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# 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** |
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| Pune ☐ | 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 | 24 |
| Q.2 | |
| Q.3 | 38 |
| Q.4 | |
| Section-B | |
| Q.5 | 38 |
| Q.6 | 6 |
| Q.7 | 40 ⇒ Very Good |
| Q.8 | |
| **Total Marks Obtained** | 146 |

Signature of Evaluator ............................ Cross Checked by ............................

15/4/26

• your are doing good... Keep it up.

• Practice more to improve accuracy. Attempt atleast 30 Q. a day

## 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.

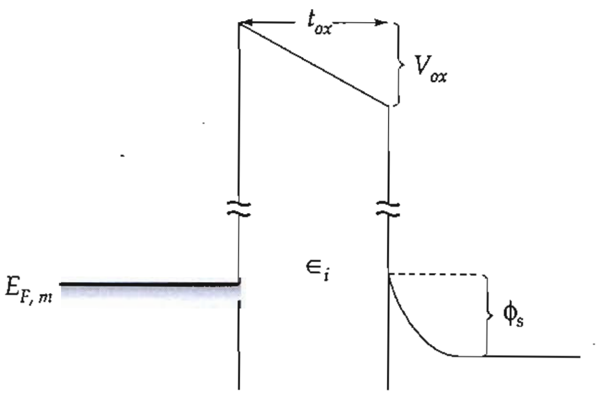
### DO'S

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.

Do not write in this margin

**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, $t_{ox} = 10$ nm, $V_{ox} = 0.4$ V, $\in_i \in_0 = 40 \times 10^{-14}$ F/cm, $\in_s \in_0 = 100 \times 10^{-14}$ F/cm.

Determine:

**(i)** The type of the semiconductor shown in the diagram and value of $\phi_s$.

**(ii)** The metal-semiconductor work-function difference.

**(iii)** The MOS capacitance at equilibrium is determined to be

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

**[4 + 4 + 4 marks]**

(a) $\phi_s$ → $E_c - E_F$

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

**[12 marks]**

Given, $I_{ph} = 3.5A$, $I_{dark(sc)}$ ($I_s$ (or)) $= 3.22 \times 10^{-11}$

Max. power point $= 1.75W$, $T = 300K$.

12

$V_{oc}$ (open ckt. vlg) $= \frac{KT}{q} \ln\left(\frac{I_{ph}}{I_{dark(s.c)}} + 1\right)$

$V_{oc} = V_T \ln\left(\frac{I_{ph}}{I_s} + 1\right)$

$V_{oc} = 25.8 \times 10^{-3} \ln\left(\frac{3.5}{3.22 \times 10^{-11}} + 1\right) = 25.8 \times 10^{-3} \ln\left(1 + \frac{10^{11} \times 3.5}{3.22}\right)$

$V_{oc} = 25.8 \times 10^{-3} \times 25.411$

$V_{oc} = 0.655$ V.

Now, Fill factor = $\frac{P_{max}}{V_{oc} \cdot I_{sc}}$ $\left(I_{sc} \approx I_{ph}\right)$

$$FF = \frac{1.75}{0.655 \times 3.5} \cong 0.76$$

**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]**

(i) Foilage → It refers to collective leafy part of tree, shrubs, plants. in transmission environment.

Foilage Loss → It refers to loss of Sig strength due to various phenomenon like absorption, Scattering, bending and various attenuation etc.

(ii) Location of cell-site and mobile unit influenced by foilage loss →

① LOS should be clear.
line of sight of propogation must be in fixed manner to get the best desired result.

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② Sig qualities decreases due to various Shadows cast by trees. or other "unnecessary barriers". Therefore it should be avoided. Various other effects must also considered like (Noise)

Good

Above two are necessary to keep in mind. by fixing Location-site and mobile unit.

**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]**

$f = 900\,MHz$  Tx. Height = 100m

$f = 9\times10^{8}\,Hz.$  Rx. Height = 2m.

(d = 4 Km.)

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

where (d → distance covered)

(λ → wavelength.)

1

**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]**

**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 $km^2$.

**(i)** 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.

**(ii)** 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, $N_E = 2 \times 10^{18}$ cm$^{-3}$, Base doping, $N_B = 2 \times 10^{16}$ cm$^{-3}$ and collector doping, $N_C = 2 \times 10^{15}$ cm$^{-3}$. The neutral basewidth $x_{B0} = 0.85$ μm, and electron diffusion coefficient in base, $D_n = 25$ cm$^2$/s. Assume $x_{B0} << L_n$ where $L_n$ : diffusion length of electron, $V_{BE} = 0.65$ V, $\epsilon_{si} = 11.7\epsilon_0$, $n_i = 1 \times 10^{10}$ cm$^{-3}$, $V_T = 0.026$ V.

