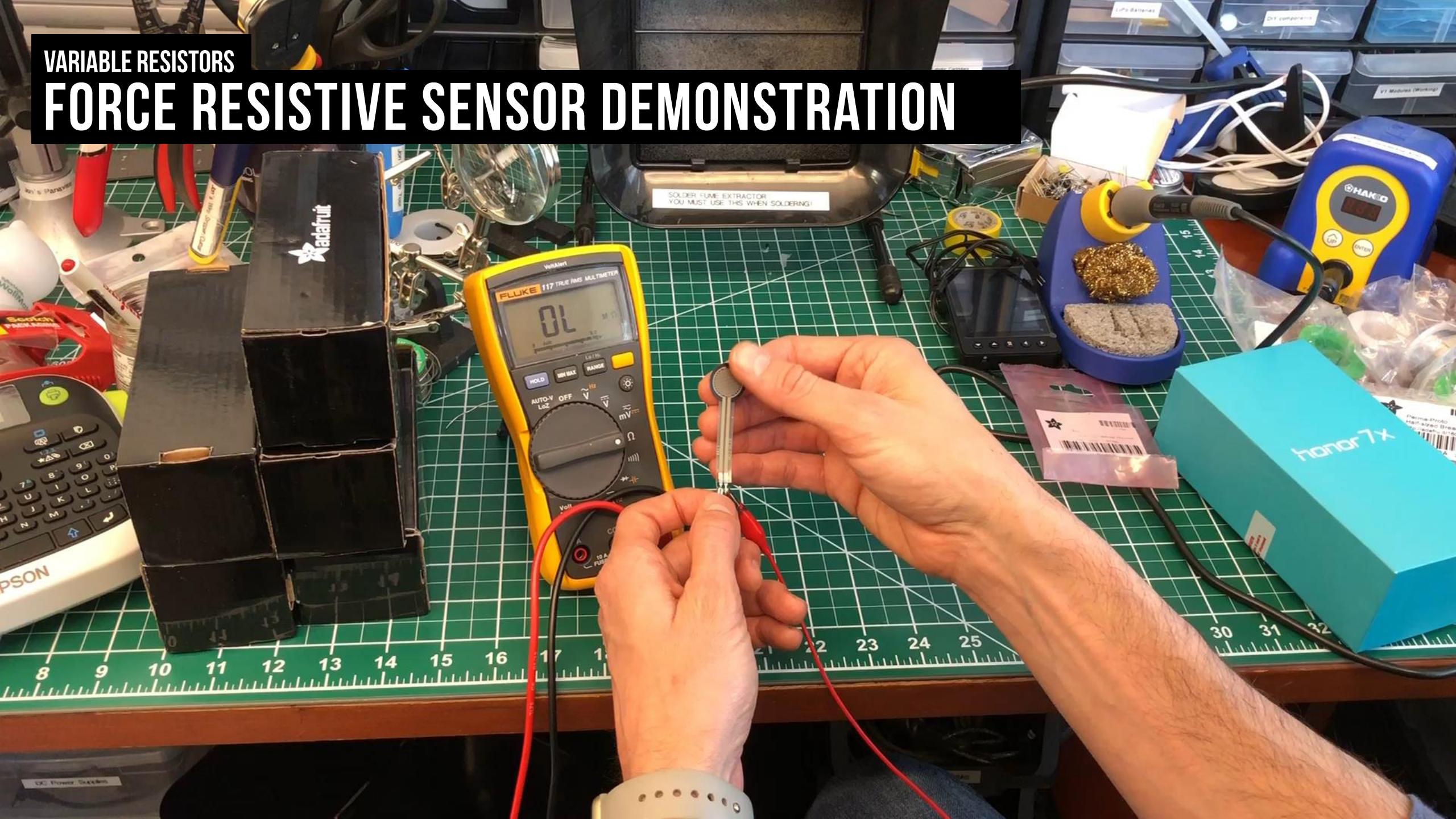
PHOTOCELL DEMONSTRATION

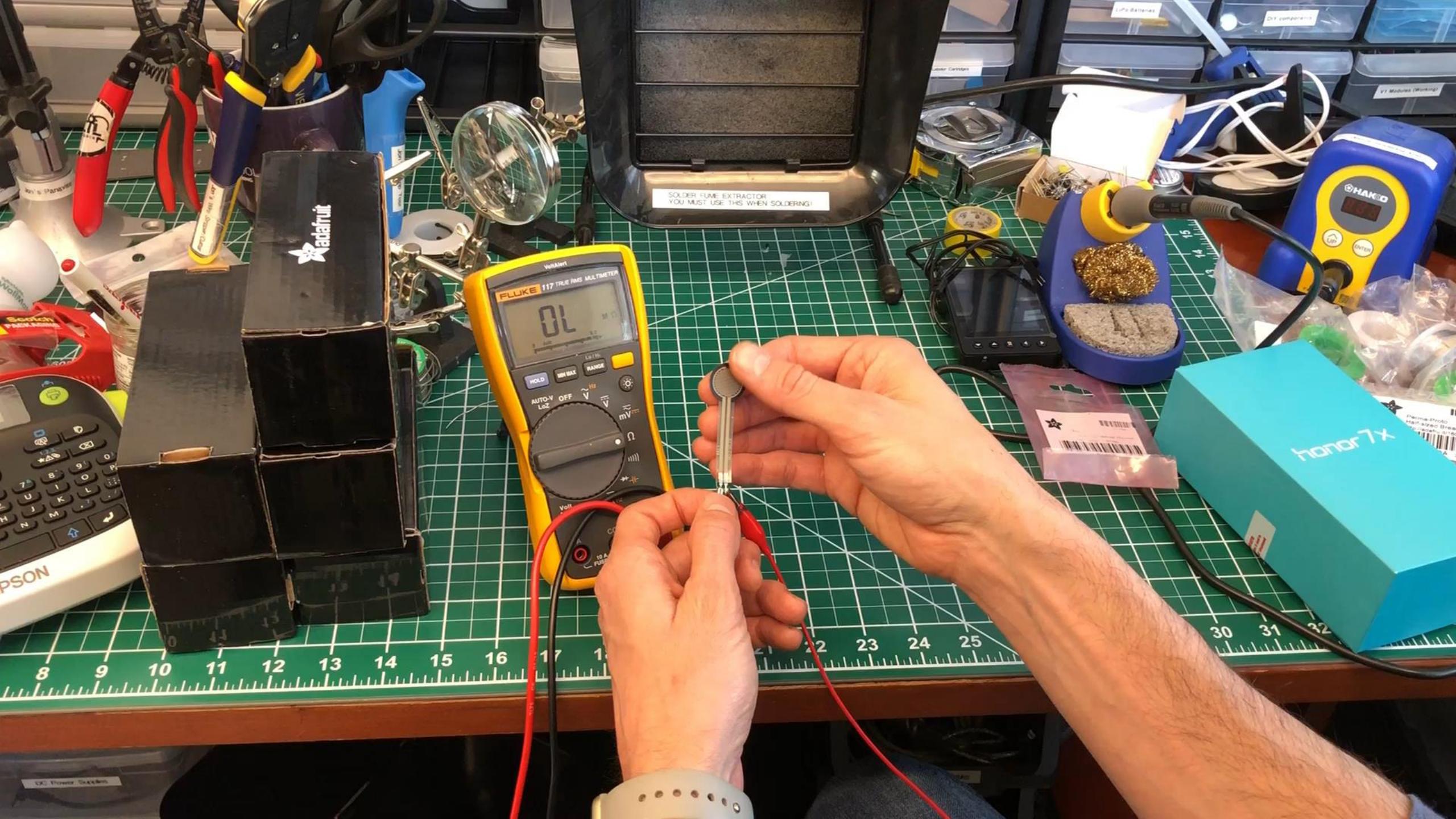




VARIABLE RESISTORS

FORCE RESISTIVE SENSOR DEMONSTRATION



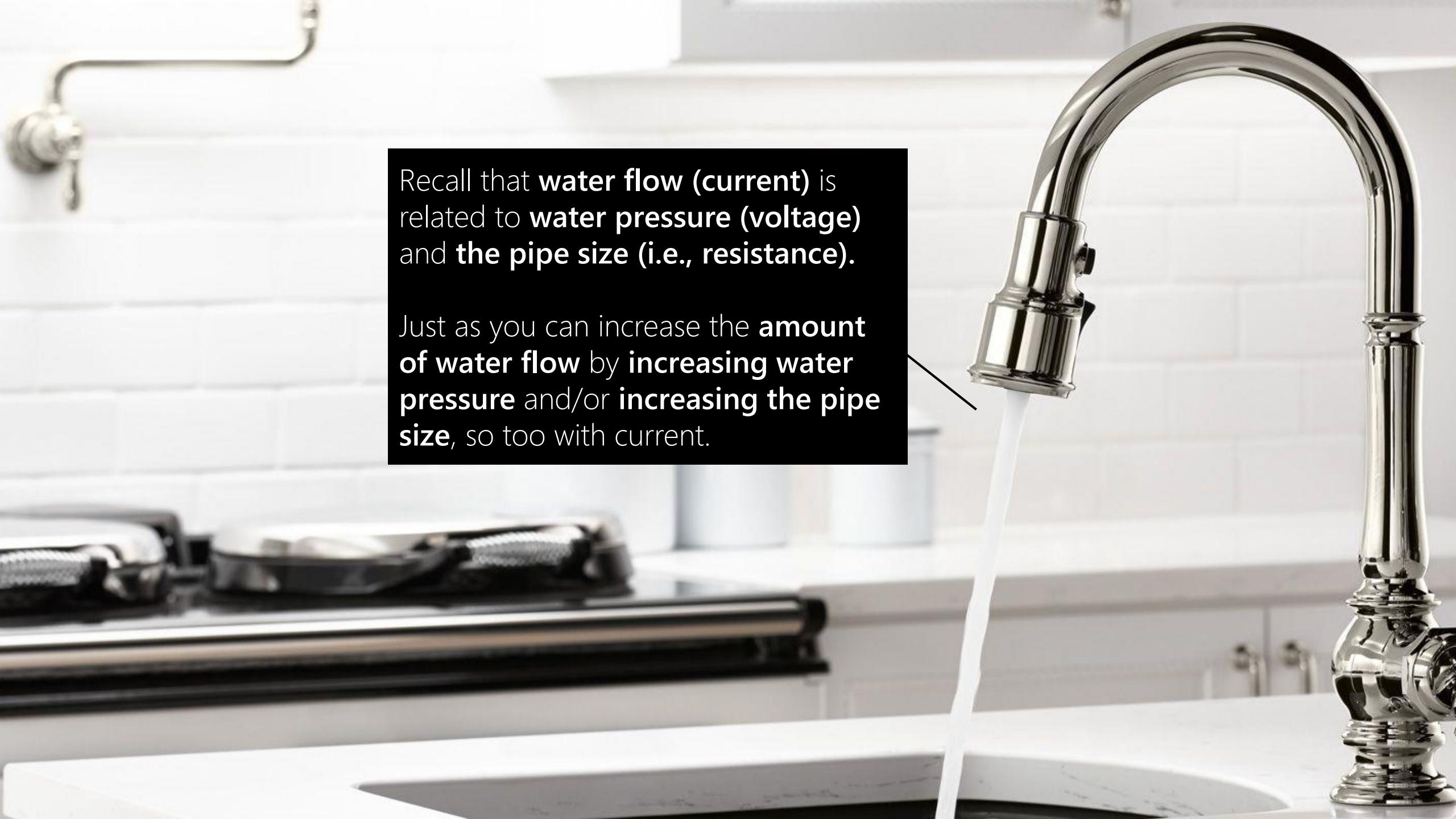


But how do we know how much **current** (measured in **amps**) is flowing through our circuit? And **why do we care?**



Recall that **water flow (current)** is related to **water pressure (voltage)** and **the pipe size (i.e., resistance)**



A close-up photograph of a chrome kitchen faucet. The faucet has a tall, ornate spout and a matching handle. Water is flowing from the spout. In the background, a white ceramic sink and some kitchen tiles are visible.

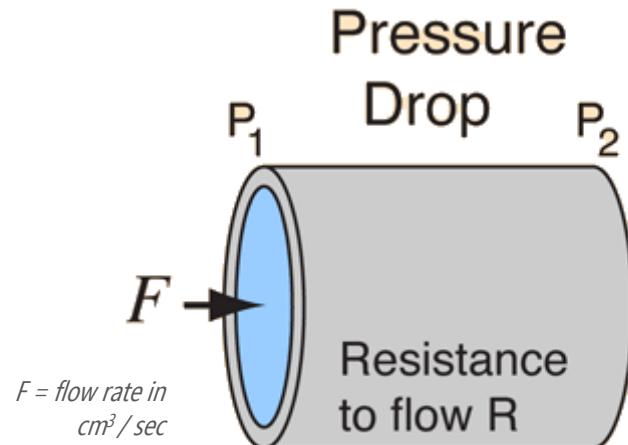
Recall that **water flow (current)** is related to **water pressure (voltage)** and **the pipe size (i.e., resistance)**.

Just as you can increase the **amount of water flow** by **increasing water pressure** and/or **increasing the pipe size**, so too with current.

OHM'S LAW

OHM'S LAW

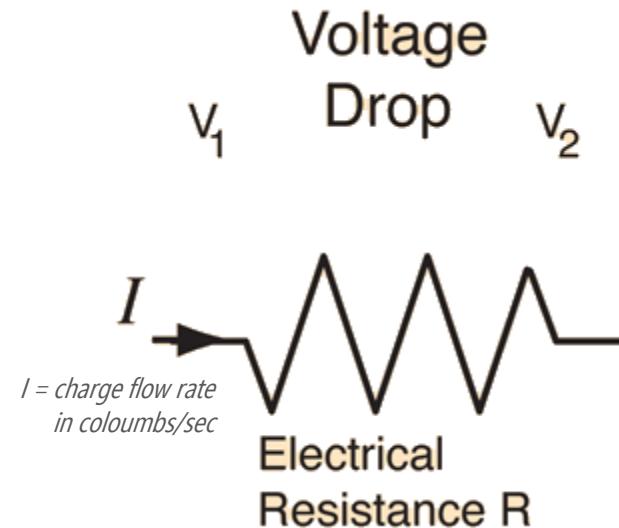
Current is linearly proportional to the amount of voltage and resistance in circuit



$$F = \frac{P_1 - P_2}{R}$$



Poiseuille's Law for fluids
circa ~1838



$$I = \frac{V_1 - V_2}{R}$$

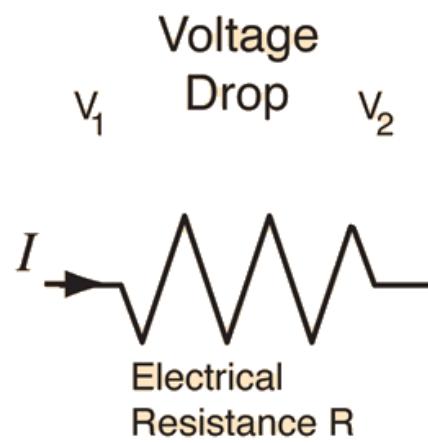
Ohm's Law for electric circuits
circa ~1825



OHM'S LAW

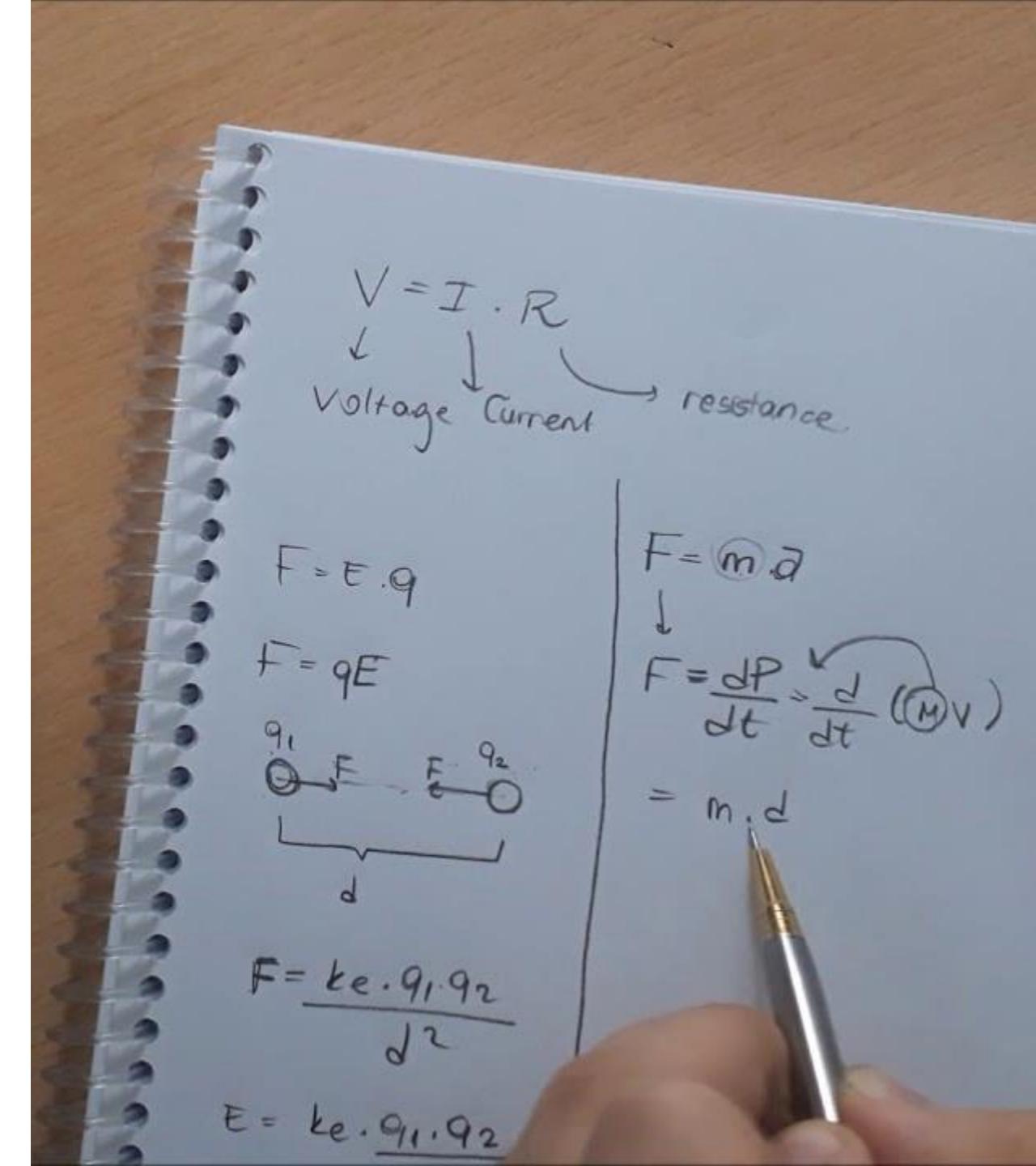
DIGGING INTO OHM'S LAW

Let's get out a pencil & paper ☺



$$I = \frac{V_1 - V_2}{R}$$

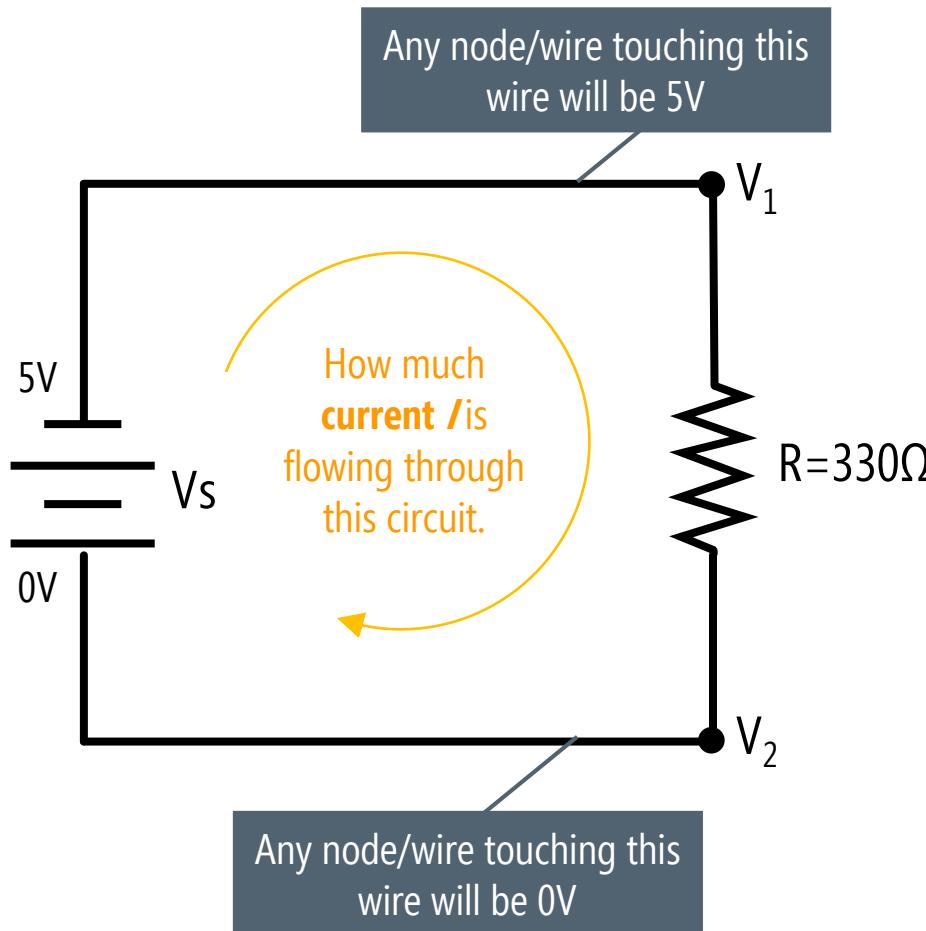
Ohm's Law for electric circuits





OHM'S LAW

OHM'S LAW EXERCISE: SOLVE FOR CURRENT

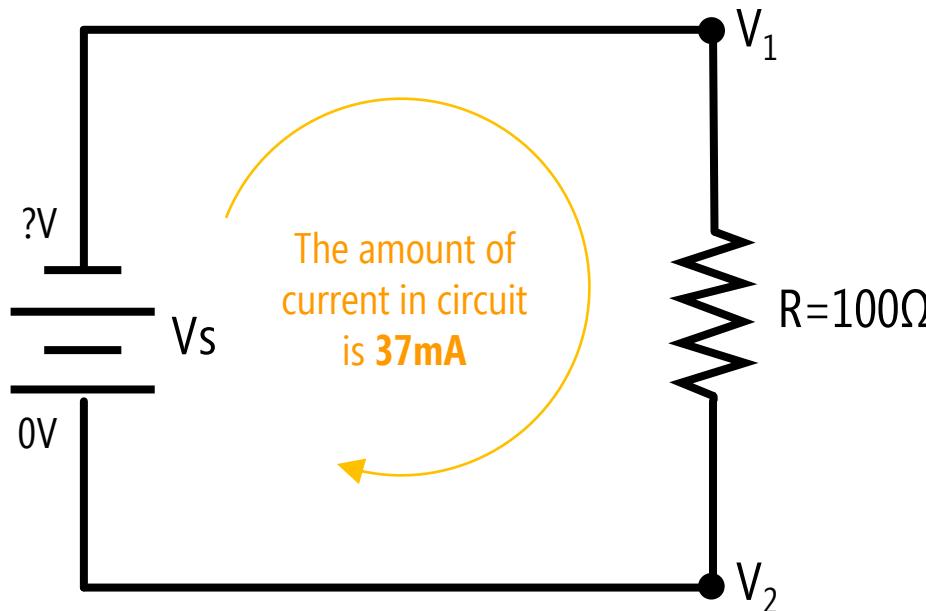


$$\text{Current} = I = \frac{V_{\text{high potential}} - V_{\text{low potential}}}{R}$$

$$\text{Current} = I = \frac{5V - 0V}{330\Omega}$$

$$\text{Current} = I = 0.015A = 15mA$$

OHM'S LAW EXERCISE: SOLVE FOR VOLTAGE



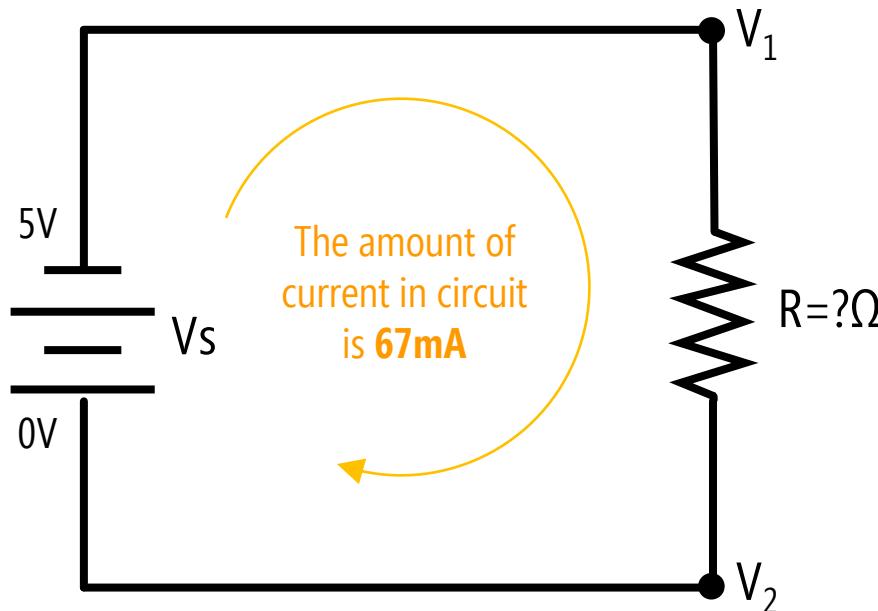
$$\text{Current} = I = \frac{V_{\text{high potential}} - V_{\text{low potential}}}{R}$$

$$\text{Voltage} = V = I * R$$

$$\text{Voltage} = V = 0.037A * 100\Omega = 3.7V$$

OHM'S LAW

OHM'S LAW EXERCISE: SOLVE FOR RESISTANCE



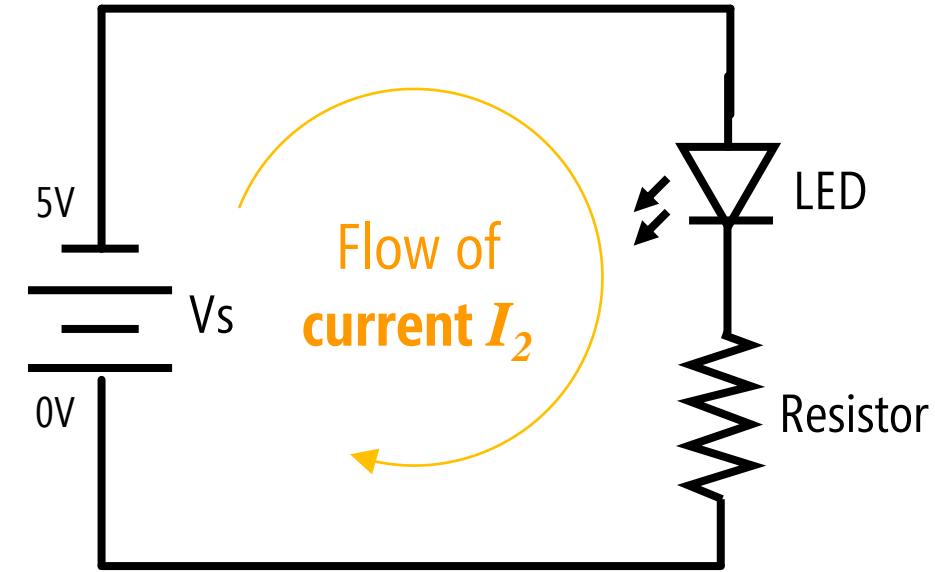
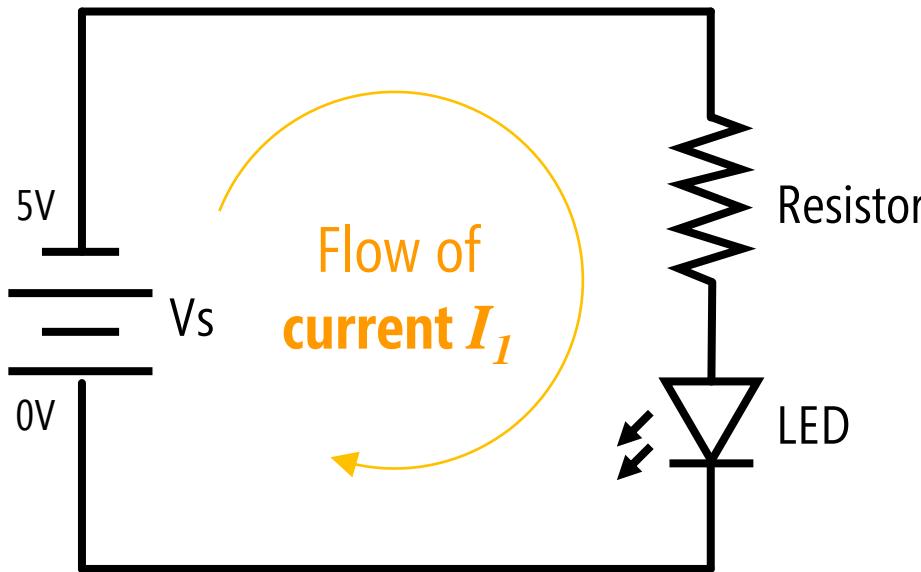
$$\text{Current} = I = \frac{V_{\text{high potential}} - V_{\text{low potential}}}{R}$$

$$\text{Resistance} = R = \frac{V}{I}$$

$$\text{Resistance} = R = \frac{5V}{0.067A} = 74.6\Omega$$

WHAT'S THE DIFFERENCE?

