Islamic University of Technology

EEE 4483
Digital Electronics & Pulse Techniques

Lecture- 8

Pulse Width Modulation

- Introduction and definitions
- Types of PWM
- Methods of generation
- Characteristics of PWM
- Applications and examples

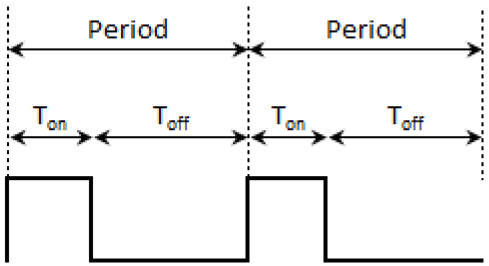
Duty Cycle : Recap

In general terms duty cycle means proportion of time for which device is operated. In terms of square wave signal it defines the percentage of time for which signal is at logic high level. For square wave it can be calculated as (high time / (high time + low time))

Duty cycle is the ratio of time a load or circuit is **ON** compared to the time the load or circuit is **OFF**.

Duty cycle, sometimes called "duty factor," is expressed as a percentage of **ON** time. A 60% duty cycle is a signal that is **ON** 60% of the time and **OFF** the other 40%

Duty cycle of 50% means that the low time and high time of the signal is same.

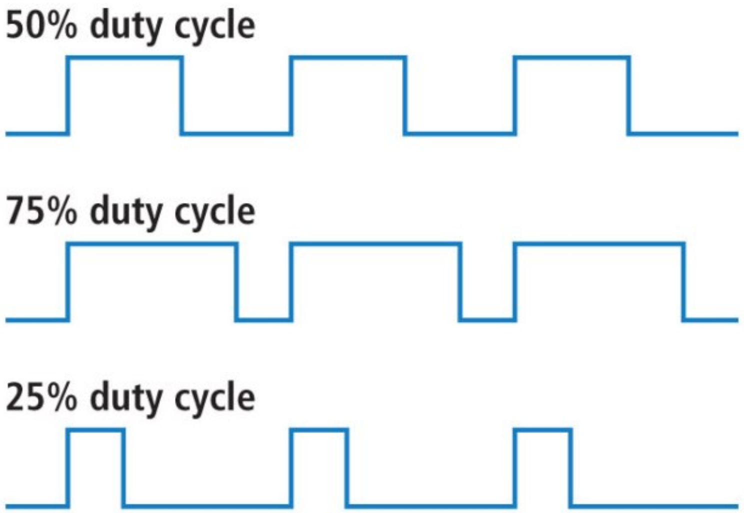


Period = 1 / Frequency

Period = $T_{on} + T_{off}$

Duty Cycle = $T_{on} / (T_{on} + T_{off})$ * 100

(On Percentage)



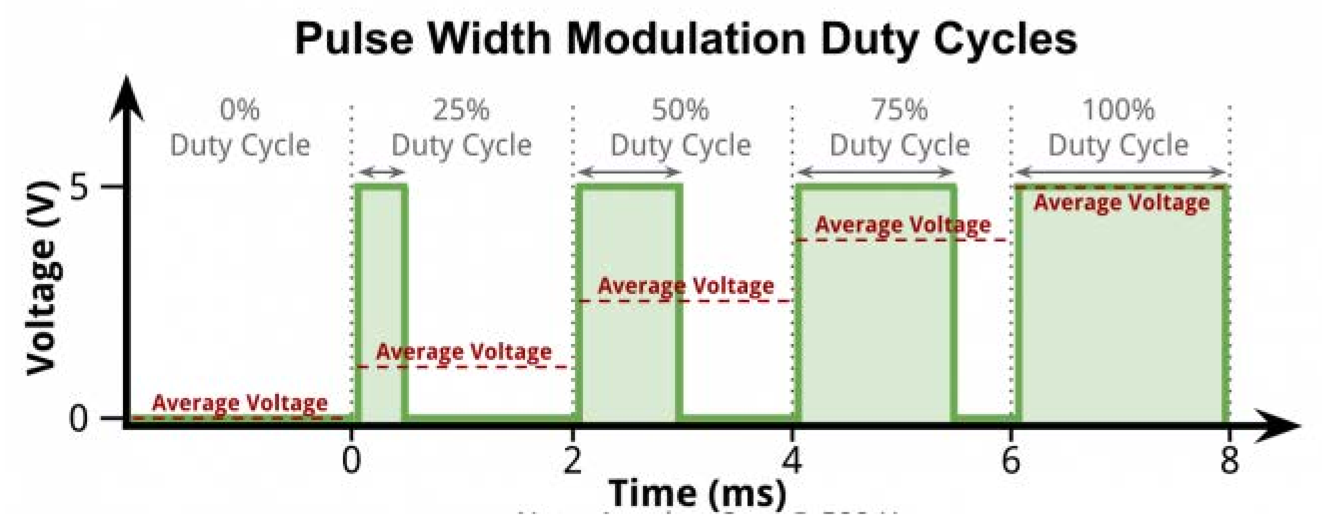
What is it (PWM)?

