Design support

Accumulator

I. Stacks and cells

Objectives

To define the minimum requirements in the context of a performance-oriented build, we based our analysis on the acceleration event of the Formula Student competition. This event places the greatest demand on instantaneous power. Although it would also be relevant to consider the endurance event, this remains out of reach for now. Our primary goal is to build a first drivable car that complies with the rules. Performance optimization will be the focus of future seasons.

Conception steps

It is extremely difficult to carry out optimal busbar welding conditions — these are the components that connect individual cells together. Such welds require dedicated equipment and time-consuming training, which we were not in a position to undertake this year. As a result, we decided to use battery modules supplied by Forsee Power, specifically taken from the Piaggio One electric scooter.

Assumptions

- Each cell: 3.2 V, 10 A
- One stack = 13 cells in series (13S), 5 cells in parallel (5P) → 13S5P
- Target performance: Reach 50 km/h in 10 seconds over 75 meters
- From our calculations, this requires approximately 12 kW of instantaneous power.

Simulations steps overview

We opted to use 6 stacks in series, each one configured as 13S5P.
This architecture results in a total system delivering:

- 38 kW
- 250 V
- 50 A

This configuration allows us to meet our initial performance objective.

Limits

In parallel, we developed an algorithm to determine the optimal battery configuration for a given power target. The results showed that the architecture imposed by the Forsee modules is not the most efficient.

Although choosing Forsee modules significantly reduced development time and complexity, it comes at the cost of suboptimal performance on track. This tradeoff reflects our current priorities — getting a reliable and rule-compliant first prototype ready — while keeping long-term performance improvements in mind.

II. Tractive System Accumulator Container (TSAC)

Objectives

The TSAC is the physical enclosure of the battery. Its main purpose is to protect the battery from external impacts or intrusions in order to ensure the safety of its internal components.

Choices

- The Formula Student regulations (Rule EV 5.5.5) define the minimum required wall thickness for the TSAC: 1.25 mm for the base and 0.9 mm for the walls.
  To simplify the design and manufacturing process, we opted to use 2 mm thick steel uniformly across the entire structure.
  Using aluminum would also have been an option; however, the minimum required thickness for the base in that case is 3.2 mm. Since we plan to manufacture the container in our school's workshop, which can bend metal sheets up to 2 mm thickness, this option was ruled out.
- The regulations (EV 5.5.3) specify that all structural parts of the TSAC must be made from fire-resistant materials conforming to the UL 94 V-0 standard.
  NOMEX meets this requirement and can be applied almost universally throughout the container. We will use it primarily in areas where we require thermal and electrical insulation.
- The TSAC is fully designed with ease of internal component access in mind. To that end, the number of bolts has been minimized — only the lid is bolted.
  We also carefully considered other regulation points, including the compartmentalization of battery modules with full-height walls, and drilling and penetration rules defined in EV 5.5.14.
- Cooling is provided by ventilation slots, whose size was carefully calculated to allow for natural (passive) convection.

Simulations steps overview

Simulations confirmed that the designed ventilation provides sufficient passive cooling. However, we have not yet been able to test this system in practice.

Limits

Due to its all-steel construction, the TSAC is relatively heavy. A possible improvement would be to build it using composite materials, which would reduce weight significantly. However, this would require more time and infrastructure than currently available in our school workshop.

III. Inside Container (IC)

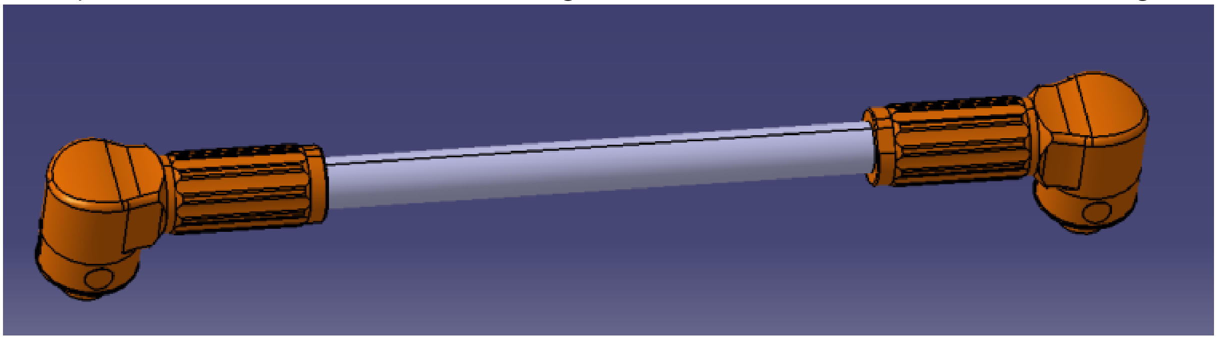
Objectives

The Inside Container (IC) is the "brain" of the battery. It houses all components responsible for controlling and monitoring the battery. Its main advantage lies in its ease of handling: the IC is fully removable, allowing for easy access and maintenance of low-voltage elements. Moreover, having a detachable and standardized module makes it easier to swap or replicate the system in case multiple battery packs are used.

Conception steps

The IC is made from FR4, chosen for its excellent electrical insulation properties. To ensure thermal insulation, the FR4 surfaces are covered with NOMEX, which complies with fire resistance regulations (UL 94 V-0)..

Battery modules are interconnected using inter-module connectors, each consisting of:



- Two TE Connectivity connectors (model H1111000301-000)
- A crimped cable with a 60 mm² cross-sectional area

These connectors were selected due to their voltage and current ratings, which allow for:

- Up to 1500 V
- Up to 200 A

This margin allows us to accommodate potential future use cases with higher power demands.

Key Components

AIR (Accumulator Isolation Relays)

- Max voltage: 900 V

- Max current: 500 A
- Crucially, the relays are Normally Open (NO), a requirement from FS regulations (EV 5.6.3). These are the most critical components in terms of isolation and safety.

Precharge Relay

- Similar constraints to the AIRs in terms of voltage
- However, it handles much lower current, since it only operates during precharge (low-current phase)
- Selected model: DCNLEV50-BAN from LittleFuse
- Also Normally Open, complying with EV 5.7.2

Main Fuse

- Protects all high-power components in the battery system
- Its main role is to cut off battery output in the event of a short circuit or current spike
- Current rating: 100 A, corresponding to 5 cells in parallel each discharging at 20 A (cell limit)
- Model: 0AKK-K100-B from Bel
- Mounting bracket: EL_22024, 3D printed
    - Printed with PETG, a non-conductive material that complies with UL 94 V-0 and withstands high temperatures

Voltage Indicator & LED Indicator

- The Accumulator Voltage Indicator board detects battery voltage levels at the AIR terminals
- It alerts external users when the AIRs are powered with over 60 V, as required by EV 5.4.10
- A key challenge: the board must be powered exclusively by high voltage
    - However, components like comparators require low voltage to operate
    - Solution: use a flyback controller to convert high voltage (up to 600 V) into 12 V
-

IV. Battery Management System (BMS)

Objectives

The BMS has four main functions:
— Measuring the voltages of each series of cells
— Measuring the temperatures of some of the cells
— Balancing the voltages between the different cells
— Transmitting the voltages and temperatures to the AMS

Conception steps

The central component of the BMS is the ADBMS1818ASWZ chip, which handles the acquisition of both voltage and temperature measurements and communicates with the AMS. For temperature measurement, we designed custom boards to correctly position the temperature sensors. Temperature is measured using an ADG728BRUZ-REEL7 chip.