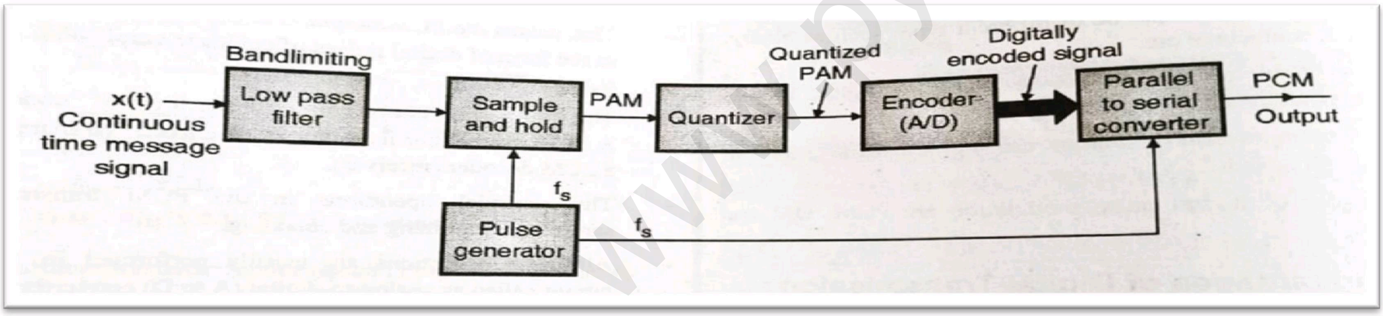
PCS NOTES UNIT 5

Digital Representation of Analog Signals

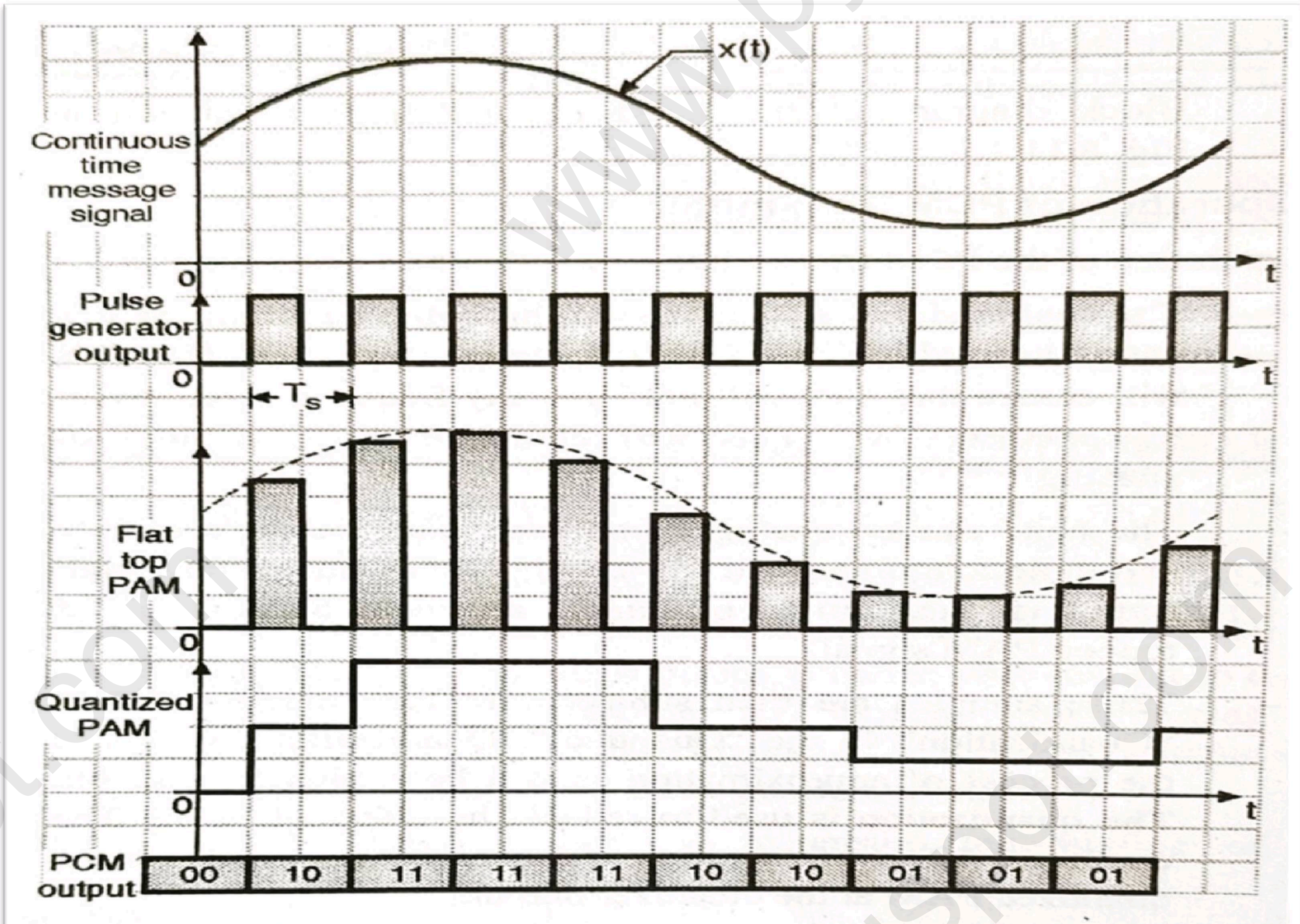
from www.pyqspot.com

4. Pulse Code Modulation- Generation(TX)



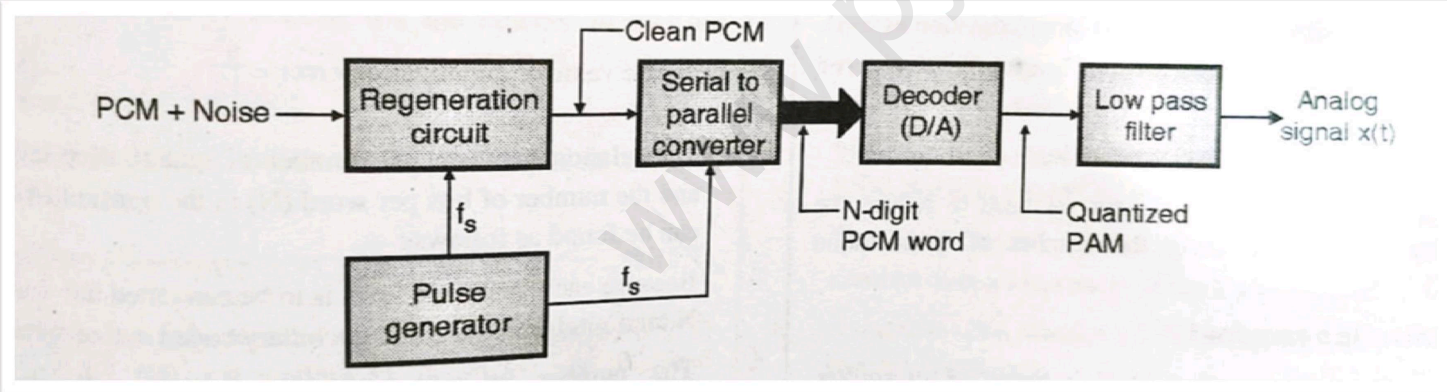
- The analog signal x (t) is applied to band limiting low pass filter, which has a cut-off frequency fc =W Hz. This will ensure that x (t) will not have any frequency is higher than "W“ Hz. This will eliminate the possibility of aliasing.
- The band limited analog signal is then applied to a sample and hold circuit where it is sampled at adequately high sampling rate.
- Output of sample and hold block is a flat topped PAM signal.
- These flat topped PAM signal are applied to "Quantizer".
- Quantization process is the process of approximateon or rounding off.
- The quantization is used to reduce the effect of noise.
- At the output of quantizer produces the quantized PAM signal.
- Quantized PAM pulses are applied to an encoder which is basically an A to D converter which convert analog signal in to digital encoded signal.
- The Encoder output is converted into a stream of pulses by the parallel to serial converter block.
- Thus at the PCM transmitter output we get a train of digital pulses .
- A pulse generator produces a train of rectangular pulses with each pulse of duration “T" seconds. The frequency of this signal is "fs," Hz.
