Embedded System Interfacing

Lecture 10
Pulse Width Modulation

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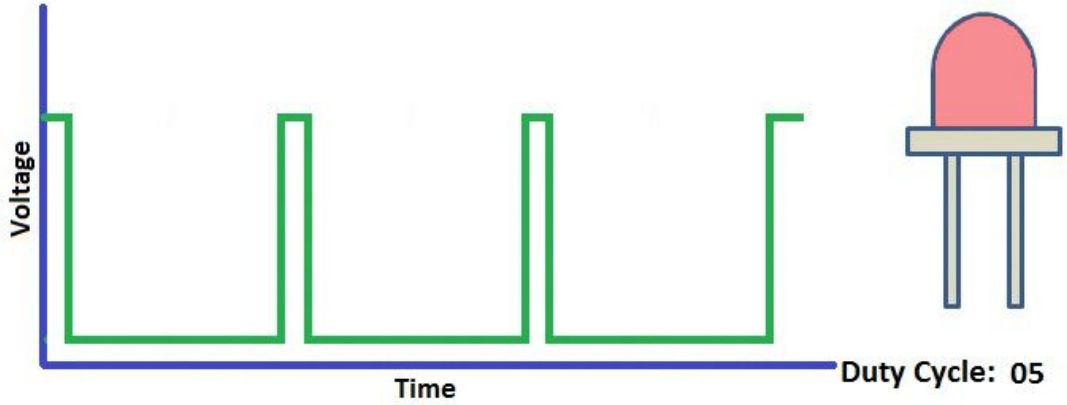
Introduction

PWM

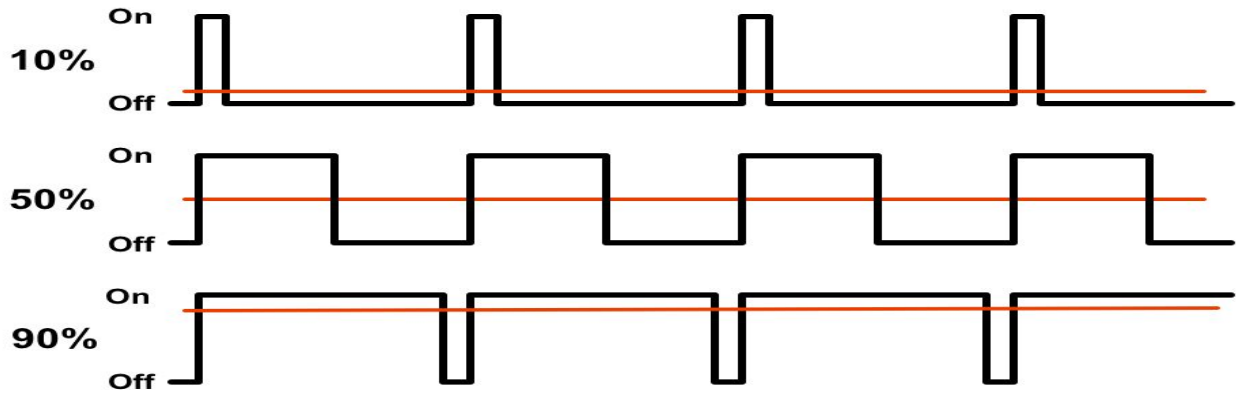


Introduction to PWM

Digital signals have two positions: on or off, interpreted in shorthand as 1 or 0. Analog signals, on the other hand, can be on, off, half-way, two-thirds the way to on, and an infinite number of positions between 0 and 1 either approaching 1 or descending down to zero. The two are handled very differently in electronics, but very often must work together (that's when we call it "mixed signal electronics.") Sometimes we have to take an analog (real world) input signal (e.g., temperature) into a microcontroller (which only understands digital). Often engineers will translate that analog input into digital input for the microcontroller (MCU) by using an analog-to-digital converter. But what about outputs?

PWM is a way to control analog devices with a digital output. Another way to put it is that you can output a modulating signal from a digital device such as an MCU to drive an analog device. It's one of the primary means by which MCUs drive analog devices like variable-speed motors, dimmable lights, actuators, and speakers. PWM is not true analog output, however. PWM "fakes" an analog-like result by applying power in pulses, or short bursts of regulated voltage.

