**Coversheet**

**The Coversheet must contain the following:**

* **Heading “Electrical System Form FSN 2024”**
* **University and Team Name**
* **Car number**

Feel free to add team logo, car picture, and the like.

1. **Requirements (delete this section after you have read and understood it):**
2. Complete all sections and tables of the ESF. If a section is not applicable to your design state that in the document, do not delete any sections.
3. Remove instructions (orange) from document as you complete the sections.
4. Provide hyperlinks to all datasheets or add them as appendices at the end of the document.
5. If you are unsure with respect to feedback of the reviewer, do not hesitate to ask the Lead E-scruti via E-mail to d.vandenbrandt@formula-student.nl
6. Parts of the ESF which are changed because of reviewer’s feedback must be marked in red.
7. Send the final document to esf@formula-student.nl
8. Following these guidelines will guarantee a swift review process.

Table of Contents

[1 System Overview 7](#_Toc188569830)

[2 Tractive System Schematics 8](#_Toc188569831)

[2.1 Tractive System Schematic (Power Electronics ONLY) 8](#_Toc188569832)

[2.2 Fusing Diagram 9](#_Toc188569833)

[3 Shutdown Circuit 10](#_Toc188569834)

[3.1 Shutdown Circuit Schematic 10](#_Toc188569835)

[3.2 Wiring 11](#_Toc188569836)

[3.3 IMD 12](#_Toc188569837)

[3.4 Inertia switch 13](#_Toc188569838)

[3.5 Brake System Plausibility Device 13](#_Toc188569839)

[3.6 Battery Management System 15](#_Toc188569840)

[4 Safety Systems 16](#_Toc188569841)

[4.1 TSAL 16](#_Toc188569842)

[4.2 Measurement Points 17](#_Toc188569843)

[4.3 HVD 19](#_Toc188569844)

[4.4 Ready to Drive Sound 20](#_Toc188569845)

[4.5 Discharge Circuit 20](#_Toc188569846)

[5 Accumulator 22](#_Toc188569847)

[5.1 Accumulator Overview 22](#_Toc188569848)

[5.2 Accumulator container 22](#_Toc188569849)

[5.3 Segments 23](#_Toc188569850)

[5.4 Cells 26](#_Toc188569851)

[5.5 Precharge Circuit 27](#_Toc188569852)

[5.6 BMS 28](#_Toc188569853)

[5.7 AIR 29](#_Toc188569854)

[5.8 Accumulator Indicator 30](#_Toc188569855)

[5.9 Charging 31](#_Toc188569856)

[5.10 External Data Connection 32](#_Toc188569857)

[5.11 Tractive System Accumulator Container Hand Cart 33](#_Toc188569858)

[6 Motor controller 34](#_Toc188569859)

[6.1 Motor controller 1 34](#_Toc188569860)

[6.2 Motor controller 2 35](#_Toc188569861)

[7 Motors 36](#_Toc188569862)

[7.1 Motor 1 36](#_Toc188569863)

[7.2 Motor 2 37](#_Toc188569864)

[8 Acceleration Pedal Positions Sensors 38](#_Toc188569865)

[8.1 Description/additional circuitry 38](#_Toc188569866)

[8.2 Wiring 38](#_Toc188569867)

[8.3 Position in car/mechanical fastening/mechanical connection 39](#_Toc188569868)

[9 Other Items 40](#_Toc188569869)

[9.1 LV part 1 40](#_Toc188569870)

[9.2 LV part 2 40](#_Toc188569871)

[9.3 Additional System Critical Signals (SCS) 41](#_Toc188569872)

[9.4 Data Logger 41](#_Toc188569873)

[9.5 Firewall 42](#_Toc188569874)

[9.6 Grounding 42](#_Toc188569875)

[9.7 Other Components 42](#_Toc188569876)

[10 Appendix 43](#_Toc188569877)

[10.1 SDS (MSDS) of accumulator cell 43](#_Toc188569878)

Table of Figures

[Figure 1 - System Block Diagram 7](#_Toc188569879)

[Figure 2 - HV System Schematic 8](#_Toc188569880)

[Figure 3 - Fuse Tree Diagram 9](#_Toc188569881)

[Figure 4 - Shutdown Circuit Schematic 10](#_Toc188569882)

[Figure 5 - Shutdown Circuit Switch Locations 11](#_Toc188569883)

[Figure 6 - IMD Latch Circuit Schematic 12](#_Toc188569884)

[Figure 7 - Inertia Switch mounting 13](#_Toc188569885)

[Figure 8 - BSPD Schematic 14](#_Toc188569886)

