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Leading Institute for ESE, GATE & PSUs

ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

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

Analog & Digital Communication Systems-1 [Part Syllabus]

Digital Circuit-2 + Microprocessors and Microcontroller-2 [Part Syllabus]


Name :

Roll No :

Test Centres	Student's Signature
Delhi <input checked="" type="checkbox"/> Bhopal <input type="checkbox"/> Jaipur <input type="checkbox"/> Pune <input type="checkbox"/> Hyderabad <input type="checkbox"/>	

- 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	24
Q.2	
Q.3	22
Q.4	
Section-B	
Q.5	53
Q.6	36
Q.7	
Q.8	38
Total Marks Obtained	173

Signature of Evaluator  Cross Checked by

15/4/26
 o Rense Adv. Comm Q&A

o Keep it up dear - student - -

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.

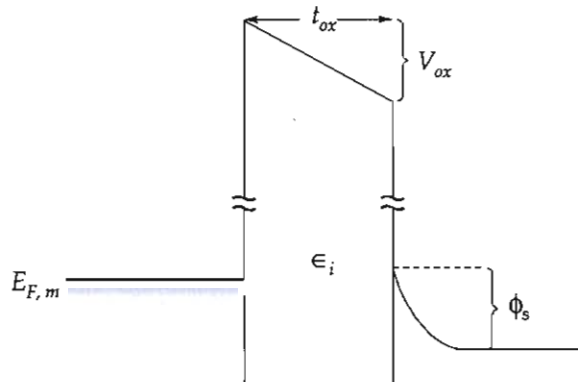
DO'S

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

Q.1 (a) A metal-oxide-semiconductor in equilibrium is shown below:

(Assume that the oxide is free of any charges or traps)



Given, $t_{ox} = 10 \text{ nm}$, $V_{ox} = 0.4 \text{ V}$, $\epsilon_i \epsilon_0 = 40 \times 10^{-14} \text{ F/cm}$, $\epsilon_s \epsilon_0 = 100 \times 10^{-14} \text{ F/cm}$.

Determine:

- The type of the semiconductor shown in the diagram and value of ϕ_s .
- The metal-semiconductor work-function difference.
- The MOS capacitance at equilibrium is determined to be

$$C(V=0)_{\text{MOS}} = \frac{1}{3} \times 10^{-7} \text{ F/cm}^2. \text{ What is the width, } W(V=0)?$$

[4 + 4 + 4 marks]

Q1 (a) (i) From observation, the band bends according to an N-type semiconductor characteristic.

And hence, semiconductor is N-type.

The value of ϕ_s would be same as the band bending in the oxide region.

$$\phi_s = 0.4 \text{ V}$$

incomplete solution

- Q.1 (b) Under standard test conditions ($T = 300 \text{ K}$), an ideal solar cell has a photogenerated current of 3.5 A , dark saturation current of $3.22 \times 10^{-11} \text{ A}$, and power at the maximum power point of 1.75 W . Determine its open circuit voltage (V_{OC}) and fill factor.

[12 marks]

Q1. (b) Given: Ideal solar cell

$$I_{ph} = 3.5 \text{ A} \quad T = 300 \text{ K}$$

$$I_0 = 3.22 \times 10^{-11} \text{ A}$$

$$P_m = 1.75 \text{ W}$$

Statement: for a solar cell, current equation is defined as,

$$I = I_{ph} - I_0 \left(e^{\frac{V}{\eta V_T}} - 1 \right)$$

under oc & sc conditions,

$$I_{sc} = I_0 \left(e^{\frac{V_{oc}}{\eta V_T}} - 1 \right)$$

$$\therefore V_{oc} = \eta V_T \ln \left(1 + \frac{I_{sc}}{I_0} \right)$$

we know,

$$I_{sc} = I_{ph} \text{ only}$$

$$\therefore V_{oc} = 1 \times 0.0258 \ln \left[\frac{1 + 3.5}{3.22 \times 10^{-11}} \right]$$

Hence, $V_{oc} = 0.655 \text{ volts}$ — (1)

Statement: Form factor is defined as

$$\text{Form factor} = \frac{P_{max}}{V_{oc} \times I_{sc}}$$

~~Good~~

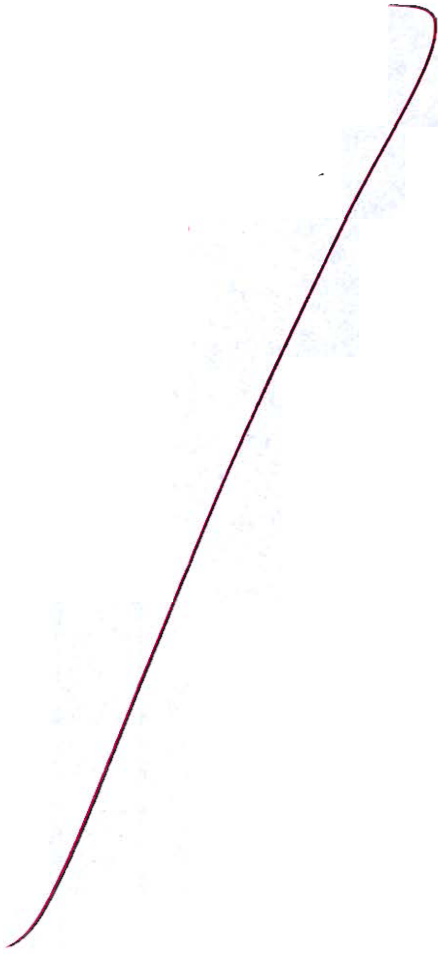
$$\therefore F.F = \frac{1.75}{0.655 \times 3.5}$$

Hence, $FF = 0.763$ — (2)

Conclusion: Hence (1) & (2) are the respective answers.

- Q.1 (c)
- (i) What is meant by foliage? Define foliage loss.
 - (ii) How is location of cell-site and mobile unit influenced by foliage loss?

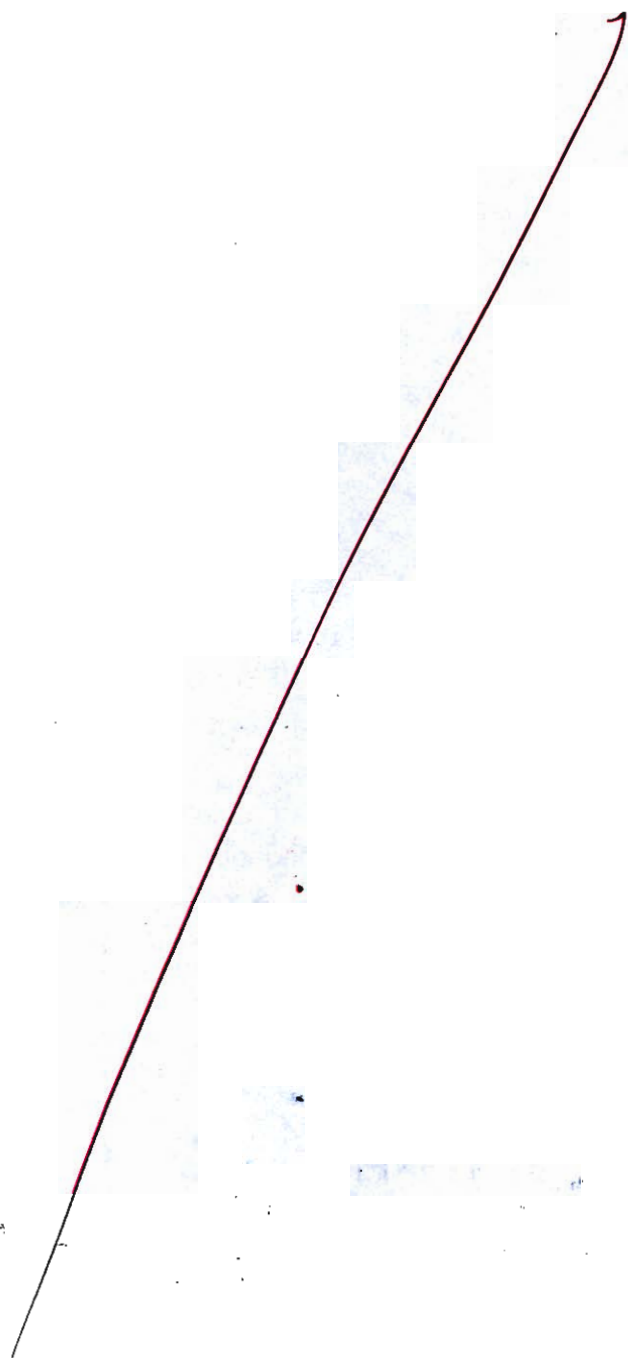
[6 + 6 marks]



- Q.1 (d) Determine the propagation path loss for a radio signal at 900 MHz cellular system operating in a large urban city, with a base station Tx antenna height of 100 m and mobile Rx antenna height of 2 m. The mobile unit is located at a distance of 4 km. Use the Hata propagation path loss model.

[12 marks]

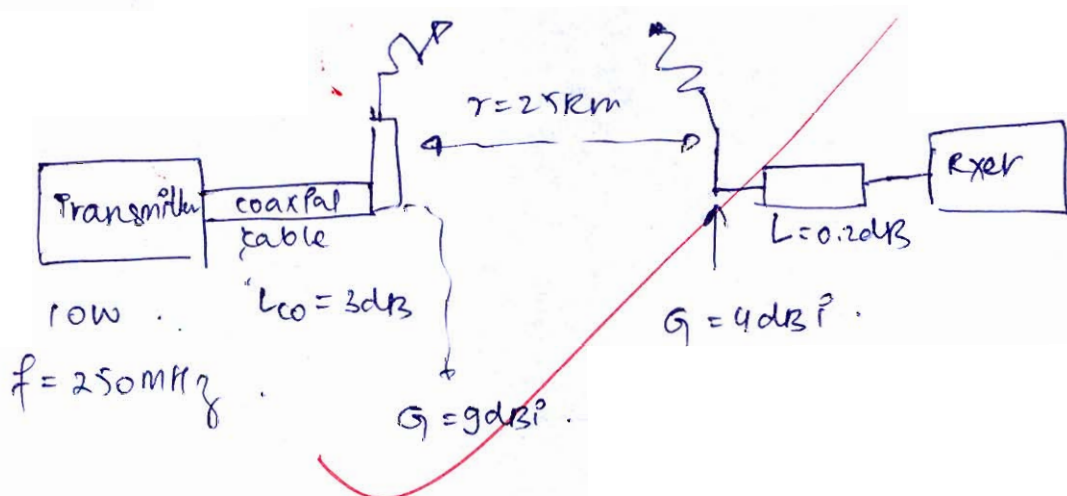
Q1 (d) given : $f = 900 \text{ MHz}$
 $h_t = 100 \text{ m}$
 $h_r = 2 \text{ m}$



- Q.1 (e) 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- Ω impedance, but the receiver input has 75- Ω impedance, resulting into a mismatch loss of about 0.2 dB. Calculate the power delivered to the receiver, assuming free-space propagation.

