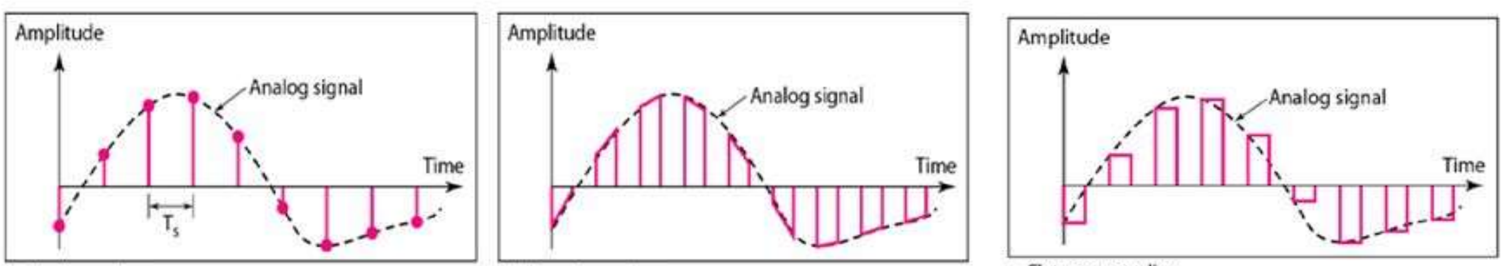
Sampling

- Process of converting the continuous time signal to a discrete time signal.
- Sampling is done by taking “Samples” at specific times spaced regularly.
  - V(t) is an analog signal
  - $V(nT_s)$ is the sampled signal
    - T_s = positive real number that represent the spacing of the sampling time
    - n = sample number integer

Sampling

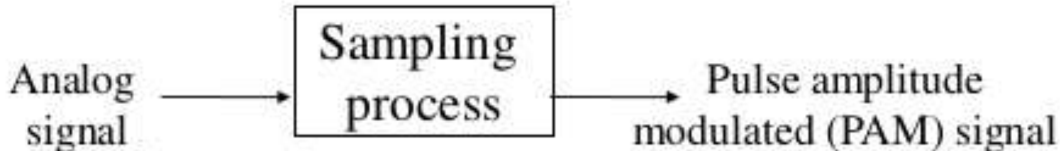
- <u>There are 3 sampling methods:</u>

- Ideal - an impulse at each sampling instant.
- Natural - a pulse of short width with varying amplitude.
- Flattop - sample and hold, like natural but with single amplitude value.



a. Ideal sampling b. Natural sampling c. Flat-top sampling

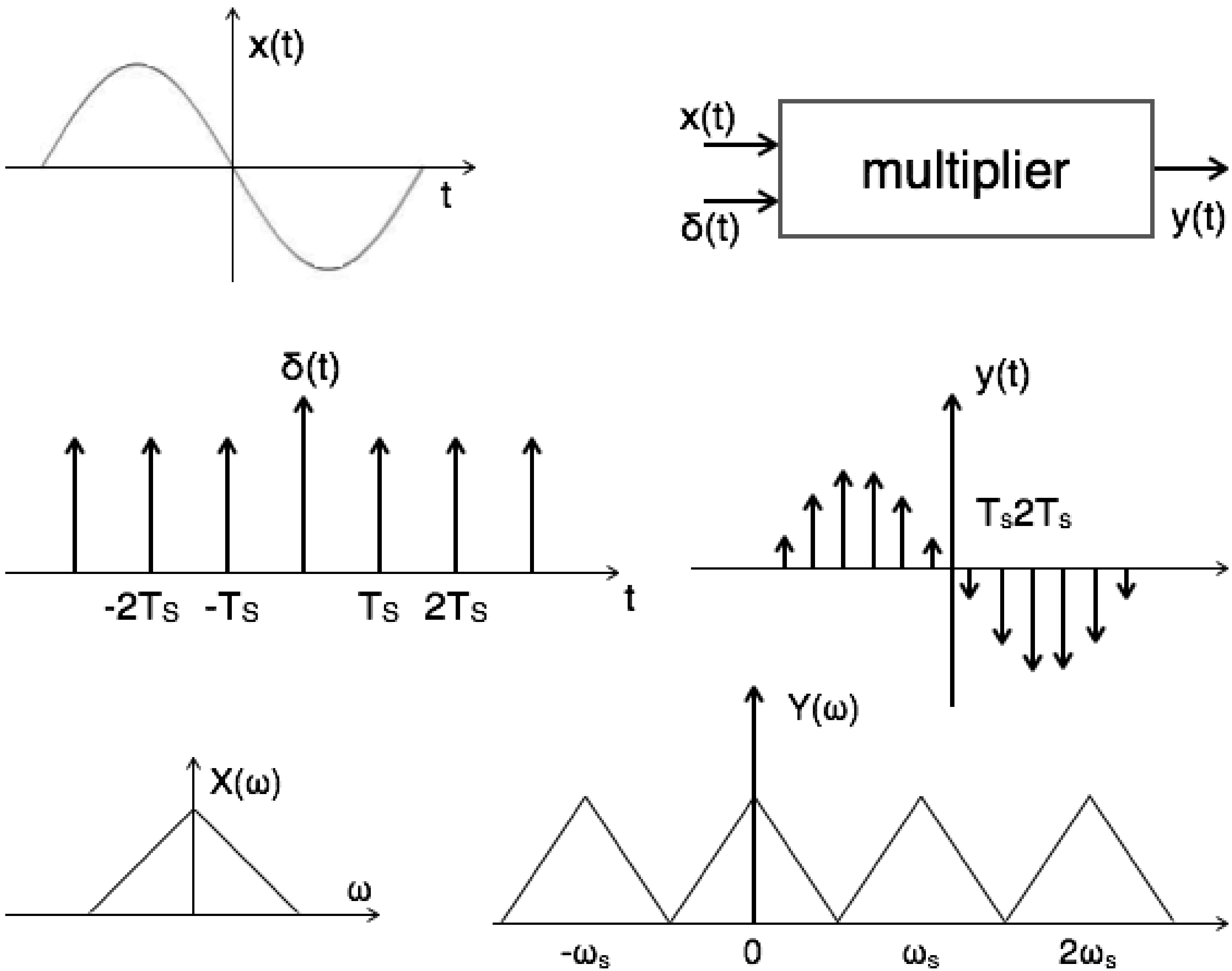
Sampling theorem

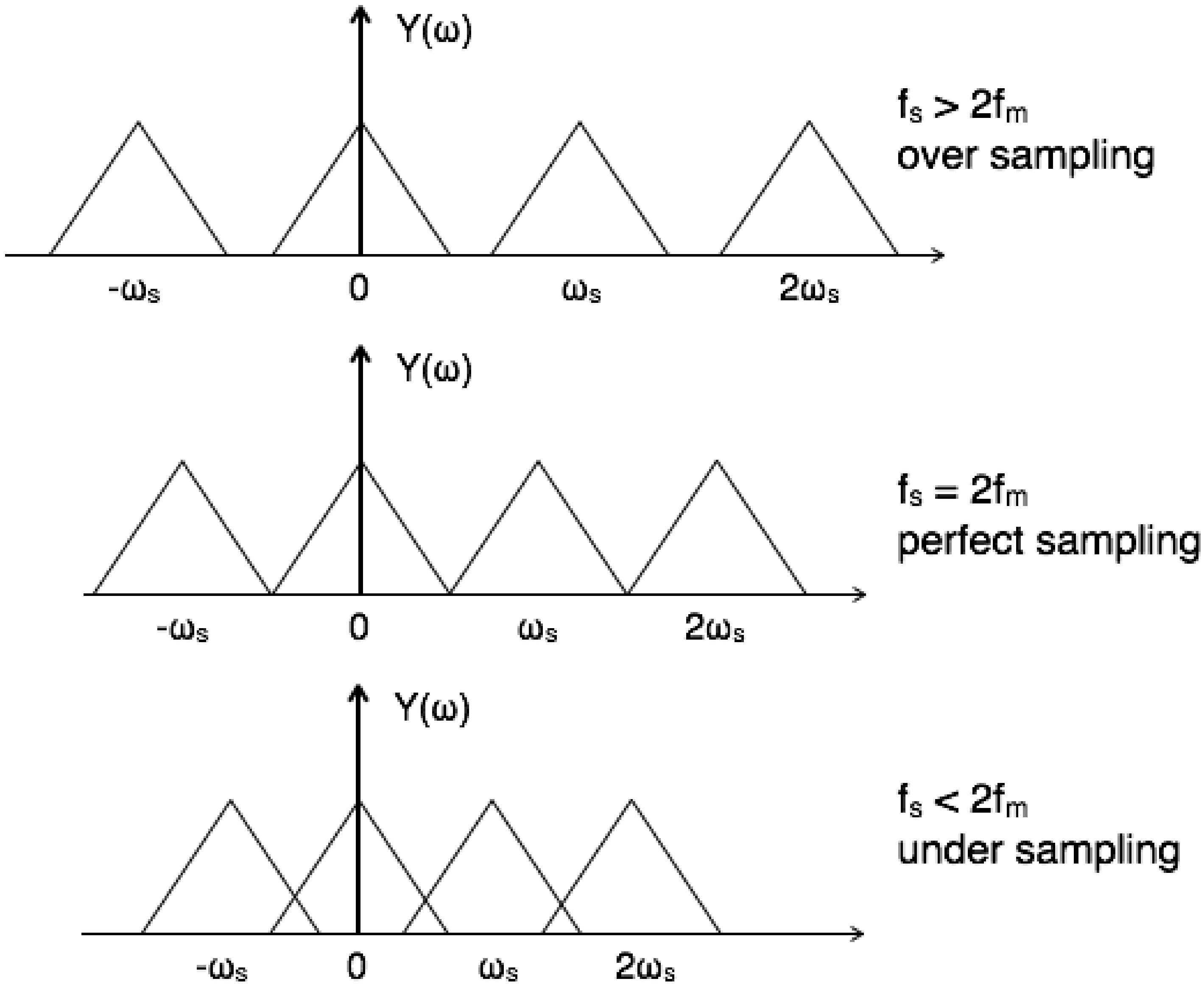


- **Sampling theorem:** A band limited signal with no spectral components beyond f_m, can be uniquely determined by values sampled at uniform intervals of

$$\boxed{T_s \le \frac{1}{2f_m}}$$

  - The sampling rate, $f_s = \frac{1}{T_s} = 2f_m$ is called Nyquist rate.


x(t)
t
x(t)
δ(t)
multiplier
y(t)
δ(t)
-2Ts
-Ts
Ts
2Ts
t
y(t)
Ts2Ts
X(ω)
ω
Y(ω)
-ωs
0
ωs
2ωs

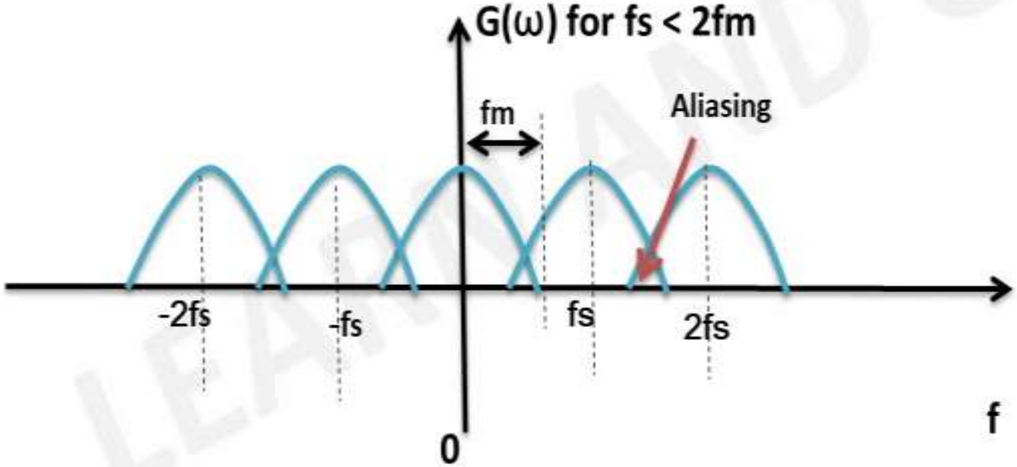


Y(ω)
fs > 2fm
over sampling
-ωs
0
ωs
2ωs
Y(ω)
fs = 2fm
perfect sampling
-ωs
0
ωs
2ωs
Y(ω)
fs < 2fm
under sampling
-ωs
0
ωs
2ωs

LAG
LEARN AND GROW

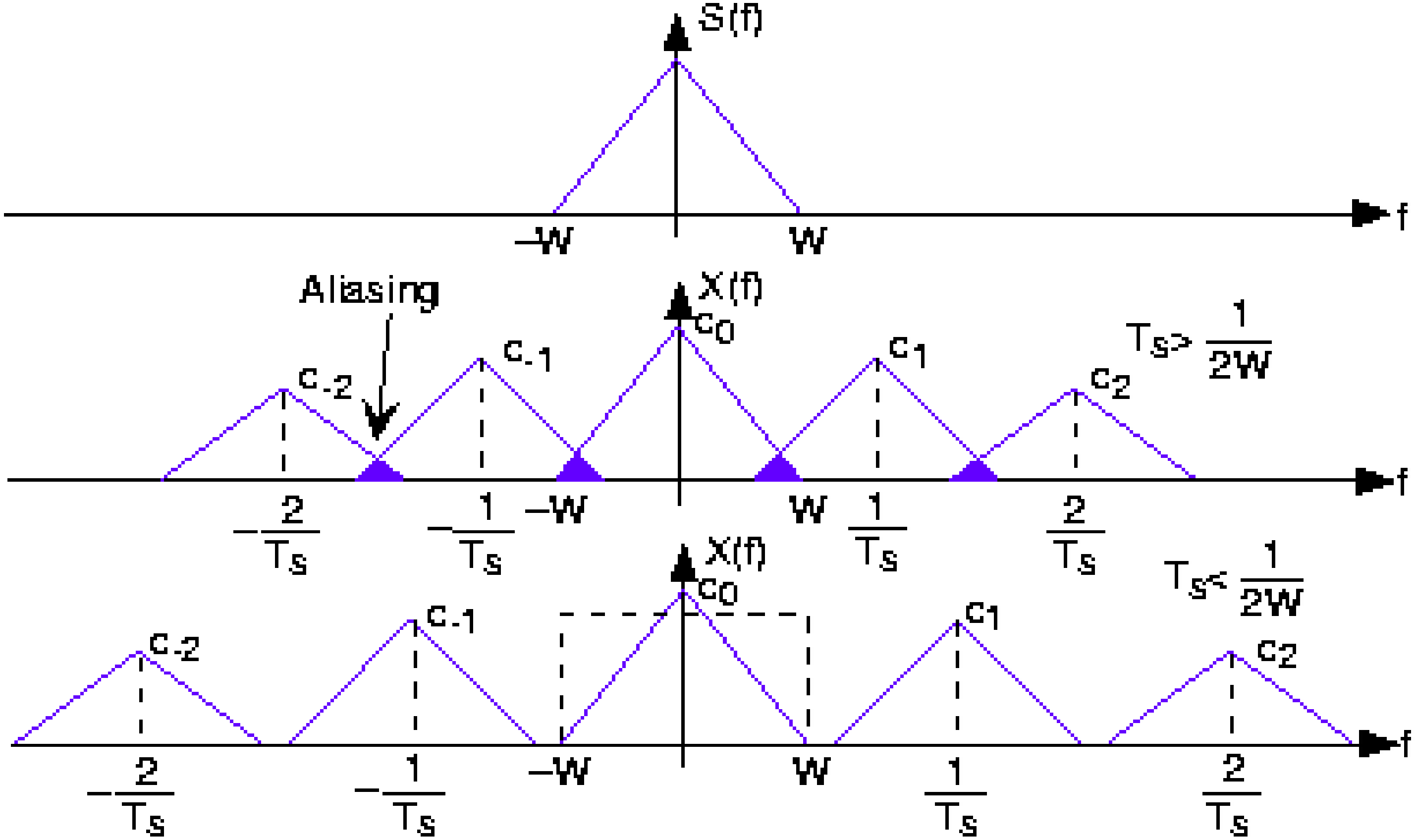
EFFECT OF UNDER SAMPLING (ALIASING)

