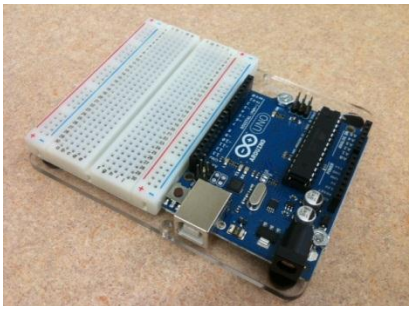
Intro to Microcontrollers

This class will provide an introduction to basic electronics, how to control electronic components via software, and various software communication protocols. Common hardware elements to all kits include an Arduino Uno, half-sized breadboard, mounting plate, USB cable, LED and matched resistor, push button and matched resistor, and a 10KΩ trimpot. Some of the concepts covered include: digital output, digital input, analog input, Pulse Width Modulation, serial communication, and I^2C communication.

Arduino

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, inventors, and anyone interested in creating interactive objects or environments.

The Arduino board provided in this class is the Arduino Uno Rev3. This board contains an ATmega328 and all necessary support circuitry. Arduino "shields" can be mounted on top of this board to provide extra functionality in a convenient package. On the software side, a simple IDE and many convenience functions aid in rapid development.



Arduino Uno R3 and half-sized breadboard.

Required Software

All projects will need the Arduino IDE to interface with the ATmega328 microcontroller. Extra points if you want to plot data in real-time with Python or MATLAB. Examples for interfacing with Python and MATLAB will be provided.

Kit Components

Each participant gets a project kit that includes specific pieces for each individual project. There are also some components common to all kits:

Component	Supplier	URL
Arduino Uno - R3	SparkFun	http://www.sparkfun.com/products/11021
Half-sized breadboard	Adafruit	https://www.adafruit.com/products/64
USB Cable A to B - 6 Foot	SparkFun	http://www.sparkfun.com/products/512
Trimpot 10K with Knob	Sparkfun	http://www.sparkfun.com/products/9806
Jumper Wires Premium 6" M/M	SparkFun	http://www.sparkfun.com/products/10897
Resistor 330 Ohm 1/6th Watt PTH	SparkFun	http://www.sparkfun.com/products/10465
Diffused Red 5mm LED	Adafruit	https://www.adafruit.com/products/299
Mini Push Button Switch	SparkFun	http://www.sparkfun.com/products/97
Resistor 10K Ohm 1/6th Watt PTH	SparkFun	http://www.sparkfun.com/products/10466
SpaceX Arduino and Breadboard Holder	SpaceX	n/a

Recommended Tutorials

It is recommended to complete these tutorials before starting on your individual projects. Additional topics and tutorials will be covered as needed for each project.

Tutorial	Skill	URL
Blink an LED	Digital Out	http://arduino.cc/en/Tutorial/Blink
Control Blink Rate w/ Potentiometer	Analog In	http://arduino.cc/en/Tutorial/AnalogInput
Control LED w/ Button	Digital In	http://arduino.cc/en/Tutorial/Button
Print Potentiometer Value Over Serial	Serial Out	http://arduino.cc/en/Tutorial/AnalogReadSerial
Control LED Brightness	PWM	http://arduino.cc/en/Tutorial/Fading

Additional Resources

These are quality less-known sites for project ideas, tutorials, and parts.

Resource	Good For	URL
Arduino	Tutorials	http://arduino.cc/
SparkFun	Parts, Tutorials	http://www.sparkfun.com/
Adafruit	Parts, Tutorials	http://adafruit.com/
Make: Projects	Tutorials	http://makeprojects.com/c/Arduino
Maker Shed	Parts	http://www.makershed.com/
Instructables	Tutorials	http://www.instructables.com
Robot Shop	Parts	http://www.instructables.com/
EngBlaze	Tutorials	http://www.engblaze.com/

Project List

Project ID	Description
p1	Digital Compass
p2	Theremin
p3	Poor Man's Laser Scanner
p4	Desk Intruder Robot
p5	Conveyer Belt Buzzer
p6	Simon Says
p7	Non-Contact Thermometer
p8	Mini Piano
p9	People Counter
p10	LED Desk Clock
p11	Soft Toss Egg
p12	Digital Force Meter

P1: Digital Compass

A circular LED bargraph will be used to display the output of a digital magnetometer. The included accelerometer reads the local magnetic field in 3 axes. The magnetometer can be read via I^2C. The LEDs on the circular bargraph can be controlled via two shift register connected in series located on the circular LED bargraph breakout board.

To account for the direction of the local magnetic field, an offset will have to be applied to the magnetometer output. This offset can either be applied on the magnetometer chip directly with special I^2C commands or after receiving the values at the Arduino.

