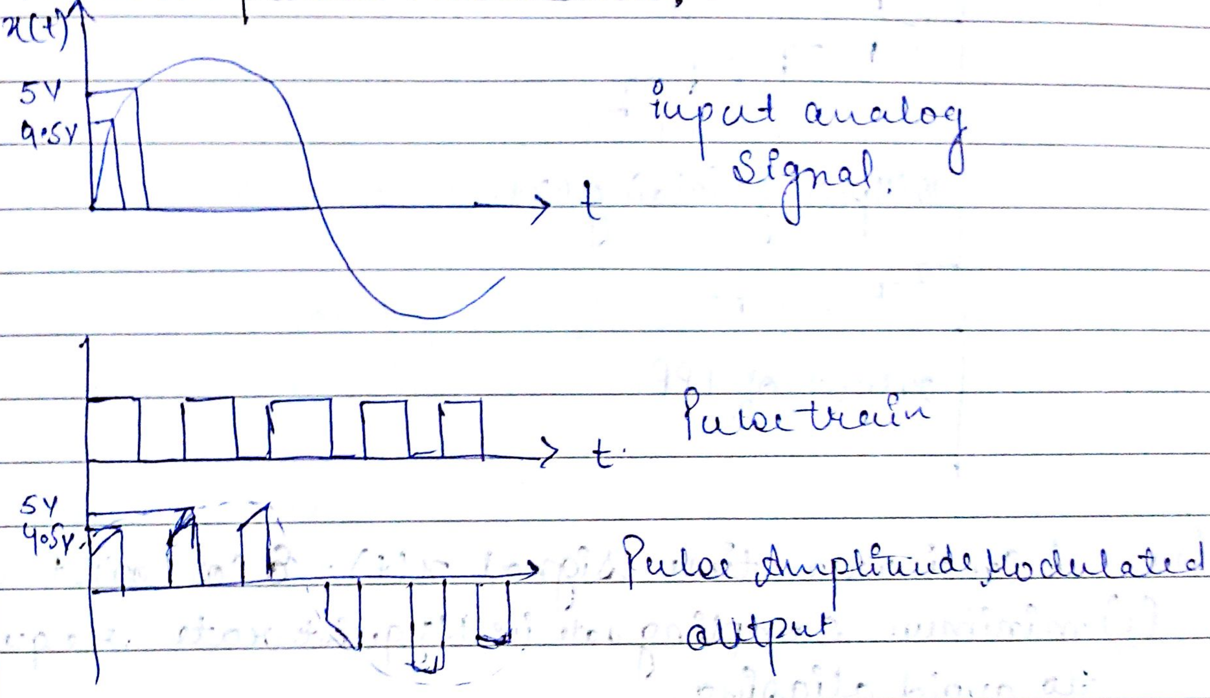
PAM : Pulse Amplitude Modulation

Pulse Modulation Technique :

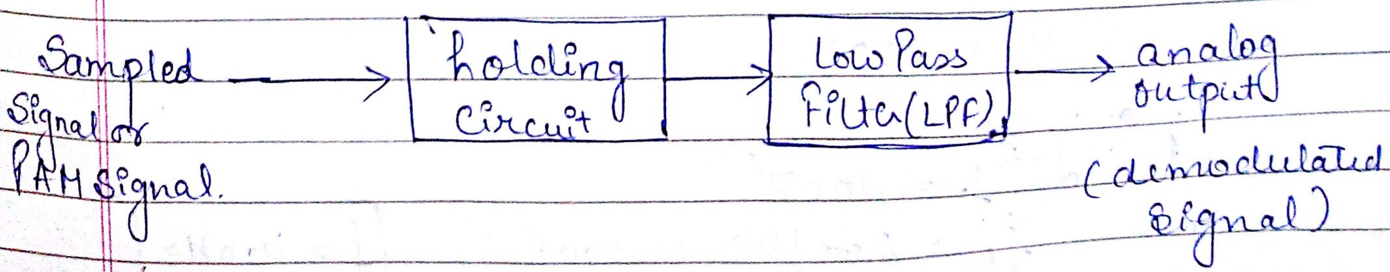
(1) PAM – Pulse Amplitude Modulation
(2) PWM – Pulse width Modulation
(3) PPM – Pulse phase Modulation

(1) Pulse Amplitude Modulation :



- Information content lies in amplitude of the signal
- PAM is similar to Natural Sampling. ~~Same~~ for
- PAM modulator is also flat top sampling circuit

PAM Demodulator :



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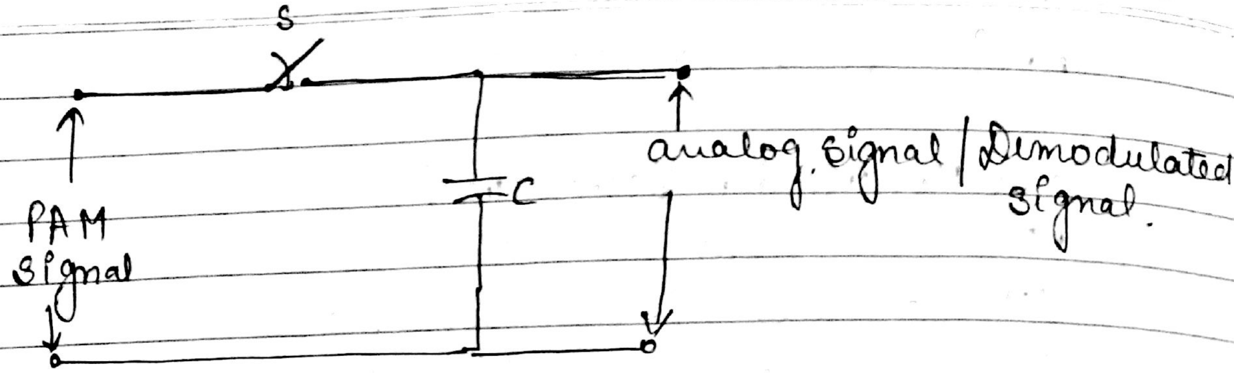
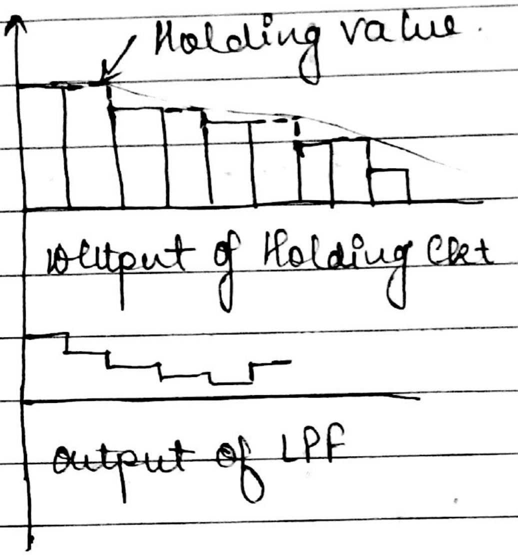




Que A Continuous time signal $x(t) = 8 \cos 200\pi t$ determine
(i) minimum sampling rate i.e Nyquist rate required to avoid aliasing.
(ii) If the sampling is 400Hz what is the discrete time signal, $x[n]$ or $x[nT_s]$ obtain after sampling
(iii) If sampling frequency $f_s = 150Hz$ what is the discrete time signal for $x[n]$ or $x[nT_s]$ obtain after sampling.

Sol

$$x(t) = 8 \cos 200\pi t$$

$$\omega_1 = 200\pi$$

frequency

$$2\cancel{\pi} f_1 = 200\cancel{\pi}$$

$$f_1 = \frac{\cancel{200}^{100}}{\cancel{2}} = 100Hz \qquad \boxed{f = 100Hz}$$

Nyquist Rate $f_s = 2f_m$

$f_m = 100 Hz$

$f_s = 2 \times 100 = 200 Hz$

(ii) $x(t) = 8\cos 200\pi t$

for Discrete signal $x(n) = A \cos 2\pi F n \longrightarrow$ no of intervals

$\downarrow$ frequency

$$F = \frac{100}{400} = \frac{1}{4}$$

$$x(n) = 8\cos \cancel{2}\pi \frac{1}{\cancel{4}_2} n$$

$$= 8\cos \frac{\pi n}{2} = 8\cos \frac{n\pi}{2}$$

(iii) $f_s = 150 Hz$

$$F = \frac{\overset{2}{\cancel{100}}}{\underset{3}{\cancel{150}}} = \frac{2}{3}$$

$$x(n) = 8\cos 2\pi \frac{2}{3} n$$

$$8\cos \frac{4\pi n}{3} = 8\cos \frac{4n\pi}{3}$$

Transmission Bandwidth in PAM:

Drawback of PAM:
we cannot transmit these signal directly through channel.

