University of Akron
Formula SAE
Electrical System Form

Electrical Safety Form

Car E217

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III List of Abbreviations

- HV: High Voltage
- GLVS: Grounded Low Voltage System
- BMS: Battery Management System
- BMM: Battery Management System Master
- BMSS: Battery Management System Slave (S)
- SAS: Sensor Acquision System
- MCS: Motor Controller System
- SS: Safety System
- DDS: Dasboard Display System

1 System Overview

The Zips Electric Racing 2016 car is a rear wheel drive electric race car sporting a single 79kW motor and a 296 cell (72 series 3 parallel) lithium polymer battery pack. The car is run and controlled by two separate electrical systems, a high voltage (HV) tractive system and grounded low voltage (GLV) system. The tractive system consists of motors, motor controllers, accumulators, AIR's main fusing, and battery management. The GLV system includes control systems, communications, sensors and a portion of the battery management system (BMS)

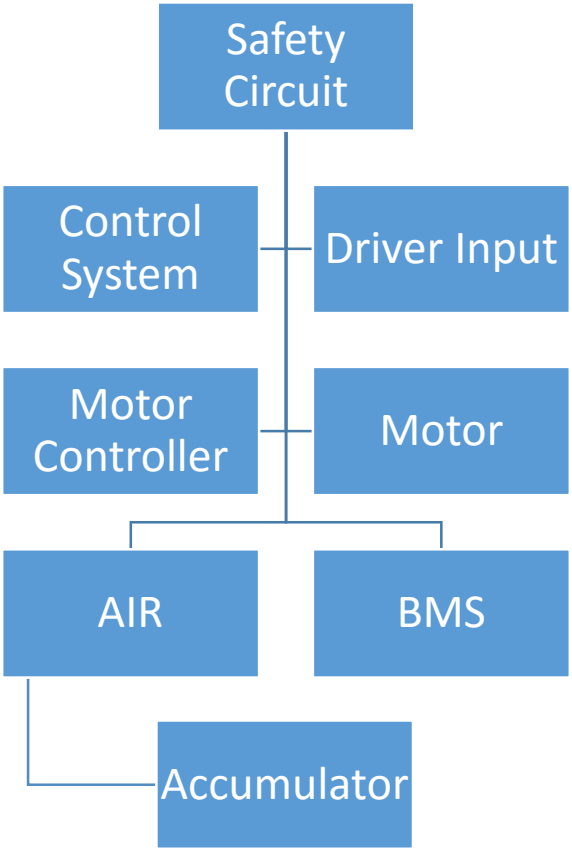


Figure 1. High Level Electrical System Block Diagram

Maximum Tractive-system voltage:	300VDC
Nominal Tractive-system voltage:	266.4VDC
Control-system voltage:	24VDC
Accumulator configuration:	72s3p
Total Accumulator capacity:	21.15Ah 6.24 kW-hours; 22.47MJ
Motor type:	Permanent Magnet Brushless AC
Number of motors:	Total 1 with mechanical differential
Maximum combined motor power in kW	79kW

Table 1.1 General parameters

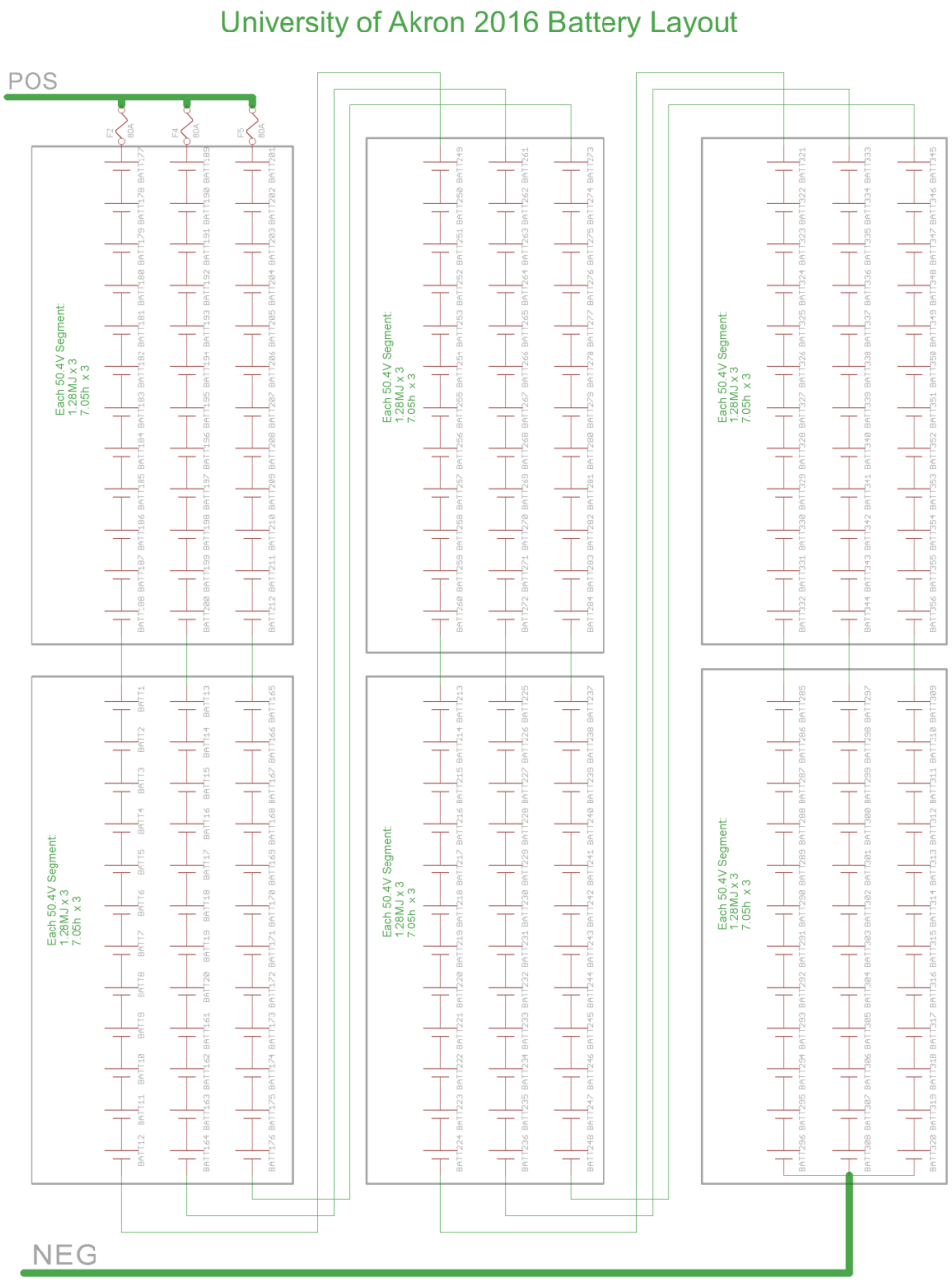


Figure 2. High Level Tractive System Battery Layout

2 Electrical Systems

2.1 Shutdown Circuit

2.1.1 Description/concept

The shutdown circuit consists of a series loop with multiple switches that make or break the control line (powered by the GLVS custom battery pack) to the normally open Accumulator Isolation Relays (AIRs). If any individual switch breaks the loop, the AIRs open and disconnect the accumulator, removing high voltage from the tractive system. System failures that automatically shut down the car include brake over travel (caused by loss of brake pressure), BMS fault (battery over temp. etc.), IMD (loss of isolation), and brake plausibility.

The ECU relay controls the car precharge (EX: the car in a non-ready-to-drive state) until the start button is hit and brake pedal is depressed. The safety circuit and ECU relay prevent the car from entering ready to drive mode if any external faults are present. The ECU relay is used to add hardware and software lockouts. The safety system faults are only cleared with a car power down (AMS,IMD, BSPD), but continuously monitored when powered up again. The shutdown system also examines where the fault occurred to alert the problem.

The car may also be shut down or prevented from starting by E-Stop Switches and the Tractive System Master Switch (TSMS), and High Voltage Disconnect (HVD). The TSMS shown in below is operated by a red key which the safety officer controls. This ensures that the car cannot be started without the safety officer present.

Figure 3. Tractive System Master Switch and Key

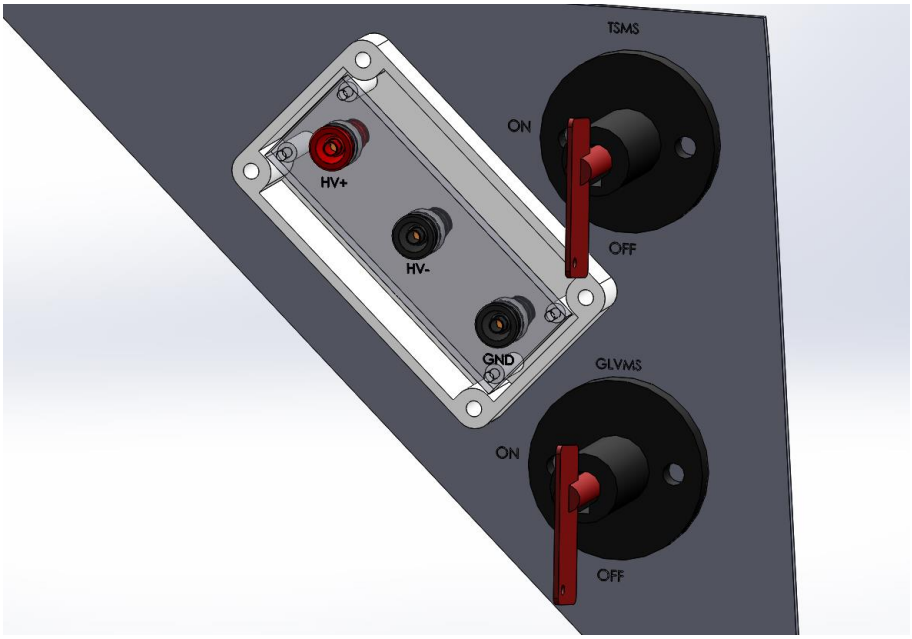


Figure 4 TSMS and GLVMS in the OFF position

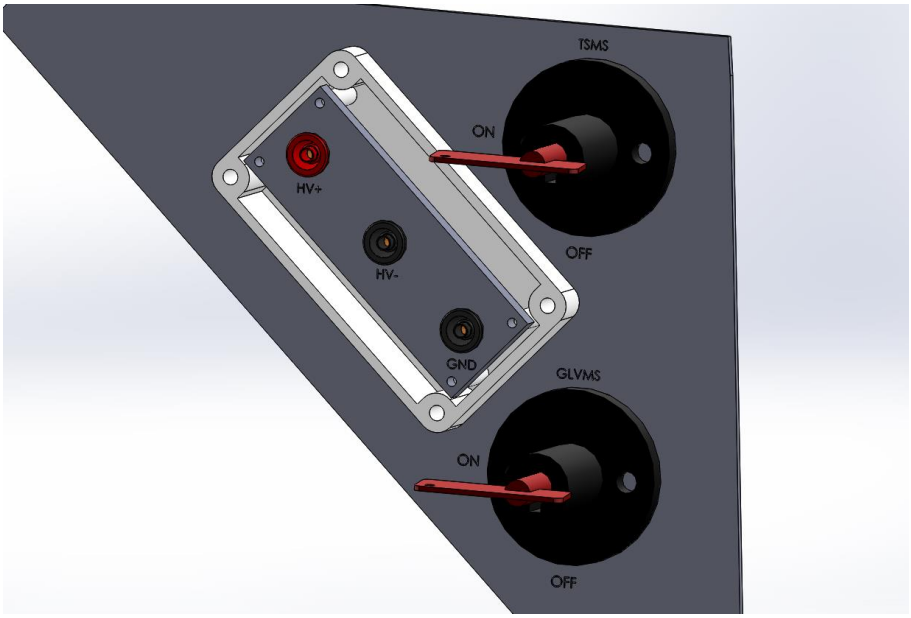


Figure 5 TSMS and GLVMS in the ON position

Part	Function
Main Switch (for control and tractive-system; CSMS, TSMS)	Normally open
Brake over travel switch (BOTS)	Normally closed
Shutdown buttons (SDB)	Normally closed
Insulation Monitoring Device (IMD)	Normally closed
Battery Management System (BMS)	Normally closed
Inertia Switch	Normally closed
Interlocks	Closed when connectors are closed
Brake System Plausibility Device	Normally Closed
Software System (ECU)	Normally Closed

Table 2.1 List of switches in the shutdown circuit

2.1.2 Wiring / additional circuitry

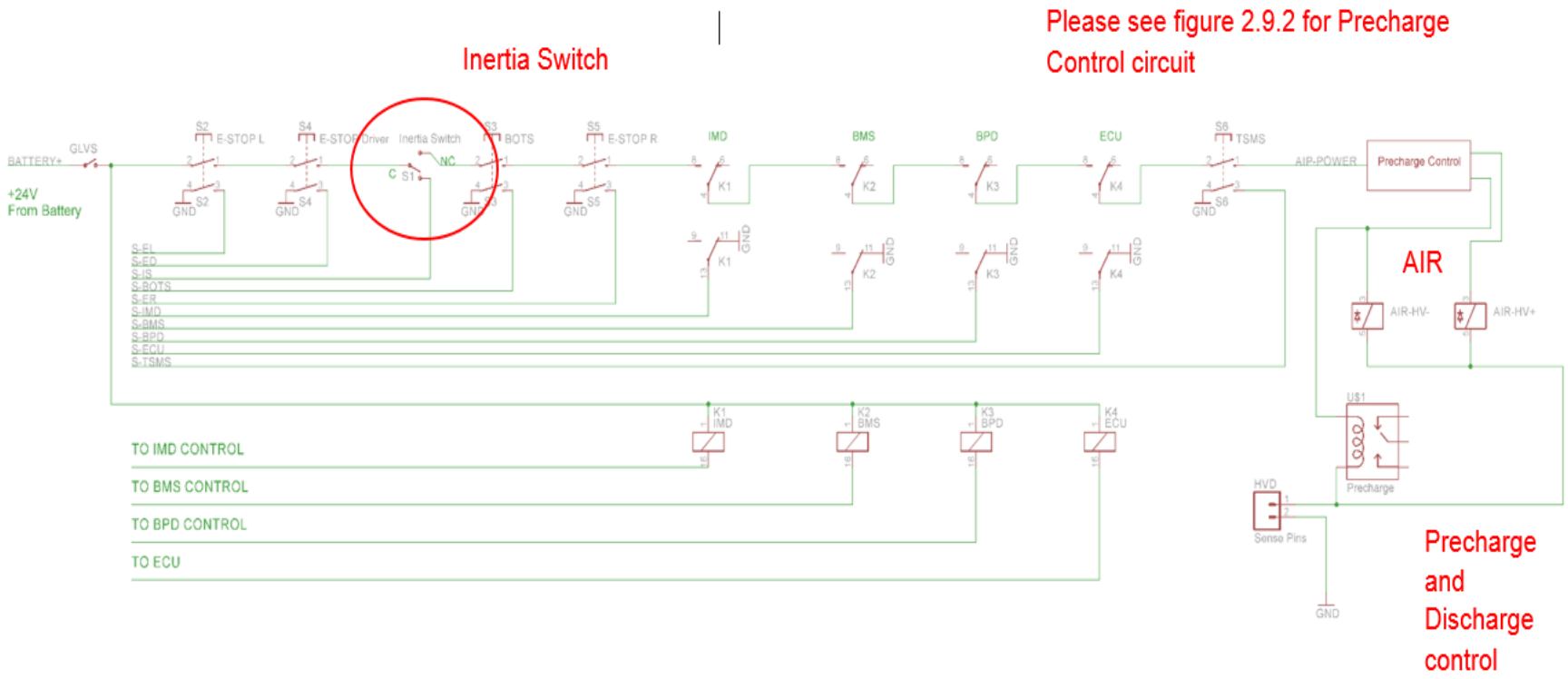


Figure 6 Safety Circuit Layout

Main and Pre+ are outputs of the pre charge control circuitry.

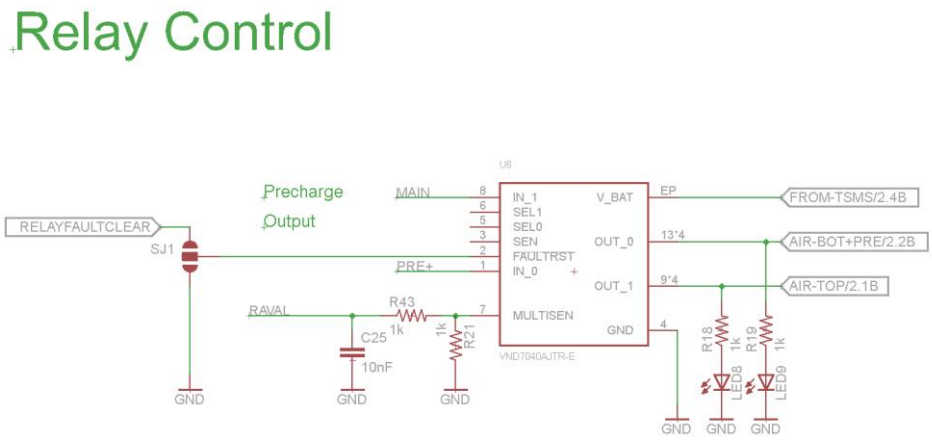


Figure 7 AIR Controller

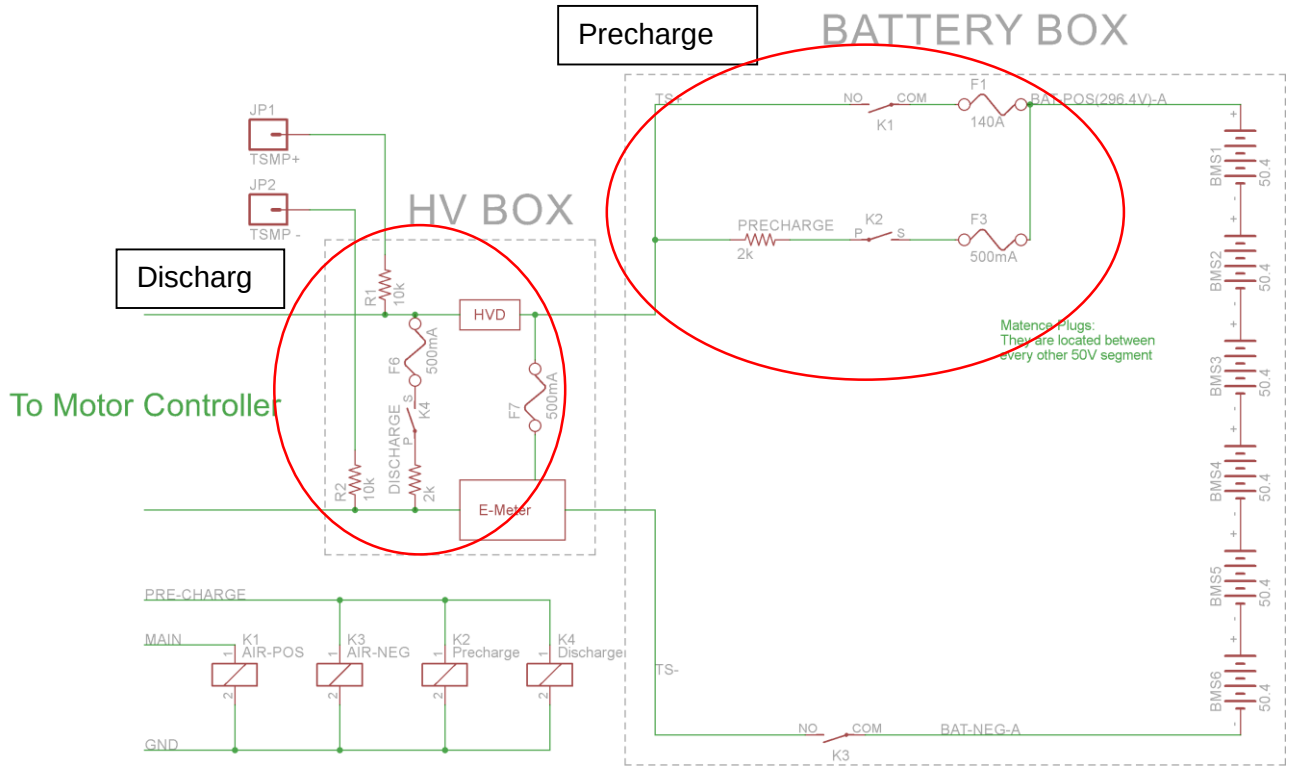


Figure 8 Pre-Charge/Discharge Circuit

Total Number of AIRs:	2
Current per AIR:	0.5A
Additional parts consumption within the shutdown circuit:	1A
Total current:	2A
Cross sectional area of the wiring used:	0.205 mm²

Table 2.2 Wiring – Shutdown circuit

2.1.3 Position in car

Disconnect, driver e-stop, and left e-stop:

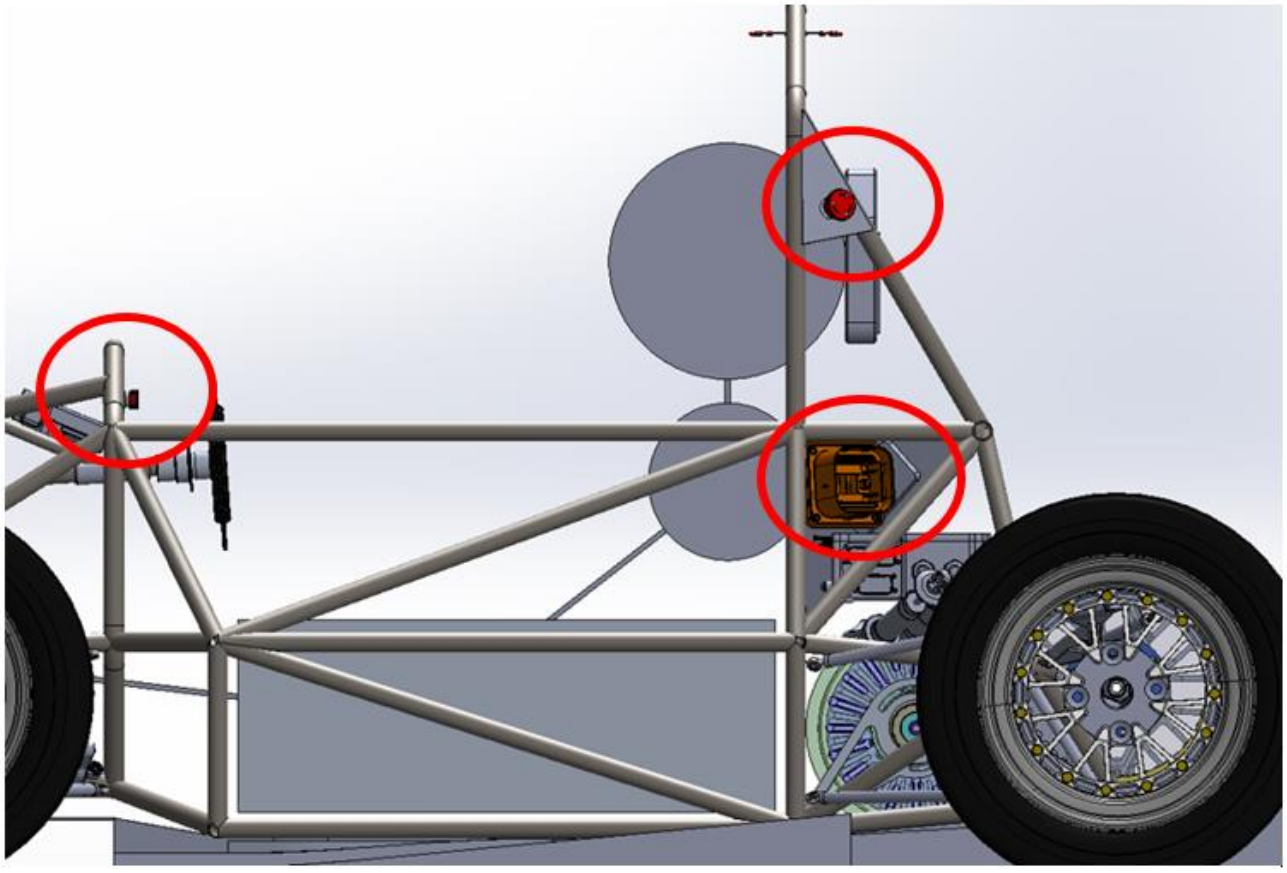


Figure 9 E-Stop Placement

Driver e-stop, right e-stop and left e-stop:

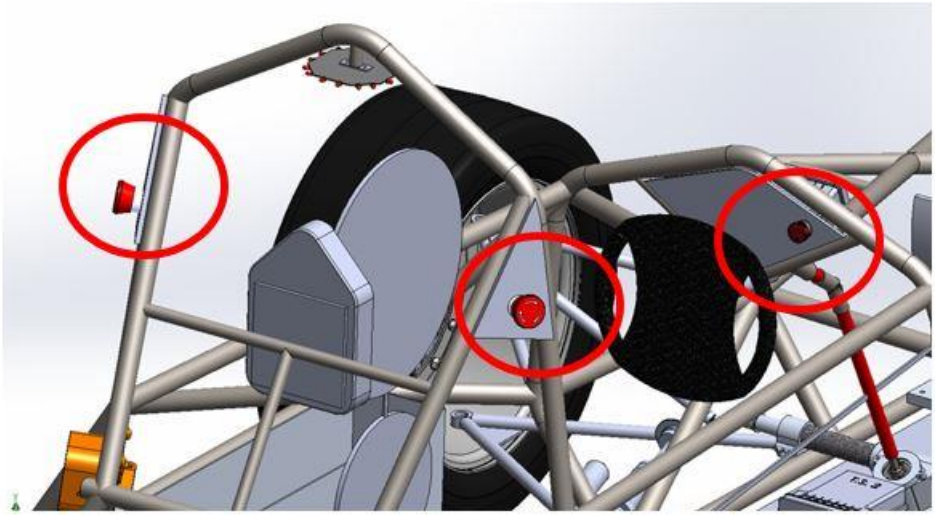


Figure 10 E-Stop Placement

BOTS:

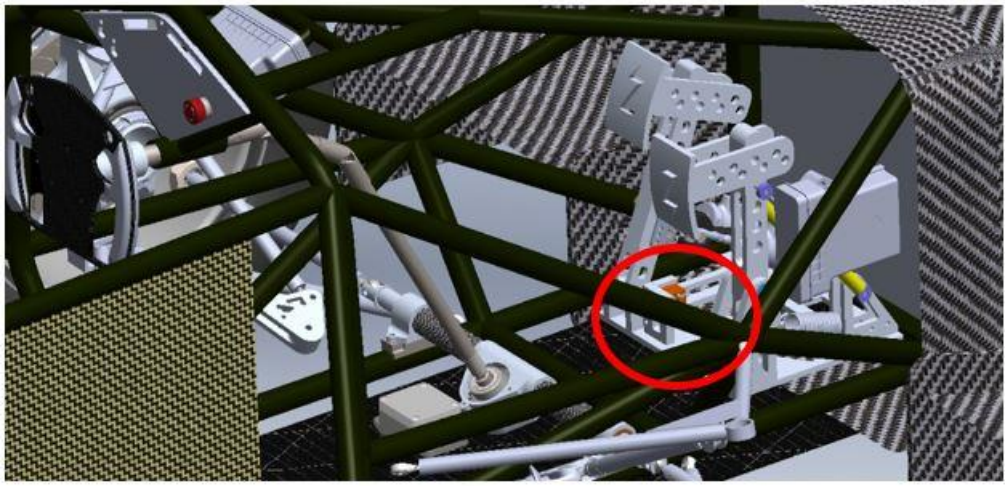


Figure 11 BOTS Switch Placement

Inertia Switch:

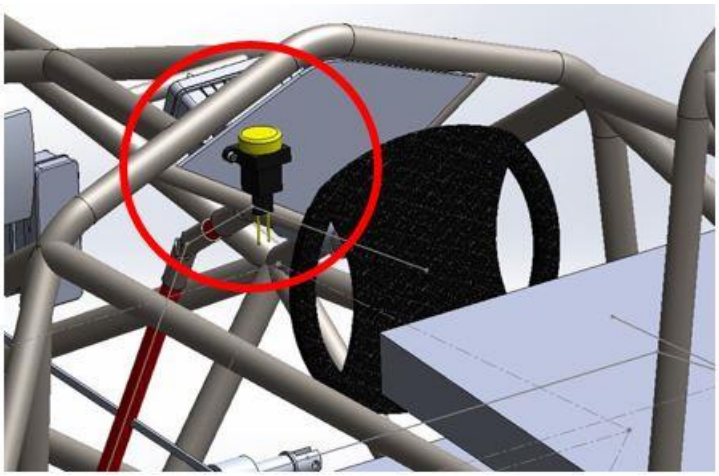


Figure 12 Crash Sensor Placement

2.2 IMD

2.2.1 Description (type, operation parameters)

Bender IR155-3203 IMD, Automatic Device Self-test and Continuous measurement of insulation resistance. The indicator is wired to the front dash. The LED is lit by software cue from the safety system (SS) to the Dashboard Display System DDS controller warning the driver. The system is not able to be reset unless there is a GLVMS power cycle. We use a Latching relay to allow for a lockout condition.

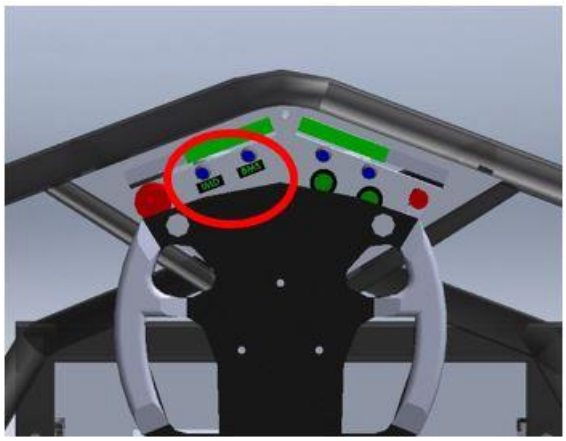


Figure 13 BMS & IMD Indicator Lights

Supply voltage range:	10..36VDC
Supply voltage	24VDC
Environmental temperature range:	-40..105°C
Selftest interval:	Always at startup, then every 20 minutes
High voltage range:	DC 0..1000V
Set response value:	147kΩ (500Ω/Volt)
Max. operation current:	500mA
Approximate time to shut down at 50% of the response value:	27s

Table 2.3 Parameters of the IMD

2.2.2 Wiring/cables/connectors/

The IMD requires 11.1.224 AWG PVC Insulated Hookup Wire with a 300v and 105C rating. We have 500mA fast blow fuses on the HV+ and -.

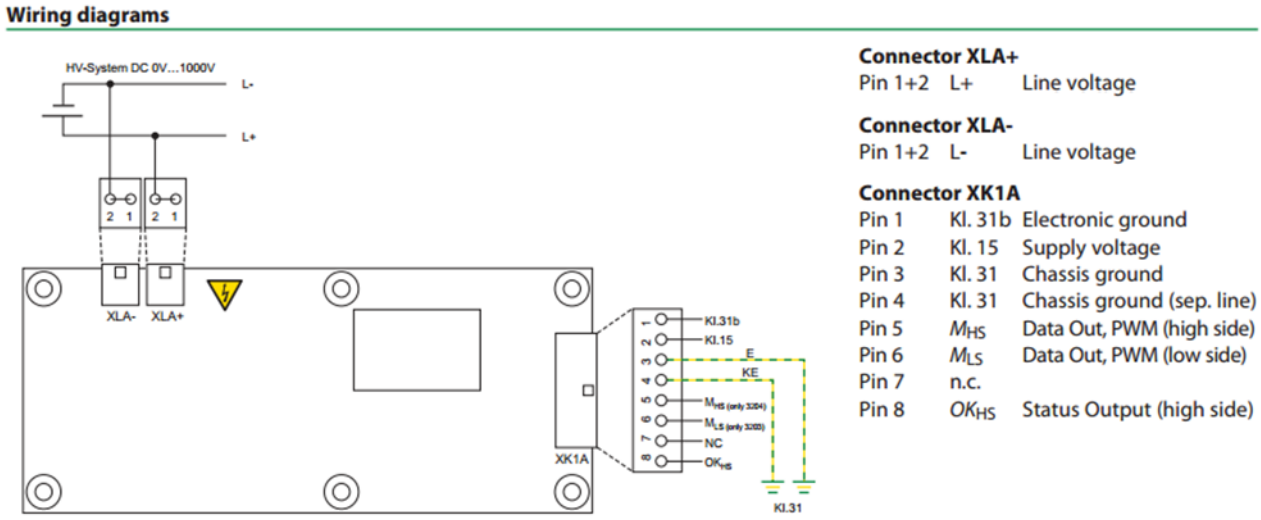
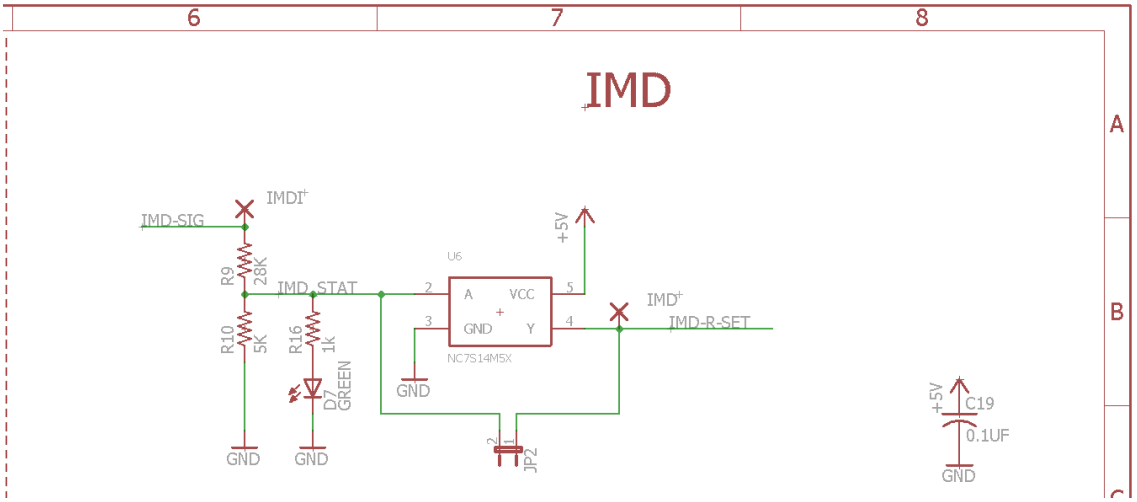
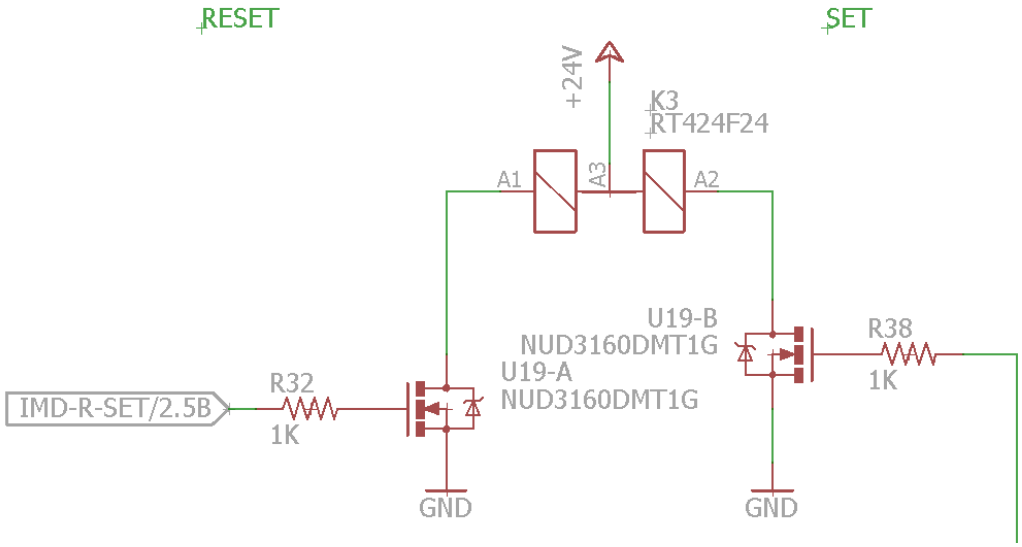


Figure 14 IMD Wiring Diagram


6
7
8
IMD
A
B
IMD-SIG
IMDI+
R9
28K
IMD_STAT
R10
5K
R16
1k
D7
GREEN
GND
GND
U6
A
VCC
GND
Y
NC7S14M5X
+5V
IMD+
IMD-R-SET
GND
JP2
+5V
C19
0.1UF
GND


RESET
SET
+24V
K3
RT424F24
A1
A3
A2
U19-B
NUD3160DMT1G
U19-A
NUD3160DMT1G
R38
1K
IMD-R-SET/2.5B
R32
1K
GND
GND

2.2.3 Position in car

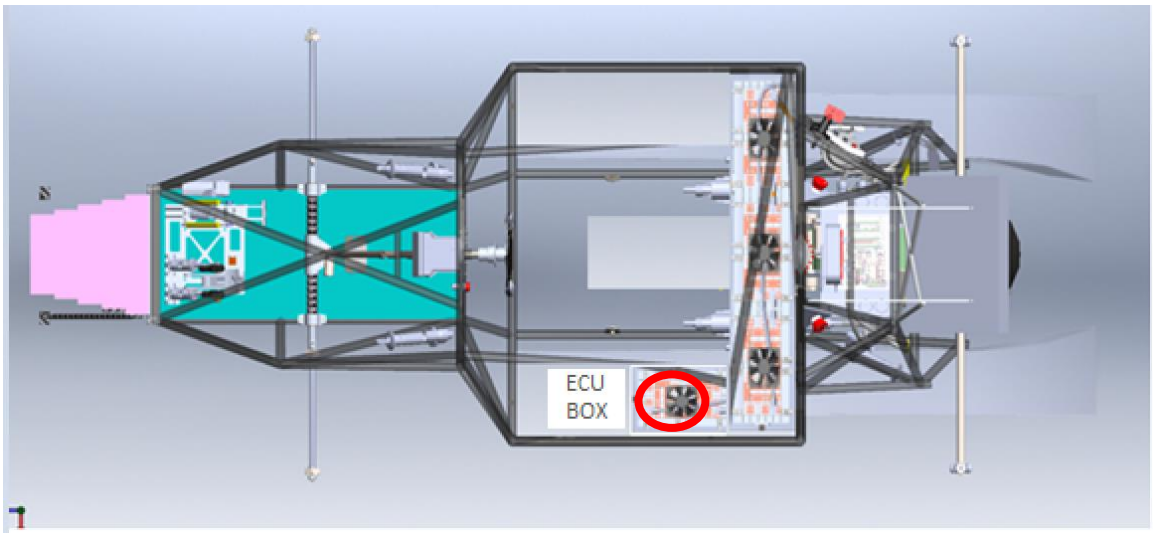


Figure 15 IMD Placement in Accumulator

2.3 Inertia Switch

2.3.1 Description (type, operation parameters)

Crash Sensor

Sensata resettable **inertial switch** will be normally closed and will open to shut down the tractive system in the event of a crash. This is hooked up in series with the other safety switches that control the AIR's so if it went off the tractive system would become unpowered. The driver will have the ability to depress the Sensata crash sensor to reset it. The crash sensor is removable from the dashboard with two screws and an electrical connector to allow for testing the device at competition.

