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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	47
Q.2	–
Q.3	20
Q.4	–
Section-B	
Q.5	45
Q.6	41
Q.7	55
Q.8	–
Total Marks Obtained	208

Signature of Evaluator: Sumeet

Cross Checked by: [illegible]

Remarks: (i) Excellent presentation !!
(ii) Very good accuracy.

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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]

2017

Let in this question $x(t) = \text{Cos}\,t$ any random process and $y(t) = \hat{x}(t)$ $y(t)$ is the hilbert transform of $x(t)$ $y(t) = \text{Cos}(t - \pi/2)$

Here $x(t) = \text{Cos}\,t$ & $y(t) = \text{Sin}\,t$ $\quad y(t) = \text{Sin}\,t$

Consider general case.

(i) first find $R_y(\tau) = E[y(t)\,y(t+\tau)] = E[y(t_1)\,y(t_2)]$ $\quad (t_2 - t_1 = \tau)$

$$R_y(\tau) = E[\text{Sin}\,t_1\ \text{Sin}\,t_2]$$

$$R_y(\tau) = E\left[\frac{1}{2} 2\,\text{Sin}\,t_1\ \text{Sin}\,t_2\right]$$

$$= E\left[\frac{1}{2}\{\text{Sin}(t_1 - t_2) - \text{Sin}(t_1 + t_2)\right]$$

$$= \frac{1}{2} E[\text{Sin}(t_1 - t_2)] - E[\text{Sin}(t_1 + t_2)]$$

$$R_y(\tau) = \frac{1}{2}\int_{-\infty}^{\infty} \text{Sin}(t_1 - t_2). \quad -\frac{1}{2}\int_{-\infty}^{\infty} \text{Sin}(t_1 + t_2)$$

$$= \frac{1}{2}\left[\int_{-1}^{1} \text{Sin}(t_1 - t_2)\right] - \frac{1}{2}\int_{-1}^{1} \text{Sin}(t_1 + t_2)$$

$$= \frac{1}{2}\left\{\frac{-\text{Cos}(t_1 - t_2)}{t_1 - t_2}\right\}_{-1}^{1}$$

(ii) $R_{xy}(\tau) = E[x(t_1)y(t_2)] = E[\sin t_2 \cos t_1] = E\left[\frac{1}{2} 2\sin t_2 \cos t_1\right]$

1

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]

8017

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

$S(t) = \cos\omega_c t + \mu \cos\omega_m t \cos\omega_c t$

$S(t) = \cos\omega_c t + \frac{\mu}{2} 2\cos\omega_c t \cos\omega_m t$

$2\cos A \cos B = \cos(A+B) + \cos(A-B)$

$S(t) = \cos\omega_c t + \frac{\mu}{2}\left[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t\right]$

$S(t) = \underbrace{\cos\omega_c t}_{\text{Carrier Signal}} + \underbrace{\frac{\mu}{2}\cos(\omega_c + \omega_m)t}_{(U.S.B)} + \underbrace{\frac{\mu}{2}\cos(\omega_c - \omega_m)t}_{(L.S.B)}$

given $\mu = 1/2$

so $S(t) = \underbrace{\cos\omega_c t}_{(\text{Carrier})} + \frac{1}{4}\underbrace{\cos(\omega_c+\omega_m)t}_{(\text{USB})} + \underbrace{\frac{1}{4}\cos(\omega_c-\omega_m)t}_{(\text{LSB})}$

$S(t) = \cos\omega_c t + \left(\frac{1}{2}\right)\left\{\frac{1}{4}\cos(\omega_c+\omega_m)t + \frac{1}{4}\cos(\omega_c-\omega_m)t\right\}$

$S(t) = \cos\omega_c t + \frac{1}{8}\left\{\cos\omega_c t\cos\omega_m t - \sin\omega_c t \sin\omega_m t\right\} + \frac{1}{4}\left\{\cos\omega_c t\cos\omega_m t + \sin\omega_c t\sin\omega_m t\right\}$

$S(t) = \left\{1 + \frac{1}{8}\cos\omega_m t + \frac{1}{4}\cos\omega_m t\right\}\cos\omega_c t + \left(\frac{1}{8}\sin\omega_m t + \frac{1}{4}\sin\omega_m t\right)$

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$S(t) = \left\{1 + \frac{3}{8}\cos\omega_m t\right\}\cos\omega_c t + \left(\frac{1}{8}\sin\omega_m t\right)\sin\omega_c t$

envelope of the modulated signal

$= \sqrt{\left(1+\frac{3}{8}\cos\omega_m t\right)^2 + \left(\frac{1}{8}\sin\omega_m t\right)^2}$

$= \sqrt{1 + \frac{9}{16\times 4}\cos^2\omega_m t + \frac{6}{8}\cos\omega_m t + \frac{1}{64}\sin^2\omega_m t}$

Ans

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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]

8017

$|t| \le 1$ $(-1 \le t \le 1)$ angle modulated signal is given as $S(t) = 10 \cos 13000t$

$\omega_c = 10{,}000$ rad/sec

(i) Consider the given angle modulated signal as PM signal.

$$S_{PM}(t) = A_c \cos\left(2\pi f_c t + K_p m(t)\right)$$

given $S(t) = 10 \cos 13000t$

so compare this $A_c = 10$

and $2\pi f_c t + K_p m(t) = 13000t$

$$2\pi\left(\frac{\omega_c}{2\pi}\right) \cdot t + K_p m(t) = 13000t$$

$$10{,}000t + K_p m(t) = 13000t$$

$$K_p m(t) = 3000t$$

$K_p = 1000$ rad/v

$$m(t) = \frac{3000t}{1000}$$

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

(ii) if given signal is consider as FM signal

$$S_{FM}(t) = A_c \cos\left(\omega_c t + K_f \int_0^t m(t)\,dt\right)$$

$A_c = 10$ $\quad \omega_c t + K_f \int_0^t m(t)\,dt = 13000t$

$$K_f \int_0^t m(t) = 3000t$$

$$1000 \int_0^t m(t)\,dt = 3000t$$

$$\int m(t)\,dt = 3t$$

differentiate both side with respect to t.

$\boxed{m(t) = 3}$ for $(|t| \leq 1)$.

So $m(t) = 3t$ for PM signal.

$m(t) = 3$ for FM signal.

12

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]

Sol: given two random variable x & y are relation between them is given

$$y = ax + b$$

The differential entropy for any continuous Random variable is defined as

$$H(x) = -\int_{-\infty}^{\infty} f_x(x) \log_2 f_x(x)\,dx$$

or

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

where $f_x(x)$ represent the density fn of x.

