PCM, PWM & PPM

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Objective

1. To discuss about PWM and PPM modulation

2. To discuss about generation and detection of PWM and PPM modulation techniques

3. To discuss about digital pulse modulation-PCM-Pulse Code Modulation

Pulse Width Modulation (PWM)

- Definition: In PWM, instantaneous pulse width at each pulse duration is proportional to the amplitude of modulating signal.
- Various steps involved in generation of PWM signal:

i) Generate PAM signal $x_{PAM}(t)$

ii) Generate saw tooth waveform $p(t)$

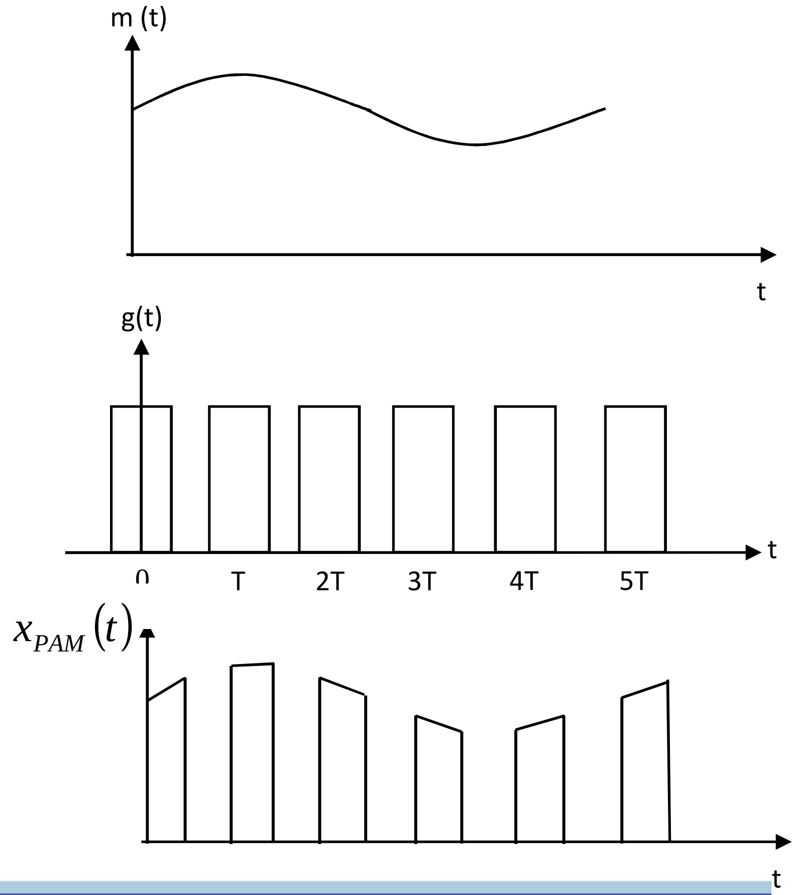
iii) Add $x_{PAM}(t) + p(t)$

iv) Slicing waveform at arbitrary threshold (V)

v) Comparator circuit output is PWM

Step 1: Generate PAM signal

PAM signal $x_{PAM}(t)$ may be obtained when $x(t)$ and $g(t)$ is applied to PAM generation circuit.



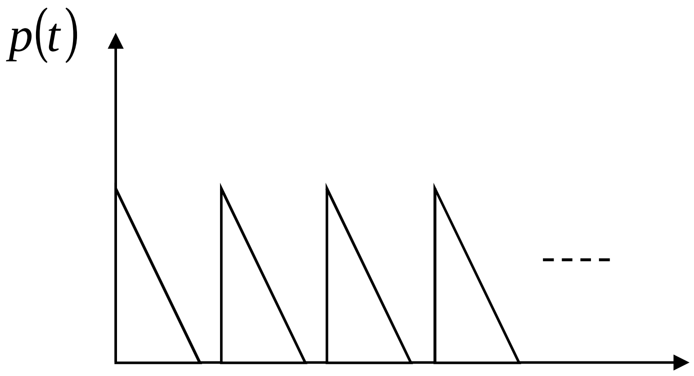
Modulating signal
m (t)

