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DIGITAL COMMUNICATION

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- PAM (Pulse Amplitude Modulation)
- Pulse Time Modulation
  - PWM (Pulse Width Modulation)
  - PPM (Pulse Position Modulation)

Good Morning

After continuous wave modulation, the next division is Pulse modulation.

In this chapter, let us discuss the following analog pulse modulation techniques.

- Pulse Amplitude Modulation
- Pulse Width Modulation
- Pulse Position Modulation

PAM

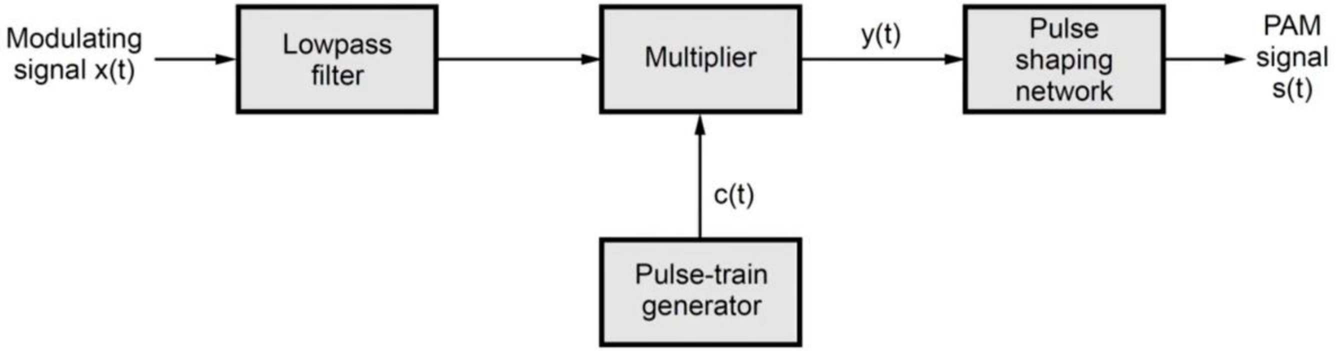
Pulse Amplitude Modulation

In **Pulse Amplitude Modulation (PAM)** technique, the amplitude of the pulse carrier varies, which is proportional to the instantaneous amplitude of the message signal.

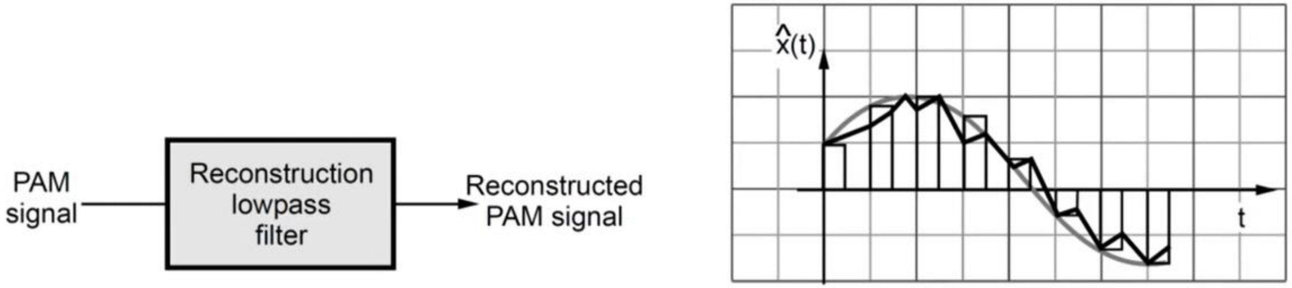
The pulse amplitude modulated signal will follow the amplitude of the original signal, as the signal traces out the path of the whole wave. In natural PAM, a signal sampled at Nyquist rate can be reconstructed, by passing it through an efficient **Low Pass Filter (LPF)** with exact cutoff frequency.

The following figures explain the Pulse Amplitude Modulation.

The amplitude of the pulse is directly proportional to amplitude of the modulating signal at the sampling instant. The width and position of the pulse remains unchanged.



