Pulse-Width Modulation Control of an LED

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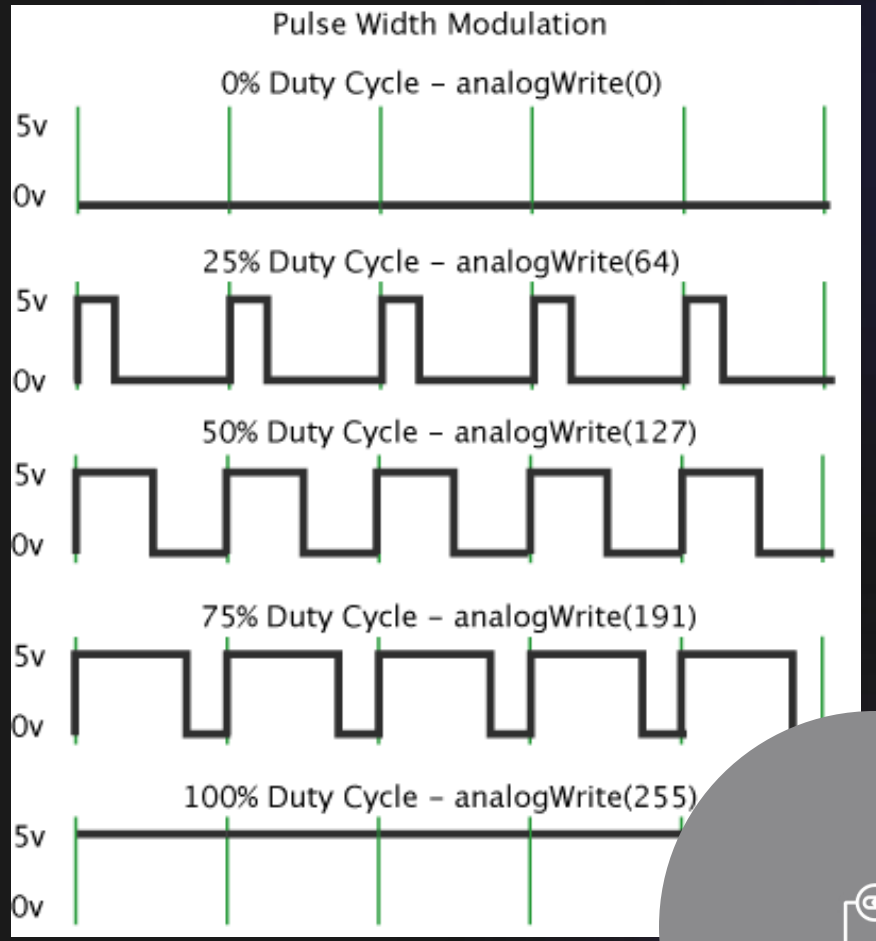
Goal

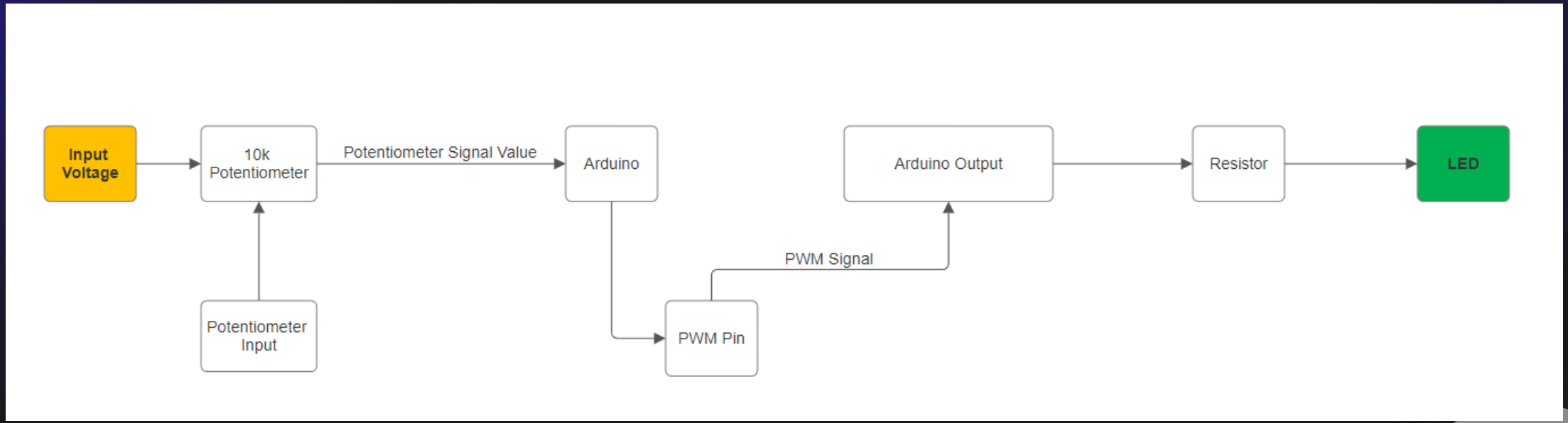
Pulse-Width modulation (PWM) is a way to control the voltage to a device through rapid pulses emitting an average voltage rather than a steady voltage. PWM works in duty cycles, where 100% is the maximum voltage and 0% is no voltage.

The goal of this project is to design a system that controls the brightness of an LED via changes in the PWM signal, in response to turning a potentiometer at the input.

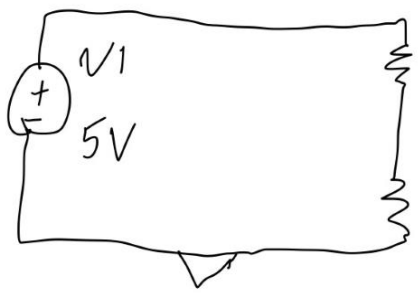


Chaitanya Jamboktar, ”Pulse Width modulation”, 2019.