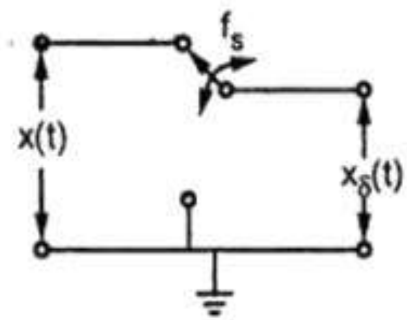
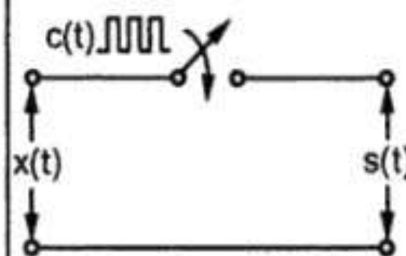
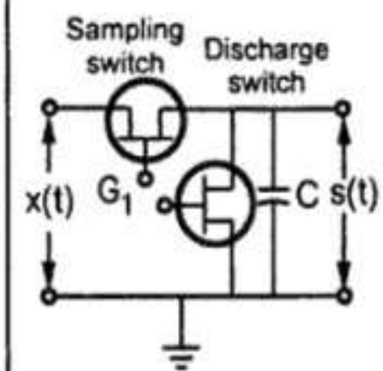
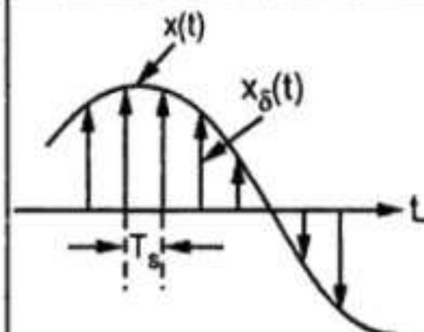
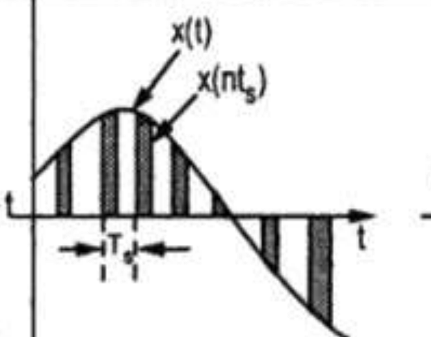
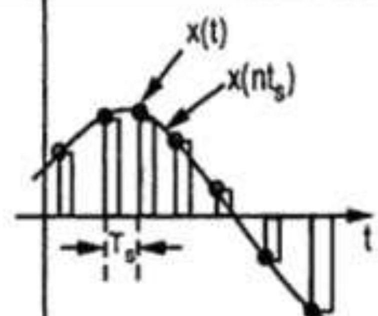
If continuous time at lower then Nyquist rate fs < 2fm cycles of spectrum is overlap With each other .



Spectrum Sampling signal

Aliasing effect (fs<2fm)



Sr. No.	Parameter of comparison	Ideal or instantaneous sampling	Natural sampling	Flat top sampling
1	Principle of sampling	It uses multiplication by an impulse function	It uses chopping principle	It uses sample and hold circuit
2	Circuit of sampler			
3	Waveforms			
4	Realizability	This is not practically possible method	This method is used practically	This method is used practically

Pulse Modulation Technique

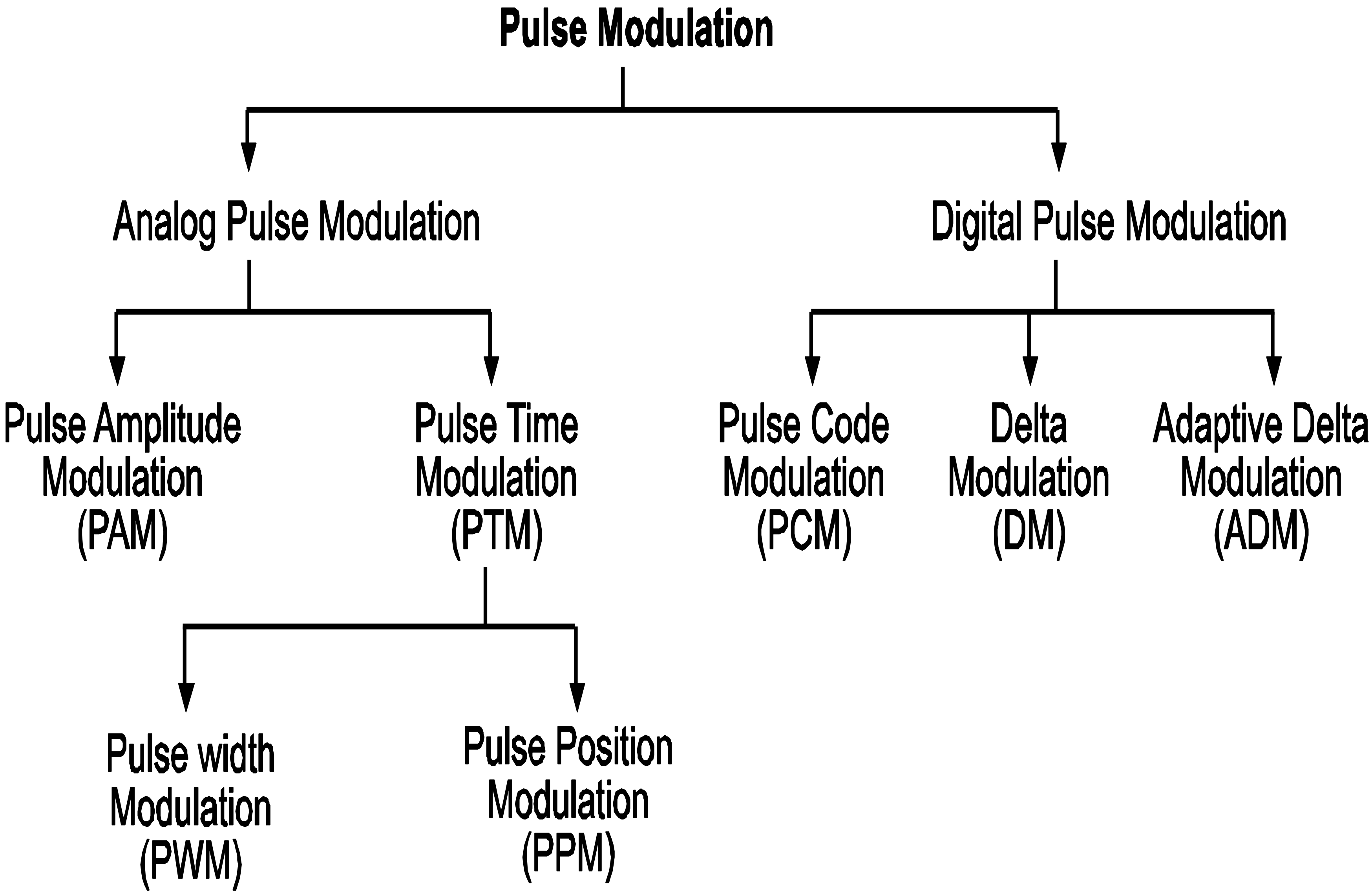
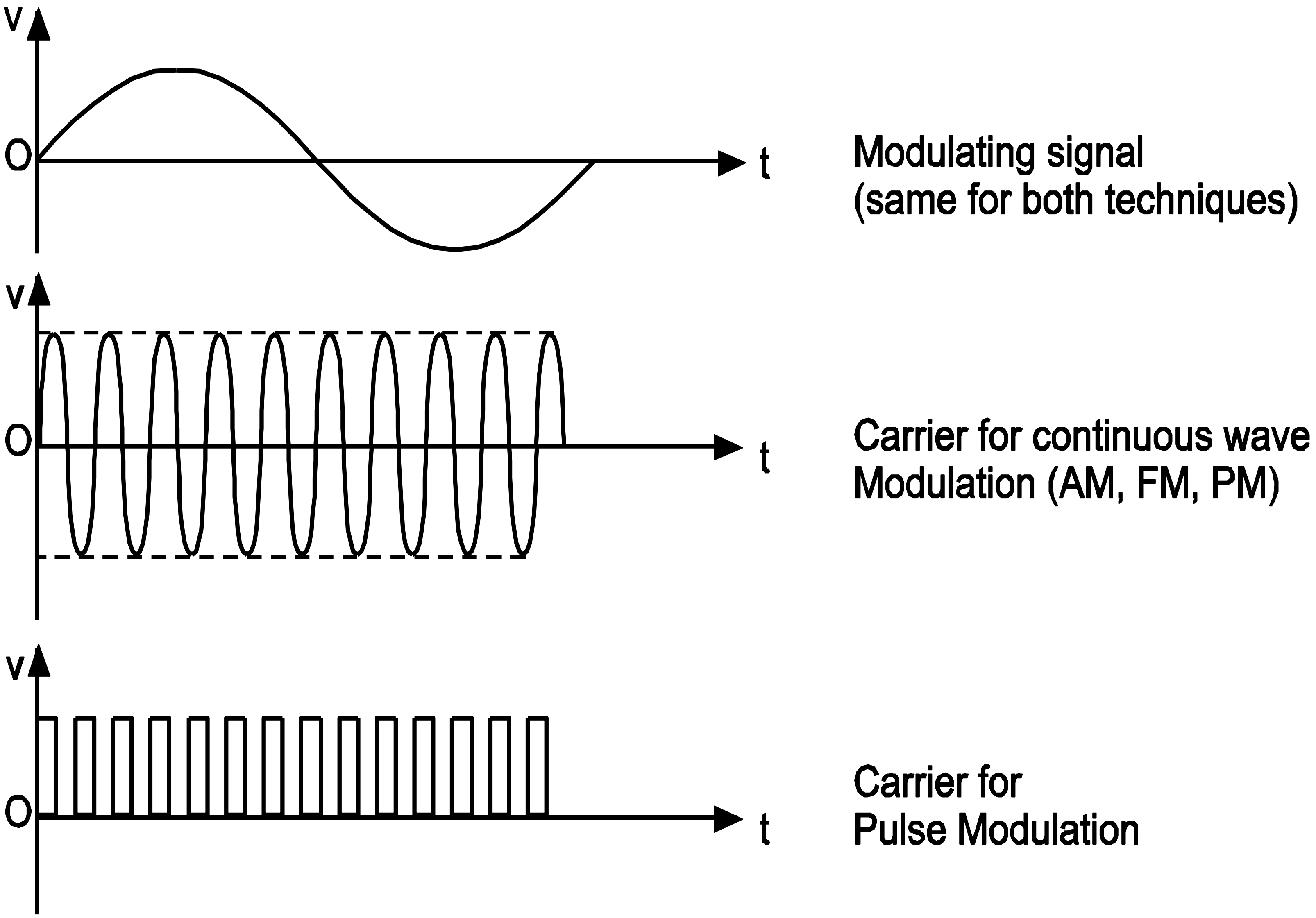


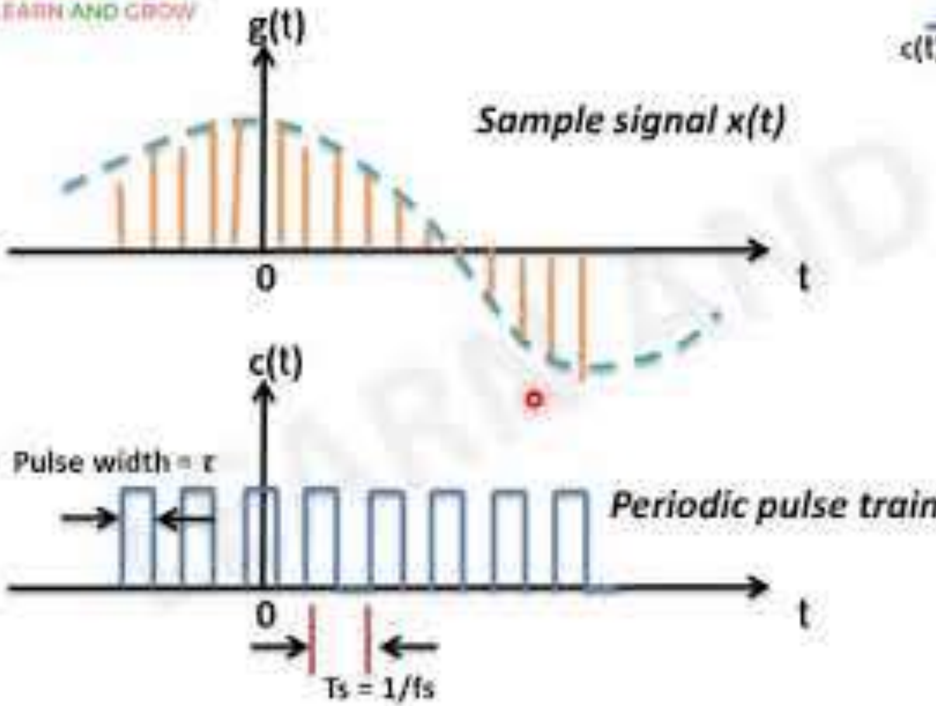
Fig. : Carrier for Continuous Wave and Pulse Modulation

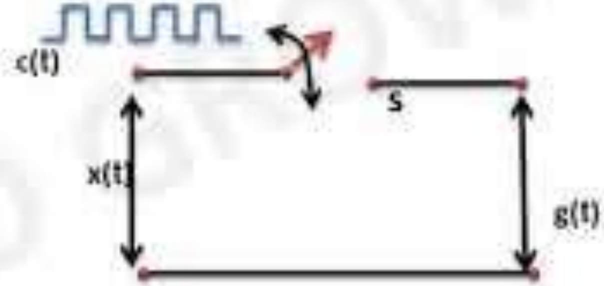


Need of Pulse Modulation

- Comparing to continuous wave modulation (like AM, FM), the performance of all pulse modulation schemes except PAM in presence of noise is very good.
- Due to better noise performance, it requires less power to cover large area of communication.
- Due to better noise performance and requirement of less signal power, the pulse modulation is most preferred for the communication between space ships and earth.

