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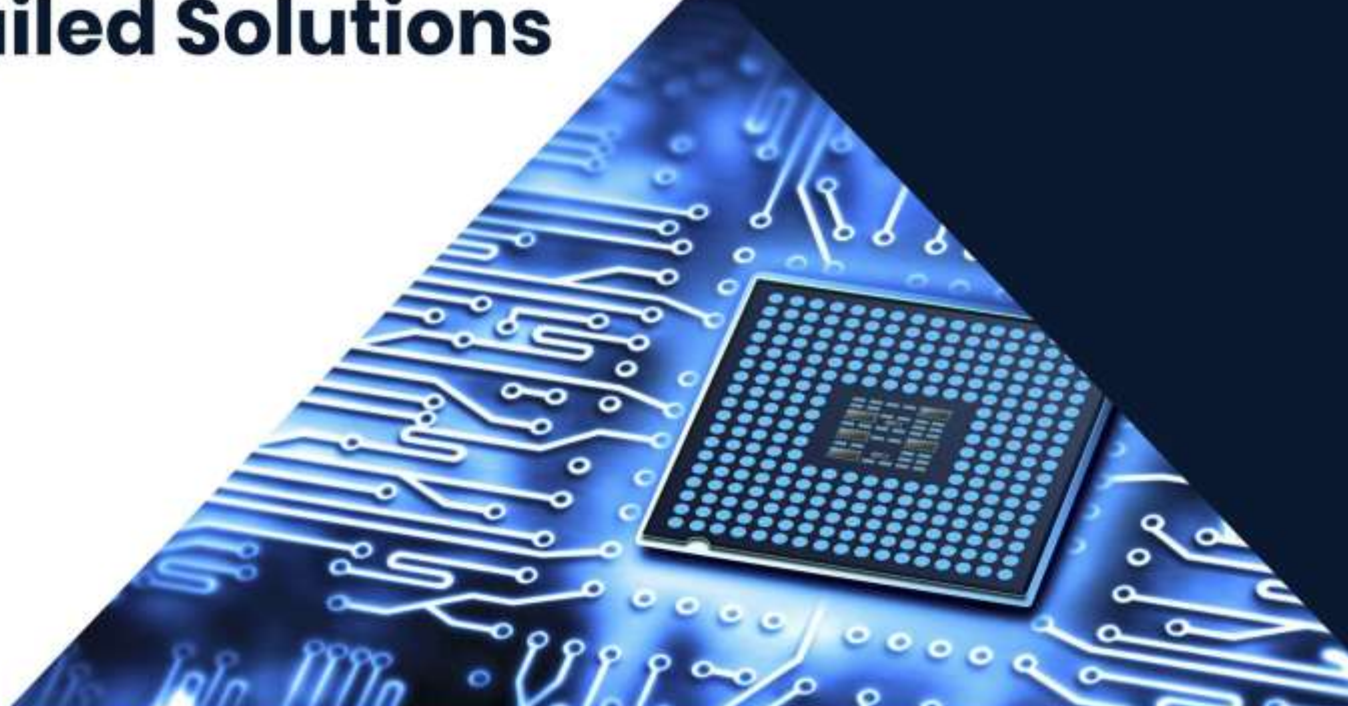
ESE (Main) Examination 2020

Electronics & Telecommunication Engineering Paper-II

Detailed Solutions



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ESE Mains 2020 Electronics Engineering Detailed Weightage Analysis

Paper-2			
S.no.	**Subjects**	**Difficulty Level**	**Marks in 2020**
1	Analog and Digital Communication Systems	Moderate	90
2	Control Systems	Easy	80
3	Control Systems Computer Organization and Architecture	Moderate	40
4	Electro Magnetics	Moderate	110
5	Advanced Electronics Topics	Moderate	130
6	Advanced Communication Topics	Moderate	30
Total			**480**

ELECTRONICS ENGINEERING

Paper-II

SECTION-'A'

1.(a) A certain speech signal is sampled at 8 kHz 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 the symbol are equiprobable, what will be the entropy?

Sol. Sampled freq. $f_s = 8$ KHz

Coding scheme = DPCM

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

$P(s_4) = 0.1$, $P(s_5) = 0.05$, $P(s_6) = P(s_7) = 0.02$, $P(s_8) = 0.01$

Entropy

$$H(s) = \sum_{\forall i}^{8} P(s_i) \log_2 \frac{1}{P(s_i)}$$

$$= 0.4 \log_2 \frac{1}{0.4} + \left(0.2 \log_2 \frac{1}{0.2}\right) \times 2 + 0.1 \log_2 \frac{1}{0.1} + 0.05 \log_2 \frac{1}{0.05} + \left(0.02 \log_2 \frac{1}{0.02}\right) \times 2 + 0.01 \log_2 \frac{1}{0.01}$$

$= 0.4 \times 1.322 + 0.4 \times 2.322 + 0.1 \times 3.322 + 0.05 \times 4.322 + 0.04 \times 5.643 + 0.01 \times 6.643$

$= 2.29809$ Bits/symbol

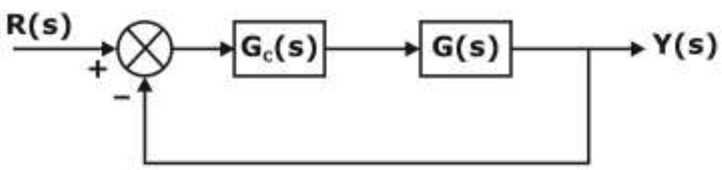
When all the symbols one equal probable

Then $P(s_1) = P(s_2) = \ldots\ldots P(s_8) = 1/8$.

$M = 8$

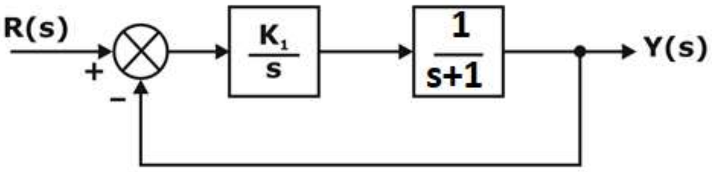
$H(s) = \log_2 M = \log_2 8 = 3 \frac{\text{Bits}}{\text{symbol}}$

(b) In the figure shown below, $G(s) = \frac{K}{(\tau s + 1)}$ has a time constant of 0.5 seconds, 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.



Sol. $G(s) = \frac{K}{s\tau + 1}$

With time constant τ = 0.5 sec& DC gain, K = 1



Open loop Transfer function

$$\Rightarrow \frac{K_1}{s(s+1)} = 0$$

Given K_V = 1

$$\lim_{s\to 0} \frac{s\,x\,K_1}{s(s+1)} = 1 \;\Rightarrow K_1 = 1$$

Closed loop Transfer function:

$$T(s) = \frac{G_c(s)\,G(s)}{1 + G_C(s)\,G(s)} = \frac{\frac{K_1}{s(s+1)}}{1 + \frac{K_1}{s(s+1)}}$$

$$T(s) = \frac{K_1}{s(s+1) + K_1}$$

Sensitivity of T(s) w.r.t K_1

$$S_{K_1}^{T} = \frac{K_1}{T}\frac{\partial T}{\partial K_1} = \frac{K_1}{\frac{K_1}{s(s+1)+k1)}} \times \frac{(s(s+1)+K_1)\times 1 - K_1(1)}{(s(s+1)+K_1)^2}$$

$$S_{K_1}^{T} = \frac{s^2 + s}{(s(s+1)+K_1)}$$

Put s = j × 1

$$S_{K_1}^{T} = \frac{-1+j}{-1+j+K_1}$$

Put K_1 = 1

$$S_{K_1}^{T} = \frac{-1+j}{j} = 1 + j$$

$$\left|S_{K_1}^{T}\right| = \sqrt{1^2 + 1^2} = \sqrt{2}$$

(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.

