Pulse Width Modulation

Yogesh M Iggalore

PWM: Introduction

- Most frequently used peripheral in embedded applications
- PWM is employed in a wide variety of applications, ranging from measurement and communications to power control and conversion.
- PWM is a powerful technique for controlling analog circuits with a microcontroller’s digital outputs.
- By controlling analog circuits digitally, system costs and power consumption can be drastically reduced.
- By keeping the signal digital, noise effects are minimized. Noise can only affect a digital signal if it is strong enough to change a logical-1 to a logical-0, or vice versa

PWM - Duty Cycle

The duty cycle (the width of the signal) is modulated.

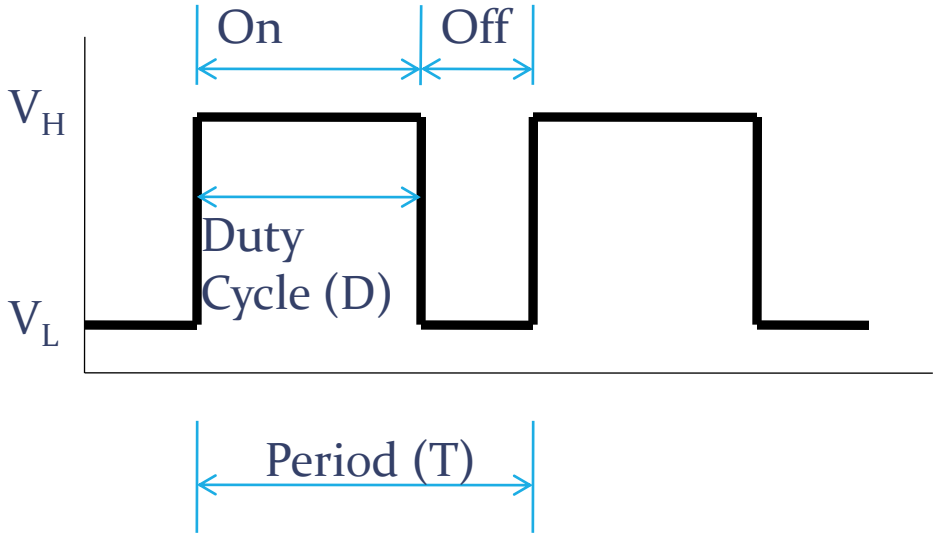
It is a percentage measurement of how long the signal stays on.

Duty Cycle is determined by:

$$Duty\ Cycle = \frac{On\ Time}{Period} \times 100\%$$

- Average signal can be found as

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



Usually, VL is taken as zero volts for simplicity.

PWM - Resolution

- PWM resolution = PWM clock ÷ PWM Switching Frequency

Case 1:

PWM clock = 3 MHz; PWM Switching Frequency = 23.44KHz

PWM Resolution = 3,000,000 ÷23437

= 128(2^ 7or 7 bit)

Case 2:

PWM clock = 3MHz; PWM Switching Frequency = 15.63KHz

PWM Resolution = 3,000,000 ÷15625

= 192(1.5x2^7or 7.5 bit)

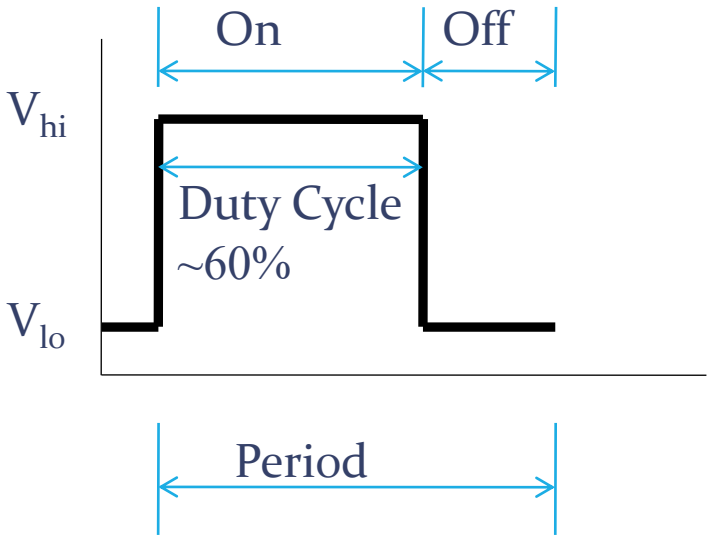
- If DC voltage is 5V DC, each bit represents:
  - 7 bit PWM resolution: 5VDC ÷128 = 39.06mV (Each step = 0.78%)
  - 7.5 bit PWM resolution: 5VDC ÷192 = 26.04mV (Each step = 0.52%)

