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ESE 2023 : 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 ☐	Jaipur ☐		
Pune ☑	Kolkata ☐	Bhubaneswar ☐	Hyderabad ☐	

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. 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.
5. Use only black/blue pen.
6. 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.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. 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	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	182

Signature of Evaluator ....

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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

Q.1 (a) A Si sample with $10^{15}/cm^3$ donors is uniformly optically excited at room temperature such that $10^{19}/cm^3$ electron-hole pairs are generated per second. Find the electron concentration, hole concentration and change in conductivity upon shining the light. (Assume electron and hole lifetimes are both 10 μs, $D_p = 12\ cm^2/sec$, $\mu_n = 1300\ cm^2/V\text{-}sec$, $V_T = 0.0259$ V, $n_i = 1.5 \times 10^{10}\ cm^{-3}$.)

[12 marks]

Given $N_d = 10^{15}\ cm^{-3}$

$\Delta n = \Delta p = 10^{19}\ cm^{-3} \times 10^{-5} = 10^{14}\ cm^{-3}$

electron concentration $= n = N_d + \Delta n$

$= 10^{15} + 10^{14} = 1.1 \times 10^{15}\ cm^{-3}$

hole concentration $p = \frac{n_i^2}{N_d} + \Delta p$

$= \frac{1.5 \times 10^{20}}{10^{15}} + 10^{14}$

$p \simeq 10^{14}\ cm^{-3}$

$\frac{D_p}{\mu_p} = kT \Rightarrow \mu_p = \frac{D_p q}{kT} = \frac{12 \times 1.6 \times 10^{-19}}{0.0259} = 463.32\ cm^2/V\text{-}sec$

change in conductivity upon shining the light $\Delta\sigma = q[\Delta n \mu_n + \Delta p \mu_p]$

$= 1.6 \times 10^{-19}[10^{19}] \times [1300 + 463.32]$

$= 2821.31\ (\Omega cm)^{-1}$

$= 1.6 \times 10^{-19} \times [1300 + 463.32]$

$= 1.6 \times 10^{-19}[1300 \times 1.1 \times 10^{15} + 463.32 \times 10^{14}]$

$= 0.2$[illegible]$\ (\Omega cm)^{-1}$

10

8

Q.1 (b) A typical single mode optical fiber has a core of diameter 8 μm and a refractive index of 1.46. The normalized index difference is 0.3%. The cladding diameter is 125 μm. Calculate the numerical aperture and the acceptance angle of the fiber. What is the single mode cut-off wavelength λ_c of the fiber?

[4 + 4 + 4 marks]

$a = 4\,\mu m \quad n_1 = 1.46 \quad \Delta = 0.3\%$

Numerical aperture (NA) $= n_1 (2\Delta)^{1/2}$

$= 1.46 \times (2 \times 0.3 \times 10^{-2})^{0.5}$

$= 0.113$

Acceptance angle $= \sin^{-1}(NA)$

$= 6.493°$

Normalised frequency $= k = \frac{2\pi a (NA)}{\lambda}$

For single mode $2.4 = \frac{2\pi a (NA)}{\lambda}$

$\lambda_c = \frac{2\pi a (NA)}{2.4}$

$= \frac{2\pi \times 4 \times 10^{-6} \times 0.113}{2.4}$

$\lambda_c = 1.18 \times 10^{-6}$ m

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Q.1 (c) A cellular system operator is allocated a total spectrum of 5 MHz for deployment of an analog cellular system based on the FDMA technique, with each simplex channel occupying 25 kHz bandwidth. Compute the number of simultaneous calls possible in the system, number of simplex channels and number of duplex channels.

[12 marks]

Total spectrum $= 5 \times 10^6$ Hz

Simplex channel Bandwidth $= 25$ kHz

No. of simplex channels $= \frac{5 \times 10^6}{25 \times 10^3}$

$= 200$

No. of duplex channels available $= \frac{5 \times 10^6}{2 \times 25 \times 10^3}$

$= 100$

200 calls can be possible simultaneously for simplex & 100 ~~cal~~ simultaneous calls possible for duplex system.

6

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Q.1 (d) An n-type semiconductor has excess carrier holes 10^{14} cm^{-3}, a minority carrier life time 10^{-6} sec in the bulk material, and a minority carrier lifetime 10^{-7} sec at the surface. Assume zero applied electric field and let $D_p = 10$ cm^2/sec. Determine the steady-state excess carrier concentration as a function of distance from the surface ($x = 0$) of the semiconductor.

[12 marks]

At zero applied field $J_P = 0$

$$\therefore -qD_P \frac{dP(x)}{dx} + q P(x) \mu_P E(x) = 0$$

$$E(x)\, q\, P(x)\, \mu_P = q D_P \frac{dP(x)}{dx}$$

$$E(x) = \frac{D_P}{\mu_P} \frac{1}{P(x)} \frac{dP(x)}{dx}$$

$$V(x) = -\frac{kT}{q} \ln(P(x))$$

$$V(0) - V(x) = +\frac{kT}{q} \ln P(x) - \frac{kT}{q} \ln P(0)$$

$$V(0) - V(x) = V_T \ln\left[\frac{P(x)}{P(0)}\right]$$

$$P(x) = P(0)\, e^{-\frac{V(x)}{V_T}} \quad \because V(0) = 0\ V$$

$$L_P = \sqrt{D_P \tau_P} = \sqrt{10 \times 10^{-6}} = \sqrt{10^{-5}}$$

steady state excess carrier concentration as function of distance

$$= \Delta P e^{-\frac{x}{L_P}}$$

$$= 10^{14} e^{-\frac{x}{\sqrt{10^{-5}}}}$$

$$= 10^{14} e^{-316.23x}$$

6

6

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Q.1 (e) Calculate the signal to co-channel interference ratio $\frac{C}{I}$ at the mobile receiver located at the boundary of its operating cell, under the influence of interfering signals from one co-channel interfering cell in the first tier in a cellular system designed with 6-sector-directional antenna cellular system and cluster size of $N = 7$. Comment on the results for a practical cellular system. Assume the path-loss exponent as '4'.

