

Analog

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Analog

Introduction

In the previous tutorials, we were focusing on **digital** read and write. We could only write and read **0** and **1** from a pin. In this tutorial, we will discuss how to write and read values between **0** and **1**.

Analog Read

In the previous tutorials, we were working with **digital** input and output. As you recall, to read a **digital** input, we had a function called `digitalRead`. To read **analog** input, we have a function as well. This function is called `analogRead`. The syntax of it is pretty similar to the `digitalRead`, the only exception is that it returns a number in a range of $[0, 1023]$. As you might have guessed from the range, **Arduino Uno** allocates 10 bits for reading analog data.

In **Arduino Uno**, we have 6 pins that we can use to read **Analog** input. These pins are labeled as **A0** to **A5**. In the image below, we show them by drawing a yellow rectangle over them.

Analog pins

Figure 1: Analog pins

For reading digital values, 5V indicates 1 and 0V indicates 0. For analog values, 5V indicates 1023 and 0V indicates 0. As you can see, we divide the values between 5V and 0V into 1024 parts. With using this technique, we are being able to read voltage between 5V and 0V.

Potentiometer

To create a voltage between 5V and 0V, we can use a device called **Potentiometer**. You can find it at **Passive/Resistors/Potentiometer** in **SimulIDE**. As you can see, a **Potentiometer** has 3 pins and a button to control the output

voltage. **Potentiometer** creates voltage with increasing and decreasing the resistance. Let's connect a **Potentiometer** to a fixed voltage to see how it works. To do so, we can follow these steps:

- Put a **Potentiometer** on the board (**Passive/Resistors/Potentiometer**).
- Connect the pin that is closer to a red line, to a **Fixed Voltage**.
- Connect the other pin to the **Ground**.
- Put a **VoltMeter** on the board (**Meters/VoltMeter**).
- Connect the output pin of the **Potentiometer** (the pin with the arrow on it) to the **red pin** of the **VoltMeter**.
- Connect the other pin of the **VoltMeter** (the pin beside the red pin) to the ground.

Your connection, should look like as following:

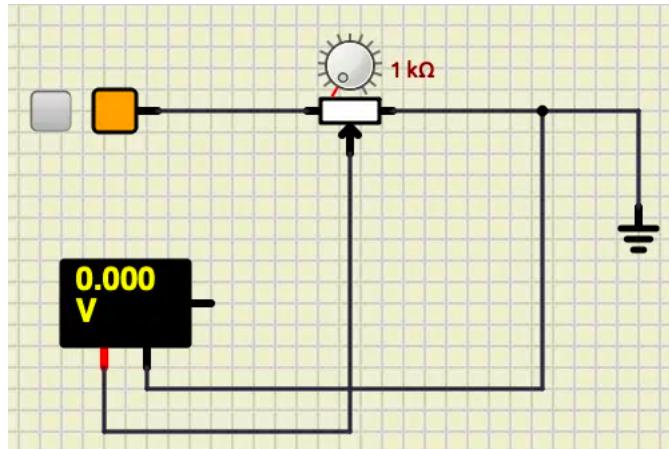


Figure 2: Potentiometer

Now, let's start the simulation and rotate the button on the **Potentiometer**.

As you can see, we can make voltages between 5V and 0V.

Potentiometer and Arduino

Now, let's connect our **Potentiometer** to the Arduino. The steps are pretty much the same.

- Connect the pin closer to the red line to a **5V**.
- Connect the pin on the opposite of the red line to the **Ground**.
- Connect the output pin (pin with an arrow on it) to **A0**.

Your connection should look like this:

Now, let's write a code to read the analog data.

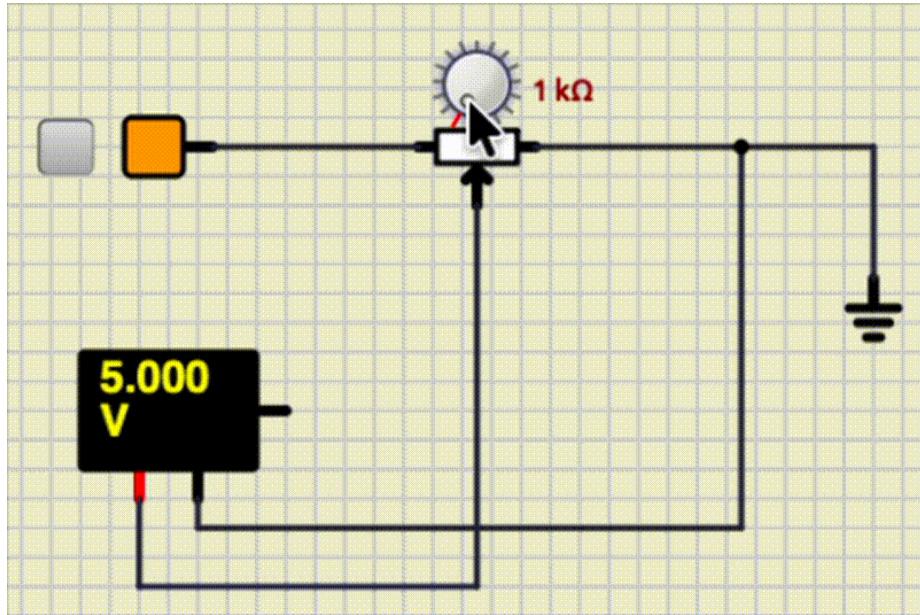


Figure 3: Potentiometer gif

```
#include <Arduino.h>

void setup()
{
    Serial.begin(9600);
}

void loop()
{
    int our_input = analogRead(A0);
    Serial.println(String(our_input));
    delay(1000);
}
```