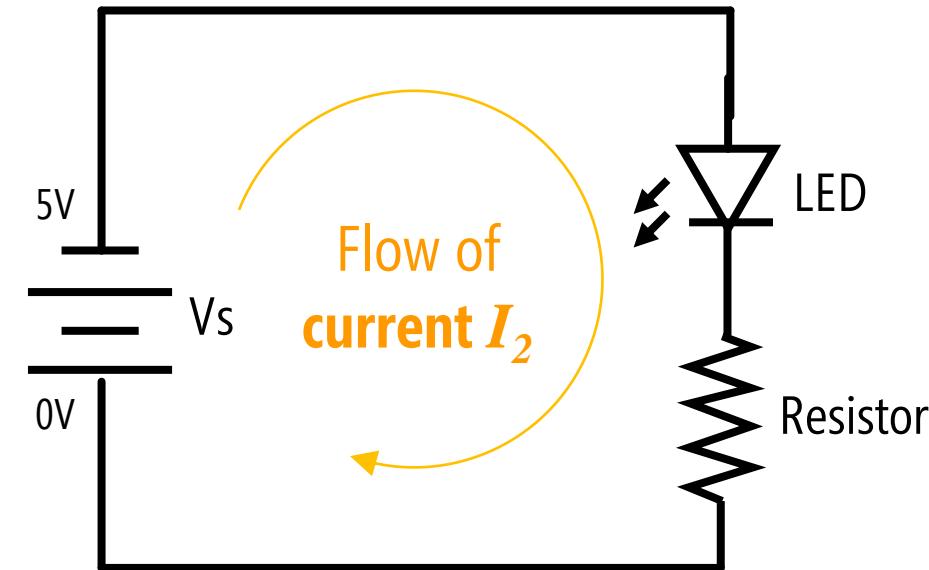
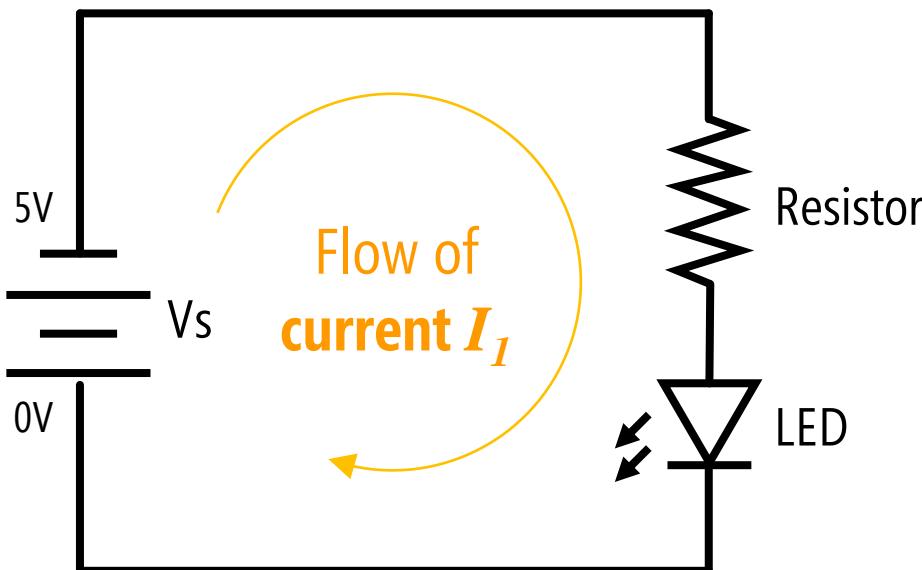
Can we put a current limiting resistor after the LED instead of before in this circuit? Is there a difference? Why or why not.



WHAT'S THE DIFFERENCE?

Can we put a current limiting resistor after the LED instead of before in this circuit?

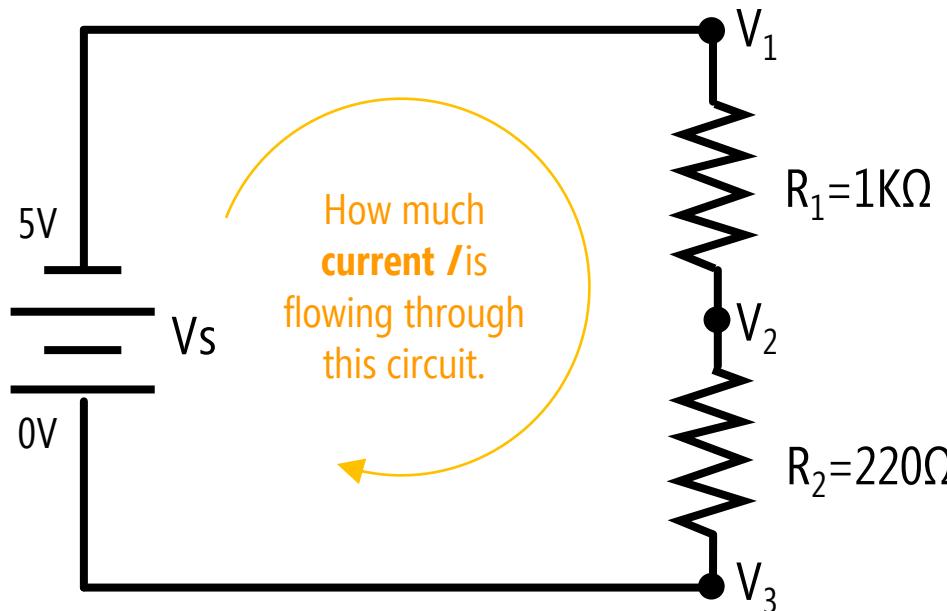
Yes! There is no difference. $I_1 = I_2$. Why? Think about Ohm's Law. The same current flows through all components in a series circuit.



SERIES VS. PARALLEL RESISTANCE

OHM'S LAW EXERCISE: RESISTORS IN SERIES

We sum resistors in series. Solve for current.



$$\text{Current} = I = \frac{V_{\text{high potential}} - V_{\text{low potential}}}{R}$$

$$\text{Current} = I = \frac{V_{\text{high potential}} - V_{\text{low potential}}}{R_1 + R_2}$$

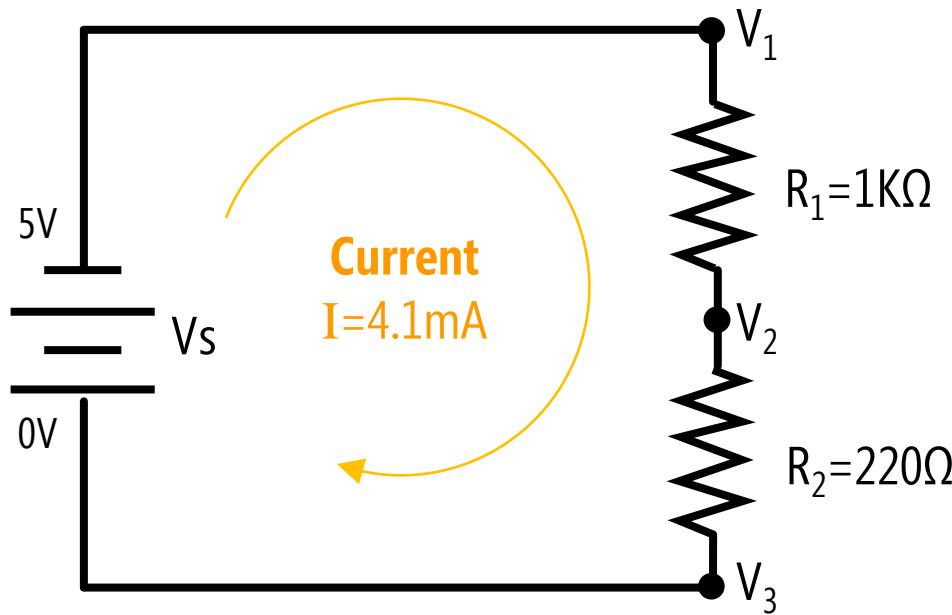
$$\text{Current} = I = \frac{5V - 0V}{1,000\Omega + 220\Omega}$$

$$\text{Current} = I = 0.0041A = 4.1mA$$

SERIES VS. PARALLEL RESISTANCE

OHM'S LAW EXERCISE: SOLVE FOR V1, V2, AND V3

How would you calculate the voltage drop over R_1 ?



$$\text{Current} = I = \frac{V_{\text{high potential}} - V_{\text{low potential}}}{R}$$

$$V_1 - V_2 = I * R_1$$

$$V_2 = V_1 - I * R_1 \quad \text{And we know } V_1 = 5\text{V}, I = 4.1\text{mA}, \& R_1 = 1\text{K}\Omega$$

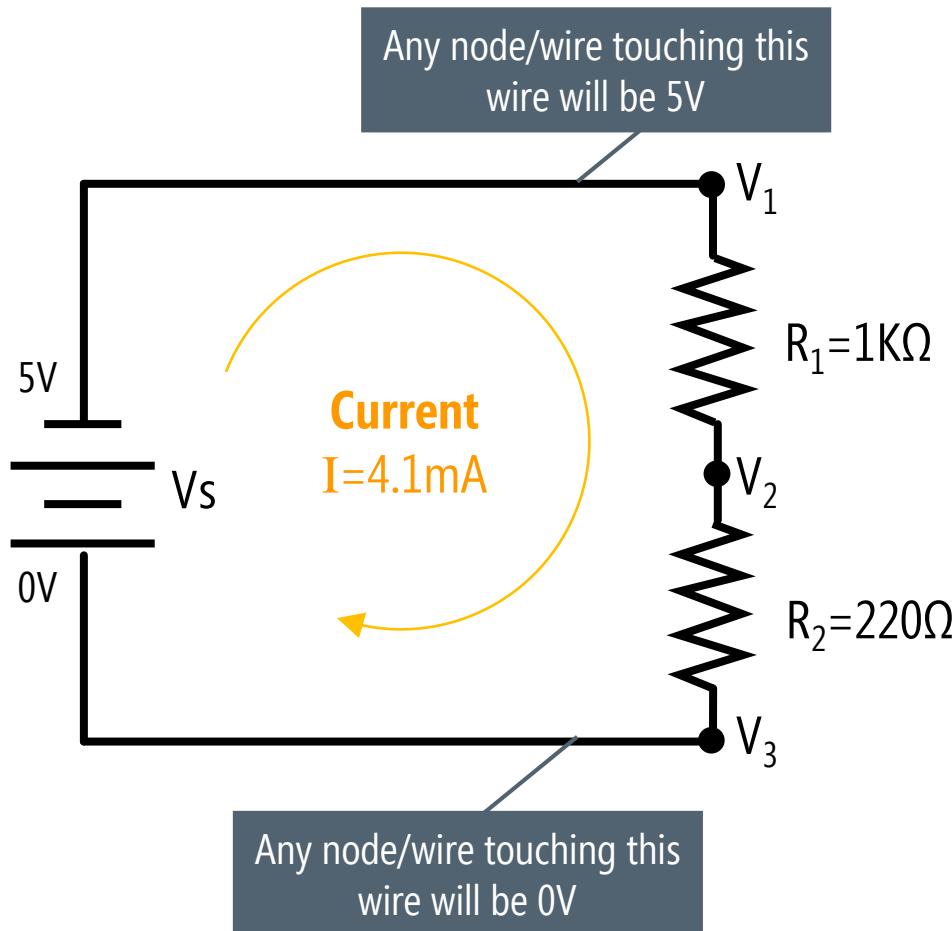
$$V_2 = 5V - 0.0041A * 1,000\Omega = 0.9V$$

$$V_3 = 0V$$

SERIES VS. PARALLEL RESISTANCE

OHM'S LAW EXERCISE: SOLVE FOR V1, V2, AND V3

How did I know V1 and V3?



$$\text{Current} = I = \frac{V_{\text{high potential}} - V_{\text{low potential}}}{R}$$

$$V_1 - V_2 = I * R_1$$

$$V_2 = V_1 - I * R_1 \quad \text{And we know } V_1=5\text{V}, I=4.1\text{mA}, \& R_1=1\text{K}\Omega$$

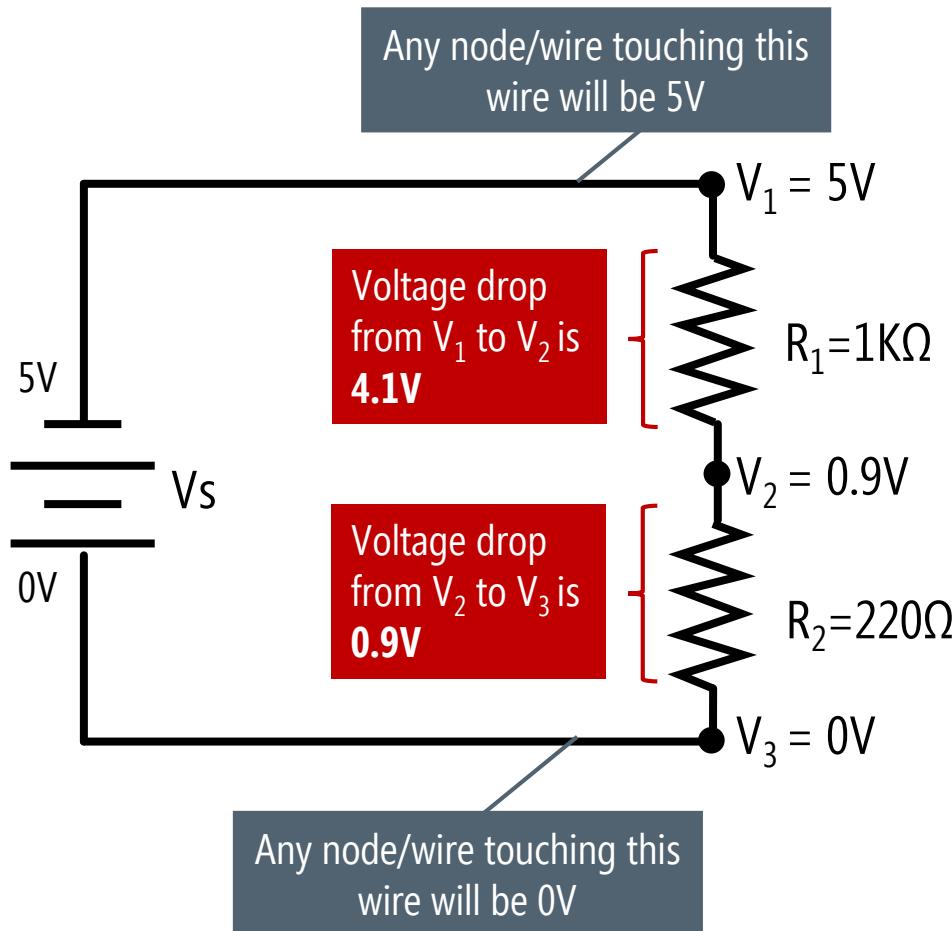
$$V_2 = 5\text{V} - 0.0041A * 1,000\Omega = 0.9\text{V}$$

$$V_3 = 0\text{V}$$

SERIES VS. PARALLEL RESISTANCE

OHM'S LAW EXERCISE: SOLVE FOR V1, V2, AND V3

How did I know V1 and V3?



$$Current = I = \frac{V_{high\ potential} - V_{low\ potential}}{R}$$

$$V_1 - V_2 = I * R_1$$

$$V_2 = V_1 - I * R_1 \quad \text{And we know } V_1=5V, I=4.1mA, \& R_1=1K\Omega$$

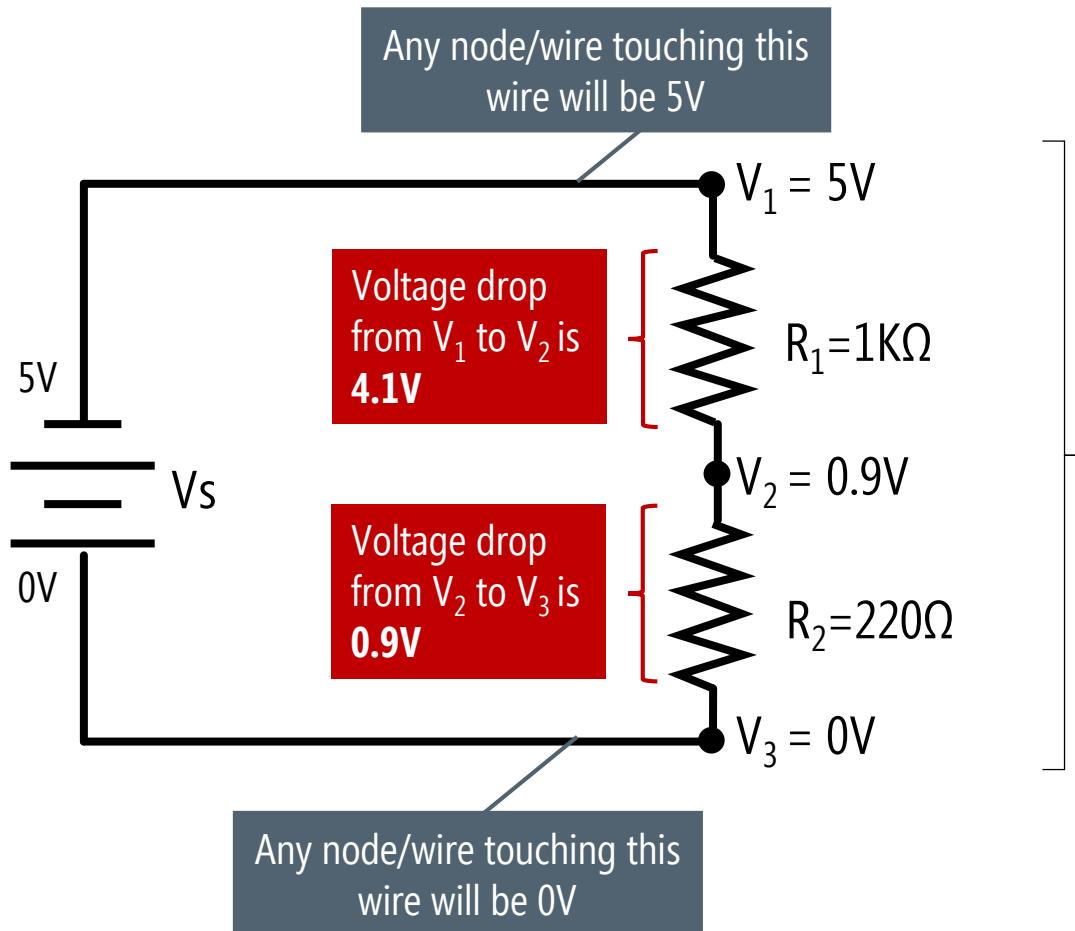
$$V_2 = 5V - 0.0041A * 1,000\Omega = 0.9V$$

$$V_3 = 0V$$

SERIES VS. PARALLEL RESISTANCE

OHM'S LAW EXERCISE: SOLVE FOR V1, V2, AND V3

How did I know V1 and V3?



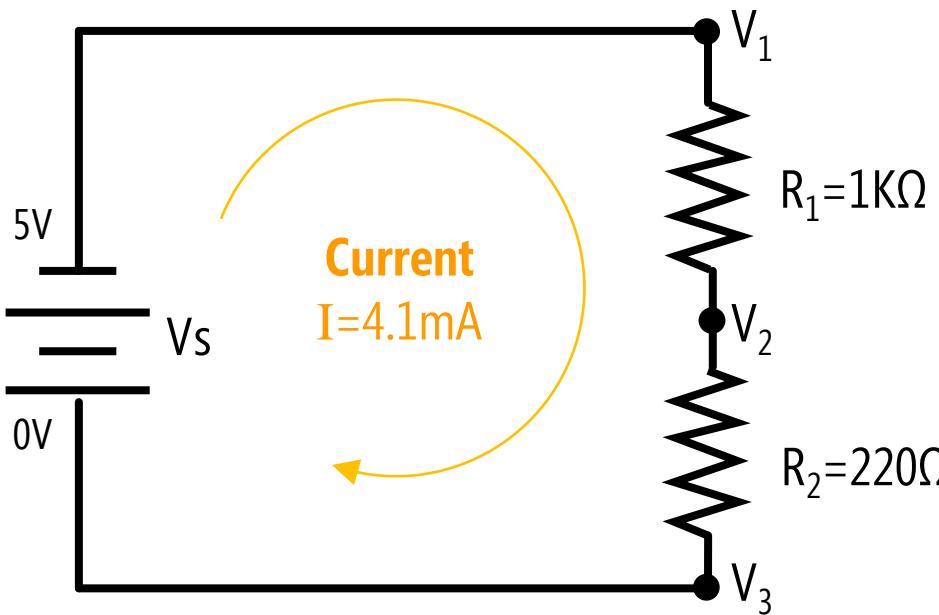
This basic circuit is called a **voltage divider** because it “splits” or “divides” voltages across nodes.

It is one of the **most common** (and useful) circuit configurations when working with microcontrollers

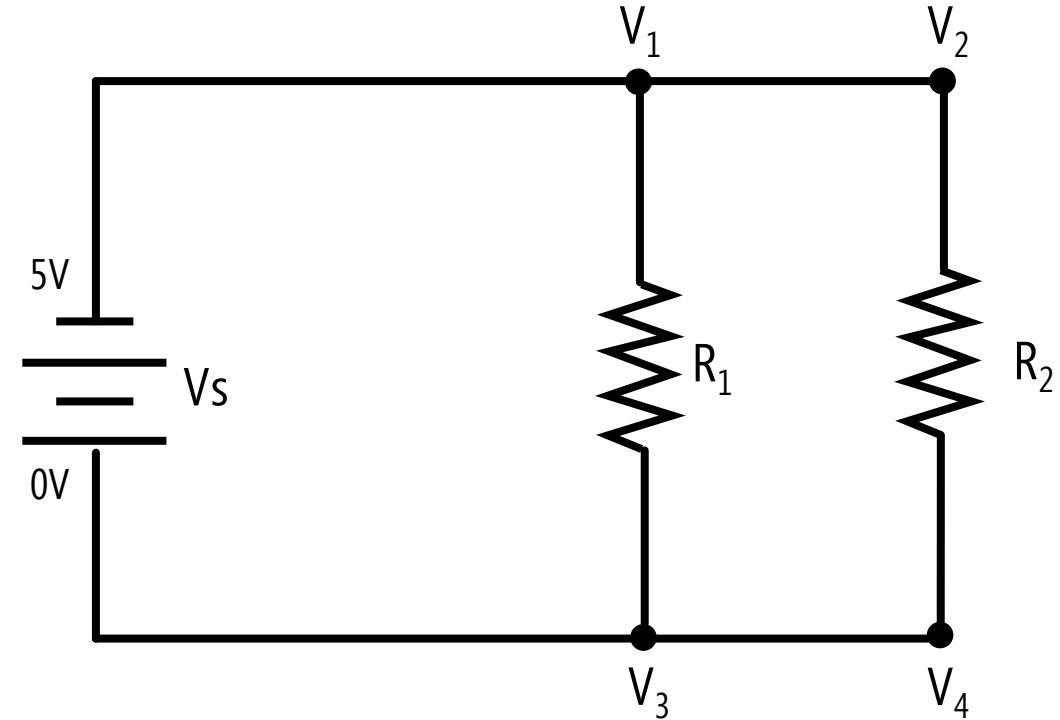
SERIES VS. PARALLEL RESISTANCE

BUT WHAT ABOUT RESISTORS IN PARALLEL?

Resistors in Series



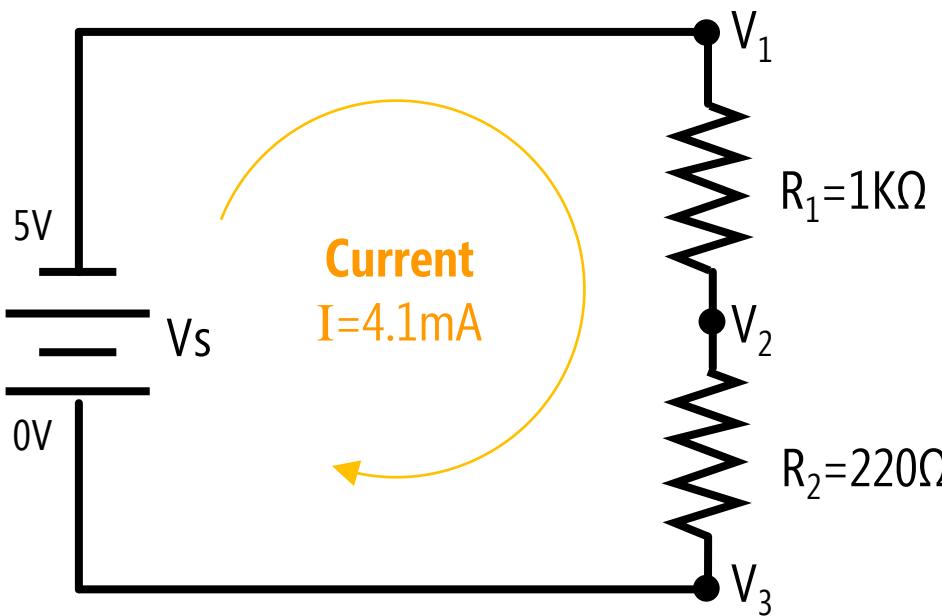
Resistors in Parallel



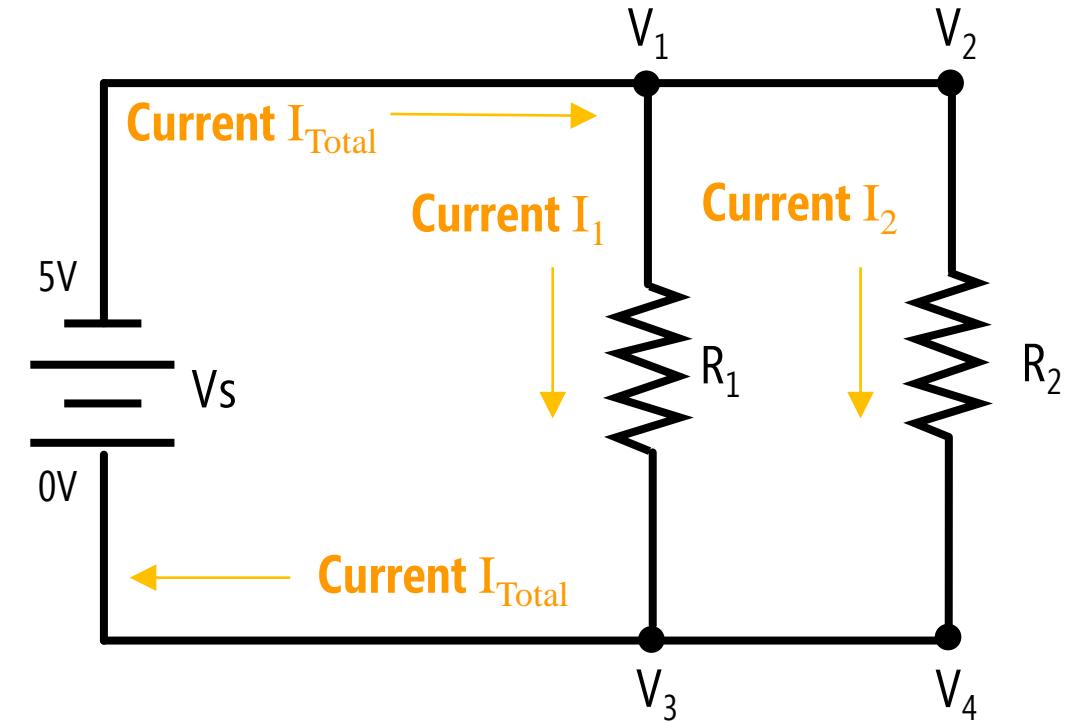
SERIES VS. PARALLEL RESISTANCE

BUT WHAT ABOUT RESISTORS IN PARALLEL?

