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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 : .....

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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	37
Q.2	—
Q.3	50
Q.4	—
Section-B	
Q.5	45
Q.6	45
Q.7	47
Q.8	—
Total Marks Obtained	224

Very good presentation & accuracy.

Signature of Evaluator

Cross Checked by

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Section A : Analog and Digital Communication Systems

Q.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]

$$x(t) \xleftrightarrow{H.T} y(t) = \hat{x}(t).$$

$$R_X(\tau) = E[x(t)x(t+\tau)]$$
$$R_Y(\tau) = E[\hat{x}(t)\hat{x}(t+\tau)]$$

$$\hat{x}(t) = h(t) * x(t)$$
$$h(t) = \frac{1}{\pi t}$$

$$R_X(\tau) \xleftrightarrow{F.T} S_X(f)$$
$$R_Y(\tau) \xleftrightarrow{F.T} S_Y(f)$$

$$\hat{x}(t) = \int x(\tau).\frac{1}{\pi(t-\tau)}.d\tau$$

$$S_X(f) = \int_{-\infty}^{\infty} R_X(\tau).e^{-j\omega\tau}.d\tau.$$

$$\hat{x}(t) \xleftrightarrow{F.T} -j\,sgn(f)\,x(f)$$

$$R_{XY}(\tau) = E[x(t)\,y(t+\tau)]$$
$$= E[x(t)\hat{x}(t+\tau)]$$

$$x(t) \longrightarrow \boxed{H.T} \longrightarrow \hat{x}(t)$$

$S_X(f)$ $\qquad$ $S_Y(f)$

$$R_{XY}(-\tau) = E[x(t)\,y(t-\tau)]$$
$$E[x(t)\hat{x}(t-\tau)]$$

4

since we know

$$S_Y(f) = S_X(f)\,|H(f)|^2$$
$$S_Y(f) = S_X(f)$$

Taking inverse F.T

$$\boxed{R_Y(\tau) = R_X(\tau)}$$

proved

2

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

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

If $\mu = \frac{1}{2}$ 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]

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

$s(t) = \left(1 + \frac{1}{2}\cos\omega_m t\right)\cos\omega_c t.$

$s(t) = \cos\omega_c t + \frac{1}{4}\cos(\omega_c + \omega_m)t + \frac{1}{4}\cos(\omega_c - \omega_m)t.$

Upper side band is attenuated by a factor of 2

so,

$s(t) = \cos\omega_c t + \frac{1}{8}\cos(\omega_c + \omega_m)t + \frac{1}{4}\cos(\omega_c - \omega_m)t.$

preenvelope $s_+(t) = s(t) + j\hat{s}(t)$ $\quad$ $\hat{s}(t) \Rightarrow$ Hilbert transform of $s(t)$

$\hat{s}(t) = \sin\omega_c t + \frac{1}{8}\sin(\omega_c + \omega_m)t + \frac{1}{4}\sin(\omega_c - \omega_m)t$

$s_+(t) = s(t) + j\hat{s}(t)$

$= (\cos\omega_c t + j\sin\omega_c t) + \left(\frac{1}{8}\cos(\omega_c + \omega_m)t + \frac{1}{8}j\sin(\omega_c + \omega_m t)\right.$

$\left. + \frac{1}{4}[\cos(\omega_c - \omega_m)t + j\sin(\omega_c - \omega_m)t]\right]$

$s_+(t) = e^{j\omega_c t} + \frac{1}{8}e^{j(\omega_c + \omega_m)t} + \frac{1}{4}e^{j(\omega_c - \omega_m)t}.$

$s_+(t) = \tilde{s}(t)\, e^{j\omega_c t}$

$\tilde{s}(t) \Longrightarrow$ complex envelope of the signal $s(t)$

$\tilde{s}(t) = s_+(t) \cdot e^{-j\omega_c t}$

$\tilde{s}(t) = \left[e^{j\omega_c t} + \frac{1}{8} e^{j(\omega_c+\omega_m)t} + \frac{1}{4} e^{j(\omega_c-\omega_m)t} \right] \cdot e^{-j\omega_c t}$

2

$\tilde{s}(t) = 1 + \frac{1}{8} e^{j\omega_m t} + \frac{1}{4} \cdot e^{-j\omega_m t}$

$\tilde{s}(t) = 1 + \frac{1}{8} e^{j\omega_m t} + \frac{1}{8} \cdot e^{-j\omega_m t} + \frac{1}{8} \cdot e^{-j\omega_m t}$

complex envelope of bandpass signal $s(t)$. $\leftarrow$ $\boxed{\tilde{s}(t) = 1 + \frac{1}{4} \cos \omega_m t + \frac{1}{8} \cdot e^{-j\omega_m t}}$

Incomplete soln

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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]

(i) $s(t) = 10\cos 13000t$

$s(t) = 10\cos[1000t + 3000t]$ — ①

Generalized expression of PM signal. $\Rightarrow s(t) = A\cos[2\pi f_c t + k_p m(t)]$ — ②

comparing the eq^n ① & eq^n ②

$k_p m(t) = 3000t$

since $k_p = 1000$ rad/V.

$k_p m(t) = 3000t = 1000 \times m(t)$

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

(ii) $s(t) = 10\cos(1000t + 3000t)$ —①

Generalized exp. of FM signal. $s(t) = 10\cos\left[1000t + 2\pi k_f \int_{-\infty}^{t} m(\tau)\, d\tau\right]$ —②

$f_i = f_c + k_f m(t)$

$f_i = \frac{1}{2\pi}\theta'(t)$

$\theta(t) = \int 2\pi f_i(t)\, dt$

$\theta(t) = 2\pi f_c t + 2\pi k_f \int m(t)\, dt$.

comparing eq^n ① & eq^n ②, we get where $k_f = $ Hz/V

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

$1000 \int_0^{\tau} m(\tau)\, d\tau = 3000t$

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

differentiating on both sides, we get

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

Write units too

10

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Q.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]

$Y = aX + b.$

$H(X) = \int_{-\infty}^{\infty} f_X(x) \log_2 \frac{1}{f_X(x)} \cdot dx \Rightarrow$ differential entropy of X.

$H(Y) = \int_{-\infty}^{\infty} f_Y(y) \cdot \log_2 \frac{1}{f_Y(y)} \cdot dy. \Rightarrow$ differential entropy of Y.

1

$Y = aX + b.$

$P(Y \le y) = P(y \le ax + b)$

$F_Y(y) = P[ax + b \ge y] = P[ax \ge y - b]$

$P[x \ge \frac{y-b}{a}]$

$= 1 - P[x < (\frac{y-b}{a})]$

3

$F_Y(y) = 1 - F_X(\frac{y-b}{a})$

Differentiating on both sides.

$f_Y(y) = -f_X(\frac{y-b}{a}) \cdot [\frac{1}{a}]$

$H(Y) = -\int_{-\infty}^{\infty} f_Y(y) \log_2 f_Y(y) \cdot dy = +\int_{-\infty}^{\infty} [f_X(\frac{y-b}{a})] \cdot (\frac{1}{a}) \log_2 (\frac{1}{a}) f_X(\frac{y-b}{a}) \cdot dy$

Let $\frac{y-b}{a} = \lambda$.

$$H(Y) = \frac{1}{a}\int_{-\infty}^{\infty} f_X\left(\frac{y-b}{a}\right) \cdot \log_2\left[\left(\frac{-1}{a}\right) \cdot f_X\left(\frac{y-b}{a}\right)\right] \cdot dy$$

$\frac{y-b}{a} = \lambda$. $\quad dy = a\,d\lambda$.

$$H(Y) = \frac{1}{a}\int_{-\infty}^{\infty} f_X(\lambda) \cdot \log_2\left[\left(-1/a\right) \times f_X(\lambda)\right] \cdot a\,d\lambda.$$

$$H(Y) = \int_{-\infty}^{\infty} f_X(\lambda) \log_2\left[-\frac{f_X(\lambda)}{a}\right] \cdot d\lambda.$$

$$H(Y) = \int_{-\infty}^{\infty} f_X(\lambda) \log_2 f_X(\lambda) + \int_{-\infty}^{\infty} f_X(\lambda) \log_2(-1/a) \cdot d\lambda$$

$H(Y) = H(X) +$

Q.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 :-

1) System becomes simple.

