2015 Formula Hybrid Electrical System Form (ESF)

Note: This ESF differs in many ways from FSAE-electric and other international competitions. However, this form was produced in cooperation with FSAE-electric and Formula Student Germany.

University Name: University of Idaho

Team Name: Vandal Hybrid Racing

Car Number: 001

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

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Requirements:

1. This ESF must be accompanied by all the drawings required by Rule **S4.4.1**[1].
2. Read the document "How to pass ESF & FMEA" which can be found at: http://www.formulastudent.de/uploads/media/FSE2011_How_to_pass_ESF_FMEA_01.pdf
3. Maximum number of pages for the complete ESF is 100 pages!
4. Links to video or audio data are not permitted.
5. If you did not fill out the tables or if you changed the format of the ESF Template, your ESF will be rejected.
6. Every part and heading of the ESF Template must be filled with content. If the respective part is not relevant for your concept, describe shortly why not.
7. The table of contents must be hyperlinked.
8. The generated PDF must contain hyperlinked bookmarks.
9. Use internal reference links. For example when describing wiring and mentioning a figure in the text then link it to the figure.
10. Do not just copy all of your datasheets in the appendix, e.g. we do not need to know what you have to do to program your motor controller; we do not need the user's manuals for your microcontrollers, etc. etc.
11. Single pages with figures and/or tables extracted from the complete datasheet that show the important parameters, etc. are usually sufficient, but the source/link to the

[1] Be sure to refer to the most recent revision of the Formula Hybrid rules. (Rev 3 as of February 26, 2015)

complete datasheet must be provided. If the datasheet describes more than one type, clearly mark in the datasheet which type you are referring to.

12. Datasheets should only be used as a reference. Please include the important data in your text by using tables, figures, etc.
13. If you refer to parts of a data sheet, then you should provide an internal document link from the text to the respective datasheet and another internal document link back from the datasheet to the text section.
    For example a link in the motor controller section “The datasheet can be found here (clickable)” and a link above the motor controller datasheet in the appendix “The section covering the motor controller can be found here (clickable)”.
14. If you do not understand the reviewer’s feedback, please e-mail and ask.
15. Parts of the ESF which are changed because of reviewer’s feedback must be marked in red.
16. When completed, this file must be saved as a pdf and submitted to:

http://formula-hybrid.com/uploads/

Important: Many of the entry fields in this form are populated with sample data. This is provided to help illustrate the information that is required. You must overwrite all of the sample data with your own, or with an explanation of why it does not apply.

Forms that are returned with fields still containing sample data may be rejected.

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III List of Abbreviations

AIR	Accumulator Isolation Relay
AMS	Accumulator Management System
GLV	Grounded Low-Voltage
HVD	High Voltage Disconnect
TS	Tractive System
TSV	Tractive System Voltage
TSAL	Tractive System Active Light
TSVP	Tractive System Voltage Present light
TSMP	Tractive System Measurement Point

Section 1System Overview

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The tactive system is designed to be incorporated in post transmission parallel hybrid architecture. The tractive system is intended to propel the vehicle at low speed and load and to assist the internal combustion engine in mid-range operations to boost the efficiency of the vehicle. The overall layout of the vehicle can be seen in Figure 1 with general parameters of the system shown in Table1.

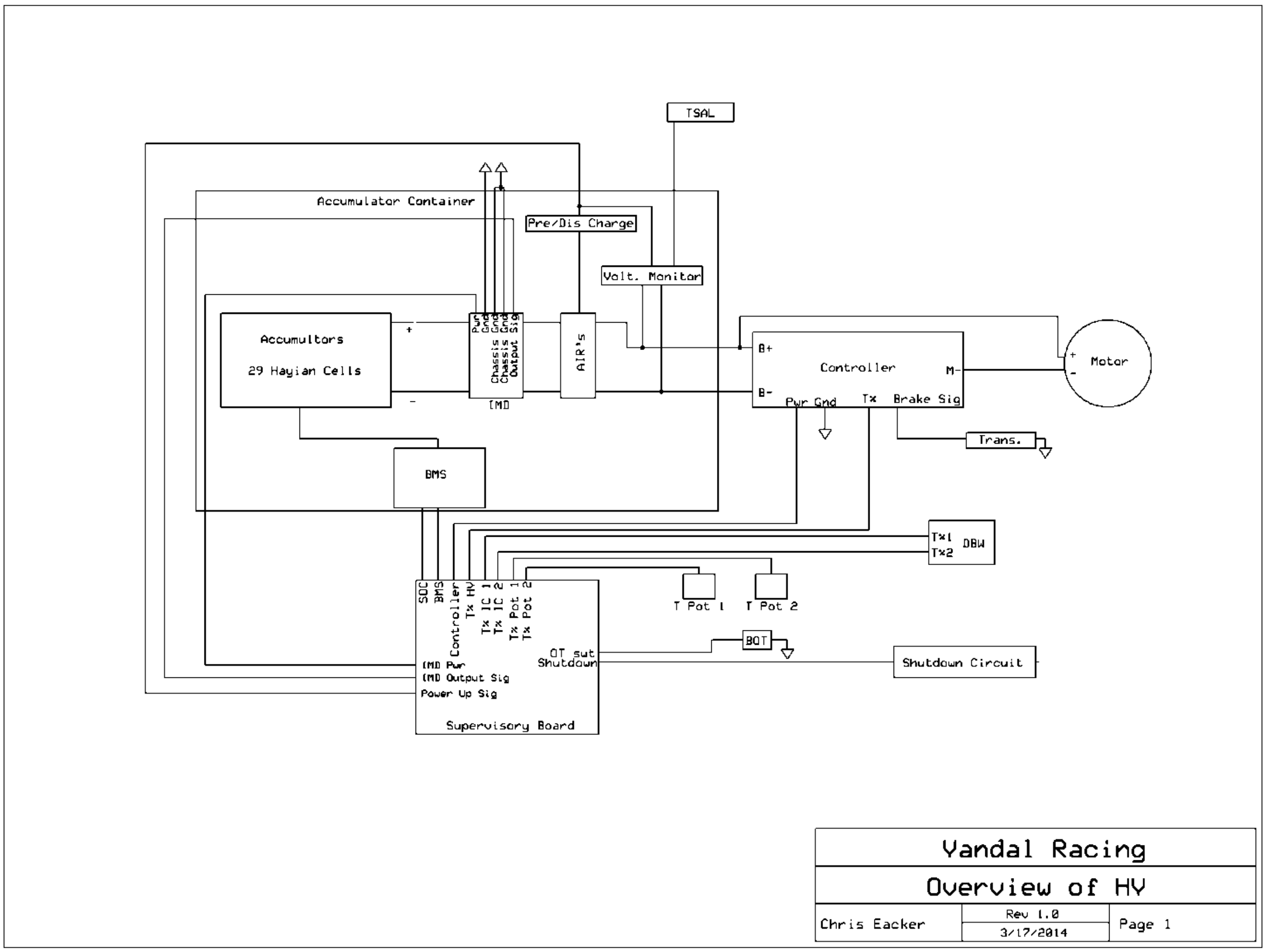

Figure 1: Overview of HV connections

Maximum Tractive-system voltage:	117.6 VDC
Nominal Tractive-system voltage:	103.6 VDC

Control-system voltage:	12 VDC
Accumulator configuration:	28 series connected LiPo cells
Total Accumulator capacity:	6 Ah
Motor type:	Permanent Magnet DC Motor
Number of motors:	1
Maximum combined motor power in kW	103.6 VDC * 200A DC = 20.72 kW

Table 1 General parameters

Note: *The motor power is calculated as the maximum expected amperage output (200A DC) times the loaded voltage of the battery cell stack (3.7 VDC/cell * 28 cells).*

Section 2 Electrical Systems

Person primarily responsible for this section:

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2.1 Shutdown Circuit

2.1.1 Description/concept

The shutdown circuit allows the driver and others near the vehicle to shut down all power from the GLV battery supply. By opening the shutdown circuit all functionality of the vehicle will stop. This occurs because of the construction of the latching circuit which powers all electrical subsystems with the exception of the high current side of the starter solenoid. The auxiliary components to the latching circuit are shown in Figure 2 with Table 2 providing the normal condition of the circuit.

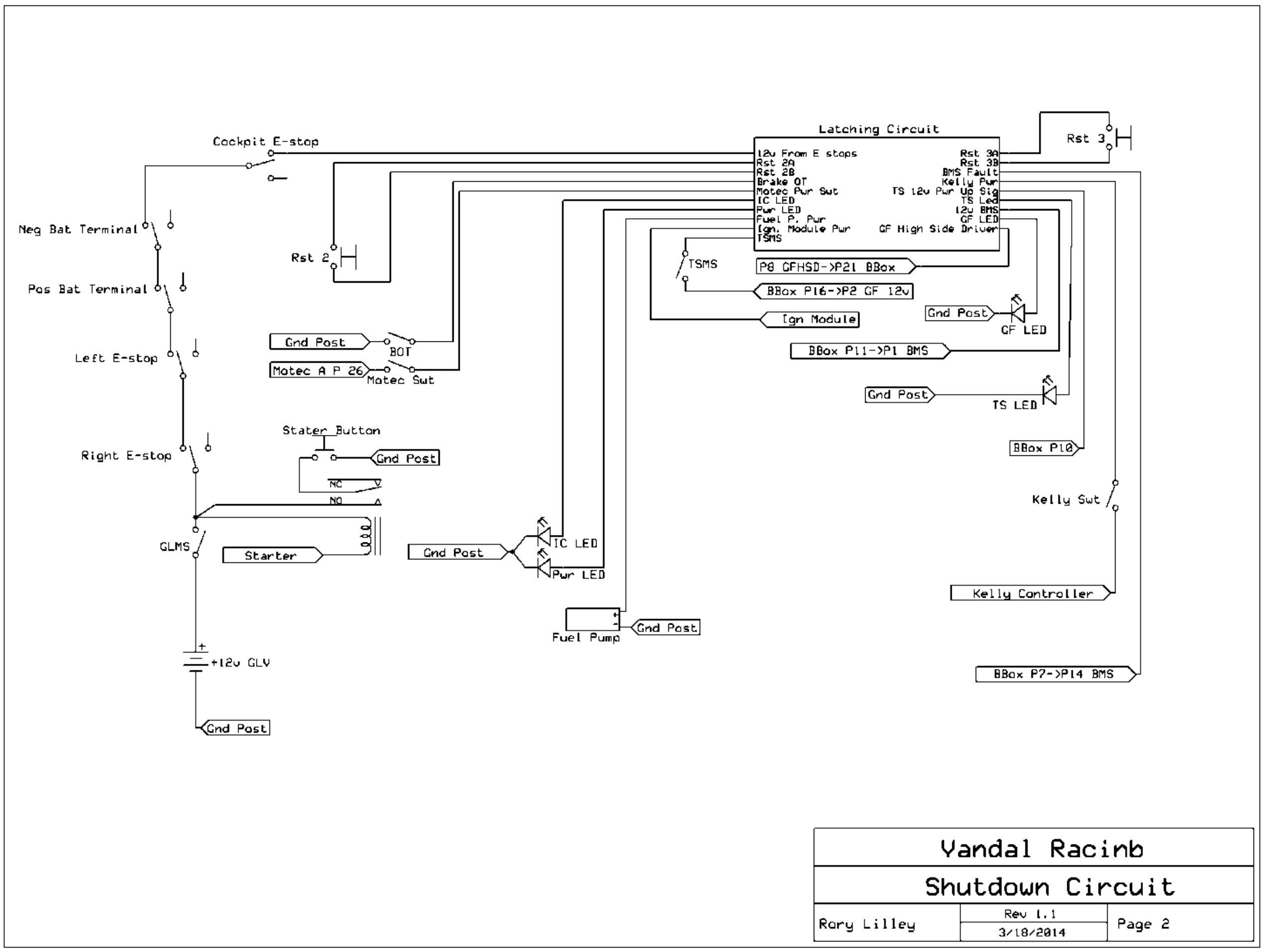

Figure 2: Shutdown Circuit

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
Interlocks	Closed when circuits are connected

Table 2 List of switches in the shutdown circuit

2.1.2 Wiring / additional circuitry within the shutdown circuit

To simplify the entire system the latching circuit was integrated into the shutdown circuit. The primary point of integration is the brake over travel (BOT) switch. The BOT is used as a latch to hold power to the IC portion of the shutdown circuit through the Tyco Electronics PCLH-202D1S relay. The shutdown circuit also carries all the current powering the control systems of the IC engine, electric motor, control and data acquisition systems on the car. With this configuration the only way to lose power to the IC engine is for one of the E-stops to be tripped or the BOT to open up the circuit. The TS may also be shutdown with this circuit but has additional requirements as well to include AMS and IMD signals. This allows us to run just the IC engine if there is a ground fault detected or an error reported by the battery management system.

However, to comply with 2015 rules, we will be modifying this latching circuit to comply with Table 17 under EV5.3.6. We will add functionality of AMS and IMD shutting off the I.C. engine in addition to the TS. At the time of this forms submission, the change has not been made, but will be in place at competition. The current latching circuit wiring is shown in Figure 3 and basic wiring information for the circuit is displayed in Table 3.

The relays are mounted to a printed circuit board housed in a waterproof container mounted behind the dash above the driver’s knees. The cross sectional area of the wire outside the container is 0.823 mm^2, on the board the cross sectional area of the trace mm^2. These sizes were selected to allow the current needed to power the car’s systems safely.

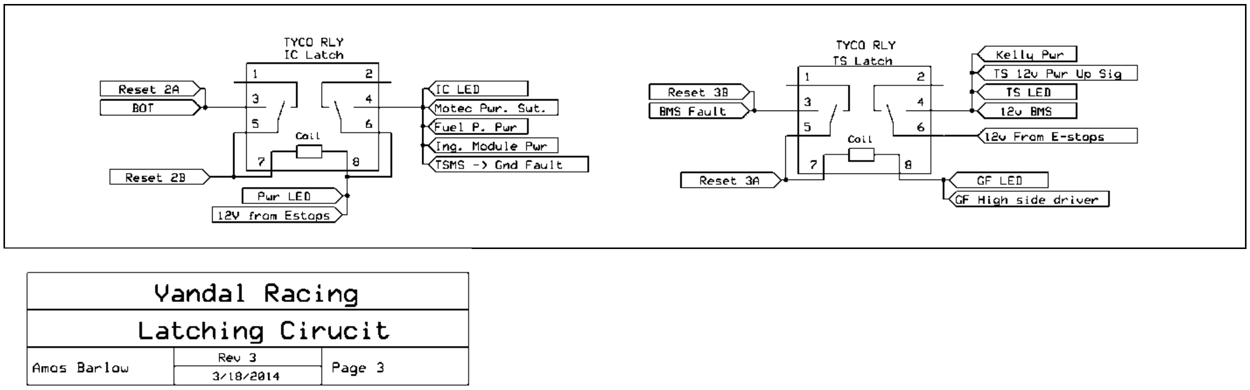

Figure 3: Latching Circuit

Total Number of AIRs:	2
Current per AIR:	0.5 A
Additional parts consumption within the shutdown circuit:	8 A
Total current:	9A
Cross sectional area of the wiring used:	0.205 mm²

Table 3 Wiring – Shutdown circuit

2.1.3 Position in car

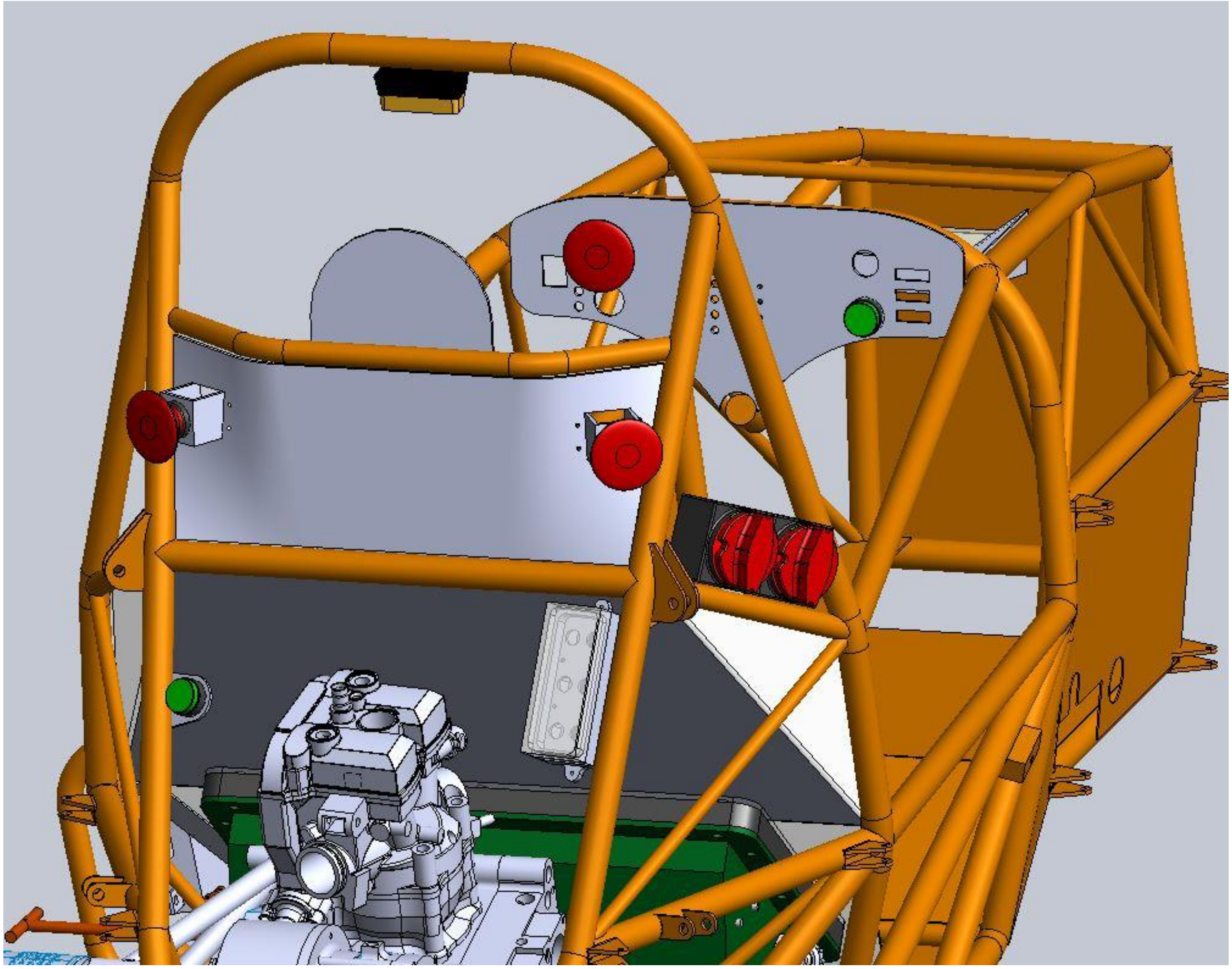

Figure 4 :Shutdown Circuit Elements Positioning

From Figure 4 we can see the location of the three E-stop buttons the location of the Accumulator pack. The render also shows the two master switches shown in red on the right side of the vehicle.

