Gateway To Space

ASEN 1400

Class #06

Colorado Space Grant Consortium
Today:

- Announcements
- Next classes
- Arduino Part 1
Announcements:

- Great job last class
- Thanks for the help setting up and cleaning up
- What did you think?
Announcements:

- HW #4 due now
- Any one **not** bring items involved with HW#4?
- HW #3 due yesterday
- One Minute Report Questions/Answers sent via email
Announcements:

- HW #5 assigned today
- Each team should take one HW#5 bag home today
- Due Next Tuesday
Announcements:

- One pre-built and one you build
Announcements:

- Match the orientation of headers
Announcements:

- Match the orientation of headers
Announcements:

- Add two resistors
Announcements:

- Add two headers in orientation shown
Announcements:

- Add three pin header as shown – Note picture shows other items installed so please ignore
Announcements:

- Analog vs. Digital
Announcements:

- Analog vs. Digital
Next Tuesday...

**Arduinos – Part 2**  **DLC 1B70**
Please be early to help setup

Bring **HW #4 and #5 hardware** and **Laptops (2 per team)**
**HW #05 DUE**
Next Tuesday Night…

Conceptual Design Reviews DLC 1B70
“Elevator Pitch”

Presentations due 4:00 PM 09-15-15

Template on the website

New Start Time 5:30 PM
Next Thursday...

**Arduinos – Part 3**  ITLL 1B50
Please be early to help setup

Bring **HW #4 and #5** hardware and **Laptops** (2 per team)
Next Thursday Night...

**Arduinos – Part 4** DLC 1B70
Please be early to help setup

Bring **HW #4 and #5** hardware and **Laptops** (2 per team)

New Start Time 5:30 PM
Questions?

Colorado Space Grant Consortium
Part 1 – Arduino Driving Lessons

A. Arduino Overview
B. Arduino Communication
C. Blink an Led, Change the World
Part 2 – Arduino Test Drive

A. LED Visual Display
B. Analog vs. Digital
C. Potentiometer
D. Balloon Shield Build
Part 3 – Arduino Road Trip

A. Humidity Sensor
B. Temperature Sensor
C. Pressure Sensor
D. Accelerometers
E. External Temp Sensor
Part 4 – Arduino Race Track

A. SHIELD Integration
B. SD Card Code Integration
C. Data Retrieval
Arduino Overview:

Goals…

1. Teach you what I know about Arduinos

2. Make you comfortable working with code and sensors connected to an Arduino

3. Record and Retrieve data on a microSD card

4. Have fun doing 1 – 3
**Arduino Overview:**

- How many of you have ever used a **laptop**?

- How many of you have ever used **MS office**?

How many of you have ever worked with **Arduinos**?

- How many of you have ever worked with **code**?

- How many of you have ever worked with **sensors**?
Part 1 – Arduino Driving Lessons

A. Arduino Overview
B. Arduino Communication
C. Blink an Led, Change the World
Arduino Overview:
Arduino Overview:

“Designing a revolutionary concept in software demanded a computer with extraordinary performance. The Tandy 2000 delivered.”

Bill Gates has been at the leading edge of personal computing from the very beginning. His company is a leading producer of microcomputer software.

“Our newest software product, MS/Windows, is an integrated windowing environment. It will let personal computer users combine individual programs into a powerful, integrated system.

“When we set out to design MS/Windows in color, we knew that the Tandy 2000 computer would let us turn an extraordinary product into a work of art. The graphics are sharp and crisp, and gave us a degree of excitability like nothing before.

“Our engineers were quite impressed with the processing speed of the Tandy 2000’s 8088 microprocessor, too. And while the finished product will utilize the 2000’s Disk Mouse, the well laid out keyboard has helped us speed through the design stage.

“We’re proud of our work. So when we want to show someone how great MS/Windows really is, we give them a demonstration. On the Tandy 2000:

1. Go ahead, watch how much faster today’s most sophisticated programs run on the high technology Tandy 2000.
2. You can choose from the hottest programs around, too, with our exclusive Express-Order Software service.
3. Tandy 2000 systems start at $2999, and can be leased for only $395 per month! Come in today and see what you’ve been missing.

Engineered for Excellence!
We’ve introduced the latest in technology for over 30 years. The Tandy 2000 offers twice the speed, graphics resolution and disk storage of other MS/DO systems.

