PCS NOTES UNIT 4

Pulse Modulation

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Unit No.4. Pulse Modulation

Theory	Practicals
❖Need of analog to digital conversion ❖sampling theorem for low pass signal in time domain, and Nyquist criteria. ❖Types of sampling- natural and flat top. ❖Pulse amplitude modulation & concept of TDM: Channel bandwidth for PAM, ❖equalization, Signal Recovery through holding. ❖Pulse Width Modulation (PWM) and Pulse Position Modulation (PPM): Generation & Detection.	Experiment No.3 Verification of Sampling Theorem, PAM Techniques, (Flat top & Natural sampling), reconstruction of original signal, Observe Aliasing Effect in frequency domain. Experiment No.4 Generation and Detection of PWM using IC 555 Experiment No.13 Verify Sampling Theorem using simulation.

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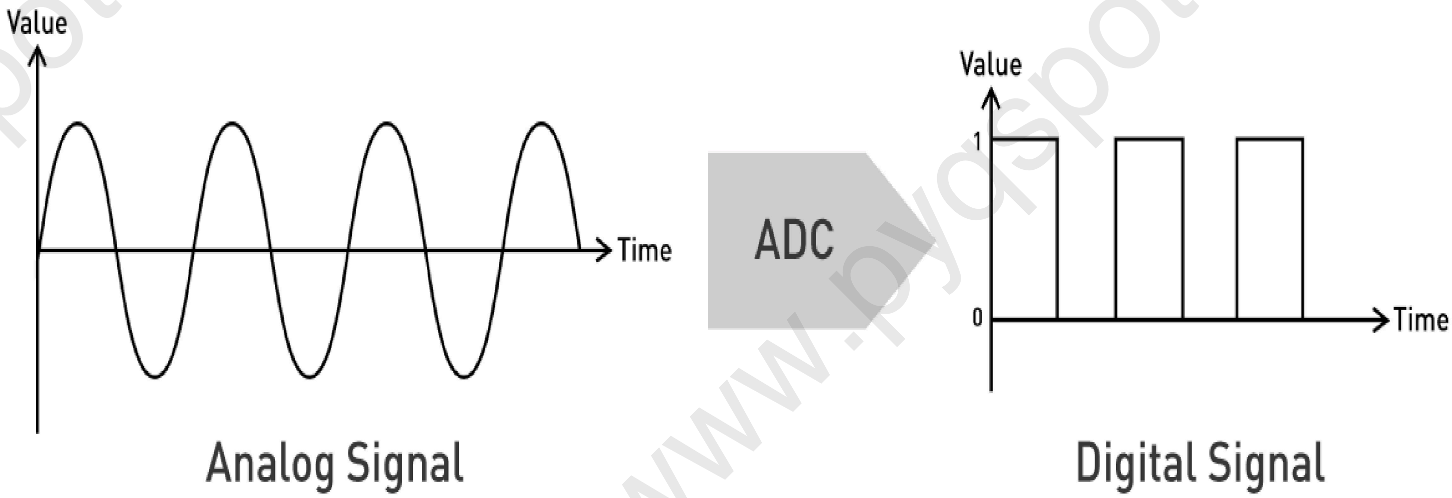
Que.1) : Discuss the Need of analog to digital conversion.

❖Need of Analog to Digital conversion

❖Analog-to-Digital converters translate analog signals, real world signals like temperature, pressure, voltage, current, distance, or light intensity, into a digital representation of that



❖This digital representation can then be processed, computed, transmitted or stored.

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Need of Analog to Digital conversion

❖Digital signal is easy to perform mathematical manipulation to the data. So the computers and microprocessors can store, analyse, understand, process, and display the results, since microprocessors deal with digital information.

❖Once the data is in digital format, it can be statistically analysed such as mathematically process it to extract, isolate, manipulate information as desired.

❖It **can be compressed** for faster transmission and minimize hardware storage capacity.

❖It **can be encrypted** for security.

❖With analog, it is pretty easy to tap into a private phone conversation; digital encryption secured privacy.

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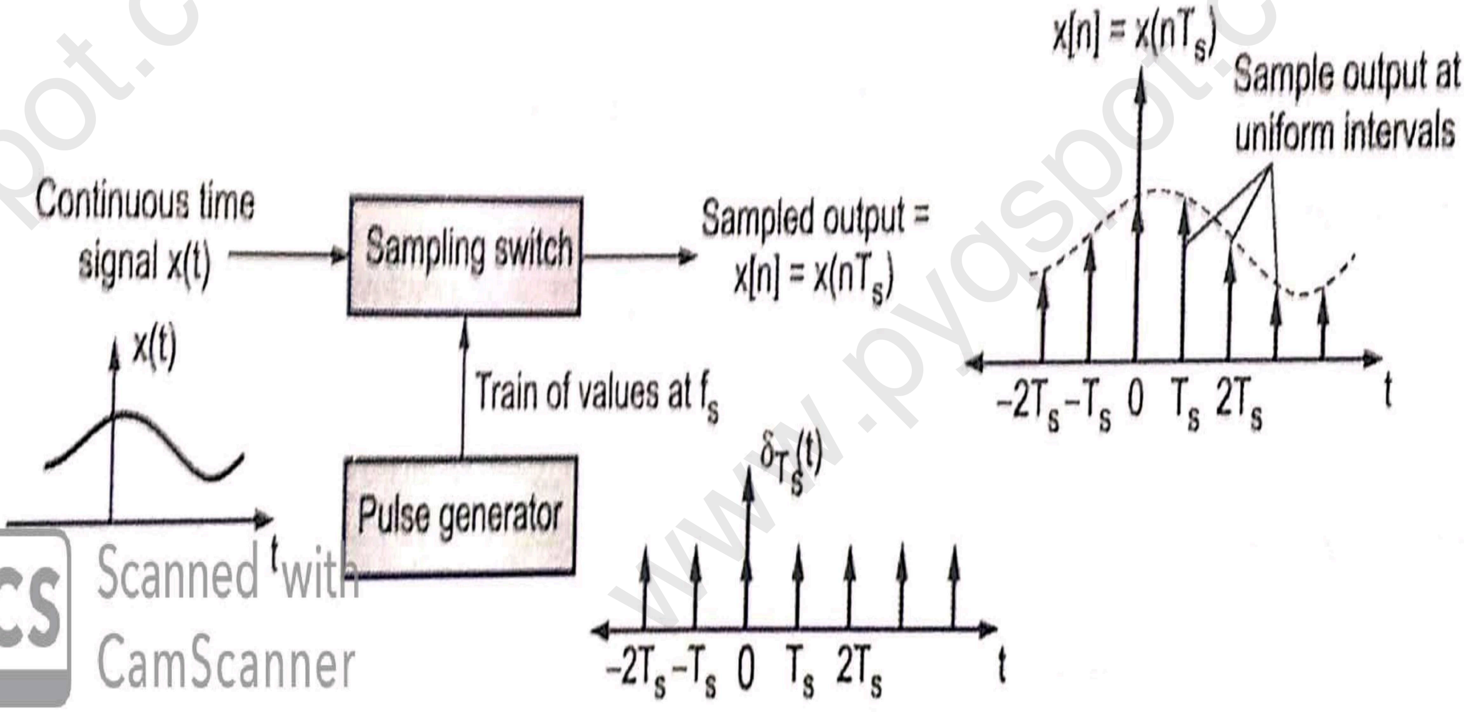
Need of Analog to Digital conversion

- It is **easy to search and compare** stored digital data.
- **Better Noise immunity**.
- Supports **high signal fidelity**.
- **Channel coding** can be possible.
- **Flexible hardware implementation**.
- Use of **regenerative repeaters is possible**.
- Digital signal is **more reliable** as compared to analog circuits.

Sampling Process

It is the process of converting continuous a analog signal to discrete analog signal. Hence sampled signal is discrete time representation of original analog signal.



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Basic Sampling Theorem Statement

Sampling theorem states that "continues form of a time-variant signal can be represented in the discrete form of a signal with help of samples and the sampled (discrete) signal can be recovered to original form when the sampling signal frequency Fs having the greater frequency value than or equal to the input signal frequency Fm.

$Fs \geq 2Fm$

If the sampling frequency (Fs) equals twice the input signal frequency (Fm), then such a condition is called the Nyquist Criteria for sampling. When sampling frequency equals twice the input signal frequency is known as **"Nyquist rate".**

$Fs = 2Fm$

If the sampling frequency (Fs) is less than twice the input signal frequency, such criteria called an **Aliasing effect.**

$Fs < 2Fm$

So, there are three conditions that are possible from the sampling frequency criteria. They are sampling, Nyquist and aliasing states.

Que.2) State and prove sampling theorem for band limited signal

Statement:-"A continuous time signal x(t) can be completely represented in its sampled form and recovered back from the sampled form if sampling frequency **Fs≥2W** where W is the maximum frequency of the continuous time signal x(t)"

Proof:- ① Continuous time Analog Signal $x(t)$

Assumptions :-

$x(t)$ be a continuous time sig.

$x(t)$ be strictly bandlimited.

$x(t)$ has finite energy.

