Pulse Modulation

Pulse Modulation is a technique in which the signal is transmitted with the information by pulses. This is divided into Analog Pulse Modulation and Digital Pulse Modulation. (**Pulse modulation** is a type of modulation in which the signal is transmitted in the form of pulses. It can be used to transmit analogue information).

Pulse modulation can be classified into two major types

1- Pulse Analog Modulation

a) Pulse Amplitude Modulation (PAM)
b) Pulse Time Modulation (PTM)
i. Pulse Width Modulation (PWM)
ii. Pulse Position Modulation (PPM)

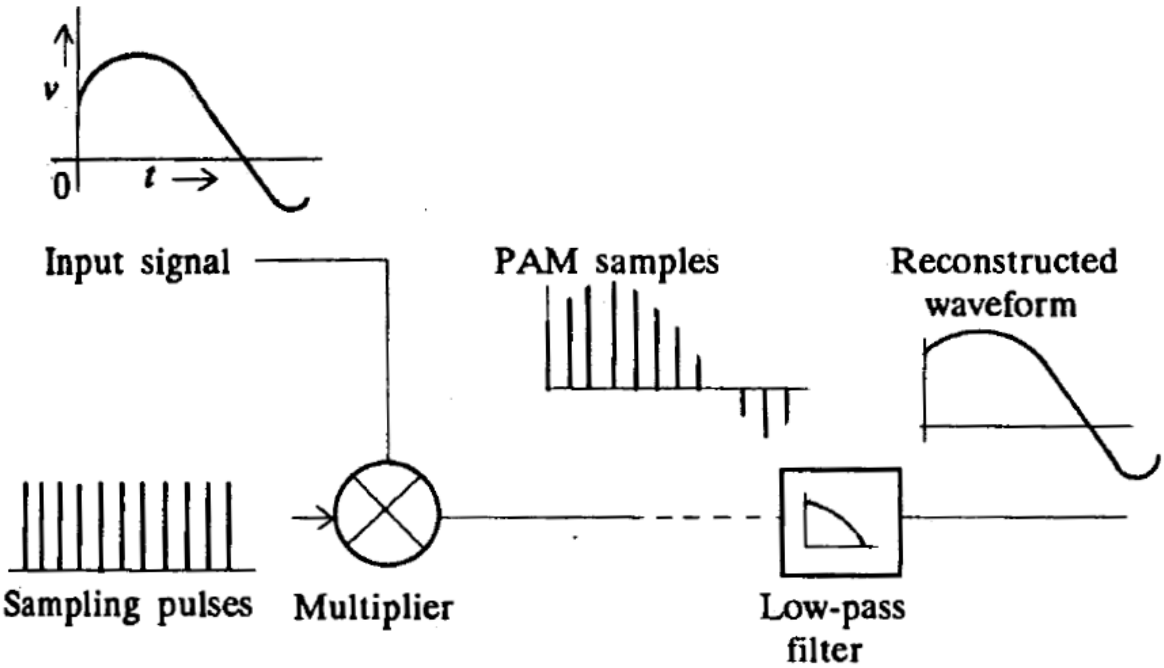
2- Pulse Digital Modulation

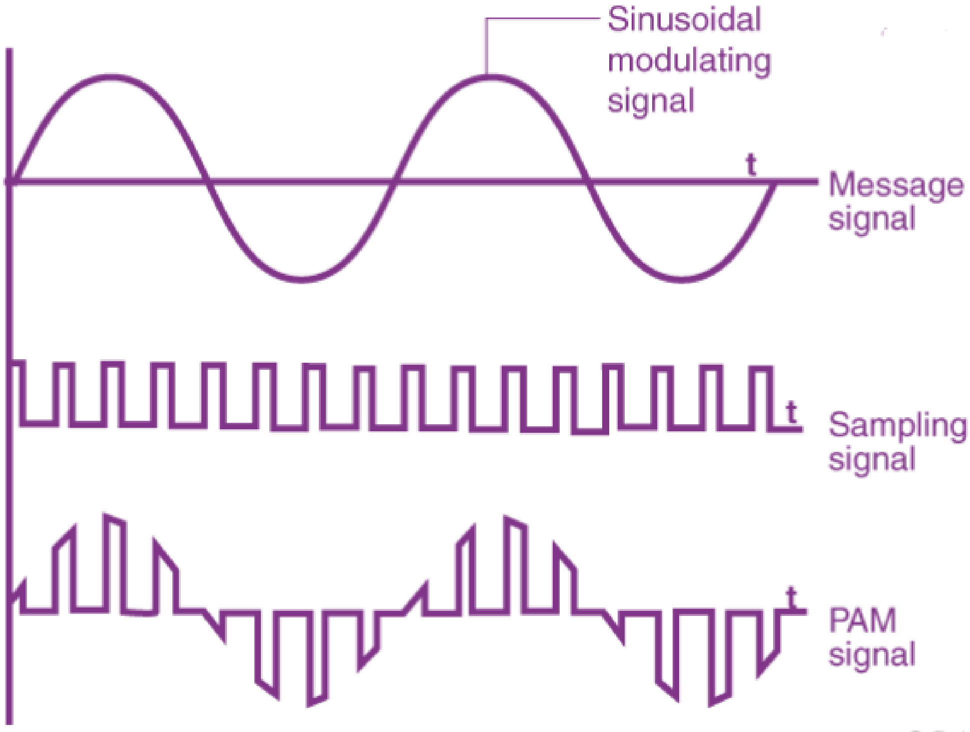
a) Pulse Code Modulation (PCM)