* Disadvantages :-

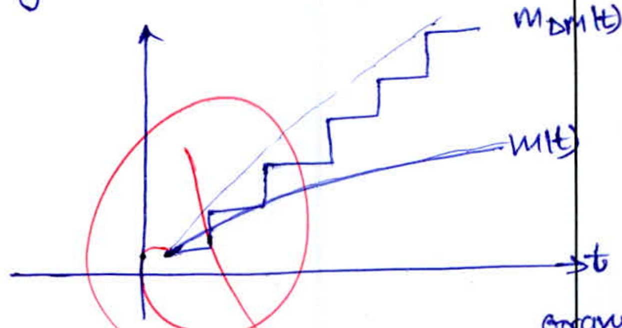
1) Bit rate is high i.e, oversampling is done to get the desired output.
2) large quantization noise present.
3) Only for those signal which have linear slope i.e, not suitable for signals having non-linear slope eg:- $\sin\omega t$, $\cos\omega t$, t^2. etc.
4) Affected by granular noise and sloap overload error.

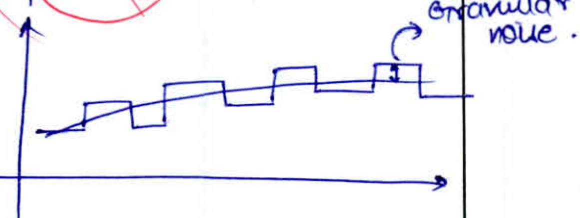
→ Noise associated with delta modulation are:-

1) Granular Noise :- It happens when the step size is so large that $\left[\frac{\Delta}{T_s} > \frac{d}{dt}[m(t)]_{max}.\right]$.

* Granular noise is removed by reducing the step size.

i.e $\frac{\Delta}{T_s} < \frac{dm(t)}{dt}$.



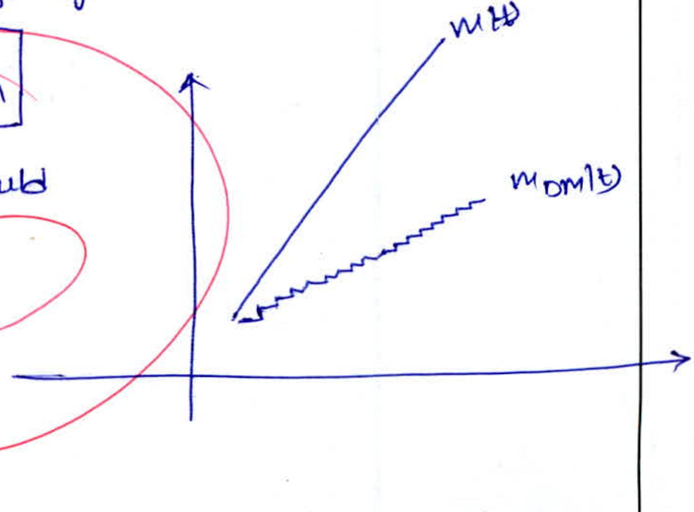


(ii) Sloap overload error :- Sload overload errors occurs when o/p of delta modulator is not able to catch up the message signal.

It occurs when $\boxed{\frac{\Delta}{T_s} \le \left.\frac{d(m(t))}{dt}\right|_{min}}$

To overcome this, the step size should be increased such that

$\frac{\Delta}{T_s} \ge \frac{d}{dt}(m(t))$



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Q.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]

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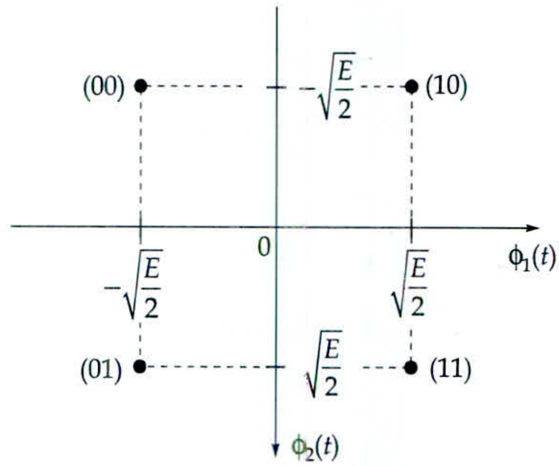
Q.2 (b) A double conversion superheterodyne receiver is designed with $f_{IF(1)}$ = 30 MHz and $f_{IF(2)}$ = 3 MHz. Local oscillator frequency of each mixer stage is set at the lower of the two possible values. When the receiver is tuned to a carrier frequency of 300 MHz, insufficient filtering by the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

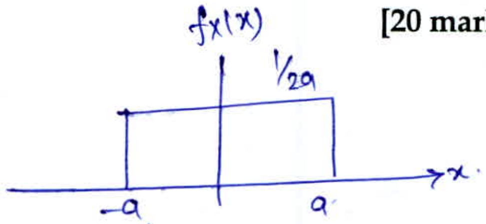
[25 marks]

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]

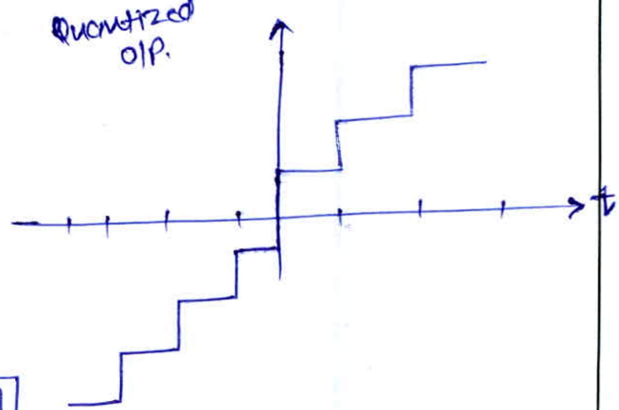
ans:

$$\frac{S}{N_Q} = \frac{\text{Power of signal}}{\text{quantization noise power.}}$$



$MSV = E[x^2(t)] = \text{total power}$

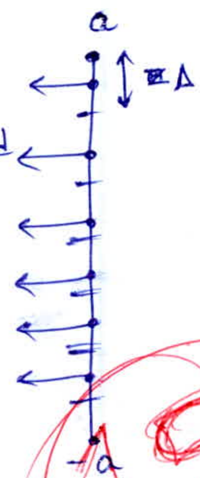
$$= \int_{-\infty}^{a} x^2 \cdot \frac{1}{2a} \cdot dx$$



$$= \frac{1}{2a} \cdot \frac{x^3}{3}\Big|_{-a}^{a}$$

$$\frac{1}{2a} * \left[\frac{a^3}{3} + \frac{a^3}{3}\right]$$

$$\frac{a^3}{3a} = \boxed{\frac{a^2}{3} = MSV = P[s(t)]}$$

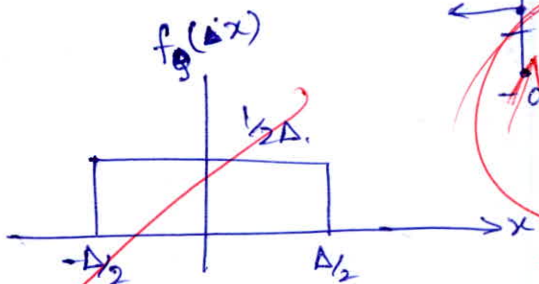


$$\underset{\text{stepsize}}{\Delta} = \frac{\text{dynamic range}}{L}$$

where $L = 2^n$ [no. of quantized levels]

$$\Delta = \frac{2a}{2^n}$$

$$N_Q = \int_{-\Delta/2}^{\Delta/2} \frac{1}{\Delta} \cdot x^2 \cdot dx$$



$$= \frac{1}{\Delta} \cdot \frac{1}{3} \cdot \left[\frac{\Delta^3}{8} + \frac{\Delta^3}{8}\right]$$

$$= \frac{1}{3\Delta} \cdot \frac{\Delta^3}{4} = \frac{\Delta^2}{12} = \left(\frac{2a}{2^n}\right)^2 \cdot \frac{1}{12}$$

can explain better

2

$$\frac{S}{N_Q} = \frac{a^2 \times 2^{2n} \cdot 12}{3 \times 4a^2} = 2^{2n} \Rightarrow \boxed{4^n = \frac{S}{N_Q}}$$

