HiBall Balloon Payload Workshop

Sensors Part 1

COLORADO SPACE GRANT CONSORTIUM

Partner

Part 1 – Arduino Test Drive
Sensors

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

Part 1 – Arduino Test Drive
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LED Visual Display:

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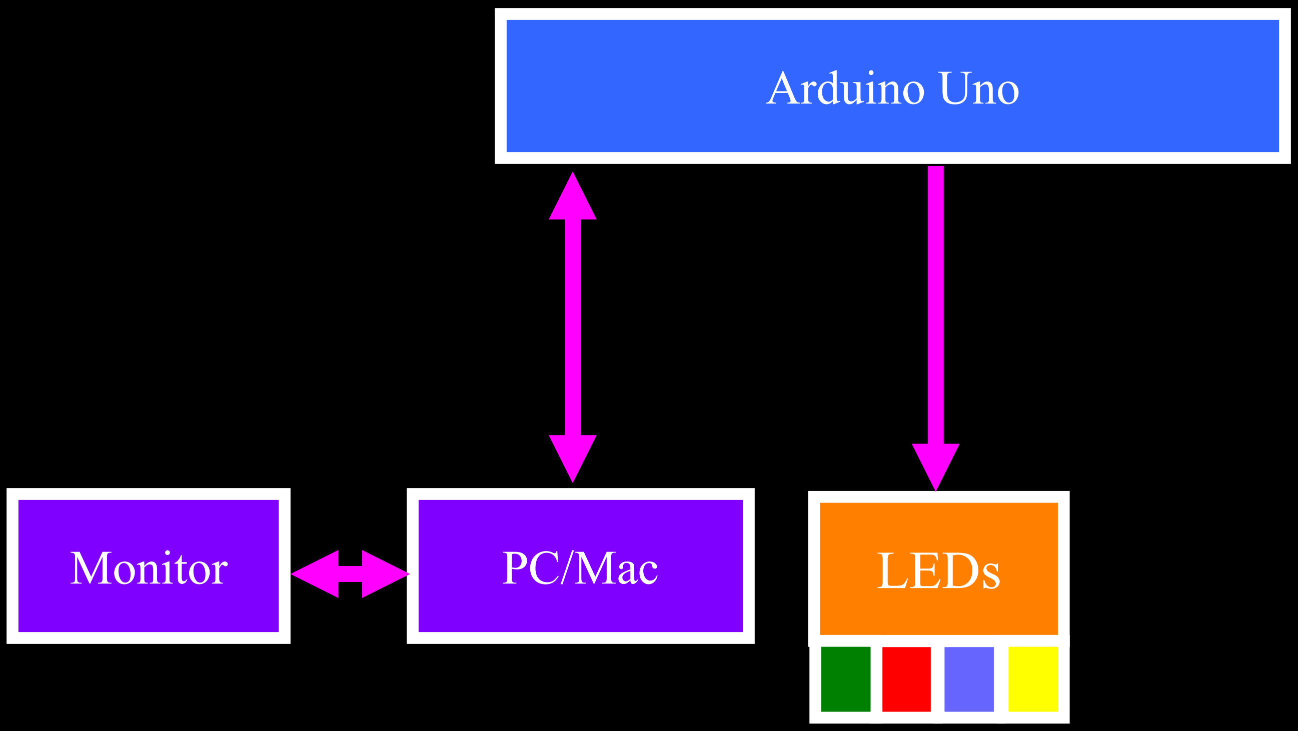

LED Visual Display:

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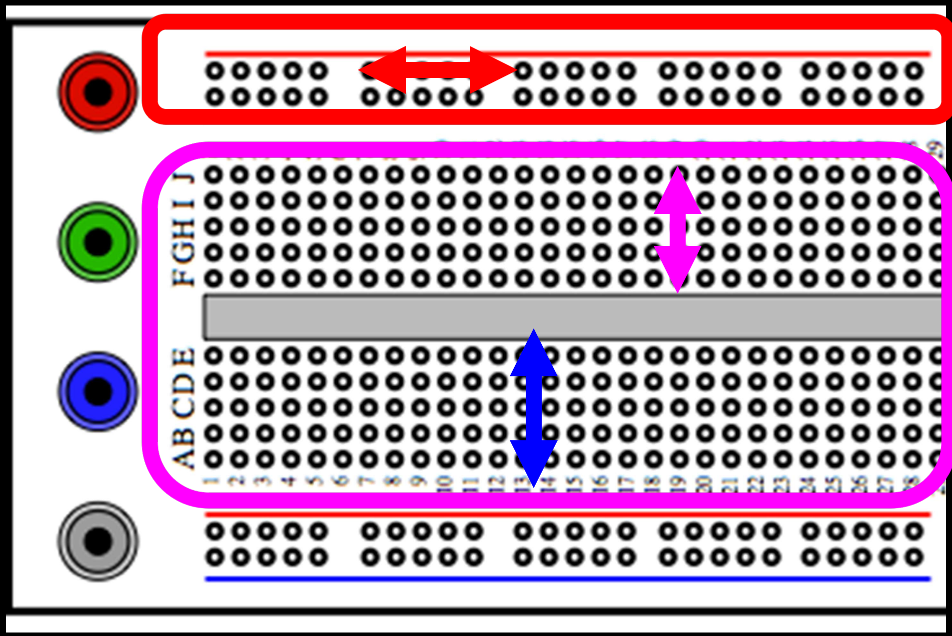
Breadboard 101

- Columns connected

- Rows connected on power rails

- Two sides

- Columns on one side not connected to columns on other side



LED Visual Display:

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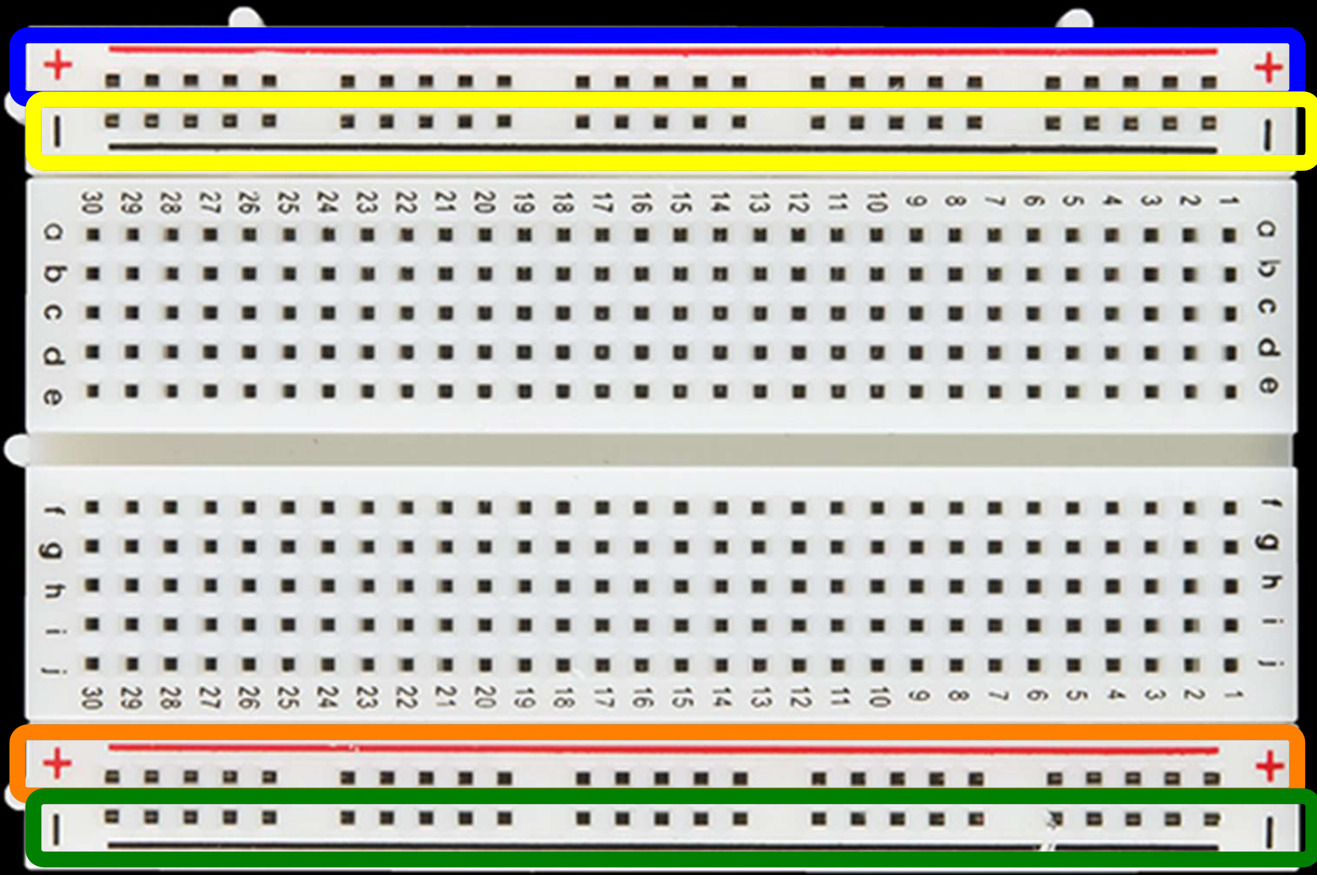
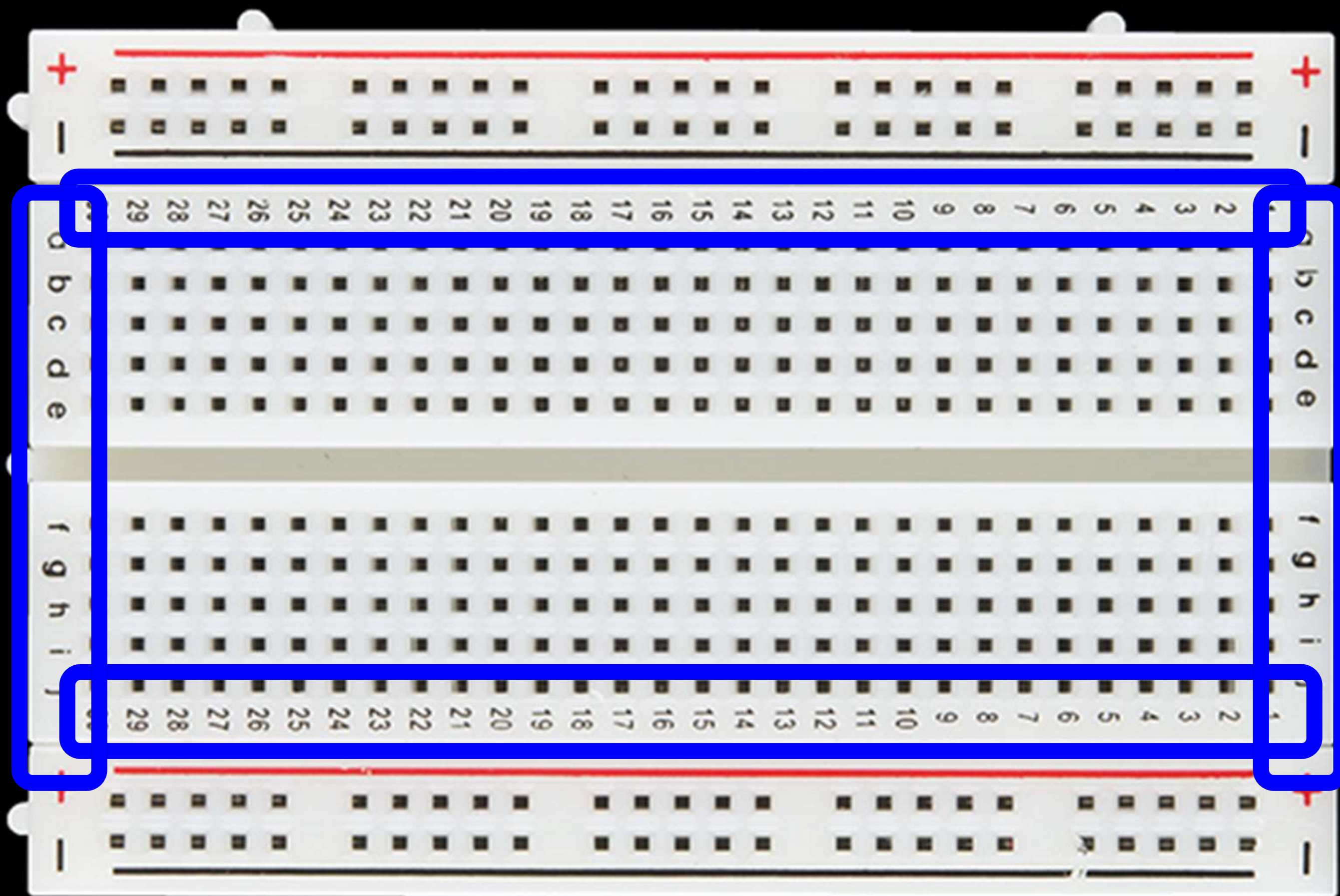
- Breadboard has power and ground rails
- Individual points on rails (rows) are connected
- One rail, and its points, are independent of other rails



LED Visual Display:

- Also has numbers and letters to coordinate builds



LED Visual Display:

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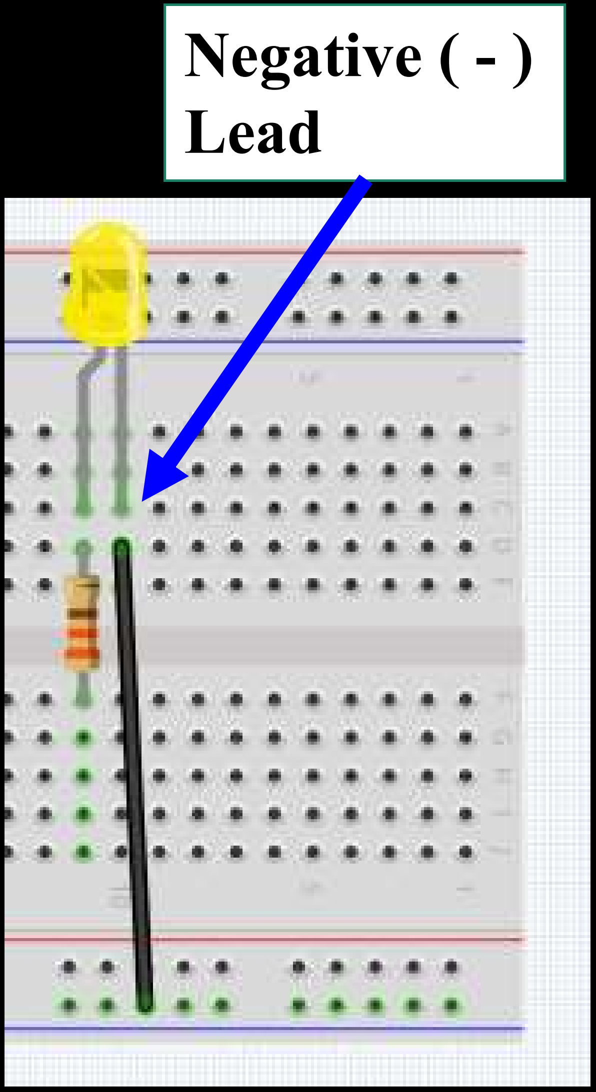
- **Connect negative lead of LED to C10 and positive lead to C11 as shown**

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

- **Connect breadboard wire to negative lead D10 to GND Rail**



LED Visual Display:

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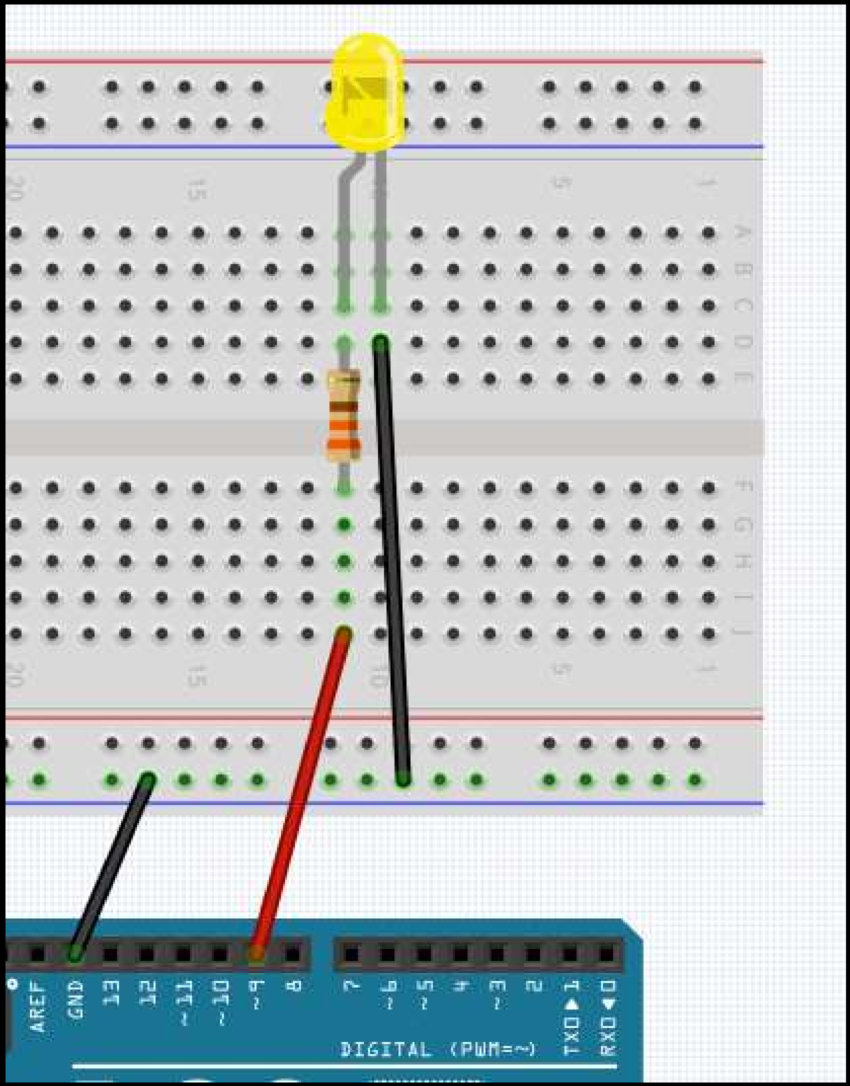
- **Connect resistor J11 to pin 9 on Arduino**

- **Connect GND Rail to GND on Arduino as shown**



LED Visual Display:

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

- Verify the LED blinks

- Tinker with the delay times

PLEASE SAVE YOUR SKETCH FILE

LED Visual Display:

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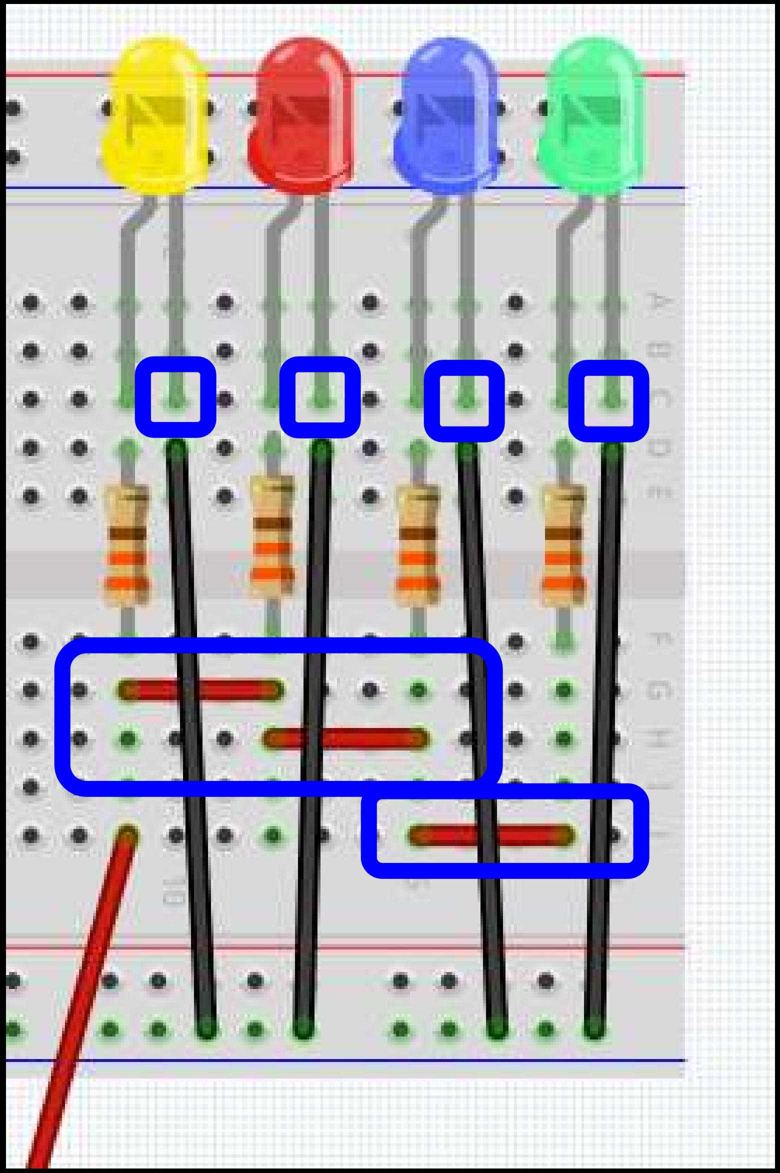
- Duplicate the LED circuit three more times

- Note negative leads and connect to GND Rail

- Keep color order (Except Blue is purple)

- Tie all resistors together



LED Visual Display:

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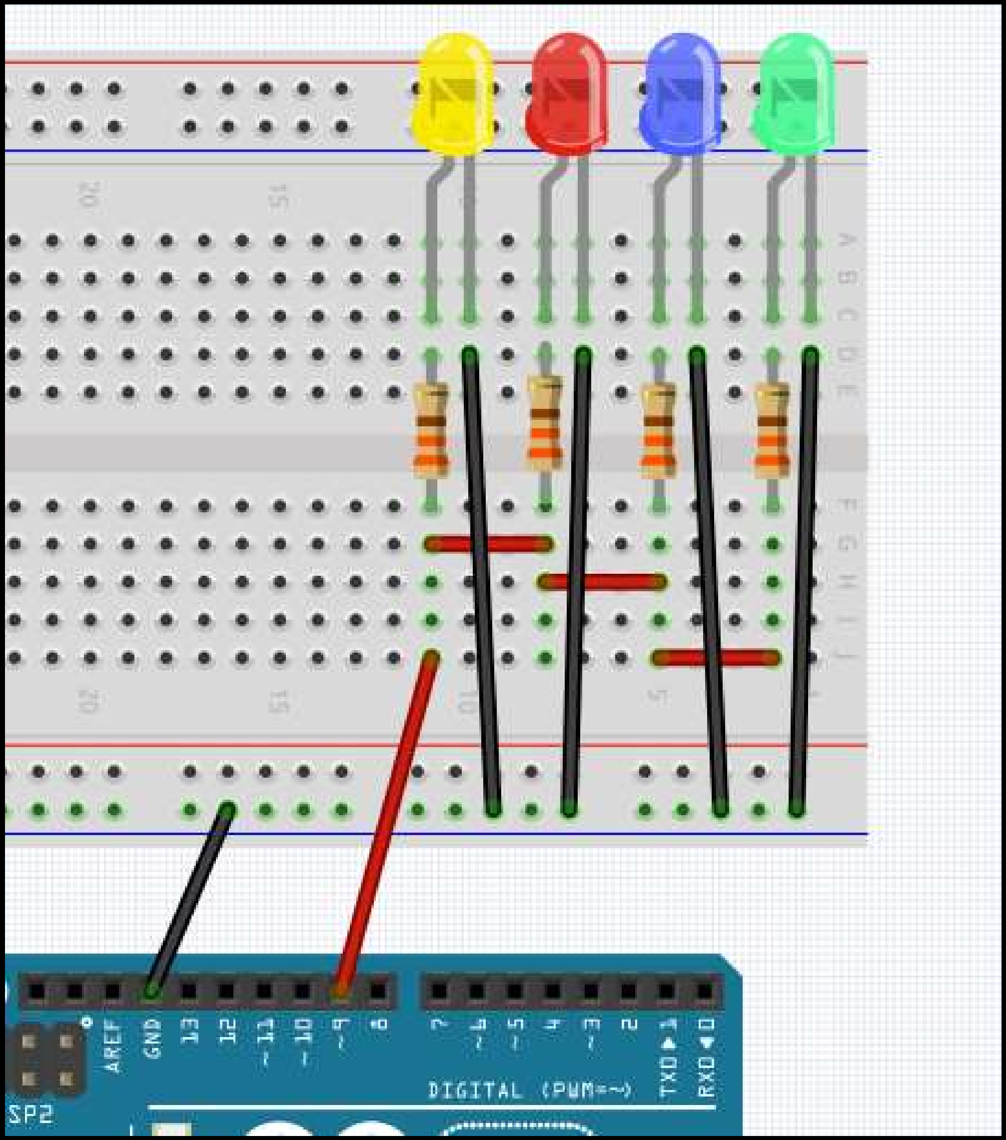
- GND should still be connected to Arduino GND

