Department of Avionics
Indian Institute of Space Science and Technology
Grid Connected Converters: AVP 612
Mid Term Examination

Sep 30, 2024
Time: 2 hours
Max. marks: 30

This question paper contains three questions. Make reasonable assumptions where necessary. Write the answers clearly and legibly so that they can be graded.

1. The circuit for a 3.1kVA single-phase active front end converter (FEC) is shown in Fig. 1. Answer all the following questions with respect to the 1-phase FEC.

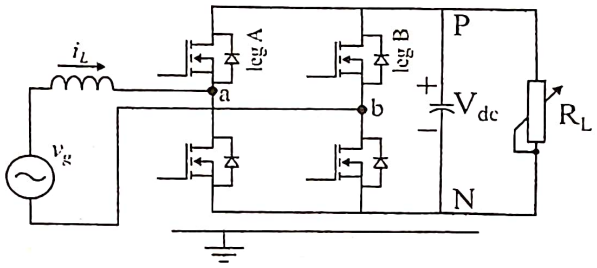

Figure 1: Circuit Diagram of a 1-phase FEC.

(a) (2 points) Assume the converter is operated such that it draws zero current from the 230V/ 50Hz grid. If the modulation index is set at 0.75, what would be the DC link voltage at this operating point? Draw the phasor diagram and explain its operation.

(b) (2 points) What should be the value of the interface inductance, if the impedance is sized at 8%

(c) (2 points) What would be the grid current if all power semiconductor switches fail as short?

(d) (2 points) Draw the phasor diagram for the converter when the current from the grid is 5A with 0.8 power factor leading.

(e) (8 points) Write expressions for modulating voltages (v_{ma} and v_{mb}) and the duty cycles (d_a and d_b) of inverter Leg A and Leg B for the following operating conditions. Assume the DC-link is set at 450V.

i (1 point) The DC load is removed.

ii (2 points) The DC load consumes 7.5 kW from the grid, and grid current is drawn at unity power factor.

iii (2 points) The FEC draws 10A of current at zero power factor leading.

iv (3 points) The DC load is removed and the converter supplies the following harmonic phase currents.

$$i_g = 0.33\sin(6\omega t) + 0.2\sin(10\omega t)$$

Total for Question 1: 16

Student's name:

Please go on to the next page...

2. A DC-DC converter to power a water heater. The water heater consists of a coil that gets hot when current flows, and the heat generated is transferred to a heat coil which is immersed in the water.

   The heating coil can operate from 24V to 48V and the resistance of the coil changes from 10Ω to 18Ω.

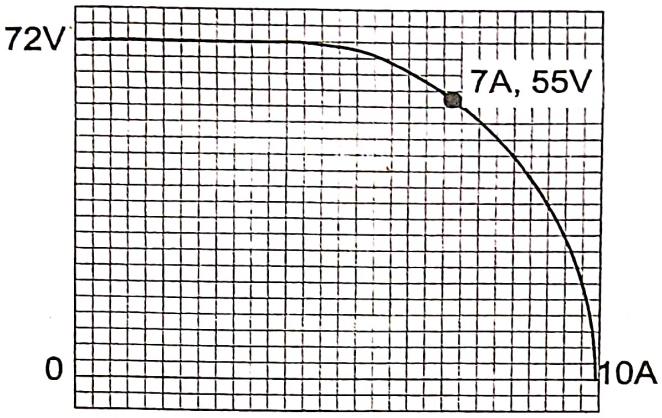

Figure 2: PV panel characteristics

   (a) (2 points) The PV panel chosen has characteristics that is shown in Fig. 2. The maximum power point is marked in the figure. What is the fill-factor of the panel? (note: Fill-factor is defined as the ratio of maximum power available from the panel to the maximum power available from an ideal voltage source V_{OC} with current limit as the short circuit current.)

   (b) (2 points) What kind of converter is required for ensuring MPP operation of the panel? Justify your answer.

   (c) (4 points) What is the operating duty cycle? Assume linear variation of resistance wrt the power dissipation in the heater.

   (d) (1 point) What would be the panel current, panel voltage?

Total for Question 2: 9

3. A 3.1kW single phase FEC is designed for a 230V/50Hz grid, with DC voltage of 450V. The interface inductance chosen is 15mH which has a coil resistance of 0.05Ω, the MOSFETs switch at 25kHz, and DC link capacitor is sized at 2.2mF.

   (a) (2 points) Draw the full control block diagram with inner current-control loop and outer voltage control loop with appropriate controllers.

   (b) (2 points) Why is it alright to choose a proportional controller (P-controller) to act as the current controller?

   (c) (3 points) How are the gains and time-constant of the converter, voltage sensor and current sensor's transfer function derived?

Total for Question 3: 7

Department of Avionics
Indian Institute of Space Science and Technology
Grid Connected Converters: AVP 612
End Semester Examination

Dec 11, 2024
Time: 3 hours
Max. marks: 50

This question paper contains four questions; answer all questions. Make reasonable assumptions where necessary. Write answers clearly and legibly so that they can be graded.

1. The circuit for a 700 VA single-phase active front end converter (FEC) is shown in Fig. 1. Answer all questions with respect to the 1-phase FEC.

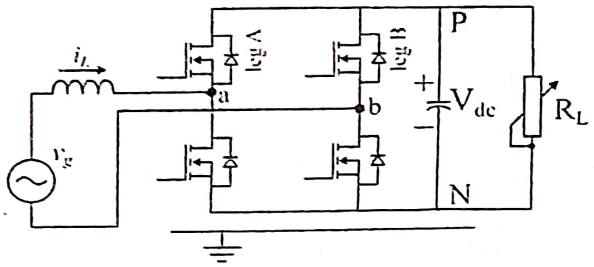

Figure 1: Circuit Diagram of a 1-phase FEC.

(a) (3 points) The converter is connected to a 110V/ 60Hz grid with an interface inductance L with a series resistance R_s, and a DC link capacitance C. The switching frequency of the converter is F_s. Draw the cascaded control loop for regulating the DC link-voltage and the grid current at UPF.

(b) (4 points) How would you choose the gain of the current loop controller if it is decided to use proportional control for the current loop? Derive the expression for controller gain and describe the design philosophy.

(c) (2 points) How are the gains and time-constant of the converter, voltage sensor and current sensor's transfer function derived?

(d) (8 points) Derive the voltage controller parameters for the voltage controller. What is the design philosophy adopted?

(e) (4 points) What is the problem encountered while designing the voltage controller via pole-zero cancellation philosophy?

Total for Question 1: 21

2. A 2kW three-phase STATCOM is connected to a 415V/50Hz grid with an interface inductance L with a series resistance R_s per phase, DC link capacitance C. The switching frequency of the converter is F_s.

(a) (4 points) Draw the reference frame diagram showing natural, stationary and synchronous reference frames with grid voltage and grid current vectors, and write down the expressions for real and reactive power in d-q axis reference frame.

Student's name:

Question 2 continues on the next page...

(b) (4 points) Draw the cascaded control block with decoupled control of real and reactive power drawn from the grid. How are the d-axis and q-axis current references derived for STATCOM operation?

(c) (8 points) Derive the voltage controller parameters for the converter. Assume that the inner control loops are identical in d-axis and q-axis. Explain the design philosophy and derive the expression for controller parameters.

(d) (4 points) Derive the expression relating DC-link current and real-component of the AC side currrent.

Total for Question 2: 20

3. A 3-phase inverter with a DC link of 700V is driving a 415V, 50Hz, 4-pole 5 kW induction motor at its near maximum load, rated speed conditions (at 0.9 power factor). The winding resistance is 0.7Ω and leakage inductance of the motor is 3 mH. If the converter is operated with sine-PWM, switches at 20kHz and deadtime is 4 μs, find the following.

(a) (3 points) Third harmonic current (RMS) flowing in the motor coils due to dead-time.

(b) (2 points) Fifth harmonic current (RMS) flowing in the motor coils due to dead-time.

(c) (4 points) Plot (a) modulating voltage of the inverter, (b) motor current, (c) effective average voltage, (d) effective deadtime voltage. Mark the amplitudes and relative phases for all the plots.

Total for Question 3: 9

4. (5 points) Dr. Jekyll is selling an LED bulb with 6 LEDs in parallel with each LED dissipating 2W power for Rs. 1200/- per bulb. His competitor Mr. Hyde is also selling a 12W LED with 4 LEDs in parallel for Rs. 800/- per bulb. How would you evaluate the quality of these bulbs in terms of service lifetime and cost as an informed engineer/ consumer? Assume the LEDs are identical with similar thermal properties.

Total for Question 4: 5

Student's name:

End of examination

INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY
THIRUVANANTHAPURAM, 695 547
B. Tech Seventh Semester ECE – Mid Term– September 2024
AV411 – Navigation Systems and Sensors
Time: Two Hours Date: 23/09/2024 Max. Marks: 30

Read **ALL** the instructions in this **NOTE**. Write your name and ID number on Answer Papers. Do **NOT** panic. Answer **ALL** questions. All the steps must be stated clearly. The steps carry more marks than the final answer. Provide illustrations wherever required.

If anything is **NOT** clear, make relevant assumptions and solve the problem. In that case state your assumptions clearly. If you feel that a particular question is wrong then solve the "nearest" correct question by stating your version of question clearly. The instructor may not be available for clarification during the examination.

The students are allowed to carry one A4 sheet written in their own handwriting containing formulas. However, no block diagrams and derivations are allowed. The sheet shall carry the student's name and SC code and should be submitted along with the answer script.

1. With a neat block diagram explain briefly the the concept of stabilised platform system. (2)
2. What is time? What are the different types of times, define each one briefly. (3)
3. Show that rotation matrices are orthogonal matrices with determinant 1. (3)
4. Show that the quaternion operator $L_p(\vec{q}) = p^*\vec{q}p$ with $||p|| = 1$ represents rotation by clearly showing the axis of rotation and angle of rotation. (5)
5. Derive the kinematics of the DCM from first principles. (2)
6. An observatory in Mount Abu needs to point its telescope to observe the satellite Astrostat. The east longitude and north latitude of the observatory is 72°46′45.12″ and 24°39′17.28″, respectively. At 9:35:15 AM Indian Standard Time (IST) on Oct., 05, 2015 the position of the Astrostat was predicted by a computer to have the topocentric right ascension of 45° and the topocentric declination of 60° in the topocentric equatorial co-ordinate system. (15)

   Note: In topocentric equatorial co-ordinate system, the axes are parallel to the ECI frame but centered at the observer. The topocentric right ascension is measured from the topocentric axis which is parallel to ECI X-axis and topocentric elevation is measured from the topocentric plane which is parallel to equatorial plane of ECI frame.

   Compute the azimuth (angle measured from local north) and angular elevation (angle measured from local horizontal plane) of the telescope for observing Edusat so that the image of the Edusat falls along the visual axis of the telescope by first determining the rotation matrices using Euler angle axis method and hence the final transformation matrix. Hence compute the azimuth and elevation in observer frame.

End of exam.

INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY
THIRUVANANTHAPURAM, 695 547
B. Tech Seventh Semester ECE – End Semester – November 2024
AV411 – Navigation Systems and Sensors
Time: Three hours Date: 29/11/2024 Max. Marks: 50

Read ALL the instructions in this NOTE. Write your name and ID number on Answer Papers. Do NOT panic. Answer ALL questions. All the steps must be stated clearly. The steps carry more marks than the final answer. Provide illustrations wherever required.

If anything is NOT clear, make relevant assumptions and solve the problem. In that case state your assumptions clearly. If you feel that a particular question is wrong then solve the "nearest" correct question by stating your version of question clearly.

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Inertial Sensors and Inertial Navigation Systems

1. Define Navigation, Guidance and Control and explain the NGC loop using a neat block diagram. (2)

2. Inertial Navigation
   (a) With a neat block diagram explain the signal flow of stabilised platform inertial navigation system. (2)
   (b) With a neat block diagram explain the signal flow of strapdown inertial navigation system. (2)

Particle dynamics in moving coordinate system

3. Let e^1, e^2 and e^3 be unit vectors of a right handed moving system where ω is the angular velocity of the moving system.
   (a) Show that derivative e^1 is orthogonal to itself. (1)
   (b) Show that $\frac{d}{dt}e^1 \cdot e^2 = -\frac{d}{dt}e^2 \cdot e^1$, where $\cdot$ stands for dot-product. (1)

4. With a neat diagram, derive the acceleration expression in terms of tangential and normal component for a particle in curvilinear motion, clearly indicating the radius of curvature. (2)

5. With a neat diagram derive the five term kinematics of a particle motion in a moving frame. (2)

6. A projectile with a mass of 1 Ton is launched vertically from the surface of the Earth with a velocity of 100m/s. Assuming negligble wind, would the projectile rise up vertically from where it was launched. Justify. Compute the position of the projectile on the sky when it reaches zero velocity in relation the observer at the launch site. Assume that the latitude and longitude of the of the launch site to be 60° and 30°, respectively. (3)

Coordinate-systems and Coordinate Transformation

7. Consider the following representation of the Euler Angles and Euler sequences

$$R_x(\theta_x)R_y(\theta_y)R_z(\theta_z) = \begin{bmatrix} c_y c_z & c_y s_z & -s_y \\ s_x s_y c_z - c_x s_z & s_x s_y s_z + c_x c_z & s_x c_y \\ c_x s_y c_z + s_x s_z & c_x s_y s_z - s_x c_z & c_x c_y \end{bmatrix}$$

Let the Euler angles be $\theta_x = 10$, $\theta_y = 90$, $\theta_z = 30$.

