SIGGRAPH2015
Xroads of Discovery

The 42nd International Conference and Exhibition
on Computer Graphics and Interactive Techniques

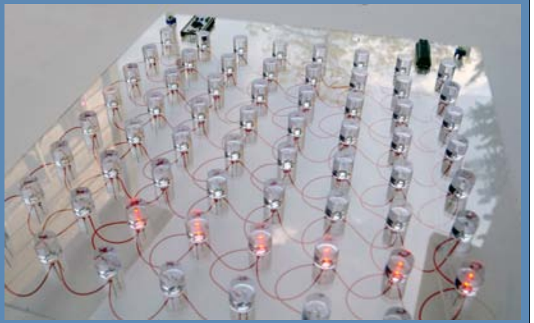
THE UNIVERSITY OF UTAH

Kinetic Sculptures:
Creating Programmable Art

Erik Brunvand
University of Utah

Context - Arts/Technology Collaborations

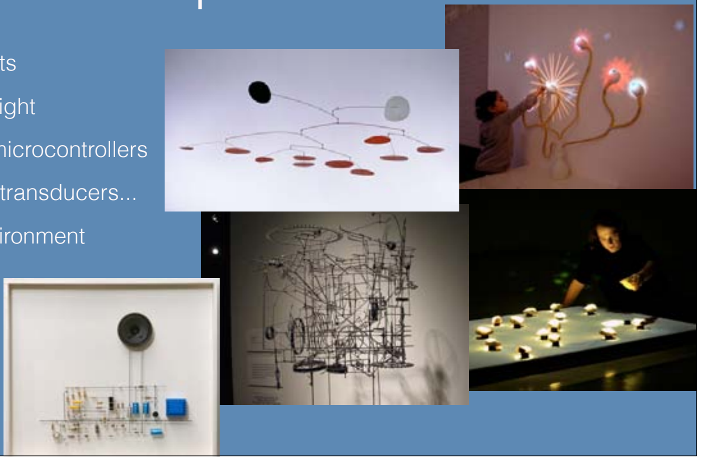
I argue that arts/technology collaboration is a powerful framework for enhancing ideas in both arenas



Serpente Rosso, 2013

Kinetic Sculpture

- Contains moving parts
  - Motion, sound, or light
- Often controlled by microcontrollers
  - Motors, actuators, transducers...
- Often reactive to environment

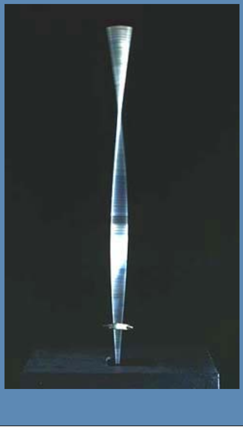


Naum Gabo

Russian - 1890-1977

Kinetic Construction (Standing Wave)

1919-1920

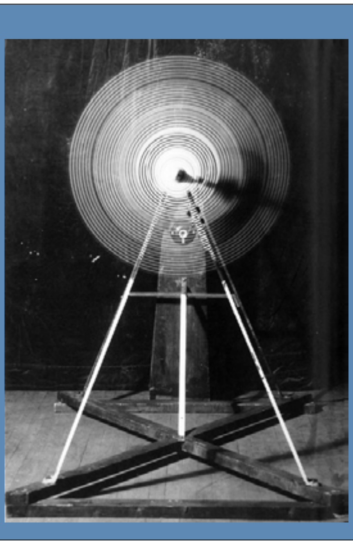


Marcel Duchamp

French (naturalized US) 1887- 1968

Rotary Glass Plates
1920

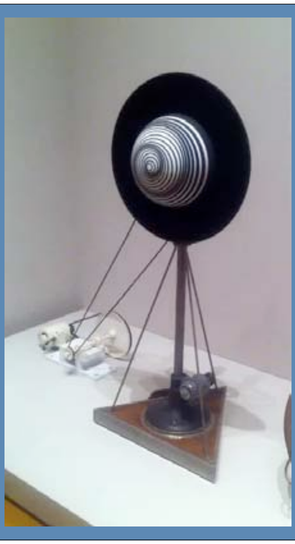
Built with the help
of Man Ray



Marcel Duchamp

French (naturalized US) 1887- 1968

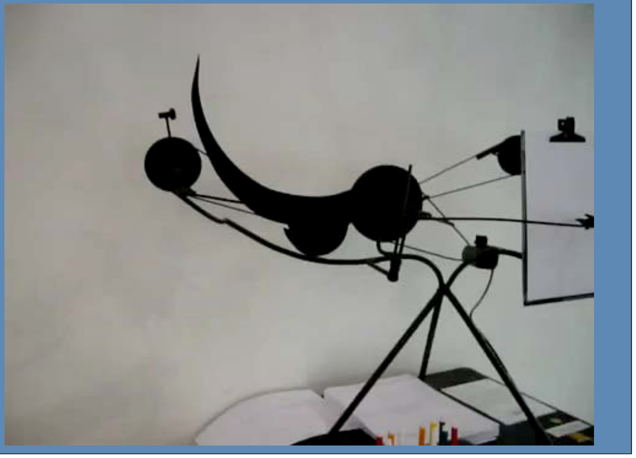
Rotary Demisphere
(Precision Optics)
1925



Jean Tinguely

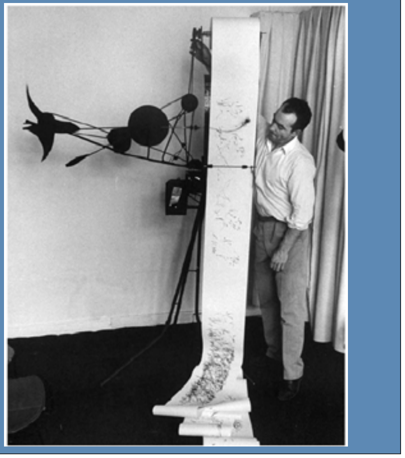
Swiss - 1925 - 1991

Metamatic - 1959

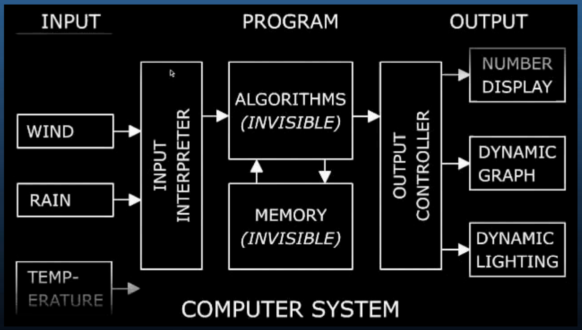


Jean Tinguely

Swiss - 1925 - 1991



Jim Campbell's Algorithm

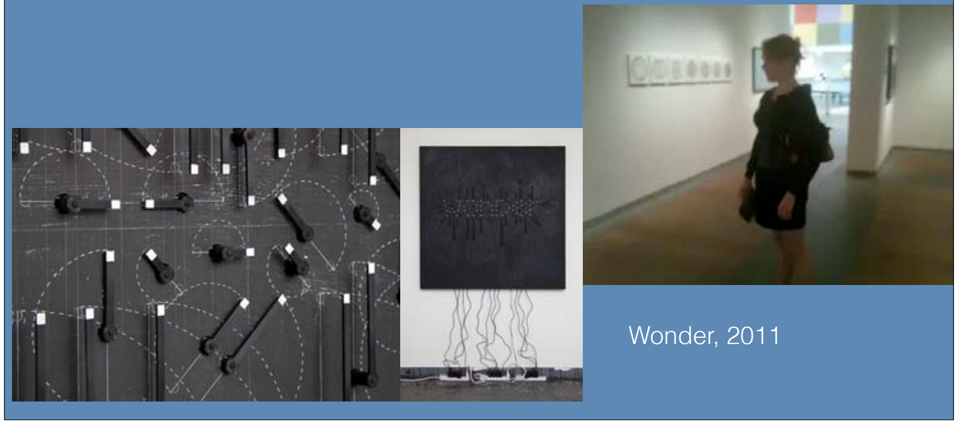

INPUT
PROGRAM
OUTPUT
WIND
RAIN
TEMP-
ERATURE
INPUT INTERPRETER
ALGORITHMS *(INVISIBLE)*
MEMORY *(INVISIBLE)*
OUTPUT CONTROLLER
NUMBER DISPLAY
DYNAMIC GRAPH
DYNAMIC LIGHTING
COMPUTER SYSTEM