- Red wire should still be connected to Arduino Pin 9



LED Visual Display:

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- **Upload same code again and verify all LEDs blink**

- **Tinker at this point if you want**

- **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:

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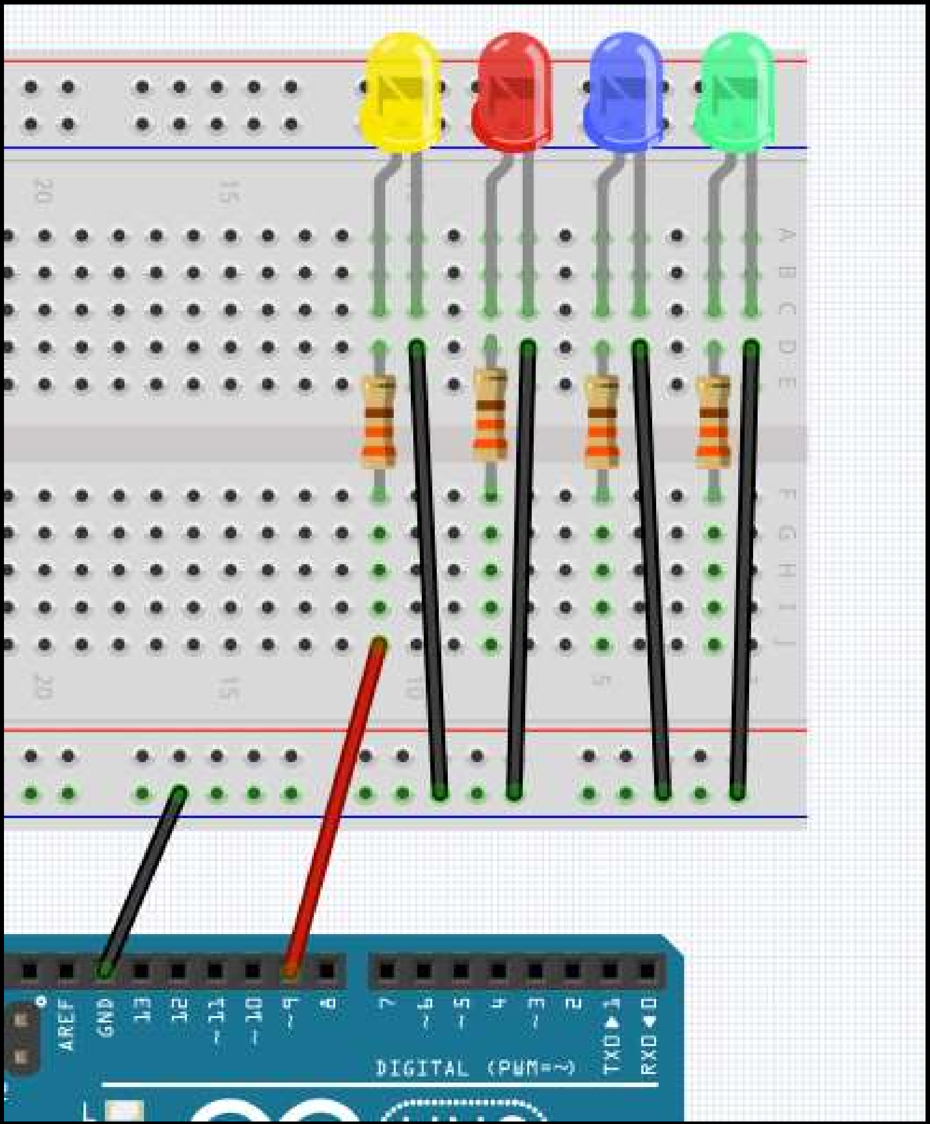
- Remove wires connecting resistors and Pin 9 from Arduino

- Now what?



LED Visual Display:

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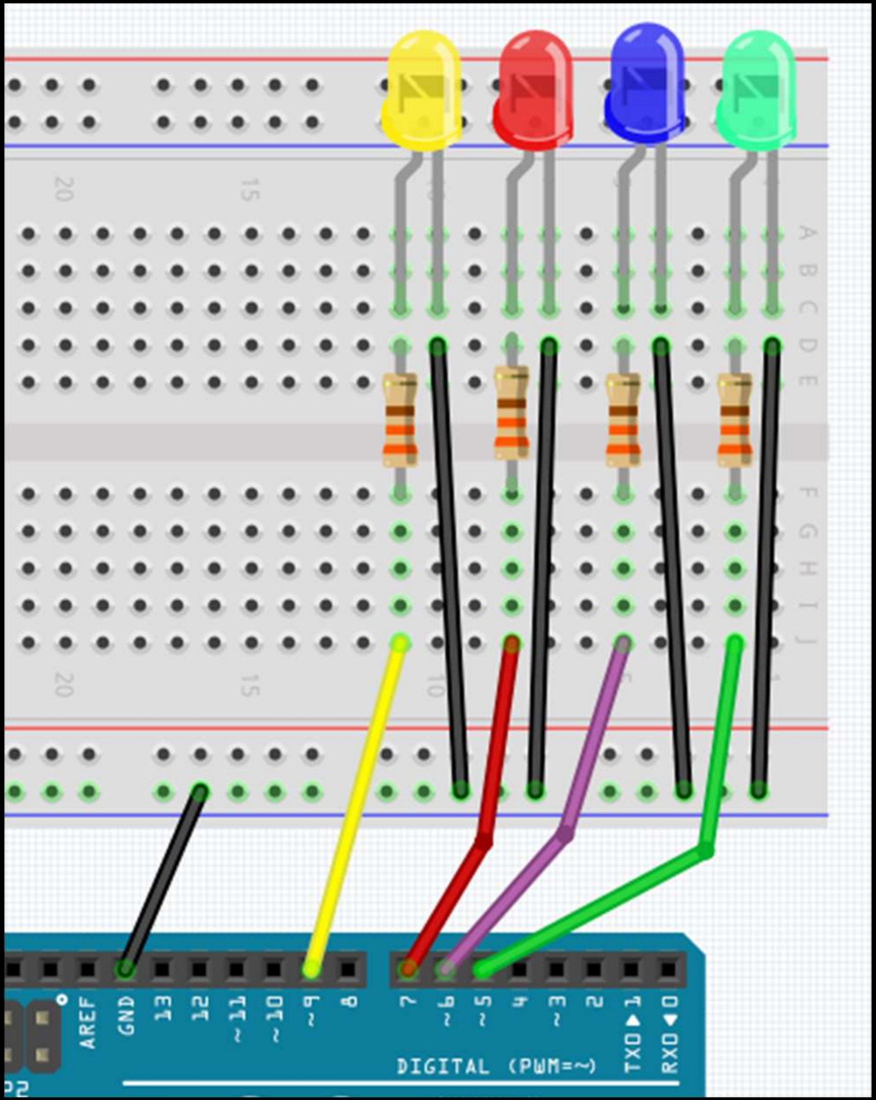
- Connect Yellow LED resistor to Pin 9

- Connect Red LED resistor to Pin 7

- Connect Purple LED resistor to Pin 6

- Connect Green LED resistor to Pin 5



LED Visual Display:

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- Time to modify your sketch

- "Comment out" int LED = 9;

- pinMode for pins 5, 6, 7, and 9 as OUTPUTs

```
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:

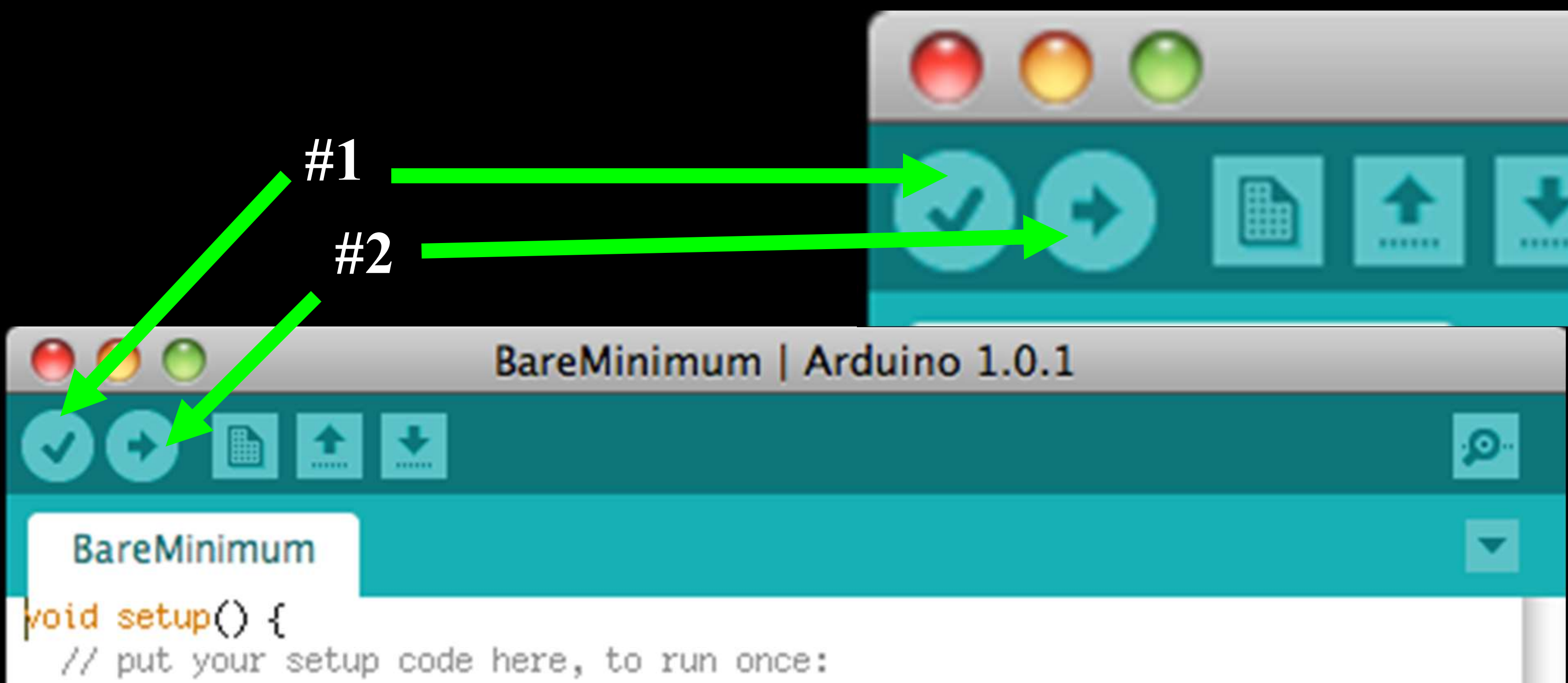
- **Comment out Serial.println**
- **Turn off LEDs at start of loop**
- **Turn on individual LEDs as shown**

```
void loop() {
//   put your main code here, to run repeate
//   Turn script running leds OFF at beginnin
     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:

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

- **Tinker with the delay times**

PLEASE SAVE YOUR SKETCH FILE

Review from Arduino Part 1:

- Serial.begin(9600);	- void setup( )
- Serial.print( );	- void loop ( )
- Serial.println( );	- void loop ( )
- pinMode(pin#, mode);	- void setup( )
- digitalWrite(pin#, value);	- void loop ( )
- delay(time);	- void loop ( )

Part 1 – Arduino Test Drive
Sensors

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

Analog vs. Digital:

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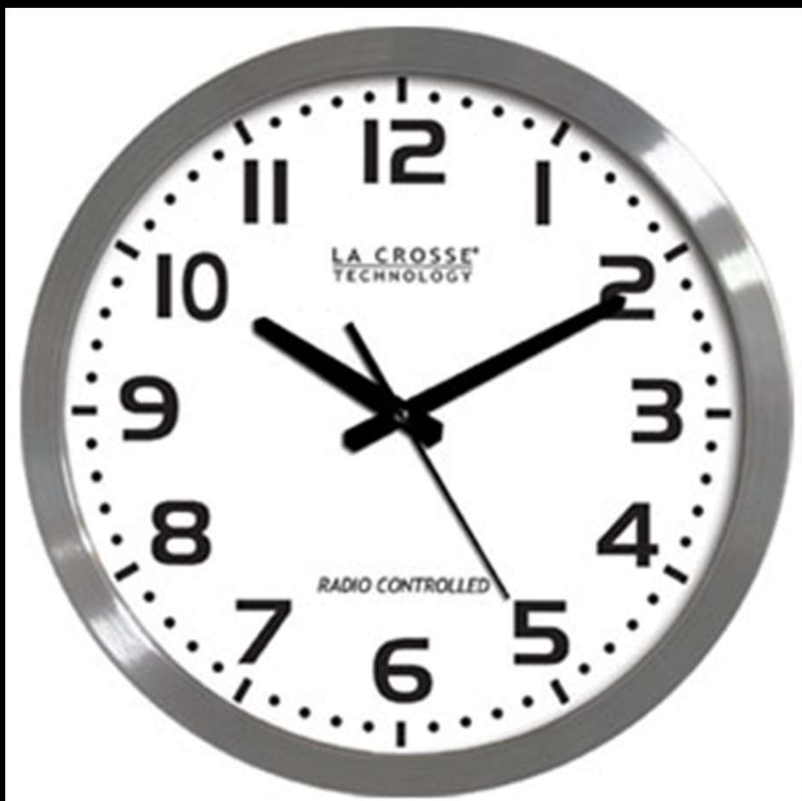
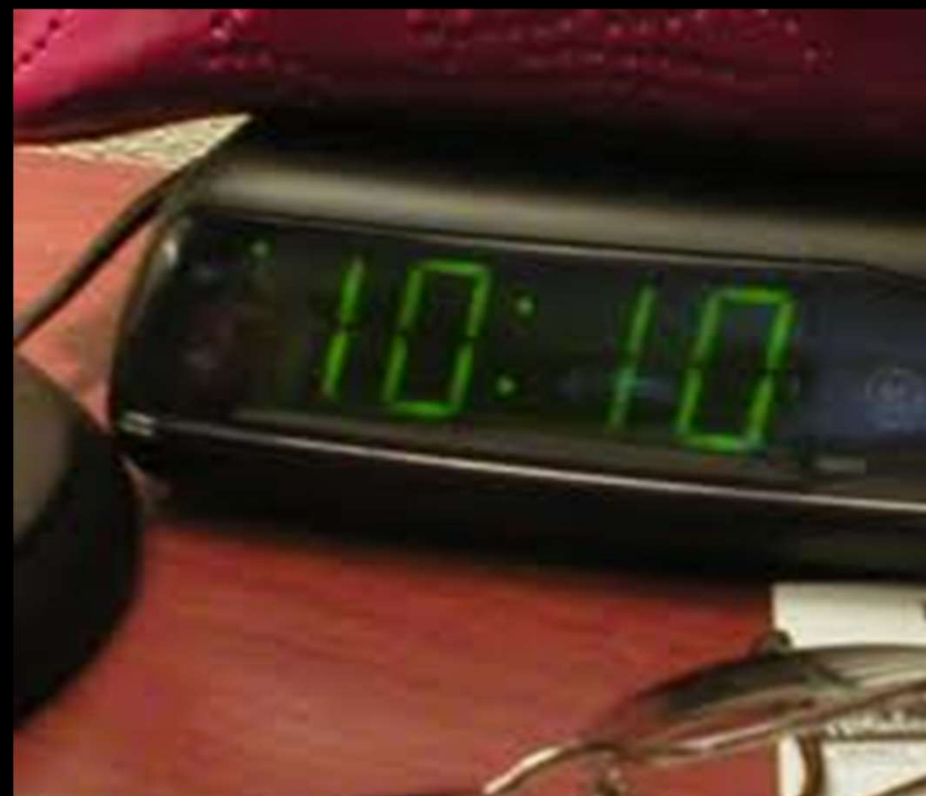
- Common Interpretation





Analog:

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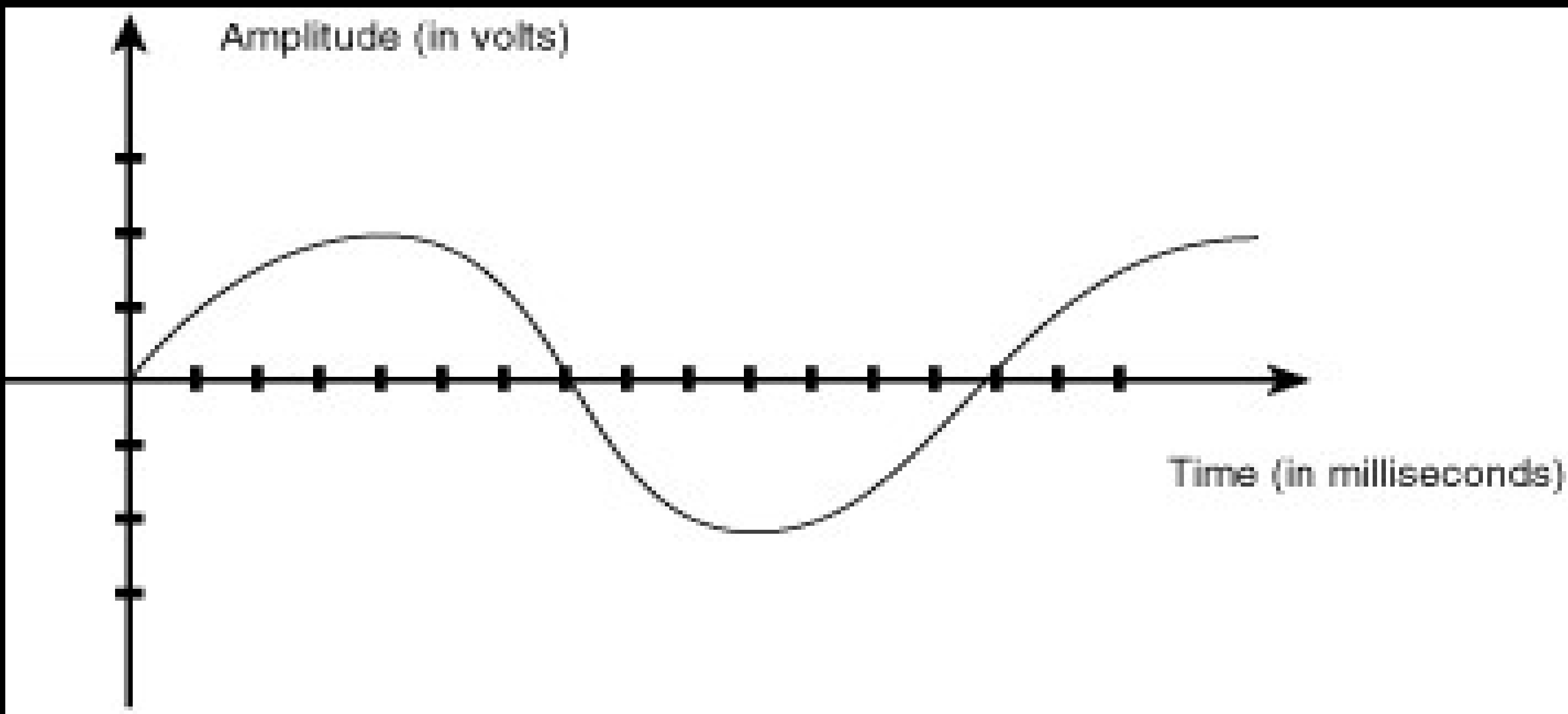
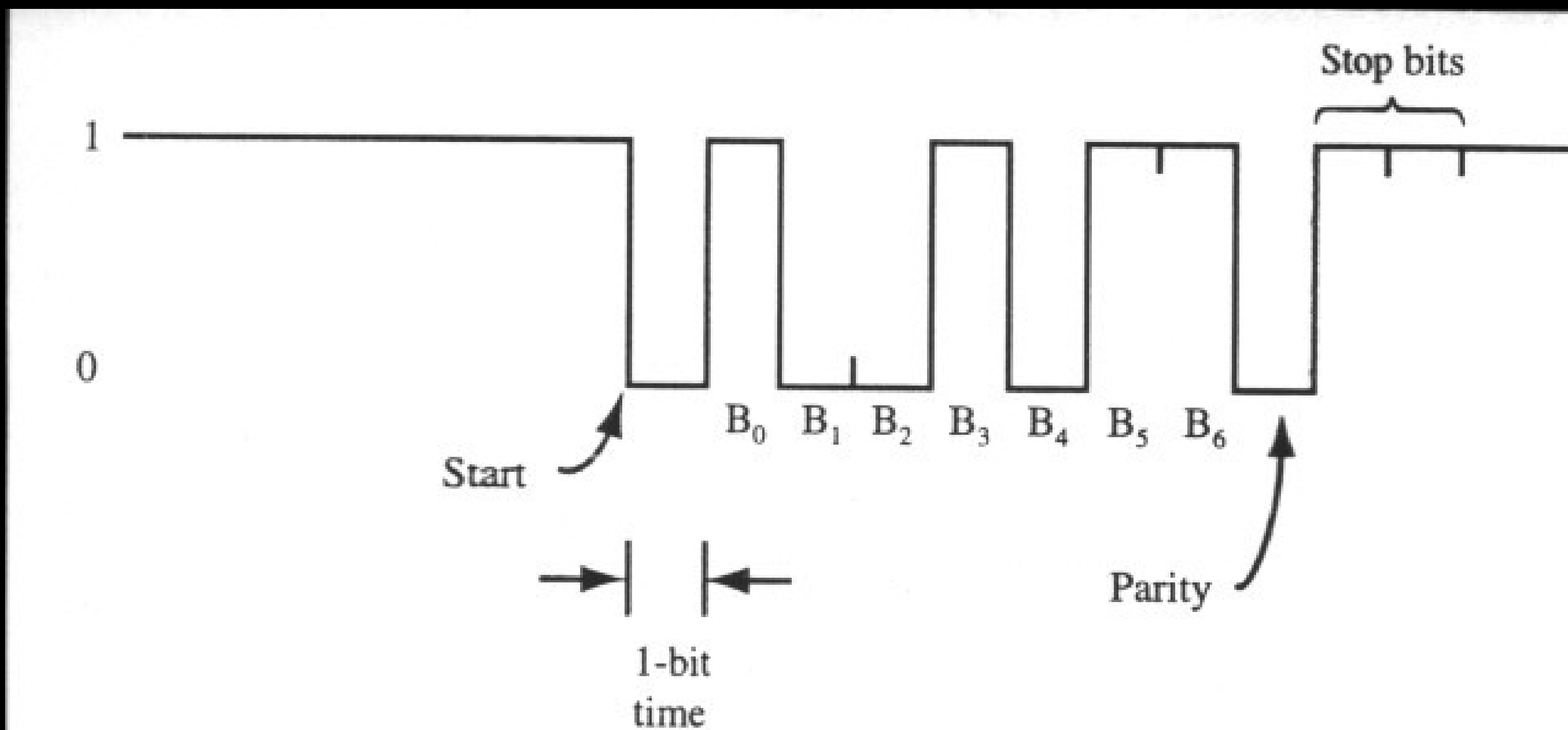
- Voltage, continuous, real-world