~~Due.~~
~~We can transmit more information~~

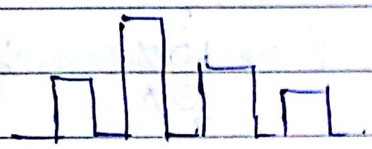
Advantage:

① Multiplexing.

- Time division multiplexing: uses different time intervals for diff. info.

- Frequency multiplexing: divide the frequency band.

Multiplexing is possible using PAM.



$\tau << T_s$ —— ① (Sampling interval (T_s) time period between any two samples)

$f_s \geq 2f_m$ —— ②

$\frac{1}{T_s} \geq 2f_m$

$T_s \leq \frac{1}{2f_m}$

$\therefore \tau << T_s \leq \frac{1}{2f_m}$ — (3)

$f_{max} = \frac{1}{\tau+\tau} = \frac{1}{2\tau}$ — (4)

Transmission Bandwidth;

$B.W \geqslant f_{max}$

$f_{max} = \frac{1}{2\tau}$; $BW \geqslant \frac{1}{2\tau}$

$\tau << \frac{1}{2f_m}$.

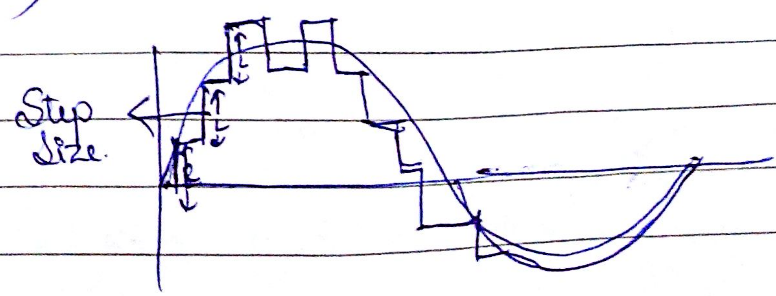
$\boxed{BW \geqslant \frac{1}{2\tau} >> f_m}$ = $\boxed{BW >> f_m}$

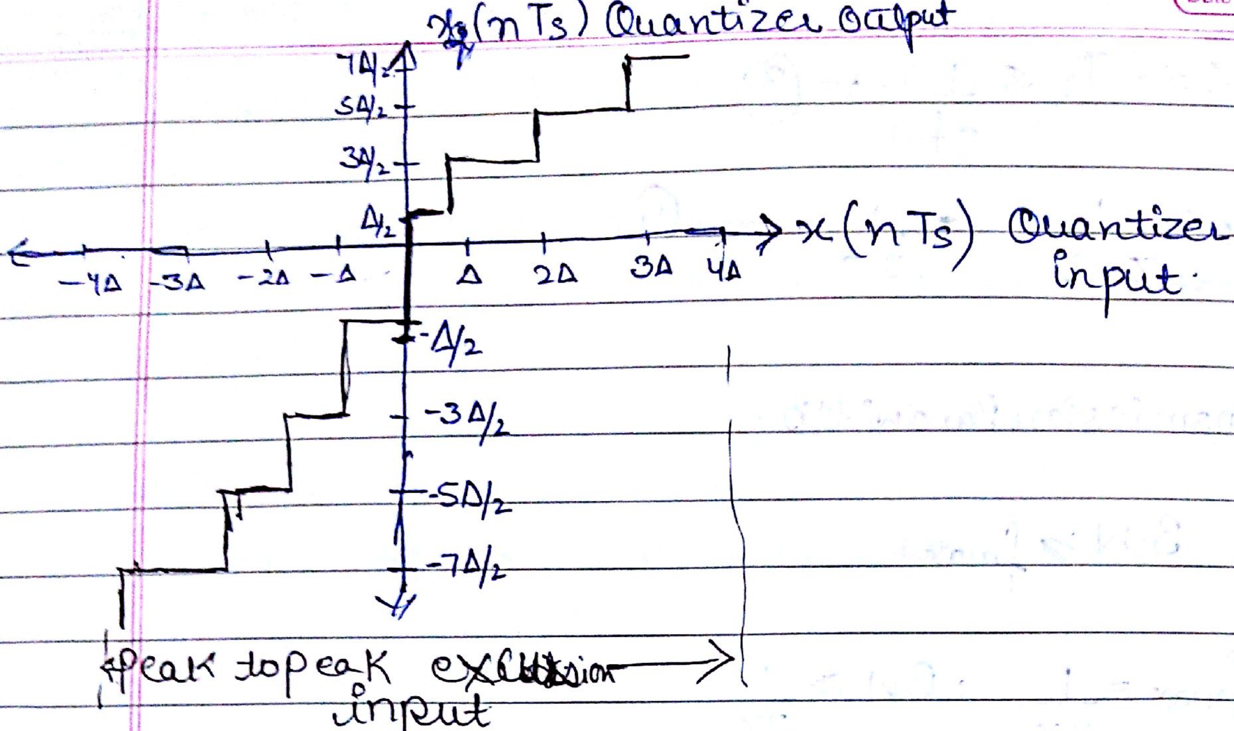
II Quantization: A particular voltage is assign ~~for~~ to a continous wave is called Quantization.

We use Quantizer for Quantization

Quantizer

- uniform Quantize (step size remain same)
- non-uniform quantizer (Step size varies)



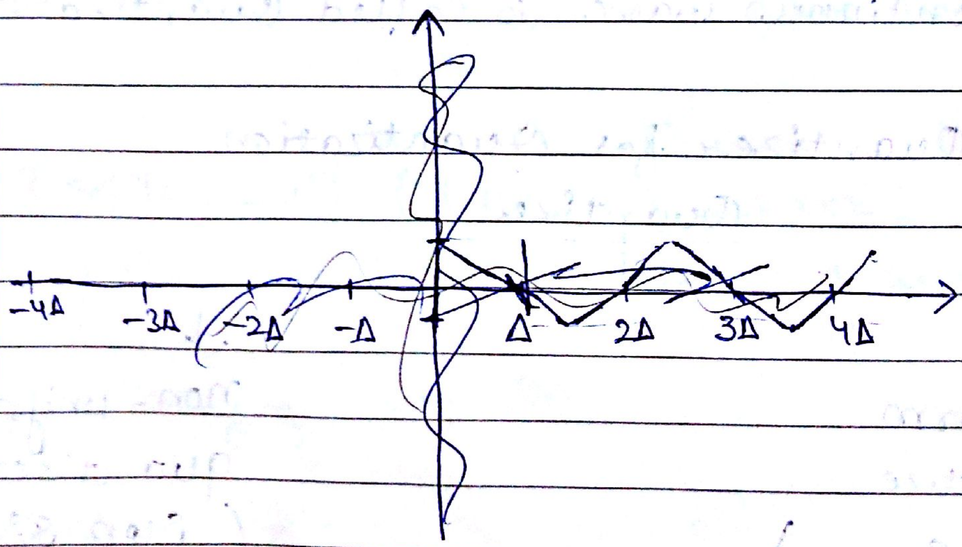


Transfer characteristic of Quantizer.

if $x(nTs) = 4\Delta$ then, $x_q(nTs) = +\frac{7\Delta}{2}$

if $x(nTs) = -4\Delta$; then. $x_q(nTs) = -\frac{7\Delta}{2}$.

$\therefore$ max quantization error $= \pm\frac{\Delta}{2}$



M.D.