Resistors in Series



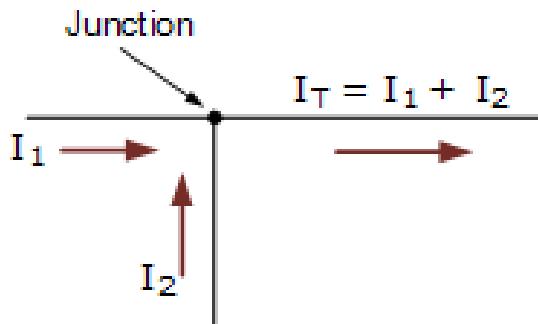
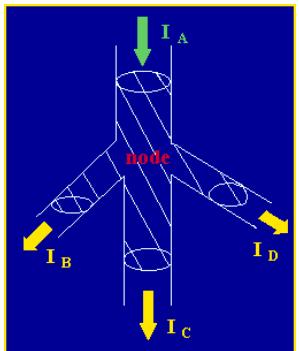
Resistors in Parallel



SERIES VS. PARALLEL RESISTANCE

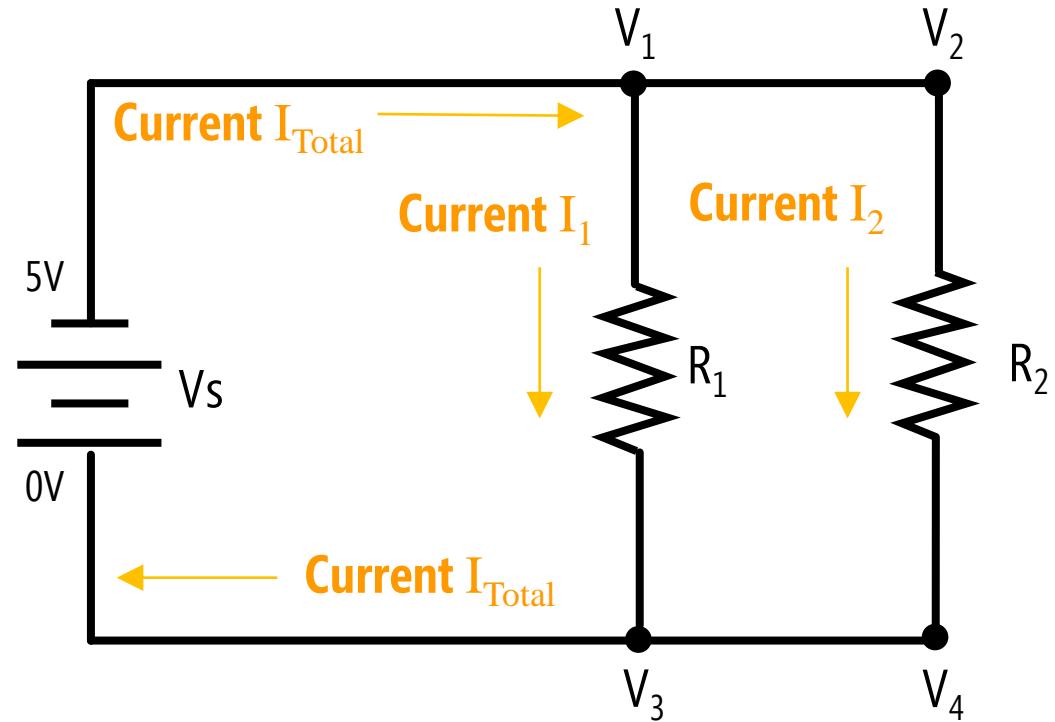
KIRCHHOFF'S CURRENT LAW (KCL)

$$\text{Current } I_{\text{Total}} = \text{Current } I_1 + \text{Current } I_2$$



Kirchhoff's Current Law: one of the most fundamental laws in circuit analysis, which states that the total current entering a circuit junction is equal to the current leaving the same junction

Resistors in Parallel

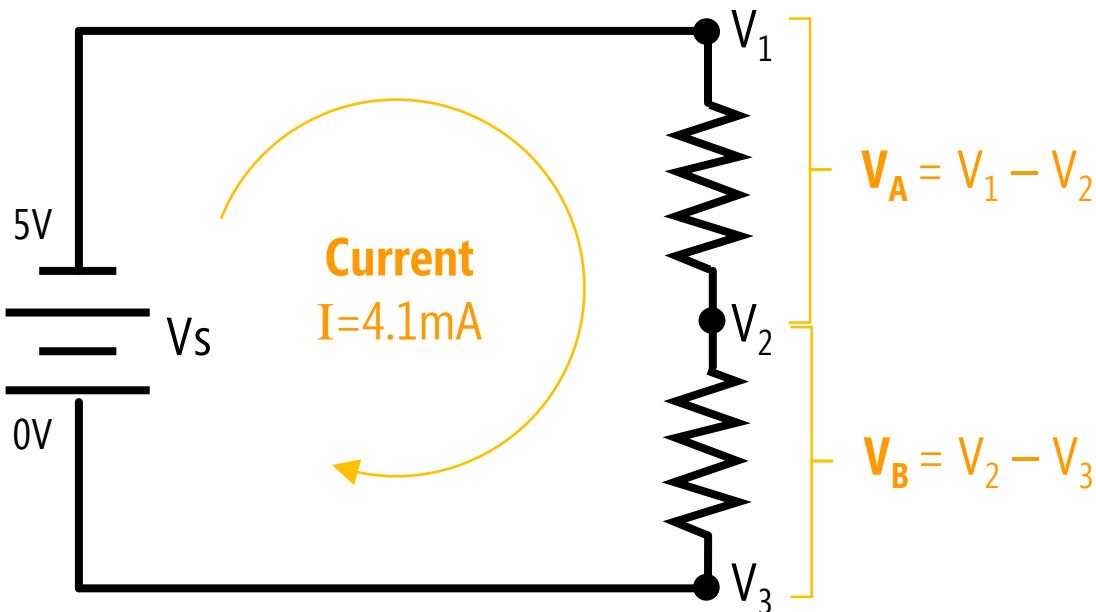


SERIES VS. PARALLEL RESISTANCE

SERIES VS. PARALLEL

Resistors in Series

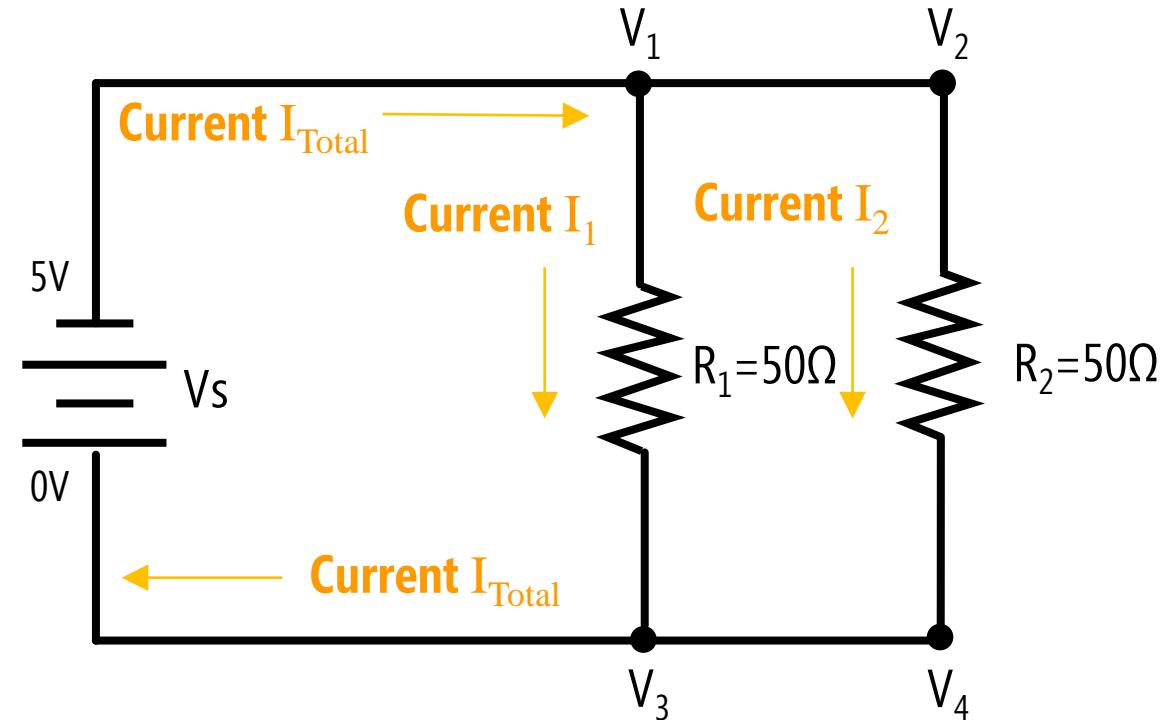
Voltage is split



Although there is a voltage drop across each resistor, there is only **one path** for the **current** to flow, so there is one current value for the entire circuit.

Resistors in Parallel

Current is split



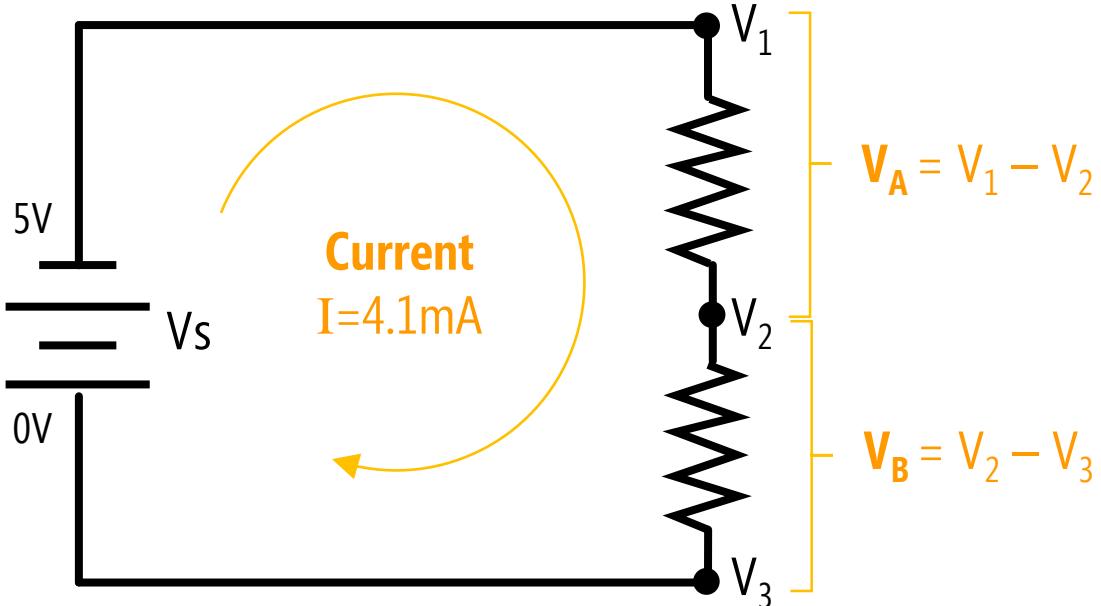
Here, there are **two** potential branches for current to flow. The amount of current across each branch is **dependent** on the **resistance** values.

SERIES VS. PARALLEL RESISTANCE

KIRCHHOFF'S VOLTAGE LAW

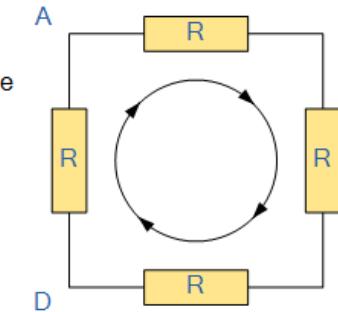
Resistors in Series

Voltage is split



$$V_S = \text{Voltage } V_A + \text{Voltage } V_B$$

The sum of all the Voltage Drops around the loop is equal to Zero



$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$

Kirchhoff's Voltage Law: "in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop" which is also equal to zero.

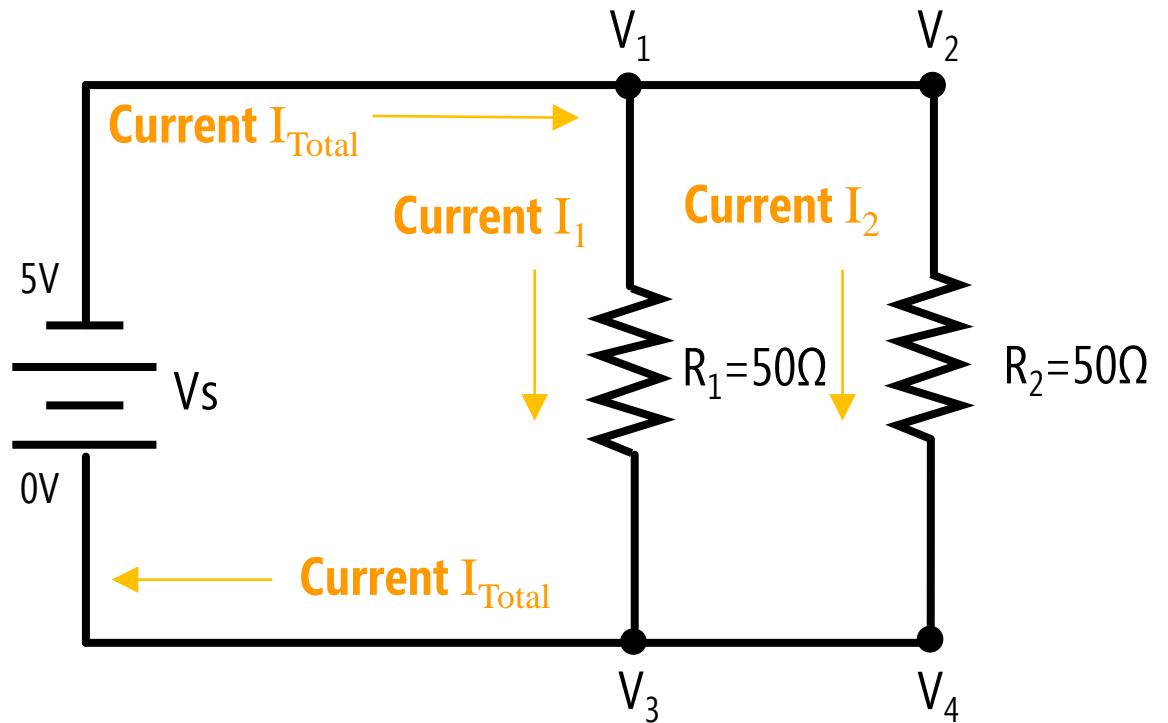
SERIES VS. PARALLEL RESISTANCE

LET'S BUILD SOME INTUITION

With respect to I_{Total} , how much current is going through each branch?

Resistors in Parallel

Current is split



SERIES VS. PARALLEL RESISTANCE

LET'S BUILD SOME INTUITION

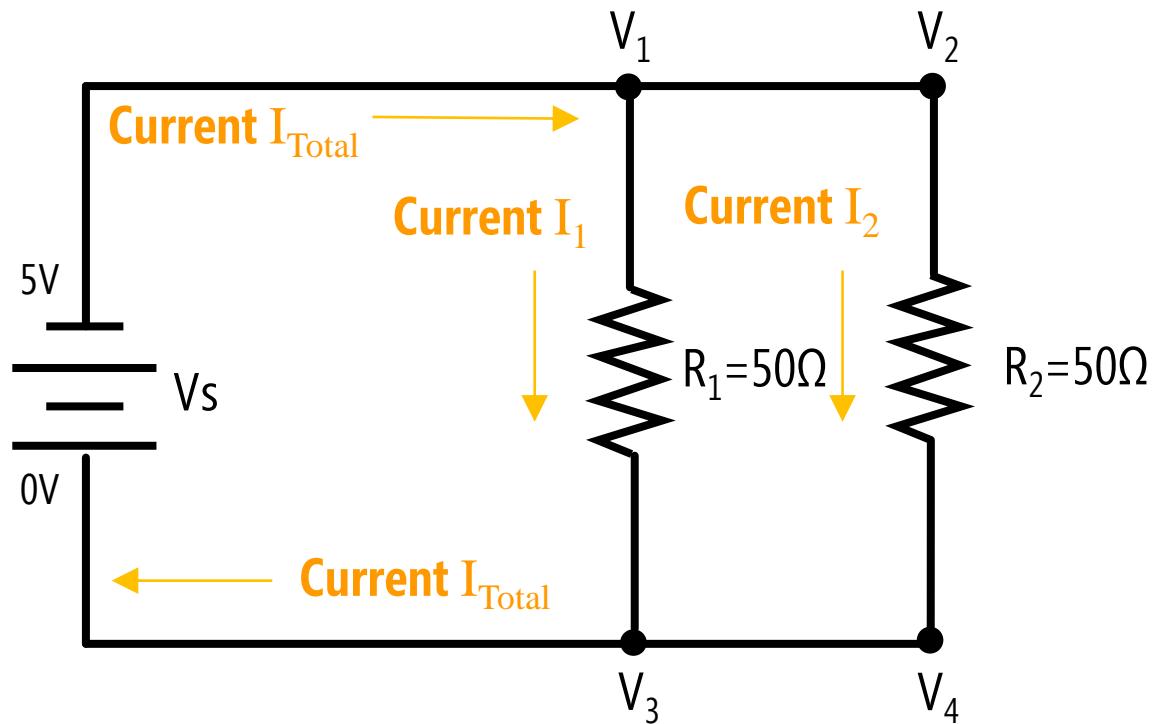
With respect to I_{Total} , how much current is going through each branch?

$$I_1 = 50\% * I_{\text{total}}$$

$$I_2 = 50\% * I_{\text{Total}}$$

Resistors in Parallel

Current is split



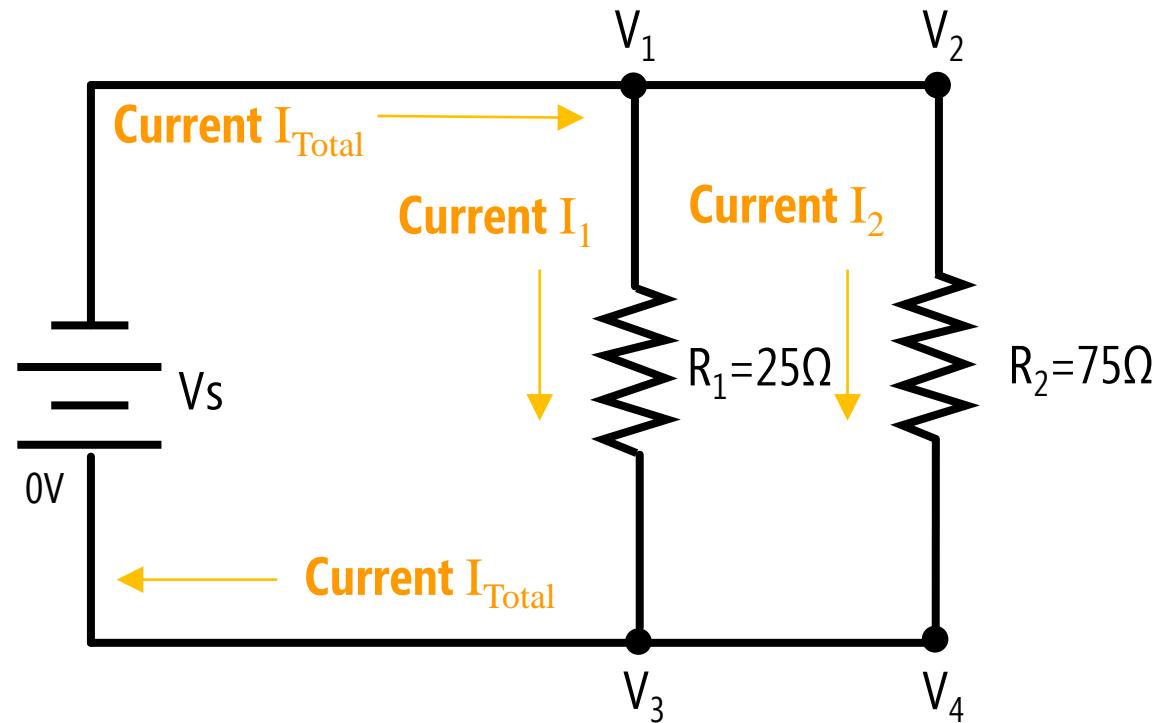
SERIES VS. PARALLEL RESISTANCE

HOW ABOUT NOW?

With respect to I_{Total} , how much current is going through each branch?

Resistors in Parallel

Current is split



SERIES VS. PARALLEL RESISTANCE

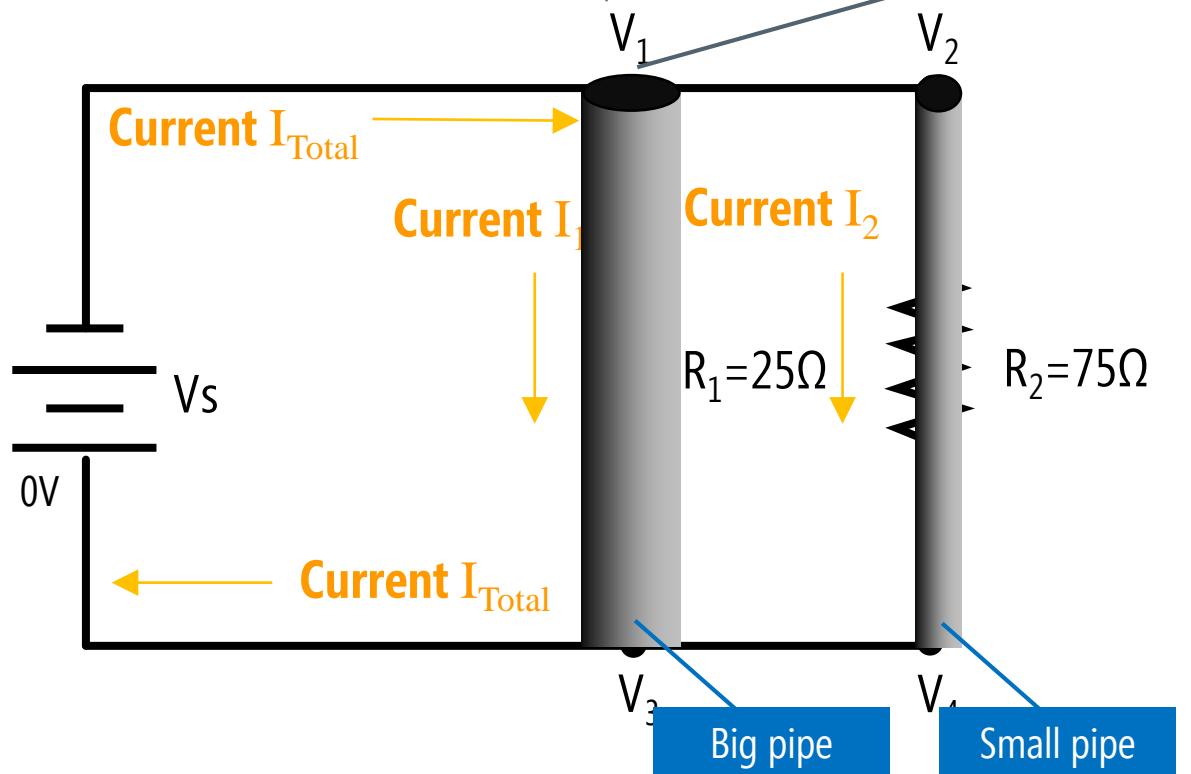
HOW ABOUT NOW?

With respect to I_{Total} , how much current is going through each branch?

Resistors in Parallel

Current is split

Which branch has more current? I_1 or I_2



SERIES VS. PARALLEL RESISTANCE

HOW ABOUT NOW?

With respect to I_{Total} , how much current is going through each branch?

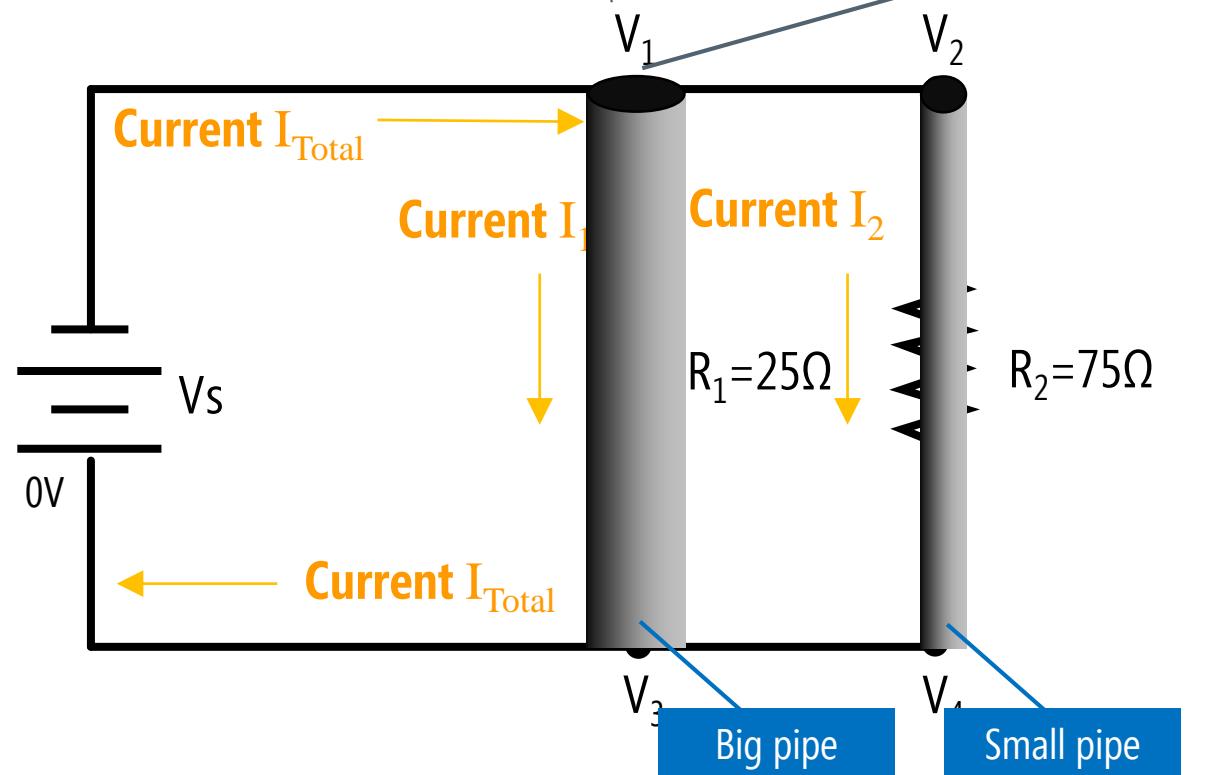
$$I_1 = 75\% * I_{\text{total}}$$

$$I_2 = 25\% * I_{\text{Total}}$$

Resistors in Parallel

Current is split

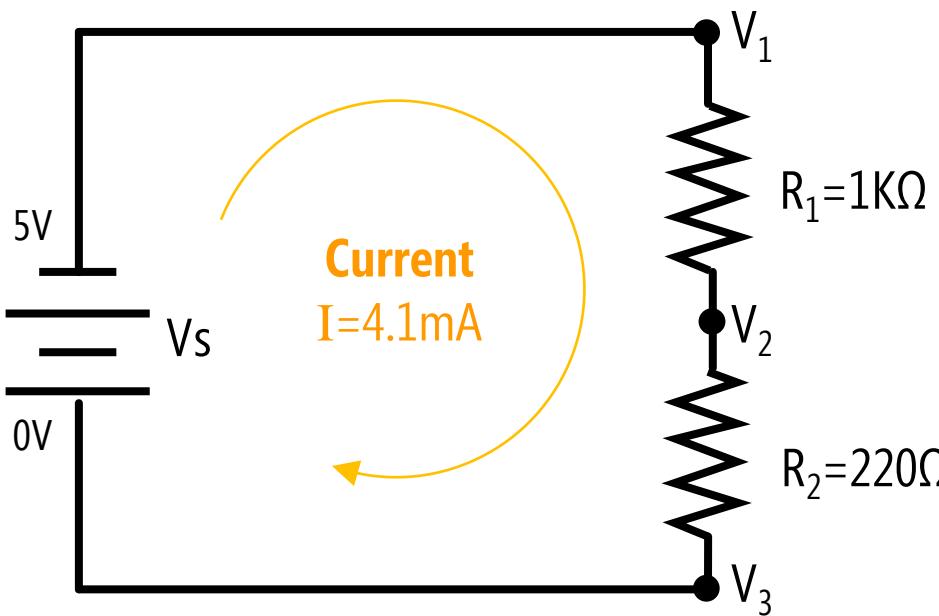
Which branch has more current? I_1 or I_2



