**Coversheet**

**The Coversheet must contain the following:**

* **Heading “Electrical System Form FSN 2022”**
* **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.
5. If you are unsure with respect to feedback of the reviewer, do not hesitate to ask the Lead E-scruti via E-mail
6. Parts of the ESF which are changed because of reviewer’s feedback must be marked in red.
7. Following these guidelines will guarantee a swift review process.

Table of Contents

[1 System Overview 7](#_Toc510478035)

[2 Tractive System Schematics 7](#_Toc510478036)

[2.1 Tractive System Schematic (Power Electronics ONLY) 7](#_Toc510478037)

[2.2 Fusing Diagram 8](#_Toc510478038)

[3 Shutdown Circuit 9](#_Toc510478039)

[3.1 Shutdown Circuit Schematic 9](#_Toc510478040)

[3.2 Wiring 10](#_Toc510478041)

[3.3 IMD 10](#_Toc510478042)

[3.4 Brake System Plausibility Device 11](#_Toc510478043)

[3.5 Battery Management System 12](#_Toc510478044)

[4 Safety Systems 13](#_Toc510478045)

[4.1 TSAL 13](#_Toc510478046)

[4.2 Measurement Points 14](#_Toc510478047)

[4.3 HVD 15](#_Toc510478048)

[4.4 Ready to Drive Sound 16](#_Toc510478049)

[4.5 Discharge Circuit 16](#_Toc510478050)

[5 Accumulator 17](#_Toc510478051)

[5.1 Accumulator Schematic 17](#_Toc510478052)

[5.2 Cells 18](#_Toc510478053)

[5.3 Segments 20](#_Toc510478054)

[5.4 Precharge Circuit 21](#_Toc510478055)

[5.5 BMS 22](#_Toc510478056)

[5.6 AIR 23](#_Toc510478057)

[5.7 Accumulator Indicator 23](#_Toc510478058)

[5.8 Mechanical 24](#_Toc510478059)

[5.9 Charging 24](#_Toc510478060)

[6 Motor controller 26](#_Toc510478061)

[6.1 Motor controller 1 26](#_Toc510478062)

[6.2 Motor controller 2 27](#_Toc510478063)

[7 Motors 28](#_Toc510478064)

[7.1 Motor 1 28](#_Toc510478065)

[7.2 Motor 2 29](#_Toc510478066)

[8 Torque encoder 30](#_Toc510478067)

[8.1 Description/additional circuitry 30](#_Toc510478068)

[8.2 Wiring 30](#_Toc510478069)

[8.3 Position in car/mechanical fastening/mechanical connection 30](#_Toc510478070)

[9 Other Items 30](#_Toc510478071)

[9.1 Energy Meter 30](#_Toc510478072)

[9.2 Firewall 31](#_Toc510478073)

[9.3 Grounding 32](#_Toc510478074)

[9.4 Other Components 32](#_Toc510478075)

[10 Appendix 32](#_Toc510478076)

[10.1 SDS (MSDS) of accumulator cell 32](#_Toc510478077)

Table of Figures

[Figure 1‑1 - System Block Diagram 7](#_Toc495303543)

[Figure 2‑1 - HV System Schematic 8](#_Toc495303544)

[Figure 3‑1 - Shutdown Circuit Schematic 10](#_Toc495303545)

[Figure 3‑2 - Shutdown Circuit Switch Locations 10](#_Toc495303546)

[Figure 3‑3 - IMD Latch Circuit Schematic 11](#_Toc495303547)

[Figure 3‑4 - BSPD Schematic 12](#_Toc495303548)

[Figure 3‑5 - BSPD Component Location 13](#_Toc495303549)

[Figure 4‑1 - TSAL Circuit Schematic 14](#_Toc495303550)

[Figure 4‑3 - TSAL Component Locations 14](#_Toc495303551)

[Figure 4‑4 - Measurement Point Location 15](#_Toc495303552)

[Figure 4‑5 - TSMP Protection Resistor Location 16](#_Toc495303553)

[Figure 4‑6 - HVD Location 17](#_Toc495303554)

[Figure 4‑7 - Discharge Circuit Component Locations 18](#_Toc495303555)