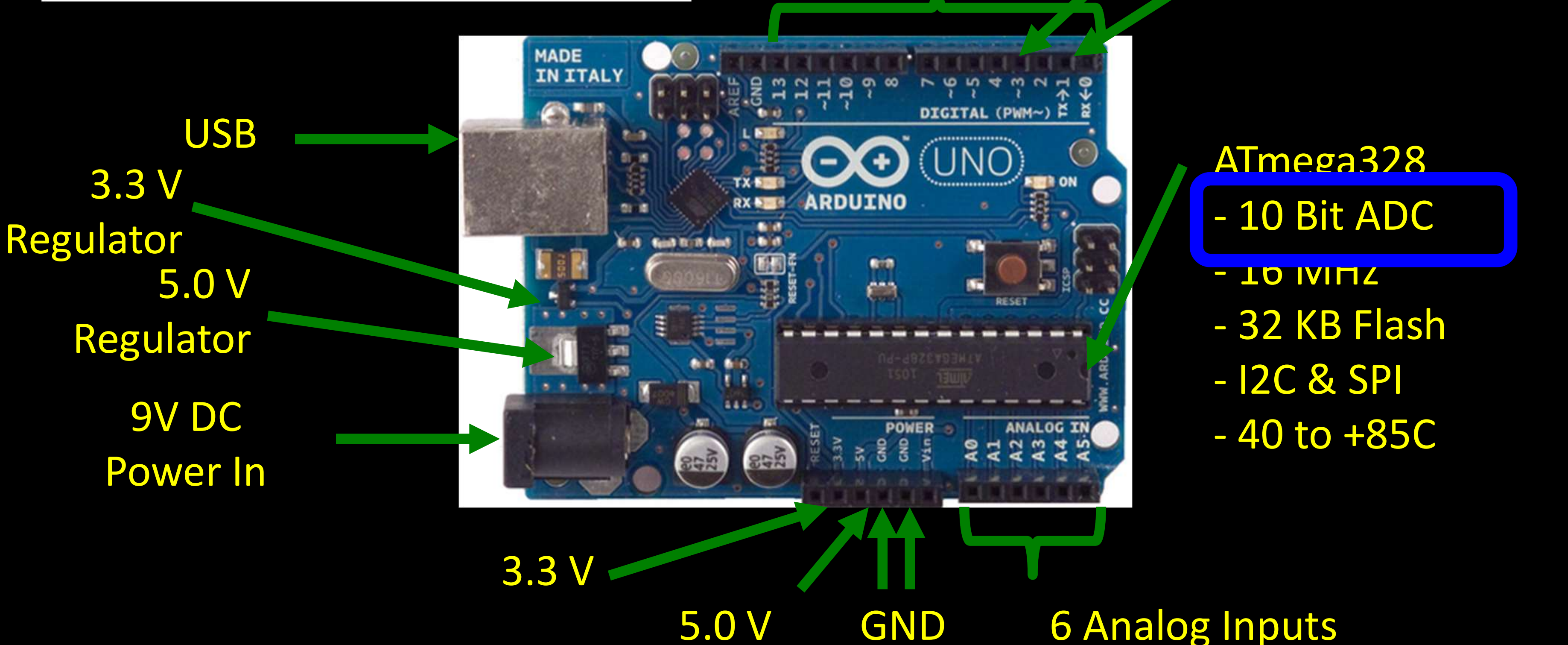
Digital:

- **Bits and Bytes, On/Off, 1 or 0, high or low, non-continuous**



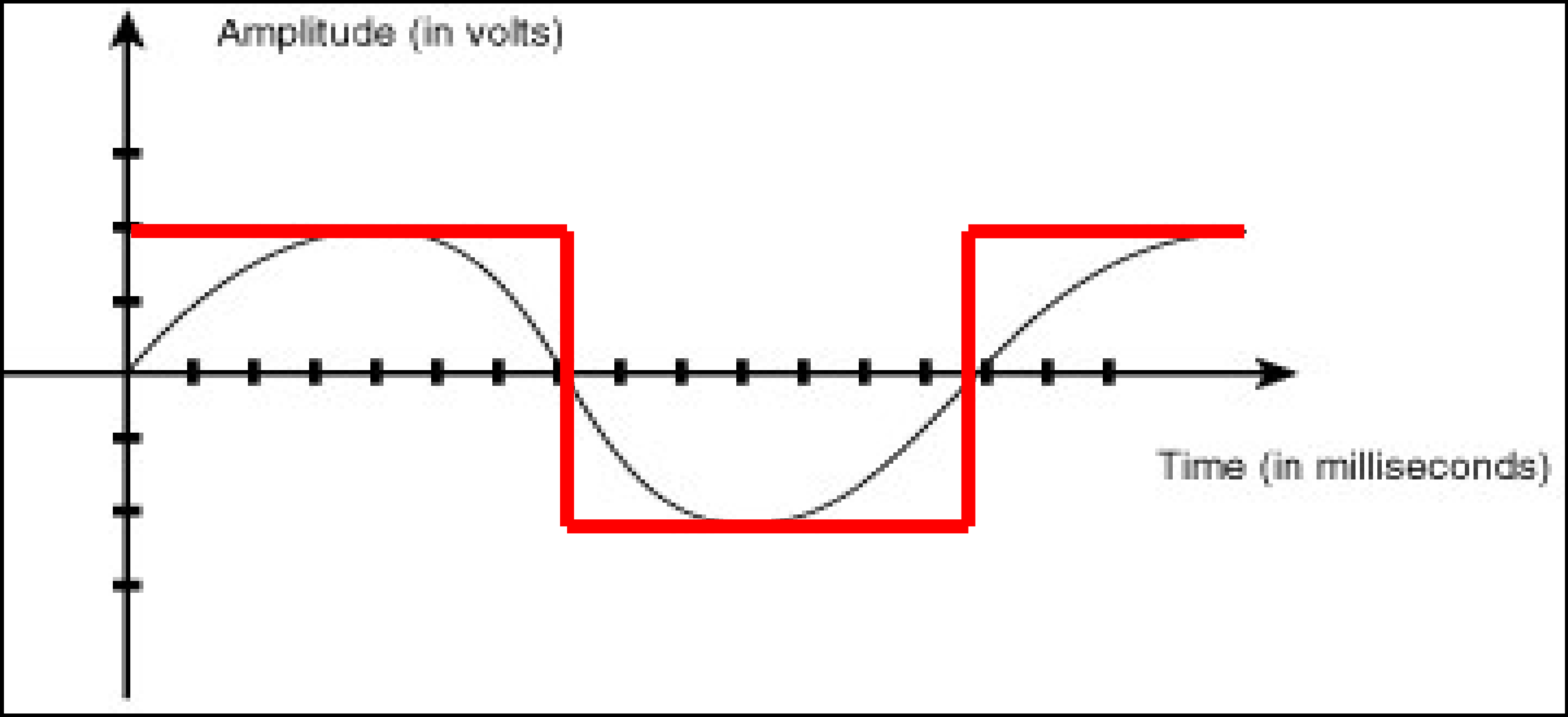
Analog vs. Digital:

- Arduino takes care of this through the ADC



Analog vs. Digital:

- Low resolution conversion (1 bit or 2 states)



Analog vs. Digital:

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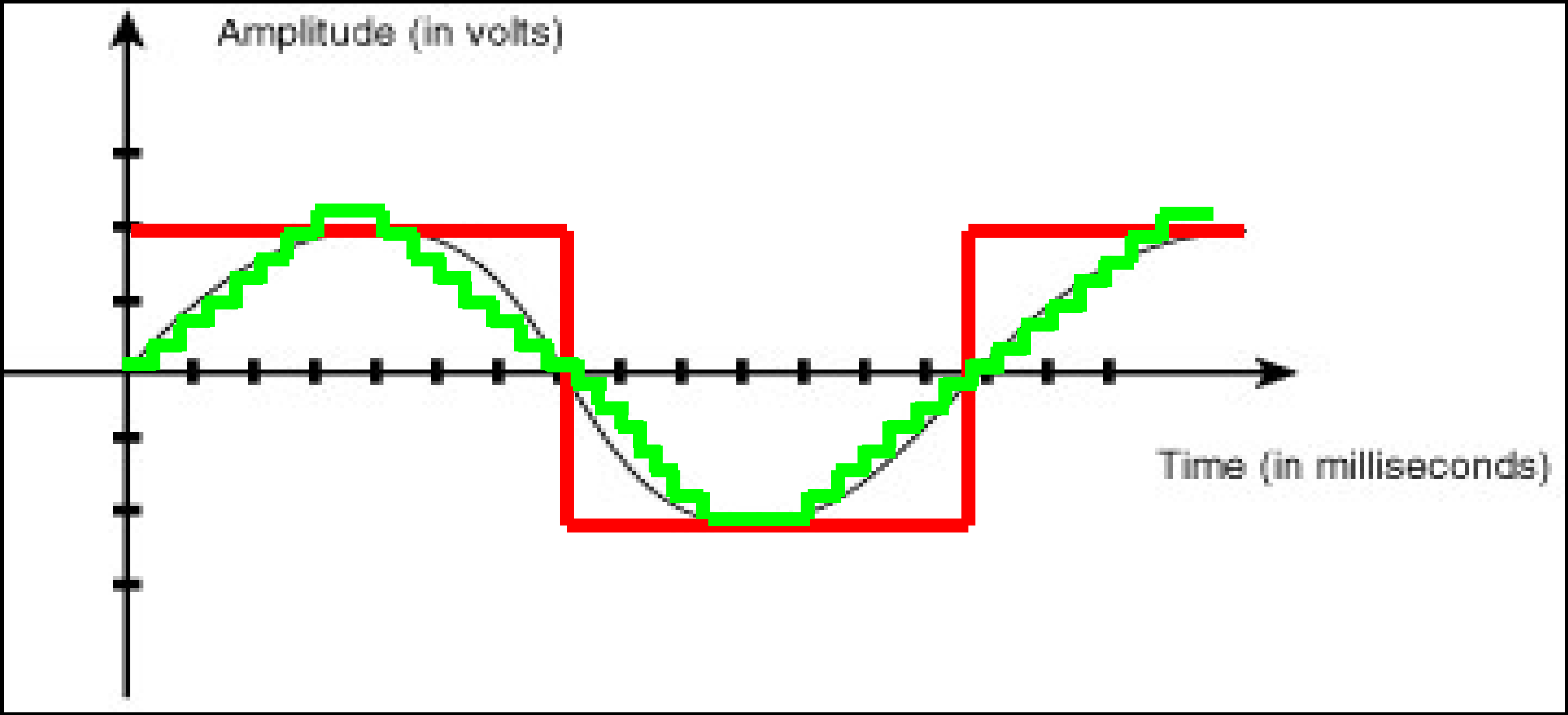
- **Bits and Bytes, On/Off, 1 or 0, high or low, non-continuous**



Red line – 2 states (1 Bit) = less info

Green line – 16 states (4 Bit) = more info

Analog vs. Digital:

Do you need to know: Is something there or is it a circle?

Analog vs. Digital:

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Level of Precision…Figuring out what you NEED to know

Say you want to hit a barn from 10 feet away with a rock. What do you need to know to do that?

Analog vs. Digital:

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Hit the barn Yes or No = one bit -> two states

0 = Miss
1 = Hit

Analog vs. Digital:

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Say you want to know if you hit specific part of the barn…

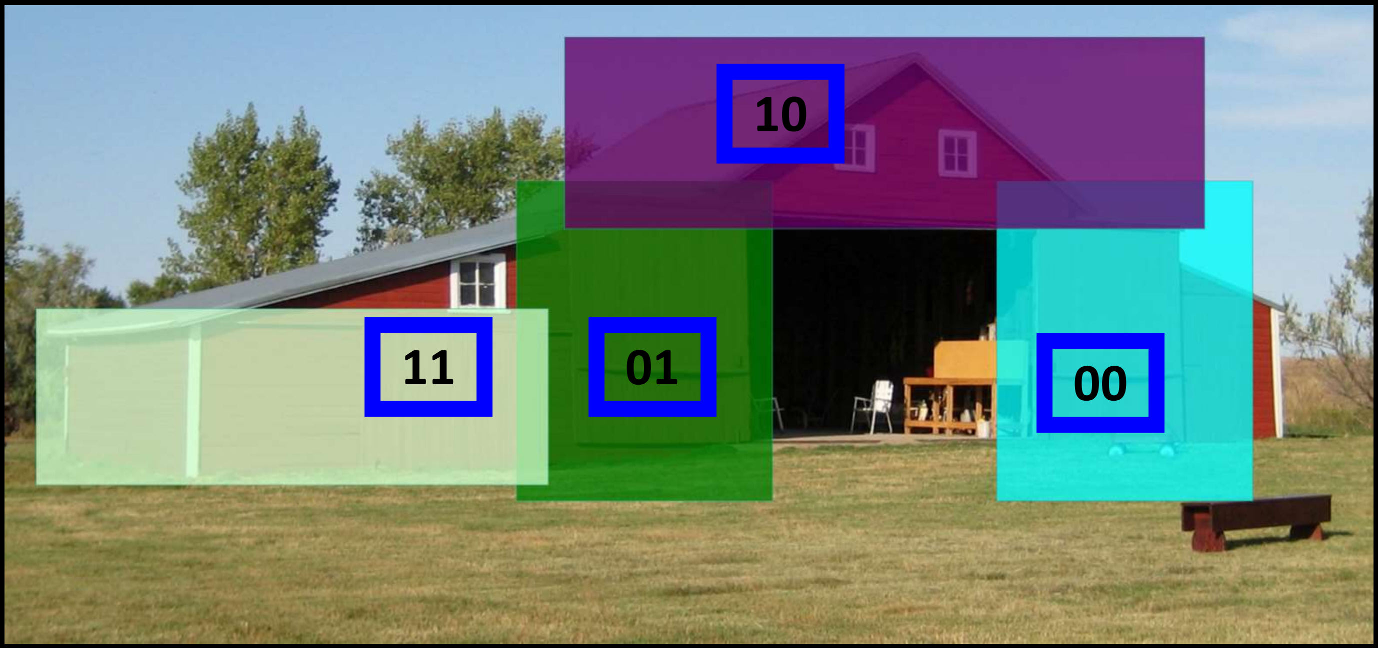
00 = Right Barn Door

01 = Left Barn Door

10 = Roof

11 = Side barn

Two bits -> Four States

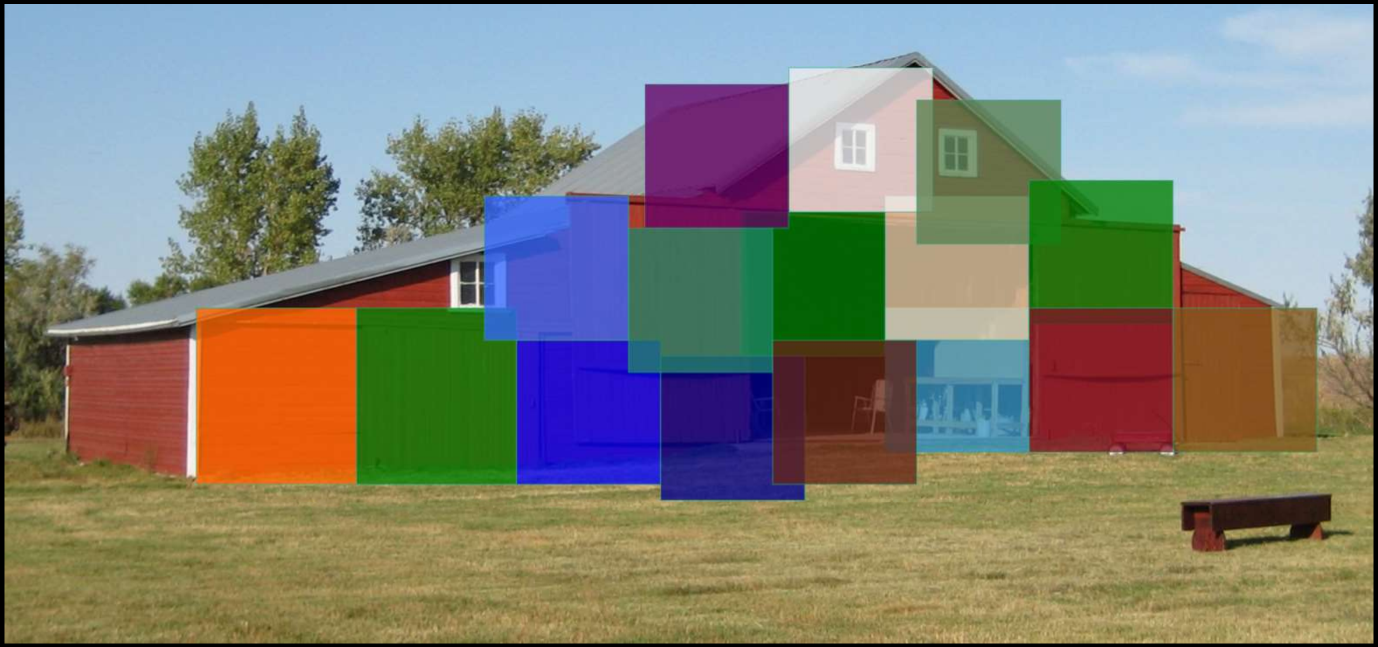


Analog vs. Digital:

How many bits (states) does this knowledge require?

4 bits -> 16 States

More resolution costs more memory/storage/bandwidth



Analog vs. Digital:

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- A state is one unique combination of bits
  - 1 bit – 0 or 1 = 2 states = 2^1
  - 2 bits – 00, 01, 10, 11 = 4 states = 2^2
  - 4 bits – 0000, 0001….1111 = 16 States = 2^4
  - 8 bits = 00000000….11111111 = 256 states = 2^8
  - 10 bits = 0000000000….1111111111 = 1024 states = 2^{10}
  - 16 bits = 0000000000000000…1111111111111111
    = 65,536 states = 2^{16}

- More bits provides more precision over a given voltage range

- If it is necessary to record small changes, more precision (bits), is required

- 8 bits is a byte
- 10 bits is how many bytes?

Analog vs. Digital:

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- **A 10-bit conversion has 2^{10} (0 to 1023) possible values**
  - **Resolution is $1/(2^{10} – 1) * 5V = 1/1023 * 5V = 0.00489$ V**
  - **For a device that is very precise, a 10-bit conversion allows for a higher resolution on the data (high-range accelerometers)**

$$0.00489V * Decimal = Voltage$$

Analog vs. Digital:

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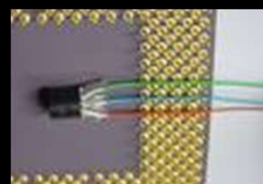
42.0 C temp
Real World

Real World to
Analog Voltage



0C = 0V **50C = 5V**

4.20V = 42.0 C

10 bit ADC

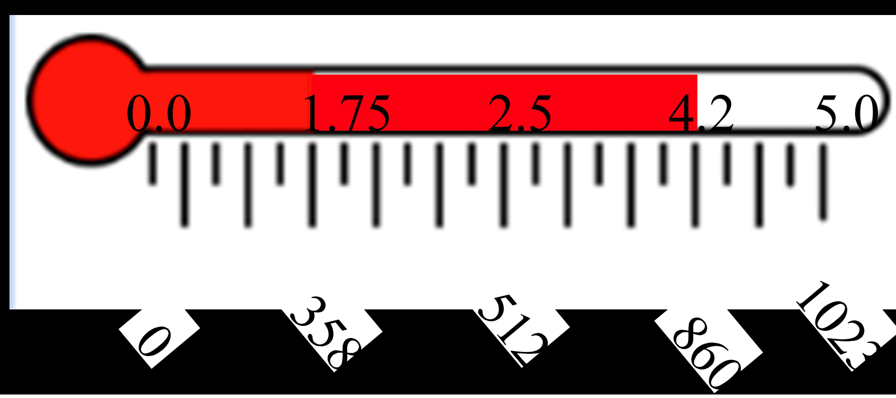
5V = 1023

0V = 0

4.20V = 860

(4.20V / 5.0V * 1023)
= 860.16
= 860

860 =
1101011100 binary



Analog vs. Digital:

- **If this seems a bit confusing – DON'T WORRY!!**

- **The more you use it the more sense it will make**

Part 1 – Arduino Test Drive

Sensors

A. LED Visual Display
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Potentiometer:

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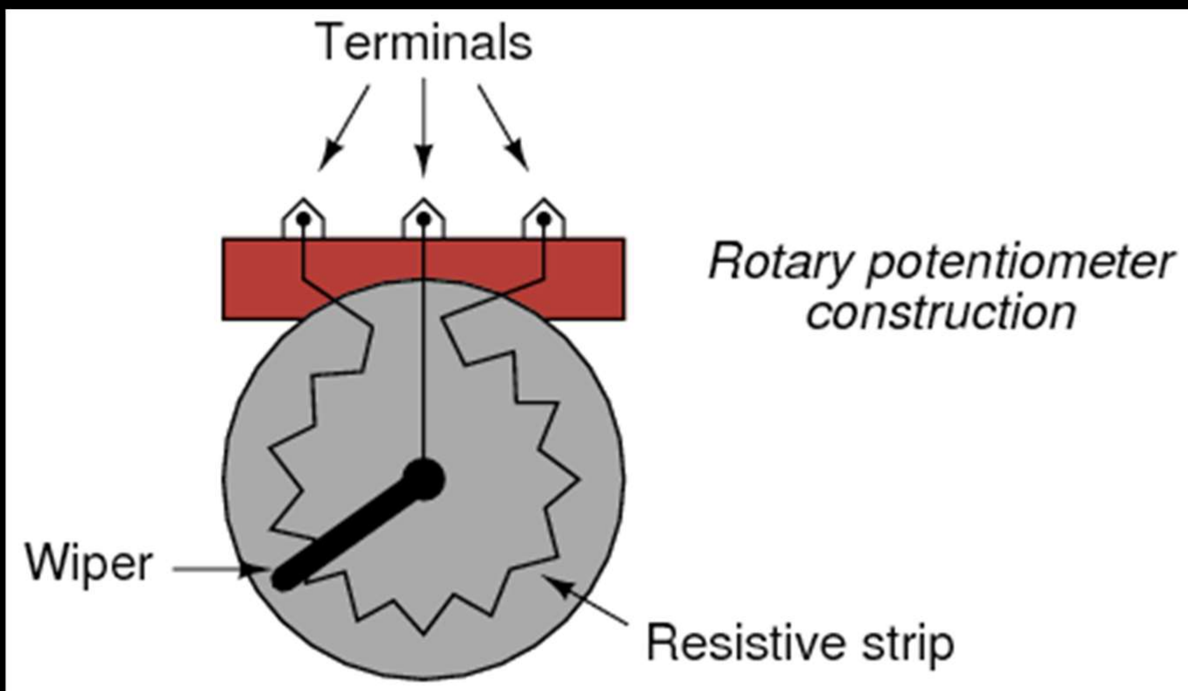
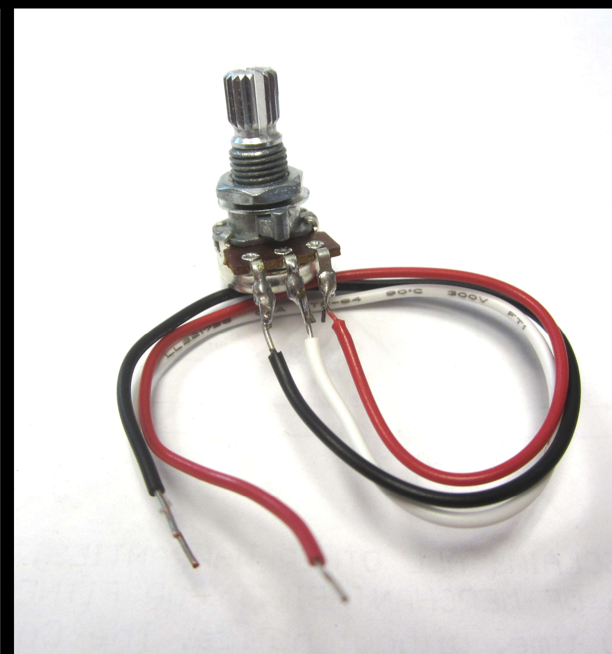
- **It can sweep its output between two voltages it is supplied.**





