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ESE – 2019
(MAINS)
Questions with Detailed Solutions

ELECTRONICS & TELECOMMUNICATION ENGINEERING

PAPER – II

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ELECTRONICS & TELECOMMUNICATION ENGINEERING

ESE _MAINS_2019_PAPER – II

SUBJECT WISE REVIEW

SUBJECT(S)	LEVEL	Marks
Control Systems	Moderate	70
Signals & Systems	Easy	30
Analog and Digital Communication Systems	Moderate	90
Advanced Communication topics	Hard	70
Advanced Electronics Topics	Moderate	50
Computer Organization and Architecture	Moderate	90
Electro Magnetics	Moderate	80

Subject Experts,

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SECTION-A

01. (a) In a narrow band digital communication system the symbol error probability for the in-phase channel is P_{eI} and for quadrature phase channel is P_{eQ}. Prove that the probability of symbol error for the overall system is given by (P_e):

$P_e = P_{eI} + P_{eQ} - P_{eI} P_{eQ}$ (10 M)

Sol: The overall probability of correct reception is

$P_C = (1 - P_{eI})(1 - P_{eQ}) = 1 - P_{eI} - P_{eQ} + P_{eI}P_{eQ}$

The overall probability of error is

$P_e = 1 - P_C = 1 - [1 - P_{eI} - P_{eQ} + P_{eI} P_{eQ}] = P_{eI} + P_{eQ} - P_{eI} P_{eQ}$

01. (b) Consider a discrete time system with impulse response $h[n] = \left(\frac{1}{5}\right)^{2n} U[n]$. Find the value of constant A such that $h[n] - Ah[n-1] = \delta[n]$ and $\delta[n]$ is a unit impulse signal. (10 M)

Sol: $h(n) - Ah(n-1) = \delta(n)$

$$\left(\frac{1}{25}\right)^n - A\left(\frac{1}{25}\right)^{n-1} u(n-1) = \delta(n)$$

If $A = \frac{1}{25}$, then only LHS = RHS.

(or)

$h(n) - Ah(n-1) = \delta(n)$

Apply z-Transforms

$H(z) - Az^{-1}H(z) = 1$

$$H(z) = \frac{1}{1 - Az^{-1}} \text{ ------ (1)}$$

But $h(n) = \left(\frac{1}{5}\right)^{2n} u(n) = \left(\frac{1}{25}\right)^n u(n)$

$$\text{Then } H(z) = \frac{1}{1 - \frac{1}{25}z^{-1}} \text{ -----(2)}$$

Compare (1) & (2)

Then $A = \frac{1}{25}$

01. (c) A digital computer has a memory unit with 32 bits per word. The instruction set consists of 240 different operations. All instructions have an operation code part (opcode) and an address part (allowed for only one address). Each instruction is stored in one word of memory.

(i) How many bits are needed for the opcode?

(ii) How many bits are left for the address part of the instruction?

(iii) What is the maximum allowable size of the memory? (10 M)

Sol: Word size= 32-bits

Number of instructions (operations) supported = 240.

Hence, number of bits in opcode = $[\log_2 240]$ = 8-bits

Instruction size = 1 word = 32-bits

one-address instruction

$\longleftarrow$ 32 $\longrightarrow$

opcode	add. 1
8	

Address size = 32–8 = 24-bits

(i) opcode bits = 8-bits

(ii) Address size = 24-bits

(iii) Size of memory = $2^{24} \times 32\text{-bits} = 2^{24} \times 4$ Bytes

$= 64$ Mbytes

01. (d) The Radiation intensity of an antenna is

$$U(\theta,\phi) = \begin{cases} 2\sin\theta\sin^3\phi & 0 \le \theta \le \pi, 0 \le \phi \le \pi \\ 0 & \text{elsewhere} \end{cases}$$

Determine the directivity of the antenna. (10 M)

Sol: $U(\theta,\phi) = 2\sin\theta\sin^3\phi$

$0 \le \theta \le \pi \quad 0 \le \phi \le \pi$

$$D = 4\pi\frac{U_{max}}{P_{rad}}$$

$$P_{rad} = \int_S U(\theta,\phi)\sin\theta\, d\theta d\phi$$

$$P_{rad} = \int_S 2\sin\theta \sin^3\phi \sin\theta\, d\theta d\phi$$

$$P_{rad} = 2\int_{\theta=0}^{\pi} \sin^2\theta d\theta \int_{\phi=0}^{\pi} \sin^3\phi d\phi = 2(2)\frac{1}{2}\frac{\pi}{2}(2)\frac{2}{3}$$

$$P_{rad} = \frac{4\pi}{3}$$

$$D = 4\pi \frac{2}{\left(\frac{4\pi}{3}\right)} = 6$$

D = 10log(6) = 7.78 dB

01. (e) A graded index fiber has a characteristics refractive index profile of 1.85 and a core diameter of 60μm. Compute the insertion loss due to a 5μm lateral offset at an index matched fiber joint assuming the uniform illumination of all guided modes. (10 M)

Sol: n_1 = 1.85, radius a = 30μm, y = 5μm

Lateral coupling efficiency

$$\eta = \frac{16n_1^2}{(1+n_1)^4} \times \frac{1}{\pi}\left\{2\cos^{-1}\left(\frac{y}{2a}\right) - \left(\frac{y}{a}\right)\left[1-\left(\frac{y}{2a}\right)^2\right]^{\frac{1}{2}}\right\}$$

Insertion loss due to lateral misalignment is

– 10logη = 0.67 dB

01. (f) A mobile network transmits data having bandwidth of 200 Hz using a carrier frequency of 800 MHz. If the maximum speed of a vehicle is 120 km/hr, calculate the bandwidth and the cut-off frequencies of the filter at the receiver input. (10 M)

Sol: Speed of the vehicle 120 km/hr = $\frac{100}{3}$ m/sec, f_c = 800 MHz, BW = 200Hz.

Doppler shift $f_d = \frac{V_r f_o}{C} = \frac{100 \times 800 \times 10^6}{3 \times 3 \times 10^8} = 88.88\text{Hz}$.

Lower Cut-off frequency = $f_c - f_d$ – 100 Hz = 800 MHz – 88.88 Hz – 100 Hz
= 800MHz – 188.88 Hz

Upper Cut-off frequency = $f_c + f_d$ + 100 Hz = 800 MHz + 88.88 Hz + 100 Hz
= 800MHz + 188.88 Hz

BW =$2f_d$ + 200 Hz = 177.77 Hz + 200 Hz = 377.77 Hz

02. (a) Two speech signals $m_1(t)$ and $m_2(t)$ are used to generate a composite signal as:

$s(t) = m_1(t) \cos\omega_c t + m_2(t) \sin\omega_c t$

Assume both the messages are low pass in nature and have W Hz bandwidth.

