Formula Imperial
ESF 2

INTRODUCTION

The goal of the ESF is to ensure that vehicles are as safe as possible, and that they comply with the Formula-Imperial completion rules. The ESF is divided seven main sections:

1 – Overview
2 – Cables, Fusing& Grounding
3 – Isolation & Insulation
4 – Electric Tractive System
5– Accumulator System
6 – Safety Controls and Indicators
7 – GLV System

The *Cables and Fusing* and *Insulation and Isolation* sections are at the beginning of the ESF as these are the areas where teams most often have trouble in complying with FI rules.

A clear, concise ESF will help you to build a better car. It will also help you to pass tech testing as most common tech problems can be addressed before the car reaches the track.

IMPORTANT INSTRUCTIONS AND REQUIREMENTS

1. Every part of this ESF must be filled with content. If a section is not relevant to your vehicle, mark it as “N/A” and describe briefly why not.
2. Please leave the written instructions in place and add your responses below them.
3. All figures and tables must be included. An ESF with incomplete tables or figures will be rejected.
4. Note that many fields ask for information that was submitted in your ESF-1. This information must be reentered – in some cases will be different than what was entered in ESF-1, which is OK.
5. When completed, this document must be converted to a pdf and submitted to: formulaimperial@imperialsociety.inhttp://formula-hybrid.com/uploads/
6. Please submit any questions, corrections and suggestions for improvement to: formulaimperial@imperialsociety.in

REVIEW PROCESS

Once submitted, your ESF will be reviewed by at least two FI reviewers.

When you submit a revised ESF, please indicate the REVISION DATE AND LETTER (starting with Letter A) and which sections have been updated in the following table:

REVISION DATE:	
REVISION: (A, B, C, etc.)	
Section	Revised (Yes / No)
1 – Overview	No
2 – Cables and Fusing	No
3 – Insulation and Isolation	No
4 – Electric Tractive System	No
5 – Accumulator System	No
6 – GLV System	No
7 – Safety Controls and Indicators	No
8 – Appendices / Datasheets	No

TITLE PAGE

University Name:	Indian Institute of Technology Kanpur
Team Name:	IITK Motorsports
Car Number:	FI-24-24

<u>Main Team Contact for ESF related questions:</u>

Name: Rishi Baghel

e-mail: rishibaghe2004@gmail.com

Table of Contents

I List of Figures

II List of Tables

III List of Abbreviations

AIR	Accumulator Isolation Relay
AMS	Accumulator Management System
FI Rules	Formula Hybrid Rule
GLV	Grounded Low-Voltage
IMD	Insulation Monitoring Device
SMD	Segment Maintenance Disconnect
TS	Tractive System
TSEL	Tractive System Energized Light
TSMP	Tractive System Measurement Point
TSV	Tractive System Voltage
TSVP	Tractive System Voltage Present
SSOK	Safety Systems OK Lamp

Section 1 **Vehicle Overview**

Person primarily responsible for this section:

Name: Rishi Baghel

e-mail: rishibaghe2004@gmail.com

Check the appropriate boxes:

Vehicle is

- ✓ New (built on an entirely new frame)
- ☐ New, but built on a pre-existing frame (FSAE, FS, FI-HIP, FI electric-only, etc.)
- ☐ Updated from a previous year vehicle

Architecture

- ☐ Hybrid
- ✓ Electric-only

Drive

- ☐ Front wheel
- ✓ Rear wheel
- ☐ All-wheel

Regenerative braking

- ☐ Front wheels
- ☐ Rear wheels
- ☐ All wheels
- ✓ None

NARRATIVE OVERVIEW

Provide a brief, concise description of the vehicles main electrical systems including tractive system, accumulator, hybrid type (series or parallel) and method of mechanical coupling to wheels. Describe any innovative or unusual aspects of the design.

Include the following figures:

- **Figure 1** – an electrical system block diagram showing all major parts associated with the tractive-system. (Not detailed wiring).
- **Figure 2** – Drawings or photographs showing the vehicle from the front, top, and side.
- **Figure 3** – A wiring diagram superimposed on a top view of the vehicle showing the locations of all major TS components and the routing of TS wiring.
- **Figure 4 --** Include a complete TSV wiring schematic showing connections between all TS components. This should include accumulator cells, AIRs, SMDs, motor controller, motor, pre-charge and discharge circuits, AMD, IMD, charging port and any other TS connections. **NOTE:** Figure 4 is the most important diagram in the ESF

Our accumulator uses LiCoO2 pouch cells in 24S2P configuration, with a maximum voltage of 96V and maximum output current of 200A. We use a 96V Tsuyo PMSM along with their proprietary motor controller. The motor is coupled to the rear axle using chain sprocket and limited slip differential.

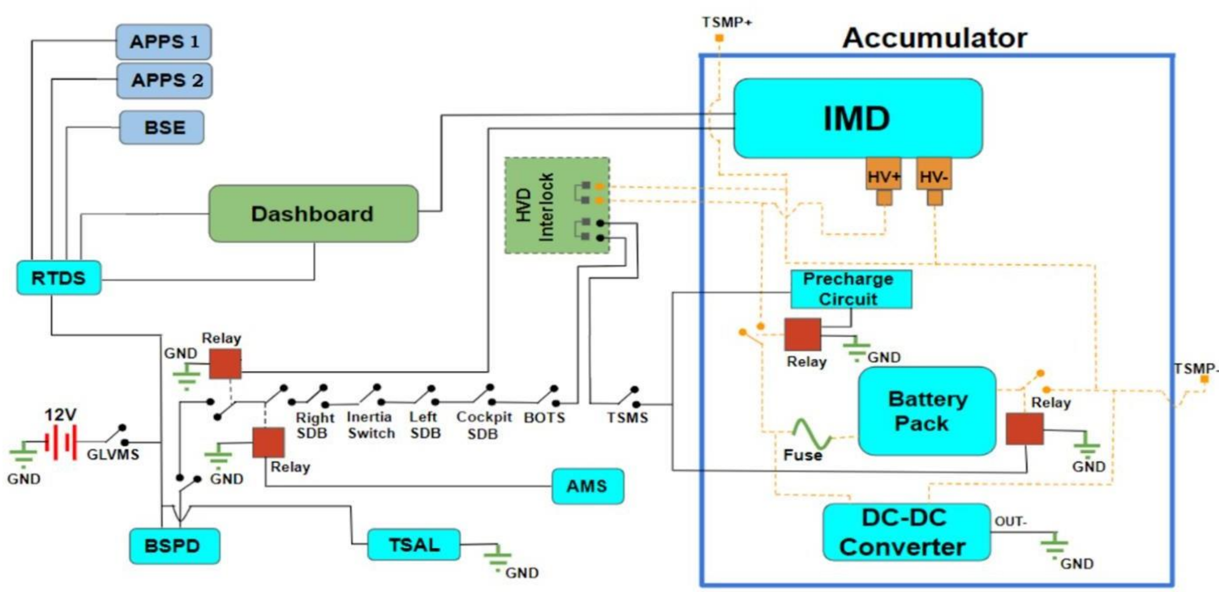
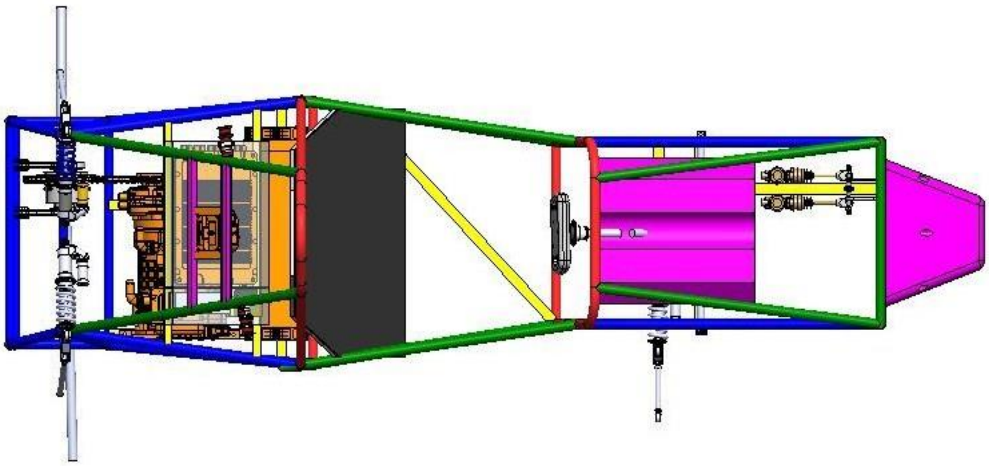
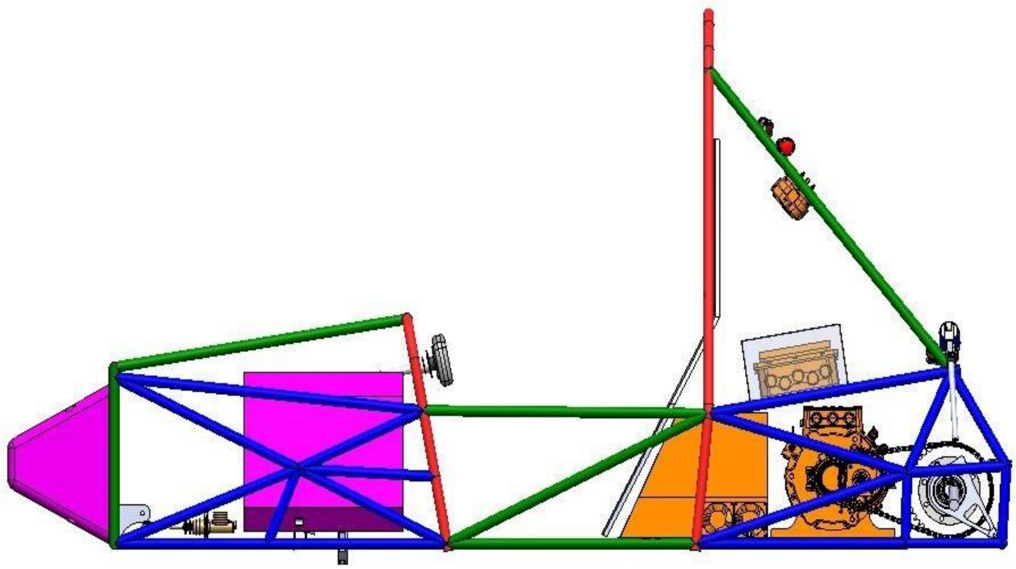


Figure 1- Electrical System Block Diagram



TOP VIEW



SIDE VIEW

FRONT VIEW

Figure 2 - Drawings showing the vehicle from the front, top, and side

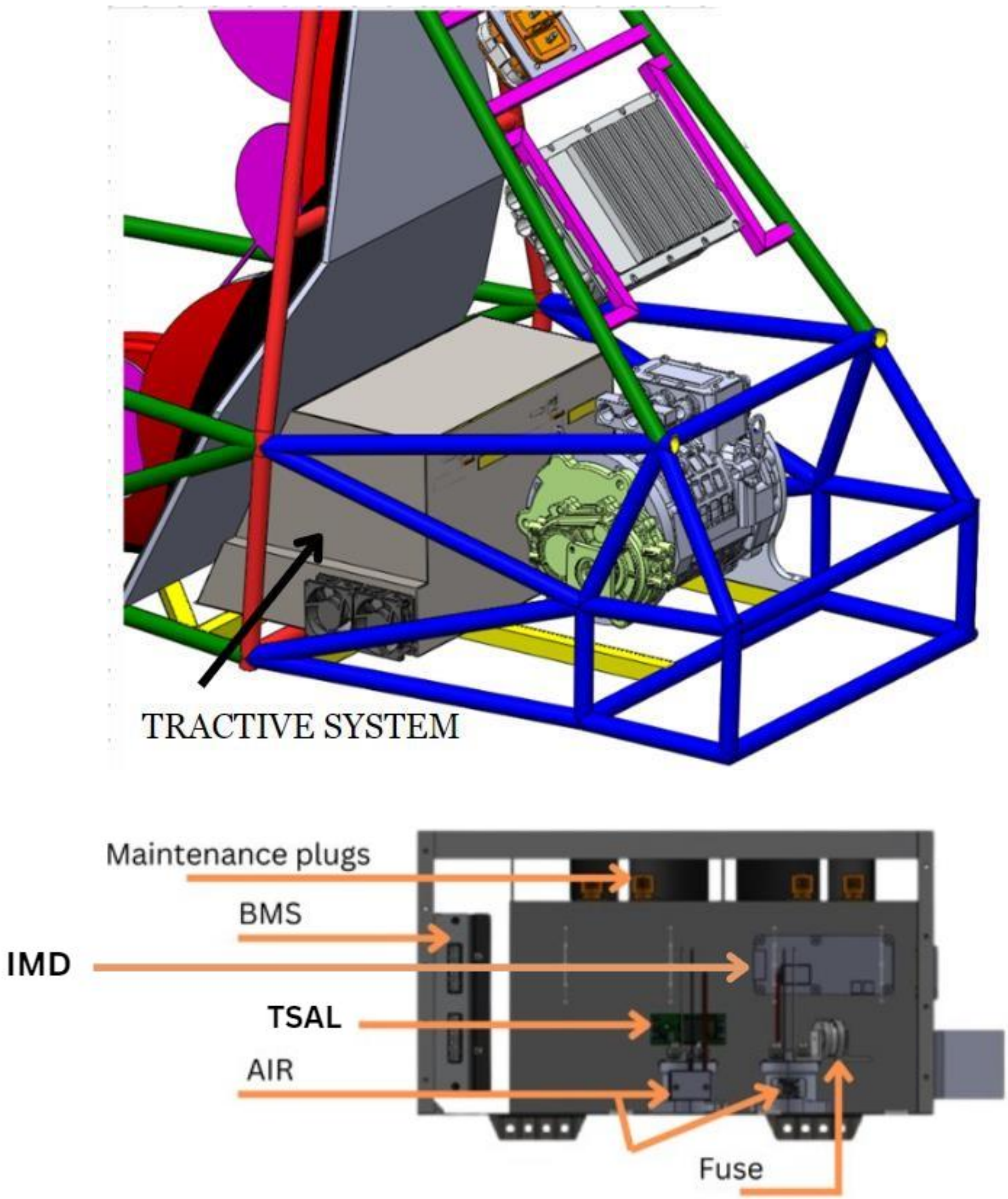


Figure 3 - Locations of all major TS components

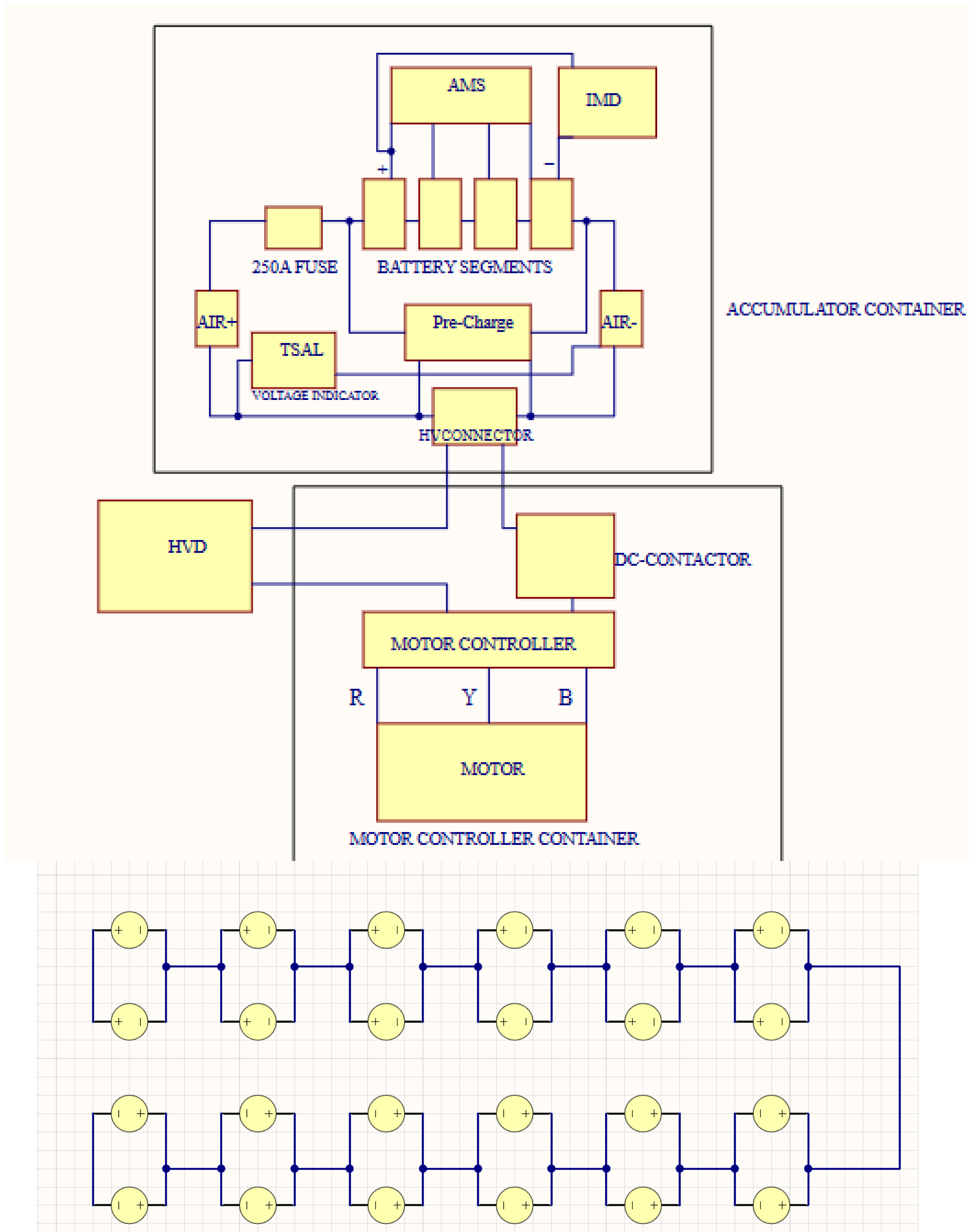


Figure 4 - TSV Wiring Schematic

Fill in the following table:

Item	Data
Nominal Tractive System Voltage (TSV)	88.8VDC
Max. TSV (typically this is during charging)	100.8VDC
Control System voltage (GLV)	12VDC
Total Accumulator capacity (Wh)	3729.60Wh
Accumulator type (Lead-acid, Li-Ion, NiMH)	Li-Ion
Number of electric motors, total	1
Are wheel motors used?	☐ Yes / ✓ No

Table 1- General Electrical System Parameters

Section 2 Cables, Fusing & Grounding

Person primarily responsible for this section:

Name: Rishi Baghel

e-mail: rishibaghe2004@gmail.com

2.1 Fusing & Over current Protection

List TS and GLV fuse (or circuit breaker) data, and where used.

