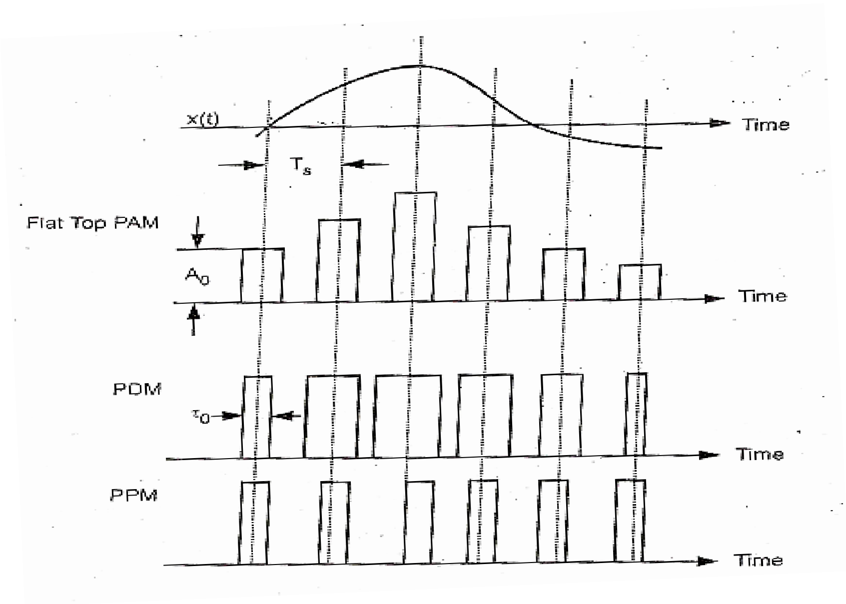
Lecture three

Objective of Lecture:

- Pulse Amplitude Modulation (PAM),
- Pulse width and Pulse Position Modulation (PWM & PPM),
- Time Division Multiplexing (TDM)
- S/N in analog pulse modulation

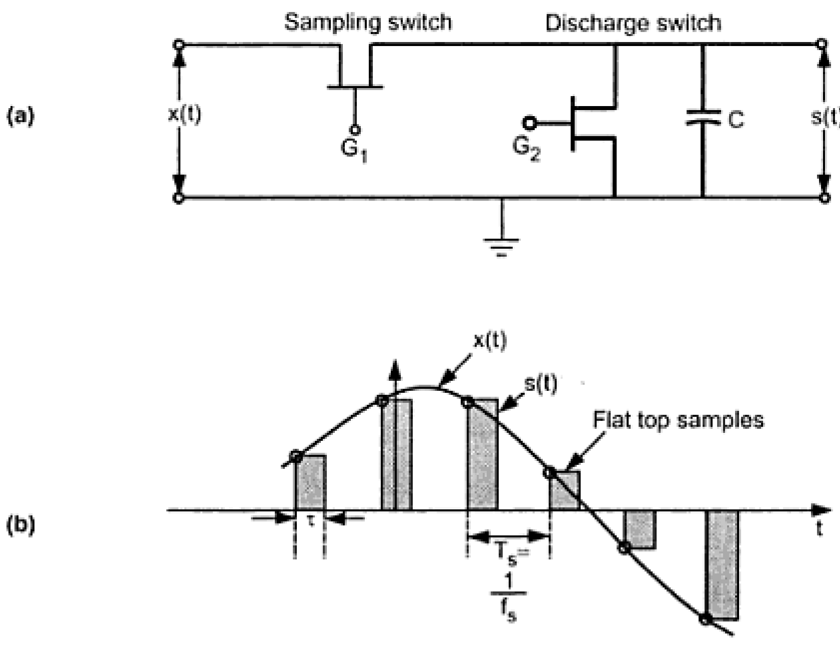
2.1-Analog Pulse Modulation Methods:

The continuous time signal x(t) to be transmitted is sampled at frequency f_s sufficiently above the highest frequency present in x(t). The amplitude of modulating signal x(t) modulates some parameters of pulse train. These parameters are amplitude, duration (width) and position as shown below:



i- <u>Pulse Amplitude Modulation (PAM):</u>

In PAM, the amplitudes of regularly spaced rectangular pulses vary with the instantaneous sample values of a continuous message. It is better to use flat top PAM, because during transmission noise interferes the top of pulses. This noise can be removed easily if the PAM pulse has flat top. In case of natural sampling, it is difficult to determine the shape of noisy top of the pulse. The figure below shows the sampling and hold to introduce flat top PAM. At the sampling instance, sampling switch is closed for very small period. During this period the capacitor C voltage becomes equal to voltage of x(t) at the instant of sampling.