2.2 IMD

2.2.1 Description (type, operation parameters)

The IMD used for the Tractive system is the IR155-3204 from Bender, which is housed inside the accumulator container. The IMD indicator light is wired to a red light mounted on the dash. The light is powered by Pin 5 from the IMD which is PWM (high side) data out line. The IMD is wired into the outgoing terminals of the AIR's housed in the battery box as seen in Figure 5 on the far right of the diagram. The rest of the data and sensor lines for the IMD are shown in the Battery box circuit diagram shown in Figure 6. The basic information regarding the functionality of the IMD is shown in Table 4.

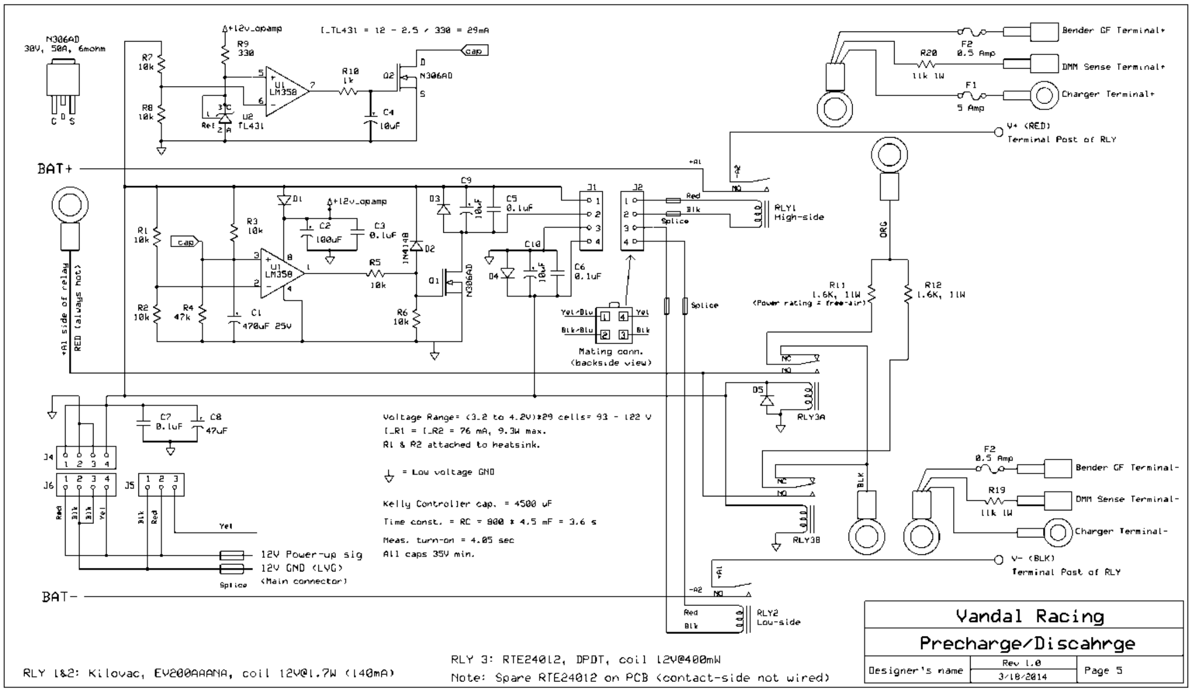

Figure 5: Precharge/Discharge Circuit

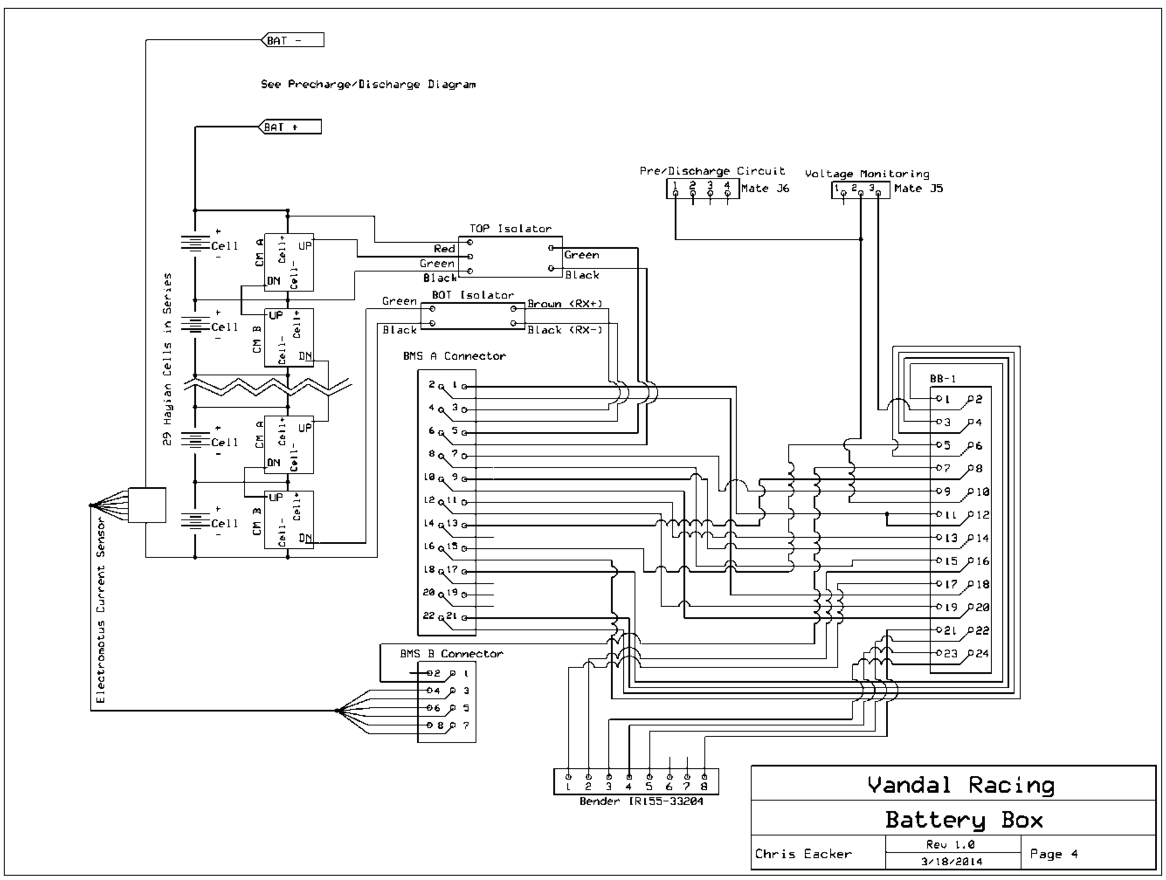

Figure 6: High Voltage Battery Box Connections

Supply voltage range:	10..36 VDC
Supply voltage	12 VDC
Environmental temperature range:	-40..105°C
Self-test interval:	Always at startup, then every 5 minutes
High voltage range:	DC 0..1000 V
Set response value:	60 kΩ (500 Ω/Volt)
Max. operation current:	150 mA
Approximate time to shut down at 50% of the response value:	20s

Table 4 Parameters of the IMD

2.2.2 Wiring/cables/connectors/

The IMD is powered from the TSMS, which receives power from the latching circuit shown in Figure 3. Power comes into the battery box through pin 16 on connection BB-1 shown in Figure 6; the IMD is grounded outside the container on the main grounding post where Pin 3 from the IMD is also grounded. Pin 4 is grounded to the mount for the accumulator itself to allow for accurate measurement of the potential across the chassis. Pin 5 from the IMD is wired to the IMD indicator on the dash and pin 8 is the High side driver that allows the system to be latched as shown in Figure 3. All the wires inside the accumulator container, pertaining to the IMD, that travel outside the container are 24 gauge wires and are connected using a Military spec connector mounted to the wall of the container.

2.3 Reset / Latching for IMD and AMS

2.3.1 Description/circuitry

The latching circuit for the IMD and AMS is designed such that if either the IMD or AMS signal a fault, the driver will be unable to reset the system until the Tractive system is restarted from the Master switch. This is achieved by using the AMS as the ground side of the latch, when the AMS senses a fault such as overheating of the cells or a large current draw on the cells it will float the ground disabling the relay from being reset by the driver. The IMD is used as the positive side of the latch shown in Figure 7. As long as the IMD senses no failure of the insulation between the TSV and the GLV systems it will hold the latch closed given no fault is sensed with the AMS. The design of the tractive system latching provides a simple system that requires full functionality from both the AMS and IMD to allow the driver to reset the system from within the vehicle should the system shut down.

2.3.2 Wiring/cables/connectors

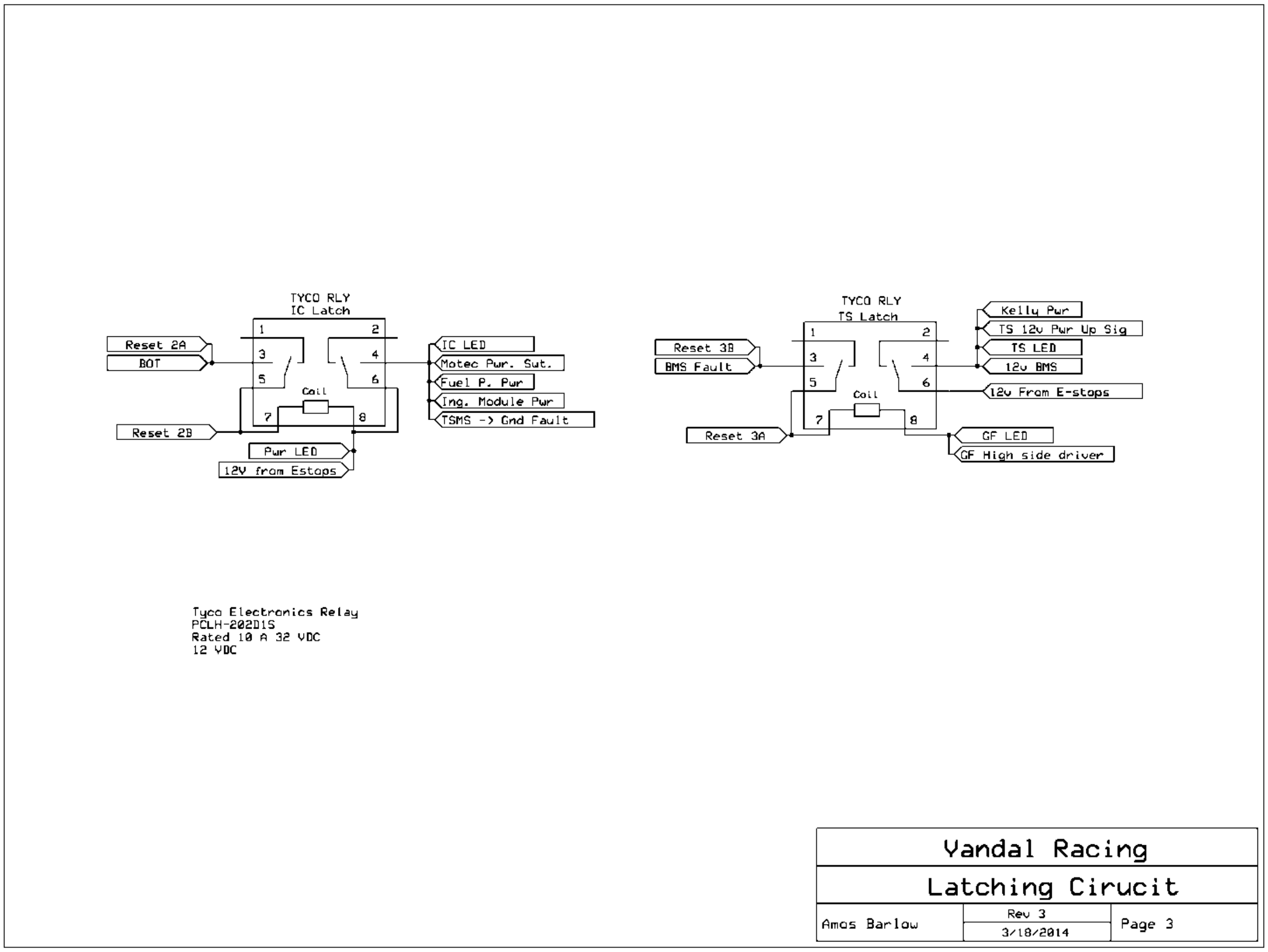

Figure 7: Latching Circuit

The latching circuit was integrated into the data acquisition system on a printed circuit board, to provide a clean, water proof system to ensure functionality. The circuit board is mounted within a waterproof case behind the dash and above the driver's knees shown in Figure 8. The paths used with the circuit board have a cross sectional area of .0884 mm^2. The circuit board is connected to three AMP Super seal 1.00 mm connectors, which allow a water tight seal at the connectors to the low voltage container.

2.3.3 Position in car

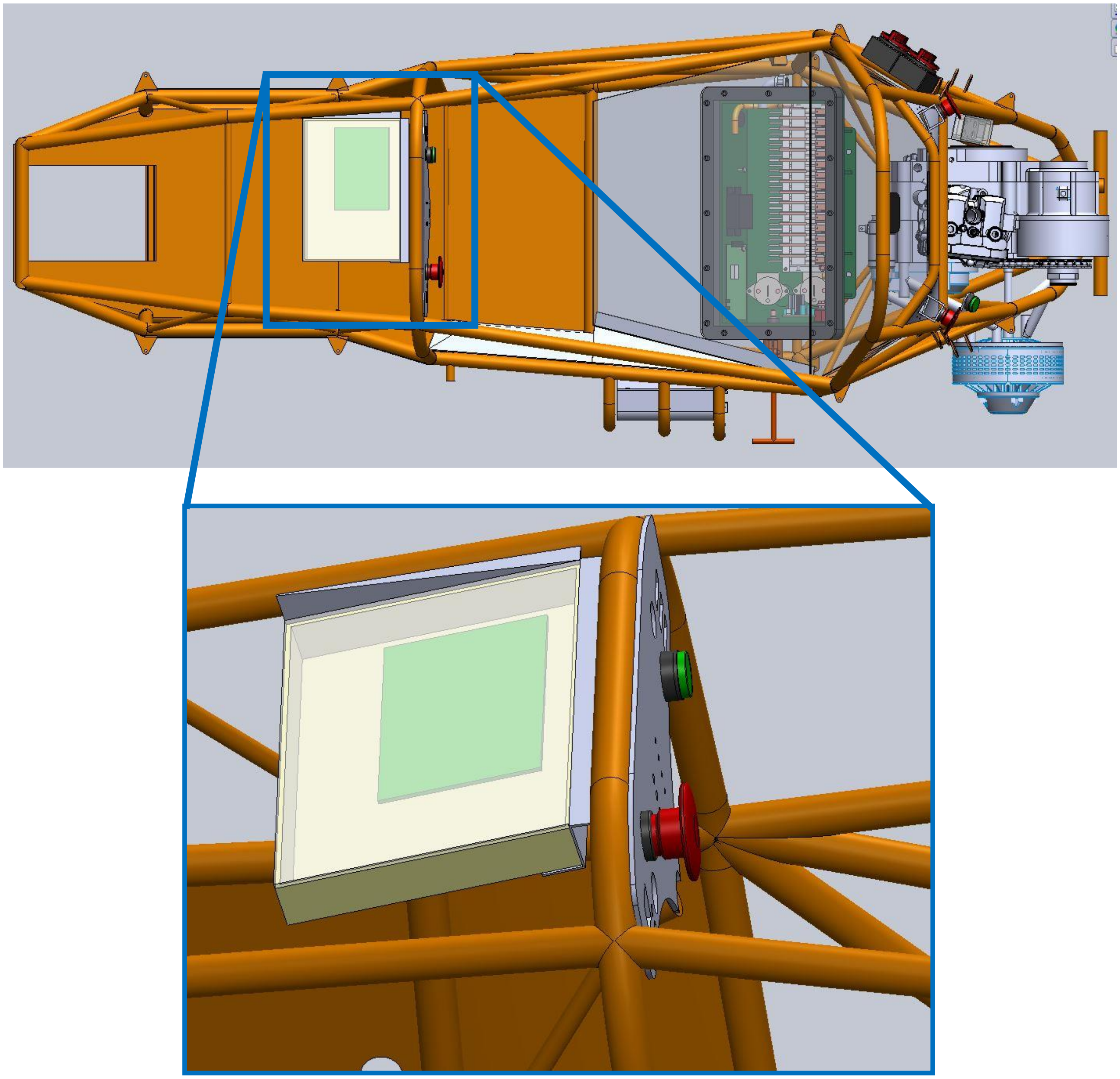

Figure 8: Latching Circuit Location

The latching circuitry is shown in Figure 8 as the green board in the low voltage box behind the dash. The green momentary button on the dash is the reset for the tractive system.

2.4 Shutdown System Interlocks

2.4.1 Description/circuitry

With the removal of rule EV4.7.5, interlocks are no longer present on any part of the car. The design is such that interlocks (i.e. for an outboard motor) are not required.

2.4.2 Wiring/cables/connectors

See 2.4.1.

2.5 Tractive system active light (TSAL)

2.5.1 Description/circuitry

The tractive system activation light is activated when the both the IMD and AMS have sensed no faults in the system and have allowed the latching circuit to supply a voltage to the pre charge, discharge circuit and voltage monitoring circuit. When these two circuits have allowed the AIR's to close then the voltage monitor allows power to activate the TSAL. Table 5 provides basic information about the functionality of the TSAL system and Figure 9 shows the wiring in the Voltage Monitoring circuit pertaining to the TSAL on the right side of the diagram after the opto-coupler.