Jim Campbell

US - b. 1956

Alicia Eggert

US - b. 1981

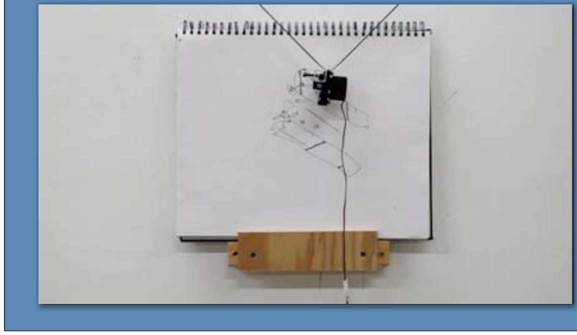


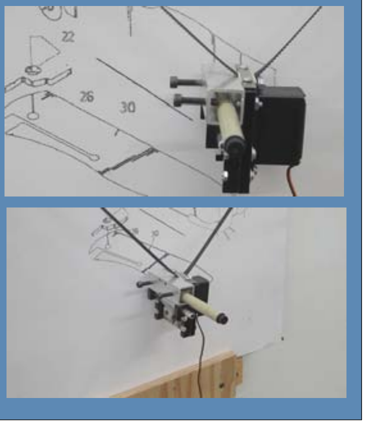
Wonder, 2011

Robert Twomey

US - b. 1979

Drawing Machine - 2013
Showed at SIGGRAPH 2013

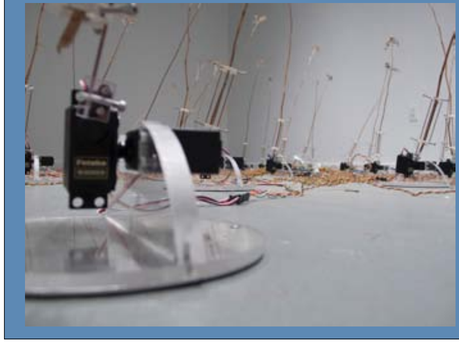




David Bowen

US - b. 1975

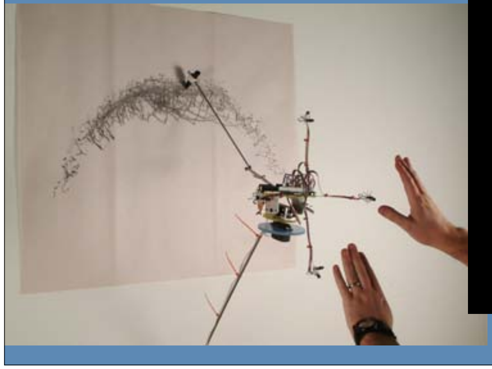
Telepresent Wind (2009)
Showed at SIGGRAPH 2011



telepresent wind
2009

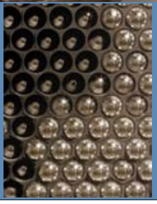
David Bowen

Infrared Drawing Machine (2003)



Daniel Rozen

US - b. 1961

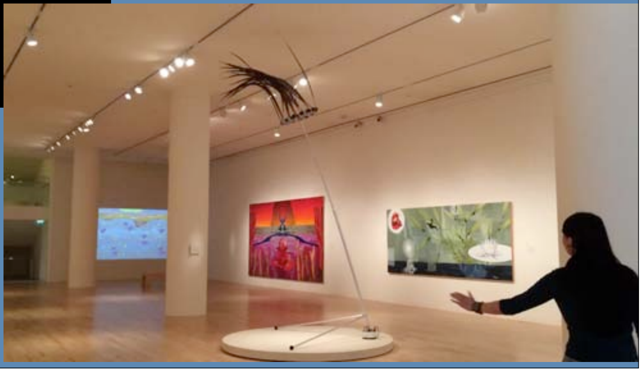


rAndom International

London-based collective

Audience (2008)

Alan Rath



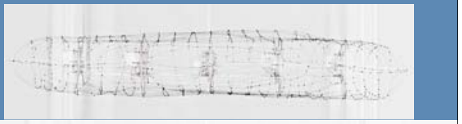
US - b. 1959

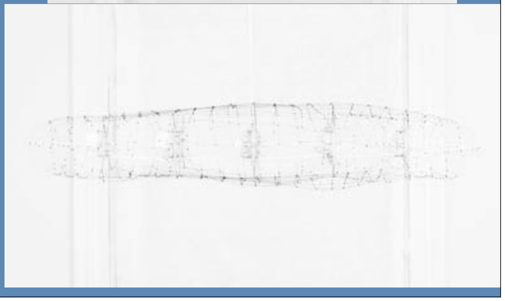
Forever (2012)
Absolutely (2012)

James Leng

Point Cloud, 2012

Architect in LA

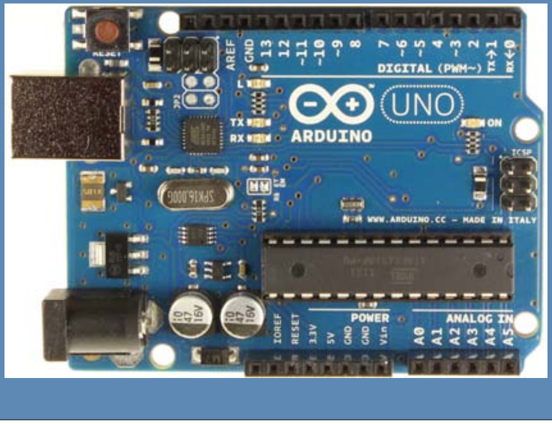


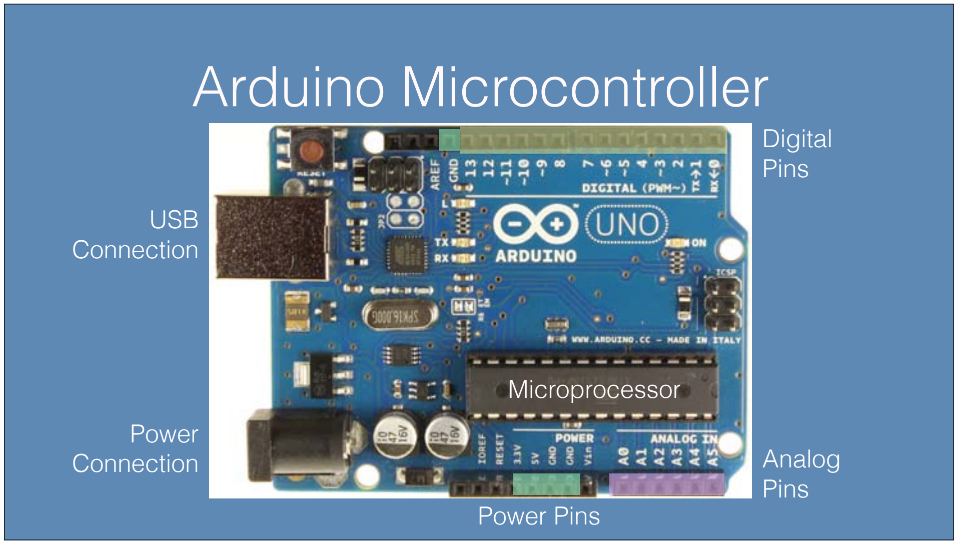


Physical Computing Essentials

- *Get some input from the environment*
  - Light, motion, heat, etc.
- *Cause something to happen*
  - Make something move!