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

1. $V_{CB} = 4$ V
2. $V_{CB} = 8$ V
3. $V_{CB} = 12$ 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 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) For Multimode graded index fiber, $(\Delta\tau)_{\substack{Total \\ Length\ 10\,Km}} = 0.5\,\mu s$

(1) $L = \dfrac{(\Delta\tau)_{Total}}{Length} = \dfrac{0.5\times10^{-6}}{10\,Km} = 0.05\,\mu s\,/\,Km$

(2) $R_b \leq \dfrac{1}{(\tau_{Total})} = \leq \dfrac{1}{0.5\times10^{-6}}$

$R_b \leq \dfrac{10^{6}}{0.5}$

$R_b \leq \dfrac{10^{6}\times10}{5} = 2\times10^{6} \leq 2\,MHz.$

$(R_b)_{max} = 2\,MHz.$

(3) Bandwidth Length product = B.W × L

$(B.L.P) = 2\,MHz \times 10\,Km$

$(BLP) = 20\,Km\cdot MHz.$

$R_b = BW$ / $\frac{R_b}{2}$

$BW = \frac{1}{4\tau}$

(3)

(ii) Given $n_1 = 1.5$ , $n_2 = 1.45$ , $L = 9$ Km.
$L = 9000$ m

① RMS pulse broadening due to Intermodal dispersion on the link →

$$\sigma_s \cong \frac{L n_1}{c\, 2\sqrt{3}} \left(\frac{n_1 - n_2}{n_1}\right)^2 = \frac{9 \times 1.5 \times 1000}{3\times10^8 \times 2 \times 1.732} \left(\frac{1.5-1.45}{1.5}\right)^2$$

$$\boxed{\sigma_s = 0.86 \times 10^{-6}}$$

$$\Delta T = \frac{L}{c} \frac{n_1 (n_1 - n_2)}{n_2} = \frac{9000\; 1.5}{3\times10^8} \left(\frac{1.5 - 1.45}{1.45}\right)$$

$$= 1.55 \,\mu sec$$

② $$\Delta \tau = \frac{L}{c}(n_1 - n_2)$$

$$= \frac{9000}{3\times10^8}(1.5 - 1.45) = 3\times10^{-5}(0.05)$$

$$= 0.15\times10^{-5} \text{ seconds.}$$

$$= 1.5 \,\mu \text{seconds.}$$

**Q.3 (b)** **(i)** An $n$-type Si sample with $N_D = 10^{15}/cm^3$ is steady illuminated such that $g_{op} = 10^{21}$ EHP/cm³-s. If $\tau_n = \tau_p = 1$ μsec for this excitation, calculate the separation in the Quasi Fermi levels, $(F_n - F_p)$.
(Assume for Si at 300 K, $n_i = 1.5 \times 10^{10}$ cm$^{-3}$, $KT = 0.026$ 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]**

(i) Given → n-type Si, $N_D = 10^{15}/cm^3$.

$g_{op} = 10^{21}$ EHP/cm³, $\tau_p = \tau_n = 1 \times 10^{-6}$ sec.

($T = 300K$, $n_i = 1.5 \times 10^{10}$ cm$^{-3}$, $KT = 0.026$ eV)

$$F_n - F_p = KT \ln\left(\frac{n \cdot p}{n_i^2}\right) \quad \text{— (1)}$$

Good

$$\Delta n = \Delta p = g_{op} \times \tau$$

$$\Delta n = 10^{21} \times 10^{-6} = 10^{15} \text{ atoms}/cm^3.$$

$$n = N_D + \Delta n = 10^{15} + 10^{15} = 2 \times 10^{15} \text{ atoms}/cm^3.$$

$$p = N_A + \Delta p = 0 + 10^{15} = 10^{15} \text{ atoms}/cm^3.$$

10

Subsitute in (1)

$$F_n - F_p = 0.026 \ln\left(\frac{2 \times 10^{15} \times 10^{15}}{1.5 \times 10^{10} \times 1.5 \times 10^{10}}\right)$$

$$= 0.026 \ln\left(\frac{2 \times 10^{30} \times 10^{-20}}{2.25}\right)$$

$$\boxed{F_n - F_p = 0.596 \text{ eV}}$$

(ii) $$\frac{\partial\, \delta n(t)}{dt} = \frac{\delta n(t)}{\tau_n} \leftarrow \text{(We know)}$$

After a long time,

at time t

$$\delta n(t) = \delta n(0)\, e^{-t/\tau_n}$$ **

(These eqn tell us that decay of excess carrier and life time of carrier)

⇒ $\delta n(t)$ → At time 't'

⇒ $\delta n(0)$ → At time '0'

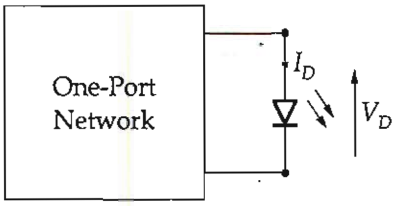
⇒ $\tau_n$. → Mean-life time. , t → time

**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:

$I_D = 0$ amperes, for $V_D < 1.5$ V

$I_D = 0.03 \times V_D - 0.045$ Amperes, for $V_D > 1.5$ 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 $N_A = 1.2 \times 10^{16}$ cm$^{-3}$. Given that diffusion length of electron and effective base width, $L_e \approx W_b = 0.7$ μm, minority carrier diffusion coefficients in emitter and base regions are 12 cm$^2$s$^{-1}$ and 30 cm$^2$s$^{-1}$ respectively and minority electron concentration in the base region is $1.88 \times 10^4$ cm$^{-3}$. Calculate the $n$-type doping concentration needed in the emitter.

