ACE
Engineering Academy
Leading Institute for ESE/GATE/PSUs

HYDERABAD | DELHI | PUNE | BANGALORE | LUCKNOW | CHENNAI | VISAKHAPATNAM | VIJAYAWADA | TIRUPATHI | KOLKATA | AHMEDABAD

ESE-2020

(MAINS)

QUESTIONS WITH DETAILED SOLUTIONS

ELECTRONICS & TELECOMMUNICATION ENGINEERING

PAPER-II

All Queries related to ESE - 2020 MAINS Solutions are to be sent to the following email address hyderabad@aceenggacademy.com

Contact Us : 040-23234418,19,20

ELECTRONICS & TELECOMMUNICATION ENGINEERING

ESE_MAINS_2020_PAPER – II

Questions with Detailed Solutions

SUBJECT WISE WEIGHTAGE

S.No	NAME OF THE SUBJECT	Marks
01	COMMUNICATION SYSTEMS	80
02	CONTROL SYSTEMS	80
03	COMPUTER ORGANIZATION AND ARCHITECTURE	40
04	ELECTROMAGNETICS	110
05	ADVANCED ELECTRONICS	110
06	ADVANCED COMMUNICATIONS	60

SECTION - A

01. (a) A certain speech signal is sampled at 8kHz and coded with DPCM, the output of which belongs to a set of 8 symbols $s_1 - s_8$.

The probabilities of these symbols are $p(s_1) = 0.4$, $p(s_2) = p(s_3) = 0.2$, $p(s_4) = 0.1$, $p(s_5) = 0.05$, $p(s_6) = p(s_7) = 0.02$ and $p(s_8) = 0.01$. Calculate the entropy in bits/sec. If all symbols are equiprobable, what will be the entropy? (10 M)

Sol: $f_s = 8kHz$

$P(s_1) = 0.4,\ P(s_2) = P(s_3) = 0.2$

$P(s_4) = 0.1,\ P(s_5) = 0.05 \quad P(s_6) = P(s_7) = 0.02$

$P(s_8) = 0.01$

$$H = -\sum_i p_i \log_2 p_i$$

$$= -[0.4\log_2 0.4 + 2\times 0.2\log_2 0.2 + 0.1\log_2 0.1 + 0.05\log_2 0.05 + 2\times 0.01\log_2 0.02 + 0.01\log_2 0.01]$$

$H = 2.298\ bit/symbol$

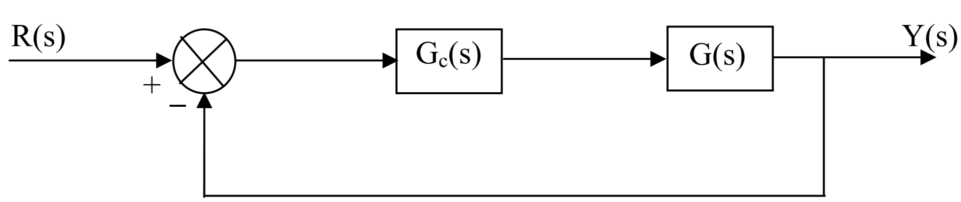
Entropy = H f_s = 18.384 k bits/sec

If 'N' symbols are equiprobable, entropy will be $H = \log_2 N$

$= \log_2 8 = 3\ bits/symbol$

Entropy = H f_s = 24 k bits/sec

01. (b) In the figure shown below, $G(s) = \frac{K}{(\tau s + 1)}$ has a time constant of 0.5seconds, and has unity DC gain. An integral controller is placed in forward path as $G_C(s) = \frac{K_1}{s}$ such that the open loop transfer function $G(s)\,G_C(s)$ has a velocity error constant $K_V = 1$. Find the sensitivity of the closed loop system transfer function with respect to K_1 at $\omega = 1$ rad/sec. (10 M)



Sol: $G(s)=\frac{K}{s\tau+1}$, $\tau=0.5\sec$

Unity DC gain $\Rightarrow G(s)|_{\omega=0}=1\Rightarrow K=1$

$$\Rightarrow G_c(s)=\frac{K_I}{s}$$

Open loop transfer function $G(s)G_c(s)=\frac{K_I}{s(s\tau+1)}$

Velocity error constant $K_V=1$

$$G(s)G_c(s)=\frac{K_I}{s(0.5s+1)}$$

$$K_V=\underset{s\to 0}{Lt}\ sG(s)G_C(s)=\underset{s\to 0}{Lt}\ s\frac{K_I}{s(0.5s+1)}=1\Rightarrow K_I=1$$

$$CLTF=\frac{K_I}{0.5s^2+s+K_I}$$

$$\Rightarrow \text{Sensitivity } S_{K_I}^T=\left[\frac{\partial T/T}{\partial K_I/K_I}\right]=\left(\frac{K_I}{T}\right)\left(\frac{\partial T}{\partial K_I}\right)$$

$$=\frac{K_I}{\left(\frac{K_I}{0.5s^2+s+K_I}\right)}\left[\frac{1\left(0.5s^2+s+K_I\right)-K_I(1)}{\left(0.5s^2+s+K_I\right)^2}\right]=\frac{0.5s^2+s}{0.5s^2+s+K_I}$$

$$\Rightarrow\left|S_{K_I}^T\right|_{\omega=|r|_{sec}}=\left|\frac{-0.5\omega^2+j\omega}{-0.5\omega^2+j\omega+1}\right|=\left|\frac{-0.5+j1}{0.5+j1}\right|=\frac{\sqrt{0.5^2+1}}{\sqrt{0.5^2+1}}=1$$

01. (c) List and define various scheduling performance criteria used for comparing various CPU-scheduling algorithms. Compute and compare the average process waiting time of First come First serve, Shortest task first and priority scheduling algorithms for the processes with their details as listed in the table. (10 M)

Process	Arrival Time	Burst Time	Priority
P_0	0	3	1
P_1	2	2	2
P_2	3	4	3
P_3	4	7	1

Sol: FCFS algorithm:

Gantt chart

P_0	P_1	P_2	P_3

0 3 5 9 16

Waiting time = Start time – Arrival time

$P_0 = 0 - 0 = 0$

$P_1 = 3 - 2 = 1$

$P_2 = 5 - 3 = 2$

$P_3 = 9 - 4 = 5$

Average W.T. = $\dfrac{0+1+2+5}{4} = 2$

Shortest Task First (Non pre-emptive):

Gantt chart

P_0	P_1	P_2	P_3

0 3 5 9 16

Working time

$P_0 = 0 - 0 = 0$

$P_1 = 3 - 2 = 1$

$P_2 = 5 - 3 = 2$

$P_3 = 9 - 4 = 5$

Average W.T. = $\dfrac{0+1+2+5}{4} = 2$

Priority scheduling (Non pre-emptive):

Gantt chart

P_0	P_1	P_2	P_3

0 3 5 12 16

Waiting time

$P_0 = 0 - 0 = 0$

$P_1 = 3 - 2 = 1$

$P_2 = 12 - 3 = 9$

$P_3 = 5 - 4 = 1$

$$\text{Average} = \frac{1+9+1+0}{4} = 2.75$$

01. (d) A uniform plane wave is propagating in z-direction with velocity 1.4×10^8 m/s in a perfect medium of intrinsic impedance 474 Ω. If $E_x(z,t) = 1750\cos(10^6\pi t - \beta z)\,V/m$ represents instantaneous electric field, what will be the magnetic field? Determine the wavelength and average power of the wave. (10 M)

Sol: Given : $E_x(z, t) = 1750 \cos(10^6\pi t - \beta z)$

Or

$$\hat{E}(z,t) = 1750\cos\left(10^6\pi t - \beta z\right)\hat{a}_x\, V/m$$

Velocity, $v_p = 1.4 \times 10^8$/sec

Wave impedance, Ω = 474 Ω

Direction propagation is $\hat{a}_k = \hat{a}_z \quad (\because +z\, direction)$

Direction of electric field is $\hat{a}_E = \hat{a}_x$

Let $\vec{H}(z,t) = H_0\cos\left(10^6\pi t - \beta z\right)\hat{a}_H$

Where $H_0 = \dfrac{E_0}{|\eta|} = \dfrac{1750}{474}$

$$\hat{a}_H = \hat{a}_k \times \hat{a}_E = \hat{a}_z \times \hat{a}_x = \hat{a}_y$$

$$\beta = \frac{\omega}{v_p} = \frac{10^6\pi}{1.4\times10^8} = 2.24\times10^{-2} \text{ rad/m}$$

∴ Magnetic field intensity is given by

$$\vec{H} = 3.69\cos\left(10^6\pi t - 2.24\times10^{-2}z\right)\hat{a}_y\, A/m$$

Wave length, $\lambda = \dfrac{2\pi}{\beta} = \dfrac{2\pi}{\dfrac{10^6\pi}{1.4\times10^8}} = 280m$

Time average poynting vector is given by

$$\vec{W}_{avg} = \frac{E_0^2}{2|\eta|}\left(+\hat{a}_z\right)$$

$$= \frac{(1750)^2}{2\times474}\left(\hat{a}_z\right)$$

$$\vec{W}_{avg} = 3230.48\,\hat{a}_z\, W/m^2$$

01. (e) Processor technology deals with computation architectures whereas IC technology deals with implementation style for a given functionality. What are the different processor and IC technologies? Is processor technology orthogonal to IC technology or interdependent with IC technology? Justify your answer. (10 M)

Sol: Processor Technology:

- The architecture of the computation engine used to implement a system's desired functionality.
- Processors vary in their customization for the problem at hand and thus processors can be categorized into three types.

  → General purpose processor

  → Application - specific processor

  → Single purpose processor

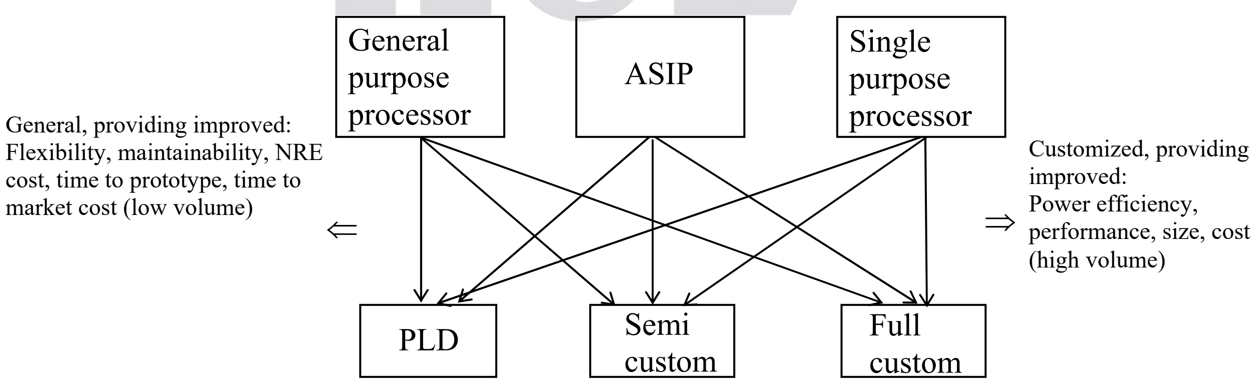
General – Purpose processor	Application specific processor	Single purpose processor
1. Programmable device used in variety of applications also known as microprocessor.	1. Programmable processor optimized for a particular class of applications having common characteristics. Compromise between general – purpose and single – purpose processors.	1. Digital circuit designed to execute exactly one program also known as coprocessor, accelerator or peripheral.
2. Features: (i) Program memory (ii) General data path with large register file and general ALU.	2. Features: (i) Program memory (ii)Optimized data path (iii) Special functional units	2. Features: (i) Contains only the components needed to execute a single program (ii) No program memory.
3. Benefits: (i) Low time to market and NRE costs. (ii) High flexibility Drawbacks: (i) High unit cost (ii) Low performance	3. Benefits: (i) Some flexibility, good performance, size and power. Drawbacks: (i) High NRE cost Ex: Microcontroller, DSP	3. Benefits: (i) Fast (ii) Low power Drawbacks: (i) No flexibility, high time to market, high NRE cost.

Integrated circuit (IC) Technology:

- The manner in which a digital (gate – level) implementation is mapped onto an IC. There are three types of IC technologies.
    - Full - custom / VLSI
    - Semi - custom ASIC (Gate array and standard cell)
    - PLD (programmable logic device)

Full – custom	Semi – custom	PLD
1. Very large scale integration. All layers are optimized for an embedded system's particular digital implementation. 2. Benefits: Excellent performance, small size, low power Drawbacks: High NRE cost, long time to market	1. Lower layers are fully or partially built. Designers are left with routing of wires and may be placing some blocks. 2. Benefits: Good performance, less NRE cost than full – custom implementation Drawbacks: Still require long time to develop.	1. The layout is composed of an array of elementary programmable modules (PAL, PLA, FPGA) implementing a generic logic function and the interconnection among the modules. The layout and fabrication process of each device is completed in advance and independently of the application. The device customization is obtained by programming on - site the device. 2. Benefits: Very low NRE cost, immediate turn around time Drawback: High unit cost, bad for large volume. Power Low performance and integration density with respect to other design styles.

