MADE EASY

India's Best Institute for IES, GATE & PSUs

ESE 2023

Main Exam Detailed Solutions

Electronics & Telecom. Engineering

PAPER-II

EXAM DATE : 25-06-2023 | 2:00 PM to 5:00 PM

MADE EASY has taken due care in making solutions. If you find any discrepency/error/typo or want to contest the solution given by us, kindly send your suggested answer(s) with detailed explanation(s) at:

info@madeeasy.in

Corporate Office : 44-A/1, Kalu Sarai, Near Hauz Khas Metro Station, New Delhi-110016

Delhi | Hyderabad | Bhopal | Jaipur | Bhubaneswar | Pune | Kolkata

9021300500 www.madeeasy.in

ANALYSIS

Electronics and Telecom. Engineering Paper-II
ESE 2023 Main Examination

Sl.	Subjects	Marks
1.	Analog and Digital Communication Systems	70
2.	Control Systems	80
3.	Microprocessors and Microcontrollers	30
4.	Electromagnetics	60
5.	Signals and Systems	20
6.	Computer Organization and Architecture	80
7.	Advanced Communication	120
8.	Advanced Electronics	20
	Total	**480**

Scroll down for detailed solutions

Section-A

Q.1 (a) A band limited random signal X(t) has two-sided power spectral density SX(f) (PSD) given by [10 marks : 2023]

$$S_X(f) = \left\{ \begin{array}{ll} 10^{-6}(300-|f| \text{ watts/Hz for } |f| < 3 \text{ kHz} \\ 0, & \text{otherwise} \end{array} \right\}$$

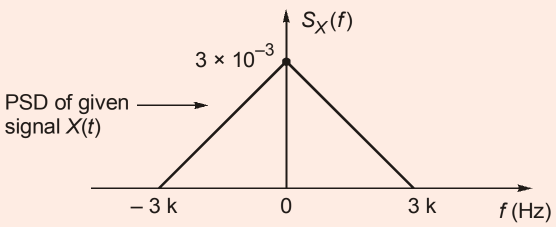
where f is frequency expressed in Hz.

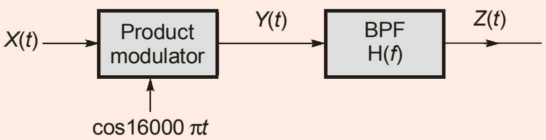
This signal modulates a carrier cos 16000-t and resultant signal is passed through an ideal band pass filter of unit gain with central frequency of 8 kHz and bandwidth of 2 kHz. Draw two-sided power spectral density diagram for the given signal, modulated carrier and the output of the filter.

Solution:

$$S_X(f) = 10^{-6}\left[3000-|f|\right]\frac{\text{Watts}}{\text{Hz}};\ |f| \leq 3\,\text{kHz}$$

$$0;\ \text{otherwise}$$

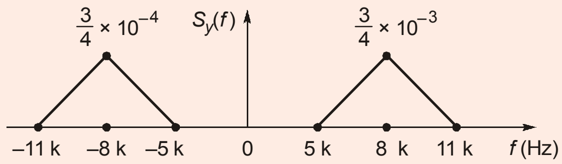




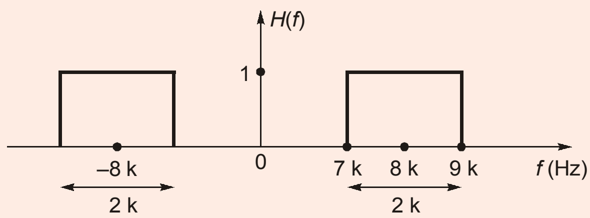
$$Y(t) = X(t)\cos 16000\pi t$$

$$S_Y(f) = \frac{X(f-f_o)+X(f+f_o)}{4};\quad \text{where } f_o = 8\text{ kHz}$$

PSD of modulated carrier signal:

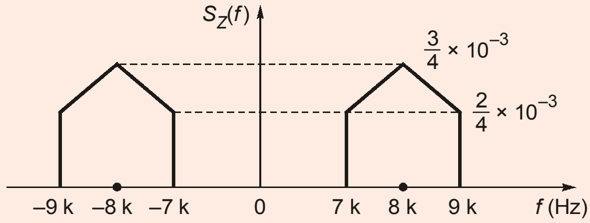


PSD of filter output → $S_z(f) = S_Y(f) \cdot |H(f)|^2$



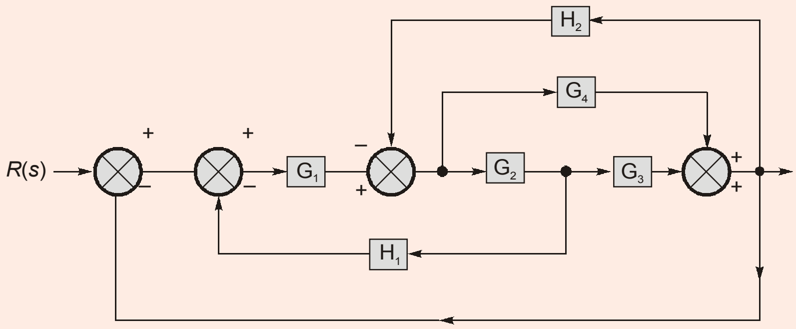
$$S_Y(f) = \frac{1}{4}\times 10^{-6} f - \frac{5}{4}\times 10^{-3}\ ;\ 5K \le f \le 8K$$

At f = 7 kHz $\Rightarrow$ $$S_Y(f) = \frac{2}{4}\times 10^{-3}$$



End of Solution

Q.1 (b) Convert the given block diagram to equivalent signal flow graph. Find the transfer function using Mason's Gain Formula.

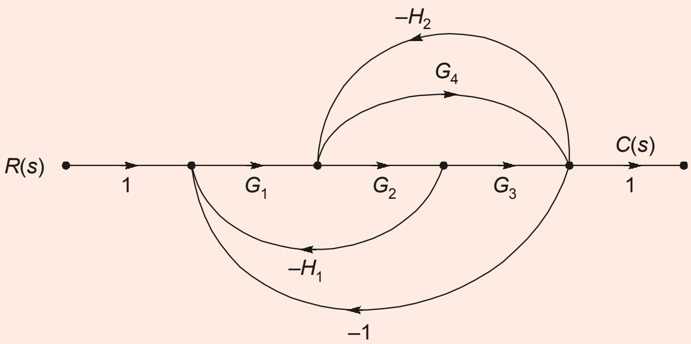


[10 marks : 2023]

Solution:

Equivalent signal flow graph:

Replace adder with Node:



Transfer function using Mason's gain formula:

$$\frac{C(s)}{R(s)} = \frac{\sum_{i=0}^{\infty} P_i \Delta_i}{\Delta}$$ N = Number of forward path

Forward Path:

$P_1 = G_1G_2G_3;\ \Delta_1 = 1$

$P_2 = G_1G_4;\ \Delta_2 = 1$

Loops:

$L_1 = -G_1G_2H_1$

$L_2 = -G_1G_2G_3$

$L_3 = -G_1G_4$

$L_4 = -G_2G_3H_2$

$L_5 = -G_4H_2$

No two non-touching loops are present.

$$\therefore \quad \frac{C(s)}{R(s)} = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta}$$

$$H(s) = \frac{E(s)}{R(s)} = \frac{G_1G_2G_3 + G_1G_4}{1 + G_1G_2H_1 + G_1G_2G_3 + G_1G_4 + G_2G_3H_2 + G_4H_2}$$

End of Solution

Q.1 (c) What do cores mean in a processor? Differentiate between Multi-core and Many-core architectures.

[4 + 6 marks : 2023]

Solution:

Processor Cores:

- Processor cores are individual processing units with in the computers CPU.
- Processor core receives instructions from a single computing task, working with the clock speed to quickly process this information and temporarily store it in the RAM.
- Most computers now have multiple processor cores that enable your computer to complete multiple tasks at once.
  E.g – Making edits to a document
  – While watching a video
  – While opening a new program etc.
- A processor with two cores is called a dual-core processor, with four cores called a Quad-core processor, six cores called as hexa-core, eight cores as octa core.
- Most consumer CPUs future between two and 12 cores.
- Work stations and servers CPUs may feature as many as 48 cores.
- Each process of core can perform operations separately from the others. Multiple cores may also work together to perform parallel operations on a shared set of data in the CPU cache memory.

Many core Processors

- Many core processors are special kinds of multi-core processors designed for a high degree of parallel processing.
- Many core processors contain numerous simpler independent processor cores from a few tens of cores to 1500 sand core more.
- Many core processors are used extensively in embedded computers and high performance computing.

- Many core processors are distinct from multi core processors in being optimized from the outset for a higher degree of explicit parallelism, and for higher. Throughput at the expense of latency and lower single thread performance.

Multicore:

- A multicore processor is a microprocessor on a single integrated circuit with two or more separate processing units called as cores, each of which reads and executes program instructions.
- The instructions are ordinary CPU Instructions (ADD, MOV, Branch) but the single processor can run instructions on separate cores at the same time, increasing overall speed for programs that support multithreading (or) other parallel computing techniques.
- Manufactures typically integrate the cores onto a single integrated circuit die known as a chip multi processor (CMP) (or) onto multiple dies in a single chip package.
- The microprocessors currently used in the personal computers are multi-core.
- A multicore processor implements multiprocessing in a single physical package. Designer may couple cores in a multicore devices tightly on loosely.
- Homogeneous multicore systems include only identical cores.
- Heterogeneous multi core systems have cores that are not identical.

Eg: Big and little endian cores that are share the same instruction set.

End of Solution

Q.1 (d) The electric field intensity of a linearly polarized uniform plane wave propagating in the +z direction in sea water is

$$\vec{E} = \hat{a}_x 100 \cos(10^7 \pi t) \text{ V/m at } z = 0$$

The constitutive parameters of sea water are

$$E_r = 72,\ \mu_r = 1, \text{ and } \sigma = 4 \text{ (S/m)}.$$

Determine the intrinsic impedance, wavelength and skin depth. The value of r0 may be taken as 8.854×10^{-12} F/m,n and $\mu_0 = 4\pi \times 10^{-7}$ H/m.

[10 marks : 2023]

Solution:

Given: $\bar{E} = \hat{a}_x 100\cos(10^7 \pi t)$ V/m at $z = 0$; $\epsilon_r = 72,\ \mu_r = 1,\ \sigma = 4$ S/m

(i)
$$\frac{\sigma}{\omega\epsilon} = \frac{4}{10^7 \pi * 8.85 \times 10^{-12} \times 72} \approx 200 >> 1$$

Hence, good conductor.

