

Introduction to Arduino Microcontrollers

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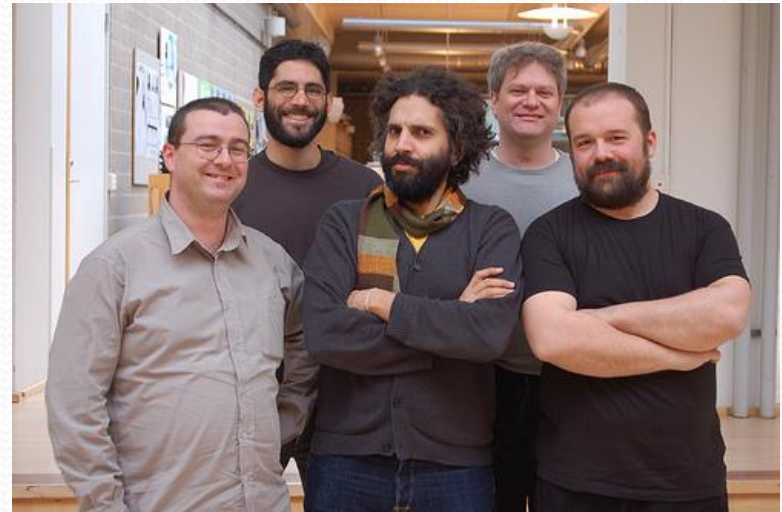
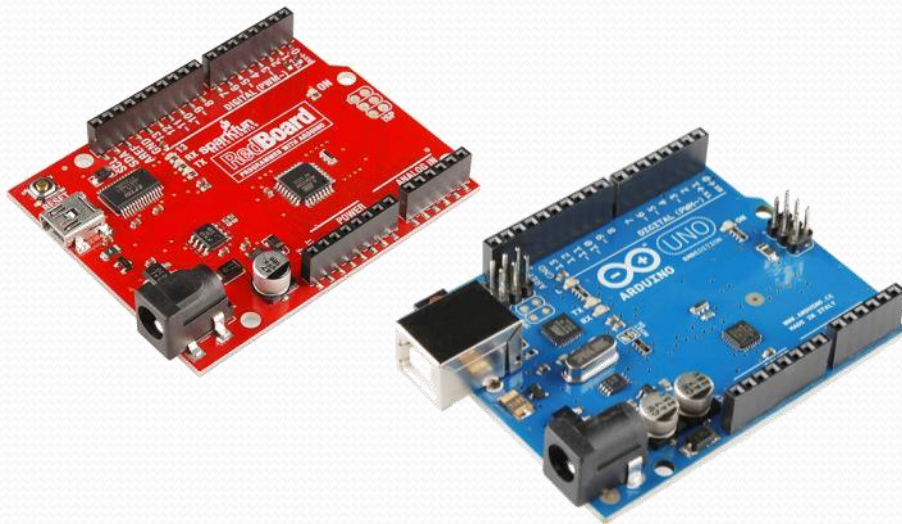
Overview of Class

- **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



Arduino Board

- “Strong Friend” Created in Ivrea, Italy
- in 2005 by Massimo Banzi & David Cuartielles
 - Open Source Hardware
 -  Processor
- Coding is accessible & transferrable → (C++, Processing, java)



MICROCONTROLLERS

- **Programmers work in the virtual world.**
- **Machinery works in the physical world.**
- **How does one connect the virtual world to the physical world?**
- **Enter the microcontroller.**
- **A microcontroller is basically a small-scale computer with generalized (and programmable) inputs and outputs.**
- **The inputs and outputs can be manipulated by and can manipulate the physical world.**



ARDUINO-Official definition

- Taken from the official web site (arduino.cc):
 - Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments.



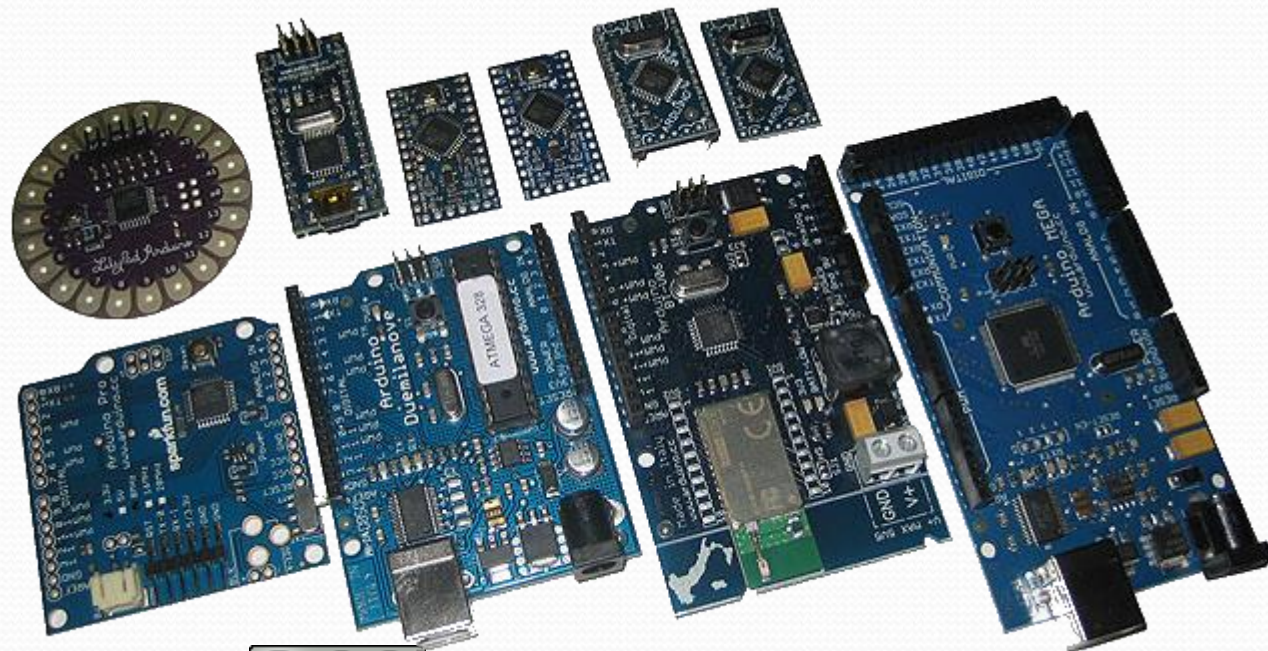
Why Arduino ?

- For whatever reason, Arduino microcontrollers have become the de facto standard.
 - Make Magazine features *many* projects using Arduino microcontrollers.
- Strives for the balance between ease of use and usefulness.
 - Programming languages seen as major obstacle.
 - Arduino C is a greatly simplified version of C++.
- Inexpensive (\$35 retail).

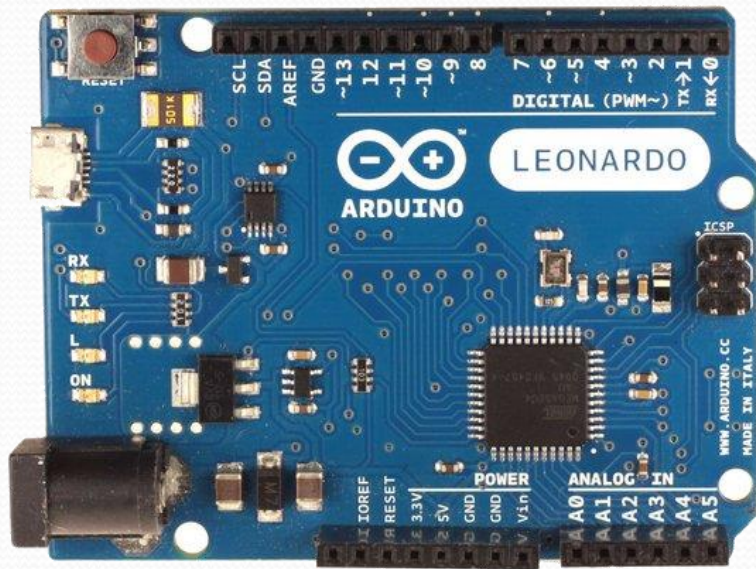


Types of Arduino

- Many different versions
 - Number of input/output channels
 - Form factor
 - Processor
- Leonardo
- Due
- Micro
- LilyPad
- Esplora
- Uno



Leonardo

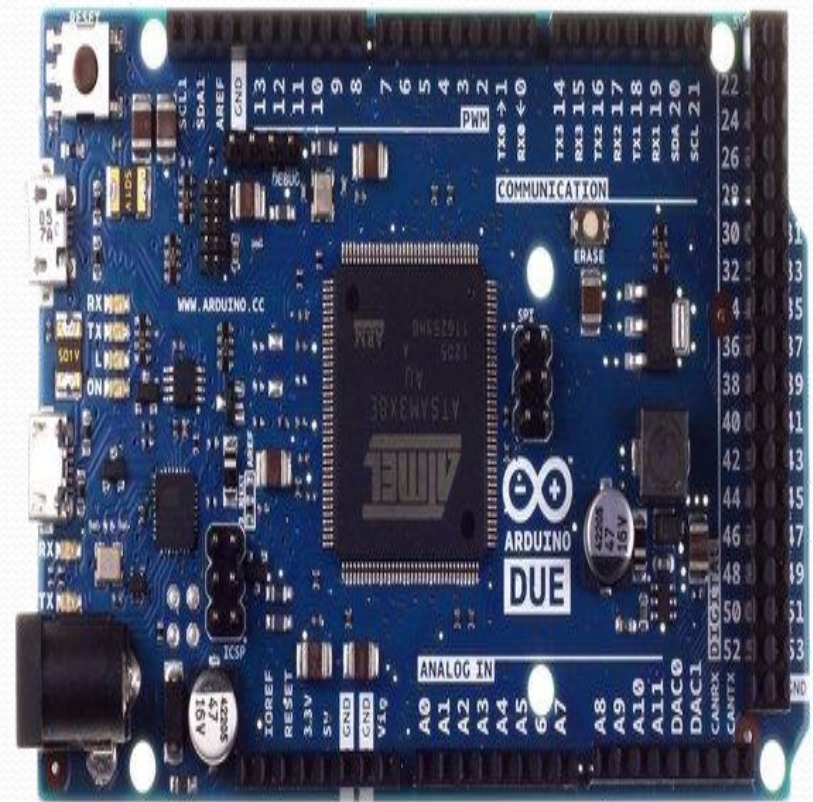


- Compared to UNO a slight upgrade
- Built in USB compatibility
- Presents to a pc as a mouse or keyboard



Due

- Much faster processor, many more pins
- Operates on 3.3 volts
- Similar to the Mega



Micro

- When size matters:
Micro, Nano, Mini
- Includes all functionality
of the Leonardo
- Easily usable on a
breadboard



Lilypad

- Lilypad is most popular for clothing based projects.



Esplora

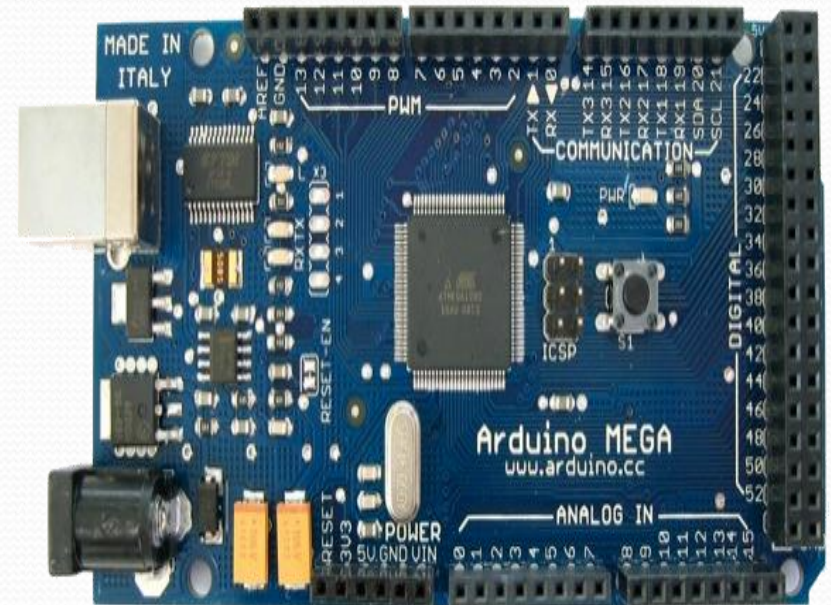


- Game controller
- Includes joystick, four buttons, linear potentiometer (slider), microphone, light sensor, temperature sensor, three-axis accelerometer.
- Not the standard set of IO pins.



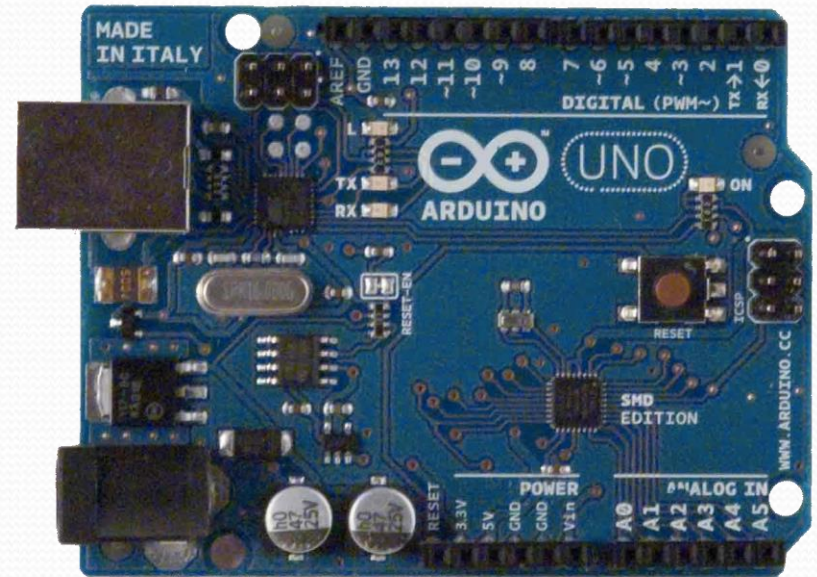
Mega

- Compared to the Uno, the Mega:
 - Many more communication pins
 - More memory
 - Some interface hardware doesn't work



Arduino UNO close up

- The pins are in three groups:
 - Invented in 2010
 - 14 digital pins
 - 6 analog pins
 - power



Where to start ?

- Get an Arduino (starter kit)
- Download the compiler
- Connect the controller
- Configure the compiler
- Connect the circuit
- Write the program
- Get frustrated/Debug/Get it to work
- Get excited and immediately start next project
(sleep is for wimps)



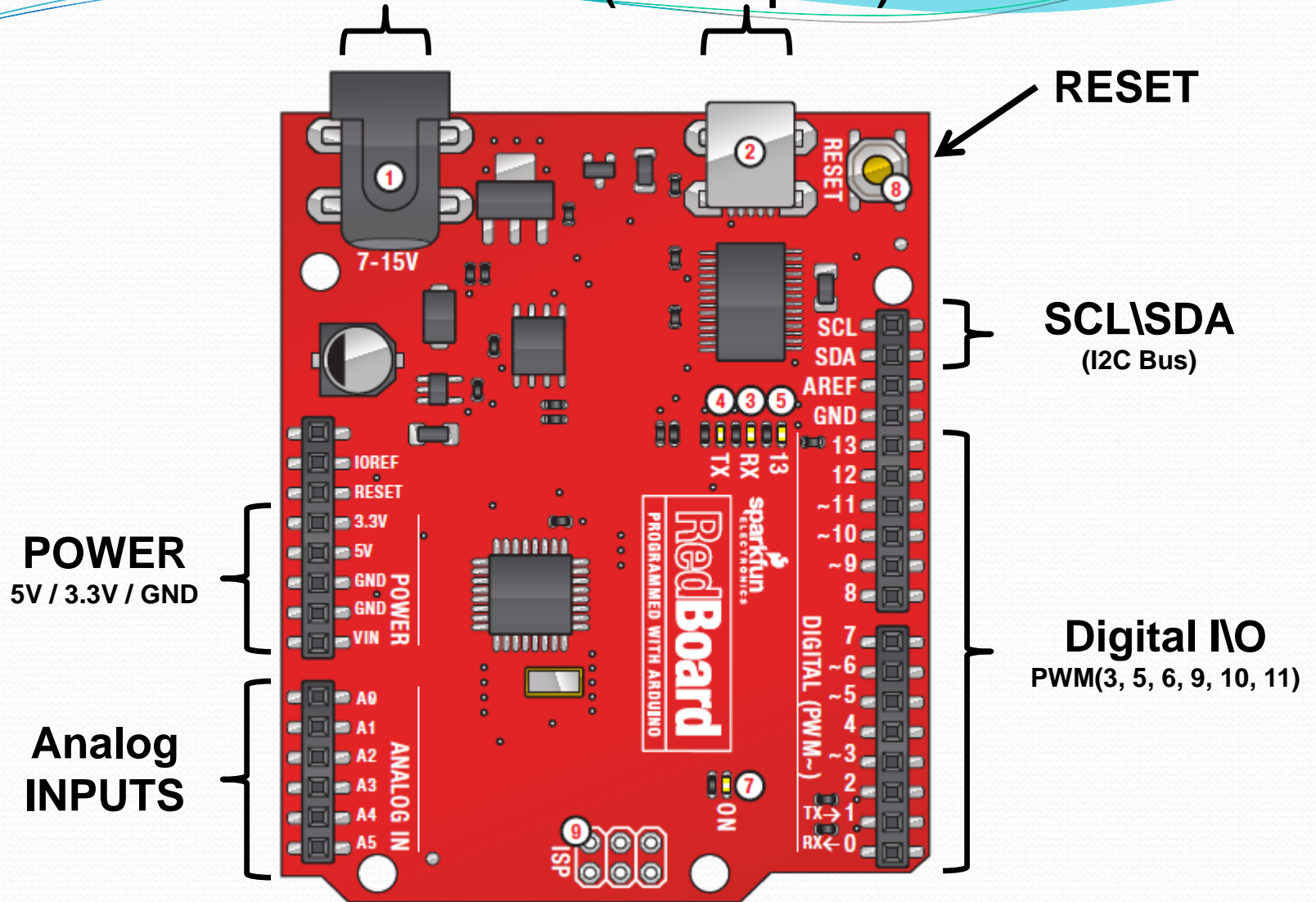
Arduino starter kits

- **Start with a combo pack (starter kit)**
 - Includes a microcontroller, wire, LED's, sensors, etc.
- **www.adafruit.com**
adafruit.com/products/68 (\$65)
- **www.sparkfun.com**
<https://www.sparkfun.com/products/11576> (\$99.95)
- **Radio Shack**
Make Ultimate Microcontroller Pack w/ Arduino Kit (\$119.99)
- **www.makershed.com**
http://www.makershed.com/Ultimate_Arduino_Microcontroller_Pack_p/msump1.htm (\$150)



PWR IN

**USB
(to Computer)**



RESET

**SCL\SDA
(I2C Bus)**

**POWER
5V / 3.3V / GND**

**Analog
INPUTS**

**Digital I/O
PWM(3, 5, 6, 9, 10, 11)**



PWR IN

**USB
(to Computer)**

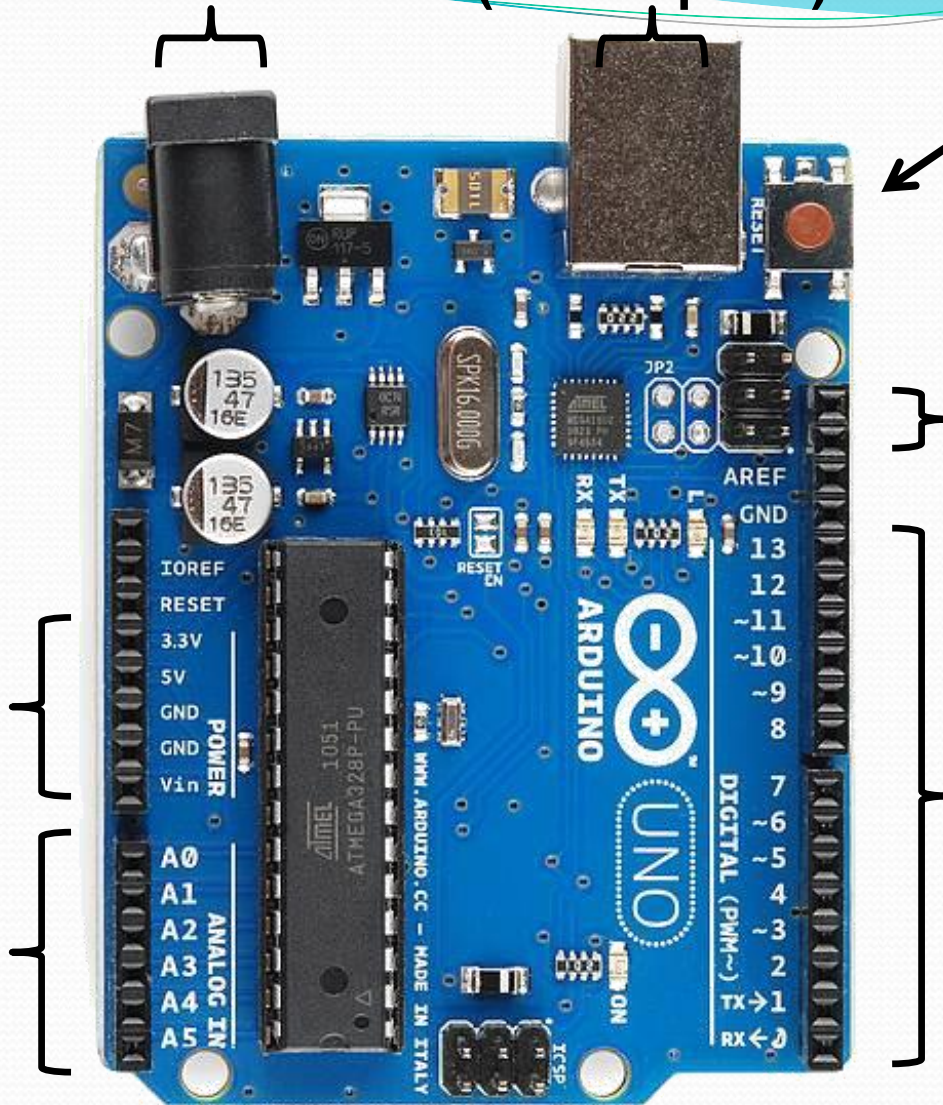
RESET

**SCL\SDA
(I2C Bus)**

**POWER
5V / 3.3V / GND**

**Analog
INPUTS**

**Digital I/O
PWM(3, 5, 6, 9, 10, 11)**



What to get.....

- **Required:**

- Arduino (such as Uno)
- USB A-B (printer) cable
- Breadboard
- Hookup wire
- LED's
- Resistors
- Sensors
- Switches

- **Good Idea:**

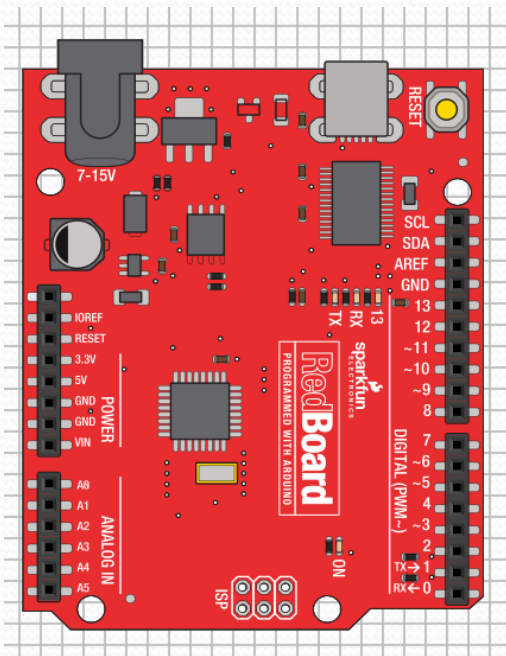
- Capacitors
- Transistors
- DC motor/servo
- Relay

- **Advanced:**

- Soldering iron & solder
- Heat shrink tubing
- 9V battery adapter
- Bench power supply



Go ahead and plug your board in!



Open up Arduino

- Hints:

- **For PC Users →**

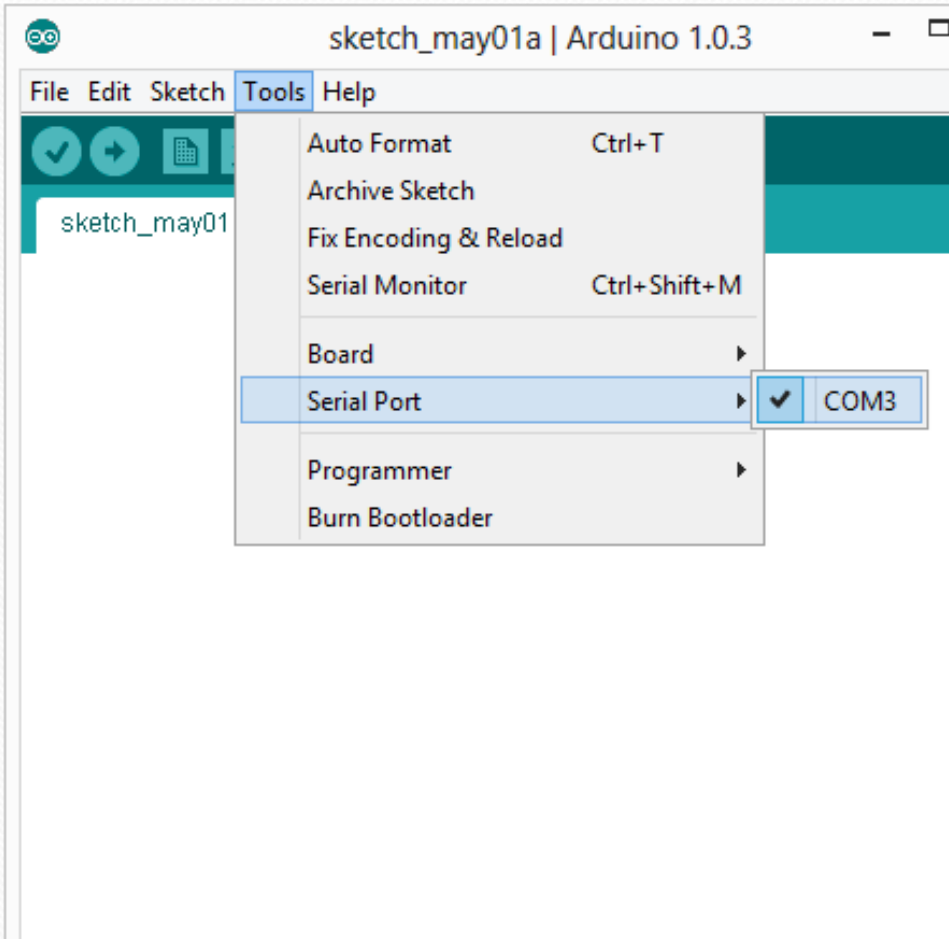
1. Let the installer copy and move the files to the appropriate locations, or
2. Create a folder under C:\Program Files (x86) called Arduino. Move the entire Arduino program folder here.