Mfg.	Fuse Part Number	Cont. Rating (A)	DC Voltage Rating	DC Interrupt Rating (A)	Where used
Eaton	250LMT	250	150	2000 DC	AIR, maintenance plug, HV Wire, and accumulator connection protection
LittleFuse	0463015.ER	15	100	200,000 DC	GLV Supply Battery **(Ye dekhna Jhawar)**

Table 2 - Fuse Table

2.2 Component Fusing

List major components (e.g., motor controller, dc-dc converter) and data sheet max fuse rating. Ensure that the rating of the fuse used is less than the maximum value for the component.

Component	Fuse Part Number	Max Fuse Rating A	Installed Fuse Rating A	Notes
Motor controller	250LMT	580	250	
AIR	250LMT	250	250	The AIRs are in the HV path, so single fuse of 250 A rating is used for motor controller, AIRs and motor.
Maintenance Plugs	250LMT	350	250	
HVD	250LMT	350(with fuse)	250	
HV wire (DC)	250LMT	310	250	
Busbar	250LMT	270	250	
Accumulator Connector	250LMT	250	250	

Table 3 - Component Fuse Ratings

2.3 System Wire Tables

List wires and cables used in the Tractive System and the GLV system - wires protected by a fuse of 1 A or less may be omitted.
Available fault current can be calculated from Fault Current= $V_{source} / (R_{source} + R_{wiring})$

Mfg.	Part Number	Size AWG /mm^2	Insulation Type	Voltage Rating	Temp. Rating C	Cable Capacity A	Fuse Part #	Fuse Cont. A	Fuse Interrupting Rating A dc	Avail. Fault Current A	Where Used & How fault current is calculated
Tsuyo	TMW X180K X-15-02-V1.0	50	Heat Shrink Tubing	1000	180	200	250L MT	250	320	135A	Motor and Motor controller The current was provided in the motor controller datasheet.
Tsuyo	TMW X180K X-B-15-02-V1.0	50	Heat shrinkable tube with glue	3000	40 to 180	600	250L MT	250	320	580A	Accumulator and motor controller The current was provided in the motor controller datasheet.
Farnell	PP000 390	1	PVC	1500	-25 to 85	15	FPK-5A	5	8	200A	Throughout the LV system including PCBs, Kill switches, etc. The current was provided in the motor controller datasheet.

Table 4- System Wire Table

2.4 Grounding System

Describe how you keep the resistances between accessible components below the required levels as defined in FI Rules ***G7.2****. If the wire is used for ground bonding, state the AWG or mm*^{2} *of the wire.*

All material used for Grounding

Material	Steel
Model	AISI4130
Thickness	1.25 mm
Dimension of Grounding Plate File	Base plate

A steel base plate is used for GLVS grounding, this ensures compliance with grounding rules.

Isolation & Insulation

Person primarily responsible for this section:

Name: Rishi Baghel

e-mail: rishibaghe2004@gmail.com

2.5 Separation of Tractive System and Grounded Low Voltage System

Describe how the TS and GLV systems are physically separated. Add CAD drawings or photographs of how TS and GLV are segregated in key areas of the electrical system.

TS and GLV are separated in the accumulator container. TS wiring and GLVS are insulated from each other by FR4 sheet.

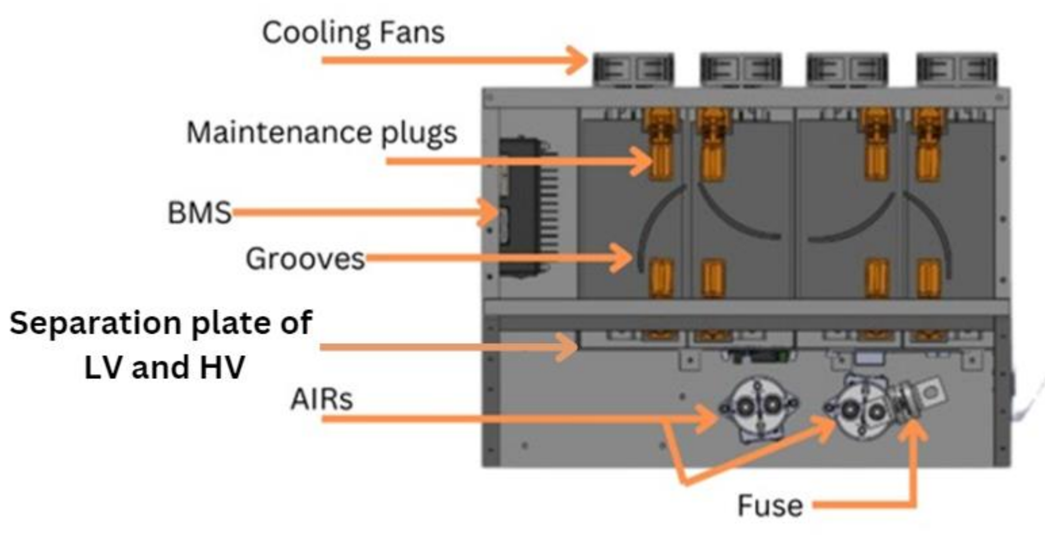


Figure 5 - TS and GLV separation

List all electrical circuit boards designed by team that contain TS and GLV voltage in the following table.

Device / PCB	TS Voltage Present (V)	Minimum Spacing (mm)	Thru Air of Over Surface (mm)	Notes
Pre-charge/Discharge Circuit	96	23.50	7.80	2 mm gap between connections over surface and 1.5 mm gap through air of components.

Table 5 - PCB Spacings

Add a figure (board layout drawing) for each team-designed PCB showing that spacing.

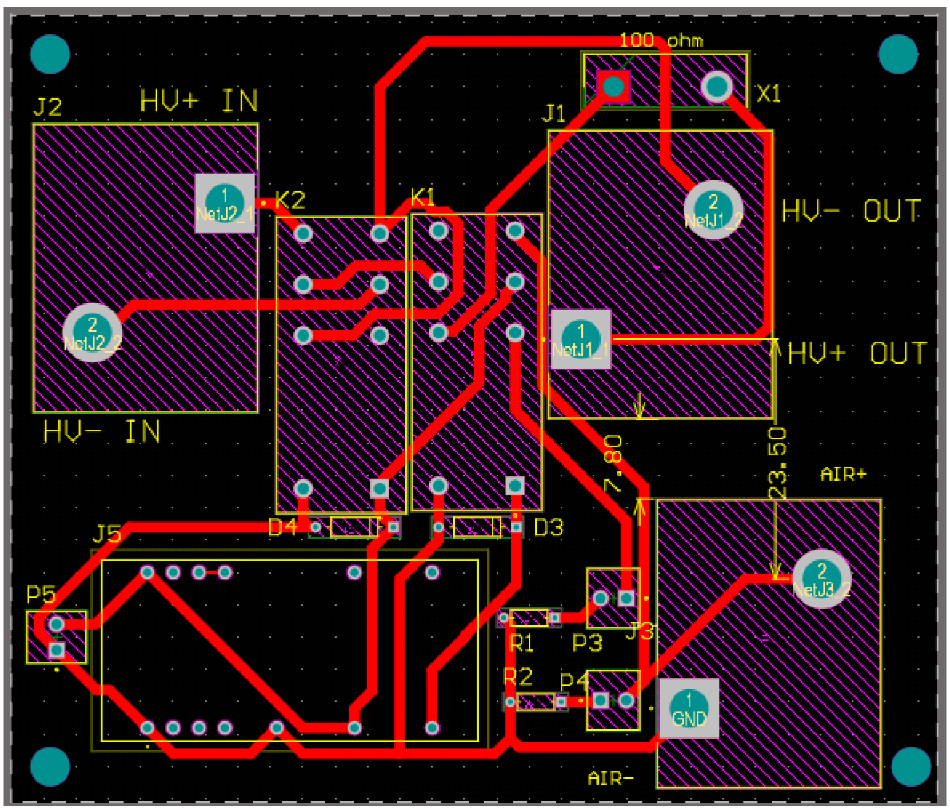


Figure 6 - Team Designed PCB Layout

List all purchased components with both TS and GLV connections (at min motor controller and AMS)

Component	Isolation Method	Link to Document Describing Isolation	Notes
AIR	Isolated through air by minimum spacing of 10 mm and internally at the contact surface.	**DATASHEET**	
BMS	Isolated through air by minimum spacing of 10 mm and internally at the contact surface	**DATASHEET**	
Motor Controller	Isolated through air by minimum spacing of 10 mm and internally at the contact surface	**DATASHEET**	
IMD	Isolated through air by minimum spacing of 10 mm and internally at the contact surface	**DATASHEET**	The IMD LV and HV wires are separated more than 10 mm, LV wires are covered with kampton tape.
HV Connector	Isolated through air by minimum spacing of 10 mm and internally at the contact surface	**DATASHEET**	The LV wires are covered with kampton tape and 10 mm separation between HV and LV lines

2.6 Isolation & Insulation

Provide a list of containers that have TS and GLV wiring in them. If a barrier is used rather than spacing, identify barrier material used.

Container Name	Segregation by Spacing (Y or N)	How is Spacing maintained	Actual Measured Spacing mm	Alt – Barrier Material P/N	Notes
Accumulator Container	Y	With the help of Kampton tape and insulation around HV wires	10 mm	N	
Motor Controller Container	Y	With the help of insulation around HV wires	10 mm	N	

Table 6 – List of Containers with TS and GLV wiring

List all insulating barrier materials used to meet the requirements.

Insulating Material / Part Number	Recognized	Rated Temperature (ºC)	Thickness (mm)	Notes
FR4 Sheet	Yes	155	1 and 1.5	Used in accumulator to insulate battery.
Dupont Nomex 410	Yes	180	4 mm	To form insulating layer between driver and tractive system
Kapton tape	Yes	260	0.2 mm	To provide insulation between wires
Aluminium firewall	Yes	425	10 mm	To form insulating layer between driver and tractive system

Table 7- Insulating Materials

2.7 Conduit

List different types of conduit used in the design. Specify location and if manufacturer's standard fittings are used.
Describe how the conduit is anchored if standard fittings are not used.

If standard fittings are not used, specific anchoring methods are needed to secure the conduit:

- **Straps:** Conduit straps made of metal or plastic secure the conduit to walls, ceilings, or other surfaces. They come in various sizes and styles to accommodate different conduit diameters.
- **Clamps:** Similar to straps, clamps encircle the conduit and provide a secure hold. They can be single-hole or multi-hole for attaching to surfaces.
- **Hanging hardware:** For suspended applications, special brackets or hangers can be used to support the conduit weight.

Conduit Type	MFR	Part Number	Diameter Inch or mm	Standard Fittings (Y or N)	Location / Use
Fire resistant PVC	Tsuyo	TMWX 180KX-B-15-02-V1.0	7.98	Y	Accumulator and motor controller
Fire resistant PVC	Tsuyo	TMWX 180KX-B-15-02-V1.0	7.98	Y	Motor and motor controller

Table 8 - Conduit Data

*Is all conduit contained within the vehicle Surface Envelope (**Y or N**). **Y***
*Do all conduits comply with **G8.5**? (**Y or N**). **Y***

2.8 Firewall(s)

Description/materials

*Describe the concept, layer structure and the materials used for the firewalls. Describe how all firewall requirements in FI Rules **E3.6** are satisfied. Show how the low resistance connection to chassis ground is achieved.*

A firewall must separate the driver compartment from hydraulic fluid (except brake system and dampers), flammable liquids, the low voltage battery, and any TS component. The details of the firewall and how it is placed is given below. The firewall is connected to the chassis directly to connect it to chassis ground.

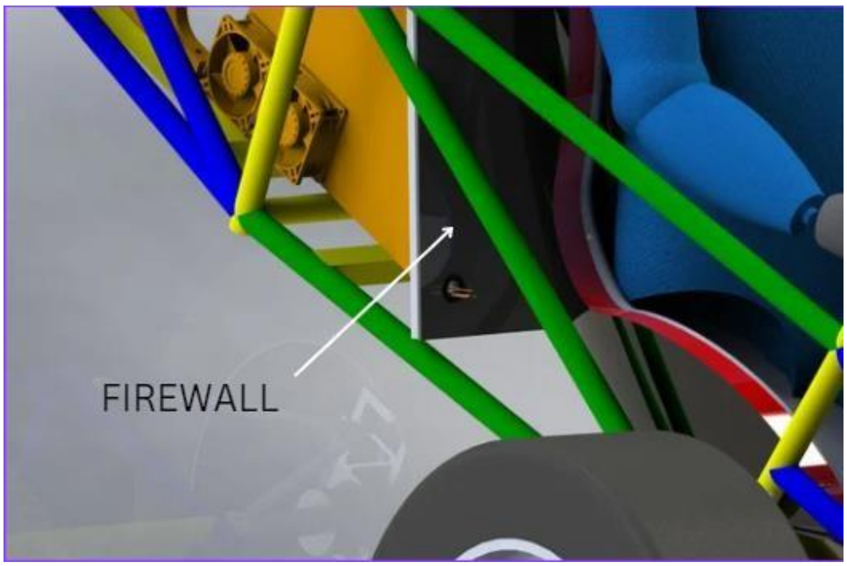
Aluminium

1. Attributes	Value
Aluminium firewall model	AL 5052
Thickness	1 mm
Aluminium layer side	Tractive system

Aluminium Layer Datasheet

Position in car

Provide CAD-rendering or photographs showing the location of the firewall(s).



Section 3 **Electric Tractive System**

Person primarily responsible for this section:

Name: Tanmay Soni

e-mail: tanmaysoni66@gmail.com

3.1 Motor(s)

Describe the motor(s) used and reason for this particular choice. Add additional tables if multiple motor types are used.

The motor used is of Permanent Magnet Synchronous type. It is rated at 96 V, having a weight of 43 kg, having a rated current of 135 A and an operating temperature of -40 to 60 degree Celsius. We have chosen this motor because of its small moment of inertia, high acceleration, high torque overload capacity, high power-to-weight ratio, wide speed range and high efficiency.

Manufacturer and Model:	TSUYO MANUFACTURING PVT LTD
Motor type (PM, Induction, DC Brush)	Permanent Magnet Synchronous Motor
Nominal motor voltage (Vrms l-l or Vdc)	96
Nominal / Peak motor current (A or A/phase)	Nom:135A / Peak:520A
Nominal / Peak motor power	Nom:15KW / Peak:30KW
Motor wiring – conductor size and type	Three phase wire – 18 mm and copper

Table 9- Motor Data

Provide calculations for currents and voltages. State how this relates to the choice of cables and connectors used.

Wiring Calculations for Motor

- Max current in HV circuit(I) = **200 Amp**
- The resistivity of the material used (copper) = $1.72 * 10^{-8}\ \Omega \cdot m$.
- Approximate length of the wire (L) = 1.5 m
- % of Maximum allowable voltage drop (U) = 1% of rated HV voltage

- Area of the cross-section of the wire A $\geq \frac{2 \times I \times L}{G \times U} = \mathbf{10.7569\ mm^2}$

Hence 50 mm^2 HV shielded cable is selected.

3.2 Motor Controller

Describe the motor controller used and reason for this particular choice.

It is a FOC AC Motor Controller. It has the features of multi-protection strategy, optimum range of operating and storage temperatures. The TEVD3/4 series is the high performance FOC AC motor controller, which is dedicatedly designed by TERCEL for his EV car family. Its nominal voltage ranges from 72VDC to 350VDC and max current even reaches 580A RMS. It has been widely used in the harsh application such as Pure electric vehicles with IP67 class, high power density and high reliability. With the feature of multi-protection strategy, accurate and smooth driving, consistent and efficient cruise, the user could experience the extraordinary driving.

Manufacturer and Model:	TSUYO MANUFACTURING PVT LTD , TEVD4-10X58F2
Maximum Input voltage:	96V
Nominal Input Current (A)	170A
Max Input Fuse (A) per Mfr.	580A
Output voltage (Vac l-l or Vdc)	96V
Isolation voltage rating between GLV (power supply or control inputs) and TS connections	500V
Is the accelerator galvanically isolated from the Tractive System?	P Yes / ☐ No

Table 10 - Motor Controller Data

If the answer to the last question is NO, give information about insulation provided complying rulebook.

Provide calculations for currents and voltages. State how this relates to the choice of cables and connectors used.

Wiring Calculations for Motor Controller

- Max current in HV circuit(I) = **200 Amp**
- The resistivity of the material used (copper) = $1.72 * 10^{-8}\ \Omega - m$.
- Approximate length of the wire (L) = 2 m
- % of Maximum allowable voltage drop (U) = 1% of rated HV voltage
- Area of the cross-section of the wire A $\geq \frac{2 \times I \times L}{G \times U} = \mathbf{11.008\ mm^2}$

Hence 50 mm^2 HV shielded cable is selected.