[Figure 9 - BSPD Component Location 14](#_Toc188569887)

[Figure 10 - TSAL Circuit Schematic 16](#_Toc188569888)

[Figure 11 - TSAL Component Locations 17](#_Toc188569889)

[Figure 12 - Measurement Point Location 18](#_Toc188569890)

[Figure 13 - TSMP Protection Resistor Location 19](#_Toc188569891)

[Figure 14 - HVD Location 20](#_Toc188569892)

[Figure 15 - Discharge Circuit Component Locations 21](#_Toc188569893)

[Figure 16 - Accumulator Overview 22](#_Toc188569894)

[Figure 17 - AIR and Fuse Detail 23](#_Toc188569895)

[Figure 18 - Cell Mounting in Accumulator 24](#_Toc188569896)

[Figure 19 - Cell Connections Detail 24](#_Toc188569897)

[Figure 20 - Maintenance Plug Locations 25](#_Toc188569898)

[Figure 21 - Temperature Sensor Location 26](#_Toc188569899)

[Figure 22 - Precharge Circuit Location 27](#_Toc188569900)

[Figure 23 - Schematic of Accumulator Indicator 30](#_Toc188569901)

[Figure 24 - Location of Accumulator Indicator 30](#_Toc188569902)

[Figure 25 - Charging Shutdown Circuit Schematic 31](#_Toc188569903)

[Figure 26 - Charging TS Schematic 32](#_Toc188569904)

[Figure 27 - TSAC Hand Cart 33](#_Toc188569905)

[Figure 28 - Motor Controller Position 35](#_Toc188569906)

[Figure 29 - Power vs. RPM 36](#_Toc188569907)

[Figure 30 - Torque vs. RPM 37](#_Toc188569908)

[Figure 31 - Motor Position 37](#_Toc188569909)

[Figure 32 - Wiring Schematics 38](#_Toc188569910)

[Figure 33 - APPS CAD-rendering 39](#_Toc188569911)

[Figure 34 - Data Logger Location 41](#_Toc188569912)

[Figure 35 - Firewall Location 42](#_Toc188569913)

Table of Tables

[Table 1 - High Level Specifications 7](#_Toc188569914)

[Table 2 - Fuse Specifications 9](#_Toc188569915)

[Table 3 - Conductor Specifications 9](#_Toc188569916)

[Table 4 - Connector Specifications 9](#_Toc188569917)

[Table 5 - Shutdown Circuit Loads 11](#_Toc188569918)

[Table 6 - IMD Specifications 12](#_Toc188569919)

[Table 7 - Inertia Switch Specifications 13](#_Toc188569920)

[Table 8 - BSPD Current Sensor Specifications 13](#_Toc188569921)

[Table 9 - BSPD Operation Details 13](#_Toc188569922)

[Table 10 - TSAL Specifications 16](#_Toc188569923)

[Table 11 - Measurement Point Specifications 17](#_Toc188569924)

[Table 12 - TSMP Protection Resistor Specifications 18](#_Toc188569925)

[Table 13 - HVD Specifications 19](#_Toc188569926)

[Table 14 - RTDS Specifications 20](#_Toc188569927)

[Table 15 - Discharge Resistor Specifications 21](#_Toc188569928)

[Table 16 - Discharge Relay Specifications 21](#_Toc188569929)

[Table 17 - Segment Specifications 23](#_Toc188569930)

[Table 18 - Maintenance Plug Specifications 25](#_Toc188569931)

[Table 19 - Cell Specifications 26](#_Toc188569932)

[Table 20 - Precharge Resistor Specifications 27](#_Toc188569933)

[Table 21 - Precharge Relay Specifications 27](#_Toc188569934)

[Table 22 - BMS Setpoints 28](#_Toc188569935)

[Table 23 - BMS Response times 29](#_Toc188569936)

[Table 24 - AIR Specifications 29](#_Toc188569937)

[Table 25 - Charger Specifications 31](#_Toc188569938)

[Table 26 - TSAC Hand Cart Specifications 33](#_Toc188569939)

[Table 27 - Motor Controller Specifications 34](#_Toc188569940)

[Table 28 - Wire Specifications 34](#_Toc188569941)

[Table 29 - Motor Controller Specifications 36](#_Toc188569942)

[Table 30 - Torque Encoder Date 38](#_Toc188569943)

[Table 31 - Firewall Specifications 42](#_Toc188569944)

Abbreviations

AIR – Accumulator Insulation Relay

AMS – Accumulator Monitoring System

APPS – Acceleration Pedal Position Sensor

BMS – Battery Monitoring System

BOTS – Brake-Over-Travel-Switch

BSPD – Brake System Plausibility Device

GLV – Grounded Low Voltage

GLVMP – Ground Low Voltage Measurement Point

HV – High Voltage

IMD – Insulation Monitoring Device

TS – Tractive System

TSAC – Tractive System Accumulator Container

TSAL – Tractive System Active Light

TSMP – Tractive System Measurement Point

# System Overview

Include brief description of vehicle (1 paragraph).