$x(t)$ be the infinite duration

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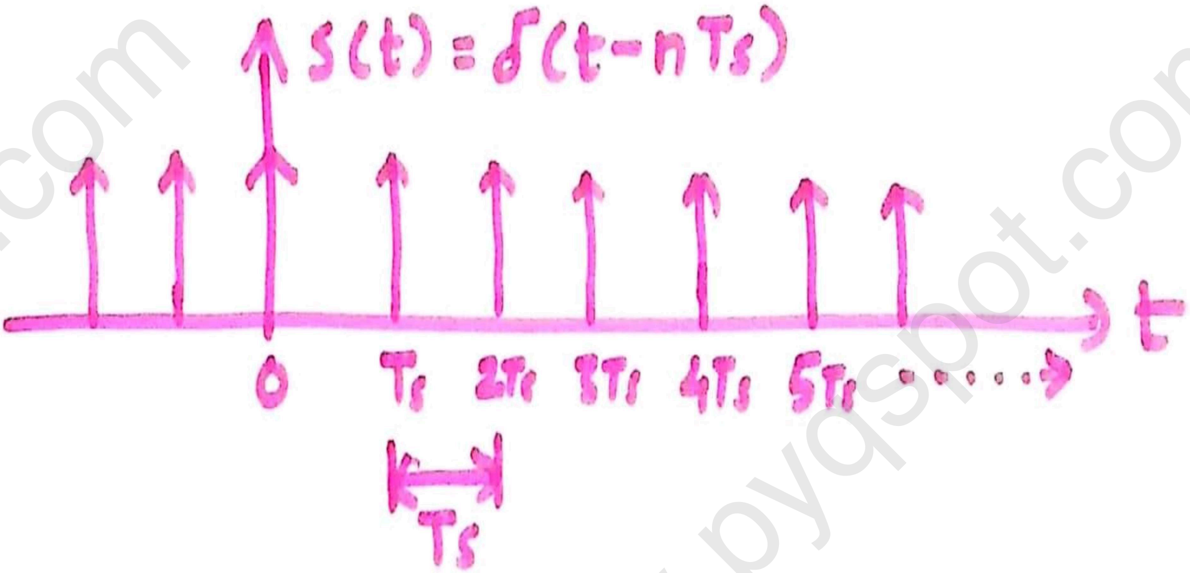
② Sampling function s(t) i.e Unit Impulses.



$$s(t) = \cdots \delta(t+2T_s) + \delta(t+T_s) + \delta(t) + \delta(t-T_s) \cdots$$

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

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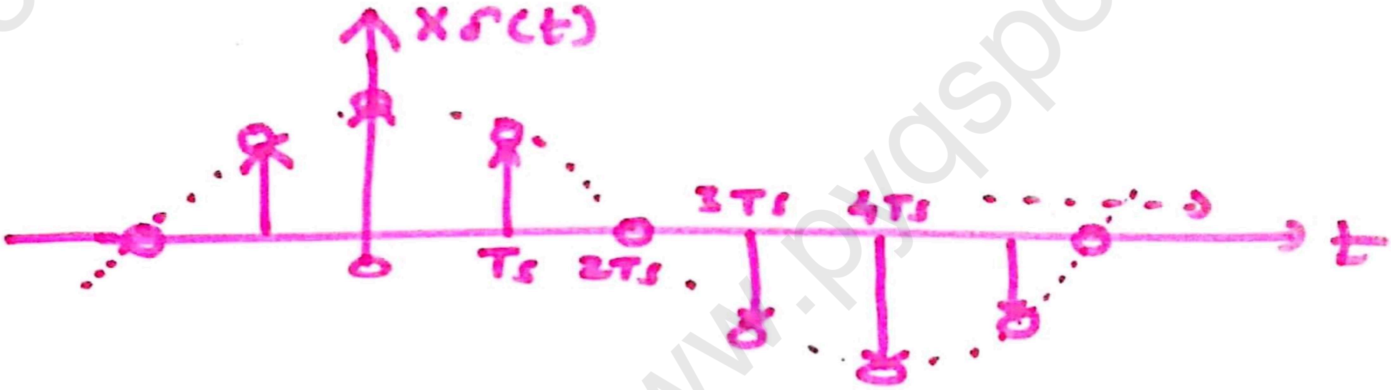
③ Sampled signal $x_\delta(t)$

$$\therefore x_\delta(t) = x(t) \times s(t)$$

$$= x(nT_s) \times s(t)$$



$$\therefore x_\delta(t) = \sum_{n=-\infty}^{\infty} x(nT_s) \cdot \delta(t - nT_s)$$

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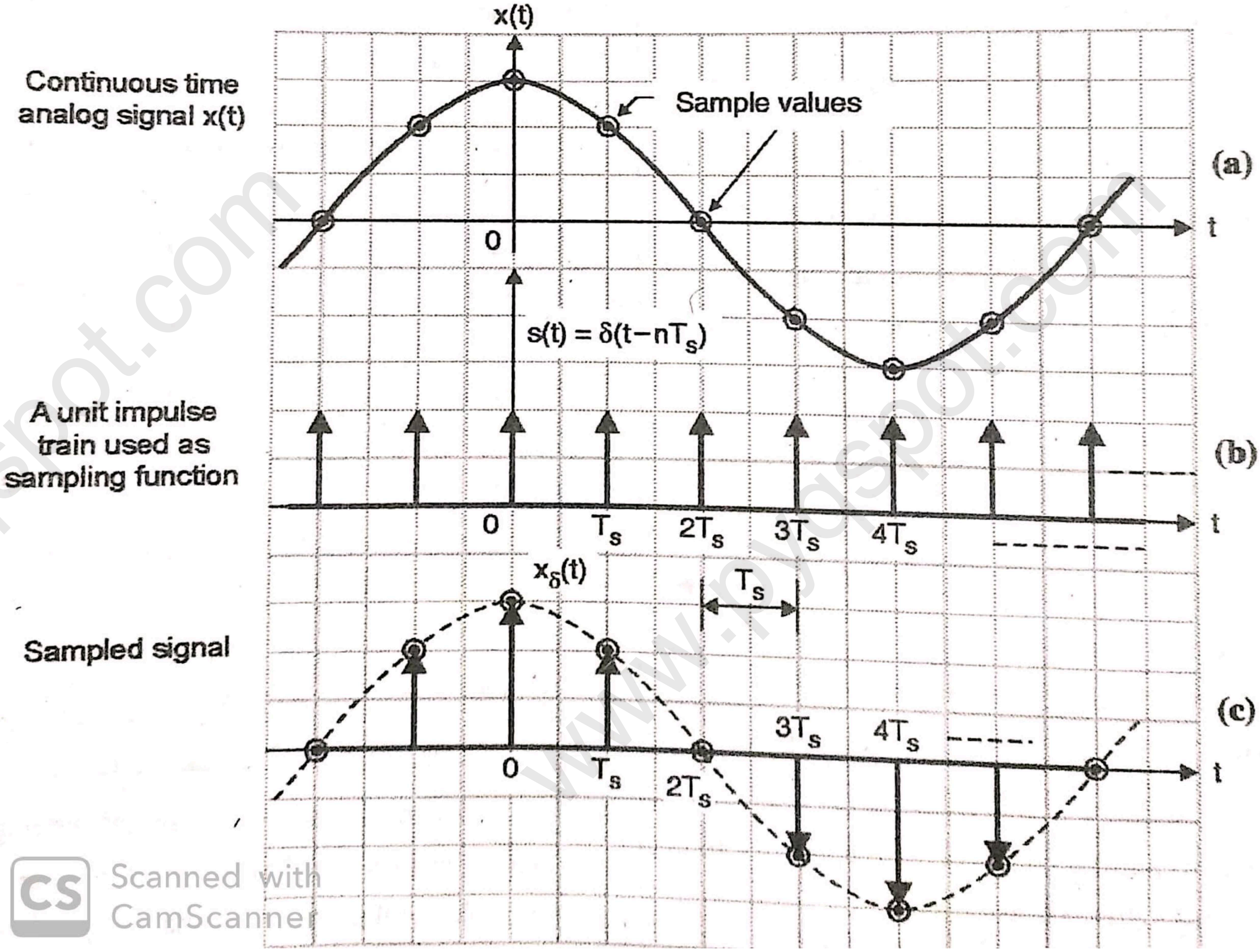

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④ Obtain Fourier transform of Sampled sig.

F.T of $x(t)$ is $X(f)$ —— I

F.T of $s(t)$ is $S(f)$ i.e.

$$\therefore S(f) = f_s \sum_{-\infty}^{\infty} \delta(f - nf_s) \quad \text{—— II}$$

F.T of $x_\delta(t)$ is $X_\delta(f)$

$$X_\delta(f) = X(f) * S(f) \quad \text{—— III}$$

$$X_\delta(f) = X(f) * \left[f_s \sum_{-\infty}^{\infty} \delta(f - nf_s) \right] \text{— IV}$$

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by interchanging order of convolution,

$$X_\delta(f) = f_s \sum_{-\infty}^{\infty} X(f) * \delta(f-nf_s) \quad \text{— V}$$

As per delta function property,
$X(f)$ & $\delta(f-nf_s)$ is $X(f-nf_s)$

$$\therefore X_\delta(f) = f_s \sum_{-\infty}^{\infty} X(f-nf_s) \quad \text{—— VI}$$

