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ESE 2020 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-15 : Full Syllabus Test (Paper-II)

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Student's Signature

Ashsingh

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	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	208

Signature of Evaluator ....

Cross Checked by ....

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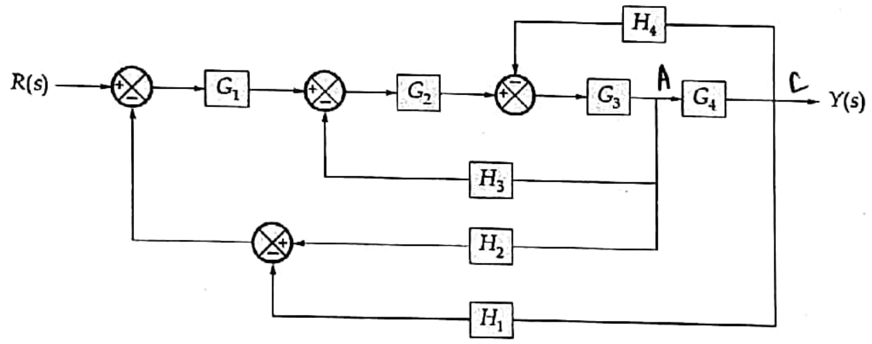
Section-A

Q.1 (a) Explain the gettering treatment used during the wafer preparation stage of IC fabrication.

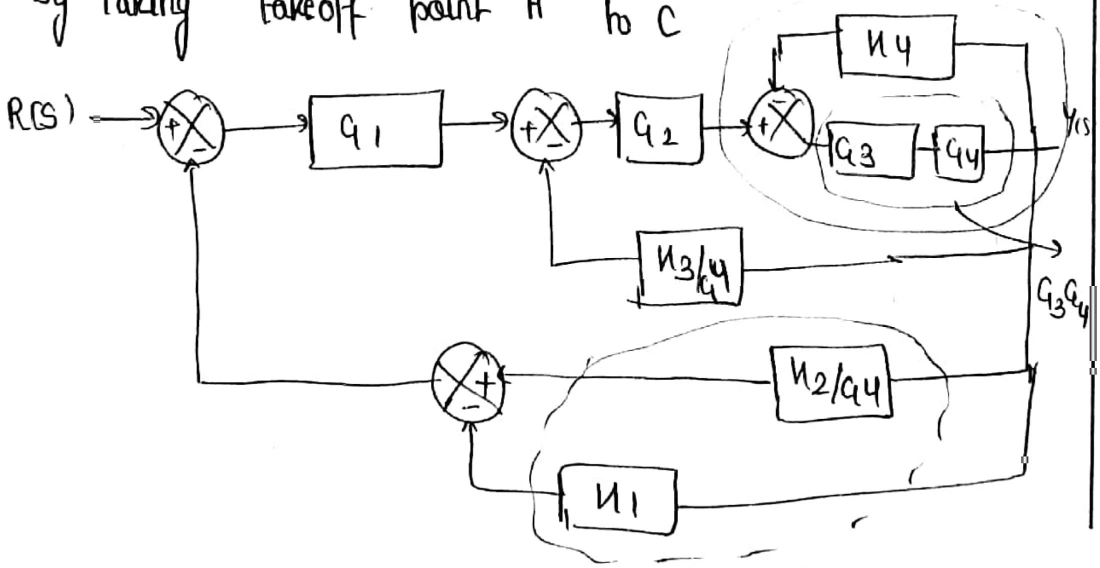
[10 marks]

Q.1 (b) Find the transfer function of the following system using block-diagram reduction technique.



[10 marks]

by Taking takeoff point A to C



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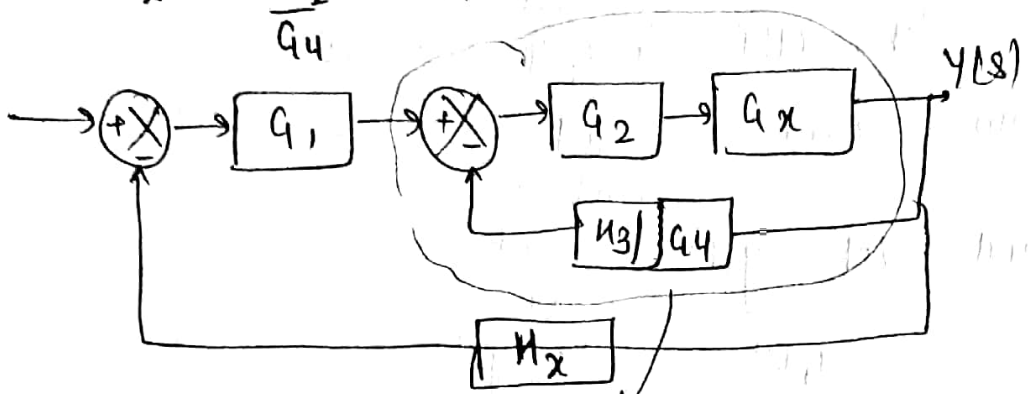
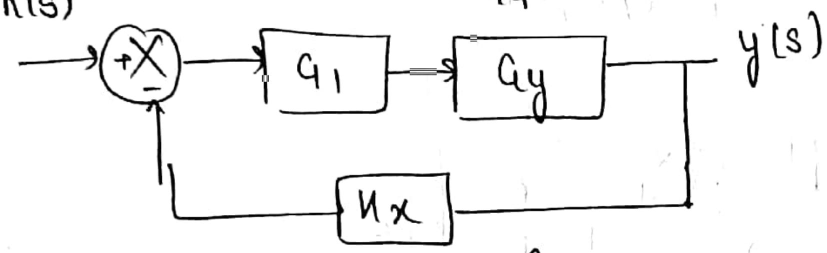
$$\frac{G}{1+GH} = \frac{G_3 G_4}{1+G_3 G_4 H_4} = G_x \quad \text{—(I)}$$

$$H_x = \frac{H_2}{G_4} - H_1 \quad \text{—(III)}$$



$$G_y = \frac{G_2 \times G_x}{1 + G_2 G_x \times \frac{H_3}{G_4}} = \frac{G_2 G_x G_4}{G_4 + G_2 G_x H_3} \quad \text{—(II)}$$



Overall Transfer function

$$T(s) = \frac{G_1 G_y}{1 + G_1 G_y H_x}$$

On substituting all values from Eq (I), (II), (III)

$$T(s) = \frac{\dfrac{G_1 G_2 G_3 G_4 G_4}{(1+G_3 G_4 H_4)(G_4 + G_2 G_x H_3)}}{1 + \dfrac{G_1 G_2 G_3 G_4 G_4 \times \left(\dfrac{H_2}{G_4} - H_1\right)}{(1+G_3 G_4 H_4)(G_4 + G_2 G_x H_3)}}$$

$$\boxed{\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_3 G_4^2}{(1+G_3 G_4 H_4)\left(G_4 + \cancel{\dfrac{G_2 G_3 G_4 H_3}{1+G_3 G_4 H_4}}\right) + G_1 G_2 G_3 G_4^2 \left(\dfrac{H_2}{G_4} - H_1\right)}}$$

03

Q.1 (c) Find the Fourier transform of the signal $x(t) = t\left(\frac{\sin t}{\pi t}\right)^2$.