Arduino Microcontroller





Arduino Microcontroller

USB Connection

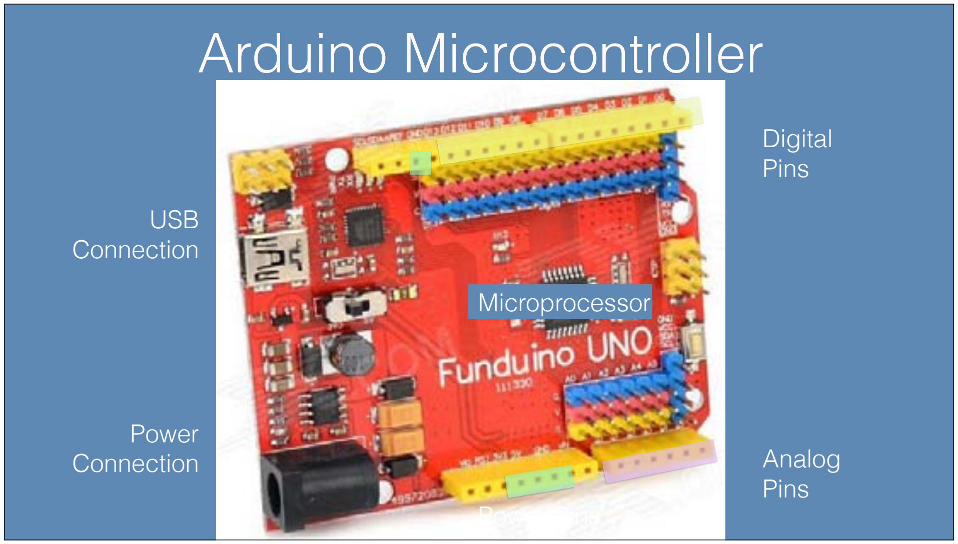
Power Connection

Microprocessor

Digital Pins

Analog Pins

Power Pins



Arduino Microcontroller

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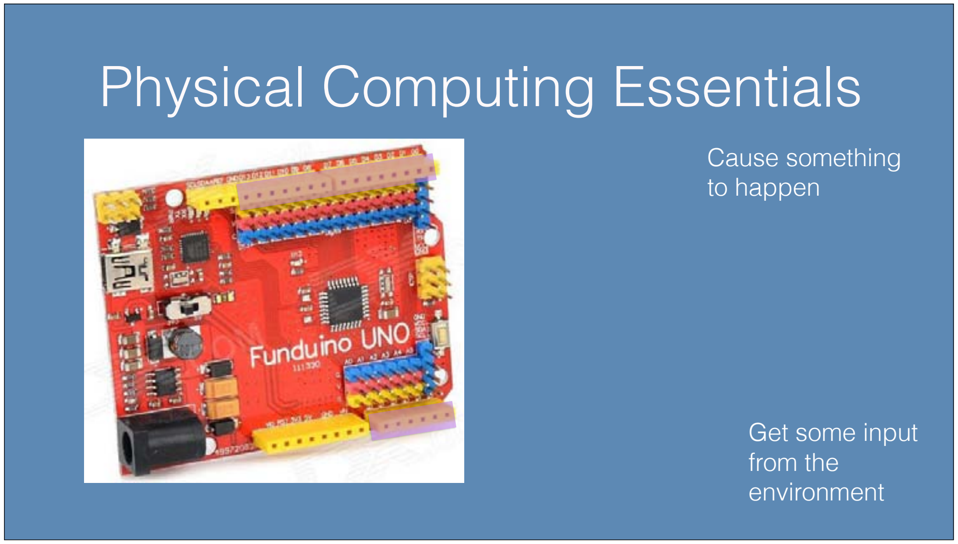
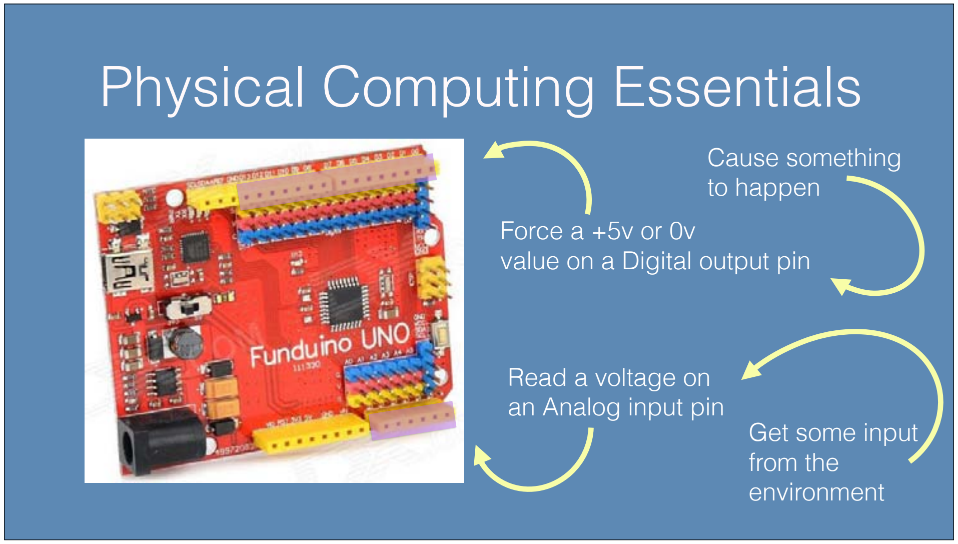


Physical Computing Essentials

Cause something to happen

Get some input from the environment



Physical Computing Essentials

Cause something to happen

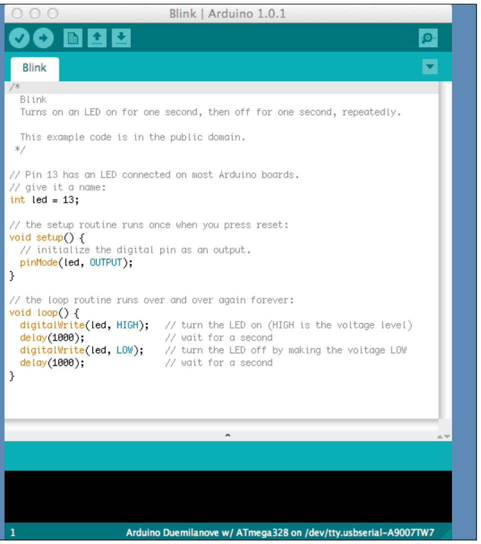
Force a +5v or 0v value on a Digital output pin

Read a voltage on an Analog input pin

Get some input from the environment

Arduino Programming Environment

- www.arduino.cc
  - Simple open source IDE
  - Arduino code is really C/C++
  - avr-gcc is the back end


Blink | Arduino 1.0.1
Blink
1
Arduino Duemilanove w/ ATmega328 on /dev/tty.usbserial-A9007TW7

```
/*
  Blink
  Turns on an LED on for one second, then off for one second, repeatedly.

  This example code is in the public domain.
 */

// Pin 13 has an LED connected on most Arduino boards.
// give it a name:
int led = 13;

// the setup routine runs once when you press reset:
void setup() {
  // initialize the digital pin as an output.
  pinMode(led, OUTPUT);
}

// the loop routine runs over and over again forever:
void loop() {
  digitalWrite(led, HIGH);   // turn the LED on (HIGH is the voltage level)
  delay(1000);               // wait for a second
  digitalWrite(led, LOW);    // turn the LED off by making the voltage LOW
  delay(1000);               // wait for a second
}
```

Physical Computing Essentials

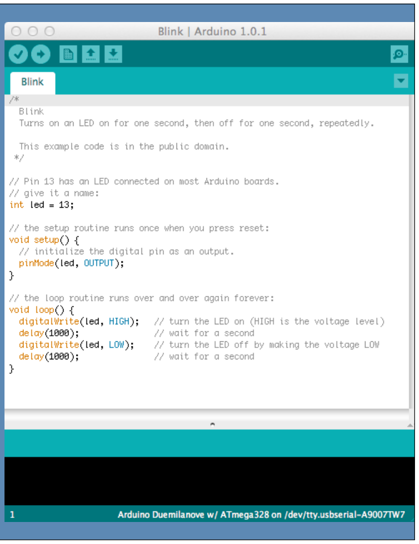
- **pinMode(pinNumber, mode);** // declare a pin INPUT or OUTPUT
- **digitalRead(pinNumber);** // read the HIGH/LOW status of pin
- **digitalWrite(pinNumber, value);** // force a pin HIGH/LOW
- **delay(milliseconds);** // delay processing (spin wait)

Physical Computing Essentials

- Each of the digital pins can be set to one of two values
  - High and Low (logic 1 (+5v) and logic 0 (0v))
- **digitalWrite(<pin-number>, <value>);**
  - **digitalWrite(13, HIGH);**
    digitalWrite(13, 1);
  - **digitalWrite(13, LOW);**
    digitalWrite(13, 0);

Arduino Programming

- Two required functions
  - **void setup(){...}** // Runs once at startup
  - **void loop(){...}** // Loops forever after setup()
- Standard(ish) C/C++ data types
  - Boolean (1 bit)
  - char (signed 8 bits), byte (unsigned 8 bits)
  - int (16 bits), long (32 bits)
  - float (32 bits), double (32 bits)


Blink | Arduino 1.0.1
Blink
1
Arduino Duemilanove w/ ATmega328 on /dev/tty.usbserial-A9007TW7

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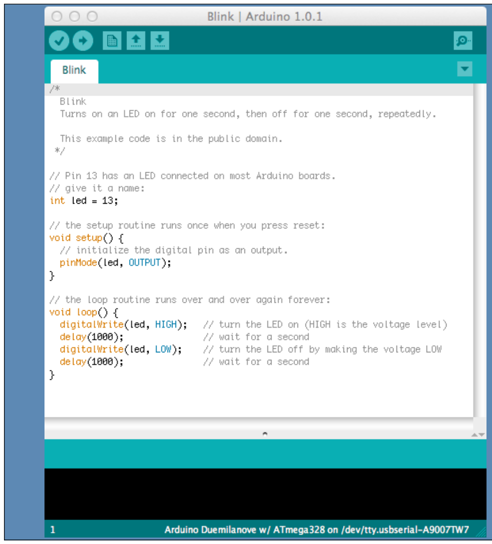
```



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  delay(1000);               // wait for a second
}
```
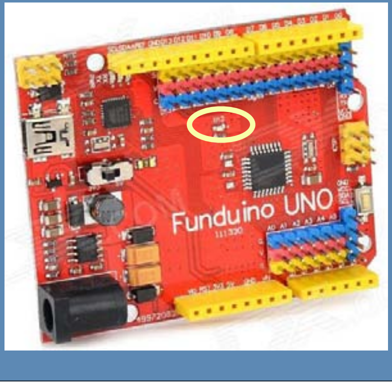

1 Arduino Duemilanove w/ ATmega328 on /dev/tty.usbserial-A9007TW7

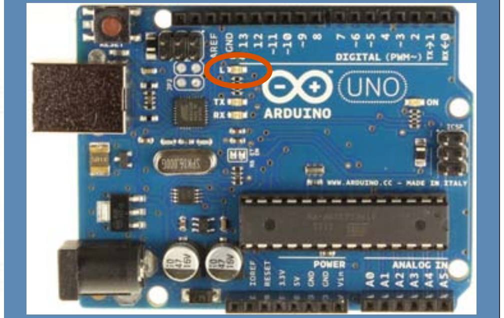
Example: Blink

```
int led = 13;

void setup() { // make pin 13 an output
  pinMode(led, OUTPUT);
}

void loop() {  // turn pin on and off
  digitalWrite(led, HIGH);
  delay(1000);  // delay argument is in ms
  digitalWrite(led, LOW);
  delay(1000);
}
```

What's Blinking?

