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# 6

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Circuit Worksheets

Ohm's Law:  $V = I * R$      $I = V / R$      $R = V / I$

**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Did you get your LED turned on?**

Make sure it's red. Switch the Arduino pin # 9 with 5v on the Arduino.

Give values for Voltage, Current and Resistance for each LED circuit setup. Find Resistance with Ohm's Law. Hint: Break the circuit between the Arduino pin and LED to measure the current.

**2.**

**330Ω (circuit as is):**

$V = \underline{\hspace{1cm}} \text{ v } I = \underline{\hspace{1cm}} \text{ mA } R = \underline{\hspace{1cm}} \Omega$

**3.**

**With two LEDs and 330Ω :**

$V = \underline{\hspace{1cm}} \text{ v } I = \underline{\hspace{1cm}} \text{ mA } R = \underline{\hspace{1cm}} \Omega$

**4.**

**One LED and 10KΩ resistor:**

$V = \underline{\hspace{1cm}} \text{ v } I = \underline{\hspace{1cm}} \text{ mA } R = \underline{\hspace{1cm}} \Omega$

**5.**

**Two LEDs and 10KΩ resistor:**

$V = \underline{\hspace{1cm}} \text{ v } I = \underline{\hspace{1cm}} \text{ mA } R = \underline{\hspace{1cm}} \Omega$

**6.**

Circle the Ground in the circuit.

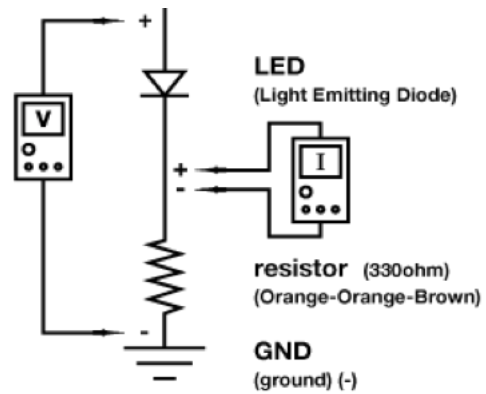
**7.**

Draw arrows to indicate direction of current on dotted line.

**8.**

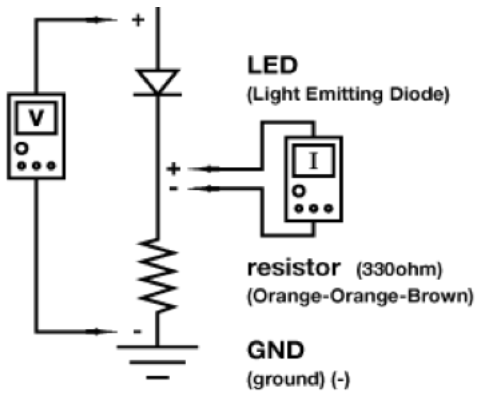
Add an on/off switch to this schematic.

Circuit:



## Circuit #1 Blink LED

Circuit:



### 10.

What circuits or projects would you like to add LEDs to? List at least three reasons you might add LEDs to an existing circuit or product that you might use. For example: to indicate when a squirt gun is running low on water or to add a flashlight to your hat.

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### 9.

Draw a logic flow chart of the circuit here:

### 11.

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

**Circuit #2 Potentiometers**

**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**5.**

Use your multimeter as indicated and measure the voltage of the potentiometer circuit while you turn the dial up and down. Explain below what happens.

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**Can you turn your LED up and down using the potentiometer?**

Great. Pay attention to this circuit, potentiometers (also called trimpots) are great for creating analog user interfaces. With a potentiometer there are up to 1024 settings on a single dial!

**2.**

Add the following to the circuit code and upload:

In Setup: `Serial.begin(9600);`

In Loop after all other code: `Serial.println(sensorValue);`

Now open the Serial Communication window.

**3.**

Replace the LED component (in the schematic) with an element or component from one of the previous circuits, extra credit if you decide to replace it with a motor. Explain which aspect of the element or component is controlled by the potentiometer. Example: replace LED with Piezo speaker and control pitch with potentiometer.

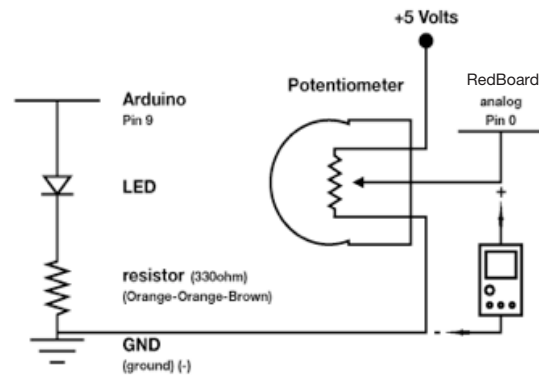
**4.**

**Aspect:**

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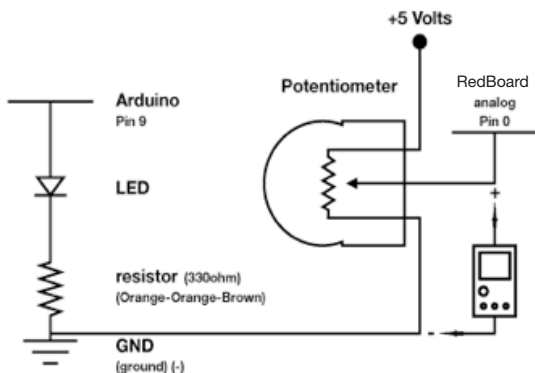
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**Circuit:**



## Circuit #2 Potentiometers

Circuit:



7.

Potentiometers are everywhere. List at least three appliances that use potentiometers as an input. Also list what the potentiometer input controls (also known as an output).

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6.

Draw a logic flow chart of the circuit here:

8.

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

Circuit #3 RGB LED

1.

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Does the RGB LED work?**

Great. Upload the Circ12Expansion Code to your Arduino, add a trimpot, a temperature sensor and a photoresistor to the circuit. Connect the trimpot to analog pin 1, the temperature sensor to analog pin 2, and the photoresistor to analog pin 0. Use some of the previous circuit schematics if you get stumped. You may also switch out the temperature sensor for the flex sensor or soft potentiometer so you have more control of the RGB LED if you like, but you will also need to change the code a little.

2.

Connect a multimeter to each line that is connected to a RedBoard pin. Notice how the voltage changes while you use the sensor or interface coupled with each pin.

3.

What should the voltage values for each pin be to make the RGB LED as red as it will get?

$V = \text{_____} \text{ v}$   $I = \text{_____} \text{ mA}$   $R = \text{_____} \Omega$

4.

What does "RGB LED" stand for?

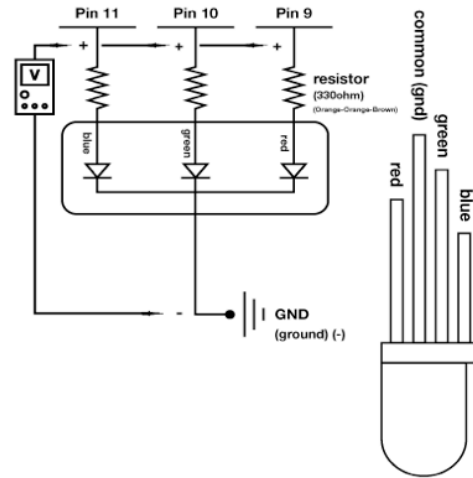
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5.

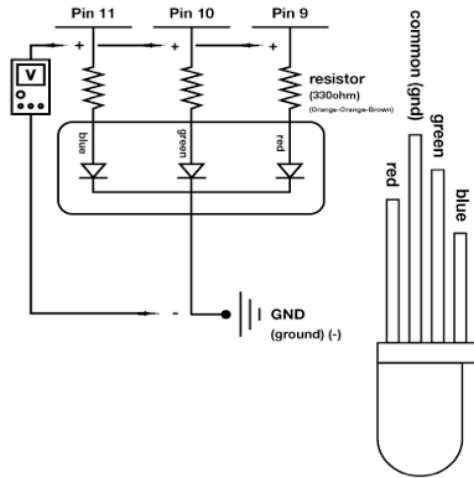
Add an On/Off switch to your schematic.

Circuit:



## Circuit #3 RGB LED

Circuit:



7.

Other than making projects pretty, what are some possible uses for a RGB LED? List at least three.

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6.

Draw a logic flow chart of the circuit here:

8.

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

**Circuit #4 Multiple LEDs**

**Ohm's Law:**  $V = I * R$      $I = V / R$      $R = V / I$

**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Did you get your LEDs turned on?**

Great. Load the Circ02Expansion Code. In this code the last LED pin is an analog output using PWM (Pulse Width Modulation). Make sure to use a red LED.

Give values for Voltage, Current and Resistance for each LED circuit setup. Find Resistance with Ohm's Law. Hint: Break the circuit between the RedBoard pin and LED to measure the current.

**2.**

**PWM @ 63.75 (or 25%)**

$V = \underline{\hspace{2cm}} \text{ v } I = \underline{\hspace{2cm}} \text{ mA } R = \underline{\hspace{2cm}} \Omega$

**3.**

**PWM @ 127.5 (or 50%)**

$V = \underline{\hspace{2cm}} \text{ v } I = \underline{\hspace{2cm}} \text{ mA } R = \underline{\hspace{2cm}} \Omega$

**4.**

**PWM @ 191.25 (or 75%)**

$V = \underline{\hspace{2cm}} \text{ v } I = \underline{\hspace{2cm}} \text{ mA } R = \underline{\hspace{2cm}} \Omega$

**5.**

**PWM @ 255 (or 100%)**

$V = \underline{\hspace{2cm}} \text{ v } I = \underline{\hspace{2cm}} \text{ mA } R = \underline{\hspace{2cm}} \Omega$

**6.**

Circle all the Power Sources in the circuit. (This one is a little trickier)

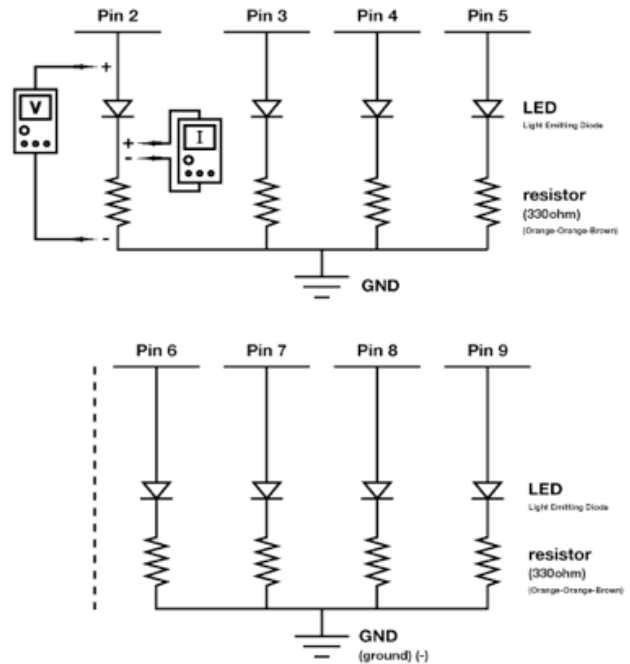
**7.**

Draw arrows to indicate direction of current on dotted line.

**8.**

Add an on/off switch for one LED to this schematic.

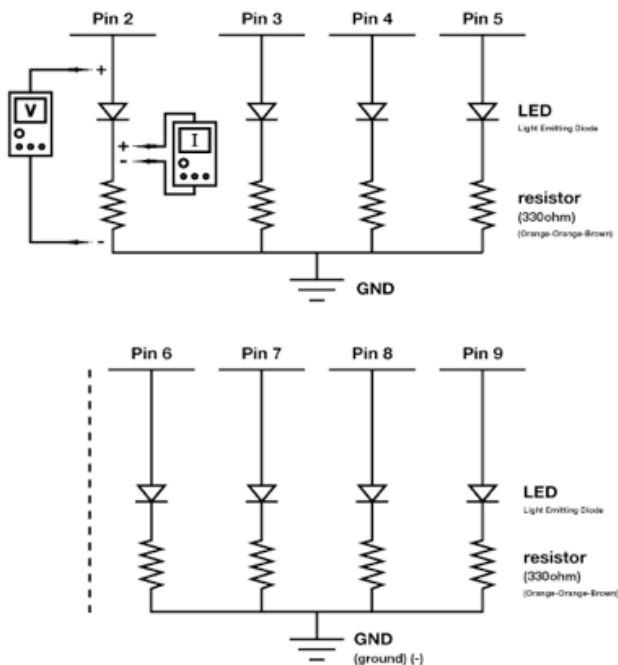
**Circuit:**





## Circuit #4 Multiple LEDs

Circuit:



10.