[10 marks]

Given :- $x(t) = t\left(\frac{\sin t}{\pi t}\right)^2$

Let $x(t) = t\,x_1(t)$ — (1)

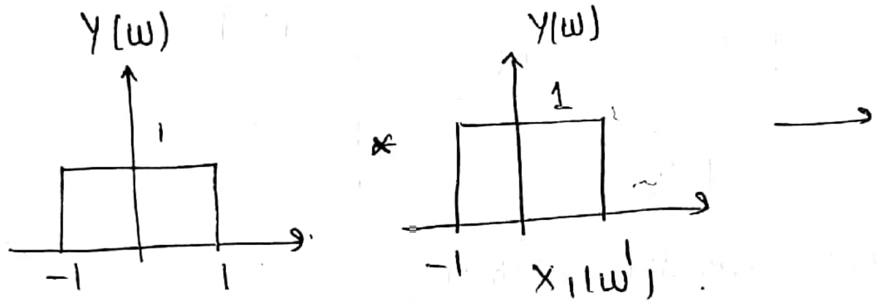
where $x_1(t) = \left(\frac{\sin t}{\pi t}\right)^2$

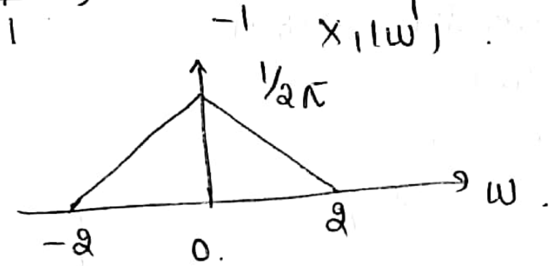
and let $y(t) = \frac{\sin t}{\pi t}$

$x_1(t) = y(t)\cdot y(t)$

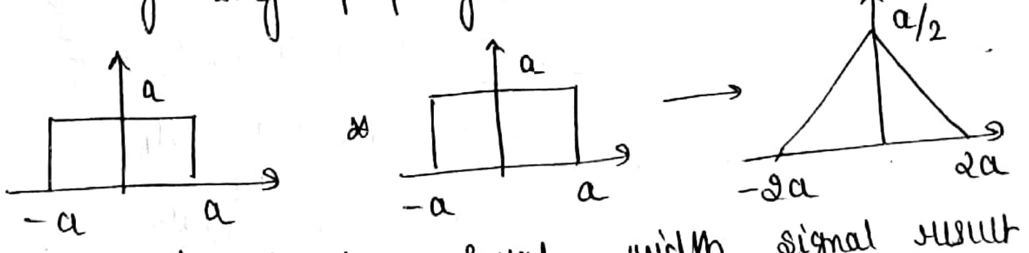
Taking fourier transform

$X_1(\omega) = \frac{1}{2\pi}\left[Y(\omega) * Y(\omega)\right]$





Note by using property



∴ convolution of two equal width signal result in triangular.

∴ Taking fourier transform of Eq (1)

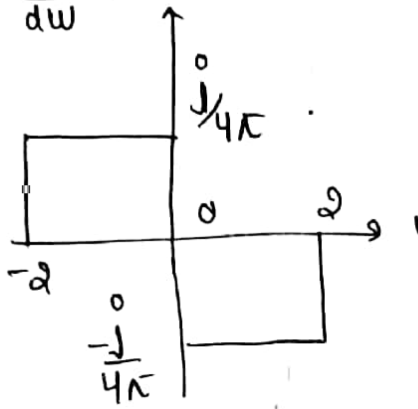
$$X(\omega) = j\frac{dX_1(\omega)}{d\omega}$$

by using property

$$x(t) \xrightarrow{FT} X(\omega)$$

$$t\,x(t) \xrightarrow{FT} j\frac{dX(\omega)}{d\omega}$$

$$j\frac{dX_1(\omega)}{d\omega}$$



$$\therefore \boxed{X(\omega) = \begin{cases} \frac{j}{4\pi} & -2 < \omega < 0 \\ -\frac{j}{4\pi} & 0 < \omega < 2 \end{cases}}$$

09

Q.1 (d) A noise process has a power spectral density given by

$$S_n(f) = 10^{-8}\left(1 - \frac{|f|}{10^8}\right), \ |f| < 10^8 \text{ Hz}$$
$$= 0, \text{ otherwise}$$

The noise is passed through an ideal band-pass filter with a unity gain and bandwidth of 2 MHz centred at 50 MHz. Find the power at the output of the filter.

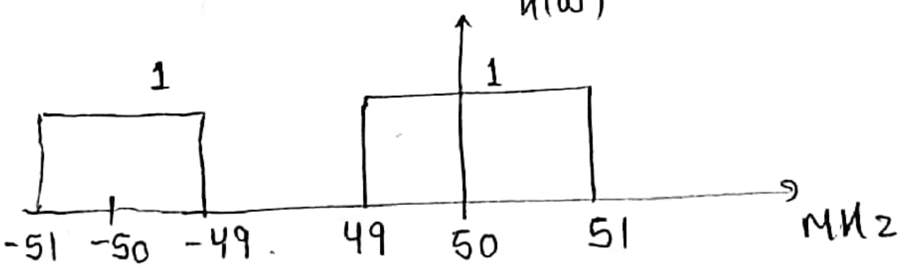
[10 marks]

Given :-

$$S_n(f) = 10^{-8}\left(1 - \frac{|f|}{10^8}\right) \quad -100\,MHz < f < 100\,MHz$$
$$= 0 \quad \text{otherwise}$$

$\therefore$ It is passed through band pass filter

$$|H(\omega)| = 1$$



$\therefore$ By wiener kinchine relation output power spectral density is given by

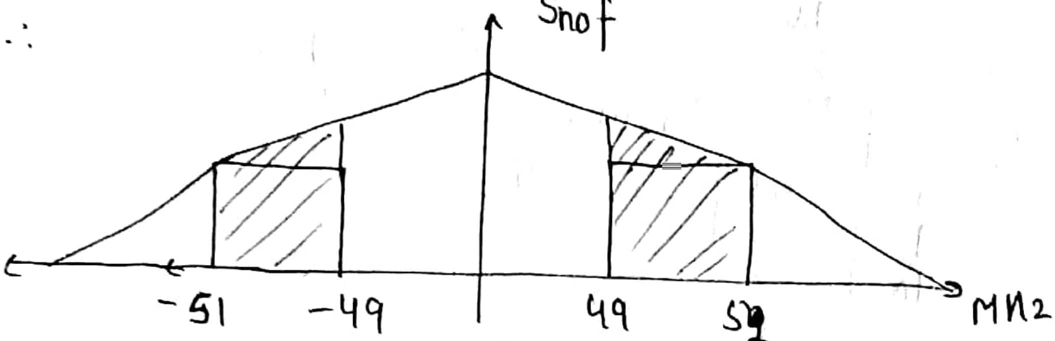
$S_{no}(f) = 10^{-8}\left(1 - \frac{|f|}{10^8}\right)$ $49 < f < 51$ (MHz) and $-49 < f < -51$ (MHz)

0, otherwise

$\therefore S_{no}(f) = |H(\omega)|^2 S_n(f)$

$(\because |H(\omega)| = 1)$ $\therefore S_{no}f = S_nf$.

$\therefore$



$\therefore$ power $(P) = \int_{-\infty}^{\infty} S_{no}(f)\,df$.

$$= 2\int_{49}^{51} 10^{-8}\left(1 - \frac{f}{10^8}\right) df.$$

$$= 2\times10^{-8}\left[\int_{49}^{51} df - \frac{1}{10^8}\int_{49}^{51} f\,df\right]$$

$$= 2\times10^{-8}\left[(f)_{49}^{51} - \frac{1}{10^8}\left[\frac{f^2}{2}\right]_{49}^{51}\right]$$

$$= 2\times10^{-8}\left[(51-49) - \frac{1}{10^8}\left[\frac{(51)^2 - (49)^2}{2}\right]\right]$$

$$= 2\times10^{-8}\left[2\times10^6 - \frac{100\times10^{12}}{10^8}\right]$$

$$= 2\times10^{-8}\times10^6$$

$\boxed{P = 20 \text{ mW}}$

$\therefore$ power at the output of filter is 20 mW.

09

Q.1 (e) Consider the random variable X with the possible values and corresponding probability as below :

x_1	x_2	x_3	x_4	x_5	x_6	x_7
0.50	0.26	0.11	0.04	0.04	0.03	0.02

Find :

(i) Binary Huffman code for X

(ii) The expected codelength for this encoding

(iii) The efficiency of the code.