- **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.



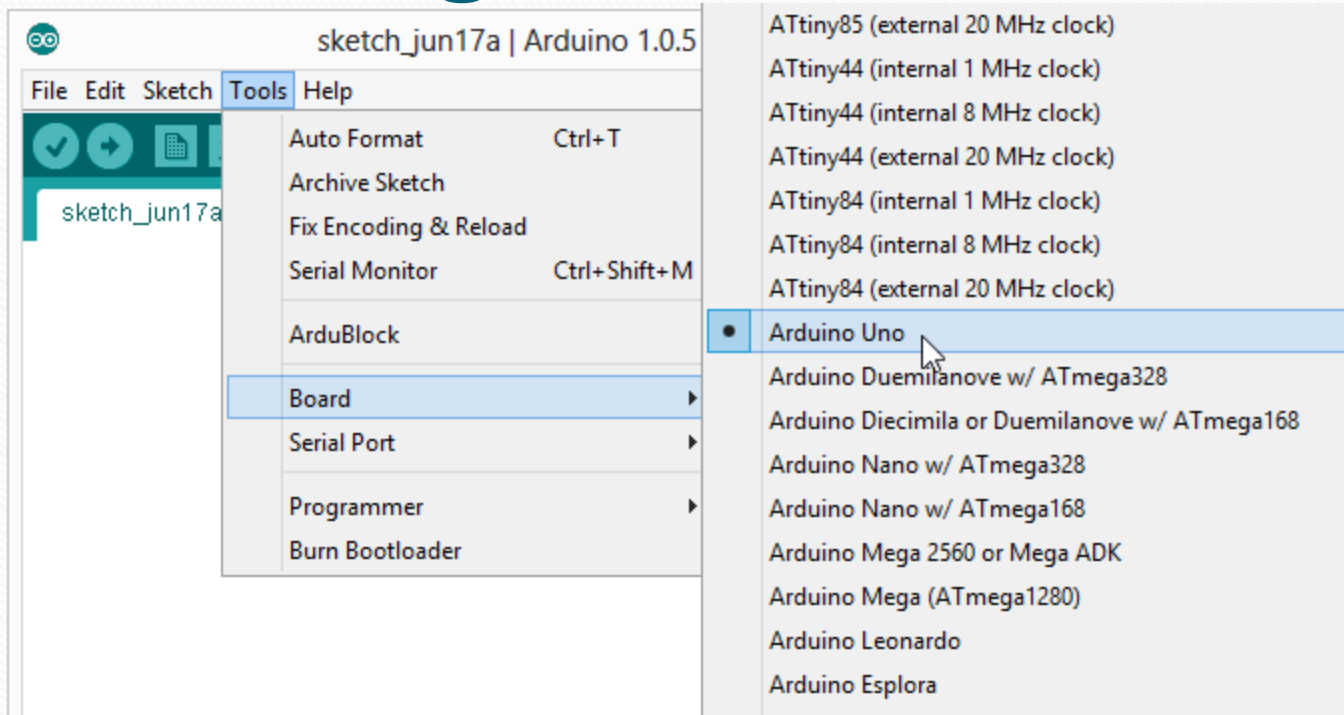
Settings: Tools → Serial Port



- 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.



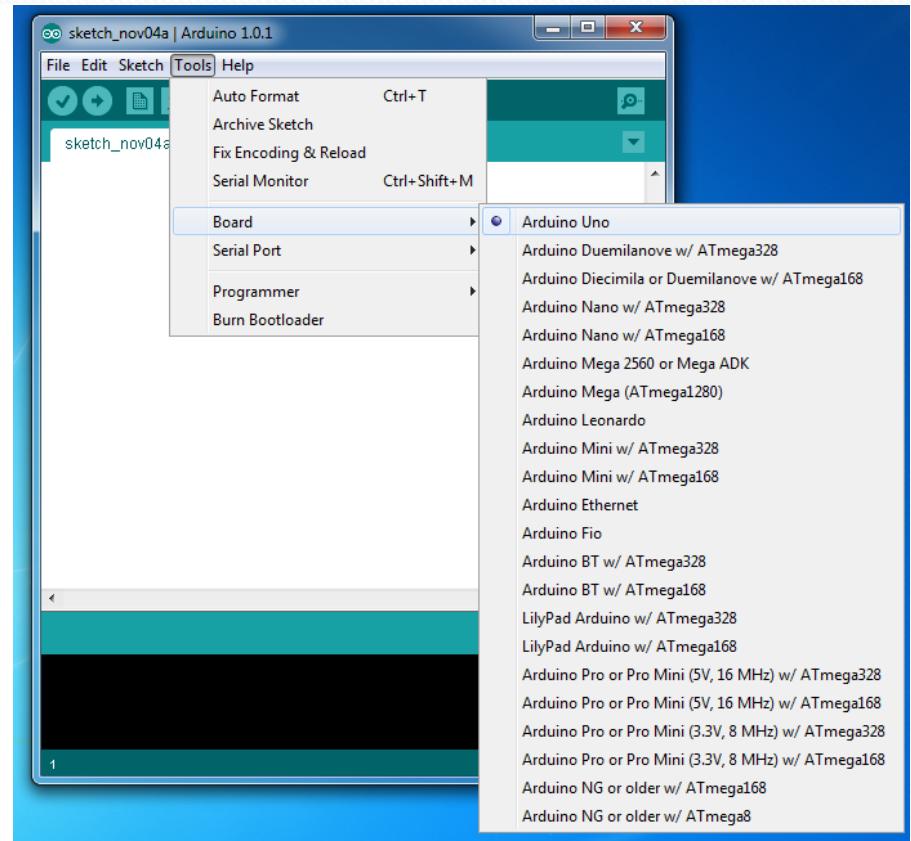
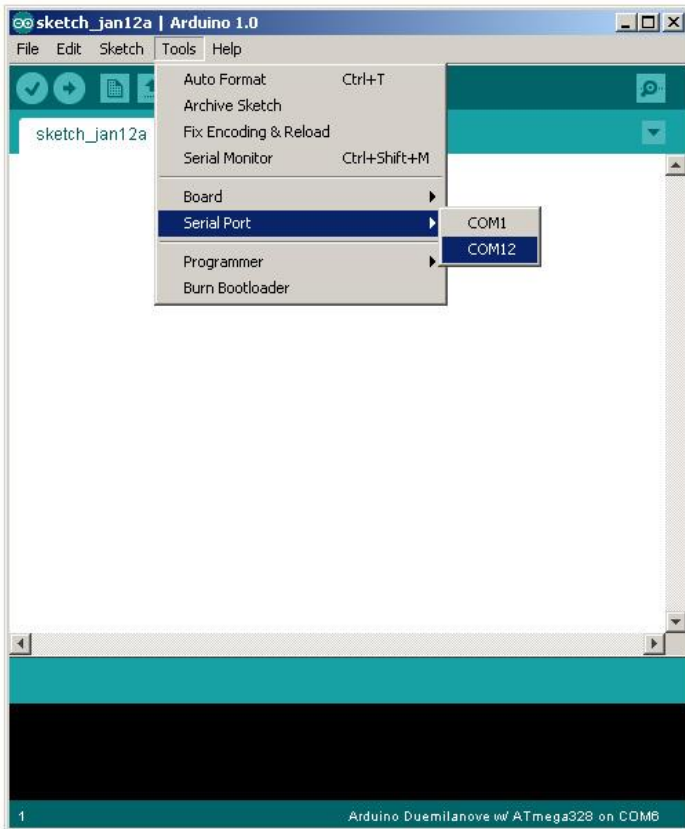
Settings: Tools → Board



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



Select Serial Port and Board



Using Arduino

- Write your sketch
- Press Compile button (to check for errors)
- Press Upload button to program Arduino board with your sketch

Try it out with the “Blink” sketch!

Load “File/Sketchbook/Examples/Digital/Blink”

```
void setup() {  
  pinMode(ledPin, OUTPUT); // sets t  
}  
void loop() {  
  digitalWrite(ledPin, HIGH); // sets t  
  delay(1000); // waits  
  digitalWrite(ledPin, LOW); // sets t  
  delay(1000); // waits  
}
```



compile



Done compiling.



upload



TX/RX flash

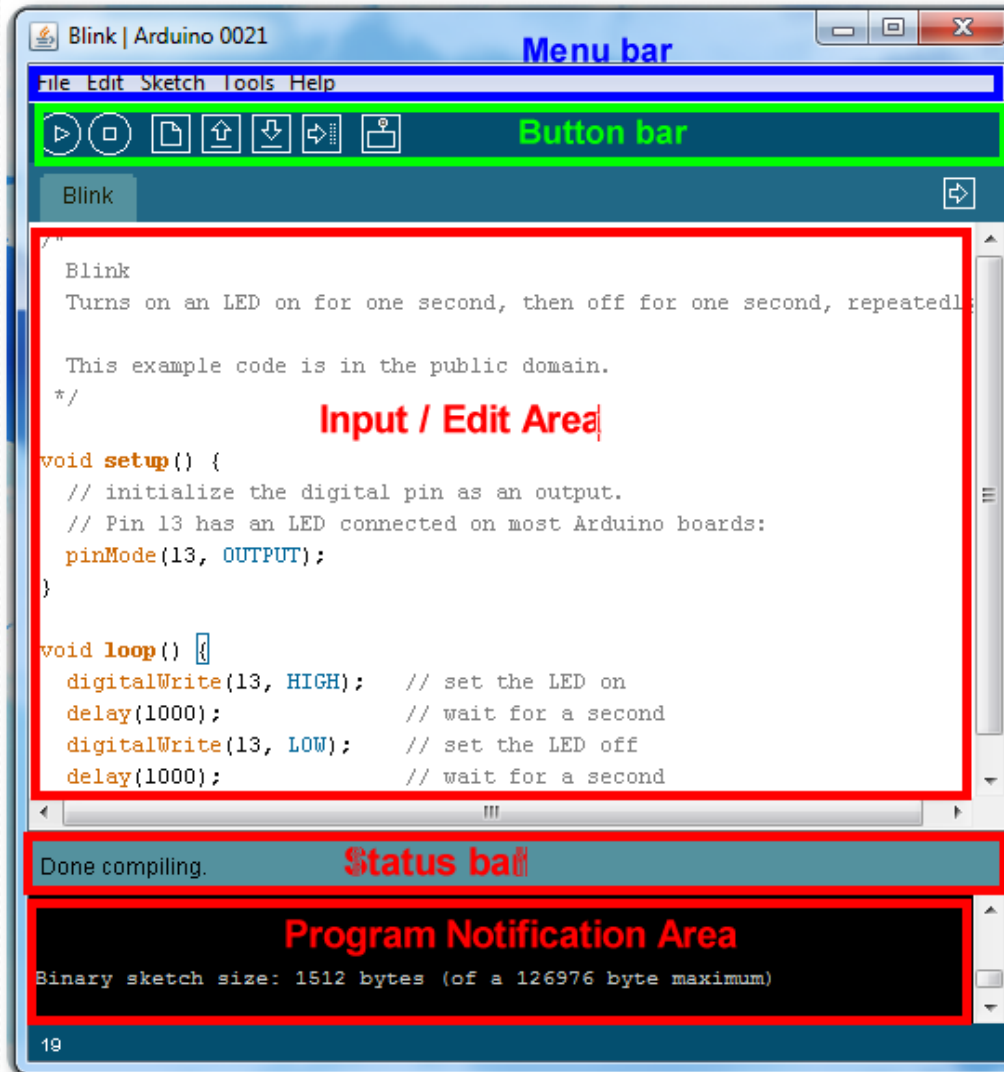


blink blink
sketch runs

todbot.com/blog/bionicarduino



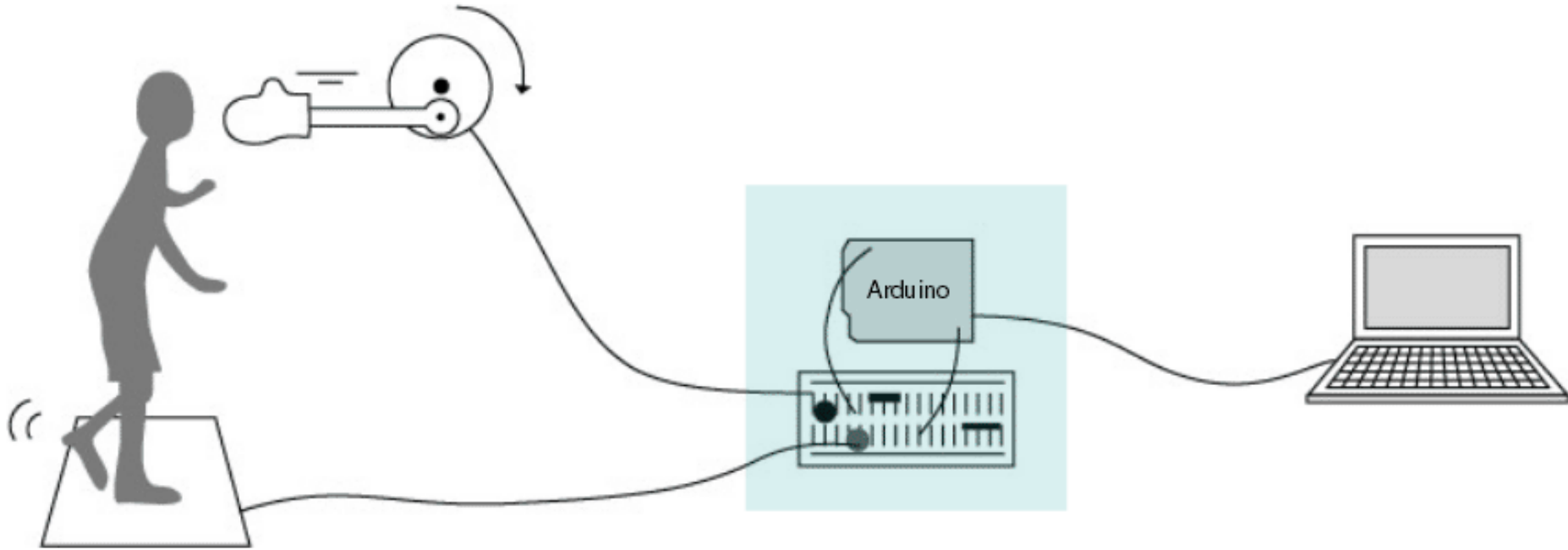
Arduino IDE



See: <http://arduino.cc/en/Guide/Environment> for more information

Input/Output

Output Transducers
actuators (e.g.,
motors, buzzers)



Input Transducers
sensors (e.g., switches,
levers, sliders, etc.)

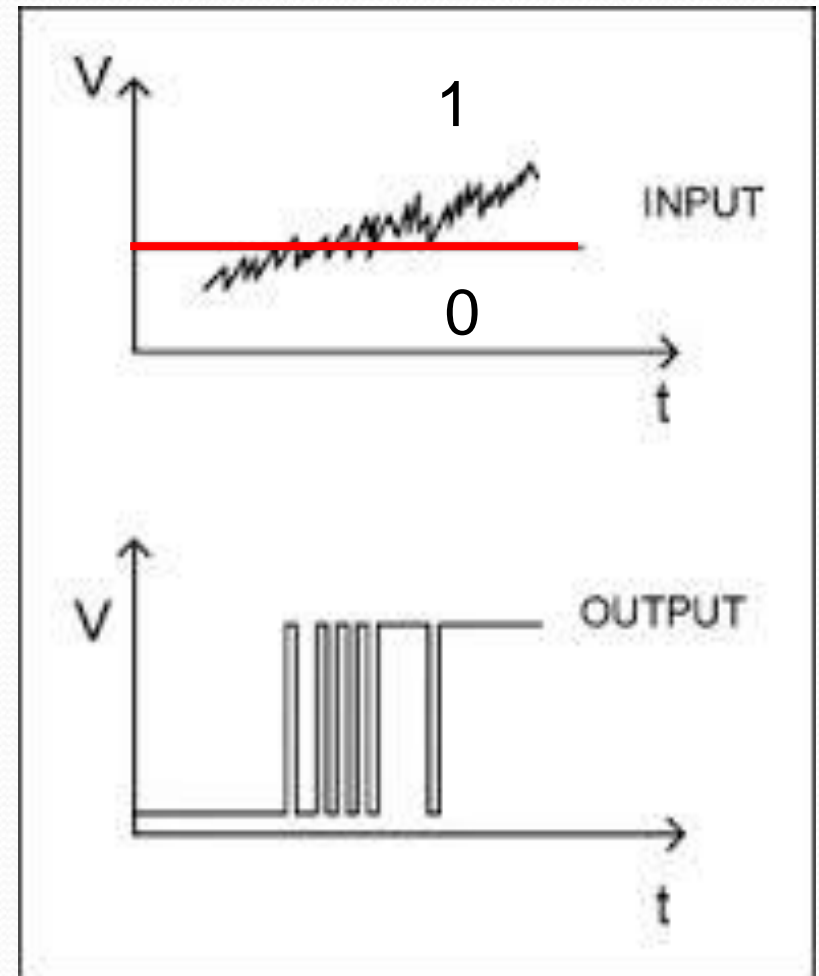


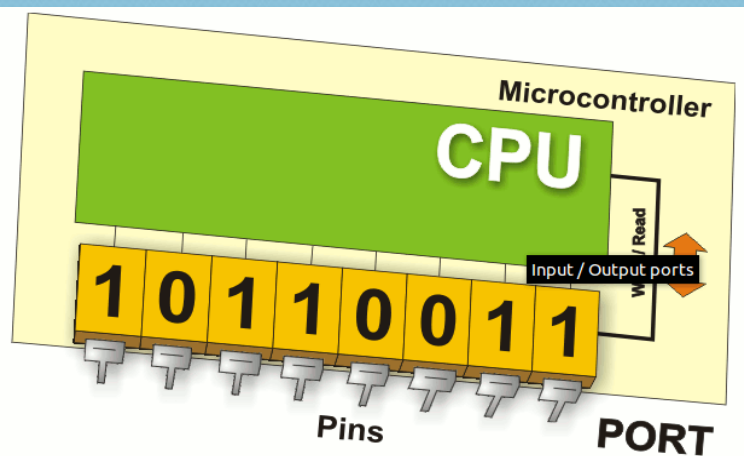
Image from *Theory and Practice of Tangible User Interfaces* at UC Berkley

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Topic 2: Digital Input/Output

- Digital IO is binary valued—it's either *on* or *off*, 1 or 0
- Internally, all microprocessors are digital, **why?**





Arduino Digital I/O

www.mikroe.com/chapters/view/1

`pinMode(pin, mode)`

Sets pin to either INPUT or OUTPUT

`digitalRead(pin)`

Reads HIGH or LOW from a pin

`digitalWrite(pin, value)`

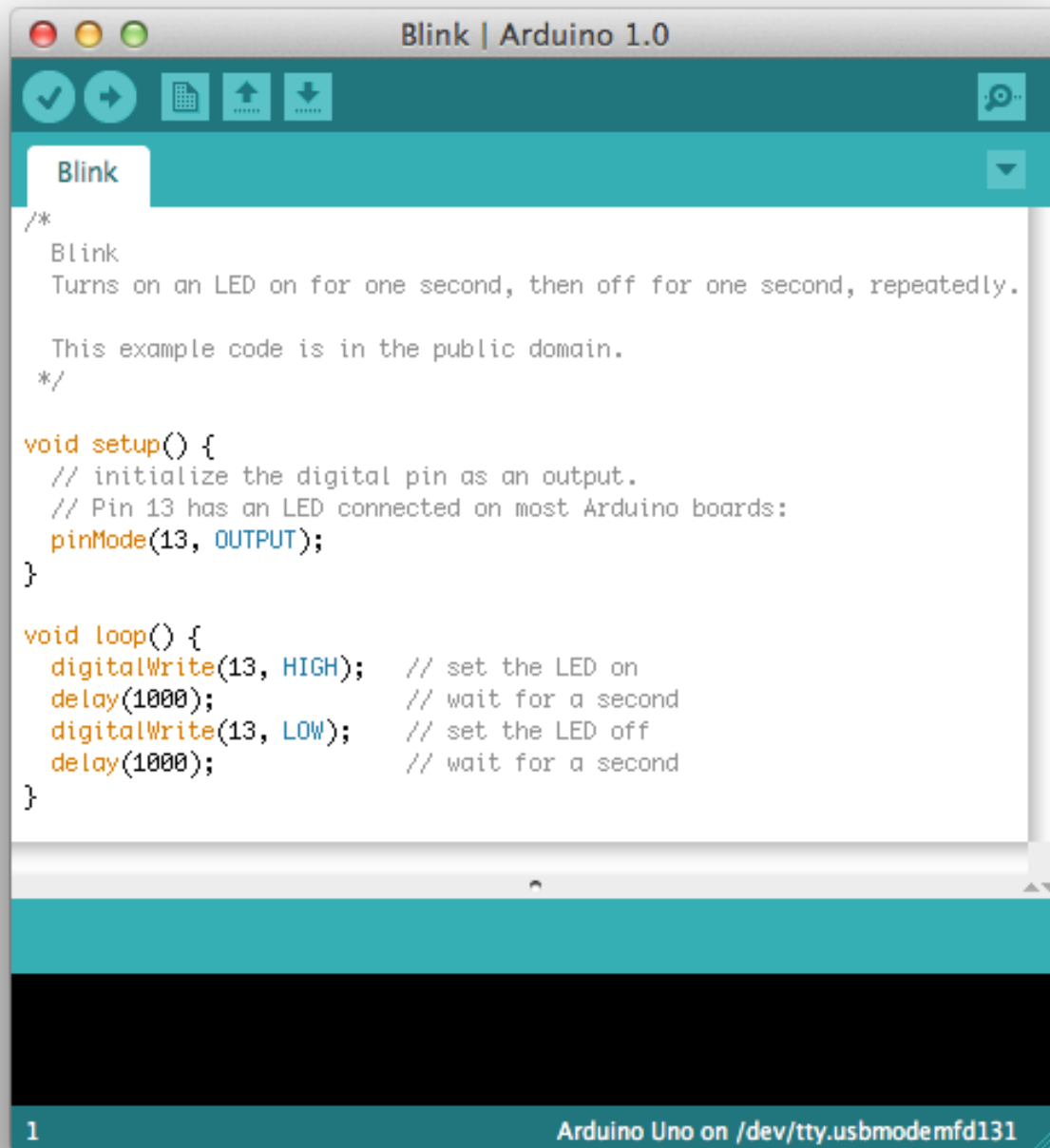
Writes HIGH or LOW to a pin

Electronic stuff

Output pins can provide 40 mA of current

Writing HIGH to an input pin installs a 20KΩ pullup

Our First Program



The image shows a screenshot of the Arduino IDE interface. The window title is "Blink | Arduino 1.0". The code editor displays the following C++ code for the Blink program:

```
/*
 * Blink
 * Turns on an LED on for one second, then off for one second, repeatedly.
 *
 * This example code is in the public domain.
 */

void setup() {
  // initialize the digital pin as an output.
  // Pin 13 has an LED connected on most Arduino boards:
  pinMode(13, OUTPUT);
}

void loop() {
  digitalWrite(13, HIGH); // set the LED on
  delay(1000);           // wait for a second
  digitalWrite(13, LOW); // set the LED off
  delay(1000);          // wait for a second
}
```

At the bottom of the IDE, the status bar shows "1" on the left and "Arduino Uno on /dev/tty.usbmodemfd131" on the right.