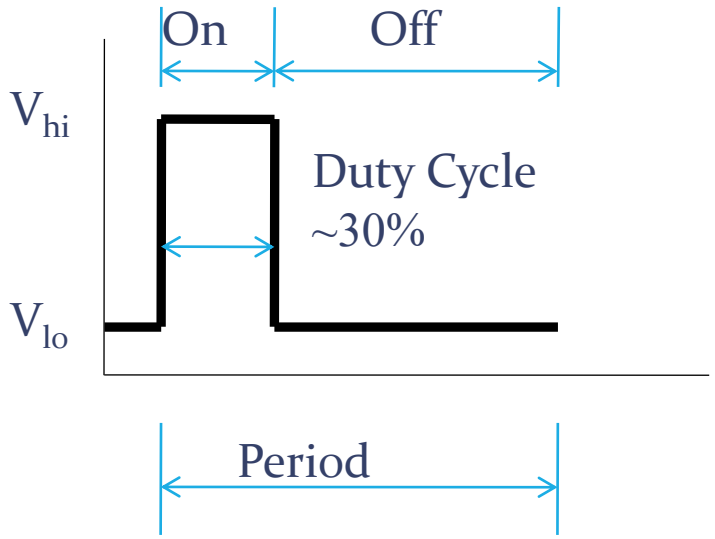
Case 2 yields higher PWM resolution, less Voltage variation per bit change. So the voltage ripple on output will be smaller.

