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ESE 2022

Main Exam Detailed Solutions

Electronics & Telecom. Engineering

PAPER-II

EXAM DATE : 26-06-2022 | 2:00 PM to 5:00 PM

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ANALYSIS

Electronics and Telecom. Engineering Paper-II
ESE 2022 Main Examination

Sl.	Subjects	Marks
1.	Analog and Digital Communication Systems	80
2.	Control Systems	70
3.	Microprocessors and Microcontrollers	20
4.	Electromagnetics	80
5.	Signals and Systems	30
6.	Computer Organization and Architecture	80
7.	Advanced Communication	80
8.	Advanced Electronics	40
	Total	**480**

Scroll down for detailed solutions

Section-A

Q.1 (a) An analog signal band limited to 3.3 kHz is sampled above Nyquist rate to have a guard band of 1.4 kHz. The samples are quantized into 4 levels. The quantization levels Q_1, Q_2, Q_3 and Q_4 are assumed to be independent and occur with probabilities $P_1 = \frac{1}{2}$, $P_2 = \frac{1}{4}$, $P_3 = P_4 = \frac{1}{8}$.

Determine the information rate of the source.

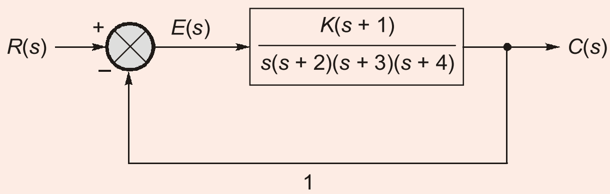
[10 marks : 2022]

Solution:

$$f_m = 3.3 \text{ kHz}$$
$$NR = 2 f_m = 6.6 \text{ kHz}$$
$$f_s = NR + \text{Guard band} = 6.6 \text{ kHz} + 1.4 \text{ kHz} = 8 \text{ kHz}$$
$$\text{Information rate } (R) = H \times f_s$$
$$H = \sum_{i=1}^{4} P_i \log_2 \frac{1}{P_i}$$
$$= \frac{1}{2}\log_2^2 + \frac{1}{4}\log_2^4 + \frac{1}{8}\log_2^8 + \frac{1}{8}\log_2^8$$
$$= \frac{1}{2} + \frac{1}{2} + \frac{3}{8} \times 2 = \frac{7}{4} = 1.75 \frac{\text{bits}}{\text{sample}}$$
$$R = 1.75 \frac{\text{bits}}{\text{sample}} \times 8K \frac{\text{samples}}{\text{sec}}$$
$$R = 14000 \frac{\text{bits}}{\text{sec}}$$

End of Solution

Q.1 (b) A feedback control system is given by the following figure:



Find the value of 'K' so that there is 10% error in the steady state.

[10 marks : 2022]

Solution:

$$GH(s) = \frac{K(s+1)}{s(s+2)(s+3)(s+4)}$$

type = 1

$$E_{ss} \text{ for ramp input} = \frac{1}{KV}$$

$$K_V = \lim_{s\to 0} SGH(s) = \frac{K}{24}$$

Given Ess = 10% = $0.1 = \dfrac{24}{K}$

$\therefore$ $K = 240$

But this is valid only if the system is stable for this value of K.

$$q(s) = s^4 + 9s^3 + 26s^2 + s(K + 24) + K = 0$$

$$\begin{array}{c|ccc} s^4 & 1 & 26 & K \\ s^3 & 9 & K+24 & \\ s^2 & \dfrac{210-K}{9} & K & \\ s^1 & \dfrac{(K-140.75)(K+35.75)}{\dfrac{210-K}{9}} & & \\ s^0 & K & & \end{array}$$

Stable $0 < K < 140.75$

The Maximum value of K = 140 for stability for this K, $e_{ss} = \dfrac{24}{140} = 0.17 = 17\%$

Hence for no value of K, e_{ss} can be 10%.

End of Solution

Q.1 (c) By taking suitable examples, differentiate between concurrency and parallelism in the context of processes in operating systems.

[10 marks : 2022]

Solution:

Concurrency	Parallelism
1. Concurrency is the task of running and managing the multiple computations at the same time.	1. While parallelism is the task of running multiple computations simultaneously.
2. Concurrency is achieved through the interleaving operation of processes on the central processing unit (CPU) or in other words by the context switching.	2. While it is achieved by through multiple central processing units (CPUs).
3. Concurrency can be done by using a single processing unit.	3. While this can't be done by using a single processing unit. It needs multiple processing units.
4. Concurrency increases the amount of work finished at a time.	4. While it improves the throughput and computational speed of the system.
5. Concurrency deals lot of things simultaneously.	5. While it do lot of things simultaneously.
6. Concurrency is the non-deterministic control flow approach.	6. While it is deterministic control flow approach.
7. In Concurrency debugging is very hard.	7. While in this debugging is also hard but simple than concurrency.

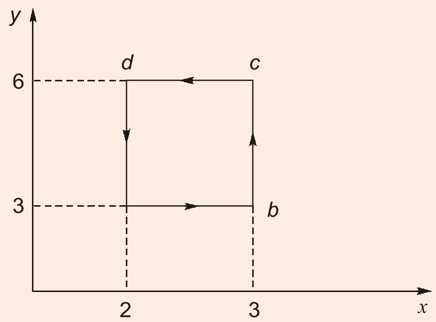
End of Solution

Q.1 (d) Given magnetic field $\vec{H} = \frac{x+2y}{z^2}\vec{a}_x + \frac{z}{2}\vec{a}_z$ A/m in free space, evaluate $\oint_L \vec{H}\cdot\vec{dL}$, where the anticlockwise closed path for the integration is the boundary defining the closed surface 2 m < x < 3 m, 3 m < y < 6 m and z = 3 m.

[10 marks : 2022]

Solution:

Given, $$\bar{H} = \frac{x+2y}{z^2}\hat{a}_x + \frac{z}{2}\hat{a}_z$$



In Cartesian coordinate system

$$d\bar{L} = dz\,\hat{a}_x + dz\,\hat{a}_z$$

$\therefore$ $$\bar{H}\cdot\bar{d}L = \frac{x+2y}{z^2}dx + \frac{z}{2}dz$$

$\Rightarrow$ $$\oint \bar{H}\cdot d\bar{L} = \left[\int_a^b + \int_b^c + \int_c^d + \int_d^a\right]\bar{H}\cdot d\bar{L}$$

$$\int_a^b \bar{H}\cdot d\bar{L}$$

For path ab, $$y = 3 \Rightarrow dy = 0$$
$$z = 3 \Rightarrow dz = 0$$

$\therefore$ $$\int_a^b \bar{H}\cdot d\bar{L} = \int_L \frac{x+2y}{z^2}dx = \int_2^3 \frac{x+6}{9}dx = \frac{1}{9}\cdot\frac{x^2}{2} + 6x\Big|_2^3$$

$$= \frac{1}{9}\left[\left(\frac{9}{2}+18\right) - \left(\frac{4}{2}+12\right)\right]$$

$$= \frac{1}{9}\left[\frac{45}{2} - \frac{28}{2}\right] = \frac{1}{9}\times\frac{17}{2} = \frac{17}{18}$$

$$\int_b^c \bar{H}\cdot d\bar{L}$$

For path bc ; $$x = 3 \Rightarrow dx = 0$$
$$z = 3 \Rightarrow dz = 0$$

$\therefore$ $$\int_b^c \bar{H}\cdot d\bar{L} = 0$$

$\int_c^d \bar{H}\cdot d\bar{L}$

For path cd; $y = 6 \Rightarrow dy = 0$

$z = 3 \Rightarrow dz = 0$

$$\therefore \quad \int_c^d \bar{H}\cdot d\bar{L} = \int_L \frac{x+2y}{z^2} = \int_{x=3}^{2} \frac{x+12}{9}\,dx = \frac{1}{9}\frac{x^2}{2} + 12x\Big|_9^2$$

$$= \frac{1}{9}\left(\frac{4}{2}+24\right) - \left(\frac{9}{2}+36\right) = \frac{1}{9}\left[\frac{52}{2} - \frac{81}{2}\right] = \frac{1}{9} * \frac{-29}{2} = \frac{-29}{18}$$

$\int_d^a \bar{H}\cdot d\bar{L}$:

Path *da* ; $x = 2 \Rightarrow dx = 0$

$z = 3 \Rightarrow dz = 0$

$$\therefore \quad \int_d^a \bar{H}\cdot d\bar{L} = 0$$

$$\therefore \quad \oint H\cdot d\bar{L} = \frac{17}{18} - \frac{29}{18} = \frac{-12}{18} = \frac{-2}{3}$$

End of Solution

Q.1 (e) What is the importance of oxidation in VLSI technology? Which types of oxidation are used to grow gate oxide and field oxide in the fabrication of NMOS transistor? Justify your answer.

[10 marks : 2022]

Solution:

Oxidation is the process of growing oxide layer on the top of the substrate.

- In a device fabrication oxide act as mask during diffusion process of impurity for doping purpose. Therefore window creation is done in oxide for selective doping process.
- Oxide is also used for isolation purpose between two devices in integrated circuits.
- Oxide specially SiO_2 acts as dielectric and insulator.
- SiO_2 is used as gate oxide in MOS devices

  Oxidation are of two types: (i) Wet oxidation, (ii) Dry oxidation

  $Si + O_2 \xrightarrow{1000-1200°C} SiO_2$ Dry oxidation

  $Si + H_2O \xrightarrow{900°C} SiO_2$ Wet oxidation

- Dry oxidation is a slow process (growth rate is slow) but quality of oxide is good. Hence for gate oxide fabrication, dry oxidation is preferred.
- Wet oxidation is a fast process (growth rate is high) but quality of oxide inferior compare to dry oxidation.

