Intro to Arduino

Zero to Prototyping in a Flash!

Material designed by Linz Craig, Nick Poole, Prashanta Aryal, Theo Simpson, Tai Johnson, and Eli Santistevan

Overview of Class

Getting Started:

Installation, Applications and Materials

Electrical:

Components, Ohm's Law, Input and Output, Analog and Digital

Programming:

Split into groups depending on experience

Serial Communication Basics:

Troubleshooting and Debugging

Virtual Prototyping:

Schematics and PCB Layout in Fritzing

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Arduino Board

“Strong Friend” Created in Ivrea, Italy

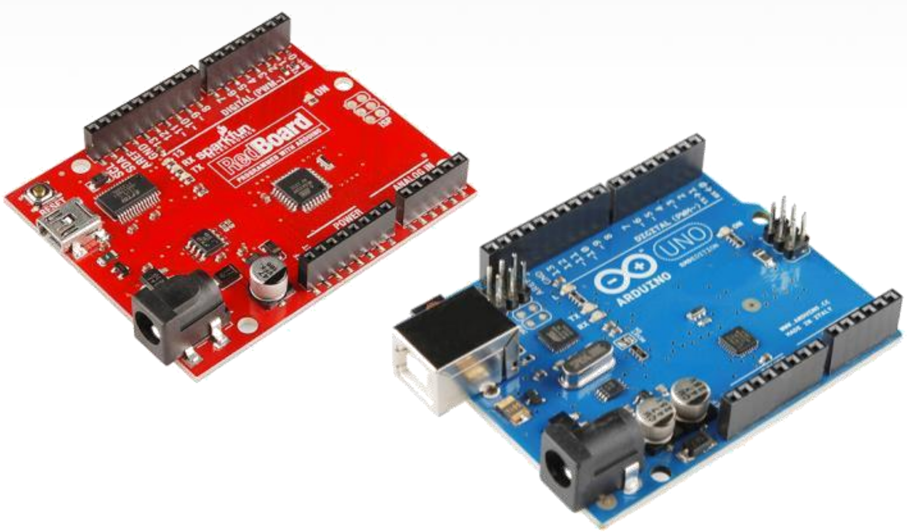
in 2005 by Massimo Banzi & David Cuartielles

Open Source Hardware

open source hardware

ATMEL Processor

Coding is accessible & transferrable → (C++, Processing, java)



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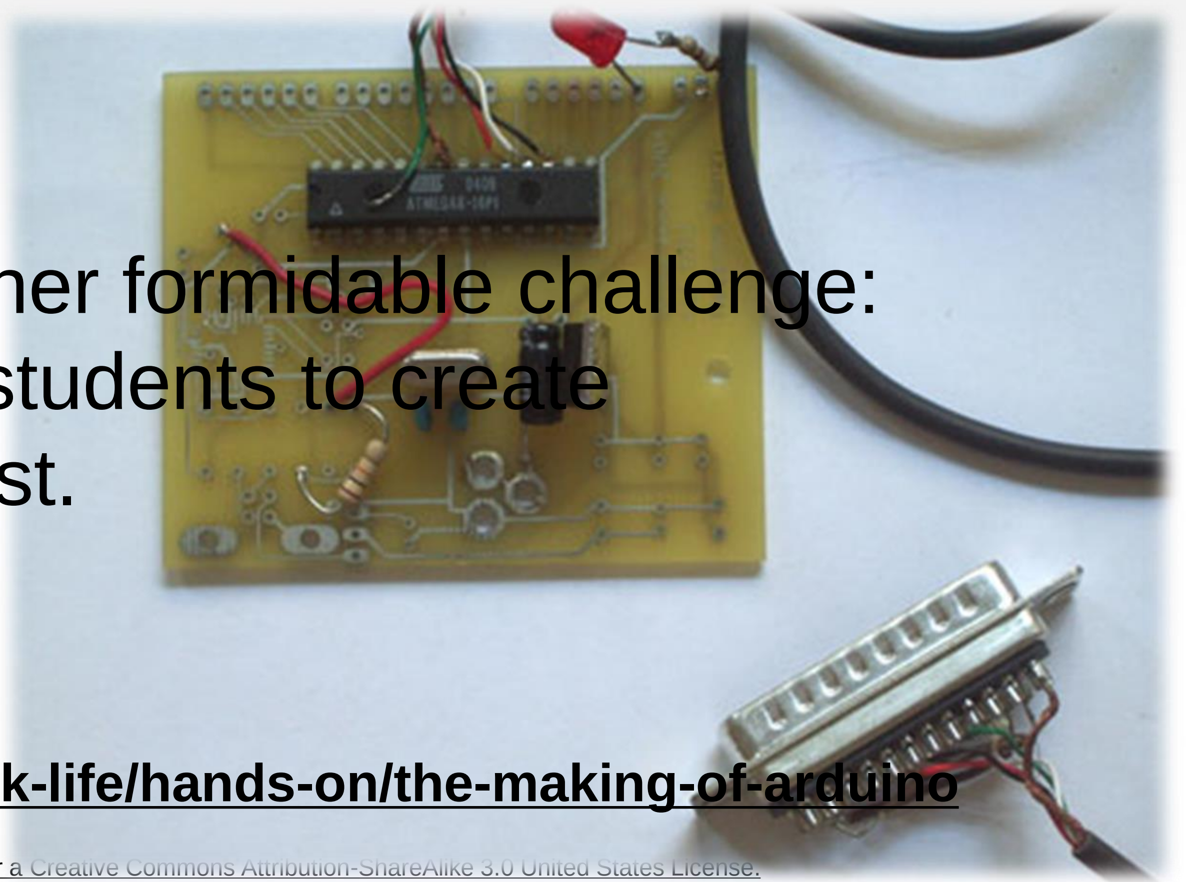
Arduino…

is the go-to gear for artists, hobbyists, students, and anyone with a gadgetry dream.

rose out of another formidable challenge: how to teach students to create electronics, fast.



http://spectrum.ieee.org/geek-life/hands-on/the-making-of-arduino

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Getting Started

- **SW Installation:** Arduino (v.1.0+)
  Fritzing
  SIK Guide Code
  Drivers (FTDI)

- **Materials:** SIK Guide
  Analog I/O, Digital I/O, Serial, & Fritzing handouts
  Arduino CheatSheet

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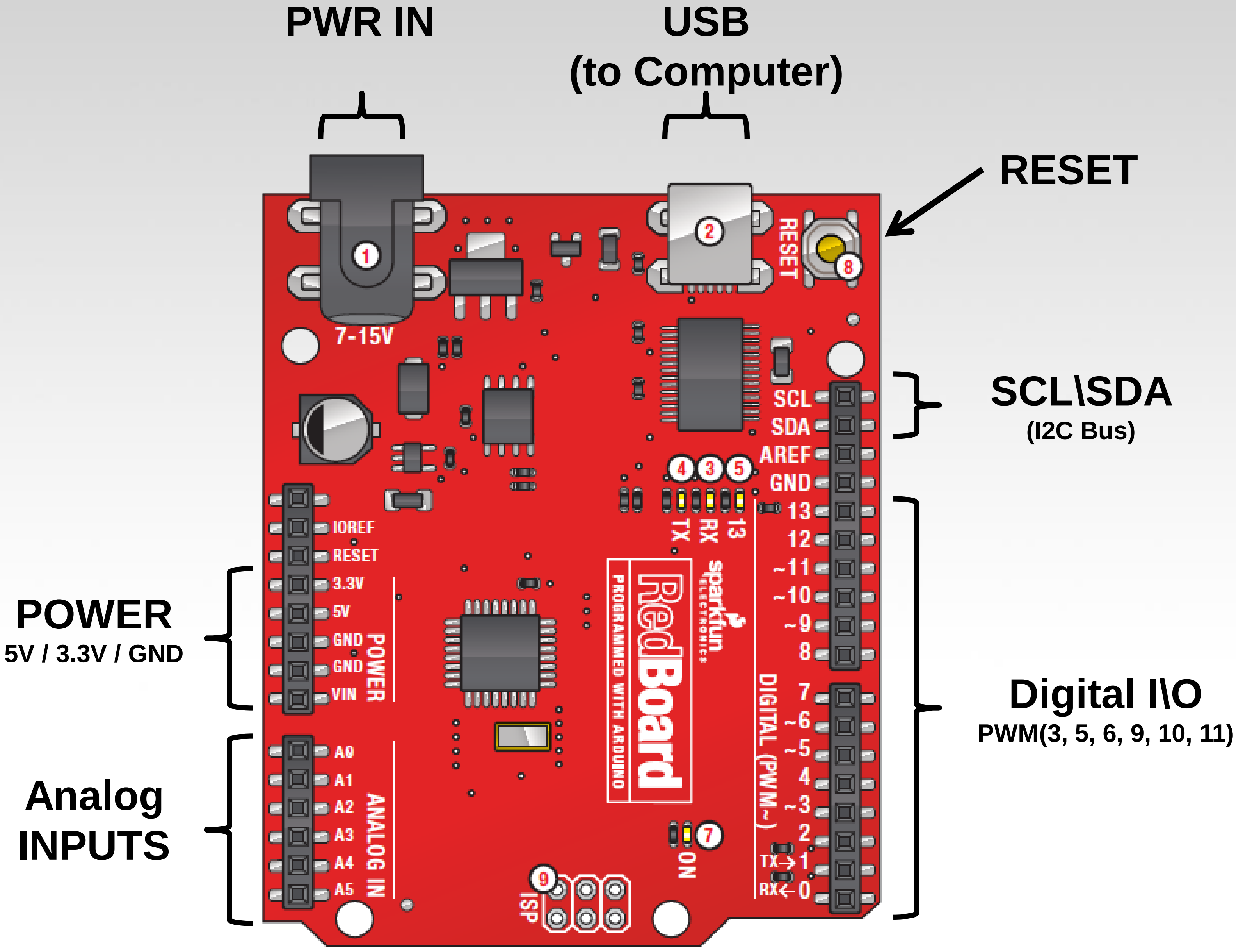

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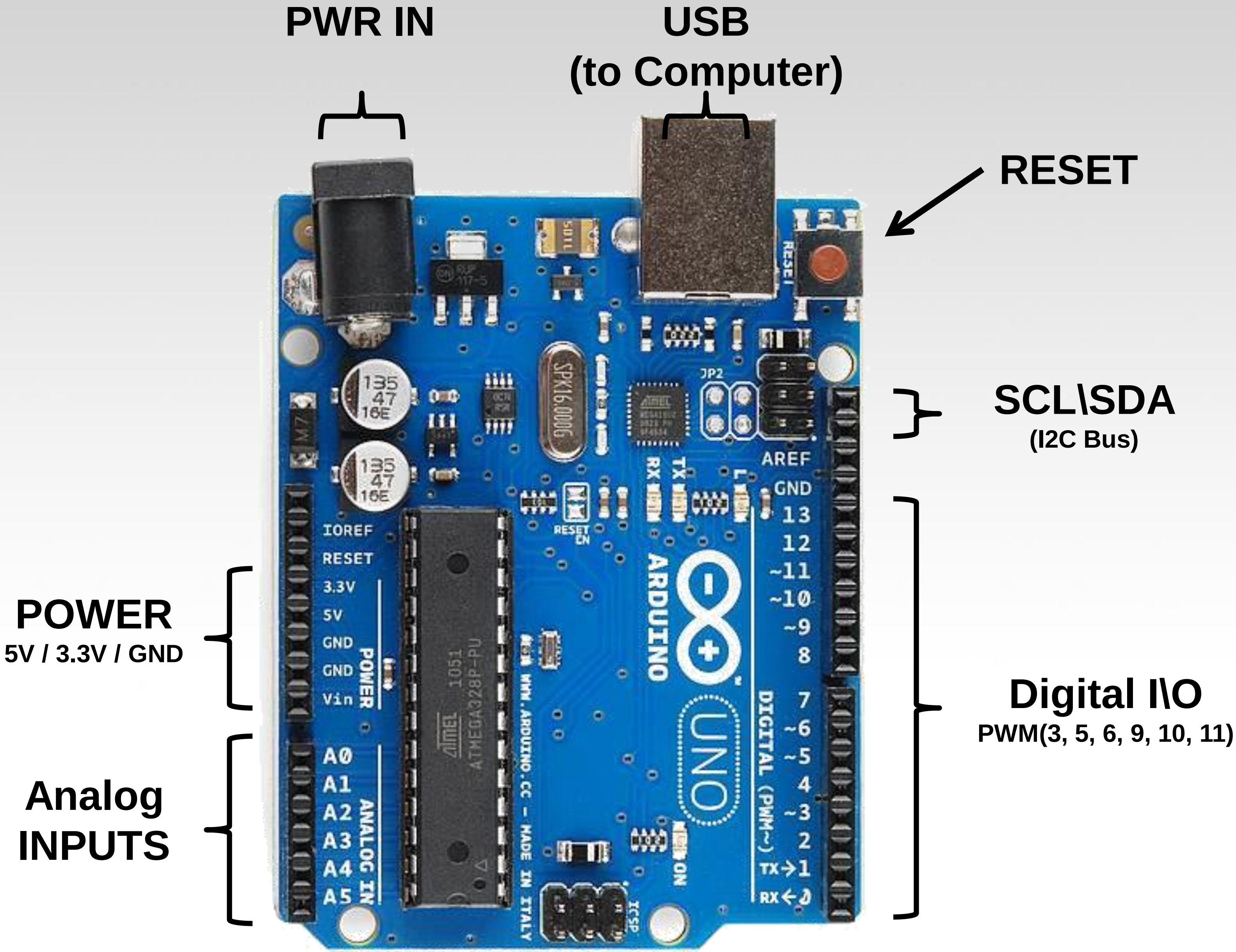

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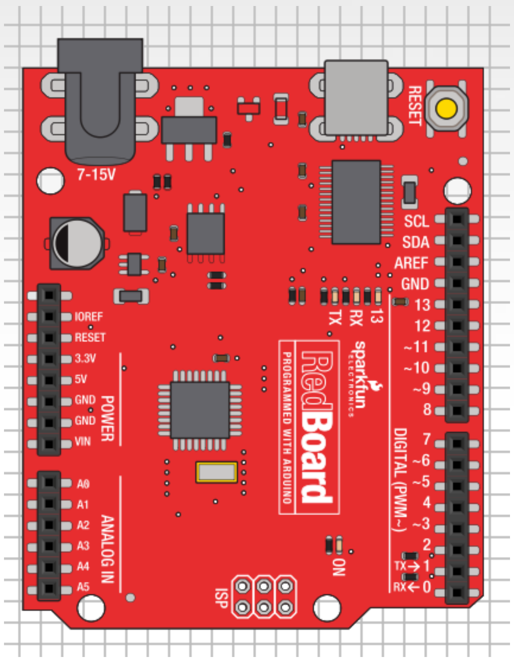
Go ahead and plug your board in!



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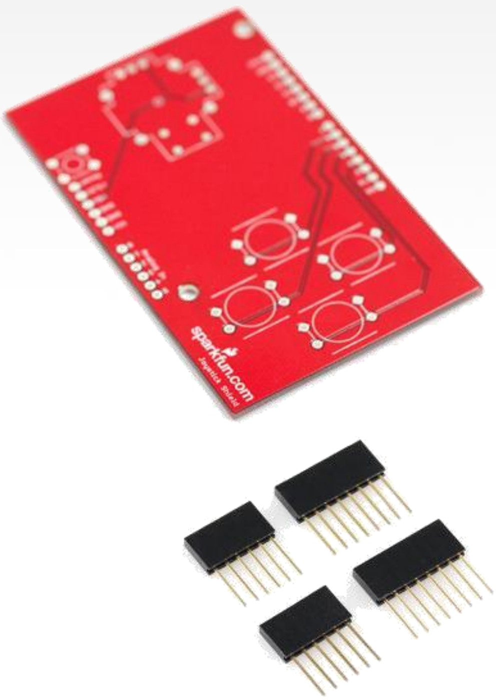
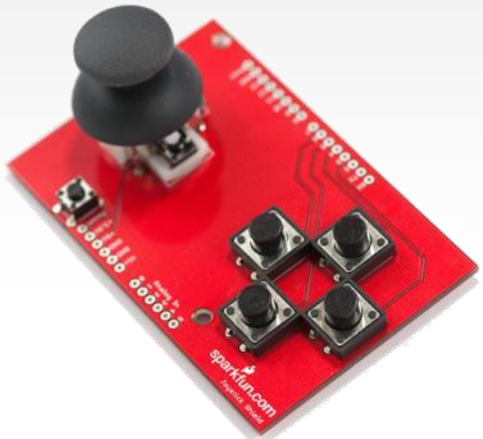
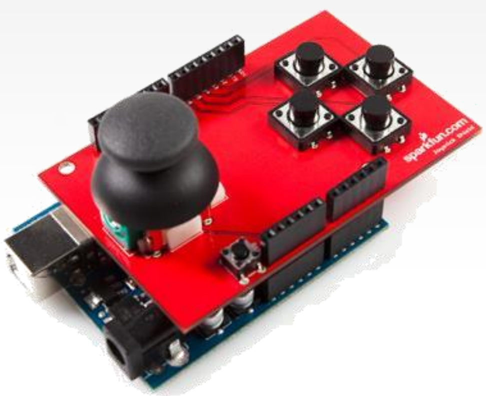
Arduino Shields

PCB	Built Shield	Inserted Shield
		

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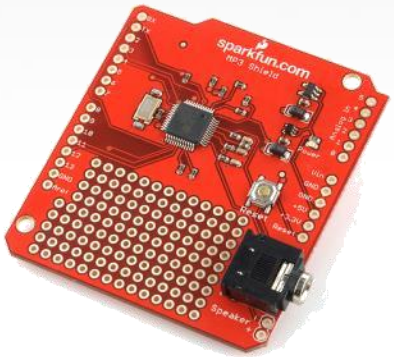
Arduino Shields

Micro SD

MP3 Trigger



LCD

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SIK Components

Name	Image	Type	Function	Notes
Push Button		Digital Input	Switch - Closes or opens circuit	Polarized, needs resistor
Trim potentiometer		Analog Input	Variable resistor	Also called a Trimpot.
Photoresistor		Analog Input	Light Dependent Resistor (LDR)	Resistance varies with light.
Relay		Digital Output	Switch driven by a small signal	Used to control larger voltages
Temp Sensor		Analog Input	Temp Dependent Resistor	
Flex Sensor		Analog Input	Variable resistor	
Soft Trimpot		Analog Input	Variable resistor	Careful of shorts
RGB LED		Dig & Analog Output	16,777,216 different colors	Ooh... So pretty.