**[10 + 10 marks]**

(ii) Given, $\gamma_e = 0.995$

$N_A = 1.2 \times 10^{16} / cm^3$, $L_e = W_b = 0.7\ \mu m$

$D_E = 12\ cm^2 s^{-1}$, $D_B = 30\ cm^2 s^{-1}$

$$\gamma_e = \frac{1}{1 + \frac{D_E W_B N_A}{D_B L_e N_D}} = \frac{1}{1 + \frac{D_E}{D_B}\frac{N_A}{N_D}} = \gamma_e$$

$$\frac{1}{\gamma_e} = 1 + \frac{D_E}{D_B}\frac{N_A}{N_D}$$

$$\frac{1}{0.995} - 1 = \frac{D_E}{D_B}\frac{N_A}{N_D} = \frac{12}{30} \times \frac{1.2\times10^{16}}{N_D}$$

$$0.005 = \frac{12}{30} \times \frac{1.2\times10^{16}}{N_D}$$

$$\frac{0.005\times30}{12\times1.2\times10^{16}} = \frac{1}{N_D}$$

$$N_D = \frac{12\times1.2\times10^{16}}{30\times0.005} = 9.6\times10^{17} \text{ atoms/cm}^3$$

10

Very Good

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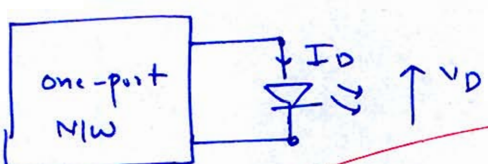
(i)




when $\left[\begin{array}{l} V_{1g},\ V_D < 1.5 \quad (\text{No current } I_D = 0) \\ V_D > 1.5,\ \ I_D = 0.03\times V_D - 0.045 \end{array}\right]$

Assume LED → ON means (F.B) conducting current,

2

**Q.4 (a)** **(i)** Consider a uniformly doped $n$-channel silicon JFET with the following parameters:

$$N_A = 10^{19}\ \text{cm}^{-3},\ N_D = 3 \times 10^{16}\ \text{cm}^{-3},\ a = 0.40\ \mu\text{m}$$

The drain-to-source voltage applied is $V_{DS} = 5$ 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 $n_i = 1.5 \times 10^{10}$ cm$^{-3}$, $V_t = 0.026$ V and $\varepsilon_{si} = 1.06 \times 10^{-12}$ 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($N_d = 10^{16}$ cm$^{-3}$) generates $20^{21}$ cm$^{-3}$/s electron-hole pairs. Si has $N_t = 10^{15}$ cm$^{-3}$ generation-recombination centers with $\sigma_n = \sigma_p = 10^{-16}$ 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, $V_t = 10^7$ cm/s.

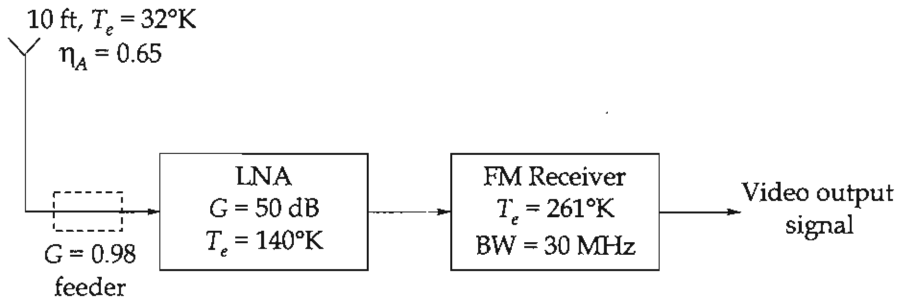
**[10 + 10 marks]**

**Q.4 (b)** (i) For an MOSFET with sufficient drain voltage to be in saturation (under constant mobility condition), the drain current is 50 μA at $V_{GS} = 1$ V and 200 μA at $V_{GS} = 3$ 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: $N_A = 10^{16}$ cm$^{-3}$, $t_{ox} = 500$ Å, $n_i = 1.5 \times 10^{10}$ cm$^{-3}$, $kT = 0.026$ eV, $\varepsilon_{si} = 1.06 \times 10^{-12}$ F/cm and $\varepsilon_{ox} = 3.45 \times 10^{-13}$ 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

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

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

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]**

(i) $B_{eq} = \frac{1}{2\pi}\int_0^\infty |H(\omega)|^2 d\omega$ , $\left[\text{where } |H(\omega)|^2_{max} = \max|H(\omega)|^2\right]$

For an ideal band-pass filter of Bandwidth 'W',
i.e., $\left(f_c - \frac{W}{2} \text{ to } f_c + \frac{W}{2}\right)$

$|H(f)| = 1$ or $(H_{max})$

$\therefore B_{eq} = \frac{W \cdot H(max)^2}{|H|^2_{(max)}} = W.$

∴ The equivalent Noise B.W of ideal Band-pass filter is 'W'

For Low pass filter, $H(f) = \frac{1}{1+j2\pi RC}$.

