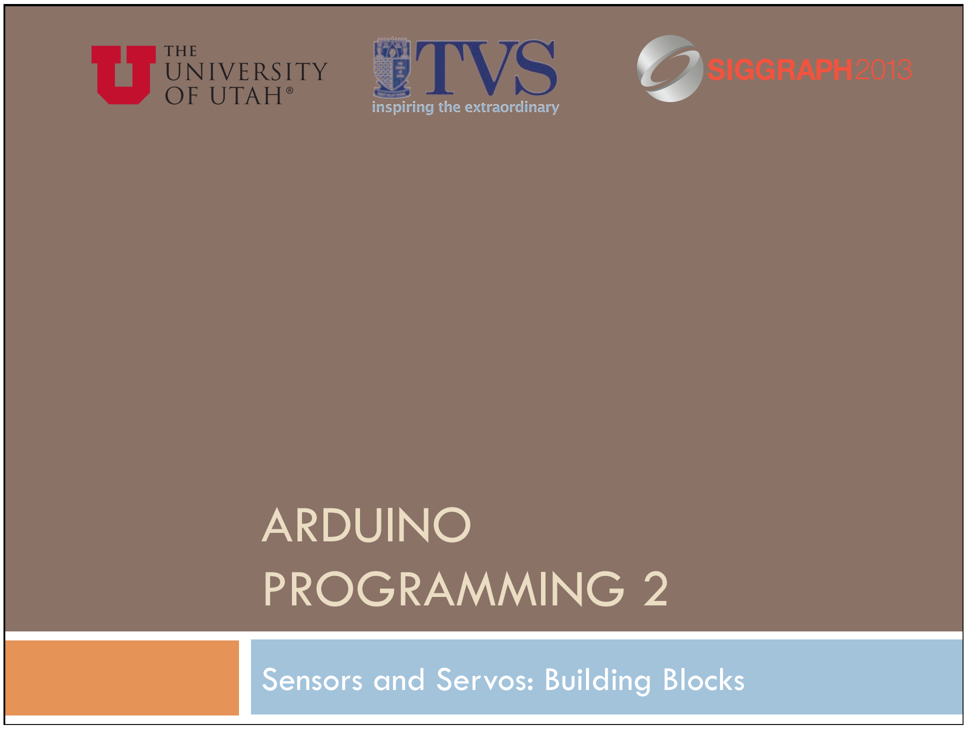

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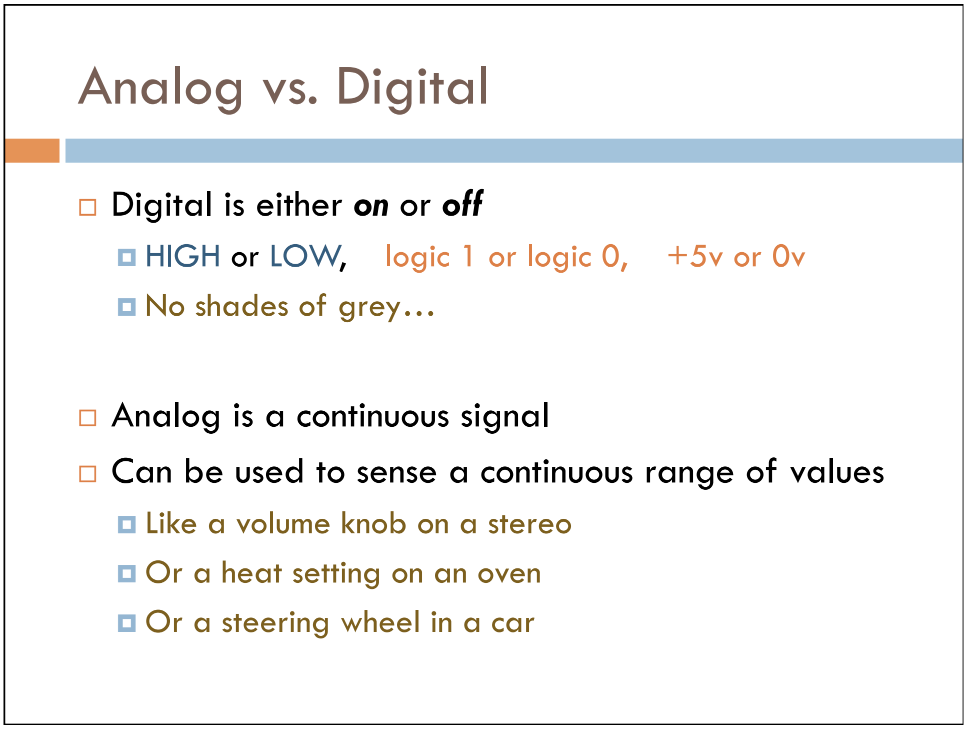
ARDUINO PROGRAMMING 2