- This signal acts as a sampling signal for the sample and hold block.
- The same signal acts as "clock" signal for the parallel to serial converter. The frequency "fs" is adjusted to satisfy the Nyquist criteria.

4. Pulse Code Modulation- Generation



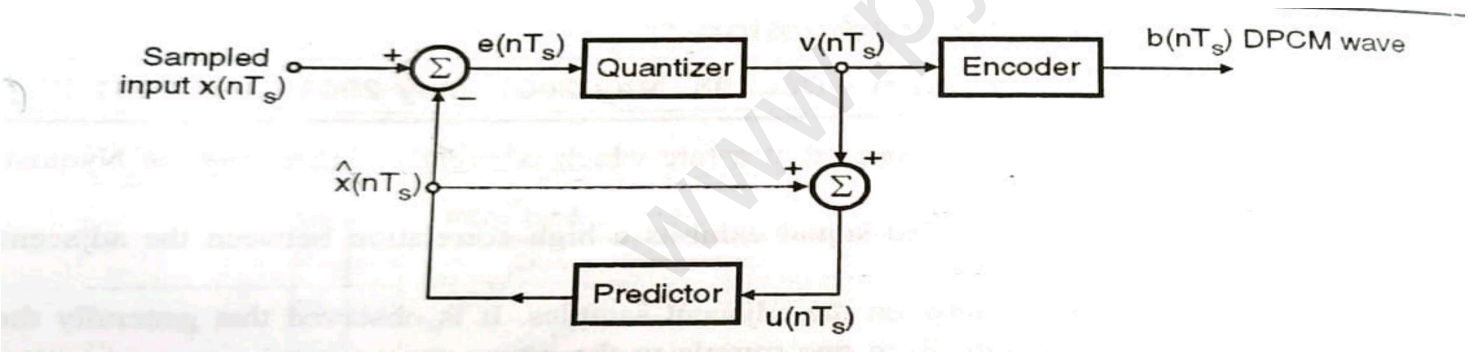
(L-222) **Fig. 8.11.2 : Waveforms at different points in PCM transmitter**

4. Pulse Code Modulation-Detection



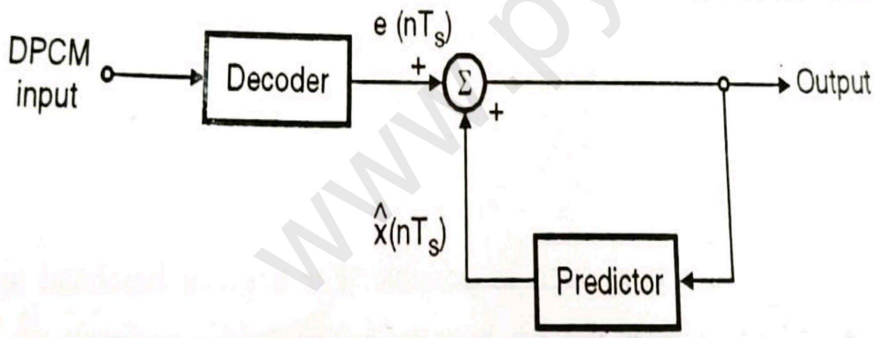
- The PCM with noise signal are applied to regeneration circuit of receiver .
- The regeneration circuit will separate out the PCM pulses from noise and generate "clean" PCM signal.
- A pulse generator produces a train of rectangular pulses with frequency "fs," Hz.
- This signal acts as a sampling signal for regeneration circuit .
- The same signal acts as "clock" signal for the serial to parallel to converter.
- The clean PCM signal is applied to serial to parallel converter then we get N Digit PCM Word.
- N Digit PCM Word is then applied to a decoder.
- The decoder is a D to A converter which performs exactly the opposite operation of the encoder.
- The decoder output is the sequence of a quantized PAM Signal.
- This quantized PAM signal is passed through a low pass filter to recover the analog signal, x(t).

