UNIT IV : DIGITAL PULSE MODULATION

Need for Digital Transmission :-

1. **Noise Immunity →** Digital signals which are usually binary are more immune to noise than analog signals because the noise amplitude must be much higher than the signal amplitude to make a binary one look like a binary zero or vice versa. Digital signals can be transmitted over a long distance without getting distorted.

2. **Error Detection and Correction →** With Digital Communication transmission errors can be detected and even corrected

3. **Compatibility with Time Division Multiplexing (TDM) →** Digital data communication is adaptable to time Division Multiplexing Scheme.

4. **Digital ICs →** Digital ICs are smaller and easier to make than linear ICs and provide a greater processing capability.

5. **Digital Signal Processing →** This converts an analog signal to Digital and then processing with a fast digital computer. Processing means filtering, equilization, phase shifting and mixing. DSP permits significant improvement in processing over equivalent analog techniques.

Limitations of Using Digital Pulse Modulation / Transmission

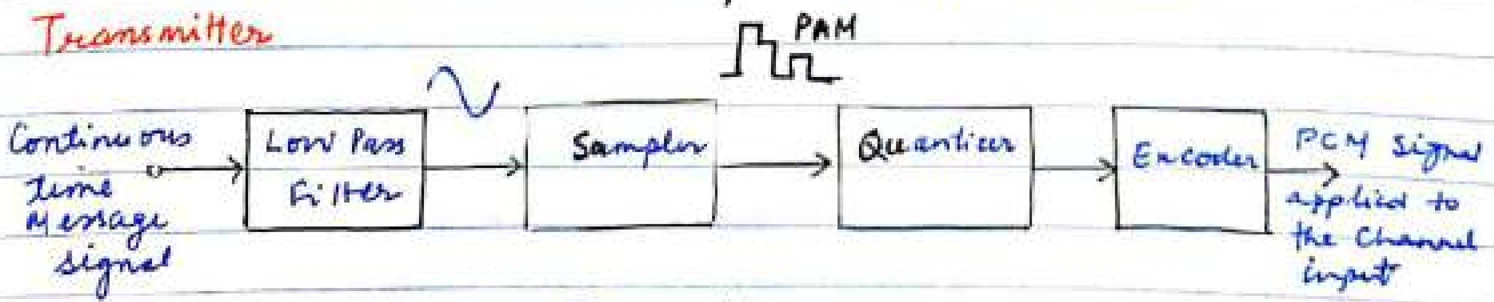
1. Bandwidth size required by a digital signal is higher than the analog.
2. Digital communication circuits are more complex than analog circuits.

PULSE CODE MODULATION → In Pulse Code Modulation (PCM), a message signal is represented by a sequence of coaded Pulses, which is accomplished by representing the signal in discrete form in both time and amplitude.

PCM operation →
1. Sampling
2. Quantization
3. Encoding

The PCM system consists of three main parts i.e. transmitter, transmission path and receiver

Transmitter



Transmitter

* Quantization → The method of sampling chooses a few points on the analog signal and then these points are joined to round off the value to a near stabilized value. Such a process is called as quantization.

Continuous time message signal is passed through low pass filter to prevent aliasing and applied to sampler.

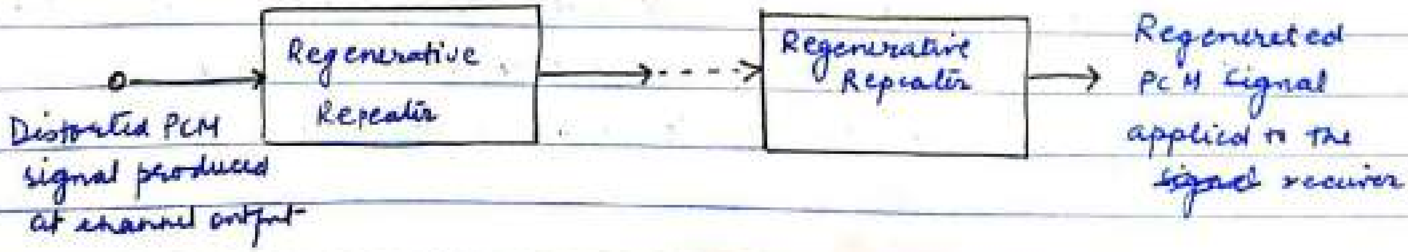
Function of Sampler → Sampler or Sampling circuit in a PCM transmitter periodically samples the continually changing analog input voltage and converts those samples to a series of constant amplitude pulses that can be easily converted to binary PCM code.