b) Delta Modulation
c) Differential Pulse Code Modulation (DPCM)

1-Pulse Analog Modulation

a) Pulse Amplitude Modulation (PAM)

Pulse amplitude modulation is a technique in which the amplitude of each pulse is controlled by the instantaneous amplitude of the modulation signal. It is a modulation system in which the signal is sampled at regular intervals and each sample is made proportional to the amplitude of the signal at the instant of sampling.





SAMPLING THEOREM

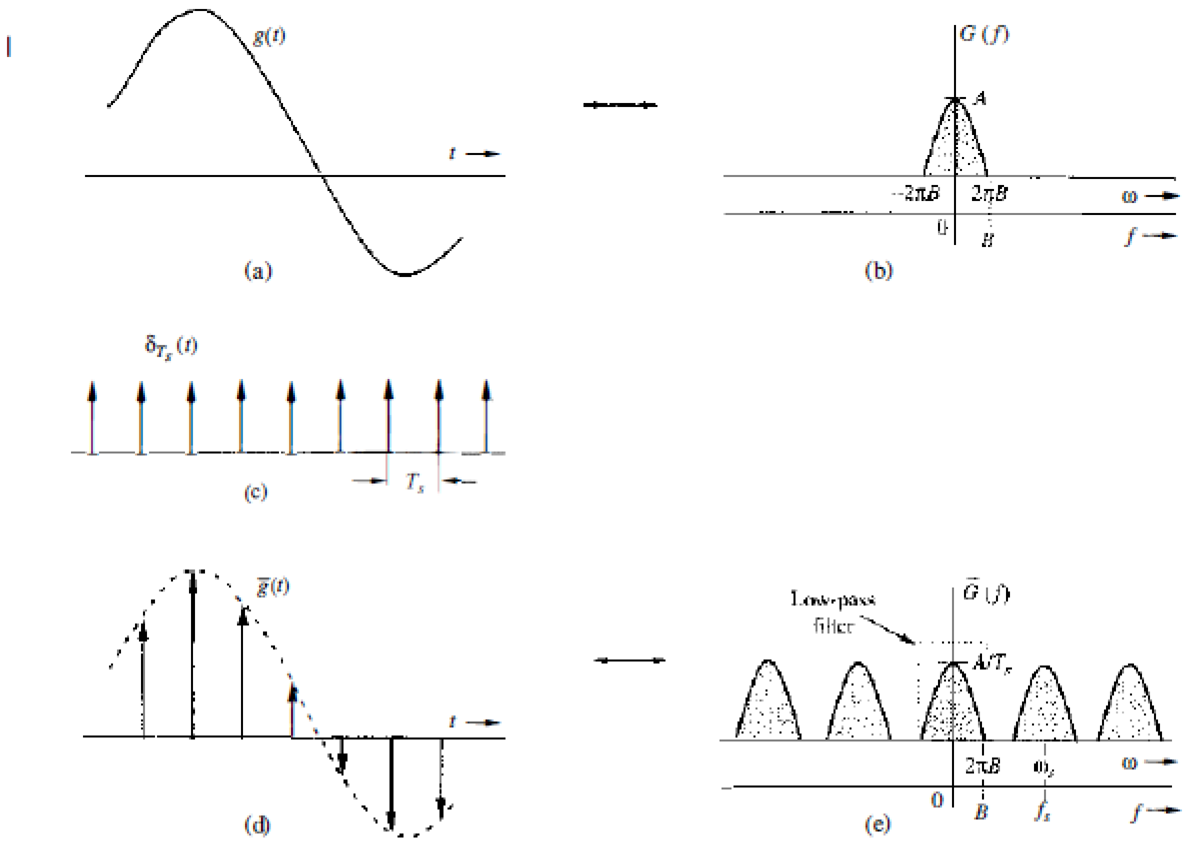
Sampling is the process of converting analog signal into a discrete signal or making an analog or continuous signal to occur at a particular interval of time, this phenomenon is known as sampling.

