



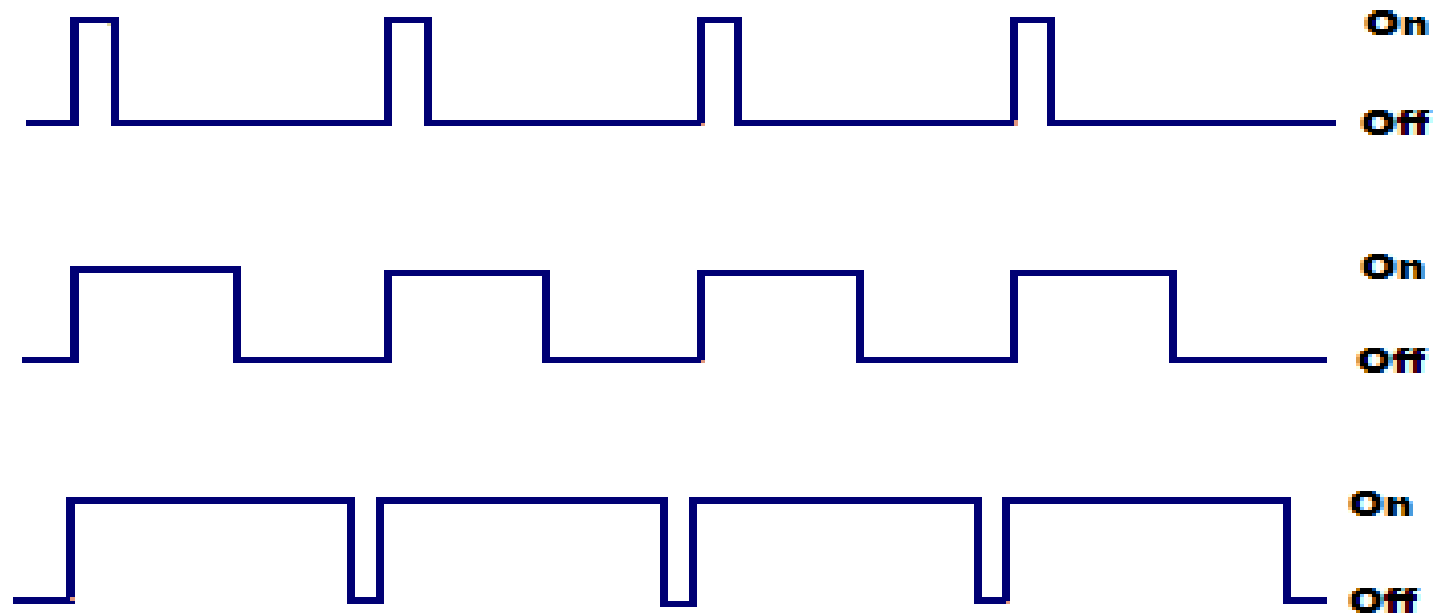
Embedded system interfacing

Lecture ten

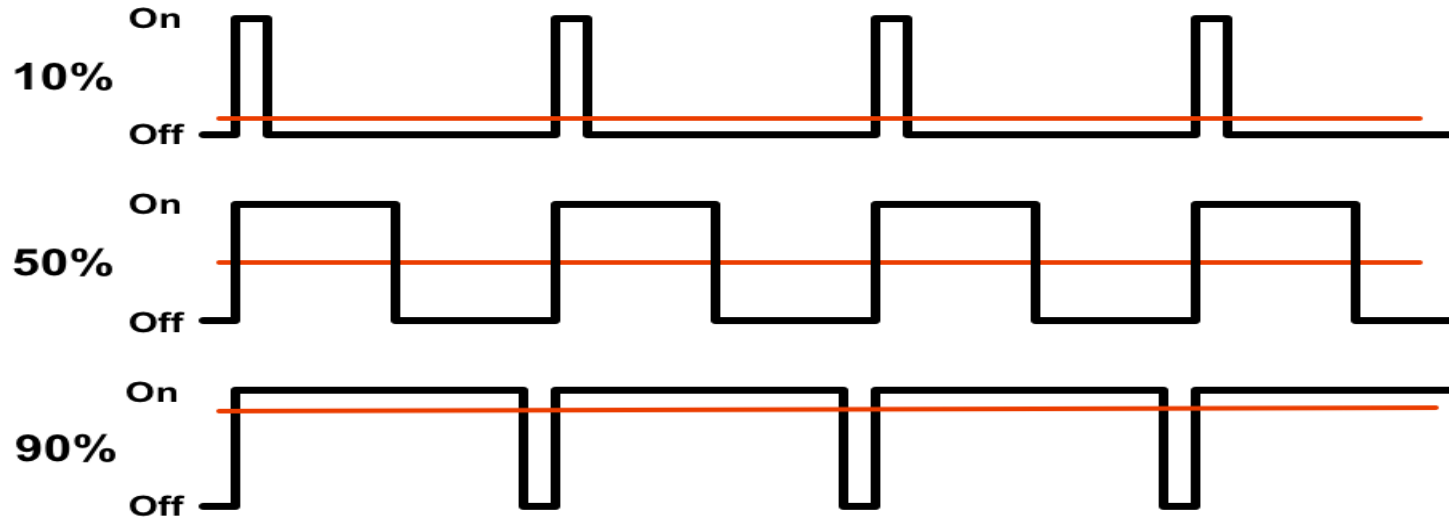
Pulse Width Modulation

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## Pulse Width Modulation



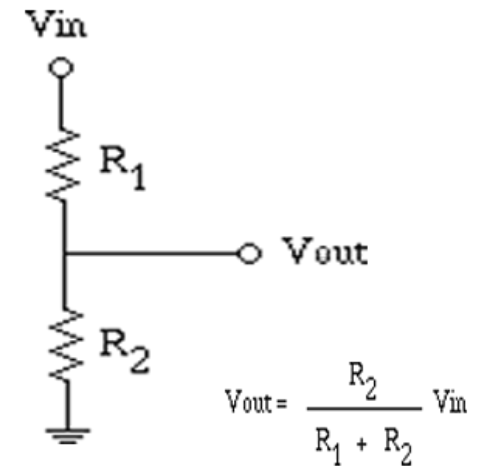
# Introduction



- ☐ 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