* Function of Quantizer → It quantizes the message signal by discretizing in both time and amplitude.

Function of Encoding → Discrete signals are encoded into more appropriate form for transmission. Such arrangement of signal made for transmitting it over the channel is called as code.

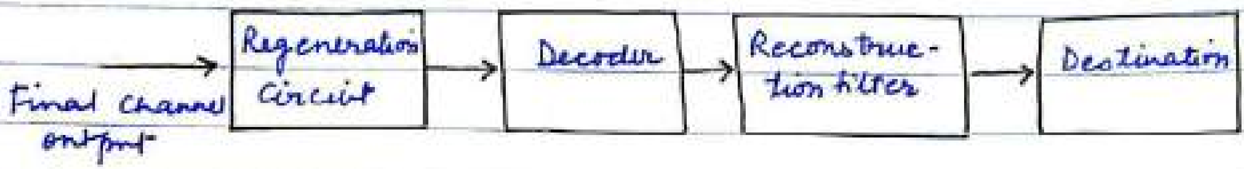
The quantizing and encoding operations are performed by analog to digital converter (ADC).

Transmission Path →



Regenerative repeaters are used along the transmission path to reconstruct the transmitted sequence of coded pulses in order to combat the accumulated effects of signal distortion and noise.

PCM Receiver →

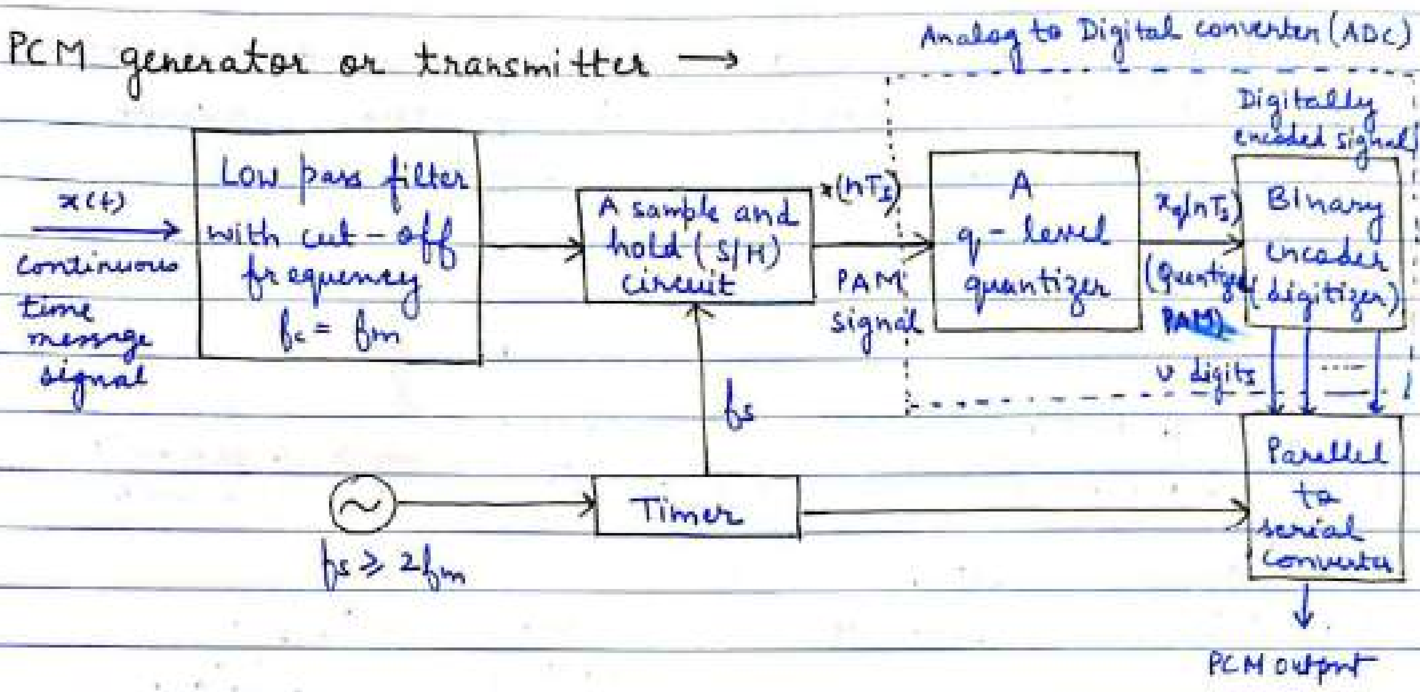


<u>Regeneration Circuit</u> is used to reconstruct the PCM signal and control the effect of distortion and noise produced through a channel. This is used to regenerate (reshape and clean up) the received pulses.

The clean pulses are then regrouped into code words and decoded into a quantized PAM signal. Decoding process involves generating a pulse, the amplitude of which is the linear sum of all the pulses in the code word with each pulse being weighted by its place value ($2^0, 2^1, 2^2, \ldots 2^{n-1}$) in the code where 'n' is the no. of bits per sample.