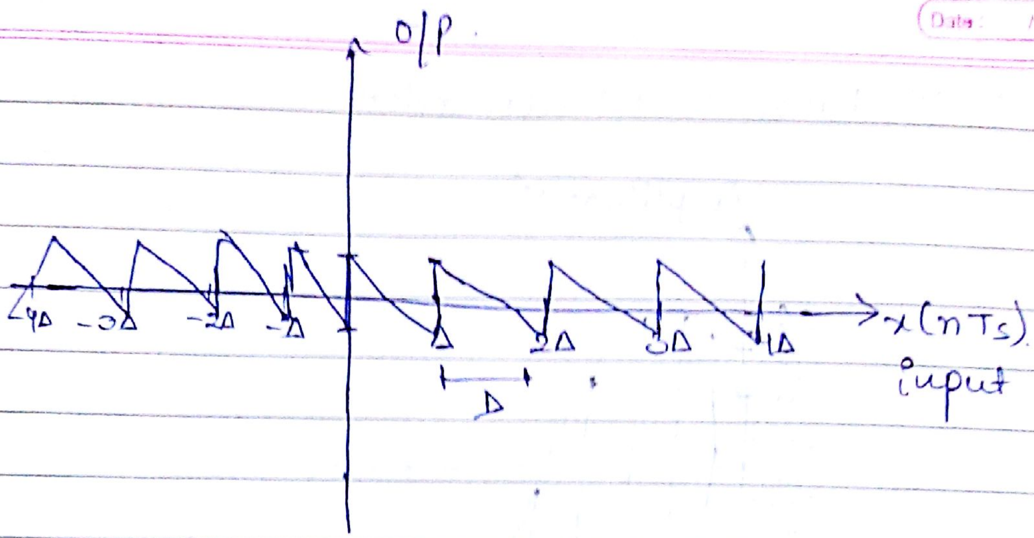


Fig: Variation of quantization error with output input

Quantization error (ε)

$$\varepsilon = x_q(nT_s) - x(nT_s)$$

when $x(nT_s) = 0$; $x_q(nT_s) = +\Delta/2$ or $-\Delta/2$

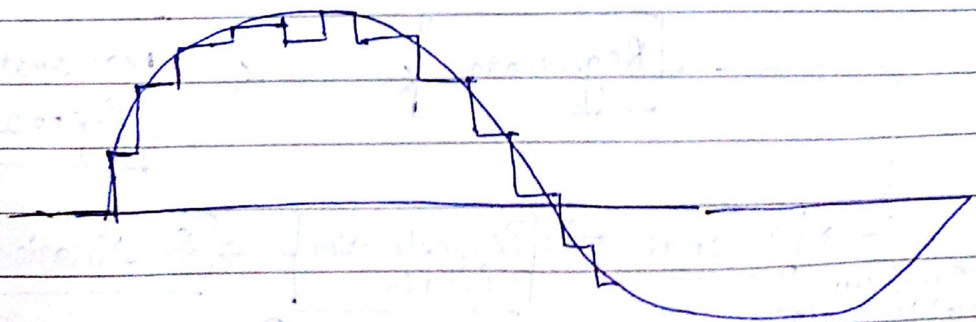
if $x_q(nT_s) = +\Delta/2$.

$$'\varepsilon' = \Delta/2 - 0 = \frac{\Delta}{2}$$

$\Delta < x(nT_s) < 2\Delta$; $x_q(nT_s) = 3\Delta/2$.

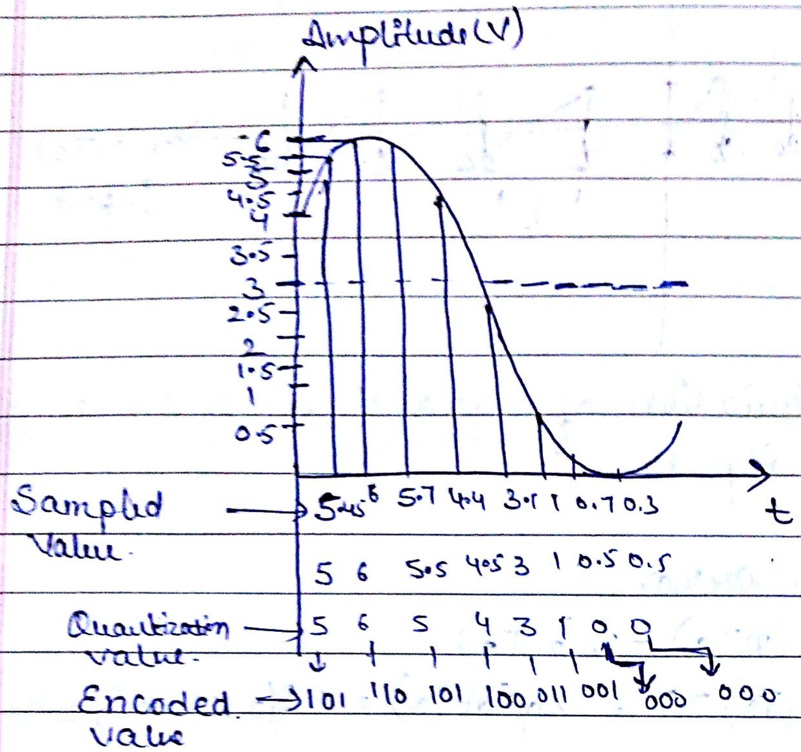
or $-\Delta < x(nT_s) < -2\Delta$; $x_q(nT_s) = -3\Delta/2$

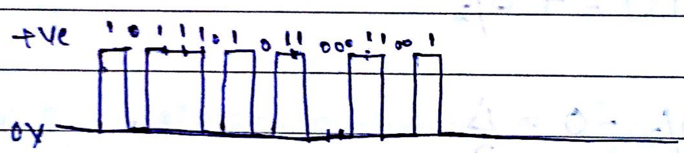
$$\therefore \varepsilon_{max} = \pm\frac{\Delta}{2} = \left|\frac{\Delta}{2}\right|$$



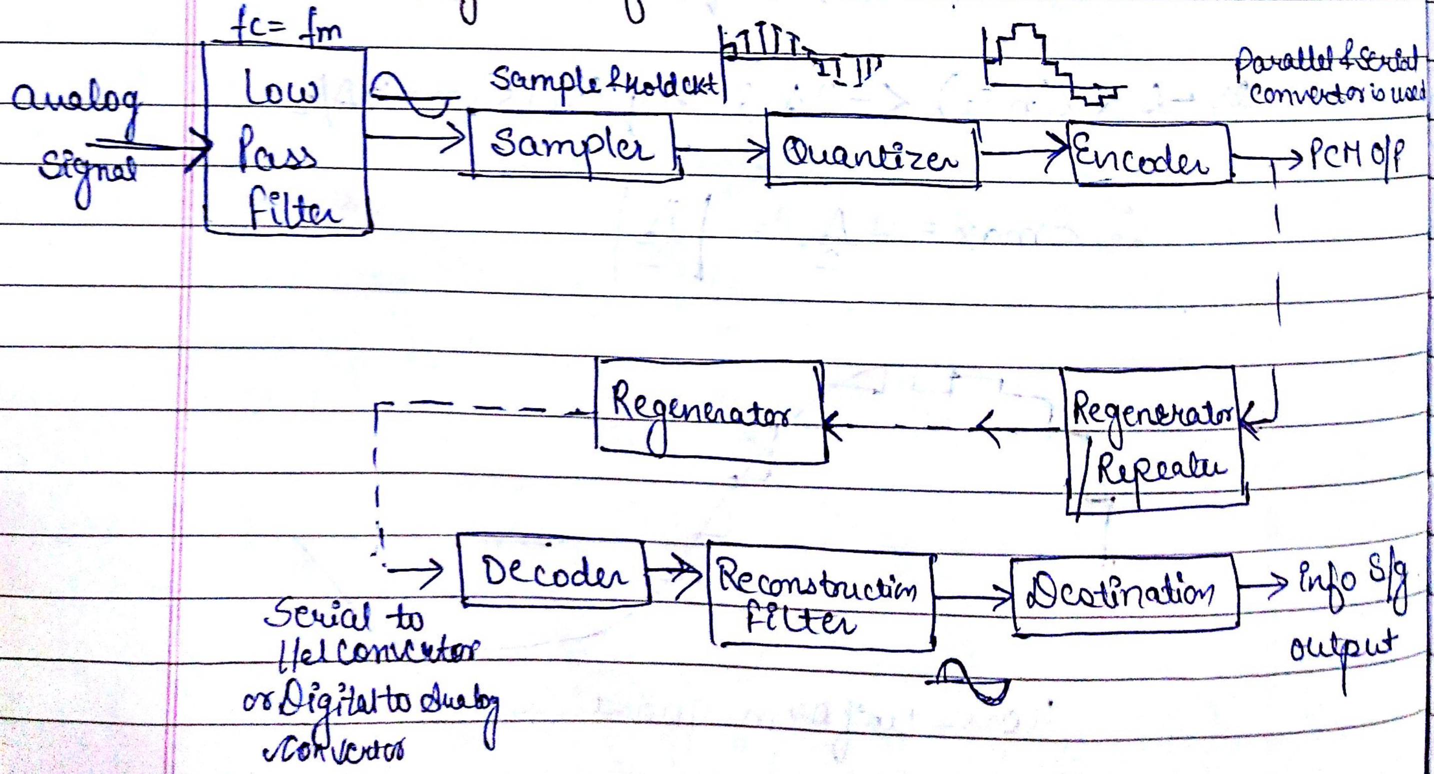
non-uniform quantizer

→ PCM (Pulse code Modulation)





Block diagram of PCM :



Page No.
Date: / /201

Transmission Bandwidth in PCM :-

If the quantizer use 'v' = no. of binary digits to represent each level

$\boxed{q = 2^v}$ no of bits quantize per level

if $V = 4$ then $q = 2^4 = 16$ levels.