Here for the random variable X

differential entropy $H(x) = \int_{-\infty}^{\infty} f_x(x) \log_2 \frac{1}{f_x(x)} dx$ — ①

for the random variable y.

differential entropy $H(y) = \int_{-\infty}^{\infty} f_y(y) \log_2 \frac{1}{f_y(y)} dy$

and relation in x & y are given as — ②

$$y = ax + b$$

Here

$$f_y(y) = f_x(x) \cdot \left|\frac{dx}{dy}\right|$$

$$ax = y - b$$

$$x = \frac{y-b}{a} = \frac{1}{a}y - \frac{b}{a}$$

$$\frac{dx}{dy} = \frac{1}{a}$$

$$f_y(y) = f_x(x) \cdot \left|\frac{1}{a}\right|$$

$$f_y(y) = \frac{1}{a} f_x(x)$$

Put these value in eq ② →

$$H(y) = \int_{-\infty}^{\infty} \frac{1}{a} f_x(x) \log_2 \frac{1}{\frac{1}{a} f_x(x)} dx \times a$$

$$= \int_{-\infty}^{\infty} f_x(x) \log_2 \frac{a}{f_x(x)} dx$$

$$= \int_{-\infty}^{\infty} f_x(x) \{ \log_2 a - \log_2 f_x(x) dx$$

$$H(y) = \log_2 a \int_{-\infty}^{\infty} f_x(x) dx + H(x)$$

$$H(y) = H(x) + \log_2 a \int_{-\infty}^{\infty} f_x(x) dx$$ Ans

$\int_{-\infty}^{\infty} f_x(x) dx =$

10

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]

Sol:- Advantage of DM over PCM:-

(i) DM is less complex as compare to PCM.

(2) There is no quantization error present in DM.

(3) Here we choose $n=1$ so less no of bits are required as compare to PCM system.

(4) Here channel BW requirement reduces to minimum value $BW = R_b = nf_s = f_s$ (DM).

Disadvantage of DM over PCM:-

① Here Slope Overload error occured.

② Here Granular error also occured.

③ Here $R_b = f_s$ so if we want to obtain high data rate comprable to PCM then we required more value of sampling freq compare to PCM.

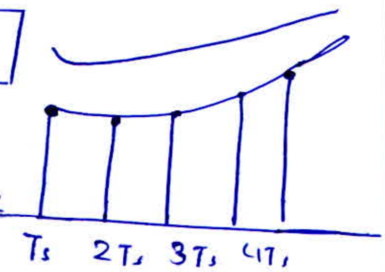
→ Deltamodulation is also called as 1 bit PCM system.

→ in delta modulation we have to choose a step size Δ at which we can reconstruct the original msg signal this is called Optimum Step size Δ_{opt}.

There are basically two types of error present in the case of Delta modulation.

① **Slope overload error** → This type of error occurred in delta modulation if $\frac{\Delta}{T_s} < \left|\frac{dm(t)}{dt}\right|_{max}$

and $\frac{\Delta}{T_s} < \frac{\Delta_{opt}}{T_s}$ So $\boxed{\Delta < \Delta_{opt}}$



So if we want to remove the the slope overload error we have to increase the value of step size Δ.

② **Granular error** → This type of error occured in Delta modulation if $\frac{\Delta}{T_s} > \left|\frac{dm(t)}{dt}\right|_{max}$

$\frac{\Delta}{T_s} > \frac{\Delta_{opt}}{T_s}$ So $\boxed{\Delta > \Delta_{opt}}$

So if we want to remove the Granualr error we have to decrease the value of step size Δ.

→ So for avoiding both types of error we used a new modulation scheme called adaptive delta modulation. Where we can ↑ or ↓ the value of step size Δ.

12

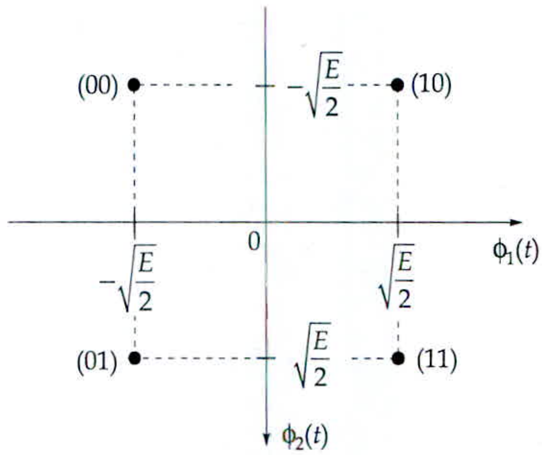
Q.2 (a) Two random variables X and Y are independent and identically distributed, each with a Gaussian density function with mean equal to zero and variance equal to σ^2. If these two random variables denote the coordinates of a point in the plane, find the probability density function of the magnitude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

[20 marks]

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]

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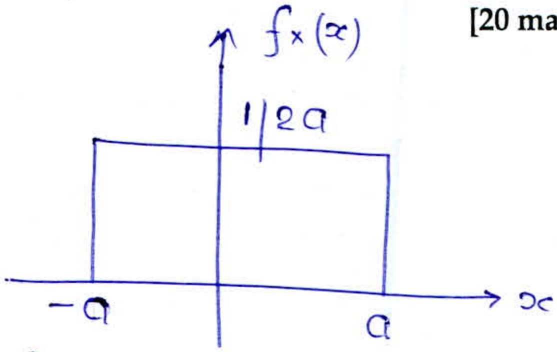
Q.3 (a) The samples of a stationary random process $X(t)$, whose amplitude is uniformly distributed in the range $[-a, a]$, are applied to an n-bit uniform mid-riser quantizer. Derive an expression for the signal-to-quantization noise ratio at the output of the quantizer, with suitable assumptions. Using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

[20 marks]



Here mean = 0

Varience = $\frac{(a+a)^2}{12}$

$= \frac{(2a)^2}{12} = \frac{4a^2}{12} = \frac{a^2}{3}$

This is also the msquare value or power

Power $= \frac{a^2}{3}$

for uniform distribution

$\left(\frac{S}{N}\right)$ dB $= 6.02n$

for 8 bit

$= 6.02 \times 8$

$= \underline{48.16 \text{ dB}}$

4

proof ??

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

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

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

[20 marks]

Sol: given $P\left(\frac{y}{x}\right) = \begin{bmatrix} \frac{2}{3} & \frac{1}{3} \\ \frac{1}{10} & \frac{9}{10} \end{bmatrix}$

$P(x) = \begin{bmatrix} \frac{1}{3} & \frac{2}{3} \end{bmatrix}$

first i) $H(x) = -\left[P(x_1)\log_2 P(x_1) + P(x_2)\log_2 P(x_2)\right]$

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

$H(x) = -(-0.5230 - 0.3900)$

$(H(x) = 0.913$ bit/symol)

(ii) $P(y) = P(x) \cdot P\left(\frac{y}{x}\right) = \begin{bmatrix} \frac{1}{3} & \frac{2}{3} \end{bmatrix} \begin{bmatrix} \frac{2}{3} & \frac{1}{3} \\ \frac{1}{10} & \frac{9}{10} \end{bmatrix}$

$P(y) = \begin{bmatrix} \frac{2}{9} + \frac{2}{30} & \frac{1}{9} + \frac{18}{30} \end{bmatrix}$

$P(y) = \begin{bmatrix} \frac{20+6}{90} & \frac{10+54}{90} \end{bmatrix}$

$P(y) = \begin{bmatrix} \frac{26}{90} & \frac{64}{90} \end{bmatrix}$

So $H(y) = -\left[\frac{26}{90} \log_2\left(\frac{26}{90}\right) + \frac{64}{90} \log_2 \frac{64}{90}\right]$

$H(y) = -\left(-0.5175 - 0.3497\right) = 0.8672$ bits/sec

(iii) ~~$H\left(\frac{y}{x}\right) = -\left[\frac{2}{3} \log_2\left(\frac{2}{3}\right) + \frac{1}{3} \log_2\left(\frac{1}{3}\right)\right.$~~

here $H\left(\frac{y}{x}\right) = -\sum_{j=1}^{M} \sum_{k=1}^{N} P(x_j, y_k) \log_2 P\left(\frac{y_k}{x_j}\right)$

Here $P(x,y) = \text{joint matrix} = \{P(x)\}_d \cdot P\left(\frac{y}{x}\right)$

$\{P(x)\}_d = \begin{bmatrix} \frac{1}{3} & 0 \\ 0 & \frac{2}{3} \end{bmatrix}$ $P\left(\frac{y}{x}\right) = \begin{bmatrix} \frac{2}{3} & \frac{1}{3} \\ \frac{1}{10} & \frac{9}{10} \end{bmatrix}$

$P(x,y) = \begin{bmatrix} \frac{2}{9} & \frac{1}{9} \\ \frac{2}{30} & \frac{18}{30} \end{bmatrix}$

(iii) $H\left(\frac{x}{y}\right) = \sum_{j=1}^{m}\sum_{k=1}^{N} P(x_j, y_k) \log_2 P\left(\frac{x_j}{y_k}\right)$ = ?

