



Saket

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## ESE 2024 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

### Electronics & Telecommunication Engineering

Test-4 : Electronic Devices & Circuits + Advanced Communication [All topics]

Analog & Digital Communication Systems-1 [Part Syllabus]

Signals and Systems-2 + Microprocessors and Microcontroller [Part Syllabus]

Name :

Roll No

#### Test Centres

#### Student's Signature

Delhi

Bhopal

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#### Instructions for Candidates

- Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
- There are Eight questions divided in TWO sections.
- Candidate has to attempt FIVE questions in all in English only.
- Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
- Use only black/blue pen.
- 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.
- Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
- There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

#### FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	43
Q.2	27
Q.3	22
Q.4	
Section-B	
Q.5	20
Q.6	
Q.7	
Q.8	33
<b>Total Marks Obtained</b>	<b>145</b>

Signature of Evaluator

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*(Signature)*

- Bush up your concepts
- You can do better

## IMPORTANT INSTRUCTIONS

**CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.**

### DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

### DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.



**Section A : Electronic Devices & Circuits  
+ Advanced Communication Topics**

a) The energy band gap of silicon (Si) depends on the temperature as follows:

$$E_g = 1.17 \text{ eV} - 4.73 \times 10^{-4} \frac{T^2}{T+636}$$

If the intrinsic carrier concentration of Si at  $T = 300 \text{ K}$  is  $1.05 \times 10^{10} \text{ cm}^{-3}$ , what is the intrinsic carrier concentration of Si at temperature  $T = 77 \text{ K}$ ? (Assume at  $300 \text{ K}$ ,  $KT = 0.026 \text{ eV}$ ,  $E_g(300 \text{ K}) = 1.12 \text{ eV}$ )

As we know,  $n_i^2 = A_0 T^3 e^{-E_{g1}/KT}$  [12 marks]

$$E_g \text{ at } (77 \text{ K}) \Rightarrow E_g = 1.17 \text{ eV} - 4.73 \times 10^{-4} \times \frac{(77)^2}{(77+636)}$$

$$E_g = 1.17 \text{ eV} - 39.332 \times 10^{-4}$$

$$E_{g2} = 1.17 - 0.0039332 \text{ eV}$$

$$E_{g2} = 1.1660 \text{ eV} \text{ at } T = 77 \text{ K}$$

Now after comparing  $n_i$  at diff. Temp.

$$\frac{(n_i)_1^2}{(n_i)_2^2} = \frac{(T_1)^3}{(T_2)^3} \frac{e^{-E_{g1}/KT_1}}{e^{-E_{g2}/KT_2}}$$

$$(1.05 \times 10^{10})^2 \times \left(\frac{T_2}{T_1}\right)^3 e^{-E_{g2}/KT_2} \cdot e^{E_{g1}/KT_1} = (n_i)_2^2$$

$$\frac{E_{g1}}{KT_1} = \frac{1.12 \text{ eV}}{0.026 \text{ eV}} = 43.0769 \text{ \& } e^{(E_{g1}/KT_1)} = 5.105 \times 10^{18}$$

$$\frac{E_{g2}}{KT_2} = \frac{1.16 \times 1.6 \times 10^{-19}}{1.38 \times 10^{-23} \times (77)} \Rightarrow \frac{1.16 \times 1.6 \times 10^{-19}}{1.38 \times 10^{-23} \times 77 \times 1.6 \times 10^{-19}}$$

$$\frac{E_{g2}}{KT_2} = \frac{1.16 \times 1.6 \times 10^{-19}}{68.41 \times 10^{-4}} = \frac{1.16 \times 1.6 \times 10^{-19}}{0.0066} = \frac{205.8787879}{1757.5757}$$

$e^{-E_{g2}/KT_2} =$

$$\frac{E_{g2}}{KT_2} = \frac{1.16}{0.0066} = 175.757 \Rightarrow e^{-\frac{E_{g2}}{KT_2}} = 4.67 \times 10^{-77}$$

After all calculation;

$$(n_i)_2^2 \Big|_{at=77K} = 0.44199 \times 10^{-39} \text{ cm}^{-3}$$

$$(n_i)_2 = \sqrt{0.44199 \times 10^{-39}}$$

$$(n_i)_2 \Big|_{at=77K} = 2.1023 \times 10^{-20} \text{ cm}^{-3}$$

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Q.1(b) Consider a silicon one-sided abrupt junction with  $N_A = 2 \times 10^{19} \text{ cm}^{-3}$  and  $N_D = 8 \times 10^{15} \text{ cm}^{-3}$ . Calculate the ratio of junction capacitance,  $\frac{C_j(V_R = 0V)}{C_j(V_R = -4V)}$  at  $T = 300 \text{ K}$ ,

where  $V_R$  is the applied voltage across the junction.

(Assume,  $V_T = 0.0259 \text{ V}$ ,  $\epsilon_s = 11.9 \epsilon_0$ ,  $n_i = 9.65 \times 10^9 \text{ cm}^{-3}$ )

Given:-  $N_A = 2 \times 10^{19} \text{ cm}^{-3}$   $N_D = 8 \times 10^{15} \text{ cm}^{-3}$  [12 marks]

$$C_j = \frac{\epsilon A}{W} \quad \frac{C_j}{A} = \frac{\epsilon}{W} \quad W = \sqrt{\frac{2\epsilon_s}{q} \left( \frac{1}{N_A} + \frac{1}{N_D} \right) (\phi_{bi} + V_R)}$$

$$\phi_{bi} = \frac{kT}{q} \ln \left( \frac{N_A N_D}{n_i^2} \right)$$

$$\phi_{bi} = 0.0259 \ln \left( \frac{2 \times 10^{19} \times 8 \times 10^{15}}{(9.65 \times 10^9)^2} \right)$$

$$\phi_{bi} = 0.0259 \ln \left( \frac{16 \times 10^{34}}{(9.65)^2 \times 10^{18}} \right)$$

$$\phi_{bi} = 0.0259 \ln \left( \frac{16 \times 10^{34}}{93.1225 \times 10^{18}} \right) = 0.0259 \ln \left( \frac{16 \times 10^{16}}{93.1225} \right)$$

$$= 0.0259 \times 35.08$$

$$= 0.9085 \text{ eV}$$

$$\neq C_j \propto \frac{1}{W}$$

$$\frac{(C_j)_1}{(C_j)_2} = \frac{W_2}{W_1}$$



$$\frac{(C_j)_1 |_{V_R=0V}}{(C_j)_2 |_{V_R=-4V}} = \frac{\sqrt{\phi_{bi} + V_{R_2}}}{\sqrt{\phi_{bi} + V_{R_1}}}$$

$$\frac{(C_j)_1 |_{V_R=0V}}{(C_j)_2 |_{V_R=-4V}} = \frac{\sqrt{\phi_{bi} + 4}}{\sqrt{\phi_{bi}}}$$

$$\frac{(C_j)_1 |_{V_R=0}}{(C_j)_2 |_{V_R=-4}} = \sqrt{\frac{0.9085 + 4}{0.9085}}$$

$$= \sqrt{\frac{4.9085}{0.9085}}$$

$$\frac{(C_j)_1 |_{V_R=0}}{(C_j)_2 |_{V_R=-4V}} = \sqrt{5.402}$$

$$= 2.32422 \quad \checkmark$$

(11)

Q.1 (c) Two step index fibers exhibit the following parameters:

- (i) A multimode fiber with a core refractive index of 1.5, a relative refractive index difference of 3% and an operating wavelength of 0.82 μm.
- (ii) An 8 μm core diameter single mode fiber with an core refractive index same as (i), a relative index difference of 0.3% and an operating wavelength of 1.55 μm.

Estimate the critical radius of curvature at which large bending losses occur in both cases.

[8 + 4 marks]

Given  $n_1 = 1.5$     $\Delta = \frac{3}{100} = 0.03$   
 $\lambda_1 = 0.82 \mu m$

$$R_c = \frac{3n_1^2 \lambda}{4\pi (n_1^2 - n_2^2)^{3/2}}$$

critical radius of curvature.