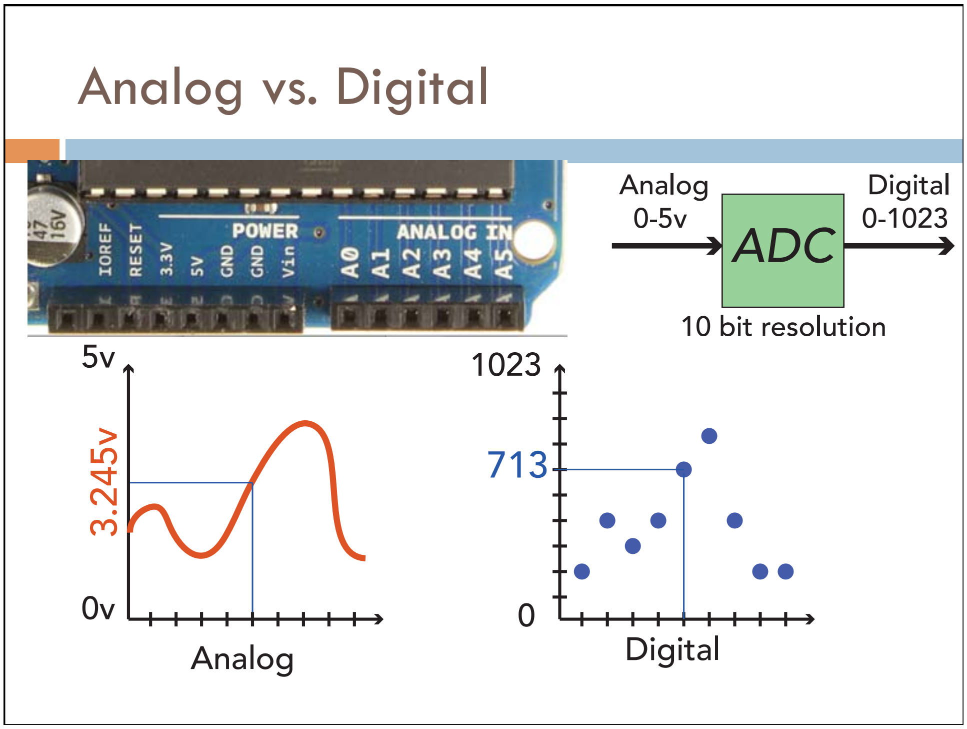
Sensors and Servos: Building Blocks



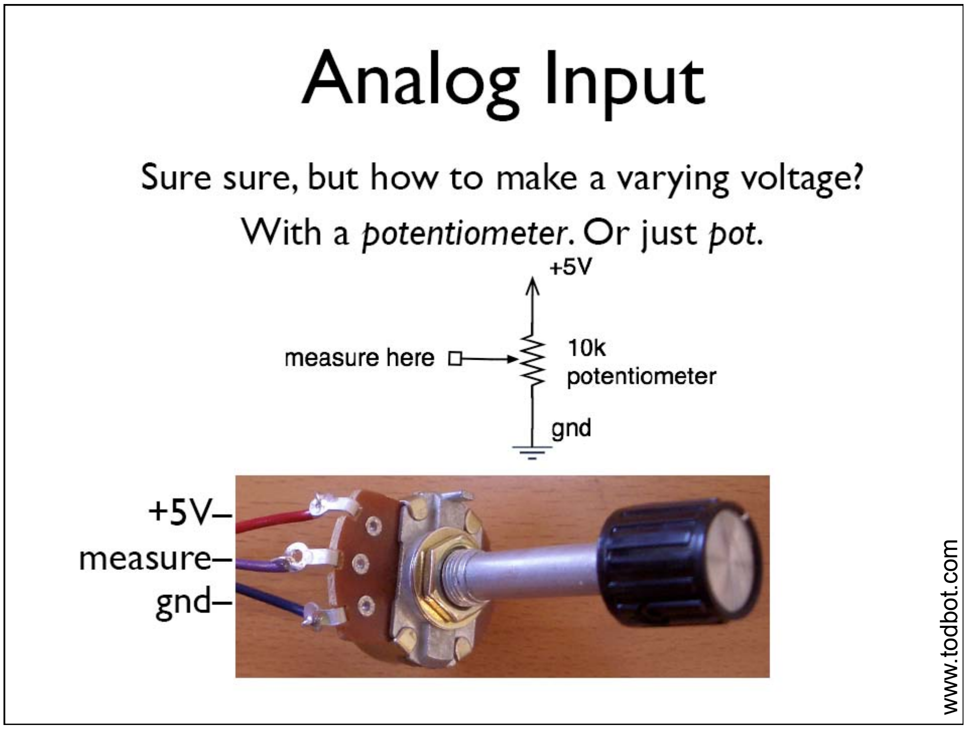
Analog vs. Digital

- Digital is either ***on*** or ***off***
  - HIGH or LOW,   logic 1 or logic 0,   +5v or 0v
  - No shades of grey…

- Analog is a continuous signal
- Can be used to sense a continuous range of values
  - Like a volume knob on a stereo
  - Or a heat setting on an oven
  - Or a steering wheel in a car



Analog vs. Digital

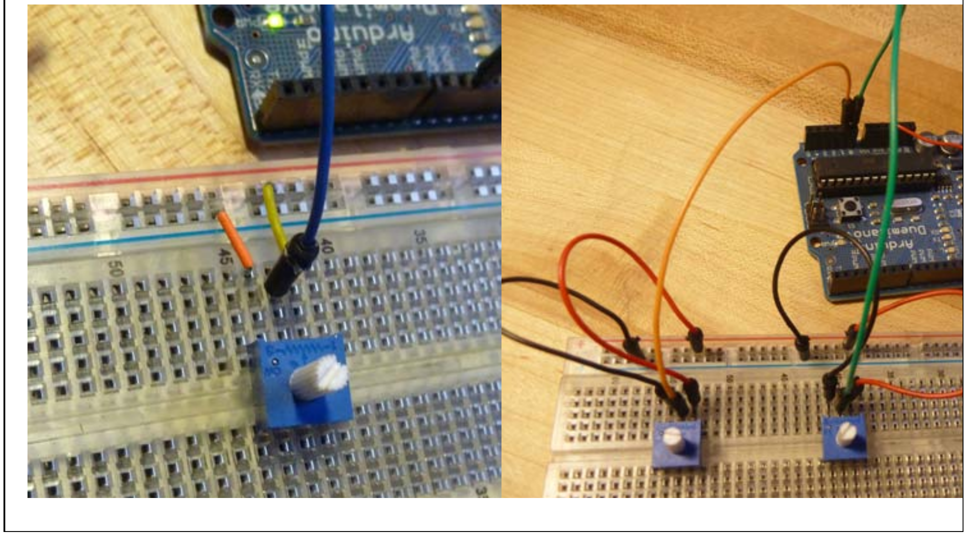


Analog Input

Sure sure, but how to make a varying voltage?

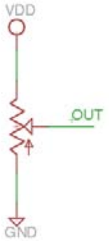
With a *potentiometer*. Or just *pot*.

Wire up a Potentiometer



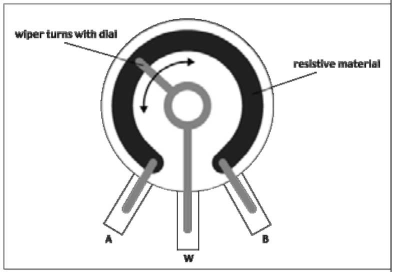
Analog Inputs and Arduino

```
int sensorPin = A2;    // Analog pin 2
int ledPin = 13;
int sensorValue = 0;

void setup() {
  pinMode(ledPin, OUTPUT);
}

void loop() {
  sensorValue = analogRead(sensorPin); // read ADC
  val = map(val, 0, 1023, 100, 255);    // Interpolate
  analogWrite(ledPin, val);   // write value to the LED
}
```



https://learn.sparkfun.com/tutorials/voltage-dividers/applications

Analog Inputs and Arduino

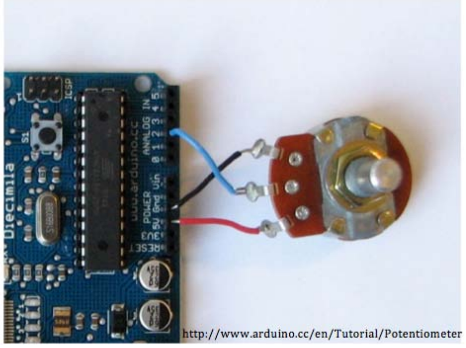


```
int sensorPin = A2;    // Analog pin 2
int ledPin = 13;
int sensorValue = 0;

void setup() {
  pinMode(ledPin, OUTPUT);
}

void loop() {
  sensorValue = analogRead(sensorPin); // read ADC
  val = map(val, 0, 1023, 100, 255);    // Interpolate
  analogWrite(ledPin, val);   // write value to the LED
}
```

Try this out with "potFade" in the DM examples

Analog Inputs and Arduino

```
int sensorPin = A2;    // Anal
int ledPin = 13;
int sensorValue = 0;

void setup() {
  pinMode(ledPin, OUTPUT);
}

void loop() {
  sensorValue = analogRead(sensorPin); // read ADC
  val = map(val, 0, 1023, 100, 255);    // Interpolate
  analogWrite(ledPin, val);   // write value to the LED
}
```

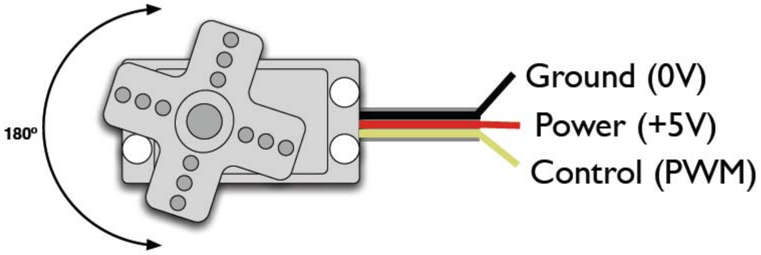


http://www.arduino.cc/en/Tutorial/Potentiometer

Moving on… Servos

- Servo motors are small DC motors that have a range of motion of 0-180°
  - Internal feedback and gearing to make it work
  - Easy three-wire interface
  - Position is controlled by PWM signals
    - Same idea as LED fading…
  - It's all hidden in a library function for you!