Potentiometer:

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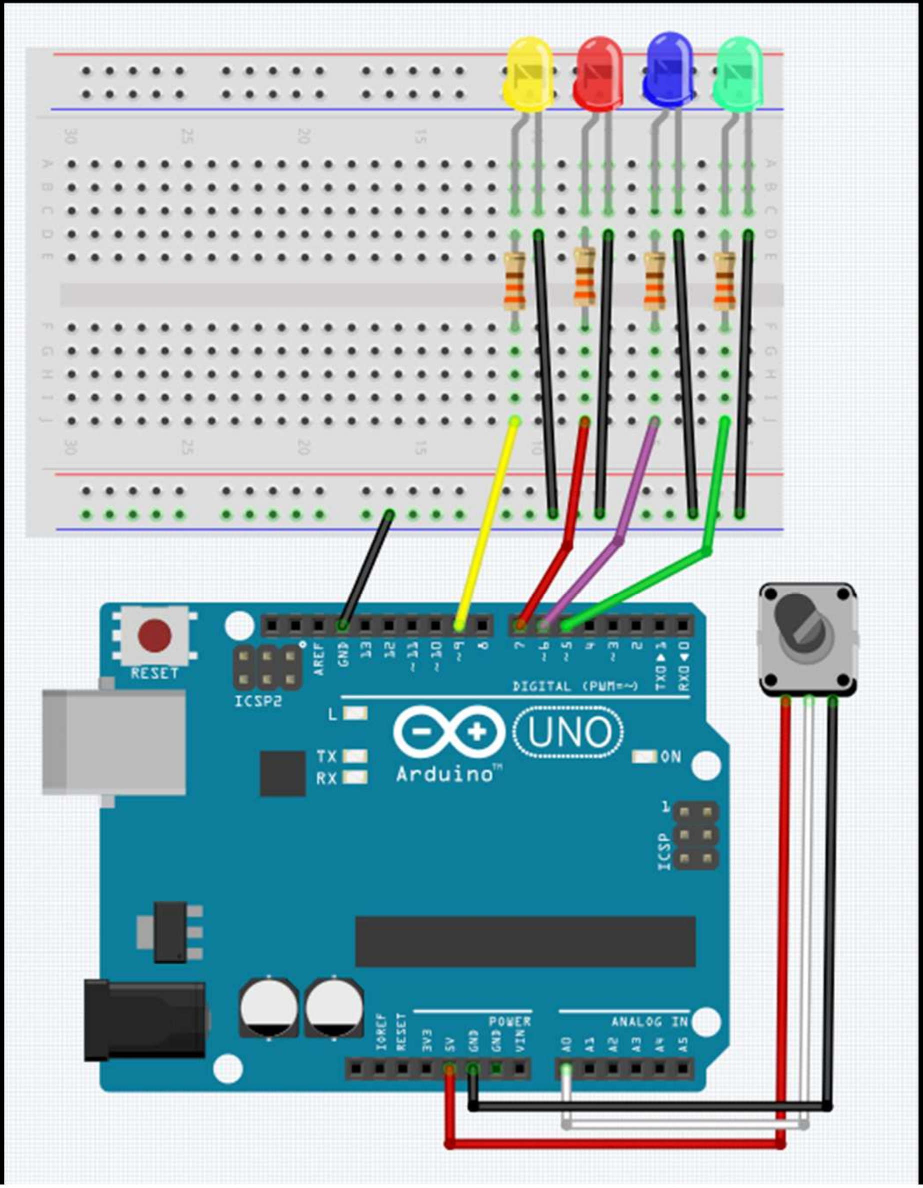
- Connect the Red wire from POT to **5V on Arduino**

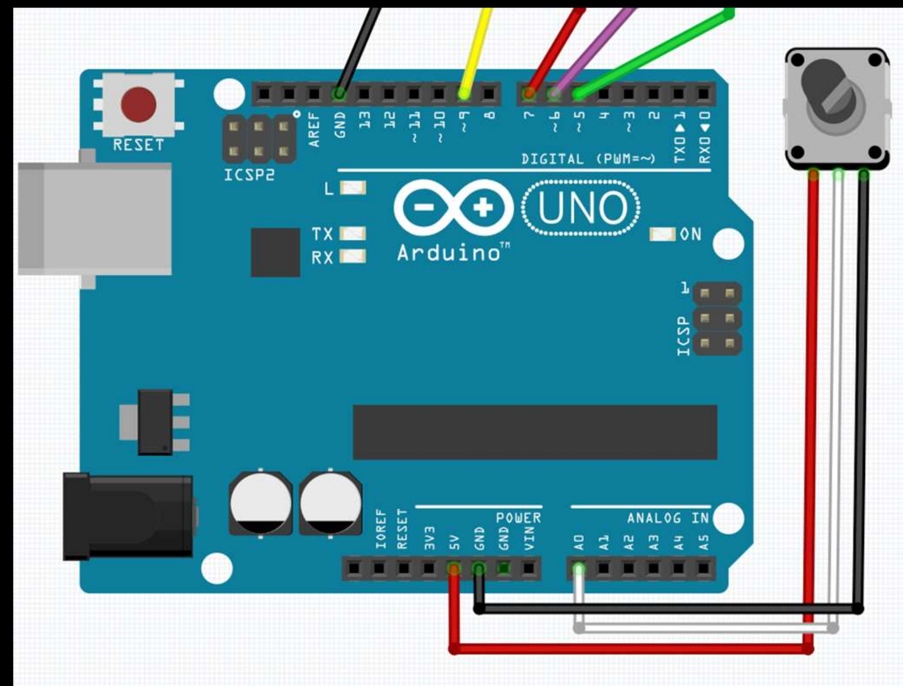
- Connect Black wire from POT to **GND on Arduino**

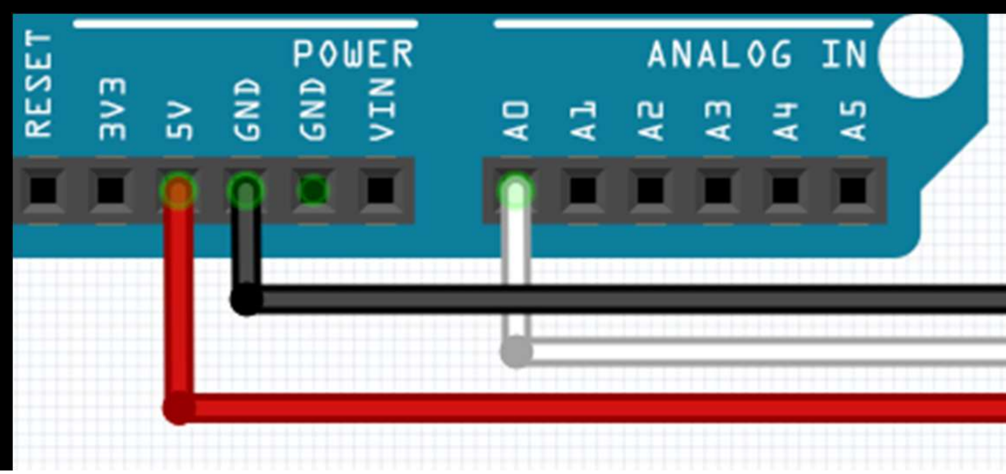


Potentiometer:

- Connect the Red wire from POT to **5V on Arduino**

- Connect Black wire from POT to **GND on Arduino**





Potentiometer:

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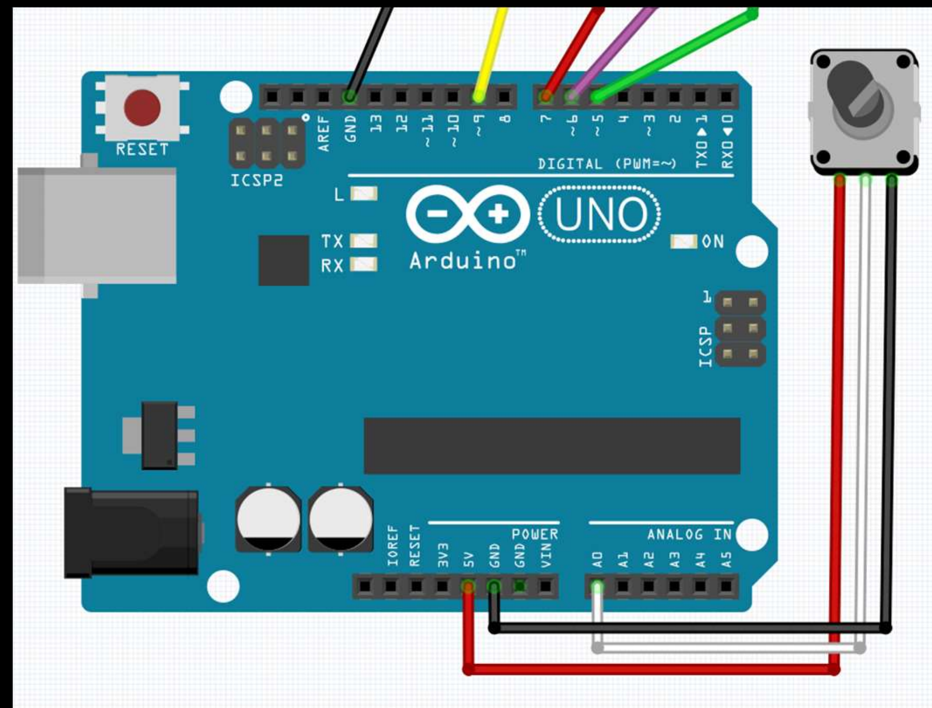
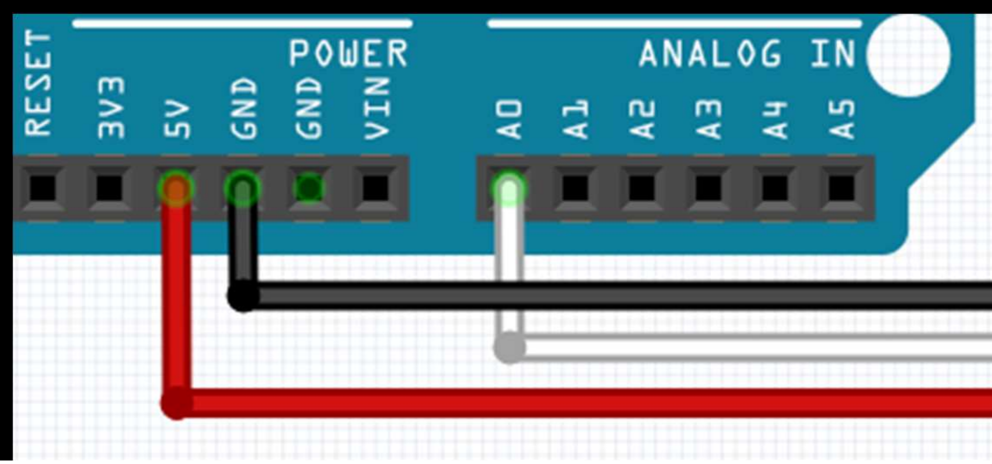
- **Connect the White wire from POT to A0 on the Arduino**





Potentiometer:

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- Modify your sketch to add the following variable

```
// Definitions
    int pot;

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

      Serial.begin(9600);

// setup the LED Visual Display
      pinMode(5, OUTPUT);  //Green LED
```

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Potentiometer:

- Read value on pin A0 by using **analogRead**

- **Serial.println** the value on A0

- Change delay to 50 ms

```
void loop() {
//   put your main code here, to r

    pot = analogRead(A0);
    Serial.println(pot);

//   Turn script running leds OFF
    digitalWrite(5, LOW);   //Gree
    digitalWrite(6, LOW);   //Purp
    digitalWrite(7, LOW);   //Red
    digitalWrite(9, LOW);   //Yell

    delay(50);

    digitalWrite(5, HIGH);   //Gre
    delay(50);
    digitalWrite(6, HIGH);   //Pur
    delay(50);
    digitalWrite(7, HIGH);   //Red
    delay(50);
    digitalWrite(9, HIGH);   //Yel
    delay(50);
}
```

Potentiometer:

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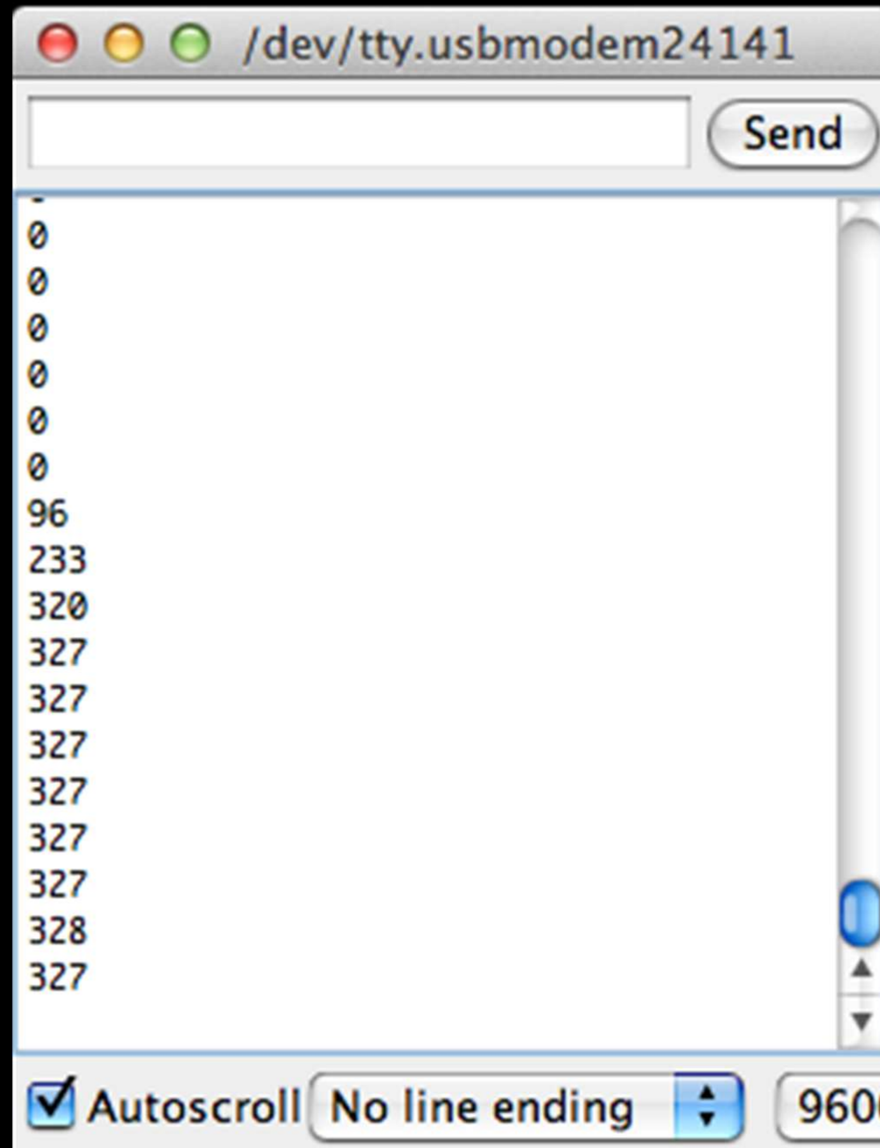
- Compile and Upload

- Start Serial Monitor

- LEDs should be blinking fast

- What does the value mean/represent?



Potentiometer:

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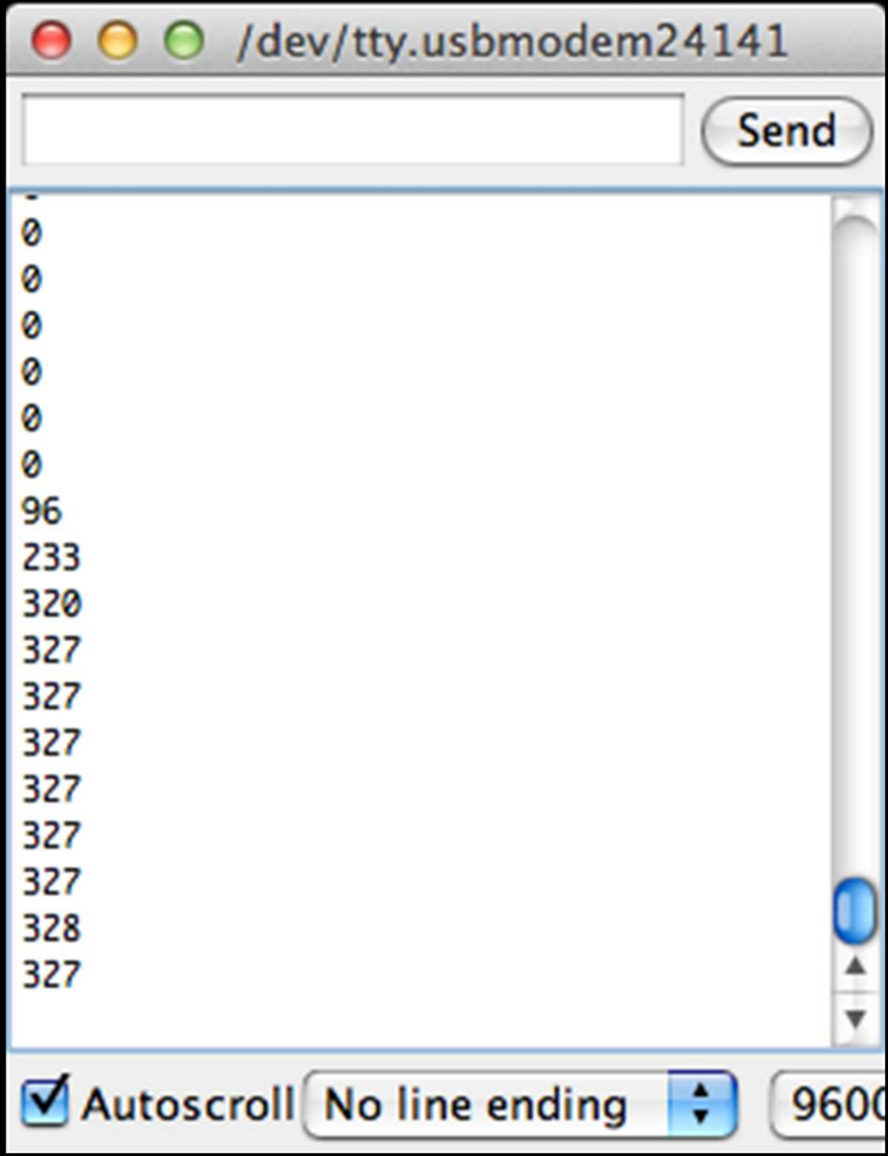
- **Value is digital (integer – whole number) equivalent of analog value**

- **When the voltage is 0.0V we see “0”**

- **When the voltage is 5.0V we see “1023”**

- **What resolution?**



Potentiometer:

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- 10-bit conversion has 2^{10} (0 to 1023) possible values

  - Resolution is…

$$0.00489V * Decimal = Voltage$$

  - What is the voltage output of the potentiometer if value is 689?

$$0.00489V * 689 = Voltage$$
$$3.3692 = Voltage$$

Potentiometer:

- **Modify the sketch to calculate the voltage based on the analogRead value and print to the screen**

- **Will need to create a new variable (float) and use some math**

- **Printing more than two items to the screen, use…**
  - > **Serial.print(“ ”)** //to print to same line
  - > Serial.print(“**\t** ______”) // to **create tab**
  - > **Serial.println(“ ”)** // to create a new line

Potentiometer:

- Let's look at the code changes

- float because its not a whole number

- Verify and Upload

```
// Definitions
    int pot;
    float potVolt;
```

```
void loop() {
//   put your main code here, to run re

    pot = analogRead(A0);
    potVolt = pot*(5.0/1023);
    Serial.print(pot);
    Serial.print("\t potVolt ");
    Serial.println(potVolt);
```

Potentiometer:

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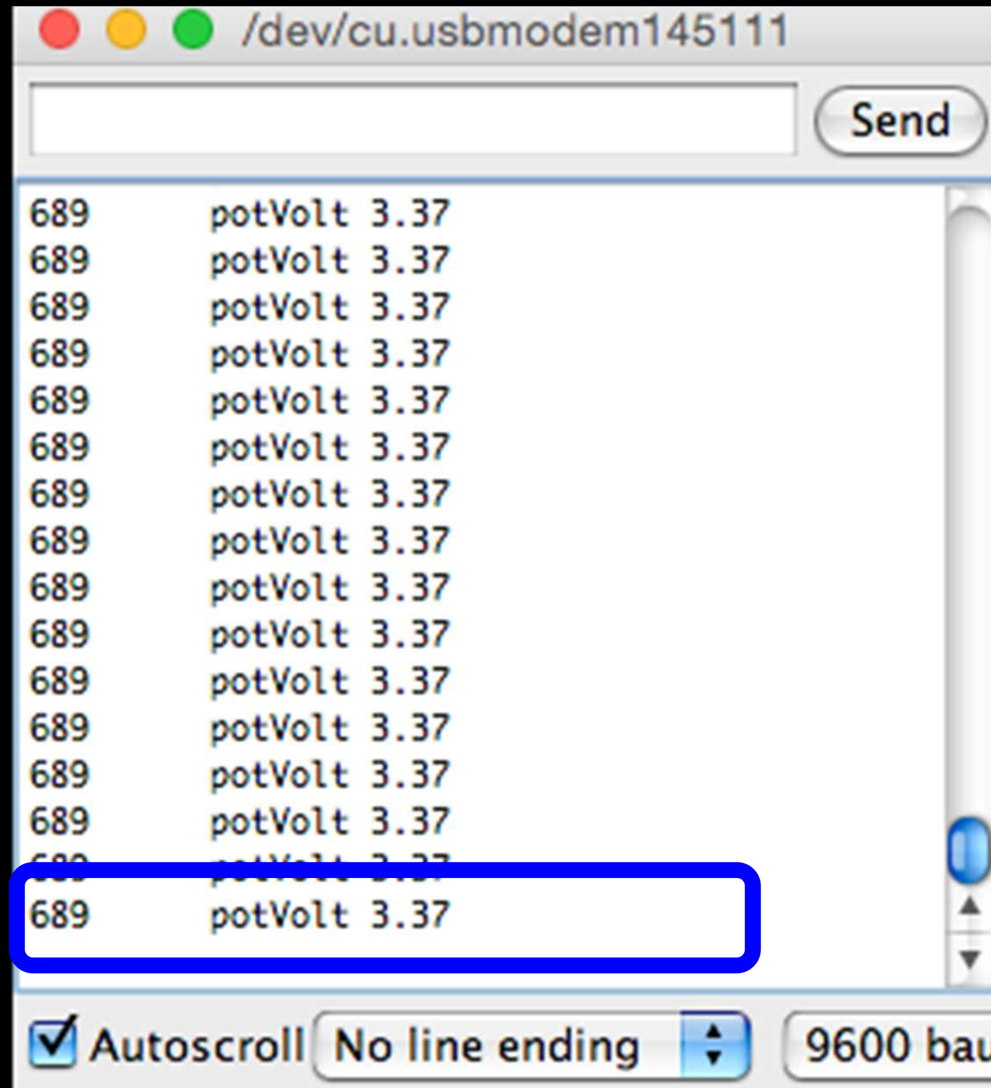
- Launch Serial Monitor