Since field oxides are thick and are generally used multiple times in device fabrication hence wet oxidation process is preferred for field oxide growth.

End of Solution

Q.1 (f) Two stations have LOS communication link with half-wave antenna at 200 km distance. If the transmitter transmits 10 kW power at 300 MHz, what is the maximum power received? The directivity gain of each antenna, is 1.6.

[10 marks : 2022]

Solution:

Given that, d = 200 kms ; P_t = 10 kW ; f = 300 MHz

$$\lambda = \frac{C}{f} = \frac{3\times 10^8 \text{ mt/sec}}{300\times 10^6 \text{ 1/sec}} = 1\text{mt}$$

$$Gt = Gr = 1.6$$

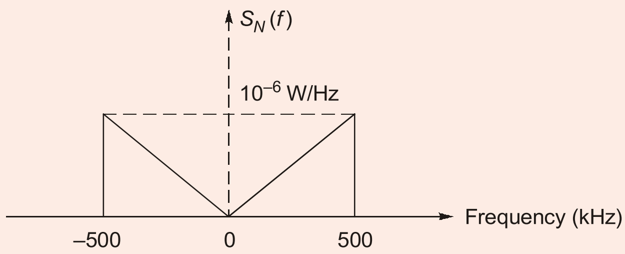
$$P_r = ?$$

$$P_r = \frac{Pt\,Gt\,Gr}{\left(\frac{4\pi d}{\lambda}\right)^2} = \frac{10\times 10^3\times 1.6\times 1.6}{\left(\frac{4\pi\times 200\times 10^3}{1}\right)^2}$$

$$P_r = \frac{10^4\times 1.6\times 1.6}{(4\pi)^2\times 4\times 10^{10}} = 4.0528\times 10^{-9}\ W = 4.0528\text{ nW}$$

End of Solution

Q.2 (a) A double sideband-suppressed carrier (DSB-SC) modulated signal with message bandwidth of 5 kHz and carrier frequency of 250 kHz is transmitted over a noisy channel. The power spectral density (PSD) of the channel noise is as shown below:



Coherent receiver is used for the demodulation.

(i) Obtain and plot the PSD of the noise at the receiver output.

[12 marks : 2022]

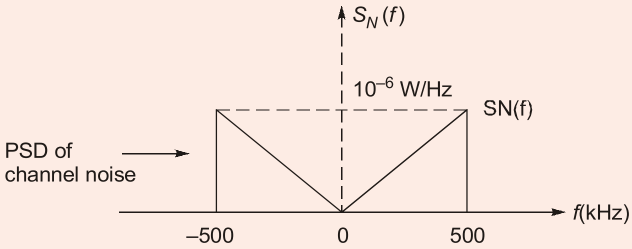
(ii) Assuming that the average power of the modulated wave is 10 Watts, calculate the output signal-to-noise ratio of the receiver.

[8 marks : 2022]

Solution:

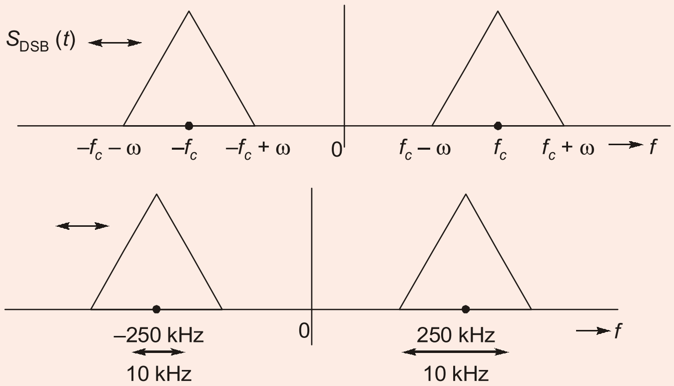
Given message bandwidth → $W = 5$ kHz

$$f_c = 250 \text{ kHz}$$

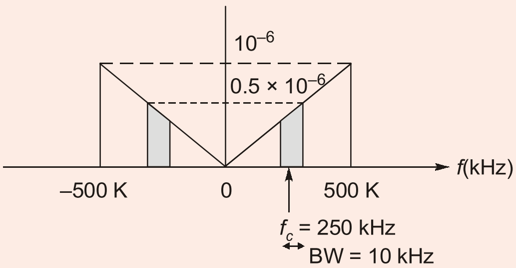


Given that coherent receiver is used for DSB – SC demodulation.

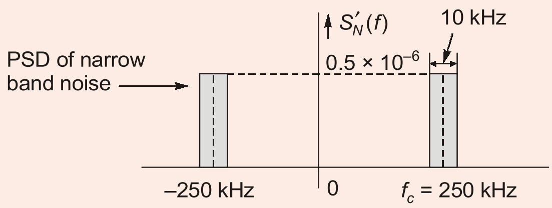
(i)



PSD of noise effecting transmitted DSB-SC signal can be obtained by passing received signal through narrow-band filter of bandwidth 10 kHz and centered about $f_c = 250$ kHz.



Since bandwidth of the filter is small compared to the carrier frequency f_c, we can approximate the PSD of resulting narrow band noise of $n'(t)$ to be flat at the level of 0.5×10^{-6} W/Hz.

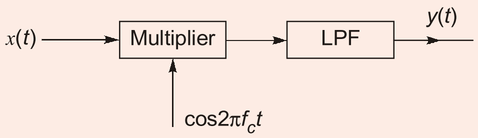


Received signal → $\quad x(t) = S_{DSB}(t) + n'(t)$

where $n'(t)$ is the narrow band noise which is interferencing with transmitted DSB-SC signal.

$$n(t) = A_c m(t)\cos 2\pi f_c t + n_i'(t)\cos 2\pi f_c t - n_q'(t)\sin 2\pi f_c t$$

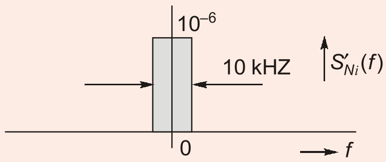
Where $n_i'(t)$ and $n_q'(t)$ are imphase and quadrature components.



$$y(t) = \frac{A_c m(t)}{2} + n_i'(t)$$

PSD of $n_i'(t)$ produced at filter output→

$$S_{Ni}'(f) = S_N'(f - f_c) + S_N'(f + f_c) \;.....\; -W \le f \le W$$



(ii) Given Avg. power of the modulated signal = 10 Watts

$$\frac{A_c^2 \cdot P_m}{2} = 10$$

$(SNR)_{o/p} = ?$

$$\text{O/P signal power} = \text{Power}\left[\frac{A_c m(t)}{2}\right] = \frac{A_c^2 P_m}{4}$$

$$\text{O/P Noise power} = \text{Power}\left[\frac{n_i'(t)}{2}\right] = \frac{1}{4} \times \text{Power}[n_i'(t)]$$

$$(SNR)_{O/P} = \frac{A_c^2 P_m}{\text{Power}\,(n_i'(t))} = \frac{2 \times 10 \text{ Watts}}{(10 \times 10^3) \times (10^{-6})}$$

$\because$ $\quad \text{Power}[n_i'(t)] = \text{Total area under } S_{Ni}'(f) = 10 \times 10^3 \times 10^{-6}$

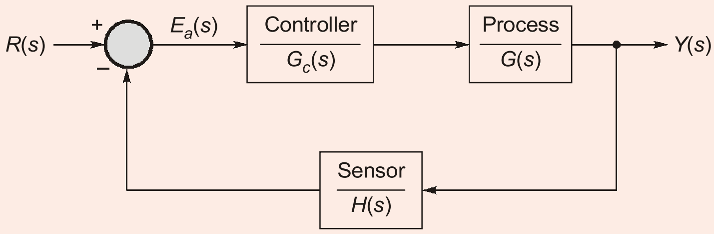
$$(SNR)_{O/P} = \frac{20}{10^{-2}} = 2000 \cong 33 \text{ dB}$$

End of Solution

Q.2 (b) A feedback control system is shown in the following figure. The controller and process transfer functions are given as

$$G_c(s) = K \text{ and } G(s) = \frac{s+40}{s(s+10)}$$

and the feedback transfer function is $H(s) = \dfrac{1}{(s+20)}$.



(i) Determine the limiting value of the gain '*K*' for a stable system.

[8 marks : 2022]

(ii) For the gain that results in marginal stability, determine the magnitude of the imaginary roots.

[4 marks : 2022]

(iii) Reduce the gain to half the magnitude of the marginal value and determine the relative stability of the system by shifting the axis and using the Routh-Hurwitz criterion.

