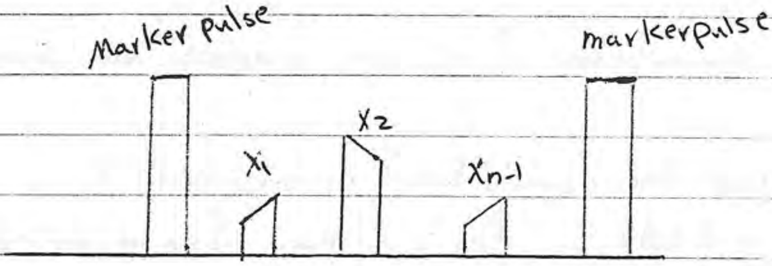


"Marker pulses"

The disadvantage of using amarker is the No. of channels to be multiplexed is reduced by one, $(N-1)$ channel are multiplexed.

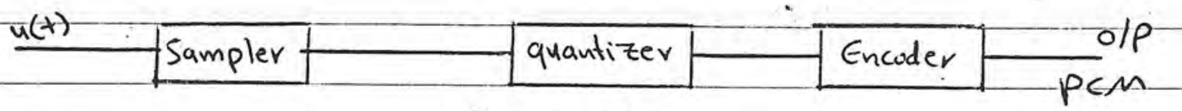
Ex// 24 Voice signal are Sampled uniformly and time multiplexed. The Sampling operation uses Samples with width 1 uses.
The multiplexing operation provides Synch. by adding extra pulse duration of 1 μsec. If $f_s = 8$ KHZ, calculate spacing between successive pulses?

Sol:- $T_s = \frac{1}{f_s} = \frac{1}{8000} = 125\ \mu sec$

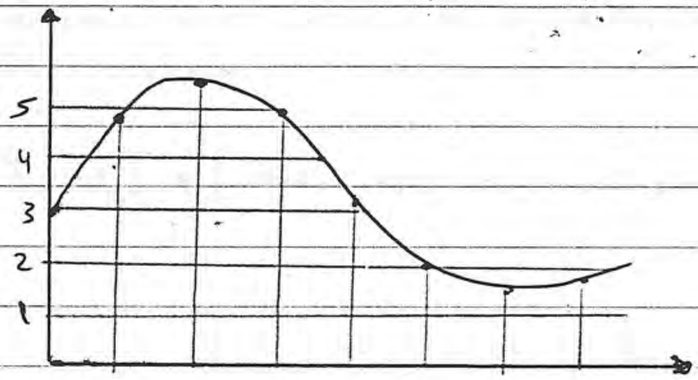
The pulse are separated by $\frac{125}{25} = 5\ \mu sec$

Pulse Code Modulation (PCM) :-

Represent analog data to digital signal (two quentity -, +)



$f_s \geq 2 f_m$



- any Sample which falls between two levels, it will be presented by the amplitude of Quantized level. This is Some Kind of approximation (close to the two Values).

- If the sample is quantized to level (5), the encoder will represent 5 in binary. The encoder Converts the quantized input to (n) bits.

- The quantization process results in a kind of error Called " quentization error".

Transmission Band width in PCM:-

let the quantizer use (n) number of binary digits to represent each level. The No. of levels that can be represented by "n" digits will be $q_r = 2^n$

q_r :- Total number of digital level quantizer.
n :- no. of bits.

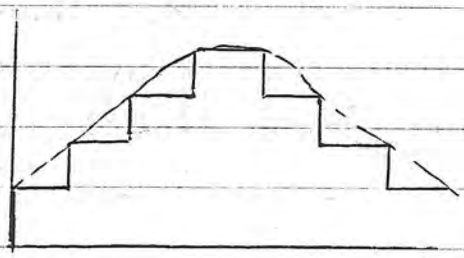
No. of bit per Second = (No. of bit per sample) * (No. of Sample/sec)
$= n * f_s$

∴ Signaling rate in PCM $(r) = n f_s$

$$B_T \geq \frac{1}{2} r$$

PCM → [Regenerate] → [D/A Converter] → [L.P.F $f_c = f_m$] → $m(t)$

" PCM receiver "



" Reconstructed wave "

It is impossible to reconstruct the exact signal $m(t)$, because of the "quantization error"

This can be reduced by increasing the Quantization levels bits per sample, but this will increase the signaling rate as well as BT. The Noise introduced by the quantization should be in a tolerable limit. الحد المسموح

Quantization :-

When quantizing a signal $x(t)$, a New Signal is created X_q. If a signal is limited to a higher and lower Value, V_H, V_L respectively, then we divide this range in to (M) equal intervals each of size "S" Called step size