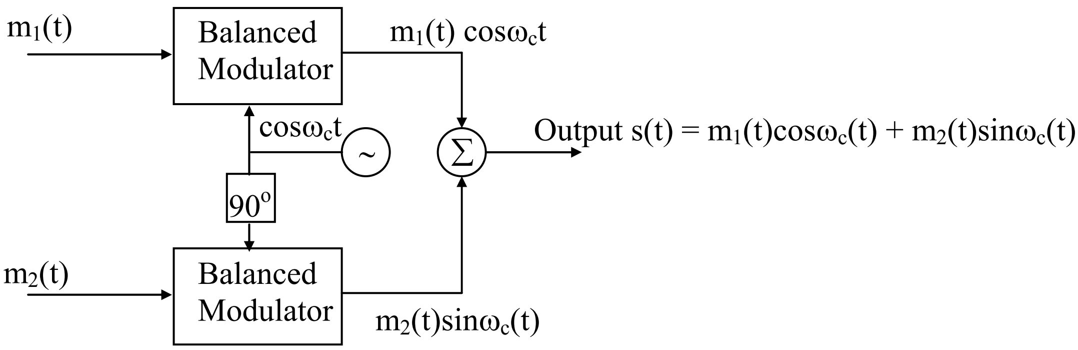
(i) Draw the block diagram and show the generation scheme of s(t). (8 M)

(ii) Propose a demodulation scheme in the form of block diagram and show the recovery of the two signals $m_1(t)$ and $m_2(t)$. Assume $\omega_c >> 2\pi$ W. (12 M)

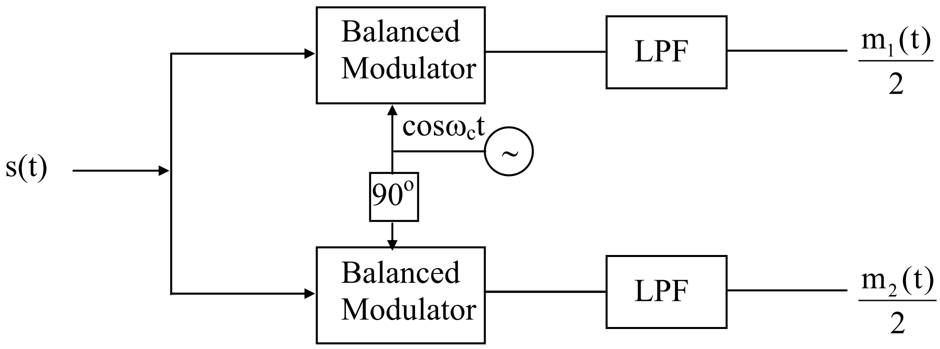
Sol:

(i) $s(t) = m_1(t) \cos\omega_c(t) + m_2(t) \sin\omega_c(t)$

Generation:



(ii) Demodulation:



Output of 1 multiplier is

$= s(t) \cos\omega_c t$

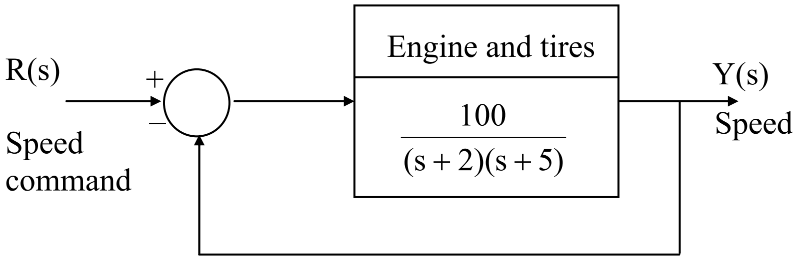
$= [m_1(t) \cos\omega_c(t) + m_2(t) \sin\omega_c(t)] \cos\omega_c t$

$= m_1(t)\cos^2\omega_c t + \dfrac{m_2(t)}{2}\sin 2\omega_c t$

Output LPF is $\dfrac{m_1(t)}{2}$

Similarly, output of 2nd LPF is $\dfrac{m_2(t)}{2}$

02. (b) The engine, body, and tires of a racing vehicle affect the acceleration and speed attainable. The speed control of the car is represented by the model as shown in the following figure.



(i) Calculate the steady state error of the car to a step command in speed. (5 M)

(ii) Calculate the overshoot of the speed to a step command. (15 M)

Sol: $G(s) = \dfrac{100}{(s+2)(s+5)}$, $H(s) = 1$

(i) Steady state error:

$$K_p = \underset{s\to 0}{\mathrm{Lt}}\, G(s) = \underset{s\to 0}{\mathrm{Lt}} \frac{100}{(s+2)(s+5)} = \frac{100}{10} = 10$$

$$e_{ss} = \frac{A}{1+K_p} = \frac{1}{1+10} = \frac{1}{11} \Rightarrow e_{ss} = 0.0909$$

(ii) Overshoot:

$$\text{CLTF} = \frac{100}{(s+2)(s+5)+100}$$

$$= \frac{100}{s^2+7s+110}$$

$$= \frac{100}{110}\left[\frac{110}{s^2+7s+110}\right]$$

$$= \frac{10}{11}\left[\frac{110}{s^2+7s+110}\right]$$

$\omega_n = 10.48$ rad/sec

$$2\xi\omega_n = 7 \Rightarrow \xi = \frac{7}{2\times 10.48} = 0.334$$

$$M_p = (AK).e^{-\pi\xi/\sqrt{1-\xi^2}} = \left(\frac{10}{11}\right).e^{-\pi\times 0.334/\sqrt{1-(0.334)^2}}$$

$M_p = 0.2986$

Peak over shoot in percentage

$\% M_p = 0.334\times 100 = 33.4\%$

02. (c) A digital computer has memory capacity of 32767 words with 48 bits per word. The instruction code format consists of 8 bits for the operation part and 16 bits for the address part. Two instructions are packed in one memory word and 48 bit instruction register IR is available in the control unit. Formulate the procedure for fetching and executing the instructions for this computer. (20 M)

Sol: Memory = 32767 × 48-bits

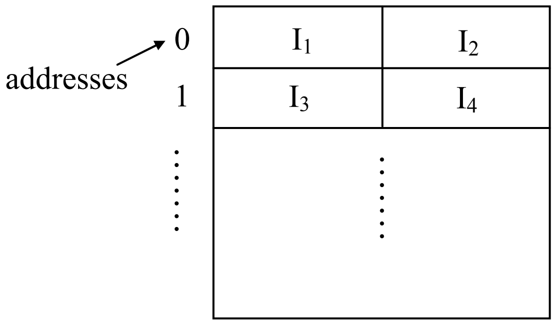
Instruction

opcode	address
8	16

Instruction size = 8+16 = 24-bits

Assume following storage of instructions in memory

Memory



I_1, I_2, -----are instructions

In memory at each address 2-instructions are stored.

Hence in one instruction fetch cycle, 2 instructions are fetched and then these 2-instructions are executed one after another.

So note that for second instruction, there will not be any instruction fetch cycle. The scenario will be good if there is no any branching. But if assume after fetching 2 instructions, first instruction is a branch instruction then one register or any other mechanism is required to keep the other instruction within the CPU; in case of return from branching (function call or interrupt service).

For execution of instructions, hardware is needed to extract one instruction from 48-bit IR and to only execute one instruction.

03. (a) A digital communication system uses five symbols {S_0, S_1, S_2, S_3, S_4} with their following probabilities of occurrence

S_0	S_1	S_2	S_3
0.55	0.20	0.10	0.10

(i) Compute Huffman code for these symbols by moving the combined symbol as low as possible. (15 M)

(ii) Calculate the average code word length. (5 M)

Sol:

(i) $S_0 = 0.55$

$S_1 = 0.20$

$S_2 = 0.10$

$S_3 = 0.10$

$S_4 = 1 - [0.55 + 0.2 + 0.1 + 0.1] = 1 - 0.95 = 0.05$

$S_0 = 0.55$	$S_0 = 0.55$	$S_0 = 0.55$	$S_0 = 0.55$ (0)
$S_1 = 0.2$	$S_1 = 0.20$	$S_2S_3S_4 = 0.25$ (0)	$S_1S_2S_3 = 0.45$ (1)
$S_2 = 0.1$	$S_3S_4 = 0.15$ (0)	$S_1 = 0.2$ (1)	
$S_3 = 0.1$ (0)	$S_2 = 0.1$ (1)		
$S_4 = 0.05$ (1)			

S_0 0

S_1 11

S_2 101

S_3 1000

S_4 1001

(ii) $H(X) = -[0.55 \log_2 0.55 + 0.2 \log_2 0.2 + 0.1 \log_2 0.1 + 0.1 \log_2 0.1 + 0.05 \log_2 0.05]$