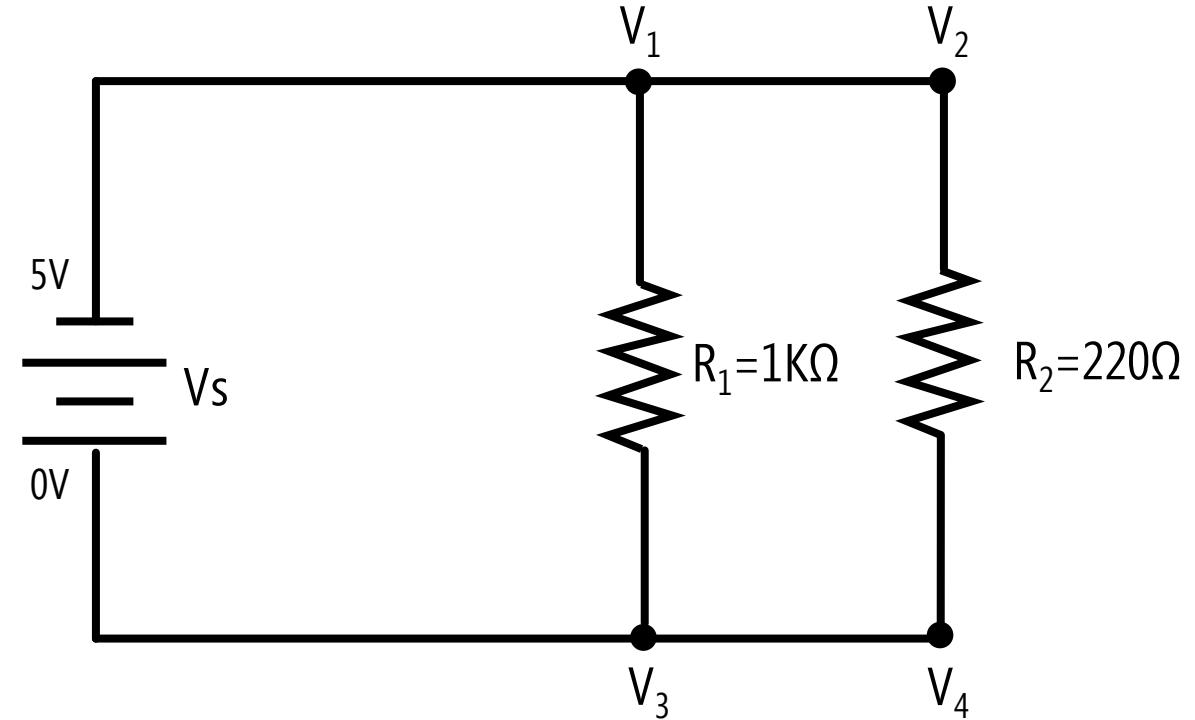
SERIES VS. PARALLEL RESISTANCE

LET'S SOLVE THE CURRENT IN THIS CIRCUIT

Resistors in Series



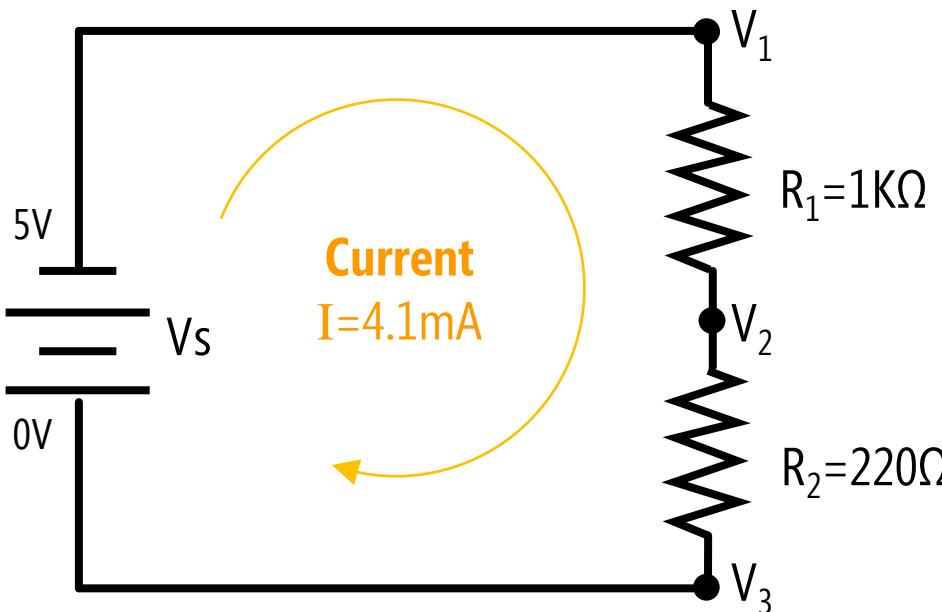
Resistors in Parallel



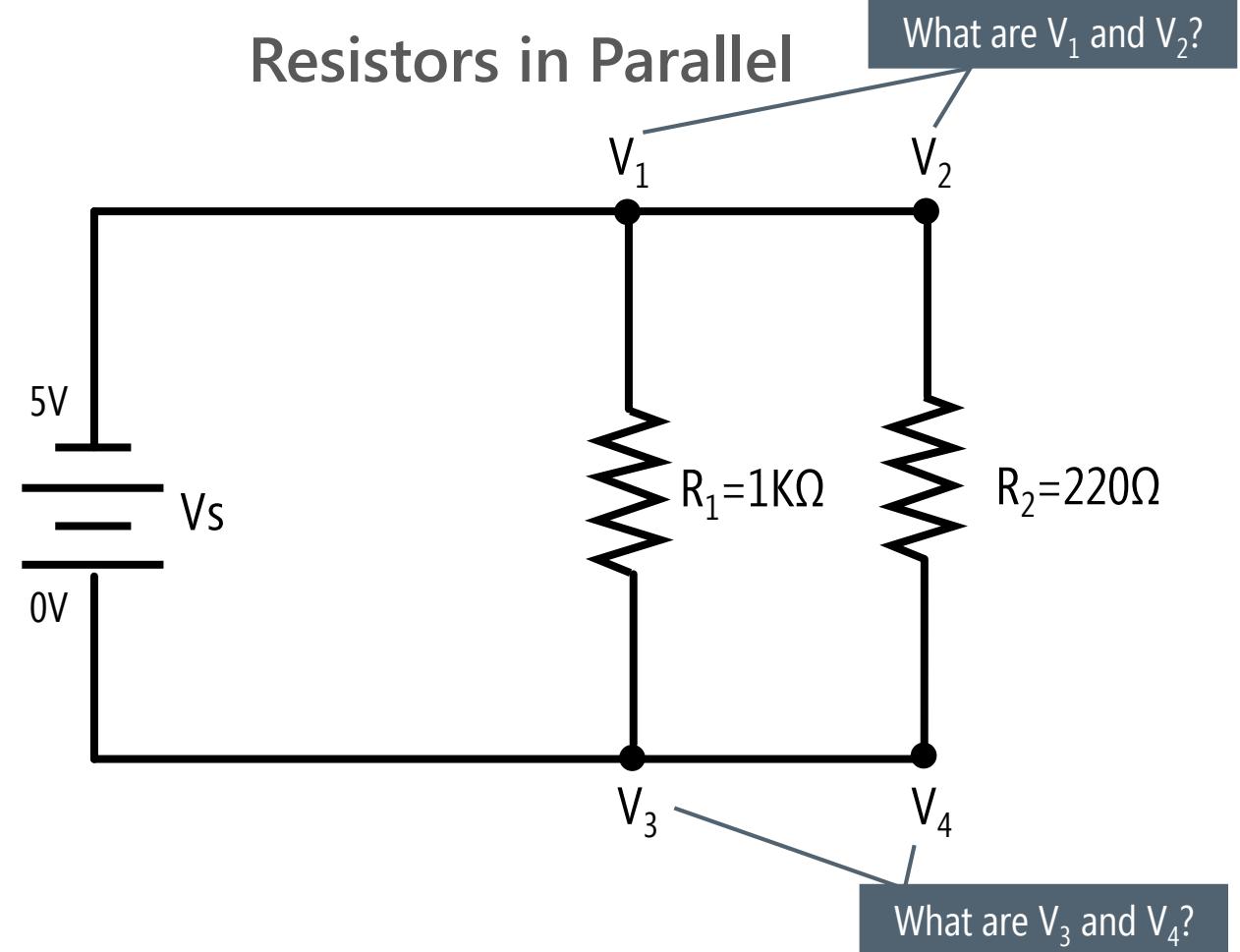
SERIES VS. PARALLEL RESISTANCE

WHAT ARE V₁, V₂, V₃ AND V₄?

Resistors in Series



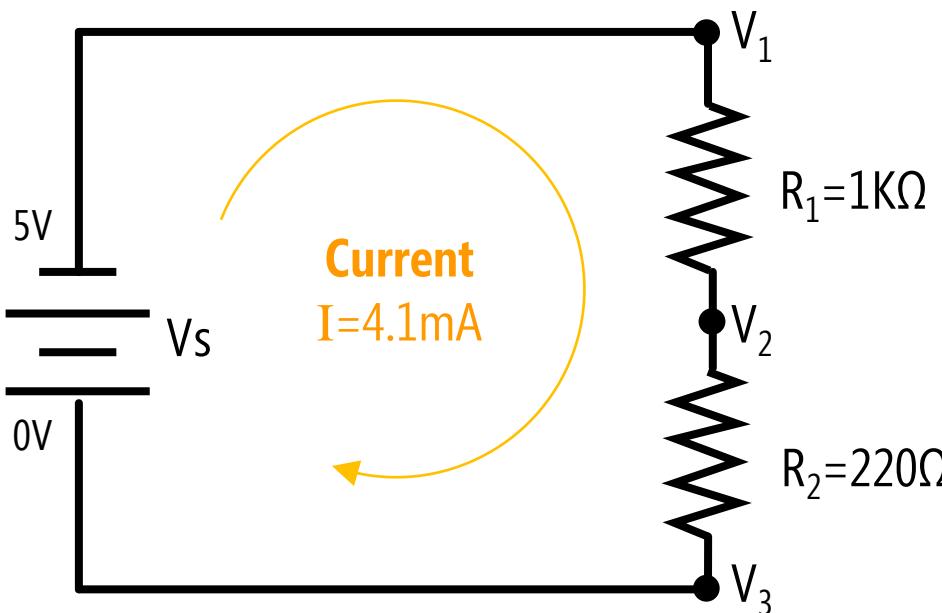
Resistors in Parallel



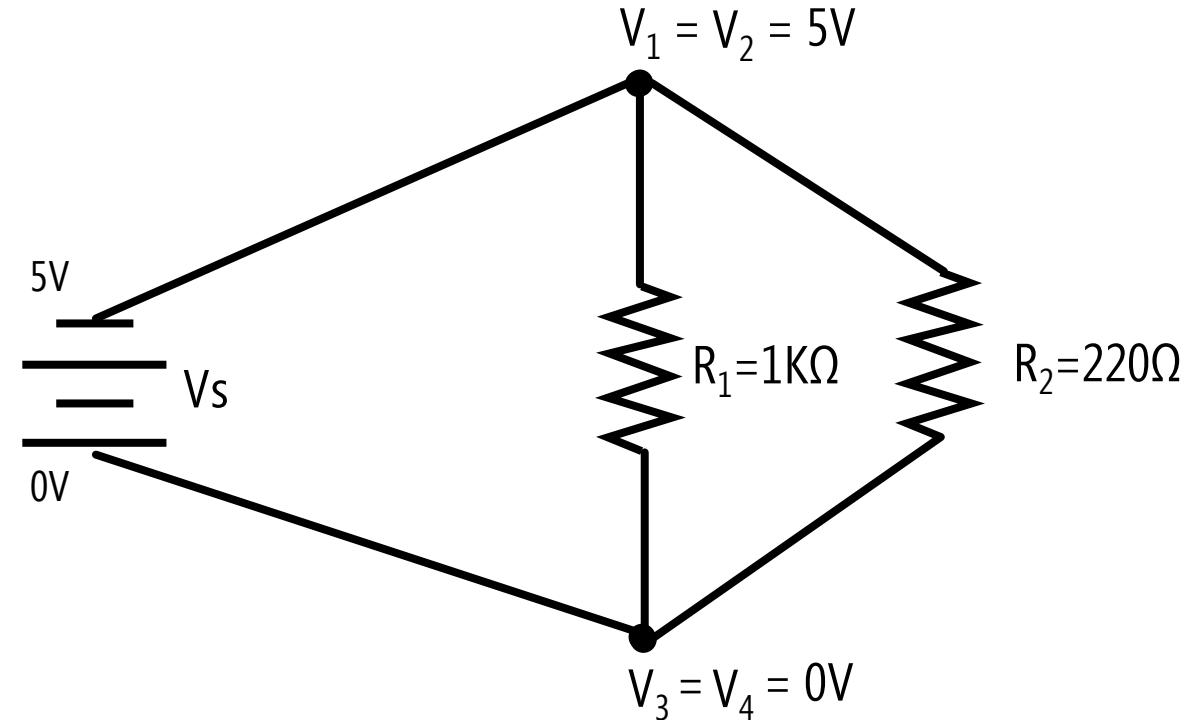
SERIES VS. PARALLEL RESISTANCE

SOMETIMES IT HELPS TO DRAW THE CIRCUIT...

Resistors in Series



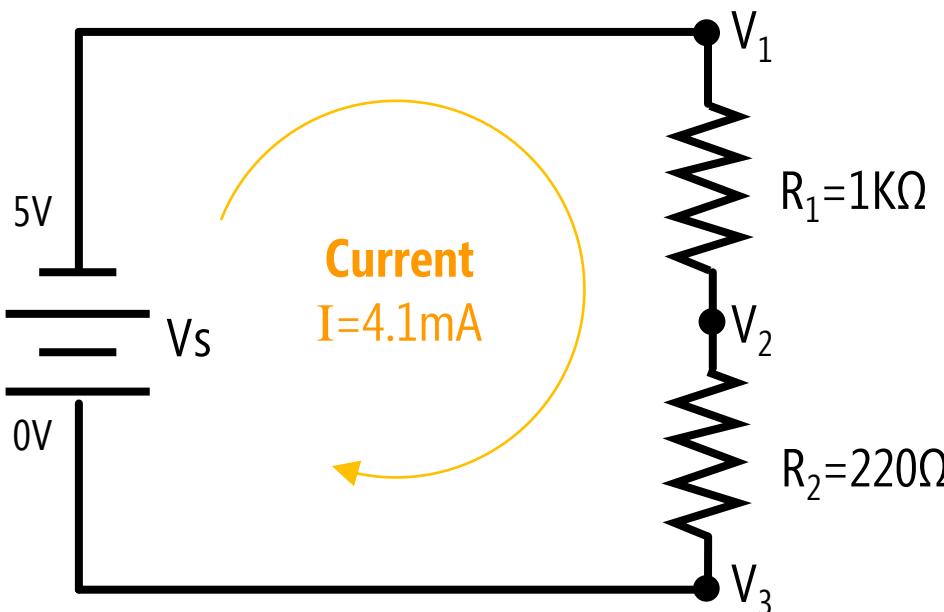
Resistors in Parallel



SERIES VS. PARALLEL RESISTANCE

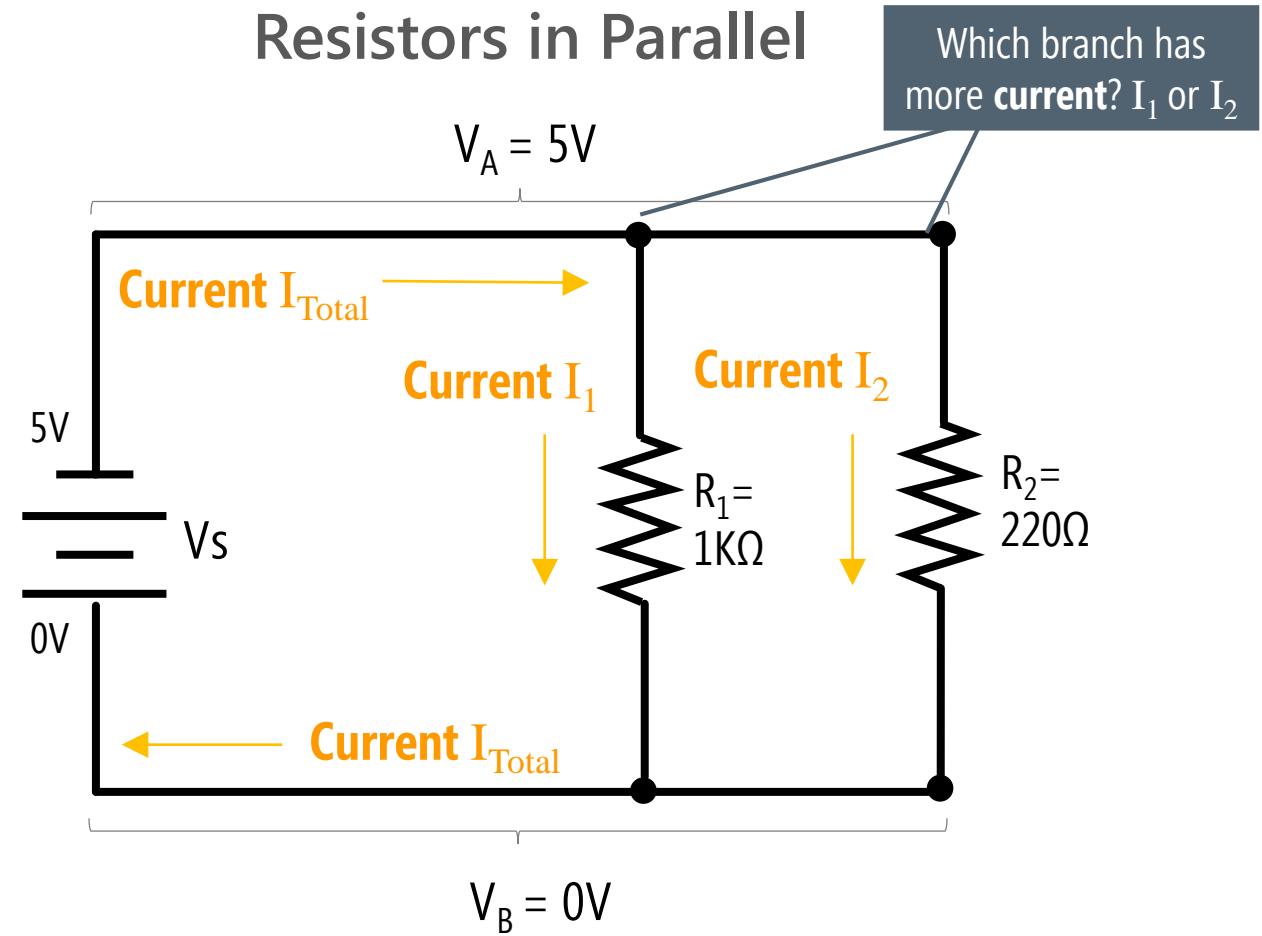
WHICH BRANCH HAS MORE CURRENT?

Resistors in Series



Although there is a voltage drop across each resistor, there is only **one path** for the **current** to flow, so there is one current value for the entire circuit.

Resistors in Parallel

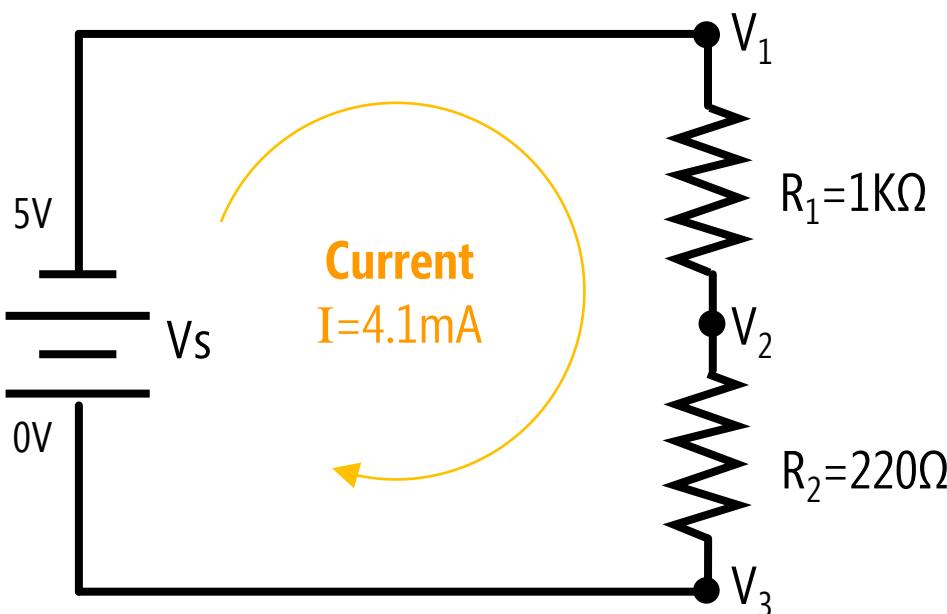


Here, there are **two** potential branches for current to flow. The amount of current across each branch is **dependent** on the **resistance** values.

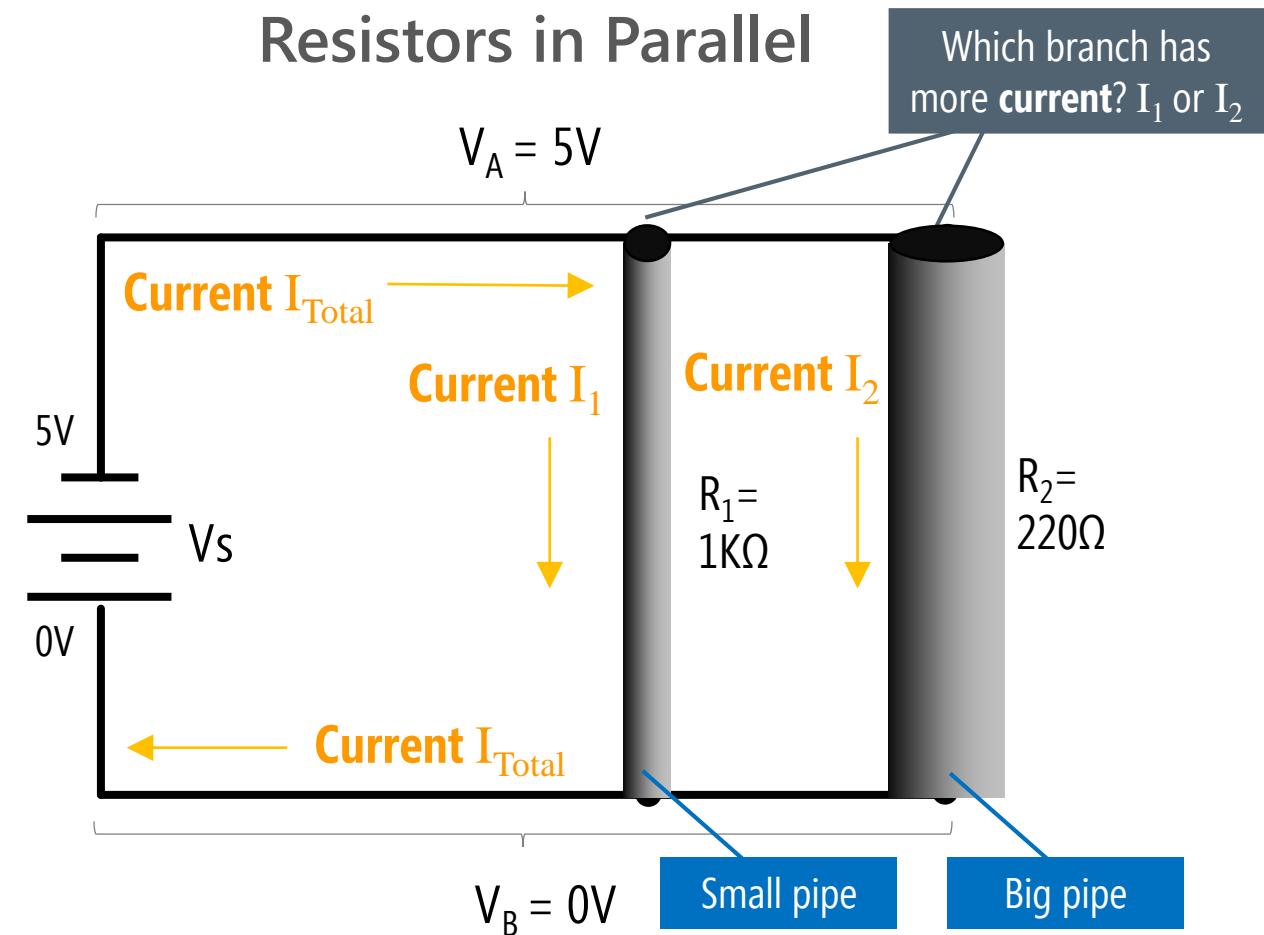
SERIES VS. PARALLEL RESISTANCE

REMEMBER OUR WATER ANALOGY... AND OHM'S LAW

Resistors in Series



Resistors in Parallel



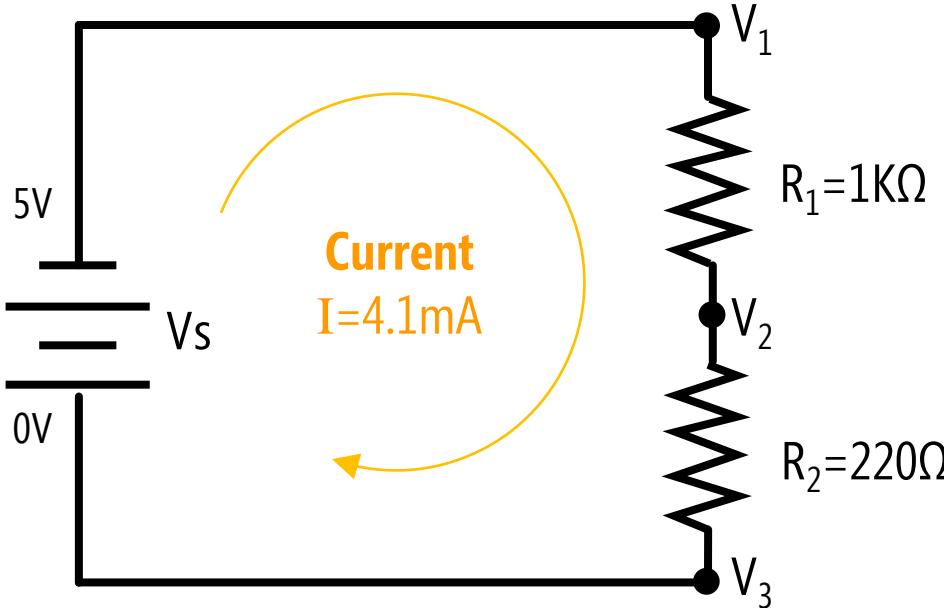
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Here, there are **two** potential branches for current to flow. The amount of current across each branch is **dependent** on the **resistance** values.

SERIES VS. PARALLEL RESISTANCE

SOLVE FOR I_1 AND I_2

Resistors in Series

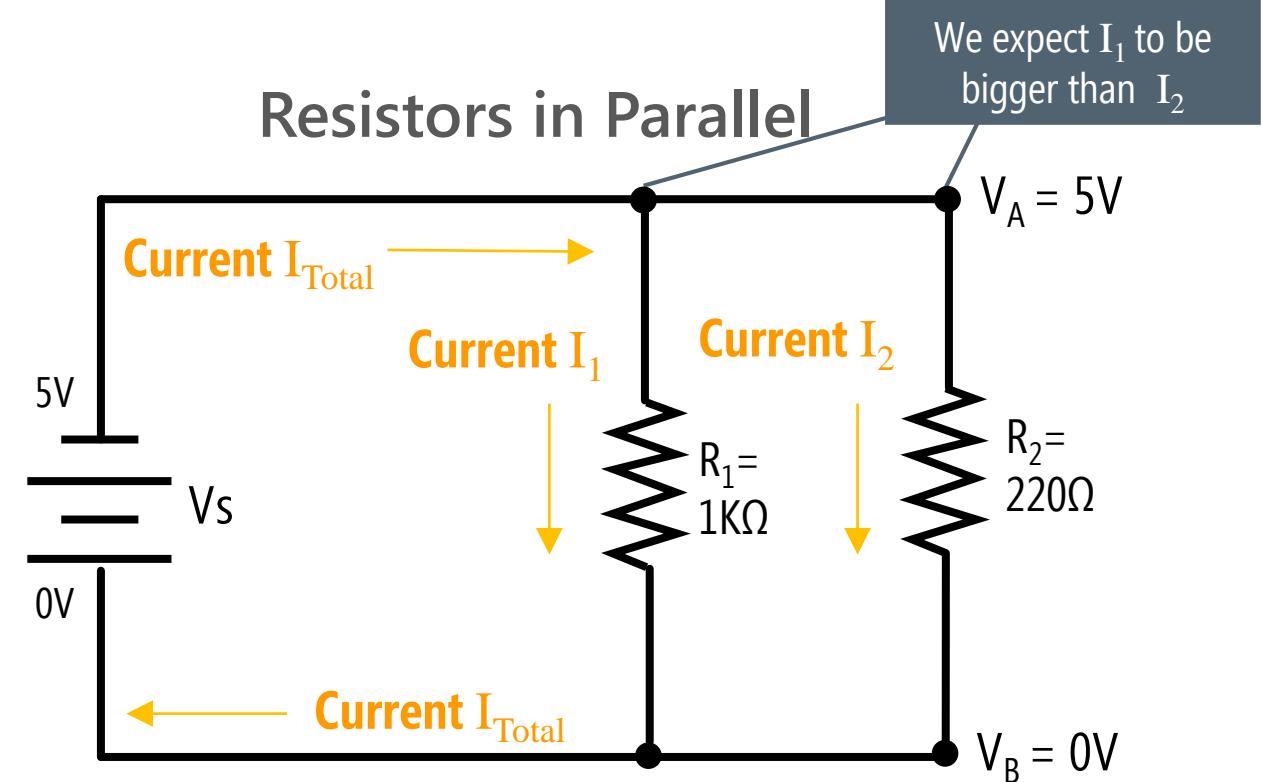


$$\text{Current} = I = \frac{V_{\text{high potential}} - V_{\text{low potential}}}{R_1 + R_2}$$

$$\text{Current} = I = \frac{5V - 0V}{1,000\Omega + 220\Omega}$$

$$\text{Current} = I = 0.0041A = 4.1mA$$

Resistors in Parallel



$$I_1 = \frac{V_A - V_B}{R_1}$$

$$I_1 = \frac{5V - 0V}{1,000\Omega}$$

$$I_1 = 0.005A = 5mA$$

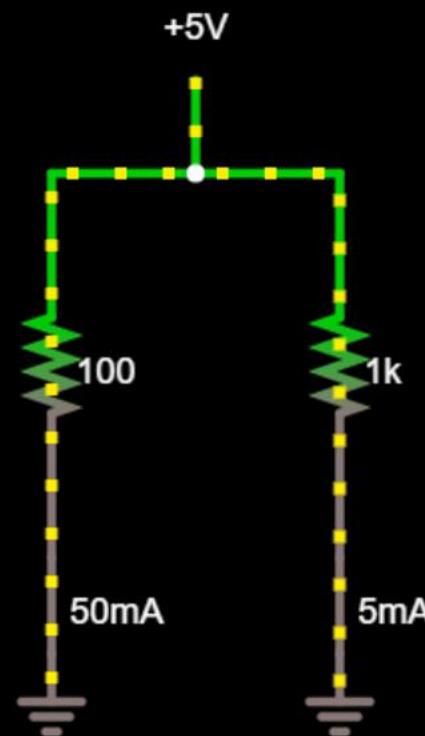
$$I_2 = \frac{V_A - V_B}{R_2}$$

$$I_2 = \frac{5V - 0V}{220\Omega}$$

$$I_2 = 0.0227A = 22.7mA$$

You can play around with this stuff via **online circuit simulators**.