[10 marks]

Given:-

$P(x_1) = 0.5, \quad P(x_2) = 0.26, \quad P(x_3) = 0.11,$

$P(x_4) = 0.04, \quad P(x_5) = 0.04, \quad P(x_6) = 0.03,$

$P(x_7) = 0.02$

$\therefore$ Entropy :- $H(x) = -\sum_{i=1}^{m} p(x_i)\log_2 p(x_i)$

$= -[p(x_1)\log p(x_1) + p(x_2)\log_2 p(x_2) + p(x_3)\log_2 p(x_3) + p(x_4)\log_2 p(x_4) + p(x_5)\log_2 p(x_5) + p(x_6)\log_2 p(x_6) + p(x_7)\log_2 p(x_7)]$

$= -[0.5\log_2 0.5 + 0.26\log_2 0.26 + 0.11\log_2 0.11 + 0.04 \times 2 \times \log_2 0.04 + 0.03\log_2 0.03 + 0.02\log_2 0.02]$

$= 1.9917$ bits/symbol

0.5 1	0.5 1	0.5 1	0.5 1	0.5 0	0.5 0
0.26 00	0.26	0.26	0.26 00	0.26 00	0.5 1
0.11 011	0.11 0101	0.11	0.13 010	0.24 01	
0.04	0.05	0.08 0100	0.11 011		
0.04	0.04 01000	0.05 0101			
0.03 01010	0.04 01001				
0.02 01011					

$0.5 \rightarrow 1 \rightarrow 1$

$0.26 \rightarrow 00 \rightarrow 2$

$0.11 \rightarrow 011 \rightarrow 3$

$0.04 \rightarrow 01000 \rightarrow 5$

$0.04 \rightarrow 01001 \rightarrow 5$

$0.03 \rightarrow 01010 \rightarrow 5$

$0.02 \rightarrow 01011 \rightarrow 5$

$$\bar{L}(x_i) = \sum L_{x_i} p(x_i)$$

$$= 1 \times 0.5 + 0.26 \times 2 + 3 \times 0.11 + 5 \times 0.04$$
$$+ 5 \times 0.04 + 5 \times 0.03 + 5 \times 0.02$$

$$= 2 \text{ bits/symbol}$$

$\therefore$ Efficiency

$$\eta = \frac{H(x)}{\bar{L}(x_i)}$$

$$= \frac{1.9917}{2}$$

$$= 99.585\%$$

(ii) expected codelength is 2 bits/symbol

(iii) efficiency of this code is 99.585%.

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Q.1 (f) Explain about the cache coherence problem in multi-processor systems.

[10 marks]

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Q.2 (a) A unity feedback control system is characterized by the following open-loop transfer function :

$$G(s) = \frac{0.4s + 1}{s(s + 0.6)}$$

(i) Determine the response for a unit step input.

(ii) Evaluate the maximum overshoot and the corresponding peak time.

(iii) Obtain the steady-state error for the system when subject to an input $r(t) = 3 + 5t$.

[20 marks]

Q.2 (b) A transistor class-A amplifier working with an efficiency of 20% is collector-modulating a transistor class-C power amplifier working with a collector circuit efficiency of 60%. The class-C power amplifier transistor is dissipating 24 W when the modulation depth is 80%.

(i) What is the carrier power in the output modulated wave?

(ii) What will be the class-C power amplifier collector dissipation for 100% modulation and the output carrier power obtained in part (i).

(iii) What should be the modulating amplifier transistor rating in watts if it is modulating the class-C amplifier at a modulation index of 0.5.

(iv) What is the overall efficiency of the circuit including class-C and class-A power amplifiers for modulation index of 0.5?

[20 marks]

Q.2 (c) Consider an LTI system with impulse response given by

$$h(t) = \frac{\sin[4(t-1)]}{\pi(t-1)}$$

Determine the output of the system when input given to the system is $\sum_{k=0}^{\infty}\left(\frac{1}{2}\right)^k \sin(3kt)$.

[20 marks]

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Q.3 (a) An M-ary PSk system is to operate with 2^n symbols over a 100 kHz channel. The bit rate is required to be atleast 750 kbps. Calculate the minimum carrier to noise density ratio required if the symbol error probability should be equal to or better than $P_s = 8 \times 10^{-6}$. (Assume inter-symbol interference free conditions. Given erfc (3.2) = 8×10^{-6}.)

[20 marks]

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Q.3 (b) Design a PD controller so that a unity feedback control system having open-loop transfer function $G(s) = \dfrac{20}{s(1+s)(1+2s)}$ will have a phase margin of 30° at a frequency of 1.2 rad/sec.

[20 marks]

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Q.3 (c) Show that the rms pulse broadening at the fiber output due to intermodal dispersion for the multimode step index fiber is given by

$$\sigma_s = \frac{Ln_1\Delta}{2\sqrt{3}\,c}$$

where Δ = relative refractive index, L = length of fibre and n_1 = refractive index of core.

[20 marks]

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Q.4 (a) Design the symmetric FIR lowpass filter whose desired frequency response is

$$H_d(\omega) = \begin{cases} e^{-j2\omega} & ; \text{ For } -\frac{\pi}{4} \le \omega \le \frac{\pi}{4} \\ 0 & ; \text{ For } \frac{\pi}{4} \le |\omega| \le \pi \end{cases}$$

The length of the filter should be 5. Use rectangular window. Also, compute the frequency response of the designed FIR filter.

[20 marks]

Given :-
$$H_d(\omega) = \begin{cases} e^{-j2\omega} & ; \text{ for } -\frac{\pi}{4} \le \omega \le \pi/4 \\ 0 & ; \text{ for } \frac{\pi}{4} \le |\omega| \le \pi \end{cases}$$

We know

$\therefore$
$$h_d(e^{j\omega}) = \frac{1}{2\pi} \int_{-\pi}^{\pi} H_d(\omega) e^{+j\omega n} d\omega.$$

$$h_d(n) = \frac{1}{2\pi} \int_{-\pi/4}^{\pi/4} e^{-j2\omega} \cdot e^{j\omega n} d\omega$$

$$= \frac{1}{2\pi} \times \int_{-\pi/4}^{\pi/4} e^{j(\omega)(n-2)} d\omega$$

$$= \frac{1}{2\pi} \left[\frac{e^{j\omega(n-2)}}{j(n-2)} \right]_{-\pi/4}^{\pi/4}$$

$$= \frac{1}{2\pi} \left[\frac{e^{j\pi/4(n-2)} - e^{-j\pi/4(n-2)}}{j(n-2)} \right]$$

$$h_d(n) = \frac{\sin(n-2)\pi/4}{\pi(n-2)}$$

given length of the filter is 5

$\therefore$ $h(1) = h(3)$ and $h(0) = h(4)$

As it is symmetrical around $\left(\frac{M-1}{2}\right) = \frac{(5-1)}{4}$
$= 2$

$\therefore$ $h_d(0) = \frac{1}{2\pi} = 0.15915 = h(4)$

$$h(1) = \frac{\sin(1-2)\pi/4}{\pi(1-2)} = \frac{-\sin \pi/4}{-2\pi}$$

$$= 0.11254 = h(3)$$

$$h(2) = \frac{\sin(n-2)\pi/4}{\pi(n-2)} = \frac{\cos(n-2)\pi/4 \times \pi/4}{\pi}$$

$$h(2) = 0.25$$

$\therefore$ Rectangular window :- function of rectangular window.

$$w(n) = 1 \quad \text{for } \frac{M-1}{2} \le n \le \frac{M-1}{2}$$

$$= 1 \quad \text{for } 0 \le n \le 4$$

$$\therefore h(n) = h_d(n)\, w(n) = h_d(n) \quad (\because w(n) = 1).$$

$$\therefore h(n) = h_d(n)$$

$$\therefore H(w) = \sum_{n=-\infty}^{\infty} h(n) e^{-jwn}$$

$$= \sum_{n=0}^{4} h(n) e^{-jwn}$$

$$= h(0) + h(1) e^{-jw} + h(2) e^{-jw2} + h(3) e^{-j3w} + h(4) e^{-j4w}$$

$$= 0.159 + 0.11254 e^{-jw} + 0.25000 e^{-j2w} + 0.11254 e^{-jw3} + 0.15915 e^{-j4w}$$

$$= e^{-j2w}\left[0.15915 e^{j2w} + 0.11254 e^{+jw} + 0.25 + 0.11254 e^{-jw} + 0.15915 e^{-j2w}\right]$$

$$\boxed{= e^{-j2w}\left[0.25 + 0.225 \cos w + 0.318 \cos 2w\right]}$$

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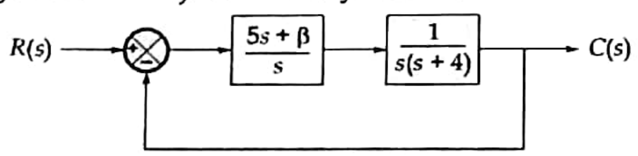
above Expression is frequency response of the filter.

Q.4 (b) The block diagram of a unity feedback system is as below :



Sketch the root locus as the parameter β is varied from 0 to ∞.