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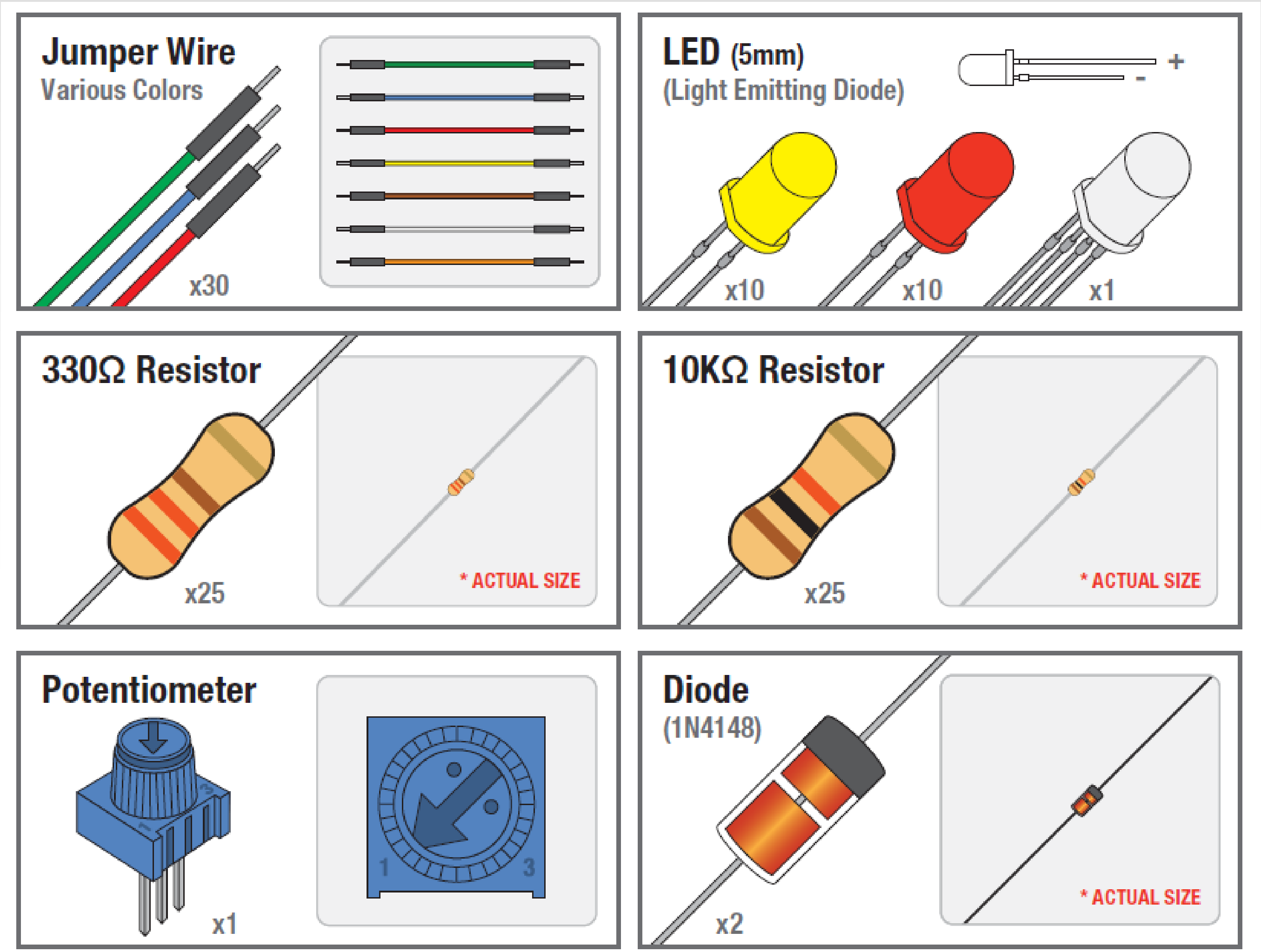
SIK Components



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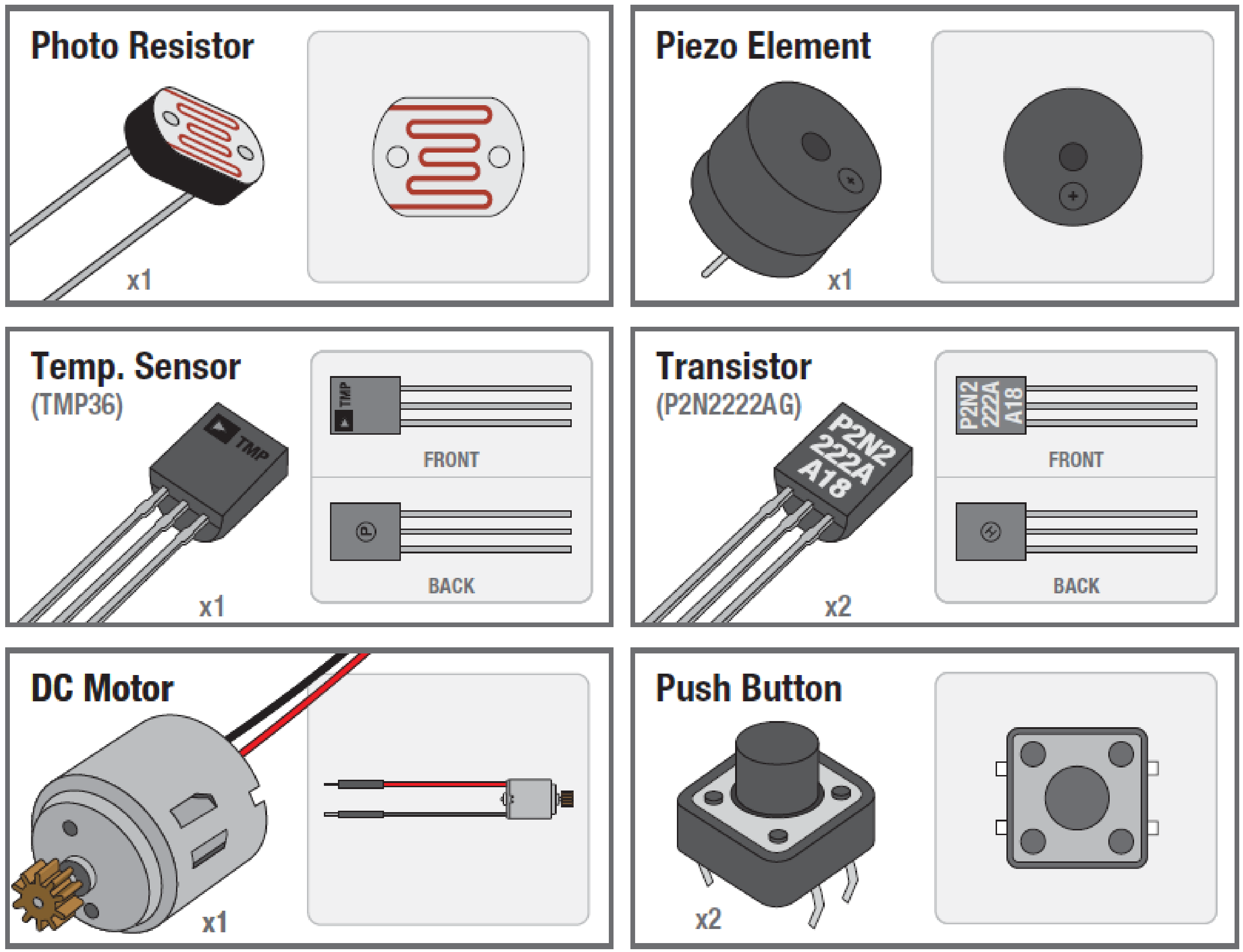
SIK Components



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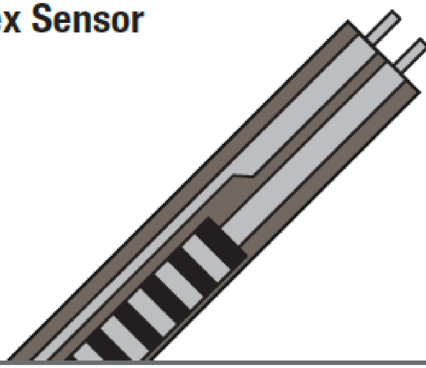
Flex Sensor



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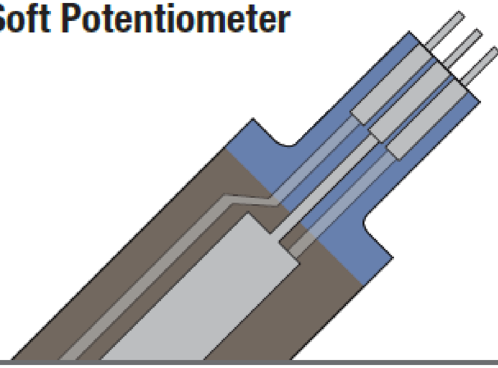
Soft Potentiometer



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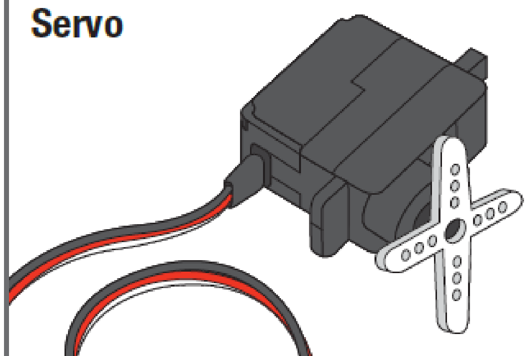
Servo



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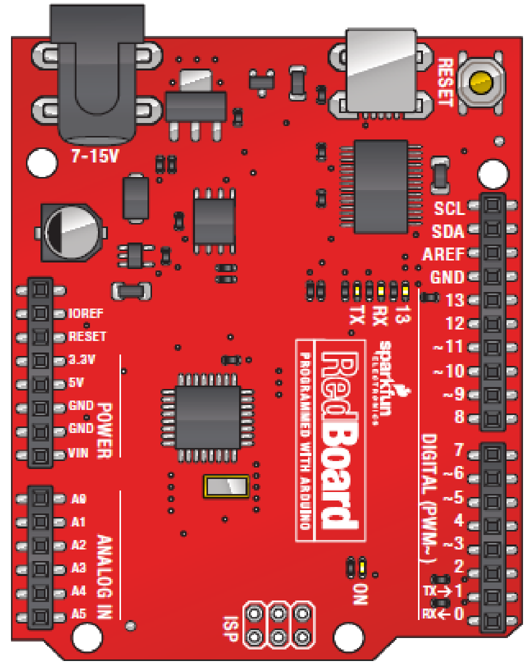
SparkFun RedBoard



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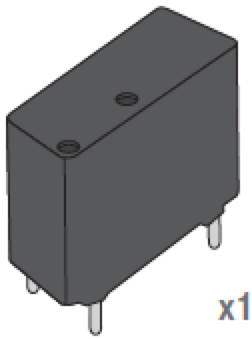
Relay



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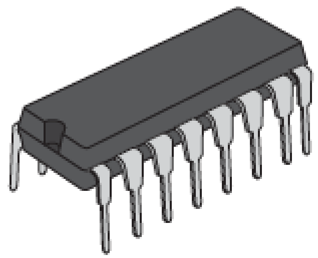
Integrated Circuit

(IC)



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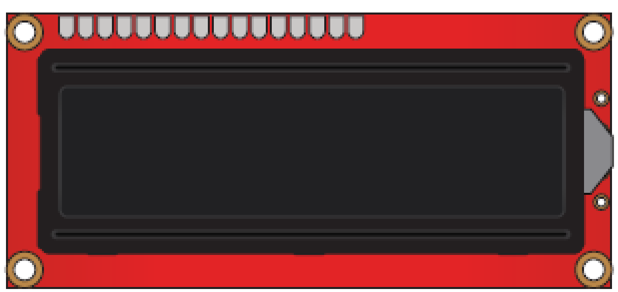
LCD



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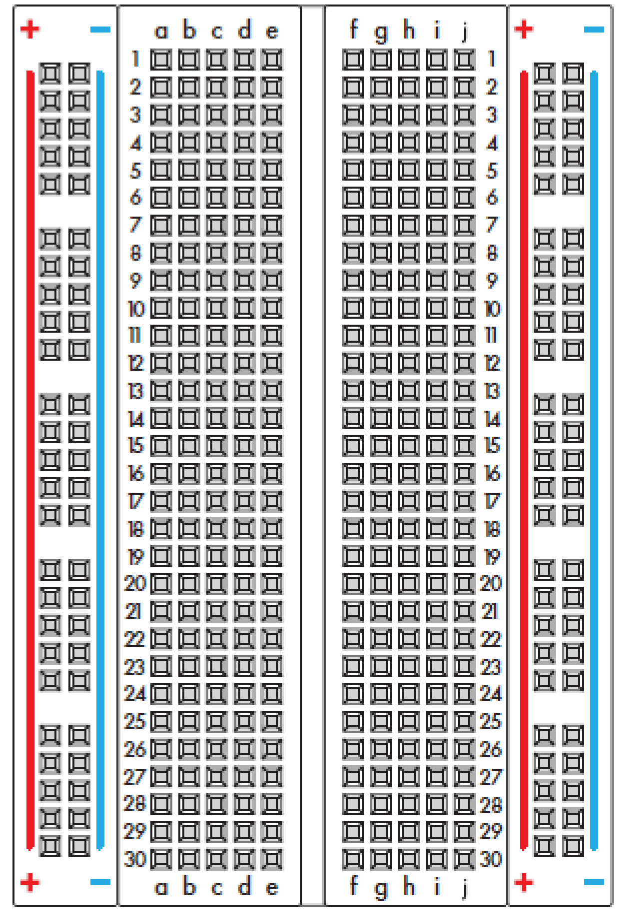
Breadboard

Standard Solderless (Color may vary)



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Electricity \ Electronics Basic Concept Review

- Ohms Law
- Voltage
- Current
- Resistance
- Using a Multi-meter

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Ohm’s Law

Ohm's Law describes the direct relationship between the Voltage (V), Current (I), and Resistance (R) of a circuit.

The three different forms of Ohm's Law are as follows:

$$V = I \cdot R \quad I = \frac{V}{R} \quad R = \frac{V}{I}$$

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$$V = I \; R$$

Electrical Properties

Voltage V	Current I	Resistance R
• Defined as the amount of potential energy in a circuit. • Units: Volts (V)	• The rate of charge flow in a circuit. • Units: Amperes (A)	• Opposition to charge flow. • Units: Ohms (Ω)

$$[V = I \cdot R]$$

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$$V = I R$$

Current Flow Analogy

High Current

Low Current

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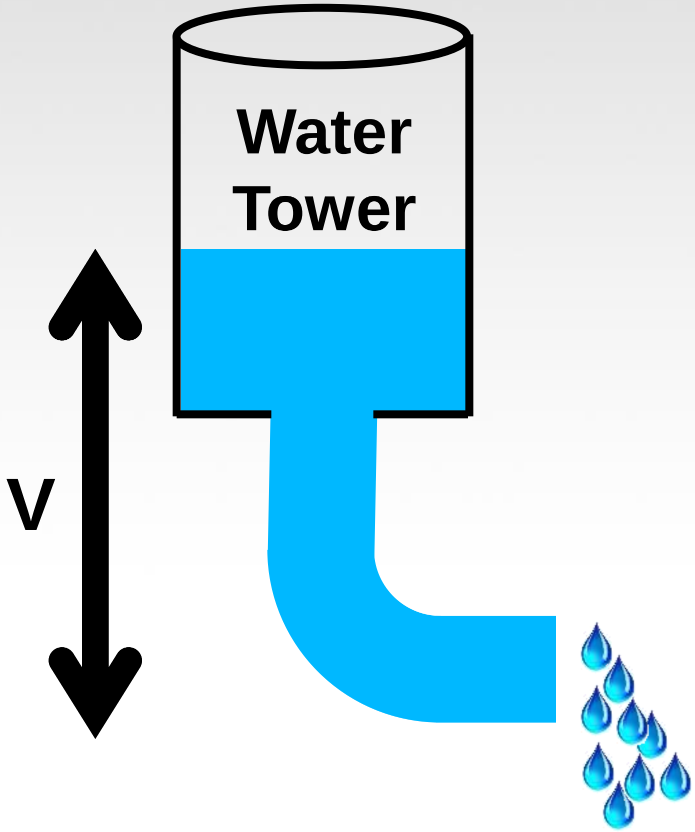
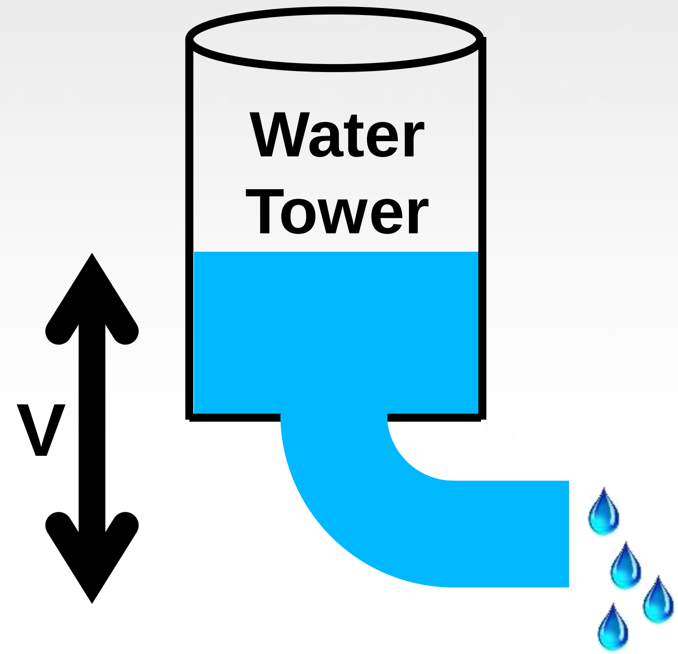
V = I R

Voltage Analogy



More Energy == Higher Voltage

V=I R



Less Energy == Lower Voltage

V = I R

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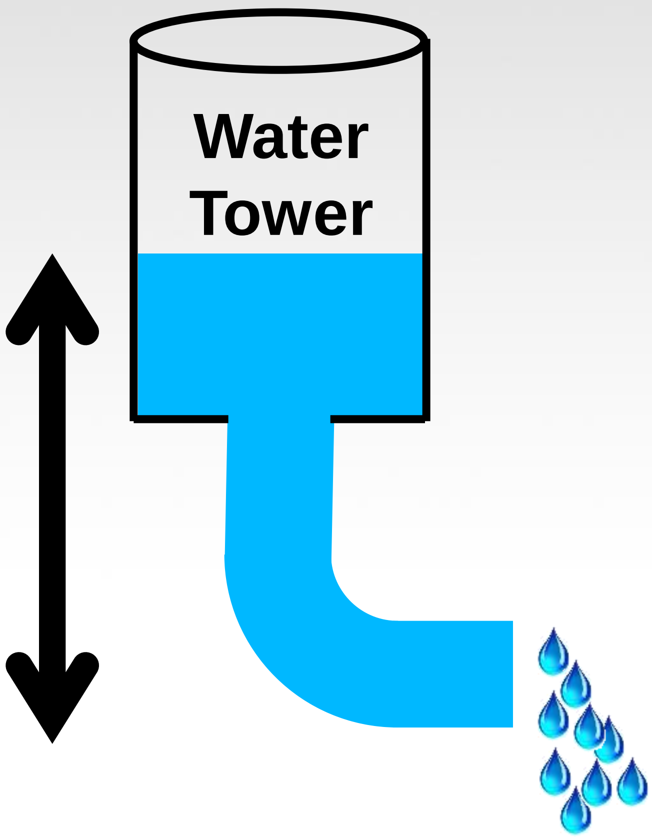
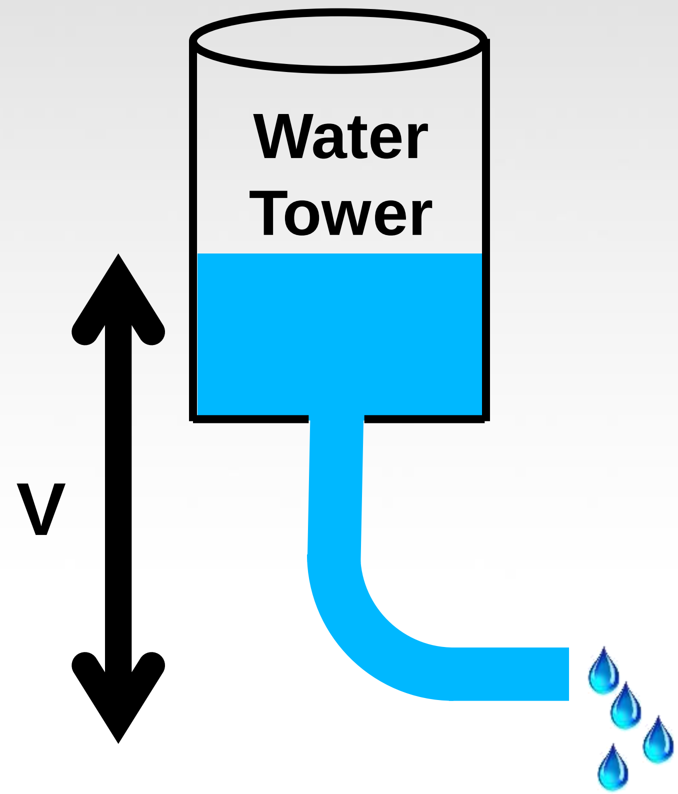
$V = I\,R$

Resistance Analogy



Big Pipe == Lower Resistance

$V = I\,R$



Small Pipe == Higher Resistance

$V = I\,R$

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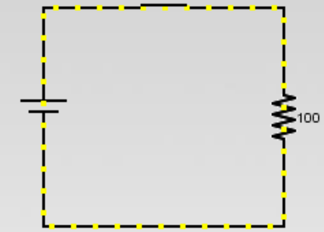
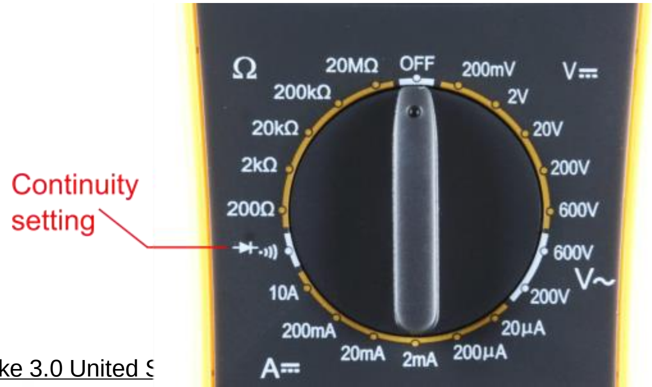
Continuity – Is it a Circuit?