NATURAL SAMPLING (SAMPLING TECHNIQUES)





Function diagram natural sampler

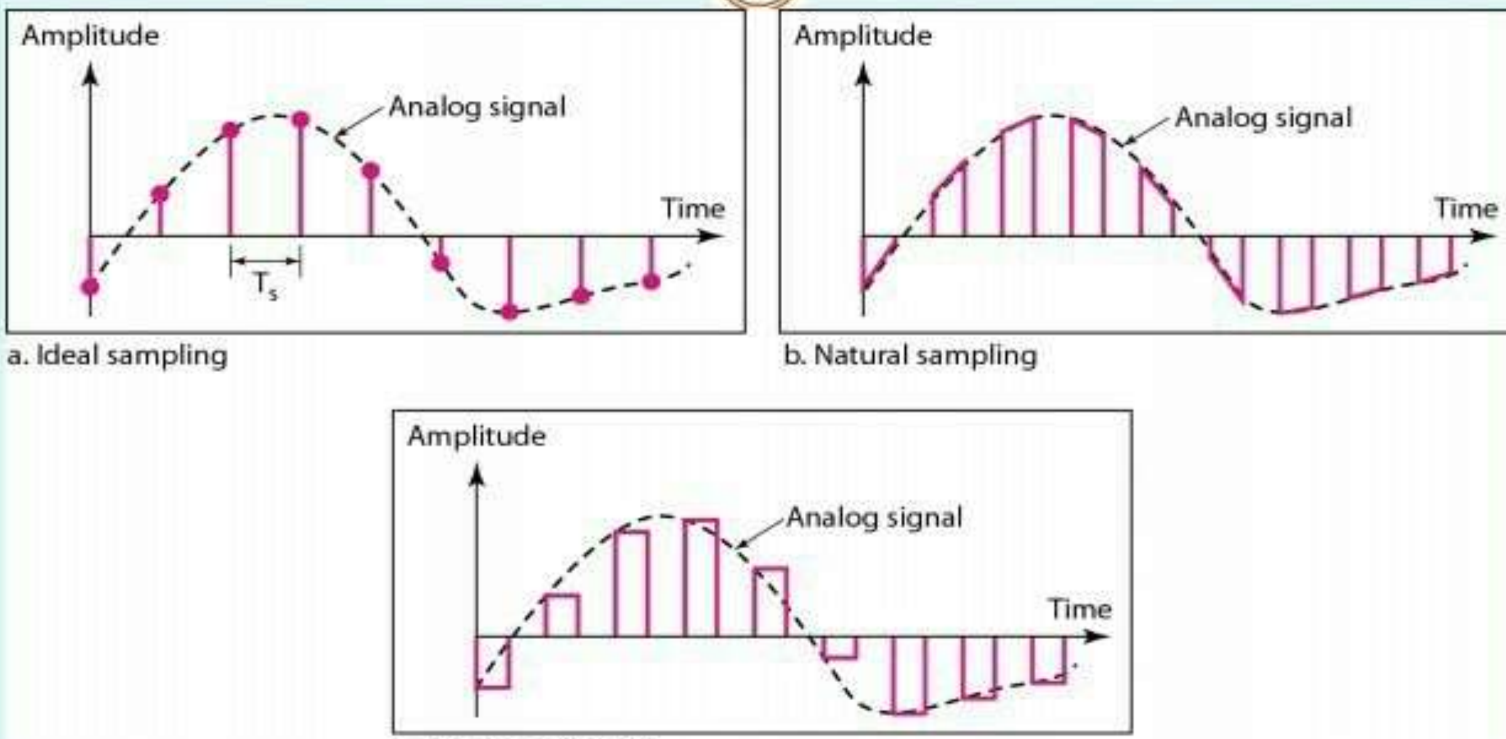
$g(t) = x(t)$ when $c(t) = A$

$g(t) = 0$ when $c(t) = 0$

Sample g(t)

$g(t) = c(t) \cdot x(t)$

Different Sampling Method

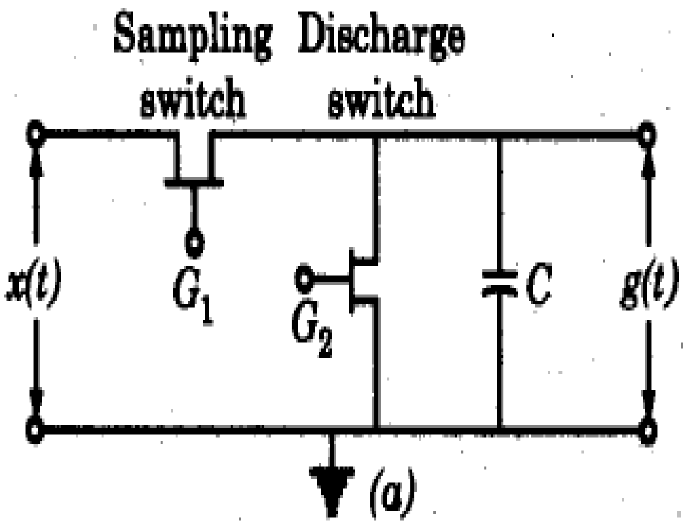


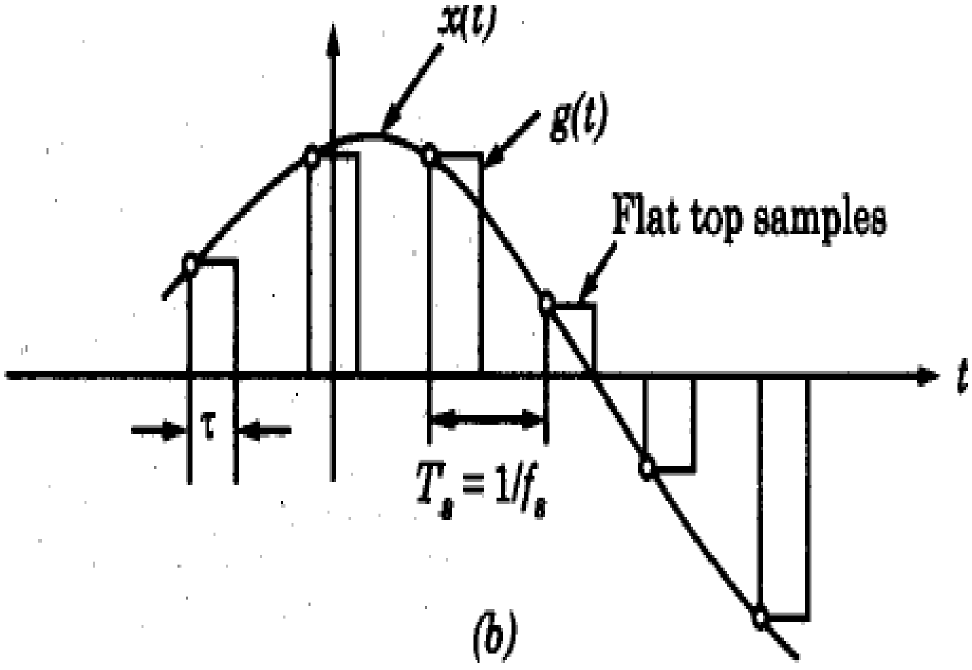
a. Ideal sampling

b. Natural sampling

c. Flat-top sampling

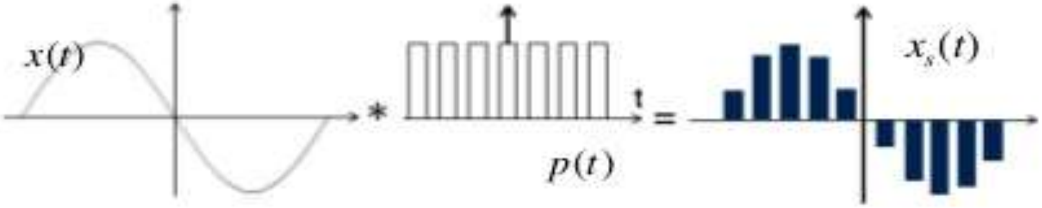
Flat top Sampling



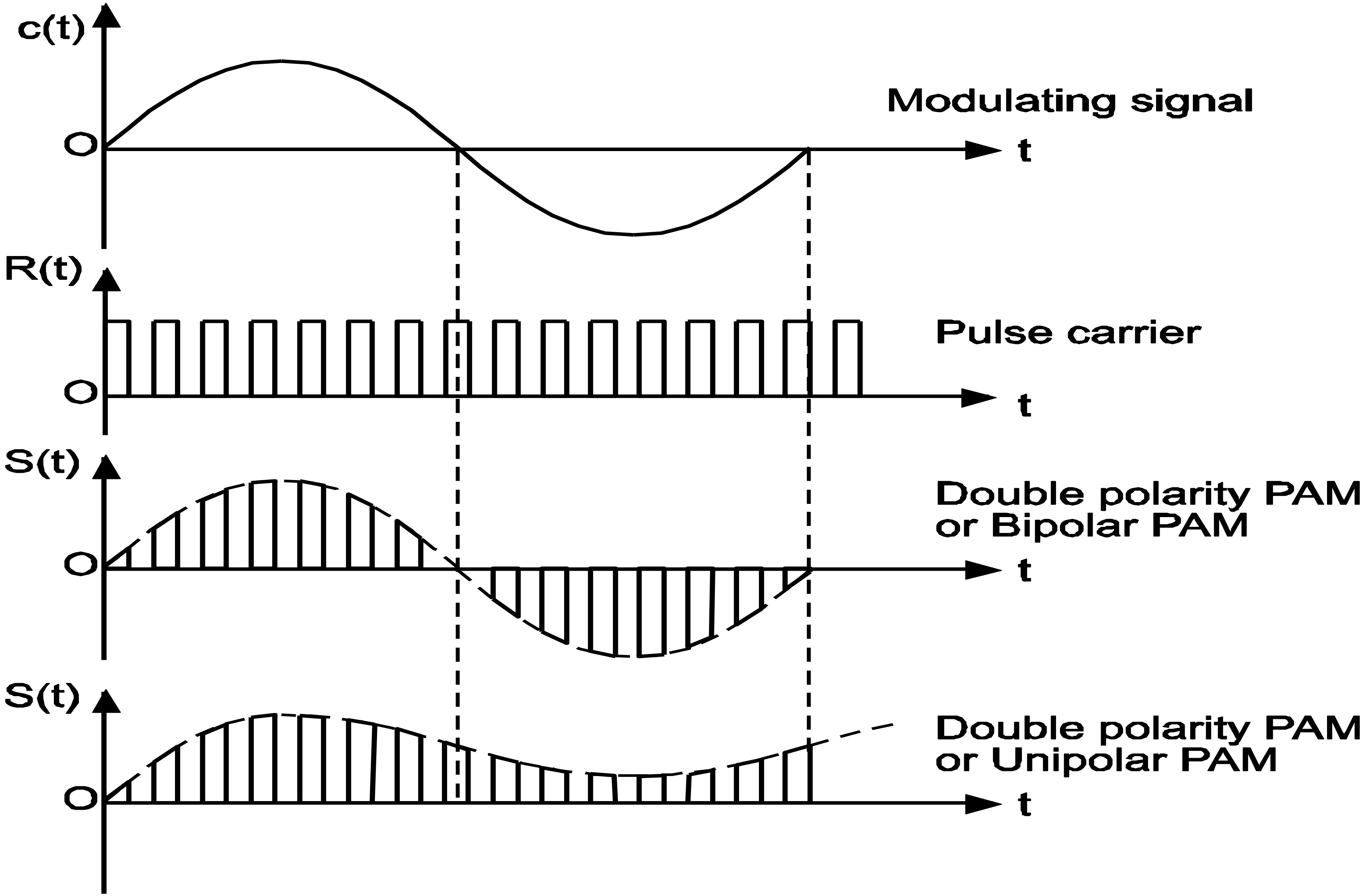


Flat-Top Sampling

- During transmission, noise is introduced at top of the transmission pulse which can be easily removed if the pulse is in the form of flat top.
- The top of the samples are flat i.e. they have constant amplitude. Hence, it is called as flat top sampling or practical sampling.



Waveforms of PAM



Advantages of PAM

- It is easy to generate and demodulate PAM.

Disadvantages of PAM

1. Since PAM does not utilize constant amplitude pulses, output is distorted due to additive noise so that it is infrequently used.
2. Transmission bandwidth required is too large.
3. Transmitted power is not constant.

Application of PAM

- Used in radio telemetry for remote monitoring and sensing.

Pulse Amplitude Modulation (PAM)

Definition:

- The amplitude of the pulsed carrier varies in accordance with the instantaneous value of modulating signal, is called PAM where width and position remains constant.

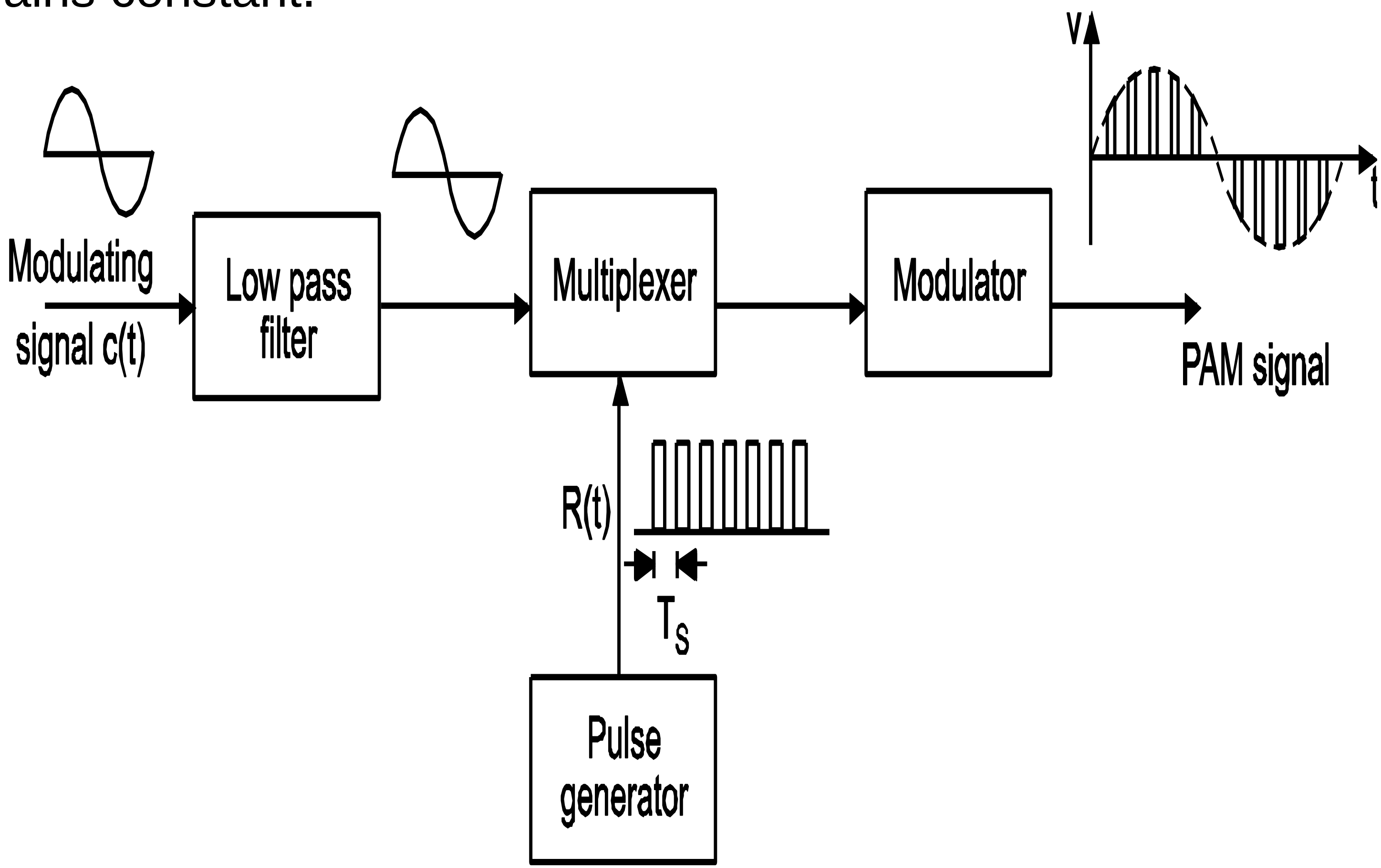
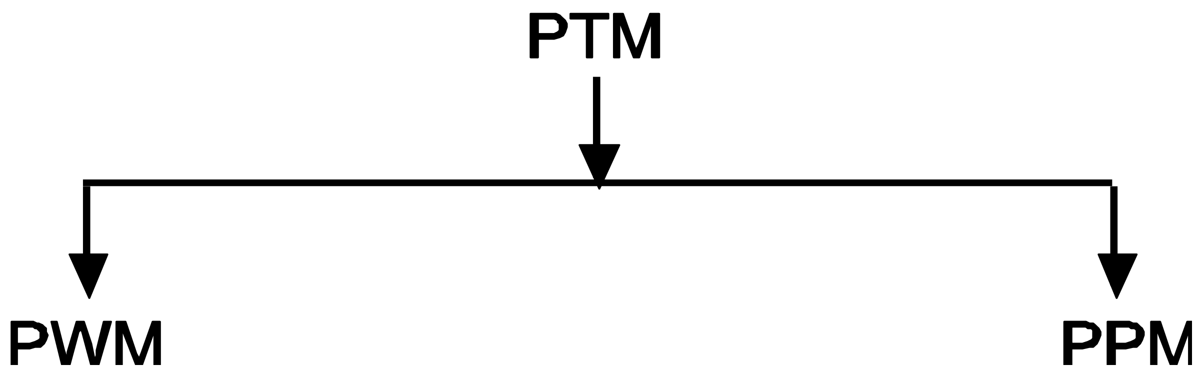


Fig. : Generation of PAM Block diagram

Pulse Time Modulation (PTM)



Definition:

- When the width of pulsed carrier varies in accordance with the instantaneous amplitude of modulating signal, is called PWM where amplitude and position remains constant.