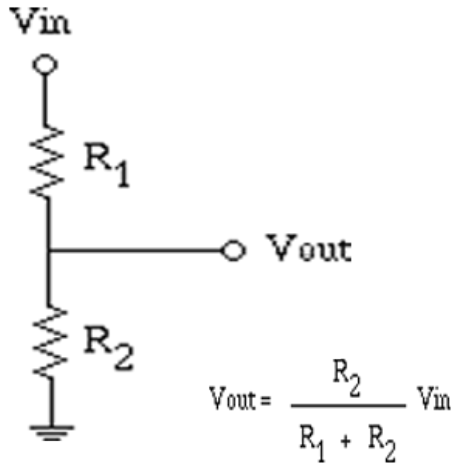
What is PWM



- Pulse Width Modulation (PWM) is a method for changing how long a square wave stays “on”.
- The on-off behavior changes the average power of the signal.
- If signal toggles between on and off quicker than the load, then the load is not affected by the toggling.

Why PWM..?

Because the PWM is on for a period and off for another period, the total power is a part for the maximum power (The On Power). It looks a like a potentiometer but with some differences ….



So , what is advantages of PWM over the potentiometer ?

PWM

Automatic control.

The total power consumed in the load

Potentiometer

Manual control.

Part of the power consumed at the potentiometer

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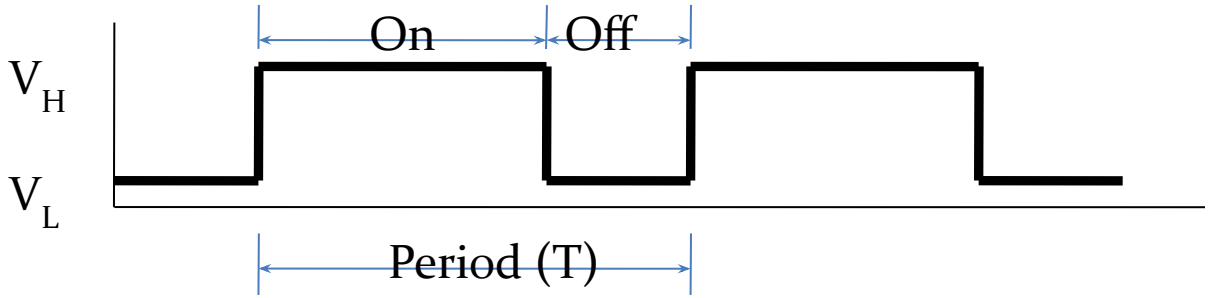
PWM Parameters

Amplitude The voltage difference between the on state and the off state.

Period The repetition time for PWM. Period = On_Time + Off_Time

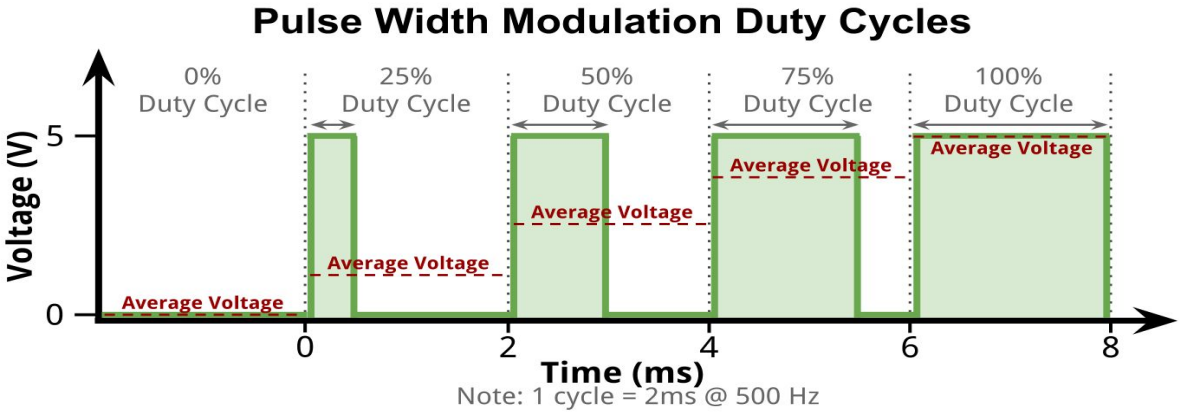
Duty cycle The percentage of the On_Time over the total time



Duty Cycle

- The duty cycle is a percentage measurement of how long the signal stays on.
- ***The effective voltage*** of the PWM signal is called Root Mean Square (RMS) which equals to:

RMS = Amplitude sqrt(Duty Cycle)



Duty Cycle

- ***Duty Cycle*** is determined by:

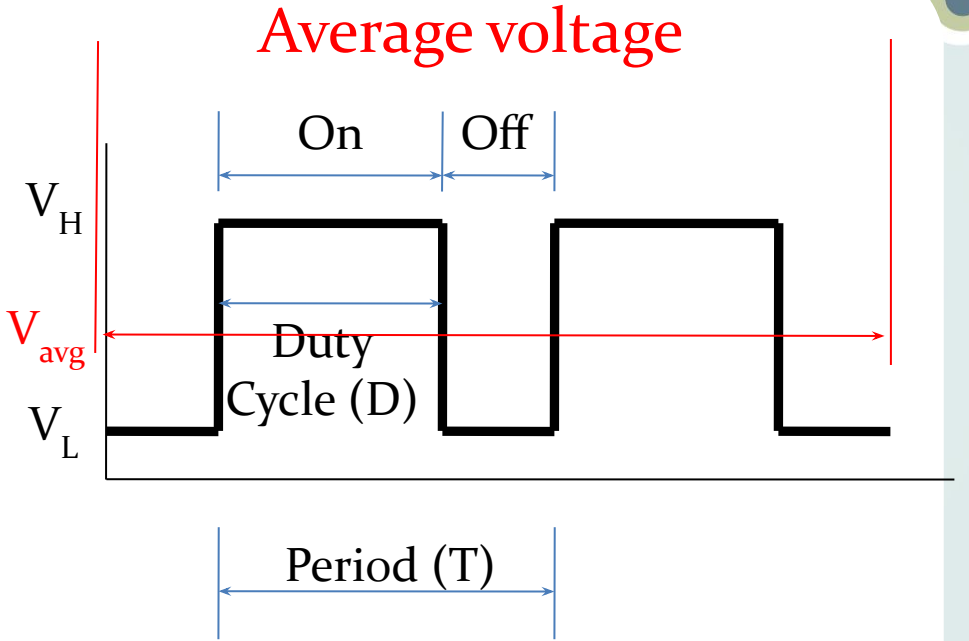
$$\text{Duty Cycle(D)} = \frac{\text{On Time}}{\text{Period}} \times 100\%$$

- ***Average signal*** can be found as:

$$V_{avg} = D \cdot V_H + (1 - D) \cdot V_L$$

- ***RMS*** can be found as:

$$RMS = Amplitude\sqrt{D}$$



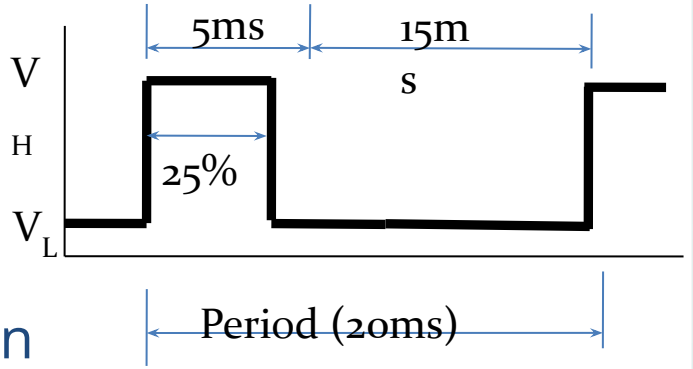
Example

Assume having 50 Hz PWM signal having 25% duty cycle.
Calculate the Ton and Toff parameters.

