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ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-8 : Full Syllabus Test (Paper-II)

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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	54
Q.2	/
Q.3	/
Q.4	46
Section-B	
Q.5	49
Q.6	/
Q.7	40
Q.8	35
Total Marks Obtained	224

Signature of Evaluator: Ch. [signature]

Cross Checked by ....

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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]

(i) $R_b = 1$ kbps, $N_0 = 10^{-10}$ W/Hz

$$BER = P_{e\,BPSK} = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \Rightarrow R_b E_b = P$$

$$\frac{A_c^2}{2} = R_b E_b$$

100 errors per day

$$\frac{100}{24\times 60\times 60} \ \frac{\text{errors}}{\text{sec}}$$

$$E_b = \frac{A_c^2}{2\times R_b}$$

$$R_b = \frac{1000 \text{ bits}}{\text{sec}}$$

$$P_{e_1} = \frac{100}{24\times 60\times 60} \times \frac{1}{1000} = 1.157\times 10^{-6}$$

(ii) $P = 10^{-6}$ W

$$E_b = \frac{P}{R_b} = \frac{10^{-6}}{10^3} = 10^{-9}$$

$$P_{e_2} = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = Q\left(\sqrt{\frac{2\times 10^{-9}}{10^{-10}}}\right) = Q(4.5)$$

$$= 3.9\times 10^{-6}$$

$P_{e_2} > P_{e_1} \Rightarrow$ so Rxed power not adequate.

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

[12 marks]

$$x(t) \longrightarrow \boxed{h(t)} \longrightarrow y(t)$$

$$y(t) = x(t) * h(t)$$

Take F.T:→ $\quad Y(\omega) = X(\omega)\cdot H(\omega)$

$$h(t) = 5e^{-t}u(t) - 16e^{-2t}u(t) + 13e^{-3t}u(t)$$

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

$$X(\omega) = 7\pi\left[\delta(\omega+2) + \delta(\omega-2)\right]$$

$$Y(\omega) = H(\omega)\cdot X(\omega) = 7\pi\left[\delta(\omega+2) + \delta(\omega-2)\right]\left[\frac{5}{1+j\omega} - \frac{16}{2+j\omega} + \frac{13}{3+j\omega}\right]$$

$$Y(\omega) = 7\pi\left[\frac{5}{1+j(\omega+2)} - \frac{16}{2+j(\omega+2)} + \frac{13}{3+j(\omega+2)} + \frac{5}{1+j(\omega-2)} - \frac{16}{2+j(\omega-2)} + \frac{13}{3j(\omega-2)}\right]$$

Taking inverse F.T :→

$$y(t) = 7\pi\Big[\,5e^{-j2t}e^{-t}u(t) - 16e^{-j2t}e^{-2t}u(t)$$

$$+13e^{-j2t}e^{-3t}u(t) + \cancel{5e^{+j2t}}e^{-t}u(t)$$

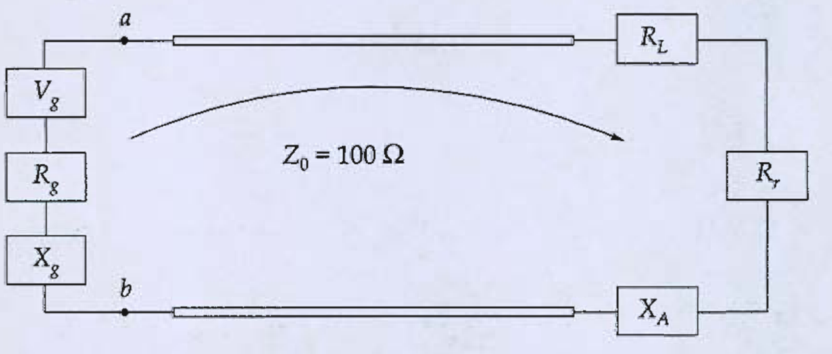
$$-16e^{j2t}e^{-2t}u(t) + 13e^{+j2t}e^{-3t}u(t)\Big]$$

$$y(t) = 7\pi\Big[\,e^{-j2t}\left(5e^{-t}u(t) - 16e^{-2t}u(t) + 13e^{-2t}u(t)\right)$$

$$+ e^{j2t}\left(5e^{-t}u(t) - 16e^{-2t}u(t) + 13e^{-2t}u(t)\right)\Big]$$

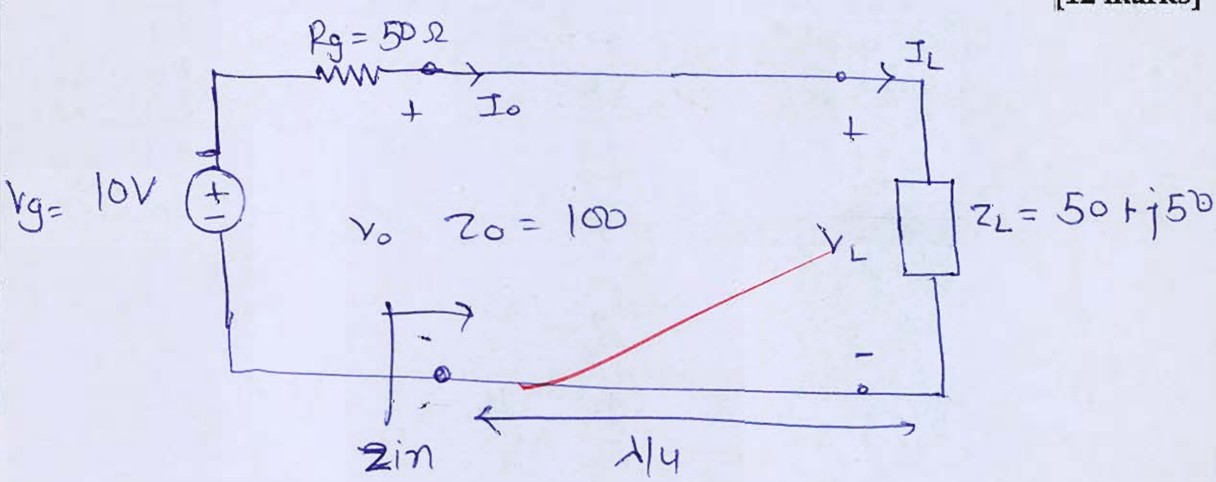
$$y(t) = 7\pi\left[e^{-j2t} + e^{j2t}\right]\left[5e^{-t}u(t) - 16e^{-2t}u(t) + 13e^{-2t}u(t)\right]$$