Supply voltage:	12 VDC
Max. operational current:	700 mA
Lamp type	LED
Power consumption:	4.5 W
Brightness	100 Lumen
Frequency:	2 Hz
Size (length x height x width):	20 mm x 10 mm x 50 mm

Table 5: Parameters of the TSAL

2.5.2 Wiring/cables/connectors

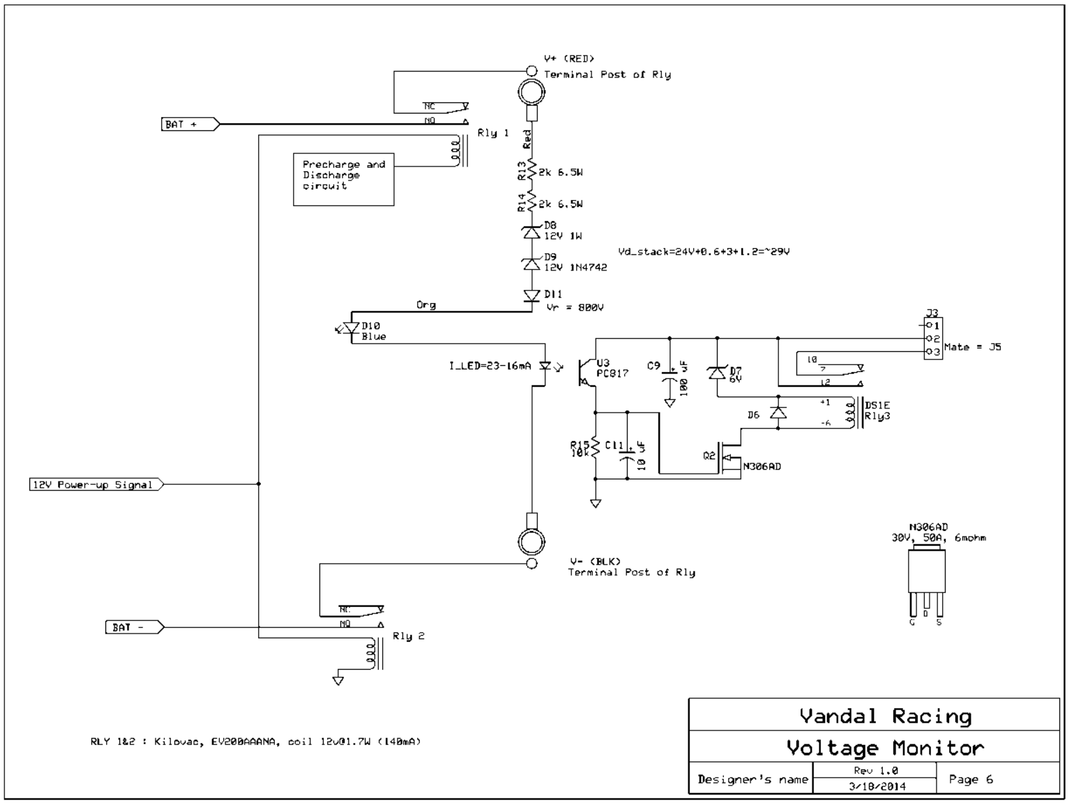

Figure 9: Voltage Monitoring Circuit

The TSAL is wired in via relay 3 activated on the voltage monitoring circuit and is isolated through an opto-coupler as in the Figure 9. The TSAL light then passes out of the battery box through connector BB-1 pin 2 shown in Figure 6 up to the light where the light is also grounded to the chassis. This design ensures TSAL is only operational when voltage is at the terminals on the outside of the accumulator container and that the light its self is not powered by the accumulator voltage.

2.5.3 Position in car

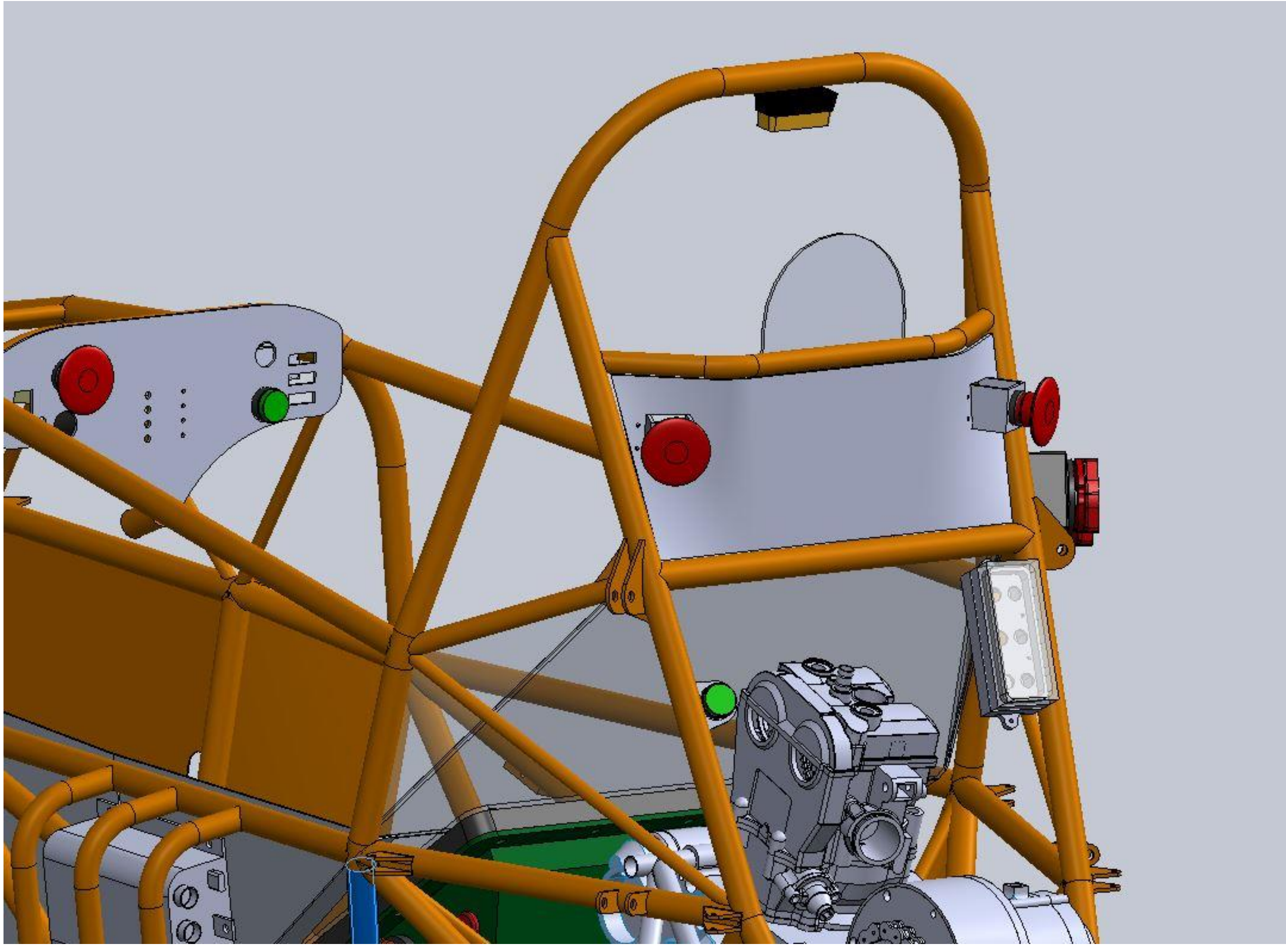

Figure 10: TSAL Positioning on Car

The tractive system activation light in amber with a black base mounted on the underside of the main roll hoop shown in Figure 10.

2.6 Tractive System Voltage Present light (TSVP)

2.6.1 Description/circuitry

The TSVP lights are not currently installed on the car at the point of this form's submission. They will be installed in compliance with the rules prior to competition.

2.6.2 Wiring/cables/connectors

The TSVP lights will be added to the existing circuitry for the TSAL. This will illuminate the TSVP lights when sufficient voltage is present at the battery box terminals. The current circuit design is shown in Figure 9 and with some simple modification power can be carried to the TSVP lights as well.

2.7 Tractive System Measurement Points (TSMP)

2.7.1 Description

The TSMP housing is made from gray PVC with a clear acrylic covering. The covering can be removed by firmly grasping the acrylic and simply pulling the covering off. To replace the covering you need to align it square with its mount and snap it back into place. The accessibility of the cover was designed to have sufficient friction to hold the covering on during vehicle operation.

2.7.2 Wiring, connectors, cables

Measuring points for the TSMP are from the outgoing side of the AIR's as shown in the Figure 11. The connectors on the terminals of the relays are ring terminals as depicted in the diagram which have a nomex sleeve all the way to the conduit at the side of the accumulator container with a small gap at the resistors shown in the diagram to drop the voltage to a manageable voltage. The wiring to and from the power resistor and banana jack is 20ga, which allows for sufficient current flow.

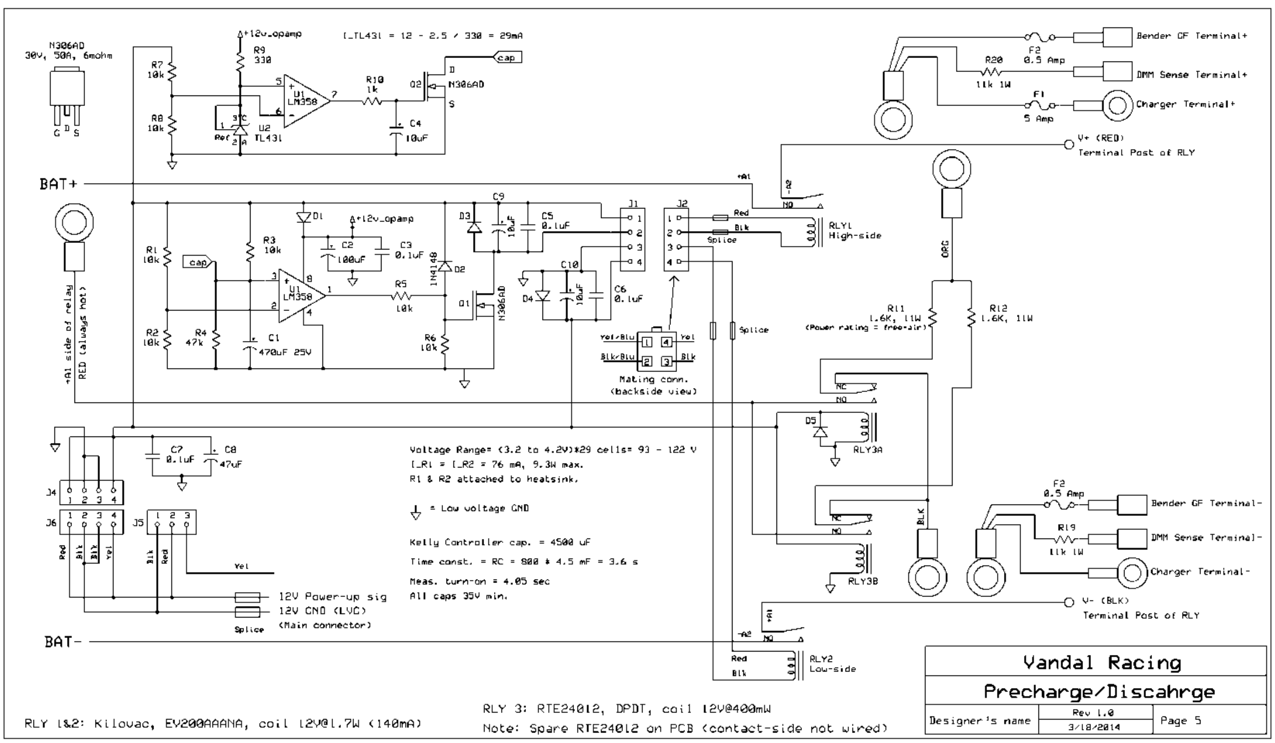

Figure 11: Precharge/Discharge Circuit

2.7.3 Position in car

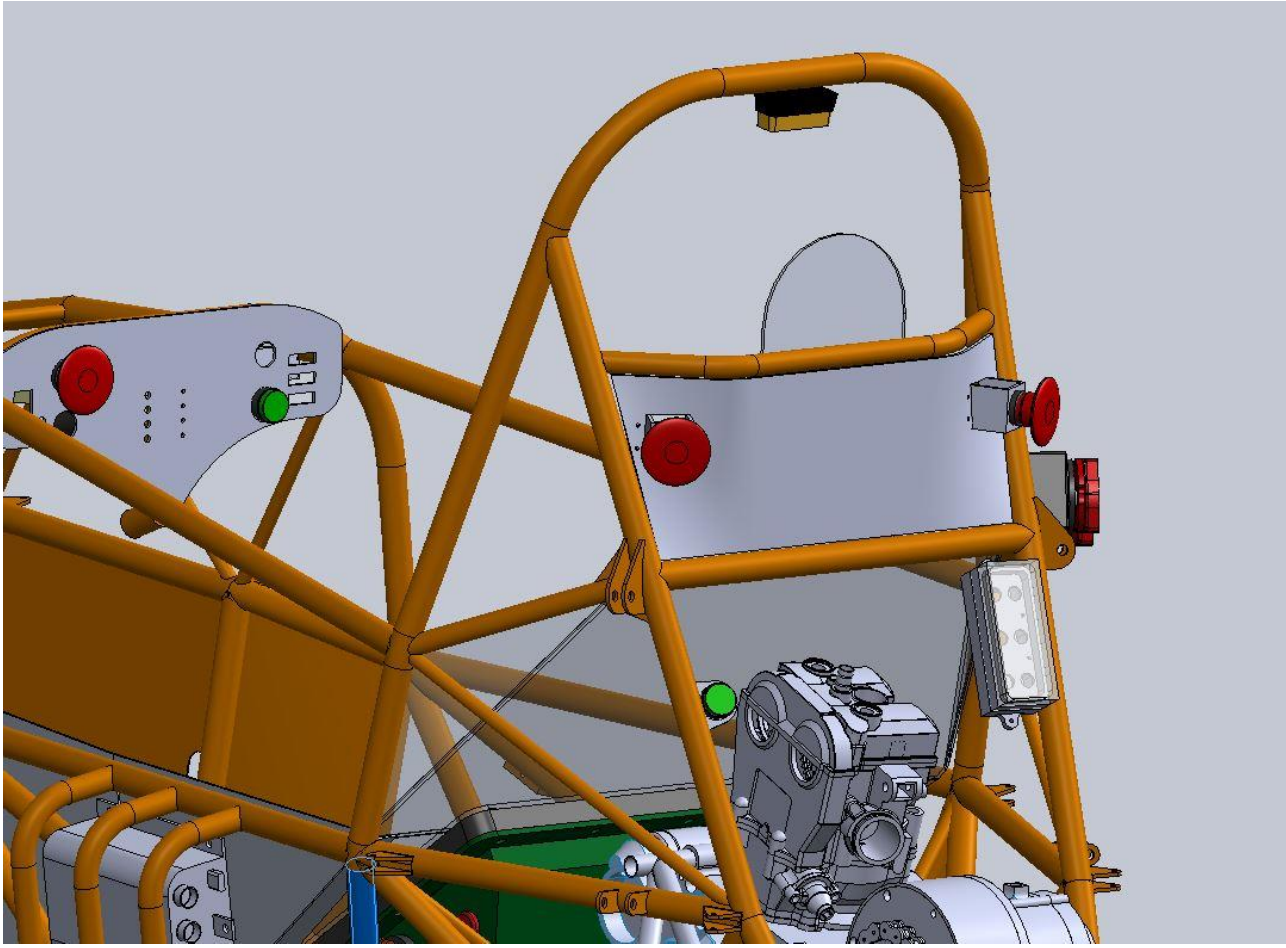

Figure 12: TSMP location

The TSMP is mounted at the rear of the vehicle on the main roll hoop bracing just to the right of the engine allowing quick and easy access in case of emergencies shown in Figure 12.

2.8 Pre-Charge circuitry

2.8.1 Description

When the power up signal is pulled high, the power is routed directly to the pre-charge relay which connects the battery high side to the output terminal through power resistors. The data for the pre-charge relay is shown in Table 7 and data for the power resistors is in Table 6. This gradually brings the potential of the terminal up to the nominal voltage. The power up signal is also passed to the AIR circuitry which delays the closing of the positive and negative AIRs. Figure 13 shows the wiring and layout of the pre-charge circuitry

2.8.2 Wiring, cables, current calculations, connectors

The indicated voltage and current plots vs. time are not available at this time. A new battery box is currently under construction with a different energy limit than last year; due to the ongoing construction, the data for these plots is unattainable prior to the submission deadline of this form.

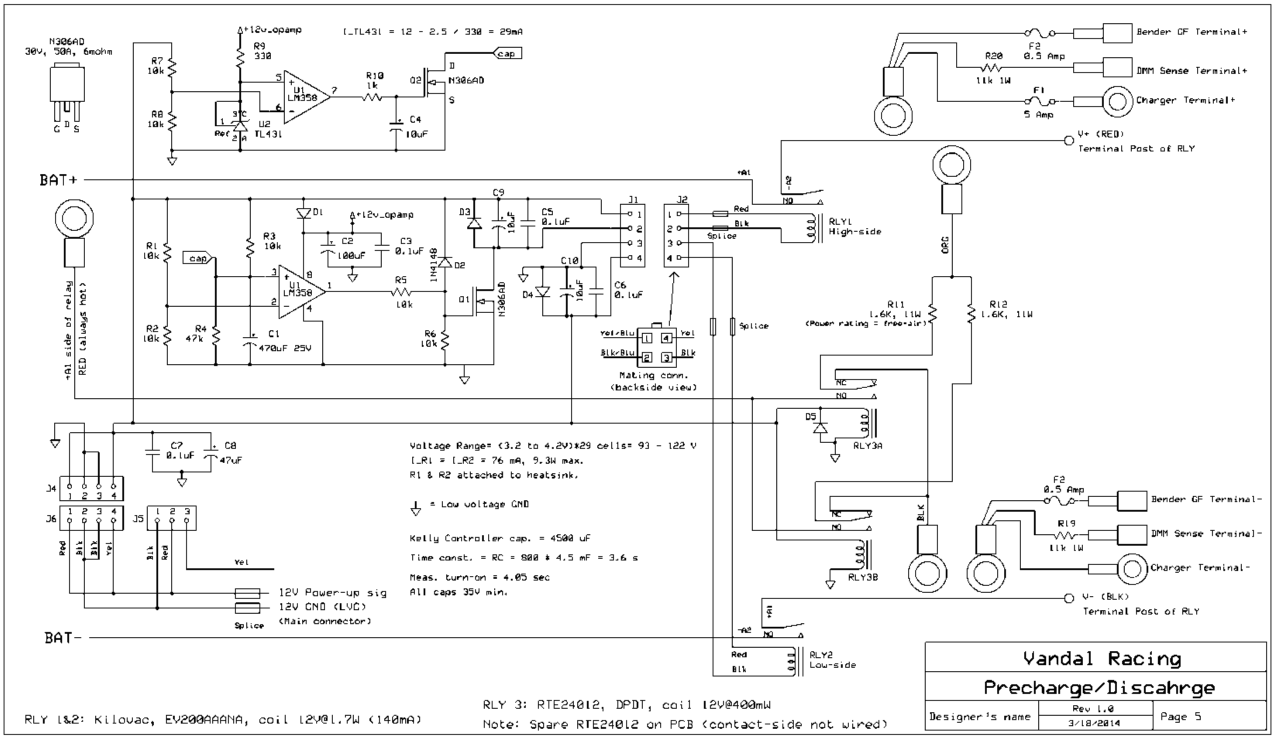

Figure 13: Precharge/Discharge Circuit

Resistor Type:	OHMITE
Resistance:	1.6 kΩ
Continuous power rating:	11 W
Overload power rating:	110 W for 5 sec
Voltage rating:	1000 V
Cross-sectional area of the wire used:	0.823 mm²

Table 5 General data of the pre-charge resistor

Relay Type:	TE Connectivity
Contact arrangement:	DPDT
Continuous DC current:	15A
Voltage rating	250 VDC
Cross-sectional area of the wire used:	0.823 mm²

Table 6 General data of the pre-charge relay

2.8.3 Position in car

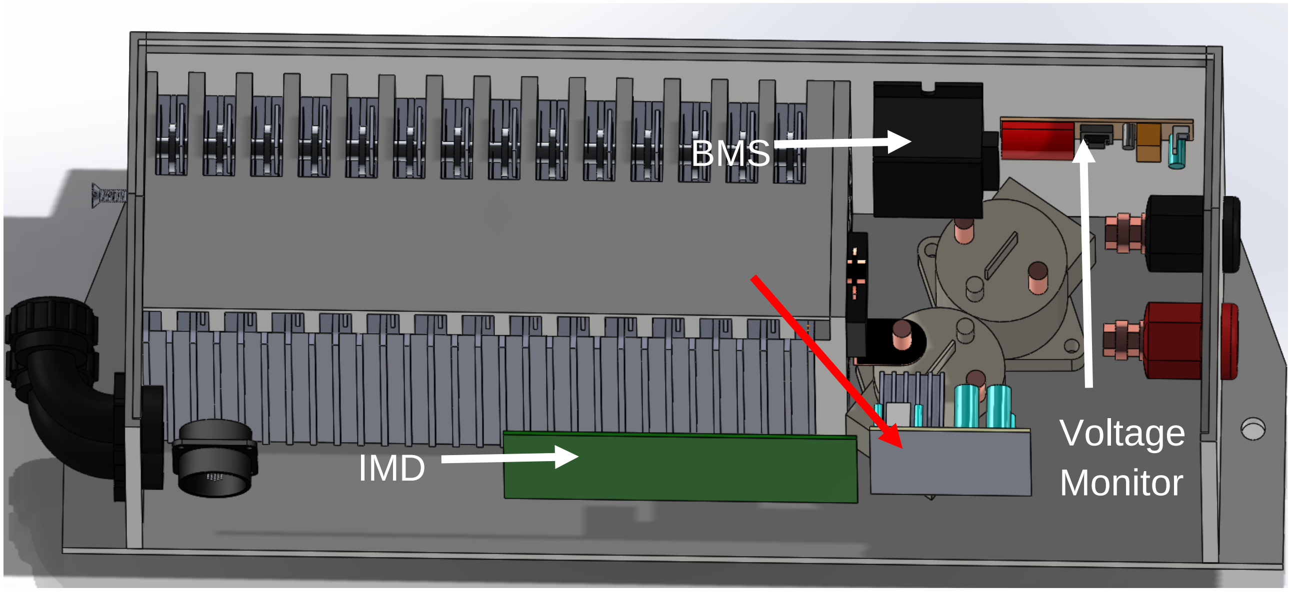

Figure 14: Precharge/Discharge Circuit Location

The pre-charge circuitry is indicated by the red arrow. It sits inside the container mounted to the front panel shown in Figure 14.

