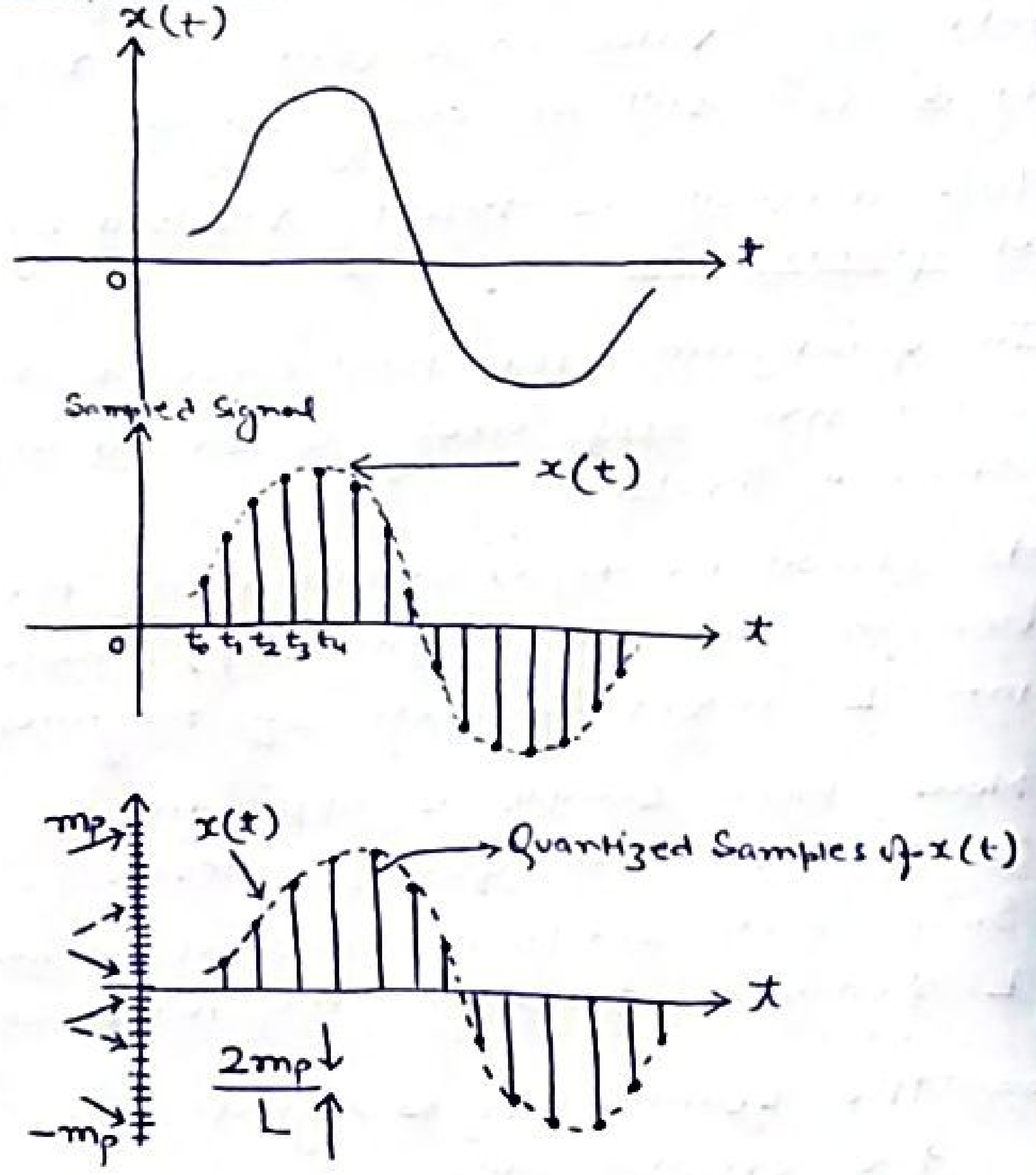
UNIT - 4

PCM & DELTA MODULATION SYSTEM

CONCEPT OF QUANTIZATION



(a) An analog signal

(b) Samples of Analog signal

(c) Quantization

In Communication system, sometimes it happens that we are available with analog signal, However, we have to transmit a digital signal for a particular application.