Differential Pulse Code Modulation-Detection



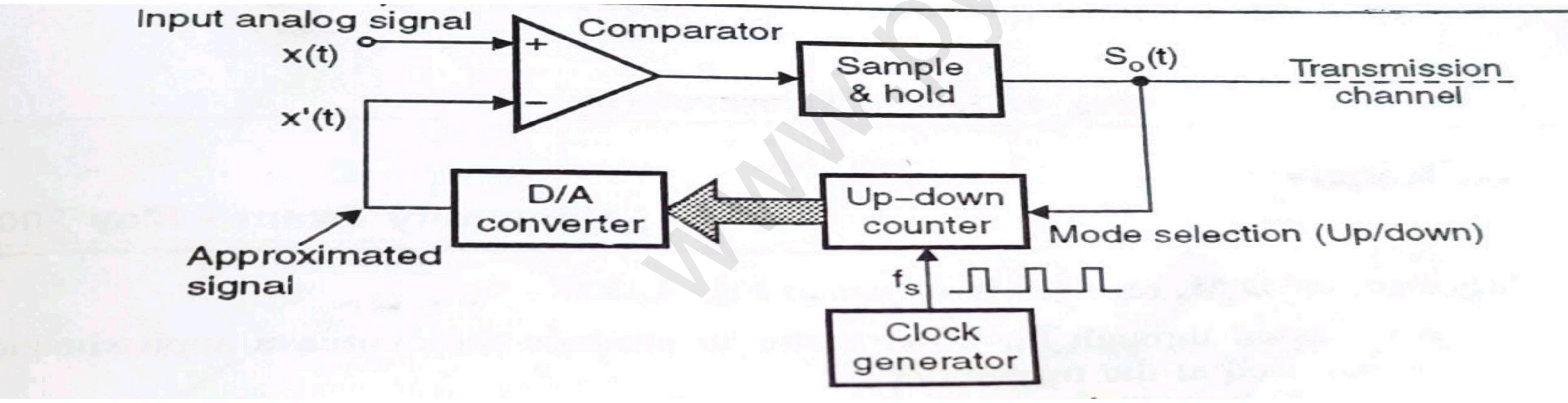
- Suppose that a baseband signal x(t) is sampled at a rate fs = 1 / Ts to produce the sampled signal x (nTs).
- This signal acts as the input signal to the DPCM transmitter.
- Let the predictor produce a predicted version of the sampled input and let the predictor output be denoted by x* (nTs).
- The predictor output is subtracted from the sampled input to obtain a difference signal e(nTs) as follows:
  - e(nTs) =x(nTs)- x *(nT s)
- The predictor value x*(nTs) is produced by the predictor whose input consist of quantized version of input signal x(nTs).
- The difference signal e(nTs) is called as **prediction error**, because it represents the difference between the sample and its predicted value.
- The quantizer output v(nTs) is encoded to obtain the digital pulses i.e. DPCM signal

Differential Pulse Code Modulation-Receiver



- The DPCM signal is applied to the decoder for reconstructing the quantized version of input.
- The decoder output is actually the reconstructed quantized error signal e(nTs).
- This signal is then added with predictor output x*(nTs) to produce the original signal.
- The predictor used at the receiver is same as that at the transmitter.
- Receiver output = e(nTs)+ x*(nTs)
- =x(nTs)

Delta Modulator-Transmitter



Waveform:

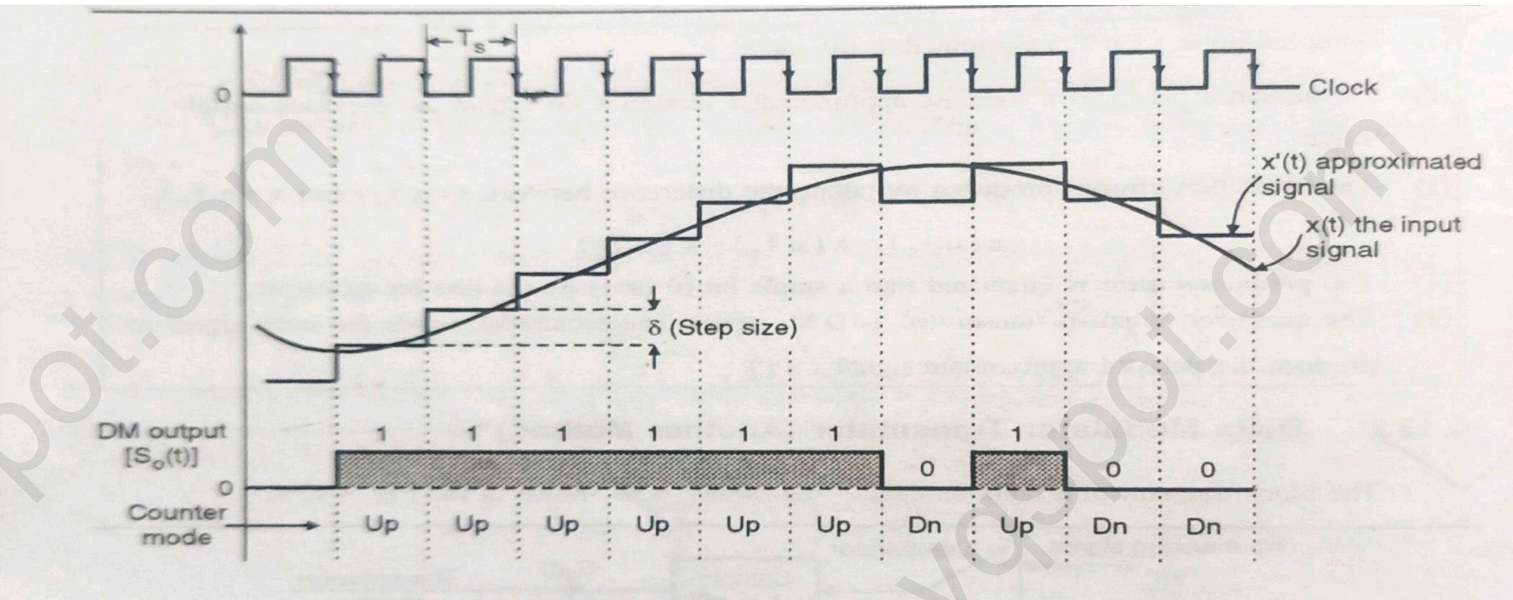
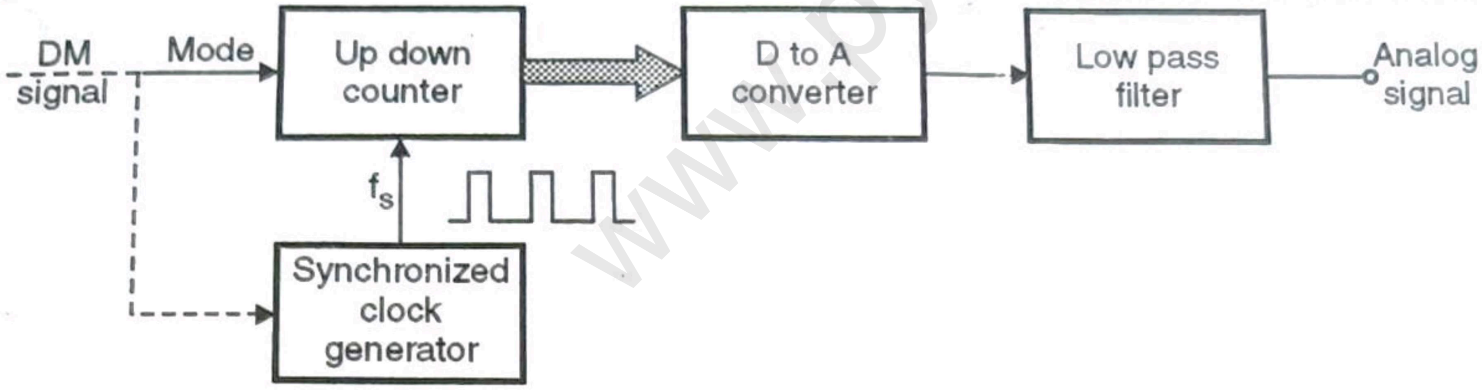