(iv) mutual information $\boxed{I(x,y) = H(y) - H\left(\frac{y}{x}\right)}$

$H\left(\frac{y}{x}\right) = -\left[\frac{2}{9}\log_2\left(\frac{2}{3}\right) + \frac{1}{9}\log_2\left(\frac{1}{3}\right) + \frac{2}{30}\log_2\left(\frac{1}{10}\right) + \frac{18}{30}\log_2\left(\frac{9}{10}\right)\right]$

$H\left(\frac{y}{x}\right) = -(-0.130 - 0.17612 - 0.2214 - 0.0912)$

$= \cancel{0.16}\ 0.61872$

(v) $I(x,y) = 0.8672 - 0.61872$

$= \underline{0.24848}$

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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).

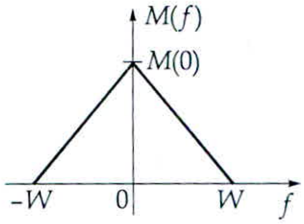

Figure (a)

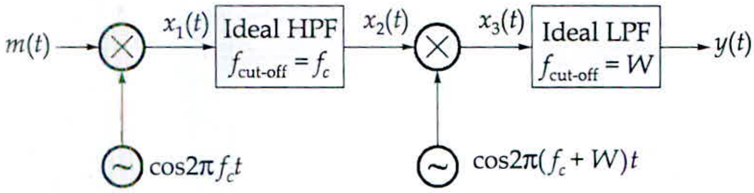

Figure (b)

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]

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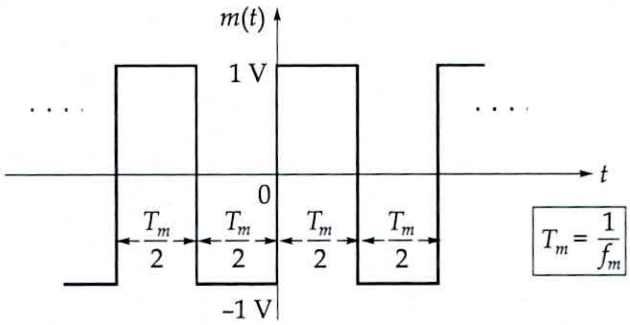
Q.4 (a) The periodic message signal $m(t)$ shown in the figure below is applied to a phase modulator to modulate the carrier signal $c(t) = \cos(2\pi f_c t)$. If the phase sensitivity of the phase modulator is $k_p = 1$ rad/V, then determine and sketch the spectrum of the modulated signal.



[25 marks]

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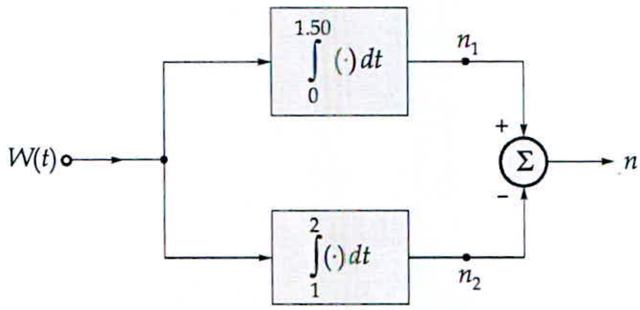
Q.4 (b) **(i)** A binary data is transmitted through an ideal AWGN channel with infinite bandwidth. The two sided power spectral density of the noise is $\frac{N_0}{2}$. If the average energy transmitted per bit is E_b, then derive the condition to be satisfied for error free transmission.

(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]

Sol:- (a) Design J-K flip flop by D flip flop:-

1) Write characterstic table of J-K flip flop.
2) write excitation table of D flip flop.
3) find the expresion for D i/p.
4) and minimize the expresion by K-map if possible and then implement the ckt.

J	K	Q_n	Q_{n+1}	$D = Q_{n+1}$
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

$D = \sum m(1, 4, 5, 6)$

K-map:-

	$\bar{K}\bar{Q}_n$	$\bar{K}Q_n$	KQ_n	$K\bar{Q}_n$
$\bar{J}$	0	1 (1)	3	2
J	1 (4)	1 (5)	7	1 (6)

$$\boxed{D\ i/p = J\bar{Q}_n + \bar{K}Q_n}$$

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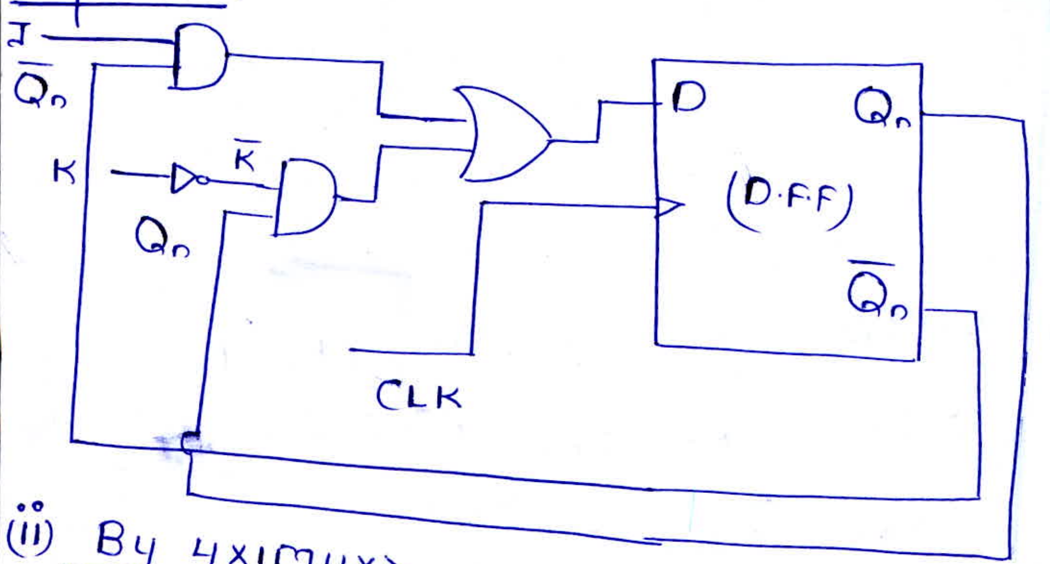
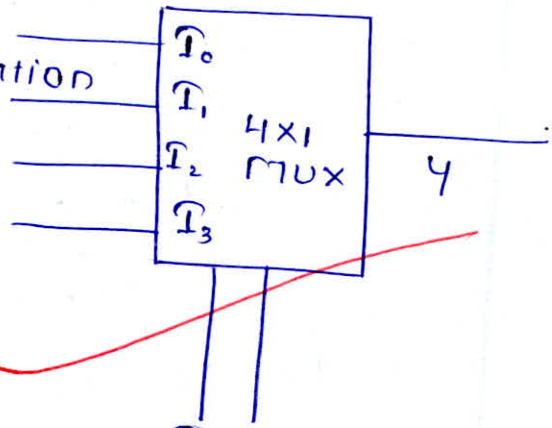
implement:



(ii) By 4x1 mux:

The characterstic equation of the JK-flip flop

$$\boxed{Q_n = J\bar{Q}_n + \bar{K}Q_n}$$

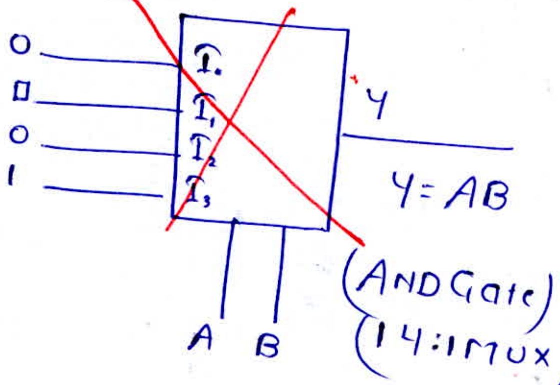


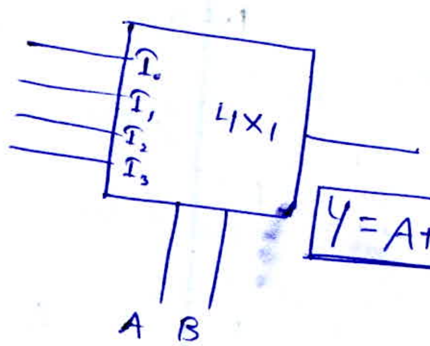
4x1 mux O/P

$$Y = \bar{S}_1\bar{S}_0 I_0 + \bar{S}_1 S_0 I_1 + S_1\bar{S}_0 I_2 + S_1 S_0 I_3$$

and in the above ckt for the implemention of the AND Gate, NOT Gate and OR Gate we required the mux ckt.

6

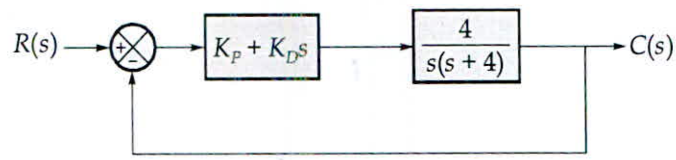




$\boxed{Y = A+B}$

Mux and DFF have to be used simultaneously

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]

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Here in the block digram $G(s)H(s) = (K_p + K_D s)\dfrac{4}{s(s+4)}$

$$G(s)H(s) = (K_p + K_D s)\frac{4}{s(s+4)}$$

now formation of the characterstic equation

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

$$1 + (K_p + K_D s)\cdot\frac{4}{s(s+4)} = 0$$

$$s^2 + 4s + (K_p + K_D s)4 = 0$$

$$s^2 + 4s + 4K_p + 4K_D s = 0$$

$$s^2 + (4 + 4K_D)s + 4K_p = 0$$

Compare with $s^2 + 2\xi\omega_n s + \omega_n^2 = 0$

So $2\xi\omega_n = 4 + 4K_D$ $\quad\quad \omega_n^2 = 4K_p$

given $\xi = 0.75$ $\quad\quad (\omega_n = 2\sqrt{K_p})$

$$2(0.75)\omega_n = 4 + 4K_D$$

$$1.5\,\omega_n = 4 + 4K_D \quad\quad 3\sqrt{K_p} = 4 + 4K_D \;\text{——}\; (1)$$

now steady state error for unit ramp i/p $e_{ss} = \dfrac{A}{K_v}$

$$K_v = \lim_{s\to 0} sG(s)H(s) = \lim_{s\to 0} \cancel{s}(K_p + K_D s)\cdot\frac{4}{\cancel{s}(s+4)}$$

$$K_v = K_p$$

$$e_{ss} = \frac{1}{K_p} = \frac{0.2\cancel{5}}{\cancel{100}\,4}$$

$$\boxed{(K_p = 4)} \;\text{——}\; (2)$$

Put the value of K_P from ② to ①:

$$3\sqrt{K_P} = 4 + 4K_D$$
$$3\sqrt{4} = 4 + 4K_D$$
$$6 - 4 = 4K_D$$
$$4K_D = 2$$
$$\boxed{K_D = 1/2}$$

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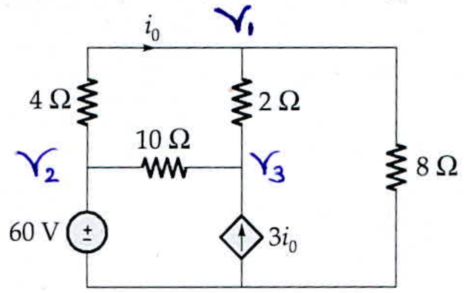
So for the given system $K_P = 4$ and $K_D = 0.5$ Ans

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



[12 marks]

Apply nodal analysis at the various nodes:

$$\frac{V_2 - V_3}{10} + \frac{V_2 - V_1}{4} = 0$$

Here $V_2 = 60V$

$$\frac{60 - V_3}{10} + \frac{60 - V_1}{4} = 0$$
$$120 - 2V_3 + 300 - 5V_1 = 0$$
$$5V_1 + 2V_3 = 420 \quad \text{——— ①}$$
$$\frac{V_1 - V_2}{4} + \frac{V_1 - V_3}{2} + \frac{V_1}{8} = 0$$
$$2V_1 - 2V_2 + 4V_1 - 4V_3 + V_1 = 0$$
$$7V_1 - 2V_2 = 4V_3$$

$$3i_0 = \frac{V_3 - V_2}{10} + \frac{V_3 - V_1}{2}$$
$$3i_0 \times 10 = V_3 - V_2 + 5V_3 - 5V_1$$
$$6V_3 - 5V_1 - V_2 = 30i_0$$
$$(i_0 = 2.35)$$

$$\left\{\begin{array}{l} V_1 = 56.47 \\ V_3 = 68.82 \end{array}\right\}$$

$$7V_1 - 4V_3 = 2(60)$$
$$7V_1 - 4V_3 = 120 \quad \text{——— ②}$$

~~Here $V_1 = 56.47$ volt~~
~~and $V_3 = 60.82$ volt~~ ~~after solving ① & ②~~

Apply nodal analysis at various nodes

$$\frac{V_1 - V_2}{4} + \frac{V_1 - V_3}{2} + \frac{V_1}{8} = 0$$

$$2V_1 - 2V_2 + 4V_1 - 4V_3 + V_1 = 0$$

$$7V_1 - 2V_2 - 4V_3 = 0 \quad \text{—— ①}$$

$$\frac{V_3 - V_2}{10} + \frac{V_3 - V_1}{2} = 3i_0$$

$$V_3 - V_2 + 5V_3 - 5V_1 = 30i_0 \qquad i_0 = \frac{V_2 - V_1}{4}$$

$$-5V_1 - V_2 + 6V_3 = 30i_0 = 30\left(\frac{V_2 - V_1}{4}\right) = 7.5(V_2 - V_1)$$

$$-5V_1 - V_2 + 6V_3 = 7.5V_2 - 7.5V_1$$

$$2.5V_1 - 8.5V_2 + 6V_3 = 0 \quad \text{—— ②}$$

Put $V_2 = 60$

$$2.5V_1 + 6V_3 = 510$$
$$7V_1 - 4V_3 = 120$$

after solving $\left\{ \begin{array}{l} V_1 = 53.076 \\ V_3 = 62.884 \end{array} \right\}$