In such cases, we have to convert an analog signal into digital signal.

for this purpose we get samples of the signal According to Sampling theorem. fig. (b).

Now we can say that the signal in fig ⓑ is defined only at the sampling instants.

This means ~~at~~ that it is no longer a continuous function of time, but rather, it is a discrete-time signal.

However, since the magnitude of each sample can take any value in a continuous range, the signal fig ⓑ is still an analog signal.

This difficulty is neatly resolved by a process known as quantization.

In quantization, the total amplitude range which the signal may ~~occ~~ occupy is divided into a number of standard levels.

As shown in fig (c) amplitude of the signal $x(t)$ lies in the range $(-m_p, m_p)$ which is partitioned into L intervals, each of magnitude $\Delta v = \frac{2m_p}{L}$.

Now, each sample is approximated or rounded off to the nearest quantized level.

Since each sample is now approximated to one of the L numbers, therefore the information is digitized.

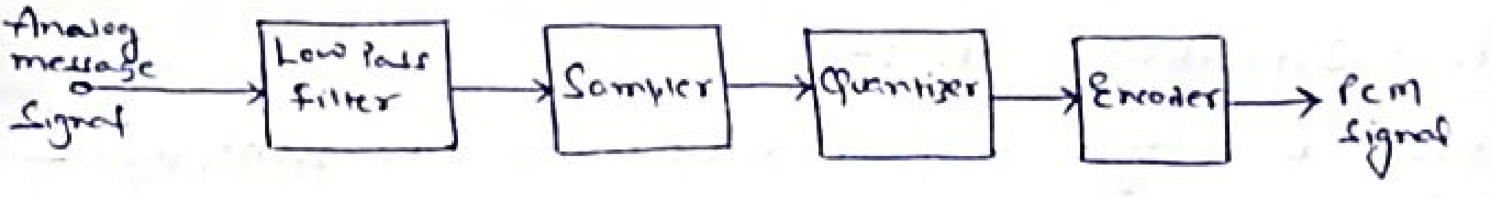
⇒ The quantization ~~…~~ signal is an approximation of the original one.

⇒ We can improve the accuracy of the quantized signal to any desired degree simply by increasing the number of levels L.

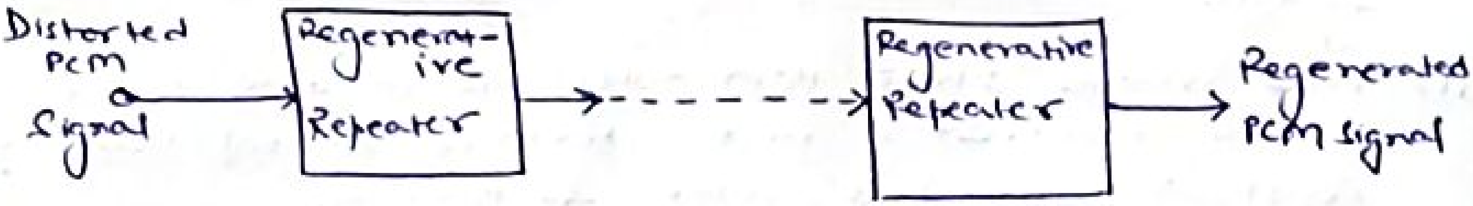
Pulse Code Modulation (PCM)

Pulse code modulation is known as a <u>digital pulse modulation technique</u>.