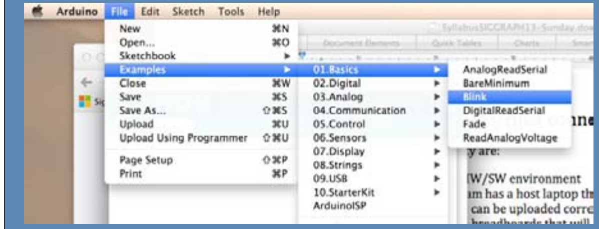
Built-in LED connected to pin 13

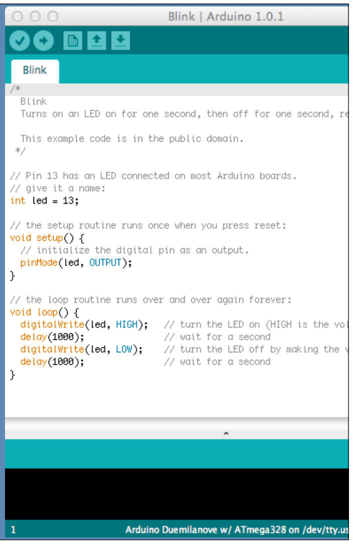




Upload Blink to Arduino

- Load the Blink program from Examples -> Basics -> Blink
- Connect your Arduino with the USB cable





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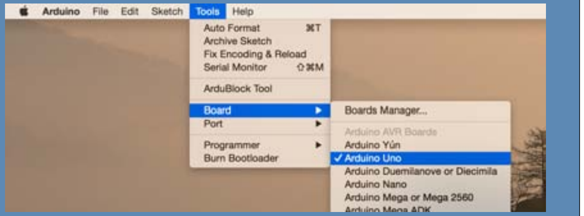
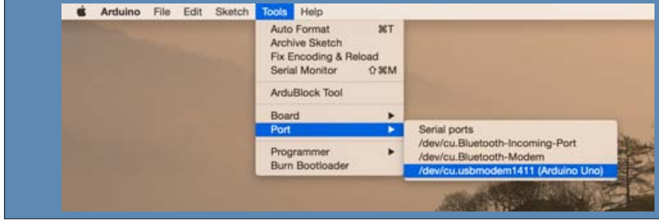
```

1 Arduino Duemilanove w/ ATmega328 on /dev/tty.us

Upload Blink to Arduino

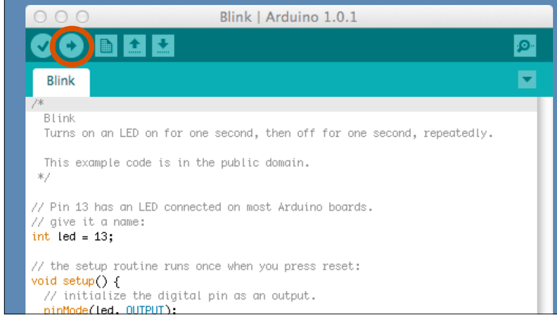
- Make sure you select the correct board
- Tools -> Board -> Uno
- Make sure you select the correct serial port
  - Not the bluetooth ports…





Upload Blink to Arduino

- Click on the upload button
  - Watch for blinky lights during upload



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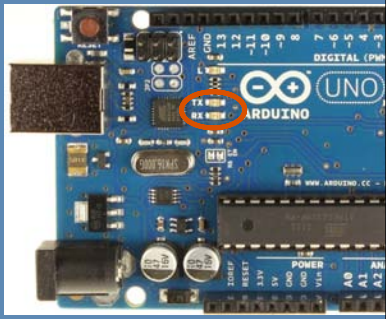

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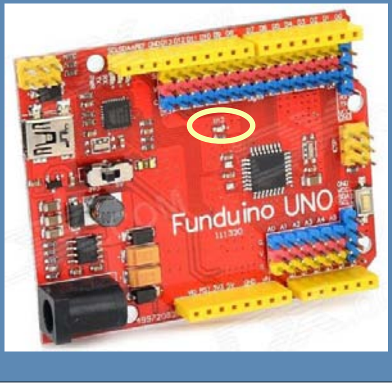
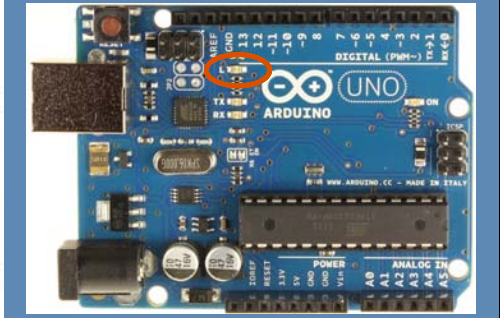


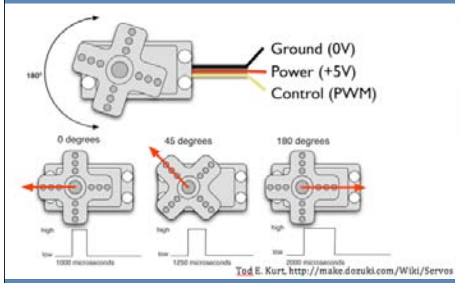


Big Deal?

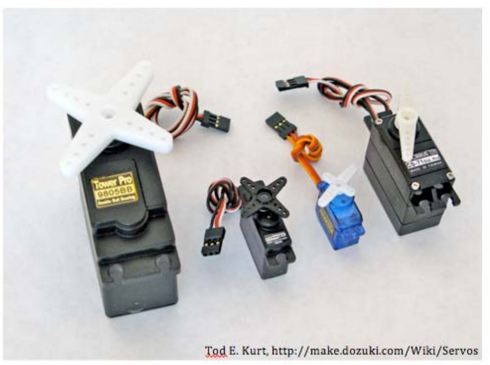
If you can blink an LED
you can control the world!

Turning a pin on and off can
control all sorts of external
devices…

Hobby Servos

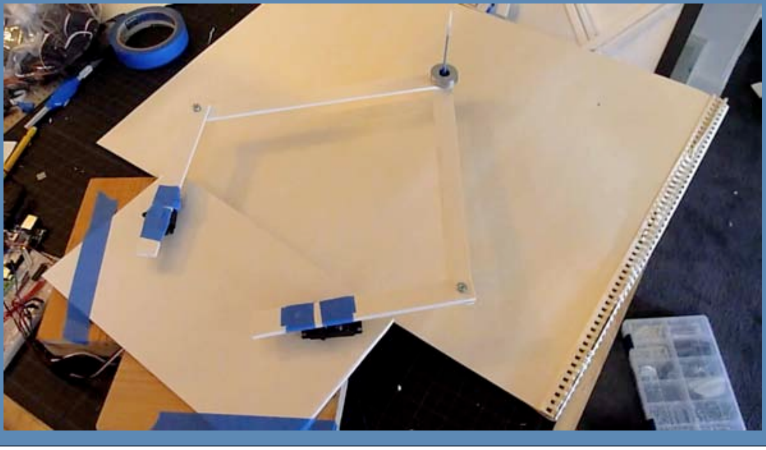


Tod E. Kurt, http://make.dozuki.com/Wiki/Servos



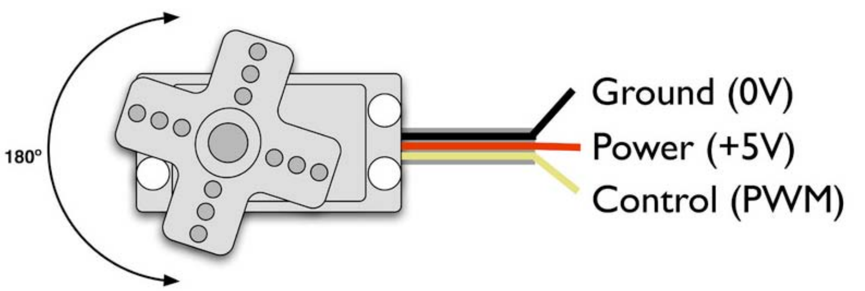
Tod E. Kurt, http://make.dozuki.com/Wiki/Servos

Arduino-Controlled Motion

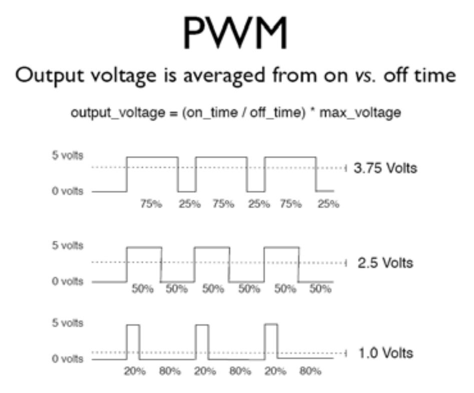


Controlling a Servo

- Pulse Width Modulation (PWM)



Pulse Width Modulation

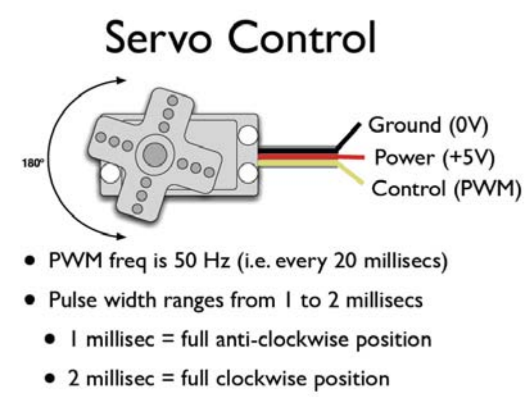


PWM

Output voltage is averaged from on *vs.* off time

output_voltage = (on_time / off_time) * max_voltage

Controlling a Servo

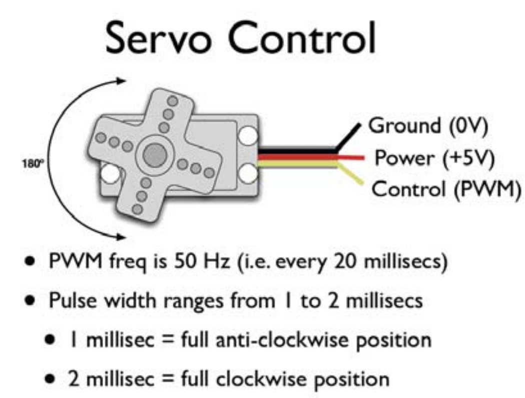


Servo Control

- 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

Controlling a Servo

Luckily you don't really need to know any of this!



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

There's built-in Arduino code for driving servos!

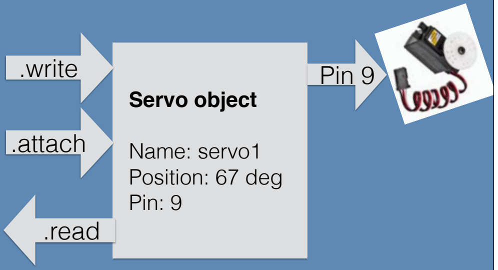
Servo Object (Class Instance)