Train of pulse g(t) –
Carrier signal

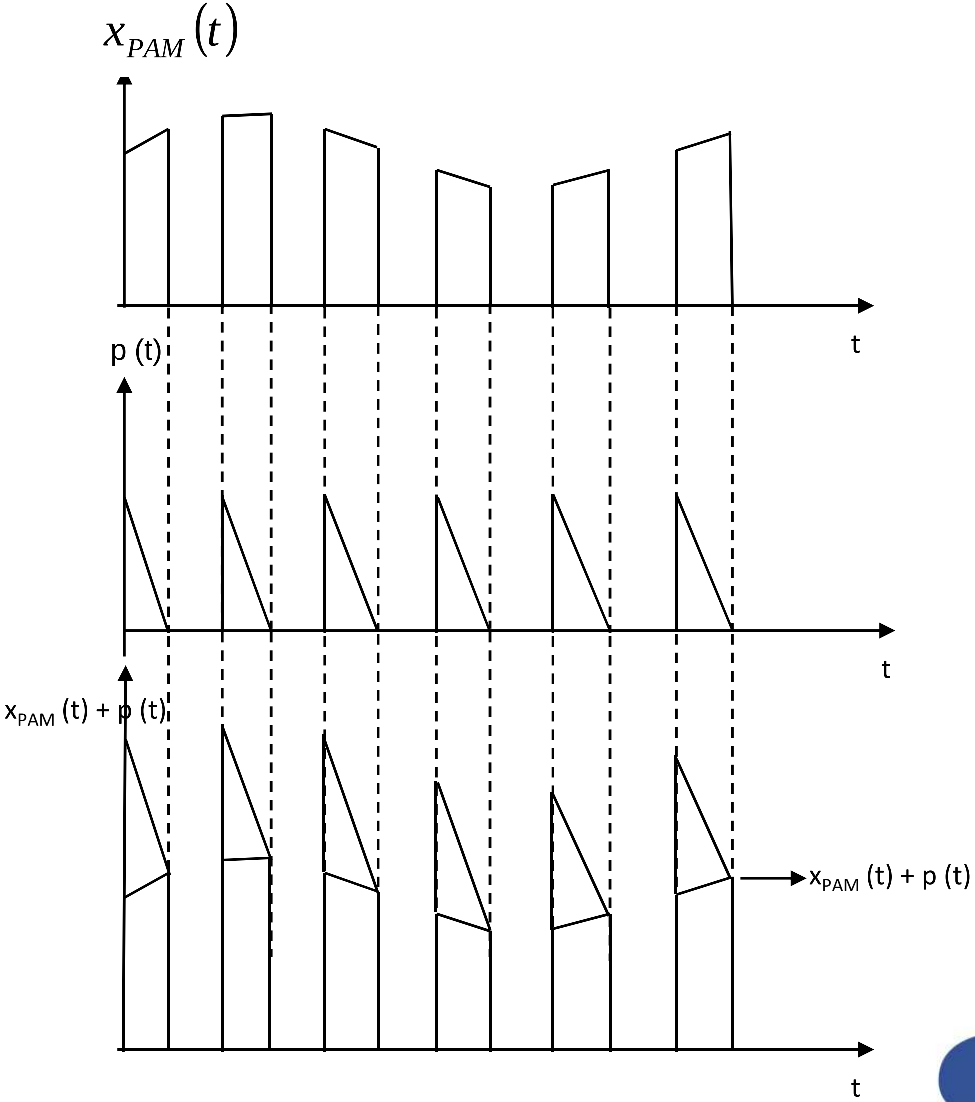
PAM signal

Generate saw tooth waveform

- Another set of pulses $p(t)$ with constant amplitude may now be generated, it has a triangular shape