[20 marks]

∴ open loop Transfer function

$$G(S)H(S) = \left(\frac{5S+\beta}{S}\right) \times \frac{1}{S(S+4)}$$

∴ characteristics Equation of given block diagram is :-

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

$$1 + \frac{(5S+\beta)}{S^2(S+4)} = 0$$

$$S^3 + 4S^2 + 5S + \beta = 0 \quad — \quad (1)$$

$$1 + \frac{\beta}{S(S^2+4S+5)} = 0$$

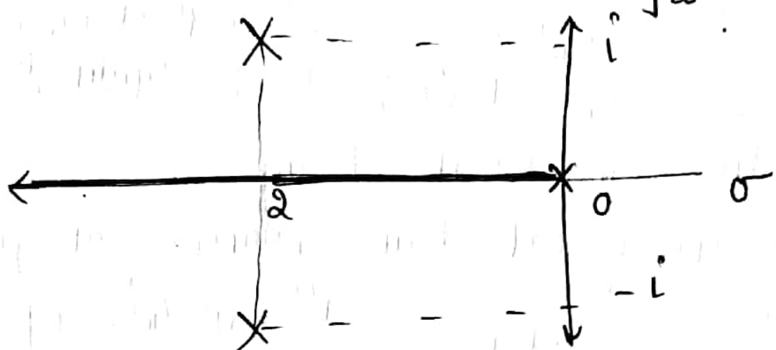
∴ open loop Transfer function become

$$G(s)H(s) = \frac{\beta}{s(s^2+4s+5)}$$

∴ Number of poles (P) = 3 at $s=0$, $s = -2 \pm i$

Number of zeroes (Z) = 0

∴ Number of root locus branch lies at infinity = $P - Z = 3 - 0 = 0$.



∴ root locus lie at the branch where sum of poles and zeroes at right is odd.

∴ Centroid :- $\sigma_A = \dfrac{\Sigma \text{ sum of real parts of poles} - \Sigma \text{ sum of real parts of zeroes}}{P - Z}$

$$\sigma_A = \frac{(-2-2)}{3} = -\frac{4}{3}$$

∴ angle of asymptotes :- It is given as

$$\phi_A = \frac{(2K+1)\,180^\circ}{P-Z}$$

where K varies from 0 to $P-Z-1$ ∴ 0 to 2

for $K = 0$

$$\phi_A = \frac{180^\circ}{3} = 60^\circ$$

for $K = 1$

$$\phi_A = \frac{(2\times1+1)\,180^\circ}{3} = 180^\circ$$

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for $K = 2$

$$\phi_A = \frac{(2K+1)180^\circ}{3} = 300^\circ$$

∴ breakaway point :- It is slouhion of $\frac{d\beta}{ds} = 0$

$$s^3 + 4s^2 + 5s + \beta = 0 \quad \ldots \text{ from Eq (1)}$$

∴ differentiate w.r.t s

$$3s^2 + 8s + 5 + \frac{\partial\beta}{\partial s} = 0$$

∴ $3s^2 + 8s + 5 = 0$ (on slaving above Equation) we get:-

∴ $s = -1, \; -1.667$

both lie on root locus.

∴ interaction of root locus branchs at jw axis :-

Characteristics Equation $= s^3 + 4s^2 + 5s + \beta$

forming Routh table for above characteristics Equation we get

s^3	1	5
s^2	4	β
s^1	$\frac{20-\beta}{4}$	0
s^0	β	

∴ $\frac{20-\beta}{4} = 0$ ∴ $\boxed{\beta = 20}$

for System to be both underdamped and marginally stable s^1 cofficient is zero.

∴ Auxillary Equation

$$4s^2 + \beta = 0$$

$$4s^2 + 20 = 0$$

$$s = \pm j\sqrt{5}$$

∴ $w = \pm\sqrt{5}$ rad/sec is frequency at which signal oscillates.

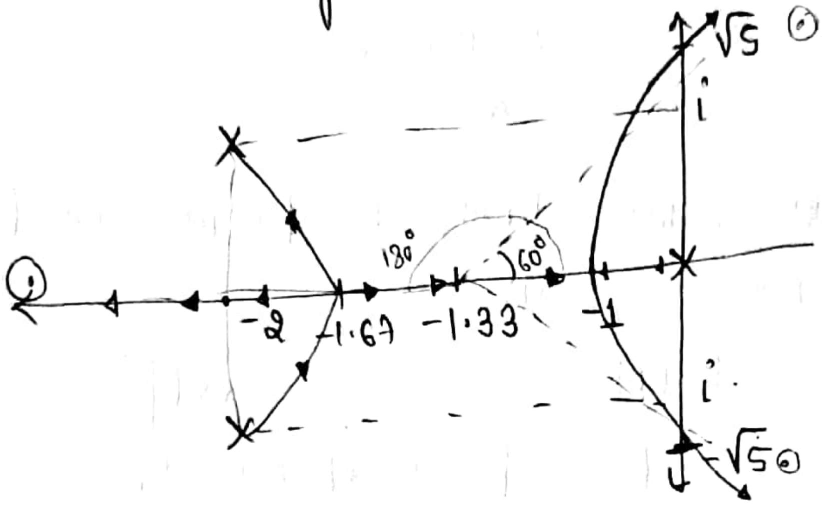
∴ angle of departure :-

$= 180^\circ - [\text{sum of angle subtended by poles} - \text{sum of angle subtended by zeroes}]$

$= 180^\circ - [90^\circ + \tan^{-1}(1/2)]$

$= \pm 63.43^\circ$

$\therefore$ from above information root locus drawn



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Q.4 (c) (i) Determine the autocorrelation function and power spectral density of the sinusoidal waveform $s(t) = \sin\omega t$.

(ii) In a receiver, the antenna is coupled directly at the input to the mixer. The loaded Q of the coupling circuit is 250. If the IF is 455 kHz and the receiver is tuned to 1 MHz, determine the image frequency and the corresponding image rejection ratio.

[10 + 10 marks]

(i) Given :- $s(t) = \sin\omega t$

we know auto correlation function is given as :-

$$R_x(\tau) = E[s(t)\cdot s(t+\tau)]$$

$$= E[\sin(\omega t)\cdot \sin(\omega(t+\tau))]$$

$$= E\left[2\times\frac{1}{2}\sin(\omega t)\cdot \sin\omega(t+\tau)\right]$$

$$= \frac{1}{2}E[2\sin(\omega t)\cdot \sin(\omega(t+\tau))]$$

As Expectation is a linear operator,

$$\Rightarrow \frac{1}{2}E[\cos(\omega\tau) - \cos(2\omega t + \omega\tau)]$$

$$= \frac{1}{2} E[\cos \omega \tau] - E[\cos(2\omega t + \omega \tau)]$$

$\therefore$ $E[\cos(2\omega t + \omega \tau)] = 0$ as whole cycle will complete in 2π time period.

$$\therefore \boxed{R_X(\tau) = \frac{\cos \omega \tau}{2}}$$

$\therefore$ power spectral density is fourier transform of autocorrelation function

$$R_X(\tau) \longrightarrow S_{XX}(f)$$

where $S_{XX}(f)$ = power spectral density.

$$FT[R_X(\tau)] = FT\left[\frac{\cos \omega \tau}{2}\right]$$

$$= \frac{\pi}{2}[\delta(\omega - \omega_0) + \delta(\omega + \omega_0)].$$

$$\boxed{S_{XX}(f) = \frac{1}{2}[\delta(f - f_0) + \delta(f + f_0)]}$$

$\therefore$ autocorrelation $R_X(\tau) = \frac{\cos \omega \tau}{2}$

PSD $S_{XX}(f) = \frac{1}{2}[\delta(f - f_0) + \delta(f + f_0)]$.