(a) Sampling and hold circuit. (b) Flat top PAM

The sampling switch is opened and capacitor C hold the charge for τ period thus flat top is generated. The discharge switch is then closed to discharge the capacitor to zero volts. Again after period T_s, sampling switch is closed to take new sample. The flat top PAM is represent by:

$$s(t) = \sum_{n=-\infty}^{\infty} x(nT_s)h(t - nT_s)$$

Here $h(t - nT_s)$ is the train of rectangular pulses. $x(nT_s)$ is the amplitude of sample at t=T_s and representing modulating signal. The spectrum of PAM signal is given by:

$$S(f) = f_s \sum_{n=-\infty}^{\infty} X(f - nf_s)H(f)$$

$H(f)$ is the Fourier transform of rectangular pulse. The pulse duration τ is supposed to be very small compared to time period T_s between the two samples. If the maximum frequency in the signal x(t) is W then by sampling theorem, f_s should be higher than Nyquist rate or,

$$f_s \geq 2W \; or \; T_s \leq \frac{1}{2W} \quad since \; f_s = \frac{1}{T_s}$$

$$t \ll T_s \leq \frac{1}{2W}$$

If ON and OFF time of the pulse is same, then frequency of the PAM pulse becomes:

$$f = \frac{1}{\tau + \tau} = \frac{1}{2\tau}$$

Then

$$f_{max} = \frac{1}{2\tau}$$

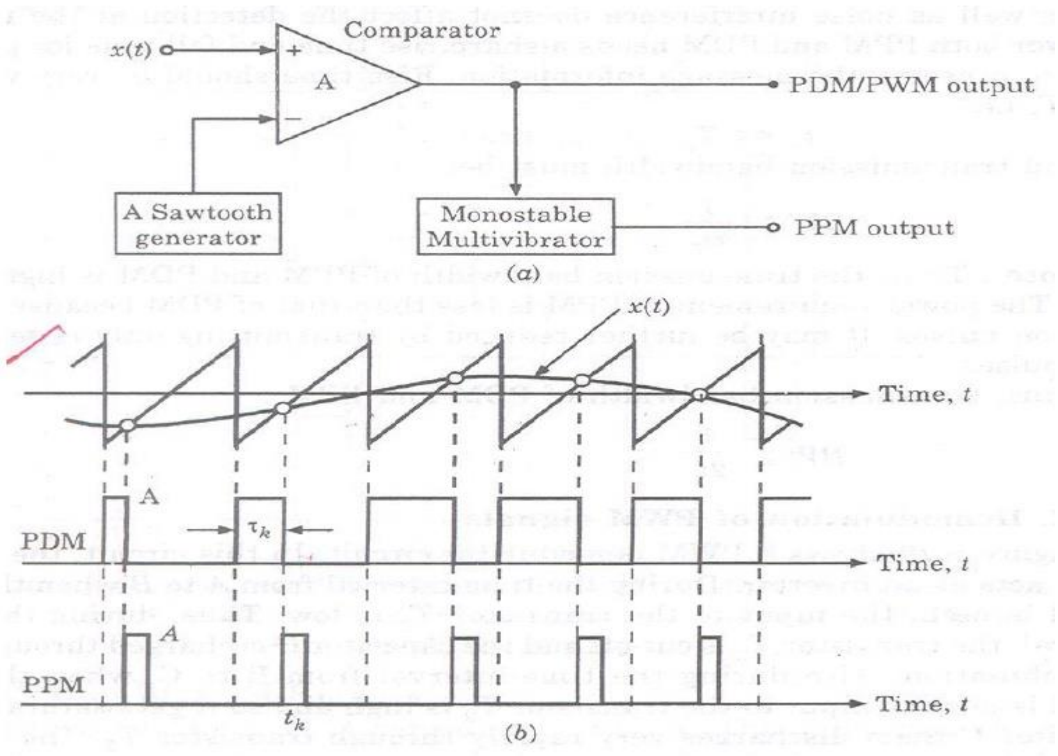
The bandwidth required of PAM signal will be equal to maximum frequency $B_T \geq f_{max}$ $or \; B_T \geq \frac{1}{2\tau} \; and \; since \; \tau \ll \frac{1}{2W}$

$$B_T \geq \frac{1}{2\tau} \gg W$$

The transmission bandwidth of PAM signal $B_T \gg W$

ii- Pulse Duration and Pulse position Modulation (PDM &PPM):

Pulse Duration Modulation (PDM) or Pulse Width Modulation (PWM) and PPM are both modulate the time parameter of the pulses. PPM has fixed width whereas the width of PWM is varied. The generation of PWM and PPM shown in figure below.



