☆ Digital Communication

- **Baseband data Tx**
  - **Analog**
    - PAM
    - PWM
    - PPM
  - **Digital**
    - PCM
    - DPCM
    - DM
    - ADM
- **Bandpass data Tx**
  - **Binary signalling**
    - ASK
    - FSK
    - PSK (or) BPSK
  - **M-ary signalling**
    - QPSK
    - 8SK
    - 16SK

* Review of Sampling Theorem:

⇒ In digital communications binary data is transmitted through the channel. To convert an analog signal into a digital signal, The signal should be sampled [illegible] every T_s seconds. This samples are to generate the binary data. At the receiver DAC is convert the binary into samples. Finally a LPF is used to reconstruct the signal from samples.

But the signal reconstruction is possible only when the following condition is satisfied.

$$\frac{1}{T_s} \geq 2 f_m \quad \text{sample/sec.}$$

⇒ The minimum sampling rate require to reconstruct the signal is called as the Nyquist rate.

$$\therefore \quad \frac{1}{T_s} = 2 f_m \quad \text{sample/sec.}$$ ← H.B

⇒ If the sampling rate is greater than the Nyquist rate then the signal is over sampled.

$$\frac{1}{T_s} > 2 f_m.$$

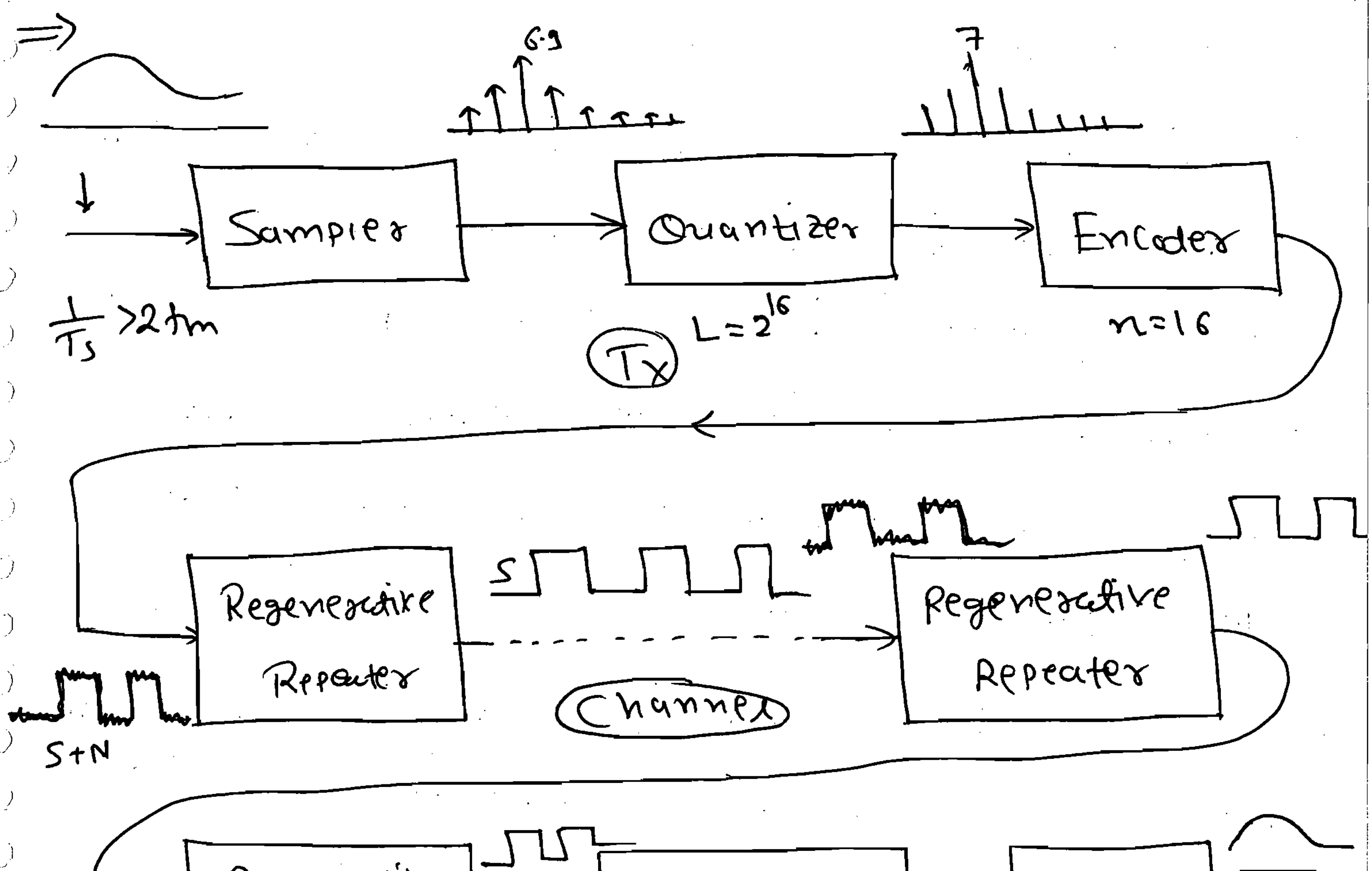
⇒ If the Sampling rate is less than the Nyquist rate then the signal is under sampled and distortion will occured.