1.1) Automatic control.

2.2) The total power consumed in the load

1) Manual control.

2) Part of the power consumed at the potentiometer

potentiometer

# PWM Parameters

## Amplitude

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

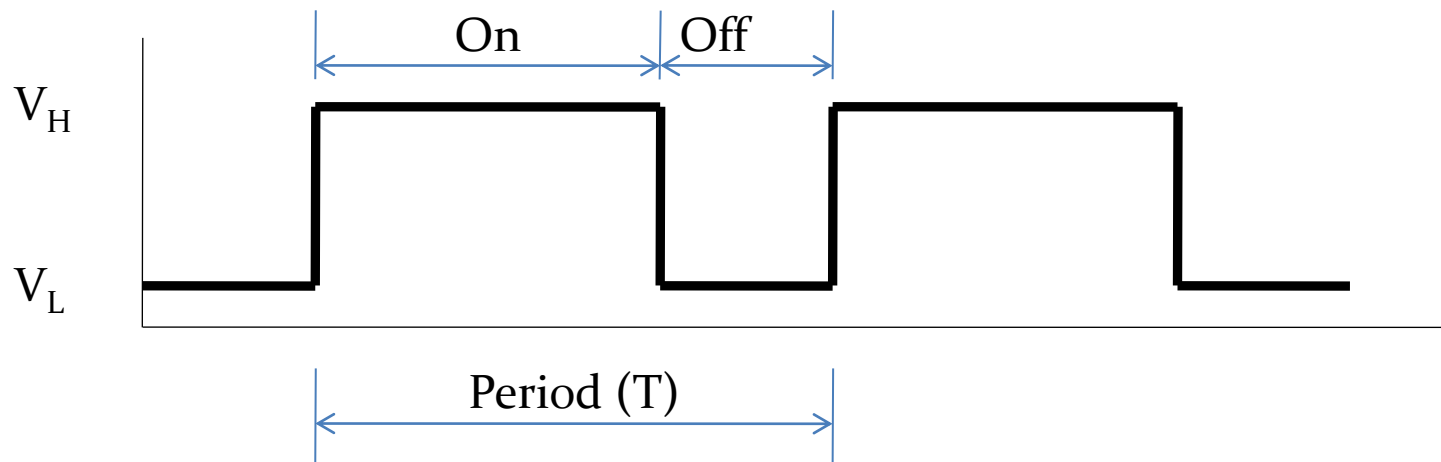
## Period

The repetition time for PWM.