Generation of PAM



(a) Detector **(b) Waveforms**

PAM detector and its waveforms

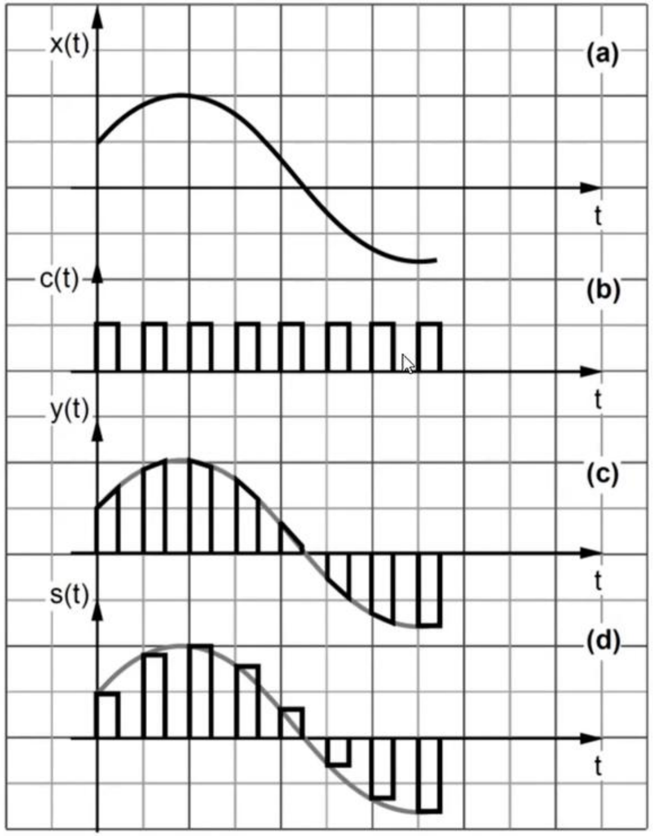
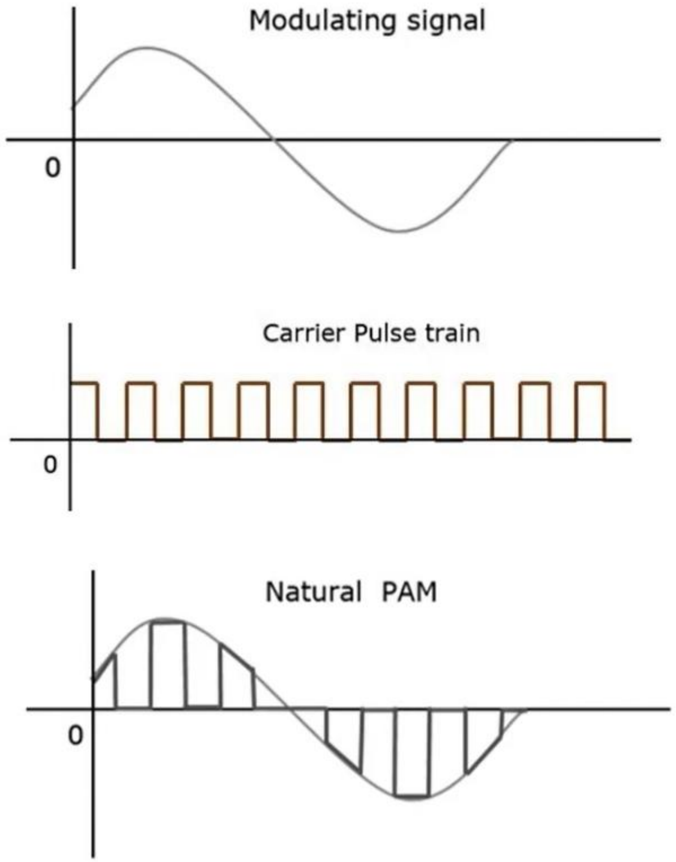
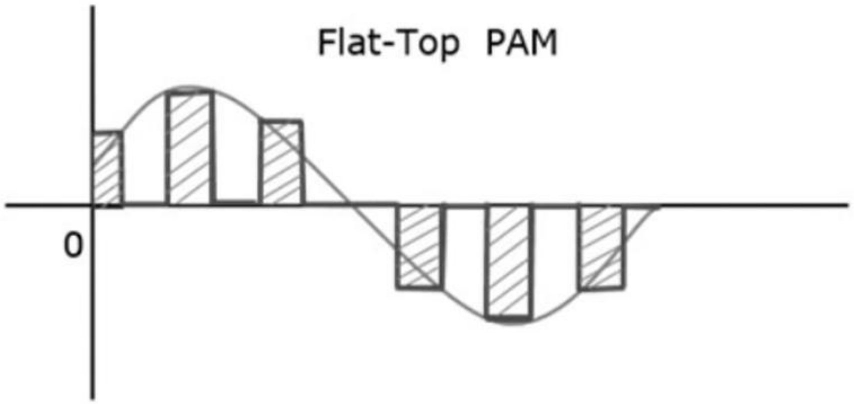


Fig. 2.1.2 PAM waveforms

PAM Waveform



Though the PAM signal is passed through a LPF, it cannot recover the signal without distortion. Hence, to avoid this noise, use flat-top sampling. The flat-top PAM signal is shown in the following figure.



Flat-top sampling is the process in which, the sampled signal can be represented in pulses for which the amplitude of the signal cannot be changed with respect to the analog signal, to be sampled. The tops of amplitude remain flat. This process simplifies the circuit design.

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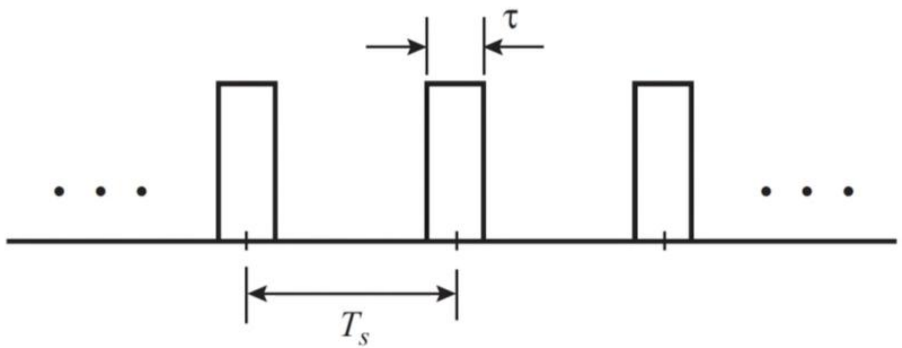
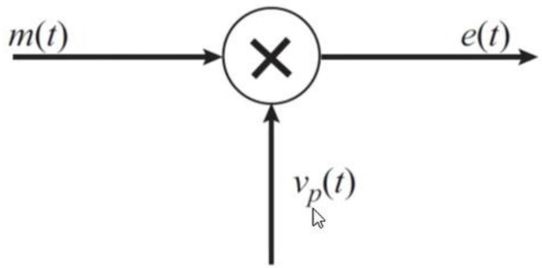


Periodic pulse train.



Product modulator used to produce natural PAM.

In pulse modulation the unmodulated carrier is a periodic train of pulses as sketched in Fig. The unmodulated pulse amplitude is shown as A and the pulse width as τ. The periodic time of the pulse train is shown as T_s. The reason for using subscript s will become apparent shortly.

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

In *pulse amplitude modulation* (PAM) the amplitudes of the pulses are varied in accordance with the modulating signal.