We first show that a signal $g(t)$ whose spectrum is band-limited to $B\ Hz$ can be reconstructed exactly (without any error) from its discrete time samples taken uniformly at a rate of R sample per second. The condition is that $R \geq 2B$.

In other word the minimum sampling frequency for perfect signal recovery is $f_s = 2B$

NYQUIST RATE (R):

Nyquist rate is the rate at which sampling of a signal is done so that overlapping of frequency does not take place. When the sampling rate become exactly equal to $2\ B$ samples per second, then the specific rate is known as Nyquist rate. It is also known as the minimum sampling rate and given by: $f_s = 2\ B$, $T_s = \frac{1}{f_s}$, $T_s = \frac{1}{2\ B}$,



$$g(t) = B\ Hz$$

Sampling $g(t)$ at rate $f_s\ Hz$ mean that we take f_s uniform samples per second. This uniform sampling can be accomplished by multiple train of impulse $\delta_{Ts}(t)$ shown in Fig. c. consisting of unit impulses repeating periodically every T_s, seconds, where

$\boldsymbol{T_s = \frac{1}{f_s}}$, The results in the sampled signal $\overline{\boldsymbol{g}}(\boldsymbol{t})$ shown in Fig. d, The sampled signal consist of impulses spaced every T_s, seconds (the sampling interval), The nth impulse. located at $t = nT_s$

$$\boldsymbol{T_s = \frac{1}{f_s}}$$

$$\boldsymbol{T_s} = \text{sampling interval} = \textbf{Nyquist interval}$$

$$t = nT_s$$

$$\boldsymbol{g}(\boldsymbol{t}) = \boldsymbol{g}(nT_s)$$

$$\overline{\boldsymbol{g}}(\boldsymbol{t}) = \boldsymbol{g}(\boldsymbol{t})\boldsymbol{\delta_{Ts}}(\boldsymbol{t}) = \sum_{\boldsymbol{n}} \boldsymbol{g}(nT_s)\boldsymbol{\delta_{Ts}}(\boldsymbol{t} - nT_s)$$

Because the impulse train $\boldsymbol{\delta_{Ts}}(\boldsymbol{t})$ is a periodic signal of period T_s. It can be expressed as an exponential Fourier series.