IO Pins

Two states (binary signal) vs. multiple states (continuous signal)

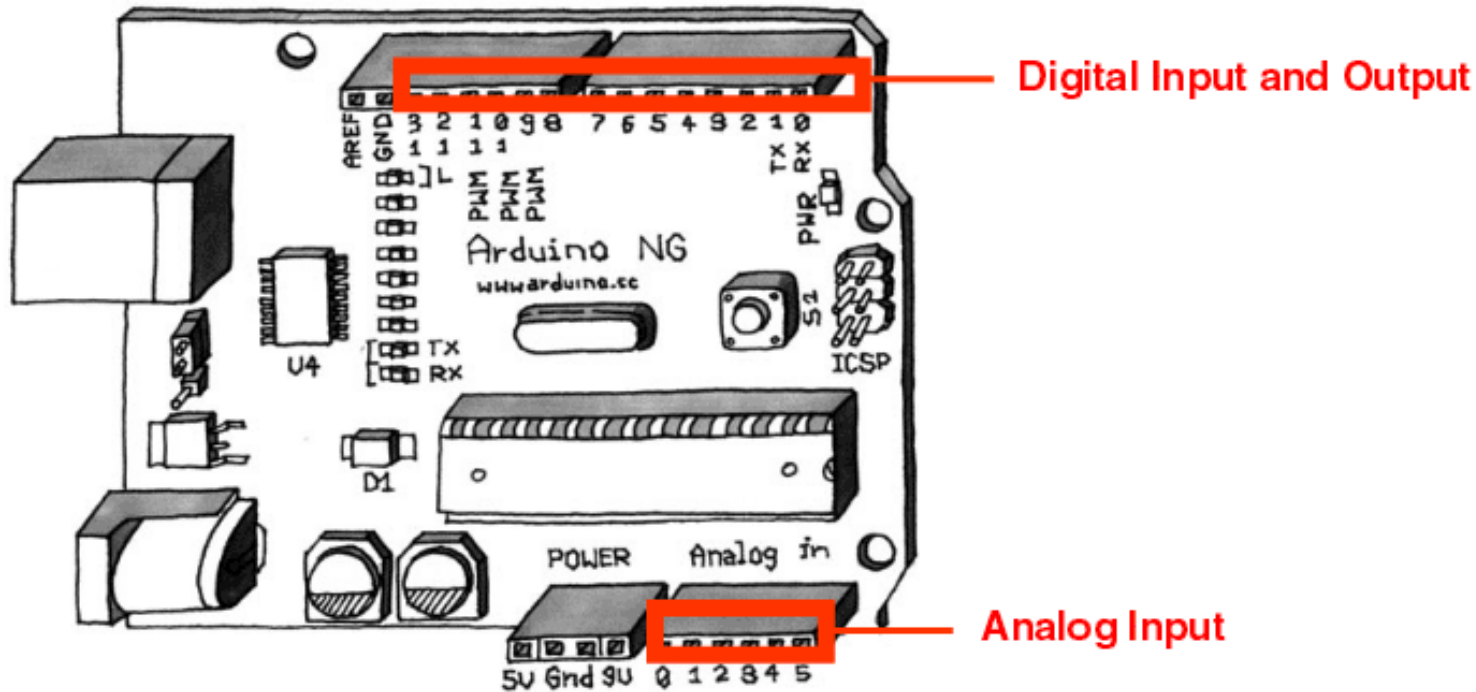
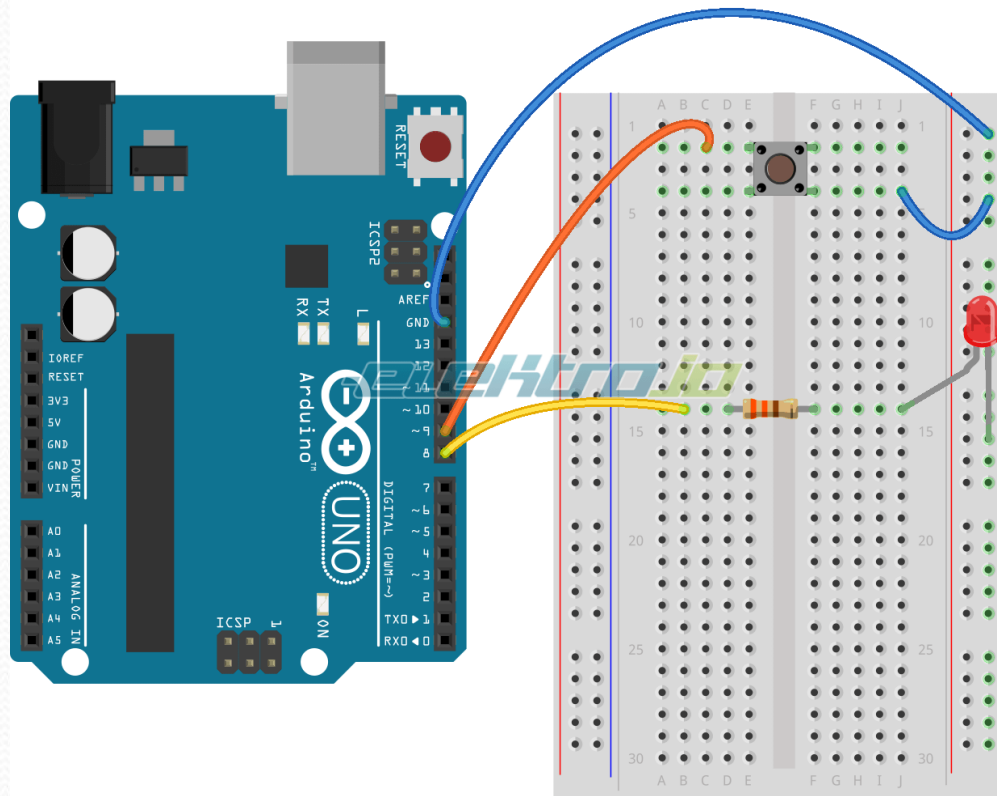


Image from *Theory and Practice of Tangible User Interfaces* at UC Berkley



In-class Exercise 1: Digital IO



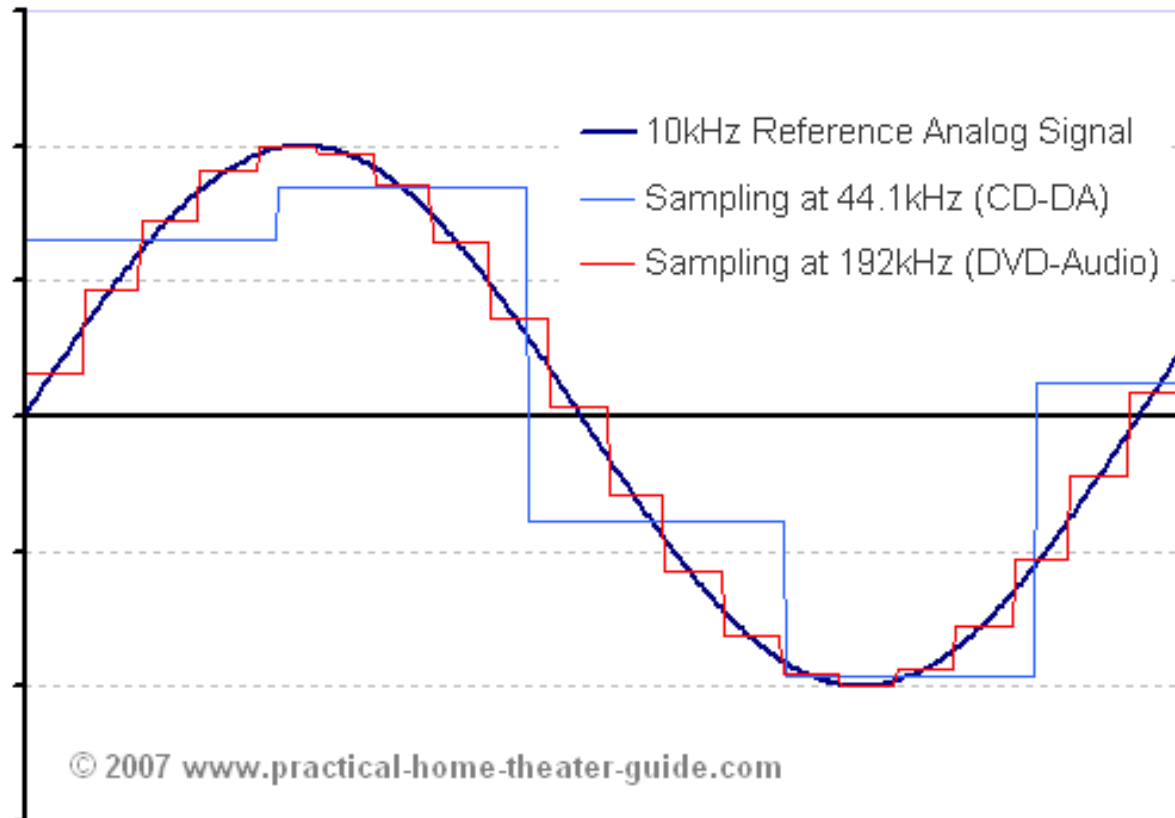
Made with  Fritzing.org

- Use a push-button to turn ON/Off LED

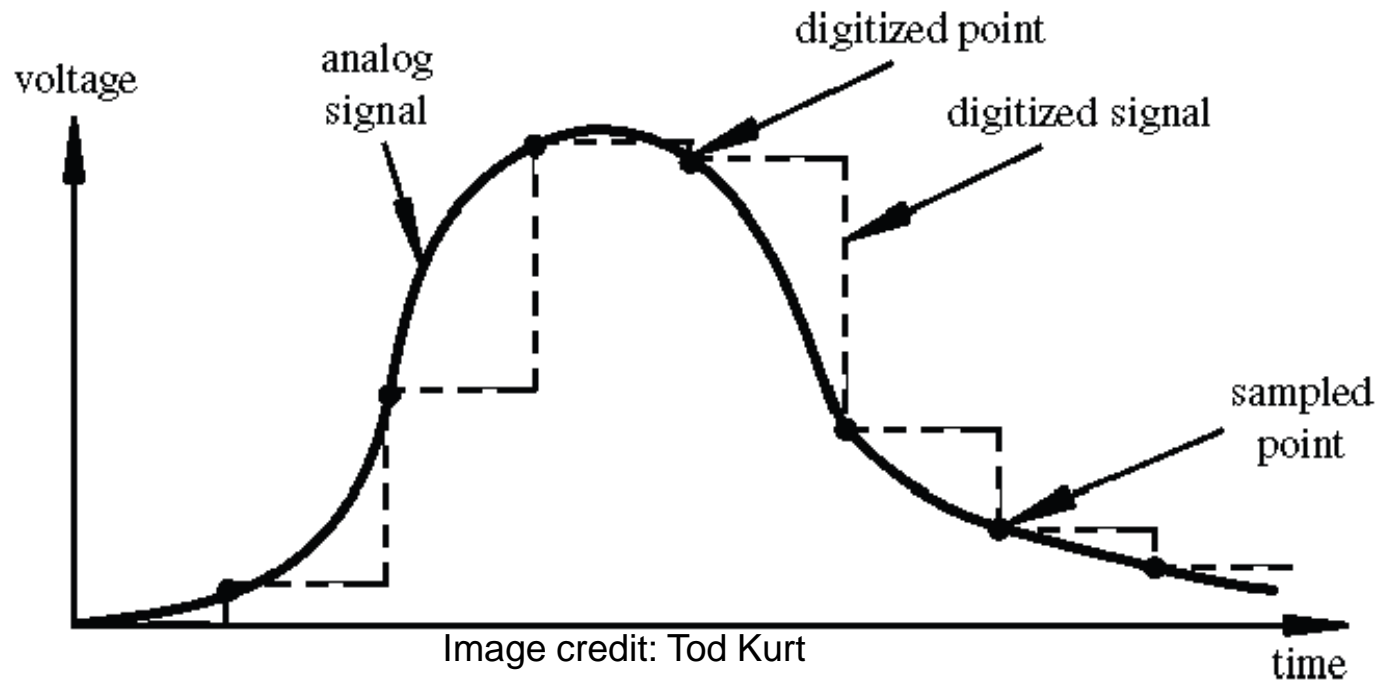


Topic 3: Analog Input

- Think about music stored on a CD---an analog signal captured on digital media
 - Sample rate
 - Word length

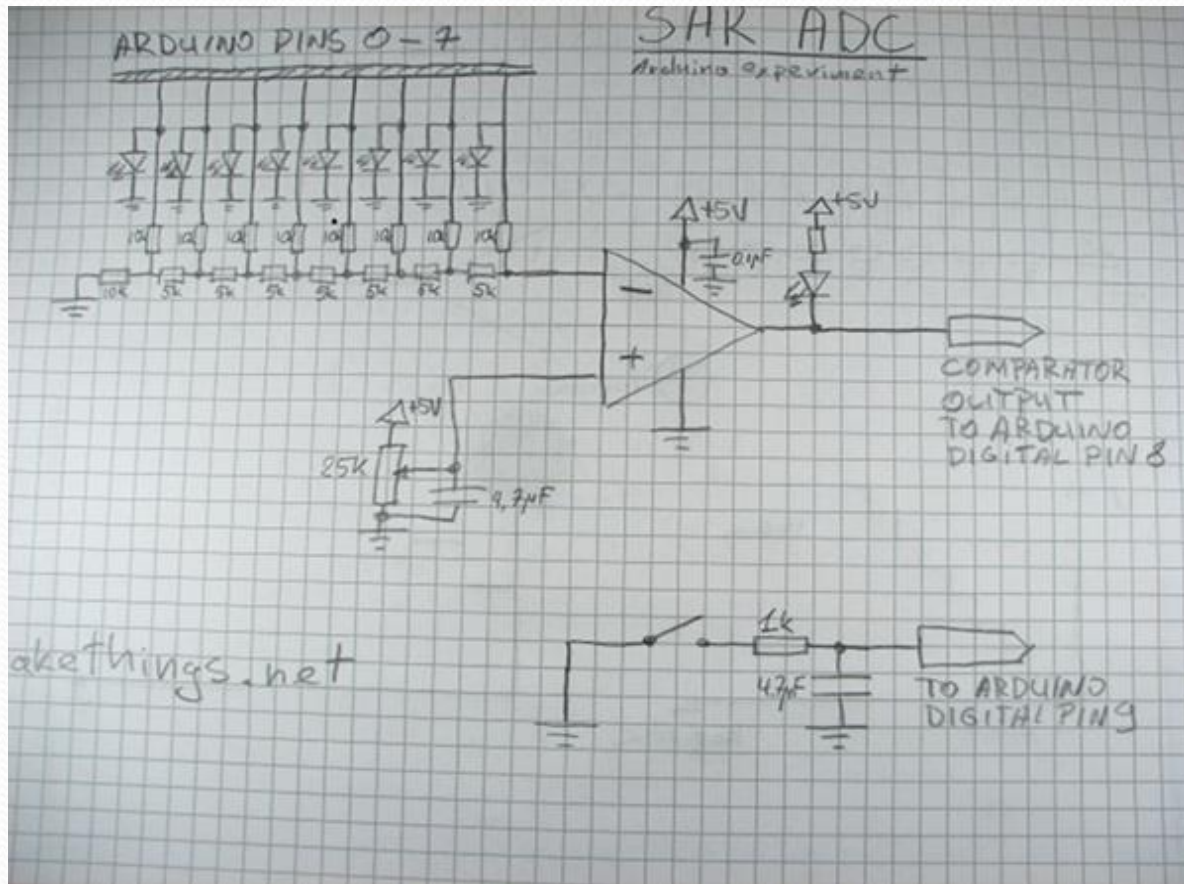


Arduino Analog Input



- *Resolution*: the number of different voltage levels (i.e., *states*) used to discretize an input signal
- Resolution values range from 256 states (8 bits) to 4,294,967,296 states (32 bits)
- The Arduino uses 1024 states (10 bits)
- Smallest measurable voltage change is $5V/1024$ or 4.8 mV
- Maximum sample rate is 10,000 times a second

How does ADC work?



- How does ADC work
- Excel Demonstration



Topic 3: Analog Output

- Can a digital device produce analog output?

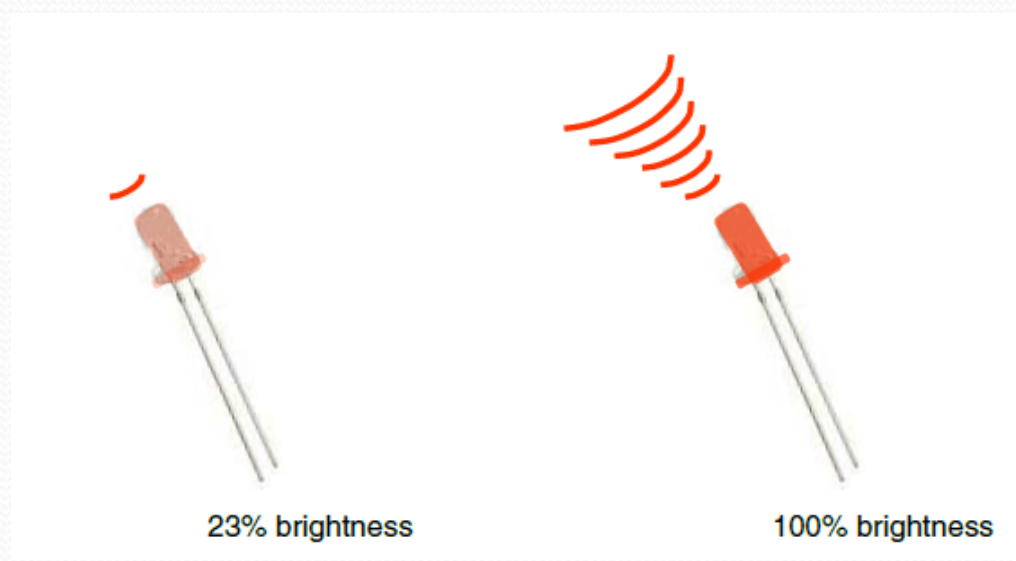


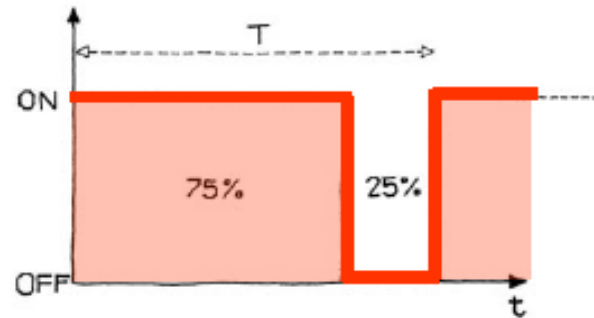
Image from *Theory and Practice of Tangible User Interfaces* at UC Berkeley

- Analog output can be simulated using pulse width modulation (PWM)

Pulse Width Modulation

Can use digital pins to directly supply say 2.5V, but can pulse the output on and off really fast to produce the same effect

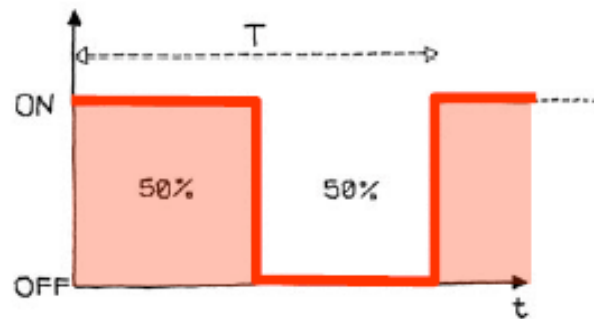
The on-off pulsing happens so quickly, the connected output device sees the result as a reduction in the voltage



75%



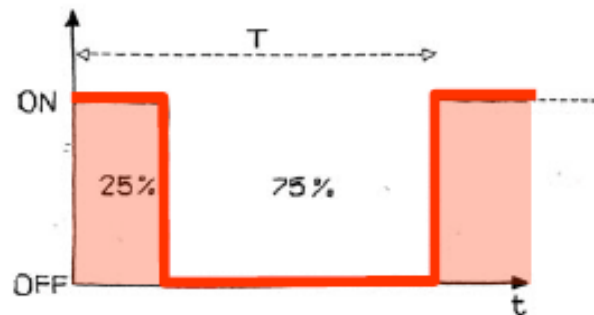
75% brightness



50%



50% brightness



25%



25% brightness

Image from  *Theory and Practice of Tangible User Interfaces* at UC Berkley

PWM Duty Cycle

$$\text{output voltage} = (\text{on_time} / \text{cycle_time}) * 5V$$

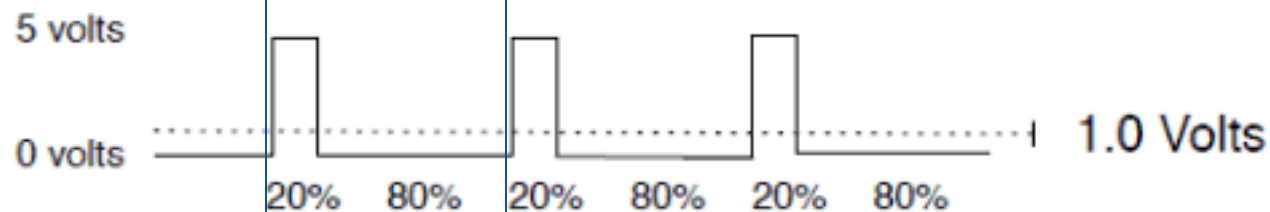
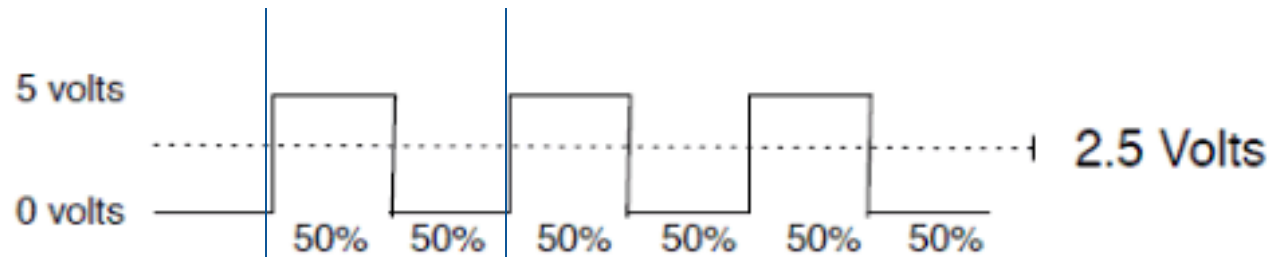
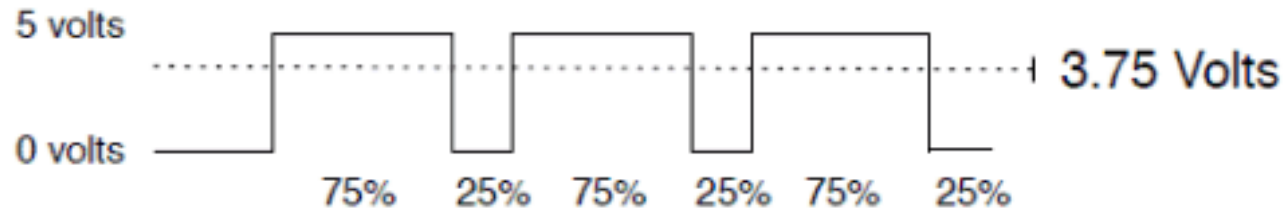


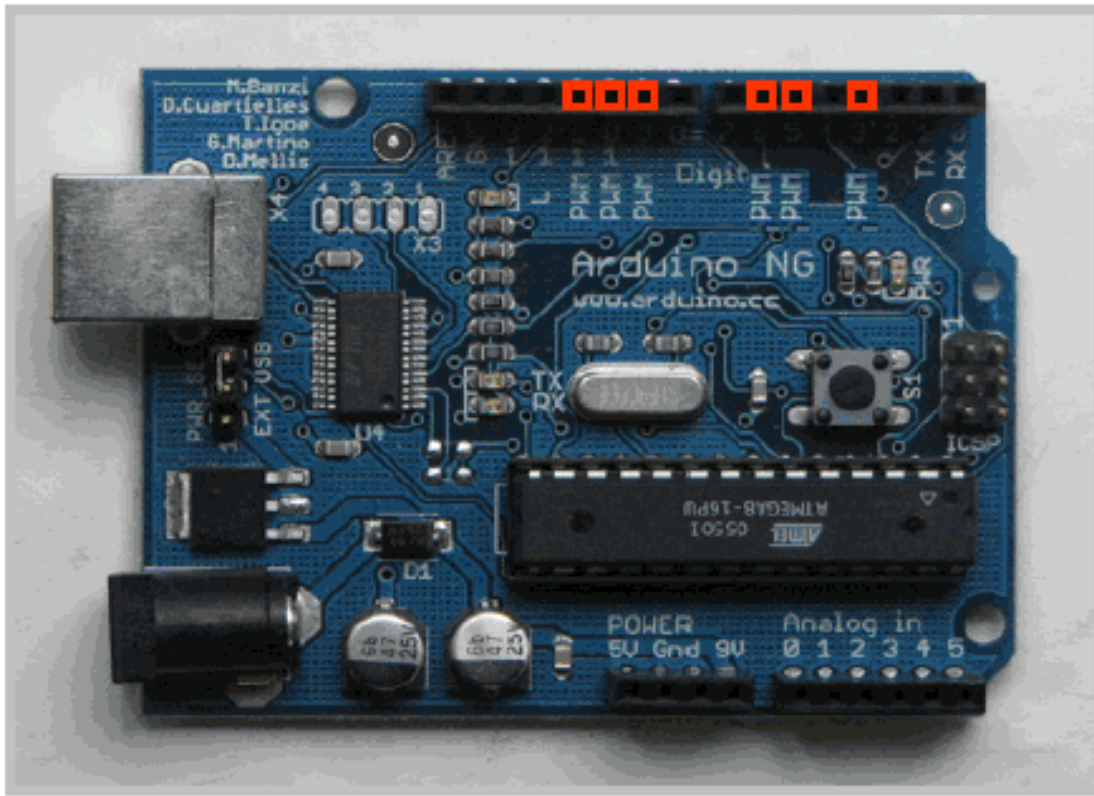
Image credit: Tod Kurt



Fixed cycle length; constant number of cycles/sec

PMW Pins

Your Arduino board has built in PWM circuits, on pins 3, 5, 6, 9, 10, and 11



Command:
`analogWrite(pin,value)`

value is duty cycle
between 0 and 255

Examples:

`analogWrite(9, 128)`
for a 50% duty cycle

`analogWrite(11, 64)`
for a 25% duty cycle

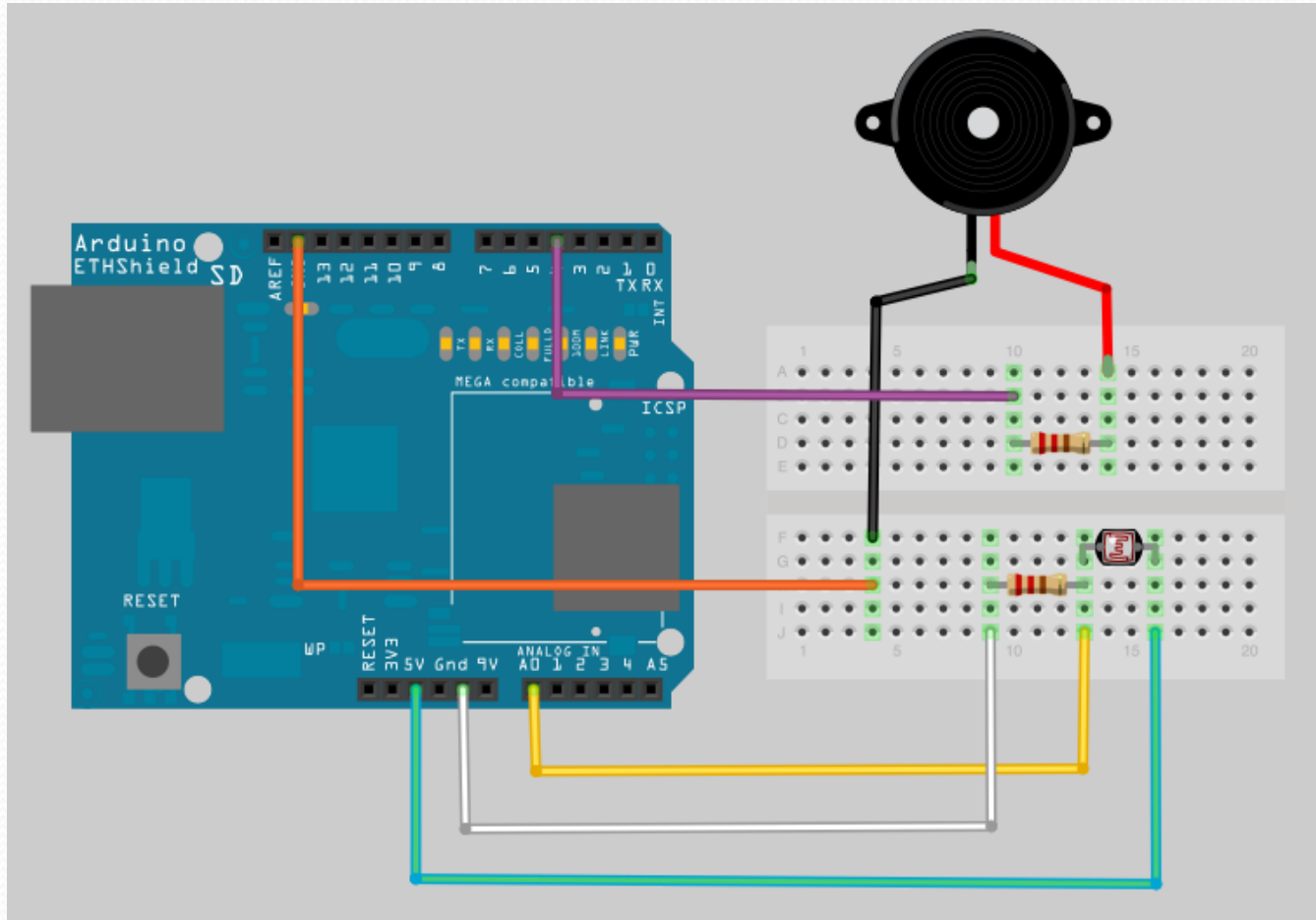
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In-class Exercise 2: Analog I/O