(a) Compute the quaternion representing the above rotation. (2)

(b) Does there exist another distinct set of Euler angles in the range [0,360] and same sequence such that it represents the same orientation. If so determine another distinct set of Euler angles ϕ_x, ϕ_y, ϕ_z that represents the same orientation otherwise justify. (2)

(c) Give the quaternion representing the above distinct set of Euler angles. (1)

(d) What do you conclude from this? (1)

8. Derive an expression for derivative of a quaternion in terms of body angular rate and derivative of the quaternion rotation operator. (2)

9. Properties of DCM matrix

(a) What are properties of DCM matrix? (1)

(b) Which, if any, of the following coordinate systems is not rotating? (1)

A. North-East-Down (NED) B. East-North-Up (ENU)
C. ECEF (Earth-centered Earth-fixed) D. Earth Centered Inertial (ECI) E. None of the above

10. Consider the following matrix

$$A = \begin{bmatrix} 0 & 0 & -1 \\ \sin(\psi) & \cos(\psi) & 0 \\ \cos(\psi) & -\sin(\psi) & 0 \end{bmatrix}$$

(a) Determine weather the above matrix is a rotation matrix and justify. If the above matrix is not a rotation matrix modify it to a rotation matrix. (1)

(b) Determine the axis and angle of rotation for the above/converted matrix. (2)

11. A given co-ordinate transformation is uniquely represented by a unit quaternion [T/F]. Justify. (1)

12. Find the quaternion corresponding to the DCM matrix $\begin{bmatrix} -\frac{5}{8} & \frac{\sqrt{3}}{4} & \frac{3^{3/2}}{8} \\ \frac{\sqrt{3}}{4} & -\frac{1}{2} & \frac{3}{4} \\ \frac{3^{3/2}}{8} & \frac{3}{4} & \frac{1}{8} \end{bmatrix}$ (1)

13. Show that for any $t \in \mathbb{R}$ the matrix Q_t defined below is a rotation matrix. Find its axis of rotation and cosine of the angle of rotation. (3)

$$Q_t = \frac{1}{1+t+t^2} \begin{bmatrix} -t & t+t^2 & 1+t \\ 1+t & -t & t+t^2 \\ t+t^2 & 1+t & -t \end{bmatrix}$$

14. The IRNSS 1A satellite was launched into geosynchronous orbit with an inclination of 27.47 degrees with equator, Perigee 35,704Km and Apogee 35,866 Km. On 31st Dec., 2020 at 12:35 IST IRNSS makes an observation of Sun and the Star Sirius. The co-ordinates as measured by IRNSS of the Sun are $(2,1,3)$ and $(1,-1,1)$ in the body and ECI frame respectively and that of the Sirius are $(1,0,1)$ and $(-1,1,0)$ in the body and ECI frame respectively.

(a) Is it possible to determine the orientation of IRNSS body frame with respect to the ECI frame with the above given measurements? Justify (1)

(b) If the answer to the above question is yes then justify by determining the transformation matrix between the IRNSS body frame and ECI frame. If the answer to the previous question is no then how many additional vector measurements are required to obtain the transformation matrix between IRNSS body frame and ECI frame? Give an example of additional measurement vectors and the corresponding transformation matrix. (2)

15. An inertial measuring unit consisting of three rate gyroscopes and three servo accelerometers are placed in a rocket at the launchpad located in Sydney, 33.8600° S, 151.2094° E Australia. The input axes of the inertial measuring unit are aligned with North, East and Zenith axis. Determine the measurements obtained by all the gyroscopes and accelerometers. (1)

16. An observatory in Mount Abu needs to point its telescope to observe the satellite Astrostat. The east longitude and north latitude of the observatory is 72°46′45.12″ and 24°39′17.28″, respectively. At 9:35:15 AM Indian Standard Time (IST) on Oct., 05, 2015 the position of the Astrostat was predicted by a computer to have the topocentric right ascension of 45° and the topocentric declination of 60° in the topocentric equatorial co-ordinate system. (8)

    Note: In topocentric equatorial co-ordinate system, the axes are parallel to the ECI frame but centered at the observer. The topocentric right ascension is measured from the topocentric axis which is parallel to ECI X-axis and topocentric elevation is measured from the topocentric plane which is parallel to equatorial plane of ECI frame.

    Compute the azimuth (angle measured from local north) and angular elevation (angle measured from local horizontal plane) of the telescope for observing Edusat so that the image of the Edusat falls along the visual axis of the telescope by first determining the rotation matrices using Euler angle axis method and hence the final transformation matrix. Hence compute the azimuth and elevation in observer frame.

17. With neat diagrams explain the working principles of the following sensors: (5)
    (a) MEMS accelerometer
    (b) Momentum wheel gyros
    (c) Coriolis Gyros
    (d) Laser Gyros
    (e) Accelerometer

Question	Points	Score
1	2	
2	4	
3	2	
4	2	
5	2	
6	3	
7	6	
8	2	
9	2	
10	3	
11	1	
12	1	
13	3	
14	3	
15	1	
16	8	
17	5	
Total:	50	

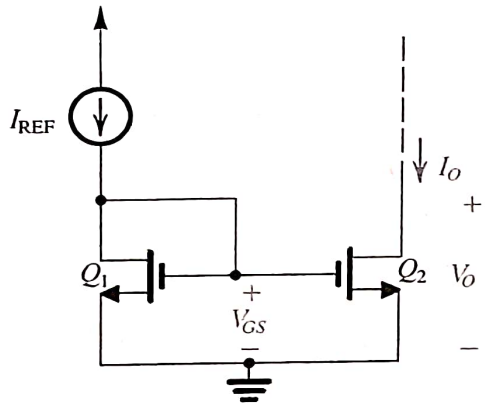
End of exam.

Indian Institute of Space Science and Technology
Department of Avionics
AVM 613 Analog VLSI Circuits
Mid Semester Examination - 2024

Time: 2 hours **Max. marks:** 30

Answer all the questions

1. Consider a simple NMOS current mirror shown below. Transistor Q_1 has a W/L = 250nm/40nm and Q_2 is made of 8 multipliers of Q_1 (8 identical transistors in parallel). I_{REF} = 20 μA. Let $\mu_n C_{ox}$ = 0.25 mA/V^2 and V_{TH} = 0.35 V. λ = 0.7. (5 marks)



   (a) What is the output current? Calculate the output impedance of the current source (Q_2).

   (b) If V_{TH} varies between 325 mV and 370 mV due to process and temperature variation, what is the variation in V_{GS}, assuming $\mu_n C_{ox}$ remains the same?

   (c) What is gradient error? And how can you design the layout of this current mirror to minimize its impact?

   (d) If V_o becomes 100 mV higher than V_{GS}, what is the change in the output current?

   (e) For Q_1, what is the standard deviation of V_{TH}, if pelgrom's coefficient $A_{V_{TH}} = 5 \times 10^{-10}$?

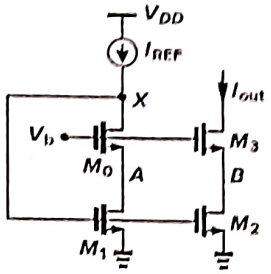
For the rest of the questions, assume the following:
V_{DD} = 1.8V

$\mu_n C_{ox} = 0.5\text{mA}/V^2$, $V_{THN} = 0.35\text{V}$

$\mu_p C_{ox} = 0.4\text{mA}/V^2$, $V_{THP} = -0.35\text{V}$

$\lambda_N = 0.1$, $\lambda_P = 0.1$.

2. In the circuit given below, $(W/L)_{1,2} = 20/0.5$, $(W/L)_{3,0} = 60/0.5$, and $I_{REF} = 100\mu\text{A}$. (5 marks)

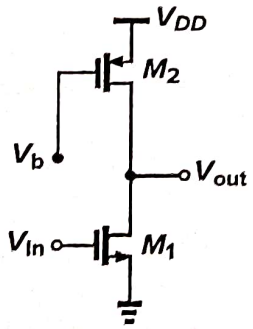


   (a) Determine V_X and the acceptable range of V_b. (neglect channel length modulation)

   (b) Calculate the output impedance of the current source.

   (c) Estimate the deviation of I_{out} from $300\mu\text{A}$ if the drain voltage of M3 is higher than V_X by 1V.

3. Consider the common source amplifier shown in the figure below. Tom, the designer is given the following specifications: $C_L = 2$ pF (total capacitance at the output); UGF = 500 MHz; Expected DC level of the input = 0.7 V. Help Tom design the circuit, by calculating the following: (7 marks)



   (a) What is the g_m and W/L that he should design M_1 for? (neglect channel length modulation effect.)

(b) What is the I_D that would result? (neglect channel length modulation effect.)

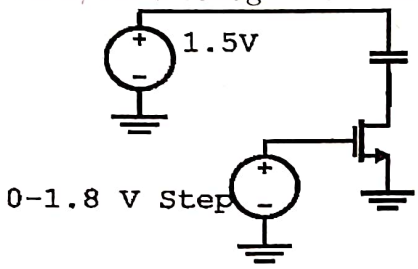
(c) For this I_D, calculate V_b at the gate of M_2 if Tom uses $\left(\frac{W}{L}\right)_2 = 2 \times \left(\frac{W}{L}\right)_1$? (neglect channel length modulation effect.)

(d) Calculate the output impedance and the small signal gain.

(e) What is the input-referred noise of this amplifier that you have helped Tom design? Provide only the expression.

4. To the circuit given above, add a resistor of 100 Ω at the source of M_1. Assume that the drain current is retained to be the same, by appropriately increasing the DC level of the input. What is the effective transconductance of the circuit? (3 marks)

5. In the figure shown below, the capacitor has a value of 1pF and for $t < 0$, has a voltage of 0V. At $t = 0$, the step happens. (3 marks)

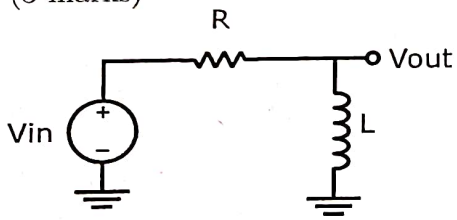


(a) What is the R_{on} of the transistor, if W/L = 2 μm/180 nm?

(b) What is the time constant of this circuit?

(c) At what time will the capacitor charge up to 95% of the final value?

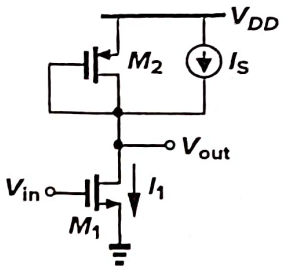
6. Consider a RL network as shown below. Let R = 1 KΩ and L= 1 μH. (3 marks)



(a) If the input is a 50% dutycycle square wave of time period 2 ns, sketch the output.

(b) If the input is a 50% duty cycle square wave of time period 100 ns, sketch the output.

7. For the figure shown below, derive the gain, input-referred noise voltage, output impedance, output signal swing limits. The current source $I_S = 0.75I_1$. Assume $\lambda = 0$. If a load capacitance (C_L) is connected to the output, what is the bandwidth? (4 marks)



Indian Institute of Space Science and Technology
Department of Avionics
AVM 613 Analog VLSI Circuits
End Semester Examination - 2024

Time: 3 hours **Max. marks:** 40

Answer all the questions For all the questions, assume the following:

$V_{DD} = 1.8$V

$\mu_n C_{ox} = 0.5$mA/V^2, $V_{THN} = 0.35$V

$\mu_p C_{ox} = 0.4$mA/V^2, V_{THP} = -0.35V

$\lambda_N = 0.1$, $\lambda_P = 0.1$.

You can assume square law model for MOSFET operation. Some formulae for use in your calculations are provided below:

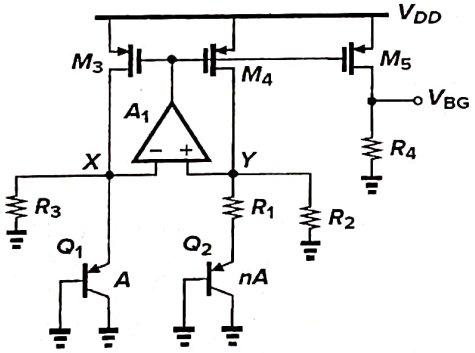
$I_D = \frac{\mu C_{ox}}{2}\frac{W}{L}(V_{GS} - V_{TH})^2$

$g_m = \mu C_{ox}(W/L)(V_{GS} - V_{TH}) = \sqrt{2I_D \mu C_{ox}(W/L)} = \frac{2I_D}{(V_{GS}-V_{TH})}$

$r_0 = \frac{1}{\lambda I_D}$

Answer all the following questions:

1. Consider the circuit shown below. Let V_T = 25mV. n=8. $|V_{BE1}|$ = 0.82V. R1=2KΩ, R2 = R3 = 4KΩ, R4 = 2KΩ. For the first four questions, you can provide the answers considering the circuit at room temperature (T=300K). (5 marks)



   (a) In steady state, what is the voltage across R1? (1 mark)

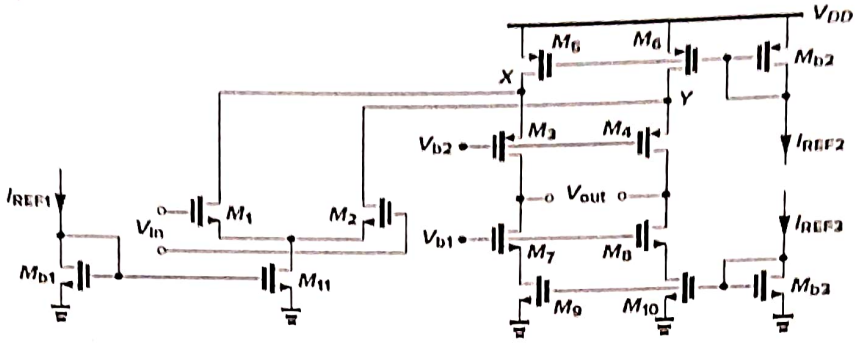
   (b) What is the current through resistors R2, R3? (1 mark)

   (c) What is the current through M4? (1 mark)

   (d) What is the bandgap boltage V_{BG}? (1 mark)

(c) What is the nature of the current through R1 and R2 (PTAT/ CTAT/ independent of temperature)? (1 mark)

2. Consider a folded cascode OTA shown in the figure. Let Iref1 = Iref2 = Iref3 = 20μA. You can assume square-law equations for calculations and neglect channel length modulation for the first few questions till it is required explicitly. The transconductance of M3, M4, M7, M8, M9, M10 = 0.8 mS and the transconductance of M5, M6 = 1.5 mS.(13 marks)



(a) If the minimum voltage required across M11 is 200mV, and $V_{CM,min}$ = 0.6V, what is the current through M1,2 required for a transconductance of 2mS? (2 marks)

(b) What is the W/L ratio of M1,2 ? (1 mark)

(c) The current through M9,10 is 40μA. What is the ratio of $(W/L)_{5,6}$ to $(W/L)_{Mb2}$? (1 mark)

(d) What is the output impedance of the OTA? (2 marks)

(e) What is the open loop gain? (1 mark)

(f) What is the bandwidth if a load capacitance of 2pF is connected at the output? (1 mark)

(g) Calculate the unity gain frequency (1 mark)