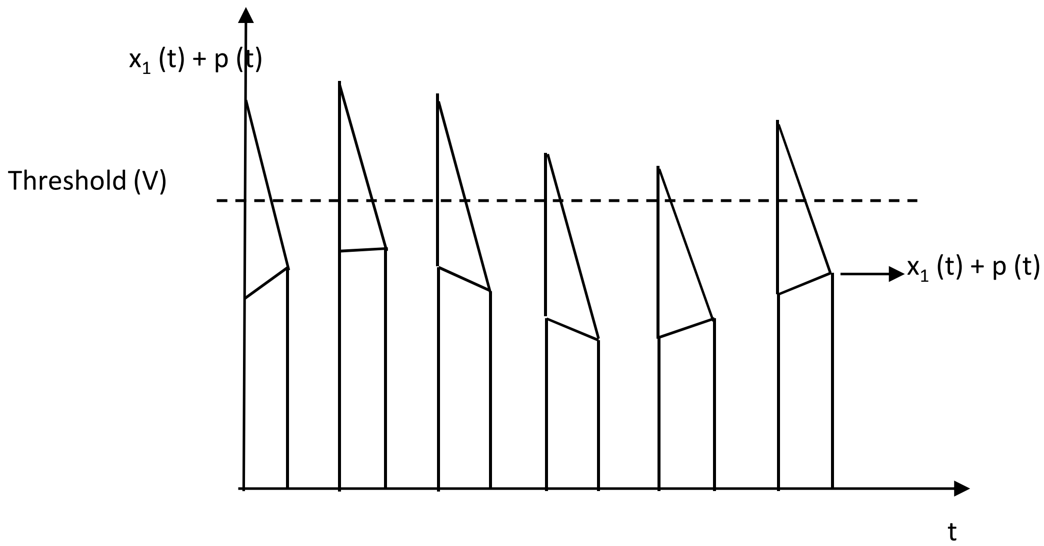


Step 3:- Add $x_{PAM}(t) + p(t)$



Step 4: Slicing waveform at arbitrary threshold

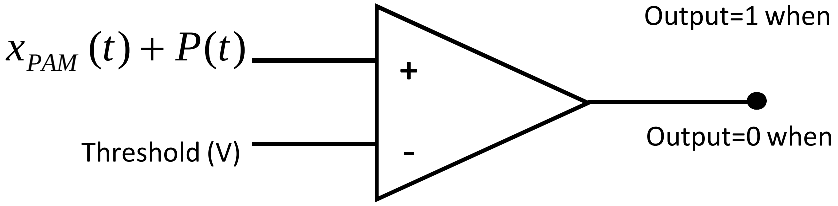
Step 4: This waveform (previous fig.) may now be sliced at some point, i.e. an arbitrary threshold (V) is to be chosen.



Step 5: Comparator circuit operation

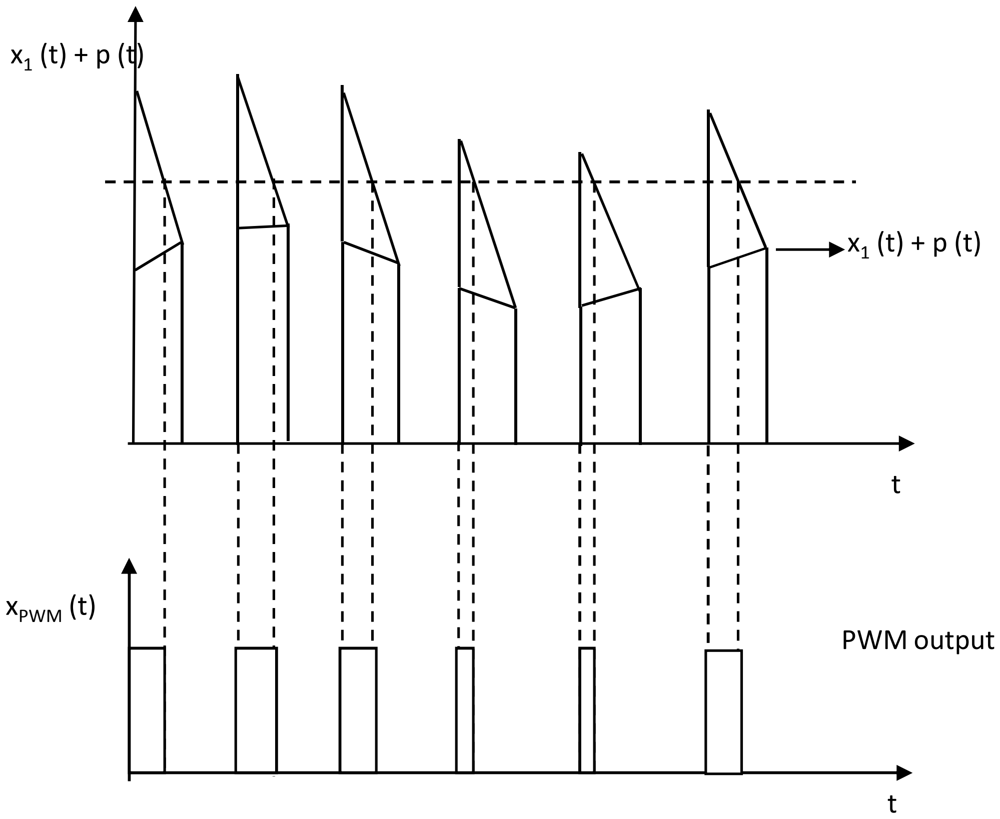
- A comparator circuit is taken as shown in figure. The input for the comparator are $x_{PAM}(t)+p(t)$ and threshold fixed (V) in the previous steps. The output of the comparators are,