The word “circuit” is derived from the <u>circle</u>. An Electrical Circuit must have a continuous LOOP from Power (V_{cc}) to Ground (GND).

Continuity is important to make portions of circuits are connect. Continuity is the simplest and possibly the most important setting on your multi-meter. Sometimes we call this “ringing out” a circuit.



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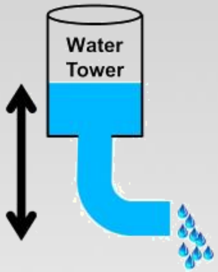
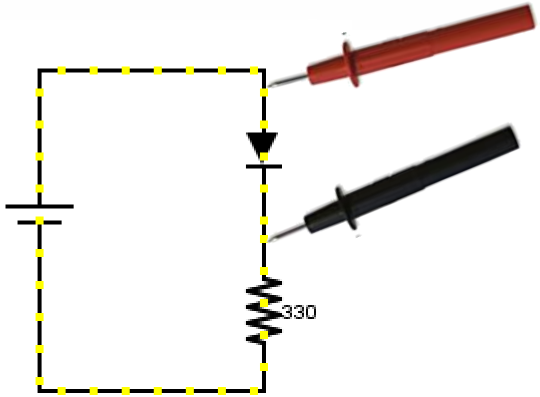
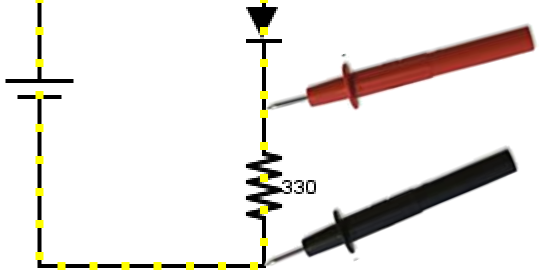
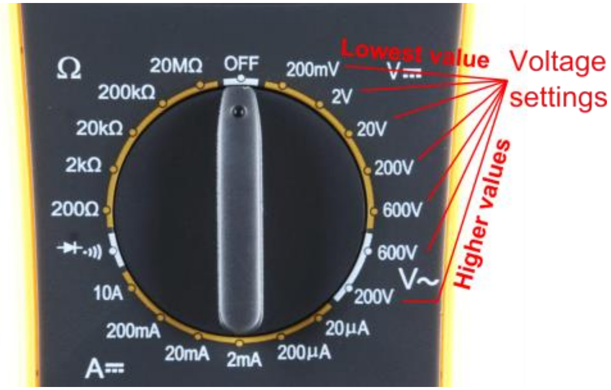
Measuring Electricity – Voltage



Voltage is a measure of potential electrical energy. A voltage is also called a potential difference – it is measured between two points in a circuit – across a device.







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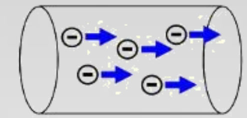
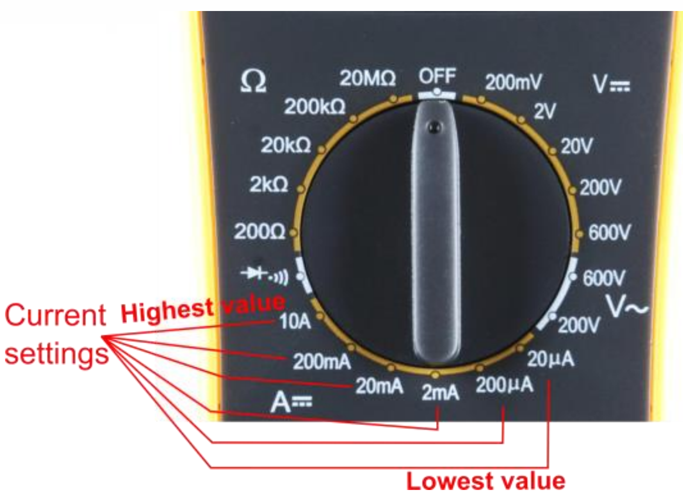
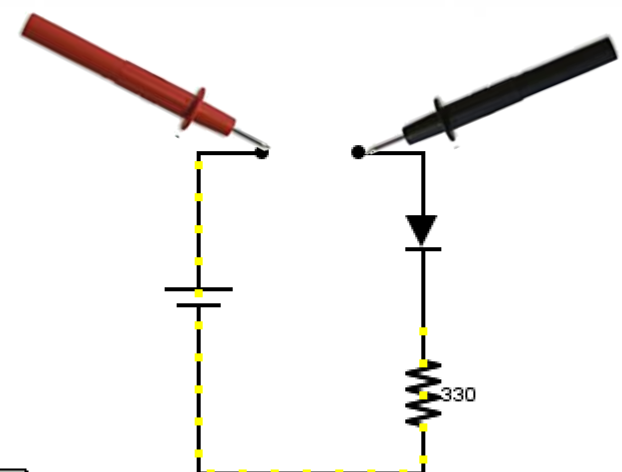
Measuring Electricity -- Current



Current is the measure of the rate of charge flow. For Electrical Engineers – we consider this to be the movement of electrons.

In order to measure this – you must break the circuit or insert the meter in-line (series).





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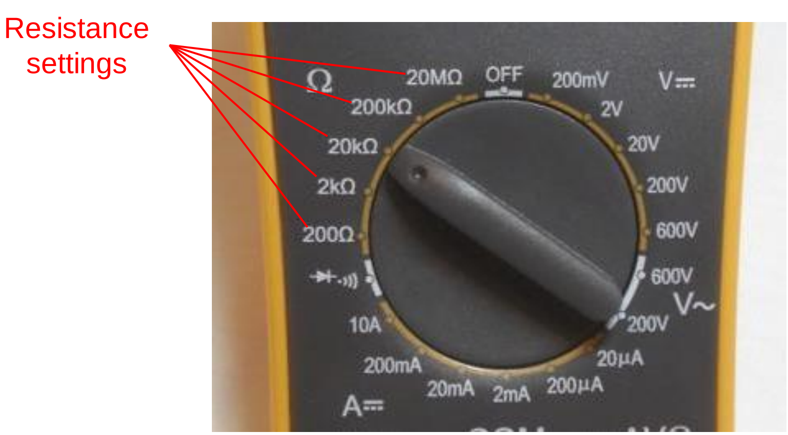
Measuring Electricity -- Resistance

Resistance is the measure of how much opposition to current flow is in a circuit.

Components should be removed entirely from the circuit to measure resistance. Note the settings on the multi-meter. Make sure that you are set for the appropriate range.



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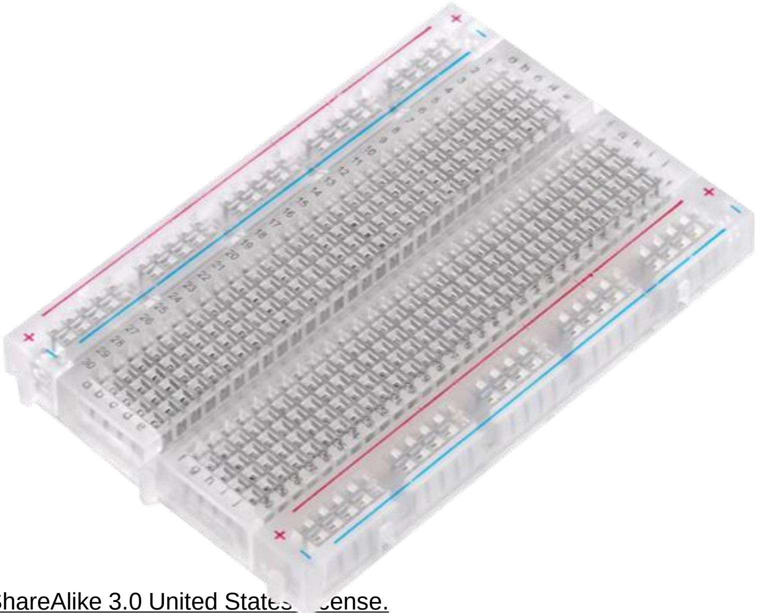
Prototyping Circuits
Solderless Breadboard

One of the most useful tools in an engineer or Maker’s toolkit. The three most important things:

- A breadboard is easier than soldering
- A lot of those little holes are connected, which ones?
- Sometimes breadboards break



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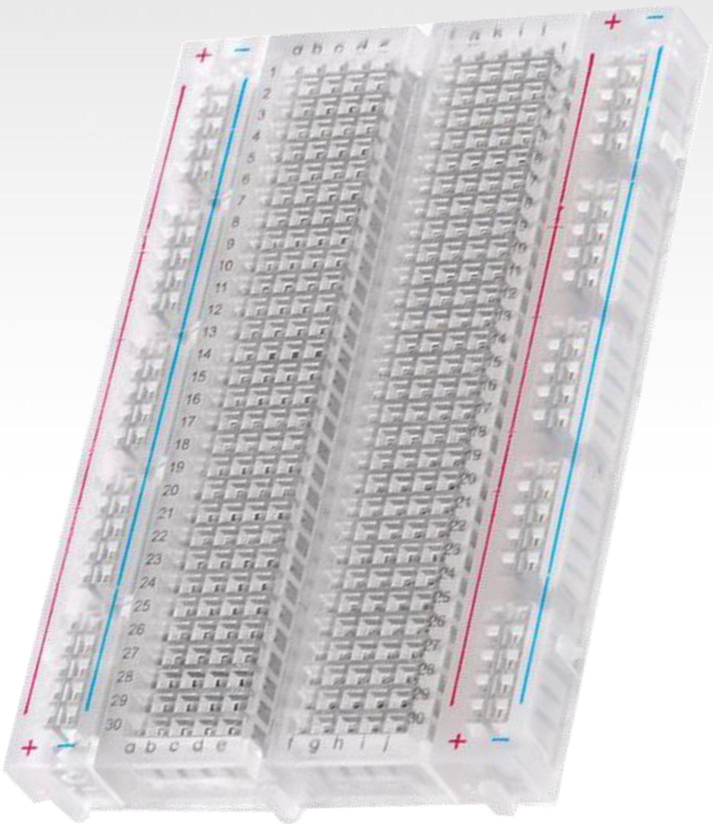
What’s a Breadboard?



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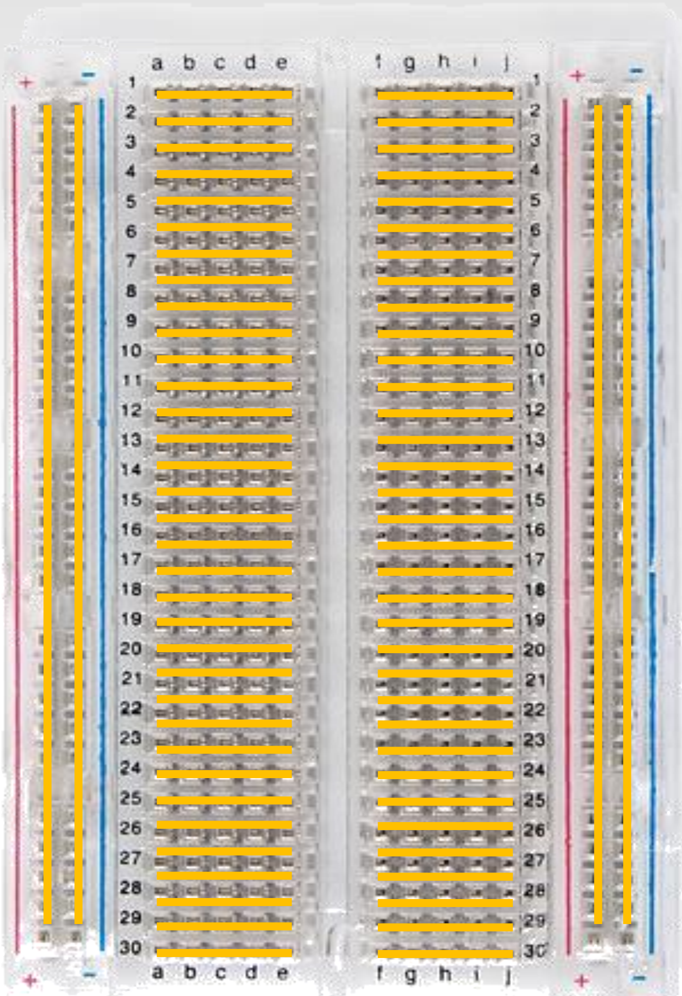
Solderless Breadboard



Each row (horiz.) of 5 holes are connected.

Vertical columns – called power bus are connected vertically

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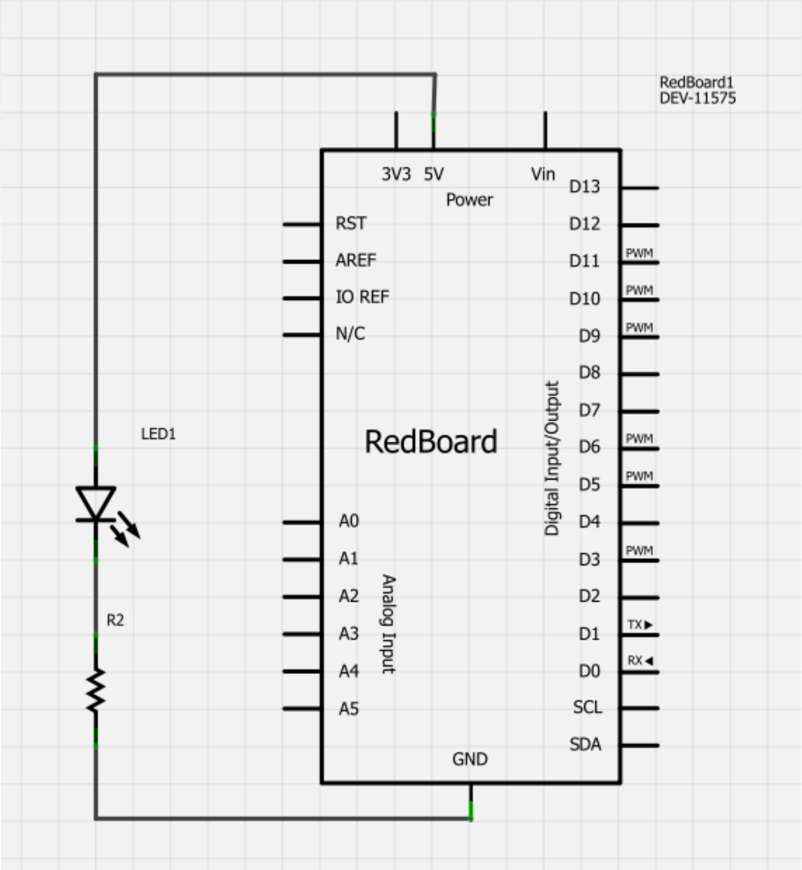
Using the Breadboard to built a simple circuit



Use the breadboard to wire up a single LED with a 330 Ohm Resistor (Orange-Orange-Brown).

Note: the longer leg on the LED is the positive leg and the shorter leg is the negative

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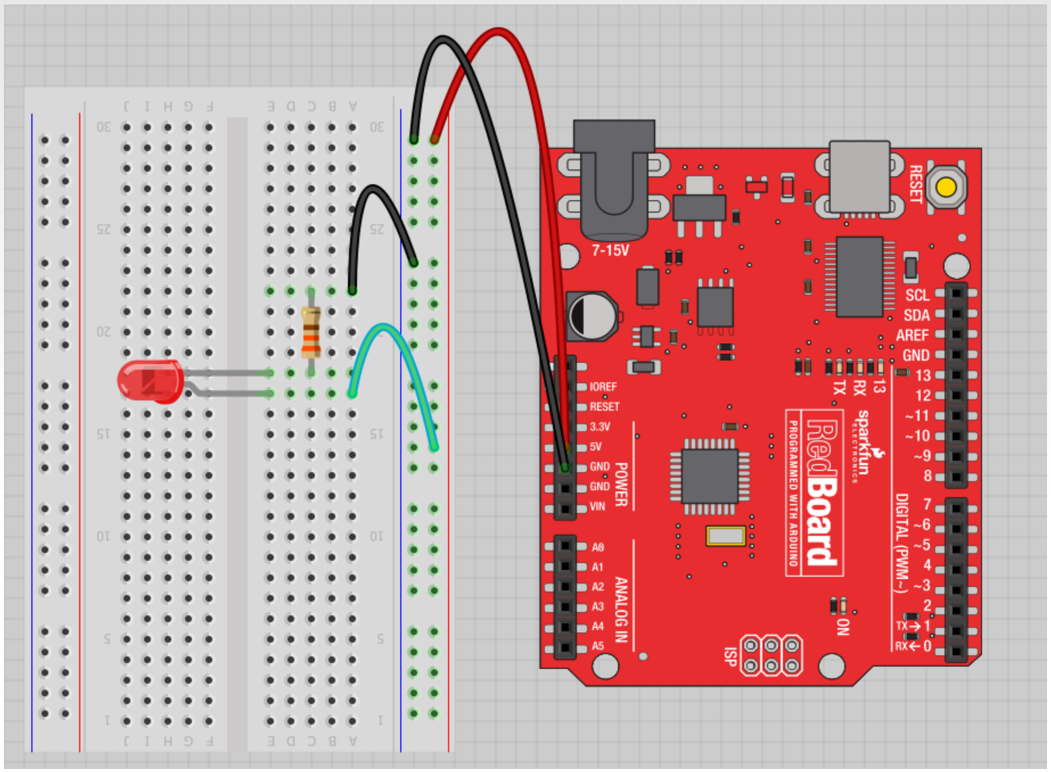
Fritzing View of Breadboard Circuit



What happens when you break the circuit?

What if you wanted to add more than one LED?

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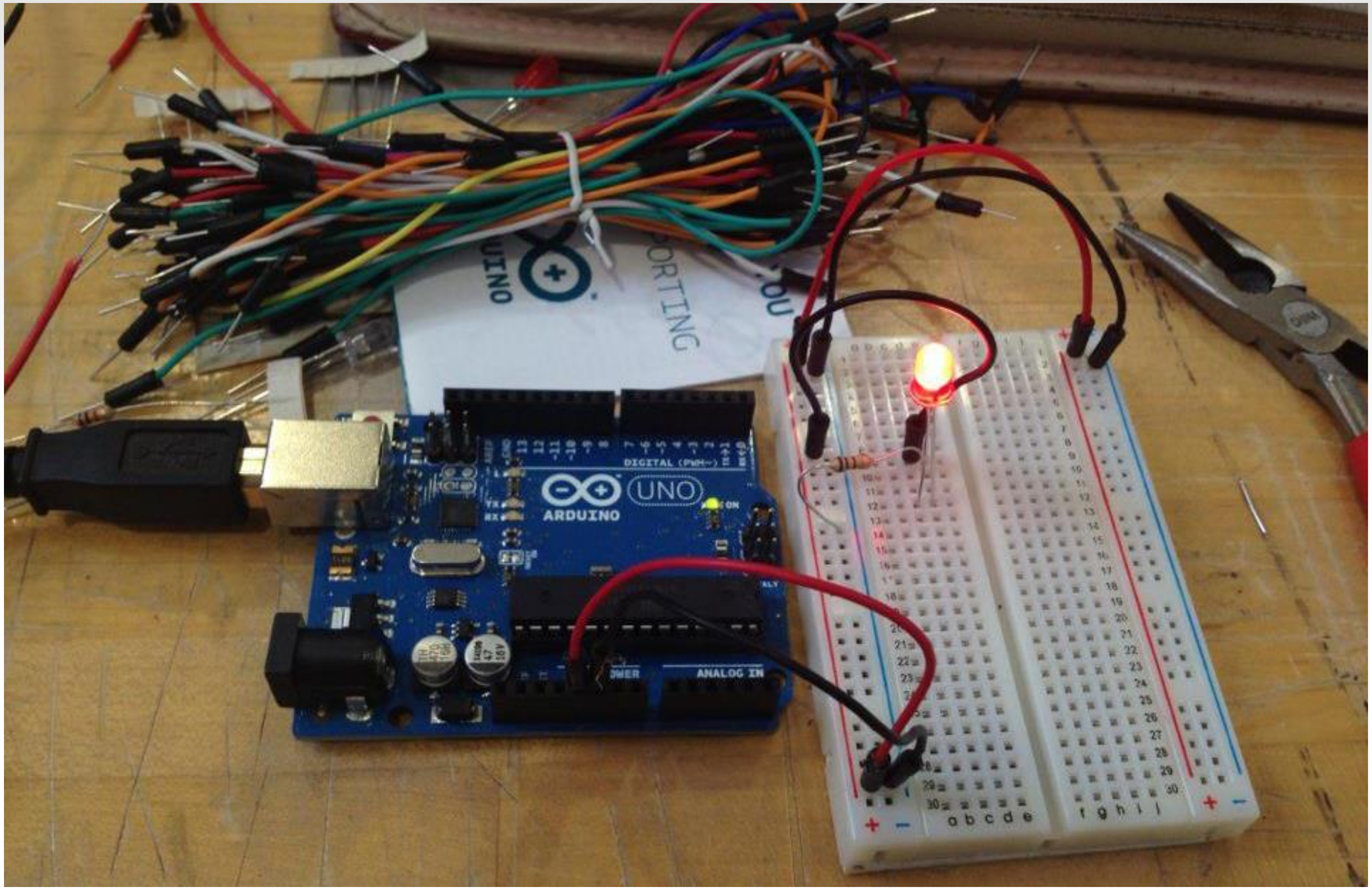
Adding control – let's use the Arduino and start programming!!!



