Techshop EEE-201: Basic programming

Chapter 3

Up to this point, we've seen how to use the serial monitor and how to control the output of a single digital pin. There isn't a whole lot we can do with just that, so let's learn some more cool stuff. In this chapter we're going to read inputs, as well as cover the idea of an analog value; we'll cover the following topics:

- Analog input
- Fading a LED with PWM
- variable type `int`
- `if` control structure

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Introduction

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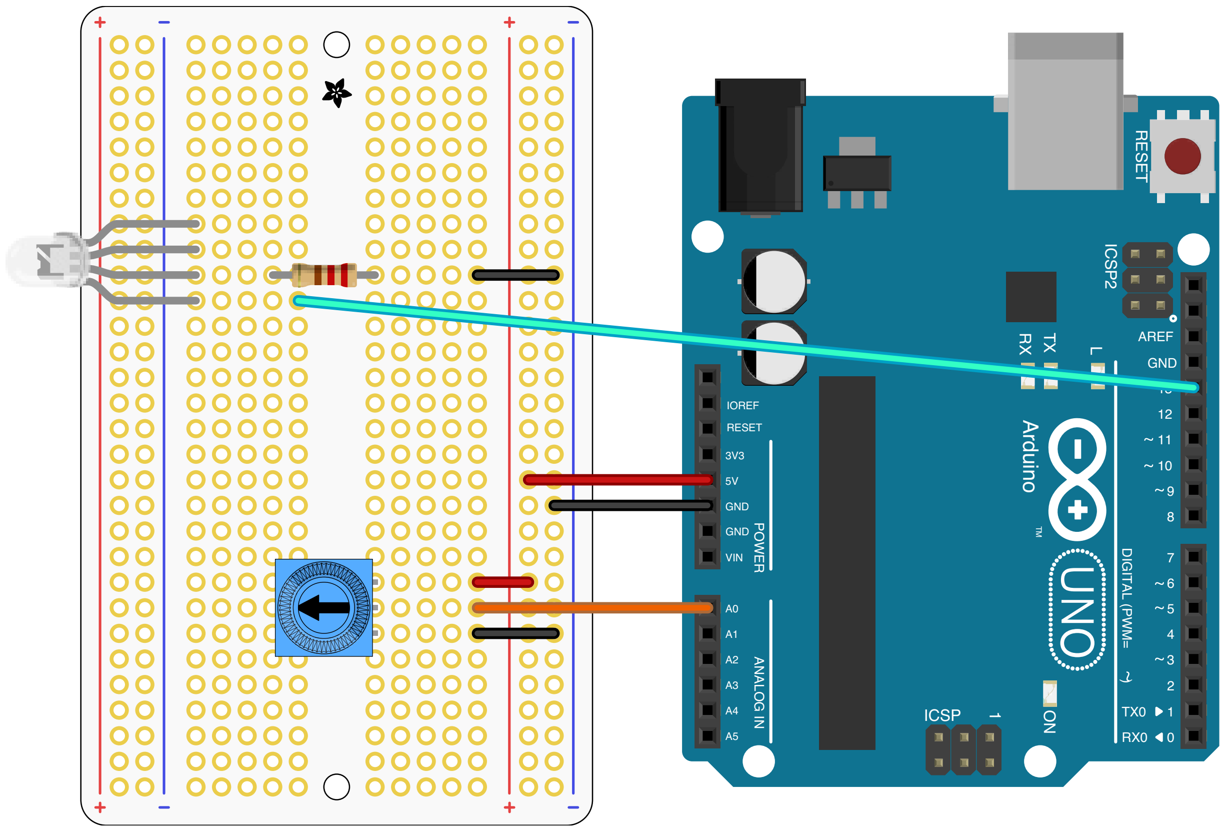
Part 1 - analog input

In Chapter 2 we used the **output** of a digital pin to control the blinking of a LED; in this first part we are going to be looking at inputs. But not just any type of input, we're going to be using an analog input. Previously, we see that we could set the digital pin to either `HIGH` or `LOW`; that is, it could be set to only two values. An analog pin is different in that it can have many values, in our case, 1024 to be exact! Let's begin with an example; the circuit we want is shown below, and the sketch your after is AnalogInput.ino.