Types of PWM – Left Aligned

Left edge is fixed with respect to period, the trailing edge is modulated

Signal changes when counter is equal to period register

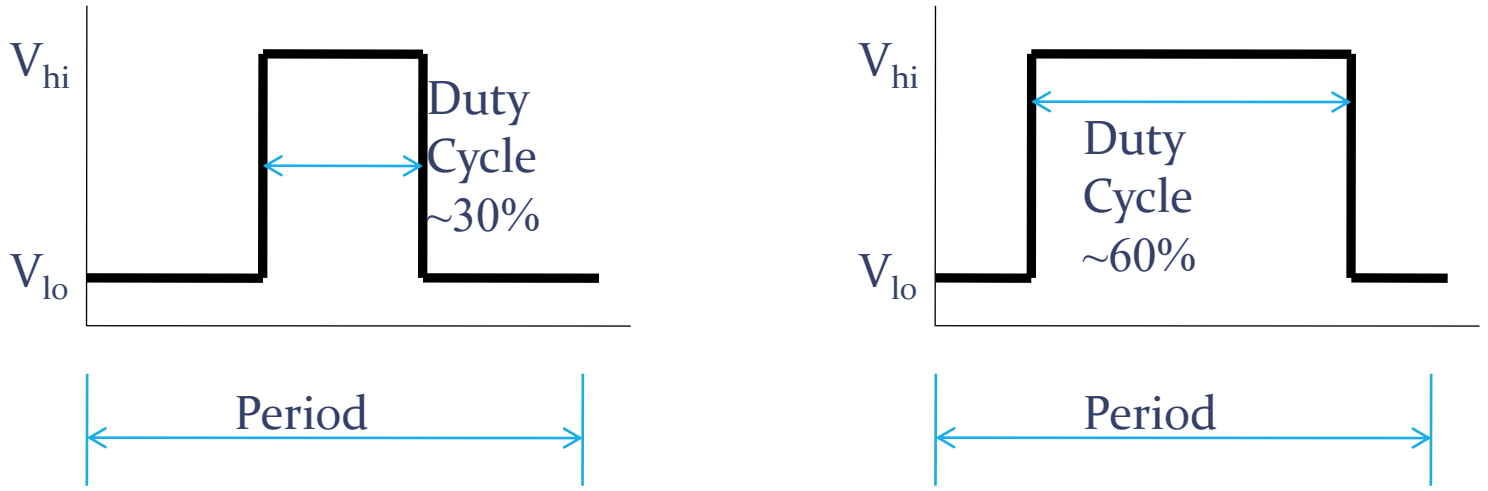




Types of PWM – Center Aligned

Center of signal is fixed with respect to period, both edges are modulated

In the center aligned mode, the PWM counter goes from a down-count to a up-count to down-count, etc.



PWM Applications

Telecommunications

DC motors

RC devices

Audio/video effects

Power delivery

Voltage regulation

Use as DAC

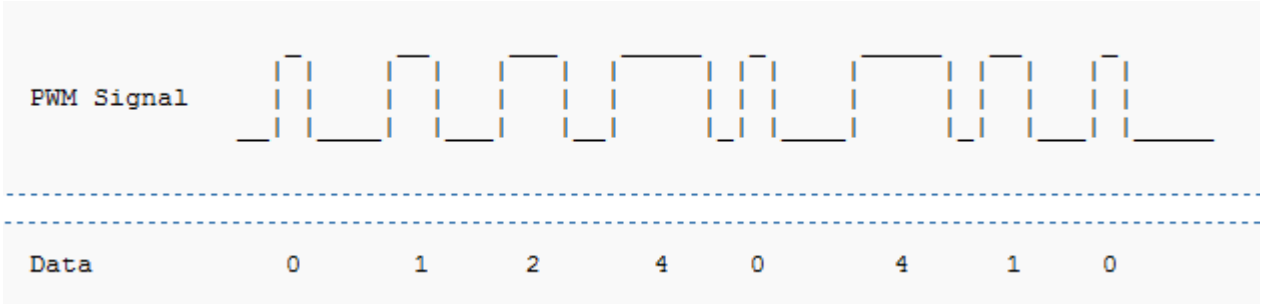
PWM Application- Telecommunications

Used in communication since a digital signal is more robust and less vulnerable to noise.

Effective at data transmission over long distance transmission lines

The widths of the pulses correspond to specific data values encoded at one end and decoded at the other.

Pulses of various lengths (the information itself) will be sent at regular intervals (the carrier frequency of the modulation).



PWM Application - DC Motors

Voltage supplied is directly proportional to the duty cycle

Ability to control the speed of the motor via the duty cycle

Example

Can be used in regulating room temperature. Sense the current temperature (using an analog-to-digital converte then automatically increase/decrease the fan's speed accordingly.

PWM Application-RC Devices

- Transmitters send PWM signals to the receivers on board of Radio controlled devices for specific control like speed, navigation.

PWM Application-Video devices

PWM dimming provides superior color quality in LED video display

PWM Applications-Audio devices

Used in audio amplifiers to generate output signals for cellphone speakers to high-power stereo systems

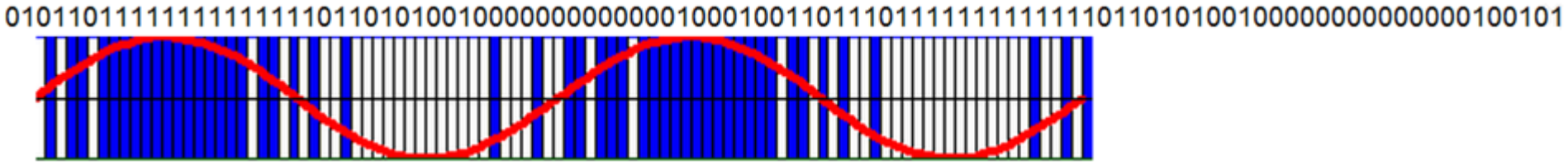
Produce less heat than traditional analog amplifiers

Saving energy. Critical for hand held electronics.