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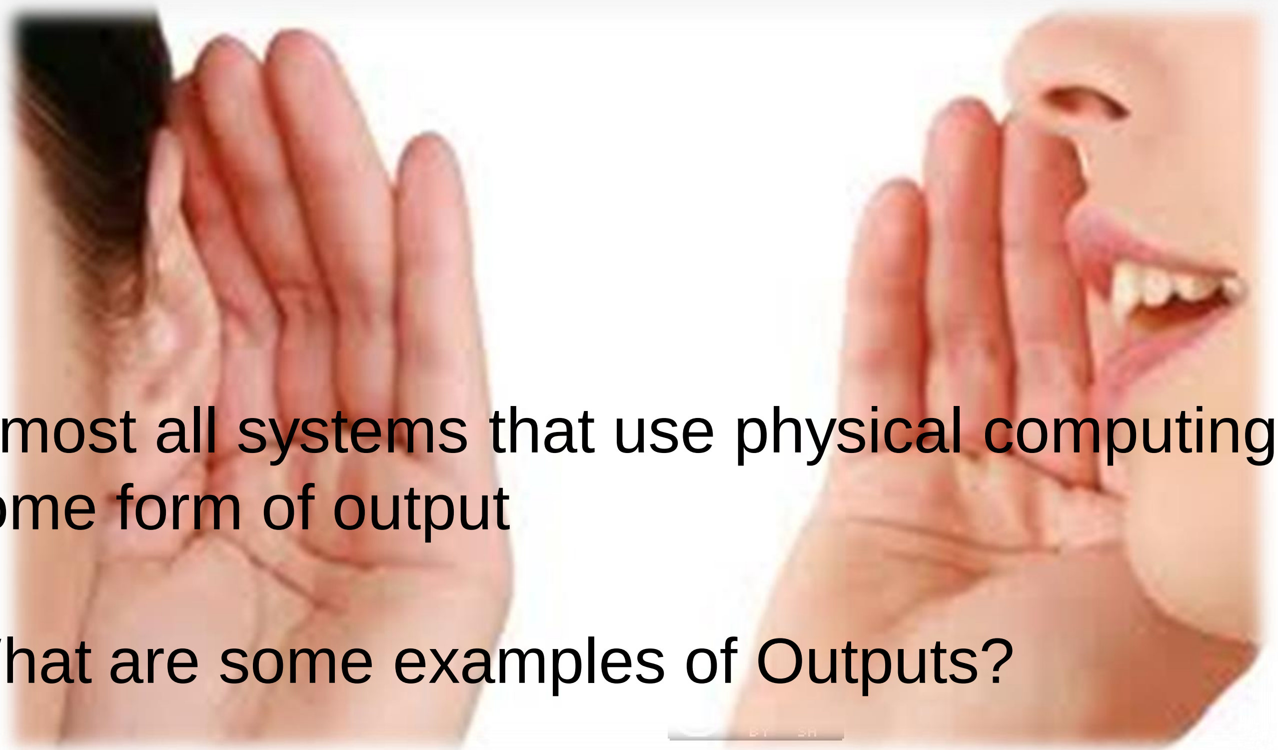
Concepts: INPUT vs. OUTPUT

Referenced from the perspective of the microcontroller (electrical board).

Inputs is a signal / information going into the board.

Output is any signal exiting the board.



Almost all systems that use physical computing will have some form of output

What are some examples of Outputs?

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Concepts: INPUT vs. OUTPUT

Referenced from the perspective of the microcontroller (electrical board).

Inputs is a signal / information going into the board.

Output is any signal exiting the board.

Examples: Buttons Switches, Light Sensors, Flex Sensors, Humidity Sensors, Temperature Sensors…	Examples: LEDs, DC motor, servo motor, a piezo buzzer, relay, an RGB LED

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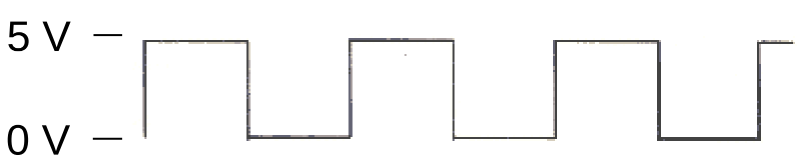
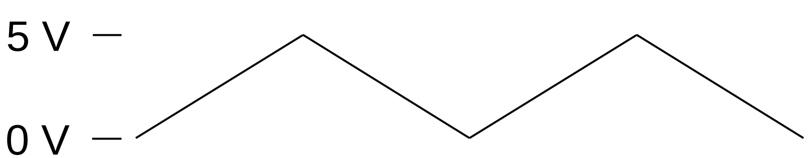
Concepts: Analog vs. Digital

Microcontrollers are **digital** devices – ON or OFF. Also called – discrete.

analog signals are anything that can be a full range of values. What are some examples? More on this later…



Digital Signal



Analog Signal

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Open up Arduino

Hints:

For PC Users →

1. Let the installer copy and move the files to the appropriate locations, or
2. Create a folder under C:\Program Files (x86) called Arduino. Move the entire Arduino program folder here.

For Mac Users →

1. Move the Arduino executable to the dock for ease of access.
2. Resist the temptation to run these from your desktop.

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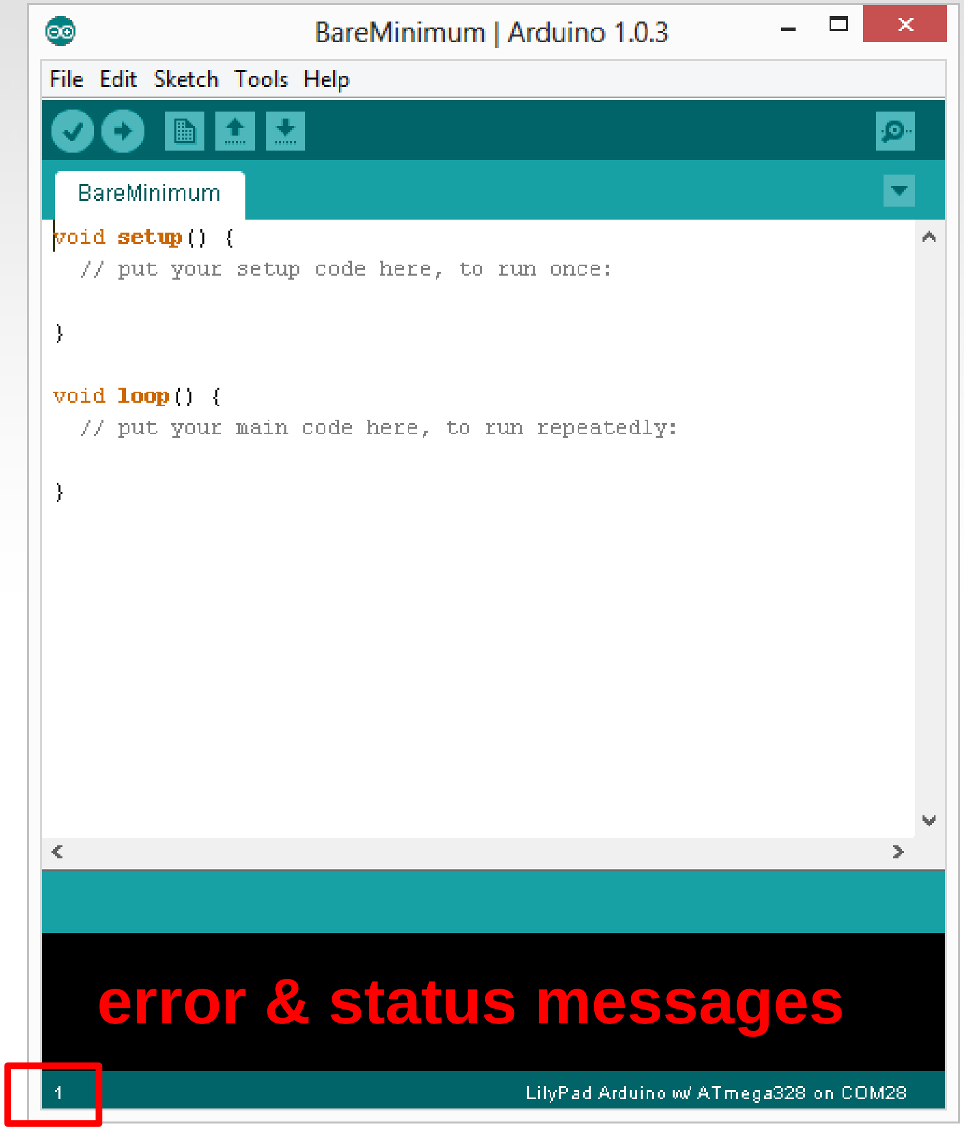
Arduino

Integrated Development Environment (IDE)

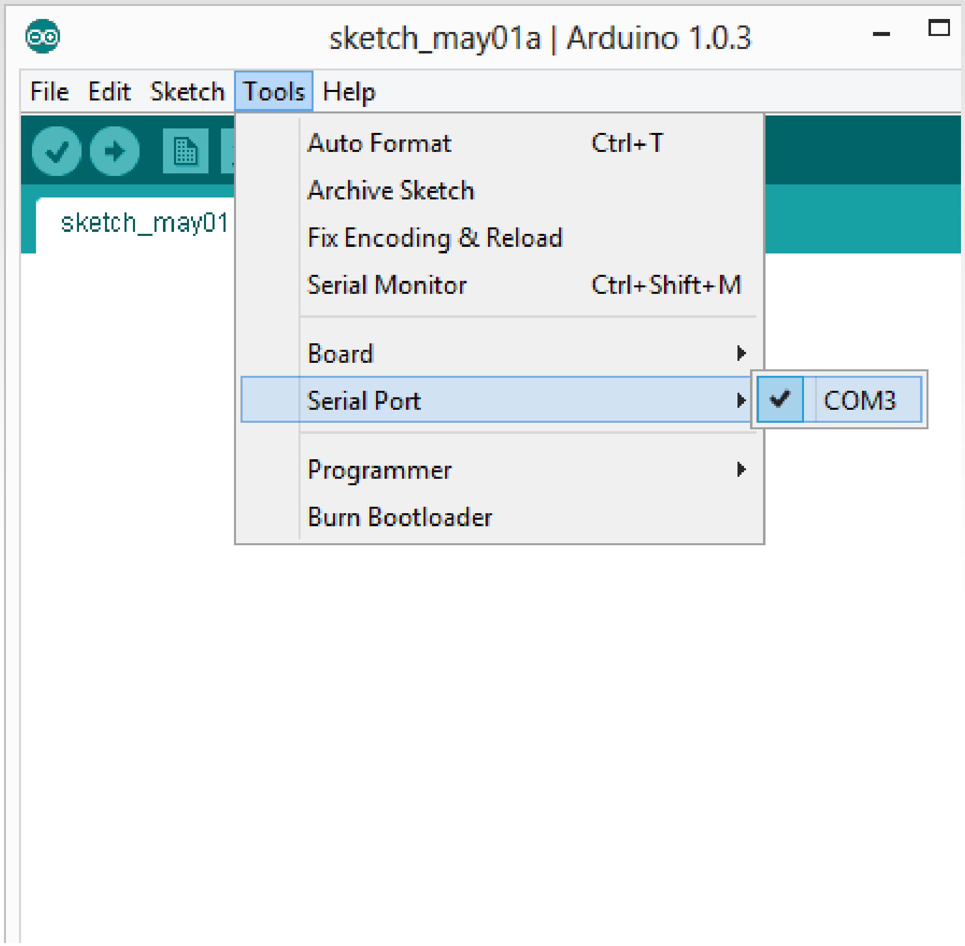


Two required functions / methods / routines:

```
void setup()
{
        // runs once
}

void loop()
{
        // repeats
}
```

Settings: Tools → Serial Port



Your computer communicates to the Arduino microcontroller via a serial port → through a USB-Serial adapter.

Check to make sure that the drivers are properly installed.

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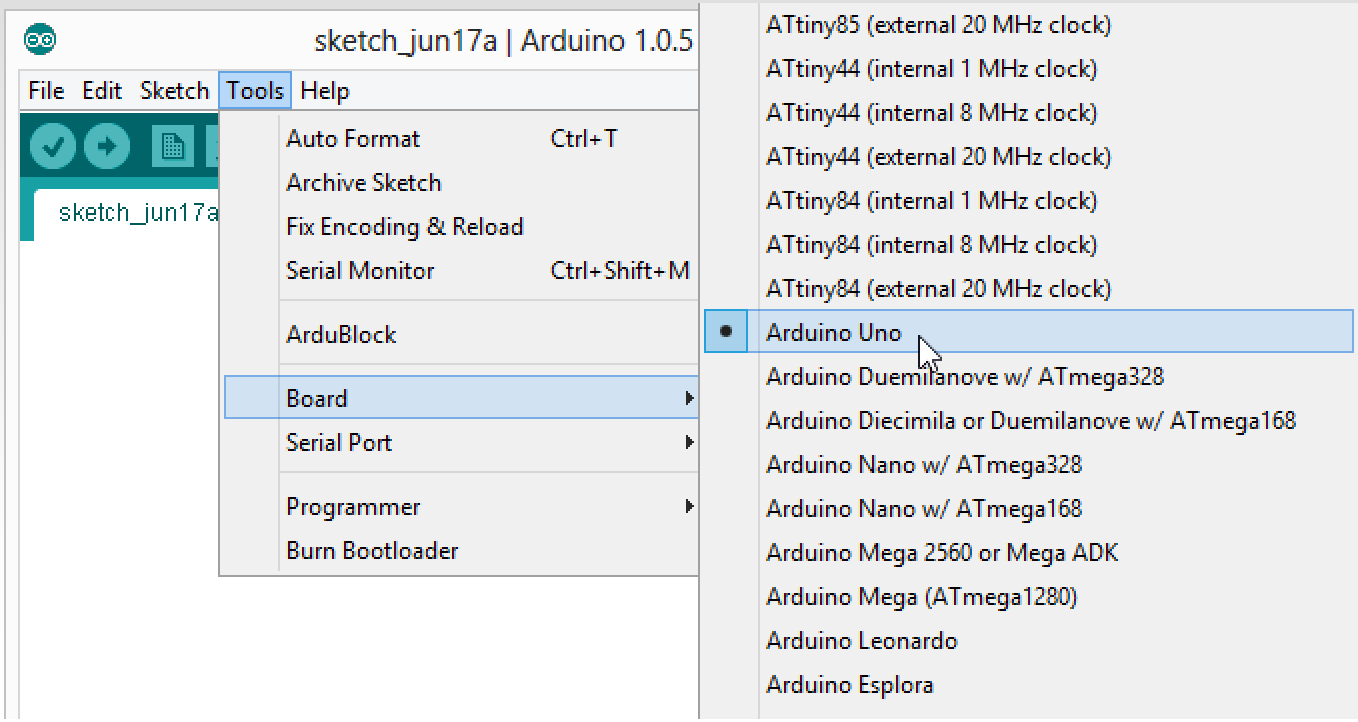
Settings: Tools → Board



Next, double-check that the proper board is selected under the Tools→Board menu.

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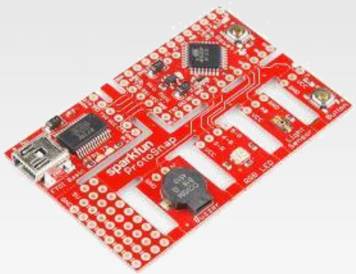
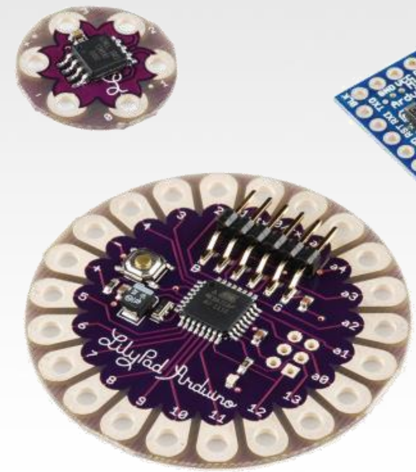
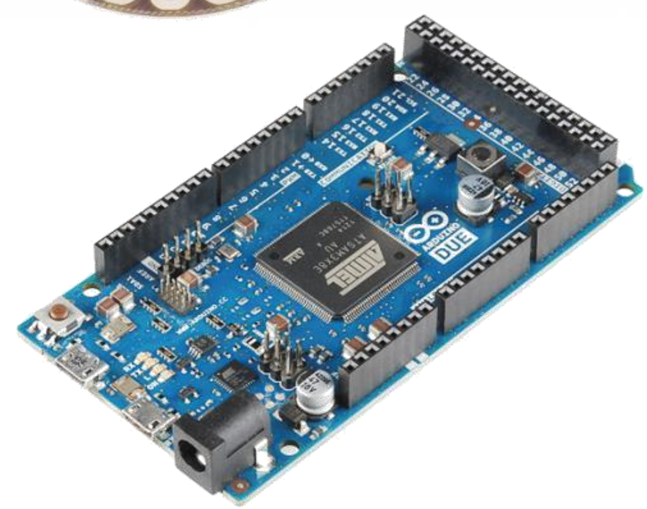
Arduino & Arduino Compatible Boards







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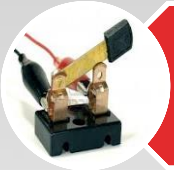
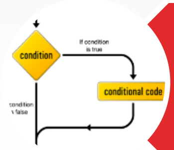
BIG 6 CONCEPTS



digitalWrite()

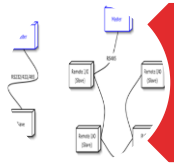
analogWrite()

digitalRead()



if() statements / Boolean

analogRead()



Serial communication

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Let’s get to coding…

Project #1 – Blink

“Hello World” of Physical Computing

Psuedo-code – how should this work?