2

for

$$\frac{S}{N_Q}\Big|_{dB} = 10\log 4^n = 10n\log 4 = 6.02n\text{ dB}$$

for $n = 8$. $\quad S/N_Q\big|_{dB} = 6.02 \times 8 = 48.16$ dB ans

Q.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]

$H(x) = -\sum p(x_i)\log_2 p(x_i)$

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

$P[Y] = \left[P[X]\cdot P[Y/X]\right]$

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

$P[Y] = \left[0.288 \,.\; 0.711\right]$

$H(X) = -\left[\frac{1}{3}\log_2\frac{1}{3} + \frac{2}{3}\log_2\frac{1}{3}\right] = \boxed{0.918 = H(X)}$

$H(Y) = -\left[0.288\log_2 0.288 + 0.711\log_2 0.711\right] = \boxed{0.865 = H(Y)}$

$$P[X:Y] = P[X_d] \cdot P[Y/X]$$

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

$$P[X,Y] = \begin{bmatrix} 2/9 & 1/9 \\ 2/30 & 18/30 \end{bmatrix} = \begin{bmatrix} 0.22 & 0.111 \\ 0.0666 & 0.6 \end{bmatrix}$$

$$H(X,Y) = H(Y/X) + H(X)$$

$$= H(X/Y) + H(Y)$$

$$H(X,Y) = -\left[\sum P(x,y) \log_2 P(x,y)\right]$$

$$= 1.5366.$$

$$H(Y/X) = H(X,Y) - H(X)$$

$$\boxed{H(Y/X) = 0.618}$$

$$H(X/Y) = H(X,Y) - H(Y)$$

$$\boxed{H(X/Y) = 0.6716}$$

$$I(X,Y) = H(X) - H(X/Y) = H(Y) - H(Y/X)$$

$$= 0.918 - 0.6716$$

$$\boxed{I(X,Y) = 0.2464}$$ ans

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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).

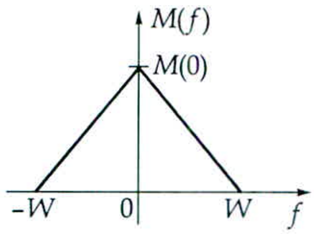


Figure (a)

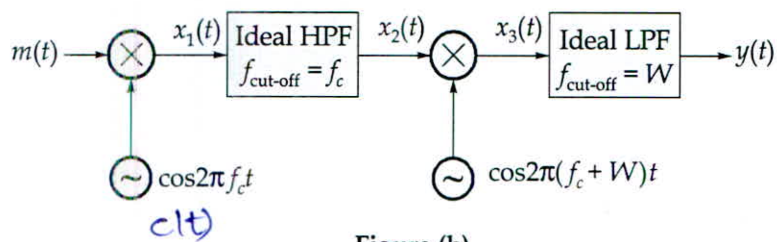


Figure (b)

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]

ans:-

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

$c(t) = 4\cos 2\pi f_c t = 4\cos\omega_c t$ $\quad [\because f_c = 100\text{HZ}]$

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

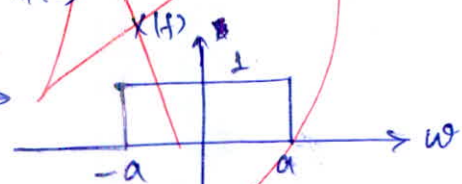
$s(t) = [2\text{sinc}(2t) - \text{sinc}^2(t)] \cdot 4\cos\omega_c t$

$S(\omega) = \frac{1}{2\pi}\left[M(\omega) * C(\omega)\right]$

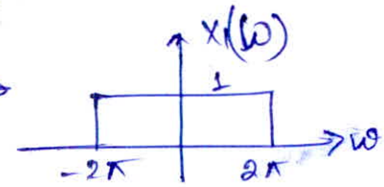
$M(\omega) = F\left[\frac{2\sin 2\pi t}{2\pi t} - \left(\frac{\sin \pi t}{\pi t}\right)^2\right]$

$\Downarrow$ $x_1(t)$ $\quad x_2(t)$

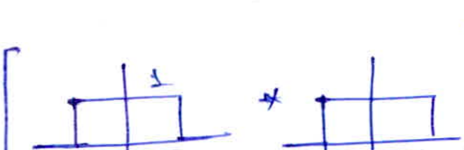
$\frac{\sin at}{\pi t} \xleftrightarrow{F.T}$



$x_1(t) = \frac{2\sin 2\pi t}{2\pi t} = \frac{\sin 2\pi t}{\pi t} \xleftrightarrow{F.T}$

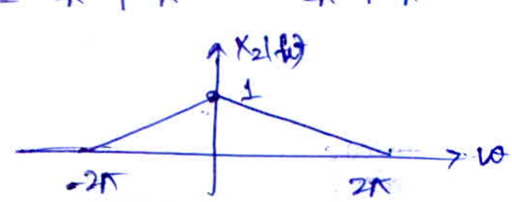


$x_2(t) = \left(\frac{\sin \pi t}{\pi t}\right)^2 \xleftrightarrow{F.T.} \frac{1}{2\pi}\Big[$

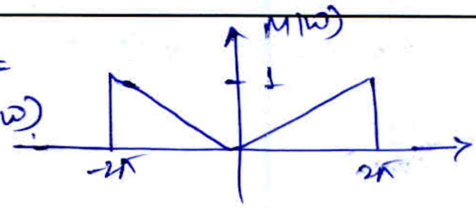


$\Big]$

$=$



$M(t) = x_1(t) - x_2(t) \xleftrightarrow{F.T.} M(\omega) = X_1(\omega) - X_2(\omega)$



$S(\omega) = \frac{1}{2\pi}\left[M(\omega) * C(\omega)\right]$

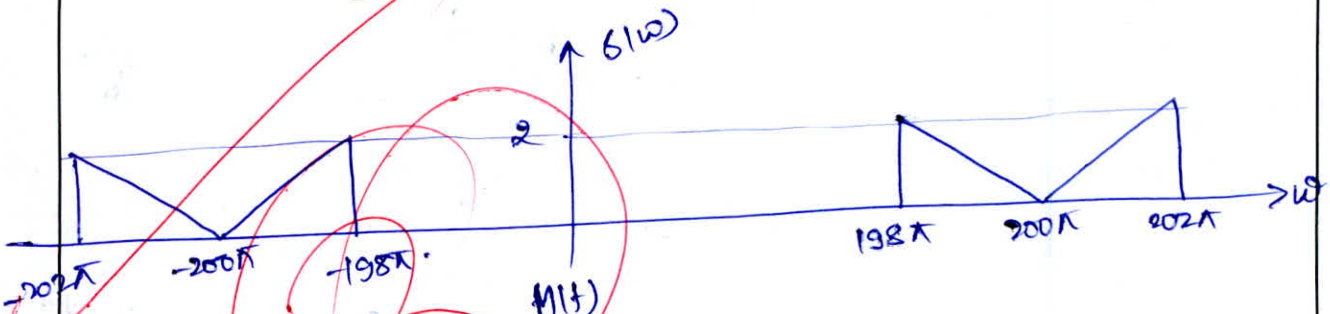
$\omega_c = 2\pi f_c$

$\omega_c = 200\pi$ rad/sec

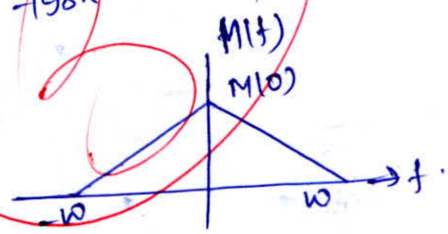
$= \frac{1}{2\pi}\left[M(\omega) * 4\cos\omega_c t\right]$