```
#include <Servo.h>   // include servo library

Servo servo1;         // create servo object

void setup() {
   servo1.attach(9);   // attach to pin 9
}

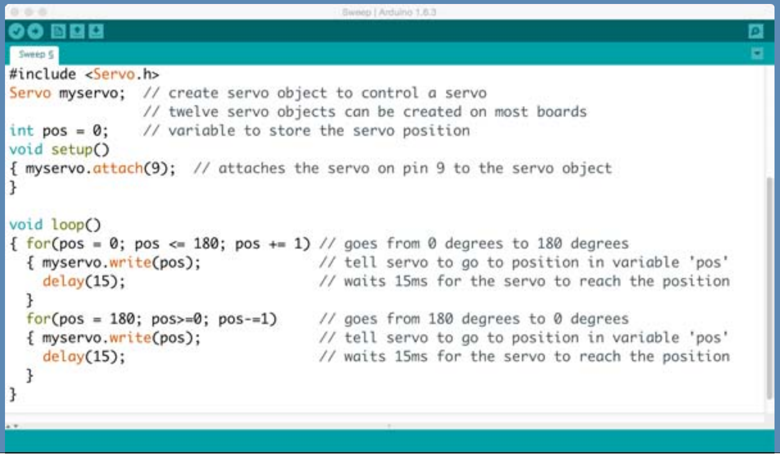
void loop() {
   servo1.write(67);  // move to 67 degrees
   delay(100);         // give it time to move
}
```



Servo Functions (C++ Class)

- **Servo myServo;** // creates an instance of Servo class named "myServo"
- **myServo.attach(pin);** // attach myServo to a digital output pin
  - doesn't need to be PWM pin - can be anything from 0-13
  - Servo library can control up to 12 servos on our boards
  - a side effect is that it disables the PWM on pins 9 and 10
- **myServo.write(pos);** // moves myServo – pos ranges from 0-179
- **myServo.read();** // returns current position of myServo (0-179)

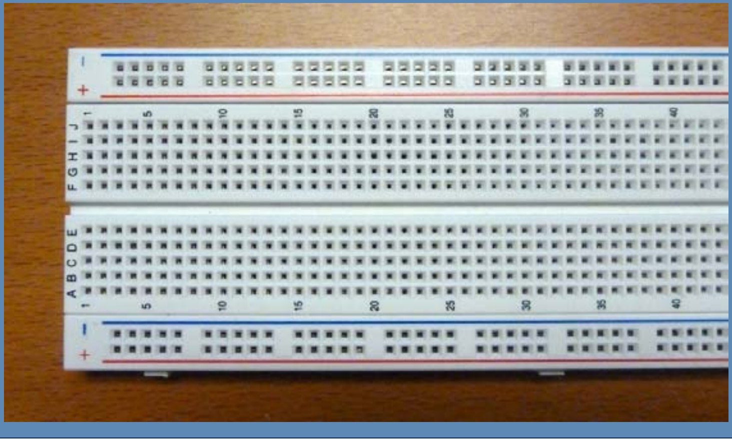
Controlling a Servo



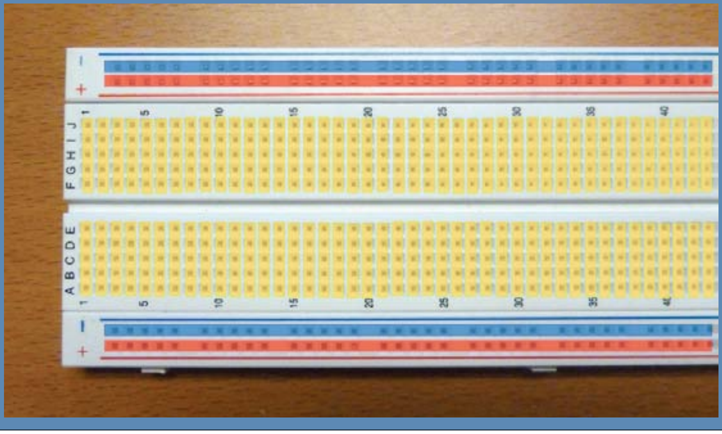
```
#include <Servo.h>
Servo myservo;  // create servo object to control a servo
                // twelve servo objects can be created on most boards
int pos = 0;    // variable to store the servo position
void setup()
{ myservo.attach(9);  // attaches the servo on pin 9 to the servo object
}

