Analog and Digital Communication

Subject Coordinator
Dr. Neeraj Kumar
Dr. Gaurav Kumar Bharti
Department of ECE
Teaching Assistant
Himanshu Singh

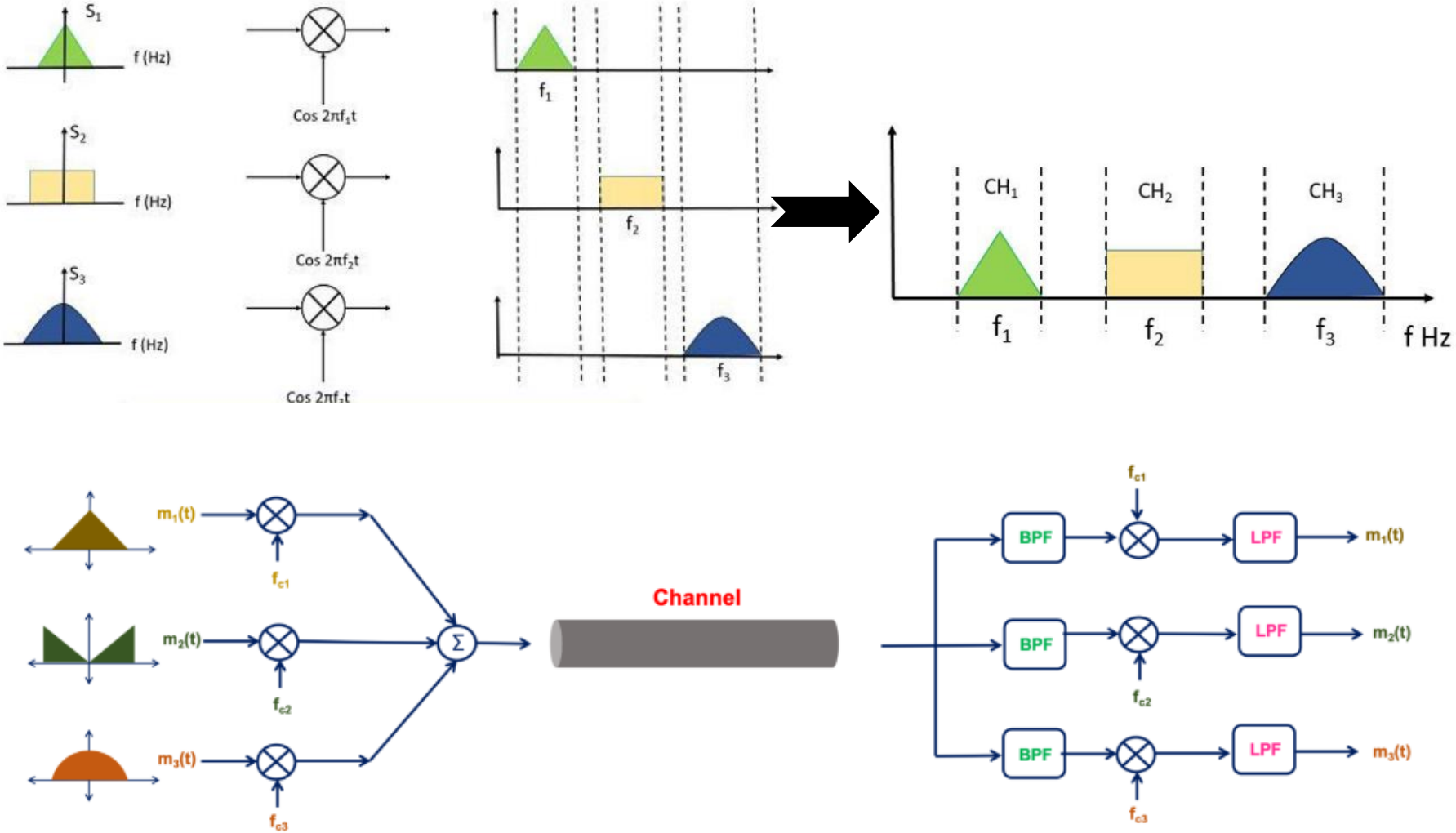
Frequency Division Multiplexing(FDM)

Frequency DivisionMultiplexing(FDM) is a technique used in communication systems to combine multiple signals for transmission over a single communication path or medium. By allocating a unique frequency band to each signal, FDM enables the simultaneous transmission of several signals. This concept is widely utilized in various forms of media including radio, television broadcasting, and the internet.