$$\text{Period} = \text{On\_Time} + \text{Off\_Time}$$

## Duty cycle

The percentage of the On\_Time over the total time

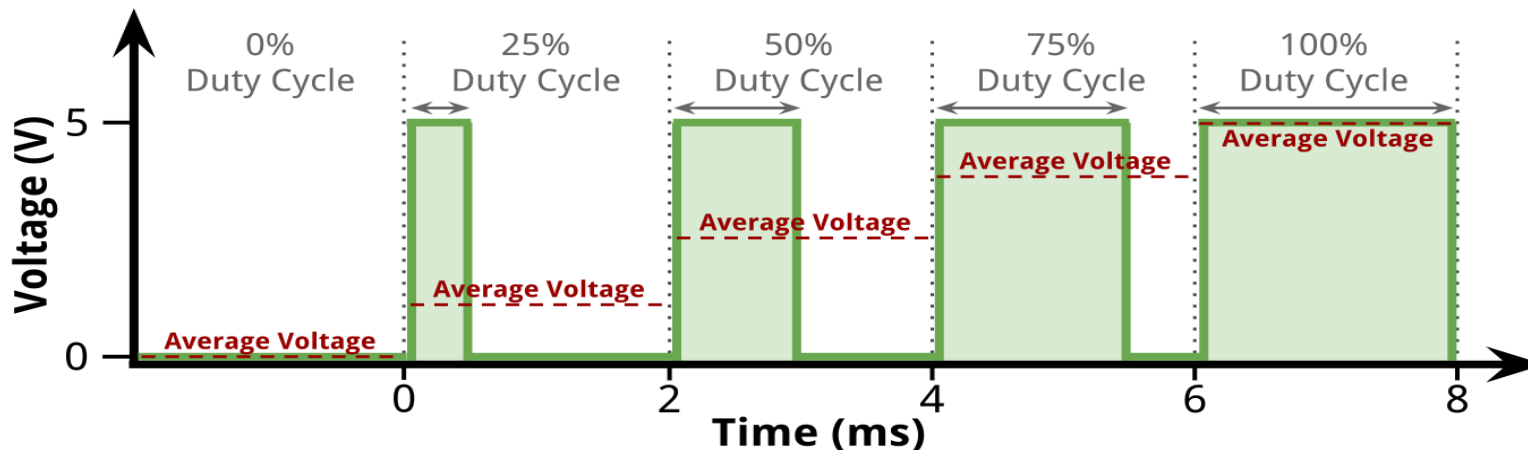


# Duty Cycle

- ❑ 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:  