$|H(f)| = \frac{1}{1+(2\pi RC)^2} \Rightarrow |H_{max}|^2 = 1$ (at $f=0$)

$f_{3\text{-}dB} = \frac{1}{2\pi RC} \rightarrow df = \frac{dx}{2\pi RC}$

Now, $B_{eq} = \frac{1}{2\pi Rc} \int_0^{\infty} \frac{1}{1+x^2} dx = \frac{1}{2\pi Rc} \left[\tan^{-1} x\right]_0^{\infty}$

$B_{eq} = \frac{1}{2\pi Rc}\left(\frac{\pi}{2}\right)$

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$\therefore B_{eq} = f_{3\text{-dB}} \times 1.57$

$$B_{eq} = 1.57\, f_{3\text{-dB}}$$ **

(ii) Expression for probability of Error of Bipolar band signal, Assuming additive white Gaussian Noise,

$1 \rightarrow +A^{a_1}$
$0 \rightarrow -A^{a_2}$ } considering.

$P_e = Q\left(\frac{a_1 - a_2}{2\sigma_n}\right) \Rightarrow$ Now, we know,

$\sigma^2 = \frac{N_0}{2}$

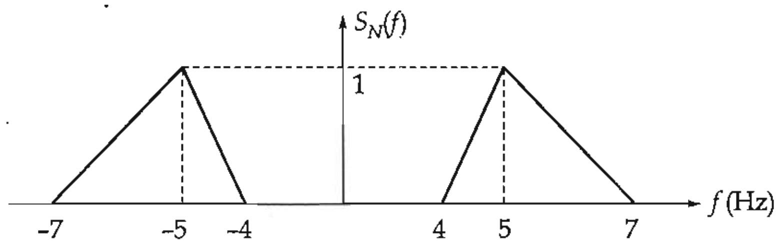
$E_b = A_c^2 T_b.$

Now, $$P_e = Q\sqrt{\frac{2E_b}{N_0}}$$ **

where, $E_b$ and $N_0$ we (know)

For Binary bipolar sig.

**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]**

(1.) Given $f_c = 5Hz$, $PSD = 1W/Hz$

$$S_{NQ}(f) \text{ (OR) } S_{NI}(f) = \begin{cases} S_N(f-f_c) + S_N(f+f_c) \\ 0 \end{cases}$$

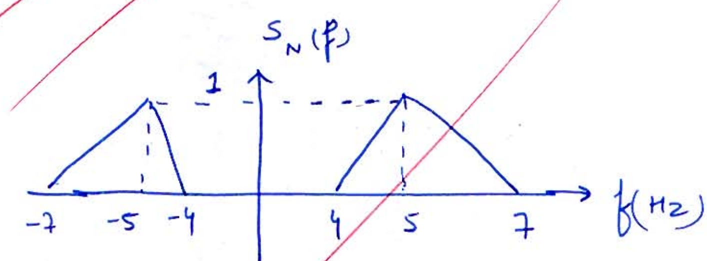
Movement

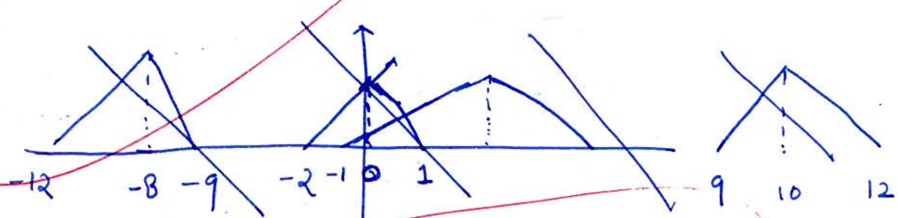
$[-7,-4] \rightarrow [-2, 1]$

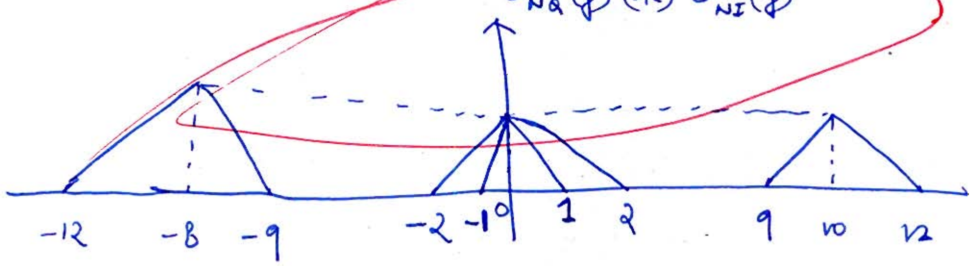
$[4,7] \rightarrow [9, 12]$

$(-7,-4) \rightarrow [-12,-9]$

$(4,7) \rightarrow [-1, 2]$



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(2) Total power is given, $P = \int_{-\infty}^{+\infty} S_N(f)$

$$P_{Total} = \frac{1}{2} \times 3 \times 1 + \frac{1}{2} \times 3 \times 1$$

$$P_{Total} = 1.5 + 1.5 = 3\,W$$

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(3) The PSD are not symmetric around the centre frequency ($f_c$) ∴ we can the in-phase and quadrature components are correlated. **

**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]**

[Given Range is (0 → 10V)]

$\therefore \quad V_{FS} = 10V$

(i) For (2-bit D/A convert) i.e, n = 2

$V_o = \frac{V_{FS}}{2^n}(D.E) = \frac{10}{2^2} \times (\text{Decimal Equivalent})$

$(10)_2 = 2$

$= \frac{10}{4} \times (10)_2 = \frac{10}{4} \times 2 = 5V$

(ii) $(0110)_2 \rightarrow 6$ For (4-bit DAC)

$V_o = \frac{V_{FS}}{2^4} \times 6 = \frac{10}{16} \times 6 = \frac{30}{8} = 3.75V$

(iii) $(10111100)_2 \rightarrow 188$ For (8-bit DAC)

$V_o = \frac{V_{FS}}{2^8} \times (\text{Decimal Equivalent})$

$V_o = \frac{10}{2^8} \times (188) = 7.34V$

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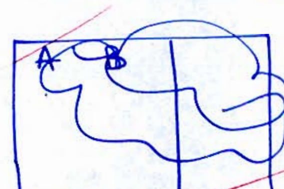
**Q.5 (d)** Design a *J-K* flip-flop using a *D* flip-flop and a 4 × 1 MUX. Write various steps involved in the process.