Our new 1985 computer catalog is yours for the asking at any Radio Shack Computer Center or participating Radio Shack store or dealer. Check out our complete line of microcomputers—from pocket models to laptop portables, from powerful desktop computers to multi-user office systems. We have it all. That’s why we invite comparisons!”
Arduino Overview:

**General Purpose computer**
- Usually has a human in the loop
- Can be reconfigured to do any number of tasks (excel, email, music)

**Embedded Systems**
- Human input not required all the time
  - Takes specific inputs and computes outputs for a very specific application
- Meets real-time goals
  - Heart monitor
  - Automatic braking systems (ABS)
Arduino Overview:

- Arduino is an embedded system

- Board supports an open source environment, lots of assistance available online

- Extremely modular

- Types of Arduinos: Uno, Due, Mega

- Each version has different capabilities

- Lots of analog and digital I/O
Arduino Overview:

Arduino Uno Rev 3
Arduino Overview:
MicroSD Card Shield:

- LEDs
- Arduino Uno
- Micro SD Card Shield
- Monitor
- PC/Mac
- LEDs
- AccelZ
- AccelX
- Pressure
- Humidity
- Temp 2
- Temp 1
Arduino Overview:

What’s under the hood?

- USB
- 3.3 V Regulator
- 5.0 V Regulator
- 9V DC Power In
- GND
- 14 Digital Input/Outputs
- External Interrupts
- Serial I/O
- ATmega328
  - 10 Bit ADC
  - 16 MHz
  - 32 KB Flash
  - I2C, Serial & SPI
  - 40 to +85C
- 3.3 V
- 5.0 V
- GND
- 6 Analog Inputs
Arduino Overview:
Arduino Overview:

- So what does all that mean?
Arduino Overview:

The Easy Stuff…
Arduino Overview:

Arduino (TM) UNO Rev3
Arduino Overview:

The Chips…

ATmega16U
- Handles the USB interface to the computer
- We don’t program this one

ATmega328
- 10 Bit ADC
- 16 MHz
- 32 KB Flash
- I2C & SPI
- 40 to +85C
Arduino Overview:

Arduino (TM) UNO Rev3
Arduino Overview: 

Other…

- 14 Digital Input/Outputs
- External Interrupts
- Serial I/O
- 6 Analog Inputs
Arduino Overview:

Arduino (TM) UNO Rev3
Arduino Overview:

- USB
- 3.3 V Regulator
- 5 V Regulator
- 9V DC Power In
- GND
- 14 Digital Input/Outputs
- External Interrupts
- Serial I/O
- ATmega328
  - 10 Bit ADC
  - 16 MHz
  - 32 KB Flash
  - I2C, Serial & SPI
  - 40 to +85C
- 3.3 V
- 5.0 V
- GND
- 6 Analog Inputs
Arduino Overview:

Let’s take it for a drive...
MicroSD Card Shield:

- LEDs
- Arduino Uno
- Monitor
- PC/Mac
- LEDs

- Temp1
- Temp2
- Pressure
- Humidity
- AccelX
- AccelZ
Arduino Overview:

Arduino Uno
Arduino Overview:

Arduino Uno

Monitor

PC/Mac
**Arduino Overview:**

- Launch the Arduino Software
- A new Sketch opens
Arduino Overview:

- Select the right board = Tools > Board > Arduino Uno
Arduino Overview:

- Select the right board =
  Tools > Board > Arduino Uno
Arduino Overview:

- Select a serial port
- For Mac use **Tools > Serial Port > /dev/tty.usbmodemxxx**

- Note: the ‘xxx’ and ‘xx’ above can be any number – it does not matter which number you choose as long as one is selected
**Arduino Overview:**

- Select a serial port
- For PC use **Tools > Serial Port > COMxx**

- Note: the ‘xxx’ and ‘xx’ above can be any number – it does not matter which number you choose as long as one is selected
Arduino Overview:

Port is big source of frustration for Windows users
- The dreaded “grayed out” port

When it happens…
- Unplug Arduino from laptop
- Close Arduino software
- Plug Arduino back into laptop
- Restart Arduino software
Arduino Overview:

Review the Sketch
Arduino Overview:

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

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

There are three main sections of code in an Arduino sketch:

- Definitions
- Void Setup
- Void Loop
Arduino Overview:

- Definitions are declared **prior to void setup** and can include pin definitions, libraries to include in the sketch, functions, and global variables.

