# TSV Preliminary Design Review

ECE 492 - Spring 2015

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## System-design baseline

This report describes the design of the entire Tractive System Voltage system, detailing the functions of both its internal components and interfaces with other areas of the LFEV-2015 project design, including GLV and SCADA. This document will also exist as a guide to aid other team members in understanding the design of the TSV, as well as to act as a resource for future LFEV teams who wish to utilize or modify the design.

## Introduction

### Scope

The TSV division of the LFEV-2015 team has been tasked to produce four fully functioning and guideline suitable battery packs, designed and fabricated to interact successfully with all other divisions of the project. As an expansion of the LFEV-2014 team's design, our system includes both modifications to improve their past design, as well as new interface connections to GLV and SCADA. With the goal of assembling a working and usable system, we as a team have scoped specific modifications within both the hardware and programming portions of TSV with hopes that it will be ready for competition and can be easily improved by any succeeding LFEV teams.

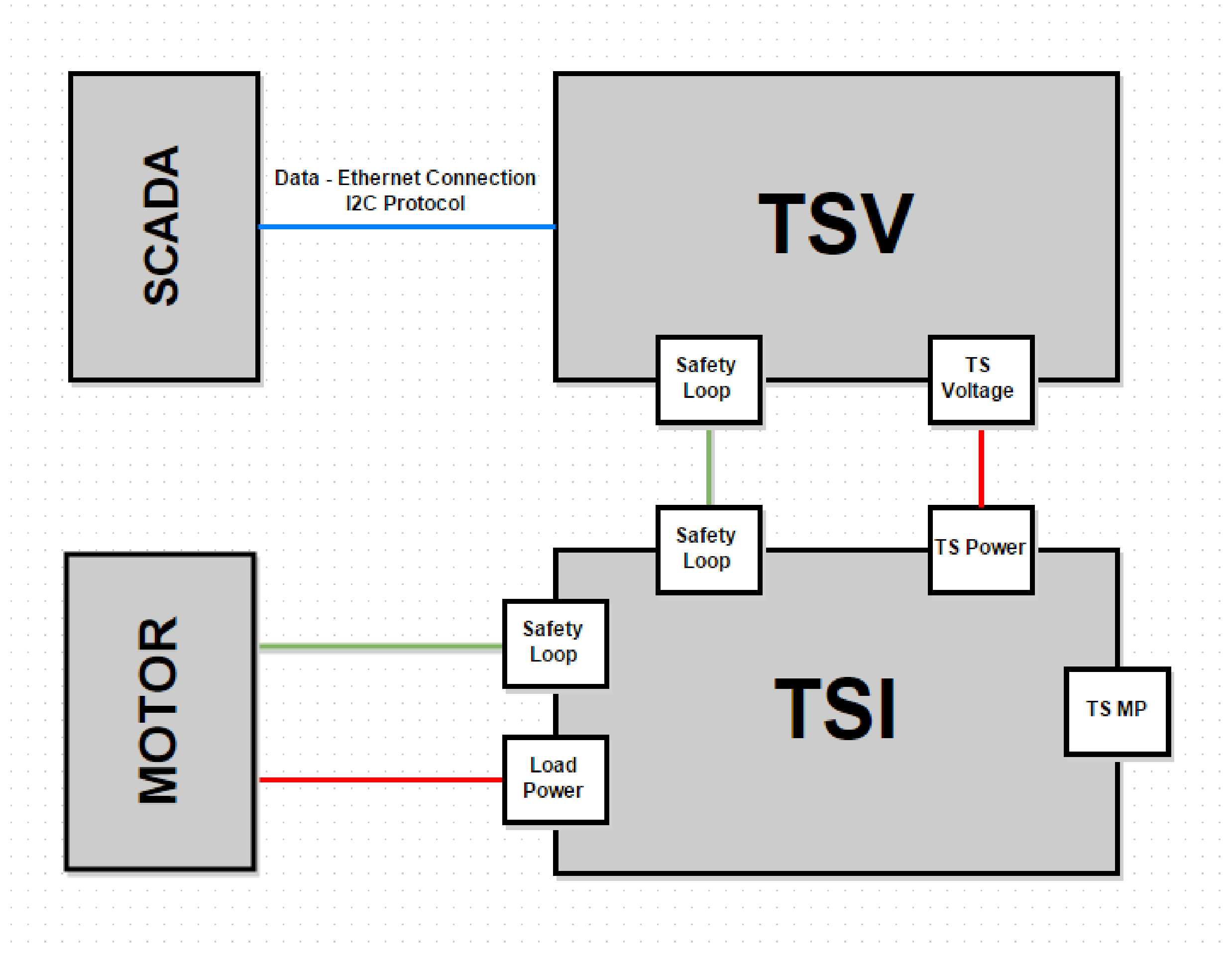
### Overview

This report begins with a System Design/Architecture top level view of the LFEV-2015 system and can be easily visualized with the supporting block diagram, highlighting how each component is connected to the TSV System Interfaces, which details how our TSV design will communicate with the other parts of the project. Also depicted here is the set-up of the individual packs and their connections within the full system. This report will then drop down to the individual battery pack layout and design, to fully cover both the LFEV-2014 team's lasting design attributes, and any circuitry or programming that we established ourselves.