FALSTAD WEB-BASED CIRCUIT SIMULATOR



t = 327.03 ms
time step = 5 μ s

Reset **RUN / Stop**

Simulation Speed

Current Speed

Power Brightness

Current Circuit:
Ohm's Law

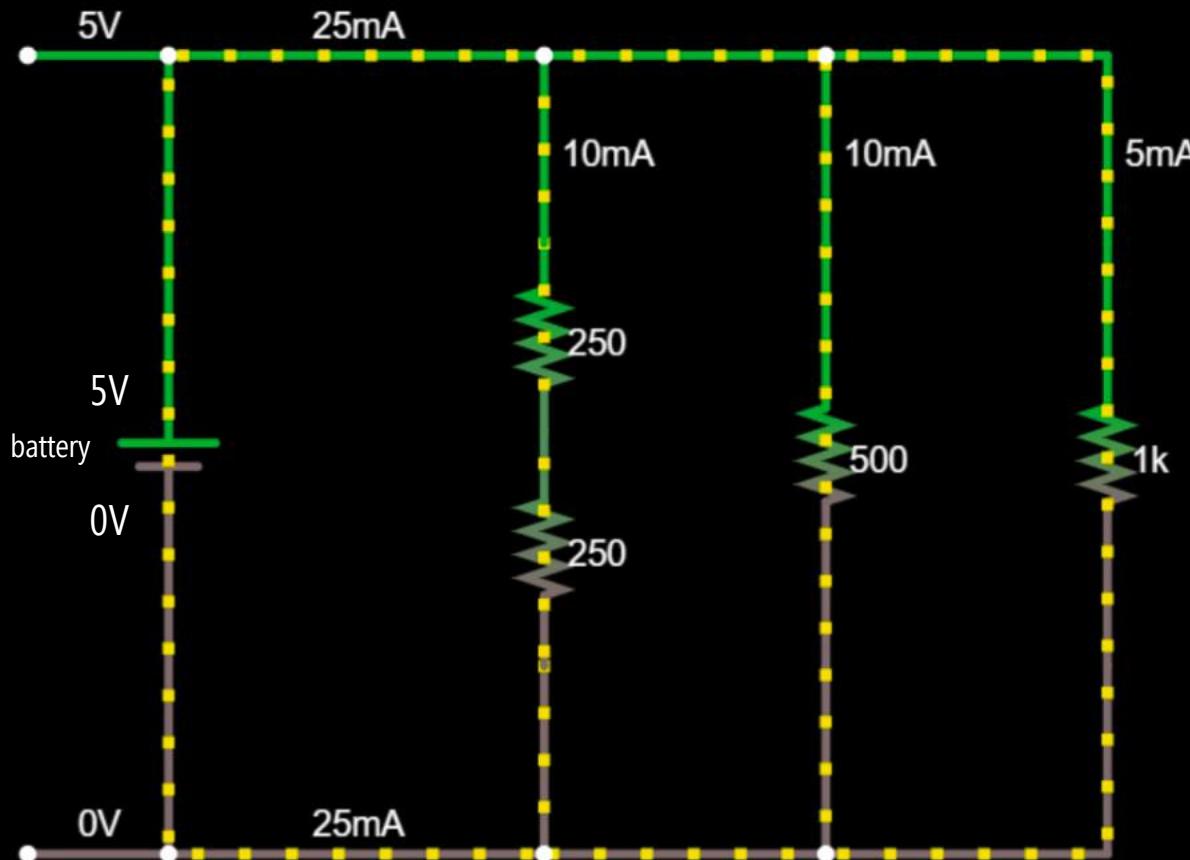
Voltage

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FALSTAD WEB-BASED CIRCUIT SIMULATOR





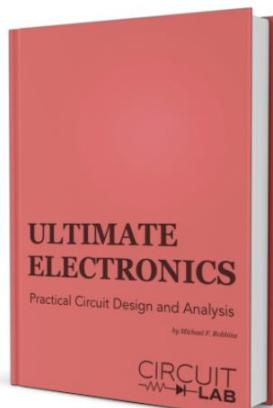
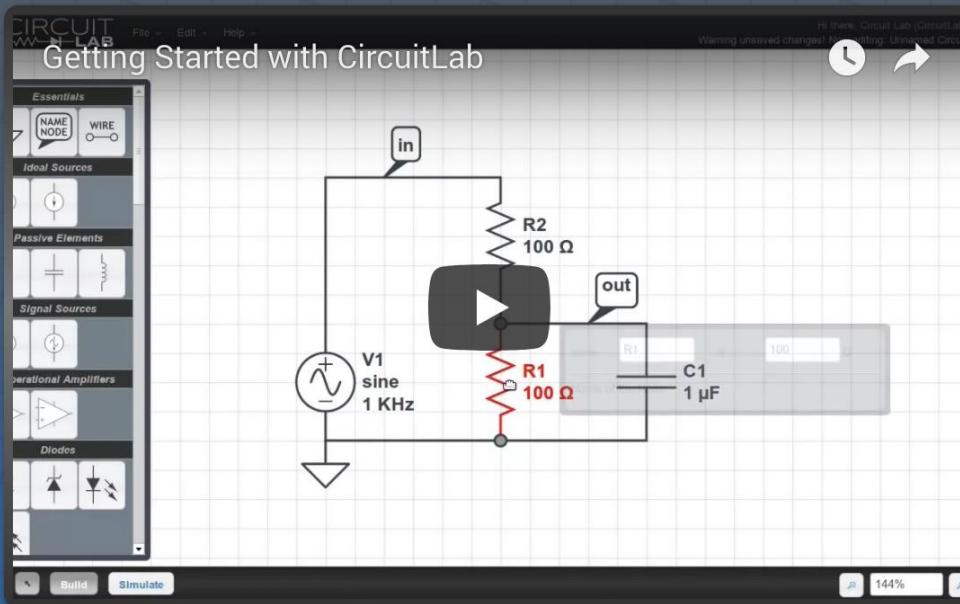
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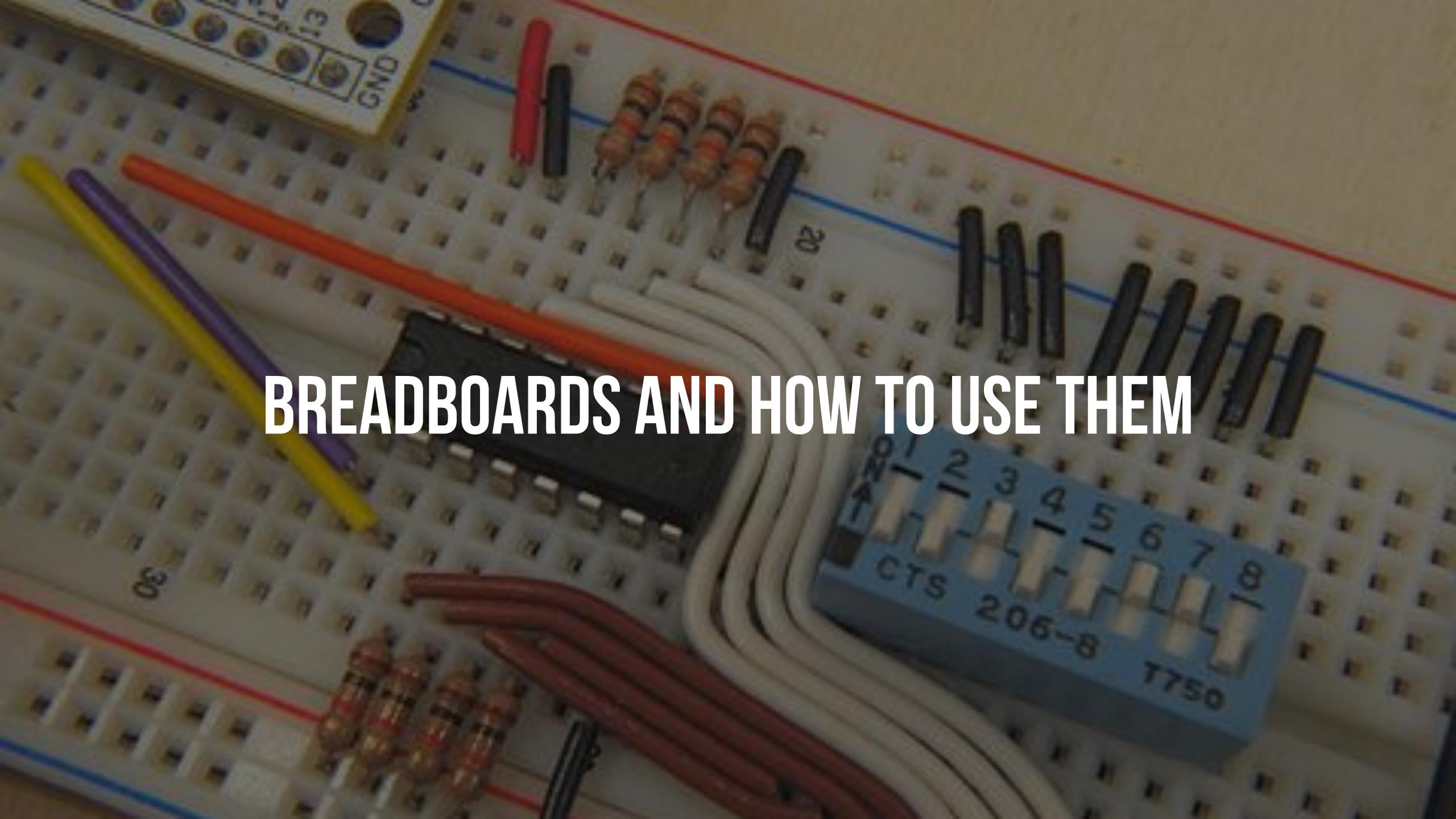


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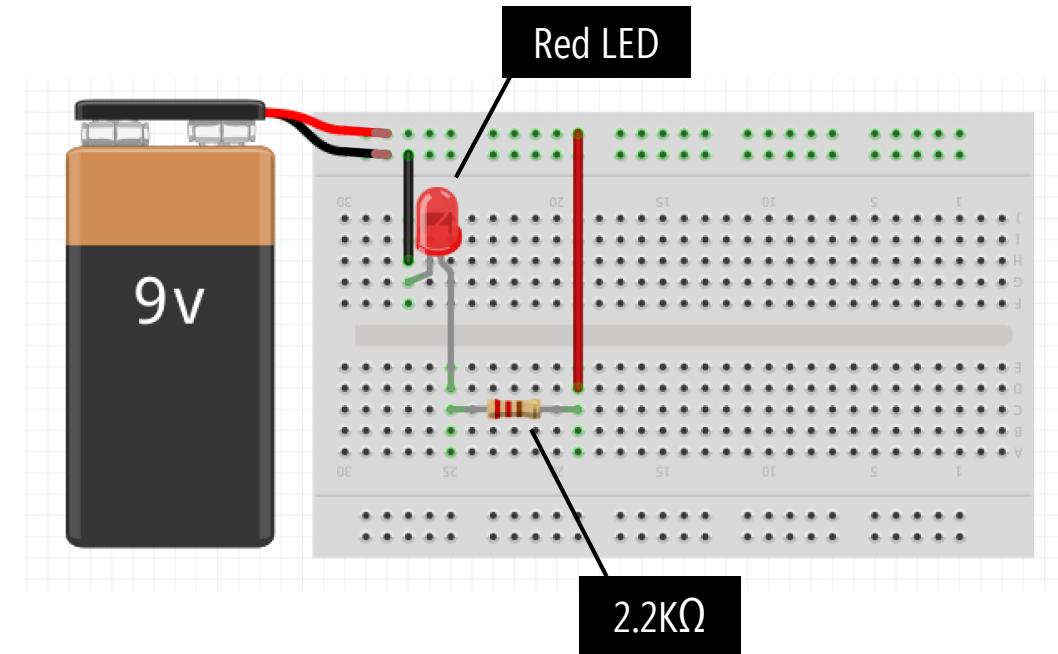
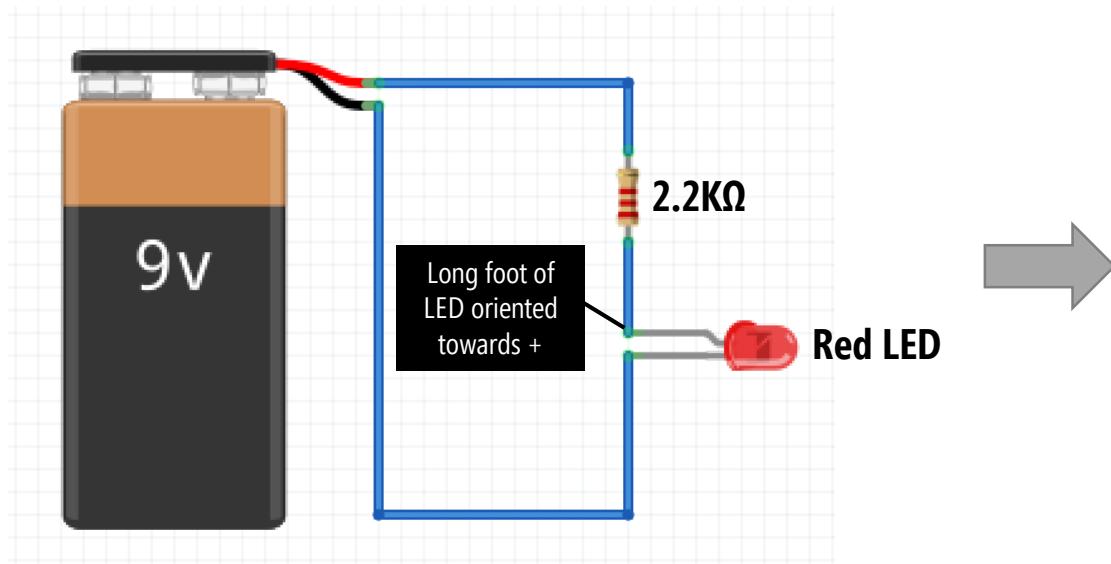
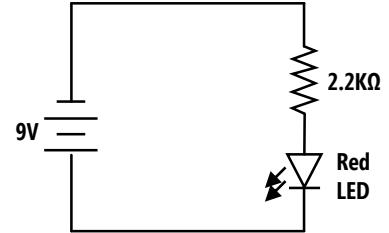
BREADBOARDS AND HOW TO USE THEM



ACTIVITY

ADAPT YOUR CIRCUIT TO USE A BREADBOARD

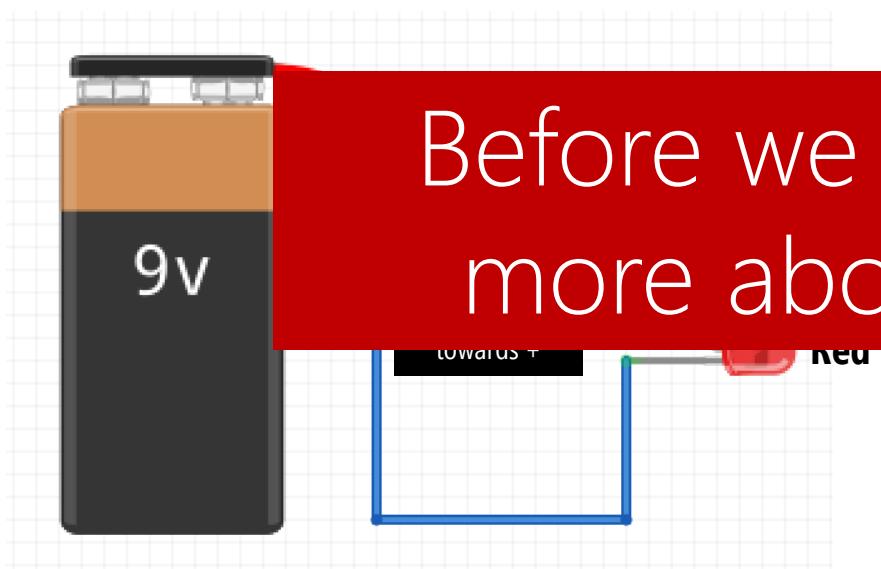
This is the same circuit as before but now we'll use a breadboard! 😊



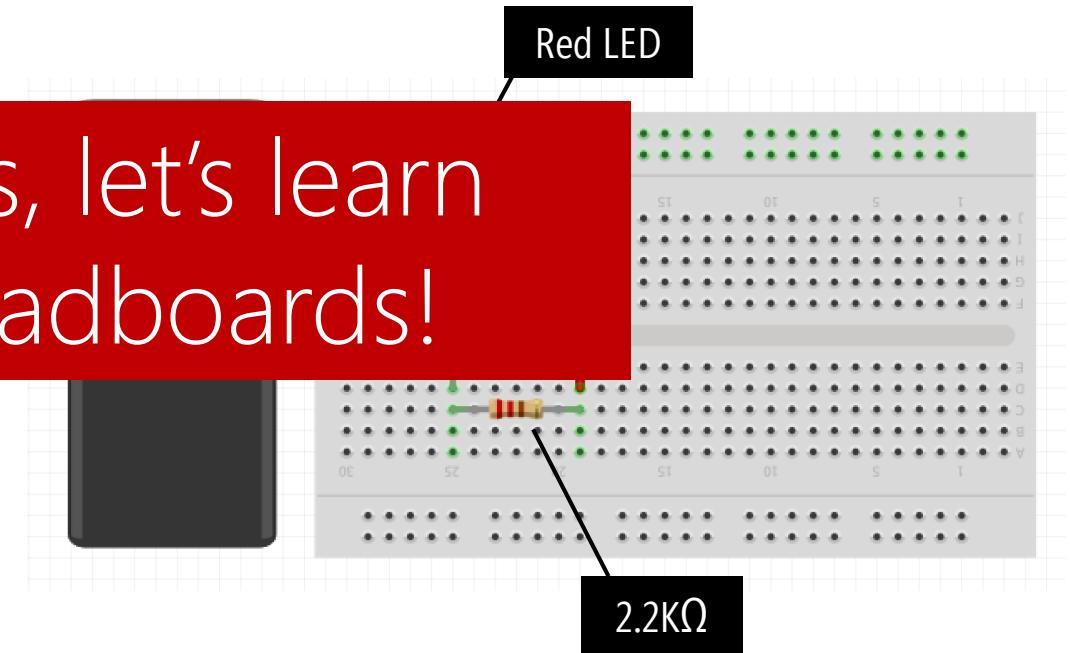
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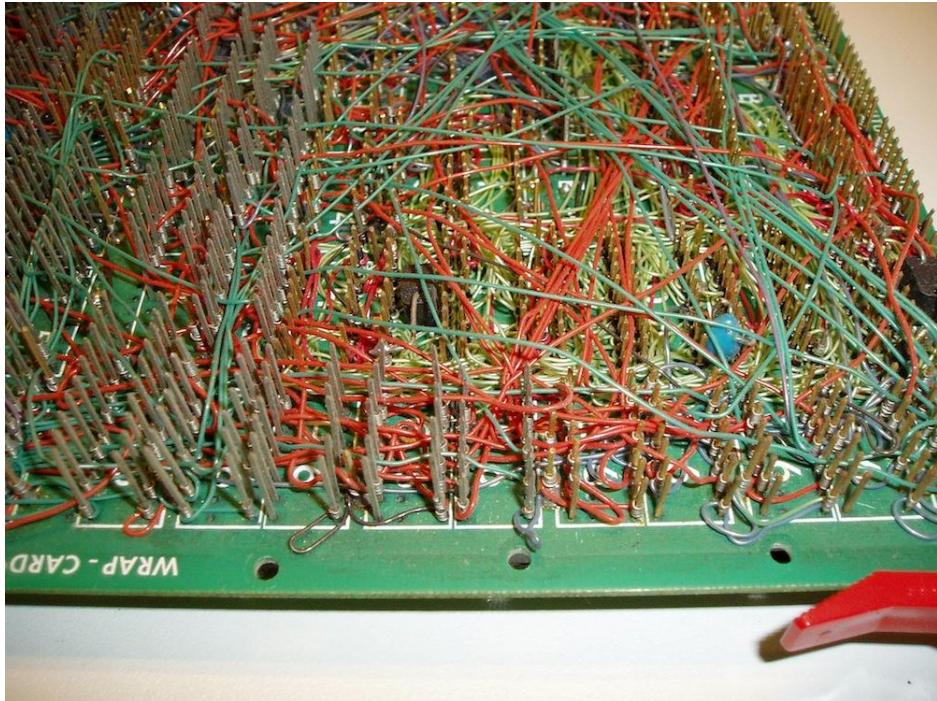
Before we do this, let's learn more about breadboards!



BREADBOARDS

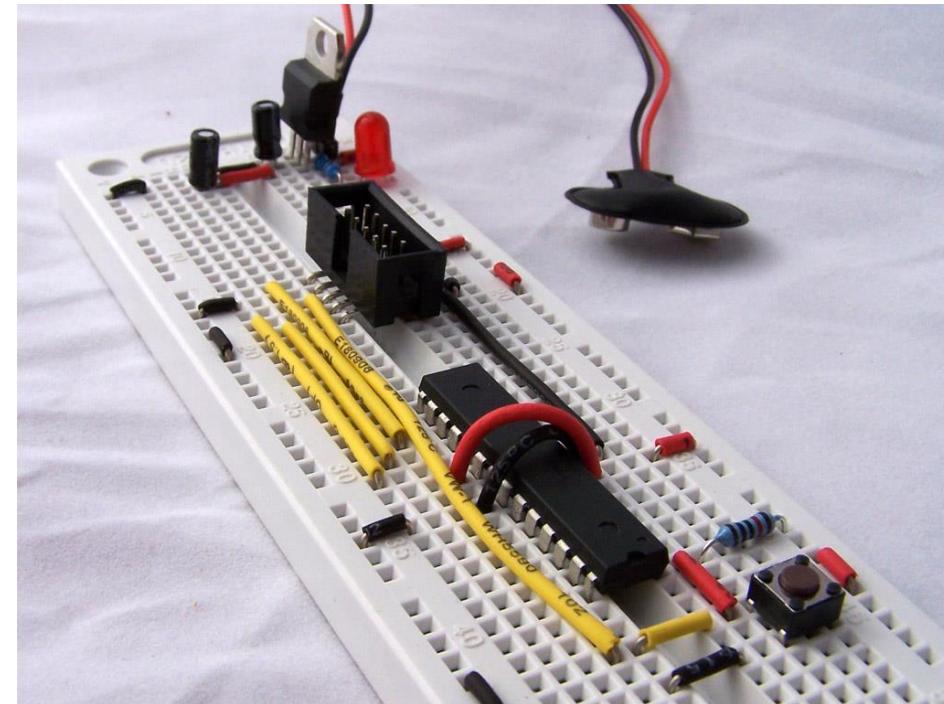
WHAT IS A BREADBOARD?

Breadboards are quick way of wiring and prototyping circuits



WIRE WRAPPING CIRCA ~1960

Wire wrapping involved wrapping wires around conductive posts attached to perfboards



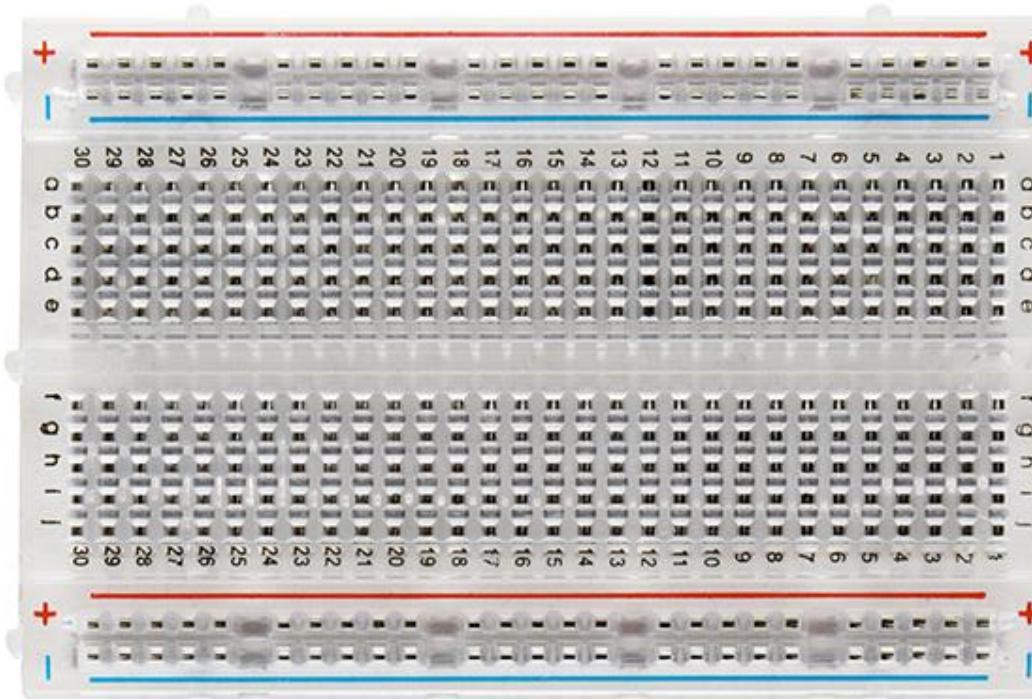
BREADBOARDING

Breadboards simplify this by having some wiring "built-in," which are accessed via holes.

BREADBOARDS

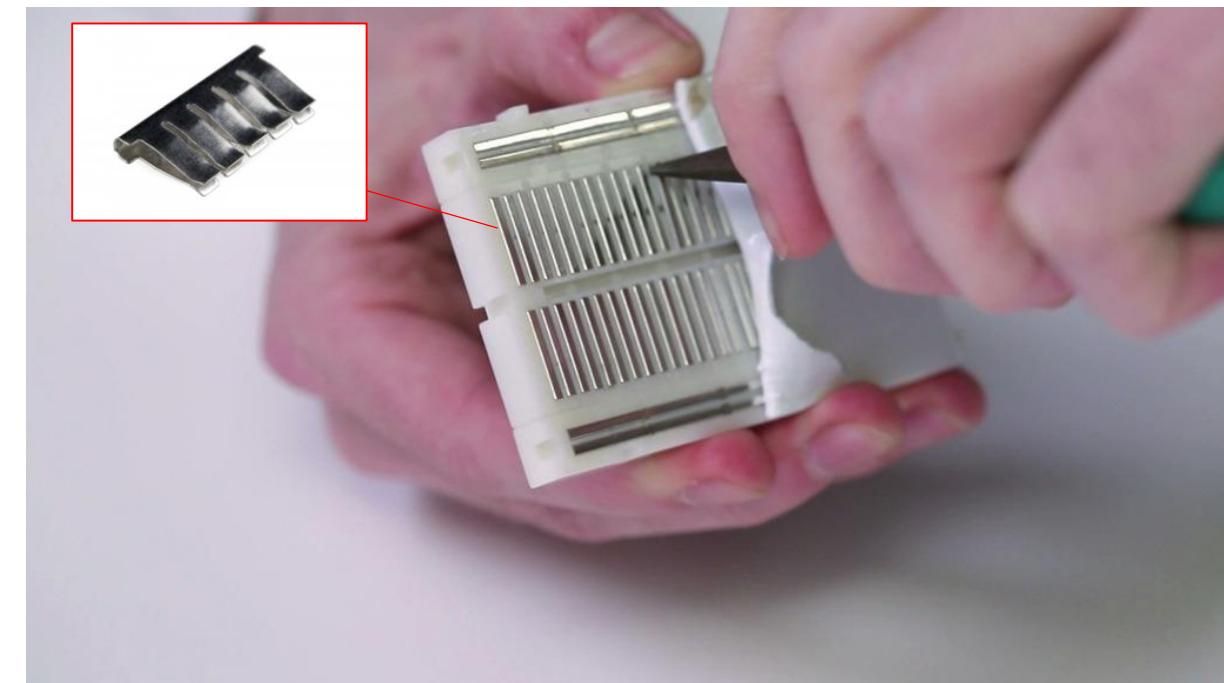
HOW DO BREADBOARDS WORK?

Breadboards are simply pre-wired boards. They are always a bit confusing at first. It will just take a bit of experience to get comfortable!