$$x_{PAM}(t)+p(t)>Threshold(V)=1$$
$$x_{PAM}(t)+p(t)<Threshold(V)=0$$



$$\boldsymbol{x_{PAM}(t)+P(t)>V}$$
$$\boldsymbol{x_{PAM}(t)+P(t)<V}$$

Step 6 Comparator output

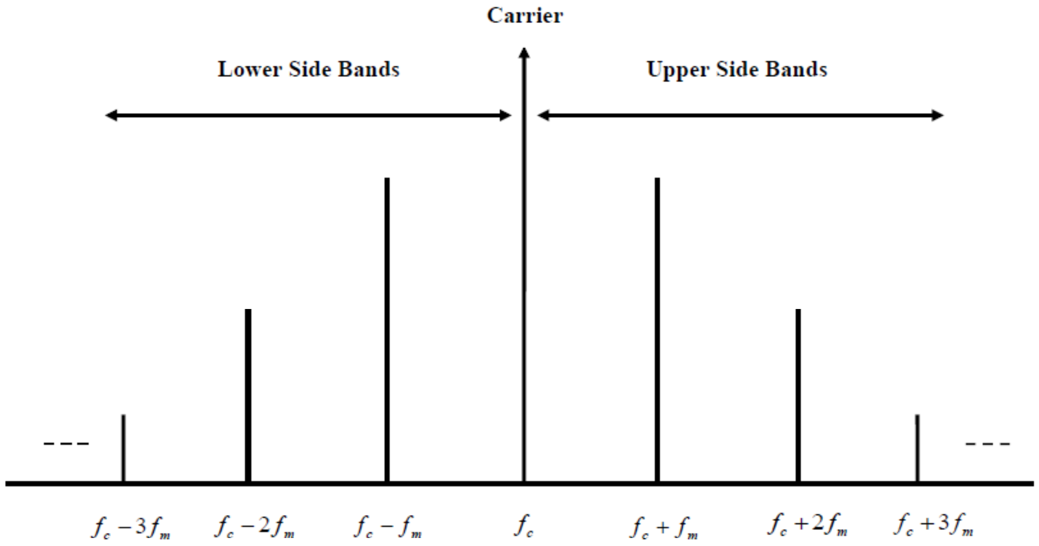


Detection of PWM signal

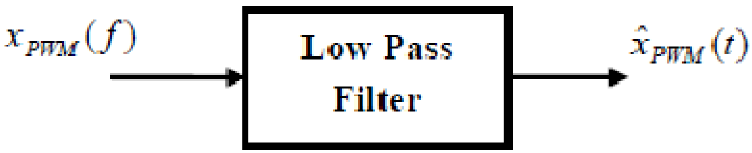
The spectrum of PWM signal is mathematically given as,

$$x_{PWM}(t) = -\frac{1}{\pi} h \sum \frac{1}{m} J_0(m\pi\beta)\left\{\left[\sin 2\pi(mf_s + mf_m)t + \frac{m\pi}{2}\right] + \sin\left[\sin 2\pi(mf_s - mf_m)t + \frac{m\pi}{2}\right]\right\} + \ldots$$

It shows that, similar to FM, PWM spectrum also consists of infinite sidebands around the desired modulating signal. This is shown in figure. Hence, with the help of a low pass filter the original signal at receiver side can be detected easily the spectrum of $x_{PWM}(f)$ may be passed to low pass filter for reconstruction. The low pass filter allows the spectrum from the band $-f_h$ to $+f_h$ and suppresses all other side bands.