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} = 0.03 \times 2 \times (1.5)^2 = n_1^2 - n_2^2$$

$$n_1^2 - n_2^2 = 0.03 \times 2 \times (1.5)^2 = 0.135$$

$$R_{c1} = \frac{3 \times (1.5)^2 \times 0.82}{4\pi (0.135)^{3/2}}$$

$$R_{c1} = \frac{3 \times 2.25 \times 0.82}{4\pi \times (0.135)^{3/2}}$$

$$R_{c1} = \frac{3 \times 2.25 \times 0.82}{4\pi \times 0.0496} = \frac{5.535}{0.62329}$$

$$R_{c1} = 8.88 \mu m$$

Different formula for single mode

$$R_{c2} = \frac{3n_1^2 \lambda}{4\pi (n_1^2 - n_2^2)^{3/2}}$$

$$\Delta = \frac{0.3}{100} = 0.003 \times 2 \times (1.5)^2$$

$$n_1^2 - n_2^2 = 0.003 \times 2 \times (1.5)^2$$

$$n_1^2 - n_2^2 = 0.0135$$

$$(n_1^2 - n_2^2)^{3/2} = 1.568 \times 10^{-3}$$



$$R_{c2} = \frac{3 \times (1.5)^2 \times 1.55}{4\pi \times 1.566 \times 10^3} = \frac{10.4625}{19.704 \times 10^3}$$

$$\Rightarrow 0.5309 \times 10^3$$

$$R_{c2} = 530.98 \text{ } \mu\text{m}$$

- (d) A base station transmitter has a power output of 10 watts operating at a frequency of 250 MHz. The transmitter is connected by 20 m of an RF coaxial cable, which has a loss of -3 dB/100 m specification, to an antenna that has a gain of 9 dBi. The receiving antenna is 25 km away and has a gain of 4 dBi. There is negligible loss in the receiver feeder line, but the receiver is mismatched; the receiving antenna and feeder cable are designed for a 50  $\Omega$  impedance, but the receiver input has 75  $\Omega$  impedance, resulting into a mismatch loss of about 0.2 dB. Calculate the power delivered to the receiver, assuming free space propagation.

[12 marks]

given:-  $P_t = 10 \text{ watts}$   $f = 250 \text{ MHz}$

$T_x$  is connected by 20m RF cable  
 whose loss  $\frac{-3 \text{ dB}}{100 \text{ m}}$

$$P_t \text{ dB} = 10 \log_{10}(10)$$

$$= 10 \text{ dB}$$

$$100 \text{ m} \rightarrow -3 \text{ dB}$$

$$20 \text{ m} \rightarrow \frac{-3}{100} \times 20 = -\frac{3}{5} \text{ dB}$$

$$= -0.6 \text{ dB loss}$$

$$G_t = 9 \text{ dB}$$

$$d = 25 \text{ km} \quad G_r = 4 \text{ dB}$$

$$\text{Loss due to mismatch} = 0.2 \text{ dB}$$

$$\text{Loss spatial} = \left(\frac{4\pi d}{\lambda}\right)^2 = \left(\frac{4\pi d f}{c}\right)^2$$

$$L = 10 \log_{10} \left(\frac{4\pi d f}{c}\right)^2 \Rightarrow L = 20 \log_{10} \left(\frac{4\pi d f}{c}\right)$$

$$\frac{4\pi d f}{c} = \frac{4 \times \pi \times 25 \times 10^3 \times 250 \times 10^6}{3 \times 10^8}$$

$$= \frac{4 \times \pi \times 25 \times 250 \times 10^9}{3 \times 10^8} = \frac{4 \times \pi \times 25 \times 2500}{3}$$

$$= 261799.3878$$

$$= 108.35 \text{ dB}$$



$$P_r = \frac{P_t G_t G_r}{\left(\frac{4\pi d}{\lambda}\right)^2 \times L_{\text{mismatch}}}$$

$$P_r = P_t (\text{dB}) + G_t (\text{dB}) + G_r (\text{dB}) - L_s - L_{\text{mismatch}} - L_{\text{RF}}$$

$$P_r = 10 + 9 + 4 - 108.35 - 0.6 - 0.2$$

$$P_r = \cancel{10 + 9 + 4} - 86.15 \text{ dB}$$

$$10 \log_{10} \left( \frac{P_r}{1 \text{ W}} \right) = -86.15$$

$$P_r = 2.42 \times 10^{-9} \text{ W}$$

- Q.1 (e) (i) A photoconductor with dimensions  $L = 6 \text{ mm}$ ,  $W = 2 \text{ mm}$  and  $D = 1 \text{ mm}$  is placed under uniform radiation. The absorption of light increases the current by  $2.83 \text{ mA}$ . A voltage of  $10 \text{ V}$  is applied across the device. As the radiation is suddenly cutoff, the current falls, initially at a rate of  $23.6 \text{ A/s}$ . The electron and hole mobilities are  $3600 \text{ cm}^2/\text{V-s}$  and  $1700 \text{ cm}^2/\text{V-s}$  respectively. Find:

- the equilibrium density of electron-hole pairs generated under radiation.
- the minority carrier lifetime.
- the excess density of electrons and holes remaining  $1 \text{ ms}$  after the radiation is cut off.

- (ii) A field transistor has  $N_A = 10^{17} \text{ cm}^{-3}$ ,  $\frac{Q_f}{q} = 10^{11} \text{ cm}^{-2}$  and an  $n^+$  polysilicon local interconnect as the gate electrode. If the requirement for sufficient isolation between device and well is  $V_{th} > 20 \text{ V}$ , calculate the minimum field oxide thickness. (Assume  $\phi_{ms} = -0.98 \text{ V}$ ,  $\epsilon_s = 11.9 \epsilon_0$ ,  $\epsilon_{ox} = 3.9 \epsilon_0$ ,  $n_i = 9.65 \times 10^9 \text{ cm}^{-3}$ ,  $V_T = 26 \text{ mV}$ )

[6 + 6 marks]

(ii) given:-  $N_A = 10^{17}$       $n_i = 9.65 \times 10^9$   
 $V_T = 26 \text{ mV}$       $\epsilon_s = 11.9 \epsilon_0$       $\epsilon_{ox} = 3.9 \epsilon_0$   
 $\phi_{ms} = -0.98$       $\frac{Q_f}{q} = 10^{11} \text{ cm}^{-2}$

$$V_{th} = \phi_{ms} + \frac{Q_{ss}}{C_{ox}} + \frac{|Q_{dep}|}{C_{ox}} + 2\phi_F$$

$$\phi_F = \frac{kT}{q} \ln \left( \frac{N_A}{n_i} \right) = 26 \times 10^{-3} \ln \left( \frac{10^{17}}{9.65 \times 10^9} \right)$$

$$= 0.026 \ln \left( \frac{10^8}{9.65} \right) = 0.419 \text{ eV}$$



$$Q_{dep} = -q N_A x d \Rightarrow x d = \sqrt{\frac{2\epsilon_s}{q} \left(\frac{1}{N_A}\right) (2\phi_F)}$$

$$Q_{dep} = q N_A \sqrt{\frac{2\epsilon_s}{q} \frac{1}{N_A} (\phi_F^2)}$$

$$\Rightarrow \sqrt{q N_A 2\epsilon_s (\phi_s)}$$

$$\phi_s = 2 \times 0.419$$

$$\phi_s = 0.838 \text{ V}$$

$$|Q_{dep}| = \sqrt{1.6 \times 10^{-19} \times 10^{17} \times 2 \times 11.9 \times 8.85 \times 10^{-14} \times 0.838}$$

$$|Q_{dep}| = \sqrt{282.412 \times 10^{-16}}$$

$$|Q_{dep}| = 1.6805 \times 10^{-7} \text{ cm}^{-3}$$

$$V_{Th} = \phi_{ms} - \frac{Q_{ss}}{C_{ox}} + \frac{Q_{dep}}{C_{ox}} + 2\phi_F$$

$$20 = -0.98 - \frac{10^{11} \times 1.6 \times 10^{-19}}{C_{ox}} + \frac{1.6805 \times 10^{-7}}{C_{ox}} + 0.838$$

$$20 + 0.98 - 0.838 = \frac{10^{11}}{C_{ox}}$$

$$20.142 = \frac{10^{11}}{C_{ox}}$$

$$C_{ox} = \frac{10^{11}}{20.142} \quad C_{ox} = 10^{11} \times 0.0496$$

$$20 + 0.98 - 0.838 = \frac{-10^{11} \times 1.6 \times 10^{-19}}{C_{ox}} + \frac{1.6805 \times 10^{-7}}{C_{ox}}$$

$$20.142 = \frac{-0.16 \times 10^{-7} + 1.68 \times 10^{-7}}{C_{ox}}$$

$$20.142 = \frac{1.52 \times 10^{-7}}{C_{ox}}$$

$$C_{ox} = \frac{1.52 \times 10^{-7}}{20.142} = \frac{C_{ox}}{t_{ox}} = \frac{1.52 \times 10^{-7}}{20.142}$$

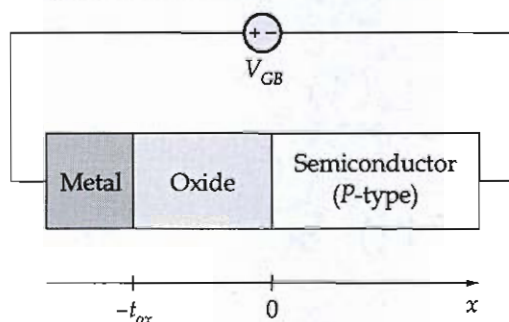
$$t_{ox} = \frac{3.9 \times 8.85 \times 10^{-14} \times 20.142}{1.52 \times 10^{-7}} = 457.369 \times 10^{-7}$$

$$t_{ox} = 45.73 \text{ nm}$$

calculation error

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Q.2 (a) Consider a MOS structure shown below:



The oxide thickness,  $t_{ox} = 50 \text{ nm}$  and the doping level in the substrate is  $N_a = 10^{16} \text{ cm}^{-3}$ . Assume, intrinsic carrier concentration of semiconductor,  $n_i = 10^{10} / \text{cm}^3$ , thermal voltage,  $V_T = 26 \text{ mV}$ ,  $\epsilon_{\text{oxide}} = 3.45 \times 10^{-13} \text{ F/cm}$ ,  $\epsilon_{\text{si}} = 1.05 \times 10^{-12} \text{ F/cm}$ .