Inertia Switch type:	Sensata resettable inertial switch XYZ
Supply voltage range:	10..36VDC
Supply voltage:	24VDC
Environmental temperature range:	-40..105°C
Max. operation current:	10A
Trigger characteristics:	6g for 50ms / 11g for 15ms

Table 2.4 Parameters of the Inertia Switch

2.3.2 Wiring/cables/connectors/

The crash sensor will be rigidly mounted to the frame of the car near the bottom to ensure that it receives the full force of any vibration or impact using a mating connector and 18 AWG PVC Insulated Hookup Wire 105C, 300v wire will be used for the electrical connections.

2.3.3 Position in car

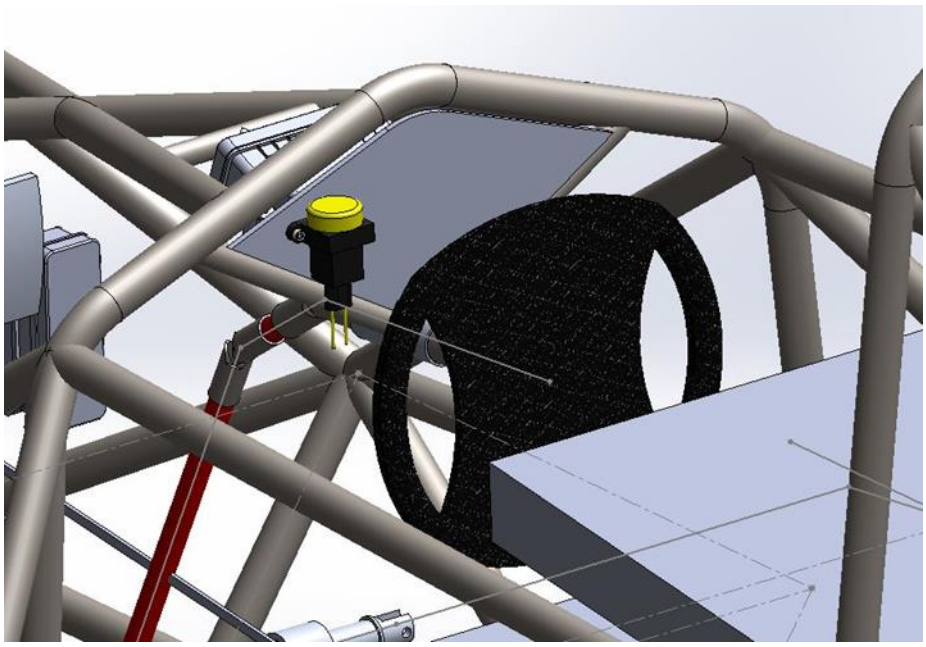


Figure 16 Inertia Switch Placement in Car

2.4 Brake Plausibility Device

2.4.1 Description/additional circuitry

The purpose of the brake plausibility system is to ensure that the brake pedal does not pass a certain threshold if the motors are being driven. It will work by using Honeywell Brake Pressure Sensors to measure braking and a current sensor on the connection between the accumulator and motor controllers to measure the current. These measured values will be compared by op-amps to pre-calculated constant threshold values set by potentiometers. The current set point is at 16.6A. To reset this system, it requires a GLVMS power cycle.

Brake sensor used:	PX2AF1XX500PAAAX (See 11.2.4.1)
Torque encoder (current sensor) used:	Current shunt
Supply voltages:	5V
Maximum supply currents:	20mA
Operating temperature:	-40..100 °C
Output used to control AIRs:	Open a relay

Table 2.5 Torque encoder data

2.4.2 Wiring

The brake plausibility system takes a 9V power input from the LV power system, along with 0-5Vdigital sensor input from the brake pedal sensor and the current sensor on the motor supply. The only output is the on or off 24v relay power that goes to the shutdown circuit. The reset of this system is done by power cycling the GLVMS.

2.4.3 Position in car/mechanical fastening/mechanical connection

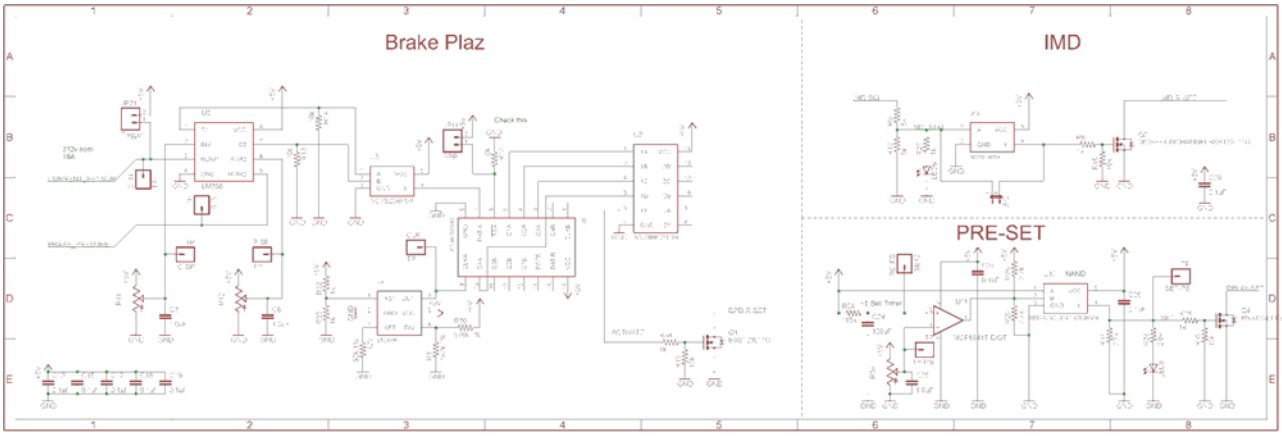


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Figure 17. Brake Plausibility Schematic

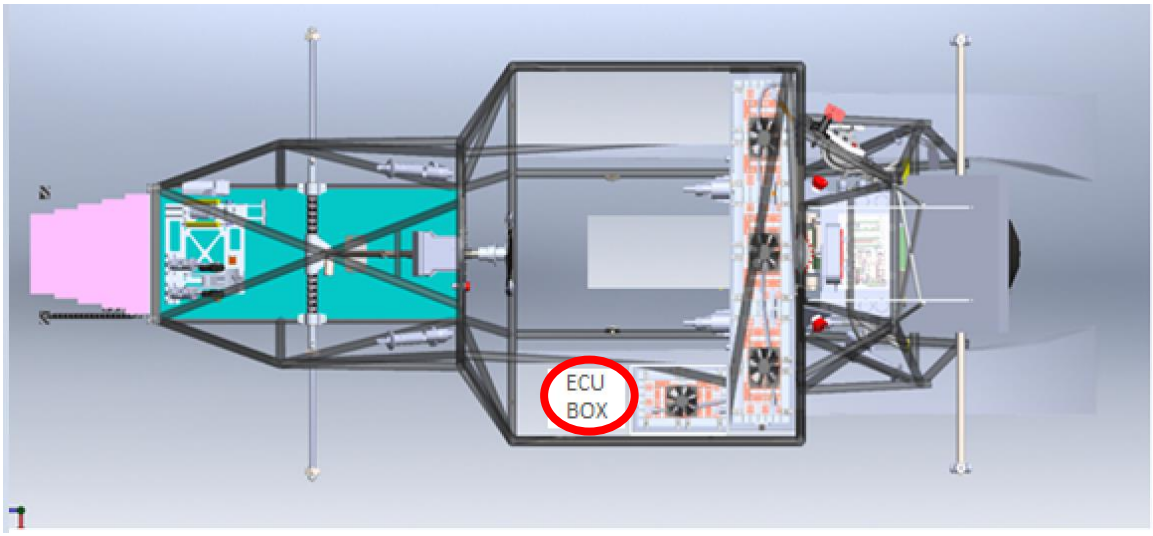


Figure 18 Brake Plausibility/ECU Location

2.5 Reset / Latching for IMD and BMS

2.5.1 Description/circuitry

If the IMD or BMS becomes tripped, the latching relays will open. A GLVS power cycle will reset these systems or pushing the reset button. The latching relays are set by the PRE-SET circuit. Below is the IMD hardware Safety System. The BMS is done in software but is only reset (turned on) during startup.

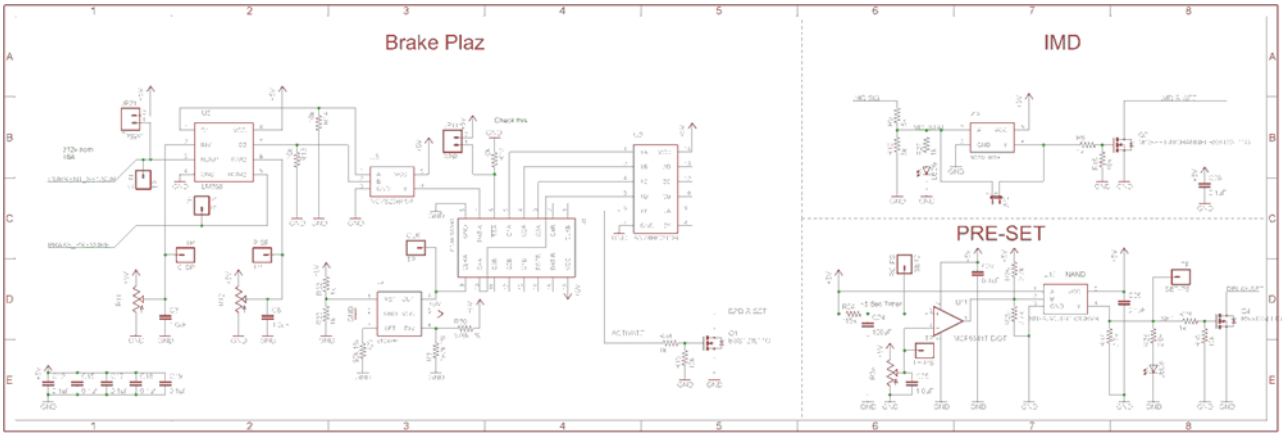


Figure 19 IMD Schematic

2.5.2 Wiring/cables/connectors

The BMS and IMD relay is wired into the shutdown system in series with other safety systems. The Tractive system active light (TSAL) is wired with 24 AWG PVC Insulated Hookup Wire with a 300v and 105C rating. The BMS has a relay on the PCB that it can trip to open the shutdown circuit.

2.5.3 Position in car

IMD:

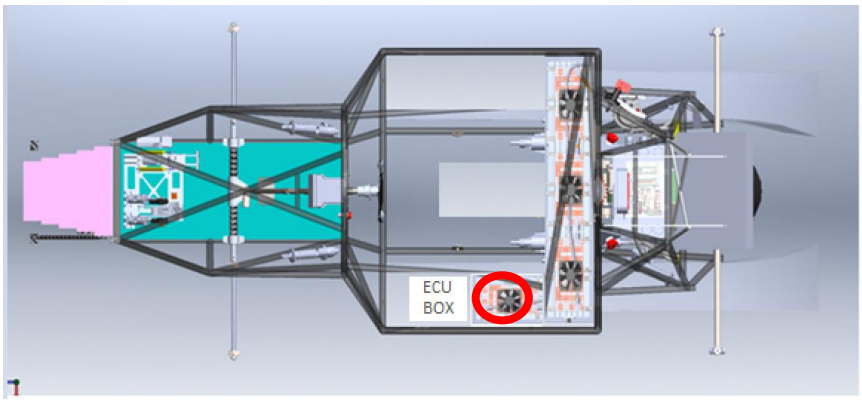


Figure 20 IMD Placement in Accumulator (Global View)

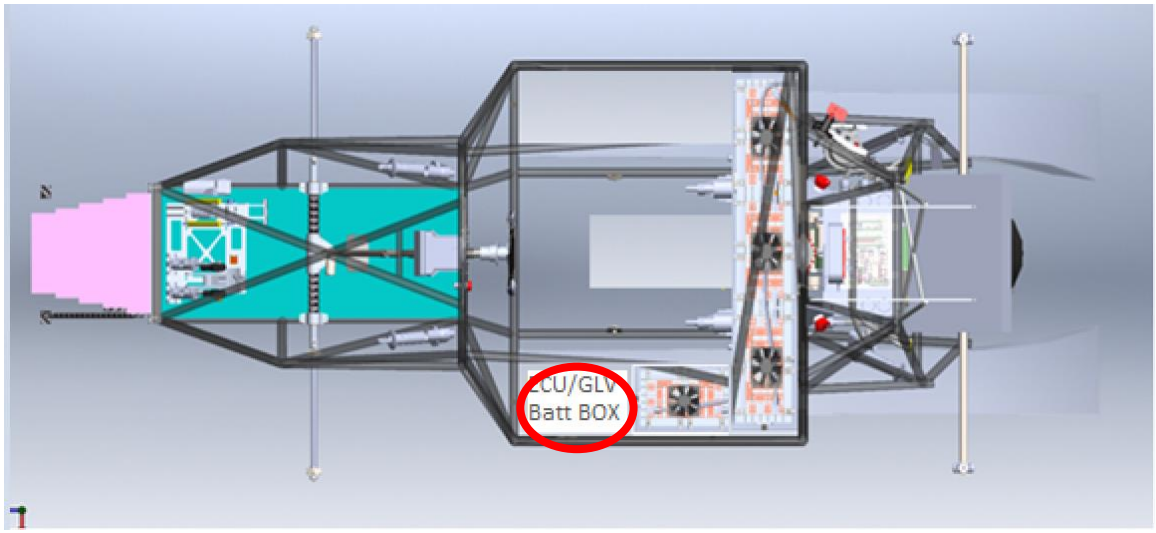


Figure 21 Control Circuitry Placement

2.6 Shutdown System Interlocks

2.6.1 Description/circuitry

The interlocks are achieved by using sense low voltage isolated pins in the connectors to detect open or closed connections. The AIR's power travel through them. We have interlocks between the HVD. All other connectors will require tools to open.

2.6.2 Wiring/cables/connectors

The HV Disconnect (HVD) requires 18 AWG PVC Insulated Hookup Wire with a 300v and 105C rating.

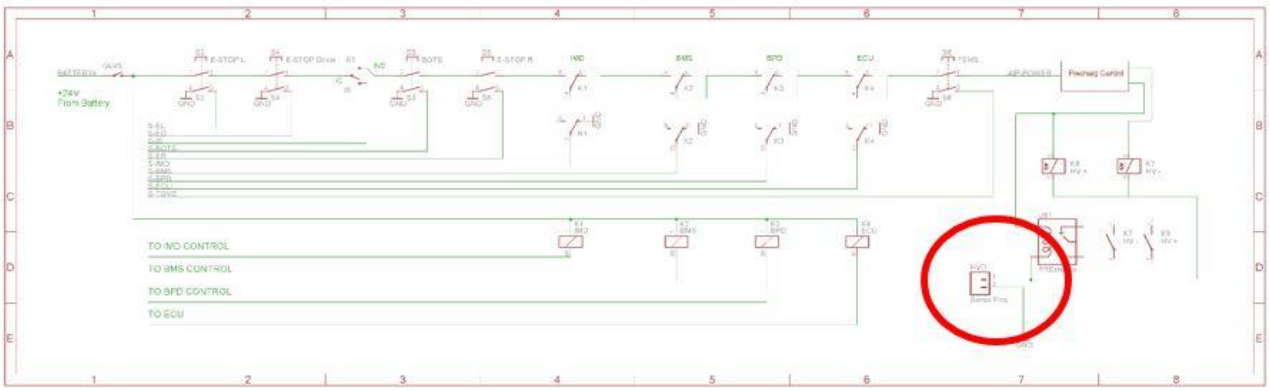


Figure 22 Interlock Schematic

2.6.3 Position in car

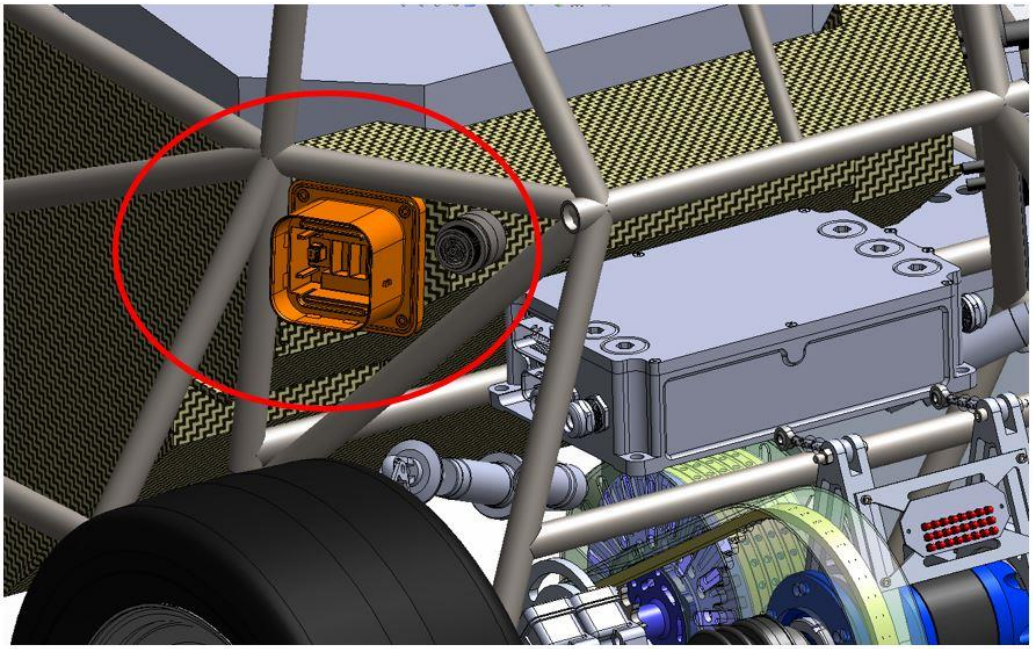


Figure 23 HVD placement

2.7 Tractive system active light (TSAL)

2.7.1 Description/circuitry

The TSAL consists of 16 100 Lumen LED's mounted every 45 degrees to form an octagon with 2 LED's on each side. The 3 Hz flashing frequency is driven by a 555 timer. This is turned on by a high voltage sensor set at 60V after the AIR's (power to the motor controller) in the battery pack. (Shown below)

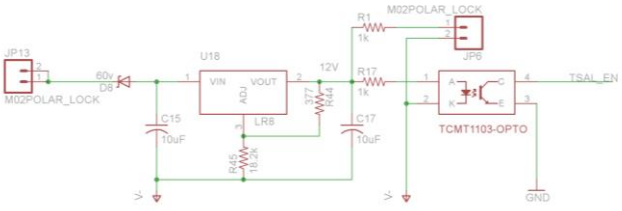


Figure 24 TSAL Control Schematic

Supply voltage:	28VDC
Max. operational current:	100mA
Lamp type	LED
Power consumption:	4.5 W
Brightness	100 Lumen
Frequency:	1.5Hz
Size (length x height x width):	20mm x 10mm x 50mm

Table 2.6 Parameters of the TSAL

2.7.2 Wiring/cables/connectors

The TSAL uses 24 AWG PVC Insulated Hookup Wire with a 300v and 105C rating.

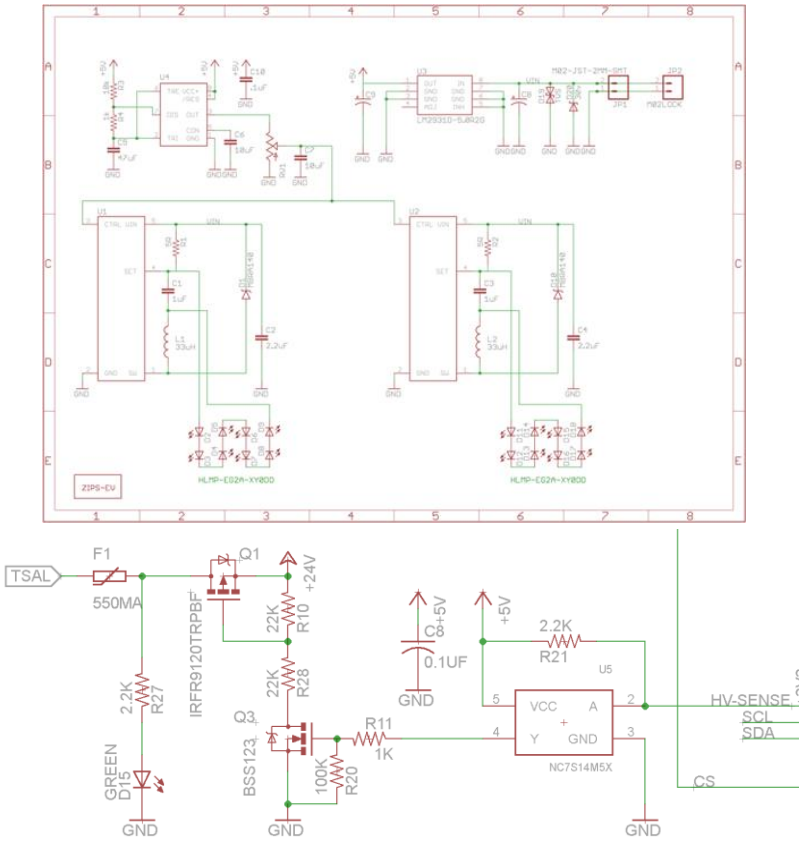


Figure 25 TSAL Schematic

2.7.3 Position in car

The TSAL is mounted to the bottom of the main roll hoop as required by the rules. It will be mounted with a metal bracket if necessary.

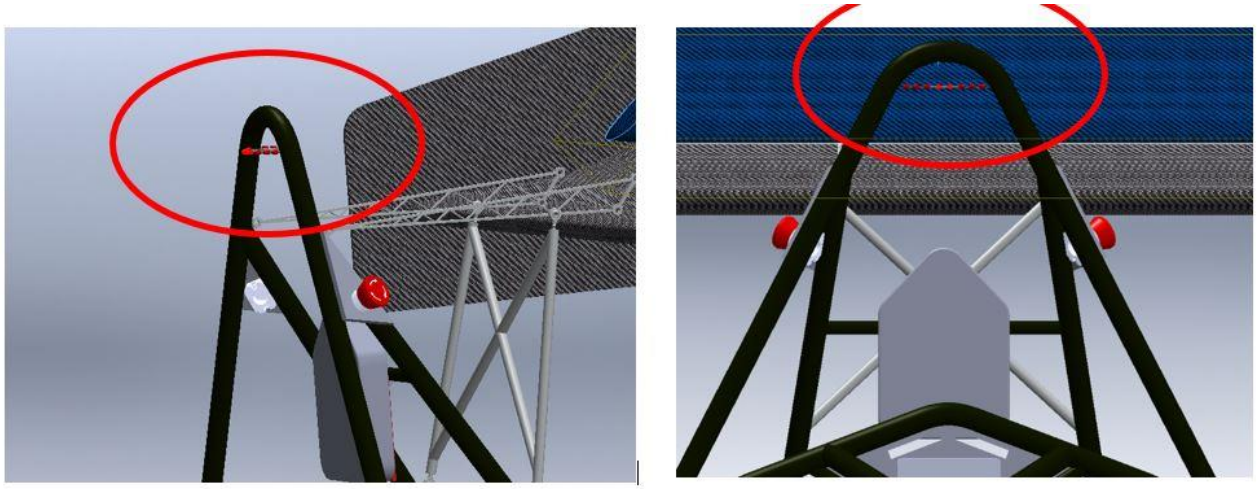


Figure 26 TSAL Posiition in Car

2.8 Measurement points

2.8.1 Description

4mm red and black banana jacks will be used to allow tractive system voltage measurement. They sit in an IP67 plastic box that has thumb screws holding on the cover. The box is UL Listed to UL508-4x, 12, & 13 specifications

TSMP Box Datasheet

TSMP Jacks Datasheet.

TSMP Resistors Datasheet

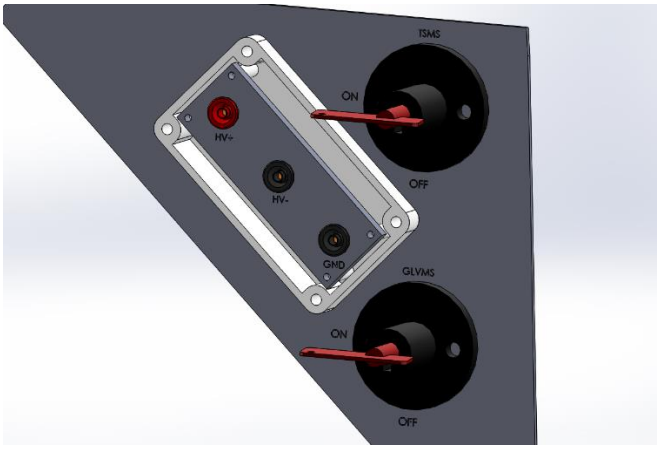


Figure 27 Tractive System Measurement Points

2.8.2 Wiring, connectors, cables

The TSMP 24 AWG PVC Insulated Hookup Wire with a 300v and 105C rating will connect the banana jacks in line with a 10kOhm resistor to the HV+ and HV- connections after the AIR's.

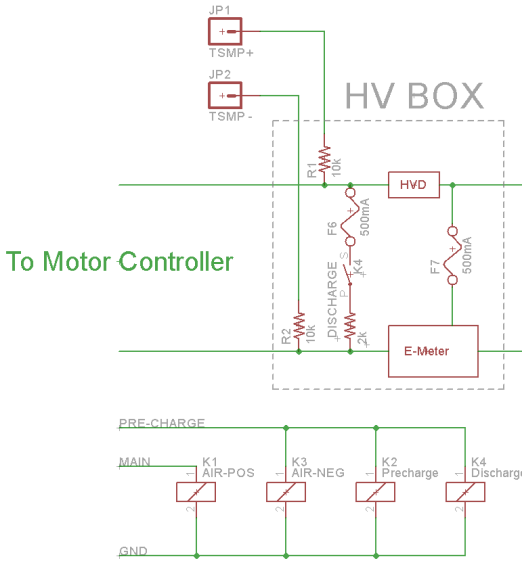


Figure 28 Tractive System Measurement Resistors

2.8.3 Position in car

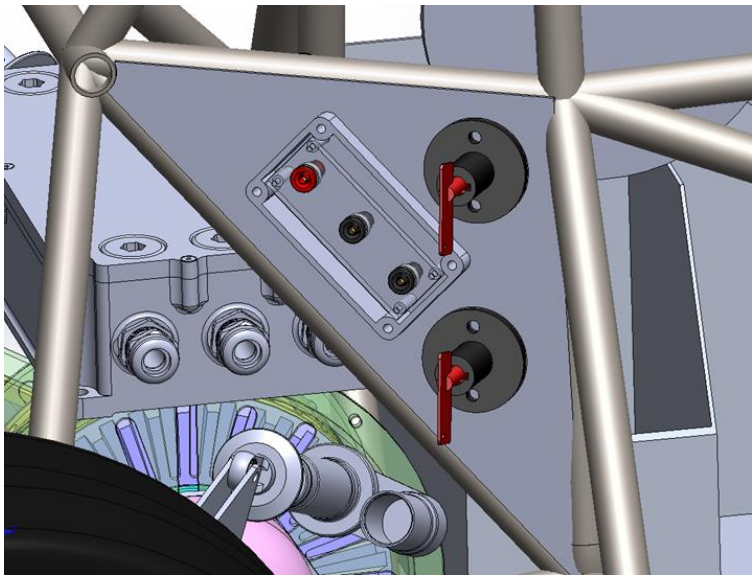


Figure 29 Tractive System Measurement Point in Car

2.9 Pre-Charge circuitry

2.9.1 Description

The Pre-Charge system of the car is used to equalize the potential of the across the AIR switch and both battery packs. Pre-Charge started when the safety system is all clear of faults. This includes the ECU clearing its fault and setting the ready to drive relay. Bottom or negative relay turns on with the Precharge High Voltage Relays in series with two 2k Ω Precharge Resistors. The hardware then waits 2.5 seconds. This 2.5 second delay originates from the safety system board. This is set by an RC timer. After the 2.5 seconds are up, the Pre-Charge relay stays on and the AIR's turn on shorting out the Pre-Charge resistor. During Pre-Charge, the car is acquiring data from the motor controller to verify voltage is present and increasing on the battery input to the device. If this doesn't happen, the car will trip ECU safety stop and report an error code. The Control circuitry is not near the high voltage.