Note: Additional circuits are labeled on the above figure as reference.

2.9 Discharge circuitry

2.9.1 Description

When the power up signal is lost (i.e. a ground fault is detected, .etc.) the discharge circuit immediately closes, pulling the high side low through the power resistors. Additionally, as power is cut from the AIR circuitry, the capacitors keep enough power to allow AIR to close just after the terminals are discharged. The wiring set up for the discharge circuit is shown in Figure 15 and general data for the circuit is shown in Table 8.

2.9.2 Wiring, cables, current calculations, connectors

The indicated plots are not available and unattainable at the time of this form's submission (see 2.8.2). As a note, the pre-charge and discharge functionalities are on the same circuit in this design.

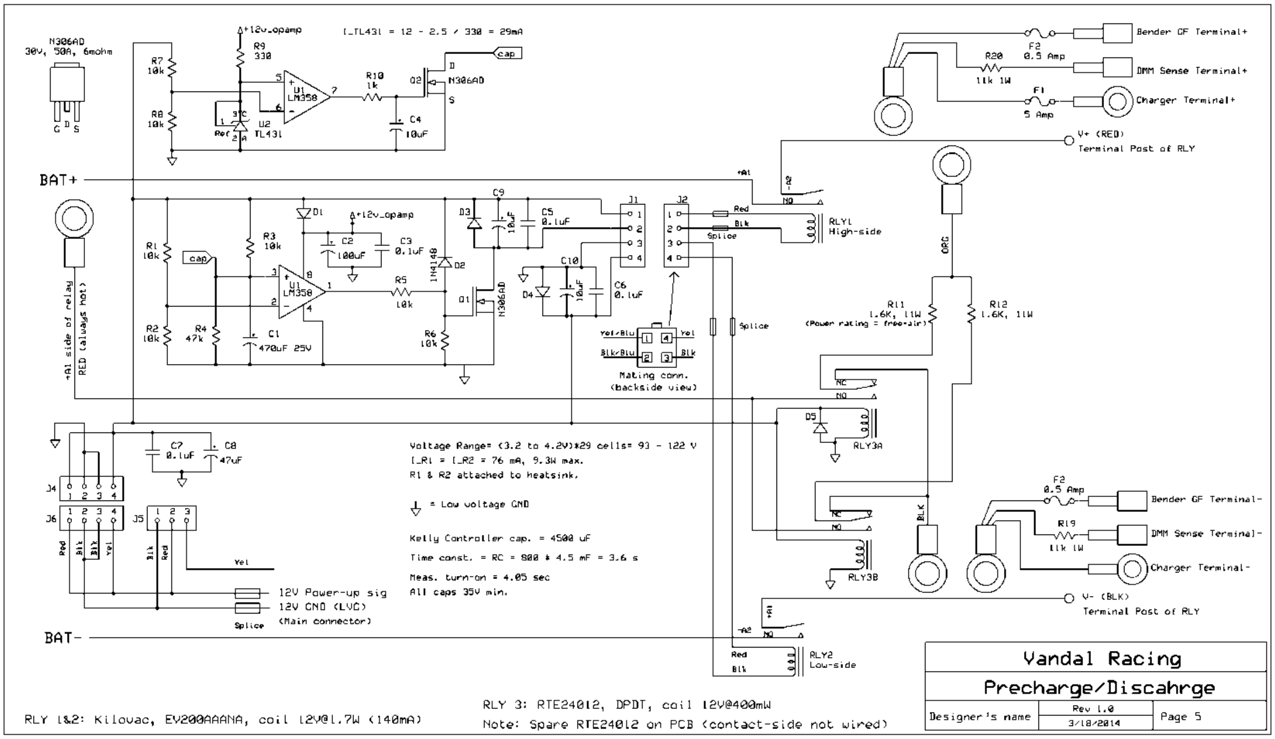

Figure 15: Precharge/Discharge Circuit

Resistor Type:	OHMITE
Resistance:	1600 Ω
Continuous power rating:	11 W
Overload power rating:	110 W for 5 sec
Voltage rating:	1000 V
Maximum expected current:	0.93 A
Average current:	0.3 A
Cross-sectional area of the wire used:	0.823 mm²

Table 7 General data of the discharge circuit.

2.9.3 Position in car

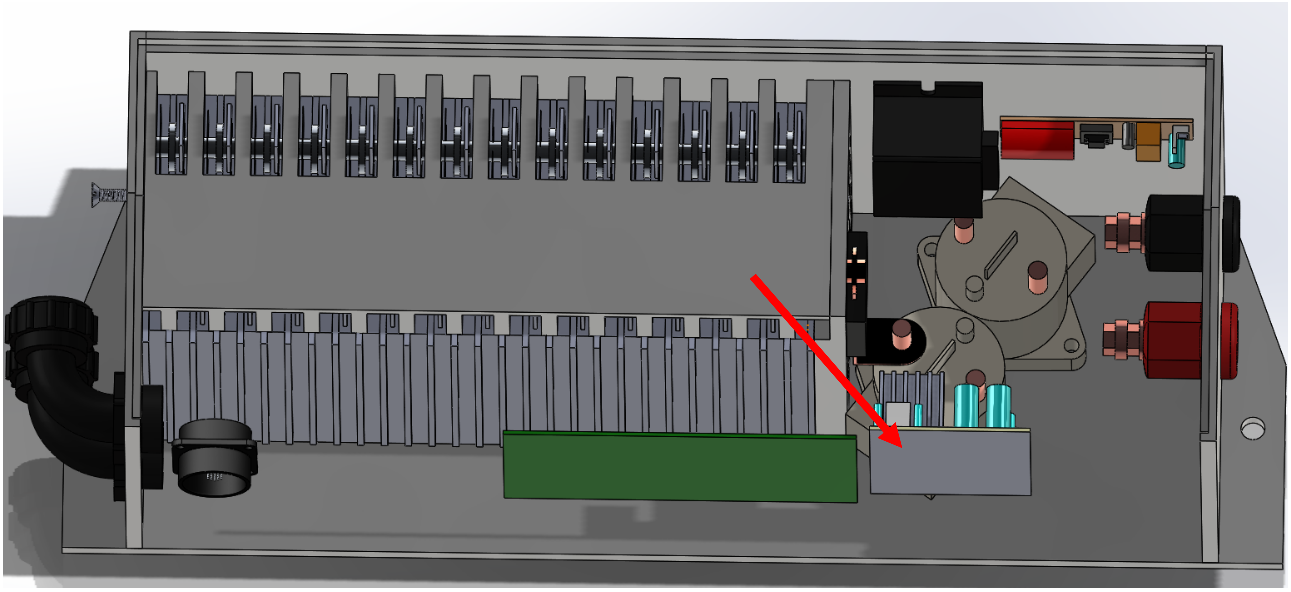

Figure 16: Location of Precharge/Discharge Circuit

Figure 16 shows the discharge circuitry which is on the same board as the pre-charge circuit. Note that the lid and front cover are hidden in the rendering.

2.10 HV Disconnect (HVD)

2.10.1 Description

The HVD is not currently installed on the car at the time of this form's submission. An original design ran into unforeseen issues recently, and a new design is being pursued.

The current intent is to use a marine rated connector which can be manually disconnected without the use of tools in order to break the current path from the tractive system shown in Figure 17. Additionally, this connector will contain the tractive system fuse. Pending some technical questions remaining unanswered from the manufacturer, the connector used to satisfy the HVD requirement will be a TE Connectivity Manual Service Disconnect receptacle, and it's respective plug:

Figure 17: Proposed connector for HVD

The connectors are rated for the maximum expected DC current of 200A, with the receptacle containing the fuse.

More information on the receptacle can be found at the following link:
http://www.te.com/catalog/pn/en/1587987-8

2.10.2 Wiring, cables, current calculations, connectors

See 2.10.1.

The receptacle will be mounted such that it can be disconnected and locked out within 10 seconds in ready-to-race condition, while still remaining as close as possible to the accumulator. The lockout procedure will be the insertion of a pin or some obstructing device that prevents the reconnection, intentional or accidental, of the HVD while it is in place.

Conductors connected to these connector assemblies will be of #1 AWG extra flexible welding cable rated for 220A with 90 degree Celsius insulation rating. Any part of this conductor outside of TS enclosures will be in UL listed conduit of size ¾". The conduit will be wrapped in rated orange sleeving.

2.11 Ready-To-Drive-Sound (RTDS)

2.11.1 Description

The RTDS is produced by a Mallory PS-520Q Sonalert. The speaker is mounted underneath the low voltage box behind the dash and above the driver's knees shown in Figure 18. The speaker is controlled by the energy management microcontroller mounted on the PCB in the low voltage box and is signaled by the relay used to latch the Tractive System. When the latching circuit closes the PCB will operate the speaker for 3 seconds.

2.11.2 Wiring, cables, current calculations, connectors

The Mallory PS-520Q is wired directly from under the low voltage box to the low voltage board using 22 gauge wire.

2.11.3 Position in car

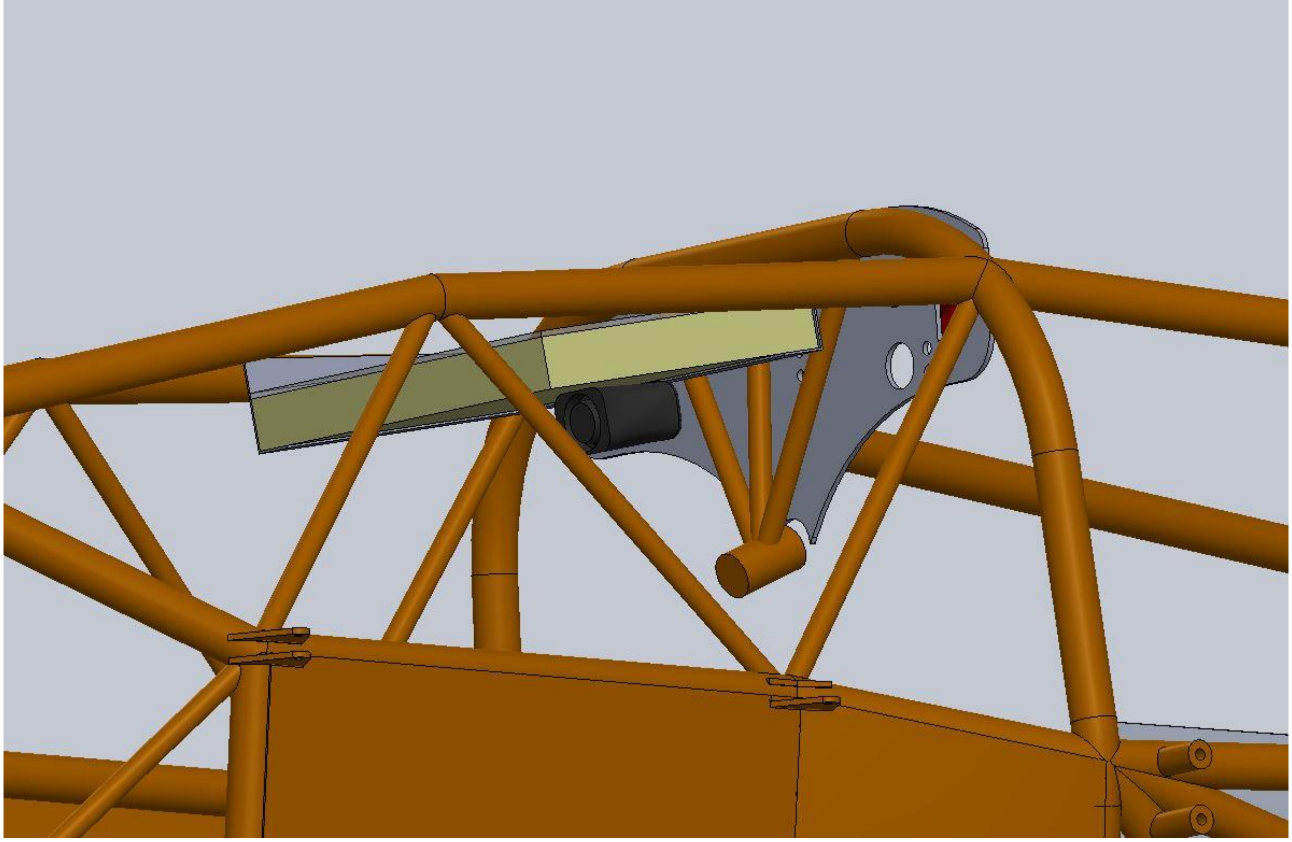

Figure 18: Position of RTDS speaker

The speaker is mounted behind the dash, and attached to the bottom of the Low Voltage box by the use of a small strip of Velcro shown in Figure 18.

2.12 HV-LV Separation

Documentation on spacing is currently limited, as electrical systems are currently being built and redesigned as issues arise.

New PCB's are in the works. Design information was unattainable at the time of this form's submission, but compliance with spacing outlined in EV4.1 will be maintained.

The separation of cell connections in the new TS accumulator design is designed for compliance with EV3.3.9. and is shown in Figure 19. The top cover seen in Figure 20 will be secured with nylon screws on either side. This top cover will also act as a method of restraining the cell tabs during normal operation as shown in Figure 21.