[8 marks : 2022]

Solution:

$$q(s) = s^3 + 30s^2 + (200 + K)S + 40\,K = 0$$

(i) $0 < K < 600$ Stability condition

(ii) for K = 600; Marginally stable

for this $K \Rightarrow S = \pm j\sqrt{800}$

$\therefore$ Magnitude of roots $= 28.28$

(iii) For half of above value of K

i.e., $K = 300$

$$q(s) = s^3 + 30s^2 + 500s + 12000 = 0$$

$$s = -27.624, -1.18 \pm j\,20.8$$

$\therefore$ The system is stable $\approx -1 \pm j\,20$

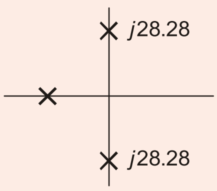
Replacing $S \rightarrow s - 1$

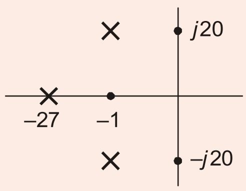
$$q(s) = s^3 + 27s^2 + (K + 143)s + (39K - 171)$$

Obtaining '*K*' for stability $K < 336$

$\therefore$ Approx value of K for roots to lie on $s = 1$ line is $K \approx 300$

for $K = 600$ for $K = 300$





End of Solution

Q.2 (c) Consider a simple system running a single process. The size of physical frames and logical pages is 16 bytes. The RAM can hold 3 physical frames. The virtual addresses of the process are 6 bits in size. The program generates the following 20 virtual address references as it runs on the CPU : 0,1, 20, 2, 20, 21, 32, 31, 0, 60, 0, 0,16, 1, 17, 18, 32, 31, 0, 61. Note that the 6-bit addresses are shown in decimal here and assume that the physical frames in RAM are initially empty and do not map to any logical page.

(i) Translate the virtual addresses above to logical page numbers referenced by the process. Assume pages are numbered starting from 0,1,2, ...

[10 marks : 2022]

(ii) Using First In First Out (FIFO) page replacement algorithm, calculate the number of page faults generated by the accesses above.

[5 marks : 2022]

(iii) Using Least Recently Used (LRU) page replacement algorithm, calculate the number of page faults generated by the accesses above.

[5 marks : 2022]

Solution:

(i) Unique addresses in the given sequence is

Page: 6 bit address

Page	6 bit address	Decimal
P_0	[00] 0000	: 0
P_0	[00] 0001	: 1
P_1	[01] 0100	: 20
P_0	[00] 0010	: 2
P_1	[01] 0101	: 21
P_2	[10] 0000	: 32
P_1	[01] 1111	: 31
P_3	[11] 1100	: 60
P_1	[01] 0000	: 16
P_1	[01] 0001	: 17
P_1	[01] 0010	: 18
P_3	[11] 1101	: 61

Address size = 6 bit

Page size = 16 B

Address format:

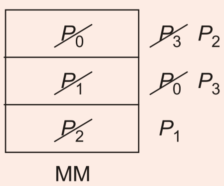
6 bit	
P	d
2 bit	4 bit

Address	Page
0	P_0
1	P_0
20	P_1
2	P_0
21	P_1
32	P_2
31	P_1
60	P_3
16	P_1
17	P_1
18	P_1
61	P_3

(ii) FIFO:

Page references:

$P_0, P_0, P_1, P_0, P_1, P_1, P_2, P_1, P_0, P_3, P_0, P_0, P_1, P_0, P_1, P_1, P_2, P_1, P_0, P_3,$



P_0 - M
P_0 - Hit
P_1 - M
P_0 - Hit
P_1 - Hit
P_1 - Hit
P_2 - M
P_1 - Hit
P_0 - Hit
P_3 - M
P_0 - M
P_0 - Hit
P_1 - M
P_0 - Hit
P_1 - Hit
P_1 - Hit
P_2 - M
P_1 - Hit
P_0 - Hit
P_3 - M

Number of misses = 8
(Number of faults)

(iii) **LRU:**

$P_0 - M$	$P_0 - H$	$P_1 - M$	$P_0 - H$	$P_1 - H$	$P_1 - H$	$P_2 - M$
						P_2
		P_1	P_0	P_1	P_1	P_1
P_0	P_0	P_0	P_1	P_0	P_0	P_0

$P_1 - H$	$P_0 - H$	$P_3 - M$	$P_0 - H$	$P_0 - H$	$P_1 - H$
P_1	P_0	P_3	P_0	P_0	P_1
P_2	P_1	P_0	P_3	P_3	P_0
P_0	P_2	P_1	P_1	P_1	P_3

$P_0 - H$	$P_1 - H$	$P_1 - H$	$P_2 - M$	$P_1 - H$	$P_0 - H$	$P_3 - M$
P_0	P_1	P_1	P_2	P_1	P_0	P_3
P_1	P_0	P_0	P_1	P_2	P_1	P_0
P_3	P_3	P_3	P_0	P_0	P_2	P_1

Number of misses = 6
(Number of faults)

End of Solution

Q.3 (a) In digital audio system, the analog audio signal with peak-to-peak voltage 'V_{pp}' is sampled and uniformly quantized into L levels.

(i) Show that the ratio of peak signal power to peak quantization noise power

$$\left(\frac{S}{N_q}\right)_{\text{peak}} = L^2.$$

[10 marks : 2022]

(ii) If the samples are encoded with PCM, determine the bit rate in bits per second for $\left(\frac{S}{N_q}\right)_{\text{peak}}$ = 84 dB. The sampling frequency is 44.1 kilo samples per second.

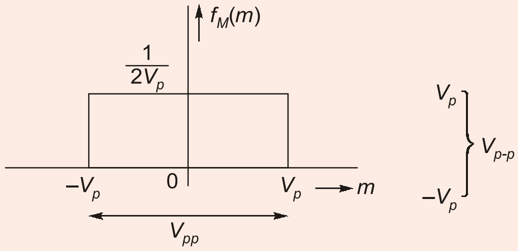
[10 marks : 2022]

Solution:

(i) Given that message having peak to peak voltage of V_{pp}.

Number of quantization levels = L

Let message signal having uniform density function



$$S = E[m^2] = \int_{-V_p}^{V_p} m^2 f_m(m)dm$$

$$= \frac{1}{2V_p} \times \frac{m^3}{3}\Bigg|_{-V_p}^{V_p} = \frac{2V_p^3}{6V_p} = \frac{V_p^2}{3}$$

We have $$V_{pp} = 2V_p \rightarrow V_p = \frac{V_{pp}}{2}$$

$$S = \frac{V_{pp}^2}{12}$$

For uniform quantization; Quantization noise power $N_q = \frac{\Delta^2}{12}$

where $$\Delta = \frac{V_{pp}}{L}$$

$$N_q = \frac{1}{12} \times \frac{V_{pp}^2}{L^2}$$

$$\frac{S}{N_q} = \frac{V_{pp}^2}{12} \Bigg/ \frac{V_{pp}^2}{12 \times L^2}$$

$$\frac{S}{N_q} = L^2$$

(ii) Given $\frac{S}{N_q} = L^2$

where $$L = 2^n$$

$$\frac{S}{N_q} = 2^{2n}$$

$$\left(\frac{S}{N_q}\right)_{dB} = 10 \log 2^{2n} \simeq 6n \text{ dB}$$

Given, $$\left(\frac{S}{N_q}\right)_{dB} = 84 \text{ dB}$$

$$6n = 84$$

$$n = 14$$

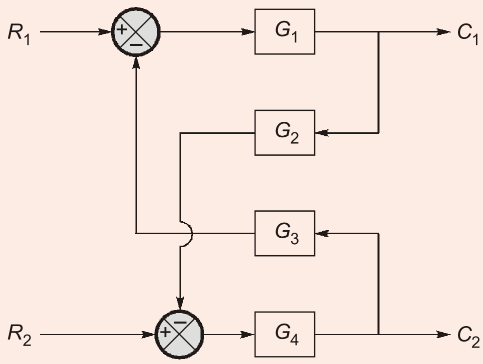
$$f_s = 44.1 \text{ kilo} \frac{\text{Samples}}{\text{Sec}}$$

$$\text{bit rate } (R_b) = nf_s = 14 \times 44.1 \text{ K}$$

$$R_b = 617.4 \text{ kbps}$$

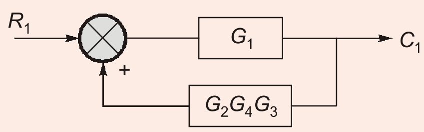
End of Solution

Q.3 (b) The system shown in the following figure is a two input-two output system. Derive the expressions for $\frac{C_j(s)}{R_i(s)}$, where i and j represent the number of inputs and number of outputs respectively in the system.

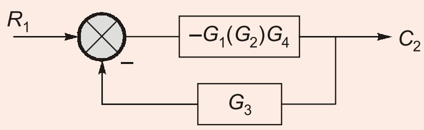


[20 marks : 2022]

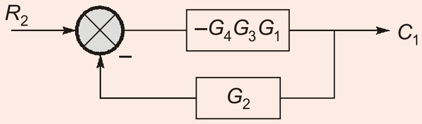
Solution:



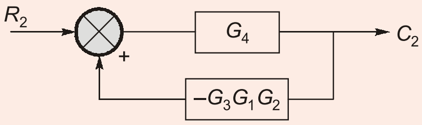
$$\frac{C_1}{R_1} = \frac{G_1}{1 - G_1G_2G_3G_4}$$



$$\frac{C_2}{R_1} = \frac{-G_1G_2G_4}{1 - G_1G_2G_3G_4}$$



$$\frac{C_1}{R_2} = \frac{-G_1G_3G_4}{1-G_1G_2G_3G_4}$$



$$\frac{C_2}{R_2} = \frac{G_4}{1-G_1G_2G_3G_4}$$

End of Solution

Q.3 (c) (i) Let '*f*' be the clock rate of a digital computer, '*N*' be the number of machine instructions to be executed in a program on the digital computer, '*p*' be the number of processor cycles needed for the instruction decode and execution, '*m*' be the number of memory references needed and '*K*' be the ratio between memory cycle and processor cycle. Derive the expression for CPU time needed to execute the program assuming single instruction type in the program.