$= \frac{2\cancel{4}}{\cancel{2}\pi}\left[M(\omega) * \cos\omega_c t\right]$

$= 2\left[M(\omega-\omega_c) + M(\omega+\omega_c)\right]$



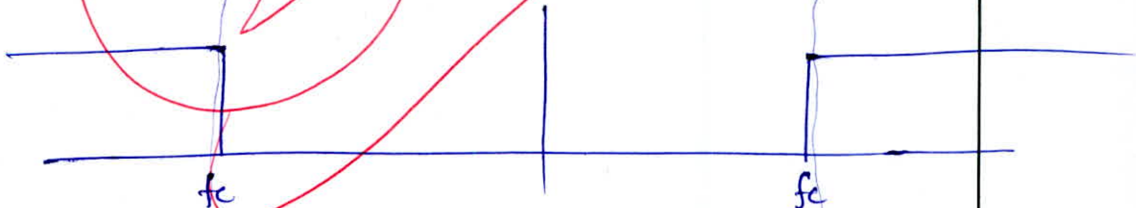
(ii) $M(f) =$



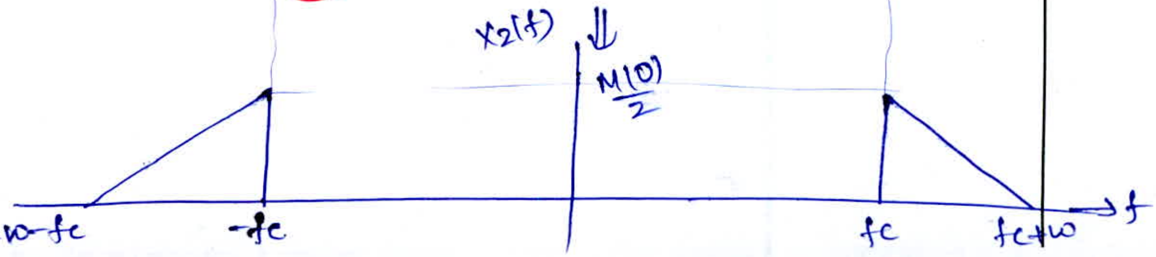
$x_1(t) = M(t) \times \cos 2\pi f_c t \xleftrightarrow{F.T.} M(f) * c(f)$

$= \frac{1}{2}\left[M(f-f_c) + M(f+f_c)\right] = X_1(f)$

⇓

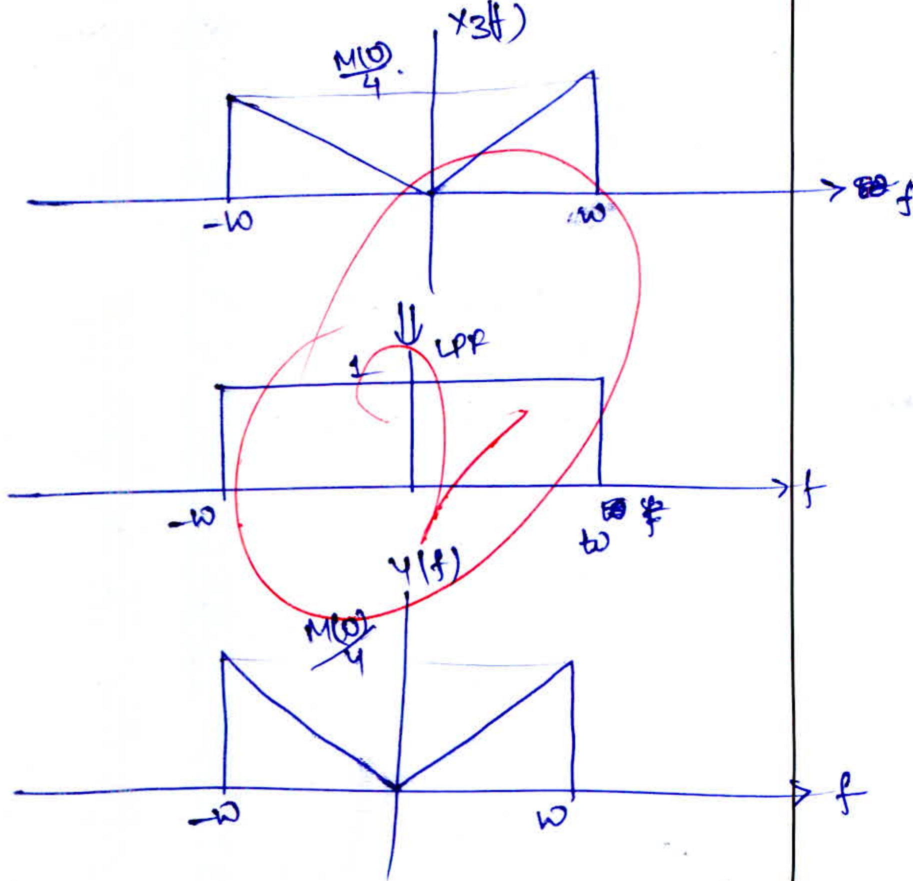


$X_2(f)$ ⇓



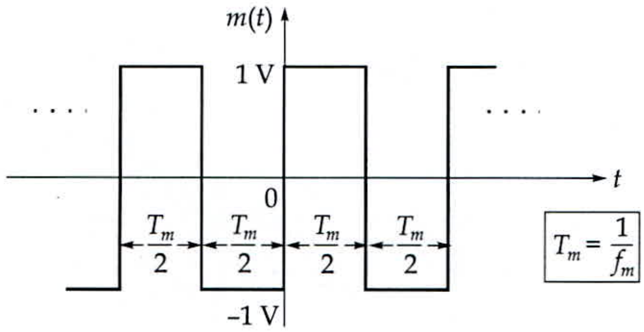
$$X_3(f) = \frac{1}{2}\left[X_2[f-(f_c+W)] + X_2[f+(f_c+W)]\right]$$

3



ans

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.



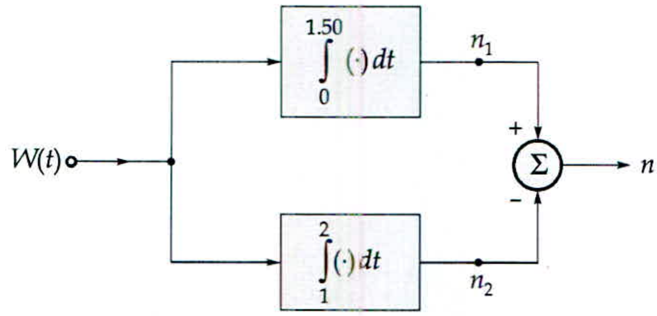
[25 marks]

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]

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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]

(a)

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

J:

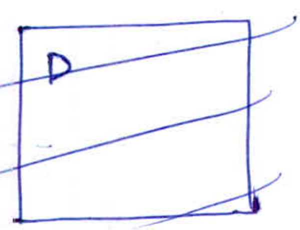
D \ Q	0	1
0	0	X
1	1	X

$\boxed{J = D}$

K:

D \ Q	0	1
0	X	1
1	X	0

$\boxed{K = \overline{D}}$



→ chracteristic table of J-K flip-flop + excitation table of D flip-flop:-

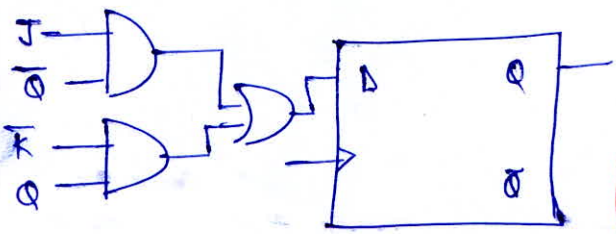
J	K	Q	Q^+	D
0	0	0	0	0
0	0	1	1	1
0	1	0	0	0
0	1	1	0	0
1	0	0	1	1
1	0	1	1	1
1	1	0	1	1
1	1	1	0	0