- Turn potentiometer until you see 689 and verify same value we calculated

- Tinker



Potentiometer:

- **What would you have to do to use the potentiometer to control the delay of LED Blink pattern**

- **Replace time in delay command with pot value**

- **Try it**

Potentiometer:

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- Let’s look at the code changes

- One more step…

```
void loop() {
//   put your main code here, to run repeat

     pot = analogRead(A0);
     potVolt = pot*(5.0/1023);
     Serial.print(pot);
     Serial.print("\t potVolt ");
     Serial.println(potVolt);

//   Turn script running leds OFF at begini
     digitalWrite(5, LOW);   //Green LED
     digitalWrite(6, LOW);   //Purple LED
     digitalWrite(7, LOW);   //Red LED
     digitalWrite(9, LOW);   //Yellow LED

     delay(pot);

     digitalWrite(5, HIGH);   //Green LED
     delay(pot);
     digitalWrite(6, HIGH);   //Purple LED
     delay(pot);
     digitalWrite(7, HIGH);   //Red LED
     delay(pot);
     digitalWrite(9, HIGH);   //Yellow LED
     delay(pot);
}
```

Potentiometer:

- Modify the sketch so we can use our LED Visual Display instead of the serial monitor to know what the sensor value / voltage is

- Use a series of if statements to turn LEDs for different values

0.00V to 1.25V = Turn on Green LED
1.26V to 2.50V = Turn on Green/Purple LED
2.51V to 3.75V = Turn on Green/Purple/Red LED
3.75V to 5.00V = Turn on Green/Purple/Red/Yellow LED

Potentiometer:

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- Let's look at the Sketch

- Comment out previous digitalWrite commands

```
delay(pot);

digitalWrite(5, HIGH);  //Green LED
delay(pot);
digitalWrite(6, HIGH);  //Purple LED
delay(pot);
digitalWrite(7, HIGH);  //Red LED
delay(pot);
digitalWrite(9, HIGH);  //Yellow LED
delay(pot);
```

Potentiometer:

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- Add the following **if statements** to your void loop

- Compile and Upload

- Verify LED Display is working by comparing with Serial Monitor and Potentiometer reading

- Tinker until everyone is at this point

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

     pot = analogRead(A0);
     potVolt = pot*(5.0/1023);
     Serial.print(pot);
     Serial.print("\t potVolt ");
     Serial.println(potVolt);

//   Turn script running leds OFF at
     digitalWrite(5, LOW);  //Green L
     digitalWrite(6, LOW);  //Purple
     digitalWrite(7, LOW);  //Red LED
     digitalWrite(9, LOW);  //Yellow

     if(potVolt > 1.24) {
     digitalWrite(5, HIGH);
     }
     if(potVolt > 2.49) {
     digitalWrite(6, HIGH);
     }
     if(potVolt > 3.74) {
     digitalWrite(7, HIGH);
     }
     if(potVolt > 4.99) {
     digitalWrite(9, HIGH);
     }
     delay(100);

/*     delay(pot);

     digitalWrite(5, HIGH);  //Green
     delay(pot);
     digitalWrite(6, HIGH);  //Purple
     delay(pot);
     digitalWrite(7, HIGH);  //Red LE
     delay(pot);
     digitalWrite(9, HIGH);  //Yellow
     delay(pot);
*/
```

Potentiometer:

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- Add the following **if statements** to your void loop
- Compile and Upload
- Verify LED Display is working by comparing with Serial Monitor and Potentiometer reading
- Tinker until everyone is at this point