[15 marks : 2022]

(ii) A given application written in the same programming language runs 12 seconds on a processor. After release of a new compiler for the same language, it requires only 0.5 as many instructions as the old compiler, but it increases the Cycles Per Instruction (CPI) by 1.2. How fast can we expect the application to run using this compiler?

[5 marks : 2022]

Solution:

(i) f : CLK rate

$\therefore$ Cycle time $= \frac{1}{f}$ sec

Number of instructions $= N$

P cycles required to decode and execute the instruction.

$K = \frac{M}{P}$ {Ratio of a memory cycles and processor cycles}

$\therefore$ $M = K \cdot P$

Memory cycle $= K \cdot P$ processor cycles

Program execution time $=$ Fetch time + Execution time

$$= \left[(N \times KP) + (N \cdot P)\right]\frac{1}{f} \text{ sec}$$

$$= (NKP + NP)\frac{1}{f}\text{ sec}$$

$$= NP(1+K)\frac{1}{f}\text{ sec}$$

(ii)

$$ET_{old} = 12\text{ sec}$$

$$ET_{new} = (0.5 * 1.2 * 12) + (0.5 * 1) = 7.7\text{ sec}$$

$$\text{Speed up} = \frac{ET_{old}}{ET_{new}} = \frac{12}{7.7} = 1.55$$

End of Solution

Q.4 (a) Binary data at a bit rate of 10^4 bits/second is to be transmitted using binary FSK.

(i) If the FSK signal is transmitted over binary symmetrical channel with noise spectral density $N_0 = 2 \times 10^{-5}$ Watts/Hz, determine the channel capacity required for error free transmission. The average power of the FSK modulated signal is 1 Watt and assume that binary 1 and binary 0 are equiprobable.

[8 marks : 2022]

(ii) Draw the block diagram and show the non-coherent demodulation of FSK. What should be the minimum separation between the two carrier frequencies representing binary 1 and binary 0? Determine the bandwidth of the bandpass filters used in the receiver system.

[12 marks : 2022]

Solution:

(i)

$$R_b = 10^4\text{ bit/second}$$

$$N_0 = 2 \times 10^{-5}\text{ Watts/Hz}$$

Power of FSK modulated wave $\rightarrow S = 1$ Watt

$$\text{Channel capacity } C = B\log_2\left(1+\frac{S}{N}\right) \qquad B = \text{Channel B.W}$$

$$\text{FSK BW} = (f_H - f_L) + R_b$$

($\because$ Assuming that binary sequence is represented with Nyquist pulses)

Since coherent/Non coherent FSK is not given

$$f_H - f_L = \frac{n}{T_b}$$

$$\text{Default } n = 1$$

$$f_H - f_L = \frac{1}{T_b} = R_b$$

$$\text{FSK BW} = R_b + R_b = 2R_b$$

$$\text{Channel BW (B)} \geq \text{Signal B.W}$$

$$\text{Default channel BW} = \text{Signal B.W only}$$

$$B = 2R_b$$

$$\text{Noise power 'N'} = N_0 B = N_0 \times 2R_b$$

$$C = B\log_2\left(1+\frac{S}{N}\right)$$

$$C = 2R_b \log_2\left(1+\frac{S}{N_0 \times 2R_b}\right)$$

$$= 2\times 10^4 \log_2\left(1+\frac{1}{2\times 10^{-5}\times 2\times 10^4}\right)$$

$$C = 36147 \text{ bits/sec}$$

$$C = 36.147 \text{ kbps}$$

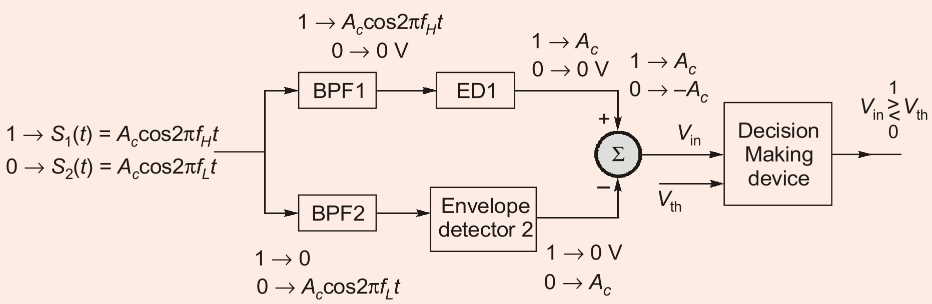
(ii) To maintain orthogonality between FSK waveforms

$$f_H - f_L = \frac{n}{T_b}$$

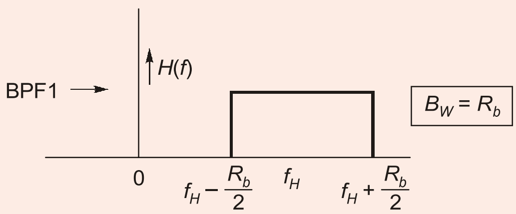
To maintain minimum separation between FSK frequencies $\rightarrow n = 1$

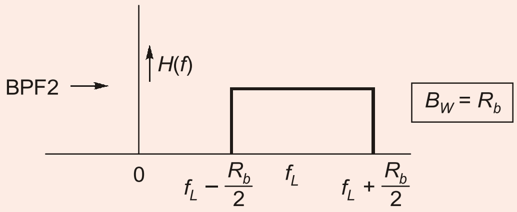
$$f_H - f_L = \frac{1}{T_b} = R_b$$

Non-coherent demodulation of FSK waveforms:



By assuming that binary sequence is represented with Nyquist pulses, band pass filters should be as follows:

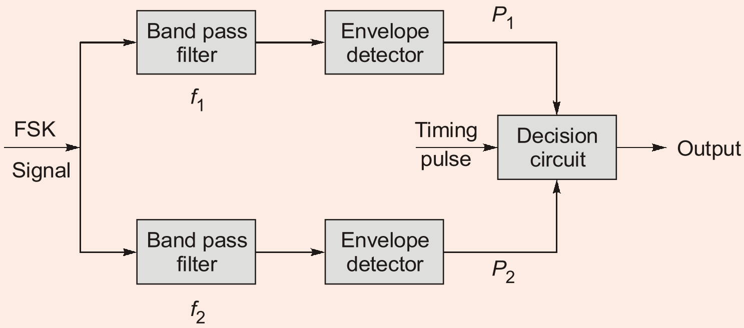




Bandwidth of bandpass filters should be equal to 'R_b'

ALTERNATE

The block diagram of non-coherent demodulator of FSK is as shown below:



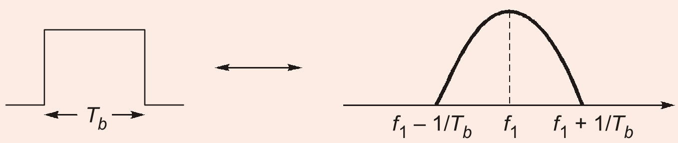
The incoming FSK modulated signal is applied to both baseband filters BPF_1 and BPF_2 having their pass bands centred at f_1 and f_2 respectively. Assume a carrier pulse of frequency f_1(binary '1') is received, the envelope detector 1 outputs a non-zero envelop $P_1(t)$ and $P_2(t)$ is approximately equal to 0. When a carrier pulse of frequency f_2(binary '0') is received, the envelope detector 2 outputs a non-zero envelope and $P_1(t)$ is approximately equal to 0. Based on the detected envelops, the decision circuit recovers the baseband digital signal

For orthogonality between non-coherent FSK signals, the minimum frequency separation is $1/T_b$ where T_b is the width of transmitted bit.

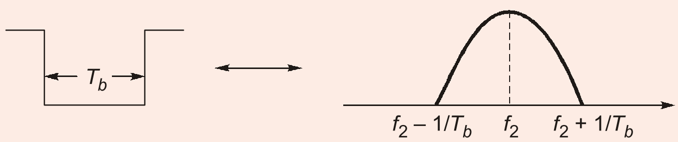
$$f_1 - f_2 = \frac{1}{T_b} = R_b$$

$$f_1 - f_2 = 10^4 \text{ Hz}$$

when binary '1' is transmitted, the spectrum is as below:



Similarly, when binary '0' is transmitted, the spectrum is as below:



Hence, the bandwidth of the bandpass filters used in the receiver system is given by

$$\text{BW} = \frac{1}{T_b} + \frac{1}{T_b} = \frac{2}{T_b} = 2R_6$$

$$\text{BW} = 2 \times 10^4 \text{ Hz} = 20 \text{ kHz}$$

End of Solution

Q.4 (b) A system is represented in state variable form as

$$\frac{dx}{dt} = Ax + Bu$$

$$y = Cx + Du,$$

where,

$$A = \begin{bmatrix} 0 & 1 \\ -4 & -K \end{bmatrix}, B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$C = [1 \;\; 0] \text{ and } D = [0]$$

(i) Determine the characteristic equation.