The pulse train acts as a periodic switching signal to the modulator, which when switched on allows *samples* of the modulating signal to pass through to the output. The periodic time of the pulse train is known as the sampling period and hence the use of the subscript s. Note that T_s is the period from the beginning of one sample to the next, not the pulse duration. The sampling frequency is

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

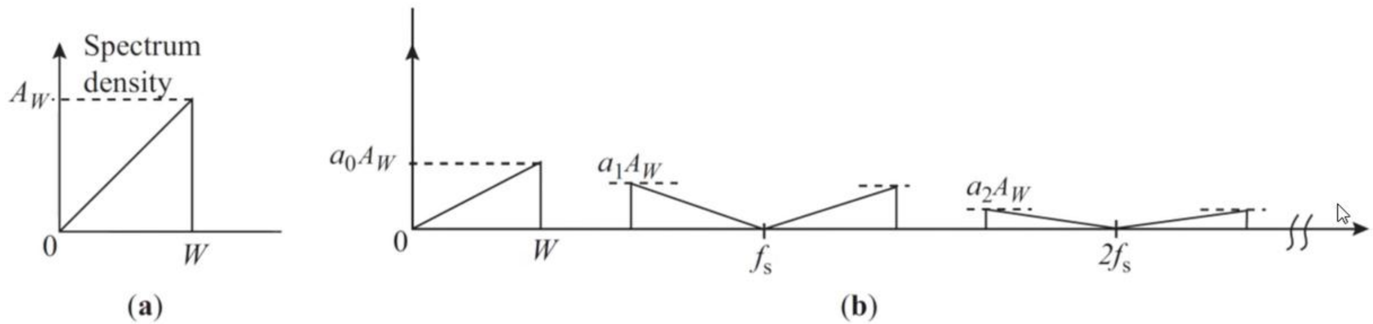
The equation describing natural PAM is found as follows. The Fourier series for the unmodulated pulse train is given by Eq.

$$\begin{aligned} v_p(t) &= a_0 + \sum_{n=1}^{n=\infty} a_n \cos \frac{2\pi n t}{T_s} \\ &= a_0 + a_1 \cos \frac{2\pi t}{T_s} + a_2 \cos \frac{4\pi t}{T_s} + \cdots \end{aligned}$$

The modulated pulse train is then

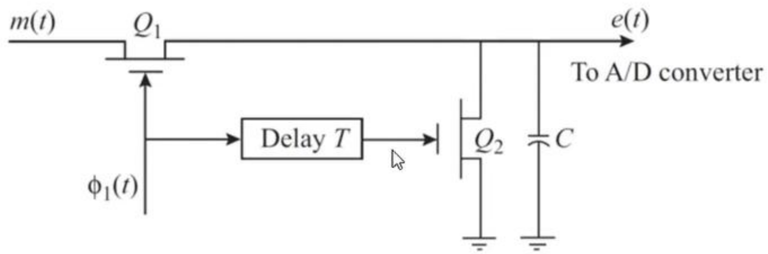
$$\begin{aligned} e(t) &= m(t) \cdot v_p(t) \\ &= a_0 m(t) + a_1 m(t) \cos \frac{2\pi t}{T_s} + a_2 m(t) \cos \frac{4\pi t}{T_s} + \cdots \end{aligned}$$

The right-hand side of this equation shows that the modulated wave consists of the modulating signal, multiplied by the dc term *a0* and a series of DSBSC-type components resulting from the harmonics in the pulse waveform. Denoting the modulating signal spectrum by *M(f)* and the highest frequency component in this by *W*, the spectrum for the PAM signal will be as shown in Fig.

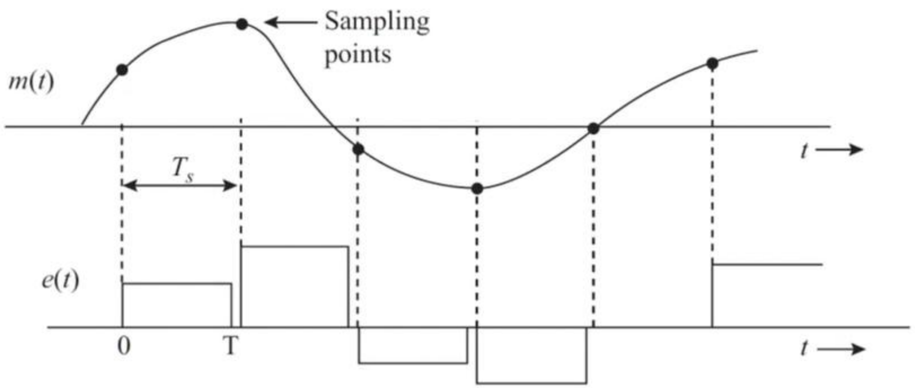


Spectrum *M(f)* (a) for the modulating signal and (b) for the natural PAM wave.

Sample & Hold Circuit for Flat-Top PAM



(a)



(b)

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Advantages

1. PAM can be easily generated and detected.
2. PAM forms the basis for many other pulse modulation techniques such as PCM, DM and ADM.

Disadvantages

1. As we have seen just now, the bandwidth needed for transmission of PAM signal is very very large compared to its maximum frequency content.
2. The amplitude of PAM pulses varies according to modulating signal. Therefore interference of noise is maximum for the PAM signal and this noise cannot be removed very easily.
3. Since amplitude of PAM signal varies, this also varies the peak power required by the transmitter with modulating signal.

Applications

1. PAM is used for transmitting signals over a short distance baseband channels and simple communication.
2. PAM is also used in instrumentation systems.
3. It is used in Analog-to-digital converters for computer interfacing.

Pulse Width Modulation

Pulse Width Modulation

In **Pulse Width Modulation (PWM)** or Pulse Duration Modulation (PDM) or Pulse Time Modulation (PTM) technique, the width or the duration or the time of the pulse carrier varies, which is proportional to the instantaneous amplitude of the message signal.

The width of the pulse varies in this method, but the amplitude of the signal remains constant. Amplitude limiters are used to make the amplitude of the signal constant. These circuits clip off the amplitude to a desired level, and hence the noise is limited.