$$\text{RMS} = \text{Amplitude} \sqrt{\text{Duty Cycle}}$$

## Pulse Width Modulation Duty Cycles



Note: 1 cycle = 2ms @ 500 Hz

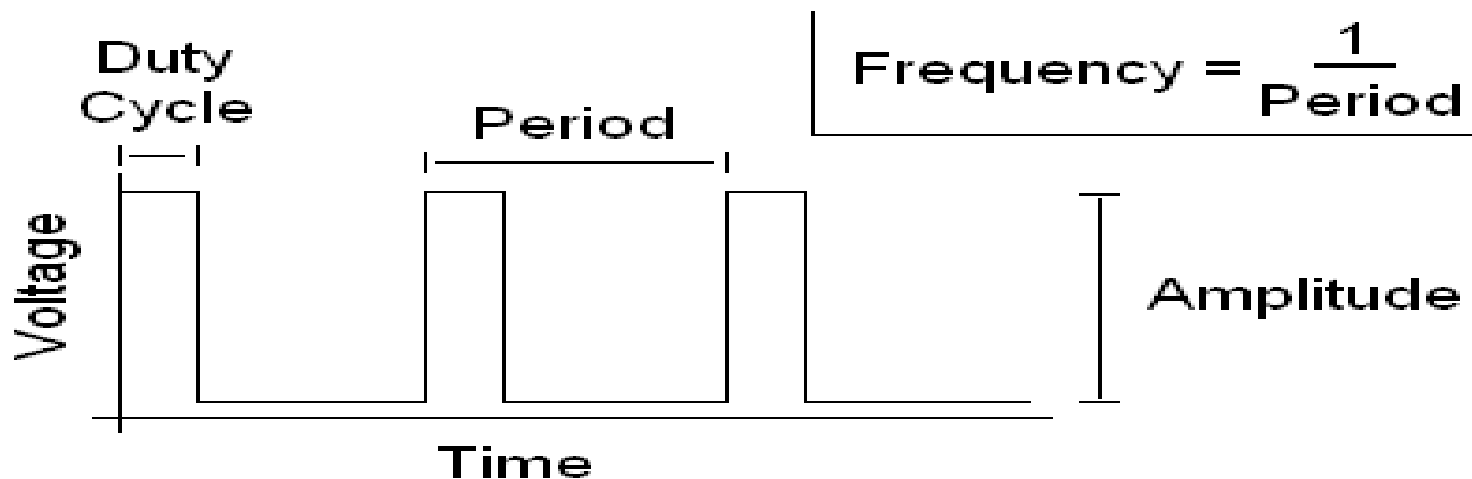
# PWM

## Important equations

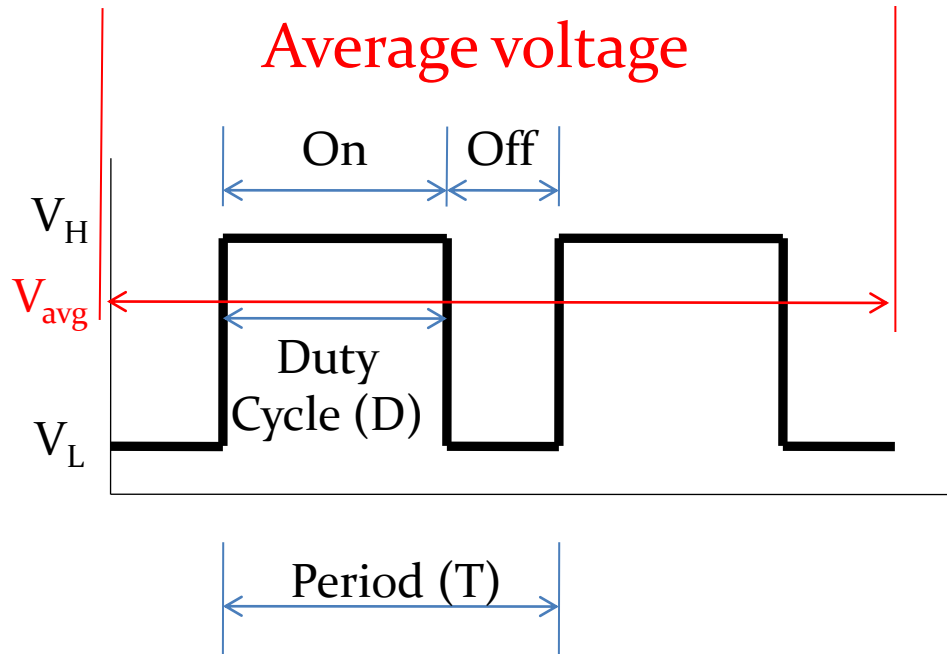
frequency = waves per second

Period =  $T_{\text{Total}}$  = seconds per wave =  $1/f$

duty cycle =  $\text{time on} / (\text{time on} + \text{time off})$



# 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:

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



# Problem statement

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

## Solution:

Frequency = 50 *HZ*

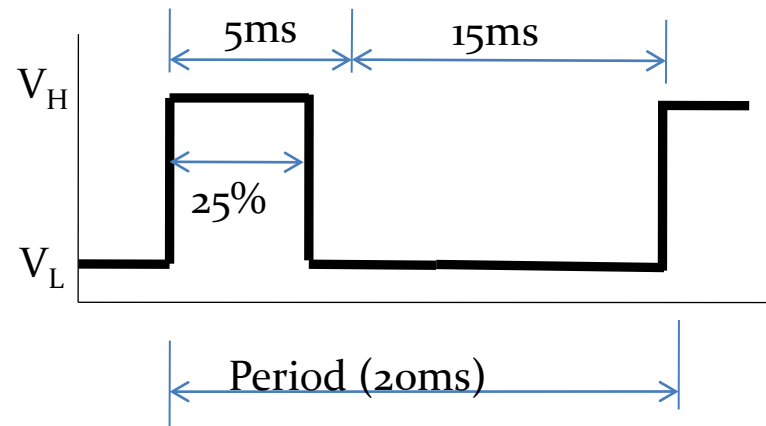
$$T = (T_{on} + T_{off}) = \frac{1}{50} = 20ms$$

$$\text{Duty cycle} = 25\% = \frac{T_{on}}{(T_{on} + T_{off})}$$

solving according to equation given above, we get

$$T_{on} = 5ms$$

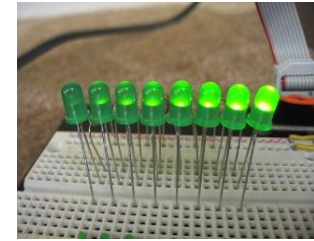
$$T_{off} = 15ms$$



# PWM Application

LED

We can control LED intensity



Buzzer

We can change the tone frequency



DC motor

We can control motor speed



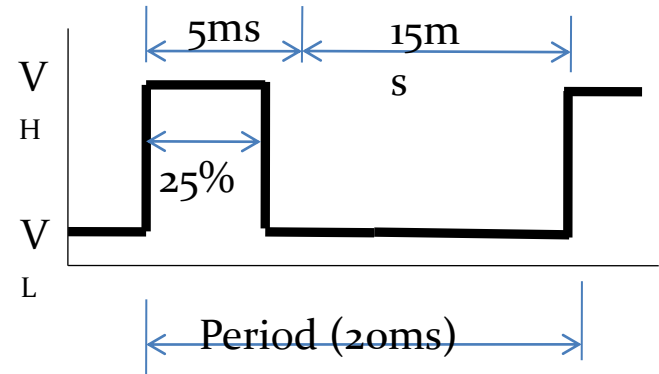
# PWM generation

**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  $T_{on} = 5ms$  and  $T_{off} = 15ms$
- ☐ we have a timer which over flow and fire an interrupt every 1ms .
- ☐ What can we do to generate this PWM signal?