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



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

[12 marks]



$$Z_{in} = \frac{Z_0^2}{Z_L} = \frac{100 \times 100}{50 + j50} = 100 - 100i$$

$$V_0 = \frac{10 \times (100 - 100i)}{100 - 100i + 50} \Rightarrow |V_0| = \frac{10 \times 14.42}{180.27}$$

$$|V_0| = 0.80V$$

$$|I_0| = \frac{10}{150 - 100i} = 55.4 \times 10^{-3} \text{ A}$$

$$\begin{bmatrix} V_0 \\ I_0 \end{bmatrix} = \begin{bmatrix} \cos\beta l & jZ_0 \sin\beta l \\ \frac{j\sin\beta l}{Z_0} & \cos\beta l \end{bmatrix} \begin{bmatrix} V_L \\ I_L \end{bmatrix}$$

$$\begin{bmatrix} V_L \\ I_L \end{bmatrix} = \begin{bmatrix} \cos\beta l & -jZ_0 \sin\beta l \\ -j\frac{\sin\beta l}{Z_0} & \cos\beta l \end{bmatrix} \begin{bmatrix} V_0 \\ I_0 \end{bmatrix}$$

$$\cos\beta l = \cos \frac{2\pi}{\lambda} \cdot \frac{\lambda}{4} = \cos\pi/2 = 0$$

$$\sin\beta l = \sin \frac{2\pi}{\lambda} \cdot \frac{\lambda}{4} = 1$$

$$V_L = -jZ_0 I_0 = -j100 \times 55.4 \times 10^{-3} = 5.54 \text{ V}$$

$$I_L = -\frac{j}{Z_0} V_0 = \frac{0.80}{100} = 0.8 \times 10^{-2} \text{ A}$$

$$P_{delivered\ to\ antenna} = I_L^2 \times R_{antenna}$$

$$= (0.8 \times 10^{-2})^2 \times 50$$

$$= 32 \times 10^{-4} \text{ W}$$

$$\eta_{antenna} = \frac{R_{rad}}{R_{rad} + R_{loss}} = \frac{48}{50} = 0.96$$

$$P_{radiated} = 30.72 \times 10^{-4} \text{ W}$$

$$P_{loss} = 1.28 \times 10^{-4} \text{ W}$$

Q.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.

[6 + 6 marks]

i) input $r(t) = u(t)$

$R(s) = \frac{1}{s}$

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

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

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

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

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

$$H(s) = \frac{C(s)}{R(s)}$$

closed loop T.F

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

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

ii) comparing with std. 2nd order sym.

$$H(s) = \frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

$\omega_n^2 = 600$, $\omega_n = \sqrt{600} = 24.494$ rad/s

undamped natural freq.

$2\xi\omega_n = 70$

$$\xi = \frac{70}{2 \times \sqrt{600}} = 1.42$$

damping ratio

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Q.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]

Std. angle modulated s/l :-

$$\phi_M(t) = A_c \cos(\omega_c t + \phi(t)) \quad -(1)$$

For PM :- $\phi(t) = k_p\, m(t) \quad -(2)$

For FM :- $\phi(t) = \cancel{2\pi}\, k_f \int_{-\infty}^{t} m(t)\, dt \quad -(3)$ (k_f in rad/s/volt)

(i) Let modulated s/l is PM s/l :-

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

$$\phi(t) = 1000\pi t + 0.3\pi = k_p\, m(t)$$

$$\boxed{m(t) = \frac{1000\pi t + 0.3\pi}{1000}}$$

ii) Let modulated sil is FM sil:-

$$\phi(t) = 1000\pi t + 0.3\pi = K_f \int_{-\infty}^{t} m(t)\,dt$$

differentiate both side :→

$$1000\pi = K_f\, m(t)$$

$$m(t) = \frac{1000\pi}{K_f} = \frac{1000\pi}{1000}$$

$$\boxed{m(t) = \pi}$$

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Q.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,

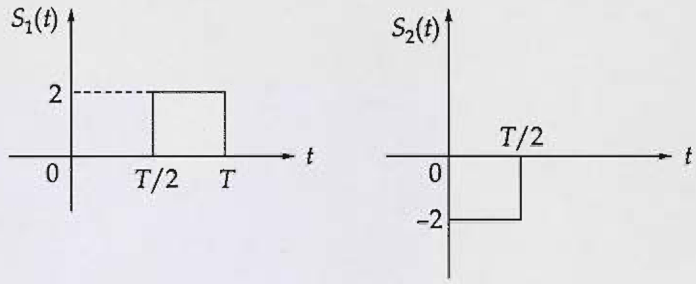
$$P_n = \frac{1}{2}\left[1-(1-2p)^n\right]$$

[20 marks]

Q.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 μs. The switch begins forwarding a packet 60 μs 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]

Q.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]

Q.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

$$E_y = \sin\left(\frac{2\pi}{a}x\right)\cos\left(\frac{3\pi}{b}y\right)\sin(10\pi\times10^{10}t-\beta z)\ \text{V/m}$$

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.