Basic Principle of FDM

The fundamental idea behind FDM is to divide the available bandwidth of a communication channel into non-overlapping frequency bands, each carrying a separate signal. This is achieved by modulating (mixing) each signal with a different carrier frequency. These modulated signals are then combined into a single composite signal for transmission. At the receiver end, demodulation takes place to extract the original signals from the composite signal.

Block Diagram FDM



Applications

- Earlier, FDM is used in the cellular telephone system and harmonic telegraphy communication system.
- Frequency division multiplexing is mainly used in radio broadcasting.
- FDM is also used in TV broadcasting.
- This type of multiplexing is applicable in the telephone system to help in transmitting several phone calls over a single link or single transmission line.
- FDM is used in a satellite communication system for transmitting various data channels.
- It is used in FM transmission systems or stereo frequency modulation.
- It is used in AM radio transmission systems/Amplitude Modulation.
- It is used for public telephones and cable TV systems.
- It is used in broadcasting.
- It is used in AM and FM broadcasting.
- It is used in wireless networks, cellular networks, etc.

Advantages:

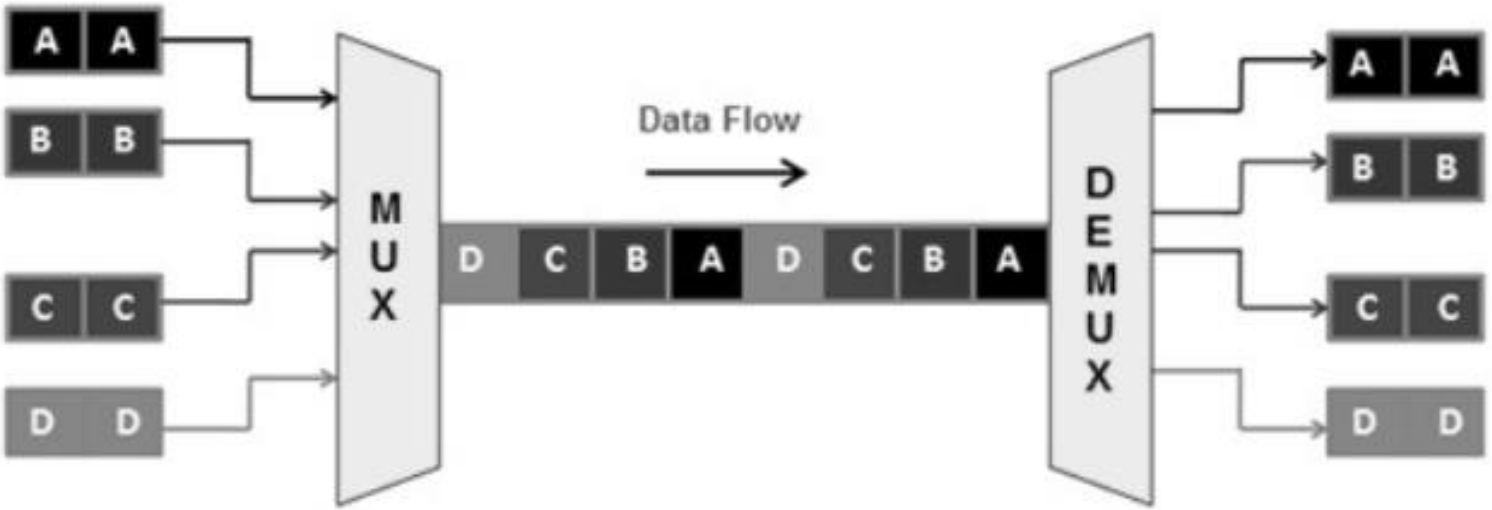
- It is a synchronization-free technique as we don’t need synchronization between transmitter and receiver.
- It facilitates the transmission of a large number of signals simultaneously.
- FDM demodulation is easy.

Disadvantages :

- The channel bandwidth required is large.
- It can result in crosstalk as several signals are transmitted during the same time interval.
- It can cause intermodulation distortion.