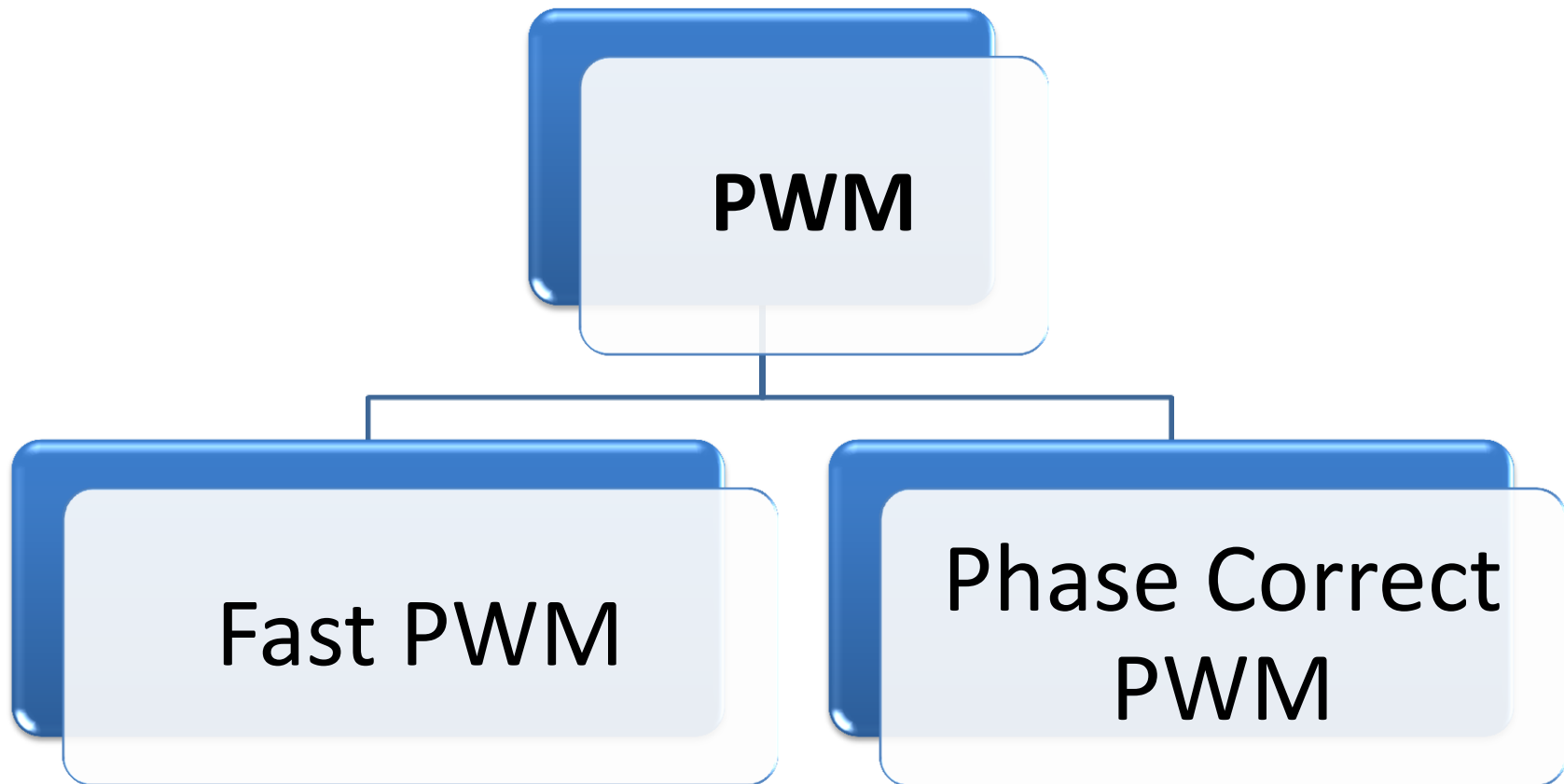


# PWM generation

```
/* 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;  
    }  
}
```

# PWM generation

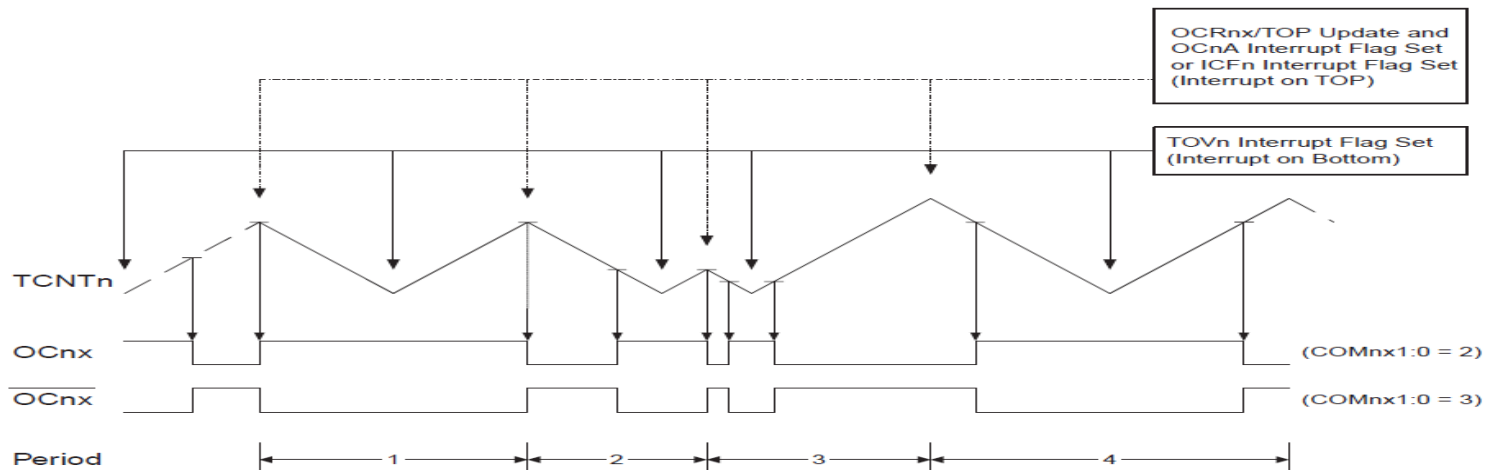