So Here $i_0 = \dfrac{V_2 - V_1}{4} = 1.731$ Amp Ans

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(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 ⟶ 7T
LOOP2: MVI C, FFH ⟶ 7T
LOOP1: DCR C ⟶ 7T 4T
JNZ LOOP1 ⟶ 10T/7T
DCR B ⟶ 7T 4T
JNZ LOOP2 ⟶ 10T/7T
RET ⟶ 5T 10T

[12 marks]

Delay: MVI B, 02H $B \leftarrow 02H$

B: $\boxed{02}$

loop2: MVI C, FFH $C \leftarrow FF$

C: $\boxed{FF}$

loop1: DCR C
JNZ loop1
DCR B
JNZ loop2
RET.

Here loop 1 executed 16 times out of 16 time 15time conditions are true and 1 time false.
and loop 2 loop2 execute 2 time 1 time true and 1 time false.

here given clock freq f = 2MHz

$T = \frac{1}{2} = 0.5\ \mu sec$

So total delay produced is

$= (7T + 7T + 7T + 7T + 7T + 10T + 5T)$
$+ (7T + 7T + 7T + 7T + 7T + 7T + 5T)$
$+ 15(7T + 7T + 7T + 10T)$
$+ (7T + 7T + 7T + 7T + 5T)$

5

?

0

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

[12 marks]

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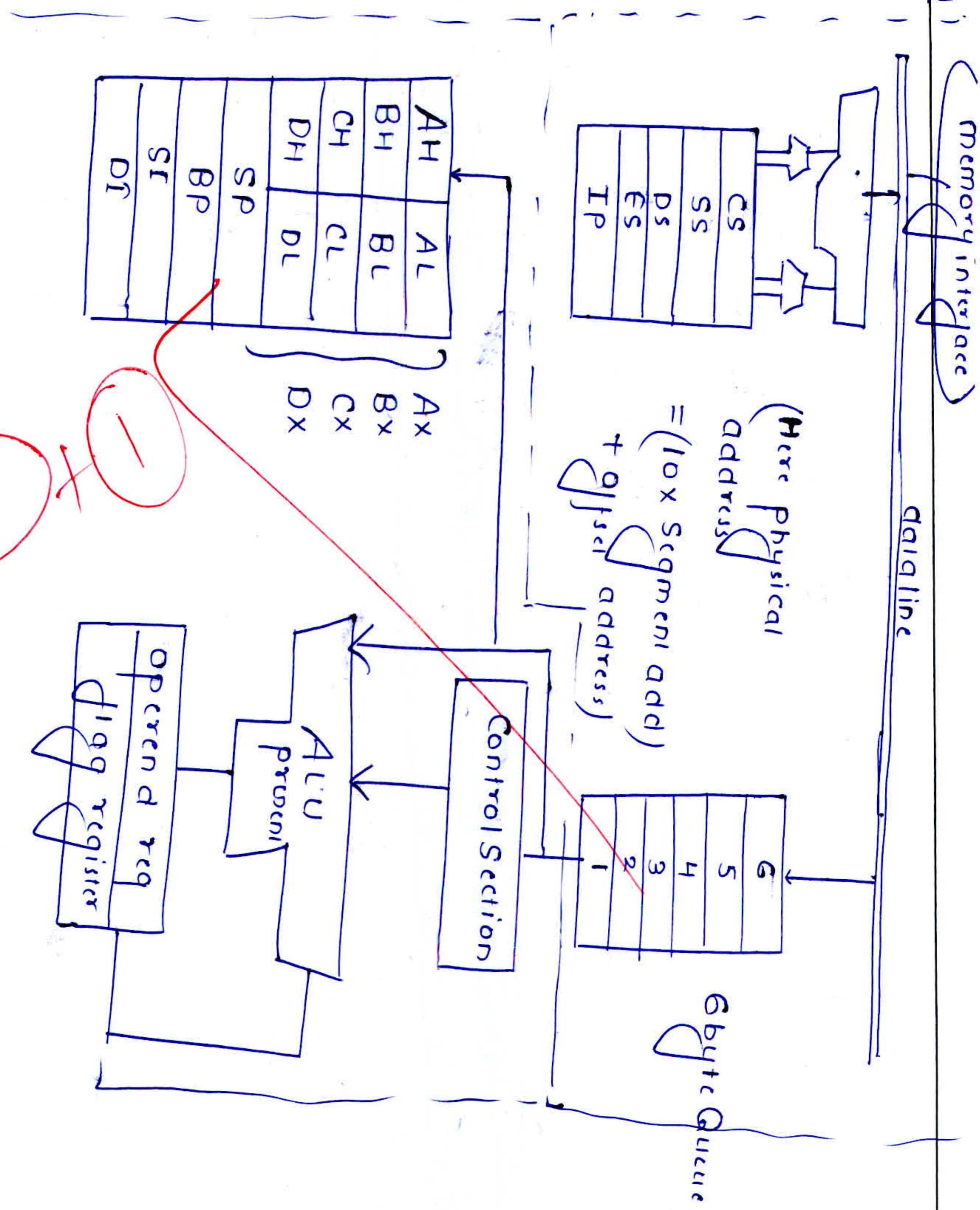
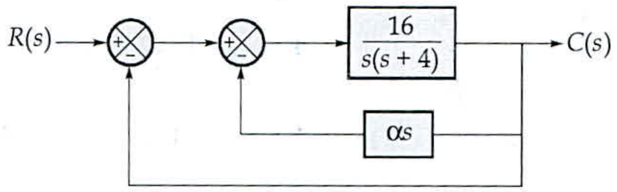
internal block digram of 8086 up is divided into two units (i) Bus interface unit. (ii) execution unit.



(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]

Q1.7 (i) in absence of the rate feedback ($\alpha = 0$)

so $G(s) = \dfrac{16}{s(s+4)}$ $H(s) = 1$

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

now the characterstic eq $1 + G(s)H(s) = 0$

$$1 + \frac{16}{s(s+4)} = 0$$

$$s^2 + 4s + 16 = 0$$

$$s^2 + 2\xi\omega_n s + \omega_n^2 = 0 \quad \text{Compare}$$

so $\omega_n = 4$ rad/sec

$$2\xi\omega_n = 4$$

$$2\xi \times \cancel{4} = \cancel{4}$$

$$\xi = 1/2$$

so peak overshoot of the system.