Part 1:



A light theremin

In-class Exercise 2: Analog IO

Part 2: Add an LED

- Add a 330 ohm resistor and an LED to pin 9
- Using the `analogWrite()` command, set the intensity of the LED as a function of the value of `prReading`



Topic 4: Serial Communication

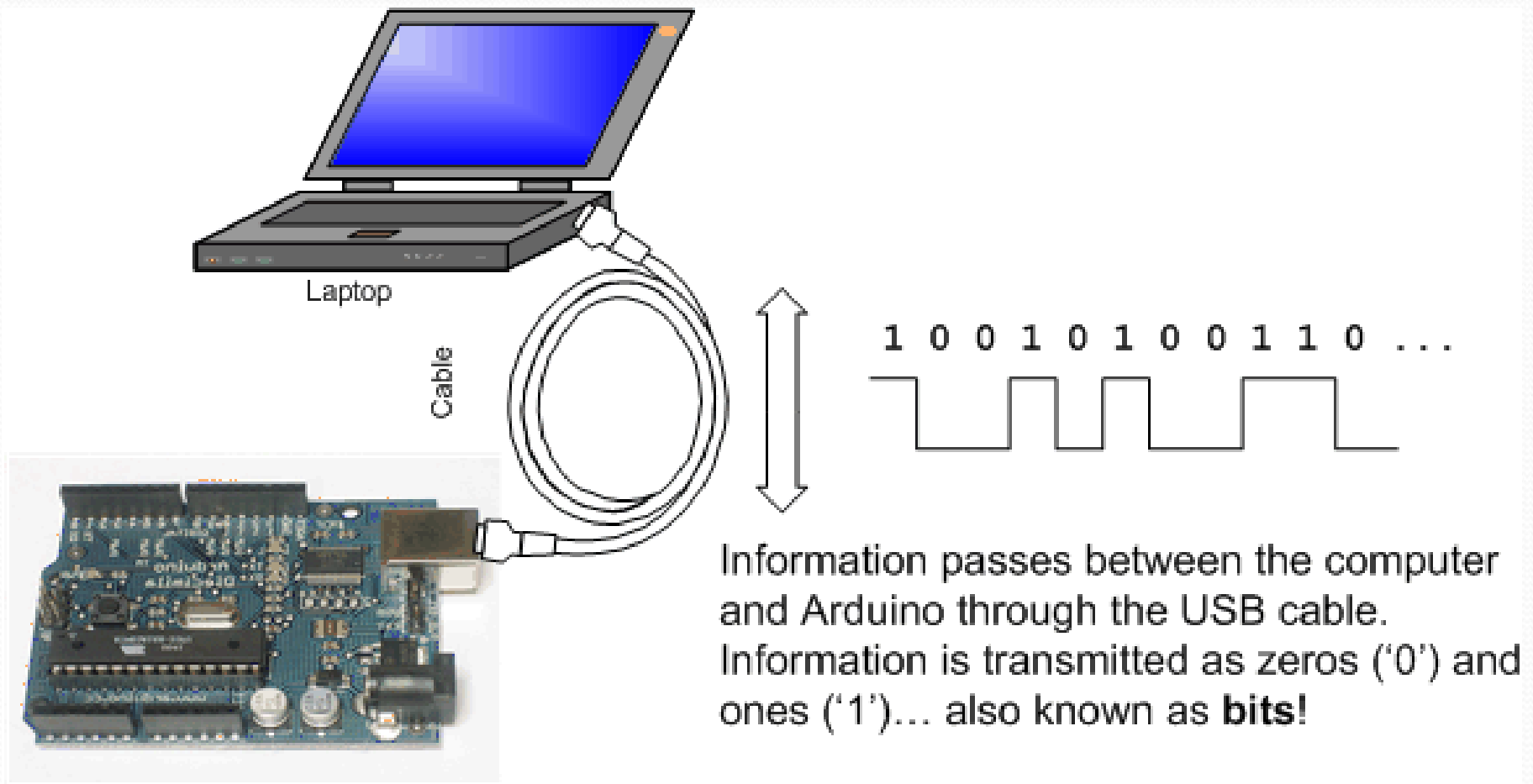


Image from <http://www.codyvada.net/learn/arduino/lesson4.htm>

Serial Communications

- “Serial” because data is broken down into bits, each sent one after the other down a single wire.

- The single ASCII character ‘B’ is sent as:

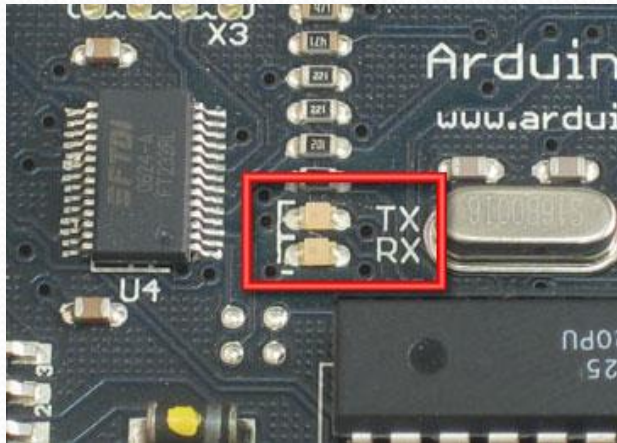
‘B’ = 0 1 0 0 0 0 1 0

= L H L L L L H L



- Toggle a pin to send data, just like blinking an LED
- You could implement sending serial data with `digitalWrite()` and `delay()`
- A single data wire needed to send data. One other to receive.

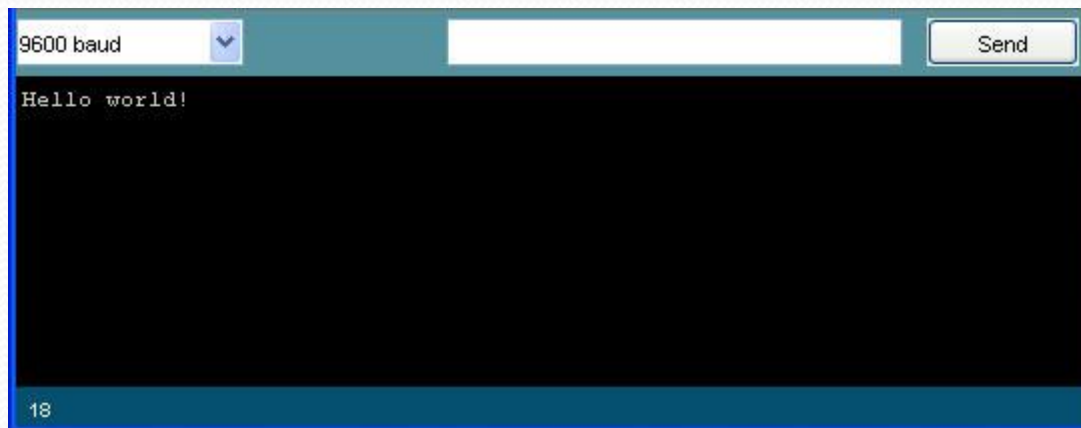
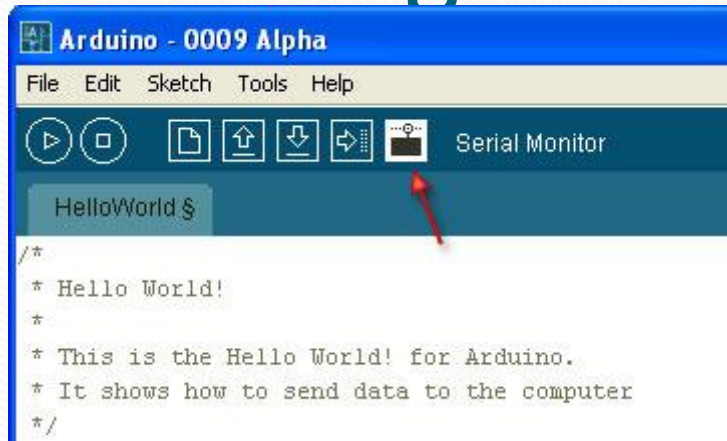
Serial Communication



- *Compiling* turns your program into binary data (ones and zeros)
- *Uploading* sends the bits through USB cable to the Arduino
- The two LEDs near the USB connector blink when data is transmitted
 - RX blinks when the Arduino is receiving data
 - TX blinks when the Arduino is transmitting data



Open the Serial Monitor and Upload the Program



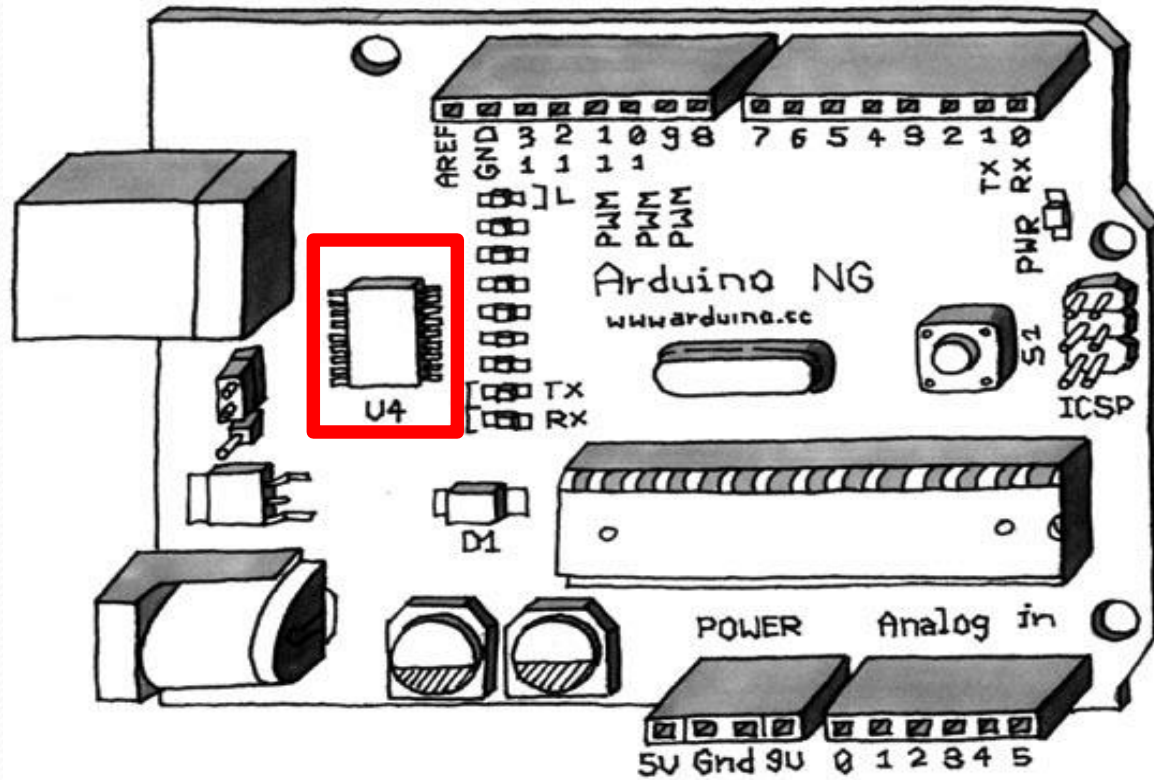
Some Commands

- `Serial.begin()`
 - e.g., `Serial.begin(9600)`
- `Serial.print()` or `Serial.println()`
 - e.g., `Serial.print(value)`
- `Serial.read()`
- `Serial.available()`
- `Serial.write()`
- `Serial.parseInt()`

- Example Program



Serial-to-USB chip---what does it do?



The LilyPad and Fio Arduino require an external USB to TTY connector, such as an FTDI “cable”.
In the Arduino Leonardo a single microcontroller runs the Arduino programs and handles the USB connection.



Image from *Theory and Practice of Tangible User Interfaces* at UC Berkley

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BIG 6 CONCEPTS



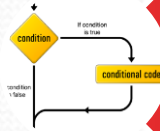
digitalWrite()



analogWrite()



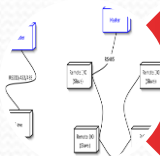
digitalRead()



if() statements / Boolean



analogRead()



Serial communication



Let's get to coding...

- Project #1 – Blink
 - “Hello World” of Physical Computing
- *Pseudo-code – how should this work?*



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...`
- `*/`




```
BareMinimum | Arduino 1.0.5
File Edit Sketch Tools Help
BareMinimum $
// Name of sketch
// Brief Description
// Date:
//

void setup()
{
  // put your setup code here, to run once:
}

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

comments



Three commands to know...

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

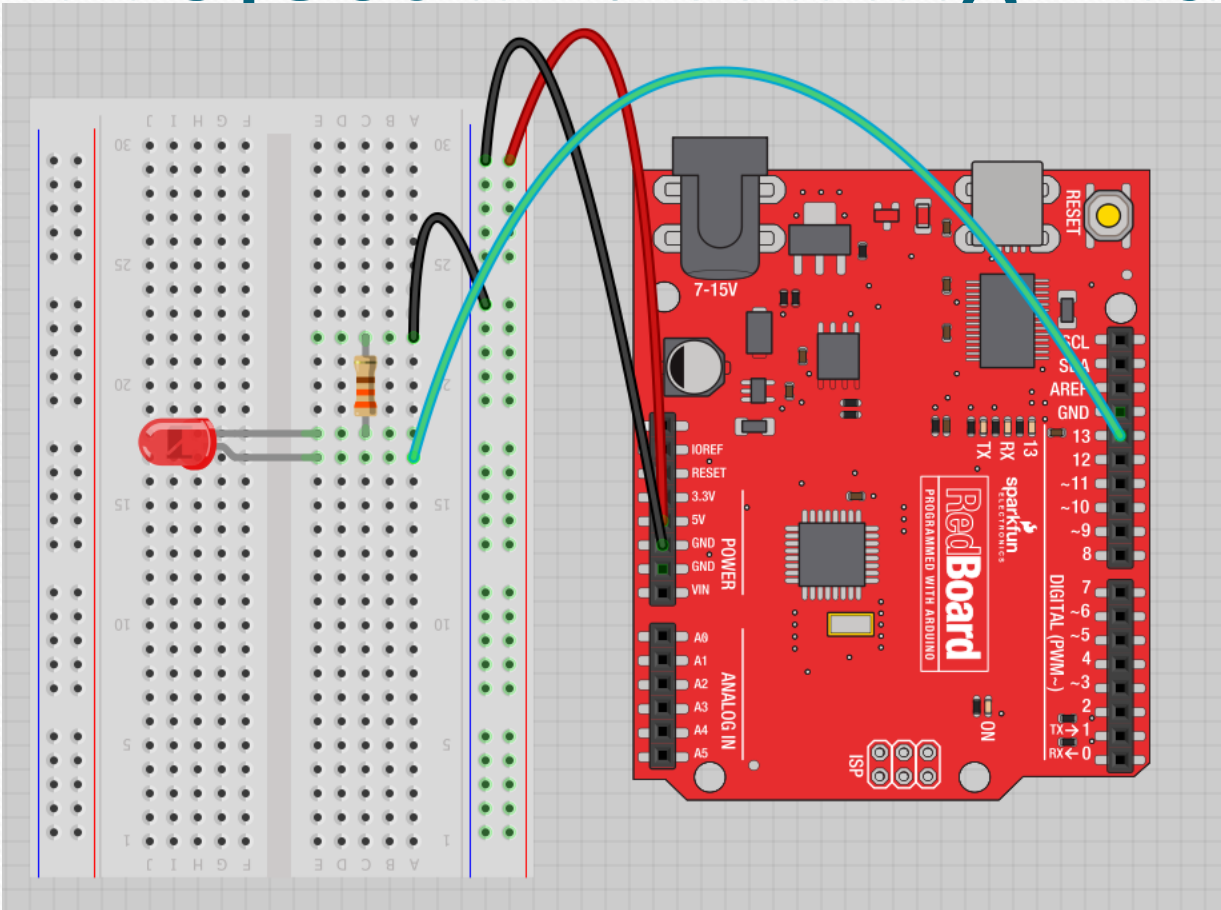
- `digitalWrite (pin, HIGH/LOW) ;`
- ex: `digitalWrite (13, HIGH) ;`

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

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



Project #1: Wiring Diagram



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

Image created in Fritzing



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???
 -



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?



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*

Programming Concepts: Variable Types

- **Variable Types:**



8 bits

byte
char



16 bits

int
unsigned int



32 bits

long
unsigned long
float



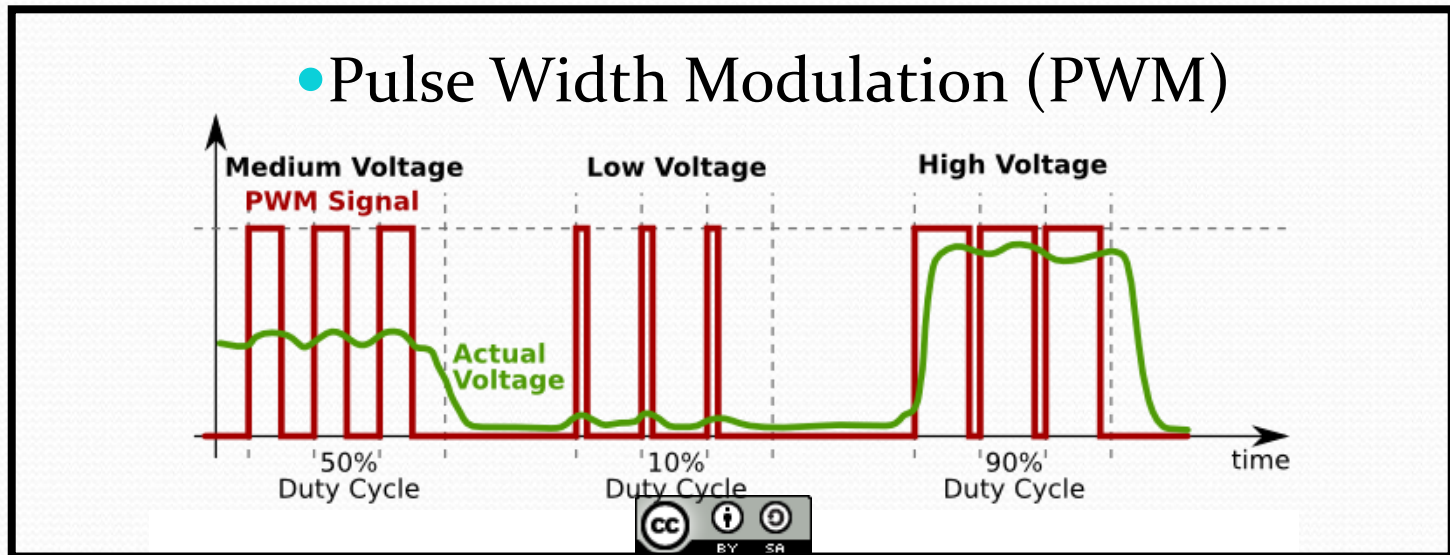
Fading in and Fading Out (Analog or Digital?)

- 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)



Concepts: Analog vs. Digital

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



Project #2 – Fading

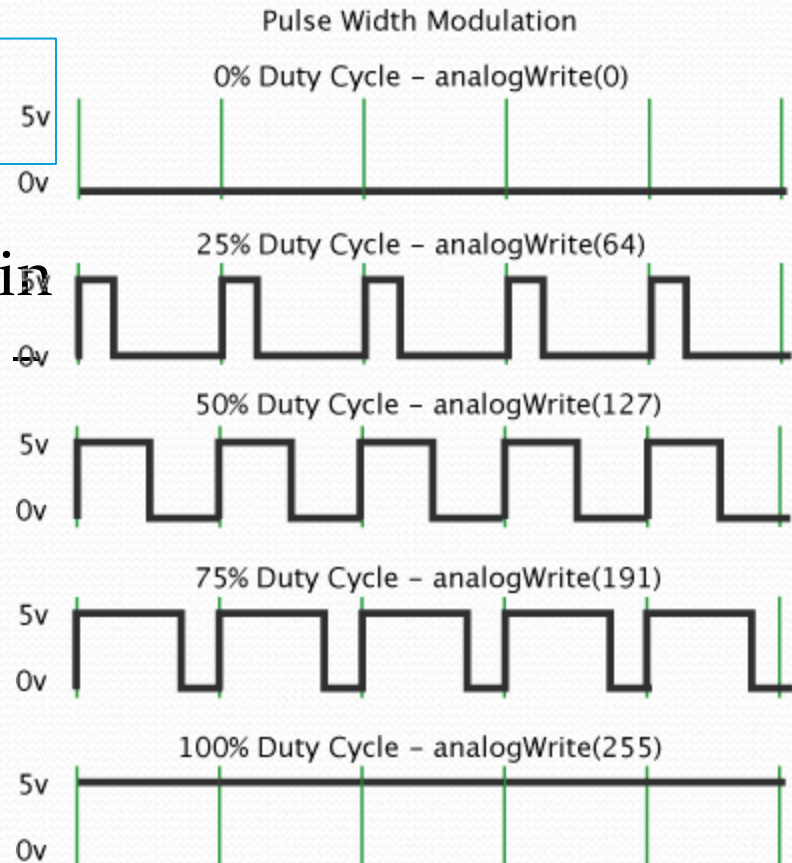
Introducing a new command...

- `analogWrite(pin, val);`

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

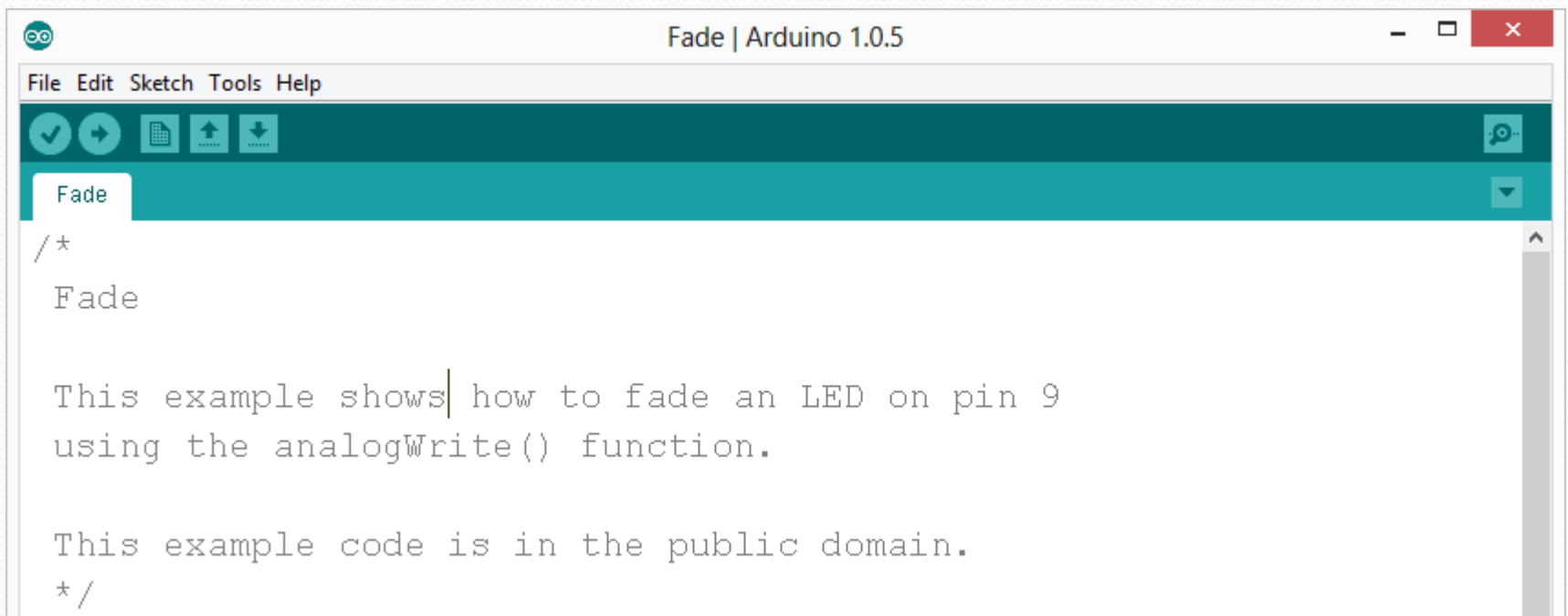
- `val` – 8 bit value (0 – 255).

- $0 \Rightarrow 0V \quad | \quad 255 \Rightarrow 5V$



Move one of your LED pins over to Pin 9

- In Arduino, open up:
- File → Examples → 01.Basics → 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.  
*/
```



Fade - Code Review



```
/*  
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
```




```
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);
}
```

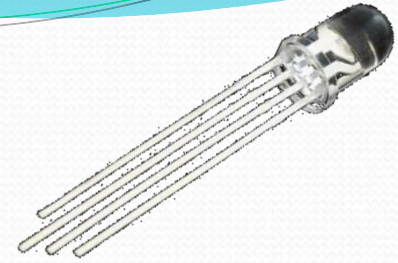
Project# 2 -- Fading

- **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.