Fig. 4.12.5 : D.M. waveforms

Delta Modulator-Transmitter

- The analog input signal x(t) is applied to non inverting terminal of comparator and quantized version of approximated signal x'(t) is applied to inverting terminal of comparator.
- Comparator is used for compare input signal x(t) as well as approximated signal x'(t).
- if x(t)> x(t) then comparator output is 1 or goes high and if x(t)<x(t) then comparator output is 0 or goes low.
- Thus the comparator output is either 1 or 0.
- The sample and hold circuit will hold this level (0 or 1) for the entire clock cycle period.
- The output of the sample and hold circuit is transmitted as the output of the DM system.
- Thus in DM, the information which is transmitted is only whether x(t)>x(t) or vice versa.
- The transmitted signal is also used to decide the mode of operation of an up/down counter.
- The counter output increments by 1 if So(t) = 1 and it decrements by 1 if So(t)-0, at the falling edge of each clock pulse.
- The counter output is converted into analog signal by a D to A converter.
- Thus we get approximated signal x'(t) at the output of the D to A converter.

Delta Modulator-Receiver



- DM Signal is applied to Up down counter. It is used to decide the mode of operation .
- Synchronized clock generator produce clock pulses and applied to Up down counter.
- At the output of Up down counter we get either 1 or 0.
- D to A Converter is used for convert digital signal in to analog signal.
- analog signal is applied to low pass filter.
- low pass filter is also called reconstruction filter to reconstruct the original analog signal

Quantization Noise:

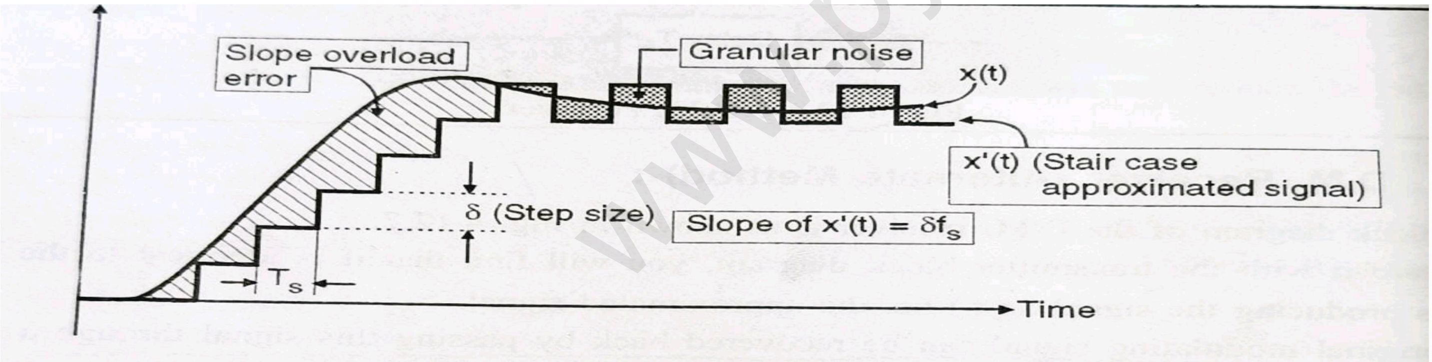


Fig. 4.12.8 : Distortions in D.M.

Slope and overload distortion:

- Due to small step size (ɗ), the slope of the approximated signal x’(t) will be small
- If slope of the analog signal x (t) is much higher than that of x ’(t) over a long duration then x’(t) will not be able to follow x(t) .
- The difference between x(t) and x ’(t) is called as the slope overload distortion.
- Thus the slope overload error occurs when slope of x(t) is much larger than slope of x ’(t)
- The slope overload error can be reduced by increasing slope of the approximated signal x’(t).
- The slop of x ’(t) can be increased and hence the slope overload error can be reduced by either increasing step size (ɗ) or by increasing the sampling frequency Fs.

Quantization Noise:

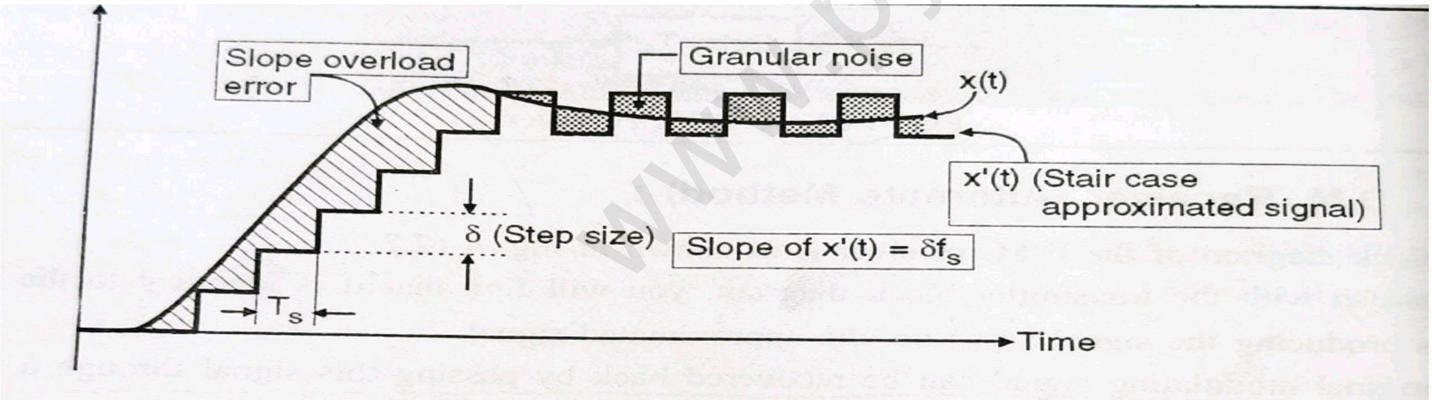
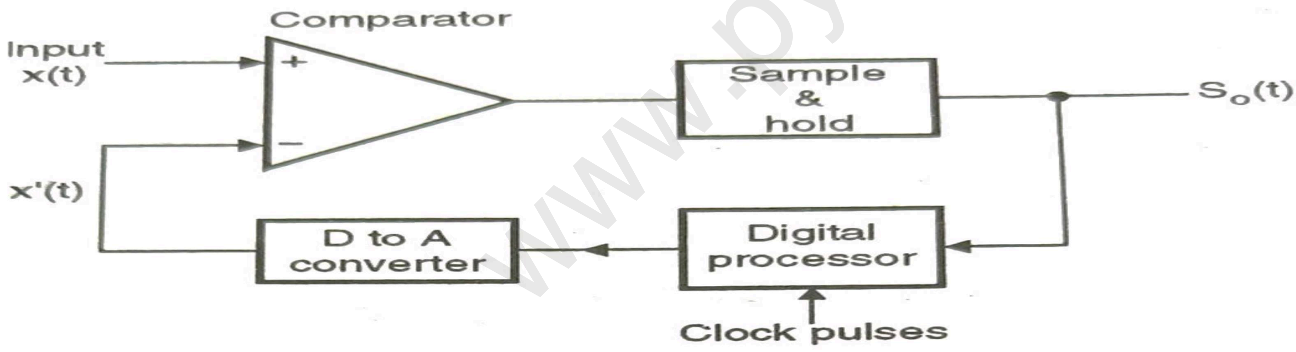


Fig. 4.12.8 : Distortions in D.M.

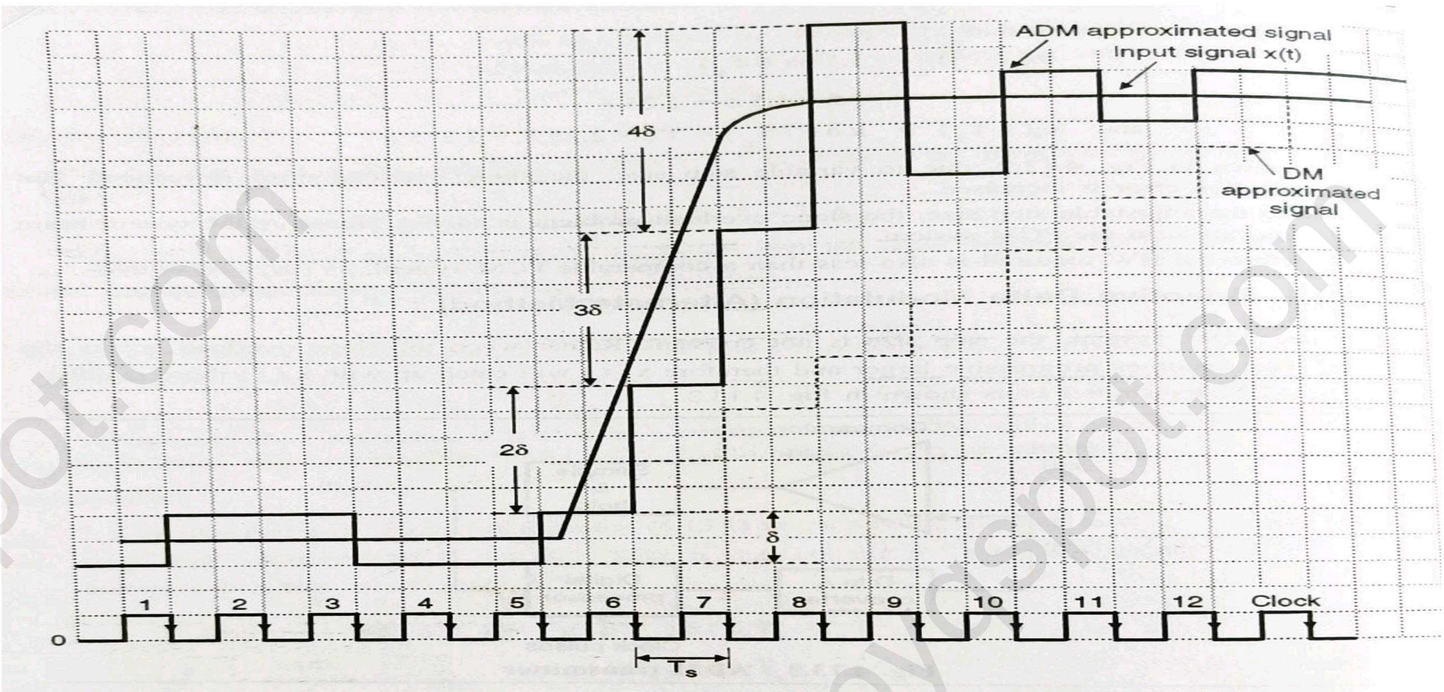
Granular noise:

- When the input signal x(t) is relatively constant in amplitude, the approximated signal x '(t) will hunt above and below x(t) as shown in Fig
- The granular noise is similar to the quantization noise in the PCM system.
- It increases with increase in the step size (ɗ) . To reduce the granular noise, the step size should be as small as possible.
- However this will increase the slope overload distortion.
- In the linear delta modulator the step size is not variable.
- If it is made variable then the slope overload distortion and granular noise both can be controlled.
- A system with a variable step size is known as the adaptive delta modulator (ADM).