$$\boxed{\frac{1}{T_s} < 2f_m}$$ ×

⇒ The o/p of the LPF is envelope of the sampled signal.

(1) Pulse Code Modulation (PCM):-

⇒



⇒ Sampler Converts the continuous time Signal into the descrete time signal but the signal should be over sampled ($\frac{1}{T_s} > 2 f_m$).

⇒ In Quantizer each sample is rounded off to the nearest quantization level.

⇒ In Voice transmission in telephone system, the sampling rate used is 8000 sample/sec and each sample is encoded into 8 bits.

⇒ In Audio CD Recording, the Sampling rate used is 44,100 sample/sec and each Sample is encoded into 16 bits.

⇒ Encoder O/P is the Binary data which is represented in the form of Rectangular Pulses.

⇒ When the binary data is transmitted through a channel, amplitude distortion

⇒ Regenerative Repeaters are used to eliminate noise from the signal and noise present at the input of the receiver.

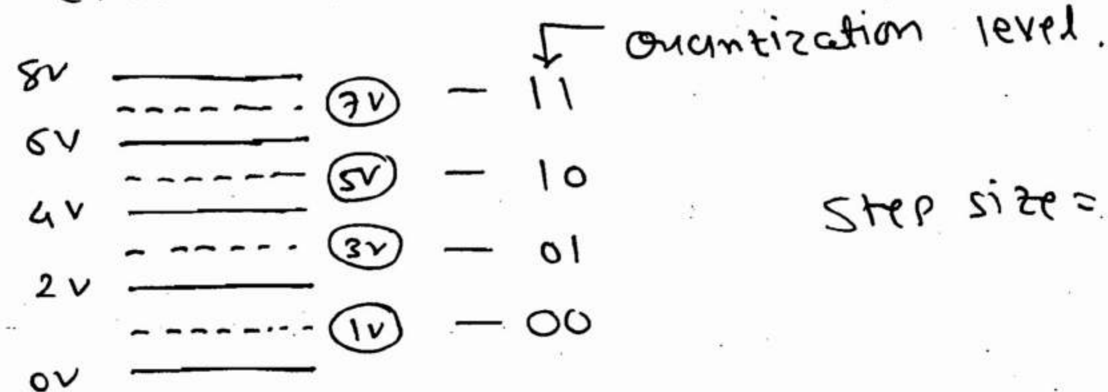
⇒ The decoder is a analog converter which convert the binary data into sample.

⇒ The LPF is used to reconstruct the signal from the samples.