Turn LED ON → Wait → Turn LED OFF → Wait → Rinse & Repeat

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Comments, Comments, Comments

Comments are for you – the programmer and your friends…or anyone else human that might read your code.

```
// this is for single line comments
// it's good to put a description at the
  top and before anything 'tricky'
/* this is for multi-line comments
   Like this…
   And this….
*/
```

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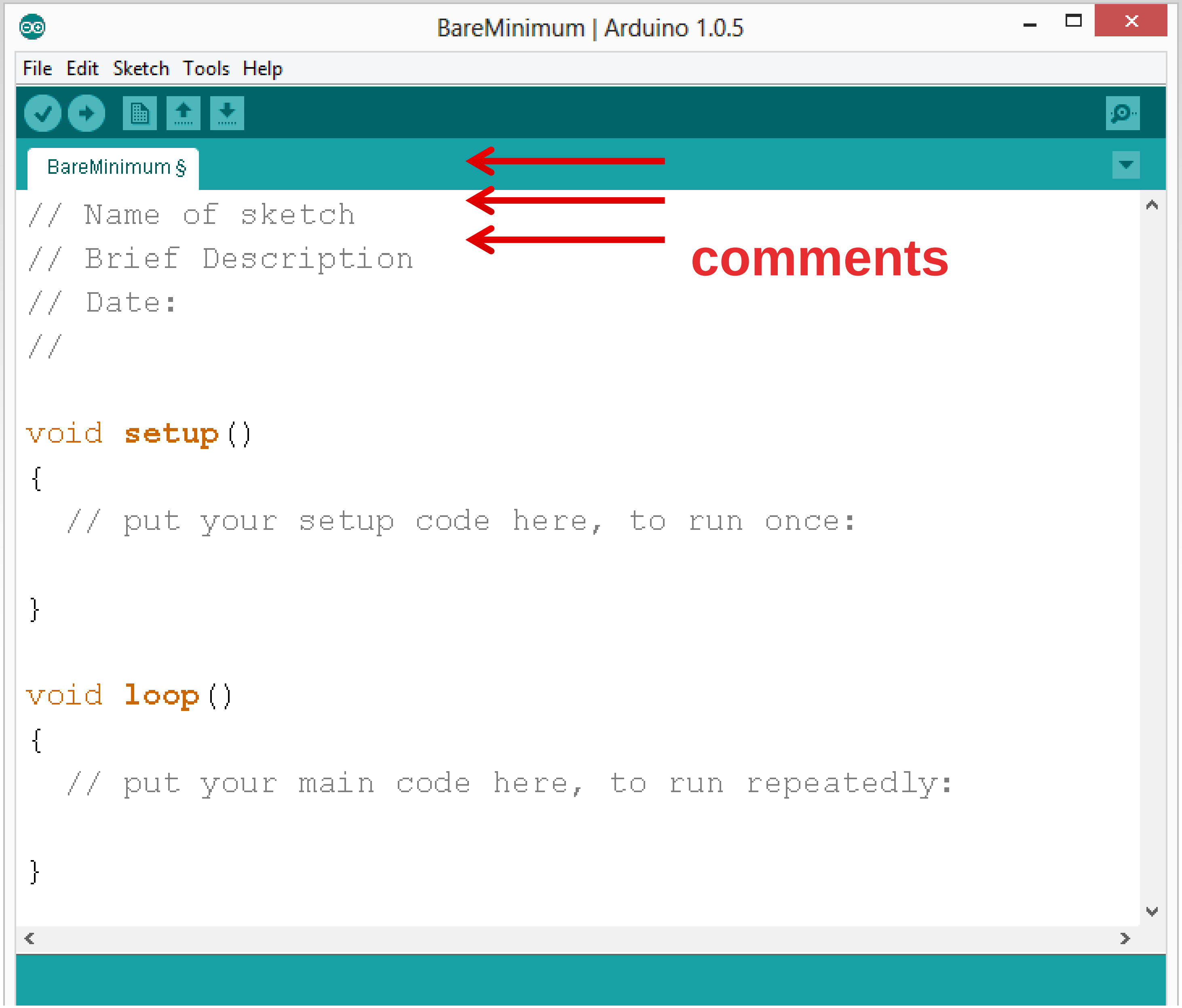

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Three commands to know…

```
pinMode(pin, INPUT/OUTPUT);
  ex: pinMode(13, OUTPUT);


digitalWrite(pin, HIGH/LOW);
  ex: digitalWrite(13, HIGH);


delay(time_ms);
  ex: delay(2500); // delay of 2.5 sec.

// NOTE: -> commands are CASE-sensitive
```

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Project #1: Wiring Diagram

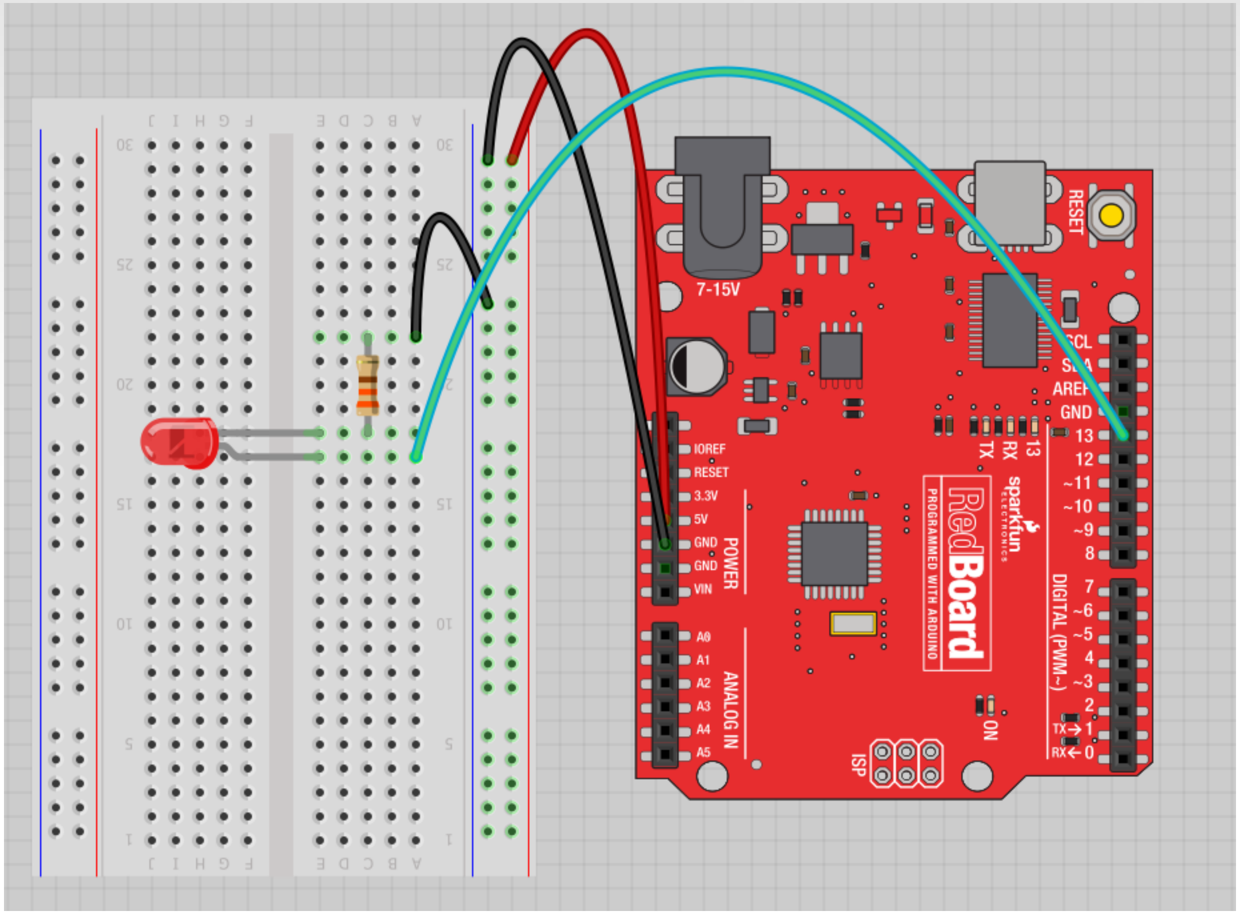

Image created in Fritzing

Move the green wire from the power bus to <u>pin 13</u> (or any other Digital I/O pin on the Arduino board.

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A few simple challenges
Let’s make LED#13 blink!

Challenge 1a – blink with a 200 ms second interval.

Challenge 1b – blink to mimic a heartbeat

Challenge 1c – find the fastest blink that the human eye can still detect…

1 ms delay? 2 ms delay? 3 ms delay???

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Try adding other LEDs

- Can you blink two, three, or four LEDs?
  - (Hint: Each LED will need it’s own 330Ω resistor.)
- Generate your own morse code flashing
- How about → Knight Rider? Disco? Police Light?

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Programming Concepts: Variables

ProtosnapProMiniExample2 §

```
// Comments go here
// Written by:  Joesephine Jones
// Date:  April 12, 2013

int sensorValue;
int ledPin;

void setup()
{
  // put your setup code here, to run once:
  int setupVariable;

}

void loop()
{
  // put your main code here, to run repeatedly:
  int loopScopeVariable
}
```

Variable Scope

Global

Function-level

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Programming Concepts: Variable Types

Variable Types:

8 bits | 16 bits | 32 bits

byte
char

int
unsigned int

long
unsigned long
float

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Fading in and Fading Out (Analog or Digital?)

A few pins on the Arduino allow for us to modify the output to mimic an analog signal.

This is done by a technique called:

Pulse Width Modulation (PWM)

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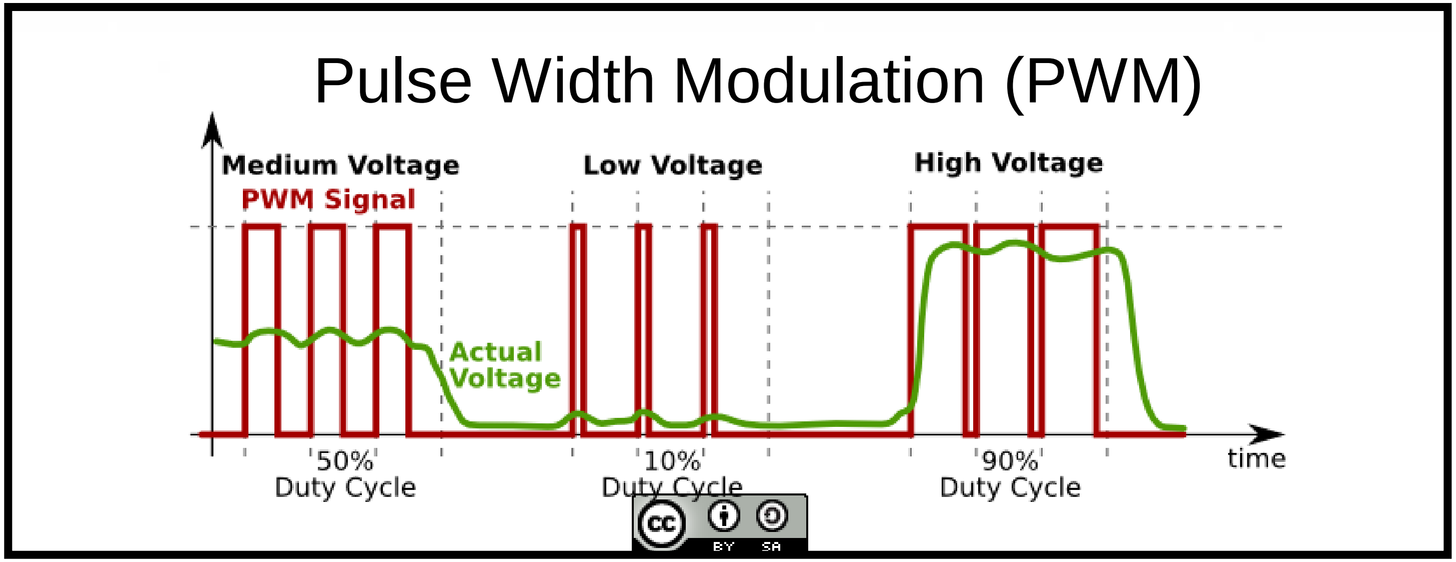
Concepts: Analog vs. Digital

To create an analog signal, the microcontroller uses a technique called PWM. By varying the <u>duty cycle</u>, we can mimic an “average” analog voltage.



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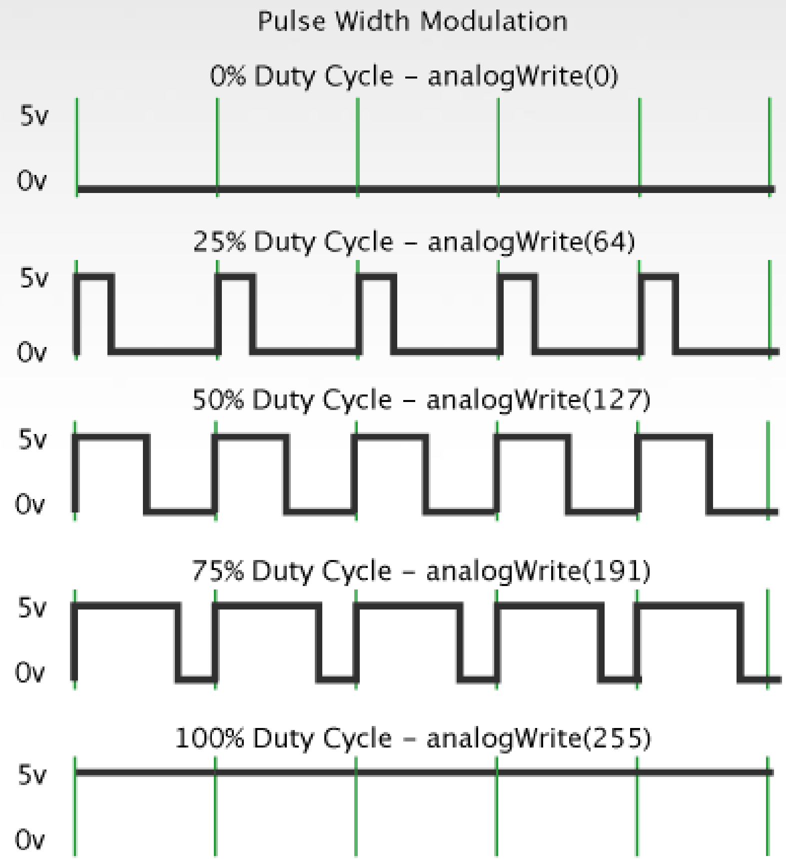
Project #2 – Fading
Introducing a new command…

```
analogWrite(pin, val);
```

pin – refers to the OUTPUT pin (limited to pins 3, 5, 6, 9, 10, 11.) – denoted by a ~ symbol

val – 8 bit value (0 – 255).

0 => 0V | 255 => 5V



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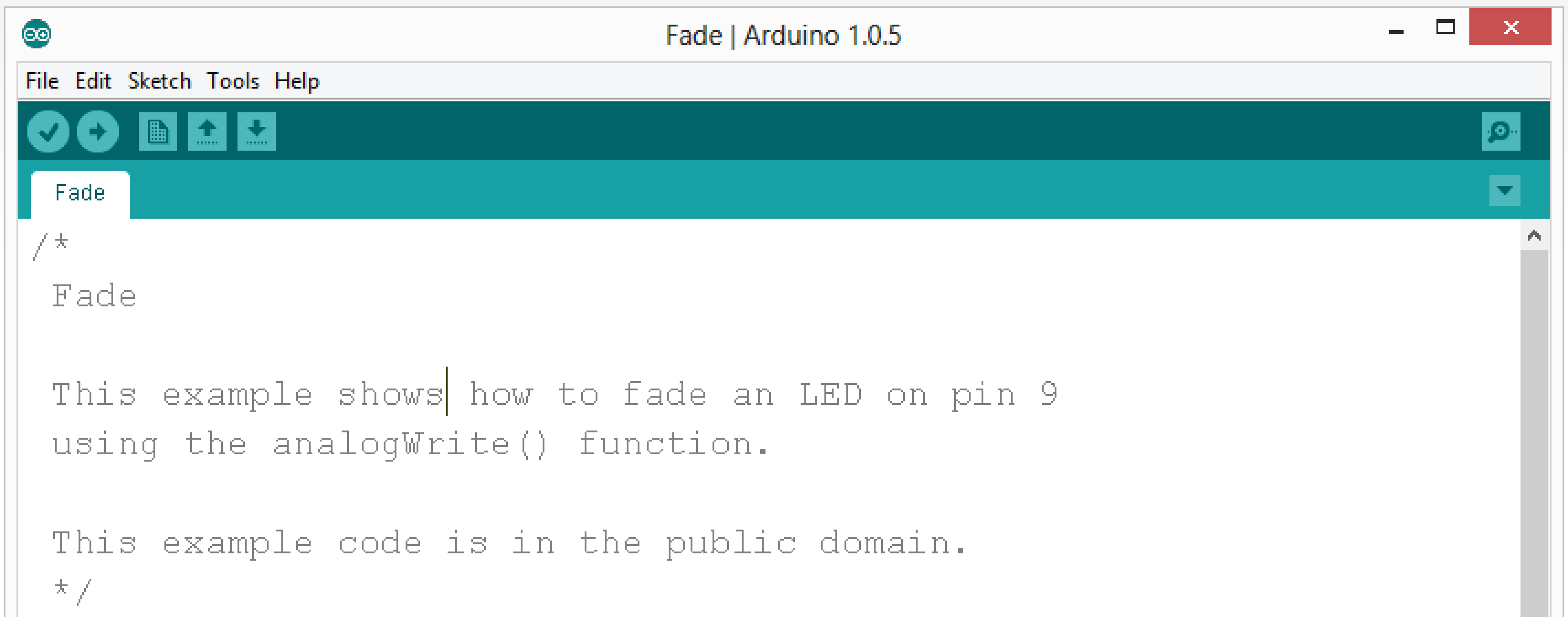
Move one of your LED pins over to Pin 9

In Arduino, open up:

File → Examples → 01.Basics → Fade



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Fade - Code Review

Fade | Arduino 1.0.5

File Edit Sketch Tools Help

Fade

```
/*
 Fade

 This example shows how to fade an LED on pin 9
 using the analogWrite() function.

 This example code is in the public domain.
 */

int led = 9;           // the pin that the LED is attached to
int brightness = 0;    // how bright the LED is
int fadeAmount = 5;    // how many points to fade the LED by
```

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Fade - Code Review

```
void setup()  {
  // declare pin 9 to be an output:
  pinMode(led, OUTPUT);
}

// the loop routine runs over and over again forever:
void loop()  {
  // set the brightness of pin 9:
  analogWrite(led, brightness);

  // change the brightness for next time through the loop:
  brightness = brightness + fadeAmount;

  // reverse the direction of the fading at the ends of the fade:
  if (brightness == 0 || brightness == 255) {
    fadeAmount = -fadeAmount ;
  }
  // wait for 30 milliseconds to see the dimming effect
  delay(30);
}
```

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Project# 2 -- Fading

Challenge 2a – Change the rate of the fading in and out. There are at least two different ways to do this – can you figure them out?

Challenge 2b – Use 2 (or more) LEDs – so that one fades in as the other one fades out.

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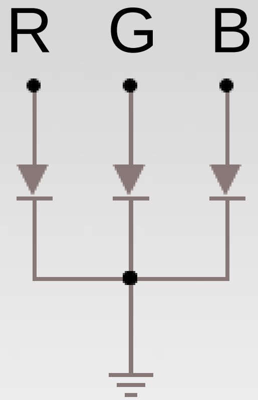
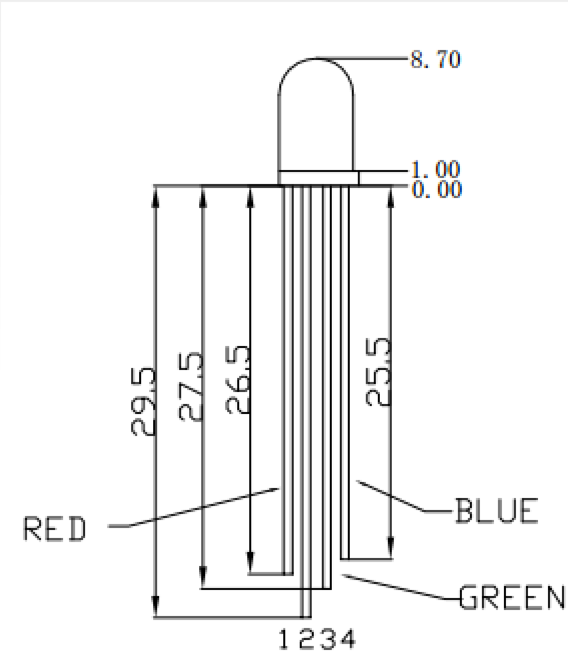


Color Mixing
Tri-color LED

In the SIK, this is a standard – Common <u>Cathode</u> LED

This means the negative side of the LED is all tied to Ground.



