**Coversheet**

**The Coversheet must contain the following:**

* **Heading “Electrical System Form FST 2021”**
* **University and Team Name**
* **Car number**

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

**Requirements (delete this section after you have read and understood it):**

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.

Remove instructions (orange) from document as you complete the sections.

Provide hyperlinks to all datasheets.

If you are unsure with respect to feedback of the reviewer, do not hesitate to ask through https://formula-student-taiwan.web.app/

Parts of the ESF which are changed because of reviewer’s feedback must be marked in red.

Following these guidelines will guarantee a swift review process.

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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

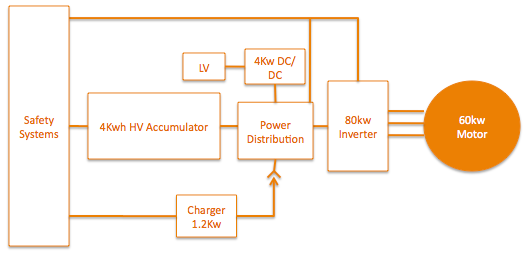


Figure 1‑1 - System Block Diagram

# 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** | **Temperature Rating** | **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** | **Datasheet** |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

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
* Precharge 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.

### IMD Demonstration

Describe numbered steps of how to demonstrate that the IMD can detect a fault at competition.

## 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.

### BMS Demonstration

Describe numbered steps of how you could demonstrate proper operation of the BMS at competition

# 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

## 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

### TSMP Demonstration

Describe numbered steps you would take to provide measurements of: Discharge Resistance value, Current Limit Resistor values, TS voltage. (veh off), and TS voltage (veh on).

Include any safety precautions.

## 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?

### HVD Demonstration

Describe the method you would use to install and remove the HVD at competition. Include any safe handling instructions ex. Not to be installed while manually pushing vehicle. Describe if method of removal allows for the use of High Voltage PPE. Include any details regarding dust covers, dummy plugs, or special handling of HVD when not installed.

## 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 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?

### 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.

### Discharge Circuit Demonstration

Describe numbered steps you would use to demonstrate that TS voltage has been discharged to <60vdc.

# Accumulator

## Accumulator Schematic

Insert a large (full page) schematic of the accumulator HV system.

Figure must include the following:

* Maintenance plugs
* Main traction loop wires (include size and details of shielding & termination)
* Details of how cells are interconnected (can be done in a secondary detail view)
* Fuse (include relative location, current and voltage rating)
* Connectors (include amperage and voltage rating...also show any additional pins for interlocks)