Diagram


Input Voltage
10k Potentiometer
Potentiometer Signal Value
Arduino
Arduino Output
Resistor
LED
PWM Signal
Potentiometer Input
PWM Pin

Mathematical Analysis



Voltage Divider

$V_{out} = V_{in}\left(\frac{R_2}{R_1+R_2}\right)$

$R_1 = 5K \qquad R_2 = 5K$

$V_{out} = 5V\left(\frac{5}{5+5}\right) = 2.5V$

$R_1 = 0 \qquad R_2 = 10K$

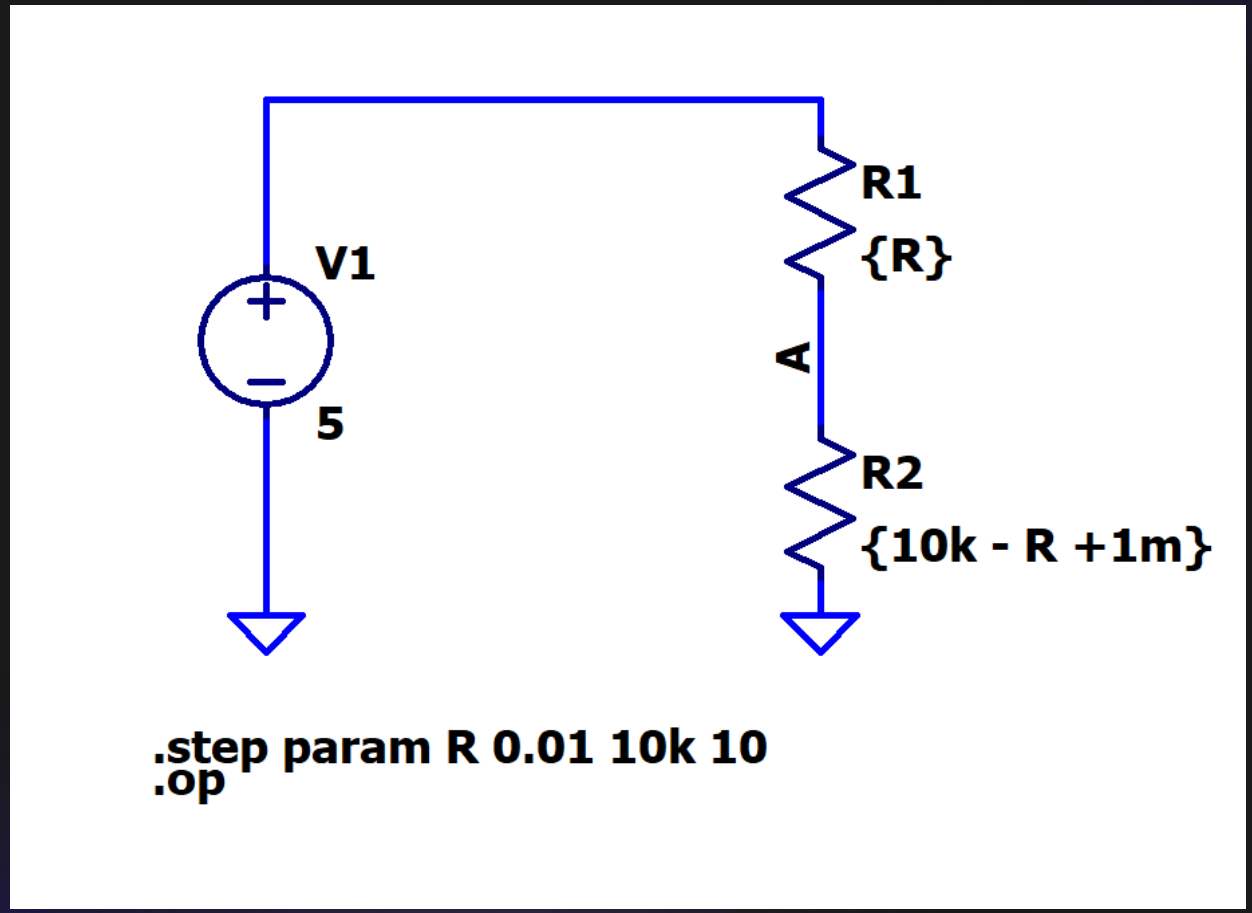
$V_{out} = 5V\left(\frac{10}{0+10}\right) = 5V$

$R_1 = 10K \qquad R_2 = 0$

$V_{out} = 5V\left(\frac{0}{10+0}\right) = 0$

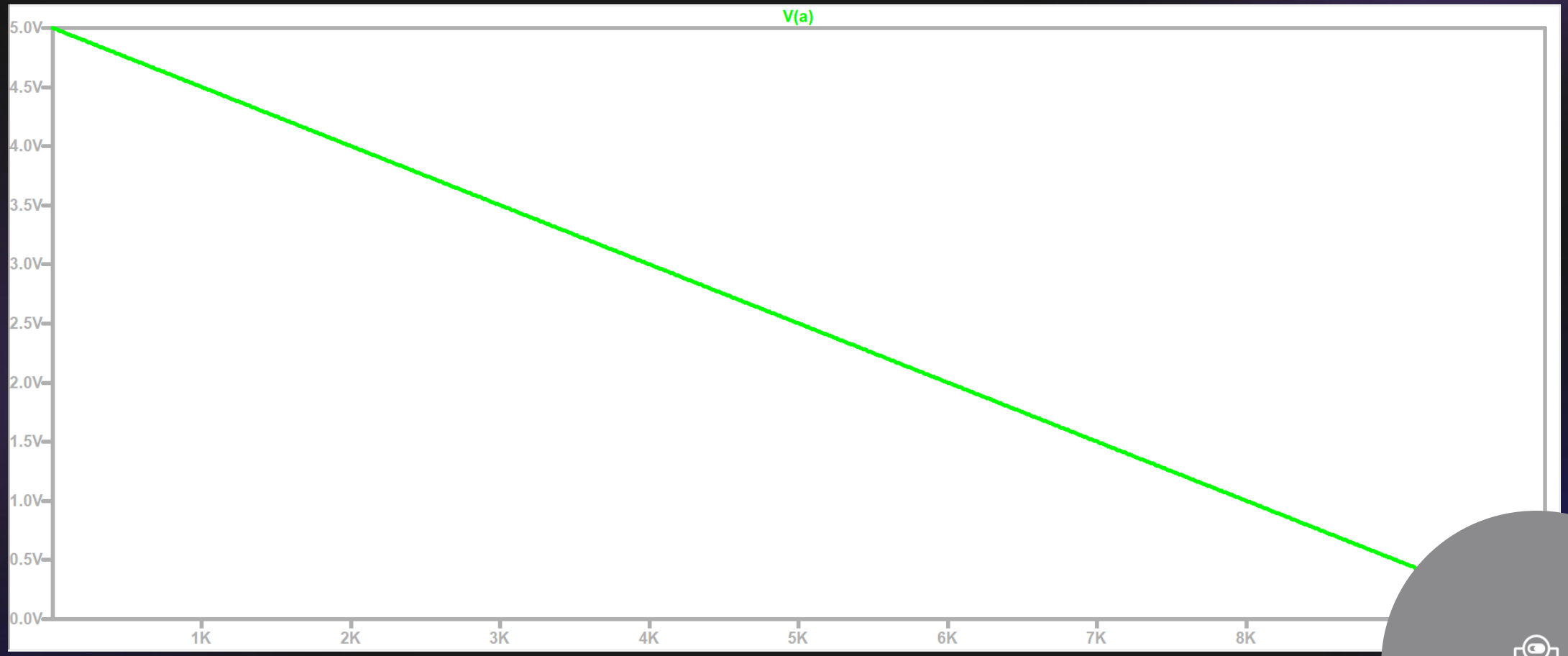
At half duty R1 and R2 are both at 5k ohms. Using the voltage divider equation Vout = 2.5V. When R2 = 10k ohms, R1 is 0 and Vout = 5V. Finally when R1 = 10k ohms, R2 is 0 and Vout is 0.