K-map:-

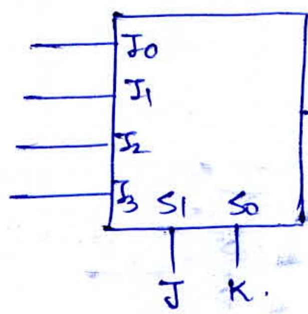
D

J \ KQ	00	01	11	10
0		1		
1	1	1		1

$\boxed{D = \overline{K}Q + J\overline{Q}}$

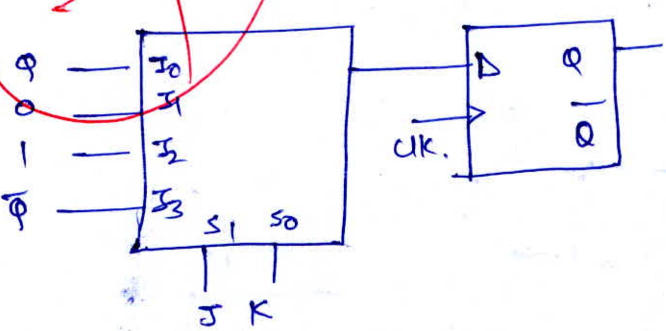


J	K	Q
1	0	0
1	1	0
0	0	1
1	0	1



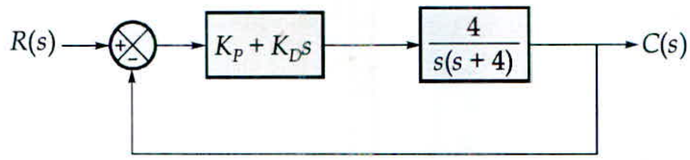
$f = J\bar{Q} + \bar{K}Q = \Sigma m\,[4, 6, 1, 5]$
(J, K, Q)

	I_0	I_1	I_2	I_3
	JKQ	JKQ	JKQ	JKQ
$\bar{Q}$	000	010	100	110
Q	001	011	101	111
	Q	0	1	$\bar{Q}$



ans

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]

Given: $\xi = 0.75$,
$e_{ss} = 0.25$ [unit ramp input].

$$G(s) = (k_p + k_D s)\frac{4}{s(s+4)}$$ [∵ $H(s) = 1$] unity feedback

characteristic equation

$$q(s) = 1 + G(s)H(s) = 1 + G(s) = 0$$

$$= 1 + \frac{(k_p + k_D s)4}{s(s+4)} = 0$$

$$= s^2 + 4s + 4k_D s + 4k_p = 0$$

$$= s^2 + (4 + 4k_D)s + 4k_p = 0 \quad -①$$

$$q(s) = s^2 + 2\xi\omega_n s + \omega_n^2 = 0 \quad -②$$

comparing eqn ① & ② we get.

$\omega_n^2 = 4k_p$.

$2\xi\omega_n = 4 + 4k_D$.

$$G(s) = \frac{(k_p + k_D s)4}{(4+s)s}$$

Type 1 system.

$$K_v = \lim_{s\to 0} sGH(s) = \lim_{s\to 0} \frac{4(k_p + k_D s)}{s+4} = k_p.$$

(for unit ramp input) $e_{ss} = \frac{1}{k_p} = 0.25 = \frac{1}{4}$.

KV

$\boxed{k_p = 4}$ -① ans

since, $\omega_n^2 = 4k_p$

$\omega_n^2 = 16$

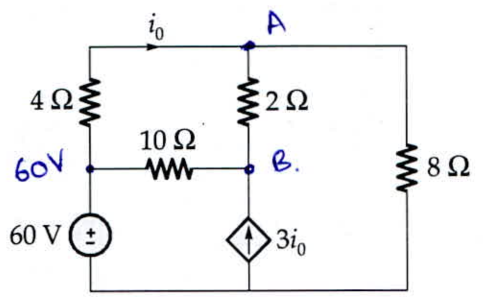
$\boxed{\omega_n = 4 \text{ rad/sec}}$

$2\xi\omega_n = 4 + 4K_D$

$2\times 0.75\times 4 = 4 + 4K_D$

$\boxed{K_D = 0.5}$ — ② ans

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



[12 marks]

using KVL:

$\frac{60 - V_A}{4} = i_0$ — ①

using KCL at node B:

$\frac{60 - V_B}{10} + 3i_0 = \frac{V_B - V_A}{2}$ — ②

Putting value of i_0 in eqn ②

$\frac{60 - V_B}{10} + 3\left[\frac{60 - V_A}{4}\right] = \frac{V_B - V_A}{2}$

$6 - \frac{V_B}{10} + 45 - \frac{3V_A}{4} = \frac{V_B}{2} - \frac{V_A}{2}$

$51 = \frac{3V_A}{4} - \frac{V_A}{2} + \frac{V_B}{2} + \frac{V_B}{10}$

$51 = \frac{V_A}{4} + \frac{\cancel{6}^{3} V_B}{\cancel{10}_{5}}$

$51\times 20 = 5V_A + 12V_B$ — ③

using KCL at A.

$i_0 = \frac{\cancel{V_B -} V_A - V_B}{2} + \frac{V_A - 0}{8}$ — ④

Putting value of i_0 in eqn ④

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$$\frac{60-V_A}{4} = \frac{V_A-V_B}{2} + \frac{V_A}{8}$$

$$\cancel{15 = \frac{V_A}{4} - \frac{V_A}{2} + \frac{V_B}{2} + \frac{V_A}{8}}$$

$$\cancel{15 = \frac{3V_A}{8} - \frac{V_A}{2} + \frac{V_B}{2}}$$

$$\cancel{15 = -\frac{V_A}{8} + \frac{V_B \times 4}{2\times 4}}$$

$$\cancel{15\times 8 = -V_A + 4V_B}$$

$$\cancel{51\times 20 = 5V_A + 12V_B}$$

$$\cancel{15\times 8\times 3 = -3V_A + 12V_B}$$

$$\cancel{660 = 8V_A}$$

$$\cancel{\boxed{V_A = 82.5}}$$

$$\cancel{i_0 = \frac{60-82.5}{4}}$$

$$\cancel{\boxed{i_0 = -5.625A}}$$

$$\frac{60-V_A}{4} = \frac{V_A-V_B}{2} + \frac{V_A}{8}$$

$$15 = \frac{V_A}{4} + \frac{V_A}{2} - \frac{V_B}{2} + \frac{V_A}{8}$$

$$15 = \frac{(2+4+1)}{8}V_A - \frac{V_B\times 4}{2\times 4}$$

$$3\times(15\times 8 = 7V_A - 4V_B)$$

$$3\times 15\times 8 = 3\times 7V_A - 12V_B$$

$$51\times 20 = 5V_A + 12V_B$$

$$26V_A = 1380$$

$$V_A = 53.0769$$

$$i_0 = \frac{60-V_A}{4}$$

$$i_0 = 1.73A \text{ ans}$$

1

3

3

Q.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 $\rightarrow 3T+4T = 7T$

LOOP2: MVI C, FFH $\rightarrow 3T+4T = 7T$

LOOP1: DCR C $\rightarrow 4T$

JNZ LOOP1 $\rightarrow 7T/10T \rightarrow$ True

↓ false

DCR B $\rightarrow 4T$

JNZ LOOP2 $\rightarrow 7T/10T$

RET $\rightarrow 10T$

[12 marks]

$f = 2MHz$

$\boxed{T = 0.5\mu sec.}$

Delay :

subroutine runs $= 7T + 7T + [254[14T] + 11T] + [14T] + 7T + [254[14T] + 11T] + 11T + 10T$