Independence of processor and IC technologies:



01. (f) Explain the following terms

(i) Modal Birefringence

(ii) Coherence Length

(iii) Beat Length

The difference between the propagation constants for the two orthogonal modes in the single mode fiber is 250. It is illuminated with light of peak wavelength 1.55 μm from an injection laser source with a spectral width of 0.8 nm. Calculate Modal Birefringence, Coherence Length and Beat Length. (10 M)

Sol:

(i) Modal Birefringence :

Local absolute value of the difference between the propagation constants of both modes.

$$\Delta\beta = \left|\beta_x - \beta_y\right| = \frac{2\pi}{\lambda}\left|n_x - n_y\right| = \frac{\omega}{c}\Delta n$$

C: speed of light

Δn : Refractive index difference (also called degree of birefringence)

(ii) Coherence length :

measure of temporal coherence expressed as the propagation distance over which the coherence significantly delays.

$$L_{coh} = C\,\tau_{ooh} = \frac{C}{\pi\Delta V}$$

ΔV : Optical bandwidth (full width at half maximum)

(iii) Beat length:

Length required for the polarization to rotate 360 degrees. It is inversely proportional to birefringence

$$L_B = \frac{2\pi}{\Delta\beta} = \frac{\lambda}{\Delta n}$$

Difference between propagation constant $\beta_x - \beta_y = 250$

$\lambda = 1.55\ \mu m$

Spectral width = 0.8 nm

$$\text{Modal Birefringence} = \beta_F = \frac{\beta_x - \beta_y}{(2\pi/\lambda)} = \frac{250}{(2\pi/1.55\mu)} = 61.67\times10^{-6}$$

Coherence length $= L_{bc} = \dfrac{\lambda^2}{\beta_F.\,\delta\lambda}$

λ : Wavelength = 1.55μm

Modal Birefringence $\beta_F = 61.67\times10^{-6}$

$\delta\lambda$: line width = 0.8nm

$$L_{bc} = \frac{1.55\times1.55\times10^{-12}}{61.67\times10^{-6}\times0.8\times10^{-9}}$$

$$L_{bc} = 48.69m$$

Beat Length $= L_B = \dfrac{\lambda}{\beta_F} = \dfrac{1.55\times10^{-6}}{61.67\times10^{-6}}$

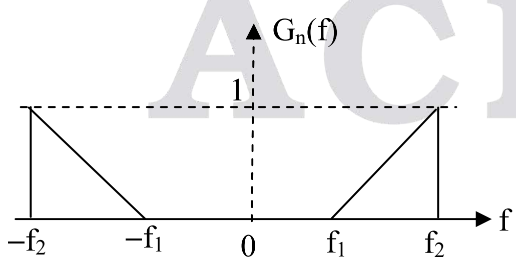
$L_B = 0.025 = 25\text{mm}$

02. (a) Narrow band noise n(t) having bandwidth 2B centered at f_0 is expressed as $n(t) = n_I(t)\cos(2\pi f_0 t) - n_Q(t)\sin(2\pi f_0 t)$, where $n_I(t)$ and $n_Q(t)$ are inphase and quadrature components respectively.

(i) Draw the block diagram of the scheme and show the extraction of $n_I(t)$ and $n_Q(t)$ from n(t). (6 M)

(ii) If $G_n(f)$ is power spectral density (PSD) of n(t), derive expressions in terms of $G_n(f)$ for PSD of $n_I(t)$ and $n_Q(t)$. (8 M)

(iii) If $G_n(f)$ is as shown, sketch PSD of $n_I(t)$ assuming $f_0 = f_1$. (6 M)

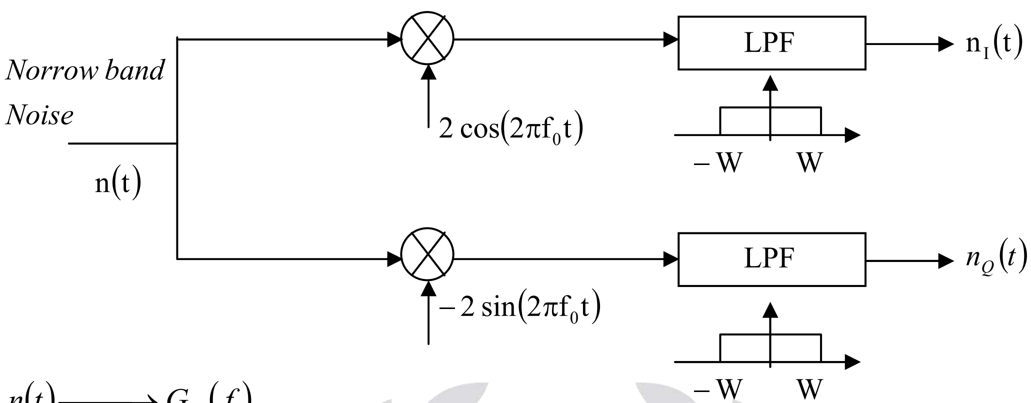


Sol: Narrow band noise $n(t) = n_I(t)\cos(2\pi f_o t) - n_Q(t)\sin(2\pi f_o t)$

$n_I(t)$: Inphase component

$n_Q(t)$: Quadrature component

(i)



(ii) $n(t)\xrightarrow[PSD]{} G_N(f)$

$n(t)=n_I(t)\cos(2\pi\ f_0 t)-n_Q(t)\sin\ (2\pi f_0 t)$

$\hat{n}(t)=n_I(t)\sin\ (2\pi f_0 t)+n_Q(t)\cos(2\pi f_0 t)$

$\hat{n}(t)$: Hilbert transform of n(t).

$n_I(t)=n(t)\cos\ (2\pi f_0 t)+\hat{n}(t)\sin\ (2\pi f_0 t)\qquad\rightarrow(1)$

$n_Q(t)=-n\ (t)\sin\ (2\pi f_0 t)+\hat{n}(t)\cos\ (2\pi f_0 t)\qquad\rightarrow(2)$

$n(t)\ \&\ \hat{n}(t)$ has same PSD ie., $G_N(f)$.

$$R_{NI}(T)=E[N_I(t)N_I(t+\tau)]$$

$$=E[(n(t)\cos(2\pi f_0 t)+\hat{n}(t)\sin(2\pi f_0 t))(n(t+T)\cos(2\pi f_0(t+\tau))+\hat{n}(t+\tau\ )\sin\ (2\pi f_0(t+\tau))]$$

$$=R_N(\tau)\cos(2\pi f_0\tau)\cos\ (2\pi f_0(t+\tau))-\hat{R}_N(\tau)\sin\ (2\pi f_0 t)\cos\ (2\pi f_0(t+\tau))$$

$$+\hat{R}_N(\tau)\cos\ (2\pi f_0 t)\sin\ (2\pi f_0(t+\tau))+R_N(\tau)\sin(2\pi f_0 t)\sin\ (2\pi f_0(t+\tau))$$

$$R_{N_I}(\tau)=R_N(\tau)\cos(2\pi f_0\tau)+\hat{R}_N(\tau)\sin(2\pi f_0\tau)$$

Similarly $R_{NQ}(\tau)=R_N(\tau)\cos(2\pi f_0\tau)+\hat{R}_N(\tau)\sin(2\pi f_0\tau)$

$$G_{N_I}(t)=G_{N_Q}(t)=FT\{R_{N_I}(\tau)\}$$

$$=\frac{G_N(f-f_o)+G_N(f+f_o)}{2}+-j\,\text{sgn}(f)\left(G_N(f)*\frac{s((f-f_0)-s(f+f_0))}{2j}\right)$$

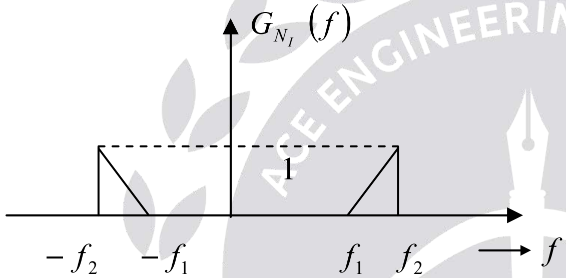
$$=\frac{G_N(f-f_0)+G_N(f+f_0)}{2}+\frac{1}{2}\text{sgn}(f+f_0)G_N(f+f_0)-\frac{1}{2}\text{sgn}\ (f-f_0)\,G_N(f-f_0)$$

$$=\frac{G_N(f-f_0)}{2}[1-\text{sgn}(f-f_0)]+\frac{G_N(f+f_0)}{2}[1+\sin(f+f_0)]$$

$$= \begin{cases} G_N(f-f_0) & f < -f_0 \\ G_N(f-f_0)+\frac{1}{2}G_N(f+f_0), & f = f_0 \\ G_N(f-f_0)+G_N(f+f_0); & |f| < f_0 \\ G_N(f+f_0)+\frac{1}{2}G_N(f-f_0), & f = f_0 \\ G_N(f+f_0), & f > f_0 \end{cases}$$

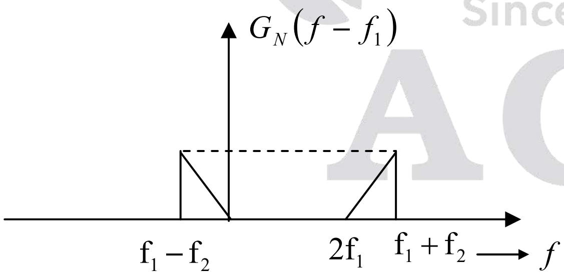
$$\therefore G_{NI}(t) = G_{NQ}(t) = \begin{cases} G_N(f-f_0)+G_N(f+f_0) & |f| < f_0 \\ 0 & elsewhere \end{cases}$$

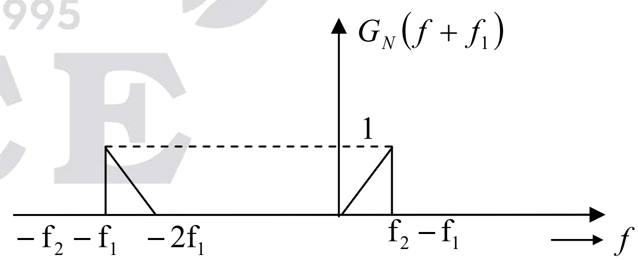
(iii)

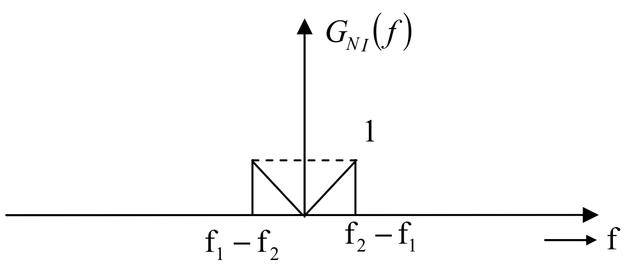


PSD of $n_I(t) = G_{N_I}(f) = G_N(f-f_0)+G_N(f+f_0), \quad |f| < f_0$

$f_0 = f_1$







02. (b) For a unity feedback system with $G(s) = \frac{3s+\alpha}{s(s+1)(s+5)}$, draw the root locus plot as parameter α varies from 0 to ∞. Also find the value of parameter α for which the closed loop system becomes unstable. From the root locus plot, obtain approximate location of the system poles with ξ = 0.707. (20 M)

Sol: $G(s) = \frac{3s+\alpha}{s(s+1)(s+5)}, H(s) = 1$

$$\xrightarrow{CE} 1 + G(s) = 0$$

$$1 + \frac{3s+\alpha}{s(s+1)(s+5)} = 0$$

$$s^3 + 6s^2 + 5s + 3s + \alpha = 0$$

$$s^3 + 6s^2 + 8s + \alpha = 0$$

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

$$G(s) = \frac{\alpha}{s(s+2)(s+4)}, H(s) = 1$$

Root Locus:

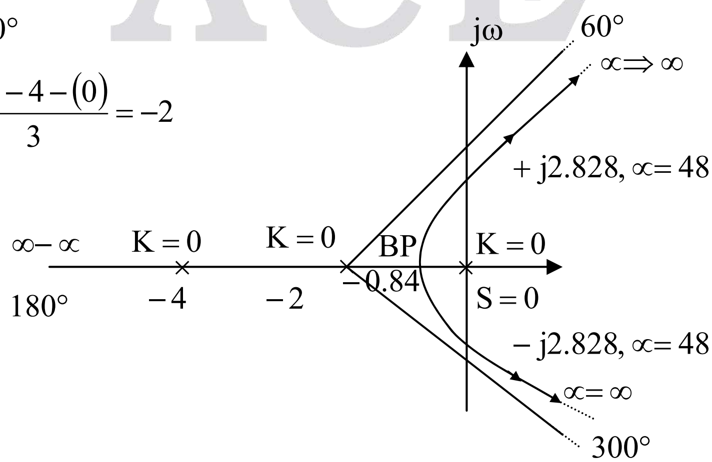
Number of root locus branches $= 3(P > z)$

Number of asymptotes N=P-Z=3

Angles of asymptotes $\theta = \frac{(2q+1)180^\circ}{(P-Z)}, q = 0,1,2$

$\theta = 60^\circ, 180^\circ, 300^\circ$

Centroid $\sigma = \frac{-2-4-(0)}{3} = -2$



Break Point $\frac{d\alpha}{ds}=0$

$CE: s^3+6s^2+8s+\alpha=0$

$\alpha=-s^3-6s^2-8s$

$\frac{d\alpha}{ds}=-3s^2-12s-8=0$

$s_1, s_2=-0.845, -3.154$

Valid break point $\delta=-0.845$

Intersection point with imaginary axis:

$\xrightarrow{CE} s^3+6s^2+8s+\alpha=0$

s^3	1	8
s^2	6	α
s^1	$\frac{48-\alpha}{6}$	
s^0	α	

For marginal stability

$\frac{48-\alpha}{6}=0 \Rightarrow \alpha=48$

$AE: 6s^2+48=0$

$s^2+8=0$

$s=\pm j\sqrt{8}=\pm j\,2.828$

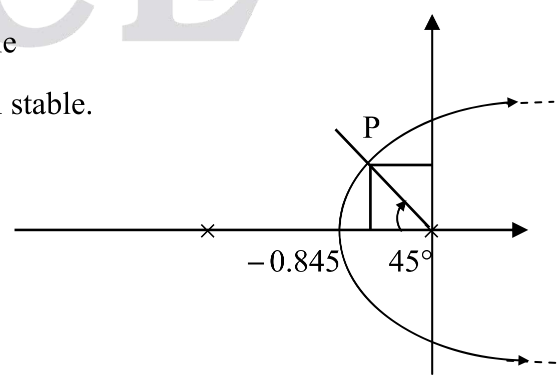
$\alpha>48$, the closed loop system is unstable

$0<\alpha<48$, the closed loop system is stable

$\alpha=48$, the closed loop system is marginal stable.

$\Rightarrow Given \quad \alpha=0.707$

$\theta=\cos^{-1}(\alpha)=\cos^{-1}(0.707)=45°$



$CE \quad s^3+6s^2+8s+\alpha=0$

$s=R<135°$

$CE: R^3<45°+6R^2<270°+8R<135°+2=0$

$$R^3\left(\frac{1}{\sqrt{2}}+j\frac{1}{2}\right)+6R^2(-j1)+8R\left(-\frac{1}{\sqrt{2}}+\frac{j}{\sqrt{2}}\right)+\alpha=0$$

Separate the real & imaginary parts and equating each to zero.

$$\frac{R^3}{\sqrt{2}}-\frac{8R}{\sqrt{2}}+\alpha=0 \ \& \ \frac{R^3}{\sqrt{2}}-6R^2+\frac{8R}{\sqrt{2}}=0$$

$$\alpha=\frac{8R}{\sqrt{2}}-\frac{R^3}{\sqrt{2}} \ \& \ R\left(R^2-8.485R+8\right)=0$$

$R=7.404$ *and* 1.08

$$\Rightarrow when\ R=7.404 \Rightarrow \alpha=\frac{8\times 7.404}{\sqrt{2}}-\frac{7.404^3}{\sqrt{2}}=-245.11$$

$$\Rightarrow when\ R=1.08 \Rightarrow \alpha=\frac{8\times 108}{\sqrt{2}}-\frac{1.08^3}{\sqrt{2}}=5.218$$

complex poles when $\alpha=5.218$ are $1.08<\pm 135°$

$1.08(-0.707\pm j0.707)=(-0.7636\pm j0.7636)$

02. (c) Memory sub-system for a product has been designed with 3-level memory hierarchy within a budget of 22,000 rupees. The known and unknown parameters for the design are tabulated below.

Memory	Access Time	Capacity	Cost per kilobyte in rupees
Cache	5ns	1MB	1
Main Memory	-	128 MB	0.1
Solid State Drive (SSD)	5μs	-	0.001

The design achieved an effective memory access time of 20 ns with cache hit ratio 0.95 and main memory hit ratio 0.99. The SSD can be only in integer powers of 2 in GB.

Find out the missing parameters in the above table. (20 M)

Sol: Calculation of capacity for SSD:

Total budget = 22000 rs

Cache = 1MB – cost per KB = 1

So, for 1MB – 1000rs

Main memory – 128MB – Cost per KB = 0.1

So, for 1MB = 1000 × 0.1 = 100rs

and 128MB = 100 × 128 = 12800rs

So, total remaining for SSD

= 22000 – (12800+1000)

= 8200

Cost per KB = 0.001rs

Which means 1GB = 1000rs

So, maximum we can have with integer power of 2 in GB

is 8GB – 8000rs

which is 2^{33} bytes

Calculation of main memory access time:

Let main memory access time = x nsec

effective memory access time = 20 nsec

$20 = 0.95 \times 5 + 0.05 \times 0.99 \times (5 + x) + 0.05 \times 0.01 \times (5 + x + 5000)$

$\Rightarrow 15.25 = 0.2475 + 0.0495x + 2.5025 + 0.0005x$

$\Rightarrow 0.05x = 12.5$

$\Rightarrow \boxed{x = 250 \text{ nsec}}$

↑

By this we can fill both the required fields.

03. (a) In a particular AM system, quadrature modulation is used where the inphase carrier modulates ($m_1(t) + V_0$) and quadrature carrier modulates $m_2(t)$, where $m_1(t)$ and $m_2(t)$ are low pass band-limited message signals and V_0 is constant

(i) Write the expression for quadrature AM signal (4 M)

(ii) Assuming V_0 is large, show that $m_1(t)$ can be recovered using envelope detector. (8 M)

(iii) Propose a coherent demodulation scheme and show the recovery of $m_2(t)$. (8 M)

Sol:

Inphase carrier modulates $(m_1(t)+V_0)$

Quadrature carrier modulates $m_2(t)$

$m_1(t), m_2(t)$ low pass band limited message signals

Where V_0 *is* constant

(i) $S_{AM}(t) = (m_1(t) + V_0)\cos(2\pi f_c t) + m_2(t)\sin(2\pi f_c\ t)$

(ii) Output of Envelope of detector for the input of

$A\cos\theta - B\sin\theta$ is $\sqrt{A^2 + B^2}$

Output of Envelope detector for the input of $S_{AM}(t)$ is,

$$\sqrt{(m_1(t) + V_0)^2 + m_2^2(t)}$$

Assuming V_0 is large, $m_1(t) + V_0 >> m_2(t)$

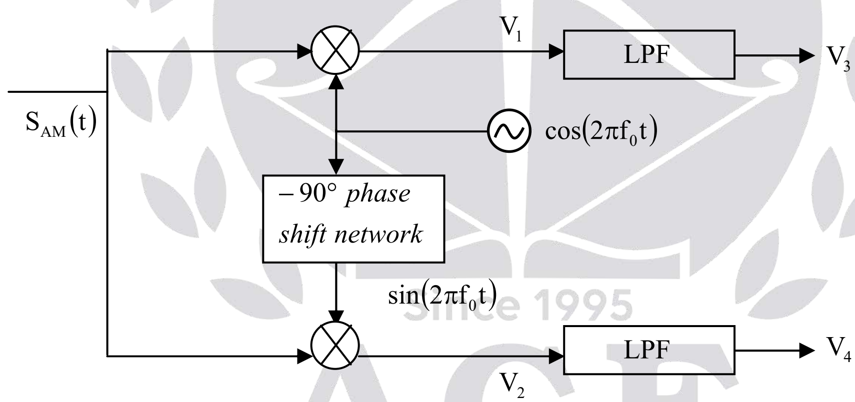
Output of envelope detector can be approximated as

$$\sqrt{(m_1(t) + v_0)^2} = m_1(t) + V_0$$

Output contains message $m_1(t)$ & constant V_0, which can be eliminated by dc blocking capacitor

$\therefore$ Output of envelope detector $m_1(t)$

(iii) Coherent demodulation



$$V_2 = S_{AM}(t)\sin(2\pi f_0 t)$$

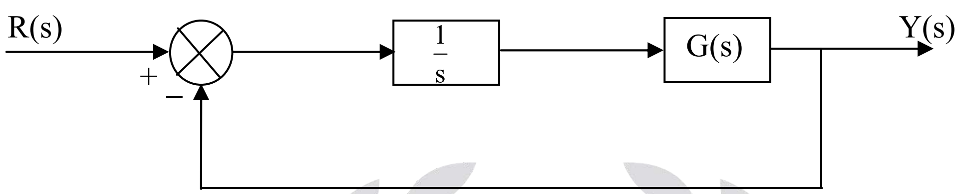
$$= [(m|t| + V_0)\cos(2\pi f_0 t) + m_2(t)\sin(2\pi f_0 t)]\sin(2\pi f_0 t)$$

$$= (m_1(t) + V_0)\frac{1}{2}\sin(4\pi f_0 t) + \frac{1}{2}m_2(t)[1 - \cos(4\pi f_0 t)]$$

Output of LPF eliminates $'2f_0'$ *terms*

$$\Rightarrow V_4 = \frac{1}{2}m_2(t)$$

03. (b) For the unity feedback system in the figure, the plant G(s) has a step response of $(3 - 6e^{-2t} + 3e^{-4t})u(t)$ and it is placed in cascade with a block of gain $\frac{1}{s}$. Sketch the Nyquist plot of the system and find its gain and phase margins. Also comment whether the closed loop system is stable or not. (20 M)



Sol: Step response of $G(s) \Rightarrow (3 - 6e^{-2t} + 3e^{-4t})u(t)$

$$TF\ G(s) = \frac{L[3 - 6e^{-2t} + 3e^{-4t}]}{L[u(t)]} = \frac{\frac{3}{s} - \frac{6}{s+2} + \frac{3}{s+4}}{\frac{1}{s}} = \frac{\frac{3(s+2)(s+4) - 6s(s+4) + 3s(s+2)}{s(s+2)(s+4)}}{\frac{1}{s}}$$

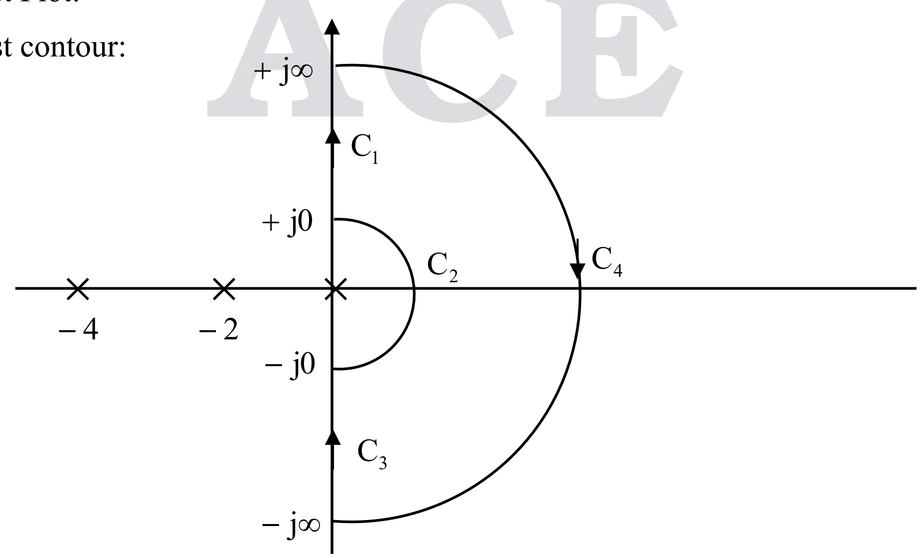
$$= \frac{3(s^2 + 6s + 8) - 6s^2 - 24s + 3s^2 + 6s}{(s+2)(s+4)} = \frac{3s^2 + 18s + 24 - 6s^2 - 24s + 3s^2 + 6s}{(s+2)(s+4)}$$

$$G(s) = \frac{24}{(s+2)(s+4)}, \quad G_c(s) = \frac{1}{s}$$

Forward path transfer function $= \dfrac{24}{s(s+2)(s+4)}$

Nyquist Plot:

Nyquist contour:



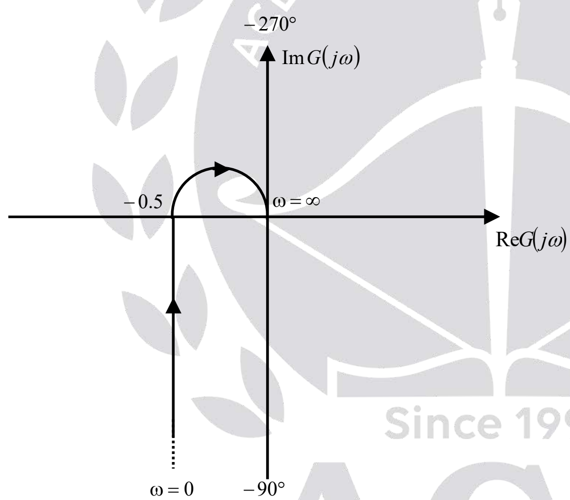
Mapping of section C_1: In section C_1, ω varies from 0 to ∞

$$G(j\omega)=\frac{24}{(j\omega)(j\omega+2)(j\omega+4)},\ H(j\omega)=1$$

$$|G(j\omega)|=\frac{24}{\omega\sqrt{\omega^2+4}\ \sqrt{\omega^2+16}}$$

$$<G(j\omega)=-90°-\tan^{-1}\left(\frac{\omega}{2}\right)-\tan^{-1}\left(\frac{\omega}{4}\right)$$

ω	$\lvert G(j\omega)\rvert$	$<G(j\omega)$
0	∞	-90°
∞	0	-270°



Intersection point with -180°

$$<G(j\omega)=-180°$$

$$-180°=-90°-\tan^{-1}\left(\frac{\omega}{2}\right)-\tan^{-1}\left(\frac{\omega}{4}\right)$$

$$90°=\tan^{-1}\left(\frac{\omega}{2}\right)+\tan^{-1}\left(\frac{\omega}{4}\right)$$

$$90°=\tan^{-1}\left(\frac{\frac{\omega}{2}+\frac{\omega}{4}}{1-\frac{\omega^2}{8}}\right)$$

$\omega = \sqrt{8}$ rad/sec

$$\left|G(j\omega)\right|_{\omega=\sqrt{8}} = \frac{24}{\sqrt{8}\sqrt{8+4}\,\sqrt{8+16}} = 0.5$$

Intersection point with $-180°$ is $(-0.5, j0)$

mapping of section C_2:It is the radius 'ε' semicircle and angle between -90° to +90°. Substitute $S = \varepsilon e^{j\theta}$ where $\varepsilon \Rightarrow 0$ and $\theta \Rightarrow -90°$ to $+90°$

$$G\left(\varepsilon\, e^{j\theta}\right) = \underset{\substack{\varepsilon\Rightarrow 0 \\ \theta\Rightarrow -90° \text{ to } +90°}}{\text{Lt}} \left(\frac{24}{\left(\varepsilon e^{-j\theta}\right)\left(\underset{0}{\not\varepsilon} e^{j\theta}+2\right)\left(\underset{0}{\not\varepsilon} e^{j\theta}+4\right)}\right)$$

$$= \underset{\substack{\varepsilon\Rightarrow 0 \\ \theta\Rightarrow -90° \text{ to } +90°}}{\text{Lt}} \frac{24}{8\left(\varepsilon e^{-j\theta}\right)} = \underset{\substack{\varepsilon\Rightarrow 0 \\ \theta\Rightarrow -90° \text{ to } +90°}}{\text{Lt}} \left(\frac{3}{\varepsilon}\right) < -\theta$$

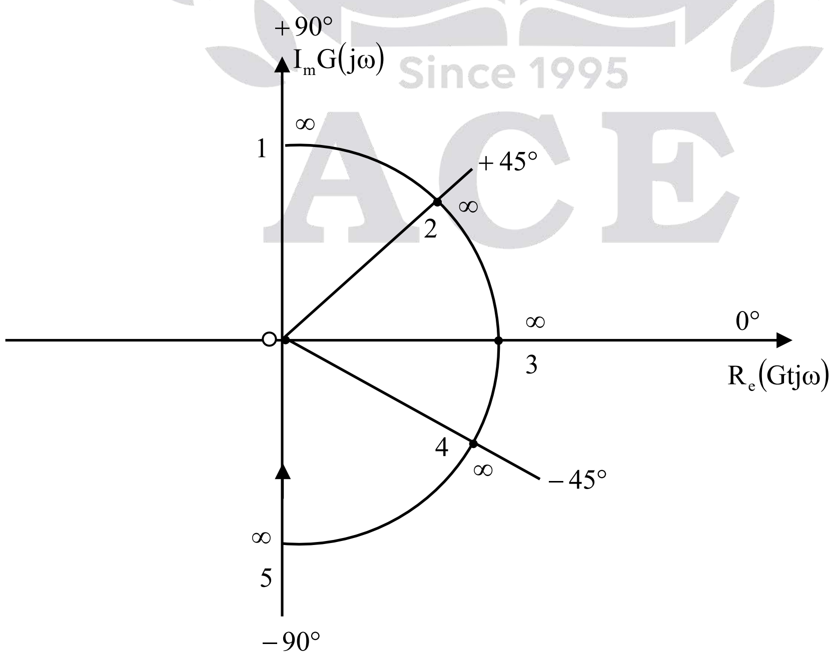
when $\theta = -90°\ \infty < +90°$

$\theta = -45°\ \infty < +45°$

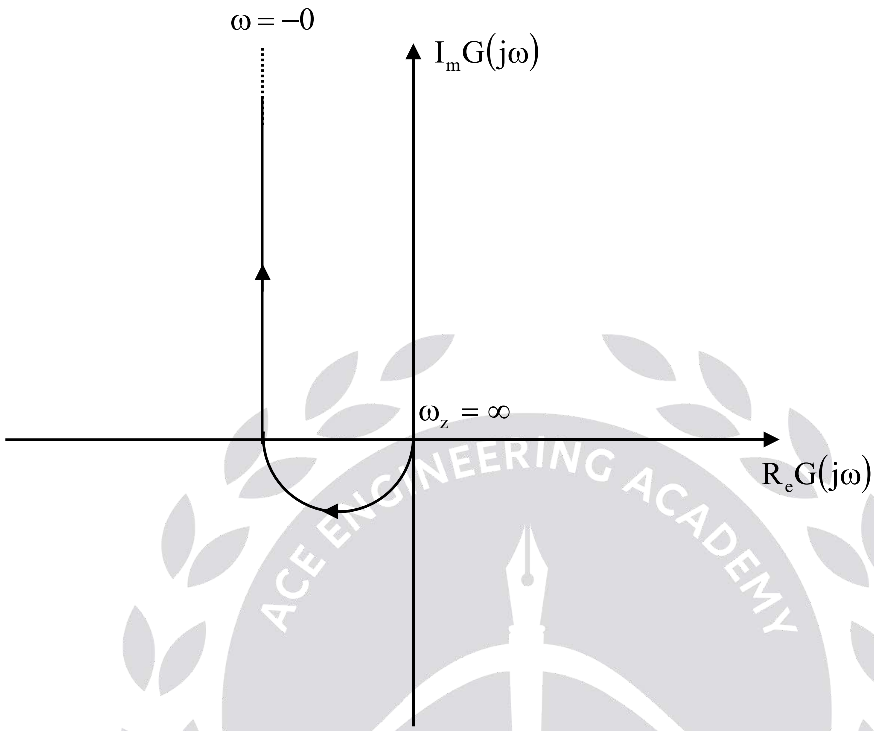
$\theta = 0°\ \infty < 0°$

$\theta = +45°\ \infty < -45°$

$\theta = +90°\ \infty < -90°$

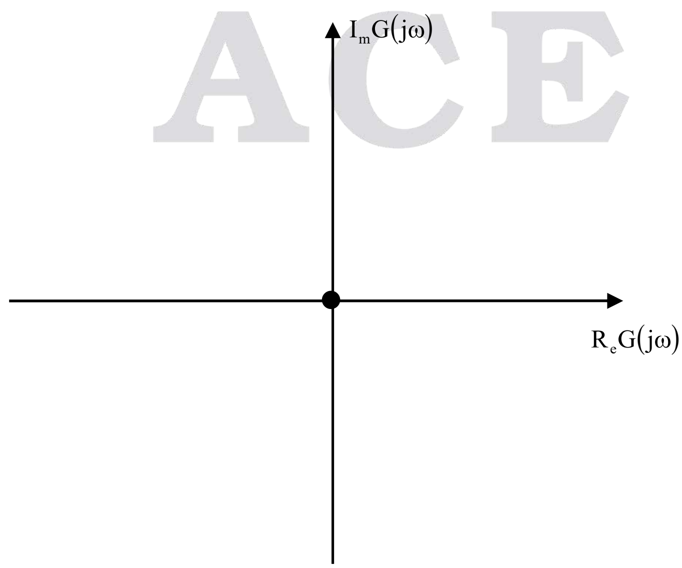


Mapping of section C_3 : it is mirror image of section C_1

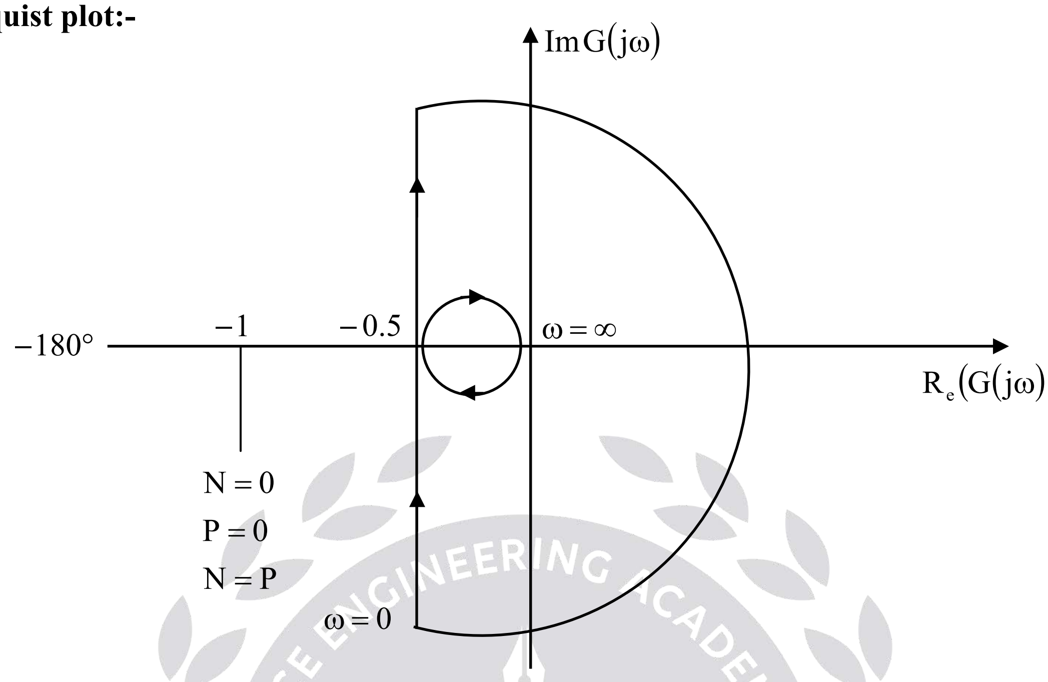


Mapping of section C_4 : It is a infinite radius semi-circle. Hence substitute $s = R\,e^{j\theta}$ where $R = \infty$ & $\theta = +90°$ to $-90°$.

$$G\left(Re^{-j\theta}\right) = \underset{\substack{R=\infty \\ \theta \Rightarrow +90° \text{ to } -90°}}{Lt} \left(\frac{24}{\left(Re^{j\theta}\right)\left(Re^{j\theta}+2\right)\left(Re^{j\theta}+4\right)}\right) = 0$$



Nyquist plot:-



$N = P \longrightarrow$ closed loop system is stable.