So,

(a) Intrinsic impedance,
$$\eta = \sqrt{\frac{\omega\mu}{\sigma}} \angle 45^\circ$$

$$\Rightarrow \quad \eta = \sqrt{\frac{10^7 \pi \times 4\pi \times 10^{-7}}{4}} \angle 45^\circ$$

$$\Rightarrow \quad \boxed{\eta = 3.14\angle 45^\circ}\ \Omega$$

(b) Wavelength λ:

$$\beta = \sqrt{\frac{\omega\mu\sigma}{2}} = \sqrt{\frac{10^7\pi \times 4\pi \times 10^{-7} \times 4}{2}} = \sqrt{8}\pi$$

$\Rightarrow$ $$\beta = \frac{2\pi}{\lambda} = \sqrt{8}\pi \quad \Rightarrow \boxed{\lambda = 0.707\text{ m}}$$

(c) Skin depth, δ:

$$\delta = \frac{1}{\alpha} = \frac{1}{\beta}; \text{ for good conductor}$$

$\Rightarrow$ $$\delta = \frac{1}{\sqrt{8}\pi} = 0.112$$

$\therefore$ $$\delta = 0.112\text{ m}$$

End of Solution

Q.1 (e) An electron beam exposure system operated at 20 kV accelerating voltage. Column length is 70 cm. Spot current is 500 nA, and numerical aperture of the final lens is 10^{-2} rad. The energy spread at the cathode is 0.2 V. If the coefficients of spherical and chromatic aberration are 10 cm and 62.5 cm respectively, determine the resolution limit at the centre of the exposure field.

[10 marks : 2023]

Solution:

The accelerating voltage is 20 kV which corresponds to a wavelength of

$$\lambda = \frac{h}{\sqrt{2\,meV}} = \frac{6.67 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 20 \times 10^3}}$$

$$\lambda = 0.874 \times 10^{-11}\text{ m}$$

Using Abbe's formula, resolution limit

$$d = \frac{0.61\lambda}{NA}, \quad \text{where } NA = \text{Numerical aperture}$$

$\therefore$ $$d = \frac{0.61 \times 0.874 \times 10^{-11}}{10^{-2}} = 5.33\text{ Å}$$

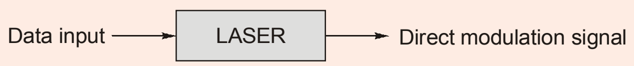
End of Solution

Q.1 (f) Between direct modulation and external modulation, which approach would you prefer as a dispersion management solution in case of optical fiber communication and why?

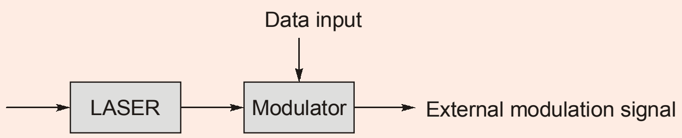
[10 marks : 2023]

Solution:

Direct modulation:



External modulation:



External modulation is preferred for dispersion management solution in optical fiber communication.

Direct modulation of LASER chips optical pulses and broadens their spectrum enough that direct modulation cannot be used at bit rates above 2.5 GB/s.

When bit rates are above 10 Gbps we employ external modulator to avoid spectral broadening induced by frequency chirping. All modern optical systems uses bit rates of 10 Gbps. So, external modulation is preferred in OFC.

End of Solution

Q.2 (a) A band limited analog signal of 5 kHz is sampled at twice the Nyquist rate. Each sample is quantized into 1024 equally likely levels that are statistically independent.

(i) Calculate information rate.

(ii) Can output of the source be transmitted without error over a Gaussian channel with a bandwidth of 50 kHz and signal to noise ratio of 30 dB?

(iii) What minimum bandwidth is needed to transmit the generated signal without error if a signal to noise ratio of 10 dB is needed to be maintained?

[20 marks : 2023]

Solution:

Given: $f_m = 5$ kHz ; $f_s = 2$ NR $= 4\,f_m = 20$ kHz

1024 levels with equal probability $\Rightarrow$ $H = \log_2 1024 = 10$ bits/sample

(i) Information rate $(R_b) = \text{H} \times f_s = 200$ kbps

(ii) $B = 50$ kHz

$$\frac{S}{N} = 30 \text{ dB} = 10^3$$

$$C = B\log_2\left(1+\frac{S}{N}\right) = 50\,k\log_2(1+10^3) = 498.3 \text{ kbps}$$

$$R_b = 200 \text{ kbps}$$

$C > R_b \rightarrow$ Output of the source can be transmitted without error.

(iii) Given $\frac{S}{N} = 10 \text{ dB} = 10$

$C \geq R_b \rightarrow B\log_2 (1 + 10) \geq 200$ k

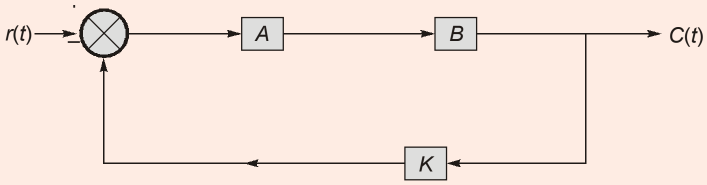
$$B \geq \frac{200\,k}{\log_2 11}$$

$$B \geq 57.81 \text{ kHz}$$

$$(B)_{min} = 57.81 \text{ kHz}$$

End of Solution

Q.2 (b) Consider the block diagram of an LTI system shown below:



Block A has impulse response $h_A(t) = e^{-2t}\,u(t)$.
Block B has impulse response $h_B(t) = e^{-t}\,u(t)$.
Block K is an ideal amplifier of gain 'K'.

(i) Calculate transfer function of the system when $K = 1$.
(ii) Find impulse response of the system when K = 0.
(iii) Find the value of K for which the system becomes unstable.

[5 + 5 + 10 marks : 2023]

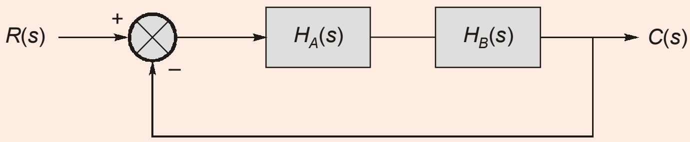
Solution:

We have;

$$h_A(t) = e^{-2t}\,u(t); \quad h_B(t) = e^{-t}u(t)$$

$$H_A(s) = \frac{1}{s+2}; \quad H_B(s) = \frac{1}{s+1}$$

(i) When $K = 1$



$$H(s) = \frac{C(s)}{R(s)} = \frac{H_A(s)\cdot H_B(s)}{1+H_A(s)\cdot H_B(s)}$$

$$= \frac{\left(\frac{1}{s+2}\right)\left(\frac{1}{s+1}\right)}{1+\left(\frac{1}{s+2}\right)\left(\frac{1}{s+1}\right)} = \frac{1}{(s+2)(s+1)+1}$$

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

(ii) When $K = 0$

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

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

(iii) The characteristic equation is given as:

$$1 + G(s)\cdot H(s) = 0$$

$$1 + H_A(s)\cdot H_B(s)\times K = 0 \qquad (\because\ H(s) = K)$$

$$1+\frac{1}{s+2}\times\frac{K}{s+1} = 0$$

$$s^2 + 3s + K + 2 = 0$$

Compare with std. 2nd order equation:

$$s^2 + 2\xi\omega_n s + \omega_n^2 = 0$$

$\because$ 'ω_n' is a positive parameter.

For system to be unstable:

$$K + 2 < 0$$

$$K < -2$$

End of Solution

Q.2 (c) (i) Write a code or pseudocode (in any standard programming language) to swap two numbers without using third variable.

[10 marks : 2023]

(ii) Write a code or pseudocode (in any standard programming language) to swap two numbers using pointers.

[10 marks : 2023]

Solution:

(i) Swapping without 3rd variable.

```
# include < stdio.h>
int main ()
{
    int x, y;
    printf("enter the values of x and y");
    scanf("%d%d",&x,&y);
    printf("before swapping numbers: %d%d\n"; x,y);
    x = x + y;
    y = x – y;
    x = x – y;
    Printf("After swapping numbers: %d %d\n", x,y);
    return 0;
}
```

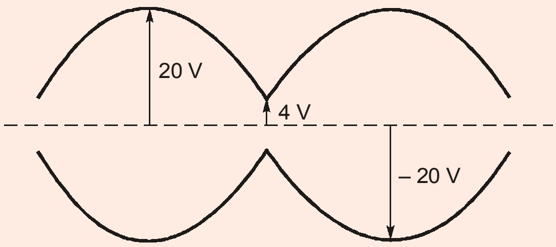
(ii) Swapping with pointers

```
#include <stdio.h>
void swap(int*n1, int*n2);
int main ()
{
    int num1 = 5; num2 = 10;
    int*Ptr1 = &num1;
    int*Ptr2 = &num2;
```

```
    printf("Before swapping Data is %d %d\n", num1, num2);
    swap (Ptr1, Ptr2);
    Printf("After swapping Data is %d%d\n", num1, num2);
    return 0;
}
Void swap (int*n1, int*n2)
{
    int temp;
    temp = *n1;
    *n1 = *n2;
    *n2 = temp;
}
```

End of Solution

Q.3 (a) (i) The AM envelope observed on a CRO is shown below:



Determine the following parameters :

(I) Peak amplitude of upper and lower sideband

(II) Peak amplitude of the carrier

(III) Peak change in amplitude of modulated carrier

(IV) Modulation index and Modulation efficiency

(V) Power in sideband and total power

[10 marks : 2023]

(ii) For a PCM system, determine :

(I) Minimum sampling rate

(II) Minimum number of bits used in PCM code

(III) Resolution

(IV) Maximum quantization error

(V) Coding efficiency

Assume :

Maximum analog input frequency = 4 kHz

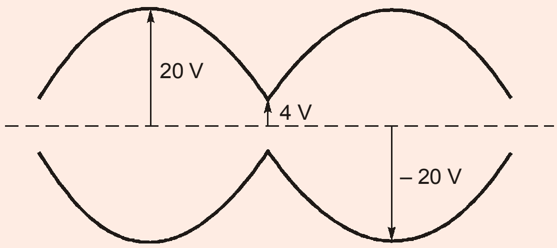
Maximum decoded voltage at R_X = ± 2.55 V

Minimum dynamic range = 46 dB

[10 marks : 2023]

Solution:

(i)



Given: $A_{max} = 20$ V and $A_{min} = 4$ V.