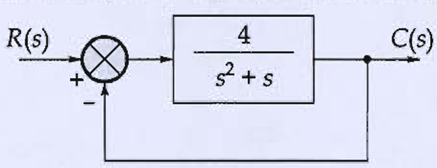
[20 marks]

Q.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, ω_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 μs. 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]

Without derivative controller:-

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

$\omega_n^2 = 4 \Rightarrow \omega_n = 2$ rad/sec. $\quad 2\xi\omega_n = 1 \Rightarrow \alpha = 0.5$

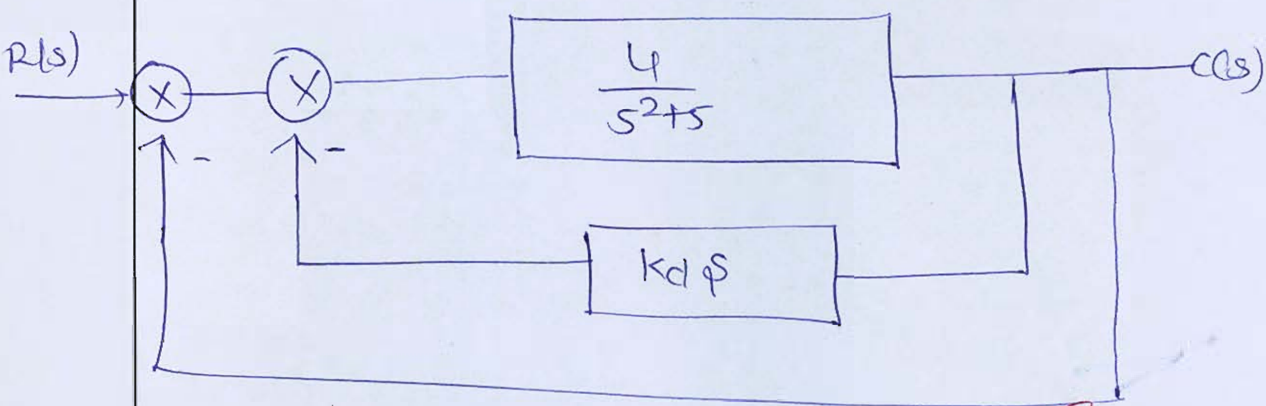
$\omega_d = \sqrt{\omega_n^2 - \alpha^2} = \sqrt{4-(0.5)^2} = 1.93 \quad \xi = \frac{1}{2\times 2} = 0.25$

Peak time $t_p = \frac{\pi}{\omega_d} = \frac{\pi}{1.93} = 1.62$ sec.

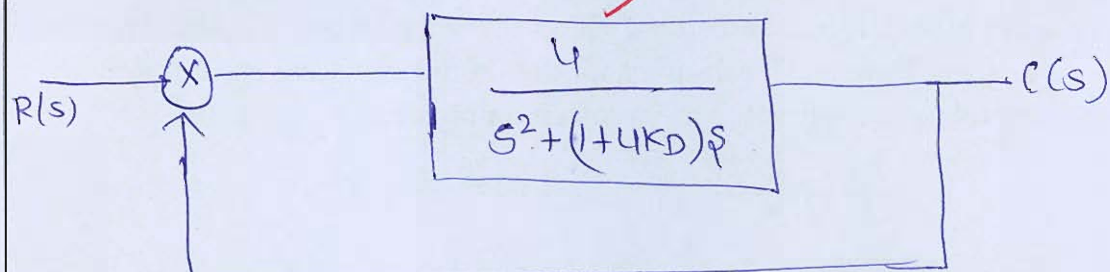
Peak overshoot $M_p = e^{-\pi\xi/\sqrt{1-\xi^2}} = e^{-\frac{\pi\times 0.25}{\sqrt{1-(0.25)^2}}} = 0.444$

Now Apply a derivative controller

$$= K_d s$$



⇓



$$\frac{C(s)}{R(s)} = \frac{\dfrac{4}{s^2+(1+4K_D)s}}{1+\dfrac{4}{s^2+(1+4K_D)s}} = \frac{4}{s^2+(1+4K_D)s+4}$$

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$$\frac{C(s)}{R(s)} = \frac{4}{s^2+(1+4K_D)s+4}$$

$\omega_n^2 = 4$

$\omega_n = 2$

$\xi = 0.75$

$(1+4K_D) = 2\xi\omega_n$

$(1+4K_D) = 2 \times \frac{3}{4} \times 2$

$\boxed{\alpha = \frac{3}{2}}$

⇑

$\boxed{K_D = 0.5} \Rightarrow \boxed{T_d = 4.5}$

Rise time $= \dfrac{\pi}{\omega d}$

$\omega d = \sqrt{\omega n^2 - \alpha^2}$

$= \sqrt{4 - (1.5)^2}$

$\omega d = 1.32$

$tp = \dfrac{\pi}{1.32} = 2.37$

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

$= e^{-\frac{\pi\, 0.75}{\sqrt{1-(0.75)^2}}} = 1.77 \times 10^{-3}$

Q.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 × 8 × 2) PLA.

[10 + 10 marks]

$t=0 \rightarrow P_1(10)$

$t=1 \rightarrow P_1(9), P_2(1)$

$t=2 \rightarrow P_1(9), P_3(2)$

$t=3 \rightarrow P_1(8), P_3(2), P_4(1)$

$t=4 \rightarrow P_1(7), P_3(2), P_4(1), P_5(5)$

$t=9 \rightarrow P_1(7), P_3(2), P_4(1)$

$t=16 \rightarrow P_3(2), P_4(1)$

$t=18 \rightarrow P_4(1)$

$t=19 \rightarrow$ end

Gantt chart :-

P_1	P_2	P_1	P_1	P_5	P_1	P_3	P_4

t = 0, 1, 2, 3, 4, 9, 16, 18, 19

Do not write in this margin

Proces	AT	CT	TAT	BT	AWT
P_1	0	16	16	10	6
P_2	1	2	1	1	0
P_3	2	18	16	2	14
P_4	3	19	16	1	15
P_5	4	9	5	5	0

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

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

(ii) $3 \times 8 \times 2$ PLA $\Rightarrow$ → Programmable AND, → Programmable OR

