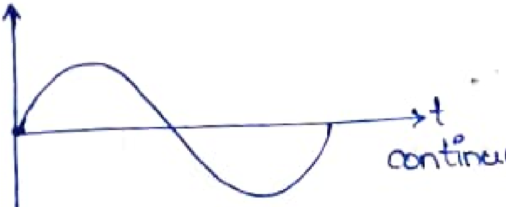
Unit - 3

Signal Sampling & Analog Pulse Communication

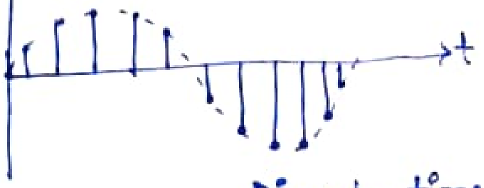
- Ideal Sampling
- Pulse Amplitude Modulation
- Pulse Width "
- Pulse position "
- Digital Communication Techniques
  - Quantization
  - Digital transmission of data
  - Parallel & serial transmission
  - Data conversion
- Pulse code Modulation
- Delta Modulation.

Introduction:-

* In continuous wave modulation, the carrier signal will be continuous in nature. However, in pulse modulation we have to use discrete time signals to represent modulated signal of pulse modulated wave.



continuous signal

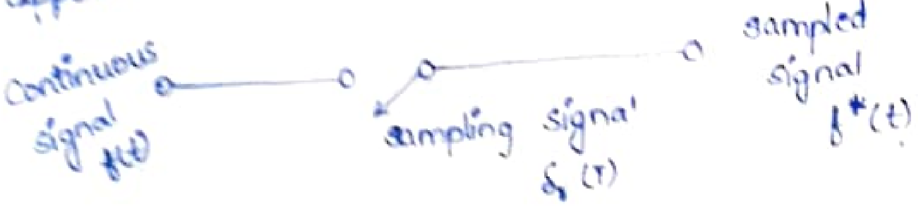


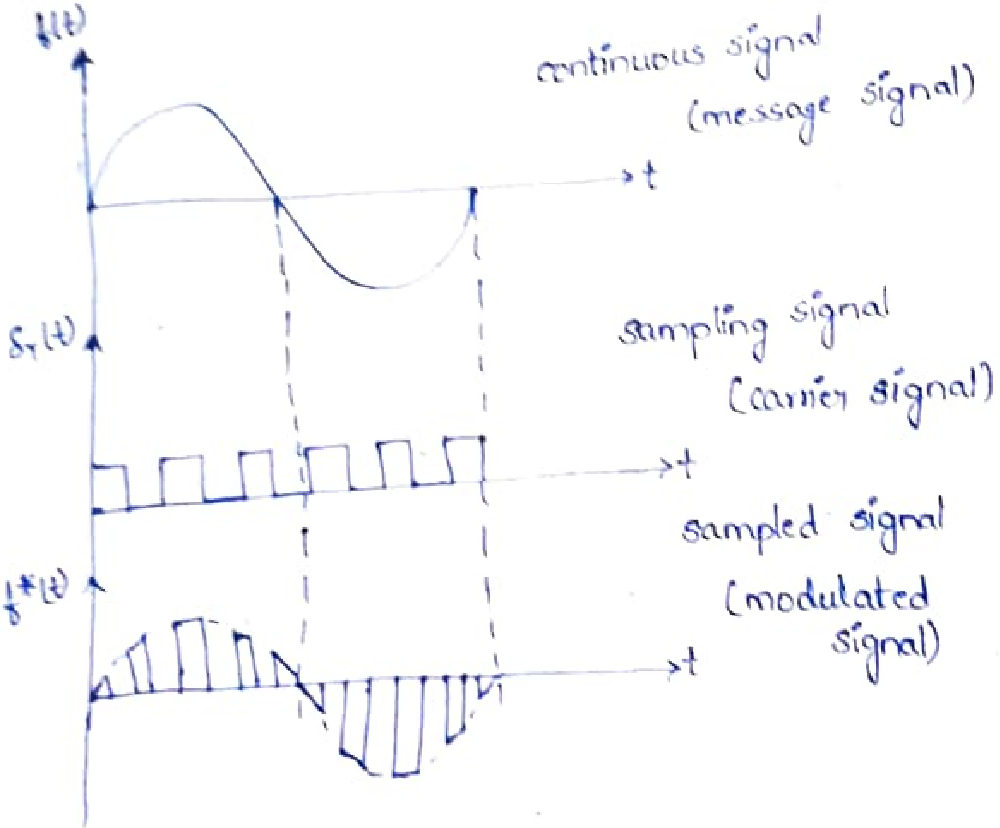
Discrete time signal.

* Sampling process is used to convert continuous time signal into discrete time signal.

Sampling Process →

* In sampling process a continuous time signal is converted to an equivalent discrete time signal
* Switch position is controlled by sampling signal.
* The sampling signal is a periodic train of pulses of unit amplitude & of period T_s the time 'T_s' is known as sampling time & during this time switch is closed, so the sampled signal is equal to the input signal.
* During remaining time switch is open & no input signal appear at o/p.





Sampling theorem:-

* A sampling theorem states that,

"A continuous time signal can be completely represented in its samples & recovered back if the sampling freq $f_s \geq 2f_m$"

$f_s \rightarrow$ sampling freq

$f_m \rightarrow$ max freq presented in signal.

Pulse Modulation →

* Some parameters (Amplitude, width & position) of a pulse train is varied according to the instantaneous value of the modulating signal, then this modulation can be referred as "pulse modulation".

Types of pulse modulation:-

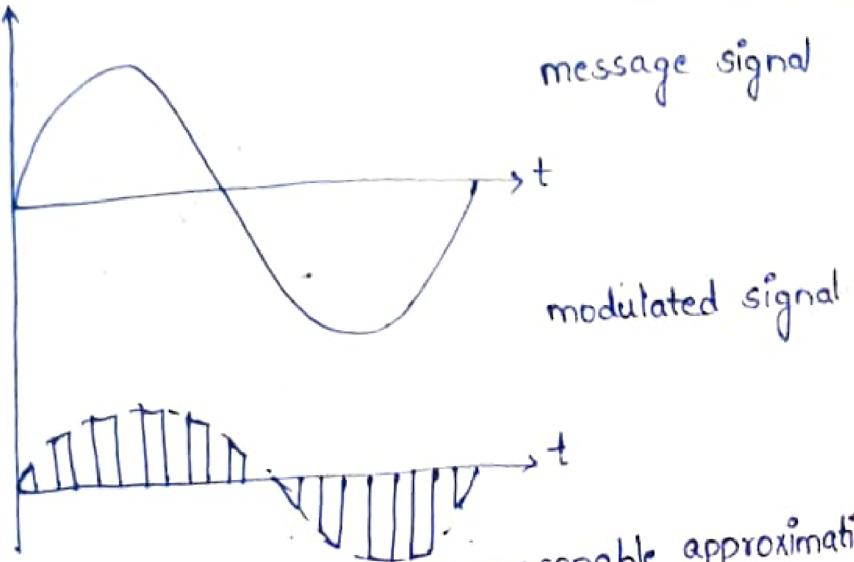
* There are two types of PM systems
  1. PAM - pulse amplitude modulation
  2. PTM - pulse time modulation

PTM → PWM ⇒ pulse width modulation; PPM ⇒ pulse position modulation.

* In PAM, the amplitude of carrier pulse train is varied in accordance with the amplitude of the modulating signal.
* In PTM, the time (width or position) of the carrier pulse train is varied in accordance with the modulating amplitude signal.
* In PWM, the width of the carrier pulse train is varied in accordance with the amplitude of the modulating signal.
* In PPM, the position of the carrier pulse train is varied in accordance with the amplitude of the modulating signal.