[12 marks]

$n = 4$. $N = 7$

$\left(\frac{C}{I}\right) = \frac{1}{6}(Q)^n$ & $Q = \sqrt{3N}$

$Q = \sqrt{3 \times 7} = \sqrt{21} = 4.58$

$\left(\frac{C}{I}\right) = \frac{1}{6}(4.58)^4$

$= 73.5$

$N = i^2 + j^2 + ij$ if $i = j = 1$ $N = 3$.

For $N = 3$ system

$\left(\frac{C}{I}\right) = \frac{1}{6}\left(\sqrt{3 \times 3}\right)^4$

$= 13.5$ $13.5 < 73.5$ so

This is less than $N = 7$ so this system is not recommended.

when $i = j = 2$ $N = 4 + 4 + 4 = 12$

for $N = 12$ system

$\left(\frac{S}{I}\right) = \frac{1}{6}\left(\sqrt{3 \times 12}\right)^4$

$= 216$.

As $\frac{C}{I} = 216$ is greater than $\frac{C}{I}$ for $N = 7$

This system is recommended.

Q.2 (a) (i) In a certain BJT (PNP), we increase the base doping by a factor of 10 and halve the base width. Calculate approximately by what factor the collector current changes in the normal active mode, assuming that everything else stays same.

(ii) In a certain BJT (PNP), the emitter doping is 100 times greater than the base doping, the emitter width is 0.1 times the base width and assume both the base and emitter widths to be much shorter than the carrier diffusion lengths L_n and L_p. What is the emitter injection efficiency and base transport factor?

[10 + 10 marks]

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Q.2 (b) (i) Write short notes on pure ALOHA and slotted ALOHA.

(ii) Determine the maximum throughput that can be achieved using pure ALOHA and slotted ALOHA protocols.

[10 + 10 marks]

i) Pure ALOHA -

- It is channel access protocol for data frame transfer
- Frames are transferred on channel & its acknowledgment is checked from same channel or other dedicated channel.
- If frames are also send by other users on same channel then both the frames collides with each other & destroyed
- Their acknowledgement doesn't comes from receiver.
- In pure ALOHA if acknowledgement doesn't come ~~for~~, then random amount of time is waited & then again frames are transmitted on same channel.

- Its throughput is Ge^{-2G}.

where G = No of frames generated during 1 frame transmission time.

Slotted ALOHA -

- It In slotted ALOHA frames can be sent only at particular time.
- Total time is sliced & frame can be sent only at the starting of time slot.
- If that slot starting is missed then again we have to wait for starting of another next time slot.
- Because of this no. of collisions between frames is reduced. So throughput increases. It is as $\underline{Ge^{-G}}$.

ii) For pure ALOHA

$\cancel{G =}$ $T = Ge^{-2G}$

$\frac{dT}{dG} = Ge^{-2G}(-2) + e^{-2G}$

for max. throughput $\frac{dT}{dG} = 0$

$\therefore Ge^{-2G}(2) = e^{-2G}$

$G = 0.5$

max. throughput occurs at $G = 0.5$

$T = 0.5 e^{-0.5\times 2} = \underline{0.183}$

For slotted ALOHA

$T = G e^{-G}$

$\frac{dT}{dG} = -G e^{-G} + e^{-G} = 0$

$e^{-G} = G e^{-G}$

$G = 1.$

$T = 1 e^{-1} = \underline{0.367}.$

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Q.2 (c) **(i)** In a particular semiconductor material, the effective density of states functions are given by $N_C = N_{c0}\left(\frac{T}{300}\right)^{3/2}$ and $N_V = N_{v0}\left(\frac{T}{300}\right)^{3/2}$ where N_{co} and N_{v0} are constant and independent of temperature. Experimentally determined concentrations are found to be $n_i = 1.4 \times 10^2\ \text{cm}^{-3}$ at $T = 200$ K and $n_i = 7.7 \times 10^{10}\ \text{cm}^{-3}$ at $T = 400$ K. (Assume E_g is constant over this temperature range). Determine the product $N_{c0} \times N_{v0}$ for both temperatures.

(ii) Boron is implanted into n-type Si sample ($N_d = 10^{16}\ \text{cm}^{-3}$), forming an abrupt junction of square cross-section with area = $2 \times 10^{-3}\ \text{cm}^2$. Assume, acceptor concentration in the p-type region is $N_a = 4 \times 10^{18}\ \text{cm}^{-3}$. Calculate V_0, x_{n0}, x_{p0}, and positive ionic space charge, Q_+ for this junction at equilibrium (300 K).

(Assume, $V_T = 0.0259$ V; $\epsilon_{Si} = 11.7\,\epsilon_0$, $n_i = 1.5 \times 10^{10}\ \text{cm}^{-3}$)