No of bits per samples = V

No of ~~bi~~ samples per second = f_s

Number of bits per second = $V \times f_s$

No of bits per second is known as signaling rate of PCM and it is denoted by 'r'.

$\boxed{r = Vf_s}$

where $f_s \geq 2f_m$

Transmission Bandwidth in PCM

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

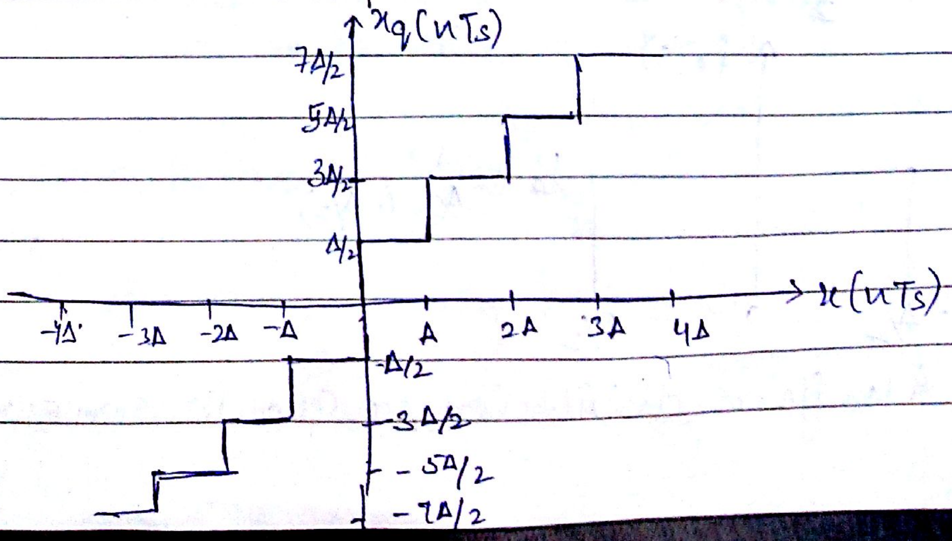
$r = Vf_s$

$BW \geq \frac{1}{2} Vf_s$

$f_s \geq 2f_m$

$BW \geq Vf_m$

Quantization Error / Noise in PCM :-



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quantization ('ε') = $x_q(nT_s) - x(nT_s)$
error
= [$-x_{max}$ to x_{max}]

if input $x(nT_s) = 4V$, $x_q(nT_s) = \frac{7\Delta}{2} = x_{max}$

input = $-4V$, $x_q(nT_s) = -\frac{7\Delta}{2} = -x_{max}$

Total Amplitude range = $x_{max} - (-x_{max})$
= $2x_{max}$

Stepsize $\Delta = \frac{x_{max} - (-x_{max})}{q} = \frac{2x_{max}}{q}$

↳ no of quantise level for a uniform quantise

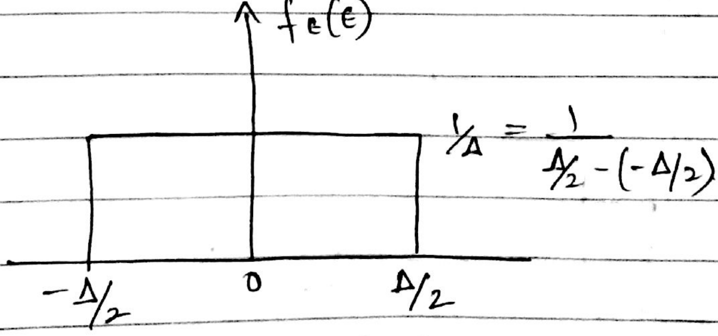
If signal is normalised to minimum or maximum value

$x_{max} = 1$, $-x_{max} = -1$

∴ Step size 'Δ' = $\frac{2}{q}$ (for normalised signal)

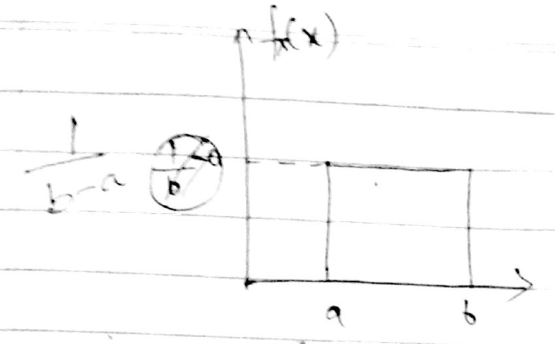
$\varepsilon_{max} = \pm\frac{\Delta}{2} = \left|\frac{\Delta}{2}\right|$ = output − input

i.e $-\frac{\Delta}{2} \leq \varepsilon_{max} \leq +\frac{\Delta}{2}$



A uniform distribution for quantization error

Meghna Dhalaria



A uniform distribution.

uniformly Distributed

The PDF of Random Variable 'X' is given by.

$$f_X(x) = \begin{cases} 0 & \text{for } x \leq a \\ \frac{1}{b-a} & \text{for } a < x \leq b \\ 0 & \text{fo } x > b \end{cases}$$

The PDF for quantization error (ε) is ;

$$f_\varepsilon(\varepsilon) = \begin{cases} 0 & \text{for } \varepsilon \leq -\frac{\Delta}{2} \\ \frac{1}{\Delta} & \text{for } -\frac{\Delta}{2} < \varepsilon \leq \Delta/2 \\ 0 & \text{for } \varepsilon > \Delta/2 \end{cases}$$

Meg

The S/N (signal to Noise ratio) for the quantizer is defined as:-

$$\frac{S}{N} = \frac{\text{Signal Power (normalized)}}{\text{Noise Power (normalized)}}$$

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

$V^2_{noise} =$

The mean sq. value of 'X' is given by:-

$$\overline{X^2} = E[X^2] = \int_{-\infty}^{\infty} x^2 f_X(x)\, dx$$

$$E[\epsilon^2] = \int_{-\infty}^{\infty} \epsilon^2 f_\epsilon(\epsilon)\, d\epsilon = \int_{-\Delta/2}^{\Delta/2} \epsilon^2 \times \frac{1}{\Delta}\, d\epsilon$$

$$= \frac{1}{\Delta}\left[\frac{\epsilon^3}{3}\right]_{-\Delta/2}^{\Delta/2} = \frac{1}{3\Delta}\left[\left(\frac{\Delta}{2}\right)^3 - \left(-\frac{\Delta}{2}\right)^3\right].$$

$$= \frac{1}{3\Delta}\left[\frac{\Delta^3}{8} + \frac{\Delta^3}{8}\right] = \frac{1}{3\Delta}\left[\frac{\cancel{2}\Delta^{\cancel{3}2}}{\cancel{8}_4}\right] = \frac{\Delta^2}{12}$$

Noise Power (Normalized) $= \frac{V^2_{noise}}{R}$ $[R = 1]$

$= V^2_{noise} = \frac{\Delta^2}{12}$ [for linear quantizer

S/N of the linear Quantizer:

$$\frac{S}{N} = \frac{\text{Normalized signal Power}}{\text{Normalized Noise power}} = \frac{P}{\Delta^2/12} \quad \text{--- (i)}$$

$q = 2^\nu$.