Calculate the hole concentration,  $P$  at the oxide-semiconductor interface (i.e.,  $x = 0$ ) under the following conditions:

- (i) At flatband.
- (ii) At threshold
- (iii) At a condition in which the potential build up from the quasi-neutral body of semiconductor to  $x = 0$  is  $0.5 \text{ V}$ .
- (iv) At a condition when the capacitance per unit area of the MOS structure is  $50 \text{ nF/cm}^2$ .

[20 marks]





- Q.2(b) (i) Explain in detail noise in photodetector.
- (ii) The quantum efficiency of a particular silicon APD operating at a wavelength of  $0.8 \mu\text{m}$  is 90%. The incident optical power is  $0.5 \mu\text{W}$ . The output current is  $13 \mu\text{A}$ . Determine the multiplication factor of the photodiode.

[10 + 10 marks]

(i) Noise in photodetector -

There are mainly 3 types of noise present in photodetector

→ Thermal noise

→ Dark noise

→ Shot noise

Thermal noise → This noise is given due to random thermal motion of  $e^-$  in photodetector.

formula for thermal noise

$$i_s^2 = \frac{4KT B}{R}$$

Dark noise - This noise is present due to the flow of dark current in photodetector.

$$i_d^2 = 2e B I_d$$

Shot noise → This noise is due to sudden rupture of bonds & thermal motion.

$$i_s^2 = 2e B I_s$$

(ii)  $\eta = \frac{90}{100} = 0.9$      $\lambda = 0.8 \mu\text{m}$

$P_i = 0.5 \mu\text{W}$      $I_0 = 13 \mu\text{A}$

Now,  $\eta = \frac{I_0 / q}{P_{opt} / h\nu}$      $\eta = \frac{I_0 \times h\nu}{q \times P_{opt}}$

$$I_0 = \frac{0.9 \times 1.6 \times 10^{-19} \times 0.5 \times 10^{-6}}{6.63 \times 10^{-34} \times 3 \times 10^8} \times 0.8 \times 10^{-6}$$



$$I_0 = \frac{0.0289 \times 10^{-31}}{10^{26}}$$

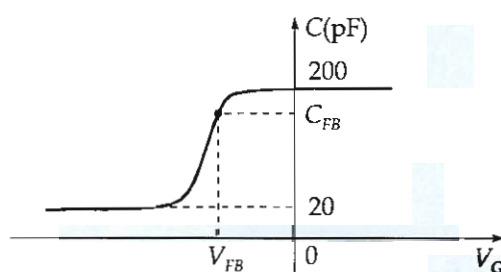
$$I_0 = 0.0289 \times 10^{-5} = 0.289 \times 10^{-6} \\ = 0.289 \mu\text{A}.$$

$$M = \frac{I}{I_0} = \frac{13}{0.289} = 44.982 \approx 45$$

$$M = 45 \text{ A}$$

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- Q.2 (c) The high frequency C-V characteristic curve of a MOS capacitor is shown in the figure below. The area of the device is  $2 \times 10^{-3} \text{ cm}^2$ . The metal-semiconductor work function difference is  $\phi_{ms} = -0.5 \text{ V}$  and  $V_{FB} = -0.8 \text{ V}$ . The oxide is  $\text{SiO}_2$  and the semiconductor is silicon with doping concentration  $2 \times 10^{16} \text{ cm}^{-3}$ . Assume  $\epsilon_{\text{si}} = 1.06 \times 10^{-12} \text{ F/cm}$ ,  $\epsilon_{\text{ox}} = 3.45 \times 10^{-13} \text{ F/cm}$ ,  $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$  and  $kT = 0.026 \text{ eV}$ .



- (i) Is the semiconductor  $n$  or  $p$ -type?
- (ii) What is the oxide thickness?
- (iii) What is the equivalent trapped oxide charge carrier density?
- (iv) Determine the flat-band capacitance  $C_{FB}$ .

[20 marks]

Sol<sup>n</sup> :- (i) Since the  $V_{FB}$  is (-ve) and on (-ve) axis of  $V_G$  so the given semiconductor is  $n$  type and have  $n$  type substrate.

(ii)  $C_{ox} = 200 \text{ pF}$

$$C_{ox} = \frac{\epsilon_{ox} A}{t_{ox}}$$

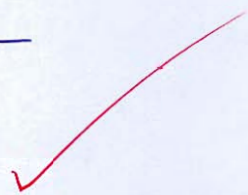


$$t_{ox} = \frac{\epsilon_{ox} A}{C_{ox}}$$

$$t_{ox} = \frac{3.45 \times 10^{-13} \times 2 \times 10^{-3}}{200 \times 10^{-12}}$$

$$t_{ox} = 0.0345 \times 10^{-4}$$

$$t_{ox} = 3.45 \text{ nm}$$



(iii)  $V_{FB} = \phi_{ms} - \frac{Q_{ss}}{C_{ox}}$

$$-0.8 = -0.5 - \frac{Q_{ss}}{C_{ox}}$$

$$-0.8 + 0.5 = - \frac{Q_{ss}}{C_{ox}}$$

$$-0.3 = - \frac{Q_{ss}}{C_{ox}} \quad Q_{ss} = 0.3 \times C_{ox}$$

$$Q_{ss} = 0.3 \times 200 \times 10^{-12}$$

$$Q_{ss} = 60 \times 10^{-12} = 60 \text{ pC/cm}^2 \rightarrow \text{C/cm}^2$$

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(iv)  $V_{FB} C_{FB} = Q_{FB}$

$$(V_{FB} - \phi_{ms}) C_{FB} = - Q_{ss}$$

$$(-0.8 + 0.5) C_{FB} = 60 \times 10^{-12}$$

$$C_{FB} = \frac{60 \times 10^{-12}}{0.3}$$

$$C_{FB} = 200 \text{ pF}$$

Refer solution

- Q.3 (a) Consider a GaAs pn diode at  $T = 300$  K with  $N_a = N_d = 10^{17} \text{ cm}^{-3}$  and with a cross sectional area of  $10^{-3} \text{ cm}^2$ . The minority carrier mobilities are  $\mu_n = 3000 \text{ cm}^2/\text{V-sec}$  and  $\mu_p = 200 \text{ cm}^2/\text{V-sec}$ . The life times are  $\tau_{p0} = \tau_{n0} = \tau_0 = 10^{-8} \text{ sec}$ . As a approximation, assume the electron-hole generation and recombination rates are constant across space charge region. Calculate the total diode current at a reverse bias voltage of 5 V and at a forward bias voltage of 0.5 V.

(Assume,  $V_t = 0.0259 \text{ V}$ ,  $n_i = 1.8 \times 10^6 \text{ cm}^{-3}$ ,  $\epsilon_G = 13.1\epsilon_0$ )

[20 marks]

Sol<sup>n</sup> given  $N_a = 10^{17}$   $N_d = 10^{17}$   
 $A = 10^{-3} \text{ cm}^2$   $\mu_n = 3000 \text{ cm}^2/\text{V-sec}$   
 $\mu_p = 200 \text{ cm}^2/\text{V-sec}$   $\tau_{p0} = \tau_{n0} = \tau_0 = 10^{-8}$