Pulse Amplitude Modulation →

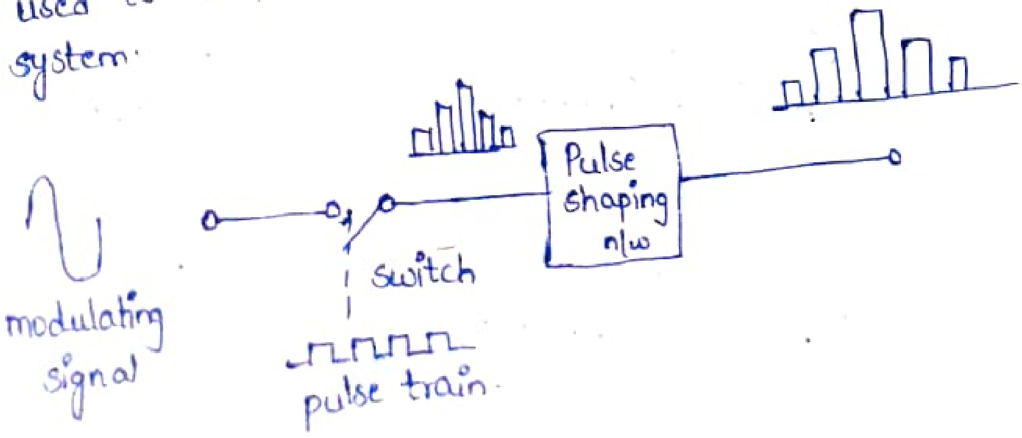
* Samples are taken at regular interval of time. Each sample is pulse, whose amplitude is determined by amplitude of variable at the instant of time at which the sample is taken.



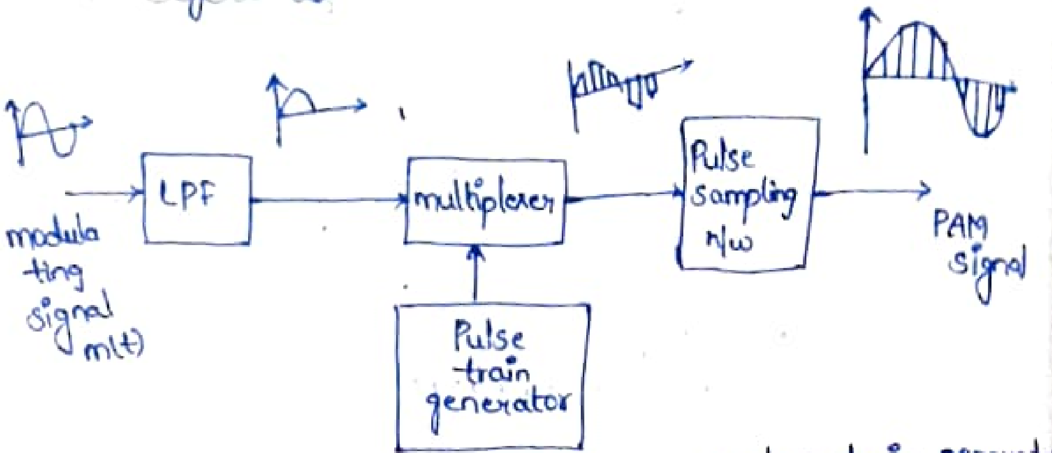
* If enough samples are taken, a reasonable approximation of the signal being sampled can be constructed at the receiving end. This is known as "pulse Amplitude modulat-ion".

Generation of PAM →

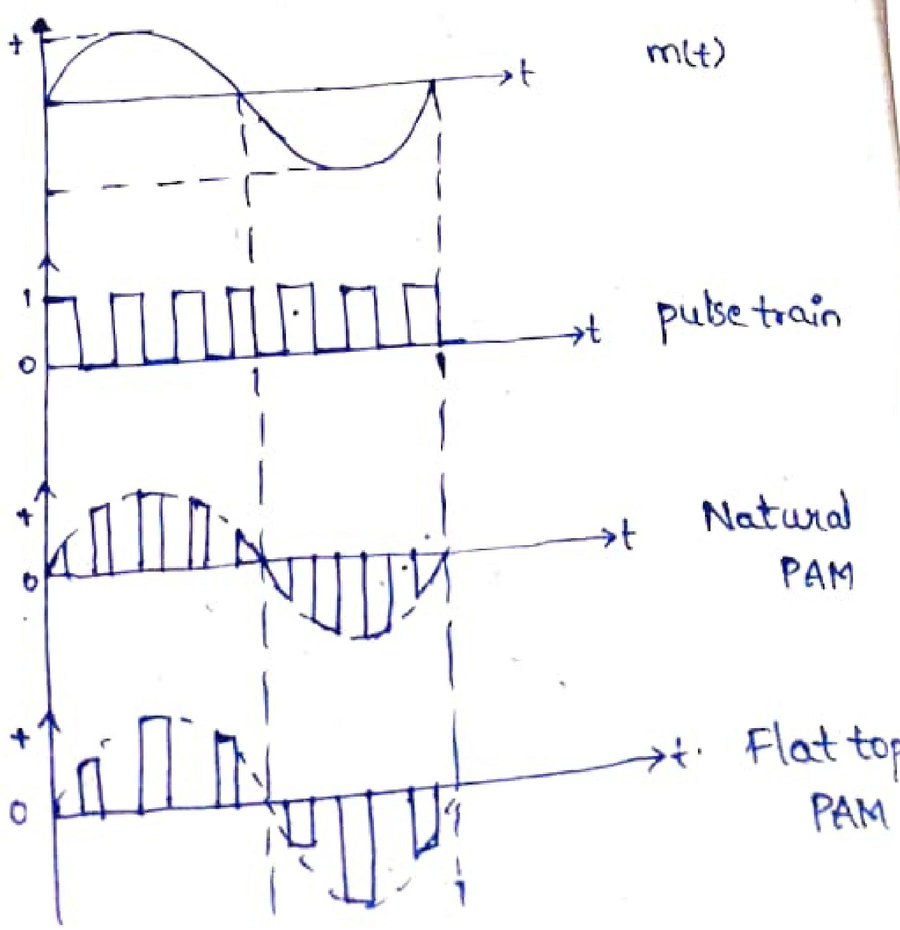
* It is very easy to generate & demodulate PAM.
* Signal to be converted to PAM is fed through switch, which is controlled by a pulse train.
* When pulse is present i.e., signal is at high level, the switch is closed.
* When pulse is absent i.e., signal is at low level, the switch is open.
* With this control action of switch, we get PAM waveform at o/p terminal of switch.
* This PAM is passed through pulse shaping network, which gives them " Flat tops". These o/p pulses can be used to frequency modulate the carrier to form PAM-FM system.



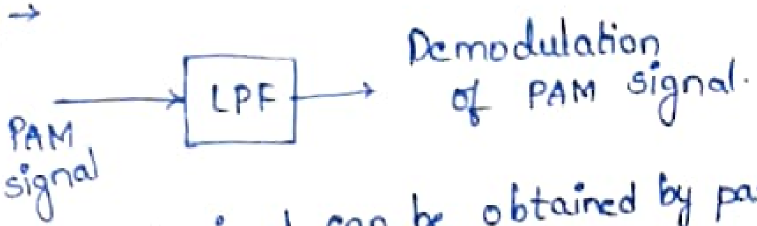
Block diagram of PAM Generation →



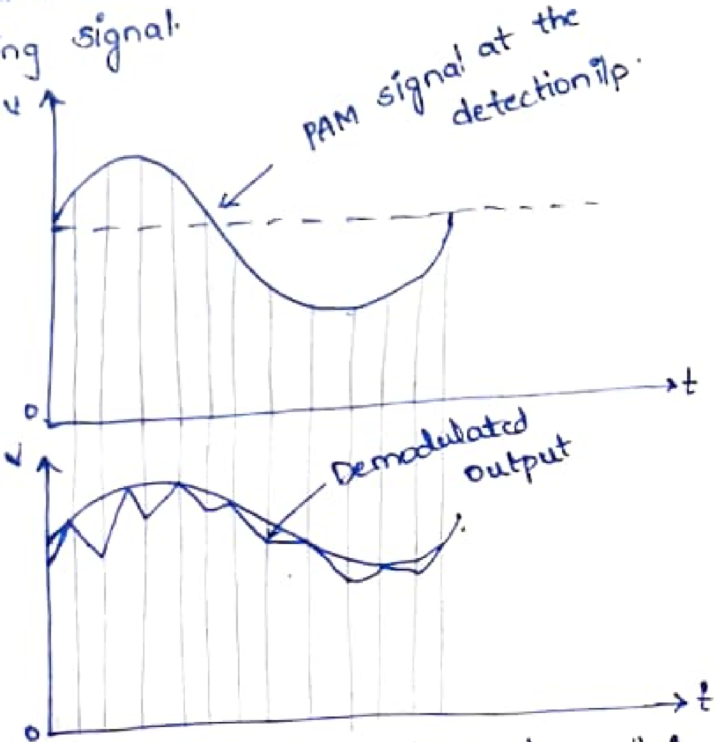
* It consists of LPF, a multiplexer & pulse train generator
* Initially m(t) is passed through LPF. The LPF removes all frequency components which are higher than "fm". This is known as " Band limiting ".
* The Band limiting is necessary to avoid the "Aliasing effect" in sampling process.
* The pulse train generator generates a pulse train at a frequency 'fs' such that $f_s \geq 2f_m$. Thus the Nyquist criteria is satisfied. The pulse sampling network does the shaping work to give flat tops.