Let's break the sketch down by looking at the top part first.

```
byte sensorPin = A0;    // select the input pin for the potentiome
byte ledPin = 13;       // select the pin for the LED
int sensorValue = 0;  // variable to store the value coming from t

void setup() {
  // declare the ledPin as an OUTPUT:
  pinMode(ledPin, OUTPUT);
  // because the analog pins are always INPUT, we don't have to de
}
```

In the first three lines, we declare three variables, two `byte` types and one `int` type. Previously, we saw that a `byte` is a number that can be any value between 0 and 255 (inclusive); `int` (which stands for integer) is another type of number, but it's much bigger; it's a 16-bit number which equates to 2^16.

Bust out the calculator and you'll see that equals 65,536! However, an `int` is special in that it can hold negative values, in fact an `int` can hold the values -32,768 to 32,767; for those that are observant you can see that 32,767 + 32,768 = 65,535 (can anyone tell me what that isn't exactly equal to 2^16?). The reason we want to declare the variable `sensorValue` as an `int` is because the range we expect it to be reading from is 0 to 1023 (the range of the analog pins).

In the `setup()` function we see that we are setting the `ledPin` (pin 13) as an `OUTPUT`. Note that we don't have to define the analog pin as an input because it can only act asn an input. Let's move on to the interesting parts:

```
void loop() {
  // read the value from the sensor:
  sensorValue = analogRead(sensorPin);

  // turn the ledPin on
  digitalWrite(ledPin, HIGH);

  // stop the program for <sensorValue> milliseconds:
  delay(sensorValue);

  // turn the ledPin off:
  digitalWrite(ledPin, LOW);

  // stop the program for for <sensorValue> milliseconds:
  delay(sensorValue);
}
```

In the `loop()`, we see a function we haven't seen before `analogRead()` - this is the function which will be reading the input values on our analog pin (pin A0). As we mentioned previously, we expect this value to be anywhere between 0 and 1023 (inclusive). The remaining lines of code we've seen in Chapter 2: we turn our LED on with `digitalWrite()`, then we pause the sketch by a value of `sensorValue` number of milliseconds, then we turn off our LED with `digitalWrite()` and then we pause again. The interesting part here is that, instead of pausing with a fixed amount, we can control the length of pause with the value that is read by `analogRead()` which we control with the trimpot. That means, we can directly control how fast our LED blinks just by twisting the trimpot to different values!

Explore: how would we change our sketch to see what value our variable `sensorValue` is set to?