Circuit Simulation



Potentiometer Circuit Simulation showing variable resistance

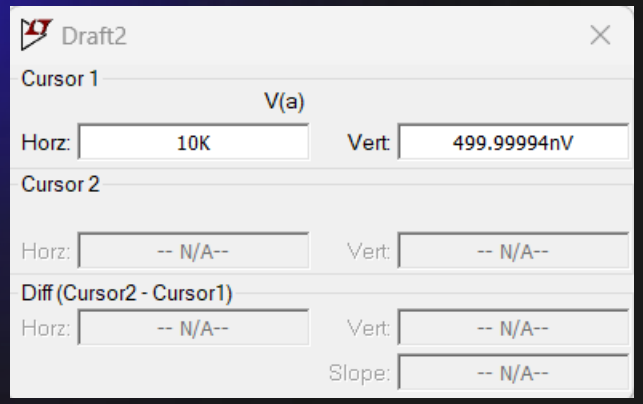
Circuit Simulation



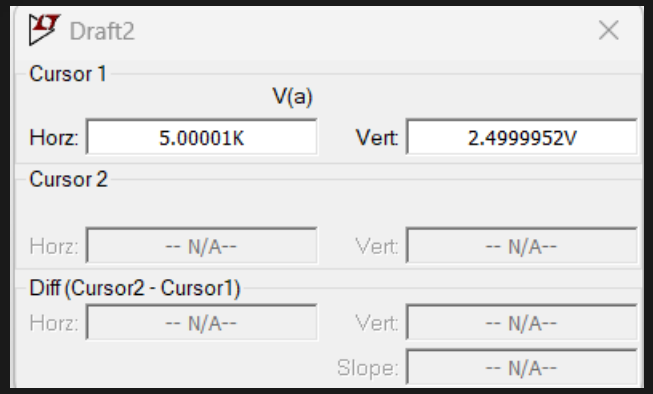
This can be seen as the potentiometer being turned from low resistance to high resistance. Or in other words, the LED being turned from fully on to off.