Servo Control



- PWM freq is 50 Hz (i.e. every 20 millisecs)
- Pulse width ranges from 1 to 2 millisecs
  - 1 millisec = full anti-clockwise position
  - 2 millisec = full clockwise position

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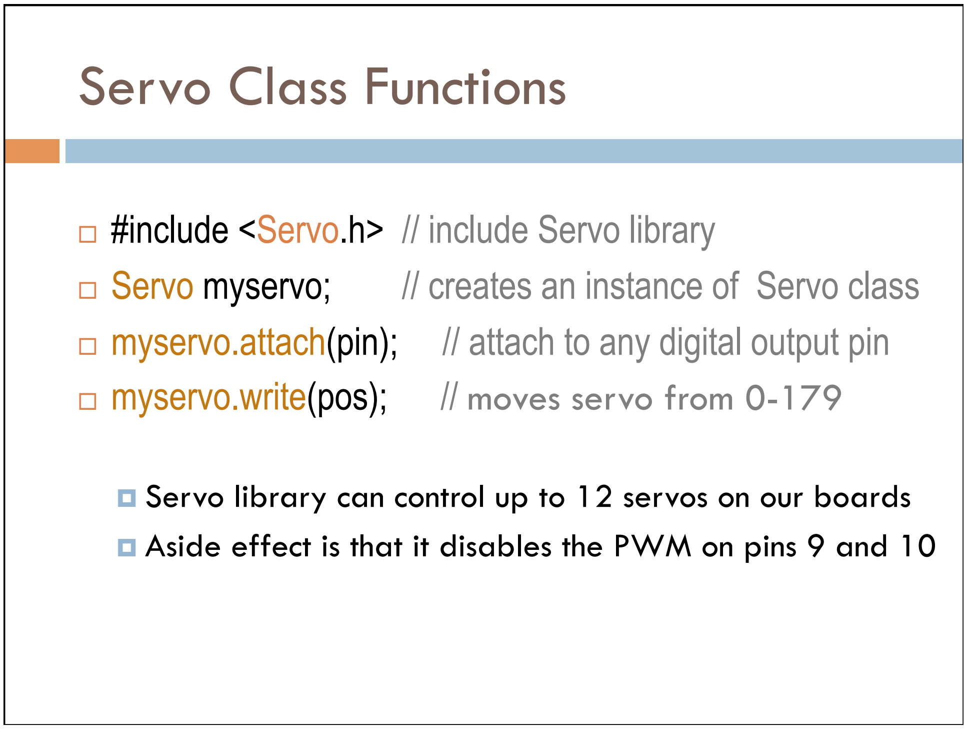
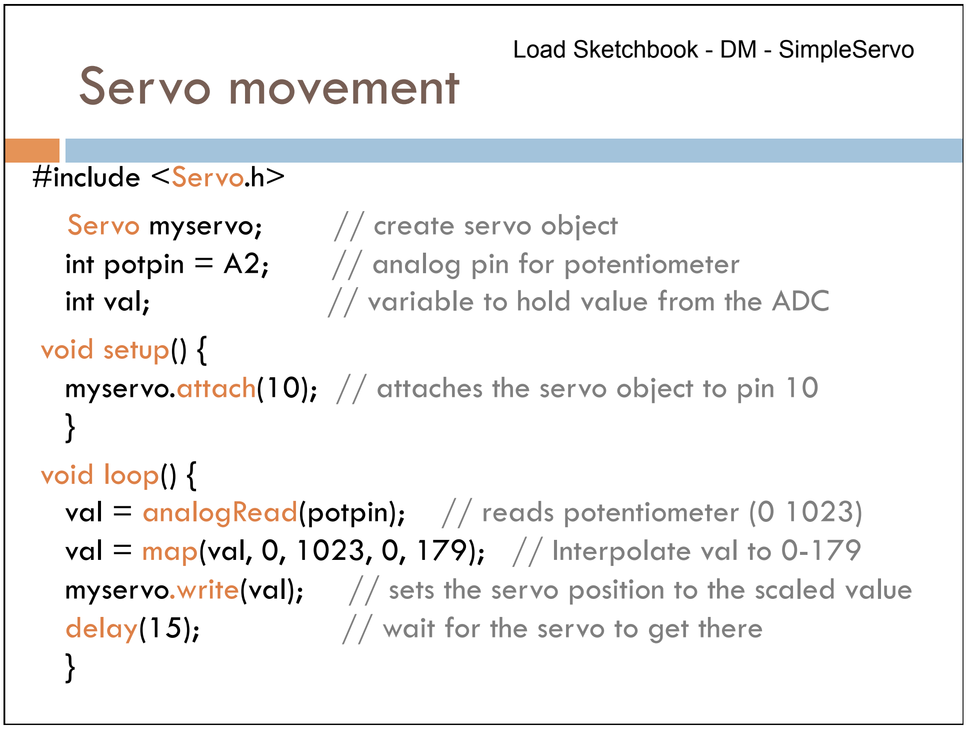


Servo Class Functions

- #include <Servo.h> // include Servo library
- Servo myservo; // creates an instance of Servo class
- myservo.attach(pin); // attach to any digital output pin
- myservo.write(pos); // moves servo from 0-179
  - Servo library can control up to 12 servos on our boards
  - Aside effect is that it disables the PWM on pins 9 and 10



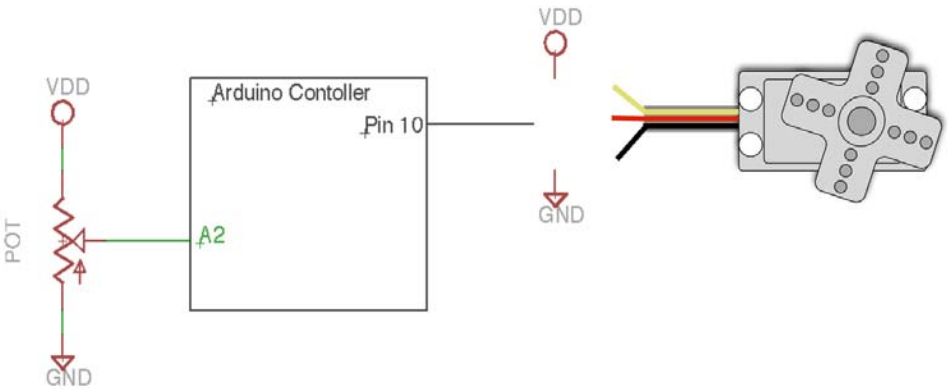
Load Sketchbook - DM - SimpleServo

Servo movement

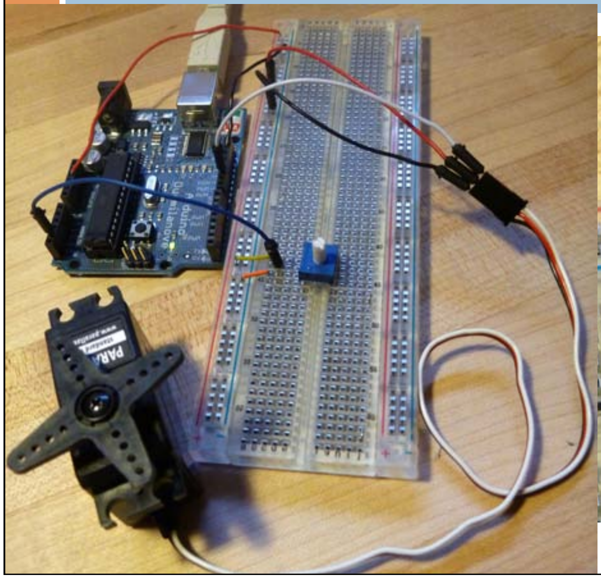
```
#include <Servo.h>
   Servo myservo;          // create servo object
   int potpin = A2;        // analog pin for potentiometer
   int val;                // variable to hold value from the ADC
 void setup() {
   myservo.attach(10);  // attaches the servo object to pin 10
   }
 void loop() {
   val = analogRead(potpin);    // reads potentiometer (0 1023)
   val = map(val, 0, 1023, 0, 179);   // Interpolate val to 0-179
   myservo.write(val);     // sets the servo position to the scaled value
   delay(15);              // wait for the servo to get there
   }
```