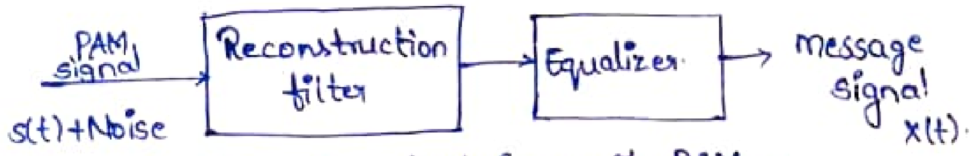
Demodulation of PAM | Reconstruction of Original Signal →



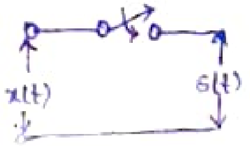
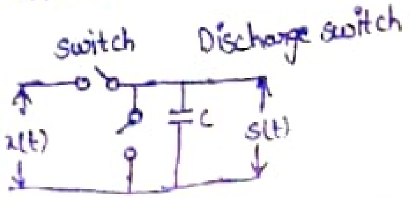
* The original signal can be obtained by passing PAM signal through a LPF.
* The LPF frequency is tuned to fm. Then LPF removes frequencies which are above "fm". & recovers the original modulating signal.

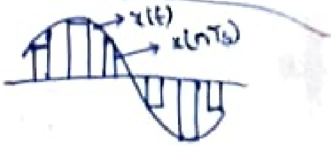


* In case of flat top PAM to reduce "Aperture effect", an equalizer is used.



Comparison of Sampling Techniques of PAM →

S.NO	Parameter	Natural sampling	Flat top sampling
1	principle of sampling	It uses chopping principle	It uses sample & hold circuit
2.	Circuit of sampler		

S.No	parameter	Natural sampling	Flat top sampling
3.	Waveforms		
4.	Use	This method is used practically	This method is used practically.
5.	sampling rate	It satisfies criteria	It satisfies criteria
6.	Noise Interference	Minimum	Maximum
7.	Time Domain Representation	$s(t) = \frac{T_A}{T_s} \sum_{n=-\infty}^{\infty} x(t) \, \text{sinc}(nT_s) e^{j2\pi n f_s t}$	$s(t) = \sum_{n=-\infty}^{\infty} x(nT_s) h(t-nT_s)$
8.	Freq domain Representation	$S(f) = \frac{T_A}{T_s} \sum_{n=-\infty}^{\infty} \text{sinc}(nf_sT) \, x(f-nf_s)$	$S(f) = f_s \sum_{n=-\infty}^{\infty} x(f-nf_s) \cdot H(f)$

Advantages of PAM :-

1. Generation & demodulation of PAM is a simple process
2. Easy construction of both Tx & Rx circuits.

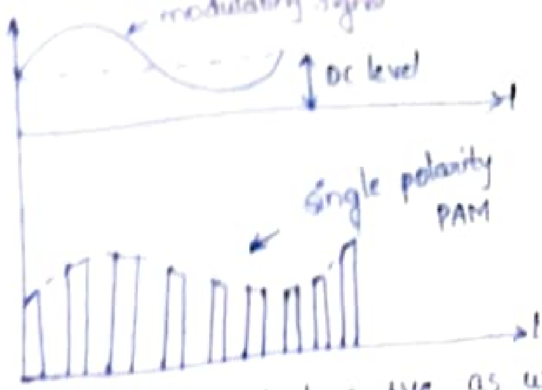
Demerits of PAM :-

1. PAM produces amplitude variations, so noise effect is more
2. The Tx requires more power to handle the pulse having max amplitude.

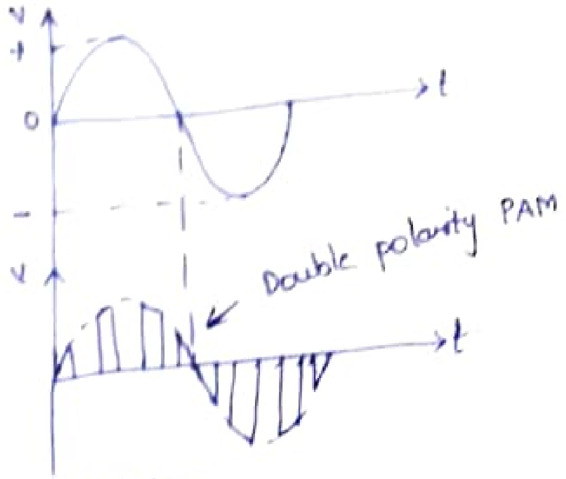
classification of PAM based on signal polarity →

* PAM can be classified into 2 types.
  1. Single polarity PAM
  2. Double polarity PAM

single polarity PAM :- In this, a fixed dc level is added to the modulating signal x(t), such that the modulated o/p i.e., PAM signal is always +ve.



Double polarity PAM:- It has +ve as well as -ve polarity



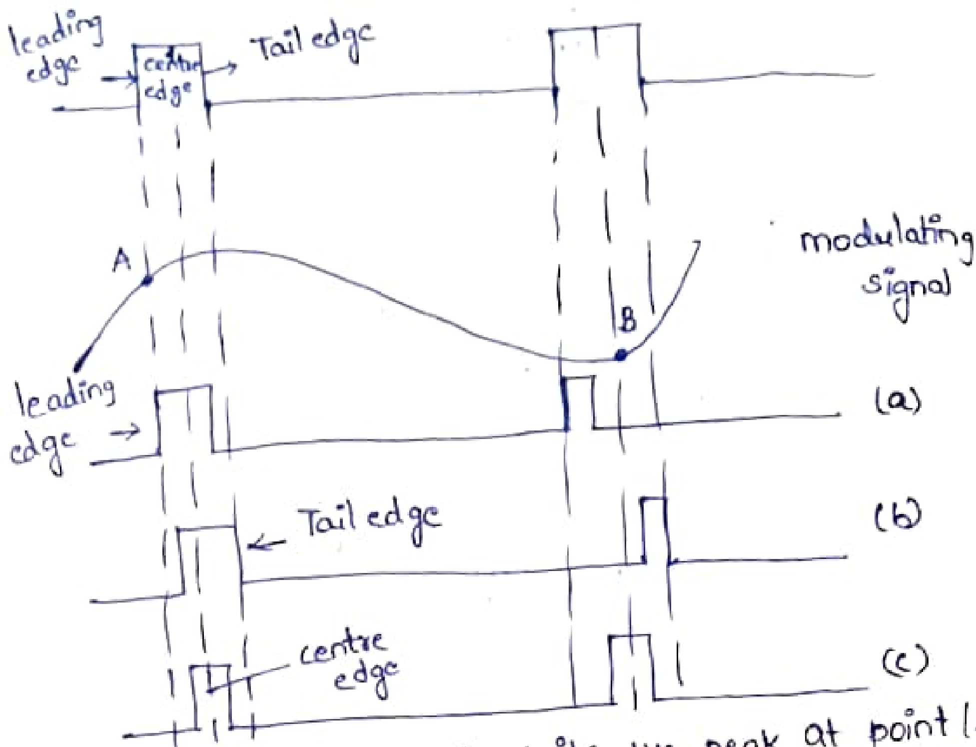
Applications of PAM →

1. Used in Ethernet communication
2. Acts as electronic driver for LED circuits
3. Used in photo-biology
4. Microcontrollers use this technique in order to generate control signals.