[5 marks : 2022]

(ii) Sketch the root locus of the system.

[10 marks : 2022]

(iii) Test the stability of the system.

[5 marks : 2022]

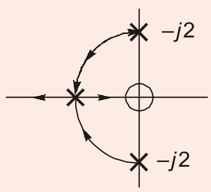
Solution:

$$q(s) = |sI - A| = 1$$

(i) $$q(s) = s^2 + K_s + 4 = 0$$

(ii) $$GH(s) = \frac{Ks}{s^2 + 4}$$

RLD:



(iii) Stable for $0 < K < \infty$

End of Solution

Q.4 (c) Write a code or pseudocode (in any standard programming language) to check whether or not there exist two elements in a given array *X*[ ] whose sum is exactly '*S*'. Consider that array *X*[ ] has '*N*' numbers and '*S*' is another number. Also write the comments for the lines in your code or pseudocode.

[20 marks : 2022]

Solution:

Given array $X[\ ]$, another number 'S' of 'n' elements.

Determines whether (or) not there exists two elements in $X[\ ]$ whose sum is exactly S.

Eg. Input : $X[\ ] = \{0, -1, 2, -3, 1\}$

$$S = -2$$

O/P : Pair with a given sum "–2" is {–3, 1}

So valid pair existed.

Eg. Input : $X[\ ] = \{1, -2, 1, 0, 5\}$

$$S = 0$$

O/P : No valid pair exist for "0".

Here, first sort the Array and find the sum value with pair the elements.

Pseudo Code:

Step 1 : Take the array with 'n' elements and initialize the values and also fix the sum value "S".

$$\underset{(N)}{(X[\ ],\ \text{size},\ S)}$$

Step 2: Sort the array in ascending order.

Step 3: Initialize two index variables to find the candidate elements (pair elements) in the sorted array.

- Initialize first to the left most Index $l = 0$
- Initialize second the right most index $r = N - 1$

Step 4: While ($l < r$)

- If ($X[l] + X[r]$ = = S) then return 1.
- Else if ($X[l] + X[r]$ < Sum) Then l++
- Else r– –

Step 5: No pair in the whole array then return 0.

End of Solution

Section-B

Q.5 (a) The carrier signal $c(t) = 8 \cos (2\pi \times 10^6\, t)$ is frequency modulated by a modulating signal $m(t) = 5 \cos (2000\, \pi t) + 6 \cos (3000\, \pi t)$. The frequency sensitivity of the modulator is 10^3 Hz/volt. Obtain the time domain expression for the FM wave and calculate the maximum frequency deviation, modulation index, transmission bandwidth (using Carson's rule) and average power in the FM wave.

[10 marks : 2022]

Solution:

$$c(t) = 8 \cos 2\pi \times 10^6 t$$

$$m(t) = 5 \cos 2000\text{pt} + 6 \cos 3000\pi t$$

$$K_f = 10^3 \frac{\text{Hz}}{\text{volt}}$$

$$S_{Fm}(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f \int m(t)dt\right]$$

$$= 8\cos\left[2\pi \times 10^6 t + 2\pi \times 10^3\left(\frac{5\sin 2000\pi t}{2000\pi} + \frac{6\sin 3000\pi t}{3000\pi}\right)\right]$$

$$S_{Fm}(t) = 8\cos[2\pi \times 10^6 t + 5\sin 2000\pi t + 4\sin 3000\pi t]$$

Maximum frequency deviation $\Delta f = K_f |M(t)|\text{max}$

$$\Delta f = 10^3 \times (5 + 6) = 11 \text{ kHz}$$

$$\text{Modulation index, } \beta = \frac{\Delta f}{f_{max}} = \frac{11\text{K}}{1.5\text{ K}} = 7.33$$

$$\text{Transmission BW} = 2[\Delta f + f_{max}]$$
$$= 2[11 \text{ kHz} + 1.5 \text{ kHz}] = 25 \text{ kHz}$$

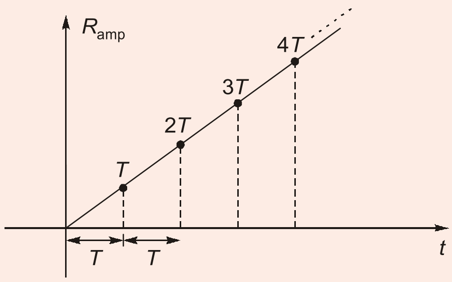
$$\text{Average power} = \frac{A_c^2}{2} = \frac{64}{2} = 32 \text{ Watts}$$

End of Solution

Q.5 (b) Prove that the Z-transform of a sampled unit ramp signal is given by $F(z) = \dfrac{Tz}{(z-1)^2}$.

[10 marks : 2022]

Solution:



$$f(t) = t\,u(t)$$

$$F(z) = \sum_{n=0}^{\infty} f(nT)z^{-n}$$

$$= 0 + Tz^{-1} + 2Tz^{-2} + 3T z^{-3} + \ldots..$$
$$= T[z^{-1} + 2z^{-2} + 3z^{-3} + \ldots..]$$
$$S = ar + 2ar^2 + 3ar^3 + 4ar^4 + \ldots..$$
$$= \frac{ar}{(1-r)^2}$$

$\therefore$ $$F(z) = \frac{Tz^{-1}}{(1-z^{-1})^2}$$ $\because a = T;\ r = z^{-1}$

$\therefore$ $$F(z) = \frac{Tz}{(z-1)^2}$$

End of Solution

Q.5 (c) Consider the following code segment in a function of a process:

```
int *y = (int *) malloc (20 * sizeof (int));
```

When this function is invoked and executed:

(i) Where is the memory for the variable 'y' allocated within the memory image (heap/stack) of the process and why?

[5 marks : 2022]

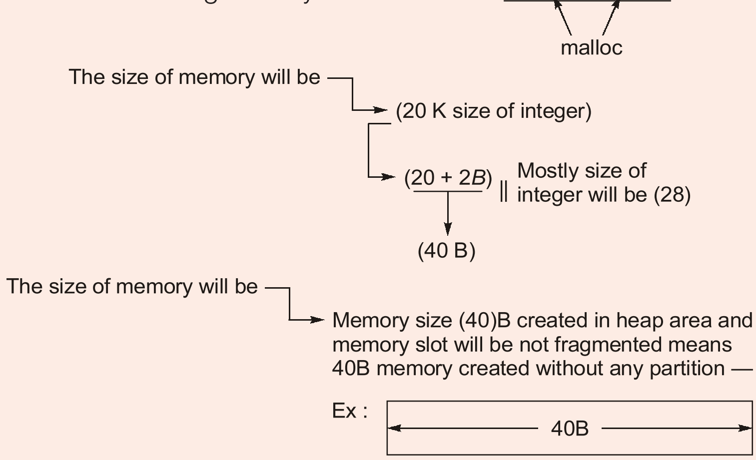
(ii) Where is the memory for the 20 integer variables allocated within the memory image (heap/stack) of the process and why?

[5 marks : 2022]

Solution:

(i) Memory of the "y" will be allocated in the heap area

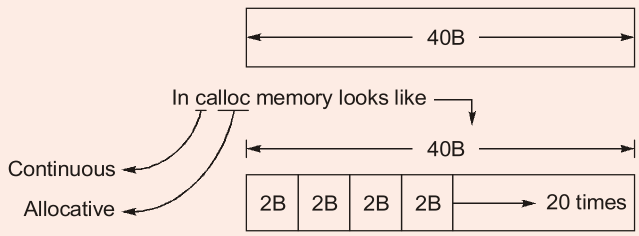
Because here we are given keyword malloc is (memory allocation)



(ii) Memory of 20 integer is created in hoop area due to dynamic memory allocation keyword malloc of the memory is not in fragmented formate as I told solution 1. Also like malloc keyword of if we use [calls 6] then memory is created in heap.

Area with same size but memory is fragmented in 2 byte each due to integer is given inside (size of).

Hence in malloc memory looks like



(1) int *y = (int *) malloc (20 * sizeof (int));

(2) int *y = (int *) calloc (20 * sizeof (int));

This tells create integer size memory into heap area that is (20) in numbers

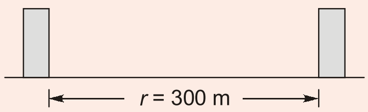
int *y = (int *) malloc (20 * sizeof (int));

End of Solution

Q.5 (d) A half-wave dipole situated with its center at the origin in free space radiates a time averaged power of 600 Watts at a frequency of 300 MHz. A receiving half-wave dipole antenna is placed at (300 m, 90°, 40°). It is oriented so that its axis is parallel to that of the transmitting antenna. Determine the available power at the receiving antenna. The directivity of half-wave dipole is 2.15 dB.