(ii) Given :- signal frequency $(f_s) = 1\ MHz$

intermediate frequency $(IF) = 455\ kHz$

Quality factor $(Q) = 250$

$\therefore$ (i) image frequency

we know $f_{si} = f_s + 2If$

where f_{si} = image frequency

On substituting the values

$= 1\,MHz + 2 \times 455\,KHz$

$$\boxed{f_{si} = 1.91\,MHz}$$

We know image rejection ratio

$$\alpha = \sqrt{1 + P^2 Q^2}$$

where $P = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$ — (11)

On substituting the value in Eq (11)

$$= \frac{1.91\,MHz}{1\,MHz} - \frac{1\,MHz}{1.91\,MHz}$$

$$\boxed{P = 1.38644}$$

on substituting the value in $\alpha = \sqrt{1 + P^2 Q^2}$ we get

$$\alpha = \sqrt{1 + (1.38644 \times 250)^2}$$

$$\boxed{\alpha = 346.61}$$

∴ image frequency is 1.91 MHz

image rejection ratio 346.61

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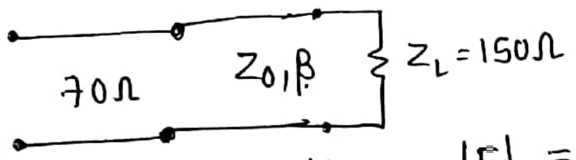
Section-B

Q.5 (a) A 70 ohms line is connected to a 150 Ω resistive load by a section of lossless line with phase-constant 5 rad/m and characteristic impedance Z_o. Calculate Z_o and the shortest length of the line to obtain the matching. **[10 marks]**

Given :- $Z_1 = 70\,\Omega$, $Z_L = 150\,\Omega$, Z_0.

and $\beta = 5\,rad/m$.



for lossless line $|\Gamma| = 0$

01

$$\therefore \Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Q.5 (b) A program executes 10,00,000 memory references. When run on a system containing a particular cache, the cache has a miss rate of 7 percent, of which 1/4 are compulsory misses, 1/4 are capacity misses and 1/2 are conflict misses.

(i) If the only change allowed to make to the cache is to increase the associativity, what is the maximum number of misses that can be eliminated?

(ii) If both increase in the cache size and increase in associativity is allowed, what is the maximum number of misses that can be eliminated?

[10 marks]

Q.5 (c) The input output equation of a continuous time domain system is given by

$$\frac{d^2y(t)}{dt^2}+\frac{6dy(t)}{dt}+8y(t)=x(t)$$

Determine the impulse response $h(t)$ of the system. Comment on the stability of the system.

[10 marks]

Given :- $\frac{d^2y(t)}{dt^2} + 6\frac{dy(t)}{dt} + 8y(t) = x(t)$

On Taking laplace transform of above differential Equation we get

$$s^2Y(s) + 6sY(s) + 8Y(s) = X(s)$$

$$Y(s)(s^2+6s+8) = X(s)$$

$$\frac{Y(s)}{X(s)} = \frac{1}{(s^2+6s+8)}$$

$\therefore$ $$H(s) = \frac{1}{s^2+6s+8} \quad \text{— (1)}$$

$\therefore$ Location of poles $s^2+6s+8=0$

$$s = -2, -4$$

$\therefore$ poles lie on the left half of s-plane therefore system is stable.

$\therefore$ from Eq (1)

$$H(s) = \frac{1}{s^2+6s+8}$$

$$= \frac{A}{(s+2)} + \frac{B}{(s+4)}$$

$$A\big|_{s=-2} = \frac{1}{(s+4)} = \frac{1}{(-2+4)} = \frac{1}{2}$$

$$B\big|_{s=-4} = \frac{1}{(-4+2)} = -\frac{1}{2}$$

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$$= \frac{1}{2(s+2)} - \frac{1}{2(s+4)}$$

On Taking inverse laplace transform

$$\boxed{h(t) = \frac{1}{2}\left[e^{-2t} - e^{-4t}\right]u(t)}$$

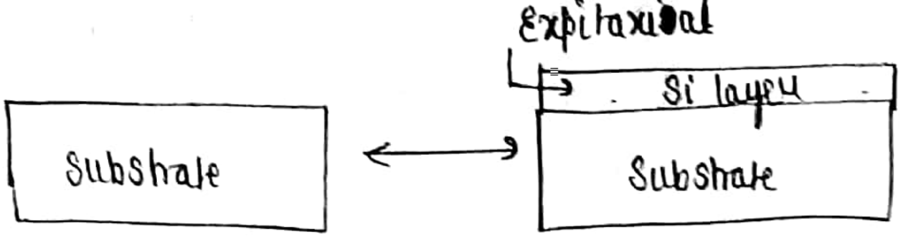
09

Q.5 (d) Write a short note on epitaxial growth process of pure silicon providing the chemical reactions involved.

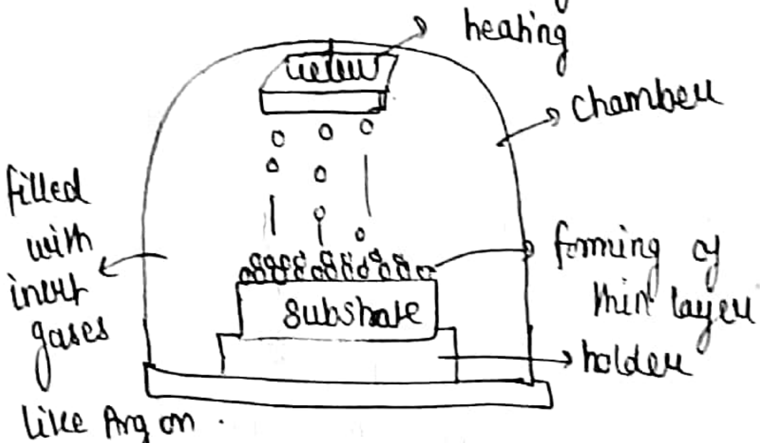
[10 marks]

<u>epitaxial growth</u> :- It is process of growing a thin layer for any Substance on the wafer

→ In this particular question it is layer of pure silicon.



→ This can be grown with many process. One process is Sputtering



→ In this the pure silicon material is heated through RF cail and it done in in an chamber filled with inert gas.

→ These energized electron gets bombard on the surface of substrate and get deposited over it.

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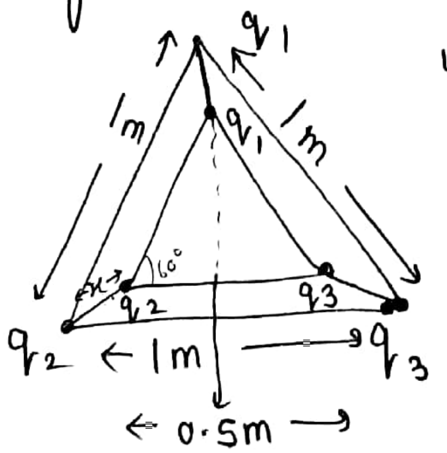
→ Result in formation of thin Layer of pure silicon over substrate.

06

Q.5 (e) Three point charges of values 1, 2 and 3 Coulombs are situated at the corners of an equilateral triangle of side 1 m. Calculate the work required to move these charges to the corners of an equilateral triangle of side 0.5 m.

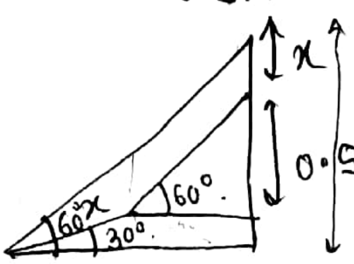
[10 marks]

According to Question



where $q_1 = 1C$
$q_2 = 2C$
$q_3 = 3C$
and $a = 1m$

$\therefore$



$$x = 1 \times \sin 60° - 0.5 \times 1 \sin 60°$$

$$= \frac{\sqrt{3}}{2} - 0.5 \times \frac{\sqrt{3}}{2}$$

$$= 0.433 \text{ m}$$

∴ potential in moving charge q_1 is given by $V = \frac{Q}{4\pi\varepsilon_0 r}$

$$\therefore V_1 = \frac{1}{4\pi\varepsilon_0 \times 0.433} = 2.078 \times 10^{10} V$$

∴ Similarly potential in moving charge q_2 is given by

$$V_2 = \frac{Q}{4\pi\varepsilon_0 r} = \frac{2}{4\pi\varepsilon_0 \times 0.433}$$

$$V_2 = 4.156 \times 10^{10} V$$

∴ Similarly potential in moving q_3

q_3 is $(V_3) = \frac{Q}{4\pi\varepsilon_0 r} = \frac{3}{4\pi\varepsilon_0 \times 0.433}$

$$= 6.235 \times 10^{10} V$$

∴ Work done $= qV$

where q = charge and V = potential

∴ Total work done $= q_1V_1 + q_2V_2 + q_3V_3$

$$\Rightarrow 2.078 \times 10^{10} \times 1 + 4.156 \times 10^{10} \times 2 + 3 \times 6.235 \times 10^{10}$$

$$\boxed{W = 2.909 \times 10^{11} J}$$

∴ Work done ~~required~~ for moving three charges are 2.909×10^{11} J.