Full adder :→ $\text{Sum} = A \oplus B \oplus C$

$$= A \oplus (B\bar{C} + \bar{B}C)$$

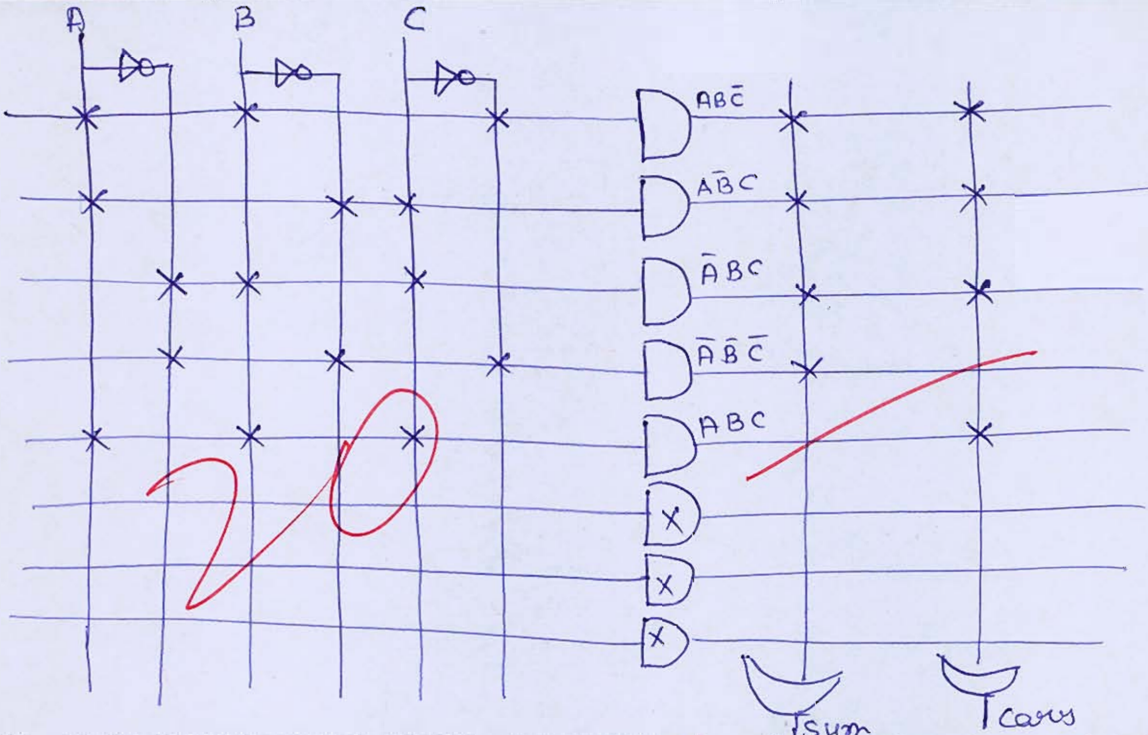
$$= A(B\bar{C} + \bar{B}C) + \bar{A}(BC + \bar{B}\bar{C})$$

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

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

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

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



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) $h = 400$, N_{max} at $\mu = 0.9$, $f = 10$ MHz

$$\mu = \sqrt{1 - \frac{81 N_{max}}{f^2}} \Rightarrow 0.9 = \sqrt{1 - \frac{81 N_{max}}{10^{14}}}$$

$$0.81 = 1 - \frac{81 N_{max}}{10^{14}} \Rightarrow N_{max} = \frac{0.19 \times 10^{14}}{81}$$

$$N_{max} = 2.34 \times 10^{11}$$

$$f_c = 9\sqrt{N_{max}} = 4.35 \text{ MHz}$$

$$f_{MUF} = 10 \text{ MHz}$$

$$f_{MUF} = f_c \sqrt{1 + \left[\frac{D}{2\left(h + \frac{D^2}{8R}\right)}\right]^2}$$

Take $R \to$ Radius of earth $= 6400$ km

$$10 = 4.35\sqrt{1 + \left(\frac{D}{2\left(400 + \frac{D^2}{6400 \times 8}\right)}\right)^2}$$

$$2 \times 2.06 = \frac{D}{400 + \frac{D^2}{6400 \times 8}}$$

$$1648 + \frac{D^2 \times 4.12}{6400 \times 8} = D$$

$$\boxed{D = 1955.8 \text{ km}}$$

(ii)

$L_{prop} = 200$ dB $\qquad \frac{G_r}{T_e} = 11$ dB/K

$L_{other} = 3$ dB

$EIRP = P_t G_t = 45$ dBW

$B = 36$ MHz

$$\left(\frac{C}{N}\right) = \frac{P_t G_t G_r}{L_s L_p \; k T_e B}$$

$$\cancel{\left(\frac{C}{N}\right)_{dB} = (P_t G_t)_{dB} + \left(\frac{G_r}{T_e}\right)_{dB}}$$

$$\left(\frac{C}{N}\right)_{dB} = (EIRP)_{dB} + \left(\frac{G_r}{T_e}\right)_{dB/K} - L_s(dB) - L_p(dB) - 10\log_{10} k - 10\log_{10} B$$

$$\left(\frac{C}{N}\right)_{dB} = 45 + 11 - 200 - 3 + 228.6 - 10\log_{10} 36\times10^6$$

$$\left(\frac{C}{N}\right)_{dB} = 6.03 \text{ dB}$$

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Section B

Q.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 '$\in_r$'. Determine the range of values of $\in_r$ such that single-mode operation can be simultaneously ensured in both guides at some frequency.

[12 marks]

Waveguide 1 :→ $\epsilon_r = 1$ For $a = 2b$, $f_{c_{10}} < f_{c_{20}} < f_{c_{01}} < f_{c_{11}}$

$$f_{c_{10}} = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} = \frac{c}{2a}$$

$$f_{c_{20}} = \frac{c}{2}\sqrt{\left(\frac{2}{a}\right)^2} = \frac{c}{a}$$

Range of freq. for single mode operation

For $\epsilon_r = 1 \Rightarrow \quad \frac{c}{2a} < f < \frac{c}{a} \quad$ —(1)

Waveguide 2 :→ $\epsilon_r = \epsilon_r$

$$f_{c_{10}} = \frac{c}{2\sqrt{\epsilon_r}} \times \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} = \frac{c}{2a\sqrt{\epsilon_r}}$$

$$f_{c_{20}} = \frac{c}{2\sqrt{\epsilon_r}} \times \sqrt{\left(\frac{2}{a}\right)^2} = \frac{c}{a\sqrt{\epsilon_r}}$$

For single operation

$$\frac{c}{2a\sqrt{\epsilon_r}} < f < \frac{c}{a\sqrt{\epsilon_r}} \quad \text{—(2)}$$