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:**

Process	Arrival	Burst time	Completion time	TAT	WT
P_0	0	3	3	3	0
P_1	2	2	5	3	1
P_2	3	4	9	6	2
P_3	4	7	16	12	5

P_0	P_1	P_2	P_3
0	3	5	9 16

Avg waiting time = 8/4 = 2

SJF:

Process	Arrival	Burst time	Completion time	TAT	AT
P_0	0	3	3	3	0
P_1	2	2	5	3	1
P_2	3	4	9	6	2
P_3	4	7	16	12	5

P_0	P_1	P_2	P_3
0	3	5	9 16

Avg waiting time = 8/4 = 2

3. Priority:

Process	AT	Burst time	Priority	TAT	WT
P_0	0	3	1	3	0
P_1	2	2	2	3	1
P_2	3	4	3	13	9
P_3	4	7	1	8	1

Assuming less integer means Higher priority

P_0	P_1	P_3	P_2
0	3	5	12 16

Avg writing time = 11/4 = 2.75

(d) A uniform plane wave is propagating in z-direction with velocity 1.4×10^8 m/s in a perfect dielectric 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.

Sol. $v = 1.4 \times 10^8$ m/sec

$\eta = 474\ \Omega$

$E_x(z, t) = 1750 \cos(10^6 \pi t - \beta z)$ V/m

$H_y(z, t) = 1750/474 \cos(10^6 \pi t - \beta z)$ A/m

$H_y(z, t) = 3.69 \cos(10^6 \pi t - \beta z)$ A/m

$\omega = 10^6 \pi$

$2\pi f = 10^6 \pi$

$f = 0.5 \times 10^6$ Hz

$$\lambda = \frac{v}{f} = \frac{1.4 \times 10^8}{0.5 \times 10^6} = 280$$

$\lambda = 280$ m

$$P_{avg} = \frac{1}{2}\frac{|E|^2}{\eta} = \frac{1}{2}\frac{|1750|^2}{474}$$

$P_{avg} = 3230.49$ W/m^2

(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.

Sol. *

(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.

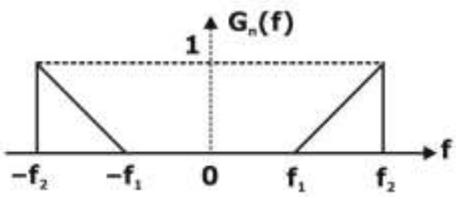
Sol. *

2. (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 in phase 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).

(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 $n_Q(t)$.

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



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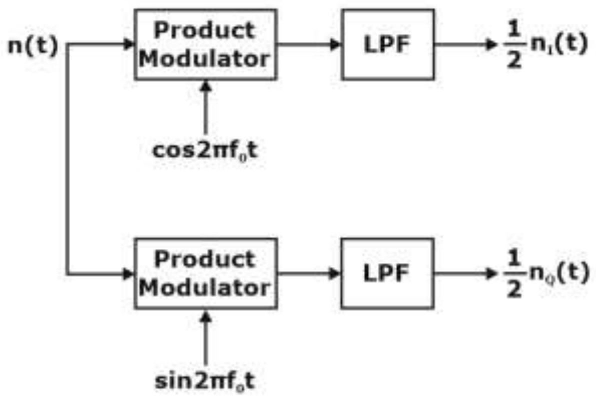
Sol. (i) $n(t) = n_I(t) \cos 2\pi f_0 t - n_Q(t) \sin 2\pi f_0 t$



Let $x(t) = \cos(2\pi f_0 t + \phi)$

$\phi = 90° \Rightarrow x(t) = \sin 2\pi f_0 t$

$\phi = 0° \Rightarrow x(t) = \cos 2\pi f_0 t$

$h(t).x(t) = (n_I(t) \cos 2\pi f_0 t - n_Q(t) \sin 2\pi f_0 t) \cos(2\pi f_0 t+\phi)$

$$\Rightarrow \frac{n_I(t)}{2}\cos(4\pi f_c t+\phi)+\frac{n_I(t)}{2}\cos\phi-\frac{n_Q(t)}{2}\sin(4\pi f_c t+\phi)+\frac{n_Q(t)}{2}\sin\phi$$

Output of LPF

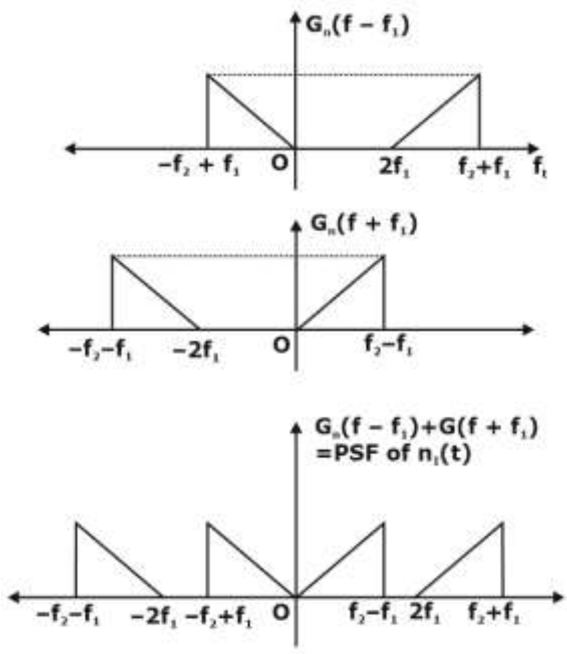
$$\Rightarrow \frac{n_I(t)}{2}\cos\phi+\frac{n_Q(t)}{2}\sin\phi$$

$\phi = 0°$ | $\phi = 90°$

Output $= \frac{n_I(t)}{2}$ | Output $= \frac{n_Q(t)}{2}$

So inphaseand quadrature both component we generated back of n(t).

(iii) PSD of $n_I(t) = G_n(f - f_1) + n_n(f + f_1)$



(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.