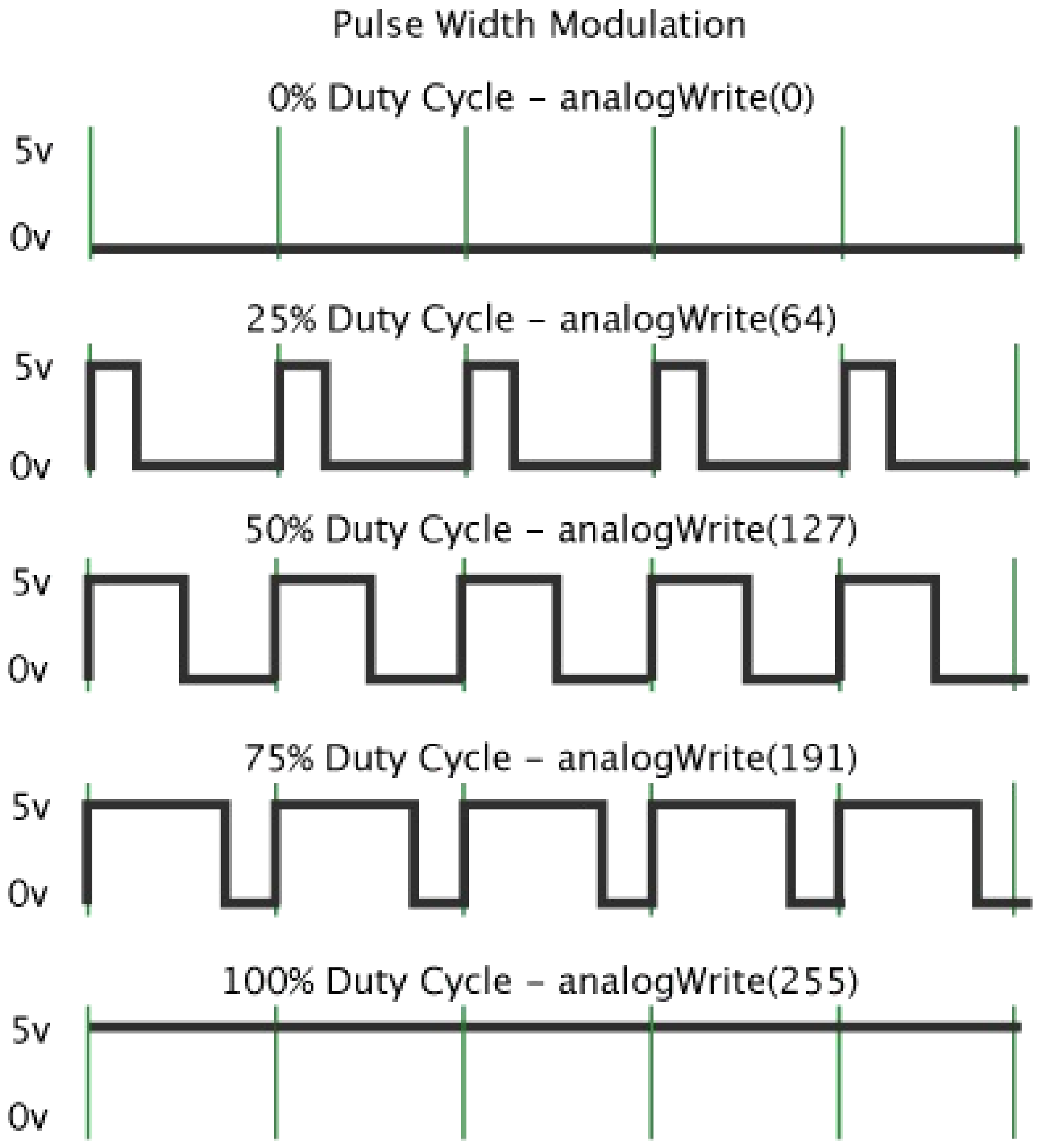
Part 2 - PWM digital output

In part 1 we covered analog inputs, but what about analog outpus? Unfortunately the Arduino can't directly do analog outputs, however we can fake it through the use of the Arudino software through a technique called pulse width modulation (PWM):

> Pulse Width Modulation, or PWM, is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off. This on-off pattern can simulate voltages in between full on (5 Volts) and off (0 Volts) by changing the portion of the time the signal spends on versus the time that the signal spends off. The duration of "on time" is called

the pulse width. To get varying analog values, you change, or modulate, that pulse width. If you repeat this on-off pattern fast enough with an LED for example, the result is as if the signal is a steady voltage between 0 and 5v controlling the brightness of the LED.

In the graphic below, the green lines represent a regular time period. This duration or period is the inverse of the PWM frequency. In other words, with Arduino's PWM frequency at about 500Hz, the green lines would measure 2 milliseconds each. A call to analogWrite() is on a scale of 0 - 255, such that analogWrite(255) requests a 100% duty cycle (always on), and analogWrite(127) is a 50% duty cycle (on half the time) for example.


Pulse Width Modulation
0% Duty Cycle - analogWrite(0)
25% Duty Cycle - analogWrite(64)
50% Duty Cycle - analogWrite(127)
75% Duty Cycle - analogWrite(191)
100% Duty Cycle - analogWrite(255)
5v
0v

Enough with the theory, let's take a look with a hands on example, upload the Fade sketch to your Aruino.

