MADE EASY

India's Best Institute for IES, GATE & PSUs

ESE 2020 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-4: Electronic Devices & Circuits + Advanced Electronics Topics (All Topics)
Analog and Digital Communication Systems-1 (Part Syllabus)
Network Theory-2 + Microprocessors and Microcontroller-2 (Part Syllabus)

Name : ...

Roll No :

Test Centres **Student's Signature**

Delhi ☑ Bhopal ☐ Noida ☐ Jaipur ☐ Indore ☐
Lucknow ☐ Pune ☐ Kolkata ☐ Bhubaneswar ☐ Patna ☐
Hyderabad ☐

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	

Signature of Evaluator Cross Checked by

Corp. office : 44 - A/1,Kalu Sarai, New Delhi-16 | **Ph:** 011-45124612, 9958995830 | **Web:** www.madeeasy.in

Section A : Electronic Devices & Circuits + Advanced Electronics Topics

1 (a) A 1 Watt laser beam of wavelength 6300 Å is incident on the surface of a sample of Si having surface area 1 cm^2 and 0.1 cm thick.

For uniform absorption of light, determine:

(i) The number of electron hole (*e*-*h*) pairs generated per unit time per unit volume.

(ii) Steady state excess minority carrier concentration if excess carrier life time is 100 µsec.

[12 marks]

Q.1(a)

11 Som

Given data

Intensity of incident light $P_o = 1$ watt

$\lambda = 6300$ Å $= 0.63 \mu m$

$A = 1\ cm^2$

$x = 0.1$ cm

$$E = \frac{1.24}{\lambda\,(\text{in}\,\mu m)}\ eV = \frac{1.24}{0.63}\ eV$$

$$\boxed{E = 1.968\ eV}$$

(i) No. of EHP Generated per unit time $= \frac{P}{E_o} = \frac{1}{1.968 \times 1.6 \times 10^{-19}}$

No. of EHP Generated per unit time per unit vol^m $= \frac{P}{(Ax)E_o}$

No. of EHP Generated $= \frac{1}{1 \times 0.1 \times 1.968 \times 1.6 \times 10^{-19}}$

$$\boxed{\text{No. of EHP Generated} = 3.175 \times 10^{19}\ EHP/sec\text{-}cm^3}$$

(ii) Steady state excess minority conc^n = ΔC

(Generation Rate) × excess carrier life time

$\Delta C = 3.175 \times 10^{19} \times 100 \times 10^{-6}$

$$\boxed{\text{Steady state excess minority conc}^n = 3.175 \times 10^{15}/cm^3}$$

Q.1 (b) Consider a silicon sample with conductivity of 0.3 ℧ cm^{-1} at 300 K. Determine shift of fermi level in the sample from intrinsic fermi level for :

(i) n-type sample (ii) p-type sample.

[given $\mu_n = 1100\ cm^2/V\text{-}s$; $\mu_p = 300\ cm^2/V\text{-}s$]

[12 marks]

Sol^n

(i) n type sample

given $\mu_n = 1100\ cm^2/v\text{-}sec$,

let for si $n_i = 1.5 \times 10^{10}/cm^3$

$\sigma_n = 0.3$ ℧ cm^{-1}

$N_D e \mu_n = 0.3$

$$N_D = \frac{0.3}{1.6 \times 10^{-19} \times 1100} = 1.704 \times 10^{15}/cm^3$$

Shif in fermi level wrt E_{Fi} i.e $E_{Fn} - E_{Fi}$

$$E_{Fn} - E_{Fi} = kT \ln \frac{N_D}{n_i}, \quad \text{let at } T = 300K \quad kT \simeq 0.026\ eV$$

$$E_{Fn} - E_{Fi} = 0.026 \ln\left(\frac{1.7045 \times 10^{15}}{1.5 \times 10^{10}}\right)$$

$$\boxed{E_{Fn} - E_{Fi} = 0.302\ eV}$$

(ii) P type sc →

$\sigma_p = 0.3$, $\mu_p = 300$

$N_A e \mu_p = 0.3$

$$N_A = \frac{\cancel{1.704}\ 0.3}{300 \times 1.6 \times 10^{-19}} = 6.25 \times 10^{15}/cm^3$$

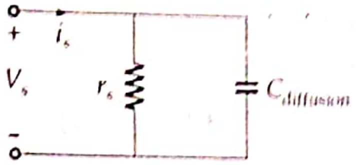
$$E_{Fi} - E_{Fp} = kT \ln \frac{N_A}{n_i} = 0.026 \ln\left(\frac{6.25 \times 10^{15}}{1.5 \times 10^{10}}\right)$$

$$\boxed{E_{Fi} - E_{Fp} = 0.3364\ eV}$$

Do not write in this margin

(c) For a forward bias p^+n silicon diode operating at room temperature, small signal equivalent circuit can be drawn as

Q1(C)



If forward current flowing through diode is 2 mA and hole lifetime in n-region is 10^{-7} second. Then calculate diode impedance at frequency of 100 kHz.

[12 marks]

Sol^n) Small signal High frequency model of diode is Represented.

where, Given data $I_f = 2\text{mA}$, $\tau_p = 10^{-7}\text{sec}$, $f = 100\text{kHz}$

$$r_s = \frac{\eta V_T}{I_f} = \frac{1 \times 0.026}{2 \times 10^{-3}} = 13\,\Omega$$

$\{\text{take } \eta = 1\}$
$V_T = 26\text{mV}$

$$C_{Diffusion} = \frac{\tau_p}{r_s} = \frac{10^{-7}}{13} = 7.6923\text{nF}$$

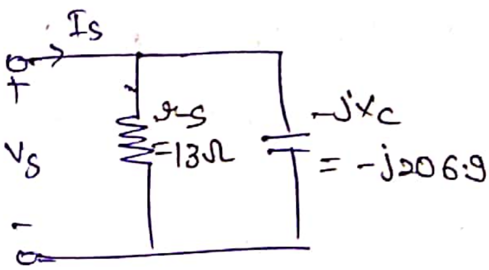
$$X_{c\,diff} = \frac{1}{\omega C} = \frac{1}{2\pi \times 100 \times 10^3 \times 7.6923 \times 10^{-9}}$$

$$X_{c\,diff} = 206.9\,\Omega$$

$$Z = r_s \parallel -jX_c$$

$$Z = 13 \parallel (-j206.90)$$

$$Z = \frac{13 \times (-j206.90)}{13 - j206.90}$$



$$\boxed{\begin{aligned} Z &= 12.948 - 0.813j\ \Omega \\ Z &= 12.974 \angle -3.595\ \Omega \end{aligned}}$$

Ans

Q.1 (d) Explain briefly:
(i) Photo mask (ii) Etching mask
(iii) Oxidation mask (iv) Implantation mask
[12 marks]

Sol^n

(i) Photo mask → used in Photolithography while exposure and alignment step. used to Prevent UV Rays where Pattern is not Required.