The code above, reads the analog input from A0. Then, it prints the read value into Serial terminal. The output looks like as following:

PWM

Before we get to work with **Analog Write**, let's learn about **PWM**. Because **Arduino Uno** uses **PWM** to write **Analog** data. **PWM** (Pulse Width Modulation), is a technique for controlling the power delivered to a component. In this technique we use different width of pulses in a signal. These signals

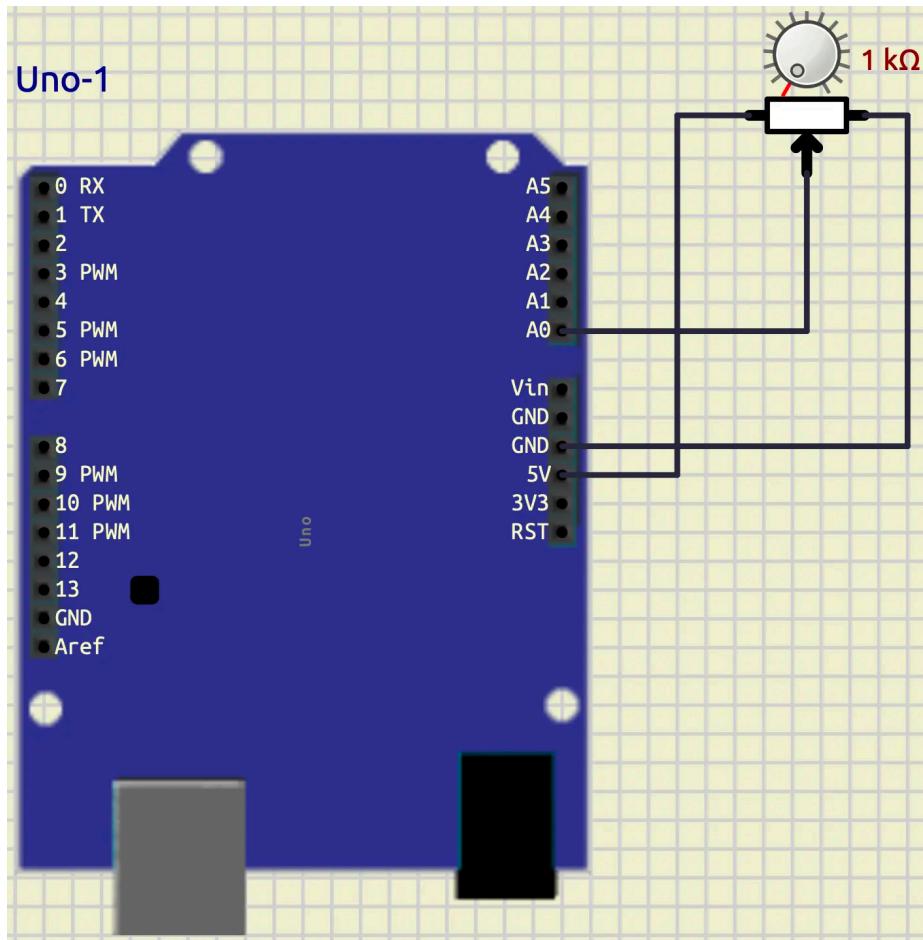


Figure 4: Analog Read

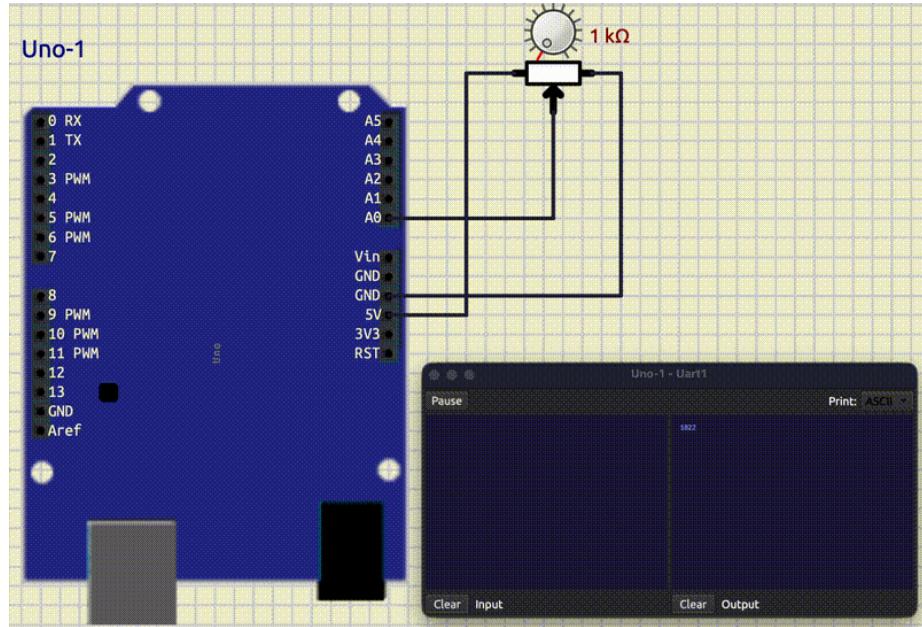


Figure 5: Analog Read.gif

switch between 0 and 1. The percentage of the time that a pulse is 1 is called **duty cycle**. The pictures below show two examples of 100Hz **PWM**, one with the 30% duty cycle and the other 60%.

Analog Write

Now, that we know about **PWM**, let's connect talk about writing analog data in **Arduino uno**. In **Arduino Uno** we have 6 pins that we can create **PWM** on them. Including: 3, 5, 6, 9, 10, and 11. These pins are shown in the board with a ~ beside them and in **SimulIDE** with **PWM**. To create our **duty cycles**, we can use the numbers in range [0, 255]. 255 means 100 and 0 means 0 duty cycles.