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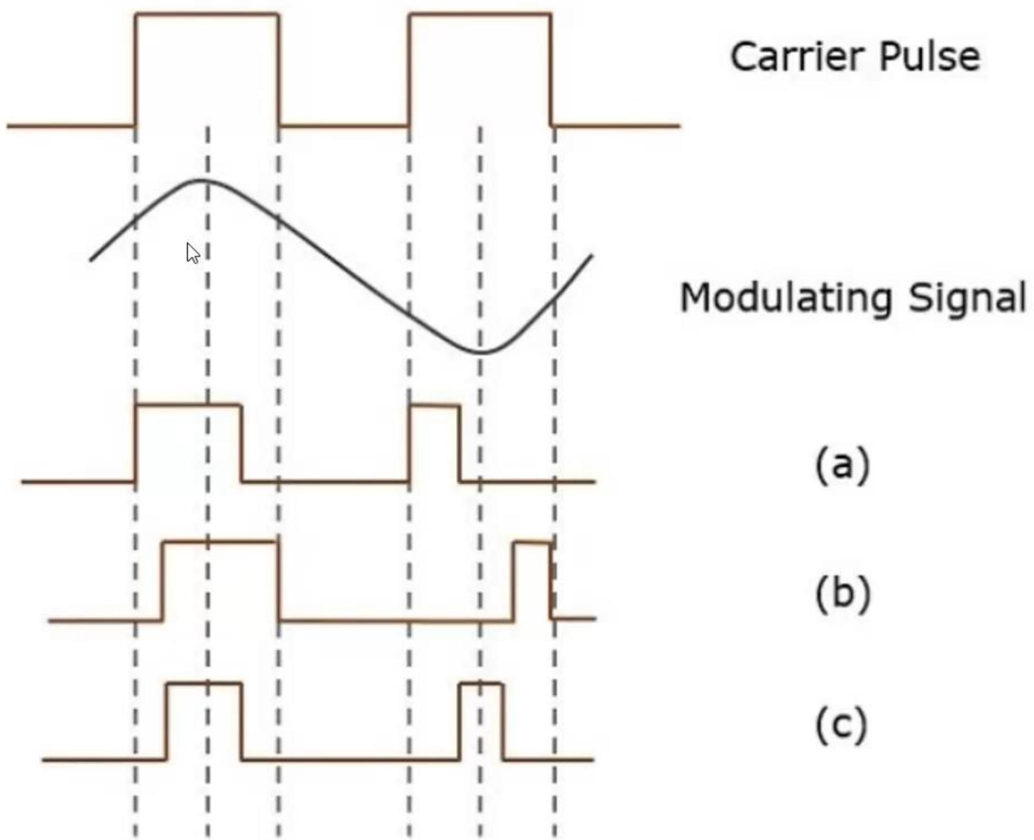
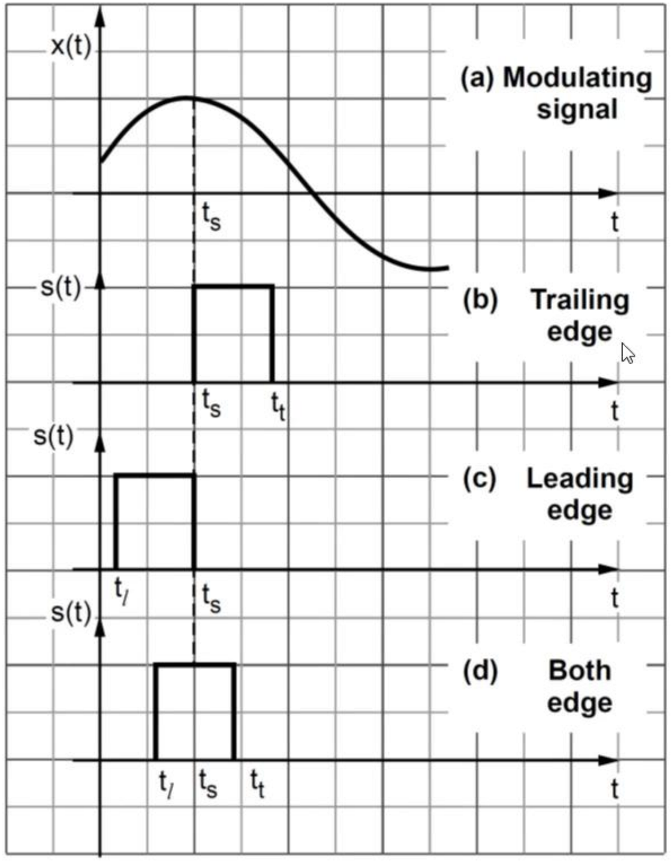
PWM Signal

The following figure explains the types of Pulse Width Modulations.



There are three types of PWM.

- The leading edge of the pulse being constant, the trailing edge varies according to the message signal. The waveform for this type of PWM is denoted as (a) in the above figure.
- The trailing edge of the pulse being constant, the leading edge varies according to the message signal. The waveform for this type of PWM is denoted as (b) in the above figure.
- The center of the pulse being constant, the leading edge and the trailing edge varies according to the message signal. The waveform for this type of PWM is denoted as (c) shown in the above figure.


x(t)
(a) Modulating signal
t_s
t
s(t)
(b) Trailing edge
t_s
t_t
t
s(t)
(c) Leading edge
t_l
t_s
t
s(t)
(d) Both edge
t_l
t_s
t_t
t

Types of PWM

If the frequency and amplitude of a pulse train are kept constant and the width of the pulses is varied with a modulating signal, then the result is a pulse width modulated (PWM) signal. Three variations are possible, as shown in Fig. (b), (c), and (d).

First, the pulse center may be fixed in the center of the repeating time window Tc and both edges of the pulse moved to compress or expand the width. Second, the lead edge can be held at the lead edge of the window and the tail edge modulated. Third, the tail edge can be fixed and the lead edge modulated. The resulting spectra are similar, and, as shown in Fig., they each contain a dc component and a base sideband containing the modulating signal, as well as phase modulated carriers at each harmonic of the pulse frequency. The amplitudes of the harmonic groups are constrained by a (sin (x))/x envelope and extend to infinity.

Since the baseband information appears in the signal and is not distorted by any modulation effects, it may be recovered using a simple low-pass filter to remove the carrier and its harmonics and a high-pass filter to remove the dc component.