For simultaneous single mode operation :-

Set (1) & ~~f~~ set (2) should not Result in null set.

i.e. $\dfrac{c}{a\sqrt{\epsilon_r}} > \dfrac{c}{2a}$

$\Downarrow$

$\dfrac{1}{\sqrt{\epsilon_r}} > \dfrac{1}{2}$

$\sqrt{\epsilon_r} < 2$

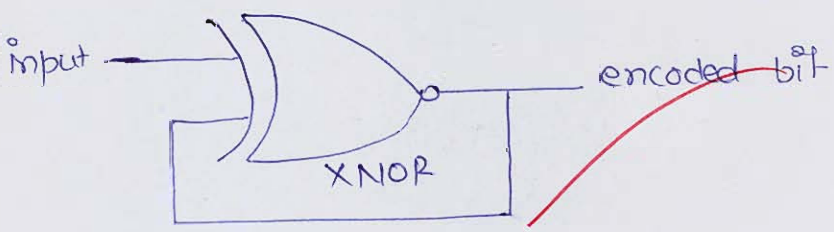
$\Rightarrow \boxed{\epsilon_r < 4}$

10

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

[12 marks]

DPSK :→ Differential Phase shift keying



Let Reference bit for DPSK encoding :→ 1

Input sequence :→

1 0 1 1 1 0 0 0 1 1

Ref=1 XNOR

encoded seq :→ $\boxed{1\ 0\ 0\ 0\ 0\ 1\ 0\ 1\ 1\ 1}$

encoded seq :→

Now for PSK, Phase shift for bit 1 :→ 0°
bit 0 :→ 180°

encoded seq :→ ⇒ 1 0 0 0 0 1 0 1 1 1

⇓

Phase seq ⇒ 0° 180° 180° 180° 180° ~~0° 180°~~ 0° 0° 0°

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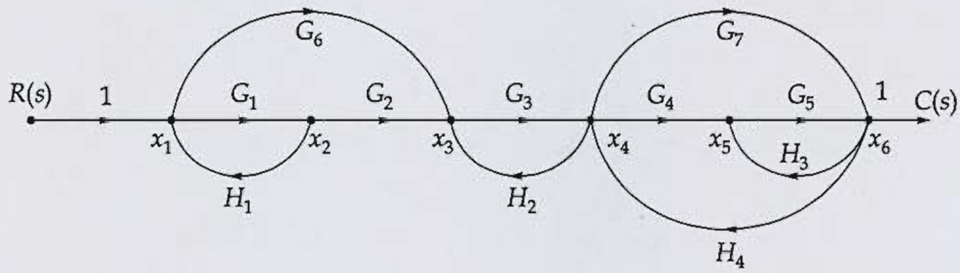
Q.5 (c) Find the transfer function of the system whose signal flow graph is shown in figure below:



[12 marks]

F/W paths :→

F_1 :- $G_1 G_2 G_3 G_4 G_5$

F_2 :- $G_6 G_3 G_4 G_5$

F_3 :- $G_6 G_3 G_7$

F_4 :- $G_1 G_2 \cancel{G_3} G_7$

Loops :→

L_1 :- $G_1 H_1$

L_2 :- $G_3 H_2$

L_3 :- $G_5 H_3$

L_4 :- $G_4 G_5 H_4$

L_5 :- $G_7 H_4$

Formula to Calculate T.F :-

$$\frac{C(s)}{R(s)} = \sum_{i=1}^{\text{no. of F/w path}} \frac{F[\Delta_{fi}]}{\Delta}$$

⇑

Mason's Gain formula

F :- Forward path Gain

Δ_{fi} = 1 − (Sum of Loop Gains of Loops not touching ith F/w path)

+ (Sum of product of not touching loops in ith F/w path

− − −

Δ = 1 − (Sum of Gains of Loops)

+ (Sum of pro. of not touching Loops)

− − − −

$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_3 G_4 G_5 [1-0] + G_6 G_3 G_4 G_5 [1-0] + G_6 G_3 G_7 [1-0] + G_1 G_2 G_3 G_7 [1-0]}{\begin{aligned} &1 - [G_1 H_1 + G_3 H_2 + G_5 H_3 + G_4 G_5 H_4 + G_7 H_4] \\ &+ [G_1 H_1 G_3 H_2 + G_1 H_1 G_5 H_3 + G_1 H_1 G_4 G_5 H_4 \\ &\quad + G_1 H_1 G_7 H_4 + G_3 H_2 G_5 H_3] \\ &- [G_1 H_1 G_3 H_2 G_5 H_3] \end{aligned}}$$

$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_3 G_4 G_5 + G_6 G_3 G_4 G_5 + G_6 G_3 G_7 + G_1 G_2 G_3 G_7}{\begin{aligned} &1 - [G_1 H_1 + G_3 H_2 + G_5 H_3 + G_4 G_5 H_4 + G_7 H_4] \\ &+ [G_1 H_1 (G_3 H_2 + G_5 H_3 + G_4 G_5 H_4 + G_7 H_4)] \\ &- [G_1 H_1 G_3 H_2 + G_5 H_3] \end{aligned}}$$

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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 μV (rms) at the output of satellite antenna?
(Assume satellite antenna is matched to 50 Ω)

[12 marks]

$r = 41935$ km $\quad G_t = 25$ dB

$f = 1$ GHz $\quad G_r = 15$ dB

$$P_r = \frac{(5\,\mu V)^2}{R} = \frac{25\times10^{-12}}{50} = 0.5\times10^{-12}\,W$$

P_r ⇓ Recieved power

In dB → P_t (dB) = −123.01 dB

Free space Prop. Loss:-

10

$$L_s = 92.5 + 20\log r + 20\log f \quad dB$$

r ⇓ km, f ⇓ GHz

$$L_s = 92.5 + 20\log 41935 + 20\log 1$$

$$L_s = 97.12\ dB$$

Friss Tx formula:-

$$P_r = \frac{P_t G_t G_r}{L_s}$$

$$P_r(dB) = P_t(dB) + G_t(dB) + G_r(dB) - L_s(dB)$$

$$P_r(dB) = -123.01\,dB + 25 + 15 - 97.12$$

$$P_r(dB) = -180.13\ dB$$

$$10\log_{10} P_r = -180.13$$

$$P_r = 9.705\times10^{-19}\ \text{Watts}$$

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

$$U(\theta, \phi) = \begin{Bmatrix} 1 & ; & 0° < \theta < 20° \\ 0.342\text{cosec}(\theta) & ; & 20° \le \theta < 60° \\ 0 & ; & 60° \le \theta \le 180° \end{Bmatrix}, 0° \le \phi \le 360°$$

Find the directivity (in dB) of the antenna.

