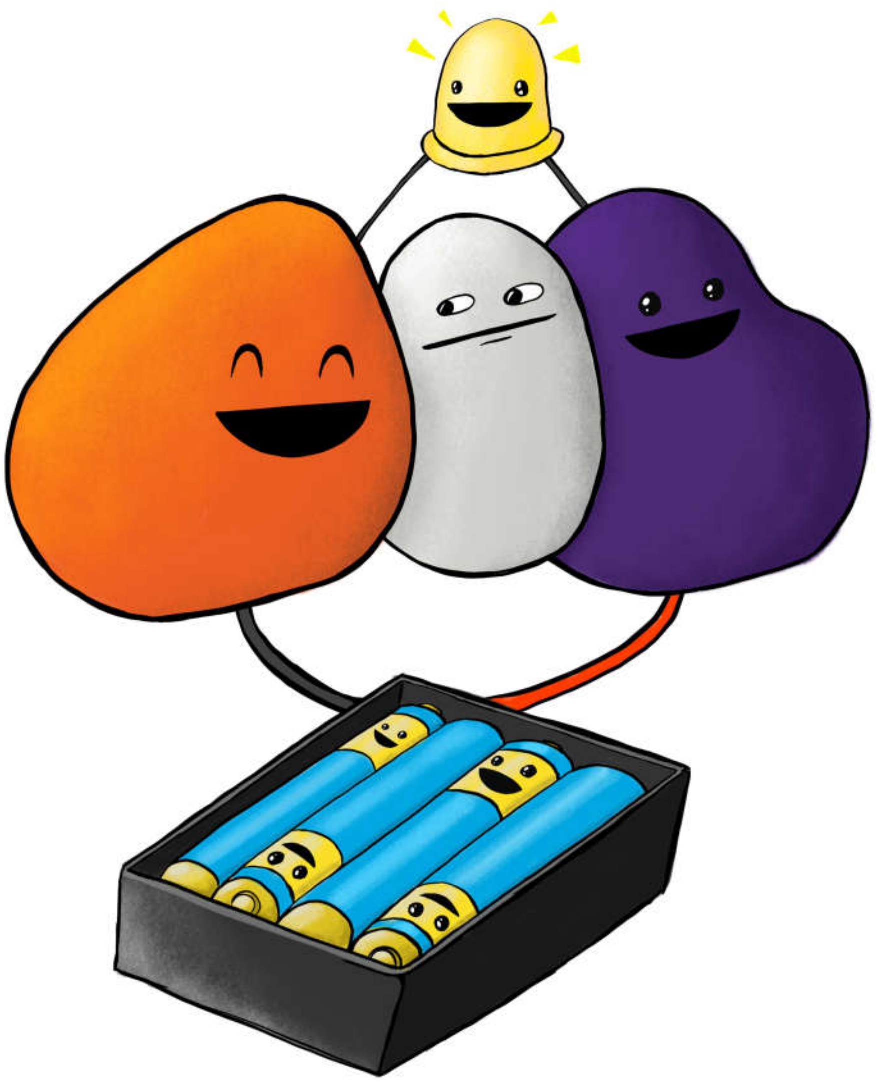
Coding with Squishy Circuits



Comments, Questions, Concerns? Please reach out at: ContactUs@SquishyCircuits.com

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Introduction

Coding with Squishy Circuits?

In these projects we use an Arduino (device similar to a small computer) to measure the resistance of conductive dough. When we change the shape of the dough the resistance also changes. For example, making the dough a longer, thinner "pipe" for the electricity to flow, increases the resistance. We can then cause an output to change based on the resistance.

Note: This project is more advanced. We include some background information but if you would like more information about something or are confused, we encourage you to research more about that particular topic or to contact us.

Learning Objectives

1. Students will be able to explain how resistance, voltage, and current are related.
2. Students will explore how resistance is based on physical shape.
3. Students will design and build a circuit to accomplish a desired outcome.
4. Students will be able to modify and implement code on their microprocessors.