$$\boldsymbol{\delta_{Ts}}(\boldsymbol{t}) = \frac{\boldsymbol{1}}{\boldsymbol{T_s}}\sum_{\boldsymbol{n=-\infty}}^{\infty} \boldsymbol{e^{jnw_s t}} \qquad w_s = \frac{2\pi}{T_s} = 2\pi f_s$$

$$\delta_{Ts}(t) = \frac{1}{T_s}[1 + e^{jw_s t} + e^{-jw_s t} + e^{j2w_s t} + e^{-j2w_s t} + e^{j3w_s t} + e^{-j3w_s t} + \cdots]$$

$$e^{jw_s t} + e^{-jw_s t} = 2\cos(w_s t)$$

$$\delta_{Ts}(t) = \frac{1}{T_s}[1 + 2\cos(w_s t) + 2\cos(2\,w_s t) + 2\cos(3\,w_s t) + \cdots]$$

$$\bar{g}(t) = g(t)\delta_{Ts}(t) = \frac{1}{T_s}\sum_{n=-\infty}^{\infty} g(t)e^{jnw_s t}$$

$$\overline{\boldsymbol{g}}(\boldsymbol{t}) = g(t)\delta_{Ts}(t) = \frac{1}{T_s}[g(t) + 2g(t)\cos(w_s t) + 2\,g(t)\cos(2\,w_s t) + \cdots]$$

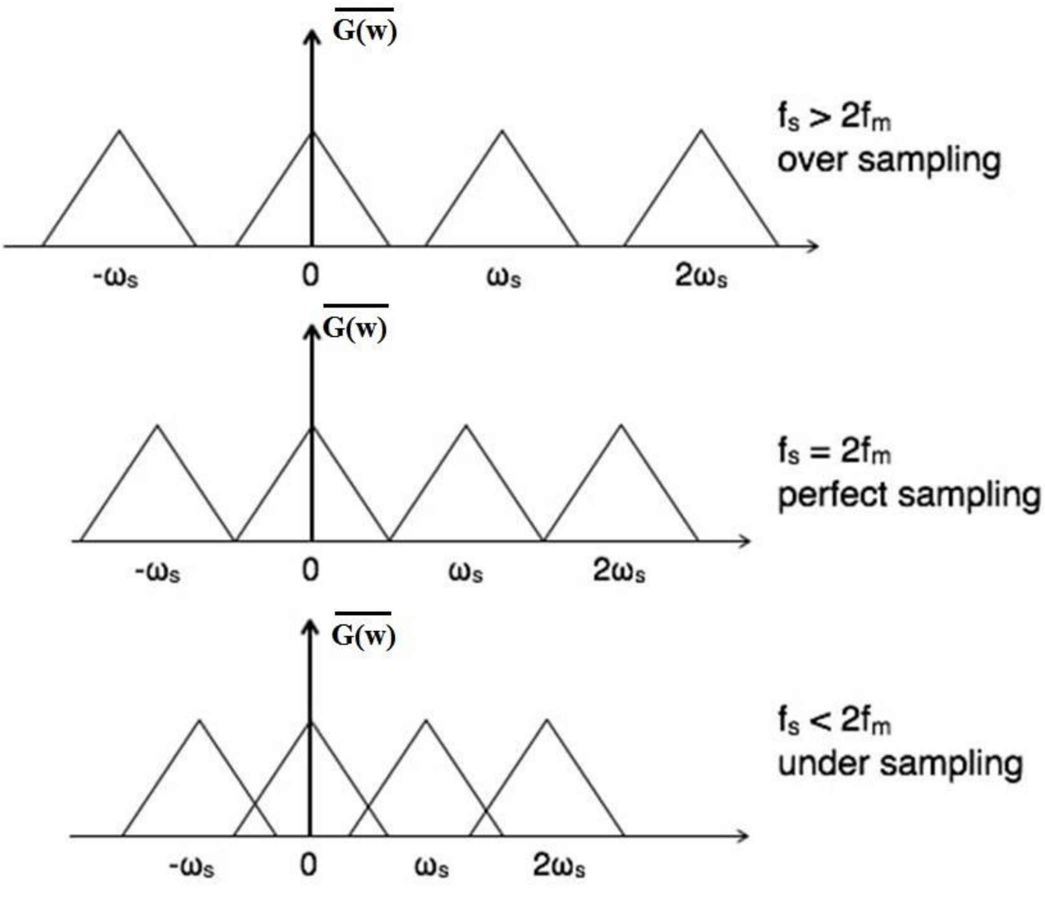
$$\bar{G}(w) = \frac{1}{T_s}\sum_{n=-\infty}^{\infty} G(w - nw_s)$$