(h) Identify the non-dominant poles (expression is sufficient). (2 marks)

(i) Write the expression for the input referred noise, including flicker noise ($\overline{V_{n,in}^2}$). (2 marks)

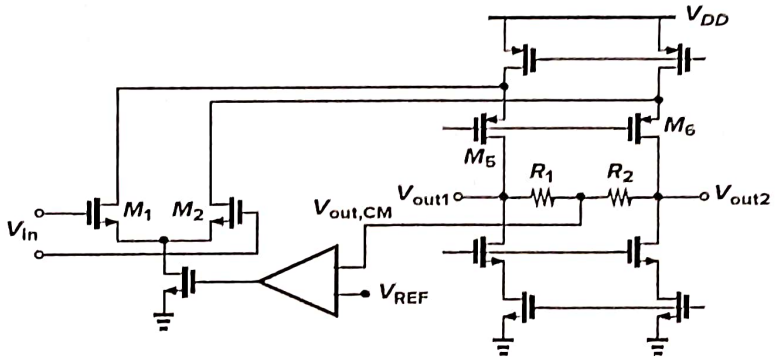
3. A two-stage opamp is being stabilized through miller compensation. Let ω_{p1} and ω_{p2} be the output poles of the 1^{st} and 2^{nd} stages respectively. Also, let $\omega_{p1} < \omega_{p2}$ In the s-plane, show how the poles move when miller compensation is used. (2 marks)

4. An engineer is working on improving the stability of an opamp. When a frequency-independent feedback network with a β of 0.4 is used with the opamp in negative feedback, the phase margin is observed to be 50°. How do you think the phase margin would change if the feedback factor β is reduced? Why? (2 marks)

5. An opamp is used in negative feedback. The bode plot of the loop gain ($A\beta$) shows that the phase margin is 25°. For the closed loop circuit, what will be the magnitude of peaking at the unity gain frequency in the frequency response? (3 marks)

6. An fully differential opamp with rail to rail output is required to be designed. The designer has employed a simple 5-stage OTA as the first stage. Can you help him complete the design with a second stage that can provide a rail-to-rail output swing? For a differential sinusoidal input, draw the waveforms at different nodes of the second stage. (3 marks)

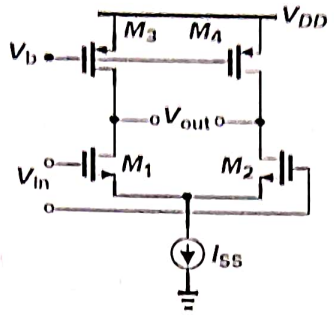
7. Consider the circuit below. (3 marks)



   (a) Identify the correct polarity of the opamp used for CMFB. (1 mark)

   (b) Write the expression of the gain of the folded cascode opamp, and comment on what is the impact of the common mode sensing resistors. (2 marks)

8. Consider the OTA shown below. I_{SS} = 0.5 mA. $(\frac{W}{L})_{1,2}$ = 20/0.35. $(\frac{W}{L})_{3,4}$ = 50/0.35. The current source has an output impedance of 20 KΩ. (9 marks)



(a) What is the transconductance of this OTA? (1 mark)

(b) Calculate the output impedance. (1 mark)

(c) Calculate the differential mode voltage gain (1 mark)

(d) Calculate the common mode gain (1 mark)

(e) Calculate CMRR (1 mark)

(f) What is the minimum input common mode voltage required? (1 mark)

(g) The OTA is loaded with a capacitance of 1pF on both differential arms. What is the unity gain frequency of the OTA? (1 mark)

(h) Calculate the value of V_b. (1 mark)

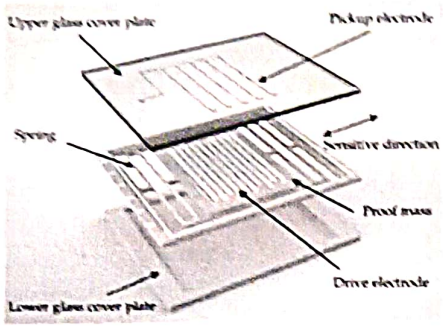
(i) Derive the input referred voltage noise PSD (including flicker noise - expression only). (1 mark)

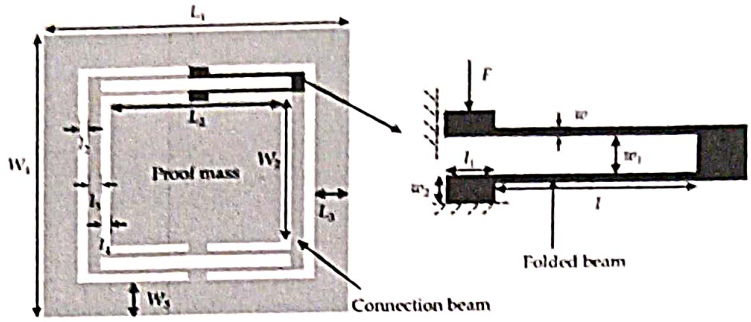
INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY

AVM 612 Introduction to MEMS **25th September 2024**

Mid Semester Exmination Marks : 40

Q.1. Consider an electrostatic MEMS accelerometer consisting of a silicon-based acceleration-sensitive spring-mass structure which is sandwiched by the upper and lower glass cover plates, as illustrated in the figure. The in-plane motion of the proof mass is sensed capacitively between the array of parallel-plate electrodes on the proof mass and the matching array of electrodes on the upper glass plate which is separated by a fixed gap above the proof mass. The dimensions are provided as Table.





Symbol	Parameters	Unit	Value
L_1	Sensor length	mm	6.5
W_1	Sensor width	mm	6.4
L_2	Proof-mass length	mm	4.2
W_2	Proof-mass width	mm	4
L_3	Frame length	mm	1
W_3	Frame width	mm	1
l	Folded beam length	mm	2
l_1	Linkage length	μm	200
l_2	Connection beam gap to frame	μm	50
l_3	Connection beam width	μm	50
l_4	Connection beam gap to mass	μm	50
w	Folded beam width	μm	16
w_1	Folded beam gap	μm	50
w_2	Linkage width	μm	50
t	Wafer thickness	μm	500

(A) Discuss the significance/advantages of this folded beams in this design

(B) Find the acceleration sensitivity (mechanical sensitivity ie. Displacement for acceleration of 1g=9.81 m/s2in respective direction. Use appropriate boundary conditions for the beams/flexures.

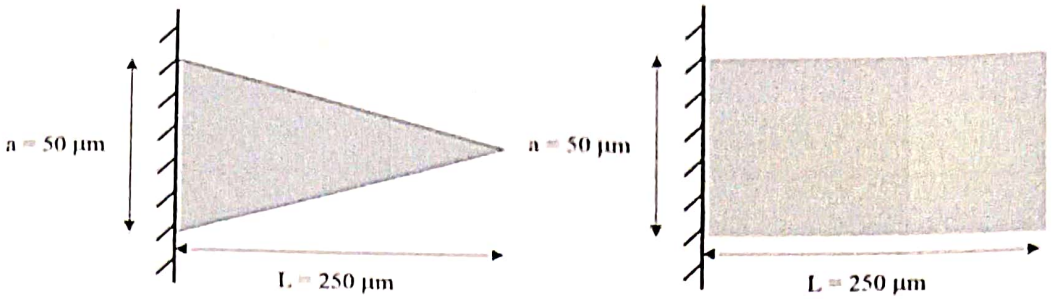
(Hint: The connecting beams are like moving trusses and need not be considered for computing stiffness)

(C) Comment on the cross axis sensitivity of this sensor in z axis. **[3+5+2]**

Q. 2 . Consider two silicon nitride (E = 270 GPa) microcantilevers having thickness of 0.5 μm and with rectangular and triangular shape (top views/planar view) shown below. They are subjected to a point load F at the tip in z direction. Assuming small deformations,

(A) Derive the bending profile (tip deflection) in terms of F, and calculate an effective spring constant for these beams. What are their displacements for a F= 40 nN. **(B)** Plot the stress profiles of these beams for end point loading in z axis and x axis. (Qualitatively ie. stress Vs. distance along the beam axis))

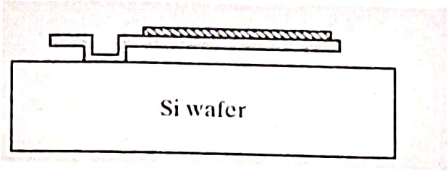
[10]



Q. 3 Consider the following MEMS device with a composite structure of Gold film on Silicon Nitride .

Is this device suitable for Sensing or Actuation or both? Discuss the working principle of the same for sensing/aactuation with importance for the mechanical and electrical elements in the device.

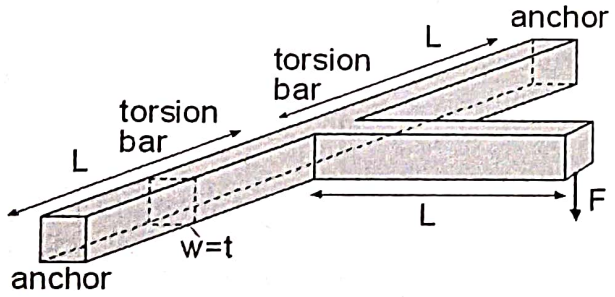
(Hint: Silicon nitride and gold have different thermal expansion coefficients) **[5]**



Q. 4 Consider the loading-unloading characteristics of a material to be obtained from one of pull test.

(A) Plot the load unload curve in such a way that the material undergoes elastic followed by plastic deformation. (B) What is the slope of the linear portion of such a characteristics? **[5]**

Q. 5 A torsional bar is anchored on two ends, with a lever attached in the middle of the bar. A force, F=0.01 μN, is applied to the end of the lever. Determine the degree of angular bending due to the rotation of the torsional bars. Do not consider the bending of the flexural lever segment. The values of L, w, and t are 1000, 10, and 10 μm, respectively. The beam is made of polycrystalline silicon. Assume Poisson's ratio of 0.22 for polysilicon and 158GPa as the value for Young's modulus . **[5]**



Q.6 Consider thermal oxidation for 500 nm of silicon dioxide film on silicon wafer of thickness 675 microns. The film was stress free at the growth temperature of 925 oC. However, when the furnace was cooled and the sample was brought to room temperature (25oC), the stress condition in film and substrate was not known. The thickness of silicon dioxide film was 0.5 μm. (A) Curvature of the sample was measured. the cooled sample was seen to have certain curvature. Whats the method of measuring curvature ? (B)What is the reason for the curvature? Can you illustrate the case showing the nature of curvature (curved up or down). (C)Compute the curvature from the information provided above. **[5]**

Assume for silicon E = 150 GPa ; Poisson's ratio= 0.40; Thermal Expansion coefficient =2.8x10-6/k ;

For silicon dioxide, E = 69 GPa ; Poisson's ratio= 0.17; Thermal Expansion coefficient =0.7x10-6/k ;

Equations

Displacement and Stress in Fixed Free beam (Case- End point loaded beam)

$$w(x) = \frac{F(3L-x)x^2}{6EI}$$

$$T(x) = \frac{Fh(L-x)}{2I}$$

Displacement and Stress on top of Fixed Guided beam (case -Beams holding a mass of Mass M)

$$w(x) = \frac{Mg}{Ebh^3} x^2 (\frac{3}{2} a_1 - x)$$

$$T_{\max} = \frac{3a_1}{2bh^2} Mg$$

Torsional Beams

$$\Phi = \frac{TL}{JG}$$

The torsional moment of inertia of the square torsion beams ,

$$\Phi = \frac{TL}{JG} \qquad J = 2.25(\frac{w}{2})^4$$

Name: _____ Roll No: _____

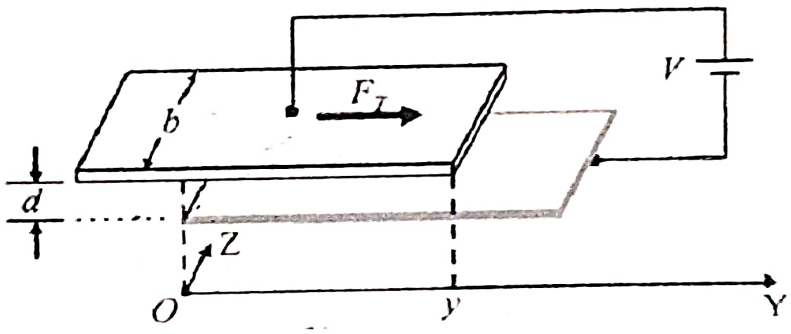
INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY
THIRUVANANTHAPURAM
M-Tech VLSI and Microsystems
B-Tech ECE Semester-VII Elective
End Semester Examination

Course Name: Introduction to MEMS
Monday, December 9, 2024

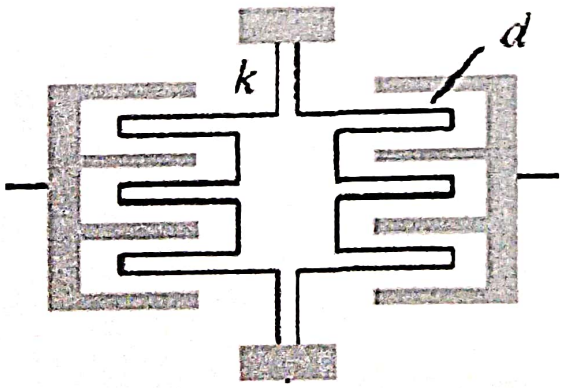
Code: AVM 612
Marks: 55

i. *Questions are self-explanatory. Please make suitable assumptions and mention wherever necessary*

1. Consider parallell plate actuators. For the actuator given below, prove that tangential electrostatic force is independent of the extend of overlap between the plates. Assume the overlap length >> the gap between the plates. **[5]**

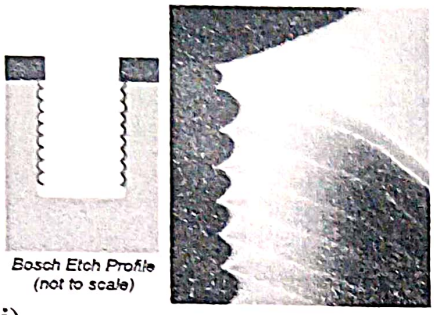


2. Consider a comb drive actuator. Consider with a biasing scheme with suitable signals so that the the actuator frequency is same as the input electrical signal frequency. Also derive the expression for electrostatic force of actuation **[5]**



3. (a) What are the advantages of deep silicon etching using DRIE as compared wet chemical etch processes using TMAH/KOH etchants?