Time Division Multiplexing (TDM)

Time-division multiplexing or TDM definition is; a multiplexing technique that is used to transmit two or above streaming digital signals above a common channel. In this type of multiplexing technique, incoming signals are separated into equivalent fixed-length time slots. Once multiplexing is done, these signals are sent over a shared medium & after de-multiplexing, they are reassembled into their original format.



Let the maximum frequency of signal ‘fm’ & the sampling frequency ‘fs’ then

$$fs \geq 2fm$$

Therefore, the duration of time in between succeeding samples is given as,

$$Ts = 1/fs$$

We know that basically pulse frequency is the number of pulses for each second which is given as

Pulse frequency = 1/spacing between two samples

$$= 1/\ Ts/N =.N/Ts$$

We know that Ts = 1/fs, the above equation will become as;

$$= N/1/fs = Nfs.$$

For a time division multiplexing signal, the pulse for each second is the rate of signaling that is denoted with ‘r’. So,

$$r = Nfs$$

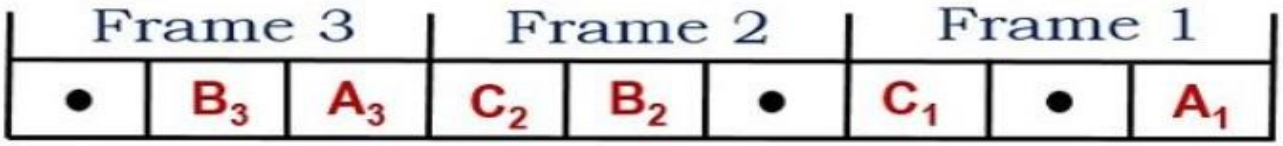
Types of TDM

There are two types of time division multiplexing; synchronous TDM and asynchronous TDM.

Synchronous TDM

The input is synchronous time division multiplexing is simply connected to a frame. In TDM, if there are ‘n’ connections, then the frame can be separated into ‘n’ time slots. So, each slot is simply allocated to every input line. In this method, the sampling rate is familiar to all signals, and thus similar clock input is given. The mux assigns the same slot to every device at all times.

The advantages of synchronous TDM mainly include; order being maintained and no addressing data is necessary. The disadvantages of synchronous TDM mainly include; it needs a high bit rate and if there is no input signal at a single channel since a fixed time slot is allocated to every channel, then the time slot for that specific channel does not hold any data & there is bandwidth wastage.

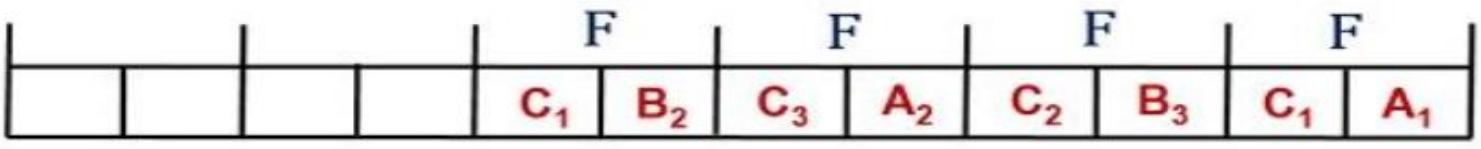


Synchronous TDM

Asynchronous TDM

Asynchronous TDM is also known as Statistical TDM which is a type of TDM where the o/p frame gathers information from the input frame till it is filled but not leaving an unfilled slot like in Synchronous TDM. In this type of multiplexing, we have to include the address of particular data within the slot that is being transmitted to the output frame. This type of TDM is very efficient because the capacity of the channel is completely used & improves the efficiency of bandwidth.

The advantages of asynchronous TDM mainly include; its circuitry is not complex, low capacity communication link is used, there is no severe crosstalk problem, no intermediation distortion and for each channel, the complete channel bandwidth is used. The disadvantages of asynchronous TDM mainly include; it needs a buffer, frame sizes are different and address data is required.



Asynchronous TDM

Advantages :

- Simple circuit design.
- It uses entire channel bandwidth for the transmission of the signal.
- The problem of Intermodulation distortion is not present in TDM.
- Pulse overlapping can sometimes cause crosstalk but it can be reduced by utilizing guard time. Thus, is not much serious.

