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Leading Institute for ESE, GATE & PSUs

## ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

### Electronics & Telecommunication Engineering Test-8 : Full Syllabus Test (Paper-II)

Name : .....

Roll No :

#### Test Centres

Delhi ☒

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#### Student's Signature

#### Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. 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.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

#### FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	53
Q.2	1
Q.3	
Q.4	55
Section-B	
Q.5	49
Q.6	
Q.7	34
Q.8	35
<b>Total Marks Obtained</b>	<b>226</b>

Signature of Evaluator

*Ch. Perfi*

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Name : Mayuri Paliwal

Roll No : E C 2 5 M T D L A 0 2 7

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## IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

### DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

### DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

## Section A

Q.1 (a) A continuously operating coherent BPSK system makes errors at the average rate of 100 errors per day. Data rate is 1 kbps. The single sided noise power spectral density is  $\eta = 10^{-10}$  W/Hz.

- (i) Assume the system to be wide sense stationary, what is the average bit error probability?
- (ii) If the value of received average signal power is adjusted to be  $10^{-6}$  W, will this received power be adequate to maintain the error rate obtained in part(i)?

(Assume,  $Q(4.5) = 3.9 \times 10^{-6}$ )

[6 + 6 marks]

given :- rate of error =  $\frac{100}{24 \times 60 \times 60}$

$R_b = 1 \text{ kbps}$

$P_b = Q\left(\frac{a_1 - a_0}{2\sigma_n}\right)$

$\frac{-\sqrt{E_b}}{2} \quad 0 \quad \frac{\sqrt{E_b}}{2}$

$P_e = Q\left(\frac{\sqrt{E_b} + \sqrt{E_b}}{2\sigma_n}\right)$

$\sigma_n^2 = \frac{N_0}{2} \quad \sigma_n = \sqrt{\frac{N_0}{2}}$

$P_e = Q\left(\frac{d_{\min}}{2\sigma_n}\right) = Q\left(\frac{2\sqrt{E_b}}{2\sqrt{\frac{N_0}{2}}}\right) = Q\left(\frac{\sqrt{2E_b}}{\sqrt{N_0}}\right)$

$P_e = Q\left(\frac{\sqrt{2E_b}}{\sqrt{N_0}}\right)$

Data rate  $R_b = 1 \text{ kbps}$

$1 \times 2^{10} \text{ bits per sec.}$

1 sec  $\rightarrow 2^{10} \text{ bits}$

60 sec  $\rightarrow 60 \times 2^{10}$

1 day =  $60 \times 60 \times 24 \times 2^{10} = 10^3$

so average prob. of error =  $\frac{100}{60 \times 60 \times 24 \times 10^3}$

$P_e = 1.15 \times 10^{-6}$



Average prob. of error  $= 1.15 \times 10^{-6}$  bits/days.  $\Delta$

$$\text{Power sig} = \frac{AC^2 T_b}{2} = E_b \quad \frac{10^{-6} \times 10^3}{2} E_b$$

$$E_b = 2^{10} \times 0.5^9 \times 10^{-3} \Rightarrow \frac{2}{512} \times 10^{-6} \text{ J.}$$

$$P_e = 0 \sqrt{\frac{2 \times 512 \times 10^{-6}}{10^{-10}}} = 3.9 \times 10^{-6} \quad \Delta$$

The received power is not adequate to maintain the the error. in obtained in I<sup>st</sup> part.

$$P_e = 0 \sqrt{\frac{2 \times 0.5 \times 10^{-3}}{10^{-10}}} \quad P_e = 0 \sqrt{10^{-7}} \Rightarrow 3.16 \times 10^{-4}$$

Q.1 (b) An LTI system has the impulse response  $h(t) = 5e^{-t} u(t) - 16e^{-2t} u(t) + 13e^{-3t} u(t)$ . The input is  $x(t) = 7 \cos(2t)$ . Compute the output  $y(t)$ .

given:-  $h(t) = 5e^{-t} u(t) - 16e^{-2t} u(t) + 13e^{-3t} u(t)$  [12 marks]

$x(t) = 7 \cos(2t)$

Taking Laplace Transform,

$$H(s) = \frac{5}{(s+1)} - \frac{16}{(s+2)} + \frac{13}{(s+3)}$$

$$H(s) = \frac{5[(s+2)(s+3)] - 16[(s+1)(s+3)] + 13[(s+1)(s+2)]}{(s+1)(s+2)(s+3)}$$

$$H(s) = \frac{5(s^2 + 5s + 6) - 16[s^2 + 4s + 3] + 13[s^2 + 3s + 2]}{(s+1)(s+2)(s+3)}$$

$$H(s) = \frac{5s^2 + 25s + 30 - 16s^2 - 64s - 48 + 13s^2 + 39s + 26}{(s+1)(s+2)(s+3)}$$

$$H(s) = \frac{2s^2 + 8}{(s+1)(s+2)(s+3)} = \frac{2(s^2 + 4)}{(s+1)(s+2)(s+3)}$$

$$X(s) = 7 \left[ \frac{s}{s^2 + \omega_0^2} \right] = 7 \left[ \frac{s}{s^2 + 4} \right]$$

$$Y(s) = H(s) \cdot X(s) \Rightarrow \frac{2(s^2 + 4)}{(s+1)(s+2)(s+3)} \times \frac{7 \times s}{(s^2 + 4)}$$

$$Y(s) = \frac{14s}{(s+1)(s+2)(s+3)}$$

$$A = \frac{-14}{1 \times 2} = -7$$

$$B = \frac{14 \times (-2)}{+1 \times 1} = 28$$

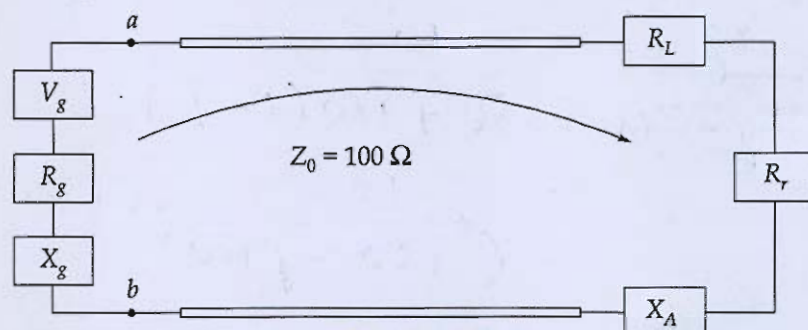
$$C = \frac{14 \times (+3)}{-2 \times +1} = -21$$

$$Y(s) = \frac{A}{(s+1)} + \frac{B}{(s+2)} + \frac{C}{(s+3)}$$

$$Y(s) = \frac{-7}{(s+1)} + \frac{28}{(s+2)} - \frac{21}{(s+3)}$$

$$y(t) = [-7e^{-t} + 28e^{-2t} - 21e^{-3t}] \text{ ult}$$

- Q.1 (c) An antenna with a radiation resistance of  $48 \Omega$ , a loss resistance of  $2 \Omega$  and a reactance of  $50 \Omega$  is connected to a generator with open-circuit voltage of  $10 \text{ V}$  and internal impedance of  $50 \Omega$  via a  $\frac{\lambda}{4}$ -long transmission line with characteristic impedance of  $100 \Omega$ .