**[12 marks]**

| J | K | Q | $Q^+$ |
|---|---|---|---|
| 0 | 0 | 0 | X |
| 0 | 1 | 1 | X |
| 1 | 0 | X | 1 |
| 1 | 1 | X | 0 |

Excitation Table of J-K.

~~Truth Table of D - Flip flop.~~

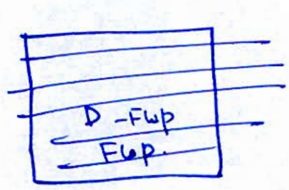


$C.E = J\bar{Q} + \bar{K}Q$

(J·K)

For D-flip flop, $C.E = Q^+$

$D = Q^+$



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

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

and $F_2 = \Sigma m(2, 9, 10, 11, 13, 14, 15)$

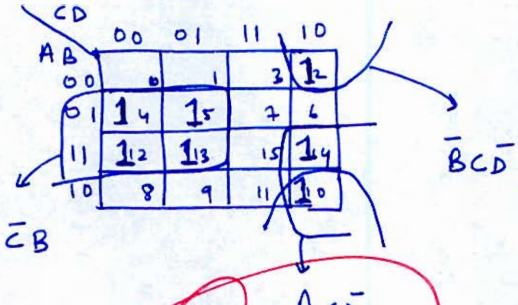
**[12 marks]**

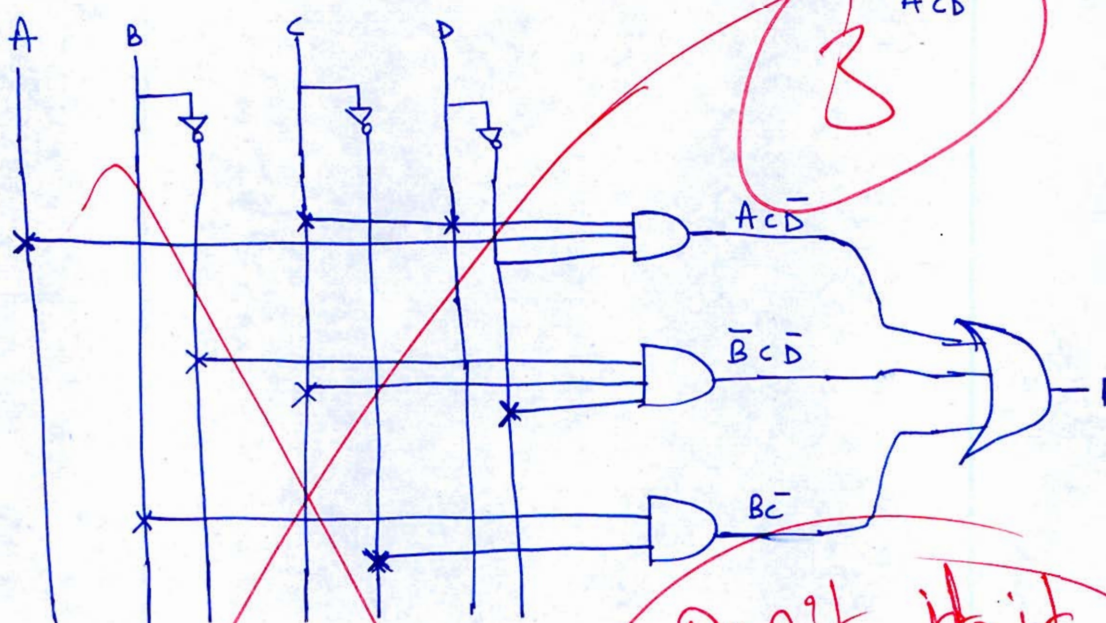
Given $F_1 = \Sigma m(2, 4, 5, 10, 12, 13, 14)$

$F_1 = AC\bar{D} + \bar{B}C\bar{D} + B\bar{C}$

(OR)