Disadvantages :

- The transmitting and receiving section must be properly synchronized in order to have proper signal transmission and reception.
- Slow narrowband fading can wipe out all the TDM channels.

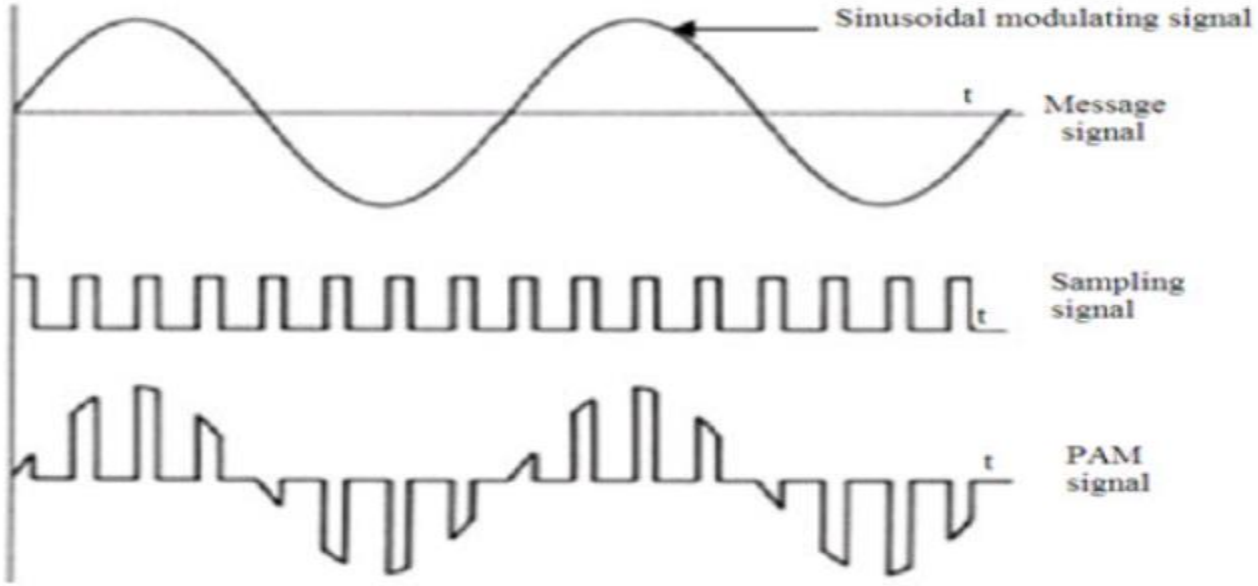
Application of TDM :

- TDM is applicable in telephone systems.
- TDM is utilized in wireline telephone lines.
- Earlier, this multiplexing technique is used in the telegraph.
- TDM is used in cellular radios, satellite access systems, and digital audio mixing systems.
- TDM is the most common technique used in fiber optic communication/optical data transmission systems.
- TDM is used for analog & digital signals where a number of channels with less speed are simply multiplexed into high-speed channels are utilized for transmission.

FDM	TDM
The term FDM stands for “frequency division multiplexing.	The term TDM stands for “time division multiplexing.
This multiplexing simply works with only analog signals.	This multiplexing simply works with both analog & digital signals.
This multiplexing has high conflict.	This multiplexing has low conflict.
FDM chip/Wiring is complex.	TDM chip/Wiring is not complex.
This multiplexing is not efficient.	This multiplexing is very efficient.
In FDM, frequency is shared.	In TDM, time is shared.
The guard band is compulsory in FDM.	The synchronization pulse in TDM is compulsory.
In FDM, all the signals with different frequencies operate simultaneously.	In TDM, all the signals with equal frequency operate at different times.
The FDM has a very high range of interference.	The TDM has a negligible or very low range of interference.
The circuitry of FDM is complex.	The circuitry of TDM is simple.