Complete the information in the table below.

|  |  |
| --- | --- |
| Maximum Tractive System Voltage: | 1000VDC |
| Nominal Tractive System Voltage: | 960VDC |
| Grounded Low Voltage System Voltage: | 2.5VDC |
| Number of Accumulator Containers: | 2 |
| Total Accumulator Capacity: | 20kWhr |
| Motor Type: | AC Induction |
| Number of Motors: | Total 4, one per wheel |
| Maximum Combined Motor Power: | 150kW |

Table - High Level Specifications

Insert a system overview block diagram showing major electrical components and system interactions.



Figure - System Block Diagram

# Tractive System Schematics

## Tractive System Schematic (Power Electronics ONLY)

Insert a large (full page) schematic of the HV system. This schematic should focus on the components that are not within the accumulator. Provide boxes and 1st level interfaces, when details will be provided later in this document. Some detail of components within the accumulator may be included for better understanding (ie AIRs).

Figure must include the following:

* Wire Size (AWG or mm2)
* Relative fuse location (end of wire vs middle)
* Fuse rating (Amperage and Voltage)
* Motor controller (1st level interfaces...inputs & outputs)
* Motor
* Inline connectors and interfaces for charging
* TSMP and relative current limiting resistor locations
* Show enclosures as dashed lines

The figure must include the following if not within the accumulator:

* IMD
* DCDC converter if used
* Precharge and Discharge circuit
* Energy Meter
* HVD



Figure - HV System Schematic

## Fusing Diagram

Include a fusing tree diagram like the one shown below.



Figure - Fuse Tree Diagram

### Fuse Specifications

Complete the information in the table below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fuse Location** | **Current Rating** | **Voltage Rating** | **Interrupt Rating** | **Datasheet** |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

Table - Fuse Specifications

### Conductor Specifications

Complete the information in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Conductor Location** | **Size** | **Voltage Rating** | **Ampacity** | **Rating of fuse providing protection** | **Datasheet** |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table - Conductor Specifications

### Connector Specifications

Complete the information in the table below.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Connector Location** | **Ampacity** | **Voltage Rating** | **Includes Interlock** | **Accepted wire gauge** | **Wire gauge connected** | **Datasheet** |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Table - Connector Specifications

# Shutdown Circuit

## Shutdown Circuit Schematic

Insert a large (full page) schematic of the shutdown circuit.

The schematic must include the following:

* All shutdown circuit switches/devices (indicate Normally Open or Closed)
* Safety interlocks associated to connectors or HVD
* BMS connection to shutdown circuit
* BSPD connection to shutdown circuit
* IMD connection to shutdown circuit (include path from output of IMD OKHS to shutdown circuit, additional detail may be provided in second figure)
* BOTS
* Inertia switch
* AIR coils including resistance of coil and voltage rating or economizer detail
* Pre-charge relay coil
* GLV battery
* Fuse(s)
* Wire Size (AWG or mm2)



Figure - Shutdown Circuit Schematic

### Switch Locations

Provide CAD-rendering(s) showing the shutdown circuit parts. Mark the parts in the renderings, if necessary. Include your design intent wire harness routing path.



Figure - Shutdown Circuit Switch Locations

## Wiring

### Shutdown Circuit Current

Complete the information in the table below.

|  |  |
| --- | --- |
| Total Number of AIRs: | 10 |
| Current per AIR: | 0.5A |
| Additional parts consumption within the shutdown circuit: | 2A |
| Total current: | 7A |

Table - Shutdown Circuit Loads

## IMD

### IMD Specifications

Complete the information in the table below.

|  |  |
| --- | --- |
| Make / Model: | Bender IR12345 |
| Supply voltage: | 2VDC |
| Environmental temperature range: | 45..55°C |
| Self-test interval: | every 20 ms |
| High voltage range: | DC 0..10V |
| Set response value: | 30kΩ (500Ω/Volt) |
| Max. operation current: | 500mA |
| Approximate time to shut down at 50% of the response value: | 80s |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - IMD Specifications

### IMD Fault Latching

Include schematic showing how latching circuit for IMD operates. Also include the IMD status indicator in the figure.