[12 marks]

Q1 (e) A9Q,



we know, $[P_{\text{transmitted}}] = [P]_{\text{input}} + [\text{losses}] - [G]$

$$[P]_{\text{trans}} = 10 - 3 - 9 = 7 \text{ dB}$$

$$(P)_{\text{input}} = 10 \log_{10} 10 \\ = 10 \text{ dB}$$

from Friis relation,

$$P_{\text{Received}} = \frac{P_t G_t G_r}{L_s L_{\text{rxd}}}$$

$$(P_{\text{rxd}})_{\text{dB}} = (P_t) + (G_t) + (G_r) - [L_s] - [L_{\text{rxd}}]$$

$$[L_s] = 32.5 + 20 \log_{10}(250) + 20 \log_{10}(25) \\ = 32.5 + 47.95 + 27.95 \\ = 108.40 \text{ dB}$$

$$[P_{\text{rxd}}] = 10 + 9 + 4 - 108.40 - 0.2 \\ = -85.60 \text{ dB}$$

∴ Power delivered to receiver,

$$P_{\text{rxd}} =$$

$$-85.60 = 10 \log_{10} P_{\text{rxd}}$$

$$P_{\text{rxd}} = 2.74 \times 10^{-9} \text{ watts}$$

$$P_{\text{rxd}} = 2.74 \text{ nWatts}$$

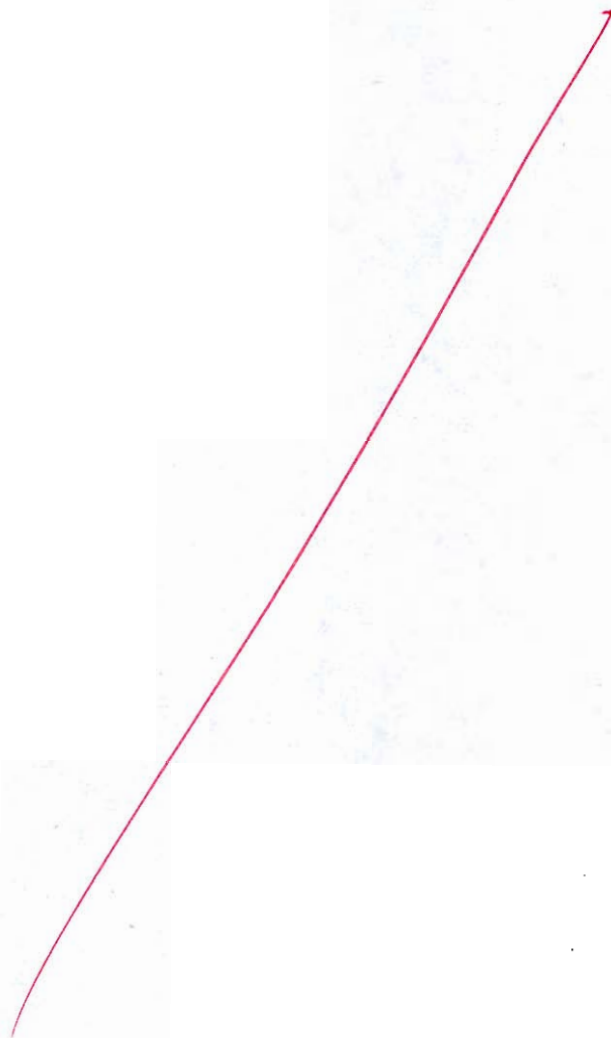
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- Q.2 (a) Consider that a geographical service area of a cellular system is 4200 km^2 . A total of 1001 radio channels are available for handling traffic. Suppose the area of a cell is 12 km^2 .
- How many times would the cluster of size 7 have to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

[10 + 10 marks]



Q.2 (b) A uniformly doped silicon npn bipolar transistor at $T = 300$ K has parameters: emitter doping, $N_E = 2 \times 10^{18} \text{ cm}^{-3}$, Base doping, $N_B = 2 \times 10^{16} \text{ cm}^{-3}$ and collector doping, $N_C = 2 \times 10^{15} \text{ cm}^{-3}$. The neutral basewidth $x_{B0} = 0.85 \mu\text{m}$, and electron diffusion coefficient in base, $D_n = 25 \text{ cm}^2/\text{s}$. Assume $x_{B0} \ll L_n$ where L_n : diffusion length of electron, $V_{BE} = 0.65 \text{ V}$, $\epsilon_{\text{si}} = 11.7\epsilon_0$, $n_i = 1 \times 10^{10} \text{ cm}^{-3}$, $V_T = 0.026 \text{ V}$.

(i) Determine the electron diffusion current density in the base for

1. $V_{CB} = 4 \text{ V}$
2. $V_{CB} = 8 \text{ V}$
3. $V_{CB} = 12 \text{ V}$

(ii) Estimate the Early voltage by using the data in part (i). (Use linear approximation for current density versus $\frac{1}{x_B}$).

[14 + 6 marks]



- Q.2 (c)
- (i) Define Linear Scattering losses in optical fiber and its types in brief.
 - (ii) Define and explain the following terms with respect to Telecommunication systems:
 1. Grade of service
 2. Offered traffic
 3. Delay system
 4. Loss system

[12 + 8 marks]

- Q.3 (a) (i) A multimode graded index fiber exhibits total pulse broadening of $0.5 \mu\text{s}$ 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]

Q3 (a) (i) Given: $L = 10 \text{ km}$.

$$\Delta t = 0.5 \mu\text{sec}$$

• multimode graded index fibre.

Statement: ①. Pulse dispersion per unit length

$$\text{Pulse Dispersion} = \frac{\Delta t}{L} = \frac{0.5 \times 10^{-6}}{10 \times 10^3}$$

$$= 0.5 \times 10^{-10} \text{ sec/m}$$

10 ns - km

② Assume NRZ pulses,

$$\therefore \text{B.W} = \frac{R_b}{2}$$

$$\text{also, } R_b \leq \frac{1}{2T}$$

$$R_b \leq 1 \text{ MHz}$$

$$\therefore \text{Hence } \boxed{(\text{B.W})_{\text{NRZ}} = 0.5 \text{ MHz}}$$

$$\text{Bandwidth length product} \\ = 0.5 \text{ MHz} \times 10 \text{ km}.$$

$$\boxed{\text{BWL} = 5 \text{ MHz} \cdot \text{km}}$$

Q3

(b) (ii) Given: $L = 9 \text{ km}$.

mmms 1

$n_1 = 1.5$

$n_2 = 1.45$

Statement:

pulse

broadening

$$\Delta f = \frac{Ln_1}{c} \cdot \Delta \quad (\text{for S.I fibre})$$

$$\Delta f = \frac{9 \times 10^3 \times 1.5}{3 \times 10^8} \left[\frac{n_1^2 - n_2^2}{2n_1^2} \right]$$

$$\Delta f = 1.475 \text{ microseconds} \quad \text{--- (1)}$$

~~10~~
RMS pulse
broadening
400 ✓

$$\text{broadening } (\sigma_s) = \frac{\Delta f}{2\sqrt{3}}$$

$$\sigma_s = \frac{1.475}{2\sqrt{3}}$$

$$\boxed{\sigma_s = 4.025 \times 10^{-7}} \quad \text{--- (2)}$$

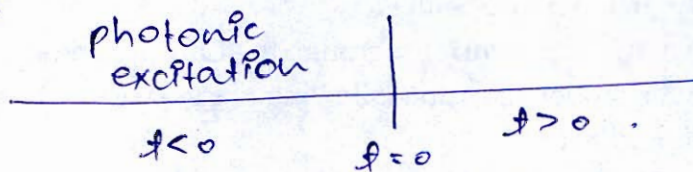
Conclusion:

Hence (1) & (2) are the respective answers.

- Q.3 (b) (i) An n -type Si sample with $N_D = 10^{15}/\text{cm}^3$ is steady illuminated such that $g_{op} = 10^{21}$ EHP/ $\text{cm}^3\text{-s}$. If $\tau_n = \tau_p = 1 \mu\text{sec}$ for this excitation, calculate the separation in the Quasi Fermi levels, $(F_n - F_p)$.
(Assume for Si at 300 K, $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$, $KT = 0.026 \text{ eV}$)
- (ii) A semiconductor sample is exposed to a photonic excitation for a long time ($t < 0$). Under low level injection, derive the equation governing the decay of excess carrier and life time of carrier if the excitation is removed at $t = 0$.

[10 + 10 marks]

Q3 (b)(ii) given: Time Instances,



which is,

$$g_p \neq 0$$

$$g_p = 0$$

statement: using continuity equations as reference,

$$\frac{dp}{dt} = -\frac{1}{q} \frac{d}{dx} J_p(x) + g_p - r_p$$

under low, level injection condition,

$$\frac{dp}{dt} = q D_p \frac{d^2 p}{dx^2} + g_p - r_p$$

for $t > 0$, $g_p = 0$.

$$\frac{dp}{dt} = q D_p \frac{d^2 p}{dx^2} - r_p$$

$$r_p = \frac{dp}{\tau_p} \quad [\text{Recombination Rate}]$$

on solving,

$$p(x, t) = p_{n0} (e$$

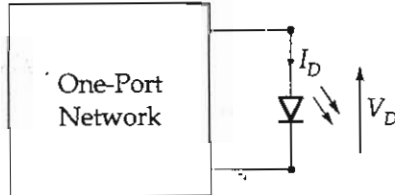
①

- Q.3 (c) (i) A light emitting diode (LED) is connected across the terminal of the one-port network as shown in the figure below.

The relationship between the current through the LED (I_D) and the voltage across the LED (V_D) can be modelled by the following piece-wise function:

$$I_D = 0 \text{ amperes, for } V_D < 1.5 \text{ V}$$

$$I_D = 0.03 \times V_D - 0.045 \text{ Amperes, for } V_D > 1.5 \text{ V}$$



Assume the LED is ON and considering the Thevenin equivalent of the network as V_{TH} and R_{TH} calculate the value of I_D and V_D .

- (ii) Consider an npn Si bipolar junction transistor which is to be designed with an emitter efficiency of $\gamma_e = 0.995$. To maintain a reasonable base resistance, the base is doped with boron for $N_A = 1.2 \times 10^{16} \text{ cm}^{-3}$. Given that diffusion length of electron and effective base width, $L_e \approx W_b = 0.7 \mu\text{m}$, minority carrier diffusion coefficients in emitter and base regions are $12 \text{ cm}^2\text{s}^{-1}$ and $30 \text{ cm}^2\text{s}^{-1}$ respectively and minority electron concentration in the base region is $1.88 \times 10^4 \text{ cm}^{-3}$. Calculate the n -type doping concentration needed in the emitter.

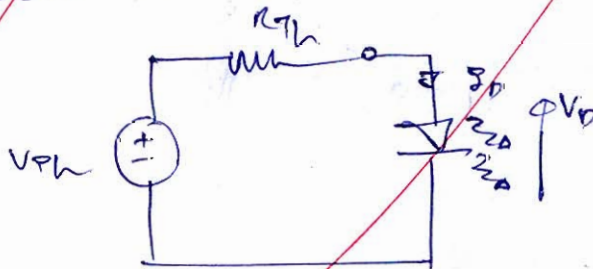
[10 + 10 marks]

Q3

(c)(i) given: $I_D = 0$ $V_D < 1.5 \text{ V}$

$$I_D = 0.03V_D - 0.045 \quad V_D > 1.5 \text{ V}$$

Replacing the circuit by Thevenin's equivalent circuit.