(ii) Ethching mask → after Post bake step Ethching is done, Etching is used to create window. we Required windown ~~cint~~ desired desired location. so Etthing mask Prevent Etching outside desired Pattern.
Etching is done with HF acid

(iii) oxidation mask ⇒ used in Locos (Local oxidation of silicon) where a thin pad Oxide is grown.

(iv) Implantation mask → used in Ion Implantation. In Ion Impltation using external Energy source SiO_2 is grown over Si wafer.

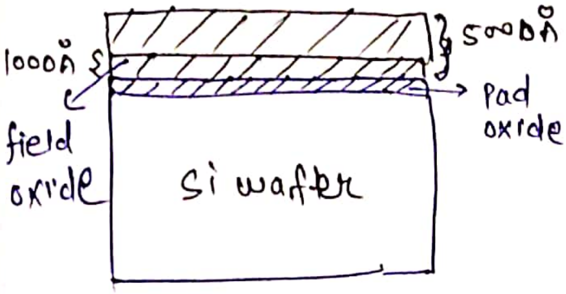
(e) In a local oxidation process (LOCOS), the whole Si wafer is first oxidized to a 1000 Å pad oxide thickness. The active regions are then masked with Si_3N_4 and wafer is further oxidized (1000°C in stream) until the field oxide reaches the desired 5000 Å thickness.

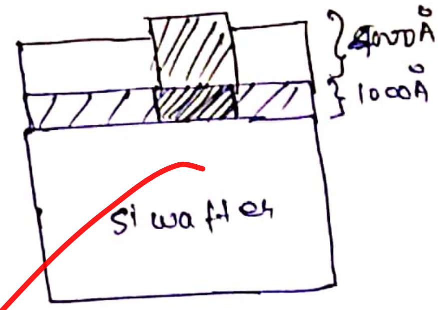
(i) Draw the cross-sectional view showing the pad oxide, field oxide and transition regions.

(ii) Calculate the oxidation time required for the steam oxidation step. For 1000°C, steam oxidation rate constants: $B = 5.2 \times 10^5 \text{Å}^2/\text{minute}$, $\frac{B}{A} = 111$ Å/min.

Q.1(e) **[12 marks]**

Sol^n





$t=0, \quad t_{ox} = 1000\,\text{Å}$

$$\cancel{A}\, t_{ox}^2 + \cancel{A}\, t_{ox} = B(t+\tau)$$

$$t_{ox}^2 + A t_{ox} = \frac{B}{\cancel{A}}(\tau)$$

$$\frac{1}{B} t_{ox}^2 + \frac{A}{B} t_{ox} = \tau$$

$$\frac{1}{5.2\times10^5} \times (1000)^2 + \frac{1000}{111} = \tau$$

$$\boxed{\tau = 10.932\ \text{min}}$$

$t = t \quad t'_{ox} = 5000\,\text{Å}, \quad t_{ox} = 5000 - 1000 = 4000$

$4000\,\text{Å} = t_{ox}$

$$t_{ox}^2 + A t_{ox} = B(t+\tau)$$

$$\frac{1}{B} t_{ox}^2 + \frac{A}{B} t_{ox} = t+\tau$$

$$\frac{(4000)^2}{5.2\times10^5} + \frac{4000}{111} = t+\tau$$

$t + 7 = 66.805$

$t = 66.805 - 10.932$

$\boxed{t = 55.873 \text{ min}}$

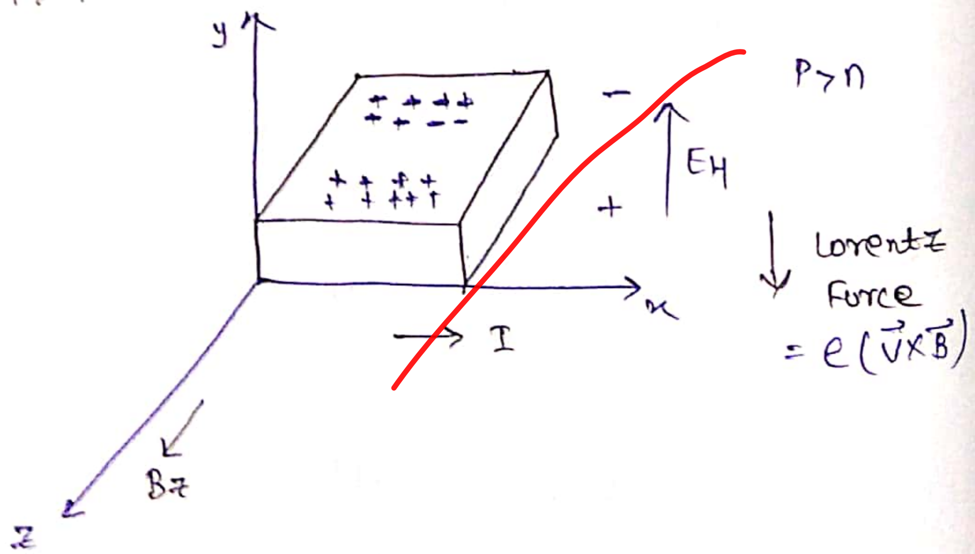
Q.2 (a) (i) Derive Hall coefficient if both electrons and holes are involved in conduction inside a semiconductor. [Assume $p > n$]

(ii) Reduce the derived expression for intrinsic semiconductor

[20 marks]

Sol^n (i) let us assume a SC sample in which conduction is due to both e^- and holes.

$P > n$



when current is flowing in x dir^n and magnetic field is applied across z direction then Lorentz force evB acts on Both hole and e^-

in downward y direction.

since $p > n$ hence lower surface will be +ve as compare to upper surface. { shown is fig. }. as more holes will come downward. hence hole E-field will developes in +ve y direction.

Net Force on hole in y direction ⇒

$$F_{py} = eE_H - eB_z V_{px}$$

$$\frac{eV_{py}}{\mu_p} = eE_H - eB_z V_{px}$$

$$V_{py} = \mu_p [E_H - B_z V_{px}] \quad -(1)$$

Net force on e^- in y direction ⇒

$$F_{ny} = -eE_H - eB_z V_{nx}$$

$$\frac{-eV_{ny}}{\mu_n} = -eE_H - eB_z V_{nx}$$

$$V_{ny} = \mu_n [E_H + B_z V_{nx}] \quad -(2)$$

Net current density in y direction is zero

$$J_{py} + J_{ny} = 0$$

$$p V_{py} + n V_{ny} = 0 \qquad \left[\because J = \rho_v V, \; J_n = enV\right]$$

put V_{py} and V_{ny} from eqn (1) & (2)

$$p\mu_p [E_H - B_z V_{px}] = -n\mu_n [E_H + B_z V_{nx}]$$

$$(p\mu_p + n\mu_n) E_H = B_z [p\mu_p V_{px} - n\mu_n V_{nx}]$$

$$(p\mu_p + n\mu_n) E_H = \frac{B_z E_x}{\cancel{E_x}} [p\mu_p^2 - n\mu_n^2] \quad \because V_{px} = \frac{\mu_p E_x}{\cancel{E_x}}$$