$ip = x(nT_s)$; $-x_{max}$ to $+x_{max}$

Total Amplitude Range $= +x_{max} - (-x_{max})$
$= 2x_{max}$

Now Step-size will be;

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

Put ~~this~~ value of eq (2) in eq (1)

$$\frac{S}{N} = \frac{P}{\left(\frac{2x_{max}}{2^{v}}\right)^2 / 12} = \frac{P}{\left(\frac{4x^2_{max}}{2^{2v}}\right) / 12}$$

$$\frac{\overset{3}{\cancel{12}}\, P \cdot (2^{2v})}{4x^2_{max}} = \frac{3P \cdot (2^{2v})}{x^2_{max}}$$

For normalized $x_{max} = 1$

$$= \cancel{3P \cdot 2^{2v}} = \frac{3P \cdot (2^{2v})}{1^2} = 3P \cdot (2^{2v})$$

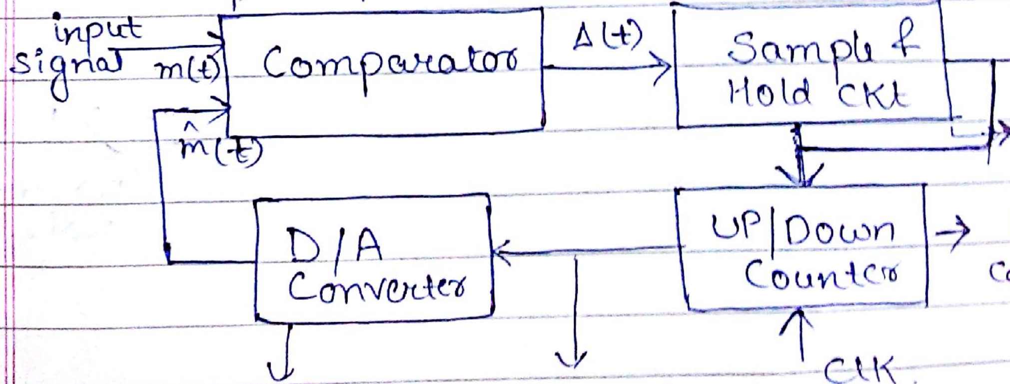
$$\left(\frac{S}{N}\right)_{dB} = 10 \log_{10} [3P \cdot (2^{2v})] \; ; \; P \leq 1 \; ;$$

$$\left(\frac{S}{N}\right)_{dB} = 10 \log_{10} (3 \times 2^{2v})$$

$$= (4.8 + 6v) \; dB$$

DELTA MODULATION :-

using subtraction we compare two signal & output of comparator is denoted by Δt



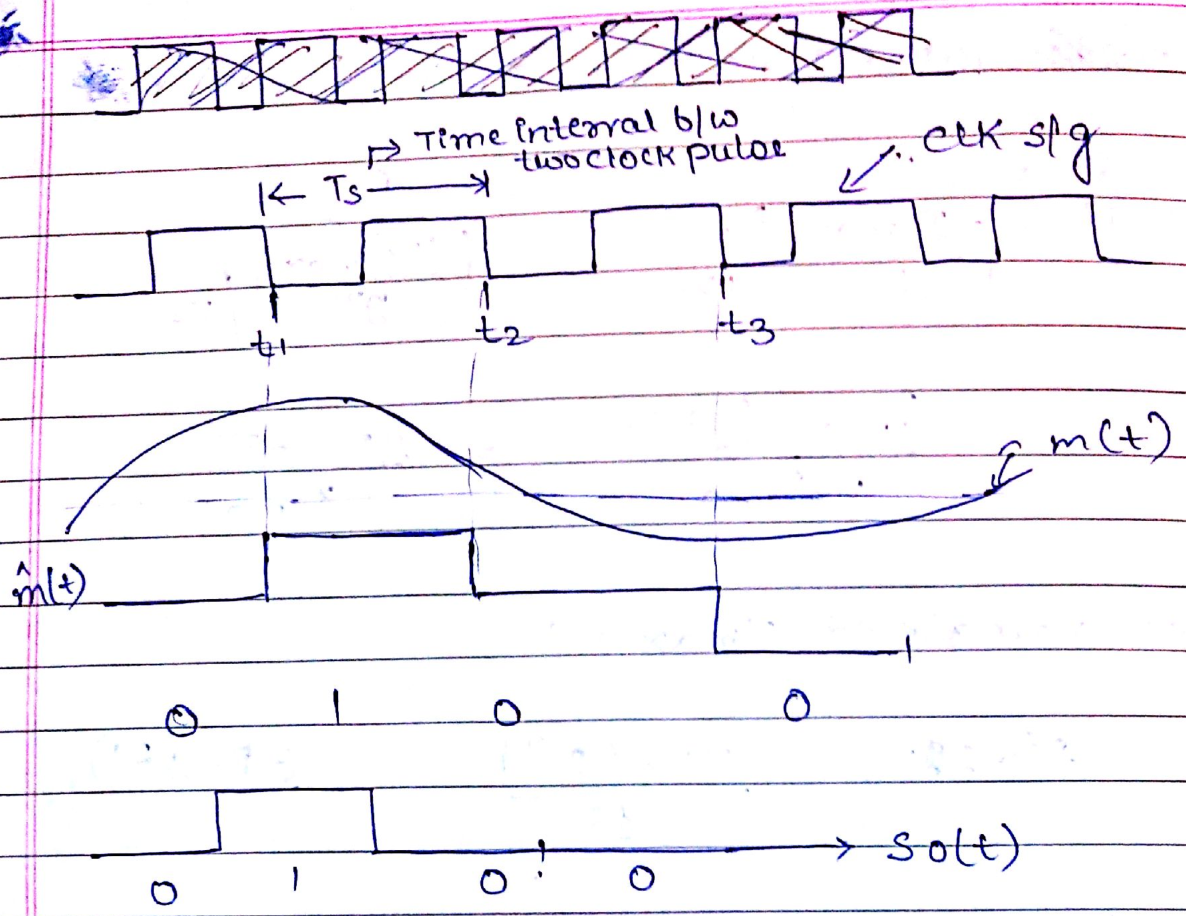
it hold the value of comparator

if $m(t) > \hat{m}(t)$ then counter will be increment by 1 mean it will count upward

if $m(t) < \hat{m}(t)$ then counter will be decrement by 1 mean it will count downward