The message signal is recovered by passing the decoder output through a low pass reconstruction filter whose cut off frequency is equal to the message bandwidth W.

PCM generator or transmitter →



Signal x(t) is passed through the low pass filter of cut off frequency fm Hz. This low pass filter blocks all the freq. components which are lying above fm Hz.

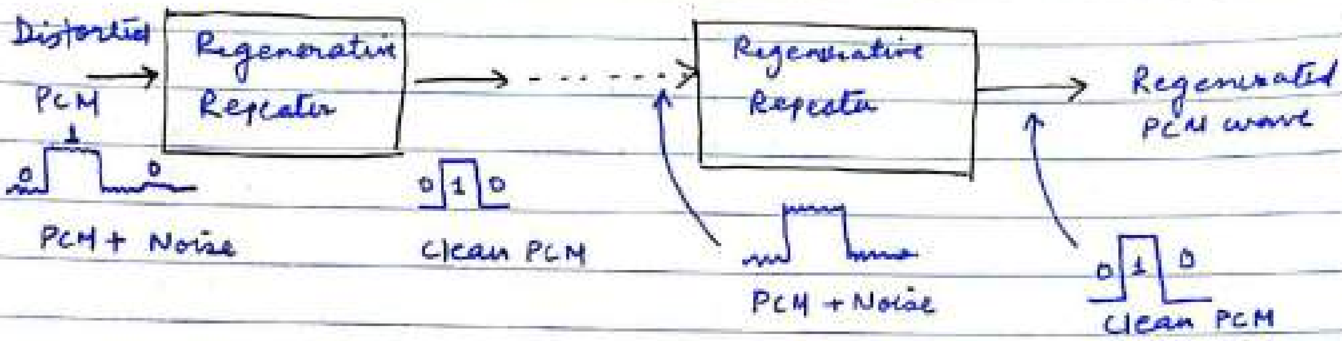
Sample and Hold circuit periodically samples the analog input signal and converts those samples to a multilevel PAM signal. The sampling frequency fs is selected as $f_s \geq 2 f_m$.

Output of sample and hold circuit is denoted by $x(nT_s)$ and this signal is discrete in time and continuous in amplitude.

The function of quantizer and digitizer is done by analog to digital converter. Quantizer compares the input $x(nT_s)$ with its fixed digital levels and assigns any one of the digital levels ~~of~~ ~~xnt~~ $x(nT_s)$ with its fixed digital levels.

output of quantizer is a digital level called as $x_q(nT_s)$ given to binary encoder. This encoder converts the input signal to 'ν' digits binary word.