Confirming Our Analysis

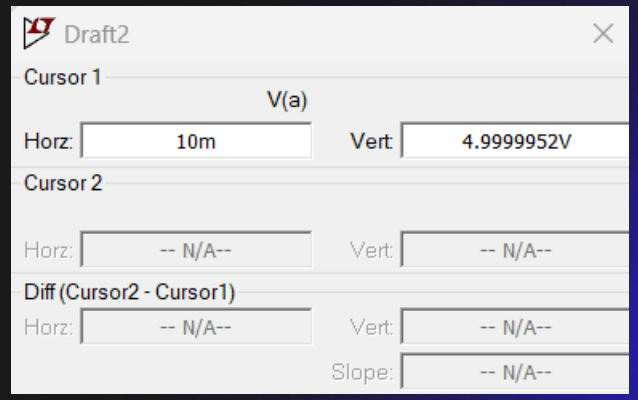
0% Duty Cycle



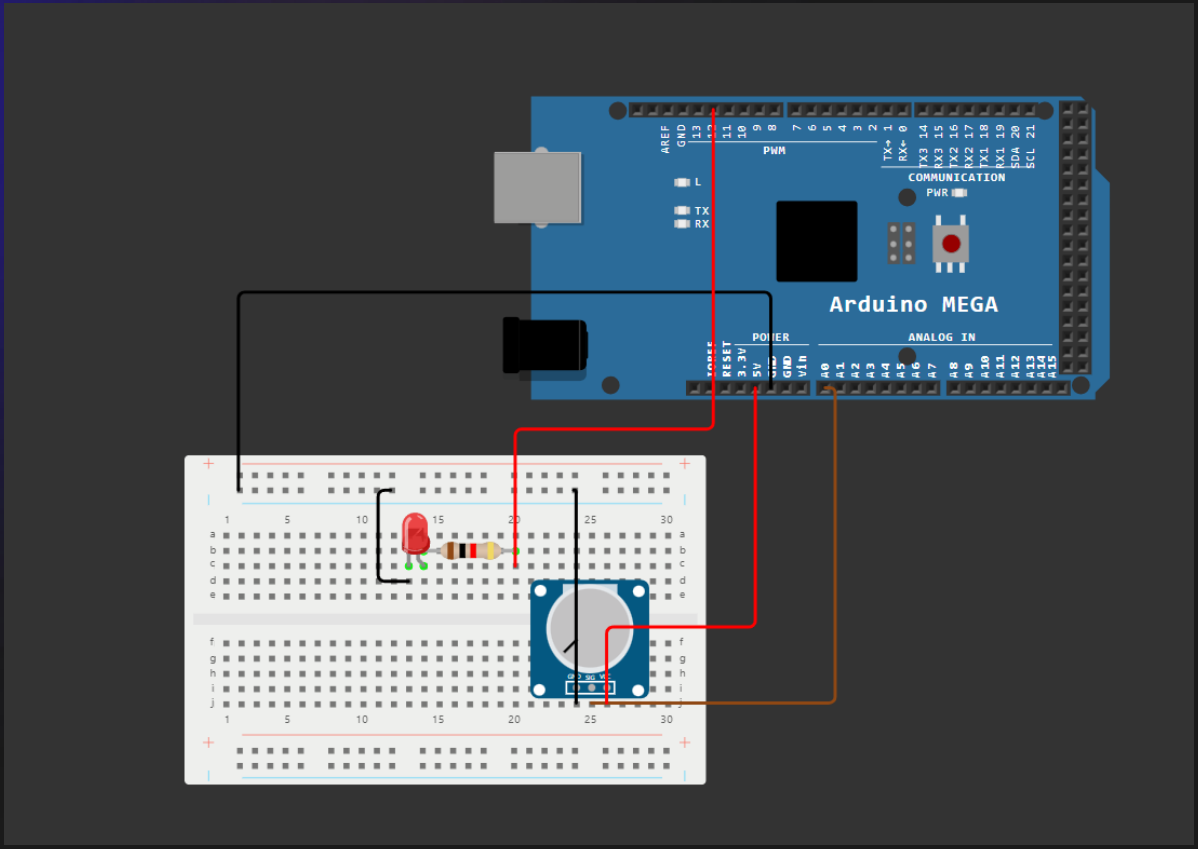
50% Duty Cycle

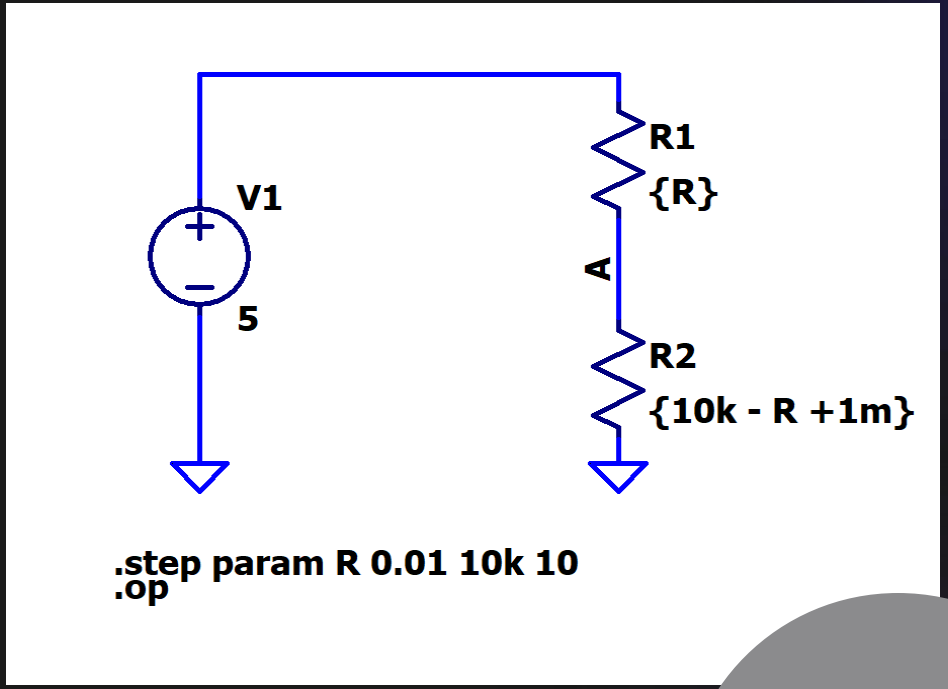


100% Duty Cycle



Our Circuit


Arduino MEGA
PWM
COMMUNICATION
PWR
POWER
ANALOG IN

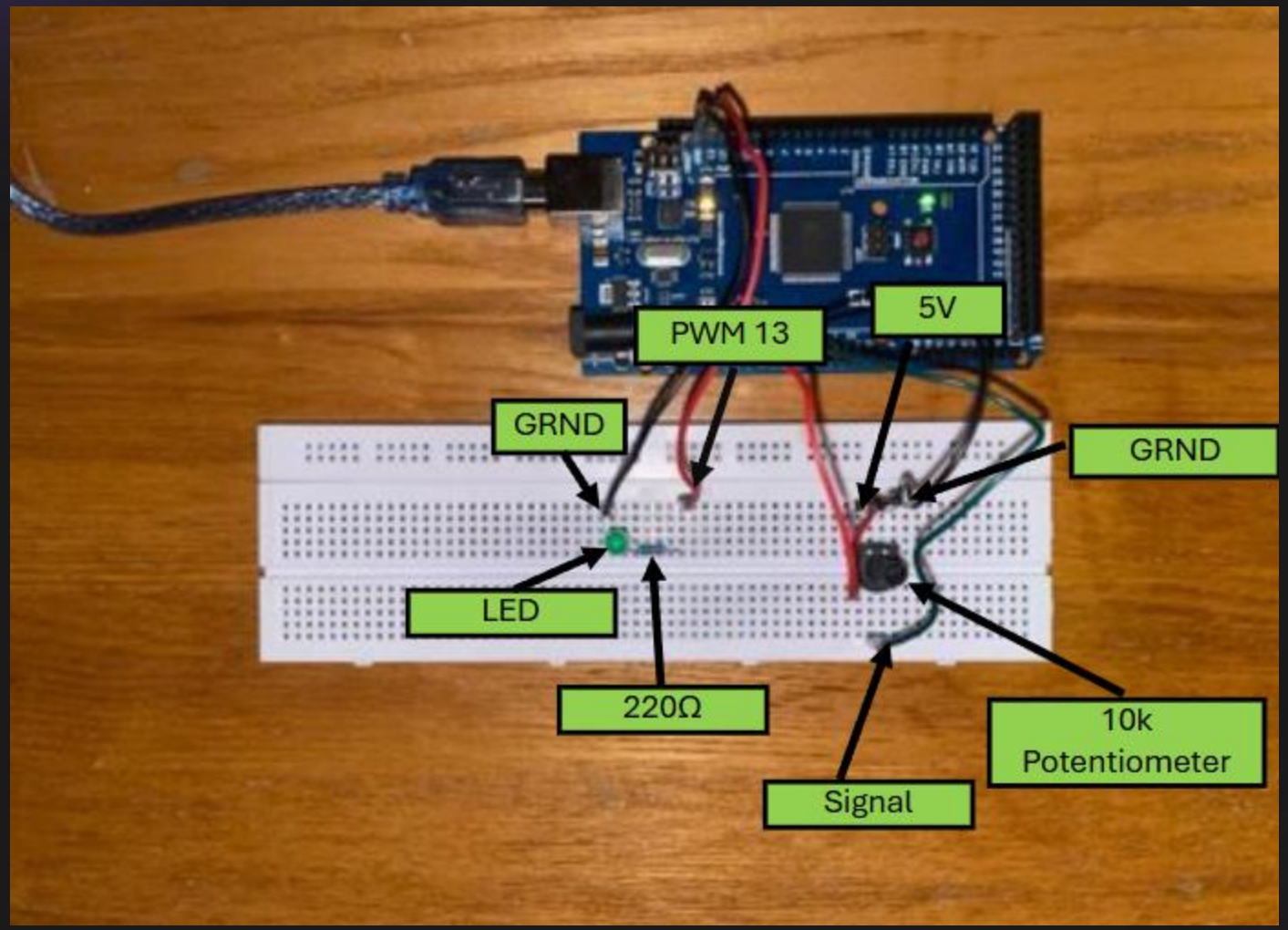

V1
5
R1
{R}
A
R2
{10k - R +1m}
.step param R 0.01 10k 10
.op

Arduino Code

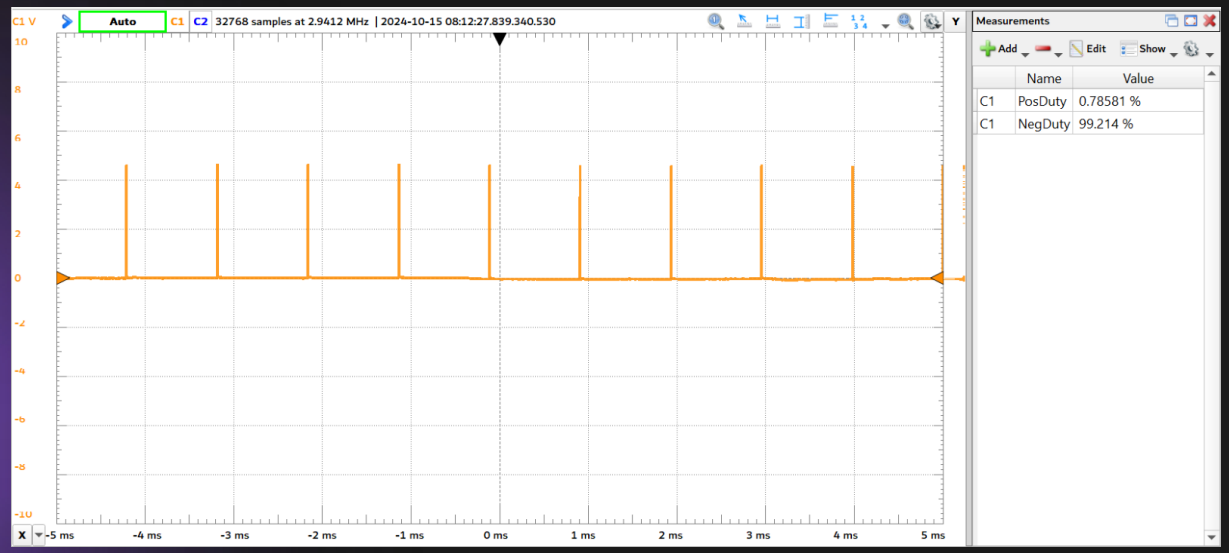
PWM_POT.ino

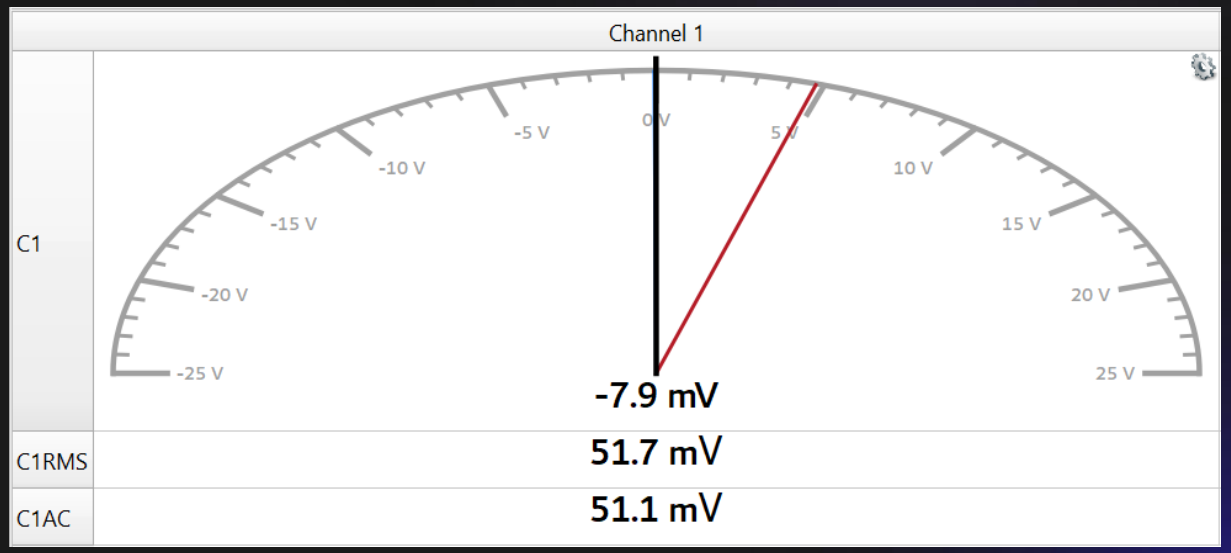
```ino
const int potPin = A0; // Analog input pin for the potentiometer
const int pwmPin = 13;  // PWM output pin

void setup() {
  pinMode(pwmPin, OUTPUT); // Set the PWM pin as an output
  Serial.begin(9600); //Start serial monitor
}

void loop() {
  int potValue = analogRead(potPin); // Read the potentiometer value (originally 0-1023)
  potValue /= 4; //Squish the value to fit within 0-255
  analogWrite(pwmPin, potValue); //Set the PWM duty cycle

  Serial.print("Potentiometer Value: ");
  Serial.println(potValue); //Print Potentiometer Value (works)

  }
```