Figure - IMD Latch Circuit Schematic

### IMD Location

Describe the location of the IMD.

Describe the location of the IMD indicator.

Describe the location of the reset button or include a CAD rendering or photograph to show its location if one is used.

### IMD Ground Connections

Describe the manner in which the ground connections of the IMD are connected to the vehicle.

## Inertia switch

### Inertia switch information

Complete the information in the table below.

|  |  |
| --- | --- |
| Make / Model: | Acme Sensor Co. ABC123 |
| Switch type: | Push/pull |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Inertia Switch Specifications

### Inertia switch triggering

Provide information on when the sensor will trigger and how the testing method of the sensor.

### Inertia switch mounting

Describe the mounting of the sensor and add a picture of how the sensor is mounted to the vehicle.



Figure - Inertia Switch mounting

## Brake System Plausibility Device

### BSPD Current Sensor

Complete the information in the table below.

|  |  |
| --- | --- |
| Make / Model: | Acme Sensor Co. ABC123 |
| Current input range: | +/- 150A |
| Output range: | 0-50V |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - BSPD Current Sensor Specifications

### BSPD Setpoint

Complete the information in the table below.

|  |  |
| --- | --- |
| Trip Current: | 62A |
| Current sensor output @Trip Current: | 35V |
| Delay time: | 200ms |

Table - BSPD Operation Details

### BSPD Schematic

Include schematic of BSPD. Clearly show current sensor input, brake input and shutdown circuit output. Be sure schematic includes details addressing latching and timing.



Figure - BSPD Schematic

### BSPD Location

Describe the location of the BSPD or include a CAD rendering or photograph to show its location.



Figure - BSPD Component Location

### BSPD Demonstration

Describe the method you will use to demonstrate the BSPD device at competition.

## Battery Management System

### BMS Faults

Describe what faults/conditions will cause the BMS to open the shutdown circuit.

### BMS Fault Latching

Describe the method used to latch the BMS fault, include a schematic if appropriate.

Describe the location of the reset button or include a CAD rendering or photograph to show its location if one is used.

# Safety Systems

## TSAL

### TSAL Specifications

Complete the information in the table below.

|  |  |
| --- | --- |
| Make/Model: | Flashy Light Co. SprBrt12 |
| Color: | Purple |
| Flash Rate: | 18Hz |
| Powered By: | GLV |
| Controlled By: | TS |
| TS Turn On Voltage: | 60 |
| TS Turn Off Voltage: | 58 |

Table - TSAL Specifications

### TSAL Schematic

Include a schematic showing the overall control circuit for the TSAL. The schematic should include all components from HV sense input to light. If team designed PCB is used with TS and GLV circuits provide CAD rendering or photograph showing spacing for TS/GLV separation.



Figure - TSAL Circuit Schematic

### TSAL Voltage Monitoring

Include a schematic showing the control circuits for the TSAL which are responsible of voltage monitoring in both vehicle and accumulator sides.

### TSAL AIRs State Monitoring

Include a schematic showing the control circuits for the TSAL which are responsible of all accumulator relays state detection.

### TSAL Location

Provide CAD-rendering(s) showing the TSAL parts. Mark the parts in the renderings, if necessary.



Figure - TSAL Component Locations

### TSAL Demonstration

How will you proof the correct functionality of the TSAL during Scrutineering?

### TSAL Green Indicator

Describe the TSAL green state indicator when working on the vehicle.

## Measurement Points

### Measurement Point Specifications

Complete the information in the table below.

|  |  |
| --- | --- |
| Make / Model: | Acme Connect Co P88943 |
| Voltage Rating: | 600V |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Measurement Point Specifications

### Measurement Point Location

Provide CAD-rendering(s) showing the measurement points. Mark the parts in the renderings, if necessary.



Figure - Measurement Point Location

### Tractive System Measurement Point Protection

Describe how the backs of the TSMPs are protected from being touched.

Describe how the fronts of the TSMPs are protected from rain entering and how the cover is removed for testing.

### Tractive System Measurement Point Current Limiting Resistor

Complete the information in the table below.

|  |  |
| --- | --- |
| Make / Model: | ResistorsRUs R10K5W |
| Resistance: | 10,000Ω |
| Voltage Rating: | 1000V |
| Power Rating: | 5W |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - TSMP Protection Resistor Specifications

### Tractive System Measurement Point Current Limiting Resistor Location

Provide CAD-rendering(s) showing the measurement point current limiting resistor location. Mark the parts in the renderings, if necessary.