[12 marks]

$$D = \frac{U_{max}}{U_{avg}} = \frac{4\pi\, U_{max}}{P_{rad}} = \frac{4\pi\, U_{max}}{\int U(\theta,\phi)\, d\Omega}$$

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$$D = \frac{4\pi}{\iint U_n(\theta,\phi)\, d\Omega}$$

where $d\Omega = \sin\theta\, d\theta\, d\phi$

$$\iint U_n(\theta,\phi) d\Omega = \int_{\phi=0}^{360°}\int_{\theta=0}^{20°} 1 \cdot \sin\theta\, d\theta\, d\phi + \int_{\phi=0}^{360°}\int_{\theta=20°}^{60°} \text{Cosec}(\theta)\cdot\sin\theta\, d\theta\, d\phi$$

$$+ \int_{\phi=0}^{360°}\int_{\theta=60°}^{\theta=180°} 0 \cdot \sin\theta\, d\theta\, d\phi$$

~~$\pi/180$~~ $180 - \pi$

$$= \int_{\phi=0}^{2\pi} d\phi \int_{\theta=0}^{20\times\frac{\pi}{180}} \sin\theta\, d\theta + \int_{\phi=0}^{2\pi} d\phi \int_{\theta=\frac{20\pi}{180}}^{\frac{60\pi}{180}} d\theta$$

$$= -(2\pi)\left(\cos\frac{\pi}{9} - \cos 0\right) + 2\pi\left(\frac{\pi}{3} - \frac{\pi}{9}\right)$$

$$= (2\pi)\, 0.06 + 2\pi\left(\frac{2\pi}{9}\right) = 4.763$$

$$D = \frac{4\pi}{\iint U_n(\theta,\phi)\, d\Omega} = \frac{4\pi}{4.763} = 2.638$$

$$D\,(dB) = 10 \log_{10} 2.638 = 4.21\ dB.$$

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]

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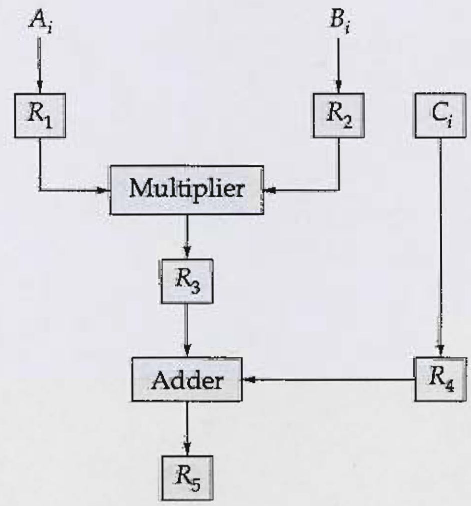
Q.6 (b) The pipeline of figure shown has the following propagation times: 40 nsec for the operands to be read from memory into registers R_1 and R_2, 45 nsec for the signal to propagate through the multiplier, 5 nsec for the transfer into R_3 and 15 nsec to add the two numbers into R_5.



(i) What is the minimum clock cycle time that can be used?

(ii) 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?

(iii) Calculate the speedup that can be achieved with pipeline for 10 tasks.

(iv) 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]

Q.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 500π rad/sec/V and 1.2π 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) $K_f = 500\pi$ rad/sec/v $\quad$ (ii) $K_p = 1.2\pi$ rad/v

$= 250$ Hz/V

$m(t) = e^{-t^2/100}$, $f_c = 10^4$ Hz

FM :-

$$[\Delta f]_{max} = \frac{1}{2\pi}\frac{d}{dt}\left(2\pi K_f \int m(t)\,dt\right)$$

$$= \frac{1}{2\pi}\frac{d}{dt}\left(500\pi \times \int m(t)\,dt\right)$$

$$= \frac{1}{2\pi} \times 500\pi \times m(t)$$

$$= 250\, m(t) = \left[250\, e^{-t^2/100}\right]_{max}$$

$f(t) = 250\, e^{-t^2/100}$ $\rightarrow$ to maximize $\frac{d}{dt}(f(t)) = 0$

$$\frac{d}{dt}(f(t)) = 250\, e^{-t^2/100}\left(-\frac{2t}{100}\right) = 0$$

$$\Rightarrow \boxed{t = 0}$$

$$\boxed{\Delta f = 250 \text{ Hz}}$$

PM :-

$$[\Delta f]_{max} = \frac{1}{2\pi}\frac{d}{dt}[K_p\, m(t)]$$

$$= \frac{1}{2\pi} \times 1.2\pi\, \frac{d}{dt}(m(t))$$

$$[\Delta f]_{max} = \left[0.6 \times e^{-t^2/100}\left(-\frac{2t}{100}\right)\right]_{max}$$

$$f(t) = \left(0.6 \cdot e^{-t^2/100}\right) \cdot \left(\frac{-2t}{100}\right)$$

$$\frac{d}{dt}(f(t)) = -\frac{2\times 0.6}{100}\left[e^{-t^2/100} + t\left(e^{-t^2/100}\right)\left(\frac{-2t}{100}\right)\right] = 0$$

$$1 - \frac{2t^2}{100} = 0$$

$$t^2 = 50 \Rightarrow t = \sqrt{50}$$

$$[\Delta f]_{Max} = \left|0.6\, e^{-t^2/100}\left(-\frac{2t}{100}\right)\right|_{t=\sqrt{50}}$$