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

Characteristic Equation 1 + G(s) H(s) = 0

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

s(s + 1) (s + 5) + 3s + α = 0

divide by s(s + 1) (s + 5) + 3s

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

$$1 + \frac{\alpha}{s(s^2+6s+8)} = 0$$

$$1 + \frac{\alpha}{s(s+2)(s+4)} = 0$$

Let's sketch root locus for

$$G_1(s) = \frac{\alpha}{s(s+2)(s+4)} = 0$$

Open loop zeros: None; Z = No. of OLZ = 0

Open loop poles: s = 0, −2, −4

P = No. of OLP = 3

1. Number of Branches: N = max(P,z) = 3
2. Branches starts from s = 0, −2, −4
3. Branches terminate at ∞,∞,∞
4. Number of Asymptotes:

n = P – Z = 3 – 0 = 3

5. Angle of Asymptotes with Real Axis:

$$\theta = \frac{2K+1}{n} \times 180°, K = 0, 1, 2, \ldots\ldots n-1$$

$$\theta = \frac{2K+1}{3} \times 180°, K = 0, 1, 2$$

θ = 60°, 180°, 300°

6. Centroid: Intersection of Asymptotes as Real Axis

$$x = \frac{\sum Poles - \sum Zeros}{P-Z} = \frac{(0-2-4)-(0)}{3-0} = -2$$

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7. Breakaway Points:

CE : $1 + \frac{\alpha}{s(s+2)\ (s+4)} = 0$

$\alpha = -[s^3 + 6s^2 + 8s]$

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

$-(3s^2 + 12s + s) = 0$

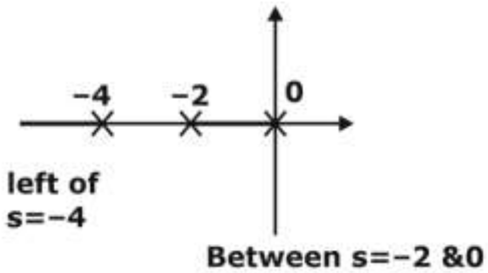
s = −0.85, −3.15

s = −0.85 is on root locus

s = −3.15 is not on Root locus, so not a breakaway point.

8. Existence of Root locus on Real Axis:

Root locus exists on real axis of total number of poles & zeroes to the right is an odd number.



9.Intersection of Root Locus with Imaginary Axis

CE: $1 + \frac{\alpha}{s(s+2)(s+4)} = 0$

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

use Routh Hurwitz criteria

s^3	1	8
s^2	6	α
s^1	48-α	0
s^0	α	0

For intersection with jω axis,

$48 - \alpha = 0$

$\Rightarrow \alpha = 48$

Roots, $6s^2 + \alpha = 0$

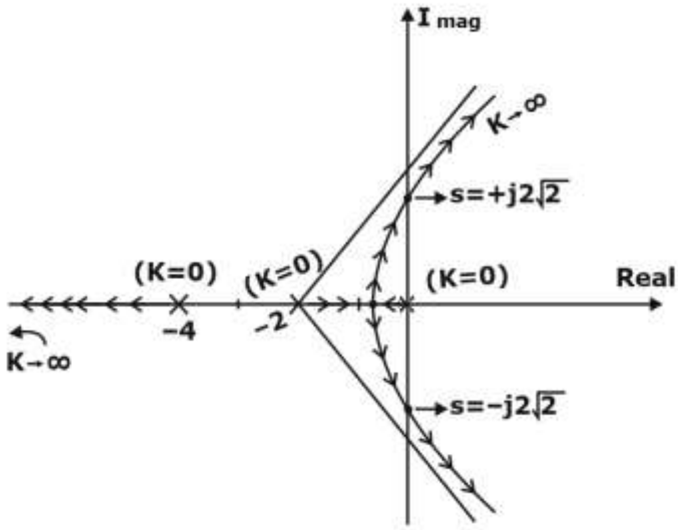
$6s^2 + 48 = 0$

$s = \pm j2\sqrt{2}$

For stability, $48 - \alpha > 0$ and $\alpha > 0$

$\Rightarrow 0 < \alpha < 48$

So, If α > 48, system is unstable.



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

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

The design achieved an effective memory access timeof 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.

Sol. Cache Access Time = T_C = 5ns

memory access time = T_m

SSD access time= T_S = 5 μsec = 5000 ns

Cache Hit ratio = 0.95= H_C

Memory hit ratio = 0.99 = H_m

Avg Access time = $T_C + (1 - H_C)[T_m + (1 - H_m)T_S]$

$20ns = 5ns + (1 - 0.95)[T_m + (1 - 0.99)5000]$

$15 = (0.05)[T_m + (0.01)5000]$

$$\frac{1500}{5} = T_m + 50$$

T_m = 250 nsec

Cache = 1 MB = 2^{20} B = 2^{10} KB

Cache cost = 2^{10} Rupees

Memory = 128 MB = = 2^{17} kB

Memory cost $= \frac{2^{17}}{10}$ Rupees

SSD = 2^x KB (Assume)

$SSD\ cost = \frac{2^x}{1000}$

$$22000 = 2^{10} + \frac{2^{17}}{10} + \frac{2^x}{1000}$$

2^x = 7868800

SSD size =7868800/2^20 GB= 7.50 GB= 2^3 GB= 8 GB

3. (a) In a particular AM system, quadrature modulation is used where the inphse 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.

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

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

Sol. Given that

(m_1 (t) + V_0) is inphase component.

& $m_2(t)$ is Quadrature component.

AM with Quadrature modulation is written as-

$S(t) = \cos(2\pi f_c t)\, I(t) - \sin 2\pi f_c t\ \ Q(t)$

$I(t) = m_1(t) + V_0$

$Q(t) = m_2(t)$

(i) Quadrature AM signal s(t) =

$s(t) = (m_1(t) + V_0) \cos 2\pi f_c t - m_2(t) \sin 2\pi f_c t$

(ii) $S(t) \cos 2\pi f_c t = \{\{m_1(t) + V_0\} \cos 2\pi f_c t - m_2(t) \sin 2\pi f_c t\}. \cos 2\pi f_c t$

$= \{\{m_1(t) + V_0\} \cos^2 2\pi f_c t - m_2(t) \sin 2\pi f_c t \cos 2\pi f_c t$

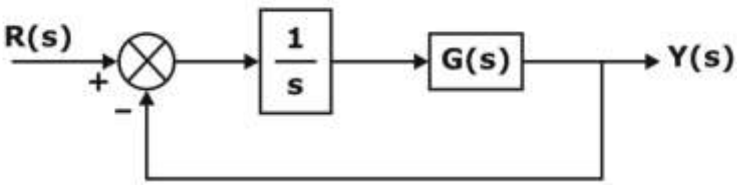
$$= \{m_1(t) + v_0\}\left[\frac{\cos 4\pi f_c t + 1}{2}\right] - \frac{m_2(t)}{2}\left[\sin 4\pi f_c t + \sin 0°\right]$$

$$= \frac{(m_1(t) + V_0)}{2} + \frac{(m_1(t) + V_0)}{2} \cos 4\pi f_c t - \frac{m_2(t)}{2} \sin 4\pi f_c t \quad \text{... (2)}$$

When (2) is passed through LPF.

Then, $\left(\frac{m_1(t) + V_0}{2}\right)$ is obtained as V_0 is large, hence $m_1(t)$ can be recovered.

(b) For the unity feedback system shown 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 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.