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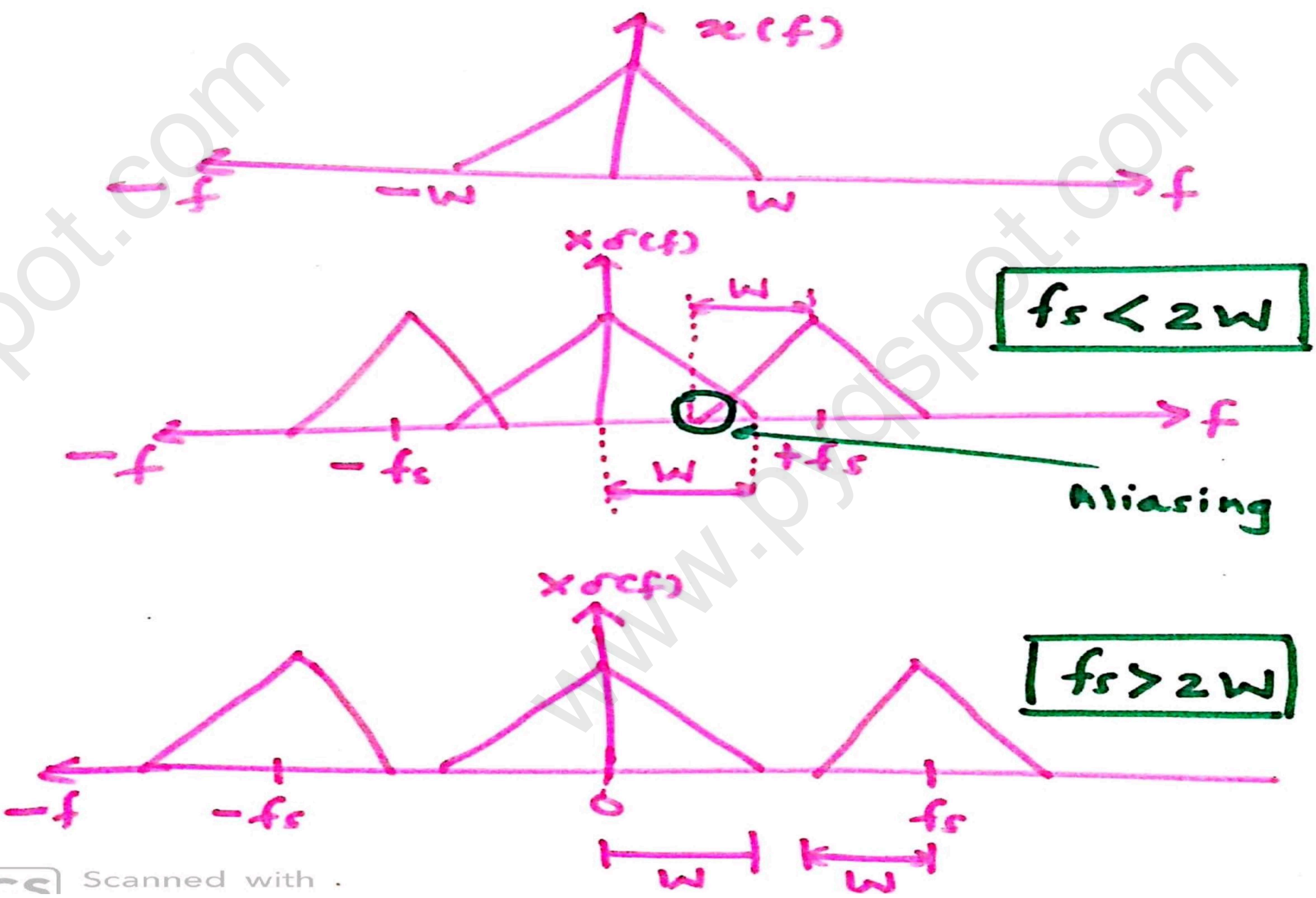
Que.3) what is aliasing how can it be avoided.



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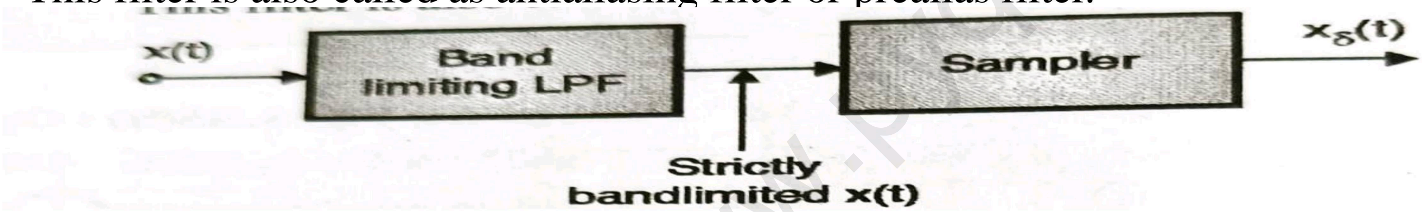
what is aliasing how can it be avoided.

Alising: This phenomenon of a high frequency in the spectrum of the original signal x (t), taking on the identity of lower frequency in the spectrum of the sampled signal x d(t) is called as aliasing or fold over error.

how can it be avoided:

- Aliasing can be completely eliminated if we take the following action: 1) Use a bandlimiting low pass filter and pass the signal x (t) through it before sampling as shown in Fig.
- This filter has a cutoff frequency at fc = W therefore it will strictly bandlimit the signal x (t) before sampling takes place.
- This filter is also called as antialiasing filter or prealias filter.



- Increase the sampling frequency f, to a great extent i.e. fs>>> 2W. Due to this, even though x (t) is not strictly bandlimited, the spectrums will not overlap. A guard band is created between the adjacent spectrums as shown in Fig.
- Thus aliasing can be prevented by:
  1. Using an antialiasing or prealiasing filter and
  2. Using the sampling frequency f,>2W.

Pulse Modulation

Introduction

Pulse modulation consists essentially *of* sampling analog information signals and then converting those samples into discrete pulses and transporting the pulses from a source to a destination over a physical transmission medium.

The four predominant methods *of* pulse modulation:

1) Pulse Amplitude Modulation (PAM)
2) Pulse Width Modulation (PWM)
3) Pulse Position Modulation (PPM)
4) Pulse Code Modulation (PCM).

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Pulse Modulation

Analog Pulse Modulation

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

Digital Pulse Modulation

- Pulse Code (PCM)

Pulse Amplitude Modulation (PAM):

*** The signal is sampled at regular intervals such that each sample is proportional to the amplitude of the signal at that sampling instant. This technique is called "sampling".**

**** For minimum distortion, the sampling rate should be more than twice the signal frequency.***

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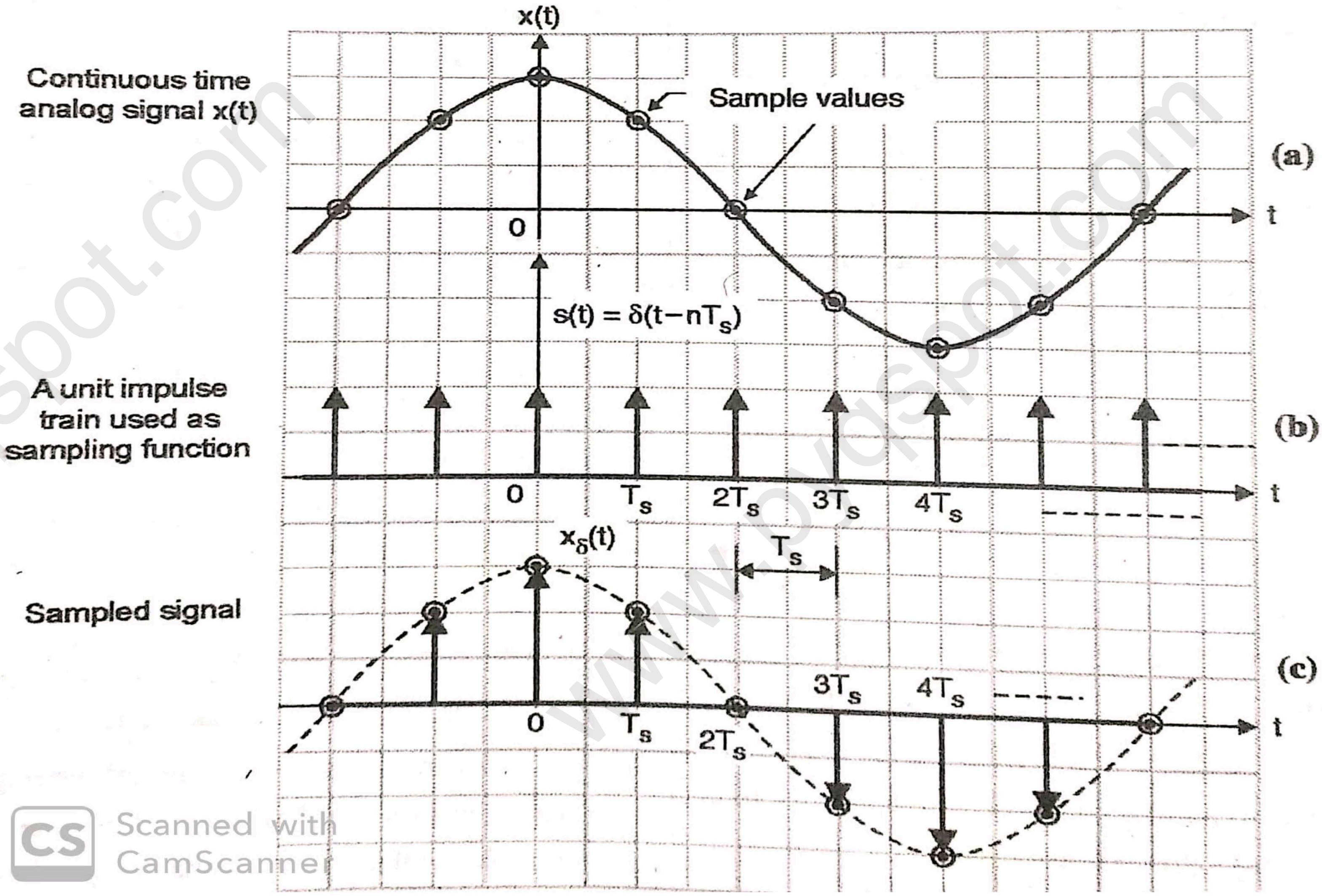
1. Pulse Amplitude Modulation (PAM)