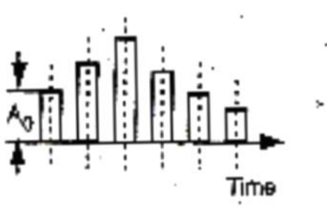
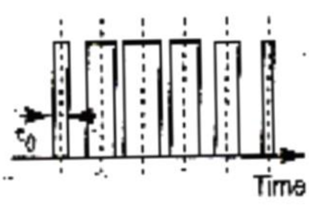
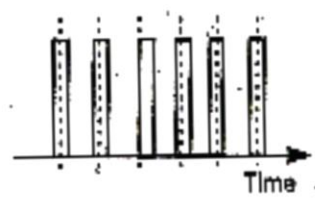
(a) Block diagram of PWM and PPM generator. (b) Waveforms

The modulating signal x(t) is applied to the noninverting input of the comparator. The output is high only when instantaneous value of x(t) is higher than that of the sawtooth waveform. Thus the leading edge of the PWM signal occurs on the fixed time period (KT_s), the trailing edge of the output of comparator depends on the amplitude of signal x(t). The trailing edge of output of comparator PWM is modulated by the signal x(t).

To generate PPM, the trailing edge of PWM is used to switch on the monostable with fixed period then goes low. The pulse is delayed from sampling time KT_s depending on the amplitude of signal x(t) at KT_s.

The rise time should be very less than T_s i.e., $t_r \ll T_s$, and transmission bandwidth of PWM and PPM should be, $B_T \geq \frac{1}{2t_r}$.

The comparison between PAM, PWM and PPM is listed in the following table

Sr. No.	Pulse Amplitude Modulation	Pulse Width/Duration Modulation	Pulse Position Modulation
1	Waveform 	Waveform 	Waveform 
2	Amplitude of the pulse is proportional to amplitude of modulating signal	Width of the pulse is proportional to amplitude of modulating signal	The relative position of the pulse is proprotional to the amplitude of modulating signal
3	The bandwidth of the transmission channel depends on width of the pulse	Bandwidth of transmission channel depends on rise time of the pulse	Bandwidth of transmission channel depends on rising time of the pulse
4	The instantaneous power of the transmitter varies.	The instantaneous power of the transmitter varies	The instantaneous power of the transmitter remains constant
5	Noise interference is high.	Noise interference is minimum	Noise interference is minimum
6	System is complex	Simple to implement	Simple to implement
7	Similar to amplitude modulation	Similar to frequency modulation	Similar to phase modulation

Example:

The voice signal with maximum frequency of $3kHz$, is to be transmitted using sampling frequency $f_s = 8kHz$, and pulse duration $\tau = 0.1\,T_s$, determine the required PAM, PWM and PPM if the rise time $t_r = 1\%$ of pulse duration.