$$= 0.6\, e^{-50/100}\left(\frac{2\times\sqrt{50}}{100}\right)$$

$$= 0.0514 \text{ Hz.}$$

(ii) $SNR_1 = 30\text{ dB} \longrightarrow SNR_2 = 42\text{dB}$

$n_1 = 10 \quad = 10^3 = 1000 \qquad n_2 = ? \quad = 10^{4.2}$

$$SNR = \frac{S_P}{N_P} = \frac{S_P}{\Delta^2/12} = \frac{12 \cdot S_P}{V_{PP}^2} \cdot 2^{2n}$$

$$\frac{SNR_1}{SNR_2} = \frac{\dfrac{12 \cdot S_P \cdot 2^{2n_1}}{V_{PP}^2}}{\dfrac{12 \cdot S_P \cdot 2^{2n_2}}{V_{PP}^2}}$$

$$\frac{1000}{10^{4.2}} = (2)^{2n_1 - 2n_2} \Rightarrow 20 - 2n_2 = \log_2 \frac{1000}{10^{4.2}}$$

$$\Rightarrow 20 - 2n_2 = -3.986 \Rightarrow \boxed{n_2 \approx 12}$$

$n_1 = 10 \rightarrow$ Bandwidth $= B_1 = \frac{R_b}{2} = \frac{n_1 f_s}{2} = 5 f_s$

$n_2 = 12 \rightarrow$ Bandwidth $= B_2$

$= \frac{R_b}{2} = \frac{n_2 f_s}{2} = 6 f_s$

fractional increase in B.W $= \frac{6 f_s - 5 f_s}{5 f_s} = \frac{1}{5} \times 100\%$

$= 20\%$ increase reqd.

20

Q.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 Δf.

(iii) Find the deviation ratio β.

(iv) Estimate the bandwidth of $\phi(t)$.

[20 marks]

(i) Power of modulated sl $\phi(t) = \frac{A_c^2}{2}$

Gen. form of $\phi(t)$:→ for angle-mod sl $\phi(t) = A_c \cos(\omega_c t + \theta(t))$

Comparing $A_c = 10$

$P = \frac{A_c^2}{2} = \frac{100}{2} = 50\,W$

(ii) freq. devn Δf :→ $\Delta f = \left[\frac{1}{2\pi}\frac{d}{dt}\phi(t)\right]_{max}$

$= \left[\frac{1}{2\pi}\frac{d}{dt}(5\sin 3000t + 10\sin 2000\pi t)\right]_{max}$

$$\Delta f = \frac{1}{2\pi}\left[15000 \cos 3000t + 20000\pi \cos 2000\pi t\right]_{max}$$

$$= \frac{1}{2\pi}\left[15000 + 20000\pi\right]$$

$$\Delta f = \cancel{14774.648\ Hz}\ 12387.324$$

(iii) Let Given modulated s/l is PM s/l

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

$$= K_p\, m(t)$$

$$m(t) = \frac{1}{K_p}\left[5\sin 3000t + 10\sin 2000\pi t\right]$$

$$f_{m_{max}} = \frac{2000\pi}{2\pi} = 1000\ Hz$$

$$\beta_{PM} = \frac{\Delta f}{f_{m\,max}} = \frac{12387.324}{1000} = 12.387$$

(iv) $BW = 2(\Delta f + f_{max}) = 2(12387.648 + 1000)$

$$\cancel{= 31549.296\ Hz} = 26774.64\ Hz$$

Let Given modulated s/l is FM s/l.

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

$$= 2\pi k_f \int m(t)\,dt$$

diff :→

$$\frac{15000\cos 3000t + 20000\pi \cos 2000\pi t}{2\pi f} = m(t)$$

$$f_{m\,max} = 1000\ Hz$$

As $f_{m\,max\,PM} = f_{m\,max\,FM}$

$\Downarrow$

$\beta_{FM} = \beta_{PM} = 12.387$

$BW_{FM} = BW_{PM} = 26774.64\,Hz$

20

.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)

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

$$K_p = \lim_{S\to 0} G(S) = \lim_{S\to 0} \frac{10}{S(0.1S+1)} = \infty$$

$$K_v = \lim_{S\to 0} S\,G(S) = \lim_{S\to 0} \frac{S \cdot 10}{S(0.1S+1)}$$

$$= \lim_{S\to 0} \frac{10}{0.1S+1} = 10$$

$$K_a = \lim_{S\to 0} S^2 G(S) = \lim_{S\to 0} \frac{S^2 \cdot 10}{S(0.1S+10)} = 0$$

(ii)

$$r(t) = \underbrace{a_0}_{x_1(t)} + \underbrace{a_1(t)}_{x_2(t)} + \underbrace{\frac{a_2}{2}t^2}_{x_3(t)}$$

$x_1(t) = a_0 u(t) \longrightarrow$ S.S. Error $= \frac{a_0}{1+K_p} = 0$

$x_2(t) = a_1 t\, u(t) \rightarrow$ S.S. error $= \frac{a_1}{K_v} = \frac{a_1}{10}$

$x_3(t) = a_2 \frac{t^2}{2} u(t) \rightarrow$ S.S error $= \frac{a_2}{K_a} = \infty$

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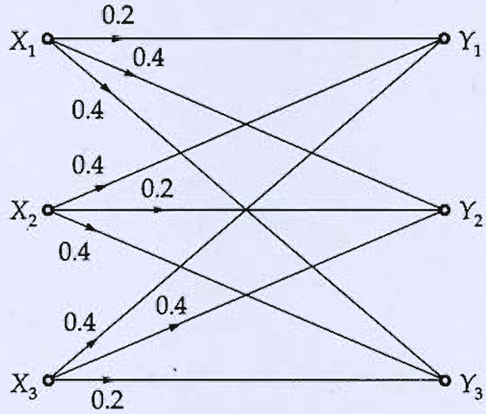
Total steady state error = $0 + \frac{a_1}{10} + \infty = \infty$

(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 $\alpha = 8$ dB/m, $\beta = 1$ rad/m and $Z_o = (60 + j40)\ \Omega$. Calculate the input impedance of transmission line.