$= 0.4743 + 0.46438 + 0.33219 + 0.33219 + 0.21609$

$= 1.8191$

$\overline{L} = 0.55\times1 + 0.2\times2 + 0.1\times3 + 0.1\times4 + 0.05\times4 = 1.85$

$$\eta = \frac{H(x)}{\overline{L}} = \frac{1.8191}{1.85} = 98.32\%$$

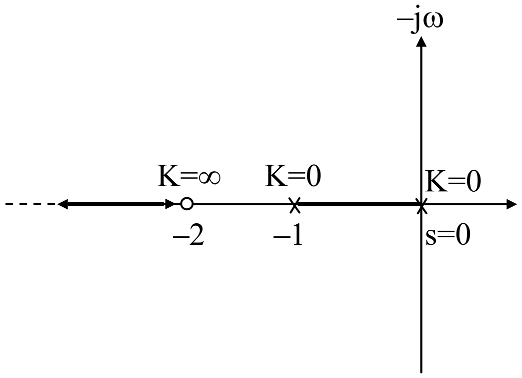
03. (b) A unity feedback control system has $KG(s)=\dfrac{K(s+2)}{s(s+1)}$

(i) Find the breakaway and entry points on the real axis. (10 M)

(ii) Find the gain and the roots when the real part of the complex roots are located at –2. (10 M)

Sol:

(i) $KG(s)=\dfrac{K(s+2)}{s(s+1)}$



Break points: $\xrightarrow{CE} 1+KG(s)=0$

$$\xrightarrow{CE} 1+\frac{K(s+2)}{s(s+1)}=0$$

$$\xrightarrow{CE} s^2+s+K(s+2)=0$$

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

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

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

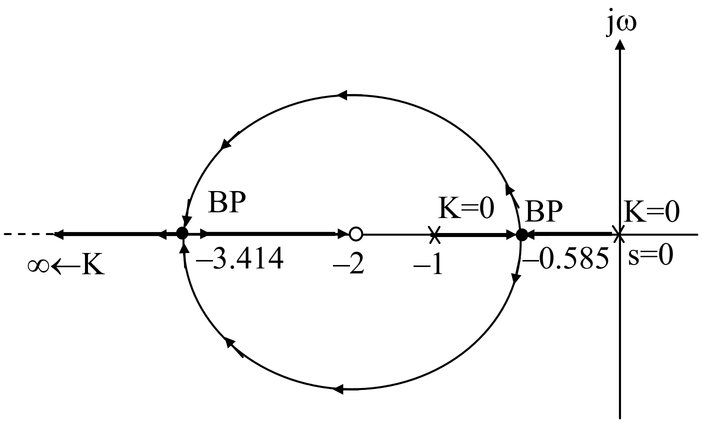
$\Rightarrow 2s^2+4s+s+2-s^2-s=0$

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

$\Rightarrow s_1, s_2=-0.585, -3.414$

Break away and entry points $\Rightarrow -0.585, -3.414$

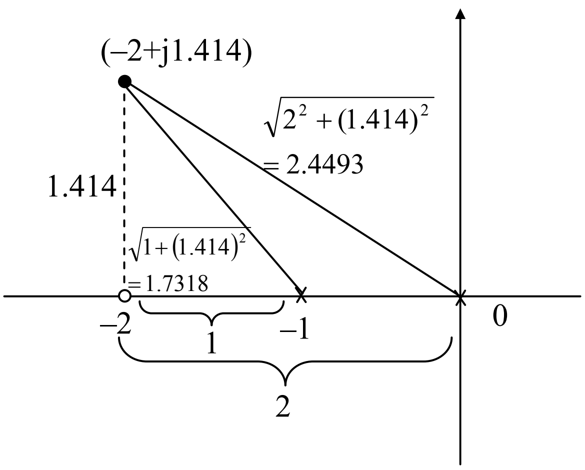
(ii)



$\Rightarrow$ Root locus diagram is circle with radius 1.414 and centre (–2, 0).

<u>K at real part of complex roots at s = –2</u>

Complex poles location is $s = -2 + j1.414$



$$K = \frac{\text{Product of lengths from point to poles}}{\text{Product of lengths from point to zeros}}$$

$$K = \frac{2.4493 \times 1.7318}{1.414} = 2.999 \approx 3$$

03. (c) What is virtual memory? How it is different from main memory? Suppose CPU generates 32 bit virtual addresses and the page size is 16 KB. The processor has a translation look-aside buffer (TLB) which can hold a total of 512 page table entries and is 4-way associative. Calculate the size of TLB tag. (20 M)

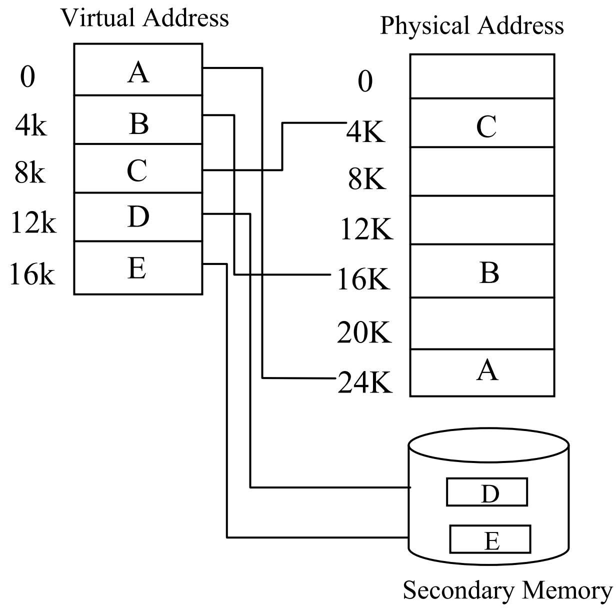
Sol: A computer can address more memory than the amount physically installed on the system. This extra memory is actually called **virtual memory** and it is a section of a hard disk that's set up to emulate the computer's RAM.

The main visible advantage of this scheme is that programs can be larger than physical memory. Virtual memory serves two purposes. First, it allows us to extend the use of physical memory by using disk. Second, it allows us to have memory protection, because each virtual address is translated to a physical address.

Following are the situations, when entire program is not required to be loaded fully in main memory.

- User written error handling routines are used only when an error occurred in the data or computation.
- Certain options and features of a program may be used rarely.
- Many tables are assigned a fixed amount of address space even though only a small amount of the table is actually used.
- The ability to execute a program that is only partially in memory would counter many benefits.
- Less number of I/O would be needed to load or swap each user program into memory.
- A program would no longer be constrained by the amount of physical memory that is available.
- Each user program could take less physical memory, more programs could be run at the same time, with a corresponding increase in CPU utilization and throughput.

Modern microprocessors intended for general-purpose use, a memory management unit, or MMU, is built into the hardware. The MMU's job is to translate virtual addresses into physical addresses. A basic example is given below



Virtual memory is commonly implemented by demand paging. It can also be implemented in a segmentation system. Demand segmentation can also be used to provide virtual memory.