2.9.2 Wiring, cables, current calculations, connectors

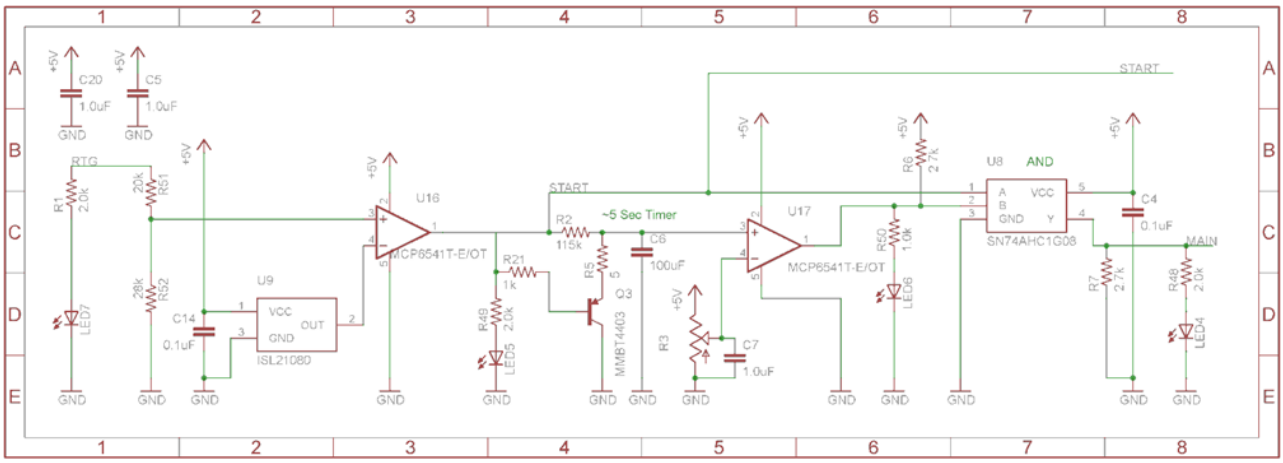


Figure 30 Pre-Charge Schematic

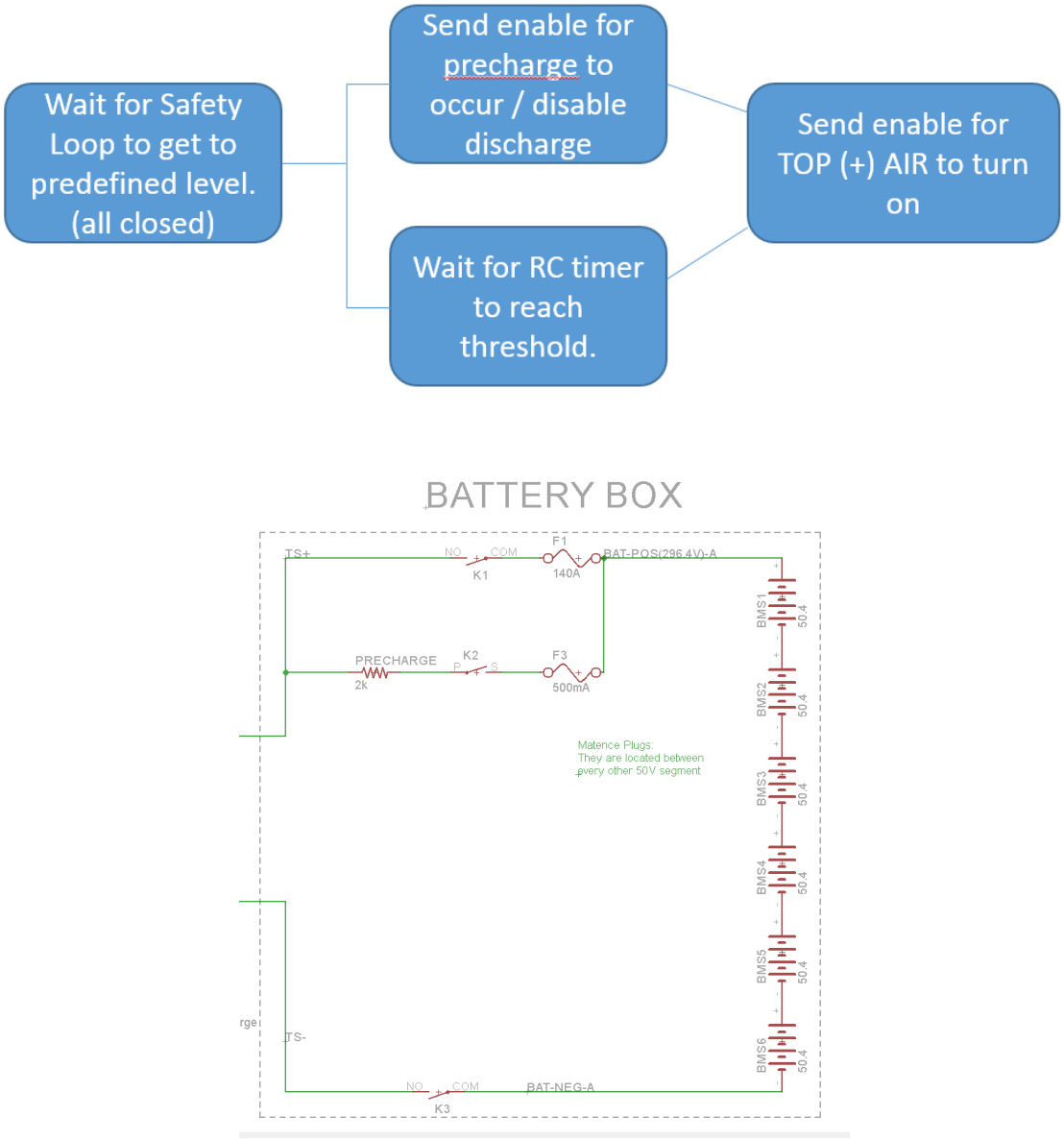


Figure 31 Pre-Charge Schematic 2

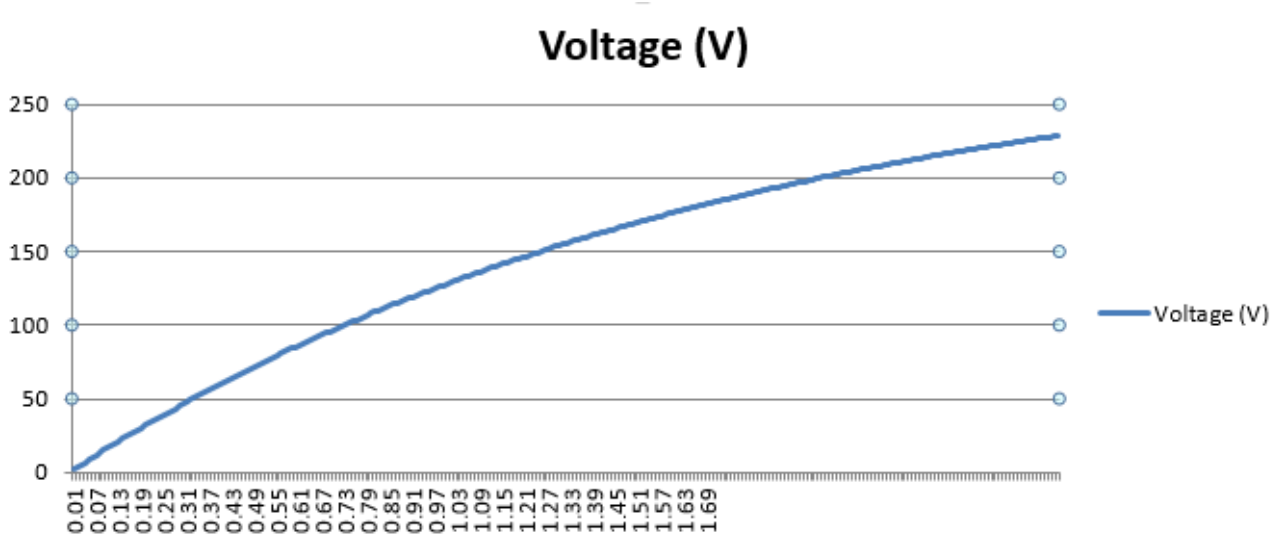


Figure 32 Pre-Charge Graph

Percentage of charge = $1 - 294.2^{\frac{-t}{2000*0.00088}}$

Voltage = Percentage of charge * pack voltage

Resistor Type:	WFH160L150JE - Wirewound
Resistance:	2kΩ
Continuous power rating:	160W
Overload power rating:	160W
Voltage rating:	600V
Cross-sectional area of the wire used:	1.31mm²

Table 2.7 General data of the pre-charge resistor

Relay Type:	DAR72410P
Contact arrangment:	SPST-NO
Continuous DC current:	3A
Voltage rating	1000VDC
Cross-sectional area of the wire used:	1.31mm²

Table 0.1 General data of the pre-charge relay

2.9.3 Position in car

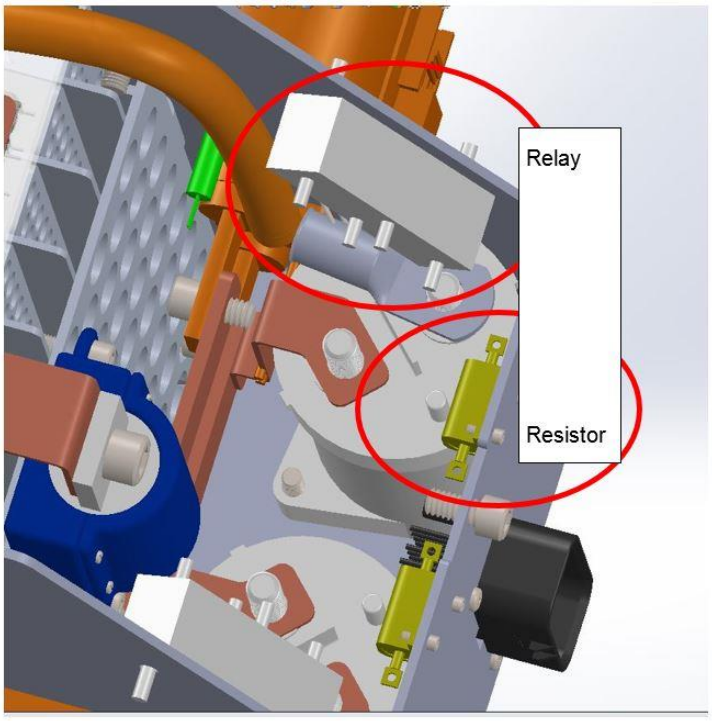


Figure 33 Pre-Charge Relay and Resistor Positions

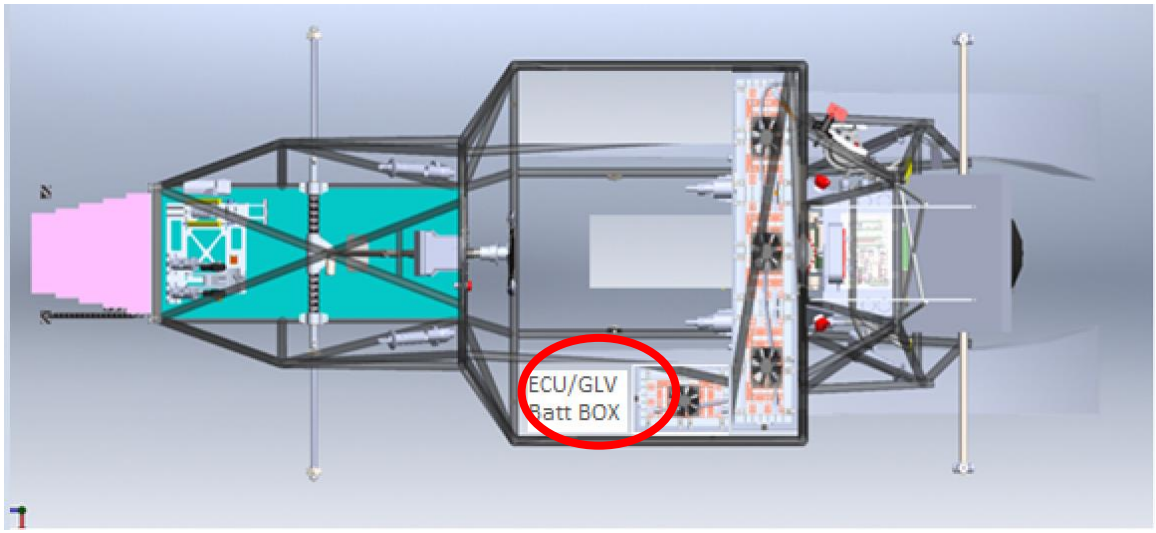


Figure 34 Pre-Charge Control Position

2.10 Discharge circuitry

2.10.1 Description

Our system requires a discharge system to get the capacitive energy out of the motor controller. Our system uses Discharge Resistors to drop the energy. We are able to discharge the energy in about 1.8 seconds. This circuit works off of the inverted precharge system relay (Discharge Relays) output. It works by being a normally closed relay shorting the HV bus on the car and only opens when the precharge system and or AIR power activates.

2.10.2 Wiring, cables, current calculations, connectors

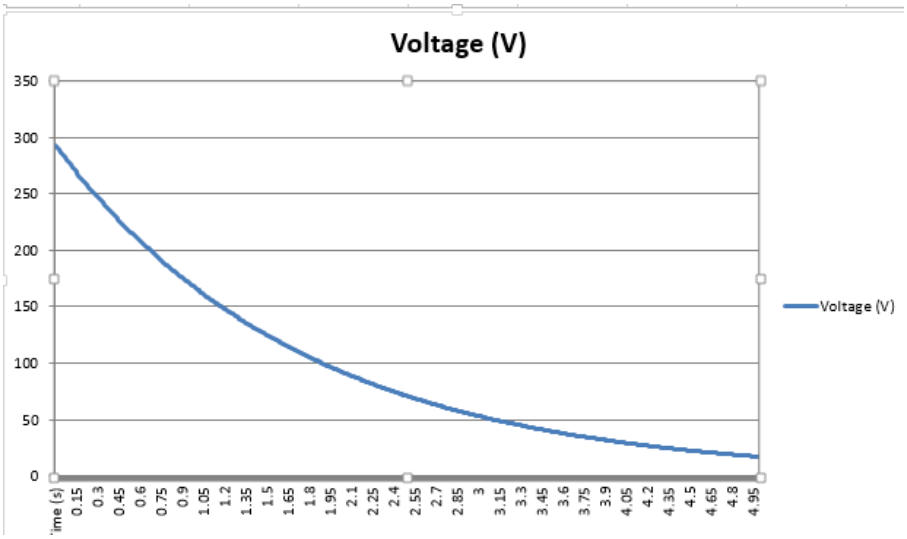


Figure 35 Discharge Voltage Graph

Formula = $\frac{295.2}{450} 2.7182^{\frac{-t}{2000*0.00088}}$

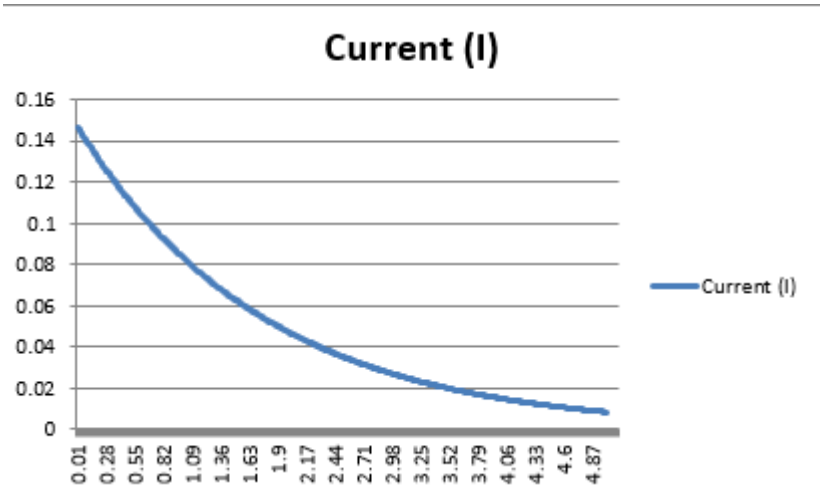


Figure 36 Discharge Current Graph

Formula = $294.2 * 2.7182^{\frac{-t}{2000*0.00088}}$

Current = $295.2 \frac{294V}{2000\ ohms} * 2.7182 \frac{-t}{2000*0.00088}$

Max Discharge current: 90mA Max Discharge wattage 26W

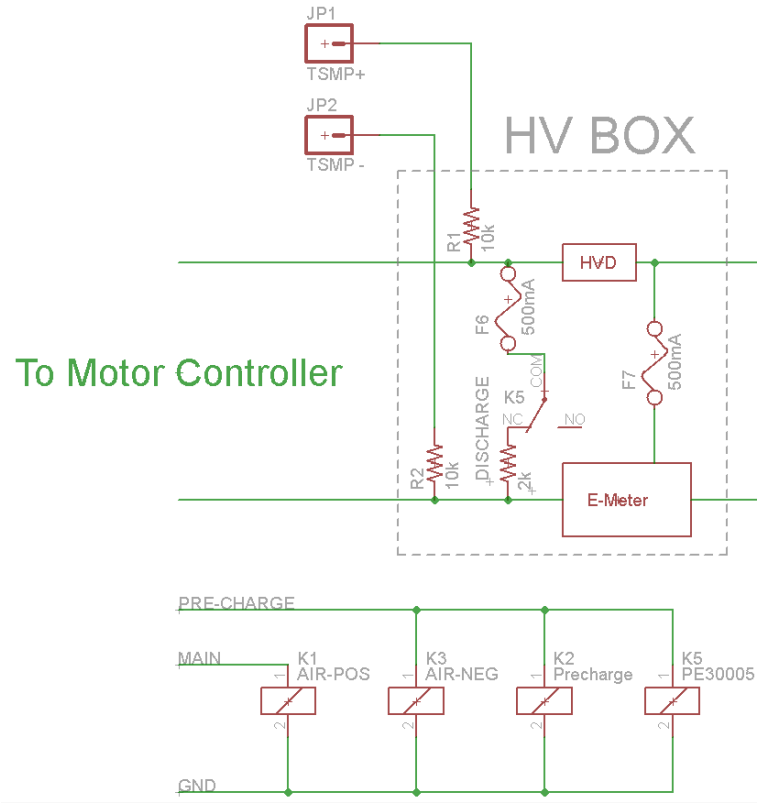


Figure 37 Discharge Circuit

Resistor Type:	UAL10-2KF8 - **Wirewound**
Resistance:	2kΩ
Continuous power rating:	12.5W
Overload power rating:	62.5W
Voltage rating:	1500V
Maximum expected current:	146mA
Average current:	48mA
Cross-sectional area of the wire used:	1.31 mm²

Table 0.1 General data of the discharge circuit

Relay Type:	DBR72410P
Contact arrangment:	SPST-NC
Continuous DC current:	3A
Voltage rating	1000VDC
Cross-sectional area of the wire used:	1.31 mm^2

Table 0.10 General data of the dis-charge relay

Resistor datasheet 11.2.8.1

Relay datasheet 11.2.8.2

2.10.3 Position in car

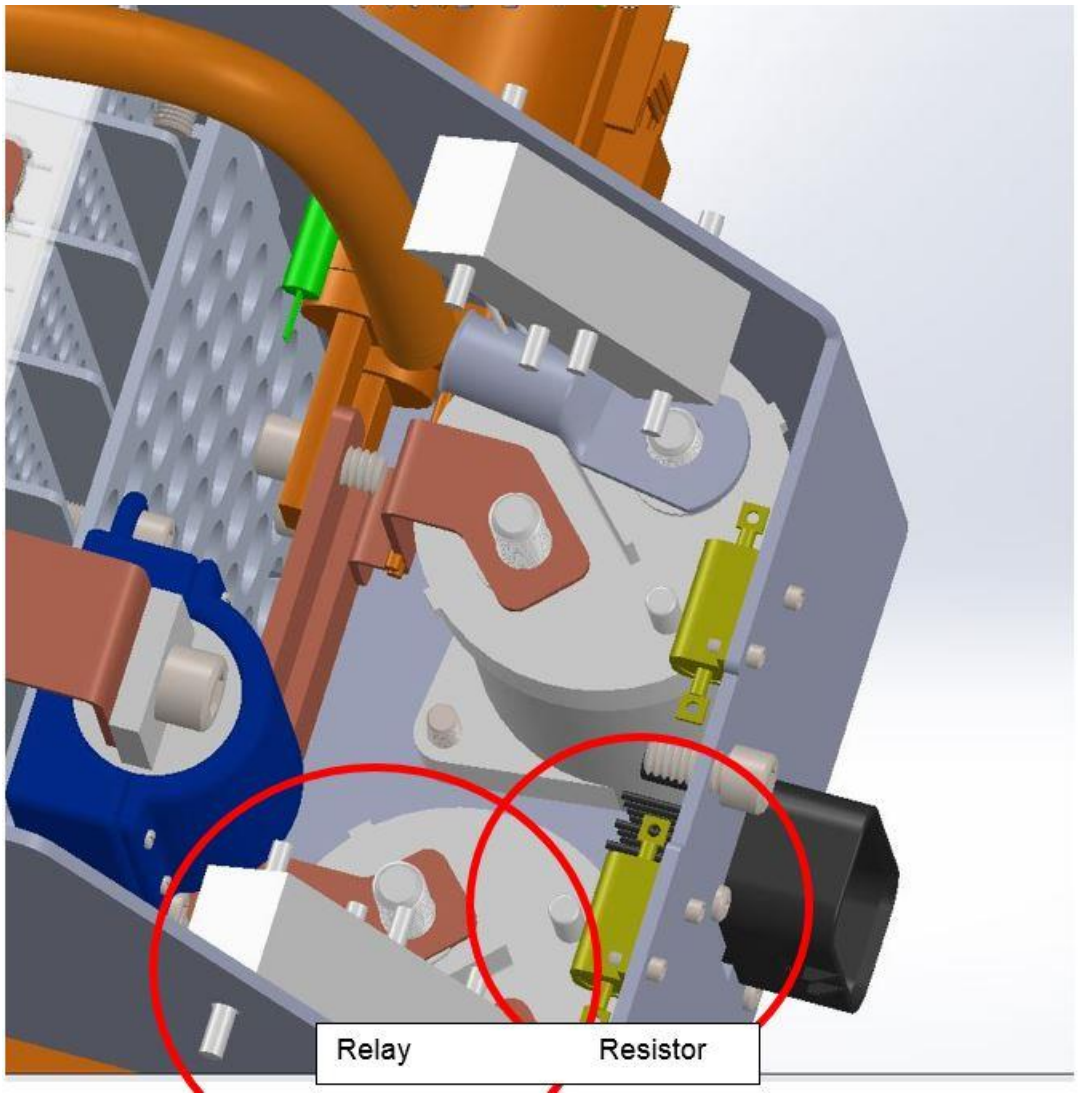


Figure 38 Discharge Relay & Resistor Position

Discharge control circuitry is in the ECU box shown in *Figure 34*.

2.11 HV Disconnect (HVD)

2.11.1 Description

The High Voltage Disconnect is a 1-1587987-7 model from TE connectivity. It is a member of their Series B connector family and is capable of 630Amps and 450V. It is disconnected by a pull handle.

2.11.2 Wiring, cables, current calculations, connectors

Wire-EXRAD Shielded Cable XLE 2 cable.

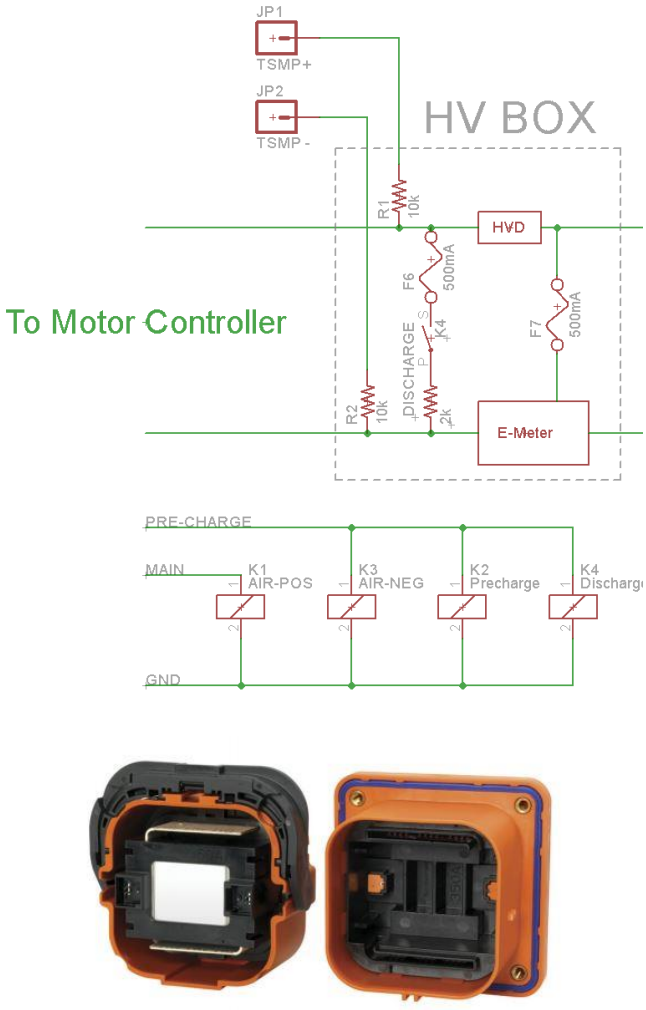


Figure 39 HVD Connector

2.11.3 Position in car

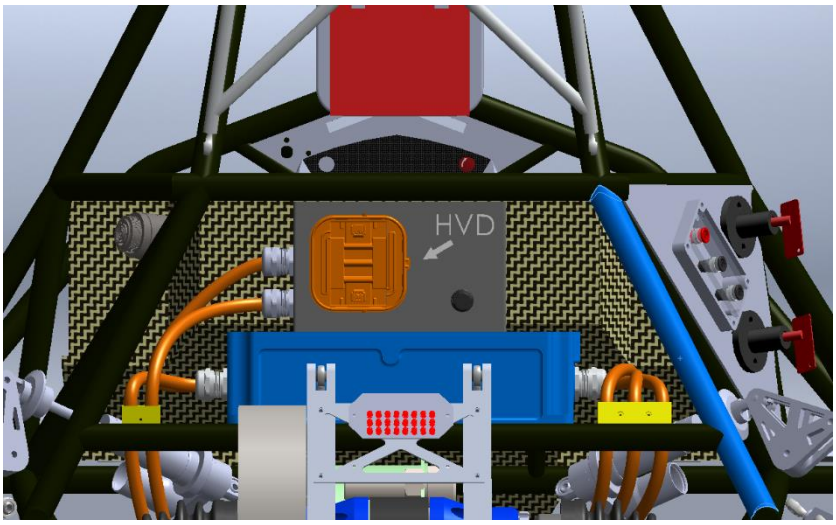


Figure 40 HVD Position in Car

2.12 Ready-To-Drive-Sound (RTDS)

2.12.1 Description

Upon the Accumulator Isolation Relays closing, and the motor controllers turning on, a 24V car horn will turn on for more than one second and less than three to notify all that the vehicle is ready to drive. The Ready to Drive Horn (Mallory PT-4632PLQ) is driven by a mosfet driver. The signal that drives the buzzer is from the ECU with software. The horn is capable of generating 83bBA at 2 meters.

2.12.2 Wiring, cables, current calculations, connectors

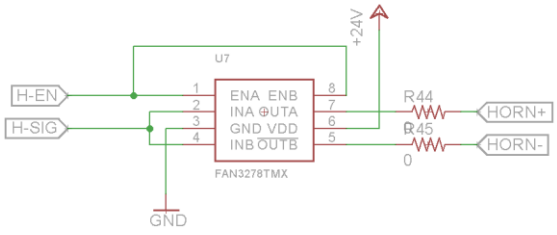


Figure 41 Horn Control Circuitry

The Horn uses 24 AWG PVC Insulated Hookup Wire with a 300v and 105C rating. There are no connectors for the Horn. **Error! Reference source not found.** datasheet

2.12.3 Position in car

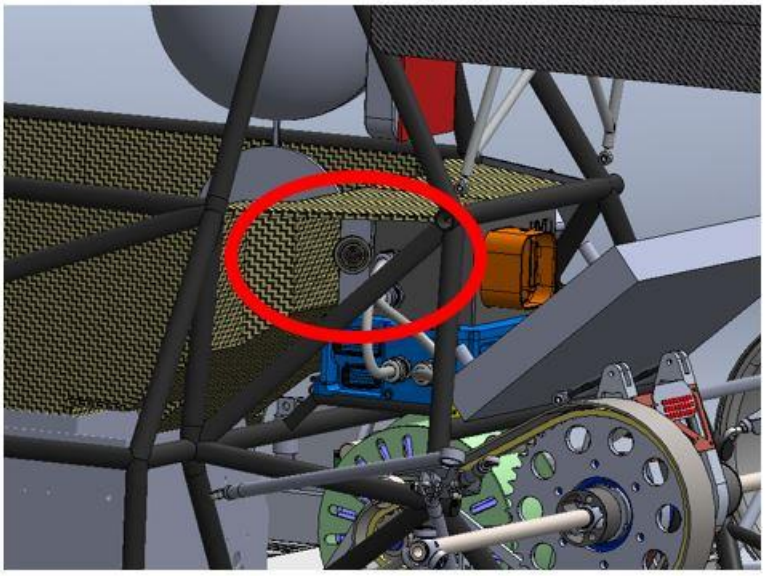


Figure 42 Horn Position in Car

3 Accumulator

3.1 Accumulator pack 1

3.1.1 Overview/description/parameters

Maximum Voltage:	302.4VDC
Nominal Voltage:	273.6VDC
Minimum Voltage:	216VDC
Maximum output current:	528A for 2s
Maximum nominal current:	423A
Maximum charging current:	42A
Total numbers of cells:	216
Cell configuration:	72s3p
Total Capacity:	$Capacity[MJ] = [Ah] \times Voltage[V] \times \#\ of\ cells * 3600\left[\frac{s}{h}\right] \times 10^{-6}[\frac{MJ}{J}]$

21.6 MJ

Capacity [MJ]	[Ah]	[# ofcells]	[Voltage]	[s/h]	
20.831904	7.05	216	3.8	0.0036	

Number of cell stacks < 120VDC 6

Table 3.1 Main accumulator parameters

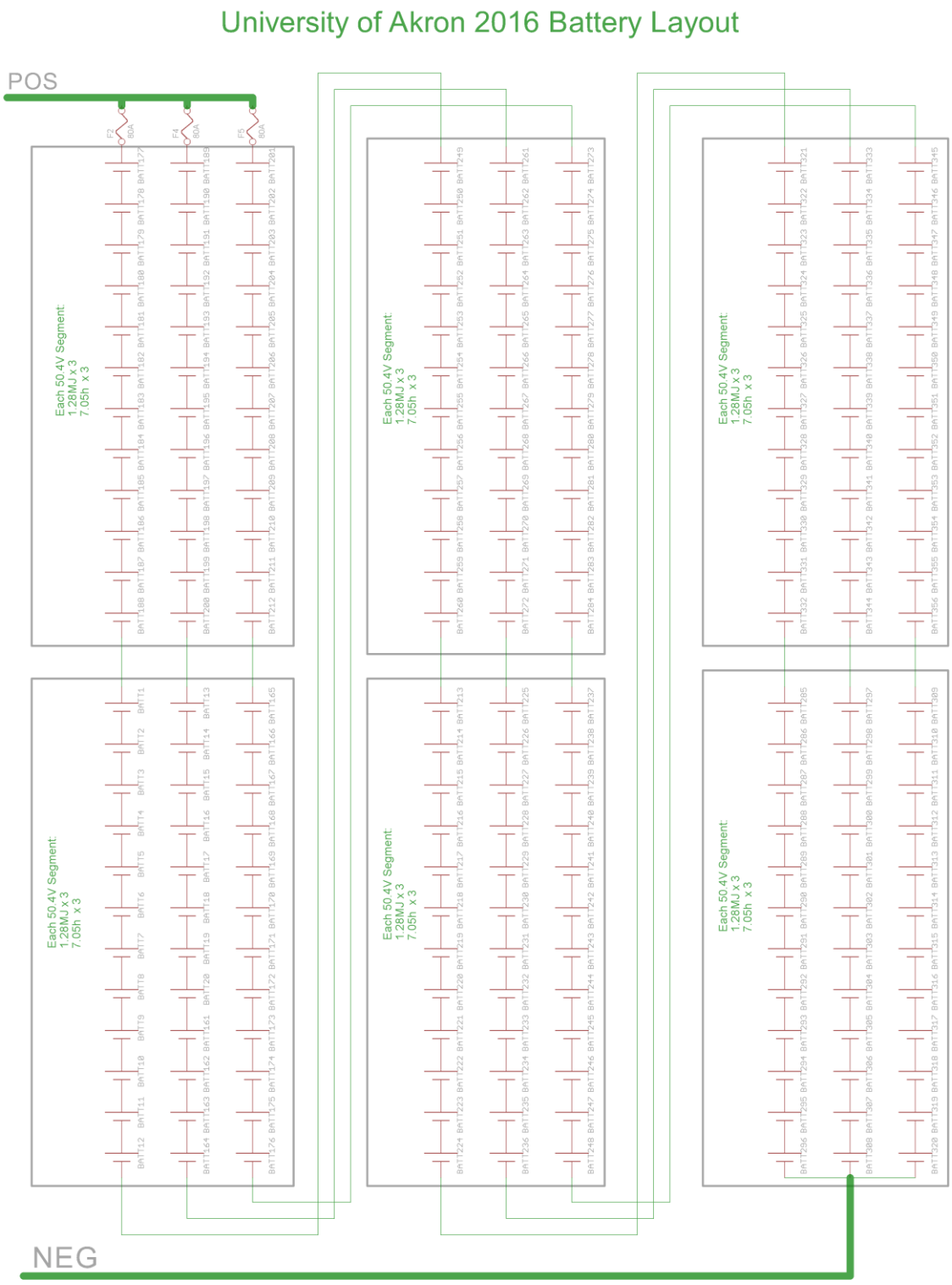


Figure 43 Accumuluator Battery Layout

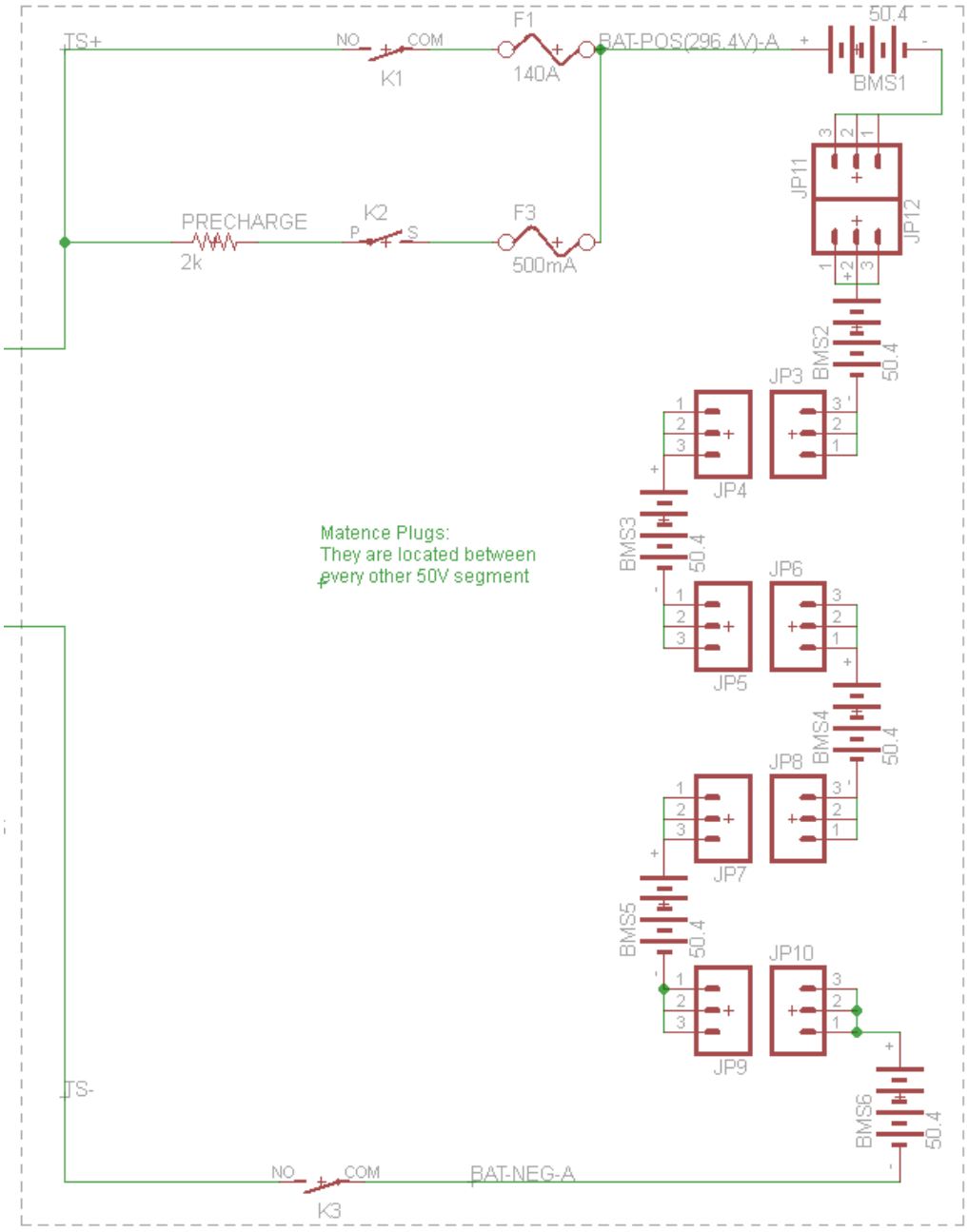


Figure 44 Accumulator Battery Layout (High Level)

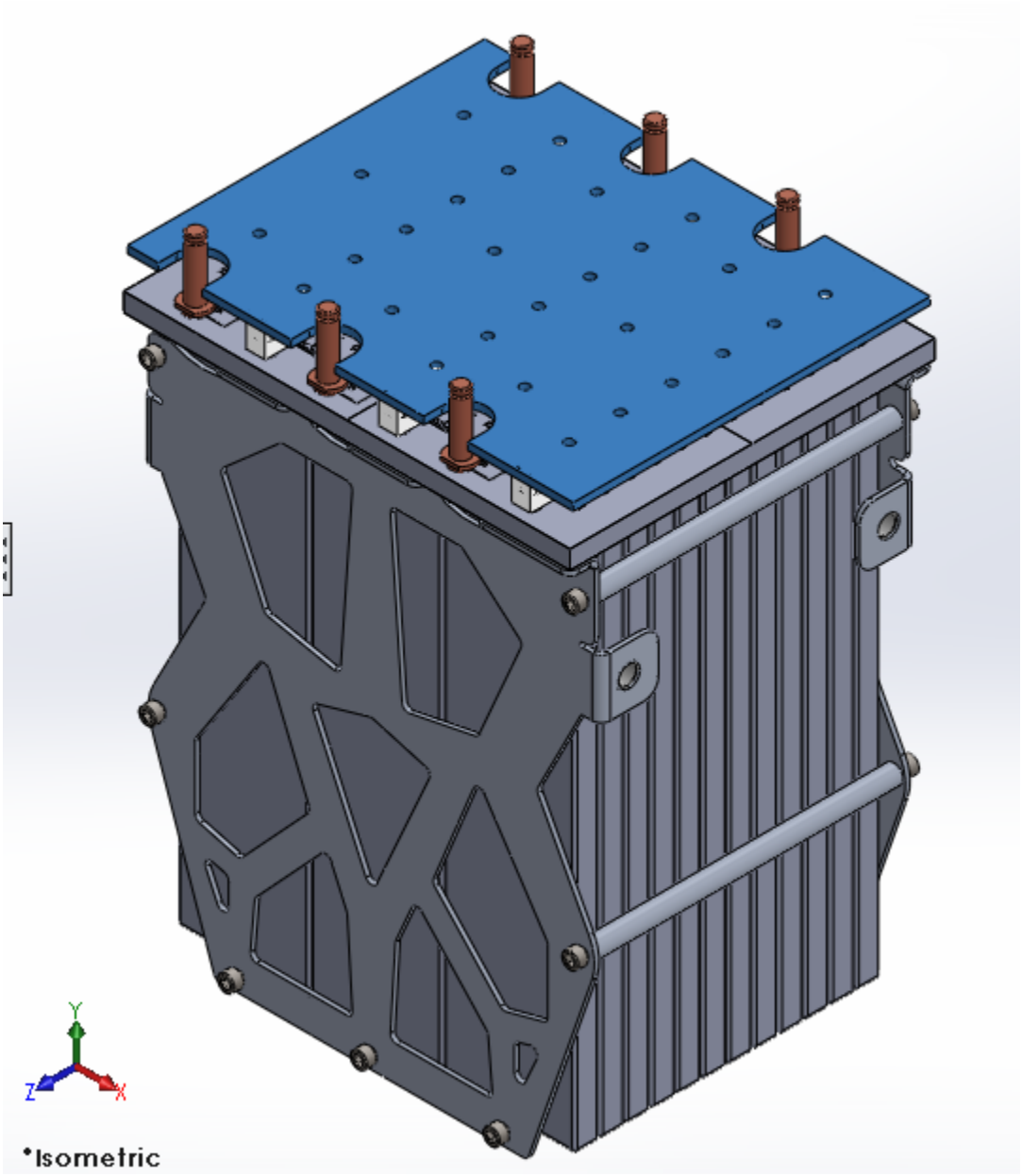


Figure 45 Battery Pack Modules (12s3p) x6 per container ~50.4v

3.1.2 Cell description

Cell Manufacturer and Type	Melasta SLPB9145180
Cell nominal capacity:	7.05 Ah
Maximum Voltage:	4.2 V
Nominal Voltage:	3.3V
Minimum Voltage:	3.0V
Maximum output current:	25C for 10s
Maximum nominal output current:	20C
Maximum charging current:	2C
Maximum Cell Temperature (discharging)	60°C
Maximum Cell Temperature (charging)	45°C
Cell chemistry:	LiPo

Table 3.2 Main cell specification

3.1.3 Cell configuration

Each accumulator contains 216 cells. The cells are separated in 6 segments containing 36 cells each. The segments are in a 3 - 12s1p arrangement. Each parallel cell in the segment is back to back. The cells are connected together by clamping tabs together. This is shown in above figure.