Determine the power radiated by the antenna (Given,  $V_g = 10 \text{ V}$ ,  $R_g = 50 \Omega$ ,  $X_g = 0$ ).

[12 marks]

given  $R_r = 48 \Omega$   $R_L = 2 \Omega$   $X_A = 50 \Omega$

$V_g = 10 \text{ V}$   $R_g = 50 \Omega$   $X_g = 0$

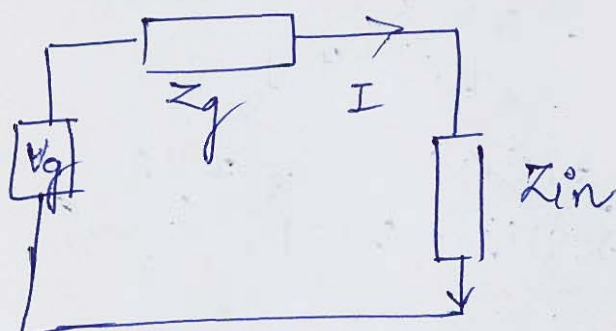
$Z_L = R + jX$   $Z = 50 + j50 \Omega$

$\beta l = \frac{2\pi}{\lambda} \cdot \frac{\lambda}{4} = \pi/2$   $\tan \pi/2 = \infty$

$$Z_{in} = Z_0 \left[ \frac{Z + jZ_0 \tan \beta l}{Z_0 + jZ \tan \beta l} \right]$$

$$Z_{in} = \frac{Z_0^2}{Z_L}$$





$$Z_{in} = \frac{Z_0^2}{Z_L} \Rightarrow \frac{1\omega \times 1\omega}{(50 + 50j)}$$

$$R_g = 50\Omega$$

$$V_{Th} = 10V$$

$$\text{Power radiated by antenna} = I^2 \times Z_{in}$$

$$I = \frac{V_g}{Z_g + Z_{in}} = \frac{10}{50 + 1\omega(1-j)}$$

$$= \frac{10}{(150 - j1\omega)} \Rightarrow 0.055 \angle 0.58$$

$$= \frac{200}{(1+j)} \times \frac{(1-j)}{(1-j)} = \frac{200(1-j)}{2} = 100(1-j)$$

$$P = (0.055)^2 \angle 0.58 \times 2 \times 1\omega \times \sqrt{2} \angle -45^\circ$$

$$(P = 0.4277 \angle -0.205)$$

$$P = V \cos \theta \times I \cos \theta_I$$

$$= VI$$

$$P = 0.4277 \cos(-0.205) W \Rightarrow 0.4187 \text{ Watt}$$

2.1 (d) Measurements conducted on a servo mechanism show the system response to be

$$c(t) = 1 + 0.2e^{-60t} - 1.2e^{-10t}$$

when subjected to a unit-step input

(i) obtain the expression for the closed-loop transfer function.

(ii) determine the undamped natural frequency and the damping ratio of the system.

given:-  $c(t) = 1 + 0.2e^{-60t} - 1.2e^{-10t}$  [6 + 6 marks]

$$C(s) = \frac{1}{s} + \frac{0.2}{(s+60)} - \frac{1.2}{(s+10)}$$

$$r(t) = u(t) = 1/s = R(s)$$

$$\frac{C(s)}{R(s)} = \frac{(s+60)(s+10) + 0.2s(s+10) - 1.2(s)(s+60)}{s \times (s+60)(s+10)}$$

$$\frac{C(s)}{R(s)} = \frac{s^2 + 70s + 600 + 0.2[s^2 + 10s] - 1.2[s^2 + 60s]}{(s+60)(s+10)}$$

$$\frac{C(s)}{R(s)} = \frac{s^2 + 70s + 600 + 0.2s^2 + 2s - 1.2s^2 - 72s}{(s+60)(s+10)}$$



$$\frac{C(s)}{R(s)} = \frac{600}{(s+60)(s+10)}$$

$$T(s) = \frac{600}{s^2 + 70s + 600}$$

(iii) comparing d/c eq<sup>n</sup> :-

$$s^2 + 70s + 600 = 0 \quad s^2 + 2\zeta\omega_n s + \omega_n^2 = 0$$

$$\omega_n^2 = 600 \quad \omega_n = \sqrt{600} = 24.49 \text{ rad/sec}$$

$$2\zeta\omega_n = 70$$

$$2 \times \zeta \times 24.49 = 70$$

$$\zeta = \frac{70}{2 \times 24.49} = 1.42$$

2.1 (e) Over an interval  $|t| \leq 1$ , an angle-modulated signal is given by,

$$\phi_M(t) = 10 \cos(13,000\pi t + 0.3\pi)$$

It is known that the carrier frequency  $\omega_c = 12000\pi$  rad/sec.

- (i) Assume the modulated signal is a PM signal with  $k_p = 1000$  rad/V, determine  $m(t)$  over the interval  $|t| \leq 1$ .
- (ii) Assume the modulated signal is a FM signal with  $k_f = 1000$  rad/sec/volt, determine  $m(t)$  over the interval  $|t| \leq 1$ .

[6 + 6 marks]

given  $\phi_M(t) = 10 \cos(13000\pi t + 0.3\pi)$

$$\phi_M(t) = 10 \cos(12000\pi t + (1000\pi t + 0.3\pi))$$

For PM  $\phi \propto m(t)$  /  $\phi = k_p m(t)$

$$1000\pi t + 0.3\pi = 1000 m(t)$$

$$m(t) = \left[ \pi t + \frac{0.3\pi}{1000} \right] \quad |t| \leq 1$$



For FM  $\Delta f \propto m(t) \Rightarrow \Delta f = k_f m(t)$

$$\frac{1}{2\pi} \frac{d\phi}{dt} = k_f m(t)$$

$$\frac{1}{2\pi} \frac{d}{dt} [1000\pi t + 0.3\pi] = k_f m(t)$$

$$\frac{1}{2\pi} \frac{d}{dt} 1000\pi = \frac{1000}{2\pi} m(t)$$

$$m(t) = \pi \quad |t| \leq 1$$

12 ✓

- 2.2 (a) A transmission line channel has  $(n - 1)$  regenerative repeaters plus a terminal receiver in the transmission of binary information. The probability of error at the detector of each receiver (or repeater) is " $p$ " and that errors among repeaters are statistically independent. Show that the binary error probability of the overall system is,

$$P_n = \frac{1}{2} [1 - (1 - 2p)^n]$$

[20 marks]





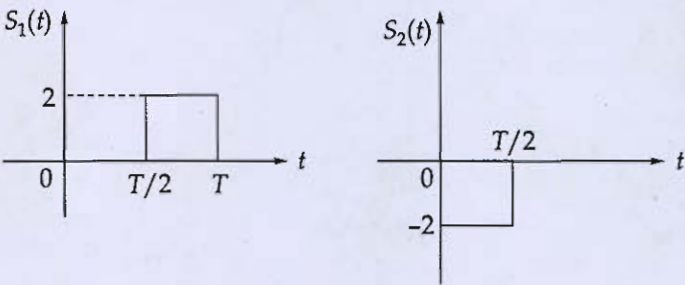
- 2 (b) Two hosts are connected via a packet switch with  $10^8$  bits per second links. Each link has a propagation delay of  $40\ \mu\text{s}$ . The switch begins forwarding a packet  $60\ \mu\text{s}$  after it receives the same. If 100000 bits of data are to be transmitted between the two hosts using a packet size of 25000 bits, then determine the time elapsed between the transmission of the first bit of data and the reception of the last bit of the data.