Virtual memory:

Virtual address = 32-bits

Page size = 16KB = 2^{14} B $\Rightarrow$ page offset = 14-bits

TLB entries = 512 = 2^9

TLB sets $= \frac{2^9}{4} = 2^7$

Virtual address

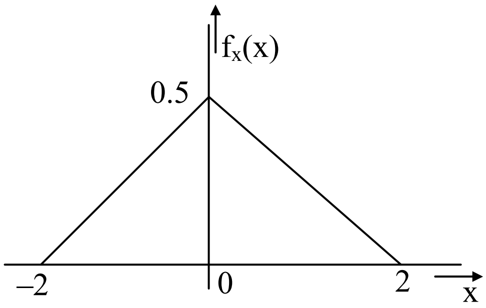
$\longleftarrow$ 32 $\longrightarrow$

Tag	TLB set number	page offset
	7	14

Tag = 32 – (7 + 14) = 11-bits

Sol:

(i) The pdf of the random process is



BW = 5kHz, n = 5

Nyquist rate = 10,000 samples/sec

Sampling rate = 10,000 samples/sec

Step size = $\Delta = \frac{2-(-2)}{2^5} = \left(\frac{4}{32}\right) = \frac{1}{8}\text{V} = 0.125\text{V}$

Noise power = $\frac{\Delta^2}{12} = \frac{(0.125)^2}{12} = \frac{16}{2^{10}\times 12}$

Signal power = mean square value = $\int x^2 f(x)dx = \int_{-2}^{2} x^2 f(x)dx$

$= 2\int_0^2 x^2[-0.25x + 0.5] = \frac{2}{3}\text{Watts}$

SNR = $\frac{2}{3}\times\frac{2^{10}\times 12}{16} = 2^9 = 27.09\,\text{dB}$

(ii) Bit rate = Sampling rate × n = 10,000 × 5 = 50 kbps

(iii) For error free transmission

$C_b \geq R_b$

C_b = 64kbps

$64\times10^3 \geq nf_s$

$64\times10^3 \geq n\times10\times10^3$

$n \leq 6.4$

$\Rightarrow$ n = 6bits

So, n value increased by 1 bit, hence improvement in signal to Noise ratio is 6dB.

04. (b) A simple unity feedback control system has a process transfer function $G(s)=\frac{K}{s}$.

The system input is a step function with an amplitude A. The initial condition of the system at time t_0 is $y(t_0) = Q$, where y(t) is the output of the system. The performance index of the system is defined as $I=\int_0^\infty e^2(t)dt$ where e(t) is the error in the system response. Show that performance index I is given as $\frac{(A-Q)^2}{2K}$ where K is gain. **(20 M)**

Sol: $e(t) = r(t) - y(t)$

At $t = t_0 \Rightarrow e(t_0) = r(t_0) - y(t_0)$

$$= 0 - Q$$

$$e(t_0) = -Q \Rightarrow e(0) = -Q$$

$$E(s)=\frac{R(s)}{1+G(s)} \Rightarrow E(s)=\frac{A/s}{1+K/s}$$

$$E(s)=\frac{A}{S+K}$$

$$sE(s) + KE(s) = A$$

$$\frac{de(t)}{dt}+KE(s)=A$$

$$sE(s) - E(0) + KE(s) = A$$

$$sE(s) + KE(s) = A + E(0)$$

$$E(s)\,[s+K] = A + E(0)$$

$$E(s)=\frac{A+E(0)}{s+K}$$

ILT

$$e(t) = (A + e(0))e^{-kt}$$

$$e(t) = (A - Q)e^{-kt}$$

$$I=\int_0^\infty e^2(t)dt=\int_0^\infty (A-Q)^2 e^{-2kt}dt = (A-Q)^2\left[\frac{e^{-2kt}}{-2k}\right]_0^\infty = \frac{(A-Q)^2}{-2k}\left[e^{-\infty}-e^{-0}\right]$$

$$I=\frac{(A-Q)^2}{2K}$$

04. (c) What are the advantages and disadvantages of recursion? Write a code/pseudocode (in any standard programming language) with proper statements to accept a string as a command line argument and hence find its length. (20 M)

Sol: Recursion in C

When a function calls itself from its body is called Recursion.

Advantages

- Reduce unnecessary calling of function.
- Through Recursion one can solve problems in easy way while its iterative solution is very big and complex.

Disadvantages

- Recursive solution is always logical and it is very difficult to trace.(debug and understand).
- In recursive we must have an if statement somewhere to force the function to return without the recursive call being executed, otherwise the function will never return.
- Recursion takes a lot of stack space, usually not considerable when the program is small and running on a PC.
- Recursion uses more processor time.

C program to find length of a string using recursion

```
#include <stdio.h>
int string_length(char*);
int main()
{
  char s[100];
  gets(s);
  printf("Length = %d\n", string_length(s));
  return 0;
}
int string_length(char *s)
{
```

```
static int c = 0;
    while (s[c] != '\0')
{
        c++;
        string_length(s+1);
}
return c;
}
```

SECTION-B

05. (a) In a system if data is transmitted to remote location using 8 bit PCM encoding, find

(i) Channel capacity if Bandwidth is 300kHz and SNR = 15 dB. (4 M)

(ii) The maximum number of channels that can be accommodated in this scheme if Time Division Multiplexing is used with each channel having 5 kHz fixed bandwidth allocation. (6 M)

Sol:

(i) $n = 8,\ B = 300\text{kHz},\ SNR = 15\text{dB} = 10^{1.5}$

Channel capacity $C = B\log_2\left[1+\frac{S}{N}\right] = 300\times10^3\log_2[1+10^{1.5}] = 1508.34$ kbps $= 1.508$ Mbps

(ii) Bandwidth of the Channel = 300 kHz

Bandwidth of each signal = 5 kHz

Number of channels $= \dfrac{300\times10^3}{5\times10^3} = 60$ channels

05. (b) A system is described by the state equations

$$\dot{X} = \begin{bmatrix} 3 & 0 \\ -1 & 1 \end{bmatrix} X + \begin{bmatrix} -1 \\ 1 \end{bmatrix} U \text{ and } Y = \begin{bmatrix} 1 & 1 \end{bmatrix} X$$

Determine whether the system is controllable and observable. (10 M)

Sol: $\dot{X} = \begin{bmatrix} 3 & 0 \\ -1 & 1 \end{bmatrix} X + \begin{bmatrix} -1 \\ 1 \end{bmatrix} U$, $[y] = [1 \quad 1]\, X$

Controllability: $Q_c = [B \quad AB]$

$$Q_c = \begin{bmatrix} -1 & -3 \\ 1 & 2 \end{bmatrix} \Rightarrow |Q_c| = -2 + 3 = 1 \neq 0 \text{ controllable.}$$

Observability: $Q_0 = [C^T \quad A^T C^T]$

$$[C^T] = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

$$[A^T] = \begin{bmatrix} 3 & -1 \\ 0 & 1 \end{bmatrix}$$

$$A^T C^T = \begin{bmatrix} 3 & -1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ 1 \end{bmatrix}$$

$$Q_0 = \begin{bmatrix} 1 & 2 \\ 1 & 1 \end{bmatrix} \Rightarrow |Q_0| = 1 - 2 = -1 \neq 0 \text{ Observable.}$$

05. (c) An analog cellular system has a total of 33 MHz of bandwidth and uses two 25kHz simplex channels to provide full duplex voice and control channels. What is the number of channels available per cell for a frequency reuse factor of 4 cells ? If 1 MHz is dedicated to a control channel then how many voice channels will be available for reuse factor of 4 cells. (10 M)

Sol: Given:

Total bandwidth = 33MHz

Channel bandwidth = 25 kHz ×2 simplex channels = 50 kHz/duplex channel

Total available channels = 33000/50 = 660 cannels

A 1MHz spectrum for control channels implies that there are 1000/50 = 20 control channels out of the 660 channels available.

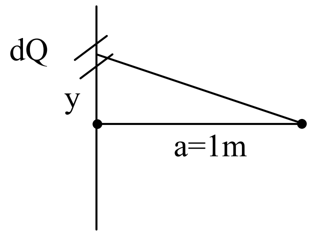
In practice, only the 640 voice channels would be allocated since the control channels are allocated separately as 1per cell.

Here, the 640 voice channels must be equitable distributed to each cell within the cluster.

For N = 4, we can have 5 control channels and 160 voice channels per cell. In practice, however, each cell only needs a single control channels. (The controls have a greater reuse distance than the voice channels). Thus one control channel and 160 voice channels would be assigned to each cell.

