Powertrain Technical Assessment 2024 - T3

Welcome to the Powertrain Technical Assessment for 2024, we are very excited to see what kind of perspective and skills you will bring to our team!

The Technical Assessment:

Please read through all the questions provided, then select questions that will highlight your skills, interests and background knowledge. You are not expected to do all of them but each question gives a chance to demonstrate different important skills, so more is better. Answer your selected questions and submit as a single PDF file including any calculations or drawings that you might have made. If you attempt Question 1 also submit the STEP file of your design.

You may use any external resources available to you, except for generative AI tools such as ChatGPT.

It is also recommended that you answer the questions with the FSAE Australiasia 2024 Rules in mind.
https://www.fsaeonline.com/cdsweb/gen/DownloadDocument.aspx?DocumentID=369d01c0-589d-4ebe-b8d4-b07544f4a52b

Best of luck!

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1. Enclosure Design and Justification (CAD)

In Powertrain, it is important to protect high and low voltage electronics. This task is based on a simplified version of a real scenario, using real low voltage components from last year's car, RB23. In RB23, several PCBs and other control electronics are mounted inside the same enclosure and you are tasked with making a smaller version of a similar enclosure. The goal of this task is to asses your creativity, design for manufacture, and basic CAD skills.

Attached are CAD files of a PCB and a relay. These electronics need to be housed inside a small aluminum enclosure in order to protect them. They also need to connect to other parts of the car through 12 wires, using a connector. We are sponsored by TE so you can use TE Connectivity: Connectors & Sensors for Harsh Environments to find any electrical connectors.

Relay.stp
14 Aug 2024, 07:24 AM

PCB.stp
14 Aug 2024, 07:24 AM

The enclosure can involve any sort of mounts, fasteners or other components you can buy or design, with any manufacturing methods. The enclosure does not have to mount to the car.

Your basic goals are:

- Hold the components in place
- Protect the components from outside debris
- Ease of manufacturing the enclosure
- Ease of access/removal of the components

If you are feeling confident some extra goals you can include are:

- Waterproof the enclosure to protect the components from rain

- Electrically insulate the inside of the box from the outside
- Electrically ground the box (you can assume one of the wires passing through the connector is a ground wire)

You can design the enclosure in any CAD program you are comfortable in, but must submit a STEP file.

If you have any questions with the task, please contact Sebastian Barrett z5316890 on Microsoft Teams.

After making your enclosure answer the following questions, including any images that support your answer:

1. Briefly describe your solution with any detail that you were not able to put into CAD.
2. Describe how you would manufacture and assemble the enclosure.
3. Justify how your design meets the goals set out above.
4. How did the FSAE rules influence any of your design decisions?
5. Explain any other design decisions you made.

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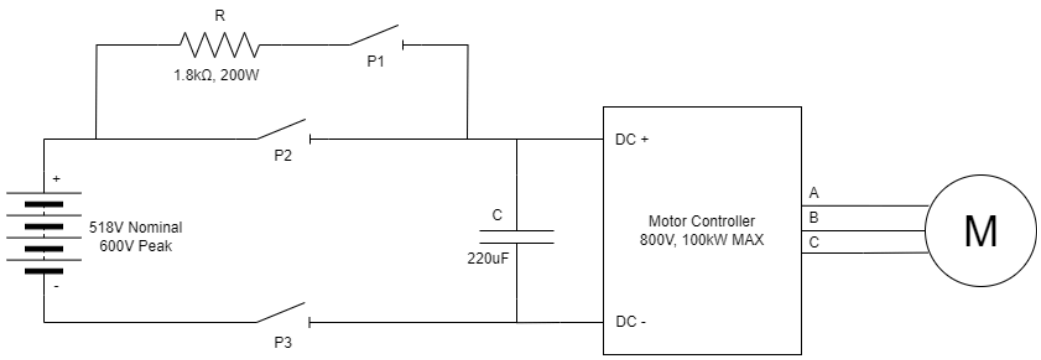
2. Motor and Inverter Theory

Below is a simplified, high-level circuit of the tractive system used on RB23. Assume P1, P2, P3 are contactors that can be controlled individually.



1. Many different motor topologies exist with different advantages and disadvantages. Compare 2 motor topologies that are appropriate for use in a high performance electric vehicle based based on a set of criteria of your choice (e.g. cost, weight etc).
2. Why are there three cables going to the motor and why would this be advantageous? You may refer to your answer in the previous section
3. What is the purpose of the capacitor C, the resistor R and the contactor P1 in this circuit? Explain your reasoning.
4. Assume C is fully charged, and contactor P3 remains closed, however due to a malfunction P2 remains open and P1 remains closed, and the motor controller is commanded to drive the motor. What will happen in this situation?
5. Performance is a critical consideration in Formula Student. Suggest ways to improve the power or efficiency of this system and list any assumptions that you make in your answers.