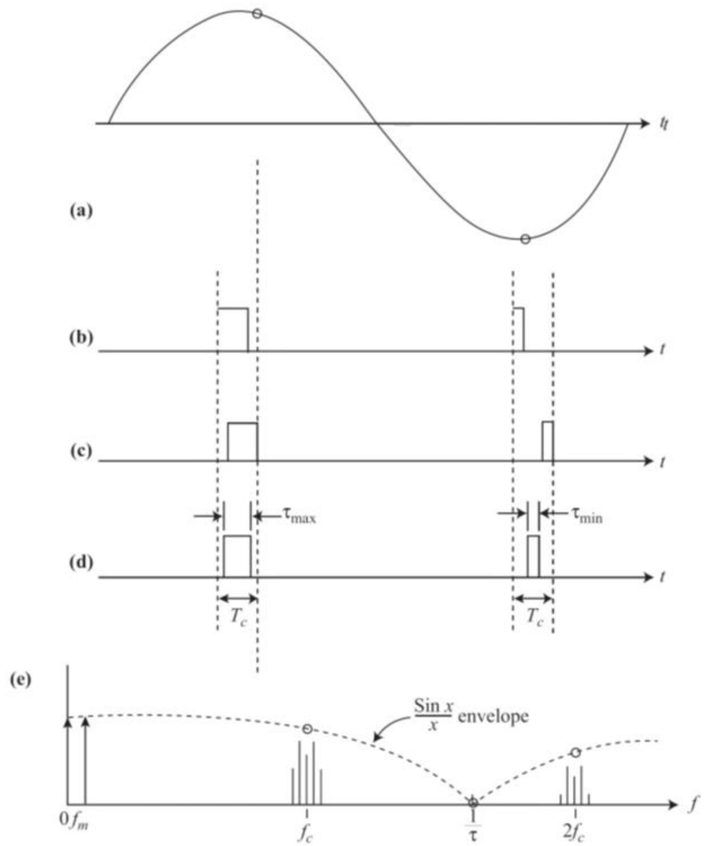
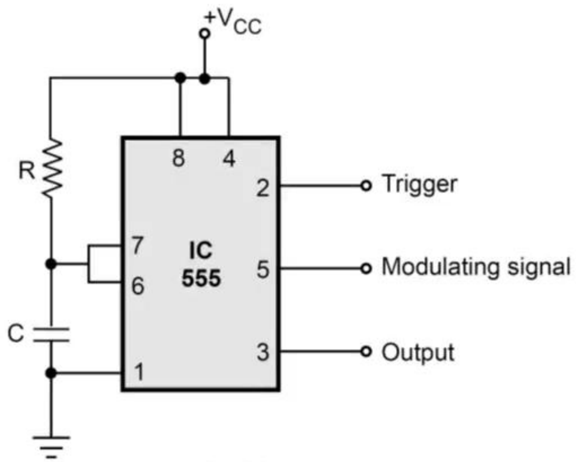
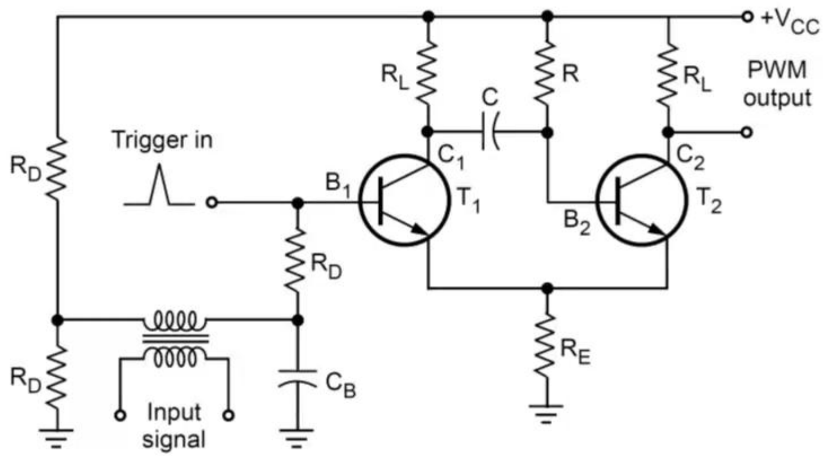


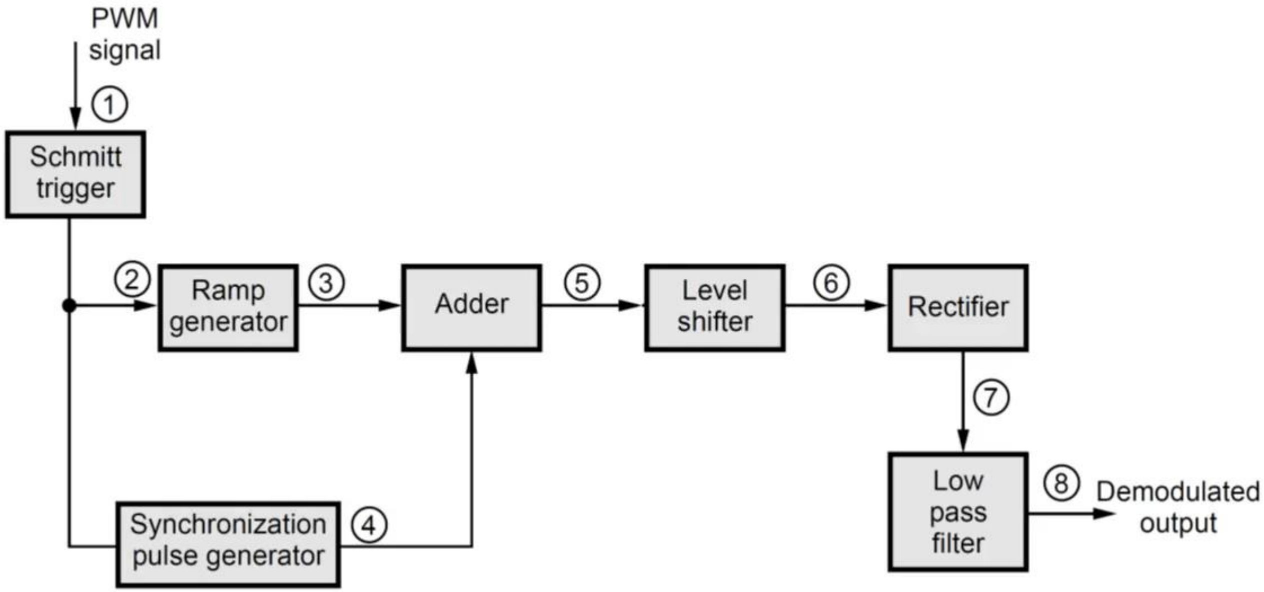
Figure Pulse width modulated (PWM) signal, (a) Modulating signal, (b), (c), and (d) PWM signals with lead edge, tail edge, or center fixed in the Tc window, (d) Spectrum of a PWM signal showing the baseband component.