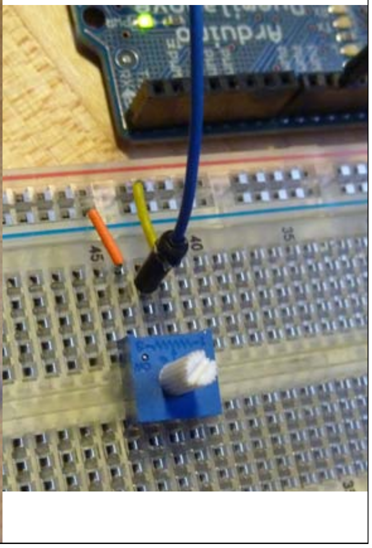
Servo + Potentiometer

Wire this up!   (Vdd is +5)
Run with potFade from the DM examples

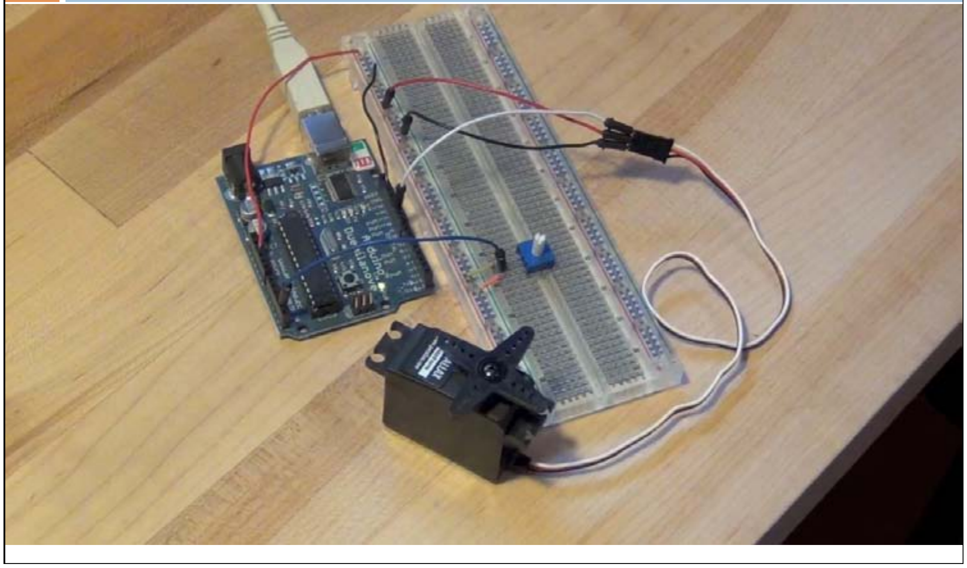


Servo + Potentiometer





Servo + Potentiometer

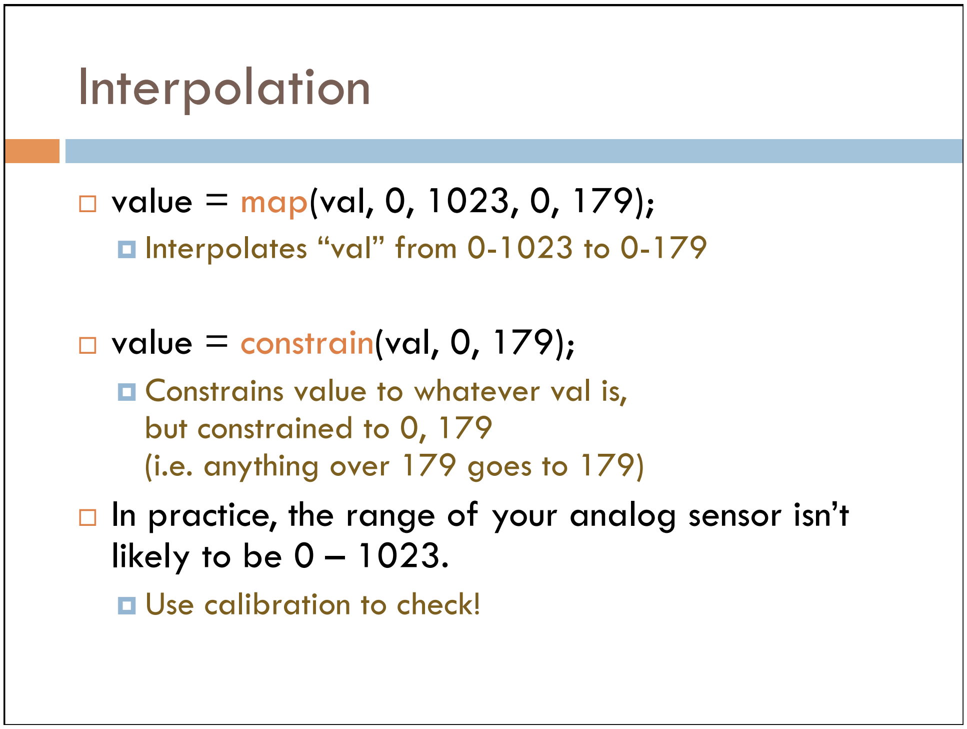


End of Activity Two

□ The pot and the servo are the basic building blocks for our drawing machine

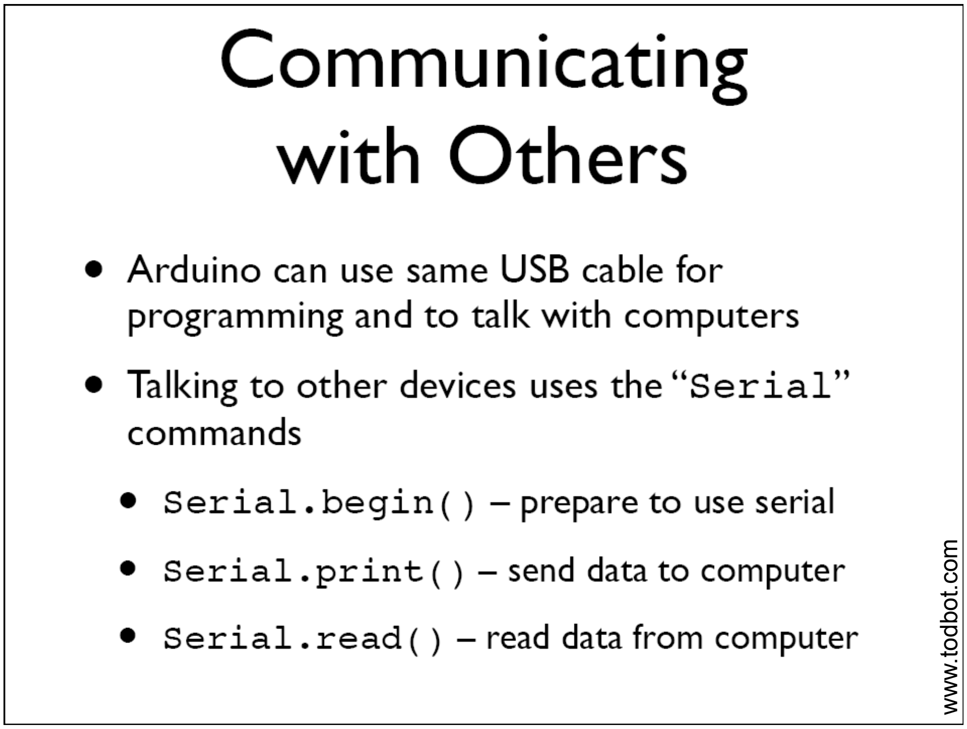
□ There are some additional slides that you can look at later

□ There's a summary at the end of the handout



Interpolation

- □ value = map(val, 0, 1023, 0, 179);
  - Interpolates “val” from 0-1023 to 0-179
- □ value = constrain(val, 0, 179);
  - Constrains value to whatever val is, but constrained to 0, 179 (i.e. anything over 179 goes to 179)
- □ In practice, the range of your analog sensor isn't likely to be 0 – 1023.
  - Use calibration to check!