Definition -

- When position of pulse carrier varies in accordance with the instantaneous value of modulating signal is called PPM, where width and amplitude of carrier remains constant.

Pulse Width Modulation

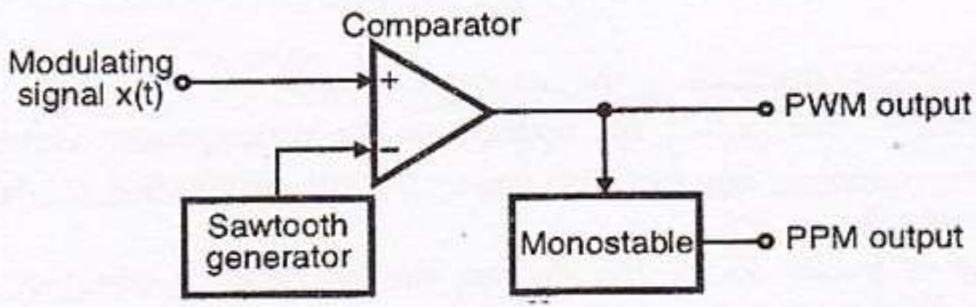


Fig. 8.4.2(a) : PWM and PPM generator

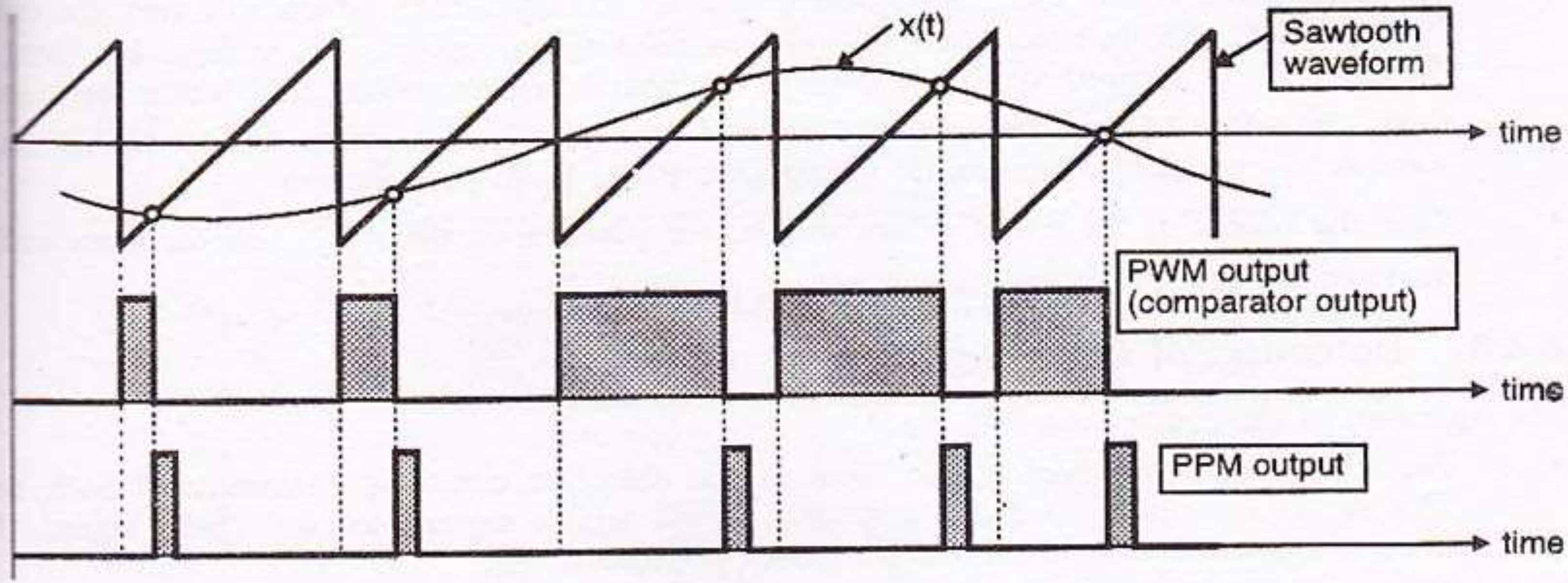
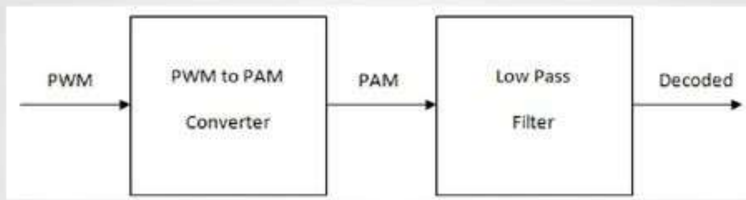


Fig. : Waveforms

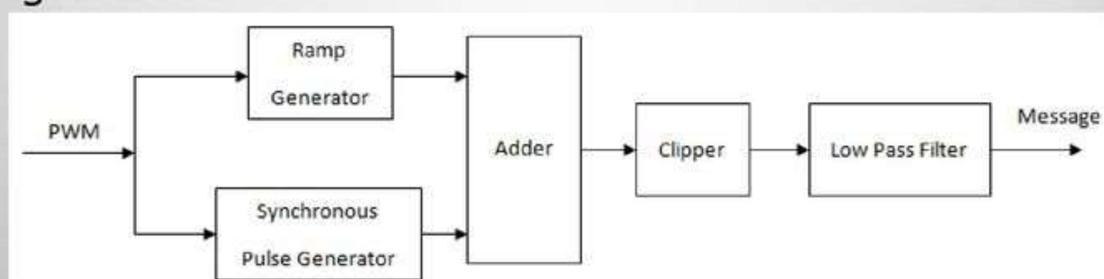
Pulse Width demodulation

Block Diagram

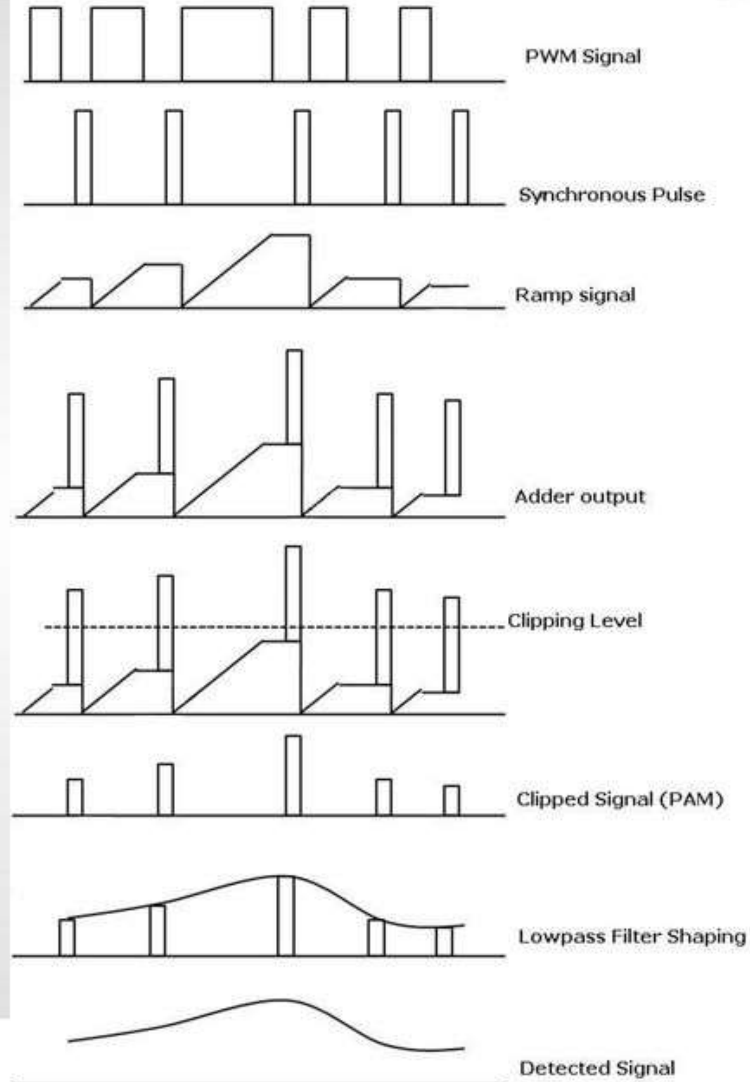
- The basic theory behind Pulse width demodulation is that converting the PWM signal to PAM (Pulse Amplitude Modulation) signal. PAM can be easily detected by suitable low pass filter.



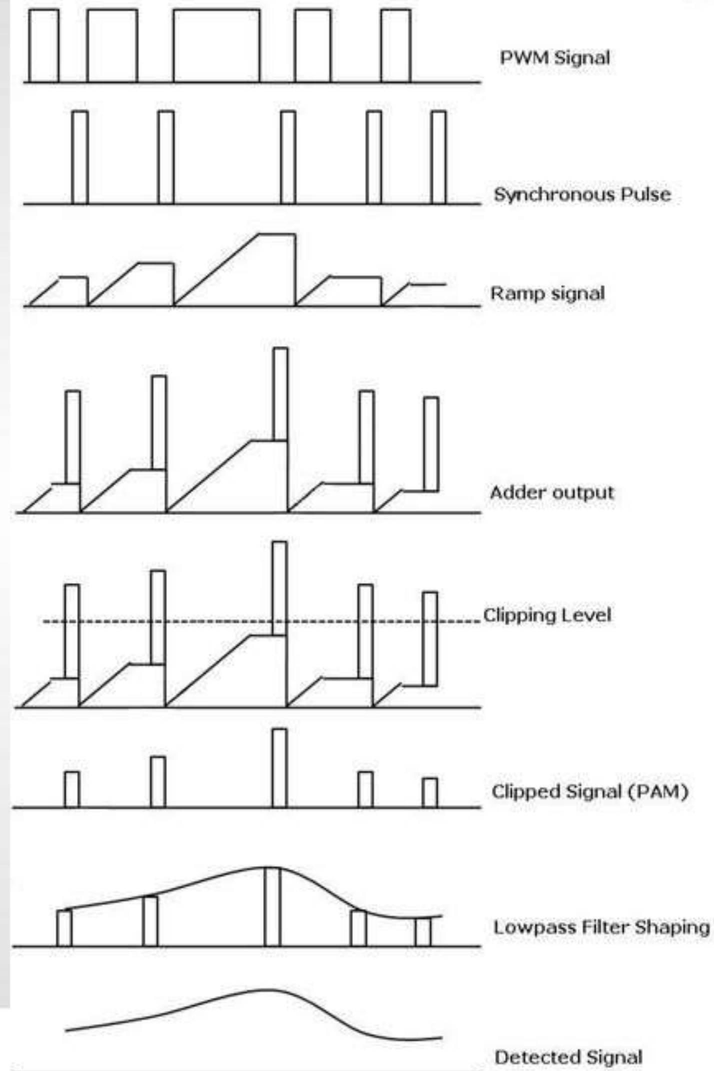
- Input PWM wave is applied to Ramp generator and Synchronous Pulse generator



- Synchronous pulse generator will generate a pulse waveform such that the pulse will end at the beginning of each PWM pulse.
- Ramp generator will produce a ramp signal whose amplitude is proportional to width of the PWM signal.
- Apply these Ramp and Synchronous pulse to an Adder circuit which adds these signals together.
- The next block is a positive Clipper with a specific voltage; Clipper clips the waveform at a particular level.



- The output of clipper will be PAM signal, now the PWM signal gets converted to PAM signal.
- The PAM can be demodulated by Low Pass filtering method.
- Ramp Generator + Synchronous Pulse + Adder + Clipper = PWM to PAM Converter



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Advantages of PWM

1. More immune to noise.
2. Synchronization between transmitter and receiver is not required.
3. Possible to separate out signal from noise.

Applications of PWM

PWM is used in special purpose communication systems mainly for **military** but is seldom used for **commercial digital transmission system.**

PPM Demodulation

- At the receiver, the PPM is typically converted into PWM and then low-pass filtered
- PWM is recovered from the PPM by using the PPM signal and a synchronization pulse at the original sampling rate
- The sync pulse can be used to set an SR flip flop and the PPM pulse can be used to reset it, thus generating a PWM signal.

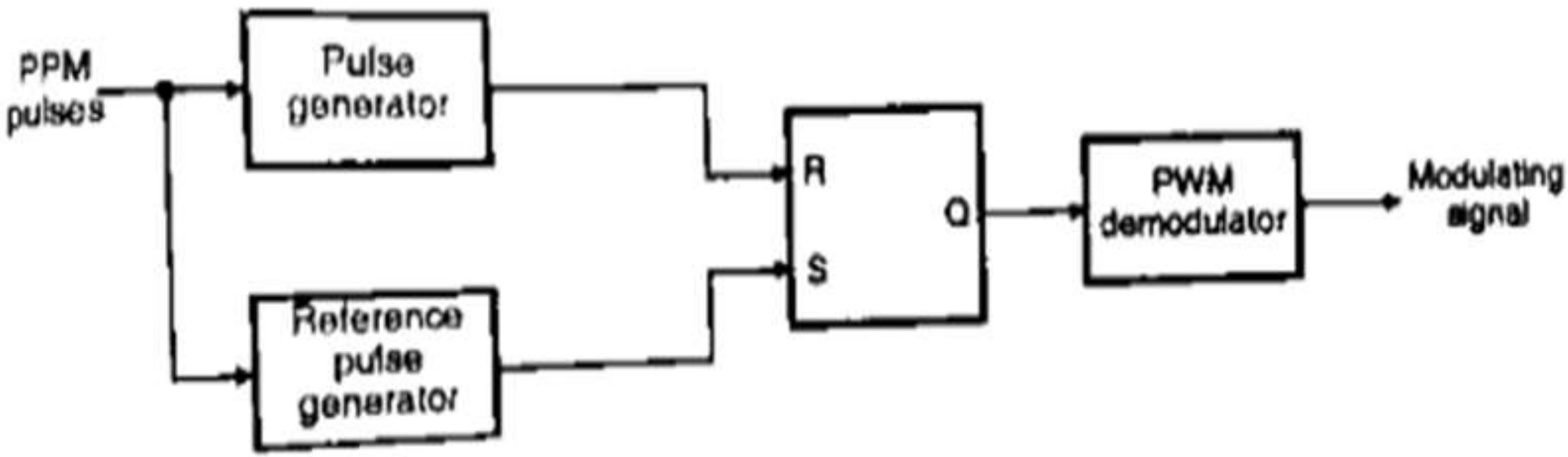


Fig: PPM demodulator circuit.