The figure must include the following if within the accumulator

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

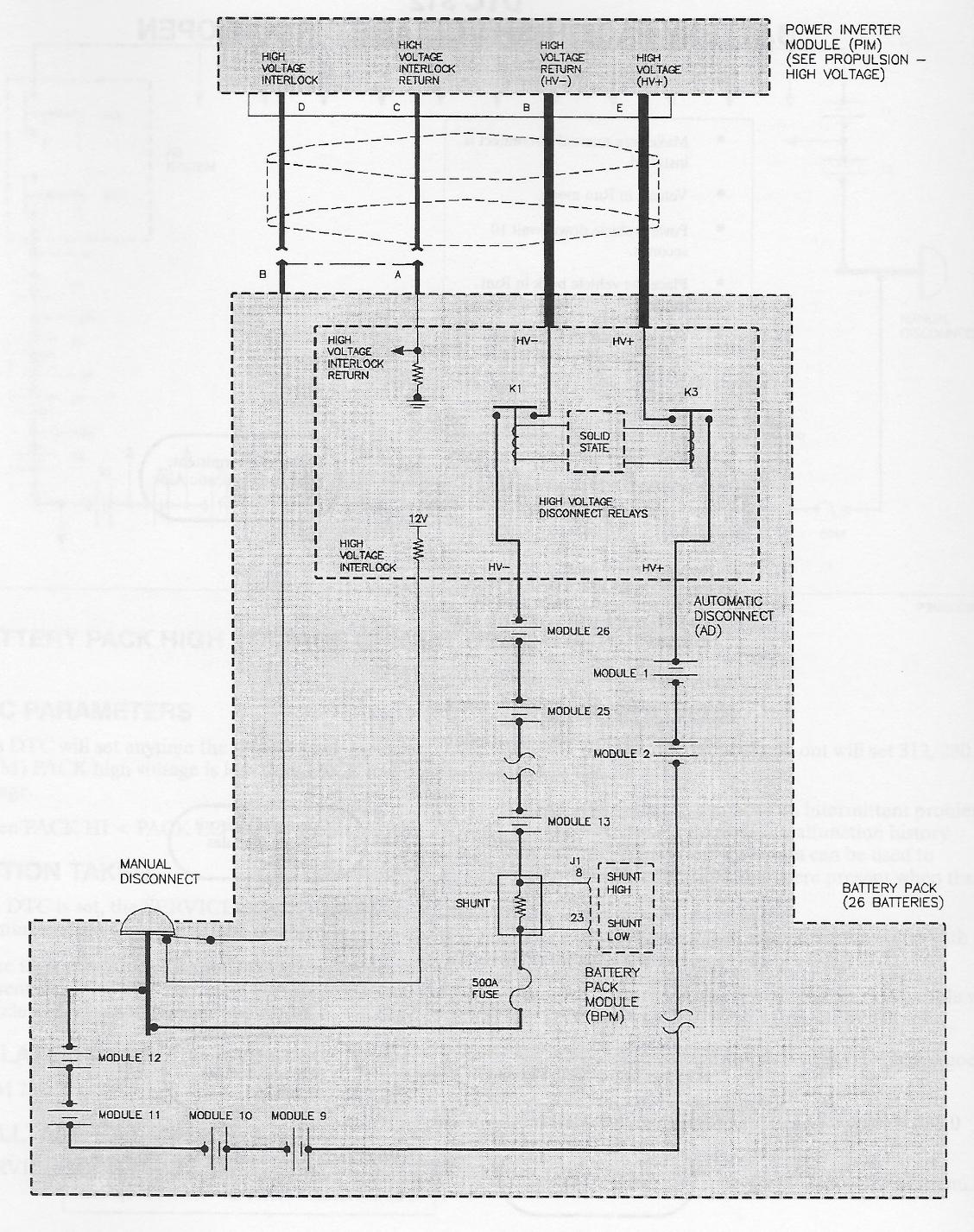


Figure 5‑1 - Accumulator Schematic

## 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 |

Table 5‑1 - Cell Specifications

### Cell Electrical Configuration

Describe how the cells are connected electrically. Series first vs parallel first, groups of parallel cells in series, etc.

### 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

### Parallel Cell Overcurrent Protection

Describe how EV.8.1.5 and EV.8.1.6 (if applicable) are met. Note that EV.8.1.5 requires per cell overcurrent protection if cells are connected in parallel. This can be done with fuses or fusible links. If fusible links are used, then EV.8.1.6 applies. If team designed fusible links are used then provide testing data and ampacity rating (calculated and measured).

### 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

## Segments

### 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

### Segment Physical Isolation

Describe how the segments are physically isolated from one another, and how design provides a safe environment from dropped tools.

### 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

Provide CAD rendering or photograph to show location and implementation of maintenance plugs.



Figure 5‑4 - Maintenance Plug Locations

### Maintenance Plug Positive Locking

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

### Maintenance Plug Unique Configuration

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

### Maintenance Plug Demonstration

Describe numbered steps you would use to demonstrate the removal/installation of maintenance plugs while wearing High Voltage PPE. What PPE is required?

## Precharge Circuit

### 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

### Precharge Circuit Location

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



Figure 5‑5 - Precharge Circuit Location

### Precharge Circuit Controls

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

## 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.

### Temperature Sensors

Complete the information in the table below.

|  |  |
| --- | --- |
| Make / Model: | ColdOrHot Inc CTC723A |
| Accuracy of sensor: | 10°C |
| Datasheet: | [Datasheet](http://www.fsaeonline.com) |
| # of sensors: | 20 |
| % of cells sensed: | 50% |

Table 5‑6 - Temperature Sensor Specifications

### Temperature Sensor Location

Describe how temp sensors meet the direct contact requirement. Provide CAD rendering(s) or photographs showing the temp sensor. Mark the parts in the renderings, if necessary.



Figure 5‑6 - Location of Temperature Sensors

### BMS Voltage Sense Leads

Describe how voltage sense leads are attached to the cells. Provide CAD rendering or photograph if necessary.

### BMS Voltage Sense Lead Overcurrent Protection

Describe how and where the voltage sense leads are overcurrent protected (fused). What size are the sense leads? What is their ampacity?

### 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

### BMS Location

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



Figure 5‑7 - BMS Location

## 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. Provide specifications and links to datasheets for key components.



Figure 5‑8 - Schematic of Accumulator Indication

## Mechanical

### Accumulator Enclosure

Describe construction of accumulator container. Describe the insulating layer between segments and container if container is conductive, include covers or any removable parts.

### AIR and Fuse Separation

Describe how the fuse and AIRs are separated from the cells and provide a CAD-rendering or photograph to illustrate.



Figure 5‑9 - AIR and Fuse Separation

## 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

### Charging Shutdown Circuit

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



Figure 5‑10 - Chrarging 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 TS Connection Interlock

Describe how the charging connectors are interlocked such that neither of them becomes energized until properly connected.

### 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

## Controls Architecture/Torque Security

Provide figure showing path of the torque signal from APPS to motor controller. Describe the rationality checks performed in each controller and how signal integrity is ensured for each link of the torque signal.



Figure 6‑1 - Toque Control Signal Path

## Galvanic Isolation

Describe how galvanic isolation is provided between GLV control signals and TS connections of motor controller.

# Other Items

## 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.