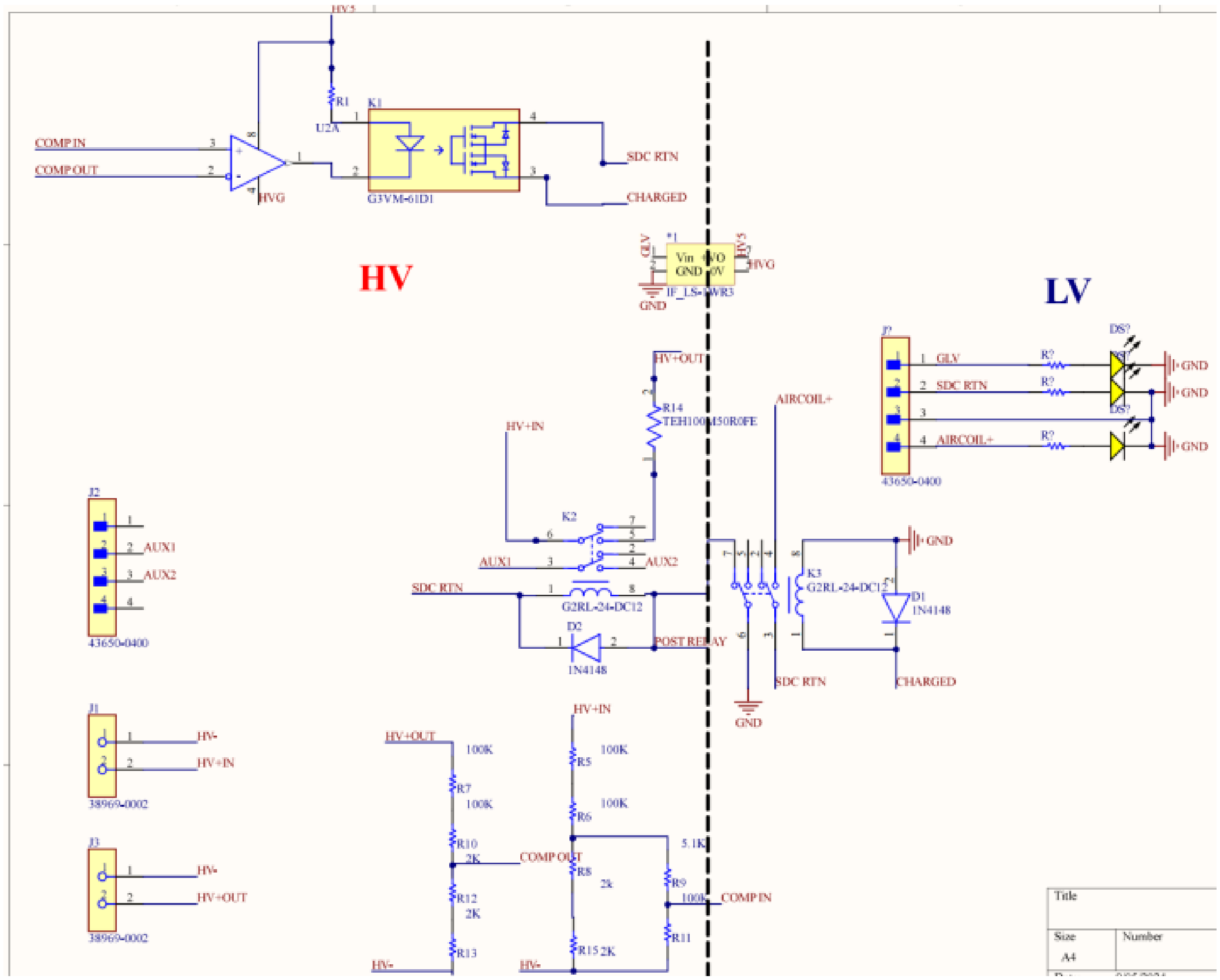
3.3 Pre-Charge circuitry

Describe your design for the pre-charge circuitry. Describe wiring, connectors and cables used.

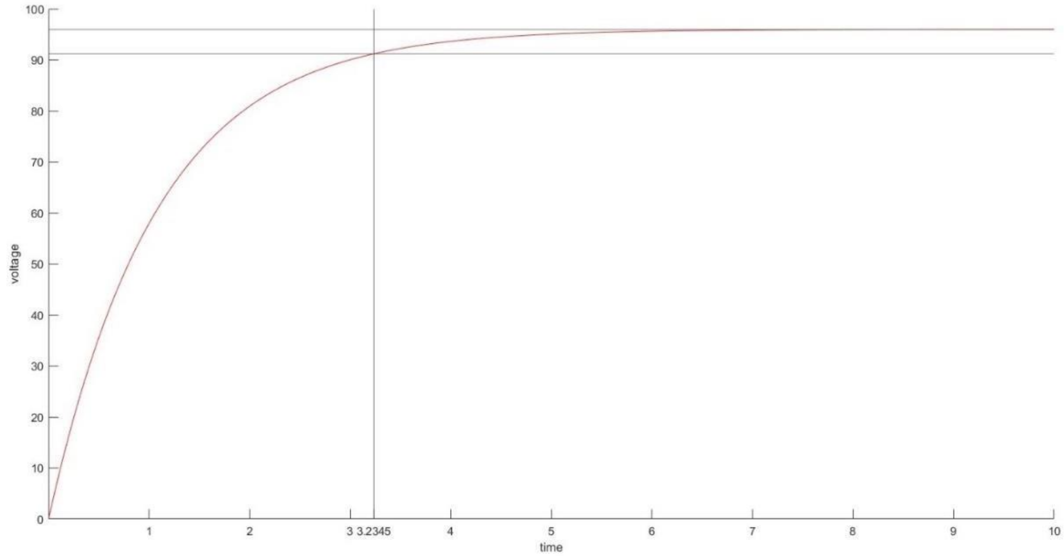
We have made pre-charge circuit in PCB. When initially connecting a battery to a load with capacitive input, there is an inrush of current as the load capacitance is charged up to the battery voltage. In our application using a large battery and powerful load, this inrush current is very high. The pre-charge circuit is required to charge the circuitry between the accumulators and the motor controller to 95% of the maximum operating voltage before closing the second AIR. This must be done to protect the motor controller and other components from the very large inrush current.

The Pre-charge circuit consists of a pre-charge resistor, to limit the inrush current and a contactor (high power relay) across the pre-charge resistor.

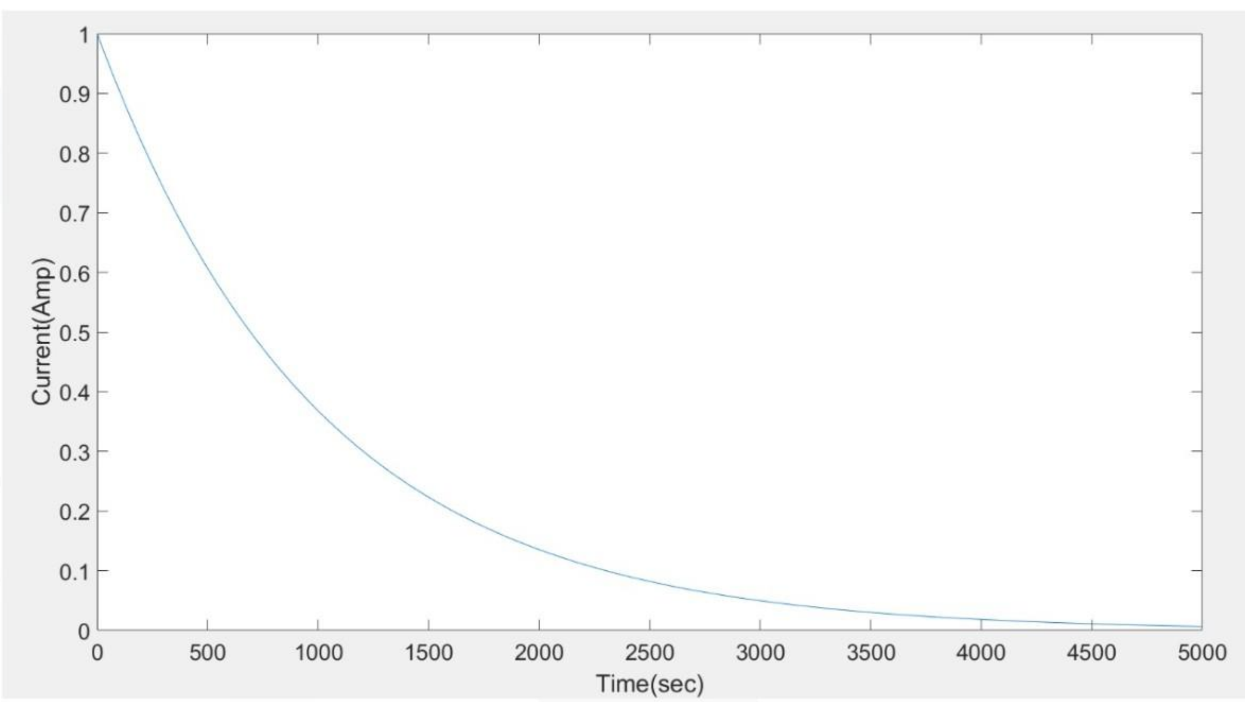
- *Include a schematic of the pre-charge circuit*



- *Include a plot of calculated TS Voltage vs. time*



- *Include a plot of calculated Current vs. time*



Provide the following information:

Resistor Type:	Non-Flammable Edgewound Tubular Wirewound Resistor
Resistance:	100 Ω
Continuous power rating:	100 W
Overload power rating:	140 W for 3 sec
Voltage rating:	600 V

Table 11- Data for the pre-charge resistor

Relay MFR &Type:	OMRON ELECTRONIC COMPONENTS Power relay
Contact arrangement (e.g. SPDT)	SPDT
Continuous DC contact current (A):	12 A
Contact voltage rating (Vdc).	24 VDC

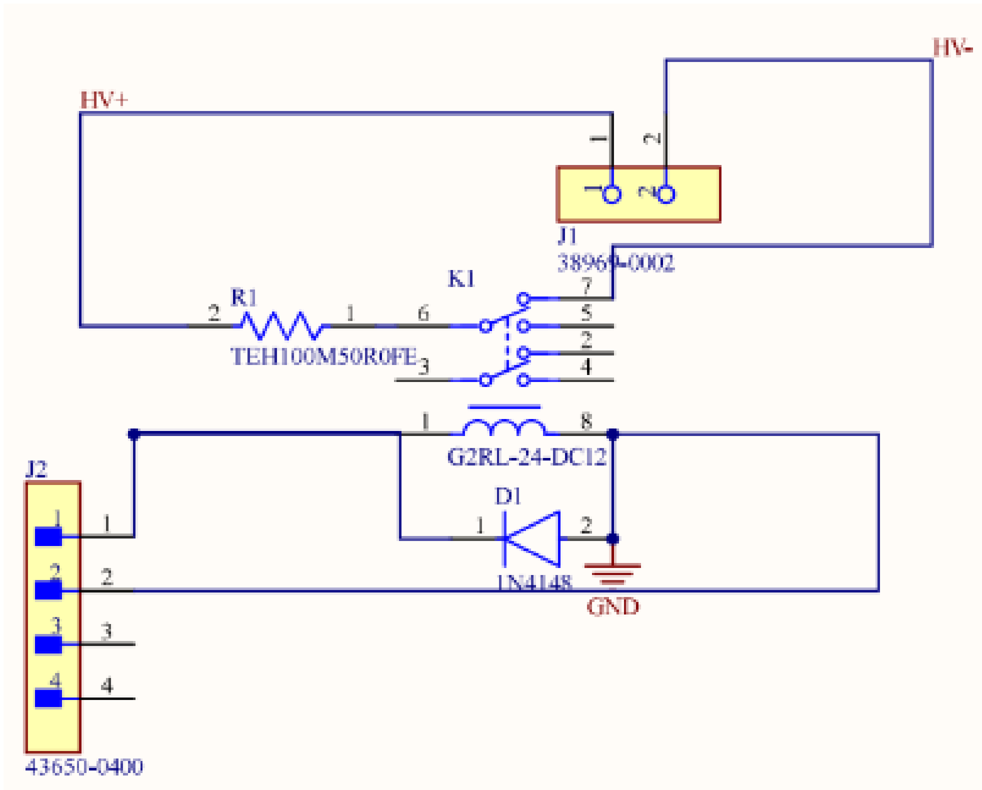
Table 12- Data of the pre-charge relay

3.4 Discharge circuitry

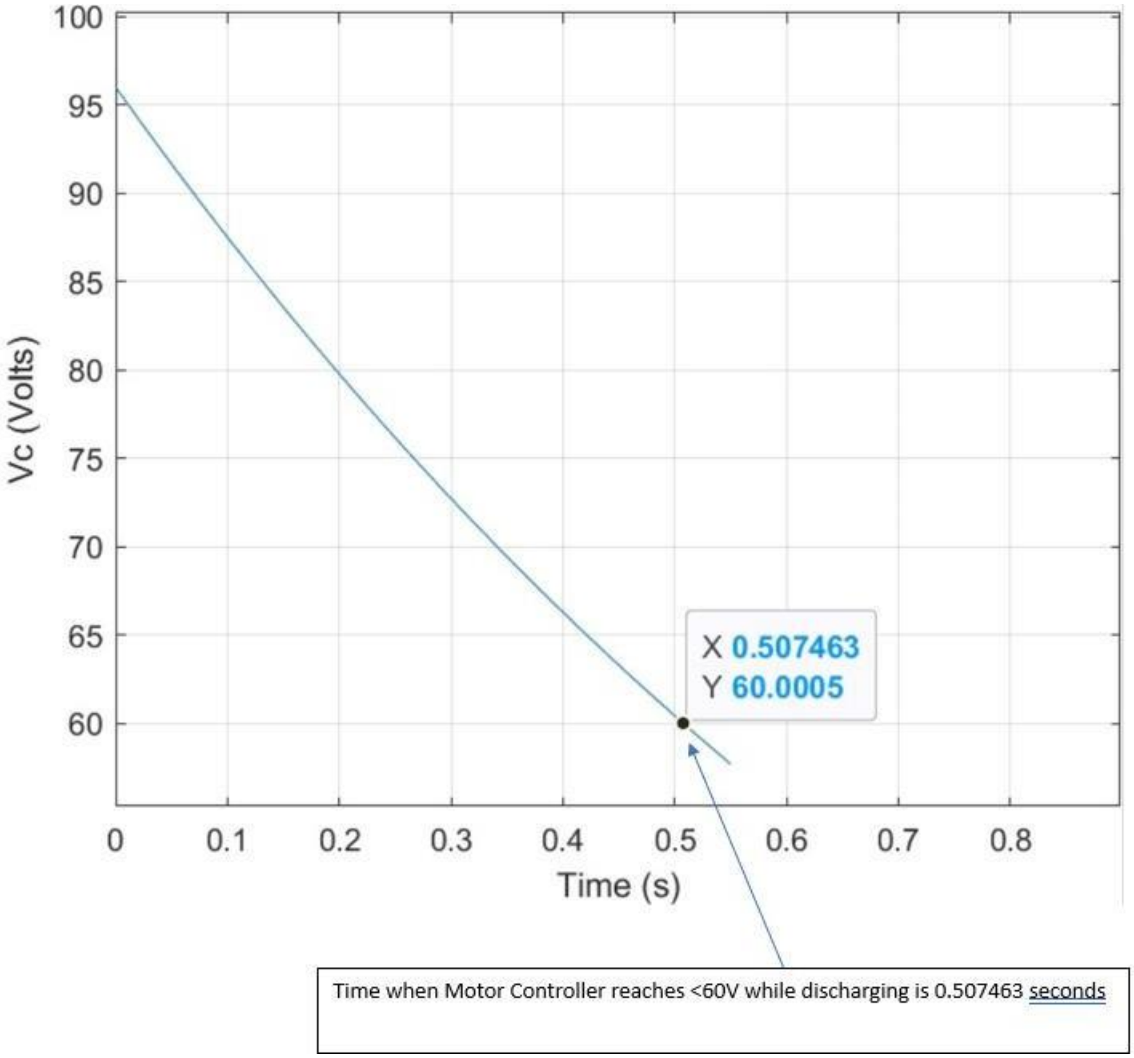
Describe your concept for the discharge circuitry. Describe wiring, connectors and cables used.

The discharge circuit allows energy stored in the motor controller's to be discharged after the tractive system is shut down. The circuit consists of a normally closed relay in series with a dissipation resistor, setup to discharge the maximum high voltage across the motor controller's internal capacitor. When the system is powered on, the relay opens, and the system operates as normal. When the shutdown circuit is open, the discharge circuit is closed, and the discharge resistor will discharge energy to less than 2V in 5 seconds. In our application pre-charge circuit and discharge circuit is one single circuit.