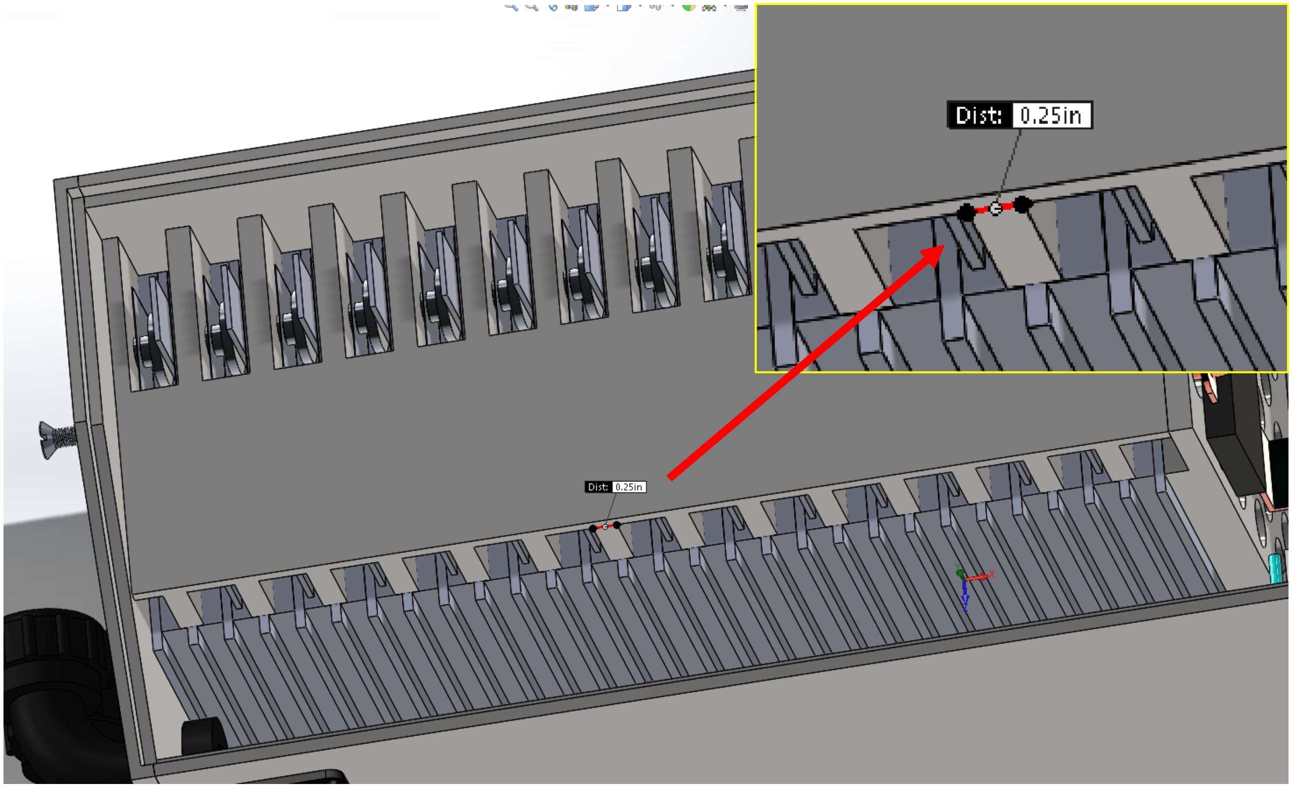

Figure 19: TS Cell connection separation in accumulator container

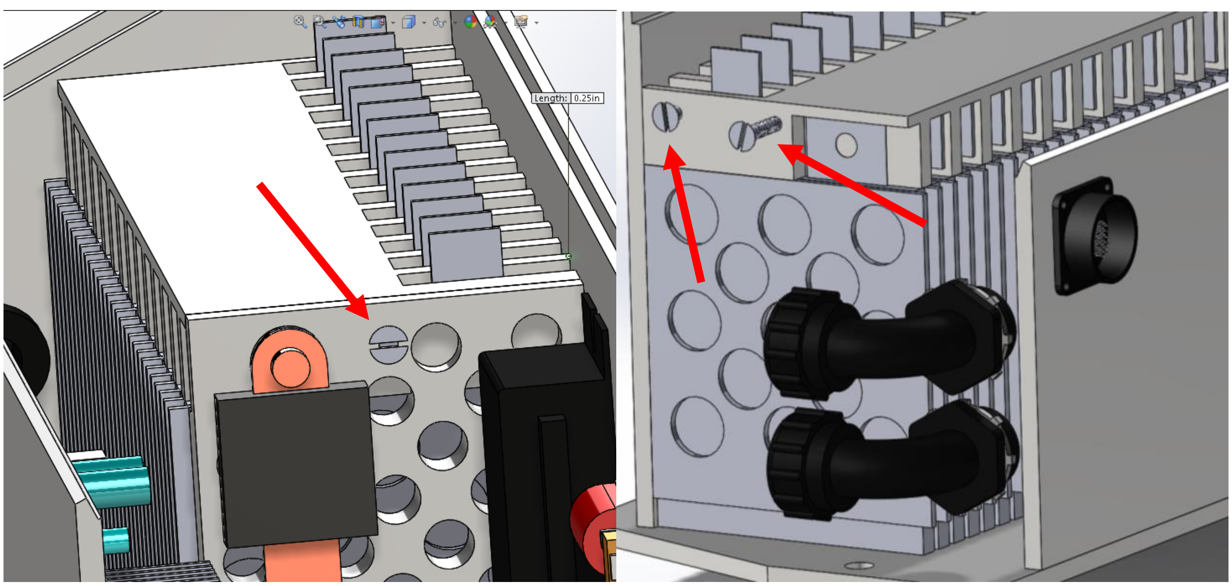

Figure 20: Screws securing cell separating cover

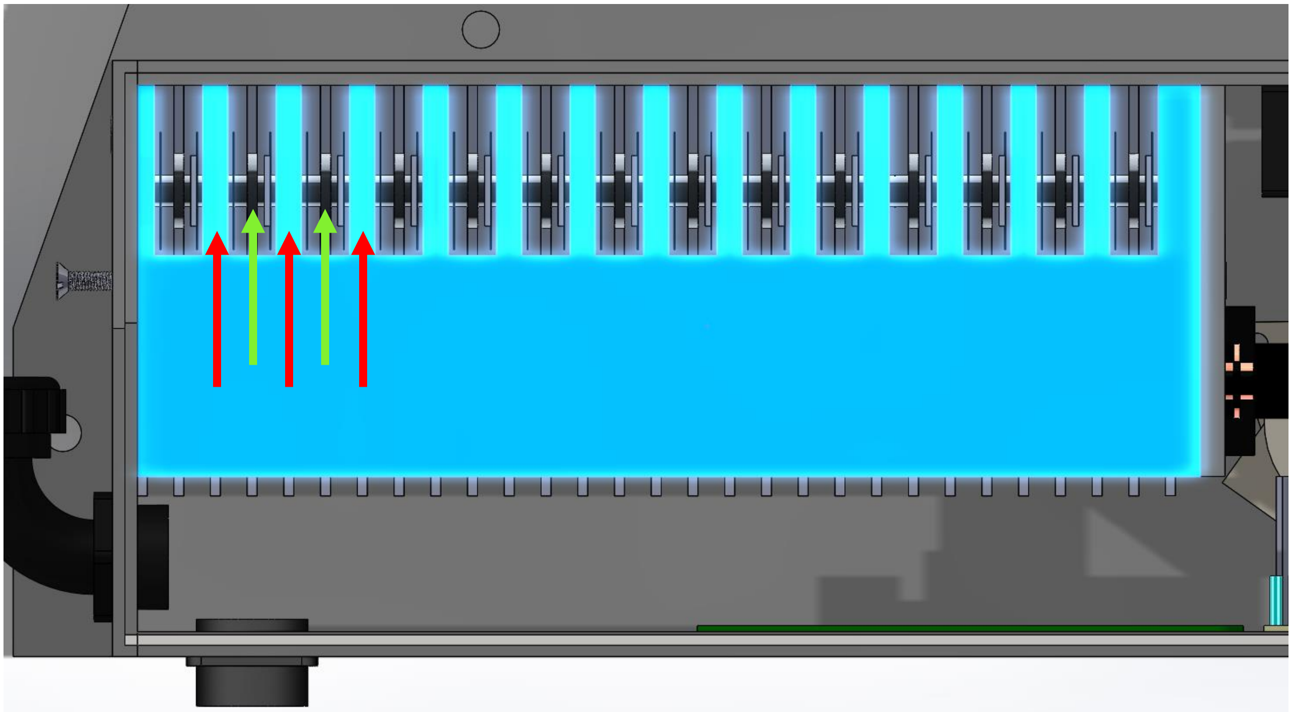

Figure 21: Cell movement restriction

The bright blue element is the top cover seen Figure 21, which is rigidly mounted by screws shown in Figure 20. The cell connectors, indicated by the green arrows, sit flush between the “teeth” of the rigid top cover, indicated with red arrows. Additionally, metal nuts lock the cell tabs in place to the connector rods. The net result is zero movement of the cell tabs in the stack during operation and prevents the nuts from accidently loosening.

Cell expansion into the filler material/expansion limiter will be allowed in this design to meet the requirements of EV3.8. The accumulator mounting set up is also shown in Figure 22 and allows for the use of 3/8in fasteners.

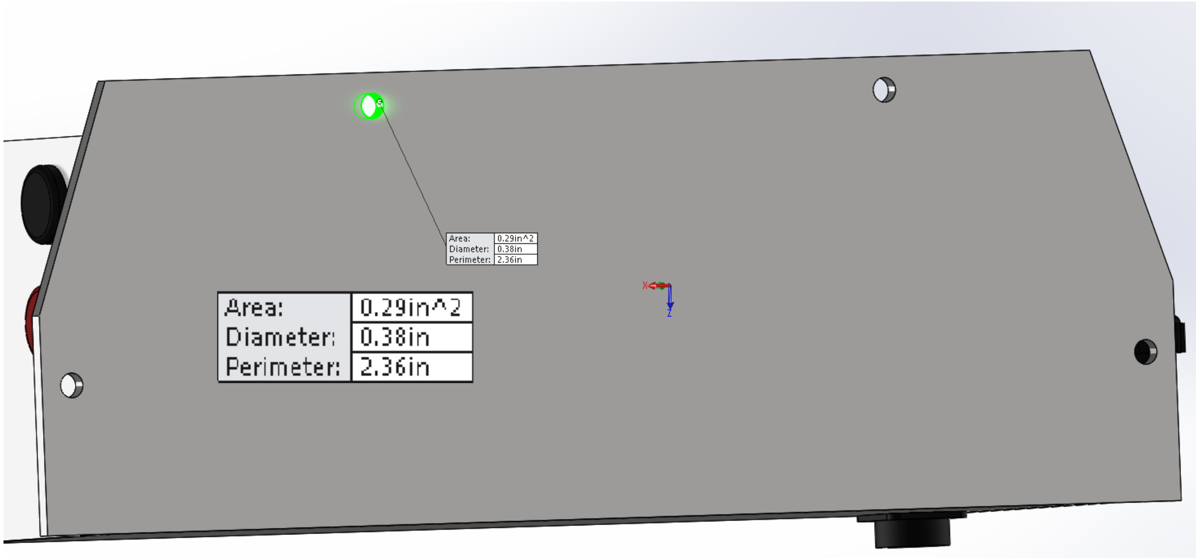

Figure 22: Accumulator container mounting points

Renderings of the accumulator container do not have low voltage wiring in them, and as the accumulator is not yet constructed, no photographic evidence is currently available either. However, all galvanic isolation requirements and spacing/insulation requirements will be met and demonstrated at competition.

The datasheet for the plastic material provided by the manufacturer is minimal. The rules committee approved this material as sufficiently fire proof after a video query showing a flame test was submitted.

Manufacturer Datasheet:
http://www.interstateplastics.com/materialspecs/web-uhmw.pdf

Generic datasheets for ultra-high molecular weight plastic of this type will indicate that even the lowest end of product has very high dielectric properties, thus serves as a great electrically insulating material (range of 360V/0.001" to 2300V/0.001"). As such, it sufficiently insulates our cell to cell connections in the series cell stack of the accumulator container.

2.13 Conduit

The conduit used will be ¾" UL Listed conduit housing a single conductor of #1 AWG size. The conduit itself is gray, but will be covered in orange sleeving for rule compliance.

The sleeving used will be Flexo F6 Orange ¾" or 1" braided self-wrapping sleeving. It has high abrasion resistance, operates in temps from -70C to 125C, melts at 250C, and resists chemicals.

The sleeving in question can be found at this link:
https://www.wirecare.com/product.asp?pn=WC01437110

Anchoring of the conduit is yet to be determined, pending some technical information about the aforementioned connector (see 2.10) we are pursuing for the tractive system. We will ensure all connections to a tractive system enclosure will be liquid tight and capable of withstanding adequate mechanical strain, as specified in the rules.

Section 3 Accumulator

Person primarily responsible for this section:

Name: Troy Ledford

e-mail: Ledf4254@vandals.uidaho.edu

3.1 Accumulator pack 1

3.1.1 Overview / description / parameters

The accumulator was designed to be as tightly packaged as possible while housing all components that require access to the TSV lines. This strategy ensures minimal exposure to the HV components and minimizes conduit and cable requirements.

The overall design of the cell pack minimizes the battery footprint while allowing maximum cell count. The pack contains 28 series cells which allows for a 6 Ah maximum and peak voltage output of 117 V. General information is to be found in Table 9.

Maximum voltage:	117 VDC
Nominal voltage:	104 VDC
Minimum voltage:	78.4 VDC
Maximum current output:	400A for <1 sec
Maximum nominal current:	200 A
Maximum charging current:	30 A
Total number of cells	28
Cell configuration	28s 1p
Total capacity	34.8kWh
Number of cell stacks < 120VDC	1

Table 8 Main accumulator parameters

3.1.2 Cell description

The Haiyin cells that are used in the Accumulator pack were chosen based upon their characteristics, such as weight, discharge rate, cost, and nominal voltage. Of the cells that were compared, we decided to use the pouch cells offered by Haiyin Technology for their cost, weight, discharge rate, and small packaging. The basic information for the Haiyin cells can be found in Table 10.

Cell Manufacturer and Type	Haiyin Technology
Cell nominal capacity:	6 Ah
Maximum Voltage:	4.2 V
Nominal Voltage:	3.7 V
Minimum Voltage:	2.8 V
Maximum output current:	400 C for <1s
Maximum nominal output current:	300 A
Maximum charging current:	5 A
Maximum Cell Temperature (discharging)	60°C
Maximum Cell Temperature (charging)	50°C
Cell chemistry:	Lithium Cobalt Oxide

Table 9 Main cell specification

3.1.3 Cell configuration

The cells have been configured in a single string of 28 cells in series. The cells are held in plastic housing with .25in thick 3595 3M thermal padding to help dissipate heat from the cells between individual cells as well as let the cells naturally expand. The cells are connected with aluminum rods between the terminals where the AMS cell modules are mounted. Figure 23 shows the assembled CAD model of the Accumulator Pack. The aluminum rods are not installed and the resistive tape and insulator on the rods has not been selected.

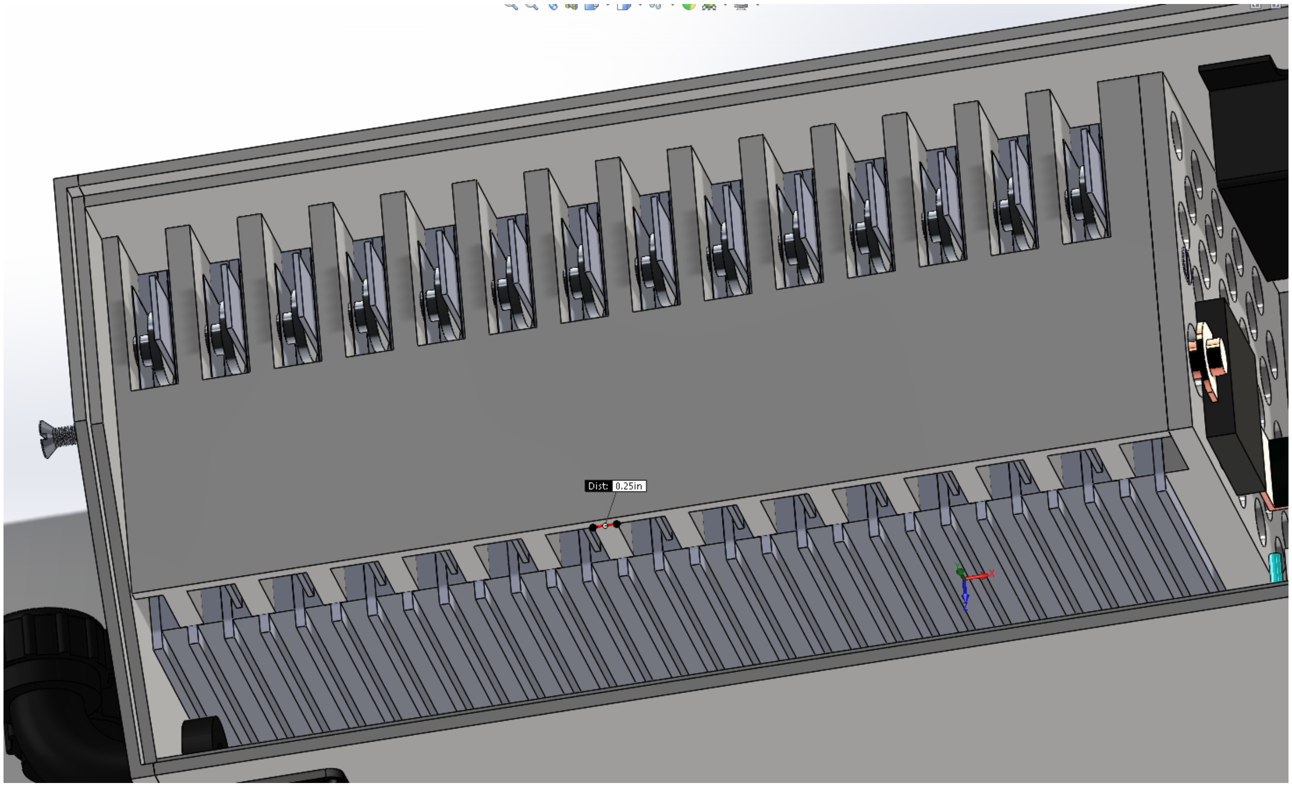

Figure 23: TS Cell connection separation in accumulator container and picture of cell stack

3.1.4 Lithium-Ion Pouch Cells

Testing on the cells to monitor expansion, temperature, current output, and voltage output was conducted to ensure the accumulator design met the rule EV3.8 and this data is available upon request. Also a filler material was chosen that met the design specifications from section EV3.8.3, and EV3.8.2.

3.1.5 Cell temperature monitoring

All the cells in the accumulator pack are monitored for temperature through the AMS. The AMS is manufactured by Electromotus and uses a series network connection between individual cell modules. The cell modules monitor the cells temperatures and report them to the AMS which opens the AIR's if any of the cells reach a critical temperature. The modules are bolted to the aluminum bar placed between the cells, the modules have two data lines and a voltage sense wire which is soldered to the aluminum bar in contact with the positive terminal of the cell. Figure 24 shows a generic wiring diagram provided by the AMS manufacturer.

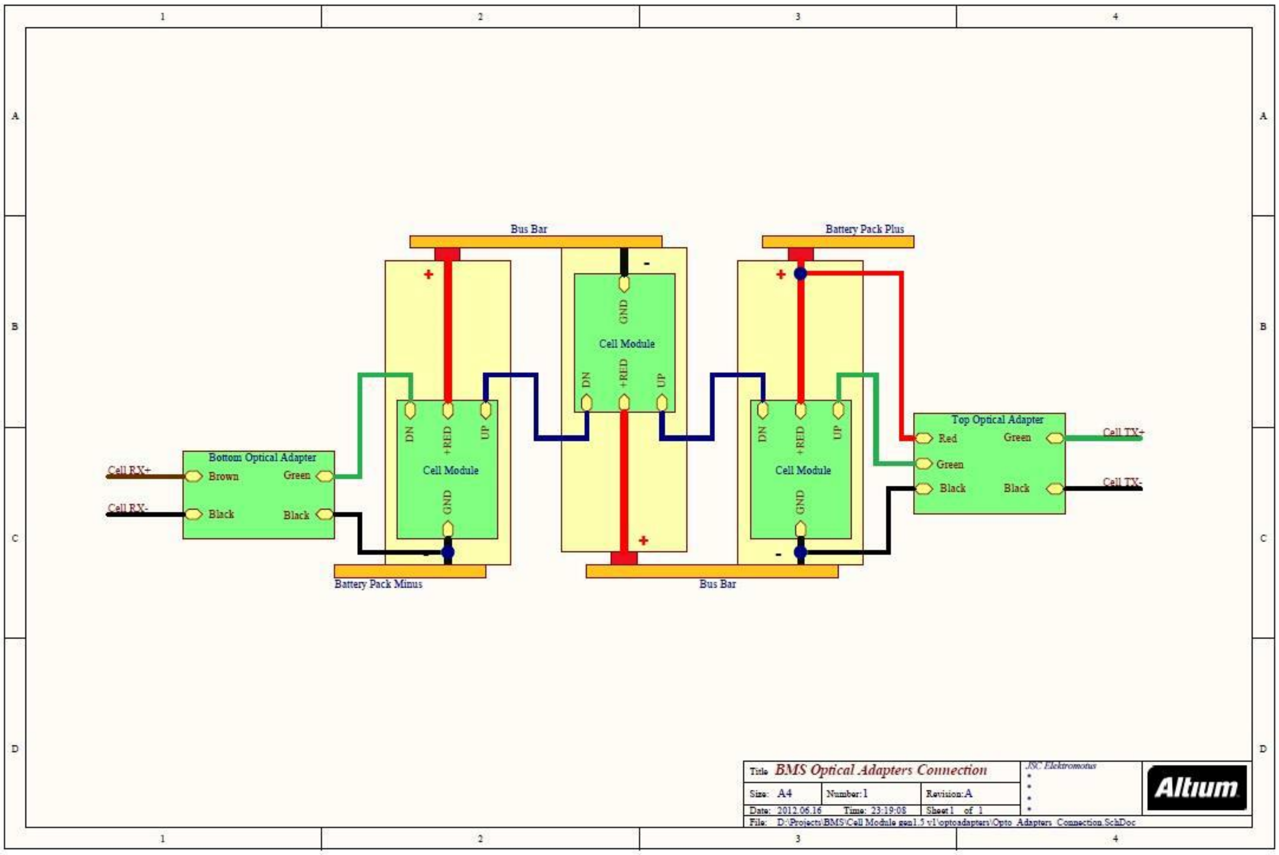

Figure 24: Cell Temperature Monitoring

3.1.6 Accumulator Isolation Relays (AIR)

The AIRs used with in the accumulator container are two Kilovac EV200 SPST normally open relays rated for 500 A. Basic information on the AIR's can be found in Table 11.