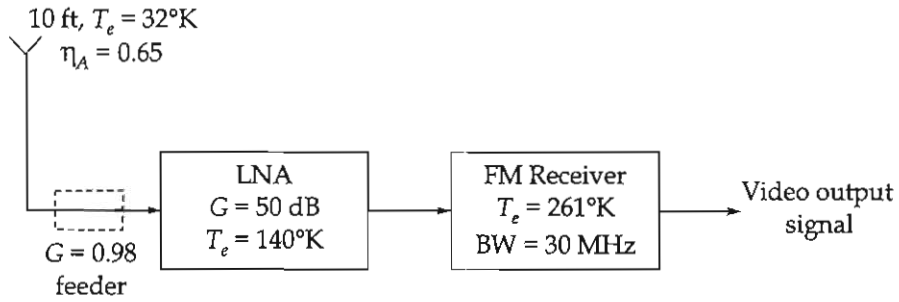
- Q.4 (a) (i) Consider a uniformly doped n -channel silicon JFET with the following parameters:
 $N_A = 10^{19} \text{ cm}^{-3}$, $N_D = 3 \times 10^{16} \text{ cm}^{-3}$, $a = 0.40 \text{ } \mu\text{m}$
 The drain-to-source voltage applied is $V_{DS} = 5 \text{ V}$ and $V_{GS} = 0$. If the effective channel length L' is the 90% of the original channel length L , then determine the value of L . Assume $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$, $V_t = 0.026 \text{ V}$ and $\epsilon_{\text{Si}} = 1.06 \times 10^{-12} \text{ F/cm}$. Also assume that the depletion region at pinched-off portion is equally extended into the channel and drain side neutral regions.
- (ii) Illumination of n -type Si ($N_d = 10^{16} \text{ cm}^{-3}$) generates $20^{21} \text{ cm}^{-3}/\text{s}$ electron-hole pairs. Si has $N_t = 10^{15} \text{ cm}^{-3}$ generation-recombination centers with $\sigma_n = \sigma_p = 10^{-16} \text{ cm}^2$. Calculate equilibrium concentration of electrons and holes if $E_t = E_i$, where E_i is the fermi level of intrinsic Si, and Thermal velocity, $V_t = 10^7 \text{ cm/s}$.

[10 + 10 marks]

- Q.4 (b)
- (i) For an MOSFET with sufficient drain voltage to be in saturation (under constant mobility condition), the drain current is $50 \mu\text{A}$ at $V_{GS} = 1 \text{ V}$ and $200 \mu\text{A}$ at $V_{GS} = 3 \text{ V}$. Find the threshold voltage of the MOSFET.
- (ii) Different parameters, with their usual notations, of an ideal n -channel MOSFET with a silicon substrate, are: $N_A = 10^{16} \text{ cm}^{-3}$, $t_{ox} = 500 \text{ \AA}$, $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$, $kT = 0.026 \text{ eV}$, $\epsilon_{si} = 1.06 \times 10^{-12} \text{ F/cm}$ and $\epsilon_{ox} = 3.45 \times 10^{-13} \text{ F/cm}$. Determine the threshold voltage of the MOSFET.

[10 + 10 marks]

- Q.4 (c) A typical receiver shown in figure below is used to receive the TV signals from geostationary satellite. If the above system works with satellite of EIRP + 36 dBW at 4 GHz downlink frequency, determine the carrier to noise ratio at the demodulator input. Assume slant distance of 39,500 km between the satellite and the earth station.



[20 marks]

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

Q.5 (a) (i) The equivalent noise bandwidth of a system is defined as

$$B_{eq} = \frac{1}{2\pi} \frac{\int_0^{\infty} |H(\omega)|^2 d\omega}{|H(\omega)|_{max}^2} \text{ Hz}$$

where $|H(\omega)|_{max}^2 = \max |H(\omega)|^2$

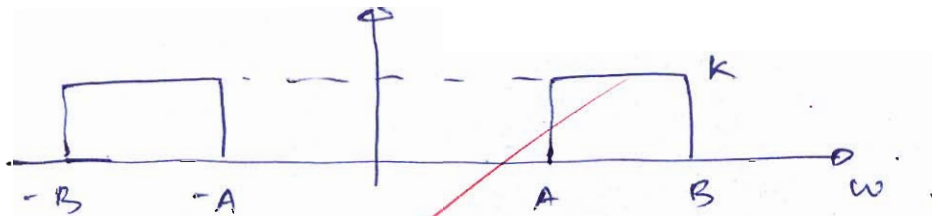
Determine the equivalent noise bandwidth of the ideal band-pass filter and that of a low pass RC filter.

(ii) Derive the expression for the probability of error of the bipolar bandband signal, assuming additive white Gaussian noise.

[6 + 6 marks]

Q5 (a) (i) for an ideal band pass filter,

let, $H(\omega)$



$|H(\omega)| = k$

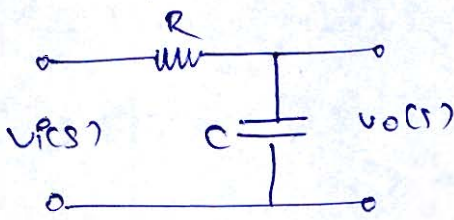
$|H(\omega)|^2 = k^2$

∴ ATQ

$$B_{eq} = \frac{1}{2\pi} \frac{\int_A^B k^2 d\omega}{k^2} = \frac{1}{2\pi} [\omega]_A^B$$

$$B_{eq} = \frac{(B - A)}{2\pi} \text{ Hz}$$

for low pass RC network



$$V_o(s) = V_i(s) \times \frac{1}{R + \frac{1}{Cs}}$$

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

$$H(\infty) = \frac{1}{j\omega RC + 1} ; |H(\omega)| = \frac{1}{\sqrt{1 + \omega^2 R^2 C^2}}$$

$$|H(\omega)|^2 = \frac{1}{1 + \omega^2 R^2 C^2}$$

$$B_{eq} = \frac{1}{2\pi} \int_0^{\infty} \frac{1}{1 + \omega^2 R^2 C^2} \cdot d\omega$$

$$\left\{ \begin{array}{l} \lim_{\omega \rightarrow 0} |H(\omega)|^2 = 1 \\ @ \omega = 0 \end{array} \right\}$$

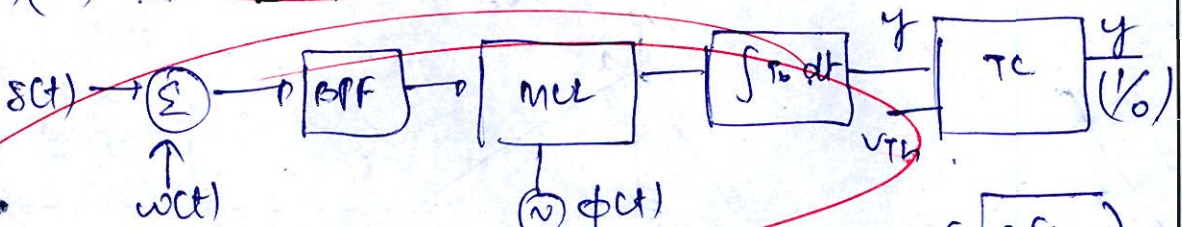
$$B_{eq} = \frac{1}{2\pi} \int_0^{\infty} \frac{1/R^2 C^2}{\frac{1}{R^2 C^2} + \omega^2} \cdot d\omega$$

$$B_{eq} = \frac{1}{2\pi} \times \frac{1}{R^2 C^2} \times R^2 C^2 \tan^{-1} \left[\frac{\omega RC}{1} \right]_0^{\infty}$$

$$B_{eq} = \frac{1}{2\pi} \left[\frac{\pi}{2} \right] = \frac{1}{4} \text{ Hz}$$

$$\therefore B_{eq} = 0.25 \text{ Hz}$$

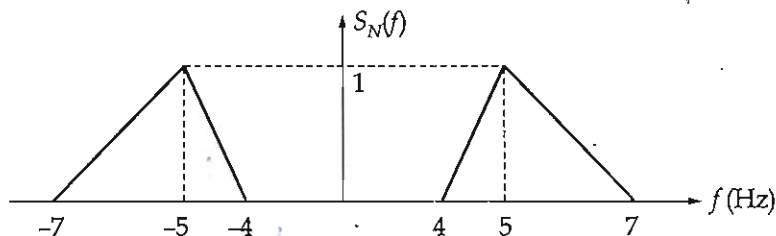
Q5 (a) (ii) $S = +A$



$$P_e = P(0)P\left(\frac{1}{0}\right) + P(1) \cdot P\left(\frac{0}{1}\right) \quad \cdot P_e = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

on calculation using G.R.V expression, $[E_b = A^2 \times T_b]$

- Q.5 (b) The Power Spectral Density (PSD) of a narrowband noise $n(t)$ is shown in the figure. The carrier frequency is $f_c = 5$ Hz. Assuming the peak value of PSD is 1 W/Hz.



1. Find and sketch the PSDs of the in-phase component $S_{NI}(f)$ and quadrature component $S_{NQ}(f)$.
2. Calculate the total average power of the original narrow band noise $n(t)$.
3. Determine if the in-phase and quadrature components are uncorrelated by examining their cross-spectral density $S_{NI,NQ}(f)$.

[6 + 3 + 3 marks]

Q.5 (b) (1)

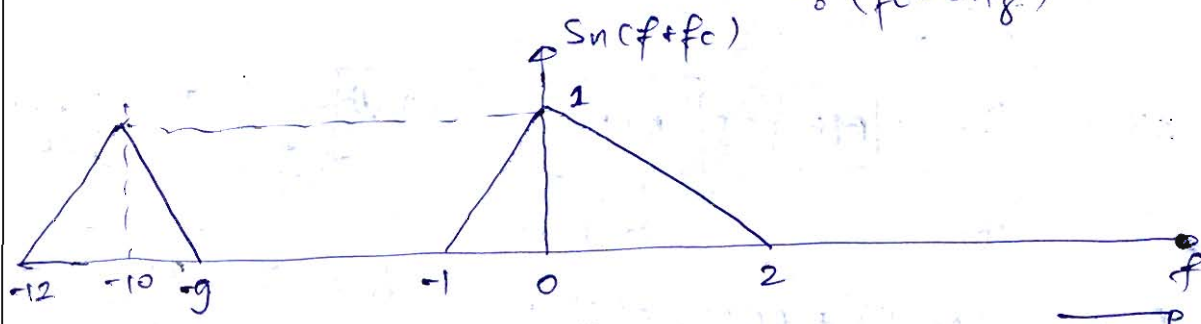
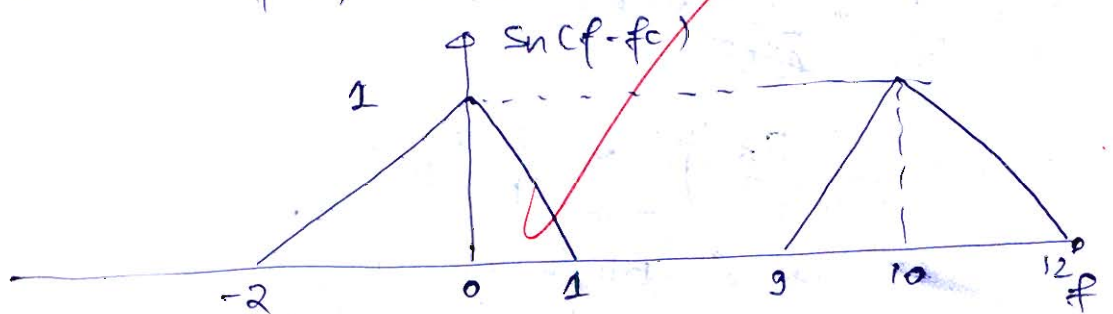
Given: PSD of noise: $S_N(f)$