(b) Deep reactive ion etching in silicon can be done using the Bosch process. Explain what you see in the scanning electron micrograph (SEMs) (i and ii)below and why these effects occur in DRIE process?



(i)

(ii)

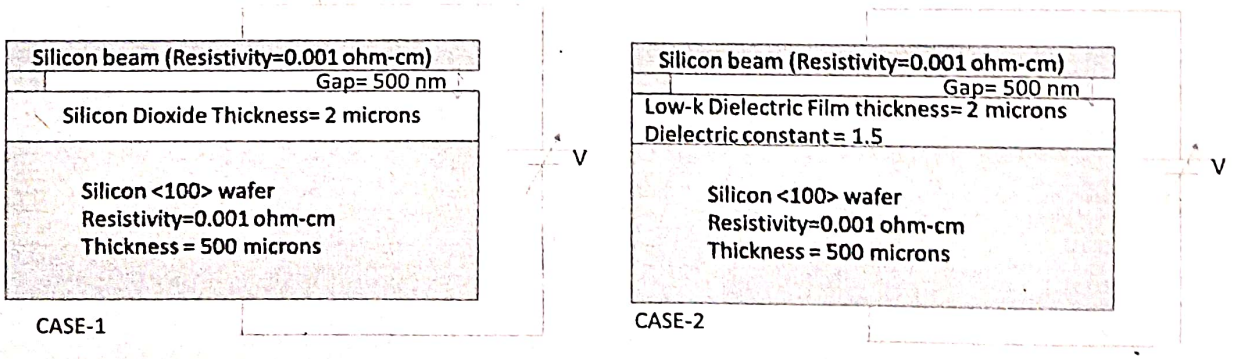
[5]

4. Consider a <110> oriented silicon beam of length 200 microns with area of 20 micron^2. Assume there is a 10 ^{o}C temperature rise from the room temperature causes the length and cross-section of the beam to change.(A) Calculate the longitudinal strain and stress associated with the lateral elongation. (B) Consider the changed cross-section also. What is the relative change of resistance due to this temperature rise (assuming the resistivity stays the same)? (C) What is the relative change of resistance due to this temperature change considering the piezoresistive effect of silicon. Assume the Young's modulus is 168 GPa and poisson ratio of 022. **[5]**

5. Consider a parallel plate electrostatic sensor [A] Derive the expression for pull-in effect.

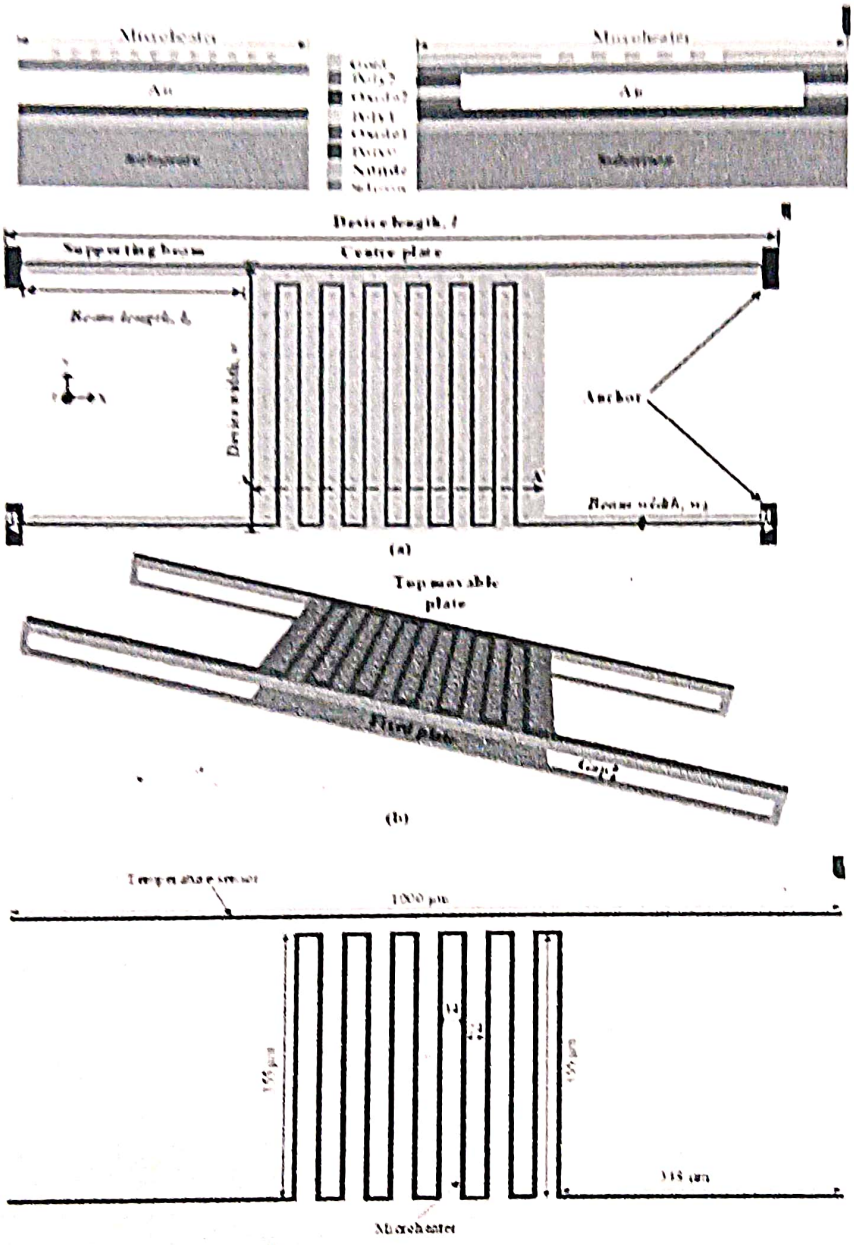
[B]. Consider the following parallel plate electrostatic actuated beams. While actuatin the beams, pull-in was observed in the first case, where as pull-in was not observed in the second case. What could be the reason. Justify your answer with suitable analytical formulation

[10]



6. Consider the MEMS Gas sensor based on electro-thermally actuated MEMS structure with capacitive sensing. Sensor is actuated at a certain frequency, and when exposed to an environment containing the desired gas, the detecting layer absorb gas.

The sensor architecture is as below with a polysilicon MEMS structure with metal based heaters and temperature sensor



The device was fabricated using PolyMUMPs process.

(A) Discuss the workign principle of such a Gas sensor based on your understanding . (Hint: Heater is for electrothermal actuation atd esired frequency)

(B) Come up with a process integration plan for realising the device using PolyMUMPs process. Please mention the type of unit process of each of the steps .

[15]

7. Consider fabrication of silicon MEMS membrane using wet KOH etching on a (100) silicon wafer. Let the thickness of the silicon wafer be 500 μm .

   (a)What feature size of the mask opening to produce a square diaphragm with 400 μm side length and 20 μm thickness ?

   (b)Is there any requirement of orientation of square mask for such a etchiing ? [5]

8. **Term Paper based Question**: Discuss the working of MEMS device as per your Term paper. Draw the device schematic and discuss the MEMS structure and transudction scheme. [5]

Essential Parameters and Equations

$$F = -\frac{1}{2}\frac{CV^2}{d} \qquad K_s = C\frac{V^2}{d^2} \qquad V_p = \frac{2x_0}{3}\sqrt{\frac{k_m}{1.5C_0}}.$$

Piezoresistive properties of C-Si

Piezoresistance coefficient ($10^{-11}Pa^{-1}$)	n-type (resistivity = 11.7 Ωcm)	p-type (resistivity = 7.8 Ωcm)
π_{11}	−102.2	6.6
π_{12}	53.4	−1.1
π_{44}	−13.6	138.1

Direction of strain	Direction of current	Configuration	Piezoresistive coefficient
<100>	<100>	Longitudinal	π_{11}
<100>	<010>	Transverse	π_{12}
<110>	<110>	Longitudinal	$(\pi_{11} + \pi_{12} + \pi_{44})/2$
<110>	<1$\bar{1}$0>	Transverse	$(\pi_{11} + \pi_{12} - \pi_{44})/2$
<111>	<111>	Longitudinal	$(\pi_{11} + 2\pi_{12} + 2\pi_{44})/2$

INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY

Date: 26 Sept., 2024 Time: 2 Hours Total Marks: 60 No. of Students: 38

Mid-Semester Dept. of Avionics

Sub. No. AV491, Sub. Name: **Advanced Sensors and Interface Electronics**

Answer all questions

Question 1

Fill the blanks. (10 Marks)

(a) An oversampling factor of 256 is needed to improve the effective number of bits of an ADC by _____.

(b) An GMR material offers _____ resistance during zero magnetic field and it offers _____ resistance during saturating value of magnetic field.

(c) Benefits of employing a magnetic shield in GMR magnetometers include: _____ and _____.

(d) Axis of sensitivity of a GMR IC and Hall IC are along _____ and _____, respectively.

(e) Two examples of excess noise include: _____ and _____.

Question 2

(a) Find the transfer function of the circuit in Fig. 1. Assume that switches are controlled by a common signal (say, V_C), whose frequency is much higher than the frequencies of V_1, V_2 and V_3. The switches will be at position A when V_C is high and at position B, else. (6 Marks)

(b) Write the general expression of power-spectral density of an IC, and discuss its constituents. (2 Marks)

(c) Determine the noise-bandwidth of the circuit given in Fig. 2. (7 Marks)

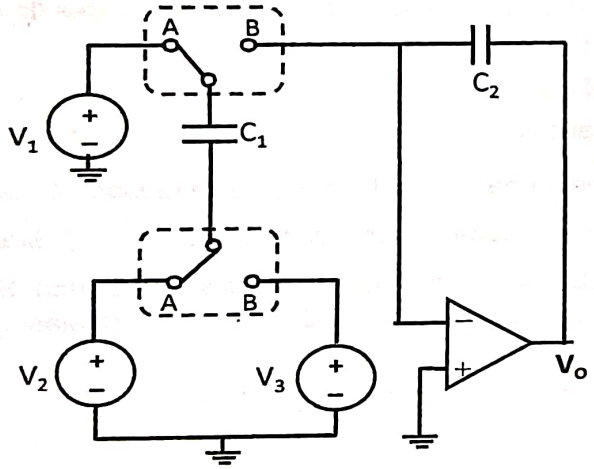


Fig. 1

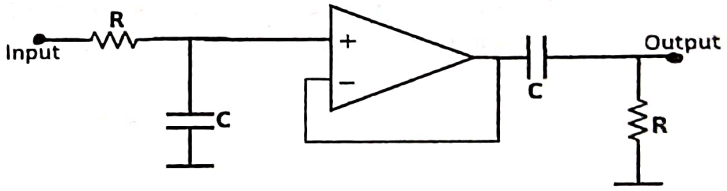


Fig. 2

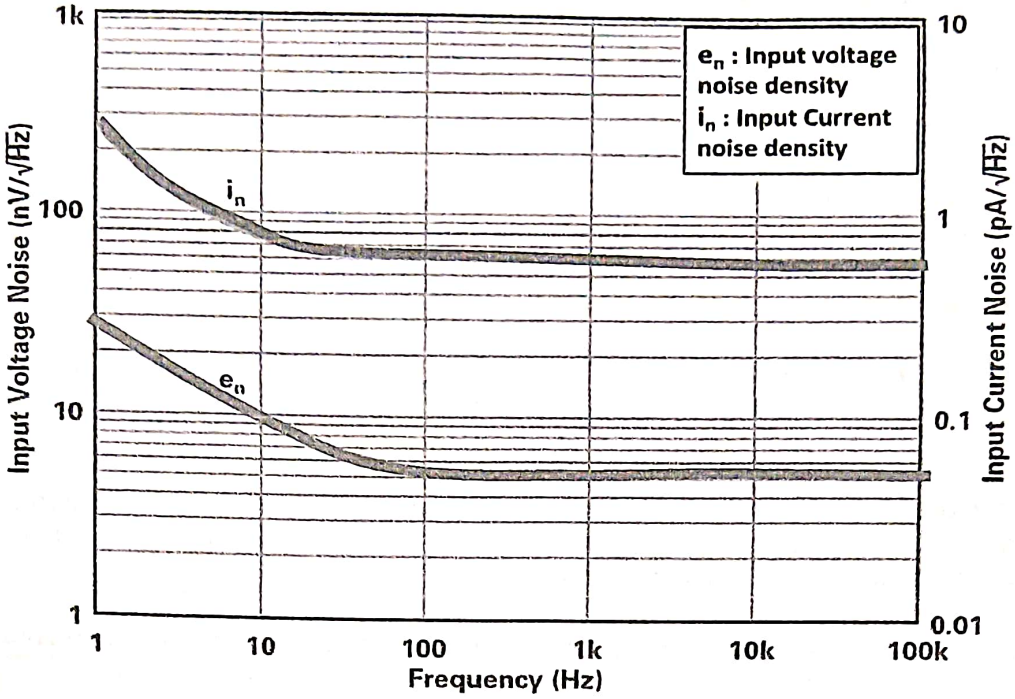
(5 + 5 + 5 = 15 Marks)

Question 3

(a) Three 10 kΩ resistors are connected in parallel. Determine the noise-voltage spectral density of this parallel network at a temperature of 27°C. Take Boltzmann constant $k = 1.4 \times 10^{-23}$ J/K.

(b) Consider a differential amplifier (gain = 1) realized using four equal resistors. Draw its noise-equivalent model. Mention the expansions of all symbols in the noise model.

(c) Estimate the RMS input voltage noise present in the input of an opamp over a frequency span of 100 Hz to 10 kHz. Refer the graphs in the below figure, for the noise characteristics of the opamp. Make necessary approximations.



Question 3

(a) Consider a 3-bit ADC having a reference voltage of 8 V. The DNL associated with the eight codes (in their increasing order) of this 3-bit ADC are specified as 0.2 V, 0.1 V, 0.2 V, -0.5 V, 1.2 V, -0.1 V, 0 V, 0 V.

(i) What will be the DNL (in V) specification and INL (in V) of the ADC.