Educator Preparation Material

Supplies needed for each student or group of students:

- Computer with Arduino Software
- Arduino Uno Board (or similar)
- Conductive Dough
- Speaker
- LEDs
- Breadboard
- 470 Ohm Resistors (or close)
- Wire

Background Knowledge

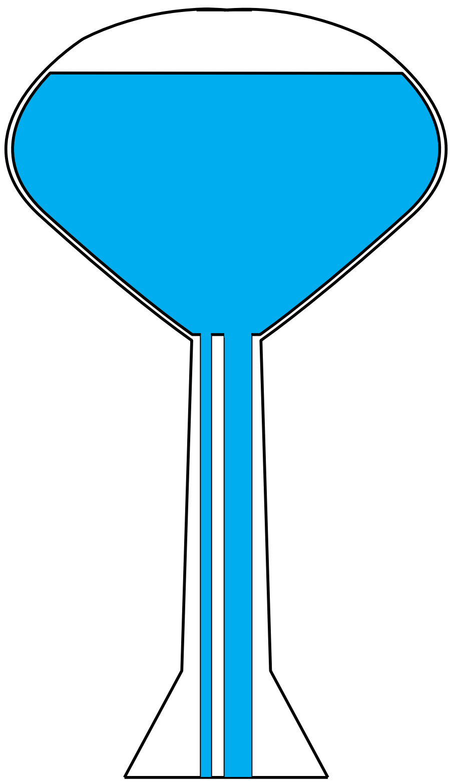
Electricity and Ohms Law

Electricity is the flow of charge called electrons. When describing electrical circuits, three terms are used – voltage, current, and resistance.

Voltage relates to how much potential there is between the positive and negative ends. It is measured in volts.

Current is a measurement of how many electrons are moving through a conductor. It is measured in amps.

Resistance is how difficult it is for the electricity to flow through the conductor. It is measure in ohms.



It can be difficult to visualize these concepts. So, a more tangible example is to think of water instead of electrons. Think of a water tower – it holds water high up in the air, which gives the water a potential. This is like voltage.

Imagine there are two pipes going from the top of the water tower to the ground - one that was big and one that is small. If you had to fill up a bucket with water, would you put the bucket under the big pipe or the small one? You would choose the big pipe because it would fill much faster. This is like the current, similar to the amount of water flowing.

If you'd measure the amount of water going through the pipes, you'd notice that there is less water flowing through the smaller pipe than the big one. It is harder to push water down a smaller pipe than a large one. This is like resistance – the bigger the pipe, the less resistance.

In electricity, these three concepts work the same way but instead of pipes and flowing water, we have conductors carrying electrical current. The three principles are related by **Ohms Law**:

$$Voltage\ (V) = \ Current\ (I) * \ Resistance\ (R)$$

Which can also be written as: $I = \frac{V}{R} \quad or \quad R = \frac{V}{I}$

The water analogy still works with Ohms law – basically the higher the water height (higher voltage) and the bigger the pipe (less resistance), the more water flows down the pipe (higher current).

Arduino®

From the Arduino website, "Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board."