Pulse Width Modulation →

* The pulse time modulation can be classified into two types: 1. pulse width / duration modulation
  2. pulse position modulation
* In pulse time modulation, amplitude of pulse is held consta-nt, whereas position of pulse or width of pulse is made propo-tional to the amplitude of the signal.
* In PWM, the width of pulse is varied in accordance with the message signal
* PWM is also called as pulse duration modulation.
* In PWM waveforms, 3 variations of PWM are possible

1 leading edge
2 Centre edge
3 Tail edge

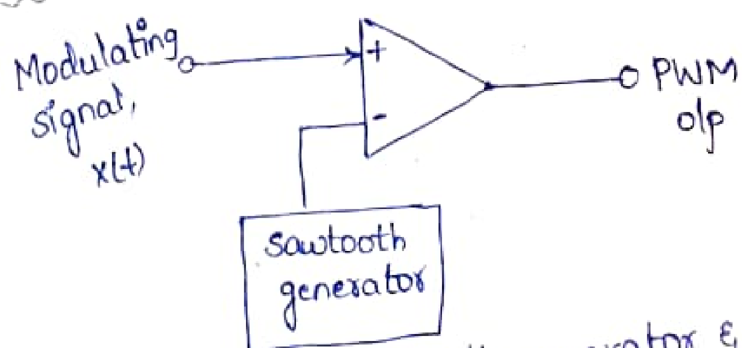


* The modulating signal is at its +ve peak at point (A) & its -ve peak at 'B'.

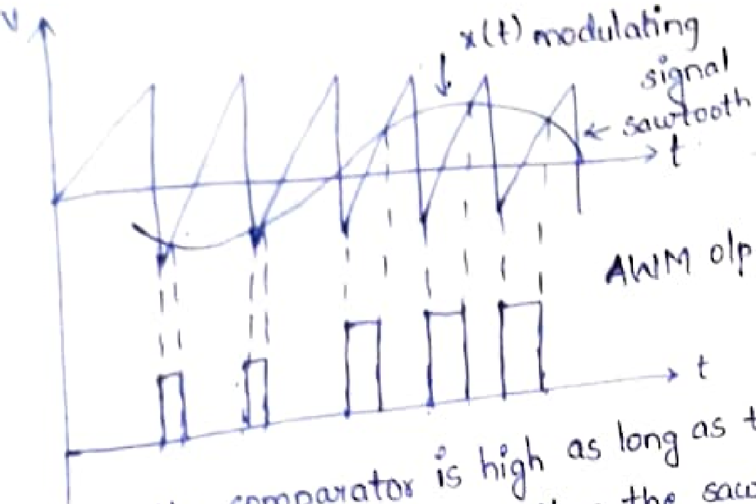
Leading edge:- It is kept constant & pulse width is measured from the lead edge.

* pulse width is more at point 'A'.
* pulse width is minimum at point 'B'.

Generation of PWM signal:-

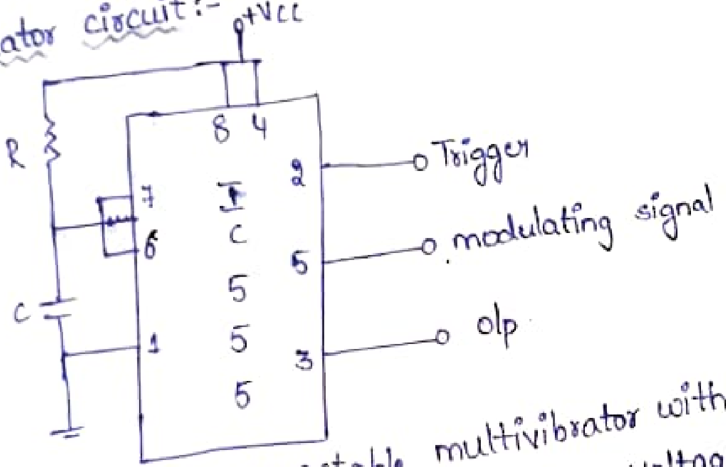


* It consists of sawtooth generator & comparator.
* The comparator compares the amplitude of modulating signal & sampling signal.

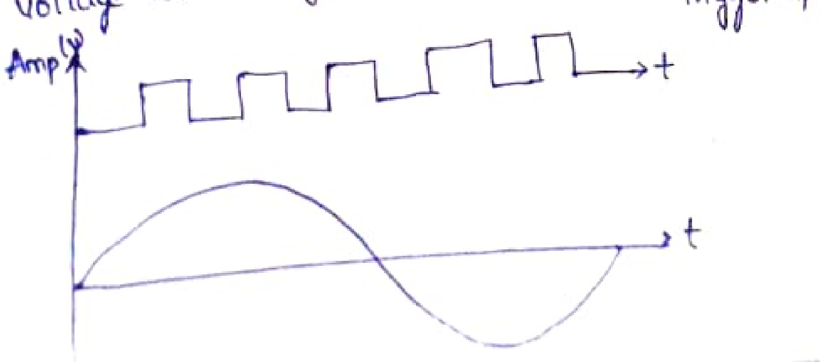


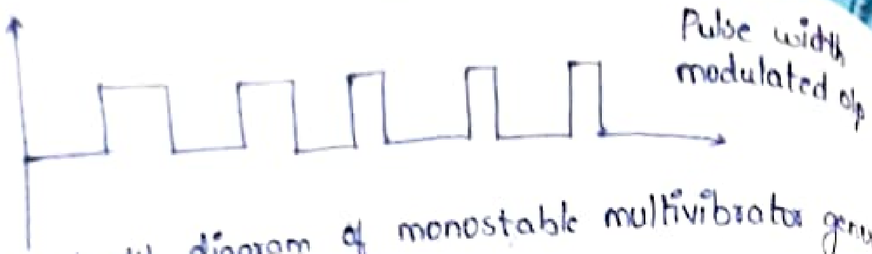
* The o/p of the comparator is high as long as the instantaneous values of x(t) is greater than the sawtooth signal.
* The duration for which the comparator o/p remains high is directly proportional to amplitude of the modulating signal. As a result the comparator o/p is PWM signal.

PWM generator circuit:-

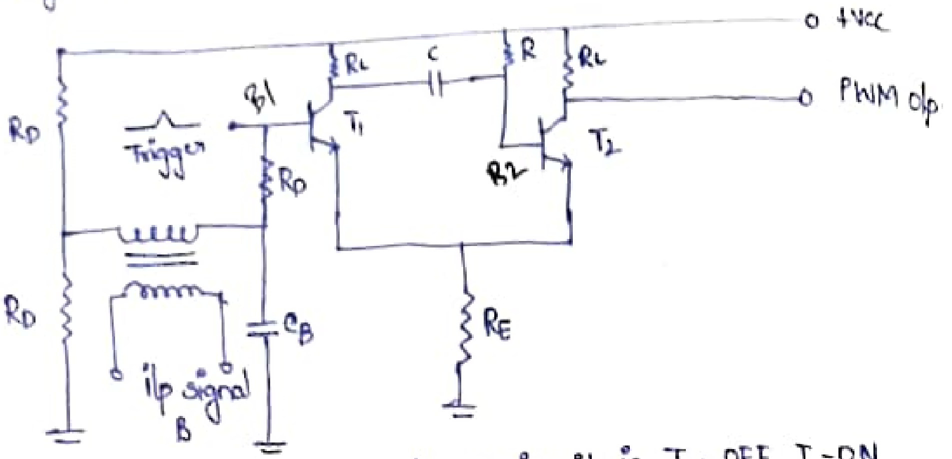


* It is basically a monostable multivibrator with a modulating i/p signal applied at the controlled voltage.
* Internally the controlled voltage is adjusted to $\frac{2}{3}$rd of Vcc.
* Externally applied modulating signal changes the control voltage & hence the threshold voltage level.
* As a result time required to charge the capacitor upto threshold voltage level changes & gives PWM signal as o/p.