(I) Peak amplitude of USB and LSB = $\frac{A_c u}{2}$

$$A_c = \frac{A_{max} + A_{min}}{2} = 12 \text{ V}$$

$$u = \frac{A_{max} - A_{min}}{A_{max} + A_{min}} = \frac{16}{24} = 0.666$$

Peak amplitude of sidebands = $12 \times \frac{16}{24} \times \frac{1}{2} = 4$ V

(II) Peak amplitude of carrier → $A_c = 12$ V

(III) Peak change in amplitude of modulated carrier

$$= A_{max} - A_c = A_c - A_{min} = 8 \text{ V}$$

(IV)
$$\mu = \frac{2}{3}$$

$$n = \frac{\mu^2}{2+\mu^2} = 18.18\%$$

(V)
$$P_{SB} = \frac{P_c \mu^2}{2} = \frac{A_c^2 \mu^2}{4} = 16 \text{ W}$$

$$P_t = P_c\left[1+\frac{\mu^2}{2}\right] = \frac{A_c^2}{2}\left[1+\frac{\mu^2}{2}\right] = 88 \text{ W}$$

(ii) (I) Minimum sampling frequency = $2 f_m = 2 \times 4$ kHz = 8 kHz

(II) Dynamic range $(DR) = \frac{V_{max}}{V_{min}} = \frac{V_{max}}{\text{Resolution}} = 2^n - 1$

$$(DR)_{dB} = 20\log_{10} DR$$
$$46 = 20\log_{10} DR$$
$$DR = 10^{2.3} = 199.5$$

Minimum dynamic range required is 46 dB i.e. 199.5

$$2^n - 1 \geq 199.5$$
$$n \geq 7.647$$
$$n = 8 \text{ bits}$$

(III) Resolution = $\frac{V_{max}}{2^n - 1} = \frac{2.55}{2^8 - 1} = 0.01\,\text{V}$

(IV) Maximum quantization error = $\frac{\text{Resolution}}{2} = 0.005\ \text{V}$

(V) Coding efficiency = $\frac{\text{Minimum number of bits required (including sign bit)}}{\text{Actual number of bits used (including sign bit)}}$

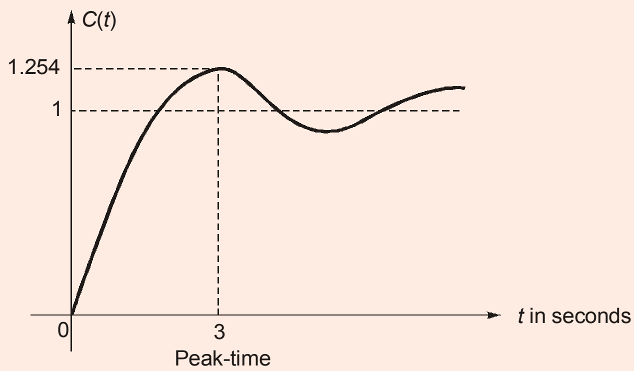
$$= \frac{7.647+1}{8+1} \times 100 = 96.08\%$$

End of Solution

Q3 (b) (i) A unity feedback system having forward transfer function

$$G(s) = \frac{K}{s(Ts+1)}$$

is subjected to a unit-step input. Determine the values of K and T from the output response C(t) curve shown below:



Also find the setting time of this system for 2% criterion.

(ii) Design a PD controller so that the system having open loop function G(s)H(s) $= \frac{1}{s(s+1)}$ will have a phase margin of 40º at 2 rad/sec.

[10+10 marks : 2023]

Solution:

(i) Peak overshoot from given response:

$$\%M_p = \frac{C(t_p) - C(\infty)}{C(\infty)} \times 100$$

$$= \frac{1.254 - 1}{1} \times 100 = 25.4\%$$

We know for unit step input:

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

$$0.254 = e^{-\xi\pi/\sqrt{1-\xi^2}}$$

$$-1.37 = \frac{-\xi\pi}{\sqrt{1-\xi^2}}$$

$$1.876 = \frac{\xi^2\pi^2}{1-\xi^2}$$

$$0.19 = \frac{\xi^2}{1-\xi^2}$$

$$0.19 - 0.19\xi^2 = \xi^2$$

$$\xi = 0.4$$

Peak time (t_p) = 3 sec

$\because$ $$t_p = \frac{n\pi}{\omega_d}$$

at $n = 1$ ....first peak overshoot

$$t_p = \frac{\pi}{\omega_d}$$

$$\omega_d = \frac{\pi}{t_p} = \frac{\pi}{3}$$

$$\omega_n\sqrt{1-\xi^2} = \frac{\pi}{3}$$

$$\omega_n\sqrt{1-0.16} = \frac{\pi}{3}$$

$$\omega_n = 1.142 \text{ rad/s}$$

System's characteristic equation is given as:

$$1 + G(s) = 0$$

$$1+\frac{K}{s(Ts+1)} = 0$$

$$s^2T + s + K = 0$$

$$s^2 + \frac{1}{T}s + \frac{K}{T} = 0$$

Compare with std. 2nd order system.

$$s^2 + 2\xi\omega_n s + \omega_n^2 = 0$$

$$\omega_n = \sqrt{\frac{K}{T}}\ ;\ 2\xi\omega_n = \frac{1}{T} \quad \Rightarrow \quad 2\times 0.4\times 1.142 = \frac{1}{T}$$

$$(1.142)^2 = \frac{K}{T} \qquad\qquad T = 1.094$$

$$K = (1.142)^2 \times (1.094)$$

$$K = 1.427$$

(ii) We have; Phase Margin = 40°

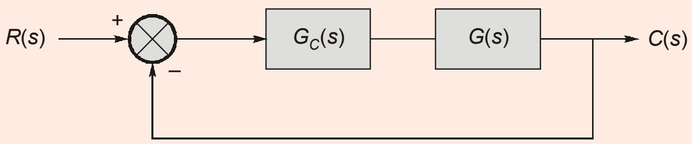
Gain crossover frequency (ω_{gc}) = 2 rad/s

$$\because \quad P_m = 180° + \angle G(\omega)\cdot H(\omega)\big|_{\omega=\omega_{gc}}$$

$$40° = 180° + \phi\big|_{\omega=\omega_{gc}}$$

$$\phi\big|_{\omega=\omega_{gc}} = -140°$$

PD controller's $G_C(s) = K_P + sK_D$



$$\therefore \quad G_C(s)\cdot G(s) = (K_P + sK_D)\cdot\frac{1}{s(s+1)}$$

$$\phi = \tan^{-1}\left(\frac{\omega K_D}{K_P}\right) - \left[90° + \tan^{-1}(\omega)\right]$$

at $\omega = \omega_{gc} = 2$ rad/s

$$-140° = \tan^{-1}\left(\frac{2K_D}{K_P}\right) - \left[90° + \tan^{-1}(2)\right]$$

$$13.43° = \tan^{-1}\left(\frac{2K_D}{K_P}\right)$$

$$0.238 = \frac{2K_D}{K_P}$$

$$0.12 = \frac{K_D}{K_P}$$

$$K_D = 0.12\,K_P$$

at $\omega = \omega_{gc}$:

$$\left|\frac{K_P + sK_D}{s(s+1)}\right|_{\omega=\omega_{gc}} = 1$$

$$\frac{\sqrt{K_P^2 + (\omega_{gc}K_D)^2}}{\omega_{gc}\sqrt{\omega_{gc}^2 + 1}} = 1$$

$$\frac{\sqrt{K_P^2 + (2K_D)^2}}{2\sqrt{4+1}} = 1$$

$$\frac{\sqrt{K_P^2 + 4K_D^2}}{2\sqrt{5}} = 1$$

$$K_P^2 + 4K_D^2 = 20$$

$$K_P^2 + 4(0.12K_P)^2 = 20$$

$$K_P^2 + 4 \times ((0.12)^2 K_P^2 = 20$$

$$K_P^2 + 0.0576K_P^2 = 20$$

$$1.0576K_P^2 = 20$$

$$K_P = 4.348$$

$$K_D = 0.12\ K_P = 0.52$$

End of Solution

Q.3 (c) Consider a set 5 processes for which arrival time, CPU time needed and the priority are given below:

Process ↓	Arrival Time (ms)	CPU time needed (ms)	Priority
P_1	0	10	5th
P_2	0	5	2nd
P_3	2	3	1st
P_4	5	20	4th
P_5	10	2	3rd

(i) What will be the average waiting time if the CPU scheduling policy is SJF (without pre-emption)?

(ii) What will be the average waiting time if the CPU scheduling policy is SJF (with pre-emption)?

(iii) What will be the average waiting time if the CPU scheduling policy is priority scheduling (without pre-emption)?

(iv) What will be the average waiting time if the CPU scheduling policy is priority scheduling (with pre-emption)?

[5 + 5 + 5 + 5 marks : 2023]

Solution:

Pid	AT	BT	Priority
P_1	0	10	5th
P_2	0	5	2nd
P_3	2	3	1st
P_4	5	20	4th
P_5	10	2	3rd

(i) SJF

P_2	P_3	P_1	P_5	P_4

0 5 8 18 20 40

	CT	TAT	WT
P_1	18	18	8
P_2	5	5	0
P_3	8	6	3
P_4	40	35	15
P_5	20	10	8

$$\text{Average WT} = \frac{(8+0+3+15+8)}{5} = 6.8 \text{ ms}$$

(ii) SJF with Pre-emption:

P_2	P_2	P_2	P_2	P_2	P_3	P_3	P_3	P_1	P_1	P_5	P_1	P_4

0 1 2 3 4 5 6 7 8 9 10 12 20 40

	CT	TAT	WT
P_1	20	20	10
P_2	5	5	0
P_3	8	6	3
P_4	40	35	15
P_5	12	2	0

$$\text{Average WT} = \frac{(10+0+3+15+0)}{5} = 5.6 \text{ ms}$$

(iii) Priority without Pre-emption:

P_2	P_3	P_4	P_5	P_1

0 5 8 28 30 40

	CT	TAT	WT
P_1	40	40	30
P_2	5	5	0
P_3	8	6	3
P_4	28	23	3
P_5	30	20	18

$$\text{Average WT} = \frac{(30+0+3+3+18)}{5} = 10.8 \text{ ms}$$

(iv) Priority with Pre-emption:

P_2	P_2	P_3	P_3	P_3	P_2	P_2	P_2	P_4	P_4	P_5	P_4	P_1

0 1 2 3 4 5 6 7 8 9 10 12 30 40

	CT	TAT	WT
P_1	40	40	30
P_2	8	5	0
P_3	5	3	0
P_4	30	25	5
P_5	12	2	0

$$\text{Average WT} = \frac{(30+0+0+5+0)}{5} = 7 \text{ ms}$$

End of Solution

Q.4 (a) A discrete memoryless source generates either 0 or 1 at a rate of 160 kbps; 0 is generated three times more frequently than 1. A coherent binary PSK modulator is employed to transmit these bits over a noisy channel. The received bits are detected in a correlator fed with the basis function of unit energy (for this BPSK scheme) as the reference signal. The receiver makes a decision in favour of 1 if the correlator output is positive, else decides in favour of 0. If 0 and 1 are represented as

$0 : \rightarrow -(6\sqrt{2}\cos 640\,\pi \times 10^3\, t)$ V

$1 : \rightarrow +(6\sqrt{2}\cos 640\,\pi \times 10^3\, t)$ V

(i) Determine transmitted signal energy per bit.

(ii) Determine basis function of unit energy for this binary PSK scheme.