[20 marks]





2.2 (c) Express the following functions in terms of orthonormal components using Gram Schmidt procedure. Draw the constellation diagram for this signal set and find the minimum distance  $d_{\min}$  between the constellation points.



[20 marks]





- 2.3 (a) In an air-filled rectangular waveguide with  $a = 2.286$  cm and  $b = 1.016$  cm, the  $y$ -component of the TE mode is given by

$$E_y = \sin\left(\frac{2\pi}{a}x\right)\cos\left(\frac{3\pi}{b}y\right)\sin(10\pi \times 10^{10}t - \beta z) \text{ V/m}$$

Find:

- (i) The mode of operation.
- (ii) The propagation constant.
- (iii)  $H_x$ .

[20 marks]





Q.3 (b) Explain different transfer modes of an 8237 DMA controller in active cycle.

[20 marks]



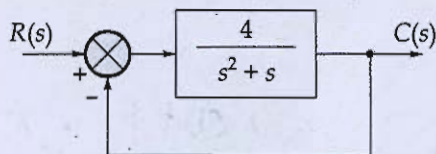
- 2.3 (c)
- (i) Determine the order of a low-pass Butterworth filter that is to provide 40 dB attenuation at  $\omega = 2\omega_0$ . (Here,  $\omega_0$  is the cut-off frequency of low pass filter)
  - (ii) Write a 8085 program to generate continuous square wave with a period of 560  $\mu\text{s}$ . Assume the system clock period is 350 ns and use I/O device connected at PORT 0 to output the square wave. Use register B as delay counter.

[10 + 10 marks]





- Q.4 (a) A closed-loop control system with unity feedback is shown in figure. By using derivative control, the damping ratio is to be made 0.75. Determine the value of  $T_d$ . Also determine the rise time, peak time and peak overshoot without derivative control and with derivative control. Assume input to the system is a unit-step.



[20 marks]

given:-  $G_H(s) = \frac{4}{(s^2 + s)}$

without ( $K_p$ ) (derivative controller).

$$1 + G_H(s) \Rightarrow s^2 + s + 4 = 0$$

$$s^2 + 2\zeta\omega_n s + \omega_n^2 = 0 \quad \omega_n^2 = 4 \quad \omega_n = 2 \text{ rad/sec}$$

$$2\zeta\omega_n = 1 \quad 2 \times \zeta \times 2 = 1 \quad \zeta = \frac{1}{4}$$

$$\zeta = 0.25$$

$$t_r = \frac{\pi - \phi}{\omega_d} \Rightarrow \frac{\pi - \cos^{-1}(0.25)}{\omega_n \sqrt{1 - \zeta^2}} = \frac{1.823}{2 \sqrt{1 - (0.25)^2}}$$

$$t_r = \frac{1.823}{2 \sqrt{1 - 0.0625}} = \frac{1.823}{2 \times 0.968} = 0.9416 \text{ sec}$$

$$t_p = \frac{n\pi}{\omega_d} = \frac{\pi}{\omega_n \sqrt{1-\zeta^2}} = \frac{\pi}{2\sqrt{1-(0.25)^2}}$$

$$t_p = \frac{\pi}{2\sqrt{1-0.0625}} \Rightarrow 1.6223 \text{ sec}$$

$$\text{Peak overshoot} = 1 + e^{-\pi \cot \phi}$$

$$\cancel{e^{-\pi \cot \phi}} \Rightarrow \cancel{e^{-\pi \cot \phi}}$$

$$\cos \theta = \zeta \quad \theta = \cos^{-1} \zeta = \cos^{-1}(0.25)$$

$$\theta = 1.318 \text{ rad}$$

$$\cot \phi \Rightarrow \tan \theta = \tan^{-1} \frac{1}{1.131}$$

$$\frac{\cot \theta}{\sin \theta} = \frac{\cos \theta}{\sin \theta} = \frac{\zeta}{\sqrt{1-\zeta^2}} = \frac{0.25}{\sqrt{1-(0.25)^2}}$$

$$\cot \theta = 0.2581$$

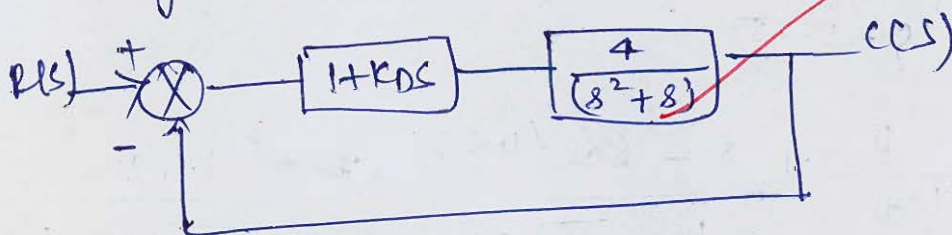
$$\text{Peak overshoot} = e^{-\pi \cot \phi} = e^{-\pi \times 0.2581}$$

$$= 0.4444$$

$$\text{Peak overshoot value} = 1 + e^{-\pi \cot \phi}$$

$$= 1.444$$

Now we introduce derivative controller in system.





$$G_H(s) = \frac{(1 + K_D s) \times 4}{(s^2 + 8)}$$

$$\text{cls eqn } 1 + G_H(s) = 0 \quad s^2 + 8 + 4 + 4K_D s = 0$$

$$s^2 + 8(1 + 4K_D s) + 4 = 0$$

$$\omega_n^2 = 4 \quad \omega_n = 2 \quad \zeta = 0.75$$

$$2\zeta\omega_n = 2 \times 0.75 \times 2 = 1 + 4K_D$$

$$2 = 4K_D \quad K_D = \frac{1}{2}$$

$$T_d \geq \frac{1}{K_D} = 2 \text{ sec}$$

$$T_{\text{delay}} = \frac{1 + 0.75}{\omega_n} = \frac{1 + 0.7 \times 0.75}{2} = 0.7625$$

$$t_r = \frac{\pi - \phi}{\omega_d}$$

$$\cos \phi = \zeta$$

$$\phi = \cos^{-1}(0.75)$$

$$t_r = \frac{\pi - 0.7227}{\omega_n \sqrt{1 - \zeta^2}} \Rightarrow \frac{\pi - 0.7227}{2 \sqrt{1 - 0.75^2}} \Rightarrow 0.72273$$

$$t_r = 1.020 \text{ sec.}$$

$$t_p = \frac{\pi}{\omega_d} = \frac{\pi}{2 \sqrt{1 - (0.75)^2}} = 2.374 \text{ sec.}$$

$$\cot \phi = \frac{\cos \phi}{\sin \phi} = \frac{\zeta}{\sqrt{1 - \zeta^2}} \Rightarrow \frac{0.75}{\sqrt{1 - (0.75)^2}} = 1.133$$

$$e^{-\pi \cot \phi} = e^{-\pi \times 1.133} = 0.0204$$

$$1 + e^{-\pi \cot \phi} \Rightarrow 1.0204 \text{ peak overshoot}$$

Since we added zero by adding derivative controller so  $M_p \downarrow$  stability  $\uparrow$  but  $\text{ess} \uparrow$  also.