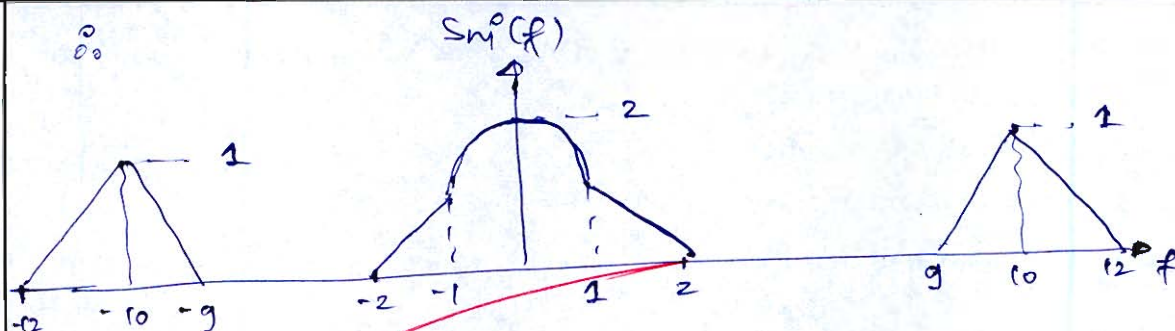
statements: The relationship between in-phase and quadrature components of noise is,

$$S_{NI}(f) = S_{NQ}(f) = S_n(f - f_c) + S_n(f + f_c)$$

hence,

for, $S_{NI}(f)$





(2) Total average power of $n(t)$:

We know, Power from PSD is the total area under PSD.

Since $S_{N^o}(f)$ is even.

$$\begin{aligned} \text{Power}[n(t)] &= \int_{-\infty}^{\infty} S_{N^o}(f) \cdot df = 2 \int_0^{\infty} S_{N^o}(f) \cdot df \\ &= 2 \times \left[\frac{1}{2} \times 1 \times 1 + \frac{1}{2} \times 2 \times 1 \right] \\ &= 3 \text{ watts.} \end{aligned}$$

Hence power is 3 watts

(3) cross correlation is defined as;

$$R_{XY}(z) = R_X(z) * R_Y(-z).$$

P_n terms of PSD,

$$\Rightarrow S_X(f) \cdot S_Y(-f).$$

for P_n -phase and quadrature components, the PSD characteristics is the same.

$$\text{also, } S_Y(-f) = S_Y(f).$$

Hence, The PSD's exist for the given spectrum, making the components not uncorrelated with each other.

Q.5 (c) What output voltage would be produced by a DAC whose output range is 0 to 10 V for the following input binary numbers?

(i) 10 (for a 2-bit D/A converter)

(ii) 0110 (for a 4-bit DAC)

(iii) 10111100 (for a 8-bit DAC)

[12 marks]

Q5
cc) given: output range = 0 to 10 V.

statement: for a DAC, the voltage (output)

is defined as,

$$V_{out} = \text{Resolution} \left[\text{decimal equivalent} \right]$$

Here, Resolution $(R) = \frac{V_{FS}}{2^n - 1}$ (V_{FS} : full scale voltage)

given, $V_{FS} = 10V$.

(i) $\therefore R = \frac{10}{2^2 - 1}$ (for case (i) $n = 2$).

$$\therefore R = \frac{10}{3}$$

Hence $V_{out} = \frac{10}{3} \times 2$ [$\therefore (10)_2 = (2)_{10}$]

$$\boxed{V_{out} = 6.67 \text{ volts}} \quad - \textcircled{1}$$

(ii) Input = 0110.

$$R = \frac{10}{2^4 - 1} = \frac{2}{3}$$

$$V_{out} = \frac{2}{3} \times 6$$
 [$\therefore (0110)_2 \Rightarrow (6)_{10}$]

Hence $V_{out 2} = 4V$ - (2)

(iii) Input = $(1011100)_2 = (188)_{10}$

$$R = \frac{10}{28-1} = \frac{10}{255}$$

$$V_{out} = \frac{10}{255} \times 188$$

$V_{out 3} = 7.37V$ - (3)

Conclusion: Hence (1), (2) & (3) are the respective output voltages.

Q.5 (d) Design a J-K flip-flop using a D flip-flop and a 4×1 MUX. Write various steps involved in the process.

[12 marks]

Q.5 (d) desire to design JK flip flop,

Truth Table for JK is,

J	K	Q^+	action
0	0	Q	[Hold]
0	1	0	[Reset]
1	0	1	[Set]
1	1	\bar{Q}	[Toggle]

Excitation Table for D can also be calculated

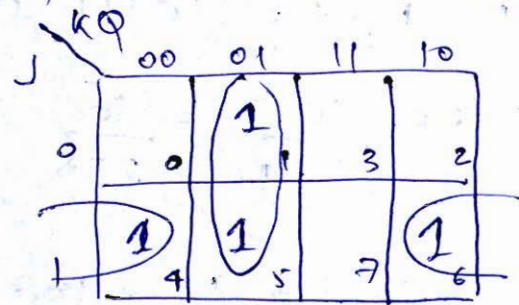
Q	Q^+	D
0	0	0
0	1	1
1	0	0
1	1	1

$$Q^+ = D$$

making a table .

J	K	Q	Q+	D
0	0	0	0	0
0	0	1	1	1
0	1	0	0	0
0	1	1	0	0
1	0	0	0	1
1	0	1	1	1
1	1	0	0	1
1	1	1	0	0

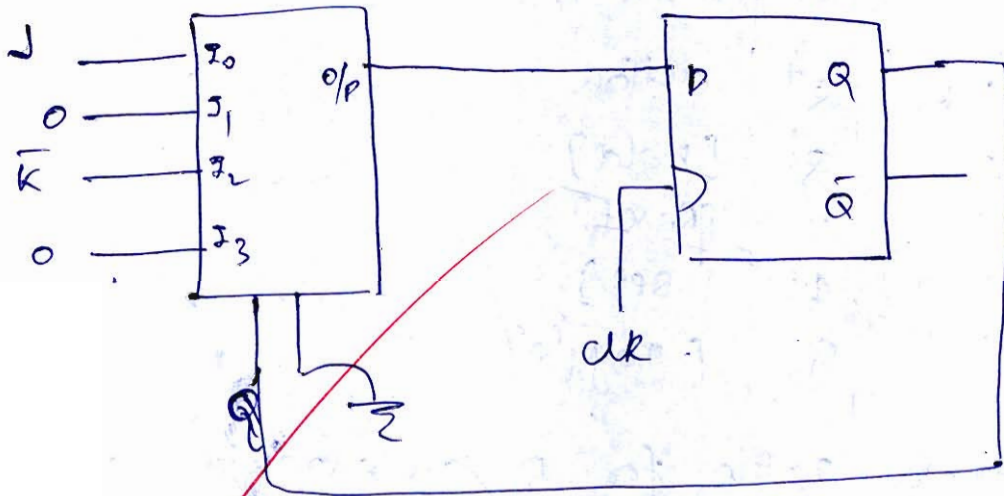
Respective K-map for D



$$D = J\bar{Q} + \bar{K}Q$$

Table for PS and NS relationship.

circuit diagram,



desired circuit

Q.5 (e) Implement the following functions using PLA.

$$F_1 = \sum m(2, 4, 5, 10, 12, 13, 14)$$

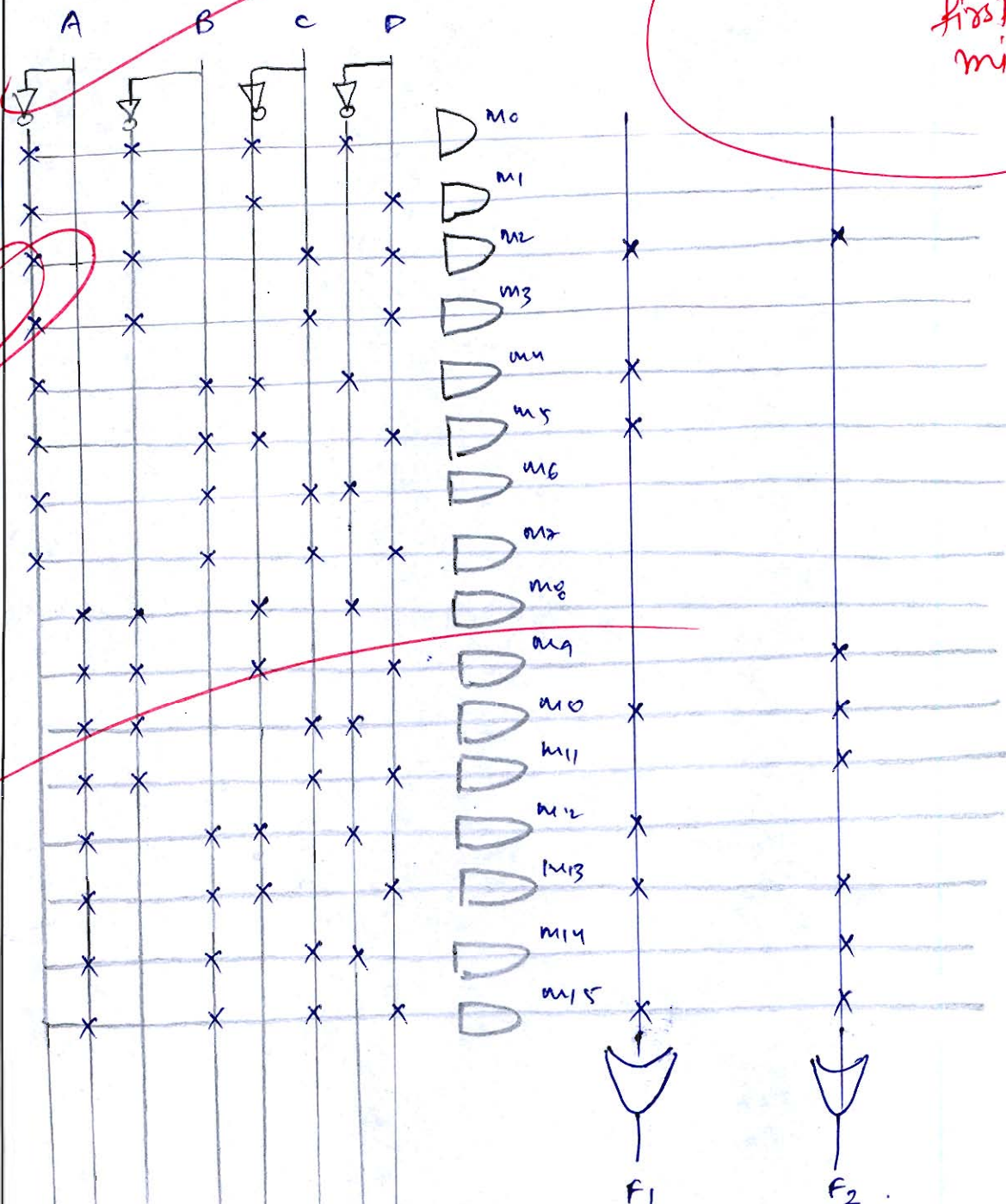
$$\text{and } F_2 = \sum m(2, 9, 10, 11, 13, 14, 15)$$

[12 marks]

Q5 (e) statement: for a PLA design, both AND and OR gates are programmable.

upto 15 minterms are there and hence there would be 4 inputs

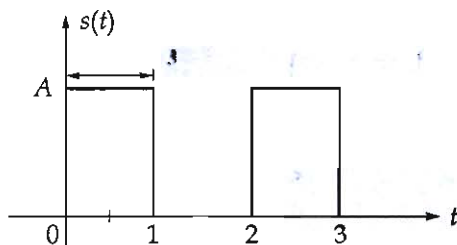
Dear student you should first minimize F_1 and F_2



PLA DESIGN

Conclusion: Hence, the above is the
desired PLA design logic implementation

- Q.6 (a) The received signal in a binary communication system that employs antipodal signals is $r(t) = s(t) + n(t)$, where $s(t)$ is shown in the figure below and $n(t)$ is AWGN with power spectral density $\frac{N_0}{2}$ W/Hz.