$F_1 = C\bar{D}(A+B) + B\bar{C}$

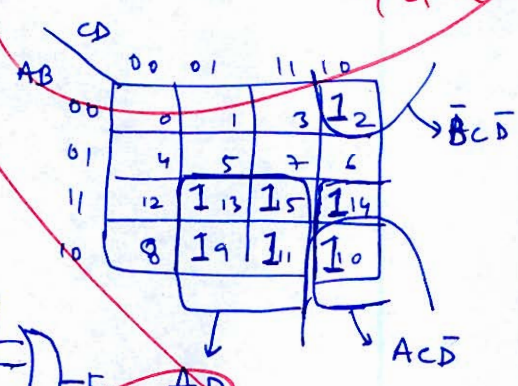


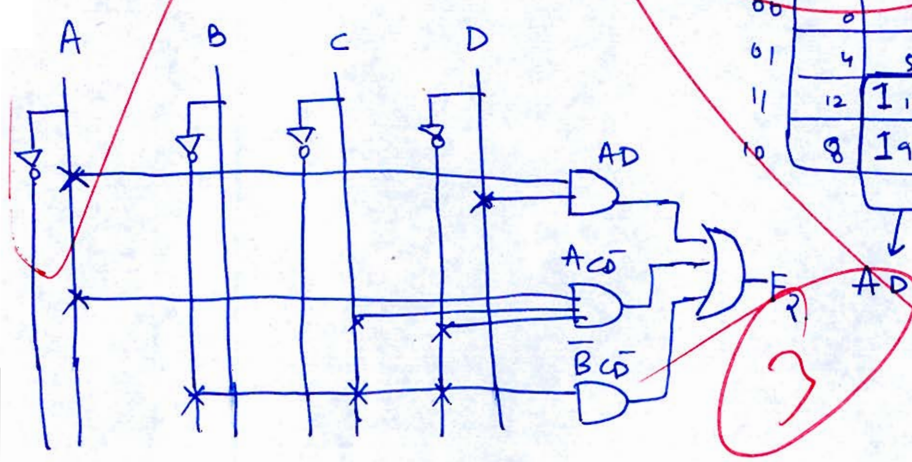




Don't do it like in exam

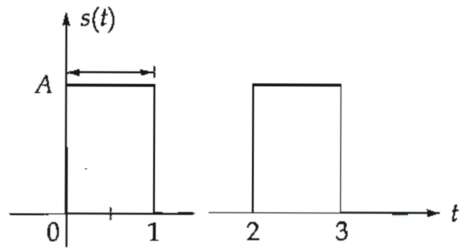
Now, for $F_2 = \Sigma m(2, 9, 10, 11, 13, 14, 15)$

$F_2 = AD + AC\bar{D} + \bar{B}C\bar{D}$



**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.




**(i)** Sketch the impulse response of the filter matched to $s(t)$.

**(ii)** Sketch the output of the matched filter when the input is $s(t)$.

**(iii)** Determine the variance of the noise at the output of the matched filter at $t = 3$.

**(iv)** Determine the probability of error as a function of $A$ and $N_0$.

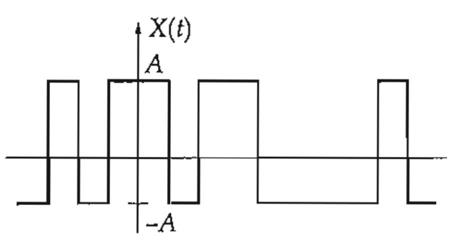
**[20 marks]**

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 $\alpha$. The probability of having exactly $k$ crossing in time $T$ is given by the Poisson distribution $P(z = k) = e^{-\alpha T} \dfrac{(\alpha T)^k}{k!}$,

where $\tau$ 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]**

(i) Given $f_m$ is used as modulating sig for both AM and FM, Now, $(\Delta f)_{Peak} = 3$ (B.W of AM)

$$(\Delta f)_{max} = 3 \times 2f_m = 6f_m \quad (1)$$

Now, for FM sig, $\beta = \frac{\Delta f}{f_m} = 6$

(1) Modulation index of FM sig $= \boxed{\beta = 6.}$ **

we know,

Now, $A_{c(FM)} = A_{c(AM)}\sqrt{1+\frac{\mu^2}{2}}$

$$\boxed{\frac{\mu A_{c(AM)}}{2} = A_{c(AM)}\sqrt{1+\frac{\mu^2}{2}}\,|J_1(\beta)|}$$ ** Standard

$$J_1(\beta) = \frac{\mu}{2\sqrt{1+\frac{\mu^2}{2}}}$$

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

Equate we get, $0.28 = \frac{\mu}{2\sqrt{1+\frac{\mu^2}{2}}}$

$$(0.56)^2 = \frac{\mu^2}{1+\frac{\mu^2}{2}} \Rightarrow \frac{2\mu^2}{2+\mu^2} = (0.56)^2$$

$$2\mu^2 = (2+\mu^2)(0.56)^2$$

$$2\mu^2 = (0.56)^2 \times 2 + (0.56)^2\mu^2$$

(2) $\boxed{\mu \simeq 0.61}$ ** ← Modulation Index of AM.

Very good

6

Do not write in this margin

**Q.6 (c)** A particular 6-bit DAC has a full-scale output rated at 1.260 V. Its accuracy is specified as ±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]**

Given $(n = 6)$ $V_{FS} = 1.260\ V$

Accuracy $= \pm 0.1\%$ of $V_{FS}$ , offset error $= 1\ mV$.

$(0.001 \times 1.260) = \pm 1.26\ mV$ = Accuracy Error.

(Total error = Accuracy Error + offset Error.)