- 2.4 (b) (i) Consider the following 5 processes with burst time (BT), arrival time (AT) and their priority as given below. Find the average waiting and turn around time using preemptive priority scheduling. Assume lower priority number implies highest priority.

Pid	Priority	AT (msec)	BT (msec)
1	3	0	10
2	1	1	1
3	3	2	2
4	4	3	1
5	2	4	5

- (ii) Realize a full adder using a  $(3 \times 8 \times 2)$  PLA.

(i) [10 + 10 marks]

Pid	Priority	AT	BT	TAT = CT - AT	WT = TAT - BT	CT
1	3	0	<del>10</del> 8	16	6	16
2	1	1	<del>1</del>	1	0	2
3	3	2	2	16	14	18
4	4	3	1	16	15	19
5	2	4	<del>5</del>	5	0	9

$P_1$	$P_2$	$P_1$	$P_1$	$P_5$	$P_1$	$P_3$	$P_4$	
0	1	2	3	4	9	16	18	19

$$\text{Average WT} = \frac{6 + 0 + 14 + 15 + 0}{5} = \frac{35}{5} = 7 \text{ msec}$$

$$\text{Average TAT} = \frac{16 + 1 + 16 + 16 + 5}{5} = \frac{54}{5} = 10.8 \text{ msec}$$

(ii) For full adder we have

$$\text{Sum} = A \oplus B \oplus C$$

$$\text{Carry} = AB + BC + CA$$



For  $3 \times 8 \times 2$  PLA 3 i/p, 8 terms, 2 OF gate

A	B	C	S	C
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

A \ BC	00	01	11	10
0	0	1	1	0
1	1	0	1	1

$$\text{Sum } F = A \oplus B \oplus C$$

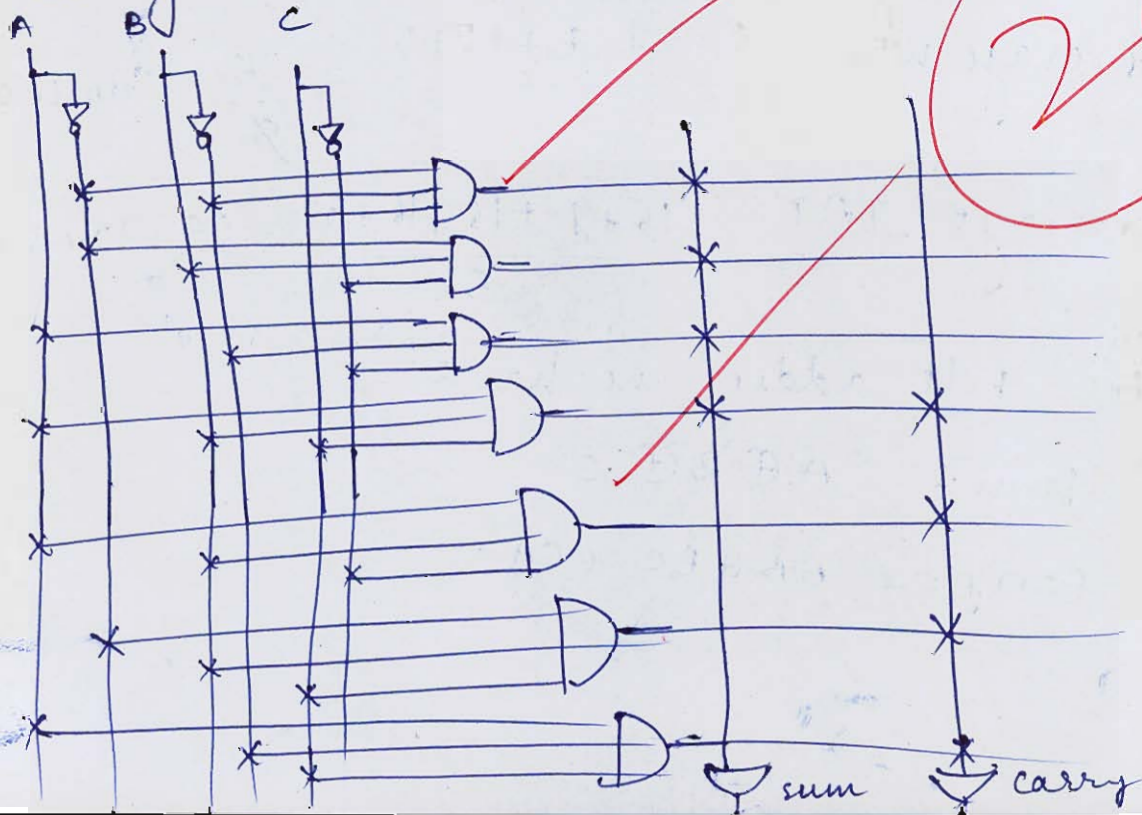
$$\bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$$

A \ BC	00	01	11	10
0	0	1	1	0
1	1	0	1	1

$$\text{Carry} = AB + BC + CA$$

$$\text{Now } C = AB(C + \bar{C}) + (A + \bar{A})BC + A(B + \bar{B})C$$

$$\text{Carry} = ABC + AB\bar{C} + \bar{A}BC + A\bar{B}C$$



- Q.4 (c) (i) In the ionospheric propagation, consider that the reflection takes place at a height of 400 km and that the maximum density in the ionosphere corresponds to a refractive index of 0.9 at frequency of 10 MHz. Determine the ground range for which this frequency is the MUF (Maximum Usable Frequency). Take the earth's curvature into consideration.
- (ii) In a satellite link, the propagation loss is 200 dB. Margins and other losses account for another 3 dB. The receiver  $[G/T]$  is 11 dB, and the  $[EIRP]$  is 45 dBW. Calculate the received  $[C/N]$  for a system bandwidth of 36 MHz.

[12 + 8 marks]

(i) given  $h = 400 \text{ km}$

$$N = ? \quad \mu = 0.9 \quad f = 10 \text{ MHz}$$

$$\mu = \frac{\sin i}{\sin r} = \sqrt{1 - \frac{81N}{f^2}} \Rightarrow (0.9)$$

$$1 - \frac{81N}{f^2} = (0.9)^2 \quad 1 - \frac{81N}{f^2} = 0.81$$

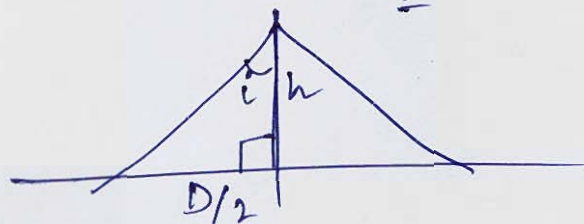
$$(1 - 0.81)f^2 = 81N \Rightarrow (0.19) \times (10 \times 10^6)^2 = N$$

$$N = 2.345 \times 10^{-3} \times 10^{14} \text{ cm}^{-3} \text{ or}$$

$$N = 2.345 \times 10^{11} \text{ cm}^{-3}$$



For max MUF  $f_{muf} = f_c \cos i^\circ$



$$\cos i^\circ = \frac{h}{\sqrt{(D/2)^2 + h^2}}$$

Let  $f_c = 30 \text{ MHz}$

$$\frac{10}{30} = \cos i = \frac{h}{\sqrt{(D/2)^2 + h^2}} \quad \frac{1}{3} = \frac{h}{\sqrt{(D/2)^2 + h^2}}$$