Top of Breadboard

Viewed from the top



Inside Breadboard

Viewed from the bottom

BREADBOARDS

HOW DO BREADBOARDS WORK?

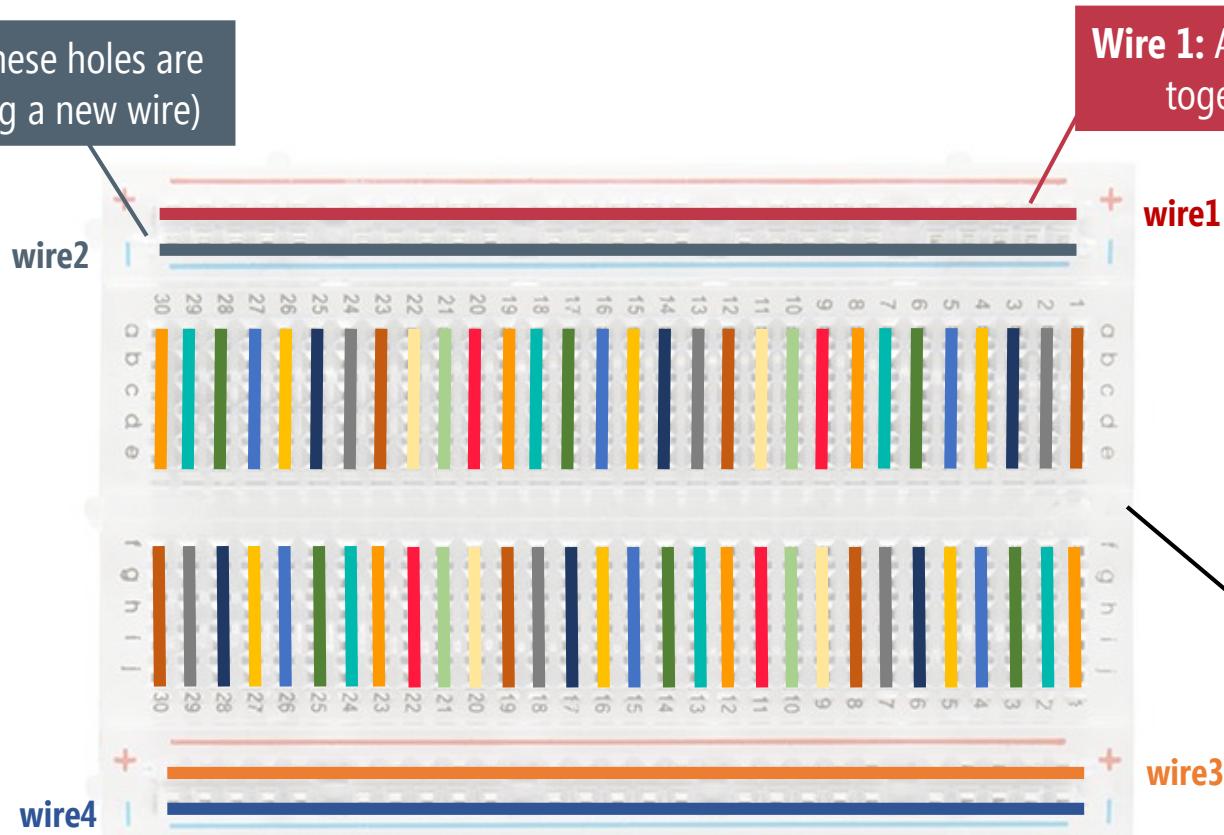
Wire 2: Similarly, all of these holes are hooked together (forming a new wire)

ROW SET 1
Each row wired together

COLUMN SET 1
Each column wired together

COLUMN SET 2
Each column wired together

ROW SET 2
Each row wired together



Wire 1: All of these holes are hooked together (to the same wire)



Importantly, wires do not cross this channel. So, the other side of a breadboard provides additional wiring

BREADBOARDS

BREADBOARD TIP 1: USE RAILS FOR VOLTAGE SUPPLY & GROUND

ROW SET 1

Each row wired together

COLUMN SET 1

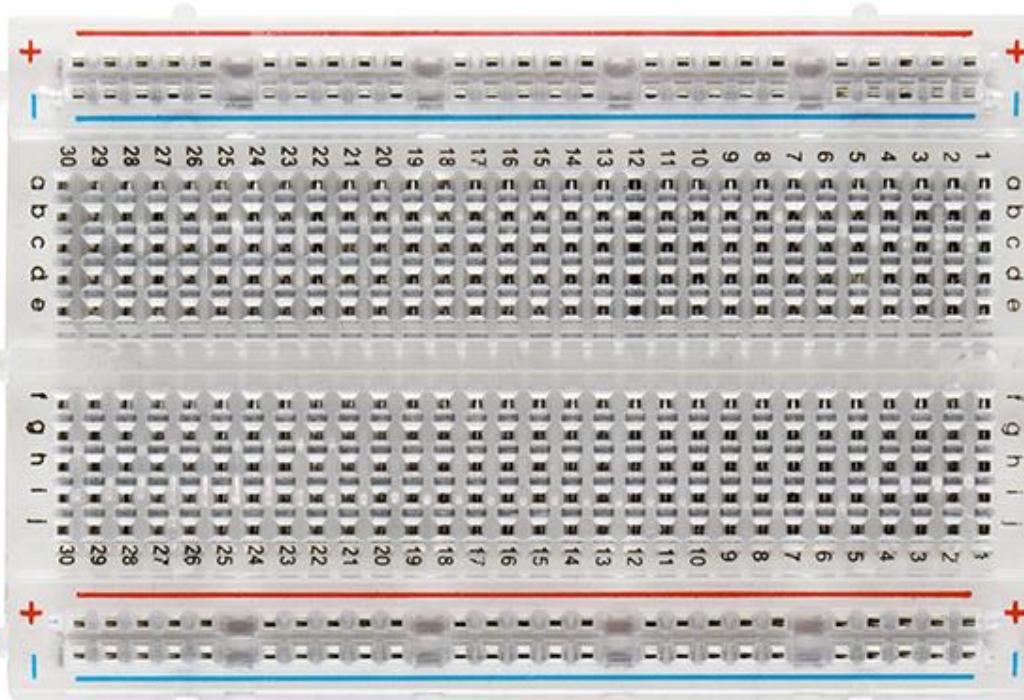
Each column wired together

COLUMN SET 2

Each column wired together

ROW SET 2

Each row wired together



Typically we hook up **V_s** (our positive voltage source) here

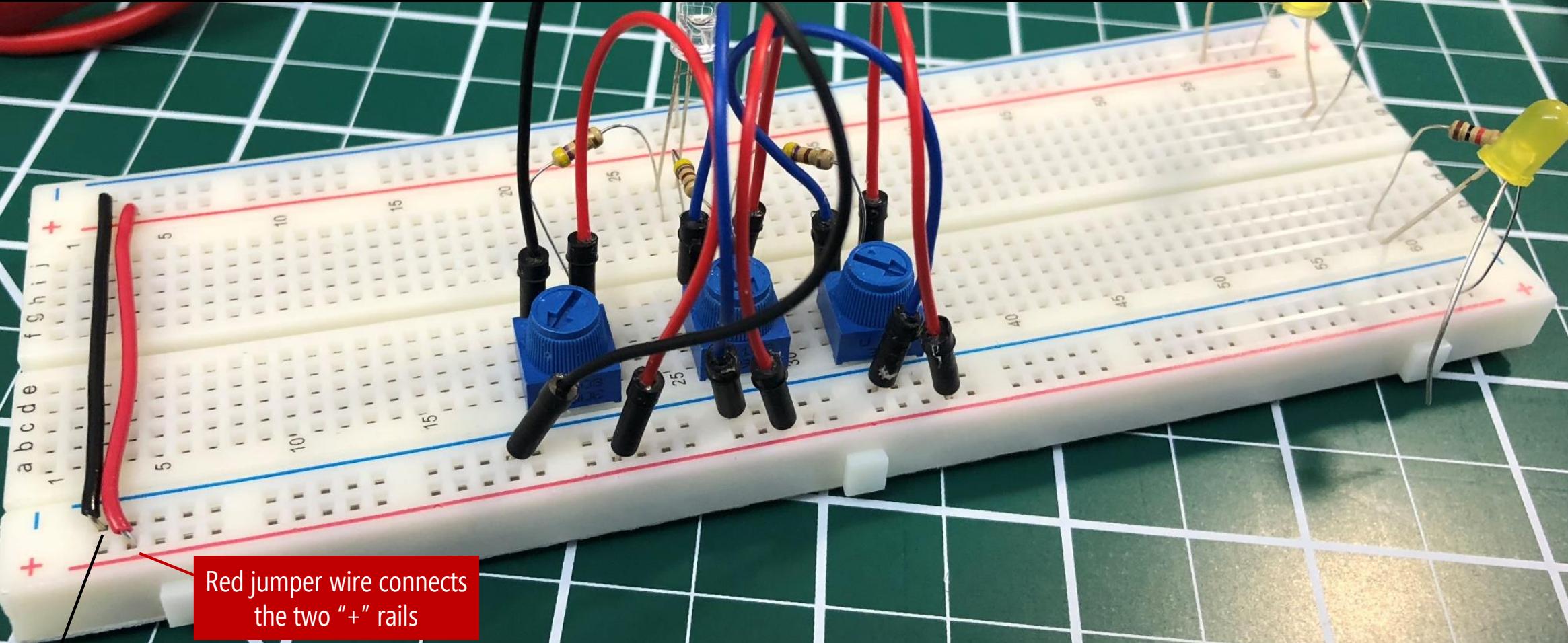
And we hook up **GND** (ground) here.

This wiring configuration just makes things easier.

In fact, this part of the breadboard is often called "power rails"

BREADBOARDS

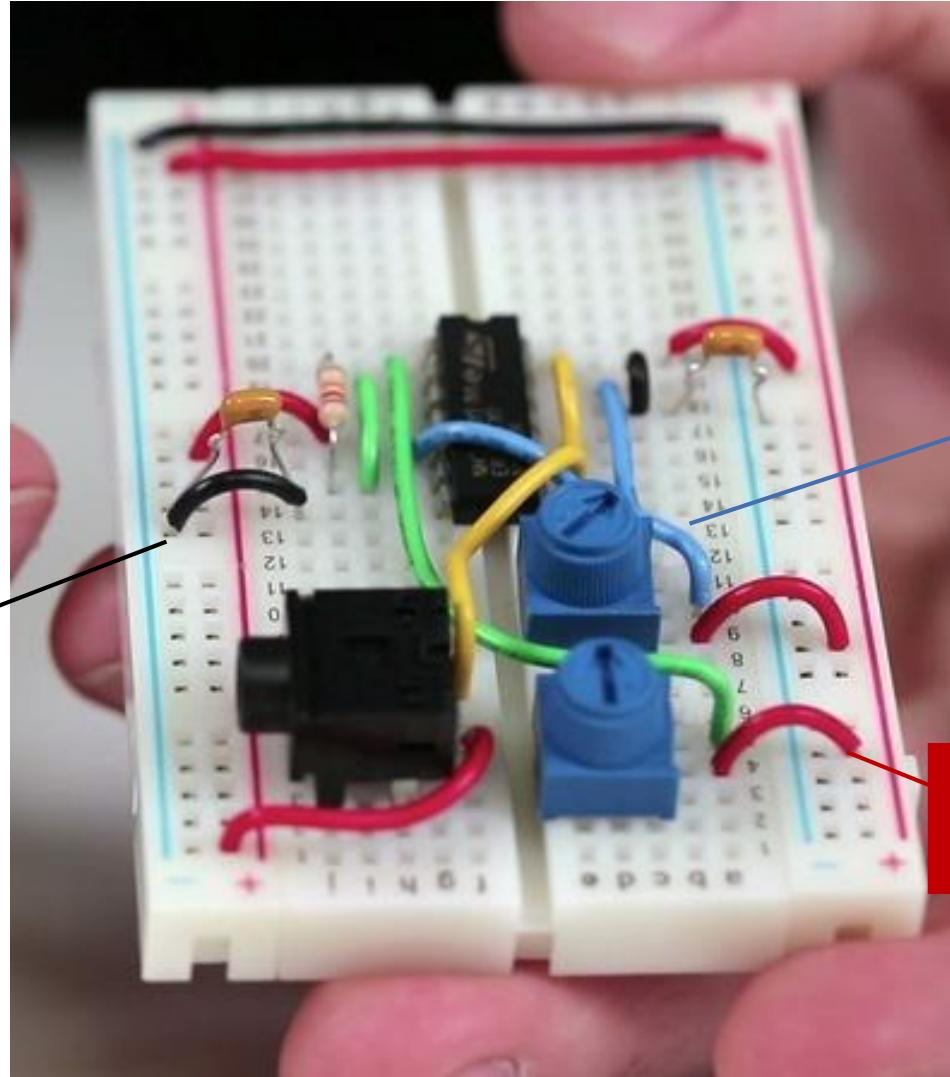
BREADBOARD TIP 2: CONNECT POWER RAILS WITH JUMPER WIRE



Black jumper wire
connects the two "-" rails

Red jumper wire connects
the two "+" rails

BREADBOARD TIP 3: USE WIRE COLOR TO MEAN SOMETHING



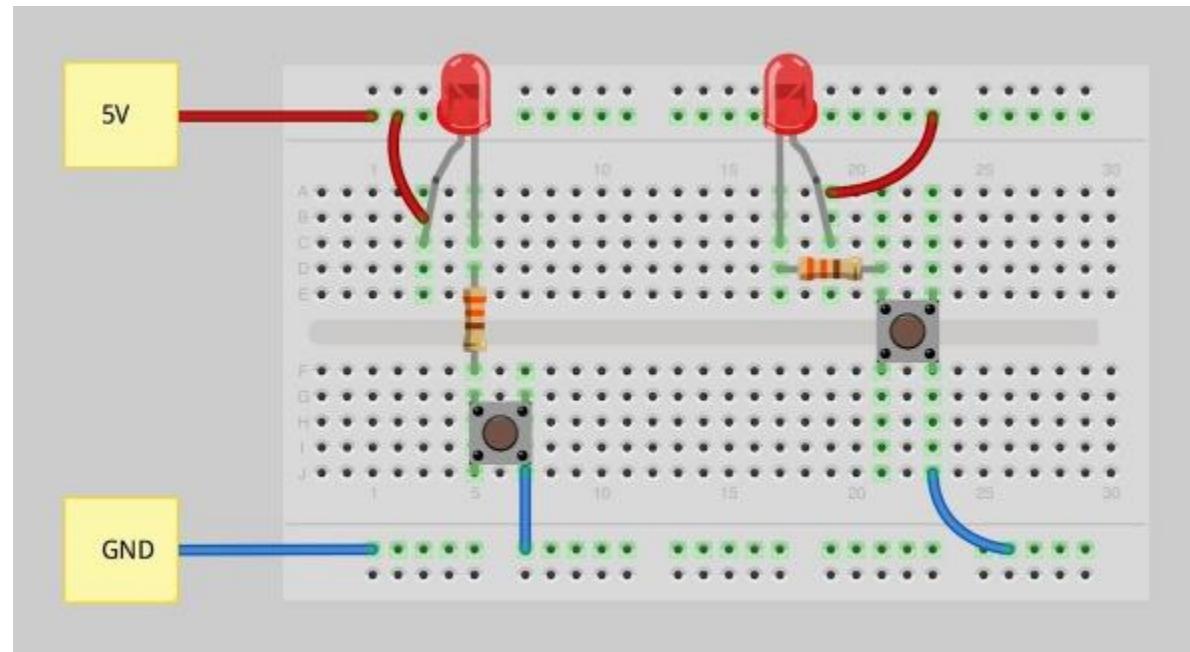
Only use black wire for wires
that connect to GND

Use other wire colors to
indicate other meaning

Only use red wire for wires that
connect to power (or Vcc)

BREADBOARD TIP 4: DEFENSIVE BREADBOARDING

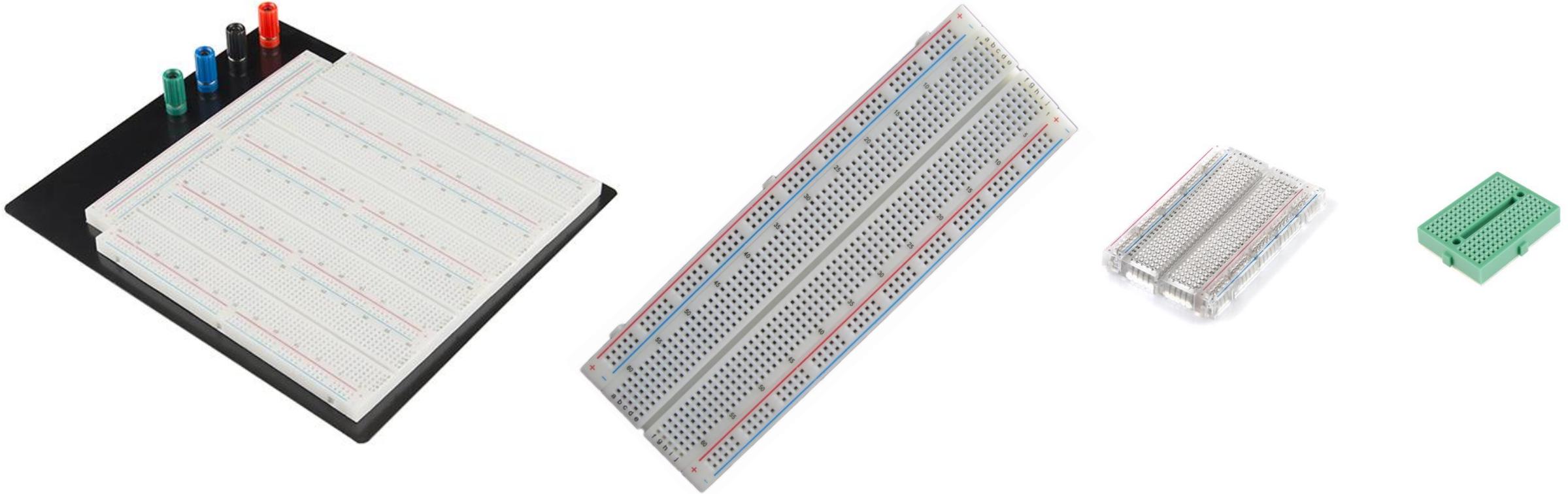
Some choose to only connect power on one side of the breadboard and ground on the other to reduce the chance of accidentally plugging a wire into the wrong socket and shorting out a circuit.



Notice how the 5V and GND rails are only connected on opposite sides of the breadboard. This is to limit stupid mistakes!

BREADBOARDS

LOTS OF DIFFERENT BREADBOARD SIZES

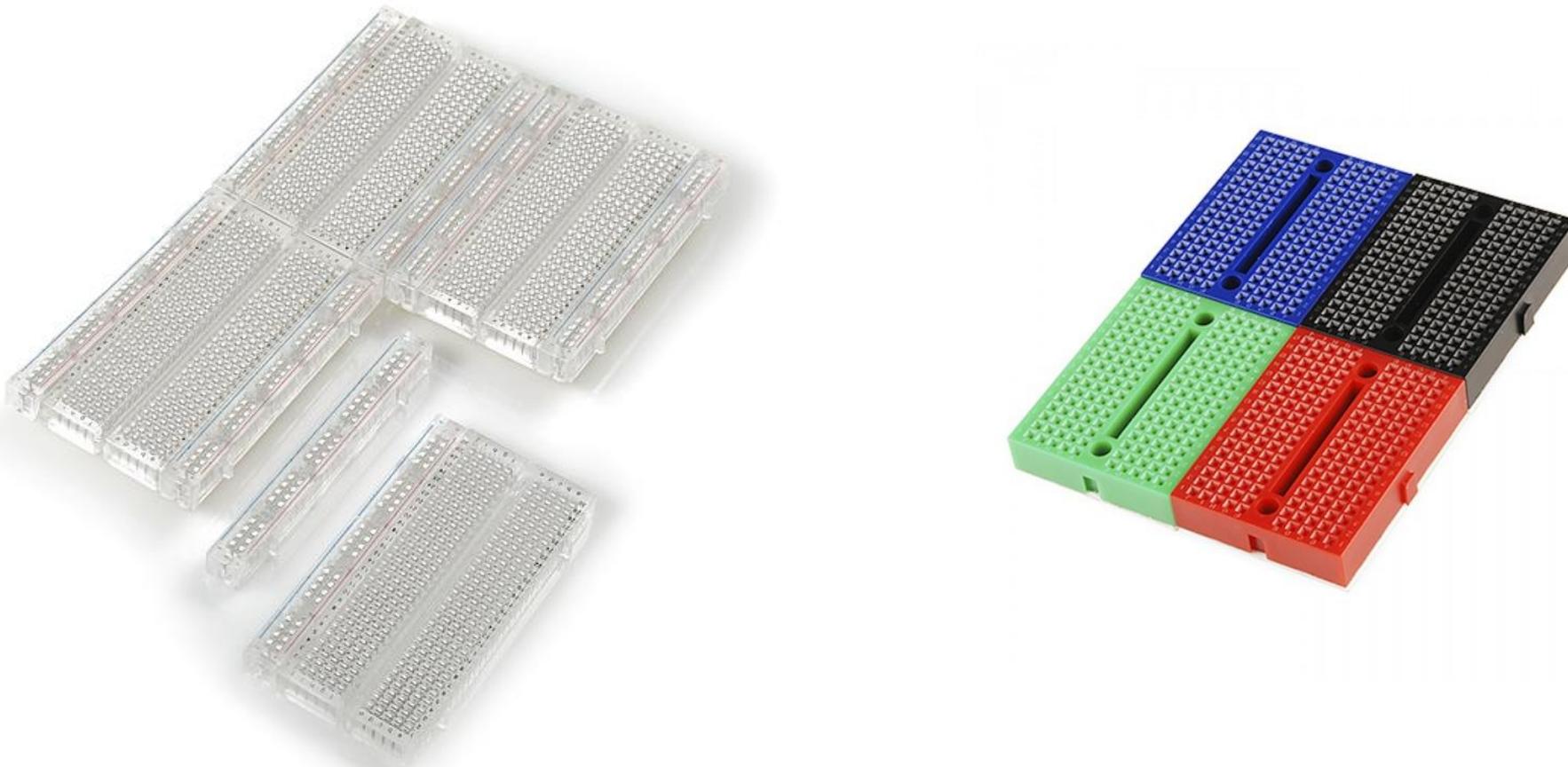


Which breadboards do you have in your Arduino kits?

BREADBOARDS

BREADBOARDS ARE LIKE LEGOS!

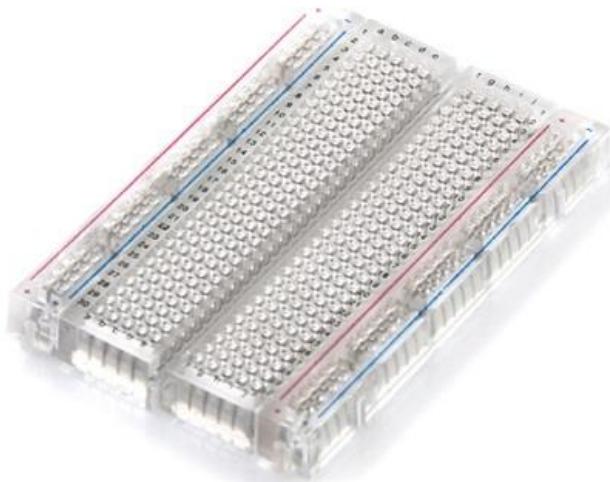
Many breadboards have little nubbins and slots on the sides, and some even have them on the tops and bottoms. These allow you to connect multiple breadboards together to form the ultimate prototyping surface.



BREADBOARDS

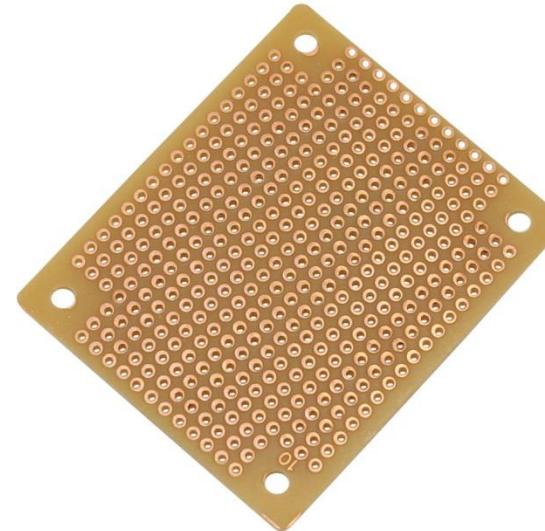
BREADBOARDS VS. PERFBOARDS

Typically, you start prototyping on a breadboard but then switch over to something like a perfboard once your design is starting to solidify or you want something more permanent. Perfboards require soldering.

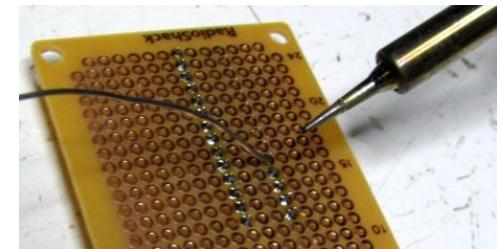


Breadboard

!=



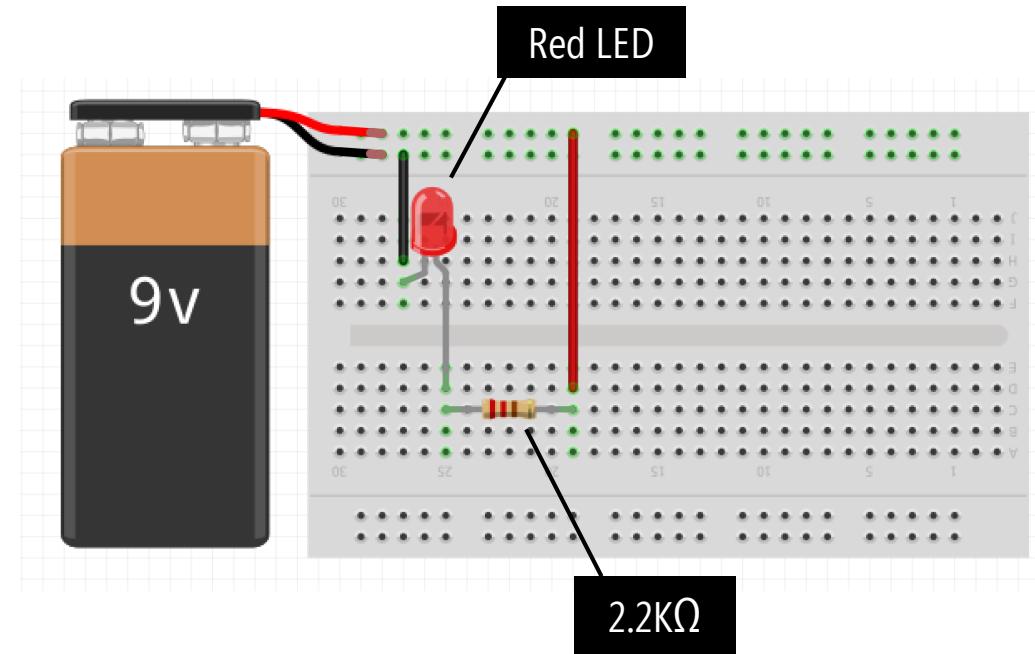
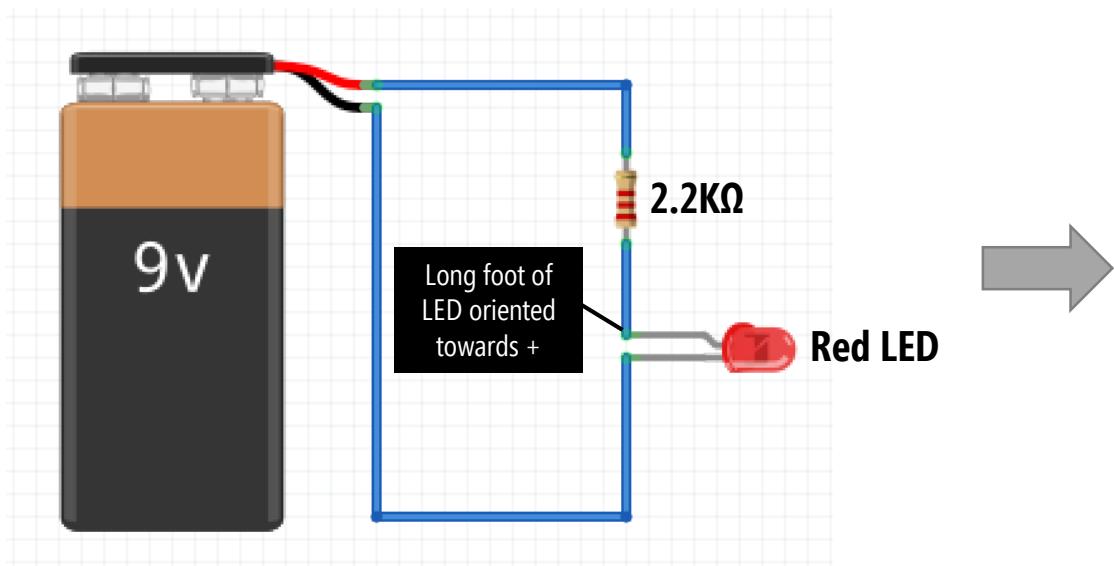
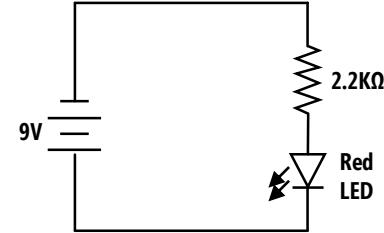
Perfboard