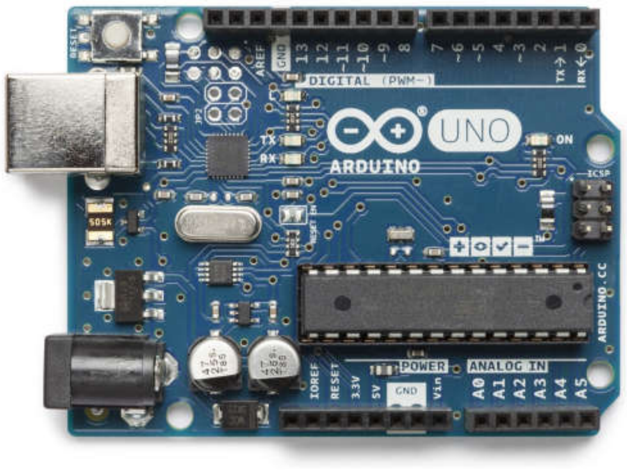


Image credit: Arduino

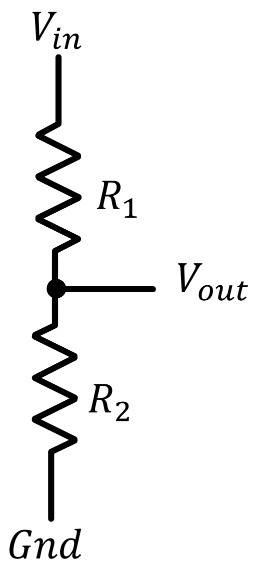
We have chosen to write this guide for Arduino boards because they are popular, inexpensive, easy to use, and have many educator resources. If you are completely unfamiliar, we suggest viewing the Arduino website, www.arduino.cc, which has guides/tutorials and the software required to program your Arduino board.

Arduino boards contain a **microprocessor** (essentially a small computer) and a host of useful prototyping tools. Using the Arduino software, instructions, called **code**, are written and programmed to the Arduino board.

Voltage Dividers

Arduinos have **analog inputs** which measure voltage. If we were to provide 5 volts on one side of the dough and connect the other side to ground, there would always be 5 volts going through the dough. This really does not do anything useful.

But, if we put another resistor in the same circuit, now we can measure the voltage at the point in-between the resistor and the dough. As the dough's resistance changes, more or less of the voltage will be present at that point because the 5 volts is split proportionately between the two resistances. This is called a voltage divider and is a fundamental circuit for engineers.



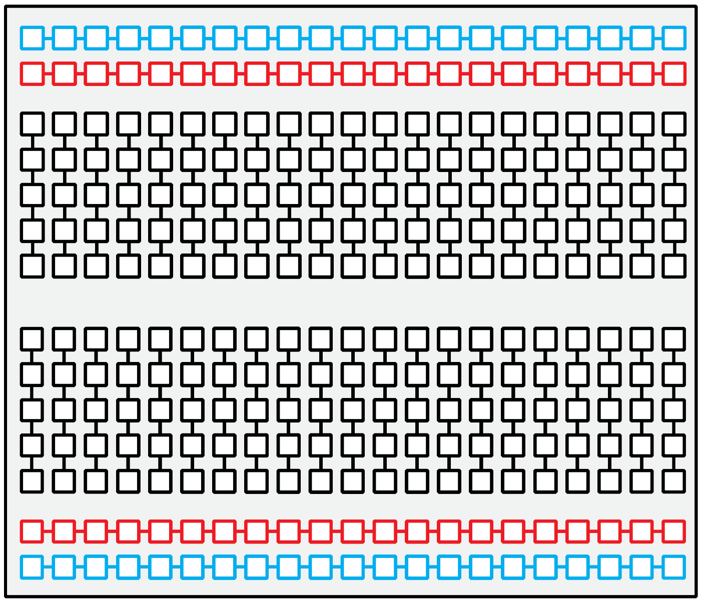
The equation that describes a voltage divider is: $V_{out} = V_{in} * \frac{R_2}{R_1+R_2}$

For these projects, we know that:
R_1 = 470 ohms
Vin = 5 volts
and V_{out} is measured by the Arduino's analog input.

By performing some algebra, we can then rearrange the equation to find the resistance of the conductive dough: $R_2 = \frac{R_1 * V_{in}}{V_{out} - V_{in}} = \frac{2350}{V_{in} - 5}$

Breadboards

Breadboards are extremely useful prototyping tools because they allow you to quickly and easily connect multiple electrical components together. They are arranged in a grid with each column of 5 connected to each other. There are also two power rails, blue for ground and red for positive. There are two sides of a breadboard and they are separated from each other. In the image below, the connections are shown with lines connecting the squares. When using breadboards, resistors, wires, and other components are inserted into each of the squares.