void loop()
{ for(pos = 0; pos <= 180; pos += 1) // goes from 0 degrees to 180 degrees
  { myservo.write(pos);              // tell servo to go to position in variable 'pos'
    delay(15);                       // waits 15ms for the servo to reach the position
  }
  for(pos = 180; pos>=0; pos-=1)     // goes from 180 degrees to 0 degrees
  { myservo.write(pos);              // tell servo to go to position in variable 'pos'
    delay(15);                       // waits 15ms for the servo to reach the position
  }
}
```

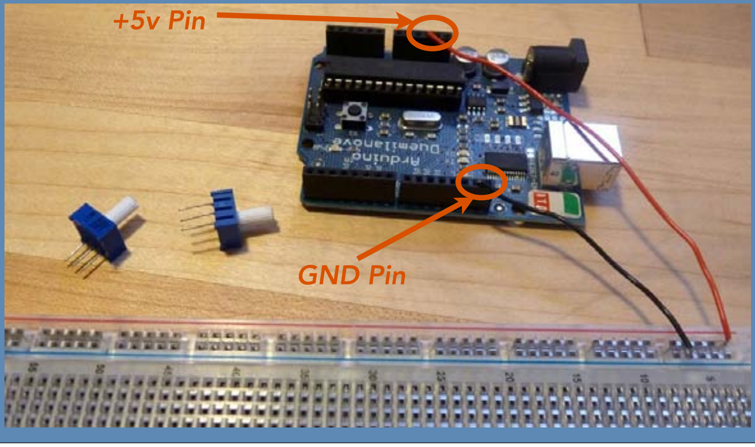
Solderless Breadboard



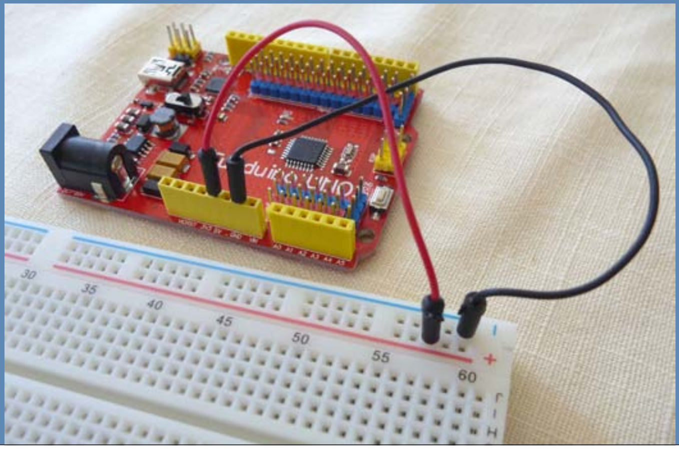
Solderless Breadboard



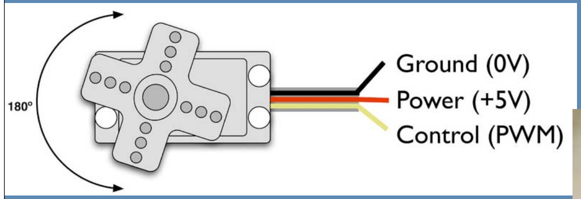
Connecting Power and Ground



Connecting Power and Ground

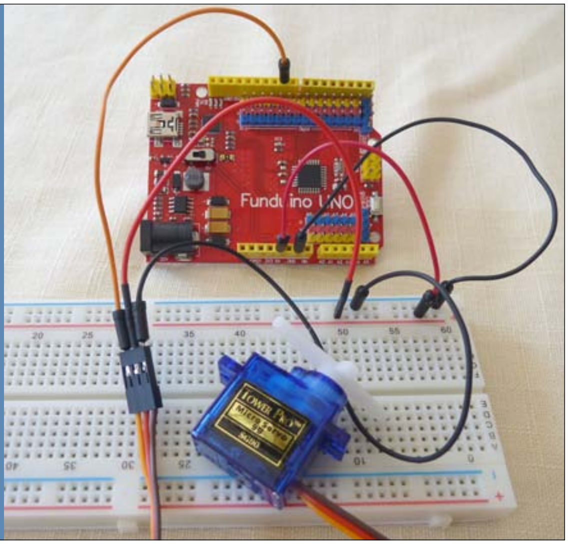


Connecting a Servo

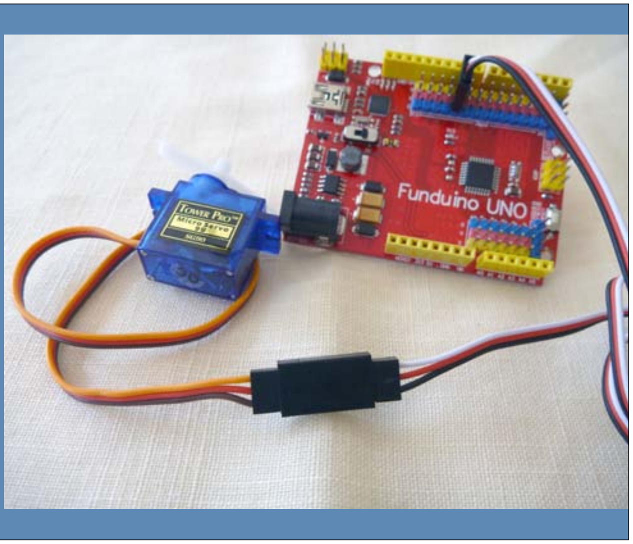


Power is always in the middle
GND is the darker of the two on the edge
Control is the lighter of the two on the edge

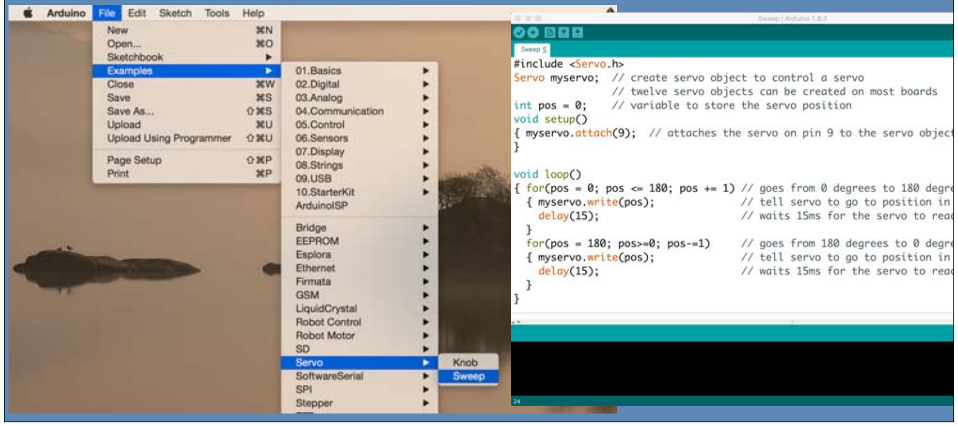
Connecting a Servo



Connecting a Servo



Load and Run Sweep



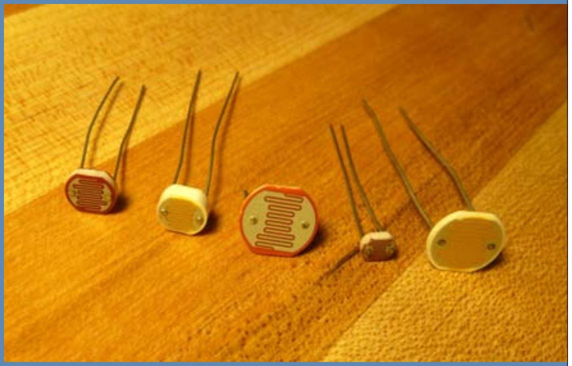
```
#include <Servo.h>
Servo myservo;  // create servo object to control a servo
                // twelve servo objects can be created on most boards
int pos = 0;    // variable to store the servo position
void setup()
{ myservo.attach(9);  // attaches the servo on pin 9 to the servo object
}