[12 + 8 marks : 2023]

Solution:

(i) Transmitted signal energy per bit $(E_b) = \int_0^{T_b} [S_1(t)]^2 dt = \int_0^{T_b} [S_2(t)]^2 dt$

where, $T_b = \dfrac{1}{R_b} = \dfrac{1}{160\times 10^3} = 0.00625\times 10^{-3} = 6.25\ \mu\text{sec}$

$$E_b = \int_0^{6.25\times 10^{-6}} (6\sqrt{2}\cos(640\pi\times 10^3 t))^2 dt$$

$$E_b = 36\times 2\int_0^{6.25\times 10^{-6}} \cos^2(640\pi\times 10^3 t)dt$$

$$E_b = 72\int_0^{6.25\times 10^{-6}} \left[\frac{1+\cos(1280\pi\times 10^3 t)}{2}\right] dt$$

$$E_b = \frac{72}{2}\left(t + \frac{\sin[1280\pi\times 10^3 t]}{1280\pi\times 10^3}\right)\Bigg|_0^{6.25\times 10^{-6}}$$

$$E_b = 36\left[6.25\times 10^{-6} + \frac{\sin(1280\pi\times 10^3\times 6.25\times 10^{-6})}{1280\times 10^3}\right]$$

$$E_b = 36[6.25\times 10^{-6}] = 225\ \mu\text{J}$$

(ii) Unit basis function $\rightarrow \phi(t) = \dfrac{S_1(t)}{\sqrt{E_{s1}}}$

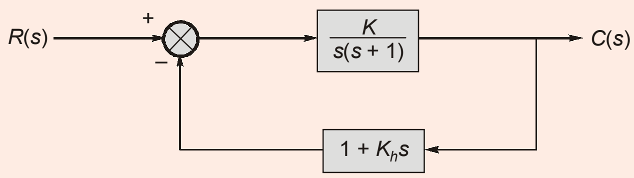
$$E_{s1} = \text{Energy}\,[S_1(t)]$$

$$= \text{Energy}\left[6\sqrt{2}\cos 60\pi\times 10^3 t\right] = 225\ \mu\text{J}$$

$$\phi(t) = \frac{6\sqrt{2}\cos(640\pi\times 10^3 t)}{\sqrt{225\times 10^{-6}}} = 565.68\cos(640\pi\times 10^3 t)$$

End of Solution

Q.4 (b) For the system shown below,

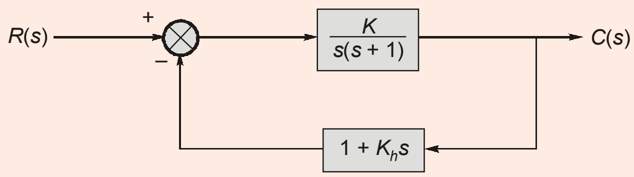


Draw the root-locus with $K_h = 0$ and K as variable. Obtain the value of K so that the system damping ratio is 0.158.

For the obtained value of K, draw the root-locus with K_h as variable. Find the value of K_h that improves the system damping ratio to 0.5.

[20 marks : 2023]

Solution:



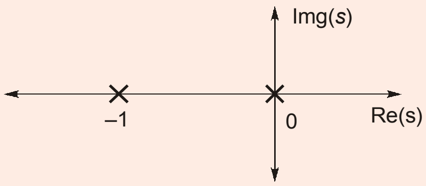
First drawing the root locus for $K_h = 0$ and K as variable

∴ So, open loop transfer function is given by,

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

$$\therefore \qquad G(s)H(s) = \frac{K}{s(s+1)}$$

The pole-zero plot is given by,



$$\text{Centroid} = \frac{\Sigma\text{Real part of open loop pole} - \Sigma\text{Real part of open loop zero}}{P\text{–}Z}$$

where $P \rightarrow$ Number of open loop pole.

$Z \rightarrow$ Number of open loop zero.

$$\therefore \qquad \text{Centroid} = \frac{0-1-0}{2} = -\frac{1}{2} = -0.5$$

$$\text{Angle of asymptote } \phi = \frac{(2K+1)180}{P-Z}$$

where $K = 0, 1, 2, \ldots. P - Z - 1$

∵ $P = 2, Z = 0$

$$\therefore \qquad K = 0 \text{ and } 1$$

$$\therefore \qquad \phi_A = 90°, 270°$$

$\Rightarrow$ Break away points is calculated by solving

$$\frac{dK}{ds} = 0$$

The characteristic equation is given by

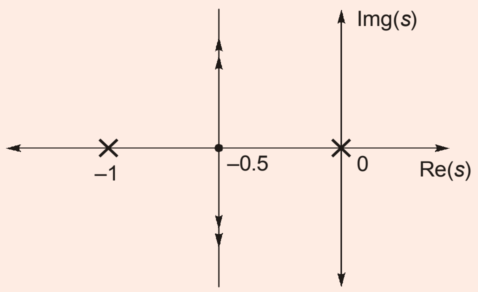
$$1 + G(s)H(s) = 0$$
$$s(s+1) + K = 0$$
$$K = -[s(s+1)]$$
$$\frac{dK}{ds} = \frac{d}{ds}\left[s^2 + s\right]$$

$\therefore$ and $-\frac{d}{ds}\left[s^2 + s\right] = 0$

$\therefore$ $2s + 1 = 0$

$S = -\frac{1}{2}$ is valid breakaway point.

The root locus diagram is



Now finding the value of K for given system having damping ratio is 0.158.

The characteristic equation is $1 + GH = 0$

$\therefore$ $s^2 + s + k = 0$

On comparing with standard 2nd order system, we get

$$2\xi\omega_n = 1 \text{ and } \omega_n = \sqrt{K}$$

where, $\xi = 0.158$ given

$\therefore$ $2 \times 0.158 \times \omega_n = 1$

$\therefore$ $\omega_n = 3.164$ rad/sec

$\therefore$ $K = \omega_n^2 = 10.01$

$\therefore$ $K \cong 10$

Now, using $K = 10$ and keeping K_h as variable, we have to plot root locus.

So, the open loop transfer function will be

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

The characteristic equation is

$$1 + G(s)H(s) = 0$$
$$1 + \frac{10(1 + K_h s)}{s(s+1)} = 0$$

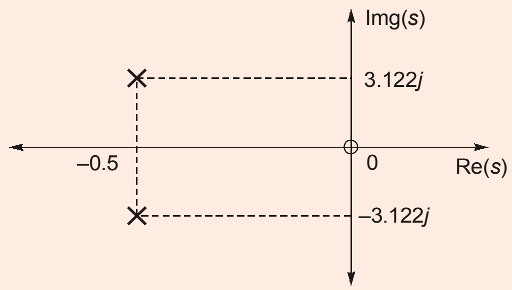
$$s(s+1)+10+10K_h s = 0$$

$$1+\frac{10K_h s}{s(s+1)+10} = 0$$

Now, the open loop transfer function can be written as

$$G(s)H(s) = \frac{K_h s}{0.1s^2+0.1s+1}$$

The pole zero plot is shown below:



$$\text{Angle of asymptote} = \frac{(2K+1)180}{P-Z}$$

where $K = 0, 1, \ldots\ldots P-Z-Z$ $[\because P=2, Z=1]$

$$\therefore \quad K = 0$$

$$\therefore \quad \phi_A = 180°$$

$$\text{Centroid} = \frac{\Sigma\text{Real part of open loop pole} - \Sigma\text{Real part of open loop zero}}{P\text{–}Z}$$

$$= \frac{-0.5-0.5-0}{2-1} = \frac{-1}{2} = -0.5$$

Now finding breakaway point by solving $\frac{dk_h}{ds} = 0$

The characteristic equation is given by

$$\therefore \quad 1+G(s)H(s) = 0$$

$$s(s+1)+10+10K_h s = 0$$

$$K_h = \frac{-[s(s+1)+10]}{10s}$$

$$\frac{dK_h}{ds} = \frac{d}{ds}\left[-\left[\frac{s(s+1)+10}{10s}\right]\right]$$

$$\therefore \quad \frac{10s[2s+1]-(s^2+s+10)10}{(10s)^2} = 0$$

$$\therefore \quad s[2s+1]-(s^2+s+10) = 0$$

$$\therefore \quad s^2 = 10$$

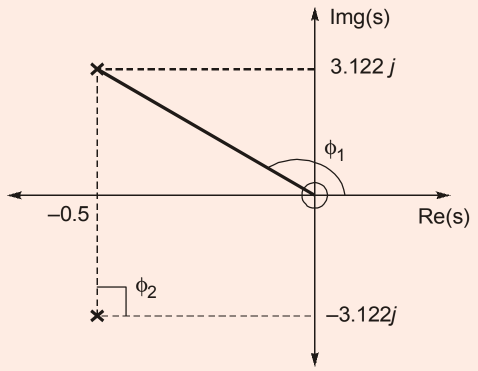
$$s = \pm 3.162$$

So, $s = -3.162$ is valid breakaway point.

There are complex poles, so we will find angle of departure ϕ_D at complex pole.

$$\phi_D = \pm[180+\phi]$$

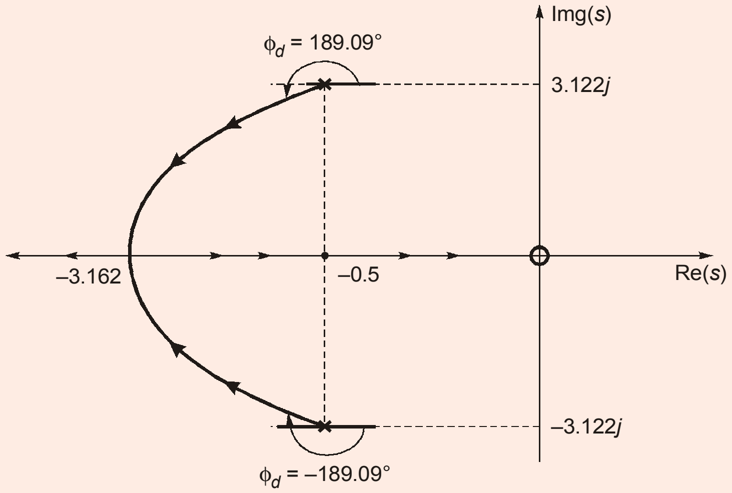
where, $\phi = \Sigma\phi_z - \Sigma\phi_p$



$$\phi = \phi_1 - \phi_2 = 99.09 - 90 = 9.098$$

$\therefore$ $$\phi_D = \pm[180 + 9.098] = \pm 189.90$$

The root locus will be



Now finding K_h for giving damping ratio to 0.5

$\therefore$ Characteristic equation is $1 + G(s)H(s) = 0$

$$s^2 + s + 10 + 10K_h s = 0$$

$$s^2 + (1 + 10K_h)s + 10 = 0$$

Comparing with standard 2nd order system

$$2\xi\omega_n = 1 + 10K_h$$

$$\omega_n^2 = 10$$

$\therefore$ $$\omega_n = \sqrt{10} \text{ rad/sec}$$

$\therefore$ $$K_h = \frac{(2\times 0.5\times\sqrt{10} - 1)}{10}$$

$\therefore$ $$K_h = 0.216$$

End of Solution

Q.4 (c) (i) A processor array has 512 processors. Each processor is capable of adding a pair of integers in 1 μ second. What is the performance (operations per second) of this processor array adding two integer vectors of length 1000, assuming each vector is allocated to the processors in a balanced fashion?

(ii) A processor array has 512 processors. Each processor is capable of adding a pair of integers in 1 μ second. What is the performance (operations per second) of this processor array adding two integer vectors of length 512, assuming each vector is allocated to the processors in a balanced fashion?

[10 + 10 marks : 2023]

Solution:

(i)
- System contain 512 processor array.
  So, 512 Data elements are processed in parallel.
- Addition of one pair of integers takes 1 μsec.
- Input Vector size = 1000.
- Vector is a one dimensional array of Data.
- In one Attempt $\rightarrow$ 512 elements are processed.
  So, 2 attempts required to process 1000 elements.

$\therefore$ 1000 elements processing time = 2 * 1 μsec
= 2 μsec.