(1) At reverse biased of 5V, total diode current = Total saturation current

$$I_0 = A q n_i^2 \left[ \frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A} \right]$$

$$I_0 = 10^{-3} \times 1.6 \times 10^{-19} \times (1.8 \times 10^6)^2 \left[ \frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A} \right]$$



$$\frac{D_p}{\mu_p} = V_T \Rightarrow D_p = 0.0259 \times 200$$

$$D_p = 5.18$$

$$D_n = 3000 \times 0.0259 = 77.7$$

$$L_p = \sqrt{D_p \tau_p} = \sqrt{5.18 \times 10^8} = 2.27 \times 10^{-4}$$

$$L_n = \sqrt{D_n \tau_n} = \sqrt{77.7 \times 10^8} = 0.814 \times 10^{-4}$$

$$I_0 = 10^{-3} \times 1.6 \times 10^{-19} \times (1.8 \times 10^6)^2 \left[ \frac{5.18}{2.27 \times 10^{-4} \times 10^7} + \frac{77.7}{0.814 \times 10^{-4} \times 10^7} \right]$$

$$I_0 = 10^{-3} \times 1.6 \times 10^{-19} \times (1.8 \times 10^6)^2 \left[ 2.28 \times 10^{-13} + 0.815 \times 10^{-13} \right]$$

$$I_0 = 10^{-3} \times 1.6 \times 10^{-19} \times (1.8 \times 10^6)^2 \times 11.095 \times 10^{-13}$$

$$I_0 = 57.516 \times 10^{-23} \text{ A}$$

(ii) For forward bias voltage of 0.5V

$$I_s = I_0 (e^{V_a/nV_T} - 1)$$

$$I_s = 57.516 \times 10^{-23} \left( e^{\frac{0.5}{0.0259}} - 1 \right)$$

$$I_s = 1.39 \times 10^{10} \times 10^{-23}$$

$$I_s = 1.392 \times 10^{-13} \text{ A Ans}$$

Incomplete solution

Refer solution

(12)

- Q.3 (b) (i) Determine the change in the electron density of E-layer when the critical frequency changes from 4.5 MHz to 1.5 MHz for ionospheric communication between mid day and sun set periods.
- (ii) In a RSA cryptosystem, a participant A uses two prime numbers  $p = 13$  and  $q = 17$  to generate public and private keys. If the public key of A is 35, then find the private key of A.

[10 + 10 marks]

(i) electron density relat<sup>n</sup> in ionospheric region is given by

$$\mu = \frac{\sin i}{\sin r} = \sqrt{1 - \frac{\delta N}{f^2}}$$

So for  $\mu = 0$   $\delta N = f^2$

$$f_{\max} = 9\sqrt{N_{\max}}$$

$$f_1 = 9\sqrt{N_1}$$

$$\sqrt{N_1} = \frac{f_1}{9} = \frac{4.5 \times 10^6}{9} = 0.5 \times 10^6 N_1 = 0.25 \times 10^{12} \text{ cm}^{-3}$$

$$N_2 = \left(\frac{f_2}{9}\right)^2 = 0.0277 \times 10^{12} \text{ cm}^{-3}$$



$$\frac{N_2 - N_1}{N_1} = \underline{0.27}$$

$$N_2 - N_1 = 0.25 \times 10^{12} - 0.0277 \times 10^{12}$$

$$= 0.2223 \times 10^{12} \text{ cm}^{-3}$$

$$\Delta N \rightarrow 2.223 \times 10^{11} \text{ cm}^{-3}$$

10

- Q.3 (c) (i) Give the performance comparison between IPv4 and IPv6 in detail.
- (ii) 1. Determine the **minimum** cluster size for a cellular system designed with an acceptable value of signal to co-channel interference ratio  $\frac{C}{I} = 18$  dB. Assume the path loss exponent as 4 and co-channel interference at the mobile unit from six equidistant co-channel cells in the first tier.
2. If the acceptable  $\frac{C}{I}$  is enhanced to 20 dB, will the cluster size determined in (i) be adequate? If not, then what should be the cluster size?

[10 + 10 marks]









- (a) (i) For the system shown in figure (a), the receiver noise figure is 12 dB, the cable loss is 5 dB, the LNA gain is 50 dB, and its noise temperature 150 K. The antenna noise temperature is 35 K. Calculate the noise temperature referred to the input. Also, repeat the calculation when the system of figure (a) is arranged as shown in figure (b).

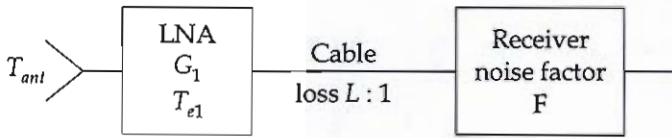


figure (a)

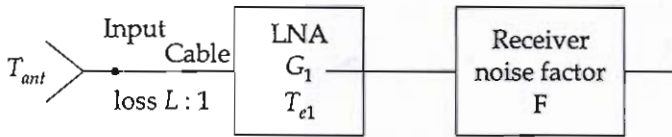


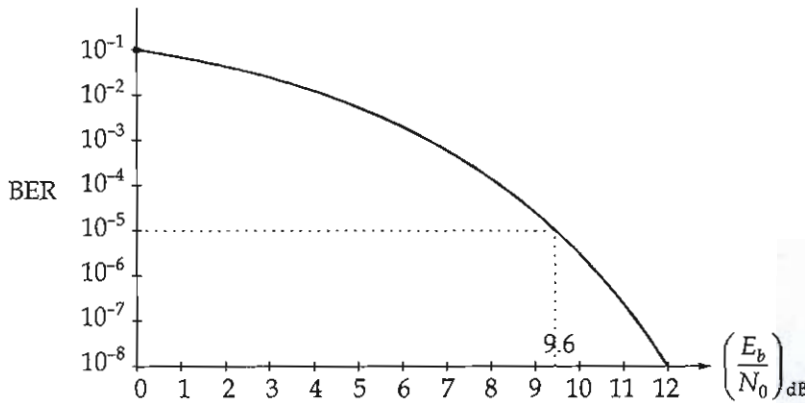
figure (b)

- (ii) A QPSK signal is transmitted by satellite. Raised cosine filtering is used, for which the roll off factor is 0.2 and a bit error rate (BER) of  $10^{-5}$  is required. For the satellite downlink, the losses amount to 200 dB, the receiving earth station  $\frac{G}{T}$  ratio is  $32 \text{ dB K}^{-1}$ , and the transponder bandwidth is 36 MHz.

Calculate:

1. the bit rate which can be accommodated, and
2. the EIRP required.

BER versus  $\left(\frac{E_b}{N_0}\right)$  plot for baseband signalling for QPSK modulated waveform is shown below:



[10 + 10 marks]





4 (b) A silicon pnp bipolar transistor at  $T = 300$  K has uniform dopings of  $N_E = 10^{18} \text{ cm}^{-3}$ ,  $N_B = 10^{16} \text{ cm}^{-3}$ , and  $N_C = 10^{15} \text{ cm}^{-3}$ . The metallurgical base width is  $1.2 \text{ } \mu\text{m}$ . Let  $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$ ,  $D_B = 10 \text{ cm}^2/\text{s}$  and  $\tau_{B0} = 5 \times 10^{-7} \text{ s}$ . Assume that the minority carrier hole concentration in the base can be approximated by a linear distribution. Let  $V_{EB} = 0.625 \text{ V}$ .

- (i) Determine hole diffusion current density in the base for  $V_{BC} = 10 \text{ V}$ .
- (ii) Estimate the Early voltage for  $V_{BC} = 5 \text{ V}$ . Use the results from part (i).

[20 marks]



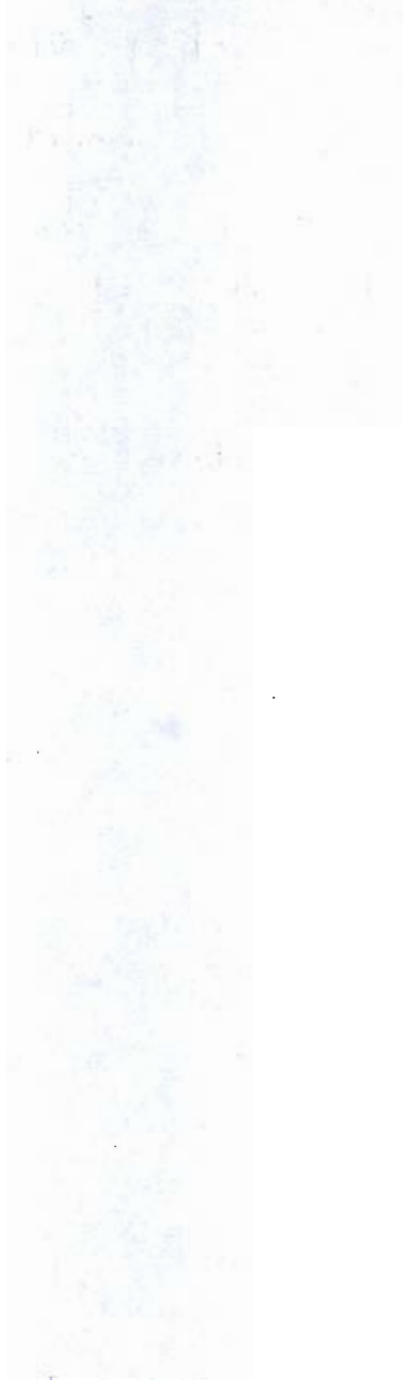
- 4 (c) (i) Consider that a geographical service area of a cellular system is  $4200 \text{ km}^2$ . A total of 1001 radio channels are available for handling traffic. Suppose the area of a cell is  $12 \text{ km}^2$ .
1. How many times would the cluster of size 7 have to be replicated in order to cover the entire service area? Calculate the number of channels per cell and the system capacity.
  2. If the cluster size is decreased from 7 to 4, then does it result into increase in system capacity? Comment on the results obtained.
- (ii) Give the performance comparison of UDP and TCP.