Gain margin $\Rightarrow |G(j\omega)|_{\omega_{pc}=\sqrt{8}} = 0.5$

$$GM = \frac{1}{|G(j\omega)|_{\omega_{pc}}} = \frac{1}{0.5} = 2$$

$$GM(dB) = -20\log(0.5) = +6dB$$

Phase margin:

$$|G(j\omega)|_{\omega_{gc}} = 1$$

$$\frac{24}{\omega\sqrt{\omega^2+4}\,\sqrt{\omega^2+16}} = 1$$

$$\omega\sqrt{\omega^2+4}\,\sqrt{\omega^2+16}$$

$$\omega\sqrt{\omega^2+4}\sqrt{\omega^2+16} = 24$$

$$\omega^2(\omega^2+4)(\omega^2+16) = 576$$

$$\omega^6 + 20\omega^4 + 64\omega^2 - 576 = 0$$

$\omega_{gc} = 1.93\ r/sec$

$PM = 180° + \angle G(j\omega)|_{\omega_{gc}}$

$$PM = 180° + \left[-90° - \tan^{-1}\left(\frac{\omega}{2}\right) - \tan^{-1}\left(\frac{\omega}{4}\right)\right]_{\omega=\omega_{gc}}$$

$$PM = 180° - 90° - \tan^{-1}\left(\frac{1.93}{2}\right) - \tan^{-1}\left(\frac{1.93}{4}\right)$$

$PM = 20.26°$

Closed loop system is stable.

03. (c) Design a 4-bit arithmetic circuit with one selection variable s and two four-bit inputs A and B. The circuit generates the following four arithmetic operations in conjunction with the input carry C_{in}. Draw the logic diagram for the following.

S	$C_{in} = 0$	$C_{in} = 1$
0	D = A + B	D = A – B
1	D = A + 1	D = A – 1

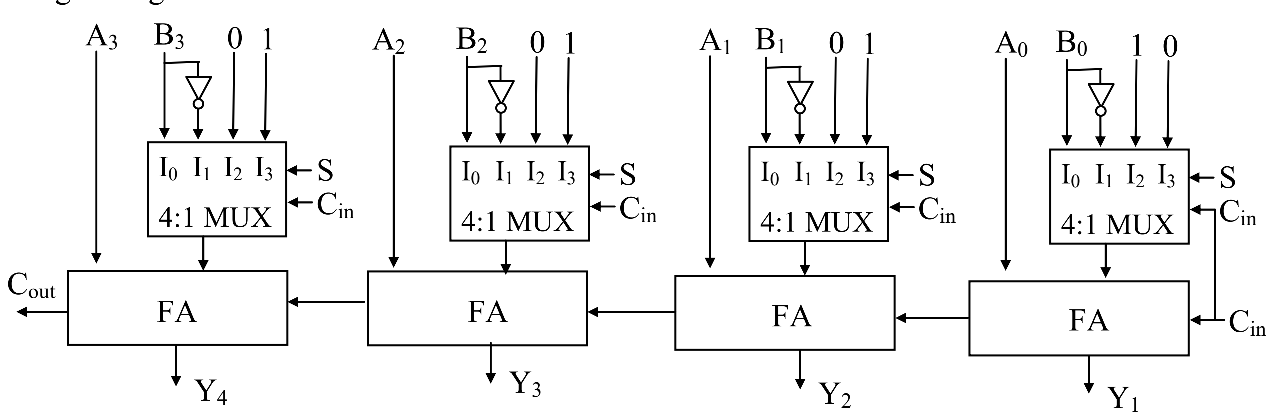
(20 M)

Sol:

S	C_{in}	Operation		Adder Inputs
0	0	A + B	→	A, B Inputs
0	1	A – B	→	A, $\overline{B}$, $C_{in} = 1$ Inputs
1	0	A + 1	→	A, 0001, $C_{in} = 0$
1	1	A – 1	→	A, 1110, $C_{in} = 1$; A + 1111 = A – 1

FA adds $A + B + C_{in}$

Logic Diagram:



04. (a) Twelve different audio signals each band-limited to 10kHz are to be multiplexed and transmitted.

(i) TDM is used with flat top samples of 1 μsec duration and with provision of one extra pulse of 1 μsec duration for synchronization. If sampling is at Nyquist rate, calculate the spacing between successive samples of TDM signal. What is the bandwidth of this TDM signal?

(ii) If the audio signals are multiplexed using FDM and transmitted using AM - SSB, what is the minimum bandwidth required? (20 M)

Sol:

(i) N = 12

$f_m = 10\ kHz$

Sampling is nyquist rate

Sampling rate 20 kHz

Since sampling rate 20000 samples per sec, period of time between sets of samples is $\frac{1}{20000}$ s

$= 50\mu$ sec.

Sample of each of 12 audio signals is sent over the period. Each of sample has a 1μsec & synchronizing pulse 1μsec thus 13 pulses has to sent over 50 μsec can allocate $50\mu/13 = 3.846\ \mu s$ for each pulse.

Spacing between successive samples = $3.846\mu s - 1\mu sec = 2.846\mu s$

(ii) $BW_{FDM} = 12 \times 10 kHz = 120\ kHz$

04. (b) Given a system transfer function $G(s) = \frac{10}{(s+1)(s+4)}$, **find the equivalent state space phase variable canonical representation in the form** $\dot{x} = Ax + Bu,\ y = Cx + Du.$ **Also design a state feedback controller u = Kx such that the system admits a peak response M_{pw} = 1.25 in frequency domain and a peak time t_p = 3.53 seconds in time step response.**

(20 M)

Sol: $G(s)=\dfrac{10}{(s+1)(s+4)}$

Transfer function $G(s)=\dfrac{y(s)}{u(s)}=\dfrac{10}{s^2+5s+4}$

$$\frac{y(s)}{u(s)}=\frac{10}{5^2+5s+4}.\frac{x(s)}{x(s)}$$

Equation u(s) can be written as

$$u(s)=(s^2+5s+4)x(s)$$

$$u(s)=s^2x(s)+5sx(s)+4x(s)$$

Apply inverse laplace transform

$$u=\ddot{x}+5\dot{x}+4x \qquad -(1)$$

$$Let\ \ x=x_1 \qquad -(2)$$

$$\dot{x}_1=\dot{x}=x_2 \qquad -(3)$$

$$\dot{x}_2=\ddot{x} \qquad -(4)$$

Substitute (2), (3) & (4) in (1)

$$U=\dot{x}_2+5x_2+4x_1$$

$$\dot{x}_2=u-4x_1-5x_2 \qquad -(5)$$

Equation (2), (3) & (5) in matrix form

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix}=\begin{bmatrix}0 & 1\\ -4 & -5\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}0\\ 1\end{bmatrix}[U]$$

Equation Y(s) can be written as

$$Y(s)=10x(s)$$

Apply inverse laplace transform

$$\Rightarrow y=10x\Rightarrow y=10x_1 \qquad -(6)$$

In matrix form

$$[Y]=[10\quad 0]\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

Peak response in frequency domain $M_{pw} = 1.25$

Peak time $t_p = 3.53\,\text{sec}$

$$M_{p\omega} = \frac{1}{2\xi\sqrt{1-\xi^2}} = 1.25$$

$$1.25 = \frac{1}{2\xi\sqrt{1-\xi^2}}$$

$$1.5625 = \frac{1}{4\xi^2(1-\xi^2)}$$

$$1.5625 = \frac{1}{4\xi^2 - 4\xi^4}$$

$$6.25\xi^2 - 6.25\xi^4 - 1 = 0$$

$$-6.25\xi^4 + 6.25\xi^2 - 1 = 0$$

$$\xi = 0.89,\ 0.44$$

Valid ξ is less than 0.707

$$\xi = 0.44$$

$$t_p = 3.53 = \frac{\pi}{\omega_d} = \frac{\pi}{\omega_n\sqrt{1-\xi^2}}$$

$$3.53 = \frac{\pi}{\omega_n\sqrt{1-0.44^2}} \Rightarrow \omega_n = \frac{\pi}{3.53\sqrt{1-0.44^2}} = 0.99\ r/s$$

Characteristic equation $\Rightarrow [SI - A_C] = 0$

$$[Ac] = [A - BK]\ where\ K = [K_1 \quad K_2]$$

$$[Ac] = \begin{bmatrix} 0 & 1 \\ -4 & -5 \end{bmatrix} - \begin{bmatrix} 0 \\ 1 \end{bmatrix}[K_1 \quad K_2]$$

$$= \begin{bmatrix} 0 & 1 \\ -4 & -5 \end{bmatrix} - \begin{bmatrix} 0 & 0 \\ K_1 & K_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -4-K_1 & -5-K_2 \end{bmatrix}$$

$$CE \Rightarrow |SI - Ac| = 0 \Rightarrow \begin{bmatrix} s & -1 \\ 4+K_1 & s+5+K_2 \end{bmatrix} = 0$$

$$\xrightarrow{CE} s[s+5+K_2] + (4+K_1) = 0$$

$$s^2 + 5s + K_2S + 4 + K_1 = 0$$

$$s^2 + s(5 + K_2) + (4 + K_1) = 0$$

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

$$\Rightarrow \omega_n^2 = 4 + K_1$$

$$0.99^2 = 4 + K_1 \Rightarrow K_1 = -3.0199$$

$$\Rightarrow 2\xi\omega_n = 5 + K_2$$

$$\Rightarrow 2 \times 0.44 \times 0.99 = 5 + K_2$$

$$0.8712 = 5 + K_2 \Rightarrow K_2 = -4.1288$$

$$[K] = [-3.0199 \quad -4.1288]$$

04. (c) Following Register Transfer statements provide the operations to be performed with flip-flop F:

$X_1T_1 : F \leftarrow 0$

$X_2T_2 : F \leftarrow 1$

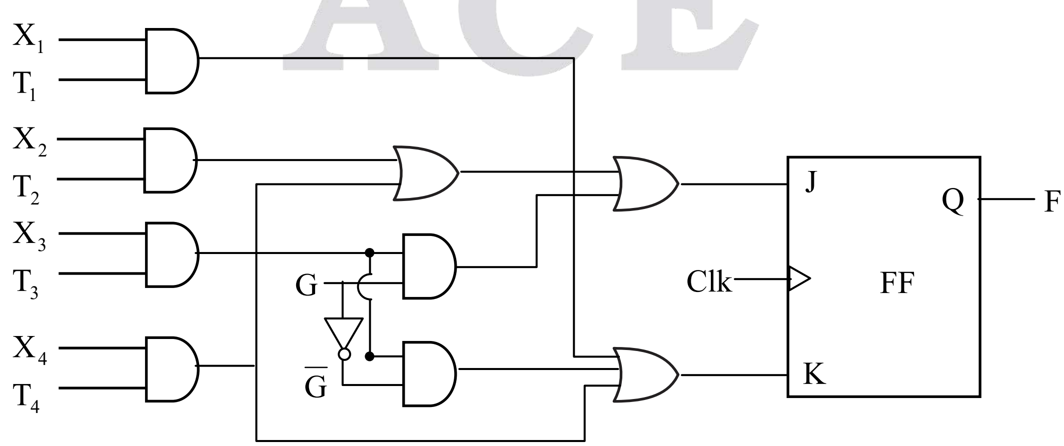
$X_3T_3 : F \leftarrow G$

$X_4T_4 : F \leftarrow \overline{F}$

In all other conditions, the contents of F do not change. Using J-K flip-flops, draw the logic diagram showing connections of the gates that implement control function for F.

(20 M)

Sol:



SECTION - B

05. (a) Band-limited message signal m(t) is encoded using PCM system which uses uniform quantizer and 8-bit binary encoding. If the bit rate is 56 Mb/sec, what is the maximum bandwidth of m(t) for satisfactory operation ?