Relay Type:	Kolovac EV200
Contact arraignment:	SPST
Continuous DC current rating:	500 A @ 85 C
Overload DC current rating:	200 A for 10 sec
Maximum operation voltage:	900 VDC
Nominal coil voltage:	9-36 VDC
Normal Load switching:	Make and break up to 300 A
Maximum Load switching	10 times at 1500 A

Table 10 Basic AIR data

3.1.7 Fusing

The fuse currently used in the Accumulator container is placed on the positive line from the Accumulator pack to the positive AIR. The fuse is from Little Fuse, and is a time delay fuse that is mounted on the outside of the container with in a Plexiglas case surrounding it that has been JB welded to the side of the accumulator container. Also, we are currently looking into a design with the fuse in the high voltage disconnect as well as replacing the fuse to get a higher current output from the accumulator but will be made from the same manufacturer if the alternative design with the HVD fails to meet the rules. Information regarding the current fuse in use in the accumulator pack can be found in Table 12, where Table 13 supplies the current rating of the components used in the TS.

Fuse type:	Little Fuse Inc.
Continuous current rating:	125 A
Max. operating voltage (specify AC or DC)	250 VDC
Type of fuse:	FLNR
I^2t rating:	1500 A^2 Sec. at 450 VDC
Interrupt Current (maximum current at which the fuse can interrupt the current)	20000 A

Table 11 Basic fuse data

Positive AIR (Kilovac EV200)	500 A
Terminal Connector (Cam-Lok)	300 A
Motor Cable (welding cable)	200 A
Kelly Motor Controller	900 A
LEM D135 Rags (Motor)	400 A

Table 13 Component Based Current Rating

3.1.8 Accumulator Management System (AMS)

The AMS used is from Elektromotus which uses a cell module on individual cells to monitor cell temperatures, voltage and current flow. The AMS uses a series network to communicate with the AMS module. The module is isolated from the TSV by the use of two opto-couplers that isolate the cell modules from the main AMS module. This is done to ensure that no TSV is able to short circuit through the cell modules to the AMS module. The AMS module monitors all 28 cell modules which monitor the cell temperature, voltage, and current draw on an individual cell basis.

The AMS module will react if the voltage goes above 4.2 volts or below 2.8 volts on any cell by opening the AIR through the Low voltage board and latching circuit. The AMS module will also open the AIR's when a single cell sees a temperature over 50 degrees C.

When the AMS module finds any kind of error such as under or over voltage, current draw, critical temperature, or loss of communication to any module it will float ground used in the TS latching circuit in on the low voltage board shown in Figure 3. By floating this ground the TS will open the AIR due to the lack of a 12 V from the latching circuit. Basic operational parameters are shown in Table 14.

Over Temperature	50 C
Over Voltage	4.2 V
Under Voltage	2.8 V

Table 14 AMS operation parameters

3.1.9 Accumulator indicator

The accumulator indicator is a blue LED that is powered by the Voltage Monitoring circuit which senses when there is a voltage at the outgoing side of the AIR's. To power the blue LED there is a combination of resistors, zenner diodes, LED, diode, and opto-coupler to drop the voltage from the accumulator pack while operating the LED and opto-coupler. The stack configuration can be seen in Figure 25.

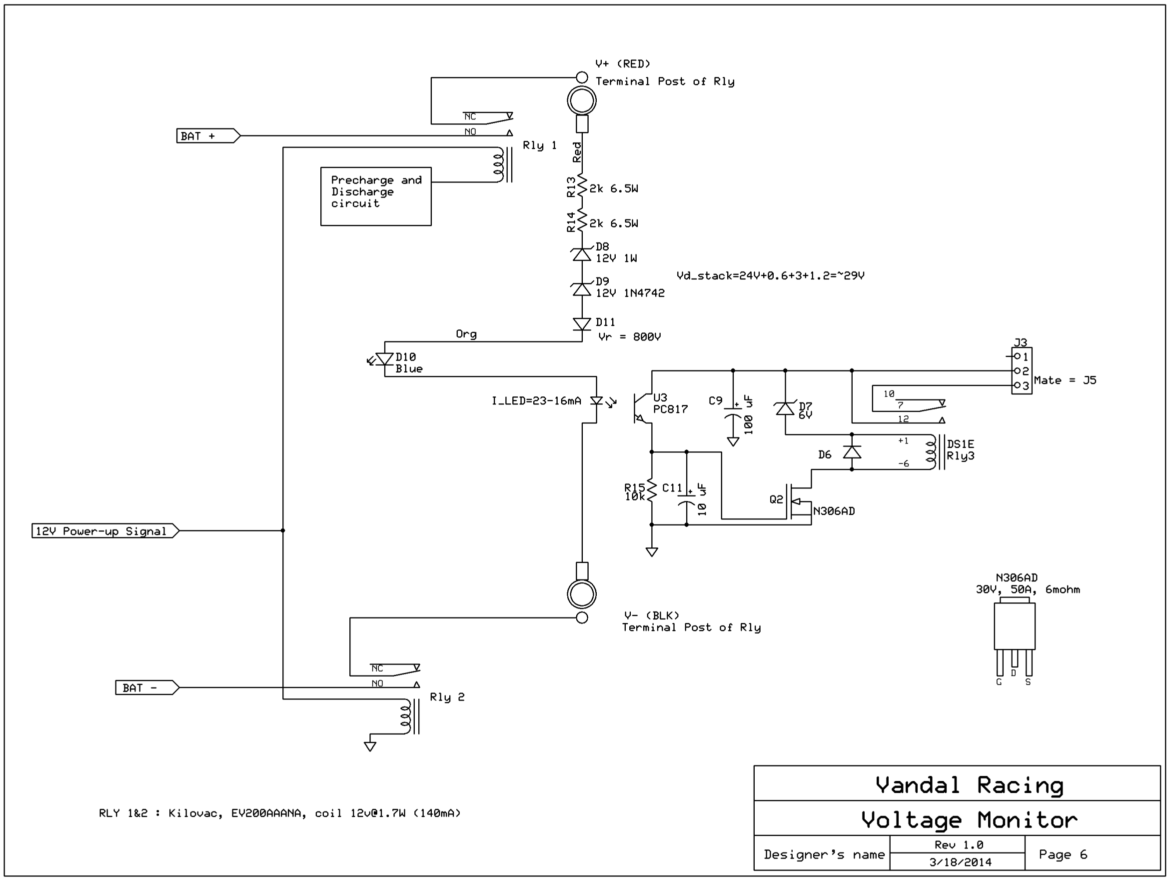

Figure 25 Voltage Monitoring Circuit

3.1.10 Accumulator wiring, cables, current calculations, connectors

All wiring inside the accumulator is insulated stranded wire. All wires in Figure 25 between the optical isolators are sheathed in nomex looming. The cell TX+/- are also loomed in nomex as they are routed near the battery pack. The module is held in place by soldering the large metal contact surface on the module (GND) to the bus bar. This keeps the modules in place and prevents inadvertent contact with other components, while reducing the number of wires within the accumulator box.

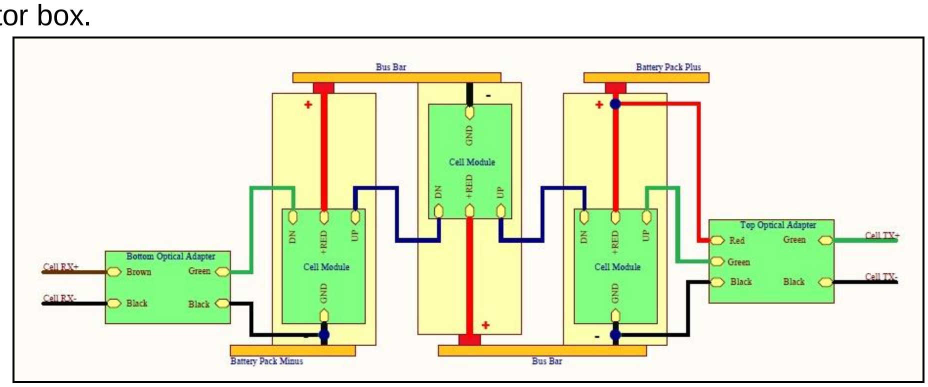

Figure 26: Cell Module Communication Diagram

[Figure 27](#) indicates the overall scheme of the accumulator and its connections to the rest of the vehicle. The green outline represents the accumulator box while the orange specifies where the HV lines are placed. All HV lines are insulated and sheathed in nomex as well. They are zip tied and VELCROed to the accumulator walls away from the LV lines. Wring information for the AMS can be found in [Table 15](#).

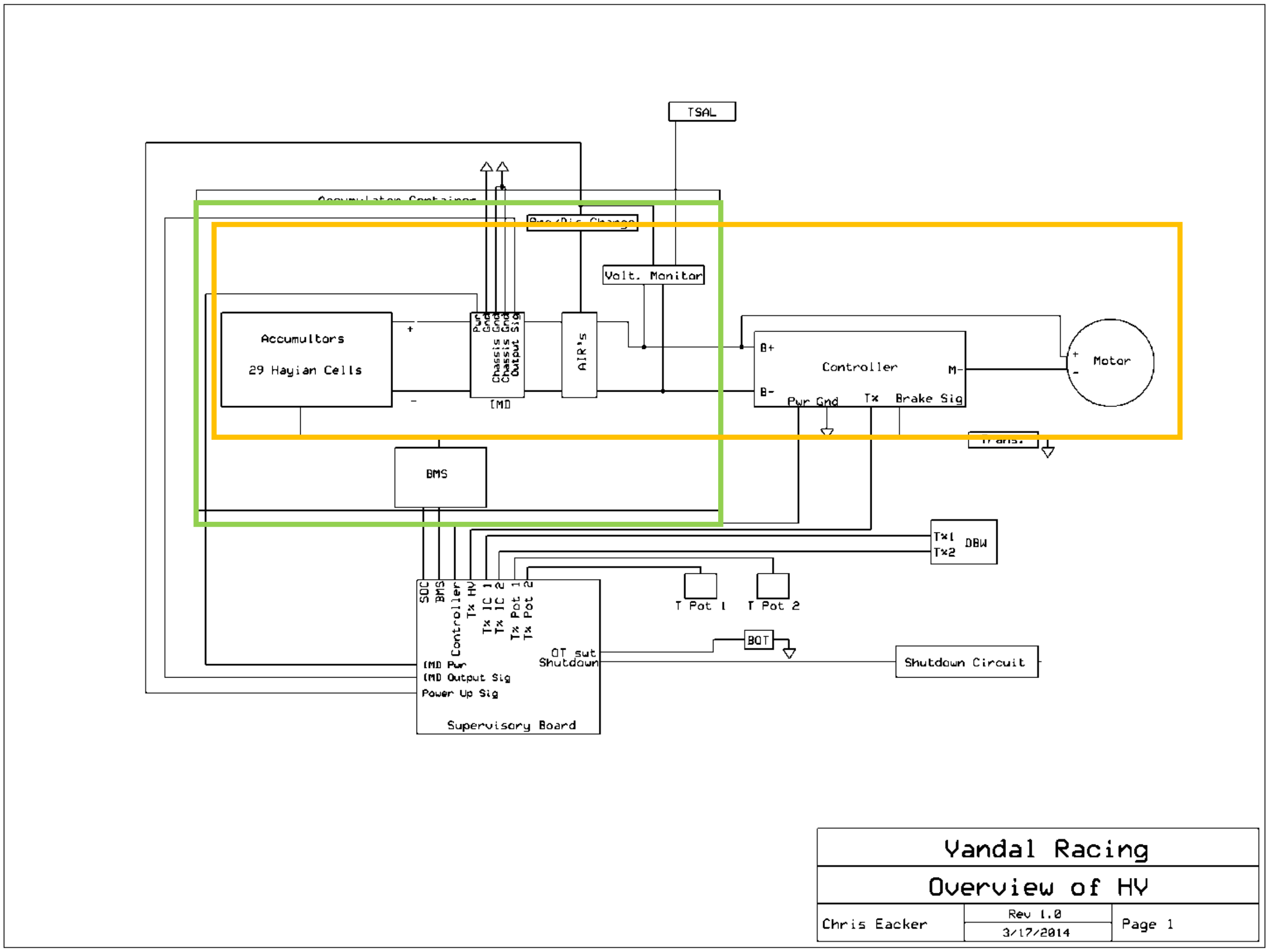

Figure 27 Overall AMS Diagram

Wire type	PVC Insulated Stranded Wire
Continuous current rating:	13 A
Cross-sectional area	0.823 mm²
Maximum operating voltage:	300 VDC
Temperature rating:	220 °F
Wire connects the following components:	Cell Modules, BMS, and IMD signals

Table 15 Wire data of company

3.1.11 Charging

The accumulator will be charged by an Elcon 15 kW charger. The charger communicates with the AMS via a CAN connection to provide the required power to adequately charge the accumulator pack. The charger attaches to the charging terminals at the side of the accumulator container and is only allowed to charge the pack when the AIR’s have been opened this ensures that the IMD and AMS are operational. General information on the charger are found in Table 16 and the wring of the charger is shown in Figure 28 on the far right side of the diagram.

Charger Type:	Elcon
Maximum charging power:	15 kW
Maximum charging voltage:	130 V
Maximum charging current:	12 A
Interface with accumulator	CAN
Input voltage:	85-265 VAC
Input current:	12.5 AAC

Table 16 General charger data

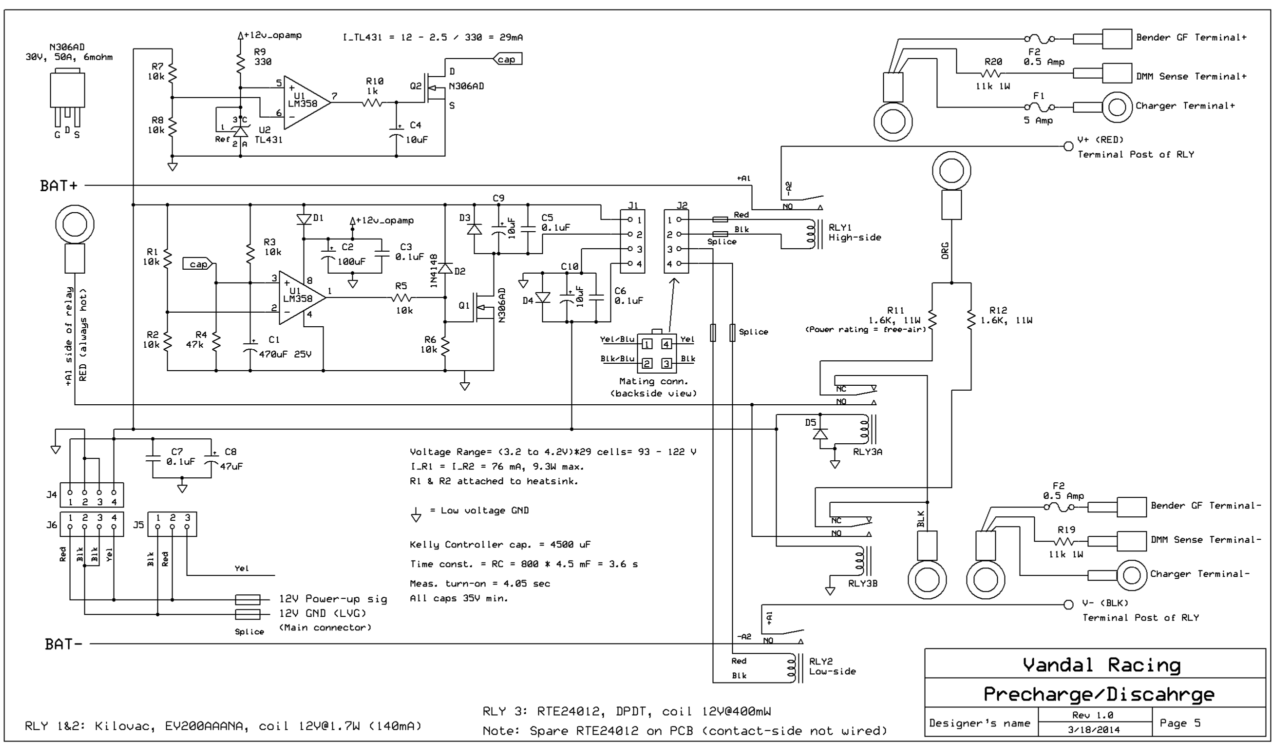

Figure 28 Pre-charge/Discharge Circuit

3.1.12 Accumulator Container/Housing

The accumulator container is made of UHMW plastic purchased from interstate plastics. The plastic was machined into individual pieces and welded together using 5/16” UHMW plastic welding rod. The plastic does not come from the manufacturer with a UL94-V0 flame rating, but an appendix J firewall equivalency test was performed and passed to certify the construction of the box using the plastic. Below you will find the copy of the email correspondence with the rules committee regarding the use of the UHMW.

University of Idaho
A LEGACY OF LEADING

To: Palmer, Benjamin (palm9050@vandals.uidaho.edu);

You forwarded this message on 2/18/2015 11:14 AM.

ben palmer,

A Rules Committee representative has replied to your support request, #797 with the following response:

Ben,

We're sorry for the delay in responding. The rules committee has been discussing your UHMW accumulator container.

The material you tested passed the Appendix J flame test. However, the committee expressed concerns relating to the thermal expansion coefficients of the UHMW plastic. Specifically, if there is a severe thermal event inside the accumulator housing, the material will most likely distort and could open gaps in the housing.

Your material is conditionally approved, contingent on your submiting drawings and/or photographs showing how the container will be constructed, and specifically how the material will be fastened to assure that no gaps will open should the panels distort.

Regards,

-fhrc

We hope this response has sufficiently answered your questions. If not, please do not send another email. Instead, login to your account for a complete archive of all your support requests and responses.

http://www.formula-hybrid.org/level2/support/view.php?auth=o1xcqaqaaa3amaaagCTnHLtJFq0nNQ%3D%3D

Email showing the passing of Appendix J firewall equivalency test and request for material construction information.

To: Palmer, Benjamin (palm9050@vandals.uidaho.edu);

You forwarded this message on 2/23/2015 10:50 AM.

ben palmer,

A Rules Committee representative has replied to your support request, #797 with the following response:

Ben,

Your accumulator housing material is approved.

The committee still has some concerns regarding the structural integrity of your housing if there were to be a thermal event resulting in distortion of the panels. Will the welded joints resist the distortion, or will they split open?

We suggest welding some sample pieces and then testing the strength of the joint. Bring your sample to the competition along with the test results to show the tech inspectors.

If the strength of the welded joints is at all questionable, you might want to consider adding an external metal frame.

-fhrc

We hope this response has sufficiently answered your questions. If not, please do not send another email. Instead, login to your account for a complete archive of all your support requests and responses.

http://www.formula-hybrid.org/level2/support/view.php?auth=o1xcqaqaaa3amaaagCTnHLtJFq0nNQ%3D%3D

Email showing material consent and information regarding construction and welded test pieces.

Figure 22 in section 2.12 High and Low Voltage separation shows the mounting of the accumulator pack using 4 3/8 in holes to mount the housing to the chassis.