- Most programs declare something, but this is not required. Examples later on...
**Arduino Overview:**

- **void setup** is the first code block in the sketch
- It is run only once
- Used for setup of pin modes, communication initialization, and any code we only want to run one time (i.e. we prepare an SD card by formatting it in the beginning)
- **void loop** is the second code block in the Arduino sketch and it continuously repeats itself

- For code that needs to repeat such as sampling a sensor every couple of seconds

- Where the primary tasks of the code are carried out
Arduino Overview:

- Even though this Sketch is not doing anything, it has all the necessary ingredients to be compiled and uploaded.
Arduino Overview:

1. Compile code and check for messages
   - #1

Should see this at the bottom...
Arduino Overview:

What is Compiling?

- It checks your code for syntax errors and returns error messages

- Converts human-readable code into machine language (zeroes and ones)

- When you tell the Arduino to upload, it first compiles then uploads (programs) your code (communicating with laptop and Arduino)
Part 1 – Arduino Driving Lessons

A. Arduino Overview
B. Arduino Communication
C. Blink an Led, Change the World
Arduino Overview:
Arduino Communication:

Arduino uses **serial communication** to communicate with your laptop.

**Serial communication** is a widely used protocol for transmitting (Tx) and receiving (Rx) binary data and requires a few easy functions to get it started with Arduino.
Arduino Communication:

2. Upload code to Arduino

*If successfully uploaded, you will know that your PC/MAC can communicate with your Arduino*
- Any problems?

- Please wait until this has been completed by each team
What is code?
Arduino Communication:

What is code?
- It is a language to talk with your computer
- Programming languages are like foreign languages
- We say “Hello,” Arduino says
  ```
  Serial.begin(9600);
  Serial.print(“Hello”);
  ```
- Arduino language is based on C/C++
Arduino Communication:

- Modify the sketch to add the following to the \texttt{void setup()}:

```cpp
void setup() {
    // put your setup code here,
    Serial.begin(9600);
}
```
**Arduino Communication:**

Serial.begin()
- **Serial.begin()** needs us to specify a communication rate (baud rate)
- **Serial.begin()** is in **setup** because this rate needs to be set only once

```cpp
void setup() {
  // put your setup code here
  Serial.begin(9600);
}
```
Modify your sketch to include the following:

```c
void loop() {
  // put your main code here, to run repeatedly:
  Serial.println("hello");
}
```

- `Serial.print()` will just print to the monitor

- `Serial.println()` will print to the monitor and then go to the next line (essentially pushes ‘return’)
1. Compile code and check for messages

2. Upload code to Arduino (will check communication with Arduino too)
Arduino Communication:

- To open the serial monitor, click here

```cpp
void setup() {
    // put your setup code here, to run once:
    Serial.begin(9600);
}

void loop() {
    // put your main code here, to run repeatedly:
    Serial.println("hello");
}
```
Arduino Communication:

- You should see this on your serial monitor

![Serial Monitor Screenshot]

Hello
Hello
Hello
Hello
Hello
Hello
Hello
Hello
Arduino Communication:

- Any problems?

- Try different text in the print command while waiting for everyone to complete this step
Arduino Communication:

- Congratulations!

- You have now successfully programmed your Arduino – You are a computer programmer

Well done!
Arduino Preferences:

Other features about Arduino IDE

Line Number of cursor in code

Arduino Mega or Mega 2560, ATmega2560 (Mega 2560) on /dev/ttys001:145121
Arduino Preferences:

Other features about Arduino IDE
**Arduino Preferences:**

**Other features about Arduino IDE**
Arduino Preferences:

Other features about Arduino IDE

```cpp
void setup() {
    // put your setup code here, to run once at startup
}

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

Other features about Arduino IDE

Editor font size: 14 (requires restart of Arduino)

Additional Boards Manager URLs:

More preferences can be edited directly in the file
/Users/koehler/Library/Arduino15/preferences.txt
(edit only when Arduino is not running)
Ada Lovelace

First computer programmer in 1842

Saw that it was more than number crunching and was a tool capable of great problem solving

“Supposing, for instance, that the fundamental relations of pitched sounds in the science of harmony and of musical composition were susceptible of such expression and adaptations, the engine might compose elaborate and scientific pieces of music of any degree of complexity or extent”
Arduino Communication:

Commenting

- Arduino ignores comments but humans read them
- Words become light gray if they commented out
- Put // in front of a line to comment out whole line
- To comment out an entire section, put /* at the beginning and */ at the end