Sol. $$G(s) = \frac{LT\{(3 - 6e^{-2t} + 3e^{-4t})\,u(t)\}}{LT\{u(t)\}}$$

$$= \frac{\frac{3}{s} - \frac{6}{s+2} + \frac{3}{s+4}}{\frac{1}{S}}$$

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

$$G(s) = \frac{24}{(s+2)(s+4)}$$

Put s = jω

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

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

$$\phi = \angle G(j\omega) = -\tan^{-1}\left(\frac{\omega}{2}\right) - \tan^{-1}\left(\frac{\omega}{4}\right)$$

$\omega = 0^+$

$$M = \frac{24}{\sqrt{4 \times 16}} = \frac{24}{2 \times 4} = 3$$

$$\phi = -\tan^{-1}(0) - \tan^{-1}(0) = 0^\circ$$

$\omega = \infty^+$

$$M = \frac{1}{\infty} = 0 \Rightarrow \text{origin}$$

$\phi = -\tan^{-1}(\infty) - \tan^{-1}(\infty) = -180^\circ$ $\Rightarrow$ –ve x axis

Also, $\phi = -\tan^{-1}\left(\frac{\omega}{2}\right) - \tan^{-1}\left(\frac{\omega}{4}\right) = -\tan^{-1}\left(\frac{\frac{\omega}{2}+\frac{\omega}{4}}{1-\frac{\omega^2}{8}}\right)$

$$\phi = -\tan^{-1}\left(\frac{6\omega}{8-\omega^2}\right)$$

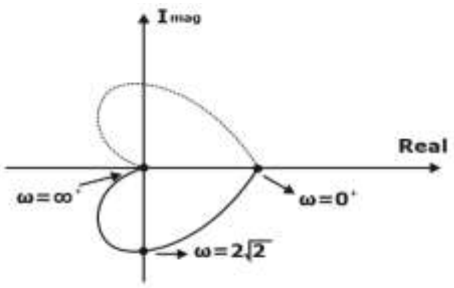
Put $8 - \omega^2 = 0$

$$\omega = \sqrt{8} = 2\sqrt{2}$$

$$\phi = -\tan^{-1}(\infty) = -90^\circ$$

$\Rightarrow$ –ve y-axis

So, Nyquist plot will be



G(s)H(s) plane

Gain Margin

ω_p = phase crossover frequency

at $\omega = \omega_P$, $\phi = \angle G(j\omega) = -180°$

So, $\omega_p = \infty$

Magnitude, M at $\omega_P = \infty, = \frac{1}{\infty} = 0$

So, $G.M. = 20 \log\left(\frac{1}{|G(j\omega_p)H(j\omega_p)|}\right) = 20 \log\left(\frac{1}{0}\right) = \infty$ dB

Phase Margin

$\omega_g \rightarrow$ gain crossover frequency

at $\omega = \omega_g$, $M = |G(j\omega)| = 1$

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

or, $(4 + \omega^2)(16 + \omega^2) = 24^2$

Put, $\omega^2 = x$

$(x + 4)(x + 16) = 576$

$x^2 + 20x + 64 = 576$

$x^2 + 20x - 512 = 0$

$x = \omega_g^2 = 14.74, -34.74$

ω_g^2 can't be negative

So, $\omega_g^2 = 14.74$

$\omega_g = 3.84$ rad/sec

So, PM = $180° + \angle G(j\omega g)$

$$= 180° + \left[-\tan^{-1}\left(\frac{3.84}{2}\right) - \tan^{-1}\left(\frac{3.84}{4}\right)\right] = 73.68°$$

Both Gain margin & phase Margin are positive,

So, the system is stable.

(c) Design a 4-bit arithmetic circuit with one selection variable s and two four-bit data 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

Sol. *

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4.(a) Twelve different audio signals each band-limited to 10 kHz are to 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 the TDM signal?

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

Sol. *

(b) Given a system with transfer function $G(s) = \frac{10}{(s+1)(s+4)}$, find its 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 times step response.

Sol. *

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

$X_1T_1 : F \leftarrow 0$

$X_2T_2 : F \leftarrow 1$

$X_3T_3 : F \leftarrow G$

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

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.

Sol. *

SECTION-'B'

5.(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.

Sol. n = 8 bits

R_b = 56 mbps (bit rate)

$R_b = nf_s$

56 Mbps = 8. f_s

$f_s = 7 \times 10^6$ Hz

f_s = 7 MHz

f_s = NR = 2fm

$2f_m$ = 7 MHz

f_m = 3.5 MHz

Maximum B.W. of m(t) is 3.5 MHz.

SNR = 1.76 + 6n dB

= 1.76 + 6 × 8

= 49.76 dB.

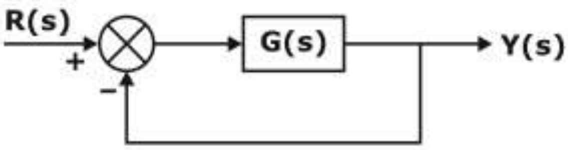
5.(b) For a unity feedback system shown in the figure, $G(s) = \frac{K}{s(s+\alpha)}$ has resonant frequency 'ω_r' which is $\frac{1}{\sqrt{2}}$ times the damped frequency 'ω_d'. G(s) also has a setting time $2\sqrt{3}$ seconds, for a 2% tolerance band in its time step response. Calculate the following:

(i) Undamped natural frequency

(ii) Decay rate

(iii) Peak overshoot

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



Sol. $G(s) = \frac{K}{s(s+\alpha)}$

CE: $1 + \frac{K}{s(s+\alpha)} = 0$

$s^2 + \alpha s + K = 0$

compare with $s^2 + 2\zeta\omega_n s + \omega_n^2 = 0$

$\omega_n = \sqrt{K}$ ...(1)

$2\zeta\omega_n = \alpha \Rightarrow \zeta = \frac{\alpha}{2\sqrt{K}}$ ...(2)

$\omega_r = \omega_n\sqrt{1-2\zeta^2}$

& $\omega_d = \omega_n\sqrt{1-\zeta^2}$

given $\omega_r = \frac{1}{\sqrt{2}}\omega_d$

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

$\Rightarrow 1-2\zeta^2 = \frac{1}{2}(1-\zeta^2)$

$2 - 4\zeta^2 = 1 - \zeta^2$

$1 = 3\zeta^2$

$\zeta = \frac{1}{\sqrt{3}}$

Also, setting time, $t_s = \frac{4}{\zeta\omega_n} = 2\sqrt{3}$

$\zeta\omega_n = \frac{4}{2\sqrt{3}}$

$\frac{1}{\sqrt{3}}\omega_n = \frac{4}{2\sqrt{3}} \Rightarrow \omega_n = 2$

use

1) $\omega_n = \sqrt{K} = 2$

$\Rightarrow k = 2^2 = 4$

2) $\zeta = \frac{\alpha}{2\sqrt{K}} = \frac{1}{\sqrt{3}}$

$$\alpha = \frac{2\sqrt{K}}{\sqrt{3}} = \frac{2\times 2}{\sqrt{3}} = \frac{4}{\sqrt{3}}$$

So, CE is $s^2 + \alpha s + K = 0$

$s^2 + \frac{4}{\sqrt{3}}s + 4 = 0$

(i) $\omega_n = 2$ rad/sec

(ii) Peak Overshoot:

$\%M_p = e^{-\pi\cot\theta}\times 100$

where $s = \cos\theta = \frac{1}{\sqrt{3}}$

$\Rightarrow \theta = 54.73$

$\Rightarrow \cot\theta = 0.707$

$\%M_p = e^{-\pi\times 0.707}\times 100 = 10.84\%$

(iv) $G(s) = \frac{K}{s(s+\alpha)} = \frac{4}{s\left(s+\frac{4}{\sqrt{3}}\right)} \Rightarrow Type$ "1"