(ii) Will this ADC have missing codes? Give reason for your answer (6 Marks)

(b) Explain an ADC-application in which DNL is a more important parameter than INL. Give reason. (4 Marks)

(c) Discuss the circuit and an application of frequency-dependant negative resistance circuit. (5 Marks)

(d) Compute the maximum possible SNR of an 8 bit ± 5 V ADC when its input, Vin equals 5sin (200πt). State two important assumptions that is used to derive the expression of SNR of an ADC. (5 Marks)

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INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY

Date: 6 Dec., 2024 Time: 3 Hours Total Marks: 100 No. of Students: 38

End-Sem Dept. of Avionics

Sub. No. AV491, Sub. Name: **Advanced Sensors and Interface Electronics**

Answer all questions

PART – A (20 Marks)

Instructions for Question 1 to 5: Mention the correct choice and main equation/concept that justifies your choice.

Question 1: Consider a bio signal which represents a human heart rate activity. Typical heart rate can be assumed as 72 beats-per-minute. The signal is affected by power line interference of 50 Hz frequency. Which one filter among the following options can be best used for proper filtering the bio signal.

(a) 1st order Low-pass-filter with 5 Hz cutoff frequency
(b) 2nd order High-pass-filter with 5 Hz cutoff frequency
(c) 2nd order Low-pass-filter with cutoff frequency of 0.05 Hz
(d) 3rd order High-pass-filter with cutoff frequency of 0.05 Hz

Question 2: A dual-slope ADC has an integration period set to 100 ms. Which of the following input signal frequencies will be rejected by the ADC?

(a) 5 Hz only (b) 5 Hz and 10 Hz (c) 50 Hz only (d) 50 Hz and 60 Hz

Question 3: For a 12-bit unipolar ADC with a 10 V full-scale range, the quantization error is

(a) 2.44 mV (b) 4.88 mV (c) 255 mV (d) 512 mV

Question 4: Let HPF, LPF, and BPF represent transfer functions of second-order low-pass, high-pass, and band-pass filters. Then, the second-order all-pass transfer function can be written as

(a) HPF + LPF (b) HPF-LPF (c) HPF+BPF-LPF (d) HPF-BPF+LPF

Question 5: Bio-impedance signal can be properly acquired using

(a) Single-electrode configuration (b) Dual-electrode configuration
(b) Three-electrode configuration (d) Four-electrode configuration

Question 6 (10 Marks)

The following table shows a list of sensing problems and some measurement electronics schemes. Choose the most feasible measurement scheme (from second column) for each sensing problem (given in first column). Briefly justify your answer, in a few sentences.

Sensing Problem	Measurement Electronics Techniques
1. Conductivity measurement of metals	A. Doppler effect ultrasonic flowmeters
2. Magnetic measurements for geophysical surveys	B. Low frequency eddy current testing
3. Flow-rate measurement of clean fluids	C. Twin hall-sensor-based ring module
4. Welding defects in sub-surface regions	D. High-frequency eddy current testing
5. Continuous heart-rate monitoring for portable applications	E. Transit time ultrasonic flowmeter
	F. Wet-electrode ECG
	G. Flux-gate sensors
	H. Dry-electrode ECG

Part B (80 Marks)

Question 7 (6 + 4 + 3 + 7 = 20 Marks)

(a) A piezoelectric transducer has a capacitance of 1000 pF and sensitivity of 400 pC/μm. The connecting cable has a capacitance of 300 pF, while the oscilloscope used for read-out has an input impedance of 1 MΩ paralleled with 50 pF.

(i) Compute the high-frequency sensitivity (mV/μm) of the entire measurement system.

(ii) What is the lowest frequency that can be measured with 5 % amplitude error by the entire system?

(b) Derive the output-expression of a simple linearizing circuit that can be used for the typical GMR-based magnetometer (present in bridge-circuit form).

(c) Draw the schematic of a through-shaft angle sensor unit and label its important parts.

(d) Consider the circuit of a linearization-scheme for magnetic angle sensors shown in Fig. 1. Here, OC_1 is a comparator, SW is a switch and *LPF* stands for a low-pass filter. V_R and $-V_R$ represent DC reference voltages. The voltage v_{sn} is the magnetic-sensor signal. v_{sn} is proportional to cosine of the angle.

(i) What should be the properties of the voltage V_A and the design criterions for the *LPF* so that the circuit can act as a linearizer with 180° range.

(ii) Derive the expression for output, v_O of this circuit provided above conditions are satisfied.

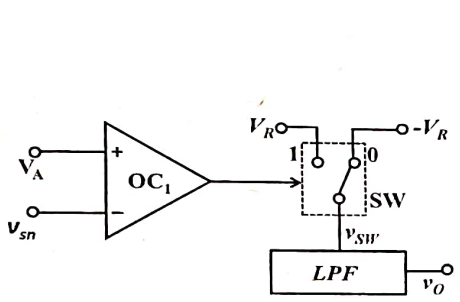

Fig. 1

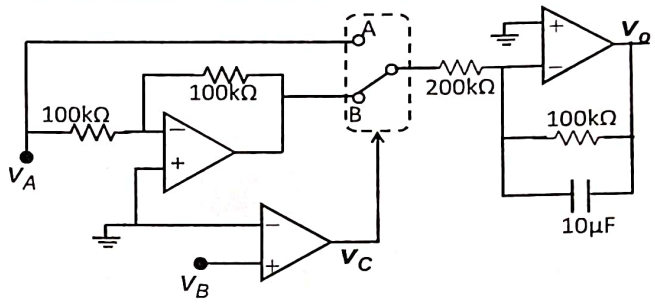

Fig. 2

Question 8 (4 + 6 + 6 + 4 = 20 Marks)

(a) With the help of BVD model, show that the parallel resonant frequency of a piezo-electric transmitter is very close to its series resonant frequency.

(b) A piezoelectric crystal has an effective mass of 10 g, stiffness of 10^{10} N m^{-1} and damping constant of 200 Ns m^{-1}. Electrical capacitance of crystal is 1000 pF and its charge to force sensitivity is 2×10^{-10} C N^{-1}. Design a closed-loop oscillator which can be used to operate the crystal at its series resonant frequency.

(c) In the circuit (Fig. 2), the switch will be at position-A if the signal, v_c = HIGH and at position B, if v_c = LOW. Determine the output, Vo for the following conditions. Make valid approximations to simplify the calculations.

(i) $v_A = \sin(100\pi t)$ and $v_B = \cos(100\pi t)$

(iii) $v_A = \sin(100\pi t)$ and $v_B = \sin(200\pi t)$

(d) Draw the internal structure of a capacitive probe that can be used for non-contact measurement of power line voltage in a cable. Comment on the effect of the thickness of the cable wire on the probe performance.

Question 9 (4 + 4 + 12 = 20 Marks)

(a) Design a two-input summing amplifier using switched capacitor technique.

(b) Design a GIC circuit which can simulate an inductance of 0.5 mH. Use a capacitance of 10 nF and equal-valued resistors in the circuit.

(c) Consider a 10-pin instrumentation amplifier (IA) IC shown in Fig. 3a. The internal structure of this IC and its pinout arrangement is shown in Fig. 3b. For example, pin 5 and 6 represent the positive and negative power supply terminals, while pin 1 represent the IC output. Assume R = 22 kΩ.

(i) Show how the above-mentioned IA IC can be used to provide a gain of 45 for a Lead-3 ECG system. Use an external resistor if needed. Draw an illustrative diagram to demonstrate the interfacing of the ECG electrodes to this IC. In your diagram, show the terminals/electrodes to which the pins 3, 4, 7, 8, 10 need to be connected.

(ii) Further, it is noted that IA IC has input impedance of 10 MΩ and CMRR = ∞. Assume that the mismatch in electrode impedances cannot exceed 20 kΩ. A 50 Hz power-line interference of amplitude 10 mV is expected to be present as a common-mode term at the input of the IA. Compute the magnitude of the 50 Hz component in the IC output (i. e., the pin-1).

(iii) Mention 1 advantage of using a right-leg driver circuit.

(iv) Illustrate how the pins 2 and 9 of the IC can be used to aid in the design of the right-leg driver circuit.

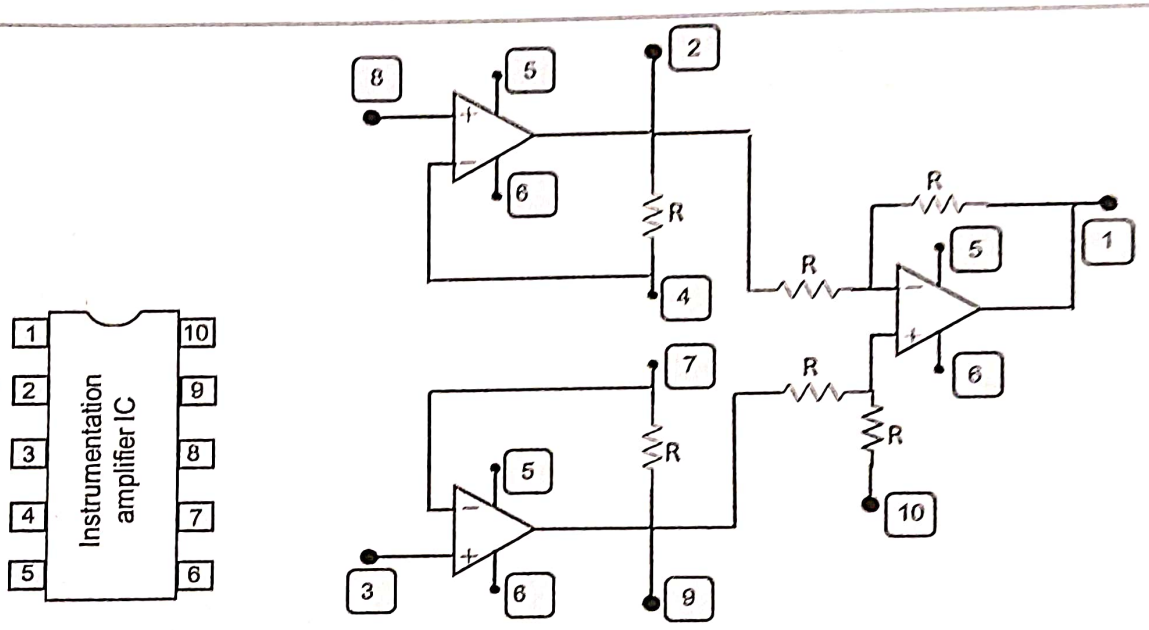

Fig. 3

Question 10 (5 + 5 + 5 + 3 + 2 = 20 Marks)

(a) Design an efficient capacitive measurement scheme for level measurement of a conductive liquid present in a plastic (cylindrical) tank.

(b) Explain a magnetic sensor arrangement that can efficiently measure the current flowing through a conductor. Assume that limited portion of the conductor can only be accessed.

(c) Prove that the sigma-delta ADC architecture provides noise shaping feature.

(d) Find the SNR of a forward-biased diode over a bandwidth of 1 MHz if the diode-current is 100 μA.

(e) Justify the statement "Cable resistance compensation can be achieved for a two-wire connected remote resistive sensor".

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INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY
THIRUVANANTHAPURAM, 695 547

B.Tech ECE – Midterm – September 2024

AV 412 – Satellite and Optical Communication

Time: 2 hour Date: 24/09/2023 Max. Marks: 30

Note: Write Part A and Part B in separate sheet

PART - A - Satellite Communication

Answer the following

1. Design an $(n, k) = (5, 2)$ linear block code.
   (a) Calculate the generator matrix for the codeword set and the parity-check matrix with the goal of maximizing d_{min}.[2]
   (b) What are the error-correcting and error-detecting capabilities of the code? Justify your answer. [1]
   (c) Make a syndrome table for the correctable error patterns [2]
2. Calculate the improvement in probability of message error relative to an uncoded transmission for a (24, 12) double-error-correcting linear block code. Assume that coherent BPSK modulation is used and that the received Eb /N0 = 10 dB.[4]

Table 5.2 Short table of Q(z) values

z	Q(z)
0	0.5
2.0	2.28 E-2
3.0	1.35 E-3
4.0	3.17 E-5
4.7	1.30 E-6
5.0	2.87 E-7
6.0	1.00 E-9
7.0	1.28 E-12
8.0	6.22 E-16

3. Explain the term shannon limit. [2]
4. Explain what is meant by coding gain as applied to error correcting (EC) coding. When EC coding is used on a digital link, a coding gain of 3 dB is achieved for the same BER as the uncoded case. What decibel reduction in transmitted carrier power does this imply? [2]
5. The bit rate for a baseband signal is 1.544 Mb/s, and EC at a code rate of 7/8 is applied before the signal is used to modulate the carrier. Given that the system uses raised-cosine filtering with a rolloff factor of 0.2, determine the bandwidth required for (a) BPSK, and (b) QPSK. [2]

PART - B - Optical Communication

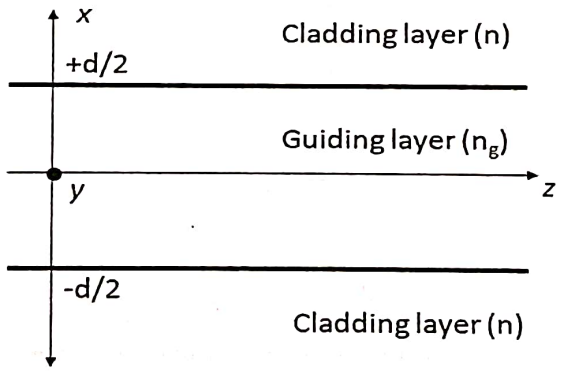
Answer the following

6. Consider a planar dielectric waveguide whose substrate has a refractive index (RI) of 1.56, guiding layer of RI=1.6 and free space as its cover material. Calculate the minimum angle with respect to the normal with which a ray of light can be incident at the guide-cover or guide-substrate interface so that it still remains confined to the guiding layer and can undergo total internal reflection. [2]

7. An optical fiber of core refractive index n1 and cladding index n2 is placed in a medium whose index is given by n. For this arrangement, obtain an expression for the maximum acceptance angle so that light launched can undergo total internal reflection. For this arrangement, define what numerical aperture is. [2]

8. Qualitatively draw the ray picture and wave picture for the fundamental and first order mode inside a symmetrical waveguide. Explain the figure what you have drawn. Your explanation should also consider leakage to the cladding. (hint: consider Goos-Hanchen shift while drawing the ray picture) [4]

9. For a symmetric dielectric slab waveguide shown below, derive the eigenvalue equation for the symmetric TE mode. The index of guiding region is ng (-d/2¡x¡d/2), and the index of cladding is n. (Points will be awarded only if every step is logically illustrated and all assumptions made and properly justified.) [5]