What circuits or projects would you like to add LEDs to? Can you think of at least three reasons you might add multiple LEDs to an existing circuit or product that you would use? For example: clock that shuts off an LED every time you are done with a class, turning off all the LEDs by the end of the day so you know you are free.

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11.

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

9.

Draw a logic flow chart of the circuit here:

**Circuit #5 Push Buttons**

**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Can you turn your LED on and off using both buttons?**

Great. Pay attention to this circuit, buttons are one of the most basic forms of user interface.

Give values for Voltage, Current and Resistance for each question. Find Current either by breaking the circuit and/or using your multimeter.

**2.**

**Button on pin 2 pushed:**

$V = \underline{\hspace{1cm}} \text{ v } I = \underline{\hspace{1cm}} \text{ mA } R = \underline{\hspace{1cm}} \Omega$

**3.**

**Button on pin 3 pushed:**

$V = \underline{\hspace{1cm}} \text{ v } I = \underline{\hspace{1cm}} \text{ mA } R = \underline{\hspace{1cm}} \Omega$

**4.**

Think about the question above. What makes the LED turn on and off?

**5.**

If the resistor's value is  $10000\Omega$ , what is the resistance of the button?  $\underline{\hspace{1cm}} \Omega$

**6.**

Replace the LED component (in the space below the schematic to the right) with an element or component from one of the previous circuits. Extra credit if you decide to replace it with a motor.

**7.**

Draw arrows indicating current direction on dotted line.

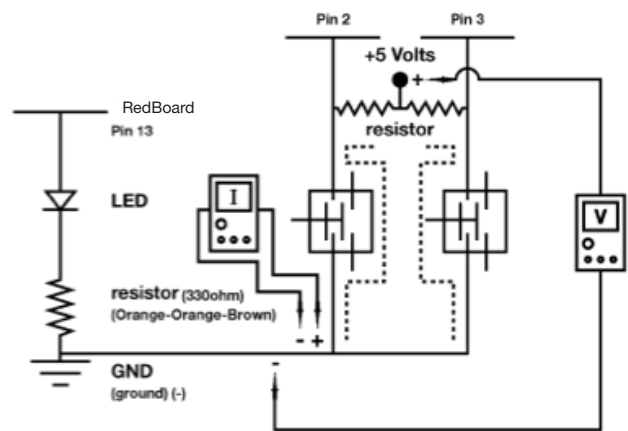
**8.**

Add another Piezo Element to the schematic so you can write harmonies. Be sure to show which Arduino pin you will attach it to.

**9.**

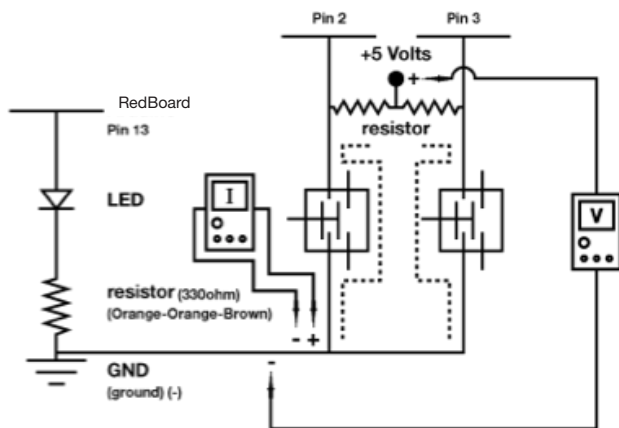
Add an on/off switch to this schematic.

**Circuit:**



## Circuit #5 Push Buttons

Circuit:



# 11.

Buttons are everywhere. List at least two different kinds of buttons that you might not think of as being buttons. Now list at least two items that are not technically buttons, but could be used as buttons. Example: snaps on a shirt.

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# 10.

Draw a logic flow chart of the circuit here:

# 12.

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

**Circuit #6 Photo Resistor**

**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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Can you turn your LED up and down using the photoresistor? Great.

**2.**

Add the following to the circuit code and upload:  
In Setup: `Serial.begin(9600);`  
In Loop after all other code: `Serial.println(lightValue);`  
Now open the Serial Communication window.  
Replace the LED component (in the space below the schematic on the right) with an element or component from one of the previous circuits, extra credit if you decide to replace it with a motor and do so correctly.

**3.**

Make sure an aspect of the element or component is controlled by the photoresistor. Example: replace LED with Piezo and control pitch with potentiometer. Aspect controlled:

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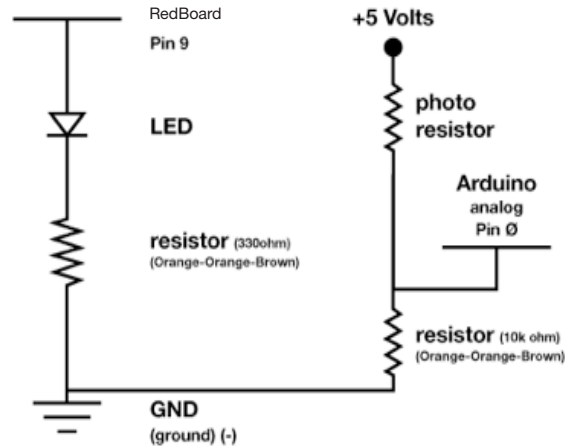
**4.**

Why does this circuit use an analog pin as an input?

**5.**

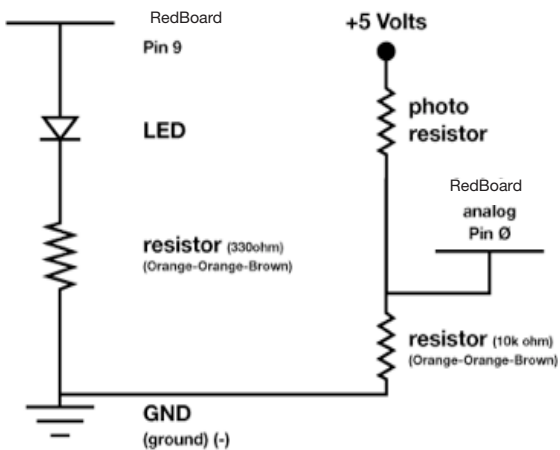
Circle all the resistors.

**Circuit:**



## Circuit #6 Photo Resistor

Circuit:



7.

The output variable `lightValue` can go all the way up to 900 but your LED input can only go up to 255. What word in the code fixes this and how would you describe this action in a mathematical sense?

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6.

Draw a logic flow chart of the circuit here:

8.

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

# 1.

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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Does your temperature sensor work? Great

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# 2.

What line in the code displays the temperature?

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# 3.

What other line in the code is necessary to establish communication with your computer so it can display the temperature?

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# 4.

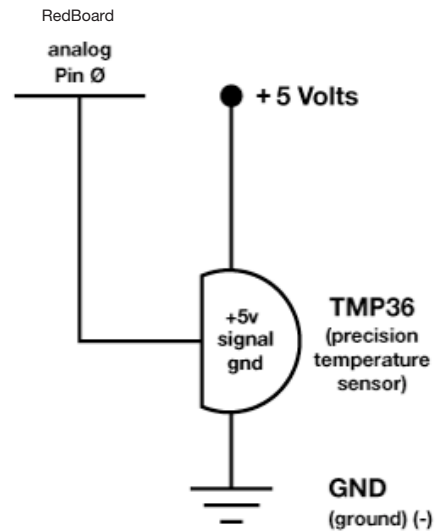
Upload the Circ10Expansion Code to your RedBoard, then add an LED and a resistor to the circuit. Control the LED's brightness with the temperature sensor. By now you should be able to do this with no help, but here's a hint anyways: PWM pins = 3, 5, 6, 9, 10, 11

# 5.

Draw arrows on the dotted line to indicate direction of current flow.

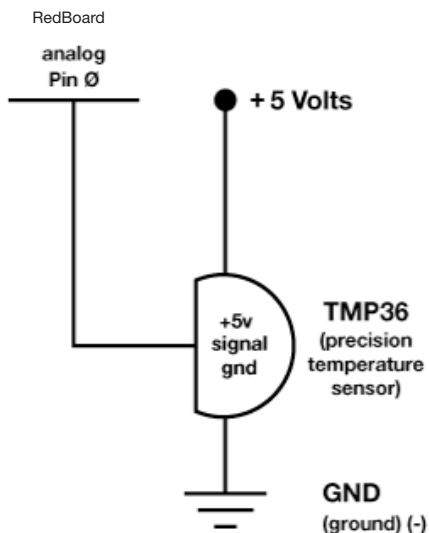
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Circuit:



## Circuit #7 Temperature Sensor

**Circuit:**



**7.**

What ways, other than controlling an air conditioner, could a temperature sensor be useful? List at least three and explain what is controlled by the temperature sensor in each.

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**6.**

Draw a logic flow chart of the circuit here:

**8.**

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

Circuit #8 Single Servo

Ohm's Law:  $V = I * R$      $I = V / R$      $R = V / I$

1.

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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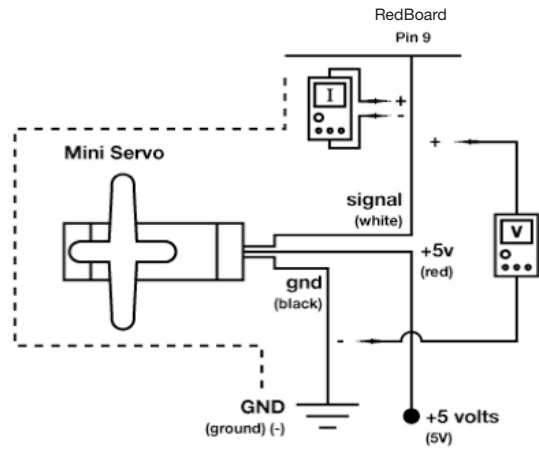


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Circuit:



Do you have your servo running? Great.

Give values for Voltage, Current and Resistance for the pin # 9 value while the servo is in motion. Find the current by breaking the circuit and measuring at multimeter with I. Find resistance using Ohm's Law.

2.

Highest reading while Servo is in motion:

$V = \text{_____} \text{v}$      $I = \text{_____} \text{mA}$      $R = \text{_____} \Omega$

3.

What does the RedBoard pin # 9 do in this circuit?

4.

Draw arrows to indicate direction of current on the dotted line.

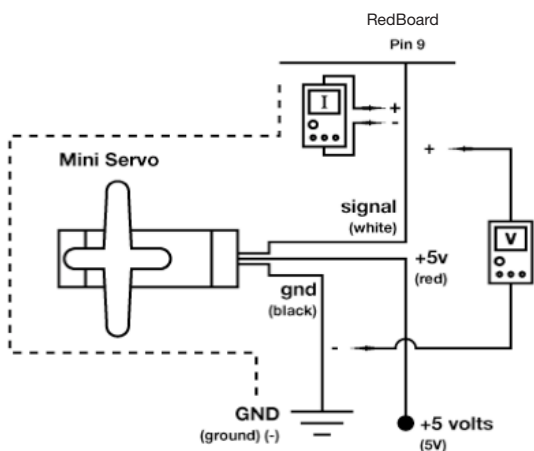
5.

Add an on/off switch to this schematic.



**Circuit #8 Single Servo**

**Circuit:**



**7.**

A Servo can't rotate continuously more than 180 degrees, as opposed to a motor which can turn all the way past 360 degrees as many times as you like. However, a servo remembers what its position is while a motor only knows if it is running forward or backwards. Can you think of any situations in which you would need a Servo instead of a motor? How about the other way around? Write three examples, at least one of each, below.

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**6.**

Draw a logic flow chart of the circuit here:

**8.**

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

Circuit #9 Flex Sensor

1.

Now we're starting to work with some more complicated sensors. The flex sensor has tons of real world applications. List three and explain why you can't use a regular potentiometer instead of a flex sensor. Example: use the sensor to measure the flex on a fishing pole and cut the line if the pole ever comes close to breaking. You could not use a potentiometer because it would be difficult to attach it.