Pulse Amplitude Modulation (PAM)

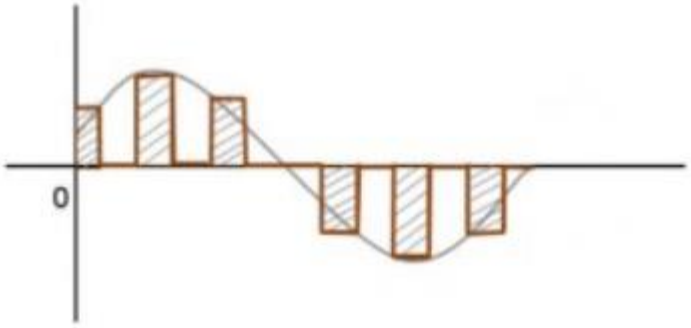
Pulse amplitude modulation is a technique in which the amplitude of each pulse is controlled by the instantaneous amplitude of the modulation signal. It is a modulation system in which the signal is sampled at regular intervals and each sample is made proportional to the amplitude of the signal at the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



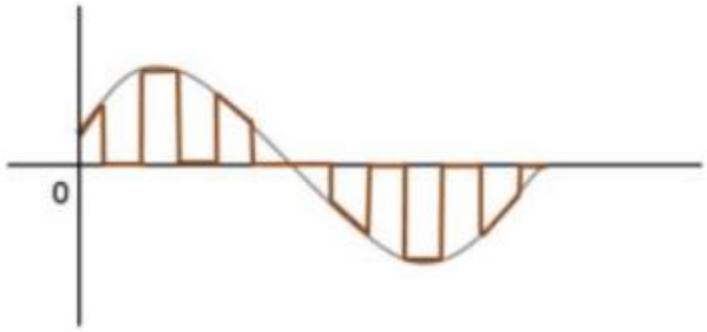
Pulse Amplitude Modulation Signal

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

Flat Top PAM
Natural PAM



Flat Top Pulse Amplitude Modulation



Natural Pulse Amplitude Modulation

In Pulse modulation, the unmodulated carrier signal is a periodic train of signals. So the pulse train can be described like the following.

$$up(t) = \sum_{k=-\infty}^{\infty} A \, \text{rect}\left(\frac{t - kTs}{\tau}\right)$$

Pulse Train

In PAM, the signal amplitudes can be changed based on the modulating signal. Here, the modulating signal like m(t), PAM can be achieved through multiplying the carrier signal with the modulating signal. The o/p is a set of pulses, where the amplitudes of signals can be changed on the modulating signal.

The pulse train's periodic time is called the sampling period.

$$Fs = 1 /Ts$$

The natural pulse amplitude modulation equation can be described as the following.

$$up(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos \frac{2\pi nt}{Ts}$$

$$= a_0 + a_1 \cos \frac{2\pi nt}{Ts} + a_2 \cos \frac{4\pi nt}{Ts} + \dots$$

PAM Equation

The modulated pulse train can be described like

$$E(t) = m(t) + Up(t)$$

$$= a0\ m(t) + a1\ m(t) \cos 2\pi nt/Ts + a2\ m(t) \cos 4\pi nt/Ts + \ldots.$$

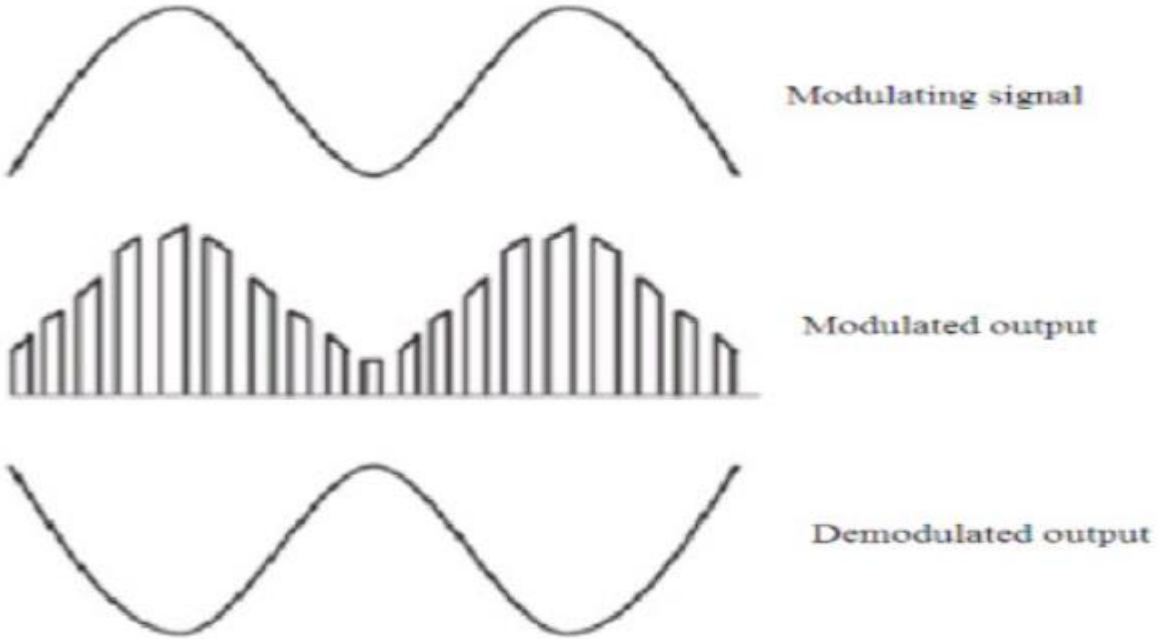
To stop the low-edge of the DSBSC range from overlapping through the less frequency range, the division Δ among these should not below zero. So