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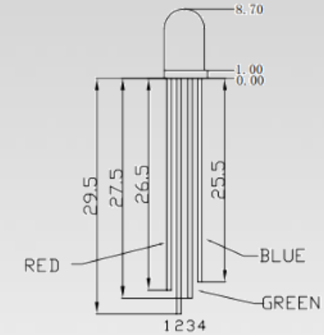
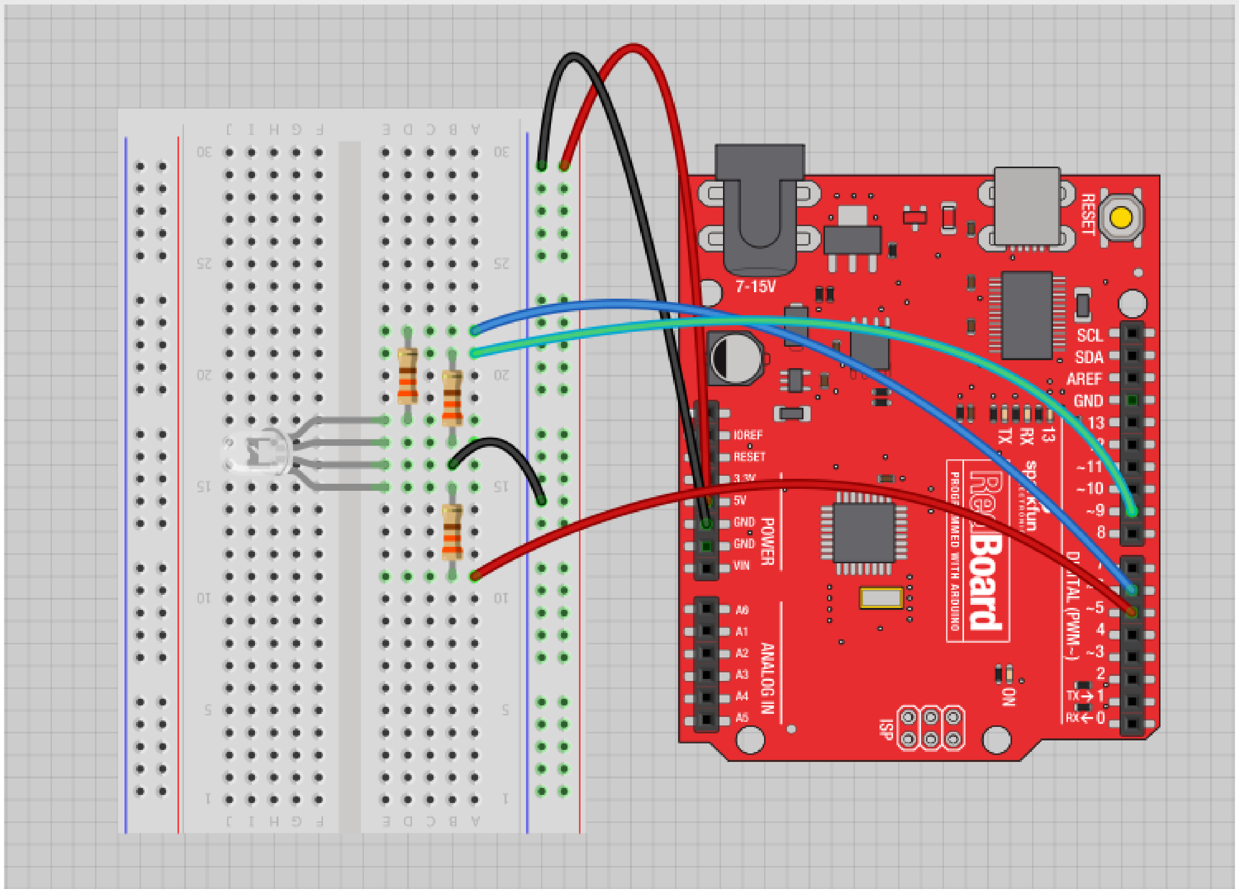
Project 3 – RGB LED





Note: The longest leg of the RGB LED is the Common Cathode. This goes to GND.

Use pins 5, 6, & 9

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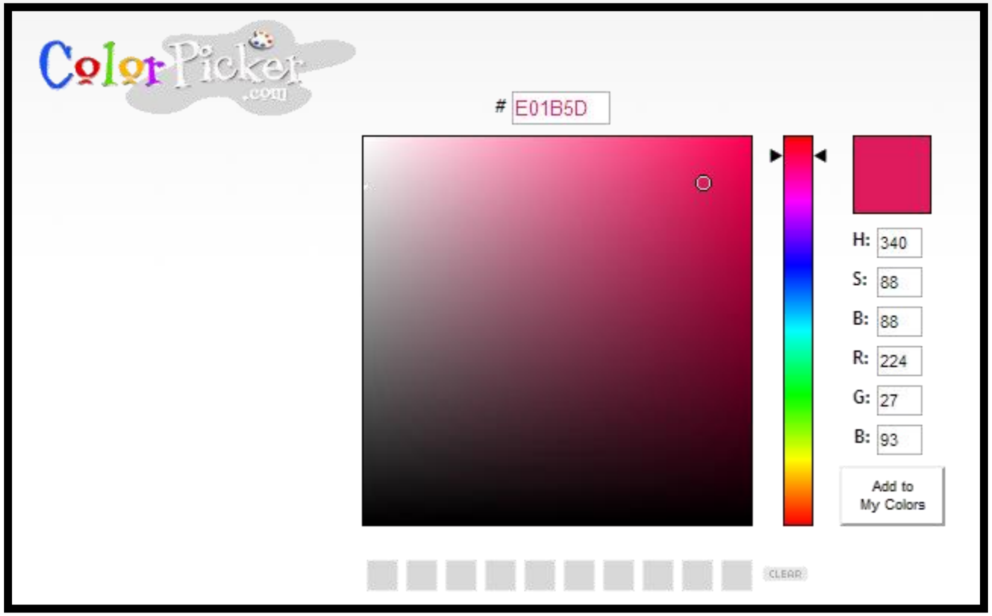
How many unique colors can you create?

$$\# \; of \; unique \; colors = 256 \cdot 256 \cdot 256$$
$$= 16{,}777{,}216 \; colors!$$



- Use Colorpicker.com or experiment on your own.
- Pick out a few colors that you want to try re-creating for a lamp or lighting display...
- Play around with this with the `analogWrite()` command.

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RGB LED Color Mixing

```
int redPin = 5;
int greenPin = 6;
int bluePin = 9;

void setup()
{
  pinMode(redPin, OUTPUT);
  pinMode(greenPin, OUTPUT);
  pinMode(bluePin, OUTPUT);
}
```

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RGB LED Color Mixing

```
void loop()
{
   analogWrite(redPin, 255);
   analogWrite (greenPin, 255);
   analogWrite (bluePin, 255);
}
```

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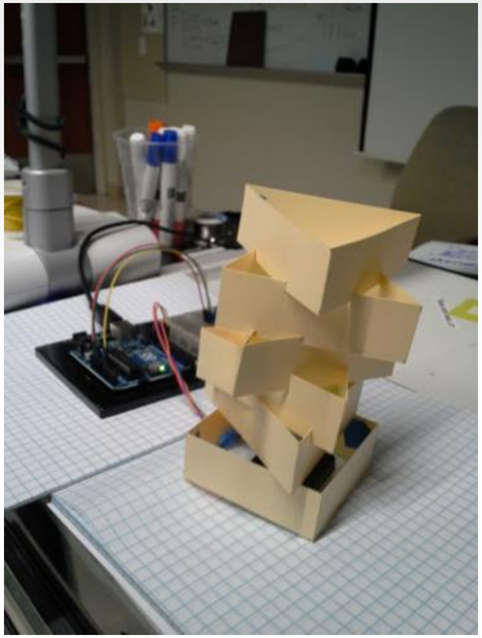
Project: Mood Lamp / Light Sculpture



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Napkin Schematics

Emphasize the <u>engineering design process</u> with students. We like to skirt the line between formal and informal with a tool called **Napkin Schematics.**

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Napkin Schematics
SparkFun Electronics Summer Semester

1. Short Description

Write a brief description of your project here. List inputs and outputs, existing systems it will integrate with and any other notes that occur to you. Don't spend too long on this section.

2. Sketch

Sketch an image of what you imagine your project or system to look like here.

3. Block Diagrams

Draw a diagram where each of the components in your project is represented by a simple square with lines connecting the components that will be connected. Don't worry about getting all the connections perfect; what's important is that you're thinking about all the different components and connections. Be sure to include things like power sources, antennas, buttons or other interface components and always include at least one LED to indicate the system is on. Although you'll probably want more LEDs than just the one, they make troubleshooting and debugging easier.

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4. Logic Flow

Logic Flow Charts are a great way to sketch out how you want a circuit or chunk of code to act once it is completed. This way you can figure out how the whole project will act without getting distracted by details like electricity or programming.

There are four major pieces that you will use over and over again when creating Logic Flow Charts. A circle, a square, a diamond and lines connecting all the circles, squares and diamonds represent these four Logic Flow pieces.

The **circle** is used to represent either a starting point, or a stopping point. This is easy to remember since you start every single Logic Flow Chart with a circle containing the word Start or Begin. Often you will end a Logic Flow Chart with an End or Finish circle, but sometimes there is no end to the chart and it simply begins again. This is the case with any circuits that never turn off, but are always on and collecting data.

The **square** is used to represent any action that has only one outcome. For example, when a video game console is turned on it always checks to see what video game is in it. It does this every time after it starts up and it never checks in a different way. This kind of action is represented by the square, it never changes and there is always only one outcome.

The **diamond** is used to represent a question or actions with more than one possible outcome. For example, once your video game has loaded there is often a menu with a bunch of options. This would be written in a Logic Flow Chart as a diamond with something like the words “Start Up Menu” written inside of it. Lines coming off the diamond leading to another square, diamond, or circle would represent each action the user can take from this menu. Maybe our example Logic Flow Chart would have three options leading away from the “Start Up Menu” diamond, one line to start a new game, one to continue a saved game and another for game settings. In the Logic Flow Chart each option is written beside the line leading away from the diamond. It is possible to have as many options as you like leading away from a diamond in a Logic Flow Chart.

The **lines** in a Logic Flow Chart connect all the different pieces. These are there so the reader knows how to follow the Logic Flow Chart. The lines often have arrows on them and lead to whichever piece (circle, square, diamond) makes the most sense next. The lines usually have explanation of what has happened when they lead away from diamonds, so the reader knows which one to follow. Often some of these lines will run to a point closer to the beginning of the Logic Flow Chart. For example, the “Save Game” option might lead back to the “Start Up Menu” diamond, or it might lead straight to “Save and Quit”. It's up to you; all it has to do is make sense to you.

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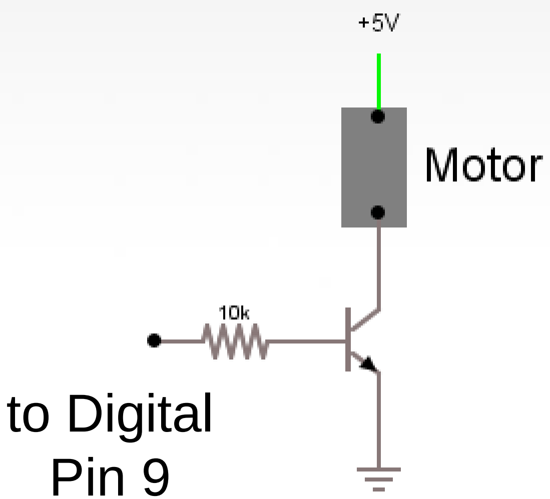
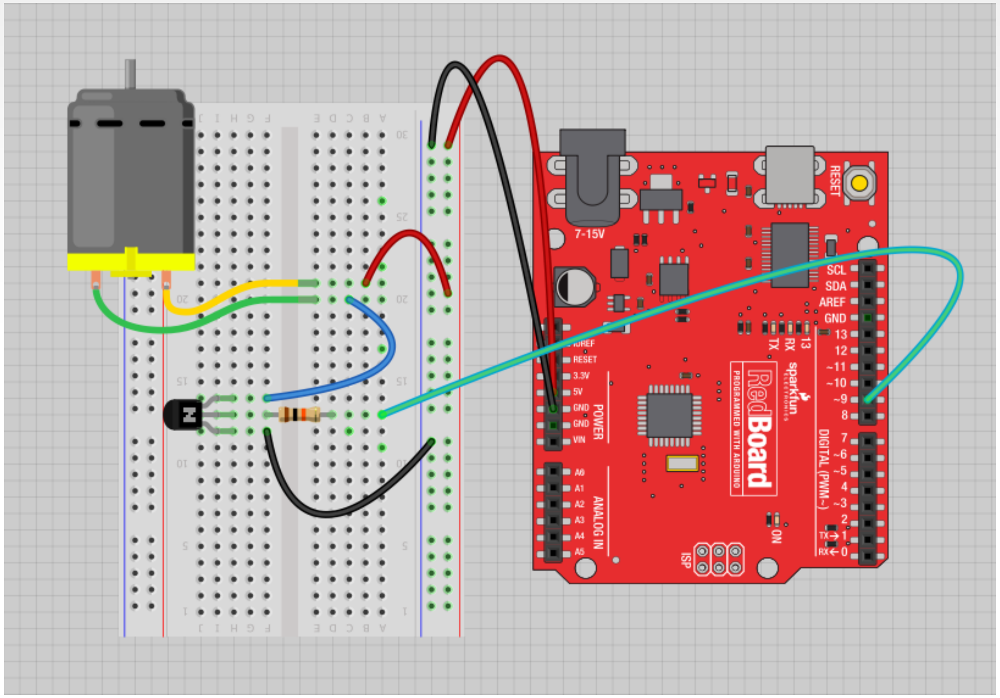
Driving Motors or other High Current Loads

NPN Transistor (Common Emitter “Amplifier” Circuit)





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Input

Input is any signal entering an electrical system.

- Both digital and analog sensors are forms of input
- Input can also take many other forms: Keyboards, a mouse, infrared sensors, biometric sensors, or just plain voltage from a circuit

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Project #4 – Digital Input

In Arduino, open up:

File → Examples → 02.Digital → Button

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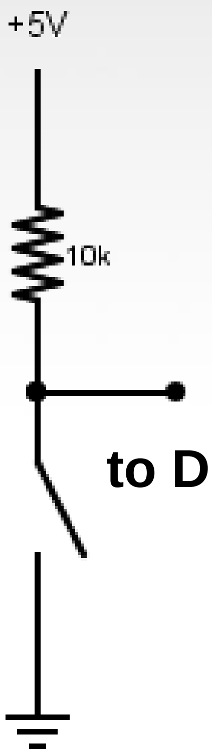
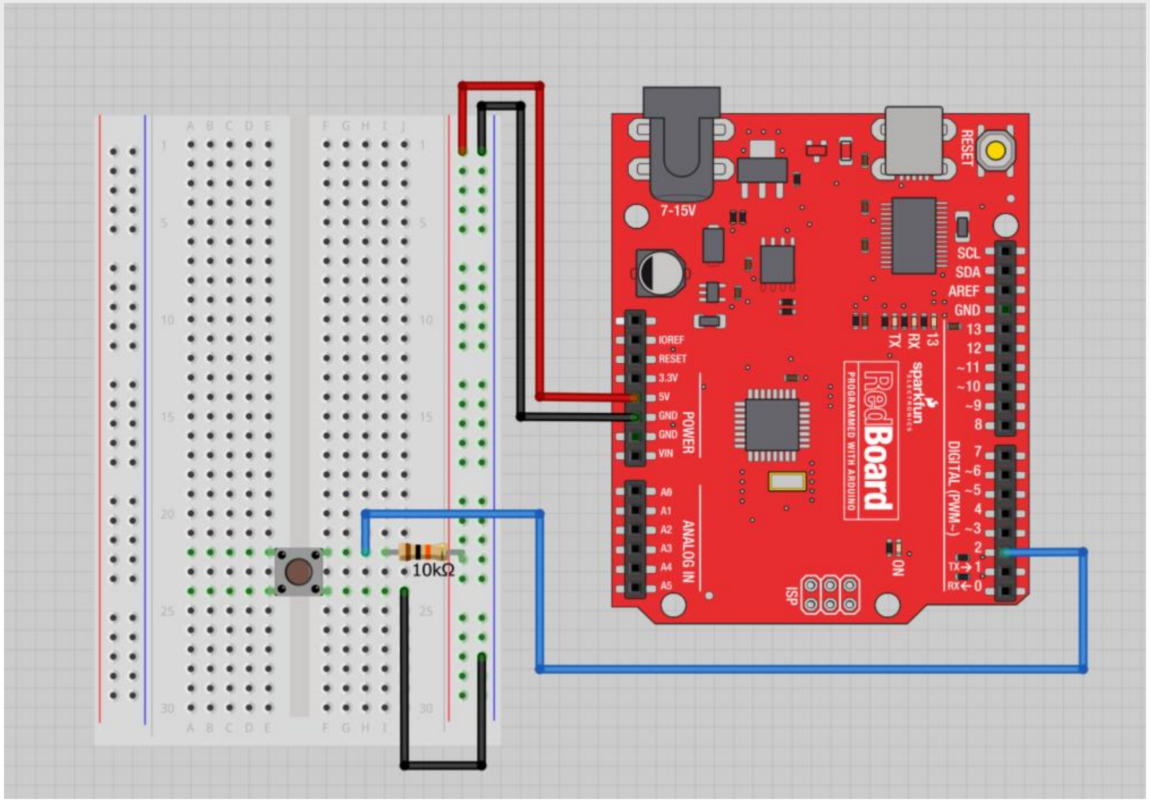
Digital Sensors (a.k.a. Switches)
Pull-up Resistor (circuit)



to Digital Pin 2



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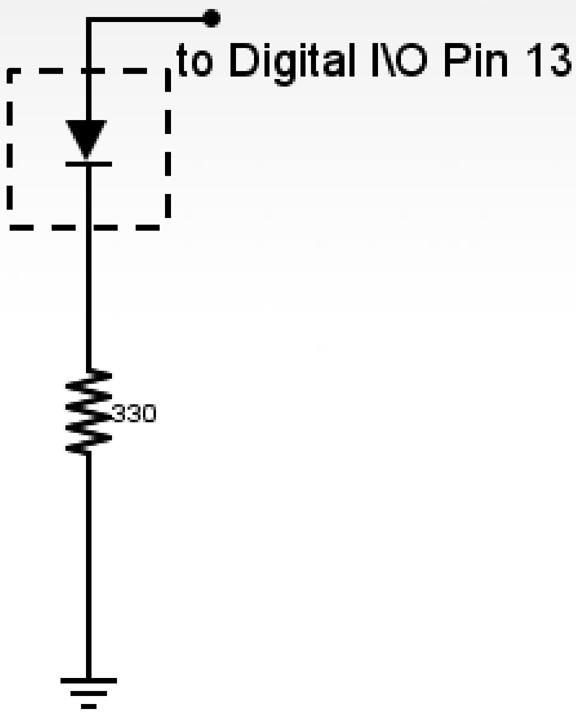
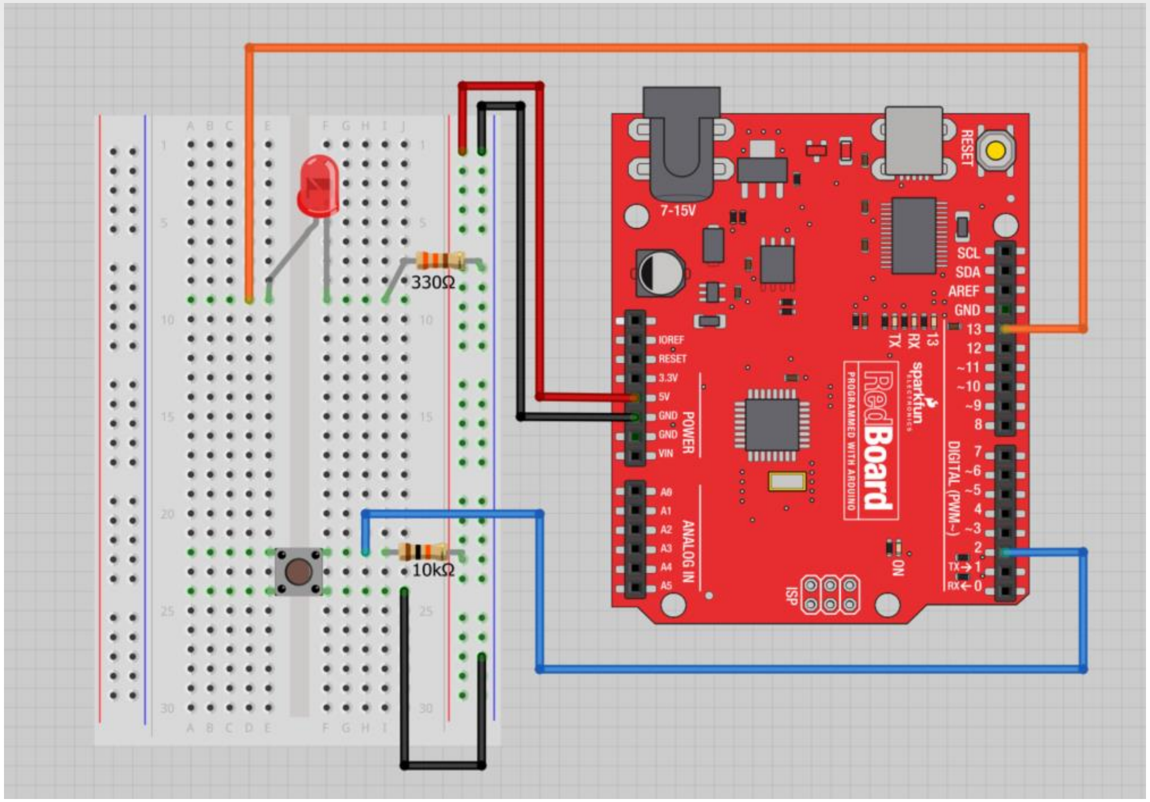
Digital Sensors (a.k.a. Switches)
Add an indicator LED to Pin 13

This is just like our 1st circuit!