The AVR already has a PWM modes



# 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.

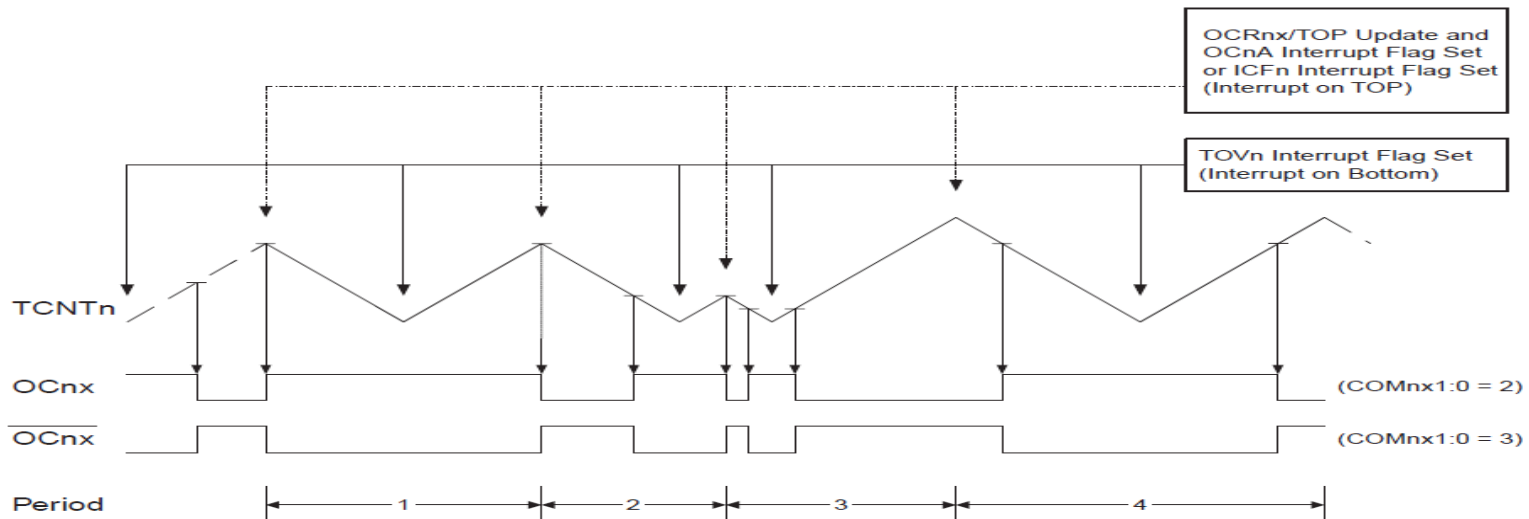
**Figure 47. Phase Correct PWM Mode, Timing Diagram**