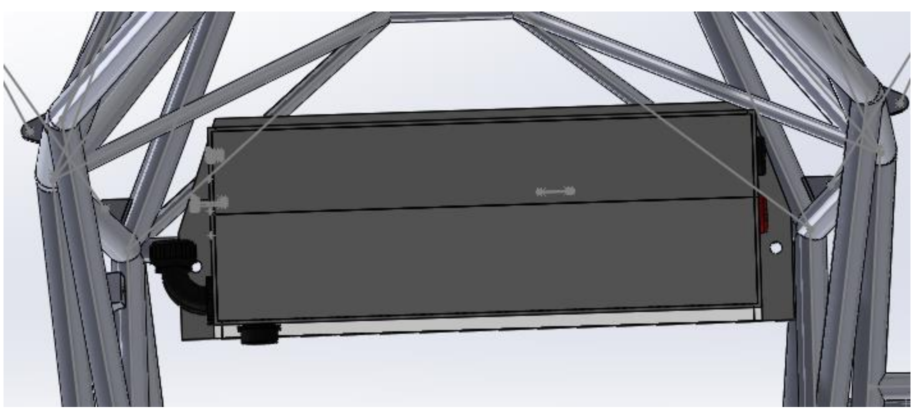

Figure 29 Accumulator placed in Vehicle

In Figure 29 the back of car is at top of picture, front is towards the bottom of the picture. Figure 29 does not show the rest of the components in the chassis, the Engine sits directly behind the accumulator with a slim fuel tank mounted in a 1 in space between the engine and accumulator pack.

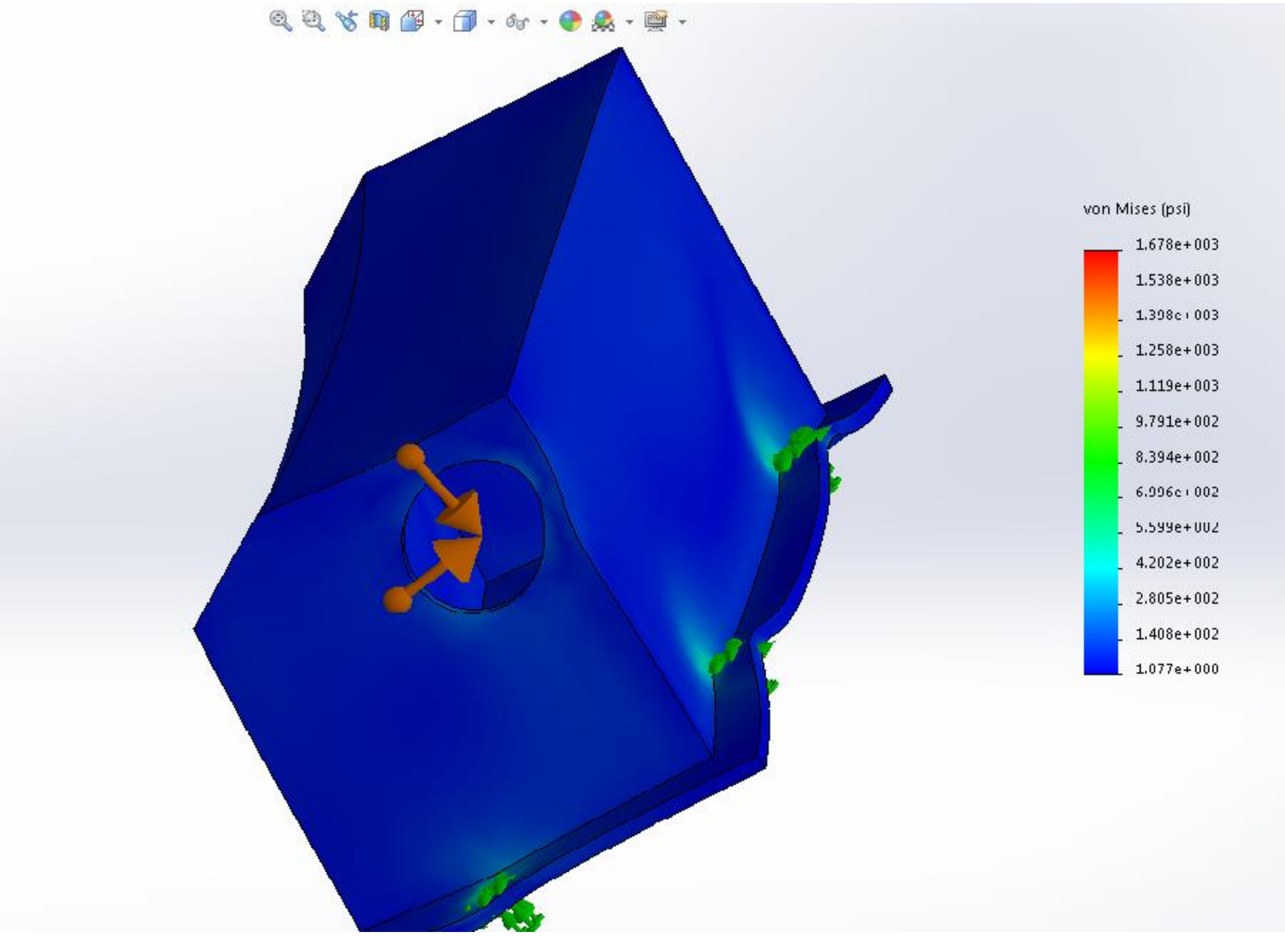

Figure 30 FEA of Accumulator Container

The housing FEA shown in Figure 30 shows a 40g horizontal loading with a 20g vertical loading and shows that the average stress seen in the container is around 600 psi which is well below the ultimate tensile strength of the material of 2600 psi. The housing material is not electrically conductive and will be used to separate the high voltage connections or poles 0.25 inches (¼ inch apart) inside of the accumulator container as shown in Figure 19.

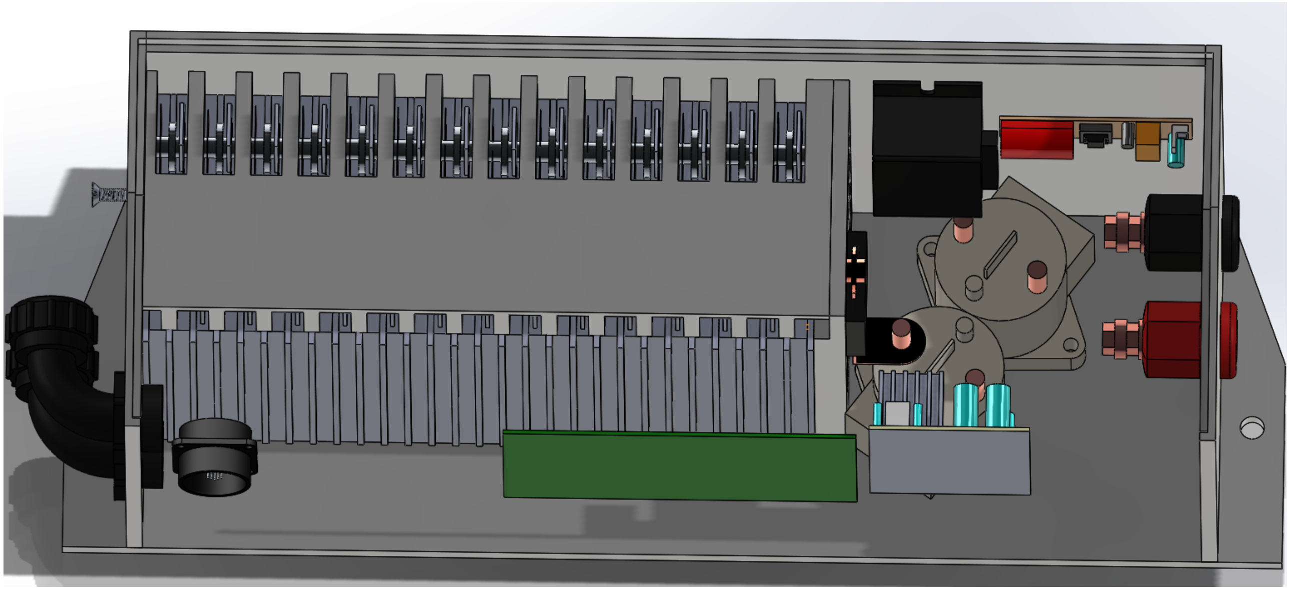

Figure 31 Accumulator Assembly

Figure 31 shows the front view of the accumulator housing showing internals and components. Note: Front and top (lid) of box are hidden.

3.2 Accumulator pack 2

Only 1 accumulator pack is used.

Section 4 Motor Controller

Person primarily responsible for this section:

Name: Troy Ledford

e-mail: Ledf4254@vandals.uidaho.edu

4.1 Motor Controller 1

4.1.1 Description, type, operation parameters

The controller selected was chosen for its reliability, efficiency, packaging and additional information can be found in Table 17.

Motor controller type:	Kelly KDHE Controller
Maximum continuous power:	40 kW
Maximum peak power:	80 kW for 60s
Maximum Input voltage:	136 VDC
Output voltage:	136 VDC
Maximum continuous output current:	300 A
Maximum peak current:	600 A for 60s
Control method:	PWM at 16.6 kHz
Cooling method:	Air
Auxiliary supply voltage:	24 VDC

Table 17 General motor controller data

4.1.2 Wiring, cables, current calculations, connectors

The controller uses a 1-5V analog input signals and 12V power supply. The controller is wired to the accumulator and motor with 1 awg Carol Super Vu-Tron Welding Cable rated for 220 amps and 600 Volts**.**

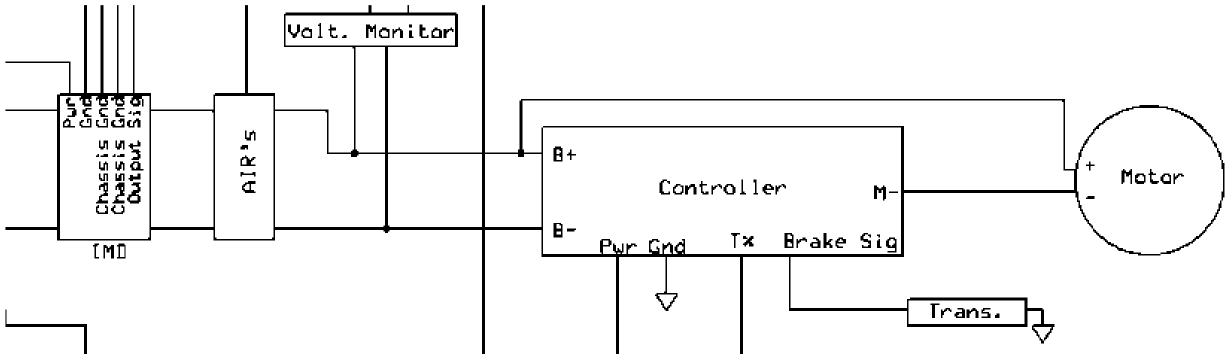

Figure 32 Motor Controller Diagram

Wire type:	Multi-Strand Welding Cable
Current rating:	220 A
Maximum operating voltage:	600 V
Temperature rating:	90 C

Table 18 Accumulator to Controller Wire Information

4.2 Motor Controller 2

Only one motor Controller.

.

Section 5 Motors

Person primarily responsible for this section:

Name: Troy Ledford

e-mail: Ledf4254@vandals.uidaho.edu

5.1 Motor 1

5.1.1 Description, type, operating parameters

The motor selected was a Lynch DC Brushed motor. It was chosen for its power to weight ratio, and packaging. Its compact configuration allows it to mate well in parallel with our combustion engine and requires minimal frame dimension allowances. Additional information on the DC motor can be found in Table 19 and speed, torque and power curves are shown in Figure 33.

Motor Manufacturer and Type:	Lynch Motor Company DC brushed Motor
Motor principle	Asynchronous, permanently excited
Maximum continuous power:	18 kW
Peak power:	36 kW
Input voltage:	110 VDC
Nominal current:	200 A
Peak current:	400 A
Maximum torque:	78 Nm
Nominal torque:	42 Nm
Cooling method:	Air

Table 19 General Motor Data

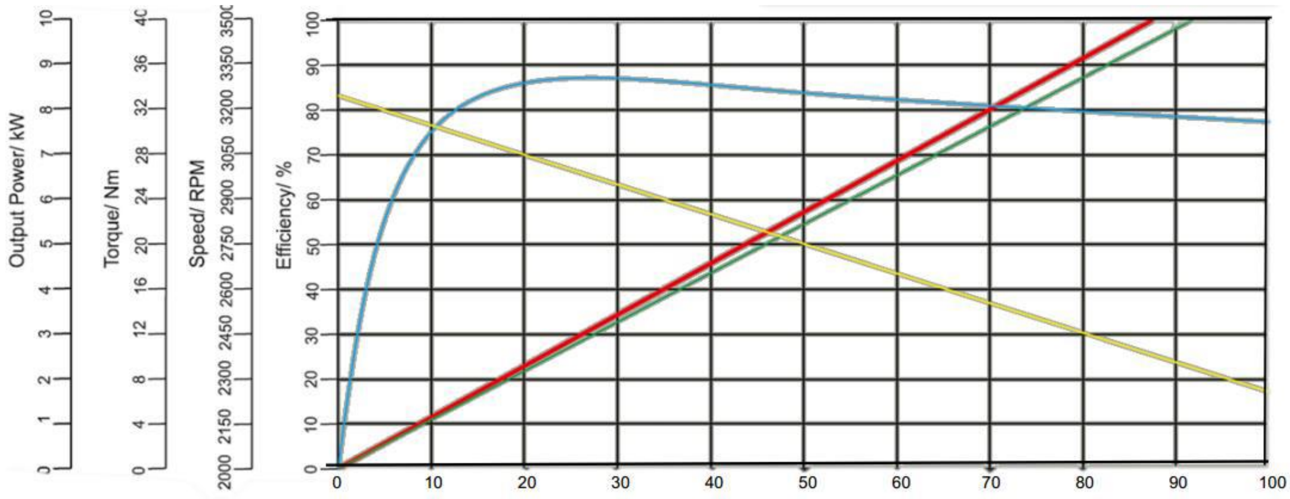

Figure 33 Torque, Power, and Speed Graph

5.1.2 Wiring, cables, current calculations, connectors

The controller is wired to the motor via 2.5ft of 600A idealy rated cable within insulating conduit. The connections are all bolted terminals covered by insulating shields. This cable is not ordered yet but this is the intended length and current rating. A wiring diagram for the Motor is shown in Figure 34. The position of the electric motor is shown in Figure 35 and Figure 36.

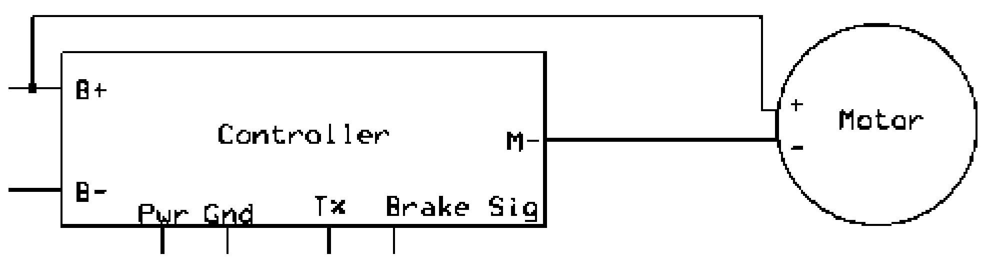

Figure 34 Motor to Controller Circuit

5.1.3 Position on Car

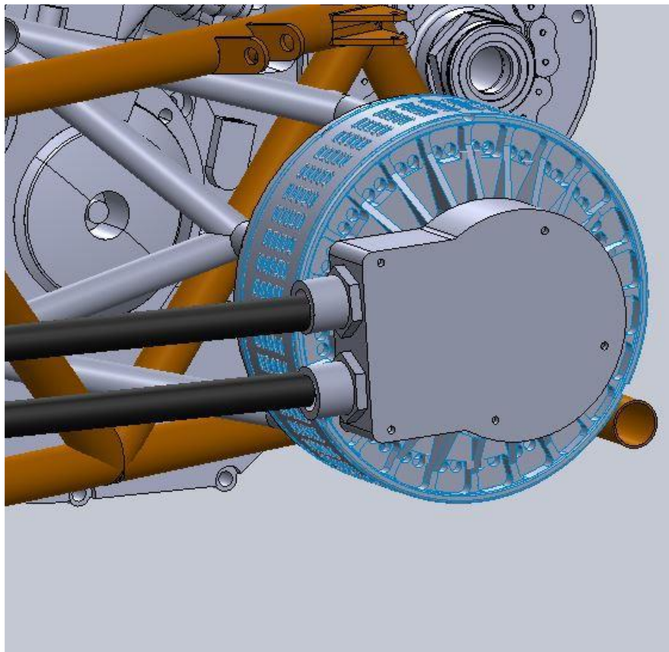

Figure 35 Controller to Motor Rendering 1

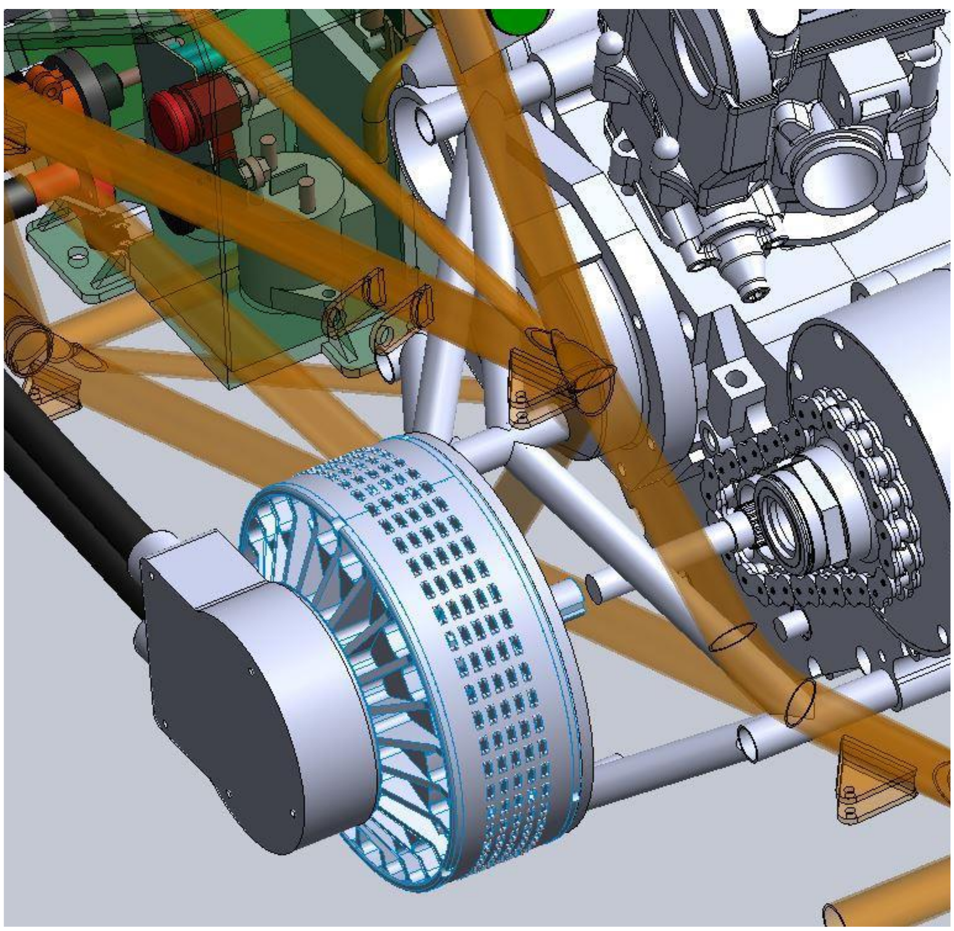

Figure 36 Controller to Motor Rendering 2

5.2 Motor 2, 3, 4…

Only One Motor

Section 6 Throttle Position Encoder

Person primarily responsible for this section:

Name: Troy Ledford

e-mail: Ledf4254@vandals.uidaho.edu

6.1 Description/additional circuitry

Our system uses two potentiometers on the pivot shaft of the accelerator pedal. The voltages are sent to the EMS where they are processed and then sent to the MOTEC and Kelly engine and motor controllers. Should an implausible signal arise, the EMS and the MOTEC will both terminate the signals until the signals return to a plausible state. Basic information regarding the Encoder can be found in Table 20. The implementation of the Encoders is shown in Figure 37 and Figure 38.