For writing **digital** values, we had a function called **digitalWrite**. We have a similar function for **analog** values as well, and it is called: **analogWrite**. Their syntax is similar, with the exception that **analogWrite** accepts an integer for its second argument.

Now, let's connect an **LED** to pin 3. Your connection should look like below:

Now, let's write a code to write analog data on pin 3.

```
#include <Arduino.h>
```

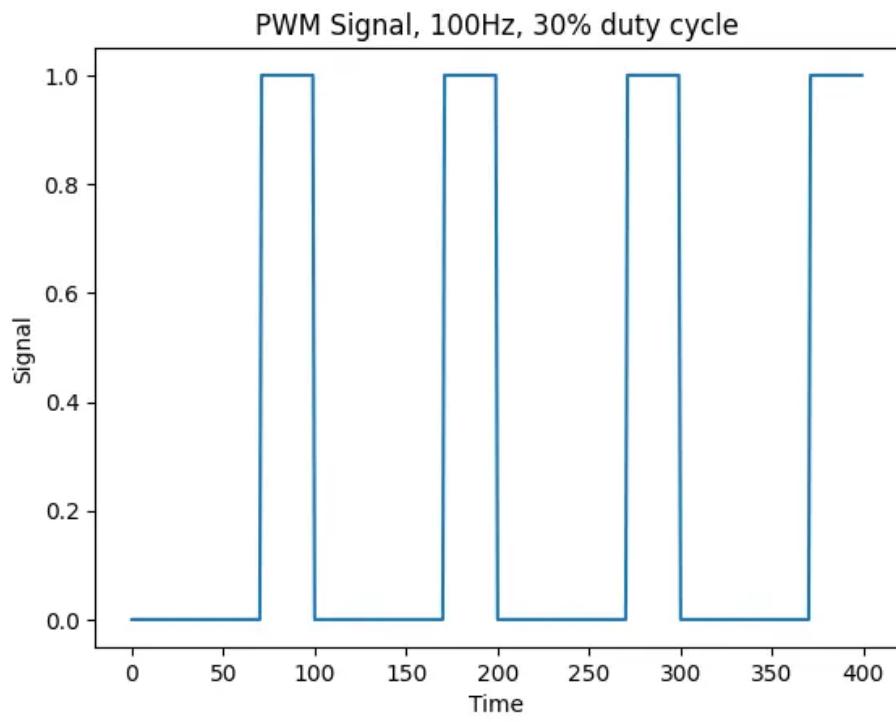


Figure 6: PWM 100hz 30d

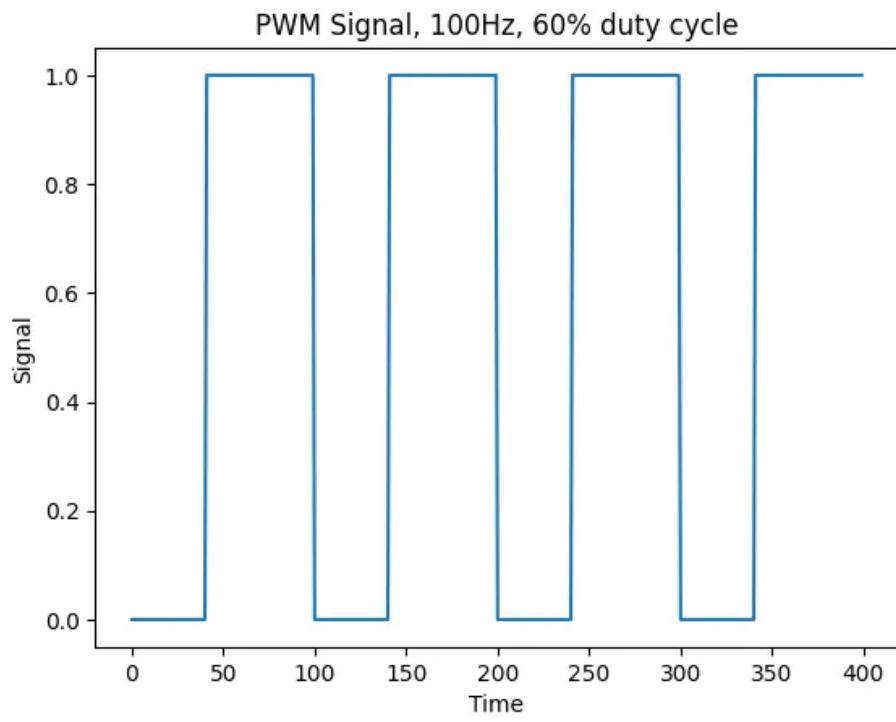


Figure 7: PWM 100hz 60d

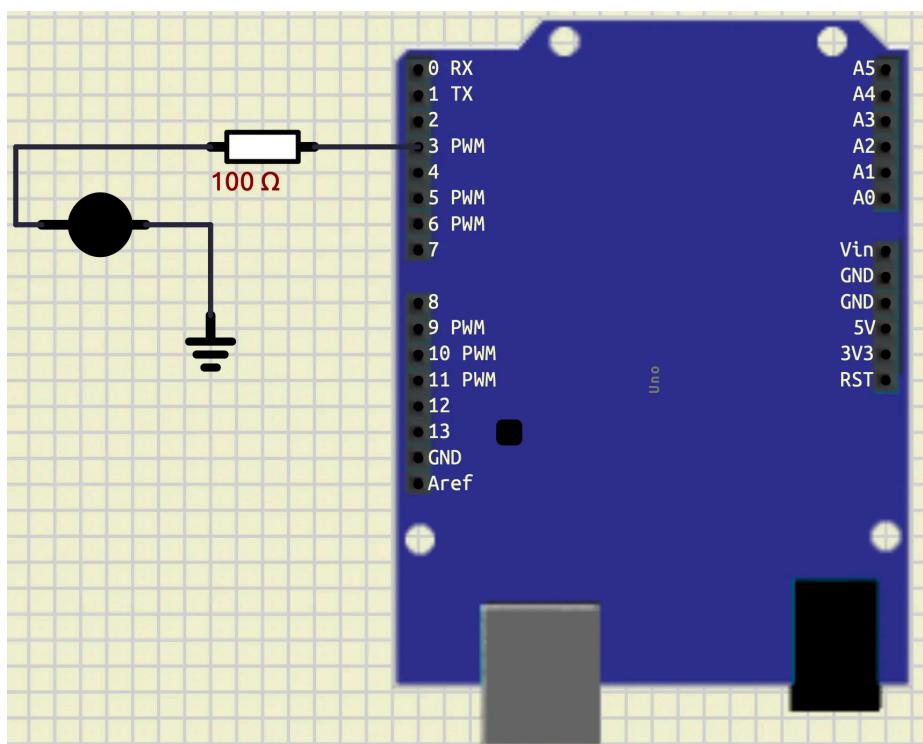


Figure 8: Analog Write

```

void setup()
{
    pinMode(3, OUTPUT);
}

void loop()
{
    for (int i = 0; i < 256; i++)
    {
        analogWrite(3, i);
        delay(10);
    }
}

```

In the code above, first we set the pin mode of pin 3 as output. Then, we have a for loop that starts from 0 and goes until 256. So, we expect the brightness of our **LED** changes from dark to light. As you can see in the output below, this is the exact thing that is happening.

If we want to see the **PWM** that we are generating, we can connect an **Oscope** to our output. To do so, we can follow these steps:

- Put an **Oscope** on the board (**Meters/Oscope**)
- Connect the bottom pin to the ground
- Connect any other pin to the output of pin 3.

Your output should look like as following:

Combining both

Now, let's combine the both reading and writing analog values together. Your connection should look like below:

Now, let's write a code that changes the brightness of the **LED** using the **Potentiometer**.

```

#include <Arduino.h>

void setup()
{
    pinMode(3, OUTPUT);
}

void loop()
{
    int our_input = analogRead(A0);
    int brightness = map(our_input, 0, 1023, 0, 255);
    analogWrite(3, brightness);
}