$$\left(\frac{D}{2}\right)^2 + h^2 = 9h^2$$

$$\left(\frac{D}{2}\right)^2 = 8h^2$$

$$D = 4\sqrt{2}h$$

$$D = 4\sqrt{2}h$$

$$D = 4\sqrt{2} \times 400 \text{ km} = 2262.7417 \text{ km}$$

$$D = 2262.7417 \text{ km}$$

(ii)  $P_r = \frac{P_t G_t G_r}{L_{\text{loss}}}$

$$N = kTB$$

$$\frac{C}{N} = \left[ EIRP + \frac{G}{T} - \text{loss} \right]$$

$$\frac{C}{N} = 45 + 11 - 200 - 3 - 10 \log_{10} K - 10 \log_{10} B$$

$$\frac{C}{N} = 56 - 203 - 10 \log_{10}(1.38 \times 10^{-23}) - 10 \log_{10}(36 \times 10^6)$$

$$\frac{C}{N} = 56 - 203 + 228.601 - (75.56)$$

$$\frac{C}{N} = 284.601 - 278.56 = 6.041 \text{ dB}$$

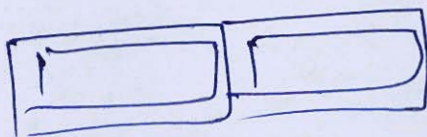
$$\frac{C}{N} = 6.041 \text{ dB}$$

## Section B

- 2.5 (a) Two rectangular waveguides are joined end-to-end. The waveguides have identical dimensions, where  $a = 2b$ . One guide is air-filled, and the other is filled with a dielectric characterized by  $\epsilon_r$ . Determine the range of values of  $\epsilon_r$ , such that single-mode operation can be simultaneously ensured in both guides at some frequency.

[12 marks]

given :-



waveguide 1:-  $a = 2b$   $TE_{10}$  dominant mode  $a = 2b$

$$\omega^2 \mu \epsilon = \left( \frac{m\pi}{a} \right)^2 + \left( \frac{n\pi}{b} \right)^2$$

for  $TE_{10}$ 

$$f_{c1} = \frac{c}{2a}$$

Waveguide 2:-

for  $TE_{10}$   $f_{c2} = \frac{c}{\sqrt{\epsilon_r} \times 2a}$

To ensure single mode operation

Since  $f_{c2} < f_{c1}$  so  $f_{c2} > f_{c1}$  to be simultaneously single mode.

$$\frac{c'}{\sqrt{\epsilon_r} \times 2a} > \frac{c}{2a}$$

$$\boxed{\sqrt{\epsilon_r} < 1}$$

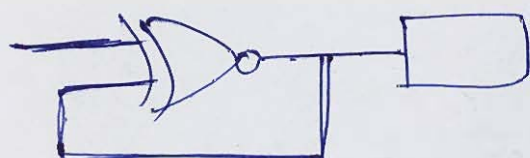
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- Q.5 (b) The bit stream 1011100011 is to be transmitted using DPSK. Determine the encoded sequence and transmitted phase sequence.

[12 marks]

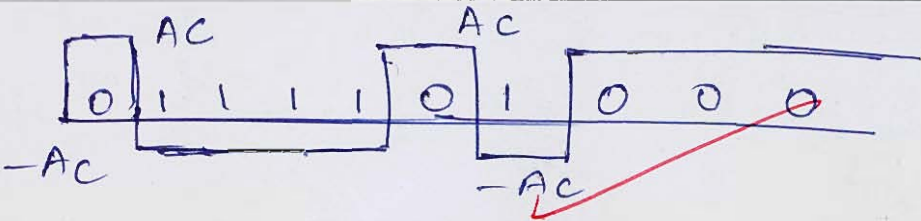


bit	1	0	1	1	1	0	0	0	1	1
Refers	0	0	1	1	1	1	0	1	0	0
	0	1	1	1	1	0	1	0	0	0

for 0  $A_c \cos \omega_c t$ 1  $-A_c \cos \omega_c t$ 

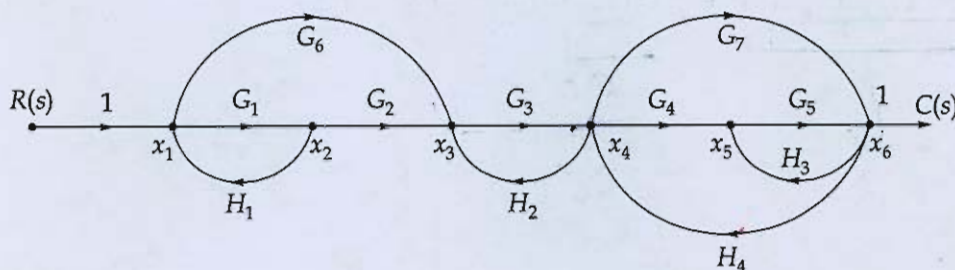
encoded 0 1 1 1 1 0 1 0 0 0

 $A_c -A_c -A_c -A_c -A_c A_c -A_c A_c A_c A_c$



7

- Q.5 (c) Find the transfer function of the system whose signal flow graph is shown in figure below:



[12 marks]

By Mason's Gain Formulae

$$T(s) = \sum_{k=1}^{\infty} \frac{P_k \Delta_k}{\Delta}$$

$$P_1 = 1 \times G_1 \times G_2 \times G_3 \times G_4 \times G_5$$

$$P_2 = 1 \times G_1 \times G_3 \times G_4 \times G_5$$

$$P_3 = 1 \times G_6 \times G_3 \times G_7 \times 1$$

$$L_1 = G_1 H_1 \quad L_2 = G_2 H_2 \quad L_3 = G_5 H_3 \quad L_4 = G_4 G_5 H_4$$

$$L_5 = G_7 \times H_4$$

$$\Delta = (1 - (L_1 + L_2 + L_3 + L_4 + L_5)) + (L_1 L_2 + L_1 L_3 + L_1 L_4 + L_1 L_5)$$

$$\Delta_1 = 1 \quad \Delta_2 = 1 \quad \Delta_3 = 1$$

$$T(s) = \frac{P_1 \Delta_1}{\Delta} + \frac{P_2 \Delta_2}{\Delta} + \frac{P_3 \Delta_3}{\Delta}$$

$$T(s) = \frac{G_1 G_2 G_3 G_4 \times G_5}{\Delta} + \frac{G_6 G_3 G_4 G_5}{\Delta} + \frac{G_6 \times G_3 \times G_7}{\Delta}$$

$$T(s) = \frac{G_1 G_2 G_3 G_4 G_5 + G_6 G_3 G_4 G_5 + G_6 G_3 \times G_7}{1 - (G_1 H_1 + G_2 H_2 + G_5 H_3 + G_4 G_5 H_4 + G_7 H_4) + (L_1 L_2 + L_3 L_4 + L_1 L_4 + L_4 L_5)}$$

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Q.5 (d)

A ground based communication system transmits to a geo-synchronous satellite located 41935 km from the transmitter at a frequency of 1 GHz. The gain of the ground based antenna is 25 dBi, and the satellite antenna has a gain of 15 dBi.