05. (d) Find the potential at a point P which is 1m radial distance from the midpoint of a 2m straight line charge of uniform density 10nC/m in air. If this line charge is bent to form an arc of a circle of radius 1m, find the percentage change in potential at the same point P. Give reason for this change. (10 M)

Sol:



$$dV = \frac{KdQ}{\sqrt{a^2+y^2}} = \frac{K\rho_L dy}{\sqrt{a^2+y^2}}$$

$$V = K\rho_L \int \frac{dy}{\sqrt{a^2+y^2}}$$

$$V = K\rho_L \int_{y=-1}^{1} \frac{1}{\sqrt{a^2+y^2}} dy$$

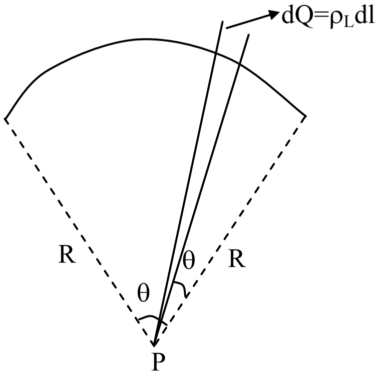
$$V = K\rho_L . \ell n\left[y+\sqrt{y^2+a^2}\right]_{-1}^{1}$$

$$V = K\rho_L \left[\ell n\left[1+\sqrt{2}\right] - \ell n\left(-1+\sqrt{2}\right)\right]$$

$$V = K\rho_L \ell n\left[\frac{\sqrt{2}+1}{\sqrt{2}-1}\right]$$

$$= 9\times10^9\times10\times10^{-9}\ell n\left[\frac{\sqrt{2}+1}{\sqrt{2}-1}\right]$$

V = 158.64



$$dV = \frac{KdQ}{R} = \frac{K\rho_L R d\theta}{R}$$

$$V = K\rho_L \int_{\theta=0}^{2} d\theta = k\rho_L(2)$$

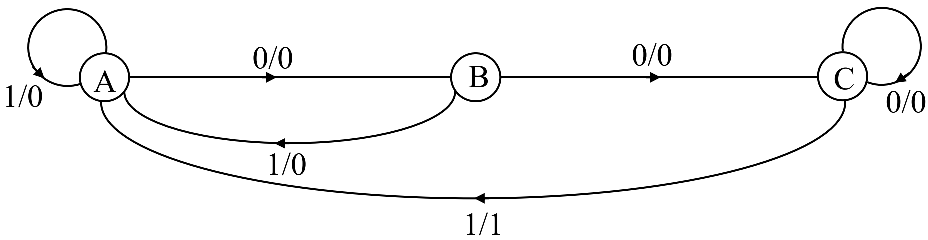
$$V = 9 \times 10^9 \times 10 \times 10^{-9} \times 2$$

$$V = 180$$

$$\% \text{ of change} = \frac{180 - 158.64}{158.64} \times 100 = 13.46\%$$

In case of a arc the distance from the point to at any point on the arc of charge is same

05. (e)



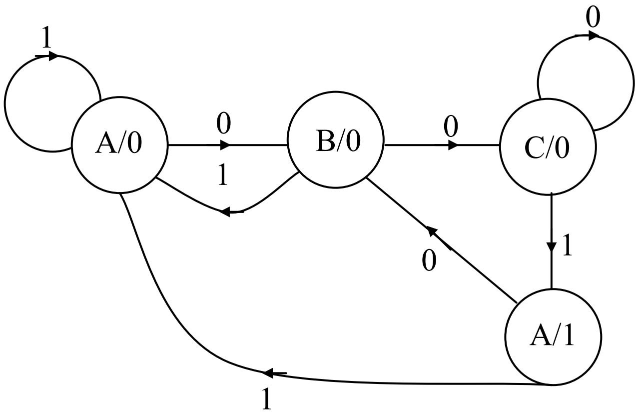
Mealy state diagram

Construct the state diagram for a Moore circuit from the given Mealy circuit. (10 M)

Sol: State Table for given Mealy circuit:

Input (x)	Present state	Next state	output
0	A	B	0
1	A	A	0
0	B	C	0
1	B	A	0
0	C	C	0
1	C	A	1

State Diagram for Moore circuit:



05. (f) A message consists of blocks of 8 bits. A checksum of 8 bits is added after every two blocks. If the first two blocks of a message are:

0011 1010 (↑ MSB) — Block 1

0010 0101 (↑ MSB) — Block 2

(i) Find the checksum bits transmitted. (5 M)

(ii) If the channel error causes bits to reverse at the MSB place of both the blocks, find the recovered bit pattern after checksum. (5 M)

Sol:

(i)

Block 1	-	0 0 1 1 1 0 1 0
Block 2	-	0 0 1 0 0 1 0 1
Block 1 + Block 2	-	0 1 0 1 1 1 1 1

1's complement of above result is checksum - 1 0 1 0 0 0 0 0

(ii) At receiver side, suppose there is no error during transmission then

Block 1 + Block 2 - 0 1 0 1 1 1 1 1

+

Checksum - 1 0 1 0 0 0 0 0

1 1 1 1 1 1 1 1

Compliment of above result is 0 0 0 0 0 0 0 0

Which indicates that there is no error

Now since channel caused error in MSB of both the blocks, the received block would be

Block 1 - 1 0 1 1 1 0 1 0

Block 2 - 1 0 1 0 0 1 0 1

0 1 0 1 1 1 1 1

1

0 1 1 0 0 0 0 0

Checksum - 1 0 1 0 0 0 0 0

0 0 0 0 0 0 0 0

1

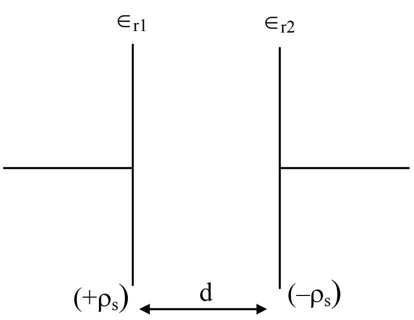
0 0 0 0 0 0 0 1

Compliment above result we have

1 1 1 1 1 1 1 0 is the recovered bit pattern

06. (a) The relative permittivity of a dielectric material between the plates of parallel plate capacitor varies uniformly from $\in r_1 = 1$ at one plate to $\in r_2 = 4$ at other plate. The area of each plate is 1 m^2. Find the capacitance per unit length of this capacitor if d = 3 mm. Derive the equation used. (20 M)

Sol:



$$\in_r = \in_{r1} + \left(\frac{\in_{r2} - \in_{r1}}{d}\right)x$$

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

$$Q = \rho_s A$$

$$V = \int_0^d \overline{E}.\overline{dl}$$

$$V = \int_0^d \frac{\rho_s}{\epsilon_o \epsilon_r} dx$$

$$V = \frac{\rho_s}{\epsilon_o} \int_0^d \frac{1}{\epsilon_{r1} + \left(\frac{\epsilon_{r2} - \epsilon_{r1}}{d}\right)x} dx$$

$$V = \frac{\rho_s}{\epsilon_o} \left. \frac{\ln\left[\epsilon_{r1} + \left(\frac{\epsilon_{r2} - \epsilon_{r1}}{d}\right)x\right]}{\left(\frac{\epsilon_{r2} - \epsilon_{r1}}{d}\right)} \right|_o^d$$

$$V = \frac{\rho_s d}{\epsilon_o \left(\epsilon_{r2} - \epsilon_{r1}\right)} . \ln\left(\frac{\epsilon_{r2}}{\epsilon_{r1}}\right)$$

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

$$C = \frac{\rho_s A}{\frac{\rho_s d}{\epsilon_o \left(\epsilon_{r2} - \epsilon_{r1}\right)} \ln\left(\frac{\epsilon_{r2}}{\epsilon_{r1}}\right)}$$

$$C = \left(\frac{\epsilon_o A}{d}\right) \left[\frac{\epsilon_{r2} - \epsilon_{r1}}{\ln\left(\frac{\epsilon_{r2}}{\epsilon_{r1}}\right)}\right] = \frac{8.854 \times 10^{-12} \times 1}{3 \times 10^{-3}} \left[\frac{4-1}{\ln(4)}\right] = \frac{8.854 \times 10^{-12}}{\ln(4) \times 10^{-3}}$$

$$C = 6.38 \times 10^{-9} \text{ F.}$$

06. (b) (i) Discuss the priority of interrupts of 8086. Draw a circuit that will terminate the INTR when interrupt request has been acknowledged. (15 M)

(ii) Explain Direct Memory Access (DMA) mode of data transfer. (5 M)

Sol:

(i) 01. Hard Interrupts:

Hardware interrupts are those interrupts which are caused by any peripheral device by sending a signal through a specific pin to the microprocessor. There are 2 hardware interrupts in 8086μp.