[Figure 5‑1 - Accumulator Schematic 20](#_Toc495303556)

[Figure 5‑1 - Cell Connection Detail 21](#_Toc495303557)

[Figure 5‑1 - Cell Mounting in Accumulator 22](#_Toc495303558)

[Figure 5‑2 - Maintenance Plug Locations 23](#_Toc495303559)

[Figure 5‑3 - Precharge Circuit Location 24](#_Toc495303560)

[Figure 5‑4 - Location of Temperature Sensors 25](#_Toc495303561)

[Figure 5‑5 - BMS Location 26](#_Toc495303562)

[Figure 5‑6 - Schematic of Accumulator Indication 26](#_Toc495303563)

[Figure 5‑7 - AIR and Fuse Separation 27](#_Toc495303564)

[Figure 5‑8 - Chrarging Shutdown Circuit Schematic 28](#_Toc495303565)

[Figure 5‑9 - Charging TS Schematic 28](#_Toc495303566)

[Figure 6‑1 - Toque Control Signal Path 29](#_Toc495303567)

[Figure 7‑1 - Energy Meter Location 29](#_Toc495303568)

[Figure 7‑2 - Firewall Location 30](#_Toc495303569)

Table of Tables

Table 1‑1 - High Level Specifications 7

Table 2‑1- Fuse Tree Diagram 8

Table 2‑2 - Fuse Specifications 9

Table 2‑3 - Conductor Specifications 9

Table 2‑4- Connector Specifications 9

Table 3‑2 - Shutdown Circuit Loads 10

Table 3‑5 - IMD Specifications 11

Table 3‑6 - BSPD Current Sensor Specifications 12

Table 3‑7 - BSPD Operation Details 12

Table 4‑1 - TSAL Specifications 13

Table 4‑2 - Measurement Point Specifications 14

Table 4‑3 - TSMP Protection Resistor Specifications 15

Table 4‑4 - HVD Specifications 16

Table 4‑5 - RTDS Specifications 17

Table 4‑6 - Discharge Resistor Specifications 18

Table 4‑7 - Discharge Relay Specifications 18

Table 5‑1 - Cell Specifications 21

Table 5‑2 - Segment Specifications 22

Table 5‑3 - Maintenance Plug Connector Specification 22

Table 5‑4 - Precharge Resistor Specifications 23

Table 5‑5 - Precharge Relay Specifications 23

Table 5‑6 - Temperature Sensor Specifications 24

Table 5‑7 - BMS Setpoints 25

Table 5‑8- AIR Specifications 26

Table 5‑9 - Charger Specifications 27

Table 7‑1 - Firewall Specifications 30

Abbreviations

AIR – Accumulator Insulation Relay

AMS- Accumulator Monitoring System

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

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 1‑1 - High Level Specifications

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

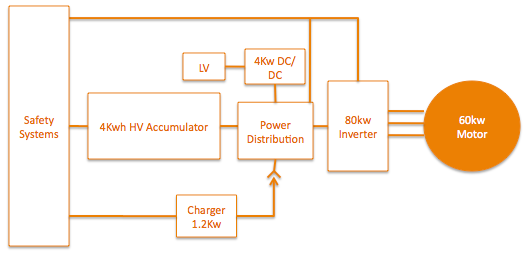


Figure 1‑1 - System Block Diagram

# 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 2‑1 - HV System Schematic

## Fusing Diagram

Include a fusing tree diagram like the one shown below.



Table 2‑1- Fuse Tree Diagram

### Fuse Specifications

Complete the information in the table below.

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

Table 2‑2 - Fuse Specifications

### Conductor Specifications

Complete the information in the table below.

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

Table 2‑3 - Conductor Specifications

### Connector Specifications

Complete the information in the table below.

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

Table 2‑4- 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 3‑1 - 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 3‑2 - 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 3‑1 - 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 3‑2 - IMD Specifications

### IMD Fault Latching

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



Figure 3‑3 - 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.

## 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 3‑3 - 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 3‑4 - 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 3‑4 - BSPD Schematic

### BSPD Location

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



Figure 3‑5 - 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.