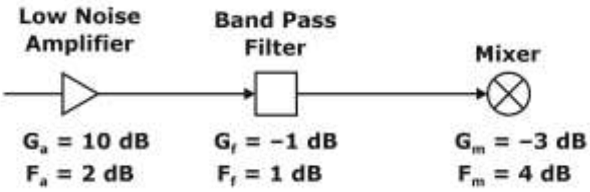
K_v = velocity error coefficient

$$K_v = \lim_{s\to 0} sG(s)$$

$$= \lim_{s\to 0} s \times \frac{4}{s\left(s + \frac{4}{\sqrt{3}}\right)} = \sqrt{3}$$

$$\text{so, } e_{ss} = \frac{1}{K_v} = \frac{1}{\sqrt{3}}$$

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



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

Sol. Overall noise figure (f) =

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2}$$

$F_1 = 1.585$ $F_2 = 1.259$

$F_3 = 2.512$, $G_1 = 10$

$G_2 = 0.794$

$$F = 1.585 + \frac{(1.259 - 1)}{10} + \frac{(2.512 - 1)}{10 \times 0.794}$$

F = 1.801

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

Sol. T_0 = 290 K

Equivalent noise Temp. (T_e) = $T_e = (F - 1)\,T_0$

$T_e = (1.801 - 1) \times 290$

$T_e = 232.29$

(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 10 MHz.

(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.

5.(d) Normalized radiation intensity of an antenna is given by

$U_n(\theta) = 1$; $0 \le \theta < 30°$

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

$= 0$; $90° \le \theta \le 180°$

It is independent of Φ.

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

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Sol. $U_n(\theta) = 1,\ 0 \le \theta < 30°$

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

$$= 0;\qquad 90° \le \theta \le 180°$$

$$D = \frac{\phi_{max}}{\phi_{av}};\ \boxed{\phi_{max} = 1}$$

$$\boxed{\phi_{av} = \frac{W_r}{4\pi} = \frac{0.768\pi}{4\pi} = 0.192 \text{ w/sr}}$$

$$W_r = \int\int \phi\, dr = \int\int \phi \sin\theta\, d\theta\, d\phi$$

$$W_r = \int_{\theta=0}^{30}\int_{\phi=0}^{2\pi} \sin\theta\, d\theta\, d\phi + \int_{\theta=30}^{90}\int_{\phi=0}^{2\pi} \frac{\cos\theta}{0.866}\sin\theta\, d\theta\, d\phi$$

$$W_r = 2\pi\left[1 - \frac{\sqrt{3}}{2}\right] + \frac{\sqrt{3}\pi}{3.464}$$

$$W_r = 0.268\pi + \frac{\sqrt{3}\pi}{3.464}$$

$$W_r = 0.268\pi + 0.5\pi$$

$$\boxed{W_r = 0.768\,\pi}$$

$$D = \frac{\phi_{max}}{\phi_{av}} = \frac{1}{0.192} = 5.208$$

$$\boxed{D = 5.208}$$

$$(Ac)_{max} = \frac{D\lambda^2}{4\pi}$$

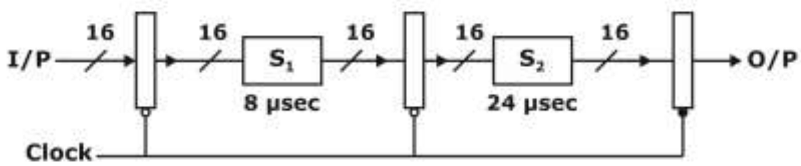
$$\lambda = \frac{c}{f} = \frac{3\times10^8}{900\times10^6} = \frac{1}{3}$$

$$(Ac)_{max} = \frac{5.208 \times \frac{1}{9}}{4\pi}$$

$$= \frac{5.208}{36\pi}$$

$$\boxed{(Ac)_{max} = 0.0460 \text{ m}^2}$$

5. (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.

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Sol. Cycle time = 24 μ sec

Latency = 2 × 24 μ sec = 48 μ sec

$$\text{Throughput} = \frac{1}{24}\frac{\text{inst}}{\mu\,\text{sec}} = 0.041$$

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

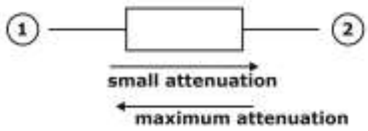
Sol. Cycle time = 8 μ sec

Latency = 4 × 8 = 32 μ sec

$$\text{Throughput} = \frac{1\,\text{inst}}{8\,\mu\,\text{sec}} = 0.125$$

5.(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.

Sol. Isolator



$$\text{Insertion loss } I_L = 10\log\frac{P_1}{P_{21}} \quad (1)$$

Pi → i/p to port-1

P_{21} → o/p from part-2

$0.5 = 10 \log P_1/P_{21}$

$P_1/P_{21} = 1.122$ ... (2)

$$\text{Isolation Loss} = 10\log\frac{P_2}{P_{12}} \ldots(3)$$

P_2 → i/p power to port 2

P_{12} → o/p power from Port (1)

$$30 = 10\log\frac{P_2}{P_{12}}$$

$$\boxed{\frac{P_2}{P_{12}} = 1000} \quad (4)$$

Scattering matrix for isolator

$$[S] = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix}$$

∵ Two ports are perfectly matched

∴ $S_{11} = S_{22} = 0$

$$S_{12} = \sqrt{\frac{P_{12}}{P_2}} = \sqrt{\frac{1}{1000}} \text{ from eq.(4)}$$

$S_{12} = 0.0316$

$$S_{21} = \sqrt{\frac{P_{21}}{P_1}} = \sqrt{\frac{1}{1.122}} \text{ from eq.(2)}$$

$S_{21} = 0.944$

$$\boxed{[S] = \begin{bmatrix} 0 & 0.0316 \\ 0.944 & 0 \end{bmatrix}}$$

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6.(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.

Sol. f = 30 MHz

L = 1 μH/m for lose-less line

C = 100 PF/m $Z_0 = \sqrt{\frac{L}{C}} = \sqrt{\frac{10^{-6}}{100\times10^{-12}}} = 100\Omega$

$Z_L = 70\,\Omega$

$Z_0' = \sqrt{Z_0 Z_L}$

$= \sqrt{100 \times 70}$

$= \sqrt{7000}$

= 83.66 Ω

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

Sol. $Z_L = 150 + i100\Omega$

$Z_0' = \sqrt{100(150 + j100)}$

$= 10\sqrt{150 + j100}$

$= 100\sqrt{1.5 + j}$

$= 100[\sqrt{3.25} < 33.69]^{1/2}$

$= 100[1.80 < 33.69]^{1/2}$

$= 100[1.80\ e^{j33.69}]^{1/2}$

$= 100[1.34\ e^{j16.84}]$

$= 134\ e^{j16.84}$

6. (b) Consider a CMOS schematic for 2-input 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

(ii) One nMOS transistor stuck short

Sol. *

6.(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 5 MHz and the thermal noise temperature is 20°C. If the overall signal to noise ratio is 5 dB, calculate the incident power.