[10 + 10 marks]

i) At $T = 200K$ →

$$n_i = \sqrt{N_c N_v}\, e^{-\frac{E_g}{2KT}}$$

$$N_c = N_{co} \times \left(\frac{200}{300}\right)^{1.5} = 0.544\, N_{co}$$

$$N_v = N_{vo} \times \left(\frac{200}{300}\right)^{1.5} = 0.544\, N_{co}$$

$$n_i = \sqrt{N_{co} N_{vo}} \times 0.544 \times e^{-\frac{E_g}{2 \times K \times 200}} = 1.4 \times 10^{2}$$

$$1.4 \times 10^{2} = \sqrt{N_{co} N_{vo}} \times 0.544 \times e^{-\frac{E_g}{2 \times K \times 200}}$$

$$N_{co} N_{vo} = \frac{(1.4 \times 10^{2})^2}{(0.544)^2\, e^{-\frac{E_g}{200K}}}$$

$$= 6.623 \times 10^{4}\, e^{\frac{E_g}{200K}}$$

At $T = 400K$

$$N_c = N_{co} \times \left(\frac{400}{300}\right)^{1.5} = 1.54\, N_{co}$$

$$N_v = N_{vo} \times \left(\frac{400}{300}\right)^{1.5} = 1.54\, N_{vo}.$$

$$n_i = \sqrt{N_{co} N_{vo}} \times 1.54\, e^{-\frac{E_g}{2 \times 400K}} = 7.7 \times 10^{10}$$

$$N_{co} N_{vo} = \frac{(7.7 \times 10^{10})^2}{(1.54)^2\, e^{-\frac{E_g}{400K}}}$$

$$= 2.5 \times 10^{21}\, e^{\frac{E_g}{400K}}$$

ii) $V_0 = V_t \ln\left(\frac{N_d N_A}{n_i^2}\right)$

$= 0.0259 \times \ln\left(\frac{10^{16} \times 4\times10^{18}}{(1.5\times10^{10})^2}\right)$

$= 0.849\ V$

$W = \sqrt{\frac{2\varepsilon V_0}{q}\left(\frac{1}{N_a} + \frac{1}{N_d}\right)}$

$= \sqrt{\frac{2\times11.7\times8.85\times10^{-14}\times0.849}{1.6\times10^{-19}}\left(10^{-16} + 0.25\times10^{-18}\right)}$

$= 3.319\times10^{-5}$ cm

$x_{no} = \frac{N_A}{N_A+N_d}\times W$

$= \frac{4\times10^{18}}{4\times10^{18}+10^{16}}\times W$

$= 3.31\times10^{-5}$ cm

$x_{po} = W - x_{no}$

$= 3.319\times10^{-5} - 3.31\times10^{-5}$

$= 9\times10^{-8}$ cm

$Q_0^+ = -N_a x_{po}\, q$

$= -4\times10^{18}\times9\times10^{-8}\times1.6\times10^{-19}$

$= 5.76\times10^{-8}\ \frac{\text{Columb}}{\text{cm}^2}$

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Q.3 (a) Consider a city of 10 square kilometers. A macrocellular system design divides the city into square cells of 1 square kilometer, where each cell can accommodate 100 users. Find the total number of users that can be accommodated in the system and the length of time it takes a mobile user to traverse a cell (approximate time needed for a handoff) when moving at 30 km per hour. If the cell size is reduced to 100 square meters and everything in the system scales so that 100 users can be accommodated in these smaller cells, find the total number of users the system can accommodate and the length of time it takes to traverse a cell.

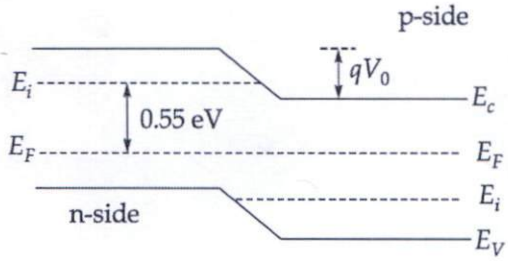
[20 marks]

Q.3 (b) Consider a Si n^+–p junction with Energy band diagram shown below. The acceptor carrier concentration, $N_a = 10^{15}$ cm^{-3}, area of junction, $A = 0.001$ cm^2.

Draw the plot $\frac{1}{C_j^2}$ vs V_R mentioning the values for reverse bias voltages (in magnitude),

$V_R = 1$ V, 5 V, 10 V

(Assume, $KT = 0.025$ eV, $\in_s = 11.7 \in_0$, $n_i = 1.5 \times 10^{10}$ cm^{-3})



[20 marks]

Q.3 (c) A satellite circuit has the following parameters:

	Uplink (in dB)	Downlink (in dB)
[EIRP]	54	34
[G/T]	0	17
[FSL]	200	198
[RFL]	2	2
[AA]	0.5	0.5
[AML]	0.5	0.5

Calculate the overall $[C/N_0]$.

[20 marks]

Q.4 (a) (i) A photodetector is provided with the following data:

1. Sensitivity = 0.6 A/W
2. The detector is kept at a distance of 3 cm from GaAs IR LED.
3. Output power of the LED = 0.6 mW
4. Peak emission wavelength = 850 nm
5. Active area of the photoconductor = 7.5×10^{-3} cm^2
6. Divergence angle of LED = 0.65 rad

Find out the value of photocurrent.

(ii) An avalanche diode is provided with following data:

1. Quantum efficiency = 0.75
2. Wavelength = 850 nm
3. Optical power = 0.6 μW
4. Avalanche multiplied current = 11 μA

Determine the avalanche multiplication factor.