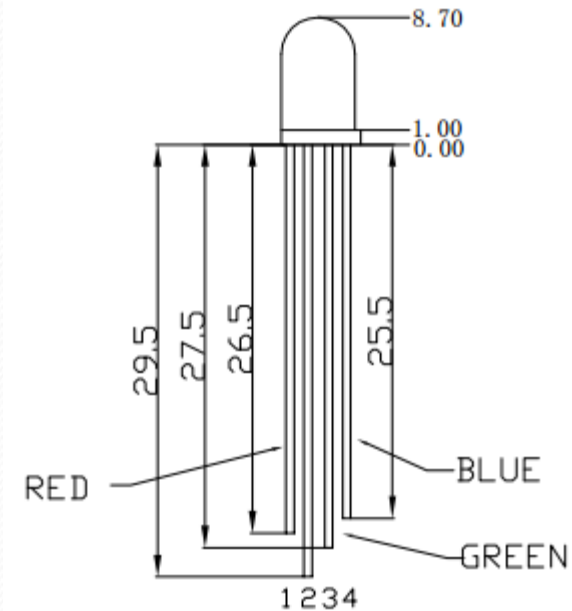




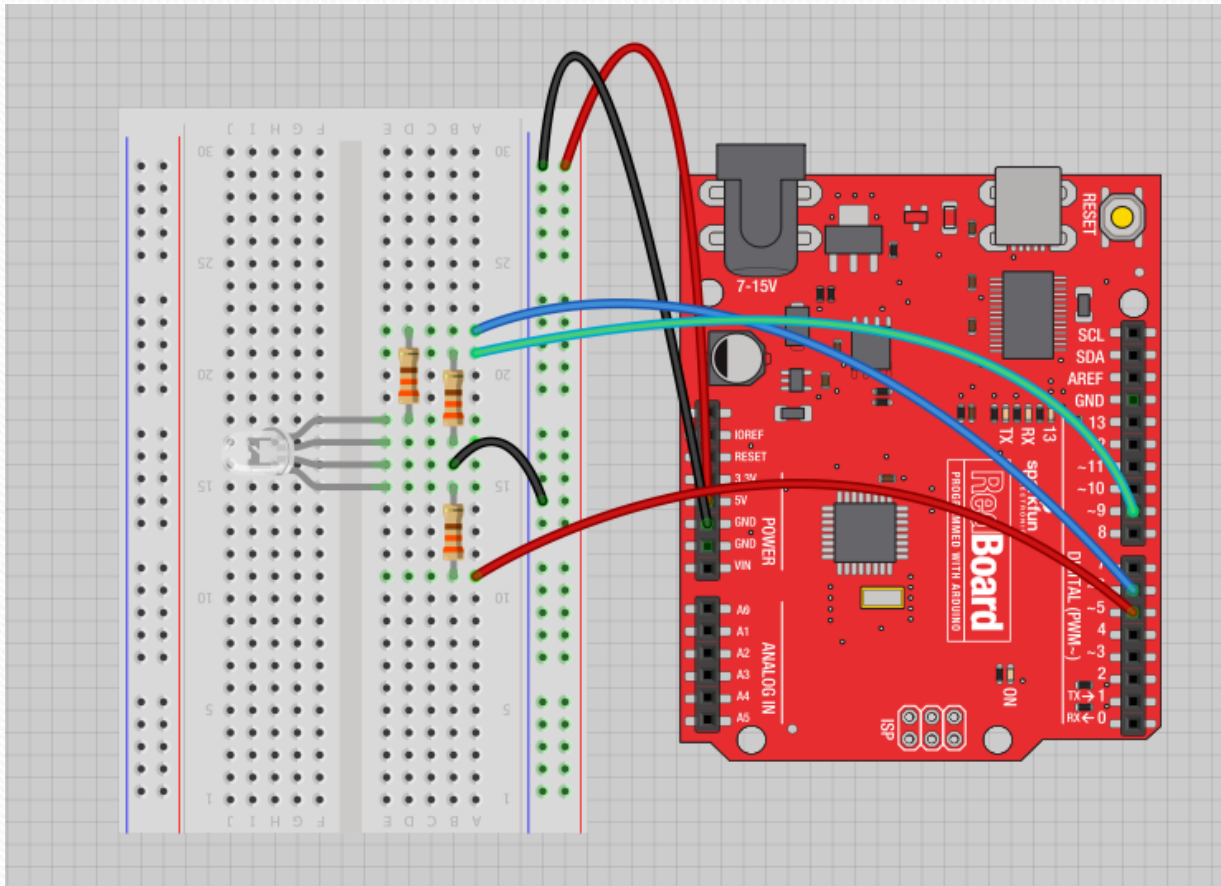
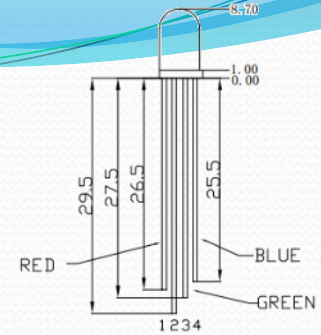
Color Mixing Tri-color LED



- In the SIK, this is a standard – Common Cathode LED
- This means the negative side of the LED is all tied to Ground.



Project 3 – RGB LED



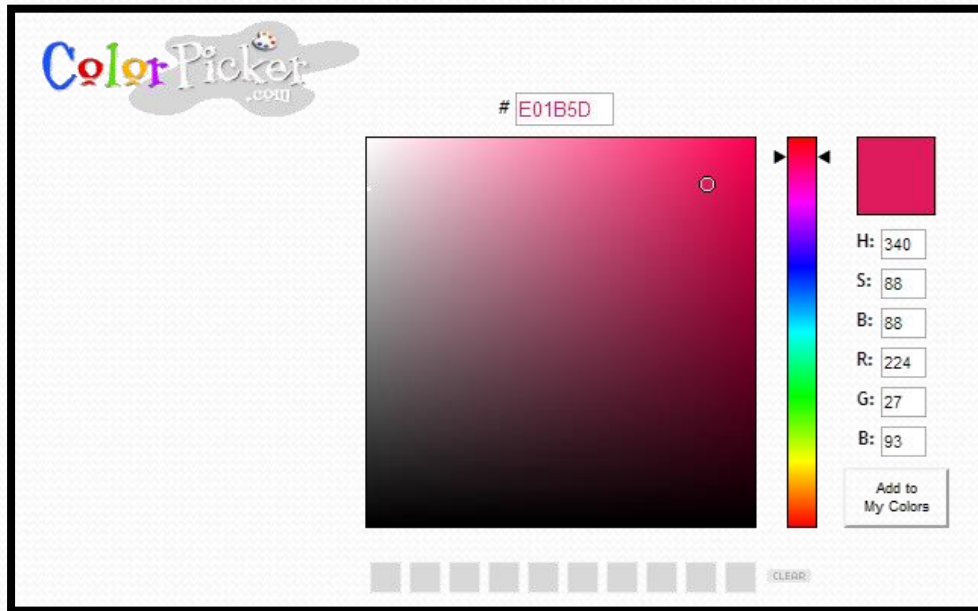
• Note: The longest leg of the RGB LED is the Common Cathode. This goes to GND.

Use pins 5, 6, & 9



How many unique colors can you create?

$$\begin{aligned} \# \text{ of unique colors} &= 256 \cdot 256 \cdot 256 \\ &= 16,777,216 \text{ colors!} \end{aligned}$$



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.



RGB LED Color Mixing

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

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

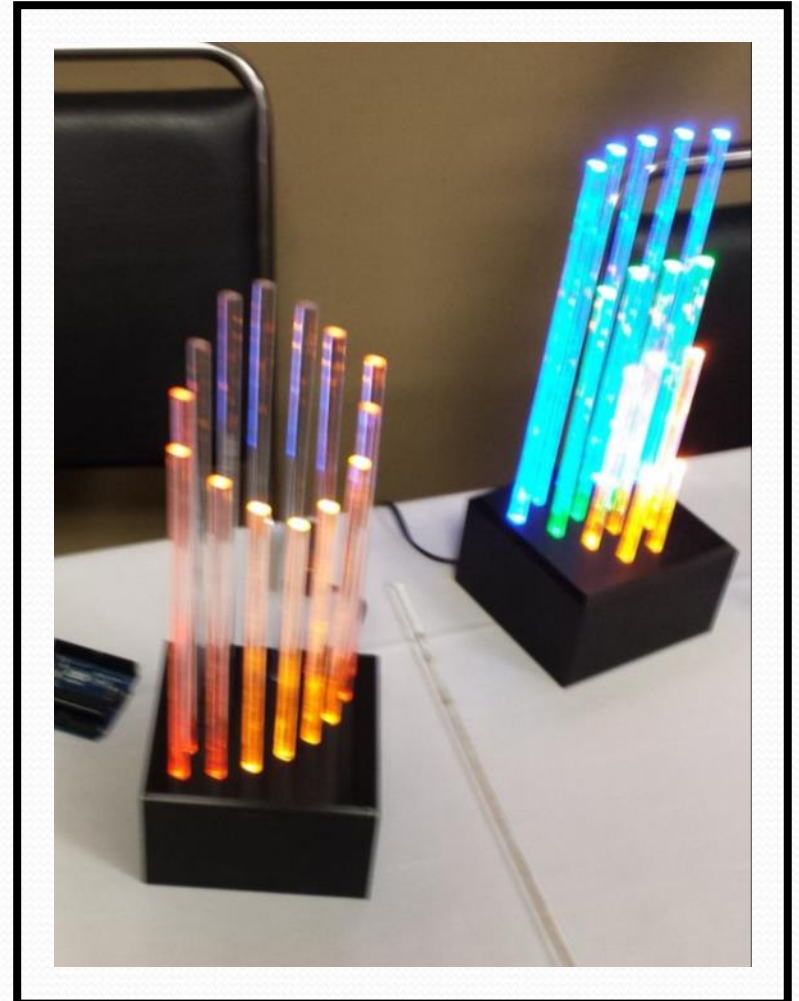
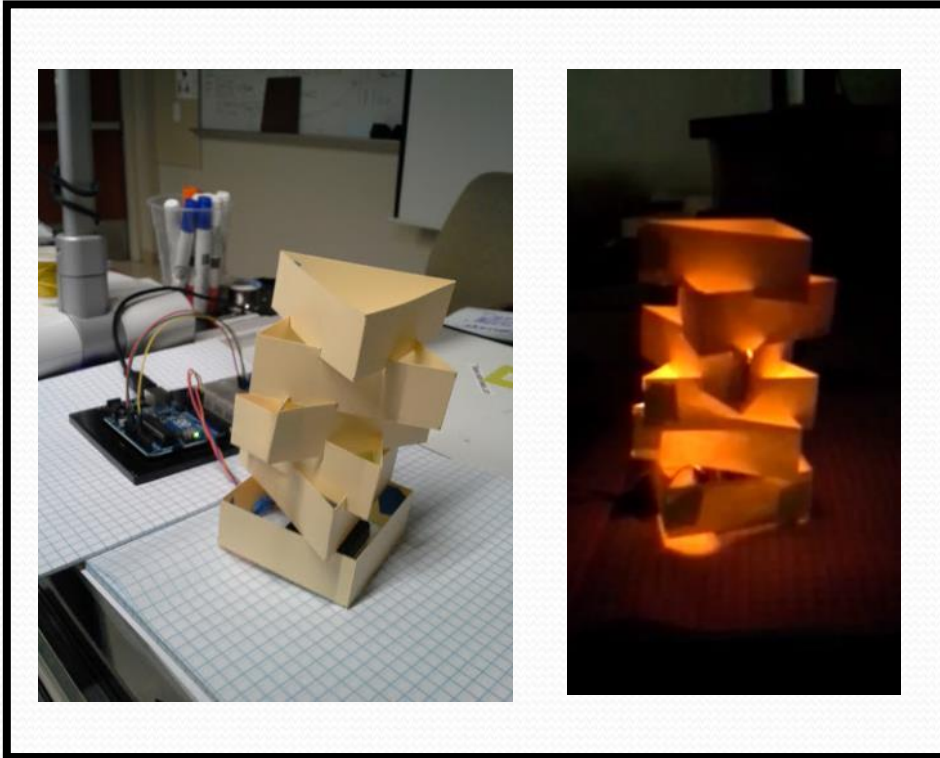


RGB LED Color Mixing

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



Project: Mood Lamp / Light Sculpture



Napkin Schematics

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

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.



Napkin Schematics

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

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.

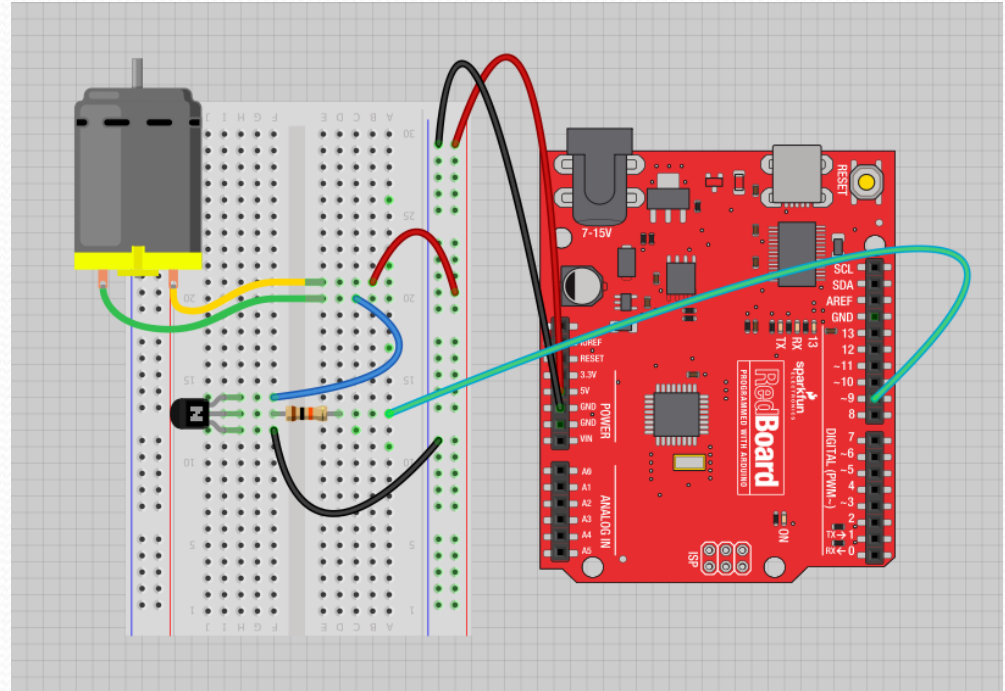
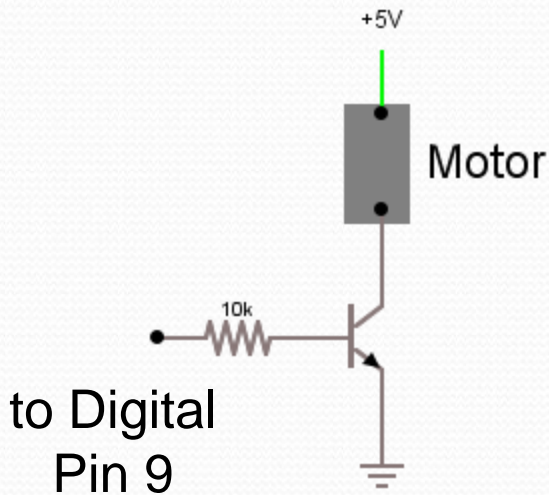
The **diamond** is used to represent a question or actions with more than one possible outcome. For example, once your video game has loaded there is often a menu with a bunch of options. This would be written in a Logic Flow Chart as a diamond with something like the words "Start Up Menu" written inside 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.



Driving Motors or other High Current Loads

- **NPN Transistor (Common Emitter “Amplifier” Circuit)**



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



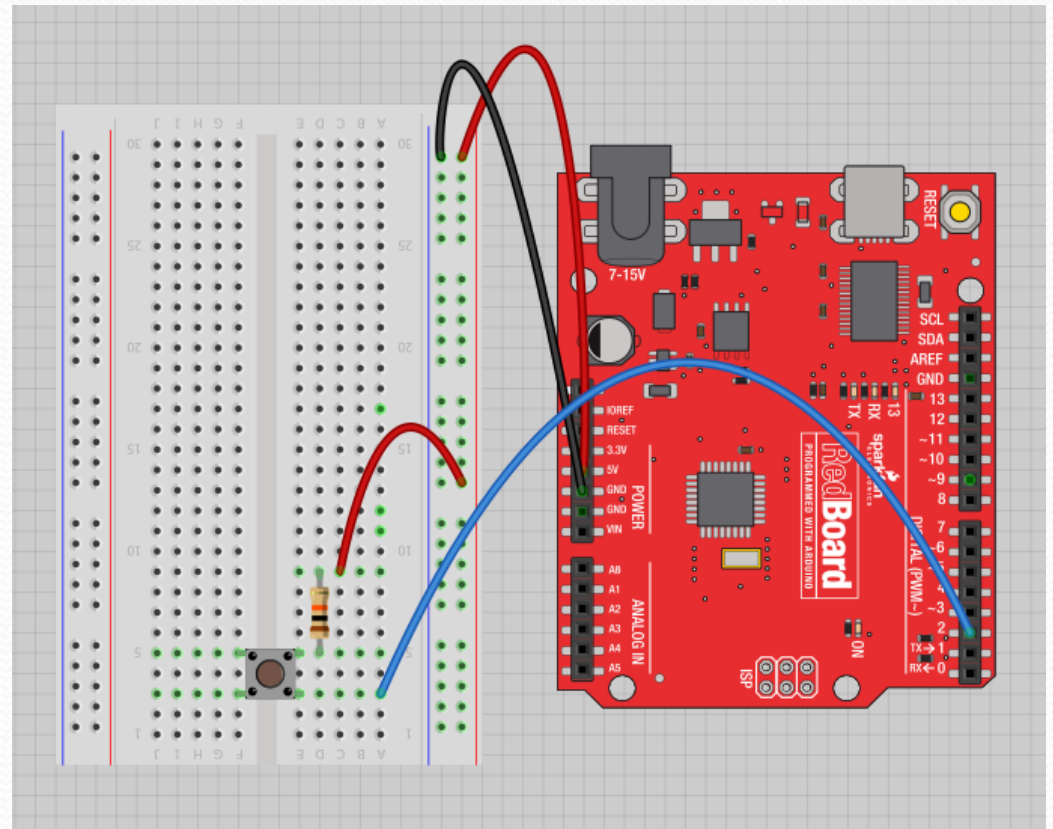
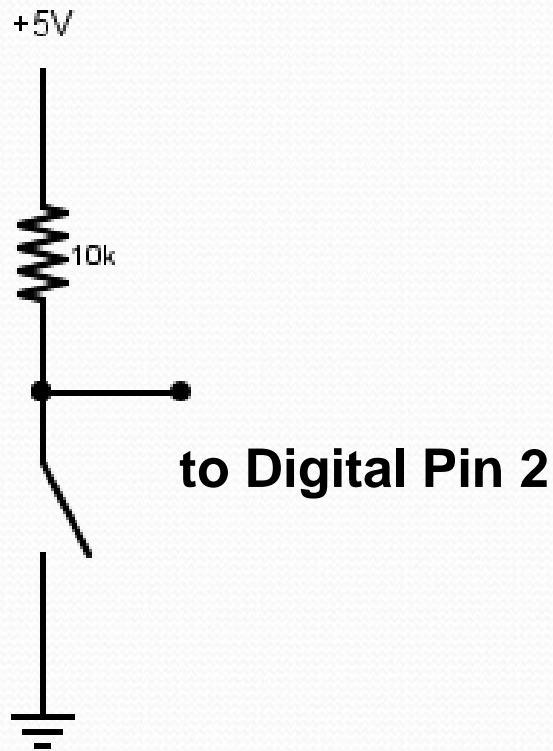
Project #4 – Digital Input

- In Arduino, open up:
- File → Examples → 02.Digital → Button



Digital Sensors (a.k.a. Switches)

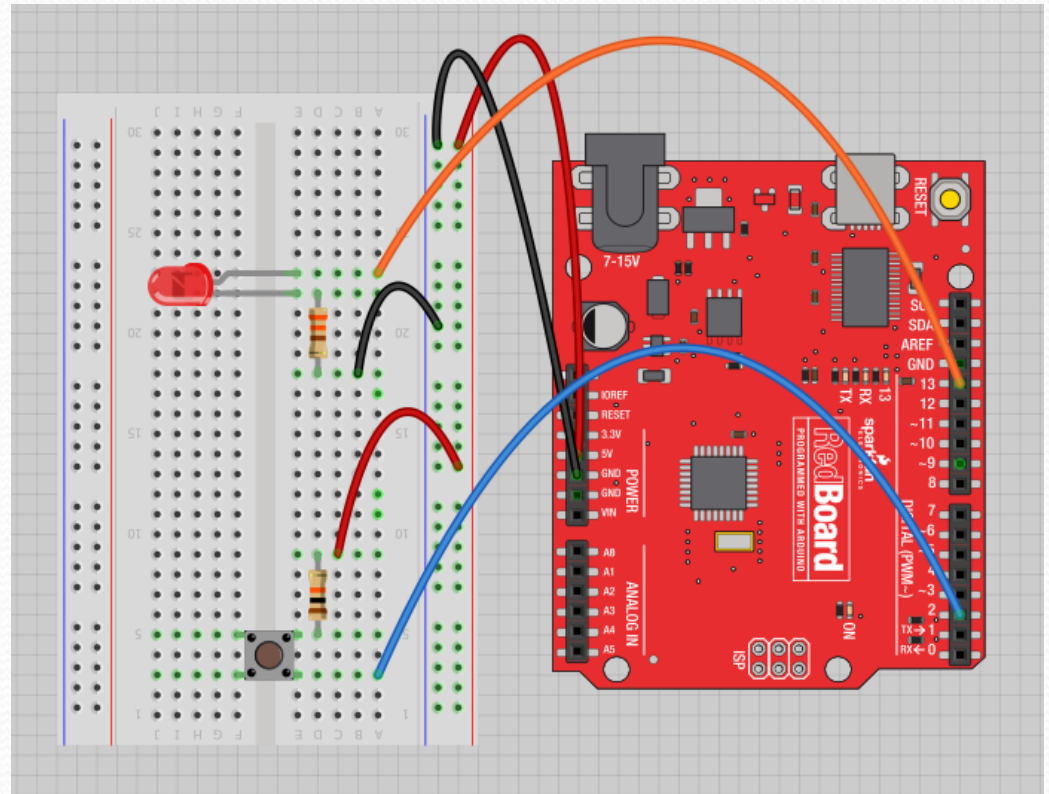
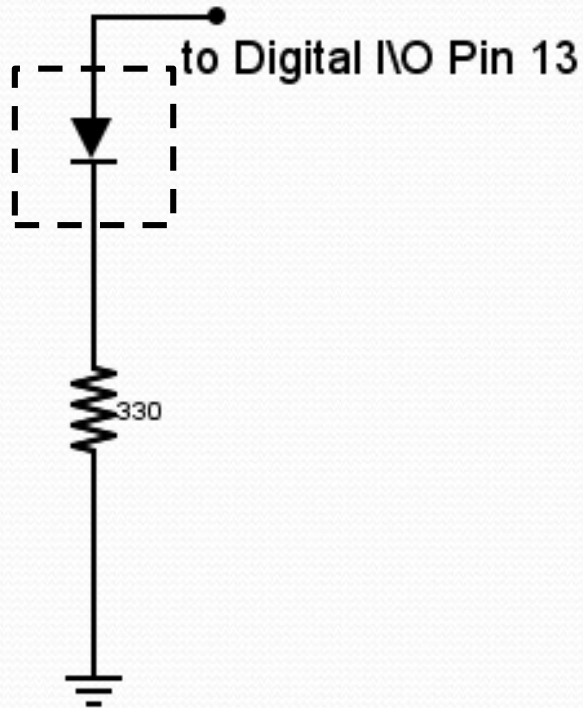
Pull-up Resistor (circuit)



Digital Sensors (a.k.a. Switches)

Add an indicator LED to Pin 13

This is just like our
1st circuit!



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)



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



We set it equal to the function `digitalRead(pushButton)`

We declare a variable as an integer.

The function `digitalRead()` will return the value 1 or 0, depending on whether the button is being pressed or not being pressed.

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

We name it `buttonState`

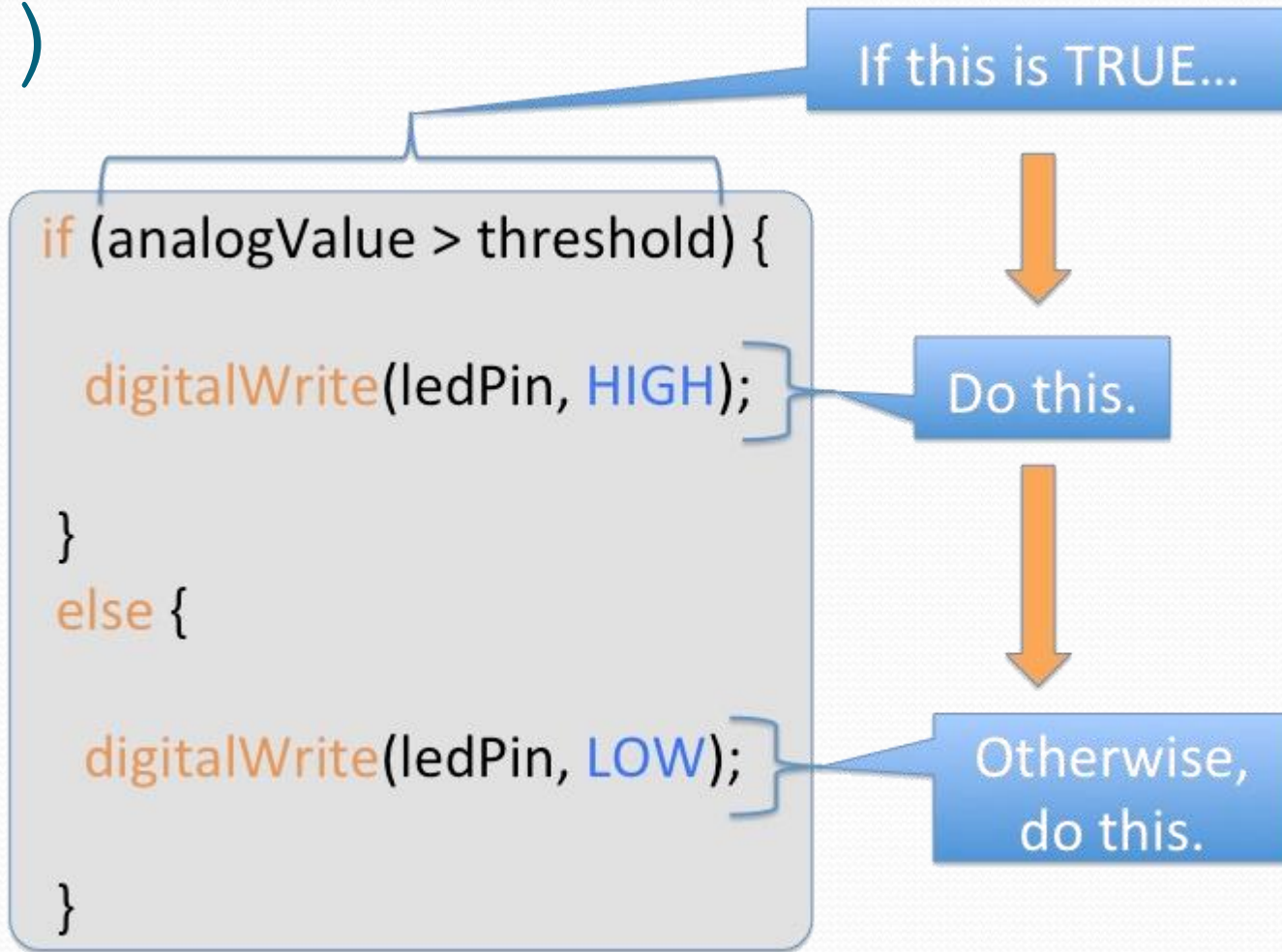
Recall that the `pushButton` variable stores the number 2

The value 1 or 0 will be saved in the variable `buttonState`.