ACTIVITY

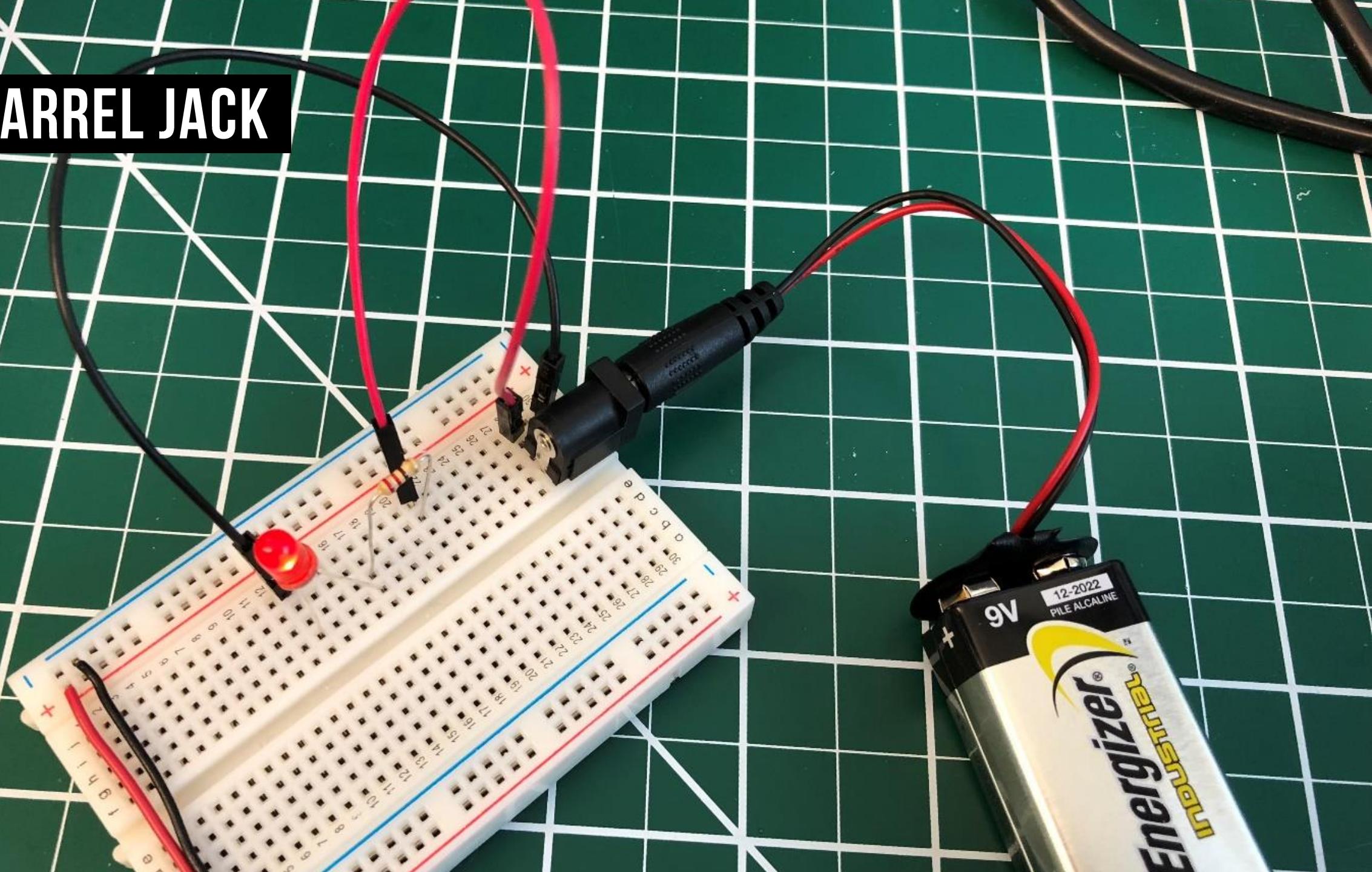
ADAPT YOUR CIRCUIT TO USE A BREADBOARD

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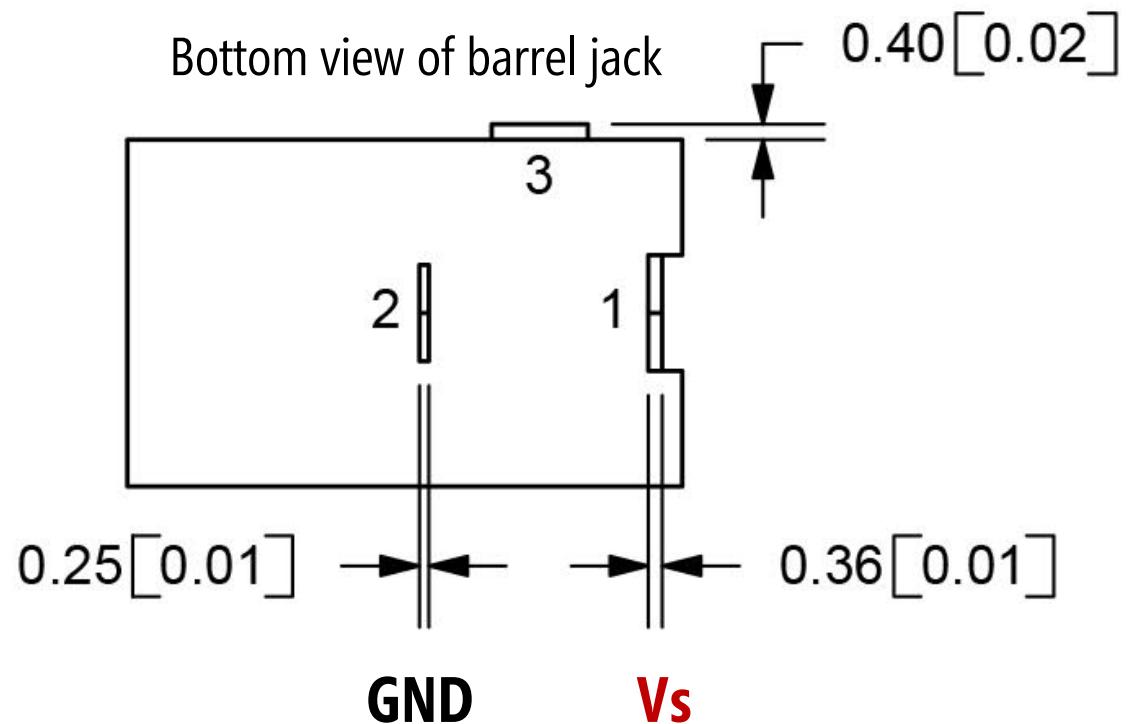
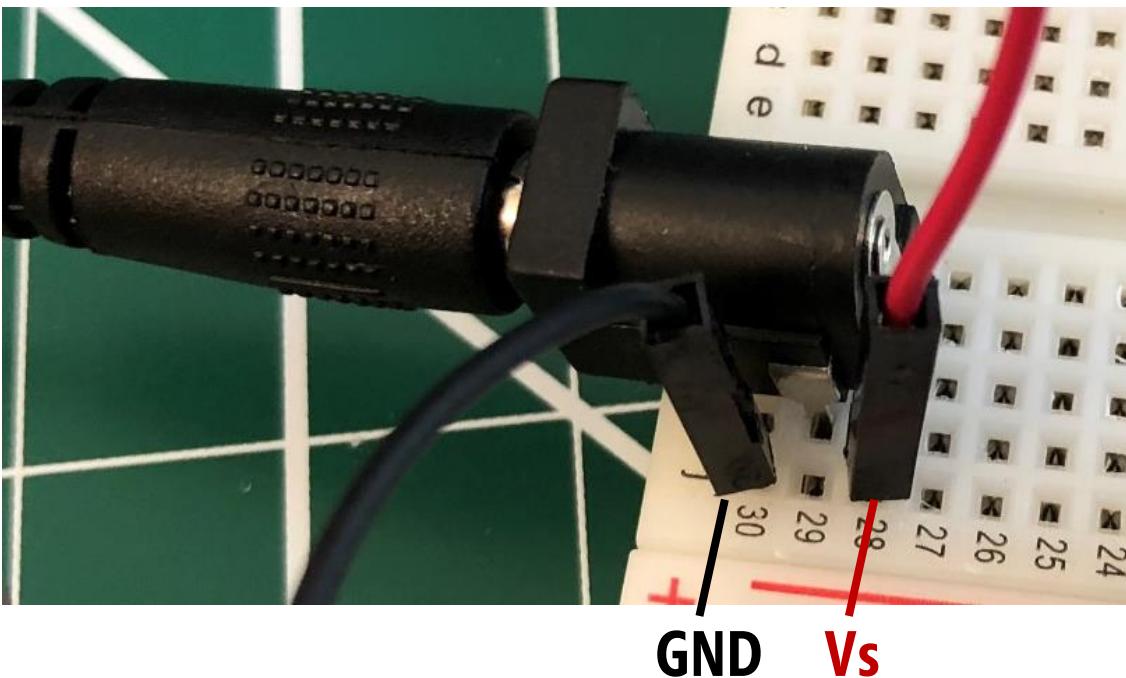
USING LEDS

THE BARREL JACK



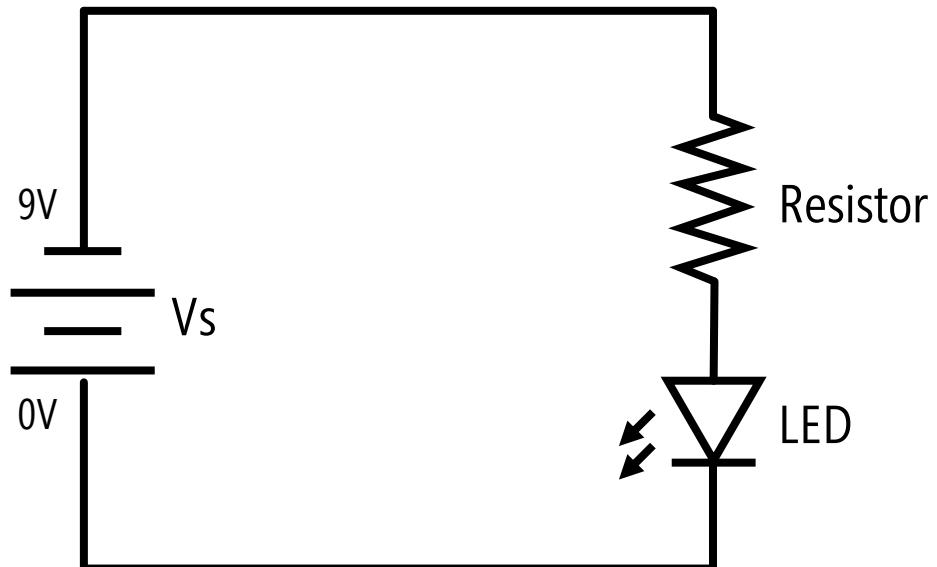
USING LEDs

THE BARREL JACK



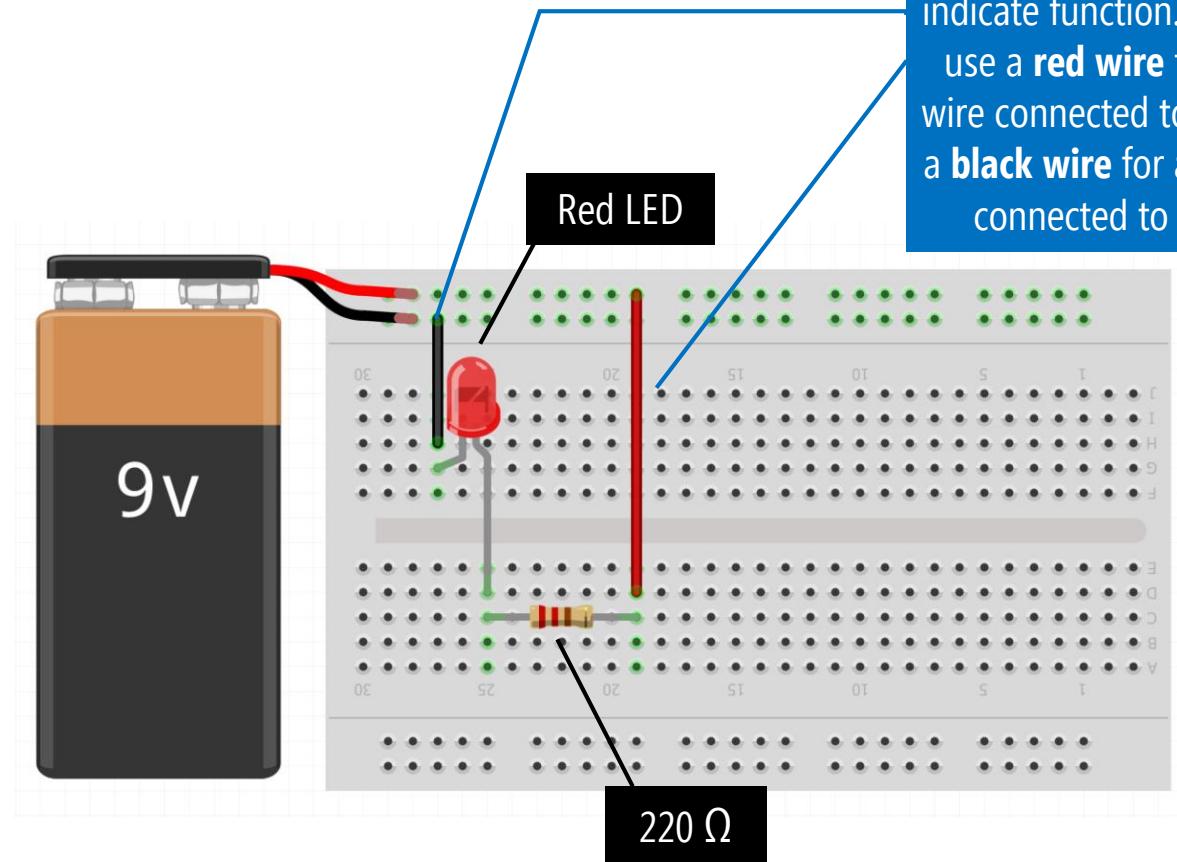
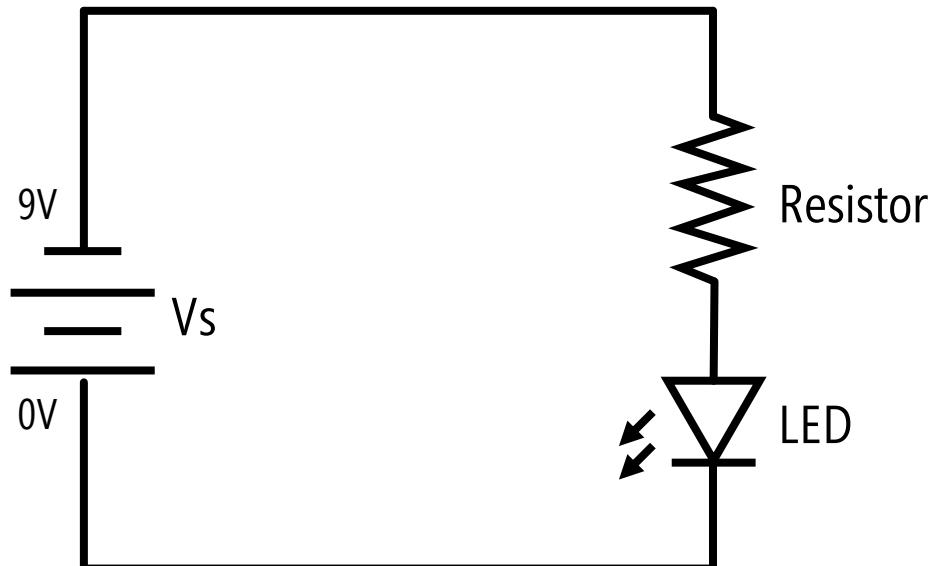
EXERCISE: LET'S HOOKUP OUR FIRST CIRCUIT!

Let's make this on a breadboard!



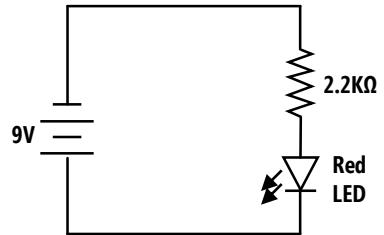
EXERCISE: ONE POTENTIAL ANSWER

Let's make this on a breadboard!

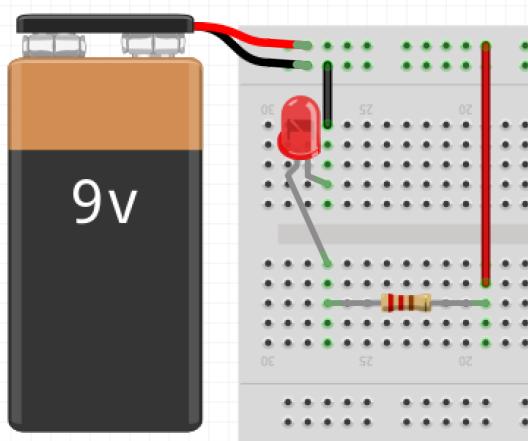


BREADBOARDS

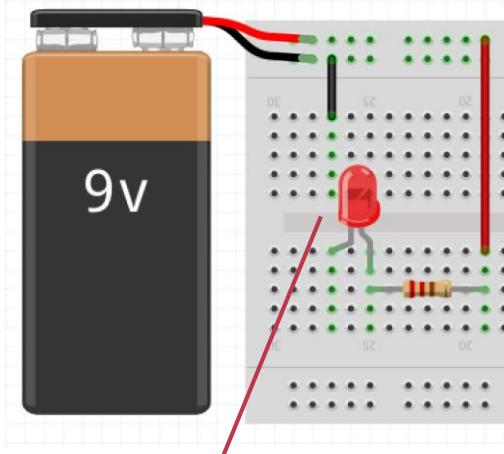
EXERCISE: CORRECT OR INCORRECT?



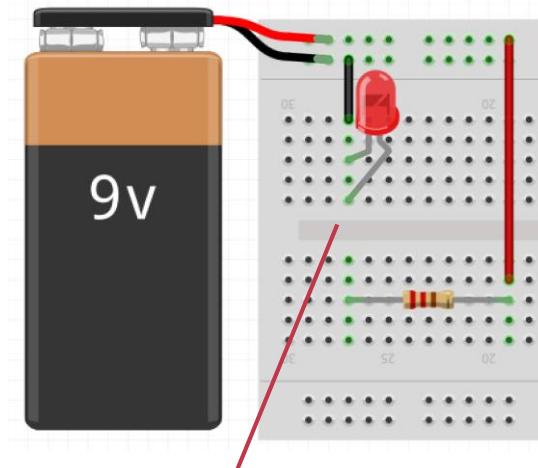
Correct or Incorrect?



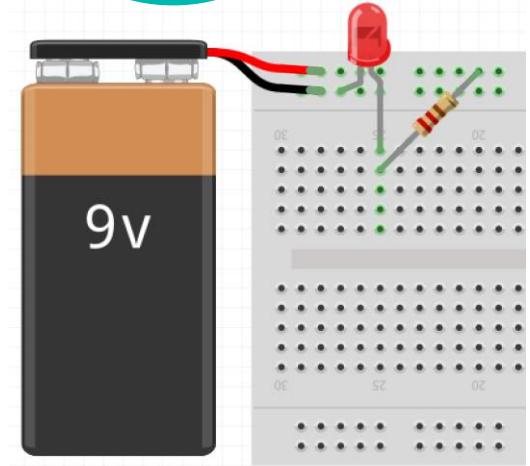
Correct or Incorrect?



Correct or Incorrect?



Correct or Incorrect?



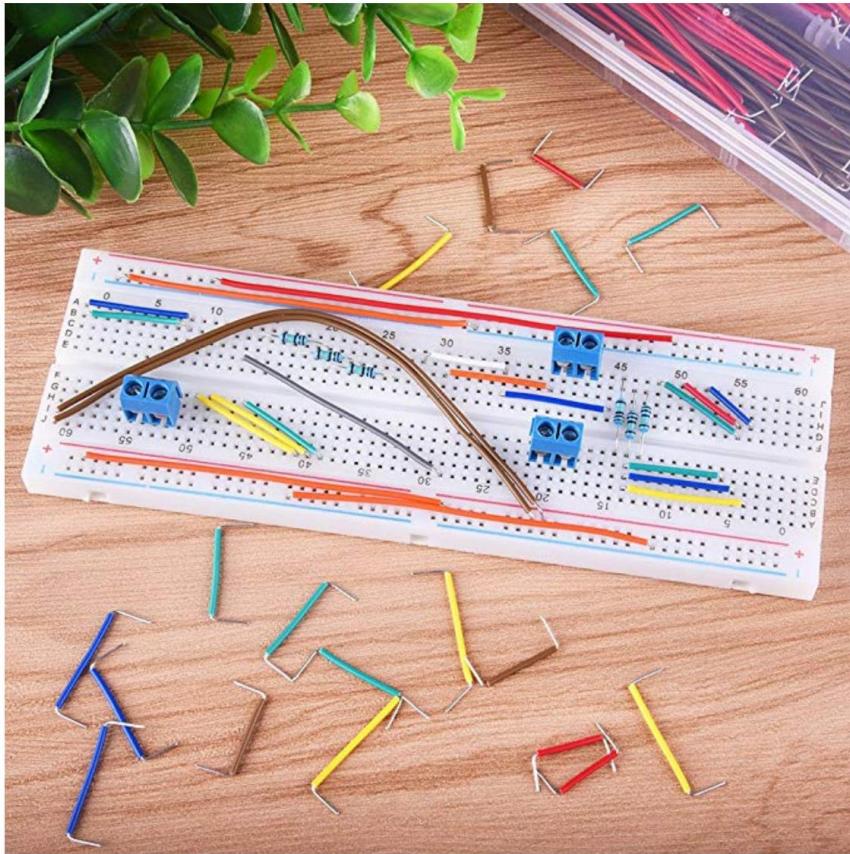
Recall that these **columns are not connected** across this split/gulf. So, the LED is not actually connected to the black wire (GND).

The **LED is connected to itself** as both legs are connected to the same column. The **LED also is not connected to the resistor** as it does not span the gulf.

BREADBOARDS

WHAT'S WRONG WITH THIS PICTURE?

« Back to results



Roll over image to zoom in

AUSTOR 840 Pieces Preformed Breadboard Jumper Wire Kit, 14 Lengths Assorted Jumper Wire for Breadboard Prototyping Solder Circuits

by AUSTOR

Be the first to review this item

Price: \$11.99

Thank you for being a Prime member. Get \$70 off instantly: Pay \$0.00 upon approval for the Amazon Prime Rewards Visa Card. No annual fee.

- Package includes: contains 840 pieces U shape preformed breadboard jumper wire kit, 14 lengths, 60 pieces per size
- Wire Length: 2 mm, 5 mm, 7 mm, 10 mm, 12 mm, 15 mm, 17 mm, 20 mm, 22 mm, 25 mm, 50 mm, 75 mm, 100 mm, 125 mm
- Easy to use: each jumper has stripped ends and preformed right-angled leads for easy insertion into your breadboard
- Wide Application: these breadboards wires are ideal for use with any breadboard, prototyping, prototype circuits, LED strip, test circuits and etc.
- Note: the breadboard wire is a little soft that convenient for changing its shape to do connect test; if you find that it can't be inserted, please check whether the cable in the pin hole of a breadboard is in good condition or not

[See more product details](#)

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New (1) from \$11.99

Report incorrect product information.

MILAPEAK

Ultra flexible silicone insulated wire, easy use.

[Shop now](#)



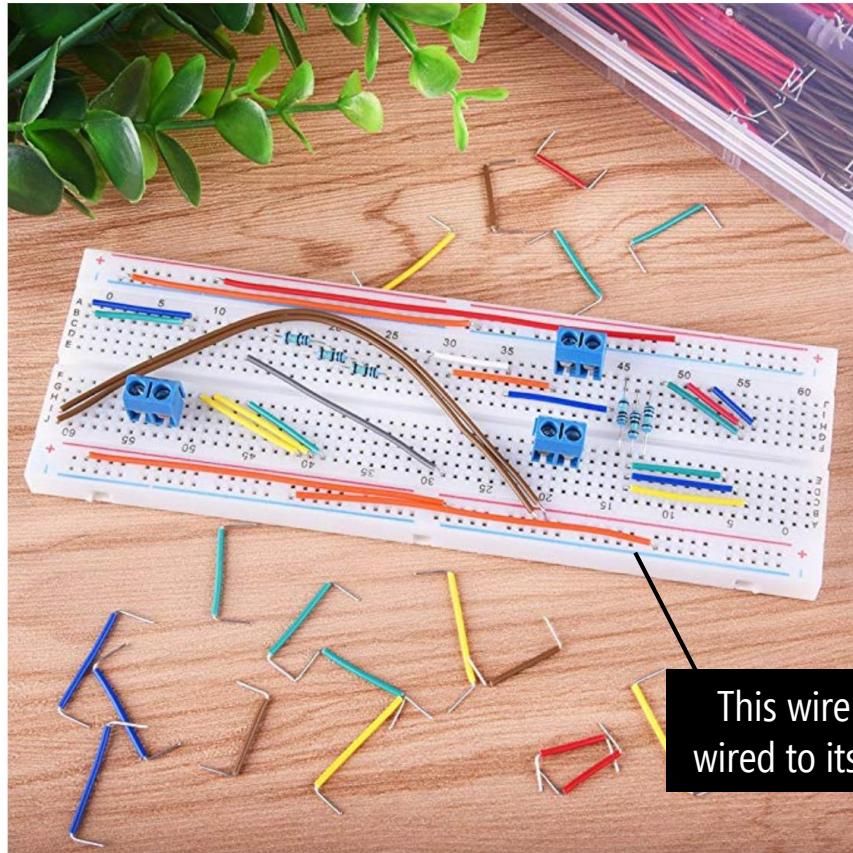
14 Gauge Silicone Wire 40 Feet
[20 ft Black and 20 ft Red] - Ultra Soft and Flexible/High Temper...

51

\$20.89

[Ad feedback](#)

WHAT'S WRONG WITH THIS PICTURE?

[« Back to results](#)[Roll over image to zoom in](#)

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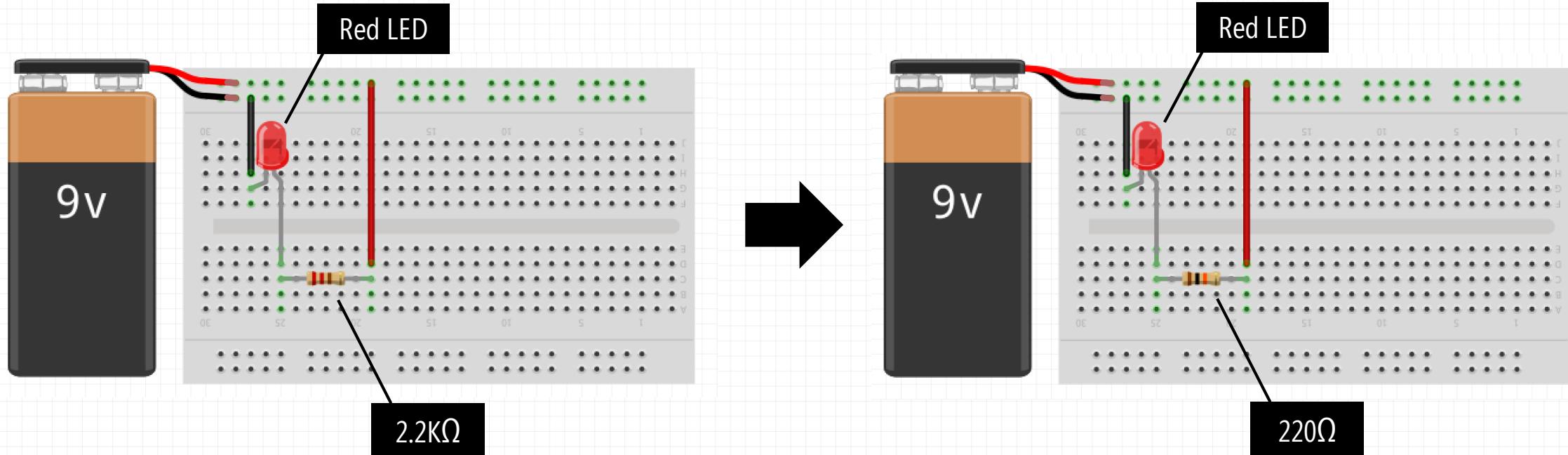
51

\$20.89

[Ad feedback](#)

ACTIVITY

SWAP THE 2.2K OHM RESISTOR WITH A 220 RESISTOR



What happens to the LED? Does it get brighter or dimmer? Why?