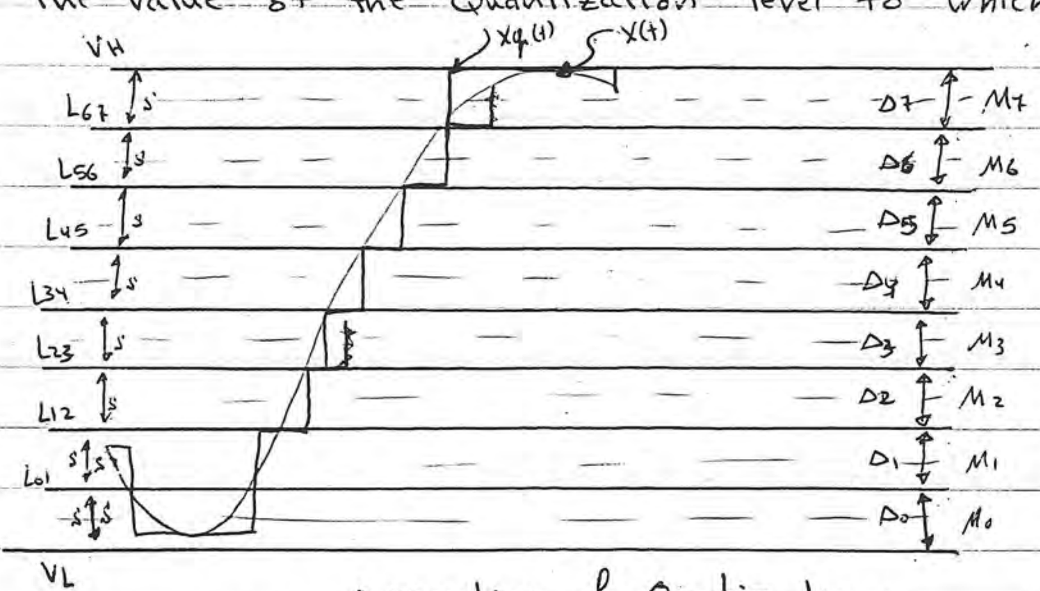
$$S = \frac{V_H - V_L}{M}$$

where M = is the No. of intervals

Taking $M = 8$, There will 8 quantization levels, the quantized signal is as fllowing:

When $x(t)$ is in the rang Δ_0, the Signal $x_q(t)$ maintains Constant level M_0 and Soon ---

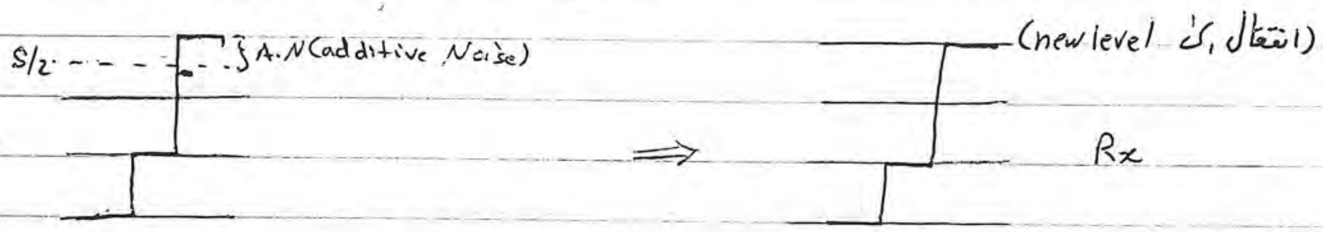
but, the transition in $X_q(t)$ from $X_q = m_0$ to $x_q = m_1$ is made abruptly, $x(t)$ passes the transition L_{01} which is midway between M_0 and m_1. This means that " at every instant of time, $X_q(t)$ has the value of the Quantization level to which $X(t)$ is closest".



"Operation of Quantization"

The Quantization error $[x(t) - x_q(t)]$ must have amagnitude less than or equal to $S/2$

As long as the noise has an instantinous amplitude less than $S/2$, the noise will not appear at the output. The figure below shows the error which results in the signal.



There are two kinds of noise, Additive noise and Quantization noise. ① The additive noise is decreased by Putting repeaters (Quantization + amplifier) in decreased spacing. This will decrease the noise power and decrease the probability of error.

Increasing the step size will also decrease the error, but the difference $X - X_q$ and results in increasing "Quantization noise".

② Quantization noise:

Beacuse of Quantization, inherent noise are introduced in the signal

$$\underset{error}{\sum} = x_q(nT_s) - X(nT_s)$$

let an input $X(nTs)$ amplitude is in the range $-X_{max}$ to $+X_{max}$. The total input Samples are mapped in to "q" levels.