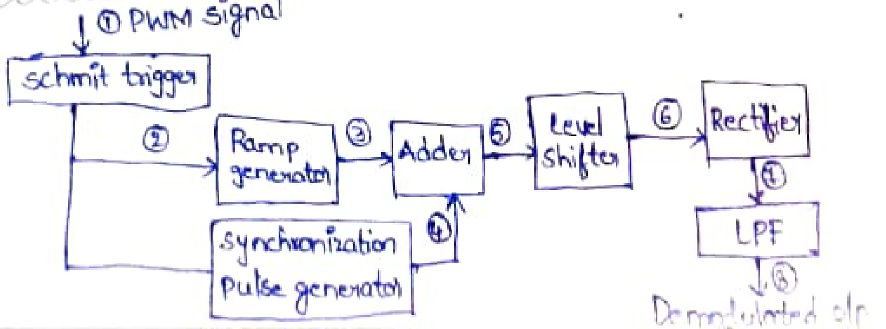


* Internal ckt. diagram of monostable multivibrator genera-ting PWM



* the stable state for above circuit is T_2 - OFF, T_1 - ON
* The +ve going triggering pulse at B_1 switches T_1 ON. Due to this voltage at C_1 falls as T_1 now begins to draw the collector current.
* As a result, ~~time required to charge~~ voltage at B_2 also falls & T_2 is switched OFF. 'c' begins to charge upto the collector supply voltage 'Vcc' through 'R'.
* After a time determined by the supply voltage & 'Rc' time constant of the charging n/w, the base of T_2 becomes sufficie-ntly '+ve' to switch T_2 ON.
* The transistor T_1 is switched OFF by regenerative action & remains OFF until the arrival of the next triggering pulse.
* At minimum signal voltage capacitor has to charge minimum voltage & we get minimum pulse width as the o/p i.e., PWM signal.

Demodulation of PWM signal →



* PWM signal is applied to schmit trigger
* The schmit trigger circuit removes the noise in the PWM wave form.
* The generated PWM signal is applied to the ramp generator & synchronization pulse generator.
* The ramp generator produces ramp for the duration of pulses such that height of ramps are proportional to width of the PWM pulses.
* On the other hand synchronous pulse generator produces reference pulses with constant amplitude & pulse width.
* These pulses are reference pulses & the o/p of ramp generator is added with the help of Adder.
* The o/p of adder is given to the level shifter & then -ve part of waveform is clipped by rectifier. Finally the o/p of rectifier is passed through a LPF to recover the modulating signal.

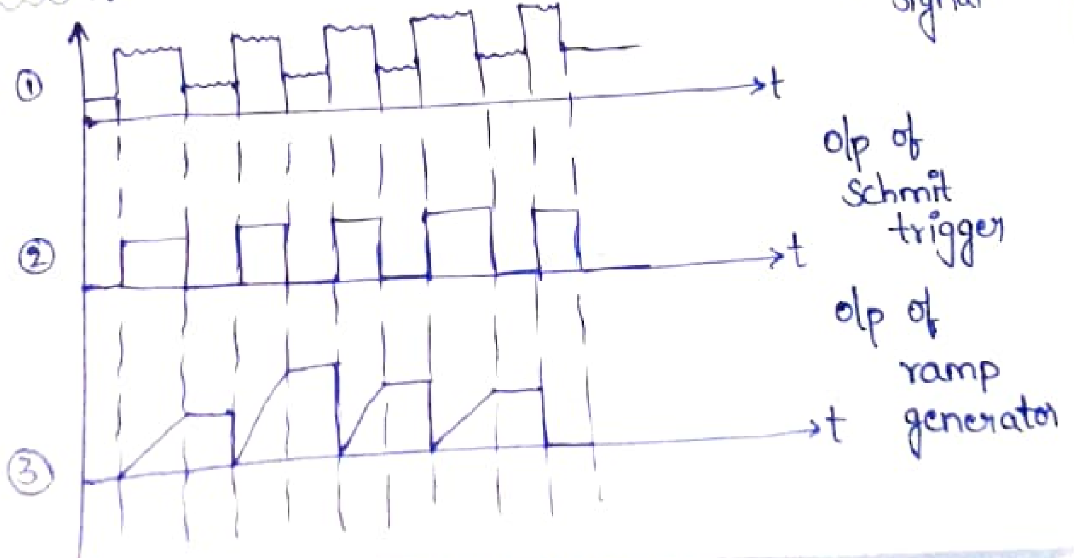
Advantages:-

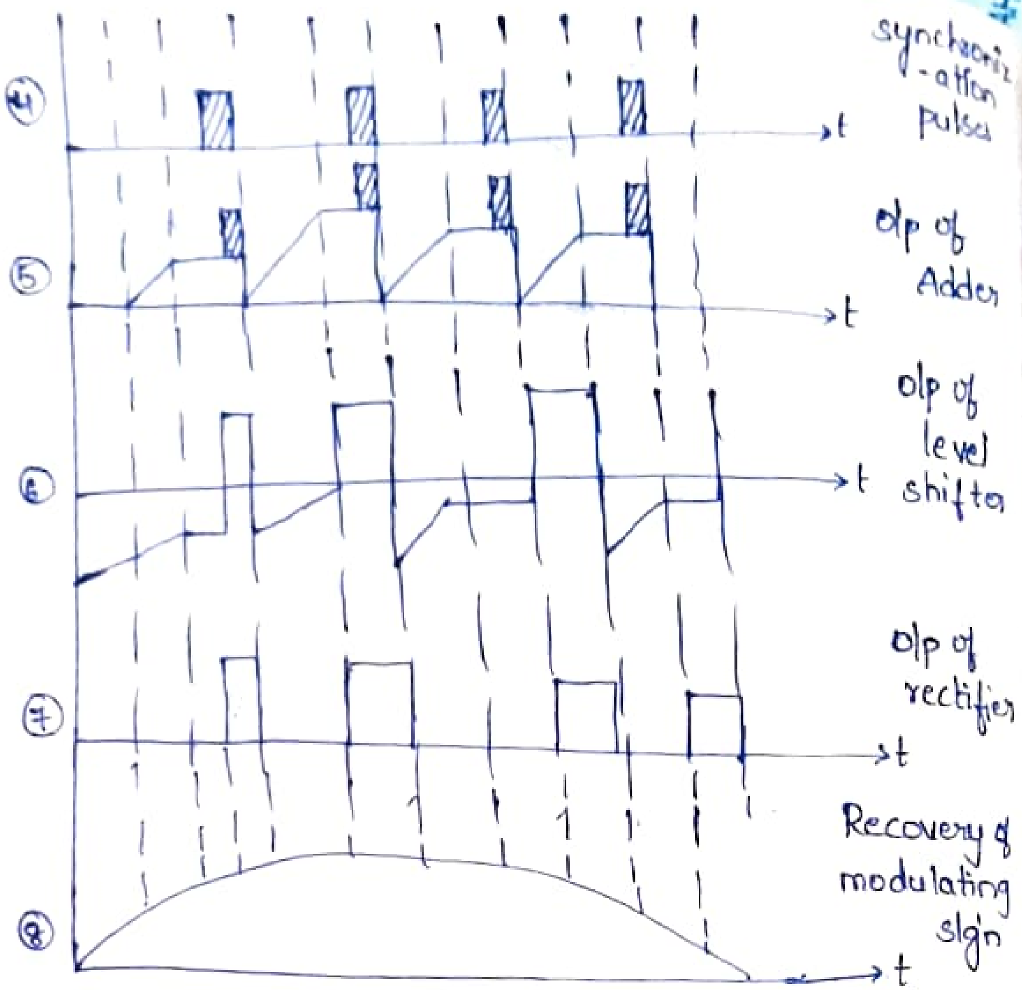
1. PWM noise is less when compared to PAM.
2. Signal to noise separation is very easy.
3. PWM doesnot require synchronisation between transmitter & receiver.