# 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 4‑1 - TSAL Specifications

### TSAL Schematic

Include a schematic showing the 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 4‑1 - TSAL Circuit Schematic

### TSAL Location

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



Figure 4‑2 - TSAL Component Locations

### TSAL Demonstration

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

## 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 4‑2 - Measurement Point Specifications

### Measurement Point Location

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



Figure 4‑3 - Measurement Point Location

### 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.

### TSMP Protection 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 4‑3 - TSMP Protection Resistor Specifications

### TSMP Protection Resistor Location

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



Figure 4‑4 - 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 4‑4 - 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 4‑5 - 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 4‑5 - 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 4‑6 - Discharge Resistor Specifications

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

Table 4‑7 - 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 4‑6 - Discharge Circuit Component Locations

### Discharge Circuit Control

Describe how the discharge relay is controlled.

# Accumulator

## Accumulator Schematic

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)

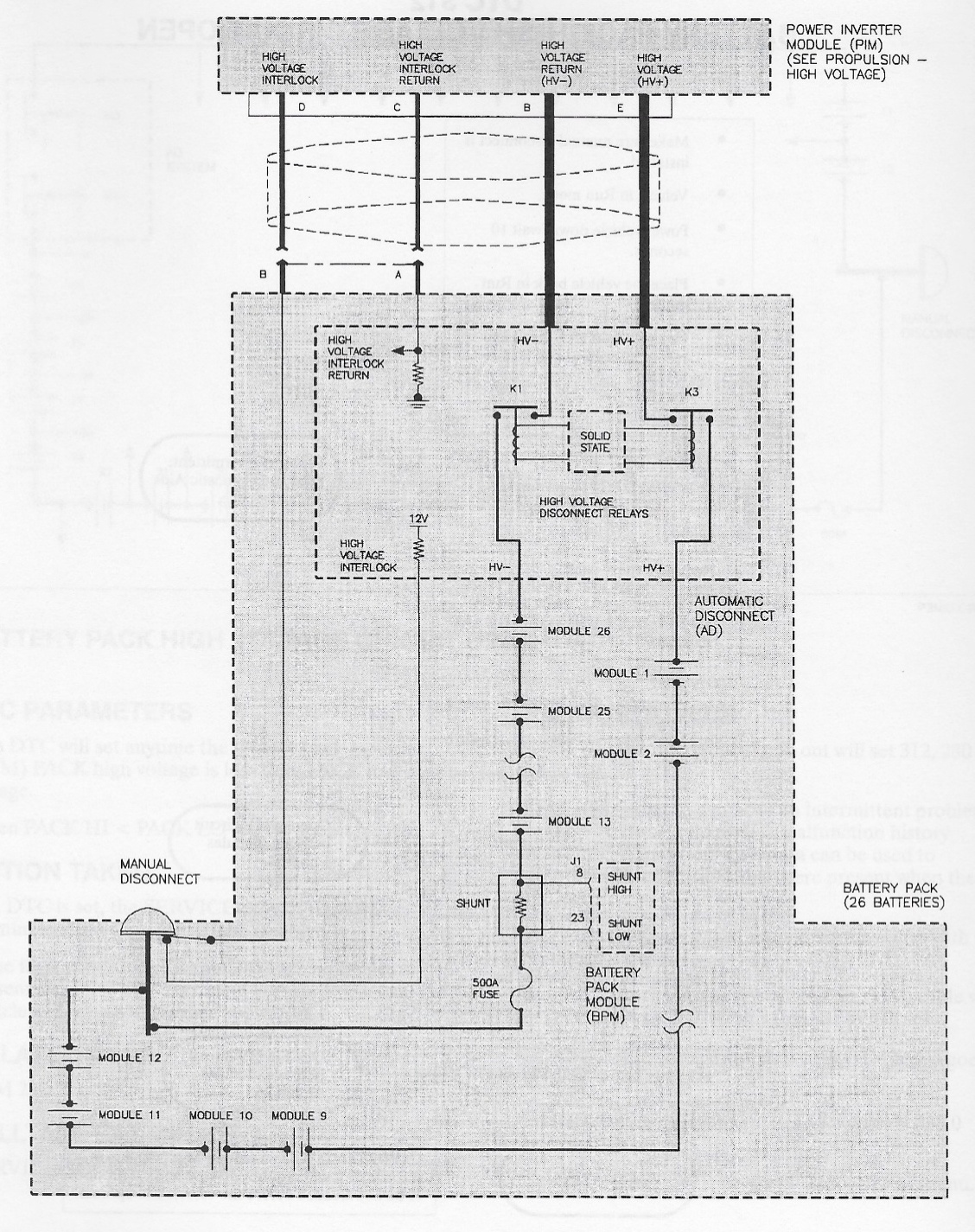


Figure 5‑1 - Accumulator Schematic

## Accumulator container

### Accumulator Enclosure

Provide details of walls materials and thickness. If cooling openings are required provide details of how thetse 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 5‑2 - Cell Connection Detail

## 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

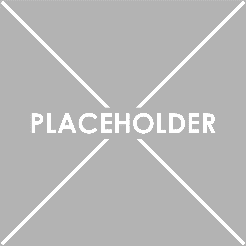
Complete the information in the table below.

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

Table 5‑2 - Segment Specifications

### Cell Mounting

Describe how cells are mounted in the accumulator container.  Provide CAD rendering or photograph to show mounting mechanism. Provide details on how cells are retained without compromising insulation and supporting isolation integrity.

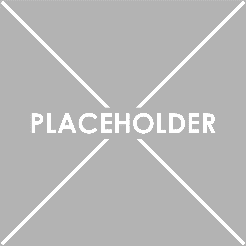


*Figure 5-3 - Cell Mounting in Accumulator*

### 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 5-2 - Cell Connection 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.

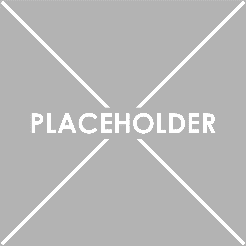
|  |  |
| --- | --- |
| Make / Model: | Connector Co.  SQV436 |
| Ampacity: | 180A |
| Voltage: | 750V |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |

*Table 5-3 - Maintenance Plug Connector Specification*

If custom component 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 5-4 - Maintenance Plug Locations*

### Temperature sensors

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

Background pattern

Description automatically generated with low confidence