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**Got your flex sensor and servo working?** Great, but what if you want to measure flex in both directions? Add the necessary components to the schematic below (add components on right) and describe (in plain English) what you would need to add to the code to keep the single servo as your output with your new schematic.

2.

Unplug the flex sensor completely and look at your Serial Communication window. You should still be getting some values even though there is no sensor plugged in. This is due to something called "float" which occurs when an RedBoard pin is expecting input but there is no sensor attached to it. What is the highest value you receive and why is it important to know about float?

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3.

What if you wanted your flex sensor to measure a smaller range of flexing (because what you are measuring is less flexible), but you want the same range of motion for your servo, how could you make it do that?

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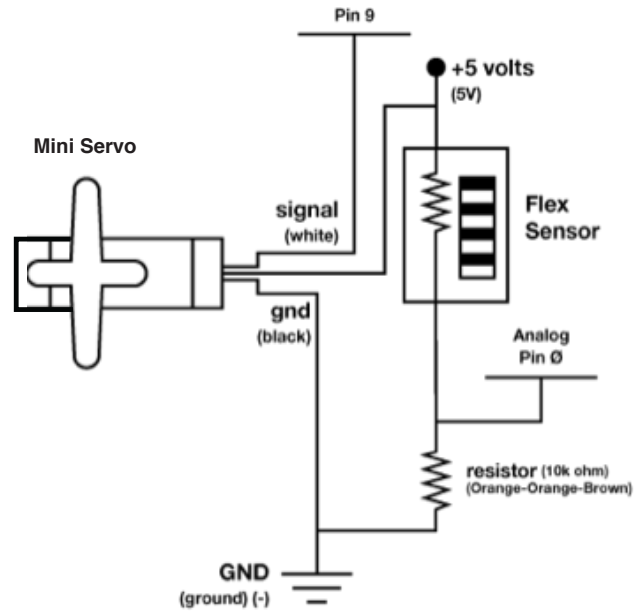
4.

Add an On/Off switch to your schematic.

5.

Circle any Arduino pins that take input on your modified schematic.

Circuit:





# 1.

The soft potentiometer is touchy, sometimes you will notice incorrect readings due to how you touch the sensor. The RGB will even change a little just before you touch the sensor! Explain how this alters the ways in which you can use this sensor. Explain at least one possible fix or work around.

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**Got your soft potentiometer and RGB LED working?** Great. Without looking at the code too much, mark on the soft potentiometer diagram below which areas cause which colors to be displayed.

Soft Potentiometer



# 2.

This will let you see the values (slowed down a little with the delay line, to see real time output remove `delay(100)`; as the soft potentiometer outputs them. What happens to the values after you stop touching the sensor? Explain why you think this happens. You may have to look up how this sensor works to figure this out.

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# 3.

Explain in your own words how you think you could use the soft potentiometer to turn the RGB LED on/off as well as controlling the color.

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# 4.

Add the following code to your Arduino code.

In Setup: `Serial.begin(9600);`

In Loop after all other code:

`Serial.`

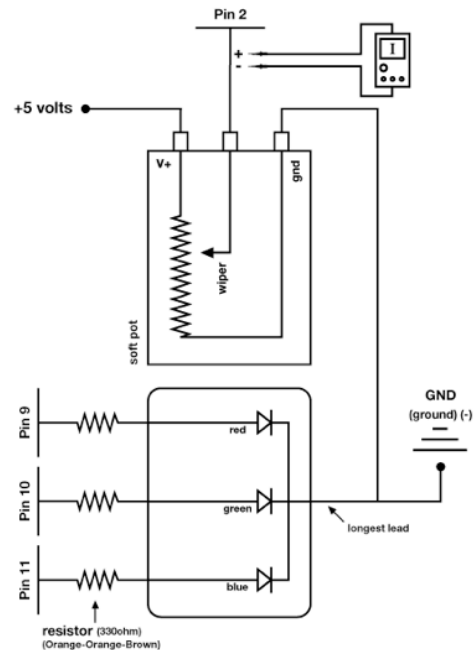
`println(sensorValue);`

`delay(100);`

# 5.

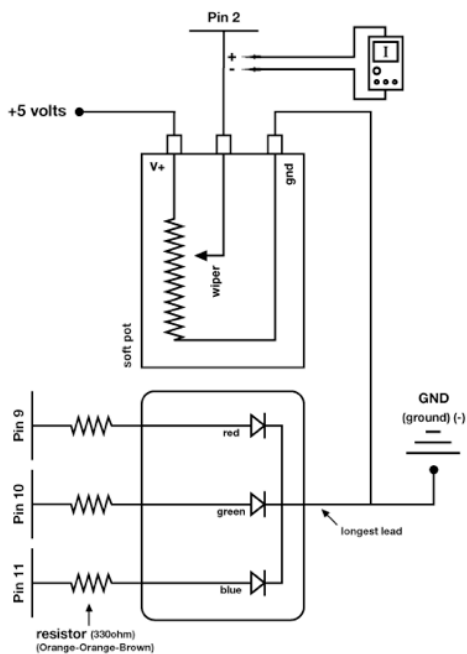
Now open the Serial Communication window.

## Circuit:



## Circuit #10 Soft Potentiometer

**Circuit:**



**6.**

Draw a logic flow chart of the circuit here:

**7.**

Calculate resistance of the potentiometer when it is blue, then green, then red. You will need to measure Voltage and Current, then calculate resistance because you can't see the RGB value while measuring resistance.

$V = \text{_____} \text{ v } I = \text{_____} \text{ mA } R = \text{_____} \Omega$

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**8.**

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

**Circuit #11 Piezo Element**

**Ohm's Law:**  $V = I * R$      $I = V / R$      $R = V / I$

**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Do you have the annoying song blaring out of your speaker?** Upload Circ06Expansion Code to your RedBoard.

Give values for Voltage, Current and Resistance for each note value. Find Current by breaking the circuit and using your multimeter. Record voltage to the thousandths place. Calculate Resistance using Ohm's Law.

**2.**

**Note A:**

$V = \underline{\hspace{1cm}}$  v  $I = \underline{\hspace{1cm}}$  mA  $R = \underline{\hspace{1cm}}$   $\Omega$

**3.**

**Note C:**

$V = \underline{\hspace{1cm}}$  v  $I = \underline{\hspace{1cm}}$  mA  $R = \underline{\hspace{1cm}}$   $\Omega$

**4.**

**Note E:**

$V = \underline{\hspace{1cm}}$  v  $I = \underline{\hspace{1cm}}$  mA  $R = \underline{\hspace{1cm}}$   $\Omega$

**5.**

**Note G:**

$V = \underline{\hspace{1cm}}$  v  $I = \underline{\hspace{1cm}}$  mA  $R = \underline{\hspace{1cm}}$   $\Omega$

**6.**

What does the Arduino pin # 9 do in this circuit?

**7.**

Draw arrows indicating current direction on dotted line.

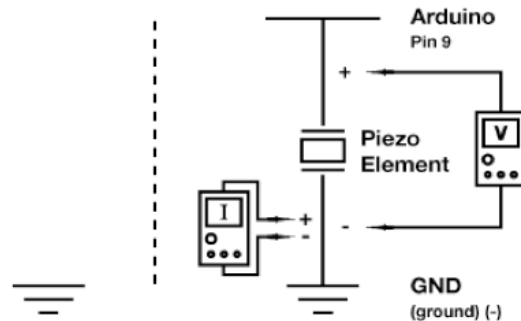
**8.**

Add another Piezo Element to the schematic so you can write harmonies. Be sure to show which Arduino pin you will attach it to.

**9.**

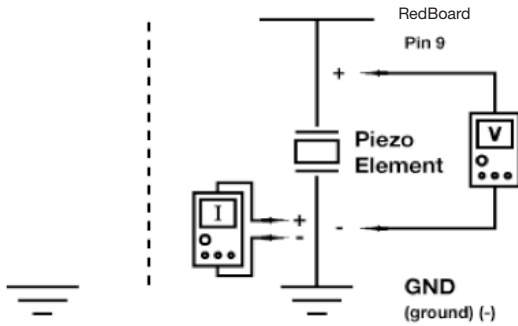
Add an on/off switch to this schematic.

**Circuit:**



## Circuit #11 Piezo Element

Circuit:



# 11.

Other than annoying your friends, how could you use the Piezo Element in a project? Example: create a timer that plays an annoying song faster and faster as time runs out. Write at least two examples.

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# 10.

Draw a logic flow chart of the circuit here:

# 12.

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

Ohm's Law:  $V = I * R$      $I = V / R$      $R = V / I$

**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Do you have your motor running?**

Great. Load the Circ03Expansion Code. Fill in the answers below.

Give values for Voltage, Current and Resistance for each motor value. Find Current by breaking the circuit and using your multimeter. Calculate the Resistance using Ohm's Law. Record all values to the hundredths place.

**2.**

**Motor 50%**

$V = \underline{\hspace{1cm}}$  v  $I = \underline{\hspace{1cm}}$  mA  $R = \underline{\hspace{1cm}}$   $\Omega$

**3.**

**Motor 60%**

$V = \underline{\hspace{1cm}}$  v  $I = \underline{\hspace{1cm}}$  mA  $R = \underline{\hspace{1cm}}$   $\Omega$

**4.**

**Motor 75%**

**5.**

$V = \underline{\hspace{1cm}}$  v  $I = \underline{\hspace{1cm}}$  mA  $R = \underline{\hspace{1cm}}$   $\Omega$

**6.**

**Motor 100%**

$V = \underline{\hspace{1cm}}$  v  $I = \underline{\hspace{1cm}}$  mA  $R = \underline{\hspace{1cm}}$   $\Omega$

**7.**

Circle the diode in the circuit.

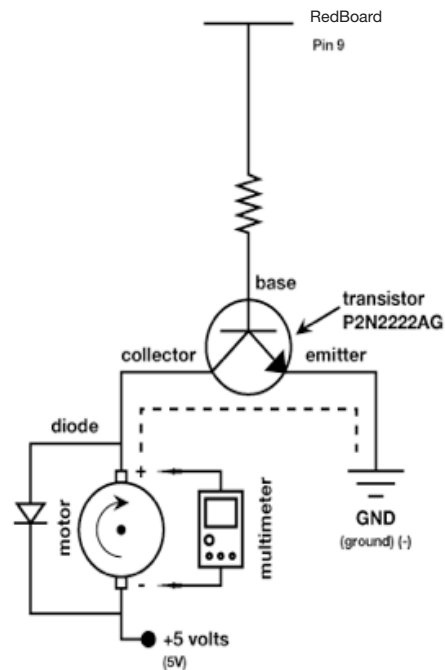
**8.**

Draw arrows to indicate direction of current on dotted line.

**9.**

Add an on/off switch to this schematic.

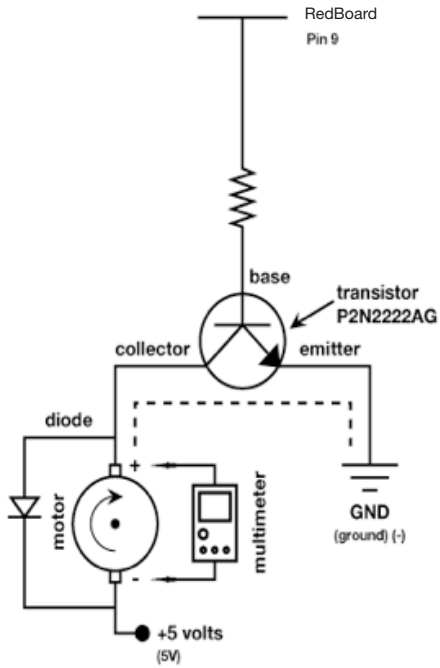
**Circuit:**





## Circuit #12 Spinning Motor

Circuit:



### 11.

How would you use this circuit if you were an engineer? Would you make a break-dancing robot penguin? To move a trapdoor? To make a yo-yo that plays itself? Get creative.

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### 12.

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

### 10.

Draw a logic flow chart of the circuit here:

Circuit #13 Relays

1.

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Does your relay work?**

If so, upload Circ11Expansion Code to your RedBoard, then add a button to your circuit and to the right of the schematic, make sure you include a pull up resistor (10KΩ resistor).

2.

Name one thing you would have to change to use a potentiometer to control the relay instead of a button, extra credit for writing what you would need to add in the code as well. Use English, not code.

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3.

If the NO in the relay stands for Normally Open, what do you think NC stands for?