```
if(potVolt > 1.24) {
digitalWrite(5, HIGH);
}
if(potVolt > 2.49) {
digitalWrite(6, HIGH);
}
if(potVolt > 3.74) {
digitalWrite(7, HIGH);
}
if(potVolt > 4.99) {
digitalWrite(9, HIGH);
}
delay(100);
```

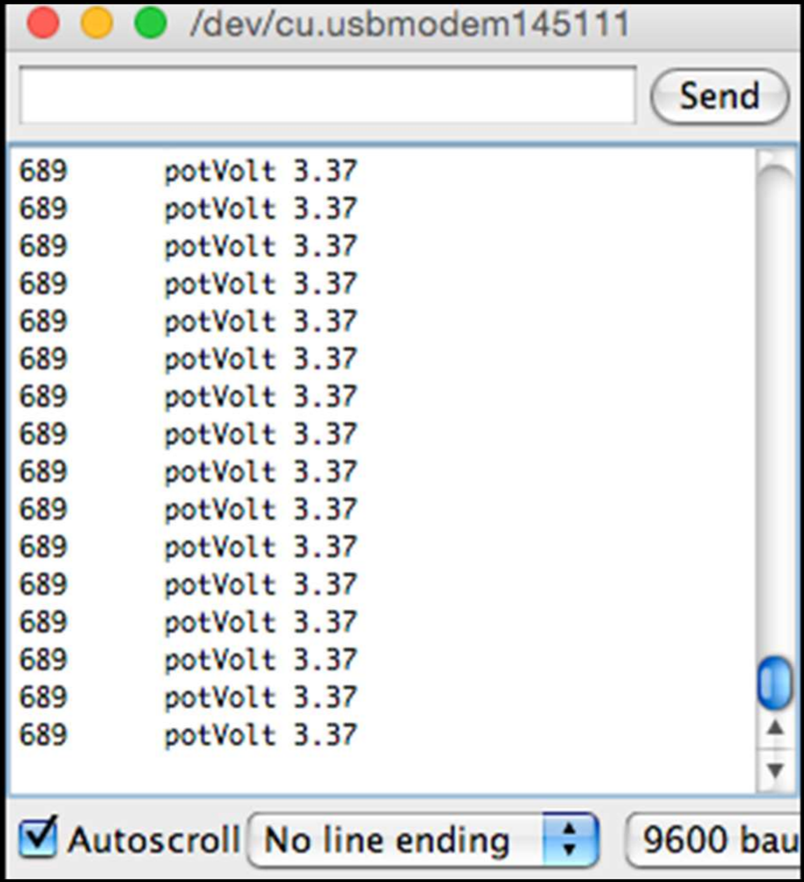
Potentiometer:

Space Minor
UNIVERSITY OF COLORADO BOULDER

- Connect USB and upload same code

- Same results?

- What happens?



Part 1 – Arduino Test Drive
Sensors

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

Balloon Shield Build Part 1:

The Balloon Shield will be used on your payload.

It will function the same as your breadboard but wires will not come loose

After certain points working with the code and wires, we will add items to the balloon shield and retest

Balloon Shield Build Part 1:

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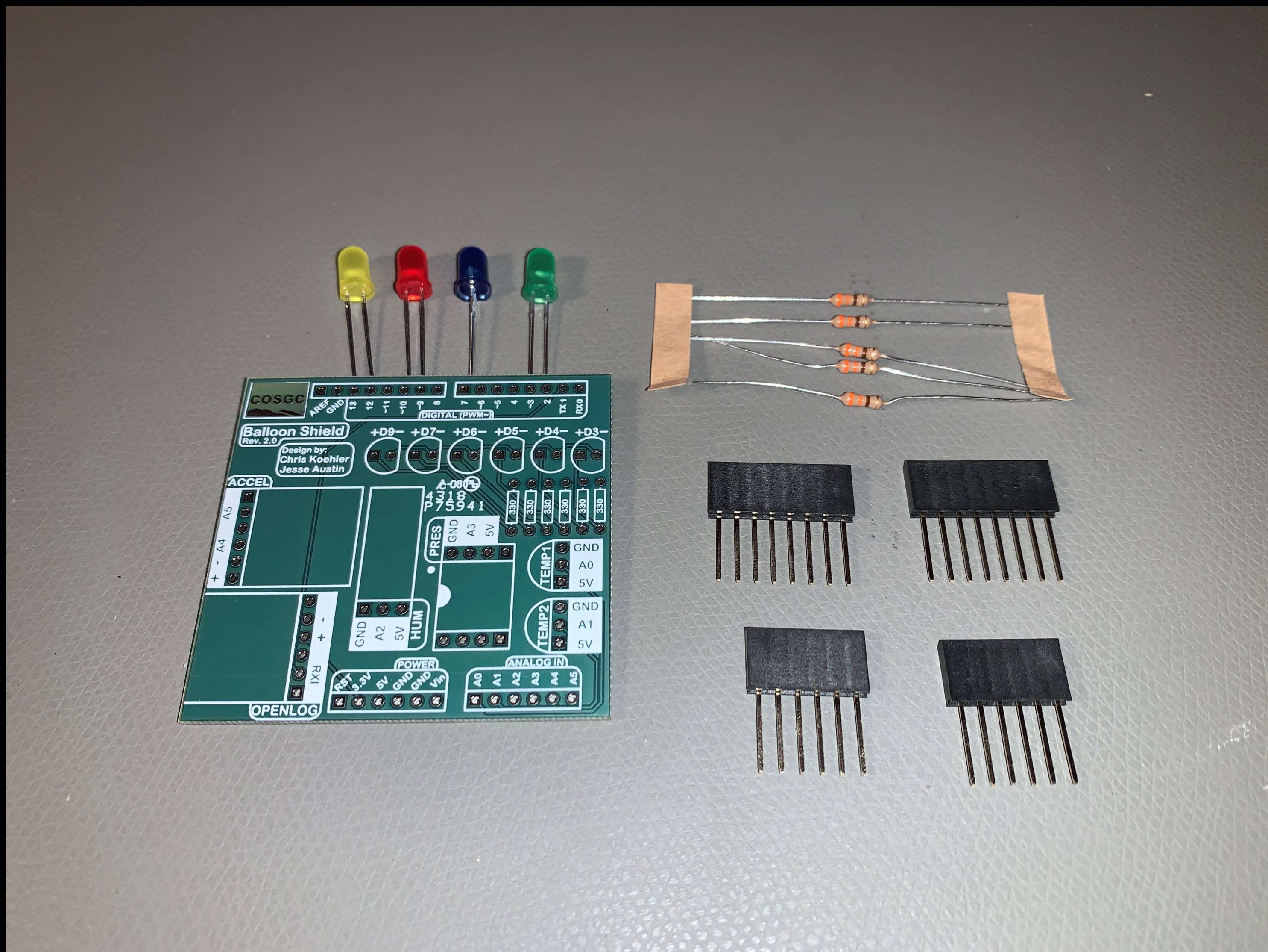

Balloon Shield Build Part 1:

Space Minor
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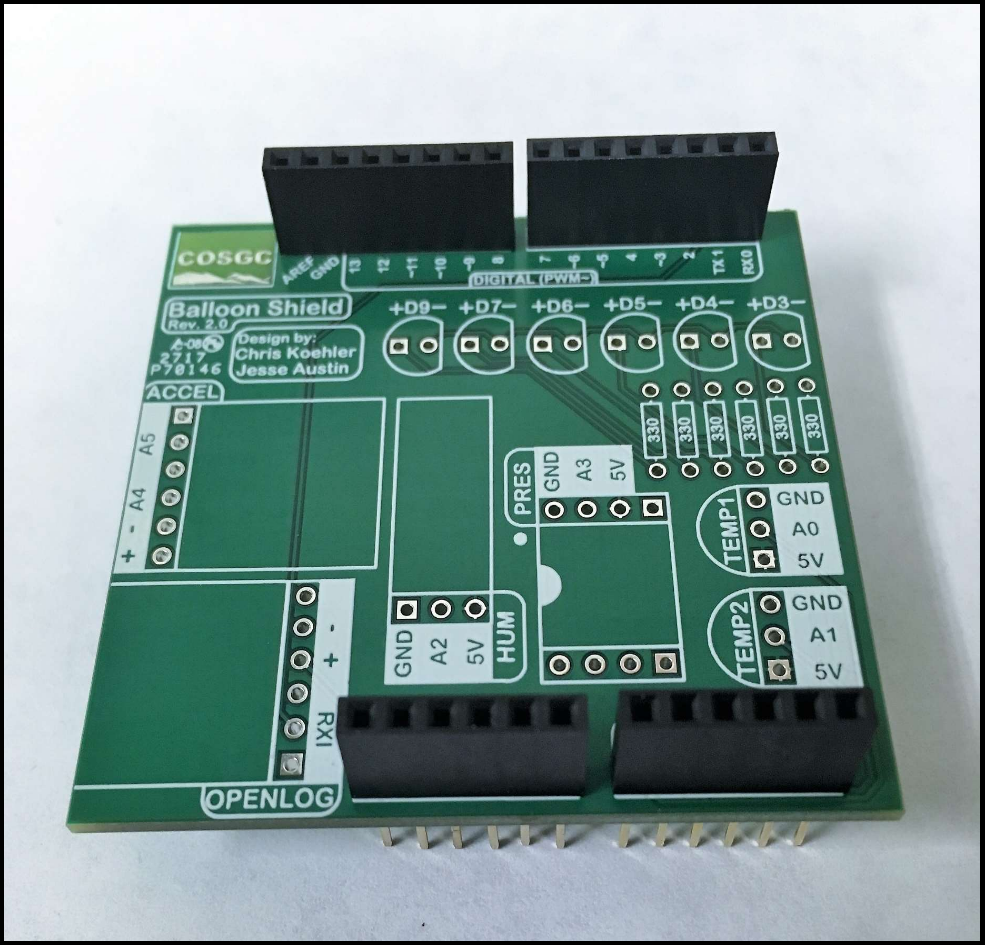
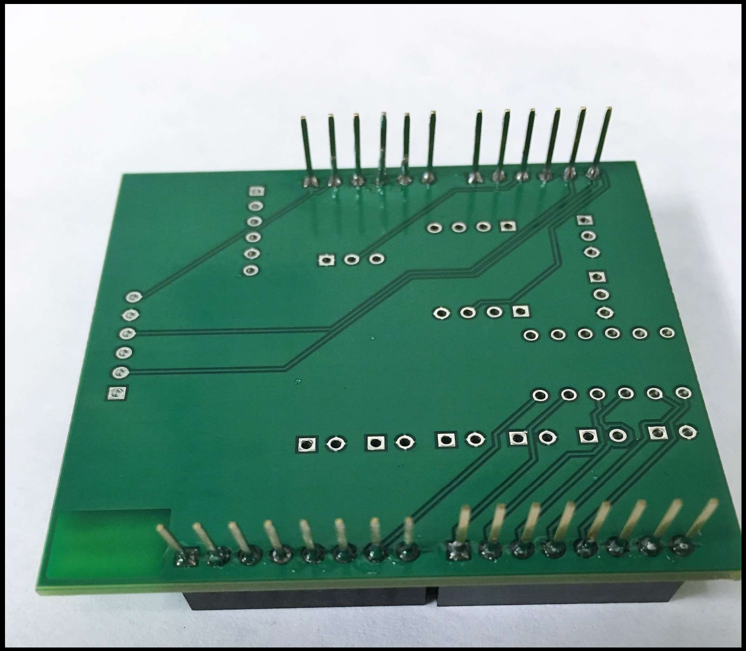
- **Add Headers**

- **Keep flush and perpendicular to board**



Balloon Shield Build Part 1:

Solder from bottom of board



Balloon Shield Build Part 1:

Space Minor
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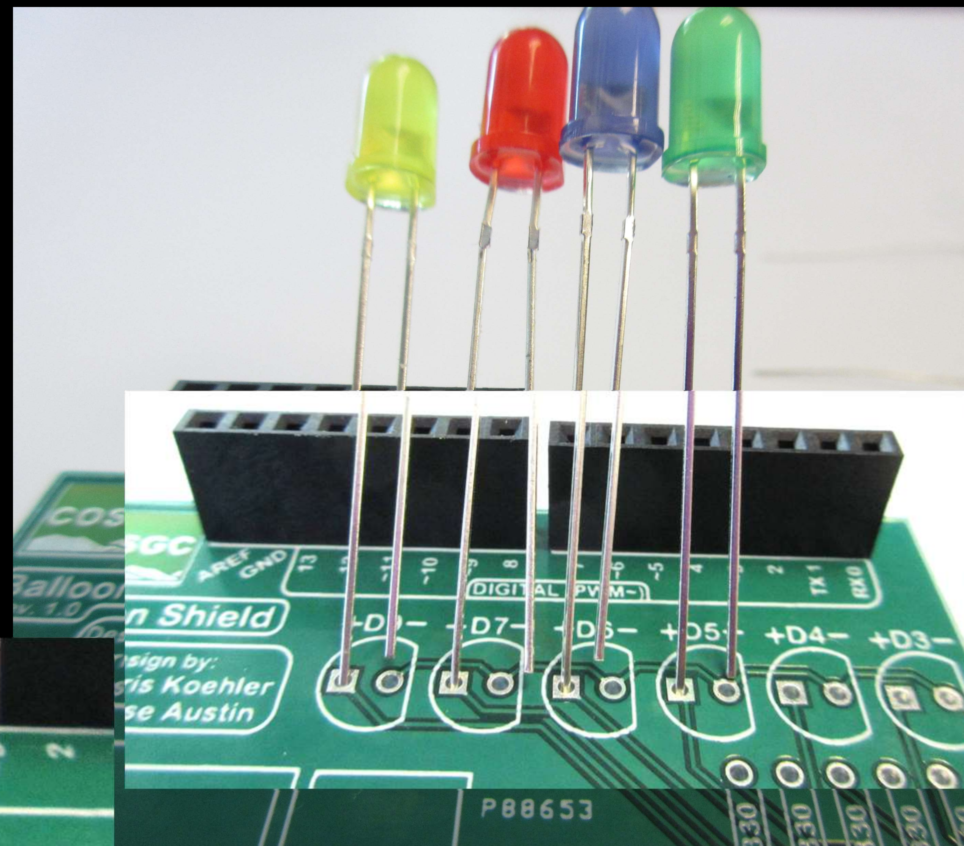
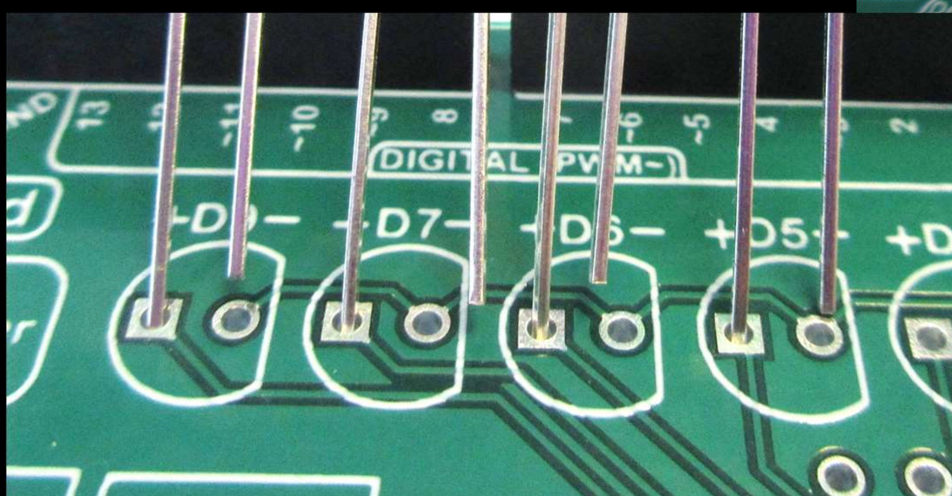
- Add LEDs

- Notice + and -





Balloon Shield Build Part 1:

Space Minor
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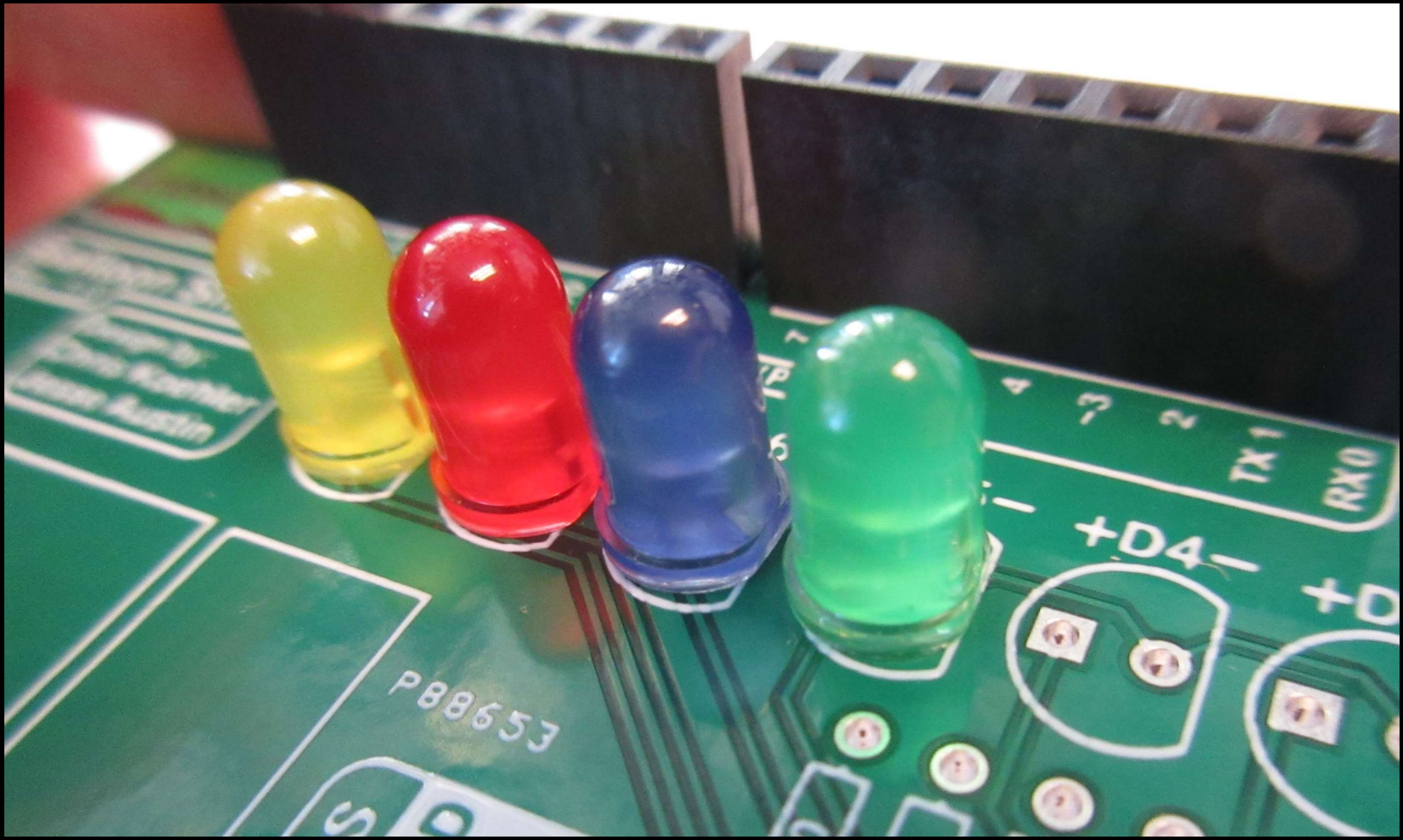
Also notice the LEDs shape on board



Balloon Shield Build Part 1:

Space Minor
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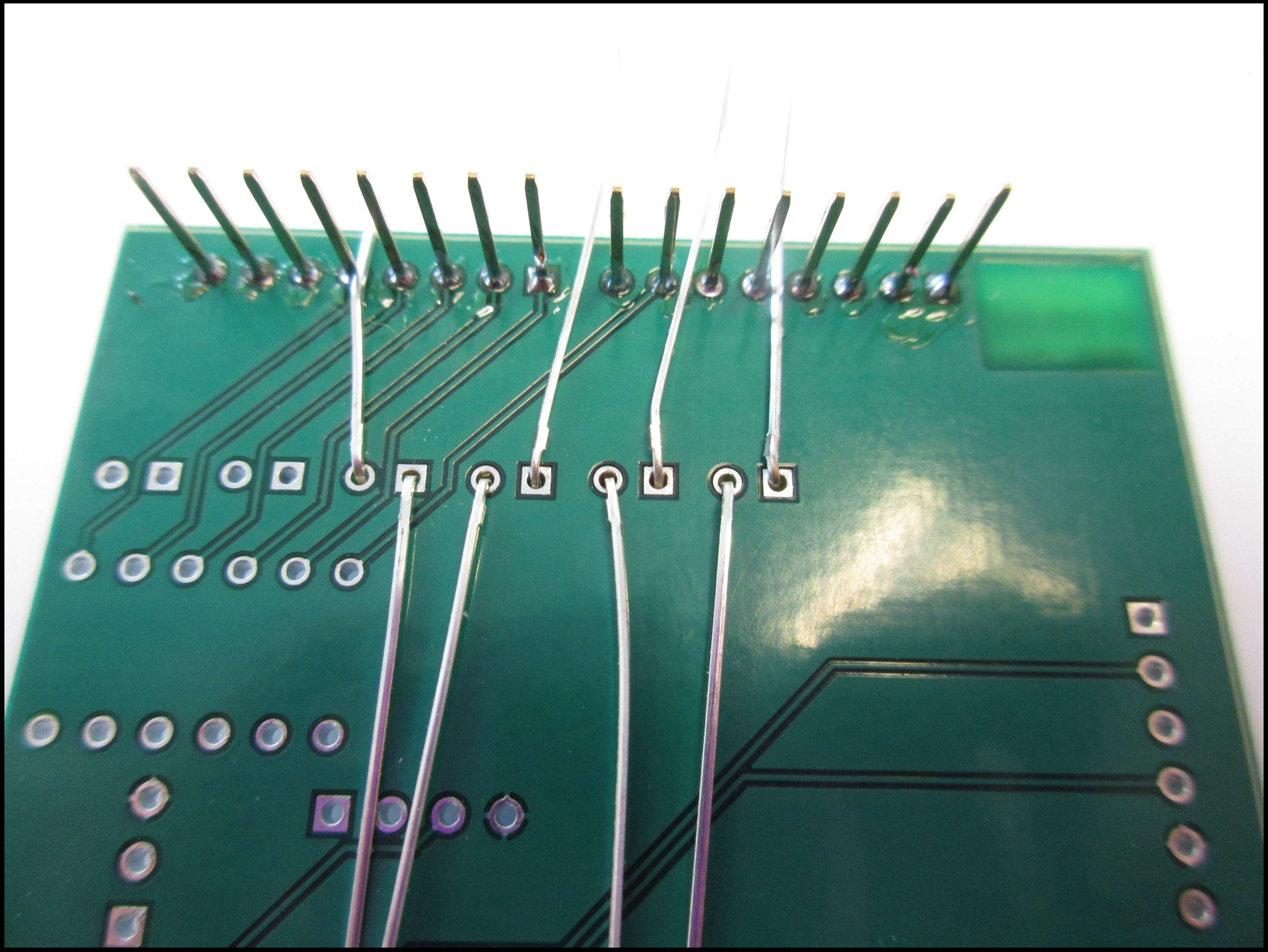
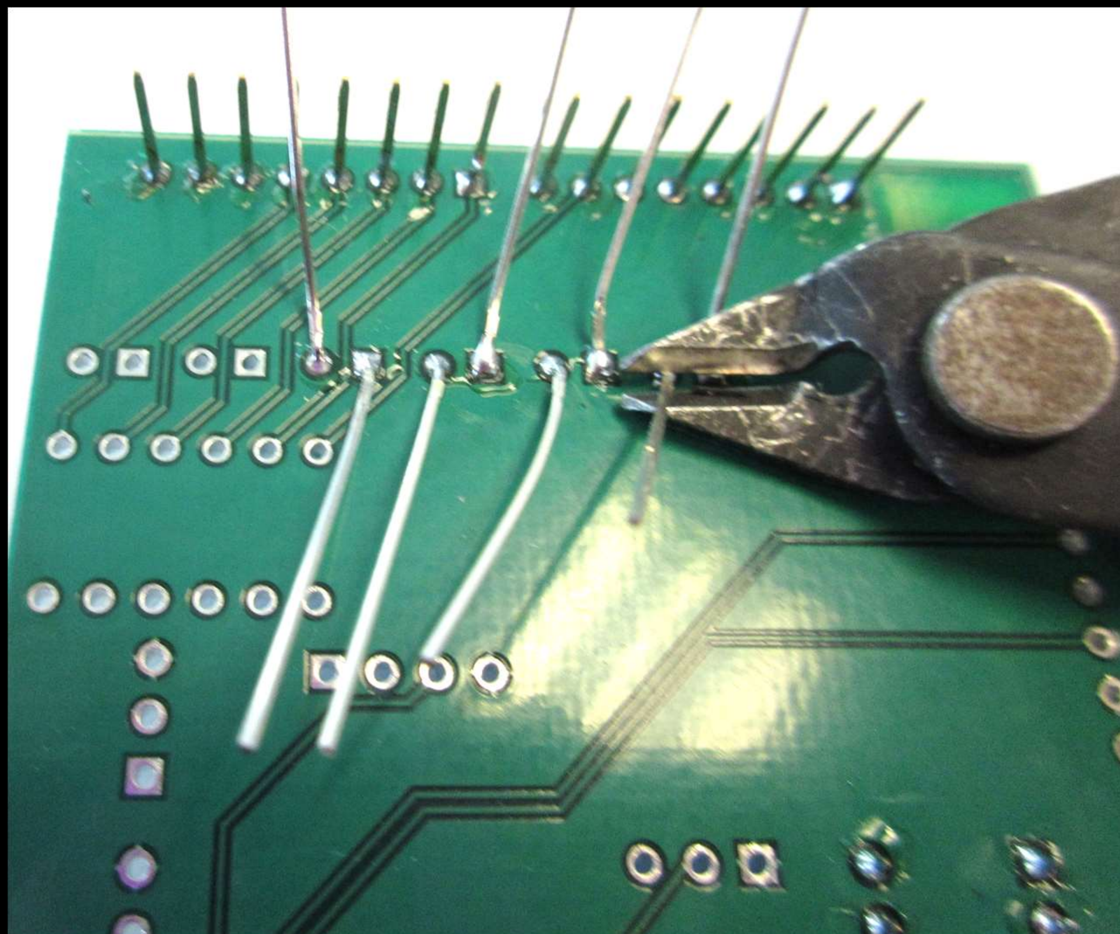
- **Bend leads over flat so LEDs are flush with top of board**



Balloon Shield Build Part 1:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

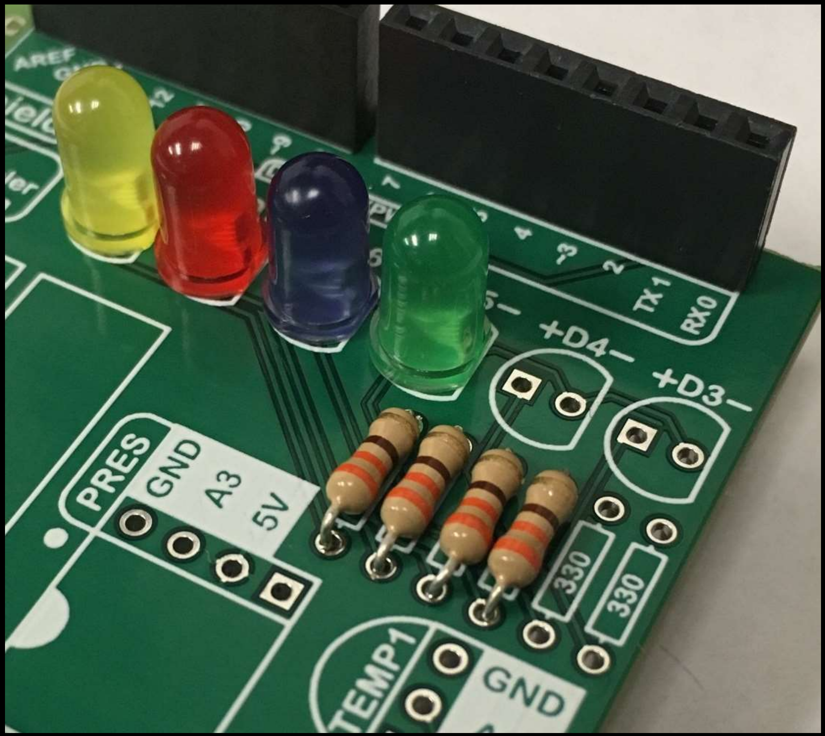
- Trim after soldering – LED LEEDS ONLY!!



Balloon Shield Build Part 1:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

Add resistors (no polarity)

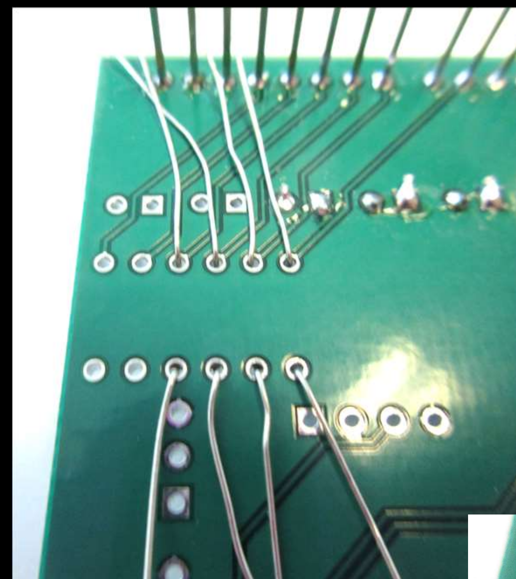


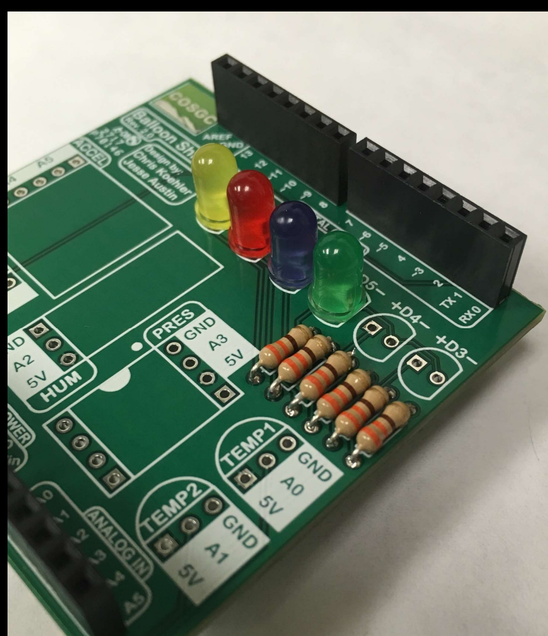
Balloon Shield Build Part 1:

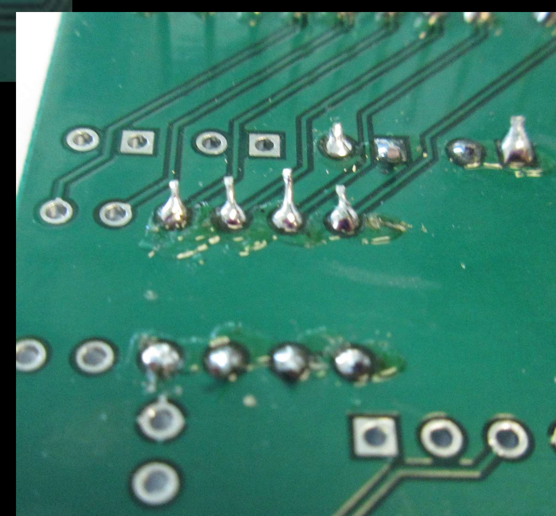
Space Minor
UNIVERSITY OF COLORADO **BOULDER**

- Bend leads so resistors are flush on top of board

- Trim after soldering



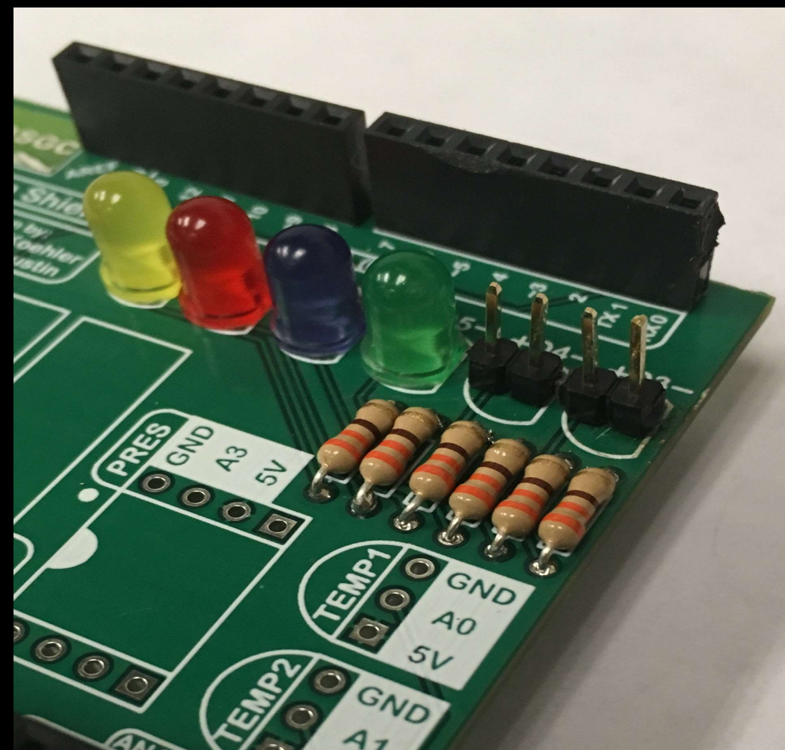




Balloon Shield Build Part 1:

Space Minor
UNIVERSITY OF COLORADO BOULDER

- **Solder 2 pin headers to D4 and D3**
- **Short pins to into board**
- **Solder from the bottom**

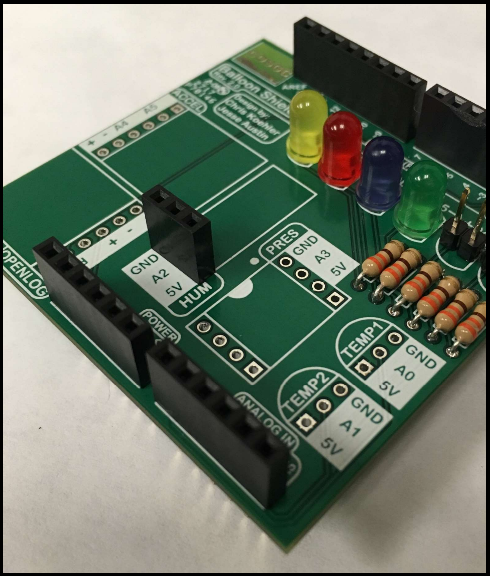


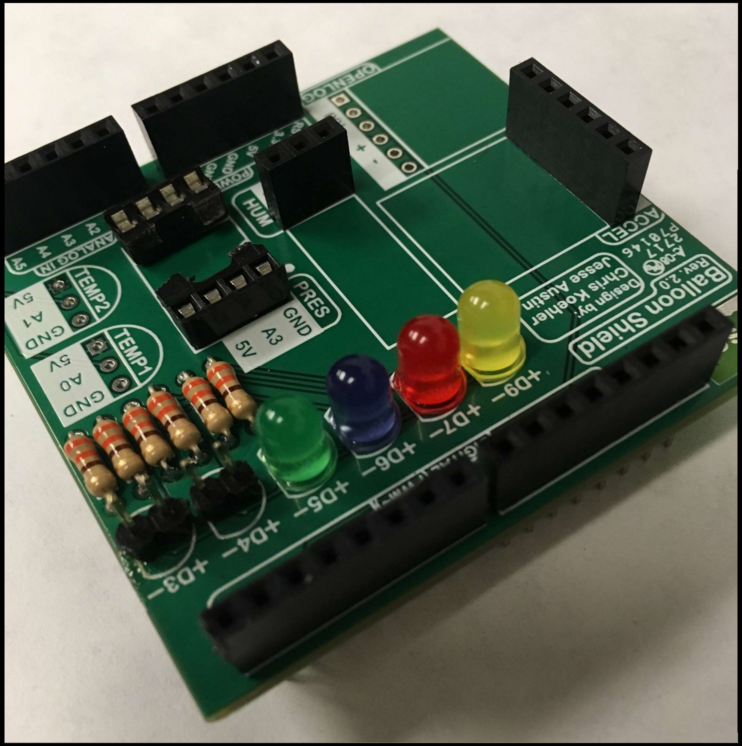
- **LONG PINS SHOULD BE ON TOP**

Balloon Shield Build Part 1:

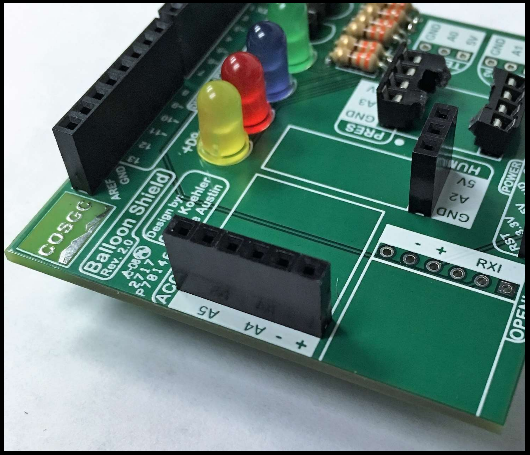
Space Minor
UNIVERSITY OF COLORADO BOULDER

- 1 - 3 pin header connector at HUM
- 2 - 4 pin header connectors at PRES
- 1- 6 pin header connector at ACCEL
- Solder on the bottom of the board





MUST BE PERPENDICULAR AND FLUSH WITH SHIELD BOARD



Balloon Shield Build Part 1:

Space Minor
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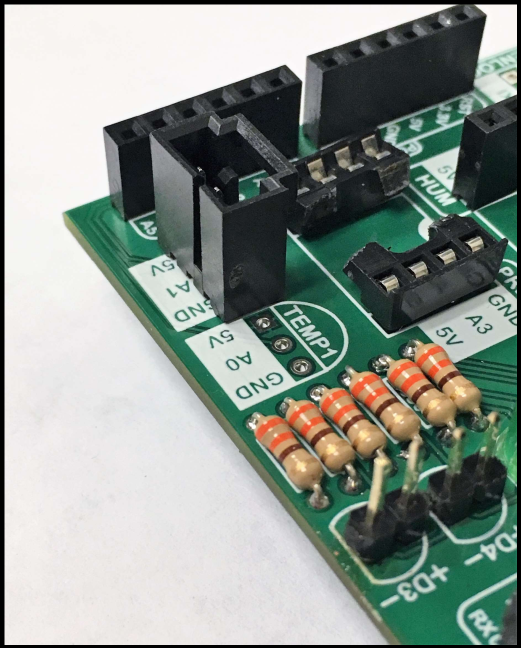
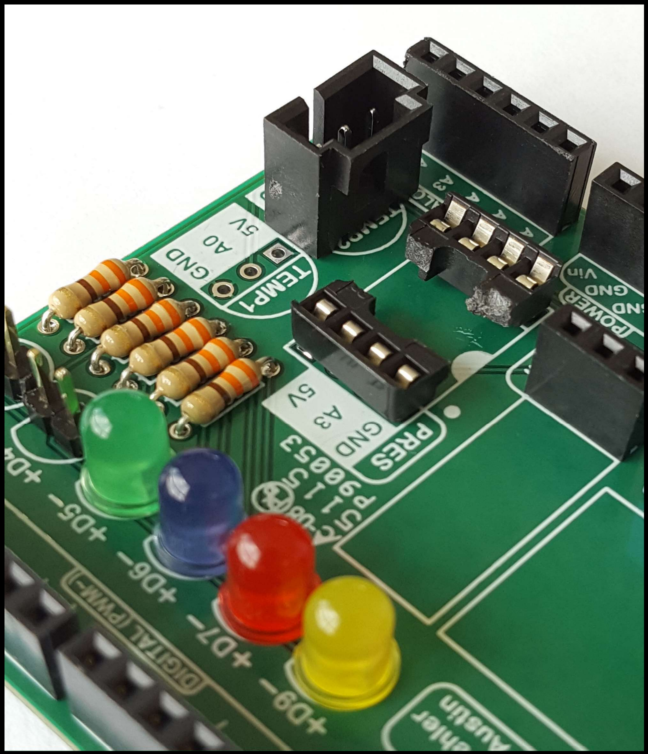
- **1 - 3 pin <u>locking</u> header at TEMP2**
- **Short pins into board.**
- **Solder from the bottom**





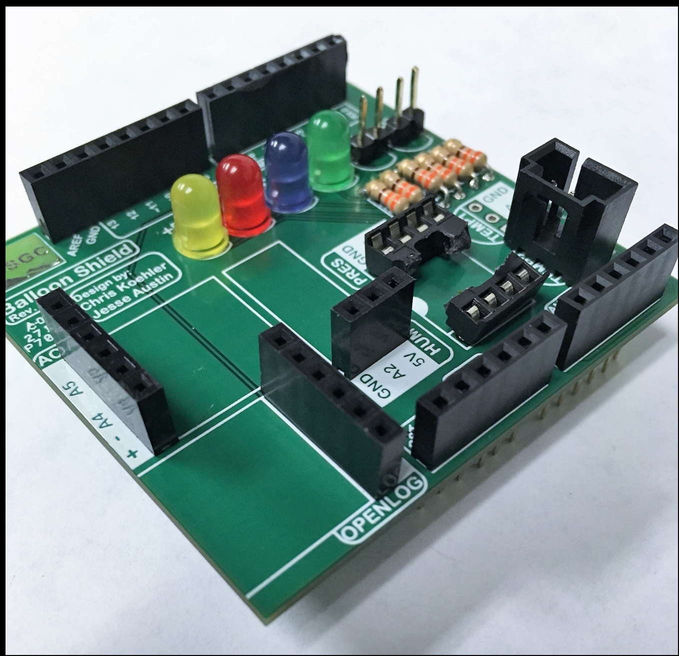
MUST INSTALL EXACTLY AS PICTURED.

BACKWARDS WILL RESULT IN TEMP SENSOR OVERHEATING

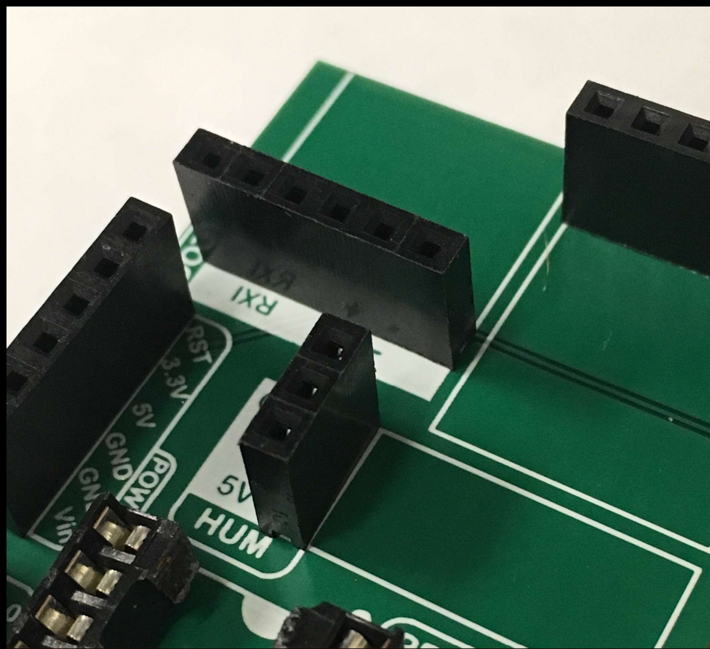
Balloon Shield Build Part 1:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

- **1– 6 pin header at OPENLOG**
- **Solder on bottom of board**



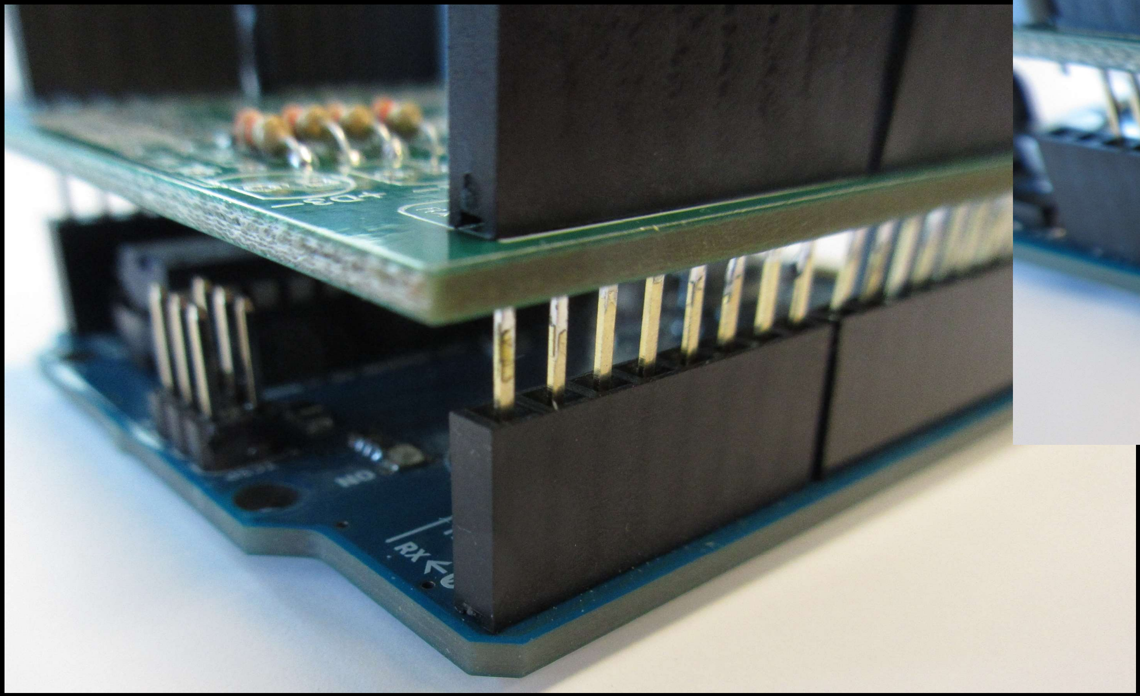
Result should look like this

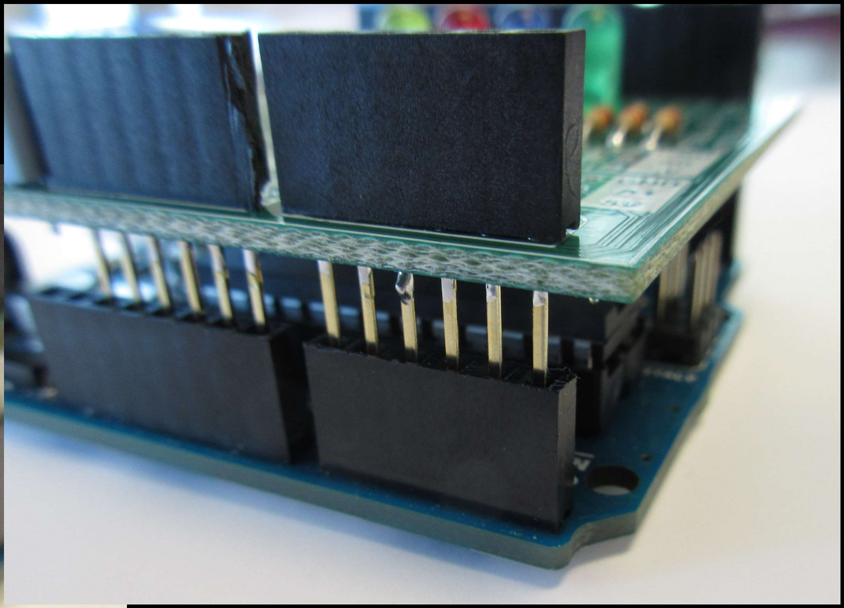


Balloon Shield Build Part 1:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

- Disconnect Arduino from laptop
- Disconnect Breadboard from Arduino
- Connect SHIELD to Arduino
- Line up before squeezing





Balloon Shield Build Part 1:

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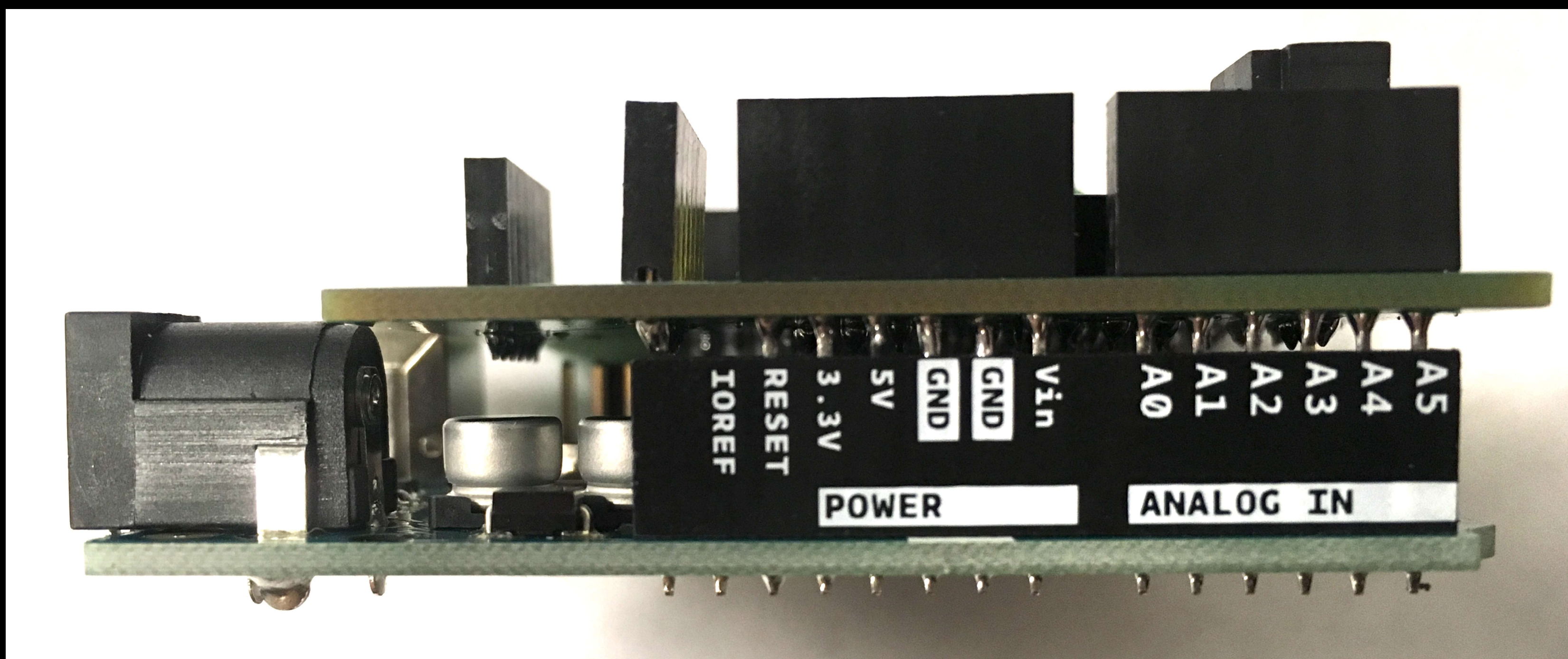
- Once aligned, gently press two together



Balloon Shield Build Part 1:

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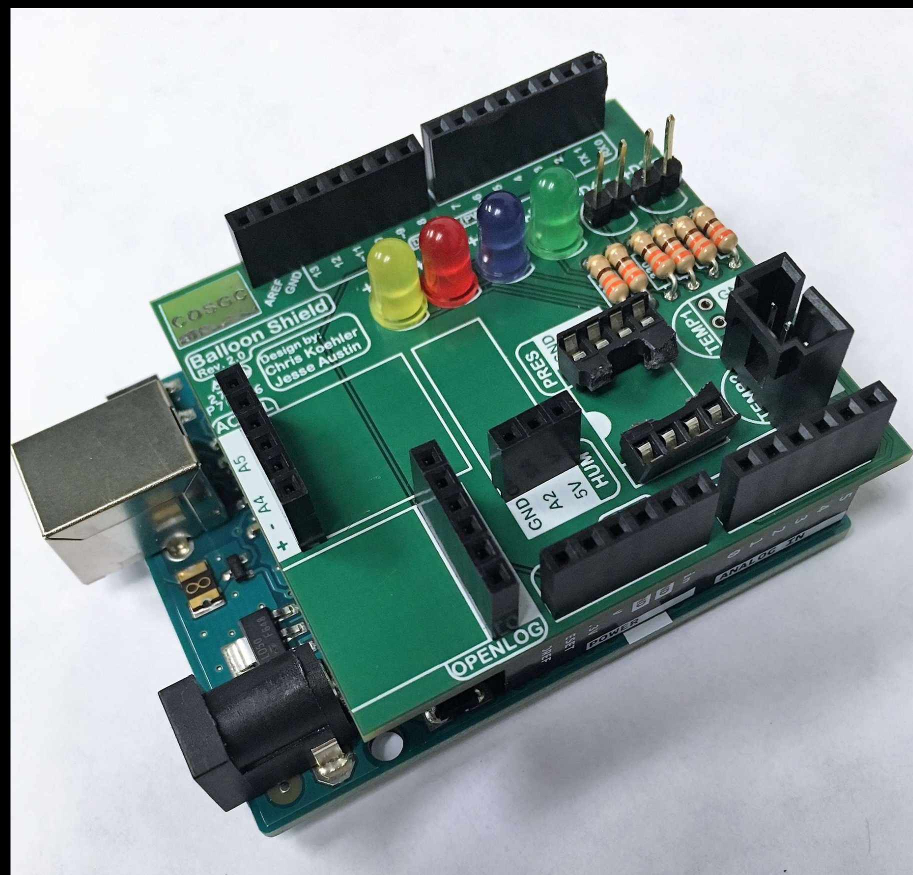
Completed product



Part 1 – Arduino Test Drive
Sensors

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

Sensor:

Space Minor
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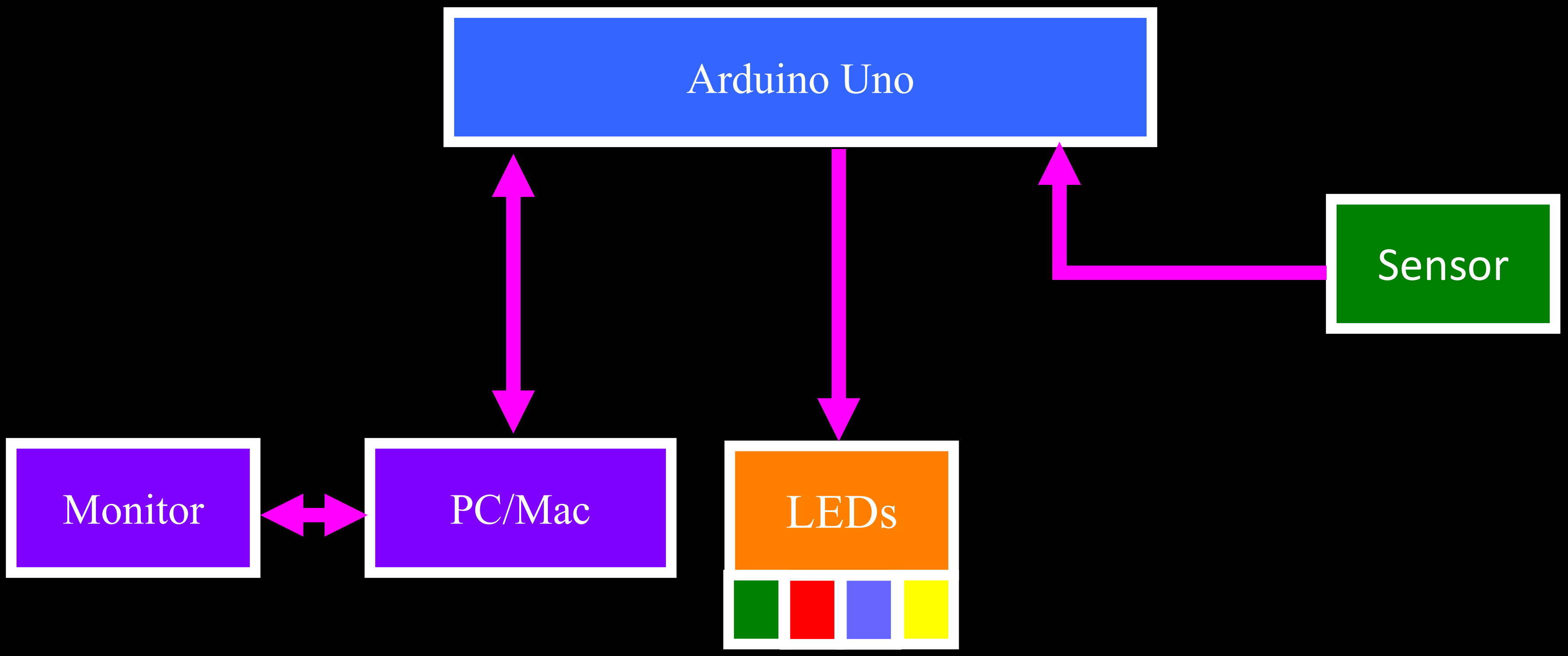


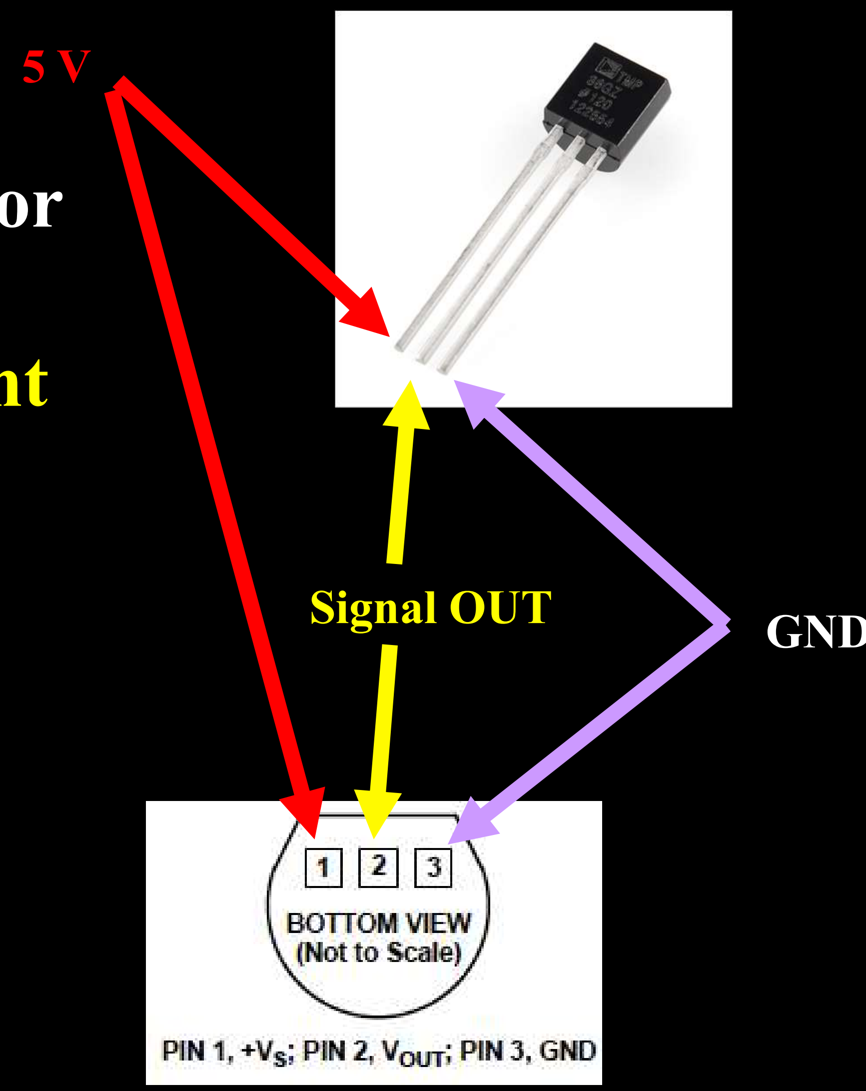
Temperature Sensor:

Space Minor
UNIVERSITY OF COLORADO BOULDER

Temperature sensor is the TMP36 - Temperature Sensor

Will use **two on balloon flight**
- One internal
- One external

Only working with internal now



Temperature Sensor:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

Leave your Balloon Shield attached to Arduino

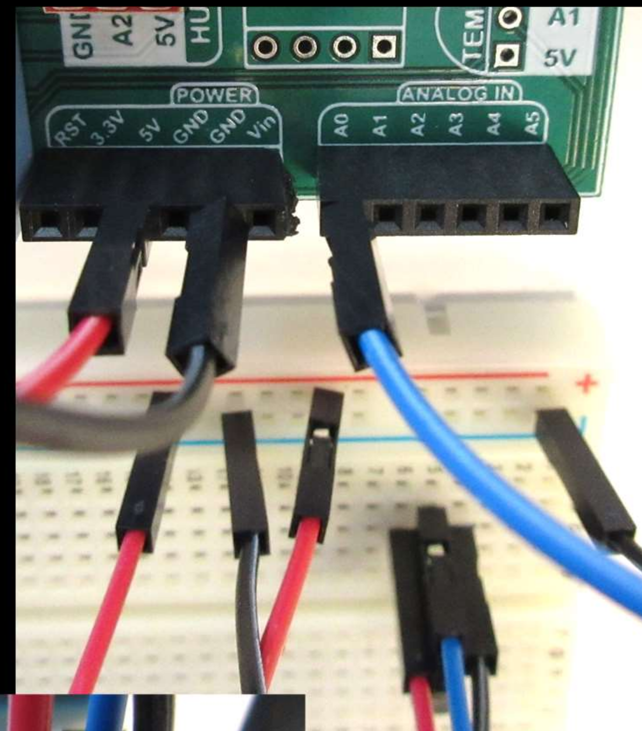
- **Wire Arduino 5V to Breadboard (BB) 5V PWR Rail**

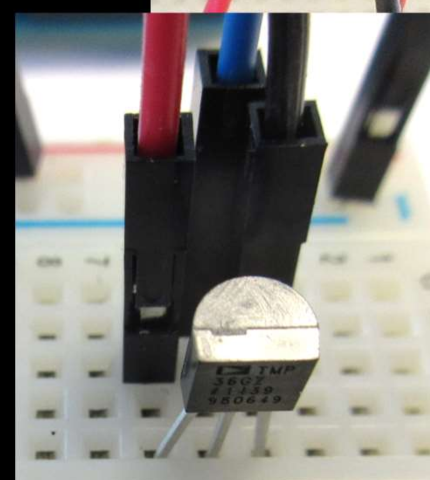
- **Wire Arduino GND to BB GND Rail**

- **Wire Sensor 5V to BB 5V Rail**

- **Wire Sensor GND to BB GND Rail**

- **Wire Sensor OUT to Arduino A0**

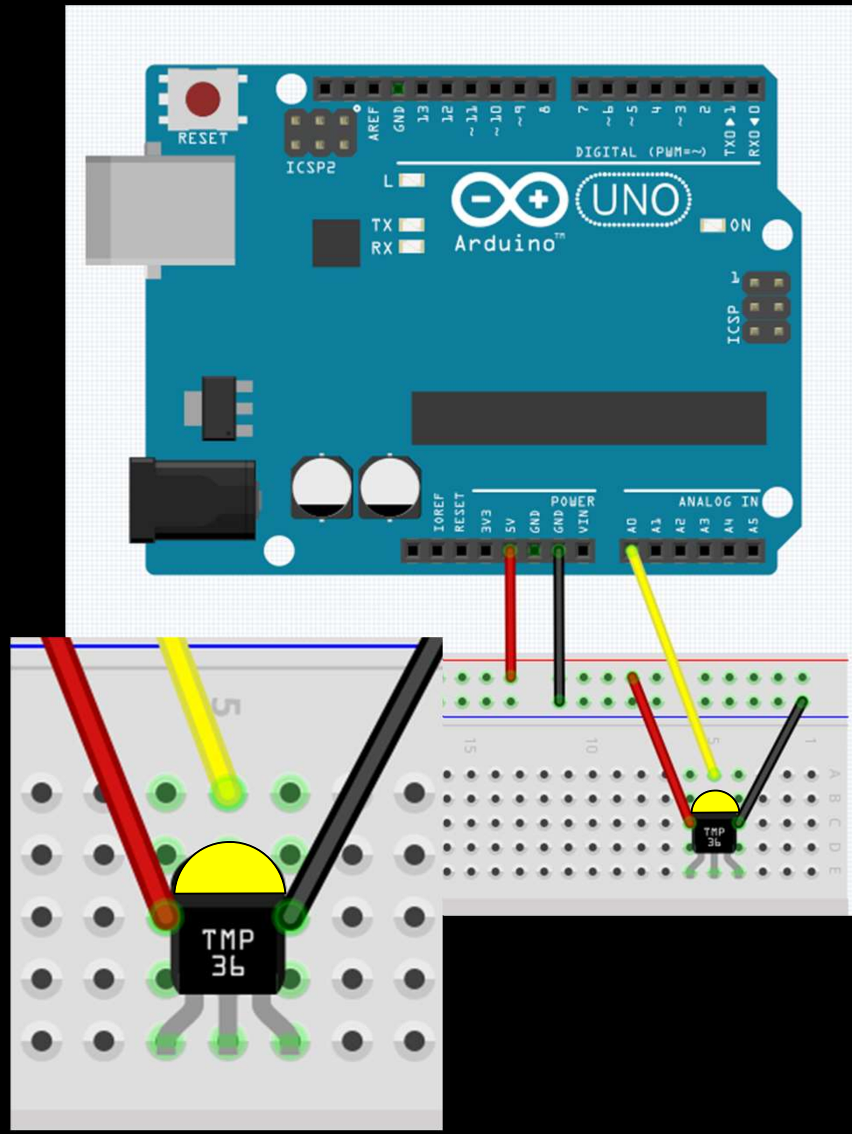




Temperature Sensor:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

Leave Balloon Shield Connected to Arduino



- **Wire Arduino 5V to Breadboard (BB) 5V PWR Rail**

- **Wire Arduino GND to BB GND Rail**

- **Wire Sensor 5V to BB 5V Rail**

- **Wire Sensor GND to BB GND Rail**

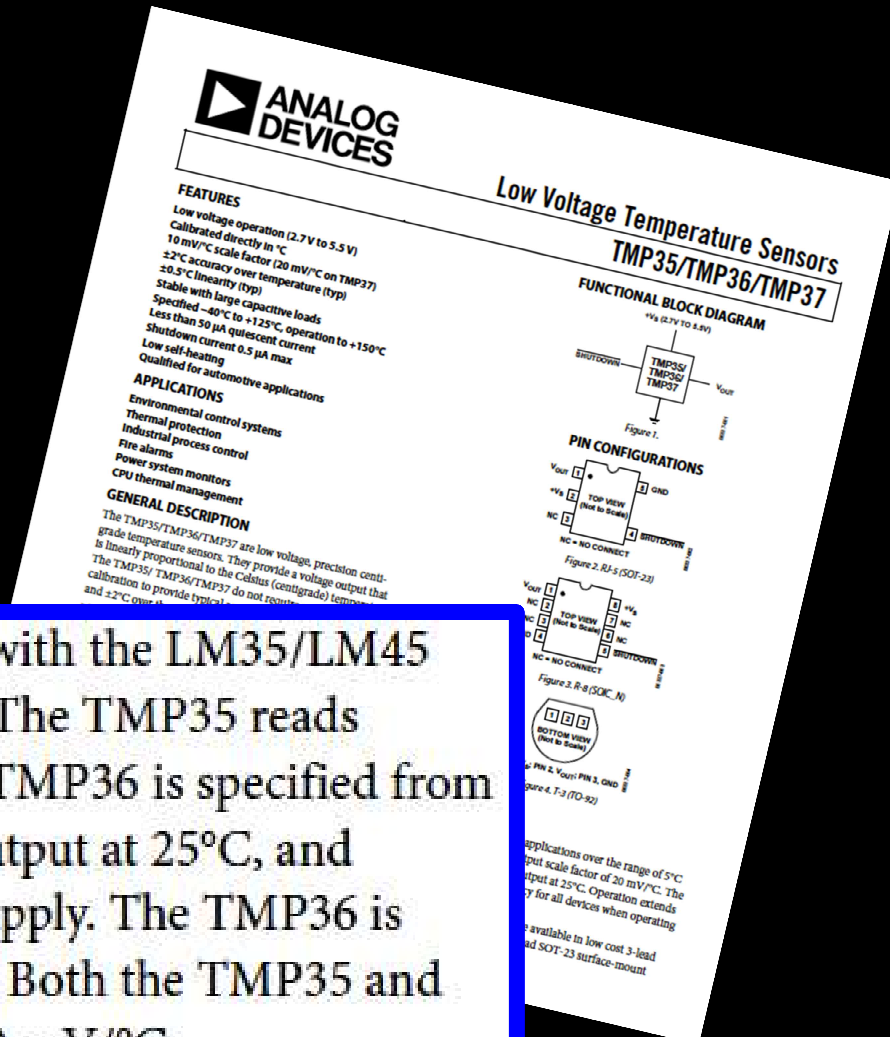
- **Wire Sensor OUT to Arduino A0**

Temperature Sensor:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

- **Let's consult the data sheet for the sensor**

- **10 mV/C (0.010V/C)**



The TMP35 is functionally compatible with the LM35/LM45 and provides a 250 mV output at 25°C. The TMP35 reads temperatures from 10°C to 125°C. The TMP36 is specified from –40°C to +125°C, provides a 750 mV output at 25°C, and operates to 125°C from a single 2.7 V supply. The TMP36 is functionally compatible with the LM50. Both the TMP35 and TMP36 have an output scale factor of 10 mV/°C.

Space Minor
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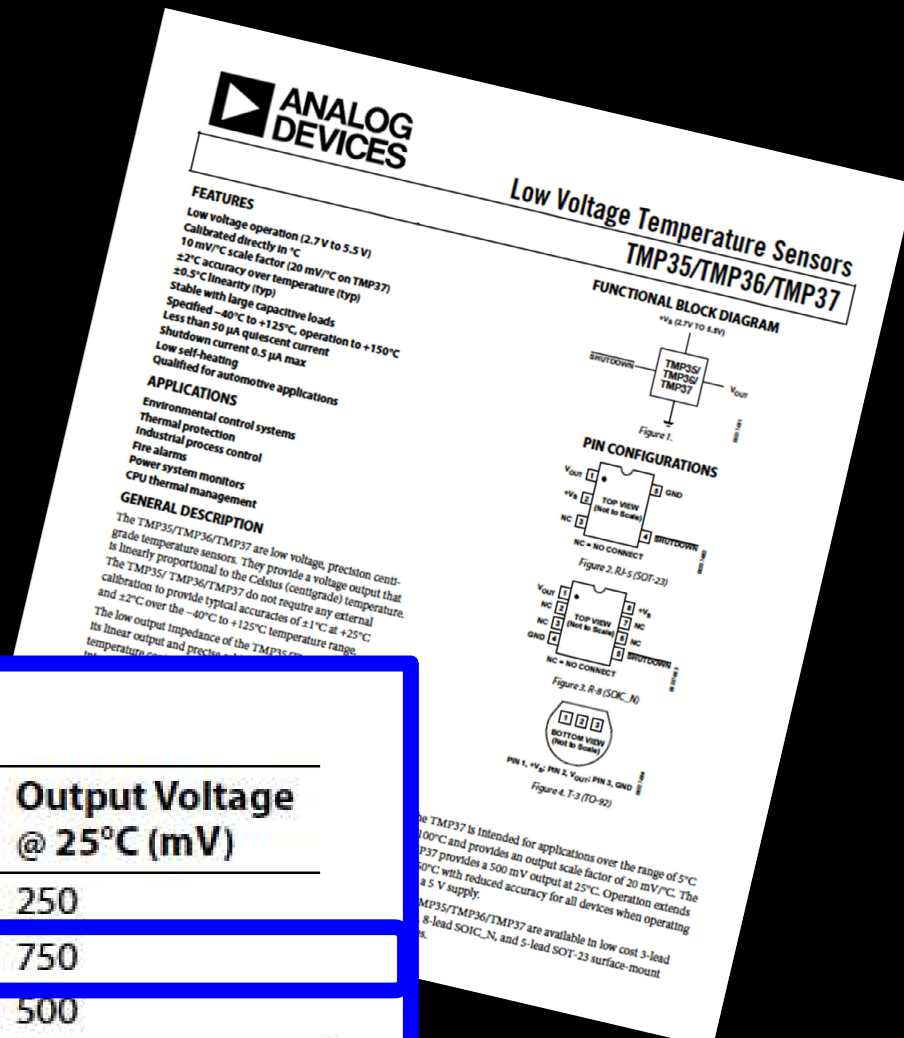
Temperature Sensor:

- Data sheet also says there is an offset

- For TMP36,
Offset = 0.5 Volts


ANALOG DEVICES

Low Voltage Temperature Sensors

TMP35/TMP36/TMP37

FEATURES

Low voltage operation (2.7 V to 5.5 V)
Calibrated directly in °C
10 mV/°C scale factor (20 mV/°C on TMP37)
±2°C accuracy over temperature (typ)
±0.5°C linearity (typ)
Stable with large capacitive loads
Specified −40°C to +125°C, operation to +150°C
Less than 50 μA quiescent current
Shutdown current 0.5 μA max
Low self-heating
Qualified for automotive applications

APPLICATIONS

Environmental control systems
Thermal protection
Industrial process control
Fire alarms
Power system monitors
CPU thermal management

GENERAL DESCRIPTION

The TMP35/TMP36/TMP37 are low voltage, precision centigrade temperature sensors. They provide a voltage output that is linearly proportional to the Celsius (centigrade) temperature. The TMP35/ TMP36/TMP37 do not require any external calibration to provide typical accuracies of ±1°C at +25°C and ±2°C over the −40°C to +125°C temperature range. The low output impedance of the TMP35 ...

FUNCTIONAL BLOCK DIAGRAM

Figure 1.

PIN CONFIGURATIONS

Figure 2. RJ-5 (SOT-23)

Figure 3. R-8 (SOIC_N)

Figure 4. T-3 (TO-92)

...he TMP37 is intended for applications over the range of 5°C ...100°C and provides an output scale factor of 20 mV/°C. The ...P37 provides a 500 mV output at 25°C. Operation extends ...0°C with reduced accuracy for all devices when operating ...a 5 V supply.

...MP35/TMP36/TMP37 are available in low cost 3-lead ... 8-lead SOIC_N, and 5-lead SOT-23 surface-mount ...

Table 4. TMP3x Output Characteristics

Sensor	Offset Voltage (V)	Output Voltage Scaling (mV/°C)	Output Voltage @ 25°C (mV)
TMP35	0	10	250
TMP36	0.5	10	750
TMP37	0	20	500

Temperature Sensor:

Space Minor
UNIVERSITY OF COLORADO BOULDER

- So to understand the data, we need to do some math to convert voltage to C

$$TempC = \frac{(tempVoltage - 0.5)}{0.01}$$

Using what we are seeing from our serial monitor, 0.77 Volts, we would get…

$$TempC = \frac{(0.77 - 0.5)}{0.01}$$

$$TempC = \frac{(0.27)}{0.01} = 27\ C$$

$$TempF = TempC * \frac{9}{5} + 32$$