Carrier
Lower Side Bands
Upper Side Bands

$f_c - 3f_m$
$f_c - 2f_m$
$f_c - f_m$
f_c
$f_c + f_m$
$f_c + 2f_m$
$f_c + 3f_m$


$x_{PWM}(f)$
Low Pass Filter
$\hat{x}_{PWM}(t)$

Pulse Position Modulation (PPM)

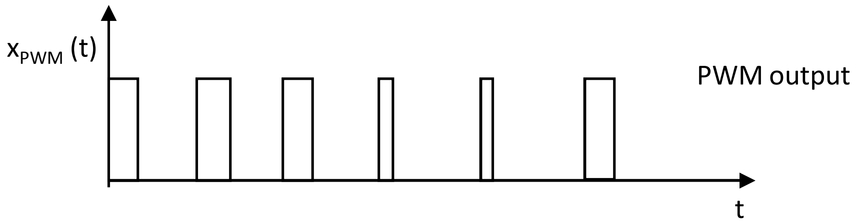
- Definition: The position of the pulse in PPM is changed with respect to the position of the reference pulse.
- Generation of PPM:

Step 1: Generate PWM signal.

Step 2: Arrow in the PWM signal indicates the trailing edge of the pulse.

Step 3: Operation of mono stable multi-vibrator gives PPM signal

Step 1:-Generation of PWM



Step 2: Arrow in the PWM signal indicates the trailing edge of the pulse.

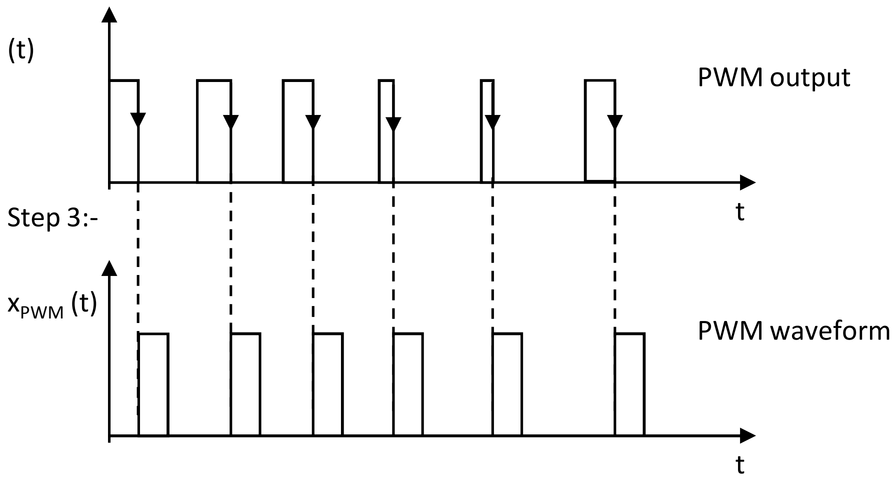
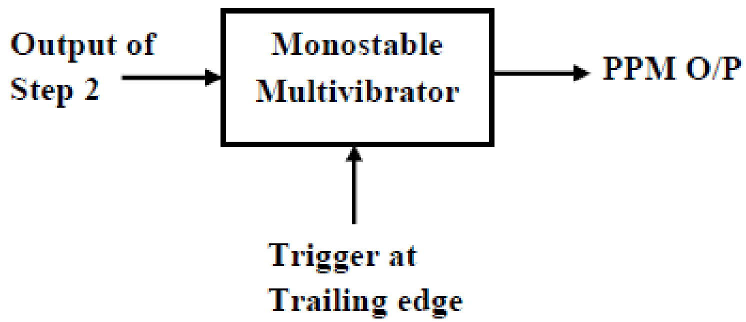


Fig. a) Trailing edge of PWM b) PPM waveform

Step 4: Operation of mono stable multi-vibrator

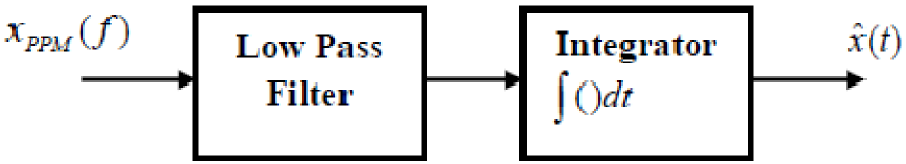
- Mono stable multivibrators are electronic circuits. When triggered by a triggering pulse, they go to a set or a stable state and come to the original state after a brief period.
- The output waveform has a constant width and amplitude but its positions differ or vary according to the triggering pulse.