[10 + 10 marks]







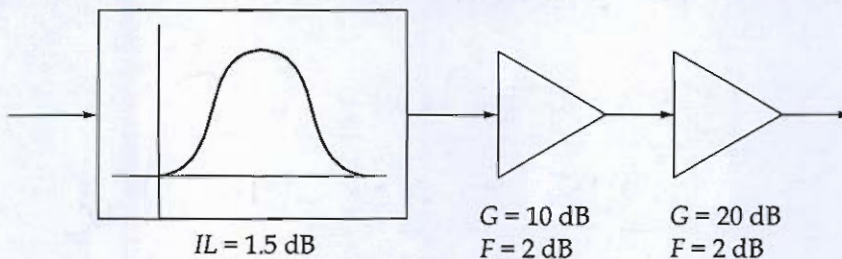




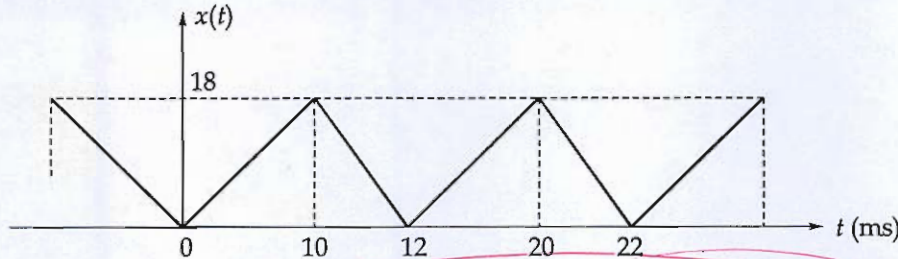
**Section B : Analog & Digital Communication Systems-1  
+ Signals and Systems-2 + Microprocessors and Microcontroller-2**

5 (a) (i) Consider the following wireless local area network (WLAN) receiver front-end as shown in figure where the bandwidth of the bandpass filter is 100 MHz centered at 2.4 GHz. Assume the system is at room temperature.

1. Find the noise figure of the overall system.
2. What is the resulting signal-to-noise ratio at the output, if the input power level is -90 dBm?
3. Can the components be rearranged to give a better noise figure?



(ii) A message signal shown below phase modulates a carrier signal  $A_c \cos \omega_c t$ , where  $f_c = 1$  MHz. If a maximum frequency deviation of 75 kHz is needed, determine the value of the phase constant ( $K_p$ ) to be used by the modulator. With this value, find the range of variation of modulated signal frequency.



[6 + 6 marks]

(i) (1) overall Noise figure  $F = F_1 + \frac{(F_2 - 1)}{G_1}$

$\log_{10} G_1 = 10$   
 $G_1 = 10$

$F = 2 + \frac{(2 - 1)}{10} = 2 + 0.1 = 2.1 \text{ dB}$

(ii) For phase Modulator PM

$\Delta\phi \propto m(t)$

$\Delta\phi = K_p m(t)$

$\frac{dm(t)}{dt} = \frac{18-0}{10-0}$   
 $= \frac{18}{10} = 1.8$

$\frac{1.8}{2} = 9 = \frac{18-0}{(12-10)}$

$\Delta f = \frac{1}{2\pi} \frac{d\phi}{dt}$

$\Delta f_{\text{max}} = \frac{1}{2\pi} K_p \left. \frac{dm(t)}{dt} \right|_{\text{max}}$

$\Delta f_{\text{max}} = \frac{1}{2\pi} \times K_p \times 9 = 75 \times 10^3$   
 $K_p = \frac{75 \times 2\pi \times 10^3}{9}$

$$k_p = 52.35 \times 10^3 \text{ rad.}$$

✓ Range of variation  
of modulated freq.

$$f_c \pm$$

$$\Delta f = f_i - f_c$$

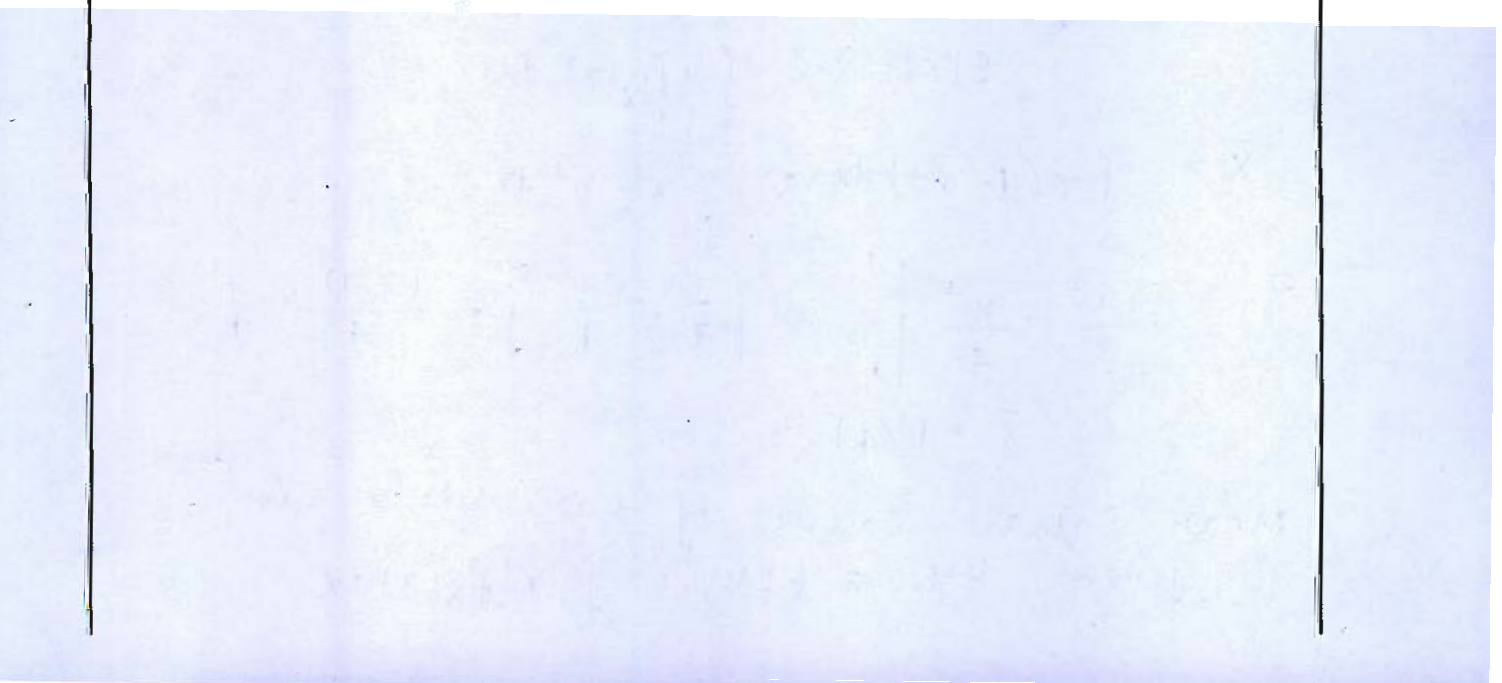
$$f_i = f_c + \Delta f$$

$$f_i = 1 \text{ MHz} \pm 75 \text{ kHz}$$

$$f_i = (1000 \pm 75) \text{ kHz}$$

$$f_i = 1075 - 925 \text{ kHz}$$

↓





Q.5 (b)

(i) 1. A WSS random process  $X(t)$  with auto correlation function

$$R_{XX}(\tau) = Ae^{-\alpha|\tau|}$$

where  $A$  and  $\alpha$  are real positive constants is applied to the input of an LTI system with impulse response,

$$h(t) = e^{-\beta t}u(t)$$

where  $b$  is a real positive constant. Find the auto correlation of the output  $Y(t)$  of the system.

2. Let  $X(t)$  and  $Y(t)$  be both zero-mean and WSS random processes. Consider the random process  $Z(t)$  defined by

$$Z(t) = X(t) + Y(t)$$

(a) Determine the auto correlation function and the power spectral density of  $Z(t)$  if  $X(t)$  and  $Y(t)$  are jointly WSS.

(b) If  $X(t)$  and  $Y(t)$  are orthogonal, then show that the mean square of  $Z(t)$  is equal to the sum of the mean squares of  $X(t)$  and  $Y(t)$ .

(ii) If the probability density function  $f_X(x)$  of a random variable  $X$  is given by

$$f_X(x) = (1 - x^2) \text{ for } 0 \leq x \leq 1$$

Find the standard deviation of this random variable.