[12 + 8 marks]

i) power o/p = 0.6 mW.

sensitivity = 0.6 $\frac{A}{W}$.

photocurrent = (~~power~~ o/p) × ~~sen~~sitivity

=

power density at 3cm $= \frac{P_t}{4\pi r^2} \times$ divergence angle

$= \frac{0.6 \times 10^{-3} \times 0.65}{4\pi \times 9}$

$= 3.45 \times 10^{-6}$ W/cm²

power received by photo conductor =

$3.45 \times 10^{-6} \times 7.5 \times 10^{-3}$

$= 2.586 \times 10^{-8}$ W.

o/p current of photodetector = power received × sensitivity

$= 2.586 \times 10^{-8} \times 0.6$

$= 2.07 \times 10^{-8}$ A.

ii) $\eta = 0.75$ $\lambda = 850\,nm$

$P_{in} = 0.6\,\mu W$

Responsivity $R = \frac{\eta e \lambda}{hc}$

$= \frac{0.75 \times 1.6 \times 10^{-19} \times 850 \times 10^{-9}}{6.6 \times 10^{-34} \times 3 \times 10^{8}}$

$= 0.515\ \frac{A}{W}$

photocurrent $= P_{in} \times$ Responsivity

$= 0.6 \times 10^{-6} \times 0.515$

$= 0.309\,\mu A$

multiplication factor $= \frac{\text{multiplied current}}{\text{photocurrent}}$

$= \frac{11\,\mu A}{0.309}$

$= 35.59$

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Q.4 (b) Consider a Si n-channel MOSFET for a gate-to-substrate work function difference ϕ_{ms} = –1.5 eV, gate oxide thickness = 100 Å, $N_A = 10^{18}$ cm^{-3} and fixed oxide charge of 5×10^{10} qC/cm^2.

(i) Calculate threshold voltage, V_T, for a substrate bias of –2.5 V.

(ii) Sketch a labelled band diagram normal to the surface at V_T showing the fermi potential, for a substrate bias of –2.5 V.

(Assume $\epsilon_{si} = 11.8\,\epsilon_0$, $\epsilon_i = 3.9\,\epsilon_0$, $\frac{kT}{q} = 0.026$ V)

[14 + 6 marks]

i) $\phi_s = 2\phi_F = 2V_t \ln\left(\frac{N_A}{n_i}\right)$

$= 2 \times 0.026 \times \ln\left(\frac{10^{18}}{1.5 \times 10^{10}}\right)$

$= 0.937$ volts surface potential

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

$= \frac{3.9 \times 8.85 \times 10^{-14}}{100 \times 10^{-8}} = \frac{F}{cm^2}$ ~~1.0443×10^{-6}~~ 3.45×10^{-7}

$V_t = \phi_{ms} - \frac{Q_{ox}}{C_{ox}} - \frac{Q_{induced}}{C_{ox}} + 2\phi_F$

$W = \sqrt{\frac{2\epsilon(\phi_s + 2.5)}{qN_A}} = \sqrt{\frac{2 \times 11.8 \times 8.85 \times 10^{-14} \times 3.437}{1.6 \times 10^{-19} \times 10^{18}}}$

$=$ ~~3.85×10^{-6} cm~~ 6.69×10^{-6} cm

$Q_{induced} = -qN_A W$

$= -1.6 \times 10^{-19} \times 10^{18} \times 6.69 \times 10^{-6}$

$=$ ~~6.16×10^{-7} qC/cm^2~~ -1.0717×10^{-6} Q/cm^2

$V_t = -1.5 - \frac{5 \times 10^{10} \times 1.6 \times 10^{-19}}{1.0443 \times 10^{-6}} + \frac{1.0717 \times 10^{-6}}{1.0443 \times 10^{-6}} + 0.937$

$=$ ~~0.0193 Volts~~ 2.52 V

ii)

Q.4 (c) **(i)** A multimode graded index fiber exhibits total pulse broadening of 0.5 μs over a distance of 10 km.

Determine:

1. Pulse dispersion per unit length.
2. The maximum possible bandwidth on the link assuming no intersymbol interference while transmitting through NRZ pulse.
3. The bandwidth length product for the fiber.

(ii) A 9 km optical link consist of multimode step index fiber with a core refractive index of 1.5 and cladding refractive index of 1.45.

Determine:

1. The RMS pulse broadening due to intermodal dispersion on the link.
2. The Delay difference between the fastest and slowest modes at the fiber output.

[10 + 10 marks]

i) 1. Pulse dispersion per unit length

$$= \frac{0.5 \times 10^{-6}}{10}$$

$$= 0.05 \ \frac{\mu s}{km}$$

2. $\delta T_s = 0.5 \ \mu sec.$

maximum possible bandwidth $= \frac{1}{2\delta T_s}$

$= \frac{1}{2 \times 0.5 \mu sec}$

$= 1$ MHZ.

3. Bandwidth length product $= 1 \times 10$

$= 10$ MHZ−km

ii) $L = 9$ km $n_1 = 1.5$ $n_2 = 1.45$

1. The rms pulse broadning

$= \frac{L n_1 \Delta}{2\sqrt{3}\, c}$

$(NA) = \sqrt{n_1^2 - n_2^2} = n_1 (2\Delta)^{\frac{1}{2}}$

$\Delta = \frac{(n_1^2 - n_2^2)}{2 n_1} = \frac{1.5^2 - 1.45^2}{2 \times 1.5} = 0.04917.$

RMS pulse broadning $= \frac{9 \times 10^3 \times 1.5 \times 0.04917}{2\sqrt{3} \times 3 \times 10^8}$

$= 6.386 \times 10^{-7}$ sec

2. Delay difference $= \frac{L n_1 \Delta}{c}$

$= 2.21 \times 10^{-6}$ sec.

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

Q.5 (a) A message signal $m(t) = \cos 2000\pi t + 2\cos 4000\pi t$ modulates the carrier $c(t) = 100\cos 2\pi f_c t$, where $f_c = 1$ MHz to produce the DSB signal $m(t) \times c(t)$.

(i) Determine the expression for the upper sideband (USB) of the DSB signal.

(ii) Determine and sketch the spectrum of the USB signal.

