MADE EASY

India's Best Institute for IES, GATE & PSUs

ESE 2019 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-3: Analog and Digital Communication Systems
Network Theory-1 + Microprocessors and Microcontroller-1
Digital Circuits-2 + Control Systems-2

Name : ....

Roll No : E C 1 9 M T N D A 6 0 6

Test Centres

Delhi ☐ Bhopal ☐ Noida ☑ Jaipur ☐ Indore ☐
Lucknow ☐ Pune ☐ Kolkata ☐ Bhubaneswar ☐ Patna ☐
Hyderabad ☐

Student's Signature

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	48
Q.2	—
Q.3	48
Q.4	—
Section-B	
Q.5	46
Q.6	22
Q.7	45
Q.8	—
Total Marks Obtained	209

Signature of Evaluator: Sumeet

Cross Checked by

Remarks : Very well presented and good accuracy! Keep it up!

Section A : Analog and Digital Communication Systems

1 (a) Let $X(t)$ be a real WSS process and another process $Y(t) = \hat{X}(t)$. i.e., $Y(t)$ is the Hilbert transform of $X(t)$. $R_X(\tau)$ and $R_Y(\tau)$ denote the auto-correlation function of $X(t)$ and $Y(t)$ respectively, and $R_{XY}(\tau)$ denotes the cross-correlation function of $X(t)$ and $Y(t)$. Then prove that the following two relations are true.

R_1: $R_Y(\tau) = R_X(\tau)$

R_2: $R_{XY}(-\tau) = -R_{XY}(\tau)$

[12 marks]

Ans

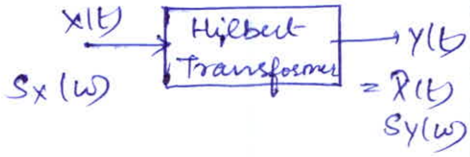
Given : $\boxed{y(t) = \hat{x}(t)}$ — ① ; $\hat{x}(t) \rightarrow$ Hilbert Transform of $x(t)$

R_1

To prove (i) $R_Y(\tau) = R_X(\tau)$

Taking Fourier Transform of eq^n-①: $\boxed{Y(\omega) = -j\,sgn(\omega)X(\omega)}$

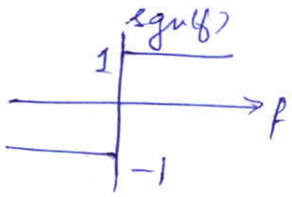
If PSD of $x(t)$ is ~~Sx(f)~~ $S_X(\omega)$



Then PSD of $y(t)$ is $S_Y(\omega)$

$$\boxed{S_Y(\omega) = S_X(\omega)\,|H(f)|^2}$$

where $H(f) = -j\,sgn(f)$



$\therefore$ $S_Y(f) = S_X(f)\,|-j\,sgn(f)|^2$

$$\boxed{S_Y(f) = S_X(f)} \quad (\because sgn^2(f) = 1)$$

Taking Inverse Fourier Transform

$$\boxed{R_Y(\tau) = R_X(\tau)}$$ Hence Proved.

6

Ans R_2

To prove : $R_{XY}(-\tau) = -R_{XY}(\tau)$

$y(t) = \hat{x}(t) \Rightarrow$ Taking Fourier Transform

$Y(\omega) = -j\,sgn(\omega)X(\omega)$.

$|Y(\omega)| = |X(\omega)|$

$\underline{\angle Y(\omega)} = \underline{\angle X(\omega) - \pi/2}$ i.e provides $-90°$ phase shift to input signal

$\therefore$ ~~Y(ω)~~ signal $y(t)$ is odd signal.

$\because$ odd so $R_{XY}(-\tau) = R_{XY}(\tau)$

Q.1 (b) Consider a single-tone AM signal as follows:

$$s(t) = [1 + \mu\cos\omega_m t]\cos\omega_c t$$

If $\mu = \dfrac{1}{2}$ and the upper sideband component is attenuated by a factor of 2, then determine the expression for the envelope of the resulting modulated signal.

[12 marks]

Sol^n) Given: $s(t) = [1 + \mu\cos w_m t]\cos w_c t$

$= \cos w_c t + \mu\cos w_m t \cos w_c t$

$= \cos w_c t + \frac{\mu}{2}\left[\cos((w_c+w_m)t) + \cos(w_c-w_m)t\right]$

$= \cos w_c t + \frac{\mu}{2}\cos(w_c+w_m)t + \frac{\mu}{2}\cos(w_c-w_m)t$

$\{$ using $2\cos A\cos B = \cos(A+B) + \cos(A-B)\}$

Since:

upper sideband component is attenuated by a factor of 2 so

$s(t) = \cos w_c t + \frac{1}{2}\cdot\frac{\mu}{2}\cos(w_c+w_m)t + \frac{\mu}{2}\cos(w_c-w_m)t$

$= \cos w_c t + \underbrace{\frac{\mu}{4}\cos(w_c+w_m)t}_{USB} + \underbrace{\frac{\mu}{2}\cos(w_c-w_m)t}_{LSB}$

<u>Now</u>

$$s(t) = \cos w_c t + \frac{\mu}{4}\left[\cos w_m t \cos w_c t - \sin w_c t \cdot \sin w_m t\right]$$

$$+ \frac{\mu}{2}\left[\cos w_c t \cdot \cos w_m t + \sin w_c t \cdot \sin w_m t\right]$$

$$= \left(1 + \frac{\mu}{4}\cos w_m t + \frac{\mu}{2}\cos w_m t\right)\cos w_c t$$

$$+ \left[\frac{\mu}{2}\sin w_m t - \frac{\mu}{4}\sin w_m t\right]\sin w_c t$$

$$\boxed{s(t) = \left(1 + \frac{3}{4}\mu\cos w_m t\right)\cos w_c t + \left(\frac{\mu}{4}\sin w_m t\right)\sin w_c t}$$

$\therefore$ Envelope of resulting modulated signal is given as:

$$A\cos(f_0 t) + B\sin f_0 t \xrightarrow{\text{Envelope}} = \sqrt{A^2+B^2}$$

<u>Similarly</u>, in given question:

envelope of modulated signal

$$= \sqrt{\left(1+\mu\frac{3}{4}\cos w_m t\right)^2 + \left(\frac{\mu}{4}\sin w_m t\right)^2}$$

2

$$= \sqrt{1 + \frac{9}{16}\mu^2\cos^2 w_m t + \frac{\mu^2}{16}\sin^2 w_m t + \frac{3}{2}\mu\cos w_m t}$$

$$= \sqrt{1 + \frac{\mu^2}{2}\cos^2 w_m t + \frac{\mu^2}{16} + \frac{3}{2}\mu\cos w_m t}$$

$\because \mu = 1/2$

so Envelope $= \sqrt{1 + \frac{\cos^2 w_m t}{8} + \frac{1}{64} + \frac{3}{4}\cos w_m t}$

$$\boxed{\text{Envelope} = \sqrt{\frac{65}{64} + \frac{3}{4}\cos w_m t + \frac{\cos^2 w_m t}{8}}}$$ // Ans

Q.1 (c) Over the interval $|t| \le 1$, an angle modulated signal is given by, $s(t) = 10\cos 13000t$. Carrier frequency $\omega_c = 10000$ rad/s.

(i) If it is a PM signal with $k_p = 1000$ rad/V, then determine $m(t)$ over the interval $|t| \le 1$.

(ii) If it is an FM signal with $k_f = 1000$ rad/s/V, then determine $m(t)$ over the interval $|t| \le 1$.

[6 + 6 marks]

Sol^n) Angle Modulated signal, $s(t) = 10\cos(13000t)$

i) If $\underline{s(t) = \text{PM signal}}$; $k_p = 1000 \frac{\text{rad}}{V}$, To find $m(t)$

General eq^n of PM signal is:

$$s(t) = A_c \cos[2\pi f_c t + k_p m(t)] \quad \text{———} (1)$$

Given eq^n: $s(t) = 10\cos[(3000 + \underbrace{10000}_{\omega_c\ (\text{given})})t]$

$$s(t) = 10\cos[2\pi f_c t + 3000t] \quad \text{———} (2)$$

comparing eq^n (1) & (2)

$$k_p m(t) = 3000t$$

$\because k_p = 1000 \Rightarrow 1000\, m(t) = 3000t$

$$\Rightarrow \boxed{m(t) = 3t} \quad \text{Ans.};\ |t| \le 1$$

(ii) If $\underline{s(t) = \text{FM signal}}$; $k_f = 1000$ rad/s/V, To find $m(t)$

General eq^n of FM signal is :-

$$s(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(\tau)d\tau\right] \quad \text{———} (3)$$

Given eq^n: $s(t) = 10\cos[(\underbrace{10000}_{\omega_c} + 3000)t]$

$$s(t) = 10\cos[2\pi f_c t + 3000t] \quad \text{———} (4)$$

Comparing eq^{n}s (3) and (4), we get

$$2\pi k_f \int_0^t m(\tau)\,d\tau = 3000t$$

$$\Rightarrow \cancel{2\pi} \times \left(\frac{1000}{\cancel{2\pi}}\right) \int_0^t m(\tau)\,d\tau = \cancel{3000}^{3}\, t \qquad k_f = \frac{1000}{2\pi}\ \text{Hz/V}$$

$$\Rightarrow \int_0^t m(\tau)\,d\tau = 3t.$$

$\Rightarrow$ differentiating both sides wrt 't'

$$\boxed{m(t) = 3} \quad ; \quad |t| \le 1$$

Ans

12

1 (d) Two continuous random variables X and Y are related as, $Y = aX + b$. If 'a' and 'b' are positive constants, then derive the relation between the differential entropies of the two random variables.

[12 marks]

21n) Given : $\boxed{Y = aX + b}$; $a > 0$, $b > 0$.