void loop()
{ for(pos = 0; pos <= 180; pos += 1) // goes from 0 degrees to 180 degre
  { myservo.write(pos);              // tell servo to go to position in
    delay(15);                       // waits 15ms for the servo to reac
  }
  for(pos = 180; pos>=0; pos-=1)     // goes from 180 degrees to 0 degre
  { myservo.write(pos);              // tell servo to go to position in
    delay(15);                       // waits 15ms for the servo to reac
  }
}
```

Light Sensor

Light-sensitive resistors

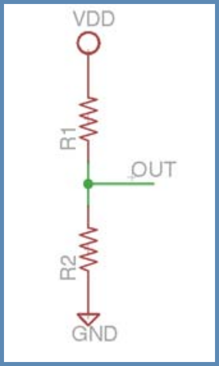
Also called photocells or CdS Sensors



Voltage Divider

- Vout is proportional to the ratio of R1 and R2

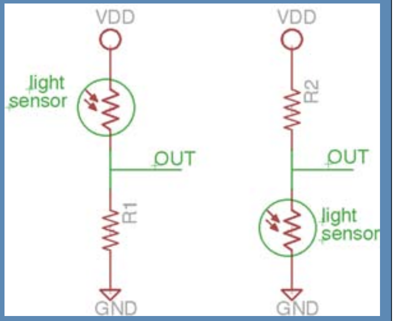
$$Vout = \frac{R_2}{(R_1 + R_2)} Vdd$$



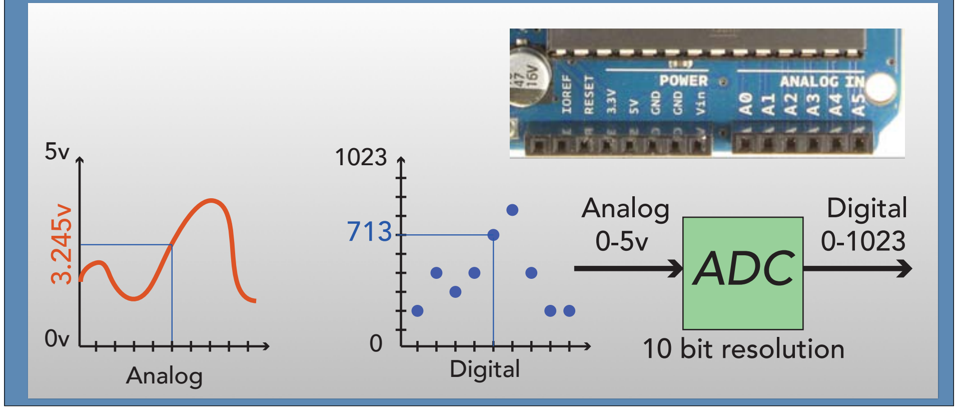
Voltage Divider

$$Vout = \frac{R_2}{(R_1 + R_2)} Vdd$$

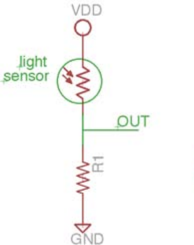
- The changing voltage at OUT can be sensed by the ADC of Arduino
- **analogRead(pinNumber);**
- This senses the voltage (0v to 5v) on the pin and returns a digital value from 0 to 1023

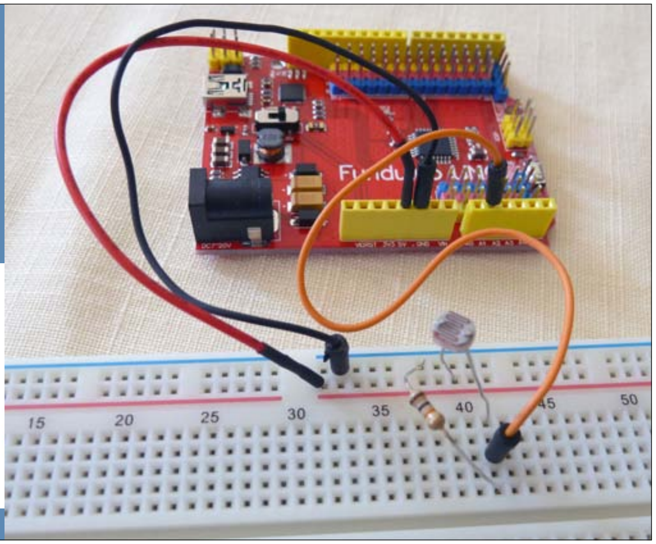


analogIn(pinNum);

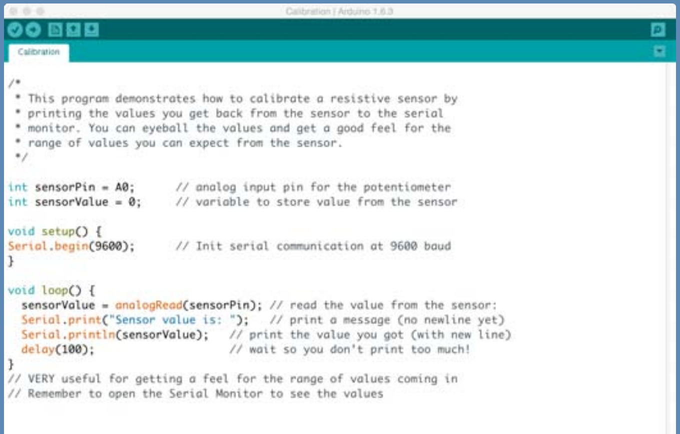


Light Sensor Connection





Calibrate Analog Voltage



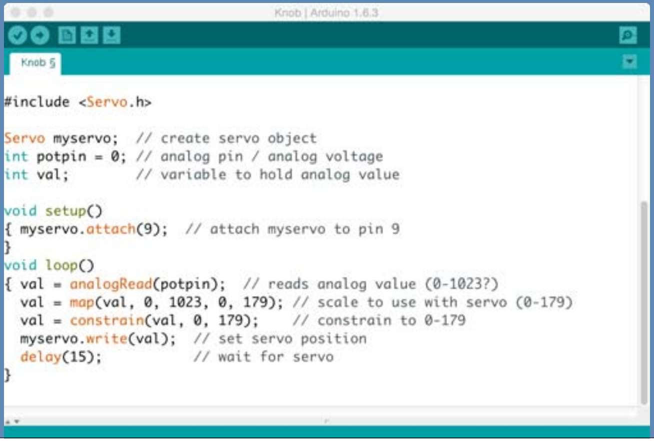
```
/*
 * This program demonstrates how to calibrate a resistive sensor by
 * printing the values you get back from the sensor to the serial
 * monitor. You can eyeball the values and get a good feel for the
 * range of values you can expect from the sensor.
 */

int sensorPin = A0;      // analog input pin for the potentiometer
int sensorValue = 0;     // variable to store value 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 (no newline yet)
  Serial.println(sensorValue);   // print the value you got (with new line)
  delay(100);                    // 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
```

Use the Analog Voltage

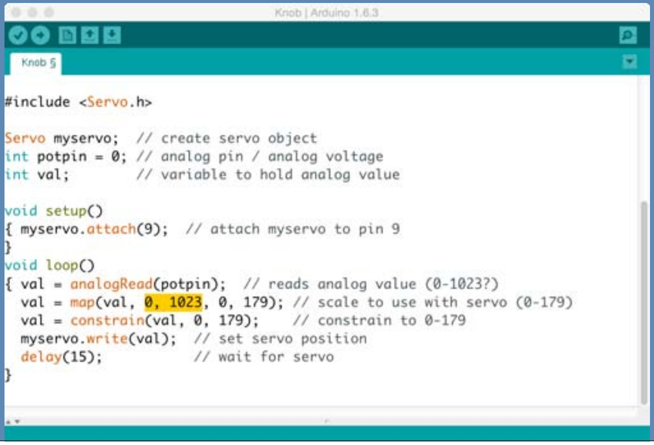


```
#include <Servo.h>

Servo myservo;  // create servo object
int potpin = 0; // analog pin / analog voltage
int val;        // variable to hold analog value

void setup()
{ myservo.attach(9);  // attach myservo to pin 9
}
void loop()
{ val = analogRead(potpin);  // reads analog value (0-1023?)
  val = map(val, 0, 1023, 0, 179); // scale to use with servo (0-179)
  val = constrain(val, 0, 179);    // constrain to 0-179
  myservo.write(val);  // set servo position
  delay(15);           // wait for servo
}
```

Use the Analog Voltage



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  val = map(val, 0, 1023, 0, 179); // scale to use with servo (0-179)
  val = constrain(val, 0, 179);    // constrain to 0-179
  myservo.write(val);  // set servo position
  delay(15);           // wait for servo
}
```
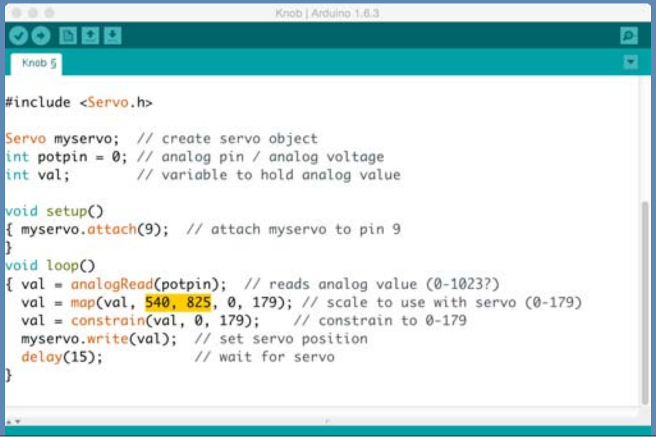
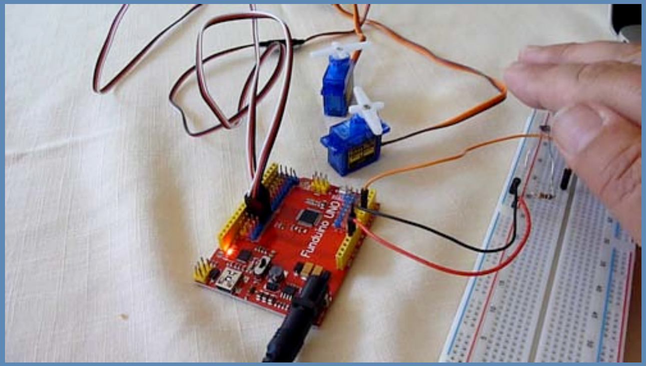

Use the Analog Voltage



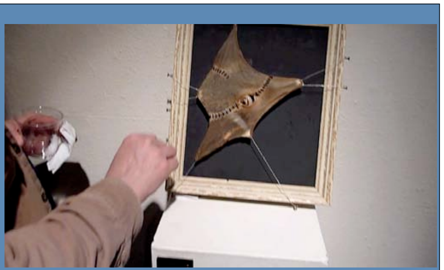
```
#include <Servo.h>

Servo myservo;  // create servo object
int potpin = 0; // analog pin / analog voltage
int val;        // variable to hold analog value

void setup()
{ myservo.attach(9);  // attach myservo to pin 9
}
void loop()
{ val = analogRead(potpin);  // reads analog value (0-1023?)
  val = map(val, 540, 825, 0, 179); // scale to use with servo (0-179)
  val = constrain(val, 0, 179);    // constrain to 0-179
  myservo.write(val);  // set servo position
  delay(15);           // wait for servo
}
```

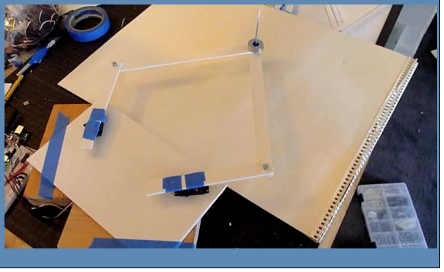
Servo/CdS Light Meter



Go Make Something!