### Reference Materials

All LFEV 2014 Documentation, specifically:
PacMan System Design Document
PacMan Program Errata Memo
PacMan Breakout Board Errata Memo
Issues with BMS Firmware

# System Architecture

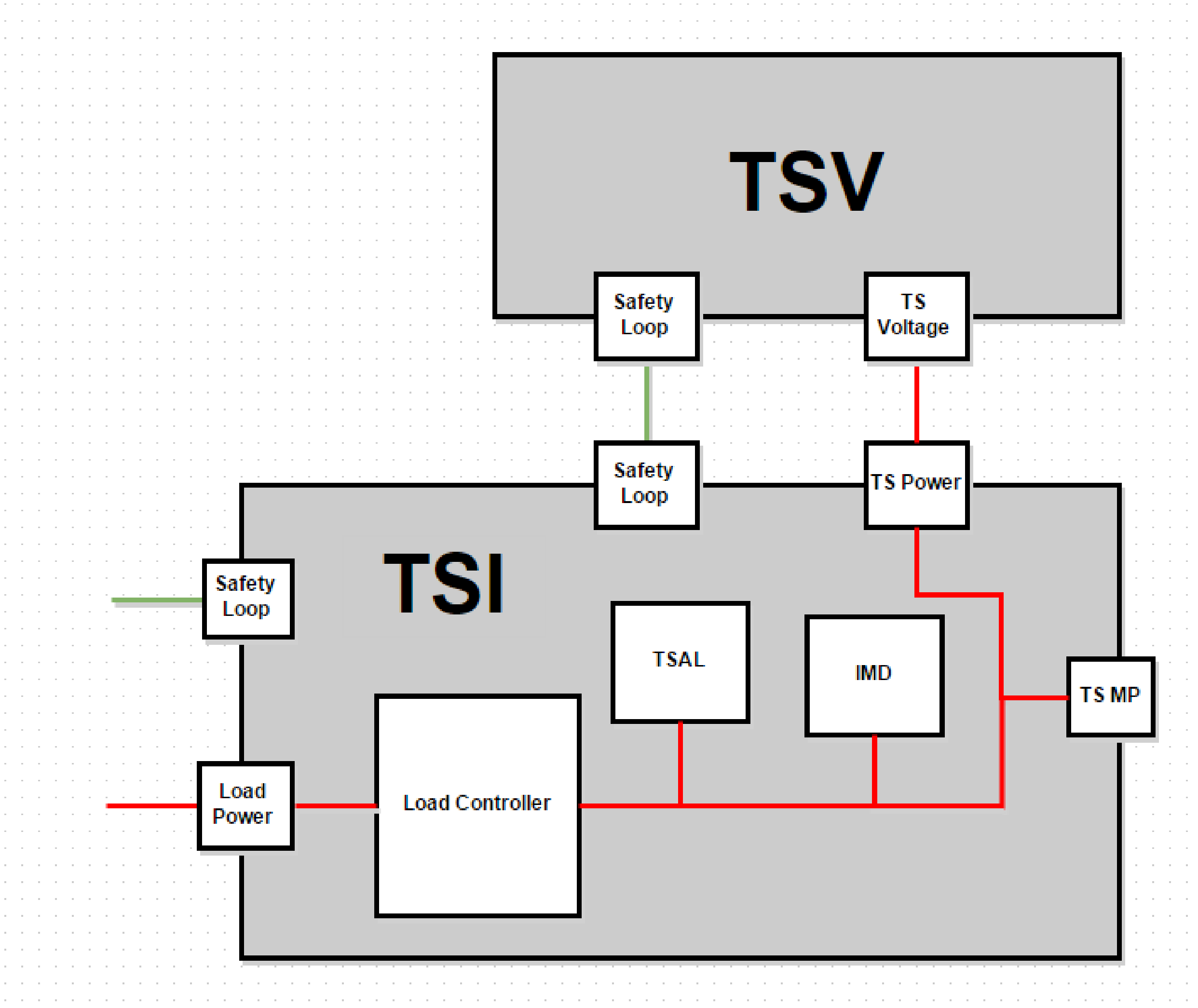



Compiled by Katherine Nellis. Modeled after Dan Zakzewski's top level block diagram.

## TSV System Interfaces

## GLV (TSI)

As the two separate power sources for the LFEV, the GLV and TSV systems are required to be galvanically isolated from one another, which puts a large amount of importance on the interface that we have designed to connect them, documented as the Tractive System Interface (TSI) by the GLV team. Within this interface exists multiple components pertaining to TSV: an Insulation Monitoring Device (IMD), the Load Controller, a Tractive System Activity Light (TSAL), and a Tractive System Measurement Point (TS- MP). As depicted in the accompanying block diagram below, the voltage from the TSV system is fed into the TSI passed through TS-MP to allow an operator to possibly measure the voltage on the system at any time. When voltage is present at the AIRs, the TSAL will indicate so by lighting. Most importantly, the GLV team will be designing and implementing an updated model of LFEV-2014's load controller, which will allow our TSV output to be fed to the motor. The IMD is also crucial to allow the TSV and GLV safety loop components be implemented on the same circuitry while still abiding by the FEV rule (EV 4.1.5) which requires them to be galvanically isolated, and as a result both the TSV safety loop and voltage outputs are fed into the IMD.




Compiled by Katherine Nellis. Modeled after Dan Zakzewski's top level block diagram.

