Avishkar Hyperloop

APPLICATION FOR ELECTRICAL SUBSYSTEM

2025-26

#LeapOntoTheLoop

INSTRUCTIONS

- Attempt all questions. A basic understanding and attempt of all the questions is expected. If you are unable to complete any question, clearly mention your thought process and roadblocks. Each question in the application tests skills related to different domains used in the team.

- If you have multiple approaches to a problem and have eliminated some to arrive at one, explain the reasoning behind your choice. Your thought process in solving the question is just as important as the final answer.

- Reasonable assumptions and interpretations can be made from publicly available literature, and the sources should be shared with your answer.

- A Google Doc link is attached where any updates or reference documents for particular questions will be added. Any corrections made will also be visible there.

- For questions that appeal to your domain of interest, provide a more in-depth answer. While this is a call to go over and above the asked questions, you are still required to attempt all questions.

- Add references to all your sources. Your application will be checked for plagiarism.

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- Limit ChatGPT usage in your application. You are free to use it as a guiding tool to get started on a topic; however, if we find your efforts lazy because of it, you will be severely penalized. Remember, in most cases, ChatGPT will give very wrong answers that can mislead you when searching for solutions.

- All applications must be submitted in digital format. Handwritten applications will not be entertained. Hand-drawn diagrams are accepted.

- Be sensible when writing your applications. Do not use overly large fonts or unnecessary content to boost the application size. Professional fonts like Times New Roman or Garamond are recommended, with sizes between 14-18.

- You are free to add humor and comedic relief to your application. In fact, it would be appreciate it, but use it in moderation. Do not use humor to hide a lack of content.

- Attempt the Bonus questions only after you've completed the other questions first. Brownie points will be given for attempting them.

In case of any queries, feel free to reach out to the corresponding Team member

Question	Team Members	Contact Information
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GENERAL QUESTIONNAIRE

1. Why do you think developing a hyperloop is necessary in India, and according to you, is the hyperloop concept feasible?

2. What motivates your interest in becoming a part of Avishkar Hyperloop? How do you envision your potential contributions to the team, and what do you hope to achieve in career development through this association?

3. What do you want to work on in the team once you join? Once you go through the app, you'll realize that the subsystem works on various aspects. What interests you the most? Mention specific details about what you would like to work on. Give some time for this question and answer it seriously. It is important for both of us to understand how you'll fit into the team.

4. Avishkar is a competition team apart from an innovation team. To compete, you should know about other players in the competition. Search about similar teams like Avishkar and write two innovations done by any team in Hyperloop and two specifically in the subsystem part.

5. What are your other PORs/commitments this academic year? How much time can you dedicate to the team every week?

6. Please list the software you are familiar with and your proficiency level. Sharing project links related to these software skills would be appreciated.

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QUESTION 1

Ohm Sweet Ohm

*Mr. Resisto was at work in his workshop, building a conveyor system for his latest project. The motor running the conveyor was simple, controlled by a **basic ON/OFF switch**. But the conveyor was too fast for precise handling of delicate materials, causing items to get misaligned and sometimes even fall off.*

Q. How can Mr. Resisto make use of switches he added to adjust the speed of the conveyor and control the motor ? Do you think he would face any problem with his setup ?

Seeing his buddy Mr. Resisto struggling with the conveyor's limitations, Dioden grabbed his cash (amount: ₹5000) and headed to the buzzing Magnetra Market. He wanted to create a controller for the motor to make it run at any speed he wants.

1: With Dioden's first attempt, Mr. Resisto managed to adjust the speed of the conveyor and slow it down for precise operations. However, a new problem emerged. They realized that they were not able to change the direction of motion of the conveyor belt. Also the motor wasn't running smoothly at all speeds.