Sol. $\frac{S}{N} = \frac{\eta P_0}{2hfB}$

η = quantum Efficiency ⇒ η = 65%

h → planks constant ⇒ $h = 6.626 \times 10^{-34}$

$$f = \frac{c}{\lambda} = \frac{2.998 \times 10^8}{0.9 \times 10^{-6}} = 3.3311 \times 10^{14} \text{ Hz}$$

B = Post detection B.N ⇒ B = 5 MHz

$$\left(\frac{S}{N}\right)_{dn} = 5\,dB = 10\log_{10}\left(\frac{\eta P_0}{2hfB}\right)$$

$$10^{1/2} = \frac{\eta P_0}{2hfB}$$

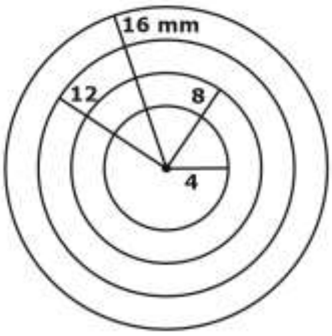
$$P_0 = \frac{2\sqrt{10}hfB}{\eta}$$

$$P_0 = \frac{2\sqrt{10}.(6.6 \times 10^{-34}) \times (3.3311 \times 10^{14})(5 \times 10^6)}{0.65}$$

$P_0 = 1.0696 \times 10^{-11}$ watts

7.(a) A coaxial capacitor of length 1 m is formed using two concentric cylindrical conductors. The inner conductor has radius 4 mm and the outpour conductor radius is 16 mm. The space between them is filled with 3 layers of perfect dielectric materials with different dielectric constants such that ε_{r_1} = 5, 4 mm < ρ < 8 mm; ε_{r_2} = 3, 8 mm < ρ < 12 mm and ε_{r_3} = 1, 12 mm < ρ < 16 mm. 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)

Sol. Capacitor C_1, C_2, C_3 are in series



$$C_1 = \frac{2\pi\varepsilon_0(5)}{\ell n[2]} = 0.40 \text{ nc}$$

$$C_2 = \frac{2\pi\varepsilon_0(3)}{\ell n[1.5]} = 0.411 \text{ nc}$$

$$C_3 = \frac{2\pi\varepsilon_0}{\ell n[4/3]} = 0.193 \text{ nc}$$

$$\frac{1}{C_{eq}} = \frac{C_2C_3 + C_1C_3 + C_1C_2}{C_1C_2C_3}$$

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$$C_{eq} = \frac{C_1C_2C_3}{C_2C_3 + C_1C_3 + C_1C_2} = 0.099 \text{ nF}$$

$$\boxed{C_{eq} = 0.099\ nF}$$

V = 100 volts given

$\theta = C_{eq}$ V

θ = 9.9 nC

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

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

Realize this system using finite number of adders, multipliers and minimum possible unit delays.

Sol. 1. $Z\{\cos(an).U[n]\} = \frac{z\{z - \cos a\}}{z^2 - 2z\cos a + 1}$

$$\therefore \cos\left(\frac{n\pi}{4}\right).U[n] \xleftrightarrow{Z.T.} \frac{z\left(z - \cos\frac{\pi}{4}\right)}{z^2 - 2z\cos\frac{\pi}{4} + 1}$$

2. If $x[n] \longleftrightarrow x(z)$

then $a^n.x[n] \longleftrightarrow x\left(\frac{z}{a}\right)$

$$\Rightarrow z\left\{a^n.\cos\left(\frac{n\pi}{4}\right).U[n]\right\} = \frac{\frac{z}{a}\left(\frac{z}{a} - \frac{1}{\sqrt{2}}\right)}{\left(\frac{z}{a}\right)^2 - 2\left(\frac{z}{a}\right)\frac{1}{\sqrt{2}} + 1}$$

Here $a = \frac{1}{4} \Rightarrow \frac{z}{a} = 4z$

$$\Rightarrow z\left\{\left(\frac{1}{4}\right)^n.\cos\left(\frac{n\pi}{4}\right).U[n]\right\}$$

$$= \frac{4z\left(4z - \frac{1}{\sqrt{2}}\right)}{(4z)^2 - 2(4z)\frac{1}{\sqrt{2}} + 1} = H(z)$$

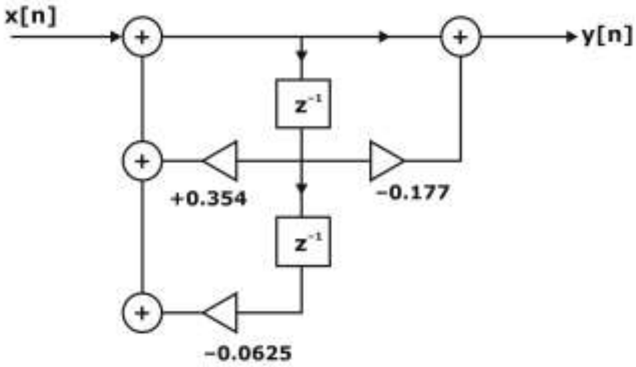
$$H(z) = \frac{16z^2 - 2\sqrt{2}z}{1 - 4\sqrt{2}z + 16z^2}$$

divide by '$16z^2$' in Numerator & Denominator

$$H(z) = \frac{1 - \left(\frac{2\sqrt{z}}{16}\right)z^{-1}}{1 - \left(\frac{4\sqrt{2}}{16}\right)z^{-1} + \left(\frac{1}{16}\right).z^{-2}}$$

$$H(z) = \frac{1 - (0.177)z^{-1}}{1 - (0.354)z^{-1} + (0.0625)z^{-2}}$$

$$H(z) = \frac{1-(0.177)z^{-1}}{1-(0.354)z^{-1}+(0.0625)z^{-2}}$$



Direct Form-II Realization structure of H(z)

Direct Form-II Realization structure uses minimum no. of delay elements

Hence DF-II structure realizes the T.F.

H(z) using finite no. of address, multipliers and minimum no. of delays.

(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.

7.(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

Sol. *

8.(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 field in the direction of propagation are zero.

Sol. Propagation of waves in R.W.G.

(or)

Non-Existence of TEM Wave in a R.W.G.

As waveguide is always placed along z–axis, if we consider a TEM wave propagating along R.W.G, It will propagate along z-axis.

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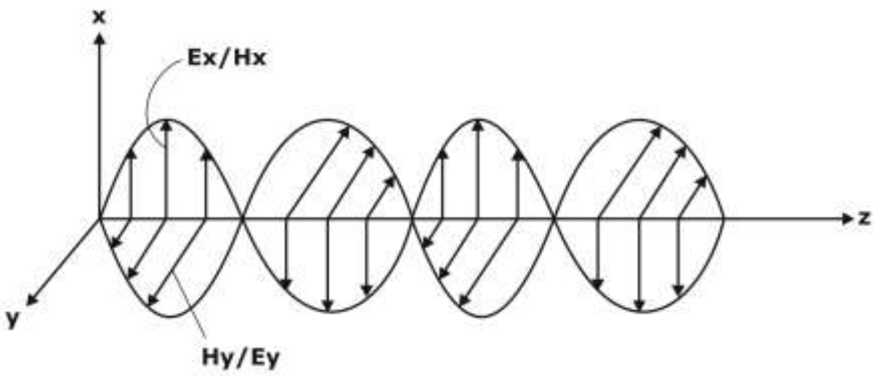
∴ Considering a TEM wave propagating along z-axis



When wave propagates along z axis, two combinations are possible

$$\begin{array}{llll} 1. & E_X \neq 0 & E_Y = 0; & \boxed{E_Z = 0} \\ & H_Y \neq 0 & H_X = 0 & \boxed{H_Z = 0} \\ 2. & H_X \neq 0 & H_Y = 0; & \boxed{H_Z = 0} \\ & E_Y \neq 0 & E_X = 0; & \boxed{E_Z = 0} \end{array}$$

In either the combination always Ez & Hz are zero

For a TEM wave propagating along Z axis, the components of E & H field along z axis [Ez & Hz] are always zero.