[8 + 4 marks]

$$(ii) \text{ standard deviation}^n = \sqrt{\text{variance}} = E[(X - \bar{X})^2]$$

$$\text{var} = E[X^2 + (\bar{X})^2 - 2X\bar{X}] = E[X^2] + E[(\bar{X})^2] - 2E[X]\bar{X}$$

$$\text{variance} = E[X^2] - E[(\bar{X})^2]$$

$$\text{variance} = \text{MSV} - (\text{Mean})^2$$

Mean of  $x$  variable given by

$$E[X] = \bar{X} = \int_{-\infty}^{\infty} x f_X(x) dx$$

$$\bar{X} = \int_0^1 x(1-x^2) dx \Rightarrow \int_0^1 x - x^3 dx$$

$$\bar{X} = \left. \frac{x^2}{2} - \frac{x^4}{4} \right|_0^1 \Rightarrow \left[ \frac{1}{2} - \frac{1}{4} \right] = \frac{(2-1)}{4} = \frac{1}{4}$$

$$\bar{X} = (1/4)$$

Mean Square value of variable  $x$  is given by  $= E[X^2] = \int_{-\infty}^{\infty} x^2 f_X(x) dx$

$$E[X^2] = \int_0^1 x^2(1-x^2) dx$$

$$E[X^2] = \int_0^1 x^2 - x^4 dx \Rightarrow \left. \frac{x^3}{3} - \frac{x^5}{5} \right|_0^1$$

$$E[X^2] = \left[ \frac{1}{3} - \frac{1}{5} \right] = \frac{(5-3)}{15} = \frac{2}{15}$$

Now variance  $\sigma^2 = E[X^2] - [E[X]]^2$

$$\sigma^2 = \frac{2}{15} - \left(\frac{1}{4}\right)^2 = \frac{2}{15} - \frac{1}{16}$$

$$\sigma^2 = \frac{2 \times 16 - 15}{15 \times 16} = \frac{32 - 15}{15 \times 16} = \frac{17}{15 \times 16}$$

$$\sigma^2 = 0.070833$$

$$\sigma = \sqrt{0.070833}$$

$$\sigma = 0.266144 \quad \checkmark$$

4

Q.5 (c) Consider the following Discrete Time Sequences:

$$x_1(n) = \{ \underset{\uparrow}{1}, a, b, 2 \} \text{ and } x_2(n) = \{ \underset{\uparrow}{c}, 2, d, 4 \}$$

- (i) If the linear convolution of the sequence is  $\{ \underset{\uparrow}{1}, 3, 7, 13, 14, 14, 8 \}$  then find, the values of  $a, b, c$  and  $d$ .
- (ii) Find circular periodic convolution of the sequences  $x_1(n)$  and  $x_2(n)$  in terms of  $a, b, c$  and  $d$ .
- (iii) Also find circular periodic convolution of the sequence  $x_1(n)$  and  $x_2(n)$  for the values of  $a, b, c$  and  $d$  calculated in (i).

Sol<sup>n</sup> linear convolution  $y(n) = x_1(n) * x_2(n)$  [12 marks]

$x_1(n) \backslash x_2(n)$	$c$	$2$	$d$	$4$
$n=0 \rightarrow 1$	$c$	$2$	$d$	$4$
$a$	$ac$	$2a$	$ad$	$4a$
$b$	$bc$	$2b$	$bd$	$4b$
$2$	$2c$	$4$	$2d$	$8$

$$y(n) = \{ c, ac+2, bc+2a+d, 2c+2b+ad+4, 4+bd+4a, 2d+4b, 8 \}$$

Comparing with  $y(n) = \{ \underset{\uparrow}{1}, 3, 7, 13, 14, 14, 8 \}$

$$\boxed{c=1}$$

$$ac+2=3$$

$$\boxed{a=1}$$

$$bc+2a+d=7$$

$$b+2+d=7$$

$$\boxed{b+d=5} \quad \text{--- (i)}$$



$$2c + 2b + ad + 4 = 13 \Rightarrow 2 + 2b + d + 4 = 13$$

$$2b + d = 7 \quad \text{--- (2)}$$

$$b + d = 5$$

$$\underline{2b + d = 7}$$

$$b = 2$$

$$b = 2$$

$$2 \times 2 + d = 7$$

$$4 + d = 7$$

$$d = 3$$

$$\text{Now } a = 1, b = 2, c = 1, d = 3$$

(iii) circular convolution of  $x_1(n)$  &  $x_2(n)$   
 $y(n) = x_1(n) \otimes x_2(n)$

$$y(n) = \begin{bmatrix} 1 & 2 & b & a \\ a & 1 & 2 & b \\ b & a & 1 & 2 \\ 2 & b & a & 1 \end{bmatrix} \begin{bmatrix} c \\ 2 \\ d \\ 4 \end{bmatrix}$$

4x4                      4x1

$$y(n) = \begin{bmatrix} c + 4 + bd + 4a \\ ac + 2 + 2d + 4b \\ bc + 2a + d + 8 \\ 2c + 2b + ad + 4 \end{bmatrix}$$

4x1

(iii) Now putting  $a=1, b=2, c=1, d=3$

$$y(n) = \begin{bmatrix} 1+4+6+4 \\ 1+2+6+4 \\ 2+2+3+8 \\ 2+4+3+4 \end{bmatrix} = \begin{bmatrix} 15 \\ 13 \\ 15 \\ 13 \end{bmatrix}$$

4x1

$$\rightarrow 2 + 1 \times 1 + 2 \times 3 + 4 \times 2$$

$$\rightarrow 17$$

$$3$$

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

[12 marks]





- Q.5 (e) A 12 MHz carrier is frequency modulated using a modulating signal  $m(t) = A_m \sin 4\pi \times 10^3 t$ . The resultant FM signal has frequency deviation of 8 kHz.
- (i) Derive the expression for capture range of a PLL used for demodulation of this signal.
- (ii) What should be the capture range of a PLL used for demodulation of this signal?  
[10 + 2 marks]



Q.6 (a) The probability density function of two independent random variables  $X$  and  $Y$  are given by

$$f_X(x) = ae^{-ax}u(x) \text{ and } f_Y(y) = be^{-by}u(y)$$

where  $a, b$  are positive real constants and  $u(\cdot)$  represents the unit step function. Determine the probability density function of the random variable  $Z$  for each of the following cases:

(Assume  $z > 0$ )

(i)  $Z = X - Y$       (ii)  $Z = \frac{X}{Y}$       (iii)  $Z = \min(X, Y)$       (iv)  $Z = \max(X, Y)$

[20 marks]







6 (b) Given a second-order transfer function,

$$H(z) = \frac{0.56(1 - z^{-2})}{1 + 1.5z^{-1} + 0.4z^{-2}}$$

Perform the filter realization and write the difference equations using the following realizations:

- (i) Direct form I and direct form II.
- (ii) Cascade form via the first-order sections.
- (iii) Parallel form via the first-order sections.

[8 + 6 + 6 marks]







- Q.6 (c) (i) Draw and describe the block diagram for processor to memory communication and processor to I/O communication.
- (ii) Write some differences between Microcontroller and Microprocessor.

[15 + 5 marks]



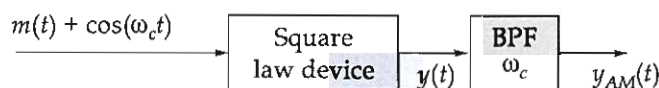


**Q.7 (a)** With the help of schematic diagram, explain the interfacing of 8255 with 8085 processor. **[20 marks]**



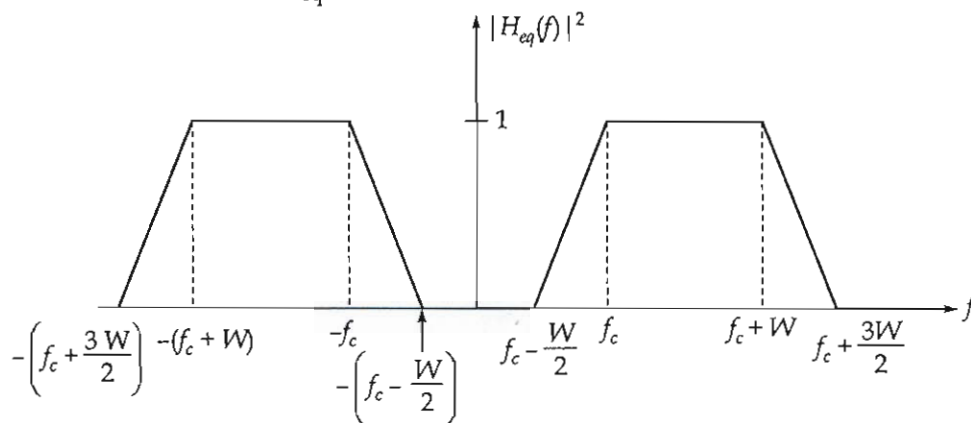
- Q.7(b) (i) Consider the system shown below used for generation of amplitude modulated signal. The average value of  $m(t)$  is zero and maximum value of  $|m(t)|$  is  $A_m$ . The square-law device with input  $x(t)$  and output  $y(t)$  is defined by

$$y(t) = 6.5x(t) + 12x^2(t)$$



What should be the value of  $A_m$  required to produce AM signal with modulation index of 0.85?