Our Circuit



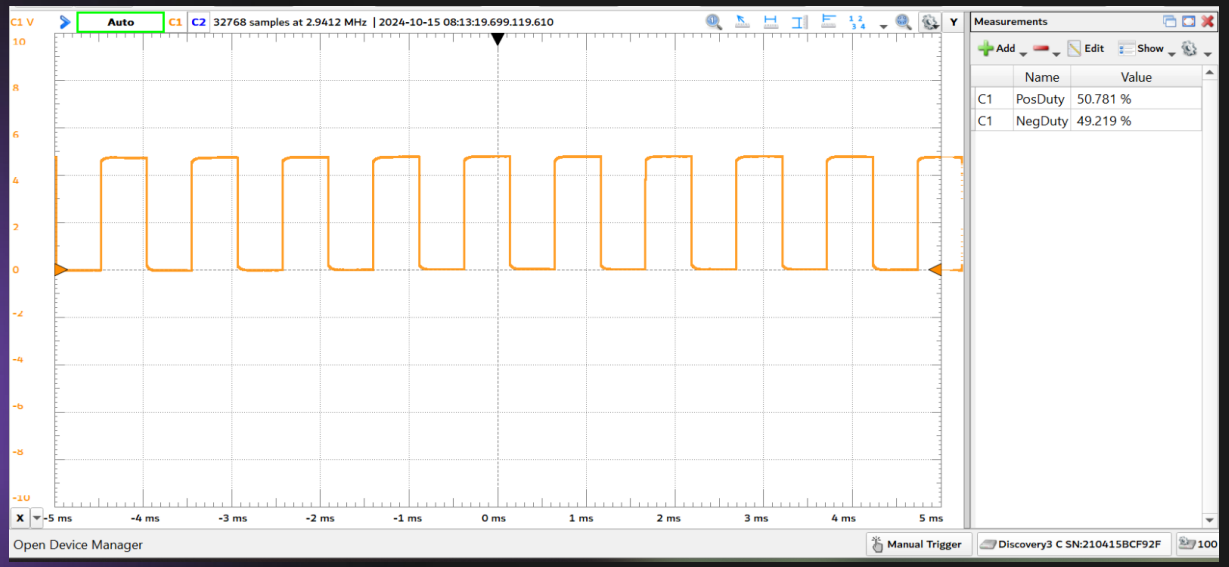
Experimental Measurement

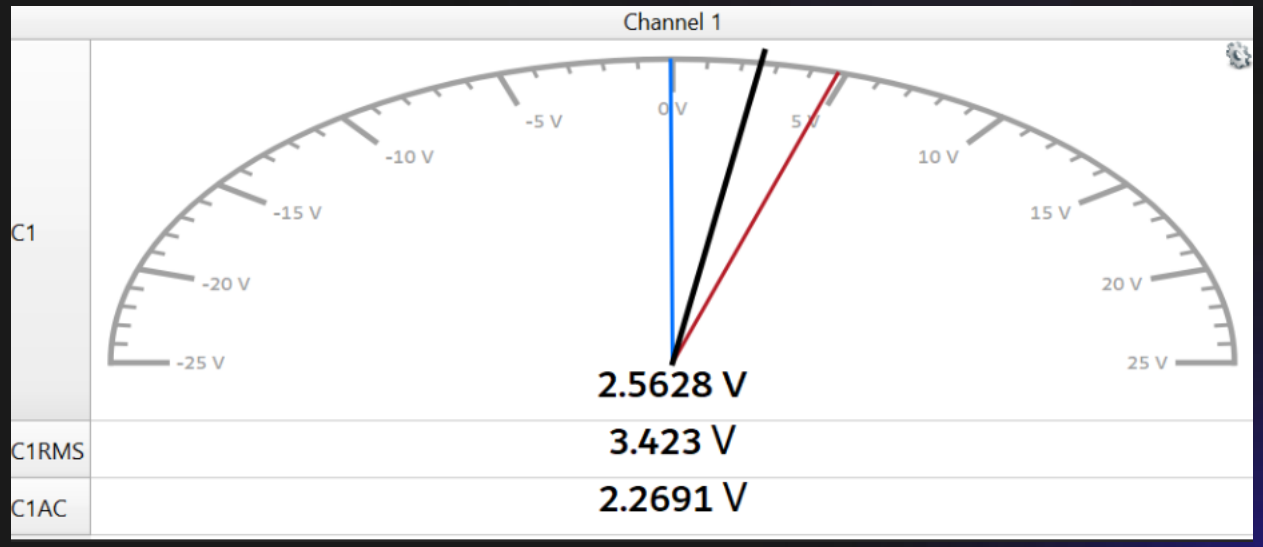




0% Duty Cycle
(Fits within analysis expectations)