[10 marks : 2022]

Solution:



$$P_{avg} = 600 \text{ W}$$
$$f = 3 \times 10^8 \text{ Hz}$$

From Friis transmission formula;

$$P_r = \frac{P_t \cdot G_{dt} \cdot G_{dl}}{\left(\frac{4\pi r}{\lambda}\right)^2}$$

$\because$ Both $T_x - R_x$ are half wave dipole antenna

$\therefore$ $G_{dt} = G_{dr} = 2.15 \text{ dB}$

$\Rightarrow$ $2.15 = 10\log 10\, G_d$

$\Rightarrow$ $G_d = 1.64$

Now,

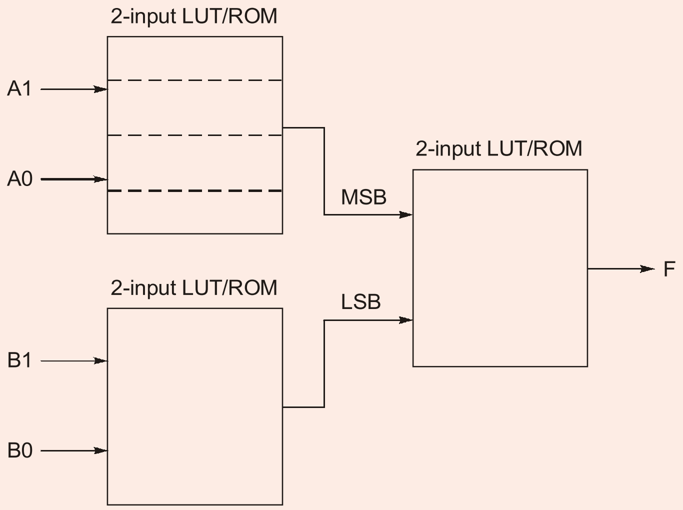
$$P_r = \frac{600 \times 1.64 \times 1.64}{\left(\frac{4\pi 300}{1}\right)^2} \qquad \lambda = \frac{c}{f} = \frac{3\times10^8}{3\times10^8} = 1$$

$$P_r = 0.113 \text{ mW}$$

End of Solution

Q.5 (e) What is the advantage of using a PLA over ROM in the realization of a combinational function? Realize the following Boolean function 'F' of three variable by storing appropriate values and settling proper inputs to a cascade of 2-input look-up tables (ROM) with only one bit output as shown below:

$$F(A, B, C) = \Sigma(0, 1, 3, 5, 6, 7)$$



[10 marks : 2022]

Solution:

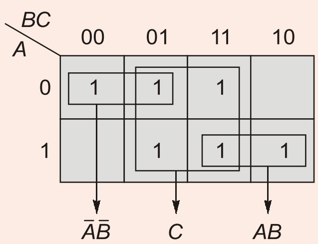
In PLA, both AND and OR arrays are configurable unlike in ROM where only the OR gates array is configurable. PLAs are more flexible than ROMs

- No need to have 2^n rows for n inputs.
- Only the minterms that are required can be generated unlike ROM where all the minterms are generated by OR array.
- It can take advantage of logic simplification.

Consider the given function

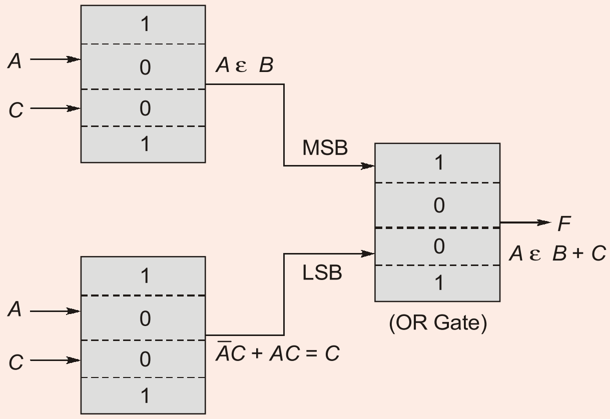
$$F(A, B, C) = \Sigma(0, 1, 3, 5, 6, 7)$$

Simplifying the above expression using *K*-map,



$$F = \bar{A}\bar{B} + AB + C = A \odot B + C$$

The above function can be implemented using the cascaded 2-input look up tables (ROM) shown below :



End of Solution

Q.5 (f) A TCP segment consisting of 1500 bits of data and 160 bits of header is sent to the IP layer, which appends another 160 bits of header. This is then transmitted through two networks, each of which uses a 24-bit packet header. The destination network has a maximum packet size of 800 bus. How many bits, including headers, are delivered to the network layer protocol at the destination?

[10 marks : 2022]

Solution:

Given that,

$$\text{Data + Transport layer} = 1500 + 160 + 160 = 1820 \text{ bits}$$

The data field of destination network has packet size is

$$800 - 24 = 776 \text{ bits}$$

Three network packets are needed

$$\text{Total bits delivered} = 1820 + 3 \times 24 = 1892 \text{ bits}$$

End of Solution

Q.6 (a) A 100 MHz uniform plane wave is propagating in a lossless medium in positive z-direction. The medium has $\varepsilon_r = 9$ and $\mu_r = 4$.

(i) Determine the propagation constant, wavelength and phase velocity of the wave.

[8 marks : 2022]

(ii) Assuming electric field in x-direction and magnetic field in y-direction, obtain expressions for Poynting vector and average power of the wave. What will be the average power if $E_{x_0} = 400$ V/m?

[12 marks : 2022]

Solution:

Given data : $f = 100 \times 10^6$ Hz ; $\epsilon_r = 9$; $\mu_r = 4$

Lossless medium

(i) (a) Propagation constant; γ

For less medium; $\alpha = 0$

$$\beta = \omega\sqrt{\mu\epsilon} = \omega\sqrt{\mu_o\epsilon_o} = \sqrt{\mu_r\epsilon_r}$$

$$\Rightarrow \quad \beta = \frac{\omega}{C}\sqrt{\mu_r\epsilon_r}$$

$$\Rightarrow \quad \beta = \frac{2\pi\times 100\times 10^6}{3\times 10^8}\sqrt{4\times 9} = \frac{2\pi\times 10^8}{3\times 10^8}\times 2 = 4\pi$$

$$\Rightarrow \quad \beta = 4\pi \text{ rad/m}$$

(b) Wavelength; λ :

$$\beta = \frac{2\pi}{\lambda} \Rightarrow \lambda = \frac{2\pi}{\beta} = \frac{2\pi}{4\pi} = \frac{1}{2} = 0.5\text{ m}$$

$$\gamma = 0.5 \text{ m}$$

(c) Phase velocity; v_p :

$$v_p = \frac{\omega}{\beta} = \frac{2\pi f}{\beta} = \frac{2\pi\times 100\times 10^6}{4\pi} = 50\times 10^6$$

$$v_p = 50\times 10^6 \text{ m/s}$$

(ii) Assuming, wave propagates in $+z$ direction

In phasor form,

$$\bar{E}(z) = E_o e^{-j\beta z}\hat{a}_x$$

$$\bar{H}(z) = H_o e^{-j\beta z}\hat{a}_y$$

$$\Rightarrow \quad \bar{H}*(z) = H_o^* e^{j\beta z}\hat{a}_y$$

$\therefore$ Poynting vector; $\bar{P} = E\times\bar{H}$

$$\Rightarrow \quad \bar{P} = E_o e^{-j\beta z}\hat{a}_x \times H_o e^{-j\beta z}\hat{a}_y$$

$$\Rightarrow \quad \bar{P} = E_o H_o e^{-j2\beta z}(\hat{a}_x\times\hat{a}_y)$$

$$\Rightarrow \quad \bar{P} = \frac{E_o^2}{\eta}e^{-j2\beta z}\hat{a}_z \text{ W/m}^2 \qquad \left[\because \frac{E_o}{H_o} = \eta\right]$$

Also,

$$\bar{P}_{avg} = \frac{1}{2}\text{Re}[\bar{E}\times\bar{H}] = \frac{1}{2}\text{Re}[E_o e^{-j\beta z}\hat{a}_x \times H_o^* e^{+j\beta z}\hat{a}_y]$$

$$= \frac{1}{2}\text{Re}\left[E_o H_o^*(\hat{a}_x\times\hat{a}_y)\right] = \frac{1}{2}\text{Re}\left[E_o\frac{E_o^*}{\eta}\hat{a}_z\right]$$

$$= \frac{1}{2}\text{Re}\left[\frac{|E_o|^2}{\eta}\hat{a}_z\right]$$

$$\therefore \qquad \bar{P}_{avg} = \frac{E_o^2}{2\eta}\hat{a}_z \text{ W/m}^2$$

Now, for $E_{xo} = 400$ V/m

$$\bar{P}_{avg} = \frac{(400)^2}{2\times 80\pi}\hat{a}_z \text{ W/m}^2$$

$$\left[\because\ \eta = 120\pi\sqrt{\frac{\mu_r}{\epsilon_r}} = 120\pi\sqrt{\frac{4}{9}} = 120\pi\times\frac{2}{3} = 80\pi\right]$$

$$\therefore \qquad \bar{P}_{avg} = 318.31\hat{a}_z \text{ W/m}^2$$

End of Solution

Q.6 (b) Write an 8085 program to generate an approximate digital clock by utilizing the delays associated with different instructions. Assume that the 8085 microprocessor is operating at a clock frequency of 3 MHz and a display routine is available to display the binary contents of memory locations 2700H, 2701H and 2702H corresponding to hours, minutes and seconds of a digital clock respectively.

[20 marks : 2022]

Solution:

To write an 8085 assembly program to design a digital clock for hour, minute and second at memory locations 2700 H, 2701 H, 2702 H, $f = 3$ MHz.