A TEM wave or a plane wave the propagates in free space and dielectrics cannot exists in R.W.G.

Let us consider maxwell Equations for free space [between walls of wave guide]

$\nabla \times H = \frac{\partial D}{\partial t}$ J = 0 as σ = 0

$\nabla \times \mathrm{H} = j\omega\varepsilon_0 \mathrm{E}$ ...(i) $\frac{\partial}{\partial t} = j\omega$ $D = \varepsilon_0 E$

$$\begin{vmatrix} ax & ay & az \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ Hx & Hy & Hz \end{vmatrix} = j\omega\varepsilon_0 \left[Ex\,ax + Ey\,ay + Ez\,az\right]$$

Replacing $\frac{\partial}{\partial z} = -\gamma\left[\text{an operator}\right]$

$$\begin{vmatrix} ax & ay & az \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & -\gamma \\ Hx & Hy & Hz \end{vmatrix} = j\omega\varepsilon_0 \left[Ex\,ay + Ey\,ay + Ez\,az\right]$$

Equating the coefficients of ax, ay & az after expansion

$$\frac{\partial Hz}{\partial y} + \gamma Hy = j\omega\varepsilon_0\, Ex \ ...(2)$$

$$\frac{\partial Hz}{\partial x} + \gamma Hx = j\omega\varepsilon_0\, Ey \ ...(3)$$

$$\frac{\partial Hz}{\partial x} - \frac{\partial Hx}{\partial y} = j\omega\varepsilon_0\, Ez \ ...(4)$$

Considering one more maxwell Equation

$\nabla \times E = \frac{-\partial B}{\partial t}$ ...(5) $B = \mu_0 H$

$$\begin{vmatrix} ax & ay & az \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & -\gamma \\ Ex & Ey & Ez \end{vmatrix} = -j\omega\mu_0[Hxax + Hyay + Hzaz]$$

$$\frac{\partial Ez}{\partial y} + \gamma Ey = -j\omega\mu_0 Hx \quad \ldots(6)$$

$$\frac{\partial Ez}{\partial x} + \gamma Ex = -j\omega\mu_0 Hy \quad \ldots(7)$$

$$\frac{\partial Ey}{\partial x} - \frac{\partial Ez}{\partial y} = -j\omega\mu_0 Hz \quad \ldots(8)$$

$$(7) \Rightarrow Hy = \frac{1}{j\omega\mu_0}\frac{\partial Ez}{\partial x} + \frac{\gamma}{j\omega\mu_0}E_x \quad \ldots(9)$$

Subs. (9) in (2)

$$\frac{\partial Hz}{\partial y} + \frac{\gamma}{j\omega\mu_0}\frac{\partial Ez}{\partial x} + \frac{\gamma^2}{j\omega\mu_0}Ex = j\omega\varepsilon_0 Ex$$

$$\frac{\partial Hz}{\partial y} + \frac{\gamma}{j\omega\mu_0}\frac{\partial Ez}{\partial x} = \left[j\omega\varepsilon_0 - \frac{\gamma^2}{j\omega\mu_0}\right]Ex$$

$$= Ex\left[\frac{-\omega^2\mu_0\varepsilon_0 - \gamma^2}{j\omega\mu_0}\right]$$

$\frac{\partial Hz}{\partial y} + \frac{\gamma}{j\omega\mu_0}\frac{\partial Ez}{\partial x} = Ex\left[\frac{-h^2}{j\omega\mu_0}\right]$ $h^2 = \gamma^2 + \omega^2\mu_0\varepsilon_0$

$$\boxed{\Rightarrow Ex = \frac{-\gamma}{h^2}\frac{\partial Ez}{\partial x} - \frac{j\omega\mu_0}{h^2}\frac{\partial Hz}{\partial y}} \quad \ldots(10)$$

Subs (10) in (7)

$$\frac{\partial E_z}{\partial x} - \frac{\gamma^2}{h^2}\frac{\partial E_z}{\partial x} - \frac{\gamma(j\omega\mu_0)}{h^2}\frac{\partial Hz}{\partial y} = j\omega\mu_0 Hy$$

$$\left[1 - \frac{\gamma^2}{h^2}\right]\frac{\partial Ez}{\partial x} - \frac{\gamma(j\omega\mu_0)}{h^2}\frac{\partial Hz}{\partial y} = j\omega\mu_0 Hy$$

$$\left[\frac{h^2 - \gamma^2}{h^2}\right]\frac{\partial Ez}{\partial x} - \frac{\gamma(j\omega\mu_0)}{h^2}\frac{\partial Hz}{\partial y} = j\omega\mu_0 Hy$$

$$\left[\frac{\omega^2\mu_0\varepsilon_0}{h^2}\right]\frac{\partial Ez}{\partial x} - \frac{\gamma(j\omega\mu_0)}{h^2}\frac{\partial Hz}{\partial y} = j\omega\mu_0 Hy$$

$$\boxed{Hy = \frac{-\gamma}{h^2}\frac{\partial Hz}{\partial y} - \frac{j\omega\varepsilon_0}{h^2}\frac{\partial Ez}{\partial x}} \ldots(11)$$

From (6)

$$Hx = \frac{-1}{j\omega\mu_0}\frac{\partial Ez}{\partial y} - \frac{\gamma}{j\omega\mu_0}Ey \quad \ldots(12)$$

sub (12) in (3)

$$\frac{\partial Hz}{\partial x} - \frac{\gamma}{j\omega\mu_0}\frac{\partial Ez}{\partial y} - \frac{\gamma^2}{j\omega\mu_0}Ey = -j\omega\varepsilon_0 Ey$$

$$\frac{\partial Hz}{\partial x} - \frac{\gamma}{j\omega\mu_0}\frac{\partial Ez}{\partial y} = \left[\frac{\gamma^2}{j\omega\mu_0} - j\omega\varepsilon_0\right]E_y$$

$$\frac{\partial Hz}{\partial x} - \frac{\gamma}{j\omega\mu_0}\frac{\partial Ez}{\partial y} = \left[\frac{\gamma^2 + \omega^2\mu_0\varepsilon_0}{j\omega\mu_0}\right]Ey$$

$$\boxed{Ey = \frac{-\gamma}{h^2}\frac{\partial Ez}{\partial y} + \frac{j\omega\mu_0}{h^2}\frac{\partial Hz}{\partial x}} \ldots(13)$$