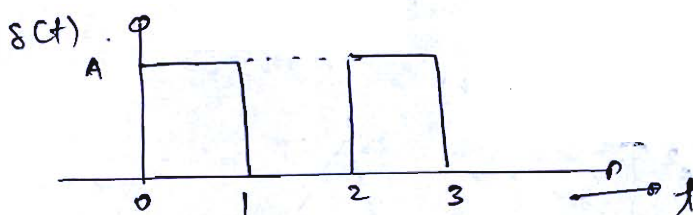


- Sketch the impulse response of the filter matched to $s(t)$.
- Sketch the output of the matched filter when the input is $s(t)$.
- Determine the variance of the noise at the output of the matched filter at $t = 3$.
- Determine the probability of error as a function of A and N_0 .

[20 marks]

Q.6.

(a) given:



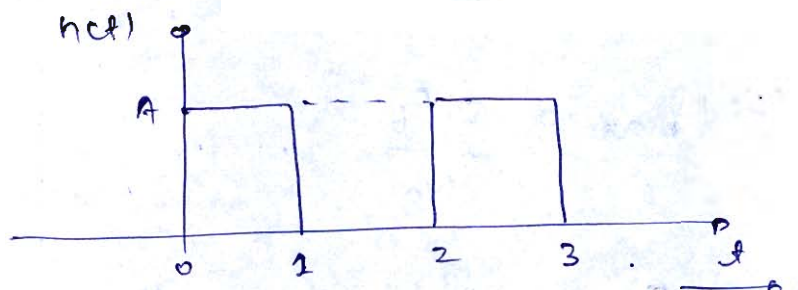
(i)

statement: Impulse response related to matched filter is given by relation,

$$h(t) = s(T-t), \quad T: \text{Time period of } s(t).$$

$$\therefore h(t) = s(3-t)$$

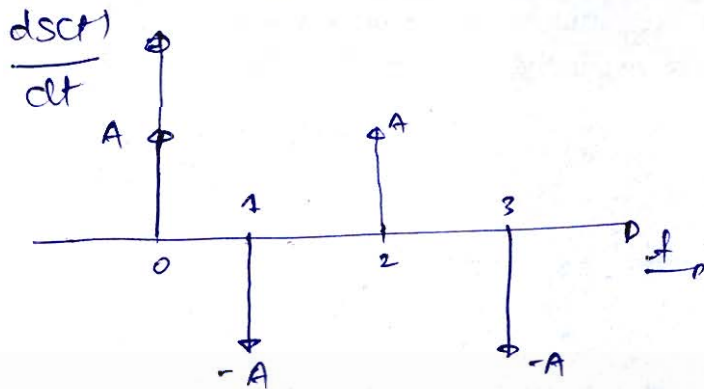
Hence



(ii) we know, $y(t) = s(t) * h(t)$.

using properties of convolution,

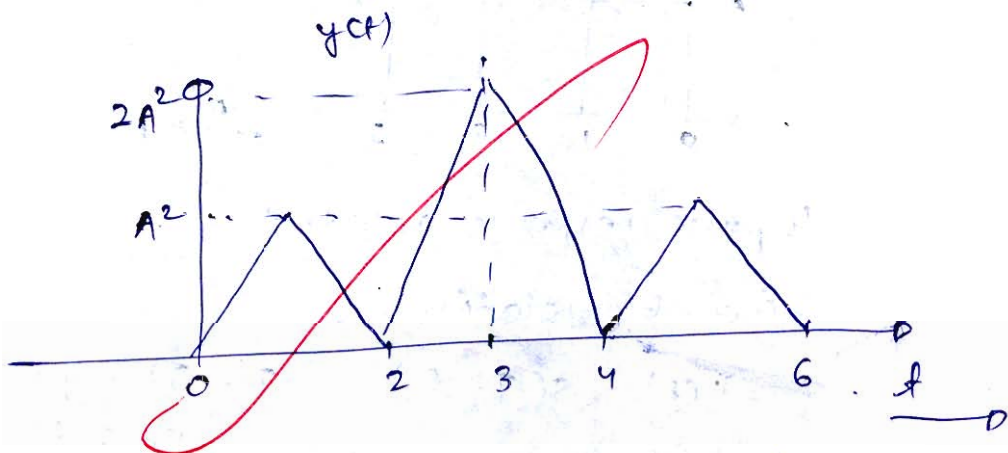
$$\frac{dy(t)}{dt} = \frac{ds(t)}{dt} * h(t)$$



$$\frac{ds(t)}{dt} = A\delta(t) - A\delta(t-1) + A\delta(t-2) - A\delta(t-3)$$

$$\int_{-\infty}^{\infty} \frac{dy(t)}{dt} = Ah(t) - Ah(t-1) + Ah(t-2) - Ah(t-3) \quad \text{--- (1)}$$

Integrating (1) to obtain $y(t)$.



output $y(t)$ of matched filter
when input $s(t)$ provided.

(iii)

$$(SNR)_{\max} = \frac{2E_b}{N_0}$$

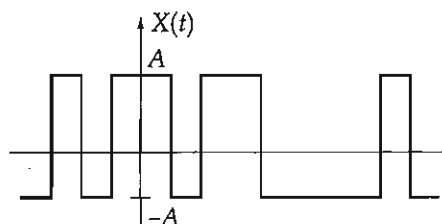
$$E_b = A^2 + A^2 = 2A^2$$

$$\frac{2A^2}{N_0} = \frac{4A^2}{N_0} \quad (\text{at } t=3)$$

$$\frac{N_0}{2} = 1$$

$$\therefore \text{var}(N) = \frac{N_0}{2} = 1$$

- Q.6 (b) (i) A certain sinusoid at a frequency f_m Hz is used as the modulating signal in both a conventional AM system and a FM system. When modulated, the peak frequency deviation of FM system is set to three times the bandwidth of the AM system. The magnitudes of those sidebands spaced at $\pm f_m$ Hz from carrier in both systems are equal and the total average powers are equal in both systems (Given $J_1(6) = 0.28$). Determine the
1. modulation index of the FM system
 2. modulation index of the AM system.
- (ii) Consider a random process $X(t)$ that assumes the values $\pm A$ with equal probability. A typical sample function of $X(t)$ is shown in figure. The average number of polarity switches (zero crossings) per unit time is α . The probability of having exactly k crossing in time T is given by the Poisson distribution $P(z = k) = e^{-\alpha T} \frac{(\alpha T)^k}{k!}$, where τ is the random variable representing the number of zero crossings. The process $X(t)$ is known as the telegraph signal. Find the auto correlation and PSD of $X(t)$.



[6 + 14 marks]

Q6

(b) (i) given condition $\beta = 6$ under modulation,

$$[\text{O.F.}]_{\text{FM}} \Big|_{\text{peak}} = 3 [\text{B.W.}]_{\text{AM}}$$

$$\beta = J_1(6) = 0.28$$

statement: for FM system,

$$S_{\text{FM}}(t) = A_c \cos(2\pi f_c t + \phi(t))$$

$$\phi(t) = 2\pi k_f \int_{-\infty}^t m(t) dt$$

$$\text{O.F.} = \frac{1}{2\pi} \frac{d\phi(t)}{dt}$$

$$\therefore [\text{O.F.}]_{\text{FM}} = k_f m(t)$$

$$\rightarrow [\text{O.F.}]_{\text{peak}} = k_f A_{m_{\text{peak}}}$$

for AM system,

$$S_{\text{AM}}(t) = A_c [1 + k_a m(t)] \cos 2\pi f_c t$$

$$m(t) = f_m$$

$$[\text{B.W.}]_{\text{AM}} = 2f_m$$

for FM system using Bessel's function,

$$S_{\text{FM}}(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta) \cos(2\pi(f_c \pm n f_m)t)$$

for $n=1$

$$S_{\text{FM}}(t) = A_c J_1(\beta) \cos 2\pi(f_c \pm f_m)t$$

$$(\text{of})_{FM} = 3(2f_m)$$

$$(\text{of})_{FM} = 6f_m$$

∴

$$\beta = \frac{\text{of}}{f_m} = 6 \quad \text{--- (1)}$$

magnitude of side bands are equation.

$$\frac{A_m}{A_c} = \frac{A_c J_1(\beta)}{2}$$

$$m = 2 J_1(\beta)$$

$$m = 2 \times 0.28$$

$$\therefore \boxed{m = 0.56} \quad \text{--- (2)}$$

Hence (1) & (2) are the respective answers.

- Q.6 (c) A particular 6-bit DAC has a full-scale output rated at 1.260 V. Its accuracy is specified as $\pm 0.1\%$ full scale, and it has an offset error of ± 1 mV. Consider the measurements made on this DAC in the table below:

Input code	Output
000010	41.5 mV
000111	140.2 mV
001100	242.5 mV
111111	1.258 mV

Check all the above measurement(s) and identify which are within (or) out of the device's (DAC's) specifications.

[20 marks]

Q6

cc) given: $n = 6$. DAC

$$V_{fs} = 1.260 \text{ V}$$

accuracy: $\pm 0.1\%$ full scale = $\pm 1.26 \text{ mV}$

offset error = $\pm 1 \text{ mV}$

Statement: for a DAC, V_o is defined,

$$[V_o = R \times D]$$

R : Resolution.

calculation of Resolution:

$$R = \frac{V_{fs}}{2^n - 1} = \frac{1.260}{2^6 - 1} = 20 \text{ mV}$$

Input ① calculation.

$$\text{Input} = (000010)_2 = (2)_{10}$$

$$V_o = 20 \times [2] = 40 \text{ mV}$$

V_o range would be

$$(40 - 1.76 - 1) \text{ to } (40 + 1.76 + 1)$$

19
Good

37.74 mV to 42.26 mV.
hence, it is in device specifications.