*Figure 5-4 - Maintenance Plug Locations*

## 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 5-1 - 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 5‑4 - Precharge Resistor Specifications

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

Table 5‑5 - 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 5‑5 - 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 |

Table 5‑7 - BMS Setpoints

## 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 5‑8- 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 5‑8 - Schematic of Accumulator Indication

## 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 5‑9 - Charger Specifications

Provide images of the charger assembly and charging setup as it’ll be used during the events (include both accumulator handcart and charger assembly if they are not integrated).

### Charging Shutdown Circuit

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



Figure 5‑10 - 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 5‑11 - 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.

# 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 |

Table 5.1 General motor controller data

### 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 |

### Position in car

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

## Motor controller 2

…

If identical parts are used, just refer to the corresponding sections, don’t copy and paste.

# 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,... |

Table 6.1 General motor data

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

give a plot of torque vs rpm including a line for nominal and maximum torque

### 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.

## Motor 2

…

If identical parts are used, just refer to the corresponding sections, don’t copy and paste.

# Torque encoder

## Description/additional circuitry

Describe the type of the torque encoder(s) 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.

|  |  |
| --- | --- |
| Torque encoder manufacturer and type: | ABC Encoder |
| Torque encoder principle: | potentiometer |
| Supply voltage: | 5V |
| Maximum supply current: | 20mA |
| Operating temperature: | -20..180 °C |
| Used output: | 0-5V |

Table 7.1 Torque encoder data

## Wiring

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

## 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.

# 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

## Energy Meter

### Energy Meter Location

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



Figure 7‑1 - Energy Meter Location

### Energy Meter GLV Supply

Describe how the Energy meter GLV power is supplied.

### Energy Meter HV Sense

Describe how the Accumulator Voltage is sensed by Energy meter. Include fusing, wire gage, terminals used.

## 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 7‑1 - Firewall Specifications

### Firewall Location

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



Figure 7‑2 - Firewall Location

## Grounding

### Composite Grounding

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

## 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.