Data Point of view

1000 operation $\rightarrow$ 2 μ sec
'X' operation $\rightarrow$ 1 sec

$$\text{'X'} \Rightarrow \frac{1000 \text{ operations}}{2\,\mu\text{sec}} \Rightarrow 500 \text{ million Operations/sec}$$

- Here, 1000 inputs given in the vector and 512 processor array given.
  In, one attempt 512 operations are running in parallel. So, at least two attempts required to process 1000 element. So, in the processor array,
  512 + 512 = 1024 operations are possible in 2 attempts.
  $\therefore$ CPU point of view
  1024 operation $\rightarrow$ 2 μsec
  'X' operations $\rightarrow$ 1 sec

$$X = \frac{1024 \text{ operations}}{2\,\mu\,\text{sec}}$$

$$\Rightarrow \quad X = 512 \text{ million operation/sec}$$

(ii) System contain 512 processor Array.
So, 512 Data elements are processed in parallel.
- Addition of one pair data takes 1 μsec.
- Input vector size = 512
- In one attempt 512 elements are processed.

- 512 elements processing time is,

$$512 \text{ operations} \rightarrow 1\ \mu\text{sec}$$
$$\text{'X' operations} \rightarrow 1 \text{ sec}$$
$$X = \frac{512 \text{ operation}}{1\mu \text{ sec}} = 512 \times 10^6 \text{ operations/sec}$$
$$= 512 \text{ million operations/sec.}$$

End of Solution

Section-B

Q.5 (a) What are the causes of attenuation of light signal through the optical fiber? A certain optical fiber has a attenuation of 0.6 dB/km at 1300 nm and 0.3 dB/km at 1550 nm. Suppose the following two optical signals are launched simultaneously into the fiber : an optical power of 150 μW at 1300 nm, and an optical power of 100 μW at 1550 nm. What are the power levels in μW of these two signals at (i) 8 km, and (ii) 20 km?

[10 marks : 2023]

Solution:

Causes for attenuation:

1. Absorption loss
2. Scattering loss
3. Waveguide bend loss/radiative loss
4. Core and clad loss
5. Dispersion
6. Coupling loss

Given that: $\alpha = 0.6$ dB/km ; $\lambda = 1300$ nm ; $P_{in} = 150\ \mu$W ; $L = 8$ km ; $P_{out} = ?$

For length of 8 kms, $P_{out} = P_{in} 10^{-\alpha L/10} = 150\,\mu\text{W} \times 10^{-\frac{0.6\times 8}{10}}$

$$P_{out} = 49.66\,\mu\text{W}$$

For length of 20 kms,

$$P_{out} = 150\,\mu\text{W} \times 10^{-\frac{0.6\times 20}{10}} = 9.46\,\mu\text{W}$$

Given that: $\alpha = 0.3$ dB/km ; $\lambda = 1550$ nm ; $P_{in} = 100\ \mu$W ; $L = 8$ km ; $P_{out} = ?$

For L = kms, $P_{out} = P_{in}\, 10^{-\alpha L/10}$

$$P_{out} = 100\,\mu\text{W} \times 10^{-\frac{0.3\times 8}{10}} = 57.54\,\mu\text{W}$$

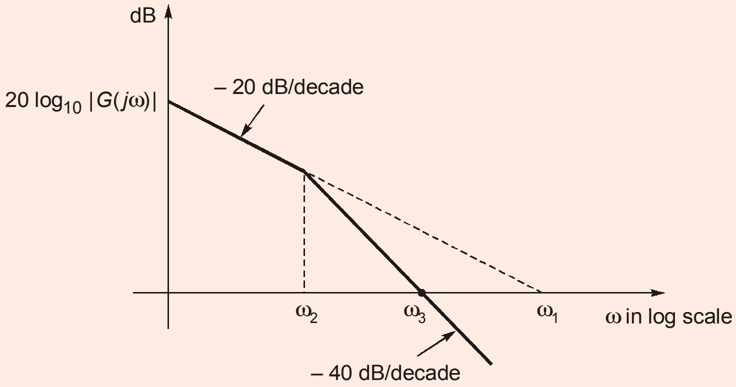
For L = 20 kms, $P_{out} = 100\,\mu\text{W} \times 10^{-\frac{0.3\times 20}{10}} = 25.11\,\mu\text{W}$

End of Solution

Q.5 (b) Consider the unity-feedback system having forward transfer function

$$G(s) = \frac{K}{s(Js+F)}$$

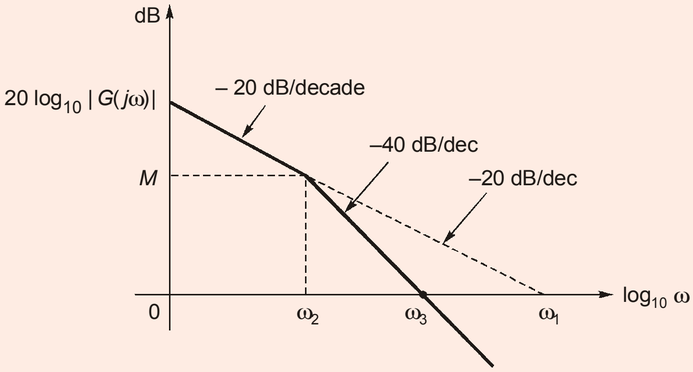
The Bode plot of G(s) is shown below as asymptotic approximation :



Express the relation between ω_1, ω_2 and ω_3. Also find the static velocity error coefficient K_v of this system. You can assume $\omega_2 << \omega_3$.

[10 marks : 2023]

Solution:



$$\text{Slope} = -40 = \frac{0-M}{\omega_3-\omega_2}$$

$$40 = \frac{M}{\omega_3-\omega_2} \quad ...(1)$$

$$\text{Slope} = -20 = \frac{0-M}{\omega_1-\omega_2}$$

$$20 = \frac{M}{\omega_1-\omega_2} \quad ...(2)$$

By (1)/(2),

$$\frac{40}{20} = \frac{\omega_1-\omega_2}{\omega_3-\omega_2}$$

$$2\omega_3 - 2\omega_2 = \omega_1 - \omega_2$$

$$2\omega_3 = \omega_1 + \omega_2$$

$$\omega_3 = \frac{(\omega_1 + \omega_2)}{2}$$

where, $\omega_3 = \log_{10} \omega_3'$

$\omega_2 = \log_{10} \omega_2'$

$\omega_1 = \log_{10} \omega_1'$

$$\therefore \quad \log_{10} \omega_3' = \frac{1}{2}\left[\log_{10} \omega_1' + \log_{10} \omega_2'\right]$$

$$[\omega_3']^2 = \omega_1' \cdot \omega_2'$$

$$\omega_3' = \sqrt{\omega_1' \cdot \omega_2'}$$

Velocity error coefficient:

$$\text{OLTF } G(s)H(s) = \frac{K/J}{s[s + F/J]}$$

For type 1 system,

$$K_V = \lim_{s \to 0} s \cdot G(s)H(s)$$

$$K_V = \frac{K/J}{F/J} = \frac{K}{F}$$

$$K_V = \frac{K}{F}$$

End of Solution

Q.5 (c) The seek time of a disk is 30 ms. It rotates at the rate of 30 rotations per second. Each track has a capacity of 300 words. What will be the access time?

[10 marks : 2023]

Solution:

- Seek time = 30 ms
- Rotational latency

$$30 \text{ revolutions} \rightarrow 1 \text{ sec}$$

$$1 \text{ revolution} \rightarrow \text{'X' time}$$

$$\Rightarrow \quad X = \frac{1}{30} \text{ sec}$$

$$\Rightarrow \quad X = 0.03333 \text{ sec}$$

$$\Rightarrow \quad X = 33.33 \text{ ms}$$

$$\therefore \text{ Average Rotational latency} = \frac{1}{2} \text{ revolution time}$$

$$= \frac{1}{2} \times 33.33 \text{ ms}$$

$$= 16.66 \text{ ms}$$

(3) Transfer time

- 1 revolution required to access time = single track data
- Here Data size not given.

So, assume as word.

$$1 \text{ revolution time} \rightarrow 300 \text{ words}$$
$$\text{'X' time} \rightarrow 1 \text{ word}$$

$$\Rightarrow \quad \text{'X'} = \frac{33.33 \text{ ms}}{300}$$

$$\Rightarrow \quad \text{'X'} = 0.1111 \text{ ms}$$

- Average time required to access one word.

⇒ Seek time + Avg. rotational latency + Transfer time

⇒ (30 ms + 16.66 ms + 0.1111 ms)

⇒ 46.77 ms.

- Average time required to access the track Data is

⇒ 30 ms + 16.66 ms + 33.33 ms

⇒ 79.99 ms

End of Solution

Q.5 (d) A wave at 10 GHz propagates in a rectangular waveguide with inner dimensions a = 1.5 cm and b = 0.6 cm. The conductivity of the waveguide walls is $\sigma = 1.57 \times 10^7$ S/m. The waveguide is filled with polyethylene with $\varepsilon_r = 2.25$ and $\mu_r = 1$. Calculate the guide wavelength and the wave impedance of the waveguide. Assume that dominant mode is propagating. Also determine the attenuation constant due to loss in the dielectric. The loss tangent of the polyethylene may be taken as 4×10^{-4} and the value of ε_0 is 8.854×10^{-12} F/m.

[10 marks : 2023]

Solution:

Given data: $f = 10$ GHz ; $a = 1.5$ cm ; $b = 0.6$ cm ; $\sigma_c = 1.57 \times 10^7$ S/m

$\epsilon_r = 2.25$; $\mu_r = 1$; Mode : TE_{10}

(i) Guide wavelength λ:

$$f_c\big|_{TE_{10}} = \frac{v}{2a} = \frac{c}{\sqrt{\epsilon_r}\cdot 2a} = \frac{3\times 10^{10}}{\sqrt{2.25}\times 2\times 1.5} = 667 \text{ GHz}$$

$$\therefore \quad \lambda = \frac{\lambda_{TEM}}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} \; ; \quad \lambda_{TEM} = \frac{v}{f} = \frac{c}{\sqrt{\epsilon_r}\, f} = 0.02$$

$$\Rightarrow \quad \lambda = \frac{0.02}{\sqrt{1-\left(\frac{6.67}{10}\right)^2}} = 0.027 \text{ m}$$

$\therefore$ Guide wavelength, $\lambda = 0.027$ m

(ii) Wave impedance, η :

$$\eta_{TE10} = \frac{\eta_{TEM}}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}; \quad \eta_{TEM} = \frac{120\pi}{\sqrt{\epsilon_r}} = 251.33\ \Omega$$

$\Rightarrow$
$$\eta_{TE10} = \frac{251.33}{\sqrt{1-\left(\frac{6.67}{10}\right)^2}} = 337.33\ \Omega$$

$\therefore$ Wave impedance of guide;

$$\eta_{TE10} = 337.33\ \Omega$$

(iii) Attenuation constant due to loss in dielectric

$$\alpha_d = \frac{\sigma_d}{2}\eta_{TE10}$$

Here, $\frac{\sigma_d}{\omega\epsilon} = 4\times10^{-4}$ given

$\Rightarrow$ $\sigma_d = \omega\epsilon \times 4\times10^{-4} = 2\pi\times10\times10^9\times8.85\times10^{-12}\times2.25\times4\times10^{-4}$

$\Rightarrow$ $\sigma_d = 5\times10{-}4$ S/m

$\therefore$ Attenuation constant due to loss in dielectric;

$$\boxed{\alpha_d = 8.44\times10^{-2}}\ \text{Np/m}$$

End of Solution

Q.5 (e) What will be the execution time for the instruction "STA addr" of 8085 with a clock frequency of 3 MHz? Number of T-states required by the instruction is 13.