$$\text{Frequency} = 50\ HZ$$

$$\text{T} = (\text{Ton} + \text{Toff}) = \frac{1}{50} = 20ms$$

$$\text{Duty cycle} = 25\% = \frac{\text{Ton}}{(\text{Ton} + \text{Toff})}$$

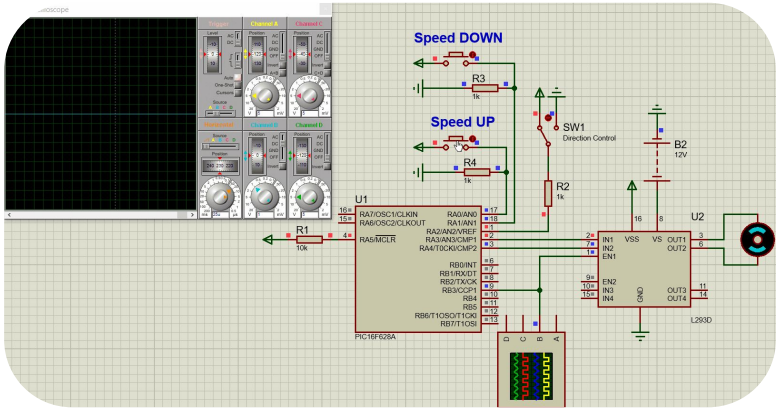


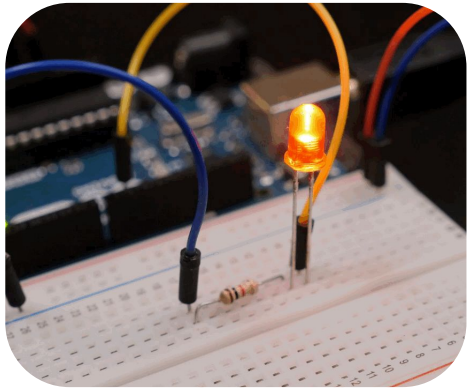
solving according to equation given above, we get

$$\text{Ton} = 5ms$$

$$\text{Toff} = 15ms$$

PWM Applications





We can control motor speed

We can control LED intensity

We can change the tone frequency

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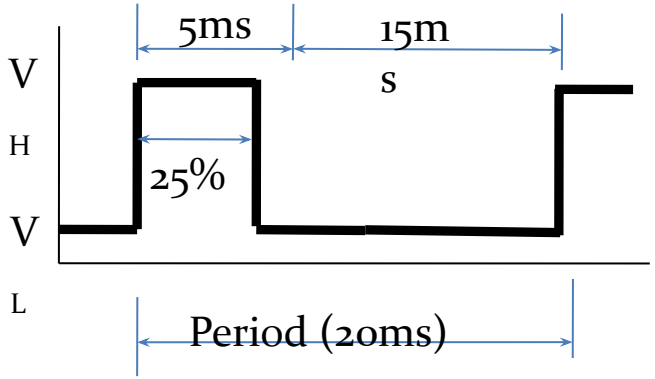
PWM Generation

Let's generate PWM signal from an AVR…

- We can generate a PWM signal using CTC or over flow modes.

Let's take the previous example to be generated :

- We need to generate PWM have Ton = 5ms and Toff = 15ms
- we have a timer which over flow and fire an interrupt every 1ms .
- What can we do to generate this PWM signal?



PWM Generation

```
/* Configure the timer to overflow after every 1ms */

ISR (OverFlow)
{
    PWM_Counter++;

    if (PWM_Counter == 5)
    {
        /* Set PIN High */
    }

    if (PWM_Counter == 20)
    {
        /* Set PIN Low */

        /* Clear the counter */
        PWM_Counter = 0;
    }
}
```