Figure - TSMP Protection Resistor Location

## HVD

### HVD Specifications

Complete the information in the table below.

|  |  |
| --- | --- |
| Make / Model: | Best HVD Company HVD111 |
| Ampacity: | 45A |
| Voltage rating: | 1000V |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - HVD Specifications

If the HVD is not an “off the shelf design” describe how it works and include a CAD rendering.

Which contacts make/break first (high current or interlock)?

### HVD Location

Provide CAD-rendering(s) showing the HVD. Mark the parts in the renderings, if necessary.

Describe the physical distance (cm) from the road surface to the bottom of the HVD.



Figure - HVD Location

### HVD Connections

Describe how the electrical connections are made to the HVD. How are these protected from rain and touch?

## Ready to Drive Sound

### RTDS Device and Control

Describe how the RTDS is controlled (what device controls it). Complete the information in the table below.

|  |  |
| --- | --- |
| Make / Model: | Loud Alerts 12VBzr95 |
| Control Voltage: | 14V |
| SPL at 2m: | 86 dBA |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - RTDS Specifications

### Ready to Drive Mode Demonstration

Describe numbered steps required to put the vehicle into ready to drive mode.

## Discharge Circuit

### Discharge Circuit Concept

Describe your discharge circuit and how it is controlled.

### Discharge Circuit Component Specifications

Complete the information in the tables below.

|  |  |
| --- | --- |
| Make / Model: | ResistorsRUs 500R10W |
| Resistance: | 500Ω |
| Voltage: | 800V |
| Power: | 10W |
| Power @15sec: | 80W |
| Datasheet | [Datasheet](http://www.fsaeonline.com) |

Table - Discharge Resistor Specifications

|  |  |
| --- | --- |
| Make / Model: | RelayCo ABCD876 |
| Contact Current Rating: | 1A |
| Contact Voltage Rating: | 750V |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Discharge Relay Specifications

What is the capacitance of the TS bus (include DCDC converter if part of design)? How long does it take to discharge to <60V?

If semiconductor elements are used include schematics and provide datasheets of the most relevant components.

### Discharge Circuit Location

Describe location or provide CAD-rendering(s) or photographs showing the discharge components. Mark the parts in the renderings, if necessary.



Figure - Discharge Circuit Component Locations

### Discharge Circuit Control

Describe how the discharge relay is controlled.

# Accumulator

## Accumulator Overview

Insert a large image (top or nearly top view) of the complete accumulator assembly without cover.

Figure must include the following:

* Separation walls (both at cells and HV electronics sections)
* >50% attachment points to car chassis
* Cell segments
* HV electronics (at least one PCB mock-up)
* AIRs
* Main fuse
* Maintenance plugs
* Main power connector

(additional images may be needed to provide clear views of all elements)



Figure - Accumulator Overview

## Accumulator container

### Accumulator Enclosure

Provide details of walls materials and thickness. If cooling openings are required provide details of how these openings are protected from dust and water.

### Segments fixations

Describe how the segments are fixed inside the container in all 3 directions. Provide loads paths and calculations of all elements under shear or buckling stress.

### AIRs and fuse fixations

Provide images of how are the AIRs and the main fuse attached to the container.



Figure - AIR and Fuse Detail

### TSAC Holes

Describe all holes in the TCAS and their functionality. Provide images or renders where required.

Show in what direction the holes are pointing when the TSAC is mounted in the car or on the hand cart.

## Segments

### Segment Overview

Insert a large image of the complete segment assembly. Describe segment materials and how design provides a safe environment from dropped tools.

### Segment Specifications

Complete the information in the table below.

|  |  |
| --- | --- |
| # of Segments: | 5 |
| Cells per segment: | 15 |
| Cell configuration in segment: | 5S3P |
| Energy in segment: | 2.8MJ / 0.78 kWh |

Table - Segment Specifications

### Cell Mounting

Describe how cells are mounted in the accumulator container.  Provide CAD rendering or photograph to show mounting mechanism.

In the case of pouch cells describe how the cell tabs are not mechanically loaded. If the cells are hold into place with friction provide calculations and information about the test setup.



Figure - Cell Mounting in Accumulator

### Cell Connections

Describe how the electrical connections are made to the cells (welded/bolted/clamped)?  Define what kind of weld (resistance/laser), what kind bolt (copper w/deforming nut), material of clamp.  If bus bars are used what is the cross-sectional area and ampacity?

Include CAD rendering.



Figure - Cell Connections Detail

### Maintenance Plugs

Describe how maintenance plugs are implemented in between the segments.  If off the shelf components are used provide link to datasheet.

Complete the information in the table below.

|  |  |
| --- | --- |
| Make / Model: | Connector Co.  SQV436 |
| Ampacity: | 180A |
| Voltage: | 750V |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Maintenance Plug Specifications

If custom components are used provide detailed images of them.