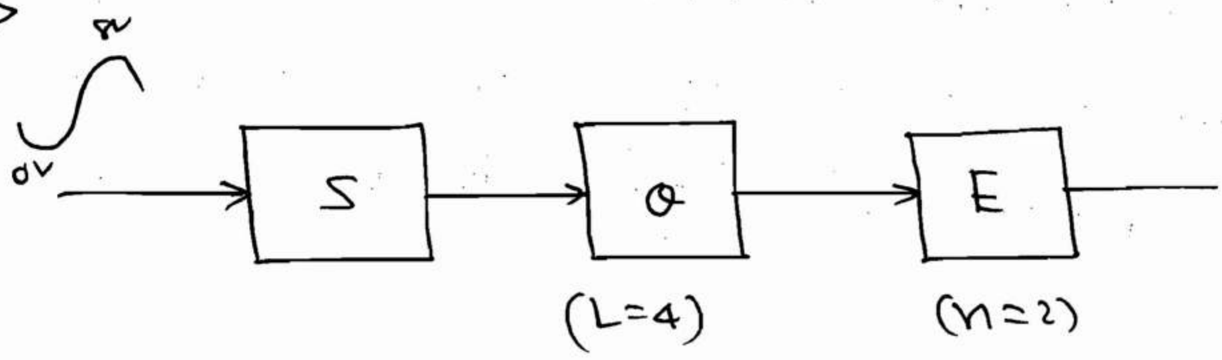
* Quantizer.

⇒ Consider the 2 bit PCM system and assume that amplitude varies from 0 to n

The max. sampled value applied to the Quantizer is 8V and the min. value is 0V. This entire range is divided into 4 equal step as shown in fig.



Step size = 2V.



S	Q	E
1.3	1	00
5.9	5	10
8	7	11

⇒ Consider an n-bit PCM System

where

→ n = no. of bits per Sample.

→ L = no. of Quantization level

$$\boxed{L = 2^n} \leftarrow \text{H.B}$$

$$\rightarrow \boxed{\Delta = \text{Step size} = \frac{V_{max} - V_{min}}{L}} \leftarrow \text{H.B}$$

$$\Delta = \frac{8-0}{4} = 2V$$

$$\rightarrow \boxed{\Delta = \frac{V_{PP}}{L}} \leftarrow \text{H.B.}$$

→ Q_e = Quantization error.

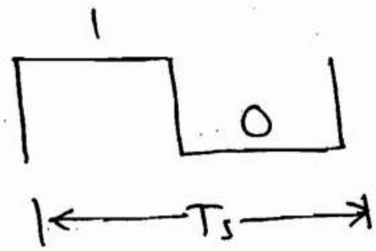
$$\boxed{Q_e = \text{Sampled value} - \text{Quantized value}}$$

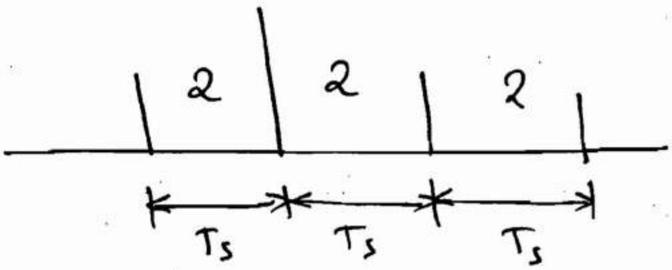
$$\Rightarrow \boxed{[Q_e]_{max} = \frac{\Delta}{2}} \left[Q_e \text{ varies from } -\frac{\Delta}{2} \text{ to } +\frac{\Delta}{2} \right].$$

↑ H.B.

$\Rightarrow$ T_b = bit duration

$$\boxed{T_b = \left(\frac{T_s}{n}\right) \text{ sec.}} \leftarrow \text{H.B.}$$





$T_b = T_s/2.$

$\Rightarrow$ R_b = Bit rate = bits/sec.