Communicating with Others

- Arduino can use same USB cable for programming and to talk with computers
- Talking to other devices uses the “`Serial`” commands
  - `Serial.begin()` – prepare to use serial
  - `Serial.print()` – send data to computer
  - `Serial.read()` – read data from computer

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Serial from Arduino to PC

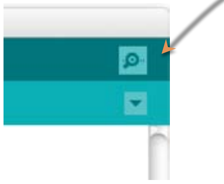
- Serial.begin(baud-rate);
  - baud-rate is 300, 1200, 2400, 4800, 9600, 14400,19200, 28800, 57600, or 115200
  - Sets serial bit rate - Use 9600 to start…
- Serial.print(arg);
  - sends arg to the serial output – can be number or string
- Serial.println(arg);
  - Same, but also prints a newline to the output

Load Sketchbook - DM - HelloWorld

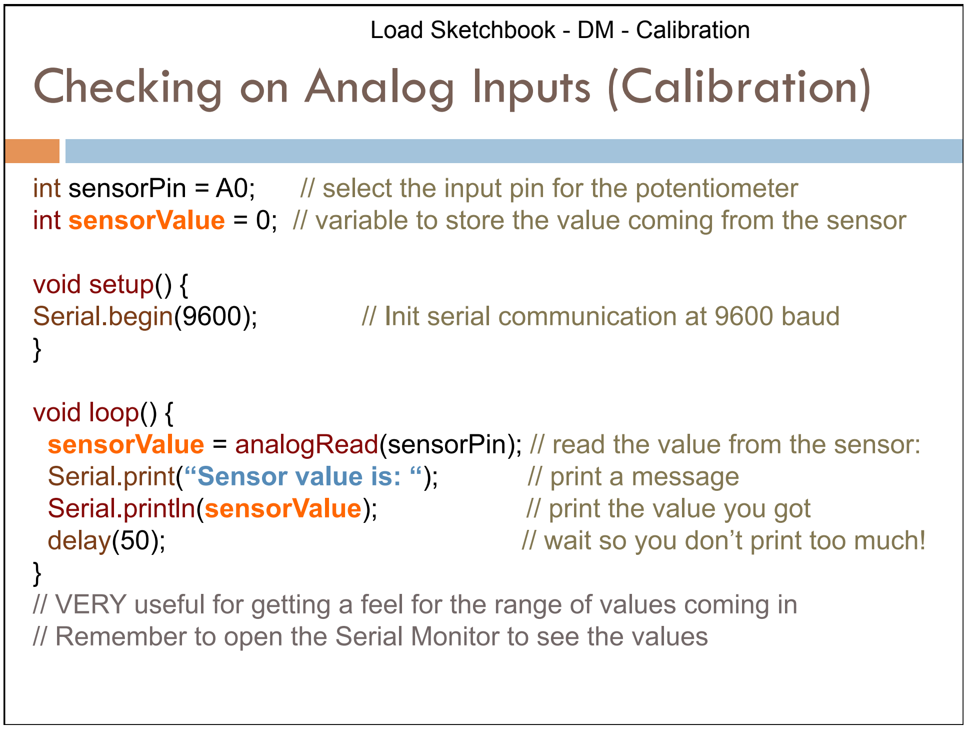
Send data to PC

```
void setup() {
  Serial.begin(9600);   // init the serial port
}

void loop() {
  Serial.println("Hello World!");  // print to the screen!
  delay(500);     // Wait so you don't print too fast
}
```



Opens the “serial monitor” on the host



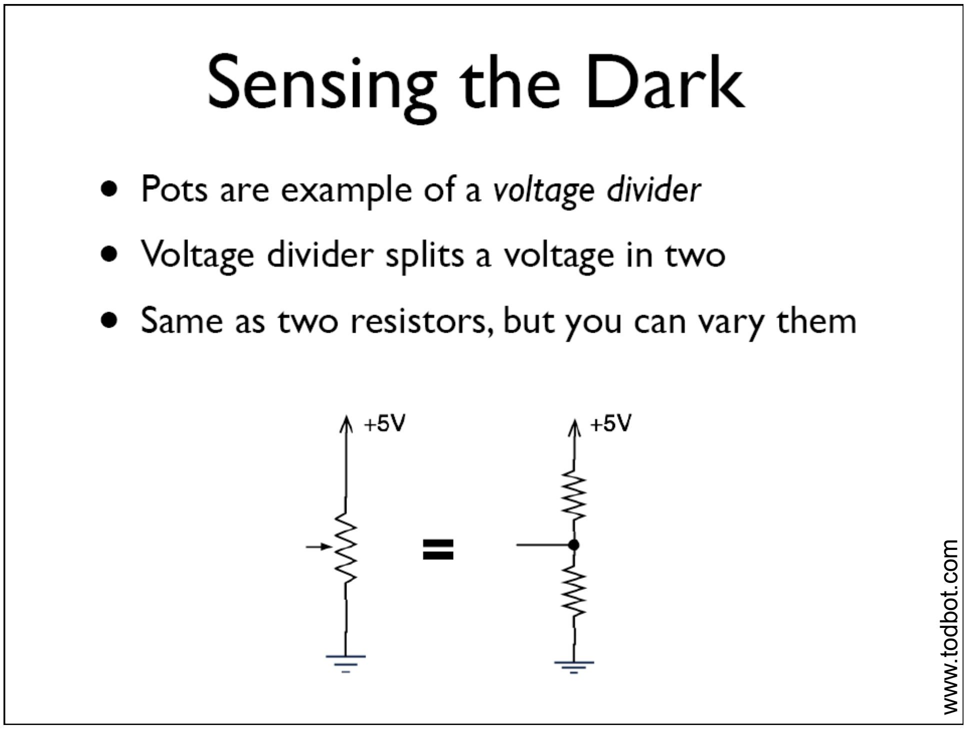
Load Sketchbook - DM - Calibration

Checking on Analog Inputs (Calibration)

```
int sensorPin = A0;      // select the input pin for the potentiometer
int sensorValue = 0;  // variable to store the value coming from the sensor

void setup() {
Serial.begin(9600);             // Init serial communication at 9600 baud
}

void loop() {
  sensorValue = analogRead(sensorPin); // read the value from the sensor:
  Serial.print(“Sensor value is: “);           // print a message
  Serial.println(sensorValue);                  // print the value you got
  delay(50);                                   // wait so you don’t print too much!
}
// VERY useful for getting a feel for the range of values coming in
// Remember to open the Serial Monitor to see the values
```



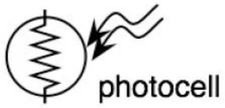
Sensing the Dark

- Pots are example of a *voltage divider*
- Voltage divider splits a voltage in two
- Same as two resistors, but you can vary them

www.todbot.com

Sensing the Dark: Photocells

- aka. photoresistor, light-dependent resistor
- A *variable* resistor
- Brighter light == lower resistance
- Photocells you have range approx. 0-10k



schematic symbol

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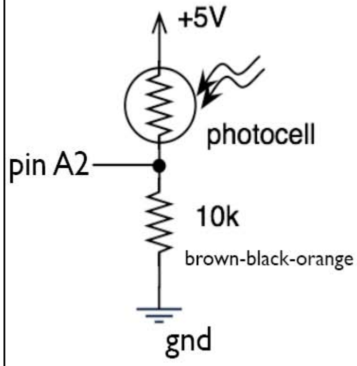
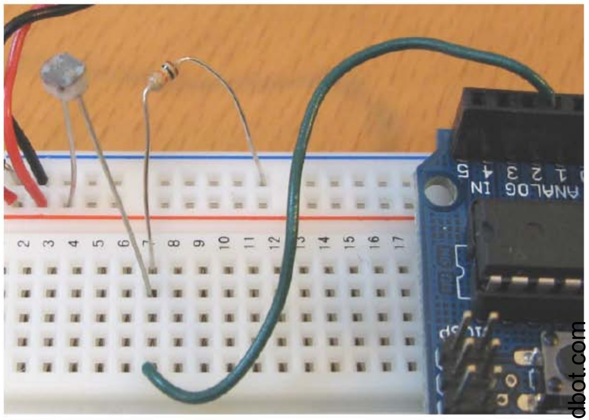
Photocell Circuit