The modules connect to each other using tool less maintenance plugs.

3.1.4 Cell temperature monitoring

Every cell will be monitored for temperature. We do this by putting an NTC resistor on the negative cell buss bar and fed back in to the battery management slave microcontroller.

3.1.5 Battery management system

216 cells will be monitored by the BMS that we made ourselves. 6 Slave devices with microcontrollers will communicate with one Master. This communication is done over ISOspi and is isolated at each cell and master. The BMS is capable of opening a relay in the shutdown circuit to

open the AIRs in the case of an error. At a minimum cell voltage of 3.2 and a maximum of 4.2, the BMS will take actions to bypass the high cell(s) during charge. The BMS also reacts to problems as follows: Short cell (0v), blown fuse (2.5v biases present), and Over 60 degrees C. These all end in a safety shutdown by removing power to the AIRs. The BMS can also measures current with a high side current shunt with orange wire. The BMS shuts down the tractive system via a relay that is tied into the safety loop. That would trip the safety system and the car would shut down. These boards are linked with locking Molex connectors. This allows for hot swapping boards. The slave boards are mounted to the tops of the modules. There is pogo pins going between the BMS PCB and the Battery pack. We have board mount fuses to protect the board and the pins. (Datasheet BMS sense fuse) Isolation is on two items the BMS and the Iso board. The devices on these parts keep isolation up to 1 kV. (Device marked with red indicators on the schematics)

Monitor	Accuracy
Voltage	±4.7mV
Temperature	0.5 C
Current	~0.5A

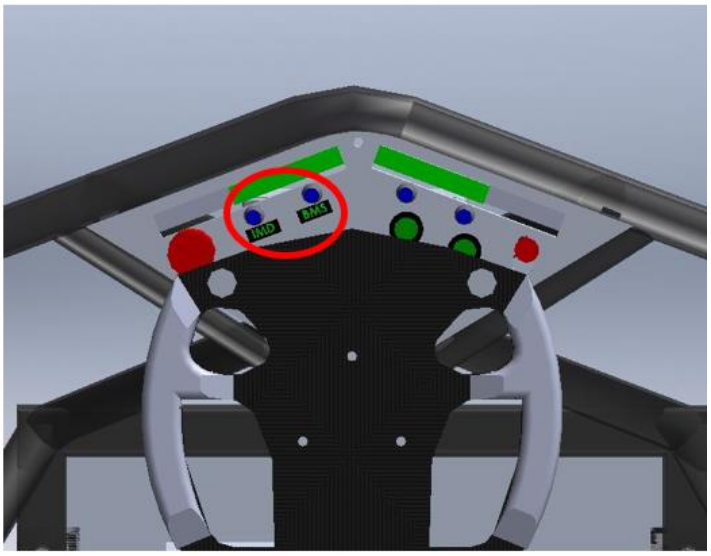


Figure 46 IMD & BMS Status Light

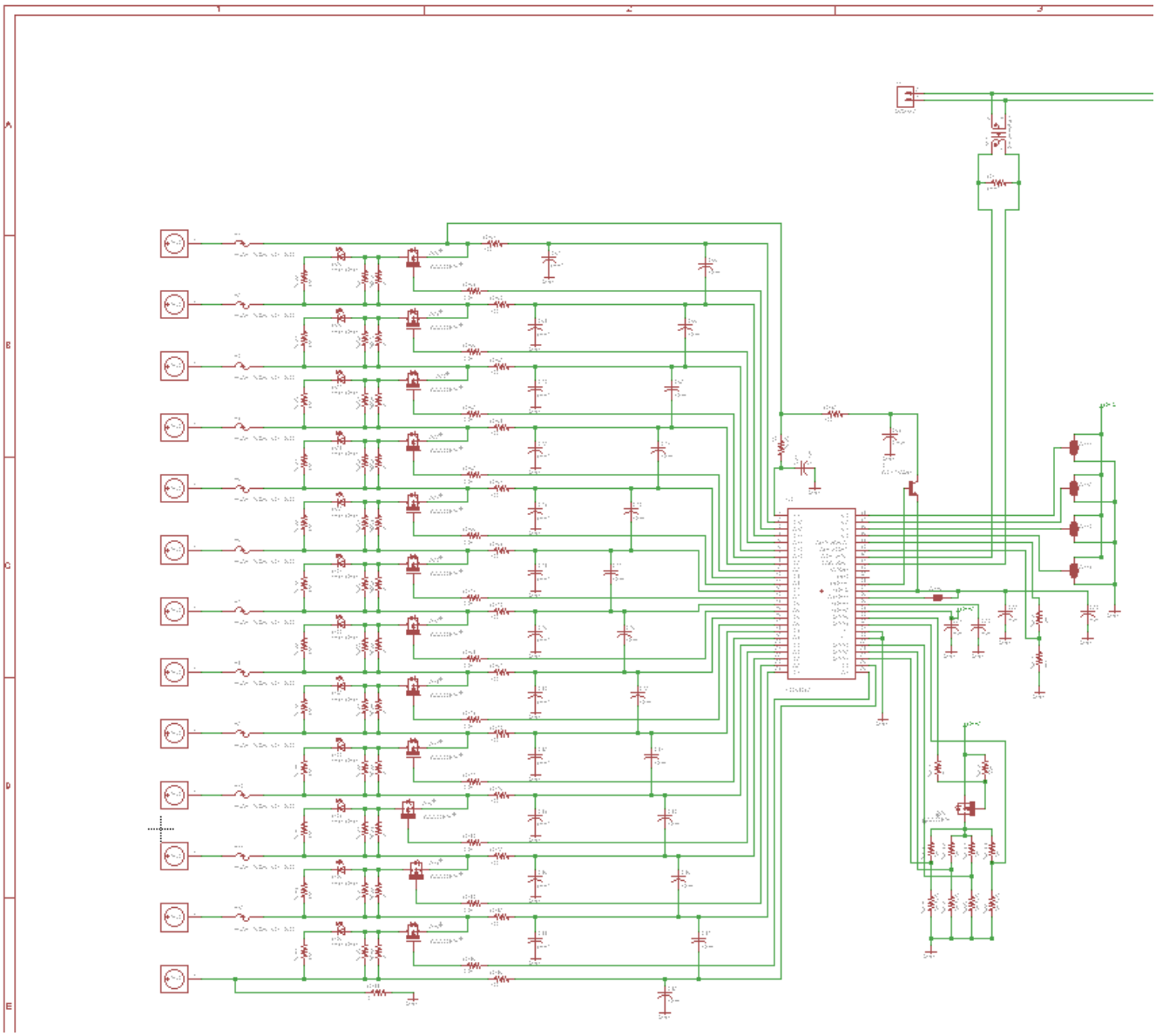
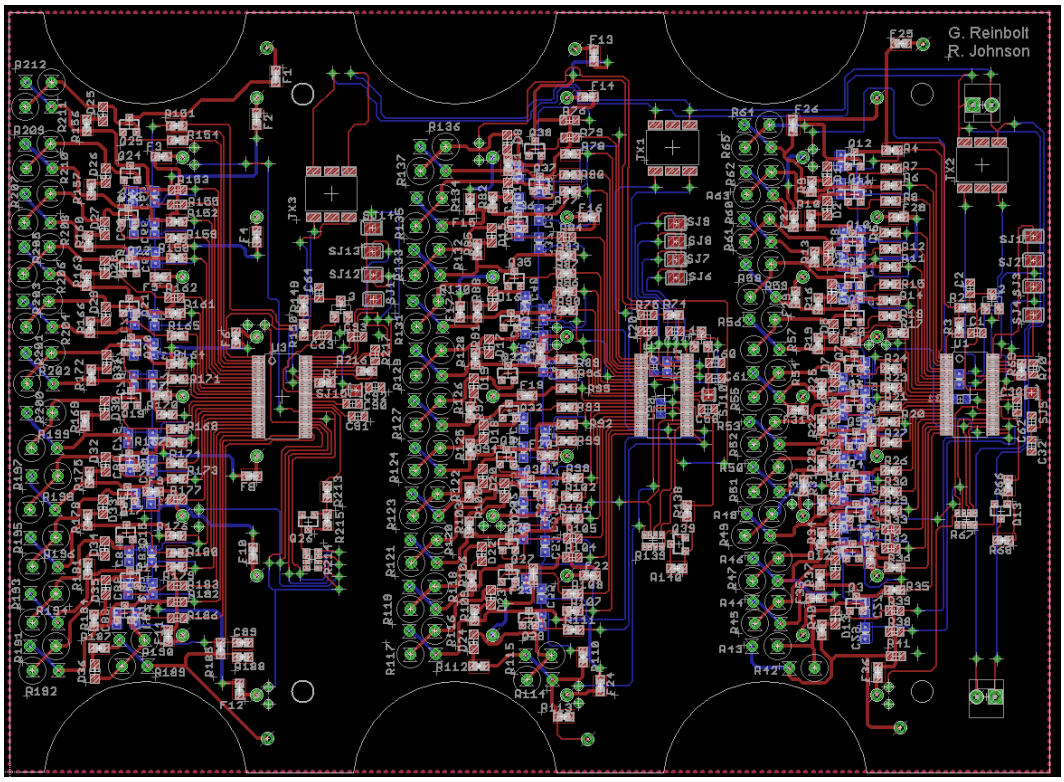
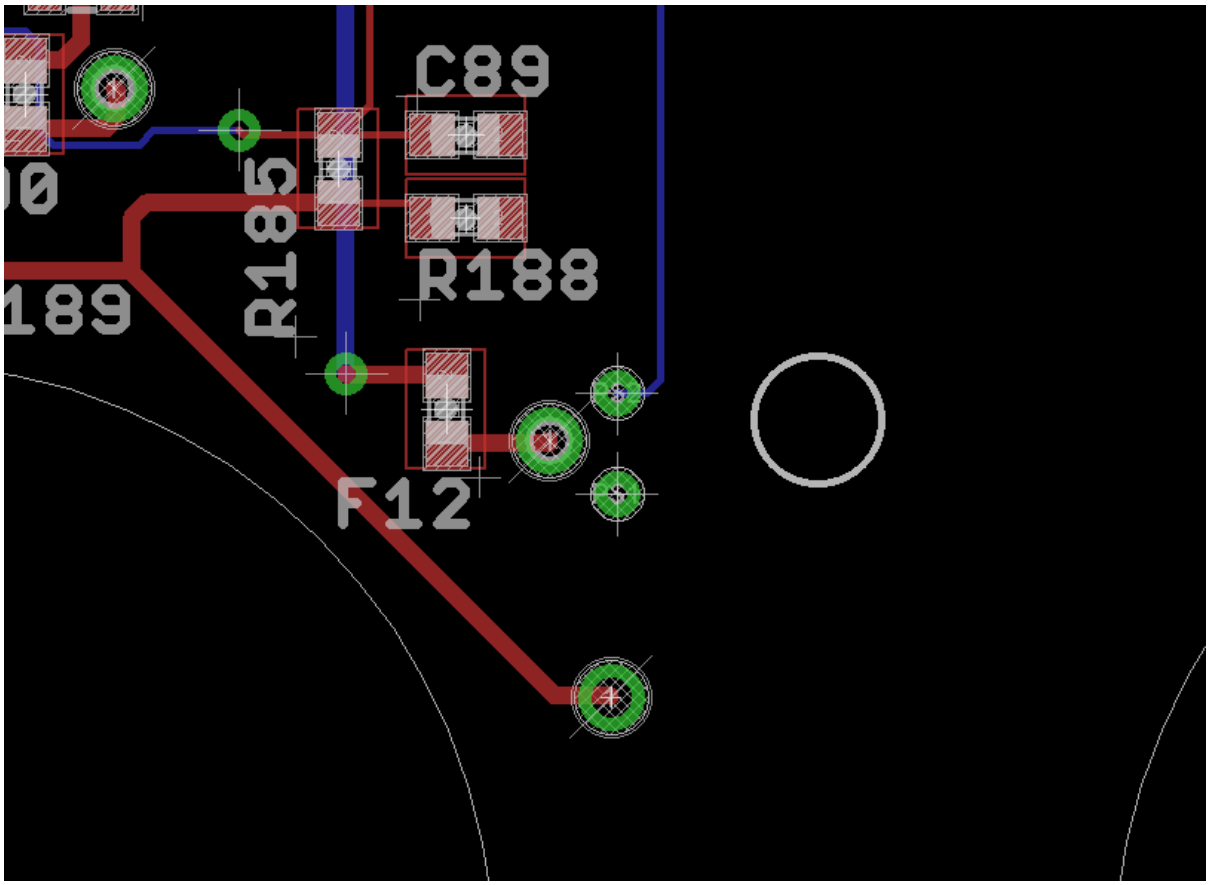


Figure 47 Battery Management Slave Schematic


G. Reinbolt
R. Johnson


C89
R185
R188
F12

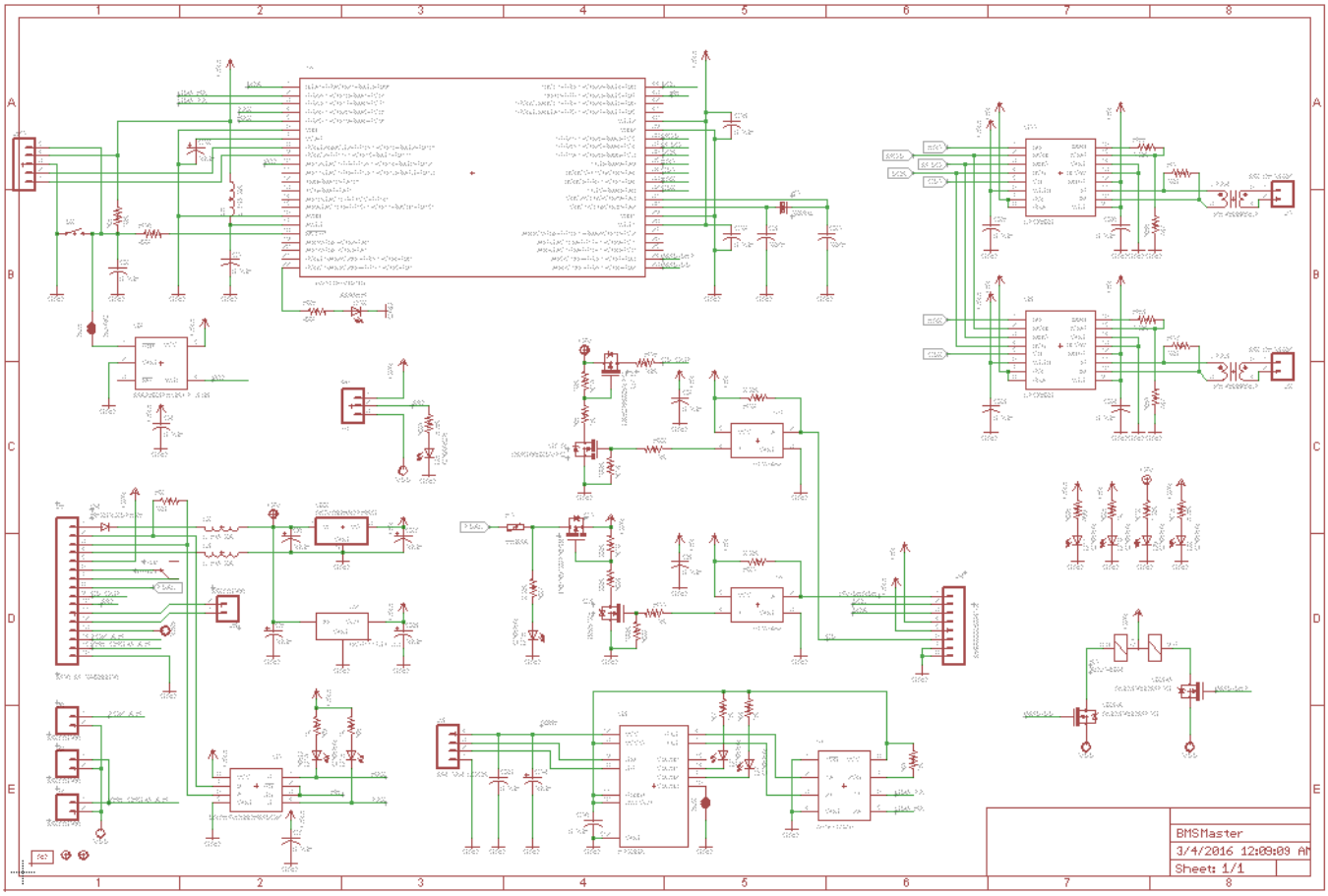
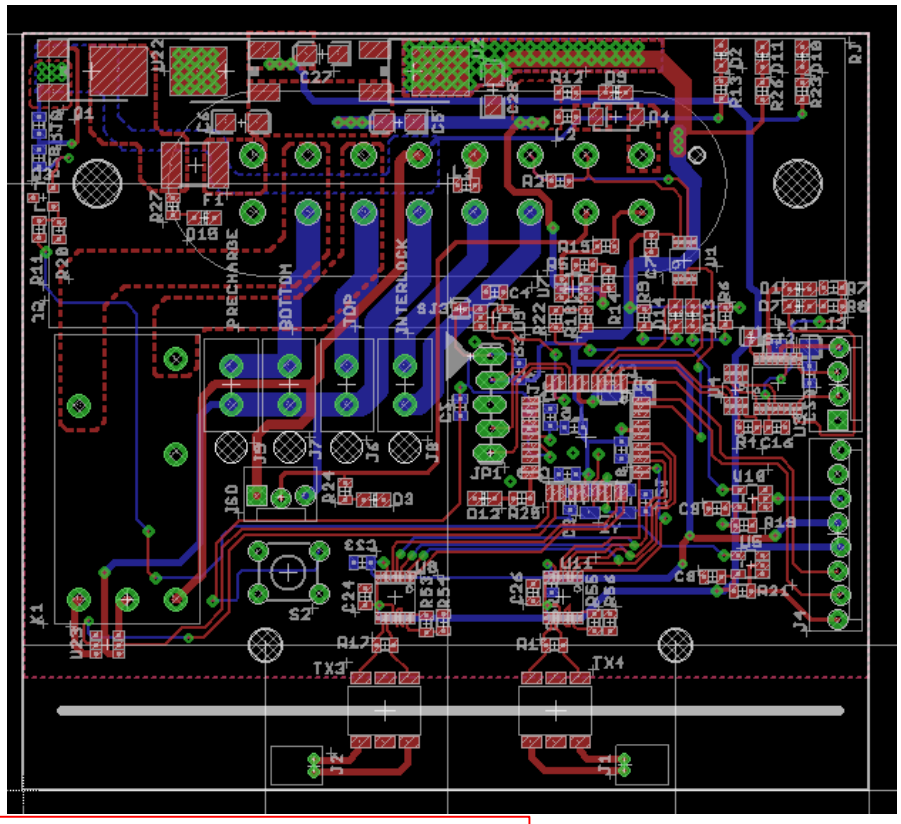
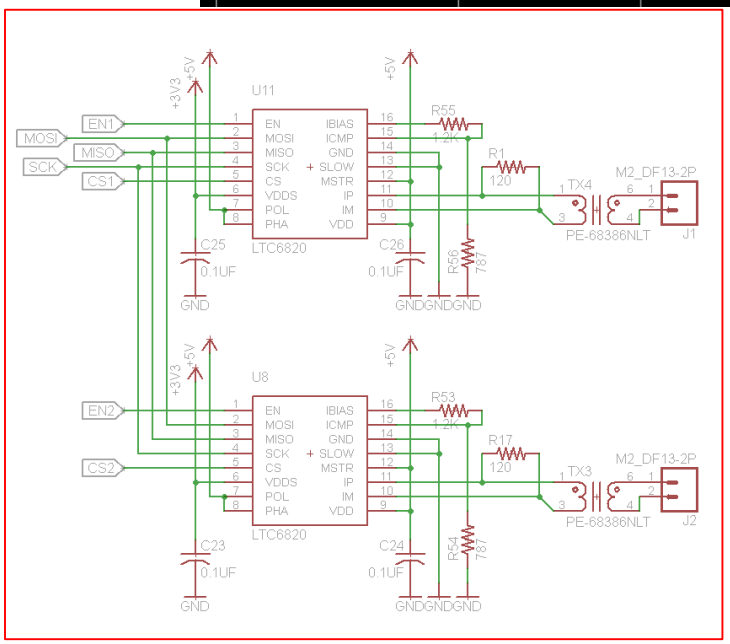


Figure 48 Battery Management Master Schematic


PRECHARGE
BOTTOM
TOP
INTERLOCK
TX3
TX4


U11
EN1
MOSI
MISO
SCK
CS1
LTC6820
R55
R1
120
TX4
M2_DF13-2P
PE-68386NLT
J1
C25
0.1UF
C26
R56
787
GND
U8
EN2
CS2
R53
R17
TX3
J2
C23
C24
R54

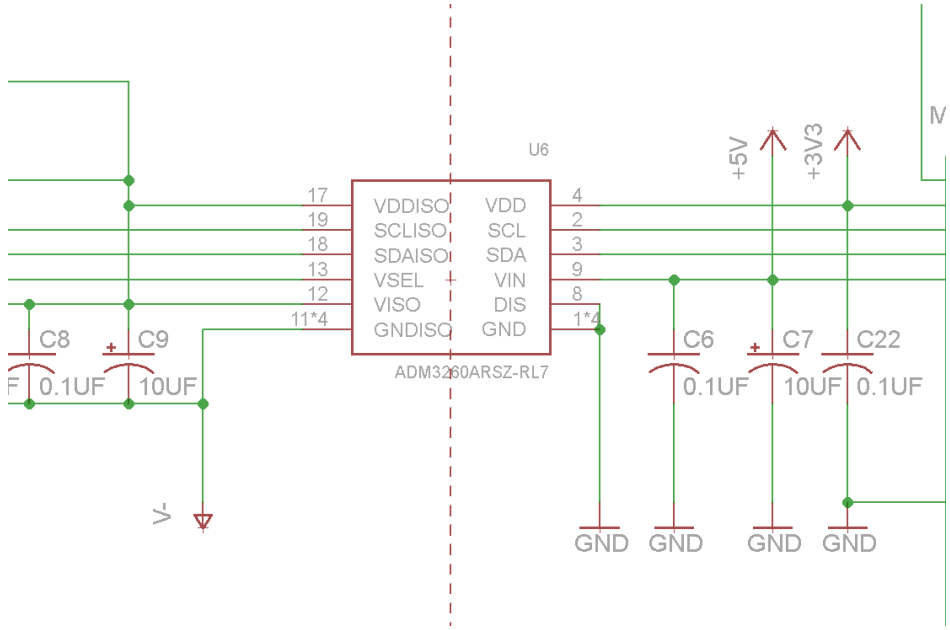
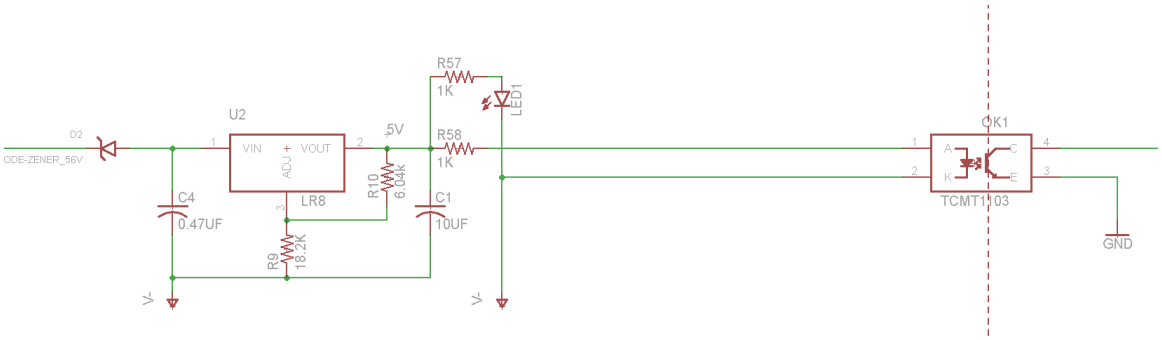
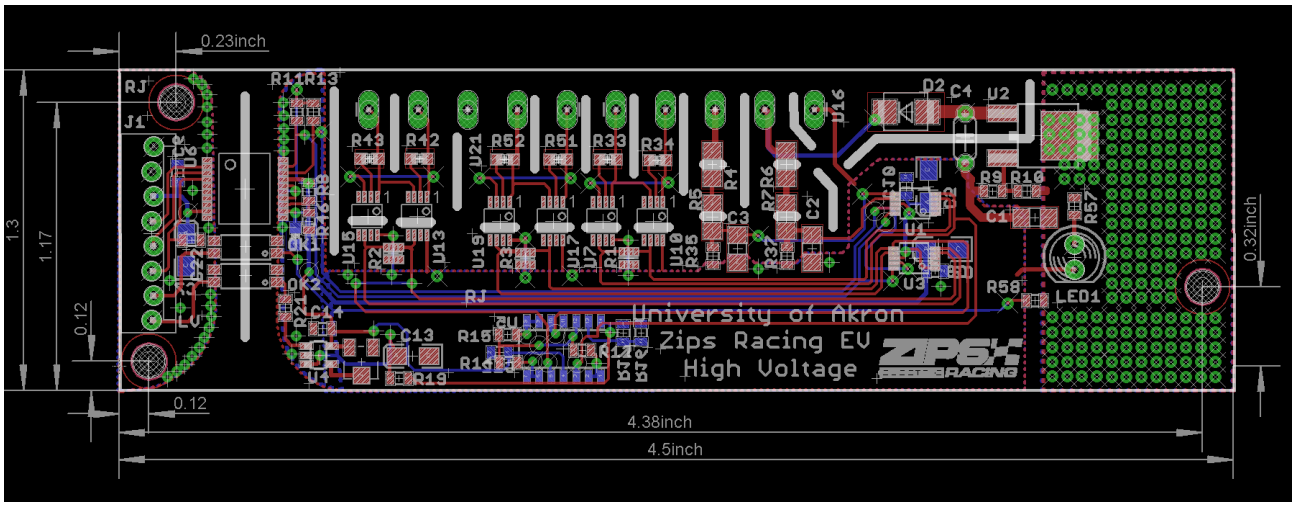


Figure 49 Battery Management Isolation Board (Master/Slave Isolation)

3.1.6 Accumulator indicator

The accumulator indicator is an LED that will be attached to the battery enclosure to indicate that the pack is active. This indicator will be wired across the top and bottom AIR's, so that it is powered when there is voltage on the vehicle side of the accumulator container. It therefore the circuit below is only powered from tractive system voltage. It does not run off of the GLVS and therefore work outside of the car. The wire used for this AWG 22. The circuit bellow illuminates the LED and TSAL at 60V. The Indicator is mounted to the PCB and light is light piped to the outside of the box.





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3.1.7 Wiring, cables, current calculations, connectors

Wire type	Buss bar
Continuous current rating:	7A
Cross-sectional area	0.030 in
Maximum operating voltage:	300V
Temperature rating:	105 °C
Wire connects the following components:	Cell and BMS

Table 3.3 Accumulator Indicator hookup wire specs

GLV wire enters the black connector in photo. The wire off the BMS master board is tied off out of the HV path.

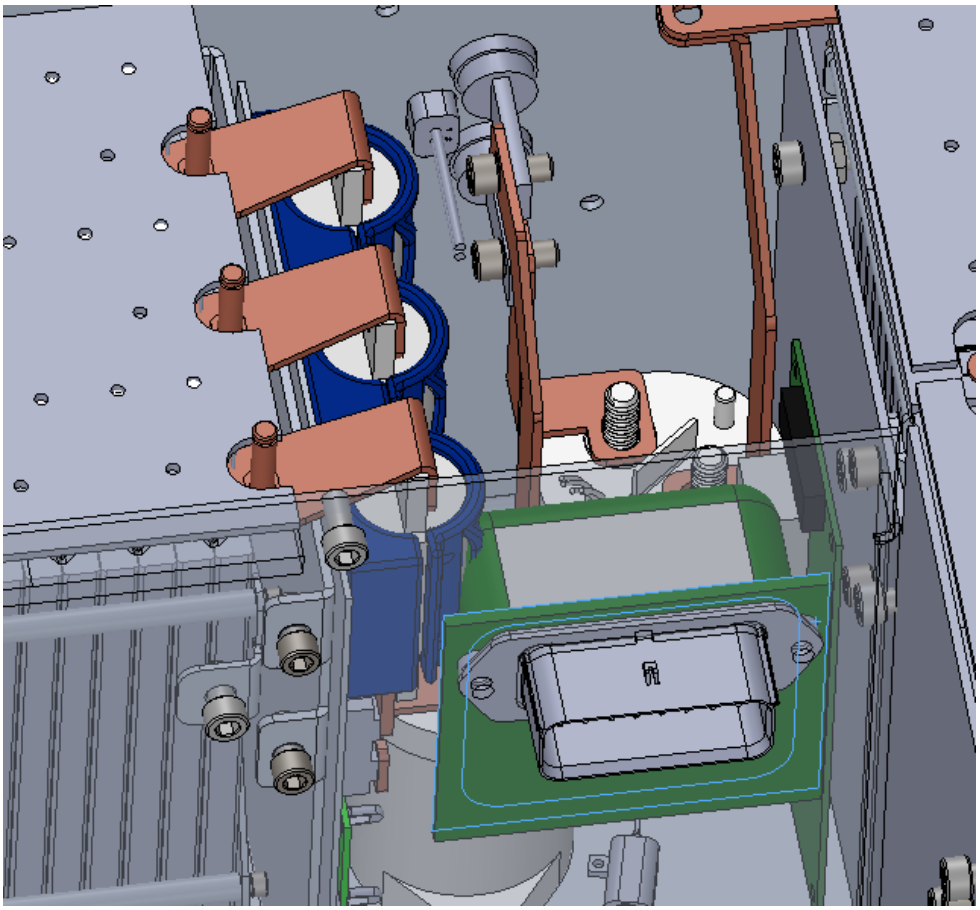


Figure 50 Accumulator Connector (Low Voltage)

3.1.8 Accumulator insulation relays

Accumulator Isolation Relay Datasheet

Relay Type:	EV200AAANA
Contact arragment:	SPST
Continous DC current rating:	500A
Overload DC current rating:	N/A
Maximum operation voltage:	900VDC
Nominal coil voltage:	24VDC
Normal Load switching:	Make and break up to 500A
Maximum Load switching	10 times at 1500A

Table 3.4 Basic AIR data

3.1.9 Fusing

We use one main fuse in the car, which fuses the outputs of the accumulator container. The HV Fuse Holder is custom designed and made with UL-94V0 material. Figure 51

Fuse manufacturer and type:	Littelfuse, Class T
Continous current rating:	150A
Maximum operating voltage	300VDC
Type of fuse:	High speed
I2t rating:	1500A2s at 450VDC
Interrupt Current (maximum current at which the fuse can interrupt the current)	20000A

Table 3.5 Basic fuse data

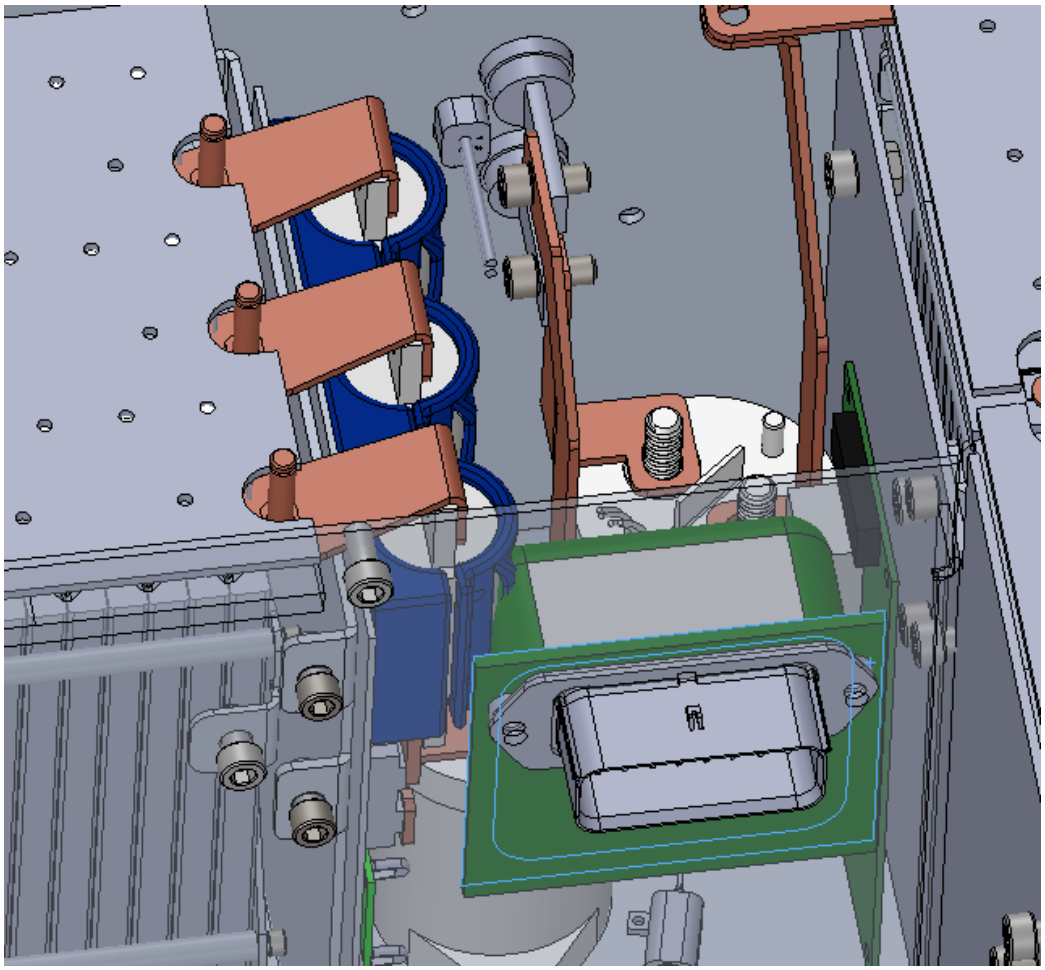


Figure 51 Accumulator Fusing

Location	Wire Size	Wire Ampacity	Fuse type	Fuse rating
Cells to AIRs	2 AWG	255	2x MNO Fuse	145
AIR to Motor controller	2 AWG	255	N/A	N/A
AIR to TSAL	24 AWG	3.5	EFG Fuse	XXX
Accumulator output connector	2 AWG	300		
Cells to BMS	22	7		

Table 3.6 Fuse Protection Table

3.1.10 Charging

The battery charging will use the battery management system to control the charger. The BMS-master by default is not able to talk to the charger directly and control the AIR's. We designed a charging control adapter board that hosts the interfaces and isolation necessary to follow the rules of the competition. This board also hosts the safety system for the IMD, E-stop, Interlock, control relays (precharge), lights and LCD display. The Charger is a kit we assembled and tested.