Adaptive Delta Modulator-Transmitter



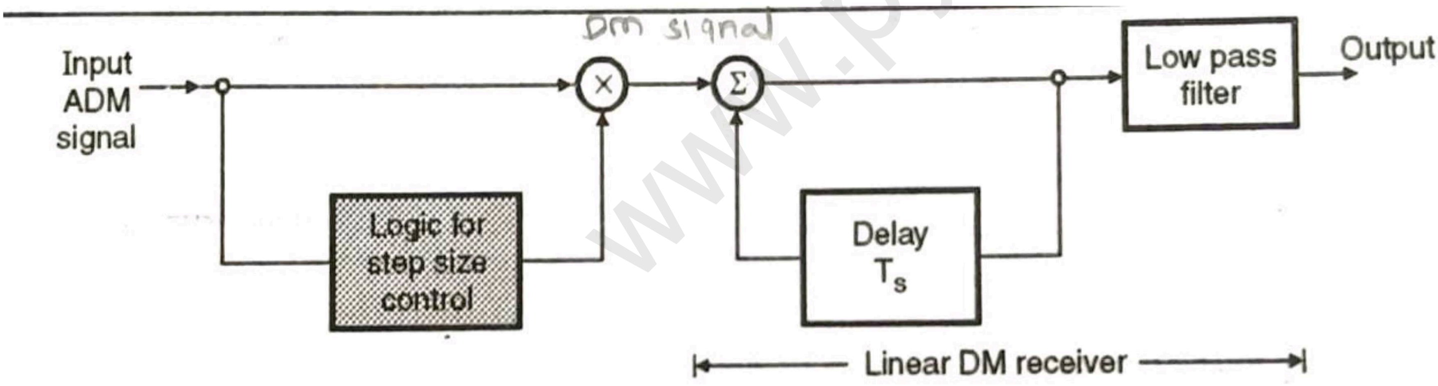
Waveform:



Working:

- The analog input signal x(t) is applied to non inverting terminal of comparator and quantized version of approximated signal x'(t) is applied to inverting terminal of comparator.
- Comparator is used for compare input signal x(t) as well as approximated signal x'(t).
- if x(t)> x(t) then comparator output is 1 or goes high and if x(t)<x(t) then comparator output is 0 or goes low.
- Thus the comparator output is either 1 or 0.
- The sample and hold circuit will hold this level (0 or 1) for the entire clock cycle period.
- The output of the sample and hold circuit is transmitted as the output of the ADM system.
- Thus in DM, the information which is transmitted is only whether x(t)>x(t) or vice versa.
- The transmitted signal is applied to Digital Processor for Generate variable step size to avoid slop overload error.
- The processor generates a step which is equal in magnitude to the step generated in response to the previous i.e. (k - 1) ^(th) clock edge.
- If the direction of both the steps is same, then the processor will increase the magnitude of the present step ɗ. If the directions are opposite then the processor will decrease the magnitude of the present step ɗ.
- The Digital Processor output is converted into analog signal by a D to A converter.
- Thus we get approximated signal x'(t) at the output of the D to A converter.

Adaptive Delta Modulator-Receiver



Working:

- ADM Signal is applied to multiplier along with step size control logic.
- The ADM signal is first converted into a D.M. signal with the help of the step size control logic.
- At the output of multiplier we get DM Sinal.
- DM Signal is applied to linear D.M. receiver.
- DM Signal is applied to low pass filter to reconstruct the original analog signal
- low pass filter is also called reconstruction Filter

COMPARISON OF PCM, DELTA MODULATION AND ADAPTIVE DELTA MODULATION

N0	PARAMETER	PULSE CODE MODULATION (PCM)	DELTA MODULATION	ADAPTIVE DELTA MODULATION
1	Levels and Step Size	Number of levels depend on number of bits Level size is fixed	Step size is fixed	Step size varies according to the rate at which the signal is varying
2	Number of Bits	Can take 4, 8 or 16 bits per sample	One bit per sample	One bit per sample
3	Quantization errors and distortion	Quantization noise is present	Has slope overload and granular noise	Quantization noise is present
4	Bandwidth	Highest bandwidth	Low bandwidth required	Least bandwidth required
5	Feedback in transmitter or receiver	No feedback	Feedback in transmitter	Feedback in transmitter
6	Complexity in implementation	High	Simple	Simple

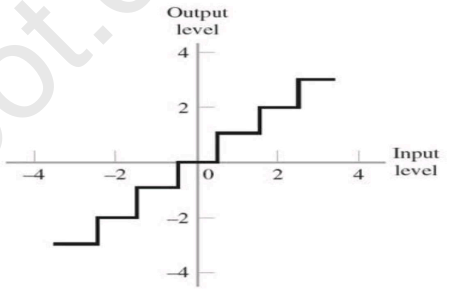
TYPES OF QUANTIZERS

Quantization

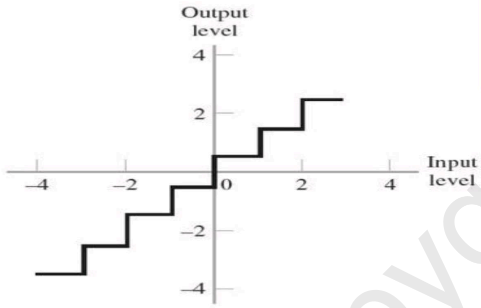
Step size is the same throughout the input signal range