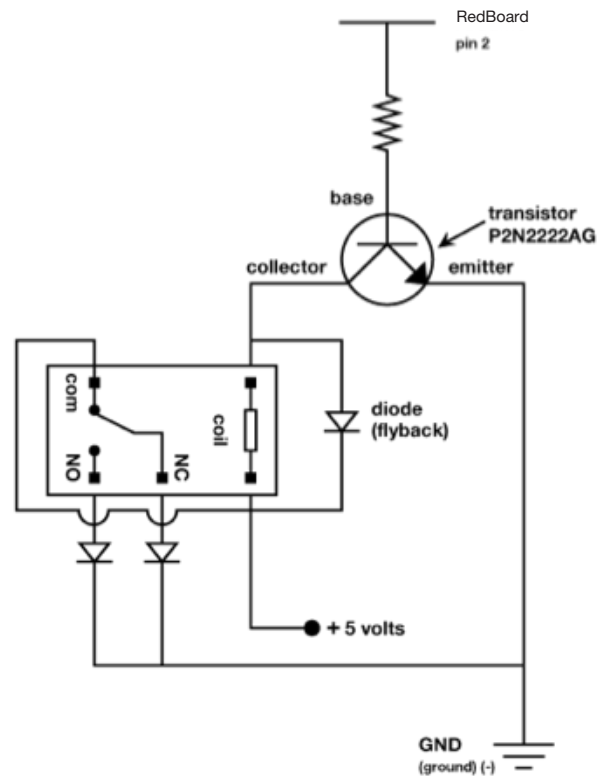
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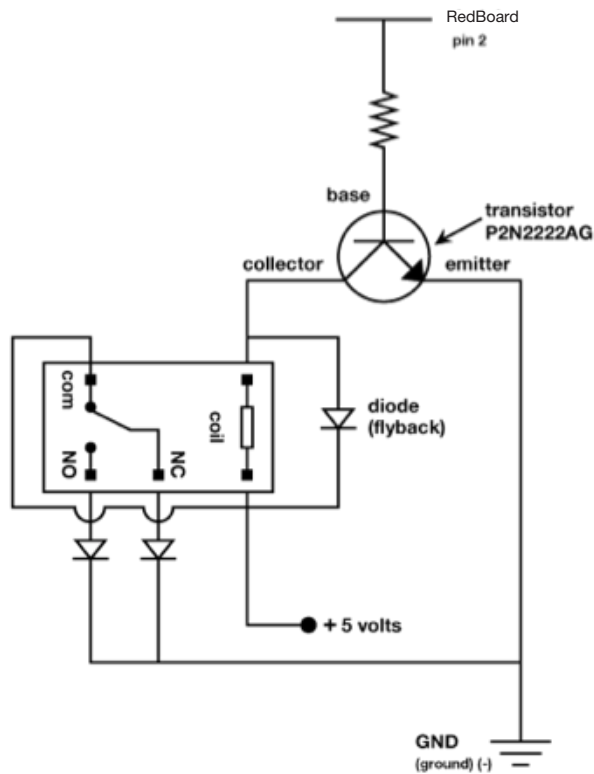
---

Circuit:



## Circuit #13 Relays

Circuit:



4.

Draw a logic flow chart of the circuit here:

5.

Imagine your perfect relay machine. What two things would your relay switch back and forth between and why? Get creative. Example: a soft serve ice cream machine and an electric caramel pump so that making sundaes would be a little less work and give you more time to eat them.

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6.

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.

Circuit #14 Shift Register

**1.**

Shift Registers are used to control multiple pins using only three input pins to set the output pins. This can be useful if you want to control more than three objects using only three pins (as long as they always operate in the same order). What objects would you control using a shift register? List at least four and make sure the objects make sense together. Ex: A waffle iron, an eggbeater, a servo to pour the batter, and a timer.

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**2.**

What does the RedBoard pin # 2 do in this circuit?

**3.**

What does the RedBoard pin # 3 do in this circuit?

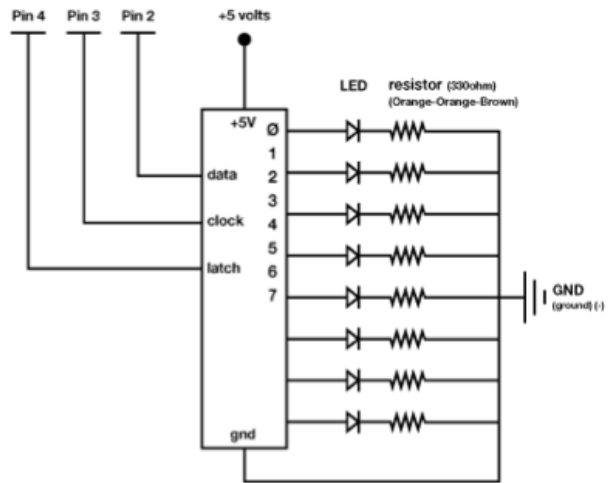
**4.**

What does the RedBoard pin # 4 do in this circuit?

**5.**

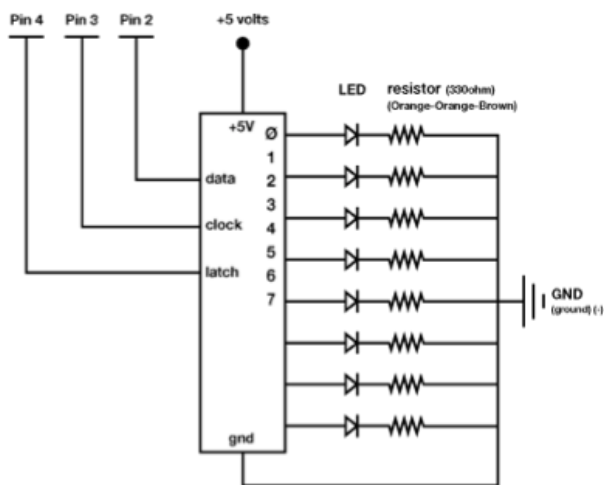
If all the LEDs are turned on, what would have to happen in order for LED # 5 to turn off?

**Circuit:**



## Circuit #14 Shift Register

**Circuit:**



**7.**

Using the circuit exactly as it is, with eight LEDs, what applications can you think of for the shift register? List at least three and explain what each LED would indicate.

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**6.**

Draw a logic flow chart of the circuit here:

**8.**

Draw one example of how this circuit could be used in everyday life. Label all components and give it a title.





Circuit #1 Blinking LED

**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Did you get your LED (Light Emitting Diode) turned on?**

Great. Fill in the answers below using red LEDs.

**2.**

**Two LEDs in series, 5V:**

$$V = \underline{\quad} \quad I = \underline{\quad} \quad R = \underline{\quad}$$

**3.**

**Two LEDs, parallel, 5V:**

$$V = \underline{\quad} \quad I = \underline{\quad} \quad R = \underline{\quad}$$

**4.**

**One LED, 3.3V power:**

$$V = \underline{\quad} \quad I = \underline{\quad} \quad R = \underline{\quad}$$

**5.**

**Two LEDs, series 3.3V:**

$$V = \underline{\quad} \quad I = \underline{\quad} \quad R = \underline{\quad}$$

**6.**

**Two LEDs, parallel 3.3V:**

$$V = \underline{\quad} \quad I = \underline{\quad} \quad R = \underline{\quad}$$

Replace your 330Ω resistor with a 10KΩ resistor.

**7.**

**Two LEDs in series, 5V:**

$$V = \underline{\quad} \quad I = \underline{\quad} \quad R = \underline{\quad}$$

**8.**

**Two LEDs, series, 3.3V:**

$$V = \underline{\quad} \quad I = \underline{\quad} \quad R = \underline{\quad}$$

**9.**

What do you think would happen if you connected a 9V battery as your power source for the first circuit?

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**10.**

Assuming the same resistance as the original circuit, what would the current equal with a 9V power source? Show your work.

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**11.**

In the code below circle the “*setup()*” method and explain below what it does in this instance.

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## 12.

Underline the code that turns the LED on.

```
int ledPin = 9;

void setup()
{
  pinMode(ledPin, OUTPUT);
}

void loop()
{
  analogWrite(ledPin, 200);
  delay(1000);
  analogWrite(ledPin, 0);
  delay(1000);
}
```

## 13.

Why does the code above use pin # 9 instead of pin # 0 or pin # 1? Explain why pin # 0 and pin # 1 are not options. Make sure you explain for both digital pins and analog input pins.

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## 14.

Explain why you might use LEDs on an illuminated shirt (or hat, etc) instead of other types of light bulbs.

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Circuit #2 Potentiometers

1.

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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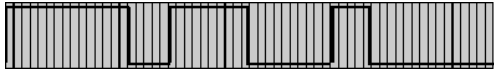
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Can you turn your LED up and down using the potentiometer? Potentiometers are also called trim pots.

2.



Describe how the potentiometer is being adjusted according to the PWM diagram above.

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3.

Who invented the potentiometer and when?

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4.

What basic component does a potentiometer act like when it is not being adjusted?

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5.

In your own words describe what voltage dividers do.

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6.

Describe how you would use potentiometers to control a marshmallow (because they are soft) launcher's trajectory. What other pieces of hardware would you need to create this marsh-mallow launcher?

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## Circuit #2 Potentiometers

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Calculate percentage for each of the `analogWrite` values, then draw a line from the PWM code on the left to the corresponding PWM diagram on the right.

**7.**

`analogWrite (ledPin, 0);` \_\_\_\_\_%

**8.**

`analogWrite (ledPin, 200);` \_\_\_\_\_%

**9.**

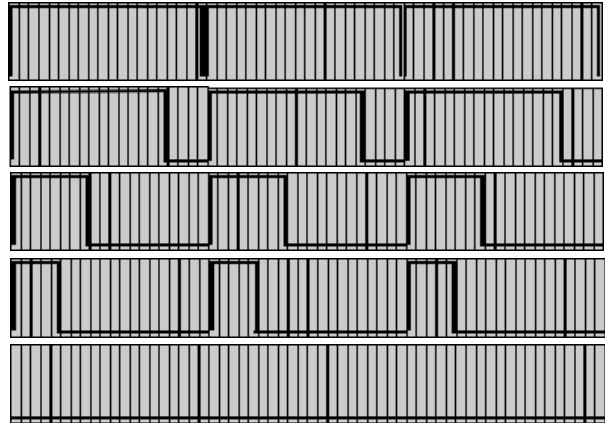
`analogWrite (ledPin, 255);` \_\_\_\_\_%

**10.**

`analogWrite (ledPin, 70);` \_\_\_\_\_%

**11.**

`analogWrite (ledPin, 100);` \_\_\_\_\_%



Circuit #3 RGB LEDs

1.

This LED has three inputs and three outputs. What other circuits have three inputs? Three outputs? Provide an example of each.

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5.

Given that there are 256 (0 – 255) different intensity values for each color in an RGB LED, how many different colors can an RGB LED emit? Show your work.

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**Does the RGB LED work?**

Great. Hint for questions below: if you're really stuck add a button to your circuit that uses `Serial.println()` to print RGB values when you press it.

Connect a multimeter to each line that is connected to a RedBoard pin. Notice how the voltage changes while you use the sensor or interface coupled with each pin.

2.

What should the voltage values for each pin be to make the RGB LED as red as it can get?

Pin 11 V = \_\_\_ v Pin 10 V = \_\_\_ v Pin 9 V = \_\_\_ v

3.

What should the voltage values for each pin be to make the RGB LED as yellow as it can get?

Pin 11 V = \_\_\_ v Pin 10 V = \_\_\_ v Pin 9 V = \_\_\_ v

4.

What should the voltage values for each pin be to make the RGB LED as white as it can get, but at 1/2 intensity?

Pin 11 V = \_\_\_ v Pin 10 V = \_\_\_ v Pin 9 V = \_\_\_ v

6.

How many different colors can a RGBY LED emit?

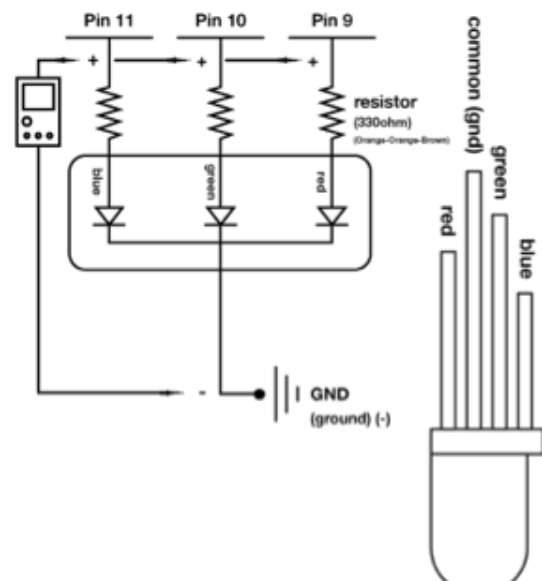
---

7.