To find: Relation between Differential entropies of X and Y

Steps: Differential Entropy of a continuous random variable is given by:

$$\boxed{H(X) = \int_{-\infty}^{\infty} f_X(x) \log_2 \frac{1}{f_X(x)}\,dx}$$

where $X \to$ continuous random variable.

Now : Similarly :

$$H[Y] = \int_{-\infty}^{\infty} f_Y(y) \log_2 \frac{1}{f_Y(y)}\,dy. \quad \text{—— (1)}$$

Given $Y = aX + b$.

we know:

$$\boxed{f_Y(y) = f_X(x) \cdot \left|\frac{dx}{dy}\right|} \quad \text{—— (2)}$$

using eq^n-2 in eq^n-1

$$H[Y] = \int_{-\infty}^{\infty} f_X(x) \left|\frac{dx}{dy}\right| \log_2\left(\frac{1}{f_X(x)\left|\frac{dx}{dy}\right|}\right) dy \quad \text{---(3)}$$

$$\because Y = aX + b \Rightarrow \frac{dY}{dX} = a \Rightarrow \left|\frac{dX}{dY}\right| = \frac{1}{a} \quad \text{---(4)}$$

substituting 4 in 3

$$H[Y] = \int_{-\infty}^{\infty} f_X(x) \left(\frac{1}{\cancel{a}}\right) \cdot \log_2\left(\frac{a}{f_X(x)}\right) (\cancel{a}\, dx)$$

$$= \int_{-\infty}^{\infty} f_X(x) \left[\log_2 a - \log_2 f_X(x)\right] dx$$

$$= \log_2 a \underbrace{\int_{-\infty}^{\infty} f_X(x)\, dx}_{\Downarrow} + \underbrace{\int_{-\infty}^{\infty} f_X(x) \log_2 \frac{1}{f_X(x)} dx}_{\Downarrow}$$

equal ~~to~~ $\cdot$ 1
By property of probability Density function.

Differential entropy of X.

$$H[Y] = \log_2 a + H[X]$$

$\therefore$ Relation between Differential entropies of Random variables X and Y is

$$\boxed{H[Y] = H[X] + \log_2 a}$$

// Hence Proved.

12

1 (e) What are the advantages and disadvantages of delta modulation compared to PCM? With the help of a sketch, mention various noises associated with delta modulation. How will you overcome these noises?

[12 marks]

Advantages of Delta Modulation over PCM is:

① No: of bits per symbol required is very less as in Delta Modulation $\boxed{n = 1 \text{ bit}}$

② Bandwidth requirement is very less as compared to PCM

③ Quantisation Error is very less in Delta Modulation

Disadvantage of Delta Modulation:

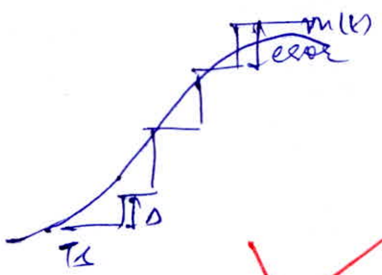
① Circuit becomes complex

② Costlier circuit

③ Slope overload ~~Error~~ & Granual Noises are the problem.

Various Noises Associated with Delta Modulation are:

① Slope overload Error (when m(t) is fast varying signal)



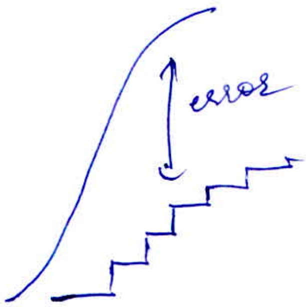
To minimise this

$$\left.\frac{dm(t)}{dt}\right|_{max} \le \frac{\Delta}{T_s}$$

$\Delta \rightarrow$ Step size

$T_s \rightarrow$ Sampling Interval

ii) Granular Noise: when m(t) is slow varying signal



To minimise this

$$\left.\frac{dm(t)}{dt}\right|_{max} \geq \frac{\Delta}{T_s}$$

7

→ Slope overload error is ~~p~~ more harmful than granular Noise ∵ it affects at low frequency.

Adaptive Delta Modulation to avoid.

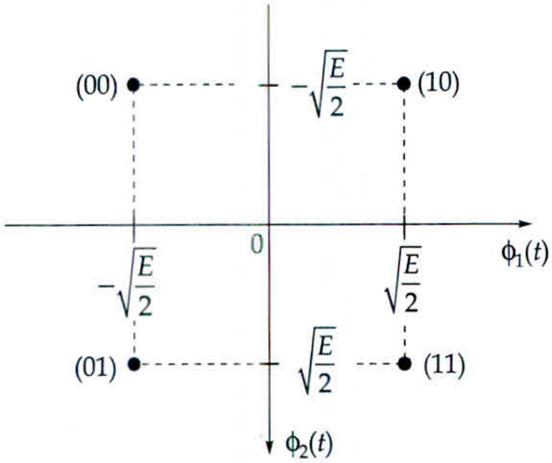
2 (a) Two random variables X and Y are independent and identically distributed, each with a Gaussian density function with mean equal to zero and variance equal to σ^2. If these two random variables denote the coordinates of a point in the plane, find the probability density function of the magnitude and the phase of that point in polar coordinates.

[20 marks]

Q.2 (b) A double conversion superheterodyne receiver is designed with $f_{IF(1)} = 30$ MHz and $f_{IF(2)} = 3$ MHz. Local oscillator frequency of each mixer stage is set at the lower of the two possible values. When the receiver is tuned to a carrier frequency of 300 MHz, insufficient filtering by the RF and first IF stages results in interference from three image frequencies. Determine those three image frequencies.

[15 marks]

Q.2 (c) Consider the signal-space diagram of a coherent QPSK system as shown in the figure below:



$\phi_1(t)$ and $\phi_2(t)$ are two orthonormal basis functions, which are represented as,

$$\phi_1(t) = \sqrt{\frac{2}{T}}\cos(2\pi f_c t)\,;\ 0 \le t \le T$$

$$\phi_2(t) = \sqrt{\frac{2}{T}}\sin(2\pi f_c t)\,;\ 0 \le t \le T$$

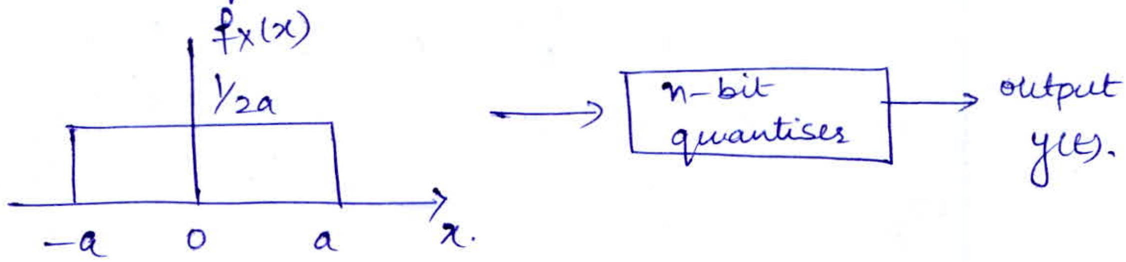
All the four message symbols are occurring with equal probability and they are transmitted through an AWGN channel with two-sided noise power spectral density of $\frac{N_0}{2}$. Suggest a receiver model to reproduce the symbols at channel output and derive an expression for the probability of symbol error.

[25 marks]

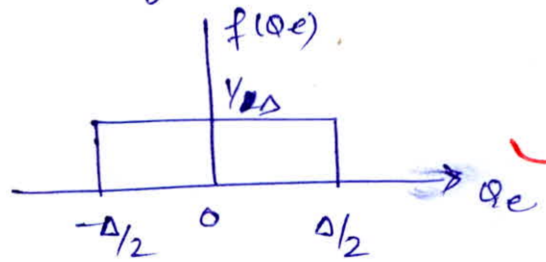
Q.3 (a) The samples of a stationary random process $X(t)$, whose amplitude is uniformly distributed in the range $[-a, a]$, are applied to an n-bit uniform mid-riser quantizer. Derive an expression for the signal-to-quantization noise ratio at the output of the quantizer, with suitable assumptions. Using the expression obtained, find the signal-to-quantization noise ratio for an 8-bit quantizer.

[20 marks]

Sol^n) Given: $X(t)$ is uniformly distributed in range $[-a, a]$ & applied to n-bit uniform mid-rise quantizer.