[10 marks : 2023]

Solution:

Given instruction "STA address" w.r.t 8085.

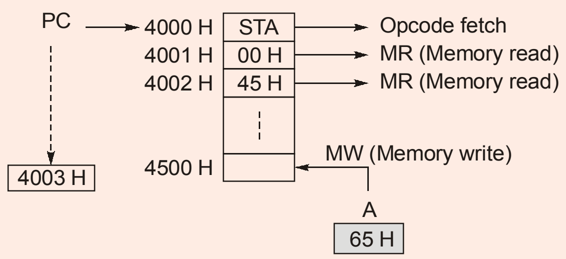
$$f_{CLK} = 3\ \text{MHz}$$

No. of T-states $\rightarrow$ 13

Meaning of the instruction $\rightarrow$ Store the constant of accumulator at 16 bit address.

[16 bit address] $\leftarrow$ [A]

Ex: 4000 H : STA 4500 H; Let [A] = 65 H



The operations required for execution are

Operations $\rightarrow$ F R R W

Clocks $\rightarrow$ 4 3 3 3

$$\text{Total execution time} = \frac{1}{f_{CLK}} \times \text{No. of T-states} \times \text{Count Values}$$

$$= \frac{1}{3 \times 10^6} \times 13 \times 1 = 4.33\ \mu s$$

STA address in a data transfer instruction with direct addressing mode. It is a 3B instruction.

End of Solution

Q.5 (f) Illustrate hop-to-hop (node-to-node) delivery by the data link layer.

[10 marks : 2023]

Solution:

(1) The data link layer is the second layer from the bottom to the top of the OSI model.

(2) Its job is to provide node-to-node delivery of data. The primary role of the data link layer is to check whether the data transmitted from one point to another node point on the physical layer is error free or not.

(3) This layer is responsible for reliable and efficient communication between devices. For transmission of information, the data link layer uses devices such as switches, bridges etc.

(4) The responsibility of the data link layer is to provide hop-to-hop delivery of data. The data link layer determines the node to which the data should be sent first, then the following node the data should be sent to, and soon, till the information arrives at the destination system.

End of Solution

Q.6 (a) A 50 Ω transmission line has phase velocity $v_p = 2.1 \times 10^8$ m/s. It is terminated by a load Z_L which has a value of

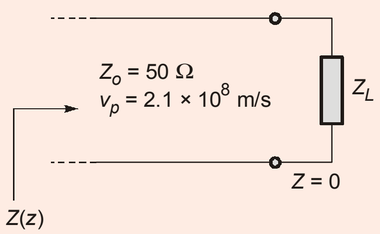
$Z_L = 75 + j25\ \Omega$ at a frequency of f = 29.6 MHz.

Find the two closest positions to the load along the line where the real part of the line impedance is equal to the characteristic impedance of the line.

[20 marks : 2023]

Solution:

Given data: $Z_o = 50\,\Omega$; $v_p = 2.1 \times 10^8$ m/s; Load impedance, $Z_L = 75 + j25\,\Omega$; Frequency, $f = 29.6$ MHz



The line impedance at any position 'z' is given by

$$Z(z) = Z_o\left[\frac{Z_L + jZ_o \tan(\beta z)}{Z_o + jZ_L \tan(\beta z)}\right] \quad \text{...(i)}$$

Here, $\beta = \dfrac{2\pi}{\lambda}$, where $\lambda = \dfrac{v_p}{f} = \dfrac{2.1\times10^8}{29.6\times10^6} = 7.09$ m

Substituting the value of Z_L and Z_o in equation (i), we get

$$Z(z) = 50\left[\frac{75 + j25 + j50\tan(\beta z)}{50 + j(75 + j25)\tan(\beta z)}\right] = 50\left[\frac{3 + j(1+2\tan\beta z)}{(2-\tan\beta z) + j3\tan\beta z}\right]$$

Multiplying both the numerator and denominator with the complex conjugate of the denominator,

$$Z(z) = 50\left[\frac{3 + j(1+2\tan\beta z)}{(2-\tan\beta z) + j3\tan\beta z} \times \frac{(2-\tan\beta z) - j3\tan\beta z}{(2-\tan\beta z) - j3\tan\beta z}\right]$$

For above, the real part of $Z(z)$ is obtained as

$$\text{Re}\{Z(z)\} = 50\left[\frac{3(2-\tan\beta z) + 3\tan\beta z\,(1+2\tan\beta z)}{(2-\tan\beta z)^2 + (3\tan\beta z)^2}\right]$$

The value of z for which we have $\text{Re}\{Z(z)\} = Z_o = 50\ \Omega$ can then be found as:

$$50\left[\frac{3(2-\tan\beta z) + 3\tan\beta z(1+2\tan\beta z)}{(2-\tan\beta z)^2 + (3\tan\beta z)^2}\right] = 50$$

$\Rightarrow$ $6 + 6\tan^2\beta z = \tan^2\beta z - 4\tan\beta z + 4 + 9\tan^2\beta z$

$\Rightarrow$ $4\tan^2\beta z - 4\tan\beta z - 2 = 0$

$\Rightarrow$ $2\tan^2\beta z - 2\tan\beta z - 1 = 0$

$\Rightarrow$ $\tan\beta z = \dfrac{2\pm\sqrt{4+8}}{2\times2} = +1.37, -0.366$

(i) For $\tan\beta z = -0.366$,

$$\beta z_1 = \tan^{-1}(-0.366) = -0.35$$

Since, $z > 0$ $\left(\dfrac{2\pi}{\lambda}\right)z_1 = \pi - 0.35$

$\Rightarrow$ $z_1 = \dfrac{(\pi - 0.35)\times7.09}{2\pi}$

$z_1 = 3.15$ m

(ii) For $\tan\beta z = 1.37$,

$$\beta z_2 = \tan^{-1}(1.37) = 0.94$$

$\Rightarrow$ $\left(\dfrac{2\pi}{\lambda}\right)z_2 = 0.94$

$\Rightarrow$ $z_2 = \dfrac{0.94\times7.09}{2\pi} = 1.06$ m

Hence, the two closest positions to the load along the line where $\text{Re}\{Z\} = Z_o$ is given by

$$z_1 = 3.15 \text{ m and } z_2 = 1.06 \text{ m}$$

End of Solution

Q.6 (b) (i) An analog filter has a transfer function

$$H(s) = \frac{10}{s^2 + 7s + 10}$$

Design a digital filter equivalent to this using impulse invariant method for $T = 0.2$ s.

(ii) Calculate the filter coefficients for a 5-tap FIR Bandpass filter with a lower cut-off frequency of 2 kHz and an upper cut-off frequency of 2.4 kHz at a sampling rate of 8 kHz.

[10 + 10 marks : 2023]

Solution:

(i) Given data:

Analog filter transfer function:

$$H(s) = \frac{10}{s^2 + 7s + 10}$$

$$T = 0.2 \text{ sec}$$

Method : Impulse invariance technique

Now,
$$H(s) = \frac{10}{(s+5)(s+2)} = \frac{10}{3}\left[\frac{1}{s+2} - \frac{1}{s+5}\right]$$

By taking inverse LT,

$$h(t) = \frac{10}{3}\left[e^{-2t}u(t) - e^{-5t}u(t)\right]$$

By performing sampling of $h(t)$ at $t = nT = 0.2$ n,

We can write,

$$h(n) = \frac{10}{3}\left[e^{-2\times 0.2n}u(n) - e^{-5\times 0.2n}u(n)\right]$$

$$= \frac{10}{3}\left[\left(e^{-0.4}\right)^n u(n) - \left(e^{-1}\right)^n u(n)\right]$$

By applying ZT,

$$H(z) = \frac{10}{3}\left[\frac{1}{1-e^{-0.4}z^{-1}} - \frac{1}{1-e^{-1}z^{-1}}\right]$$

Therefore, digital filter transfer function is,

$$H(z) = \frac{10(e^{-0.4} - e^{-1})z^{-1}}{3\left(1-e^{-0.4}z^{-1}\right)(1-e^{-1}z^{-1})}$$

$\Rightarrow$
$$H(z) = \frac{10(e^{-0.4} - e^{-1})z^{-1}}{3\left[1-(e^{-0.4}+e^{-1})z^{-1} + e^{-1.4}z^{-2}\right]}$$

(ii) Given data:

BPF with $f_{c1} = 2$ kHz and $f_{c2} = 2.5$ kHz

$f_s = 8$ kHz

filter length : $M = 5$

Cut-off frequency of digital filter,

$$\omega_{c1} = \frac{\Omega_{c1}}{f_s} = \frac{2\pi f_{c1}}{f_s} = \frac{2\pi \times 2\times 10^3}{8\times 10^3} = \frac{\pi}{2}\text{rad/sample}$$

$$\omega_{c2} = \frac{\Omega_{c2}}{f_s} = \frac{2\pi f_{c2}}{f_s} = \frac{2\pi \times 2.5 \times 10^3}{8 \times 10^3} = \frac{5\pi}{8} \text{rad/sample}$$

Now,
$$H_d(\omega) = \begin{cases} 1, & \frac{\pi}{2} < |\omega| < \frac{5\pi}{8} \\ 0, & \text{otherwise} \end{cases}$$

By taking inverse DTFT,

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

$$= \frac{1}{2\pi}\left[\int_{-\omega_{c2}}^{-\omega_{c1}} 1\cdot e^{j\omega n}d\omega + \int_{\omega_{c1}}^{\omega_{c2}} 1\cdot e^{j\omega n}d\omega\right]$$

$$= \frac{\sin(n\omega_{c2})}{\pi n} - \frac{\sin n\omega_{c1}}{\pi n}$$

Put $n = 0$;
$$h_d(0) = \frac{\omega_{c2} - \omega_{c1}}{\pi} = \frac{\frac{5\pi}{8} - \frac{\pi}{2}}{\pi} = 0.125$$

$$h_d(-1) = h_d(1) = \frac{\sin\left(\frac{5\pi}{8}\right) - \sin\frac{\pi}{2}}{\pi} = -0.024$$

$$h_d(2) = h_d(2) = 0.112$$

Thus, the digital filter impulse response is

$$h_d(n) = \{-0.112, -0.024, \underset{\uparrow}{0.125}, -0.024, -0.112\}$$

But the above filter is non-causal. So, for causal type filter, the desired impulse-response will be

$$h_c(n) = h_d(n-2)$$

$$= \{\underset{\uparrow}{-0.112}, -0.024, 0.125, -0.024, -0.112\}$$

End of Solution

Q.6 (c) (i) A digital fiber optical link working at 850 nm requires a maximum Bit Error Rate (BER) of 10^{-10} at a Data Rate (DR) or 20 Mbps for a simple binary level signalling scheme. Take detector quantum efficiency as 1. [h = 6.626×10^{-34} J.s]

Determine the incident optical power that must fall on the photo detector to achieve the above-mentioned BER and DR.