10. Obtain an expression for the multi-path time dispersion in optical fibers. Explain how can you minimize this dispersion? [2]

INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY
THIRUVANANTHAPURAM, 695 547
B.Tech End Semester Exam – December 2024

AV 412 – Satellite and Optical Communication

Time: 3 hour Date: 2/12/2024 Max. Marks: 50

Note: Write Satellite Communication in Seal A Answer sheet and Optical Communication in Seal B

PART - A - Satellite Communication

Answer the following

1. A receiver front end (RF front end) has a noise figure of 10 dB, a gain of 80 dB, and a bandwidth of 6 MHz. The input signal power is 10^{-11}W. Assume that the line is lossless and the antenna temperature is 150 K.
   (i) Find system noise temperature and (C/N) [3]
   (ii) If a preamplifier is used before the receiver front end with a noise figure of 3 dB, a gain of 13 dB. Find the improvement in (C/N) [2]
   (iii) If a coaxial feeder is connected between the preamplifier and receiver front end and has a loss of 2 dB, calculate the system noise temperature [2]
   (iv) If a feeder cable is connected between the antenna and the preamplifier, calculate the system noise temperature and Comment on the result. [2]
2. The following parameters apply to a satellite downlink: EIRP 22.5 dBW, free-space loss 195dB, other losses 1.5 dB, earth station (G/T) 37.5 dB/K. Calculate the (C/N_o) at the earth station. Assuming an output Back off power of 6dB is applied, what is the new value of (C/N_o)? [2]
3. Explain how rain attenuation affects the computation of the C/N ratio in the uplink and downlink scenarios. [3]
4. Explain the procedure of finding the generator polynomial of an (n,k) binary cyclic code. [2]
5. Describe the procedure for generating a systematic code for an (n,k) binary cyclic code, and provide a detailed explanation of the encoding circuit along with its illustration for (7,4) code. [2]
6. A convolutional code is described by $g_1 = [110]$ $g_2 = [101]$ $g_3 = [111]$. Find the transfer function and free distance for this code. [4]
7. Prove with a mathematical equation how the maximum likelihood decoder is equivalent to the minimum distance decoder for linear block code. [3]

PART - B - Optical Communication

Answer the following

1. Using energy band diagrams, explain the operation of an Erbium Doped Fiber Amplifier (EDFA). What is the importance of the metastable state in the energy band diagram? What are the sources of noise in this amplifier? Can a two-level system work as a laser? Explain. [4 marks]

2. A fibre optic communication link has the following parameters. (i) Source power = 0 dBm (ii) Detector sensitivity =-45 dBm (iii) Connector loss = 1 dB/connector (iv) Splice loss = 0.06 dB/Splice. If the total link length of 100 km is spanned by connecting two hundred 500 m cables of attenuation coefficient 0.3 dB/km and a system margin of 5 dB is required, determine whether or not an amplification of the optical signals is required in the link. If yes, determine the required minimum amount of amplification in dB. Assume that the fiber cables are connected to the source, detector, and amplifier using connectors and that individual fibre cables are connected through splicing. [4 marks]

3. With figure, discuss the design of a pn photodiode receiver. How do you decide the thickness of p and n layers? Define Quantum efficiency and Responsivity of a Photodiode. Plot the responsivity as a function of photon wavelength for a photodiode? Define cut-off wavelength for a Photodiode. What are the draw backs of conventional p-n photodiode? How does p-i-n photodiodes help in overcoming them? [4 marks]

4. The Figure 1 shows a Mach-Zehnder interferometer modulator made of LiNbO3. The rectangular shaped waveguides are made of Ti diffused LiNbO3 having an index of 2.355 while the refractive index of LiNbO3 is 2.30. The diffused waveguide is 3 m wide and has a depth of 500 nm. A Silica step index optical fiber which has a clad index of 1.55 and a core index which is 1 % higher than that of the clad index has to be coupled at the In and Out ports. Explain the various coupling losses and any other losses that can occur in this scheme. Discuss the coupling mechanisms by which those losses can be minimized. How do you ensure that the fiber is mechanically well connected with the LiNbO3 substrate? [5 marks]

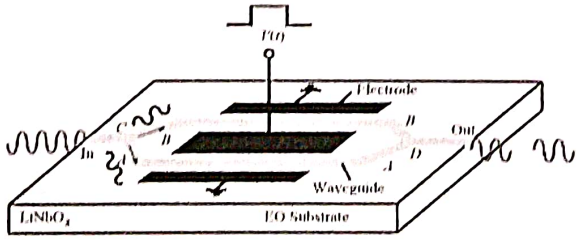


Figure 1: Mach-Zehnder interferometer modulator

5. For a Mach-Zehnder interferometer as shown in Figure 1, we have studied that when the phase of the waves in two arms differ by 180o, destructive interference occurs,

we get no light at the output port [Termed as 0]. If no light appears at the output port, explain what happens to that light. In other words, where does that light go? [2 marks]

6. Considering a cosine electric field inside the core and exponentially decaying fields in both the claddings of a symmetric dielectric planar waveguide, obtain an expression for the optical confinement factor for this waveguide. [6 marks]

End of exam.

AVD862

Indian Institute of Space Science and Technology Trivandrum

I SEMESTER , 2024

ExamType: Mid-Term-1

DEPARTMENT OF AVIONICS

Digital Image Processing

(Time allowed: TWO hours)

NOTE: Read all questions first. **Attempt all the questions.** If something is missing in a problem description, clearly mention your assumptions with your solution. If required, use sketches to illustrate your findings. Exam date and time: 30/09/2024, 2:00 AM to 4:00 PM

1. Consider the 5x5 image below. (5 marks)

   (a) Calculate the intensity histogram for this image h(i).
   (b) Calculate the cumulative intensity histogram for this image H(i).
   (c) Describe how the histogram equalization algorithm uses this information to enhance an image. Perform the actual equalization for this image

$$I = \begin{bmatrix} 2 & 2 & 3 & 9 & 9 \\ 2 & 2 & 3 & 9 & 9 \\ 3 & 3 & 3 & 9 & 9 \\ 9 & 9 & 9 & 9 & 9 \\ 9 & 9 & 9 & 9 & 8 \end{bmatrix}$$

2. SVD: Let f =

$$f = \begin{bmatrix} 1 & 0 & 3 & 0 \\ 0 & 4 & 0 & 2 \end{bmatrix}$$

(5 marks)

   (a) Compute an SVD of f
   (b) Express f as a linear combination of its elementary images.

3. We call $H_n(t)$ as the n-th Haar function. where $n \in \mathbb{N} \cup \{0\}$ (5 marks)

   (a) Show the definition of $H_n(t)$.
   (b) Write down the Haar transformation matrix $\tilde{H}$ for 4×4 images.
   (c) Show that the Haar transformation matrix is unitary.
   (d) Suppose the matrix A is given by following

$$A = \begin{bmatrix} 2 & 4 & 7 & 6 \\ 2 & 3 & 1 & 0 \\ 1 & 2 & 1 & 5 \\ 2 & -1 & 1 & 1 \end{bmatrix}$$

Compute the Haar transform A_{Haar} of A, and compute the reconstructed image $\hat{A}$ after setting the 4 smallest (**in absolute value**) nonzero entries of A_{Haar} to 0.

4. Explain the difference between Gaussian Low pass and Gaussian High Pass filter. Write appropriate equations and plot the filter shape. Why Gaussian filter is preferred over a box filter? Now Consider a Gaussian high-pass filter

$$H(u,v) = 1 - exp(-\frac{u^2 + v^2}{2\sigma^2})$$

Suppose $H(-2,0) = \frac{5}{3}H(1,1)$. Find σ^2 (4 marks)

5. Write the difference between convolution and correlation. Write commutative, associative, and distributive properties for convolution and correlation. Let f be an image of size $M \times N$, and w is the filter kernel of size $m \times n$. Now, refer to the equation for the convolution operation (Linear Spatial invariant)in discrete form.

$$(f * w)(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t) f(x-s, y-t)$$

where the minus signs align the coordinates of f and w when one of the functions is rotated by 180 degrees. Write the computational complexity (number of mathematical operations) of this operation. Now consider if the kernels are separable. Write the revised computational complexity. Thus, write the expression for the computational advantage of performing convolution with a separable kernel instead of a nonseparable one. (3 marks)

6. Explain Bilateral filtering. How it is different than that of the Non-local means filter. What drawbacks of the Gaussian filter bilateral filter overcomes? (3 marks)

7. A 3 bits/pixel image of size 5×5 is given below. Find the following: (a) the output of a 3×3 averaging filter at $(1,1)$, (b) the output of a 3×3 median filter at $(1,1)$ and (c) the gradient magnitude at $(1,1)$ using the Sobel masks shown below (5 marks)

$$I = \begin{bmatrix} 3 & 7 & 6 & 2 & 0 \\ 2 & 4 & 6 & 1 & 1 \\ 4 & 7 & 2 & 5 & 4 \\ 3 & 0 & 6 & 2 & 1 \\ 5 & 7 & 5 & 1 & 2 \end{bmatrix}$$

$$G_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}, G_y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

AVD862

Indian Institute of Space Science and Technology Trivandrum

I SEMESTER , 2024

ExamType: EnD Sem Exam

DEPARTMENT OF AVIONICS

Digital Image Processing

(Time allowed: THREE hours)

NOTE: Read all questions first. **There are questions worth 50 marks. Attempt all questions** If something is missing in a problem description, clearly mention your assumptions with your solution. If required, use sketches to illustrate your findings. Solve easy question First. 03/12/2024, 9:30 AM to 12:30 PM

1. Explain how the Difference of Gaussian (DoG) or Laplacian of Gaussian (LoG) filters work in detecting edges in noise-corrupted images. If the noise is impulse noise, will DoG or LoG work? Why or why not? Describe the operations you would perform to detect edges when the image contains both uniform and impulse noise. Justify your selection of operations. Comments on the edge maps that you would get via applying first-order derivatives and second-order derivatives, respectively. (5 marks)

2. The pixel intensity values of a gray level image have the probability density function $p_r(r)$ given by $p_r(r) = 2(1-r)$, for $0 \leq r \leq 1$, and zero otherwise. It is desired to transform the gray levels of the image so that they have the probability density function $p_z(z) = 2z$, for $0 \leq z \leq 1$, and zero otherwise. Assume that r and z are continuous random variables. Find the transformation that accomplishes that. (5 marks)

3. Write 4x4 unitary DFT matrix and show that it is unitary. What is the FT of $cos(4\pi x) + cos(10\pi x)$? How many samples should we obtain according to the Nyquist theorem in order to avoid aliasing? (2 marks)

4. Explain how homomorphic filtering works. What is the reason that we first apply the $log()$ function on the image? (3 marks)

5. image compression

   (a) The following image is given:

$$\begin{bmatrix} 21 & 21 & 21 & 95 & 169 & 243 & 243 & 243 \\ 21 & 21 & 21 & 95 & 169 & 243 & 243 & 243 \\ 21 & 21 & 21 & 95 & 169 & 243 & 243 & 243 \\ 21 & 21 & 21 & 95 & 169 & 243 & 243 & 243 \end{bmatrix}$$

   (4 marks)

   (i). Compute its first order entropy.

   (ii) Construct the Huffman code for this image.

(iii) What is the average number of bits/pixel in this case? Is this a good code?

(b) Draw the block diagram of the JPEG image compression scheme. Explain each block briefly. Why is zig-zag scanning preferred? What changes must be made in JPEG compression to make it a lossless compression scheme? (3 marks)

(c) What is Arithmetic Coding? Write the differences between Arithmetic coding and Huffman Coding. How arithmetic coding overcomes Huffman coding problems. (3 marks)

6. Answer the following questions about morphological image processing.

(a) Shown below are two tables with expressions that relate to binary morphological image processing. Associate each expression in the left table with one from the right table. (3 marks)

a	$A - B$
b	B
c	$A \div B$
d	$A \ominus B$
e	$A \circ B$
f	$A \bullet B$

1	$\{w \mid w = -b, \text{ for } b \in B\}$
2	$\{z \mid (B)_z \bigcap A \neq \emptyset\}$
3	$(A \div B) - B$
4	$A \bigcap B^c$
5	$(A \div B) \div B$
6	$\{z \mid (B)_z \subseteq A\}$

Answers					
a	b	c	d	e	f

Figure 1: Morphological Operators definition

(b) Explain Hit and Miss Transform in Morphological Operation. (2 marks)

7. image Restoration

(a) What do we mean in image restoration when we say that the degradation function H is linear and shift-invariant? Use appropriate mathematical explanation (similar to the things that we discussed in class) to answer this questions. Just theoretical answer with no mathematical expression will not be accepted. (2 marks)

(b) How is the degradation process modeled assuming linearity and shift invariance? Prove it. Show all of your work. (3 marks)

(c) Do the derivation for constrained Least squares restoration filter. Show all the steps and How smoothness factor is incorporated in the solutions.What could be other alternatives one can try in such filtering. (3 marks)

(d) A degraded image is represented by $G(u, v)$ in the frequency domain and an estimation of its degradation function is

$$H(u, v) = \sigma\sqrt{2\pi}(u^2 + v^2)e^{-j2\pi^2\sigma^2(u^2+v^2)}$$

Provide the expression in the frequency domain of the restored image using the Wiener filter. Assume that the power spectrum of the undegraded image is ten times the power spectrum of the noise throughout all the image. (2 marks)

8. Image Segmentation

(a) Histogram of a 3-bit image is shown in the following table

$$Gray\ level = [0\ \ 1\ \ 2\ \ 3\ \ 4\ \ 5\ \ 6\ \ 7]$$
$$number\ of\ pixels = [2\ \ 3\ \ 2\ \ 1\ \ 2\ \ 3\ \ 2\ \ 1]$$

Find the optimal threshold using Otsu. (2 marks)

(b) How graph based segmentation works. Explain normalized cut algorithm. What is Rayleigh quotient and Fielder vector. Write steps to obtain image segmentation using Grpahs. (3 marks)

9. Image Processing

(a) What is Hough transform. Suppose that the Hough transform is applied to the image shown below. (2 marks)

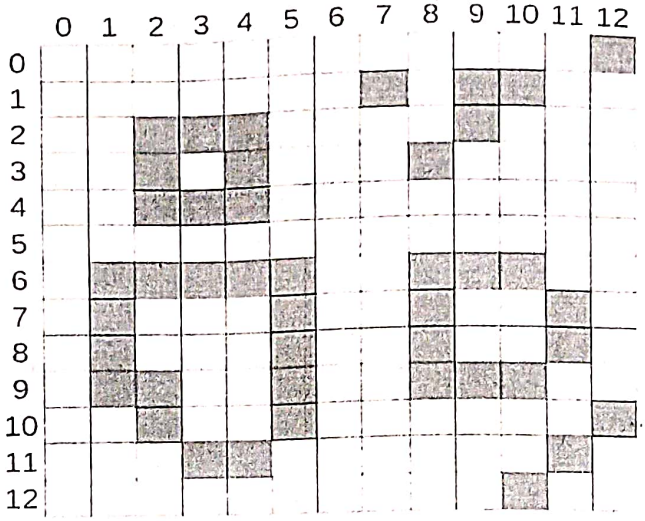


Figure 2: hough transform

(i) What is the maximum value in the accumulator cells?