Gives a sound effect similar to chorus when used in audio circuit.

Pulse-density modulation, or PDM, is a form of modulation used to represent an analog signal with digital data. In a PDM signal, it is the relative density of the pulses that corresponds to the analog signal's amplitude. PWM is the special case of PDM where all the pulses corresponding to one sample are contiguous in the digital signal.

Two periods of a sine wave would appear as shown below:



1s represented by blue, 0s represented by white, overlaid with the sine wave.

In pulse-*density* modulation, a high *density* of 1s occurs at the peaks of the sine wave, while a low *density* of 1s occurs at the troughs of the sine wave.

PWM Applications - Power delivery

Effective at data transmission over long distance transmission line

Power transfer: PWM used to reduce the total power given to a load without relying on resistive losses

- Variable-speed fan controllers for computers
- Light dimmers
- In electric cookers, continuously-variable power is applied to the heating elements such as the hob or the grill using a simmer start that employs PWM to vary duty cycle
- PWM-controlled brake- The output of a PWM controller could be connected to a switch between the supply and the brake. To produce more stopping power, the software need only increase the duty cycle of the PWM output. If a specific amount of braking pressure is desired, measurements would need to be taken to determine the mathematical relationship between duty cycle and pressure

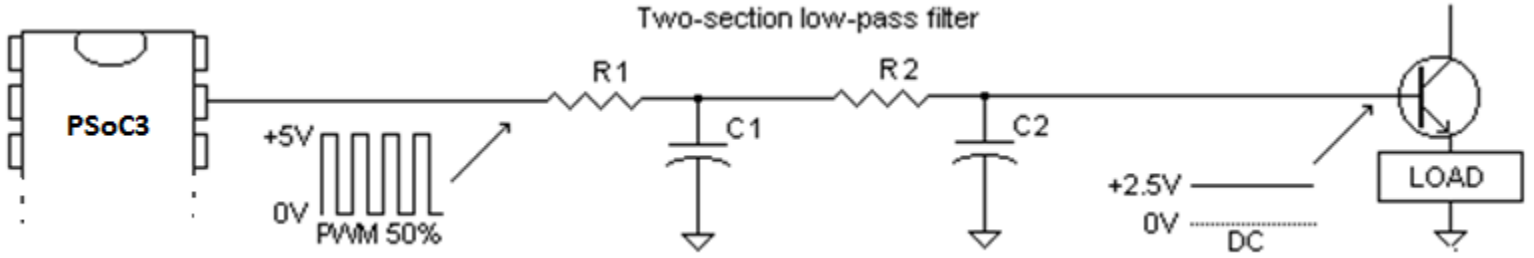
PWM Application-Voltage Regulation

- PWM is also used in efficient voltage regulators like SMPS. By switching voltage to the load with the appropriate duty cycle, the output will approximate a voltage at the desired level. The switching noise is usually filtered with an inductor and a capacitor

PWM Application- As DAC

Any shape waveform can be created

PWM frequency should be much higher than the frequency of waveform generated



Choosing PWM Frequency

Application dependent.

Not too low:

- Audible frequencies
- 10 Times higher than control system frequency

Not too high:

- Transistors generate more heat at higher frequencies
- Some loads will not respond at higher frequencies

PWM – Advantages & Disadvantages

Advantages

- Average value proportional to duty cycle, D
- Low power used in transistors used to switch the signal
- Fast switching possible due to MOSFETS and power transistors at speeds in excess of 100 kHz
- Digital signal is resistant to noise
- Less heat dissipated versus using resistors for intermediate voltage values

Disadvantages

- Cost
- Complexity of circuit
- Radio Frequency Interference
- Voltage spikes
- Electromagnetic noise