$$(p\mu_p + n\mu_n)E_H = \frac{B_z J_x}{\sigma}\left[p\mu_p^2 - n\mu_n^2\right]$$

$$\frac{E_H}{B_z J_x} = \frac{p\mu_p^2 - n\mu_n^2}{e(p\mu_p + n\mu_n)^2} \qquad \{\sigma = (n\mu_n + p\mu_p)e\}$$

$$\boxed{R_H = \frac{(p\mu_p^2 - n\mu_n^2)}{e(p\mu_p + n\mu_n)^2}}$$

Ans

(ii) for intrinsic sc $n = p = n_i$

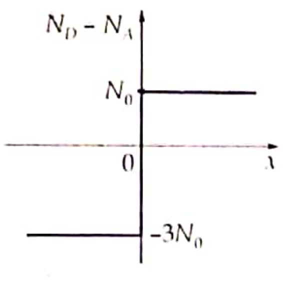
$$R_H = \frac{\mu_p^2 - \mu_n^2}{e n_i(\mu_p + \mu_n)^2} \Rightarrow \boxed{R_H = \frac{\mu_p - \mu_n}{e n_i}}$$

$\mu_n > \mu_p$ hence

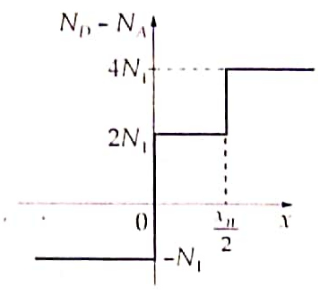
R_H is -ve for intrinsic sc

Q.2 (b) For a pn junction under thermal equilibrium, the width of depletion region on n-side is x_n and the width of depletion region on p-side is x_p. Determine the relation between x_n and x_p for each of the following doping profiles:

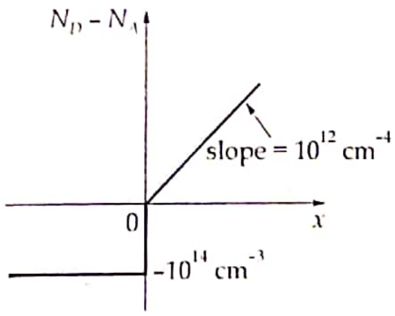
(i)



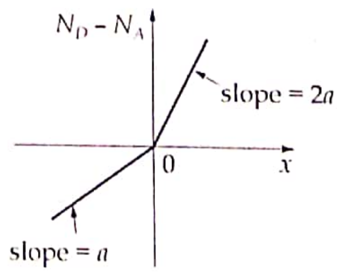
(ii)



(iii)

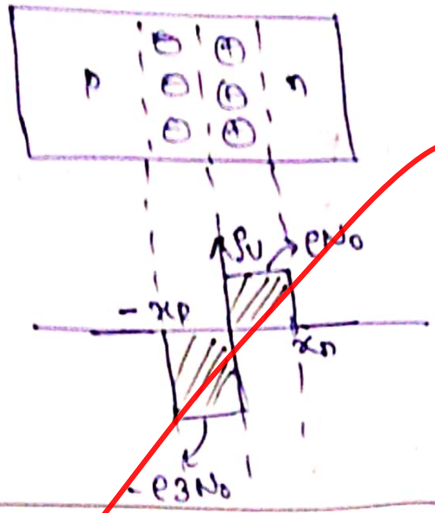


(iv)



[20 marks]

Sol^n (i)



$N_D = n_0$

$N_A = +3n_0$

Charge density plot

$\rho_v = eN_D = eN_0$
$0 < x < x_n$

$\rho_v = -eN_A$
$= -e3N_0$
$-x_p < x < 0$

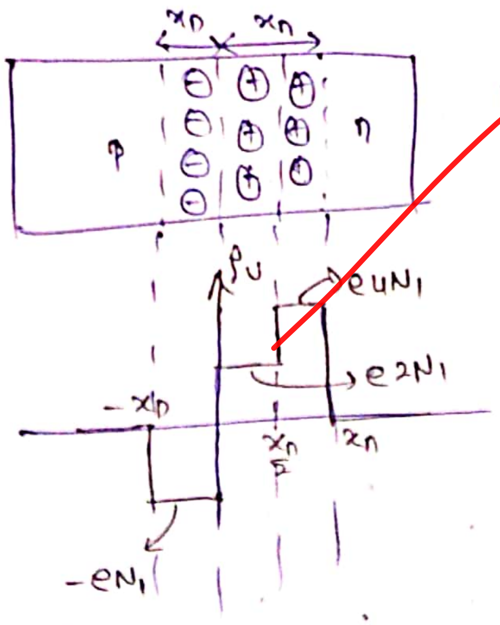
Using charge neutrality eq^n

$-ve$ Area $= +ve$ Area — (1)

$$(e3N_0)\, x_p = eN_0\, x_n$$

$$\boxed{x_n = 3x_p}$$

(ii)



$N_D = 2N_1$
$0 < x < \frac{x_n}{2}$

$N_D = 4N_1$
$x_n < x < \frac{x_n}{2}$

$N_A = N_1$
$-x_p < x < 0$

Using eq(1)

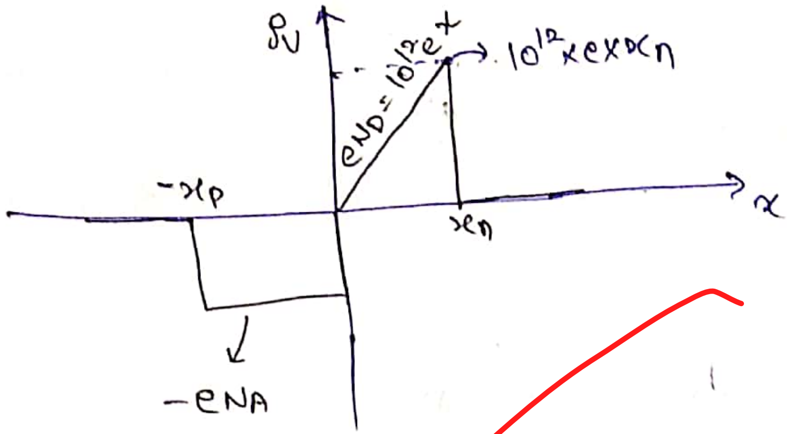
$$(-eN_1)(-x_p) = e2N_1\left(\frac{x_n}{2}\right) + e4N_1\left(\frac{x_n}{2}\right)$$

$$N_1 x_p = N_1 x_n (1+2)$$

$$\boxed{x_p = 3x_n}$$

(3) $N_D = 10^{12} x \quad 0 < x < x_n$

$N_A = 10^{14} \quad -x_p < x < 0$



Using eqⁿ (1)