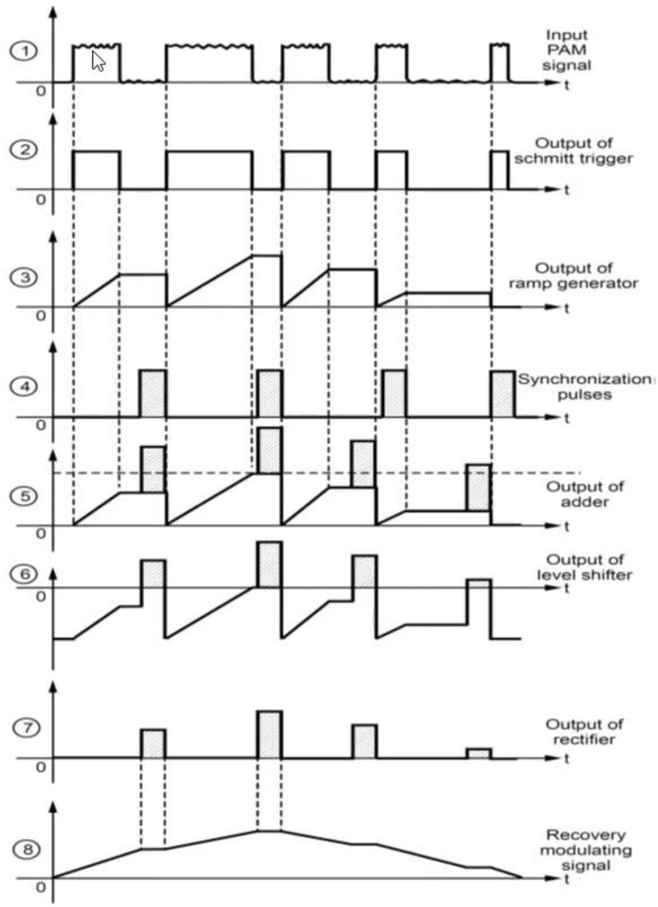
PWM generation circuit



Monostable multivibrator generating pulsewidth modulation



PWM detector



Waveforms for PWM detection circuit

Advantages

1. Unlike, PAM, noise is less, since in PWM, amplitude is held constant.
2. Signal and noise separation is very easy, as shown in Fig.
3. PWM communication does not require synchronization between transmitter and receiver.

Disadvantages

1. In PWM, pulses are varying in width and therefore their power contents are variable. This requires that the transmitter must be able to handle the power contents of the pulse having maximum pulse width.
2. Large bandwidth is required for the PWM communication as compared to PAM.