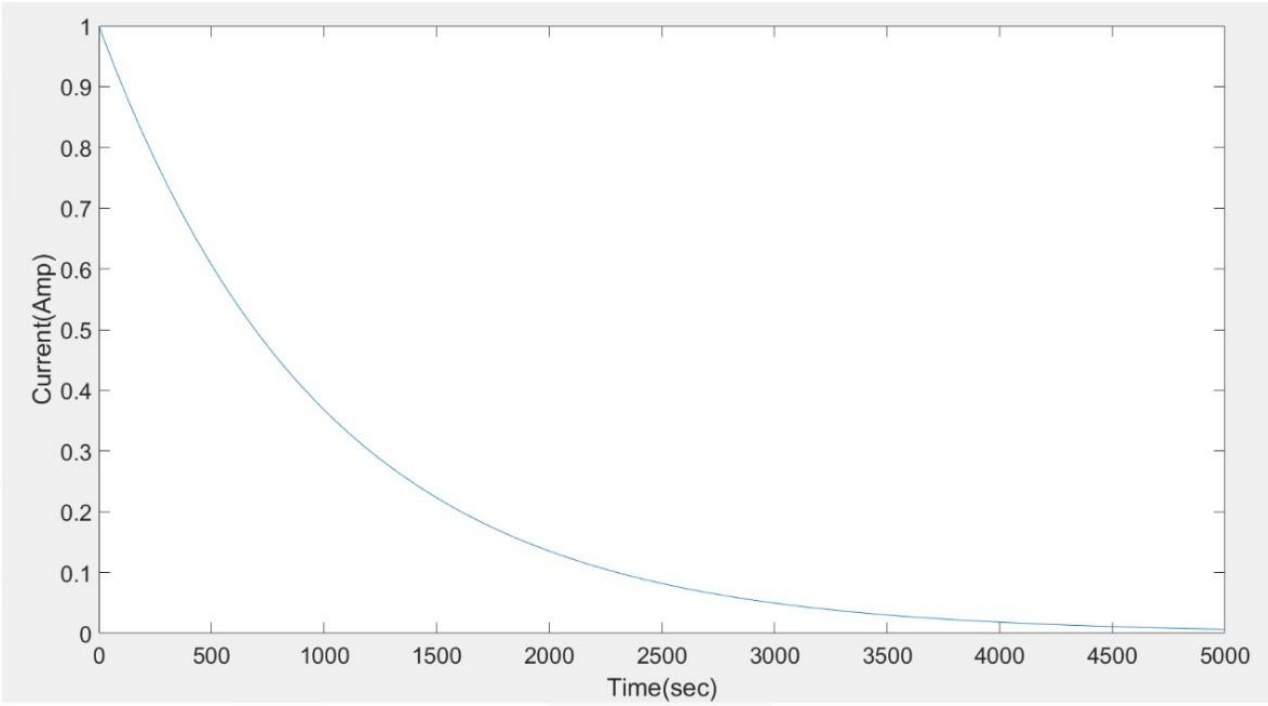
- *Include a schematic of the discharge circuit*



- *Include a plot of calculated TS Voltage vs. time*



- *Include a plot of calculated "Discharge current" vs. time*



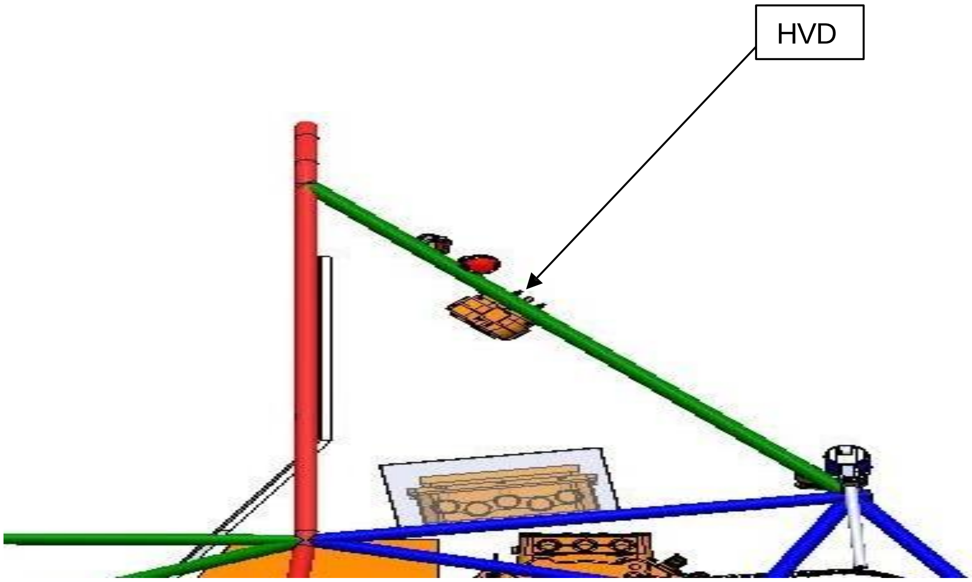
Provide the following information:

Resistor Type:	Non-Flammable Edgewound Tubular Wirewound Resistor
Resistance:	100Ω
Continuous power rating:	100W
Overload power rating:	114W for sec
Voltage rating:	600 V
Maximum expected current:	0.96 A
Average current:	0.26A

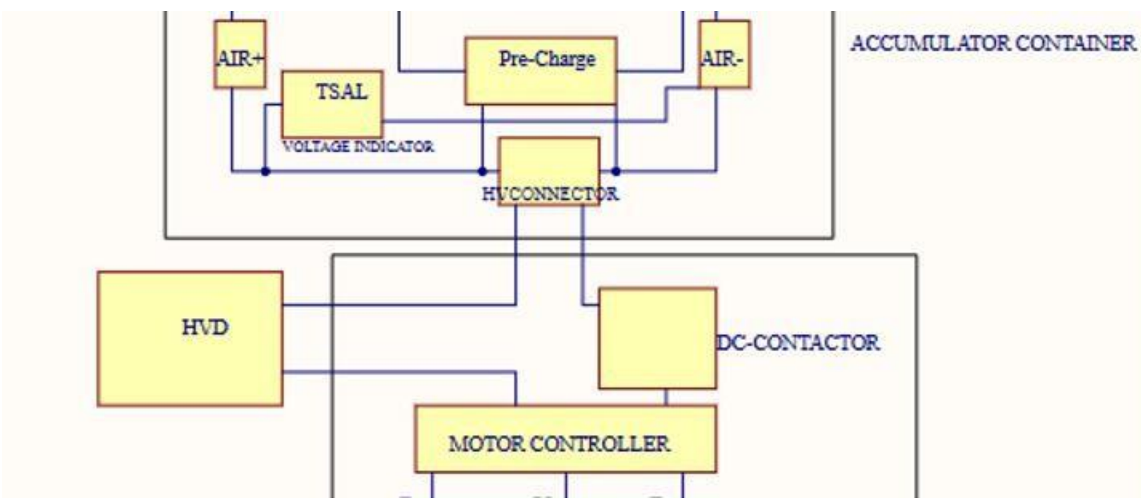
Table 13- Data of the discharge circuit.

3.5 HV Disconnect (HVD)

*Describe your design for the HVD and how it is operated, wiring, and location. Describe how your design meets all requirements for **G8.6.***



We bought HVD from Amphenol. It is located on the top part of the main hoop bracing. Head of the HVD is pulled to disconnect one pole of the accumulator from the motor controller.



Type	HVD
Make	Amphenol
Model	MSDF000F
Rated Voltage	1000V DC
Current Rating	250A

Material	Nylon
IP Rating	IP67

HVD Design

3.6 Accelerator Actuator / Throttle Position Sensor

Describe the accelerator actuator and throttle position sensor(s) used, describe additional circuitry used to check or condition the signal going to the motor controller. Describe wiring, cables and connectors used. Provide schematics and a description of the method of operation of any team-built signal conditioning electronics.

We have connected the accelerator actuator to the motor controller. In case of plausibility, it is connected to the motor controller through a relay. In case of failure, the relay is latched open preventing the sensor's signal to the motor controller.

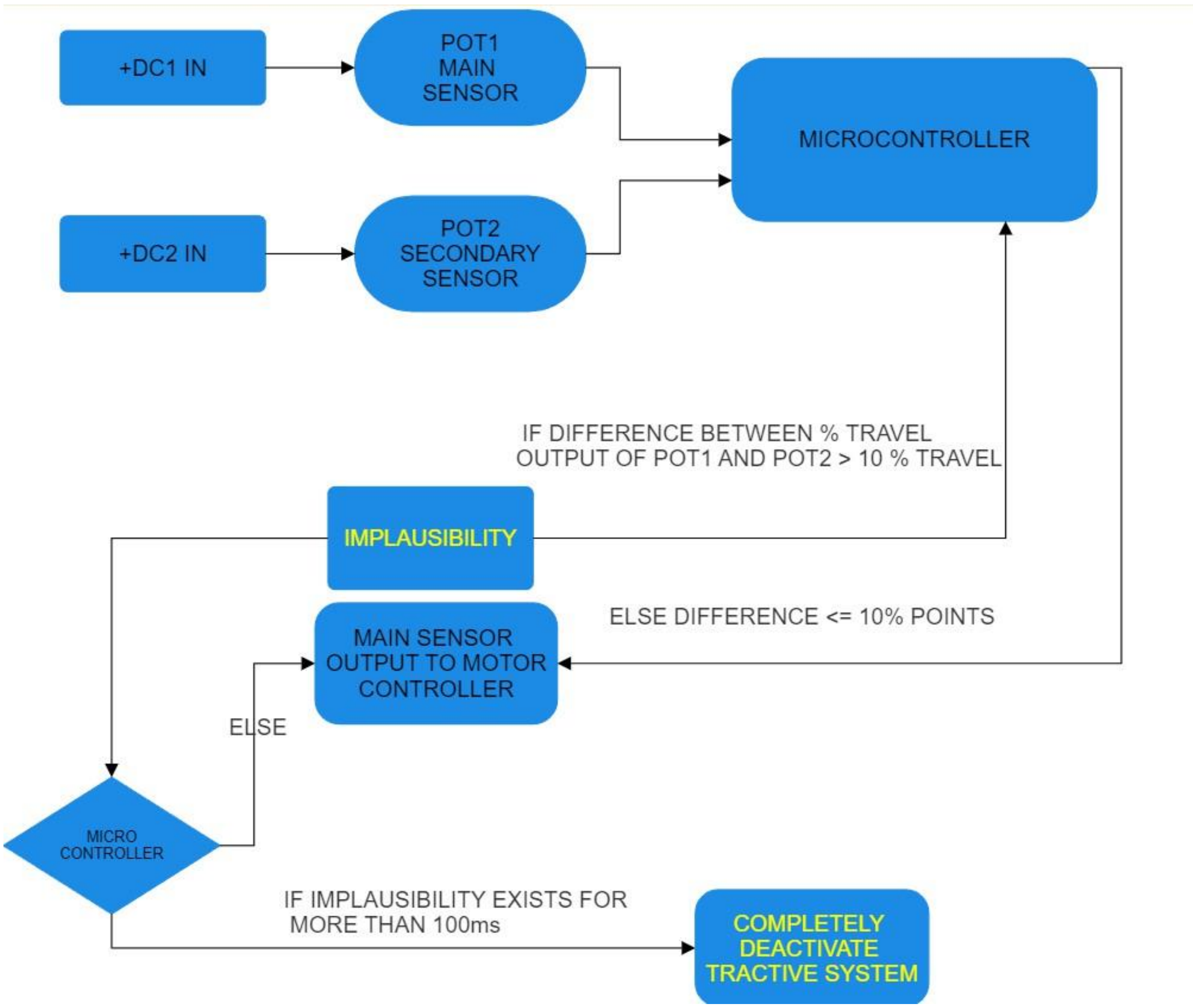
Actuator / Encoder manufacturer and model:	Tata Nexon
Encoder principle (e.g.Potentiometer):	Two separate potentiometers
Output:	Main : 1 – 4 V Secondary :0.5 - 3.5 V
Is motor controller accelerator signal isolated from TSV?	☐ Yes / P No

Table 14- Throttle Position encoder data

3.7 Accelerator / throttle position encoder error check

Describe how the system reacts if an error (e.g. short circuit or open circuit or equivalent) is detected. Describe circuitry used to check or condition the signal going to the motor controller. Describe how failures (e.g. Implausibility, short circuit, open circuit etc.) are detected and how the system reacts if an error is detected.

Logic is shown in the block diagram below:



Section 4 **Accumulator System**

Person primarily responsible for this section:

Name: Tanmay Soni

E-mail: Tanmaysoni66@gmail.com

4.1 Accumulator Pack

Provide a narrative design of the accumulator system and complete the following table.

The accumulator contains battery cells of Lithium Cobalt Oxide (LCO) chemistry in the form of pouch cells. The configuration is 24s2p and the cells have been fit into 4 segments. The segments and the pouch cells have been arranged in a way to make the packing efficient. Copper busbars have been used for connections to reduce the resistance due to said connections. The weight of the accumulator stands at around 32 kilograms. FR4 sheets have been used to provide fire retardation. The accumulator has metal sheets which allow heat to transfer to the lower side of accumulator container and air cooling with proper directions has been used.

Maximum Voltage (during charging):	100.8VDC
Nominal Voltage:	88.8 VDC
Total number of cells:	48
Cell arrangement (x in series / y in parallel):	24/2
Are packs commercial or team constructed?	☐Commercial / ✓ Team
Total Capacity (per FI Rules):	42Ah
Maximum Segment Capacity	3.36MJ

Table 15- Main accumulator parameters

4.2 Cell description

Describe the cell type used and the chemistry and complete the following table.

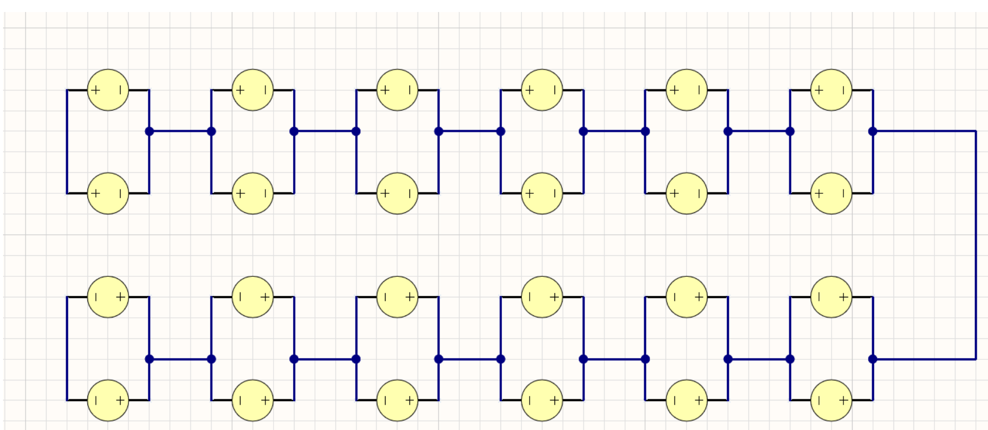
Cell Manufacturer and Model	Shenzhen Melasta Battery Co.,Ltd
Cell type (prismatic, cylindrical, pouch, etc.)	Pouch
Are these pouch cells	✓ Yes / ☐ No
Cell nominal capacity at 2C (0.5 hour) rate:	5.25Ah
Data sheet nominal capacity	21Ah at __8_C rate
Maximum Voltage (during charging):	4V
Nominal Voltage (data sheet value):	3.7V
Minimum Voltage (AMS setting):	3.2V
Maximum Cell Temperature (charging - AMS setting)	45°C
Maximum Cell Temperature (discharging - AMS setting)	60°C
Cell chemistry:	$LiCoO_2$

Table 16- Main cell specification

4.3 Cell Configuration

Describe cell configuration, show schematics, cover additional parts like internal cell fuses etc.
Describe configuration.

The configuration of the cells is 24S2P that is there are total of 48 cells, of which 24 cells are connected in series with one cell in parallel to each cell connected in series. Two cells are connected in parallel making a single module which is connected in series with 11 more modules.

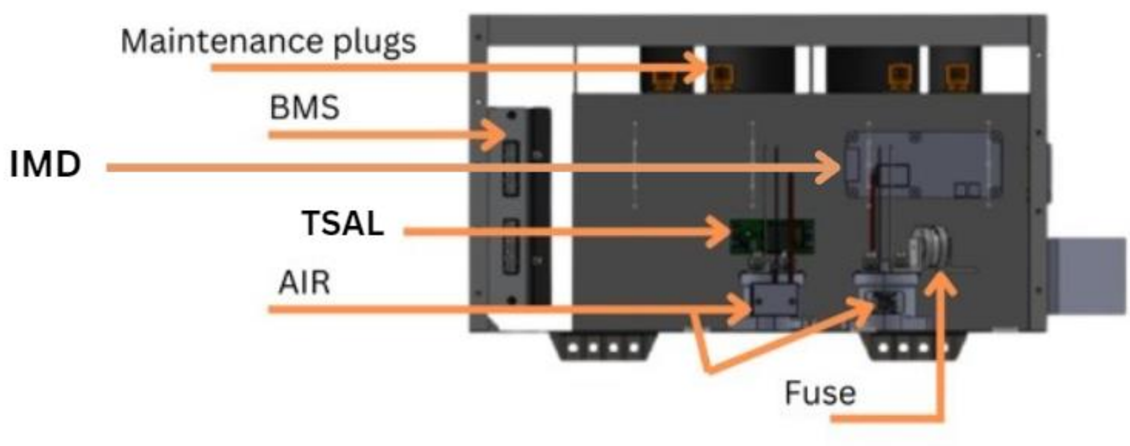


*If your team has designed your accumulator system using individual Lithium-Ion pouch cells, include drawings, photographs and calculations demonstrating compliance with all rules. If your system has been issued a variance to **rules** by the Formula Imperial rules committee, include the required documentation from the cell manufacturer.*

4.4 Accumulator Isolation Relays (AIR)

Describe the number of AIRs used and their locations. Also complete the following table.

We will use 2 AIRs and they will be in tractive system.