Assuming a delay program for 1 second and display subroutine, the following program is implemented

```
Start :   LXI   H,  2700 H  ┐
          MVI   M,  00H     │
          INX   H           │ Initializing hour, min, sec as 00 : 00 : 00
          MVI   M,  00H     │
          INX   H           │
          MVI   M,  00H     ┘
          MVI   C,  00H    ; Counter for 60 sec
AGAIN:    CALL  display
          CALL  display sec
          INR   C
          MOV   A, C
          DAA
          STA   2702H
          CPI   60H;   to check, sec = 60 or not
          JNZ   AGAIN
          MVI   C, 00H
```

```
LXI   H, 2701H  ┐
INR   M         │
MOV   A, M      │
DAA             ├ To check min = 60 or not
CPI   60H       │
JNZ   AGAIN     │
MVI   M, 00H    ┘
LXI   H, 2700H  ┐
INR   M         │
MOV   A, M      │
DAA             ├ To check hour = 24 or not
CPI   24H       │
JNZ   AGAIN     │
MVI   M, 00H    ┘
JMP   Start
```

End of Solution

Q.6 (c) A continuous 12 km long optical fiber link has a loss of 1.5 dB/km.

(i) What is the minimum optical power level that must be launched into the fiber to maintain an optical power level of 0.3 μW at the receiving end?

[10 marks : 2022]

(ii) What will be the input power required, if the fiber link is increased by 100% and fiber loss is reduced to 1 dB/km?

[10 marks : 2022]

Solution:

(i) Given that, $L = 12$ km ; $\alpha = 1.5$ dB/km ; $P_{out} = 0.3\ \mu W$; $P_{in} = ?$

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

$$0.3\ \mu W = P_{in} \cdot 10^{-\frac{1.5\times 12}{10}}$$

$$P_{in} = \frac{0.3\ \mu W}{10^{-\frac{1.5\times 12}{10}}} = \frac{0.3\ \mu W}{10^{-1.8}} = 18.93\ \mu W$$

(ii) Given that, the fiber link is increased by 100%

$$L' = L + 100\%\ L = L + \frac{100}{100}\times L = 2L$$

$$L' = 2 \times 12 \text{ kms} = 24 \text{ kms}$$

$$\alpha = 1 \text{ dB/km}$$

$$P_{out} = 0.3\ \mu W = P_{in}\, 10^{-\alpha L/10}$$

$$0.3\ \mu W = P_{in}\, 10^{-1\times 24/10}$$

$$P_{in} = \frac{0.3\ \mu W}{10^{-2.4}} = 75.35\ \mu W$$

End of Solution

Q.7 (a) A certain lossless transmission line is 1.6 m long and has characteristic resistance R_0 = 500 Ω. The line is operating in air and frequency of operation is 500 MHz.

(i) The line is terminated with a short circuit. It is observed that the maximum voltage at any point on the line is 11.56 volts. What will be the magnitude of input voltage? Determine the current through the short circuit.

[10 marks : 2022]

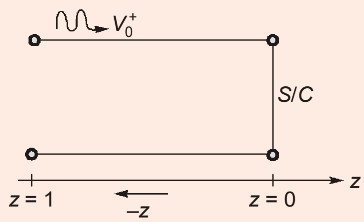
(ii) The short circuit is replaced by a resistance load of 200 Ω. The input voltage is varied so that 100 Watts of power is delivered to the load. Find the reflection coefficient, voltage standing wave ratio and power in the incident wave.

[10 marks : 2022]

Solution:

Given data, l = 1.6 m; R_0 = 500 Ω; $f = 500 \times 10^6$ Hz

(i) From the question



$$V_{max} = V_0^+\left[1+|\Gamma|\right]$$

For short circuit line, $$\Gamma = \frac{R_L - R_0}{R_L + R_0} = -1$$

$\Rightarrow$ $$|\Gamma| = 1$$

$\Rightarrow$ $$11.56 = V_0^+[1+1]$$

$\Rightarrow$ $$V_0^+ = \frac{11.56}{2} = 5.78 \text{ V} \quad \Rightarrow \quad V_0^+ = 5.78 \text{ V}$$

Now, $$I_s(z) = \frac{V_0^+}{Z_0}e^{-j\beta z} - \frac{V_0^-}{Z_0}e^{+j\beta z}$$

At $z \rightarrow -z$

$$I_s(z) = \frac{V_0^+}{Z_0}e^{j\beta z} - \frac{V_0^-}{Z_0}e^{-j\beta z}$$

At $z = 0$, $$I_s(z=0) = \frac{V_0^+}{Z_0} - \frac{V_0^-}{Z_0} = \frac{V_0^+}{R_0}\left[1 - \frac{V_0^-}{V_0^+}\right]$$

Now, $$\begin{bmatrix} V_o \\ I_o \end{bmatrix} = \begin{bmatrix} \cos\beta l & jZ_o\beta l \\ \dfrac{j\sin\beta l}{Z_o} & \cos\beta l \end{bmatrix}\begin{bmatrix} V_L \\ I_L \end{bmatrix}$$

Here, $V_L = 0$, $I_L = 0.023$ A

$$\beta l = \frac{2\pi}{\lambda} \times 1.6$$

$$\lambda = \frac{C}{f} = \frac{3\times 10^8}{5\times 10^8} = 0.6$$

$$\beta l = \frac{2\pi}{0.6} \times 1.6 = 16.75$$

$\Rightarrow$ $\cos\beta l = -0.5$

$\sin\beta l = -0.86$

$\therefore$ $V_o = jZ_o \sin\beta l \, I_L$

$= j500 \times -0.86 \times 0.023$

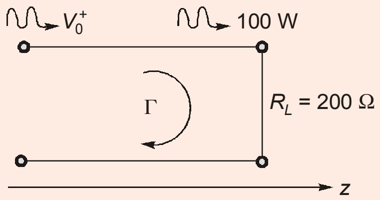
$= -j9.89 \simeq 10\angle{-\pi/2}$

$\therefore$ Input voltage, $V_o = 10\angle{-\pi/2}$ V

$$\Rightarrow \quad I_s(z=0) = \frac{5.78}{500}[1-\Gamma] = \frac{5.78}{500} \times 2 = 0.023 \text{ A}$$

$\therefore$ Current through short circuit, $I_{sc} = 2.312$ mA

(ii)



(a) Reflection coefficient; Γ:

$$\Gamma = \frac{R_L - R_0}{R_L + R_0} = \frac{200-500}{200+500} = \frac{-3}{7}$$

(b) Voltage standing wave ratio; S:

$$S = \frac{1+|\Gamma|}{1-|\Gamma|} = \frac{1+3/7}{1-3/7} = \frac{10}{4} = 2.5$$

(c) Power in the incident wave, P_{in}:

As, power delivered to the load;

$$P_L = \{1 - |\Gamma|^2\}\frac{|V_0^+|^2}{2R_0}$$

$$\Rightarrow \quad P_L = \{1 - |\Gamma|^2\}P_{inc}$$

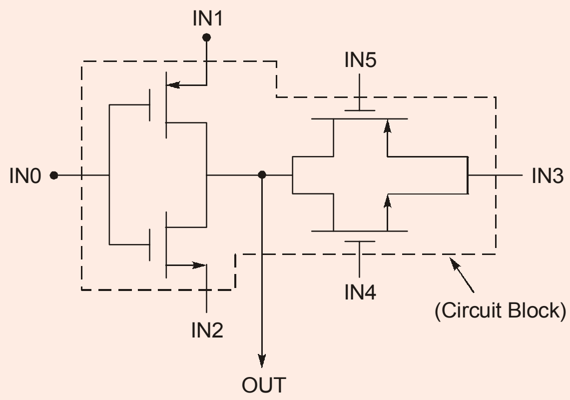
$$\Rightarrow \quad P_{inc} = \frac{P_L}{1-|\Gamma|^2} = \frac{100}{1-\left|\frac{3}{7}\right|^2} = 122.5 \text{ W}$$

$\therefore$ $P_{inc} = 122.5$ W

End of Solution

Q.7 (b) Realize a 'sum' output of a full adder by using appropriate number of circuit blocks shown below and inverters.

$$\text{Sum} = ((A \oplus B) \oplus C_{in})$$



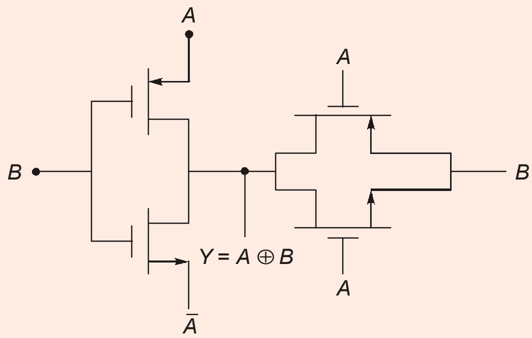
The circuit block has six inputs IN0, IN1, ... IN5 and one output 'OUT'.