H.B.

$$\boxed{R_b = [\text{Sampling rate} \times n] \text{ bits/sec.}} \quad \text{— (1)}$$

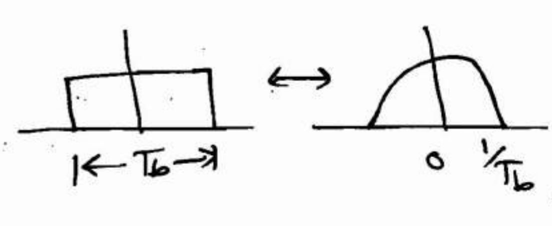
$$= \frac{\text{sample}}{\text{sec}} \times \frac{\text{bits}}{\text{samp.}} = \text{bits/sec.}$$

$$\rightarrow R_b = \frac{1}{T_s} \times n = \frac{n}{T_s} \text{ bps.}$$

H.B. $\rightarrow$

$$\boxed{R_b = \frac{1}{T_b} \text{ bps.}} \quad \text{— (2)}$$

$$\Rightarrow \boxed{(BW)_{max} = \left(\frac{1}{T_b}\right) \text{Hz.}}$$



Q-1 A signal whose amplitude varies from 0 to 10 V is Band limited to 4 KHz and transmitted through a channel using 5 bit PCM. The sampling rate is 50% higher than the nyquist rate. Calculate all parameters of a PCM system.

Soln:

$f_m = 4\ KHz$, $V_{max} = 10V$

$V_{min} = 0V$.

$n = 5$ bit

Sampling rate = 1.5 of nyquist rate

$= 1.5 \times (2 f_m)$

$= \frac{3}{2} \times 2 \times 4000$

Sampling rate $= 12000$ sample / sec $= \frac{1}{T_s}$

$\rightarrow L = 2^n = 2^5 = 32$ = Quantization level.

$\Delta = \frac{V_{max} - V_{min}}{L} = \frac{10-0}{32} = \frac{10}{32}$ V.

$\rightarrow [Q_e]_{max} = \frac{\Delta}{2} = \frac{10}{64}$ Volts.

T_b = bit duration $= \left(\frac{T_s}{n}\right)$ sec

$T_b = \frac{1}{12000 \times 5}$

$\therefore \quad R_b = 12000 \times 5$

$R_b = 60000$ bits/sec

$\boxed{R_b = 60 \text{ kbps.}}$

$$(BW)_{max} = \frac{1}{T_b} = 60 \text{ KHZ.}$$

→ The minimum BW of the channel to transmitt the PCM signal without any distortion is 60 KHZ.

Q-2 A vedio signal is Bandlimited to 4.5 MHZ and Transmitted through a Channel using PCM.

① Determine the Sampling rate if the signal is sampled at a rate of 20% higher than the nyquist rate.

② Determine the bit rate if the no. of quantization level is 1024.

Soln:

$f_m = 4.5$ MHZ

⇒ Nyquist rate $= 2f_m = 9 \times 10^6$ sample/sec.

→ Sampling rate $= 1.2 \times$ Nyquist rate

Samping rate $= 10.8 \times 10^6$ sample/rate.

② $L = 1024$

$\therefore L = 2^n \Rightarrow \boxed{n=10}$

bit rate $R_b = \left(\frac{1}{T_s} \times n\right)$

$\therefore R_b = 10.8 \times 10^6 \times 10$

$\therefore R_b = 10.8 \times 10^7$.

$\boxed{R_b = 108 \text{ MHz/sec.}}$

$(BW)_{max} = 108$ MHZ.

IMP

Q-3 A sinusoidal signal is Band limited to 5 KHZ and transmitted through a channel using pcm. The sampling rate is twice the nyquist rate. The max. quantization error should be 0.1 % of the peak signal amp. Determine the bit rate.

Soln:
$f_m = 5$ KHZ

$\Rightarrow$ Nyquist rate $= 2f_m = 10{,}000$ sample/sec.

$\Rightarrow$ Sampling rate $= 2$ (N.R.).