Input - ② $(000111)_2 = (7)_{10}$.

$$V_0 = (20) \times (7)$$

$$V_{02} = 140 \text{ mV}$$

$$V_{02} \text{ range} : 140 - 1 - 1.26 \text{ to } 140 + 1 + 1.26$$

$$: 137.74 \text{ to } 142.26 \text{ mV}$$

Hence, 140.2 mV is in range.

Input - ③ $(001100)_2 = (12)_{10}$

$$V_0 = (20) \times 12 = 240 \text{ mV}$$

$$V_{03} \text{ range} : 240 - 1 - 1.26 \text{ to } 240 + 1 + 1.26$$

$$: 237.74 \text{ mV to } 242.26 \text{ mV}$$

$$\text{But } V_{03} = 242.5 \text{ mV}$$

Hence it is NOT in device specifications.

Input - ④ $(111111)_2 = (63)_{10}$.

$$V_0 = (20) \times 63$$

$$= 1260 \text{ mV}$$

$$V_{04} \text{ range} : 1260 - 1 - 1.26 \text{ to } 1260 + 1 + 1.26$$

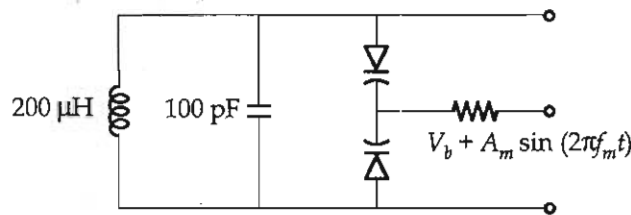
$$V_{04} : 1257.74 \text{ mV to } 1262.26 \text{ mV}$$

Hence it is not in device
range.

- Q.7 (a) (i) The below figure shows the frequency determining network of a voltage - controlled oscillator. Frequency modulation is produced by applying the modulating signal $A_m \sin 2\pi f_m t$ plus a bias V_b to a pair of varactor diodes connected across the parallel combination of a $200 \mu\text{H}$ inductor and 100 pF capacitor. The capacitor of each varactor diode is related to the voltage V (in volts) applied across its electrodes by $C = 100 V^{-1/2} \text{ pF}$.

The unmodulated frequency of oscillations is 1 MHz . The VCO output is applied to a frequency multiplier to produce an FM signal with a carrier frequency of 64 MHz and a modulation index of 5. Determine:

1. The magnitude of the bias voltage V_b and
2. The amplitude A_m of the modulating wave, given $f_m = 10 \text{ kHz}$.

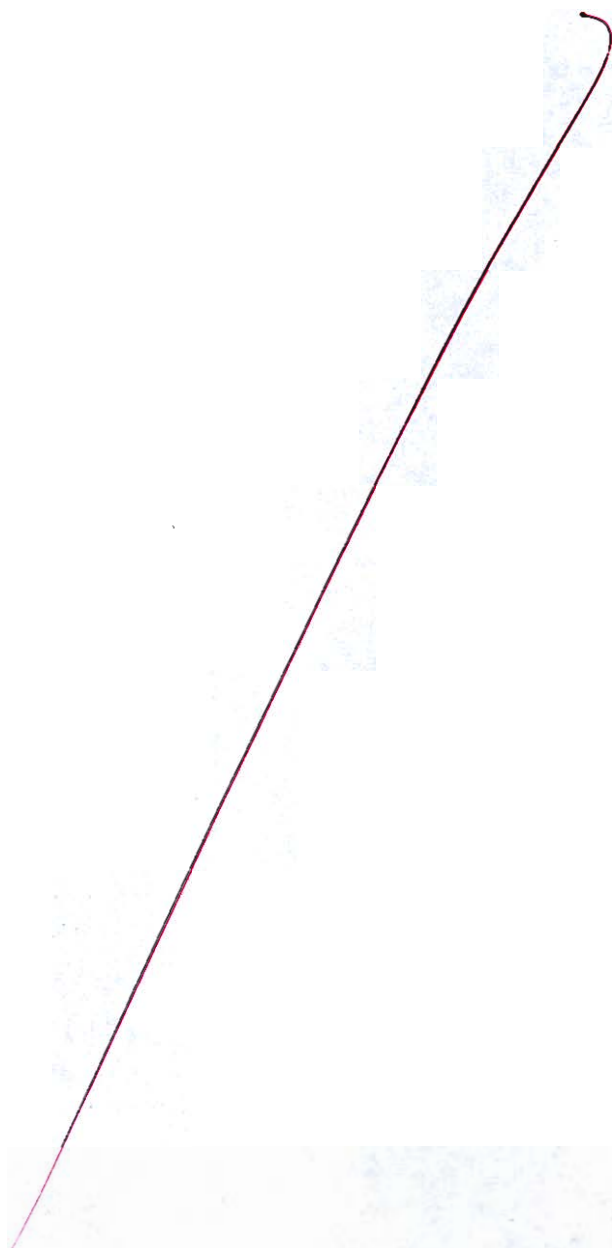


- (ii) An angle-modulated signal is described by

$$x_c(t) = 10 \cos[2\pi(10^6)t + 0.1 \sin(10^3)\pi t]$$

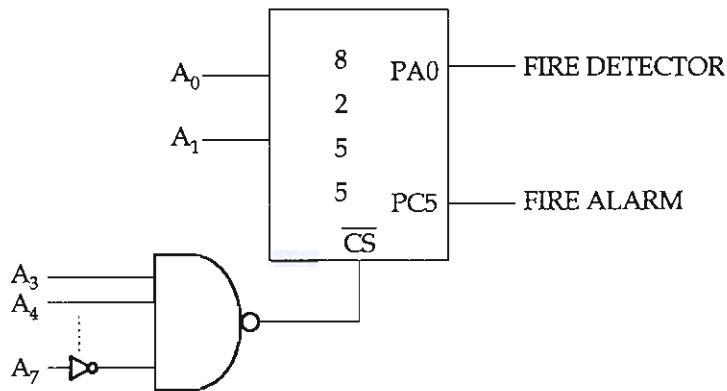
1. Considering $x_c(t)$ as a PM signal with $k_p = 10 \text{ rad/V}$, find $m(t)$
2. Considering $x_c(t)$ as a FM signal with $k_f = 10\pi \text{ Hz/V}$, find $m(t)$

[12 + 8 marks]



Q.7 (b) For the 8255 programmable peripheral interface (PPI) shown in figure, the address of Port A, B, C and control register are 40 H, 41 H, 42 H and 43 H respectively.

- (i) Determine the control word to detect the fire and on/off the alarm.
- (ii) Develop an 8085 assembly language program to read from the detector and control the alarm.



[10 + 10 marks]

- Q.7 (c)
- (i) A $100\text{ k}\Omega$ resistor is connected in parallel with a 100 pF capacitor. Determine the effective noise bandwidth and the noise voltage appearing at the terminals of the combination at 27°C .
- (ii) Consider a phase-locked loop (PLL) consisting of a multiplier, loop filter and voltage controlled oscillator (VCO). Let the signal applied to the multiplier input be defined as $s(t) = A_c \cos[2\pi f_c t + k_p \cdot m(t)]$, where k_p is the phase sensitivity and data signal $m(t)$ is having value $+1$ for binary symbol 1 and -1 for binary symbol 0. The VCO output is $r(t) = A_v \sin[2\pi f_c t + \theta(t)]$. Evaluate the loop filter output, assuming that the filter removes the modulated components with frequency $2f_c$. Show that the loop filter output is proportional to the data signal $m(t)$, when the loop is phase-locked, that is $\theta(t) = 0$. Illustrate your answer with a neat sketch.

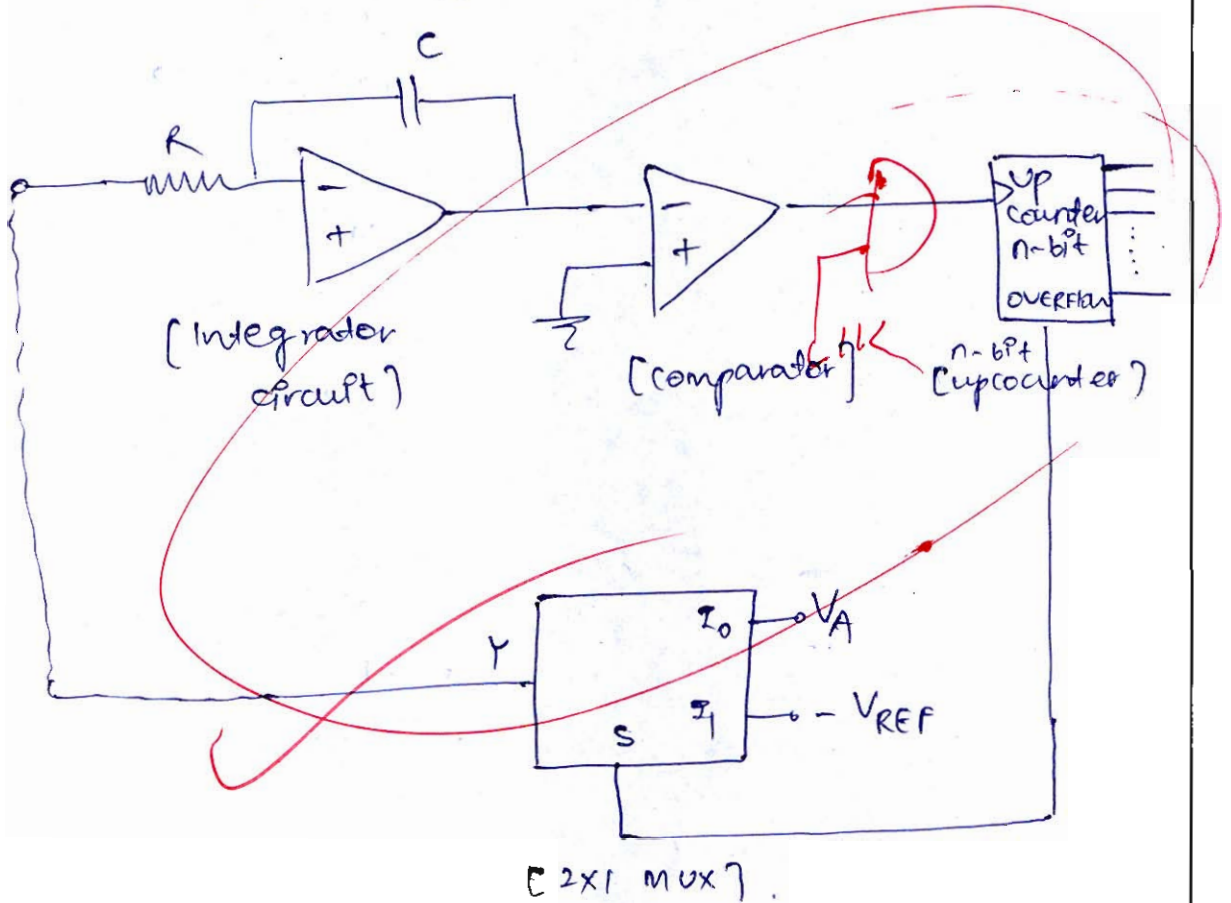
[8 + 12 marks]

[Faint handwritten text and diagrams are visible in the main body of the page, but they are illegible due to low contrast and blurriness.]