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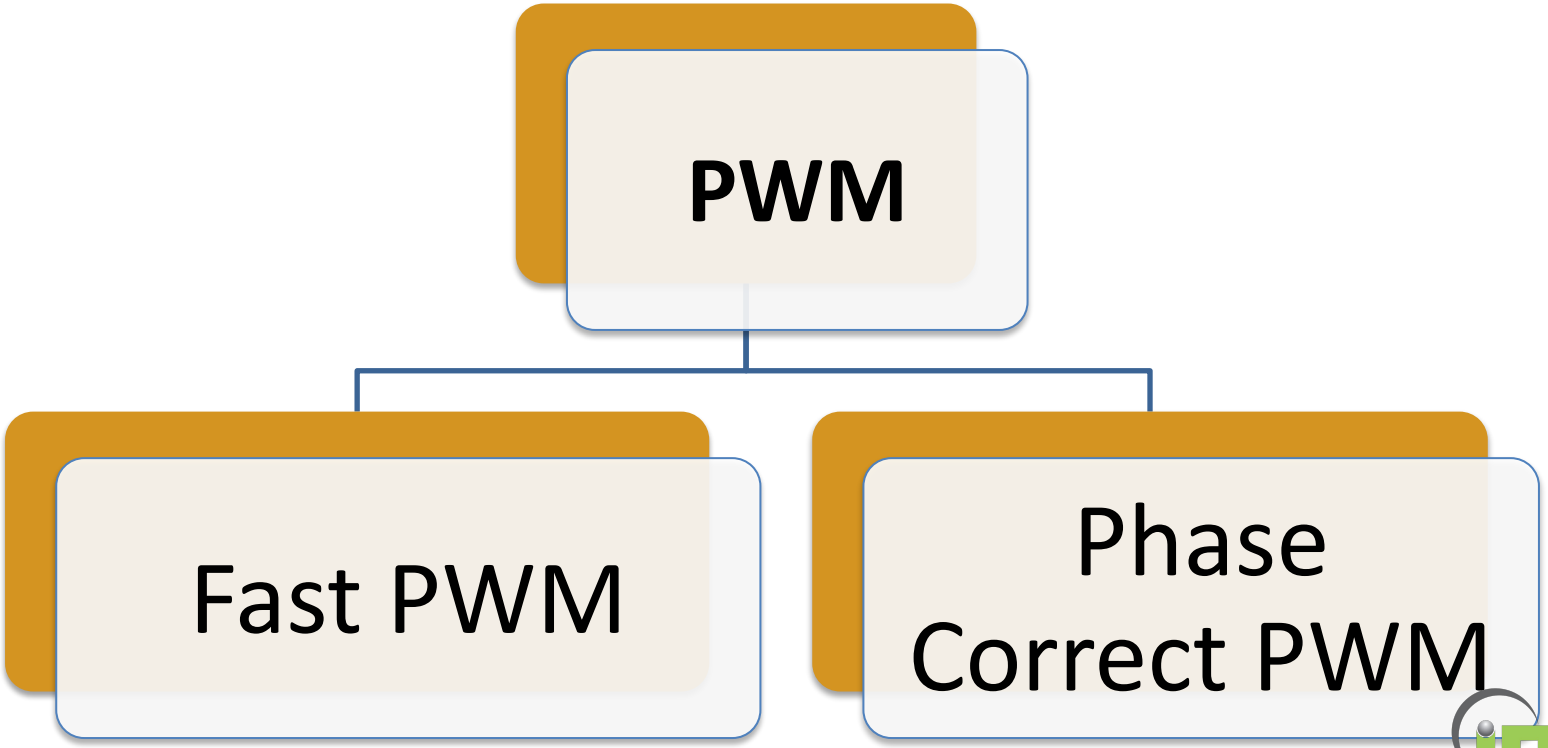
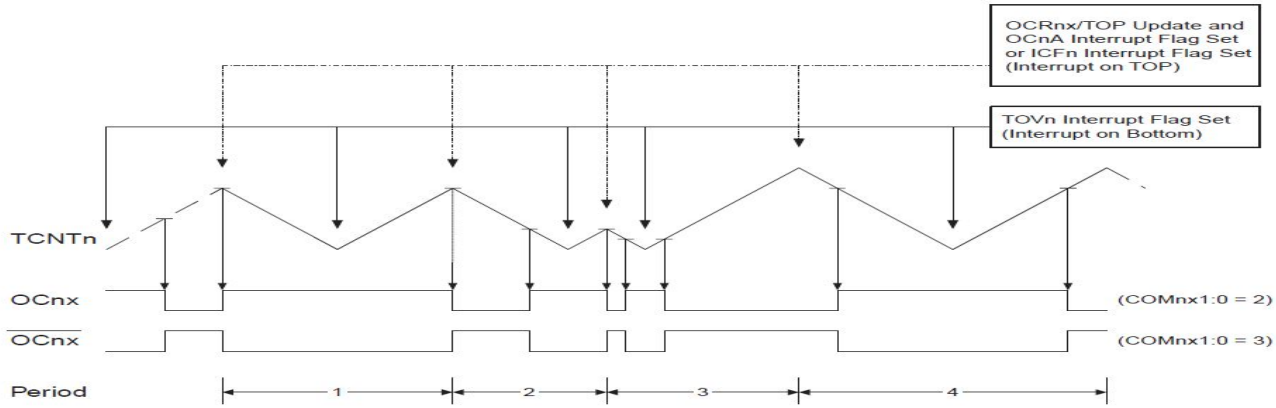
PWM Modes



Fast PWM

- Fast PWM mode provides a high frequency PWM waveform generation option.
- The counter counts from BOTTOM to TOP then restarts from BOTTOM.
- In non-inverting Compare Output mode, the Output Compare (OC1x) is set on the compare match between TCNT1 and OCR1x, and cleared at TOP.