$$(eN_A)\, x_p = \frac{1}{2} \times x_n \times 10^{12} \times e \times x_n$$

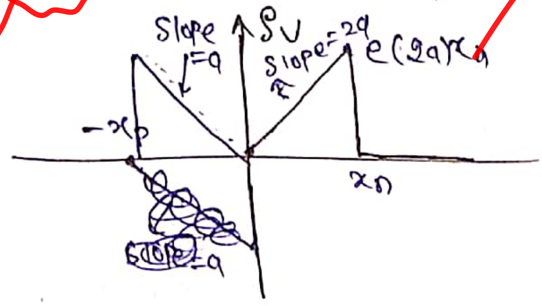
$$10^{14}\, x_p = \frac{1}{2}\, x_n^2 \times 10^{12}$$

$$x_n^2 = 200\, x_p$$

$$\boxed{x_n = 10\sqrt{2\, x_p}}$$

(4) $N_D = (2a)\, x \quad 0 < x < x_n$

$N_A = (a)\, x_0 \quad -x_p < x < 0$



$$x_p\left(\frac{1}{2} \times a \times e\, x_p\right) = \left(\frac{1}{2} \times 2a \times e\, x_n\right) x_n$$

$$x_p^2 = 2 x_n^2$$

$$\boxed{x_p = x_n\sqrt{2}}$$

(c) Implement the following functions using (3 × 6 × 4) programmable logic array (PLA).

Q.2(c)

$$F_1(A, B, C) = \Sigma m(1, 2, 4, 6)$$
$$F_2(A, B, C) = \Sigma m(0, 1, 6, 7)$$
$$F_3(A, B, C) = \Sigma m(2, 6)$$
$$F_4(A, B, C) = \Sigma m(1, 2, 3, 5, 7)$$

[20 marks]

Soln

$F_1(A,B,C) = \Sigma m(1,2,4,6) \Rightarrow \overline{F_1} = \Sigma m(0,3,5,7)$

$F_2(A,B,C) = \Sigma m(0,1,6,7) \Rightarrow \overline{F_2} = \Sigma m(2,3,4,5)$

$F_3(A,B,C) = \Sigma m(2,6) \Rightarrow \overline{F_3} = \Sigma m(0,1,3,4,5,7)$

$F_4(A,B,C) = \Sigma m(1,2,3,5,7) \Rightarrow \overline{F_4} = \Sigma m(0,4,6)$

F_1

A \ BC	00	01	11	10
0		1		1
1	1			1

$F_1 = B\overline{C} + A\overline{C} + \overline{A}\,\overline{B}C$

$\overline{F_1}$

A \ BC	00	01	11	10
0	1		1	
1		1	1	

$\overline{F_1} = \overline{A}\,\overline{B}\,\overline{C} + AC + BC$

F_2

A \ BC	00	01	11	10
0	1	1		
1			1	1

$F_2 = \overline{A}\,\overline{B} + AB$

$\overline{F_2}$

A \ BC	00	01	11	10
0			1	1
1	1	1		

$\overline{F_2} = A\overline{B} + \overline{A}B$

F_3

A \ BC	00	01	11	10
0				1
1				1

$F_3 = B\overline{C}$

$\overline{F_3}$

A \ BC	00	01	11	10
0	1	1	1	
1	1	1	1	

$\overline{F_3} = \overline{B} + C$

F_4

A \ BC	00	01	11	10
0		1	1	1
1		1	1	

$F_4 = B + \overline{A}B$

$\overline{F_4}$

A \ BC	00	01	11	10
0	1			
1	1			1

$\overline{F_4} = \overline{B}\,\overline{C} + A\overline{C}$

$F_1 = B\overline{C} + A\overline{C} + \overline{A}\,\overline{B}C$

$\overline{F_1} = \overline{A}\,\overline{B}\,\overline{C} + AC + BC$

$F_2 = \overline{A}\,\overline{B} + AB$

$\overline{F_2} = A\overline{B} + \overline{A}B$

$F_3 = B\overline{C}$

$\overline{F_3} = \overline{B} + C$

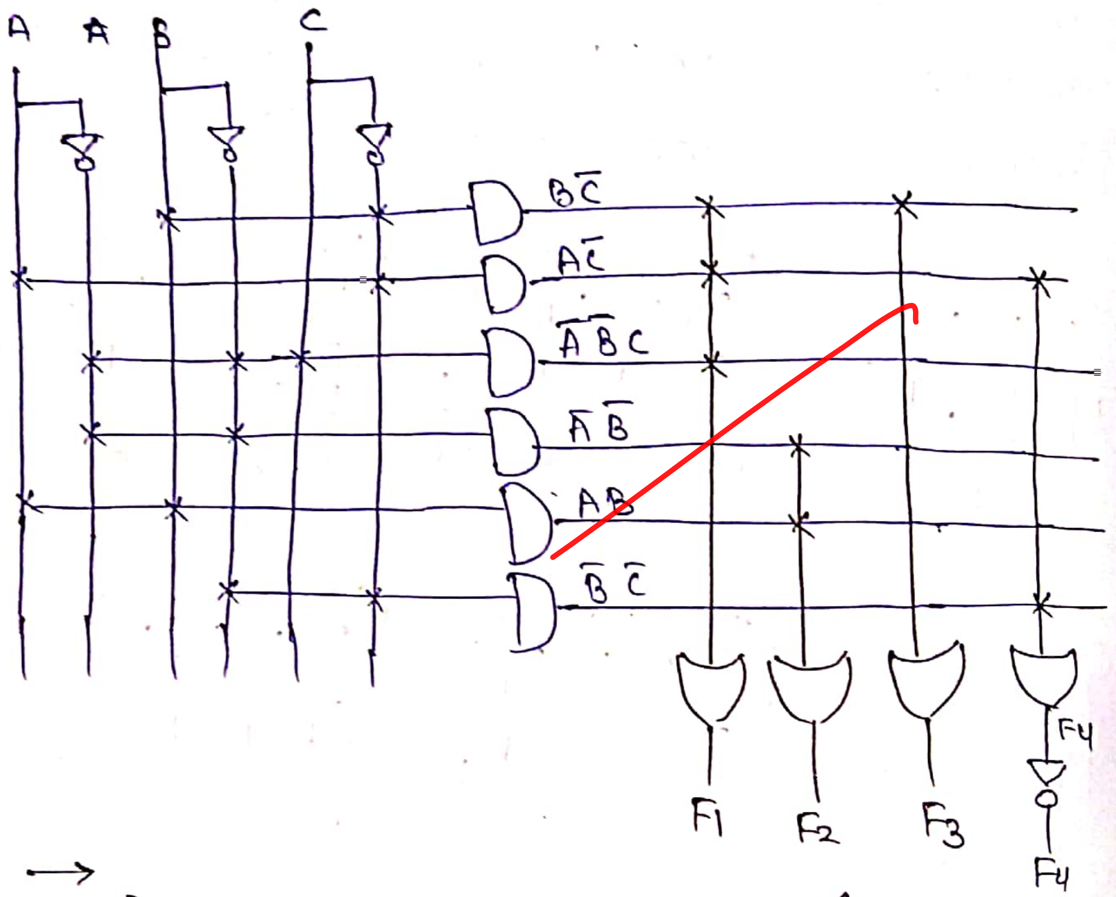
$F_4 = B + \overline{A}B$

$\overline{F_4} = \overline{B}\,\overline{C} + A\overline{C}$

Since given PLA IC has only 6 Product term Hence from these 8 combination 4 combination is selected which has only 6 Product term combined.