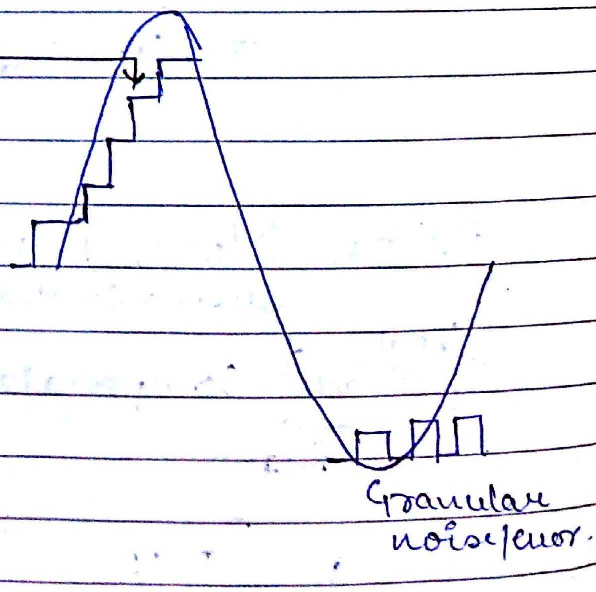
Covert the Digital in Analog form

Output is in Binary digit

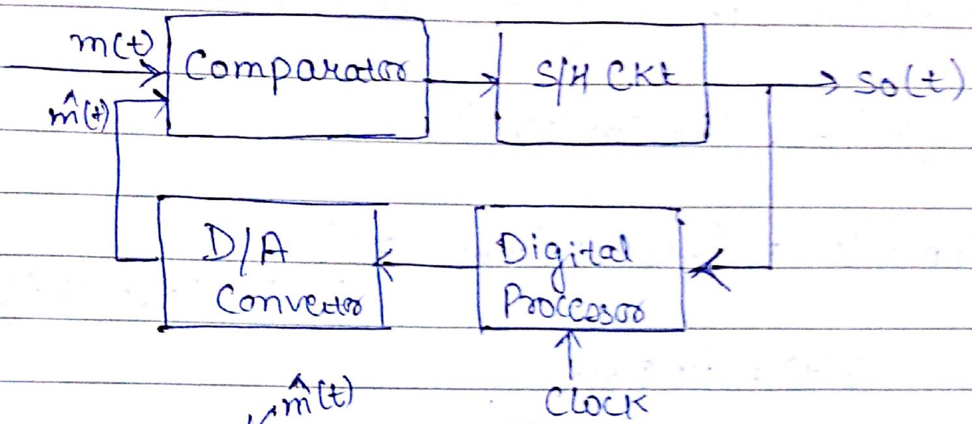


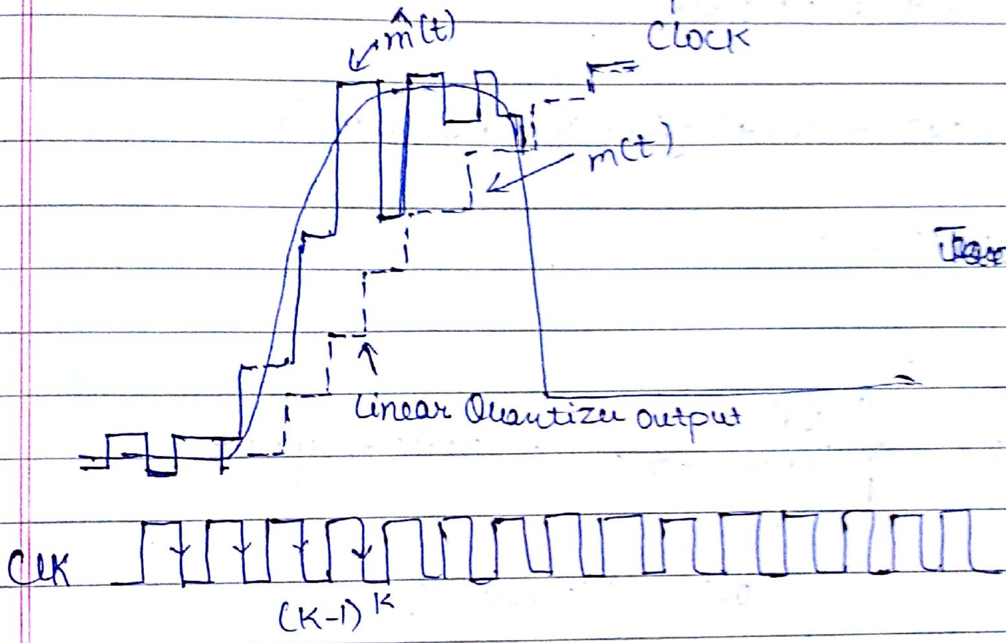
Advantage:
- Bandwidth will be smaller than PCM

Disadvantage:
- Slope overload error
- Granular noise/error



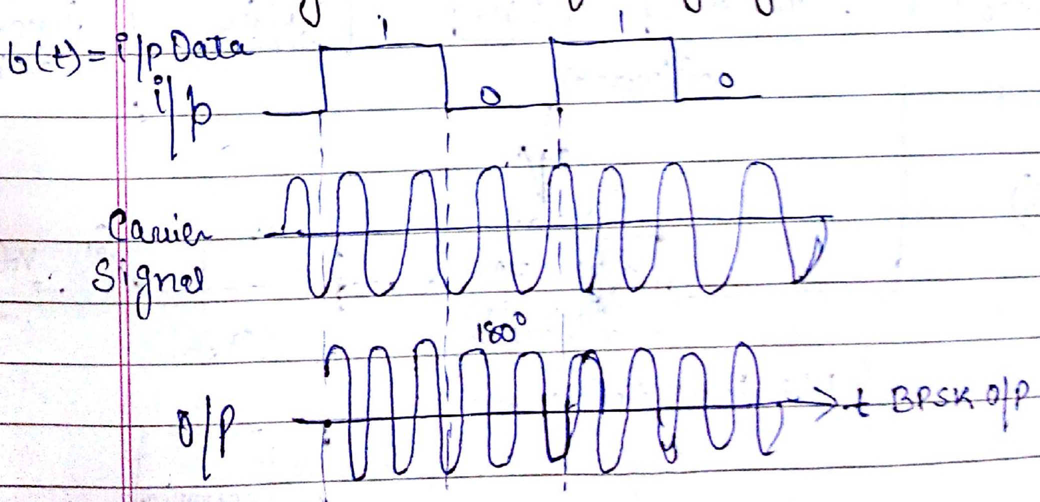
Adaptive Delta Modulation :-





~~Tarab~~ Tavd & Schilling

Binary Phase Shift Keying (BPSK):-



when value change from 1 to 0 it give 180° phase shift.

Amplitude = A for the transmitted Signal.

Power of Signal $P_s = \frac{1}{2} A^2$, $A = \sqrt{2P_s}$

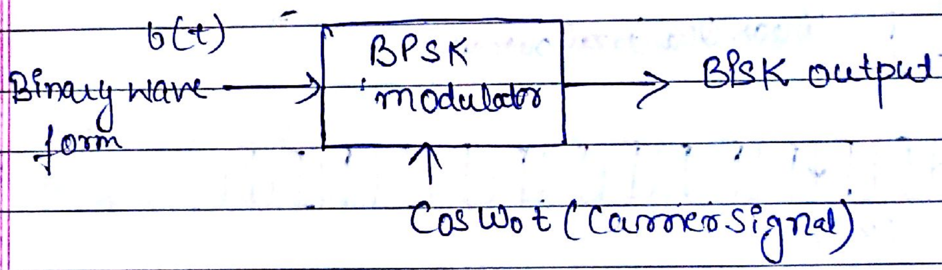
$V_{BPSK}(t) = \sqrt{2P_s} \cos(\omega_0 t)$.

Or $V_{BPSK}(t) = \sqrt{2P_s} \cos(\omega_0 t + \pi)$ → Phase shift → 180°

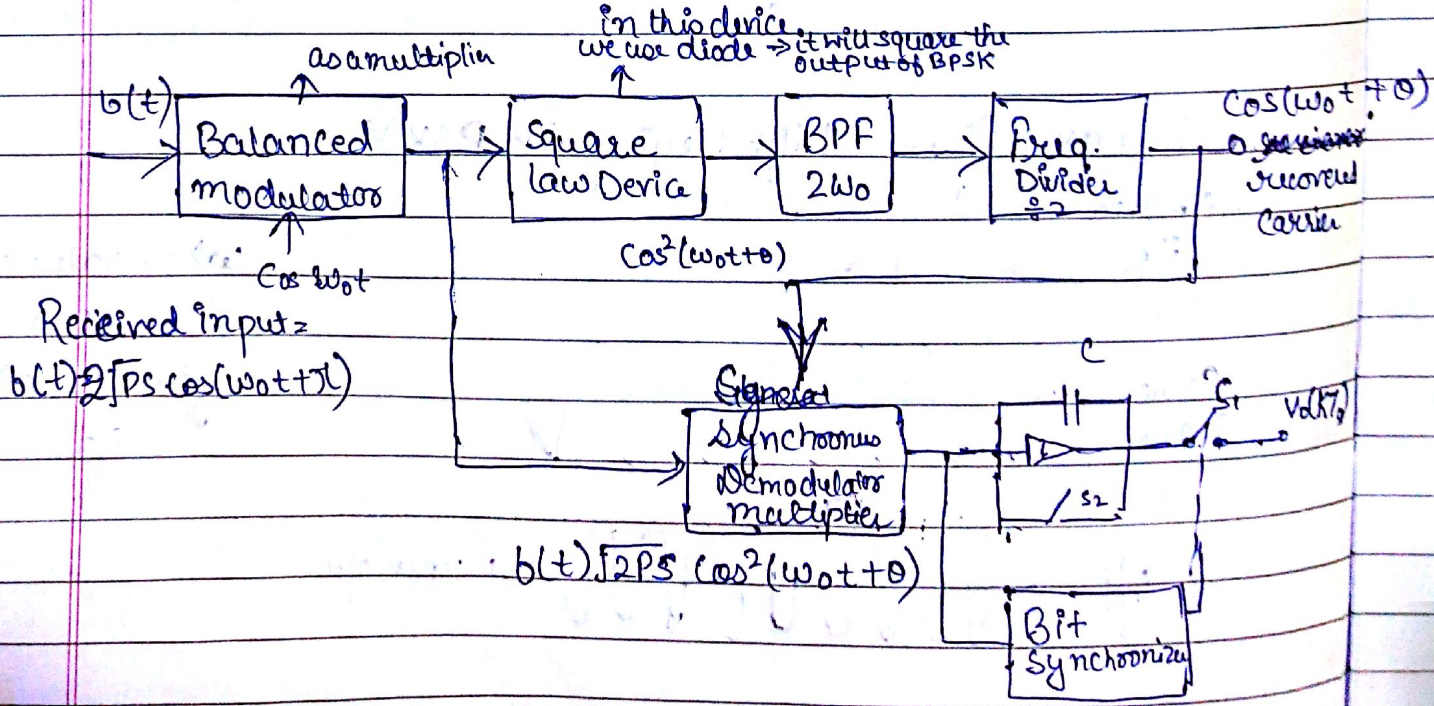
$b(t)$ = i/p Data.