## SCADA

As the brain of the LFEV, SCADA is required to be constantly monitoring a large stream of data from all portions of the project, especially data from TSV. As the main battery source for the LFEV, our system is expected to be in direct contact with SCADA to relay any data requested, such as voltage levels, temperatures, and state of charge values. Although the LFEV-2014 team did not scope the completion of a working interface between these two systems, their documentation states that the TSV Pack Manager program - a 2014 design which will be detailed later - communicates with SCADA using serial communication. Through collaboration within our team and the SCADA, we have agreed that a physical connection such as ethernet would be more reliable and applicable to what we hope to accomplish. One of the proposed methods of communication is actually to use a similar I2C configuration, where VSCADA is the master, and our PacMan board is one of its slaves. I2C fits under the HV/LV segregation rules, and should work for all operational models used in this project. It seems plausible to foster communication this way, however some additional planning and programming may be needed to ensure that PacMan can act as both a slave to SCADA, yet still being a master to each of the BMS boards.

## Pack System Design

As seen in the provided block diagram, our TSV system consists of 4 complete and operational battery packs connected in series with each other to create the main voltage source for our LFEV motor. The powerhouse behind our whole system is how each of the four individual battery packs function, and their design was developed largely from the LFEV-2014 team's accomplishments, with additions and modifications from this year's team.

## Pack Mechanical

Although the LFEV-2014 team's mechanical design was fitting to the scope of their project, it was necessary for this year's team to include additional hardware to further ensure that any pack, and TSV as a whole, would be fit for competition. An area of example is the casing in which each pack is assembled. One downfall of the previous year's design is that they chose to run major pack wiring through a plastic track for safety reasons, however, that track was designed to be attached to the rear plate of the pack case. While this is an intuitive use of safety precautions, it unfortunately led to minimal access to the back side of the pack, since the track restricted the back plate from being fully removed. To improve this, our team has opted to design another plate for pack assembly, which includes a removable window that can be slid on or off of the back plate, and allow access to the pack for maintenance purposes.
Another mechanical consideration for our team was that although each BMS board was attached to their respective cells by banana jacks (as per last year's design), we

concluded that an additional mechanical attachment was needed to ensure that each board would remain in place when subject to movement during actual competition. Since our team is expected to deliver a fully operational TSV system fit for competition, it is necessary that all mechanical packaging of our packs should be compliant with all of the FEV rules. One specific requirement is that each pack must have an indicator that allows the driver or other operator to be aware of when there is over 30 V DC. We as a team have chosen to use a simple LED as such an indicator.

## PacMan Program

One of the LFEV-2014 team's greatest contribution to the production of the TSV system was their development of the Pack Manager program, nicknamed PacMan, which runs on TS 8160-4200, as a single boarded computer. Although an intricate and complete design report can be found listed under the Reference Materials of this document, the program's main functions are to gather data from all of the individual cell's BMS boards, pass on the compiled data to the SCADA interface, and to act as central control over the charging process of the battery pack. It operates under 3 different states of processes:

1. Start up & configuration
2. Active Monitoring
3. Charging

Within the first state, the PacMan controls an automatic start up program, downloads the user configuration file, and checks for any code or safety errors to begin the second state of normal activity. In order to produce a more suitable configuration file to fit project requirement GPR005, our team intends on expanding the previous year's file to include more configurable parameters for a better ease of use. While active, the PacMan iterates through a program that is constantly polling data from the BMS boards using I2C, relaying data to SCADA when requested, displaying relevant information to the LCD display, logging all events, and checking for any inconsistencies or errors. Altering the information provided on the LCD display was a suggested task, one that our team is confident we could complete, however, since it is not integral to the operation of the TSV system, we plan on completing other more important tasks before addressing this issue.

One significant design consideration was a bug that was documented by LFEV-2013's team, and patched with some coding by last year's team. In order to eradicate this bug, our team has opted to peruse through the code archive and attempt to circumvent the problem. Since this is a programmable fix, it may be a design requirement that our team does not end up scoping for completion, with hopes that following teams could easily implement a lasting fix. Since our TSV design is an expanded version of last year's, with

4 complete packs instead of one, it is necessary that our system includes 4 separate PacMan boards - one for each pack. For safety reasons, this ensures that a potential malfunction in one is not catastrophic to the entire system, and can be easily isolated and addressed.

## Battery Management System (BMS) Board

For each of the seven cells within each of the four packs in our TSV design, there is a customized management system board to monitor the voltage and temperature of each designated cell. The original design was developed by Ben Richards of the LFEV-2014 team, and its full documentation of operation can be found listed under the Reference Materials in this report. One of the important attributes of this design is the unique address that each board must be configured with, in order to properly communicate to the PacMan board using I2C.

While most of the functionality detailed here is a product of last year's incredibly detailed design, there are a couple integral flaws to the firmware that our team has been tasked to address. Specifically, when the PacMan requests data from any of the BMS boards, the boards themselves do not currently ask that the PacMan wait for their request to be processed, which can cause multiple requests and result in data returns that were unexpected. One of the suggested fixes for this would be to manipulate the clocks so that no additional requests could be sent by PacMan until the original was processed. Another similar issue involves a collision of requests that involve both the reading and the writing of memory concurrently. In addition, our team has decided to implement temperature sensors on the boards, so as to ensure that the PacMan can compile a valid assumption of what the ambient temperature is within a pack at all times, for safety reasons.

A last concern is to design and implement a system reset, using a suggestion by LFEV 2014, which details that each board could be reset by shorting two specific pins. Using this knowledge, we intend to implement some small circuitry to simultaneously reset all of the boards in a pack.