*2: Dioden scratched his head. He realized they needed a better way to make the conveyor run smoothly at different speeds and spin backward to retrieve items. So, he went back to the store, and the shopkeeper suggested using a MOSFET based circuit for **smooth speed control and bidirectional movement.***

Q. **What might Mr. Resisto and his buddy Dioden have done in each case to resolve these issues?**

Q. **Bonus:** Use the resources given below and your creativity to help Dioden choose the right components to build a circuit that allows:

- Smooth speed control.
- Bidirectional motor operation.

Note: Assume all voltage to be DC. Circuit diagrams, simulations, or Tinkercad prototypes are encouraged. Mentioning of specific Sub-Category of the components is also encouraged. Block diagrams illustrating the circuit concepts are sufficient for this exercise. Data-sheet are Just for reference . Well also make sure Dioden doesn't get bankrupt..![Optimize on Cost) .Find-Datasheet links here.

The List of items in the market is given below as a list and their prices:

Item	Price (per unit)
Variable Resistor (Potentiometer)	₹15
Resistor (any value)	₹20
Capacitor (any value)	₹20
Inductor (any value)	₹25
Switch (SPST)	₹15
MOSFET (logic level)	₹150
Square Wave Generator (adjustable duty cycle)	₹600
555 Timer IC	₹50
Voltage Divider Circuit	₹30
Voltage Divider Circuit	₹30
Diodes (any value)	₹10
Heat Sinks	₹150
Push Button Switch	₹30
Microcontroller Board (e.g., Arduino)	₹800
Relay Switch	₹20
Oscillator Crystal	₹35
Op-Amp IC	₹120
Motor Driver	₹650
High-power MOSFET	₹60
Gate Driver	₹40
Any logic gates	₹75

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QUESTION 2

No Sparks, Just Starts!

Given below is a circuit diagram of a battery supplying power to an induction motor M. Notice the switch labeled as pre-charge. Read about pre-charge and answer the following questions:

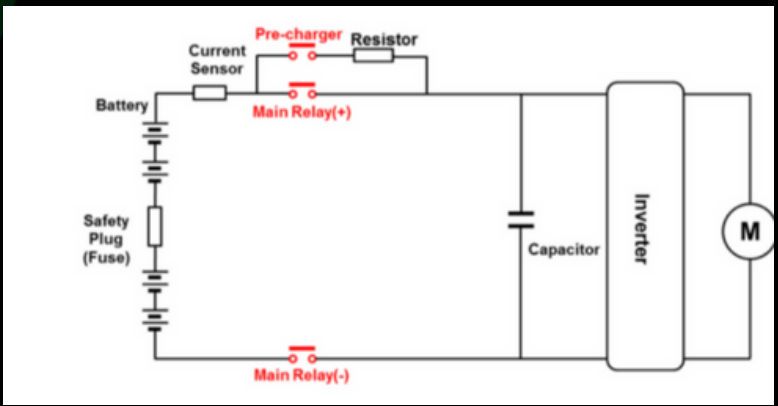


Figure 3: Pre-charge Circuit for the Propulsion System

1. The battery can be connected to the inverter by closing the Main relay(+) and main relay(-). If that's the case , then why are the pre-charge relay and the resistor connected? What purpose do they serve?

2. Think of an approach to calculate the value of the resistor that should be used. (Assume battery voltage V and capacitance value C. Make other assumptions if necessary, but clearly state them.)

3. Explain the purpose of the capacitor in this circuit. In continuation, describe how you would calculate the value of this capacitor. Mention all the parameters that you need and how you will work with them.

QUESTION 3

The Battery Rebuilding Challenge

You have a perfect battery pack that meets all your requirements: A **12s8p configuration of NCR18650BD cells**.

Excited, you test the battery pack only to face a crushing disappointment-- the pack is faulty and cannot be used. You search the workspace thoroughly hoping to find another battery pack. After hours of rigorous searching, you find a forgotten unopened box of cells in a dusty corner. You open the box to a new surprise-- inside are **LFP 26650 cells**. A completely different set of cells!