Programming: Conditional Statements

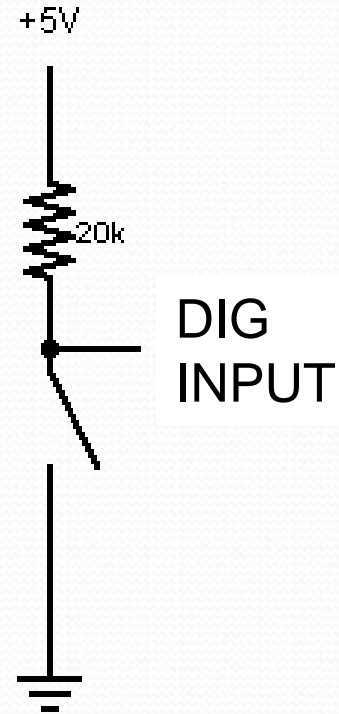
`if ()`



Statements

if ()

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



Boolean Operators

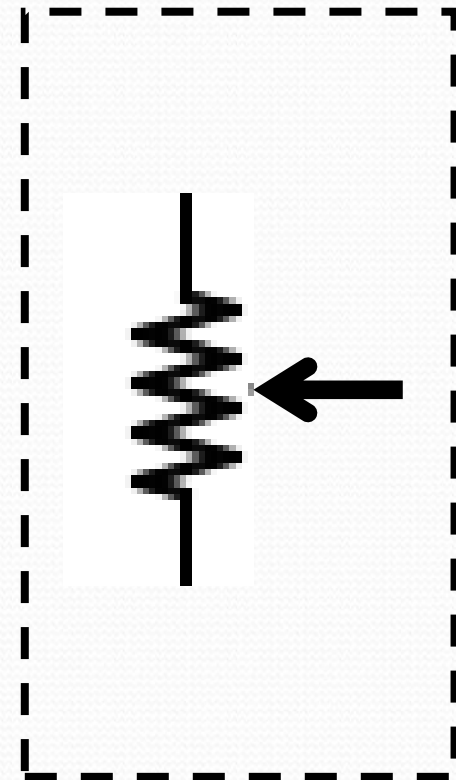
<Boolean>	Description
() == ()	is equal?
() != ()	is not equal?
() > ()	greater than
() >= ()	greater than or equal
() < ()	less than
() <= ()	less than or equal



Trimpot (Potentiometer) Variable Resistor



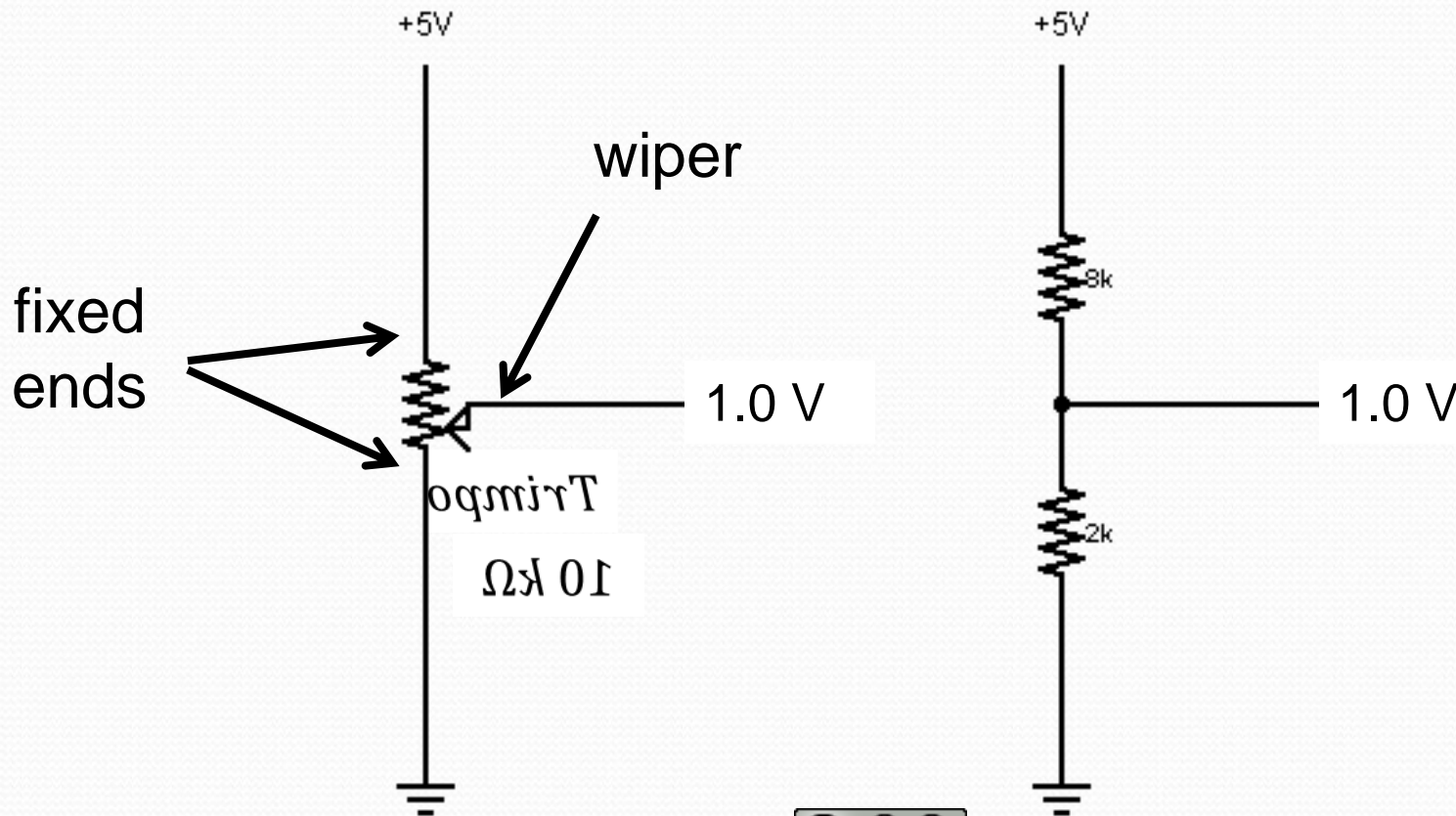
fixed end
wiper
fixed end



Analog Sensors

3 Pin Potentiometer = var. resistor (circuit)

a.k.a. Voltage Divider Circuit



Ohms Law... (just the basics)

Actually, this is the “voltage divider”



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

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

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



analogRead()

- Arduino uses a 10-bit A/D Converter:
- this means that you get input values from 0 to 1023
 - $0\text{ V} \rightarrow 0$
 - $5\text{ V} \rightarrow 1023$
- Ex:
- `int sensorValue = analogRead(A0);`

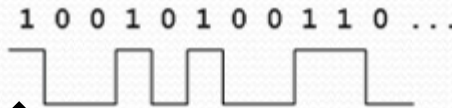


Using Serial Communication

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.



Serial Monitor & analogRead()

```
sketch_apr02a | Arduino 1.0.3
File Edit Sketch Tools Help
sketch_apr02a $
// analogRead() & Serial.print()
//
//
int sensorValue = 0;
int sensorPin = A0;

void setup()
{
  Serial.begin(9600);
  pinMode(A0, INPUT);
}

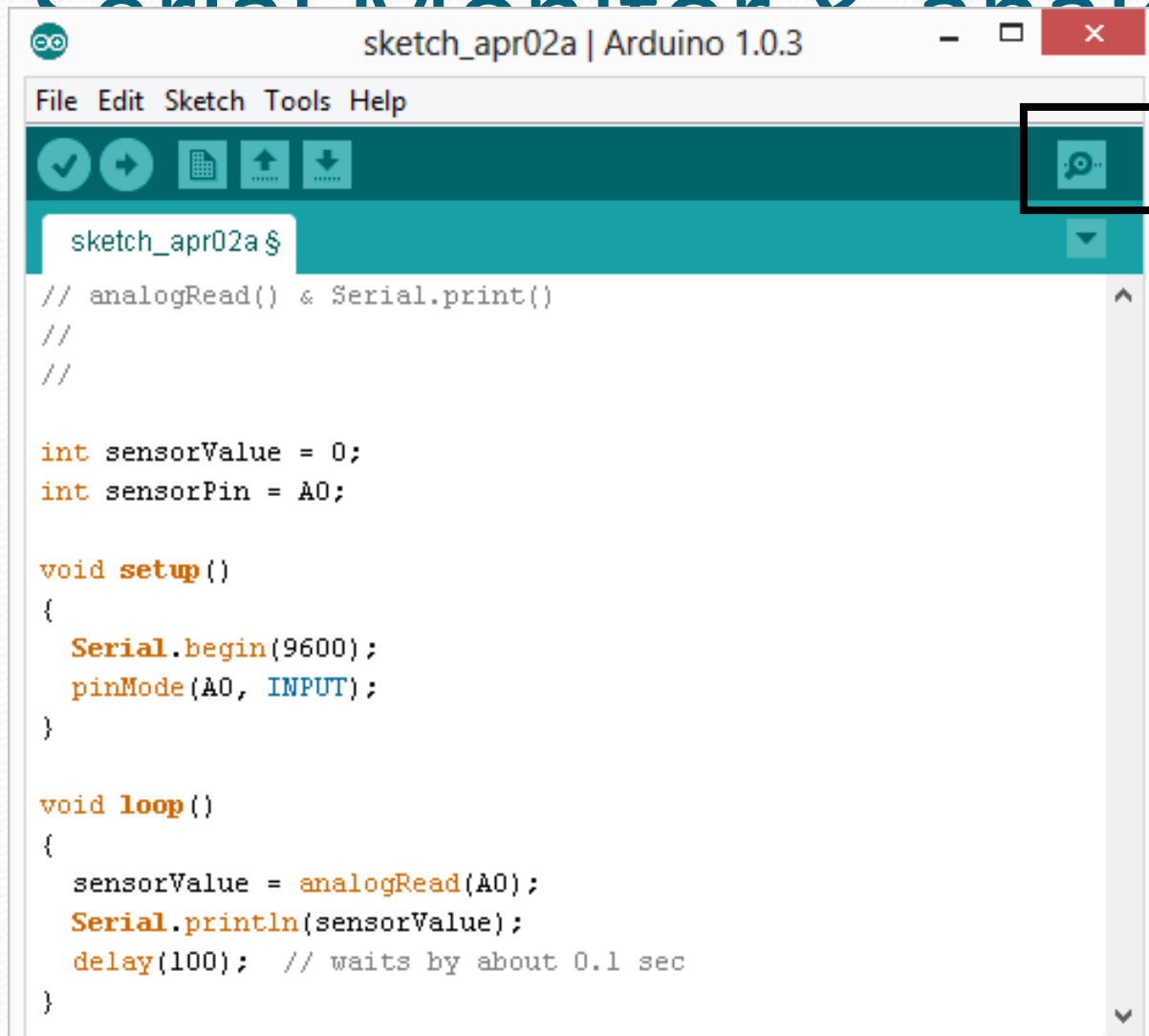
void loop()
{
  sensorValue = analogRead(A0);
  Serial.println(sensorValue);
  delay(100); // waits by about 0.1 sec
}
```

Initializes the Serial
Communication

9600 baud data rate

prints data to serial bus

Serial Monitor & analogRead()



```
sketch_apr02a | Arduino 1.0.3
File Edit Sketch Tools Help
sketch_apr02a $
// analogRead() & Serial.print()
//
//
int sensorValue = 0;
int sensorPin = A0;

void setup()
{
  Serial.begin(9600);
  pinMode(A0, INPUT);
}

void loop()
{
  sensorValue = analogRead(A0);
  Serial.println(sensorValue);
  delay(100); // waits by about 0.1 sec
}
```

Opens up a
Serial Terminal
Window

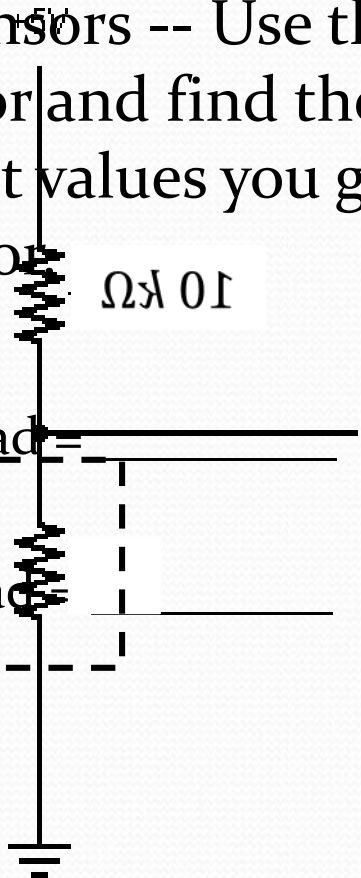
Analog Sensors

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 =` out

- `MinAnalogRead`



Analog Sensors

- Examples:

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



Additional Serial Communication

Sending a Message

```
void loop ( )  
{  
  Serial.print("Hands on ") ;  
  Serial.print("Learning ") ;  
  •   Serial.println("is Fun!!!") ;  
  
}
```



BareMinimum | Arduino 1.0.5

File Edit Sketch Tools Help

COM24

BareMinim

```
void s
// p
Seri
}

void l
{
  Hands on Learning is Fun!!!
  Hands on Learning is Fun!!!
  Hands on Learning is Fun!!!
  Hands on Learning is Fun!!!
  Hands on Learning is Fun!!!
  Hands on Learning is Fun!!!
  Hands on Learning is Fun!!!
  Hands on Learning is Fun!!!
  Hands on Learning is Fun!!!
  Hands o
```

Send

Autoscroll No line ending 9600 baud

Done uploading.

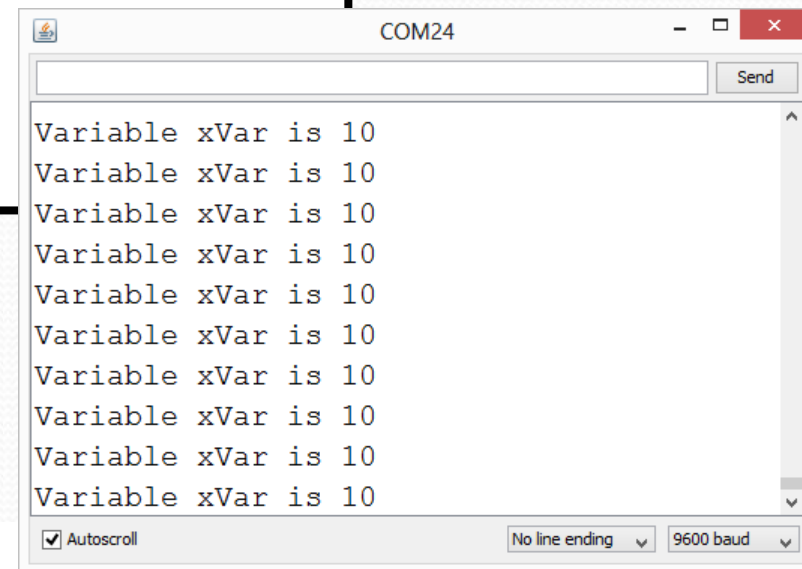
Binary sketch size: 1,980 bytes (of a 32,256 byte maximum)

3 Arduino Uno on COM24



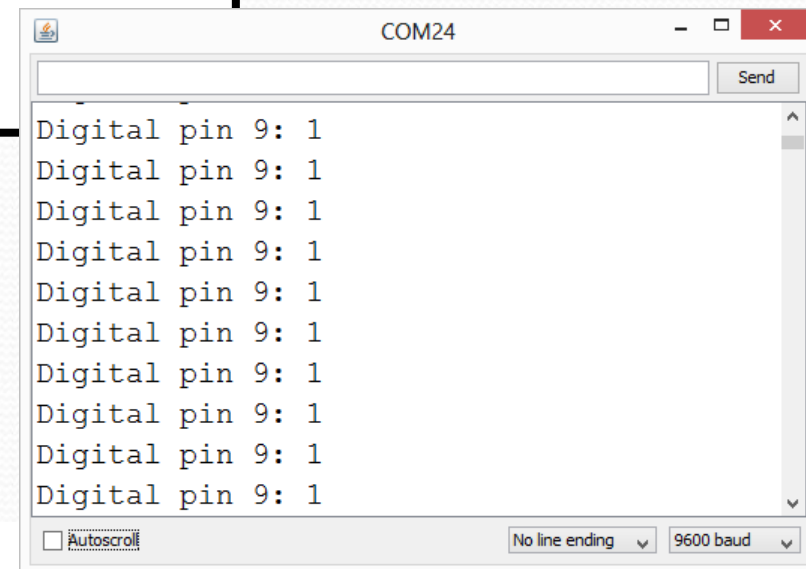
Serial Communication: Serial Debugging

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



Serial Communication: Serial Troubleshooting

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

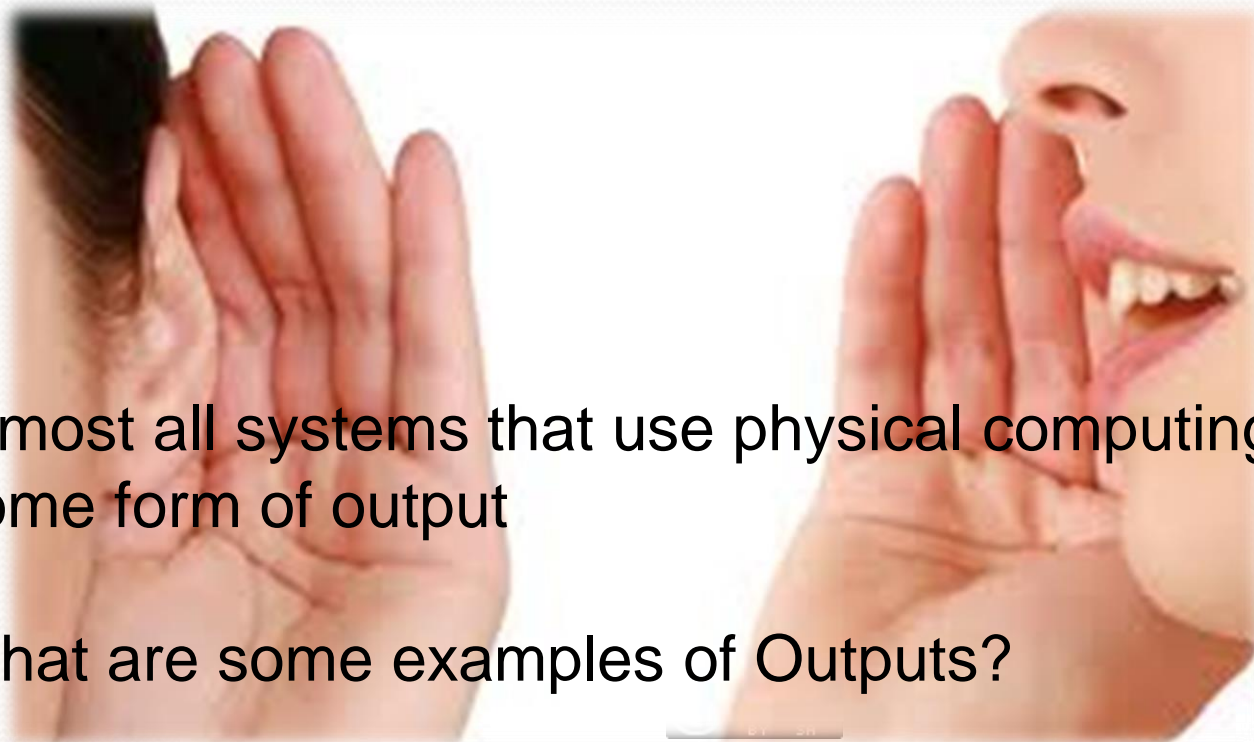


Concepts: INPUT vs. OUTPUT

- 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?

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.

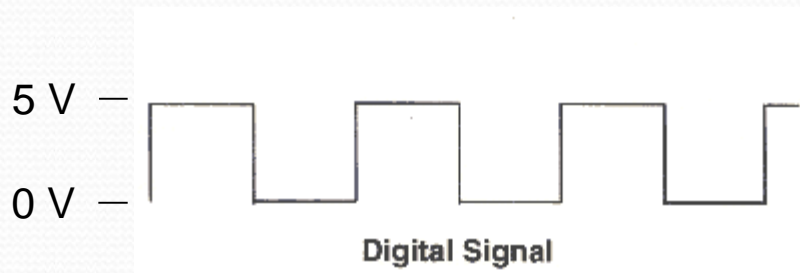
Examples: Buttons Switches, Light Sensors, Flex Sensors, Humidity Sensors, Temperature Sensors...

Examples: LEDs, DC motor, servo motor, a piezo buzzer, relay, an RGB LED



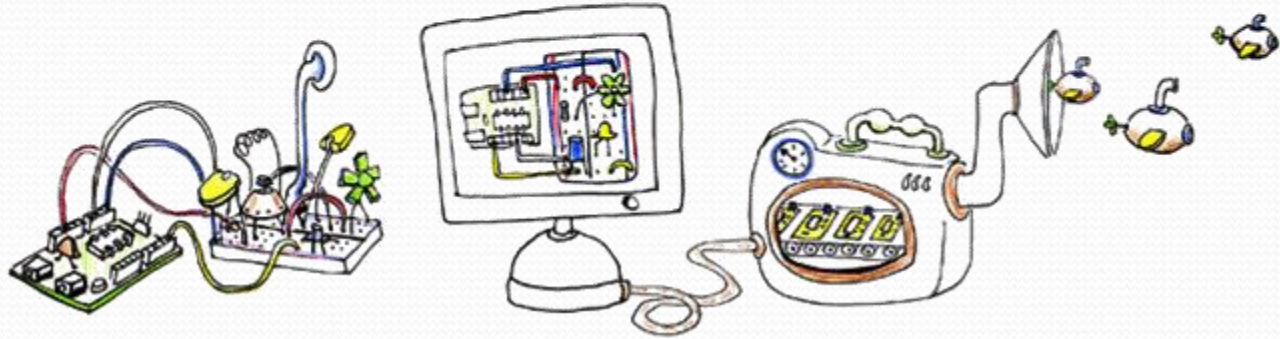
Concepts: Analog vs. Digital

- 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...