Charger Type:	ElectricMotorWerks SmartCharge 12000
Maximum charging power:	12kW
Maximum charging voltage:	350V
Maximum charging current:	70A
Interface with accumulator	serial communication
Input voltage:	120-230 VAC
Input current:	Up to 50A

Table 3.7 General charger data

3.1.11 Mechanical Configuration/materials

The accumulator consists of a single container housing all the tractive system battery cells, battery management boards, and AIRs. The single L-shape container is fabricated from steel or aluminum (following EV 3.4.6), is marked with HV warning stickers, and contains a single Molex HV connector. The only other entry into the accumulator is the air duct, which has several baffles to prevent water intrusion. The bottom of the accumulator container is flared out to make a flange, which allows the accumulator to be bolted to the frame of the car. The accumulator container is positioned behind the driver and the firewall and is in front of the front roll hoop. The container was designed with minimizing the number of internal fasteners in mind. The lid bolts onto the accumulator container and fully seals off the HV from water and foreign objects.

The battery pack consists of 5 segments/modules (<6MJ) that are separated by aluminum walls. In order to isolate each segment, the aluminum dividers are covered in an envolope of IG Formex. Additionally, the inside walls of the accumulator container are covered with Formex and attached using Kapton tape. Figure 53 shows a single battery module, which consists of 3 parallel strings of 12 parallel batteries, a metal mounting/compression structure, and a battery management board. The battery tabs are pressed together using a clamping system, with the tabs and bus bar captured between two layers of acrylic, see Figure 54. Each battery module uses an in house designed toolless maintenance plug to satisfy the 6MJ/120V limit. These Maintenance Plugs

use RADLOK connect from amphenol with a heat shrink boot to cover up the connector. Bus bar dimensions (XX by XX by XX) are connected to the packs to the fuses and AIRs.

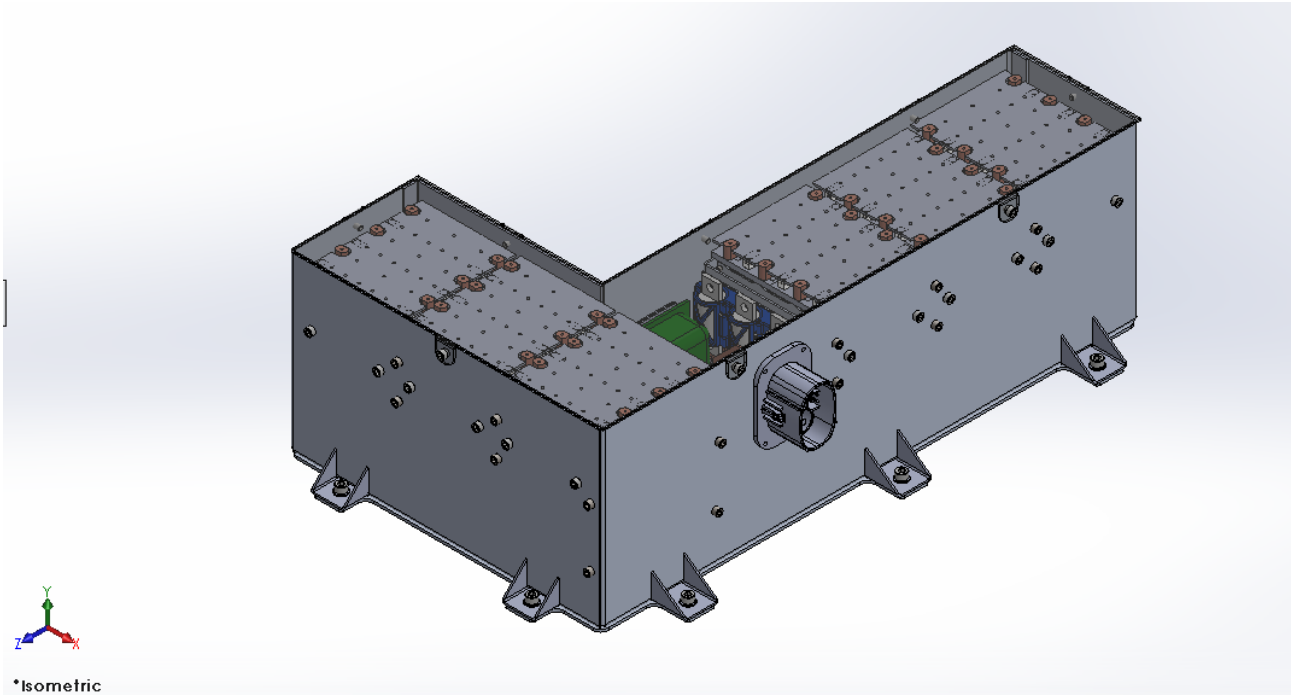


Figure 52. Full Accumulator Pod

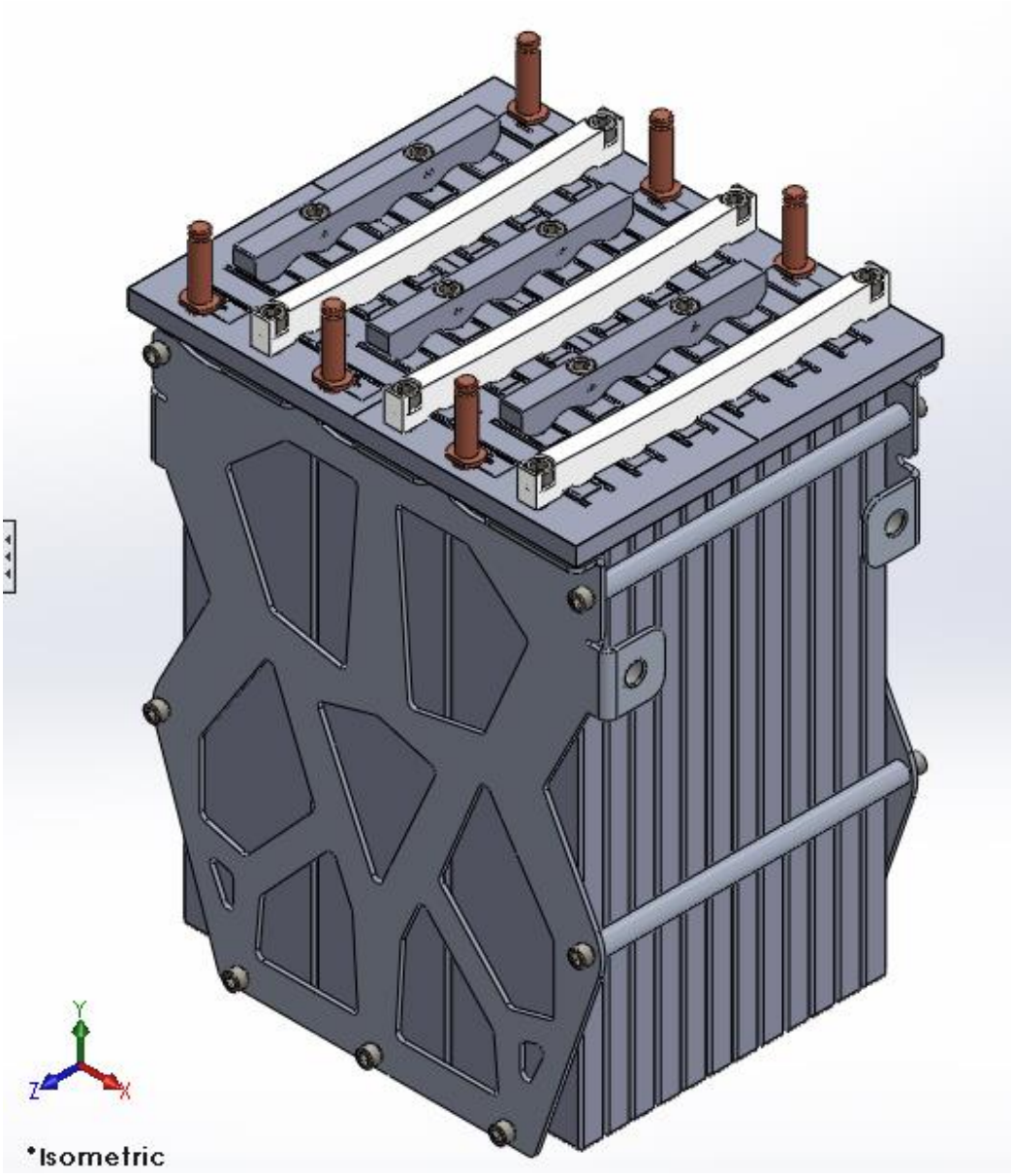


Figure 53. Accumulator Battery Module (<6MJ)

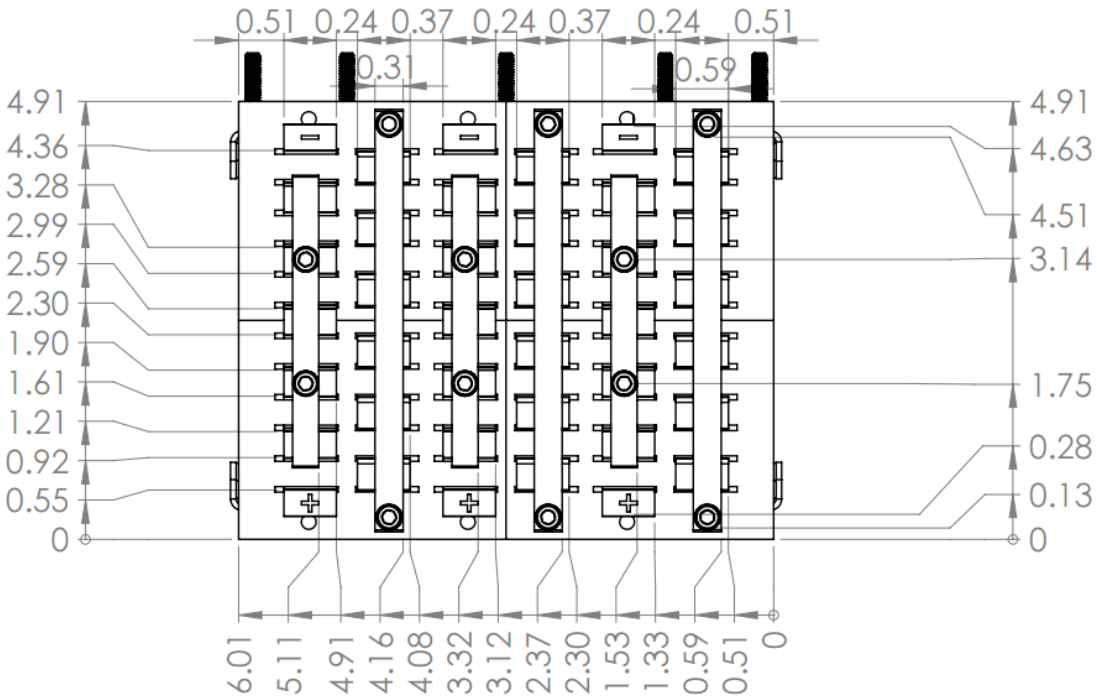


Figure 54. Individual Battery Module Hookup

3.1.12 Position in car

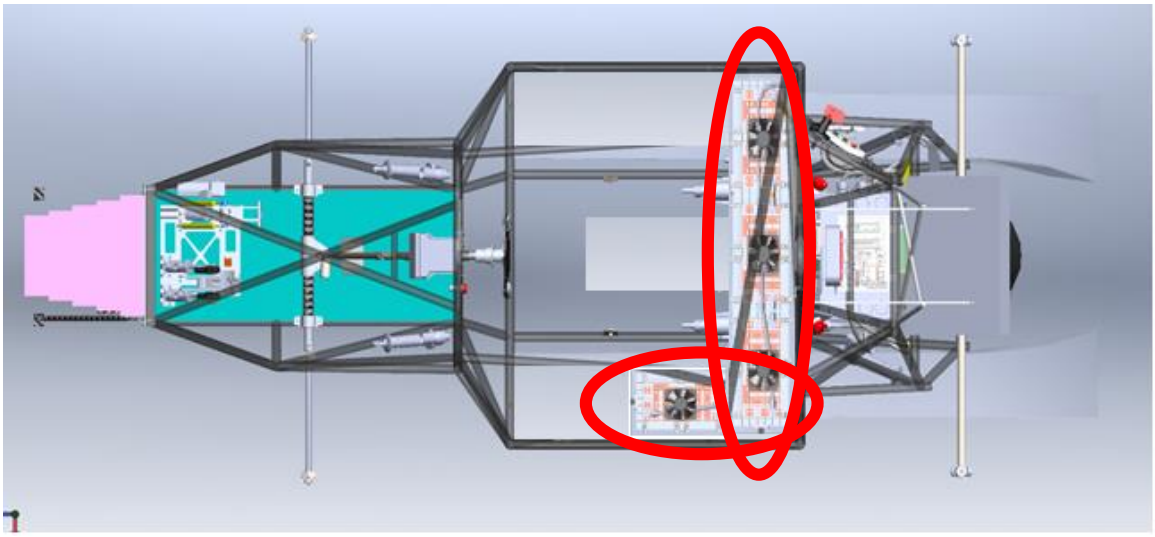


Figure 55. Accumulator Position in Car

3.2 Accumulator pack 2

Only 1 accumulator will be used in the car.

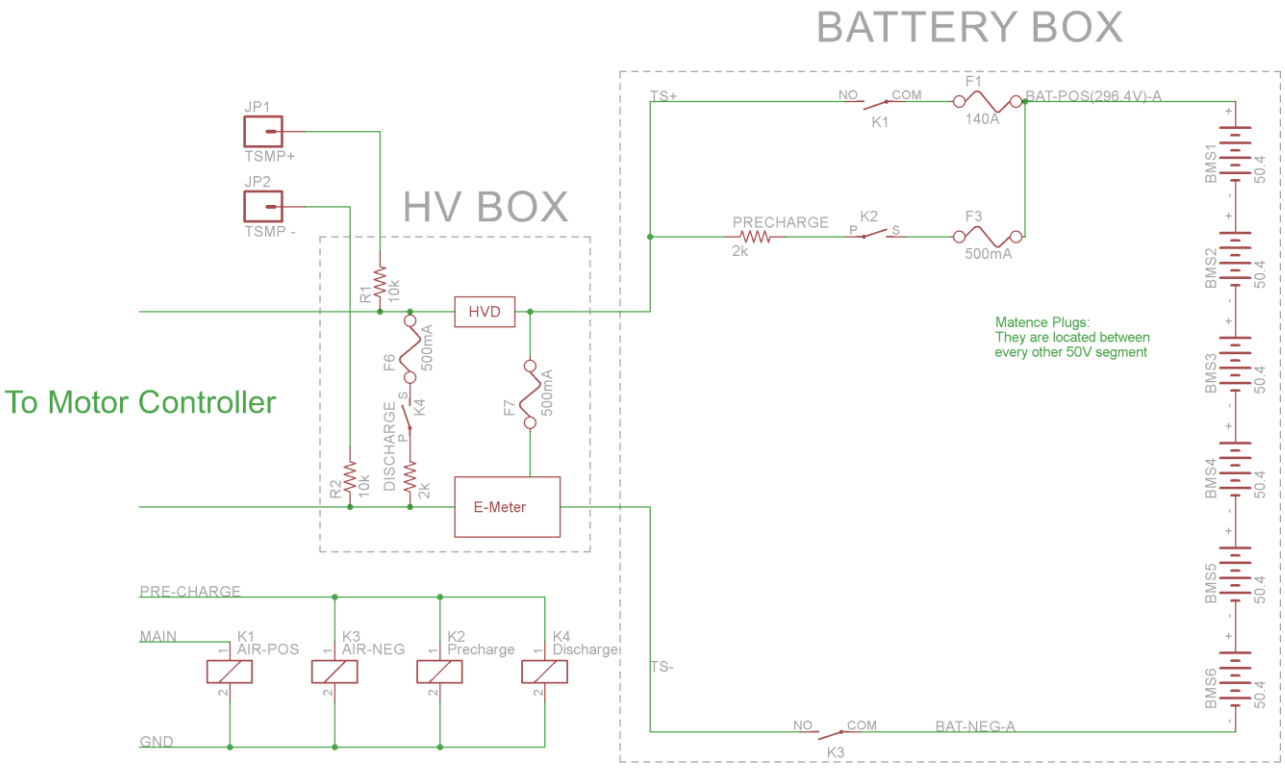
4 Energy meter mounting

4.1 Description

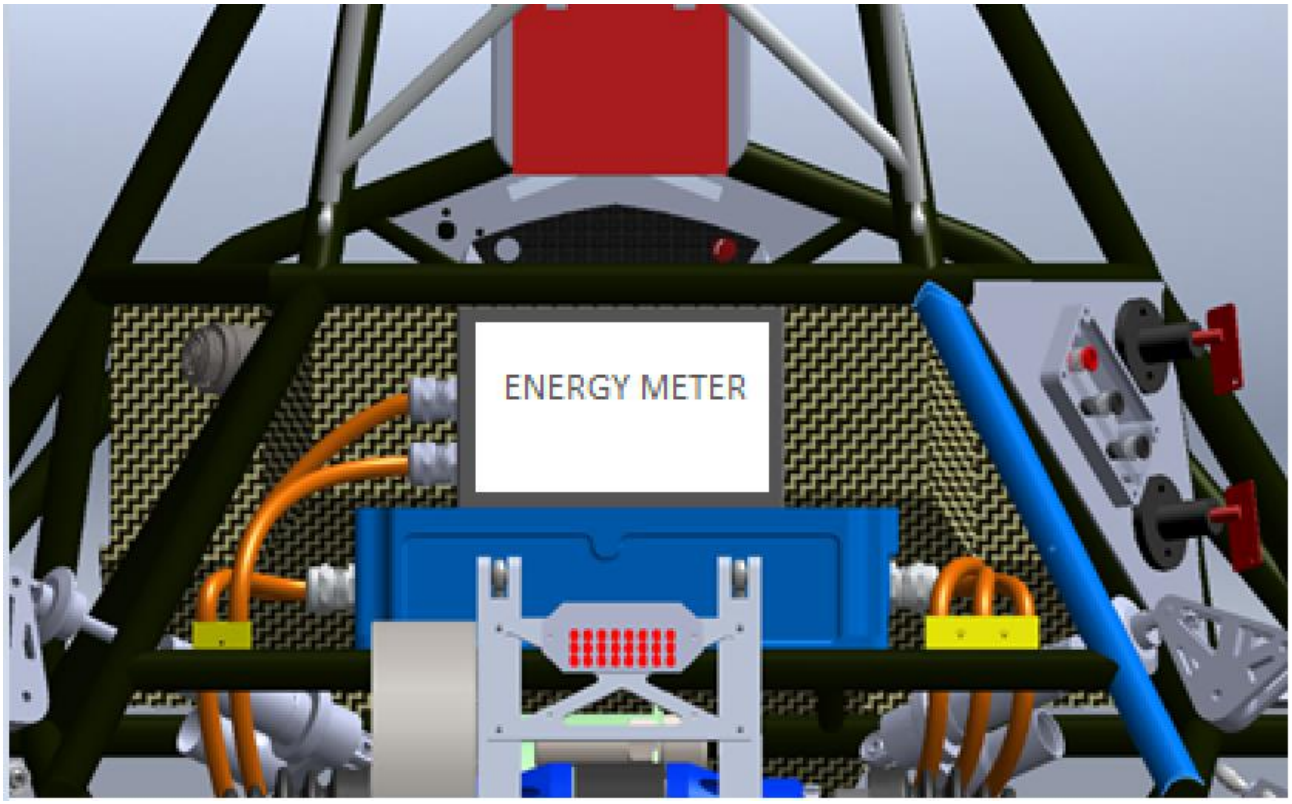
We are fabricating a plastic box to hold the e-meter. This box will also hold the HVD and the discharge system.

4.2 Wiring, cables, current calculations, connectors

The high current path has EXRAD Shielded Cable XLE 2 cable. We use 20 gauge cable for the LV 24V connection and for the HV connection use 300v wire.



4.3 Position in car



5 Motor controller

5.1 Motor controller 1

5.1.1 Description, type, operation parameters

The motor controller(s) used on this car is a Rinehart Motion Systems PM100DX permanent magnet brushless AC motor controller. It is capable of 0-360V and 300Arms. The motor controller is commanded via analog signals sent by our self-designed motor controller PCB (MCS). It communicates over a RS485 communication bus from the ECU. The motor controller also controls the regenerative braking of the car. This is set from hardware controlled by our software. The controller is isolated. Because of that, nothing connecting to it needs isolated from chassis ground.

Motor controller type:	Rinehart Motion Systems PM100DX brushless AC
Maximum continous power:	108kW
Maximum peak power:	126kW for 30s
Maximum Input voltage:	360VDC
Output voltage:	250VAC
Maximum continuous output current:	300Arms
Maximum peak current:	350Arms for 30s
Control method:	analog signal
Cooling method:	water
Auxiliary supply voltage:	12VDC

Table 5.1 General motor controller data

5.1.2 Wiring, cables, current calculations, connectors

All connections to the accumulator, the motors, and the energy meter are all EXRAD Shielded Cable XLE 2 cable. The motor controller will do all of our shield grounding for us on the High power

cable. They go through grounding cable glands. This makes a sealed connection. The conductor is clampe in a bus bar in the motor controller.

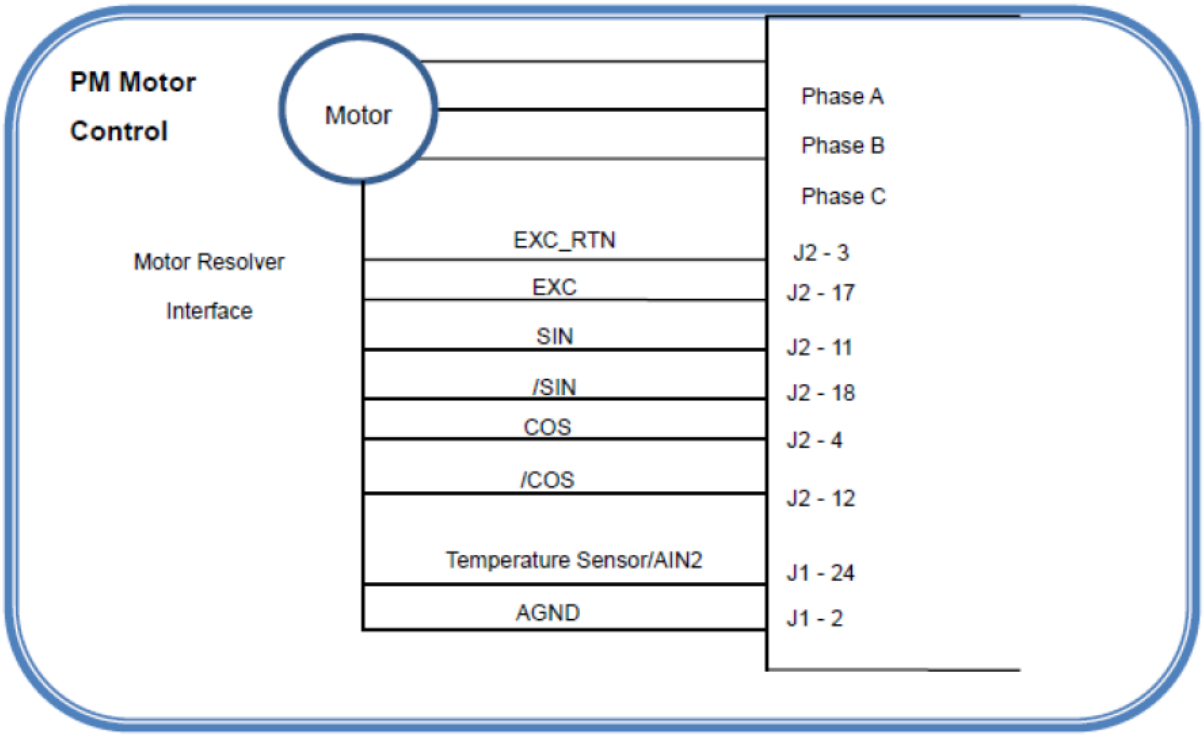


Figure 56 Motor Controller Wiring Diagram

Wire type:	Champlain EXRAD Shielded Cable xlx2x
Current rating:	255A
Maximum operating voltage:	1000V
Temperature rating:	240 °C

Table 5.2 Wire data of Champlain Exrad Shielded Cable

5.1.3 Position in car

The motor controller is position in the rear of the car (behind the main roll hoop) above the motor.

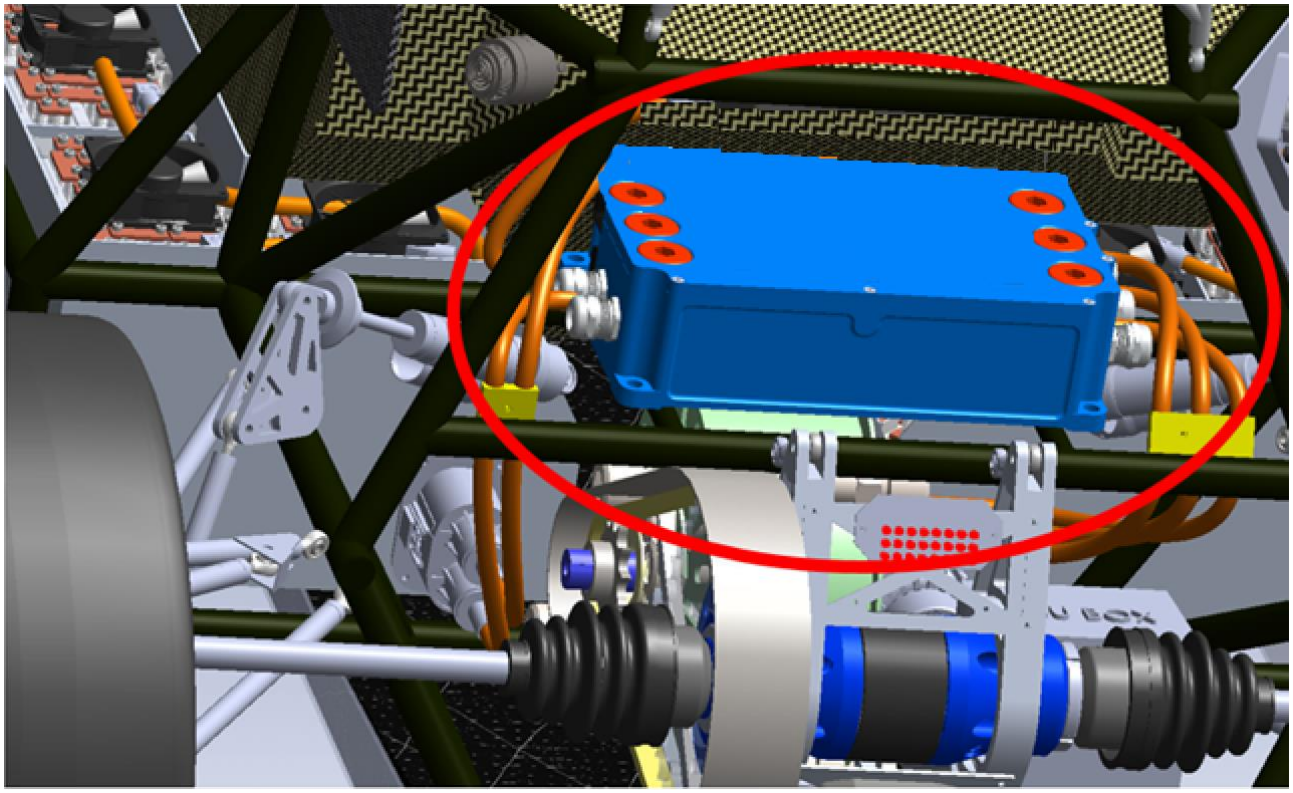


Figure 57 Motor Controler Position in Car

5.2 Motor controller 2

…

This vehicle only uses 1 motor and 1 motor controller

.

6 Motors

6.1 Motor 1

6.1.1 Description, type, operating parameters

Motor Manufacturer and Type:	Enstroj EMRAX228 HV
Motor principle	Brushless Synchronus Three Phase AC
Maximum continuous power:	45kW
Peak power:	100kW for 3s
Input voltage:	50-600Vdc
Nominal current:	115A
Peak current:	240A
Maximum torque:	240Nm
Nominal torque:	125Nm
Cooling method:	Water

Table 6.1 General motor data

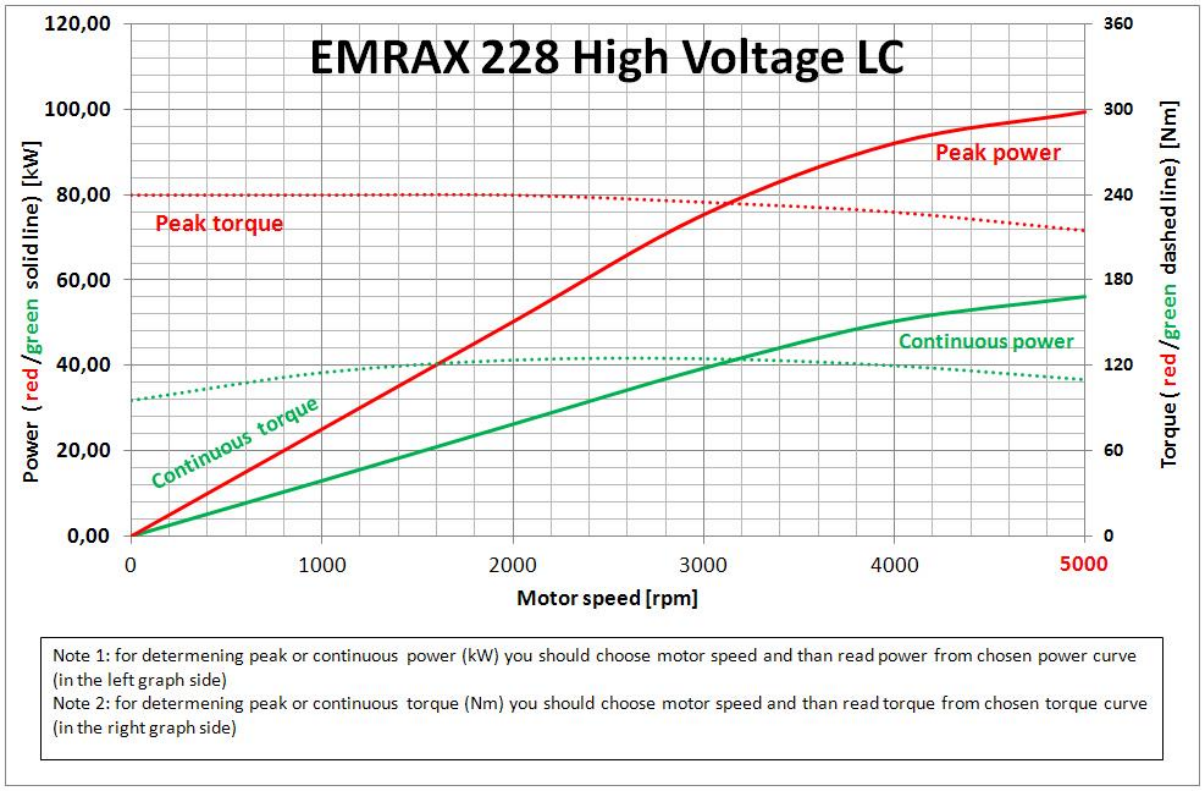
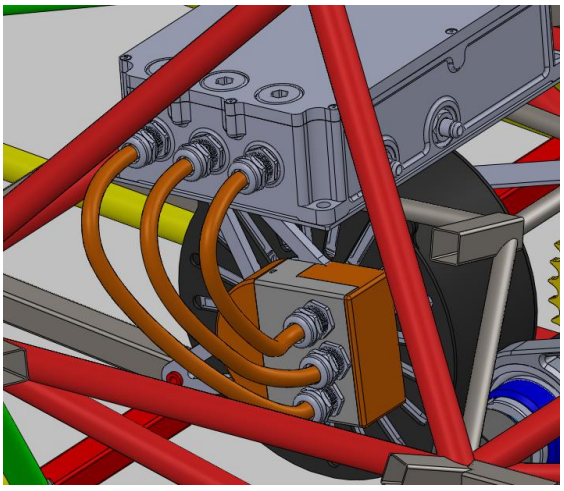


Figure 58 Motor Torque/Speed & Power/Speed Data

6.1.2 Wiring, cables, current calculations, connectors

The three shielded wires coming to the motor have 90 degree crimp terminals and then bolted on to the connections to the motor. We are adding locking nuts to prevent looseness of the connection. We are 3D printing a cover that goes over these terminals to provide isolation spacing and to protect people. Additionally strain relief and vibration isolation will be achieved by adding grommets in the 3D printed cover.



6.1.3 Position in car

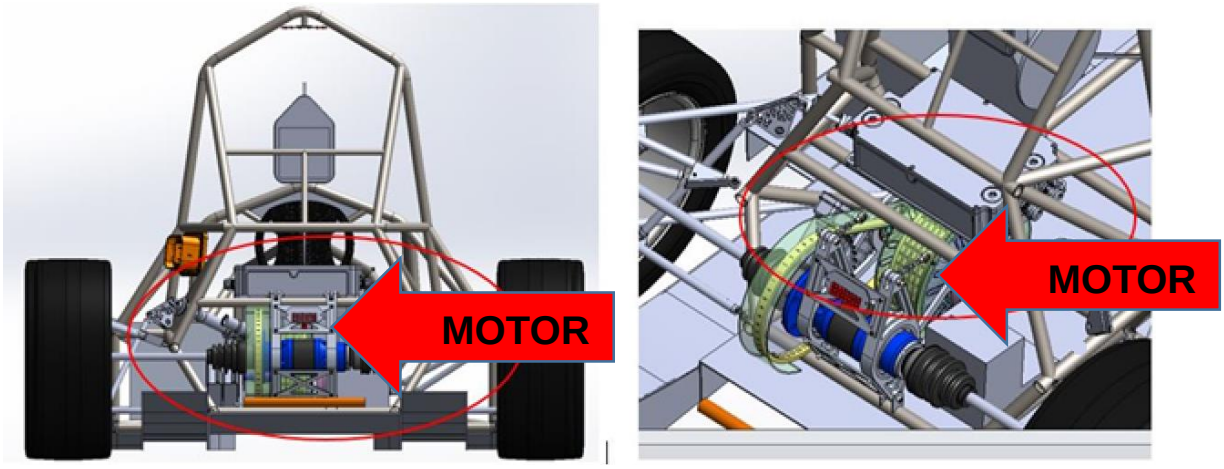


Figure 59 Motor Position in Car (Rear & Isometric View)

6.2 Motor 2

…

This vehicle only uses 1 motor.

7 Torque encoder

7.1 Description/additional circuitry

The two CLS1322-075 sensors are linear displacement sensor. They will be connected to the throttle pedals of the vehicle. As the pedal moves the sensor will slide with the pedal and provide an analog output to the system. That output will be sent as an input to a conditioning circuit. Once conditioned, the signal will be sent to the main controller.

Torque encoder manufacturer and type:	CLS1322-075
Torque encoder principle:	potentiometer
Supply voltage:	3.3V
Maximum supply current:	20mA
Operating temperature:	-20..180 °C
Used output:	150mV-3.2V

Table 7.1 Torque encoder data

7.2 Torque Encoder Plausibility Check

If an error occurs in the measuring requested torque from the throttle pedal the main controller will shut the vehicle down. A number of errors could occur. If the communication is lost between the SAS (Where the analog signal is measured) and ECU the car will be shutdown (AIR's opened). If at any time the conditioning circuit is shorted or becomes open the controller will see the loss of signal (30ms) and will shut the car down. If the outputs of the two potentiometers differ by more than 10% the vehicle will be shut down as stated in the rules.

We check for above failures by first, monitoring data integrity by using CRC check sums in serial data and in code. We monitor position sensors integrity by using the sensors as rheostats and adding a 5 ohm resistor in series with the sensor. We added a 100 ohm pull up on the ADC pin. With the sensor connected to the ADC pin to ground we can measure all fault modes.

The analog output to the motor controller is made created by an I2C DAC. It is buffered by an op-amp. That signal goes to a SPDT relay. The output to the motor controller is on the common pin. The DAC is connected to the NO pin. The NC pin is pulled to ground. The uC reads the DAC to verify output matched set point. If they match, the relay opens and stays open as long as the car is on and output matches set point.