Why are there 256 LED intensities, and not 300?

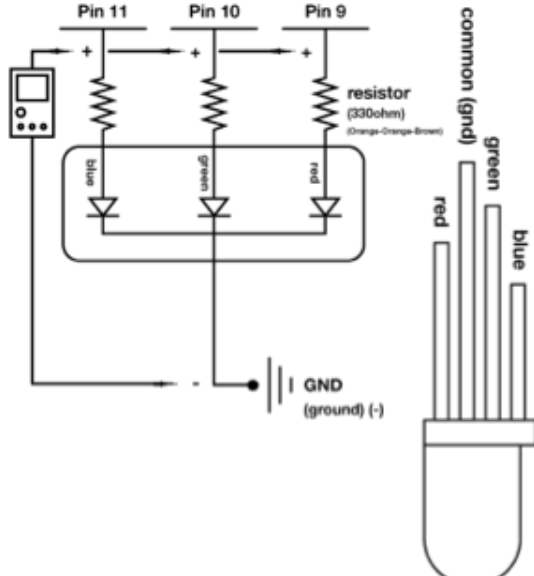
---

**Circuit:**



## Circuit #3 RGB LEDs

### Circuit:



**8.**

Light is a small part of a big group of electromagnetic fields called the Electromagnetic Spectrum. Name at least three other electromagnetic fields and state if their frequencies are higher or lower than light.

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**9.**

Who discovered the theory of Electromagnetic Spectrum? Who expanded it beyond light?

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**10.**

Upload Circ12BExpansion to your Arduino and add a piezo element to digital pin # 1. Change the code so you don't go crazy listening to "Twinkle, Twinkle Little Star". Explain how you could add another RGB LED so it also changes color depending on the note your piezo plays, but with different code so it displays a different color.

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**11.**

Other than Red, Green and Blue, what else could RGB stand for? Example: Roasted Gooey Baloney, Random Gargantuan Baboons, Rappers Got Beef, or Robot Guild Butlers. List at least three.

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Circuit #4 Multiple LEDs

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**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Did you get your LED turned on?**

Great. Now you are going to add a dimmer switch to your LED on pin # 9.

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**2.**

What user interface component will you need to use as a dimmer?

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**3.**

Add the necessary text to the `oneOnAtATime()` method for the code heavy way to add the dimmer.

**4.**

There are three different way to add a dimmer without changing or adding code. Try to find one of these ways without destroying your LED.

**5.**

Draw a schematic of your circuit in the space to the right, adding your dimmer component so that it works. There are four different ways to do this.

**6.**

What other component does the dimmer component in this circuit act as?

---

**7.**

The LED needs a PWM value that ranges from 0 – 255. The dimmer component gives you values from 0 – 1023. Write an equation below that will convert the value the dimmer component outputs to a LED friendly value.

---

**8.**

The LED values 0 – 255 actually represent 256 different values. Why is that?

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**9.**

Imagine your LED circuit (without dimmer) as a meter indicating a sensor reading. Decide what kind of sensor you would like to use as an input and describe in your own words what would cause the meter to rise and fall.

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**5.**

Draw a logic flow chart of the LED with dimmer:

**Circuit #4 Multiple LEDs**

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Circuit #5 Push Buttons

1.

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Can you turn your LED on and off using both buttons?**

Great. Upload Circ07Expansion Code to your RedBoard and add an RGB LED to pins 9, 10 and 11. Check the code if you are unsure which leads go to which pins.

2.

The buttons in your circuit now adjust the variable "RGBValue" either up or down. What are the upper and lower parameters of "RGBValue"?

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3.

With the code as is, what happens if you press the "down" button while pressing the "up" button? Why do you think this is?

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4.

What could you add to the code to fix this bug?

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5.

In the code below underline the command that happens when the button is not being pressed.

```
void loop()
{
  buttonState = digitalRead(buttonPin);

  if (buttonState == HIGH) {
    digitalWrite(ledPin, HIGH);
  }
  else {
    digitalWrite(ledPin, LOW);
  }
}
```

6.

Explain the difference between = and ==.

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7.

Buttons are everywhere, however it is possible to substitute other user interface components for buttons, list at least three components that you could switch with a button in some way.

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## Circuit #5 Push Buttons

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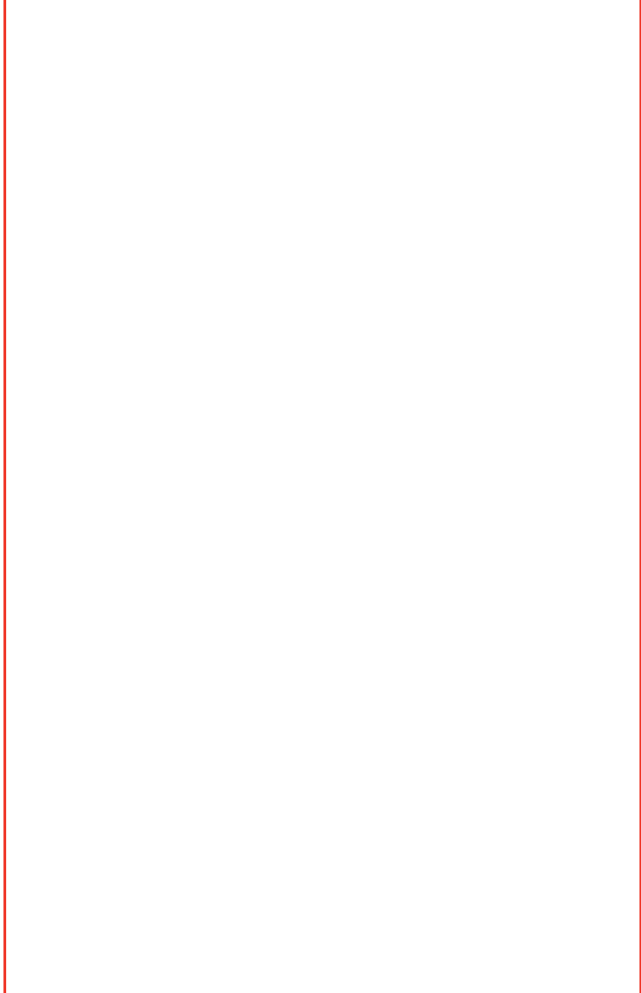
**8.**

Draw a logic flow chart of the expanded circuit here:



**9.**

In the space below draw the symbols for a two way switch (SPST), a three way switch (SPDT), and a double pole switch (DPST).



Circuit #6a Photo Resistor

1.

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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Can you turn your LED up and down using the photoresistor? Great.

2.

In the code you uploaded to your Arduino board change the line:

```
lightLevel = map(lightLevel, 0, 900, 0, 255);  
to: lightLevel = map(lightLevel, 0, 900, 255, 0);
```

3.

How does this change the way your circuit acts?

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4.

Leave the code above in and turn your photoresistor so that it faces the LED. Turn the lights off. Does your LED turn all the way off? Why is this?

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5.

What two lines do you need to add to your code to see what the output values from the photoresistor are and where do you need to add them?

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6.

Who invented the photoresistor, or photocell, and where was it invented?

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7.

There are three reasons the code below will not work, find all three errors and change or add the necessary code so it does work.

```
int lightPin = 0;  
int ledPin = 8;
```

```
void setup()  
{  
  pinMode(ledPin, OUTPUT)  
}
```

```
void loop()
```

```
  int lightLevel = analogRead(lightPin);  
  lightLevel = map(lightLevel, 0, 900, 0, 255);  
  lightLevel = constrain(lightLevel, 0, 255);  
  analogWrite(ledPin, lightLevel);  
}
```

8.

From the code above copy the command you would need to change if you wanted the LED to light up only when the photoresistor value is above 50%.

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**9.**

Write below what you would need to change the command to so that it functions as described above.

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**10.**

Photoresistors are great for light control, what else would you like to control with them? You can turn other circuits on or off by turning on your lights or opening your blinds. List at least three circuits.

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## Circuit #6b Photo Resistor

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**3.**

In order to make the alarm work during daylight you will need to be out of any direct lighting and you will need to change one of the values in the code. In the space below, write the line you changed in the code and explain why.

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**4.**

What component in the SIK do you think you could use to physically change the sensitivity of the photoresistor so you don't have to change the code whenever the sunlight levels change? Explain how.

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**Circuit #7 Temperature Sensor**

**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Does your temperature sensor work?**

Great. Upload Circ10BExpansion Code to your RedBoard. Attach the shift register and LEDs as shown in the schematic below. You may have to alter some code depending on how hot or cold it is where you are.

Write voltage values for the two temperature values below. Also record the amount of LEDs that light up with each temperature. For the first temperature use whatever temperature your room currently is.

**2.**

\_\_\_\_\_ °F ≈ \_\_\_\_\_ °C (room temperature, fill in degrees)

V = \_\_\_\_\_ v LEDs = \_\_\_\_\_

**3.**

98.6°F = 37°C (use a cup of cocoa to warm up sensor)

V = \_\_\_\_\_ v LEDs = \_\_\_\_\_

**4.**

50°F = 10°C (use an ice pack to cool down sensor)

V = \_\_\_\_\_ v LEDs = \_\_\_\_\_

Using the values above, formulate an equation so you can calculate values for the temperatures below.

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**5.**

105°F ≈ 40.5°C V = \_\_\_\_\_ v LEDs = \_\_\_\_\_

**6.**

86°F ≈ 30°C V = \_\_\_\_\_ v LEDs = \_\_\_\_\_

**7.**

32°F ≈ 0°C V = \_\_\_\_\_ v LEDs = \_\_\_\_\_

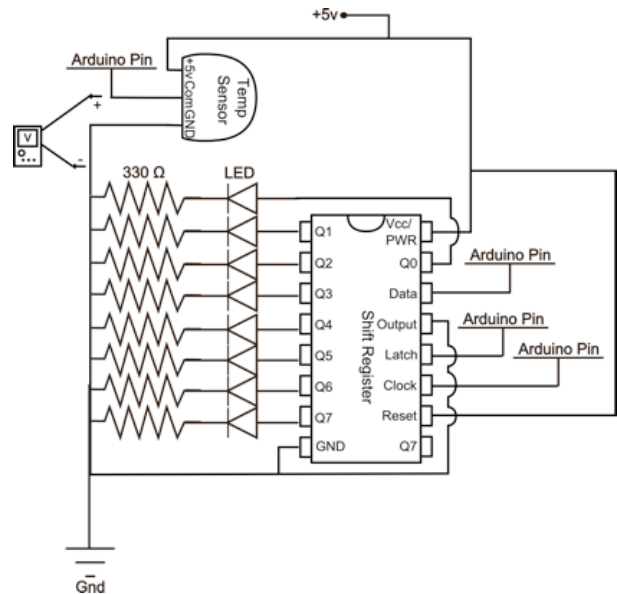
**8.**

-49°F ≈ -45°C V = \_\_\_\_\_ v LEDs = \_\_\_\_\_

**9.**

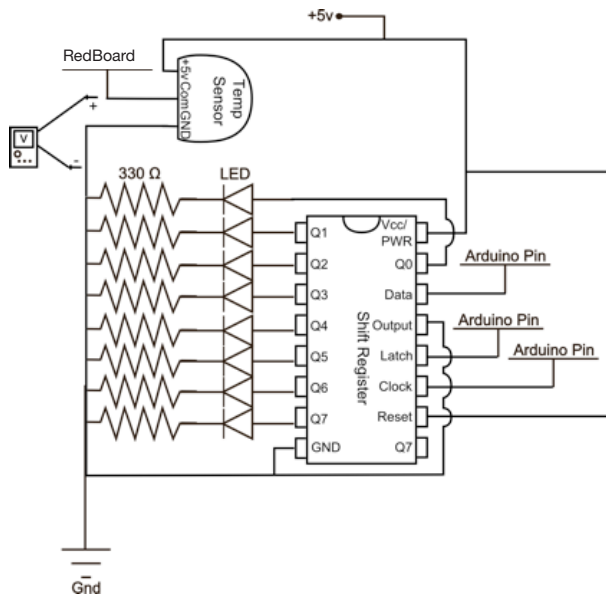
It is impossible to get a reading for one of the temperatures above. Place an X beside this value.