FRICTZING



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

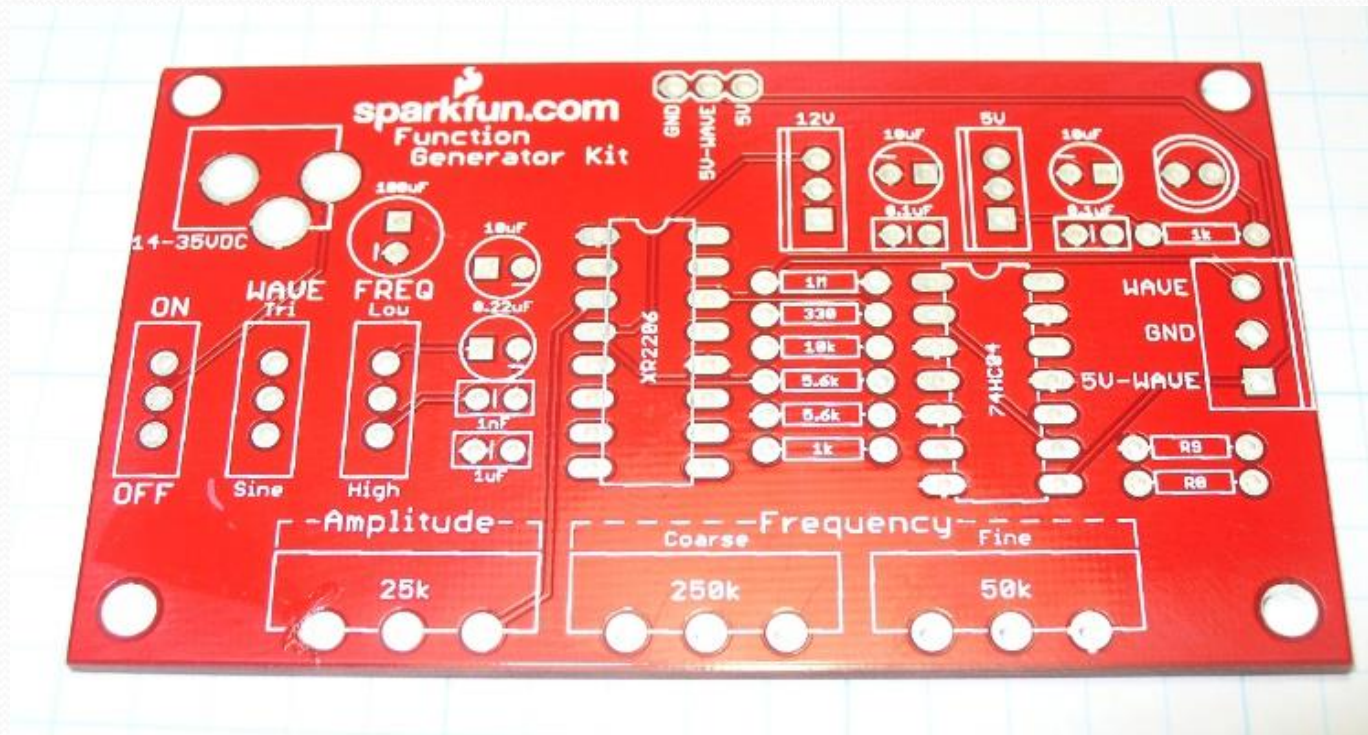




FRITZING



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

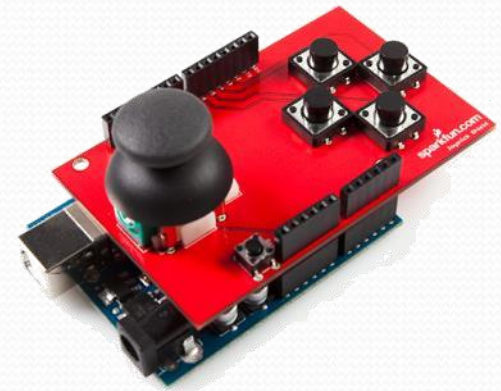
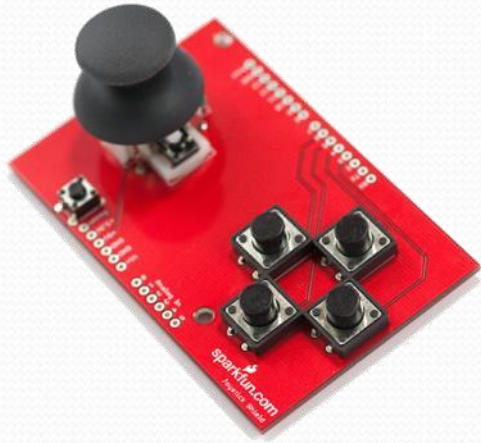
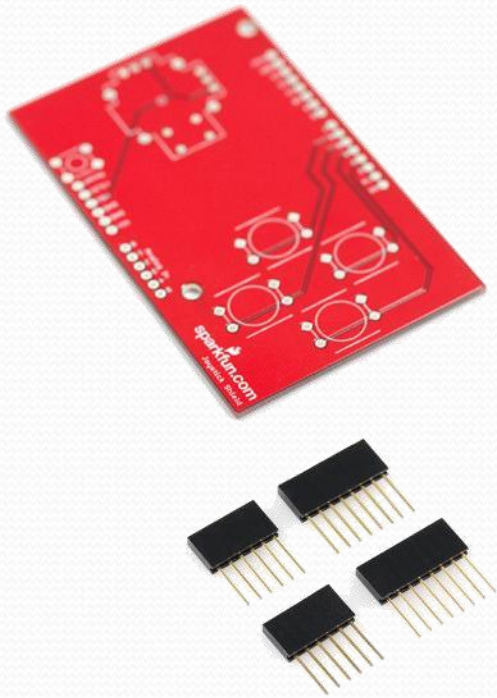


Arduino Shields

PCB

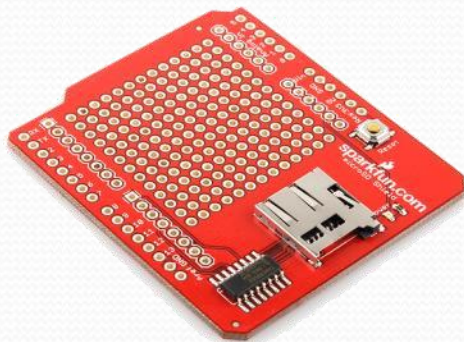
Built Shield

Inserted Shield

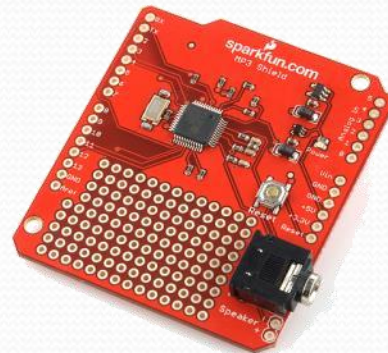


Arduino Shields

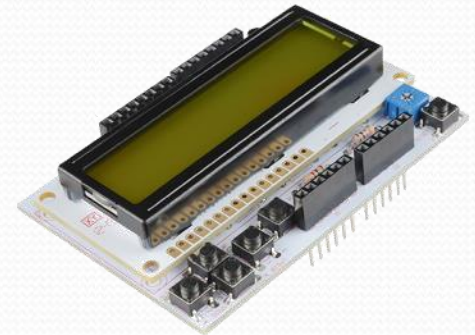
Micro SD




MP3 Trigger



LCD

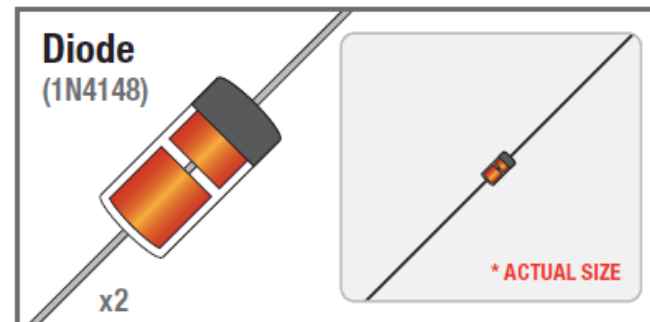
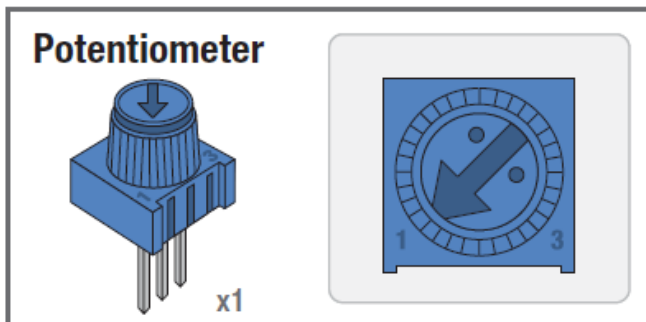
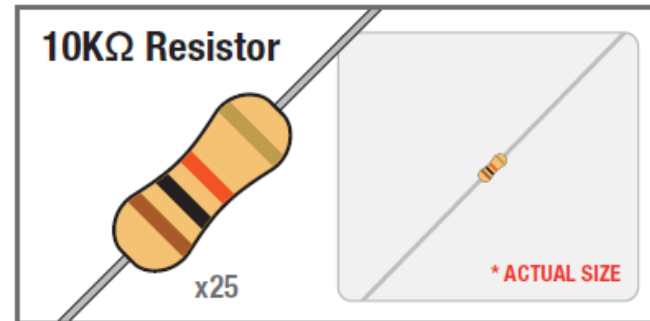
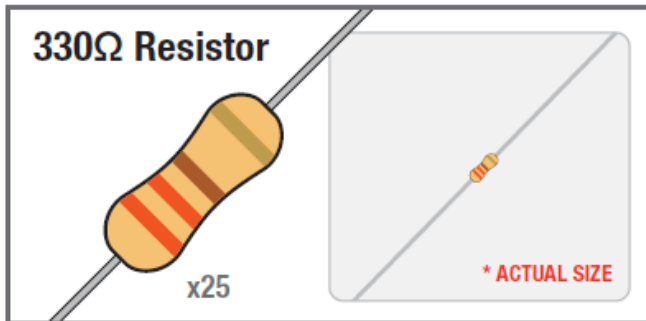
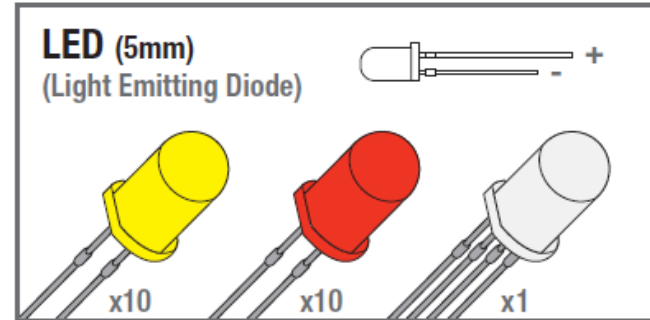
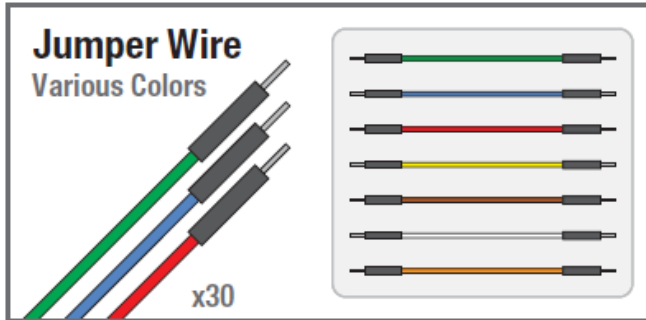


SIK Components

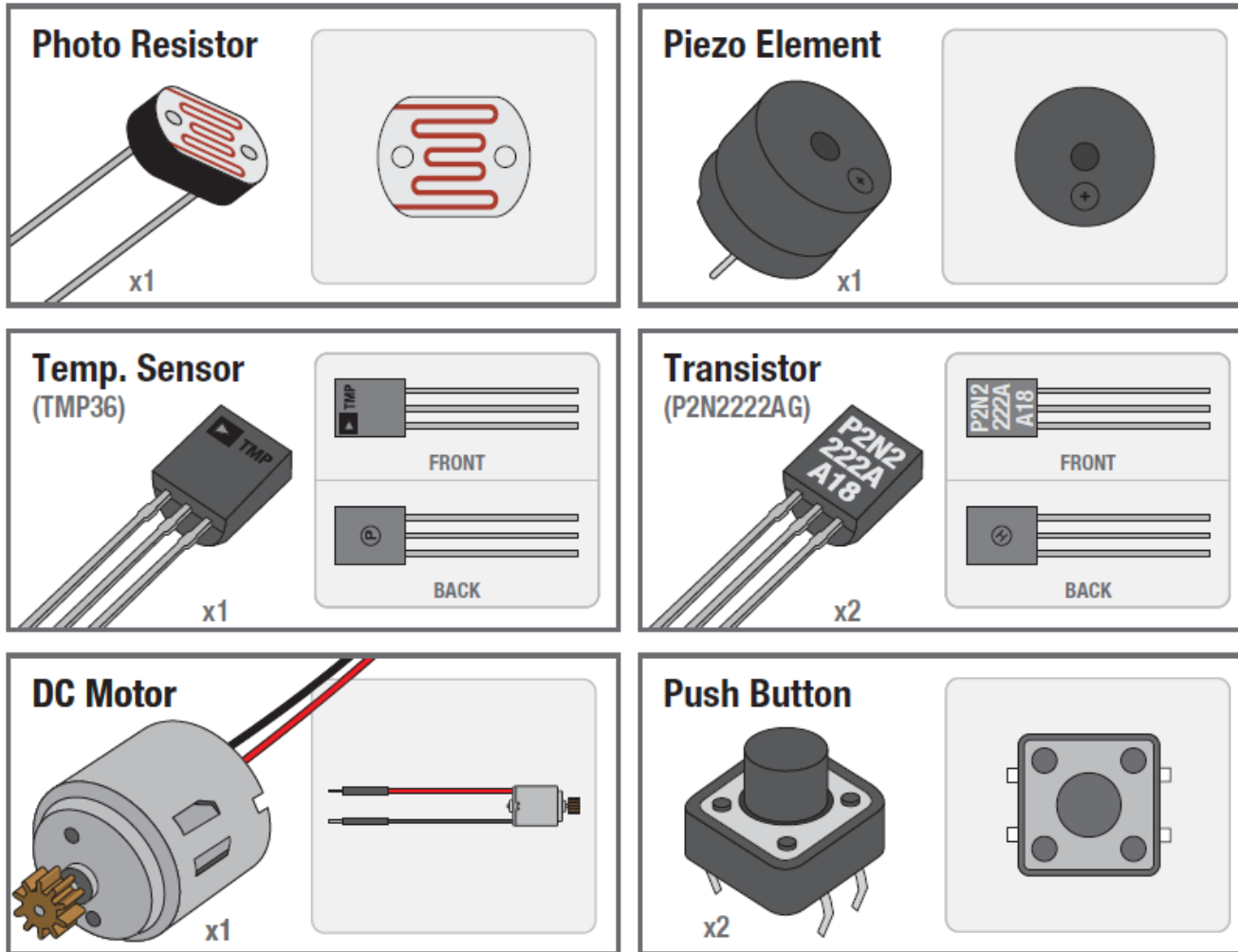
Name	Image	Type	Function	Notes
Push Button		Digital Input	Switch - Closes or opens circuit	Polarized, needs resistor
Trim potentiometer		Analog Input	Variable resistor	Also called a Trimpot.
Photoresistor		Analog Input	Light Dependent Resistor (LDR)	Resistance varies with light.
Relay		Digital Output	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.



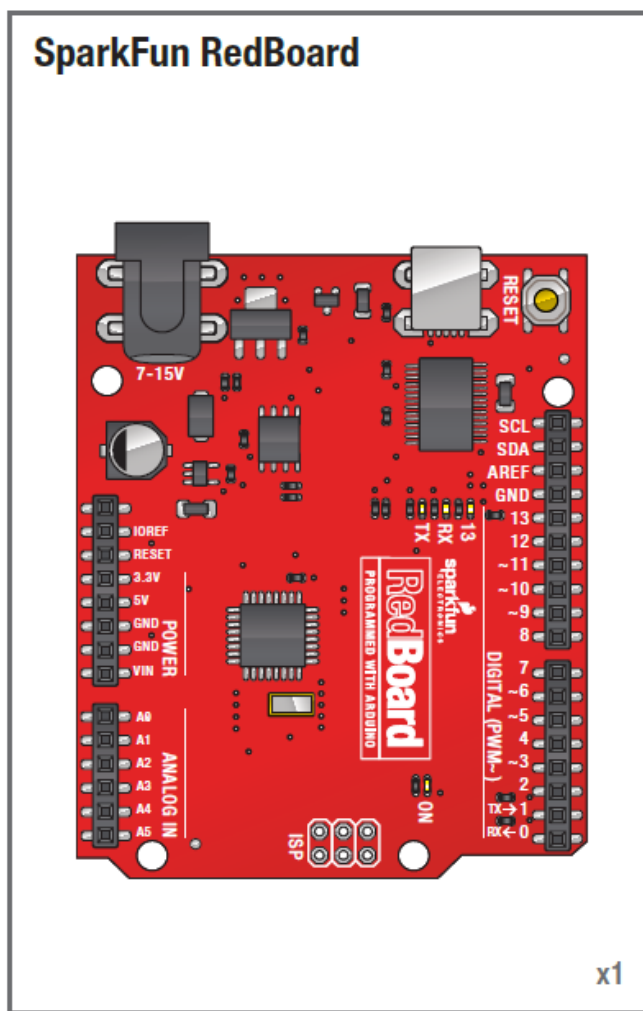
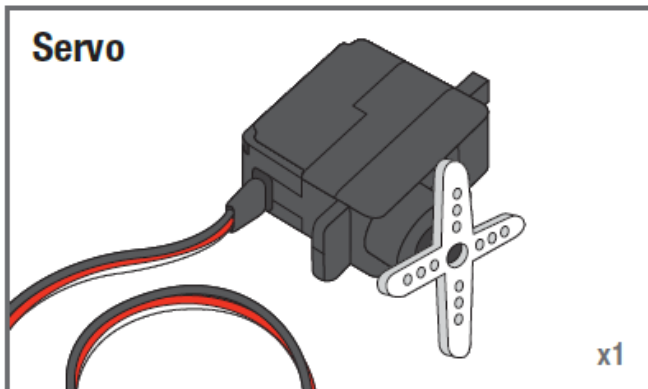
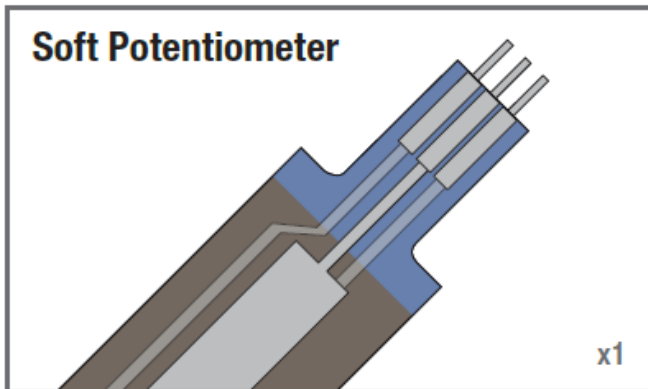
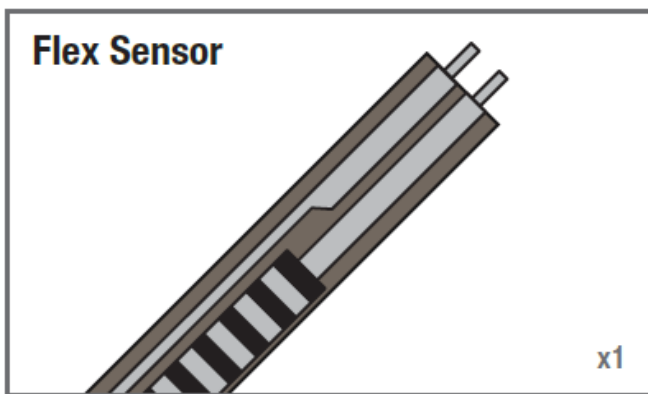
SIK Components



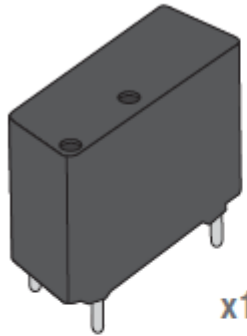
SIK Components



SIK

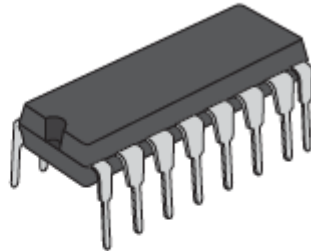


Relay



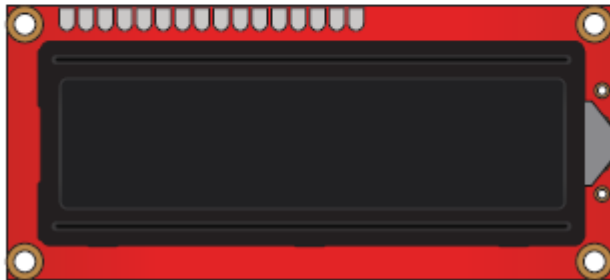
x1

Integrated Circuit (IC)



x1

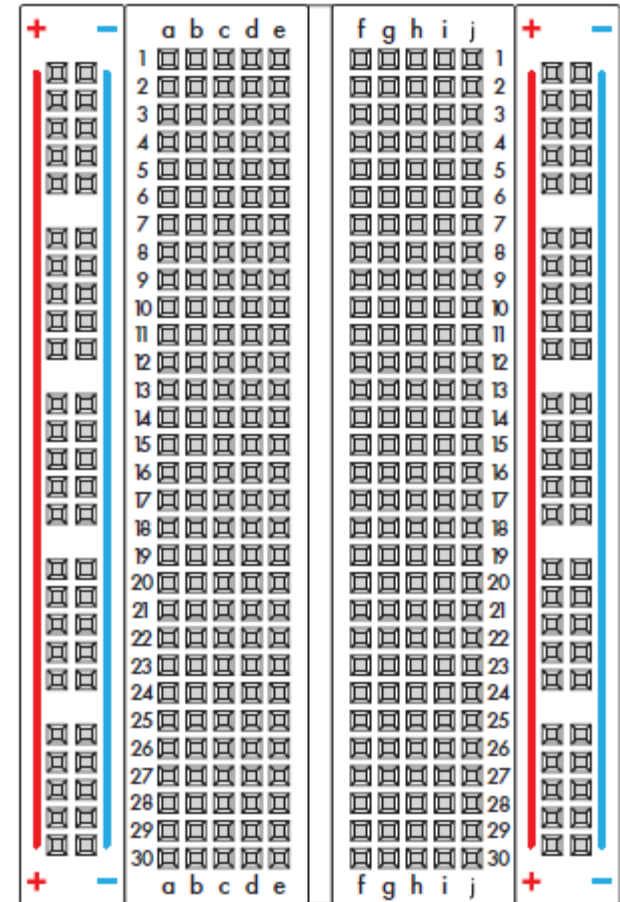
LCD



x1

Breadboard

Standard Solderless (Color may vary)



x1



Electricity \ Electronics Basic Concept Review

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



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:

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



$$V = I R$$

Electrical Properties

Voltage

V

- Defined as the amount of potential energy in a circuit.
- Units: Volts (V)

Current

I

- The rate of charge flow in a circuit.
- Units: Amperes (A)

Resistance

R

- Opposition to charge flow.
- Units: Ohms (Ω)



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

$$V = I R$$

Current Flow Analogy



High Current

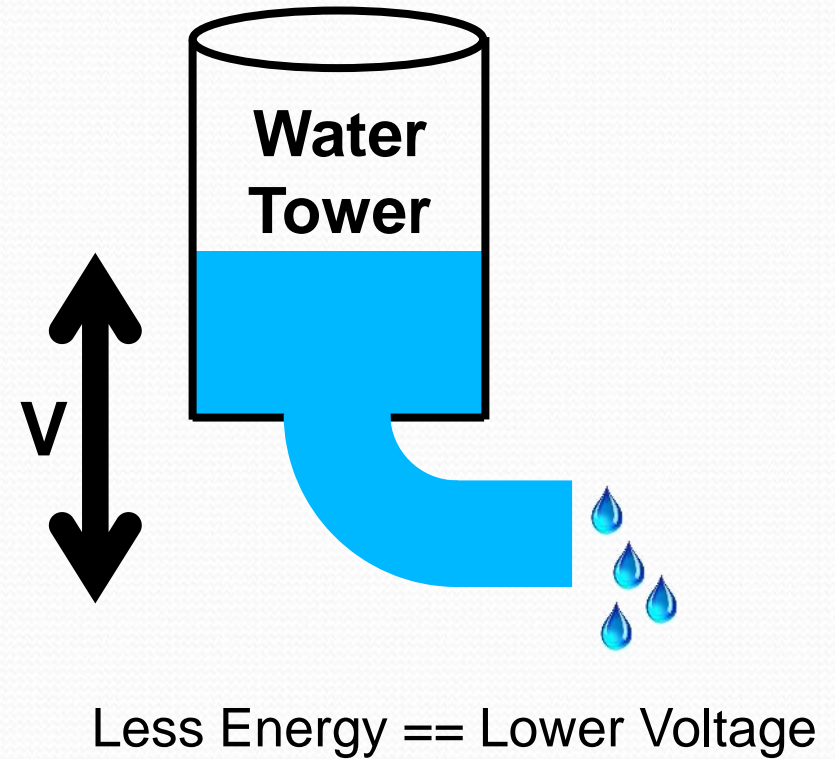
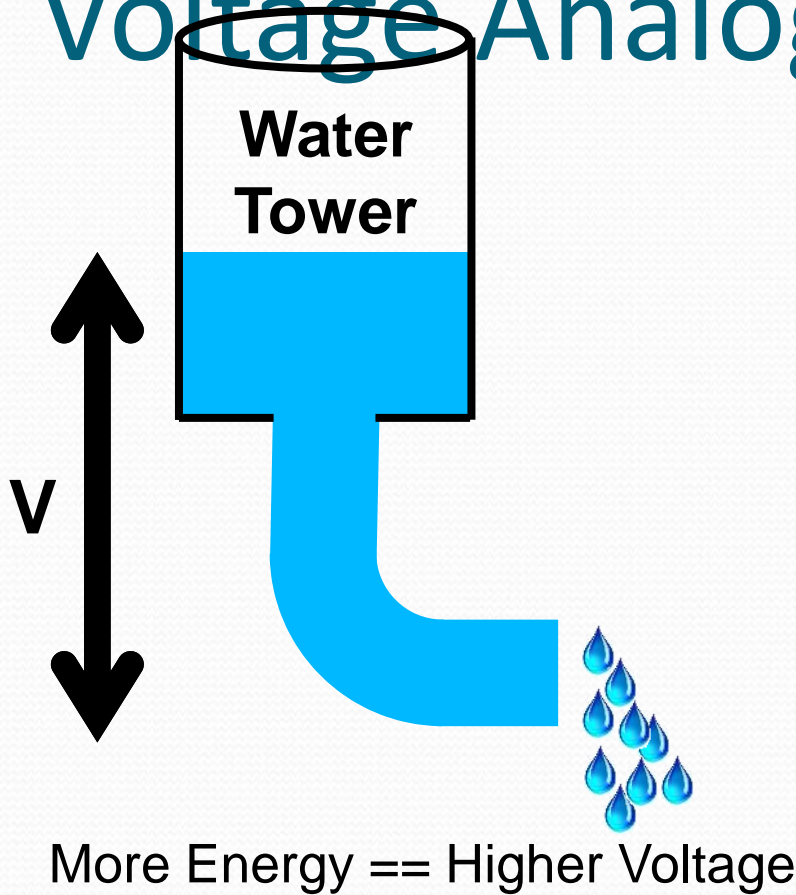


Low Current



$$V = I R$$

Voltage Analogy



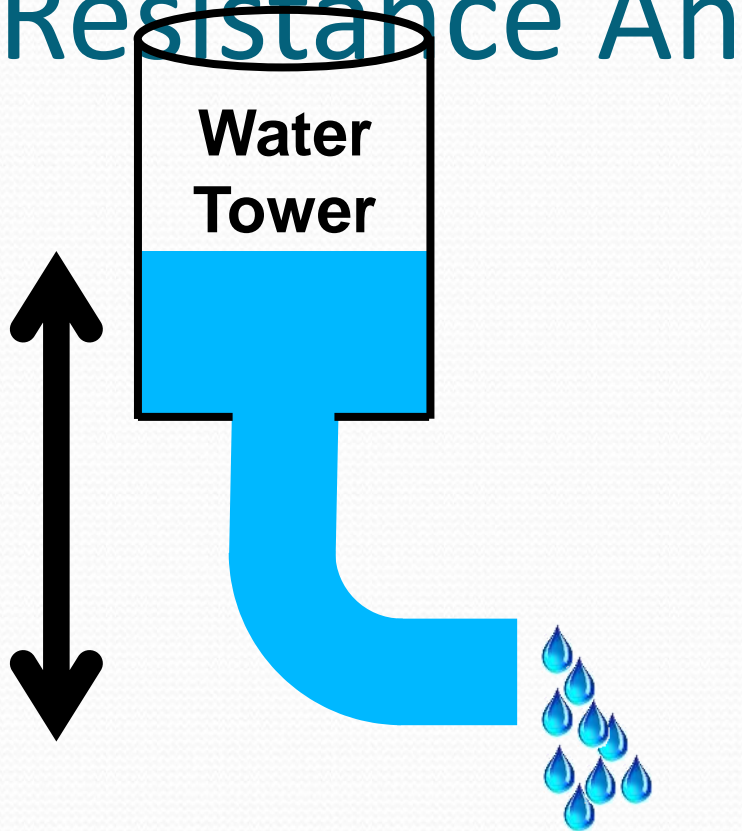
$$V = I R$$

$$V = I R$$



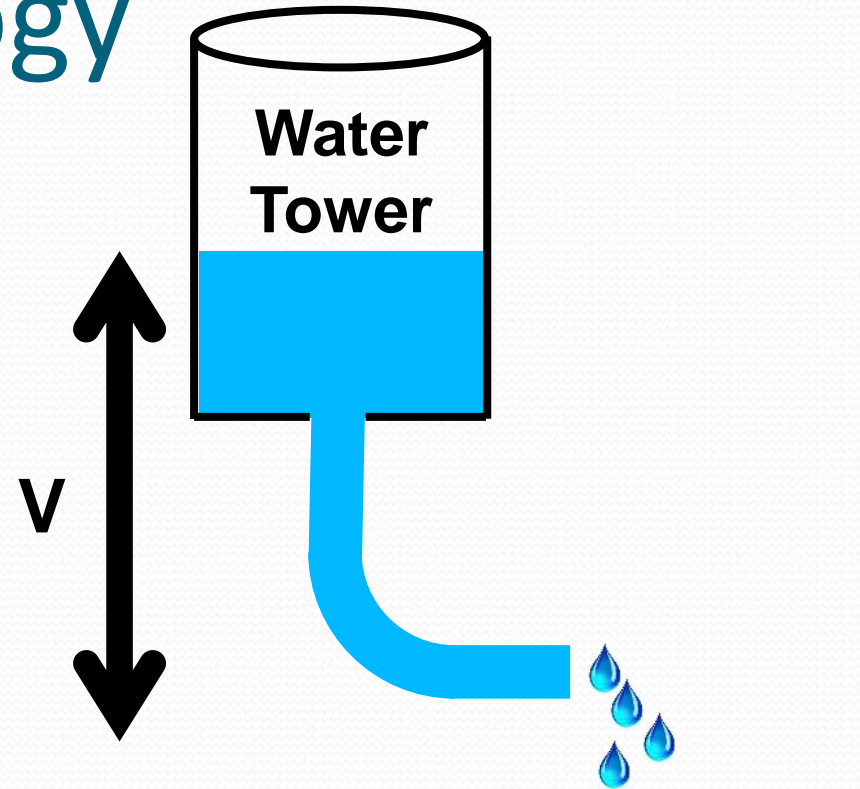
$$V = I R$$

Resistance Analogy



Big Pipe == Lower Resistance

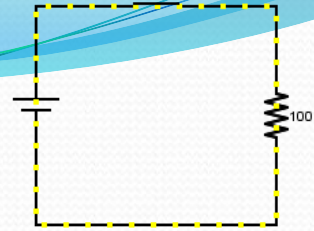
$$V = I R$$



Small Pipe == Higher Resistance

$$V = I R$$



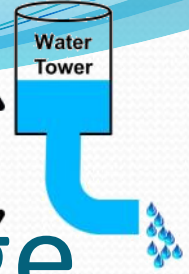


Continuity – Is it a Circuit?