Assuming free-space propagation path loss, what must be the transmitter power in watts to produce 5  $\mu$ V (rms) at the output of satellite antenna?

(Assume satellite antenna is matched to 50  $\Omega$ )

[12 marks]

By friss formulae  $\Rightarrow$

$$P_r = \frac{P_t G_t G_r}{\left(\frac{4\pi d}{\lambda}\right)^2}$$

$$P_r = \frac{V_{Th}^2}{R_{Th}} \Rightarrow \frac{V_{rms}^2}{R} \Rightarrow \frac{(5 \times 10^{-6})^2}{50} \Rightarrow \frac{25 \times 10^{-12}}{50} \text{ W}$$

$$P_r = 0.5 \times 10^{-12} \text{ watt}$$

$$L = \left(\frac{4\pi d}{\lambda}\right)^2 = \left[\frac{4\pi \times 41935 \times 1000 \times 10^9}{3 \times 10^8}\right]^2$$

$$L = \left[\frac{4\pi \times 41935 \times 10^{12}}{3 \times 10^8}\right]^2 = (175567.866 \times 10^4)^2$$

$$G_t = 10 \log_{10}(G_t) = 25$$

$$G_t = 10^{2.5} = 316.227$$

$$G_r = 10 \log_{10}(G_r) = 15$$

$$G_r = 10^{1.5} = 31.6227$$

$$\frac{P_r \times \left(\frac{4\pi d}{\lambda}\right)^2}{G_t G_r} = P_t \Rightarrow \frac{0.5 \times 10^{-12} \times (175567.866 \times 10^4)^2}{316.227 \times 31.6227}$$

$$P_t = 1541211.14 \times 10^{-4}$$

$$P_t = 154.1211 \text{ W}$$

$\checkmark$

- Q.5 (e) In target-search ground mapping radars, it is desirable to have echo power received from a target of constant cross section to be independent of its range. For one such application; the desirable radiation intensity of the antenna is given by

$$U(\theta, \phi) = \begin{cases} 1 & ; 0^\circ < \theta < 20^\circ \\ 0.342 \operatorname{cosec}(\theta) & ; 20^\circ \leq \theta < 60^\circ \\ 0 & ; 60^\circ \leq \theta \leq 180^\circ \end{cases}, 0^\circ \leq \phi \leq 360^\circ$$

Find the directivity (in dB) of the antenna.

[12 marks]

$$\text{Directive gain} = \frac{4\pi U(\theta, \phi)}{P_{\text{rad}}}$$

$$\text{Directivity} = \frac{4\pi U(\theta, \phi)_{\text{max}}}{P_{\text{rad}}}$$

$$P_{\text{rad}} = \iint U(\theta, \phi) d\Omega$$

$$\text{Directivity} = \frac{4\pi}{\frac{\iint U(\theta, \phi) d\Omega}{U(\theta, \phi)_{\text{max}}}}$$

$$\text{Since } \frac{\iint U(\theta, \phi) d\Omega}{U(\theta, \phi)_{\text{max}}} = \iint \frac{U(\theta, \phi)}{U(\theta, \phi)_{\text{max}}} d\Omega$$

$$U_N(\theta, \phi) = \begin{cases} 1 & 0^\circ < \theta < 20^\circ \\ \cos \theta & 20^\circ \leq \theta \leq 60^\circ \\ 0 & 60^\circ \leq \theta \leq 180^\circ \end{cases}$$

$$P_{\text{rad}} = \int_0^{360^\circ} \int_0^{20^\circ} 1 \sin \theta d\theta d\phi + \int_0^{360^\circ} \int_{20^\circ}^{60^\circ} \cos \theta \sin \theta d\theta d\phi + \int_0^{360^\circ} \int_{60^\circ}^{180^\circ} 0 d\theta d\phi$$

$$U_N(\theta, \phi) = \left[ -\cos \theta \right]_0^{20^\circ} + (60^\circ - 20^\circ) + 0 \times 360^\circ$$

$$= \left[ -\cos 20^\circ + \cos 0^\circ \right] + 40^\circ \times 360^\circ$$

$$= \left[ (-0.939 + 1) + 40^\circ \right] \times 360^\circ$$

$$\Rightarrow \left[ 0.061 + \frac{40 \times \pi}{180} \right] \times \frac{360^\circ \times \pi}{180^\circ}$$

$$\Rightarrow (0.061 + 0.6981) \times 6.283$$

$$\Rightarrow 4.769$$

$$\text{Directivity} = \frac{4\pi}{4.769} \Rightarrow 2.635$$

$$\text{in dB} \Rightarrow 10 \log_{10} 2.635 = 4.207 \text{ dB}$$

$$\boxed{\text{Directivity} = 4.207 \text{ dB}}$$



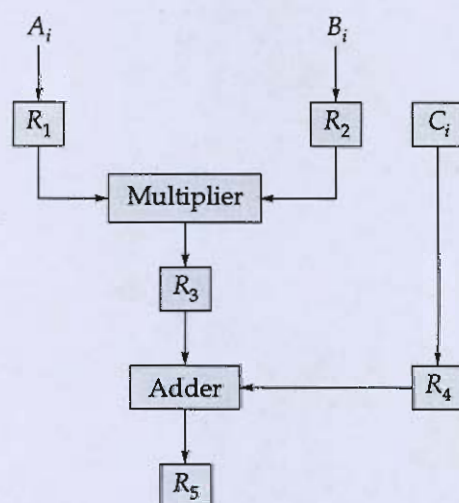
- Q.6 (a)
- (i) Write a program in 8086 microprocessor to find out the largest among 8-bit  $n$  numbers where size " $n$ " is stored at memory address 2000 : 500 and the numbers are stored from memory address 2000 : 501. Store the result (largest number) into memory address 2000 : 600. (Assume instructions starting from Memory address 0400H)
  - (ii) Explain the Bus Interface Unit of 8086 microprocessor.

[10 + 10 marks]





- Q.6 (b) The pipeline of figure shown has the following propagation times: 40 nsec for the operands to be read from memory into registers  $R_1$  and  $R_2$ , 45 nsec for the signal to propagate through the multiplier, 5 nsec for the transfer into  $R_3$  and 15 nsec to add the two numbers into  $R_5$ .



- What is the minimum clock cycle time that can be used?
- A non-pipeline system can perform the same operation by removing  $R_3$  and  $R_4$ . How long will it take to multiply and add the operands without using the pipeline?
- Calculate the speedup that can be achieved with pipeline for 10 tasks.
- What is the maximum speed up that can be achieved?

[20 marks]





Q.6 (c) Draw the complete root locus for the system with open-loop transfer function,

$$G(s)H(s) = \frac{K}{s(s+6)(s^2+4s+13)}$$

[20 marks]









- 2.7 (a) (i) Given message signal as  $m(t) = e^{-t^2/100}$ , carrier frequency  $f_c = 10^4$  Hz, frequency and phase sensitivities as  $500\pi$  rad/sec/V and  $1.2\pi$  rad/V respectively. Find the frequency deviation for FM and PM.
- (ii) The output signal to noise ratio (SNR) of a 10-bit PCM was found to be 30 dB. The desired SNR is 42 dB. It was decided to increase the SNR to the desired value by increasing the number of quantization levels. Find the fractional increase in the transmission bandwidth required for this increase in SNR.