$F_1, F_2, F_3, \overline{F_4}$ ⇒ contain 6 product term which are.; $B\bar{C}$, $A\bar{C}$, $\bar{A}\bar{B}C$, $\bar{A}\bar{B}$, AB, $\bar{B}\bar{C}$

Here may be other combination which contain 6 product term but from designing prospective this is simplest.



→ PLA Design of given function ←

$\boxed{\text{PLA } (3 \times 6 \times 4)}$

14

Section B : Analog & Digital Communication Systems-1
Network Theory-2 + Microprocessors and Microcontroller-2

Q.5 (a) Show that at the output of phase discrimination method of SSB modulation, the difference of the signal at the summing junction produces the upper side band of the SSB signal. **[12 marks]**

Q5(a)

Soln as we know Phase discrimination method is a method of SSB Generation.

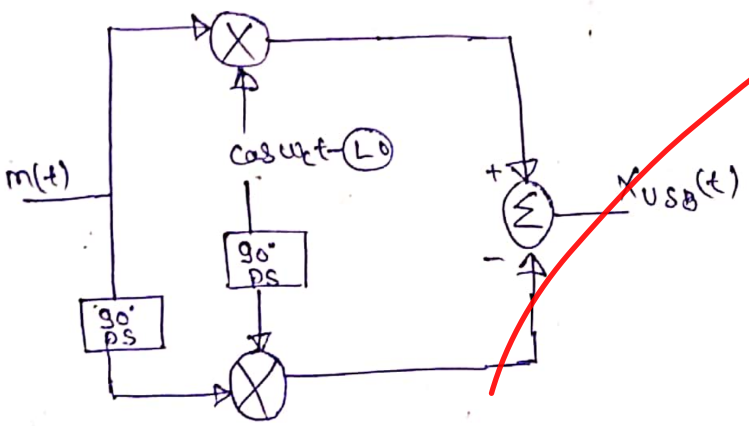
we also know General equation of SSB signal

$$x_{SSB}(t) = m(t)\cos\omega_c t \mp \hat{m}(t)\sin\omega_c t$$

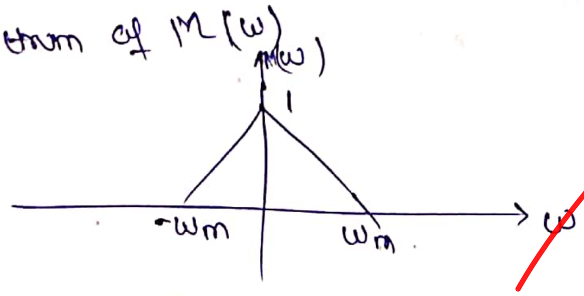
where (-) is used for USB and '+' is used for LSB

$$x_{USB}(t) = m(t)\cos\omega_c t - \hat{m}(t)\sin\omega_c t$$

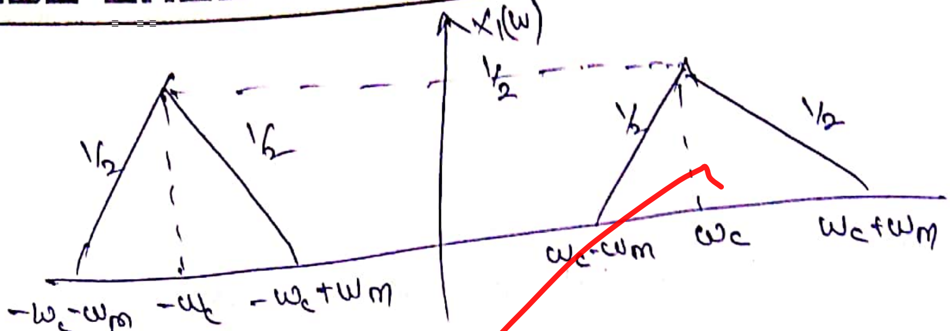
Basic Block diagram



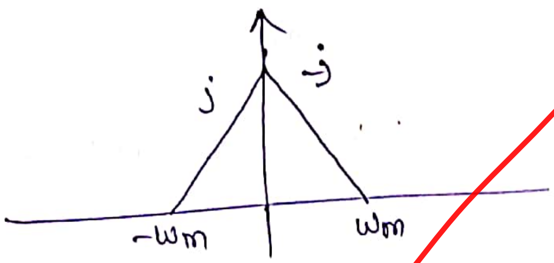
let spectrum of $M(\omega)$



$$m(t)\cos\omega_c t \xleftrightarrow{FT} \frac{M(\omega-\omega_c)+M(\omega+\omega_c)}{2} = X_1(\omega)$$
$$= x_1(t)$$

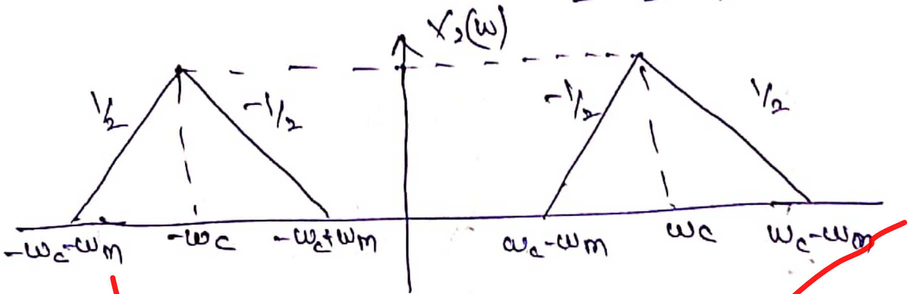


$\hat{m}(t) \xleftrightarrow{FT} -j\,\mathrm{sgn}(\omega)\, M(\omega)$



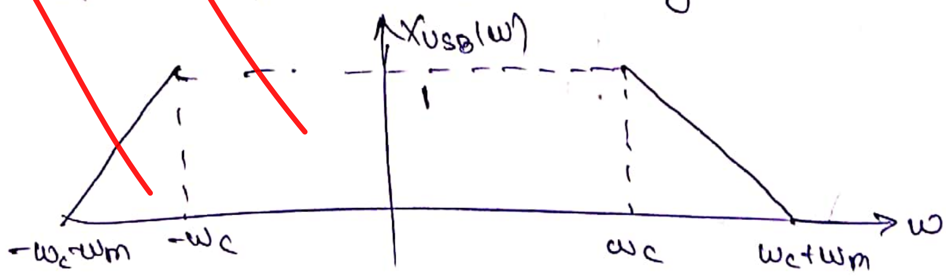
$\hat{m}(t)\sin\omega_c t \leftrightarrow \dfrac{-j\,\mathrm{sgn}(\omega)}{2j}\left[M(\omega-\omega_c) - M(\omega+\omega_c)\right]$

$= x_2(t) = \qquad = X_2(\omega)$



$x_{USB}(t) = x_1(t) + x_2(t)$

$X_{USB}(\omega) = X_1(\omega) + X_2(\omega)$ { adding spectrum ① & ② }



Ans

5(b) A random process $X(t)$ is defined as

Q.5(b) $$X(t) = X\cos(2\pi f_o t) + Y\sin(2\pi f_o t)$$

Where X and Y are two zero mean independent Gaussian random variable each with variance σ^2.