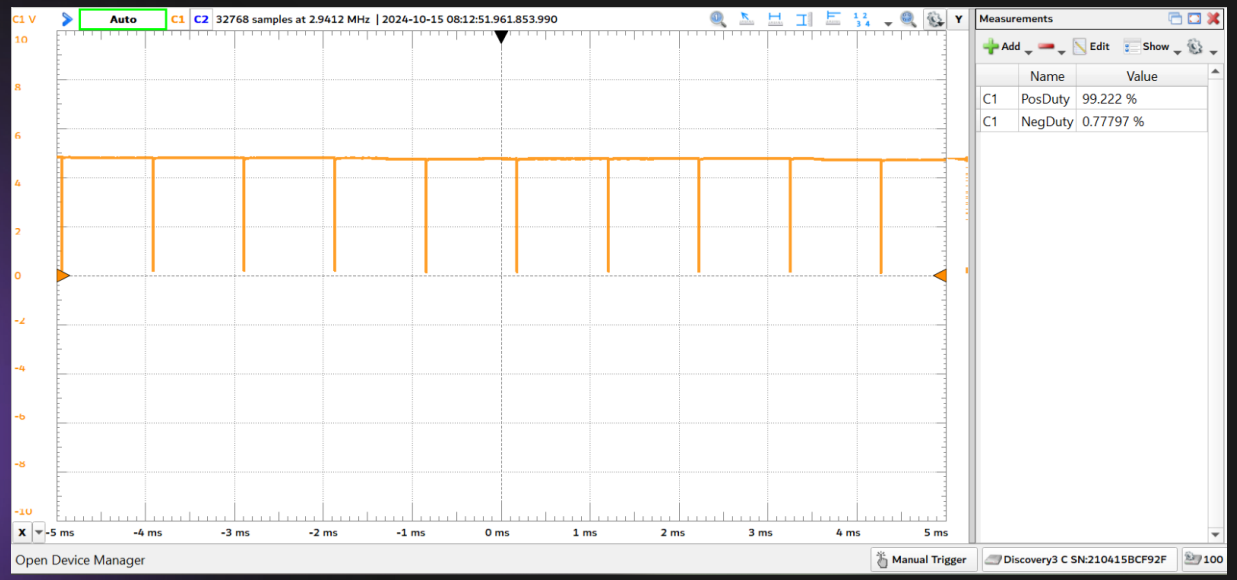
Experimental Measurement

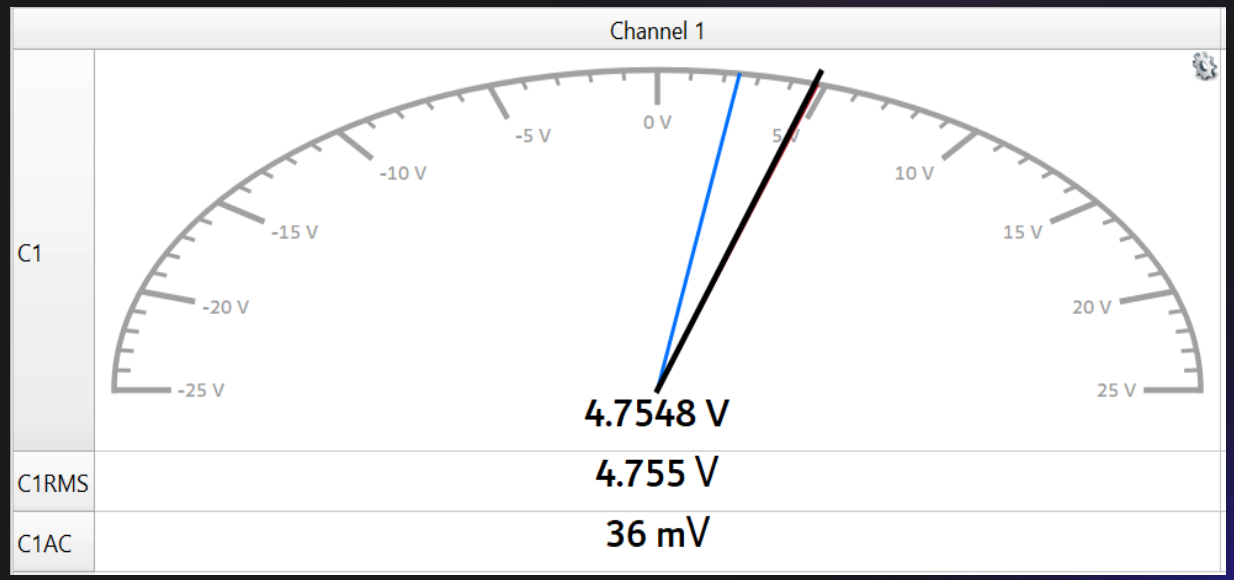




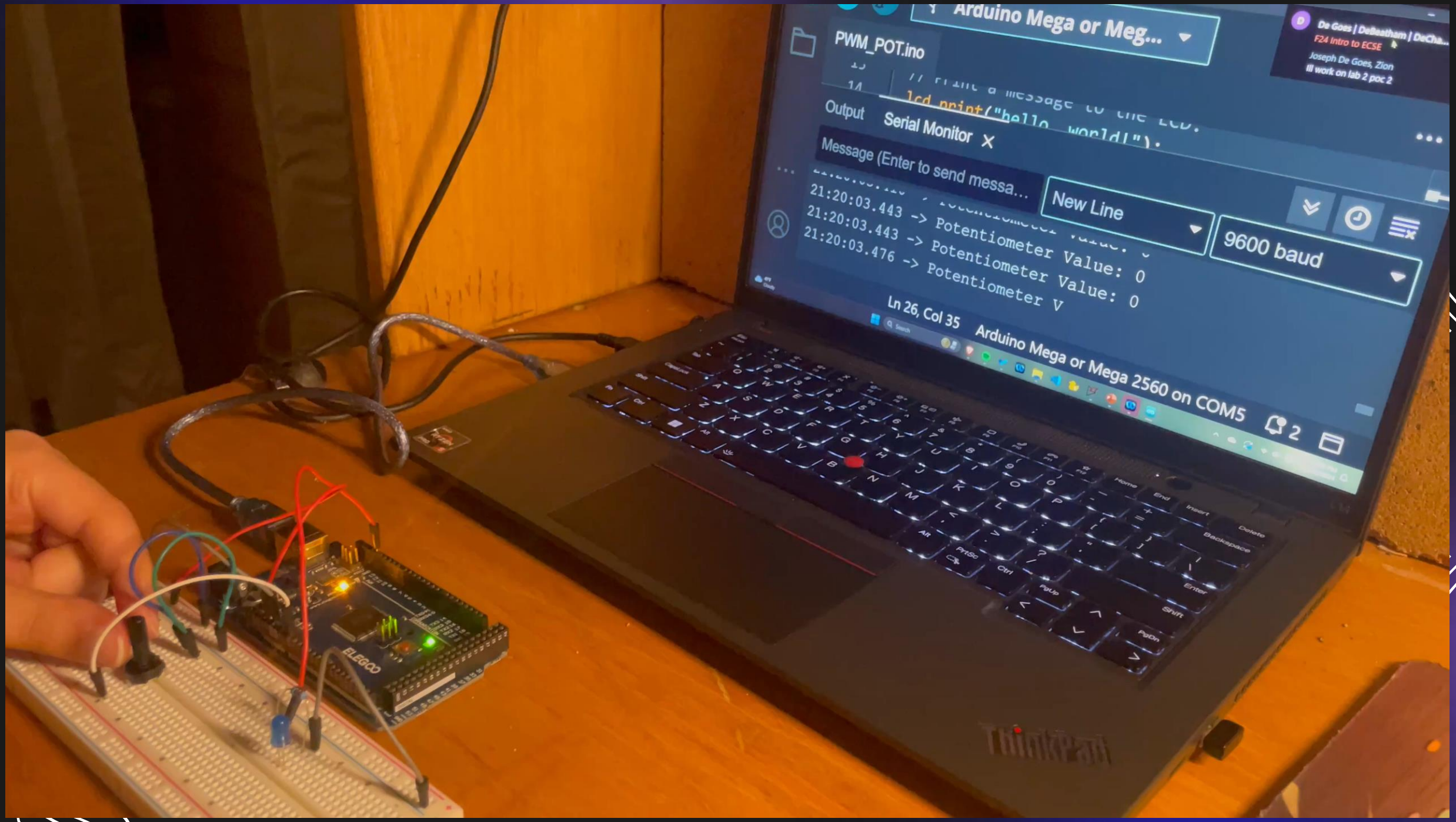
50% Duty Cycle
(Fits within analysis expectations)

Experimental Measurement





100% Duty Cycle
(Fits within analysis expectations)