Describe how positive locking is provided for maintenance plugs such that they cannot unintentionally come loose.

Describe how maintenance plugs are designed such they cannot be installed or removed incorrectly.



Figure - Maintenance Plug Locations

### Temperature sensors

Provide images showing where the temperature sensors are placed and how they are in direct contact with the negative cell tab. How many sensors are used and which percentage of cells is monitored?



Figure - Temperature Sensor Location

## Cells

### Cell Specifications

Complete the information in the table below.

|  |  |
| --- | --- |
| Cell Make / Model / Style: | Kokam XYZ- pouch, cylindrical, or metal can |
| Cell nominal capacity: | 5.4 Ah |
| Maximum Voltage: | 4.2 V |
| Nominal Voltage: | 3.7V |
| Minimum Voltage:  | 2.8V |
| Maximum output current: | 20C for 10s |
| Maximum continuous output current: | 15C |
| Maximum charging current: | 5C |
| Maximum Cell Temperature (discharging): | 65°C |
| Maximum Cell Temperature (charging): | 55°C |
| Cell chemistry: | LiFePO4 |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Cell Specifications

## Precharge Circuit

### Precharge Circuit concept

Describe your precharge circuit and how it is controlled. What is the bus capacitance? How long will it take to recharge? How does your system determine the end of the precharge process?

### Precharge Circuit Component Specifications

Complete the information in the tables below.

|  |  |
| --- | --- |
| Make / Model: | ResistorsRUs 500R01W |
| Resistance: | 500Ω |
| Voltage: | 650V |
| Power: | 0.1W |
| Power @15sec: | 1W |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Precharge Resistor Specifications

|  |  |
| --- | --- |
| Make / Model: | RelayCo ABCD876 |
| Contact Current Rating: | 1A |
| Contact Voltage Rating: | 750V |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Precharge Relay Specifications

If a constant current precharge is used include schematics and datasheets of the relevant components.

### Precharge Circuit Location

Provide CAD rendering(s) or photographs showing the pre-charge components. Mark the parts in the renderings, if necessary.



Figure - Precharge Circuit Location

Explain how the power sinking elements of the precharge circuit are cooled.

## BMS

### BMS Specifications

Describe the BMS that has been selected. How is galvanic isolation provided between GLV and TS connections? How is isolation provided at maintenance plug boundaries? If student designed provide CAD showing that PCB spacing requirements are met for GLV/TS separation.

### Voltage Monitoring

Provide details of the voltage measurement system (accuracy, acquisition frequency, …).

Describe how and where the voltage sense leads are overcurrent protected (fused). What size are the sense leads? What is their ampacity? If your sense leads are not fused please reason why and how your system detects a malfunction of one of the measurements?

### Temperature Monitoring

Provide details of the temperature measurement system (accuracy, acquisition frequency, …). Give details of the temperature sensors used.

### BMS Limits

Complete the table below.

|  |  |
| --- | --- |
| Max Cell Voltage: | 6.8V |
| Min Cell Voltage: | 4.2V |
| Max Temperature: | 60°C |
| Min Temperature: | -5°C |
| Max Charge Current: | 5A |
| Max Discharge Current: | 3A |

Table - BMS Setpoints

### BMS Response times

Complete the table below.

|  |  |
| --- | --- |
| Time to detect an open wire in cell voltage monitoring and opening of the shutdown circuit: | 2s |
| Time to detect a short to supply voltage in cell voltage monitoring and opening of the shutdown circuit: | 2s |
| Time to detect a short to GND in cell voltage monitoring and opening of the shutdown circuit: | 2s |
| Time to detect an implausibility due to out of range in cell voltage monitoring and opening of the shutdown circuit: | 2s |
| Time to detect failure of digitally transmitted signals in cell voltage monitoring and opening of the shutdown circuit: | 2s |
| Time to detect an open wire in cell temperature monitoring and opening of the shutdown circuit: | 2s |
| Time to detect a short to supply voltage in cell temperature monitoring and opening of the shutdown circuit: | 2s |
| Time to detect a short to GND in cell temperature monitoring and opening of the shutdown circuit: | 2s |
| Time to detect an implausibility due to out of range in cell temperature monitoring and opening of the shutdown circuit: | 2s |
| Time to detect failure of digitally transmitted signals in cell temperature monitoring and opening of the shutdown circuit: | 2s |

Table - BMS Response times

## AIR

### AIR Specifications

Complete the information in the table below.

|  |  |
| --- | --- |
| Make / Model: | RelayCo DaBIG1 |
| Contact Current: | 345A |
| Contact Voltage: | 350V |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - AIR Specifications

## Accumulator Indicator

### Accumulator Indicator Schematic

Provide schematic of accumulator indicator circuit. Give details of the HV supply for the LED and the activation threshold voltage. Provide specifications and links to datasheets for key components.