MFR & Model	Littlefuse DCNHR250QFA
Contact arraignment:	1 Form A
Continuous DC current rating:	500 A
Overload DC current rating:	8000 A for 5 milliseconds
Maximum operation voltage:	900VDC
Nominal coil voltage:	500 VDC
Normal Load switching:	Make and break up to 1 A

Table 17 - AIR data

4.5 Accumulator Management System (AMS)

Describe the AMS and how it was chosen. Describe generally how it meets the requirements of ***G9.6.***

AMS MFR and Model	Ewert Energy Systems, Inc, Orion BMS 2
Number of AMSs	1
Upper cell voltage trip	96V
Lower cell voltage trip	76.8 V
Temperature trip	60 °C

Table 18 - AMS Data

- *Describe other relevant AMS operation parameters.*

1. Monitors every cell voltage in series
2. Intelligent cell balancing (efficient passive balancing)
3. Enforces min. and max. cell voltages
4. Enforces maximum current limits
5. Enforces temperature limits
6. Monitors state-of-charge
7. Retains lifetime data about battery history

- *Describe how many cells are monitored by each AMS board, the configuration of the cells, the configuration of the boards and how AMS communications wiring is protected and isolated.*

  We are using Orion BMS, which is a centralized AMS, so all the cells are centrally monitored via a single centralized AMS. Our cell configuration is 24s2p. CAN bus and other communication wires are shielded, i.e. have an extra layer of insulation. The CAN bus wires are electrically isolated from battery pack by using a motor controller which allows CAN communication.

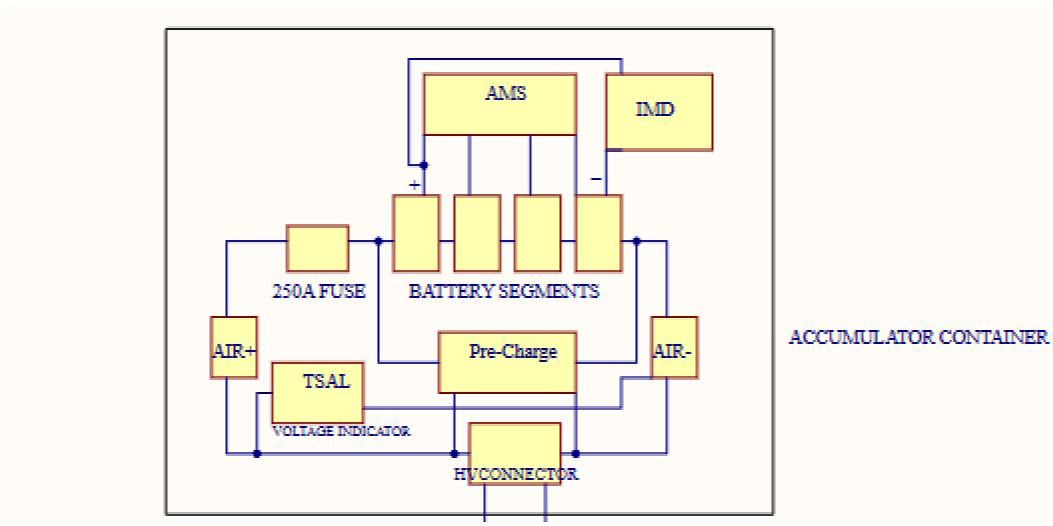
- *Indicate in the AMS system the location of the isolation between TS and GLV*

4.6 Accumulator wiring, cables, current calculations

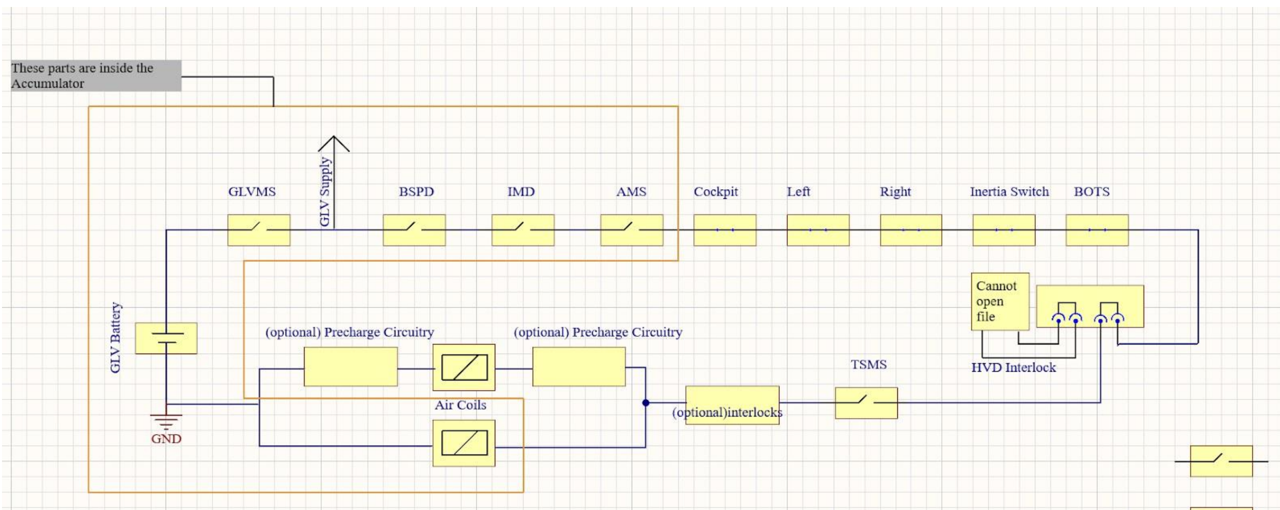
Describe internal wiring with schematics if appropriate. Provide calculations for currents and voltages and show data regarding the cables and connectors used. Discuss maximum expected current, DC and AC, and duration Compare the maximum values to nominal currents.

• Peak Motor Power (Pmax): 30 kW
• Continuous Motor Power (P_{cont}): 15 kW
• Nominal Accumulator Voltage : 88.8
• Continuous Motor Power (P_{cont}): 15 kW
• Maximum Motor Current (Imax): 520 A
• Nominal Voltage of the accumulator = 88.8V
• Maximum current allowed in the HV wires is 600A.
• Nominal current = 15000/88.8 = 168.91A

Our Tractive system is a DC system.



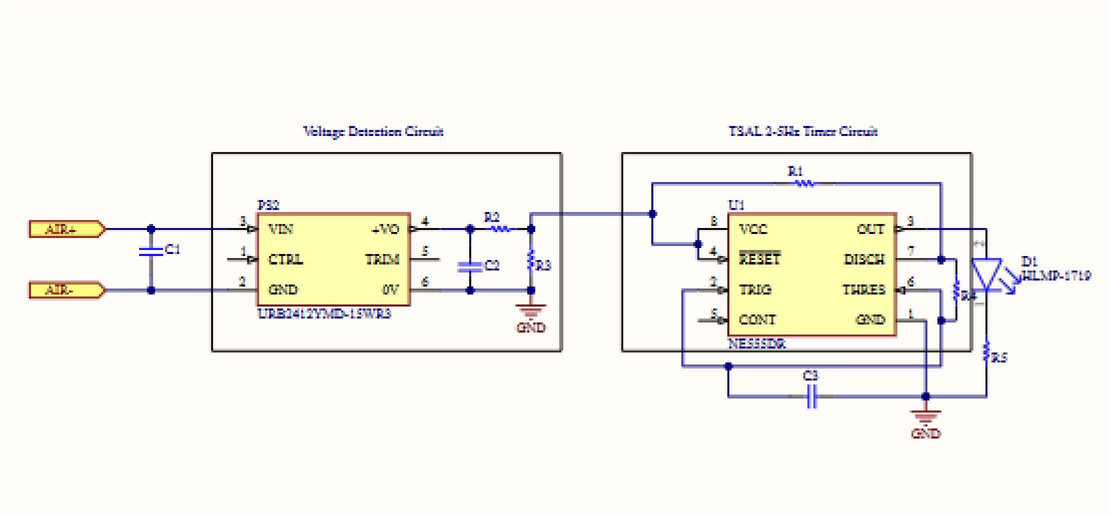
Electrical Layout of Accumulator (High Voltage Path with all the component integrated)



Electrical Layout of Accumulator (Low Voltage Controls)

4.7 Accumulator indicator

Describe the indicator, including indicating voltage range



Voltage indicator (Voltage indicator will light up when voltage cross 60V). The DC-DC converter has a input voltage range of 60-140V, i.e. the indicator will only light up when DC converter gets more than 60V.

4.8 Charging

Describe how the accumulator will be charged. How will the charger be connected? How is the accumulator to be supervised during charging?

The charger is of onboard type and provides overheat, short-circuit and battery reverse connection protection. Along with these it also provides low input voltage and overvoltage protection. The charger has been designed for wide storage and operating temperature and has the feature of fully automatic shutdown.

Charger Manufacturer and model:	Evlithium Electronics
Maximum charging power:	3.3 kW
Isolation	✓ Yes / ☐ No
Do you have a waiver from the FI rules committee?	☐Yes / ☐ No-
Maximum charging voltage:	132V
Maximum charging current:	32 A
Interface with accumulator (e.g. CAN, relay etc.)	CAN Bus Normal

Input voltage:	90 to 264 VAC single phase
Input current:	32A

Table 19- Charger data

4.9 Accumulator Container/Housing

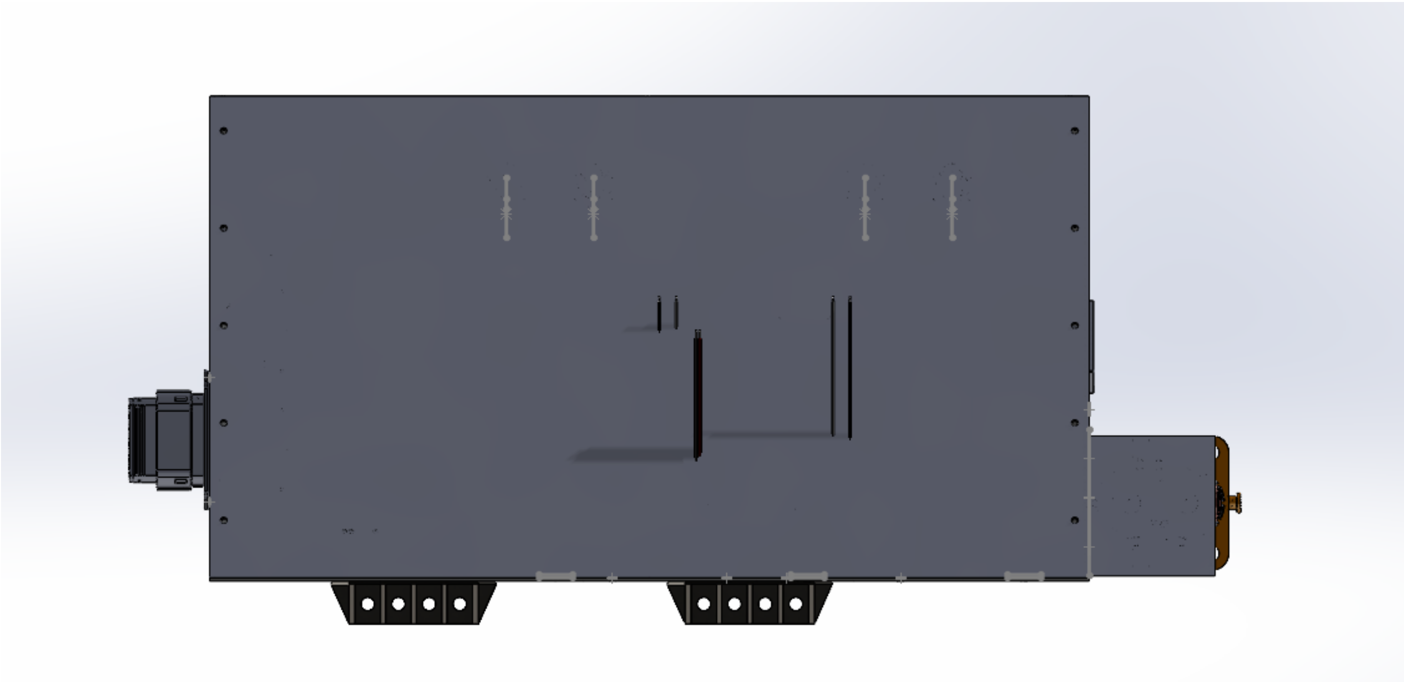
Describe the design of the accumulator container. Include the housing material specifications and construction methods. Include data sheets for insulating materials.
*Include additional photographs if required to comply with rule **G13.4.***

The accumulator contains battery cells of Lithium Cobalt Oxide ($LiCoO_2$) chemistry in the form of pouch cells. The configuration is 24s2p and the cells have been fit into 4 segments. The segments and the pouch cells have been arranged in a way to make the packing efficient. Copper busbars have been used for connections to reduce the resistance due to said connections. The weight of the accumulator stands at around 32 kilograms. FR4 sheets have been used to provide fire retardation. The accumulator has metal sheets which allow heat to transfer to the lower side of accumulator container and air cooling with proper directions has been used.

Insulating material used (Material Datasheet and invoice)

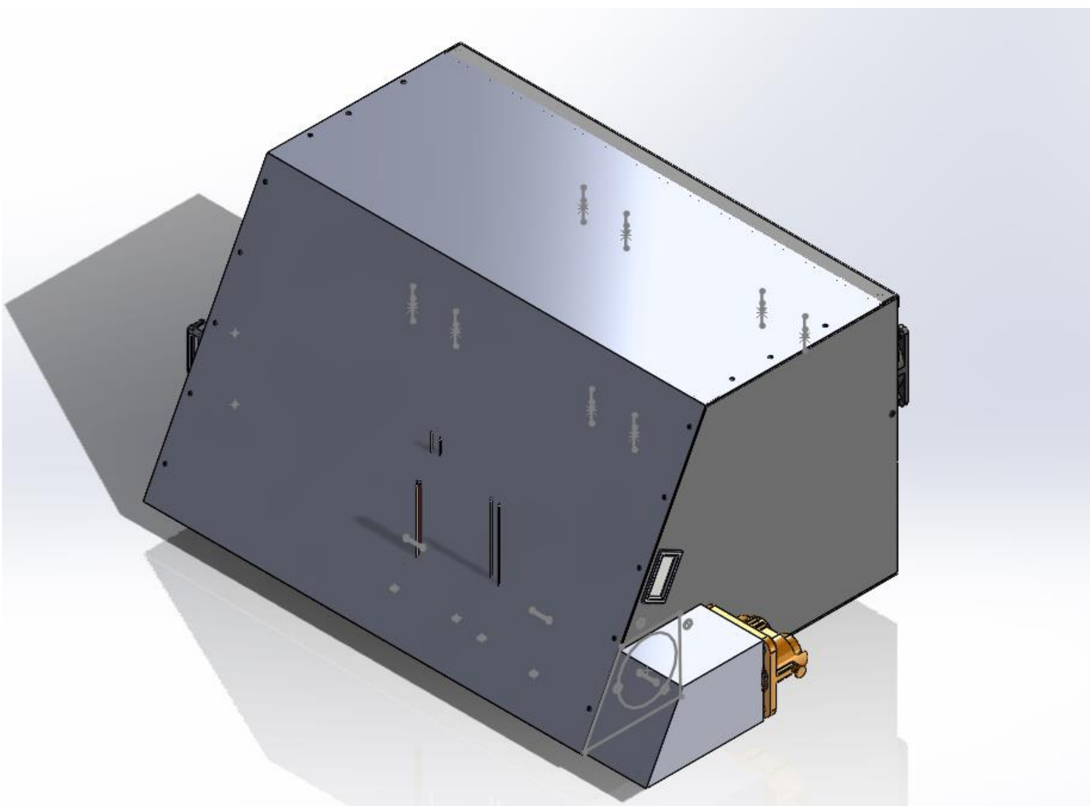
Attributes	Value
Insulating Material Make / Model	DuPont Nomex 410
Thickness	2 mm
Insulating layer side	driver

Insulating Material Datasheet



FRONT VIEW

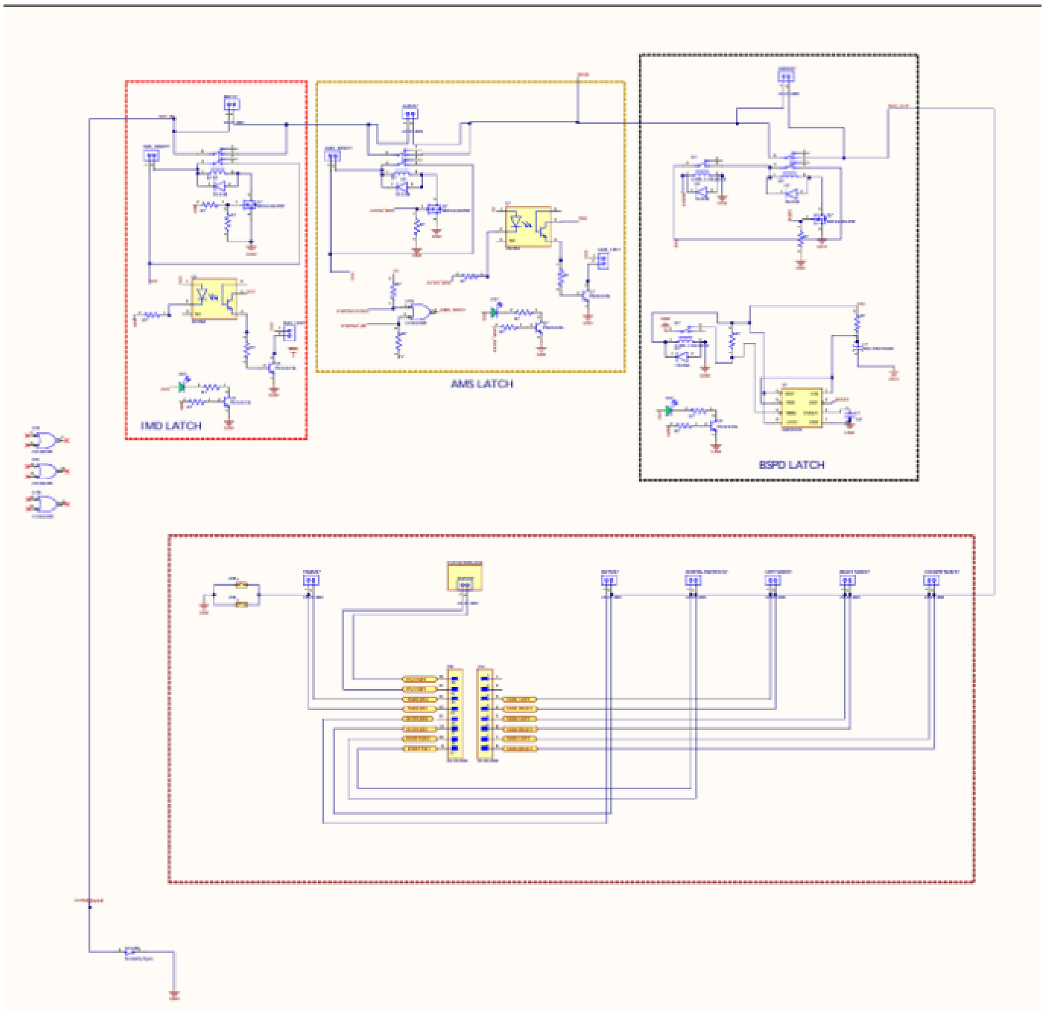
TOP VIEW



ISOMETRIC VIEW

Section 5 **Safety Controls and Indicators**

5.1 Shutdown Circuit



Include a schematic of the shutdown circuit for your vehicle including all major components in the loop

Figure 7 – Safety Shutdown Circuit Schematic

Describe the method of operation of your shutdown circuit, including the master switches, shutdown buttons, brake over-travel switch ,etc. Also complete the following table

The master switches have a lockout capability, they can be locked in off position. The shutdown buttons are push to open type. The inertia switch, once opened due to fault remains open until manually reset.