03

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Q.5 (f) Explain the classes of IPv4 address and identify the class of each of the following IPv4 addresses :

(i) 152.66.2.3

(ii) 1.2.3.4

(iii) 192.192.192.192

(iv) 247.250.0.255

[10 marks]

∴ classes of IPV4 address are

(i) class A :- in this one bit is fixed ~~and~~ and represent as 0

(ii) class B :- in this two bits are fixed and represented as 10

(iii) class C :- in this three bits are fixed and represented as. 110

(iv) class D :- in this four bits are reversed and represented as 1110

(v) class E :- which is reversed for future purpose.

(i) 152·66·2·3

(i) Starting of address 100 this is class B.

(ii) 1·2·3·4

000001 starting of address is 0 hence class A

(iii) 192·192·192·192

110 Starting of address is ~~A~~ 110 hence class C.

(iv) 247·250·0·255

Starting of ~~add~~ address 1111 hence class E.

09

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Q.6 (a) A plane wave travelling in +z-direction is normally incident on an infinitely thick dielectric slab of refractive index 2. Show that the phase velocity of the total waves in the air (incident wave + reflected wave) can be expressed as :

$$V_p = c\left\{\frac{1}{2}\cos^2\beta z + 2\sin^2\beta z\right\}$$

where β is the phase constant of wave in air.

[20 marks]

Q.6 (b) **(i)** A photodiode circuit has dark current, I_d = 2 nA, a load resistance of 1 kΩ, responsitivity R = 0.5 A/W, incident optical power of 10 μW, T = 300 K and bandwidth B = 1 MHz.

1. Calculate the mean square shot noise and thermal noise current.
2. Calculate the signal to noise ratio.

(ii) A satellite is in elliptical orbit with perigee of 1100 km and apogee of 4000 km. Determine the period of orbit and eccentricity of the orbit. Assume the earth radius to be 6378 km and Kepler's constant, $\mu = 3.986 \times 10^5\ \text{km}^3/\text{s}^2$.

[12 + 8 marks]

Q.6 (c) (i) Write a program in C language to find the factorial of a number using recursion.

(ii) An amplitude modulated signal given by $s(t) = (1 + \mu \sin\omega_m t)\sin\omega_c t$ is demodulated using a square law detector whose characteristics are given by $V_o = a + bV_i + cV_i^2$. Find the highest permissible modulation index μ if the second harmonic distortion is not to exceed 10%.

[10 + 10 marks]

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Q.7 (a) Consider three processes, all arriving at time zero, with total execution time of 10, 20 and 30 units respectively. Each process spends the first 20% of execution time doing I/O, the next 70% of time doing computation and the last 10% of time doing I/O again. The operating system uses a shortest remaining compute time first scheduling algorithm and schedules a new process either when the running process gets blocked on I/O or when the running process finishes its compute burst. Assume that all I/O operations can be overlapped as much as possible.

(i) Compute the percentage of time CPU remain idle.

(ii) Calculate the average waiting time and the average turn around time.

[15 marks]

Given :- let three process as P_1, P_2, P_3

$AT = 0$, $BT = 10, 20, 30$ respectively

∴

process id	Arrival time	Burst time
P_1	0	10
P_2	0	20
P_3	0	30

∴ process chart

P_1	P_2	P_3

0   10   30   60

∴ Turnaround time $(TAT) = CT - AT$

CT = completion time

AT = arrival time

(WT) waiting time = Turnaround time − burst time

CT	TAT	WT
10	10	0
30	30	10
60	60	30

∴ average turnaround time $= \dfrac{60+10+30}{3}$

$= \boxed{40 \text{ units}}$

$\therefore$ average waiting time $= \frac{0+10+30}{3}$

$= \frac{40}{3}$

$= \boxed{13.33 \text{ units}}$

$\therefore$ average waiting time $= 13.33$ units

average turn around time $= 40$ units,

(i) for process P_1 CPU idleness is

$= \frac{30}{100} \times$ total execution time

$= \frac{30}{100} \times 10 = 3$ units.

for process P_2 CPU idleness time is

$= \frac{30}{100} \times$ total execution time

$= \frac{30}{100} \times 20 = 6$ units.

for process P_3 CPU idleness time is

$= \frac{30}{100} \times$ total execution time

$= \frac{30}{100} \times 30 = 9$ units

Total idleness time

$\Rightarrow$ 3 units + 6 units + 9 units

$=$ 18 units.

$\therefore$ CPU remain idle for

$=$ 18 units + 13.33 units

$= \boxed{31.33 \text{ units}}$

12

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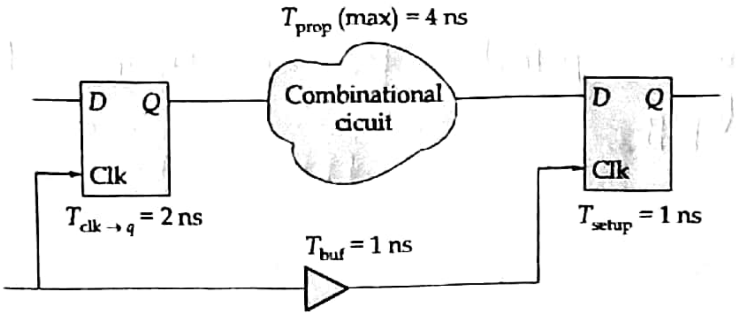
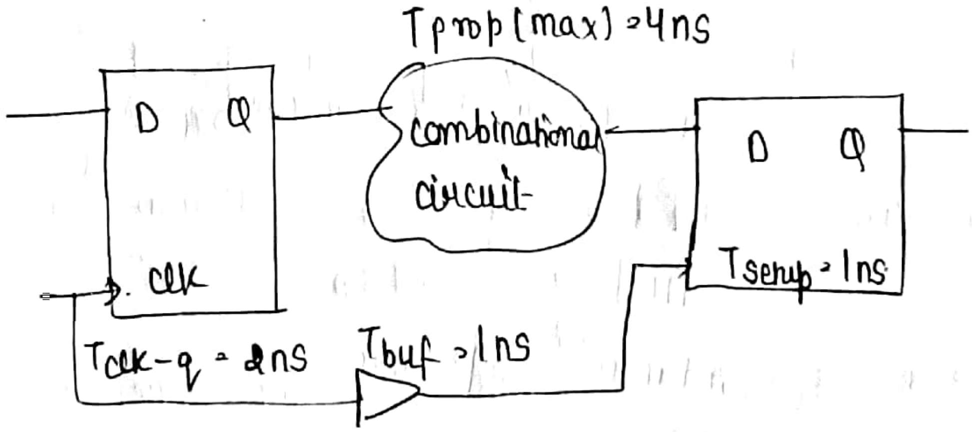
Q.7 (b) Define the setup time and hold time of a flip-flop. For the sequential circuit shown below, find out the maximum frequency of operation.



[15 marks]

Setup time :- It is time required for the signal to hold a particular value such that there no variation in the signal at input of flip flop.

hold time :- It is time required after the applied input to which the output of the flip flop stable or hold the output value.



$\therefore$ Tclk = Tpropogation delay

$= 2ns + 4ns$

$\boxed{T_{clk} = 6ns}$

frequency of operation $= \frac{1}{T_{clk}} = \frac{1}{6ns} = 1.67 \times 10^{8}$

$\boxed{\approx 167.77 \text{ MHz}}$

$\therefore$ frequency required for operation is 167.77 MHz.

14

Q.7 (c) The electric field of a uniform plane wave propagating in positive z-direction is given by

$$\vec{E} = E_o \cos(\omega t - \beta z)\hat{a}_x + E_o \sin(\omega t - \beta z)\hat{a}_y$$

Determine the expression for magnetic field intensity and the Poynting vector.

[15 marks]

Given :-

$$\vec{E} = E_0 \cos(\omega t - \beta z)\hat{a}_x + E_0 \sin(\omega t - \beta z)\hat{a}_y$$

We know $\dfrac{|\vec{E}|}{|\vec{H}|} = \eta$

where η is intrinsic impedance.