## PacMan Breakout Boards

The PacMan Breakout Board (BoB) is necessary circuitry that was designed and implemented by the LFEV-2014 team to act as a bookend for the operations of both the Pack Manager and BMS boards. Its main functionality is to allow measurements of certain pack attributes like current and temperature, operate data relay between systems, and to also act as an isolation between high and low voltage circuits. As a result of LFEV-2014's design, last year's team noted and documented certain design flaws on their BoB boards, which can be found detailed in length in the errata memo that is listed under this report's Reference Materials.

According to the previous year's documentation, most of the board errata were simple layout considerations, such as silkscreen errors, certain physical placement errors, and transistor sizing, all of which included suggestions as how to fix or improve the board design. Although our team has decided to scope improving the layout of this board, there is however a more crucial circuitry design error that we need to address. Currently, should there be an unexpected malfunction within the PacMan during charging, there is no circuitry to open the relays within the charging circuit, which can essentially overcharge the cells and result in an unsafe environment. As a result, this task has been something our team has scoped to address in the near future.

## Requirements Analysis Matrix

This documents outlines all of the requirements that the TSV team of the LFEV-2015 project seeks to fulfill. Included are the requirements that stem directly from the 2015 Formula Hybrid rules, those that are related to bug fixes for the systems designed in previous years of the project, and specific deliverables for the completion of the Senior Design 492 class.

| Requirement | Description | Subsystems | Functional Requirement/Interface | MET |
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| Formula Hybrid Rules | | | | |
| 1.2.1 | The maximum permitted operating voltage for Formula Hybrid is 300 V. | TSV, TSMP | Measured from tractive system measuring points. These have yet to be created. | T000 |
| 1.2.4 | The tractive and GLV system must be galvanically isolated from one another | TSV, GLV, IMD | Any connections from TSV system to GLV or to VSCADA must be made using galvanically isolated cables. Also the insulation between the systems will be monitored by the IMD | T001 |
| 1.2.5 | The tractive system must be completely electrically isolated from the chassis and any other conductive parts of the car. | TSV, MECHE | Tractive system voltage will only be available through the TSMP and the TSV + and - terminals. | T002 |
| 1.2.6 | The tractive system motor(s) must be connected to the accumulator through a motor controller. Bypassing the control system and connecting the tractive system accumulator directly to the motor(s) is prohibited. | TSV, DYNO, motor controller, TSV load controller | The TSV load controller will be the only way the motor controller will have access to the overall + and - of the TSV accumulator system. This will ensure that the motor controller is protected by the safety loop. | |
| 1.3 | All Electrical insulating materials used must be UL recognized, be rated for the maximum expected operating temperatures at the location of use or | TSV, GLV | Each wire used will be documented and cross-checked with UL database. Additionally, there will be temperature readings taken throughout testing, and these will be cross-referenced with the UL database. | |

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| | have a minimum temperature rating of 90C. (Whichever is greater) | | | |
| 3.1 | Accumulators used must be either batteries or capacitors. Not including molten salt batteries, thermal batteries, fuel cell, atomic and flywheel mechanical batteries | TSV | LiFePO4 batteries have been used. We will provide the documentation from the manufacturer's site to show that they follow all of the requirements. | |
| 3.2 | All batteries or capacitors which store the tractive system energy must be enclosed in (an) accumulator container(s). Spares must be copies of the replaced packs. If the accumulator container(s) is not easily accessible during Electrical Tech Inspection, detailed pictures of the internals taken during assembly must be provided. | TSV | 4 accumulator packs will be created for the purposes of competition. They will have a sliding window pane or similar mechanically operated access panel so that it can be easily inspected. There will be no spares in the current design plan. | |
| 3.3.1 | The poles of the accumulator stack(s) and/or cells must be electrically insulated from the inside wall of the accumulator container by insulating material rated for the maximum voltage of the tractive system. All conductive surfaces on the outside of the container must have a low-resistance connection to the GLV system ground. | TSV, GLV | Will check that the connectors for the poles coming out of the accumulator box are rated for the maximum voltage and current coming from the pack by checking the manufacturer's specifications. The conductive parts of the battery pack will rest on the chassis of the car, which the GLV system is grounded to. | T003, T004 |
| 3.3.2 | Every accumulator container must contain at least one fuse. | TSV | Currently there are fuses protecting the AIRs in the pack. | |

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| 3.3.3 | All batteries or capacitors that make up the accumulator must be divided into accumulator segments. A Segment Maintenance Disconnect (SMD) must be installed between each segment. | TSV, HVD | Each pack is only approximately 24V so by putting a SMD only between each pack, the specification for competition is met. This is already fulfilled through the current plan for the high voltage disconnect (HVD). However, we still must check that each segment contains less than the maximum 12MJ of energy. | |
| 3.3.4 | The SMD may be implemented with a switch or a removable maintenance plug. There must be a positive means of securing the SMD in the disconnected state; for example, a lockable switch can be secured with a padlock or simply a clip. | TSV, HVD | The current SMD implemented through the HVD uses a plug which must be turned and locked into place before it is connected, so it cannot be accidentally connected. | |
| 3.3.5 | Contacting / interconnecting the single cells by soldering in the high current path is prohibited. | TSV | No soldering was used on the high current path. | |
| 3.3.6 | Each accumulator container must have a prominent indicator, such as an LED, that is visible through a closed container and will illuminate whenever a voltage greater than 30 VDC is present at the vehicle side of the AIRs | TSV, TSAL | A TSAL light will be created to show when tractive system voltage is present outside of the battery pack. | T005 |
| 3.3.7 | The accumulator voltage indicator (3.3.6) must be directly controlled by voltage being present at the connectors using hard-wired electronics. (No software control is permitted). Activating the indicator with the control signal which | TSV, TSAL | A non-softwared controller circuit will be created by the TSV team whcih will activate when tractive voltage is present at the poles of the pack. | |