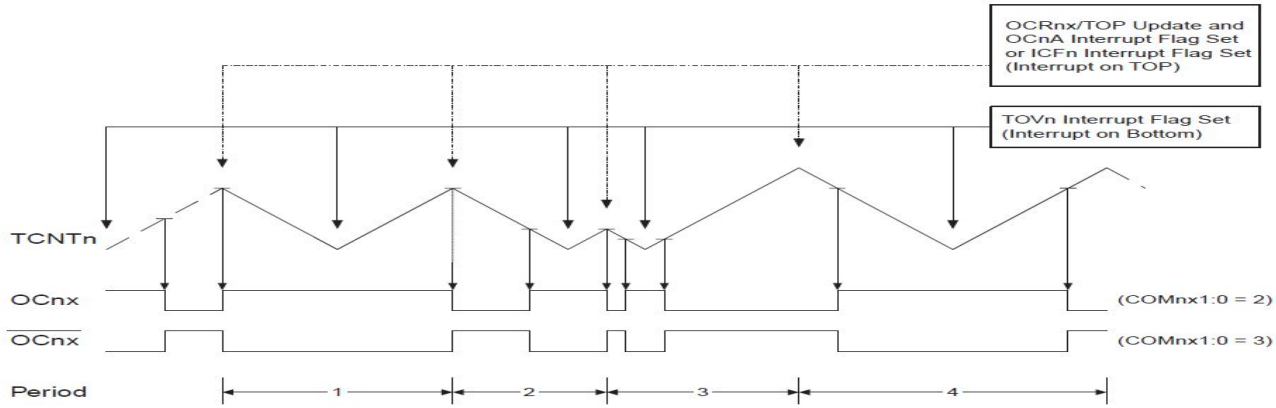
Figure 47. Phase Correct PWM Mode, Timing Diagram