```

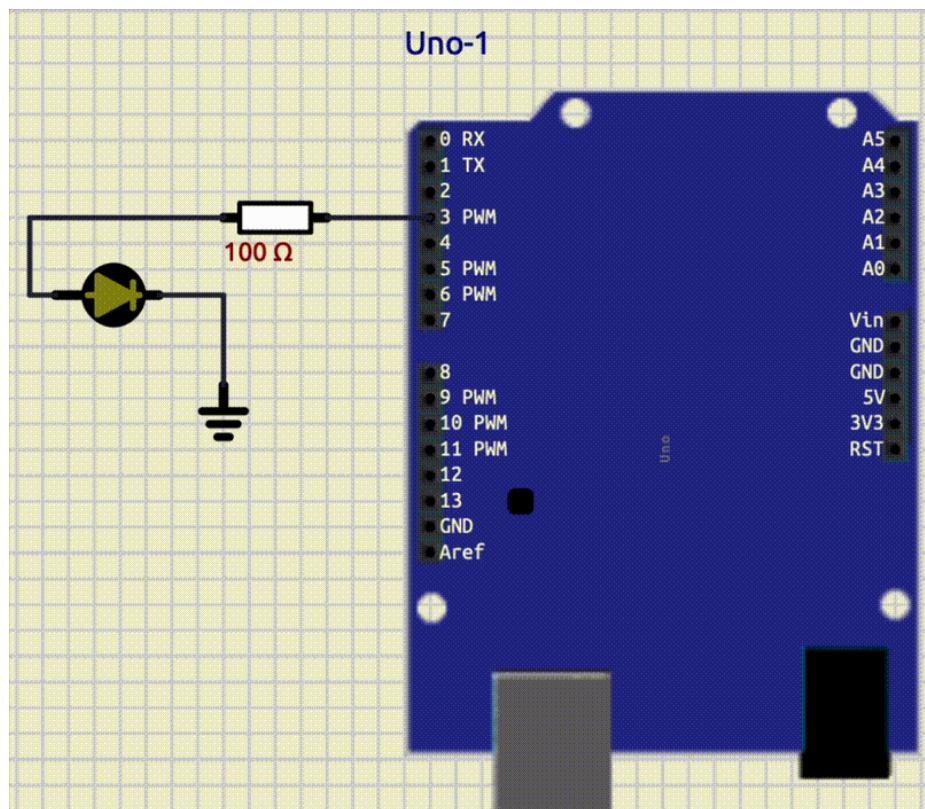


Figure 9: Analog Write gif

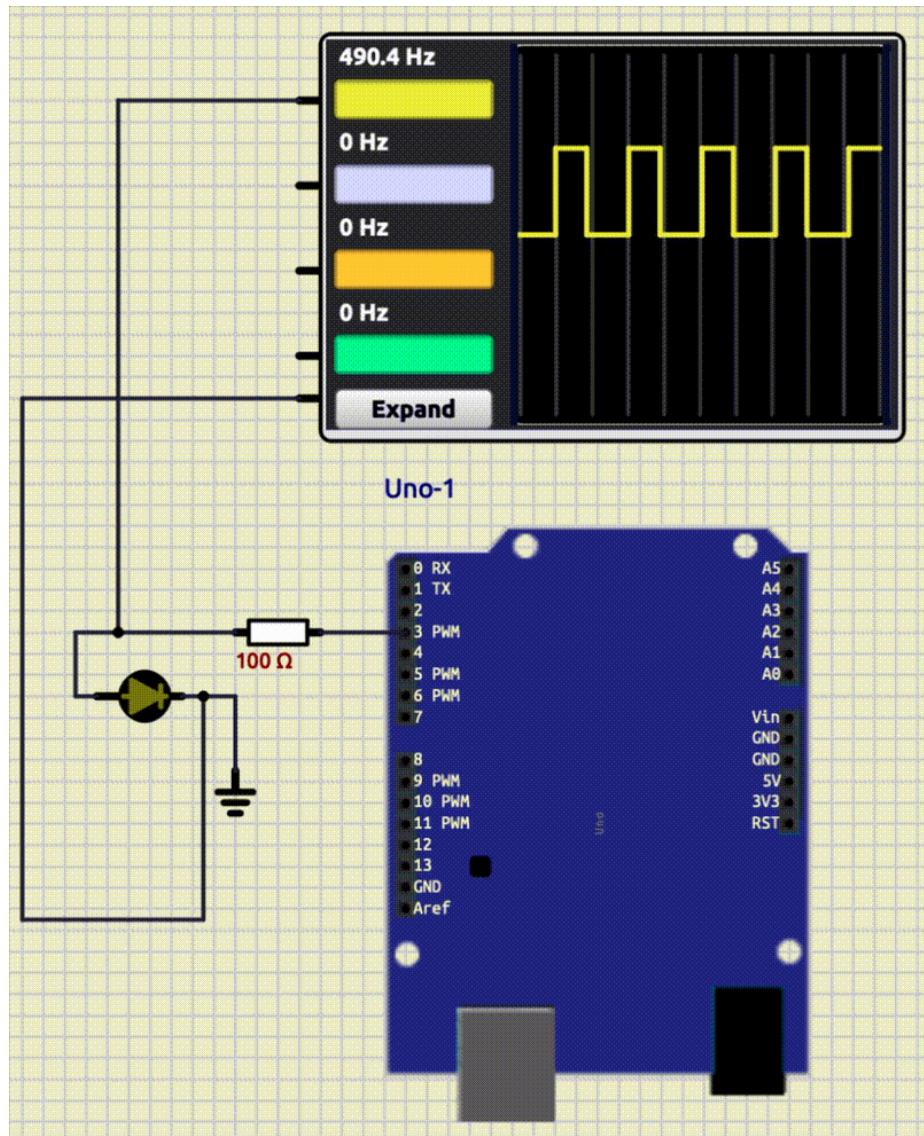


Figure 10: Analog Write Oscope gif

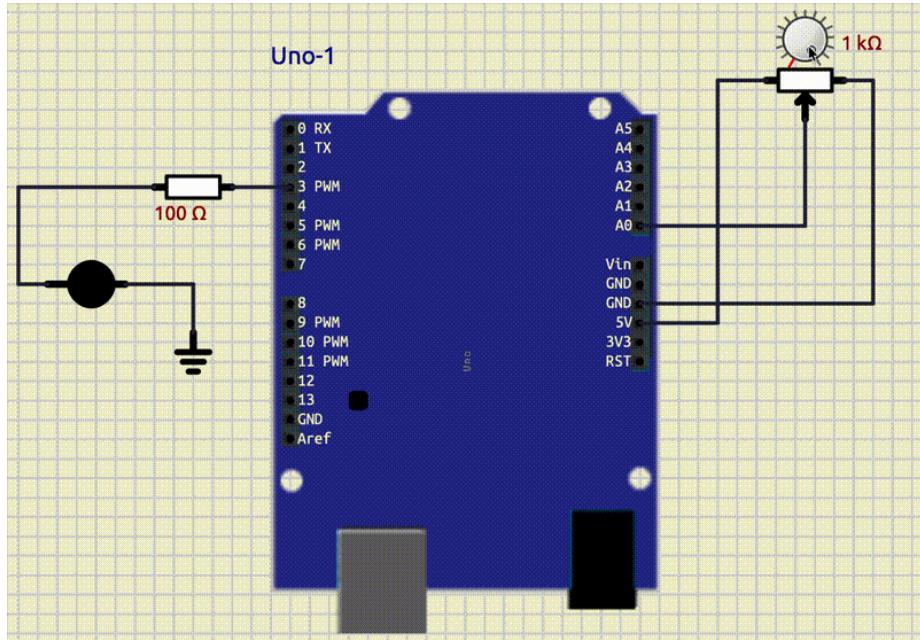


Figure 11: Combining Both

```
    delay(1000);
}
```

As you can see, in the code above, we read analog data from pin A0. The value is in the range of [0, 1023]. To write it on the pin 3, we need to rescale the value to the range of [0, 255]. To do so, we have used a function called `map`. This function takes our input as its first argument, then takes the current range and the target range and outputs the rescaled value. After that, we are able to write that rescaled value to pin 3. The output looks like as following:

If we want to see the **PWM**, we can connect an **Scope** like below:

DC motor

DC motor is a device that converts electrical energy into rotation. We use a **DC motor** in so many different things like, saw, drill, toys and e.t.c. To connect a **DC Motor** to an Arduino we should consider that, a **DC Motor** takes too much current, and we should not connect it directly to an **Arduino pin**. In **SimulIDE** it is not going to be a problem, but in real life we should not do that. To practice real life connection, we use a battery to power our **DC motor**. Also, we use a **Mosfet** to write analog data on our **DC motor**. Now, let's change our **LED** to a **DC motor** with these following steps:

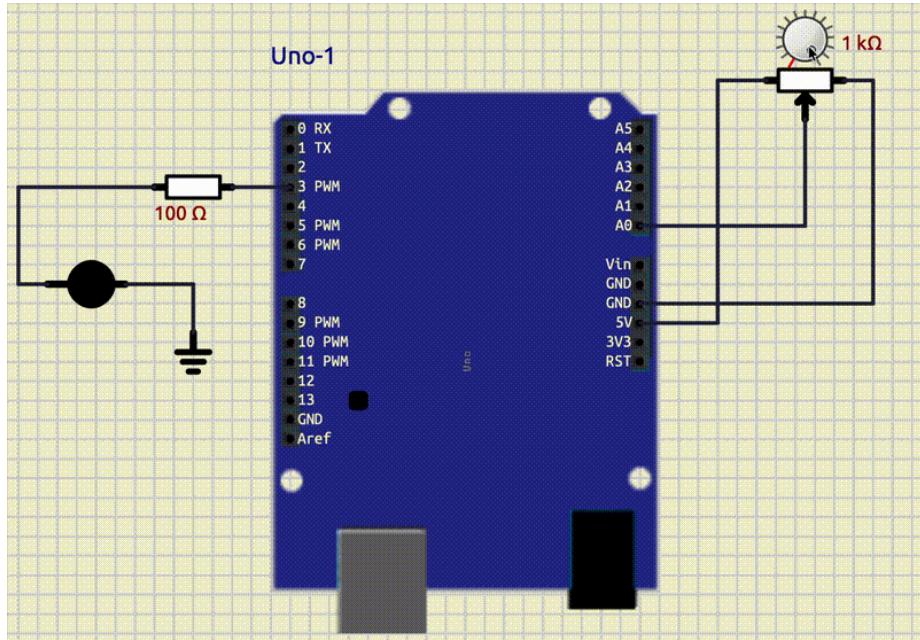


Figure 12: Combining Both gif

- Remove the **LED**
- Put a **DC motor** on the board (**Outputs/Motors/DC Motor**).
- Put a **Battery** on the board (**Sources/Battery**).
- Put a **Mosfet** on the board (**Active/Transistor/Mosfet**).
- Connect pin 3 to the middle pin of the mosfet (pin with the arrow).
- Connect one pin of the mosfet to the ground.
- Connect the other pin of the mosfet to the negative (-) of the **DC Motor**.
- Connect the positive (+) of the motor to the positive (red) of the battery.
- Connect the negative (black) of the battery to the ground.

Your connection should look like below:

There is no need to change our code. So, if we run our simulation with the code that we already have written for the **LED**, the output would look like below:

Servo Motor

Servo motor is a type of electric motor that is designed for precise control. It is widely used in robotics. We can control the position of the servo motor by sending a **PWM** signal to it. In this session, we will be using a simple DC servo motor which only take angles in range of [-90, 90]. The desired PWM frequency for this servo motor is 50Hz. This servo motor has three pins: VCC, GND, and signal. So, let's connect a **Servo motor** to an **Arduino Uno**.