~~Let~~ Quantizer characteristic is uniform: (given)



Signal to Noise Ratio at o/p:

Signal Power: $= E[X^2(t)]$

$$= \int_{-\infty}^{\infty} x^2(t) \cdot f_X(x)\, dx$$

$$= \int_{-a}^{a} \left(\frac{1}{2a}\right) \cdot x^2(t)\, dx$$

$$= \left(\frac{1}{2a}\right) \left| \frac{x^3}{3} \right|_{-a}^{a}$$

$$= \frac{1}{2a} \times \frac{1}{3} \times (a^3 + a^3)$$

$$\boxed{P_S = \frac{a^2}{3}}$$

Quantization Noise Power : $P_{nq} = E[Qe^2]$

$$P_{nq} = \int_{-\Delta/2}^{\Delta/2} Qe^2 f(Qe)\, dQe = \int_{-\Delta/2}^{\Delta/2} Qe^2 \left(\frac{1}{\Delta}\right) dQe$$

$$= \frac{1}{\Delta} \cdot \left| \frac{Qe^3}{3} \right|_{-\Delta/2}^{\Delta/2}$$

$$= \frac{1}{3\Delta}\left(\frac{\Delta^3}{8} + \frac{\Delta^3}{8}\right) = \frac{\Delta^{\cancel{3}2}/4}{3\cancel{\Delta}}$$

$$\boxed{P_{nq} = \frac{\Delta^2}{12}} \Rightarrow \boxed{P_{nq} = \frac{\Delta^2}{12}}$$

∴ Signal to Quantization Noise Ratio is

$$SN_qR = \frac{P_s}{P_{nq}} = \frac{a^2/3}{\Delta^2/12} = 4\left(\frac{a}{\Delta}\right)^2$$

where $\Delta = \frac{V_{p-p}}{2^n} = \frac{(2a)}{2^n}$

$$\therefore \quad SN_qR = 4\left(\frac{\cancel{a} \cdot 2^n}{2\cancel{a}}\right)^2$$

$$\boxed{SN_qR = 2^{2n}}$$

$$\boxed{\begin{aligned} SN_qR \text{ in dB} &= 10\log_{10} 2^{2n} \\ &= 20n\log_{10} 2 = 6.02n \text{ dB} \end{aligned}}$$

Now : using this Relation,

SN_qR of $n = 8$ bit quantizer is :

$SNqR = 2^{2\times 8} = \underline{\underline{2^{16}}}$

$(SNqR)$ in dB $= 10\log_{10}(2^{16})$

$= 160 \log_{10} 2$

$= \underline{\underline{48.164}}$ dB

19

.3 (b) A binary channel matrix is given by,

$$\begin{array}{ccc} & & \text{Outputs} \\ & & \begin{array}{cc} y_1 & y_2 \end{array} \\ \text{Inputs} & \begin{array}{c} x_1 \\ x_2 \end{array} & \begin{bmatrix} \frac{2}{3} & \frac{1}{3} \\ \frac{1}{10} & \frac{9}{10} \end{bmatrix} \end{array}$$

If $P(x_1) = 1/3$ and $P(x_2) = 2/3$, then determine: $H(x)$, $H(x\,|\,y)$, $H(y)$, $H(y\,|\,x)$ and $I(x\,;y)$

[20 marks]

Soln)

$P[X] = \begin{bmatrix} \frac{1}{3} & \frac{2}{3} \end{bmatrix}$, $P\left[\frac{Y}{X}\right] = \begin{array}{c|c} & \begin{array}{cc} y_1 & y_2 \end{array} \\ \begin{array}{c} x_1 \\ x_2 \end{array} & \begin{bmatrix} \frac{2}{3} & 1/3 \\ 1/10 & 9/10 \end{bmatrix} \end{array}$

$H[X] = -\sum_{i=1}^{2} p(x_i)\log_2 p(x_i)$

$= \frac{1}{3}\log_2 3 + \frac{2}{3}\log_2 1.5$

$\boxed{H[X] = \frac{1}{3}[1.584 + 1.1699] = \underline{\underline{0.917}}\ \frac{\text{bits}}{\text{symbol}}}$

$P[X,Y] = P[X]_d\, P\left[\frac{Y}{X}\right]$

$= \begin{bmatrix} 1/3 & 0 \\ 0 & 2/3 \end{bmatrix} \cdot \begin{bmatrix} 2/3 & 1/3 \\ 1/10 & 9/10 \end{bmatrix} = \begin{bmatrix} 2/9 & 1/9 \\ 1/15 & 3/5 \end{bmatrix}$

$$\therefore P\left[\frac{X}{Y}\right] = \frac{P(X,Y)}{P(Y)_d} = \begin{bmatrix} 0.769 & 0.1562 \\ 0.23 & 2.343 \end{bmatrix}$$

$$P[Y] = P[X] \cdot P\left[\frac{Y}{X}\right] = \begin{bmatrix} \frac{1}{3} & \frac{2}{3} \end{bmatrix} \begin{bmatrix} 2/3 & 1/3 \\ 1/10 & 9/10 \end{bmatrix}$$

$$P[Y] = \left[\frac{2}{9} + \frac{1}{15} \quad \frac{1}{9} + \frac{3}{5} \right]$$

$$\boxed{P[Y] = \begin{bmatrix} \frac{13}{45} & \frac{32}{45} \end{bmatrix}}$$

$$H[Y] = \sum_{j=1}^{2} P[y_j] \log_2 P[y_j]$$

$$= \frac{13}{45} \log_2\left(\frac{45}{13}\right) + \frac{32}{45} \log_2\left(\frac{45}{32}\right)$$

$$= 0.5175 + 0.349$$

$$\boxed{H[Y] = 0.8665 \text{ bits/symbol}}$$

$$\therefore H\left[\frac{X}{Y}\right] = -\sum_{j=1}^{2}\sum_{k=1}^{2} p(x_j, y_k) \log_2 P\left(\frac{x_j}{y_k}\right)$$

$$= -\left[\frac{2}{9}\log_2(0.769) + \frac{1}{9}\log_2(0.1562) + \frac{1}{15}\log_2(0.23) + \frac{3}{5}\log_2(2.343)\right]$$

$$= -\left[-0.0842 - 0.2976 - 0.1413 - 0.737\right]$$

$$\boxed{H\left[\frac{X}{Y}\right] = 1.2601 \text{ bits/symbol}}$$

$$H\left[\frac{Y}{X}\right] = -\sum_{j=1}^{2}\sum_{k=1}^{2} p(x_j, y_k)\log_2 P\left(\frac{y_k}{x_j}\right)$$

$$= -\left[\frac{2}{9}\log_2(2/3) + \frac{1}{9}\log_2(1/3) + 1/15\log_2(1/10) + \frac{3}{5}\log_2(9/10)\right]$$

$$= -\left[-0.1299 - 0.1761 - 0.221 - 0.0912\right]$$

$$\boxed{H\left[\frac{Y}{X}\right] = 0.6182 \text{ bits/symbol}}$$

$$I(X;Y) = H[Y] - H\left[\frac{Y}{X}\right]$$

$$= \cancel{0.917}$$

$$= 0.8665 - 0.6182$$

$$\boxed{I(X;Y) = 0.2483 \text{ bits/symbol}}$$

16

Q.3 (c) **(i)** In a DSBSC system, the message signal $m(t)$ is multiplied with the carrier signal $c(t) = 4\cos(2\pi f_c t)$ to form a modulated signal $s(t)$. If $m(t) = 2\text{sinc}(2t) - \text{sinc}^2(t)$ and $f_c = 100$ Hz, then determine and sketch the spectrum of the modulated signal $s(t)$. Assume that, $\text{sinc}(t) = (\sin \pi t)/\pi t$.

(ii) The spectrum of the message signal $m(t)$ is shown below in Figure (a). This signal is processed by the system shown below in Figure (b).

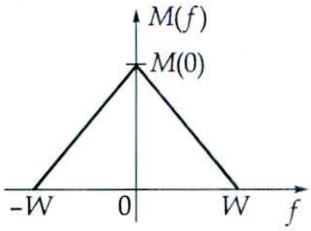


Figure (a)

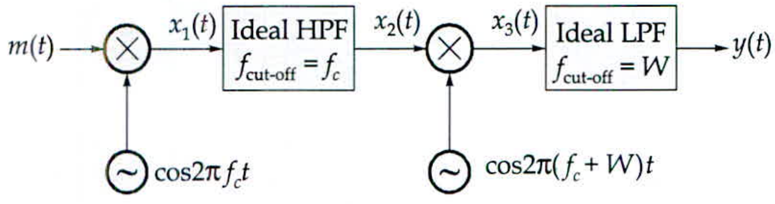


Figure (b)

If each filter has a passband gain of 1, then determine and sketch the spectrum of the output signal $y(t)$. Assume that $f_c >> W$.

[8 + 12 marks]

Sol^n (i) Given DSBSC system:

$m(t) = 2\,\text{sinc}(2t) - \text{sinc}^2(t)$,

$c(t) = 4\cos(2\pi f_c t)$; $f_c = 100$ Hz.

DSBSC modulated signal is given by:

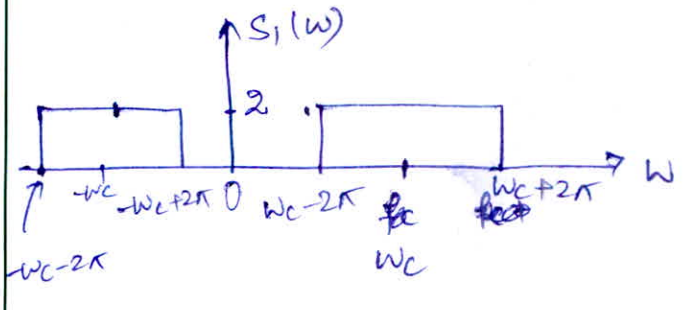
$s(t) = m(t)\cdot c(t)$

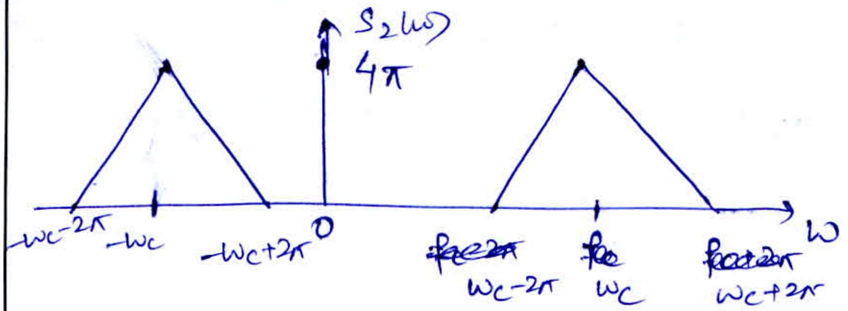
$= [2\,\text{sinc}(2t) - \text{sinc}^2(t)]\cdot[4\cos[2\pi f_c t]]$

$= 8\dfrac{\sin 2\pi t}{2\pi t}\cos(2\pi f_c t) - 4\,\text{sinc}^2(t)\cos 2\pi f_c t$