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

$$M_p = e^{\frac{-3.14 \times 0.5}{\sqrt{1-(0.5)^2}}} = e^{\frac{-3.14 \times 0.5}{0.866}} = e^{-1.81293}$$

$\boxed{M_p = 16.33\%}$

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now the Steady State error for the unit ramp i/p

$e_{ss} = \frac{A}{K_v}$ $\quad K_v = \lim_{s \to 0} sG(s)H(s)$

$e_{ss} = \frac{1}{4} = 0.25$ $\quad K_v = \lim_{s \to 0} \cancel{s} \cdot \frac{16}{\cancel{s}(s+4)}$

$= \frac{16}{4} = 4$

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so $\left\{ \begin{array}{l} M_p = 16.31\% \\ \text{and } e_{ss} = 0.25 \end{array} \right\}$ Ans

(ii) part:> for given system $\dfrac{\frac{16}{s(s+4)}}{1 + \frac{16}{s(s+4)} \cdot \alpha s} = \dfrac{16}{s(s+4) + 16\alpha s}$

Here new $G(s)H(s) = \dfrac{16}{s(s+4) + 16\alpha s} = \dfrac{16}{s[s+4+16\alpha]}$

new e_{ss} for unit ramp i/p

$e_{ss} = \frac{A}{K_v}$

and here $K_v = \lim_{s \to 0} sG(s)H(s) = \left(\dfrac{16}{4+16\alpha}\right)$

now characterstic eq:>

$\left(e_{ss} = \dfrac{4+16\alpha}{16}\right)$

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

$1 + \dfrac{16}{s(s+4) + 16\alpha s} = 0$

given

$M_p = 1.25\%$

8

$s^2 + 4s + 16\alpha s + 16 = 0$

$s^2 + (4 + 16\alpha)s + 16 = 0$

$\frac{1.25}{100} = e^{-\pi\xi/\sqrt{1-\xi^2}}$

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

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

$(8\xi = 4 + 16\alpha)$

$\boxed{\alpha = 0.1564}$

$\cancel{-}4.3820 = \dfrac{\cancel{-}\pi\xi}{\sqrt{1-\xi^2}}$

$19.20(1-\xi^2) = 9.8596\xi$

$29.06\xi^2 = 19.20$

$\boxed{\xi = 0.8128}$

So steady state error ~~$e_{ss} = \frac{16}{4+16(0.1564)}$~~ $= \frac{16}{6.5024}$

~~$\boxed{e_{ss} = 2.46}$~~ * $\boxed{e_{ss} = 0.4064}$

(iii) part→

given e_{ss} for unit ramp i/p $e_{ss} = 0.25$

$M_p = 1.25\%$.

So $G(s)H(s) = \frac{16}{s(s+4+16\gamma)}$

$e_{ss} = \frac{A}{K_v} \rightarrow K_v = \frac{16}{4+16\gamma}$

$e_{ss} = \frac{1}{\frac{16}{4+16\gamma}} = \left(\frac{4+16\gamma}{\cancel{16}_4}\right) = \frac{1}{4}$

Here $M_p = 1.25\%$.

$\xi = 0.8128$

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

$s^2 + (4+16\gamma)s + 16 = 0$

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

$\omega_n = 4$ $(2 \times 0.8128) \times 4 = 4 + 16\gamma$

$\boxed{\alpha = 0.1564}$

0

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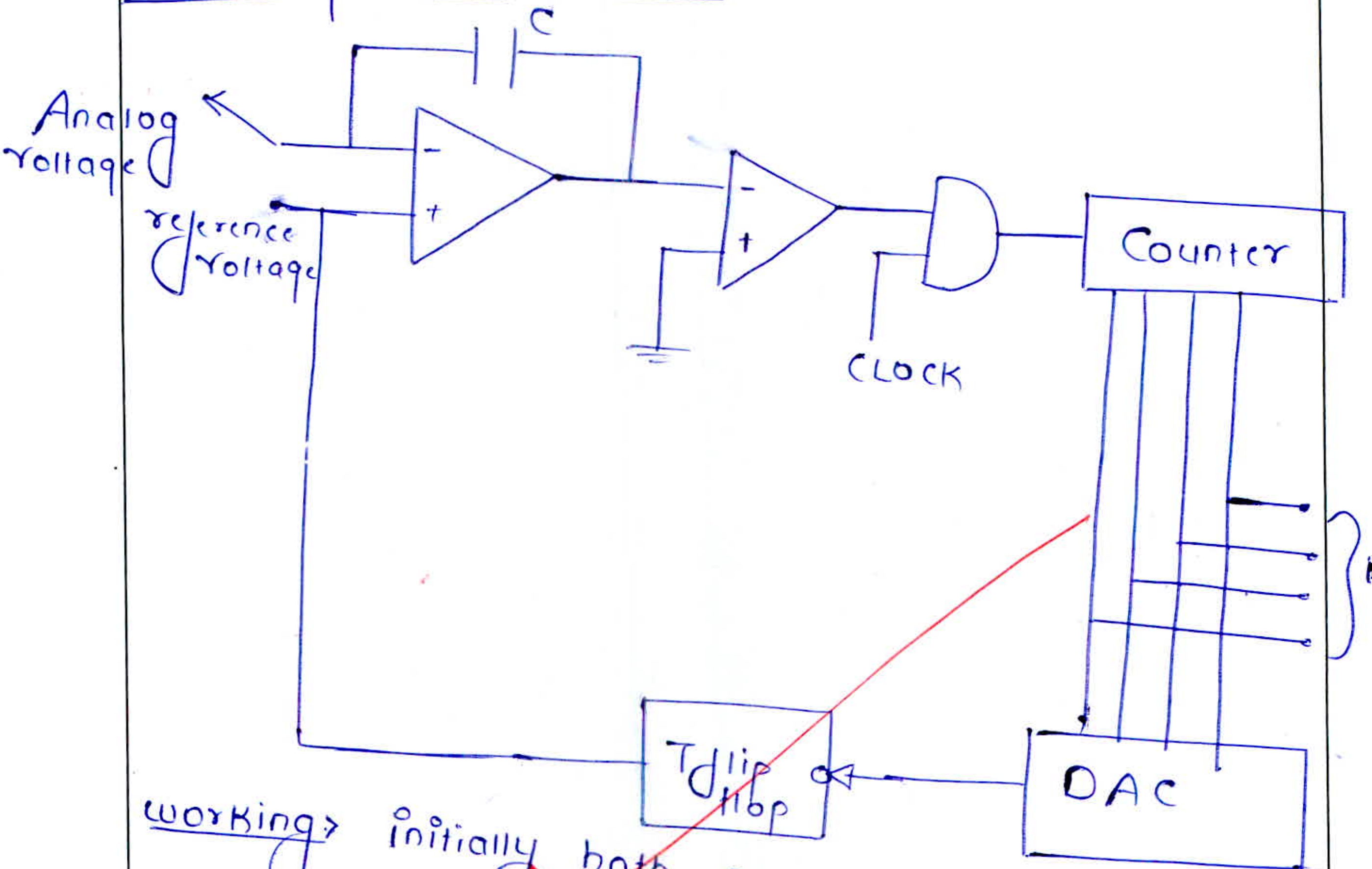
Q.6 (b) **(i)** Explain with a block diagram, the working principle of a dual-slope A/D converter. Derive the expression for the output and maximum conversion time of the circuit.

(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 :-



working :- initially both counter and T flip flop are in reset condition. Here firstly switch is connected to analog i/p voltage and integration of this is performed. and o/p of integrator is negative. So o/p of comparator is at logic 1 so AND Gate o/p = 1 and counter continuously count. after count 2^N clock pulse counter count to 0000. so T flip flop operates in toggle mode.

and now reference i/p is connected to integration and counter will count upto N2.

$$-\frac{V_a}{RC}T_1 + \frac{V_r}{RC}(T_1 - T_2) = 0$$

Her $\boxed{V_a T_1 = V_r (T_2 - T_1)}$

integration period (deintegration period).