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| | closes the Accumulator Isolation Relays (AIRs) is not sufficient. | | | |
| 3.3.8 | The accumulator voltage indicator must always work, e.g. even if the container is removed from the car. | TSV | The accumulator voltage indicator will be powered by the batteries themselves, and will not be connected to the GLV system of the car. | T005 |
| 3.3.9 | The minimum spacing or creepage distance for conductive materials at different voltages in the Accumulator shall be ⅛” over air and ¼” over surface. | TSV, MECHE | When designing the new pack, these requirements will be taken into consideration. | |
| 3.5 | At least two “normally open” isolation relays must be installed in every accumulator container, one at each pole. If these relays are open, no TSV may be present outside of the accumulator container. The fuse protecting the accumulator circuit must have a rating lower than the voltage and current ratings of the isolation relays. | TSV | The current system design has this implemented already. There are two “normally open” AIRs which are controlled by the PacMan and cover both the + and - terminals of the tractive system. | |
| 3.6 | AMS must measure individual cell voltages, temperatures. If voltage measurement is interrupted, AMS must report critical voltage problem. Must measure temperature of at least 15% of cells. Any voltage or temperature errors must shutdown the IC drive system and open AIRs, reset must come from someone other than | TSV, AMS, PacMan | The current system measures voltage, but temperature sensing must be added. Additionally, the AMS testing port and protocol for testing must be developed. Lastly, it must be verified that critical failures of temperature or voltage will open the AIRs and shutdown the IC drive system. | T006, T007 |

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| | driver. AMS board must be dedicated to AMS, and must have watchdog timeout. Must have an AMS test port. | | | |
| 4.1 | Electrical separation of GLV and TSV systems must be at least 1cm for non-PCB materials, and 6.4mm for PCB materials. All of this must be documented in the ESF | TSV, GLV | The TSV and GLV systems will only interface where documented in the ICD, and the ICD will follow the specifications given by the Formula Hybrid rules. | |
| 4.2 | All parts of the tractive system must be safely attached to the car. This includes all aspects of the the TS within the envelope of the car, and the TS being protected from collisions, as well as not protruding from the bottom of the vehicle. | TSV, MECHE | This will not be scoped for this year of the project | N/A |
| 4.3 | All accessible parts of the vehicle must be within certain resistance tolerances to be considered a safe ground. | TSV,GLV, MECHE | This will not be scoped for this year of the project | N/A |
| 4.4 | There must be two tractive system measuring points (TSMP) using 4mm safety banana jacks that accept shrouded (sheathed) banana plugs with non-retractable shrouds. The TSMPs must be protected by a non-conductive housing, and must be inaccessible by hand even when the housing is open. The TSMPs must connect to the motor controller supply lines. | TSV, TSMP, DYNO, MECHE | This will be designed around the interface with the DYNO teams' motor controller, and designed with the mechanical engineers input for the housing of the TSMPs. | |

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| 4.5 | The Tractive System must have all of its wires properly insulated as per requirement 1.3, and must be labelled. Additionally, the TS must be enclosed and protected from water, strain, vibration and unable to be breached by a 10cm long .6cm diameter probe. | TSV, MECHE | All of the cables will be checked to the manufacturer's specifications to ensure that they are appropriate. These will be labelled in plain sight. The case will be designed with the stress tests in mind, and will have minimized openings. | |
| 4.6 | Any tractive system enclosure must be labelled with a "High Voltage" sticker if its voltage exceeds 30V DC. | TSV | In each pack, the voltage does not exceed 30V, but when all packs are connected in parallel, the voltage will exceed 30V. | |
| 4.7 | It must be possible to positively break the current path of the tractive system accumulator quickly by turning off a disconnect switch or removing an accessible element, fuse or connector. An interlock must open the shutdown circuit when the HVD is removed. It must be labelled HVD and operable without the use of tools. It also must be able to be secured in the disconnected state. | TSV, HVD | The current connection port for the TSV + terminal is labelled HVD and satisfies most of these requirements. This will most likely be expanded to the the overall system HVD once all of the accumulators are connected together. | |
| 4.8 | The driver must be able to re-activate or reset the tractive system from within the cockpit without the assistance of any other person except for situations in which the AMS or IMD have shut down the tractive system. At least one action in addition to enabling the shutdown circuits is required to set the car to ready-to-drive | TSV, GLV, TSV load controller, SCADA, PacMan | This will likely run through SCADA where the signal will be relayed via ethernet to the PacMans to close the AIRs. To get to the ready-to-drive mode, the action will most likely interface with the TSV load controller. | T008, T009 |