(i) Find $m_X(t)$ (ii) Find $R_X(t+\tau, t)$

[12 marks]

Sol

Give $E(x) = 0$ $\quad Var(x) = E(x^2) = \sigma^2$

$E(y) = 0$ $\quad Var(y) = E(y^2) = \sigma^2$

(i) $M_x(t) = E[x(t)] = E[x\cos 2\pi f_o t + y\sin 2\pi f_o t]$

$M_x(t) = \cos 2\pi f_o t\, E[x] + \sin 2\pi f_o t\, E[y]$

$E[x] = 0, \quad E(y) = 0$

$\boxed{M_x(t) = 0}$ Ans

(ii) $R_x(t+\tau, t) = E[x(t+\tau)x(t)]$

$R_x(t+\tau,t) = E[(x\cos 2\pi f_o(t+\tau) + y\sin 2\pi f_o(t+\tau)) \cdot (x\cos 2\pi f_o t + y\sin 2\pi f_o t)]$

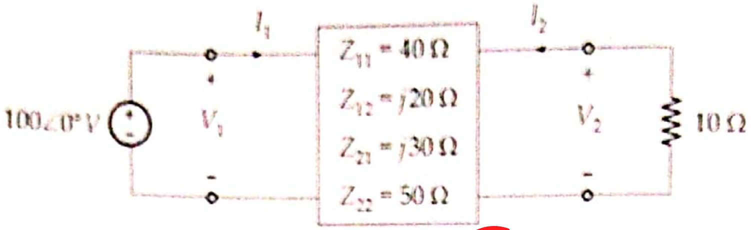
$R_x(\tau) = E[x^2\cos 2\pi f_o(t+\tau)\cos 2\pi f_o t + xy\cos 2\pi f_o(t+\tau)\sin 2\pi f_o t + xy\sin 2\pi f_o(t+\tau)\cos 2\pi f_o t + y^2\sin 2\pi f_o(t+\tau)\sin 2\pi f_o t]$

$R_x(\tau) = \cos 2\pi f_o(t+\tau)\cos 2\pi f_o t\, E[x^2] + \sin 2\pi f_o(t+\tau)\sin 2\pi f_o t\, E[y^2]$ $\quad \because E[xy] = E[x]E[y] = 0$

$R_x(\tau) = \sigma^2\cos(2\pi f_o(t+\tau-t))$

$\boxed{R_x(t+\tau,t) = \sigma^2\cos(2\pi f_o \tau)}$ Ans

Q.5 (c) Find I_1 and I_2 in the circuit shown below:



[12 marks]

Soln

From given 2 Port Parameter Standard equation can be Represented as

$$\cancel{100}V_1 = Z_{11} I_1 + Z_{12} I_2$$

$$V_1 = 40 I_1 + j20 I_2 \quad — (1)$$

$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

$$V_2 = j30 I_1 + 50 I_2 \quad — (2)$$

KVL in I/p loop

i.e. $V_1 = 100 \quad — (3)$

from O/p loop

i.e. $V_2 = -10 I_2 \quad — (4)$

Put eqn (3) in eqn (1)

$$4 I_1 + j2 I_2 = 10 \quad — (5)$$

Put eqn (4) in eqn (2)

$$-2 I_2 = j I_1 \quad — (6)$$

Put I_2 from eqn (6) to eqn (5)

$$4 I_1 + j2\left(\frac{-j}{2}\right) I_1 = 10$$

$$5 I_1 = 10$$

$$\boxed{I_1 = 2 \text{ Amp.}} \quad \text{or} \quad \boxed{I_1 = 2\angle 0° \text{ Amp.}}$$

Ans

Put I_1 in eqn (6)

$$\boxed{I_2 = -j \text{ Amp}} \quad \text{or} \quad \boxed{I_2 = 1\angle -90 \text{ Amp}}$$

Ans

5(d) The fundamental cut-set matrix of a network is given as follows:

Q.5(d)

Twigs			Links		
a	c	e	b	d	f
1	0	0	1	0	1
0	1	0	0	1	1
0	0	1	1	1	1

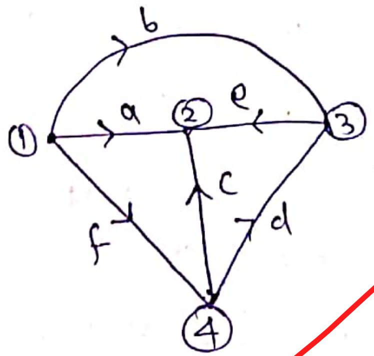
Draw the oriented graph.

[12 marks]

Sol

cutset matrix is twig dependent matrix. hence twig branches a, c, e, = 3

6



graph correspond to possible Tree

Q.5 (e) Describe the program status word register present in the 8051 microcontroller.

[12 marks]

PSW of 8051

└→ | A | Flag |

Flag

Cy	AC	F	RS_1	RS_0	OV	X	P

Cy ⇒ carry (set when there is carry at o/p)

AC ⇒ Auxillary carry (carry from lower Nibble to Higher)

F ⇒ user defined flag

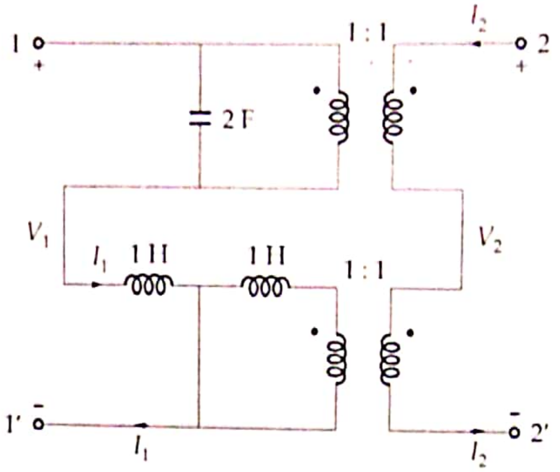
RS_1 RS_0 ⇒ To select Register bank

0 0 → RB_0
0 1 → RB_1
1 0 → RB_2
1 1 → RB_3

OV → Overflow flag (set when resultant bit exceeds)

P → Parity flag (set when there is even parity

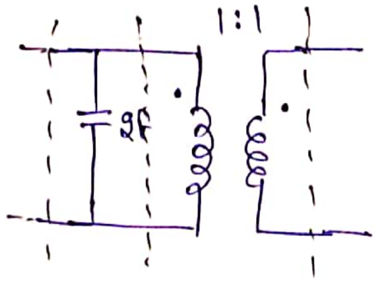
Q.6 (a) For the network shown below, find the Z-parameters. Find whether the network is symmetrical and reciprocal?