**Circuit:**



## Circuit #7 Temperature Sensor

### Circuit:



10.

Draw a logic flow chart of the circuit here:

11.

Write the equation below that solves for the change in voltage (V) given a change in temp (X).

---

12.

There are four main types of temperature sensors, thermocouples, resistance temperature detectors, thermistors, and temperature-transducing ICs. Which one are you playing with and is it analog or digital?

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13.

How is this similar to a LED? To a motor?

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14.

Find a way to quickly change the temp read by the sensor. How fast can you get it to change by 20°F?

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Circuit #8 Single Servo

1.

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

\_\_\_\_\_
\_\_\_\_\_
\_\_\_\_\_
\_\_\_\_\_
\_\_\_\_\_

Got your servo running? Great.

Upload Circ04Expansion to your RedBoard and add a temperature sensor (pin 0) to your circuit so it controls the position of the servo depending on the temperature.

2.

Decide what the parameters of your temperature gauge will be in Celsius. Find the line of code that controls this and change as necessary.

3.

Using the delay(); command change the code so that the speed of the servo is also controlled by the temperature. You can make it move faster or slower depending on the temperature sensor input. Ideally you will only need to change a single line of code to do this. Write the line of code you used below.

\_\_\_\_\_
\_\_\_\_\_
\_\_\_\_\_

4.

Add a button to the schematic on the right which allows the user to change what aspect of the servo the temperature sensor controls. Extra credit if you can modify the code so your circuit does this in real life.

5.

Define a servomechanism in your own words.

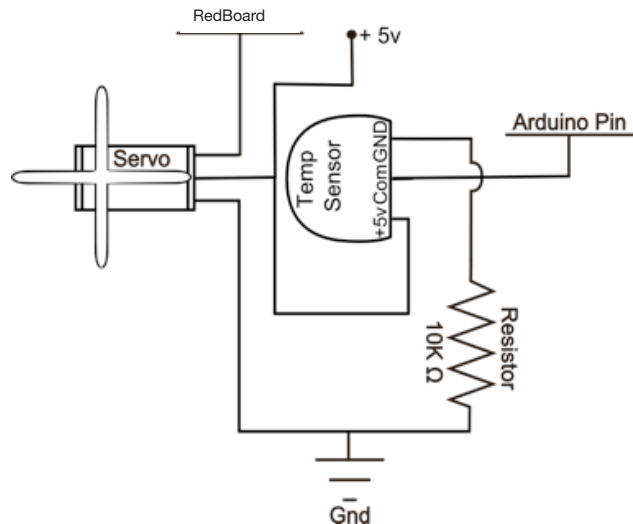
\_\_\_\_\_
\_\_\_\_\_
\_\_\_\_\_
\_\_\_\_\_
\_\_\_\_\_

6.

There are many types of servomechanisms that are not simple motors with position feedback, what is the most complicated servo you can think of?

\_\_\_\_\_
\_\_\_\_\_
\_\_\_\_\_
\_\_\_\_\_
\_\_\_\_\_

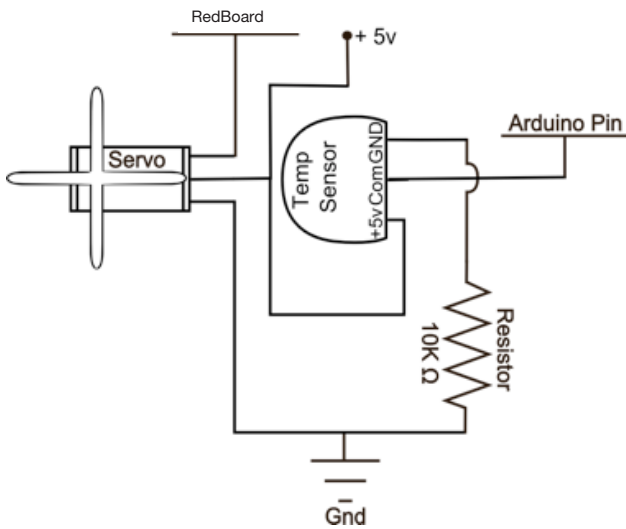
Circuit:





## Circuit #8 Single Servo

### Circuit:



**7.**

In your own words explain what this transistor does and the ways in which the motor's action would change if it were hooked up directly to a 5V power source and a ground?

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**8.**

Instead of a temperature sensor you could have added almost any sensor or interface component to your servo. Document at least three other options and explain briefly how you would control the servo.

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**9.**

It is possible to do amazing things with servomechanisms. In your own words, explain below how you could use the servo to create an autonomous marshmallow (because they are soft) launcher that corrects its angle depending on where the previous shot landed. Don't worry about how to get data about where the previous marshmallow landed, just explain how the servo would react to a marshmallow that went too far or too short.

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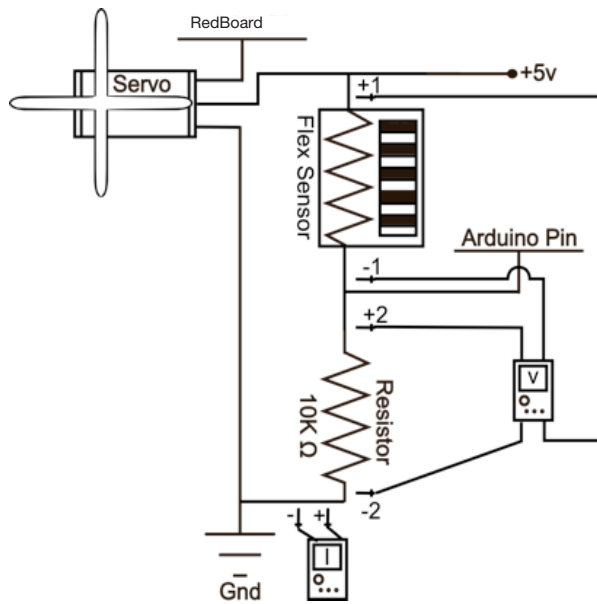
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## Circuit #9 Flex Sensors

### Circuit:



**10.**

What other kinds of sensors is this similar to?

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**11.**

How could you figure out the values for the second multimeter placement given the first set of values?

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**12.**

If the flex sensor itself is a resistor, why is the 10K resistor necessary? Explain.

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**13.**

Take your favorite hypothetical project that you have written about so far in these worksheets, explain how and why you might add at least one flex sensor to this project.

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Circuit #10 Soft Potentiometers

1.

The soft potentiometer is very touchy; sometimes you will notice incorrect readings due to how you touch the sensor. Be careful not to touch below the sensor pad, you will short out the sensor. Also the sensor reads a value even when you are not touching it. Explain how this alters the ways in which you can use this sensor. Explain at least one possible fix or work around.

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2.

Add the following code to your Arduino code.

In setup: `Serial.begin(9600);`

In loop (at end):

`Serial.println(sensorValue);`

`delay(100);`

3.

Now open the Serial Communication window.

This will let you see the values (slowed down a little with the delay line, to see real time output remove `delay(100);`) as the soft trimpot outputs them. What happens to the values after you stop touching the sensor? Explain why you think this happens.

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Give values for sensorValue, Voltage, Current and Resistance for each question. To measure resistance; disconnect trimpot, press area that corresponds to color and attach the multimeter to the com line and ground. Find Current by calculating with Ohm's Law.

4.

RGB in red range:  $V = \_\_\_ v$   $I = \_\_\_ mA$   $R = \_\_\_ \Omega$

sensorValue =  $\_\_\_\_\_\_$

5.

in blue range:  $V = \_\_\_ v$   $I = \_\_\_ mA$   $R = \_\_\_ \Omega$

sensorValue =  $\_\_\_\_\_\_$

6.

in green range:  $V = \_\_\_ v$   $I = \_\_\_ mA$   $R = \_\_\_ \Omega$

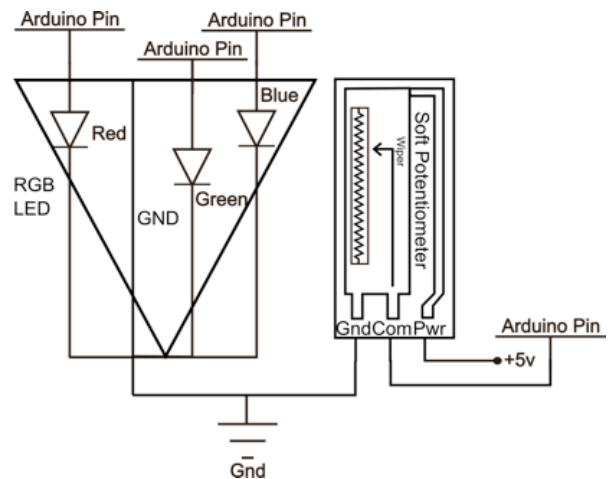
sensorValue =  $\_\_\_\_\_\_$

7.

in yellow range:  $V = \_\_\_ v$   $I = \_\_\_ mA$   $R = \_\_\_ \Omega$

sensorValue =  $\_\_\_\_\_\_$

Circuit:



## Circuit #10 Soft Potentiometers

8.

What RGB values do you need to display purple?

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9.

Touch the sensor lightly (don't push or hold it) and run your finger from one end to the other. What happens? Why do you think this is? Explain.

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10.

You can make the RGB LED display red when you touch the bottom and blue when you touch the top by changing two lines of code. Write one these lines of code below as well as what you need to change it to.

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11.

Write an if statement you could add to your `loop()` method that causes the RGB LED to display purple when you touch the absolute top of the trimpot.

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12.

Imagine your soft potentiometer is thirty feet long. Explain at least three things you could use it for.

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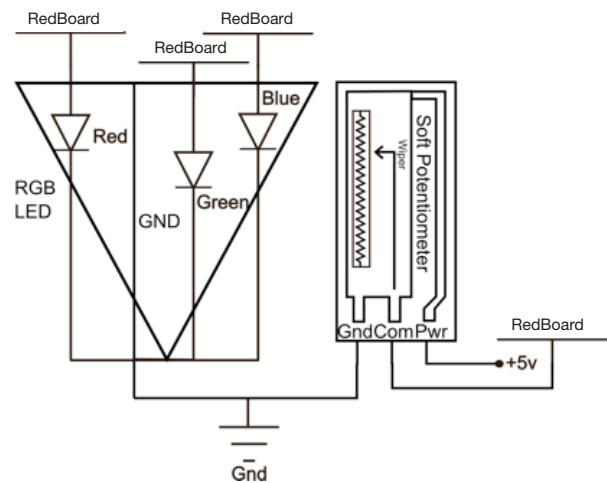
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Circuit:



## Circuit #11 Piezo Element

**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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Got your incredibly annoying song blaring out of your tiny speaker? Great.

**2.**

The piezo speaker uses digital pulsing (on or off) to create an analog sound value which can rise or fall in an analog fashion even though it is technically digital. What other digitally simulated analog signal is this similar to?

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**3.**

Although the action of the piezo speaker is similar to the simulated analog signal, what word or command in the code shows us that it is different? What command would you use if you wanted to use the simulated analog signal instead of the purely digital one?

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**4.**

Is it possible to make the piezo speaker play a note so low that the human ear cannot hear it?

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**5.**

Piezo elements are used for many things other than playing music. In fact you might have a piezo element in your pocket right now. List at least three usages of a piezo element other than a piezoelectric speaker.

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**6.**

Find and correct the three errors in the code below.

```
void loop() {
  for (int i = 0; i < length; i++) {
    if notes[i] == ' ' {
      delay(beats[i] * tempo); // rest
    } else {
      playNote(notes[i], beats[i] * tempo);
    }
    pause between notes
    Delay(tempo / 2);
  }
}
```

**7.**

Underline all instances of matrices in the code above.

**Fun Fact:**

There are now digital turntables which manipulate digital sound samples similar to this piezo element. When the sample is slowed down the sample's frequency drops as well due to the increase in gap size between the digital values. When the sample is sped up the pitch rises because the gaps decrease.



Circuit #11 Piezo Element

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## 12.

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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## 13.

Got your incredibly annoying song blaring out of your tiny speaker? Great.