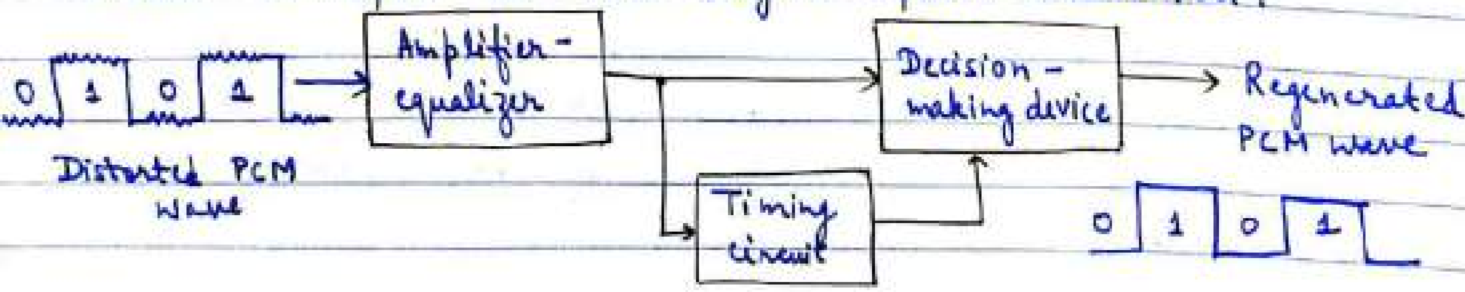
PCM transmission Path →



The path between the PCM transmitter and receiver over which the PCM signal travels is called as the PCM transmission path.

By using regenerative repeaters, the effect of distortion and noise is minimized. Such repeaters are spaced close enough to each other on the transmission path.

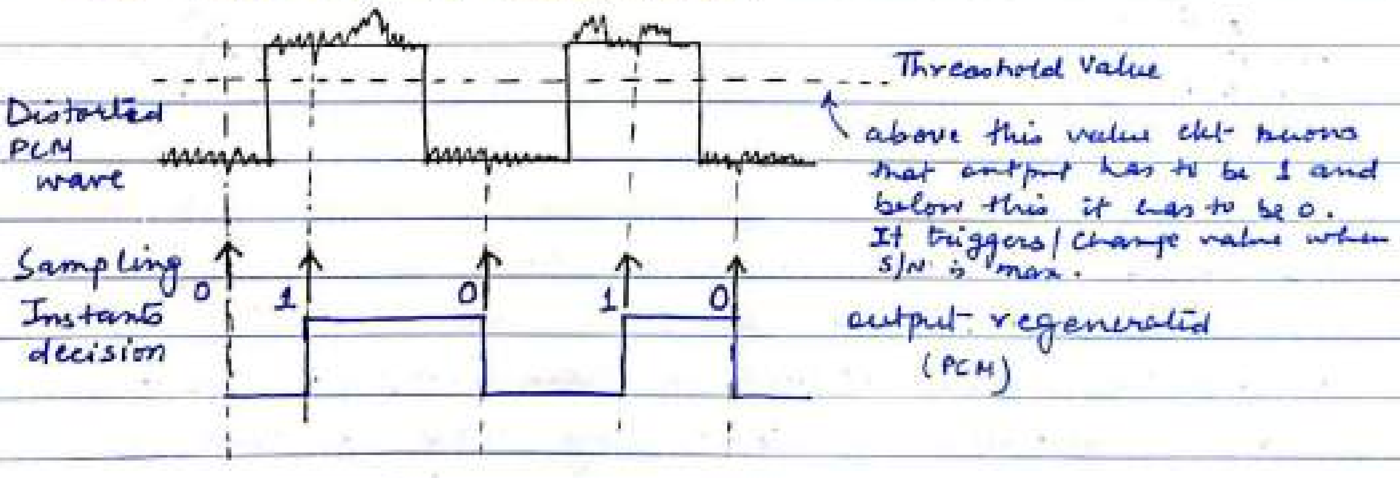
Regenerative Repeaters → This performs three basic operations namely :- equalization, timing and decision making. ~~Eca~~ Each repeater actually reproduces the clean noise free ~~xx~~ PCM signal from distorted.



Amplifier - equalizer shapes the received pulses so as to compensate for the effects of amplitude and phase distortions produced by the non ideal transmission characteristics of the channel.

Timing circuitary provides a periodic pulse train, derived from the received pulses, for sampling the equalized pulses at the instants of time where S/N ratio is maximum.