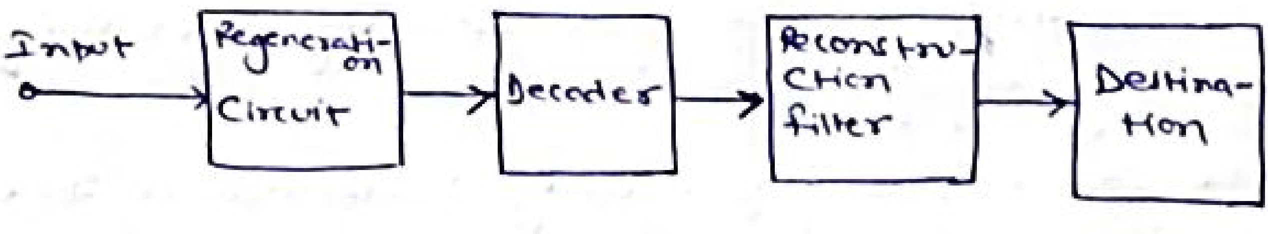
Elements of PCM system



(a) Transmitter



(b) Transmission Path



(c) Reciever

It consists of three main parts. Transmitter, Transmission path & Reciever.
The essential operation in the transmitter of a PCM system are sampling, Quantizing, & Encoding.
The essential operations in the Reciever are regeneration of impaired signals, decoding & demodulation of the train of quantized samples.

Recievers, regenerative repeaters are used to reconstruct the transmitted sequence of coded pulse in order to combat the accumulated effects of signals distortion & noise.

"It is a combined use of quantizing & coding that distinguishes pulse code modulation from analog modulation techniques."

Few Important Points :-

(i) PCM is a type of pulse modulation like PAM, PWM & PPM, but there is an important difference between them. PAM, PWM, PPM are 'analog' pulse modulation systems, whereas PCM is a digital pulse modulation system.

ii) This means that PCM output is in the coded digital form. It is in the form of digital pulse of constant amplitude, width & position.

iii) The information is transmitted in the form of code words. A PCM system consists of a PCM encoder (Tx) & a PCM decoder (Rx).

iv) The essential operation are sampling, quantizing & encoding at Tx.

v) All the operations are usually performed in the same ckt. called Analog to digital converter. (ADC) or (DAC).

vi) It should be understood that the PCM is not modulation in the conventional sense.

vii) Because in modulation, one of the characteristics of the carrier is varried in proportion with the amplitude of the modulating signal.
Nothing of that sort happen in PCM.