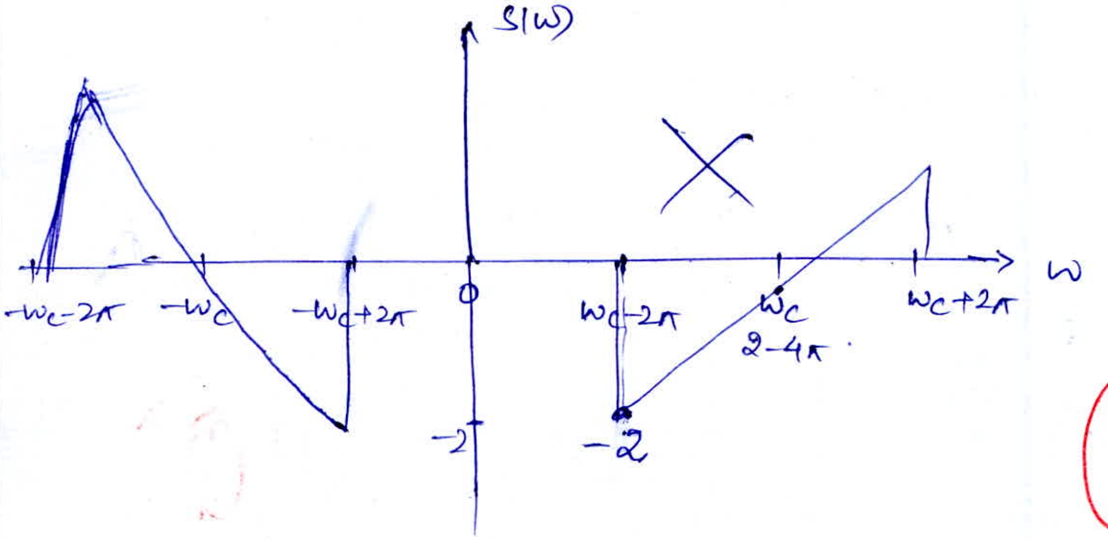
$$s(t) = \underbrace{4\frac{\sin(2\pi t)}{\pi t}\cos 2\pi f_c t}_{s_1(t)} - \underbrace{4\left(\frac{\sin \pi t}{\pi t}\right)^2\cos 2\pi f_c t}_{s_2(t)}$$

Spectrum of $s_1(t)$ & $s_2(t)$ are as:



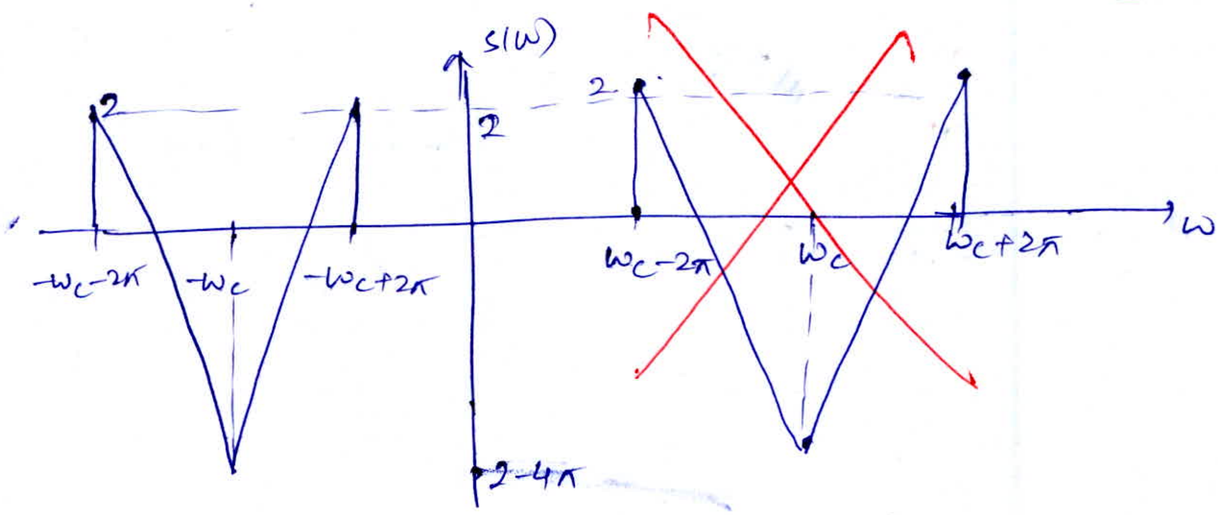


$\therefore$ overall spectrum of $s(t)$ is $S_1(\omega) - S_2(\omega)$

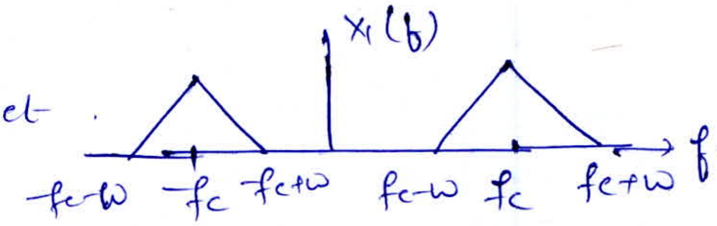


2-(-1

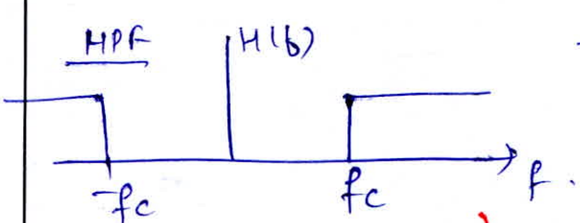
3



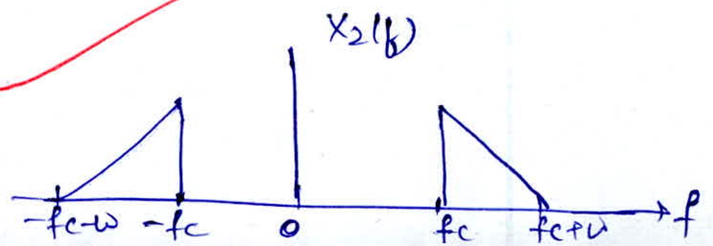
ii) $x_1(t) = m(t)\cdot \cos 2\pi f_c t$



HPF

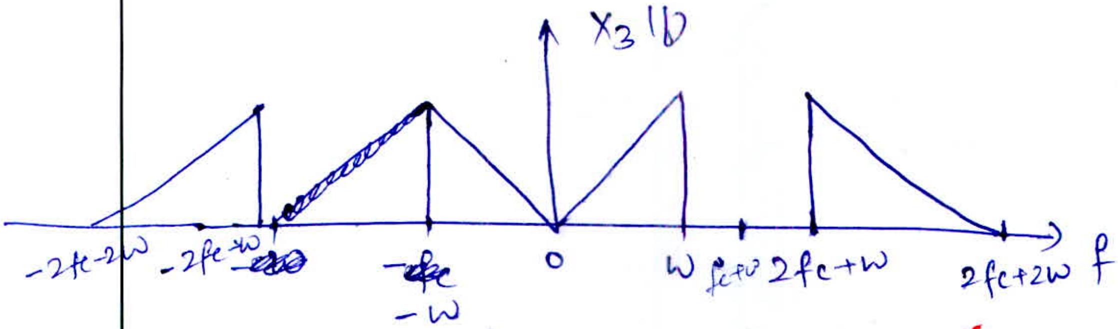


$x_2(t) = x_1(t) * h(t)$

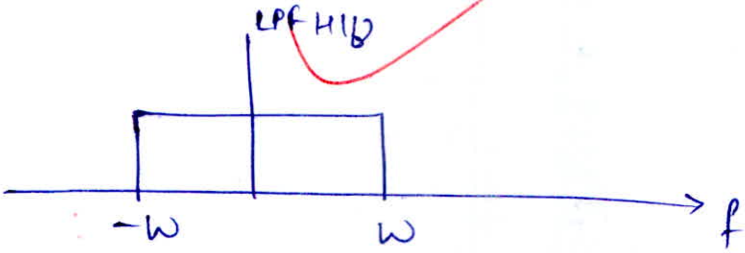


$x_3(t) = x_2(t) \cdot \cos 2\pi(f_c+W)t$.

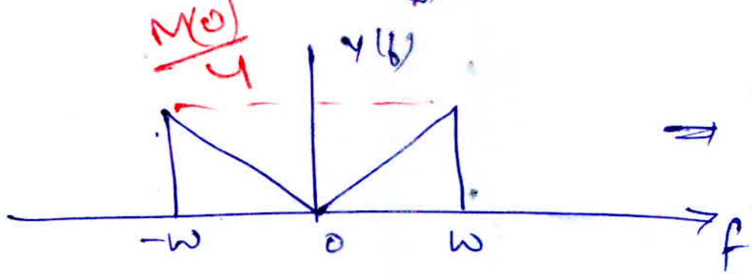
f_c	W
$-f_c-W$	$-f_c-W$
$-W$	$-f_c$



$x_3(t) \longrightarrow \boxed{\begin{matrix}\text{LPF}\\ f_c = W\end{matrix}} \longrightarrow y(t)$



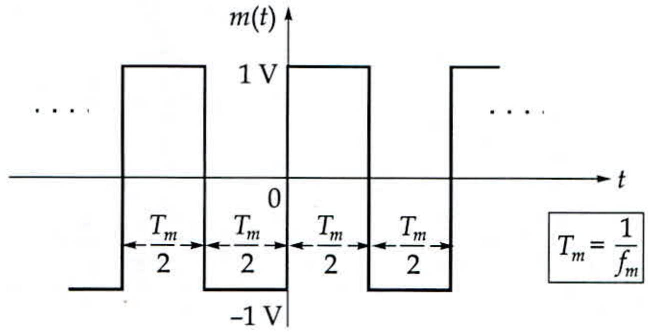
$\Downarrow$



$\Rightarrow$ spectrum of output signal $y(t)$

10

Q.4 (a) The periodic message signal $m(t)$ shown in the figure below is applied to a phase modulator to modulate the carrier signal $c(t) = \cos(2\pi f_c t)$. If the phase sensitivity of the phase modulator is $k_p = 1$ rad/V, then determine and sketch the spectrum of the modulated signal.