## 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**

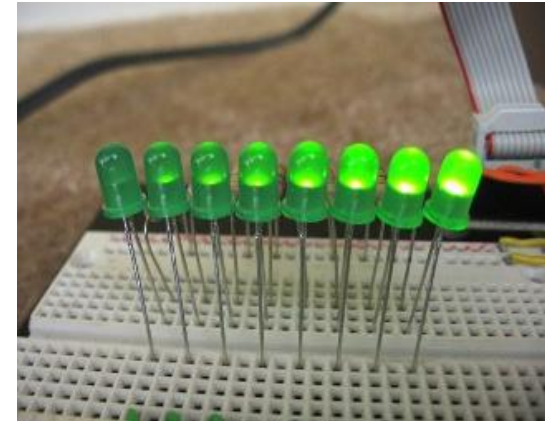


# Application

## lab 1 :

### Description :

Using a potentiometer, control the intensity of the LED. The potentiometer is connected to ADC pin and the LED is connected to PWM Pin, according to the value of the potentiometer, change the Duty Cycle of the PWM on the LED.

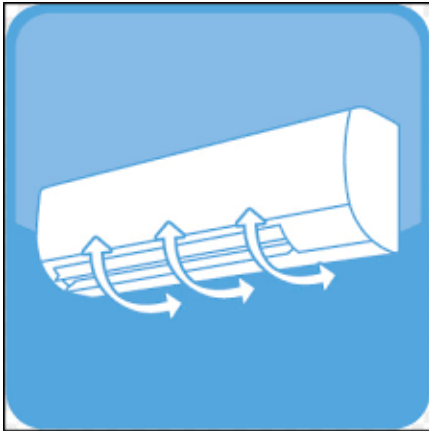




# Servo motor

**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 motors

## 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..



# How it works?

Servo motor is consisting of a regular dc motor connected to a gear box and a potentiometer with control circuit that give the feed back for angle position.

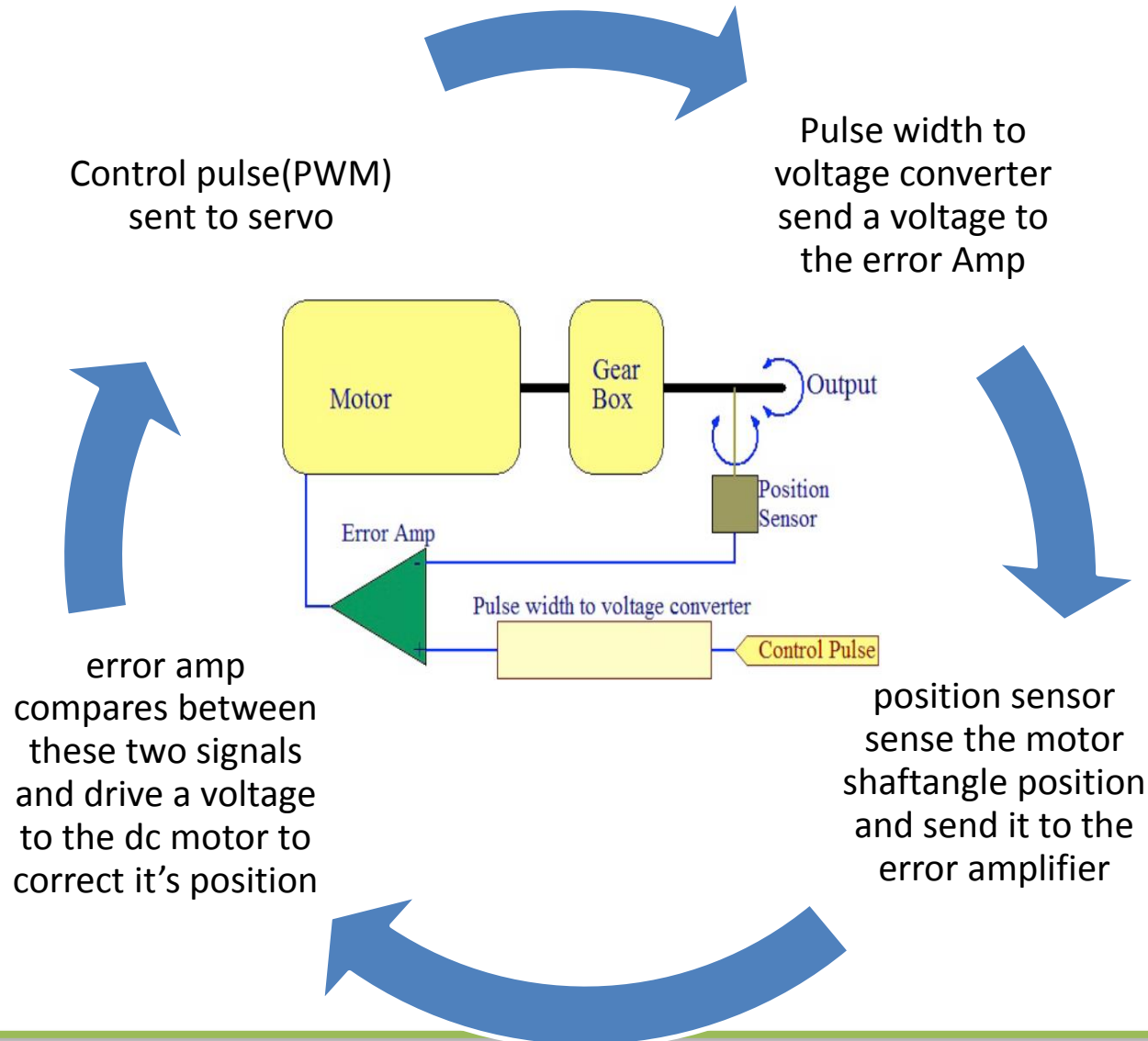
This control circuit is closed loop circuit (self correction).