- The word “circuit” is derived from the circle. 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.

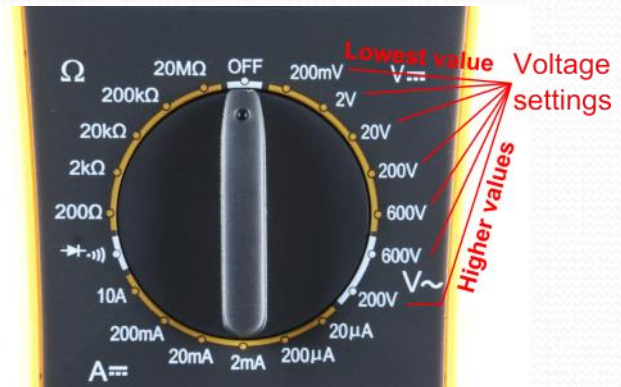
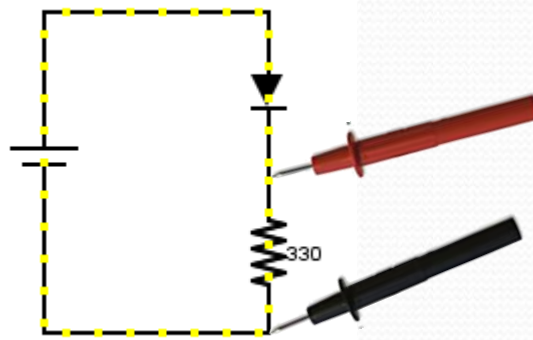
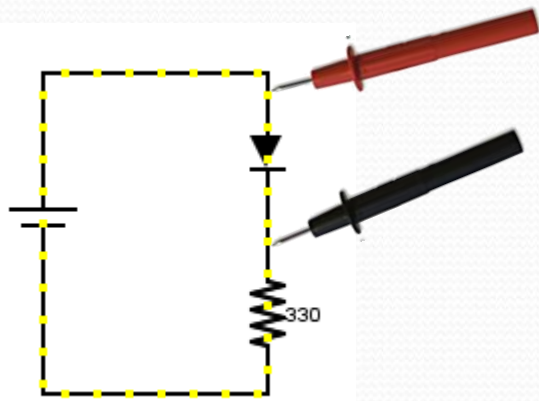
Continuity
setting

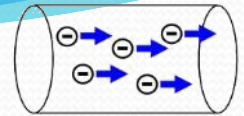




Measuring Electricity – Voltage

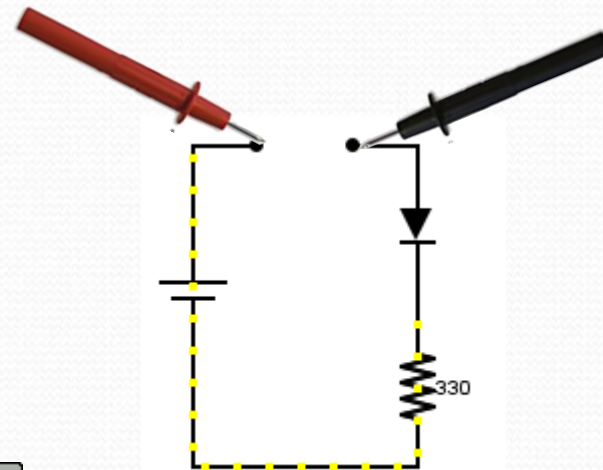
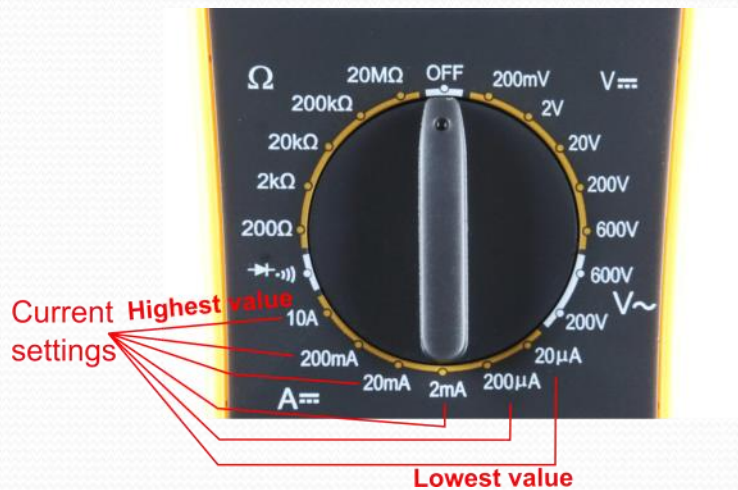
- Voltage is a measure of potential electrical energy. A voltage is also called a potential difference – it is measured between two points in a circuit – across a device.





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).





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.

Resistance settings



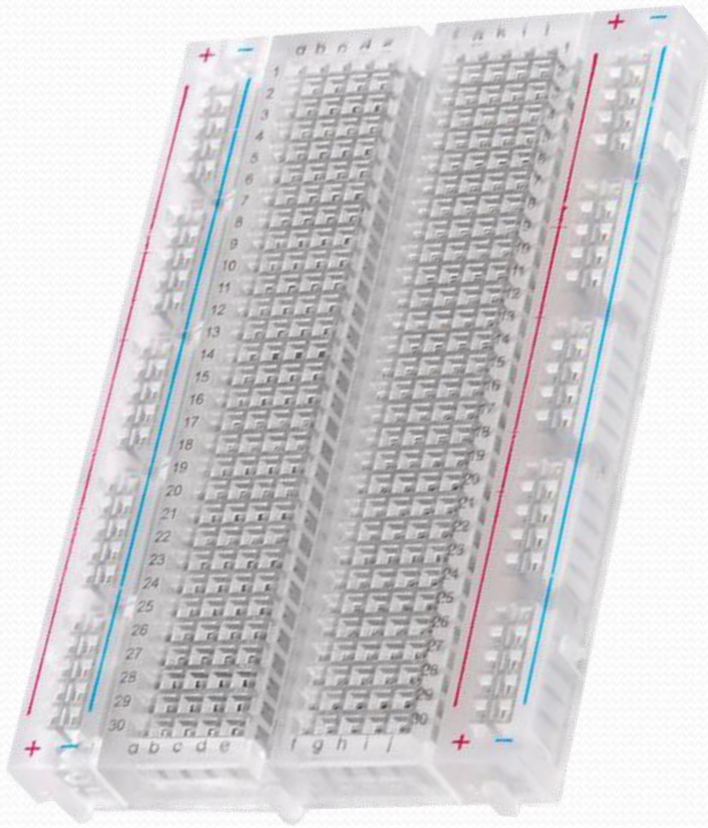
Prototyping Circuits

Solderless Breadboard

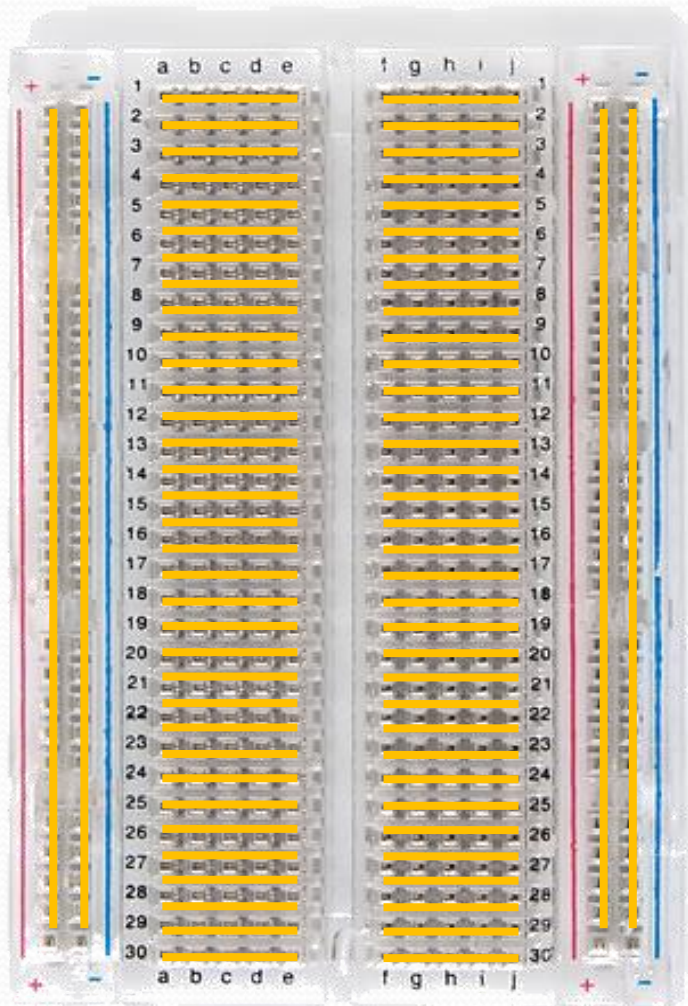
- One of the most useful tools in an engineer or Maker's toolkit. The three most important things:
 - A breadboard is easier than soldering
 - A lot of those little holes are connected, which ones?
 - Sometimes breadboards break



What's a Breadboard?



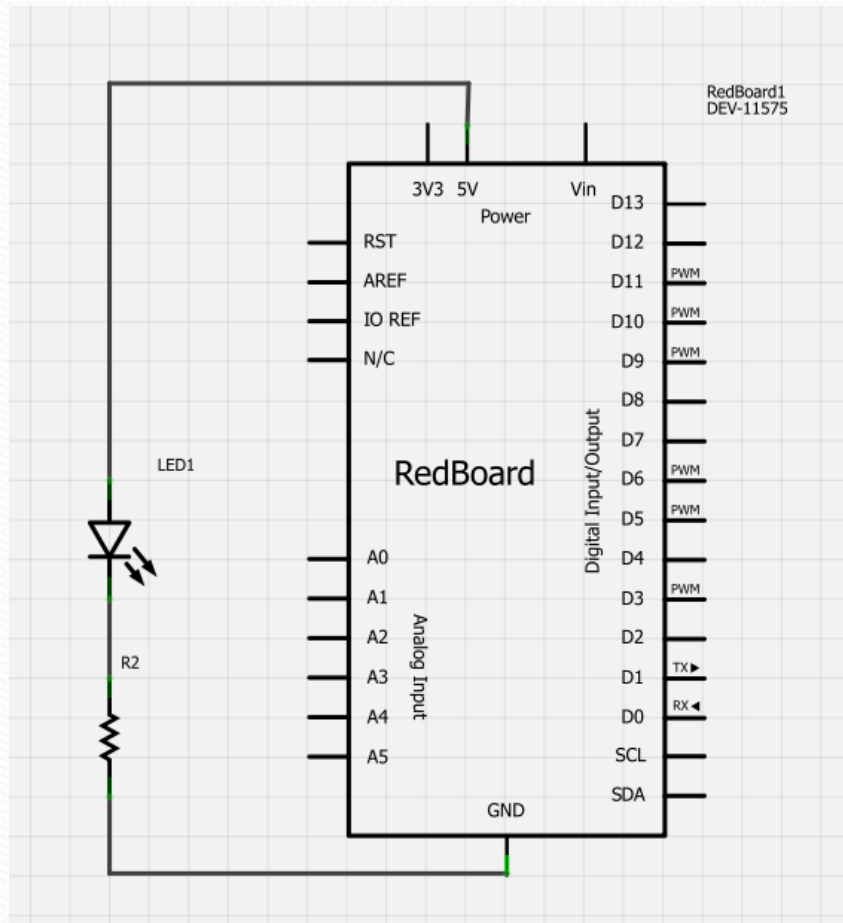
Solderless Breadboard



- Each row (horiz.) of 5 holes are connected.
- Vertical columns – called power bus are connected vertically



Using the Breadboard to built a simple circuit

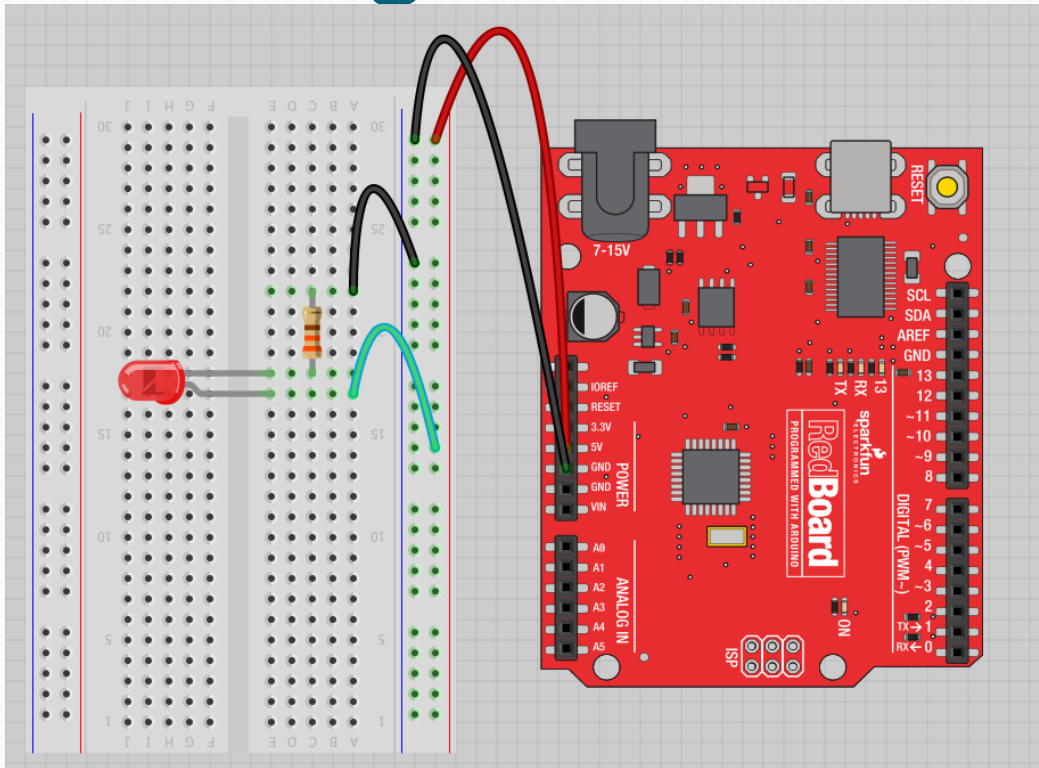


- Use the breadboard to wire up a single LED with a 330 Ohm Resistor (Orange-Orange-Brown).

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



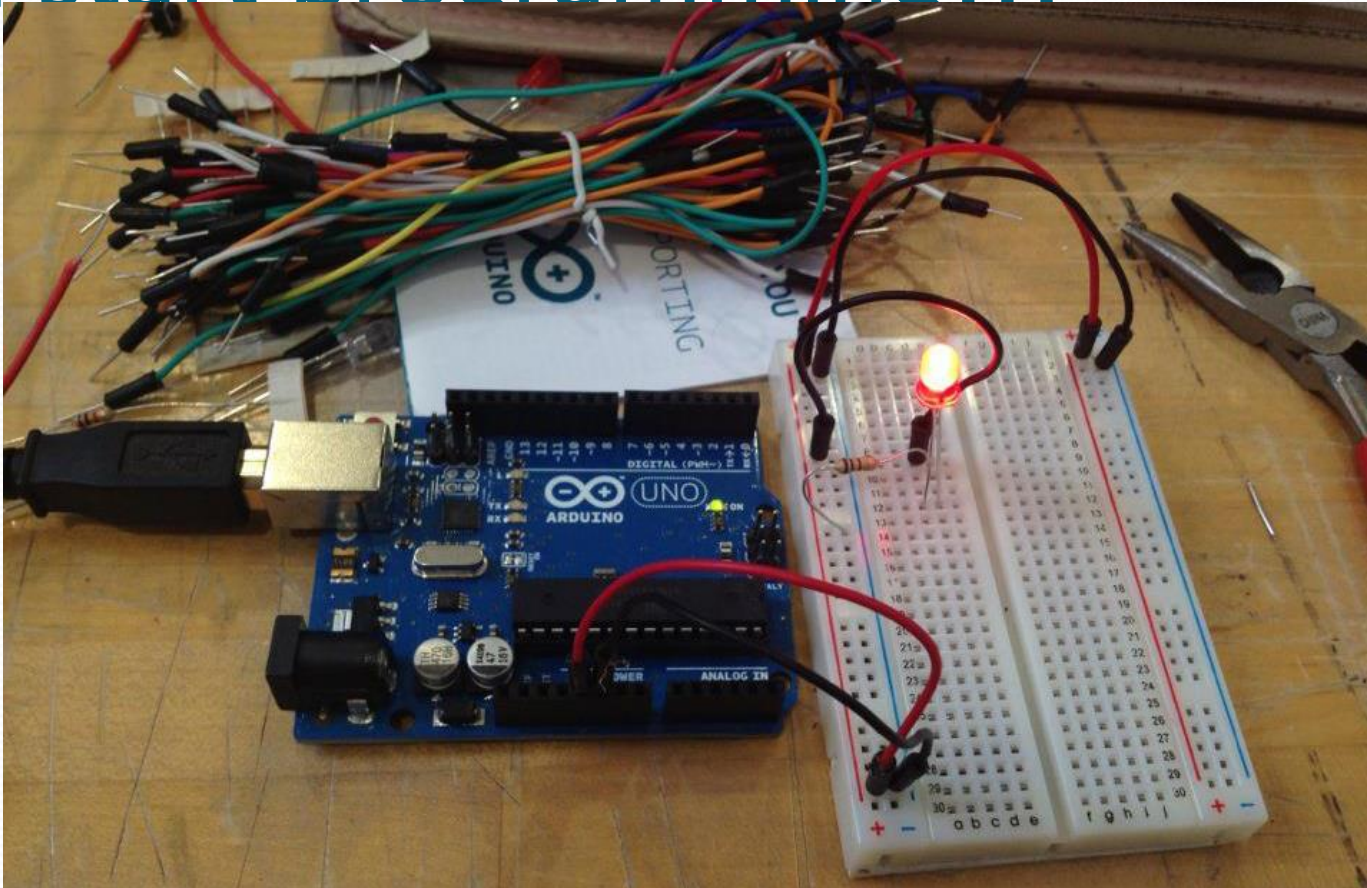
Fritzing View of Breadboard Circuit



- What happens when you break the circuit?
- What if you wanted to add more than one LED?



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



“Competitors” to the Arduino

- PIC controller
 - Microcontroller programmed with C or assembler
- Alternatives to the Arduino line
 - Pinguino – PIC controller
 - MSP430 – Texas Instruments; \$4.30
 - Others: customs, Teensy, etc.
- Netduino
- Computers
 - Raspberry Pi
 - BeagleBones – TI; has computer and controller



Netduino

- Microcontroller and development tools created by Microsoft to work with the .NET Micro Framework.
- VASTLY better development environment.
 - visualmicro.com
 - Other alternatives
- Differences
 - Pins on a Netduino are 3.3V (not 5).
 - Netduinos have a much faster processor.
 - 60K of RAM (versus an Uno's 2K).
- Largely compatible with the Arduino, but it is not a drop-in replacement (can fry it).



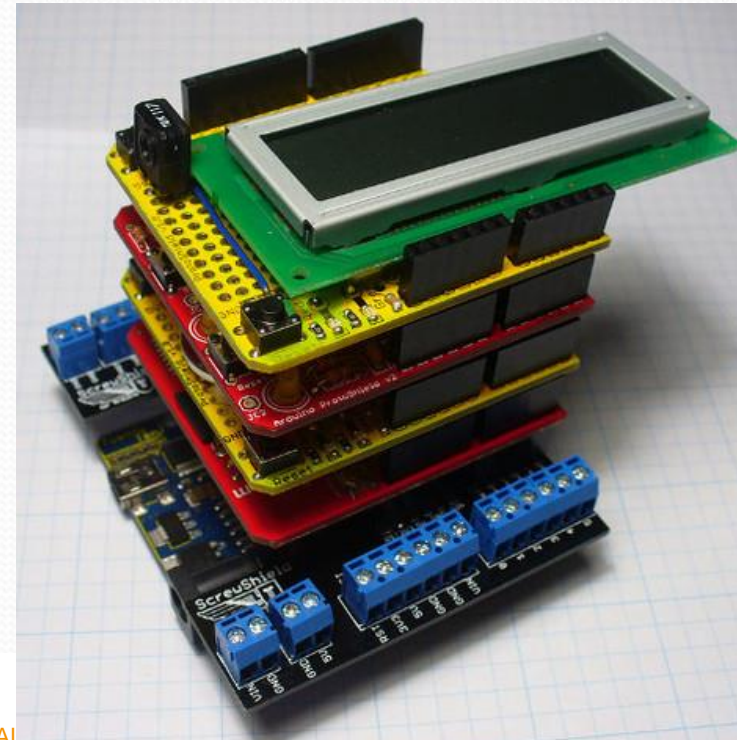
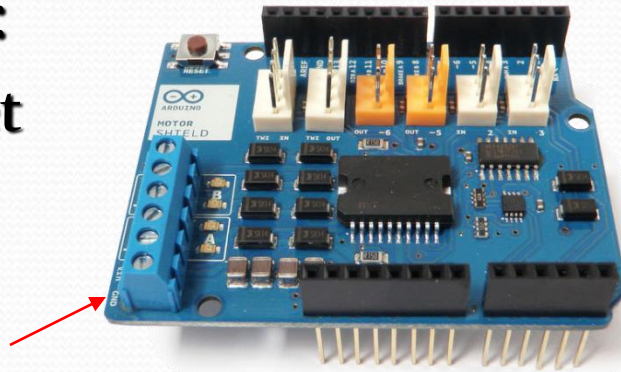
Raspberry Pi

- Low end computer, not a controller
- Uses Debian Linux
 - Arch Linux ARM, Fedora, FreeBSD, Slackware...
- Programmed with Python
 - BBC BASIC, C, Perl
- As it is a computer and not a controller, its role in these projects is different.
- Hierarchy: computers control controllers, controllers control hardware.



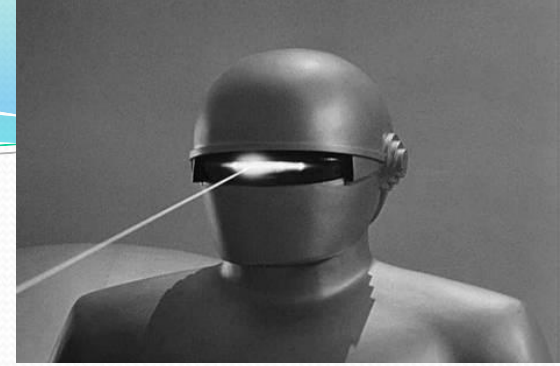
Shields

- Shields are circuit boards that plug into the top of an Arduino.
- They extend the capabilities of an Arduino.
- Examples:
 - Ethernet
 - GPS
 - Motor
 - Prototype
- shieldlist.org





Conclusion



- The Arduino microcontroller is a low cost way to enter into the hobby of robotics.
- The Arduino has two plusses over any other:
 - The user community
 - Extensive online library of code and projects
- Viewed as the "base" system, upon which all other microcontrollers are built. Compatibility.
- So get a kit, and start ushering in the inevitable takeover of our robotic overlords!



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



Introduction to Arduino Microcontrollers

AJLON Technologies
www.Ajlontech.com