$\therefore$ for $|\vec{E}| = E_0$

$$|\vec{H}| = \frac{|\vec{E}|}{\eta} = \frac{E_0}{\eta}$$

$\therefore$ As power flow is in $+z$ direction then for electric field $\hat{a}_x$ component magnetic field direction is given

$$\hat{a}_H = \hat{a}_P \times \hat{a}_E$$

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$$= \hat{a}_z \times \hat{a}_x = \hat{a}_y$$

similarly for $\hat{a}_y$ direction we get.

$$= \hat{a}_z \times \hat{a}_y = -\hat{a}_x$$

∴ magnetic field intensity expression is given by :

$$\vec{H} = \frac{E_0}{\eta} \cos(\omega t - \beta z)\, \hat{a}_y - \frac{E_0}{\eta} \sin(\omega t - \beta z)\, \hat{a}_x$$

$$\boxed{\vec{H} = \frac{E_0}{\eta} \cos(\omega t - \beta z)\, \hat{a}_y - \frac{E_0}{\eta} \sin(\omega t - \beta z)\, \hat{a}_x}$$

(ii) Poynting vector $= \frac{1}{2}(\vec{E} \times \vec{H})$

$$= \frac{1}{2}\left(E_0 \cos(\omega t - \beta z)\, \hat{a}_x + E_0 \sin(\omega t - \beta z)\, \hat{a}_y \right]$$

$$\times \left[\frac{E_0}{\eta} \cos(\omega t - \beta z)\, \hat{a}_y - \frac{E_0}{\eta} \sin(\omega t - \beta z)\, \hat{a}_x \right]$$

$$= \frac{1}{2}\left[\frac{E_0^2}{\eta} \cos^2(\omega t - \beta z)\, \hat{a}_z + \frac{E_0^2}{\eta} \sin^2(\omega t - \beta z)\, \hat{a}_z \right]$$

$$= \frac{1}{2}\left[\frac{E_0^2}{\eta} \left[\frac{1}{2}[1 + \cos(2(\omega t - \beta z)] + \frac{1}{2}[1 - \cos(2(\omega t - \beta z)] \right] \hat{a}_z \right.$$

$$= \frac{1}{2} \times \frac{E_0^2}{2\eta} \left[1 + \cos(2(\omega t - \beta z)) + 1 - \cos(2(\omega t - \beta z)) \right] \hat{a}_z$$

$$= \frac{E_0^2}{2\eta} \times \frac{2}{2}$$

$$\boxed{\text{power} = \frac{E_0^2}{2\eta}\, \hat{a}_z}$$

12

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Q.7 (d) (i) Discuss the advantages of IPv6 over IPv4.

(ii) Determine the change in the electron density of the E-layer when the critical frequency changes from 4.5 MHz to 1.5 MHz for ionospheric communication between mid-day and sun-set periods.

[5 + 10 marks]

(i) Advantages of IPV6 over IPV4 is

(i) IPV6 has better security as compared to IPV4

(ii) IPV6 has more number of ~~feautures as~~ features as compared to IPV4

(iii) IPV6 allow more number of user allottment as compared to IPV4.

(iv) IPV6 has authencation of user which is not there in IPV4 using passwords.

(v) better error control means do error correction and detection.

(ii) Given :- Given $f_{c_1} = 4.5\ MHz$

$f_{c_2} = 1.5\ MHz$

We know refractive index

$$\mu = \sqrt{1 - \frac{81N^2}{f}}$$

$\therefore$ for critical frequency $f_c^2 = 81N^2_{max}$

$$\therefore f_c = 9\sqrt{N_{max}}. \quad — (1)$$

for $f_{c_1} = 4.5\ MHz$

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$$N_{max_1} = \frac{f_{c_1}^2}{81}$$

$$= \frac{(4.5\times10^6)^2}{81}$$

$$\boxed{N_{max_1} = 2.5\times10^{11}} \quad \text{—(I)}$$

for $f_{c_2} = 1.5$ MHz

$$N_{max_2} = \frac{f_c^2}{81} = \frac{(1.5\times10^6)^2}{81}$$

$$\boxed{N_{max_2} = 2.77\times10^{10}} \quad \text{—(II)}$$

dividing (I) by (II) we get

$$\frac{N_{max_1}}{N_{max_2}} = \frac{2.5\times10^{11}}{2.77\times10^{10}}$$

$$\boxed{\frac{N_{max_1}}{N_{max_2}} = 9}$$

10

∴ if critical frequency changes from 4.5 MHz to 1.5 MHz then electron density decreases by 9 times.

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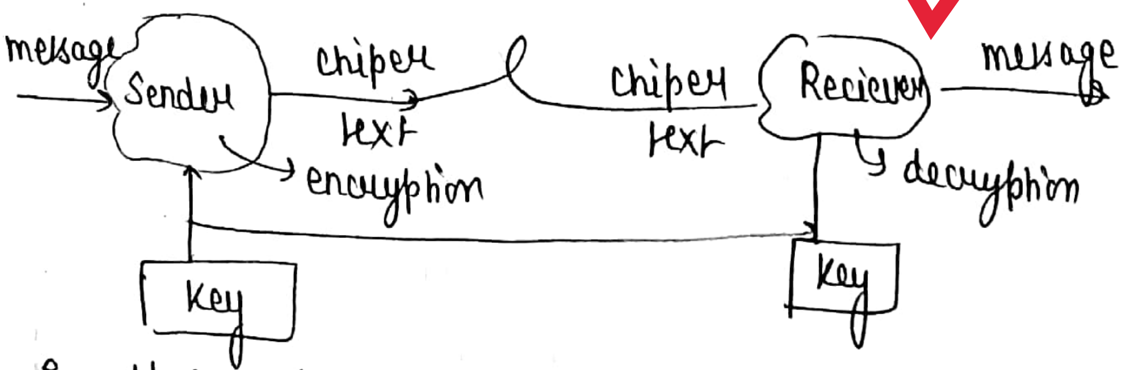
Q.8 (a) (i) Differentiate between symmetric and asymmetric cryptography.

(ii) In a RSA cryptosystem, a participant A uses two prime numbers $p = 13$ and $q = 17$ to generate public and private keys. If the public key of A is 35, then find the private key of A.

[5 + 10 marks]

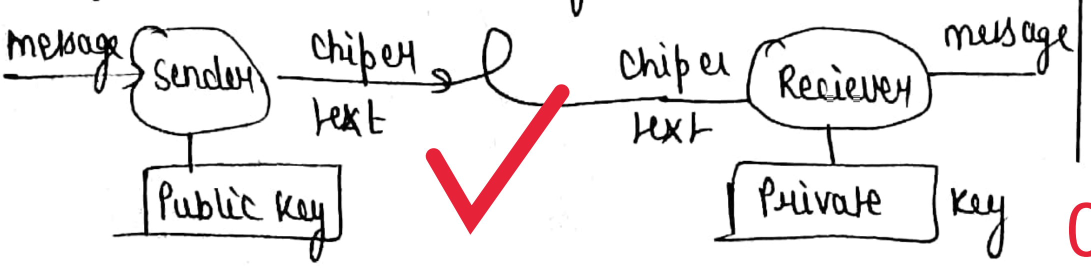
(i) Symmeteric cryptography :- In this type of cryptography same key it used by the sender to encrypt the message and by reciever to decrypt it.



Example :- Hello message is send as o Hell then reciever will ~~decc~~ decode by same process as sender encrypt it then Hello is recieved.

disadvantage :- (i) To secure key another key is required.

(ii) asymmetric cryptography :- In this sender encrypt the message using its public key and reciever decrypt the message using its private key



05

Q.8 (b) The open-loop transfer function $G(s)$ and feedback $H(s)$ of a control system is

$$G(s) = \frac{K}{s(s+p)}, \quad H(s) = 1 + \alpha s$$

Determine the sensitivity of the transfer function of the closed-loop system to changes in K, p and α. The nominal values of the parameters are $K = 10$, $p = 2$ and $\alpha = 0.1$.