PCM Generator or Transmitter

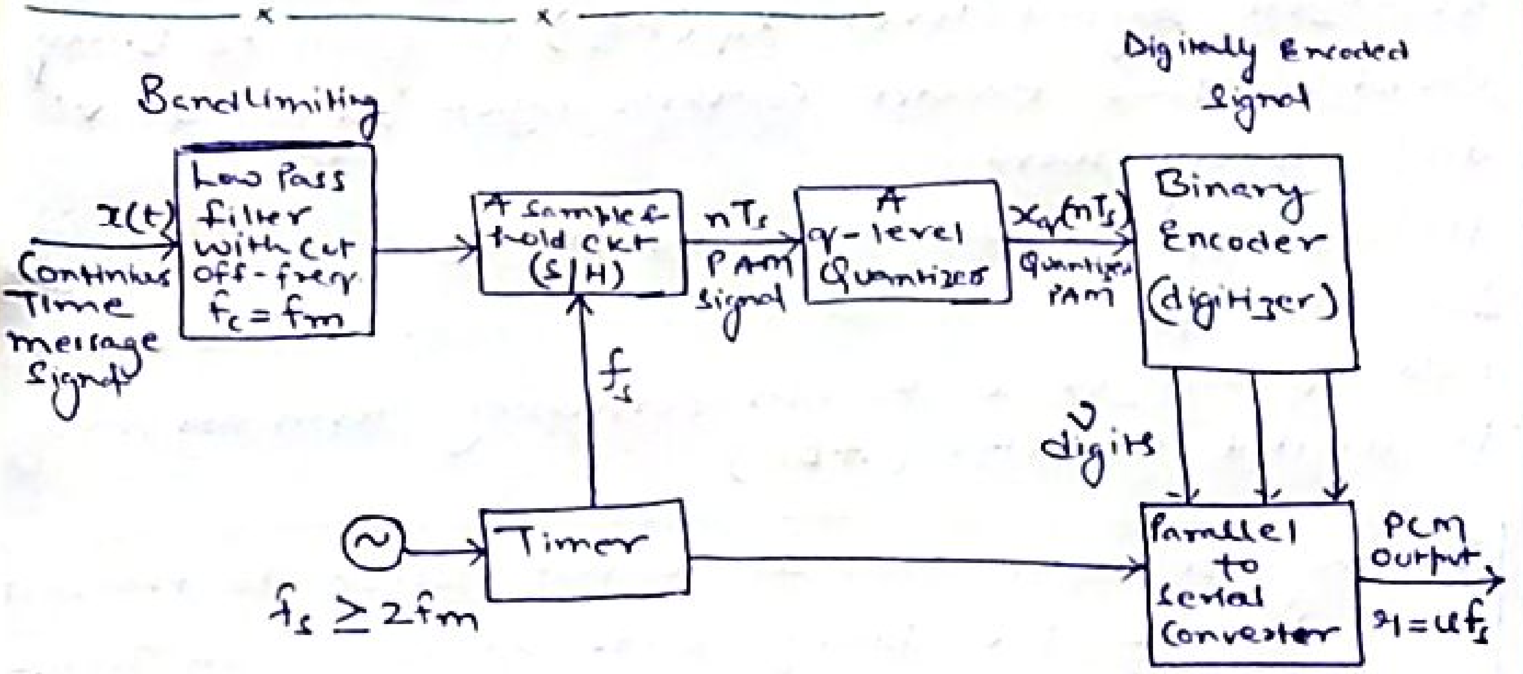


fig. A Practical PCM Generator

In PCM Generator, the signal $x(t)$ is first passed through the low pass filter of cutoff frequency f_m Hz. This low pass filter blocks all the frequency components which are lying above f_m Hz.

Now the signal is band limited to f_m Hz. The sample & hold ckt then samples the signal at the rate of f_s. Sampling freq. f_s is selected above Nyquist rate to avoid aliasing

$$f_s \geq 2f_m$$

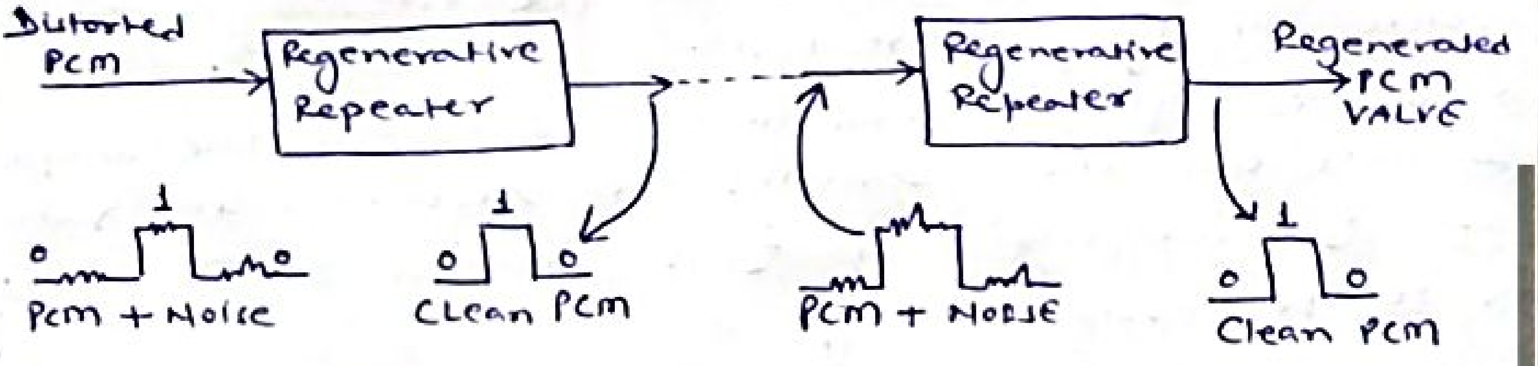
The output of sample & hold ckt is denoted by $x(nT_s)$. This signal is discrete in time & continious in Amplitude.