Figure - Schematic of Accumulator Indicator

### Accumulator Indicator Position

Provide CAD rendering(s) or photographs showing the accumulator indicator on the TSAC assembly.



Figure 24 - Location of Accumulator Indicator

## Charging

### Charger Specifications

Complete the information in the table below.

|  |  |
| --- | --- |
| Make / Model: | ElectronPusher Inc 100V200 |
| Power: | 0.082kW |
| Output Voltage: | 300V |
| Output Current: | 0.273A |
| Input Voltage: | 120V |
| Input Current: | 1A |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Charger Specifications

Provide images of the charger assembly and charging setup as it’ll be used during the events.

### Charging Shutdown Circuit

Insert a schematic of the shutdown circuit while charging. Include all required components for the charging shutdown circuit.



Figure 5 - Charging Shutdown Circuit Schematic

### Charging TS Circuit

Insert a schematic of the TS connections when charging, show the energy path and how charging is controlled/interrupted.



Figure 6 - Charging TS Schematic

### Charger Control

Describe how the BMS can control the charger, in particular how it can stop the charger.

### Charger Demonstration

Describe numbered steps you would use to demonstrate the safe operation of charging, include how to connect, and how to disconnect. Include any safe use practices, as well as what to look for proper operation vs. a faulted condition.

## External Data Connection

Describe external data connections with the charger assembly/accumulator that will be used to get real time data, in particular on systems isolation.

## Tractive System Accumulator Container Hand Cart

### TSAC Hand Cart Specifications

Complete the information in the table below.

|  |  |
| --- | --- |
| Width: | 500mm |
| Length: | 1000mm |
| Height: | 1000mmm |
| Number of wheels: | 18 |

Table - TSAC Hand Cart Specifications

Provide a description and images of the TSAC Hand Cart.



Figure 7 - TSAC Hand Cart

### TSAC Hand Cart Braking System

Describe the construction of the TSAC Hand Cart Braking System and add pictures where required.

### TSAC Hand Cart Firewall

Describe the construction of the TSAC Hand Cart Firewall and add pictures where required.

# Motor controller

## Motor controller 1

### Description, type, operation parameters

Describe important functions, provide table with main parameters like resulting voltages->minimum, maximum, nominal, currents etc.

Fill out the following table:

|  |  |
| --- | --- |
| Motor controller type: | ABC Controller |
| Maximum continous power: | 60kW |
| Maximum peak power: | 75kW for 10s |
| Maximum Input voltage: | 600VDC |
| Output voltage: | 250VAC |
| Maximum continuous output current: | 100A |
| Maximum peak current: | 200A for 5s |
| Control method: | PWM, analog signal... |
| Cooling method: | Air, water, oil... |
| Auxiliary supply voltage: | 24VDC |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Motor Controller Specifications

### Wiring, cables, current calculations, connectors

Describe the wiring, show schematics, provide calculations for currents and voltages and show data regarding the cables and connectors used.

Additionally fill out table:

|  |  |
| --- | --- |
| Wire type: | Company A, 0.205 mm² |
| Current rating: | 150A |
| Maximum operating voltage: | 800V |
| Temperature rating: | 150 °C |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Wire Specifications

### Position in car

Provide CAD-renderings showing the relevant parts. Mark the parts in the rendering, if necessary.



Figure 8 - Motor Controller Position

## Motor controller 2

Is a second motor controller used?

If this controller is of a different type, add the same subsections, tables and figures for the second type as above.

If identical parts are used, just refer to the corresponding sections.

# Motors

## Motor 1

### Description, type, operating parameters

Describe the motor used, provide table with main parameters like resulting voltages->minimum, maximum, nominal, currents, resulting motor power, use figures to show important characteristics. Describe the casing and if the casing rotates the finger guards used.

Additionally fill out table:

|  |  |
| --- | --- |
| Motor Manufacturer and Type: | ABC Motor |
| Motor principle: | Asynchronous, permanently excitated |
| Maximum continuous power: | 25kW |
| Peak power: | 70kW for 5s |
| Input voltage: | 250VAC |
| Nominal current: | 50A |
| Peak current: | 70A |
| Maximum torque: | 60Nm |
| Nominal torque: | 20Nm |
| Cooling method: | Water, oil, air,... |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Motor Controller Specifications

Give a plot of power vs. RPM including a line for nominal and maximum power.