Applications

1. PWM is used for asynchronous transmission over noisy channel.
2. PWM is used for generate PPM.
3. Motor control.

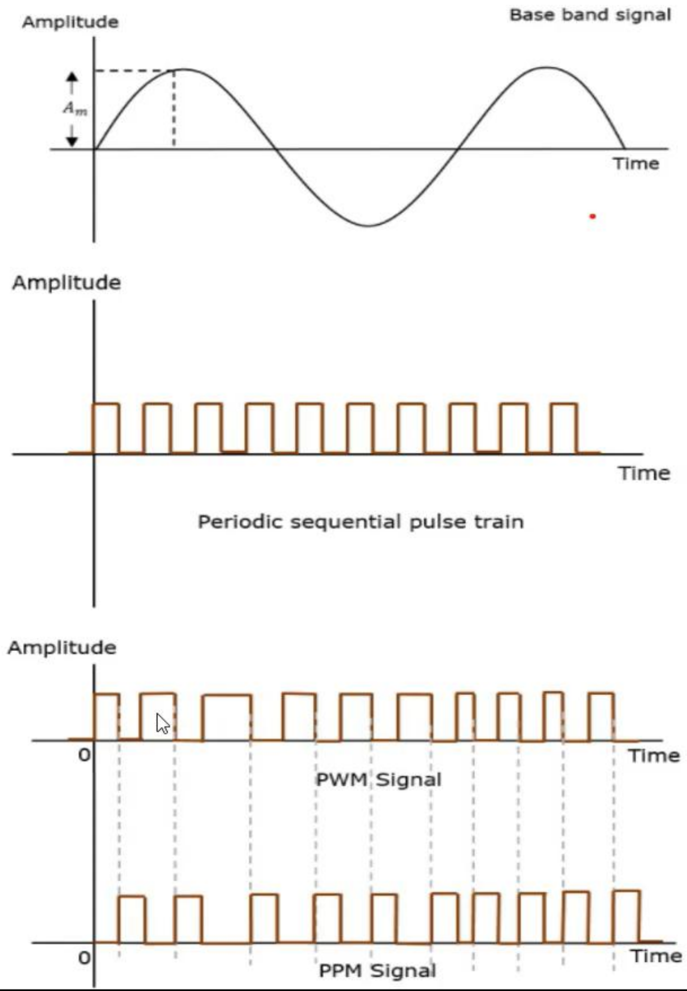
Pulse Position Modulation

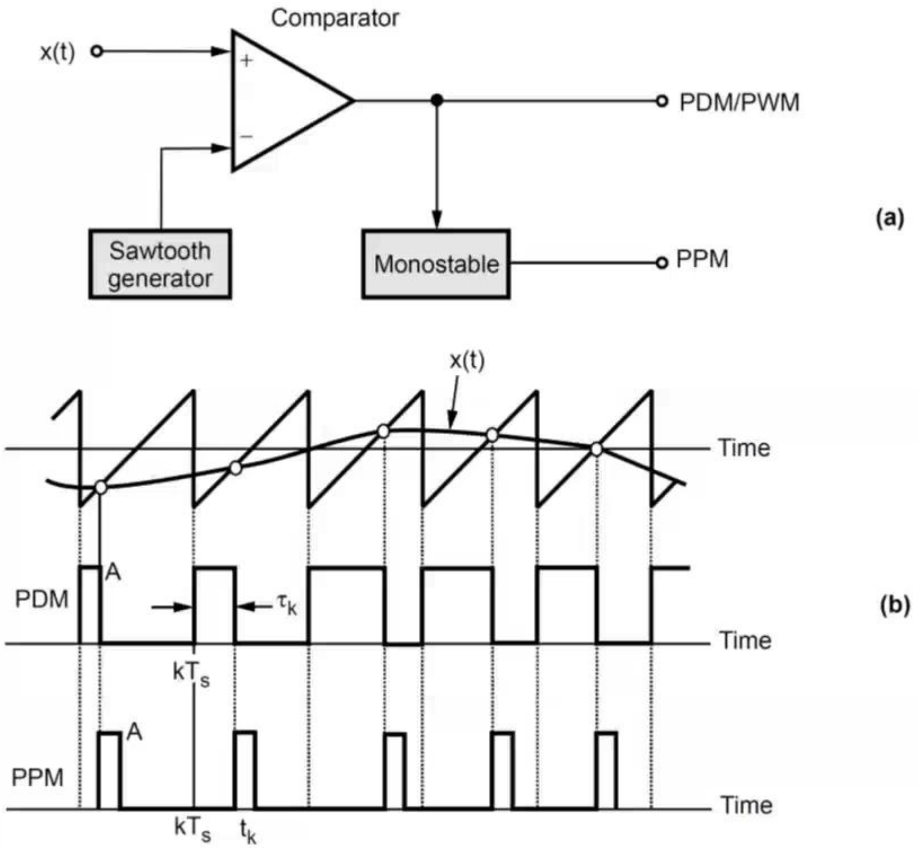
Pulse Position Modulation

Pulse Position Modulation (PPM) is an analog modulating scheme in which the amplitude and width of the pulses are kept constant, while the position of each pulse, with reference to the position of a reference pulse varies according to the instantaneous sampled value of the message signal.

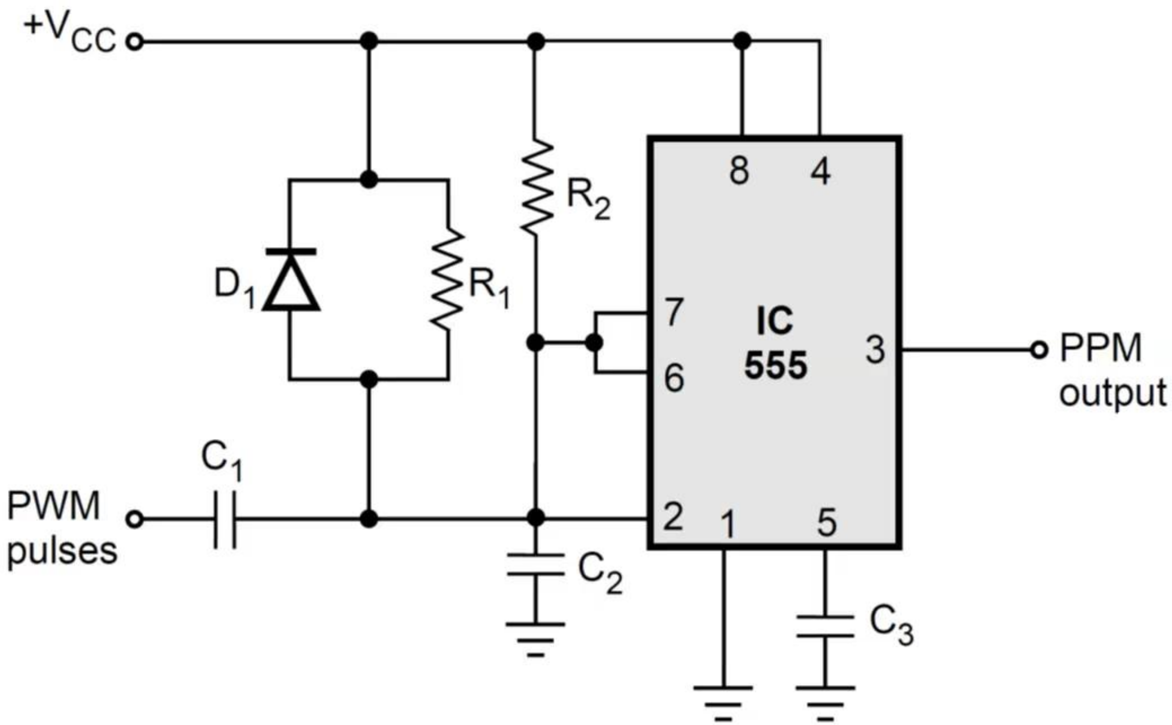
The transmitter has to send synchronizing pulses (or simply sync pulses) to keep the transmitter and receiver in synchronism. These sync pulses help maintain the position of the pulses. The following figures explain the Pulse Position Modulation.

Pulse position modulation is done in accordance with the pulse width modulated signal. Each trailing of the pulse width modulated signal becomes the starting point for pulses in PPM signal. Hence, the position of these pulses is proportional to the width of the PWM pulses.