```
// Definitions
    int sensor;
    float sensorVolt;
    float sensorUnits;
    float sensorUnitsC;
```

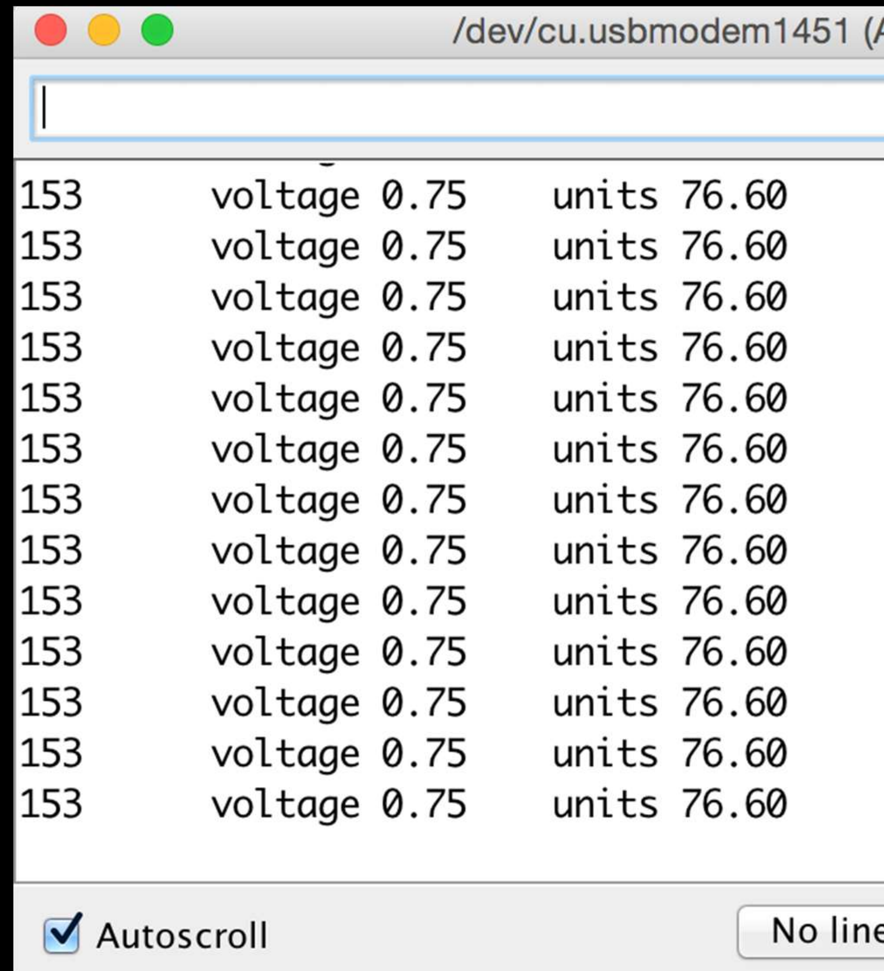
```
void loop() {
//   put your main code here, to run rep