[12 marks]

i)

$m(t).c(t) = [\cos 2000\pi t + 2\cos 4000\pi t] \times [100 \cos 2\pi f_c t]$

$= 100 \cos 2\pi f_c t \cos 2000\pi t + 200 \cos 2\pi f_c t \cos 4000\pi t$

$= 50[\cos 2\pi(f_c+1000)t + \cos(2\pi(f_c - 1000)t] +$

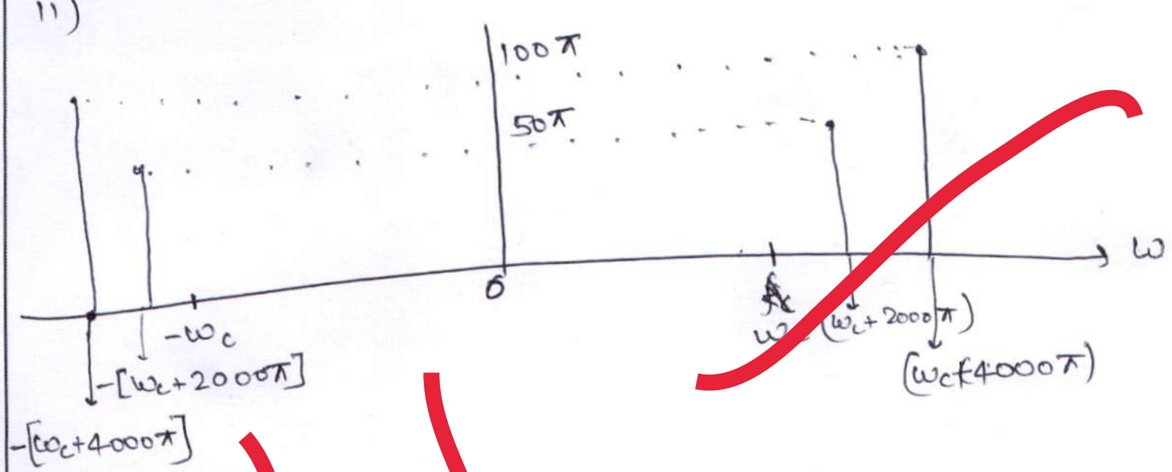
$100[\cos 2\pi(f_c+2000)t + \cos 2\pi(f_c-2000)t]$

$USB = 100 \cos 2\pi(f_c+2000)t + 50 \cos 2\pi(f_c+1000)t$

$LSB = 50 \cos 2\pi(f_c-1000)t + 100 \cos 2\pi(f_c-2000)t$

$\cos \omega_0 t \xleftrightarrow{F.T.} \pi[\delta(\omega-\omega_0) + \delta(\omega+\omega_0)]$

ii)



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Q.5 (b) Find the Z-transform of given signal and also draw ROC:

$$x[n]=\left(\frac{1}{3}\right)^n \sin\left(\frac{\pi}{4}n\right)u[n]$$

[12 marks]

$$X(z) = \sum_{-\infty}^{\infty} x(n) z^{-n}$$

$$= \sum_{0}^{\infty} \left(\frac{1}{3}\right)^n \left[\frac{e^{j\frac{\pi}{4}n} - e^{-j\frac{\pi}{4}n}}{2j}\right] z^{-n}$$

$$= \frac{1}{2j}\left[\sum_{0}^{\infty}\left\{\left(\frac{1}{3}e^{j\frac{\pi}{4}}z^{-1}\right)^n - \left(\frac{1}{3}e^{-j\frac{\pi}{4}}z^{-1}\right)^n\right\}\right]$$

$$= \frac{1}{2j}\left[\frac{1}{1-\frac{1}{3}e^{j\frac{\pi}{4}}z^{-1}} - \frac{1}{1-\frac{1}{3}e^{-j\frac{\pi}{4}}z^{-1}}\right]$$

$$= \frac{1}{2j}\left[\frac{1-\frac{1}{3}e^{-j\frac{\pi}{4}}z^{-1} - 1 + \frac{1}{3}e^{j\pi/4}z^{-1}}{\left(1-\frac{1}{3}e^{j\frac{\pi}{4}}z^{-1}\right)\left(1-\frac{1}{3}e^{-j\frac{\pi}{4}}z^{-1}\right)}\right]$$

$$= \frac{\left[\frac{\frac{1}{3}e^{j\frac{\pi}{4}}z^{-1} - \frac{1}{3}e^{-j\frac{\pi}{4}}z^{-1}}{2j}\right]}{1-\frac{1}{3}e^{-j\frac{\pi}{4}}z^{-1} - \frac{1}{3}e^{j\frac{\pi}{4}}z^{-1} + \frac{1}{9}z^{-2}}$$

$$= \frac{\frac{z^{-1}}{3}\sin\left(\frac{\pi}{4}\right)}{1-\frac{1}{3}\left[e^{-j\frac{\pi}{4}}z^{-1} + e^{j\frac{\pi}{4}}z^{-1}\right] + \frac{1}{9}z^{-2}}$$

$$= \frac{\frac{1}{3}\sin\frac{\pi}{4}\, z^{-1}}{1-\frac{2}{3}\cos\frac{\pi}{4}\, z^{-1} + \frac{1}{9}z^{-2}} \quad \ldots \; e^{+j\frac{\pi}{4}} + e^{-j\frac{\pi}{4}} = 2\cos\frac{\pi}{4}$$

Do not write in this margin

Q.5 (c) Describe in brief about different data transfer modes of DMA controller. How are HOLD and $\overline{HLDA}$ lines used in DMA operations? **[12 marks]**

Data transfer modes of DMA :-

1. Cycle stealing mode -
 - This is word by word data transfer mode
 - Here only one cycle is stealed from CPU when CPU is using system bus.
 - In that one cycle CPU can not use system bus & one word of data is transferred
 - Here CPU is interrupted for 1 cycle

2. Interleaved mode:-
 - Here system bus are used by DMA only when CPU doesn't requires system bus & it is executing other work.
 - It is slowest data transfer mode
 - CPU is not interrupted in this mode

3. Burst mode.
 - In this block of data is transferred.
 - Here CPU releases the control of system bus system bus is used by DMA controller for data transfer
 - Upon completion of data transfer bus control is returned to CPU. Mean while CPU is executing other work which doesnot require system bus.