[20 marks]

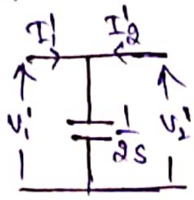
Soln Here 2, 2 Port N-W are connected in series-Series connection hence their Z Parameter will added directly.

① NW-1

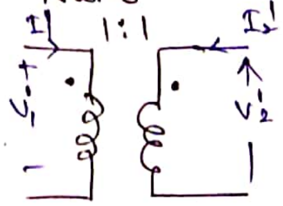


⇒ given NW-1 is also cascade of 2 NW hence their T parameter will be multiplied

a) NW-a



b) NW-b



$V_1' = V_2'$ — ①

$I_1' = \frac{V_2'}{1/2s} - I_2'$

$I_1' = 2s\,V_2' - I_2'$ — ②

$\frac{V_1'}{V_2'} = 1 \Rightarrow V_1' = V_2'$ — ③

$\frac{I_1'}{I_2'} = -1 \Rightarrow I_1' = -I_2'$ — ④

Standard 2 Port T Parameter eqn

$V_1 = AV_2 - BI_2$ — ⑤

$I_1 = CV_2 - DI_2$ — ⑥

from eqn ①, ②, ③, ④ by comparing with ⑤ & ⑥

$T_{1A} = \begin{bmatrix} 1 & 0 \\ 2s & 1 \end{bmatrix}$ $T_{1B} = \begin{bmatrix} 1 & 0 \\ 0 & +1 \end{bmatrix}$

$$T = [T_{1A}][T_{1B}] = \begin{bmatrix} 1 & 0 \\ 2s & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 2s & 1 \end{bmatrix}$$

hence $V_1' = V_2'$

$I_1' = 2s V_2' - I_2'$

as we know standard Z parameter eqn

$$V_1 = Z_{11} I_1 + Z_{12} I_2 \quad - (7)$$

$$V_2 = Z_{21} I_1 + Z_{22} I_2 \quad - (8)$$

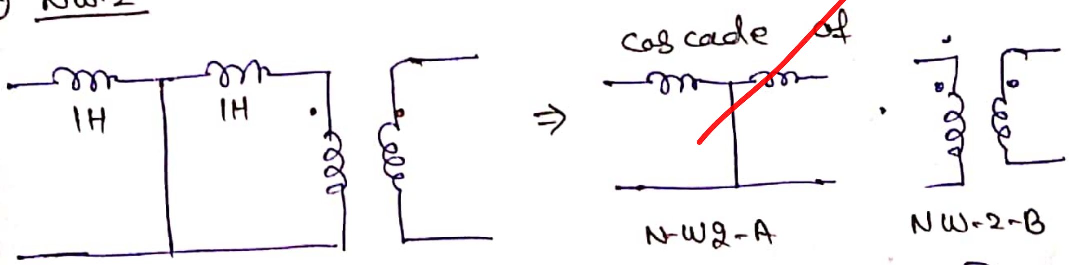
~~for~~ $V_2' = \frac{1}{2s} I_1' + \frac{1}{2s} I_2' \quad - (9)$

$V_1' = \frac{1}{2s} I_1' + \frac{1}{2s} I_2' \quad - (10)$

Comparing eqn (9) & (10) with (7) & (8)

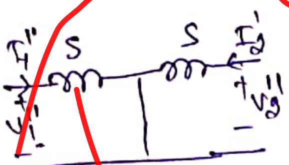
$$\boxed{Z_1 = \begin{bmatrix} \frac{1}{2s} & \frac{1}{2s} \\ \frac{1}{2s} & \frac{1}{2s} \end{bmatrix}} \quad - (I)$$

(2) NW-2



NW-2-B is same as NW-1B Hence $T_{2B} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

NW-2-A



$V_1'' = I_1'' S \quad - (11)$

$V_2'' = I_2' S \quad - (12)$

Here again $T_2 = [T_{2A}][T_{2B}] \rightarrow$ unity matrix

Hence $T_2 = [T_{2A}]$

from eqn (11) & (12) $Z_2 = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} \quad - (II)$

Since in $Z_{ov} \Rightarrow Z_{11} = Z_{12}$ Hence symmetric

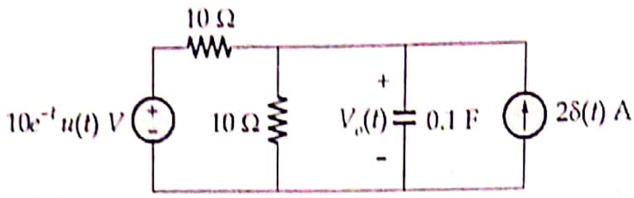
& $Z_{12} = Z_{21} =$ Hence Reciprocal

overall Z parmet.

$Z_{ov} = Z_I + Z_{II}$

$$\boxed{Z_{ov} = \begin{bmatrix} \frac{1}{2s} + s & \frac{1}{2s} \\ \frac{1}{2s} & \frac{1}{2s} + s \end{bmatrix}}$$

Q.6 (b) Find $V_o(t)$ in the circuit figure shown below:

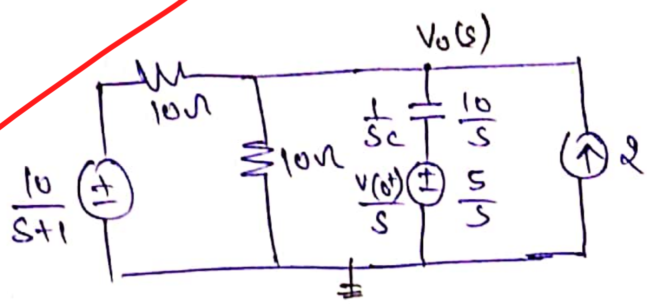


Assume $V_o(0) = 5$ V.

[20 marks]

Sol

drawing circuit in s domain using initial condition



Apply KCL at $V_o(s)$

$$\frac{V_o(s) - \frac{10}{s+1}}{10} + \frac{V_o(s)}{10} + \frac{V_o(s) - \frac{5}{s}}{10/s} = 2$$

$$V_o(s)\left(\frac{1}{10} + \frac{1}{10} + \frac{s}{10}\right) - \frac{1}{s+1} - \frac{1}{2} = 2$$

$$V_o(s)\left(\frac{2+s}{10}\right) = \frac{5}{2} + \frac{1}{s+1}$$

$$V_o(s)\left(\frac{s+2}{10}\right) = \frac{5s+5+2}{2(s+1)}$$

$$V_o(s) = \frac{5(5s+7)}{(s+1)(s+2)}$$

using partial fraction

$$V_o(s) = \frac{A}{s+1} + \frac{B}{s+2}$$

$$A = \frac{5(-5+7)}{(-1+2)} = 10$$

$$B = \frac{5(-10+7)}{(-2+1)} = 15$$

$$V_o(s) = \frac{10}{s+1} + \frac{15}{s+2}$$

taking Inverse Laplace

$$\boxed{V_o(t) = \left(10\,e^{-t} - 15\,e^{-2t}\right)u(t)}$$ Ans

14

Q.6 (c) Discuss briefly the following parameters which are used to describe an AM receiver.
(i) Selectivity (ii) Sensitivity
(iii) Dynamic range (iv) Fidelity
[20 marks]