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| | mode. | | | |
| 4.10 | The car must be equipped with a Tractive System Active Light mounted under the highest point of the main roll hoop which must be lit and clearly visible any time the AIR coils are energized. The TSAL must be red or amber, and must flash continuously with a frequency between 2 Hz and 5 Hz while it must not be possible for the driver's helmet to contact the TSAL. | TSV, TSAL | Connections from the pack will be routed to the TSAL through connections which follow specifications for safety from the previous rules. | T005 |
| 4.12 | There must be two TSVP lamps. One mounted on each side of the roll bar in the vicinity of the sidemounted shutdown button. They must be lit and clearly visible any time the voltage outside the accumulator containers exceeds 30 VDC. No software control is premitted. | TSV | Connections directly from the TSV + and - terminals will dictate when the light is on. Note: This requirement may be met by locating an isolated dc-dc converter inside a TS enclosure, and connecting the output of the dc-dc converter to the lamps. | T010 |
| 5.1 | The shutdown circuit must directly carry the current driving the accumulator isolation relays (AIRs). It consists of at least 2 master switches, 3 shut-down buttons, the brake-overtravel-switch, the IMD, all required interlocks and the AMS. If opened, the motor must free-spin. | TSV, GLV, SCADA | The safety mechanisms as well as the master switches and shutdown buttons will be communicated to the PacMans to open the AIRs. | T011 |
| 5.5 | An insulation monitoring device must be installed which will be set to 500 v/ohm. An IMD | TSV, GLV, IMD | The IMD will communicate with the circuit preceding the AIRs to tell it when an IMD fault has occurred and open the AIRs. | T012 |

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| | fault must open the AIRs without the use of logic and must remain open until reset by someone other than the driver. | | | |
| 6.1 | All electrical systems must be properly fused. The fuse protecting a circuit or must be physically located at the end of the wiring closest to an uncontrolled energy source. | TSV | All of the fuses and connections in the pack will be referenced to the manufacturer's specifications to ensure that every requirement is met. | |
| 8.1 | Whenever the accumulator containers are opened the accumulator segments must be separated by using the maintenance plugs and whenever the accumulator or tractive system is being worked on, only appropriate insulated tools may be used. | TSV | These are safety requirements which must be met whenever the packs are being worked on. These specifically refer only to the competition, but it is good practice to follow these guidelines anyway. | |
| 8.2 | These guidelines refer to safety precautions for charging the packs during competition. (See the Formula Hybrid ruels) | TSV | These are safety requirements which must be met whenever the packs are being charged. These specifically refer only to the competition, but it is good practice to follow these guidelines anyway. | |
| 9.1 | All teams must submit clearly structured documentation of their entire electrical system called the Electrical System Form (ESF). The ESF must illustrate the interconnection of all electric components including the voltage level, the topology, the wiring in the car and the construction and build of the accumulator(s). | TSV, GLV | As each piece of the TS is designed, it will be documented, and in the end these documents will be compiled into the ESF. | |

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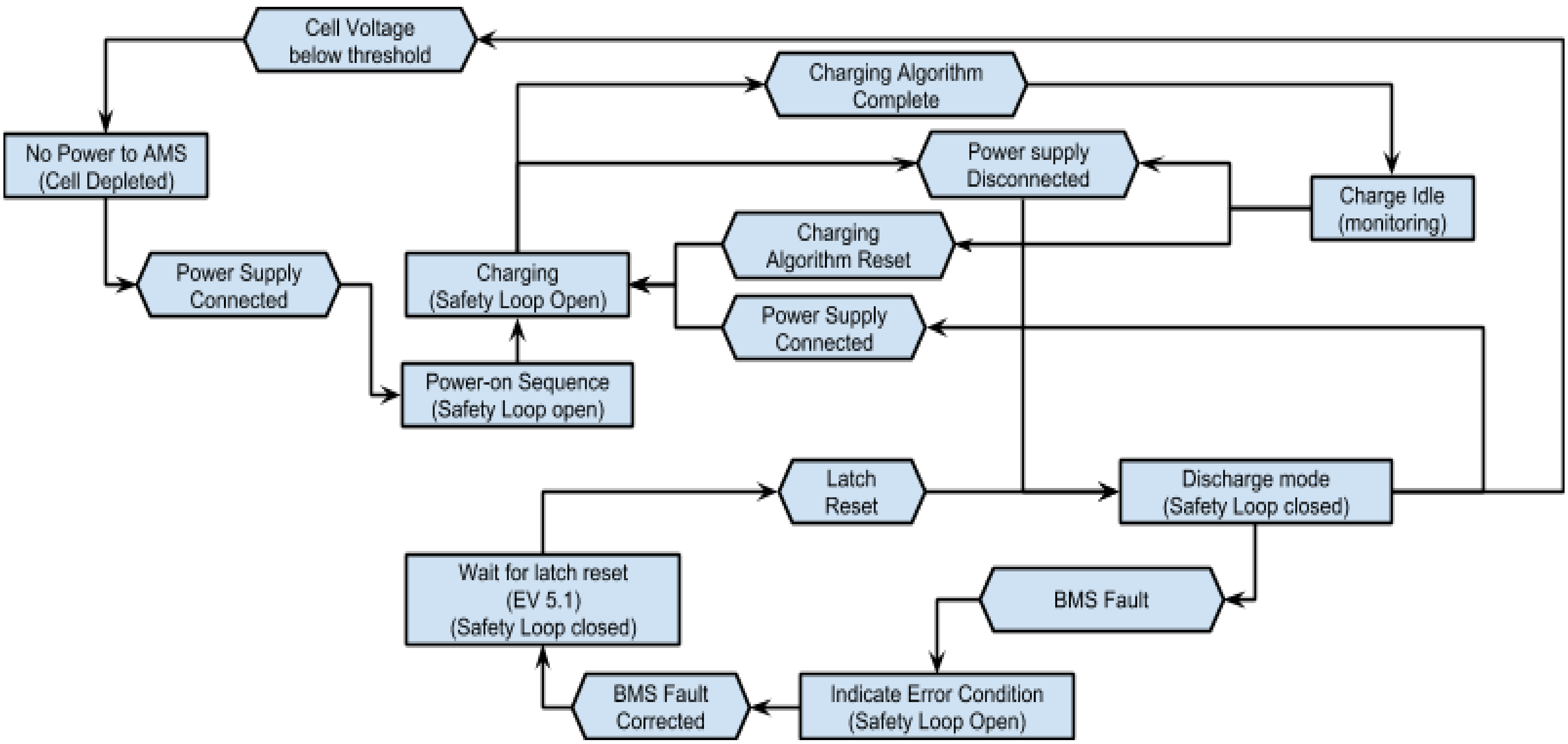
| 9.2 | Teams must submit a complete failure modes and effects analysis (FMEA) of the tractive system prior to the event. (Available online) | TSV,GLV | The format and specifications for this document will follow the template online. | |
| 2014 LFEV Design Bugs/Errata | | | | |
| R001,R004 | Fix issue where pack will not charge once depleted. | TSV | This occurs, because in order to charge the cells, the AIRs must be closed. However, these are controlled by the PacMan which also derives its power from the cells. A new charging circuit must be desgned. | T013 |
| R001,R004 | Implement ambient temperature sensors in pack. | TSV, SCADA, PacMan | Ambient temperature sensors must be installed in the pack. These should feed information to the PacMan, which should then make that available to SCADA. | |
| R001,R004 | Implement full system reset button. | TSV | Currently, all of the reset buttons are not accessible from the outside of the pack. Also they are all separate. All of the resets should be linked to a single button. | T014 |
| R001,R004 | Modify existing pack structure. | TSV, MECHE | Add way to hold AMS boards in place, a sliding window for maintenance, and do shock, vibration, humidity, temperature testing. | |
| R001,R004 | Correct AMS board errata. | TSV, AMS | Fix the documented errata from the LFEV 2014 technical memos. | |
| R001,R004 | Implement new LCD diplay | TSV | The current LCD display only contains minimal information, and should be replaced or updated to show additional and more relevant info. | |
| R001,R004 | Implement failure sensors for AIRs and main fuse. | TSV | Currently, when the fuses or AIRs are broken, there is no sort of indicator. One should be added. | T015 |
| R001,R004 | Implement an indicator for low battery warning. | TSV, PacMan | Currently, charge is monitored by the pack, but there is no indicator if the charge is running low. This will most likely be a simple LED. | T016 |
| R001,R004 | Update PacMan source code to follow coding guidelines. | TSV, PacMan | The current documentation for the PacMan source code is severely lacking, and this should be corrected so that future years can use it easily. | |
| R001,R004 | Create a better charge algorithm | TSV, AMS,PacMan | The current charge determination algorithm uses only voltage, and should be improved to take other factors such as temperature into account. | |