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3. Battery Theory

RB23's main high voltage battery, referred to as the Accumulator, consists of 144 Sony VTC6 18650 Li-ion cells in series, each with 6 cells in parallel totaling 864 cells. Combined, the pack has a nominal voltage of 518V and 18Ah of capacity.

1. What are the advantages of lithium-ion based cell chemistries?
2. What are the peak and continuous current ratings of a single Sony VTC6 18650 cell?
3. Why must cells be combined in series and parallel to get a desired nominal voltage and capacity? What are the implications of doing so when charging and discharging the battery? Justify your reasoning.

4. Lithium Ion cells can potentially be dangerous when mistreated. List four precautions that must be taken to ensure the safe use and handling of lithium ion batteries.

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4. Cooling Theory

i. A big problem our team has encountered over the past years is how to efficiently cool our accumulator. The accumulator is our high voltage battery for the vehicle and has a 144s6p configuration. The first step in overcoming this cooling problem is identifying how much heat is required to be rejected from the accumulator. Given that we know all the electrical parameters of these modules in the accumulator (voltage, current and resistance) how would you estimate the heat output?

ii. Onboard our vehicle, there is a liquid cooling loop that circulates distilled water through the motor and inverter to the radiator, rejecting the heat outputted by the motor and inverter. This loop is just a loop that runs in series from component to component. How much heat is being outputted by the motor and inverter during normal operation could be theoretically calculated. Assuming all this heat is being rejected into the cooling loop:

Calculate the temperature drop of the distilled water coolant across the radiator if the motor is outputting 800W of heat, the inverter is outputting 900W of heat, and the cooling loop is circulating water at 10L/min. Please attempt this question even if you are not sure, leaving lots of notes outlining your logic. You are not expected to find the correct answer.

5. High Voltage Safety Theory

Below is a picture of the Insulation Monitoring Device, a critical safety component of the car mandated by FSAE rules. It is designed to monitor isolation between high and low voltage/chassis ground circuits in the car, by injecting a small, high frequency signal into the high voltage circuit and measuring the amount of this signal present in low voltage circuits.

ISOMETER® IR155-3203/IR155-3204

1. Why is it important to maintain galvanic isolation between high voltage circuits and low voltage/chassis ground?
2. What are some potential situations that can cause a breakdown of the isolation barrier?
3. Why is the normal operation of the tractive system not affected by the injected signal?

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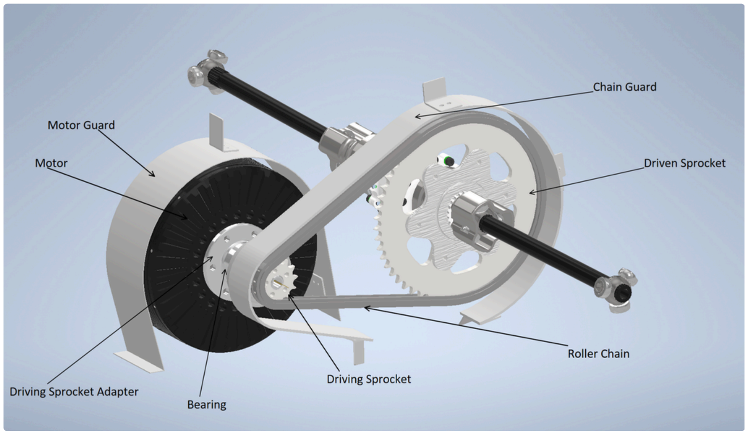
6. Motor Topology Theory

Context

Driveline focuses on designing a system to deliver power from the vehicle's motor to its wheels. Reflecting the car industry's shift from internal combustion engines towards electric vehicles, FSAE vehicles have followed a similar trend, with most current FSAE vehicles in Australia being electrically powered, including Redback's previous RB23 and RB21 cars. The most common two driveline configurations for electric FSAE vehicles are a single inboard motor, or quad hub motors (a motor connected to each wheel).



Single Inboard Motor Layout

Hub Motor Layout

The Task

Your task consists of three main parts:

1. Justify why many FSAE teams may start off with a single inboard motor and then transition to hub motors.
2. Find 2 off the shelf hub motors which may be suitable for a future Redback FSAE car, and compare them based on a set of criteria of your choice (e.g. cost, weight etc).

The exact structure of your response is up to you, however based on your comparison of the layouts, you must suggest which one you think would be best.

Keep in mind the context of an FSAE vehicle, including the 2024 FSAE rules which can be found online, the upskilling required to design and manufacture each system as well as how each system may positively or negatively impact the other systems in the car.

You may choose to include additional details such as specific motor suppliers, calculations and any other relevant information. The amount of detail you include is up to you, however the relatively short time frame for this task will be kept in mind when reviewing the depth of responses.

You may also find the following information about our next FSAE car to be helpful

- Overall car weight with driver: 300 kg
- Tire coefficient of friction estimation 1.6
- Straight line maximum acceleration target 1.05 Gs