$= 14T + 2[254(14T) + 11T] + 21T + 11T + 10T$

$= 7190T$

Delay $= 7190 \times 0.5 \mu sec$

$\boxed{\text{Delay} = 3.595 \text{ msec.}}$

2

2

4

2

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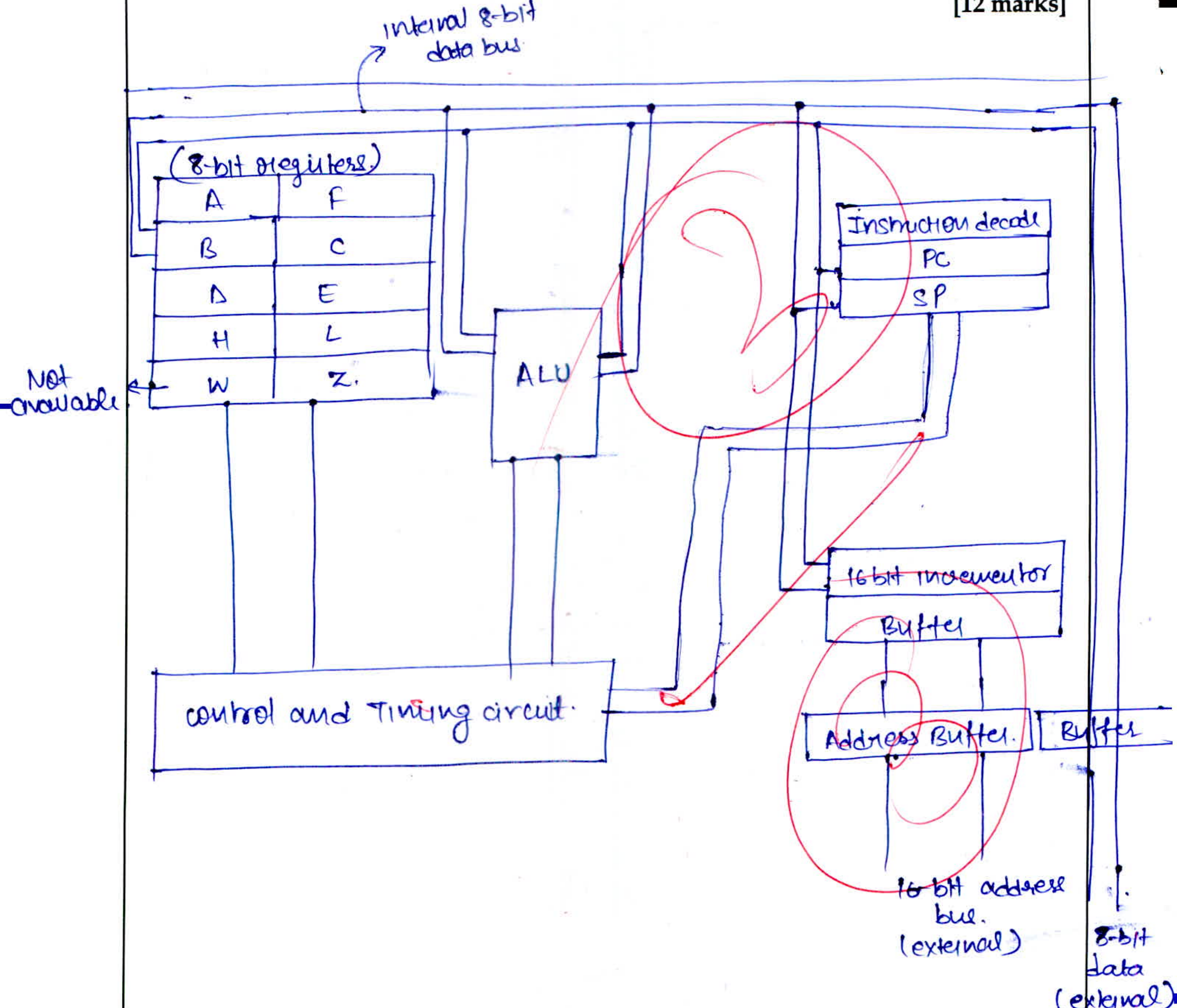
Q.5 (e) Sketch the internal block diagram of an 8086 microprocessor.

[12 marks]



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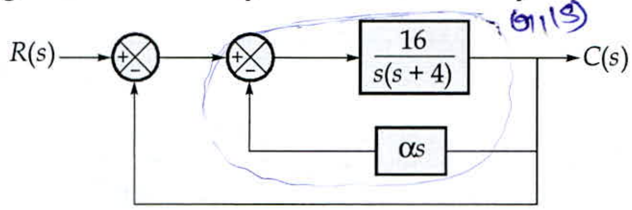
Q.6 (a) The following figure shows a unity feedback control system with rate feedback loop.



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]

(i)

$G(s) = \dfrac{16}{s(s+4)}$ $\quad [\because H(s) = 1]$

$q(s) = 1 + G(s)H(s) = s^2 + 4s + 16 = 0 \quad -①$

$q(s) = s^2 + 2\xi\omega_n s + \omega_n^2 = 0 \quad -②$

$T(s) = \dfrac{G(s)}{1+G(s)}$

$T(s) = \dfrac{16}{s^2+4s+16}$

comparing the eqn ① & ②

$2\xi\omega_n = 4.$

$\omega_n^2 = 16$

$\omega_n = 4\,rad/sec.$

$2 \times \xi \times 4 = 4$

$\boxed{\xi = 0.5}$

6

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

$= A\,e^{-\pi \times 0.5/\sqrt{1-0.5^2}}$

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

$[\because A = 1] \rightarrow$ standard second order transfer function.

$\boxed{M_p = 0.163.}$ $-①$ ans.

$G(s) = \dfrac{16}{s(s+4)}$

Type-1 system, so, for ramp i/p. (unity gain) $e_{ss} = 1/K_v$

where $K_v = \lim_{s\to 0} sG(s)$

$K_v = \lim_{s\to 0} s.\dfrac{16}{s(s+4)} = 4$

$e_{ss} = 1/K_v = 1/4 \Rightarrow \boxed{0.25 = e_{ss}}$ $-②$ ans

$\% M_p' = 12.5\%$

$\boxed{M_p' = 0.125}$

$$G_1(s) = \frac{\frac{16}{s(s+4)}}{1 + \frac{16}{s(s+4)} \cdot (\alpha s)} = \frac{16}{s(s+4) + 16\alpha s}$$

$$= \frac{16}{s^2 + 4s + 16\alpha s}$$

open loop Transfer function when rate feedback is included. $\Leftarrow$ $G_1(s) = \frac{16}{s[s + 16\alpha + 4]}$

$q(s) = 1 + G_1(s) = s^2 + (16\alpha + 4)s + 16 = 0$ — ①

$q(s) = s^2 + 2\xi\omega_n s + \omega_n^2 = 0$ — ②

comparing eqn ① & eqn ②

$\omega_n^2 = 16$

$\boxed{\omega_n = 4}$

$M_p' = e^{-\pi\xi/\sqrt{1-\xi^2}} = 0.125$

$\boxed{\cancel{\xi = 0.5524}}$ $\xi = 0.8127$

$2\xi\omega_n = 16\alpha + 4$

$2 \times 0.8127 \times 4 = 16\alpha + 4$

$\boxed{\alpha = 0.1563}$

Since, $G_1(s) = \frac{16}{s[s + 16\alpha + 4]} = \frac{16}{s[s + 6.5]}$

Type-1 system:

for unit ramp input $e_{ss} = 1/K_v$

$K_v = \lim_{s\to 0} sG_1(s) = \lim_{s\to 0} s \cdot \frac{16}{s(s+4.416)} = 2.46$

$e_{ss} = 1/K_v \Rightarrow \boxed{0.4063 = e_{ss}(\text{new})}$ ans

(ii) $e_{ss} = 0.25$

$M_p = 1.25\%$

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

$\boxed{\xi = 0.8127}$

$G_1(s) = \dfrac{16}{s(s+16\alpha+4)}$

3

for unit ramp i/p:

$e_{ss} = \dfrac{1}{K_v}$. where $K_v = \lim_{s\to 0} sG_1(s)$

$K_v = \lim_{s\to 0} sG_1(s) = \lim_{s\to 0} \dfrac{16}{16\alpha+4} = 0.25 = \dfrac{1}{4}$

$64 = 16\alpha + 4$

$60 = 16\alpha$

$\boxed{\alpha = 3.75}$ × wrong cal

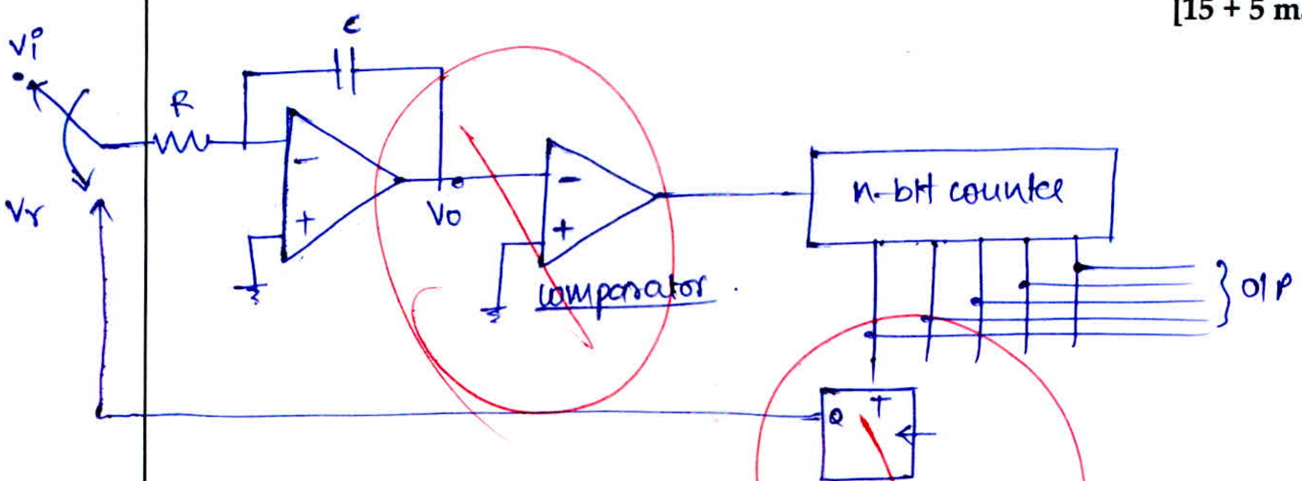
2

Make $\xi = 0.8127$ & $\alpha = 3.75$, we get the desired characteristic.