Uniform Quantization

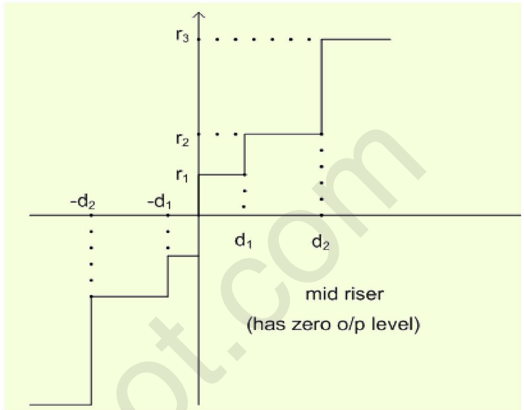
Midtread Quantization



Midrise Quantization

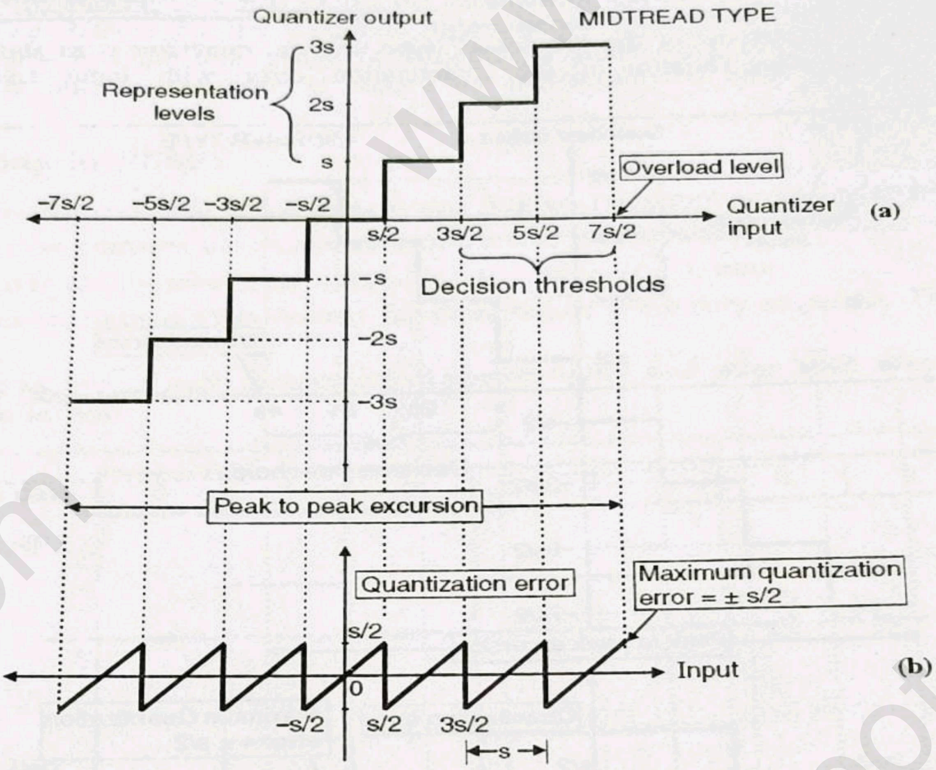


Non-Uniform Quantization



Step size varies according the input signal values

MIDTREAD QUANTIZER



(a) Transfer characteristic of quantizer of midtread type

(b) Variation of quantization error with input

Fig. 4.3.2

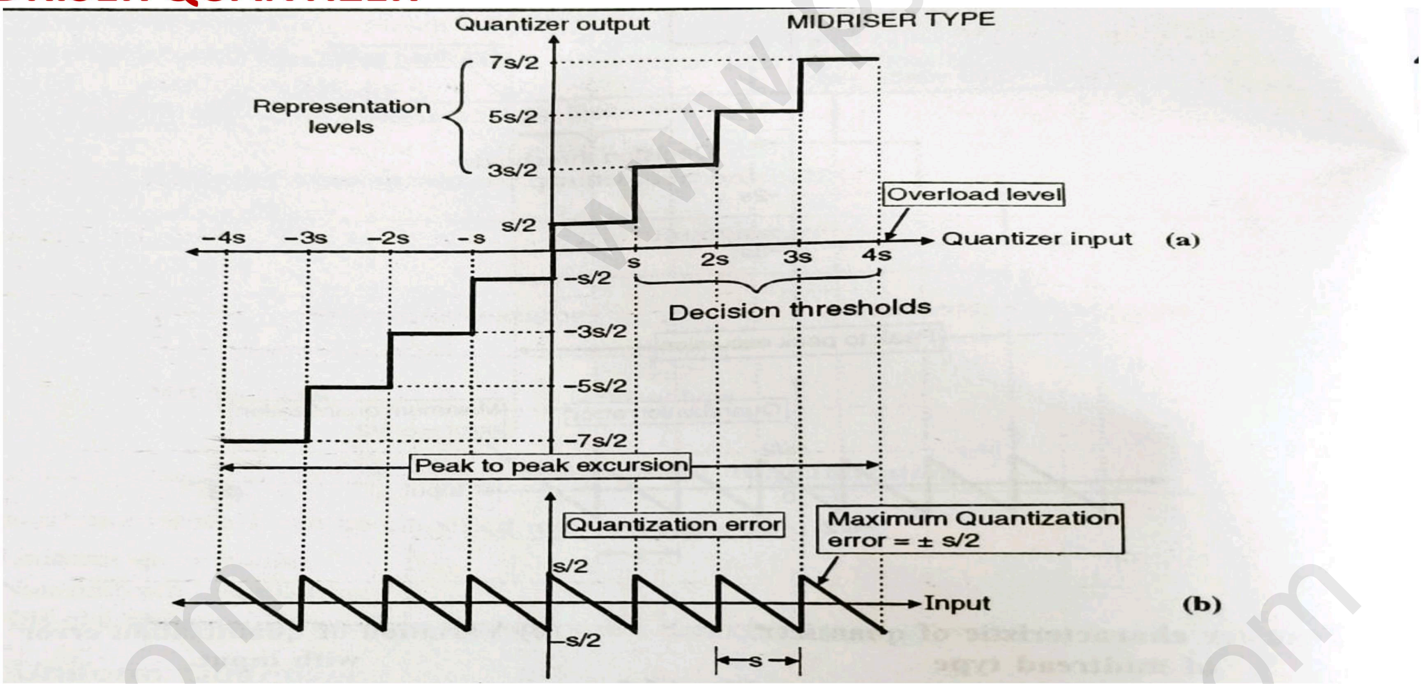
MIDTREAD QUANTIZER

- It is called mid-tread because the origin lies in the middle of a tread of a staircase- like graph.
- Graphically the quantizing process means that a straight line representing the relation between the input and output of a linear analog system is replaced by a transfer characteristics of staircase type.

The quantization process has a two fold effect as follows:

- (1) The peak to peak range of the input is divided into a finite set of decision levels or decision thresholds. These levels have been aligned with the "risers of the staircase
- (2) The output is assigned a discrete value selected from a finite set of representation levels or reconstruction value. These levels are aligned with the "treads" of the staircase.
- The separation between the decision thresholds and the separation between the representation levels have the same value equal to step size "s".
- In Fig. the decision thresholds are located at S/2, 3S/2, ± 5S/2... and the representation levels are located at 0, ±s, ± 2s... where "s" is the step size.