Ideal Sampling:-



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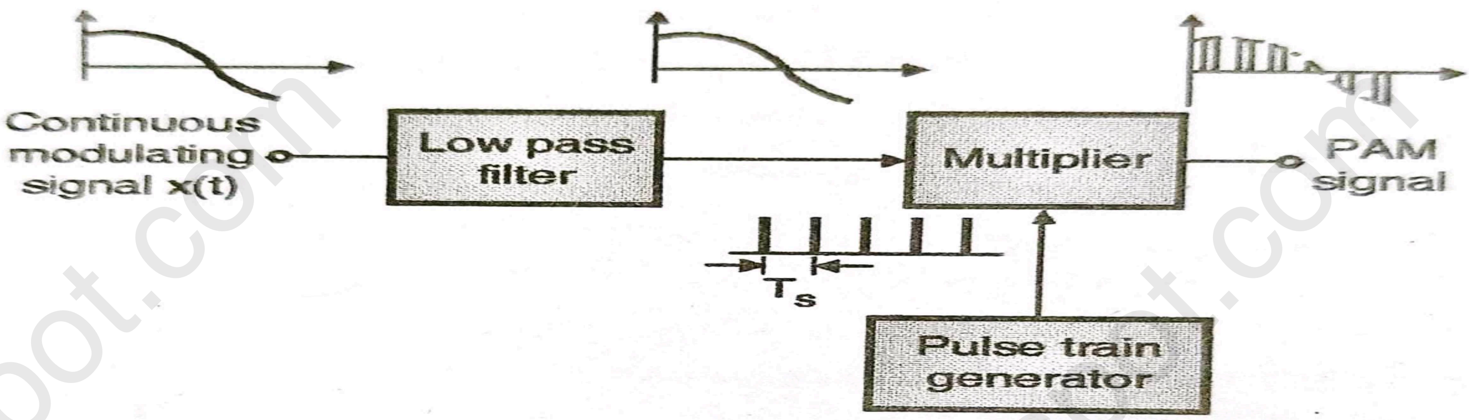
Que.4) Explain How PAM (Pulse Amplitude Modulation) signal may generated

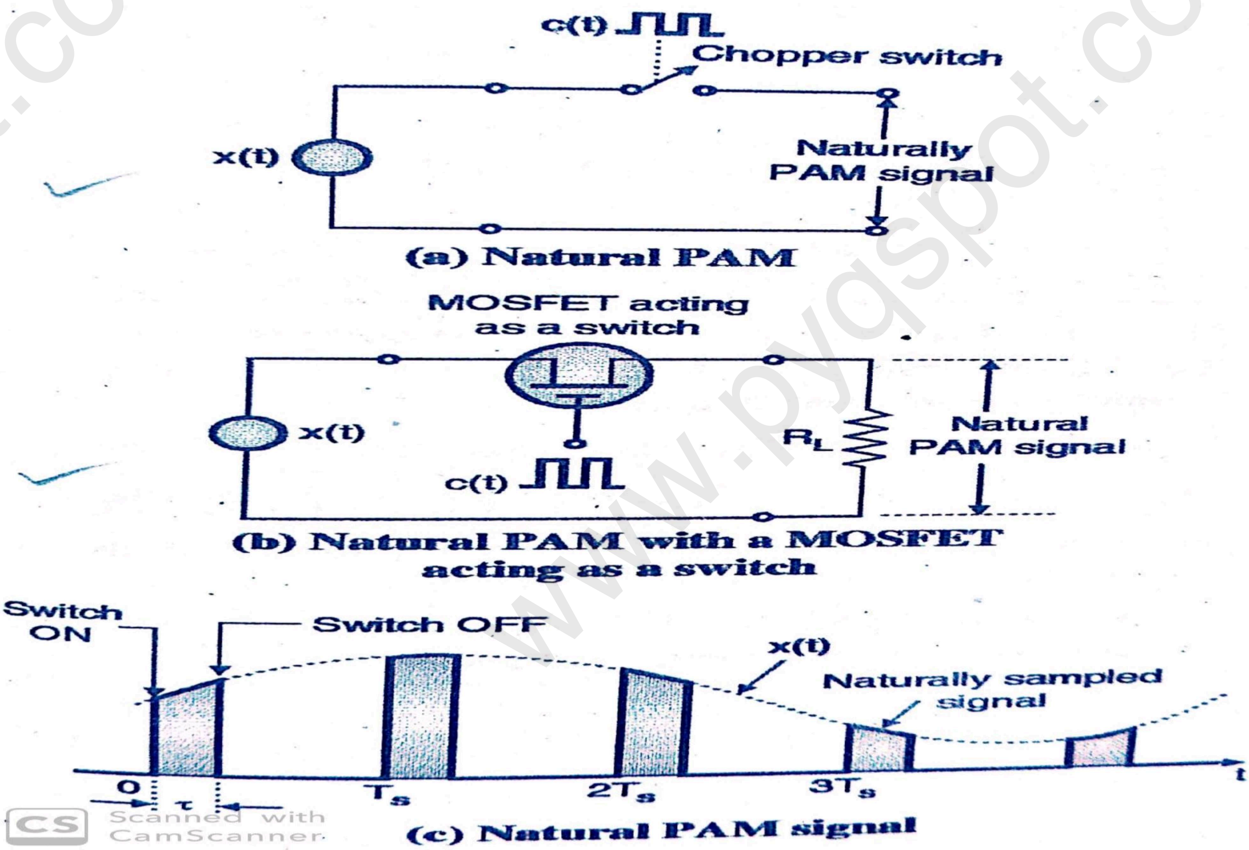


(L-181) Fig. 8.7.1 : Generation of PAM

- The continuous modulating signal x(t), is passed through a low pass filter.
- The LPF will bandlimit this signal to fm. That means all the frequency components higher than the frequency fm are removed.
- Bandlimiting is necessary to avoid the "aliasing" effect in the sampling process.
- The pulse train generator generates a pulse train at a frequency fs, such that fs≥ 2fm. Thus the Nyquist criteria is satisfied.
- The carrier pulses generated by the pulse train generator would carry out the uniform "sampling" in the multiplier block, to generate the PAM signal

Que.5) : Draw and explain a circuit for Natural sampling or Draw and explain a circuit for Natural PAM

1) Pulse Amplitude Modulation:
Natural PAM /Sampling or Chopper Sampling:-



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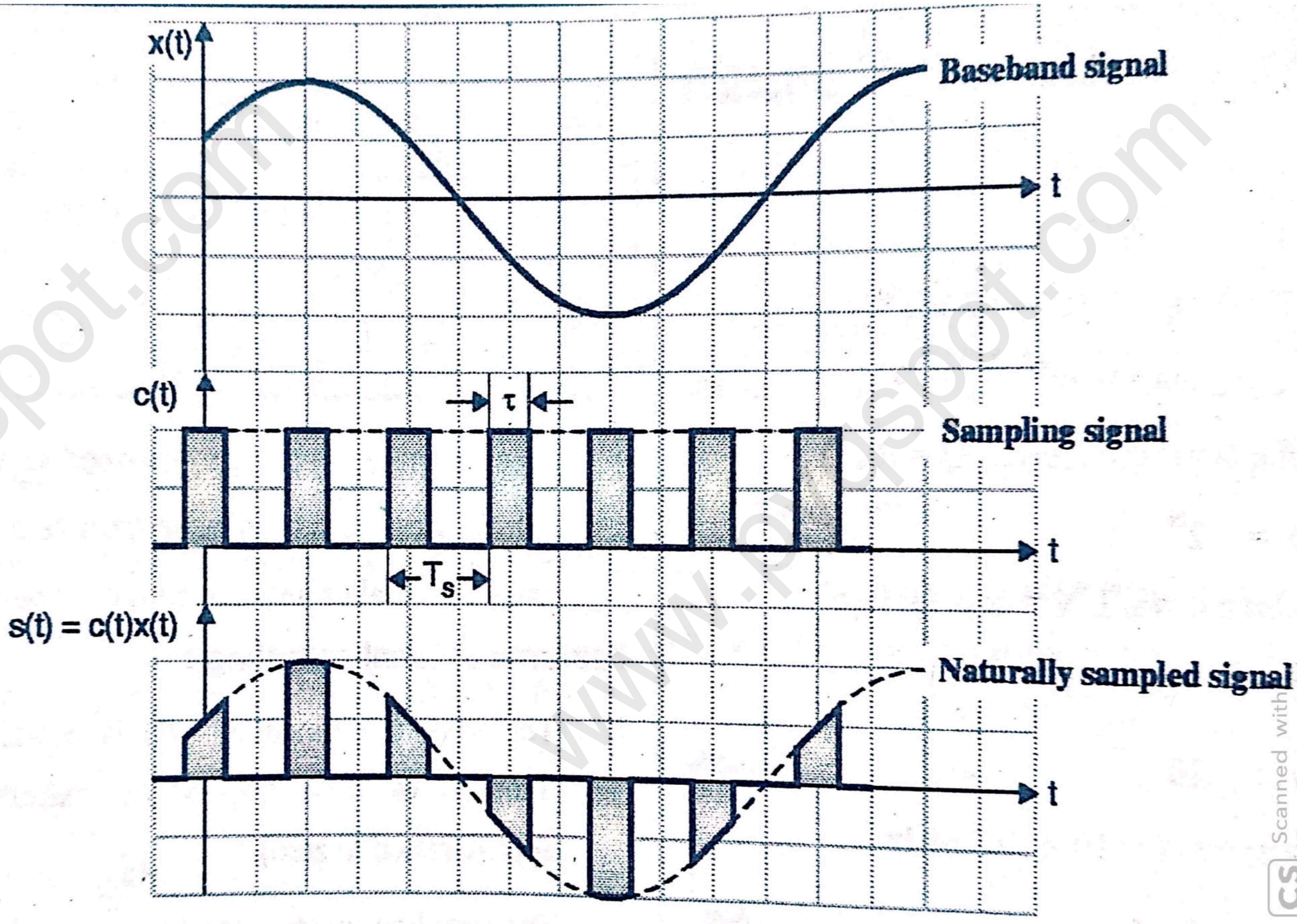
Natural Sampling Waveforms