(ii) An optic fiber system uses a directly-modulated Distributed Feed-Back (DFB) laser as an optical source at the transmitter. If the operating bit rate = 2.5 Gbps, the dispersion parameter = 10 ps/(nm-km) and RMS spectral width of the pulse = 0.15 nm. Determine the maximum transmission distance.

[10 + 10 marks : 2023]

Solution:

(i) Given that, $\lambda = 850$ nm; BER = 10^{-10}; DR = 20 Mbps.; $\eta_Q = 1$; $h = 6.626 \times 10^{-34}$ J.s

$P_o = ?$

Probability that n = 0 electrons are excited in a time interval t is

$Pr(0) = e^{-N}$ where, N = Average number of electrons hole pairs,

BER = e^{-N} Pr(0) = Error probability or Bit error rate

$e^{-N} = 10^{-10}$

Apply natural log on both sides

$$N = 10 \ln(10) = 23$$

Thus, 23 photons per pulse is required for this BER = 10^{-10}

Incident optical power $P_0 = \frac{Nhc}{\lambda} \cdot \frac{B}{2}$; B = Data Rate (DR)

$$P_0 = \frac{23 \times 6.626 \times 10^{-34} \times 3 \times 10^8}{850 \times 10^{-9}} \times \frac{20 \times 10^6}{2}$$

$$P_0 = 5.382 \times 10^{-11} \text{ W.}$$

(ii) Given that $R_b = \frac{1}{T_b} = 2.5$ Gbps

$$\Delta t = 10 \text{ ps/nm-km}$$

$$\sigma_\lambda = 0.15 \text{ nm}$$

$$L = ?$$

For maximum transmission distance of directly-modulated distributed feedback LASER;

$$L < \frac{1}{4 R_b \,|\Delta t|\, \sigma_\lambda}$$

where R_b = Bitrate; D = Dispersion parameter; σ_λ = RMS spectral width of pulse

$$L < \frac{1}{4 \times 2.5 \times 10^9 \times 10 \times 10^{-9} \times 0.15}$$

$L < 0.066$ Kms.

End of Solution

Q.7 (a) The scattering matrix of a two-port network is given by

$$[S] = \begin{bmatrix} 0.1 \angle 0 & 0.8 \angle 90^\circ \\ 0.8 \angle 90^\circ & 0.2 \angle 0 \end{bmatrix}$$

(i) Determine whether the network is reciprocal or lossless.

(ii) If a short circuit is placed on port 2, what will be the resulting return loss at port 1?

[5 + 15 marks : 2023]

Solution:

Given S-matrix,

$S_{11} = 0.1 \angle 0^\circ$; $S_{12} = 0.8 \angle 90^\circ$; $S_{21} = 0.8 \angle 90^\circ$; $S_{22} = 0.2 \angle 0^\circ$

$$[S] = \begin{bmatrix} 0.1\angle 0^\circ & 0.8\angle 90^\circ \\ 0.8\angle 90^\circ & 0.2\angle 0^\circ \end{bmatrix};$$

(i) For reciprocal, $S_{12} = S_{21} = 0.8\angle 90^\circ$; hence reciprocal.

For lossless, $|S_{11}|^2 + |S_{21}|^2 = 1$

(or) $|S_{12}|^2 + |S_{22}|^2 = 1$

$\therefore$ $(0.1)^2 + (0.8)^2 \neq 1$: not lossless

(or) $(0.8)^2 + (0.2)^2 \neq 1$

Therefore, network is reciprocal but not lossless.

(ii) When port 2 is short circuited,

Then, for short circuit; $Z_L = 0$; $\Gamma_L = -1$

$$\therefore \quad \Gamma_{in} = S_{11} - \frac{S_{12}S_{21}}{1+S_{22}} = \frac{S_{11} + S_{11}S_{22} - S_{12}S_{21}}{1+S_{22}}$$

$$\Rightarrow \quad \Gamma_{in} = \frac{0.1\angle 0^\circ + 0.02\angle 0^\circ - 0.64\angle 180^\circ}{1+0.2\angle 0^\circ} = \frac{0.76\angle 0^\circ}{1.2\angle 0^\circ}$$

$$= 0.633.$$

$\therefore$ Return loss (dB) $= -20\log_{10}|\Gamma_{in}| = -20\log_{10}(0.633)$

Return loss (dB) = 3.96 dB.

End of Solution

Q.7 (b) **Write an 8085 assembly language program to sort N numbers in descending order where value of N is available in memory location 9000 H. Also note that numbers are stored in consecutive memory locations starting from 9001 H.**

[20 marks : 2023]

Solution:

To write an assembly program to sort 'N' numbers in descending order. Numbers from 9001 H 'N' at 9000 H

Algorithm:

1. Move 'N – 1' to count register 'C', as there would be 'N – 1' comparisons.
2. Copy the same count to register 'B', as in the first phase, the smallest number would be stored at last location and remaining numbers should be compared again.
3. **Comparison:**
   (i) Access first number into 'A' and compare with memory content after incrementing memory pointer.
   (ii) If $CY \rightarrow 0$, then go to next comparison.
   Else exchange the contents of memory location considered for comparison.
4. Repeat the same logic till e = 00 H
5. If C = 00 H, Decrement 'B' and check if not equal to 00 H. If true so far second phase and copy 'B' to 'C' and repeat step (3) and so on.
6. Finally the number are in descending order in memory from 9001 H.

Assumptions for the programs:

C $\rightarrow$ As count register for a phase /single phase of comparison i.e., in loop.

B → As count register for number of comparison phases.
A → Accumulator for comparison operation.
D → For use in exchange in memory contents for ['A'] < [Memory].
Program starts at 8000 H

```
        LXI H, 9000 H   ;  Initialize memory pointer at 9000 H
        MOV C, M        ;  Move 'N' count into 'C'
        DCR C           ;  Decrement 'C' for 'N – 1' comparisons in singe loop.
        MOV B, C        ;  Move [C] to [B]
        INX H           ;  Increment memory pointer
Rept:   MOV A, M        ;  Move memory content to 'ACC'
        INX H           ;  Increment memory pointer
        CMP M           ;  Compare [A] with memory content
        JNC Next        ;  Jump if 'Cy = 0' to next. Else to next instruction.
        MOV D, M        ;  Exchange the two memory contents.
        MOV M, A        ;  if [A] < [Memory]
        DCX H           ;
        MOV M, D        ;
        INX H           ;  Increment 'HL' pair.
Next :  DCR C           ;  Decrement 'C' and check if ≠ ∞
        JN Z Rept       ;  If condition true i.e., Z ≠ 1/Z = 0 Skip repeat
        DCR B           ;  Decrement 'B' by 1
        MOV C, B        ;  Move [B] ⇒ [C]
        LXI H, 9001 H   ;  [HL] = 9001 H for next phase of comparison.
        JNZ Rept        ;  Z = 0? w.r.t [B] if true, so
        HLT             ;  So rept, else stay.
```

End of Solution

Q.7 (c) (i) In the downlink of a GSM system, the carrier frequency is 950 MHz and according to GSM specifications the receiver sensitivity is – 102 dBm. The output power of the transmitter amplifier is 30 W. The antenna gain of the transmitter antenna is 12 dB, and the aggregate attenuation of connectors, combiners, etc. is 7 dB. The fading margin is 12 dB and breakpoint d_{break} is at a distance of 100 m. What distance can be covered? Take path loss exponent as 3.5.

(ii) It is required to keep track of Mach 8 (1 Mach = 330 m/s) missiles coming towards a ship (positive Doppler shifts only) from a 500 km range with a L-band ($\lambda \approx$ 30 cm) radar. The perfect waveform would have its range rate ambiguity beyond Mach 8 and its range ambiguity beyond 500 km. In this scenario, calculate PRF necessary to provide range rate ambiguity and range ambiguity. Also comment upon the result.

[10 + 10 marks : 2023]

Solution:

(i) Given that

$$\text{Carrier frequency} = 950\text{ MHz}$$
$$R_x \text{ sensitivity } P_S = P_{min} = -102\text{ dBm}$$
$$\text{Transmission power } P_t = 30\text{ W}$$
$$P_t(\text{dBm}) = 10\log_{10}\left(\frac{30}{1\times10^{-3}}\right) = 44.77\text{ dBm}$$

Transmission antenna gain,

$$G_t = 12\text{ dB}$$
$$\text{Loss due to connector} = -7\text{ dB}$$
$$\text{Fading margin} = 12\text{ dB}$$
$$d_{break} = 100\text{ m}$$

Transmission antenna gain in dB

$$G_t(\text{dB}) = 12\text{ dB}$$
$$\text{EIRP} = P_t + G_t - \text{Loss} = 44.77 + 12 - 7$$
$$\text{EIRP} = 49.77\text{ dBm}$$
$$\text{Received power, } P_r = P_S + P_M$$
$$P_r = -102\text{ dBm} + 12\text{ dB} = -90\text{ dBm}$$
$$P_r = -90\text{ dBm}$$
$$\text{Admissible path loss} = \text{EIRP} - P_r = 49.77 + 90 = 139.77\text{ dB}$$
$$\text{Path loss at } d_{break} = \left[\frac{\lambda}{4\pi d}\right]^2 = \left[\frac{3\times10^8}{4\pi\times950\times10^6\times100}\right] = 72\text{ dB}$$
$$\text{Path loss beyond break point} = \alpha d^{-n} = 139.77 - n(10\log_{10}100)\text{ dB.}$$
$$= 70\text{ dB}$$
$$\text{Coverage distance, } d_{coverage} = 100\times10^{70/(10n)}$$
$$= 100\times10^{70/10\times3.5}$$
$$= 100\times10^{70/35}$$
$$= 100\times10^2\text{ m}$$
$$d_{coverage} = 10\text{ kms.}$$

(ii) Given that

$$\text{Range } R = 500\text{ km}$$
$$L \text{ band } \lambda = 30\text{ cm}$$
$$\text{PRF} = ?$$
$$\text{Round Trip time for 500 kms} = \frac{500\times10^3}{3\times108}\times20 = \frac{1}{300} = 3.3\text{ msec.}$$
$$\frac{1}{\text{PRF}} > 3.3\text{ msec}$$
$$\text{PRF} < 330\text{ Hz}$$

$$\text{Range Rate} = \frac{dR}{dt}$$

$$\text{Velocity of object} = 330 \text{ m/sec (mach 8)}$$

$$\text{Doppler Shift in frequency, } f_d = f_s\left(\frac{C}{C-v}\right) = \frac{3\times10^8}{30\times10^{-2}}\left[\frac{3\times10^8}{3\times10^8-330}\right]$$

$$f_d = 1 \text{ GHz}$$

PRF for range rate ambiguity= 1 GHz.

End of Solution

Q.8 (a) An electric field strength of 10 μV/m is required at a point which is 200 km from a half-wave dipole antenna in the horizontal plane i.e. $\theta = \frac{\pi}{2}$. The antenna is operating in air at 50 MHz.

Calculate the current that must be fed to the antenna. Also find the average power radiated by the antenna. If a transmission line with characteristic impedance Z_0 = 75 Ω is connected to the antenna, determine the value of standing wave ratio.