Each sample so extracted is compared to a predetermined threashold in the decision making device.
A decision making device gives one (1) or zero (0) on the basis of whether the threashold is exceeded or not. If threashold is exceeded, a new pulse (1) is transmitted to the next repeater otherwise another clean new pulse (0) is transmitted.

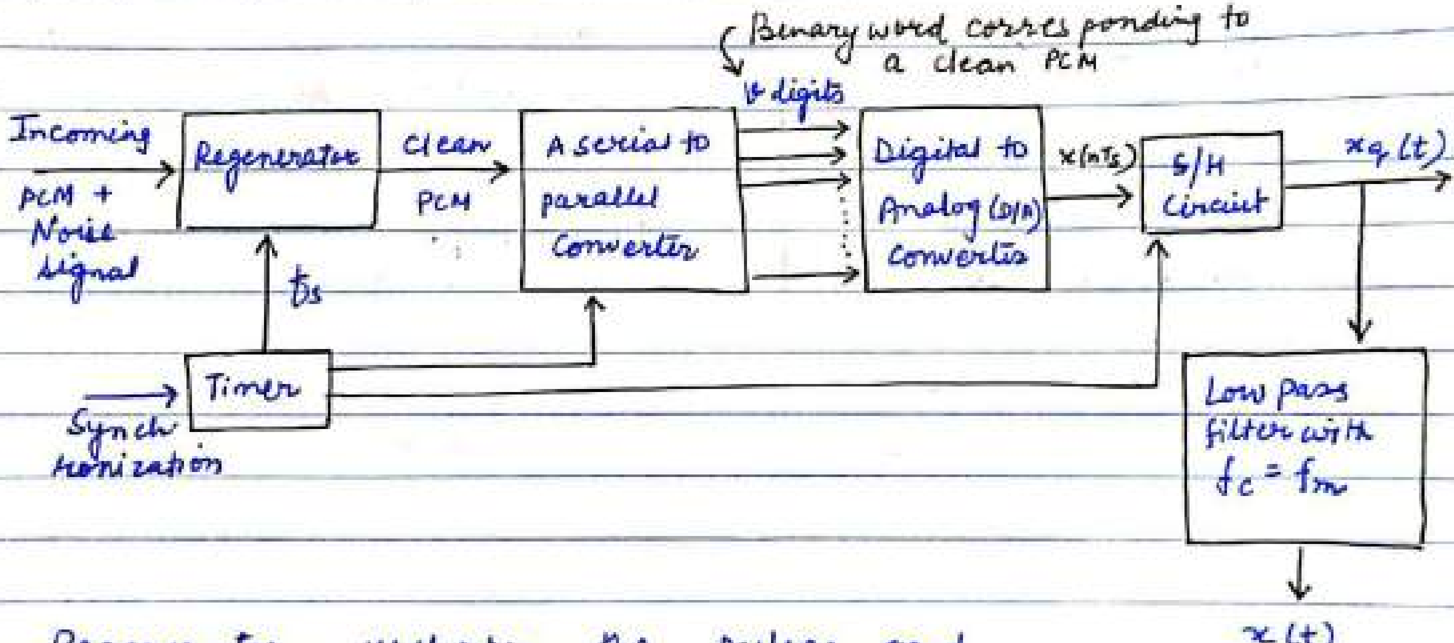


Ideally except for a delay, the regenerated signal is exactly the same as the signal originally transmitted. The regenerated signal departs from the original signal for two reasons :-