- Output signal alternates between on and off within specified period
- Controls power received by a device
- The voltage seen by the load is directly proportional to the source voltage

What is it (PWM)? : continued ..

A Pulse Width Modulation (PWM) Signal is a method for generating an analog signal using a digital source. A PWM signal consists of two main components that define its behavior: a duty cycle and a frequency. The duty cycle describes the amount of time the signal is in a high (on) state as a percentage of the total time of it takes to complete one cycle. The frequency determines how fast the PWM completes a cycle (*i.e.* 1000 Hz would be 1000 cycles per second), and therefore how fast it switches between high and low states. By cycling a digital signal off and on at a fast enough rate, and with a certain duty cycle, the output will appear to behave like a constant voltage analog signal when providing power to devices.

The Pulse Width Modulation (PWM) is a technique which is characterized by the generation of constant amplitude pulse by modulating the pulse duration by modulating the duty cycle.



What is it (PWM)? : self-study reading

An example would be to apply full voltage to a motor or lamp for fractions of a second or pulse the voltage to the motor at intervals that made the motor or lamp do what you wanted it to do. In reality, the voltage is being applied and then removed many times in an interval, but what you experience is an analog-like response. The fan and its motor do not stop instantly due to inertia, and so by the time you re-apply power it has only slowed a bit. Therefore, you do not experience an abrupt stop in power if a motor is driven by PWM. The length of time that a pulse is in a given state (high/low) is the “width” of a pulse wave.

A device that is driven by PWM ends up behaving like the average of the pulses. The average voltage level can be a steady voltage or a moving target (dynamic/changing over time). To simplify the example, let’s assume that your PWM-driven fan has a high-level voltage of 24 volts. If the pulse is driven high **50%** of the time, we call this a **50%** duty cycle.

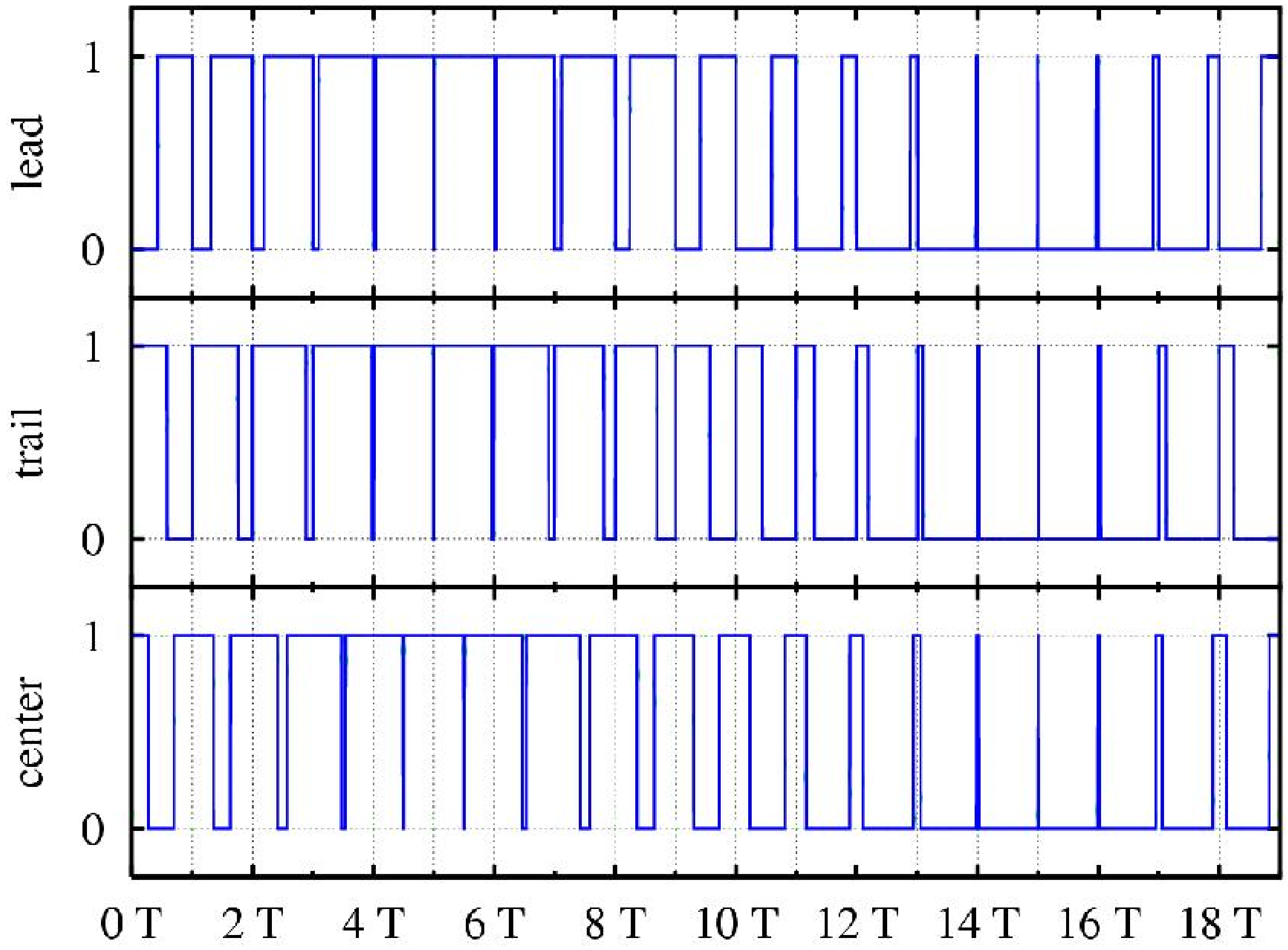
Continuing the fan-motor example, if we know that the high voltage is 24 V, the low is 0 V, and the duty cycle is **50%**, then we can determine the average voltage by multiplying the duty cycle by the pulse’s high level. If you want the motor to go faster, you can drive the PWM output to a higher duty cycle. The higher the frequency of high pulses, the higher the average voltage and the faster the fan motor will spin.