(i) NMI (Non Maskable Interrupt):

It is a single pin non maskable hardware interrupt which cannot be disabled. It is the highest priority interrupt in 8086μp.

(ii) INTR (Interrupt request):

It provides a single interrupt request and is activated by I/O port. This interrupt can be masked or delayed. It is a level triggered interrupt.

02. Software Interrupts:

These are instructions that are inserted within the program to generate interrupts. There are 256 software interrupts in 8086μp. The address range of interrupt vector table is from 00000H to 003FFH. These are 2 byte instructions. Some of the software interrupts are:

(i) TYPE 0 corresponds to division by zero.

(ii) TYPE 1 is used for single step execution for debugging of program.

(iii) TYPE 2 represents NMI and is used in power failure conditions.

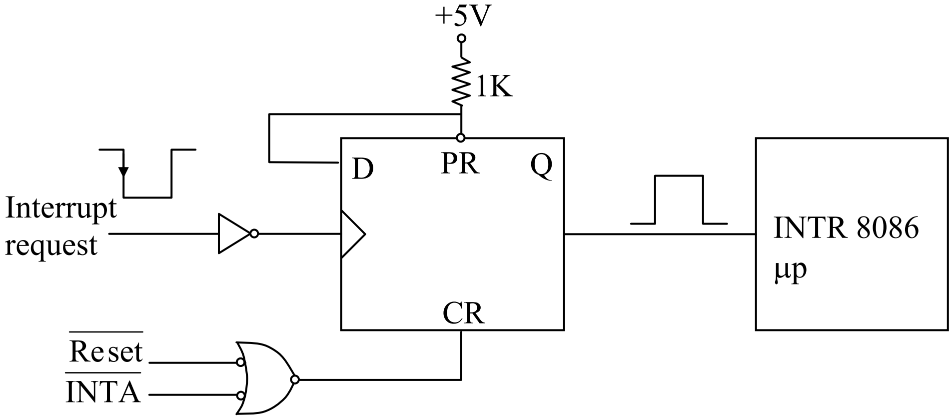
(iv) TYPE 3 represents a break-point interrupt.

(v) TYPE 4 is the overflow interrupt.

⇒ As far as the 8086, Interrupt priority are

Interrupt	Priority
Divide Error, Int n, Into	HIGHEST
NMI	↓
INTR	↓
SINGLE STEP	LOWEST

⇒ Termination of INTR Interrupt when request has been acknowledged:



When Interrupt request comes from external devices the falling edge triggers the D-flipflop making the INTR '1'. Then the $\overline{\text{INTA}}$ pulse from µp, resets the flipflop, making INTR to become 0.

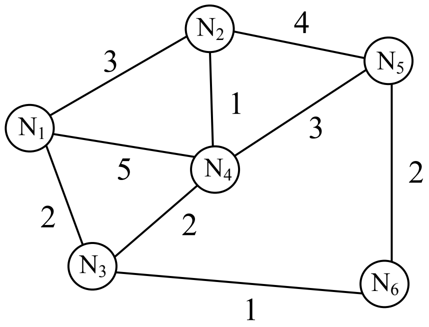
(ii) Direct Memory Access(DMA) is a method that allows an input/output (I/O) device to send or receive data directly to or from the main memory, bypassing the CPU to speed up memory operations. This process is managed by a chip known as a DMA controller. The data transfer between a fast storage media such as magnetic disk and memory unit is limited by the speed of the CPU. Thus we can allow the peripherals directly communicate with each other using the memory buses, removing the intervention of the CPU. During DMA the CPU is idle and it has no control over the memory buses.

06. (c) A network with 6 nodes with associated cost function is given in the Table below. Calculate the routing table using the shortest path Dijkstra's Algorithm assuming Node 1 as the source node. NC represents no connection between the nodes.

Node Number → ↓	1	2	3	4	5	6
1	–	3	2	5	NC	NC
2	3	–	NC	1	4	NC
3	2	NC	–	2	NC	1
4	5	1	2	–	3	NC
5	NC	4	NC	3	–	2
6	NC	NC	1	NC	2	–

(20 M)

Sol:



Source $\longrightarrow N_1$

Node	Distance	Parent	Visit
N_1	0		✓
N_2	$\cancel{\infty}\,3$	N_1	✓
N_3	$\cancel{\infty}\,2$	N_1	✓
N_4	$\cancel{\infty}\ \cancel{5}\ 4$	$\cancel{N_1}\ N_3$	✓
N_5	$\cancel{\infty}\,\cancel{7}\,5$	$\cancel{N_2}\ N_3$	✓
N_6	$\cancel{\infty}\,3$	N_3	✓

N_1 Routing Table

Node	N_1	N_2	N_3	N_4	N_5	N_6
Path	N_1	$N_1 \to N_2$	$N_1 \to N_3$	$N_1 \to N_3 \to N_4$	$N_1 \to N_3 \to N_6 \to N_5$	$N_1 \to N_3 \to N_6$
Distance	0	3	2	4	5	3

07. (a) A lossless line with L = 0.5 μH/m and C = 150 PF/m is operated at a frequency 10 MHz. Find the shortest length of line at which it acts as

(i) 150 PF Capacitor on an open circuit and short circuit

(ii) 2 μH Inductor on an open circuit and short circuit. (20 M)

Sol: $$Z_0 = \sqrt{\frac{L}{C}}$$

$$Z_0 = \sqrt{\frac{5\times10^{-7}}{150\times10^{-12}}}$$

$Z_0 = 57.73\Omega$

$$\nu_P = \frac{1}{\sqrt{LC}} = 1.15\times10^8\,\text{m/sec}$$

$$\lambda = \frac{1.15\times10^8}{10^7} = 11.5\text{m}$$

(i) 150 pF capacitor

Open circuit:

$Z_{oc} = -jZ_o\cot\beta l$

$$\frac{-j}{\omega C} = -jZ_o\cot\beta l$$

$\tan\beta l = \omega CZ_o$.

$\tan\beta l = 2\pi \times 10^7 \times 150 \times 10^{-12} \times 57.73$.

$\tan\beta l = 0.544$

$\beta l = 28.5^o$

$$l = 28.5^o \times \frac{\lambda}{360^o}$$

$l = 0.91$ m

Short circuit:

$Z_{SC} = jZ_o\tan\beta l$

$$jZ_o\tan\beta l = \frac{-j}{\omega C}$$

$$\tan\beta l = \frac{-1}{\omega CZ_o}$$

$\tan\beta l = -1.83$

$\beta l = -61.34^o$

$$l = -61.34^o \times \frac{\lambda}{360^o}$$

$l = -1.96$

so, $l = -1.96 + 5.75$

$l = 3.79$m

(ii) $L = 2\mu H$

Open circuit

$Z_{oc} = -jZ_o\cot\beta l$

$-jZ_o\cot\beta l = j\omega L$

$$-\frac{Z_o}{\omega L} = \tan\beta l$$

$$\tan\beta l = \frac{-57.73}{2\pi\times10^7\times2\times10^{-6}}$$

$\tan\beta l = -0.459$

$\beta l = -24.65^o$

$l = -0.787\text{m}$

so, $l = 4.96\text{m}.$

Short circuit:

$Z_{SC} = jZ_o\tan\beta l$

$jZ_o\tan\beta l = j\omega L$

$$\tan\beta l = \frac{\omega L}{Z_o}$$

$\tan\beta l = 2.17$

$\beta l = 65.25^o$

$l = 2.08\text{m}.$

07. (b) (i) Implement the following Boolean function using PLA:

Sum $(A, B, C_{in}) = \sum m(1, 2, 4, 7)$

Cout$(A, B, C_{in}) = \sum m(3, 5, 6, 7)$ (10 M)

(ii) Explain photolithography process. Also, explain the importance of photoresists. (10 M)

Sol:

(i) K-Map for sum:

A \ BC_{in}	00	01	11	10
0		1		1
1	1		1	

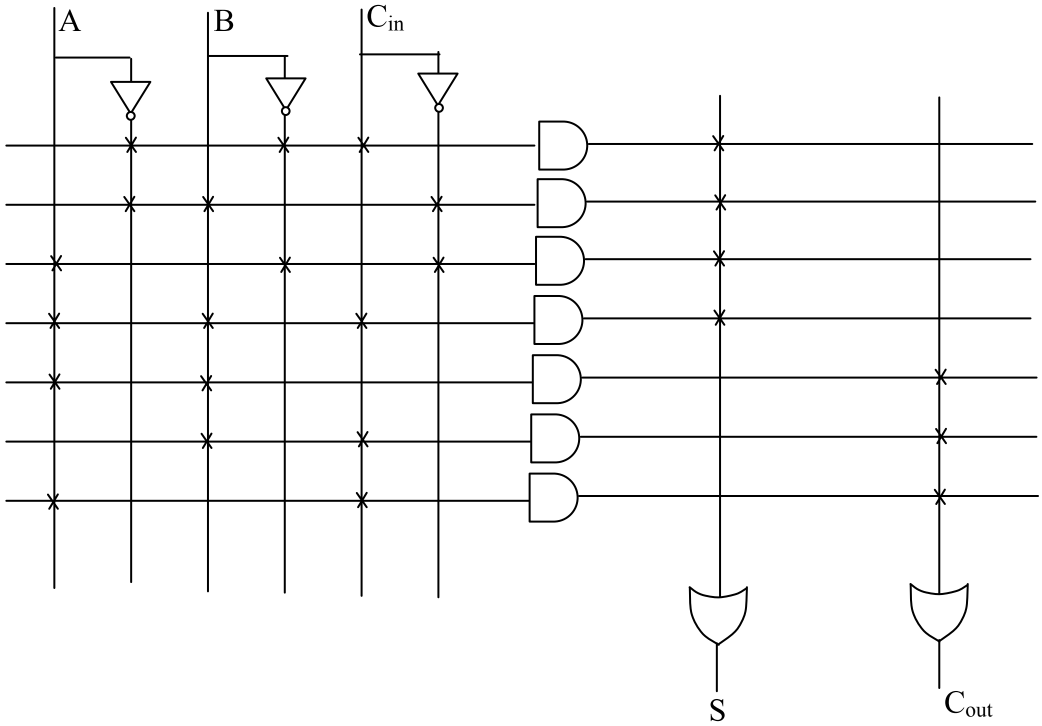
Sum = $\overline{A}\,\overline{B}C_{in} + \overline{A}B\overline{C}_{in} + A\overline{B}\,\overline{C}_{in} + ABC_{in}$

K-Map for C_{out}:

A \ BC_{in}	00	01	11	10
0			1	
1		1	1	1

$C_{out} = AC_{in} + AB + BC_{in}$

Designing using PLA



(ii) PHOTOLITHOGRAPHY:-

Photolithography is the process of transferring patterns of geometric shapes on a mask to a thin layer of photosensitive material (called photoresist) covering the surface of the semiconductor wafer. These patterns define the various regions in an IC, such as the implantation/diffusion regions, the contact windows, and the bonding pad areas. Pattern transfer is accomplished by an Etching process that selectively removes unmasked portions of a layer.

PHOTORESIST:-

Photoresist is a radiation sensitive compound that can be classified as positive or negative, depending on how it responds to radiation.

For positive resists, the exposed regions become more soluble and thus are easily removed in the development process. Prior to exposure, the photoresistive compound is insoluble in the developer solution. After exposure, the photosensitive compound absorbs radiation in the exposed pattern areas, changes its chemical structure and becomes soluble in the developer solution. After development, the exposed areas are removed.

The net result is that the patterns formed (images) in the photoresist are the same as those on the mask.

Negative photoresistive compounds on exposure to light undergo a polymer cross-linking reaction that becomes insoluble in the developer solution. After development the unexposed areas are removed, and the patterns formed in the negative resist are the reverse of the mask pattern.

07. (c) (i) Calculate the degradation in the downlink $\left(\frac{C}{I}\right)$ ratio when orbital spacing between the satellites is reduced from 5° to 2°, all the other factors remaining unchanged. Assume antenna characteristics as per Federal Communications Commission (FCC) norms. (10 M)

(ii) A low noise amplifier is connected to a receiver which has a noise figure of 12 dB. The power gain of the low noise amplifier is 1000 and its noise temperature referred to the low noise amplifier input. (10 M)

Sol:

(i) As per FCC.

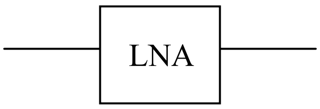
$$\text{C/I degradation} = 25\log\left(\frac{\phi_i}{\phi_f}\right)$$

ϕ_i - Initial separation = 5^0, ϕ_f - Final separation = 2^0

$\phi_i - \phi_f = 5^0 - 2^0 = 3^0$

$$\text{C/I degradation} = 25\log\frac{\phi_i}{\phi_f} = 25\log\frac{5}{2} = 9.94$$

(ii)



Noise Figure = F = 12 dB = $10^{1.2}$

G = 1000

Noise temperature $T_e = (F - 1)\, T_0$

$T_0 = 290^oK$

$T_e = (10^{1.2} - 1)\, 290^oK = 4306.19^oK$

08. (a) The inside dimensions of 9 GHz air filled waveguide are 2.286 cm × 1.016 cm. Find the maximum power that can be transmitted in the TE mode assuming that the breakdown electric field intensity is 3×10^6 V/m. (20 M)

Sol: $$P_{max} = \frac{1}{4}\frac{E_o^2}{\eta_{TE10}}(ab)$$

$$f\big|_{TE10} = \frac{C}{2}\frac{1}{a} = \frac{3\times10^8}{2}\times\frac{1}{2.286\times10^{-2}}$$

$$f|_{TE10} = 6.5\text{GHz}$$

$$\eta_{TE10} = \frac{\eta}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} = \frac{377}{\sqrt{1-\left(\frac{6.5}{9}\right)^2}} = 545\Omega$$

$$P_{max} = \frac{1}{4}\frac{\left(3\times10^6\right)^2}{545}\left(2.286\times1.016\times10^{-4}\right) = 958.86\text{ kW}.$$

08. (b) (i) For given discrete time systems, where y[n] and x[n] are the output and the input sequences, respectively. Determine, whether or not the system is linear, causal, stable and time- invariant.

(A) $y[n] = n^2x[n]$ (B) $y[n] = x[n-5]$ (10 M)

(ii) Develop two different cascade canonic realization of given causal IIR transfer function

$$H(z) = \frac{\left(0.3-0.5z^{-1}\right)\left(2+3.1z^{-1}\right)}{\left(1+2.1z^{-1}-3z^{-2}\right)\left(1+0.67z^{-1}\right)}$$ **(10 M)**

Sol:

(i) (A) $y(n) = n^2x(n)$

$y_1(n) = n^2x_1(n)$

$y_2(n) = n^2x_2(n)$

$y_3(n) = n^2[\alpha x_1(n) + \beta x_2(n)] = \alpha y_1(n) + \beta y_2(n)$

So, linear system.