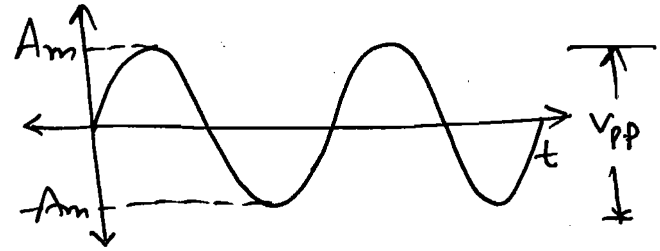
$= 20{,}000$ sample/sec.

$[Q_e]_{max} = \frac{\Delta}{2} = \frac{V_{p-p}}{2L}$.

=> Peak- value $V_P = A_m$

Peak-peak value

$V_{P-P} = 2A_m.$



$$[Q_e]_{max} = \frac{0.1}{100} \times V_P.$$

$$\therefore \frac{V_{P-P}}{2L} = \frac{0.1}{100} \times V_P.$$

$$\therefore \frac{2A_m}{2L} = \frac{0.1}{100} \times A_m$$

$$\therefore \boxed{L = 1000}$$

$$\Rightarrow 2^n = L = 1000 \Rightarrow \boxed{n = 10}$$

$$R_b = \left(\frac{1}{T_s} \times n\right) \text{ bps}$$

$$\therefore R_b = 20{,}000 \times 10.$$

$$\boxed{R_b = 0.2 \text{ Mbps.}} \Rightarrow \boxed{B_{max} = 0.2 \text{ MHz}}$$

(Q-4) A signal $m(t) = 4\cos 10^3 t \times 2\pi$ is sampled at Nyquist rate and transmitted through a channel using 3 bit PCM.

① Calculate all parameters.

② If the sampled values are 3.8, 2.8, 2.1, 1.7, −0.5, −3.2, −4.

Determine the quantizer o/p and quantization error for each sample.

$\underline{Sol^n}$: ① $V_p = A_m = 4$ V.

$V_{p-p} = 2 \times V_p = 8V$.

$V_{max} = 4V$, $V_{min} = -4V$.

→ $n = 3$ bit

$L = 2^n = 2^3 = 8$ level.

$\Delta = \frac{V_{p-p}}{L} = \frac{8}{8} = 1\ V$ = step size.

$[Qe]_{max} = \frac{\Delta}{2} = \frac{1}{2} = 0.5\ V$.

→ $f_m = 1$ KHZ

Samping rate = Nyquist rate = $2f_m$.

∴ Samping rate $= \frac{1}{T_s} = 2000$ sample/sec.

→ Bit rate $R_b = \frac{1}{T_s} \times n$

$\Rightarrow R_b = 2000 \times 3 = 6000$ bps

$R_b = 6$ KbPS.

$(BW)_{max} = \frac{1}{T_b} = 6$ KHZ.