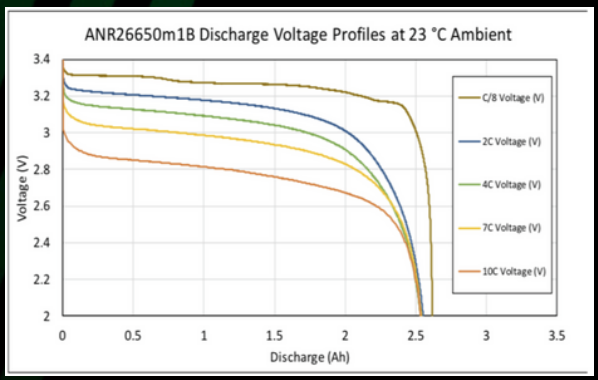
The challenge is clear: **Replicate the original battery pack using LFP 26650 cells.**

Find the datasheets here
What configuration of LFP 26650 cells would be required to achieve the same voltage and max current requirements?

You dive into the calculations, and satisfied that it would sufficiently supply the required voltage and current.

Your mentor comes across you working on the pack. You are advised, "Remember, it's not just about replicating voltage and current. The **state of charge (SoC) and C-rate** are critical metrics. Here's the task: if you want to **discharge both packs continuously for at least 20 minutes, what's the maximum amperage you can safely draw from each pack?**"

A cell's voltage to capacity relation varies with the C-rate at which it is charged or discharged.



For LFP26650 cells, how does the **nominal voltage change** for:

- C/8
- 2C
- 10C

Learning about different SoC curves, you must realise that the rate at which you discharge will affect your configuration and you need to redesign the pack.

Putting all of these constraints together, we have

- Total voltage required
- Change in the cell's nominal voltage for different C-rates
- Current requirement
- Total capacity based on required discharge time

Which of these constraints would affect the series and which would affect the parallel configuration?

Now, considering C-rate and SoC curves, design the final battery pack for the following constraints

- The same pack voltage as 12s8p pack of NCR18650BD cells
- The pack must be discharged for 15 minutes at 52 A

Inside the same box of cells you find another component. It simply looks like a big silver metal box with some fins on top. Intrigued you look it up and find that it is a **Battery Management System**.

A BMS helps us in 3 ways:

1. Measurement
2. Protection
3. Cell balancing

But what are we measuring? **What do you think are the important parameters to be measured in a battery?**

Here's a tougher question: We take a single measurement of voltage for cells connected in parallel. **How would the BMS figure out that one of the cells connected in parallel is damaged?**

A BMS must ensure that all cells in the pack stay balanced, or you'll face problems like uneven aging and inefficiencies. This is where cell balancing comes into play.
Read about active and passive cell balancing. Which one in your opinion is better for our pod?

QUESTION 4

Problematic Circuit Board

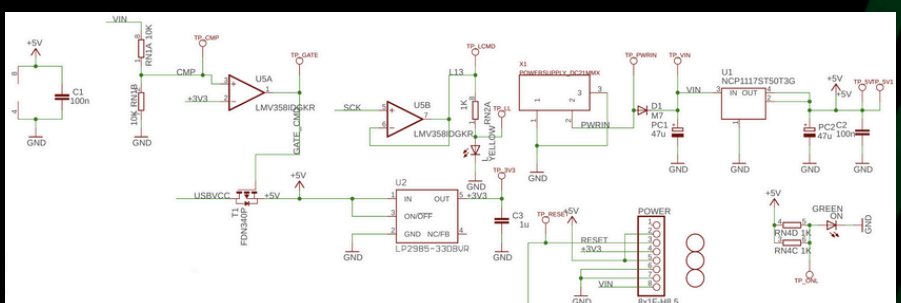
PCB Designing is one of the basic skills that you'll learn during your tenure at Avishkar. A well-designed PCB does not just take into account its various inputs and outputs but also considers the protection of various critical components against unpredictable cases of voltage, current and thermal abnormalities. To cover the basics:

A) Explain the following terms briefly:

- Traces
- Vias
- Polygon pours
- Silkscreen
- Pads
- Solder mask
- Differential pair

B) The Arduino Uno R3 is a board that is frequently used for hobbyist purposes*. Here is the official schematic of the board assigned for reference. **Use this schematic for this question.**

Q. Analyse the power circuitry on the Arduino, and explain how the various sources of **power (PWRIN, VIN, USBVCC)** are used together to give the +5V and 3V3 supply. Every Capacitor, Resistor and Diode on the board serves a purpose; understand it.