7.3 Wiring

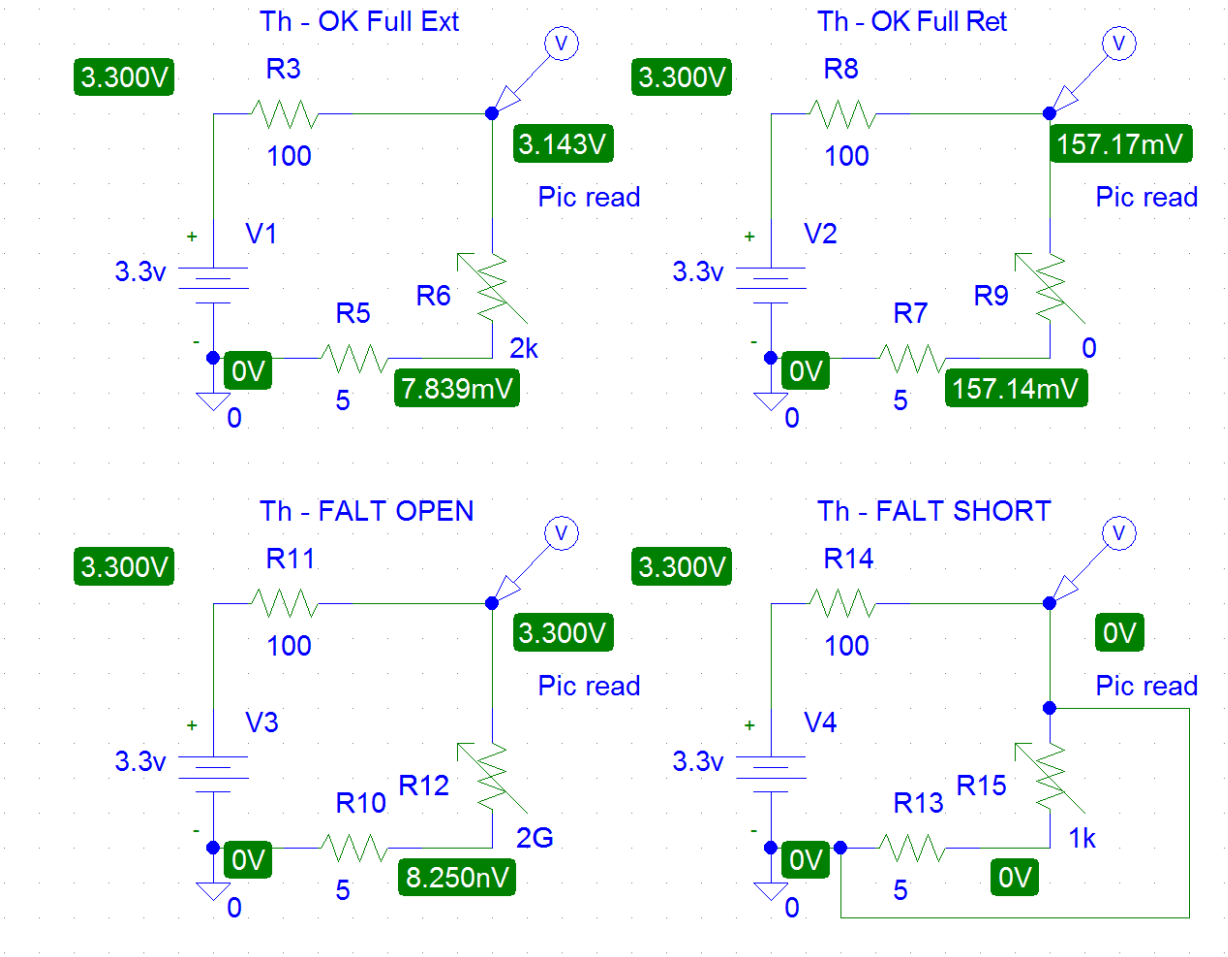


Figure 60 Throttle Sensor Fault Conditions

7.4 Position in car/mechanical fastening/mechanical connection

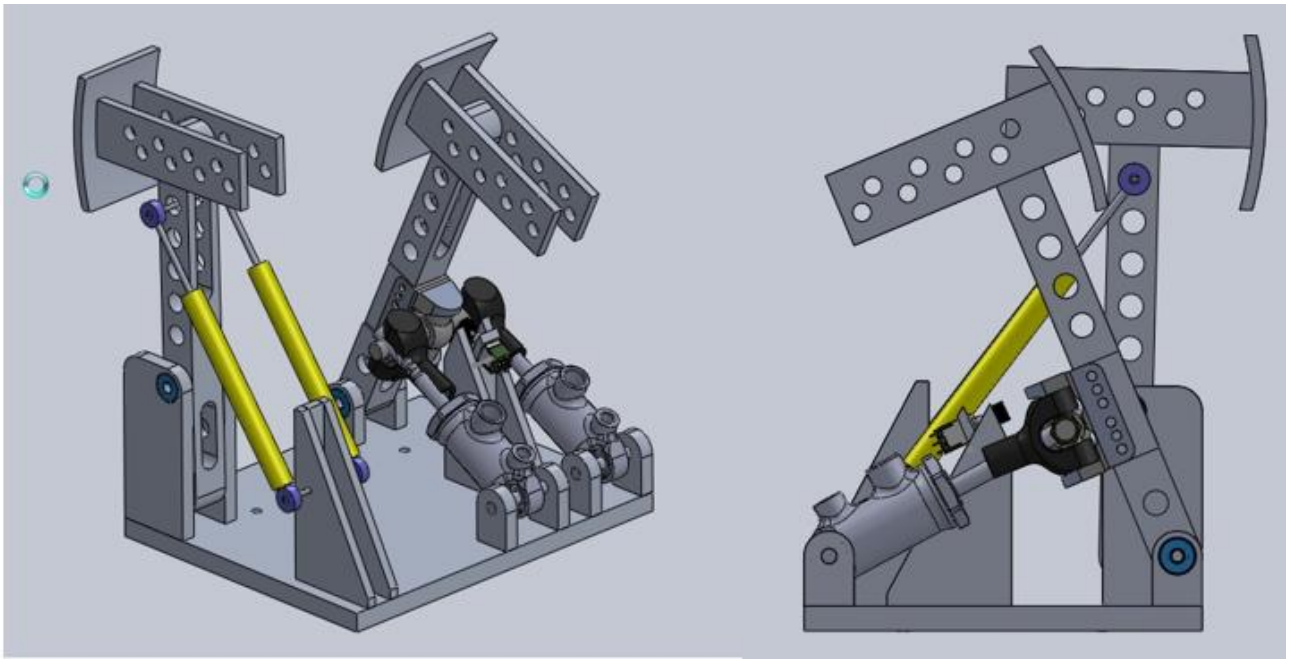


Figure 61 Throttle Pedal and Sensor Position in Car

8 Additional LV-parts interfering with the tractive system

8.1 LV part 1 – GLVS BMS

8.1.1 Description

Our GLVS is powered by a custom battery pack. This pack is protected by a student designed battery management system that is from a reference design from Linear Technologies.

Seven cells will be monitored by the in-house fabricated BMS board. The BMS is capable of opening a relay to disconnect the pack. This removes all GLV power to the car, shutting the car down. The BMS will monitor cells for minimum voltage of 2.75v and a maximum of 4.2. Our BMS will take actions to bypass the affected cell(s) of higher voltage and shutdown the GLVS system if necessary. The BMS also reacts to temperature problems at 60°C. The BMS can also measure current and trigger the safety system. There is a wire going between the BMS PCB and the Battery pack.

8.1.2 Wiring, cables,

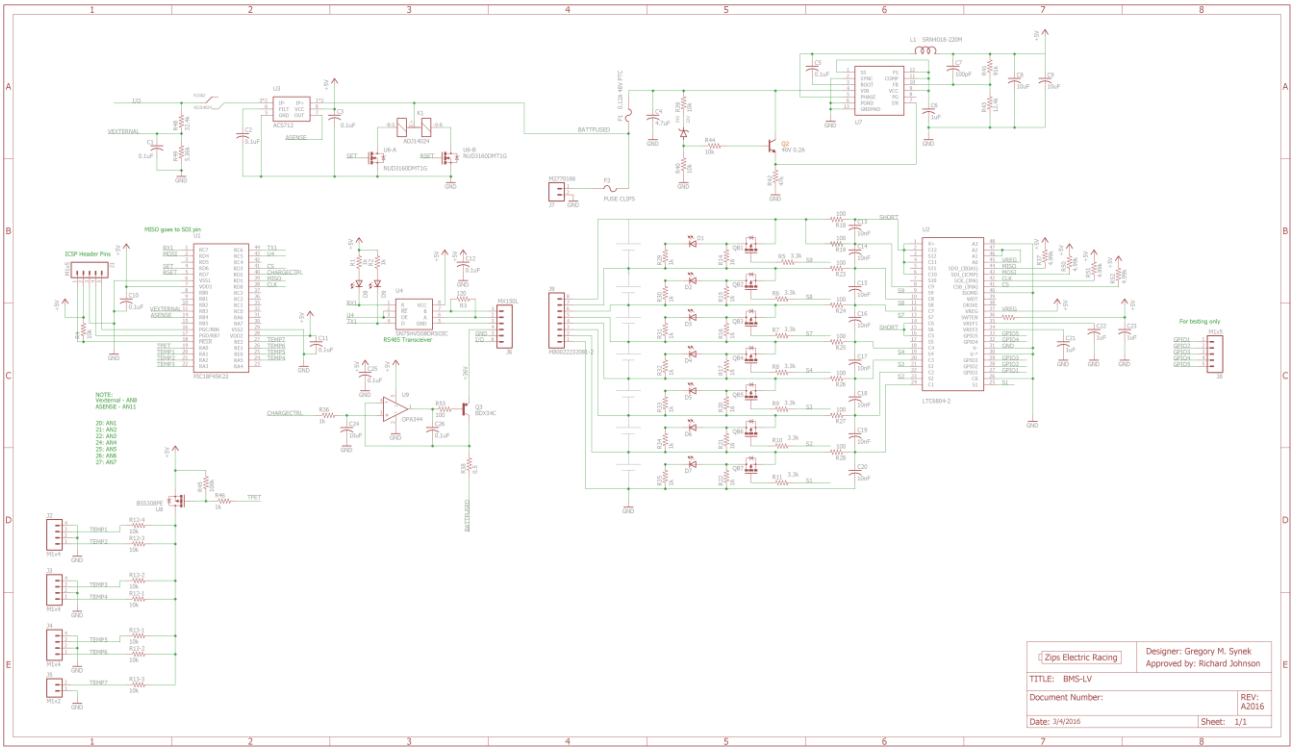


Figure 62. GLVS Wiring and BMS circuit

8.1.3 Position in car

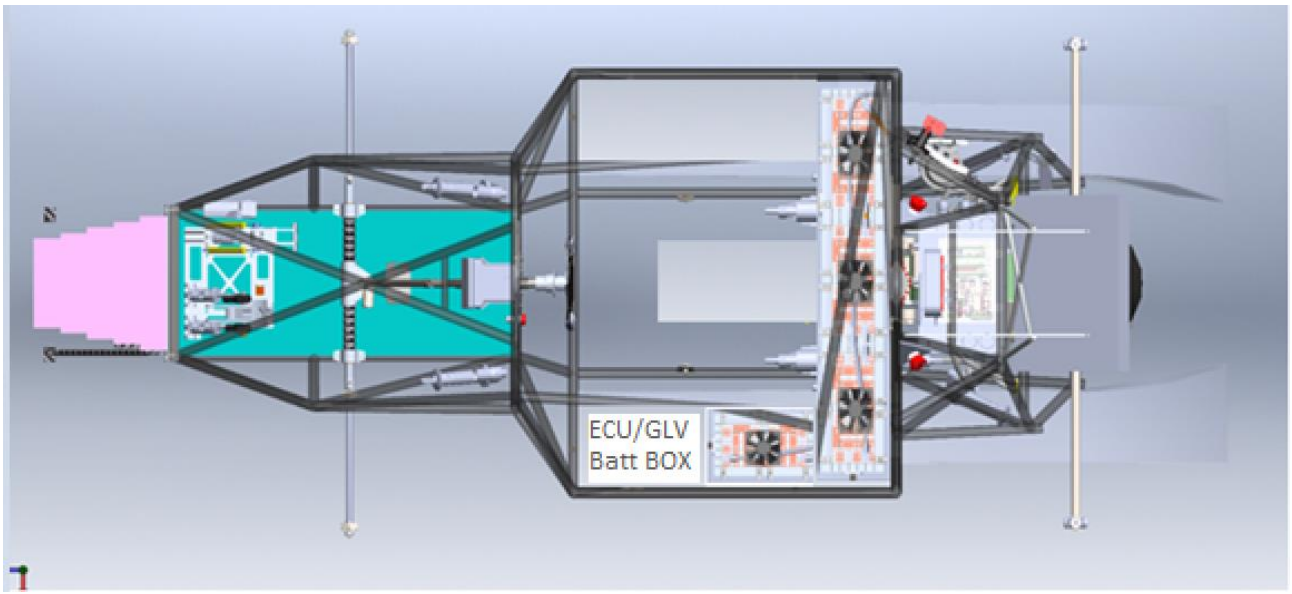
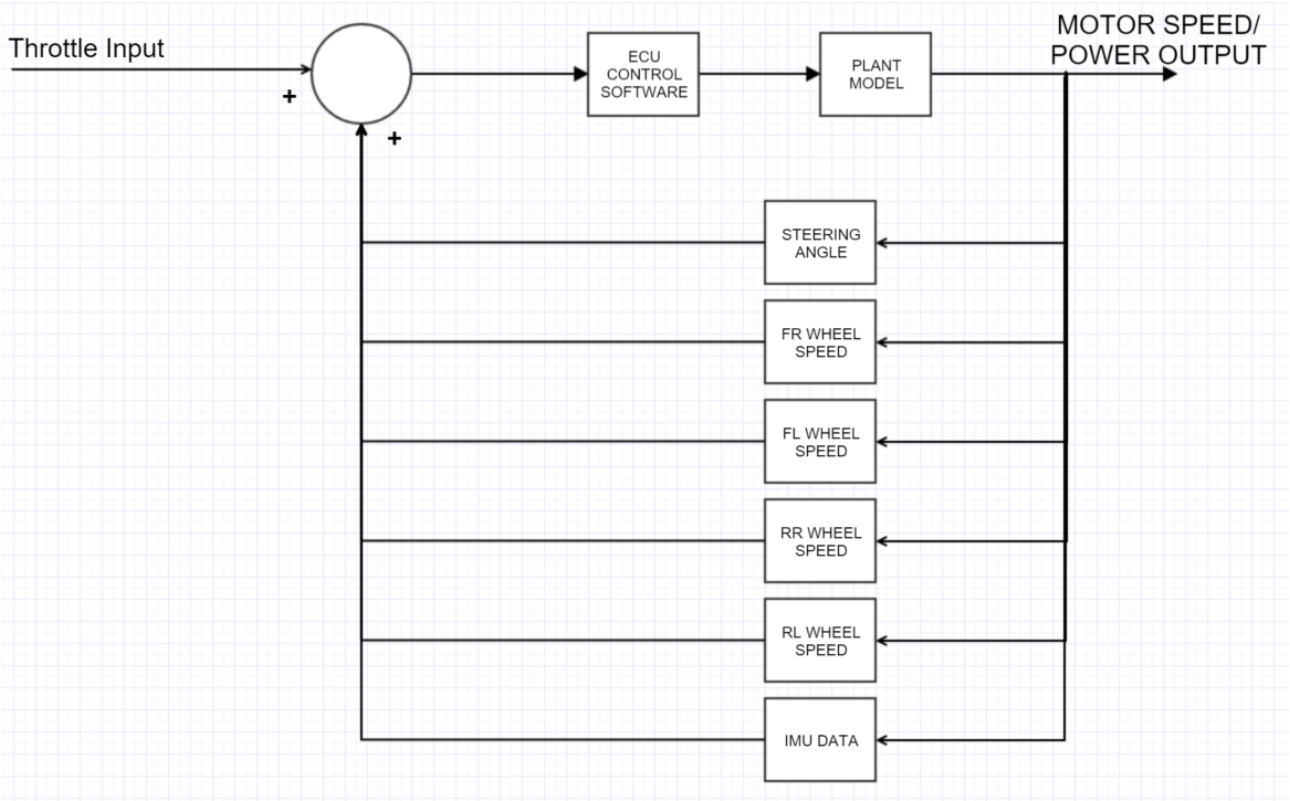


Figure 63. GLVS battery pack location in car

8.2 LV part 2 Traction Control System

The Traction Control System of the car will control power delivered to the motor and wheel slip. Power limiting will be calculated using feedback from wheel speed sensors, IMU DATA, and steering angle. The flowchart below outlines the control system.


Throttle Input
+
+
ECU CONTROL SOFTWARE
PLANT MODEL
MOTOR SPEED/ POWER OUTPUT
STEERING ANGLE
FR WHEEL SPEED
FL WHEEL SPEED
RR WHEEL SPEED
RL WHEEL SPEED
IMU DATA

9 Overall Grounding Concept

9.1 Description of the Grounding Concept

The chassis is made from conductive chrome-moly and will provide low resistance paths through the frame. The steering wheel will have a ground wire thru the quick disconnect to ensure low resistance. Firewalls will be mounted to the car via tabs welded to the frame. The tabs will have paint removed to make a robust electrical connection to the firewall

9.2 Grounding Measurements

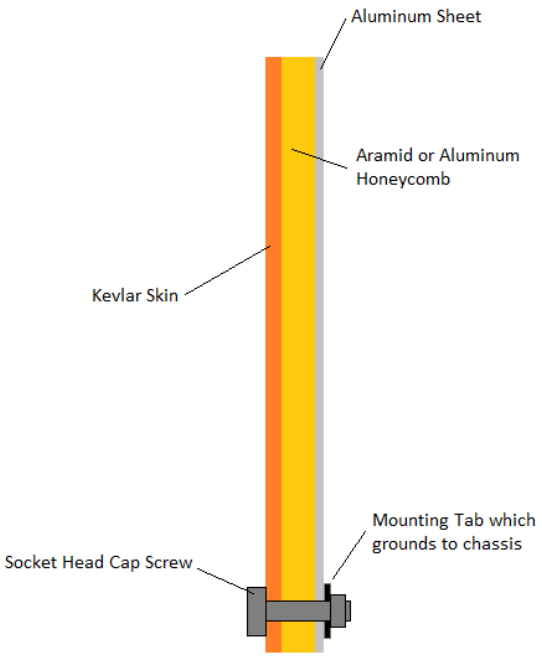
The grounded low voltage measurement point (GLVMP) location is a frame bolt which is connected to a wire coming from the GLV battery lead. Measurements between various points and this frame bolt will be tested to ensure compliance with EV4.3.

10 Firewall(s)

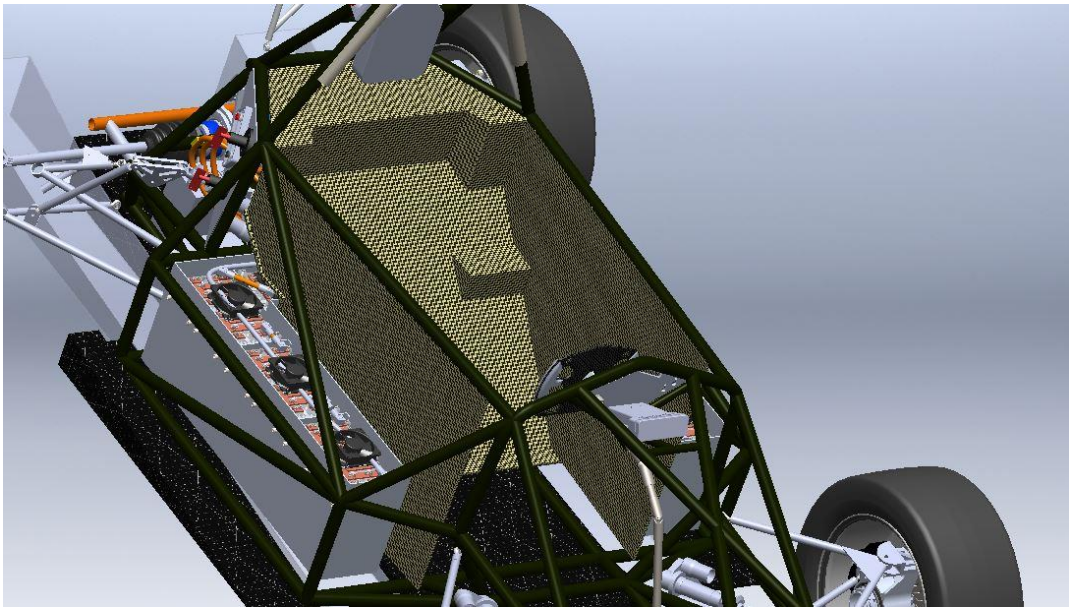
10.1 Firewall 1

10.1.1 Description/materials

The Tractive System Firewall serves a dual purpose of protecting the driver from potential hazard, but also supporting the driver in the car. Because the seat is molded foam and not rigidly mounted to the chassis, the firewall must be capable of supporting the driver's torso and seat throughout the dynamic events. The proposed firewall is a composite structure consisting of fire retardant materials. This allows us to make a stiff panel that is also fire resistant. The concept, attached below, consists of an aluminum skin (0.5 mm thick) facing the HV components (per the required firewall rules) and fire resistant core materials, followed by a Kevlar skin. A thick kevlar skin will be sufficient in preventing piercing of the firewall, and the honeycomb structure will give the panel enough stiffness to support the loads required. The firewall is grounded to the chassis via the mounting system used to secure it to the chassis. This consists of Socket head cap screws through the firewall and tabs welded directly to the chassis. In the event that this grounding method is not sufficient, a properly sized grounding strap will be added to the aluminum skin and attached to the chassis.



10.1.2 Position in car



10.2 Firewall 2

This car only has 1 firewall.

11 Appendix

11.1 System Overview

11.1.1 18 AWG PVC Insulated Hookup Wire

Referred to

PART NO. 3055

Construction

		Diameters (In)
1) Component 1	1 X 1 HOOKUP	
a) Conductor	18 (16/30) AWG TC	0.047
b) Insulation	0.016" Wall, Nom. PVC	0.079+/- 0.002
(1) Print	ALPHA WIRE E163869-* RU AWM STYLES 1569 105C OR 1007 80C VW-1 300V 18 AWG ---- LXXXX CSA TR-64 90C FT1 ROHS {0} * = Factory Code *[Note: Product may have c(UL) or CSA markings depending upon plant of manufacture.]*	
(2) Color(s)	WHITE, BLACK, RED, GREEN, YELLOW, BLUE, BROWN ORANGE, SLATE, VIOLET, WHITE/BLACK, WHITE/RED WHITE/GREEN, WHITE/YELLOW, WHITE/BLUE WHITE/BROWN, WHITE/ORANGE, WHITE/SLATE WHITE/VIOLET, GREEN/YELLOW, YELLOW/GREEN, PINK	

Applicable Specifications

1) UL	AWM/STYLE 1007	80°C / 300 V_{RMS}
	AWM/STYLE 1569	105°C / 300 V_{RMS}
	VW-1	
2) CSA International	TR-64	90°C
	FT1	

Full datasheet can be found here

11.1.2 24 AWG PVC Insulated Hookup Wire

Referred to :2.2.2, 2.3.2

PART NO. 3050

Construction

		Diameters (In)
1) Component 1	1 X 1 HOOKUP	
a) Conductor	24 (7/32) AWG Tinned Copper	0.024
b) Insulation	0.016" Wall, Nom. PVC	0.056+/- 0.002
(1) Print	ALPHA WIRE E163869-* RU AWM STYLES 1569 105C OR 1007 80C VW-1 300V 24 AWG ---- LXXXX CSA TR-64 90C FT1 ROHS {0} * = Factory Code *[Note: Product may have c(UL) or CSA markings depending upon plant of manufacture.]*	
(2) Color(s)	WHITE, BLACK, RED, GREEN, YELLOW, BLUE, BROWN ORANGE, SLATE, VIOLET, WHITE/BLACK, WHITE/RED WHITE/GREEN, WHITE/YELLOW, WHITE/BLUE WHITE/BROWN, WHITE/ORANGE, WHITE/SLATE WHITE/VIOLET, GREEN/YELLOW, PINK	

Applicable Specifications

1) UL	AWM/STYLE 1007	80°C / 300 V_{RMS}
	AWM/STYLE 1569	105°C / 300 V_{RMS}
	VW-1	
2) CSA International	TR-64	90°C
	FT1	

Environmental

Full Datasheet can be found here

11.1.3 TSMS/HV Sense Wire

AlphaWire

Enlarge

Images are for reference only
See Product Specifications

Mouser Part #:	602-6460-100-04
Manufacturer Part #:	6460 OR005
Manufacturer:	Alpha Wire
Description:	Multi-Paired Cables 22AWG 2C SHIELD 100ft SPOOL ORANGE

Add to Compare List

Share | 8+1 0

Specifications | **My Notes**

Manufacturer:	Alpha Wire	☑
Product Category:	Multi-Paired Cables	☑
RoHS:	RoHS Details	
Number of Pairs:	1	☐
Wire Gauge - AWG:	22 AWG	☐
Stranding:	7 x 0.0096	☐
Shielding:	Shielded	☐
Length:	100 ft	☐
Voltage Rating:	300 V	☐
Jacket Material:	Polyvinyl Chloride (PVC)	☐
Insulation Material:	Polypropylene (PP)	☐
Type:	Industrial Automation	☐
Jacket Color:	Orange	☐
Brand:	Alpha Wire	
Conductor Material:	Tinned Copper	

Full datasheet: here

11.2 Electrical System Datasheets

11.2.1 Shutdown Circuit

11.2.1.1 E-Stop Switches

Referred to: 2.1.1

SSA-EB Series Emergency Stop Buttons

BANNER
more sensors, more solutions

Datasheet

Figure 1. SSA-EBM-xxE Series with Enclosure

Figure 2. SSA-EBP-xxE Series with Enclosure

- Push-to-stop, twist-to-release operation
- Rugged, modular design; easy assembly and installation
- Kits available for easy selection
- Choice of metal or plastic button base with or without enclosure; all kits include disc label with "Emergency Stop" legend
- Choice of normally closed (safety) or combination normally closed/normally open (non safety) contacts
- Latching design complies with ISO 13850; direct (positive) opening operation per IEC 60947-5-1

Models		Button Base Material	Contacts	Enclosure Included
SSA-EBM-02L		Metal	2 normally closed	No
SSA-EBM-11L			1 normally closed and 1 normally open	
SSA-EBM-12L			2 normally closed and 1 normally open	
SSA-EBP-02L		Plastic	2 normally closed	
SSA-EBP-11L			1 normally closed and 1 normally open	
SSA-EBP-12L			2 normally closed and 1 normally open	
SSA-EBM-02E		Metal	2 normally closed	Yes
SSA-EBM-11E			1 normally closed and 1 normally open	
SSA-EBM-12E			2 normally closed and 1 normally open	
SSA-EBP-02E		Plastic	2 normally closed	
SSA-EBP-11E			1 normally closed and 1 normally open	
SSA-EBP-12E			2 normally closed and 1 normally open	

Dimensions

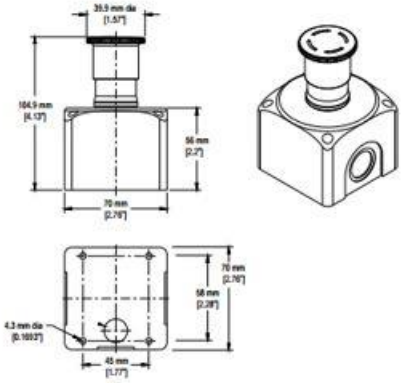


Figure 4. SSA-EBM-xxE and EBP-xxE Series E-Stop Buttons

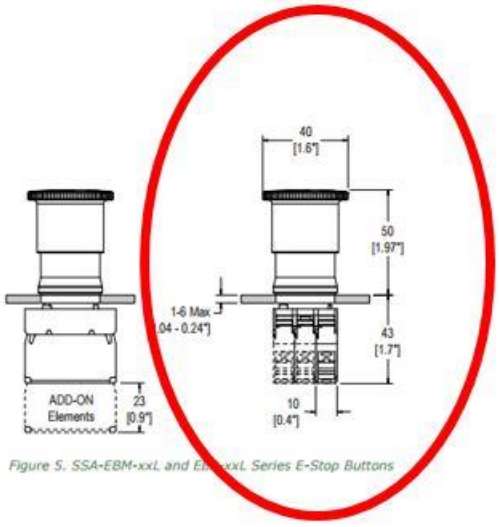


Figure 5. SSA-EBM-xxL and EBP-xxL Series E-Stop Buttons

Full Datasheet: [here]

11.2.1.2 Tractive System Master Switch

Referred to: 2.1.1

Click to Enlarge Image

Clearance Price: $11.00

1 Add To Cart + Wish List + Compare

Fast Shipping | Tech Advice | Low Price Guarantee | Easy Returns

★★★★½ (8)

Review This Product

Battery Disconnect Switch, Light Duty, Manual, Rotary, 12 V, 175 Continuous amp Rating, Each

Estimated Ship Date: Today

Would you rather pick it up? Select Location

Clearance parts have limited quantities, order yours now!

Overview | Suggested Parts | Reviews | Show All

Brand:	G-FORCE Racing
Manufacturer's Part Number:	3101
Part Type:	Battery Disconnect Switches
Product Line:	G-FORCE Light-Duty Battery Disconnect Switches
Summit Racing Part Number:	GFR-3101
Switch Activation:	Manual
Switch Actuation:	Rotary (turn)
Voltage Compatibility:	12
Continuous Amp Rating:	175 amps
Surge Amp Rating:	500 amps
Includes Alternator Disconnect:	Yes
Includes Magneto Disconnect:	No
Waterproof:	No
Mounting Bracket Included:	No
Emergency Off Decal Included:	No
Quantity:	Sold individually.
In-Store Pickup:	Choose In-store pick-up (OH, GA, NV) on our web site.

11.2.2 Bender IR155-3203 IMD

Referred from 2.1.1., 2.2

Technical data

Insulation coordination acc. to IEC 60664-1	
Protective separation (reinforced insulation)	
	between (L+/L-) – (Kl. 31, Kl. 15, E, KE, M_{HS}, M_{LS}, OK_{HS})
Voltage test	AC 3500 V/1 min
Supply/IT system being monitored	
Supply voltage U_S	DC 10…36 V
Max. operating current I_S	150 mA
Max. current I_k	2 A
	6 A/2 ms inrush current
HV voltage range (L+/L-) U_n	AC 0…1000 V (peak value)
	0…660 V rms (10 Hz…1 kHz)
	DC 0…1000 V
Power consumption	< 2 W
Response values	
Response value hysteresis (DCP)	25 %
Response value R_{an}	100 kΩ…1 MΩ
Undervoltage detection	0…500 V
Measuring range	
Measuring range	0…10 MΩ
Undervoltage detection	0…500 V default setting: 0 V (inactive)
Relative uncertainty	
SST (≤ 2 s)	good > 2* R_{an}; bad < 0.5* R_{an}
Relative uncertainty DCP	0…85 kΩ ▸ ± 20 kΩ
(default setting 100 kΩ)	100 kΩ…10 MΩ ▸ ±15%
Relative uncertainty output M (fundamental frequency)	±5 % at each frequency
	(10 Hz; 20 Hz; 30 Hz; 40 Hz; 50 Hz)
Relative uncertainty	
undervoltage detection	U_n ≥ 100 V ▸ ±10 %; at U_n ≥300 V ▸ ±5 %
Relative uncertainty (SST)	"Good condition" ≥ 2* R_{an}
	"Bad condition" ≤ 0.5* R_{an}

Complete data sheet located here

11.2.3 Crash Sensor

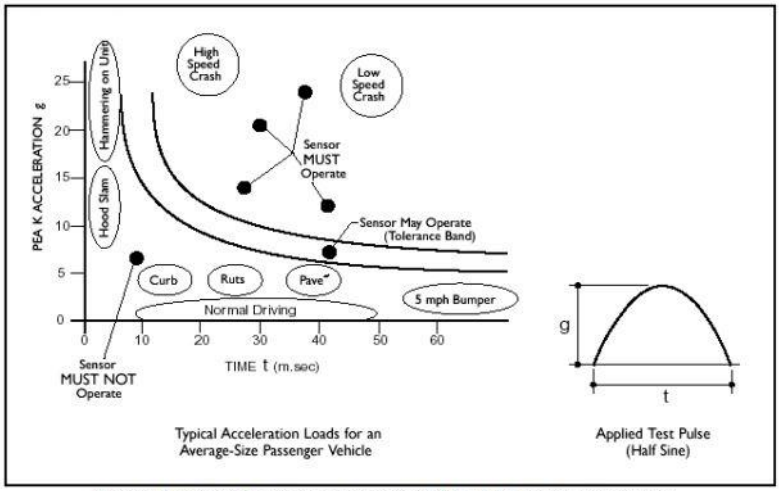
11.2.3.1 Sensata resettable inertial switch

Referred from 2.3

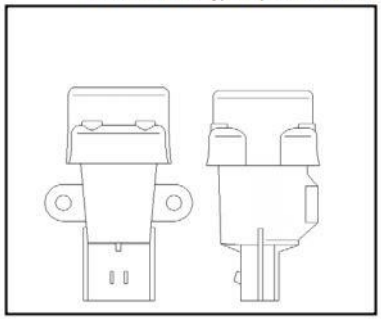
Features:

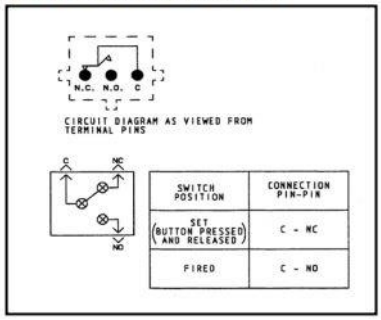
- Unique magnet restrained mass inertia mechanism
- Rated at 10 Amps electrical load
- Manually resettable

www.sensata.com Printed in U.S.A., December 2010



Above are the typical performance characteristics of resettable crash sensors





Datesheet here

11.2.4 Brake Plausibility

11.2.4.1 Honeywell Brake Pressure Sensor

Referred to 2.3.1

Heavy Duty Pressure Transducers	PX2 Series
Pressure connection	7/16-20 UNF 1/4 in 45° Flare Female Schrader (SAE J512), 7/16-20 UNF 45° Flare Male (SAE J513), 7/16-20 UNF 37° Flare Male (SAE J514), G1/4 (ISO 1179-3), G1/8 (ISO 1179-3), M12 x 1.5 (ISO 6149-3), 1/4-18 NPT, 1/8-27 NPT, 9/16-18 UNF, (SAE J1926-3), 7/16-20 UNF (SAE J1926-3)
Measurement type	absolute, sealed gage, vented gage
Construction	port and housing: 304 stainless steel; connector: PBT 30% GF
Pressure range	1 bar to 70 bar | 100 kPa to 7 MPa | 15 psi to 1000 psi
Output	ratiometric: 5.0 V, 10 %Vs to 90 %Vs; 5.0 V, 5 %Vs to 95 %Vs; 3.3 V, 10 %Vs to 90 %Vs; 3.3 V, 5 %Vs to 95 %Vs regulated: 1 Vdc to 6 Vdc, 0.25 Vdc to 10.25 Vdc, 0.5 Vdc to 4.5 Vdc, 1 Vdc to 5 Vdc current: 4 mA to 20 mA
Accuracy	±0.25 %FSS
Total Error Band	±2 %FSS at -40 °C to 125 °C [-40 °F to 257 °F]
Amplified	yes
Compensated temperature range	-40 °C to 125 °C [-40 °F to 257 °F]
Termination	Delphi Metri-Pack 150 (UL 94 HB or V-0 options), Micro M12, DIN, Deutsch, cable harness (1 m, 2 m, 3 m, or 5 m).

sensing.honeywell.com 3

Full datasheet can be found here

11.2.5 Tractive System Active Light

11.2.5.1 100 Lumen LED

Referred to: 2.7.1

Red LED (InGaAlN)

absolute maximum ratings: (TA=25°C)

PARAMETER	SYMBOL	Rating	UNIT
Power Dissipation	PD	85	mW
Continuous Forward Current	IF	30	mA
Peak Forward Current (1/10th duty cycle, 0.1ms pulse width)	IFM	100	mA
Reverse Voltage	VR	5	V
Operating Temperature	TA	-20~+80	°C
Storage Temperature	Tstg	-30~+100	°C
Reverse Current (VR=5V)	IR	10	μa
Lead Soldering Temperature (3mm from body) 260C (for 3 seconds)			

Optoelectric Characteristics

PARAMETER	SYMBOL	MAX	TYP	UNIT	TEST
View Angle of Half Power	2ø1/2		120	Degree	
Forward Voltage	VF	2.4	2.0	V	IF=20mA
Dominant Emission Wavelength	ÿD		630	625	IF=20mA
Spectrum Width of Half Value			21	nm	IF=20mA
Luminous Intensity	IV		1200	mcd	IF=20mA

Full datasheet can be found here

11.2.6 Tractive System Measurement Points

Referred to: 2.8

11.2.6.1 TSMP Box

Referred to 2.8

WC-22 WC Series Polycarbonate Enclosure with Clear Cover - NEMA 4X Rated for outdoor use

PHOTO GALLERY | 3D MODEL | 2D DRAWINGS | MATERIAL SPECS

WC-22

The WC-22 offers

- Designed to IP65 of IEC 529 and NEMA 1, 2, 4, 4x, 12 and 13 specifications
- Silicone rubber gasket makes this ideal for outdoor use in a wide range of adverse conditions
- Captive, stainless steel screws thread into brass inserts for cover on/cover off applications
- UL Listed to UL508-4x specifications (File E194432)
- PCB mounting bosses with brass inserts are standard
- Durable, impact-resistant UV Stabilized Polycarbonate material
- Assembly includes base, gasket, cover, and 4 enclosure screws
- For this case with mounting flanges, click here

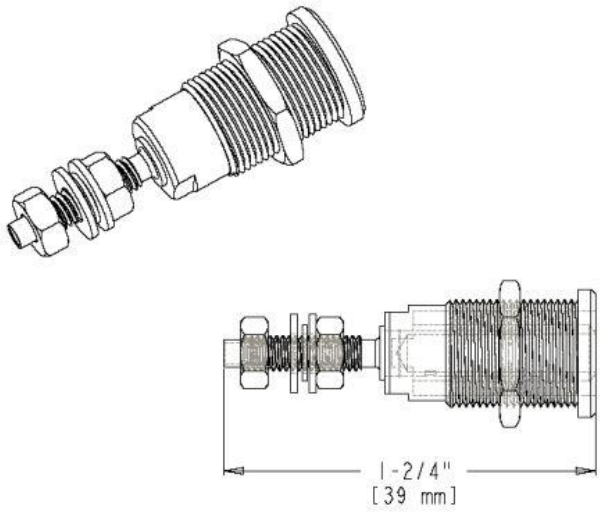
Full datasheet: here

11.2.6.2 TSMP Jacks

Referred to 11.2.6

MUELLER

Part Number: BU-31607- *
Description: Screw-in Safety Socket with Stud and Metal Nut
1308



- Screw-in Safety Socket with Stud and Metal Nut
- Material: Hardware: nickel-plated brass; Insulator: ABS-nylon composite
- Length: 1.53" (39 mm)
- *Std. Colors: -0 Black, -2 Red
- Rating: 600Volts, category III, 1000Volts, category II, 45 Amps, IEC 1010 Compliant
- RoHS Compliant

Mueller Electric Company
1625 E. 31st Street
Cleveland, Ohio 44114

ISO 9001:2000
Over 95 Years Of Innovation
www.muellerelectric.com

TEL. 800-955-2629
TEL. 216-771-5225
FAX. 216-771-3068

Full datasheet: here

11.2.6.3 TSMP Resistors

Referred to 11.2.6

VISHAY
www.vishay.com

RS, NS
Vishay Dale

Wirewound Resistors, Industrial, Precision Power, Silicone Coated, Axial Lead

FEATURES

- High temperature coating (> 350 °C)
- Complete welded construction
- Meets applicable requirements of MIL-PRF-26
- Available in non-inductive styles (type NS) with Ayrton-Perry winding for lowest reactive components
- Excellent stability in operation (typical resistance shift < 0.5 %)
- MIL-PRF-26 qualified, type RW resistors can be found at: www.vishay.com/doc?30281
- Material categorization: For definitions of compliance please see www.vishay.com/doc?99912

Pb Pb-free Available
e3
RoHS* Available
HALOGEN FREE Available
GREEN (5-2008) Available

Note
* This datasheet provides information about parts that are RoHS-compliant and/or parts that are non-RoHS-compliant. For example, parts with lead (Pb) terminations are not RoHS-compliant. Please see the information/tables in this datasheet for details.