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Digital Input

- Connect digital input to your Arduino using Pins # 0 – 13 (Although pins # 0 & 1 are also used for programming)

- Digital Input needs a `pinMode` command:

```
pinMode (pinNumber, INPUT);
```

Make sure to use ALL CAPS for ***INPUT***

- To get a digital reading:

```
int buttonState = digitalRead (pinNumber);
```

- Digital Input values are only **HIGH** (On) or **LOW** (Off)

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Digital Sensors

- Digital sensors are more straight forward than Analog
- No matter what the sensor there are only two settings: On and Off
- Signal is always either HIGH (On) or LOW (Off)
- Voltage signal for HIGH will be a little less than 5V on your Uno
- Voltage signal for LOW will be 0V on most systems

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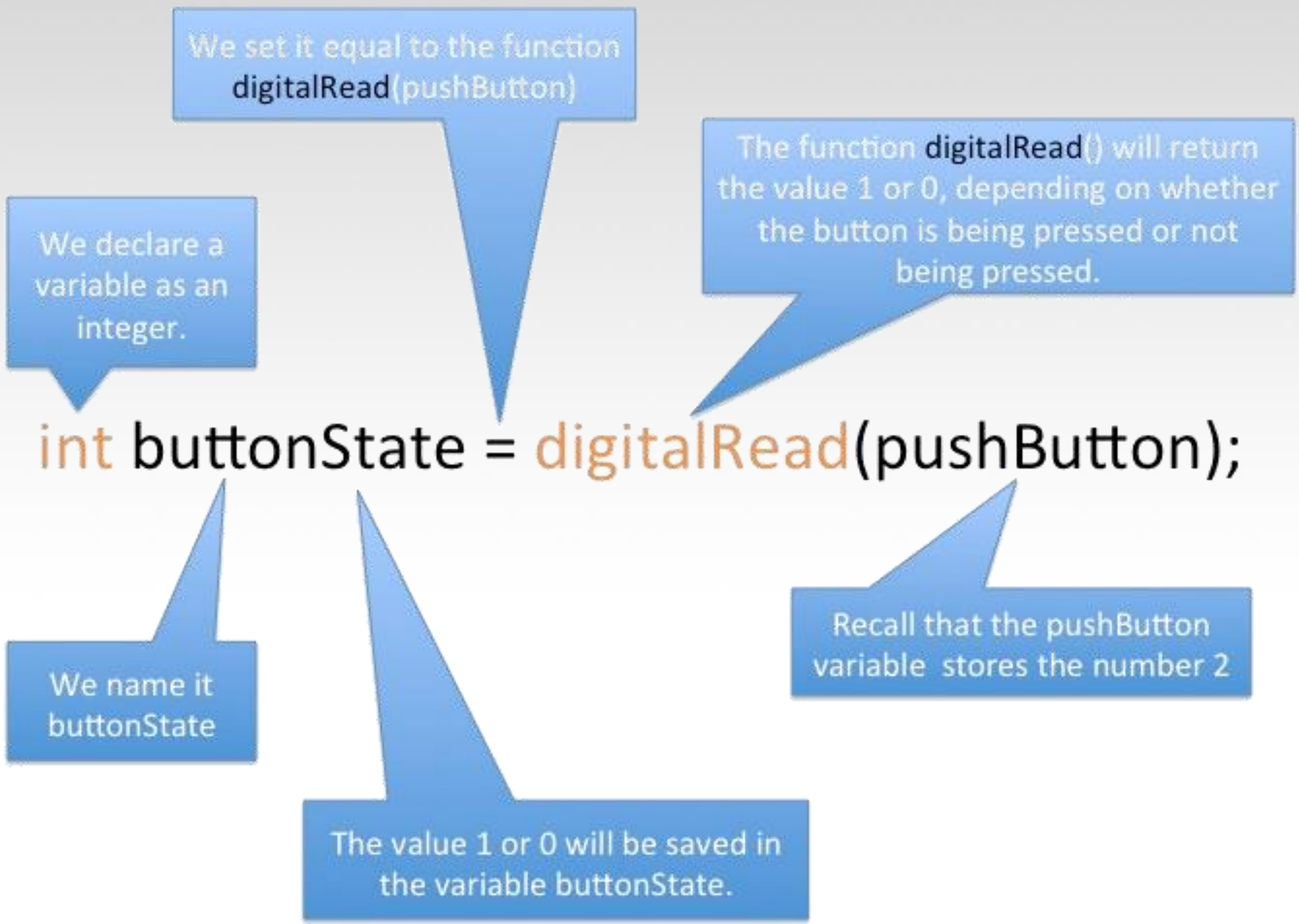

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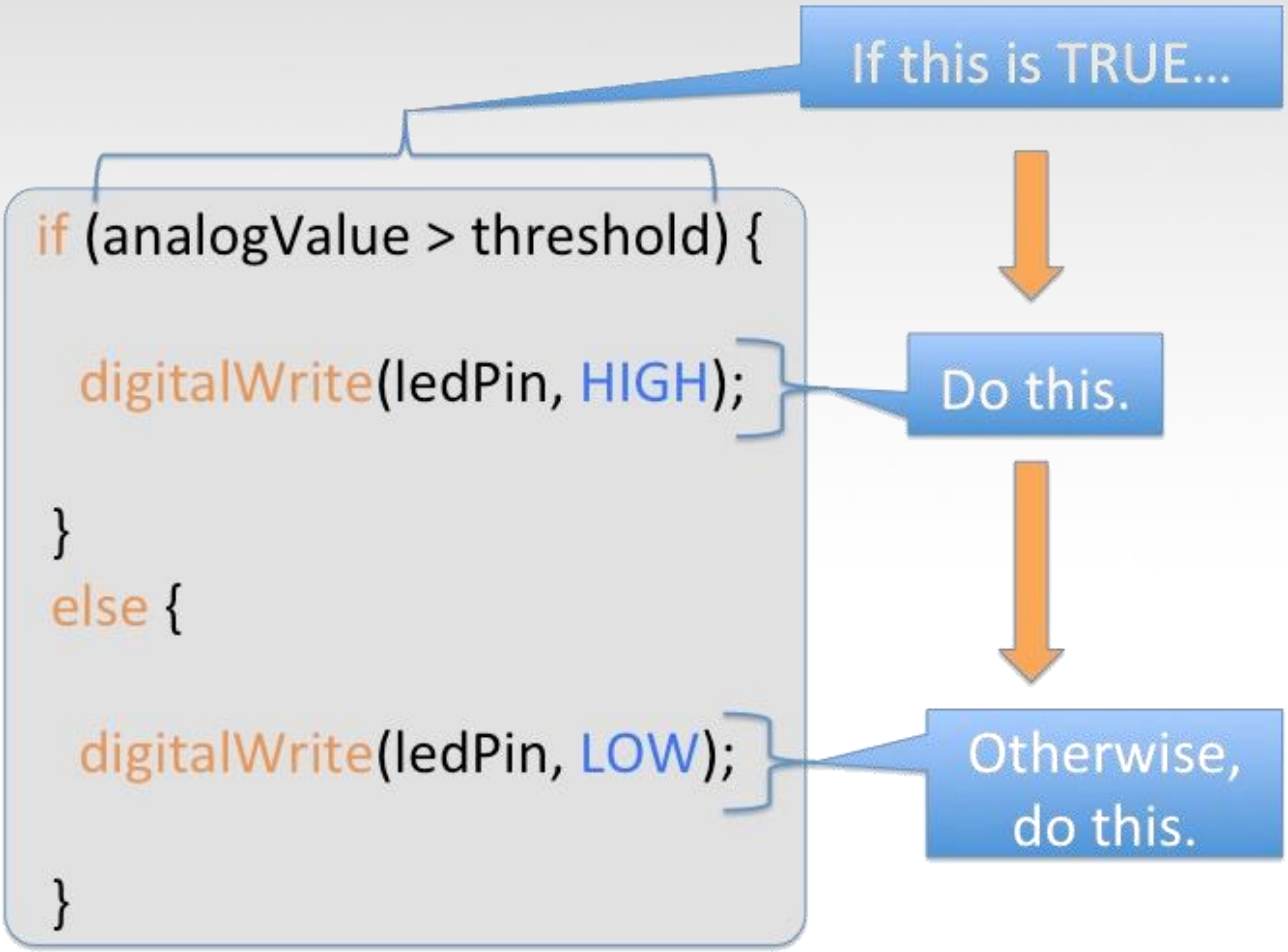
http://opensourcehardwarejunkies.com/tutorial-03-digitalread-and-

Programming: Conditional Statements

`if()`



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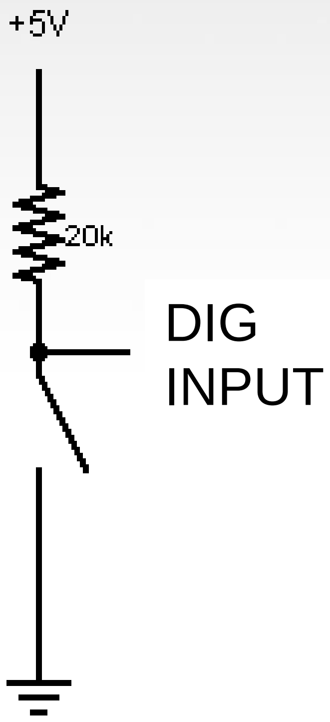
Programming: Conditional Statements

if()

```
void loop()
{
  int buttonState = digitalRead(5);
  if(buttonState == LOW)
  {  // do something
  }
  else
  {  // do something else
  }
}
```



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Boolean Operators

<Boolean>	Description
( ) == ( )	is equal?
( ) != ( )	is not equal?
( ) > ( )	greater than
( ) >= ( )	greater than or equal
( ) < ( )	less than
( ) <= ( )	less than or equal

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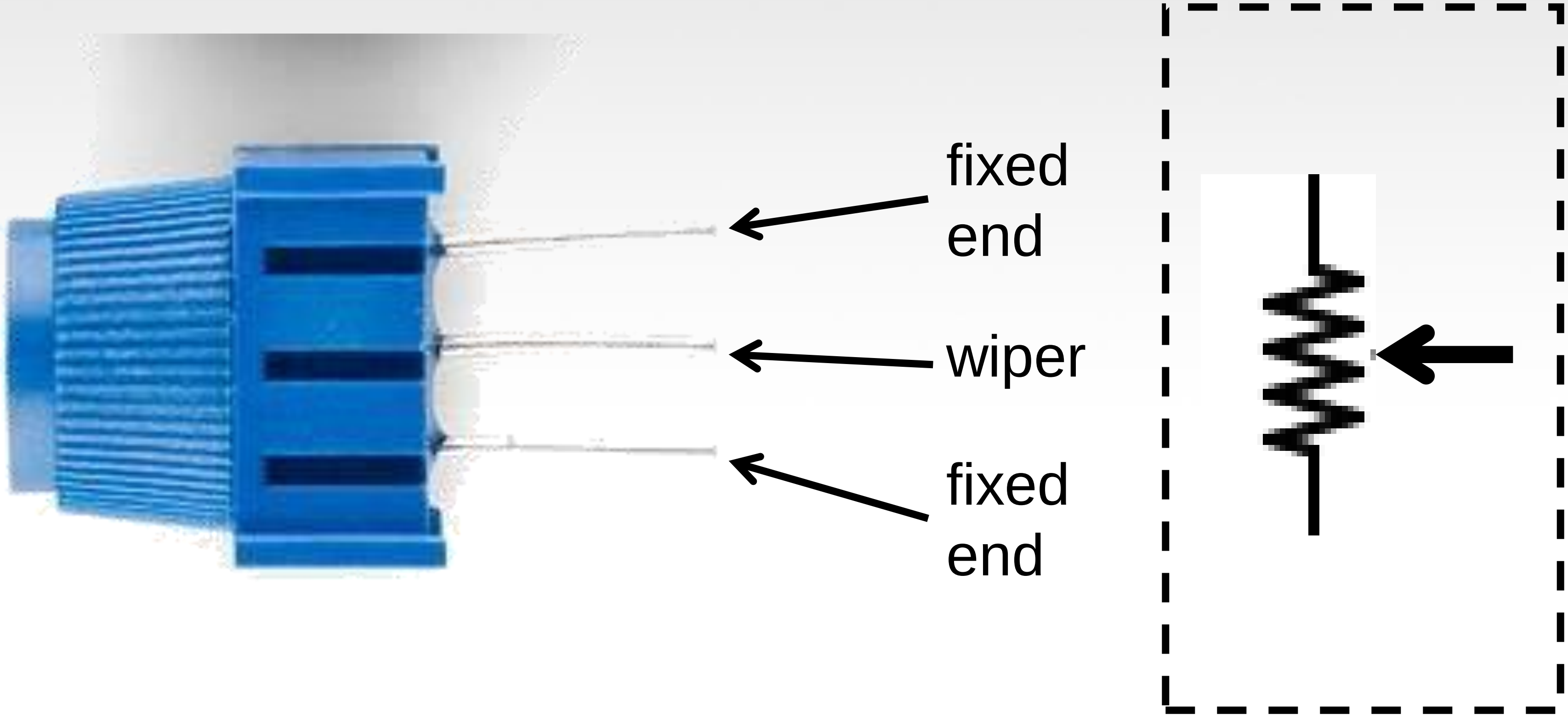
Trimpot (Potentiometer)
Variable Resistor



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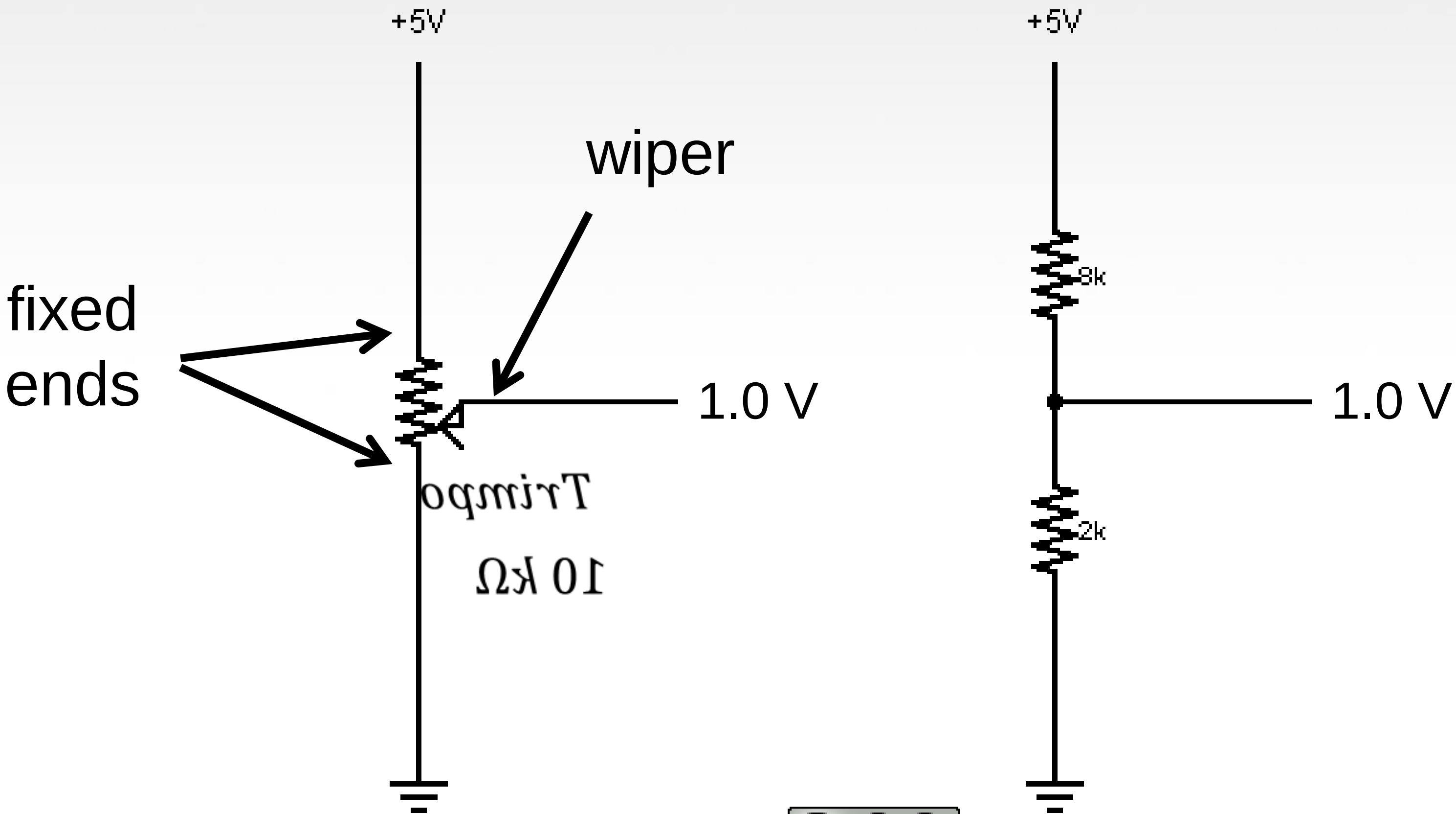
Analog Sensors

3 Pin Potentiometer = var. resistor (circuit)

a.k.a. Voltage Divider Circuit



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Ohms Law… (just the basics)
Actually, this is the "voltage divider"

$$V_{R1} = V_{CC} \cdot \left(\frac{R_1}{\mathrm{R}_{Total}} \right)$$

$$V_{R2} = V_{CC} \cdot \left(\frac{R_2}{\mathrm{R}_{Total}} \right)$$

$$R_{Total} = R_1 + R_2$$

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analogRead()

Arduino uses a 10-bit A/D Converter:

- this means that you get input values from 0 to 1023
  - 0 V → 0
  - 5 V → 1023

Ex:

```
int sensorValue = analogRead(A0);
```

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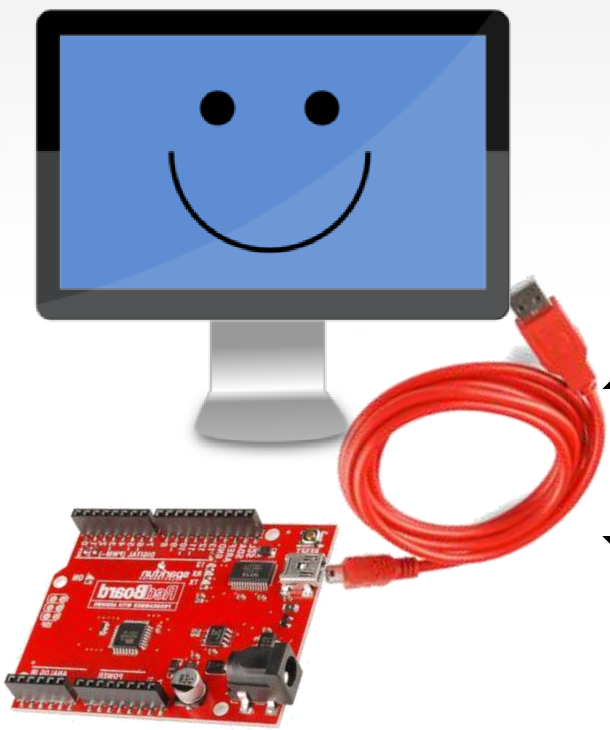
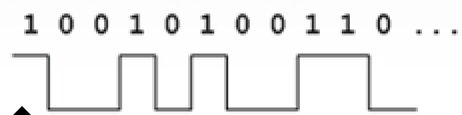
Using Serial Communication

Method used to transfer data between two devices.



Data passes between the computer and Arduino through the USB cable. Data is transmitted as zeros ('0') and ones ('1') sequentially.



Arduino dedicates Digital I/O pin # 0 to receiving and Digital I/O pin #1 to transmit.