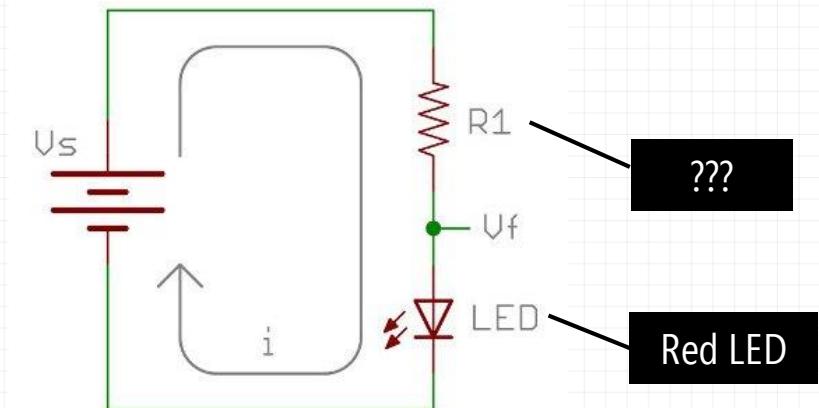
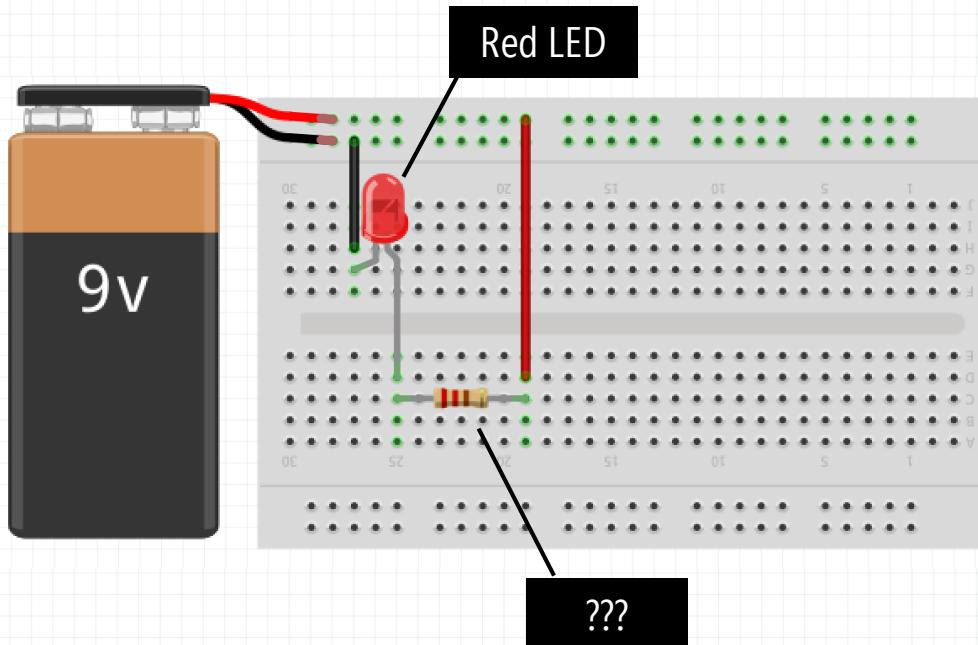
USING LEDs

EASY WAY TO TEST IF AN LED STILL WORKS

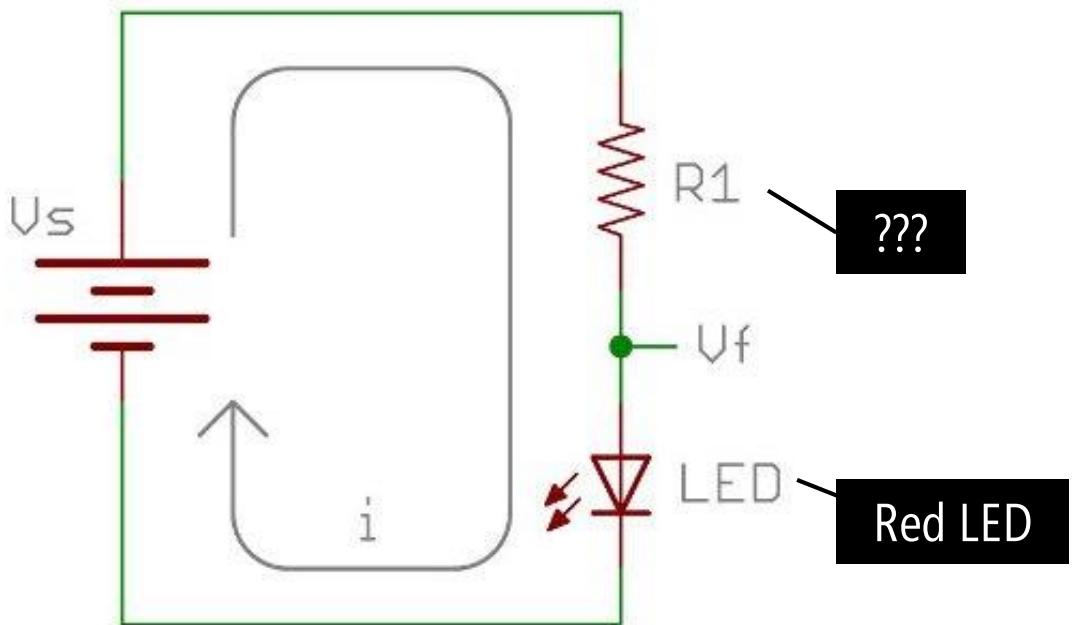
Just use a coin cell battery (e.g., a 3V CR2025 or similar)



HOW TO SELECT AN APPROPRIATE CURRENT LIMITING RESISTOR



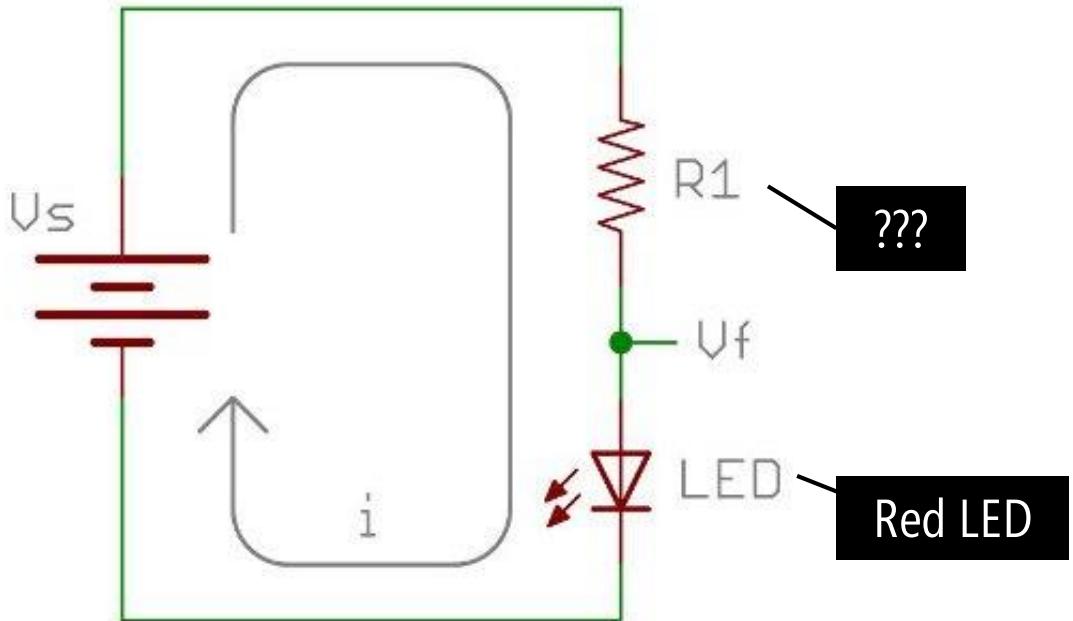
HOW TO SELECT AN APPROPRIATE CURRENT LIMITING RESISTOR



We need to know three things:

1. **LED forward current in Amps** (which is found in the LED datasheet). We will design our circuit around this desired current. Call this i .
2. **LED forward voltage in Volts** (again, consult the LED datasheet). Call this V_f
3. **The supply voltage**. Call this V_s . In our case, we are using a 9V battery, so $V_s = 9V$. Later, when we use Arduino, our V_s will shift to 5V.

HOW TO SELECT AN APPROPRIATE CURRENT LIMITING RESISTOR



With these three values, use this equation derived from Ohm's Law to find the value of the resistor:

$$R = \frac{V_s - V_f}{i}$$

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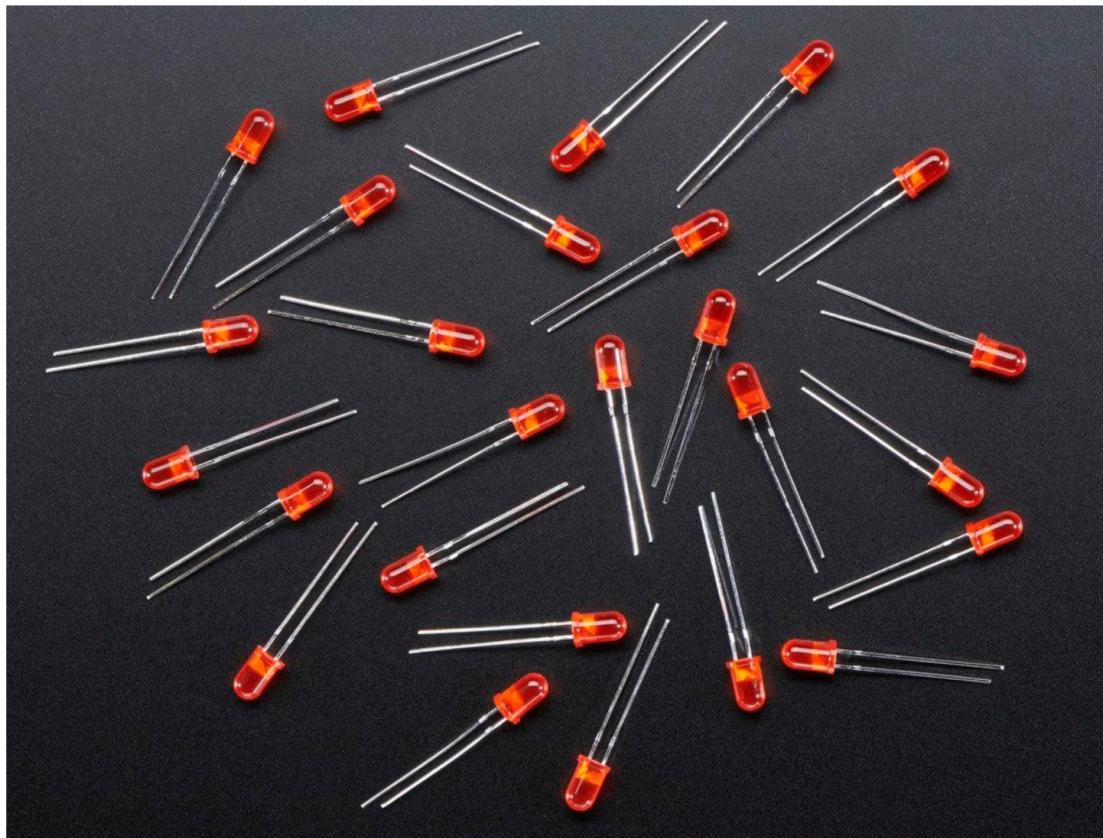
USING LEDs

FINDING THE DATASHEET





LEDS / BARE LEDS / DIFFUSED RED 5MM LED (25 PACK)



DESCRIPTION

Need some indicators? We are big fans of these diffused red LEDs, in fact we use them exclusively in our kits. They are fairly bright so they can be seen in daytime, and from any angle. They go easily into a breadboard and will add that extra zing to your project.

- Pack of 25 diffused red LEDs
- 5mm diameter
- 660 nm wavelength
- 1.85-2.5V Forward Voltage, at 20mA current
- 250 mcd typical brightness
- [Datasheet](#)

If you need some help using LEDs, please read our "Introduction to using LEDs" tutorial for any electronics project.

Diffused Red 5mm LED (25 pack)

PRODUCT ID: 299

\$4.00

OUT OF STOCK

Please enter your details below and we will send you an email when this item is back in stock. You will only be emailed about this product!

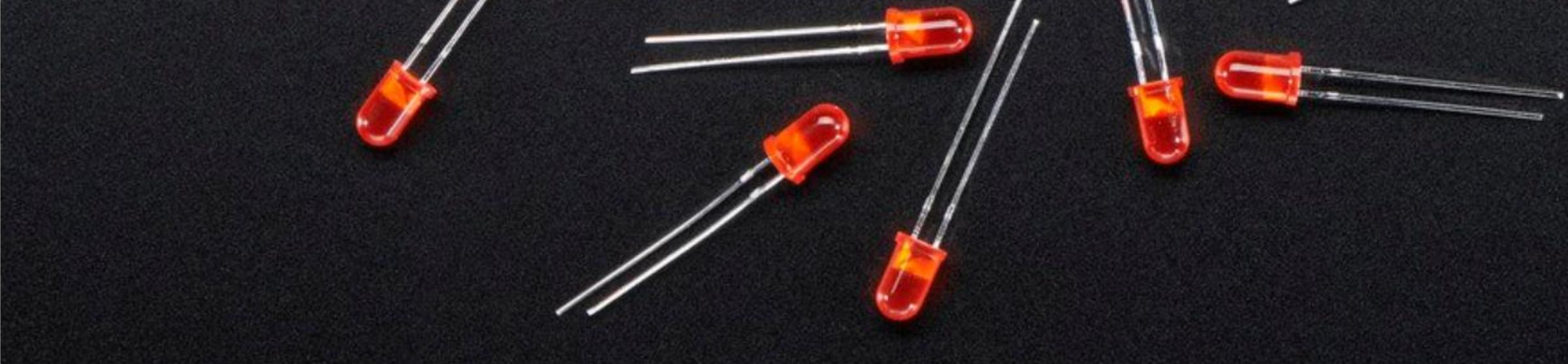
YOUR NAME

YOUR EMAIL

NOTIFY ME

ADD TO WISHLIST

DESCRIPTION**TECHNICAL DETAILS****LEARN**



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Kingbright

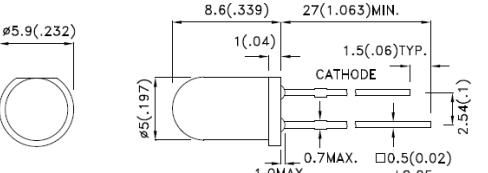
T-1 3/4 (5mm) SOLID STATE LAMP

Part Number: WP7113SRD/D Super Bright Red

Features

- LOW POWER CONSUMPTION.
- POPULAR T-1 3/4 DIAMETER PACKAGE.
- GENERAL PURPOSE LEADS.
- RELIABLE AND RUGGED.
- LONG LIFE - SOLID STATE RELIABILITY.
- AVAILABLE ON TAPE AND REEL.
- RoHS COMPLIANT.

Package Dimensions



Notes:
 1. All dimensions are in millimeters (inches).
 2. Tolerance is ±0.25(0.01") unless otherwise noted.
 3. Lead spacing is measured where the leads emerge from the package.
 4. Specifications are subject to change without notice.



Kingbright

Selection Guide

Part No.	Dice	Lens Type	Iv (mcd) [2] @ 20mA		Viewing Angle [1]
			Min.	Typ.	
WP7113SRD/D	Super Bright Red (GaAlAs)	RED DIFFUSED	180	250	201/2

Notes:

1. θ1/2 is the angle from optical centerline where the luminous intensity is 1/2 the optical centerline value.
2. Luminous intensity/luminous Flux: +/-15%.

Electrical / Optical Characteristics at TA=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
Apeak	Peak Wavelength	Super Bright Red	660		nm	I _f =20mA
AD [1]	Dominant Wavelength	Super Bright Red	640		nm	I _f =20mA
Δλ1/2	Spectral Line Half-width	Super Bright Red	20		nm	I _f =20mA
C	Capacitance	Super Bright Red	45		pF	V _r =0V; f=1MHz
V _f [2]	Forward Voltage	Super Bright Red	1.85	2.5	V	I _f =20mA
I _R	Reverse Current	Super Bright Red		10	uA	V _r = 5V

Notes:

1. Wavelength: +/-1nm.
2. Forward Voltage: +/-0.1V.

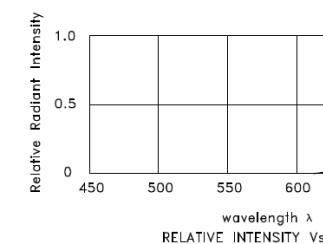
Absolute Maximum Ratings at TA=25°C

Parameter	Super Bright Red	Units
Power dissipation	75	mW
DC Forward Current	30	mA
Peak Forward Current [1]	155	mA
Reverse Voltage	5	V
Operating/Storage Temperature	-40°C To +85°C	
Lead Solder Temperature [2]	260°C For 3 Seconds	
Lead Solder Temperature [3]	260°C For 5 Seconds	

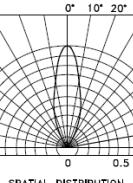
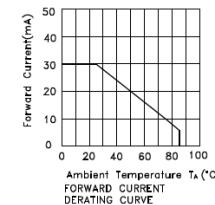
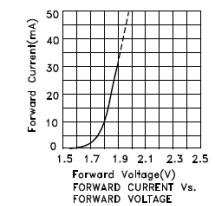
Notes:

1. 1/10 Duty Cycle, 0.1ms Pulse Width.
2. 2mm below package base.
3. 5mm below package base.

Kingbright



Super Bright Red WP7113SRD/D



READING AN LED DATASHEET

<https://www.sparkfun.com/datasheets/Components/LED/COM-09590-YSL-R531R3D-D2.pdf>

ITEMS	Symbol	Absolute Maximum Rating	Unit
Forward Current	I_F	20	mA
Peak Forward Current	I_{FP}	30	mA
Suggestion Using Current	I_{SU}	16-18	mA
Reverse Voltage ($V_R=5V$)	I_R	10	uA
Power Dissipation	P_D	105	mW
Operation Temperature	T_{OPR}	-40 ~ 85	°C
Storage Temperature	T_{STG}	-40 ~ 100	°C
Lead Soldering Temperature	T_{SOL}	Max. 260°C for 3 Sec. Max. (3mm from the base of the epoxy bulb)	

Forward Current: how much current your LED will be able to handle continuously. In this case, 20mA.

Peak Forward Current: how much current the LED can sustain in short bursts. In this case, 30mA.

Suggestion Using Current: not all data sheets provide this, but this company recommends operating the LED at 16-18mA for best performance

Reverse Voltage: The maximum reverse voltage that the LED can sustain without damage (pay attention to this value if you often accidentally connect your LED anode to GND and cathode to VSS)

Power Dissipation: The amount of power in milliWatts that the LED can use before taking damage

READING AN LED DATASHEET

<https://www.sparkfun.com/datasheets/Components/LED/COM-09590-YSL-R531R3D-D2.pdf>

ITEMS	Symbol	Test condition	Min.	Typ.	Max.	Unit
Forward Voltage	V_F	$I_F=20\text{mA}$	1.8	---	2.2	V
Wavelength (nm) or TC(k)	$\Delta \lambda$	$I_F=20\text{mA}$	620	---	625	nm
*Luminous intensity	I_v	$I_F=20\text{mA}$	150	---	200	mcd
50% Viewing Angle	$2\theta_{1/2}$	$I_F=20\text{mA}$	40	---	60	deg

Forward Voltage: The forward voltage is the voltage drop across the LED. You must reach this threshold to turn 'on' the LED. In this case, 1.8V to 2.2V

Wavelength: A precise way of explaining the color of the LED, in this case its 620-625nm

LED Brightness: A measure of how bright the LED can get. The unit, millicandela (mcd), is standard for measuring the intensity of a light source. This LED has a luminous intensity of 150-200, which would make for a good indicator light (super bright LEDs can have 160,000-180,000mcd).

Viewing Angle: Different style LEDs will incorporate different types of lenses, reflectors, or diffusers to concentrate light or spread it widely.

Electrical / Optical Characteristics at TA=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
λ_{peak}	Peak Wavelength	Super Bright Red	660		nm	$I_F=20mA$
λ_D [1]	Dominant Wavelength	Super Bright Red	640		nm	$I_F=20mA$
$\Delta\lambda_{1/2}$	Spectral Line Half-width	Super Bright Red	20		nm	$I_F=20mA$
C	Capacitance	Super Bright Red	45		pF	$V_F=0V, f=1MHz$
V_F [2]	Forward Voltage	Super Bright Red	1.85	2.5	V	$I_F=20mA$
I_R	Reverse Current	Super Bright Red		10	uA	$V_R = 5V$

Notes:

- Wavelength: +/-1nm.
- Forward Voltage: +/-0.1V.

Absolute Maximum Ratings at TA=25°C

Parameter	Super Bright Red	Units
Power dissipation	75	mW
DC Forward Current	30	mA

Electrical / Optical Characteristics at TA=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
λ_{peak}	Peak Wavelength	Super Bright Red	660		nm	$I_F=20\text{mA}$
λ_D [1]	Dominant Wavelength	Super Bright Red	640		nm	$I_F=20\text{mA}$
$\Delta\lambda_{1/2}$	Spectral Line Half-width	Super Bright Red	20		nm	$I_F=20\text{mA}$
C	Capacitance	Super Bright Red	45		pF	$V_F=0\text{V}, f=1\text{MHz}$
V_F [2]	Forward Voltage	Super Bright Red	1.85	2.5	V	$I_F=20\text{mA}$
I_R	Reverse Current	Super Bright Red		10	uA	$V_R = 5\text{V}$

Notes:

1. Wavelength: +/-1nm.

2. Forward Voltage: +/-0.1V.

Absolute Maximum Ratings at TA=25°C

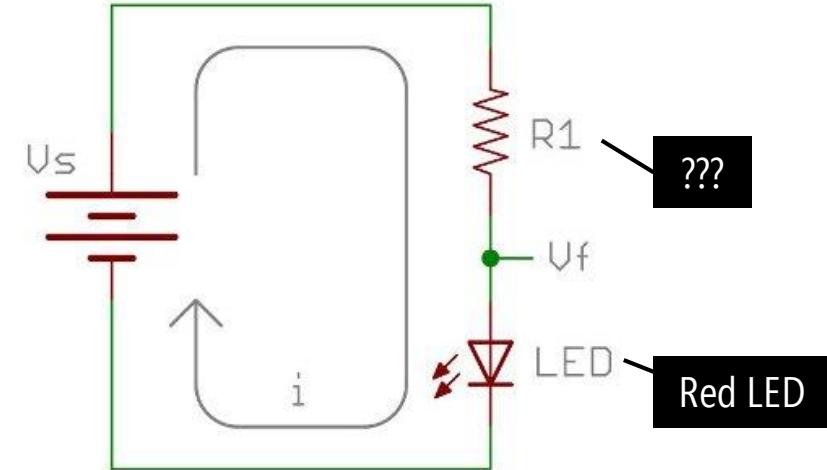
Parameter	Super Bright Red	Units
Power dissipation	75	mW
DC Forward Current	30	mA
Peak Forward Current [1]	155	mA
Reverse Voltage	5	V
Operating/Storage Temperature	-40°C To +85°C	
Lead Solder Temperature [2]	260°C For 3 Seconds	
Lead Solder Temperature [3]	260°C For 5 Seconds	

Notes:

1. 1/10 Duty Cycle, 0.1ms Pulse Width.

2. 2mm below package base.

3. 5mm below package base.



Recall that our equation for finding the value of the current limiting resistor is:

$$R = \frac{V_s - V_f}{i}$$

Let's plugin some values:

$$R = \frac{9V - 2V}{0.02A}$$

Which results in:

$$R = 350\Omega$$

Electrical / Optical Characteristics at TA=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
λ_{peak}	Peak Wavelength	Super Bright Red	660		nm	$I_F=20\text{mA}$
λ_D [1]	Dominant Wavelength	Super Bright Red	640		nm	$I_F=20\text{mA}$
$\Delta\lambda/2$	Spectral Line Half-width	Super Bright Red	20		nm	$I_F=20\text{mA}$
C	Capacitance	Super Bright Red	45		pF	$V_F=0V, f=1\text{MHz}$
V_F [2]	Forward Voltage	Super Bright Red	1.85	2.5	V	$I_F=20\text{mA}$
I_R	Reverse Current	Super Bright Red		10	uA	$V_R = 5V$

Notes:

1. Wavelength: +/-1nm.
2. Forward Voltage: +/-0.1V.

USING LEDs

TWO GOTCHAS!

If you exceed the **Peak Forward Current**, your LED will **burnout**!

Absolute Maximum Ratings at TA=25°C

Parameter	Super Bright Red	Units
Power dissipation	75	mW
DC Forward Current	30	mA
Peak Forward Current [1]	155	mA
Reverse Voltage	5	V
Operating/Storage Temperature	-40°C To +85°C	
Lead Solder Temperature [2]	260°C For 3 Seconds	
Lead Solder Temperature [3]	260°C For 5 Seconds	

Notes:

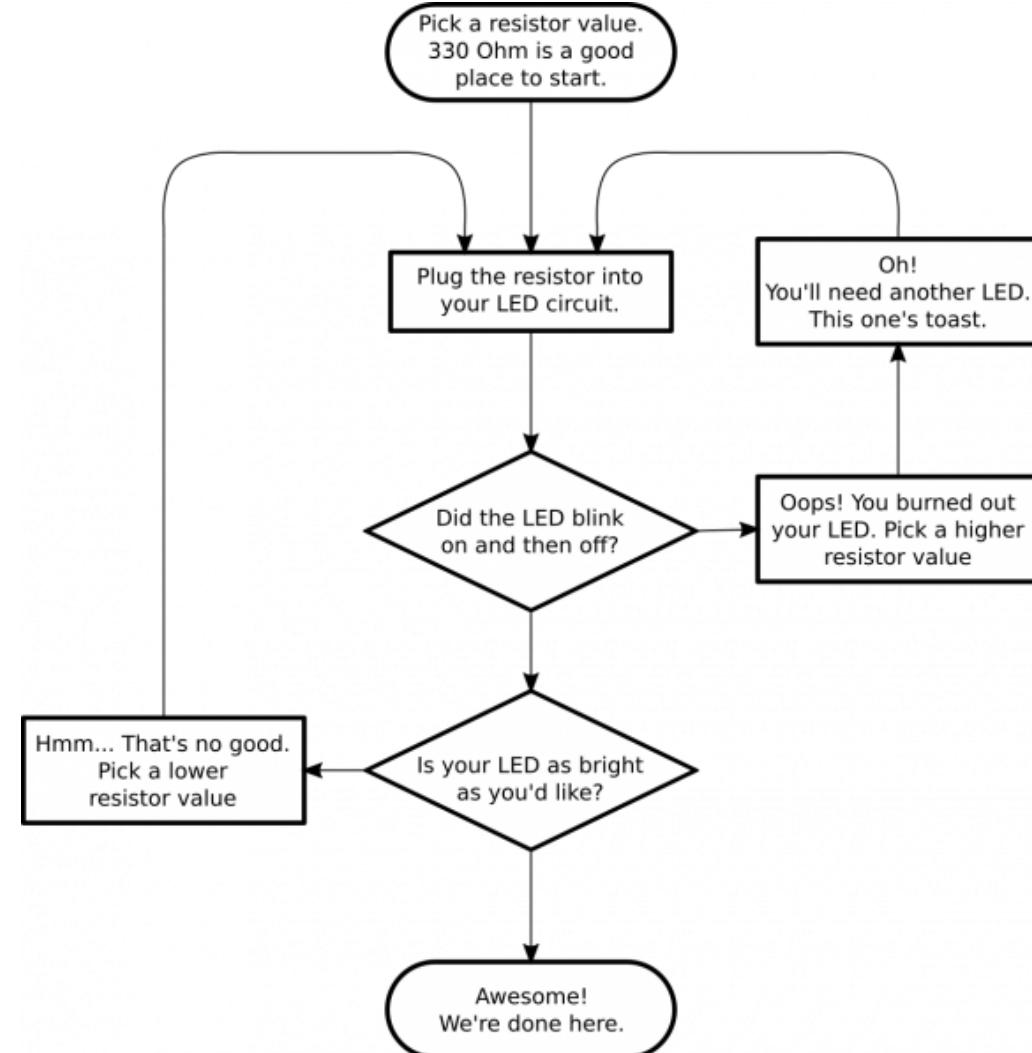
1. 1/10 Duty Cycle, 0.1ms Pulse Width.
2. 2mm below package base.
3. 5mm below package base.

Typically, if you hook up your LED in reverse (*i.e.*, cathode to positive, anode to negative), nothing will happen. However, if you accidentally do this and **exceed the Reverse Voltage** (5V in this case), again you can damage your LED.

OK, that's the formal way. But typically, most LEDs have forward currents of 20-35mA so with a **5V supply, starting with a ~200-400Ω resistor** is a good rule of thumb.

HOW TO SELECT AN APPROPRIATE CURRENT LIMITING RESISTOR

THE TRIAL AND ERROR METHOD



REVIEW: TODAY WE WENT OVER...

What is a **circuit, voltage, current, and resistance**

What is a **resistor** and how to use it

What is an **LED** and how to use it (e.g., polarity, current limiting resistor)

What is **Ohm's Law** and why is it useful?

Series vs. **parallel** resistive circuit configurations

What is a **breadboard** and how to use it

How to **read a datasheet**