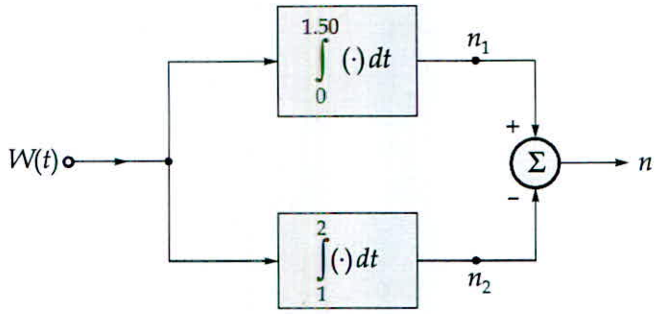
[25 marks]

Q.4 (b) **(i)** A binary data is transmitted through an ideal AWGN channel with infinite bandwidth. The two sided power spectral density of the noise is $\frac{N_0}{2}$. If the average energy transmitted per bit is E_b, then derive the condition to be satisfied for error free transmission.

(ii) A binary signal is transmitted through an ideal AWGN channel with infinite bandwidth. The two-sided PSD of the channel noise is 7 μW/Hz. By using the condition obtained in part (i), determine the minimum average bit energy required for error-free transmission.

[12 + 3 marks]

Q.4 (c) A zero mean white Gaussian noise $W(t)$ is processed by the section of a receiver shown below.



If the two-sided noise power spectral density of the input white Gaussian noise $W(t)$ is $\frac{N_0}{2} = 1\ \text{W/Hz}$, then determine the variance of the corresponding output random variable "n".

[20 marks]

Section B : Network Theory-1 + Microprocessors and Microcontroller-1 + Digital Circuits-2 + Control Systems-2

Q.5 (a) Design a *J-K* flip-flop using a *D* flip-flop and a 4 × 1 MUX. Write various steps involved in the process. **[12 marks]**

Sol^n) To design : JK flip flop using D-flip flop and 4x1 MUX.

Steps : ① Write the characteristic Table of Required flip flop.

② From the characteristic Table, write excitation Table for D-flip flop i.e D-inputs.

③ Solve K-map for D-inputs.

we get D = Σm (   )

④ Now Design D = Σm(- -) using (4 × 1) MUX using Implementation Table.

⑤ Draw the circuit.

Characteristic Table : Excitation Table

J	K	Q	Q^+	D
0	0	0	0	0
0	0	1	1	1
0	1	0	0	0
0	1	1	0	0
1	0	0	1	1
1	0	1	1	1
1	1	0	1	1
1	1	1	0	0

Characteristic Table.

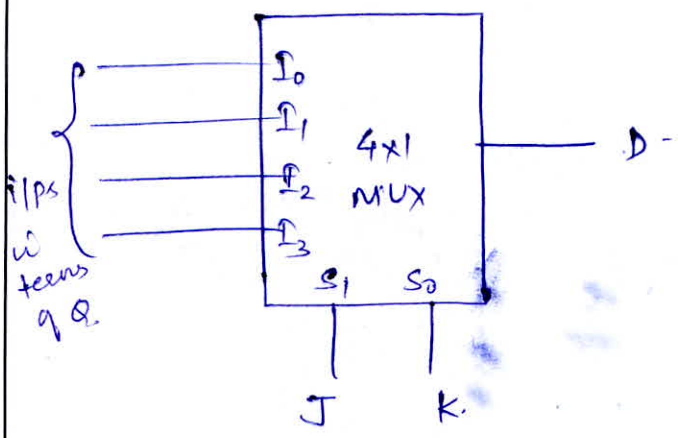
Excitation Table for D-ff

Q	Q^+	D
0	0	0
0	1	1
1	0	0
1	1	1

i.e $\boxed{Q^+ = D}$

Now : $D = \Sigma m(1, 4, 5, 6)$

Now Designing $D = \sum m(1,4,5,6)$ using 4×1 MUX



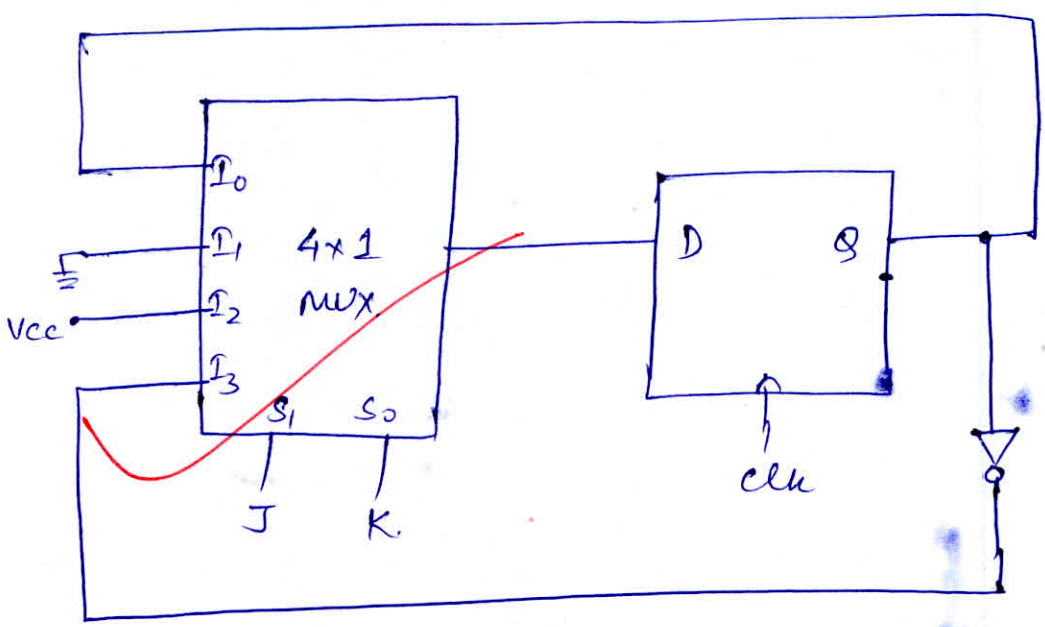
Implementation Table :

	I_0	I_1	I_2	I_3
	JKQ	JKQ	JKQ	JKQ
$\bar{Q}$	0	2	4	6
Q	1	3	5	7
	Q	0	1	$\bar{Q}$

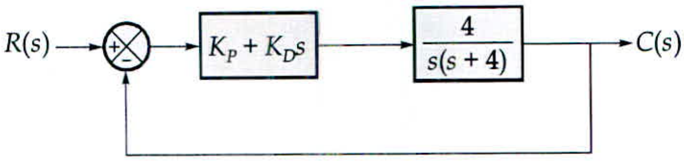
$\therefore$ $\boxed{\begin{aligned} I_0 &= Q \\ I_1 &= 0 \\ I_2 &= 1 \\ I_3 &= \bar{Q} \end{aligned}}$

12

Circuit Diagram :



Q.5 (b) A control system with PD controller is shown below:



Determine the value of K_P and K_D such that the damping ratio of the system will be 0.75 and the steady state error for unit ramp input will be 0.25.

[12 marks]

Ans The Transfer function of given system is

$$\frac{C(s)}{R(s)} = \frac{(K_P + K_D s)\left(\frac{4}{s(s+4)}\right)}{1 + (K_P + K_D s)\left(\frac{4}{s(s+4)}\right)}$$

$$\frac{C(s)}{R(s)} = \frac{4(K_P + K_D s)}{s(s+4) + 4(K_P + K_D s)}$$

$$\boxed{\frac{C(s)}{R(s)} = \frac{4(K_P + K_D s)}{s^2 + (4 + 4K_D)s + 4K_P}} \quad \text{— ①}$$

Required ξ of system $= 0.75$

Comparing Denominator of Transfer function with standard characteristic eq^n $s^2 + 2\xi\omega_n s + \omega_n^2 = 0$ — ②

~~to eq~~ we get

$$\boxed{\begin{aligned} \omega_n^2 &= 4K_P \quad \text{— (A)} \\ 2\xi\omega_n &= 4 + 4K_D \quad \text{— (B)} \end{aligned}}$$

Now put $\xi = \frac{3}{4}$ in eq^n (B) and eq^n (A) in eq^n (B)

$$\cancel{2} \times \frac{3}{\cancel{4}\,2} \times \cancel{2}\sqrt{K_P} = 4 + 4K_D$$

$$\boxed{3\sqrt{K_P} = 4 + 4K_D} \quad \text{— (C)}$$

Given e_{ss} for unit Ramp input $= 1/4$.

we know $e_{ss} = \dfrac{1}{K_V}$, $K_V = \lim\limits_{s\to 0} s\cdot G(s)H(s)$

$$G(s)H(s) = \frac{4(K_P + K_D s)}{s^2 + (4+4K_D)s + 4K_P - \cancel{4K_P} - \cancel{4K_D s}} = \frac{4(K_P+K_D s)}{s(s+4)}$$

$\therefore K_V = \lim\limits_{s\to 0} s \cdot \dfrac{4(K_P + K_D s)}{s(s+4)} = K_P$

12

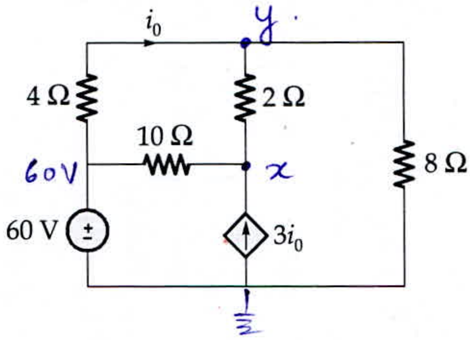
$\therefore e_{ss} = \dfrac{1}{K_P} = \dfrac{1}{4} \Rightarrow \boxed{K_P = 4}$ —— (D)

put (D) in (C)

$3\sqrt{K_P} = 4 + 4K_D \Rightarrow K_D = \dfrac{3\sqrt{4}-4}{4} = 1/2$

$\Rightarrow \boxed{K_D = 1/2}$ //

5 (c) Find the current i_0 in the circuit shown below using nodal analysis.