(ii) What are the corresponding values of (ρ, θ)? As shown, the origin lies at the top left corner.

(b) Short questions with a very brief reasoning. No marks will be awarded if only a True or false answer is given. (3 marks)

(i) Consider the following image.

$$\begin{bmatrix} 3 & 4 & 5 & 4 & 3 \\ 2 & 10 & 4 & 5 & 1 \\ 0 & 5 & 6 & 2 & 0 \\ 1 & 6 & 3 & 0 & 5 \\ 0 & 15 & 3 & 3 & 2 \end{bmatrix}$$

A. Provide the result of the central pixel after using a harmonic mean filter. The neighborhood size is 3×3.

B. Provide the result of the central pixel after using a midpoint filter with a neighborhood size of 5×5.

(ii) Inverse filtering will yield as good results as Wiener filtering when processing an image that has been degraded by motion blurring only .{True or False}

(iii) Median filtering can be implemented efficiently using convolution. {True or False}

(iv) (True/False give reasoning) The Canny edge detector is a linear filter because it uses the Gaussian filter to blur the image and then uses the linear filter to compute the gradient.

Indian Institute of Space Science and Technology

B. Tech Seventh Semester Mid Term Examination

HS461 Science Fiction

Time: 2 hrs **Marks: 30**

I. Answer **any 10** (5 marks)

1. "It was a pleasure to burn. It was a special pleasure to see things eaten, to see things blackened and changed." This appears in an SF text we discussed. Name the title.
2. The science fiction critic who considered SF as an open-ended cultural phenomenon that reflects times of great cultural and technological change..
3. Darko Suvin considers Science Fiction as a symbolic system centered upon.....
4. "The Pedestrian" is written by.....
5. The movie *Twelve Monkeys* is inspired by another 1962 film we discussed in the class. Name it.
6. Name the essay that deals with a fraudulent automaton chess player (mechanical simulation) called The Turk written by Poe.
7. "This is the story of a man marked by an image from his childhood." Name the title
8. The idea of willing suspension of disbelief is introduced by.....
9. Name the short story based on which *Space Odyssey* is written
10. *Walking the Clouds: An Anthology of Indigenous Science Fiction* is written by
11. Star child appears in
12. Octavia E. Butler Landing is the landing site of the Perseverance rover in ..... Crater on Mars

II. Answer **any three** (5 marks each)

1. Structural Fabulation is neither scientific in its methods nor a substitute of actual science. Critically look at this statement with reference to any SF work that we discussed.

2. Conflict between ignorance and knowledge in *Fahrenheit 451*.
3. Significant features of an Afro Futuristic Science fiction based on any work that you have discussed
4. Describe the three types of Science Fiction explained by Raymond Williams
5. Man Machine struggle in *2001: A Space Odyssey*

III. Answer **any one** (10 marks)

1. Elucidate *2001: A Space Odyssey* as an epic Science fiction movie
2. "What can a nation of farmers offer to the rest of the world?" This question is from a movie that we discussed. Explain the context and critically evaluate the significance of such a question.
3. Discuss *La Jetée* as a post-apocalyptic science fiction.

INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY

Department of Humanities and Social Sciences

Institute Elective: HS461 Science Fiction

End Semester Exam, Nov 2024

Time: 3 hrs **Max Marks: 100**

I. Answer **any ten** (5 marks)

1. Science Fiction writer who won Nobel prize for literature in 2017
2. Cooting Machines appear in
3. The comic strip character Suki is created by
4. The short story "The Breath of Life" is translated into English from Malayalam by
5. *The Gospel According to Jesus Christ* is a novel by
6. Name the award received by the Play *Harvest* for original theatrical Drama in 1997
7. The novel *Enmakaje* is written by
8. Indian English author who wrote Ibis Trilogy
9. BeautifulHandwrittenLetters.com appears in
10. Name the conduit through which we hear the story of Victor and his monster.
11. "There is no gene for the human spirit" is the tagline of the movie....
12. Science fiction author who is called Chip
13. The short film "The Nostalgist" is based on a short story of the same name written by .....
14. Name any two Martian Poets

II. Answer **any seven** of the following (5 marks each)

1. "There is nothing unique about human beings, nothing that our modern tools can't excavate, copy, or transfer." Explain this statement based on the work that you have studied.
2. "I don't think we did go blind, I think we are blind. Blind but seeing, Blind people who can see, but do not see." Critically look at this statement.

3. "A country loosing the art of having children." Explain this statement based on a play that you discussed.
4. Subaltern representation in the science fiction *The Calcutta Chromosome.*
5. Critically examine the prophetic significance of the short story "The Breath of Life."
6. Journey motive in the novel *Frankenstein.*
7. How could one combat racism in Science Fiction? Explain with reference to the essay written by Samuel Delany.
8. How does "Martian Sends a Postcard Home" use the perspective of an alien observer to challenge the reader's assumptions about everyday human experiences and objects?
9. How does *Klara and the Sun* use Klara's artificial intelligence perspective to explore themes of human connection, loneliness, and the ethical implications of technological advancements?

III. Answer **any three** of the following. (20 marks each)

1. "I'll die knowing that you, who only live to win, will have lost to a poor, weak, and helpless woman." Examine the significance of this statement with reference to the play you have discussed in class.
2. How does *The Calcutta Chromosome* blend elements of science fiction and mysticism to challenge conventional ideas about scientific discovery, immortality, and the transfer of knowledge?
3. Do you consider *Her* as a science fiction movie on communication? Why?
4. Individual's determination and genetic determinism in the movie *Gattaca.*
5. How does "The Nostalgist" use its futuristic setting and technology to explore the emotional and psychological impact of nostalgia in a science fiction context?
6. In what ways does *Solaris* use the concept of an alien intelligence to reflect on humanity's struggles with guilt, love, and unresolved trauma?

Indian Institute of Space Science and Technology
Thiruvananthapuram
END SEMESTER EXAMINATION, December 2024

ID411 Basic Course on Astrobiology

(Elective B. Tech. VII Semester)

13.12.2024 **Duration 3h** **Max. Marks 50**

General instructions: This question paper has four sections- A, B, C and D. Use separate sheet for answering each section. Answer all the questions. Use schematics and equations wherever applicable.

Section A- Astrochemistry

1. In interstellar medium (ISM), the H_2 can form via different pathways. Explain any three ways of formation of H_2 in ISM (with the chemical reactions) (6 marks)

2. Explain an experimental set-up that can simulate the formation of amino acids in ISM conditions. (with the help of a simple scheme, reactants, reaction conditions, etc.) (4 marks)

Section B- Astronomy

1. What are some of the main observational biases in the (a) radial velocity (b) transit method, and (c) high contrast direct imaging techniques for finding extrasolar planets? (5 marks)

2. Why is the detection of atmospheres of exoplanets important for the discussion of the possibility of life on those planets? (5 marks)

Section C - Survival Strategies in Extreme Environments

Choose the best option for questions 1-10 (1 mark each)

1. A researcher is studying the divergence time between prokaryotes and eukaryotes using molecular clock analysis. Which of the following genes would be most suitable for this study?

a. Histone genes
b. 16S ribosomal RNA genes
c. Protein-coding genes involved in metabolic pathways
d. Genes encoding membrane proteins

2. Which of the following best explains the evolutionary transition from RNA to DNA as the primary genetic material in early life forms?

a. DNA's ability to catalyze complex biochemical reactions
b. DNA's reduced mutation rate due to the presence of thymine instead of uracil
c. The absence of prebiotic synthesis pathways for RNA molecules
d. DNA's ability to form ribozymes

3. Which of the following is absent in prokaryotes?

a. Plasma membrane
b. Cytoskeleton
c. Membrane-bound organelles
d. Ribosomes

4. Which domain in the ToL includes most of the organisms that thrive in extreme environments?

a. Bacteria
b. Eukarya
c. Archea
d. Protista

5. The pre-RNA world hypothesis suggests that early life forms relied on RNA molecules because:

a. RNA is more stable than DNA
b. RNA can both store genetic information and catalyze chemical reactions
c. RNA is the only molecule capable of forming double helices
d. RNA can replicate without enzymes

6. The microbe *Picrophilus torridus* lives at extreme pH levels near to 0. Which type of extremophile is it?

a. a xerophile.
b. a barophile
c. an alkaliphile
d. an acidophile

7. Which among the following statements about viruses is **not** correct?

a. Viruses hiijacks the cellular machinery of the host to effectively become a living, cellular organism
b. Viruses are included as the fourth branch in the tree of llfe
c. DNA viruses generally have more genes than RNA viruses
d. The origin and evolution of viruses in the living world is a topic of debate

8. Assign the correct names for the different species concepts provided below

A. Species are distinct of they are reproductively isolated

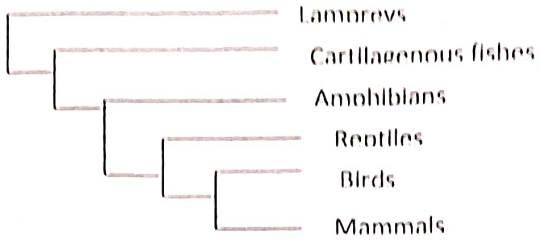
B. Phylogenetic trees and analyses of ancestry can differentiate species

C. Species separate based on their use of different ecological niches and their presence in different environments and habitats

D. Differences in physical characteristics or molecular characteristics are used to distinguish species

a) C - biological; D - phylogenetic; A - evolutionary; D - ecological
b) C - ecological; D - phylogenetic; A – biological; B – evolutionary
c) C- evolutionary; A – biological; D – ecological; B – phylogenetic
d) D - phylogenetic; B – evolutionary; A – ecological; C - biological

9. With reference to the phylogenetic tree provided below, identify the true statement



a) Cartilagenous fishes are the ancestors of amphibians
b) Lampreys and mammals are not related
c) Amphibians, reptiles, birds and mammals share a common ancestor
d) Birds are more closely related to reptiles than mammals

10. Refer the given table for a list of characteristics for a species that make it more vulnerable to extinction. Pick the correct combination of characteristics that is appropriate for the species which is most vulnerable to extinction.

i)	Common	ii)	Rare
iii)	High dispersal rate	iv)	Low dispersal rate
v)	High variability	vi)	Low variability
vii)	Long life span	viii)	Short life span
ix)	High reproductive out put	x)	Low reproductive out put

a) i, iii, v, vii, ix
b) ii, iv, v, viii, x
c) iii, vi, vii, x
d) i, iv, v, vii, ix

Provide brief answers to the following questions

11. a. Unique archaeal adaptations to seemingly inhospitable environments suggest their potential in biotechnological applications. Bring out *any one* such adaptations and discuss the distinct features at a cellular/molecular level. (2.5 marks)

b. "Early life originated in the oceans" – Do you support this statement? Depict your views with the support from the findings by astrobiology researchers. (2.5 marks)

OR

12. a. Highlight the distinctive features of space laboratories. (2 marks)

b. Assuming that you are entrusted to conduct a space biology experiment, discuss the criticalities in the hardware design (choose any biological sample as the experimental subject) for the successful achievement of the objectives. (3 marks)

SECTION D
PLANETARY GEOSCIENCES

I.Answer the following questions in a word or one or two sentences (1 mark each)

(a) Name a chemical sedimentary rock that is geologically old, includes alternate layers of silica and metallic iron, and has evidence about ancient life on earth.

(b) Why do tectonic plates float above the asthenosphere, causing the formation of diverse landforms on our planet?

(c) Outline the significance of impact craters in astrobiology research.

(d) List out the evidence for biosignatures in Archaean Eon?

(e) How are gullies formed on Mars?

II. Match the following Group A with the best fit to Group B (3 marks)

Group A	Group B
Clay	Transform Boundary
San Andreas Fault	Highland regions on Moon
Magma ocean	Evidence for water
Hydrothermal Vents	Openings on the ocean floor
Hesperian period	Habitable site
Rilles	Sulfates on Mars

III. What are the potential astrobiological target sites on Earth's moon? (2 marks)

IV. Discuss the evidence for flow of liquid water on early Mars (2.5 marks)

V. Briefly discuss the evolution of Earth's atmosphere and its significance in the formation of life (2.5 marks)

Indian Institute of Space Science and Technology Trivandrum

I SEMESTER , 2024

ExamType: EndSem

DEPARTMENT OF AVIONICS

Machine Learning for Signal Processing

(Time allowed: 3 hours)

NOTE: Read all questions first. **Attempt all the questions.** If something is missing in a problem description, clearly mention your assumptions with your solution. If required, use sketches to illustrate your findings. don't spent too much time on the last problem a brief methodology is OK. 05/12/24, 9:30 AM to 12:30 PM

1. Decision tree (5 marks)

(a) Give at least one advantage and one limitation of the decision tree algorithm.

(b) What is the conditional entropy, $H(C|A)$, for the following set of 8 training examples

A	B	C
T	F	T
T	T	T
T	F	T
T	T	T
T	F	T
F	T	T
F	F	F
F	T	F

(c) In a problem where each example has n real-valued attributes, where each attribute can be split at 2 possible thresholds, to select the best attribute for a decision tree node at depth k, where the root is at depth 0, how many conditional entropies must calculated?