Solution: $T_s = \frac{1}{f_s} = \frac{1}{8\times10^3} = 0.125\,msec$

$$\tau = 0.1\,T_s = 0.1 \times 0.125 = 0.0125\,msec$$

For PAM the bandwidth: $B_T \geq \frac{1}{2\tau}$

$$B_T \geq \frac{1}{2 \times 0.0125 \times 10^{-3}} = 40kHz$$

For PDM and PPM the bandwidth $B_T \geq \frac{1}{2t_r}$

$$t_r = 0.01\tau = 0.01 \times 0.0125msec = 0.125\mu sec$$

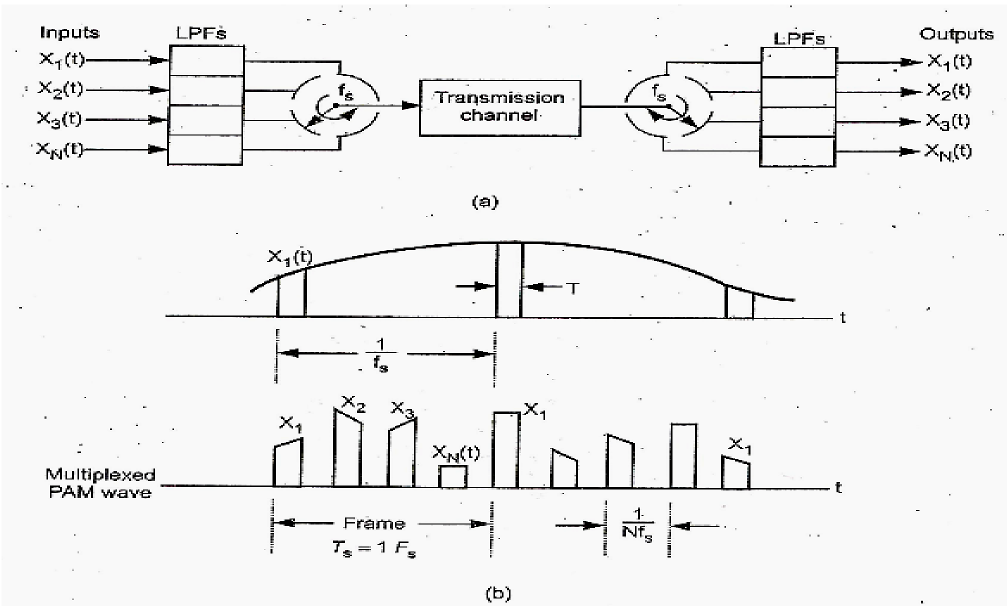
$$B_T \geq \frac{1}{2 \times 0.125 \times 10^{-6}} = 4MHz$$

H.W:

If the bandwidth of PAM system not exceed 4kHz is used to transmit voice signal sampled at Nyquist frequency. Calculate the bandwidth required to transmit the same signal using PPM system with rise time of 2% of pulse duration.

2.2 Time Division Multiplexing (TDM):

In PAM, PWM and PPM the pulses is present for short duration and the most time between two pulses is free space, which can be occupied by pulses from other channels. This called TDM. The following figure shows the block diagram of TDM in (a) and the waveforms in (b).



If the highest signal frequency is W and its sampling rat f_s should be $f_s \geq 2W$, therefore the time space between two pulses $T_s = \frac{1}{f_s}$, thus the time interval T_s should contain one sample from each N input channel. That is on frame of T_s seconds contain total N samples. So that the space between two samples$= \frac{T_s}{N} = \frac{1}{Nf_s}\ sec$, and number of pulses per second is $= \frac{N}{T_s} = \frac{N}{1/f_s} = Nf_s$, or the signaling rate $r = Nf_s$, and we have $f_s \geq 2W$, then the signaling rate $r = 2NW$.

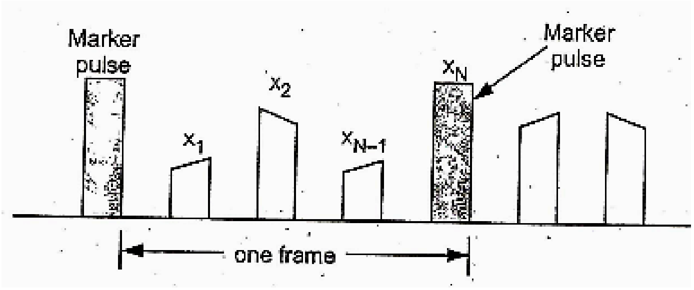
The TDM signal should pass through low pass filter with bandwidth B_b of half signaling rate:

$B_b = \frac{1}{2}r = \frac{1}{2}Nf_s$, the transmission bandwidth of TDM B_T channel must equal to B_b

$$B_T = B_b = \frac{1}{2}Nf_s, \quad and\ we\ have\ the\ sampling\ rate\ f_s = Nyquist\ rate = 2W$$

$$\therefore\ B_T = \frac{1}{2}N \times 2W = NW$$

The receiver of TDM should operate in perfect synchronization with the transmitter. Therefor marker pulses are inserted to indicate the separation between two frames as shown in the figure:



Because each frame will increased by one pulse for the purpose of synchronization, the number of channels will reduced to N-1.

Example 2:

Twenty four voice signals are sampled uniformly and then time division multiplexed. The highest frequency component for each voice signal is 3.4 kHz.If the signal is pulse amplitude modulated using Nyquist rate sampling, what is the minimum channel bandwidth required.

Solution:

Here $N = 24, and\ \ W = 3.4kHz,\ so\ the\ minimum\ band\ required\ is$:

$$B_T = NW = 24 \times 3.4kHz = 81.6kHz$$