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Natural Sampling/ Natural PAM Working:

- The continuous modulating signal x(t) is applied to Chopper switch/ MOSFET.
- The pulse train generator generates a pulse train c(t) at a frequency fs,, such that fs, ≥ 2fm Thus the Nyquist criteria is satisfied.
- Pulse train c(t) is applied to Chopper switch/ MOSFET Chopper switch/ MOSFET act as Switch.
- If switch is on then we get Natural PAM Signal
- .If switch is off then we can not get Natural PAM Signal

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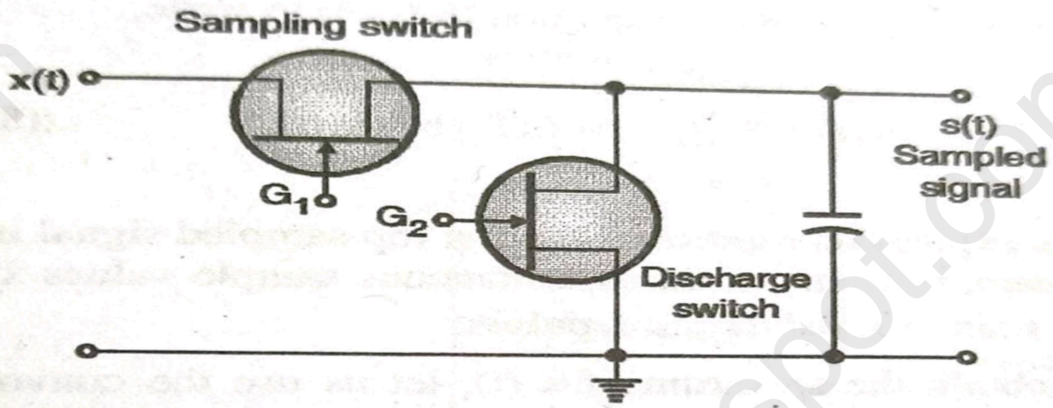
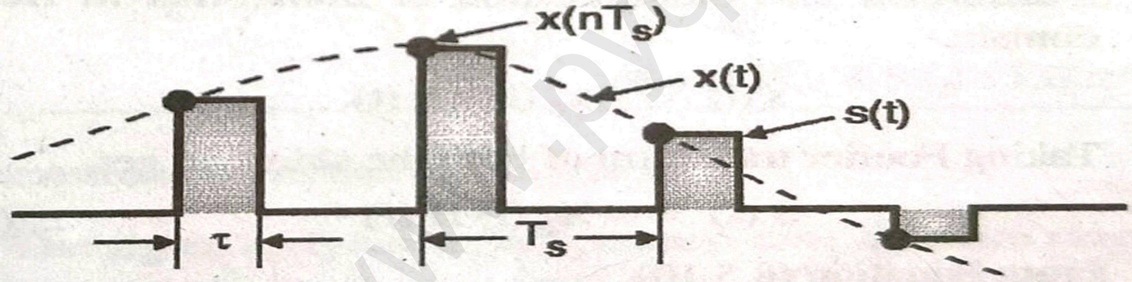
Que.6) : Draw and explain a circuit for Flat top sampling.
Or Draw and explain a circuit for Flat top PAM



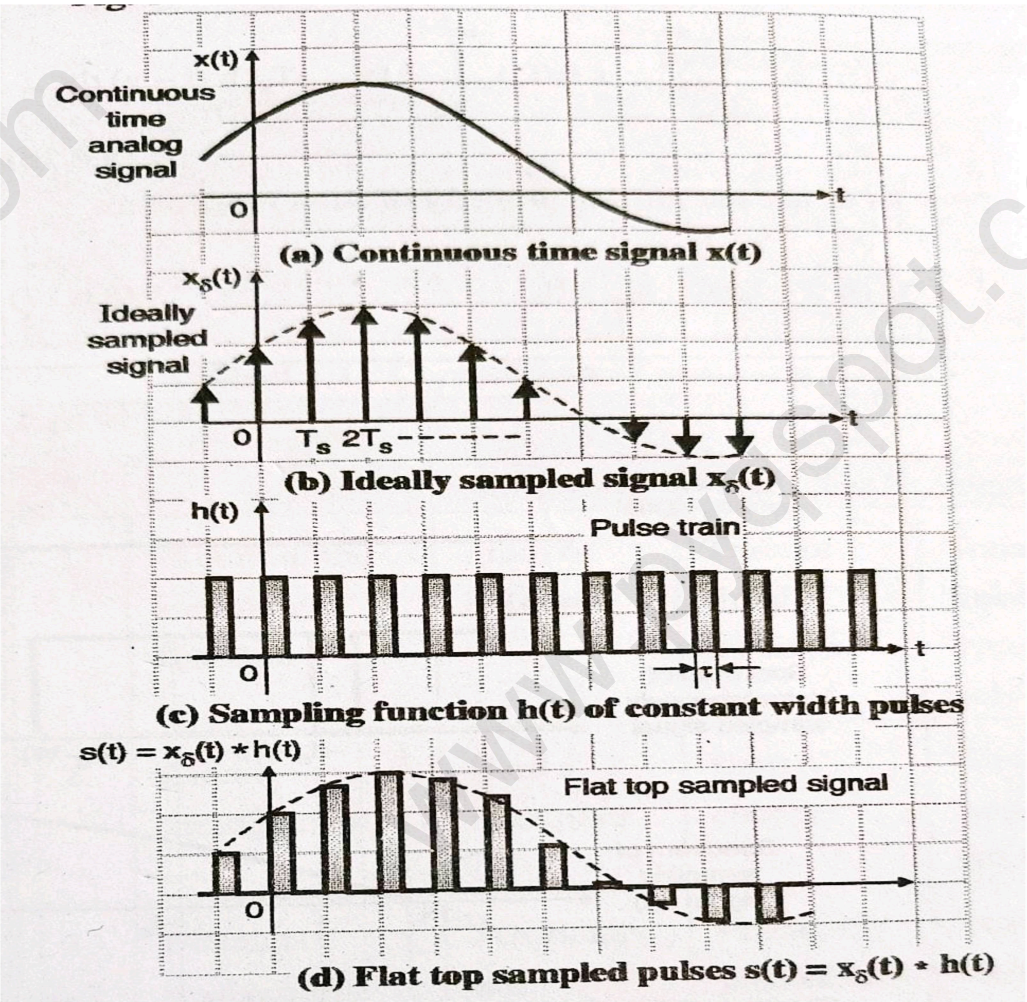
(a) Sample and hold circuit to obtain the flat topped samples



(b) Flat top sampled signal

(D-433) **Fig. 8.6.6**

Waveform:



x(t)
Continuous time analog signal
0
t
(a) Continuous time signal x(t)
$x_\delta(t)$
Ideally sampled signal
0
T_s $2T_s$
t
(b) Ideally sampled signal $x_\delta(t)$
h(t)
Pulse train
0
t
τ
(c) Sampling function h(t) of constant width pulses
$s(t) = x_\delta(t) * h(t)$
Flat top sampled signal
0
(d) Flat top sampled pulses $s(t) = x_\delta(t) * h(t)$

Working:

- The sample and hold circuit consists of two FET switches and a capacitor.
- The analog signal x (t) is applied at the input of this circuit and the sampled signal s(t) is obtained across the capacitor.
- A gate pulse will be applied to gate G1 at the instant of sampling for a very short time. The sampling switch will turn on and the capacitor charges through it to the sample value x (nTs).
- The sampling switch is then turned off. Both the FETs will remain OFF for a duration of “T" seconds and the capacitor will hold the voltage across it constant for this period. Thus the pulse is stretched to “T" seconds.
- At the end of the pulse interval (t), a pulse is applied to G_2 i.e. gate terminal of discharge FET. This will turn on the discharge FET and short circuit the capacitor. The output voltage then reduces to zero.

Working: **Reconstruction of Flat Top PAM:**

An amplitude distortion as well as a delay is introduced in the flat top sampled signal.
This distortion can be corrected by connecting an equalizer after the reconstruction filter (low pass filter) as shown in

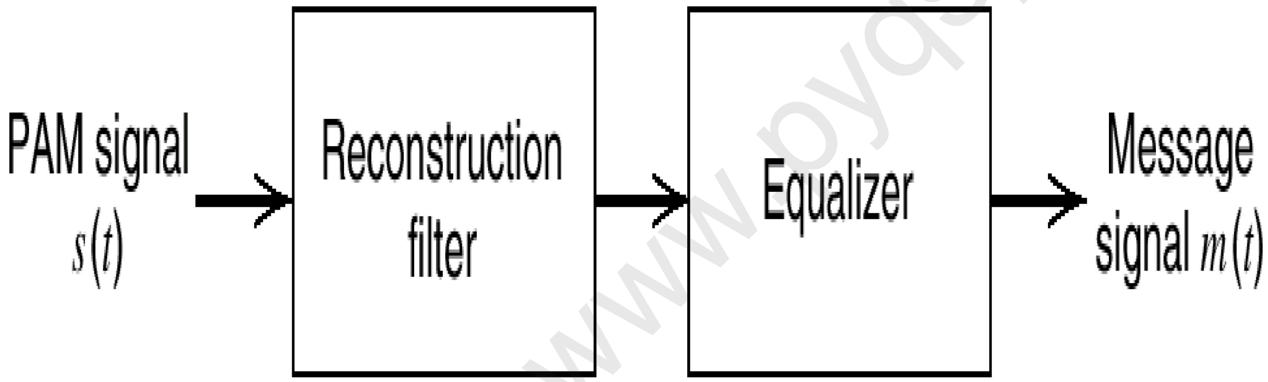
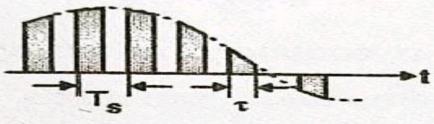
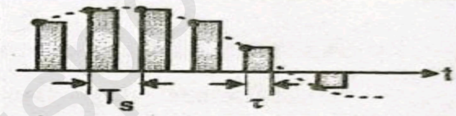


Fig. Recovering the original message signal m(t) from PAM signal

Que.7) Compare Ideal sampling, Natural sampling and Flat top sampling.