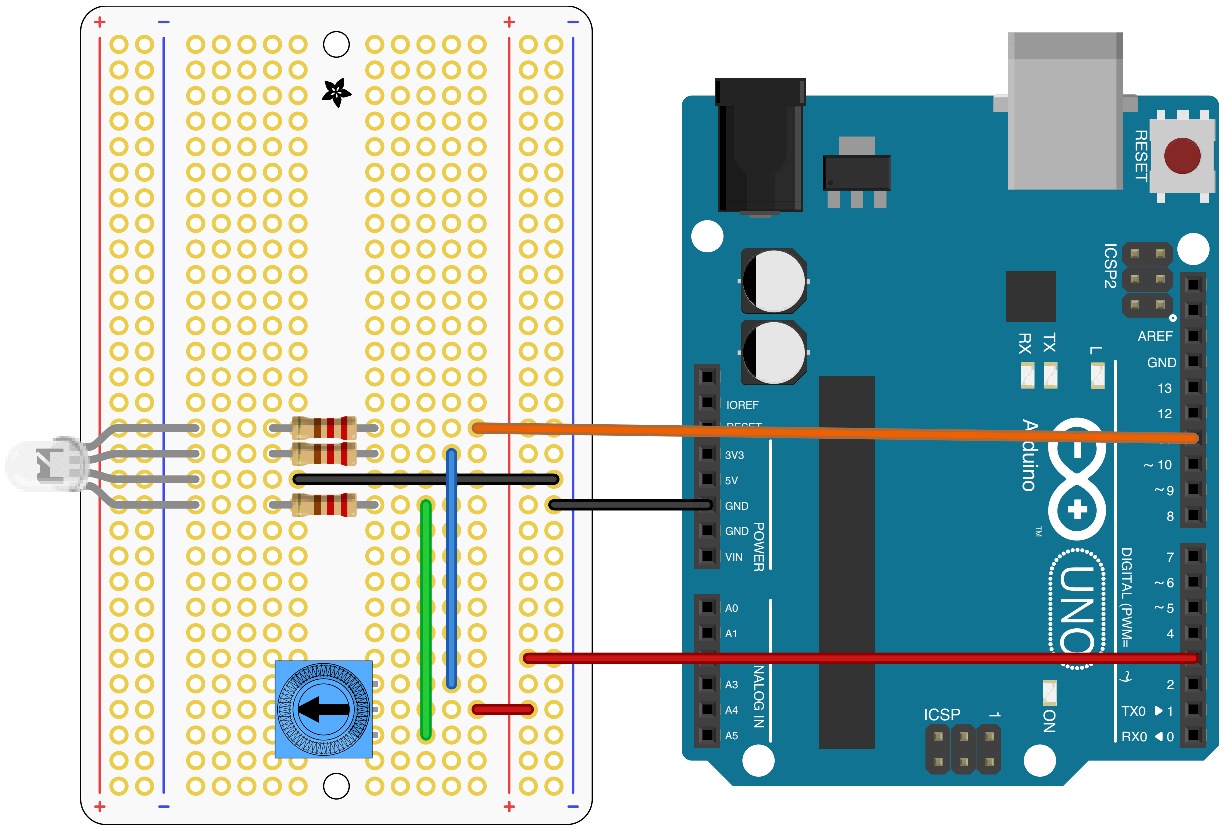
The only new part in this sketch is the use of the `analogWrite()` function. All we're doing is generating an analog output through PWM at various frequencies. We start it at 0% duty cycle (LED is off), and then increase the frequency slowly, pausing for half a second at each frequency change. What you should be seeing is that the LED changes in brightness as the PWM frequency is increased.

Part 3 - Putting it all together

So far we've completely ignored the fact that the LED we've been using is actually 3 LEDs built into one. So, for this last part of this class, we are going to put everything we learned together to control all three colors of the LED. But before we do that, we need to learn one more thing: the `if` control statement.

TODO explain `if`

The circuit you need to build is seen below and the sketch we're going to use is the FadeIf.ino sketch.



TODO explain circuit/sketch

Explore:

- How can we see what voltage is being set by the trimpot?
- Right now the trimpot controls two of the RGB channels, how can we change our circuit so that one channel automatically blinks with a frequency of 1Hz (once a second)?
- How to make the LED show a white color? How about purple?