Disadvantages:-

1. Bandwidth is more compared to PAM.
2. In PWM pulses are varying in width & therefore their power content is variable.

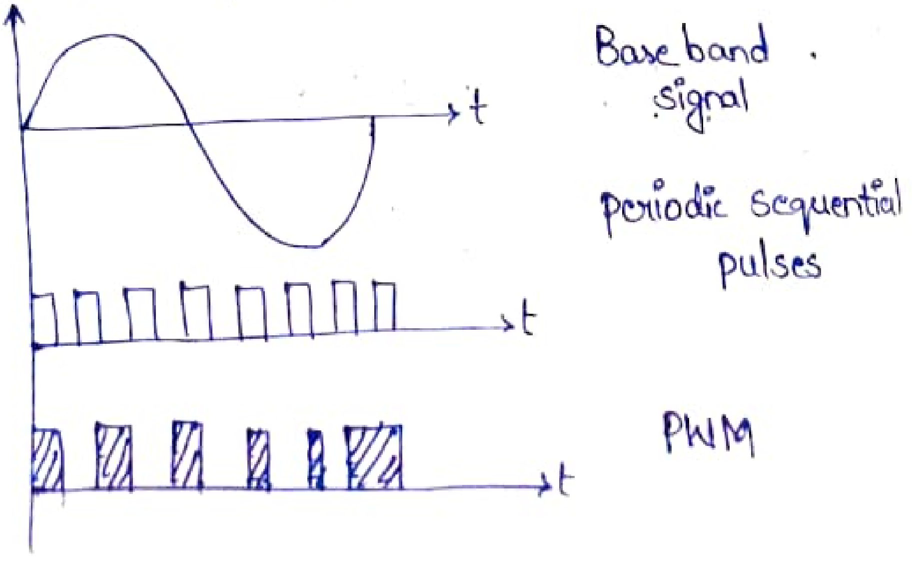
Waveforms:-





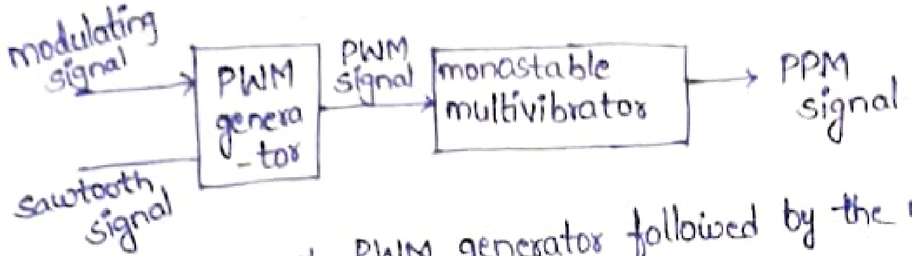
Pulse Position Modulation →

* In PPM, the width & amplitude of the pulses are kept constant.
* While the position of each pulse with reference to the position of reference pulse is changed according to the instan-taneous amplitude value of the modulating signal.
* The position of pulse carrier is varied with the instantan-eous value of message signal.



* PPM is obtained from PWM, each trailing edge of the PWM is a starting point of the pulse in the PPM.

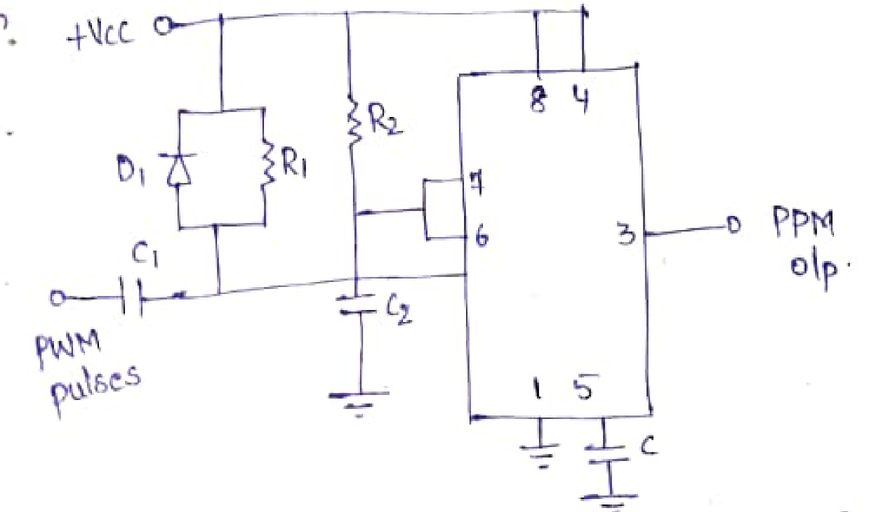
Generation of PPM signal →



* It consists of PWM generator followed by the monostable multivibrator.
* Since in PPM, o/p remains high for fixed duration from the trailing edge of the PWM signal.
* The trailing edge of the PWM signal is used to trigger i/p for the monostable multivibrator.

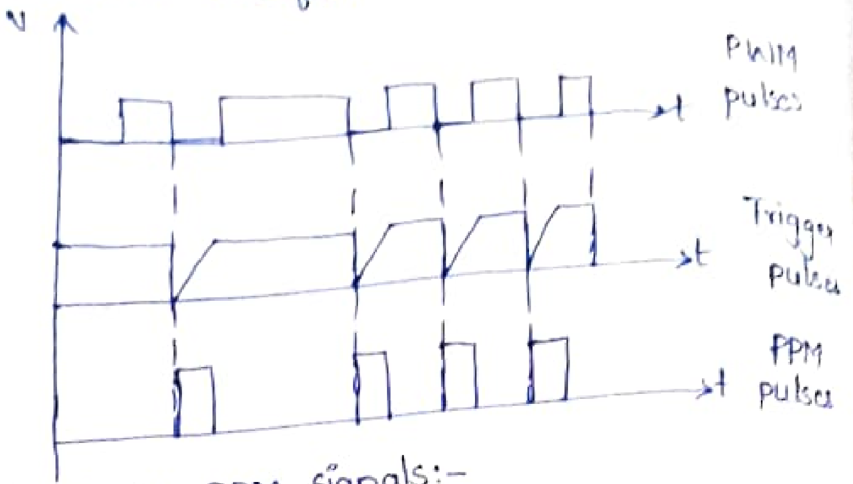
practical PPM generator circuit:-

* It consists of differentiator & a monostable multivibrator
* The i/p of the differentiator is a PWM waveform.
* The differentiator +ve & -ve spikes corresponding to leading & trailing edges of the PWM waveform.

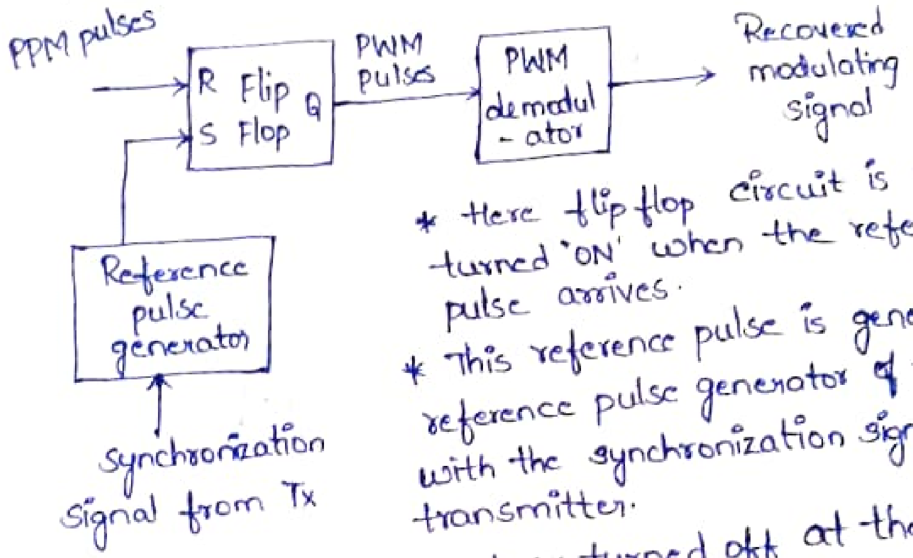


* Diode D_1 is used to bypass the +ve spikes.
* The -ve spikes are used to trigger the monostable multivibrator

* The monostable multivibrator generates the pulses of Same width & amplitude with reference to trigger the pulse position modulated waveform

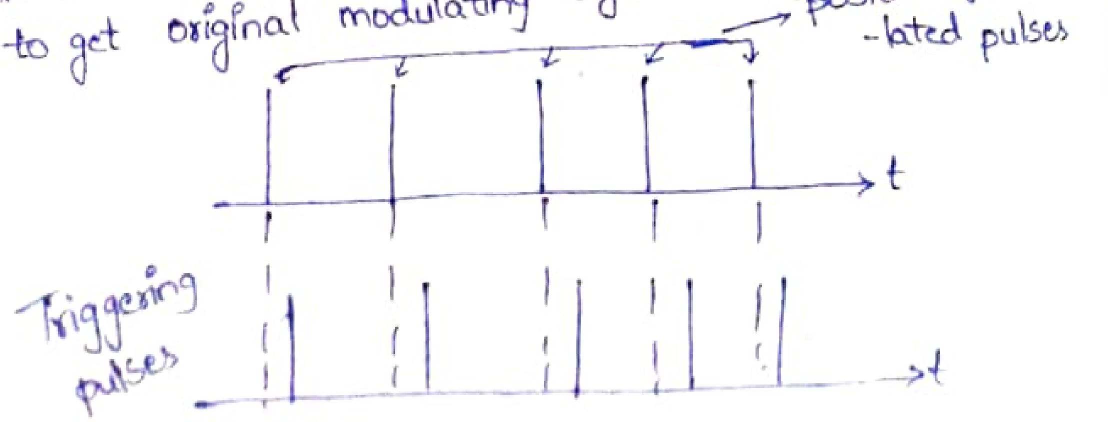


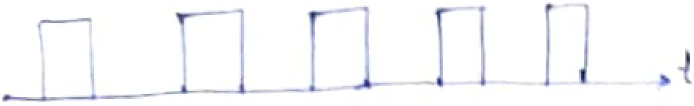
Demodulation of PPM signals:-



* Here flip flop circuit is set (or) turned 'ON' when the reference pulse arrives.
* This reference pulse is generated by the receiver reference pulse generator of the receiver with the synchronization signal from transmitter.