Detection of PPM

Let us assume the modulating signal as $m(t) = A\cos 2\pi f_m t$. The spectrum of PPM signal is given by the expression, $x_{PPM}(t) = f_s - \beta f_m \sin 2\pi f_m t + \sum\sum \cdots$

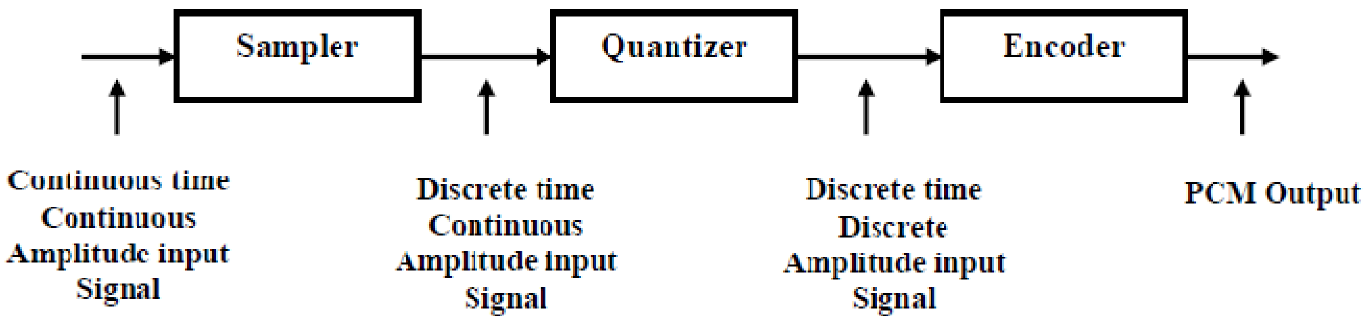
- This expression shows the spectrum as consisting of a derivative of modulating signal and higher order terms.
- Hence the PPM signal can be detected by a low pass filter followed by an integrator circuit.



- The spectrum of $x_{PPM}(f)$ has to be passed on to a low pass filter for reconstruction of the signal. Low pass filter allows the spectrum from the band $-f_h$ to $+f_h$ and suppresses all other side bands. These outputs are then given to an integrator, which detects the original signal at the receiver side.

Comparison of Pulse modulation techniques

S.No.	Parameter	PAM	PWM	PPM
1	Type of carrier	Train of pulses	Train of pulses	Train of pulses
2	Variable characteristic of pulsed carrier	Amplitude	Width	Position
3	Bandwidth requirement	Low	High	High
4	Noise immunity	Low	High	High
5	Information is contained in	Amplitude variation	Width variation	Position variation
6	Transmitted power	Varies with amplitude of pulses	Varies with variation in width of pulse	Constant
7	Synchronization pulse	Not needed	Not needed	Necessary
8	Complexity level of generation and detection	Complex	Easy	Complex


Sampler
Quantizer
Encoder
Continuous time
Continuous
Amplitude input
Signal
Discrete time
Continuous
Amplitude input
Signal
Discrete time
Discrete
Amplitude input
Signal
PCM Output

Quantiser

It converts a discrete-time, continuous-amplitude signal into an discrete time and discrete amplitude signal. Quantization is a process in which the amplitude of each sample is round off to the nearest permissible level. The process of quantization introduces a quantization error.