[15 + 5 marks]

(i)  $m(t) = e^{-t^2/100}$   $f_c = 10^4 \text{ Hz} = 10 \text{ KHz}$

$k_f = 500\pi \text{ rad/sec/V}$   $k_f = \frac{500\pi}{2\pi} \text{ Hz/sec/V}$   
 $= 250 \text{ Hz/sec/V}$

$k_p = 1.2\pi \text{ rad/sec}$

For FM  $\Delta f \propto m(t)$

$\Delta f = k_f m(t)$

$\Delta f = 250 \times e^{-t^2/100}$

$[\Delta f = 250 \times e^{-t^2/100}] \text{ Hz}$  ✓

For PM  $\phi \propto m(t)$   $\Delta f = \frac{1}{2\pi} \frac{d\phi}{dt}$

$\Delta f = \frac{1}{2\pi} \frac{d}{dt} (1.2\pi \times e^{-t^2/100})$

$\Delta f = 0.6 e^{-t^2/100} \cdot \frac{-2t}{100}$

$\Delta f = -0.012 t e^{-t^2/100}$  ✓

(ii)  $\text{SNR} = 30 \text{ dB}$   $n = 10$   $(\text{SNR})_{\text{desi}} = 42 \text{ dB}$

$n' = n \uparrow$  Let assume msg sig is sinusoidal

$\text{SNR} = 1.8 + 6n$

$\text{SNR} = \frac{P_m}{\frac{\Delta^2}{12}}$

$40 - 30 = 6(n_2 - n_1)$   
 $10 = 6(n_2 - n_1)$

$$(n_2 - n_1) = \frac{10}{6} = 1.66 \approx 2$$

For PCM  $BW = \frac{R_b}{2}$       $R_b = n f_s$

$BW \propto n$

fractional increase in  $n$  gives the fractional increase in  $BW$ .

$$\Delta n = n_2 - n_1 = 1.66$$

$$\frac{\Delta n}{n_1} = \frac{n_2 - n_1}{n_1} = \frac{1.66}{10} \approx \frac{2}{10} = \frac{1}{5}$$

$$\therefore \frac{\Delta n}{n_1} = \frac{1}{5} \times 100 = 20\%$$

$$\frac{\Delta n}{n_1} = \frac{1}{5} \quad \frac{\Delta BW}{BW} = \frac{1}{5}$$

$\therefore \text{increase} = 20\%$  5

5



2.7 (b) An angle-modulated signal with carrier frequency,  $\omega_c = 2\pi \times 10^5$  rad/sec is described by the equation

$$\phi(t) = 10 \cos(\omega_c t + 5 \sin 3000t + 10 \sin 2000\pi t)$$

- (i) Find the power of the modulated signal.
- (ii) Find the frequency deviation  $\Delta f$ .
- (iii) Find the deviation ratio  $\beta$ .
- (iv) Estimate the bandwidth of  $\phi(t)$ .

[20 marks]

given:-  $\phi(t) = 10 \cos(\omega_c t + 5 \sin 3000t + 10 \sin 2000\pi t)$

$$\phi = 5 \sin 3000t + 10 \sin 2000\pi t$$

$$\Delta f = \frac{1}{2\pi} \frac{d\phi}{dt} \Rightarrow \frac{1}{2\pi} \frac{d}{dt} (5 \sin 3000t + 10 \sin 2000\pi t)$$

$$(ii) \Delta f = \frac{1}{2\pi} [5 \cos 3000t (3000) + 10 \times 2000\pi \cos 2000\pi t]$$

$$(\Delta f)_{\max} = \frac{5 \times 3000 + 10 \times 2000\pi}{2\pi} = 12387.324 \text{ Hz}$$

$$f_1 = \frac{3000}{2\pi} = 477.464 \text{ Hz} \quad f_2 = \frac{2000\pi}{2\pi} = 1000 \text{ Hz}$$

$$(iii) \beta_T = \frac{(\Delta f)_{\max}}{f_{\max}} = \frac{12387.324}{1000} = 12.387$$

$\boxed{\beta \Rightarrow 13}$



Since  $\beta > 1$  so this is wide band FM

(i) Power of modulated s/g =  $\frac{Ac^2}{2}$

$$P_T = \frac{10 \times 10}{2} = 50W$$

(iv) Bandwidth of WBFM s/g given by

$$\Rightarrow f_c + n f_m$$

$$n = (\beta + 1) \Rightarrow n = 13 + 1 = 14$$

$$f_{max} = f_c + n f_{mH}$$

$$BW = 14(1000 - 477.464)$$

$$BW = 14(7315.504 \text{ Hz})$$

$$BW = 14000 \text{ Hz}$$

$$BW = 14 \text{ KHz}$$

- Q.7 (c)
- (i) Write short notes on pure ALOHA and slotted ALOHA.
  - (ii) Determine the maximum throughput that can be achieved using ALOHA and slotted ALOHA protocols.

[10 + 10 marks]







- Q.8 (a) (i) The open-loop transfer function of a servo system with unity feedback is

$$G(s) = \frac{10}{s(0.1s + 1)}$$

Evaluate the static error coefficients ( $K_p$ ,  $K_v$ ,  $K_a$ ) for the system.

- (ii) Obtain the steady-state error the system when subjected to an input given by the polynomial,

$$r(t) = a_0 + a_1 t + \frac{a_2}{2} t^2; t > 0$$

Also evaluate the dynamic error using the dynamic error coefficients.

[10 + 10 marks]

(i) given :-  $G(s) = \frac{10}{s(0.1s + 1)}$

position error coeff =  $K_p = \lim_{s \rightarrow 0} G(s)H(s)$   
 $\boxed{K_p = \infty}$

$$e_{ss} = \frac{1}{1 + K_p} = \frac{1}{1 + \infty} = 0$$

velocity error coeff =  $K_v = \lim_{s \rightarrow 0} sG(s)H(s)$   
 $\Rightarrow 10$

$$\boxed{K_v = 10}$$

acceleration error  $K_a = \lim_{s \rightarrow 0} s^2 G(s)H(s)$   
 $= \lim_{s \rightarrow 0} s^2 \times \frac{10}{s(0.1s + 1)}$   
 $\Rightarrow 0$

$$\boxed{K_a = 0}$$

(ii) if given i/p  $\Rightarrow r(t) = a_0 + a_1 t + \frac{a_2}{2} t^2$

for  $a_0 = e_{ss} = \frac{1}{1 + K_p} = \frac{1}{1 + \infty} = 0$

for  $a_1 = e_{ss} = \frac{1}{K_v} = \frac{1}{10} = 0.1$

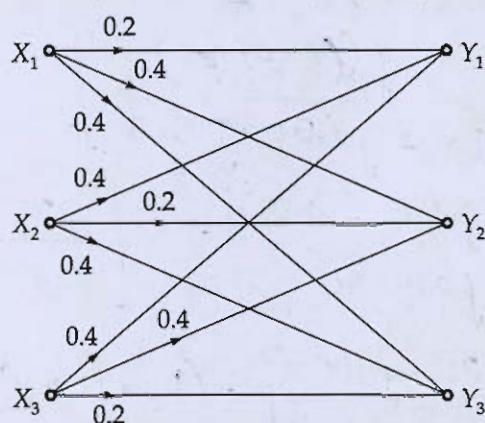
for  $a_2 = e_{ss} = \frac{1}{K_a} = \frac{1}{0} = \infty$







- 8 (b) (i) Consider the following channel having equal probability of source symbols:



Determine the capacity of above channel.