- When DMA want to transfer data it sends HOLD signal to CPU. CPU executes its current instruction & sends $\overline{HLDA}$ (hold acknowledge) signal to DMA controller & transfer system bus control to DMA controller.

Q.5 (d) The carrier $C(t) = A \cos 2\pi 10^6 t$ is angle modulated (PM or FM) by the sinusoid signal $m(t) = 2 \cos 2000\,\pi t$. The deviation constants are $K_p = 1.5$ rad/V and $K_f = 3000$ Hz/V.

(i) Determine the modulation index, β_f and β_p.

(ii) Determine the bandwidth in each case using Carson's rule.

[12 marks]

i) $B_p = k_p \times m(t)|_{max}$ $\quad f_m = 1000$ HZ

$= 1.5 \times 2 = 3$ rad

$B_f = \frac{\Delta f}{f_m} = \frac{k_f A_m}{f_m}$

$= \frac{3000 \times 2}{1000}$

$B_f = 6$

ii) By carson's rule $BW = 2(B+1) f_m$

For PM, $BW = 2(B_p + 1) f_m$

$= 2(3+1) \times 1000$

$= 8$ KHZ

For FM - $BW = 2(6+1) \times 1000$

$= 14$ KHZ

Q.5 (e) An FIR system is characterized by $y[n] = 0.2x[n-2] + 0.2x[n] + 0.4x[n-3]$. If the input sequence {–1, 1, 0, –1} is applied to this system, find the summation of output $y[n]$.

[12 marks]

Taking z transform

$Y(z) = (0.2z^{-2} + 0.4z^{-3} + 0.2)\, X(z)$

$H(z) = \frac{Y(z)}{X(z)} = (0.2 + 0.2z^{-2} + 0.4z^{-3})$

Taking inverse z transform,

$h(n) = \{\underset{\uparrow}{0.2}, 0, 0.2, 0.4\}$

$x(n) = \{\underset{\uparrow}{-1}, 1, 0, -1\}$

$y(n) = x(n) * h(n)$

By linear convolution,

	0.2	0	0.2	0.4
−1	−0.2	0	−0.2	−0.4
1	0.2	0	0.2	0.4
0	0	0	0	0
−1	−0.2	0	−0.2	−0.4

$y(n) = \{\underset{\uparrow}{-0.2}, 0.2, -0.2, -0.4, 0.4, -0.2, -0.4\}$

Q.6 (a) Write a program to generate a square wave of frequency 2 kHz on ports pins P1.0 using timer 0, assuming that the clock frequency of the 8051 system is 12 MHz. Explain it in detail.

[20 marks]

Q.6 (b) Determine the cascade and parallel realizations for the system described by the system function

$$H(z)=\frac{10\left(1-\frac{1}{2}z^{-1}\right)\left(1-\frac{2}{3}z^{-1}\right)\left(1+2z^{-1}\right)}{\left(1-\frac{3}{4}z^{-1}\right)\left(1-\frac{1}{8}z^{-1}\right)\left[1-\left(\frac{1}{2}+j\frac{1}{2}\right)z^{-1}\right]\left[1-\left(\frac{1}{2}-j\frac{1}{2}\right)z^{-1}\right]}$$

[20 marks]

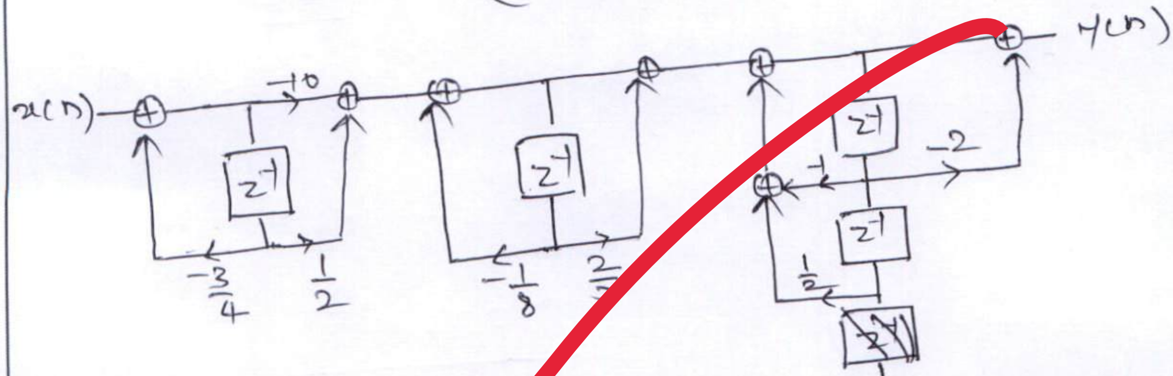
$$H(z)=\frac{10\left(1-\frac{1}{2}z^{-1}\right)\left(1-\frac{2}{3}z^{-1}\right)\left(1+2z^{-1}\right)}{\left(1-\frac{3}{4}z^{-1}\right)\left(1-\frac{1}{8}z^{-1}\right)\left[\left(1-\frac{z^{-1}}{2}-\frac{jz^{-1}}{2}\right)\left(1-\frac{1}{2}z^{-1}+j\frac{z^{-1}}{2}\right)\right]}$$

$$=\frac{10\left(1-\frac{1}{2}z^{-1}\right)\left(1-\frac{2}{3}z^{-1}\right)\left(1+2z^{-1}\right)}{\left(1-\frac{3}{4}z^{-1}\right)\left(1-\frac{1}{8}z^{-1}\right)\left[1-z^{-1}+\frac{1}{4}z^{-2}+\frac{z^{-2}}{4}\right]}$$

$$=\frac{10\left(1-\frac{1}{2}z^{-1}\right)\left(1-\frac{2}{3}z^{-1}\right)\left(1+2z^{-1}\right)}{\left(1-\frac{3}{4}z^{-1}\right)\left(1-\frac{1}{8}z^{-1}\right)\left(1-z^{-1}+\frac{1}{2}z^{-2}\right)}$$