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

* Vi (input signal) is first applied to the integrator, and the integrator, integrate the voltage.

O/P voltage of integrator $\Leftarrow v_0 = \frac{(-1)}{RC}\int v_i\,dt$

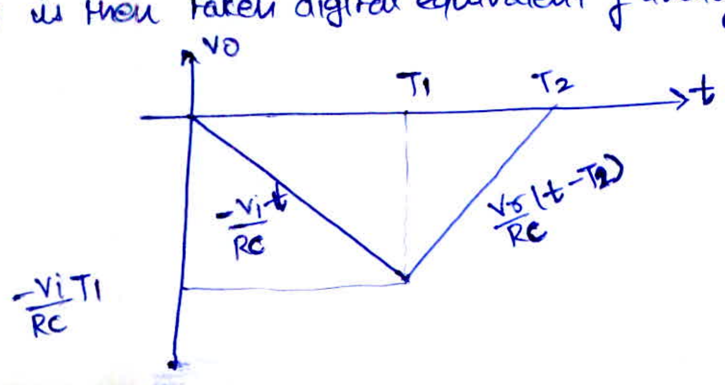
* The rate at which the O/P voltage of integrator is increasing, is directly proportional to the input voltage applied.

* The I/P voltage is applied until, the counter is fully loaded.

* when the counter again resets to 0, the toggle flip-flop acts as a switch and connect the integrator I/P to reference voltage which is generally taken greater than the I/P voltage.

* since Vr is -ve, so, the Vo starts increasing in the direction. when the Vo crosses 0V, the output of comparator becomes 0 and the counter stops counting.

* The value in the counter is then taken digital equivalent of analog input.



at $T = T_1$

$$\frac{-V_i}{RC} T_1 = \frac{V_r}{RC}(T_1 - T_2)$$

$$\frac{-V_i}{V_r} T_1 = T_1 - T_2$$

$$T_2 = T_1\left[1 + \frac{V_i}{V_r}\right]$$

$$T_2 - T_1 = N\,T$$

$T \rightarrow$ clock Time interval

$N \rightarrow$ decimal equivalent of counter.

$$+\frac{V_i}{RC} T_1 = 2^n T$$

$$T_1 = \frac{+2^n \times T}{}$$

$$\frac{+V_i T_1}{V_r} = T_1 - T_2$$

$$\frac{+V_i}{V_r} \times \frac{2^n \cancel{T}}{} = N \cancel{T}.$$

$$\boxed{V_i = \frac{V_r}{2^n} N}$$

Maximum conversion time $= (2^n + 2^{n-1})\,T$

$$\simeq 2^{(n+1)}\,T$$

(ii) no. of bits in counter $= 4$.

$$T = \frac{1}{3.2\text{KHz}}.$$

$$T_S = \frac{V_r}{2^n} \cdot N = \frac{V_r}{2^n} \times 2^{n+1} \cdot T$$

$$2^{n+1}\,T = T$$

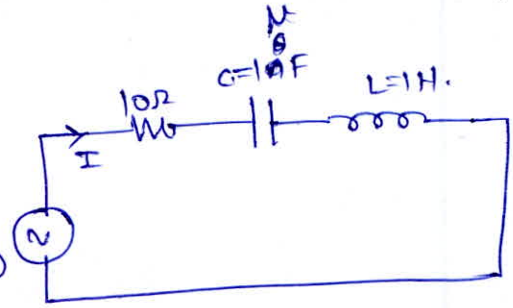
$$2^5 \cdot \frac{1}{3.2k} = T$$

sampling rate $\leftarrow \boxed{f = 100 \text{ samples / sec}}$

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]

At resonance, $X_L = X_C$, and V & I are in phase.



$Z|_{Resonance} = R = 10\Omega$

$I = \frac{V_s}{I} = \frac{100}{10} = 10\text{ A (rms)}$

$P = VI = 10 \times 100 = \boxed{1\text{kW} = P}$ at resonance.

$P_1 = 10\%$ of P

$P_1 = \frac{10 \times 1000}{100} = \boxed{100\text{W} = P_1}$ at particular frequency ω.

$Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$

$I = \frac{V}{Z} = \frac{100}{10 + j\left(\omega L - \frac{1}{\omega C}\right)}$

$|I| = \frac{100}{\sqrt{100 + \left(\omega L - \frac{1}{\omega C}\right)^2}} = \frac{100}{\sqrt{100 + (X_L - X_C)^2}} = \frac{100}{\sqrt{100 + X^2}}$.

$P_1 = VI = \frac{100 \times 100}{\sqrt{100 + X^2}} = 100$

$\sqrt{100 + X^2} = 100$

$X^2 + 100 = (100)^2$

$X^2 = 100^2 - 100$

$X^2 = 100 \times 99$.

$X = 99.498$

$\omega \times 1 - \frac{10^6}{\omega \times 1} = 99.498$

$\omega^2 - 99.498\omega - 10^6 = 0$

$\omega = \frac{99.498 \pm \sqrt{(99.498)^2 + 4 \times 10^6}}{2} = \frac{99.498 + 2002.473}{2}$

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$\boxed{\omega = 1050.98 \text{ rad/sec.}}$ ans

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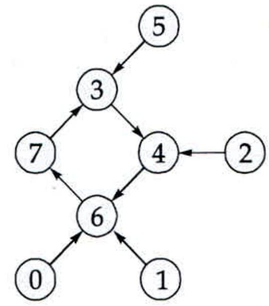
7 (a) Design a synchronous counter, whose sequence diagram is shown below, using *D* flip-flops.



[20 marks]

Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	D_2	D_1	D_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

3

D_2

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

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

1

D_1

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

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

2

D_0

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

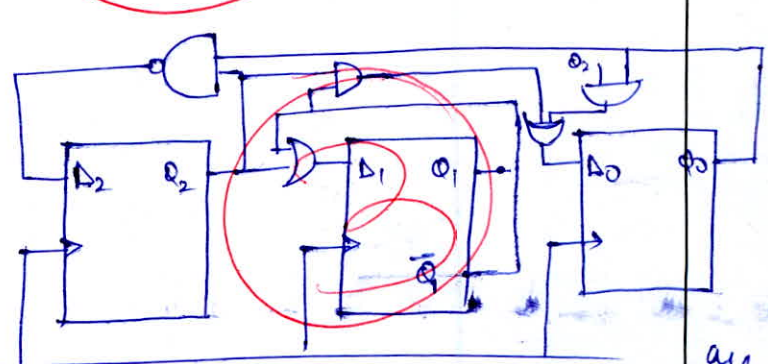
6

can explain better

$D_0 = Q_2 Q_0 + Q_2 Q_1$

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

3



3

ans

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]

$\dot{X} = AX + BU$ —(1)

$Y = CX + DU.$

$X(0) = \begin{bmatrix} 1 \\ 0 \end{bmatrix}, \quad A = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$

Take Laplace transform of eq^n (1).