Total amplitude $= x_{max} - (-X_{max})$

$= 2x_{max}$

If the amplitude is divided in to "q" level of Quantization, then the step "S"

$$S = \frac{X_{max} - (-X_{max})}{q}$$

$$= \frac{2\,x_{max}}{q}$$

If the signal is normalized to minimum and Maximum equal value S

$X_{max} = 1$

$-X_{max} = 1$

$$\boxed{S = \frac{2}{q}} \quad \text{for normilized signals}$$

for a uniform Quantizer the maximum error is:-

$$\mathcal{E}_{max} \leqslant \left| \frac{S}{2} \right|$$

Noise power:

$$\text{Noise Power} = \frac{\overline{V^2_{noise}}}{R}$$

where V^2_{noise} is the mean square value of noise voltage.
Since noise is defined by random Variable "$\mathcal{E}$" and PDF $f_{\mathcal{E}}(\mathcal{E})$, it's mean square value is:-

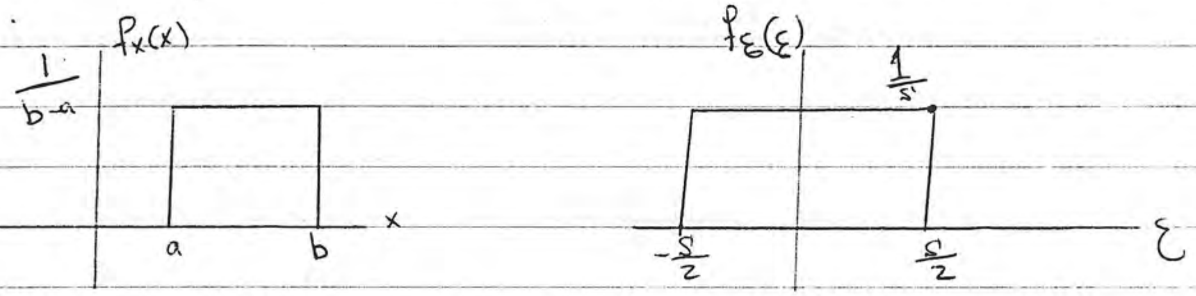
$$\text{mean square value} = E\left\{\mathcal{E}^2\right\} = \overline{\mathcal{E}^2}$$

The mean squre value of random variable "x" is given as:-

$$\boxed{\overline{X^2} = E\left[x^2\right] = \int_{-\infty}^{\infty} x^2 \underbrace{f_x(x)}_{\text{PDF}} \, dx}$$

uniform

PDF



Non distrubtion

* So the above equation becomes

$$E[\varepsilon^2] = \int_{-\frac{S}{2}}^{\frac{S}{2}} \varepsilon^2 * \frac{1}{S} \, d\varepsilon$$

$$\boxed{\text{Quantization noise power} = \frac{S^2}{12}} \text{ for } R=1$$

Maximum signal to Quantization noise for linear Quantization:-

$$\frac{S}{N} = \frac{\text{Normilized signal power}}{\text{Normilized noise power}}$$

$$= \frac{\text{Normilized signal power}}{S^2/12}$$

The Number of bit "n" and Quantization levels 'q' are related:

$$q = 2^n$$

$$S = \frac{2\,max}{2^n} \qquad \text{Sub in } S/N$$

$$= \frac{\text{Normilized signal Power}}{\left(\frac{2x_{max}}{2^n}\right)^2/12}$$

$$S/N = \frac{3\bar{P}^2}{X_{max}^2} 2^{2n}$$

if we assume the input $x(t)$ is Normilized

$x_{max} = 1$

$$S/N = 3 * 2^{2n}\bar{P}^2$$

if the destination signal "p" is Normilized

$P \leq 1$

$$S/N \leq 3 * 2^{2n}$$

$S/N\ db = 4.8 + 6n$

Expressing S/N in decibles

$$\frac{S}{N} dB = 10 \log \left[3 * 2^{2n}\right]$$

Ex// A television signal with abandwidth of 4.2 MHZ is transmitted using binary PCM, if the No. of Quantization levels is 512 calculated:

① The length of o/p code word

② BT

③ bitrate (signaling rate)

④ o/p signal to Quantization noise ratio.

Sol:

$W = 4.2$ MHZ

$q = 512$

Rama .Co

① $q_v = 2^n \Longrightarrow 512 = 2^n$

$$\log 512 = \log 2^n$$
$$\log 512 = n \log 2$$

$$n = \frac{\log 512}{\log 2} = 9 \text{ bit (length of code word)}$$

② $B_T \geq nW$

$B_T \geq 9 * 4.2 * 10^6$ HZ — bandwidth = f_{max}

$B_T \geq 37.8$ MHZ — = frequency اعلى

③ $r = n f_s$ — $f_s \geq 2 f_m$

$= 2nW$

$= 2 * 9 * 4.2 * 10^6$

$= 75.6 * 10^6$ bit/sec

④ $S/N \text{ dB} \leq [4.8 + 6n]$

$S/N \leq [4.8 + 6*9]$

$S/N \leq 58.8$ dB

Ex// The bandwidth of asignal input to the PCM is restricted to 4KHZ. The input varation is between −3.8V — +3.8V the average power of input is 30mW. A S/N is required to be 20dB. Assuming auniform Quantization and binary output.

① No. of bits per Sample

② output of 30 such pcm coders are time Multiplexed. what is the minimum required transmission bandwidth for the Multiplexed Signal?