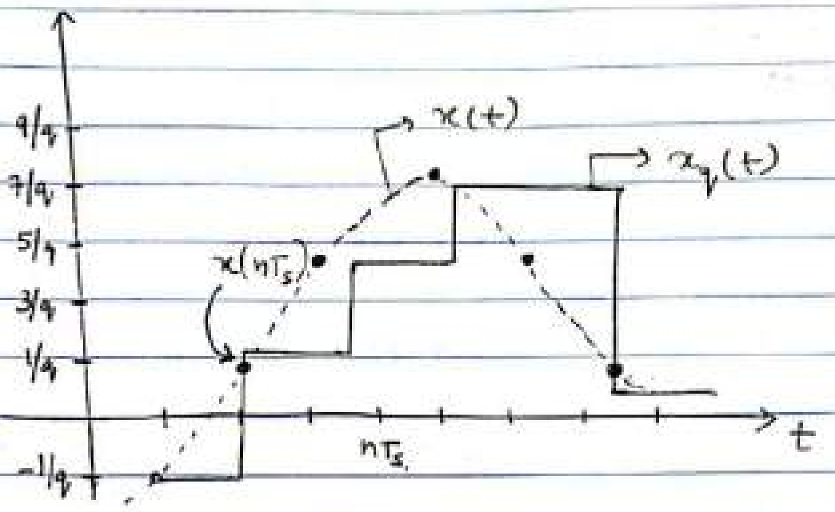
1. The ~~unavoid~~ unavoidable presence of channel noise and interference causes the repeaters to make wrong decisions ocassionally thereby introducing bit errors into regenerated signals.

2. If the spacing between received pulses deviates from its assigned value. A jitter is introduced into the regenerated pulse position thereby causing distortion.

PCM Receiver →



Regenerator reshapes the pulses and removes the noise. This signal is then converted to parallel digital words for each sample. Digital word is converted to its analog value denoted as $x_q(t)$ using sample and hold circuit. This signal is allowed to pass through a low pass reconstruction filter to get the appropriate original message signal, $x(t)$.



$x(nT_s)$ → Discrete signal values

$x_q(t)$ → Quantized PCM signal (output S/H circuit)

$x(t)$ → Low freq. continuous message signal.

Sampling → This is the conversion of continuous time signal into a discrete time signal obtained by taking samples of the continuous time signals at discrete time instants.

Consider a signal, $x(t)$, applied to the sampler. The output of the sampler, $x(nT_s)$, is given by

$$x(n) = x(nT_s) \quad -\infty < n < \infty$$

Where T_s is the sampling period or sampling interval and $1/T_s = f_s$ is called as the sampling frequency or sampling rate. The variables t and n are related as

$$t = nT_s = n/f_s$$

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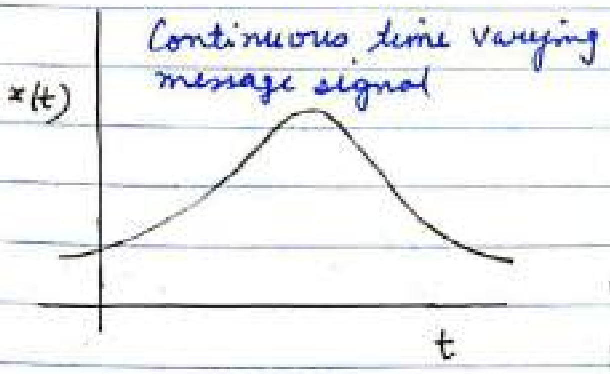
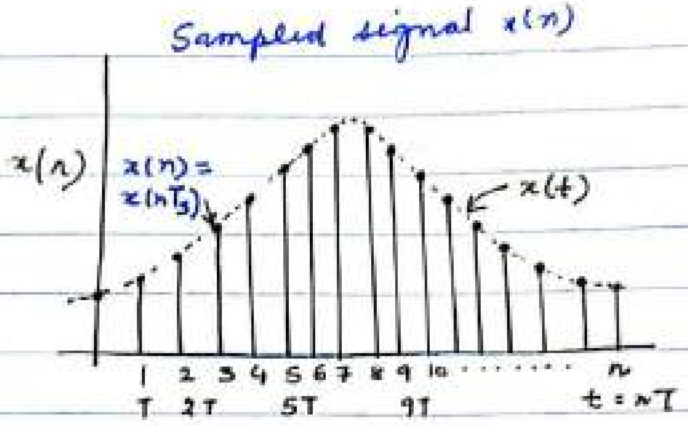




$x(nT_s) \rightarrow$ sampled signal

Quantization → The process of converting an infinite no of possibilities to a finite number of conditions. In this amplitude of flat-top samples are rounded off to a manageable number of levels.