STANDARD ELECTRICAL SPECIFICATIONS

GLOBAL MODEL	HIST. MODEL	POWER RATING (1) $P_{25\,°C}$, W U ± 0.05 % to ± 5 %	POWER RATING (1) $P_{25\,°C}$, W V ± 3 % to ± 10 %	RESISTANCE RANGE Ω ± 0.05 %	RESISTANCE RANGE Ω ± 0.1 %	RESISTANCE RANGE Ω ± 0.25 %	RESISTANCE RANGE Ω ± 0.5 %, ± 1 %	RESISTANCE RANGE Ω ± 3 %, ± 5 %, ± 10 %	WEIGHT (typical) g
RS1/4	RS-1/4	0.4	-	1 to 1K	0.499 to 1K	0.499 to 3.4K	0.1 to 3.4K	0.1 to 3.4K	0.21
RS1/2	RS-1/2	0.75	-	1 to 1.3K	0.499 to 1.3K	0.499 to 4.9K	0.1 to 4.9K	0.1 to 4.9K	0.23
RS01A	RS-1A	1.0	-	1 to 2.74K	0.499 to 2.74K	0.499 to 10.4K	0.1 to 10.4K	0.1 to 10.4K	0.34
RS01A...300	RS-1A-300	1.0	-	-	0.499 to 2.74K	0.499 to 10.4K	0.1 to 10.4K	-	0.34
RS01M	RS-1M	1.0	-	1 to 1.32K	0.499 to 1.67K	0.499 to 6.85K	0.1 to 6.85K	0.1 to 6.85K	0.30
RS002	RS-2	4.0	5.5	0.499 to 12.7K	0.499 to 12.7K	0.1 to 47.1K	0.1 to 47.1K	0.1 to 47.1K	2.10
RS02M	RS-2M	3.0	-	0.499 to 4.49K	0.499 to 4.49K	0.1 to 18.74K	0.1 to 18.74K	0.1 to 18.74K	0.65
RS02B	RS-2B	3.0	3.75	0.499 to 6.5K	0.499 to 6.5K	0.1 to 24.5K	0.1 to 24.5K	0.1 to 24.5K	0.70
RS02B...300	RS-2B-300	3.0	-	-	0.499 to 6.5K	0.1 to 24.5K	0.1 to 24.5K	-	0.70
RS02C	RS-2C	2.5	3.25	0.499 to 8.6K	0.499 to 8.6K	0.1 to 32.3K	0.1 to 32.3K	0.1 to 32.3K	1.6
RS02C...17	RS-2C-17	2.5	3.25	0.499 to 8.6K	0.499 to 8.6K	0.1 to 32.3K	0.1 to 32.3K	0.1 to 32.3K	1.6
RS02C...23	RS-2C-23	-	3.25	-	-	-	-	0.1 to 32.3K	1.6
RS005	RS-5	5.0	6.5	0.499 to 25.7K	0.499 to 25.7K	0.1 to 95.2K	0.1 to 95.2K	0.1 to 95.2K	4.2
RS005...69	RS-5-69	5.0	-	-	0.499 to 25.7K	0.1 to 95.2K	0.1 to 95.2K	0.1 to 95.2K	4.2
RS005...70	RS-5-70	-	6.5	-	-	-	-	0.1 to 95.2K	4.2
RS007	RS-7	7.0	9.0	0.499 to 41.4K	0.499 to 41.4K	0.1 to 154K	0.1 to 154K	0.1 to 154K	4.7
RS010	RS-10	10.0	13.0	0.499 to 73.4K	0.499 to 73.4K	0.1 to 273K	0.1 to 273K	0.1 to 273K	9.0
RS010...38	RS-10-38	10.0	-	-	0.499 to 73.4K	0.1 to 273K	0.1 to 273K	0.1 to 273K	9.0
RS010...39	RS-10-39	-	13.0	-	-	-	-	0.1 to 273K	9.0

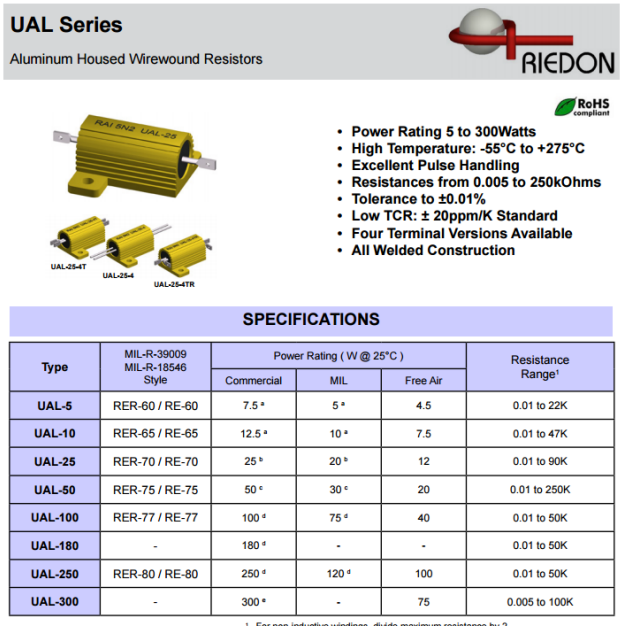
Notes

Full datasheet: here

11.2.7 Precharge Circuitry

11.2.7.1 2kΩ Precharge Resistors

Referred to 2.9.1



UAL Series

Aluminum Housed Wirewound Resistors

RIEDON

RoHS compliant

- Power Rating 5 to 300Watts
- High Temperature: -55°C to +275°C
- Excellent Pulse Handling
- Resistances from 0.005 to 250kOhms
- Tolerance to ±0.01%
- Low TCR: ± 20ppm/K Standard
- Four Terminal Versions Available
- All Welded Construction

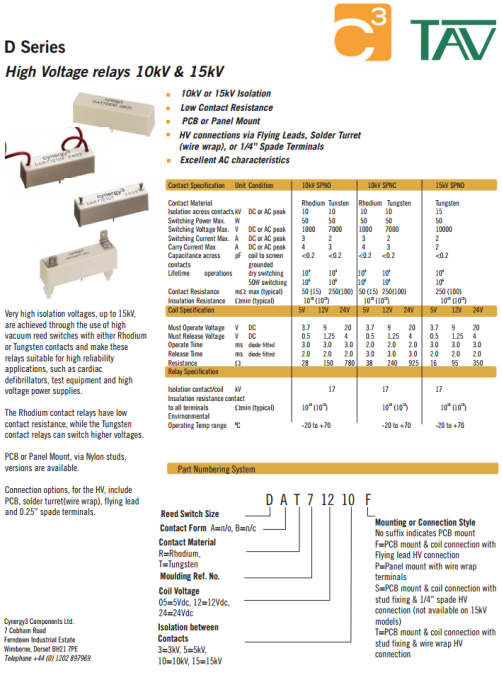
SPECIFICATIONS

Type	MIL-R-39009 MIL-R-18546 Style	Power Rating (W @ 25°C)			Resistance Range[1]
		Commercial	MIL	Free Air	
UAL-5	RER-60 / RE-60	7.5 [a]	5 [a]	4.5	0.01 to 22K
UAL-10	RER-65 / RE-65	12.5 [a]	10 [a]	7.5	0.01 to 47K
UAL-25	RER-70 / RE-70	25 [b]	20 [b]	12	0.01 to 90K
UAL-50	RER-75 / RE-75	50 [c]	30 [c]	20	0.01 to 250K
UAL-100	RER-77 / RE-77	100 [d]	75 [d]	40	0.01 to 50K
UAL-180	-	180 [d]	-	-	0.01 to 50K
UAL-250	RER-80 / RE-80	250 [d]	120 [d]	100	0.01 to 50K
UAL-300	-	300 [e]	-	75	0.005 to 100K

Full datasheet: here

11.2.7.2 Precharge High Voltage Relays

Referred to 2.9.1



D Series

High Voltage relays 10kV & 15kV

TAV

- *10kV or 15kV Isolation*
- *Low Contact Resistance*
- *PCB or Panel Mount*
- *HV connections via Flying Leads, Solder Turret (wire wrap), or 1/4" Spade Terminals*
- *Excellent AC characteristics*

Contact Specification	Unit	Condition	10kV SPNO		10kV SPNC		15kV SPNO
Contact Material			Rhodium	Tungsten	Rhodium	Tungsten	Tungsten
Isolation across contacts	kV	DC or AC peak	10	10	10	10	15
Switching Power Max.	W		50	50	50	50	50
Switching Voltage Max.	V	DC or AC peak	1000	7000	1000	7000	10000
Switching Current Max.	A	DC or AC peak	3	2	3	2	2
Carry Current Max.	A	DC or AC peak	4	3	4	3	2
Capacitance across contacts	pF	coil to screen grounded	<0.2	<0.2	<0.2	<0.2	<0.2
Lifetime operations		dry switching	10^8	10^8	10^8	10^8	10^8
		50W switching	10^6	10^6	10^6	10^6	10^6
Contact Resistance	mΩ	max (typical)	50 (15)	250(100)	50 (15)	250(100)	250 (100)
Insulation Resistance	Ω	min (typical)	10^{14} (10^{15})		10^{14} (10^{15})		10^{14} (10^{15})
Coil Specification			5V 12V 24V		5V 12V 24V		5V 12V 24V
Must Operate Voltage	V	DC	3.7 9 20		3.7 9 20		3.7 9 20
Must Release Voltage	V	DC	0.5 1.25 4		0.5 1.25 4		0.5 1.25 4
Operate Time	ms	diode fitted	3.0 3.0 3.0		2.0 2.0 2.0		3.0 3.0 3.0
Release Time	ms	diode fitted	2.0 2.0 2.0		3.0 3.0 3.0		2.0 2.0 2.0
Resistance	Ω		28 150 780		38 240 925		16 95 350
Relay Specification							
Isolation contact/coil	kV		17		17		17
Insulation resistance contact to all terminals	Ω	min (typical)	10^{14} (10^{15})		10^{14} (10^{15})		10^{14} (10^{15})
Environmental Operating Temp range	°C		-20 to +70		-20 to +70		-20 to +70

Very high isolation voltages, up to 15kV, are achieved through the use of high vacuum reed switches with either Rhodium or Tungsten contacts and make these relays suitable for high reliability applications, such as cardiac defibrillators, test equipment and high voltage power supplies.

The Rhodium contact relays have low contact resistance, while the Tungsten contact relays can switch higher voltages.

PCB or Panel Mount, via Nylon studs, versions are available.

Connection options, for the HV, include PCB, solder turret(wire wrap), flying lead and 0.25" spade terminals.

Part Numbering System

D A T 7 12 10 F

Reed Switch Size

Contact Form A=n/o, B=n/c

Contact Material
R=Rhodium, T=Tungsten

Moulding Ref. No.

Coil Voltage
05=5Vdc, 12=12Vdc, 24=24Vdc

Isolation between Contacts
3=3kV, 5=5kV, 10=10kV, 15=15kV

Mounting or Connection Style
No suffix indicates PCB mount
F=PCB mount & coil connection with Flying lead HV connection
P=Panel mount with wire wrap terminals
S=PCB mount & coil connection with stud fixing & 1/4" spade HV connection (not available on 15kV models)
T=PCB mount & coil connection with stud fixing & wire wrap HV connection

Cynergy3 Components Ltd.
7 Cobham Road
Ferndown Industrial Estate
Wimborne, Dorset BH21 7PE
Telephone +44 (0) 1202 897969

Full datasheet: here

11.2.8 Discharge Circuitry

11.2.8.1 Discharge Resistors

Referred to 2.10.1

UAL Series

Aluminum Housed Wirewound Resistors

RIEDON

RoHS compliant

- **Power Rating 5 to 300Watts**
- **High Temperature: -55°C to +275°C**
- **Excellent Pulse Handling**
- **Resistances from 0.005 to 250kOhms**
- **Tolerance to ±0.01%**
- **Low TCR: ± 20ppm/K Standard**
- **Four Terminal Versions Available**
- **All Welded Construction**

SPECIFICATIONS

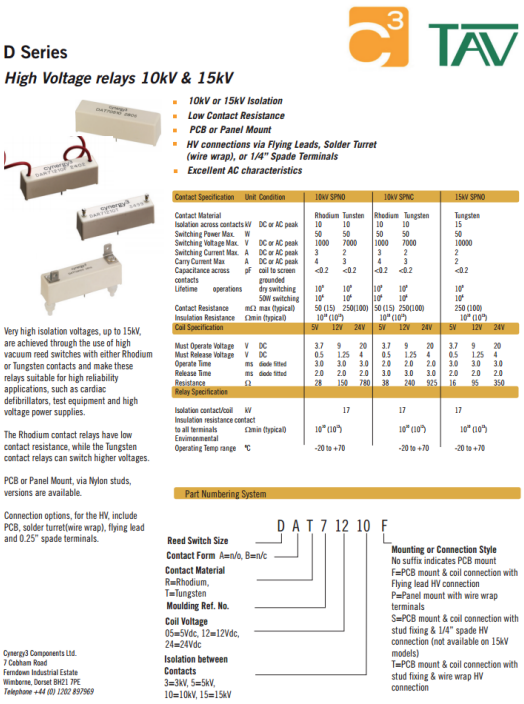
Type	MIL-R-39009 MIL-R-18546 Style	Power Rating (W @ 25°C)			Resistance Range[1]
		Commercial	MIL	Free Air	
UAL-5	RER-60 / RE-60	7.5 [a]	5 [a]	4.5	0.01 to 22K
UAL-10	RER-65 / RE-65	12.5 [a]	10 [a]	7.5	0.01 to 47K
UAL-25	RER-70 / RE-70	25 [b]	20 [b]	12	0.01 to 90K
UAL-50	RER-75 / RE-75	50 [c]	30 [c]	20	0.01 to 250K
UAL-100	RER-77 / RE-77	100 [d]	75 [d]	40	0.01 to 50K
UAL-180	-	180 [d]	-	-	0.01 to 50K
UAL-250	RER-80 / RE-80	250 [d]	120 [d]	100	0.01 to 50K
UAL-300	-	300 [e]	-	75	0.005 to 100K

1. For non-inductive windings, divide maximum resistance by 2.

Full datasheet: here

11.2.8.2 Discharge Relays

Referred to 2.10.1



D Series

High Voltage relays 10kV & 15kV

- *10kV or 15kV Isolation*
- *Low Contact Resistance*
- *PCB or Panel Mount*
- *HV connections via Flying Leads, Solder Turret (wire wrap), or 1/4" Spade Terminals*
- *Excellent AC characteristics*

Contact Specification	Unit	Condition	10kV SPNO		10kV SPNC		15kV SPNO	
Contact Material			Rhodium	Tunsten	Rhodium	Tungsten	Tungsten	
Isolation across contacts	kV	DC or AC peak	10	10	10	10	15	
Switching Power Max.	W		50	50	50	50	50	
Switching Voltage Max.	V	DC or AC peak	1000	7000	1000	7000	10000	
Switching Current Max.	A	DC or AC peak	3	2	3	2	2	
Carry Current Max	A	DC or AC peak	4	3	4	3	2	
Capacitance across contacts	pF	coil to screen grounded	<0.2	<0.2	<0.2	<0.2	<0.2	
Lifetime operations		dry switching	10^8	10^8	10^8	10^8	10^8	
		50W switching	10^6	10^6	10^6	10^6	10^6	
Contact Resistance	mΩ	max (typical)	50 (15)	250(100)	50 (15)	250(100)	250 (100)	
Insulation Resistance	Ωmin (typical)		10^{10} (10^{11})		10^{10} (10^{11})		10^{10} (10^{11})	
Coil Specification			5V	12V 24V	5V	12V 24V	5V	12V 24V
Must Operate Voltage	V	DC	3.7	9 20	3.7	9 20	3.7	9 20
Must Release Voltage	V	DC	0.5	1.25 4	0.5	1.25 4	0.5	1.25 4
Operate Time	ms	diode fitted	3.0	3.0 3.0	2.0	2.0 2.0	3.0	3.0 3.0
Release Time	ms	diode fitted	2.0	2.0 2.0	3.0	3.0 3.0	2.0	2.0 2.0
Resistance	Ω		28	150 780	38	240 925	16	95 350
Relay Specification								
Isolation contact/coil	kV			17		17		17
Insulation resistance contact to all terminals	Ωmin (typical)		10^{10} (10^{11})		10^{10} (10^{11})		10^{10} (10^{11})	
Environmental								
Operating Temp range	°C		-20 to +70		-20 to +70		-20 to +70	

Very high isolation voltages, up to 15kV, are achieved through the use of high vacuum reed switches with either Rhodium or Tungsten contacts and make these relays suitable for high reliability applications, such as cardiac defibrillators, test equipment and high voltage power supplies.

The Rhodium contact relays have low contact resistance, while the Tungsten contact relays can switch higher voltages.

PCB or Panel Mount, via Nylon studs, versions are available.

Connection options, for the HV, include PCB, solder turret(wire wrap), flying lead and 0.25" spade terminals.

Cynergy3 Components Ltd.
7 Cobham Road
Ferndown Industrial Estate
Wimborne, Dorset BH21 7PE
Telephone +44 (0) 1202 897969

Part Numbering System

D A T 7 12 10 F

Reed Switch Size

Contact Form A=n/o, B=n/c

Contact Material
R=Rhodium,
T=Tungsten

Moulding Ref. No.

Coil Voltage
05=5Vdc, 12=12Vdc, 24=24Vdc

Isolation between Contacts
3=3kV, 5=5kV, 10=10kV, 15=15kV

Mounting or Connection Style
No suffix indicates PCB mount
F=PCB mount & coil connection with Flying lead HV connection
P=Panel mount with wire wrap terminals
S=PCB mount & coil connection with stud fixing & 1/4" spade HV connection (not available on 15kV models)
T=PCB mount & coil connection with stud fixing & wire wrap HV connection

Full datasheet: [here]

11.2.9 High Voltage Disconnect

Referred to 2.11

AMP+ Manual Service Disconnect Fused Version

KEY FEATURES

- Finger proof, touch safe
- Finger actuated - 2 stage lever assist latching
- No tool required to unmate
- 2x integrated internal HVIL
- Scalable design
- Current rating determined by fuse rating or shunt
- Available with integrated fuse up to 630A or with shunt
- USCAR-2, USCAR-37, IEC 60529, RoHS compliant
- Tested to 50 mating cycles
- Sealed

TE Technical Support Center

Canada:	+1.905.470.4425
C. America:	+52.0.55.1106.0814
China:	+86.0.400.820.6015
France:	+33.0.1.3420.8686
Germany:	+49.0.6251.133.1999
Great Britain:	+44.0.8706.080208
India:	+91.80.285.40800
Japan:	+81.44.844.8111
Korea:	+82.2.3415.4500
Mexico:	+52.0.55.1106.0814
Netherlands:	+31.0.73.6246.999
South America:	+55.0.11.2103.6000
USA:	+1.800.522.6752

te.com

APPLICATIONS

- HV battery pack or remote location
- Energy storage systems (ESS)

MECHANICAL

- Latching style: Finger actuated - 2 stage lever assist
- Mating cycles: Tested to 50
- Stud: M6
- IP rating: Mated: IPx7, IP6k9k Unmated: IP2xb
- HVIL: 2x integrated, internal

ELECTRICAL

- Fuse rating: Up to 630A
- Voltage rating for fused version: 450 VDC
- Shunted version for higher voltages
- Operating temperature: -40 °C to 65 °C
- Storage temperature: -40 °C to 85 °C
- Current rating: Based on fuse selection

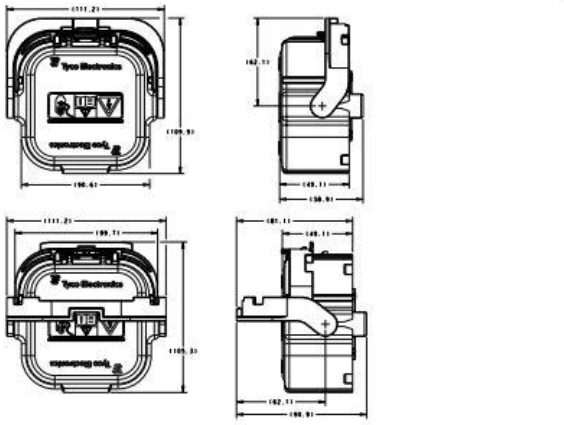
STANDARDS AND SPECIFICATIONS

- USCAR-2
- USCAR-37
- IEC 60529
- RoHS

PRODUCT OFFERING

1587987-8	Receptacle Assembly, 200A, MSD
2103172-8	Plug Assembly, 200A, MSD, Market label
1587987-9	Receptacle Assembly, 250A, MSD
2103172-9	Plug Assembly, 250A, MSD, Market label
1-1587987-1	Receptacle Assembly, 350A, MSD
1-2103172-1	Plug Assembly, 350A, MSD, Market label
1-1587987-7	Receptacle Assembly, Shunt (No fuse), MSD
1-2103172-7	Plug Assembly, Shunt (No fuse), MSD, Market label

PRODUCT DIMENSIONS



TE connectivity

Full Datasheet: here

11.2.10 Ready To Drive Sound

11.2.10.1 Ready to Drive Horn

Referred to 2.12

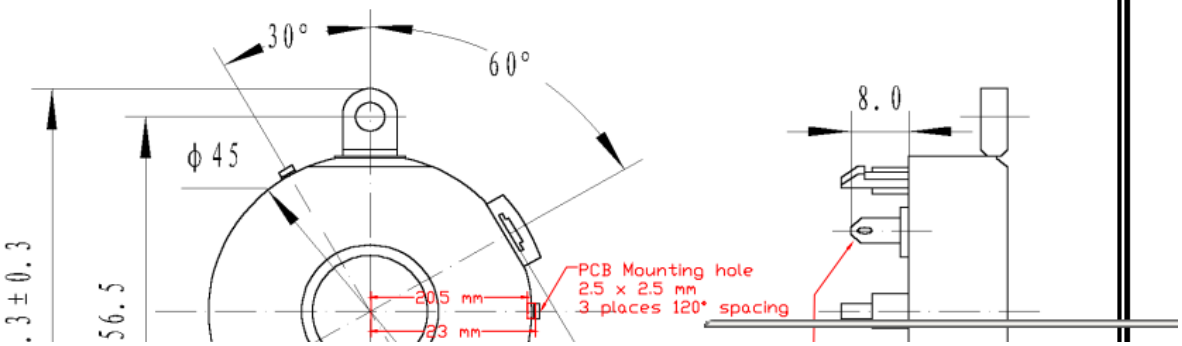
Mallory Sonalert Products Inc. | Part # **PT-4532PLQ**

Sales Outline Drawing | Revision **C**

Specifications:

Resonant Frequency (Hz)	3200 ± 500
Operating Voltage (Vp-p/max)	3 ~ 50
Rated Voltage (Vp-p)	12
Current Consumption (mA/max)	30 at Rated Voltage
Sound Pressure Level (dB/min)	100 at 50cm at Rated voltage
Capacitance (pF)	25,000 ± 30% at 120 Hz
Operating Temperature (°C)	-40 ~ +95
Storage Temperature (°C)	-40 ~ +105
Housing	PAG plastic resin (Color: Black)
Lead Pins	Tin Plated Brass
Weight (Grams)	11.0
Condition by wave soldering (°C)	245 ±5 / 3±0.5 sec
Condition by hand soldering (°C)	350 ±20 / within 5 sec
Options	For other options contact factory

Dimensions: (units: mm) **ROHS Compliant**



Full Datasheet here

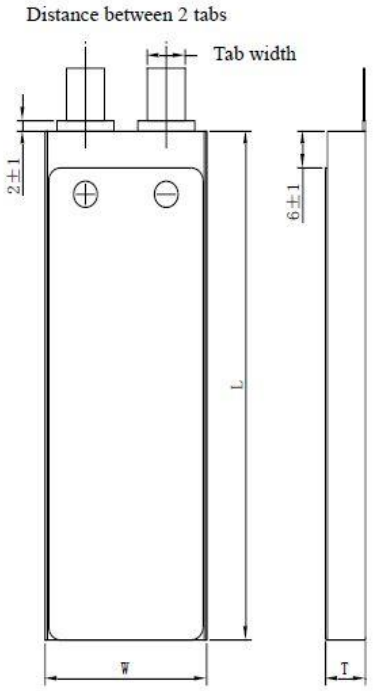
11.3 Accumulator

11.3.1.1 High Voltage Battery

Referred to 3.1.2

3. 产品规格 SPECIFICATION

单颗电池规格 Specifications of single cell



◆标称容量 Typical Capacity①		7.05Ah
◆标称电压 Nominal Voltage		3.7V
◆ 充电条件 Charge Condition	最大持续电流充电 Max. Continuous charge Current	14.1A
	峰值充电 Peak Charge current	28.2A(≤1sec)
	电压 Voltage	4.2V±0.03V
◆ 放电条件 Discharge Condition	Max Continuous Discharge Current	141A
	Peak Discharge Current	176.25A
	Cut-off Voltage	3.0V
◆交流内阻 AC Impedance(mOHM)		<2.0
◆循环寿命【充电:1.0C,放电:20C】 Cycle Life【CHA:1.0C,DCH:20C】		>100cycles
◆使用温度 Operating Temp.	充电 Charge	0℃~45℃
	放电 Discharge	-20℃~60℃
◆ 电芯尺寸 Cell Dimensions	厚度 Thickness(T)	8.8±0.3mm
	宽度 Width(W)	45±0.5mm
	长度 Length(L)	181.5±0.5mm
	极耳间距 Distance between 2 tabs	21±1mm
◆ 极耳尺寸 Dimensions of Cell tabs	极耳宽度 Tab Width	15mm
	极耳厚度 Tab Thickness	0.2mm
	极耳长度 Tab Length	Max 30mm
◆重量 Weight(g)		157.5±2
①标称容量：0.5CmA,4.2V~3.0V@23℃±2℃ Typical Capacity:0.5CmA,4.2V~3.0V@23℃±2℃		

Full datasheet here

11.3.1.2 Maintenance Plugs

Referred to 3.1.11

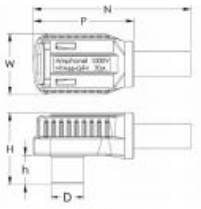
Dimensions

RADLOK™ Connector (Tubular Version)

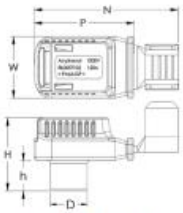
RADLOK™ Size (mm)	W	N	H	h	D	P
3.6	15.5	38.0	18.3	7.3	8.1	27.0
5.7	18.5	47.7	22.9	9.4	11.2	33.0
8.0	21.6	56.0	27.7	11.8	14.6	38.8
10.0	26.0	61.0	35.3	15.9	17.5	37.0
10.3	26.0	61.0	35.3	15.9	17.5	37.0
12.0	28.5	70.5	35.9	15.0	20.0	44.5

RADLOK™ Connector (Stamped Version)

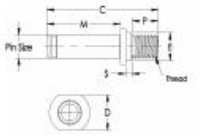
RADLOK™ Size (mm)	W	N	H	h	D	P
5.7	18.5	46.0	21.9	9.2	11.2	30.0
8.0	21.7	54.4	27.7	12.5	14.6	34.3
10.0	25.7	65.0	33.3	16.1	17.5	35.7



Tubular Lug Version



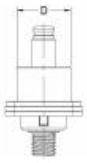
Stamped Lug Version

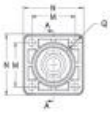


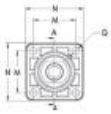
Pin Type	Pin End	RADLOK™ Pin Size (mm)	Current (A)	RADLOK™ Dimensions (mm)												
				C	D	E	G	L	M	N	P	Q	S	W	Thread
Pin	N/A	3.6	70	25.2	5.3	Φ 4.8			17.4		5		1.5		M 3 x 0.5-6g
		5.7	120	33.9	7.8	Φ 7.0			21.1		10		1.5		M 6 x 1.0-6g
		8	200	40.2	12.8	Φ 10.0	N/A	N/A	26.4	N/A	10	N/A	2.2	N/A	M 8 x 1.25-6g
		10	300	47.4	12.8	Φ 12.0			32.2		10		3.2		M 10 x 1.5-6g
		10.3	350	47.4	12.8	Φ 12.0			32.2		10		3.2		M 10 x 1.5-6g
		12	400	47.9	15.8	Φ 14.5			32.9		10		2.8		M 12 x 1.75-6g
Feed Thru	Thread	3.6	70	32.5	13.1	Φ 13.7	19.2		16	24.5	5	M3			M 3 x 0.5-6g
		5.7	120	42.1	16.2	Φ 16.2	21.7		18	27	10				M 6 x 1.0-6g
		8	200	48.4	19.6	Φ 18.2	23.7	N/A	21	30	10		4.2	N/A	M 8 x 1.25-6g
		10	300	62	23.0	Φ 20.2	25.7		24	33	16	M4			M 10 x 1.5-6g
		10.3	350	62	23.0	Φ 20.2	25.7		24	33	16				M 10 x 1.5-6g
		12	400	65	25.5	Φ 22.2	27.7		26	36	16				M 12 x 1.75-6g
	Lug	3.6	70	42.9	13.1	Φ 19.6	11.6	6	16	24.5	16.5	M3		4.2	
		5.7	120	51.1	16.2	Φ 21.6	13.6	8	18	27	18.5			6.3	
		8	200	62.4	19.6	Φ 23.6	15.6	10.5	21	30	22		N/A	8.5	N/A
		10	300	71.2	23.0	Φ 25.6	17.6	12.5	24	33	24	M4		10.5	
		10.3	350	71.2	23.0	Φ 25.6	17.6	12.5	24	33	24			10.5	
		12	400	76	25.5	Φ 27.6	19.6	14.5	26	36	26			13	
	Pin	3.6	70	42.8	13.1	Φ 13.7	19.2		16	24.5		M3			
		5.7	120	51.2	16.2	Φ 16.2	21.7		18	27					
		8	200	64	19.6	Φ 18.2	23.7	N/A	21	30	N/A		4.2	N/A	N/A
		10	300	78.5	23.0	Φ 20.2	25.7		24	33		M4			
		10.3	350	78.5	23.0	Φ 20.2	25.7		24	33					
		12	400	80.2	25.5	Φ 22.2	27.7		26	36					

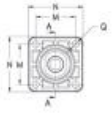
Technical Data

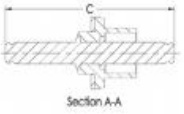
DC Voltage Rating	1000V
DC Current Rating	70A - 400A
Flammability Rating	UL94 V0
Operating Temperature Range	-40° C to 125° C
Mating Cycles	500











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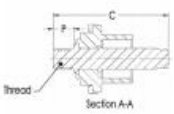
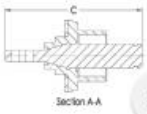
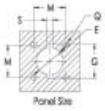


Thread

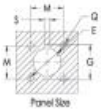
Section A-A



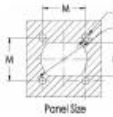
Section A-A



Panel Size



Panel Size



Panel Size

Full datasheet here

11.3.1.3 Accumulator Isolation Relay

Referred to 3.1.8

Product Facts

- **Designed to be the smallest, lightest weight, lowest cost sealed contactor in the industry with its current rating (500+A carry, 2000A interrupt at 320VDC).**
- **Built-in coil economizer – only 1.7W hold power @ 12VDC and it limits back EMF to 0V. Models requiring extenal economizer also available.**
- **Optional auxiliary contact for easy monitoring of power contact position.**
- **Hermetically sealed – intrinsically safe, operates in explosive/harsh environments with no oxidation or contamination of coils or contacts, including long periods of non-operation.**
- **Versatile coil/power connections.**
- **CE marked for EC applications.**
- **AIAG QS9000 designed, built and approved**

EV200 Series Contactor (CZONKA® Relay, Type III)

CE

c UL us **File E208033**

Typical EV200 applications include battery switching and back-up, DC voltage power control, circuit protection and safety.

For factory-direct application assistance, dial 800-253-4560, ext. 2055, or 805-220-2055.