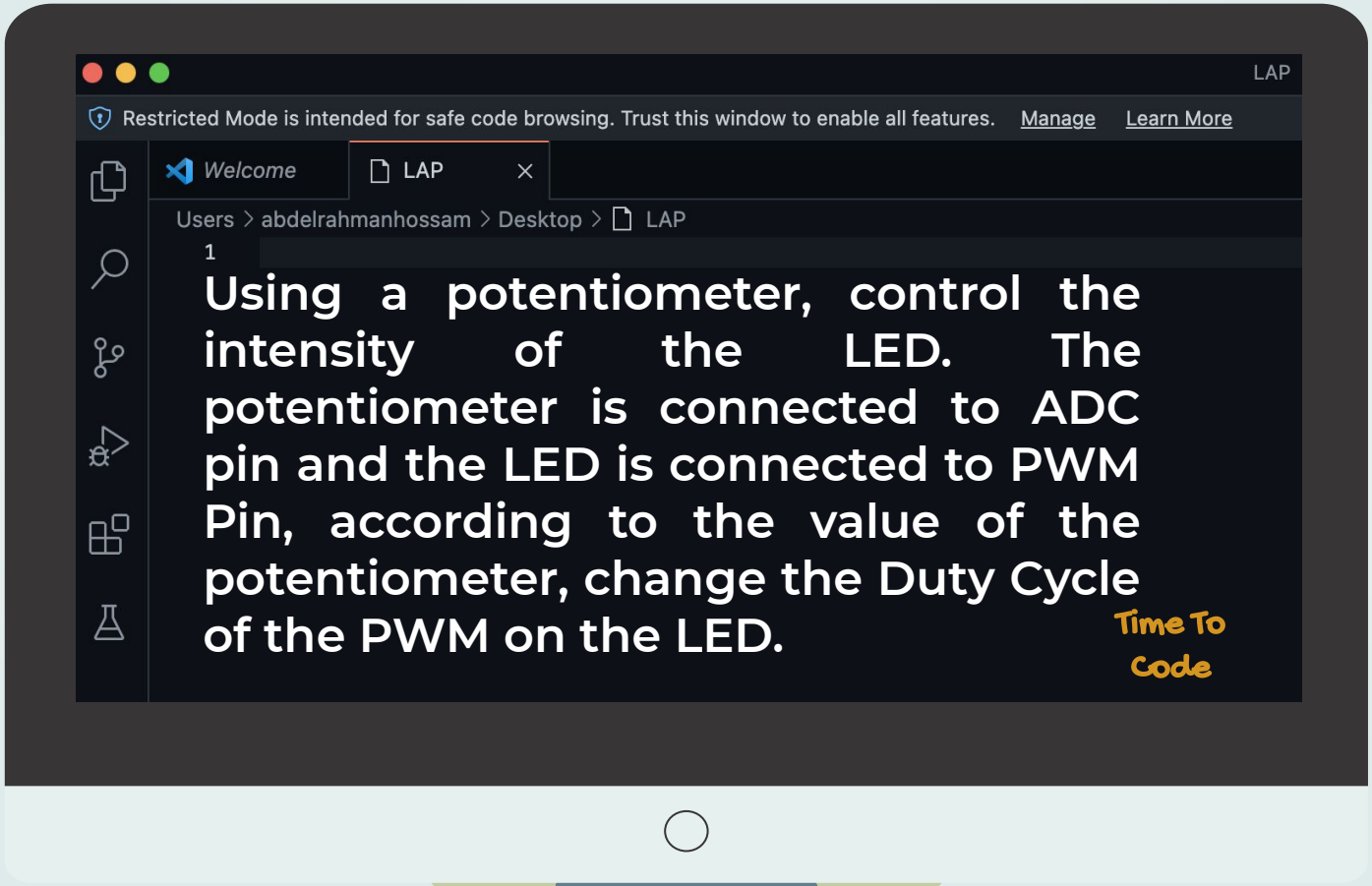
Phase Correct PWM

- phase correct PWM mode provides a high resolution phase correct PWM waveform generation option.
- The phase correct PWM mode is based on a dual-slope operation.
- The counter counts repeatedly from BOTTOM (0x0000) to TOP and then from TOP to BOTTOM.
- In Compare Output mode, the Output Compare (OC1x) is cleared on the compare match between TCNT1 and OCR1x while up counting, and set on the compare match while down counting.

Figure 47. Phase Correct PWM Mode, Timing Diagram



LAb 1



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Servo Motor

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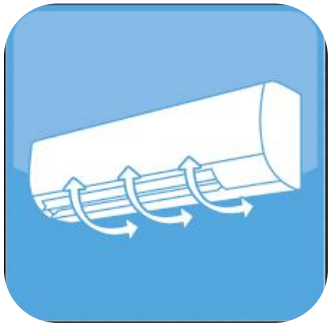
Servo Introduction

Have you ever wonder how car's mirrors, windshield wiper or air conditioner swings' motors moves at specific angle ?

Can we make a DC motor to move to specific angle ? Why?



Servo Motor

What is servo motor?

Unlike dc motors, with servo motors you can position the motor shaft at a specific position (angle) using control signal.
The motor shaft will hold at this position as long as the control signal not changed.

Why servo motor?

useful for controlling robot arms. Any object that you want it to move at certain angle and stay at its new position..

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How it Works

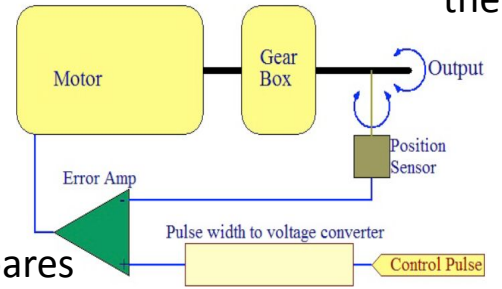
Servo motor is consisting of a regular dc motor connected to a gearbox and a potentiometer with control circuit that give the feedback for angle position.
This control circuit is closed loop circuit (self correction).

Servo motors have their own language to send them your instructions .
This language is PWM ” pulse width modulation”

How it Works

Control pulse(PWM) sent to servo

Pulse width to voltage converter send a voltage to the error Amp



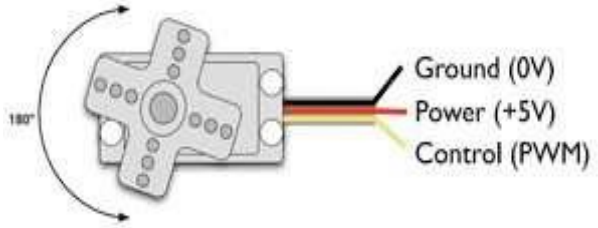
error amp compares between these two signals and drive a voltage to the dc motor to correct it's position

position sensor sense the motor shaft angle position and send it to the error amplifier

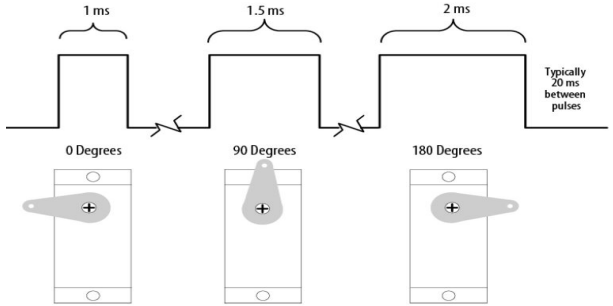
How it Works

Your servo have 3 wires :