Total Error = $1\ mV + 1.26\ mV = 2.26\ mV$

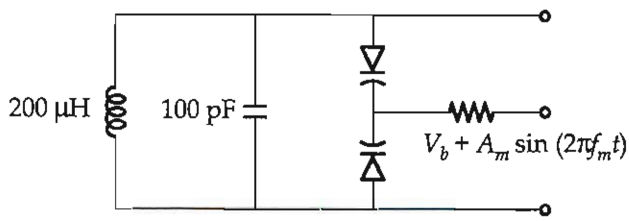
Step size $= \dfrac{V_{FS}}{2^n - 1} = \dfrac{1.260}{2^6 - 1} = 0.02\ V$

$= 20\ mV$

**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 μH inductor and 100 pF capacitor. The capacitor of each varactor diode is related to the voltage V (in volts) applied across its electrodes by $C = 100\ V^{-1/2}$ 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 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 rad/V, find $m(t)$
2. Considering $x_c(t)$ as a FM signal with $k_f = 10\pi$ Hz/V, find $m(t)$

**[12 + 8 marks]**

(i)

① Given, (VCO) vlg controlled oscillator,

($m(t) = A_m \cos 2\pi f_m t$ + bias $V_b$ to pair of varactor diode)

Modulating sig.

$L = 200\ \mu H$
$L = 200\times10^{-6}\ H$

and $C_f = 100\ pF = 100\times10^{-12}$

$C_v = 100\, V_b^{-1/2}\times10^{-12}$ F

$C_{v_{eff}} = \frac{C_v}{2} = 50 V_b^{-1/2}$ pF, $\left(C_T = C_f + C_{v_{eff}}\right) = 100 + 50V_b^{-1/2}$

$1\text{MHz} = f_c = \frac{1}{2\pi\sqrt{LC_T}} = \frac{1}{2\pi\sqrt{200\times10^{-6}\times 100 + 50(V_b)^{-1/2}\times10^{-12}}}$

Now = $f_u^2 = \dfrac{1}{4\pi^2 \times 200\times10^{-6}\left(100+50V_b^{-1/2}\right)\times10^{-12}} = (10^6)^2$

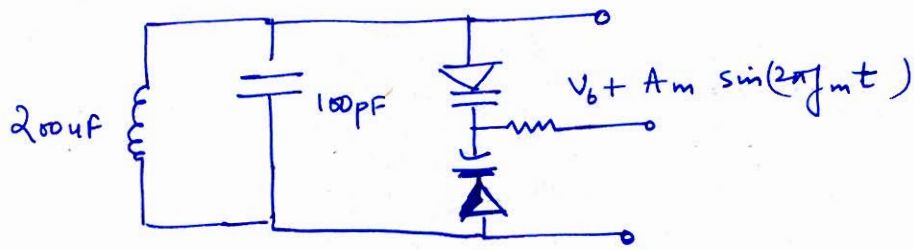
Now, $\left(100+50V_b^{-1/2}\right) = \dfrac{1}{4\pi^2\times10^{-18}\times 200\times10^{12}}$

$100+50V_b^{-1/2} = \dfrac{1}{4\pi^2\times200\times10^{-6}} = \dfrac{1}{8\pi^2\times10^{-4}}$

Solving, we get, $\boxed{V_b \simeq 3.52\ V}$

Very good

(2)




given $f_m = 10KHz$, $\boxed{\text{Find } A_M = ?}$, $\beta = 5$

$n = \dfrac{64MHz}{1MHz} = 64$.

$\Delta f_{out} = \beta\cdot f_m = 5\times10KHz = 50KHz$.

$\Delta f = \dfrac{\Delta f_{out}}{n} = \dfrac{50KHz}{64} = 781.25\ Hz$.

6

$\boxed{\dfrac{f_u}{2}\dfrac{\Delta C}{C_T} = \Delta f}$

$\Delta C = \left(\dfrac{\partial c_T}{dV}\right)A_m = \left[\dfrac{\partial}{\partial V_b}(50V_b)^{-1/2}\right]A_m.$

Substitute in equation,

$$\Delta f = \frac{f_x}{2}\frac{\Delta C}{C_T} = \frac{1\times10^6}{2}\times\frac{\left[\frac{\partial}{\partial v_b}(50v_b)^{-1/2}\right]A_m}{(100+50v_b^{-1/2})\times10^{-12}}$$

$$\Delta f = 781.25 = \frac{10^6}{2}\frac{\left[\frac{\partial}{\partial v_b}(50v_b)^{-1/2}\right]A_m}{(100+50v_b^{-1/2})\times10^{-12}}$$

$$781.25 = \frac{10^6}{2}\frac{50^{-1/2}\left[\frac{\partial}{\partial v_b}(v_b)^{-1/2}\right]A_m}{(100+50v_b^{-1/2})\times10^{-12}}.$$

Solving and put value of $V_b = 3.52V$, we get

$$A_m \cong 52.2\ mV$$ **

7(a)(ii) $x_c(t) = 10\cos\left[(2\pi\times10^6)t + (0.1)\sin(10^3)\pi t\right]$ ($\phi(t)$)

(i) For PM sig → $K_p = 10\,rad/V$.

$K_p\cdot m(t) = 0.1\sin(10^3)\pi t$

$m(t) = 0.01\sin(1000\pi t)$ Ans.

(ii) For FM sig → $K_f = 10\pi\ Hz/v$.