Now you are going to add volume control to your piezo speaker. First place a  $330\Omega$  resistor on the circuit. Draw the two possible schematics of this new circuit to the right. What changes when you add the  $330\Omega$  resistor?

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## 14.

Next replace the  $330\Omega$  resistor with a  $10K\Omega$  resistor. What changes this time? What does this lead you to believe about resistors and the piezo speaker? Explain.

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Now replace the resistor with the potentiometer. Measure the resistance of the potentiometer and write below the lowest resistance value it can be set to and the highest resistance value it can be set to.

Lowest resistance: \_\_\_\_\_  $\Omega$

Highest resistance: \_\_\_\_\_  $\Omega$

But wait! Can't we just turn down the volume using a lower PWM value in the code? Why are we changing resistors when it's so much easier to just rewrite the code a little? Find the line of code you will need to

## 15.

change to try using PWM to control the volume instead of a resistor and write it below.

---

---

---

Now actually change the code and listen to the results. Can't hear any difference? Try using a lower PWM value. You should definitely notice a difference now. That's different from changing the volume right? Now use your potentiometer to change the PWM value of the piezo speaker circuit. You will need to change

## 16.

the code to do this. Write the three essential lines of code you used to make this happen below, don't forget semicolons. (Hint, one of them is a variable declaration before the setup() method.)

---

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---

Does your piezo speaker turn off when you turn your potentiometer all the way one way? This is because the analog values go up to 1023 but the PWM only go to 255. You can use the map() method to fix this. Write the line of code which will fix the problem below. (If it still turns off with map, make sure your PWM value never goes all the way down to zero.)

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The effect that changing the PWM has on "Twinkle, Twinkle Little Star" is kind of like an effect that many musicians use in on their instruments in modern music. What is that effect?

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## Circuit #11 Piezo Element

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Circuit #12 Spinning Motor

1.

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

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**Got your motor running?**

Upload Circ03Expansion Code to your RedBoard. Fill in the answers below.

Give Voltage values for each PWM value listed at each multimeter location. You will need to change the code to measure the PWM values listed.

2.

Position 1:

PWM @ 100%, V = \_\_\_\_\_ v

3.

Position 1:

PWM @ 75%, V = \_\_\_\_\_ v

4.

Position 2:

PWM @ 100%, V = \_\_\_\_\_ v

5.

Position 2:

PWM @ 75%, V = \_\_\_\_\_ v

6.

Position 3:

PWM @ 100%, V = \_\_\_\_\_ v

7.

Position 3:

PWM @ 75%, V = \_\_\_\_\_ v

8.

Position 4:

PWM @ 100%, V = \_\_\_\_\_ v

9.

Position 4:

PWM @ 75%, V = \_\_\_\_\_ v

10.

The amount the voltage decreases by as it passes through components is called voltage drop. What is the correlation between the various voltage drops you just measured?

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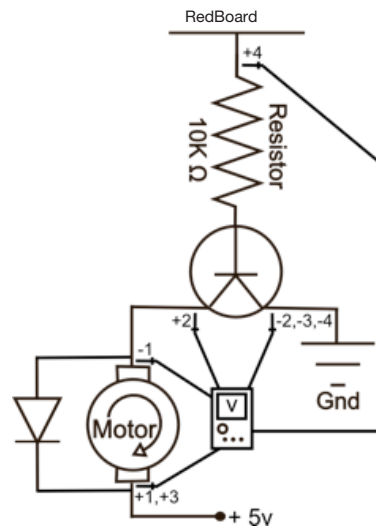


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**Circuit:**



## Circuit #12 Spinning Motor

**11.**

In your own words explain what this transistor does and the ways in which the motor's action would change if it were hooked up directly to a 5V power source and a ground?

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**12.**

Without using any code how could you make the motor run the other direction?

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### A Little History:

**13.**

The word transistor is a combination of what two words?

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**14.**

What was the first type of transistor to be mass produced, and by who?

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**15.**

Transistors are used in almost every piece of modern electronics and considered one of the most important inventions of the 20th century. What are some of your favorite items that contain a transistor? Name at least five.

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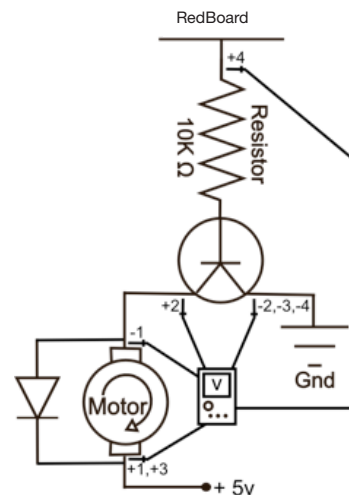
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### Circuit:



Circuit #13 Relays

**1.**

How is this circuit, or a circuit like it, used in everyday life? Provide at least three examples.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Does your relay work? Great.

**2.**

There are many different types of relays. List at least three and explain the differences between them.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**3.**

Give values for Voltage, Current and Resistance for the multimeter position shown. Break the circuit or use Ohm's law to solve for current and resistance. You should get two different sets of values depending on the action of the relay.

**4.**

Value # 1:

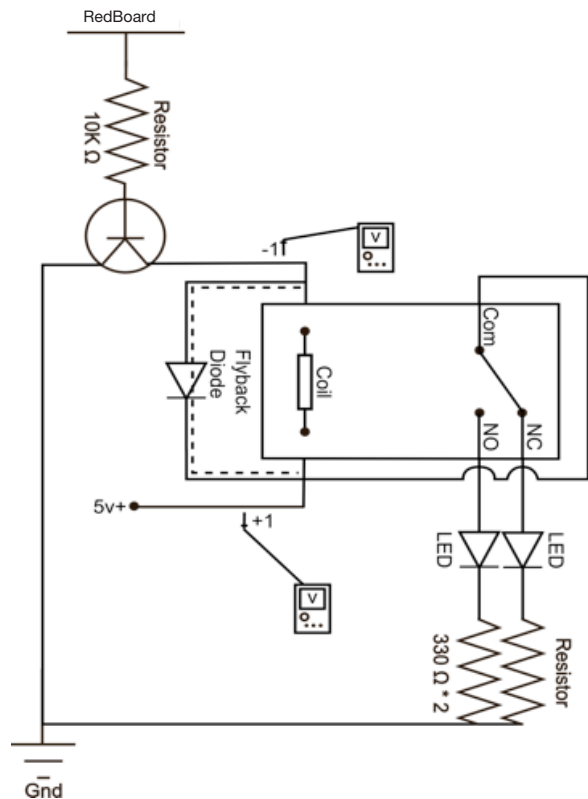
$V = \text{_____} \text{ v } I = \text{_____} \text{ mA } R = \text{_____} \Omega$

**5.**

Value # 2:

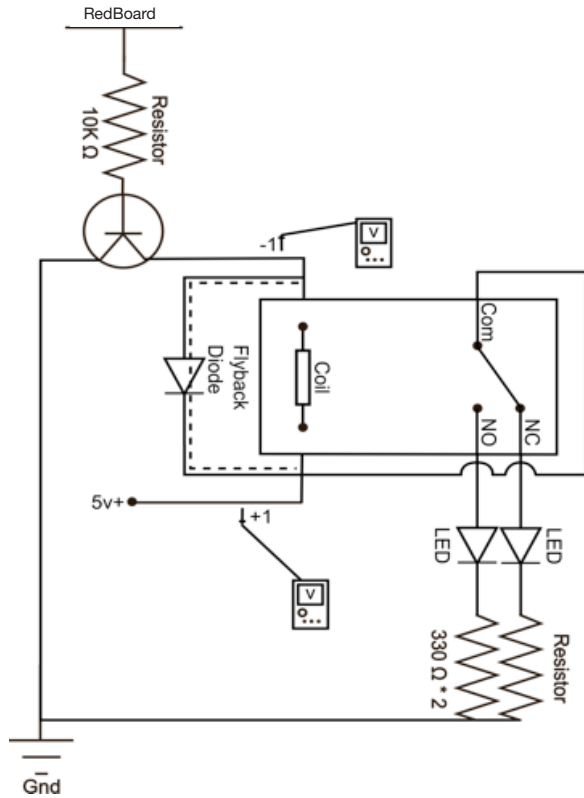
$V = \text{_____} \text{ v } I = \text{_____} \text{ mA } R = \text{_____} \Omega$

**Meter 1:**



## Circuit #13 Relays

### Meter 1:



**6.**

Draw arrows on the dotted line to show possible direction of current flow when RedBoard is turned off.

**7.**

Explain the two sets of values for the Voltage, Resistance and Current and what each set does.

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**8.**

Explain how a diode effects the current flow of a circuit.

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**9.**

Given what you answered above, explain what you think is the reason for the Flyback Diode, also explain what might happen without this Flyback Diode.

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**10.**

What machine houses your favorite relay? Why is it your favorite relay? Because of the machine that houses it? Because it keeps someone safe? Because it's really big and powerful? Explain.

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Circuit #14 Shift Register

**1.**

The byte in this circuit's shift register is used to turn LEDs on and off. It can also be used to represent many other types of data in binary. Explain how a number is written in binary, then write the number nine using ones and zeros.

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Does your shift register light up all the LEDs in a pattern? Great.

**2.**

Explain why the shift register needs the clock pin as part of how it operates.

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**3.**

Fill in the diagram below if you were trying to shift in the following bits for data: 11100110

**Latch:** 

**Clock:** 

**Data:**

**4.**

On the schematic to the right label the most significant bit's pin with MSB and the least significant bit's pin with LSB.



**5.**

While shifting bits in and out of your chip you can move them so you drop either the MSB, or the LSB. Assuming you drop the LSB and are adding a 1 to the byte above, what is the resulting byte?

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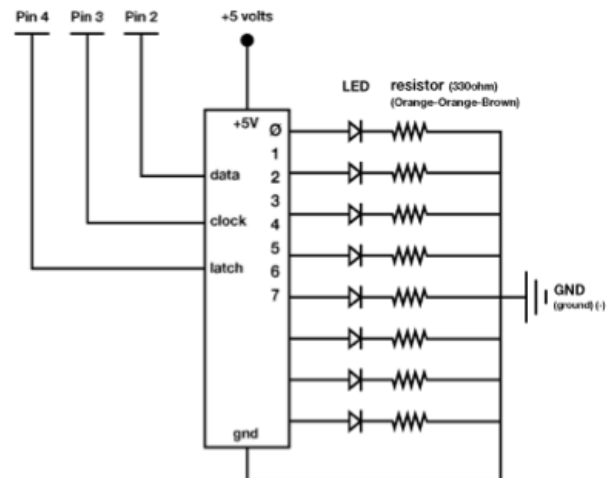
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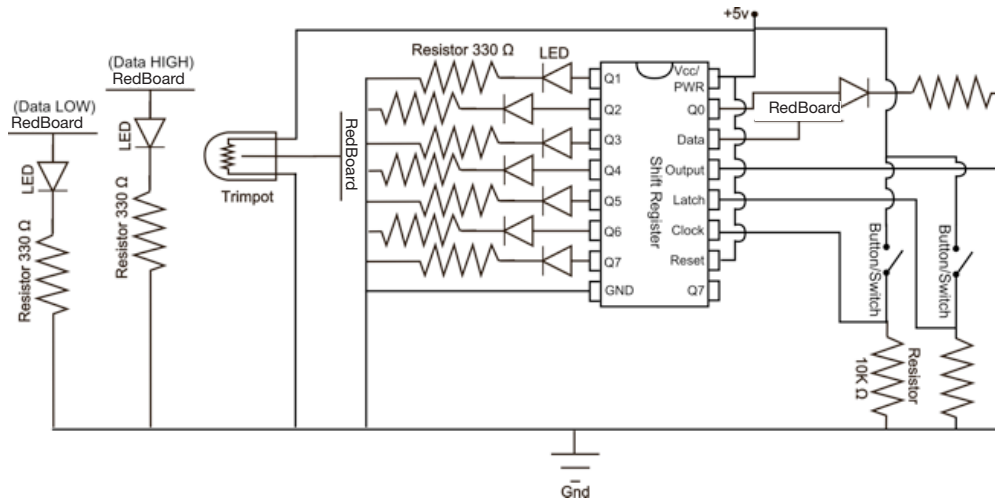
**Circuit:**





Circuit #14b Shift Register

Circuit:



1.

The byte in this circuit's shift register is used to turn LEDs on and off. It can also be used to represent many other types of data in binary. Explain how a number is written in binary, then write the number fifteen using ones and zeros.