Advantages of PPM

1. Good noise immunity.
2. Requires constant transmitter power output.

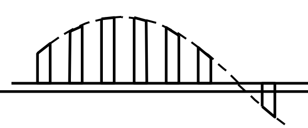
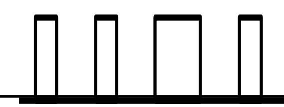
Disadvantages of PPM

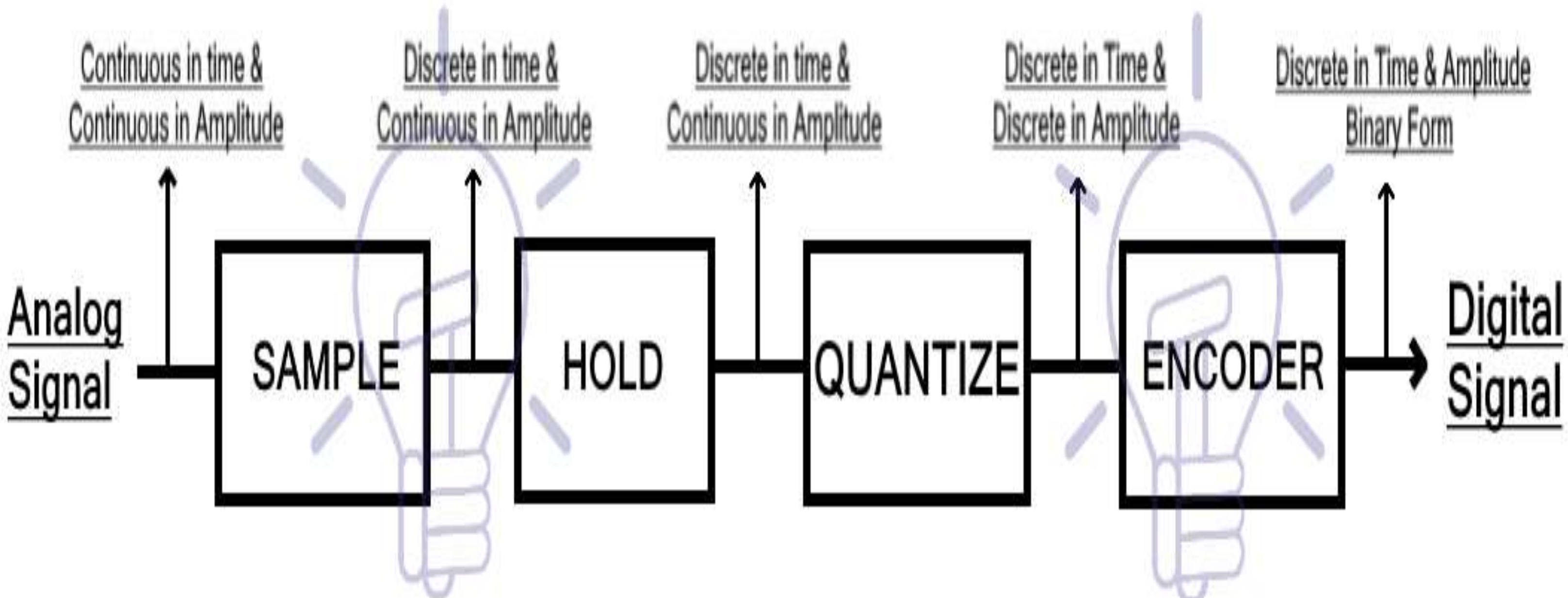
1. Requires synchronization between transmitter and receiver.
2. Large Bandwidth requirement.

Applications of PPM

1. It is used for optical communication system where there is no N multipath interference.
2 PPM is useful for narrowband FM channel allocation, with these channel characteristics in the **radio control** and model aircraft, boats and cars.
3. PPM is also used for military applications.

Comparison of PAM, PWM and PPM

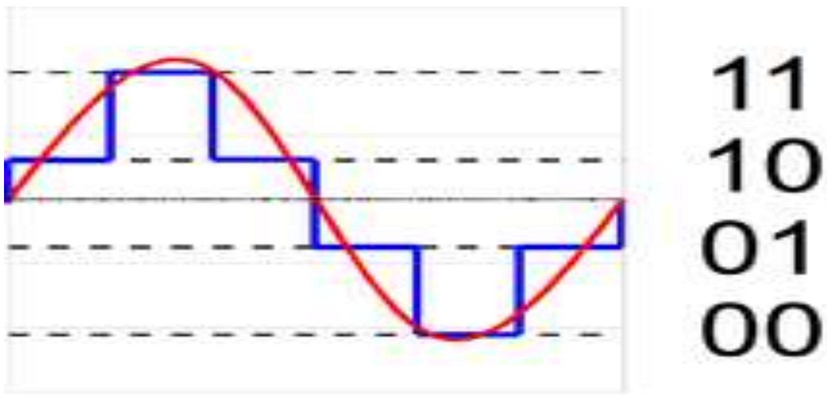
Parameter	PAM	PWM	PPM
1. Variable parameter of pulsed carrier.	Amplitude	Width	Position
2. Bandwidth requirement	Low	High	High
3. Transmitted power	Varies with amplitude of pulses	Varies with variation in width	Remains constant
4. Noise immunity	Low	High	High
5. Information contained in	Amplitude variations	Width variations	Position variation
6. Output waveform			



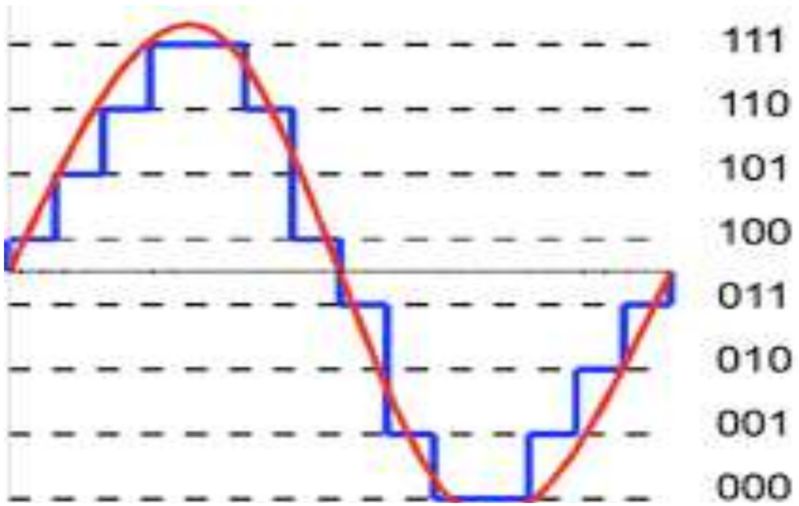
ANALOG TO DIGITAL CONVERTER

Quantization levels

4 levels



8 levels



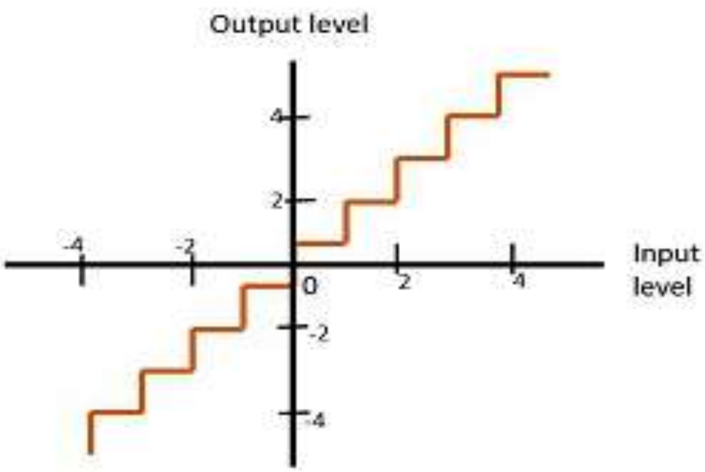


Fig 1 : Mid-Rise type Uniform Quantization

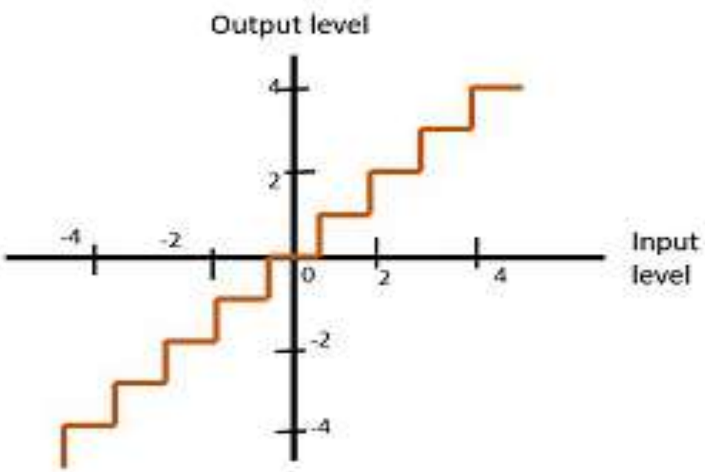
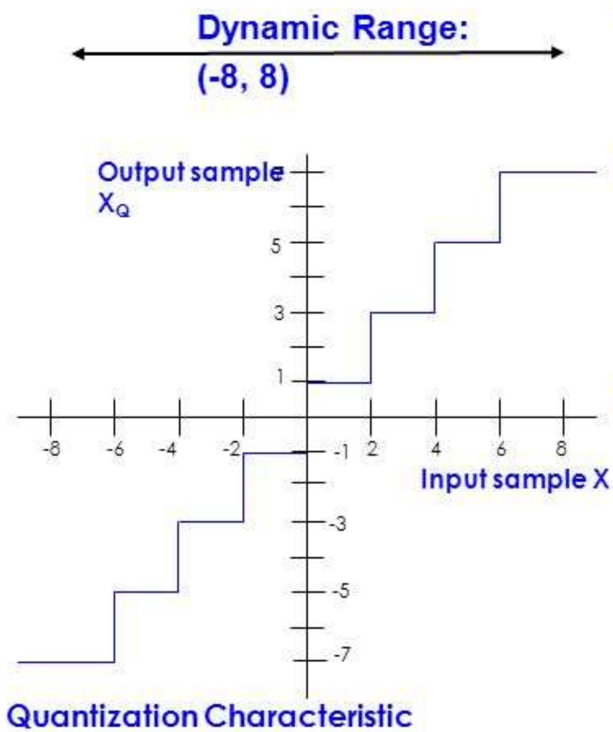


Fig 2 : Mid-Tread type Uniform Quantization

Uniform Quantization



Example: Uniform n =3 bit quantizer

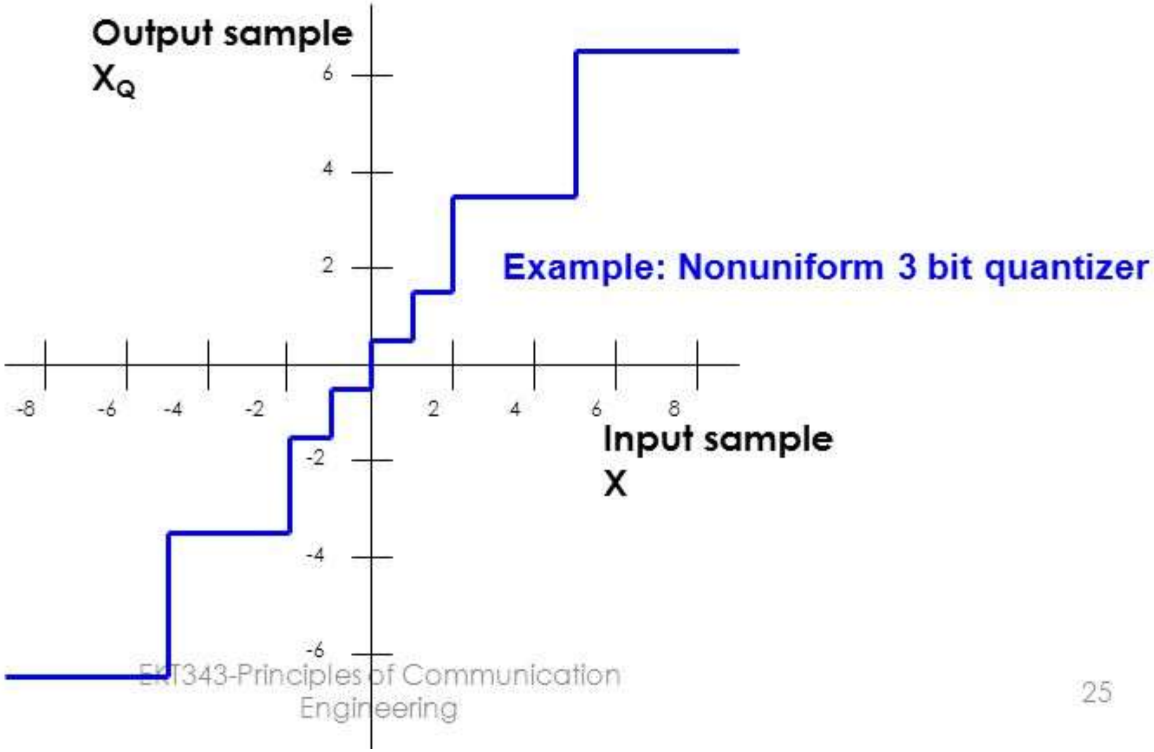
L=8 and $X_Q = \{\pm1,\pm3,\pm5,\pm7\}$

- Most ADC's use ***uniform quantizers***.
- The quantization levels of a uniform quantizer are equally spaced apart.
- Uniform quantizers are optimal when the input distribution is uniform. When all values within the *Dynamic Range* of the quantizer are equally likely.

Nonuniform Quantization

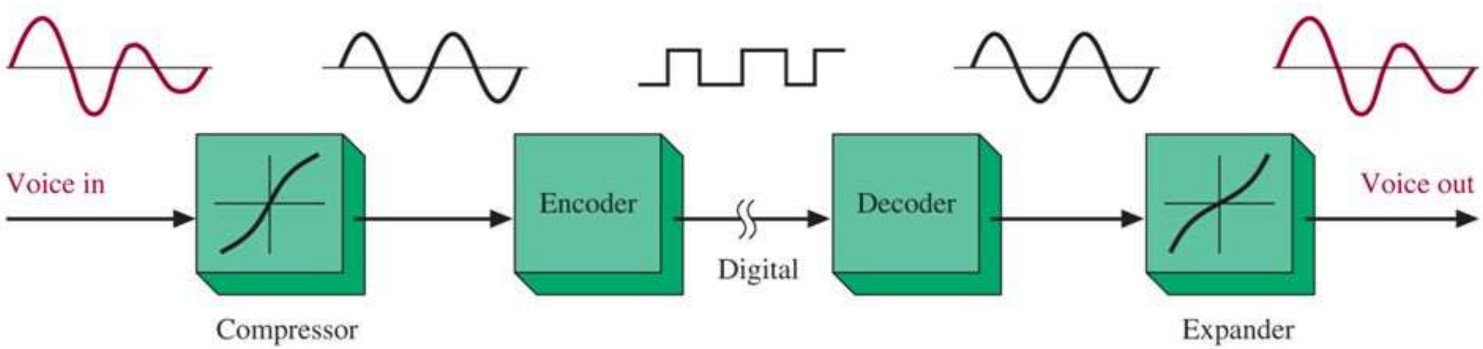
- Many signals such as speech have a nonuniform distribution.
  - The amplitude is more likely to be close to zero than to be at higher levels.

- Nonuniform quantizers have unequally spaced levels
  - The spacing can be chosen to optimize the SNR for a particular type of signal.



Companding

- Nonuniform quantizers are difficult to make and expensive.
- An alternative is to first pass the speech signal through a nonlinearity before quantizing with a uniform quantizer.
- The nonlinearity causes the signal amplitude to be ***Compressed***.
  - The input to the quantizer will have a more uniform distribution.
- At the receiver, the signal is ***Expanded*** by an inverse to the nonlinearity.
- The process of compressing and expanding is called ***Companding***.



Method of Companding

- For the compression, two laws are adopted: the μ-law in US and Japan and the *A*-law in Europe.