Calculate signal to quantization noise ratio if m(t) is full load single tone sinusoidal signal of frequency 1 MHz. (10 M)

Sol: $n = 8$

$r_b = 56 \text{ Mbps} = n\, f_s$

$f_s = 56M/8 = 7Msps$

$f_s = 2f_m$

Maximum bandwidth of $m(t)$, for satisfactory operation $= 2f_m = f_s$

$f_m = f_s/2 = 3.5\ MHz$

$\text{SQNR, dB} = (6n + 1.8)$

$= 6 \times 8 + 1.8$

$= 49.8 \text{ dB}$

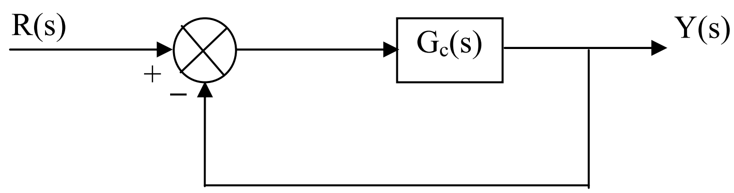
05. (b) For a unity feedback system shown in the figure, $G(s) = \dfrac{K}{s(s+\alpha)}$ **has resonant frequency 'ω_r' which is $\dfrac{1}{\sqrt{2}}$ times the damped frequency 'ω_d'. G(s) also has a setting time of $2\sqrt{3}$ seconds, for a 2% tolerance band in its time step response. Calculate the following:**

(i) Undamped natural frequency

(ii) Decay rate

(iii) Peak overshoot

(iv) Steady state error for the input r(t) = t u(t)



(10 M)

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

$$\Rightarrow \omega_r = \frac{1}{\sqrt{2}}\omega_d \text{ r/sec}$$

$$\omega_n\sqrt{1-2\xi^2} = \frac{1}{\sqrt{2}}\omega_n\sqrt{1-\xi^2}$$

$$\sqrt{2}\sqrt{(1-2\xi^2)} = \left(\sqrt{1-\xi^2}\right)$$

$$\Rightarrow 2(1-2\xi^2) = (1-\xi^2) \Rightarrow (2-4\xi^2) = (1-\xi^2)$$

$$\Rightarrow 2-4\xi^2-1+\xi^2 = 0 \Rightarrow 1-3\xi^2 = 0 \Rightarrow \xi = \frac{1}{\sqrt{3}}$$

$$\Rightarrow t_s = 2\sqrt{3} = \frac{4}{\xi\omega_n} \Rightarrow 2\sqrt{3} = \frac{4}{0.577\omega_n}$$

$$\Rightarrow \omega_n = \frac{4}{0.577\times 2\sqrt{3}} = 2 \text{ rad/sec}$$

$$\text{CLTF} = \frac{K}{s^2+\propto s+\mu}$$

$$\omega_n = \sqrt{K} \Rightarrow K = \omega^2 = 4$$

$$\alpha = 2\xi\omega_n = 2\times 0.577\times 2 = 2.3$$

$$\text{CLTF} = \frac{K}{s^2+\propto s+K} =$$

i. undammed natural frequency ω_n =2rad/sec

ii. Decay rate $= \xi\omega_n = \frac{1}{\sqrt{3}}\times 2 = 1.154 \sec$

iii. Peak overshoot $\Rightarrow m_p = e^{-\left(\pi\xi/\sqrt{1-\xi^2}\right)} = e^{-\left(\pi\times 0.577/\sqrt{1-0.577^2}\right)}$

$m_p = 0.1086$

$\%m_p = 10.86\%$

iv. e_{ss} *for* $r(t) = tu(t)$

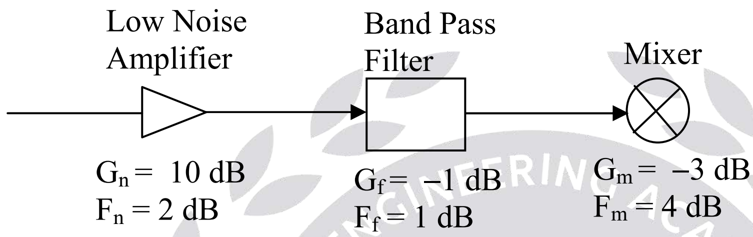
$$G(s) = \frac{K}{s(s+\alpha)} = \frac{4}{s(s+2.308)},\ H(s)=1$$

$$K_v = \underset{s\to 0}{Lt}\ SG(s) = \underset{s\to 0}{Lt}\ s\left(\frac{4}{s(s+2.308)}\right) = \frac{4}{2.308}$$

$$K_v = 1.733$$

$$e_{ss} = \frac{A}{K_v} = \frac{1}{1.733} = 0.577$$

05. (c) The block diagram of a wireless receiver front end is shown below:



(i) Compute the overall Noise Figure of the sub-system.

(ii) Compute equivalent noise temperature (overall) assuming system temperature T_0 = 290 K.

(iii) Compute overall gain.

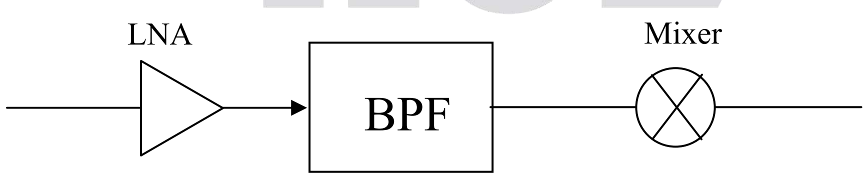
(iv) Compute output noise power assuming input noise power from the feeding antenna at 150 K temperature and 1 F.

(v) Bandwidth of 10MHz.

(vi) Compute input power if we require minimum signal to noise ratio of 20 dB.

(vii) Compute minimum signal voltage assuming characteristic impedance of 150 Ω. (10 M)

Sol:



$G_a = 10dB \quad G_f = -1dB \quad G_m = -3dB$

$F_a = 2dB \quad F_{ft} = 1dB \quad F_m = 4\ dB$

(i) $F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1\, G_2}$

$F_a = 1.58 = 10^{0.2},\ G_a = 10$

$F_f = 10^{0.1} = 1.25,\ G_f = 0.79$

$F_m = 10^{0.4} = 2.51, G_m = 0.5$

F, Overall noise Figure $= 1.58 + \frac{1.25 - 1}{10} + \frac{2.51 - 1}{10 \times 0.79}$

$F = 1.58 + 0.025 + 0.19 = 1.795$

F dB = 2.54 dB

(ii) $T_e = T_{e1} + \frac{T_{e_2}}{G_1} + \frac{T_{e_3}}{G_1 G_2}$

$T_{e_1} = T_0(F_1 - 1), T_{e_3} = T_0(F_3 - 1)$

$T_{e_2} = T_0(F_2 - 1)$

$T_{e_1} = 290(1.58 - 1) = 168.2$

$T_{e_2} = 290(1.25 - 1) = 72.5$

$T_{e_3} = 290(2.51 - 1) = 437.9$

$T_e = 168.2 + \frac{72.5}{10} + \frac{437.9}{10 \times 0.79}$

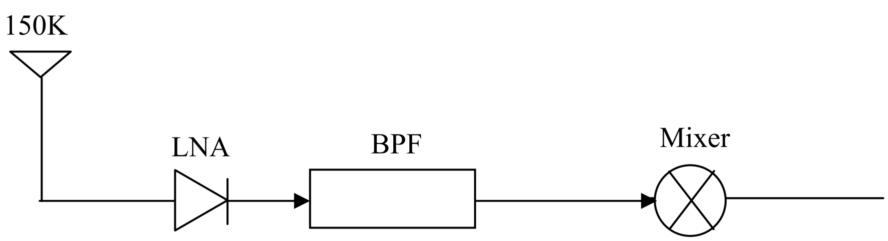
$= 168.2 + 7.25 + 55.43 = 230.88$

(iii) Overall gain $G = G_1 G_2 G_3$

$= 10 \times 0.79 \times 0.5 = 3.95$

$G = 10 \log 3.95 = 5.96$ dB

(iv)



Output noise power $= K\ T_e\ B\ G\ F$

$$= 1.38\times10^{-23}\times(230.88+150)\times10\times10^{6}\times3.95\times1.795$$

$$= 0.37\ pWatts$$

(vi) Minimum signal to noise ratio = 20dB = 100.

$$(SNR)_{I/P} = F(SNR)_{O/P}$$

$$= 1.795\times100 = 179.5$$

Input noise power = K TB

$$= 1.38\times10^{-23}\times380.88\times10\times10^{6}$$

$$= 525.61\times10^{-16}$$

Input signal power $= 179.5\times525.61\times10^{-16} = 9.4\,pW$

(vii) Minimum signal voltage $V = \sqrt{4\ KTBR}$

$$= \sqrt{4\times1.38\times10^{-23}\times380.88\times10\times10^{6}\times150}$$

$$= \sqrt{315368.64\times10^{-17}}$$

$$= 1.775\ \mu\,Volt.$$

05. (d) Normalised radiation intensity of an antenna is given by

$U_n(\theta) = 1,\ 0^o \le \theta < 30^o$

$$= \frac{\cos\theta}{0.866};\ 30^o \le \theta < 90^o$$

$$= 0;\ 90^o \le \theta \le 180^o$$

It is independent of Φ.

Determine exact directivity and maximum aperture area at operating frequency of 900 MHz.

(10 M)

Sol: $U_n(\theta) = 1 \quad 0 \le \theta \le 30^0$

$$= \frac{\cos\theta}{0.866};\ 30^0 \le \theta \le 90^0$$

$$= 0;\ 90^0 \le \theta \le 180^0$$

f = 900 MHz

Directivity:

$$D = \frac{4\pi}{\int_\theta\int_\phi [F(\theta,\phi)]^2 \sin\theta d\theta d\phi}$$

Where $[F(\theta,\phi)]^2 = u_n(\theta)$

$$D = \frac{4\pi}{\int_{\phi=0}^{2\pi} d\phi \underbrace{\int_\theta u_n(\theta)\sin\theta d\theta}_{Integral(I)}} = \frac{4\pi}{2\pi * I}$$

$$D = \frac{2}{I}$$

$$I = \int_\theta u_n(\theta)\sin\theta d\theta = \int_0^{30^0} (1)\sin\theta d\theta + \int_{30^0}^{90^0} \frac{\cos\theta}{0.866}\sin\theta d\theta$$

$$= (-\cos\theta)_0^{30^0} + \frac{1}{0.866}\left[\frac{\sin^2\theta}{2}\right]_{30^0}^{90^0}$$

$$= -\left[\frac{\sqrt{3}}{2} - 1\right] + \frac{1}{2\times 0.866}\left[1^2 - \left(\frac{1}{2}\right)^2\right]$$

$$= \left(1 - \frac{\sqrt{3}}{2}\right) + \frac{1}{2\times 0.866}\times\frac{3}{4} = 0.1339 + 0.433$$

I = 0.5669254041570438

$$D = \frac{2}{I} = \frac{2}{0.566925} = 3.527$$

D = 3.527

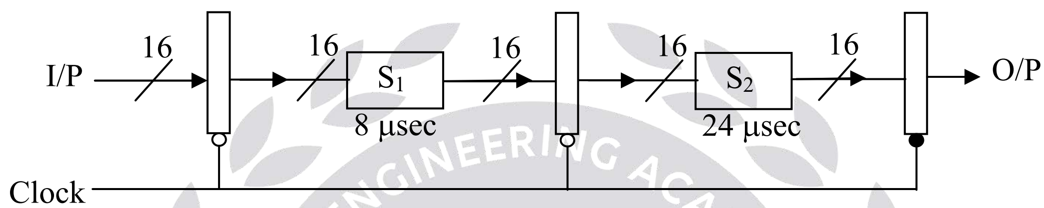
$$D = \frac{4\pi}{\lambda^2} A_e \qquad \lambda = \frac{c}{f} = \frac{3\times 10^8}{900\times 10^6} = \frac{1}{3}$$

$$A_e = \frac{D\lambda^2}{4\pi}$$

$$A_e = \frac{3.527}{4\pi} \times \frac{1}{9}$$

$A_e = 0.0311855\ m^2$

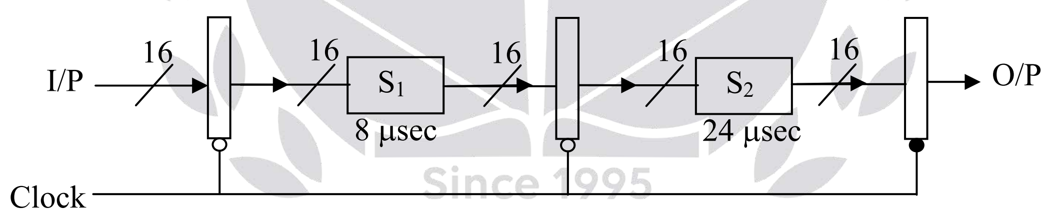
05. (e) The figure shown below indicates a two-stage pipeline with stage delays indicated below the stages. Latch delays are to be ignored.



(i) Calculate throughput and latency of the pipeline shown above. (5 M)

(ii) The pipeline stage 2 is now split in three equal sub-stages. Find out the new throughput and latency for the complete pipeline. (5 M)

Sol:



(i) Cycle time $\tau = \max(8, 24) + \text{Latch delay}$

$= 24 + 0\ \mu\text{sec}$

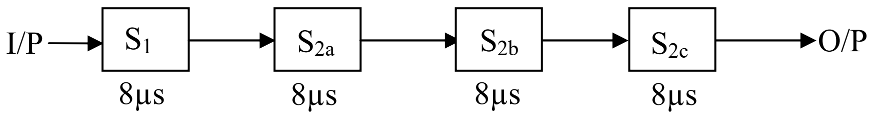
$= 24\mu\text{sec}.$

$$\text{Throughput} = \frac{1}{CT} = \frac{1}{24\times10^{-6}} = 0.0416\ \text{inst./}\mu\text{sec.}$$

Latency = time taken for pipeline to fill

$= 2.CT = 2\times24\mu s = 48\mu s.$

(ii) Stage 2 is split into 3 stages



Cycle Time, $\tau = \max\left(S_1,\ S_{2a},\ S_{2b},\ S_{2c}\right) + \text{latch delay}$

$\tau = 8\mu\text{sec} + 0\mu\text{sec} = 8\mu\text{sec}$

Throughput $= \dfrac{1}{\tau} = \dfrac{1}{8\times10^{-6}} = 0.125$ instruction/μsec

Latency $= 4\times\tau = 4\times8\ \mu\text{sec} = 32\ \mu\text{sec}$

05. (f) An isolator has an insertion loss of 0.5 dB and an isolation of 30 dB. Determine the scattering matrix of the isolator if the isolated ports are perfectly matched to the junction.