Project 1: Squishy Sound

Summary and Background Knowledge

The most popular example of a Squishy Circuits microprocessor project is Squishy Sound. Squishy Sound uses the conductive dough to change the pitch of a speaker – the higher the resistance, the higher the pitch.

Materials:

- Computer with Arduino Software
- Arduino Uno Board (or similar)
- Conductive Dough
- Speaker (the piezoelectric buzzer sold on our website does NOT work for Squishy Sound)
- Breadboard
- 470 Ohm Resistors (or close)
- Wire

Schematic:

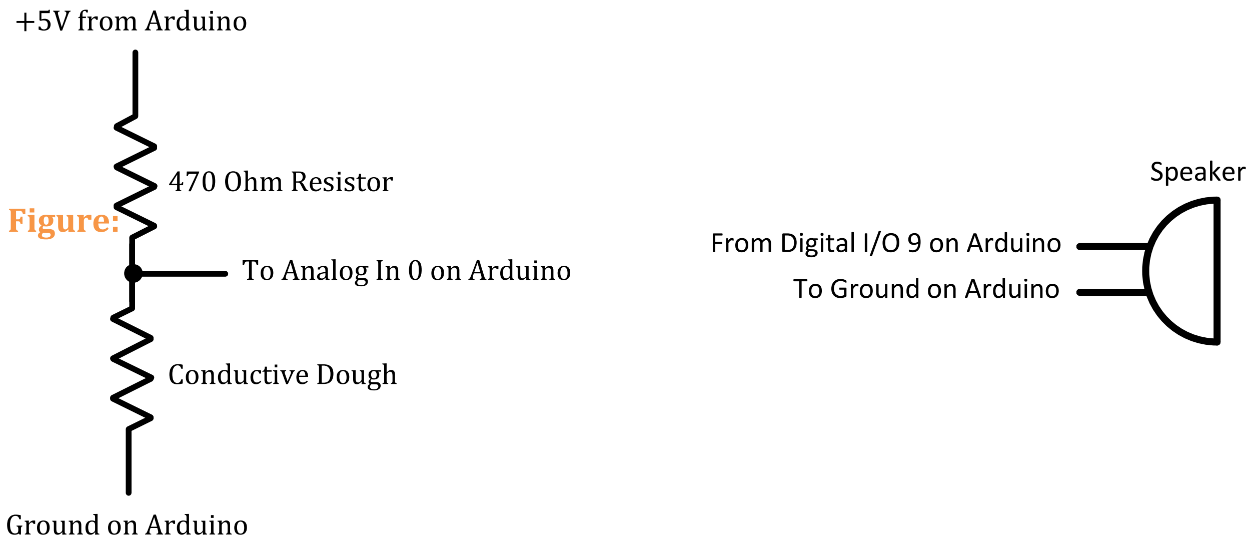


Figure:

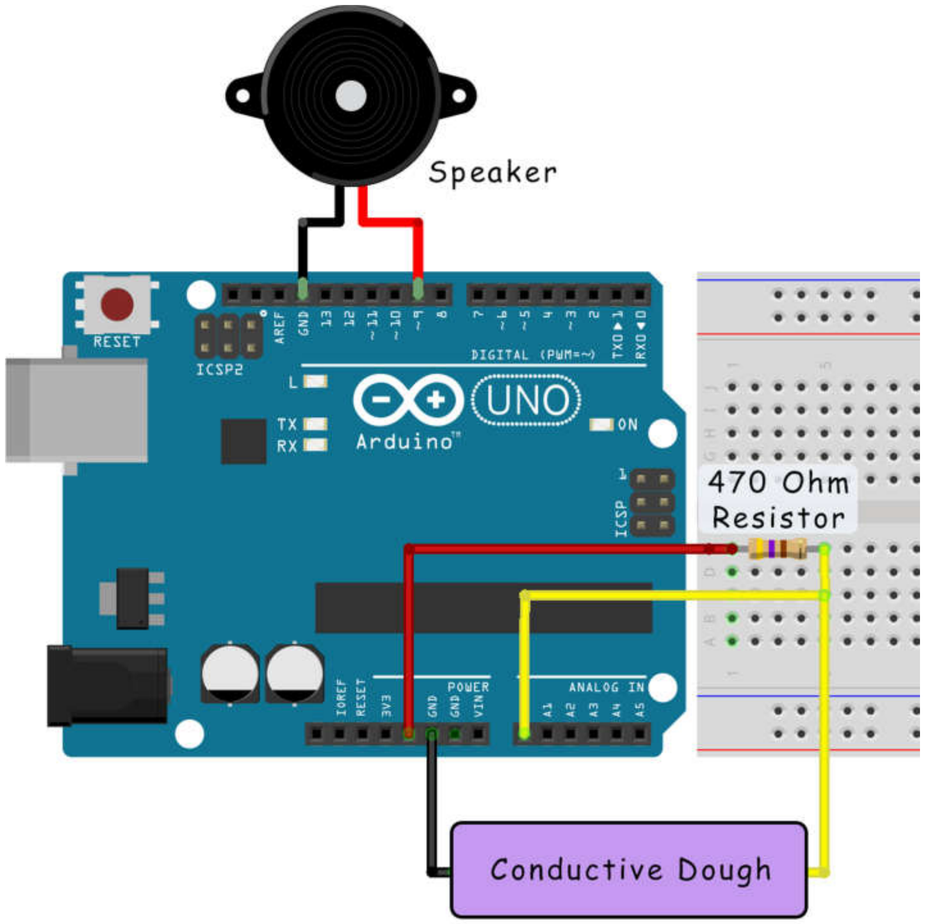


Image created with Fritzing

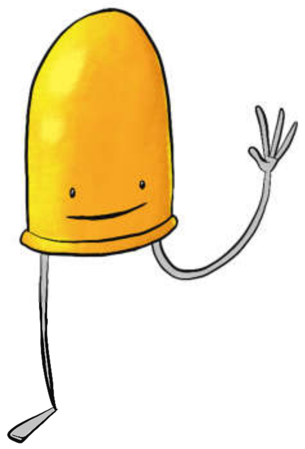
Code:

```
//Squishy Sound - Code written by Sam Johnson and Modified by Matthew Schmidtbauer for the Squishy
Circuits Project

//Port Definitions and Variable Declarations:
        #define SpeakerOutput 9
        int analog = 0; // Common resistor connected to analog pin 0 outside leads to ground and +5V
        int raw = 0; // Variable to store the raw input value
        int frequency = 0; // Variable to store Frequency

void setup()
         {}

void loop()
        {
        raw = analogRead(analog); // Read Voltage over Dough
        frequency = raw*2; // Calculate Frequency
        tone(SpeakerOutput,frequency); // Output Frequency to Sounding Device
        }
```

Project 2: Squishy RGB LED Controller

Summary and Background Knowledge:

In this project, we will use three different voltage divider circuits to control the brightness of three different LEDs. The color of the LEDs do not matter, but we have chosen to use a red, green, and blue LED which are the primary colors of light. Using them, we can make any color depending on the brightness of each color. This is similar to a pixel on your TV or cell phone which work the same way, but are so small your eyes cannot see the individual colors. The light has to mix together to create different colors so putting it through a semi-translucent obeject will help mix the colors (wax paper works well). All colors mixed together make white!