Thus, as long as the sampling frequency $\boldsymbol{f_s}$ is greater than twice the signal bandwidth B (in hertz), $G(f)$ will consist of nonoverlapping repetitions of $G(f)$. When this is true, Fig.e shows that $\boldsymbol{g}(\boldsymbol{t})$ can be recovered from its samples $\boldsymbol{g}(\boldsymbol{t})$ by passing the sampled signal $\boldsymbol{g}(\boldsymbol{t})$ through an ideal low-pass filter of bandwidth $\boldsymbol{B}\,Hz$. The minimum sampling rate $\boldsymbol{f_s = 2B}$ required to recover $\boldsymbol{g}(\boldsymbol{t})$ from its samples $\boldsymbol{g}(\boldsymbol{t})$ is called the ***Nyquist rate*** for $\boldsymbol{g}(\boldsymbol{t})$, and the corresponding sampling interval $\boldsymbol{T_s = \frac{1}{2B}}$ is called the ***Nyquist interval*** for the low-pass signal $\boldsymbol{g}(\boldsymbol{t})$ **.**

Effect of Under Sampling: ALIASING

It is the effect in which overlapping of a frequency components takes place at the frequency higher than Nyquist rate. Signal loss may occur due to aliasing effect. We can say that aliasing is the phenomena in which a high frequency component in the frequency spectrum of a signal takes identity of a lower frequency component in the same spectrum of the sampled signal.

Because of overlapping due to process of aliasing, sometimes it is not possible to overcome the sampled signal $\bar{g}(t)$ from the sampled signal $g(t)$ by applying the process of low pass filtering since the spectral components in the overlap regions . hence this causes the signal to destroy.

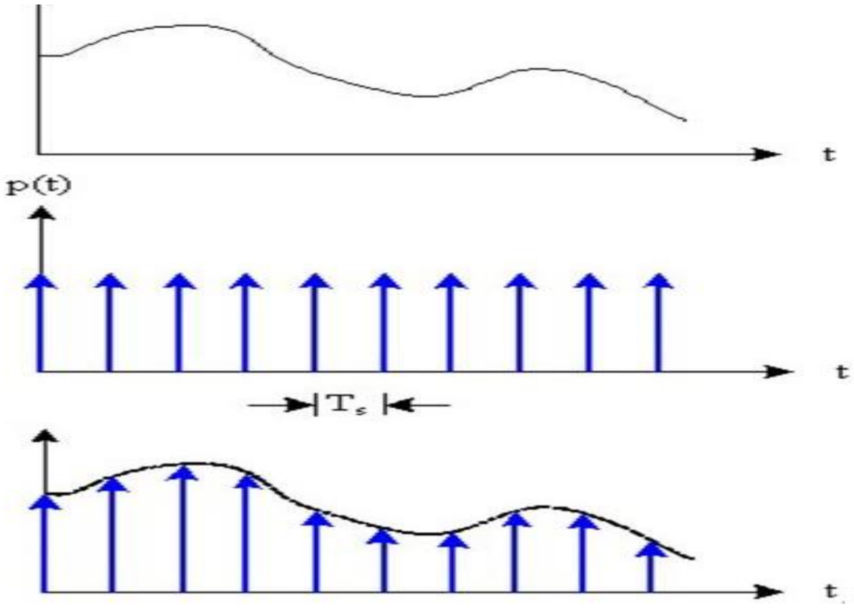


There are three types of sampling techniques for transmitting a signal using PAM. They are:

1. Ideal sampling PAM
2. Flat top sampling PAM
3. Natural sampling PAM

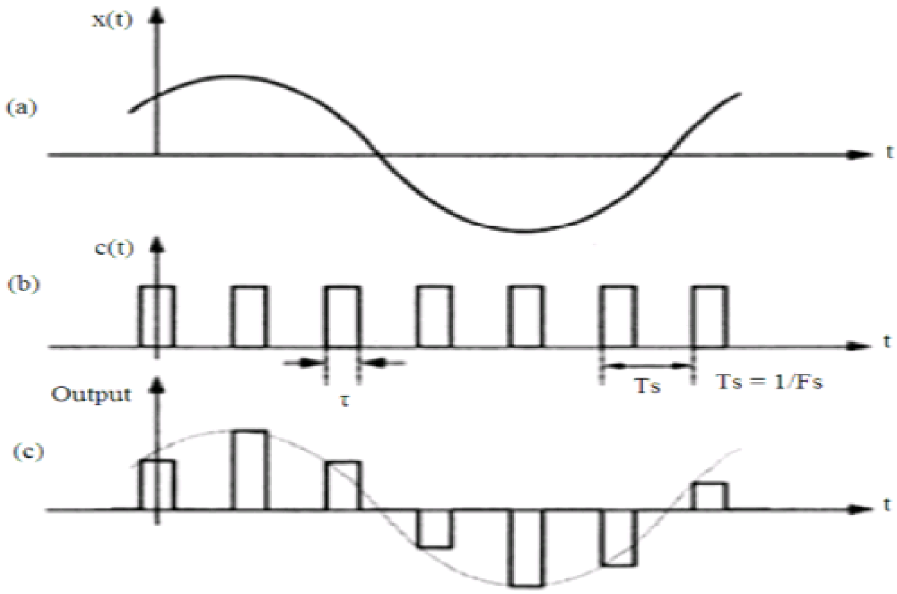
1- Ideal Sampling PAM

Ideal Sampling is also known as Instantaneous sampling or Impulse Sampling. Train of impulse is used as a carrier signal for ideal sampling. In this sampling technique the sampling function is a train of impulses and the principle used is known as multiplication principle.



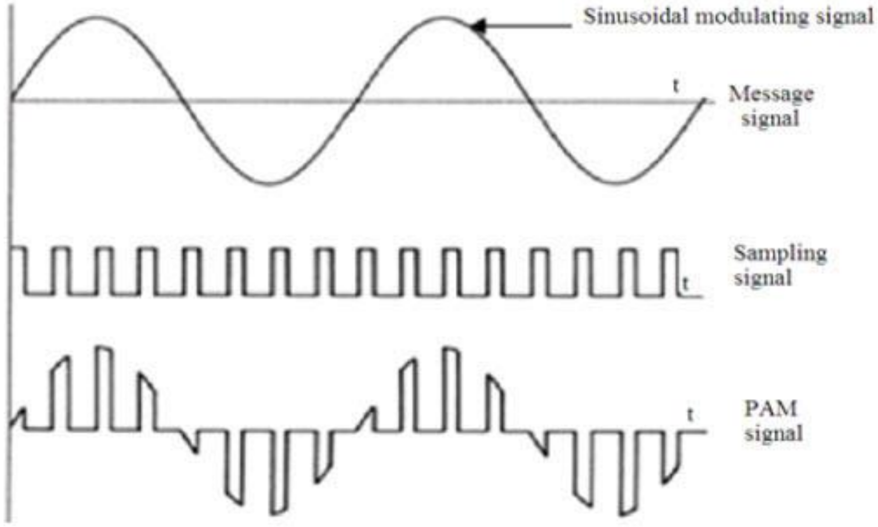
2- Flat Top Sampling PAM

The amplitude of each pulse is directly proportional to modulating signal amplitude at the time of pulse occurrence. The amplitude of the signal cannot be changed with respect to the analog signal to be sampled. The tops of the amplitude remain flat.



3- Natural Sampling PAM

The amplitude of each pulse is directly proportional to modulating signal amplitude at the time of pulse occurrence. Then follows the amplitude of the pulse for the rest of the half-cycle.



Applications of PAM

a) It is used in Ethernet communication.
b) It is used in many micro-controllers for generating control signals.
c) It is used as an electronic driver for LED lighting.
d) This modulation technique is mostly used in digital data transmission & applications changed by PCM &PPM.

Advantage of PAM

a) Simple modulation and demodulation .
b) Transmitter and receiver very simple and easy to construct .

Disadvantage of PAM

a) Wide bandwidth require $B_{PAM} \geq \frac{1}{2\tau}$ $\quad \tau$ *is width pulse.*
b) High noise interference .
c) Vary the peak power required for transmitter.