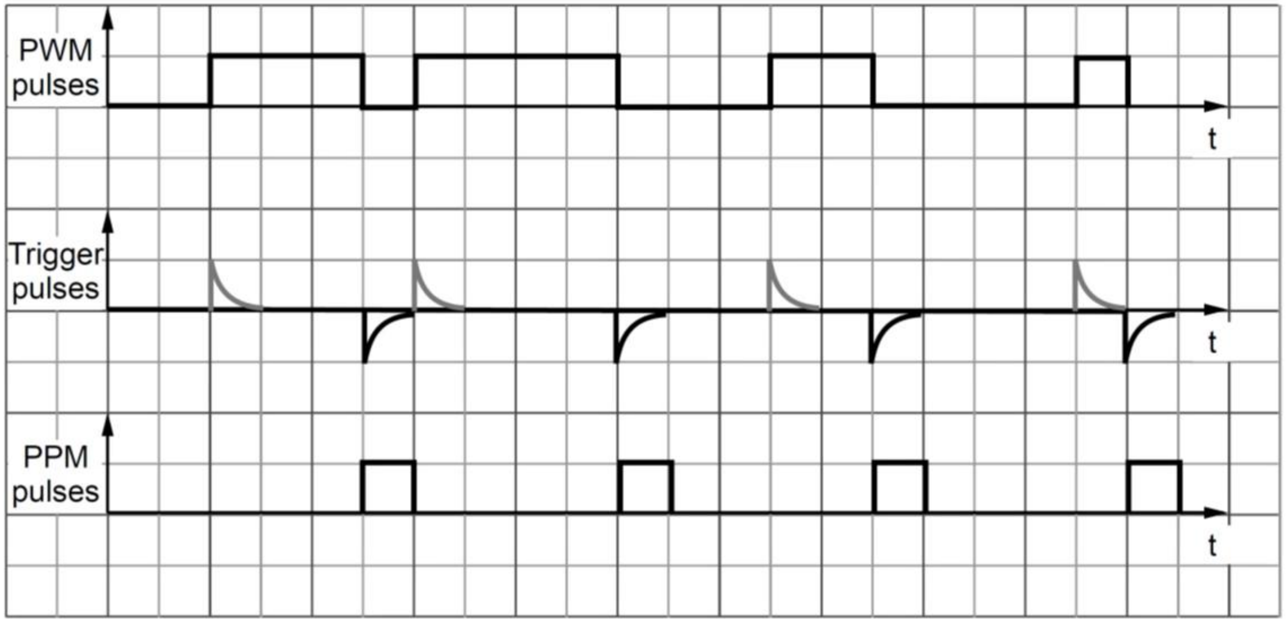

Amplitude
Base band signal
A_m
Time
Amplitude
Time
Periodic sequential pulse train
Amplitude
0
Time
PWM Signal
0
Time
PPM Signal



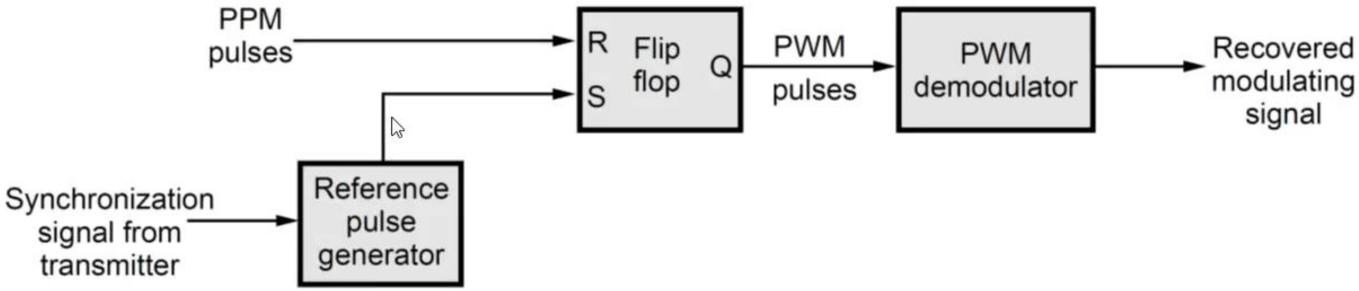
Generator of PPM and PWM (a) Block diagram (b) Waveforms



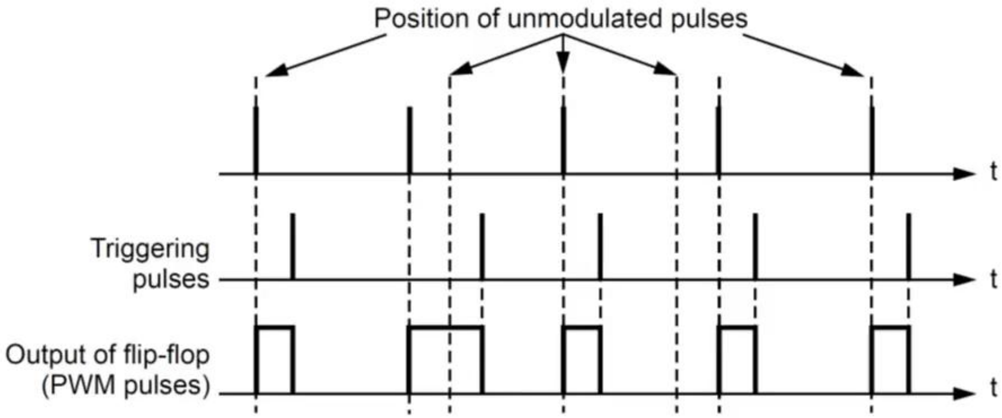
PPM generator



Waveforms of PPM generator



PPM demodulator



Demodulation waveforms for PPM

Advantages

1. Like PWM, in PPM amplitude is held constant thus less noise interference.
2. Like PWM, signal and noise separation is very easy.
3. Due to constant pulse widths and amplitudes, transmission power for each pulse is same.

Disadvantages

1. Synchronization between transmitter and receiver is required.
2. Large bandwidth is required as compared to PAM.

Application

1. Synchronous communication of analog pulses over short distances.