For cascade realization using direct form II

$$10\left(\frac{1-\frac{1}{2}z^{-1}}{1-\frac{3}{4}z^{-1}}\right)\times\frac{\left(1-\frac{2}{3}z^{-1}\right)}{\left(1-\frac{1}{8}z^{-1}\right)}\times\left(\frac{1+2z^{-1}}{1-z^{-1}+\frac{1}{2}z^{-2}}\right)$$



Parallel realization

$$H(z)=\frac{A}{1-\frac{3}{4}z^{-1}}+\frac{B}{1-\frac{1}{8}z^{-1}}+\frac{Cz+D}{1-z^{-1}+0.5z^{-2}}$$

$$\therefore 10\left(1-\frac{1}{2}z^{-1}\right)\left(1-\frac{2}{3}z^{-1}\right)\left(1+2z^{-1}\right)=$$

$$A\left(1-\frac{1}{8}z^{-1}\right)\left(1-z^{-1}+0.5z^{-2}\right)+B\left(1-\frac{3}{4}z^{-1}\right)\left(1-z^{-1}+0.5z^{-2}\right)+$$

$$(Cz+D)\left(1-\frac{3}{4}z^{-1}\right)\left(1-\frac{1}{8}z^{-1}\right)$$

Put $z^{-1} = 8$

$10\times(1-4)(1-\frac{16}{3})(1+16) = B(1-6)(1-8+32)$

$(10)(-3)(-4.33) = B(-5)(25)$ $B = \frac{-17.66}{\cancel{-1.04}}$

Put $z^{-1} = 4$.

$10(1-2)(1-\frac{8}{3})(1+8) = A(1-\frac{1}{2})(1-4+8)$

$10(-1)(9)(-1.67) = 0.5\times 5A$ $A = 60$

Put $z^{-1} = 0$

$10 = A + B + D$ $D = 10 - A - B = 10 - 60 + 17.66$

$D = -32.34$

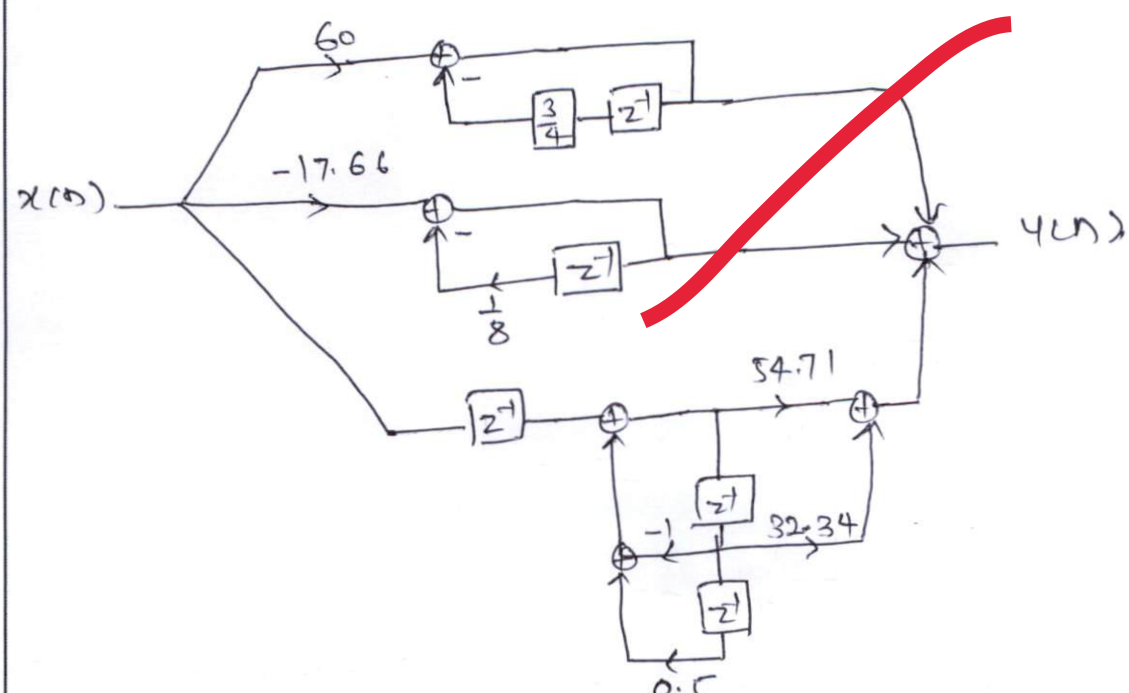
Put $z^{-1} = 1$

$10\times 0.5(\frac{1}{3})\times 8 = 60\times\frac{7}{8}\times 0.5 - 17.66\times\frac{1}{4}\times 0.5$
$+ (c - 32.34)(\frac{1}{4})(\frac{7}{8})$

$\frac{7}{32}(c - 32.34) = 5 - 26.25 + 2.2075$
$= -19.0425$

$c = -54.71$

$H(z) = \frac{60}{1-\frac{3}{4}z^{-1}} + \frac{-17.66}{1-\frac{1}{8}z^{-1}} + \frac{-54.71z - 32.34}{1 - z^{-1} + 0.5z^{-2}}$



Q.6 (c) A random process provides measurements x between the values 0 and 1 with a probability density function (PDF) given as

$$f_X(x) = 12x^3 - 21x^2 + 10x\,; \quad \text{for } 0 \le x \le 1$$
$$= 0 \quad ; \quad \text{otherwise}$$

Determine the following:

(i) $P\left[X \le \frac{1}{2}\right]$ and $P\left[X > \frac{1}{2}\right]$.