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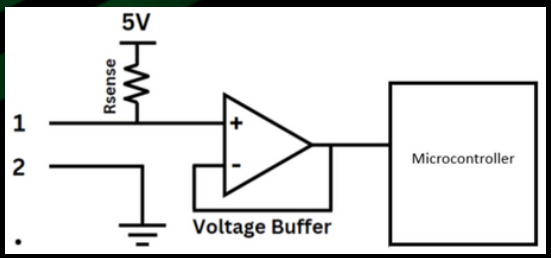
C) Hyperloop Pod relies on sensors to gather data about its performance. These sensors continuously measure temperature, pressure, speed, etc to ensure optimal operation. However, microcontrollers, the brain behind these systems, are digital creatures—they can only process data in binary form. This presents a challenge: how do we convert analog data into something that a microcontroller can understand? The answer lies in Analog-to-Digital Conversion (ADC).

Given below is the Calibration Chart of the thermistor that we use in our thermal system.

GE Refrigerator Thermistor-Temperature Data Chart

Temperature Degrees (C)	Temperature Degrees (F)	Resistance in Kilo-Ohms
-40	-40	166.8 kΩ
-35	-31	120.5 kΩ
-30	-22	88 kΩ
-25	-13	65 kΩ
-20	-4	48.4 kΩ
-15	5	36.4 kΩ
-10	14	27.6 kΩ
-5	23	21 kΩ
0	32	16.3 kΩ
5	41	12.7 kΩ
10	50	10 kΩ
15	59	7.8 kΩ
20	68	6.2 kΩ
25	77	5 kΩ
30	86	4 kΩ
35	95	3.2 kΩ
40	104	2.6 kΩ
45	113	2.2 kΩ
50	122	1.8 kΩ
55	131	1.5 kΩ
60	140	1.2 kΩ

Following Circuitry is used to find the temperature of thermistor using our microcontroller MSP432E401Y (here is the datasheet for the same) .



Q. What are Thermistors ? How are they used to measure Temperature ?

Here a thermistor is connected between points 1 and 2 in a circuit. The microcontroller (MSP) has an integrated ADC that converts analog voltage signals into digital values for analysis.

Q. Refer to the datasheet to understand the characteristics of ADC (**A detailed reading of the datasheet is NOT necessary; understanding the fundamental features is sufficient**) and explain the purpose of this circuit.

Q. How can it be used to measure the resistance of the thermistor and, subsequently, determine its temperature? Additionally, calculate the minimum value of Rsense required to achieve the desired voltage level.

For a Temperature Range – (30 – 60 degree Celsius)
Q. Write a C code to convert this digital value of the voltage obtained by the microcontroller to get the resistance value of the thermistor. Take Rsense = 10kΩ.

Q. Now that we have managed to receive values from our ADC it is noticeably noisy and unusable. Here is the **measured CSV data** of the reading and use a form of software post processing to clean it. **Attach code and plot of raw and processed data.**

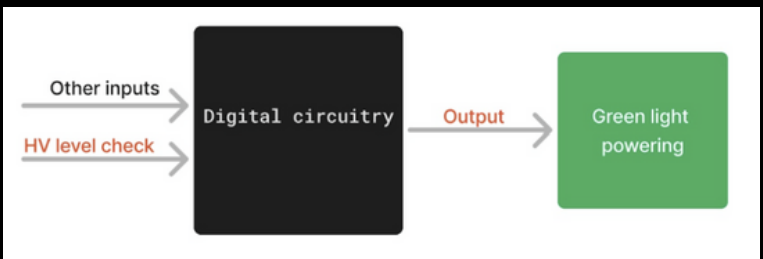
QUESTION 5

Red light Green light

What is a Relay? How do Mechanical Relays work? What is an auxiliary signal and what's the purpose of it?