[20 marks : 2023]

Solution:

Given data,

$$|E_\theta| = 10 \ \mu\text{v/m.}$$

$$r = 200 \text{ km}$$

$$l = \frac{\lambda}{2} \text{ dipole antenna} \quad (\text{for } \theta = \frac{\pi}{2}).$$

$$f = 50 \text{ MHz.}$$

(i) Current, I_0:

$$\text{For } \frac{\lambda}{2} \text{ dipole antenna, } |E_\theta| = \frac{60\, I_o \cos\left(\frac{\pi}{2}\cos\theta\right)}{r\sin\theta}$$

$$\text{For } \theta = \frac{\pi}{2}, \quad E_\theta = \frac{60\, I_0}{r}$$

$$\Rightarrow \quad I_0 = \frac{E_\theta\, r}{60} = \frac{10\times10^{-6}\times200\times10^3}{60} = 0.033 \text{ A}$$

Hence, Current fed to antenna, I_0 = 0.033 A.

(ii) Average power radiated, P_{rad} :

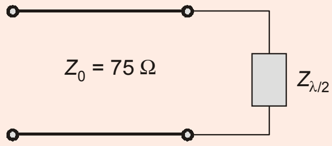
$$P_{rad} = I_{rms}^2 \cdot R_{rad}$$

$$= \frac{1}{2} I_0^2 \cdot R_{rad}$$

$$= \frac{1}{2} \times (0.33)^2 \times 36.5 = 0.0397 \text{ W}$$

(iii)

$$Z_{\lambda/2} = 73 + j42.5\ \Omega$$
$$Z_0 = 75\ \Omega$$



$$\therefore \quad \Gamma = \frac{Z_{\lambda/2} - Z_0}{Z_{\lambda/2} + Z_0}$$

$$= \frac{73 + j\,42.5 - 75}{73 + j\,42.5 + 75}$$

$$\therefore \quad \Gamma = \frac{-2 + j\,42.5}{148 + j\,42.5} = \frac{42.54\angle 92.69^\circ}{153.98\angle 16.02} = 0.276\angle 76.67^\circ$$

$$\therefore \quad S = \frac{1 + |\Gamma|}{1 - |\Gamma|} = \frac{1 + 0.276}{1 - 0.276} = 1.762$$

Hence, standing wave ratio, $S = 1.762$.

End of Solution

Q.8 (b) (i) **What do you mean by electro-static Discharge (ESD)? Why is ESD protection required? Suggest a protection method for ESD.**

(ii) **Design a combinational circuit to generate the 9's complement of a BCD digit, using only two NOT gates, two 2-Input OR gates and one 2-Input X-OR gate.**

[10 + 10 marks : 2023]

Solution:

(i) Electrostatic discharge (ESD) is the release of static electricity when two objects come into contact. Familiar examples of ESD include the shock we receive when we walk across a carpet and touch a metal doorknob and the static electricity we feel from clothes coming out of the dryer. Lightning is also electrostatic discharge.

While most of ESD events are harmless to the human body, they can cause challenging and expensive problems in certain industrial environments. Static electricity is a problem for electronic and medical device manufacturing, vehicle fabrication, industries that use plastics and paper, and ones that need clean room environments. ESD issues can slow production, negatively affect product quality issues, attract contaminants and create safety issues.

High voltage isn't necessarily the issue with ESD. Many electronic devices are susceptible to low voltage ESD damage. For example, hard drive components are sensitive to 10 volts of electrostatic discharge.

The heat from an ESD event can be extremely hot, although we might not feel the heat when we are shocked. However, when the static discharge is released onto an electronic device, such as a semiconductor or an expansion slot or card, the heat from the charge can melt or vaporize the tiny parts, causing the part to fail.

Sometimes an ESD event can damage sensitive devices, but they continue to function. This is called a latent defect, which is hard to detect but ultimately shortens the life of the device.

To manage and prevent ESD Electrostatic discharges can occur without warning. Prevention requires understanding the environment in which an electronic device is manufactured, handled and used, and taking measures to reduce the likelihood of an event.

Electronics manufacturers incorporate various ESD protection measures to prevent issues in the manufacturing process, which includes fabricating, testing, shipping and handling.

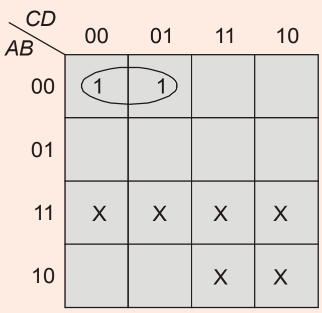
ESD preventive measures include the following:

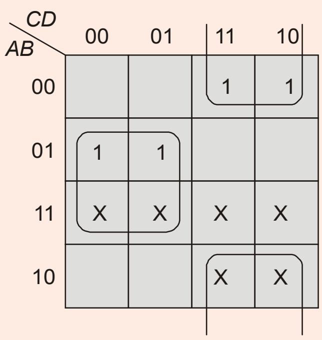
1. Use devices, chairs and other furnishing that are classified as ESD-safe.
2. Ensure all devices and machines are grounded according to American National Standards Institute (ANSI) standards.
3. Use personal grounding equipment and methods, such as antistatic wrist straps and footwear.
4. Cover floors with antistatic mats that send charges into the ground and away from devices. "Store devices in static-reducing containers.
5. Package electronics using materials that shield them from ESD.
6. Make antistatic spray available where appropriate.
7. Only use static-attracting components in an area that is static-minimized.
8. Avoid coming into contact with metallic parts or components, such as wires and connectors.
9. Remove unnecessary components from static-protected work areas.

(ii) 9's complement is calculated by subtracting 9 from the given number.

	BCD Digit				9's Complement			
	A	*B*	*C*	*D*	*P*	*Q*	*R*	*S*
Valid BCD	0	0	0	0	1	0	0	1
	0	0	0	1	1	0	0	0
	0	0	1	0	0	1	1	1
	0	0	1	1	0	1	1	0
	0	1	0	0	0	1	0	1
	0	1	0	1	0	1	0	0
	0	1	1	0	0	0	1	1
	0	1	1	1	0	0	1	0
	1	0	0	0	0	0	0	1
	1	0	0	1	0	0	0	0
Invalid BCD	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X

Solving K-map for *P*, *Q*, *R*, *S*.

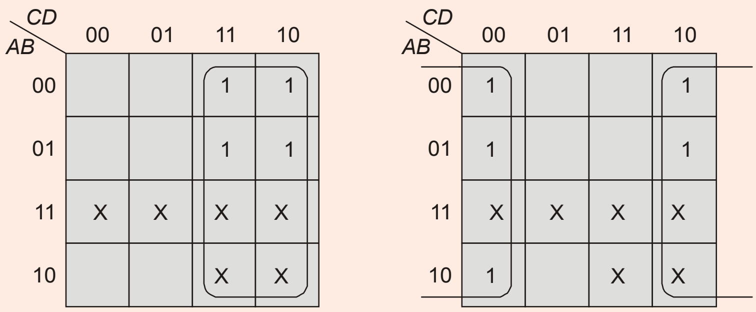




$P = \bar{A}\bar{B}\bar{C}$

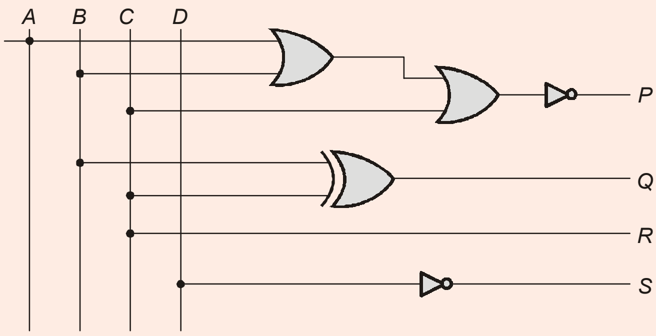
$P = \overline{A + B + C}$

$Q = B\bar{C} + \bar{B}C = B \oplus C$



$R = C$

$S = \bar{D}$



End of Solution

Q.8 (c) (i) At a distance of 40,000 km from a point on the surface of Earth, a satellite radiates a power of 12 W from an antenna having a gain of 16 dB in the direction of the observer. Determine the flux density at the receiving point, and the power received by an antenna at this point with an effective area of 10 m^2. Express both flux density and power received in decibels as well.

(ii) Consider a satellite uplink has (C/No) of 82.2 dB and downlink has (C/No) of 79.8 dB. Assume bandwidth of the system as 1.2 MHz.

(I) Determine Numeric Value (NV) for each (C/No) value.

(II) Calculate (C/No) for the system (C/No)s.

(III) Determine (C/N) at 1.2 MHz BW.

[10 + 10 marks : 2023]

Solution:

(i) Given that

$R = d = 40000 \text{ km} = 4 \times 10^7 \text{ m}$

$P_t = 12 \text{ W}; \; G_t = 16 \text{ dB}; \; A_e = 10 \text{ m}^2; \; G_t = 16 \text{ dB}$

$$10 \log_{10}(G_t) = 16 \text{ dB}$$

$$\log_{10}(G_t) = 1.6$$

$$(G_t) = 10^{1.6} = 39.81$$

$$\text{Flux density (F)} = \frac{P_t G_t}{4\pi R^2} = \frac{12 \times 39.81}{4\,\pi \times (4 \times 10^7)^2} = 2.37 \times 10^{-14}\ \text{W/m}^2$$

The power received with an effective area is

$$P_r = F \times A_e$$
$$P_r = 2.37 \times 10^{-14} \times 10$$
$$P_r = 2.37 \times 10^{-13}\ \text{W}$$

Flux density in dB is

$$F(\text{dB}) = 10 \log (2.37 \times 10^{-14})\ \text{dB(W/m}^2)$$
$$= -136.25\ \text{dB (W/m}^2)$$

Power received in dB is

$$P_r(\text{dB}) = 10 \log (2.37 \times 10^{-13})\ \text{dBW}$$
$$= -126.25\ \text{dBW}$$

(ii) Given that

$$(C/N_0)_U = 82.2\ \text{dB}$$
$$(C/N_0)_D = 79.8\ \text{dB}$$
$$B = 1.2\ \text{MHZ.}$$

(I) Numerical value for each (C/N_0) value

$$(C/N_0)_U = 82.2\ \text{dB}$$
$$(C/N_0)_U = 10^{82.2/10} = 165958690.743$$
$$(C/N_0)_D = 79.8\ \text{dB}$$
$$(C/N_0)_D = 10^{79.8/10} = 95499258.602$$

(II) Calculate system $(C/N_0)_s$

$$\frac{1}{(C/N_0)_S} = \frac{1}{(C/N_0)_U} + \frac{1}{(C/N_0)_D}$$

$$(C/N_0)_S = \frac{(C/N_0)_U (C/N_0)_D}{(C/N_0)_U + (C/N_0)_D} = \frac{165958690.743 \times 95499258.602}{165958690.743 + 95499258.602}$$

$$(C/N_0)_S = 60{,}617{,}517.9$$

(III) (C/N) at 1.2 MHz BW.

$$N = N_0 B$$

$$\left(\frac{C}{N}\right)_S = \left(\frac{C}{N_0 B}\right)_S = \left(\frac{C}{N_0}\right)_S \cdot \frac{1}{B}$$

$$= \frac{60{,}617{,}517.9 \times 1}{1.2 \times 10^6}$$

$$(C/N)_S = 50.514$$

End of Solution

■■■■