[20 marks : 2022]

Solution:

$$\text{Sum} = ((A \oplus B) \oplus C_{in})$$

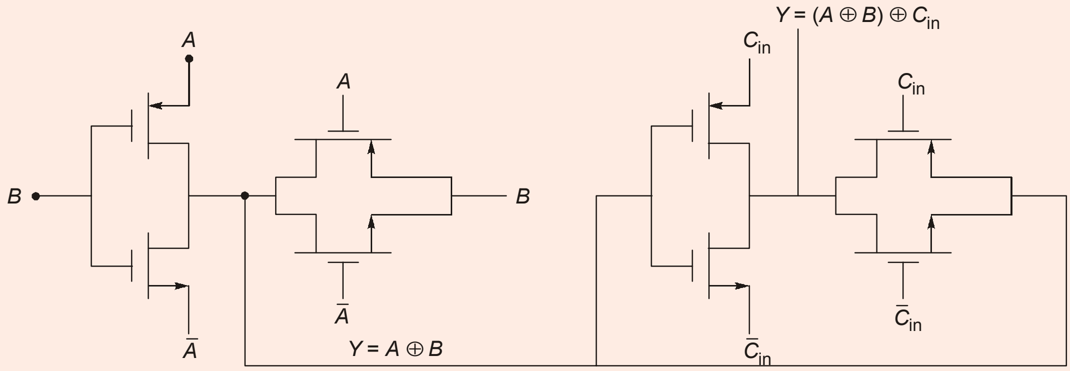
From the given circuit block, the XOR operation can be implemented as below:



The operation of the circuit can be explained as below

- If A is 0, both transistors in the inverter will always be in cut-off. Thus, the inverter doesn't affect the output. The output will be equal to B passed by the transmission gate.
- If A is 1, the inverter acts like an inverter passing the complement of B to the output. The transmission gate doesn't affect the circuit because it is in the blocking state.

The sum output of full adder can be realized using the given circuit block as below:



End of Solution

Q.7 (c) (i) A telephone network consists of two end offices and one intermediate switch with a 1 MHz full duplex trunk between each end office and the intermediate switch. The average telephone is used to make four calls per 8 hour work day, with a mean call duration of six minutes. Ten percent of the calls are long distance. What is the maximum number of telephones an end office can support?

[10 marks : 2022]

(ii) In a pure ALOHA system, the channel bit rate is 2400 bits/second. Each terminal transmits a 100 bits message every minute. Determine the maximum number of terminals that can use the channel.

[10 marks : 2022]

Solution:

(i) Given that, Full duplex trunk = 1 MHz

The average telephone is used to make 4 calls per 8 hour work day with a mean call duration of 5 minutes.

$$= \frac{4}{8} = \frac{1}{2} = 0.5 \text{ Calls/hour}$$

The mean call duration of 6 minutes is

$$= 0.5 \times 6 = 3 \text{ min/hour}$$

The 20 telephones can share the circuit in an hour.

Given 10% of calls are long distance so 200 telephone can share a long distance circuit.

$$\text{The number of circuits} = \frac{1\text{MHz}}{4\text{kHz}} = 250 \text{ circuits}$$

The maximum number of telephones support are

$$= 250 \times 200 = 50000$$

(ii) Given that, pure ALOHA channel bit rate is 2400 bps.

Each terminal transmits = 100 bits/minute.

Let the number of terminals be N.

Maximum channel bandwidth for pure ALOHA is 18.4% of channel bandwidth i.e. 18.4% × 2400 bps.

$$\frac{18.4}{100} \times 2400 \text{ bps} = N \times \frac{100}{60} \text{ bits/sec}$$

$$N = \frac{18.4 \times 24 \times 60}{100} = 264.96 \simeq 265$$

End of Solution

Q.8 (a) An air-filled rectangular waveguide is to be constructed for single mode operation at 15 GHz. The design condition is that the frequency is 20 percent higher than the cut-off frequency for the fundamental mode, while being 20 percent lower than the cut-off frequency for the next higher order mode.

(i) Determine the guide dimensions *a* and *b*.

[10 marks : 2022]

(ii) Find the propagation constant, wavelength and phase velocity for the guided mode.

[10 marks : 2022]

Solution:

(i) Assume, TE_{10} mode with $a \times b$,

Given, $1.2 f_C|_{TE_{10}} \le f \le 0.8 f_C|_{TE_{01}}$

$$\Rightarrow \quad 1.2 f_C|_{TE_{10}} = 0.8 f_C|_{TE_{01}} = f$$

Now,
$$f_C|_{TE_{10}} = \frac{c}{2a} = \frac{f}{1.2}$$

$$\Rightarrow \quad \frac{3 \times 10^8}{2a} = \frac{15 \times 10^9}{1.2}$$

$$\Rightarrow \quad a = 1.2 \text{ cm}$$

Also,
$$f_c|_{TE_{01}} = \frac{c}{2b} = \frac{f}{0.8}$$

$$\Rightarrow \quad \frac{3 \times 10^8}{2b} = \frac{15 \times 10^9}{0.8}$$

$$\Rightarrow \quad b = 0.8 \text{ cm}$$

(ii) (a) Propagation constant; γ_g :

For air filled waveguide;

$$\gamma_g = j\beta_g$$

$$\therefore \quad \beta_g = \beta\sqrt{1 - \left(\frac{f_c}{f}\right)^2}$$

$$\therefore \quad f_c = \frac{c}{2a} = \frac{3 \times 10^8}{2 \times 1.2 \times 10^{-2}} = 12.5 \text{ GHz}$$

$$\Rightarrow \quad \beta_g = \frac{\omega}{c}\sqrt{1 - \left(\frac{12.5}{15}\right)^2} = \frac{2\pi \times 15 \times 10^9}{3 \times 10^8}\sqrt{1 - \left(\frac{12.5}{15}\right)^2}$$

$$\beta_g = 173.65 \text{ rad/m}$$

$$\therefore \quad \gamma_g = j173.65 \text{ /m}$$

(b) Guided wavelength ; λ_g:

$$\lambda_g = \frac{2\pi}{\beta_g} = \frac{2\pi}{173.65} = 0.036 \text{ m}$$

$$\Rightarrow \quad \lambda_g = 3.62 \text{ cm}$$

(c) Phase velocity; v_p :

$$v_p = \frac{c}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} = \frac{3\times10^8}{\sqrt{1-\left(\frac{12.5}{15}\right)^2}} = 5.43\times10^8$$

$$\therefore \quad v_p = 5.43 \times 10^8 \text{ m/s}$$

End of Solution

Q.8 (b) (i) Design a block level architecture of a seven coefficient FIR filter by using appropriate number of multipliers, adders and registers. Assume that all the input operands are available in 8 bit, 2's complement fixed point representation. The architecture should give one output per clock cycle.

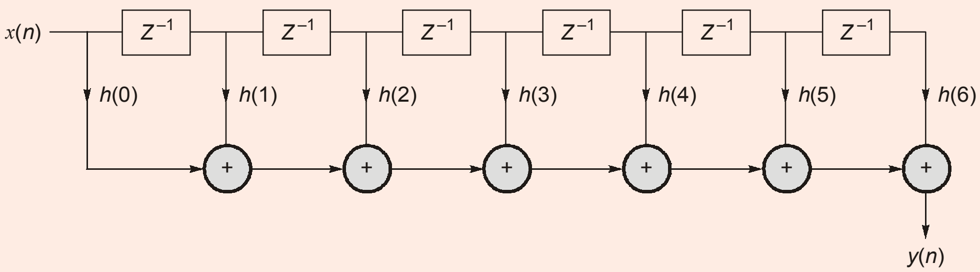
[12 marks : 2022]

(ii) Identify the different blocks required, if the FIR filter is to be realized by using a single multiplier and an adder. Justify your answer.

[8 marks : 2022]

Solution:

(i) 7 coefficient FIR filter structure:



where, $x(n)$ = sys i/p

$y(n)$ = sys o/p

$h(n)$ = Impulse response of FIR filter

Since, $h(n)$ has 7 coefficients i.e.

$$h(n) = \{h(0), h(1), h(2), h(3), h(4), h(5), h(6)\}$$

Number of multipliers = 7

Number of adders = 7 – 1 = 6

End of Solution

Q.8 (c) A QPSK signal is transmitted by satellite. Raised-cosine filtering is used, for which the roll-off factor is 0.2 and a BER of 10^{-5} is required. For the satellite downlink, the losses amount to 200 dB, the receiving earth station G/T ratio is 32 dBK^{-1}, and the transponder bandwidth is 36 MHz. Calculate

(i) The maximum bit rate that can be accommodated.

[10 marks : 2022]

(ii) The required equivalent isotropic radiated power.

Assume that $\left(\frac{E_b}{N_o}\right)$ ratio for 10^{-5} BER is 10 dB.

[10 marks : 2022]

Solution:

Given,

$$\text{Roll off factor, } \alpha = 0.2$$
$$\text{BER, Pe} = 10^{-5}$$
$$\text{Losses} = 200 \text{ dB}$$
$$G/T = 32 \text{ dB/K}^{-1}$$
$$\text{Bandwidth BW} = 36 \text{ MHz}$$

(i) We know,

For *QPSK*, $M = 4$

$$\text{BW} = \frac{R_b}{\log_2 M}(1+\alpha)$$

$$36 \times 10^6 = \frac{R_b}{\log_2(4)}(1+0.2)$$

$$R_b = 60 \times 10^6 \text{ bps}$$

$$\text{Bit rate, } R_b = 60 \text{ Mbps}$$

(ii) The required EIRP,

$$\text{EIRP} = \left[\frac{E_b}{N_0}\right] + [R_b]_{dB} - \left[\frac{G}{T}\right]_{dB} + [\text{Losses}]_{dB} + [K]_{dB}$$

$$= 10 + 10\log(60 \times 10^6) - 32 + 200 + 10\log(1.38 \times 10^{-23})$$

$$\text{EIRP} = 10 + 77.78 - 32 + 200 - 228.6$$

$$\text{EIRP} = 27.179 \text{ db}$$

End of Solution

■■■■