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shifted into the register so far hit the latch button. To really get a feel for how shift registers work first set all the LEDs LOW, then start playing with different patterns of data values.

Before answering the questions below set all your pins all back to LOW, or off (Remember, LOW == 0)

2.

Try setting just one data pin before hitting the latch button. What happens?

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Does your shift register light up all the LEDs in a pattern?

Upload Circ05Expansion to your RedBoard and add two buttons, two LEDs and a trimpot to your circuit, use the schematic for reference.

Your two buttons now pulse the clock and latch the shift register. Make sure you don't confuse the two! You will use the trimpot to set your data either HIGH or LOW. Play with the trimpot to figure out which setting is HIGH and which is LOW. One of the indicator LEDs will light up depending on which value it represents. Then use the clock pulse button to send the data value to the shift register. To see the data that you have

3.

Try setting eight data pins before hitting the latch button. What happens?

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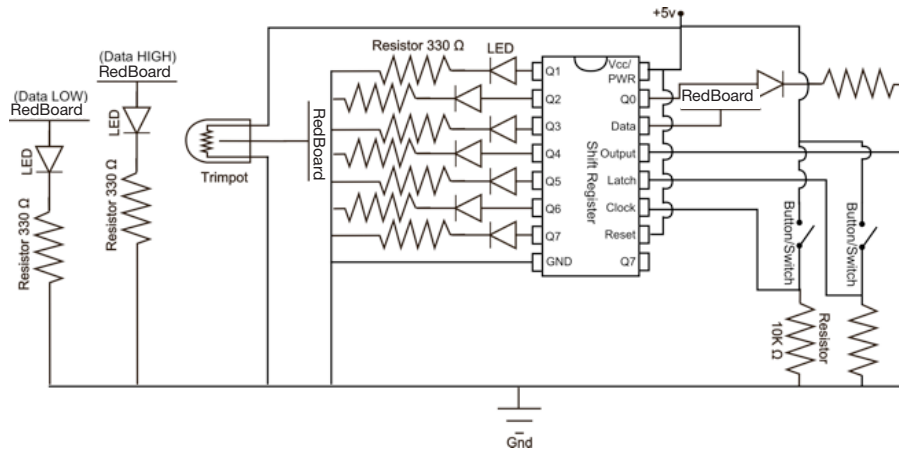


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## Circuit #14b Shift Register

### Circuit:



**4.**

Now set seven data pins before hitting the latch button. What happens this time?

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**5.**

Now enter nine bits in the following order: 0,1,0,0,1,1,0,0,0. What does your LED pattern look like? Answer in binary.

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**6.**

Explain how the LED pattern and shift register would act if you were shifting out the Most Significant Bit instead of the Least Significant Bit. Find the one command or word you would need to change in the code to make this happen and write it below.

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PWM

We know by now that PWM is represented in Arduino language as a value somewhere between 0 and 255. We also know that the PWM signal is just the RedBoard turning the PWM pin ON, or HIGH, then LOW, or OFF, a bunch of times really, really fast. The thing is the computer can turn the signal HIGH and LOW a lot faster than a human can follow. So what does the PWM signal look like to us and how can we measure it? Good question. Upload the PWM Expansion Code to your Arduino, attach PWM pin # 9 to ground on your breadboard and measure the voltage between the two wires. Switch values and reload the code as necessary to fill in the table below.

Fill in the table below:

Percentage:	0	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
PWM value:	0					127					255

What is the equation you use to convert the percentage to PWM values and back again?

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Why does the PWM value only go up to 255 if it represents 256 different values?

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Often you will use analog sensors with your digital microprocessor. These analog sensors are even more difficult than the PWM signal. They talk to the microprocessor in 1024 little pieces!

Fill in the table below:

Percentage:	0	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Analog value:	0					511					1023

What is the equation you use to convert the percentage to analog values and back again?

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## PWM

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Fill in the table below:

Percentage:	0%	25%	50%	75%	100%
PWM value:	0				255
Analog value:	0				1023

What is the relationship between the analog and PWM value? Explain with words or math.

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What is one advantage to representing an analog sensor's value with 1024 numbers instead of just 100?

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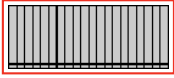
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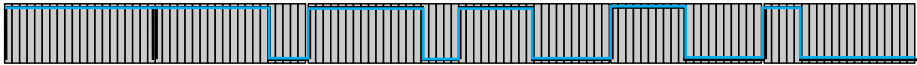
**PWM**

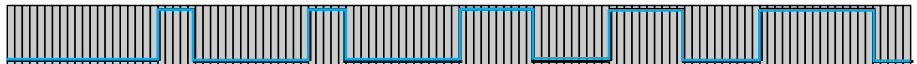
Below are a bunch of different PWM wave diagrams.  
The “window” is this size:




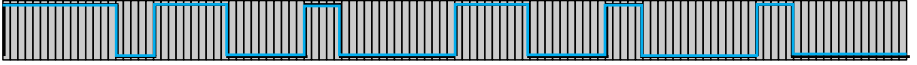
Record below each wave diagram the starting value in the unit given, the highest value the PWM wave reaches (PWM value, 0 - 255), the lowest value the PWM wave reaches (PWM value, 0 - 255), and the ending value of the wave diagram. Finally, draw a line through the diagram showing the PWM value as it rises and falls.


Remember for the SIK PWM values: 100% = 255 PWM = 1.8mV

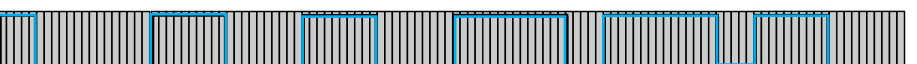
1.   
\_\_\_\_\_ starting PWM    \_\_\_\_\_ Highest PWM    \_\_\_\_\_ Lowest PWM    \_\_\_\_\_ ending PWM


2.   
\_\_\_\_\_ starting %    \_\_\_\_\_ Highest PWM    \_\_\_\_\_ Lowest PWM    \_\_\_\_\_ ending %

3.   
\_\_\_\_\_ starting voltage    \_\_\_\_\_ Highest PWM    \_\_\_\_\_ Lowest PWM    \_\_\_\_\_ ending voltage

4.   
\_\_\_\_\_ starting PWM    \_\_\_\_\_ Highest PWM    \_\_\_\_\_ Lowest PWM    \_\_\_\_\_ ending PWM

5.   
\_\_\_\_\_ starting %    \_\_\_\_\_ Highest PWM    \_\_\_\_\_ Lowest PWM    \_\_\_\_\_ ending %

6.   
\_\_\_\_\_ starting voltage    \_\_\_\_\_ Highest PWM    \_\_\_\_\_ Lowest PWM    \_\_\_\_\_ ending voltage

7.   
\_\_\_\_\_ starting PWM    \_\_\_\_\_ Highest PWM    \_\_\_\_\_ Lowest PWM    \_\_\_\_\_ ending PWM

These PWM windows are nicely divided into ten sections so you can count out the windows and figure out the PWM values and percentages easier. Real PWM signals are not so convenient and are usually represented by one of the following with no diagram: the PWM value, a percentage, or a voltage value.



PWM

We know by now that PWM is represented in Arduino language as a value somewhere between 0 and 255. We also know that the PWM signal is just the Arduino turning the PWM pin ON, or HIGH, then LOW, or OFF, a bunch of times really, really fast. The thing is the computer can turn the signal HIGH and LOW a lot faster than a human can follow. So what does the PWM signal look like to us and how can we measure it? Good question. Upload the PWMExpansion Code to your Arduino, attach PWM pin # 9 to ground on your breadboard and measure the voltage between the two wires. Switch values and reload the code as necessary to fill in the table below.

Percentage:	0%	10%	25%	33%	50%	66%	75%	80%	90%	100%
PWM value:	0		63.75				191.25			
Analog Value	0				511.5					1023
Voltage (mV)	0									

One of the easiest ways to find a correlation between numbers is to look at a lower set of values and compare them to a larger set of values with a common denominator. Look at all the values for 10% and then look at all the values for 100%. If there is a pattern it should be easier to see it with these two set of values simply because they are different by a factor of 10, or one decimal place.

Now, you should be able to mash these two equation together into one equation that you can use to convert from analog to voltage. Think this is tough? Lucky we're not using a temperature sensor and making you also convert Fahrenheit and Celsius and resistance values! Write your equation below.

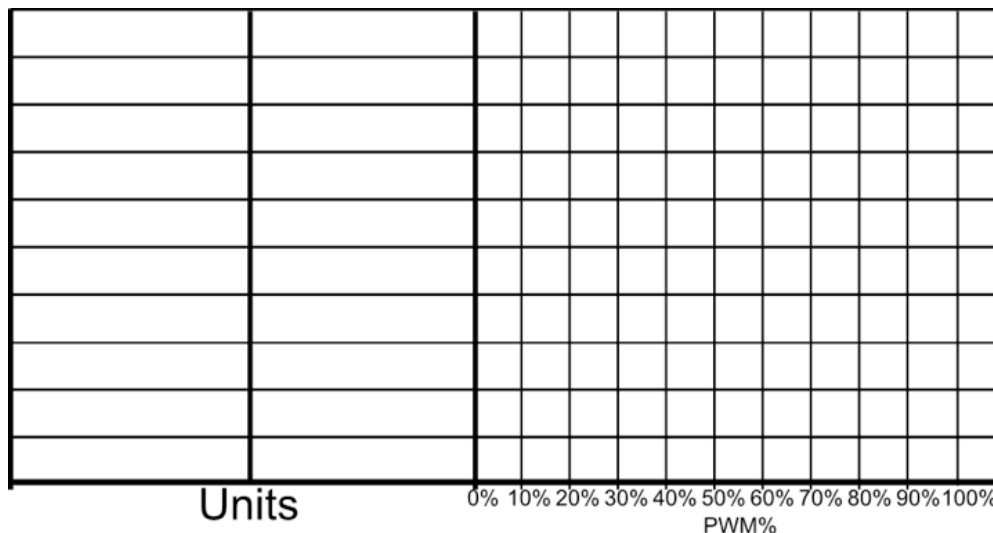
Using the table above create an equation that you can use to change PWM or Percentage into an analog value. Don't forget that zero is a value in PWM and analog. Write that equation below:

Using your equations fill in the line graph below for the analog and voltage variables above. Label your graph wherever you think necessary. Use a different color for the analog and voltage lines.

\_\_\_\_\_ =analog value

Using the table above create an equation that you can use to change a PWM or Percentage value into a voltage value. Take into account any difference in units that may make the math weird. Write that equation below:

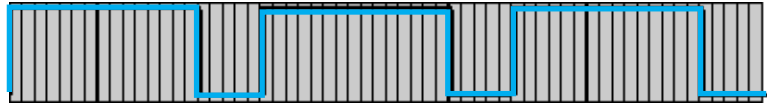
\_\_\_\_\_ =voltage (mV)



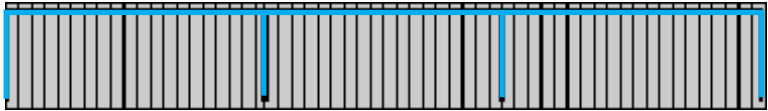
PWM

Write below these different values whether they are a PWM value, an analog sensor value, a percentage or a voltage. Then match each value below with the PWM wave diagram that best represents them by drawing a line from the value to the diagram.

50%



1.8 mV



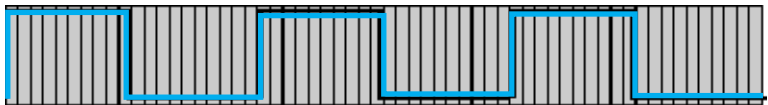
`analogWrite(pin, 64)`



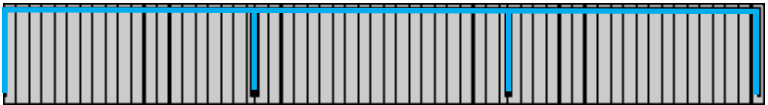
`analogRead(pin) = 768`



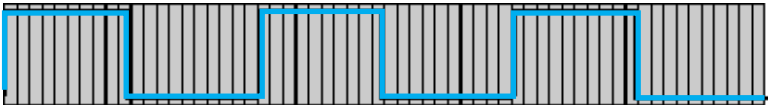
511



194 out of 256



.45mV



100 out of 100