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Here in this the conversion time is the highest among all A/D convertor.

$$\boxed{T_{conv} = 2^{n+1} T_{CLK}}$$

but the accuracy is best among all A/D convertor.

(ii) part→ Resolution = 4 bits

$f_{CLK} = 3.2\ KHz$

max sampling freq f_s

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$$\boxed{T_{conv} = 2^{n+1} T_{CLK}}$$

$$T_{con} = 2^5 \times \frac{10^{-3}}{3.2} = 10^{-2} \times \frac{10}{10}$$

$$= 10ms$$

So $f_s = \frac{1000}{10} = \underline{100\ Hz}$

8

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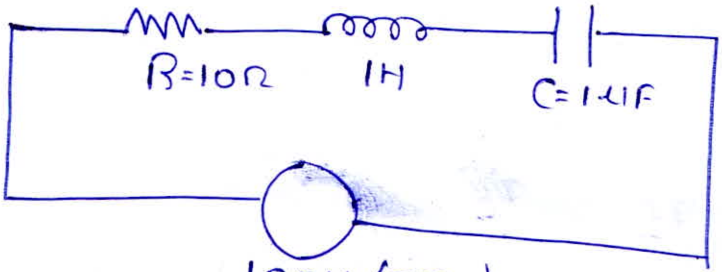
(c) A circuit is made up of a 10 Ω resistance, a 1 μF capacitance and 1 H inductance all connected in series. A sinusoidal voltage of 100 V (rms) at varying frequencies is applied to the circuit. Find the frequency at which the circuit would consume only 10% of the power it consumed at resonance?

[15 marks]



At resonance $I = \frac{V}{R} = \frac{100}{10} = 10\,\text{Amp}$

So power consumed in resonance condition

$P = 10 \times 100 = 1000\,\text{watt}$

10% of this power $10\cancel{00} \times \frac{10}{1\cancel{00}}$

$(P = 100W)$

Consumed by this circuit.

$$I(s) = \frac{V(s)}{R + SL + \frac{1}{SC}} = \frac{V(s)}{\frac{RSC + S^2LC + 1}{SC}}$$

2

$$I(s) = \frac{S\cancel{C}V(s)}{L\cancel{C}\left(S^2 + \frac{R}{L}S + \frac{1}{LC}\right)} = \frac{\frac{S}{L}V(s)}{\left(S^2 + \frac{R}{L}S + \frac{1}{LC}\right)}$$

$V(t) = 100V$

$V(s) = \frac{100}{S}$ $\quad I(s) = \frac{\frac{S}{1} \times \frac{100}{S}}{S^2 + 10S + \frac{1}{10^{-6}}}$

$$\boxed{I(s) = \frac{100}{S^2 + 10S + 10^6}}$$

$$I(j\omega) = \frac{100}{-\omega^2 + 10j\omega + 10^6}$$

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$$|I(j\omega)| = \frac{100}{\sqrt{(10^6-\omega^2)^2 + 100\omega^2}}$$

$$|I|^2 = \frac{(100)^2}{\left[(10^6-\omega^2)^2 + 100\omega^2\right]}$$

$$\text{Power} = I^2 \cdot R = \frac{(100)^2 \times 10}{(10^6-\omega^2)^2 + 100\omega^2} = \cancel{100}$$

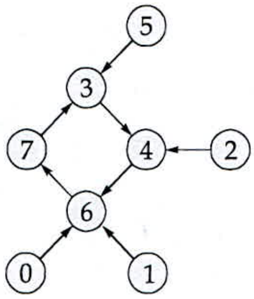
$$1000 = (10^6-\omega^2)^2 + 100\omega^2$$

find ω from Here.

6

good approach but finish it

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



[20 marks]

1.7 given sequence →

Present State			Next State			Excitation required		
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

now the expresion of D_2, D_1, D_0 by K-map →

	$\overline{Q}_1\overline{Q}_0$	$\overline{Q}_1 Q_0$	$Q_1 Q_0$	$Q_1\overline{Q}_0$
$\overline{Q}_2$	1 (0)	1 (1)	1 (3)	1 (2)
Q_2	1 (4)	(5)	(7)	1 (6)

$$\boxed{D_2 = \overline{Q}_0 + \overline{Q}_2 Q_0}$$

$$D_2 = \left(\overline{Q}_2 Q_0 + \overline{Q}_0\right) = \left(\overline{Q}_2 + \overline{Q}_0\right)$$

now for D_1 ->

	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1 Q_0$	$Q_1 Q_0$	$Q_1\bar{Q}_0$
$\bar{Q}_2$	1 0	1 1	3	2
Q_2	1 4	1 5	1 7	1 6

$$\boxed{D_1 = Q_2 + \bar{Q}_1}$$

now for D_0 ->

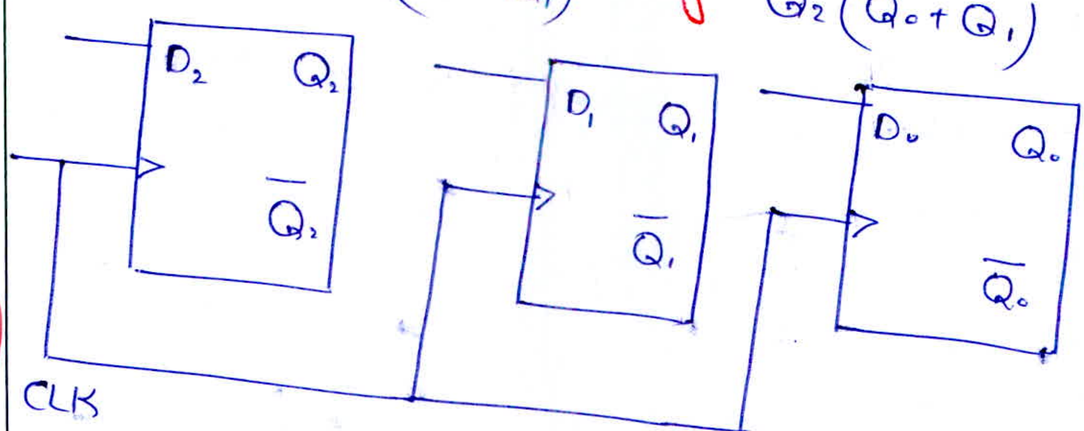
	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1 Q_0$	$Q_1 Q_0$	$Q_1\bar{Q}_0$
$\bar{Q}_2$	0	1	3	2
Q_2	4	1 5	1 7	1 6

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

Design of counter ->

Show the gates if possible.

$(\bar{Q}_2 + \bar{Q}_0)$ $\quad$ $(Q_2 + \bar{Q}_1)$ $\quad$ $Q_2(Q_0 + Q_1)$



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Here total 8 state so minimum 3 D flip flops are required here.