[12 marks]

Assume Nodes x and y:

KCL at x : $\dfrac{x-60}{10} + \dfrac{x-y}{2} - 3i_0 = 0$

$$\frac{x - 60 + 5x - 5y - 30i_0}{10} = 0$$

$\Rightarrow \boxed{6x - 5y - 30i_0 = 60}$ —— (1)

KCL at y: $\dfrac{y}{8} + \dfrac{y-x}{2} + \dfrac{y-60}{4} = 0$

$$\frac{y + 4y - 4x + 2y - 120}{8} = 0$$

$\boxed{7y - 4x - 120 = 0}$ —— (2)

from ckt : $\boxed{i_0 = \frac{60-y}{4}}$ — ③

put ③ in eqⁿ-①, $6x - 5y - \cancel{30}^{15}\left(\frac{60-y}{\cancel{4}_{2}}\right) = 60$

$12x - 10y - 900 + 15y = 120$

$\Rightarrow \boxed{12x + 5y = 1020}$ — ④

from eqⁿ ② $\boxed{4x - 7y = -120}$ — ② ×3

solving eqⁿs ② and ④

$$\begin{aligned} \cancel{12x} + 5y &= 1020 \\ \cancel{12x} - 21y &= -360 \\ (-) \quad (+) \quad & \quad (+) \end{aligned}$$

$26y = 1380$

$$\boxed{y = \frac{1380}{26} = 53.07 \text{ V.}}$$

12

$$x = \frac{7 \times \frac{1380}{26} - 120}{4}$$

$$\boxed{x = 62.87 \text{ V}}$$

$\therefore \quad i_0 = \frac{60-y}{4} = \frac{60 - 53.07}{4}$

$$\boxed{i_0 = 1.7325 \text{ A}}$$ Ans.

5 (d) Calculate the delay produced by the following subroutine program of an 8085 microprocessor, which is operating with a clock frequency of 2 MHz.

```
DELAY :  MVI B, 02H
LOOP2:   MVI C, FFH
LOOP1:   DCR C         → 4T
         JNZ LOOP1     → 7T/10T   (→ False, → True)
         DCR B         → 4T
         JNZ LOOP2
         RET → 5T      10T
```

1111 111
128 256

[12 marks]

Ans) Delay Produced by Loop 1 :

DCR C
JNZ Loop1 } executed 255 times.

DCR B
JNZ Loop 2

Total Delay For B = 2

runs 2 times → (Loop 1) → 255 times True + 1 Time False.

B = 1 : 7 ·
4T

Total Delay =

$$= 2 \times 255 (14T) + 2 (11T) + 14T + 7T + 5T + 8T + 4T.$$

$$= (510 \times 14 T) + 22T + 21T + 17T$$

$$= 7140T + 60T$$

$$= 7200 T.$$ 7190 T

$$= 7200 \times \frac{1}{2 \times 10^{6}}$$ 4

$$= 36 \times 10^{-4} \text{ sec}$$

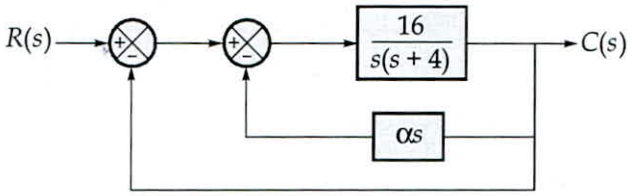
$$= 3.6 \text{ msec}$$

10

Q.5 (e) Sketch the internal block diagram of an 8086 microprocessor.

[12 marks]

5 (a) The following figure shows a unity feedback control system with rate feedback loop.



Determine:

(i) The peak overshoot of the system for unit step input and the steady state error for unit ramp input in the absence of rate feedback.

(ii) The rate feedback constant 'α' which will decrease the peak overshoot of the system for unit step input to 1.25%. What is the steady state error to unit ramp input with this setting.

(iii) Illustrate how in the system with rate feedback, the steady state error to unit ramp input can be reduced to the same level as in part (i) while the peak overshoot to unit step input is maintained at 1.25%.

[7 + 8 + 10 marks]

Q7) i) In Absence of Rate Feedback :, it becomes standard 2nd order system
-ve FB

$$\frac{C(s)}{R(s)} = \frac{16/s(s+4)}{1+\frac{16}{s(s+4)}} = \frac{16}{s^2+4s+16} \quad \text{—— (1)}$$

comparing with transfer function of std. 2nd order system

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2} \quad \text{—— (2)}$$

we get $\boxed{\omega_n = 4}$ rad/sec , $2\xi\omega_n = 4$

$$\boxed{\xi = \frac{4}{2\times 4} = 0.5}$$

Peak overshoot :

$$M_p = e^{-\pi\xi/\sqrt{1-\xi^2}}$$

$$= e^{-\pi\times 0.5/\sqrt{1-(1/2)^2}}$$

$$= e^{-1.813} = \underline{0.163}$$

7

Steady state error for unit Ramp Input

$$e_{ss} = \frac{1}{K_v}, \quad K_v = \lim_{s\to 0} s.G(s)H(s)$$

$$G(s)H(s) = \frac{16}{s^2+4s} \qquad \therefore K_v = \lim_{s\to 0} s\left(\frac{16}{s(s+4)}\right)$$

$$\boxed{K_v = 4}$$

$$\therefore \boxed{e_{ss} = \frac{1}{K_v} = \frac{1}{4} = 0.25}$$
//

(ii) With Rate feedback present :-

$$\frac{C(s)}{R(s)} = \frac{\left(\frac{16/s(s+4)}{1+\frac{16}{s(s+4)}(\alpha s)}\right)}{1+\left[\frac{16/s(s+4)}{1+\frac{16}{s(s+4)}(\alpha s)}\right]} = \frac{\frac{16}{s^2+4s+16\alpha s}}{1+\frac{16}{s^2+4s+16\alpha s}}$$

$$\boxed{\frac{C(s)}{R(s)} = \frac{16}{s^2+4s+16\alpha s+16} = \frac{16}{s^2+(16\alpha+4)s+16}}$$

comparing with std. 2nd order system equation

$\boxed{\omega_n = 4 \text{ rad/sec}}$ (B) $\boxed{2\xi'\omega_n = 16\alpha+4}$ (A)

Now : %Mp reduced to 1.25%

$$M_p = 0.0125 = e^{-\pi\xi'/\sqrt{1-(\xi')^2}}$$

$$-4.382 = \frac{-\pi\xi'}{\sqrt{1-(\xi')^2}}$$

$$(\xi')^2 = (1-(\xi')^2)\,1.945$$

$$(\xi')^2 = 1.945 - 1.945(\xi')^2$$

$$2.945(\xi')^2 = 1.945$$

$$\boxed{\xi' = 0.812}$$

put ξ' in eq^n (A)

$$\therefore 2 \times 0.812 \times 4 = 16\alpha + 4$$

$$\Rightarrow \boxed{\alpha = 0.156}$$
//

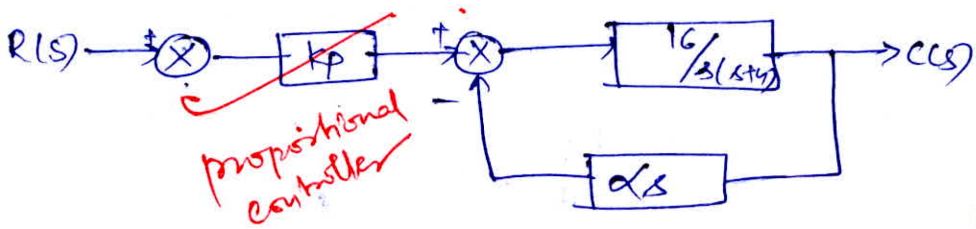
$e_{ss} = \frac{1}{K_v}$ $\qquad K_v = \lim_{s\to 0} s \cdot \frac{16}{s[s+(16\alpha+4)]}$

$e_{ss} = \frac{16\alpha+4}{16}$ $\qquad K_v = \frac{16}{(16\alpha+4)}$

$= \frac{16\times 0.156+4}{16} \Rightarrow \boxed{e_{ss} = 0.406}$

ii) Maintaining peak overshoot same at 1.25% but reducing e_{ss} to same as that in part i) ie $e_{ss} = 0.25$, we can use a

P-D controller :· Gain of the system has to be increased.



$\because e_{ss} = \frac{1}{K_v} = \frac{16\alpha+4}{16} = 0.25$

$\boxed{\alpha = 0}$

$\Downarrow$

Derivative feedback has to be removed but can't be removed ∵ it improves ξ thereby reducing M_p.

So Increase Gain to reduce e_{ss}.