$$W + \Delta = fs - W, \text{ with } \Delta \geq 0$$

$$fs \geq 2W$$

Demodulation of PAM

For the demodulation of the PAM signal, the PAM signal is fed to the low pass filter. The low pass filter eliminates the high-frequency ripples and generates the demodulated signal. This signal is then applied to the inverting amplifier to amplify its signal level to have the demodulated output with almost equal amplitude with the modulating signal.



Demodulation of PAM signal

Advantages :

- It is a simple process for both modulation and demodulation.
- The FM available is infinite; therefore the development of PAM can be done frequently to permit enhanced data throughput over accessible networks.
- It is the simplest type of modulation
- For all types of digital modulation methods, it is the base and simple method for both modulation & demodulation.
- For both the transmission as well as reception, it doesn't require complex circuitry. The circuit design of the Transmitter & receiver is very simple.
- This modulation can generate other types of pulse modulation signals & also carries the message at the same time.

Disadvantages :

- Bandwidth should be large for transmission PAM modulation.
- Noise will be great.
- Pulse amplitude signal varies so the power required for transmission will be more.

Applications Of PAM

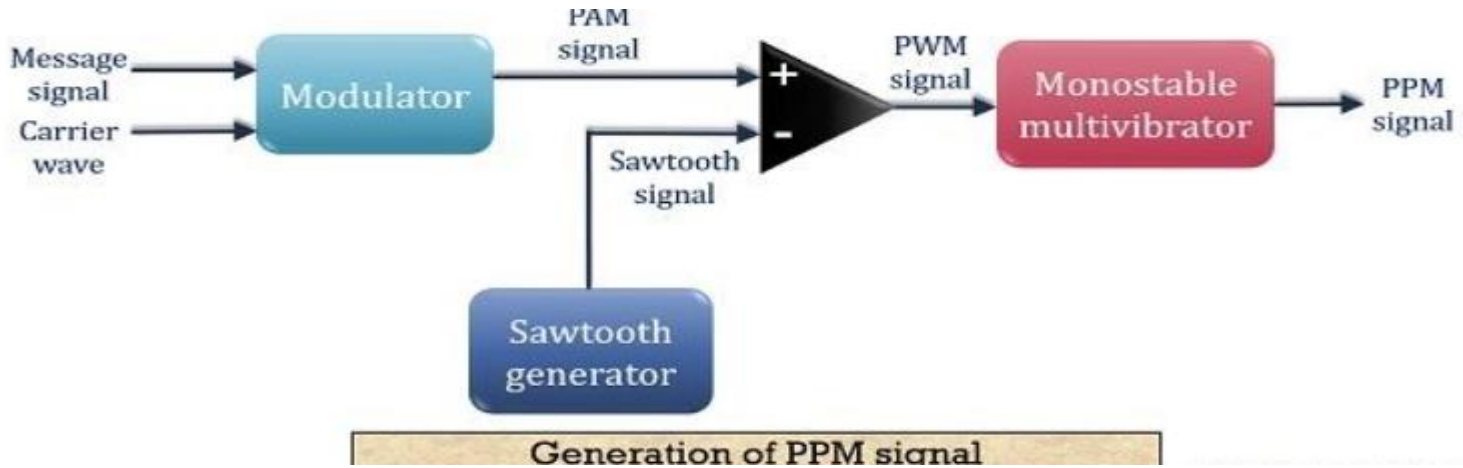
- It is used as an electronic driver for LED lighting.
- PAM is used in the Ethernet network which is used to connect two systems & used to transfer data among these systems. So PAM is used in Ethernet communications.
- The control signals can be generated in various microcontrollers by using PAM