- **μ-law**

$$V_{out} = \frac{V_{max} \ln\left(1 + \mu\left(\frac{V_{in}}{V_{max}}\right)\right)}{\ln(1 + \mu)}$$

- **A-law**

$$V_{out} = \begin{cases} V_{max} \dfrac{A\left(\frac{V_{in}}{V_{max}}\right)}{1 + \ln A} & 0 \le \dfrac{V_{in}}{V_{max}} \le \dfrac{1}{A} \\ \dfrac{1 + \ln\left(A\left(\frac{V_{in}}{V_{max}}\right)\right)}{1 + \ln A} & \dfrac{1}{A} \le \dfrac{V_{in}}{V_{max}} \le 1 \end{cases}$$

V_{max}= Max uncompressed analog input voltage

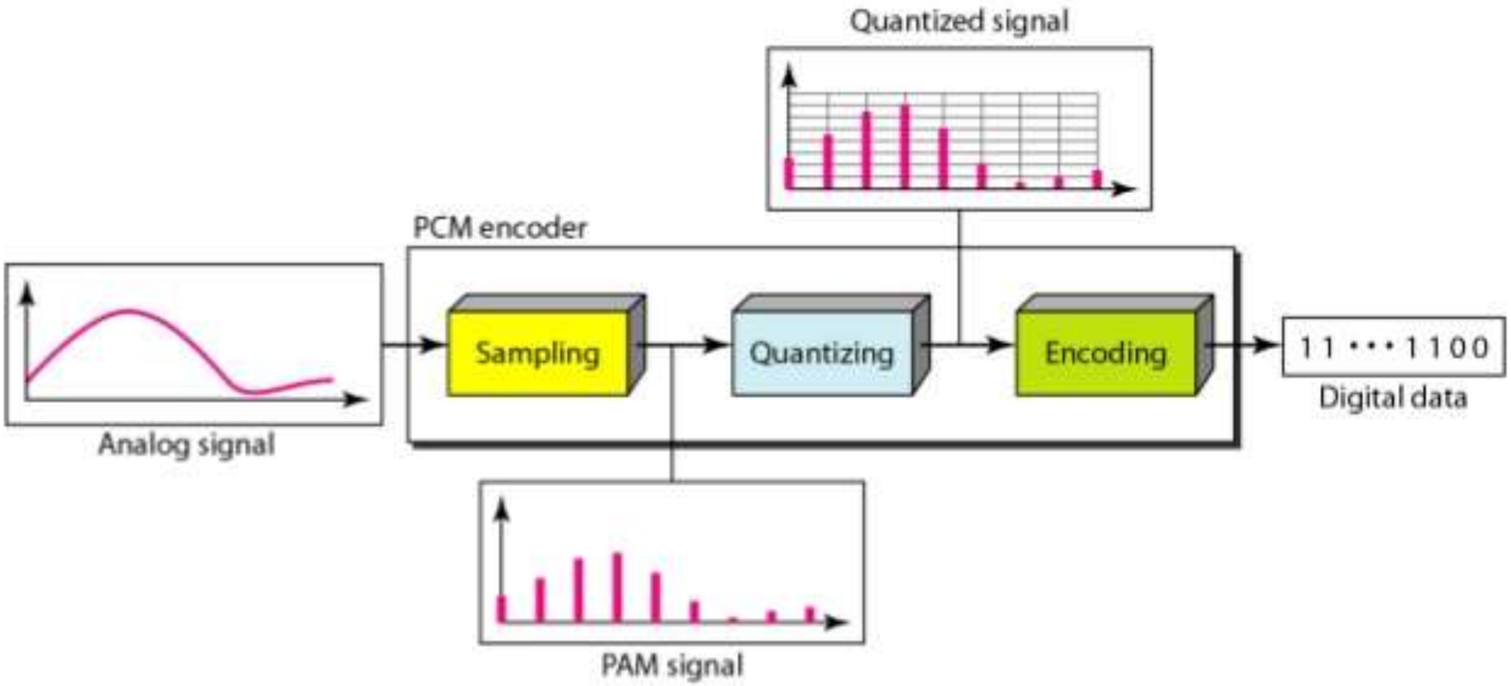
V_{in}= amplitude of the input signal at a particular of instant time

V_{out}= compressed output amplitude

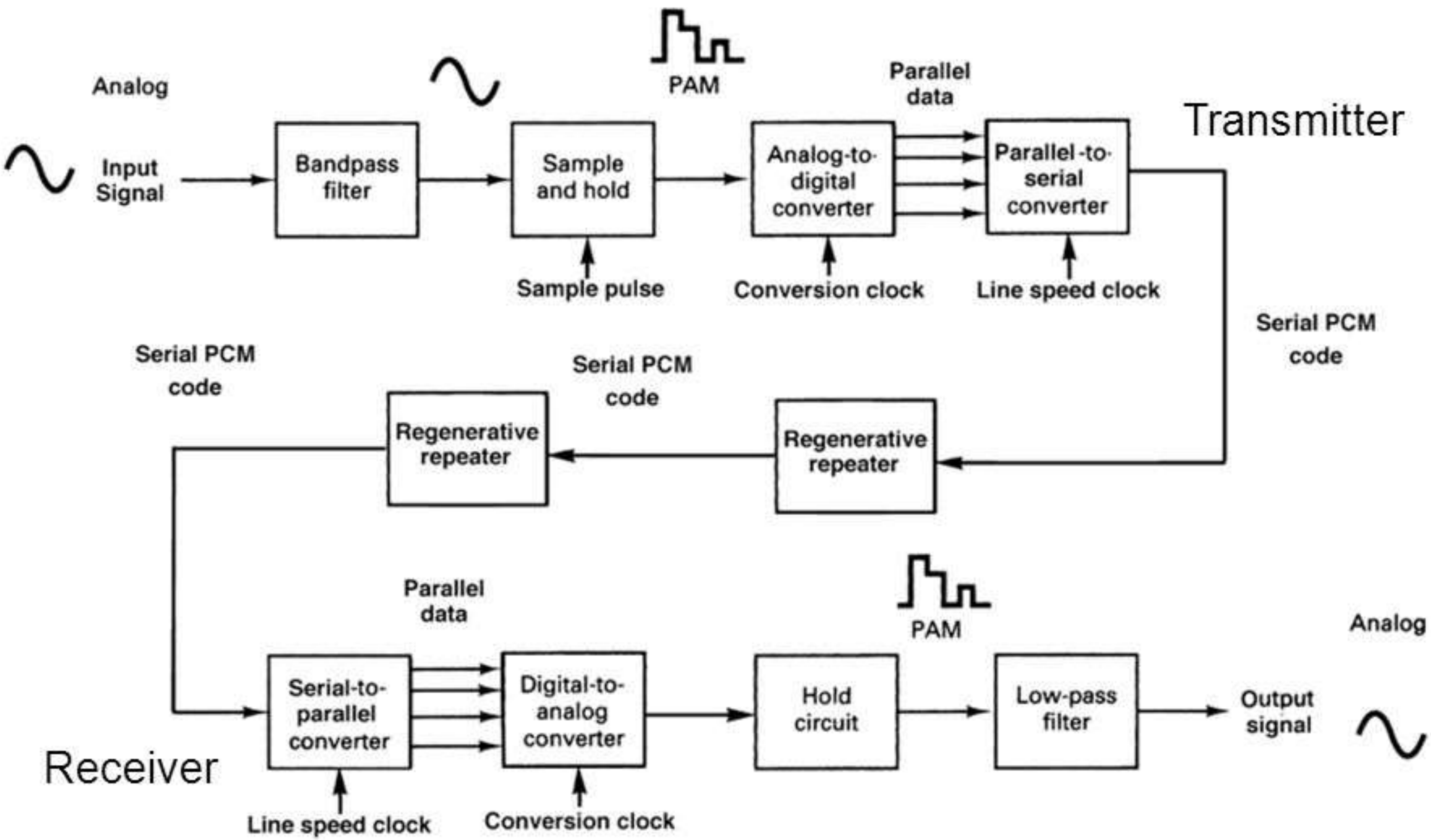
A,μ = parameter define the amount of compression

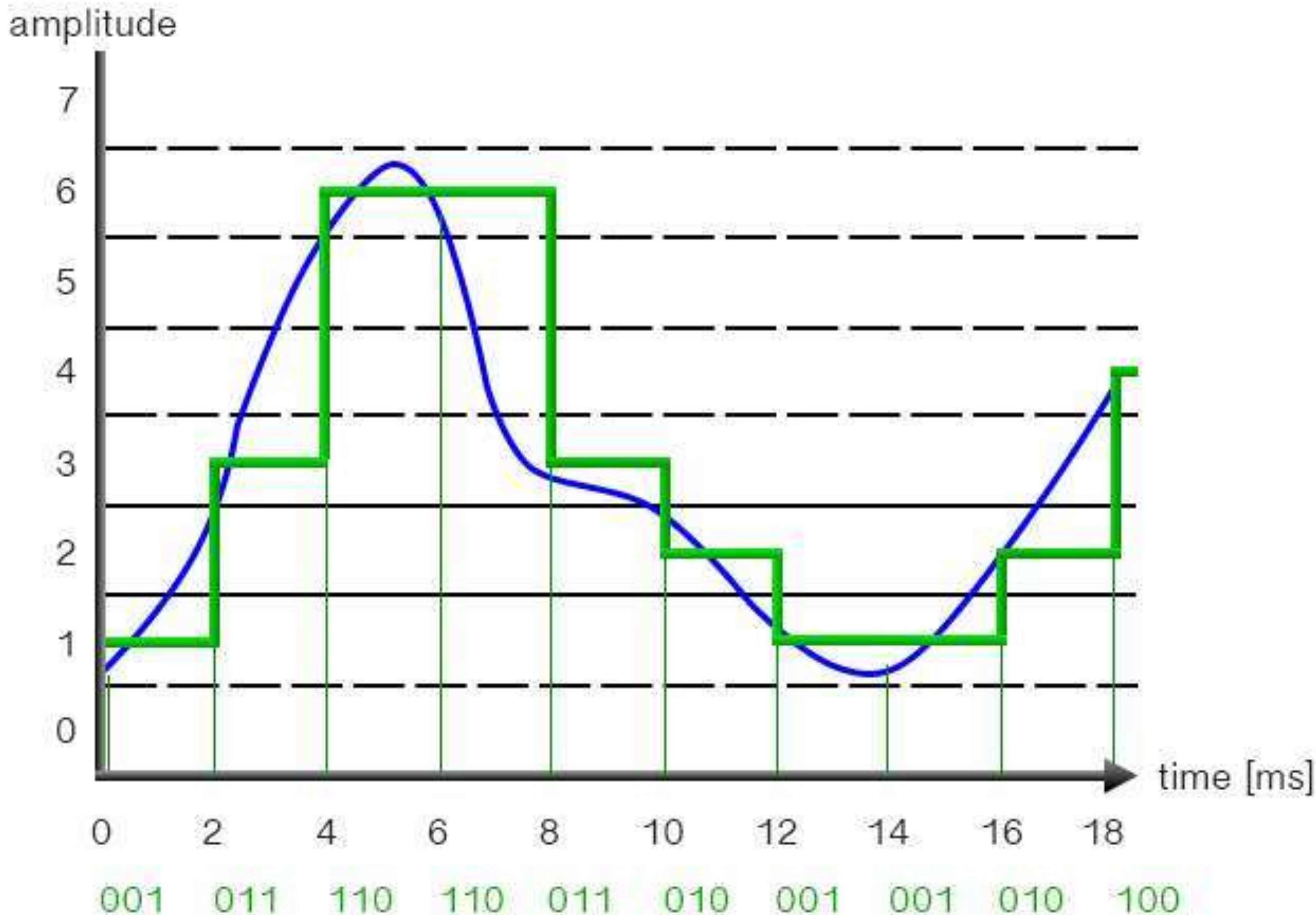
- The typical values used in practice are: **μ=255** and ***A*=87.6**.
- After quantization the different quantized levels have to be represented in a form suitable for transmission. This is done via an encoding process.

BLOCK DIAGRAM OF PCM



PCM system Block Diagram





amplitude
7
6
5
4
3
2
1
0
time [ms]
0 2 4 6 8 10 12 14 16 18
001 011 110 110 011 010 001 001 010 100

Advantages of PCM

1. Secured.
2. Encoding is possible.
3. Very high noise immunity.
4. Convenient for long distance communication.
5. Good signal to noise ratio.

Disadvantages of PCM

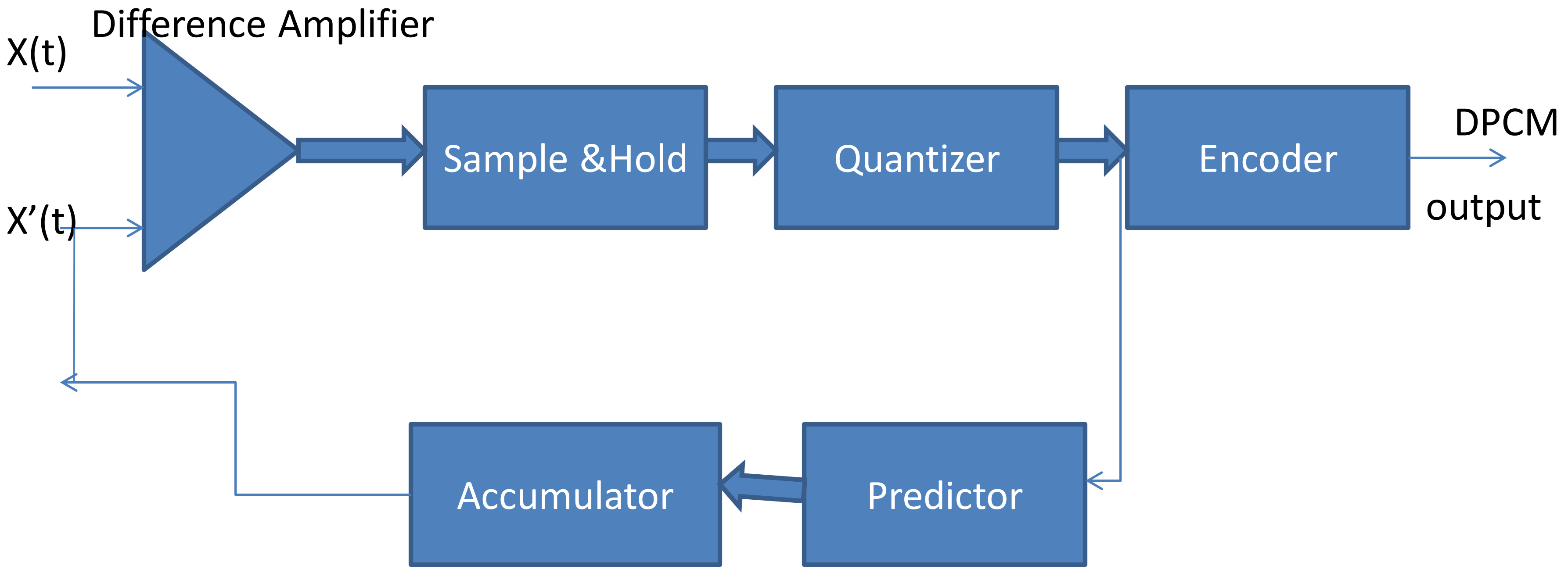
1. Complex circuitry.
2. Requires large bandwidth.
3. Synchronization is required between transmitter & receiver.