[15 marks]

∴ Given :- $G(s) = \dfrac{K}{s(s+p)}$ and

$H(s) = 1 + \alpha s$, $K = 10$, $p = 2$, $\alpha = 0.1$

∴ Transfer function of closed loop system

$$T(s) = \frac{G(s)}{1 + G(s)H(s)} = \frac{\frac{K}{s(s+p)}}{1 + \frac{K}{s(s+p)}(1+\alpha s)}$$

$$= \frac{K}{s^2 + ps + K\alpha s + K}$$

$$T(s) = \frac{K}{s^2 + (K\alpha + p)s + K} \quad — ①$$

(i) Sensitivity of $T(s)$ w.r.t (with respect to K) is :-

$$S_K^T = \frac{\partial T(s)}{\partial K} \times \frac{K}{T(s)} \quad (∴ \text{differentiate Eq ① w.r.t K})$$

$$\frac{\partial T(s)}{\partial K} = \left[\frac{s^2 + (K\alpha + p)s + K - (1 + \alpha s)K}{(s^2 + (K\alpha + p)s + K)^2} \right]$$

$$\Rightarrow \frac{s^2 + ps}{(s^2 + (K\alpha + p)s + K)^2} \times \frac{\cancel{K}}{\frac{\cancel{K}}{(s^2 + (K\alpha + p)s + K)}}$$

$$= \frac{s(s+p)}{s^2 + (K\alpha + p)s + K}$$

On substituting the value

$$\boxed{S_K^T = \frac{s(s+2)}{s^2 + 3s + 10}}$$

(ii) Sensitivity w.r.t p.

$$S_p^{T(s)} = \frac{\partial T(s)}{\partial p} \times \frac{p}{T(s)}$$

differentiate eq ① w.r.t p

$$\frac{\partial T(s)}{\partial p} = \frac{-Ks}{(s^2+(K\alpha+p)s+K)^2}$$

$$= \frac{-\cancel{K}s}{(s^2+(K\alpha+p)s+K)^{\cancel{2}}} \times \frac{p}{\frac{\cancel{K}}{\cancel{(s^2+(K\alpha+p)s+K)}}}$$

$$= \frac{-ps}{s^2+(K\alpha+p)s+K}$$

On substituting the value

$$\boxed{S_p^{T(s)} = \frac{-2s}{s^2+3s+10}}$$

(iii) sensitivity w.r.t α

$$S_\alpha^{T(s)} = \frac{\partial T(s)}{\partial \alpha} \times \frac{\alpha}{T(s)}$$

differentiating eq ① w.r.t α

$$\frac{\partial T(s)}{\partial \alpha} = \frac{-K \times Ks}{(s^2+(K\alpha+p)s+K)^2}$$

$$= \frac{-K^{\cancel{2}}s}{(s^2+(K\alpha+p)s+K)^{\cancel{2}}} \times \frac{\alpha}{\frac{K}{\cancel{(s^2+(K\alpha+p)s+K)}}}$$

$$= \frac{-K\alpha s}{s^2+(K\alpha+p)s+K}$$

On substituting the values

$$\boxed{S_\alpha^{T(s)} = \frac{-s}{s^2+3s+10}}$$

14

Q.8 (c) A TE wave propagating in a dielectric-filled waveguide of unknown permittivity has dimensions $a = 5$ cm and b = 3 cm. If the x-component of electric field is given by

$$E_x = -36\cos(40\pi x)\sin(100\pi y)\sin(2.4\pi\times10^{10}t - 52.9\pi z)\ \text{V/m}$$

Determine

(i) the mode number.

(ii) permittivity of the material in the guide.

(iii) the cut-off frequency, and

(iv) the expression for H_y.

[15 marks]

∴ Given :- $a = 5\text{cm}$

$b = 3\text{cm}$

$E_x = -36\cos(40\pi x)\sin(100\pi y)\sin(2.4\pi\times10^{10} t - 52.9\pi z)$ V/m

On comparing with standard Equation

$E_x = +E_0\cos\left(\frac{m\pi}{a}x\right)\sin\left(\frac{n\pi}{b}y\right)\sin(\omega t - \beta z)$

we get

$\frac{m\pi}{a} = 40\pi$ — (I) & $\frac{n\pi}{b} = 100\pi$ — (II), $\omega = 2.4\pi\times10^{10}$ rad/sec, $\beta = 52.9\pi$

∴ from Eq (I)

$m = \frac{40\cancel{\pi}\times a}{\cancel{\pi}} = 40\times5\times10^{-2}$

$m = 2$

and from Eq (2)

$n = \frac{100\cancel{\pi}\times b}{\cancel{\pi}} = 100\times3\times10^{-2} = 3$

(i) mode number is TE_{mn} i.e. $\boxed{TE_{23}}$

∴ mode is TE_{23}

(ii) permittivity of material ϵ_r :-

we know phase velocity $v_p = \frac{\omega}{\beta}$

$$= \frac{2.4\pi \times 10^{10}}{52.9\pi}$$

$$v_p = 4.536 \times 10^{8}\ m/s.$$

$\therefore$ and we know $v_p = \frac{c}{\sqrt{\mu_r \varepsilon_r}}$

as dielectric - filled therefore $\mu_r = 1$

$$v_p = \frac{c}{\sqrt{\varepsilon_r}}$$

$$\therefore \quad 4.536 \times 10^{8} = \frac{3 \times 10^{8}}{\sqrt{\varepsilon_r}}$$

$$\sqrt{\varepsilon_r} = \frac{3 \times 10^{8}}{4.536 \times 10^{8}}$$

$$\therefore \quad \boxed{\varepsilon_r = 0.437}$$

(iii) cut off frequency

$$f_c = \frac{v_p}{2} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

On substituting the values we get

$$= \frac{4.536 \times 10^{8}}{2} \sqrt{\left(\frac{2}{5 \times 10^{-2}}\right)^2 + \left(\frac{3}{3 \times 10^{-2}}\right)^2}$$

$$\boxed{f_c = 24.427\ GHz}$$

$\therefore$ cut off frequency $f_c = 24.427\ GHz$

(iv) Expression for H_y

we know $\frac{|\vec{E}|}{|\vec{H}|} = \eta$

$\therefore \quad |\vec{H}| = \frac{|\vec{E}|}{\eta}$ where η = intrinsic impedance

$$= \frac{36}{\frac{120\pi}{\sqrt{\epsilon\mu}}} = \frac{36}{\frac{120\pi}{\sqrt{0.437}}}$$

$$= 63.156 \text{ mA/m}$$

$\therefore$ direction of magnetic field

$$\hat{a}_H = \hat{a}_P \times \hat{a}_E$$

$$= \hat{a}_z \times (-\hat{a}_x)$$

$$= -\hat{a}_y$$

$\therefore$ Expression for H_y is

$$\boxed{H_y = -63.156 \cos(40\pi x) \sin(100\pi y) \sin(2.4\pi \times 10^{10} t - 52.9\pi z) \text{ mA/m}}$$

14

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Q.8 (d) Find the inverse Fourier transform for the signal.

$$X(j\omega) = \frac{25 - 10j(\omega-7) - (\omega-7)^2}{\left[25 + (\omega-7)^2\right]^2}$$

[15 marks]

∴ Given :-

$$X(j\omega) = \frac{25 - 10j(\omega-7) - (\omega-7)^2}{[25 + (\omega-7)^2]^2}$$

$$\Rightarrow \frac{[25 - 5\times 2j(\omega-7) + (j(\omega-7))^2]}{[25 + (\omega-7)^2]^2}$$

$$\Rightarrow \frac{[5 - j(\omega-7)]^2}{[25 + (\omega-7)^2]^2}$$

$$= \frac{[5 - j(\omega-7)]^2}{[[5+j(\omega-7)][5-j(\omega-7)]]^2}$$

$$= \frac{\cancel{[5 - j(\omega-7)]^2}}{[5+j(\omega-7)]^2\,\cancel{[5-j(\omega-7)]^2}}$$

$$X(j\omega) = \frac{1}{[5+(j(\omega-7))]^2}$$

$$X(j\omega) = j \times \frac{-j}{[5+(j(\omega-7))]^2}$$

∴ by property of differentiation in frequency

$$x(t) \xrightarrow{FT} X(\omega)$$

$$\therefore\ t\,x(t) \xrightarrow{FT} j\frac{dX(\omega)}{d\omega}$$

$$\therefore\ X(j\omega) = j\frac{d}{d\omega}\left[\frac{1}{5+j(\omega-7)}\right]$$

$$X(\omega) = \frac{1}{5+j(\omega-7)}$$

On Taking inverse fourier transform

$$= e^{7t} \times [e^{-5t}u(t)]$$

by using property

(i) shifting property

$$e^{+j\omega_0 t} x(t) \xrightarrow{FT} X(\omega-\omega_0)$$

and

$$e^{-at}x(t) \xrightarrow{FT} \frac{1}{j\omega+a}$$

$\therefore$ inverse fourier transform of signal will be

$$\boxed{x(t) = t[e^{7t}[e^{-5t}u(t)]]}$$

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