Subs (13) in (6)

$$\frac{\partial Ez}{\partial y} + \gamma\left[\frac{-\gamma}{h^2}\frac{\partial Ez}{\partial y} + \frac{j\omega\mu_0}{h^2}\frac{\partial Hz}{\partial x}\right] = -j\omega\mu_0 Hx$$

$$\frac{\partial Ez}{\partial y} - \frac{\gamma^2}{h^2}\frac{\partial Ez}{\partial y} + \frac{\gamma(j\omega\mu_0)}{h^2}\frac{\partial Hz}{\partial x} = -j\omega\mu_0 Hx$$

$$\left[1 - \frac{\gamma^2}{h^2}\right]\frac{\partial Ez}{\partial y} + \frac{\gamma(j\omega\mu_0)}{h^2}\frac{\partial Hz}{\partial x} = -j\omega\mu_0 Hx$$

$$\left[\frac{\omega^2\mu_0\varepsilon_0}{h^2}\right]\frac{\partial Ez}{\partial y} + \frac{\gamma(j\omega\mu_0)}{h^2}\frac{\partial Hz}{\partial x} = -j\omega\mu_0 Hx$$

$$\frac{-(j\omega\mu_0)(j\omega\varepsilon_0)}{h^2}\frac{\partial Ez}{\partial y} + \frac{\gamma(j\omega\mu_0)}{h^2}\frac{\partial Hz}{\partial x} = -j\omega\mu_0 Hx$$

$$\boxed{Hx = \frac{-\gamma}{h^2}\frac{\partial Hz}{\partial x} + \frac{j\omega\varepsilon_0}{h^2}\frac{\partial Ez}{\partial y}} \ldots(14)$$

$$Ex = \frac{-\gamma}{h^2}\frac{\partial Ez}{\partial x} - \frac{j\omega\mu_0}{h^2}\frac{\partial Hz}{\partial y}$$

$$Ey = \frac{-\gamma}{h^2}\frac{\partial Ez}{\partial y} + \frac{jw\mu_0}{h^2}\frac{\partial Hz}{\partial x}$$

$$Hx = \frac{-\gamma}{h^2}\frac{\partial Hz}{\partial x} + \frac{j\omega\varepsilon_0}{h^2}\frac{\partial Ez}{\partial y}$$

$$Hy = \frac{-r}{h^2}\frac{\partial Hz}{\partial y} - \frac{j\omega\varepsilon_0}{h^2}\frac{\partial Ez}{\partial x}$$

For a TEM wave propagating in z direction, Ez & Hz are zero.

∴ Ex, Ey, Hx and Hy will become zero. As all the components became zero, we can say that TEM wave cannot exists in R.W.G.

(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.

Sol. Cut off frequency & cut off wavelength

we know

$$h^2 = A^2 + B^2 = \gamma^2 + \omega^2\mu_0\varepsilon_0 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2$$

$$\Rightarrow \gamma^2 + \omega^2\mu_0\varepsilon_0 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2$$

$$\gamma^2 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 - \omega^2\mu_0\varepsilon_0$$

$$\gamma = \alpha + j\beta = \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 - \omega^2\mu_0\varepsilon_0} \ldots(1)$$

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Case (i) $\omega^2\mu_0\varepsilon_0 < \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2$

$\boxed{\gamma = \alpha}$ only attenuation, no propagation

→ attenuator

→ γ is real

→ Evanescent mode

Case (ii)

$\omega^2\mu_0\varepsilon_0 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2$

$\boxed{r = 0}$ $\boxed{\omega = \omega_c}$

$$\omega_c^2\mu_0\varepsilon_0 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2$$

$$\omega_c^2 = (2\pi fc)^2 = \left[\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2\right]\frac{1}{\mu_0\varepsilon_0}$$

$$\Rightarrow 2\pi f_c = \left[\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2\right]\frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

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

$$\Rightarrow \boxed{f_c = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}} \qquad f_c = \frac{c}{\lambda c}$$

$$\lambda_c = \frac{c}{f_c} = \frac{c}{\frac{c}{2}\sqrt{\frac{m^2}{a^2} + \frac{n^2}{b^2}}} = \frac{1}{\frac{\sqrt{m^2b^2 + n^2a^2}}{2ab}}$$

$$\boxed{\lambda_c = \frac{2ab}{\sqrt{m^2b^2 + n^2a^2}}} \Rightarrow \lambda_c \text{ does not depend on } \varepsilon \ \& \ \mu$$

Case (iii): $\omega^2\mu_0\varepsilon_0 > \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2$

$\boxed{\gamma = j\beta}$

→no attenuation

→ only propagation

→ H.P.F.

Summary:

At	$f<f_c$	$\gamma = \alpha$	Attenuator
	$f= f_c$	$\gamma = 0$	
	$f > f_c$	$\gamma = j\beta$	H.P.F.

(iii) If a = 2 cm and b = 1 cm, determine the range of frequency at which only one mode propagates. ($\varepsilon = 8.854 \times 10^{-12}$ F/m, $\mu_0 = 4\pi \times 10^{-7}$ H/m)

Sol.

a = 2 cm, b = 1 cm

a ≥ b

dominant node

TE_{10}

$$f_c = \frac{c}{2a} = \frac{3\times10^8}{2\times2\times10^{-2}} = \frac{3}{4}\times10^{10} = 7.5\text{ GHz}$$

Next node

$$TE_{20}\ f_c = \frac{c}{a} = 15\text{ GHz}$$

7.5 GHz ≤ f ≤ 15 GHz — only TE_{10} mode will propagate.

8.(b) A display is connected to port 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 start at location 400H. Assume that sub-routine for delay is available directly. Comment on your program appropriately and mention any necessary assumptions explicitly.

Sol. *

8.(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.

Sol. a = 6 cm, b = 4 cm

distance between maximum and minimum $\frac{\lambda_g}{4} = 4.47$ cm

f_0 = ? $\boxed{\lambda_g = 17.88\text{ cm}}$

$$\lambda_g = \frac{\lambda_0}{\sqrt{1+\left(\frac{\lambda_0}{\lambda_c}\right)^2}} \qquad \lambda_c = 2a$$

$$17.88 = \frac{\lambda_0}{\sqrt{1-\left(\frac{\lambda_0}{12}\right)^2}}$$

$$\frac{17.88}{12} = \frac{\lambda_0}{\sqrt{144-\lambda_0^2}} \qquad \boxed{\lambda_c = 12\text{ cm}}$$

$$1.49 = \frac{\lambda_0}{\sqrt{144-\lambda_0^2}} \quad \text{(squaring both sides)}$$

$$(1.49)^2 = \frac{\lambda_0^2}{(144-\lambda_0^2)}$$

$$2.2201 = \frac{\lambda_0^2}{144-\lambda_0^2}$$

$$319.6944 - 2.2201\lambda_0^2 = \lambda_0^2$$

$$319.6944 = 3.2201\lambda_0^2$$

$$\lambda_0^2 = \frac{319.6944}{3.2201} = 99.28$$

$$\lambda_0 = 9.96\text{ cm}$$

$$f = \frac{c}{\lambda_0} = \frac{3\times10^{10}}{9.96} \approx 3.01\text{ GHz}$$

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