    sensor = analogRead(A0);
    sensorVolt = sensor*(5.0/1023);
    sensorUnitsC = (sensorVolt - 0.5)/(0.01);
    sensorUnits = (sensorUnitsC*(9.0/5.0) + 32);
    Serial.print(sensor);
    Serial.print("\t voltage ");
    Serial.print(sensorVolt);
    Serial.print("\t units ");
    Serial.println(sensorUnits);
```

```
if(sensorUnits > 78.0) {
digitalWrite(5, HIGH);
}
if(sensorUnits > 79.0) {
digitalWrite(6, HIGH);
}
if(sensorUnits > 80.0) {
digitalWrite(7, HIGH);
}
if(sensorUnits > 81.0) {
digitalWrite(9, HIGH);
}
delay(100);
```

Temperature Sensor:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

- **Build and Upload the code and look at serial monitor**
- **Should see ~0.77 V**
- **Put your fingers on temp sensor and lightly squeeze**
- **Look at monitor and LEDs for change**



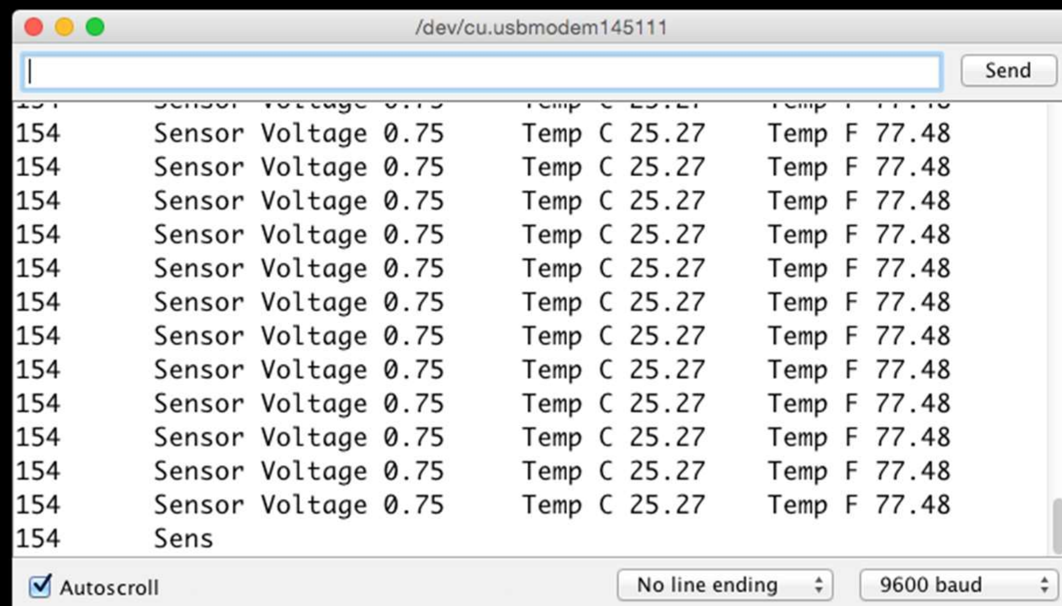
PLEASE SAVE YOUR SKETCH FILE

Temperature Sensor:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

- **Build and Upload**

- **Test by touching your temp sensor**



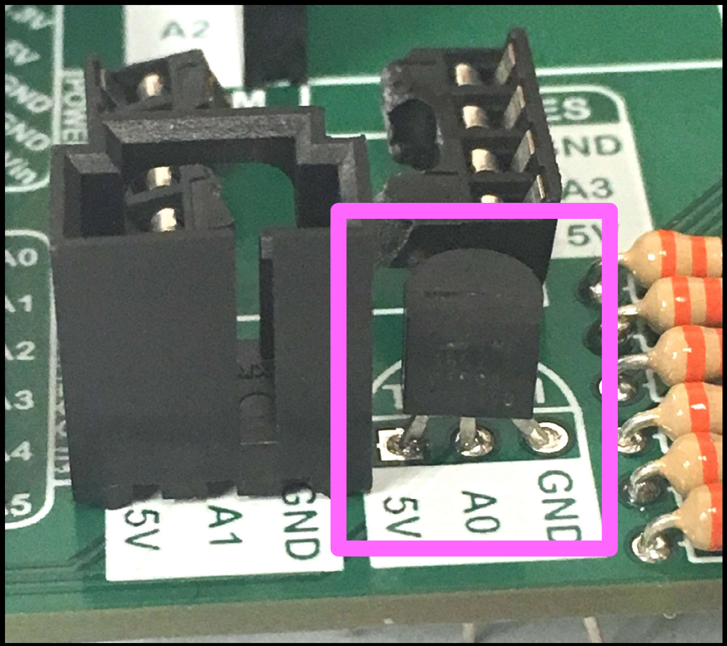
PLEASE SAVE YOUR SKETCH FILE

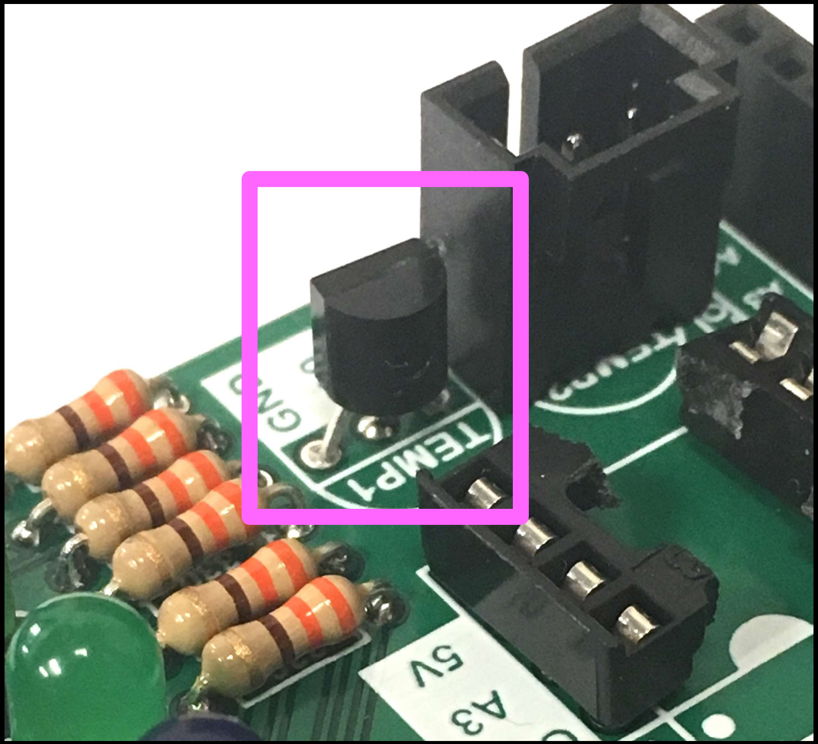
Balloon Shield Build Part 2:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

- Disconnect you Balloon Shield and add the Temperature Sensor 1

- Note the orientation

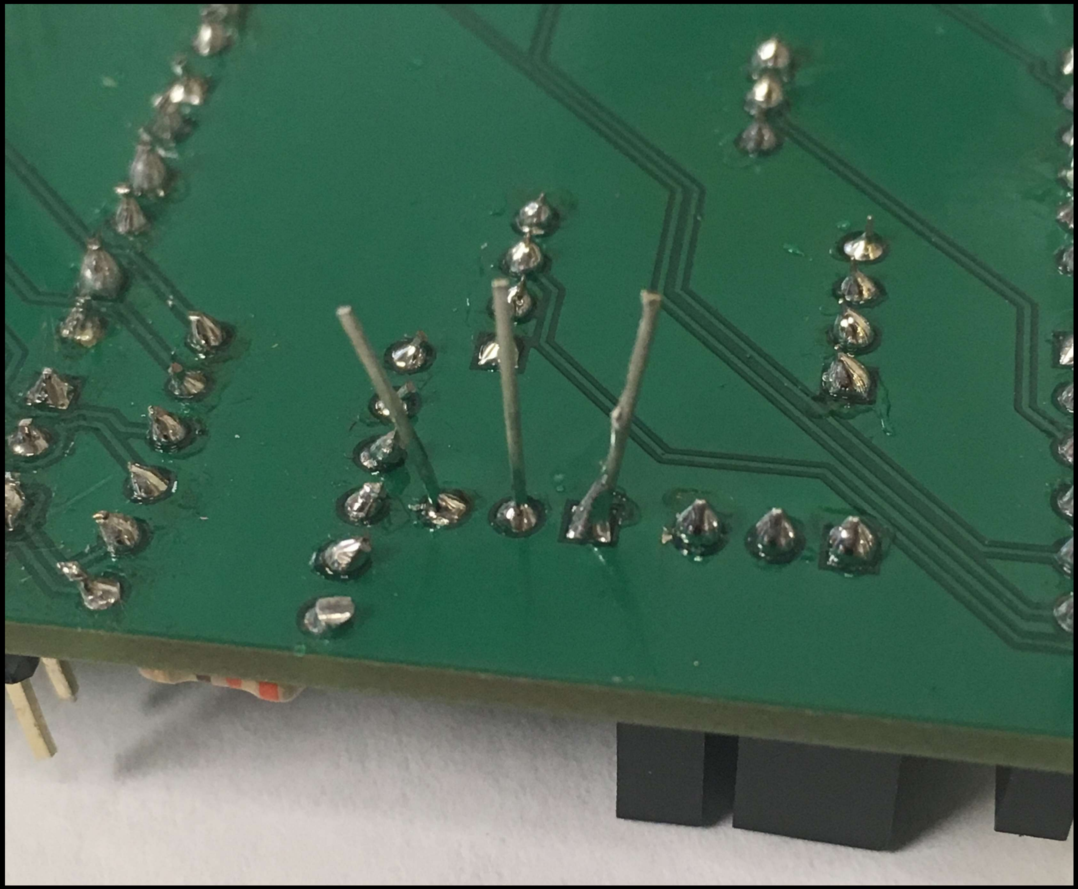




Balloon Shield Build Part 2:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

- **Solder from bottom of board and then trim leads**



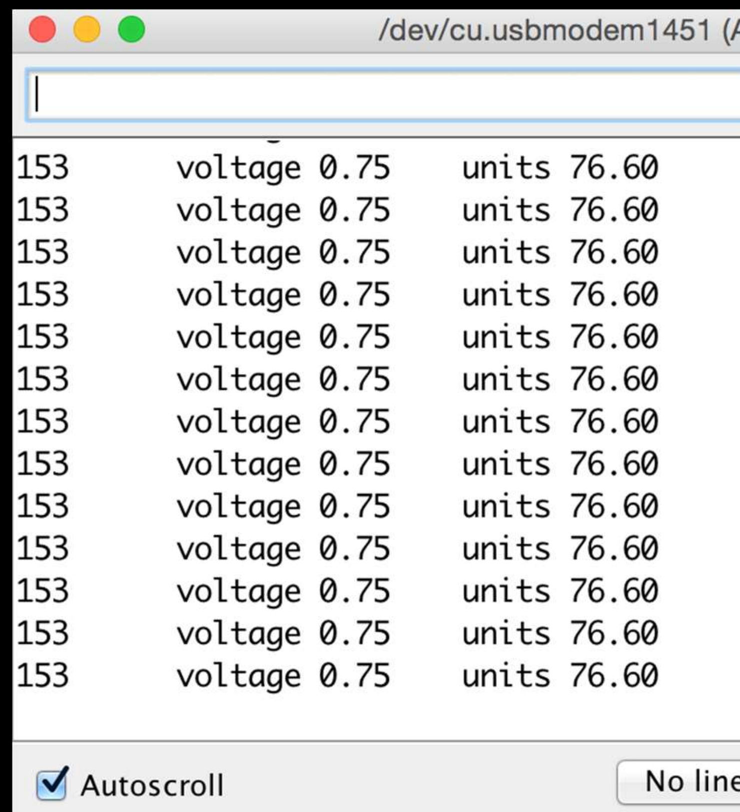
Balloon Shield Build Part 2:

Space Minor
UNIVERSITY OF COLORADO **BOULDER**

- Reconnect your Balloon Shield to the Arduino

- Connect USB and reload code

- Verify same results



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