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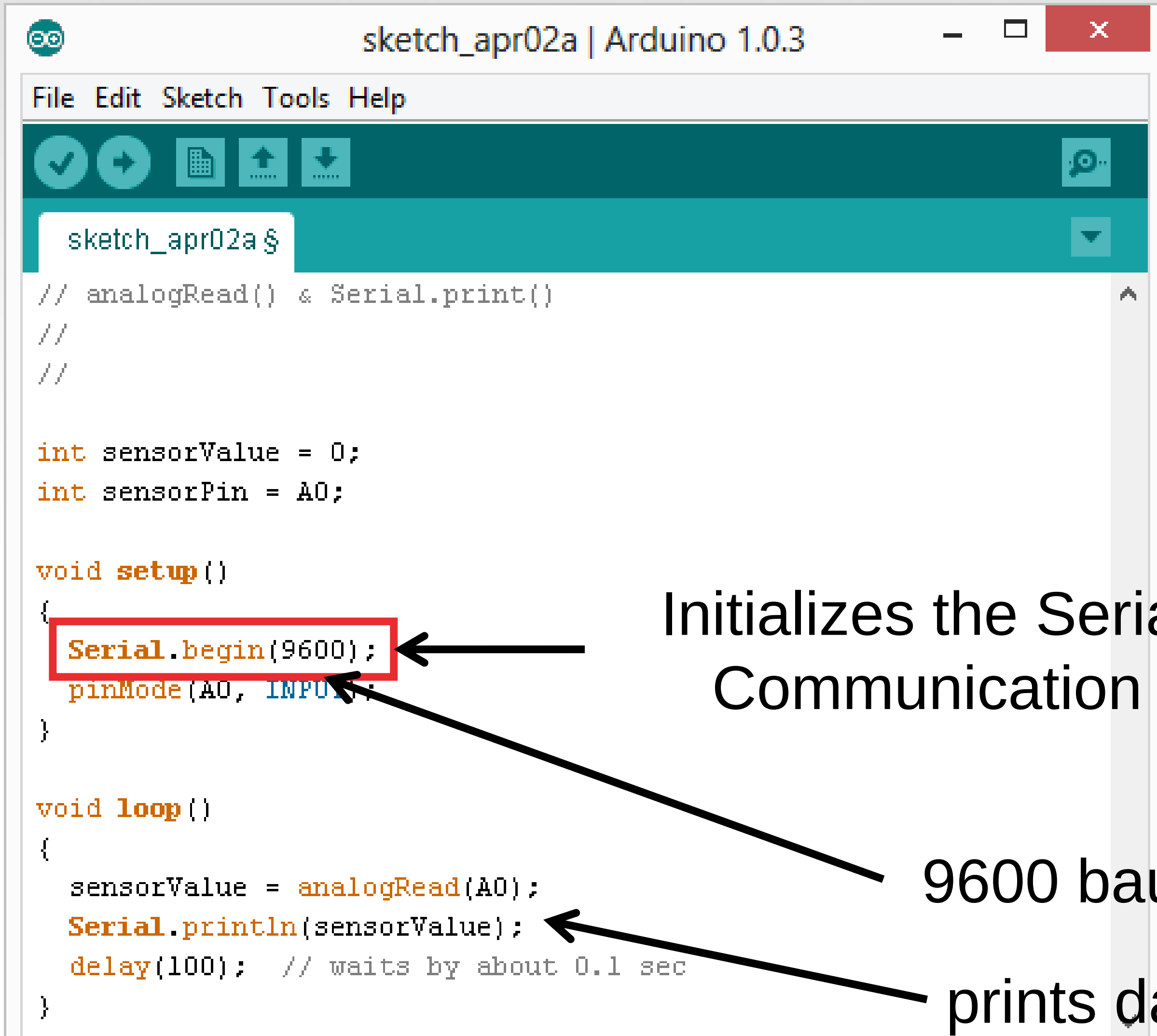
Serial Monitor & analogRead()



Initializes the Serial Communication

9600 baud data rate

prints data to serial bus

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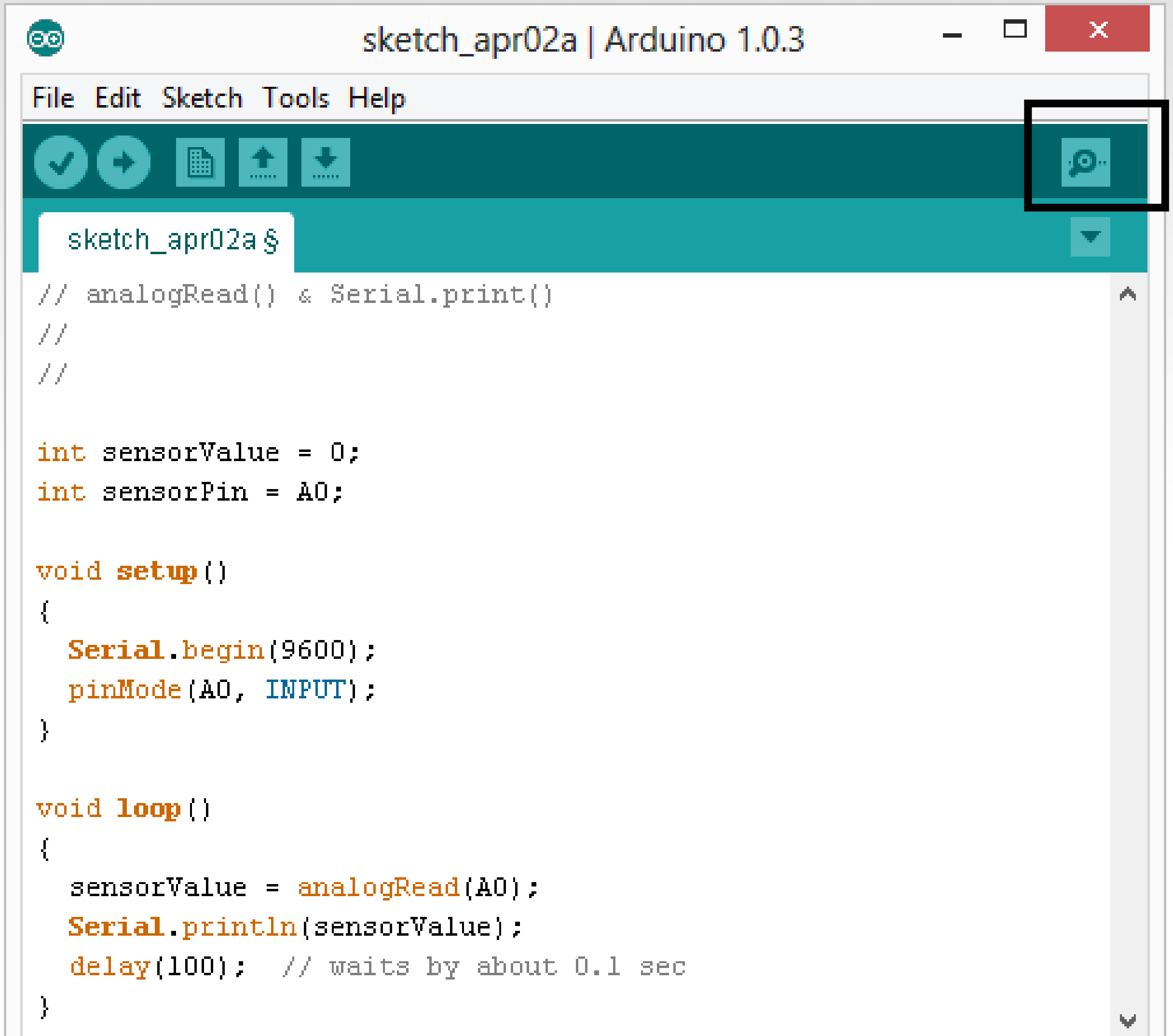
Serial Monitor & analogRead()



Opens up a Serial Terminal Window

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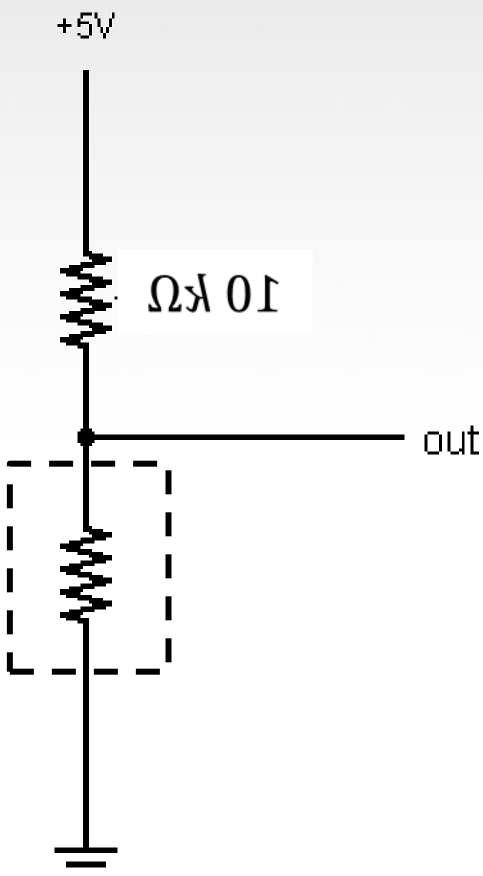
Analog Sensors
2 Pin Analog Sensors = var. resistor



Take two sensors -- Use the Serial Monitor and find the range of input values you get for each sensor.

MaxAnalogRead = __________

MinAnalogRead = __________

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Analog Sensors

Examples:

Sensors	Variables
Mic	soundVolume
Photoresistor	lightLevel
Potentiometer	dialPosition
Temp Sensor	temperature
Flex Sensor	bend
Accelerometer	tilt/acceleration

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Additional Serial Communication
Sending a Message

```
void loop ( )
{
  Serial.print(“Hands on “) ;
  Serial.print(“Learning ”) ;
  Serial.println(“is Fun!!!”) ;


}
```

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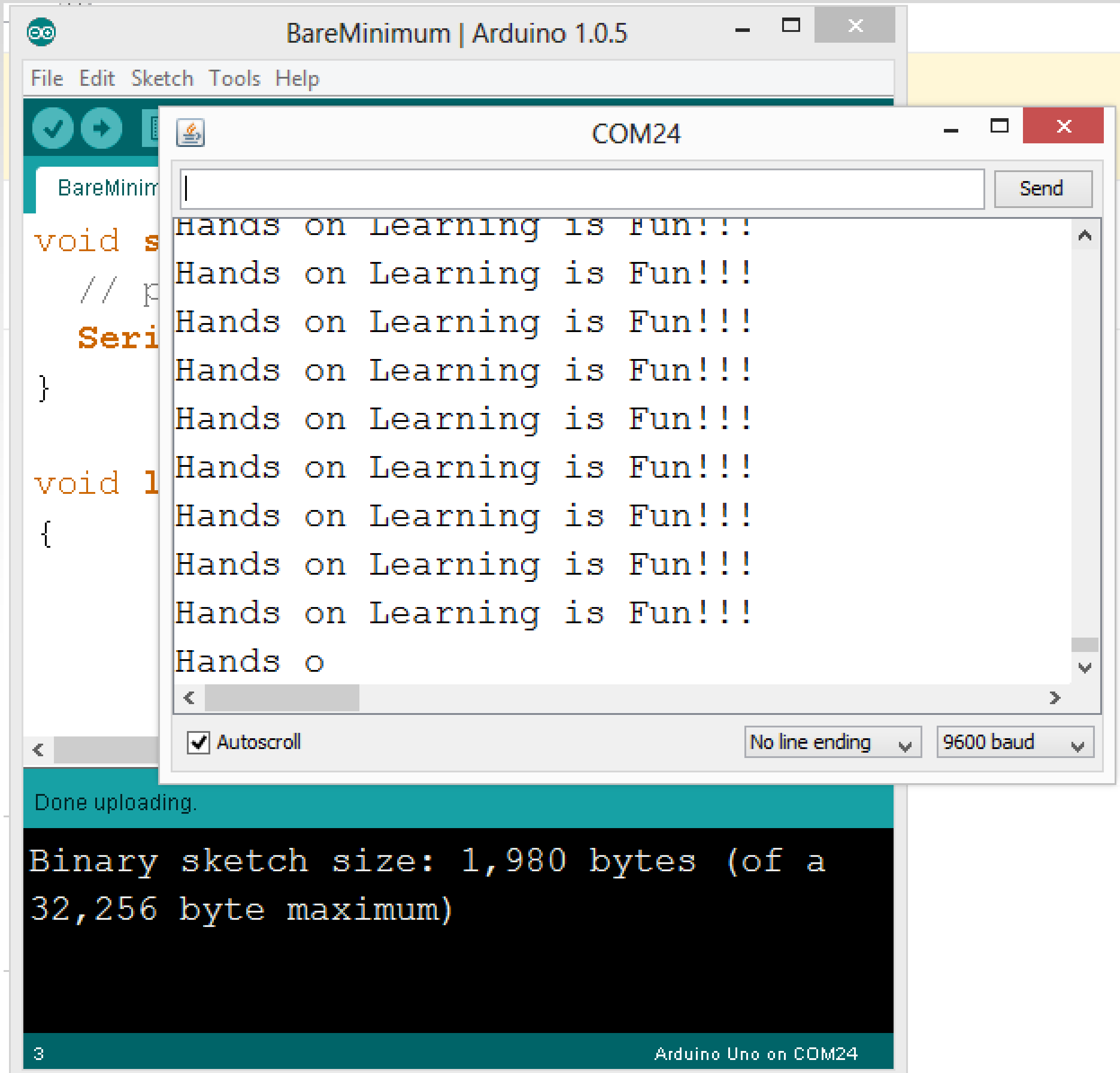

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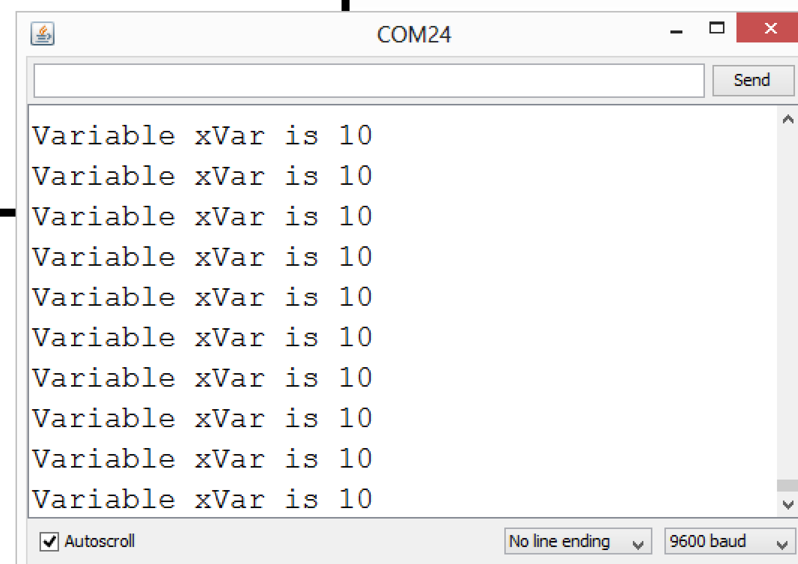
Serial Communication: Serial Debugging

```
void loop()
{
  int xVar = 10;
  Serial.print ( "Variable xVar is " ) ;
  Serial.println ( xVar ) ;
}
```



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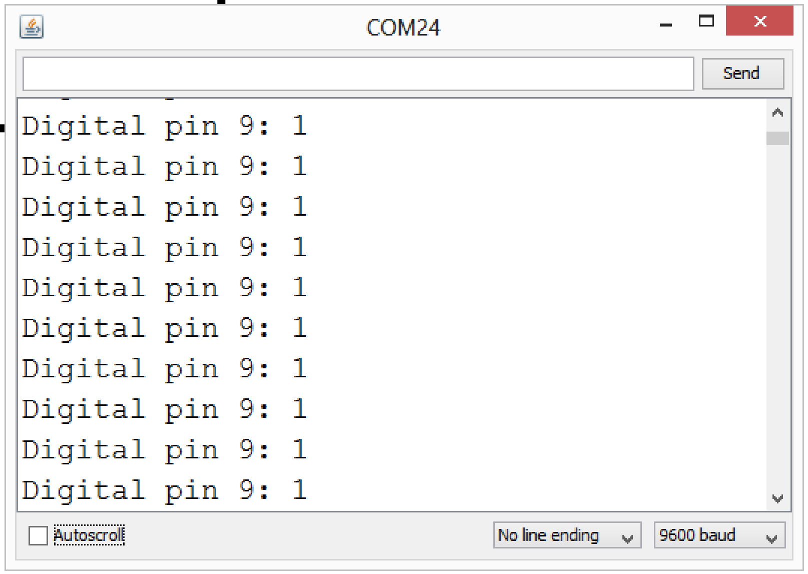
Serial Communication: Serial Troubleshooting

```
void loop ( )
{
   Serial.print ("Digital pin 9: ");
   Serial.println (digitalRead(9));
}
```



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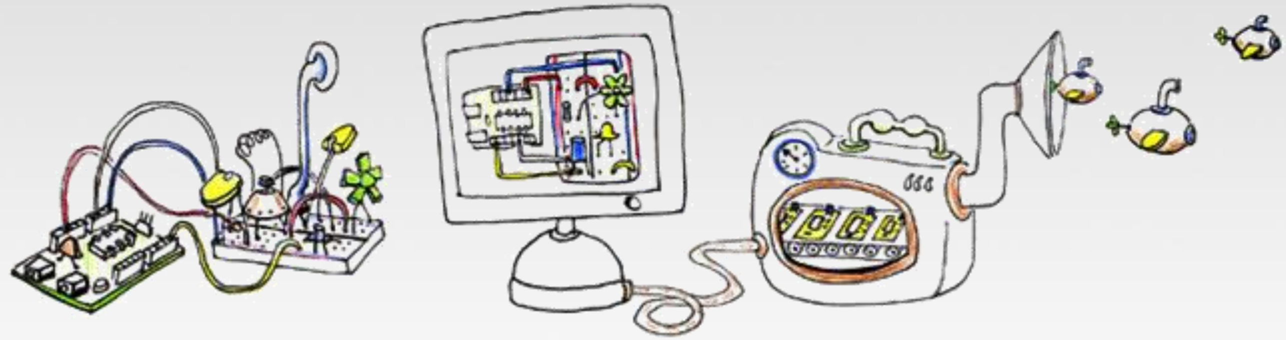
FRITZING



Virtual Electrical Prototyping Project

started in 2007 by the Interaction Design Lab

at the University of Applied Science Potsdam, Germany

Open Source

Prototypes: Document, Share, Teach, Manufacture

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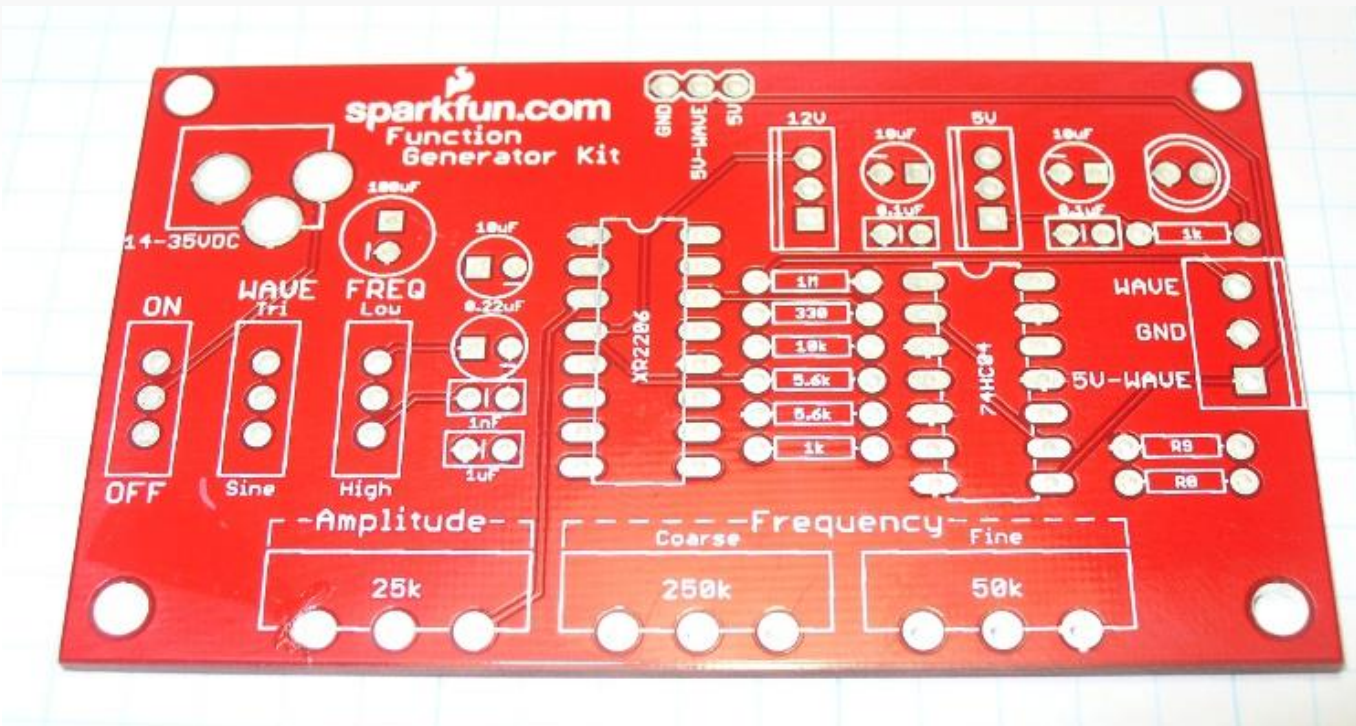
Now that you feel comfortable putting together circuits with your breadboard let’s talk about how to go from the breadboard to a PCB



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Free Time

The rest of the class is dedicated to free pursuit

Experiment with the various circuits and lessons in the SIK.

Explore the additional tutorials available on learn.sparkfun.com

Thank you for attending our Intro to Arduino class

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Questions?

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