A q-level Quantizer compares input $x(nT_s)$ with its fixed digital levels. It then Assigns any one of the digital levels to $x(nT_s)$ which result in minimum distortion or error. This error is called <u>Quantization error</u>.

Thus output of Quantizer is $x_q(nT_s)$. Now the Quantized signal level $x_q(nT_s)$ is given to binary encoder. This encoder converts input signal to 'v' digit binary words.
This Encoder is also known as digitizer.
In the pulse code modulation generator, sample & hold, quantizer & Encoder combinely form an Analog to digital converter (ADC)

It may be noted that it is not possible to transmit Each bit of the binary words seperately on Transmission Line. Therefore 'v' binary digits are converted to serial bit stream to generate single baseband signal.

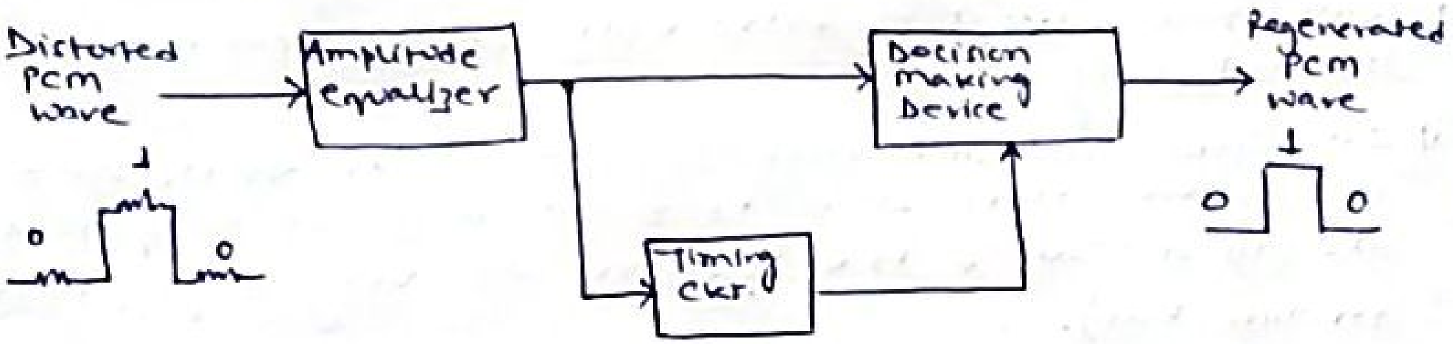
PCM Transmission PATH



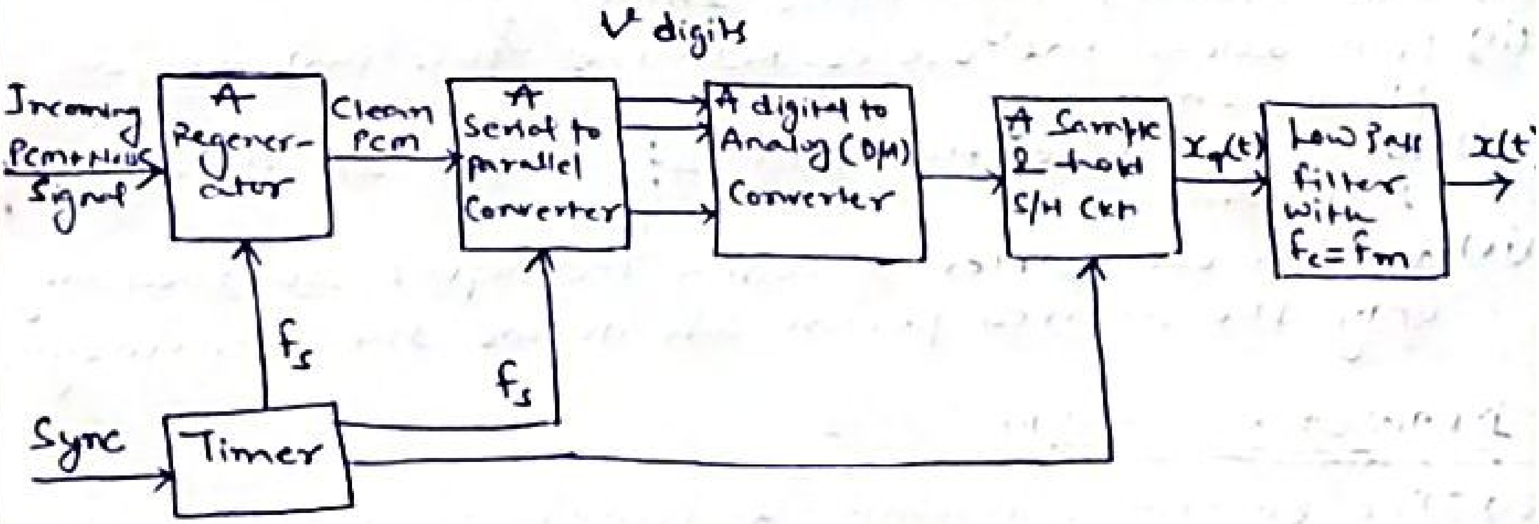
The path between the PCM Tx & PCM Rx over which the PCM signal travel, is called as PCM Transmission Path.
The most important part / features of PCM system lies in its ability to control the effects of distortion & Noise PCM Accomplishes this capacity by means of using a chain of regenerative Repeaters.

The regenerative repeaters perform three basic operations namely, equalization, timing, & decision making. Hence each repeater actually reproduces the clean noise free PCM signal.

Block Diagram of a Repeater



PCM RECEIVER



PCM Receiver