(10 M)

Sol: Given Isolator

Insertion loss of 0.5 dB

Isolation of 30dB

$L_{in} = -20\log|S_{21}| = 0.5\text{ dB}$

ISOLATOR $\begin{bmatrix} 0 & 0 \\ S_{21} & 0 \end{bmatrix}$

FOR MATCHED PORTS

$S_{11} = S_{22} = 0$

$$\log S_{21} = \frac{-0.5}{20} = -0.025$$

$$S_{21} = 10^{-0.025} = 0.944$$

$L_I = -20\log|S_{21}| = 30\text{ dB}$

$\log|S_{21}| = -1.5$

$S_{12} = 10^{-1.5} = 0.0316$

$$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \begin{bmatrix} 0 & 0.0316 \\ 0.944 & 0 \end{bmatrix}$$

06. (a) Lossless transmission line operating at 30 MHz has inductance L = 1 μH/m and capacitance C = 100 pF/m. Quarter wave transformer line is used to couple this transmission line to different loads for impedance matching.

(i) Calculate the characteristic resistance of the quarter wave line if load is an antenna offering pure resistance of 70 Ω. (8 M)

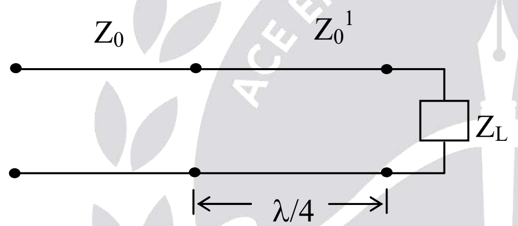
(ii) If load is Z_L = 150 + j100 Ω, determine the characteristic resistance of the quarter wave line. (12 M)

Sol: Given Loss less

f = 30MHz

L = 1μH/m

C = 100 pF/m



$$z_0 = \sqrt{\frac{L}{C}} = \sqrt{\frac{1\times10^{-6}}{100\times10^{-12}}} = \sqrt{\frac{10^6}{100}} = \sqrt{10^4} = 100\Omega$$

(i) If $Z_L = 70\Omega$

$$z_0^1 = \sqrt{z_0 z_L} = \sqrt{70\times100} = 10\times\sqrt{70}$$

$$z_0^1 = 83.66\Omega$$

(ii) If $z_L = 150 + j100\Omega$

$$z_0^1 = \sqrt{z_0 z_L} = \sqrt{100(150+j100)} = 10\sqrt{(150+j100)}$$

$$z_0' = 128.4 + j38.9$$

06. (b) Consider a CMOS schematic for 2-iput NOR gate.

Design appropriate test scheme to check the following faults through control/observation of voltage/current levels at input/Output/supply.

(i) One pMOS transistor stuck open (10 M)

(ii) One nMOS transistor stuck short (10 M)

Sol:

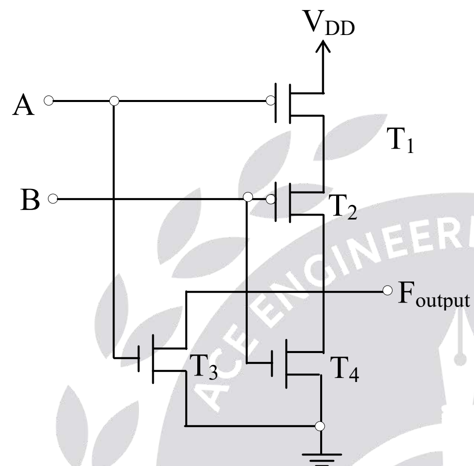


Figure: CMOS 2 – input NOR gate

(1) (i) Consider T stuck – open fault.

(ii) When A = 0 and B = 0, output F will be 1 in the absence of the fault.

(iii) In the presence of fault, the output is floating and voltage at F will depend on charge stored in load capacitor.

(iv) Apply two patters.

(a) A = 1, B = 0 to initialize f to 0

(b) A = 0, B = 0 to detect / sensitize the fault.

(2) (i) consider T_4 stuck – short fault.

(ii) When A = 0 and B = 0, output F will be 1 in the absence of the fault (pull up network conducts)

(iii) In presence of fault, the pull down network also starts conducting, resulting in high current from V_{DD} to GND.

Output F becomes intermediate value denoting neither one nor zero. Here fault is sensitized.

06. (c) Write the expression for signal to noise ratio for PIN diode. A silicon PIN photodiode incorporated into the optical receiver has a quantum efficiency of 65% when operating at wavelength of 0.9 μM. The dark current at this point is 3 nA and load resistance is 4 kΩ. The post detection bandwidth of the receiver is 5MHz and the thermal noise temperature is 20°C. If the overall signal to noise ratio is 5dB, calculate the incident power. (20 M)

Sol: $SNR_{PIN} = \dfrac{I_{ph}^2}{I_{n-s}^2}$

I_{ph} : (signal) photocurrent

I_{n-s} : Noise current

$\eta = 0.65$

$\lambda = 0.9\ \mu m$

$I_{dark} = 3nA = 3\times10^{-9}\ A$

$R_{Load} = 4k$

$B = 5MHz$

$T = 20$

Overall SNR = 5 dB

$SNR = 10^{0.5} = 3.16$

$\text{Input power} = P_0 = ?$

Overall SNR = 5 dB

$SNR = 10^{0.5} = 3.15$

$$\frac{I_{ph}^2}{I_{n-s}^2} = 3.15$$

$$I_{ph} = \eta\frac{P_0.q\lambda}{hc}$$

$$= 0.65\times\frac{P_0\ 1.6\times10^{-19}\times0.9\times10^{-6}}{6.62\times10^{-34}\times3\times10^{8}}$$

$I_{Ph} = 0.47\ P_o$

$$\text{Dark noise} = I_{n-d} = \sqrt{2q\ IB} = \sqrt{2\times1.6\times10^{-19}\times3\times10^{-9}\times5\times10^{6}}$$

$$= 6.92\times10^{-11}\ A$$

Shot Noise, $I_{n-s} = \sqrt{2q\, I_{ph} B} = \sqrt{2\times 1.6\times 10^{-19}\times 0.47\, P_o \times 5\times 10^{6}}$

$= 8.67\times 10^{-7}\times \sqrt{P_o}$

Johnson noise $= I_{n.-J} = \sqrt{4\, KTB\, R} = \sqrt{4\times 1.38\times 10^{-23}\times (20+273)\times 5\times 10^{6}\times 4\times 10^{3}}$

$= 17.98\times 10^{-6}$

$I^2_{n-noise} = I^2_{n-.d} + I^2_{n-.s} + I^2_{n.-J} = 47.88\times 10^{-22} + 75.17\times 10^{-14}\, P_o + 323.4\times 10^{-12}$

$\frac{I^2_{ph}}{I^2_{n.noise}} = 3.15$

$0.22\ P_0^2 = 3.15\left[32.34\times 10^{-11} + 75.17\times 10^{-14}\ P_o\right]$

$0.22\ P_0^2 = 10.18\times 10^{-10} + 236.785\times 10^{-14}\ P_o$

$P_0^2 - 1076.29\times 10^{-14}\ P_o - 46.27\times 10^{-10} = 0$

$P_0^2 - 0.11\times 10^{-10}\ P_o - 46.27\times 10^{-10} = 0$

$$P_o = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{0.11\times 10^{-10} \pm \sqrt{0.0121\times 10^{-20} + 4\times 46.27\times 10^{-10}}}{2}$$

$$= \frac{0.11\times 10^{-10} \pm 13.604\times 10^{-5}}{2}$$

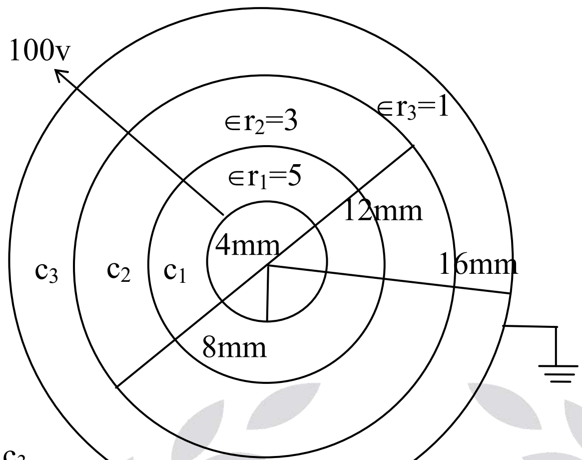
$P_o = 6.802\times 10^{-5}\ W$

Incident power $P_0 = 68.02\ \mu W$

07. (a) A coaxial capacitor of length 1 m is formed using two concentric cylindrical conductors. The inner conductor has radius 4 mm and the outer conductor radius is 16 mm. The space between them is filled with 3 layers of perfect dielectric materials with different dielectric constants such that $\varepsilon_{r_1} = 5, 4\,mm < \rho < 8mm;\ \varepsilon_{r_2} = 3, 8\,mm < \rho < 12mm$ **and** $\varepsilon_{r_3} = 1, 12\,mm < \rho < 16mm.$ **If the potential difference between the inner and outer conductor is 100 V, determine the capacitance and charge on the inner conductor** $(\varepsilon_0 = 8.854\times 10^{-12}\,F/m)$

(20 M)

Sol: $l = 1$ m



$c_{eq} = c_1 // c_2 // c_3$

$r_1 = 4$ mm

$r_2 = 8$ mm

$r_3 = 12$ mm

$r_4 = 16$ mm

$$c_{eq} = \frac{1}{\frac{1}{c_1}+\frac{1}{c_2}+\frac{1}{c_3}}$$

$$c_1 = \frac{2\pi \in l}{\ln\left(\frac{r_2}{r_1}\right)} \qquad c_2 = \frac{2\pi \in l}{\ln\left(\frac{r_3}{r_2}\right)} \qquad c_3 = \frac{2\pi \in l}{\ln\left(\frac{r_4}{r_3}\right)}$$

$$c_{cq} = \frac{1}{\frac{\ln(2)}{2\pi\in l}+\frac{\ln\left(\frac{3}{2}\right)}{2\pi\in l}+\frac{\ln\left(\frac{4}{3}\right)}{2\pi\in l}} = \frac{2\pi\in l}{\ln(2)+\ln\left(\frac{3}{2}\right)+\ln\left(\frac{4}{3}\right)} = \frac{2\pi\in_0 \ell}{\frac{\ln(2)}{\in_{r1}}+\frac{\ln\left(\frac{3}{2}\right)}{\in_{r2}}+\frac{\ln\left(\frac{4}{3}\right)}{\in_{r3}}}$$

$$= \frac{2\pi\in_0 \ell}{\frac{\ln(2)}{5}+\frac{\ln\left(\frac{3}{2}\right)}{3}+\frac{\ln\left(\frac{4}{3}\right)}{1}}$$

$c_{cq} = 99.08$pF

$$C = \frac{Q}{V}$$

$Q = 99.08\times10^{-12}\times100 = 99.08\times10^{-10}$C

07. (b) (i) The impulse response of an LTI system is given by

$$h(n) = \left[\left(\frac{1}{4}\right)^n \cos\left(\frac{\pi}{4}n\right)\right]u(n)$$

Realise this system using finite number of adders, multipliers and minimum possible unit delays. (10 M)

(ii) Consider an initially relaxed system whose output y(n) for n ≥ 0 is the Fibonacci series. Describe this system in the form of difference equation relating input and output. Obtain impulse response of this system. (10 M)

Sol: (i). $h(n) = \left(\frac{1}{4}\right)^n cos\left(\frac{\pi n}{4}\right)u(n)$, Let $x(n) = \left(\frac{1}{4}\right)^n u(n)$