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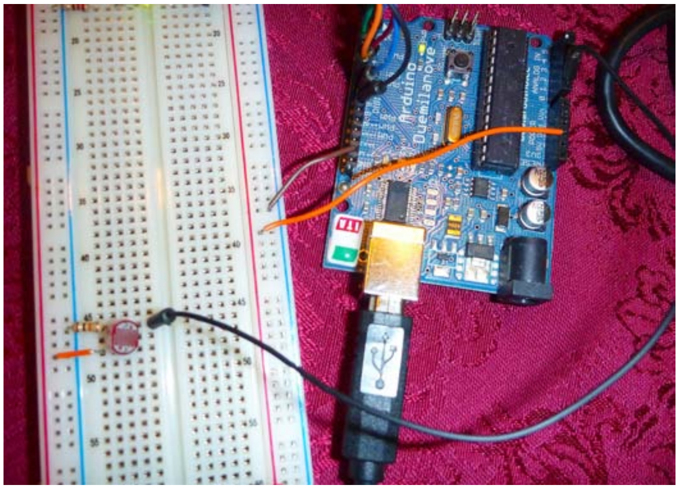
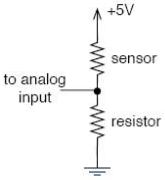
CDS light sensor



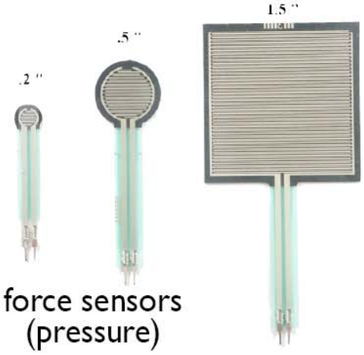
Resistive sensors

thermistor
(temperature)

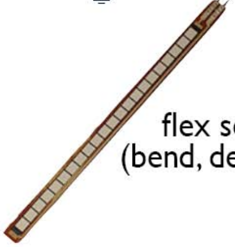
circuit is the same
for all these



photocell
(light)



force sensors
(pressure)



flex sensor
(bend, deflection)

also air pressure
and others

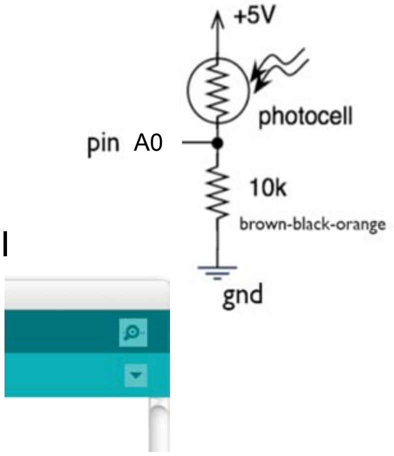
Load Sketchbook - DM - BlinkRate

Use sensor to control blink rate

```
int sensorPin = A0;    // select the input pin for the potentiometer
int ledPin = 13;       // select the pin for the LED
int sensorValue;        // variable to store the value coming from the sensor

void setup() {
pinMode(ledPin, OUTPUT); // declare the ledPin as an OUTPUT:
// Note that you don’t need to declare the Analog pin – it’s always input
}

void loop() {
  sensorValue = analogRead(sensorPin); // read the value from the sensor:

  digitalWrite(ledPin, HIGH); // turn the ledPin on
  delay(sensorValue); // stop the program for <sensorValue> milliseconds:
  digitalWrite(ledPin, LOW); // turn the ledPin off:
  delay(sensorValue); // stop the program for for <sensorValue> milliseconds:
}
```

Load Calibration (prev. page)

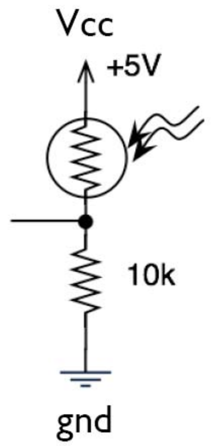
- Wire a pot or a light sensor using a 10k resistor
  - Put the middle point on Analog pin A0
- Upload, and click on the Serial Monitor once it’s loaded
- Turn the knob, or block the light sensor, and note what range of values you see

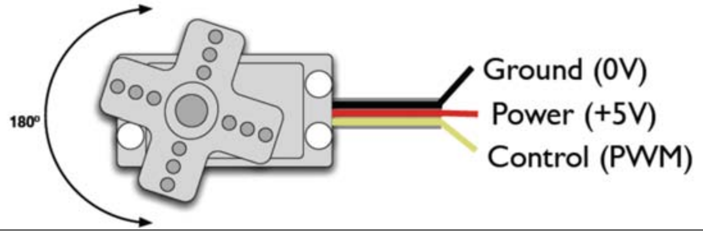


Remember this calibration technique!

Servo/Light Practice

- □ Use a photocell on the input
  - put in series with 10k ohm resistor
- □ Use a servo on the output
  - create a servo object
- □ make the servo do something in response to the amount of light falling on the photocell



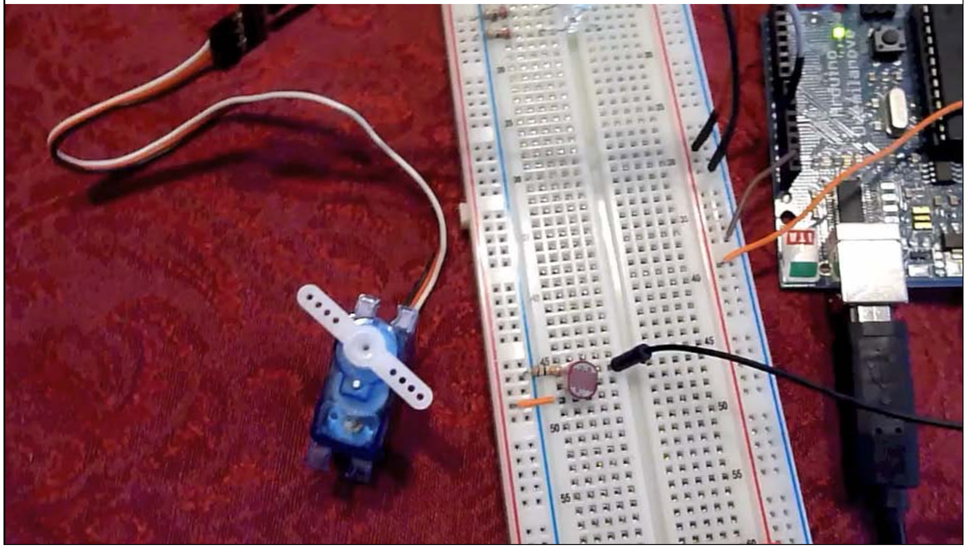


With Calibration

Load Sketchbook - ServoCalibration

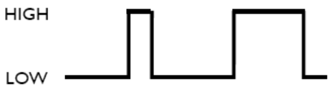
```
#include <Servo.h>
  Servo myservo;       // create servo object to control a servo
    int sensorPin = A0;  // analog pin used to connect the potentiometer
    int sensorVal;       // variable to read the value from the analog pin
    int scaledVal;       // variable to hold the mapped and constrained value
 void setup() {
    myservo.attach(9);  // attaches the servo object control wire to pin 9
    Serial.begin(9600);      // init the serial port at 9600 baud
    }
void loop() {
    sensorVal = analogRea(sensorPin);            // read the value of the sensor
    scaledVal = map(sensorVal, 0, 1023, 0, 179);  // scale it to use it with the servo
    scaledVal = constrain(scaledVal, 0, 179);     // make sure it stays in range

    Serial.print("sensor = " );        // This print section is used for calibration
    Serial.print(sensorVal);           // Write down the values you see from the sensor
    Serial.print("\t output = ");      // and replace the "0, 1023" above with the
    Serial.println(scaledVal);         // range of values you actually see
  myservo.write(scaledVal);  // sets the servo position according to the scaled value

    delay(20);                   // wait for the servo to get there
    }
```

Sensor/Servo Coordination



Getting Input (Digital)

- Switches make or break a connection
- But Arduino wants to see a voltage
  - Specifically, a "HIGH" (5 volts)
  - or a "LOW" (0 volts)



How do you go from make/break to high/low?