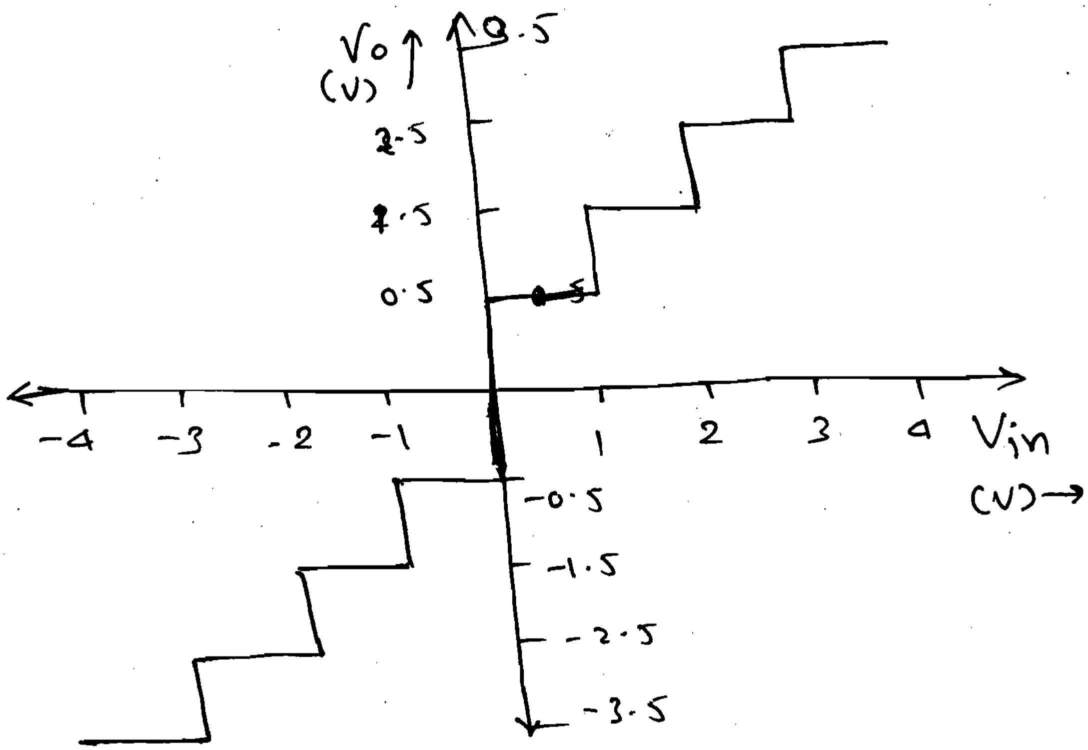
→ Bit duration $= T_b = \frac{T_s}{n} = \frac{1}{6000}$ sec.

② Sample values are 3.8, 2.8, 2.1, 1.7,

S(V)	Q(V)	Q_e(V) $= S - Q$	E
3.8	3.5	0.3	111
2.1	2.5	−0.4	110
1.7	1.5	0.2	101
−0.5	−0.5	0	011
−3.2	−3.5	0.3	000
−4	−3.5	−0.5	000

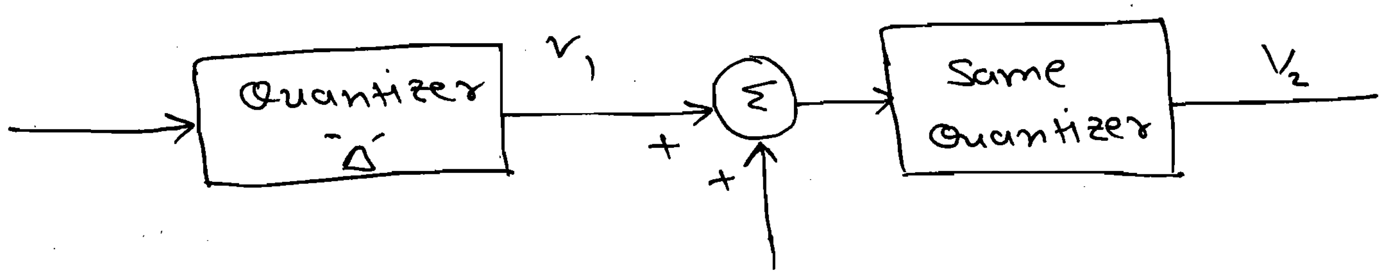
Q-level		Encoder O/P.
−3.5	→	000
−2.5	→	001
−1.5	→	010
−0.5	→	011
+0.5	→	100
+1.5	→	101
+2.5	→	110
+3.5	→	111

(3) Transfer Chara.



Q-5 Consider a system as shown in fig.