* The flip flop ckt is reset or turned off at the leading edge of the position modulated pulse. This repeats & we get PWM pulses at the o/p of flip flop.
* Then PWM pulses are demodulated by PWM demodulator to get original modulating signal.





o/p of flip flop

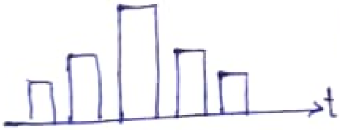
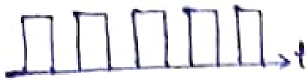
Advantages of PPM →

1. Amplitude & width is constant, so effect of noise is less.
2. signal & noise separation is very easy
3. Due to constant pulse width & amplitude transmission power for each pulse is same.

Disadvantages of PPM →

1. Synchronization btw TX & RX is required
2. Band width is more compared to PAM

Comparison btw PAM, PWM & PPM :-

PAM	PWM	PPM
1. Waveform 	1. Waveform 	1. Waveform 
2. Amplitude of the pulse is proportional to amplitude of modulating signal	2. Width of pulse is proportional to amplitude of modulating signal.	2. position of the pulse is proportional to the amplitude of the modulating signal.
3. Noise is more	3. Noise is less	3. Noise is less
4. System is complex	4. system is simple	4. system is simple
5. Similar to AM	5. Similar to FM	5. Similar to PM
6. power utilization is more	6. power utilization is more	6. power utilization i less & constant
7. Bandwidth is less	7. Band width is more	7. B.W is more compar to PAM & less compar to PWM

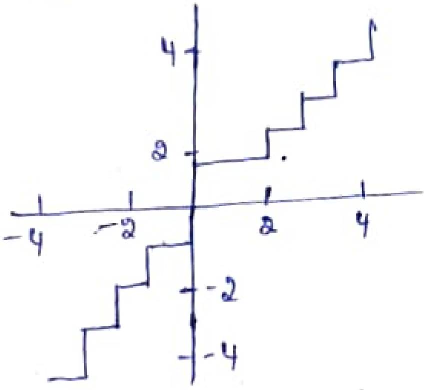
Quantization→

* Quantization approximates the sample values to the nearest discrete value from a set of finite discrete levels.

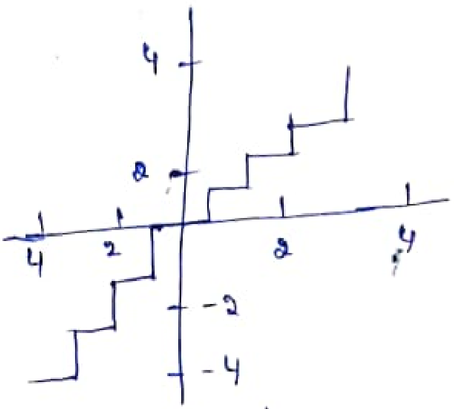
There are two types of Quantization.

1. Uniform Quantization - Quantized levels are uniform
2. Non-uniform Quantization - Quantization levels are unequal.

* There are two uniform Quantizers are
   1. Mid-rise type
   2. Mid-tread type



Mid-rise.



Mid-tread

Quantization step size $\Delta = \frac{X_{max} - X_{min}}{Q}$

Q ↳ No. of Quantized levels

$$\Delta = \frac{X_{max} - X_{min}}{2^n}$$

$n \rightarrow$ no of bits used to represent each level

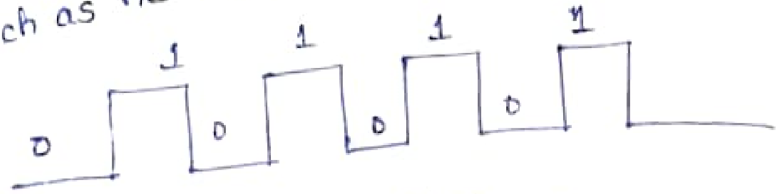
Quantization error $= \pm \Delta/2$

$$Q_e = x_q(nT_s) - x(nT_s)$$

Digital transmission of data→

* Data transmission is the sending of information over a physical communications media in the form of digital signals.

* Transmission of signals that vary discretely with time between two values of some physical quantity, one value representing the binary number 0 & the other 1.
* Digital signals use discrete values for the transmission of binary information over a communication medium such as network cable or a telecommunication link.



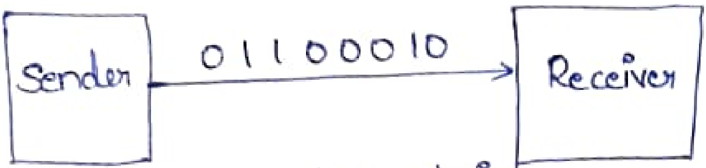
Serial & Parallel transmission →

Serial transmission:-
* In Serial transmission, data-bit flows from one data bit at a time via a communication channel.
* 8 bits are conveyed at a time in serial transmission, with a start bit & stop bit.

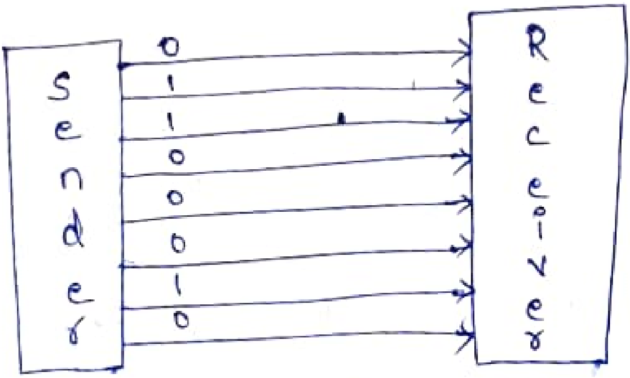
Parallel transmission:-
* It means transmitting multiple binary bits simultaneously in data transmission.

Key	Serial transmission	Parallel transmission
Definition	Serial transmission is the type of transmission in which a single communication link is used to transfer the data from one end to another.	Parallel transmission is the mode of transmission in which multiple parallel links are used that transmit each bit of data simultaneously.
Bit transmission	Only one bit is transferred at one clock pulse	8-bits transferred at one clock pulse
Cost Efficiency	As single link is used in serial transmission, it can be implemented easily without having to spend a huge amount. It is cost	Multiple links need to be implemented in case of parallel transmission, hence it is not cost efficient

	Cost efficient	
Performa-nce	As single bit gets transmi-tted per clock in case of serial transmission, its performance is comparatively lower as compared to llel transmission	8-bits gets transfered per clock in case of llel transmission, hence it is more efficient in performance
Preferen-ce	long distance transmission	short distance transmission
Complexity	less complex	More complex



a) Serial transmission ~~conversion~~



b) Parallel transmission

Data Conversions →

* There are two types of data converters.
  1) Analog to Digital Converter
  2) Digital to Analog Converter

Analog to Digital Converter :-

* If we want to connect the o/p of a ~~digital~~ analog circuit,

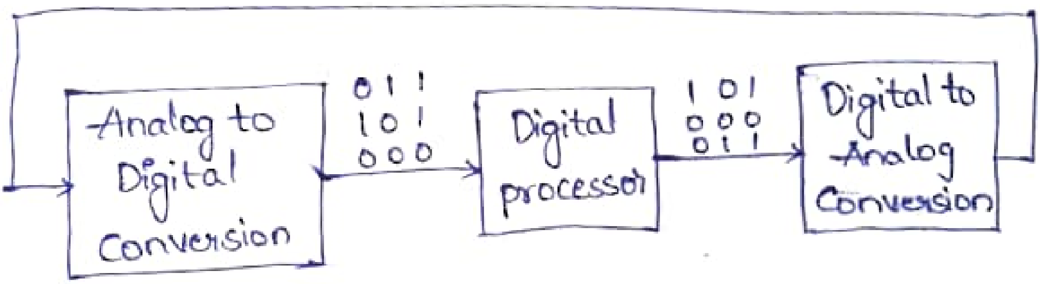
as an i/p of a digital circuit, then we have to place an interfacing circuit between them.