- Q.8 (a) (i) Explain with a block diagram, the working principle of a dual-slope A/D converter. Derive the expression for the output and maximum conversion time of the circuit.
- (ii) A dual-slope A/D converter has a resolution of 4 bits. If the clock rate is 3.2 kHz, then calculate the maximum sampling rate with which the samples can be applied to the A/D converter.

[15 + 5 marks]

Q8 (a) (i) working of dual slope ADC:



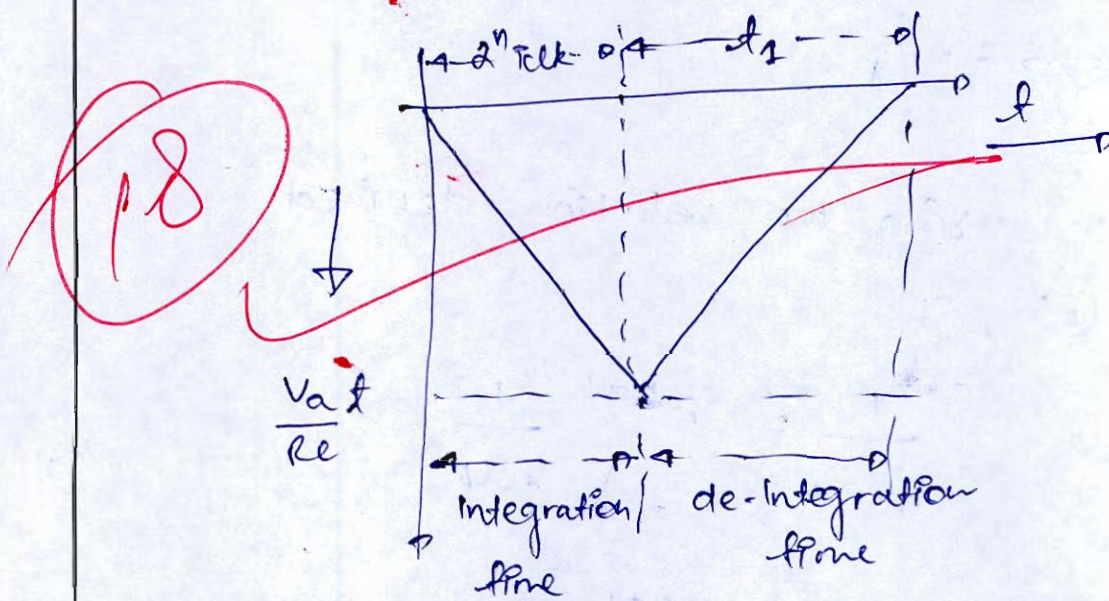
Dual slope ADC

Above is the block diagram, for dual slope ADC.

Initially, the select bit of (2x1) mux is set to "0", hence selecting the applied analog voltage.

The Integrator charges upto the applied voltage.

- After 2^n Tclk cycles, overflow condition occur and hence the select line now switches to "1", Applying the Reference (opposite polarity) voltage.
- It drives the Integrator, or de-Integrates the integrator, eventually stopping and achieving the desired digital output.



The reference voltage is applied to negate the effect of V_a .

$$\frac{V_a}{R C} \times 2^n T_{clk} = \frac{V_{REF}}{R C} \times t_1$$

$$V_a \cdot 2^n T_{clk} = V_{REF} \times t_1 \quad \text{--- (1)}$$

And hence, the ADC is also independent of R, C values.

$$\text{Maximum Conversion time} = 2^n T_{clk} \times 2$$

If the de-integration also takes the same amount of time as the integration took, we would get a max^m conversion time state,

$$\therefore \boxed{T_{\max} = 2^{n+1} \cdot T_{ck}} \quad - (2)$$

conclusion: (1) & (2) are the desired expressions.

(ii) $n = 4$.

$$f_{ck} = 3.2 \text{ kHz}$$

from using the relation derived

in (2),

$$\frac{1}{f_{\max}} = 2^{n+1} \cdot \frac{1}{f_{ck}}$$

$$f_{ck} = 2^{n+1} \cdot f_{\max}$$

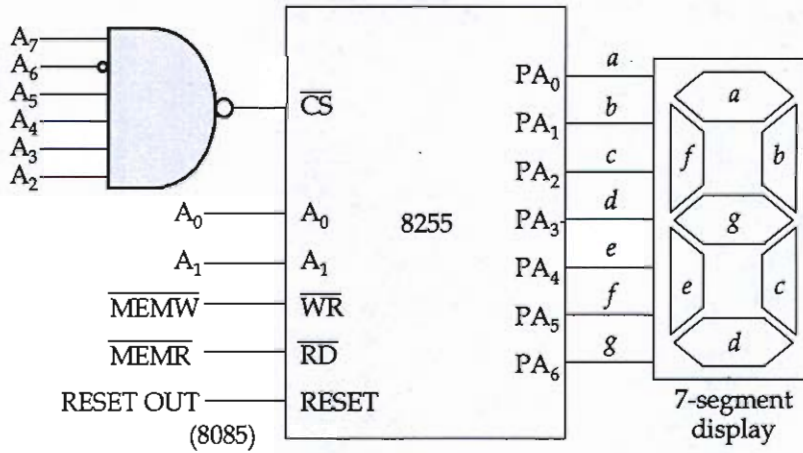
$$\therefore f_{\max} = \frac{f_{ck}}{2^{n+1}}$$

$$f_{\max} = \frac{3.2 \text{ kHz}}{2^{4+1}}$$

$$f_{\max} = 0.1 \text{ kHz}$$

$$\therefore \boxed{f_{\max} = 100 \text{ Hz}}$$

- Q.8 (b) An 8085 microprocessor is interfaced with 8255 programmable Peripheral Interface (PPI) to control the seven-segment display as shown in figure.



Write an assembly language program to display the last six digits of your mobile number with each digit being displayed after some delay.

Assume I/O Addressing as

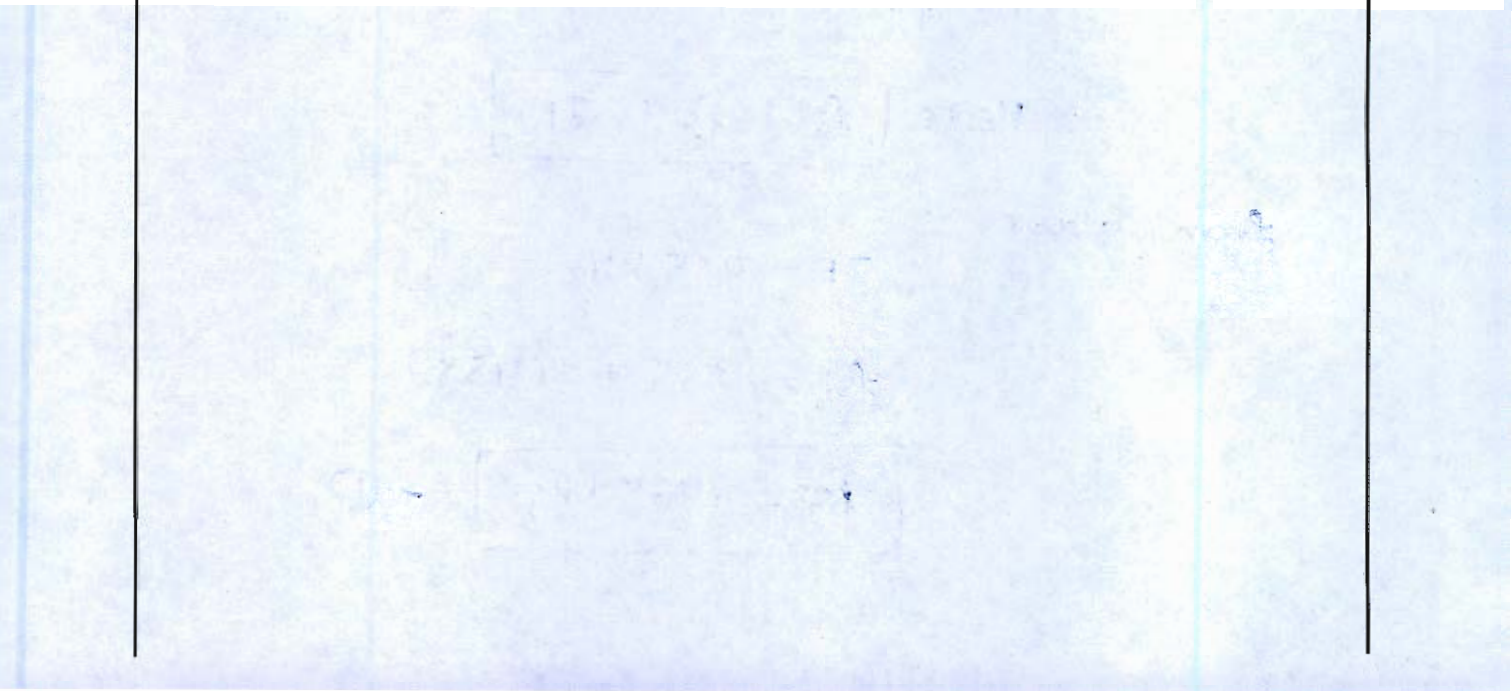
PORT A = 00 H

PORT B = 01 H

PORT C = 02 H

CONTROL = 03 H

[20 marks]



- Q.8 (c) (i) When a superheterodyne receiver is tuned to 555 kHz, its local oscillator provides the mixer with an input at 1010 kHz. What is the image frequency? The antenna of this receiver is connected to the mixer via a tuned circuit whose loaded Q is 40. What will be the rejection ratio for the calculated image frequency?
- (ii) In an Armstrong modulator, the crystal oscillator frequency is 200 kHz. The angular deviation is set to 0.2. The system is to accommodate modulation frequencies between 50 Hz and 15 kHz. The carrier frequency at the output is 108 MHz and the maximum frequency deviation is 80 kHz. Draw the block diagram of the modulator showing the details and select multiplier and mixer oscillator frequencies to accomplish this.

[6 + 14 marks]

Q8 (c) (i) Given: $f_s = 555 \text{ kHz}$
 $f_l = 1010 \text{ kHz}$

Statement: for a STD Receiver, the standard
 is down conversion,

$$\text{Hence, } f_l - f_s = IF$$

IF : Image frequency.

concept of Image frequency,

$$f_{si} - f_l = IF$$

$$\therefore f_{si} = f_l + IF$$

$$\text{Hence } \boxed{f_{si} = f_s + 2IF}$$

from above,

$$IF = 455 \text{ kHz}$$

$$f_{si} = 555 + 2(455)$$

$$\boxed{f_{si} = 1465 \text{ kHz}} \quad - (1)$$

$$Q = 40$$

IRR (Image Rejection ratio) ; $\alpha = \sqrt{1 + P^2 Q^2}$

where, $P = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$

$$P = \frac{1465}{555} - \frac{555}{1465} = 2.25$$

$$\alpha = \sqrt{1 + (2.25)^2 \times (40)^2}$$

$$\alpha = 90.05$$

$$\boxed{\alpha \approx 90} \quad - (2)$$

Conclusion: Hence, (1) & (2) are the respective answers.