DPCM (differential pulse code modulation:

- Samples of the signal are highly correlated with each other
- This is due to the fact that signal does not change fast
- Adjacent samples carry the same information with little difference
- After encoding resulting encoded signal contains some redundant information
- If this redundancy is reduced then overall bit rate will decrease & no. of bits required per sample will also reduced
- This scheme of PCM is called as DPCM

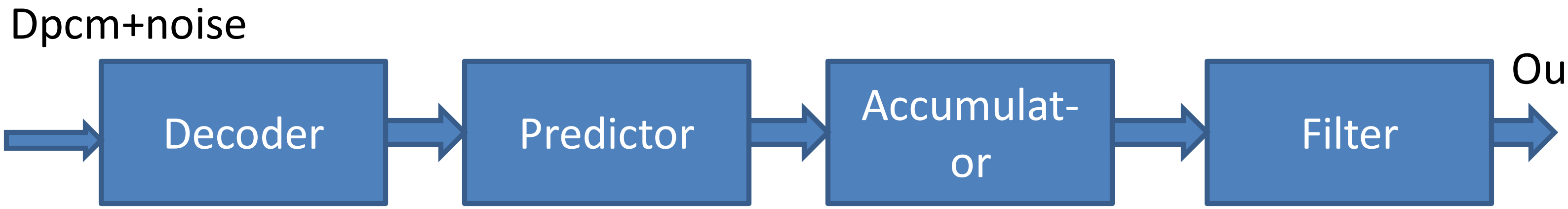
Dpcm transmitter:

- Block diagram of DPCM transmitter is shown below:



Dpcm receiver:

- The block diagram of DPCM is shown below:



- In DPCM ,the digital equivalent of each quantized sample is not transmitted.
- The difference between the present sample value & the previous sample value is transmitted.

Operation:

- X(t) is analog input signal
- X’(t) is approximated signal
- We have to find whether x(t) is greater or x’(t) & by how much.
- Difference amplifier compares x(t)&x’(t) ,sample & hold circuit will hold the result

Role of predictor in dpcm:

- It is observed that if sampling takes place at rate which is higher than the Nyquist rate then there is a correlation between successive samples of the signal x(t)
- Hence a knowledge of past sample values or difference helps us to predict the range of next required increment or decrement at the predictor output.
- This reduces the error

Advanteges:

- Less number of quantization levels are required so less no. of bits to represent them
- Signaling rate & BW will be less

Comparison of PCM & DPCM

PCM

- No.of bits can be 4,8,16 etc
- Step size is depends on quantization levels
- Quantization error
- BW highest
- Complex
- Noise immunity is good

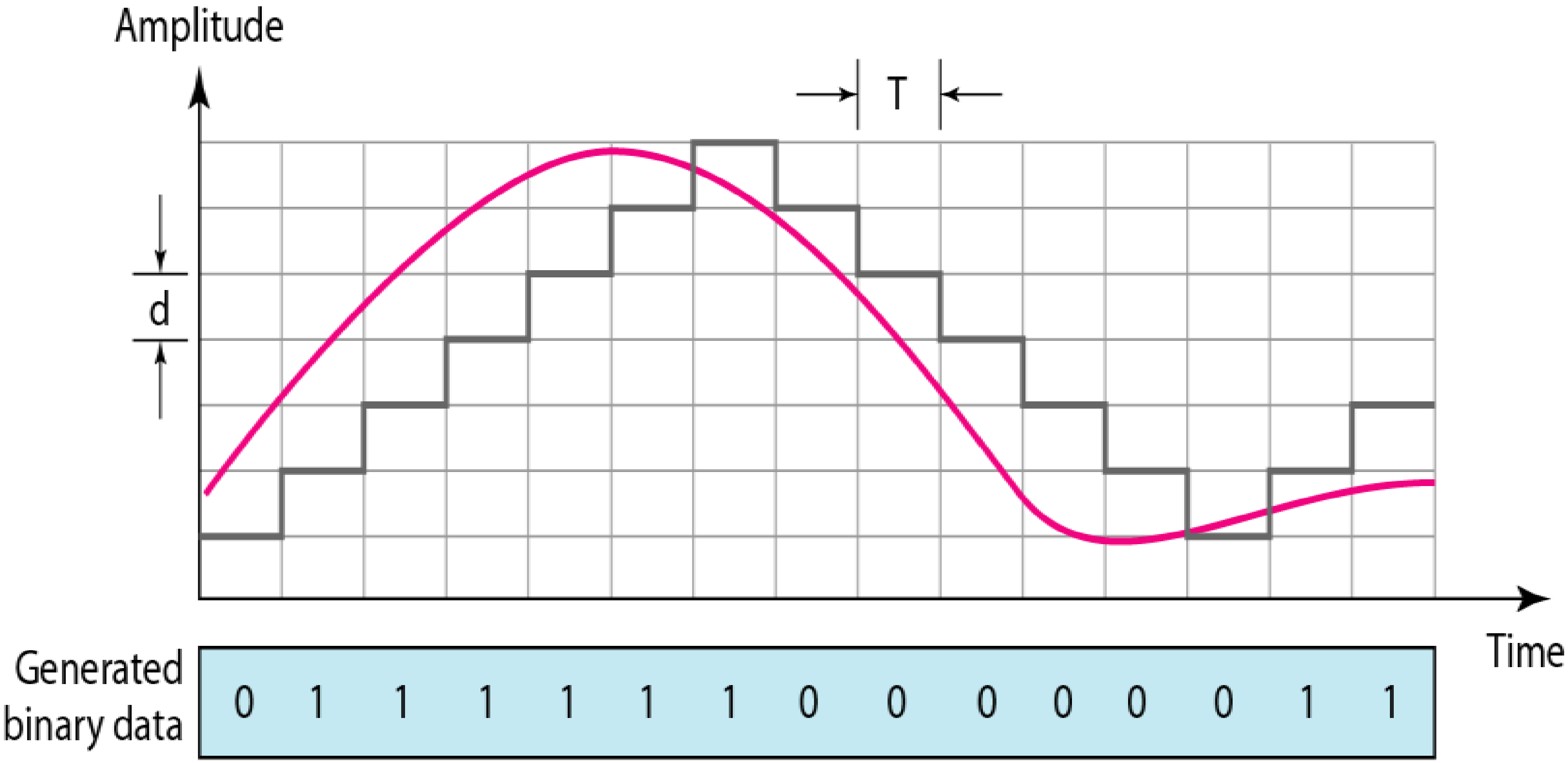
DPCM

- No.of bits are more than 1 but less than that for PCM
- Step size is fixed
- Slope overload & granular noise
- BW lower than PCM
- Simple
- Noise immunity is good

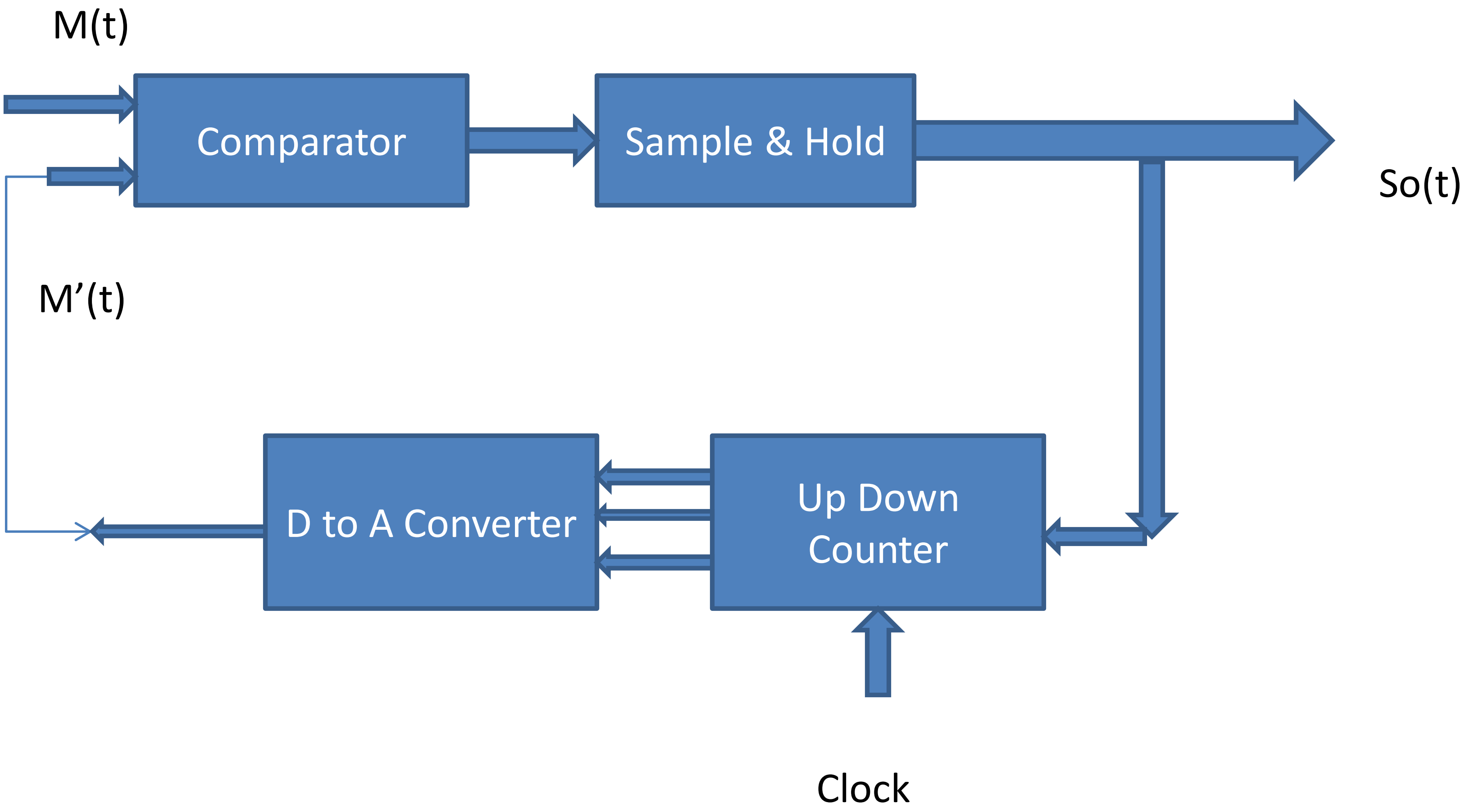
Delta modulation:

- This scheme sends only the difference between pulses, if the pulse at time t_{n+1} is higher in amplitude value than the pulse at time t_n, then a single bit, say a “1”, is used to indicate the positive value.
- If the pulse is lower in value, resulting in a negative value, a “0” is used.
- This scheme works well for small changes in signal values between samples.
- If changes in amplitude are large, this will result in large errors.

The process of delta modulation:



Delta modulator:



Operation:

- Comparator compares the input signal & approximated sampled signal
- Output of comparator will decide the direction of counting(up & down)
- Counter will increase or decrease the signal
- S0=1………counter up
- S0=0……….counter down

Dm receiver:

Advantages:

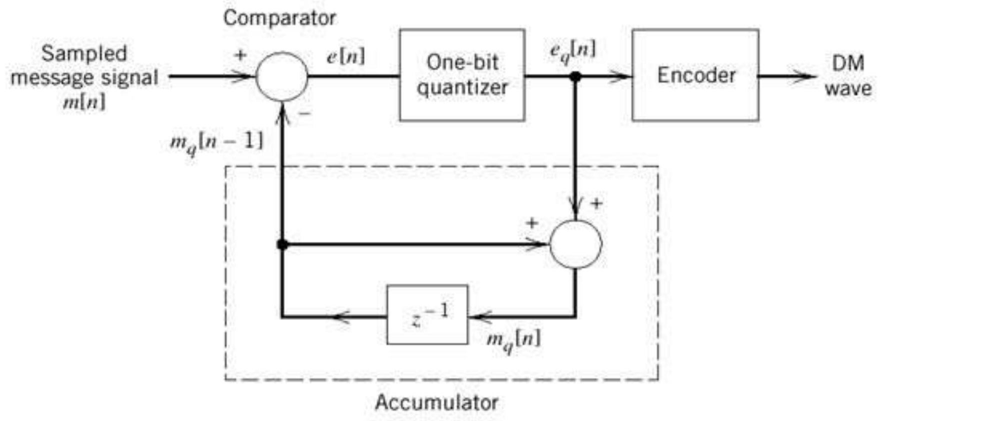
- *Transmits only one bit per sample therefore signaling rate & BW is quit small*
- *Transmitter & Receiver implementation is very much simple*

Disadvantages:

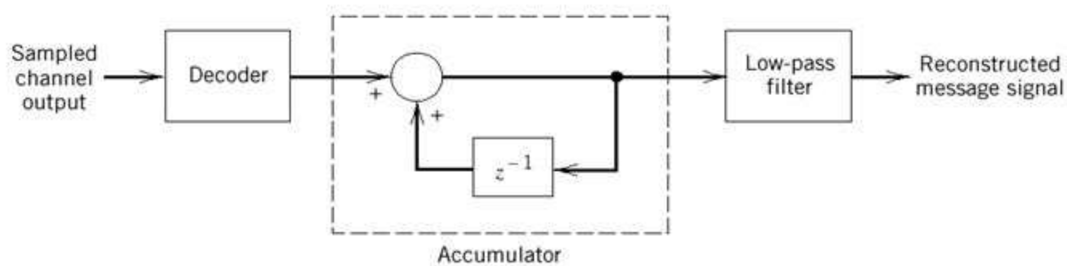
- Slope overload distortion
- Granular noise

Figure 3.23

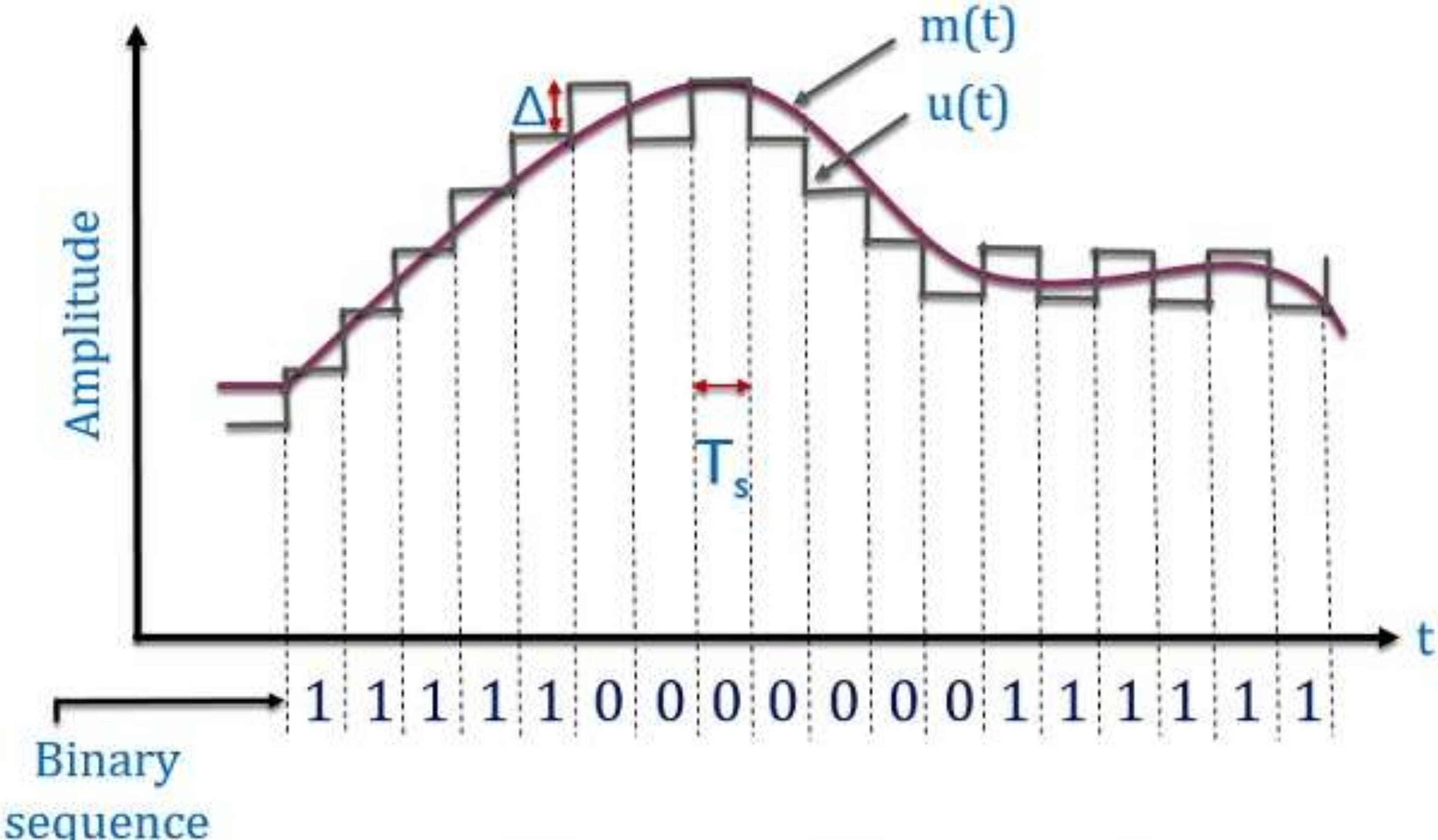
DM system.
(a) Transmitter.
(b) Receiver.