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(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]

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

and $x(0) = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$

$\dot{X}(t) = Ax(t)$ it is called homogenous state eq

and solution of this $\boxed{X(t) = \phi(t) \cdot x(0)}$

Here $\phi(t)$ = State transistion matrix.

$$\boxed{\phi(t) = L^{-1}(SI - A)^{-1}}$$

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

$$[SI - A] = \begin{bmatrix} S & 0 \\ 0 & S \end{bmatrix} - \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} = \begin{bmatrix} S-1 & 0 \\ -1 & S-1 \end{bmatrix}$$

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

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

now taking the inverse laplace transform of this.

$$L^{-1}(SI-A)^{-1} = \begin{bmatrix} e^t & 0 \\ te^t & e^t \end{bmatrix}$$

(i) homogeneous solution $= x(0)\,\phi(t)$

$$= \begin{bmatrix} e^t & 0 \\ te^t & e^t \end{bmatrix}\begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

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zero i/p response (ZIR) $= \begin{bmatrix} e^t \\ te^t \end{bmatrix}$

(ii) for non homogeneous system of equation → **Ans**

$$\dot{x}(t) = Ax(t) + Bu(t)$$

the solution of this state equation

$$X(t) = ZIR + ZSR$$

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

Here $(SI-A)^{-1} = \begin{bmatrix} \frac{1}{(S-1)} & 0 \\ \frac{1}{(S-1)^2} & \frac{1}{S-1} \end{bmatrix}$ $\quad$ i/p = u(t), $X(s) = 1/S$

$$(SI-A)^{-1}BU(s) = \left[\begin{bmatrix} \frac{1}{(s-1)} & 0 \\ \frac{1}{(s-1)^2} & \frac{1}{(S-1)} \end{bmatrix}\begin{bmatrix} 0 \\ 1 \end{bmatrix}_{2\times1} \frac{1}{S}\right]_{\times 1\times 1}$$

$$= \left\{\begin{bmatrix} \frac{1}{(s-1)} & 0 \\ \frac{1}{(s-1)^2} & \frac{1}{(S-1)} \end{bmatrix}\begin{bmatrix} 0 \\ \frac{1}{S} \end{bmatrix}\right\}_{2\times2\times2\times1}$$

$$= \begin{Bmatrix} 0 \\ \frac{1}{S(S-1)} \end{Bmatrix}$$

$$L^{-1}\left((SI-A)^{-1}BU(s)\right) = L^{-1}\begin{Bmatrix} 0 \\ \dfrac{1}{(s-1)s} \end{Bmatrix}$$

$$S(s-1) = \frac{A}{s} + \frac{B}{(s-1)} = \frac{-1}{s} + \frac{1}{(s-1)}$$

$-s+1+s$

$$= L^{-1}\begin{Bmatrix} 0 \\ \dfrac{-1}{s} + \dfrac{1}{(s-1)} \end{Bmatrix} = \begin{Bmatrix} 0 \\ -1+e^t \end{Bmatrix}$$

So complete response of the system $= (ZIR + ZSR)$

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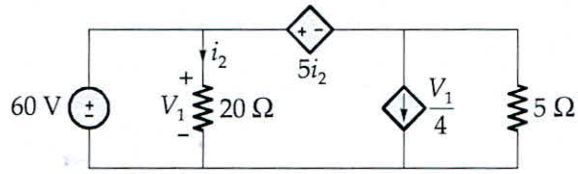
$$x(t) = \begin{bmatrix} e^t \\ te^t \end{bmatrix} + \begin{bmatrix} 0 \\ -1+e^t \end{bmatrix} = \begin{bmatrix} e^t \\ te^t - 1 + e^t \end{bmatrix}$$

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]

(i) Tellegen's theorem → According to this theorem for any network the amount of power delivered is always equals to the ammount of power absorbed.

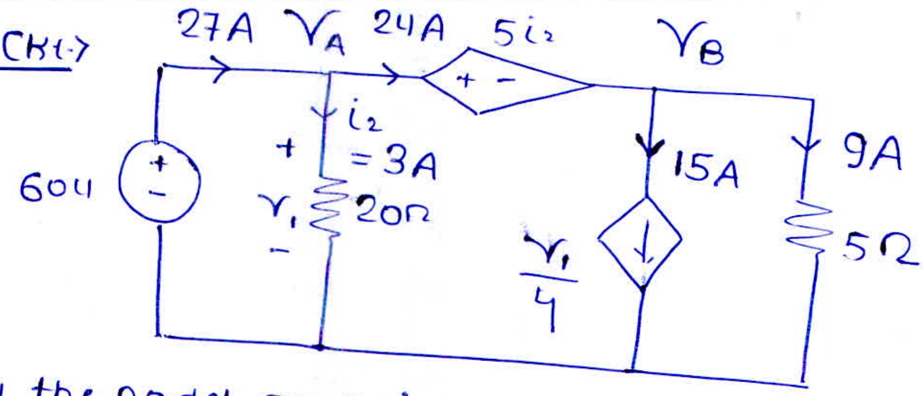
$$\sum_i V_i I_i = 0$$

5

→ Tellegen's theorem is applicable for any type of network like lumped, distributed, time varient, time invarient, linear etc.

→ Tellegen's theorem is basically verified by the KVL and KCL equation.

Given Ckt→



Apply the nodal analysis→

$$\frac{V_A}{20} + \frac{V_B}{5} + \frac{V_1}{4} = 0$$

Here $V_A - V_B = 5i_2$

$$\frac{V_A}{20} + \frac{V_B}{5} + \frac{V_1}{4} = 0$$

Here $\boxed{V_1 = V_A = 60V}$

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

$60 - V_B = 5(3)$

$60 - V_B = 15$

$\boxed{V_B = 45V}$

Here for various sources→

For 60V source Current = 27A $\quad P_1 = 1620W$

For 20Ω resistance $V = 60V \quad I = 3A \quad P_2 = 180W$

For $5i_2$ dependence source =

For $\frac{V_1}{4}$ ——————— = $\quad P_3 = 15 \times 24 = 360W$

For 5Ω resistance = $\quad P_4 = 15 \times 45 = 675W$

$P_5 = \underline{405W}$

and total delivered power by 60V source i_8 ⇒ $P_{\text{delivered}} = 1620$ watt.

and total absorbed power

by 20Ω resistance = 60×3 = 180W

$5i_2$ dependent source = 15×24 = 360W

$\frac{V_1}{4}$ dependent source = 15×45 = 675W

and 5Ω resistance = 45×9 = 405W

so here total absorbed power = 1620W

so Here delivered power = absorbed power

so verified tellegen's theorem.

Ans

12

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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]

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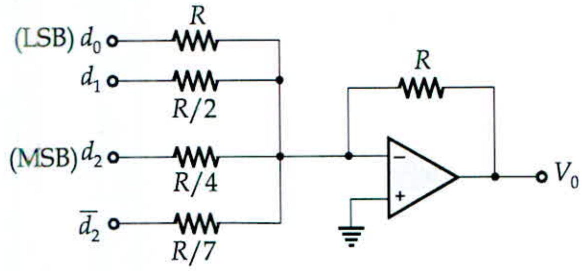
Q.8 (b) Consider the circuit shown in the figure below:

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



(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]

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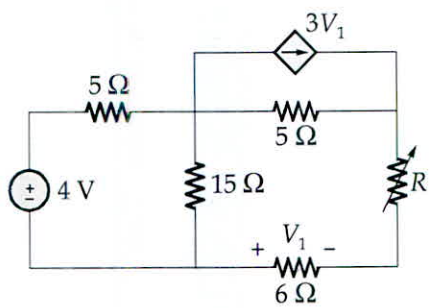
Q.8 (c) **(i)** State and prove the maximum power transfer theorem for purely resistive source circuit with variable load resistance.

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



[10 + 10 marks]

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OOOO

Space for Rough Work

Space for Rough Work