Parts List

Component	Supplier	URL
LED RingCoder Breakout	SparkFun	http://www.sparkfun.com/products/10704
Circular LED Bargraphs	SparkFun	http://www.sparkfun.com/products/10595
Triple Axis Magnetometer Breakout - HMC5883L	SparkFun	http://www.sparkfun.com/products/10530

Additional Reading

Tutorial	URL
Serial to Parallel Shifting-Out with a 74HC595	http://www.arduino.cc/en/Tutorial/ShiftOut
Arduino I^2C Example	http://arduino.cc/en/Tutorial/SFRRangerReader

Bonus Round

Vary the brightness of an additional LED via PWM signals to indicate the total field strength.

P2: Theremin

A theremin is a musical instrument in which the pitch is controlled without physical contact from the musician. In this case, create a theremin using a photocell and a piezo speaker.

A photocell is a light dependent resistor. The resistance of the device should be measured via an analog input to control the pitch of the piezo speaker.

The membrane in a piezo speaker needs to be oscillated to make a continuous tone. The can be achieved by connecting the speaker to a digital out pin and oscillated the output between 0 and 1. The rate of oscillation determines the pitch that the speaker produces.

Parts List

Component	Supplier	URL
Mini Photocell	SparkFun	http://www.sparkfun.com/products/9088
Buzzer - PC Mount 12mm 2.048kHz	SparkFun	http://www.sparkfun.com/products/7950

Additional Reading

Tutorial	URL
Piezo Tone	http://arduino.cc/en/Tutorial/Tone
Button Debounce	http://arduino.cc/en/Tutorial/Debounce

Bonus Round

Create a looping feature on the theremin. Add a button to the thermin and record input while the button is pressed. Play back the previously recorded section while the button is not pressed. Use button debouncing for best results.

P3: Poor Man's Laser Scanner

The goal of this project is to create a 2D plot of a room using a server and an ultrasonic sensor. A servo will be used to sweep an ultrasonic sensor 180 degrees while taking measurements. The servo can be controlled via PWM. The sonar is most easily read using an analog input. It might be appropriate to take an average of values at each degree for best results.

A MATLAB script should be created that sends a trigger via serial to start measurements. When the measurement set is complete, the Arduino should send the number of data points followed by the data points in the format of angle followed by distance. MATLAB should then plot the data. Data example:

180

1

40

2

43

3

40

…

Parts List

Component	Supplier	URL
Ultrasonic Range Finder - Maxbotix LV-EZ4	SparkFun	http://www.sparkfun.com/products/8504
2x Servo - Medium	SparkFun	http://www.sparkfun.com/products/10333

Additional Reading

Tutorial	URL
MATLAB Serial Interaction	http://www.mathworks.com/matlabcentral/fileexchange/26711
Servo Sweep	http://arduino.cc/en/Tutorial/Sweep

Bonus Round

Make it 3D with an extra servo!

P4: Desk Intruder Robot

Create a robot watchdog to detect an intruder in your office cube. Use an ultrasonic range finder to detect the presence of an intruder. Scare off intruders with a buzzer, two flashing eyes (red LEDs), and two moving arms (attached to servos.)

The sonar can be read via analog in. Lights can be controlled with one digital out. Servos can be controlled with one PWM digital out.

Parts List

Component	Supplier	URL
Ultrasonic Range Finder - Maxbotix LV-EZ1	SparkFun	http://www.sparkfun.com/products/639
2x Servo - Small	SparkFun	http://www.sparkfun.com/products/9065
Buzzer - PC Mount 12mm 2.048kHz	SparkFun	http://www.sparkfun.com/products/7950

Additional Reading

Tutorial	URL
Piezo Tone	http://arduino.cc/en/Tutorial/Tone
Servo Sweep	http://arduino.cc/en/Tutorial/Sweep

Bonus Round

Connect to a computer and send a notification email about the intruder via Python.

P5: Conveyer Belt Buzzer

Create a device to detect when a conveyer belt is full. When full, parts are not able to move off of the conveyer belt and their position is fixed. Use an infrared distance sensor to detect the distance from a part. When the distance hasn't changed in a while, it can be assumed that the parts are stuck. Sound off a buzzer to notify personal. Display the maximum stall time on the character LCD.

The Sharp infrared distance sensor outputs a known voltage depending on the distance of the closest object. First create a function mapping a voltage read via an analog in to a distance. The datasheet provides a graph of voltage vs. distance. One suggestion is to list points in an Excel spreadsheet and have Excel generate the equation of the curve.

The membrane in a piezo speaker needs to be oscillated to make a continuous tone. The can be achieved by connecting the speaker to a digital out pin and oscillated the output between 0 and 1. The rate of oscillation determines the pitch that the speaker produces.