$V_{BPSK}(t) = b(t) \cdot \sqrt{2P_s} \cos(\omega_0 t + \pi)$

$b(t) = 1$



BPSK Receiver :-



Page No.
Date : / /201

③ BPF → Band pass filter
Sq law device output = $\cos^2(\omega_0 t+\theta)$
$$= \frac{1+\cos 2(\omega_0 t+\theta)}{2}$$
$$= \underbrace{\frac{1}{2}}_{\text{D.C Component}} + \frac{1}{2}\cos 2(\omega_0 t+\theta)$$

It only pass the component which is centered around $2\omega_0$ and other are ~~rejec~~ component are rejected by the filter
The output of BPF is $\cos 2(\omega_0 t+\theta)$

④ Frequency Divider ÷2 = It divide the output of BPF is divided by 2
$$\frac{\cos \cancel{2}(\omega_0 t+\theta)}{\cancel{2}} = \cos(\omega_0 t+\theta)$$

In this operational Amplifier is ~~act~~ used as integrator

we use a feedback capacitor so that it as ~~as~~ a Integrator.
it integrate the output of Synchronus demodulator multiplier
Bit Synchronizer: It will synchronize ~~or~~ detect the start of the bit or the end of the bit

If the ~~integra~~ input is 1 given to Bit Synchronizer then S_1 is closed & give the output

If the input is 0 ~~then~~ is given to Bit Synchronizer ~~Discharge~~ then S_1 act as open & no output is obtain.

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$K-1$ = Previous bit
K = Present bit.

Page No
Date: / /201

Bit Synchronizer:

$$V_0(KT_b) = b(KT_b)\sqrt{2P_s}\int_{(K-1)T_b}^{KT_b} \frac{1}{2}\,dt + b(KT_b)\int_{(K-1)T_b}^{KT_b} \frac{1}{2}\cos 2(\omega_0 t + \theta)$$

$$= b(KT_b)\sqrt{\frac{2P_s}{4}}\left[\int_{(K-1)T_b}^{KT_b} 1\cdot dt + \int_{(K-1)T_b}^{KT_b} \cos 2(\omega_0 t + \theta)\,dt\right]$$

$$= b(KT_b)\sqrt{\frac{2P_s}{4}}\left[\left[t\right]_{(K-1)T_b}^{KT_b} + 0\right]$$

$$= b(KT_b)\sqrt{\frac{\cancel{2}P_s}{\cancel{4}\,2}}\left[KT_b - (K-1)T_b\right]$$

$$= b(KT_b)\sqrt{\frac{P_s}{2}}\left[\cancel{KT_b} - \cancel{KT_b} + T_b\right]$$

$$= b(KT_b)\sqrt{\frac{P_s}{2}}\left[T_b\right] = b(KT_b)\sqrt{\frac{P_s}{2}} \times T_b$$

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Page No.
Date: / /201

Q A television signal having a bandwidth of 4.2 MHz is transmitted using binary PCM system given that no of quantization levels is 512 determine
1. Code word length
2. Transmition bandwidth
3. Final bit Rate
4. Output signal to quantization noise Ratio

Sol (1)
$$q = 2^{v}$$
$$512 = 2^{v}$$
$$(2)^{9} = 2^{v}$$
$$\boxed{v = 9}$$

(2)
$$B = v f_m$$
$$= 9 \times 4.2$$
$$= 37.8 \text{ MHz}$$

(3)
$$R = v f_s$$
$$= 9 \times 8.4 = 75.6$$
$f_s = 2 f_m$.
$f_s = 2 \times 4.2 = 8.4 \text{ MHz}$

(4)
$$\left(\frac{S}{N}\right) = 4.8 + 6V$$
$$= 4.8 + 54$$
$$= 58.8 \text{ dB}$$

Q A signal having bandwidth 3.5 KHz is sampled Quantized and coded by a PCM system. Decoded signal then transmitted over a transmission channel a supporting a transmission rate of 50 Kilo bits per sec. Determine the max signal to Noise Ratio that can be obtained by these signal the Input signal has peak to peak value of 4V and r.m.s value of 0.2

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Sol

$B = 3.5\,MHz$

$R = 4V$, $rms = 0.2$

$r = Vfs \Rightarrow fs = 2 \times 3.5\,MHz$

$= 7.0\,KHz$

$50\,KBit/sec = VX$

$V = \frac{50}{7} = 7.14 = 8$

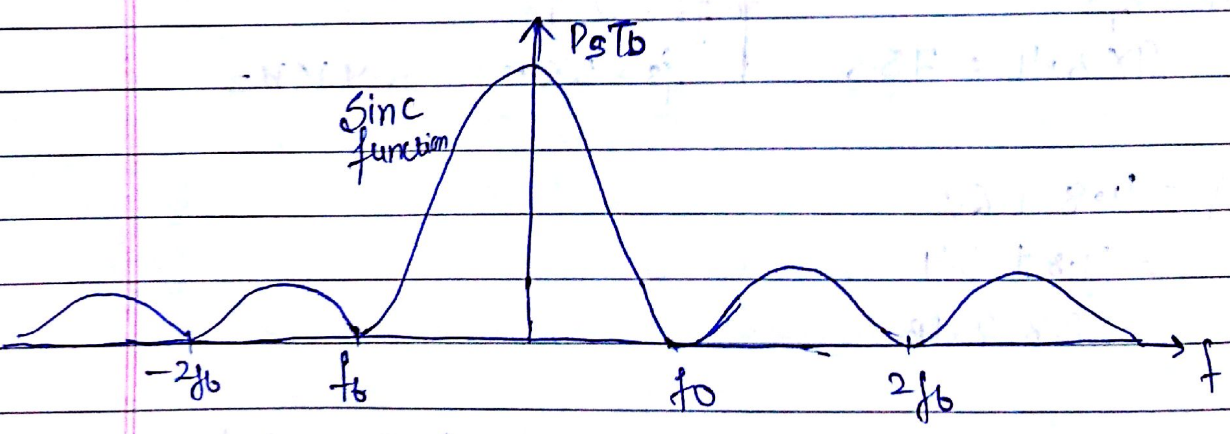
$P = \frac{(V_{rms})^2}{R} = \frac{(0.2)^2}{1} = 0.04$

$\frac{S}{N} = \frac{3 \cdot P \cdot 2^{2V}}{(X_{max})^2} = \frac{3 \times 0.04 \times 2^{16}}{(2)^2} = 0.12 \times 2^{14} = 1966.08$

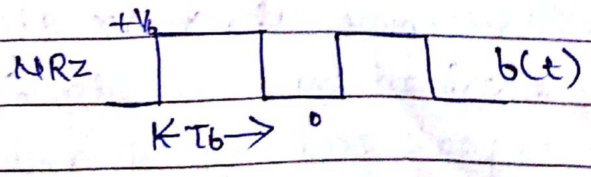
$\log(1966.08)$

$dB = 33\,dB$

The spectrum of BPSK is



Plot of PSD of NRZ Baseband signal



$$\text{sinc}(\theta) = \frac{\sin\theta}{\theta} = 1$$

The Fourier Transform of the pluse is :

$$X(f) = V_b T_b \frac{\sin(\pi f T_b)}{\pi f T_b}$$

Now of large no of pulses, the Parse spectral density (PSD) $S(f)$ is

$$S(f) = \frac{X(f)^2}{T_s} = \frac{V_b^2 T_b^2}{T_s}\left[\frac{\sin(\pi f T_b)}{\pi f T_b}\right]^2$$

Here $(T_s = T_b)$

$$S(f) = \cancel{x}\frac{V_b^2 T_b^{\cancel{2}}}{\cancel{T_b}}\left[\frac{\sin(\pi f T_b)}{\pi f T_b}\right]^2$$

$$S(f) = V_b^2 T_b\left[\frac{\sin(\pi f T_b)}{\pi f T_b}\right]^2$$

$$f_{BPSK} = f_c + f$$
$$= f_c - f$$

The $S_{BPSK}(f) = V_b^2 T_b \left[\frac{1}{2}\left[\frac{\sin[\pi(f_c - f_b)]}{[\pi(f_c - f)T_b}\right] + \frac{1}{2}\left[\frac{\sin[\pi(f_c+f)T_b]}{[\pi(f_c+f)T_b]}\right]^2\right.$$