Quantizer Stepsize = Δ



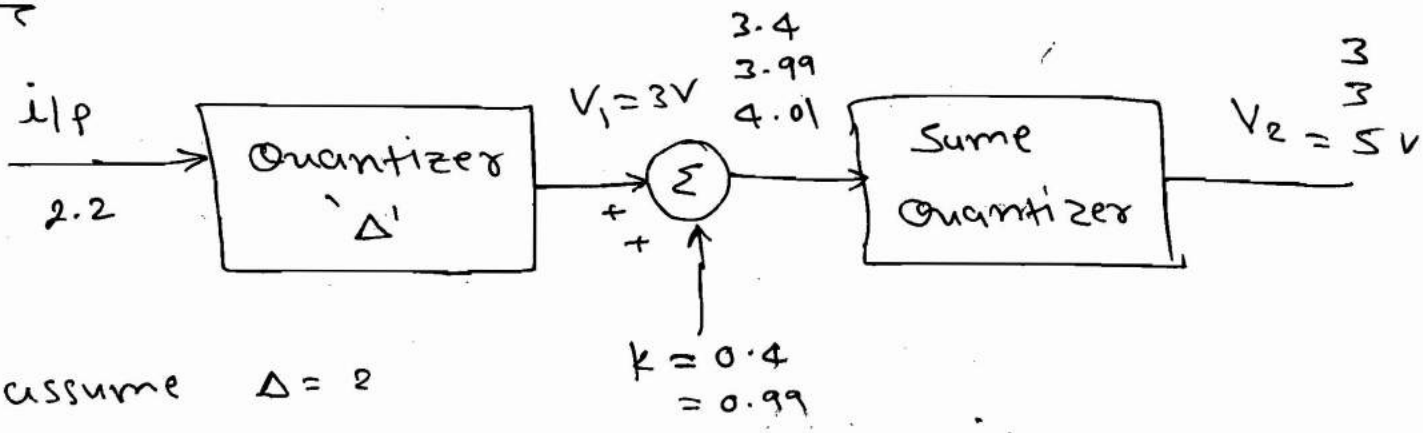
value of K that

V_2 are different.

(A) Δ (B) 2Δ

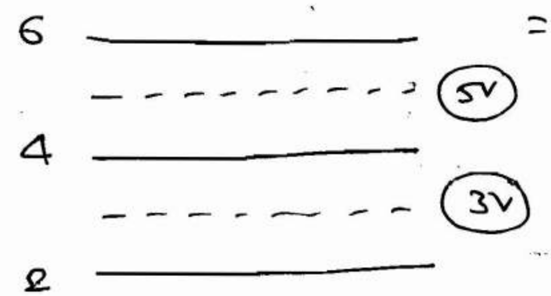
(C) $\frac{\Delta}{2}$ (D) Δ^2.

Sol^n:



assume $\Delta = 2$

let, i/p = 2.2 V



$K = 1.01 = \frac{\Delta}{2}$.

So, Ans is $\frac{\Delta}{2}$.

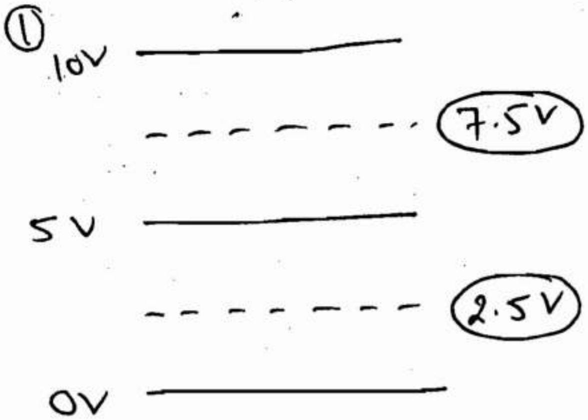
Q-6 The i/p to the Quantizer varies from 0 to 10 volts.