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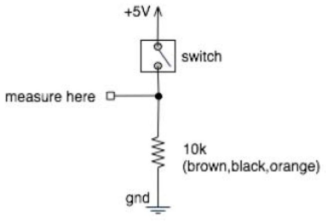
Switches

- Digital inputs can "float" between 0 and 5 volts
- Resistor "pulls down" input to ground (0 volts)
- Pressing switch sets input to 5 volts
- Press is HIGH
  Release is LOW



"pull-down"

Why do we need the "pull down" resistor?

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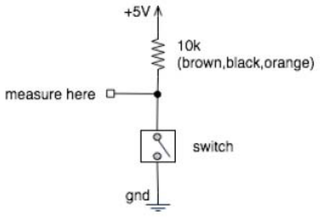
Another Switch

- Resistor pulls up input to 5 volts
- Switch sets input to 0 volts
- But now the sense is inverted
  - Press is LOW
  - Release is HIGH



"pull-up"

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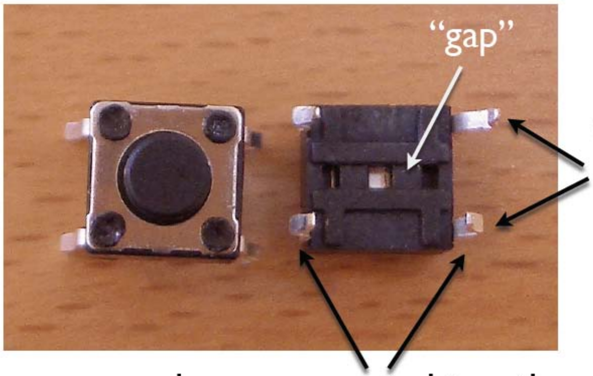
A Switch



“gap”

connect when pushed

always connected together

Pressing the button, “closes the gap”

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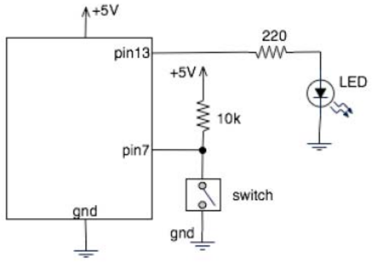
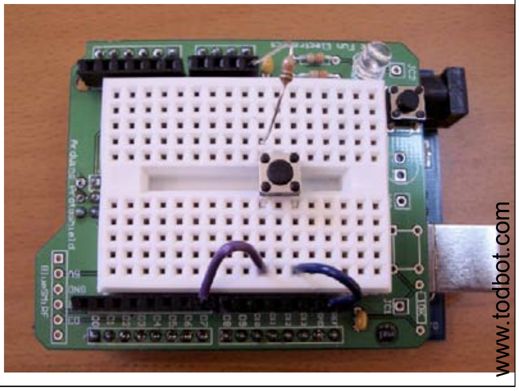
Using a Switch





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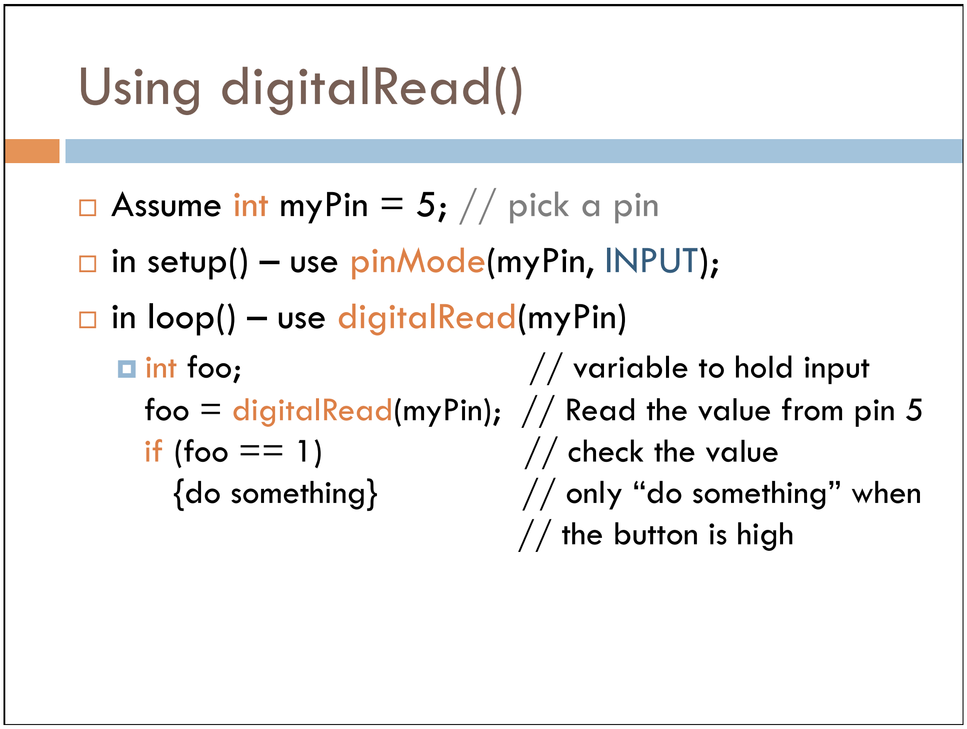
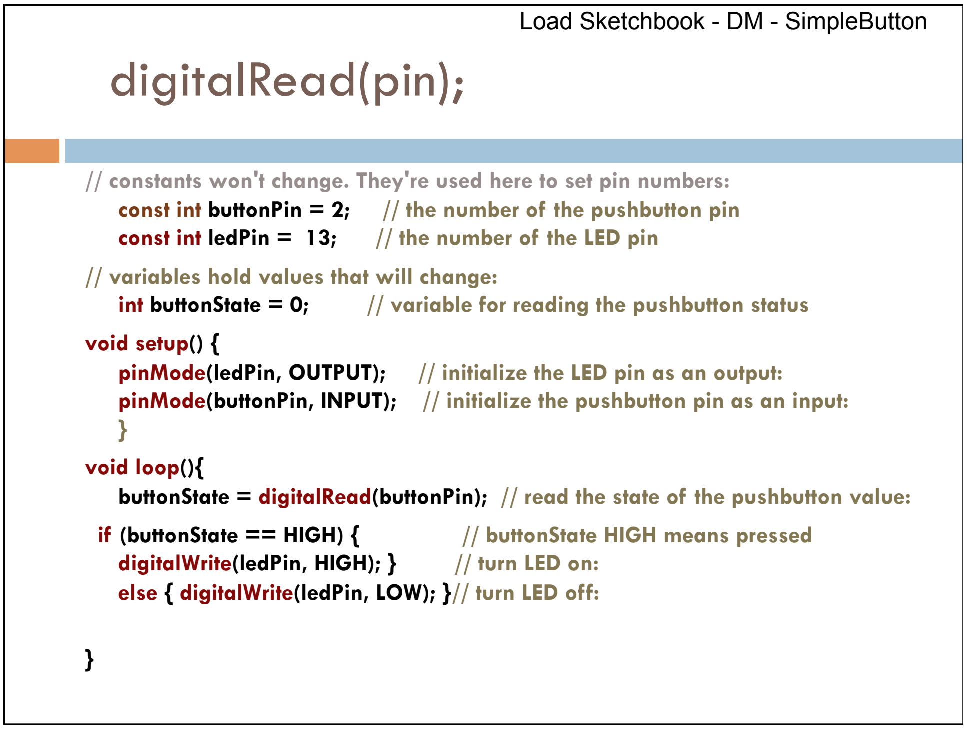


Using digitalRead()

- Assume int myPin = 5; // pick a pin
- in setup() – use pinMode(myPin, INPUT);
- in loop() – use digitalRead(myPin)