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

Apply z-transform

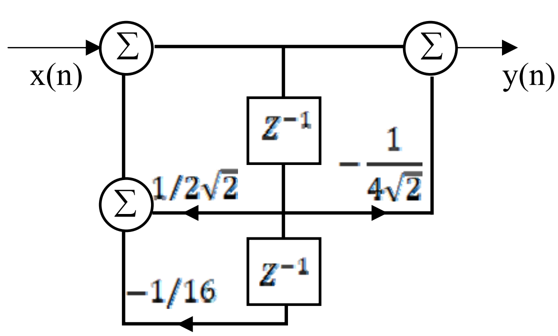
$$\left[X(z) = \frac{1}{1-\frac{1}{4}z^{-1}}\right]\left[a^n u(n) \xrightarrow{Z.T} \frac{1}{1-az^{-1}}\right]\left[\alpha^n x(n) \longrightarrow X(z/\alpha)\right]$$

$$H(z) = \frac{X(z/e^{j\pi/4}) + X(z/e^{-j\pi/4})}{2} = \frac{1}{1-\frac{1}{4}(z/e^{j/\pi 4})^{-1}} + \frac{1}{1-\frac{1}{4}(z/e^{-j/\pi 4})^{-1}}$$

$$= \frac{1-\frac{1}{4}cos\pi/4\, z^{-1}}{1-2\left(\frac{1}{4}\right)cos(\pi/4)z^{-1} + (1/4)^2 z^{-2}}$$

$$H(z) = \frac{1-\frac{1}{4\sqrt{2}}z^{-1}}{1-\frac{1}{2\sqrt{2}}z^{-1}+\frac{1}{16}z^{-2}} \qquad \left[a^n \cos\omega_0 n u(n) \xrightarrow{Z.T} \frac{1-az^{-1}\cos\omega_0}{1-2az^{-1}\cos\omega_0 z^{-1} + a^2 z^{-2}}\right]$$

Direct form II [Canonical form]



(ii) $y(n) = y(n-1) + y(n-2) + x(n),\ y(0) = 0, y(1) = 1$

Take Z.T $\qquad x(n-n_0) \xrightarrow{Z.T} z^{-n_0}X(z)$

$Y(z) = z^{-1}Y(z) + z^{-2}Y(z) + X(z)$

$Y(z)[1 - z^{-1} - z^{-2}] = X(z)$

$H(z) = \frac{Y(z)}{X(z)} = \frac{1}{1-z^{-1}-z^{-2}} = \frac{z^2}{z^2-z-1}$

Take $\frac{H(z)}{z} = \frac{z}{z^2-z-1}$

$z^2 - z - 1 = 0$

$z = \frac{1\pm\sqrt{1+4}}{2} = \frac{1\pm\sqrt{5}}{2}$

$= \frac{1\pm 2.236}{2} = 1.618, -0.618$

$\frac{H(z)}{z} = \frac{z}{(z-1.618)(z+0.618)}$

$\frac{H(z)}{z} = \frac{0.723}{z-1.618} + \frac{0.276}{z+0.618}$

$H(z) = \frac{0.723\,z}{z-1.618} + \frac{0.276\,z}{z+0.618}$

As it is stated

Impulse response h(n) $= 0.723(1.618)^n u(n) + 0.276\,(-0.618)^n u(n)$

07. (c) A hexagonal cell within a four cell system has a radius of 1.387 km. A total of 60 channels are used in the entire system. If the load per user is 0.029 Erlangs and λ = 1 call/hour, compute the following for an Erlang C system that has 5% probability of a delayed call

(i) How many users per square km will this system support?

(ii) What is the probability that a delayed call will have to wait for more than 10 s?

(iii) What is the probability that a call will be delayed for more than 10 s?

Erlang C Traffic Table

Maximum offered load versus B and N

N \ B	1	2	5	10	15
14	6.70	7.31	8.27	9.15	9.76
15	7.39	8.03	9.04	9.97	10.60
16	8.09	8.76	9.82	10.79	11.44

(20 M)

Sol: For cell system radius $R = 1.387$ km

Area $= 2.598 \times (1.387)^2 = 5$ sq km

load per user 0.029 Erlangs

$\lambda = 1$ call/hour

Probability of delayed call = 5% = 0.05

(i) Channels per cell $C = 60/4 = 15$

traffic intensity = 9 erlangs

Number of users = total traffic intensity / traffic per user $= 9/0.029 = 310$ users

310 users / 5 sq km = 62 users / sq km

(ii) $\lambda = 1$, Holding time

$H = A_u/\lambda = 0.029 \text{ hour} = 104.4 \text{ sec}$

$P(\text{delay} > t/\text{delay}) = e^{-(-(c-A)t/H)} = e^{-(-(15-9)10/104.4)} = 56.29\%$

(iii) $P(\text{delay} > 0) = 5\% = 0.05$

$P(\text{delay} > 10) = P(\text{delay} > 0)P(\text{delay} > t/\text{delay})$

$= 0.05 \times 0.5629 = 2.81\%$

08. (a) Consider an air filled rectangular waveguide with inner dimension of width and height a and b respectively (a > b)

(i) With clear reasoning describe why propagation is not possible if both electric and magnetic fields in the direction of propagation are zero. (6 M)

(ii) The propagation constant γ for TE and TM mode is given by

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

where m and n are integers.

Obtain an expression for minimum frequency below which propagation is not possible (6 M)

(iii) If a = 2cm and b = 1 cm, determine the range of frequency at which only one mode propagates $(\varepsilon = 8.854\times10^{-12}\ \text{F/m}, \mu_0 = 4\pi\times10^{-7}\ \text{H/m})$ **(8 M)**

Sol: (i). Given : Rectangular waveguide : a × b (a > b)

Assume the wave is propagating along +z direction. Transverse components of electric field intensity and magnetic field intensity are given by

$$E_x = \frac{-\bar{v}}{h^2}\frac{\partial E_z}{\partial x} - \frac{j\omega\mu}{h^2}\frac{\partial H_z}{\partial y}$$

$$E_y = \frac{-\bar{v}}{h^2}\frac{\partial E_z}{\partial y} + \frac{j\omega\mu}{h^2}\frac{\partial H_z}{\partial x}$$

$$H_x = \frac{-\bar{v}}{h^2}\frac{\partial H_z}{\partial x} + \frac{j\omega\in}{h^2}\frac{\partial E_z}{\partial y}$$

$$H_y = \frac{-\bar{v}}{h^2}\frac{\partial H_z}{\partial y} - \frac{j\omega\in}{h^2}\frac{\partial E_z}{\partial x}$$

If both the electric field and magnetic field (longitudinal) components are zero along the direction of propagation, then this mode is TEM (Transverse Electromagnetic)

i.e for TEM wave : $E_z = 0$ and $H_z = 0$

by substituting these conditions, in the above transverse components

$E_x = 0$, $E_y = 0$, $H_x = 0$, $H_y = 0$

Hence all the transverse components are vanished. No wave propagation exist.

In order to exist wave propagation in a waveguide, either of the longitudinal components must necessarily present.

i.e. when $E_z = 0$, H_z should not be zero (or)

when $H_z = 0$, E_z should not be zero.

This indicates rectangular waveguide does not support TEM mode, rather it will support TE and TM modes.

TE mode : $E_z = 0, H_z \neq 0$

TM mode : $H_z = 0, E_z \neq 0$

(ii) Given propagation constant $\bar{v}^2 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 - \omega^2\mu\in$

The minimum frequency at which, rectangular waveguide can support propagation of modes is called cutoff frequency. Below this frequency wave propagation is not possible.

at $\omega = \omega_c$, $\bar{v} = 0$

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

$$\pi^2\left[\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2\right] = 4\pi^2 f_c^2\mu\in$$

$$f_c = \frac{1}{2\sqrt{\mu\in}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

$\therefore$ cutoff frequency , $f_c = \frac{v}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$

Where, $v = \frac{c}{\sqrt{\in_r}}$; for dielectric filled rectangular WG

v = c ; for airfilled rectangular WG

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

(iii) Given: a = 2cm

b = 1 cm

$\in_0 = 8.854 \times 10^{-12}$ F/m

$\mu_0 = 4\pi \times 10^{-7}$ H/m

Assume only dominant mode (which is having lowest cut off frequency) is propagating.

To propagate dominant mode (TE_{10}), $f > f_c(TE_{10})$

To reject next higher order mode (TE_{20}), $f < f_c(TE_{20})$

$$f_c(TE_{10}) = \frac{c}{2a} = \frac{3\times10^{10}}{2\times2} = 7.5GHz$$

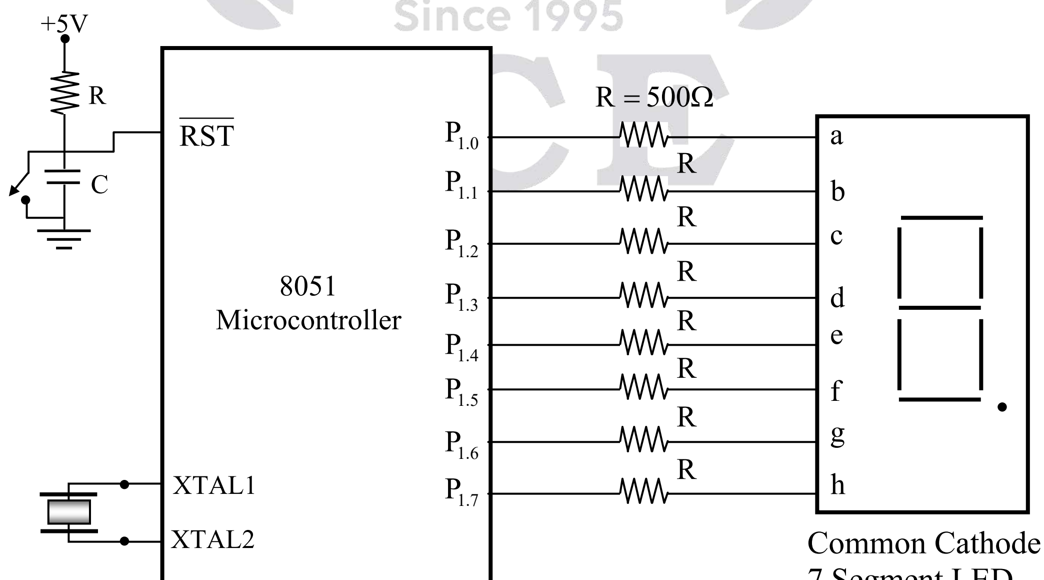
$$f_c(TE_{20}) = \frac{c}{a} = \frac{3\times10^{10}}{2} = 15GHz$$

Therefore the range of frequency at which only dominant mode is propagating is

7.5 GHz < f < 15GHz.

08. (b) A display is connected to part P1 of 8051 microcontroller. A sequence of 7-bit patterns are to be displayed in cyclic manner continuously. Write a program in 8051 assembly to display the bit-patterns (8-bit each) with a delay of 1 second between each pair of bit-patterns. The bit-patterns are stored in program memory space at the location 400H. Assume that sub-routine for delay is available directly. Comment on your program appropriately and mention any necessary assumptions explicitly. (20 M)

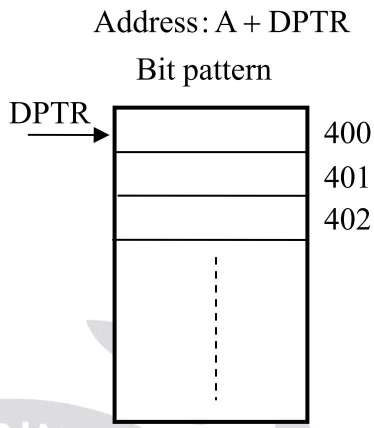
Sol:



Common Cathode
7 Segment LED
[i.e. 1 → LED is ON]

Program:

```
        ORG 000H
Start:  MOV A, #00H
        MOV DPTR, #400H
        MOV R0, #Count
Repeat: MOV A, B
        INC A
        MOV B, A
        MOVC A, @ A+DPTR
        MOV P1, A
        ACALL Delay
        DJNZ R0, Repeat
        SJMP Start
```



Note:

(1) The 8 bit patterns to be displayed on the interfaced display are stored in Program memory starting at 400_H memory location.

(2) ORG is an Assembler Directive, which initializes the location counter with the value given in ORG statement.

08. (c) The dominant mode TE_{10} is propagated in a rectangular waveguide of dimensions a = 6 cm and b = 4 cm. The distance between maximum and minimum is found to be equal to 4.47 cm with the help of travelling wave detector. Determine the signal frequency. (20 M)

Sol: Given :

Dominant mode, propagation,

Dimension : a = 6 cm, b = 4 cm

The distance between maximum and minimum is given by $\frac{\lambda_g}{4} = 4.47$ cm

Guide wavelength, $\lambda_g = 17.88$ cm

Cutoff wavelength, $\lambda_c(TE_{10}) = 2a = 2 \times 6 = 12$ cm

$$\frac{1}{\lambda_g^2} = \frac{1}{\lambda_0^2} - \frac{1}{\lambda_c^2}$$

$$\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

$$= \frac{1}{(17.88)^2} + \frac{1}{(12)^2}$$

$$\frac{1}{\lambda_0^2} = 0.010072$$

$\therefore$ $\lambda_0 = 9.963$ cm

$$\frac{c}{f} = 9.963cm$$

$$f = \frac{3\times 10^{10}}{9.963}$$

Therefore signal frequency, f = 3 GHz