$f_i = f_c + 50\cos(1000\pi t) = f_c + K_f\,m(t)$

$m(t) = \frac{50}{10\pi}\cos(1000\pi t)$

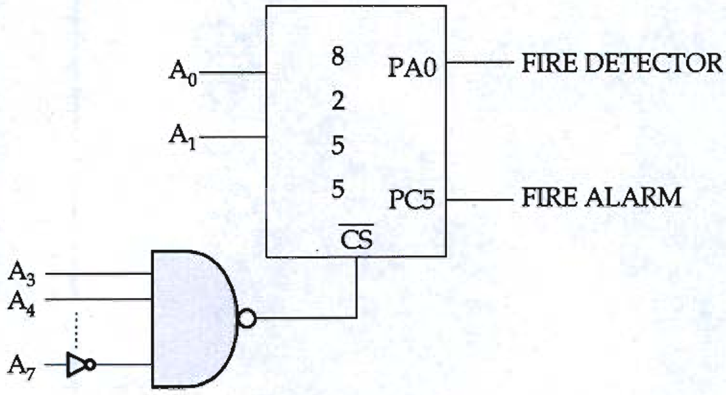
$= \frac{5}{\pi}\cos(1000\pi t)$

8

**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 kΩ 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 $r(t) = A_u \sin[2\pi f_c t + \theta(t)]$. 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]**

Given, $R = 100\,K\Omega$ connected in parallel with 100 pF (capacitor)

Effective Noise Bandwidth $= B = \frac{1}{4RC} = \frac{1}{4 \times 100 \times 10^3 \times 100 \times 10^{-12}}$

$$B = \frac{10^{12}}{4 \times 10^5 \times 100} = \frac{10^5}{4} = 25\,KHz.$$

8

Noise vtg at terminal of combination,

$$V = \sqrt{\frac{KT}{C}}$$

where, $K = 1.38 \times 10^{-23}$ J/K

$T = 273 + 27 = 300\,K$

$C = 100 \times 10^{-12}$.

$$V = \sqrt{\frac{1.38 \times 10^{-23} \times 300}{100 \times 10^{-12}}} = \sqrt{\frac{1.38 \times 10^{-11} \times 300}{100}}$$

$$V = \sqrt{1.38 \times 3 \times 10^{-11}}$$

$$V = 6.43\,\mu V.$$

(ii) $s(t) = A_c \cos[2\pi f_c t + K_p \cdot m(t)]$ (Given)

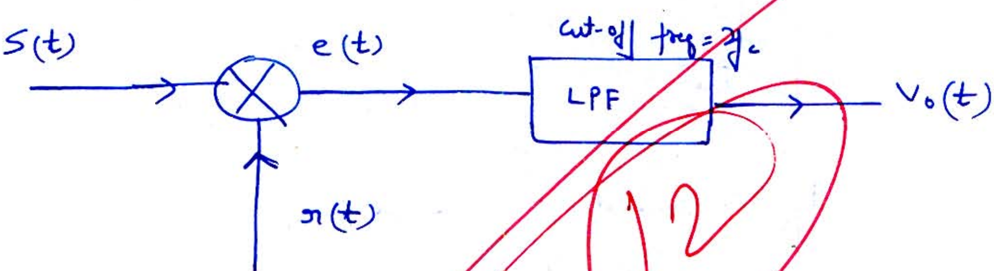
$r(t) = A_u \sin[2\pi f_c t + \theta(t)]$ (Given)

$e(t) = s(t) \cdot r(t) = A_c \cos[2\pi f_m t + K_p \cdot m(t)] \, A_u \sin[2\pi f_c t + \theta(t)]$

$e(t) = \frac{A_c A_v}{2} \sin[4\pi f_c t + \theta(t) + K_p m(t) + \sin\theta(t) + \ldots]$

removing $2f_c$ terms..

$$\left[ V_o(t) = \frac{A_c A_v}{2} \sin(K_p m(t)) \right]$$



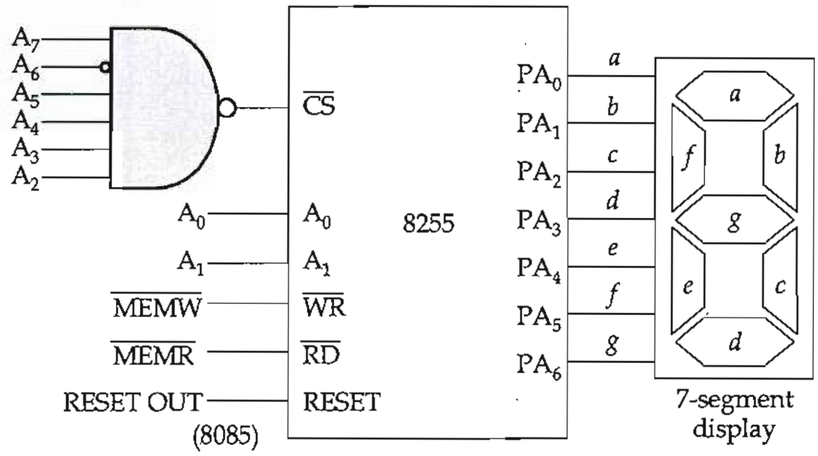

12

**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]**

**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]**

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**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 turned 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]**

OOOO

**Space for Rough Work**

Space for Rough Work

## Space for Rough Work

## Space for Rough Work