Parts List

Component	Supplier	URL
Clear Enclosure for Arduino	Adafruit	https://www.adafruit.com/products/337
Standard LCD 16x2	Adafruit	https://www.adafruit.com/products/181
Wall Adapter Power Supply - 9VDC 650mA	Sparkfun	http://www.sparkfun.com/products/298
Sharp Infrared Proximity Sensor Long Range	Sparkfun	http://www.sparkfun.com/products/8958
Infrared Sensor Jumper Wire - 3-Pin JST	Sparkfun	http://www.sparkfun.com/products/8733
Buzzer - PC Mount 12mm 2.048kHz	SparkFun	http://www.sparkfun.com/products/7950

Additional Reading

Tutorial	URL
Character LCDs	http://www.ladyada.net/learn/lcd/charlcd.html
Piezo Tone	http://arduino.cc/en/Tutorial/Tone

Bonus Round

Add a potentiometer to control the stall time without having to reprogram.

P6: Simon Says

Create a Simon Says game with fore buttons and four LEDs. The object of the game is to repeat a random pattern. Each button has an LED of one color. The pattern starts with one LED and adds additional LEDs each round. After the pattern is display to the player, the player must repeat the pattern by pushing the corresponding buttons in the correct order.

The provided breakout board enforces one to use the components in a very specific way. View the break board schematic to deduce this information.

Parts List

Component	Supplier	URL
Button Pad 2x2 - Breakout PCB	SparkFun	http://www.sparkfun.com/products/9277
4x LED - RGB Diffused Common Cathode	SparkFun	http://www.sparkfun.com/products/9264
Button Pad 2x2 Top Bezel	SparkFun	http://www.sparkfun.com/products/8746
Button Pad 2x2 - LED Compatible	SparkFun	http://www.sparkfun.com/products/7836
4x Diode Small Signal - 1N4148	SparkFun	http://www.sparkfun.com/products/8588
4x Screw - Phillips Head (1/2", 4-40, black)	SparkFun	http://www.sparkfun.com/products/8763
4x Nut - Nylon (4-40)	SparkFun	http://www.sparkfun.com/products/10231
Jumper Wire - 0.1", 4-pin, 12"	SparkFun	http://www.sparkfun.com/products/10374

Additional Reading

Tutorial	URL
Simon Says Retail Tutorial	http://www.sparkfun.com/tutorials/249

Bonus Round

Decrease the time between lights each round. Decrease the time to except the repeated pattern each round. Change the color/button mapping each round.

P7: Non-Contact Thermometer

Create a non-contact infrared thermometer and output the result to two seven-segment LED displays.

The thermometer can be accessed over I^2C. An eight-bit shift register will be used to control each seven-segment display to reduce the number of pins required by the microcontroller for control.

Parts List

Component	Supplier	URL
Infrared Thermometer - MLX90614	SparkFun	http://www.sparkfun.com/products/9570
2x 7-Segment Red LED	SparkFun	http://www.sparkfun.com/products/8546
74HC595 Shift Register	Adafruit	https://www.adafruit.com/products/450

Additional Reading

Tutorial	URL
Serial to Parallel Shifting-Out with a 74HC595	http://www.arduino.cc/en/Tutorial/ShiftOut
Arduino 7 Segment Display Tutorial	http://allaboutee.com/2011/02/05/arduino-7-segment-display-tutorial/
Arduino I^2C Example	http://arduino.cc/en/Tutorial/SFRRangerReader

Bonus Round

Activate an extra LED when going over 100 degrees.

P8: Mini Piano

Create a mini piano using an eight inch resistive membrane and a piezo speaker.

The resistive membrane reacts with a different resistance depending on where on the membrane it is touch. This can be used to identify repeatable touch points. An analog input can read this resistance. This can then be used to control the frequency of a piezo speaker to create different sounds.

The membrane in a piezo speaker needs to be oscillated to make a continuous tone. The can be achieved by connecting the speaker to a digital out pin and oscillated the output between 0 and 1. The rate of oscillation determines the pitch that the speaker produces.

Parts List

Component	Supplier	URL
6”x12”x1/8” G10	McMaster	9910T15
SoftPot Membrane Potentiometer - 200mm	SparkFun	http://www.sparkfun.com/products/8679
Buzzer - PC Mount 12mm 2.048kHz	SparkFun	http://www.sparkfun.com/products/7950

Additional Reading

Tutorial	URL
Piezo Tone	http://arduino.cc/en/Tutorial/Tone

Bonus Round

Add a button to bump the output sounds up one octave when while pressed.