- (ii) In a receiver meant for the demodulation of SSB AM signals, the band-pass filter has the characteristics  $H_{eq}(f)$  as shown in the figure below. Find FOM of the system.



[5 + 15 marks]







- 7 (c) (i) The message signal  $m(t)$  has a bandwidth of 15 kHz, a power of 18 W. It is desirable to transmit this message to a destination via a channel with 85 dB attenuation and additive white noise with power spectral density,  $S_n(f) = \frac{N_0}{2} = 10^{-13}$  W/Hz and achieve a SNR at the receiver output of at least 55 dB. What is the required transmitter power and channel bandwidth if the following modulation schemes are employed?
1. DSB AM
  2. SSB AM
  3. Conventional AM with modulation index equal to 0.65.
- (ii) For a superheterodyne receiver having no RF amplifier, the loaded  $Q$  of the antenna coupling circuit is 120. If the super heterodyne receiver is to be improved for HF reception so that its image rejection at 30 MHz is as good as at 1500 kHz. Assuming IF of 455 kHz, determine:
1. loaded  $Q$  of an RF amplifier to be used for achieving the improved performance.
  2. new IF for achieving the improved performance in the absence of RF amplifier.
- [12 + 8 marks]





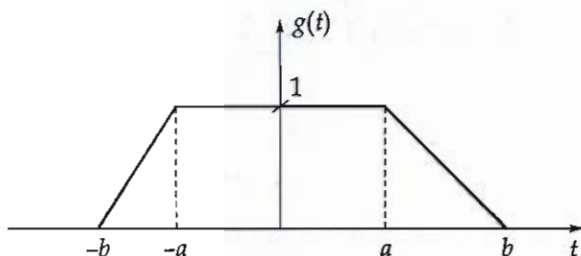




⇒ (a) (i) Find the inverse z-transform of

$$X(z) = \frac{z^3 - 10z^2 - 4z + 4}{2z^2 - 2z - 4}; \text{ with ROC } |z| < 1$$

(ii) 1. Using time shifting and time differentiation properties; find the Fourier transform  $G(j\omega)$  of the trapezoidal signal shown below:



What is the condition under which this procedure is valid?

2. Calculate the value of  $G(2j)$ , if  $a = \frac{b}{2} = 1$ .

[10 + 7 + 3 marks]

(1) To calculate inverse z-transform —  
 Arrange terms of Nr & Dr in decreasing order for  $|z| < 1$  i.e. left hand side sequence.

$$\begin{array}{r}
 -1 + 6/4z + 5/4z^2 - 1/8z^3 \\
 -4 - 2z + 2z^2 \sqrt{4 - 4z - 10z^2 + z^3} \\
 \hline
 + \cancel{4} + 2z - 2z^2 \\
 \hline
 -6z - 8z^2 + z^3 \\
 -6z - 3z^2 + 3z^3 \\
 \hline
 -5z^2 - 2z^3 \\
 -5z^2 - \frac{5}{2}z^3 + \frac{5}{2}z^4 \\
 \hline
 \frac{1}{2}z^3 - \frac{5}{2}z^4 \\
 \frac{1}{2}z^3 + \frac{1}{4}z^4 - \frac{1}{4}z^5 \\
 \hline
 -\frac{11}{4}z^4 + \frac{1}{4}z^5
 \end{array}$$



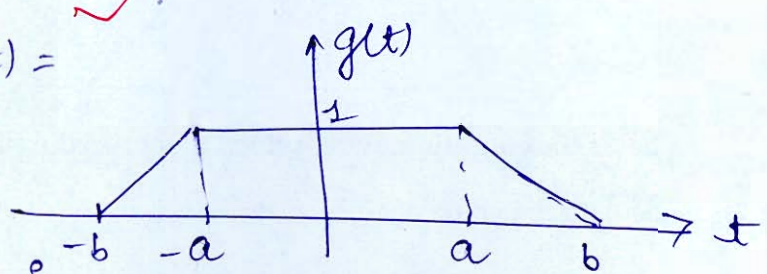
Hence,  $Seq. = -1 + \frac{6}{4}z + \frac{5}{4}z^2 - \frac{1}{8}z^3$

~~$g(n) = -\delta(n) + \frac{6}{4}$~~

9

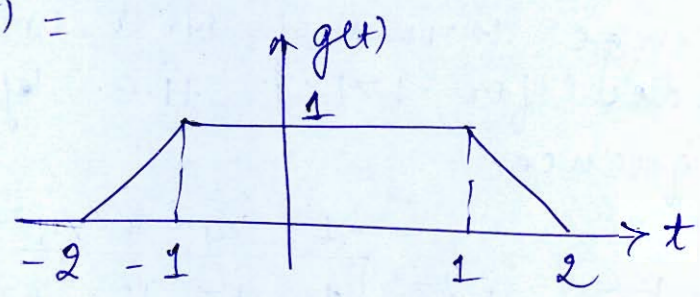
$y(n) = -\delta(n) + \frac{6}{4}x(n+1) + \frac{5}{4}x(n+2) - \frac{1}{8}x(n+3)$

(ii) given  $g(t) =$

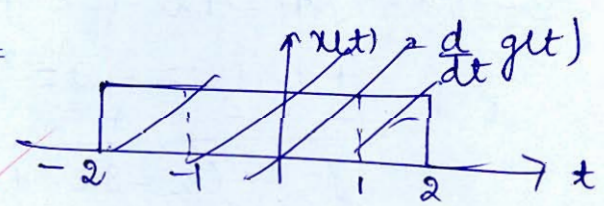


so as given in part-2  $a=1, b=2$

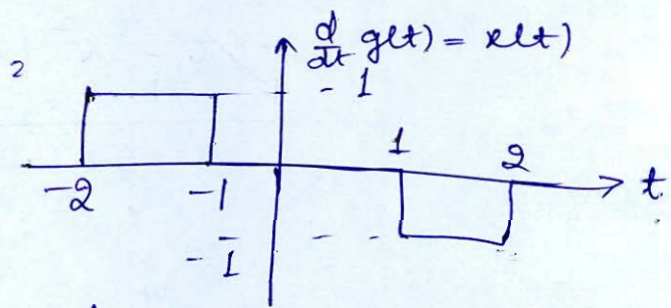
we have  $g(t) =$



$\frac{d}{dt} g(t) = x(t) =$



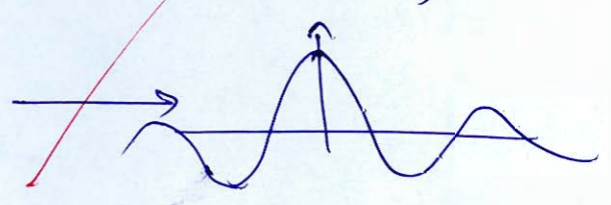
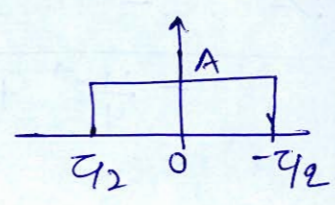
$\frac{d}{dt} g(t) = x(t)$



$x(t) = \text{rect}\left(\frac{t+0.5}{1}\right) + (-1) \text{rect}\left(\frac{t-0.5}{1}\right)$

$x(t) = \text{rect}(t+0.5) - \text{rect}(t-0.5)$

Now, for  $A \text{ rect}(t/\tau) \xrightarrow{F.X.} A \tau \text{ Sa}\left(\frac{\omega \tau}{2}\right)$



So  $x(t + t_0) \rightarrow e^{j\omega t_0} X(j\omega)$   
 $x(t - t_0) \rightarrow e^{-j\omega t_0} X(j\omega)$

$x(t) = \text{rect}(t + 0.5) - \text{rect}(t - 0.5)$

$X(j\omega) = e^{j\omega \times 0.5} \text{Sa}\left(\frac{\omega}{2}\right) - e^{-j\omega \times 0.5} \text{Sa}\left(\frac{\omega}{2}\right)$

6

Now  $\frac{d}{dt} g(t) = x(t) \Rightarrow j\omega G(j\omega) = X(j\omega)$

$j\omega G(j\omega) = e^{j\omega \times 0.5} \text{Sa}\left(\frac{\omega}{2}\right) - e^{-j\omega \times 0.5} \text{Sa}\left(\frac{\omega}{2}\right)$

$G(j\omega) = \text{Sa}\left(\frac{\omega}{2}\right) \left[ \frac{e^{j\omega \times 0.5} - e^{-j\omega \times 0.5}}{j\omega} \right]$