(a)



(b)



Waveform representation of Delta Modulation

Electronics Coach

Quantization Errors

- Slope-overload distortion
  - Occurs when the step size is too small
  - The approximation signal falls behind the message signal
- Granular noise
  - Occurs when the step size is too large
  - The staircase approximation hunts around a flat segment.

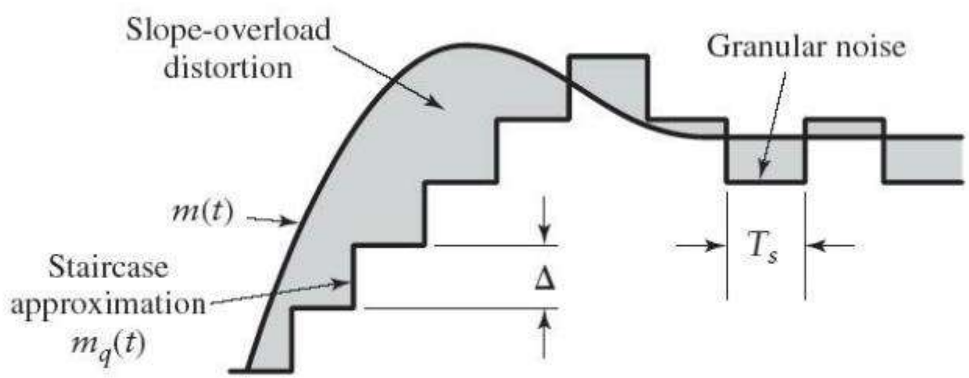


FIGURE 5.16 Illustration of quantization errors, slope-overload distortion and granular noise, in delta modulation.

Advantages of Delta Modulation

1. It transmits only 1 – bit per sample. Hence reducing the transmission channel bandwidth.
2. Tx – Rx implementation is simple as compared to PCM system.

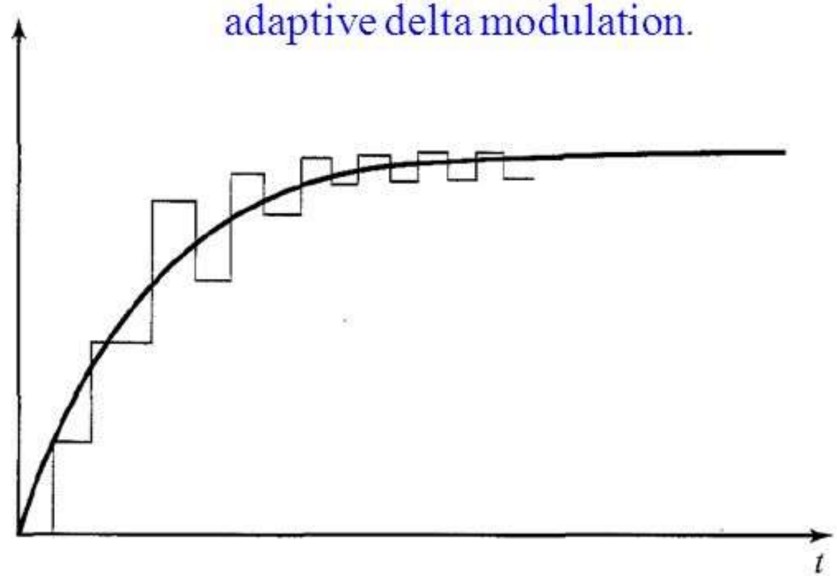
Disadvantages of Delta Modulation

1. Poor start-up response
2. Slope Overload Distortion
3. Granular Noise/ Idle Noise

Adaptive Delta Modulation

- We have seen that a step size that is too large causes granular noise, and a step size too small results in slope overload distortion
- This means that a good choice for Δ is a "medium" value; but in some cases, the performance of the best medium value (i.e., the one minimizing the mean squared distortion) is not satisfactory
- An approach that works well in these cases is to change the step size according to changes in the input
- If the input tends to change rapidly, the step size must be large so that the output can follow the input quickly and no slope overload distortion results
- When the input is more or less flat (slowly varying), the step size changed to a small value to prevent granular noise : Figure 7.16.

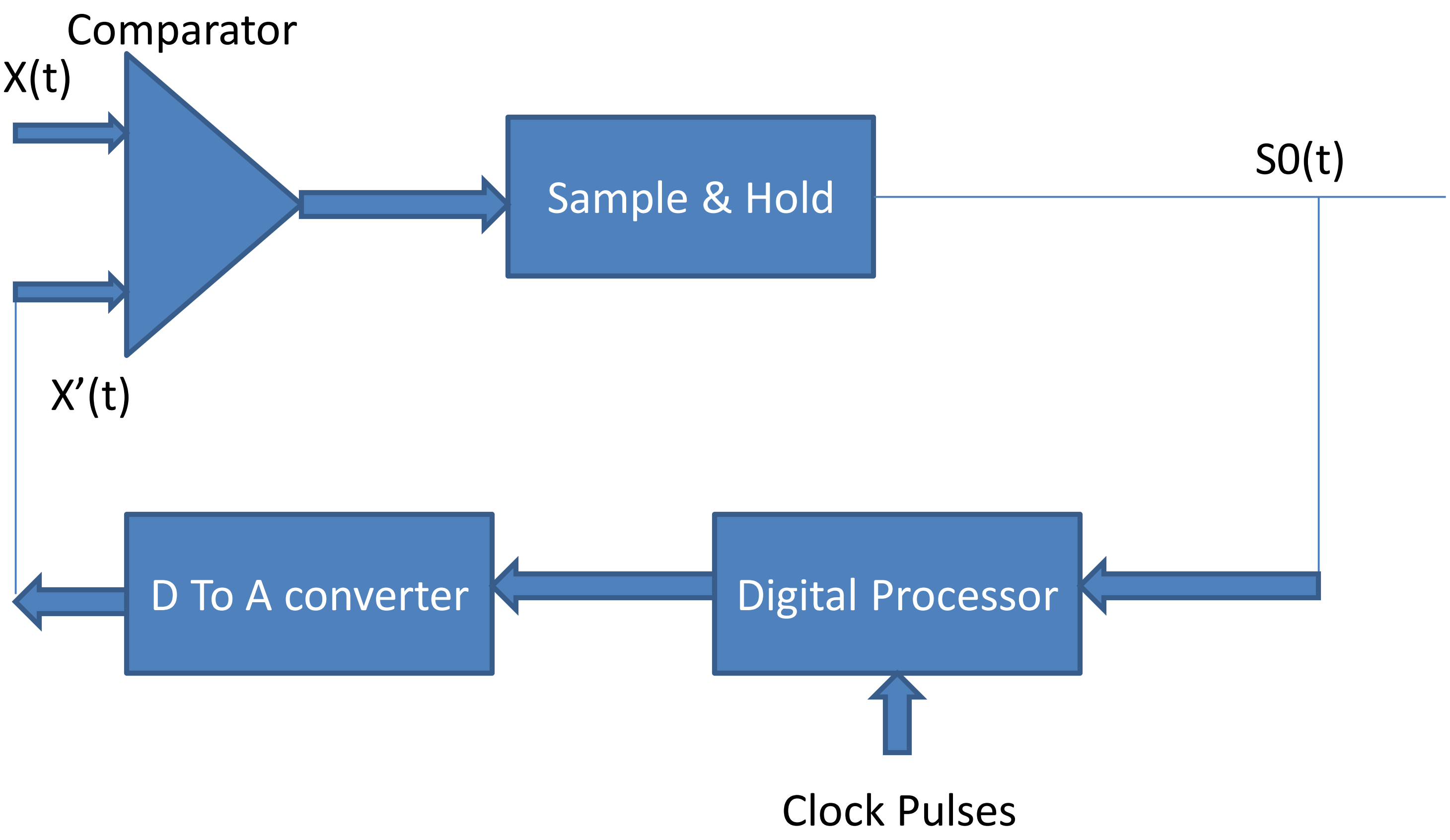
Figure 7.16 Performance of adaptive delta modulation.



Adaptive delta modulation:

- In this step size is variable
- In this we are using digital processor instead of the counter
- Because of the variable step size we can reduced the slope overload distortion & granular noise
- The block diagram of ADM transmitter shown below:

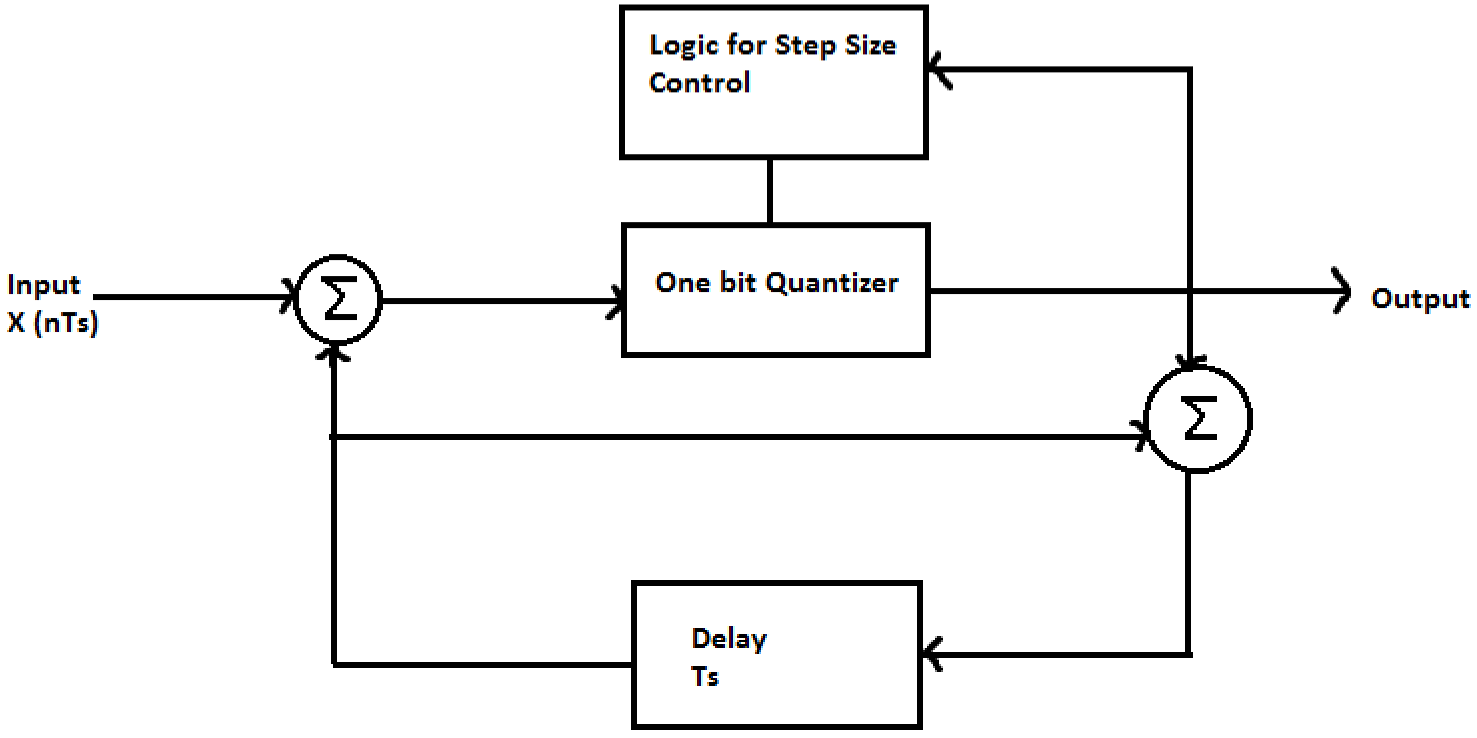
Adm transmitter:



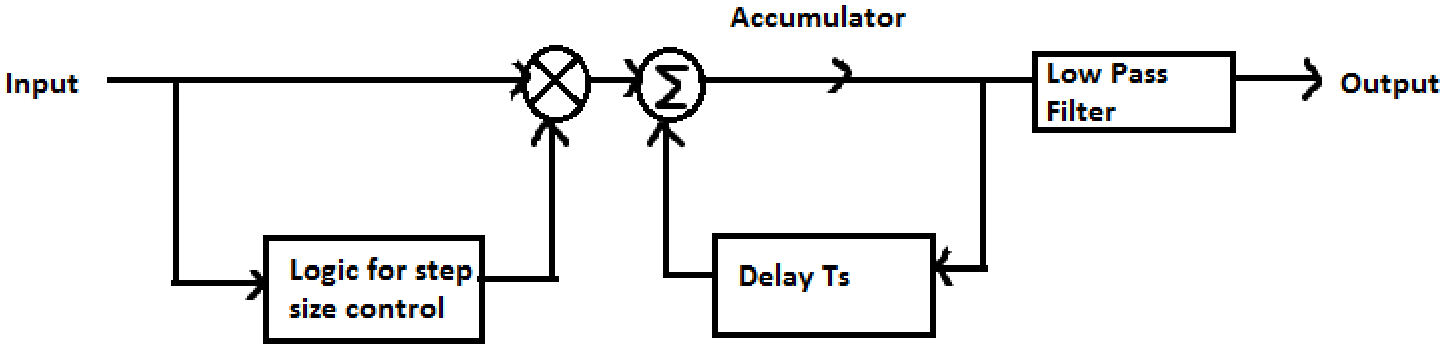
Operation:

- Process of getting variable step size according to the input is controlled by digital processor.
- If comparator output is positive means $x(t)>x'(t)$ then step size is doubled
- If comparator output is negative then step size will be reduced.

Adaptive delta Modulation (ADM)



Adaptive delta Demodulation



Advantages :

- Reduction in slope overload distortion
- Improved signal to noise ratio
- Wide dynamic range due to variable step size
- Better utilization of BW compared to DM

Comparison of DM & ADM

DM

- No. of bits per sample is equal to 1
- Step size is fixed
- Slope overload &granular noise
- BW & signaling rate is low
- Simple
- Noise immunity is good

ADM

- No. of bits per sample is equal to 1
- Step size is variable
- Granular noise
- Signaling rate &BW lowest
- Simple
- Noise immunity is very good

No	Comparison	Modulation (PCM)	(DM)	Modulation (ADM)
1	Number of bits	It can use 4, 8 or 16 bits per sample	It uses one bit for one sample	Only one bit is used to encode one sample
2	Levels and step size	The number of levels depends on number of bits. Level size is fixed.	Step size is kept fixed and cannot be varied	Step size varies according to the signal variation
3	Quantisation error and distortion	Quantisation error depends on the number of levels	Slope-overload distortion is present	Quantisation noise is present but no other errors
4	Bandwidth	Highest bandwidth is needed since no. of bits are high	Lowest bandwidth is enough	Lowest bandwidth is enough
5	Feedback	There is no feedback in transmitter or receiver	Feedback exists in the transmitter	Feedback exists in the transmitter
6	Complexity	Complex system to implement	Simple to implement	Simple to implement