# System State Analysis

The overall system states for TSV are outlined below. The system states will be primarily stored as a value in a register within the program on the PacMan board. The information gathered from the attached sensors will provide the program with inputs which will determine the current state of the pack.

## System State Diagram




## System States

The existing system state diagram developed by the 2014 team was modified to add an auto-charge feature when the system is connected to the power supply. This fixes a system design flaw in which the battery cannot charge once the battery has been depleted below the protective threshold.

### *Power-On*

The system will power on from a depleted state upon connection to the power supply. The pack will then enter the charging state, and the safety loop will be open so that the pack cannot be discharged while charging.

### *Charging*

When the power supply is connected from the discharging state, the pack will open the safety loop and begin charging. Once the charge algorithm has finished and determined the pack is as fully charged as it can be, the pack will enter an idle state, where the pack will be monitored but no longer charging. If the power supply is disconnected during idle, pack will automatically enter discharge mode. If the charging algorithm is manually or otherwise reset, the pack will restart the charging cycle, returning to the charging state and waiting for the charging algorithm to be complete.

*Discharge*

The pack will close the safety loop upon entering discharge mode, to allow current to flow through the pack's terminals. If the cell voltage drops below a set threshold, power to the pack system will be shut off, so that the cells are not damaged by being drained completely.

*Fault*

If a fault is detected by means of an open safety loop or a fault in the PacMan program, an error condition will be indicated on the LCD display and the AIRs will be opened to prevent current flow from the cells. The only way to resume normal operation will be to manually reset the pack as per the specifications listed in EV 5.1 of the competition rules.

# Risk Analysis

This document provides potential risks that the TSV team might face while trying to accomplish the project. The risks are divided into four categories: safety, time management/efficiency, program budget and technical issues. Descriptions of specific risks related to each of those four general categories are identified. Possible consequences, risk level (high, medium, low) and contingency plan are also provided along with those risks.

| Risk Category | Descriptions of Risks | Possible Consequences | Risk Level | Contingency Plan |
|---|---|---|---|---|
| Safety "Always Expect The Unexpected" | Working Alone | Injuries/Death | H | Always work with someone else when working with any physical parts related to the cells or anything that can possibly cause an electrical shock, arc, or blast especially when assembling the cells and charging the pack. |
| | Presence of food/drinks | Malfunctioning of the pack and/or lowering the resistance in human touch which can cause injuries | H | No food or drinks when working with any physical parts of the project. |
| | Unsafe dress code | Unexpected electric shock, arc, or blast | H | Always wear insulated gloves when working with the cells or live wires. Avoid metal accessories such as watches, necklaces, bracelets, rings, etc. Avoid wearing conductive clothes. |
| Time Management / Efficiency | Procrastination of the documentation/proofs until the final report is due | This can result in an incomplete project without you even knowing or not having enough time to finish the documentation. | H | The work is not finished until there is documentation proving that the work is successful. Always remember to thoroughly document your work every time: providing simulations, timing diagrams, all physical components you used for a task. |