Figure 9 - Power vs. RPM

Give a plot of torque vs. RPM including a line for nominal and maximum torque.



Figure - Torque vs. RPM

### Wiring, cables, current calculations, connectors

Describe the wiring, show schematics, provide calculations for currents and voltages and show data regarding the cables and connectors used.

### Position in car

Provide CAD-renderings showing all relevant parts. Mark the parts in the rendering, if necessary and clearly identify the structure used to protect all relevant parts.



Figure 1 - Motor Position

## Motor 2

Is a second (or more) motor(s) used?

If this motor is of a different type, add the same subsections, tables and figures for the second type as above.

If identical parts are used, just refer to the corresponding section

# Acceleration Pedal Positions Sensors

## Description/additional circuitry

Describe the type of the APPS used, provide tables with main operation parameters, and describe additional circuitry used to check or manipulate the signal going to the motor controller. Describe how the system reacts if an implausibility or error (eg. short circuit or open circuit or equivalent) is detected.

|  |  |
| --- | --- |
| APPS manufacturer and type: | ABC Encoder |
| APPS principle: | potentiometer |
| Supply voltage: | 5V |
| Maximum supply current: | 20mA |
| Operating temperature: | -20..180 °C |
| Used output: | 0-5V |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

Table - Torque Encoder Date

## Wiring

Describe the wiring, show schematics, show data regarding the cables and connectors used.



Figure 2 - Wiring Schematics

## Position in car/mechanical fastening/mechanical connection

Provide CAD-renderings showing all relevant parts and discuss the mechanical connection of the sensors to the pedal assembly. Mark the parts in the rendering, if necessary.



Figure 3 - APPS CAD-rendering

# Other Items

## LV part 1

Describe those parts here which interfere or influence the tractive system, for example a controlling unit that measures wheel speeds and steering angle and calculates a target torque for each motor or a DC/DC-Converter providing power for the LV-system from the HV-system, etc.

### Description

Describe the parts used and their circuitry, and provide main operation parameters, use tables or figures, etc.

### Wiring, cables,

Describe the wiring, show schematics, etc.

### Position in car

Provide CAD-renderings showing the relevant parts. Mark the parts in the rendering, if necessary.

## LV part 2

Section reserved for more LV parts which interfere or influence the tractive system. If such components are present make this section the same as section 9.1. Else remove this section. Add more sections for other LV parts when required.

## Additional System Critical Signals (SCS)

Add an overview of System Critical Signals handling for components that are not listed before. Provide details for both analog and digital signals. Add details of which systems are enabled when the vehicle is in safe state.

## Data Logger

Currently the FSG rules specify two sections for the Data Logger. At FSN we are interested in the Data Logger of section EV 4.6 for measuring the TS Voltage and TS Current. More information on the Data Logger used during FSN will be published on the website in due time.

### Data Logger Location

Provide CAD rendering(s) or photographs showing the Data Logger location and the download connector location. Mark the parts in the renderings, if necessary.



Figure 4 - Data Logger Location

### Data Logger GLV Supply

Describe how the Data Logger GLV power is supplied.

### Data Logger TS+ Sense

Describe how the TS Voltage is sensed by Data Logger. Include fusing, wire gage, terminals used and add figures where required.

## Firewall

### Firewall Layer Specifications

Complete the information in the table below.

|  |  |
| --- | --- |
| Aluminum layer thickness: | 0.2mm |
| Insulating layer thickness: | 2mm |
| Insulating Material Make / Model: | Conductive Co. FLDPRDCT |
| Insulating Material Datasheet: | [Datasheet](http://www.fsaeonline.com) |
| Insulating layer side: | Driver |

Table - Firewall Specifications

### Firewall Grounding

Provide details of how firewall’s detachable parts grounding is ensured (if any).

### Firewall Location

Provide CAD rendering(s) or photographs showing the firewall components. Mark the parts in the renderings, if necessary.



Figure 5 - Firewall Location

## Grounding

### TS Enclosure Grounding

Describe how all TS enclosures will be grounded to meet the required grounding regulations.

### Composite Grounding

Describe how any composites will be grounded to meet the required grounding regulations.

### Suspension & Wheel Assembly Grounding

Describe how parts near the wheel motors (if any) will be grounded.

## Other Components

Add additional sections here to discuss other unique aspects of your design that you feel are appropriate for the ESF. For example, DCDC converters, details of team designed motor controller or battery chargers, etc.

# Appendix

## SDS (MSDS) of accumulator cell

Insert SDS for accumulator cells here.