* This interfacing circuit that converts the analog signal into digital signal is called as Analog to Digital converter.

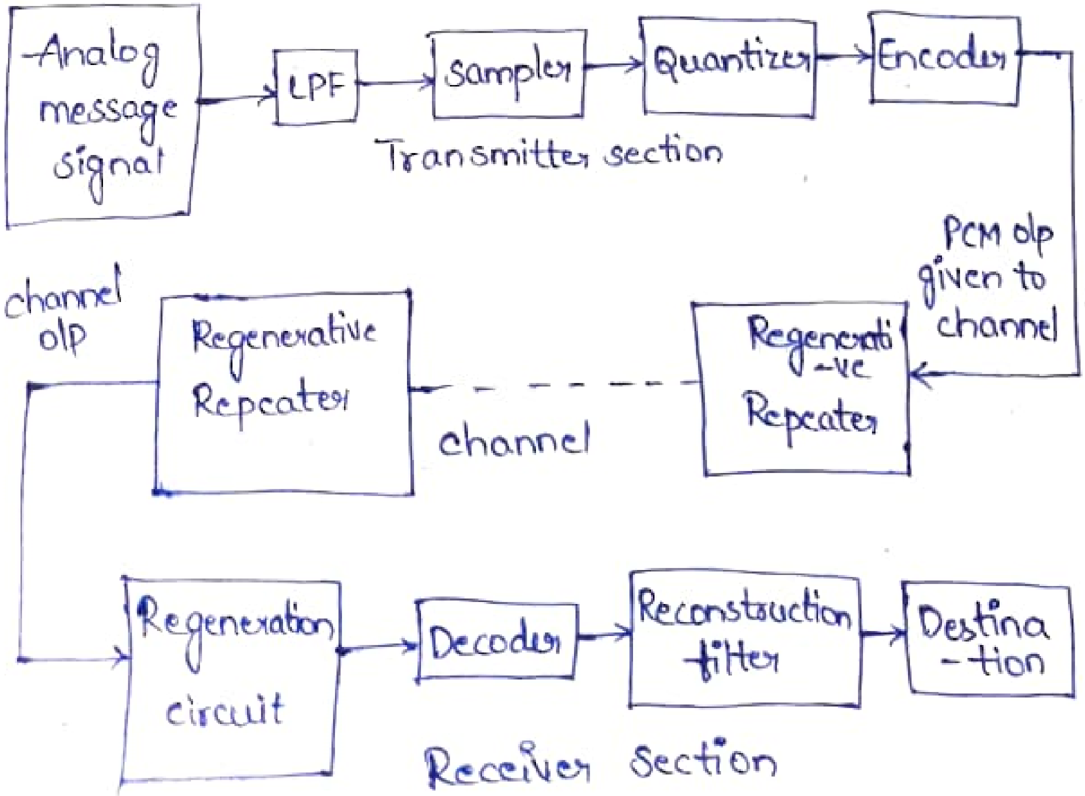
Digital to Analog Converter:-

* If we want to connect the o/p of a digital circuit, as an i/p of a analog circuit, then we have to place an interfacing circuit between them.

* This interfacing circuit that converts the digital signal into analog signal is called as Digital to Analog converter.



Pulse code Modulation →



Low pass filter:-
* This filter eliminates the high frequency components present in the i/p analog signal which is greater than the highest frequency of the message signal, to avoid aliasing of the message signal

Sampler:-
* This is the technique which helps to collect the sample data at instantaneous values of message signal, so as to reconstruct the original signal.
* The sampling rate must be greater than twice the highest frequency component of message signal in accordance with the sampling theorem

$$f_s \geq 2f_m$$

Quantizer:-
* It is a process of reducing the excessive bits and confining the data. The sampled o/p which given to Quantizer, reduces the redundant bits & compress the value

Encoder:-
* The digitization of analog signal is done by the encoder.
* It designates each quantized level by a binary code.
* The sampling done here is the sample-and-hold process
* These three sections (LPF, Sampler & Quantizer will act as an analog to digital converter.
* Encoding minimizes the bandwidth used.

Regenerative Repeater:-
* This section increases the signal strength.
* The o/p of the channel also has one regenerative repeater circuit, to compensate the signal loss & reconstruct the signal, & also to increase its strength.

Decoder:-
* The decoder circuit decodes the pulse coded waveform

to reproduce the original signal. This circuit acts as the demodulator.

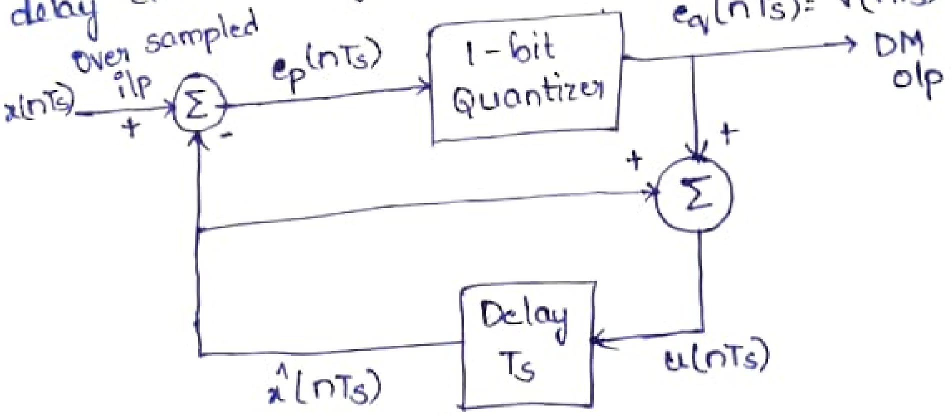
Reconstruction filter:-

* After the digital-to-analog conversion is done by the regenerative circuit & the decoder, a low pass filter is employed, called as the reconstruction filter to get back the original signal.

Delta Modulation →

* The type of modulation, where the sampling rate is much higher & in which the step size after quantization is of a smaller value Δ, such a modulation is termed as delta modulation.

* The delta modulator comprises of a 1-bit quantizer & a delay circuit along with two summer circuits.



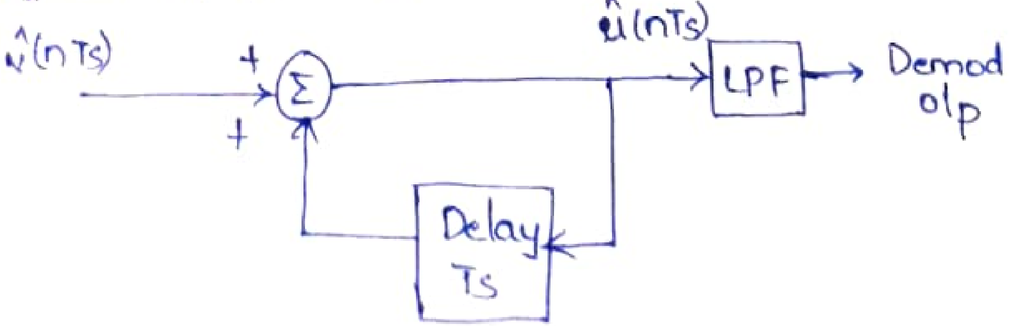
$x(nTs)$ → over sampled i/p

$e_p(nTs)$ → summer o/p & quantizer i/p

$e_q(nTs)$ → quantizer o/p

$\hat{x}(nTs)$ → o/p of delay circuit

$u(nTs)$ → i/p of delay circuit



PCM	DM
1. PCM stands for Pulse code modulation	1. DM stands for Delta Modulation
2. Feedback doesnot exist in transmitter & receiver	2. Feedback exists in transmitter
3. Per sample 4, 8 or 16 bits are used	3. only one bit is used per sample
4. Highest bandwidth	4. lowest bandwidth
5. complex in terms of complexity of implementation	5. Simple in terms of complexity of implementation
6. Costly	6. cheap
7. Good signal to noise ratio	7. poor signal to noise ratio
8. Signal requires encoder & decoder both sides	8. signal can modulate & demodulate
9. Used in video telephony & audio telephony	9. Used in speeches as well as images