Black wire : GND (ground) !
RED wire :+5v
Colored wire: control signal

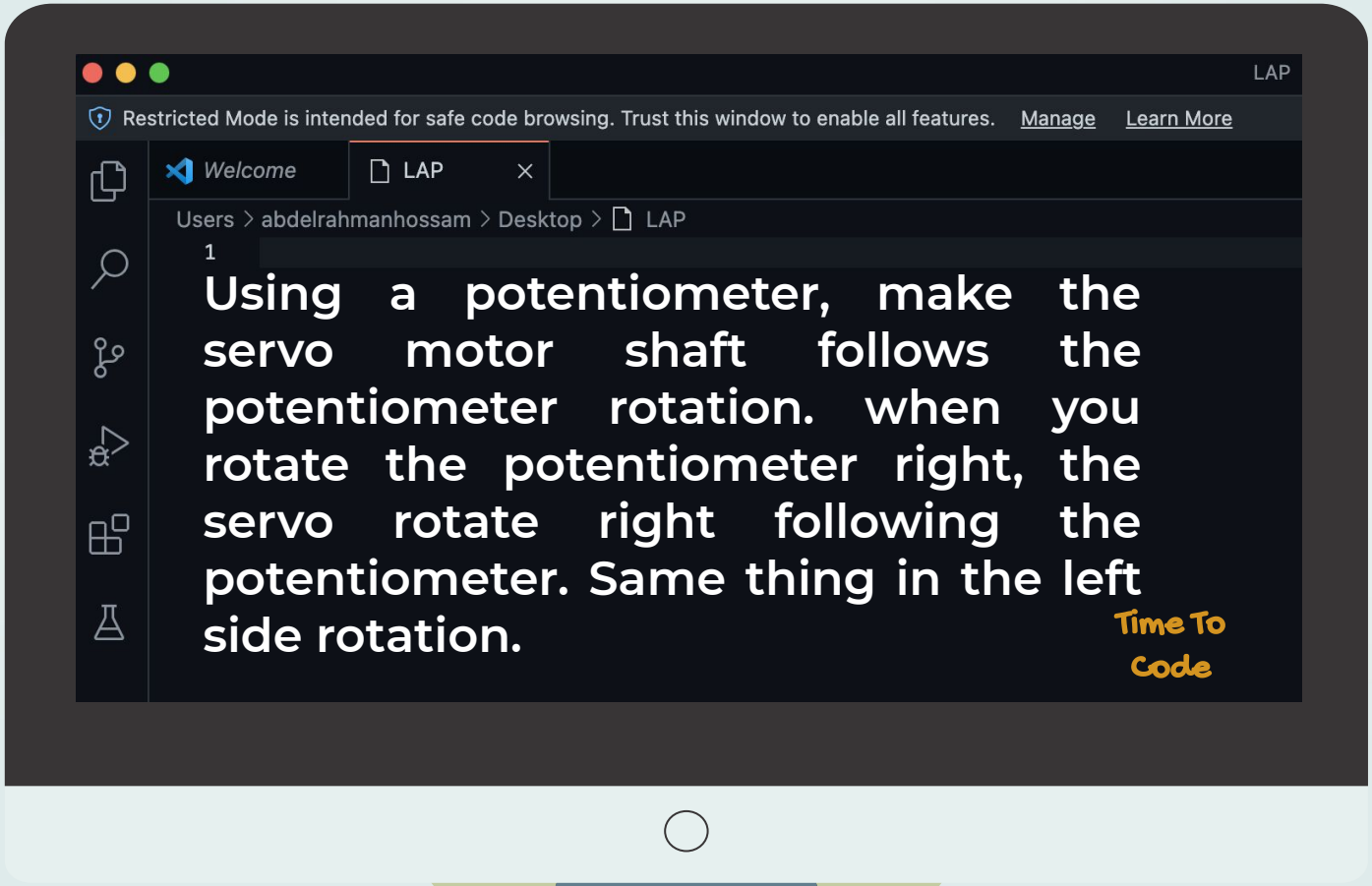


- The most common servos works at 50 HZ frequency.
- This means that the period is 20ms



The pulse width sent to servo ranges as follows:
Minimum: 1 millisecond ---> Corresponds to 0 rotation angle.
Maximum: 2 millisecond ---> Corresponds to 180 rotation angle

LAb 2



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The End

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Assignments

Talk is cheap
show me the Code

- Linus Torvalds

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Assignment 1

Using Keypad, LCD and Servo Motor, make a system that controls the rotation angle of the servo motor. The user writes the desired angle on the LCD using the keypad, then the servo motor shall rotate to the desired angle.

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