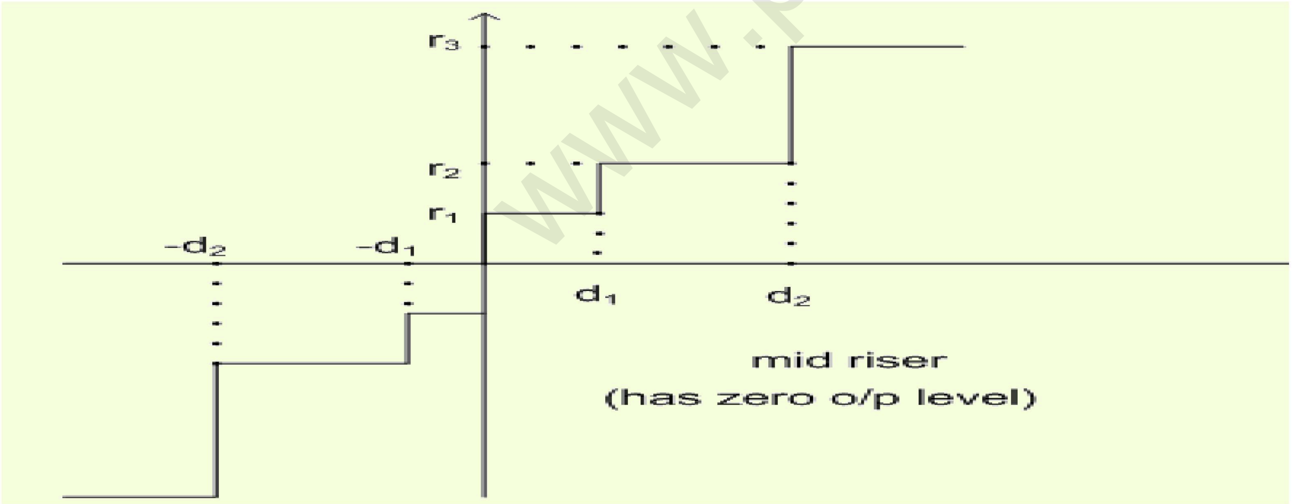
MIDRISER QUANTIZER



1. The origin lies in the middle of the rising part of the staircase-like characteristic graph.

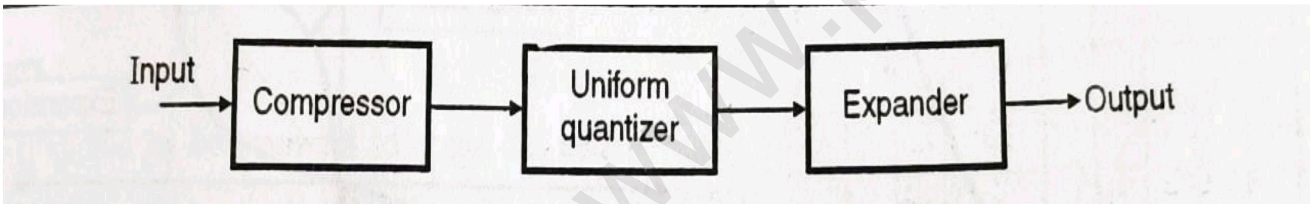
2. The decision thresholds are located a 0, ± s, ± 2s etc. and the representation levels are located at ± s/2, ± 3s/2... This is called as the midriser type characteristics because in this case the origin lies in the middle of a riser of the staircase

Non-Uniform Quantization



- If the quantizer characteristics is nonlinear and the step size is not constant instead if it is variable, dependent on the amplitude of input signal then the quantization is called as nonuniform quantization.
- In non-uniform quantization, the step size is reduced with reduction in signal level. For weak signals (P<<1), the step size is small, therefore the quantization noise reduces, to improve the signal to quantization noise ratio for weak signals.
- The step size is thus varied according to the signal level to keep the signal to noise ratio adequately high. This is non-uniform quantization.
- The non-uniform quantization is practically achieved through a process called "companding".

Companding



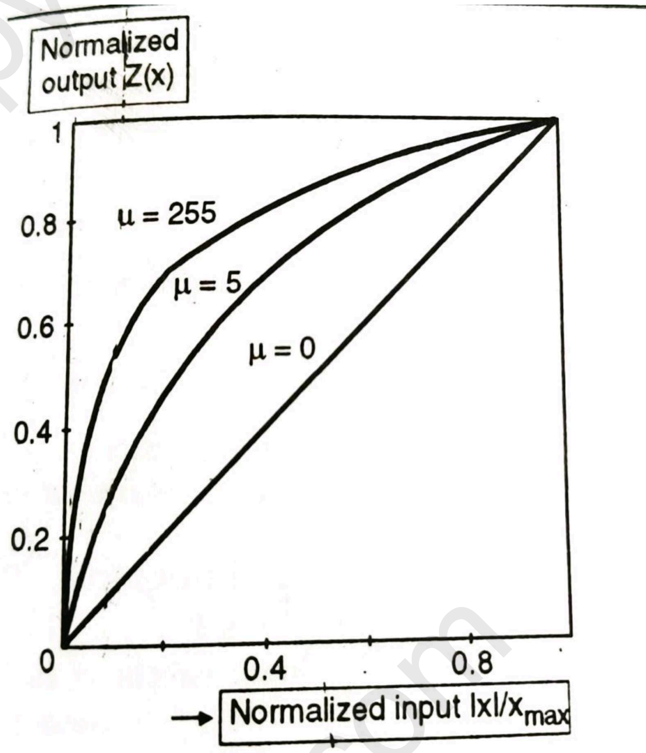
Working:

- Companding is a term derived from two words, compression and expansion.
- Companding= Compressing+ Expanding
- The weak signals are amplified and strong signals are attenuated before applying them to a uniform quantizer.
- This process is called as "compression" and the block that provides it is called as a "compressor"
- At the receiver exactly opposite process is followed which is called expansion.
- The circuit used for providing expansion is called as an "expander".
- The compression of signal at the transmitter and expansion at the receiver is combined to be called as "companding".

μ Low Companding

- In the μ law companding, the compressor characteristic is continuous.
- It is approximately linear for smaller values of input levels and logarithmic for high input levels.
- The μ -law compressor characteristic is mathematically expressed as,

$$F(x) = \operatorname{sgn}(x)\frac{\ln(1+\mu|x|)}{\ln(1+\mu)} \qquad -1 \le x \le 1$$



- Here F(x) represents the output and x is the input to the compressor. |x|/xmax, represents the normalized value of input with respect to the maximum value Xmax.
- (Sgnx) term represents +-1 positive and negative values of input and output.
- The practically used value of μ is 255. The characteristic corresponding to μ =0 corresponds to the uniform quantization.
- The μ -law companding is used for speech and music signals. It is used for PCM telephone

A Low Companding

- In the A-law companding, the compressor characteristic made up of a linear for low level inputs and a logarithmic for high level inputs.
- linear for smaller values of input levels and logarithmic for high input levels.
- Fig shows the A-law compressor characteristics for different values of A.
- Corresponding to A=1 we observe that the characteristic is linear which corresponds to a uniform quantization.
- The practically used value of "A" is 87.56.
- The A-law companding is used for PCM telephone systems in Europe.