② Now @  $\boxed{\omega = 2}$   $G(j2) = ?$

$G(j2) = \text{Sa}\left(\frac{2}{2}\right) \left[ \frac{e^{j \times 2 \times 0.5} - e^{-j \times 2 \times 0.5}}{j2} \right]$

$G(j2) = \text{Sa}(1) \frac{e^j - e^{-j}}{2j}$

Refer solution



Q.8 (b) Explain the Envelope detection and synchronous detection methods for demodulation of AM signal. Show that in an envelope detector, to avoid diagonal clipping,

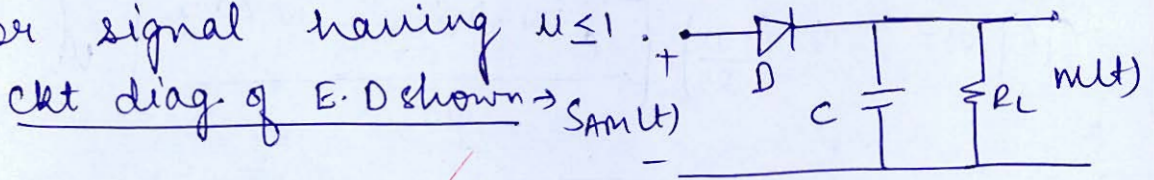
$RC \leq \frac{1}{\omega_m} \frac{\sqrt{1-\mu^2}}{\mu}$ . Also, explain the Quadrature null effect in synchronous detector.

[20 marks]

given:- Mainly 2 methods are used for demodulation of AM sig.

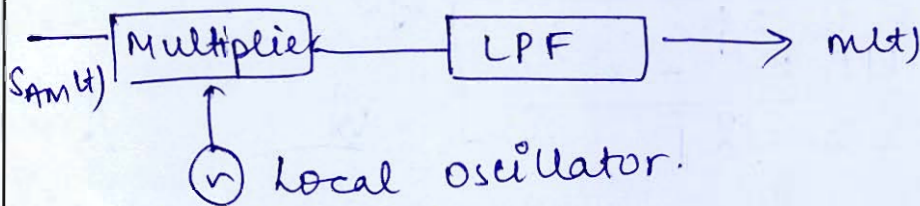
- ① Envelope Detector
- ② Synchronous detection.

① Envelope Detector - This method is useful for signal having  $\mu \leq 1$ .



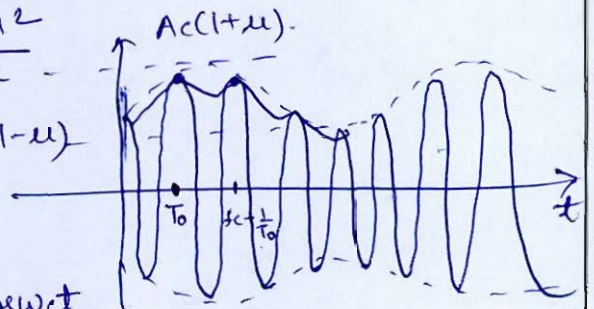
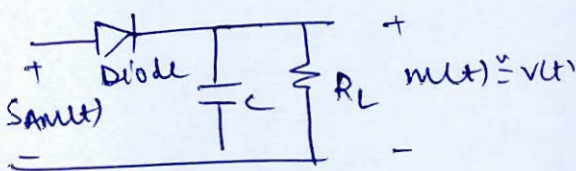
② Synchronous detector -

This method is used for all value of  $\mu$  but this method is quite complex.



ckt diag. of syn. Detector

Now, To avoid diagonal clipping, show that  $RC \leq \frac{1}{\omega_m} \frac{\sqrt{1-\mu^2}}{\mu}$



$S_{AM}(t) = A_c(1 + \mu \cos w_m t) \cos w_c t$

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at  $t = t_0$   $v(t_0) = A_c(1 + \mu \cos w_m t_0) \cos w_c t_0$

Now at  $t = (t_0 + 1/f_c)$



$$V_c(t_0 + \frac{1}{f_c}) = V_c(t_0) e^{-\frac{t}{R_L C}}$$

and  $e^x = 1 - x + \frac{x^2}{2!} - \frac{x^3}{3!} \dots$

$$V_c(t_0 + \frac{1}{f_c}) = V_c(t_0) \left[ 1 - \frac{1}{R_L C f_c} \right]$$

To avoid diagonal clipping,

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~~$V_c(t_0 + \frac{1}{f_c}$~~

$$V_c(t_0) \left[ 1 - \frac{1}{R_L C f_c} \right] \leq V_c(t_0 + \frac{1}{f_c})$$

$$\Rightarrow A_c (1 + \mu \cos \omega_m t_0) \cos \omega_c t_0 \left[ 1 - \frac{1}{R_L C f_c} \right] \leq A_c (1 + \mu \cos \omega_m (t_0 + \frac{1}{f_c})) \cos \omega_c (t_0 + \frac{1}{f_c})$$

$$(1 + \mu \cos \omega_m t_0) \cos \omega_c t_0 \left[ 1 - \frac{1}{R_L C f_c} \right] \leq \left[ 1 + \mu \cos \left( \omega_m t_0 + \frac{\omega_m}{f_c} \right) \right] \cos \left( \omega_c t_0 + \frac{\omega_c}{f_c} \right)$$

$$-\frac{\mu \cos \omega_m t_0}{R_L C f_c} \leq \mu \left[ \cos \omega_m t_0 \cos \frac{\omega_m}{f_c} - \sin \omega_m t_0 \sin \frac{\omega_m}{f_c} \right]$$

Since  $\frac{\omega_m}{f_c} \ll 1$   $\cos \theta \approx 1$   $\sin \theta \approx \theta$ .

$$-\frac{\mu \cos \omega_m t_0}{R_L C f_c} \leq \mu \left[ \cos \omega_m t_0 - \sin \omega_m t_0 \frac{\omega_m}{f_c} \right]$$

Hence after solving we get

$$R_L C \leq \frac{1}{2\pi f_m} \frac{\sqrt{1 - \mu^2}}{\mu}$$

\* Quadrature Null effect

$$A_c (1 + K_a m(t)) \cos \omega_c t \times \cos(\omega_c t + \phi) = S_{mult}$$

$$S_{mult} = \frac{A_c}{2} [1 + K_a m(t)] [\cos(2\omega_c t + \phi) + \cos \phi]$$

After LPF  $\rightarrow$

$$S_{mult} = \frac{A_c}{2} (1 + K_a m(t)) \cos \phi$$

if  $\phi = 90^\circ$  then  $[m(t) = 0] \rightarrow$  hence shows quadrature null effect

Q.8 (c) Briefly describe the 8255 A programmable peripheral interface and also draw the block diagram of 8255 A.

[20 marks]







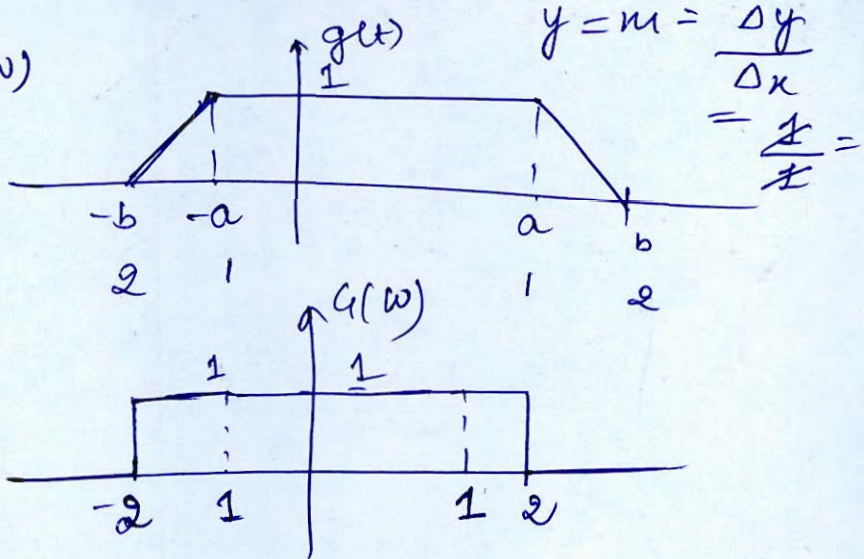
## Space for Rough Work

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Space for Rough Work

$$\frac{d}{dt} g(t) = j\omega G(\omega)$$

$$x(t) =$$



$$A \text{ rect}(t/2) \rightarrow A \text{ Sa}\left(\frac{\omega T}{2}\right)$$

$$1 \text{ rect}(t/4) = 1 \times 4 \text{ Sa}\left(\frac{\omega \times 4}{2}\right)$$

$$= 4 \text{ Sa}(2\omega)$$

$$x(t+2) - x(t+1) - x(t-1) + x(t-2)$$

$$u(t+2) - u(t+1) - u(t-1) + u(t-2)$$