Servo motors have their own language to send them your instructions .

This language is PWM " pulse width modulation"



# How it works?



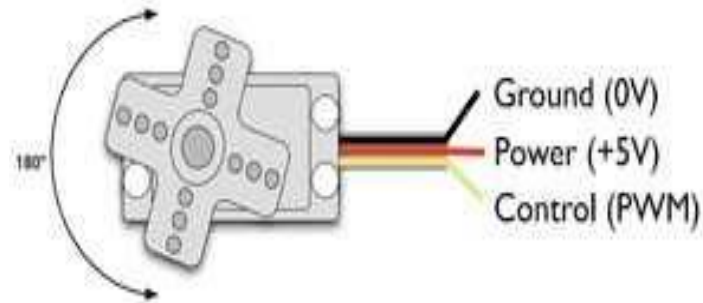
# How it works?

**Your servo have 3 wires :**

**Black wire** : GND (ground) !

**RED wire** : +5V

**Colored wire**: control signal

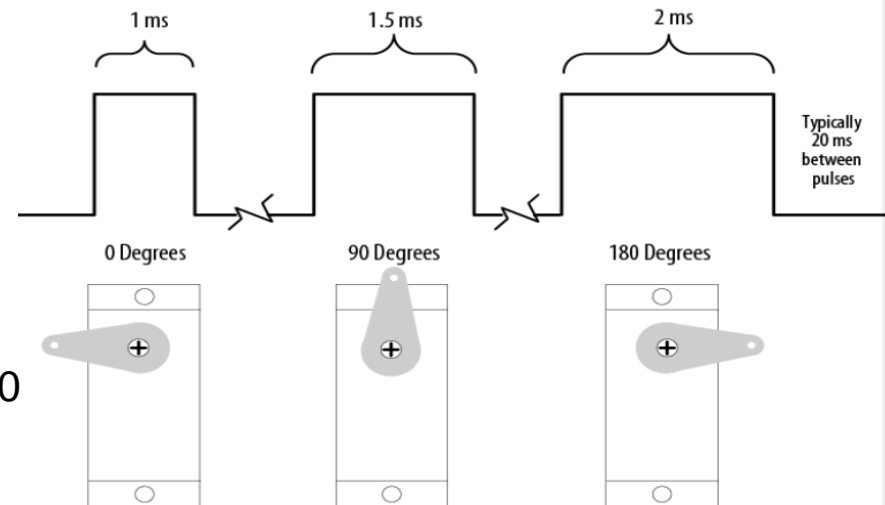


- ☐ The most common servos works at 50 HZ frequency.
- ☐ This means that the period is 20ms

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



# Application

## lab 2 :

### Description :

Using a potentiometer, make the servo motor shaft follows the potentiometer rotation. when you rotate the potentiometer right, the servo rotate right following the potentiometer. Same thing in the left side rotation.



The End ...



# Assignment

**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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