*According to **Rules and Regulations of EHW 25**, we are supposed to include a simple Lighting check based on power supplied to the parts of the pod. This is called **High Voltage (system) Active Light**. And we need Relays for this.*

Read up the High voltage active lights part in R&R from **E.82 - E.86**. Ignore the points about red light.



Q. Having measured the voltage across the High Voltage Battery Pack, think about what could be the **other inputs/constraints** that would help determine plausibility of the digital circuit in the black box.

The High voltage check mentioned in E.85 is the HV level check given which basically gives high input if the voltage level inside the High Voltage enclosure is greater than 60 VDC or 50 V AC RMS.

Design the circuitry that gets the job done for us. If you are using logic gates, use gates with 2 inputs only.

QUESTION 6

CANfused

One thing that every automobile needs is a reliable and efficient communication architecture. Having a protocol which ensures both efficiency and speed can be a gamechanger. Enter the CAN (Controller Area Network) protocol, a powerful and widely adopted communication standard designed specifically for vehicles. With its robust design, CAN enables seamless communication between various electronic control units (ECUs) in a vehicle, ensuring that critical systems like braking, motor control, and safety features work in harmony.

A) Controller Area Network (CAN), one of the most widely automotive communication technologies, is based on a Layered Architecture called “OSI”.

- Read about the different layers in OSI and explain in brief.
- Specify which layers are utilized by CAN and describe their roles.

B)There are different types of frames which are sent by ECU’s in a vehicle. Elaborate on how a CAN message frame is structured, detailing the purpose of each of its components.

C)Explain the process of bus arbitration in CAN communication and how the protocol seamlessly ensures that messages are prioritized and transmitted without conflicts.

D) *Imagine a scenario where you are expecting an important mail. But your mailbox is filled with all sorts of junk- both meant for you and spam and you’re gonna have a hard time finding your important mail in that.*

Now imagine your mailbox is a rather smart device and can "filter out" the more important ones from the junk. This is exactly what filtering is in CAN

- Why is message filtering essential in a Hyperloop pod? Is filtering managed at the protocol level or hardware level? What potential issues could arise if messages are not filtered? Explain the message filtering process in CAN communication.

Now that you have learned about how filtering works in CAN. Lets try out this "Sorta" real life scenario:

Q. Here is a Node A and this node needn't necessarily accept in all the messages, so while designing we assign it a filter and a mask as given below

FilterID : 0x15203424
MaskID: 0x1FAB677E
How many and what are the message IDs that Node A can read?

Q. Now that you know How Mask ID and Filter ID Work, How can I make this Node A-
i) read all message IDs?
ii) read no message IDs?

E) *Influence of external stimuli on electronic devices is inevitable. A message may be sent to immediately stop the pod and it just might be our luck that external stimulus decides to affect our message by flipping a bit or adding noise causing other nodes to think everything is fine, while the vehicle is crashing. This is why it is upto us to find mechanisms/algorithms to check if a message sent by a particular node is something which it intended to send*

- The CAN frame and protocol has been intelligently designed to act as a key to ensuring that the CAN message integrity is not compromised. Explain briefly how this has been implemented in CAN.