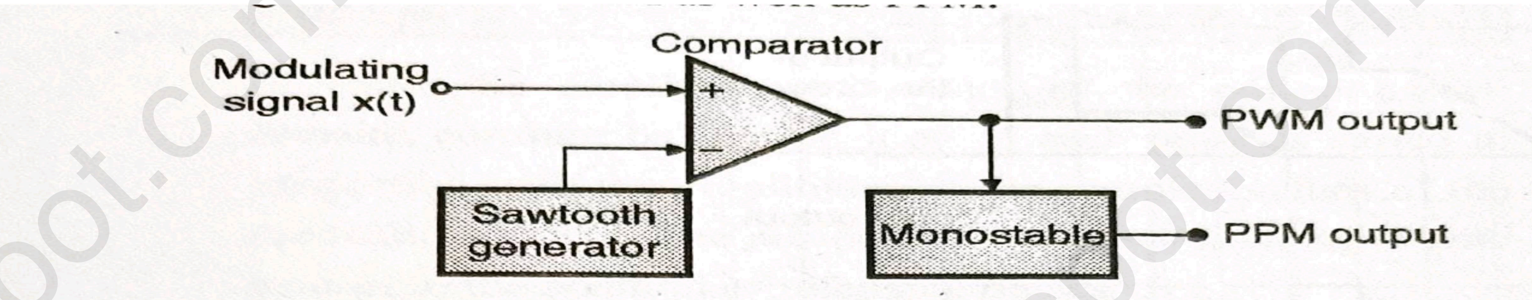
Sr. No.	Parameter	Ideal sampling	Natural sampling	Flat top sampling
1.	Nature of the sampling function	Train of impulses	Train of finite duration pulses	Train of finite duration pulses
2.	Circuit arrangement	Uses a multiplier	Uses a chopper	Uses a sample and hold circuit
3.	Practical realizability	Practically not realizable	Practically realizable	Practically realizable
4.	Waveforms	Refer Fig. A	Refer Fig. B	Refer Fig. C
5.	Sampling rate	Tends to infinity	Satisfies Nyquist criteria	Satisfies Nyquist criteria
6.	Mathematical representation in time domain	$x_\delta(t) = \sum_{n=-\infty}^{\infty} x(nT_s)\, \delta(t - nT_s)$	$s(t) = \frac{\tau A}{T_s} \sum_{n=-\infty}^{\infty} x(t)\, \text{sinc}(nf_s\tau)\, e^{j2\pi n f_s t}$	$s(t) = \sum_{n=-\infty}^{\infty} x(nT_s)\, h(t - nT_s)$
7.	Frequency spectrum	$X_\delta(t) = \infty$	$S(f) = \frac{\tau A}{T_s} \sum_{n=-}^{\infty} \text{sinc}(nf_s\ X(f - nf$	$S(f) = f_s \sum_{n=-\infty}^{\infty} X(f - nf_s)\, H(f)$
8.	Signal power	Very low due to the use of impulses	Increases with increase in the pulse width τ	Increases with increase in pulse width τ
9.	Bandwidth requirement	Very high	Increases with the reduction in pulse width	Increases with reduction in pulse width
10.	Effect of noise	Maximum	Moderate	Moderate

Que.8) : Compare Natural PAM and Flat top PAM

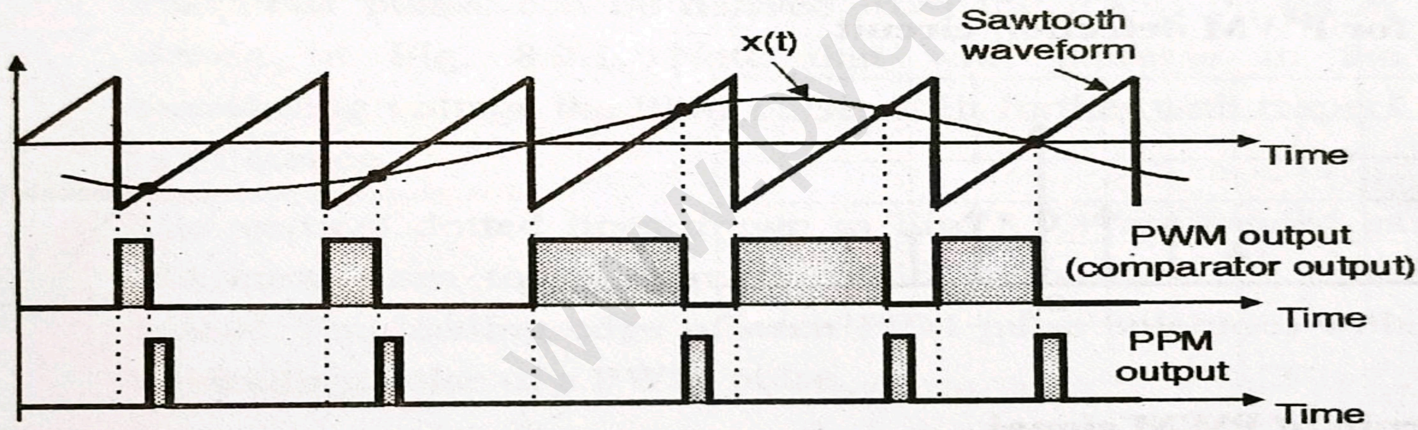
Sr. No.	Parameter	Natural PAM	Flat top PAM
1.	Nature of the sampling function	Train of finite duration pulses	Train of finite duration pulses
2.	Circuit arrangement	Uses a chopper	Uses a sample and hold circuit
3.	Practical realizability	Practically realizable	Practically realizable
4.	Waveforms	 (D-452)	
5.	Sampling rate	Satisfies Nyquist criteria	Satisfies Nyquist criteria
6.	Mathematical representation in time domain	$s(t) = \frac{\tau A}{T_s} \sum_{n=-\infty}^{\infty} x(t) \operatorname{sinc}(nf_s\tau)\, e^{j2\pi nf_s t}$	$s(t) = \sum_{n=-\infty}^{\infty} x(nT_s)\, h(t - nT_s)$
7.	Frequency spectrum	$S(f) = \frac{\tau A}{T_s} \sum_{n=-\infty}^{\infty} \operatorname{sinc}(nf_s\tau)\, X(f - nf_s)$	$S(f) = f_s \sum_{n=-\infty}^{\infty} X(f - nf_s)\, H(f)$
8.	Signal power	Increases with increase in the pulse width τ.	Increases with increase in pulse width τ.

Que.9) Draw and explain with the neat schematic of generation and Detection of PWM signal.

2. Pulse Width Modulation (PWM generation):



(D-455) **Fig. 8.8.2(a) : PWM and PPM generator**



(D-456) **Fig. 8.8.2(b) : Waveforms**

Working:-

- A sawtooth generates a sawtooth signal. It is applied to the inverting terminal of a comparator.
- The modulating signal x (t) is applied to the non-inverting terminal of the same comparator.
- The comparator output will remain high as long as the instantaneous amplitude of x (t) is higher than that of the ramp signal c (t).
- This will generate the PWM signal at the comparator output.
- Note that the leading edges of the PWM waveform coincide with the falling edges of the ramp signal.
- Thus the leading edges of PWM signal are always generated at fixed time instants.
- Trailing edges will be dependent on the instantaneous amplitude of x(t).
- Therefore this PWM signal is said to be trail edge modulated PWM.

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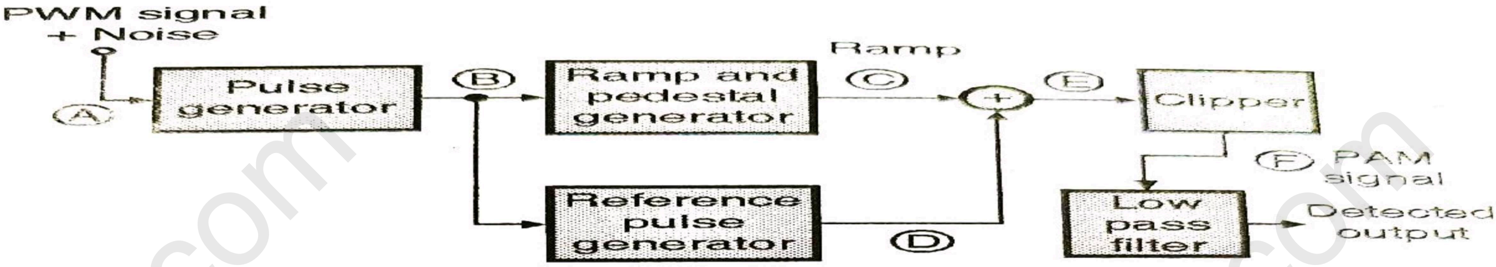
PWM detection:

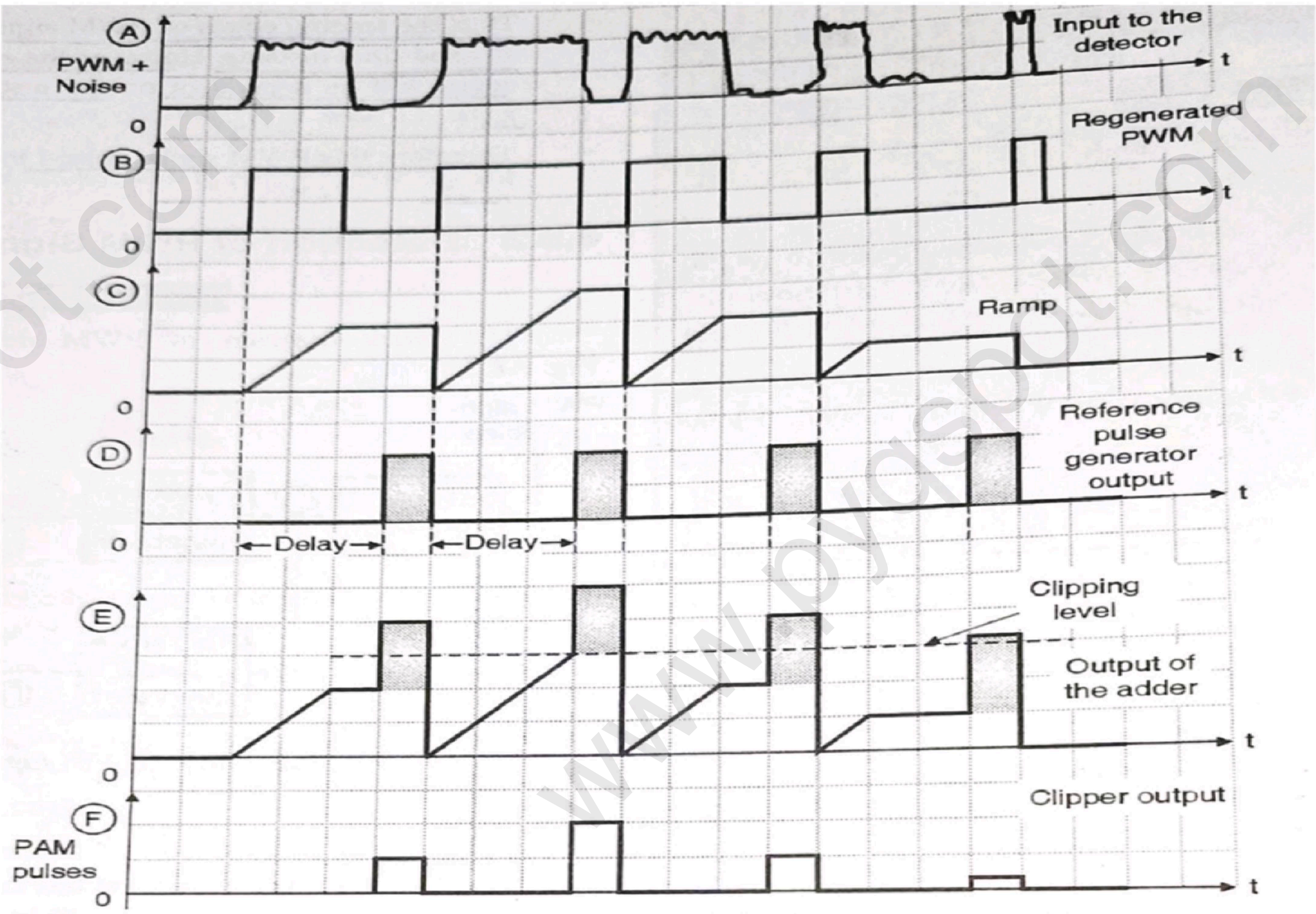


(D-457) **Fig. 8.8.3 : PWM detection circuit**

Working:-

- The PWM signal received at the input of the detection circuit is mixed with noise.
- This signal is applied to pulse generator circuit which regenerates the PWM signal. Thus some of the noise is removed and the pulses are squared up.
- The regenerated pulses are applied to a reference pulse generator.
- It produces a train of constant amplitude, constant width pulses.
- The regenerated PWM pulses are also applied to a ramp generator. At the output ramp generator we get a constant slope ramp signal.
- The height of the ramp is thus proportional to the widths of the PWM pulses.
- The constant amplitude pulses at the output of reference pulse generator and the ramp signal are then added to in adder
- The output of the adder is then clipped off at a threshold level to generate a PAM signal at the output of the clipper.
- A low pass filter is used to recover the original modulating signal from the PAM signal.

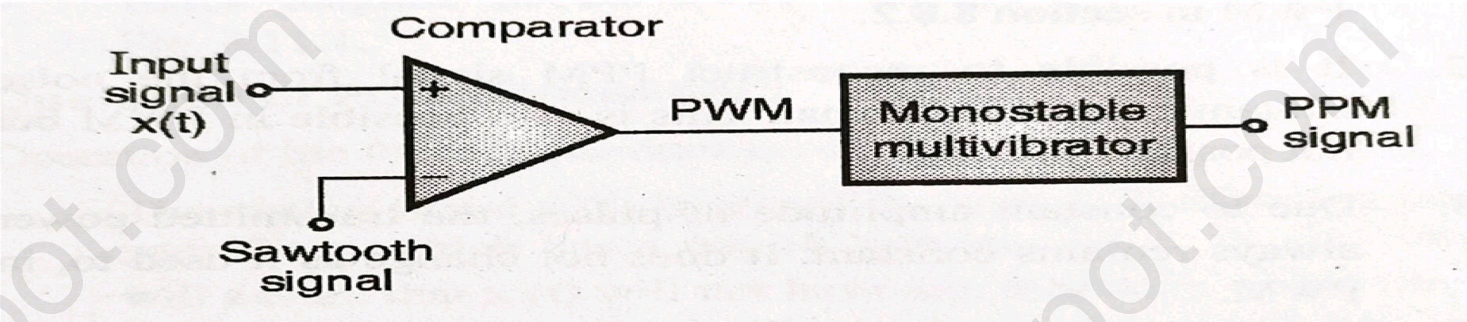
Waveform : Demodulation of PWM



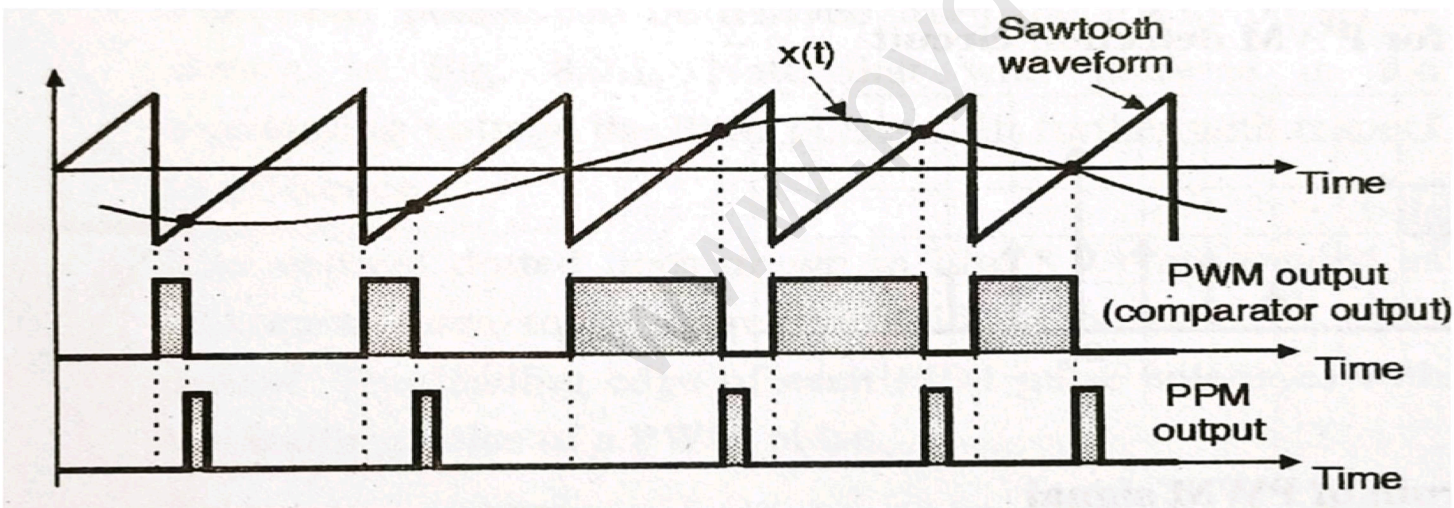
(D-458) **Fig. 8.8.4 : Waveforms for PWM detection circuit**

Que.10) Explain the generation and detection of PPM wave with waveforms.