- You have the basic tools you need
  - You can make something move
  - You can respond to light
- Use your imagination and the resources of the Studio
  - Printers
  - Laser cutters
  - Cardboard, foam core, paper, etc.

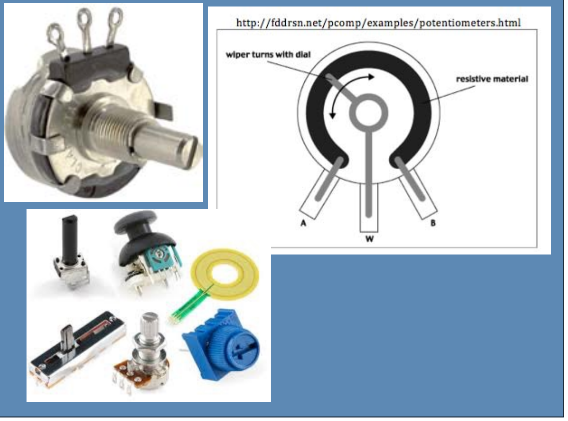




Extra Material

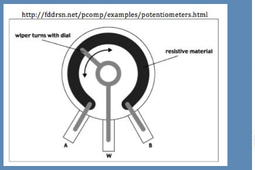
Potentiometers (Knobs)

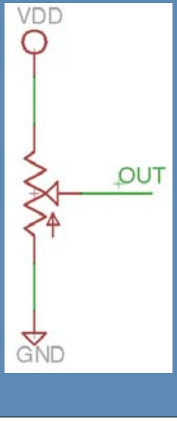
- Variable resistors with a knob



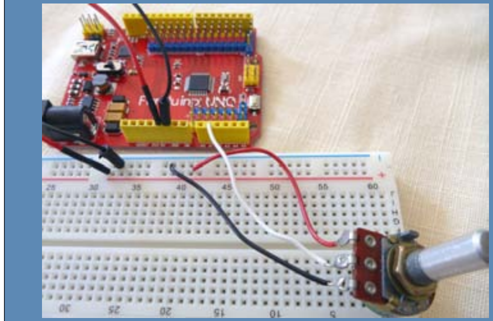
Potentiometers (Knobs)

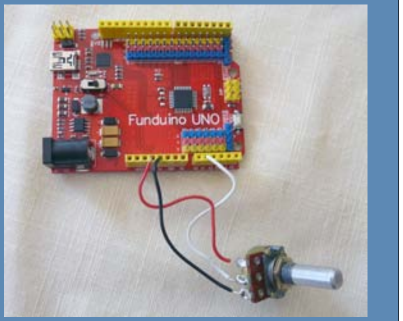
- Variable resistors with a knob
  - Use them just like a CdS light sensor





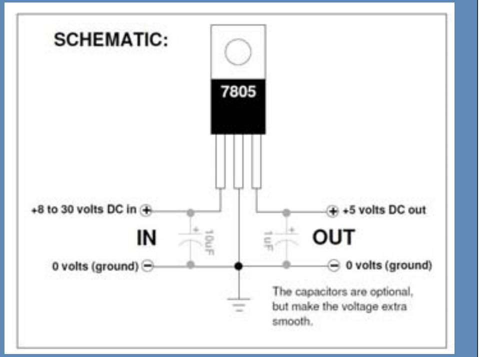
Potentiometers (Knobs)





Voltage Regulation

- Take a higher voltage (e.g. 9v) and reduce it to a regulated lower voltage (e.g. 5v)
  - Extra voltage is converted to heat!
- Provides up to 1.5A of current with an appropriate heat sink
  - Will drive lots of servos!
  - Cap values not critical…



Voltage Regulation

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  - Extra voltage is converted to heat!
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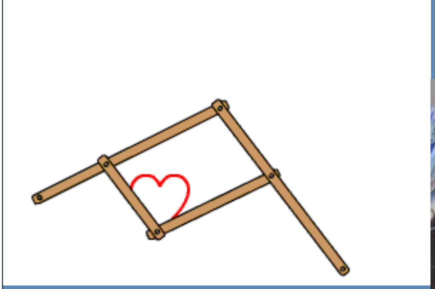
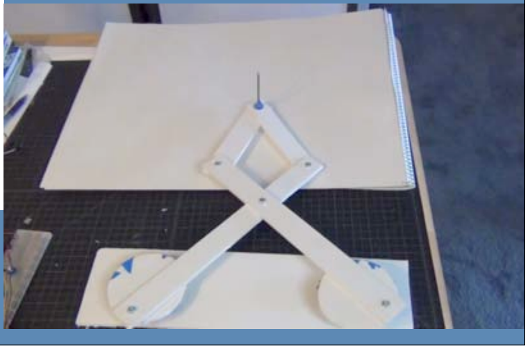
  - Will drive lots of servos!
  - Cap values not critical…

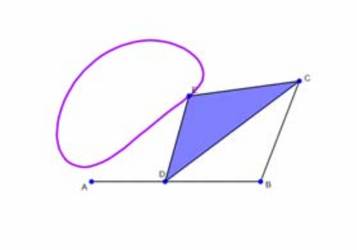
Include picture of regulator on breadboard

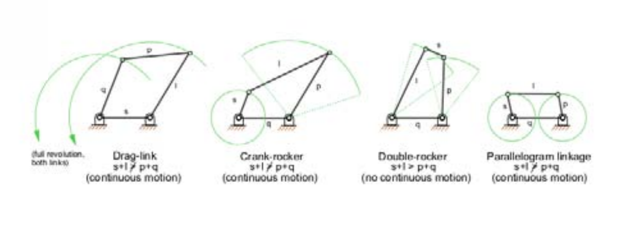
Linkages: Pantograph



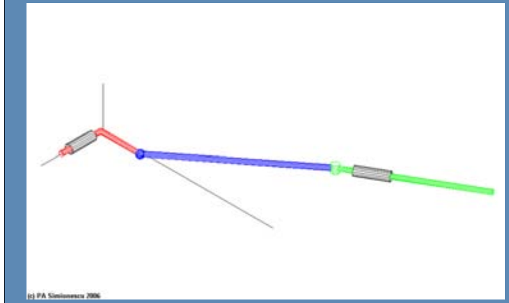


Linkages: Four-Bar

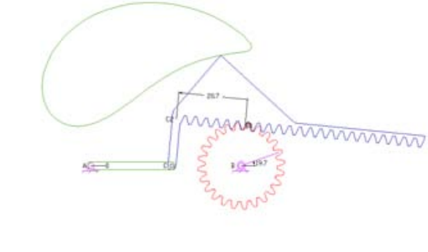




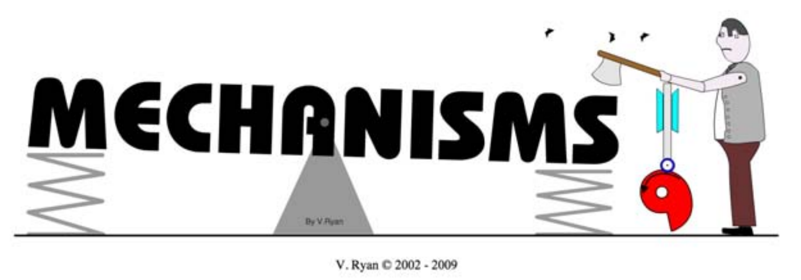
Linkages: Slider-Crank, Rack & Pinion



(c) FA Simionescu 2006



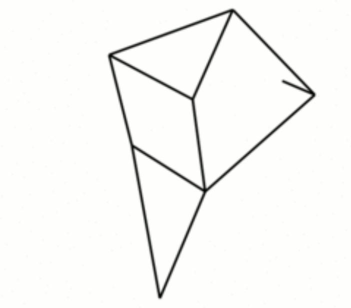
Linkages: Cams

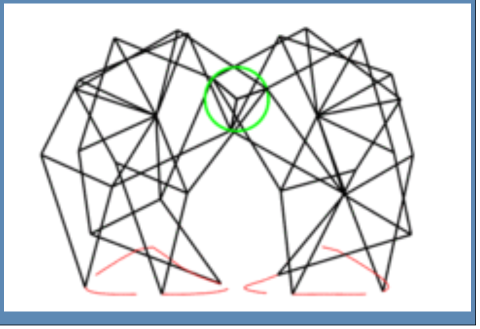


http://www.technologystudent.com/cams/camdex.htm

Linkages: Jansen's Linkage

Theo Jansen, Dutch, b. 1948
Strandbeest





Linkages: Jansen's Linkage

Theo Jansen, Dutch, b. 1948
Strandbeest

Linkages: Klann's Linkage

Patented by Joe Klann, 1994