The regenerator at the start of PCM reciever reshapes the pulse & removes the noise. The signal is then converted to parallel digital words for each sample.

Now the digital word is converted to its analog value denoted as $x_q(t)$ with the help of sample & hold ckt.

This signal, at the output of sample & hold ckt, is allowed to pass through a Low pass filter to get the Appropriate original message signal denoted as $y(t)$.

APPLICATIONS of PCM

(i) with the advent of fibre optic cables, PCM is used in telephony.

(ii) In space communication, space craft transmits signals to earth. Here the transmitted power is quite small (10 or 15W) & the distance are very large (few million km).

However, due to noise immunity, only PCM system can be used in such Applications.

ADVANTAGES of PCM

(i) PCM Provides high Noise Immunity.
(ii) PCM allows the use of Repeaters, This improves its Noise Immunity.
(iii) we can store the PCM signal due to its digital Nature.
(iv) we can use different Coding Techniques, so that only only the desired person can decode the Recieved signal

DRAWBACKS of PCM

(i) The Encoding, decoding & Quantizing Circuitry of PCM is Complex.

(ii) PCM requires a large bandwidth as compared to other systems.

QUANTIZER :-

As discussed earlier, a q-level quantizer compares the discrete-time-input $x(nT_s)$ with its fixed digital levels. It Assigns any one of the digital level to $x(nT_s)$ with its fixed digital levels.

It then assigns any of the digital level to $x(nT_s)$ which result in minimum distortion or error.