Part	Function (Momentary, Normally Open or Normally Closed)
Main Switch (for control and tractive system; CSMS, TSMS)	Normally open
Brake over-travel switch (BOTS)	Normally closed
Shutdown buttons (BRB)	Normally closed
Insulation Monitoring Device (IMD)	Normally open
Battery Management System (AMS)	Normally open
Interlocks (if used)	N/A

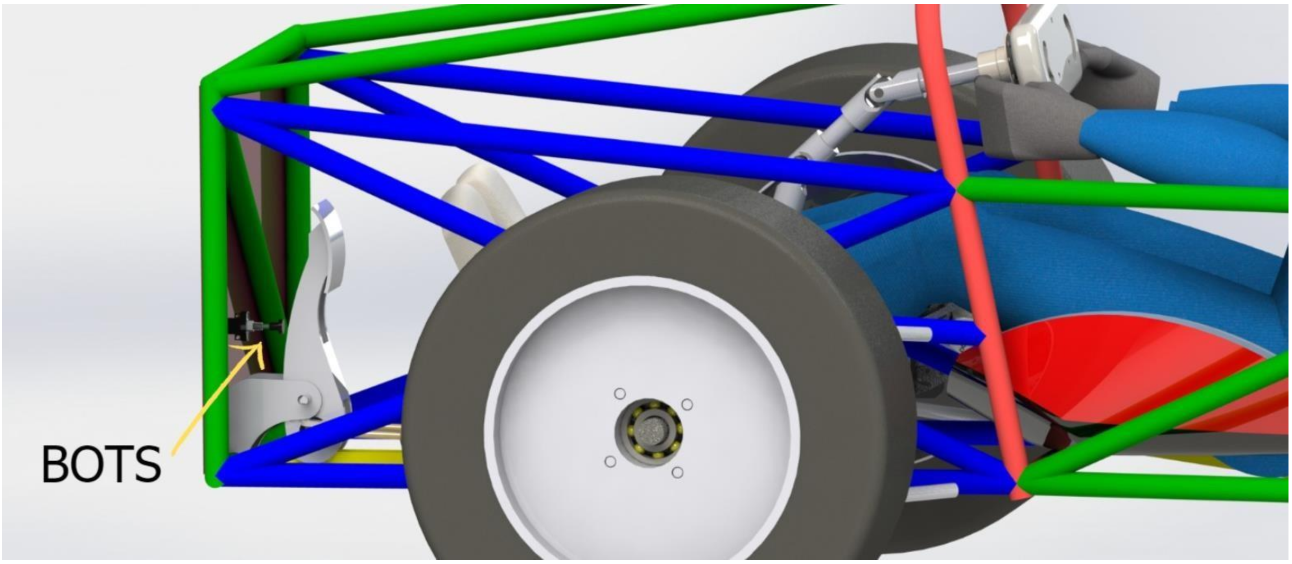
Table 20- Switches& devicesinthe shutdowncircuit

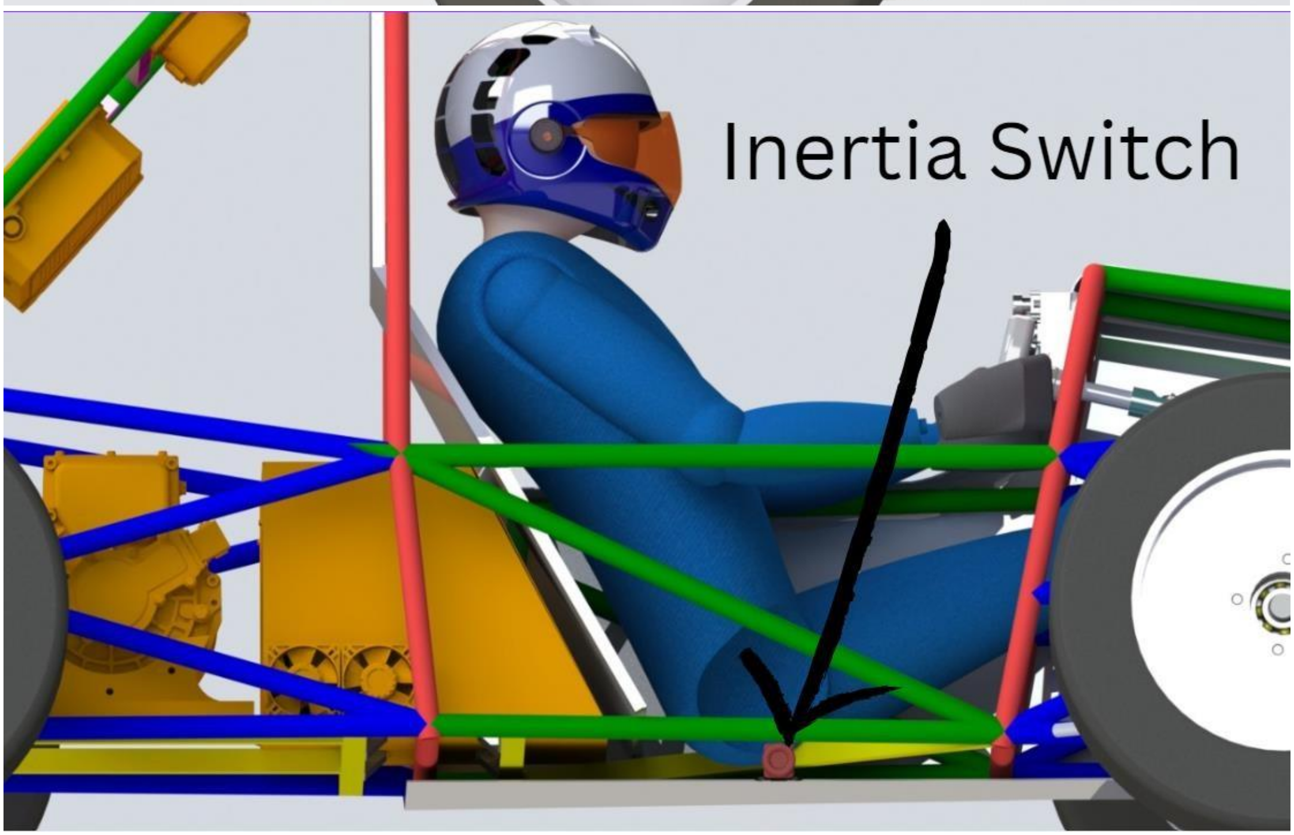
Describe wiring and additional circuitry controlling AIRs. Write a functional description of operation

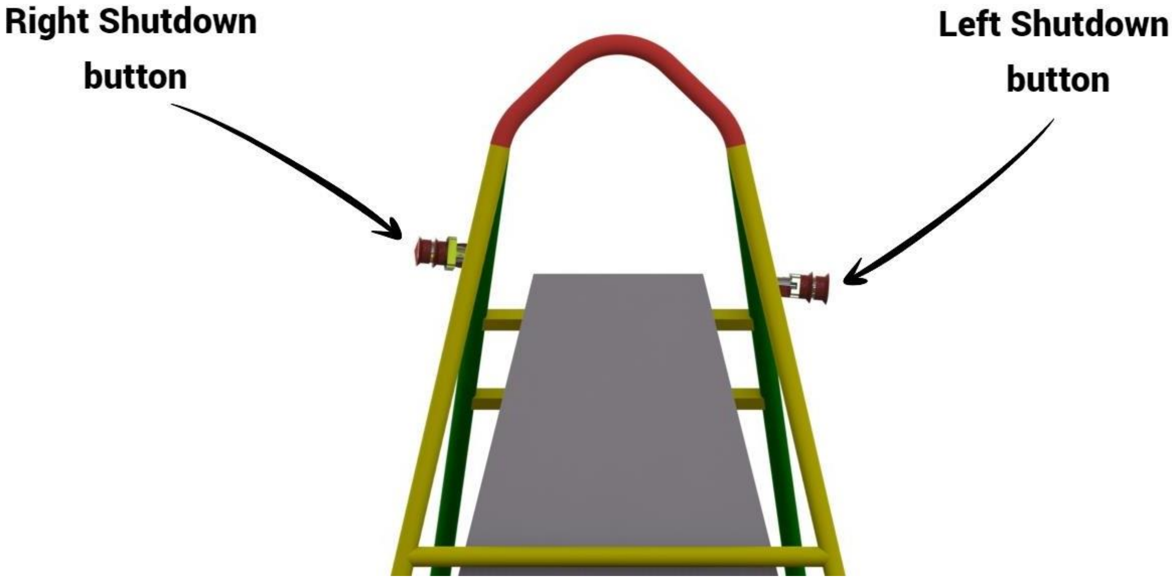
Total Number of AIRs:	2
Coil holding current per AIR:	0.25 A
Current drawn by other components wired in parallel with the AIRs.	2 A
Total current:	2.5 A(nominal)

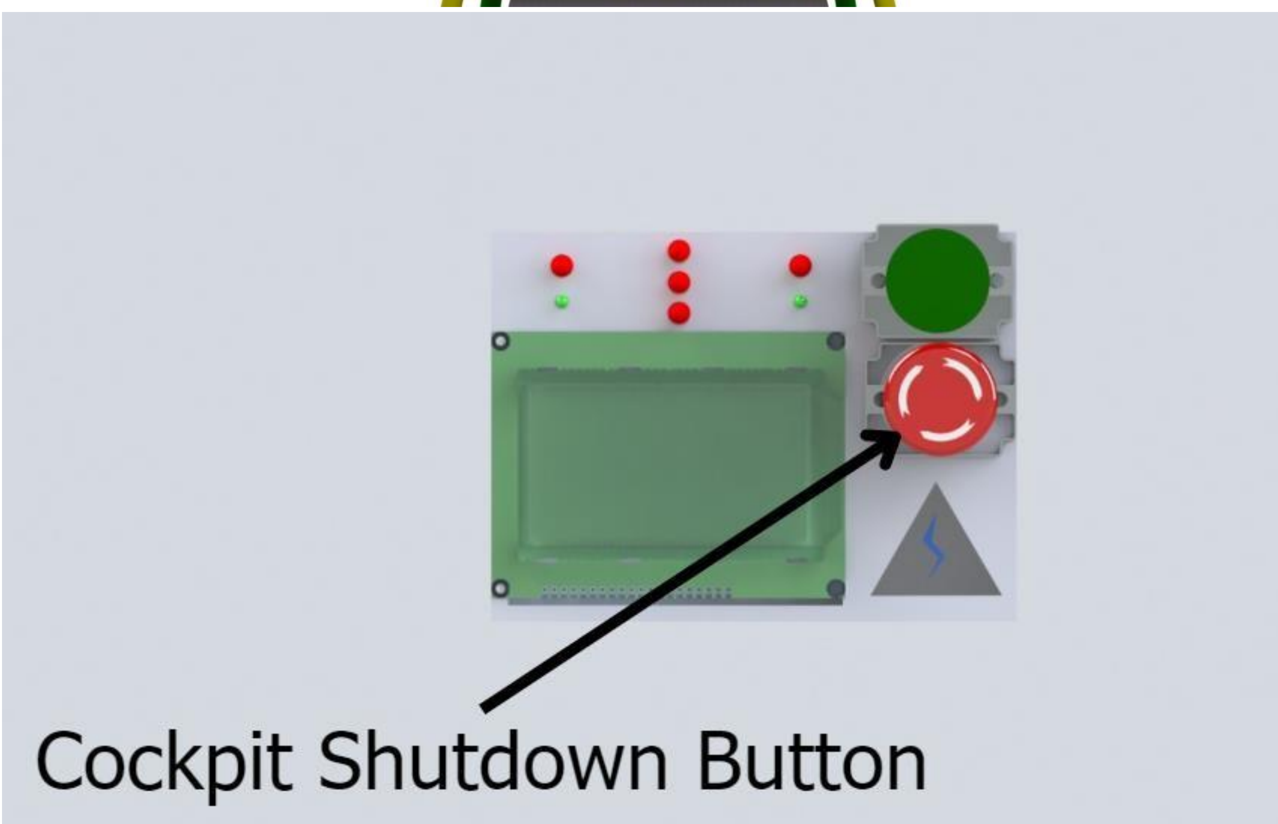
Table 21- Shutdown circuit Current Draw

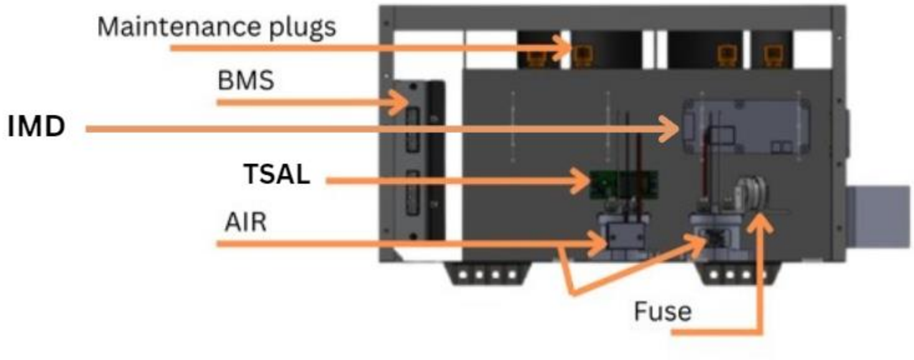
Provide CAD-renderings showing the shutdown circuit parts. Mark the parts in the renderings


BOTS


Inertia Switch


Right Shutdown button
Left Shutdown button


Cockpit Shutdown Button



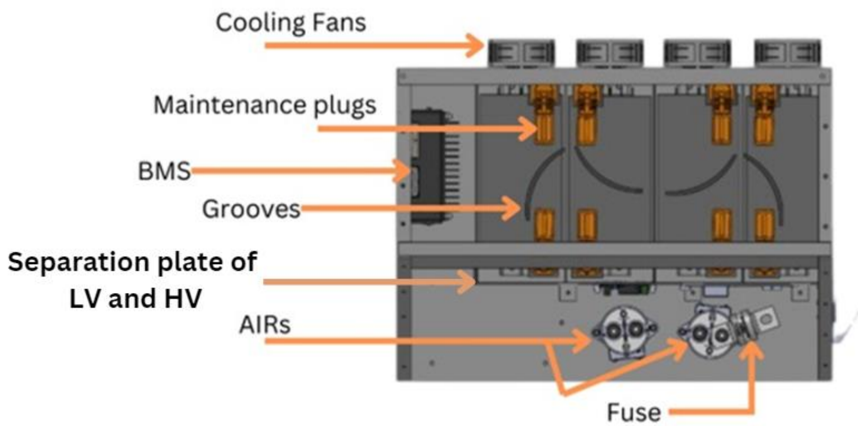


Figure 8 – Location of Shutdown Circuit Components

5.2 IMD

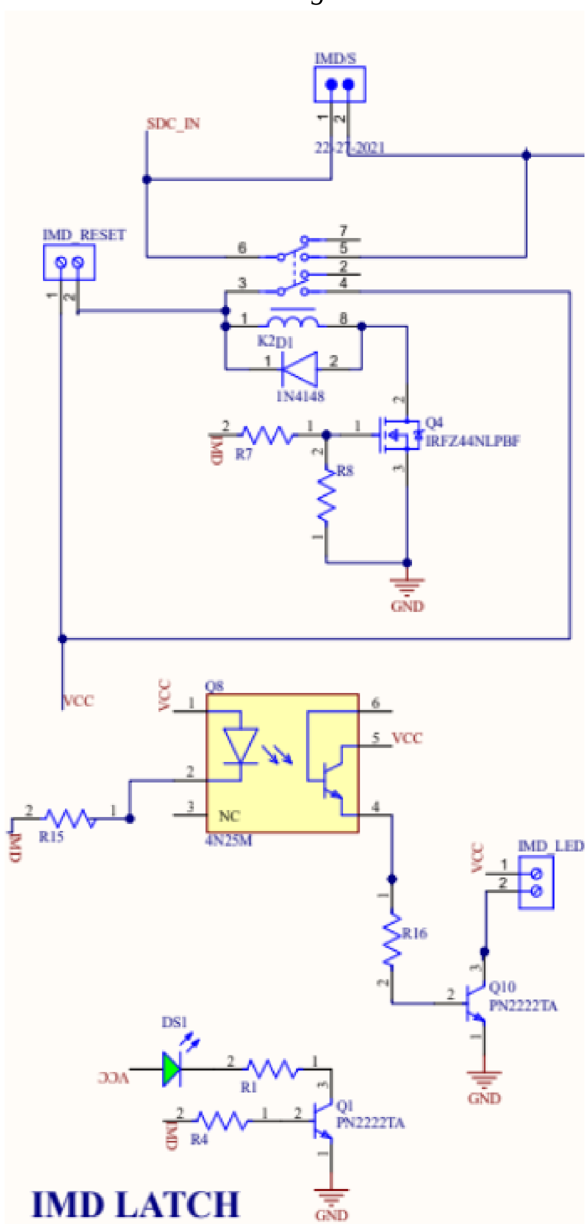
Describe the IMD used and use a table for the common operation parameter like supply voltage, temperature, etc. Describe how the IMD indicator light is wired. Complete the following table.