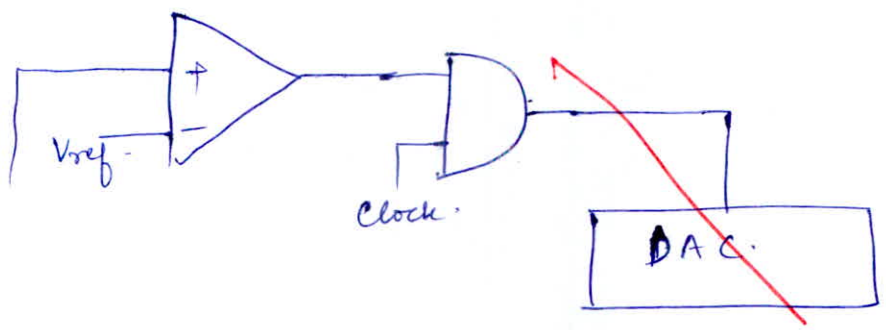
$\therefore$ $\boxed{P+D}$ controller is used.

Q.6 (b) **(i)** Explain with a block diagram, the working principle of a dual-slope A/D converter. Derive the expression for the output and maximum conversion time of the circuit.

(ii) A dual-slope A/D converter has a resolution of 4 bits. If the clock rate is 3.2 kHz, then calculate the maximum sampling rate with which the samples can be applied to the A/D converter.

[15 + 5 marks]

Dual Slope A/D Converter :



Resolution = 4 bits = n

f_{clk} = clock rate = 3.2 KHz

To find Max^m sampling Rate.

$$T_{conversion} = 2^{N+1} T_{clk} \le T_s.$$

↳ Sampling Time.

$$\Rightarrow 2^5 \times \frac{1}{3.3 \times 10^3} \le T_s$$

$$\Rightarrow T_s \geq \frac{32}{3.3} \times 10^{-3}$$

$$\boxed{T_s \geq 9.696 \text{ msec}}$$

Max^m sampling Rate: (f_s)

$$\frac{1}{f_s} \geq 9.696 \text{ msec}$$

$$\Rightarrow f_s \le \frac{1}{9.696} \times 10^3 \text{ Hz}$$

4

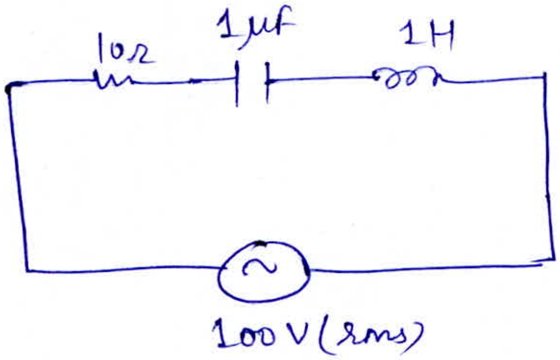
$$\Rightarrow f_{s\,max} = 0.103 \text{ KHz}$$

$$\boxed{f_{s\,max} = 103 \text{ Hz}}$$

Do not write in this margin

6 (c) A circuit is made up of a 10 Ω resistance, a 1 μF capacitance and 1 H inductance all connected in series. A sinusoidal voltage of 100 V (rms) at varying frequencies is applied to the circuit. Find the frequency at which the circuit would consume only 10% of the power it consumed at resonance?

[15 marks]



To find : f at which 10% of Power consumed at resonance.

At resonance : $I = \frac{V}{R} = \frac{100}{10} = 10\,A$

Power in circuit $= I^2 R$

$= 10^2 \times 10 = \underline{\underline{1000\,W}}$

Power reqd = 10 % of Power at Resonance

$= \frac{10}{100} \times 1000$

$= \underline{\underline{100\,W}}$

2

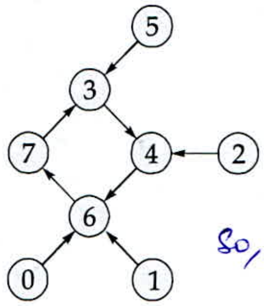
$P = I^2 (R + X_L + X_C)$

$X_L = 2\pi f$, $X_C = \frac{1}{2\pi f} \times 10^6$

$Z = 10 + j(2\pi f) - \frac{j}{2\pi f} \times 10^6$.

$I^2 (Z) = 100\,W$.

7 (a) Design a synchronous counter, whose sequence diagram is shown below, using *D* flip-flops.



∵ States are from 0 to 7.

So, Required No: of flip-flops $= \log_2 8 = 3$

[20 marks]

17)

State Table :

Present State			Next State			Flip Flop Inputs		
Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	$D_2 = Q_2^+$	$D_1 = Q_1^+$	$D_0 = Q_0^+$
0	0	0	1	1	0	1	1	0
0	0	1	1	1	0	1	1	0
0	1	0	1	0	0	1	0	0
0	1	1	1	0	0	1	0	0
1	0	0	1	1	0	1	1	0
1	0	1	0	1	1	0	1	1
1	1	0	1	1	1	1	1	1
1	1	1	0	1	1	0	1	1

Now Kmap for D_2

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	1	1	1	1
1	1			1

$$D_2 = \overline{Q_2} + \overline{Q_0}$$
$$= \overline{Q_2 \cdot Q_0}$$

K-map for D_1:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	1	1		
1	1	1	1	1

$$D_1 = Q_2 + \overline{Q_1}$$

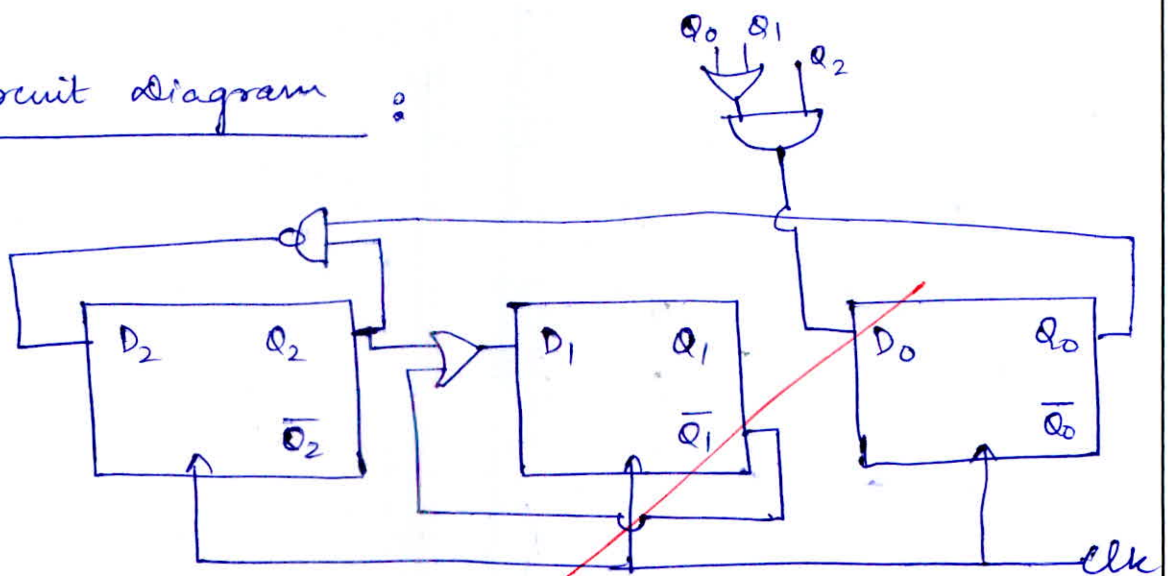
K-map for ~~$\bullet$~~ D_0

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0				
1		1	1	1

$$D_0 = Q_2Q_0 + Q_2Q_1$$

$$\boxed{D_0 = Q_2(Q_0 + Q_1)}$$

Circuit Diagram :



19

7 (b) A linear time invariant system is characterised by the homogeneous state equation,

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

(i) Compute the solution of the homogeneous equation assuming the initial state vector $x(0) = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$.

(ii) Consider now the system has a forcing function and is represented by the following non-homogeneous state equation:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

where u is a unit step input function. Compute the solution of this equation assuming initial conditions of part (i).

[10 + 10 marks]

7b) (i)
$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \underbrace{\begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}}_{A} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \quad \text{--- (1)}$$

Initial state vector = $x(0) = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$ (Given).

Solution of Homogeneous state equation is given by

$$\boxed{X(t) = \phi(t) \cdot x(0)}$$

where $\phi(t) = L^{-1}\left[(sI - A)^{-1}\right]$

So from given ~~mat~~ state equation, A matrix is

$$A = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$$

$$(sI - A) = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} = \begin{bmatrix} s-1 & 0 \\ -1 & s-1 \end{bmatrix}$$

$$\cancel{\phi(t)} = (sI - A)^{-1} = \frac{1}{(s-1)^2} \begin{bmatrix} s-1 & 0 \\ 1 & s-1 \end{bmatrix}$$

$$= \begin{bmatrix} \frac{1}{(s-1)} & 0 \\ \frac{1}{(s-1)^2} & \frac{1}{(s-1)} \end{bmatrix}$$

$\therefore \ \phi(t) = L^{-1}\left[(sI-A)^{-1}\right] = L^{-1}\begin{bmatrix} \frac{1}{(s-1)} & 0 \\ \frac{1}{(s-1)^2} & \frac{1}{(s-1)} \end{bmatrix}$

$$\phi(t) = \begin{bmatrix} e^t & 0 \\ te^t & e^t \end{bmatrix}$$

$\therefore$ Solution of Homogeneous equation is :

$x(t) = \phi(t)\,x(0) = \begin{bmatrix} e^t & 0 \\ te^t & e^t \end{bmatrix}\begin{bmatrix} 0 \\ 1 \end{bmatrix}$

$$\boxed{x(t) = \begin{bmatrix} \cancel{0} \\ e^t \end{bmatrix}}$$ Ans.