[10 + 10 marks]

(ii) $l = 2m$, $Z_L = 20 + j50\ \Omega$

$\alpha = 8$ dB/m , $\beta = 1$ rad/m , $Z_o = (60 + j40)\ \Omega$

$\alpha \neq 0$, so this is a lossy line.

α in Napier $= \dfrac{\alpha \text{ in dB}}{8.865} = \dfrac{8}{8.865} = 0.902$

$$Z_{in} = Z_o \left[\frac{Z_L + Z_o \tan(h\beta l)}{Z_o + Z_L \tan(h\beta l)} \right]$$

6

$\beta = 1$, $l = 2m$ $\beta l = 2$ $\tan h\beta l = \dfrac{\sinh \beta l}{\cosh \beta l} = \dfrac{e^{\beta l} - e^{-\beta l}}{e^{\beta l} + e^{\beta l}} = \dfrac{e^{2} - e^{-2}}{e^{2} + e^{-2}} = 0.964$

$$Z_{in} = (60+j40)\left(\frac{20+j50 + (60+j40)(0.964)}{60+j40 + (20+j50)(0.964)}\right)$$

$$= \frac{(60+j40)(77.84 + 88.56i)}{79.28 + 88.2i}$$

$$= 59.20 + 40.429i$$

(i) $P(X) = \begin{bmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix}_{1\times 3}$

$$P[Y/X] = \begin{array}{c|ccc} & y_1 & y_2 & y_3 \\ \hline x_1 & 0.2 & 0.4 & 0.4 \\ x_2 & 0.4 & 0.2 & 0.4 \\ x_3 & 0.4 & 0.4 & 0.2 \end{array}_{3\times 3}$$

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

$$P(Y) = P(X)\cdot P(Y/X)] = \begin{bmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix}$$

$$P(X,Y) = [P(X)]^{D} \cdot P[Y/X] = \begin{bmatrix} \frac{0.2}{3} & \frac{0.4}{3} & \frac{0.4}{3} \\ \frac{0.4}{3} & \frac{0.2}{3} & \frac{0.4}{3} \\ \frac{0.4}{3} & \frac{0.4}{3} & \frac{0.2}{3} \end{bmatrix}$$

8

$H(Y) \Rightarrow$ All equal probabilities, so $\Rightarrow H(Y) = \log_2 3$
$= 1.584$ bits/sym

$$H(Y/X) = -\sum_i \sum_j P(x,y) \log_2 P(Y/X)$$

$$= -\left[\frac{0.2}{3}\log_2 0.2 + \frac{0.4}{3}\log_2 0.4 + \frac{0.4}{3}\log_2 0.4 + \text{-------} \right]$$

$$H(Y/X) = -\left[0.2\log_2 0.2 + 0.8\log_2 0.4\right] = 1.521 \text{ bits/sym}$$

$$I(X;Y) = H(Y) - H(Y/X) = 0.0639 \text{ bits/symbol}$$

$$\text{Capacity} = \text{Max}(I(X:Y)) = 0.0639 \text{ bits/symbol}$$

(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) $x(t) \rightleftharpoons X(\omega)$

1. $x(t) \to$ Real $\to$ Non-ve

2. $F^{-1}\left[(1+j\omega)X(\omega)\right] = Ae^{-2t}u(t)$

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

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

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

$$X(\omega) = A\left[\frac{(2+j\omega)-(1+j\omega)}{(2+j\omega)(1+j\omega)}\right]$$

$$X(\omega) = A\left[\frac{1}{1+j\omega} - \frac{1}{2+j\omega}\right]$$

Take Inv. F.T.

$$\boxed{x(t) = A\left[e^{-t} + e^{-2t}\right]u(t)} \quad -(1)$$

$$\text{Energy of } x(t) = \left(\frac{1}{2\pi}\right) \text{Energy of } X(\omega)$$

From (3) :- $\text{Energy of } x(t) = \frac{1}{2\pi} \times 2\pi = 1$

6

$$\int_{-\infty}^{\infty} |x(t)^2| \, dt = 1$$

$$A \int_{0}^{\infty} (e^{-t} - e^{-2t})^2 \, dt = 1$$

$$A \left[\int_{0}^{\infty} (e^{-2t} + e^{-4t} - 2e^{-3t}) \, dt \right] = 1$$

$$A \left[\left| \frac{e^{-2t}}{-2} + \frac{e^{-4t}}{-4} - 2\frac{e^{-3t}}{-3} \right|_{0}^{\infty} \right] = 1$$

$$A \left[- \left[-\frac{1}{2} - \frac{1}{4} + \frac{2}{3} \right] \right] = 1$$

$$A \left[\frac{3}{4} - \frac{2}{3} \right] = 1 \Rightarrow A \left(\frac{9-8}{12} \right) = 1$$

$$\boxed{A = 12}$$

$$\boxed{x(t) = 12 (e^{-t} - e^{-2t}) u(t)}$$

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

$$= \frac{A}{s+0.5} + \frac{Bs + C}{(s^2 + 0.5s + 2)}$$

$$H(s) = \frac{As^2 + 0.5As + 2A + Bs^2 + Cs + 0.5Bs + 0.5C}{(s+0.5)(s^2+0.5s+2)}$$

$A + B = 0$, $0.5A + C + 0.5B = 0$

$2A + 0.5C = 1$ $\Rightarrow A + C = 0$

$A + C = 0 \Rightarrow C = -A$

$\cancel{C = 0} \Rightarrow \cancel{A + B = 0}$

$-1.5C = 1$ $C = \frac{-1}{1.5} = -\frac{2}{3}$, $A = \frac{2}{3}$

$B = -2/3$

$$H(s) = \frac{2}{3}\left(\frac{1}{s+0.5}\right) - \frac{2}{3}\frac{(s+1)}{s^2+0.5s+2}$$

$$h(t) = \frac{2}{3}e^{-0.5t} - \frac{2}{3}$$

OOOO

Space for Rough Work

Space for Rough Work

$z = e^{sT_s}$

$\cancel{\sigma + j\omega = e}$

$$\frac{\frac{4}{s^2+s}}{1 + \frac{4}{(s^2+s)} K_D s}$$