Let $x_q(n)$ denotes the sequence of quantized samples at the output of the quantizer

$$x_q(n) = Q[x(n)]$$

↑ quantization of each value of $x(n)$.

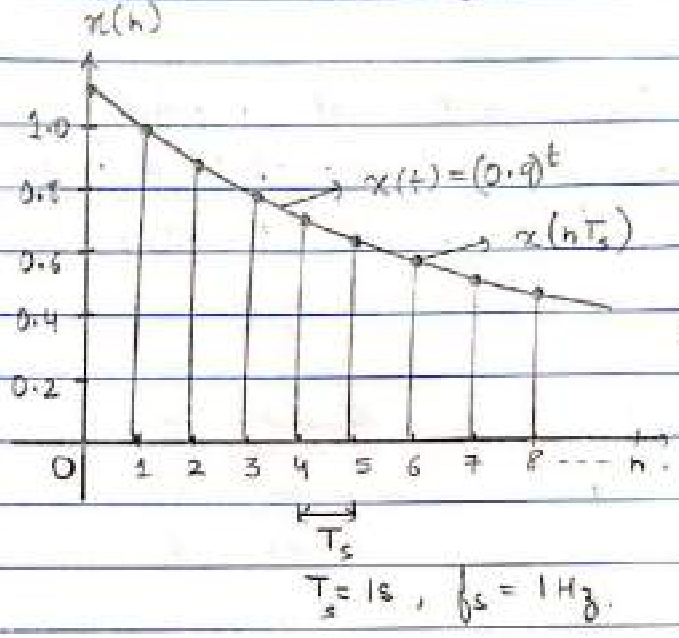
The error introduced in representing the continuous-valued signal by a finite set of discrete value & levels is called the quantization error or quantization noise. Hence, quantization error is the difference between the quantized value and the actual sample value.

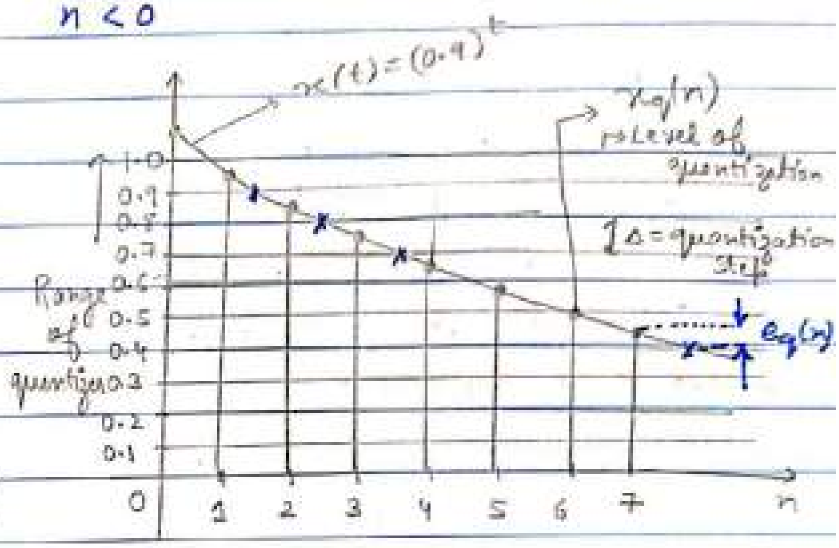
$$e_q(n) = x_q(n) - x(n)$$

↑ quantization error

Let us take an example, consider the discrete time signal

$$x(n) = \begin{cases} (0.9)^n & n \geq 0 \\ 0 & n < 0 \end{cases}$$





n	$x(n)$ Discrete time	$x_q(n)$ Truncation	$x_q(n)$ Rounding	$e_q(n) = x_q(n) - x(n)$ (rounding)
0	1	1.0	1.0	0.0
1	0.9	0.9	0.9	0.0
2	0.81	0.8	0.8	−0.01
3	0.729	0.7	0.7	−0.029
4	0.6561	0.6	0.7	0.0439
5	0.59049	0.5	0.6	0.00951
6	0.531441	0.5	0.5	−0.031441

The values allowed in the digital signal are called as the quantization levels whereas the distance Δ between two successive quantization levels is called as quantization step size or resolution.