4

(ii) Now $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \underset{2\times2}{\begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}}\underset{2\times1}{\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}} + \underset{2\times1}{\begin{bmatrix} 0 \\ 1 \end{bmatrix}}\underset{(1\times1)}{u}$

initial condn : $x(0) = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$

Solution of Non-Homogeneous state equation is given by

$$\boxed{x(t) = \underbrace{\phi(t)\cdot x(0)}_{\text{same as computed in part (i)}} + L^{-1}\left[\phi(s)\,B\,U(s)\right]}$$

$\phi(s) = \begin{bmatrix} \frac{1}{(s-1)} & 0 \\ \frac{1}{(s-1)^2} & \frac{1}{(s-1)} \end{bmatrix}$, $B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$, $U(s) = \left[\frac{1}{s}\right]$

$\phi(s)\,B\,U(s) = \begin{bmatrix} \frac{1}{s-1} & 0 \\ \frac{1}{(s-1)^2} & \frac{1}{s-1} \end{bmatrix}\begin{bmatrix} 0 \\ 1 \end{bmatrix}\left[1/s\right]$

$$= \begin{bmatrix} \frac{1}{s-1} & 0 \\ \frac{1}{(s-1)^2} & \frac{1}{(s-1)} \end{bmatrix}_{2\times 2} \begin{bmatrix} 0 \\ 1/s \end{bmatrix}_{2\times 1}$$

$$= \begin{bmatrix} 0 \\ \frac{1}{s(s-1)} \end{bmatrix}$$

4

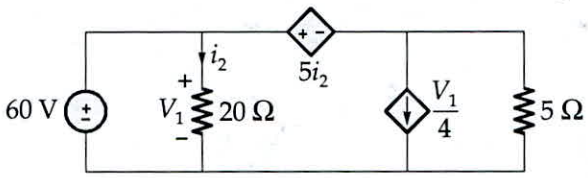
∴ Sol^n is :

$$X(t) = \begin{bmatrix} 0 \\ e^t \end{bmatrix} + L^{-1}\begin{bmatrix} 0 \\ \frac{1 = s-(s-1)}{s(s-1)} \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ e^t \end{bmatrix} + \begin{bmatrix} 0 \\ (e^t-1) \end{bmatrix} = \begin{bmatrix} 0 \\ 2e^t - 1 \end{bmatrix} \text{ Ans.}$$

(c) (i) State and explain the Tellegen's theorem.

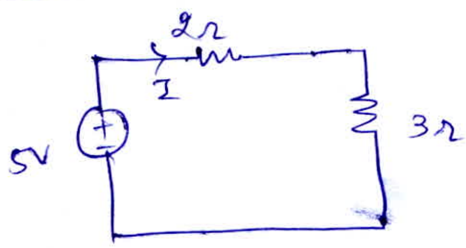
(ii) For the network shown below, show that it will satisfy Tellegen's theorem.



[8 + 12 marks]

1^n Tellegen's Theorem states that in any network ~~the~~, total power delivered by the system is equal to the ~~tota~~ total power absorbed / consumed by the system

i.e Sum, Total of all the powers absorbed / delivered in any network is zero.

Ex: 

Consider a Network shown.

$$I = \frac{5}{2+3} = 1\,A$$

Power delivered by 5V battery $= -5 \times 1$
$= -5W$

Power absorbed by 2Ω resistance $= I^2R$

$= (1)^2 \times 2 = \underline{\underline{2W}}$

Power absorbed by 3Ω resistance $= I^2R$

$= (1)^2 \times 3 = \underline{\underline{+3W}}$

7

Total Sum of Power absorbed / delivered

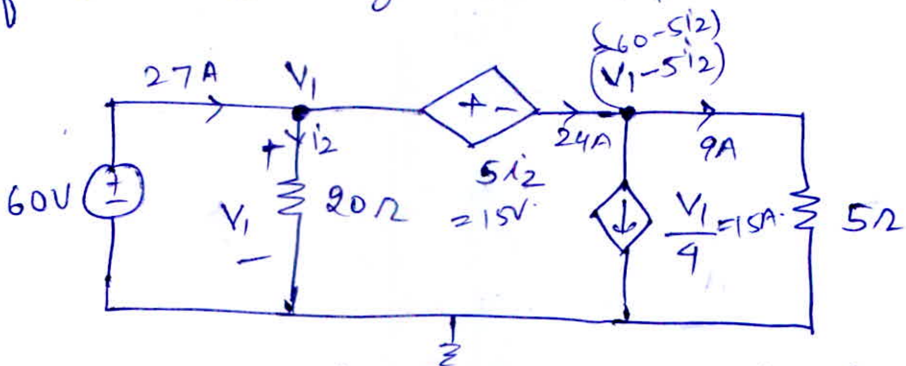
$= -5 + 2 + 3$

$= \underline{\underline{0\,W}}$] Tellegen's Theorem verified.

Note:

Tellegen's Theorem is applicable for all kind of Networks viz active, passive, etc

ii)



To show : given Network satisfies Tellegen's Theorem :

Apply Nodal at $\boxed{V_1 = 60V}$

$$\boxed{i_2 = \frac{60}{20} = 3A}$$

Current in $5\Omega = \frac{V_1 - 5i_2}{5} = \frac{60 - 5\times 3}{5} = 9A$

$\therefore$ Power delivered by $60V = -60 \times 27A$

$= \underline{\underline{-1620\,W}}$

Power in $20\Omega = V_1 \times i_2$

$= 60 \times 3 = \underline{\underline{180W}}$

Power in 5Ω = 9×45

= $\underline{\underline{405}}$ W

Power in $\frac{V_1}{4}$ current source = 15×45

= $\underline{\underline{675}}$ W

Power in $5i_2$ battery = $24 \times 5i_2$

$= 24 \times 15 = \underline{\underline{360 W}}$

Σ Power = $-1620 + 180 + 405 + 675 + 360$

$= -1620 + 1620$

$= \underline{\underline{0 W}}$

Hence proved

Tellegen's Theo satisfied

11

Q.8 (a) Two 8-bit numbers are stored in the memory locations 2000H and 2001H. Write 8085 assembly language programs to multiply these two numbers using,

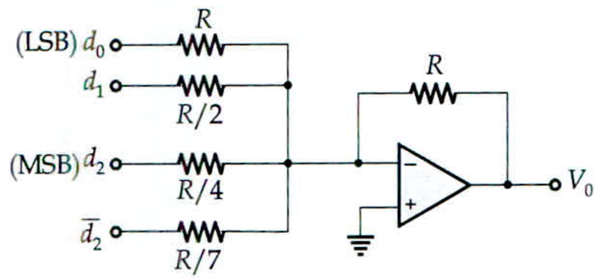
(i) Successive addition method **(ii)** Shift and add method

The final result should be stored at the memory locations 3000H and 3001H.

[10 + 10 marks]

Q.8 (b) Consider the circuit shown in the figure below:

$$d_i = \begin{cases} +\frac{1}{2}\text{V}; & \text{for logic}-0 \\ -\frac{1}{2}\text{V}; & \text{for logic}-1 \end{cases}$$



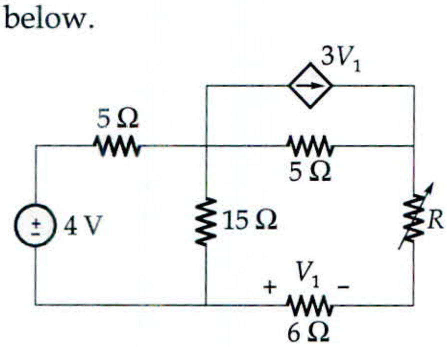
(i) Derive an expression for output voltage, V_0 in terms of input logic values.

(ii) Using the result obtained in part (i), determine the value of V_0 for all the possible binary combinations of input and comment on the operation performed by the circuit.

[12 + 8 marks]

Q.8 (c) **(i)** State and prove the maximum power transfer theorem for purely resistive source circuit with variable load resistance.

(ii) Determine the maximum power that can be delivered to the variable resistor R in the circuit shown below.



[10 + 10 marks]

OOOO

Space for Rough Work

$f_c + w$ · $2f_c + 2w$ · $2f_c + 2w$

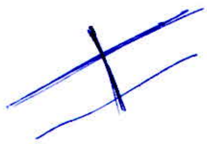
$\cancel{f_c} + \cancel{f_c} + w$

w

$-f_c - f$ 0

Space for Rough Work

Mean = 0

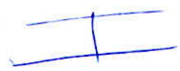


$w(t)$

$n_1 = \int_0^{1.5} w(t)\,dt$

$n_2 = \int_1^2 w(t)\,dt$

n_1



Var = E

$e_{ss} = \lim_{t \to \infty} e(t)$

$= \lim_{s \to 0} sE(s)$

$n(t) = (n_1 - n_2)$

$E[n^2(t)] = E[(n_1 - n_2)^2]$

$= E[n_1^2(t)] + E[n_2^2(t)]$ 0

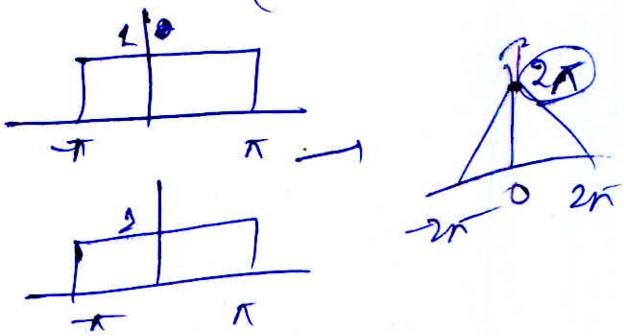
$\frac{sR(s)}{1+G(s)H(s)}$

$\boxed{\text{Now}}$

$\frac{s-(s-1)}{s(s-1)}$

$\frac{1}{(s-1)} - \frac{1}{s}$

$(e^t - 1)$



$1 \times 2\pi$

26) 1380 (5
130
80

$\frac{2\pi t}{}$

$\frac{4\pi^2}{2\pi}\,\omega$

2ω

$(2\omega) + C$ $3 + 10$

$2 - 2\omega$

$5 + 27$