Encoder manufacturer and type:	Master Pro
Encoder principle:	Potentiometer
Supply voltage:	3.3V
Maximum supply current:	20mA
Operating temperature:	-20..180 °C
Used output:	.5-2.5V

Table 20 Throttle Position encoder data

6.2 Throttle position encoder plausibility check

Throttle signals are passed first to the energy management system. The EMS checks differences between the signals and if the difference is greater than 10%, the outputs to the engine and motor controller are set to null until the input signals regain appropriate coherence. It also has high and low limits. In the event of an open or short circuit, the controller will shut down the output, until the issue is resolved.

In addition, the engine controller requires the signals coming from the EMS be within a very tight tolerance and again within a certain range. This ensures that the outputs from the EMS are plausible, and prevents any loss of control due to short or open circuited connections.

6.3 Wiring

The potentiometers are powered from a 3.3v regulator on the LV circuit and grounded to the frame. The output wires are connected via 16ga wire to the LV circuit, through an RC low pass filter, and to the EMS controller. The EMS controller then processes the signals and outputs analog signals which are passed through 16ga wire to the MOTEC™ engine controller and Kelly™ motor controller where they are again checked and processed before any power is generated.

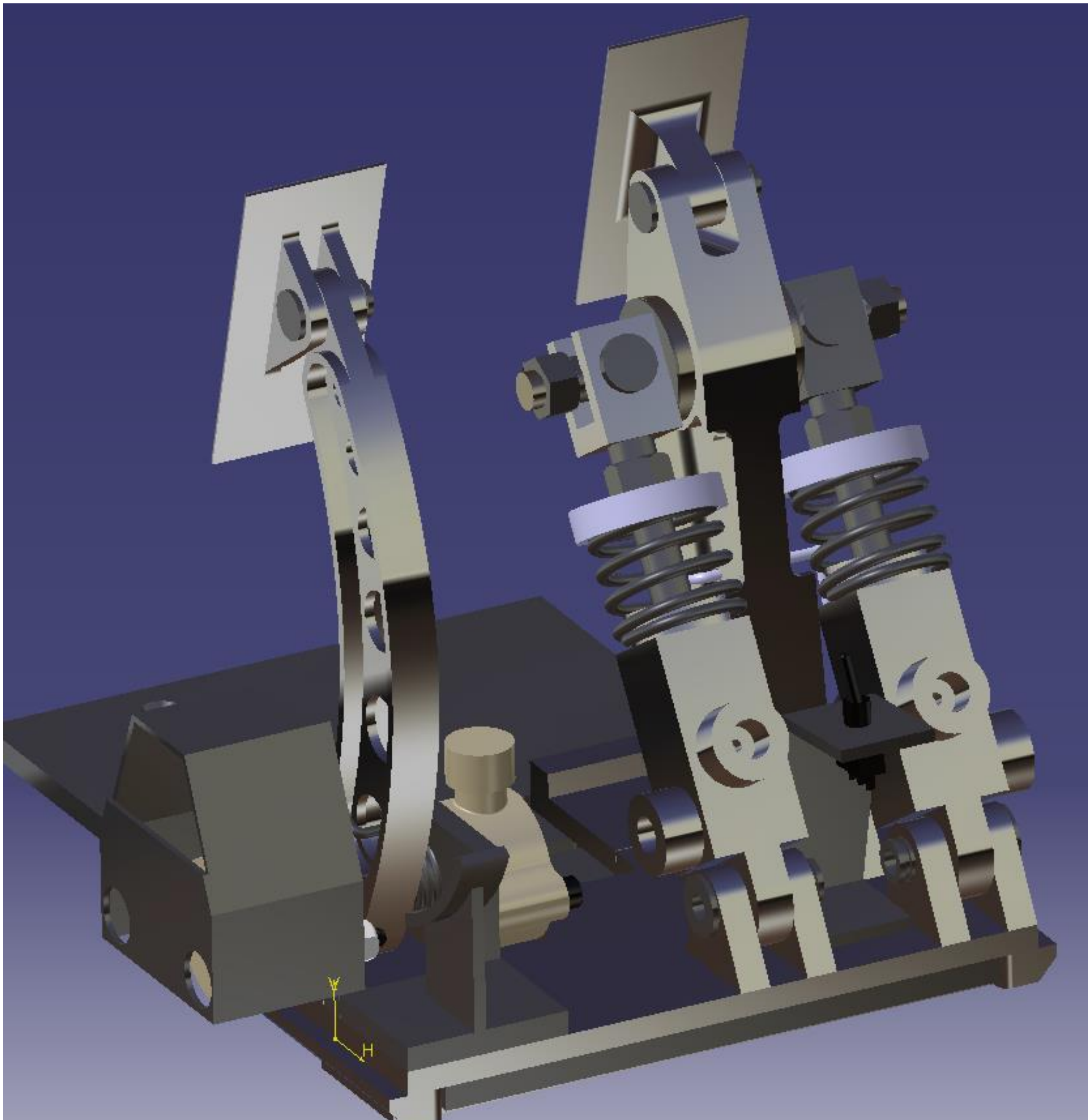

Figure 37 Throttle Controller Rendering 1

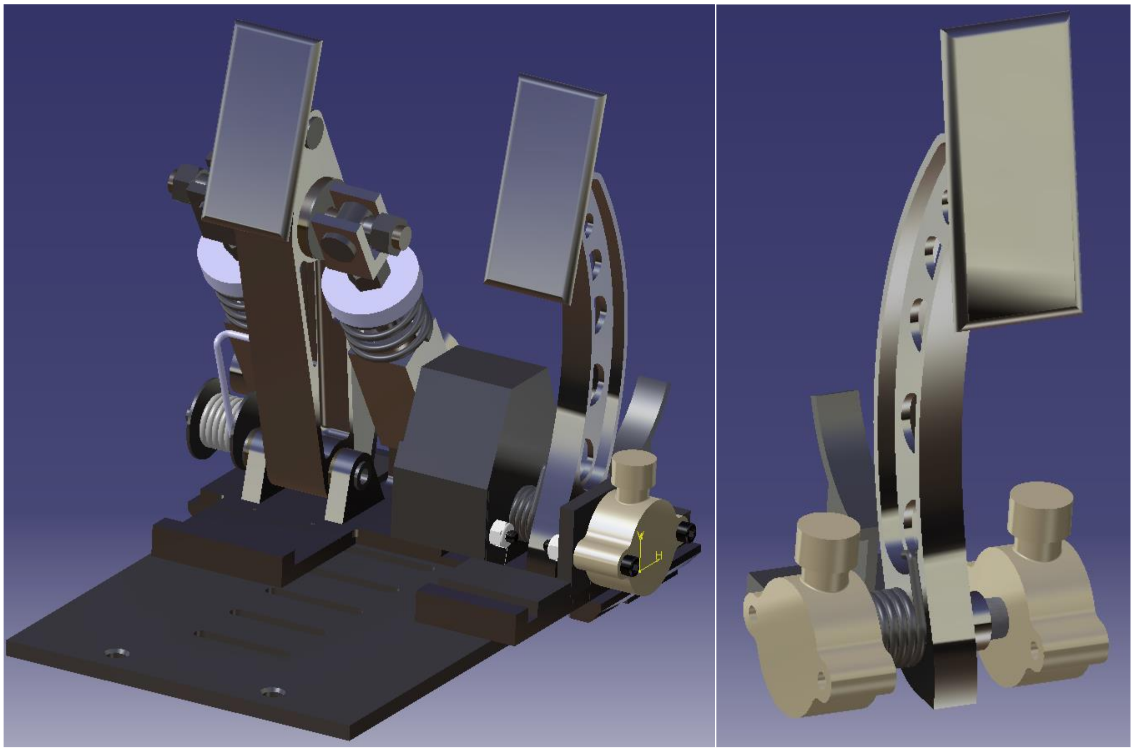

Figure 38 Throttle Controller Rendering 2 and 3

Section 7 Additional LV-parts

Person primarily responsible for this section:

Name: Troy Ledford

e-mail: Ledf4254@vandals.uidaho.edu

7.1 Data Acquisition Circuitry (DAC)

7.1.1 Description

The microcontroller board used for energy management is limited to 3 or 5 volts. An accidental 12V will short components within the controller. To protect the controller, opto-couplers are inserted in the path between the connectors and the controller to ensure proper isolation. Figures 39 and Figure 40 show the schematics for the output and input sides respectively for the DAQ system used on the vehicle.

Additionally, for PWM signals, low pass filters are inserted to create an analog signal. These also provide an additional layer of protection as a 1kOhm resistor limits the amount of current that will enter the board. Figures 41 and Figure 42 outline the circuitry for the filters. The position of the DAC is shown in Figure 43 behind the dash above the drivers knees.

7.1.2 Wiring, cables,

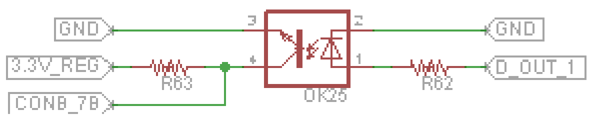

Figure 39 Digital Output Protection Circuit

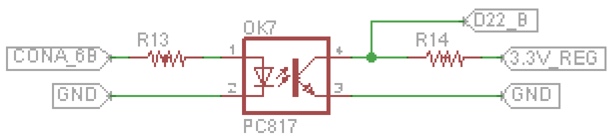

Figure 40 Digital Input Protection Circuit

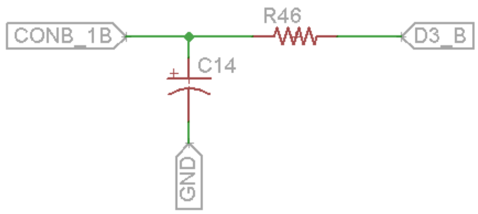

Figure 41 Analog Output Filter

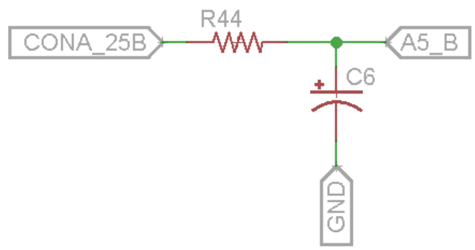

Figure 42 Analog Input Filter

7.1.3 Position in car

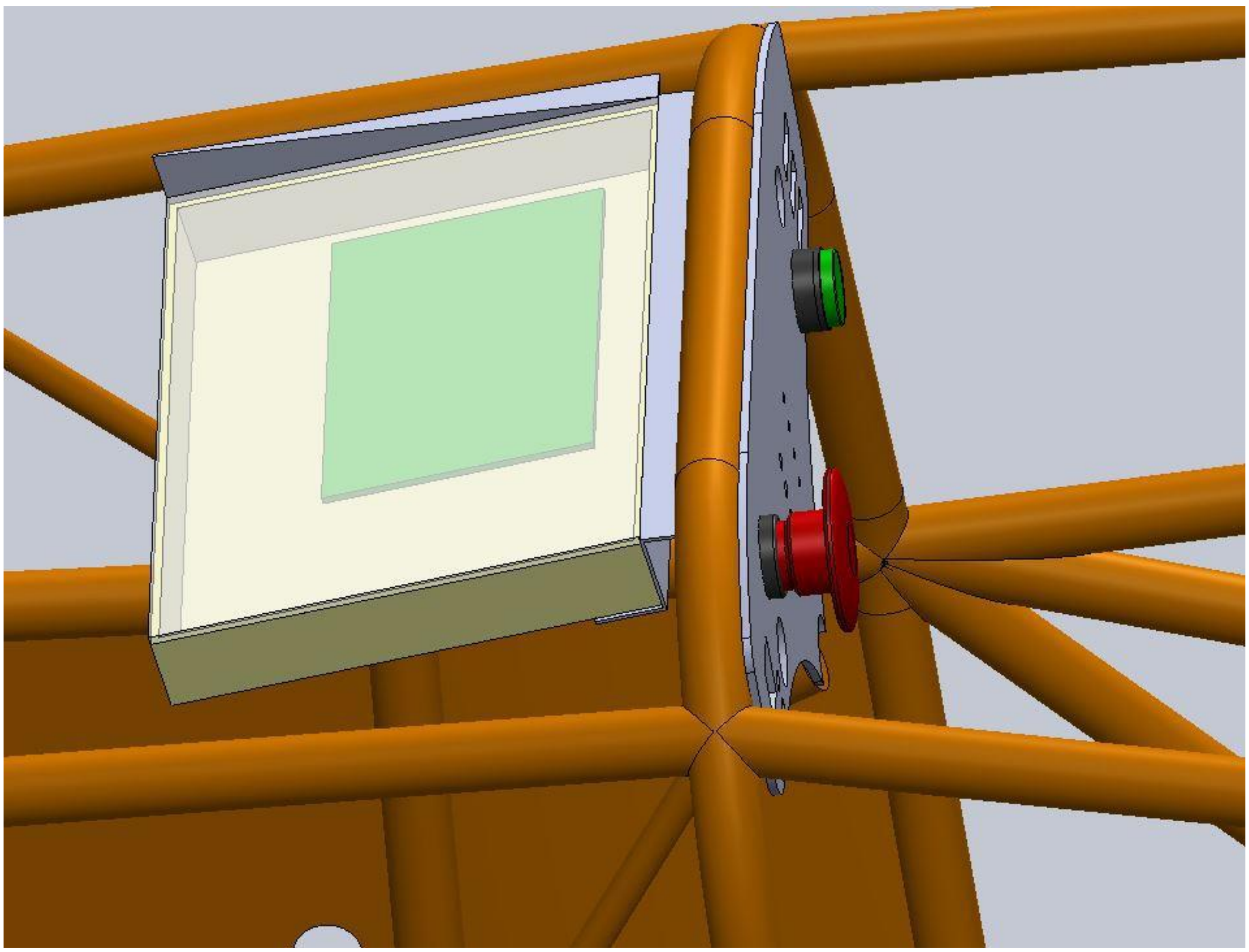

Figure 43 DAC is located behind dash

Section 8 Grounding

Person primarily responsible for this section:

Name: Troy Ledford

e-mail: Ledf4254@vandals.uidaho.edu

8.1 Description of the Grounding

All GLV systems are grounded to the frame to ensure the best available path. Any parts not directly grounded via mounting location, are grounded via wire to the frame

8.2 Carbon Fiber panels

The current configuration of the vehicle does not use carbon fiber panels in the design of the vehicle.

8.3 Grounding Measurements

Each part of the vehicle which contains conductive material will be tested against the frame to test for resistance. Measurements will be taken across the body in a systematic process to ensure each body part is compliant throughout the entirety of the piece.

Section 9 Firewall(s)

Person primarily responsible for this section:

Name: Troy Ledford

e-mail: Ledf4254@vandals.uidaho.edu

9.1 Firewall 1

9.1.1 Description/materials

In order to accommodate the updated rules and further protect our drivers, the main firewall consists of 5 pieces of at aluminum at least 0.059 inches thick. It consists of a piece on either side of the driver, extending from the bottom plate up to the side impact member. These pieces start at the front roll hoop and wrap around the seat plate. The seat plate itself is part the firewall which protects against hazards under and behind the driver. There are also two other sections of firewall on either side of the drivers shoulders to protect against parts of the fuel system.
The firewall pieces were bent in order to fit the frame and avoid certain parts already in place as shown in Figure 44. Minimizing the number of firewall panels simplifies assembly and reduces the time it takes to have an appropriate seal. The pieces are fastened together to form a non-permeable barrier that protects the driver from hot fluids, gasses, among other hazards. Fire-rated seals are in place to create a proper seal between the firewall pieces and the frame. Grommets are also used in cable pass-through to create a seal between wiring and the firewall. Every firewall piece is bolted to at least one flange on the frame. This achieves a low resistance Control System ground connection on the firewall.

9.1.2 Position in car

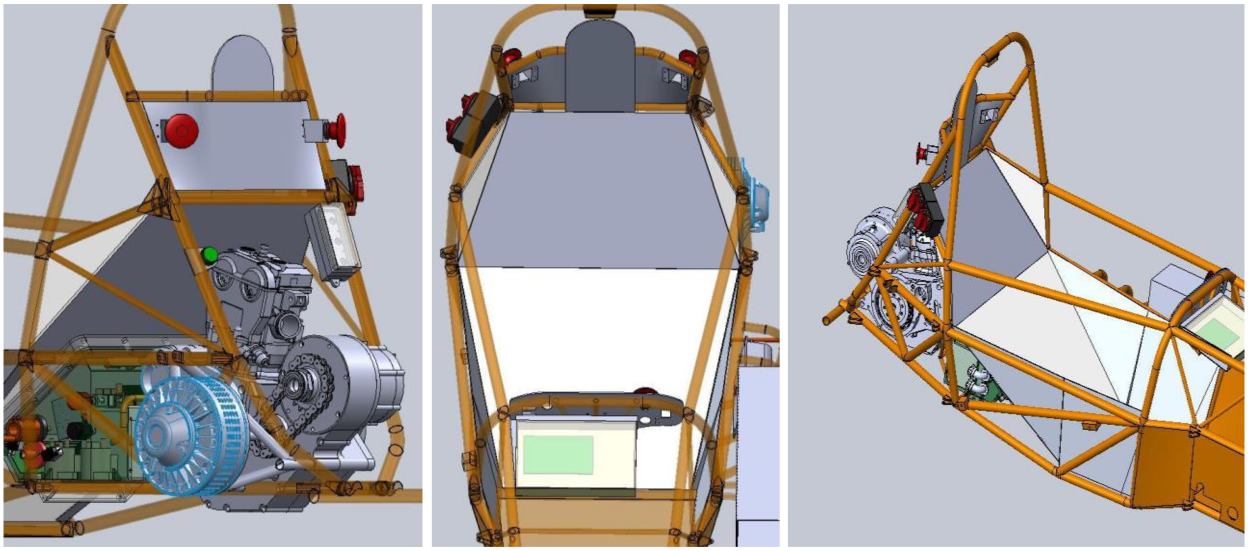

Figure 44: Firewall 1 position

9.2 Firewall 2

9.2.1 Description/materials

9.2.2 Position in car

Section 10 Wire Table

The car is currently being analyzed to be wired none of the wires have been ordered and the DC/AC analysis is still in progress for wire sizing and rating. The proposed wires will be aluminum instead of copper to reduce weight.

Section 11 Appendix