QUESTION 7

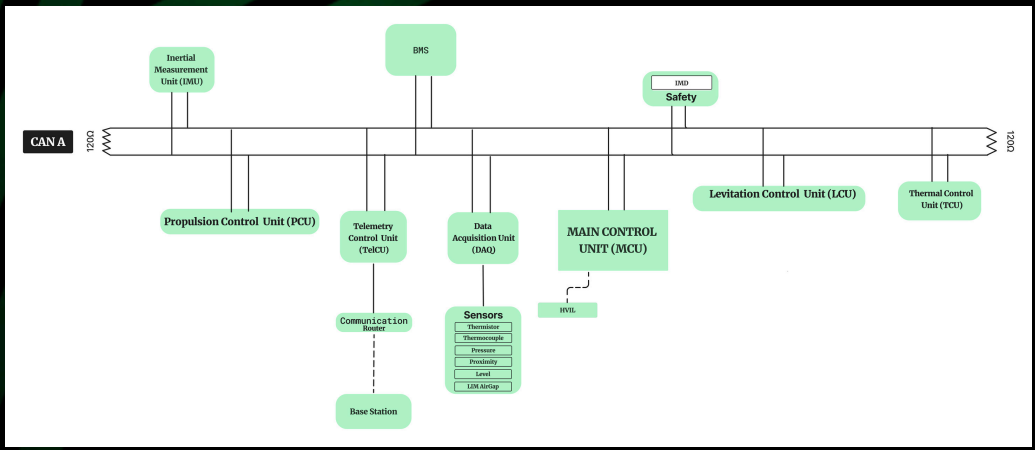
Houston, We have a Problem !

The Avishkar Pod travels at high speeds, continuously transmitting critical data about the **pod's vitals to a central base station** for real-time monitoring and control. Data is split into small packets (~1500 bytes) for transmission, while the base station sends to the pod essential commands for initialization and safety. This demands a reliable wireless communication model to ensure seamless data exchange.

Wireless communication allows devices to exchange data without physical connections, using electromagnetic waves.

Q. As you know, data is typically broken into small, manageable units called data packets. How is data broken into packets for wireless transmission, and why is packet-switching important for efficient communication in systems like the Hyperloop Pod?

Q. Not only do we receive real time data from the pod but also send out commands for initialization as well as safety messages. Below is the network architecture diagram of Avishkar Pod. You can notice that TelCU which is the Telemetry control unit which formulates and encapsulates periodic data it receives from the other ECUs as well as delivers the commands to the Main control unit. A list of messages sent and received from the pod are given below :



1. Stop the Pod
2. Airgap data
3. Brakes
4. Brakes actuation Failure Alert
5. Start Inverter
6. Levitation Failure Alert
7. Battery Overheating Alert
8. Temperature data
9. Inverter Current
10. Start Pod

Try grouping them in a way, stating the direction of message transmission and which messages are frequently sent/received and which are not.

BONUS

Try designing a basic wireless communication model **using a protocol of your choice** which you think would be suitable for a Hyperloop Pod . Include all your necessary components . Try mentioning different layers (as mentioned in the CAN question) of your model (if they use any).

QUESTION 8

Richie Rich's Bank Dilemma

A) Give a detailed explanation on the difference between threads and processes.

BONUS: In some CPUs you may notice a hardware thread count is given and often times this hardware thread count is much lesser than the software thread count shown in ur task manager. Explain why this occurs

B) Mr and Mrs Richie are having a joint family bank account. Both of them can withdraw or deposit money into the bank account simultaneously. The Bank decides to have separate threads to process data from Mr and Mrs Richie's Transaction. You are writing the code for this for the bank.

Q. Provide a basic pseudo code on how you plan on executing this. Now try to think what happens when you try to have two threads each running for the two independent simultaneous transactions from Mr and Mrs Richie. Do you think we will encounter an error?

Q. Provide a brief description on some techniques used in software development to handle resources that are altered by 2 different lines of code parallely.

BONUS:

Write a C program to:

1. Create two threads: one for Mr. Richie's transactions and another for Mrs. Richie's transactions.
2. Use a global variable to maintain the current balance of the account.
3. Increment another global counter every time a transaction (deposit or withdrawal) is performed.

The program should print the final account balance and the total number of transactions processed.

Run your code with for about 2000 deposits and withdrawals (e.g., ₹500 deposits and ₹300 withdrawals in a loop). Check if the final balance and transaction count are correct.

If discrepancies occur, explain why this happens and suggest a solution to ensure the correctness of the balance and transaction count.

HAPPY APPING !!

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