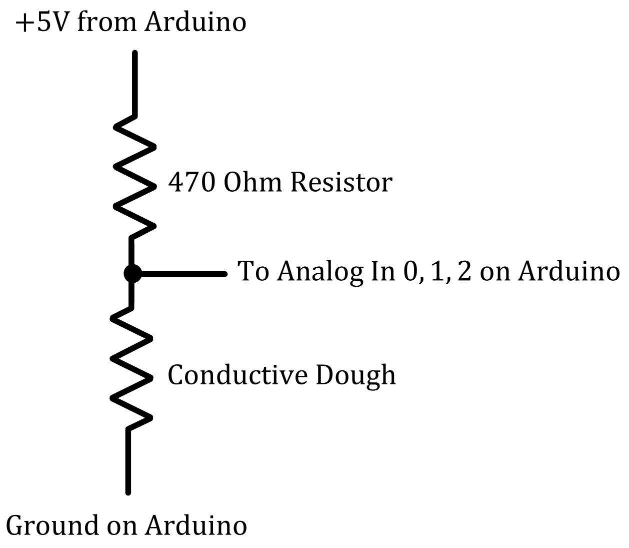


Materials:

- Computer with Arduino Software
- Arduino Uno Board (or similar)
- Conductive Dough
- 3 LEDs
- Breadboard
- 3 - 470 Ohm Resistors (or close)
- Wire

Schematic:

3 Voltage Divider Circuits:



3 LED Circuits:

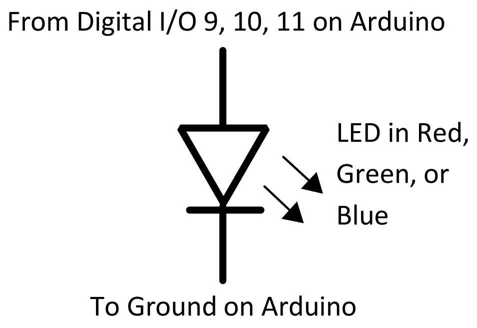

From Digital I/O 9, 10, 11 on Arduino
LED in Red, Green, or Blue
To Ground on Arduino

Figure:

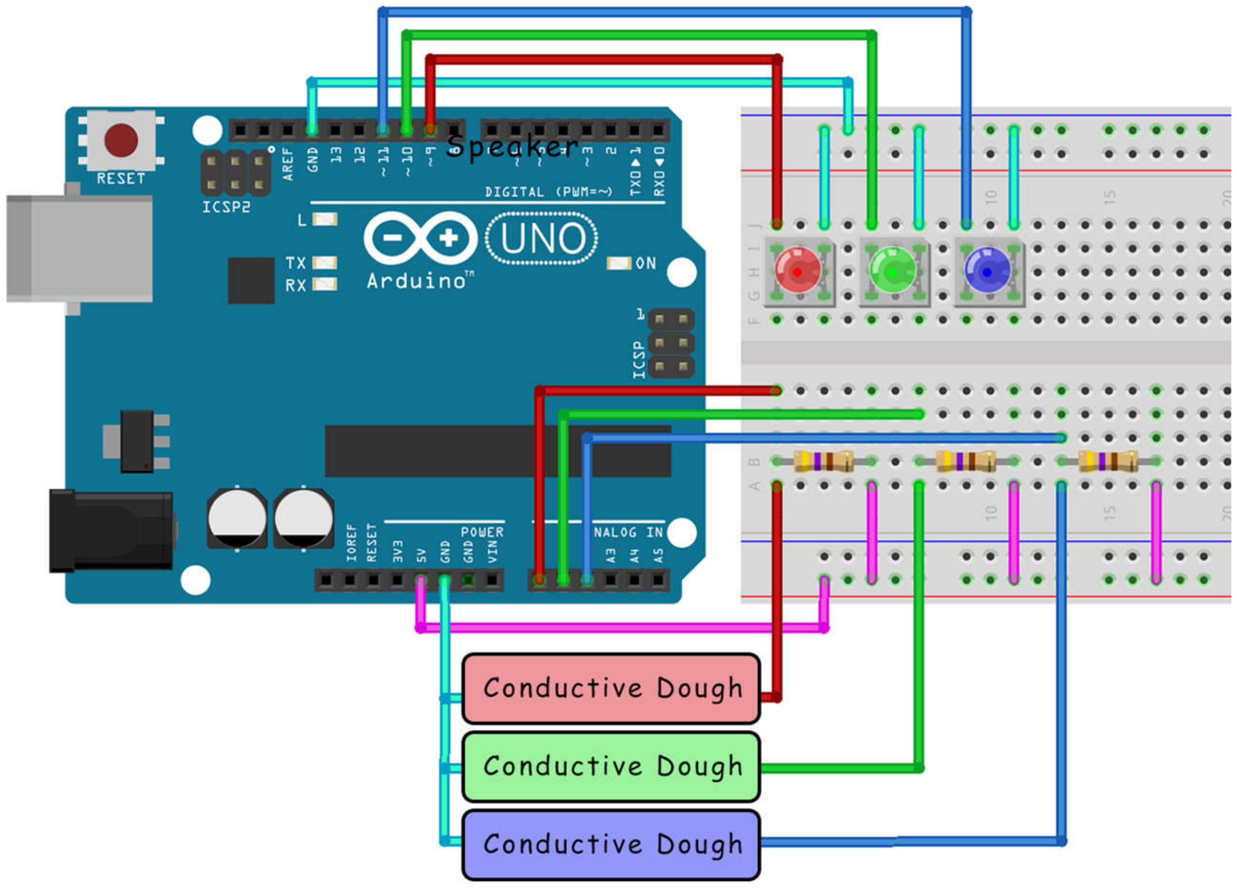


Image created with Fritzing

Code:

```
//Squishy RGB LED Controller
//Port Definitions and Variable Declarations:
#define RED_LED 9
#define GREEN_LED 10
#define BLUE_LED 11
int analog_RED = 0; // common resistor connected to analog pin 0 outside leads to ground and +5V
int raw_RED = 0; // variable to store the raw input value
int BRIGHTNESS_RED = 0; //Variable to store Brightness Value (0-255)
int analog_GREEN = 1; // common resistor connected to analog pin 1 // outside leads to ground and +5V
int raw_GREEN = 0; // variable to store the raw input value
int BRIGHTNESS_GREEN = 0; //Variable to store Brightness Value (0-255)
int analog_BLUE = 2; // common resistor connected to analog pin 2 // outside leads to ground and +5V
int raw_BLUE = 0; // variable to store the raw input value
int BRIGHTNESS_BLUE = 0; //Variable to store Brightness Value (0-255)

void setup()
        {
        pinMode(RED_LED, OUTPUT);
        pinMode(GREEN_LED, OUTPUT);
        pinMode(BLUE_LED, OUTPUT);
        }
void loop()
        {
        //Read Voltages over Dough:
        raw_RED = analogRead(analog_RED);
        raw_GREEN = analogRead(analog_GREEN);
        raw_BLUE = analogRead(analog_BLUE);

        //Generate Brightness Value (PWM Values = 0-255) from Raw Voltages (0- 1023)
        if(raw_RED <=150) {BRIGHTNESS_RED=255;}
        if(raw_RED >=500) {BRIGHTNESS_RED=0;}
        else {BRIGHTNESS_RED=-.7286*raw_RED+364.45;}
        analogWrite(RED_LED, BRIGHTNESS_RED); //Output PWM Value to Light

        if(raw_GREEN <=150) {BRIGHTNESS_GREEN=255;}
         if(raw_GREEN >=500) {BRIGHTNESS_GREEN=0;}
        else {BRIGHTNESS_GREEN=-.7286*raw_GREEN+364.45;}
        analogWrite(GREEN_LED, BRIGHTNESS_GREEN); //Output PWM Value to Light

        if(raw_BLUE <=150) {BRIGHTNESS_BLUE=255;}
        if(raw_BLUE >=500) {BRIGHTNESS_BLUE=0;}
        else {BRIGHTNESS_BLUE=-.7286*raw_BLUE+364.45;}
        analogWrite(BLUE_LED, BRIGHTNESS_BLUE); //Output PWM Value to Light
        }
```