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|---|---|---|---|---|
| Time Management / Efficiency | Lack of constructive communication between groups and members of the group. Each group relies on clear communication between another group or inner members. EVERYTHING IS INTERRELATED. Designing a system without discussing with other groups who might be related to the work may cause a minor or major problems later. Another example of the risk would be that one team member's task or one group's task can be only achievable after another member's task or another team's task is finished. | Lack of communication can lead to compatibility issues within the projects themselves. The risk can cause conflicts between groups and failure to meet the desired program schedule. | H | When determining tasks for individuals or a team, always discuss what should be done beforehand to accomplish the task and determine which tasks may influence other group and vice versa. Let your teammates or other group know about the problem accordingly. |
| | Focus only on one's own tasks | There can be mistakes and errors that an individual cannot see. | M | Have frequent group meetings in the middle of the week, not just at the beginning or end of the week and proof read or comment on what other members have been working on. |
| Program Budget | Insufficient budget | There can be important parts that we may not get to due to limited budget. | L | Early petition preparations, cost reduction analysis or design modifications. |
| Technical Issues | Assembling 4 packs can be a disaster because of the countless components that make up each pack such as wires, wire housing/casings, boards, screws, chips, etc. We are also redesigning the pack architecture. | Even for the most perfect pack assembly design that we might come up with, there are definitely going to be unexpected problems and conflicts our team will face. New modifications on the design may be required in the middle of building a pack, forcing us to modify all four packs, re-build them or order more parts. | M | Work on one pack only and finish it before building the other three packs. First purchase order should include four of the same major parts that will definitely be needed even with any unexpected extreme modifications and the other minor parts for just one pack. Finish and document what goes into the first pack thoroughly and then you can order three of the same parts that went into the pack after completely finishing the first pack. Always discuss with mechanical engineering students and professors on ideas and designs that make up the pack. |
| | To debug last year's errata and make improvements, we have to completely read and understand their codes. Lack of comments on codes can lead to confusions. It is always a hassle to understand other's codes. | Our group might become frustrated or confused about why and how certain algorithms and parts were implemented and how we will deal with it. | L | Trying emailing previous year's engineers or build new algorithms. Make many comments in details while coding to facilitate future users. |

## Cost Analysis

This document provides the minimum budget needed to complete four packs for TSV – this does not account for shipping costs and sales taxes. Costs for the four major systems that make up the pack are financially analyzed and estimated: AMS (Accumulator Management System), PacMan, the electrical parts for the pack, and the mechanical parts for the pack. In each of the four sections, costly components are listed with specifics and relatively cheaper components are generally estimated from the bill of materials from LFEV-Y2-2014.

### AMS

| Description | Unit Price | QTY | Total Price |
|---|---|---|---|
| Advanced Circuits PCB<br>28 AMS Boards and 4 BOB | $33.00 | 32 | $1,056.00 |
| parts from Mouser | N/A | N/A | ~ $459.29 |
| parts from Digikey | N/A | N/A | ~ $141.7 |

| | |
|---|---|
| **Minimum AMS Total:** | **~ $1656.99** |

### PacMan

| Description | Unit Price | QTY | Total Price |
|---|---|---|---|
| Microcontroller | $308 | 4 | $924.00 |
| Micro SD Card 4GB Class 10 Industrial | $10.54 | 4 | $42.15 |

| | |
|---|---|
| **Minimum PacMan Total:** | **~ $966.15** |

## Pack Electrical Components

| Description | Unit Price | QTY | Total Price |
|---|---|---|---|
| Fuse, 200A, Class T, A3A, 300VAC/160VDC | $28.34 | 4 | $113.36 |
| Fuse Holder, 200A AC, 300V, 1 Pole, Molded | $71.81 | 4 | $287.24 |
| Fans 119x25 24DC 100CFM 5W 2900RPM 43dBA BB | $40.95 | 4 | $163.80 |
| AIR - 350A Contractor, 24VDC coil, 24-in flying leads, no auxiliary contact | $94.35 | 8 | $754.80 |
| 50A miniTactor, 24VDC coil | $40.00 | 8 | $320.00 |
| Panel Drain, Line 3, Grey | $51.26 | 4 | $205.04 |
| Panel Source, Neutral, Blue | $54.33 | 4 | $217.32 |
| LCD Character Display Module STN Y/G | $27.00 | 4 | $108.00 |
| Fixed Bridges (10 Position) | ~ $8.50 | 8 | $68.00 |
| Galvanically Isolated Ethernet | ~ $130.00 | 4 | ~ $520.00 |
| other 55 parts - fuses, fuse holders, pin&socket connectors, headers, plugs, wire housings&casings, wire ducts, BOB parts, etc. | N/A | N/A | ~ $1600 |

| Minimum Pack Electrical Total: | ~ $4357.56 |
|---|---|

## Pack Mechanical Components

| Descriptions | Unit Price | QTY | Total Price |
|---|---|---|---|
| 25 Mechanical parts - casings, aluminium bars&plates, stainless screws, etc. | N/A | N/A | ~ $2700 |

| Minimum Pack Mechanical Total: | ~ $2700 |
|---|---|

## Total Cost

| AMS | PacMan | Pack Electrical Parts | Pack Mechanical Parts | Mininmum Grand Total Budget |
|---|---|---|---|---|
| ~ $1656.99 | ~ $966.15 | ~ $4357.56 | ~ $2700 | ~ $9680.7 |