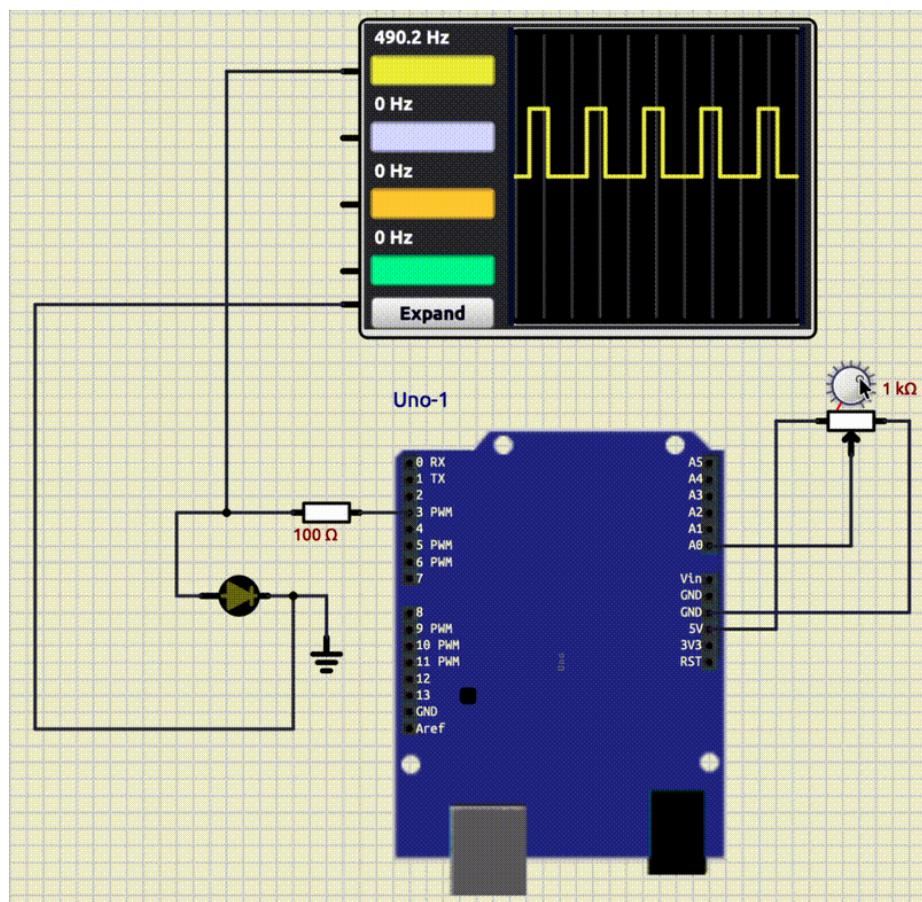


Figure 13: Combining Both Oscope gif

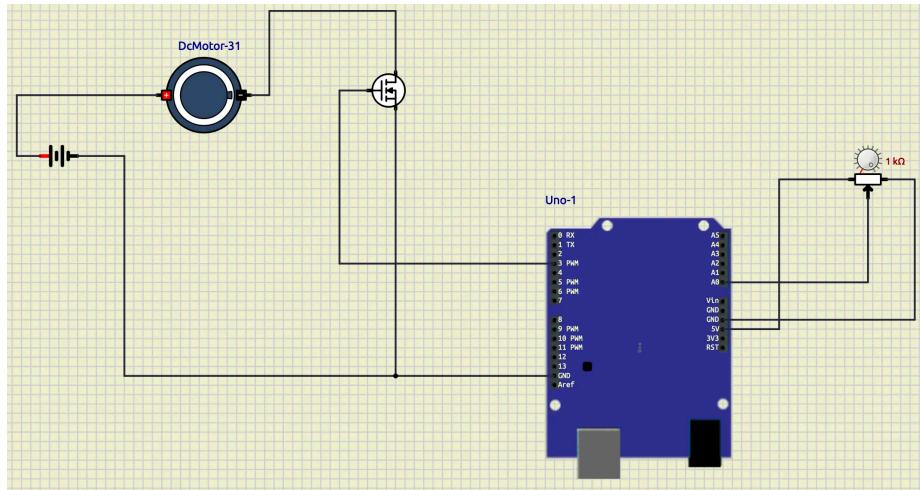


Figure 14: DC Motor

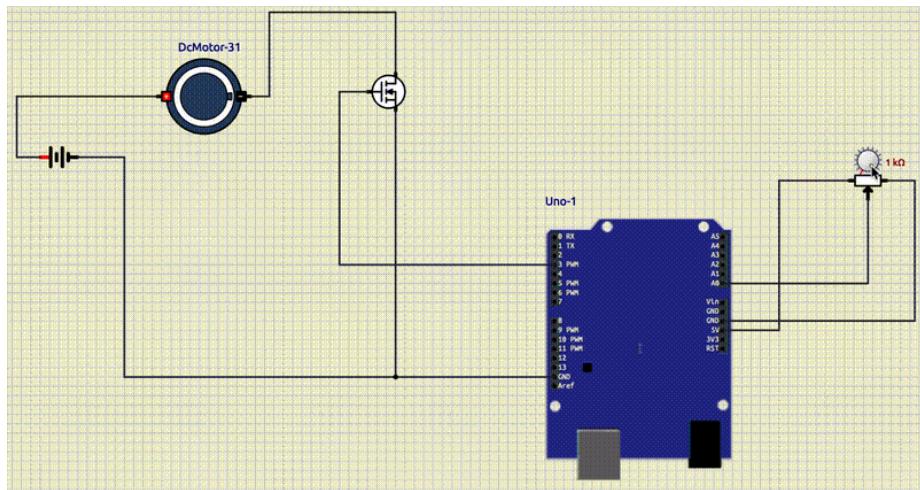


Figure 15: DC Motor gif

- Put a **Servo motor** on the board (**Outputs/Motors/Servo Motor**).

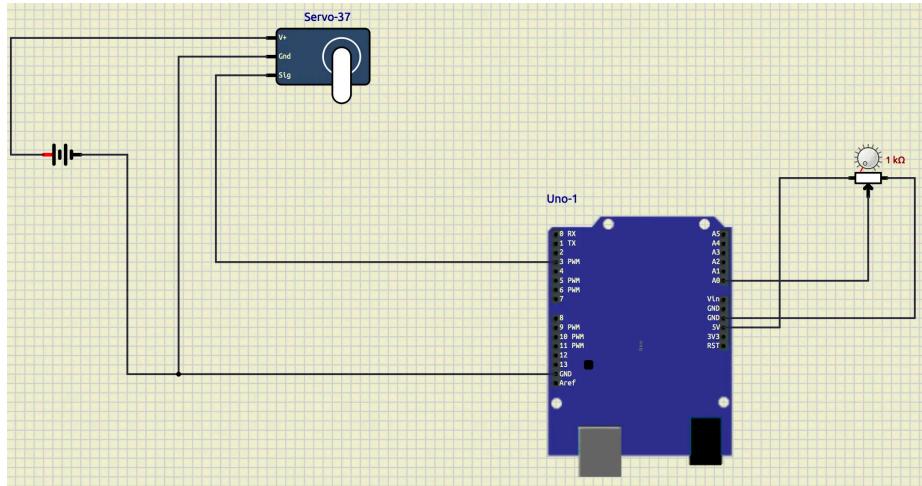


Figure 16: Servo motor

So, to control a **Servo motor** we need to create a **PWM** signal with the frequency **50hz**. To do so, we can use a library called **Servo**. We can add it to our **PlatformIO** project like this:

```
lib_deps =
...
arduino-libraries/Servo
```

Then, we can include it like below:

```
#include <Servo.h>
```

Now, we should create an object of **Servo** like below:

```
Servo my_servo;
```

Then, we need to do the initialization by using a function called **attach**. For example, let's attach our servo to pin 3.

```
my_servo.attach(3);
```