Performance Data

Parameter	Units	Value for EV200 Series
Contact Arrangement, power contacts		1 Form X (SPST-NO-DM)
Rated Operating Voltage	VDC	12 - 900
Continuous (Carry) Current, Typical *Consult Factory for required conductors for higher (500+ A) currents*	A	500 @ 85°C, 400 mcm conductors
Make/Break Current at Various Voltages [1]	A	See next page
Break Current at 320VDC [1]	A	2,000, 1 cycle [3]
Contact Resistance, Typ. (@200A)	mohms	0.2
Load Life	Cycles	See next page
Mechanical Life	Cycles	1 million
Contact Arrangement, auxiliary contacts		1 Form A (SPST-NO)
Aux. Contact Current, Max. Aux. Contact Current, Min.	A mA	2A @ 30VDC / 3A @ 125VAC 100mA @ 8V
Aux. Contact Resistance, Max.	ohms	0.417 @ 30VDC / .150 @ 125VAC
Operate Time @ 25°C Close (includes bounce), Typ. Bounce (after close only), Max. Release (includes arcing), Max @ 2000A	 ms ms ms	 15 7 12
Dielectric Withstanding Voltage	Vrms	2,200 @ sea level (leakage <1mA)
Insulation Resistance @ 500VDC	megohms	100 [2]
Shock, 11ms 1/2 sine, peak, operating	G	20
Vibration, sine, 80-2000Hz., peak	G	20
Operating Ambient Temperature	°C	-40 to +85
Weight, Nominal	lb.(kg)	.95 (.43)

Coil Operating Voltage (valid over temperature range)			
Voltage (will operate)	9-36VDC	32-95VDC	48-95VDC
Voltage (Max.)	36VDC	95VDC	95VDC
Pickup (close) Voltage Max.	9VDC	32VDC	48VDC
Hold Voltage (Min.)	7.5VDC	22VDC	34VDC
Dropout (open) Voltage (Min.)	6VDC	18VDC	27VDC
Inrush Current (Max.)	3.8A	1.3A	0.7A
Holding Current (Avg.)	0.13A@12V, 0.07A@24V	0.03A@48V	0.02A@72V
Inrush Time (Max.)	130ms	130ms	130ms

Part Numbering System

Typical Part Number	EV200	A	A	A	N	A

Series:
EV200 = 500+ Amp, 12-900VDC Contactor

Contact Form:
A = Normally Open H = Normally Open with Aux. Contacts

Coil Voltage:
A = 9-36VDC (1 = requires external coil economizer)
D = 32-95VDC (2 = requires external coil economizer)
J = 48-95VDC (3 = requires external coil economizer)
R = 28VDC with Mechanical Economizer

Coil Wire Length:
A = 15.3 in (390 mm) B = 6.0 in (152 mm)

Coil Terminal Connector:
N = None

Full datasheet here

11.3.1.4 High Voltage Fuse

Referred to 3.1.9

POWR-GARD® Fuse Datasheet

Littelfuse
Expertise Applied | Answers Delivered

CLASS T – JLLN / JLLS SERIES FUSES

300/600 VAC • Fast-Acting • 1-1200 A

RoHS

Description

JLLN / JLLS fuses are less than ½ the size of comparable Class R fuses and are typically used for short circuit protection of drives and surge sensitive components. When rated in accordance with the NEC®, JLLN / JLLS fuses provide fast-acting overload and short circuit protection for non-inductive circuits and equipment.

Features/Benefits

- Extremely current-limiting
- Compact design
- 200 kA Interrupting Rating

Applications

- Variable speed drive protection
- Compact mains switches

Specifications

Voltage Ratings
AC: 300 V (JLLN)
600 V (JLLS)
DC: 160 V (JLLN 1 – 60 A)
125 V (JLLN 70 – 1200 A)
300 V (JLLS)

Interrupting Ratings
AC: 200 kA rms symmetrical
DC: 20 kA (JLLN 35-1200 A only)

Ampere Range
1 – 1200 A

Approvals
AC: Standard 248-15, Class T
UL Listed (File: E81895):
JLLN (1 – 1200 A)
JLLS (1 – 800 A)
UL Recognized (File: E71611)
JLLN PCB Mount (35 – 60 A)
JLLS (900 – 1200 A)
CSA Certified (File: LR29862)
JLLN/JLLS (1 – 600 A)
DC: UL Listed (File: E81895):
JLLN (35 – 1200 A)
Littelfuse self-certified
JLLN (1 – 30 A)
JLLS (1 – 1200 A)

Environmental
RoHS Compliant
(Note: Not all amperages are RoHS compliant. Contact the factory for additional details.)

Ordering Information

AMPERE RATINGS					
1	25	70	175	450	1100
2	30	80	200	500	1200
3	35	90	225	600	
6	40	100	250	700	
10	45	110	300	800	
15	50	125	350	900*	
20	60	150	400	1000	

*JLLS only

Part Numbering System

JLLN xxxx V –

- Series: JLLN
- Amperage: xxxx
- Package Quantity: V
  - T = 10 (1-60 A)
  - V = 5 (70-100 A)
  - X = 1 (110-1200 A)
- Options:
  - Blank = Standard Non-Plated
  - XP = Premium Plated
  - XL = Leaded[1]
  - XV = Vertical Mount[1]
  - XLS = Solder Lead[1]

SERIES	AMP	PACK SIZE	PLATING SUFFIX	MOUNT SUFFIX	CATALOG NUMBER	ORDERING NUMBER
JLLS	6	T	–	–	JLLS006	JLLS006T
JLLN	35	V	–	XL[1]	JLLN035L	JLLN035VXL
JLLN	100	V	XP	–	JLLN100P	JLLN100VXP

[1]Option is available for JLLN 35-60 A only. Premium plating is standard

Web Resources

Download TC Curves, CAD drawings and other technical information: **littelfuse.com/jlln**
littelfuse.com/jlls

Recommended Fuse Holders

LFT30 Series
LFT60 Series
LSCR Series for 700-800 A

Dimensions

Please refer to the Class T dimensions on page 4

Full datasheet here

11.3.1.5 HV Fuse Holder

Referred to 3.1.9

POWR-GARD® Blocks and Holders Datasheet

Littelfuse
Expertise Applied | Answers Delivered

LSCR SERIES HIGH-SPEED FUSE BLOCKS

700 Vac/dc • 1-800A

RoHS

Specifications

Voltage Rating	LSCR001: 700 V LSCR002: 700 V
Ampere Ratings	LSCR001: 1 – 400 A capacity LSCR002: 70 – 800 A capacity
Approvals	UL Recognized (File: E14721), CSA Certified (File: 73160)
Stud Size	LSCR001: ¼ -20 thread (Torque 61 in-lbs) LSCR002: ⅜ -16 thread (Torque 192 in-lbs)
Material	**Base:** Molded phenolic. 150° C temperature rating **Terminal Construction:** Plated steel. Supplied with nut and belleville washer
Environmental	RoHS Compliant
Country of Origin	China

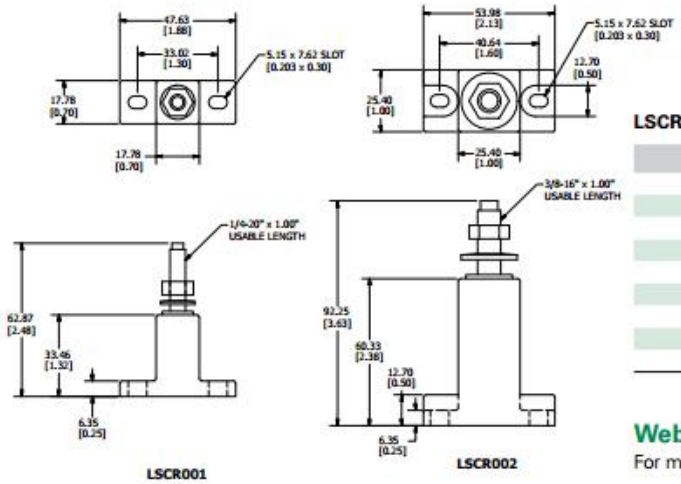
Description

The LSCR Series are modular fuse blocks designed to accommodate a wide range of High-Speed and Class T fuses.

Features/Benefits

- Modular design reduces inventory requirements
- Sold in pairs for convenience
- Constructed of molded phenolic (with plated steel studs)

Dimensions mm (inches)



LSCR001 LSCR002

Recommended Fuses

High-Speed and Class T fuses. See tables below.

LSCR001 High-Speed Fuse Block Selection Guide

FUSE SERIES	AMPERE RATINGS
L15S	70-400
L17T	70-250
L25S	35-200
L50S	35-200
L60S	35-200
KLC	35-60
L70S	35-100
JLLN	70-200
JLLS	70-200

LSCR002 High-Speed Fuse Block Selection Guide

FUSE SERIES	AMPERE RATINGS
L15S	500-800
L17T	300-800
L25S	225-800
L50S	225-800
L60S	225-800
KLC	70-800
L70S	125-800
JLLN	225-800
JLLS	225-800

Web Resources

For more information, visit: **littelfuse.com/lscr**

Full Sheet Here

11.3.1.6 BMS Sense Fuse

Referred to 3.1.5

Surface Mount Fast Acting Chip Fuse

HF Pb C1F Series - 1206 Size RoHS 6 Compliant

Features

- Fast Acting, with improved surge withstand performance
- Small size, 1206 SMD
- Current rating from 250mA to 8A,fuse marked with ampere code
- Wide operating temperature range from -55℃ to 125℃
- Tape and Reel for automatic SMD placement
- Compatible with reflow and wave soldering
- RoHS 6 compliant (MSL = 1)
- Halogen Free
- Leadfree

Applications

- Notebook
- LCD monitor
- PC computer
- Office electronic equipment
- Industrial equipment
- Medical equipment
- POE, POE+
- LCD / LED monitor
- Power supply
- LCD / LED TV
- DC-DC Converter

LEAD FREE = Pb

HALOGEN FREE = HF

Typical Part Marking

Fuse body (ceramic white side) marked with marking code.

Example:

Current Rating	Marking Code	Current Rating	Marking Code
250mA	E	2.5A	T
375mA	H	3A	3
500mA	J	3.5A	Z
750mA	M	4A	4
1A	1	5A	5
1.25A	P	6A	6
1.5A	R	7A	7
2A	2	8A	8

Electrical Characteristics (UL STD. 248-14)

Testing Current	Blow Time	
	Minimum	Maximum
100%	4 Hrs.	N/A
200%	N/A	5 Sec
300%	N/A	0.2 Sec

Safety Agency Approvals

SAFETY AGENCY	SAFETY AGENCY CERTIFICATE	AMPERE RANGE / VOLT @ I.R ABILITY
cULus	E20624	250mA - 6A / 100A@ 125V AC 50A@ 63V DC
		7A - 8A / 35A@125V AC 50A @ 63V DC

Physical Specifications

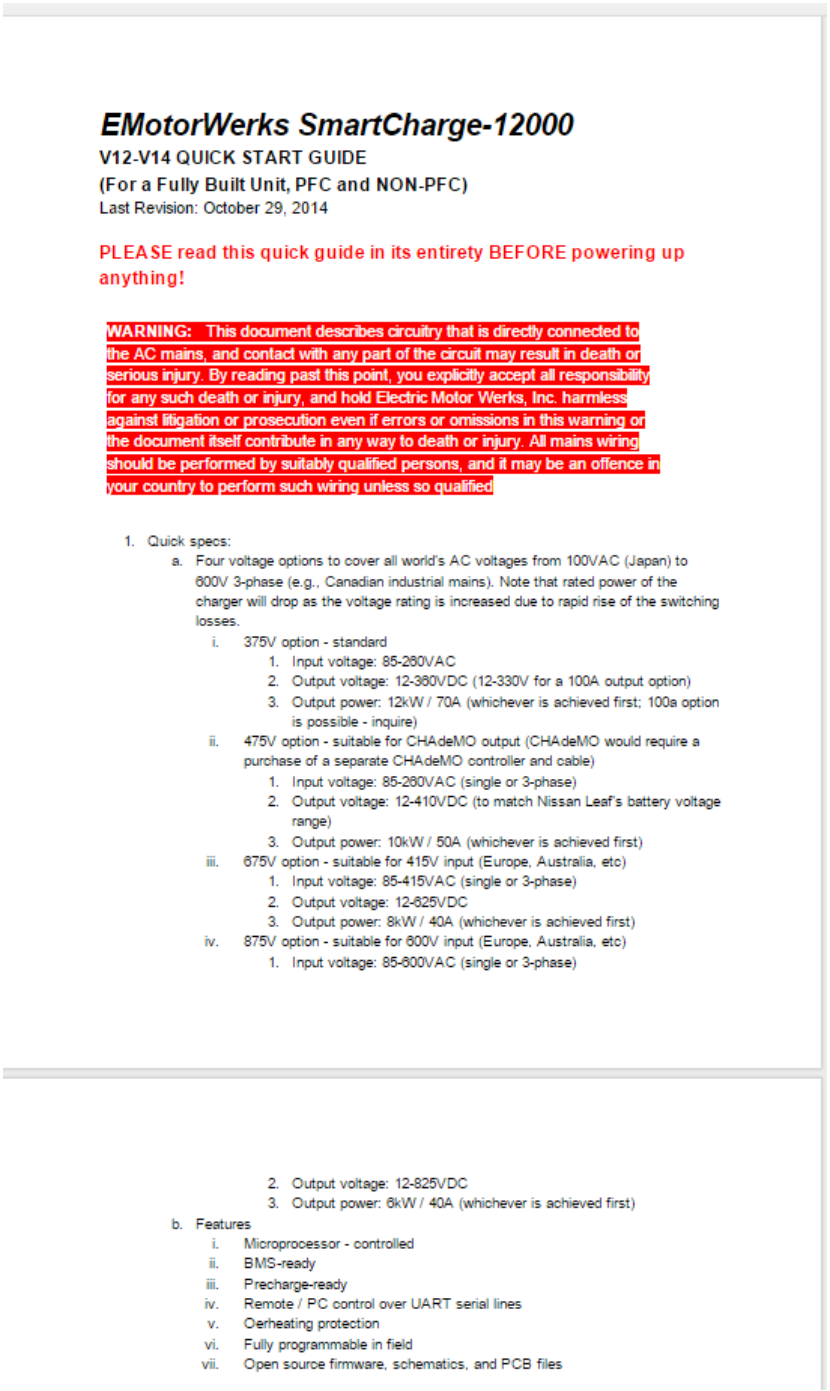
Materials	Body : Ceramic Substrate
	Terminations : Ag / Ni / Sn (100% Lead-free)
	Element Cover Coating : Lead-free Glass
Marking	On Fuse :
	Marking Code
	On Label :
	"bel", "C1F", "Current Rating", "Voltage Rating", "Interrupting Rating", " Appropriate Safety Logos" and " ", " "(China RoHS compliant).

Specifications subject to change without notice

Full datasheet: here

11.3.1.7 Charger

Referred to 3.1.10



EMotorWerks SmartCharge-12000

V12-V14 QUICK START GUIDE

(For a Fully Built Unit, PFC and NON-PFC)

Last Revision: October 29, 2014

PLEASE read this quick guide in its entirety BEFORE powering up anything!

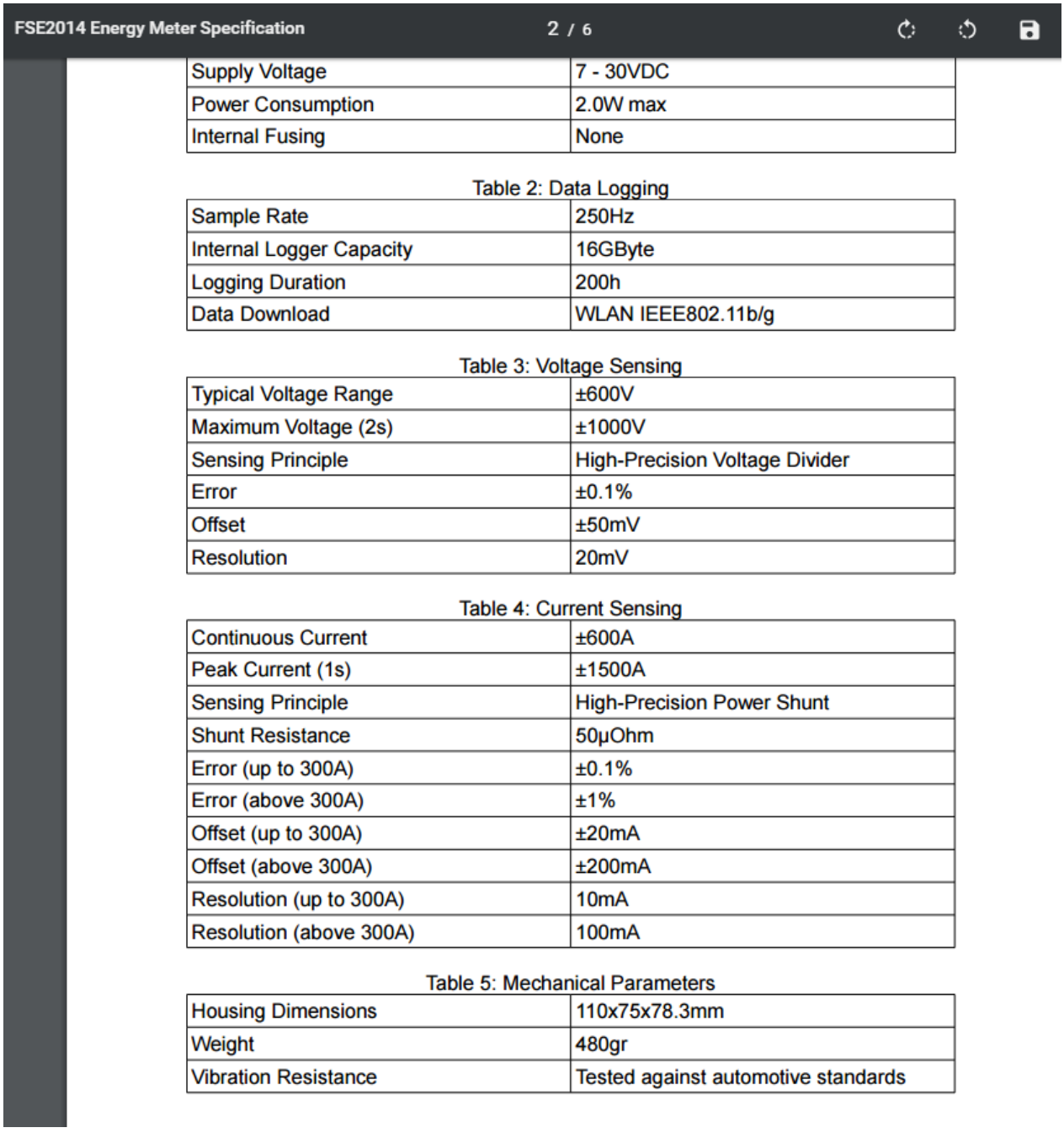
WARNING: This document describes circuitry that is directly connected to the AC mains, and contact with any part of the circuit may result in death or serious injury. By reading past this point, you explicitly accept all responsibility for any such death or injury, and hold Electric Motor Werks, Inc. harmless against litigation or prosecution even if errors or omissions in this warning or the document itself contribute in any way to death or injury. All mains wiring should be performed by suitably qualified persons, and it may be an offence in your country to perform such wiring unless so qualified

1. Quick specs:
   a. Four voltage options to cover all world's AC voltages from 100VAC (Japan) to 600V 3-phase (e.g., Canadian industrial mains). Note that rated power of the charger will drop as the voltage rating is increased due to rapid rise of the switching losses.
      i. 375V option - standard
         1. Input voltage: 85-260VAC
         2. Output voltage: 12-360VDC (12-330V for a 100A output option)
         3. Output power: 12kW / 70A (whichever is achieved first; 100a option is possible - inquire)
      ii. 475V option - suitable for CHAdeMO output (CHAdeMO would require a purchase of a separate CHAdeMO controller and cable)
         1. Input voltage: 85-260VAC (single or 3-phase)
         2. Output voltage: 12-410VDC (to match Nissan Leaf's battery voltage range)
         3. Output power: 10kW / 50A (whichever is achieved first)
      iii. 675V option - suitable for 415V input (Europe, Australia, etc)
         1. Input voltage: 85-415VAC (single or 3-phase)
         2. Output voltage: 12-625VDC
         3. Output power: 8kW / 40A (whichever is achieved first)
      iv. 875V option - suitable for 600V input (Europe, Australia, etc)
         1. Input voltage: 85-600VAC (single or 3-phase)
         2. Output voltage: 12-825VDC
         3. Output power: 6kW / 40A (whichever is achieved first)
   b. Features
      i. Microprocessor - controlled
      ii. BMS-ready
      iii. Precharge-ready
      iv. Remote / PC control over UART serial lines
      v. Overheating protection
      vi. Fully programmable in field
      vii. Open source firmware, schematics, and PCB files

Full datasheet: here

11.4 Energy Meter

Referred to 4.1



FSE2014 Energy Meter Specification 2 / 6

Supply Voltage	7 - 30VDC
Power Consumption	2.0W max
Internal Fusing	None

Table 2: Data Logging

Sample Rate	250Hz
Internal Logger Capacity	16GByte
Logging Duration	200h
Data Download	WLAN IEEE802.11b/g

Table 3: Voltage Sensing

Typical Voltage Range	±600V
Maximum Voltage (2s)	±1000V
Sensing Principle	High-Precision Voltage Divider
Error	±0.1%
Offset	±50mV
Resolution	20mV

Table 4: Current Sensing

Continuous Current	±600A
Peak Current (1s)	±1500A
Sensing Principle	High-Precision Power Shunt
Shunt Resistance	50µOhm
Error (up to 300A)	±0.1%
Error (above 300A)	±1%
Offset (up to 300A)	±20mA
Offset (above 300A)	±200mA
Resolution (up to 300A)	10mA
Resolution (above 300A)	100mA

Table 5: Mechanical Parameters

Housing Dimensions	110x75x78.3mm
Weight	480gr
Vibration Resistance	Tested against automotive standards

Full Specs here

11.5 Motor Controller

11.5.1 Rinehart Motion Systems PM100DX

Referred to: 5.1

RINEHART MOTION SYSTEMS LLC
7929 SW Burns Way, Suite B, Wilsonville, OR 97070 503.344.5085

AC Motor Controller for Electric and Hybrid Vehicles

Product Summary

The Rinehart Motion Systems LLC (RMS) PM Family of AC Motor Controllers are designed for on- and off-road Electric (EV) or Hybrid Electric (HEV) applications. The motor controller converts the DC power from the vehicle ESS (Energy Storage System / Battery) to the 3-phase AC required by the motor. These Traction drives are fabricated using a patented high heat flux thermal design approach that dramatically reduces the size and weight of the finished drive, and improves its life in the automotive environment. With extensive experience in automotive and military vehicle traction and power electronics applications, RMS has achieved a major breakthrough in integrating Motor Control into a vehicle.

RMS offers several different models within the PM Family of motor controllers to suit the DC bus voltage and motor current requirements of your specific vehicle. The PM Family has been designed to operate with many types of motors, including Induction Motors (IM) and Permanent Magnet motors (PMSM or IPM). Contact RMS for the latest list of motors supported by our controllers. The Drive can also be tuned to your new motor - contact the factory for more information.

The primary difference between models in the PM Family is the rated voltage and current (ultimate power output):

Controller Model	PM100DX	PM100DZ	PM100DXR *	PM150DX	PM150DZ
Maximum DC Voltage – operating	360 V	720 V	400 V	360 V	720 V
Maximum DC Voltage – non-operating	500 V	900 V	500 V	500 V	900 V
Motor Current Continuous	300 Arms	150 Arms	300 Arms	450 Arms	225 Arms
Motor Current Peak **	350 Arms	200 Arms	450 Arms	450 Arms	300 Arms
DC Bus Capacitance	440 µF	280 µF	440 µF	880 µF	560 µF
Size	See drawing	See drawing	See drawing	See drawing	See drawing
Weight	7.5 kg	7.5 kg	7.5 kg	10.7 kg	10.7 kg
Minimum Conductor Size	4 AWG			2 AWG	4 AWG***
Maximum Conductor Size	1 AWG			3/0 AWG	1 AWG
Minimum Cable O.D.	9.0 mm			11.0 mm	
Maximum Cable O.D.	16.5 mm			21.0 mm	

* The PM100DXR is only available for special applications (i.e. racing), use must be approved by RMS.

** Peak current is defined as a maximum of 30 seconds.

*** Depending on cable, it may be necessary to add additional sleeve to cable to meet the minimum Cable O.D. of the cable gland.

Full datasheet can be found here

11.5.2 EXRAD Shielded Cable

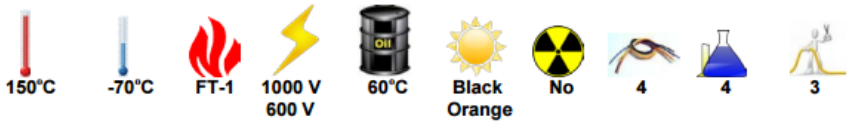
Referred to: 5.1.2 and 2.11.2

EXRAD FX 600 - 1000 VOLT SHIELDED CABLE

EXRAD FX 1000 volt shielded battery cable designed specifically to handle the higher voltage and current required by today's hybrid and electric power vehicles. These cables significantly reduce the effects of EMI and RFI. The jacket insulation isolates any stray currents making this cable very safe. Our thin wall and high temperature insulations allow for lower weight and less space.

EXRAD FX 1000 volt shielded battery cable has an irradiated cross-linked polyolefin insulation able to withstand temperatures of 240°C and higher. Thinner and lighter than other shielded battery cables, it is flexible enough for easy routing yet tough enough to withstand the roughest environments.

The end result is an automotive wire ideally suited to applications where a combination of flexibility, long life and performance is required. Save money and reduce weight by shortening the cable length. EXRAD FX 1000 volt shielded battery cable can be routed through twists and turns where other battery cables fail.



* Ampacity 150°C rated single-insulated conductor in free air at 40°C ambient air temperature.

Product Number	Standard Conductors Bare Copper	Nom. Dia Conductor in.	Nom. Dia Conductor mm.	Nom. Dia. Primary insulation in.	Nom. Dia. Primary insulation mm.	Nom. Dia Shield in.	Nom. Dia Shield mm.	Nom. Dia. Outside in.	Nom. Dia. Outside mm.	Shield Cover -age	Volt- Age Rating	Min. Static Bend Radius	Weight lbs/mft	Ampa -city
EXRAD-FSX16X	16 (19/29)	.055	1.40	.087	2.21	.105	2.67	.145	3.68	95%	600	22mm	17.8	31
EXRAD-FSX14X	14 (105/34)	.070	1.78	.100	2.54	.118	3.00	.168	4.27	95%	600	27mm	26.1	46
EXRAD-FSX12X	12 (105/32)	.095	2.40	.127	3.22	.150	3.80	.190	4.83	95%	600	29mm	41.0	60
EXRAD-FSX10X	10 (105/30)	.114	2.89	.156	3.96	.178	4.52	.218	5.54	95%	600	33mm	58.0	80
EXRAD-FSX8X	8 (133/29)	.166	4.22	.224	5.69	.252	6.40	.303	7.70	95%	1000	55mm	92.0	106
EXRAD-FSX6X	6 (133/27)	.195	4.95	.252	6.40	.280	7.11	.330	8.37	95%	1000	60mm	126.0	155
EXRAD-FSX4X	4 (133/25)	.242	6.15	.302	7.67	.326	8.28	.386	9.80	95%	1000	70mm	187.0	190
EXRAD-FSX2X	2 (665/30)	.318	8.08	.393	9.98	.421	10.69	.481	12.21	95%	1000	85mm	295.0	255
EXRAD-FSX1X	1 (779/30)	.346	8.79	.440	11.18	.468	11.89	.528	13.41	95%	1000	94mm	334.0	293
EXRAD-FSX1/0X	1/0 (1007/30)	.390	9.91	.490	12.45	.518	13.57	.598	15.19	95%	1000	105mm	412.0	339
EXRAD-FSX2/0X	2/0 (1254/30)	.438	11.13	.548	13.92	.571	14.50	.651	16.54	95%	1000	115mm	523.0	390
EXRAD-FSX3/0X	3/0 (1615/30)	.475	12.07	.585	14.86	.613	15.57	.693	17.60	95%	1000	125mm	620.0	451
EXRAD-FSX4/0X	4/0 (2107/30)	.602	15.29	.712	18.08	.748	19.00	.828	21.03	95%	1000	150mm	876.0	529

Full Datasheet can be found here

11.6 Motor(s)

11.6.1 EMRAX 228

Referred to 6.1.1

EMRAX 228 Technical Data Table

Type / Technical data	EMRAX 228 High Voltage			EMRAX 228 Medium Voltage			EMRAX 228 Low Voltage		
Air cooling = AC Liquid cooling = LC Combined cooling = Air + Liquid cooling = CC	AC	LC	CC	AC	LC	CC	AC	LC	CC
Ingress protection	IP21	IP65	IP21	IP21	IP65	IP21	IP21	IP65	IP21
Cooling medium specification (Air Flow = AF; Water Flow = WF – if inlet water temperature and/or ambient temperature are lower, then continuous power is higher)	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C
Weight [kg]	12,0	12,3	12,3	12,0	12,3	12,3	12,0	12,3	12,3
Diameter ø / width [mm]	228 / 86								
Battery voltage range [Vdc]	50 – 600 (*700 – to get 6500 RPMp)			50 – 450 (*540 – to get 6500 RPMp)			24 – 150 (*180 – to get 6500 RPMp)		
Peak motor power (few min at cold start / few seconds at hot start) [kW]	**100**								
Continuous motor power (depends on the motor RPM 3000 - 5000) [kW]	28 - 42	28 - 42	35 - 55	28 - 42	28 - 42	35 - 55	28 - 42	28 - 42	35 - 55
Maximal rotation speed [RPM]	5500 (*6500 RPM peak)								
Maximal motor current (for 2 min if cooled as described in Manual for EMRAX) [Arms]	240			340			900		
Continuous motor current [Arms]	115			160			450		
Maximal motor torque (for a few seconds) [Nm]	240								
Continuous motor torque [Nm]	125								
Torque / motor current [Nm/1Aph rms]	**1,1**			**0,75**			**0,27**		
Maximal temperature of the copper windings in the stator and also max. temp. of the magnets [°C]	120								
Motor efficiency [%]	93 – 98								
Internal phase resistance at 25 °C [mΩ]	18			8,0			1,12		
Input phase wire cross-section [mm^2]	10,2			15,2			38		
Induction in Ld/Lq [µH]	175/180			75/80			10,6/11,2		
Controller / motor signal	sine wave								
Specific idle speed (no load RPM) [RPM/1Vdc]	9,8			14			40		
Specific load speed (depends on the controller settings) [RPM/1Vdc]	8 – 9,8			11 – 14			34 – 40		
Magnetic field weakening (for higher RPM at low torque) [%]	up to 100								
Magnetic flux – axial [Vs]	0,0542			0,0355			0,0131		
Temperature sensor in the motor	kty 81/210								
Number of pole pairs	10								
Rotor inertia (mass dia=175mm, m=5,5kg) [$kg*cm^2$]	421								
Bearings SKF _ FAG	R/R 6206/6206 or R/AR 6206/7206 or AR/AR 7206/7206 (»O« orientation)								

*For a few seconds.
Maximal battery voltage is 700 Vdc (EMRAX 228 High Voltage). Maximal RPM must not be exceeded.
It is possible to weaken the magnetic field (up to 100%) to get higher RPM at existing battery voltage. Maximal RPM must not be exceeded.
These data are valid for the motors, which were sold after January 2014.
EMRAX motors that had been made before May 2012 have 30% lower power/torque and RPM than new generation of EMRAX motors.

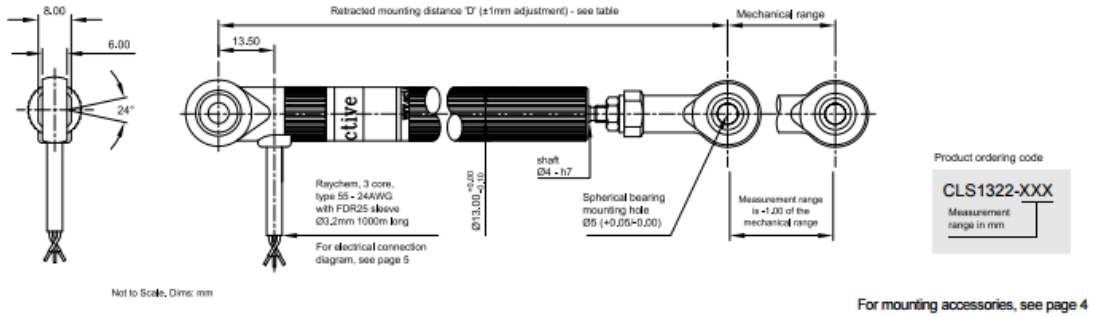
Full datasheet here

11.7 Torque Encoder

11.7.1 Active Sensors Linear Potentiometer

Referred to 7.1

CLS1322 - rod-end mounting



For mounting accessories, see page 4

Electrical & mechanical information for CLS1320 range

Measurement range (±0.5mm)	25	50	75	100	125	150	175	200	225	250	300	350	mm
Retracted mounting distance (D)	123	148	173	198	223	248	273	298	323	348	398	448	mm
Retracted shaft length (R)	-	38.5	53.5	58.5	-	88.5	-	-	-	-	-	-	mm
Body length (C)	81	106	131	156	181	206	231	256	281	306	356	406	mm
Body length (G)	85	110	135	160	185	210	235	260	285	310	360	410	mm
Resistance (Typical)	1	2	3	4	5	6	7	8	9	10	12	14	kohms
Non-linearity	<±0.25		<±0.15										%
Applied voltage	<22	<45	<65	<90	<110	<130	<130	<130	<130	<130	<130	<130	Volts
Wiper load	>500	>500	>500	>500	>500	>600	>700	>800	>900	>1000	>1100	>1200	kohms
Mechanical range	Measurement range +1												mm
Shaft velocity	<10												m/sec
Insulation resistance (at 500V dc.)	>100												Mohms
Operating temp. range	-30° to +125°												°C
Sealing	CLS1321, 22, 24, 25, 26 - IP66. CLS1323 - IP50												
Shaft operating force	200 (typical)												grams
Shaft operating force (CLS1323)	150 - 350 (typical)												
Weight (approx.)	60	66	73	78	85	90	96	102	108	114	120	126	grams
Materials	Case - Aluminium 6063 - Sulphuric acid anodised Shaft - Stainless steel - 303 series Rod end bearing - Aluminium 6262 housing & Stainless steel ball												

Full Datasheet can be found here

11.8 LV Parts

11.8.1 Low Voltage BMS

11.8.1.1 Low Voltage Battery

Referred to 8.1

Polymer Lithium-ion battery Product Specification	Doc. No.	Q/WMDCJ06011-2007
	Edition No.	1.0
	Sheet	1/6

1、Scope:

This product specification describes Wanma polymer lithium-ion battery. Please using the test methods that recommend in this specification. If you have any opinions or advices about the test items and methods, please contact us. Please read the cautions recommended in the specifications first, take the credibility measure of the cell's using.

If the cells should be using at the environment that not preferred in this document, please connect with our first and get our authorization.

It is claimed that we should have no any responsibility with the contingency and loss due to the cells' wrong usage (not preferred in the product specification).

2、Product Type, Model and Dimension:

2.1 Type: Polymer lithium-ion battery

2.2 Model: PL-9759156-5C(Cell or adding Cu tabs)

2.3 Cell Dimension with Torelence +/- 0.5mm (Thickness×Width×Length, mm^3): 9.8×59.5×157.0

Pack Dimension(Max, Thickness×Width×Length, mm^3): _____

3、Specification:

Item		Specifications	Remark
Nominal Capacity		10100 mAh	0.2C_5A discharge
Typial Capacity		10000 mAh	0.2C_5A discharge
Nominal Voltage		3.7V	Average Voltage at 0.2C_5A discharge
Charge Current		Standard: 0.2 C_5A; Max: 1C_5A	Working temperature: 0~45℃
Charge cut-off Voltage		4.200±0.05V	
Discharge Current		Continuously:5C_5A; Max: 10C_5A	Working temperature: 0~60℃
Discharge cut-off Voltage		2.75V	
Cell Voltage		3.7~3.9V	When leave factory
Impedance		≤15mΩ	AC 1KHz after 50% charge
Weight		Approx210g	
Storage temperature	≤1month	-20~45℃	Best 20±5℃ for long-time storage
	≤3month	0~30℃	
	≤6month	20±5℃	
Storage humidity		65±20% RH	

Full Datasheet here

11.9 Grounding Concept

Referred to 9.1

11.10 Firewall

Referred to 10.1

11.11 Brake plausibility