Arduino Mega or Meg...
PWM_POT.ino
De Goes | DeBeatham | DeCha...
F24 Intro to ECSE
Joseph De Goes, Zion
Ill work on lab 2 poc 2
Output
Serial Monitor
Message (Enter to send messa...
New Line
9600 baud
21:20:03.443 -> Potentiometer Value: 0
21:20:03.443 -> Potentiometer Value: 0
21:20:03.476 -> Potentiometer V
Ln 26, Col 35
Arduino Mega or Mega 2560 on COM5
2
ELEGOO

Design Choices

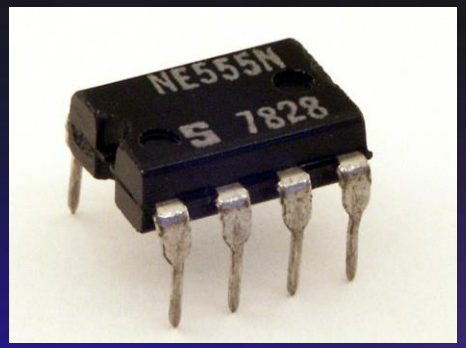
555 Timer

Advantages:

- Versatile, wide ranges of applications
- Lower power consumption than an entire microcontroller.

Disadvantages:

- Higher complexity pinout (needs more wires)
- Not programmable
- Only one PWM output
- Limited by internal tolerances



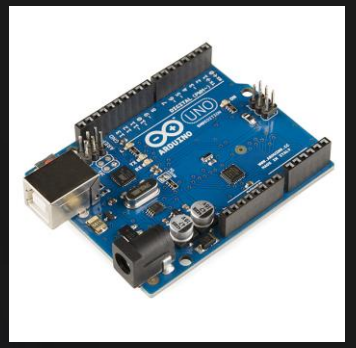
Arduino

Advantages:

- Multi-use for very complex projects.
- Can be programmed in C++
- Multiple PWM outputs
- Very precise
- Serial monitor for real time PWM monitoring.

Disadvantages

- Uses more power
- Bulky to carry around



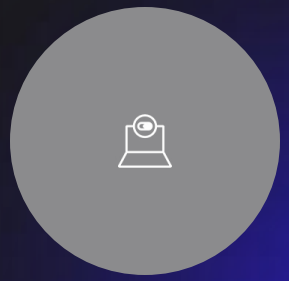
New Knowledge

Microcontrollers

- We used an Arduino as the heart of our project, and PWM is one of its many powers. Many functions of microcontrollers are unknown to us. How are they different from microprocessors anyway? We can learn more in ECSE 4790 - Microprocessor Systems

FFT --> Fast Fourier Transform

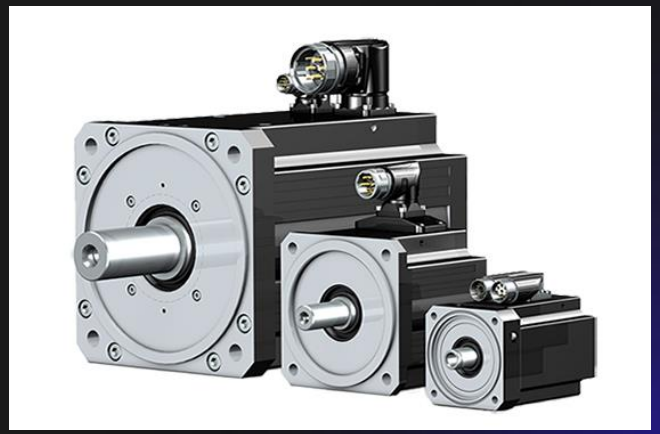
- PWM waves are square wave pulses. At its core, these waves can be broken into its components by the FFT. This is something we learned through our research.
- Although we did not have to break down the waves ourselves, we can learn more in ECSE 4530 - Digital Signal Processing.



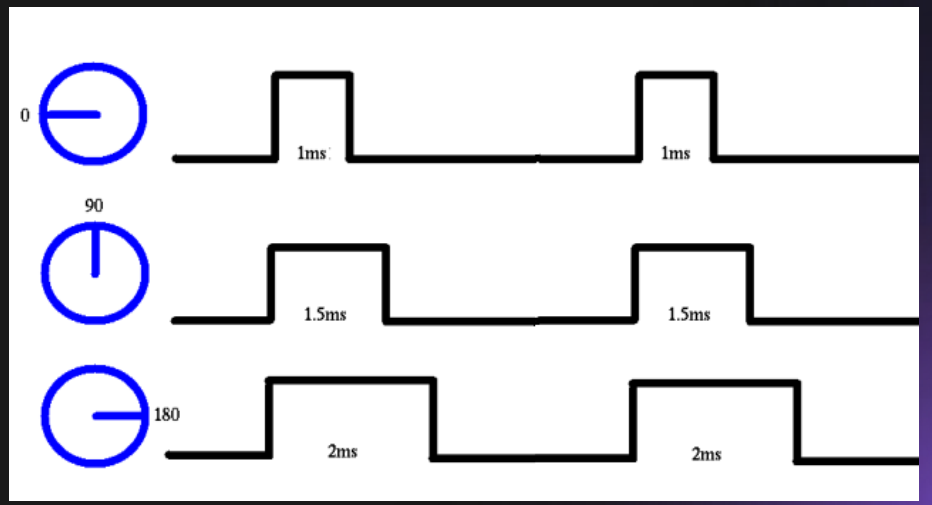
Real World Applications

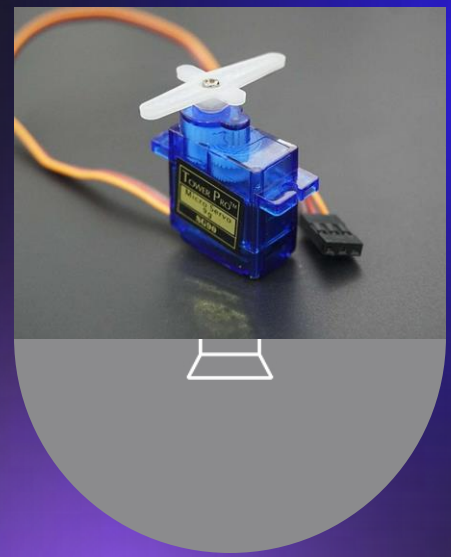
Motor Control

(PWM)



Servo motors are a motor type that use PWM to control the position of the motor. PWM control is efficient and accurate and correlates the duty cycle to the angle of the motor.





A Question for you!

- What changes would one have to make to substitute a 555 timer in place of the Arduino, would it change the other components?