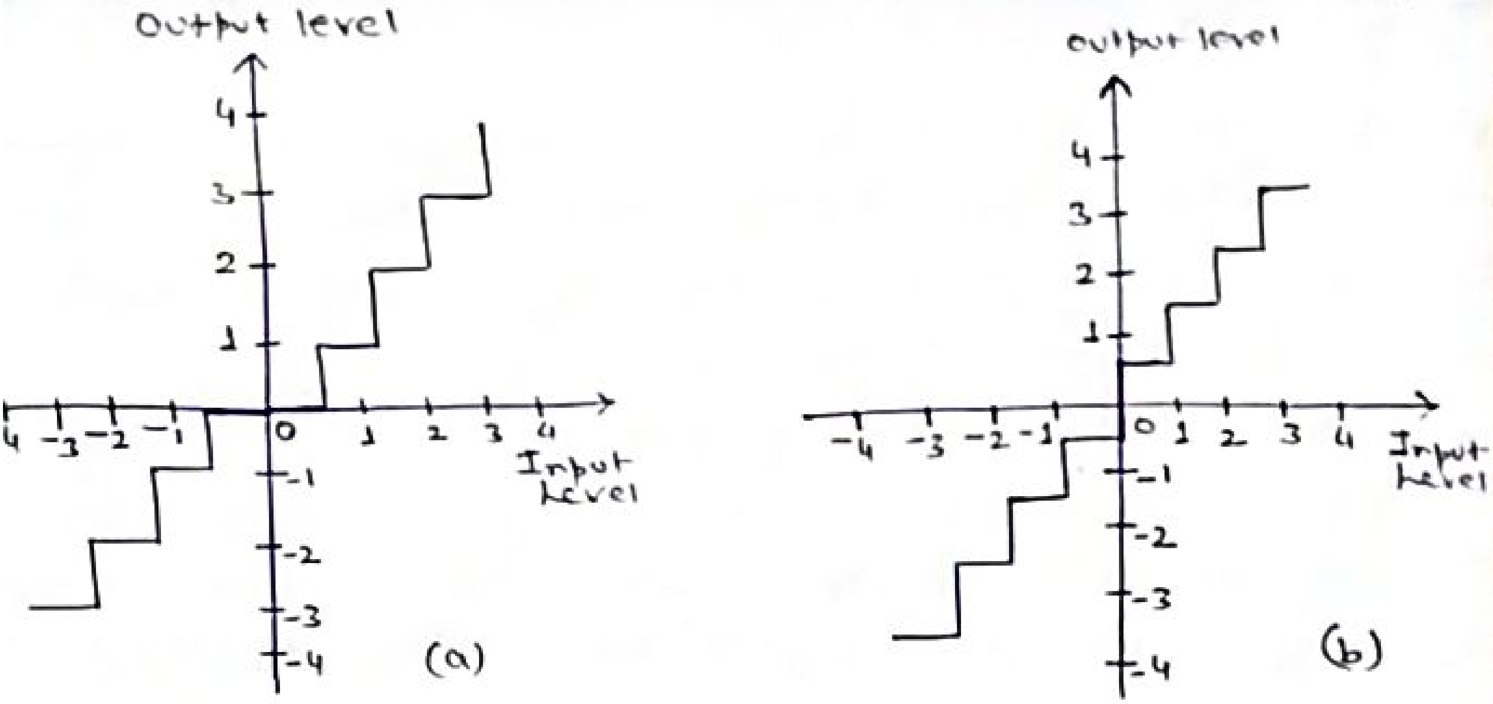
This error is called Quantization error. Thus the o/p of a quantizer is a digital level called $x_q(nT_s)$.

Classification of Quantization Process :

- Quantization
  - Uniform Quantization
    - Midtread type
    - Midrise Type
  - Non-Uniform Quantization

⇒ A uniform quantizer is that type of quantizer in which the "step size" remains same throughout the Input Range

⇒ A non uniform quantizer is that type of quantizer in which the 'step-size' varies According to the input signal values.