P9: People Counter

Use a laser module and a photocell to detect the presence of people moving in a hallway. Use the LCD screen to display stats about hallway traffic.

A photocell is a light dependent resistor. The resistance of the device should be measured via an analog input.

The black and white LCD can be controller over serial. Use the RJ45 jacks and an Ethernet cord to locate the screen in a more visible location.

Parts List

Component	Supplier	URL
Mini Photocell	SparkFun	http://www.sparkfun.com/products/9088
Graphic LCD 84x48 - Nokia 5110	SparkFun	http://www.sparkfun.com/products/10168
RJ45 8-Pin Connector	SparkFun	http://www.sparkfun.com/products/643
Breakout Board for RJ45	SparkFun	http://www.sparkfun.com/products/716
Laser Card Module - Red	SparkFun	http://www.sparkfun.com/products/594

Additional Reading

Tutorial	URL
Philips PCD8544 (Nokia 3310) driver	http://www.arduino.cc/playground/Code/PCD8544

Bonus Round

Graph the hallway traffic over time on the LCD.

P10: LED Desk Clock

Create an LED clock using a real time clock module and a seven-segment serial display.

The real time clock module is used to keep accurate time. It includes a battery so that time is kept even when the Arduino is powered off. The module can be accessed via I^2C.

The seven-segment serial display includes four individual seven-segment displays. It takes care of doing all shift register work for you. It can be controlled via serial.

Parts List

Component	Supplier	URL
7-Segment Serial Display – Red	SparkFun	http://www.sparkfun.com/products/9766
Real Time Clock Module	SparkFun	http://www.sparkfun.com/products/99

Additional Reading

Tutorial	URL
Arduino I^2C Example	http://arduino.cc/en/Tutorial/SFRRangerReader
RTC1307 - Real Time Clock	http://combustory.com/wiki/index.php/RTC1307_-_Real_Time_Clock

Bonus Round

Create an alarm functionality using a buzzer and a button.

P11: Soft Toss Egg

Create a device that is sensitive to high g's (large accelerations) and complains about it. Use a triple axis accelerometer to detect acceleration. Complain via a RGB lights and buzzer.

The accelerometer can be read via I^2C. The lights can be controlled via digital outs. The membrane in a piezo speaker needs to be oscillated to make a continuous tone. The can be achieved by connecting the speaker to a digital out pin and oscillated the output between 0 and 1. The rate of oscillation determines the pitch that the speaker produces.

Parts List

Component	Supplier	URL
Ball	Michaels	n/a
Triple Axis Accelerometer Breakout - MMA8452Q	SparkFun	http://www.sparkfun.com/products/10955
Arduino Pro Mini 328 - 3.3V/8MHz	SparkFun	http://www.sparkfun.com/products/9220
ProtoBoard - Square 1" Single Sided	SparkFun	http://www.sparkfun.com/products/8808
USB Mini-B Cable - 6 Foot	SparkFun	http://www.sparkfun.com/products/598
FTDI Basic Breakout - 3.3V	SparkFun	http://www.sparkfun.com/products/9873
2x Coin Cell Holder - 20mm	SparkFun	http://www.sparkfun.com/products/783
2x Coin Cell Battery - 20mm	SparkFun	http://www.sparkfun.com/products/338
Receiver Switch	HobbyKing	http://www.hobbyking.com/hobbyking/store/uh_viewItem.asp?idProduct=4841

Additional Reading

Tutorial	URL
Arduino Pro Mini Tutorial	http://www.arduino.cc/en/Guide/ArduinoProMini
Arduino I^2C Example	http://arduino.cc/en/Tutorial/SFRRangerReader
AVR and Arduino sleep mode basics	http://www.engblaze.com/hush-little-microprocessor-avr-and-arduino-sleep-mode-basics/

Bonus Round

Change LED color depending on the acceleration vector. (Three axes… Three color channels…)

P12: Digital Force Meter

Create a digital scale using a force sensitive resistor and a seven-segment serial display. Such a meter could be used in conjunction with a motor test stand to better measure the output of a motor.

The force sensitive resistor can be measured using an analog input. The seven-segment serial display includes four individual seven-segment displays. It takes care of doing all shift register work for you. It can be controlled via serial.

Parts List

Component	Supplier	URL
Force Sensitive Resistor 0.5"	SparkFun	http://www.sparkfun.com/products/9375
7-Segment Serial Display - Yellow	SparkFun	http://www.sparkfun.com/products/9764

Additional Reading

Tutorial	URL
MATLAB Serial Interaction	http://www.mathworks.com/matlabcentral/fileexchange/26711

Bonus Round

Turn on an LED (as a stand in for a motor power relay) via MATLAB and return a data set of force readings to MATLAB. Graph output.