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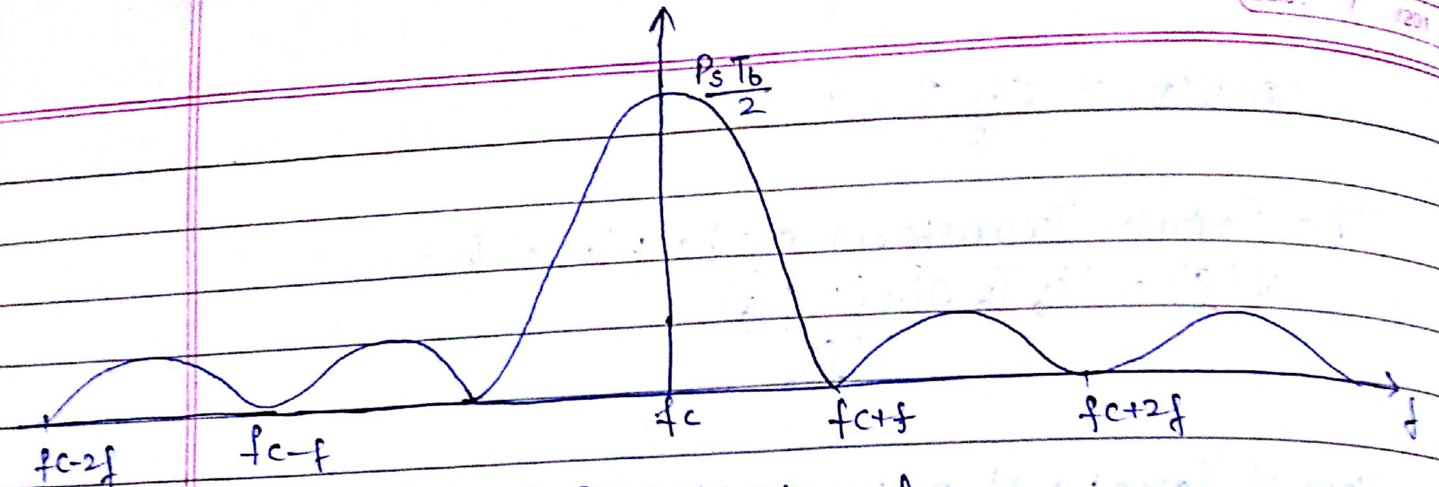


Plot PSD of BPSK signal.

Assume;

$$\pm V_b = \pm\sqrt{P_s}$$

$$S_{BPSK}(f) = P_s T_b \left\{ \frac{1}{2} \frac{[\sin(\pi(f_c - f_b)) T_b]}{[\pi(f_c - f_b)] T_b} + \frac{1}{2} \frac{[\sin(\pi(f_c + f)T_b)]}{[\pi(f_c + f) T_b]} \right\}$$

Geometrical Representation of BPSK signal:

$$V_{BPSK}(t) = b(t)\sqrt{2P_s}\cos\omega_0 t$$

$$= b(t)\sqrt{P_s T_b}\sqrt{\frac{2}{T_b}}\cos\omega_0 t$$

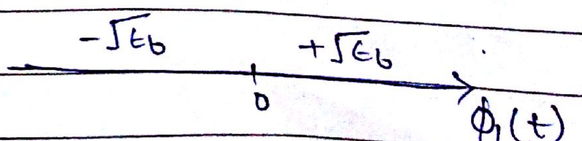
Let $\boxed{\phi_1(t) = \sqrt{\frac{2}{T_b}}\cos\omega_0 t}$

$$V_{BPSK}(t) = b(t)\sqrt{P_s T_b}\,\phi_1(t)$$

$\boxed{E_b = P_s T_b}$

$b(t) = 1 = +V_e$
$b(t) = 0 = -V_e$

$\therefore V_{BPSK}(t) = \pm\sqrt{E_b}\,\phi_1(t)$



$$d = +\sqrt{E_b} - (-\sqrt{E_b})$$

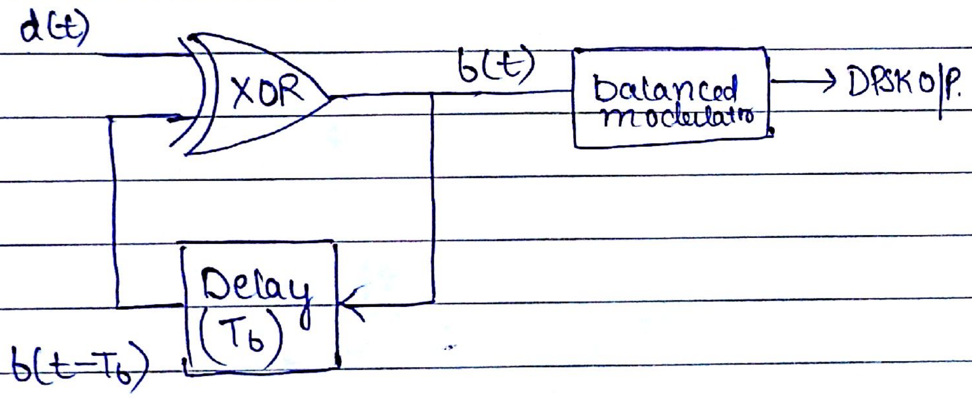
$$\boxed{d = 2\sqrt{E_b}}$$

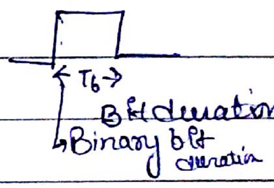
If ~~d~~ d is increasing the ~~So~~ isolation between two binary Value is increasing and error decrease

Bandwidth for BPSK signal :

$$BW = f_c + f - (f_c - f)$$
$$= \cancel{f_c} + f - \cancel{f_c} + f$$
$$= 2f.$$

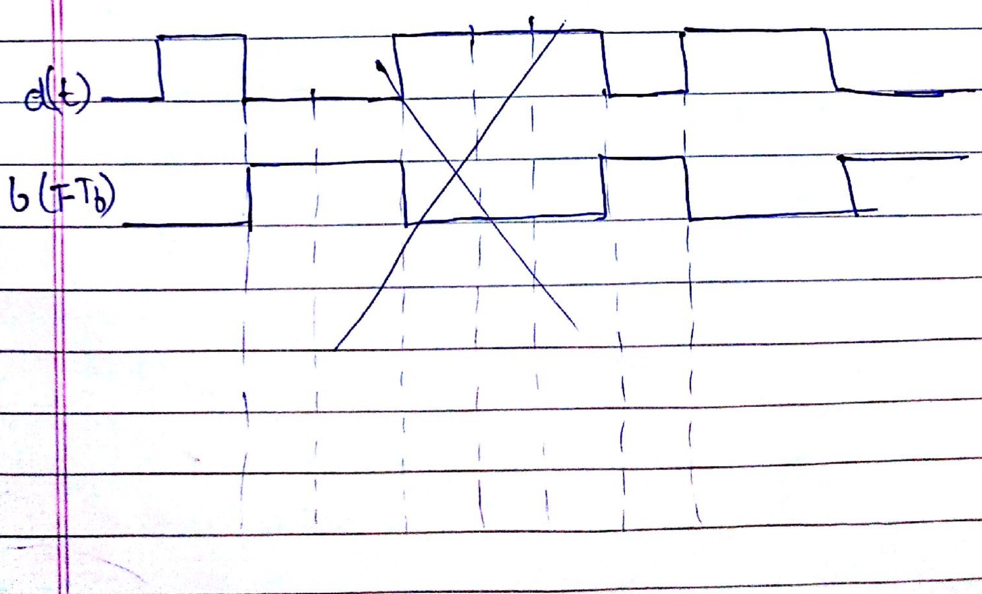
DPSK (Differential Phase Shift Keying) :

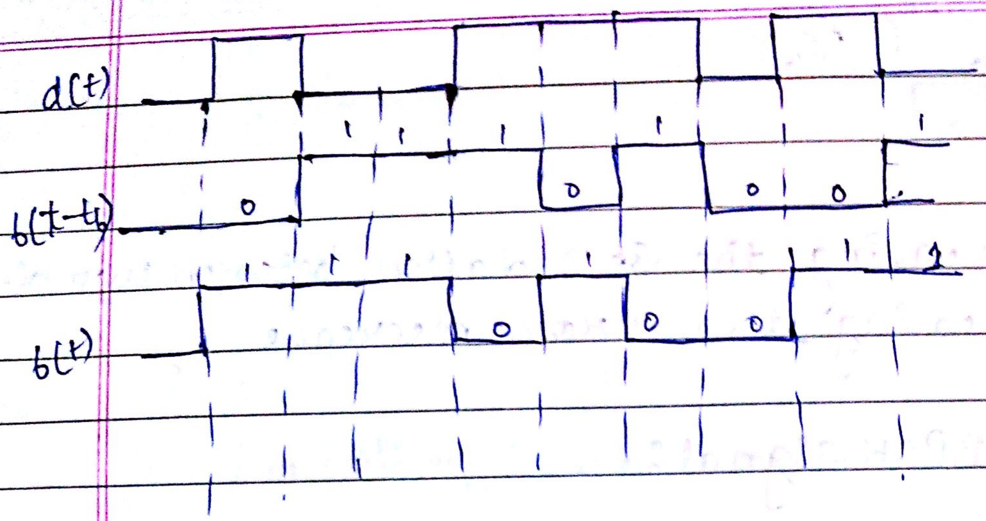




XOR Gate

d(t)	b(t−Tb)	O/P
0	0	0
0	1	1
1	0	1
1	1	0




d(t)
b(t-tb)
b(t)