Sol^n (ii) Sensitivity → Sensitivity of Am Receiver is defined as minimum Strength signal which can be at i/p of Am Receiver for faith full detection.
Sensitivity is ability to amplify weak signal.
Sensitivity is low for low freq. signal and it is High for High freq. signal
for SHRR (i) RF Amp^r (ii) IF Amp^r Gives Sensitivity ~~Info~~ Information

(i) Selectivity →
Selectivity of Am Receiver is defined as ability to Reject or eliminate unwanted signal.
Selectivity is very much Imp^r to avoid distortion in Received signal.
Selectivity for tuned Amp^r is also Relates to Quality factor Higher the Quality factor Higher will be its selectivity

(iii) dynamic Range → dynamic Range of Am Receiver is defined as max^m variation in i/p signal for that faithful detection of signal. beyond max^m variation ~~of~~ Received Signal will be distorted.

(iv) Fidelity →

Ability of An Amplifier to reproduce all frequency component Present at the I/p.

For ~~Poor~~ Good fidelity An Ampr. must produce all freq. component with proper Strength so that It Can be transferred to loud speaker.

Poor fidelity will cause distortion of O/p of an Ampr.

Fidelity is given by Audio Ampr at the O/p stage of SHRR (Super Hetrodyne Radio Receiver)

1G

Q.7 (b) The independent random variables X and Y have variance 36 and 16 respectively. If two new random variables $U = X + Y$ and $V = X - Y$ are defined, then find the value of correlation coefficient (ρ_{UV}) between U and V.

[20 marks]

Sol^n

Given x and y are Independent R.V.

$Var.(X) = 36$ $\quad$ $Var.(Y) = 16$

let $E[X] = 0$ $\quad$ $E[Y] = 0$

$U = X + Y$ $\quad$ $V = X - Y$

$E[U] = E[X+Y]$ $\quad$ $E[V] = E[X-Y]$

$E[U] = 0$ $\quad$ $E[V] = 0$

ρ_{UV} is defined as

$$\boxed{\rho_{UV} = \frac{cov.(u,v)}{(\sigma_U, \sigma_V)}} \quad \text{—(1)}$$

$$cov(u,v) = E[UV] - E[U]\,E[V]$$

$$= E[(X+Y)(X-Y)] - 0$$

$$\mathrm{cov}(u,v) = E[x^2] - E[y^2]$$

$$E(x^2) = 36 \quad , \quad E[y^2] = 16$$

since mean = 0

$$\boxed{\mathrm{cov}(u,v) = 36 - 16 = 20} \quad -(2)$$

$$\sigma_u^2 = E(u^2) - (E(u))^2 = E(u^2)$$

$$\sigma_v^2 = E(v^2) - (E(v))^2 = E(v^2)$$

$$\sigma_u^2 = E(u^2) = E[(x+y)^2] = E[x^2 + y^2 + 2xy]$$

$$\sigma_u^2 = E(x^2) + E(y^2) + \underbrace{2E[xy]}_{=0}$$

$$\sigma_u^2 = 36 + 16 = 52 \Rightarrow \boxed{\sigma_u = \sqrt{52}} \quad -(3)$$

$$\sigma_v^2 = E[v^2] = E[(x-y)^2] = E[x^2 + y^2 - 2xy]$$

$$\sigma_v^2 = E[x^2] + E(y^2) - \underbrace{2E(xy)}_{=0}$$

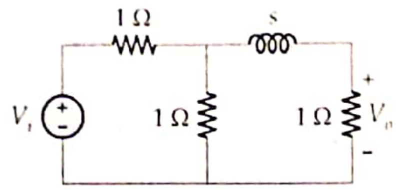
$$\sigma_v^2 = 36 + 16 = 52 \Rightarrow \boxed{\sigma_v = \sqrt{52}} \quad -(4)$$

put 2, 3, 4 in eqn (1)

$$\rho_{u,v} = \frac{20}{\sqrt{52}\sqrt{52}} = \frac{5}{13}$$

$$\boxed{\rho_{uv} = 0.3846}$$

Q.7 (c) For the s-domain circuit in figure shown below:



Find :

(i) The transfer function

(ii) The impulse response

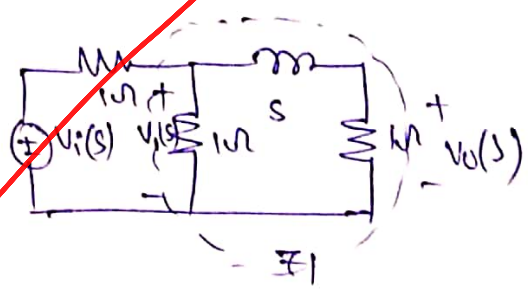
(iii) The response when $V_i(t) = u(t)$ V

[20 marks]

Soln

(i) $Z_1 = (S+1) \parallel 1$

$Z_1 = \dfrac{S+1}{S+2}$



Using voltage divideder

$V_1(s) = \dfrac{V_i(s) \times Z_1}{1 + Z_1}$

$$\frac{V_1(s)}{V_i(s)} = \frac{Z_1}{1+Z_1} = \frac{\frac{S+1}{S+2}}{1+\frac{S+1}{S+2}} = \frac{S+1}{2S+3} \quad -(1)$$

from circuit diagram It is clear that $V_1(s)$ is divided b/w S and 1Ω

$$\frac{V_o(s)}{V_1(s)} = \frac{1}{s+1} \quad -(2)$$

eqn (1) $\otimes$ eqn (2)

$$\frac{V_o(s)}{V_1(s)} \times \frac{V_1(s)}{V_i(s)} = \frac{1}{\cancel{s+1}} \times \frac{s+1}{2s+3}$$

$$\boxed{\frac{V_o(s)}{V_i(s)} = \frac{1}{2s+3}} \text{ Ans}$$

(ii) T.F $\frac{V_o(s)}{V_i(s)} = \frac{1}{2s+3}$

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

taking Inverse Laplace

$$\boxed{h(t) = \frac{1}{2} e^{-\frac{3}{2}} u(t)} \text{ Ans}$$

(iii) if $V_i(t) = u(t)$

$$V_i(s) = \frac{1}{s}$$

Hence

$$V_o(s) = \left(\frac{1}{2s+3}\right)\frac{1}{s}$$

$$V_o(s) = \frac{1}{3}\left(\frac{1}{s} - \frac{2}{2s+3}\right)$$

taking Inverse Laplace

$$\boxed{V_o(t) = \frac{1}{3}\left(1 - e^{-\frac{3t}{2}}\right) u(t)} \text{ Ans}$$

29