A DPDT relay is wired parallel to the latch which is used to drive the IMD indicator.

MFR / Model	Bender ISOMETER IR155-3204
Set response value:	48 kΩ (500Ω/Volt)

Table 22 Parameters of the IMD

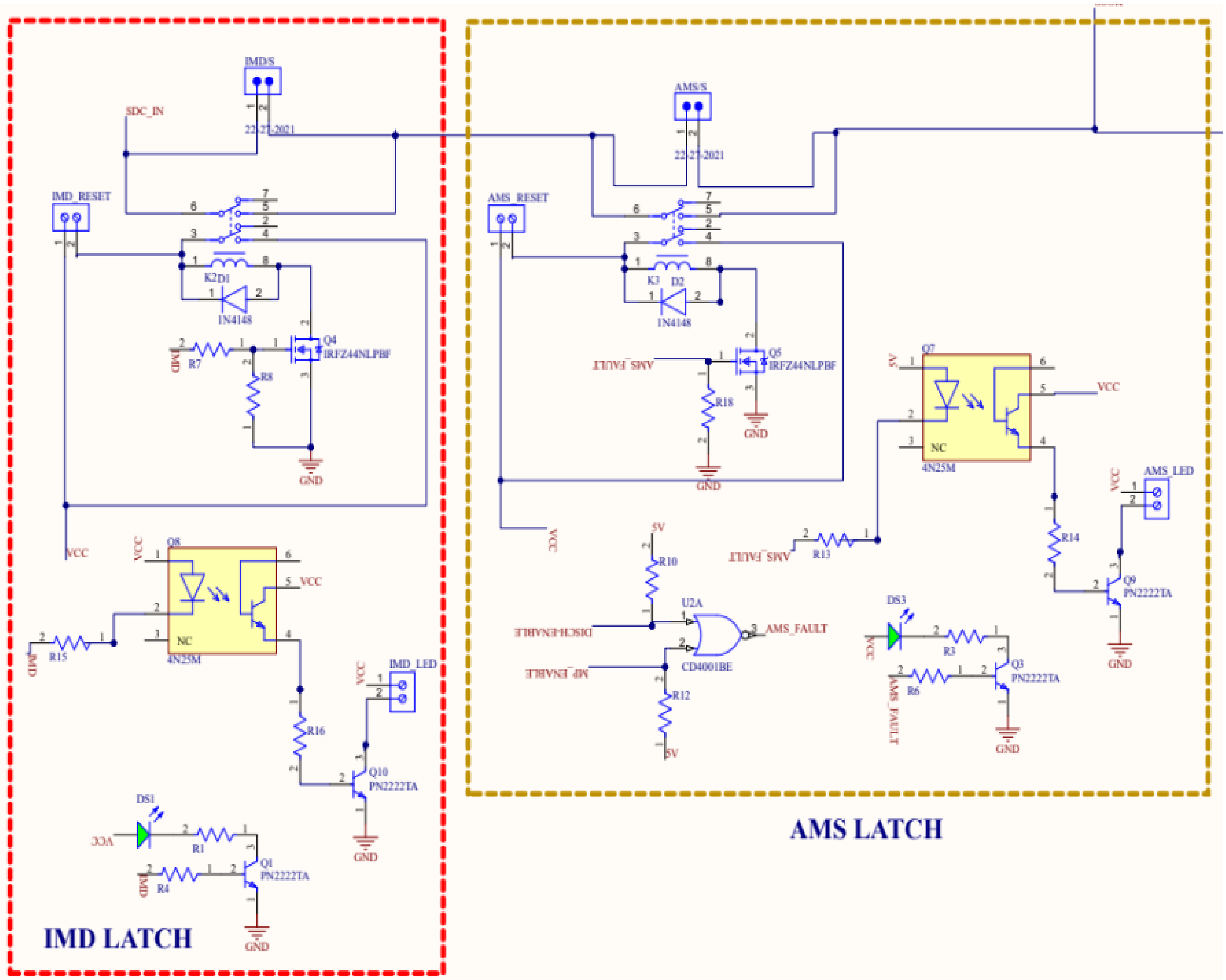
Describe IMD wiring with schematics.



5.3 Reset / Latching for IMD and AMS

Describe the functioning and circuitry of the latching/reset system for a tripped IMD or AMS. Describe wiring, provide schematics.

Both the AMS and IMD output low when fault is detected, once fault is detected, the latch becomes open and remain open until a reset button not accessible to the drive is pressed and the IMD and AMS signals no fault.



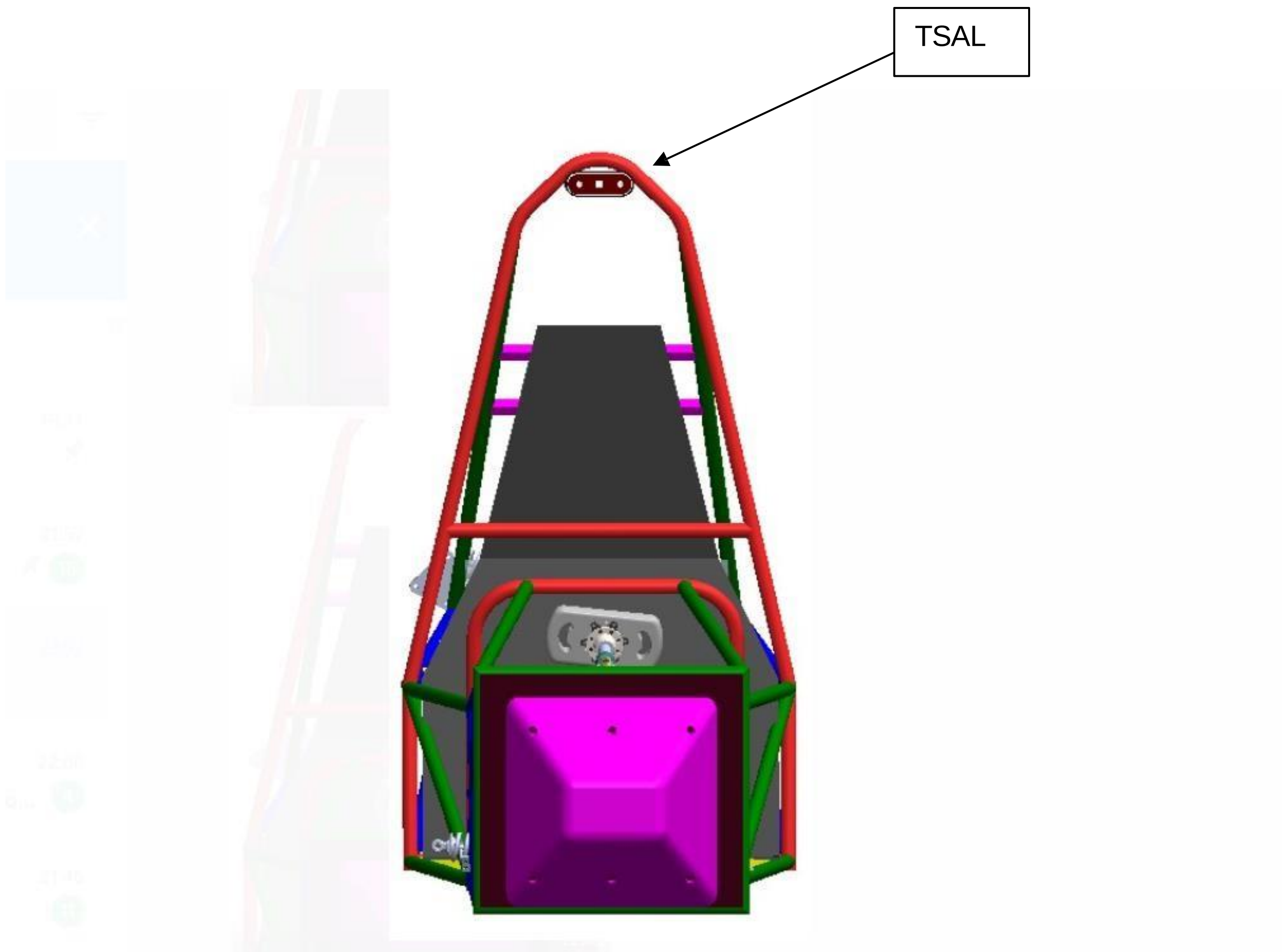
5.4 Shutdown System Interlocks

(If used) describe the functioning and circuitry of the Shutdown System Interlocks. Describe wiring, provide schematics.

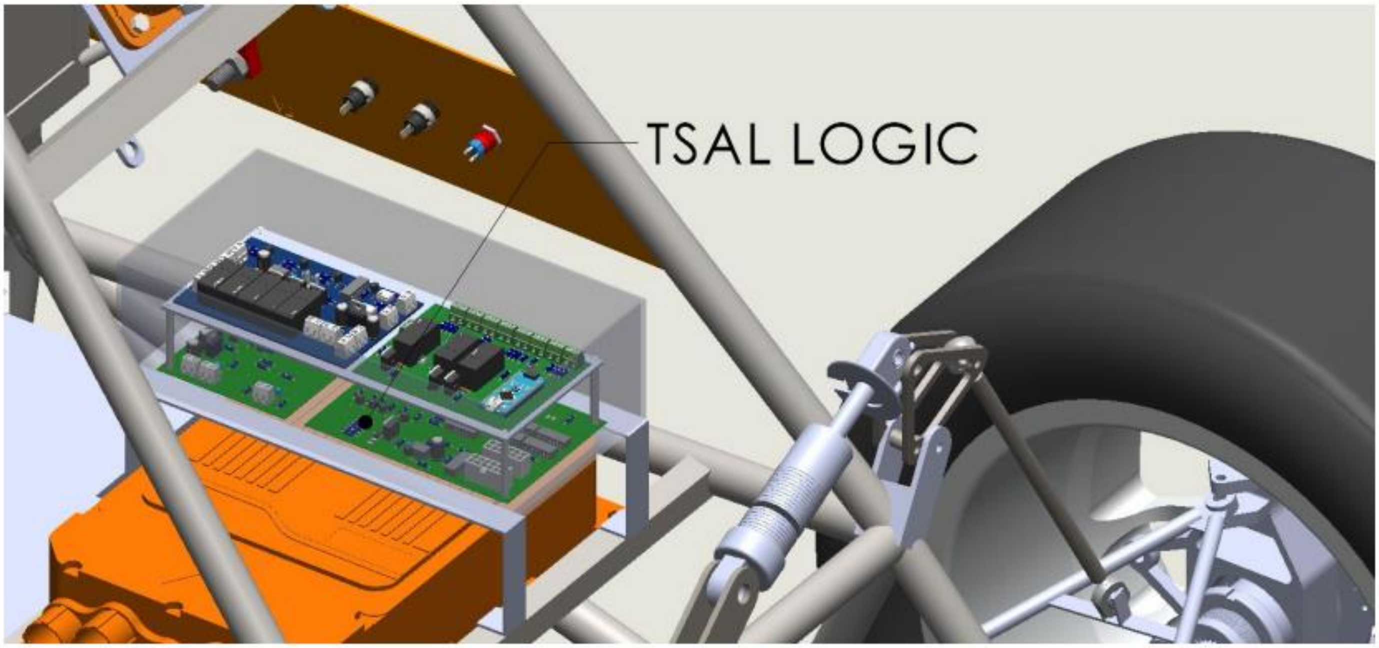
The HVD and accumulator HV connector has a LV interlock which is connected in series in the shutdown circuit. The AIR will remain open if any of the two connectors are disconnected.

5.5 Tractive System Active Lamp (TSAL)

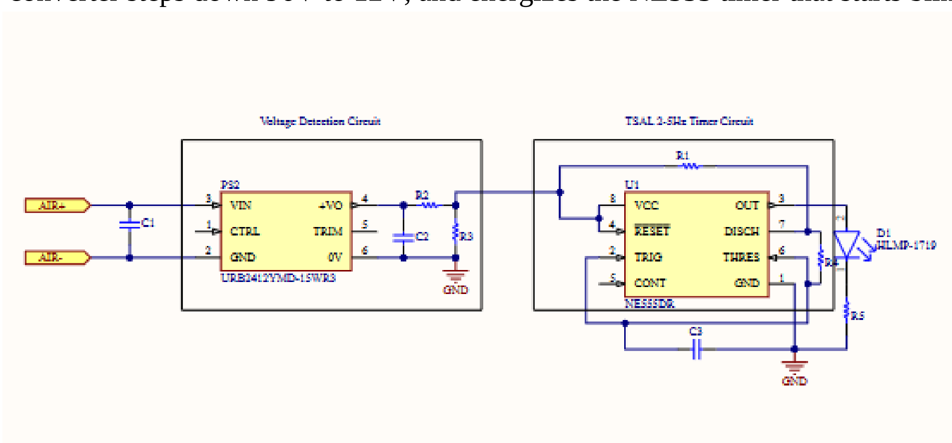
*Describe the tractive system energized light components and method of operation. Describe location and wiring, provide schematics. See **EV7.1.***