```cpp
// you can type anything you want here!
this is NOT a comment!! // uh oh!
/*
I can type whatever I want here.
Notice how it's gray?
*/
```
Commenting – MOST IMPORTANT THING!!

It makes your code readable, provides context, helps draft out what you want to next.

- Click to the top of the sketch hit enter to create a new line above void setup()

- Try out your own comment. Insert your name at the top of the sketch. Try out both methods.
Part 1 – Arduino Driving Lessons

A. Arduino Overview
B. Arduino Communication
C. Blink an Led, Change the World
Blink an LED:

- Arduino Uno
- Monitor
- PC/Mac
- LEDs
Blink an LED:
- Connect an LED (positive lead) to pin 13 and (negative lead) to GND
- Negative lead is usually the shorter lead
**Blink an LED:**

- Add the following to the **definitions** area of your sketch - *above* **void setup()**

- Add some comments too
Blink an LED:

- Note that “int” turned blue ⇒ we are defining a data type
- Arduino knows variable “led” represents an integer
- Anytime “led” is used in the code, Arduino sees 13
  - Ex. 12 + led = 25
- There are many more data types
**Blink an LED:**

- Add the following to the your sketch in `void setup()`

```c
void setup() {
    // put your setup code here, to run once:
    // initialize the digital pin as an output
    pinMode(led, OUTPUT);
    Serial.begin(9600);
}
```
Blink an LED:

- `pinMode(pin#, mode)`

  - “pin#” refers to a specific pin on the Arduino you are wanting to use (in our case pin 13 aka “led”)

  - “mode” is either INPUT or OUTPUT

  - **OUTPUT** sets up the pin so it can give outputs

  - **INPUT** sets up the pin so it can receive inputs

```c
// initialize the output
pinMode(led, OUTPUT)
```
Blink an LED:

- Add the following to your sketch in `void loop()`

```cpp
void loop() {
    // put your main code here
    Serial.println("hello");
    digitalWrite(led, HIGH);
    delay(1000);
    digitalWrite(led, LOW);
    delay(1000);
}
```

- `void loop()` …
- Runs once `void setup` is finished
- Loops through the code within `forever`
**Blink an LED:**

```c
Serial.println("Hello");
digitalWrite(led, HIGH);
delay(1000);
digitalWrite(led, LOW);
delay(1000);
```

`digitalWrite(pin#, value)`
- “pin#” is whichever pin you are writing to
- “value” can be either HIGH or LOW
  - **HIGH** means the pin is at 5V – “on”
  - **LOW** means the pin is at 0V – “off”
**Blink an LED:**