Two Types of Quantization (Uniform)
(a) Midtread (b) Midrise

figure (a) shows the input output characteristics of a Uniform quantizer of the midtread type, which is so called because the origin lies in the middle of a tred of the staircase like graph.

fig (b) shows the corresponding input-output characteristics of a Uniform quantizer of the midrise type, in which the origin lies in the middle of a rising part of staircase like graph.

QUANTIZATION NOISE/ ERROR IN PCM

In this section, we shall derive an expression for quantization noise in a PCM system for linear quantization. Because of quantization, inherent errors are introduced in the signal. This error is called quantization error. The quantization error is given as,

$$\varepsilon = x_q(nT_s) - x(nT_s) \quad \ldots\ldots (i)$$

Normalized Noise Power
or Quantization noise Power
or Quantization error (in terms of Power) = $\frac{\Delta^2}{12}$

SIGNAL TO QUANTIZATION NOISE RATIO

In a PCM system for linear Quantization the signal to Quantization noise ratio is given as,

$$\frac{S}{N} = \frac{\text{Normalized Signal Power}}{\text{Normalized Noise Power}}$$

But, normalized Noise Power has been calculated as $\frac{\Delta^2}{12}$

$$\therefore \quad \frac{S}{N} = \frac{\text{Normalized Signal Power}}{(\Delta^2/12)} \quad \text{------- (i)}$$

The number of bits 'v' & Quantization levels are related as,

$$q = 2^v \quad \text{------- (ii)}$$

Let us Assume that input $x(nT_s)$ to a linear Quantizer has continious Amplitude in the range $-x_{max}$ to $+x_{max}$. Therefore the total Amplitude range

$$= x_{max} - (-x_{max}) = 2x_{max}$$

Now, the Step size will be

$$\Delta = \frac{2x_{max}}{q} \quad \text{------- (iii)}$$

Here, subistituting the value of q from eq (ii) we get,

$$\Delta = \frac{2x_{max}}{2^v}$$

Now substituting this value in eq (i) we get

$$\frac{S}{N} = \frac{\text{Normalized signal Power}}{\left(\frac{2x_{max}}{2^v}\right)^2 \cdot \frac{1}{12}}$$

Let the Normalized signal Power be denoted as 'P'.

Then $$\frac{S}{N} = \frac{P}{\frac{4x^2_{max}}{2^{2v}} \times \frac{1}{12}} = \frac{3P}{x^2_{max}} \cdot 2^{2v}$$

This is the required relation for signal to quantization noise ratio for linear quantization in a PCM system.

Hence, signal to quantization Noise Ratio:-

$$\boxed{\frac{S}{N} = \frac{3P}{x^2_{max}} \cdot 2^{2v}}$$

$$\frac{S}{N} dB \leq (4.8 + 6v) dB.$$

COMPANDING :-

Companding is non-uniform quantization. It is required to be implemented to improve the signal to quantization noise ratio of weak signals.

Companding = Compressing + Expanding

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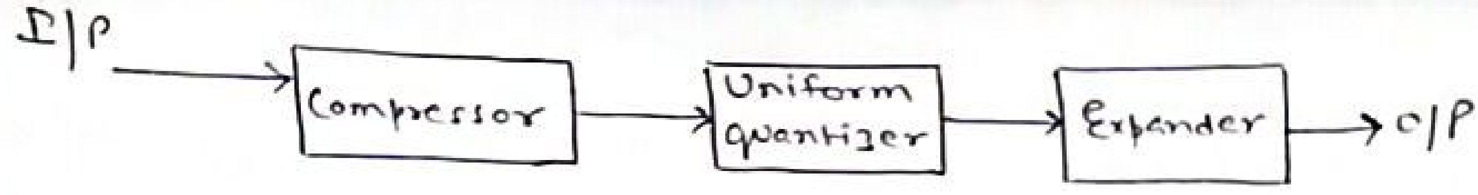

An Companding Model.