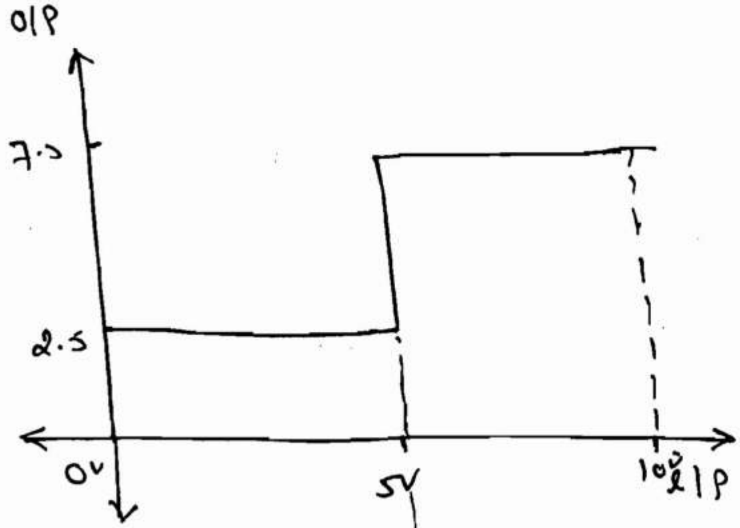
① When the input lies bet^n 0 to 5V the o/p is 2.5 V and from 5 to 10 o/p lies is 7.5V. Sketch the transfer chara. and Variation of Quantization error.

② When the i/p lies bet^n 0 to 5V. The o/p is 2V and when the i/p bet^n 5 to 10V the o/p is 9V. Sketch the ... chara. and Variation of

Solⁿ:

①





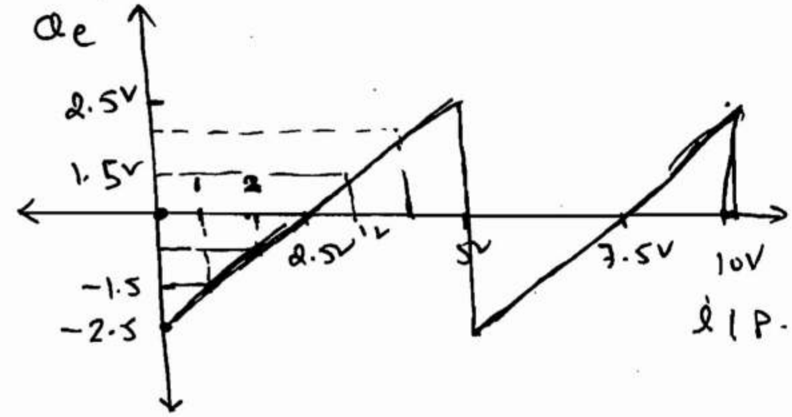
Transfer chara.

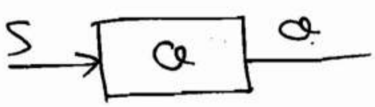
Step size 'Δ' = 5V

$[Q_e]_{max} = \frac{\Delta}{2} = 2.5V$

Q_e varies betⁿ

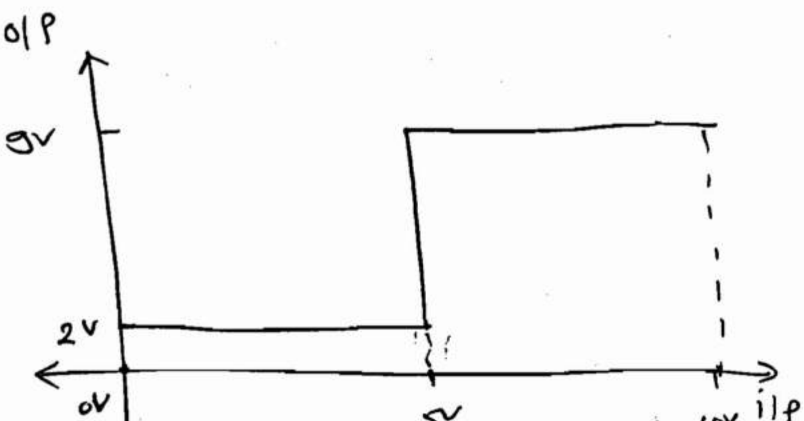
$\frac{\Delta}{2}$ to $\frac{-\Delta}{2}$ i.e. 2.5V to −2.5V





(2) $Q_e = S - Q$ = i/p − o/p

S	Q
0	2.5
1	2.5
2	2.5



②