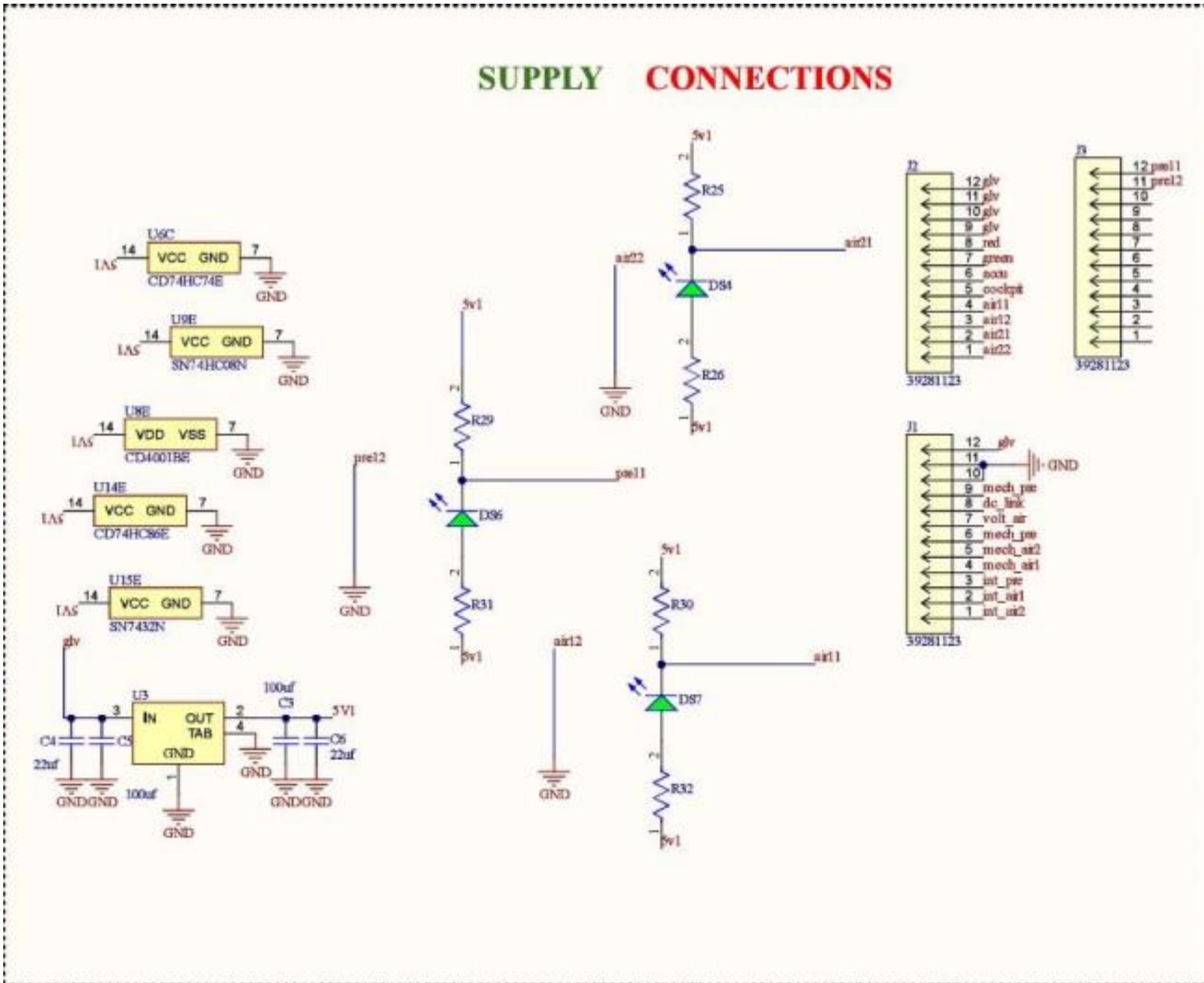


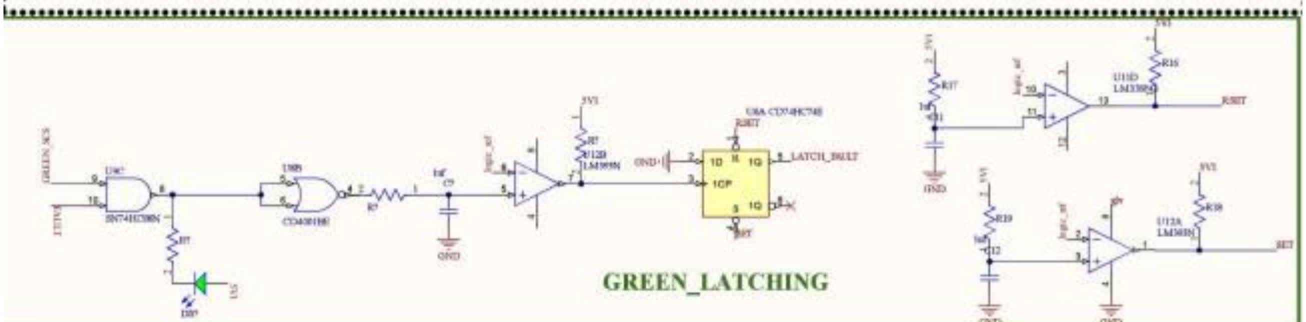
2. Placement of TSAL PCB

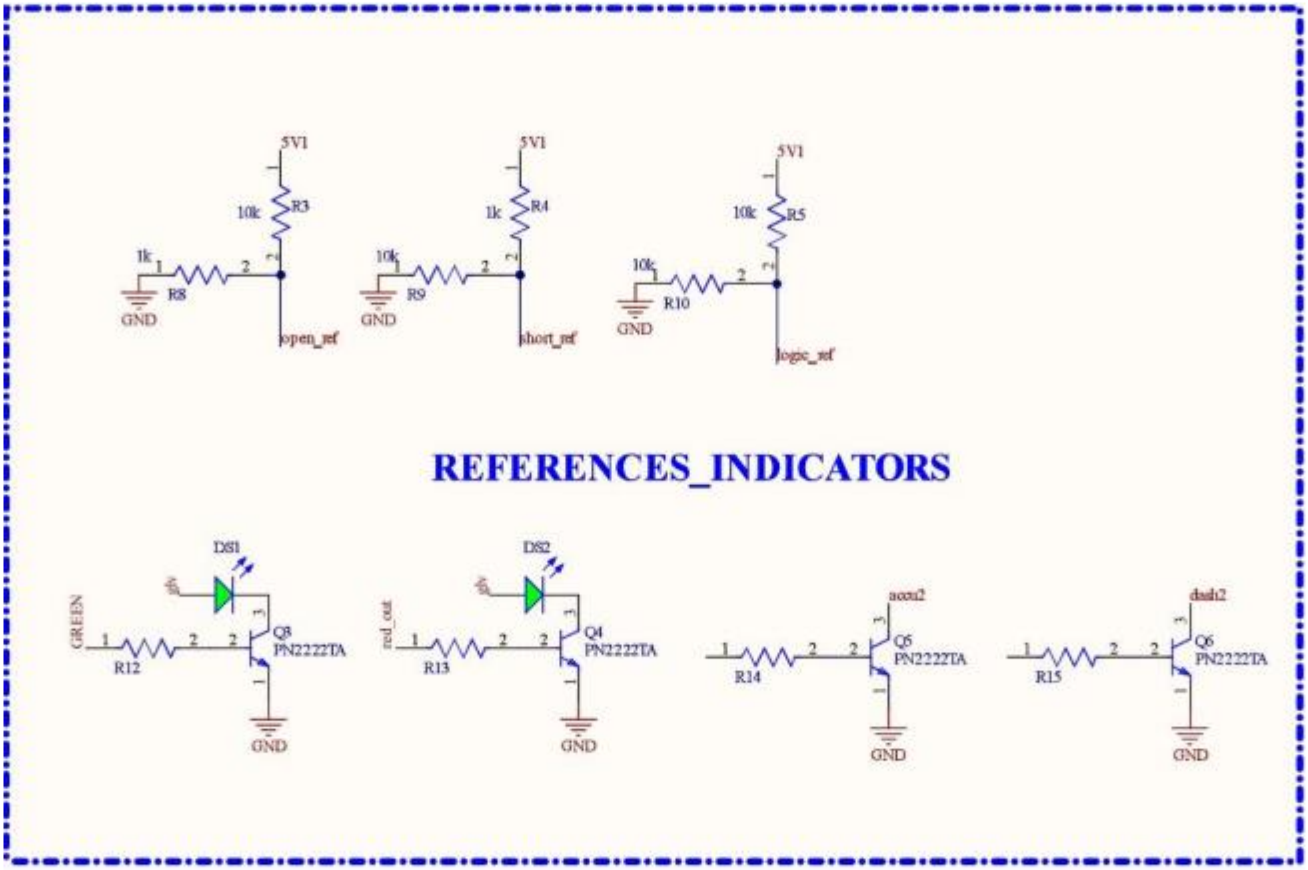


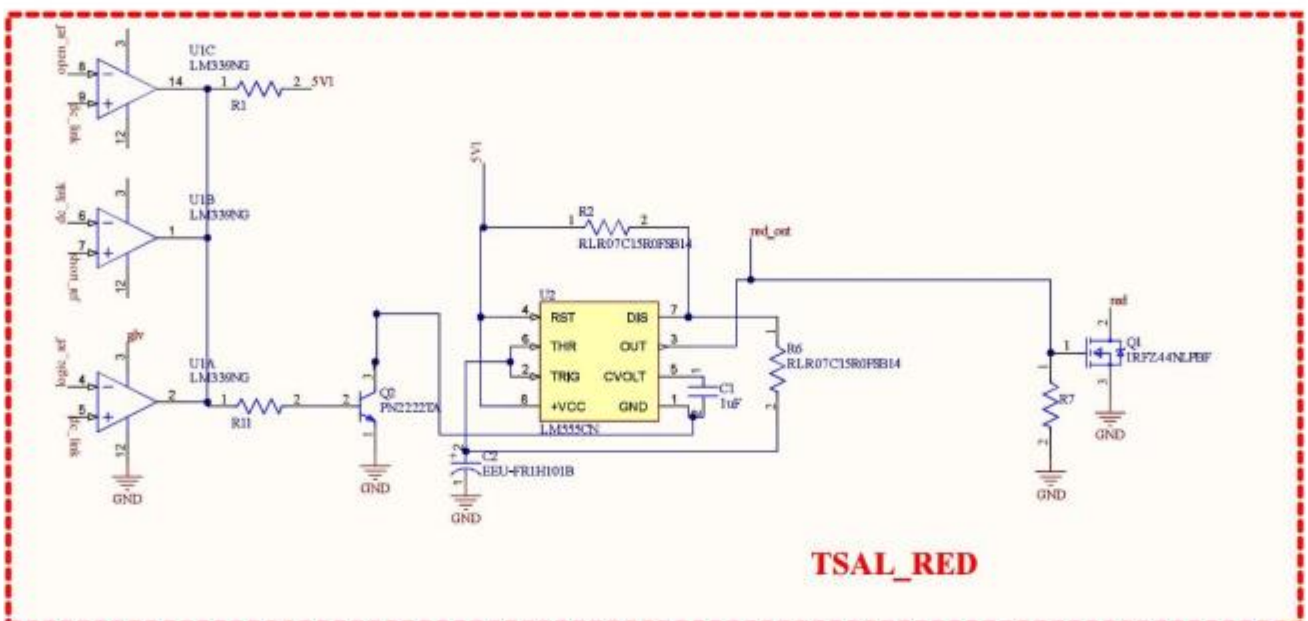
We are using a DC-DC converter that is directly connected to the output side of the AIRs, whenever the AIRs are closed, the converter steps down 96V to 12V, and energizes the NE555 timer that starts blinking at 4Hz.

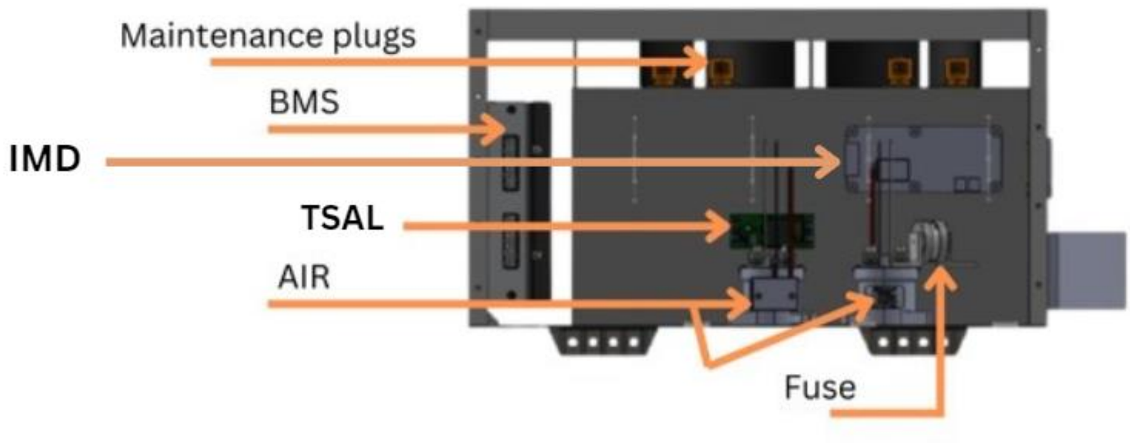



SUPPLY CONNECTIONS
U6C
VCC GND
CD74HC74E
U9E
SN74HC08N
U8E
VDD VSS
CD4001BE
U14E
CD74HC86E
U15E
SN7432N
IAS
GND
glv
U3
IN
OUT
TAB
C4
C5
C3
C6
22uf
100uf
5V1
5v1
R25
R26
R29
R30
R31
R32
DS4
DS6
DS7
air21
air22
air11
air12
pre12
pre11
J2
12 glv
11 glv
10 glv
9 glv
8 red
7 green
6 accu
5 cockpit
4 air11
3 air12
2 air21
1 air22
39281123
J3
12 pre11
11 pre12
J1
12 glv
11
10
9 mech_pre
8 dc_link
7 volt_air
6 mech_pre
5 mech_air2
4 mech_air1
3 int_pre
2 int_air1
1 int_air2


GREEN_LATCHING
SN74HC08N
CD4001BE
LATCH_FAULT
RSET
SET
GND

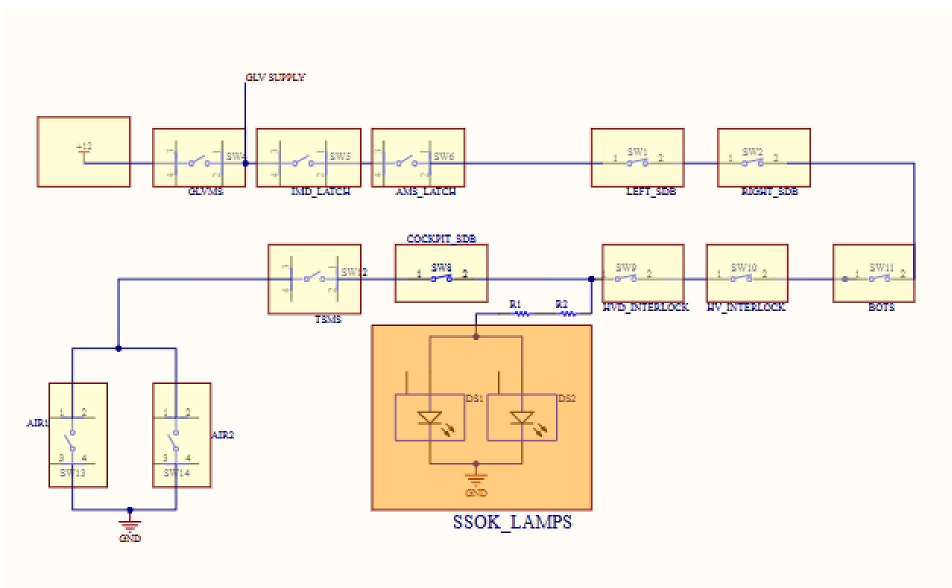

REFERENCES_INDICATORS
5V1
10k
R3
1k
R8
GND
open_ref
1k
R4
10k
R9
short_ref
R5
R10
logic_ref
DS1
DS2
GREEN
red_out
R12
R13
R14
R15
Q3
Q4
Q5
Q6
PN2222TA
accu2
dash2


TSAL_RED
open_ref
U1C
LM339NG
R1
5V1
dc_link
U1B
U1A
logic_ref
R11
Q2
PN2222TA
GND
R2
RLR07C15R0FSB14
red_out
U2
RST
THR
TRIG
+VCC
DIS
OUT
CVOLT
LM555CN
C1
1uF
C2
EEU-FR1H101B
R6
RLR07C15R0FSB14
R7
Q1
IRFZ44NLPBF



5.6 Safety Systems OK Lamp (SSOK)

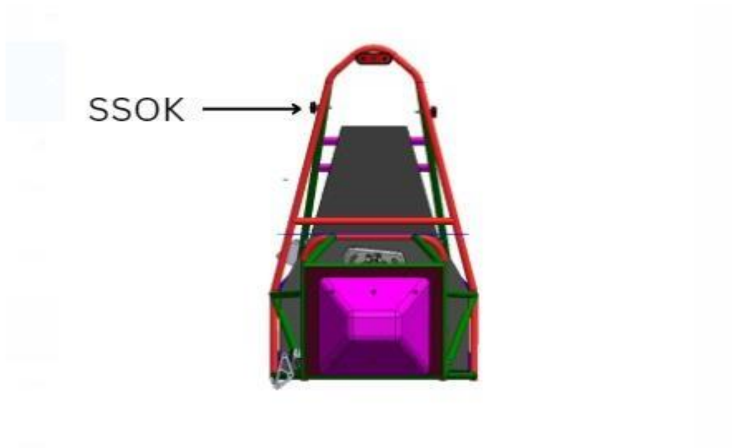
Describe the Safety System OK Lamp components and method of operation. Describe location and wiring, provide schematics.

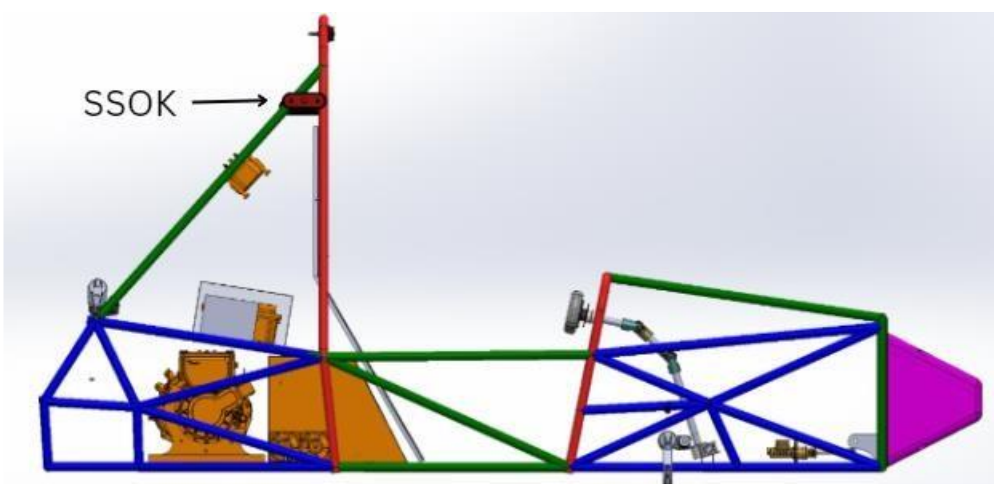


- The SSOK Lamp is wired parallel to the shutdown circuit, if any of the following components:
  - GLV Master Switch
  - Both Side Mounted Shutdown buttons
  - Brake Overtravel Switch
  - Accumulator Monitoring System Latch
  - IMD Latch
  - HV and HVD interlocks

Are open, like Logical AND (if any of the following are open due to fault) will automatically break GLV supply to the SSOK lamp, thus the lamps are automatically extinguished. Also since the cockpit shutdown button and TS master switch are not wired in the SSOK loop, they would not extinguish the lamps.

Location: - One is mounted on each side of the roll bar next to kill switches.





Section 6 **GLV System**

Person primarily responsible for this section:

Name: Rishi Baghel

e-mail: rishibaghe2004@gmail.com

6.1 GLV System Data

Provide a brief description of the GLV system and complete the following table.

GLV System Voltage	12 V
GLV Main Fuse Rating	5 A
Is a Li-Ion GLV battery used?	☐ Yes / ✓ No
If Yes, is a firewall provided?	☐ Yes / ✓ No
Is a dc-dc converter used from TSV?	☐ Yes / ✓ No
Is the GLV system grounded to chassis?	✓ Yes / ☐ No
Does the design comply with **EV3.3**?	✓ Yes/ ☐ No

Table 23- GLV System Data

Section 7 Appendices

Include only highly-relevant data. A link to a web document is often more convenient for the reviewer.

Data Sheets of the components and other related documents can be included here.

- Melasta Cell Datasheet
- Orion BMS-2
- Motor Datasheet
- Motor Controller Datasheet
- All High Voltage Datasheets
- Fuse
- Charger Datasheet
- Fan Datasheet
- FR4 Datasheet