3. Pulse Position Modulation Generation:



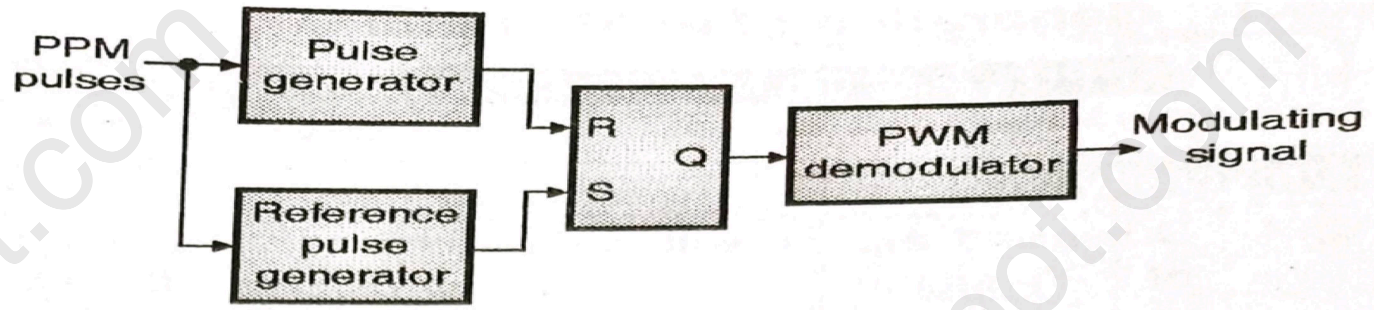
(D-461) Fig. 8.9.2 : Generation of PPM signal



Working:-

- A sawtooth signal generator generates a sawtooth signal. It is applied to the inverting terminal of a comparator.
- The modulating signal x (t) is applied to the non-inverting terminal of the same comparator.
- The comparator will compare modulating signal x (t) as well as sawtooth signal
- The comparator output will remain high as long as the instantaneous amplitude of x (t) is higher than that of the ramp signal c (t).
- Comparator will generate the PWM signal at the output.
- PWM pulses obtained at the comparator output are applied to a monostable multivibrator.
- The monostable multivibrator is negative edge triggered. Hence corresponding to each trailing edge of PWM signal, the monostable multivibrator. output goes high.
- It remains high for a fixed time decided by its own RC components.
- At the output of monostable multivibrator we get PPM pulses.
- Thus as the trailing edges of the PWM signal keep shifting in proportion with the modulating signal x(t), the PPM pulses also keep shifting

PPM Detection:

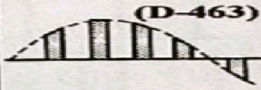
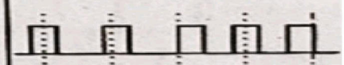


(D-462) **Fig. 8.9.3 : PPM demodulator circuit**

Working:-

- The PPM Pulses with noise are received by the PPM demodulator circuit.
- The pulse generator develops a pulsed signal waveform at its output and apply these pulses to the reset pin (R) of a SR flip-flop.
- Reference pulse generator develop fixed period reference pulse signal and applied to set pin (R) of a SR flip-flop.
- Due to the set and reset signals applied to the flip-flop, we get a PWM signal at its output.
- The PWM signal can be demodulated using the PWM demodulator.
- At the output of PWM demodulator we get modulating signal.

Que.11) Differentiate between PAM, PPM, PWM

Sr. No.	Parameter	PAM	PWM	PPM
1.	Type of carrier	Train of pulses	Train of pulses	Train of pulses
2.	Variable characteristic of the pulsed carrier	Amplitude	Width	Position
3.	Bandwidth requirement	Low	High	High
4.	Noise immunity	Low	High	High
5.	Information is contained in	Amplitude variations	Width variation	Position variation
6.	Transmitted power	Varies with amplitude of pulses	Varies with variation in width	Remains constant
7.	Need to transmit synchronizing pulses	Not needed	Not needed	Necessary
8.	Complexity of generation and detection	Complex	Easy	Complex
9.	Similarity with other modulation systems	Similar to AM	Similar to FM	Similar to PM
10.	Output waveforms	(D-463) 		

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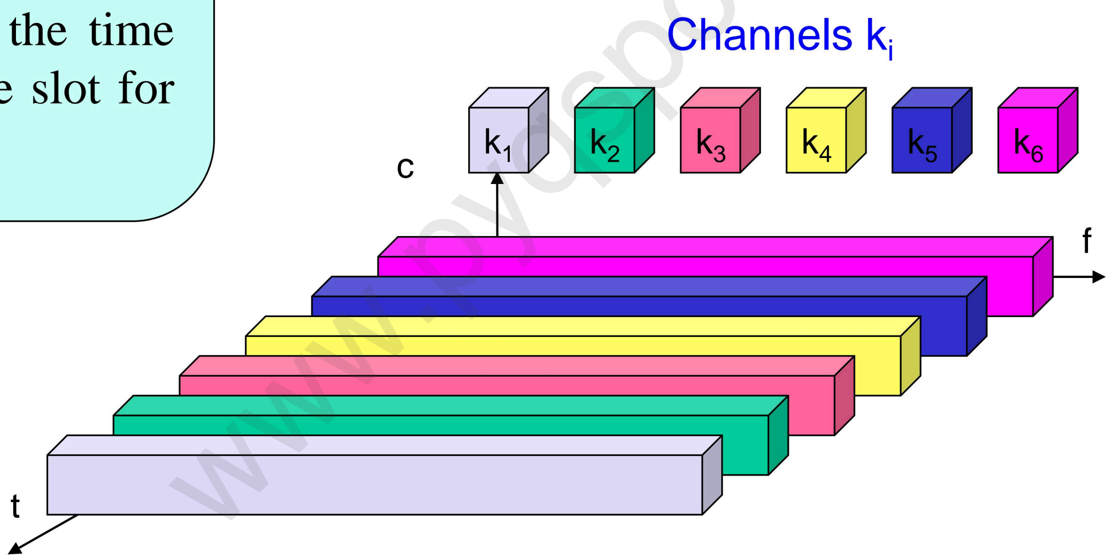
Time Division Multiplexing (TDM)

TDM is a technique used for transmitting several message signal over single communication channel by dividing the time frame in to slots, one slot for each message signal.

Definition: Time Division Multiplexing (TDM) is the time interleaving of samples from several sources so that the information from these sources can be transmitted serially over a single communication channel.



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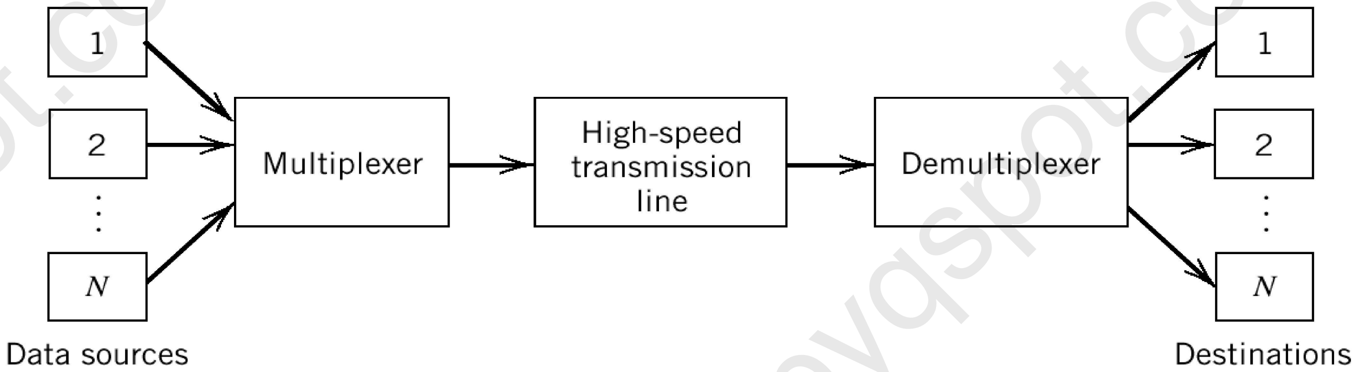
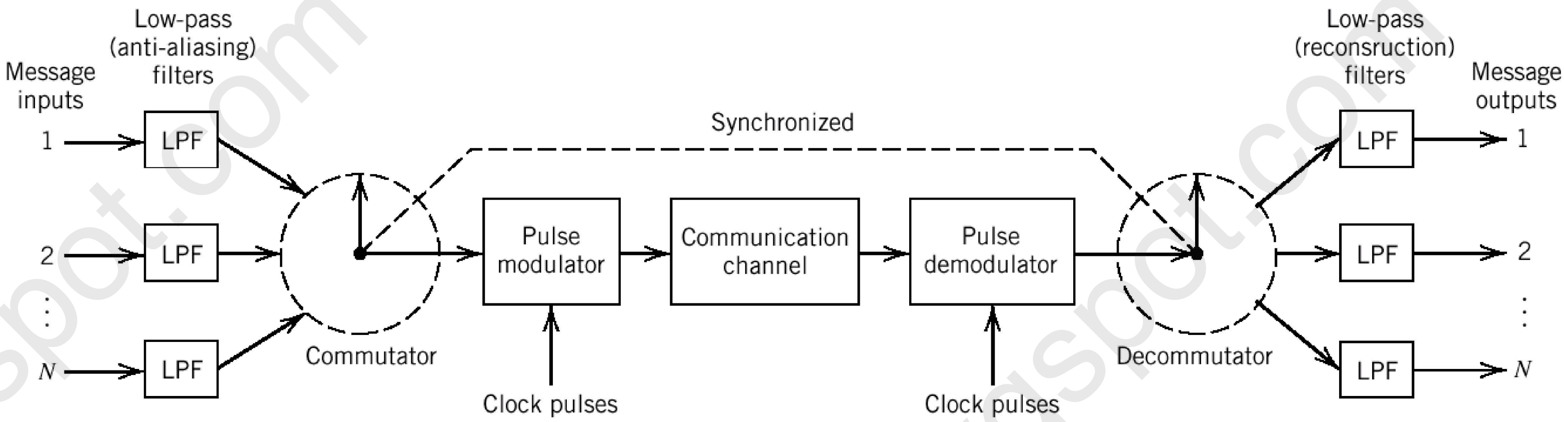
Conceptual diagram of multiplexing-demultiplexing.



Que.12) Explain PAM –TDM System (Time Division Multiplexing) in detail.

PAM –TDM System



- Bandlimited signals are applied Low pass Filter. LPF is called as antialising Filter for to avoid Aliasing Effect. LPF output is applid to the contact point of a rotary switch.
- All the signals are sampled in a sequential manner when the rotary arm of switch swings.
- Pulse modulater is used for to modulate PAM signal and applied to communication channel.
- communication channel is used for transpar the signal from one place to another place.
- Receiver commutator switch is in synchronism with that of transmitter communicator switch.
- With each revolution of the switch, one sample is taken as input and provided to receiver.
- At the receiver, train of pulses pass through filter and original signal m(t) reconstructed.

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Applications of TDM

✓Digital Telephony

✓ Data communications

✓Satellite Access

✓ Cellular radio.

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