```c
void setup()
{
  Serial.begin(9600);  
  pinMode(led, OUTPUT); 
}

void loop()
{
  Serial.println("Hello");  
  digitalWrite(led, HIGH);   
  delay(1000);              
  digitalWrite(led, LOW);    
  delay(1000);              
}
```

- Arduino will wait a specific amount of time (in milliseconds) before going to the next line of code
Blink an LED:

1. Compile code and check for messages
2. Upload code to Arduino
Blink an LED:

- Does LED blink?
- Change the delay in the sketch and try again
- Do you see a change?
Blink an LED:

- Remove the LED from PIN 13 and GND
- Another LED on the board should start blinking
- The “L” on the Uno stands for LED
- Do you see this?
**Blink an LED:**

- Say you wanted to blink an LED on Pin 9, what would you change in the code?

- int LED = 9;
Blink an LED:

- Could you connect LED directly to Pin 9 and GND like for Pin 13?

- No (OK for a few seconds) but why?

- LED requires some current limiting (resistor)
**Blink an LED:**

- Let’s look at Pin 13 on the schematic

Follow the line and find a built in 1K resistor
Blink an LED:

- So if we use any other pin to light up an LED, we need to add a resistor

- We will do that in Part 2

- But first…
Blink an LED:

- If you can Blink an LED, you can change the world

- Why?

PLEASE SAVE YOUR SKETCH FILE
Part 1 – Arduino Driving

A. Arduino Overview
B. Arduino Communication
C. Blink an Led, Change the World
Part 2 – Arduino Test Drive

A. LED Visual Display
B. Analog vs. Digital
C. Potentiometer
D. Balloon Shield Build
Part 2 – Arduino Test Drive

A. LED Visual Display
B. Analog vs. Digital
C. Potentiometer
D. Balloon Shield Build
LED Visual Display:

- Arduino Uno
- Monitor
- PC/Mac
- LEDs
LED Visual Display:

Breadboard 101
- Columns connected
- Rows connected on power rails
- Two sides
- Columns on one side not connected to columns on other side
LED Visual Display:

- Breadboard has power and ground rails
- Individual points on rails (rows) are connected
- One rail, and its points, are independent of other rails
**LED Visual Display:**

- Also has numbers and letters to coordinate builds
**LED Visual Display:**

- Remove LED from 9 and GND

- Connect negative lead of LED to **C10** and positive lead to **C11** as shown

- Connect 330 ohm resistor to positive lead at **D11** and **F11**

- Connect breadboard wire to negative lead **D10** to GND Rail
LED Visual Display:

- Connect resistor J11 to pin 9 on Arduino
- Connect GND Rail to GND on Arduino as shown
LED Visual Display:

- Upload the same code from the end of Part 1 with led = 9

- Verify the LED blinks

- Tinker with the delay times until all teams here

PLEASE SAVE YOUR SKETCH FILE

Dude...

Wait, what?
**LED Visual Display:**

- Duplicate the LED circuit three more times

- Note negative leads and connect to **GND Rail**

- Keep color order (Except Blue is purple)

- Tie all resistors together
- GND should still be connected to Arduino GND
- Red wire should still be connected to Arduino Pin 9
LED Visual Display:

- Upload same code again and verify all LEDs blink

- Tinker until all are at this point

- Now that we know all the LEDs on our Display are working, let’s use the Arduino to control each LED individually
LED Visual Display:

- Remove wires connecting resistors and Pin 9 from Arduino

- Now what?
LED Visual Display:

- Connect Yellow LED resistor to Pin 9
- Connect Red LED resistor to Pin 7
- Connect Purple LED resistor to Pin 6
- Connect Green LED resistor to Pin 5
**LED Visual Display:**

- Time to modify your sketch
- “Comment out” int LED = 9;
- pinMode for pins 5, 6, 7, and 9 as OUTPUTs

```cpp
void setup() {  
  // put your setup code here, to run once
  Serial.begin(9600);

  // setup the LED Visual Display
  pinMode(5, OUTPUT); //Green LED
  pinMode(6, OUTPUT); //Purple LED
  pinMode(7, OUTPUT); //Red LED
  pinMode(9, OUTPUT); //Yellow LED
}
```
LED Visual Display:

- Comment out Serial.println
- Turn off LEDs at start of loop
- Turn on individual LEDs as shown

```cpp
void loop() {
  // put your main code here, to run repeatedly
  // Turn script running leds OFF at beginning
  digitalWrite(5, LOW);  //Green LED
  digitalWrite(6, LOW);  //Purple LED
  digitalWrite(7, LOW);  //Red LED
  digitalWrite(9, LOW);  //Yellow LED

  delay(1000);

  digitalWrite(5, HIGH);  //Green LED
  delay(500);
  digitalWrite(6, HIGH);  //Purple LED
  delay(500);
  digitalWrite(7, HIGH);  //Red LED
  delay(500);
  digitalWrite(9, HIGH);  //Yellow LED
  delay(500);
}
```
Blink an LED:

1. Compile code and check for messages

2. Upload code to Arduino
LED Visual Display:

- Should see Green LED turn on, then Purple, then Red, then Yellow

- Tinker with the delay times until all teams here

PLEASE SAVE YOUR SKETCH FILE

ADC (next slide) or Balloon Shield Testing 142)
LED Visual Display:

- Same circuit as bread board but embedded in PCB from HW #4
LED Visual Display:

- Disconnect Arduino from laptop
- Disconnect Breadboard from Arduino
- Connect SHIELD to Arduino
- Line up before squeezing
LED Visual Display:

- Once aligned, gently press two together
LED Visual Display:

- What changes do you have to make to the software?
- None, reconnect to laptop and blink pattern should be same

- Verify then your done!
Part 2 – Arduino Test Drive

A. LED Visual Display
B. Analog vs. Digital
C. Potentiometer
D. Balloon Shield Build