- (ii) A certain transmission line 2 m long terminated by a load of  $20 + j50 \Omega$  has  $\alpha = 8 \text{ dB/m}$ ,  $\beta = 1 \text{ rad/m}$  and  $Z_0 = (60 + j40) \Omega$ . Calculate the input impedance of transmission line.

[10 + 10 marks]

(ii) given:-  $l = 2 \text{ m}$   $Z_L = 20 + j50$

$\alpha = 8$   $\beta = 1 \text{ rad/m}$   $Z_0 = 60 + j40$

$$Z_{in} = Z_0 \left[ \frac{Z_L + j Z_0 \tanh(\gamma l)}{Z_0 + j Z_L \tanh(\gamma l)} \right]$$

$$\tanh(\gamma l) = \tanh(\alpha + j\beta) l$$

$$\therefore \tanh(\alpha l + j\beta l) = \tanh(16 + j2)$$

$$\alpha l = 8 \times 2 = 16 \quad \beta l = 1 \times 2 = 2$$

$$\tanh \theta = \frac{e^{\theta} - e^{-\theta}}{e^{\theta} + e^{-\theta}} = \frac{e^{(16+j2)} - e^{-(16+j2)}}{(e^{16+j2} + e^{-(16+j2)})}$$

$$\tanh \theta = \frac{e^{\theta} - e^{-\theta}}{e^{\theta} + e^{-\theta}} = \frac{e^{16} \cdot e^{j2} - e^{-16} \cdot e^{-j2}}{e^{16} \cdot e^{j2} + e^{-16} \cdot e^{-j2}}$$

$$\tanh \theta = \frac{e^{16} (\cos 2 + j \sin 2) - e^{-16} (\cos 2 - j \sin 2)}{e^{16} (\cos 2 + j \sin 2) + e^{-16} (\cos 2 - j \sin 2)}$$



since  $e^{-1} \ll 1$   
so neglected  $\tan h VL = 1$

$$Z_{in} = Z_0 \left[ \frac{20 + j50 + j(60 + j40)}{60 + j40 + j(20 + j50)} \right]$$

$$Z_{in} = Z_0 \left[ \frac{20 + j50 + j60 - 40}{60 + j40 + j20 - 50} \right] = Z_0 \left[ \frac{-20 + j110}{10 + j60} \right]$$

$$Z_{in} = (60 + j40) \left[ \frac{-20 + j110}{10 + j60} \right] = (60 + j40)(1.838 \angle 19.76^\circ)$$

$$Z_{in} = 72.11 \angle 33.69^\circ \times 1.838 \angle 19.76^\circ$$

$$Z_{in} = 132.538 \angle 53.45^\circ$$

(i) Capacity of channel =  $\text{Max } I(X, Y) = \text{Max of mutual info.}$

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

$$\text{Max } [H(Y) - H(Y/X)] = 1 - \text{Max } H(Y/X)$$

$$H(Y/X) = - \sum_{i=1}^n \sum_{j=1}^n P(x_i, y_j) \log_2 P(y_j/x_i)$$

$$P(X, Y) = P(X) \cdot P(Y/X) \quad P(Y/X) = \begin{bmatrix} y_1 & y_2 & y_3 \\ x_1 & 0.2 & 0.4 & 0.4 \\ x_2 & 0.4 & 0.2 & 0.2 \\ x_3 & 0.4 & 0.4 & 0.2 \end{bmatrix}$$

$$\text{Capacity} = 1 - 2p \log_2 p + (1-p) \log_2 (1-p)$$

$$C = 1 + 2(0.4) \log_2 (0.4) + (1-0.8) \log_2 (1-0.8)$$

$$C = 1 + 2[-1.321] + [0.2] \times -2.321$$

$$C = 1 - 2.642 - 0.4642$$

$$C = 1 - 2.642 = 0$$

- 8 (c) (i) Determine  $H(z)$  using the impulse invariant technique for the following analog system function:

$$H(s) = \frac{1}{(s + 0.5)(s^2 + 0.5s + 2)}$$

- (ii) Consider a signal  $x(t)$  with Fourier transform  $X(\omega)$ . Suppose we are given the following facts:

1.  $x(t)$  is real and non-negative.
2.  $F^{-1}[(1 + j\omega)X(\omega)] = Ae^{-2t}u(t)$ , where  $A$  is independent of  $t$ .

$$3. \int_{-\infty}^{\infty} |X(\omega)|^2 d\omega = 2\pi.$$

Determine the closed-form expression of  $x(t)$ . (Where  $F^{-1}$ : Inverse Fourier Transform)

[10 + 10 marks]

(ii)  $x(t)$  real and non negative  
 $x(t)$  means fouries transform is conjugate symmetric

$$\boxed{x(-t) = x(t)}$$

$$\boxed{X^*(\omega) = X^*(-\omega)}$$

$$(1 + j\omega) X(\omega) = F(Ae^{-2t}u(t))$$

$$(1 + j\omega) X(\omega) = \frac{A}{(j\omega + 2)}$$

$$\boxed{|X(\omega)|^2 = \frac{A^2}{(j\omega + 2)(1 + j\omega)}}$$

$$|X(\omega)| = \frac{A}{\sqrt{\omega^2 + 4} \sqrt{\omega^2 + 1}} \quad |X(\omega)|^2 = \frac{A^2}{(\omega^2 + 4)(\omega^2 + 1)}$$

$$\int_{-\infty}^{\infty} \frac{A^2}{(\omega^2 + 4)(\omega^2 + 1)} d\omega = 2\pi$$

$$A^2 \int_{-\infty}^{\infty} \left( \frac{-1}{8(\omega^2 + 4)} + \frac{1}{8(\omega^2 + 1)} \right) d\omega = 2\pi$$



$$A^2 \left[ -\tan^{-1} \frac{\omega}{3} \Big|_{-\infty}^{\infty} + \tan^{-1} \left( \frac{\omega}{1} \right) \Big|_{-\infty}^{\infty} \right] = 2\pi$$

$$A^2 \left[ -\tan^{-1} \infty + \tan^{-1}(-\infty) + \tan^{-1} \infty - \tan^{-1}(-\infty) \right] = 2\pi$$

$$A^2 \left[ +\frac{\pi}{2} + \frac{\pi}{2} + \frac{\pi}{2} + \frac{\pi}{2} \right] = 2\pi$$

$$A^2 = 2$$

$$A = 1$$

$$X(\omega) = \frac{1}{(j\omega + 2)(1 + j\omega)}$$

$$X(\omega) = \frac{-1}{(j\omega + 2)} + \frac{1}{(j\omega + 1)}$$

$$x(t) = -e^{-2t} u(t) + e^{-t} u(t)$$





## Space for Rough Work

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Space for Rough Work

$$\cos 2t = \frac{e^{j0} + e^{-j0}}{2}$$

$$\frac{1}{(s+2)} + \frac{1}{(s-2)}$$

$$\frac{s-2+s+2}{s^2-4} = \frac{2s}{s^2-4}$$