$\rightarrow$ Present output depends on present input. So, causal system

$\rightarrow$ For a bounded input, gives unbounded output. So, unstable system.

$\rightarrow$ $y_1(n) = n^2x(n-n_0)$

$y(n-n_0) = (n-n_0)^2x(n-n_0)$

$y_1(n) \neq y(n-n_0)$ so, time vairant

(B) $y(n) = x(n-5)$

$\rightarrow$ $y_1(n) = x_1(n-5)$

$y_2(n) = x_2(n-5)$

$y_3(n) = \alpha x_1(n-5) + \beta x_2(n-5) = \alpha y_1(n) + \beta y_2(n)$

so, linear system

→ Present output depends on past inputs. So, it is a causal system.

→ For a bounded input, bounded output produces. So, it is a stable system.

→ $y_1(n) = x(n - 5 - n_o)$

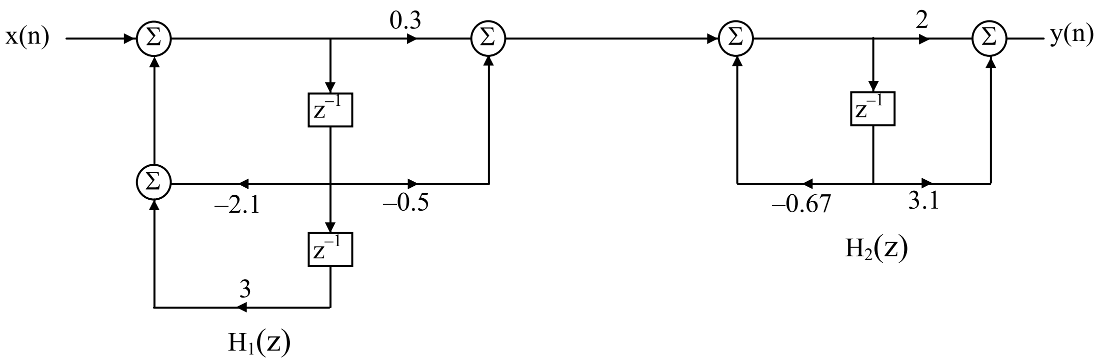
$y(n - n_0) = x(n - n_0 - 5)$

$y_1(n) = y(n - n_o)$

so, Time invariant.

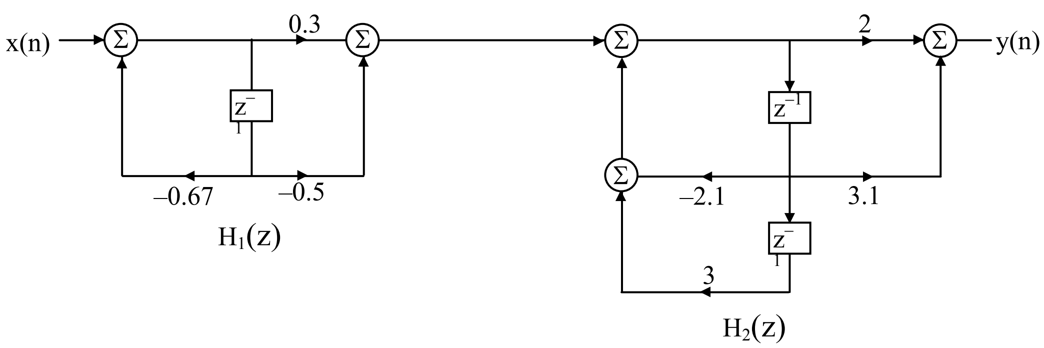
(ii) Technique 1:

$$H_1(z) = \frac{0.3 - 0.5z^{-1}}{1 + 2.1z^{-1} - 3z^{-2}}, H_2(z) = \frac{2 + 3.1z^{-1}}{1 + 0.67z^{-1}}$$



Technique 2:

$$H_1(z) = \frac{0.3 - 0.5z^{-1}}{1 + 0.67z^{-1}}, H_2(z) = \frac{2 + 3.1z^{-1}}{1 + 2.1z^{-1} - 3z^{-2}}$$



08. (c) Describe the mechanism of intermodal dispersion in a multimode step index fiber. Show that the total broadening of a light pulse δT_s due to intermodal dispersion in a multimode step index fiber may be given as:

$$\delta T_s \approx \frac{L(NA)^2}{2n_1 C}$$

Where L is the fiber length, NA is the numerical aperture of the fiber, n_1 is the core refractive index and C is the velocity of light is a vacuum.

(5 + 15 M)

Sol: Multimode Step Index fiber:

Using the ray theory model, the fastest and slowest modes propagating in the step index fiber may be represented by the axial ray and the extreme meridional ray (which is incident at the core-cladding interface at the critical angle ϕ_c) respectively. The paths taken by these two rays in a perfectly structured step index fiber are shown in figure. The delay difference between these two rays when travelling in the fiber core allows estimation of the pulse broadening resulting from intermodal dispersion within the fiber. As both rays are travelling at the same velocity within the constant refractive index fiber core, then the delay difference is directly related to their respective path lengths within the fiber. Hence the time taken for the axial ray to travel along a fiber of length L gives the minimum delay time T_{Min} and:

$$T_{Min} = \frac{\text{distance}}{\text{velocity}} = \frac{L}{(c/n_1)} = \frac{Ln_1}{c} \quad \text{-----} (1)$$

Where n_1 is the refractive index of the core and c is the velocity of light in a vacuum.

The extreme meridional ray exhibits the maximum delay time T_{Max} where:

$$T_{Min} = \frac{L/\cos\theta}{(c/n_1)} = \frac{Ln_1}{c\cos\theta} \quad \text{------} (2)$$

Using Snell's law of refractive at the core-cladding interface following equation

$$\sin\phi_c = \frac{n_2}{n_1} = \cos\theta \quad \text{------} (3)$$

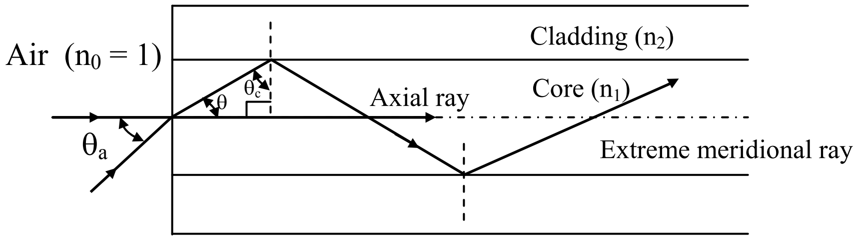


Figure: The paths taken by the axial and an extreme meridional ray in a perfect multimode step index fiber.

Where n_2 is the refractive index of the cladding. Furthermore, substituting into equation for cosθ gives:

$$T_{Max} = \frac{Ln_1^2}{cn_2} \text{ ------ } (4)$$

The delay difference δT_s between the extreme meridional ray and the axial ray may be obtained by subtracting equation (1) from equation (4), Hence:

$$\delta T_s = T_{Max} - T_{Min} = \frac{Ln_1^2}{cn_2} - \frac{Ln_1}{c} = \frac{Ln_1^2}{cn_2}\left(\frac{n_1 - n_2}{n_1}\right) \approx \frac{Ln_1^2\Delta}{cn_2} \quad \text{when } \Delta << 1 \text{ equation (5)}$$

Where Δ is the relative refractive index difference. However, when Δ << 1, then from the definition given by equation, the refractive index difference index difference may also be given approximately by:

$$\Delta \approx \frac{n_1 - n_2}{n_2}$$

Hence rearranging equation we get

$$\delta T_s = \frac{Ln_1}{c}\left(\frac{n_1 - n_2}{n_2}\right) \approx \frac{Ln_1\Delta}{c}$$

Also substituting for Δ from equation gives:

$$\delta T_s \approx \frac{L(NA)^2}{2n_1c}$$

Where NA is the numerical aperture for the fiber.