$sX(s) - x(0) = AX(s)$

$(sI - A)X(s) = x(0)$

$X(s) = (sI - A)^{-1} x(0)$

$X(t) = L^{-1}\left[(sI - A)^{-1} x(0)\right]$

2

$$[sI - A] = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} s-1 & 0 \\ -1 & s-1 \end{bmatrix}$$

$$[sI - A]^{-1} = \frac{1}{(s-1)^2} \begin{bmatrix} (s-1) & 0 \\ +1 & (s-1) \end{bmatrix}$$

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

2

$$[sI - A]^{-1} x(0) = \begin{bmatrix} \frac{1}{s-1} & 0 \\ \frac{1}{(s-1)^2} & \frac{1}{s-1} \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{1}{s-1} \\ \frac{1}{(s-1)^2} \end{bmatrix}$$

$$x(t) = L^{-1}\left[(SI-A)^{-1}x(0)\right]$$

$$\boxed{x(t) = \begin{bmatrix} e^{t}u(t) \\ te^{t}u(t) \end{bmatrix}}$$ ans

4

(ii) $\dot{x} = AX + BU$
$Y = CX + DU$

$$sX(s) - X(0) = AX(s) + BU(s)$$

$$(SI-A)X(s) = x(0) + BU(s)$$

$$X(s) = L^{-1}\{\underbrace{(SI-A)^{-1}X(0)}_{ZIR}] + L^{-1}\{\underbrace{(SI-A)^{-1}B.U(s)}_{ZSR}\}$$

$$ZIR = x(t)|_{ZIR} = \begin{bmatrix} e^{t}u(t) \\ te^{t}u(t) \end{bmatrix}$$ as calculated in part (i).

$$[SI-A]^{-1} = \begin{bmatrix} \frac{1}{S-1} & 0 \\ \frac{1}{(S-1)^2} & \frac{1}{(S-1)} \end{bmatrix}$$

$$[SI-A]^{-1}B = \underset{2\times2}{\begin{bmatrix} \frac{1}{S-1} & 0 \\ \frac{1}{(S-1)^2} & \frac{1}{S-1} \end{bmatrix}}\underset{2\times1}{\begin{bmatrix} 0 \\ 1 \end{bmatrix}} = \underset{2\times1}{\begin{bmatrix} 0 \\ \frac{1}{S-1} \end{bmatrix}}$$

$$[SI-A]^{-1}B\,U[S] = \underset{2\times1}{\begin{bmatrix} 0 \\ \frac{1}{S-1} \end{bmatrix}}\underset{1\times1}{\begin{bmatrix} \frac{1}{s} \end{bmatrix}} = \underset{2\times1}{\begin{bmatrix} 0 \\ \frac{1}{s(s-1)} \end{bmatrix}} = \begin{bmatrix} 0 \\ \frac{1}{s-1} - \frac{1}{s} \end{bmatrix}$$

4

$$ZSR = L^{-1}\left[(SI-A)^{-1}BU(s)\right] = \begin{bmatrix} 0 \\ (e^{t}-1)u(t) \end{bmatrix}$$

$$x(t)|_{ZSR} = \begin{bmatrix} 0 \\ (e^{t}-1)u(t) \end{bmatrix}$$

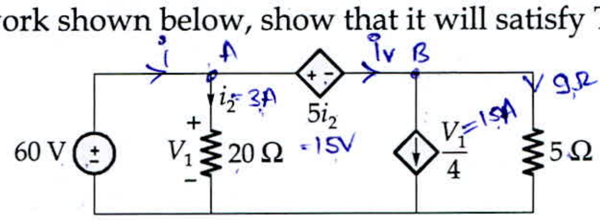
total Response

$$x(t) = ZIR + ZSR$$
$$= \begin{bmatrix} e^{t}u(t) \\ te^{t}u(t) \end{bmatrix} + \begin{bmatrix} 0 \\ e^{t}u(t) - u(t) \end{bmatrix}$$

$$x(t) = \begin{bmatrix} e^{t}u(t) \\ \left[(t+1)e^{t}-1\right]u(t) \end{bmatrix} \text{ ans}$$

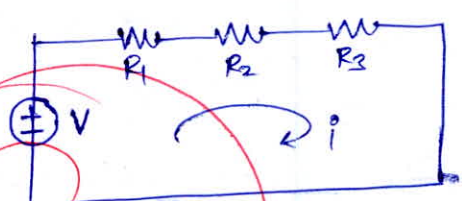
Q.7 (c) (i) State and explain the Tellegen's theorem.

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



[8 + 12 marks]

* Tellegen's theorem :- Tellegen's theorem is nothing but the power conservation theorem. It states the sum of power absorbed by all the element in the ckt is always equal to 0.



from KVL:

$$V = i(R_1 + R_2 + R_3)$$

$$i = \frac{V}{R_1 + R_2 + R_3}$$

$$P_V = Vi = \frac{V^2}{R_1 + R_2 + R_3}$$
(delivered)

$$P_{R_1} = i^2 R_1 = \frac{V^2 R_1}{(R_1 + R_2 + R_3)^2}$$
(absorbed)

$$P_{R_2} = i^2 R_2 = \frac{V^2 R_2}{(R_1 + R_2 + R_3)^2}$$
(absorbed)

$$P_{R_3} = i^2 R_3 = \frac{V^2 R_3}{(R_1 + R_2 + R_3)^2}$$
(absorbed)

According to Tellegen's theorem. $P_{absorbed} = P_{delivered}$

or $\sum P_{absorbed} = 0$.

$$P_{absorbed} = P_{R_1} + P_{R_2} + P_{R_3}$$

$$= \frac{V^2 R_1}{(R_1+R_2+R_3)^2} + \frac{V^2 R_2}{(R_1+R_2+R_3)^2} + \frac{V^2 R_3}{(R_1+R_2+R_3)^2}$$

$$= \frac{V^2}{(R_1+R_2+R_3)} = P_V = P_{delivered}.$$

Hence proved.

(ii) from ohm's law.

$$i_2 = \frac{V}{20} = 3A.$$

from KVL:

$$V_B = 60 - 5i_2 = 60 - 15 = 45V.$$

$$i_{5\Omega} = \frac{V_B}{5\Omega} = \frac{45V}{5} = \boxed{9A = i_{5\Omega}}$$

$$P_{absorbed} = P_{5\Omega} + P_{cs} + P_{20\Omega} + P_{vs}$$

cs → current source

vs → voltage source.

$$P_{5\Omega} = i_5^2 \times R = (9)^2 \times 5 = 405W$$

$$P_{cs} = V \times i_{cs} = 45 \times 15 = 675W.$$

$$P_{20\Omega} = i_2^2 R = (3)^2 \times 20 = 180W.$$

$$P_{vs} = i_V \times 5i_2 = 24 \times 15 = 360W$$

using KCL at B.

$$i_V = \frac{V_1}{4} + i_5 = 15 + 9 = 24A.$$

$$P_{absorbed} = 405 + 675 + 180 + 360$$

$$= 1620W.$$

using KCL at node A

$$i = i_2 + i_V = 3 + 24 = 27$$

$$P_{delivered} = Vi = 27 \times 60$$

$$= 1620W.$$

proved

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,

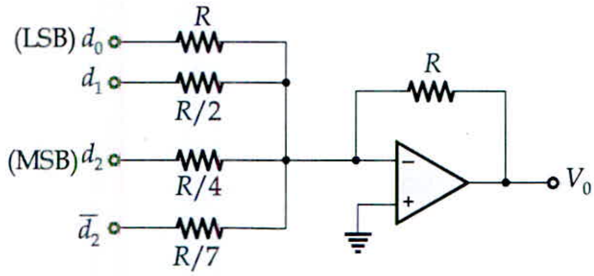
(i) Successive addition method **(ii)** Shift and add method

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:

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



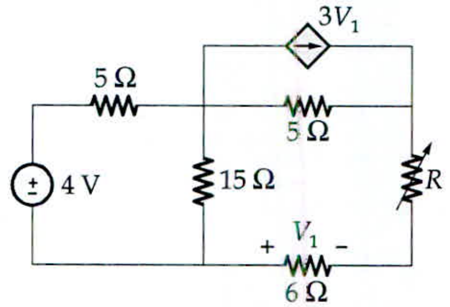
(i) Derive an expression for output voltage, V_0 in terms of input logic values.

(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

Space for Rough Work