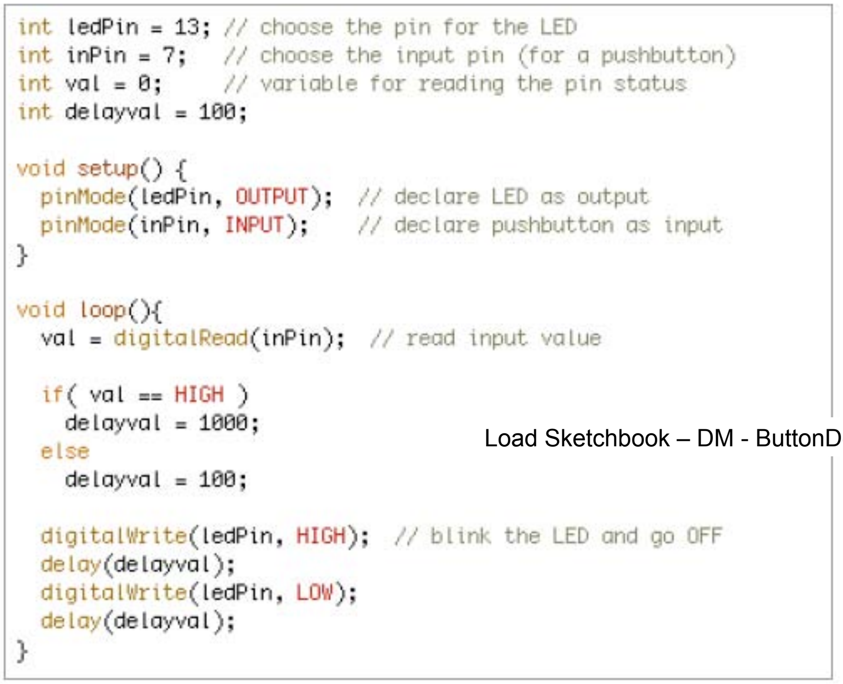
```
int foo;                    // variable to hold input
foo = digitalRead(myPin);  // Read the value from pin 5
if (foo == 1)              // check the value
   {do something}          // only “do something” when
                           // the button is high
```



Load Sketchbook - DM - SimpleButton

digitalRead(pin);

```
// constants won't change. They're used here to set pin numbers:
    const int buttonPin = 2;     // the number of the pushbutton pin
    const int ledPin =  13;      // the number of the LED pin

// variables hold values that will change:
    int buttonState = 0;         // variable for reading the pushbutton status

void setup() {
    pinMode(ledPin, OUTPUT);     // initialize the LED pin as an output:
    pinMode(buttonPin, INPUT);   // initialize the pushbutton pin as an input:
    }

void loop(){
    buttonState = digitalRead(buttonPin);  // read the state of the pushbutton value:

  if (buttonState == HIGH) {             // buttonState HIGH means pressed
    digitalWrite(ledPin, HIGH); }        // turn LED on:
    else { digitalWrite(ledPin, LOW); }// turn LED off:

}
```



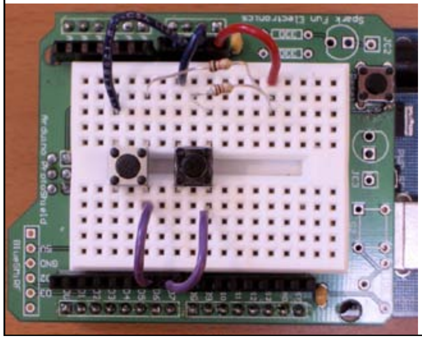
```
int ledPin = 13; // choose the pin for the LED
int inPin = 7;   // choose the input pin (for a pushbutton)
int val = 0;     // variable for reading the pin status
int delayval = 100;

void setup() {
  pinMode(ledPin, OUTPUT);  // declare LED as output
  pinMode(inPin, INPUT);    // declare pushbutton as input
}

void loop(){
  val = digitalRead(inPin);  // read input value

  if( val == HIGH )
    delayval = 1000;
  else
    delayval = 100;

  digitalWrite(ledPin, HIGH);  // blink the LED and go OFF
  delay(delayval);
  digitalWrite(ledPin, LOW);
  delay(delayval);
}
```

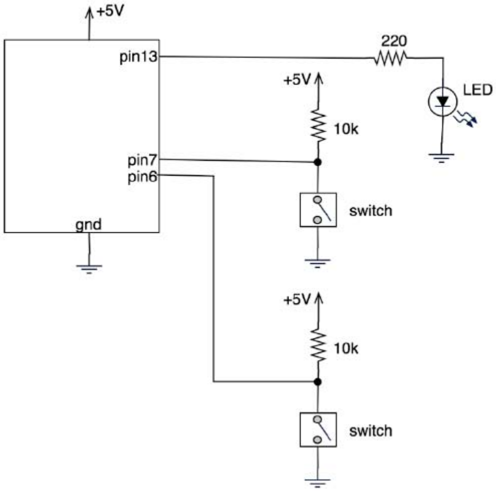
Load Sketchbook – DM - ButtonDelay

Multiple Switches

Just like an LED – each switch needs its own resistor.

Same sub-circuit, just duplicate





Make Your Own Switches

- Anything that makes a connection
- Wires, tin foil, tinfoil balls, ball bearings
- Pennies!
- Nails, bolts, screws

- Or repurpose these tiny switches as bump detectors or closure detectors

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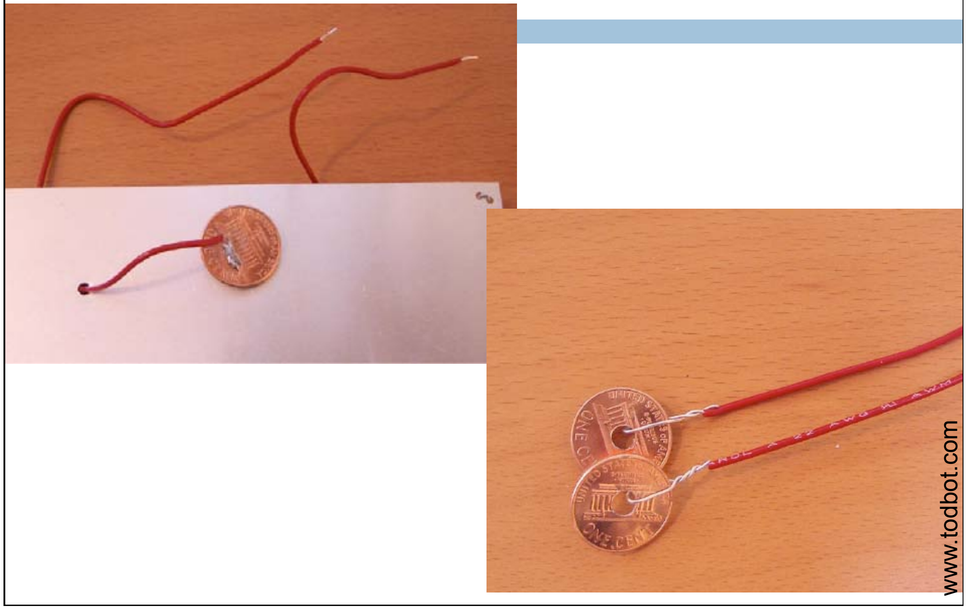
Make Your Own Switches



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Side Note - Power

- Servos can consume a bit of power
  - We need to make sure that we don't draw so much power out of the Arduino that it fizzles
  - If you drive more than a few servos, you probably should put the servo power pins on a separate power supply from the Arduino
  - Use a wall-wart 5v DC supply, for example
  - Not necessary for what we're up to today!

Summary – Whew!

- LEDs – use current limiting resistors (220Ω to 470Ω) (remember color code!)
  - drive from digitalWrite(pin, val); for on/off
  - drive from analogWrite(pin, val); for PWM dimming (values from 0-255)
- buttons – current limiting resistors again (10k Ω)
  - active-high or active low (pullup or pulldown)
  - read with digitalRead(pin);
- potentiometers (pots)– voltage dividers with a knob
  - use with analogRead(pin); for values from 0-1023

Summary – Whew!

- photocells – variable resistors
  - use with current-limiting resistors (1k-10k) (to make voltage divider)
- Serial communications – write a value to the host
  - communicate to the Arduino environment, or your own program
- Servos – use Servo library to control motion
  - might need external power supply
  - range of motion 0-180°
- Also setup( ) and loop( ) functions, and various libraries

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