Duty Cycle x High Voltage Level = Average Voltage

Types of Pulse Width

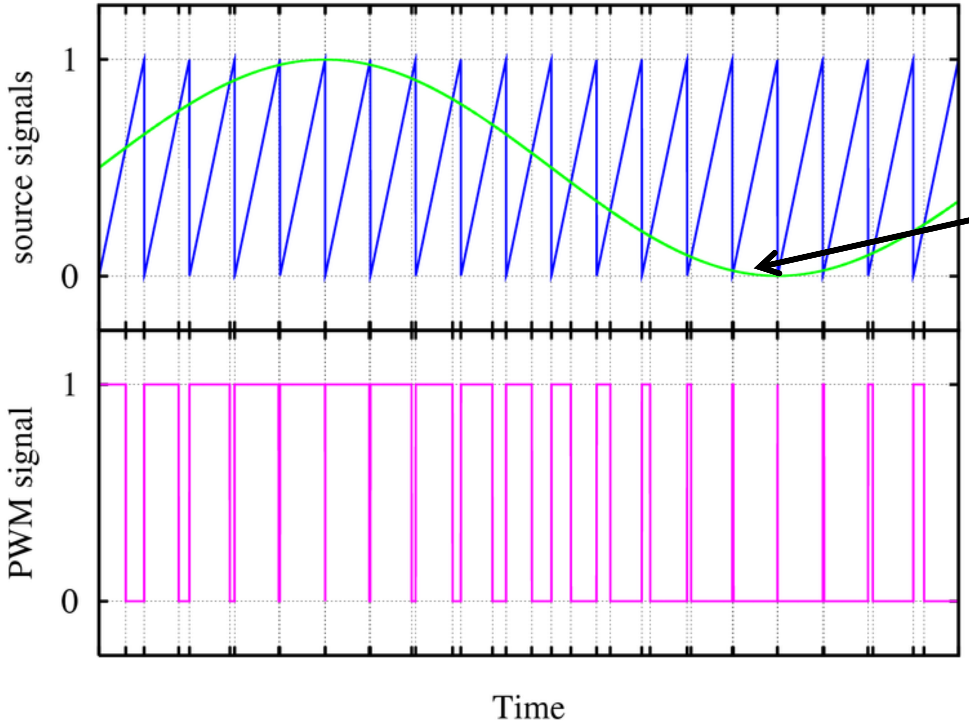
- Pulse Center Fixed, edges modulated
- Leading Edge Fixed, tailing edge modulated
- Tailing Edge Fixed, leading edge modulated
- Pulse Width Constant, period modulated

Types of Pulse Width : continued ..



Analog Generation of PWM

Analog PWM signals can be made by combining a saw- tooth waveform and a sinusoid



PWM output is formed by the intersection of the saw-tooth wave and sinusoid

Digital Methods of Generating PWM

- **Digital**: Counter used to handle transition
- **Delta** : used to find the PWM at a certain limit
- **Delta Sigma**: used to find the PWM but has advantage of reducing optimization noise

Applications

PWM signals are used for a wide variety of control applications. Their main use is for controlling DC motors but it can also be used to control valves, pumps, hydraulics, and other mechanical parts. The frequency that the PWM signal needs to be set at will be dependent on the application and the response time of the system that is being powered. Below are a few applications and some typical minimum PWM frequencies required:

- Heating elements or systems with slow response times: 10-100 Hz or higher
- DC electric motors: 5-10 kHz or higher
- Power supplies or audio amplifiers: 20-200 kHz or higher