Then we can use the **write** function to write the angle that we want. For example let's write 45 on it.

```
my_servo.write(45);
```

Now, write a code that maps the data of the **Potentiometer** to the servo angles. Your output should look like as following:

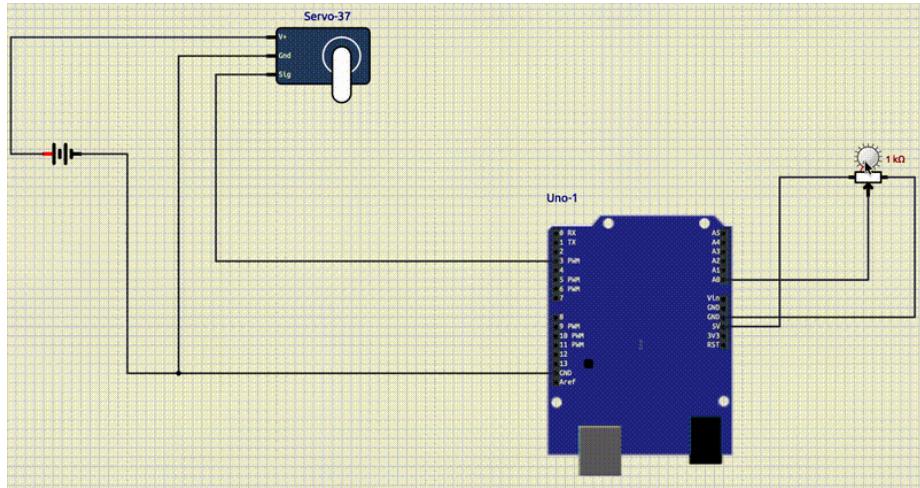


Figure 17: Servo motor gif

If we want to see the generated **PWM**, we can add a **Scope** like below:

Combine All

Now, let's combine all the things that I have learned. We need two **Potentiometers**, one for controlling the **Servo motor** and the other one for controlling the speed of **DC motor** and the brightness of the **LED**. Your output should be like below:

Conclusion

In this tutorial, we have Learned about how to deal with **Analog** data in **Arduino Uno**. First, we learned about `analogRead`. Then, we introduced **PWM** and that **Arduino** uses **PWM** to write analog data using `analogWrite`. After that, we have explained about two of the use cases of the `analogWrite`, which were **DC motor** and **Servo motor**. Finally, we combined all the things that we have learned so far.

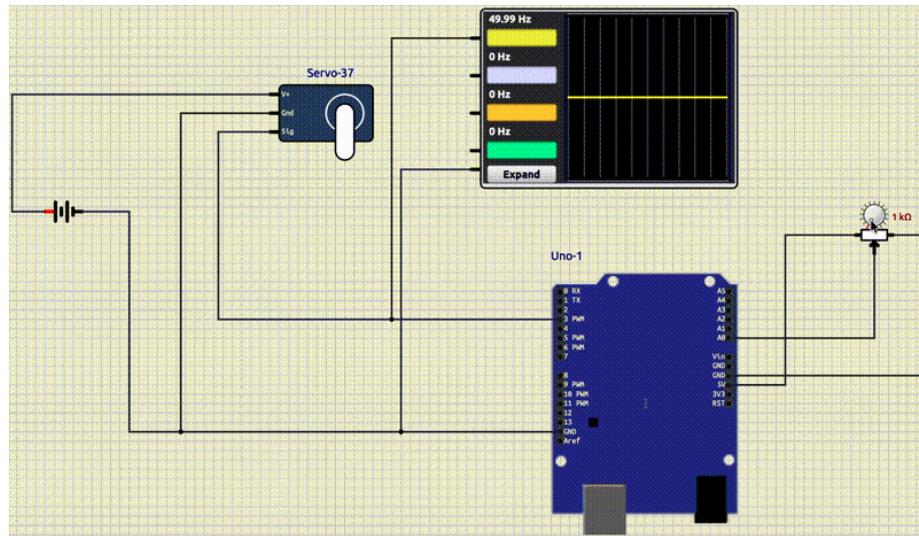


Figure 18: Servo motor oscilloscope gif

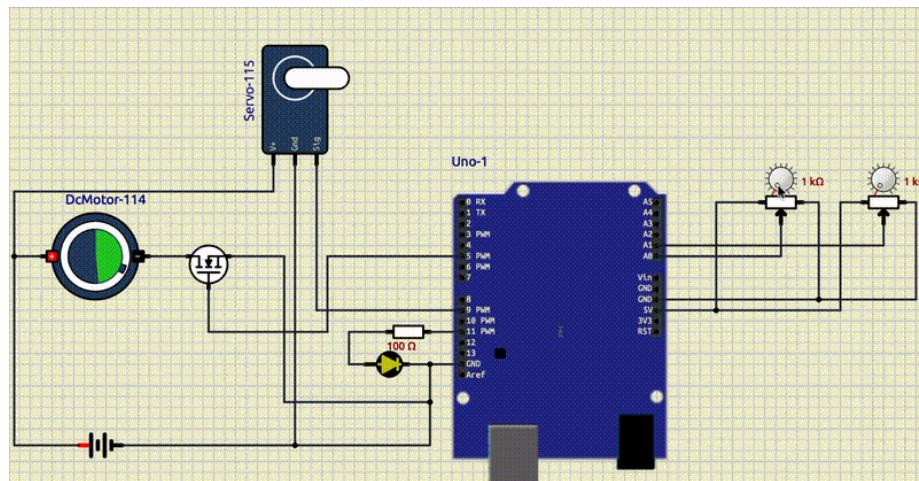


Figure 19: Combine all gif