Pulse Position Modulation (PPM)

A modulation technique that allows variation in the position of the pulses according to the amplitude of the sampled modulating signal is known as Pulse Position Modulation (PPM). It is another type of PTM, where the amplitude and width of the pulses are kept constant and only the position of the pulses is varied.

The pulse displacement is directly proportional to the sampled value of the message signal.The information is transmitted with the varying position of the pulses in pulse position modulation.

The basic idea about the generation of a PPM waveform is that here, as the amplitude of the message signal increases, the pulse shifts according to the reference.

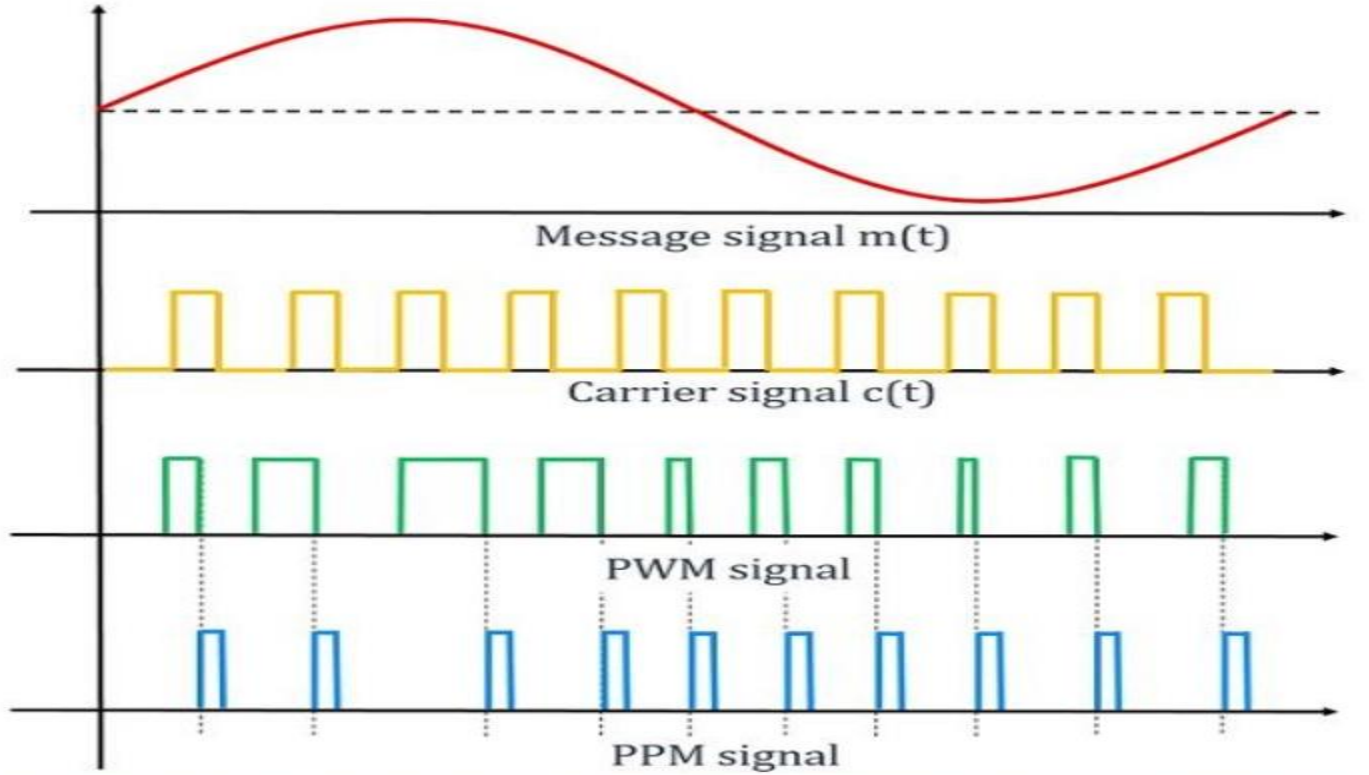


Generation of PPM signal

The output of the comparator is fed to a monostable multivibrator. It is negative edge triggered. Hence, with the trailing edge of the PWM signal, the output of the monostable goes high.