Q8. (c) (ii) Given conditions: $f_c = 200 \text{ kHz}$

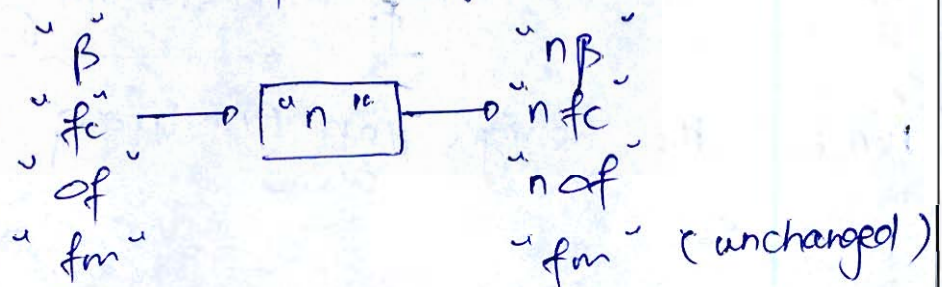
$$\beta = 0.2$$

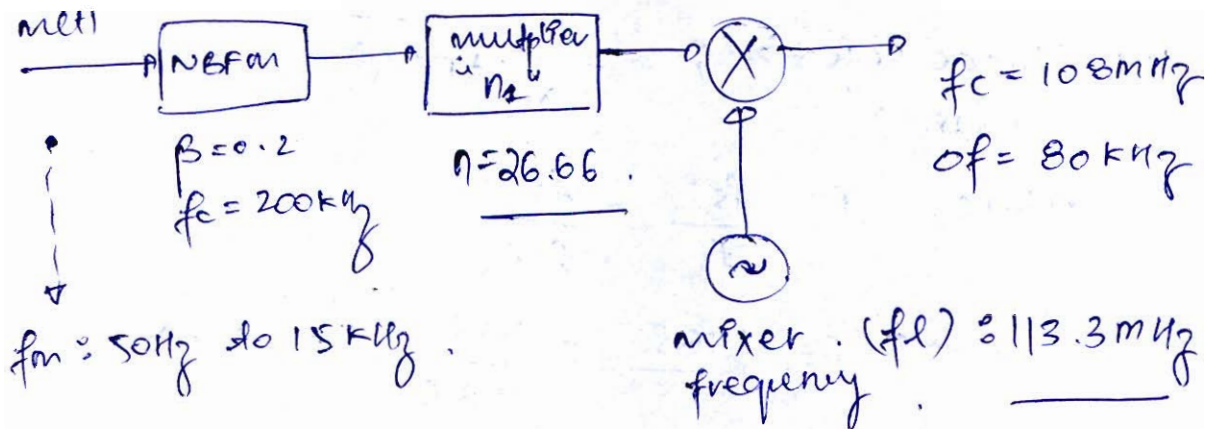
$$f_m: 50 \text{ Hz to } 15 \text{ kHz}$$

$$(f_c) @ \text{ output} = 108 \text{ MHz}$$

$$(Bf)_{\text{max}} = 80 \text{ kHz}$$

Statement: when passed through a multiplier of value 'n', the following changes occur





Range of frequency deviation at input

$$o_f_1 = \beta \times f_m = 0.2 \times 50 \text{ Hz} = 10 \text{ Hz}$$

$$o_f_2 = 0.2 \times 15 \text{ kHz} = 3 \text{ kHz}$$

desired $(o_f)_{\max} = 80 \text{ kHz}$

$$\therefore \eta = \frac{80}{3} = 26.66$$

β after multiplier: $\beta \times 26.66 = 5.332$

$$f_c = 200 \times 26.66 = 5.33 \text{ MHz}$$

desired $f_c' = 108 \text{ MHz}$ [@ output]

$$\therefore f_l - f_c = f_c'$$

$$f_l = f_c + f_c'$$

$$f_l = 113.3 \text{ MHz}$$

Hence, the design for Armstrong modulator

oooo

Space for Rough Work

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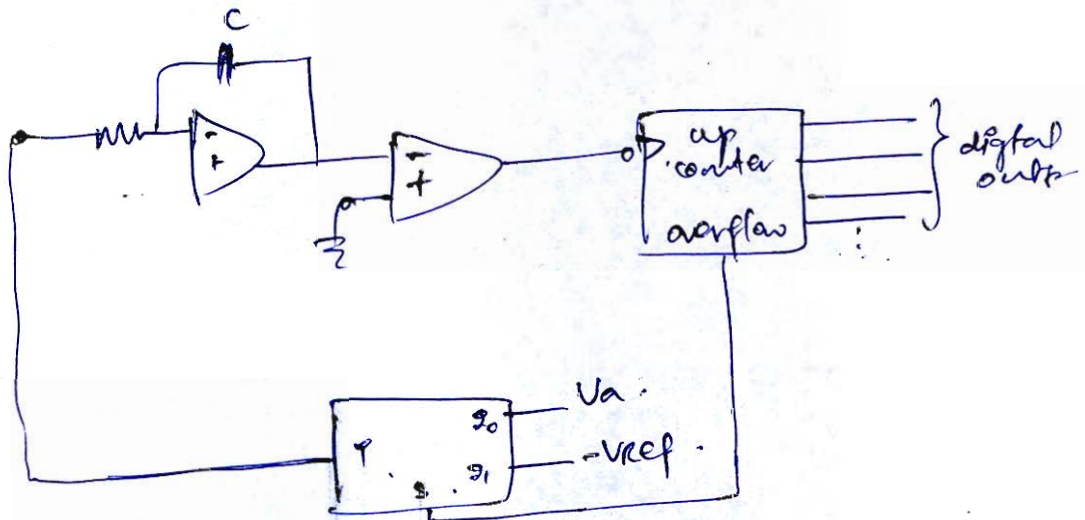
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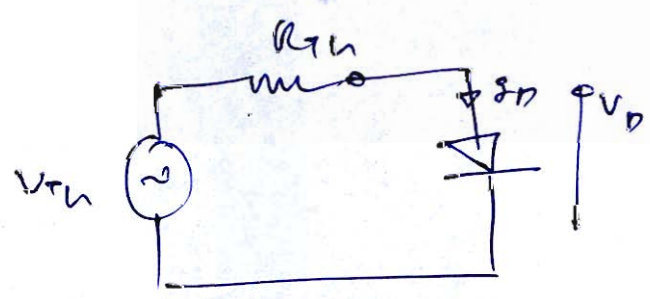
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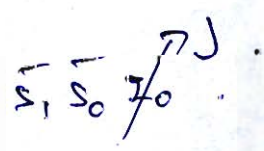


$$\beta = \frac{of}{fm}$$

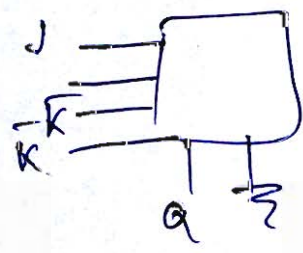
(of) = max



$$D = J\bar{A} + \bar{K}A$$



$$\bar{Q}J(1)$$

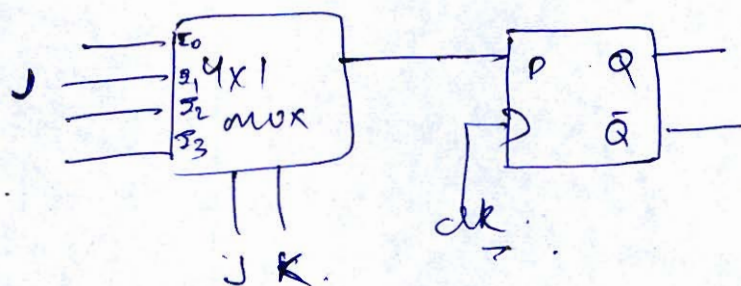


\$s_1, s_0\$

+

Space for Rough Work

$$I_{ph} = I_{SC} = I_0 (e^{V_{oc}/nV_T} - 1)$$



$$D = J\bar{Q} + \bar{K}Q$$

$f_2 = J\bar{K}I_0 + JK I_1 + J\bar{K} I_2 + JK I_3$ \odot car input

$I_0 = 0$ $I_1 = 0$ $I_2 = 1$ $I_3 = \bar{Q}$

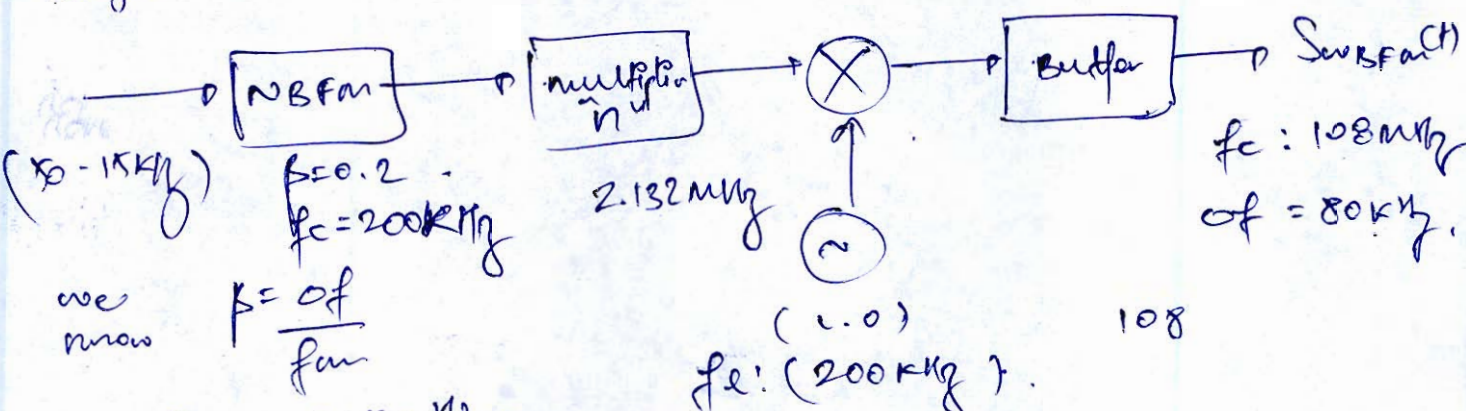
$I_0(J+Q)$ $J\bar{Q}\bar{K} + JK\bar{Q}$ $J\bar{Q}(1)$

$$f_c = Q \left(\sqrt{\frac{d_{min}^2}{2w_0}} \right) = \frac{2\epsilon_0}{w_0}$$

$\oplus A$ δ PRR $2\sqrt{\epsilon_0}$ $\frac{2 \times \epsilon_0}{2w_0}$

$f_d = 200 \text{ kHz}$
 $\beta = 0.2$

freq range 50 kHz - 15 kHz



we know $\beta = \frac{\omega_f}{\omega_c}$

$\omega_{f1} = 0.2 \times 50 \text{ kHz}$
 $\omega_{f2} = 0.2 \times 15 \text{ kHz}$
 $\omega_{f2} = 3 \text{ kHz}$

$n = 10.66$ \rightarrow 80 kHz

$n = \frac{80}{7.5}$
 $n = 10.66$