(d) The Information Gain at the root node of any Decision Tree must always be at least as large as the Information Gain at any other node in that tree.(true or false give reasoning)

(e) Two different decision trees (constructed using different methods) that both correctly classify all the examples in a given training set will also classify any other testing example in the same way (i.e., both trees will predict the same class for any other example) (true or false give reasoning)

2. Explain the Expectation Maximization(EM) Algorithm. derive the equation for EM algorithm for the Gaussian Mixture Model (GMM) context. Give a reasoning why E-step is done first always. What would happen if we do Maximization first and then perform expectation. (5 marks)

3. (True or False, with proper reasoning) Algorithm A is better than Algorithm B if the training error of algorithm A is better than that of B (1 mark)

4. (True or False, with proper reasoning) For any classification problem, the Bayes optimal classifier can achieve an error rate of 0. (1 mark)

5. Do the derivation for bias-variance trade-off with reference to least squares errors. show the necessary steps. For $z \in R$, you are trying to estimate a true function $g(z) = 2z^2$ with least-squares regression, where the regression function is a line $h(z) = wz$ that goes through the origin and $w \in R$. Each sample point $x \in R$ is drawn from the uniform distribution on $(-1, 1)$ and has a corresponding label $y = g(x) \in R$. There is no noise in the labels. We train the model with just one sample point Call it x, and assume $x \neq 0$. We want to apply the bias-variance decomposition to this model. (5 marks)

   (a) In one sentence, why do we expect the bias to be large?

   (b) What is the bias of your model h(z) as a function of a test point $z \in R$? (Hint: start by working out the value of the least-squares weight w.) Your final bias should not include an x; work out the expectation.

   (c) What is the variance of your model h(z) as a function of a test point $z \in R$? Your final variance should not include an x; work out the expectation

6. MLE,MAP, Linear regresion

   (a) You receive xi telephone calls on day i, for i = 1, . . . , n. You wish to model this as X1, . . . , Xn i.i.d. from some distribution. Which of the following distributions would make sense to use? Give a proper reasoning. (1 mark)

   (b) Suppose $X, X_1, X_2..., X_N$ are i.i.d. and assume $E|X| < \infty$ and $V(X) < \infty$. What is the standard deviation of (2 marks)

$$\frac{1}{N}\sum_{i=1}^{N} X_i$$

   (c) Write three difference between MAP and MLE. What do you mean by conjugate priors. (1 mark)

   (d) Suppose you have a coin whose probability of landing heads is p = 0.5, that is, it is a fair coin. However, you do not know p and would like to form an estimator $\hat{\theta}$ for the probability of landing heads p. In this question, you will derive an estimator that assumes p can take on only two possible values: 0.3 or 0.6.

      (i) You flip the coin 3 times and note that it landed 2 times on tails and 1 time on heads. Find the maximum likelihood estimate $\hat{\theta}$ of p over the set of possible values (0.3, 0.6). (2 marks)

      (ii) Suppose that you have the following prior on the parameter p: $P[p = 0.3] = 0.3$ and $P[p = 0.6] = 0.7$. Again, you flip the coin 3 times and note that it landed 2 times on tails and 1 time on heads. Find the MAP estimate $\hat{\theta}$ of p over the set (0.3, 0.6), using this prior. (2 marks)

      (iii) Suppose that the number of times you flip the coin tends to infinity. What would be the maximum likelihood estimate $\hat{\theta}$ of p over the set (0.3, 0.6) in that case? Justify your answer. (1 mark)

(iv) Suppose that the number of times you flip the coin tends to infinity. What would be the MAP estimate $\hat{\theta}$ of p over the set (0.3, 0.6), using the prior defined in part 2 of this question? Justify your answer. (1 mark)

7. FLD

(a) What is the Fisher linear discriminant method(write the results of FLD mathematically) ? How it is different than that of Principal component analysis (PCA). Write limitation and advantages of PCA and FLD. (2 marks)

(b) Given the 2-d data for two classes: (3 marks)

$$1 = [(1,1),(1,2),(1,4),(2,1),(3,1),(3,3)]$$

and

$$2 = [(2,2),(3,2),(3,4),(5,1),(5,4),(5,5)]$$

as shown in the figure:

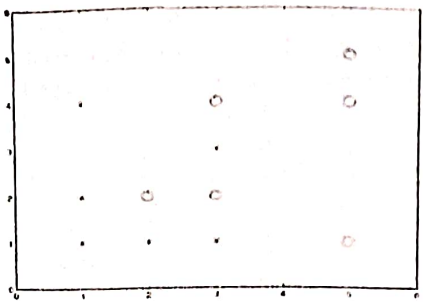


Figure 1: FLD

(i) Determine the optimal projection line in a single dimension

(ii) Show the mapping of the points to the line as well as the Bayes discriminant assuming a suitable distribution.

8. Kernel density estimate

(a) Write the key difference between KNN based non-parametric density estimate and parzen window (kernel density estimation) base density estimation methods. Mention the what are the important criteria any kernel function must satisfy in order to qualify as the kernel function. (3 marks)

(b) Let $x_1 = [0,0]'$, $x_2 = [1,0]'$, $x_3 = [1,1]'$, $x_4 = [0,1]'$, $x_5 = [0,2]'$, $x_6 = [2,1]'$, $x_7 = [2,0]'$, $x_8 = [1,2]'$. If first four samples belongs to class-1 and others to class-2, classify points $(0.4, 1.6)$ and $(1.4, .6)$. Assume $P(w_1) = P(w_2)$. (2 marks)

(i) By Parzen windows approach taking square window of width 1 and 3 units.

(ii) By 3-Nearest Neighbor estimator, using Euclidean distance.

9. SVM

(a) Write Hard Margin and Soft Margin SVMs expression or loss function. Explain each term clearly. (1 mark)

(b) What is Kernel Trick in SVM and why it is useful in implementing SVM? Suppose we have a kernel $K(\cdot,\cdot)$, such that there is an implicit high-dimensional feature map $\phi : R^d \rightarrow R^D$ that satisfies $\forall x; z \in R^d$; $K(x,z) = \phi(x) \cdot \phi(z)$, where $\phi(x) \cdot \phi(z) = \sum_{i=1}^{D} \phi(x)_i \phi(z)_i$ is the dot product in the D-dimensional space. Show how to calculate the Euclidean distance in the D-dimensional space

$$|| \phi(x) - \phi(z) || = \sqrt{\sum_{i=1}^{D} (\phi(x)_i - \phi(z)_i)^2}$$

without explicitly calculating the values in the D-dimensional vectors. For this question, you should provide a formal proof. (2 marks)

(2 marks)

(c) SVM problem

(i) Support vector machines learn a decision boundary leading to the largest margin from both classes. You are training SVM on a tiny dataset with 4 points shown below. This dataset consists of two examples with class label -1 (denoted with plus), and two examples with class label +1 (denoted with triangles).

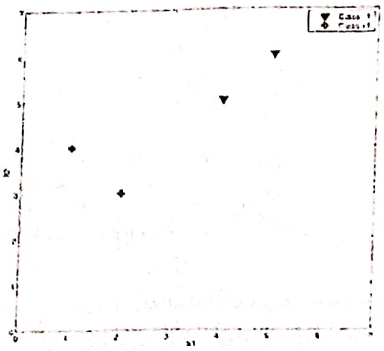


Figure 2: SVM

(ii) Write down the SVM loss function for this data and state how to find the weight vector w and bias b.

(iii) Draw the (approximate) decision boundary.

10. Bayes decision theory (5 marks)

(a) For a single feature, what are the optimal decision regions where: $\Omega = (\omega_1, \omega_2)$, $P(x|\omega_1) = N(4,1)(Normaldistribution)$, $P(x|omega_2) = N(3, 0.4)$, $P(\omega_1) = 2/3$, $P(\omega_1) = 1/3$ $\lambda_{11} = 0, \lambda_{12} = 1, \lambda_{21} = 1, \lambda_{22} = 0$,

(b) Select the optimal decision regions for the above problem when:$\lambda_{11} = 1, \lambda_{12} = 4, \lambda_{21} = 3, \lambda_{22} = 2$

(c) In many pattern classification problems one has the option either to assign the pattern to one of c classes, or to reject it as being unrecoonizable. If the cost for rejects is not too high, rejection may be a desirable action. Let

$$\lambda(\alpha_i|\omega_j) = 0, \text{if}, i = j, i,j=1.....c \ , \ (\text{i.e. Correct Classification})$$

$$\lambda(\alpha_i|\omega_j) = \lambda_r, \text{if} \ \ i = c+1 (\text{i.e. Rejection})$$

$$\lambda(\alpha_i|\omega_j) = \lambda_s, otherwise (\text{i.e. Substitution Error})$$

where λ_r is the loss incurred for choosing the (c+1)th action, rejection and λ_s is the loss incurred for making any substitution error. Show that the minimum risk is obtained if we decide ω_i if $P(\omega_i|x) \geq P(\omega_j|x)$ for all j and if $P(\omega_i|x) \geq 1 - \frac{\lambda_r}{\lambda_s}$, and reject otherwise. What happens if $\lambda_r = 0$? What happens if $\lambda_r > \lambda_s$?

(d) Show that the maximum likelihood (ML) estimation of the mean for a Gaussian is unbiased but the ML estimate of variance is biased (i.e., slightly wrong). Show how to correct this variance estimate so that it is unbiased.

11. Suppose you want to develop a machine learning solution for the nano-sattelite docking in the space. You will be interested in both classification and regression kind of problems here. Clearly list at least three different problems that are of classification nature and of regression nature for this case. Now propose your solution for this problem. Draw the complete pipeline including feature extraction, dimension reduction and the choice of classifier. Suggest innovative solution and be creative. (3 marks)

INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY
THIRUVANANTHAPURAM, 695 547
B.Tech End Semester Exam – December 2024

AV 412 – Satellite and Optical Communication

Time: 3 hour Date: 2/12/2024 Max. Marks: 50

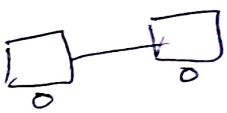
Note: Write Satellite Communication in Seal A Answer sheet and Optical Communication in Seal B

PART - A - Satellite Communication

Answer the following

1. A receiver front end (RF front end) has a noise figure of 10 dB, a gain of 80 dB, and a bandwidth of 6 MHz. The input signal power is 10^{-11}W. Assume that the line is lossless and the antenna temperature is 150 K.
   (i) Find system noise temperature and (C/N) [3]
   (ii) If a preamplifier is used before the receiver front end with a noise figure of 3 dB, a gain of 13 dB. Find the improvement in (C/N) [2]
   (iii) If a coaxial feeder is connected between the preamplifier and receiver front end and has a loss of 2 dB, calculate the system noise temperature [2]
   (iv) If a feeder cable is connected between the antenna and the preamplifier, calculate the system noise temperature and Comment on the result. [2]
2. The following parameters apply to a satellite downlink: EIRP 22.5 dBW, free-space loss 195dB, other losses 1.5 dB, earth station (G/T) 37.5 dB/K. Calculate the (C/N_o) at the earth station. Assuming an output Back off power of 6dB is applied, what is the new value of (C/N_o)? [2]
3. Explain how rain attenuation affects the computation of the C/N ratio in the uplink and downlink scenarios. [3]
4. Explain the procedure of finding the generator polynomial of an (n,k) binary cyclic code. [2]
5. Describe the procedure for generating a systematic code for an (n,k) binary cyclic code, and provide a detailed explanation of the encoding circuit along with its illustration for (7,4) code. [2]
6. A convolutional code is described by $g_1 = [110]$ $g_2 = [101]$ $g_3 = [111]$. Find the transfer function and free distance for this code. [4]
7. Prove with a mathematical equation how the maximum likelihood decoder is equivalent to the minimum distance decoder for linear block code. [3]

PART - B - Optical Communication



Answer the following

1. Using energy band diagrams, explain the operation of an Erbium Doped Fiber Amplifier (EDFA). What is the importance of the metastable state in the energy band diagram? What are the sources of noise in this amplifier? Can a two-level system work as a laser? Explain. [4 marks]

2. A fibre optic communication link has the following parameters. (i) Source power = 0 dBm (ii) Detector sensitivity = -45 dBm (iii) Connector loss = 1 dB/connector (iv) Splice loss = 0.06 dB/Splice. If the total link length of 100 km is spanned by connecting two hundred 500 m cables of attenuation coefficient 0.3 dB/km and a system margin of 5 dB is required, determine whether or not an amplification of the optical signals is required in the link. If yes, determine the required minimum amount of amplification in dB. Assume that the fiber cables are connected to the source, detector, and amplifier using connectors and that individual fibre cables are connected through splicing. [4 marks]

3. With figure, discuss the design of a pn photodiode receiver. How do you decide the thickness of p and n layers? Define Quantum efficiency and Responsivity of a Photodiode. Plot the responsivity as a function of photon wavelength for a photodiode? Define cut-off wavelength for a Photodiode. What are the draw backs of conventional p-n photodiode? How does p-i-n photodiodes help in overcoming them? [4 marks]

4. The Figure 1 shows a Mach-Zehnder interferometer modulator made of LiNbO3. The rectangular shaped waveguides are made of Ti diffused LiNbO3 having an index of 2.355 while the refractive index of LiNbO3 is 2.30. The diffused waveguide is 3 m wide and has a depth of 500 nm. A Silica step index optical fiber which has a clad index of 1.55 and a core index which is 1 % higher than that of the clad index has to be coupled at the In and Out ports. Explain the various coupling losses and any other losses that can occur in this scheme. Discuss the coupling mechanisms by which those losses can be minimized. How do you ensure that the fiber is mechanically well connected with the LiNbO3 substrate? [5 marks]

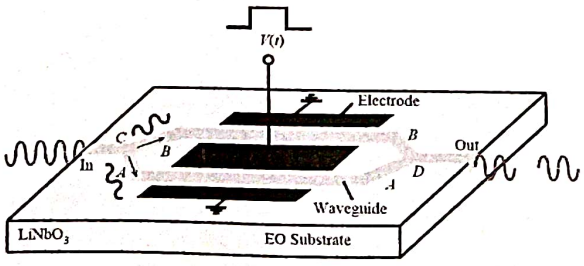


Figure 1: Mach-Zehnder interferometer modulator

5. For a Mach-Zehnder interferometer as shown in Figure 1, we have studied that when the phase of the waves in two arms differ by 180o, destructive interference occurs,

 Please go on to the next page...

we get no light at the output port [Termed as 0]. If no light appears at the output port, explain what happens to that light. In other words, where does that light go? [2 marks]

6. Considering a cosine electric field inside the core and exponentially decaying fields in both the claddings of a symmetric dielectric planar waveguide, obtain an expression for the optical confinement factor for this waveguide. [6 marks]

End of exam.