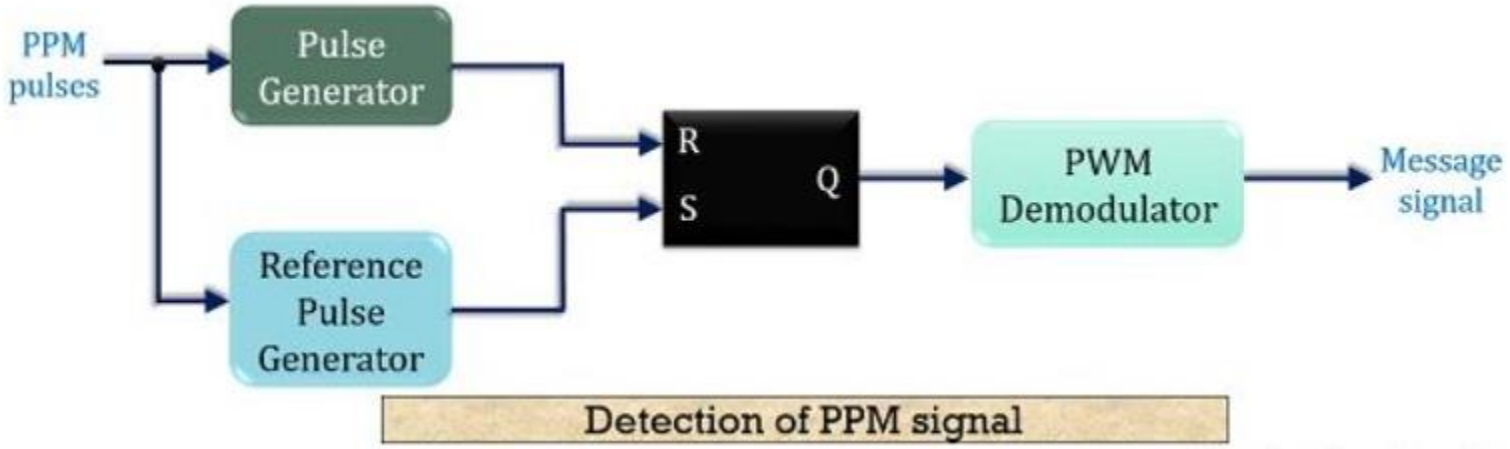
This is why a pulse of PPM signal begins with the trailing edge of the PWM signal.

It is to be noted in case of PPM that the duration for which the output will be high depends on the RC components of the multivibrator. This is the reason why a constant width pulse is obtained in case of the PPM signal.



Waveform representation of PPM signal generation

Detection (Demodulation) of PPM signal



Detection of PPM signal

The PPM signal transmitted from the modulation circuit gets distorted by the noise during transmission. This distorted PPM signal reaches the demodulator circuit. The pulse generator employed in the circuit generates a pulsed waveform. This waveform is of fixed duration which is fed to the reset pin (R) of the SR flip-flop.

The reference pulse generator generates, reference pulse of a fixed period when transmitted PPM signal is applied to it. This reference pulse is used to set the flip-flop.

These set and reset signals generate a PWM signal at the output of the flip-flop. This PWM signal is then further processed in order to provide the original message signal.

Advantages of Pulse Position Modulation

- As the amplitude and width of the pulses remain constant. Thus the transmission power also remains constant and does not show variation.
- Recovering a PPM signal from distorted PPM is quite easy.
- Interference due to noise in more minimal than PAM and PWM.

Disadvantages of Pulse Position Modulation

- In order to have proper detection of the signal at the receiver, transmitter and receiver must be in synchronization.
- The bandwidth requirement is large.

Application of PPM

- PPM is used in noncoherent detection wherever a receiver does not require any Phase lock loop or PLL to track the carrier's phase.
- It is used in RF (radio frequency) communication.
- It is also utilized in high-frequency, contactless smart cards, radio frequency ID tags, etc