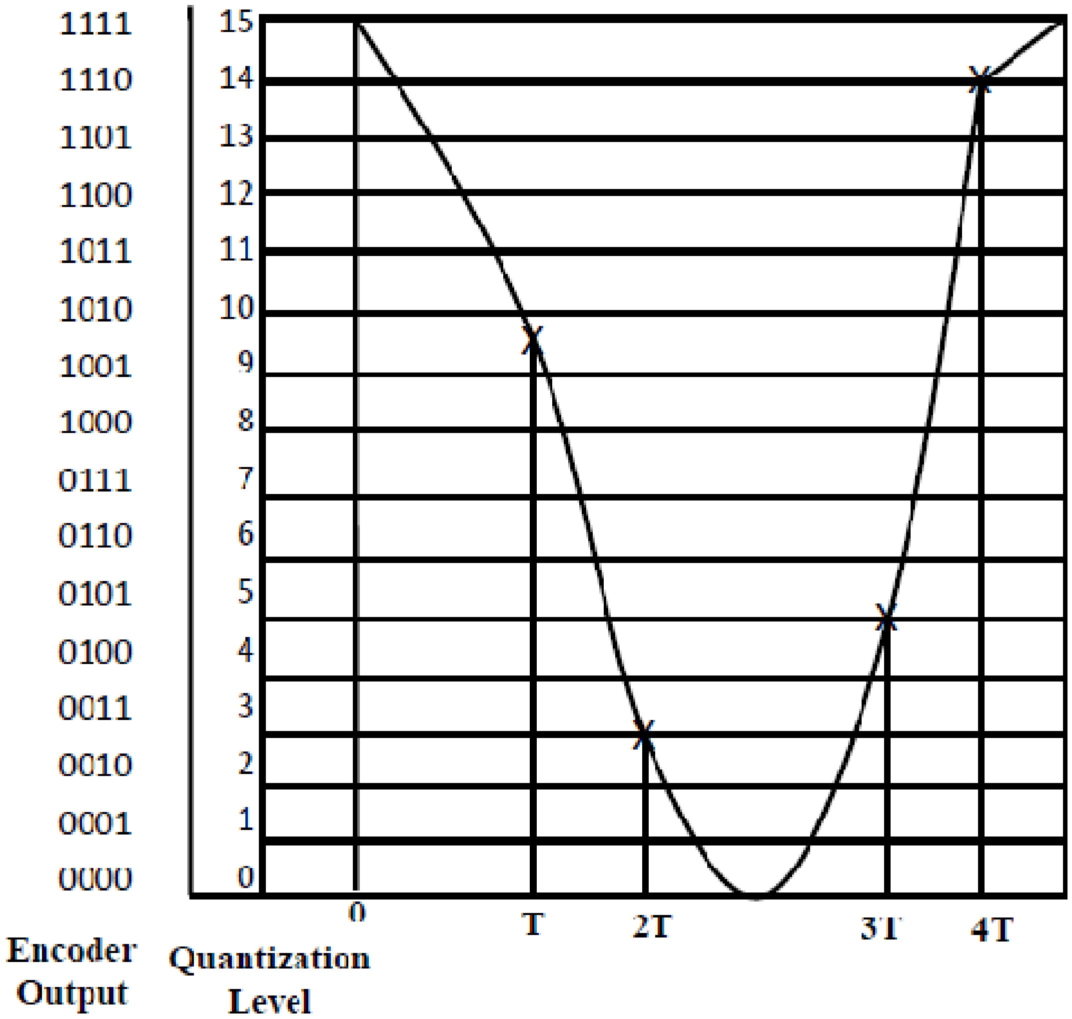
Quantization error:

The difference between the original amplitude level to round off amplitude value.

For example in the figure, at time instant T, the original amplitude of signal is 9.8, but this value is round off to the nearest level in the quantization process as 10.

Now the quantization error=10-9.8=0.2.

Sampling interval is to be higher for reducing the error in quantization.


1111
1110
1101
1100
1011
1010
1001
1000
0111
0110
0101
0100
0011
0010
0001
0000
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
T
2T
3T
4T
Encoder Output
Quantization Level

- *Encoder:* It represents each permissible level into an equivalent digital word. For example in the figure, at time instant 2T, output of quantiser is 3V. Now the equivalent digital word for 3V is 0011. This type of conversion is referred to as an enco
- The number of bits per encoder output is based on the number of quantization level. total number of quantization levels is 16. Hence the number of bits to represent the level is four. ding operation.