(ii) Obtain the value of K such that $P[X \le K] = \frac{1}{2}$.

[10 + 10 marks]

i) $P\left[x \le \frac{1}{2}\right] = \int_{x=0}^{\frac{1}{2}} f_x(x)\,dx$

$= \int_0^{0.5} (12x^3 - 21x^2 + 10x)\,dx$

$= \left[\frac{12x^4}{4} - \frac{21x^3}{3} + \frac{10x^2}{2}\right]_0^{0.5}$

$= \left[3x^4 - 7x^3 + 5x^2\right]_0^{0.5}$

$= 0.5625$

$P\left[x > \frac{1}{2}\right] = 1 - P\left[x \le \frac{1}{2}\right]$

$= 1 - 0.5625$

$= 0.4375$

ii) $P[x \le k] = \int_0^k f_x(x)\,dx$

$= \int_0^k (12x^3 - 21x^2 + 10x)\,dx$

$0.5 = \left[3x^4 - 7x^3 + 5x^2\right]_0^k$

$3k^4 - 7k^3 + 5k^2 = 0.5 \Rightarrow 3k^4 - 7k^3 + 5k^2 - 0.5 = 0$ —①

$k^2\left[3k^2 - 7k + 5\right] = 0.5$

8

2

$P(X \le k) = \frac{1}{2}$ so $P(X \ge k) = \frac{1}{2}$

$P(X > k) = \int_k^1 (12x^3 - 24x^2 + 10x)\,dx$

$= [3x^4 - 7x^3 + 5x^2]_k^1$

$= 3 - 7 + 5 - (3k^4 - 7k^3 + 5k^2) = 0.5$

$k^2 = 0.5$

$k = 0.707$

Q.7 (a) A pair of noise processes $n_1(t)$ and $n_2(t)$ are related by

$$n_2(t) = n_1(t)\cos(2\pi f_c t + \theta) - n_1(t)\sin(2\pi f_c t + \theta)$$

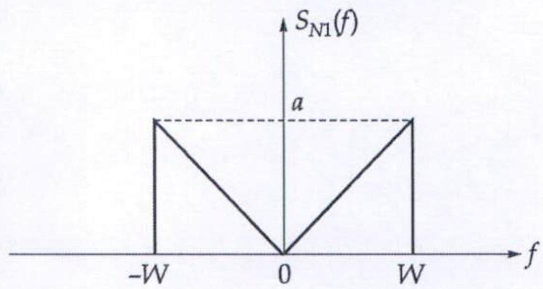
where f_c is a constant and θ is the value of a random variable θ whose probability density function is defined by

$$f_\theta(\theta) = \begin{cases} \dfrac{1}{2\pi}, & 0 \le \theta \le 2\pi \\ 0, & \text{else} \end{cases}$$

$n_1(t)$ and θ are independent.

The noise process $n_1(t)$ is stationary and its power spectral density is shown in figure below.

Find and plot the corresponding power spectral density of $n_2(t)$.

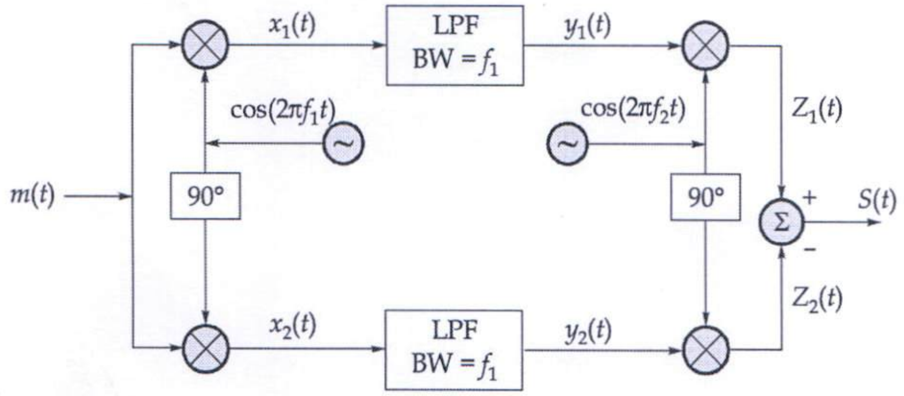


[20 marks]

Q.7 (b) Explain features and architecture of 8259 programmable interrupt controller (PIC) in details with block diagram.

[20 marks]

Q.7 (c) (i) The message signal applied to the Weaver's SSB modulator shown below is $m(t) = \cos(2\pi f_m t)$.



If $f_1 = 2f_m$ and $s(t)$ is an USSB signal with a carrier frequency of 1 MHz, then determine the value of the frequency "f_2".

(ii) Explain in brief about Quadrature-Carrier Multiplexing with its transmitter and receiver block diagram.

[10 + 10 marks]

Q.8 (a) Explain in detail about envelope detector used in demodulation of AM with circuit diagram and waveform. Also, derive equation for the optimum value of time constant (RC) of the detector circuit.

[20 marks]

Q.8 (b) (i) Explain the operation of phase locked loop (PLL) using block diagram.

(ii) Derive the expression for PLL detection of FM signals.

[20 marks]

Q.8 (c) Determine the variance of the round-off noise at the output of the two cascade realization of filter with system function

$$H(z) = H_1(z)\,H_2(z)$$

where $$H_1(z) = \frac{1}{1-\frac{1}{2}z^{-1}}$$

$$H_2(z) = \frac{1}{1-\frac{1}{4}z^{-1}}$$

[20 marks]

OOOO

Space for Rough Work

$\frac{2.4}{8} = \lambda$