

TSV Accumulator User Manual

ECE 492 - Spring 2019

Latest Revision: 04/16/2019

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Abstract

This document is intended to provide details on the use of, operation of, and technical information for the Tractive System Voltage (TSV) subsystem within the LFEV 2019 Electric Car Project.

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FAQ

- 1) *What is an accumulator?* An accumulator, in the context of LFEV, is the connection of 4 “packs” to produce a nominal 96V to power the vehicle.
- 2) *What is a pack?* A single pack is ½ of the LFEV-2018 TSV design. It provides 48V, contains 14 cells, 14 CellMan boards, 2 SegMans, and 1 PacMan. It is contained in an aluminum enclosure with an excessive amount of screws. A synonym for Pack is “Accumulator Container” in Formula hybrid lingo.
- 3) *What is an AMS?* AMS stands for Accumulator Management System. It encompasses the connection of CellMan and SegMan to PacMan. These boards communicate through ISO-SPI where the PacMan is the master and the SegMan and CellMan boards are the slaves.
- 4) *What is a PacMAN?* A PacMAN is the Pack Manager. It is used to aggregate cell data from its corresponding SegMans and CellMans boards. It then sends information such as state, SOC, cell voltage & temp, and safety loop status to the LCD.
- 5) *What is a CellMan?* A CellMan is a PCB that mounts on top of a cell and measures Cell’s voltage and temperature and send that information to SegMan using a custom serial interface.
- 6) *What is a SegMan?* A SegMan is a PCB that mounts on the divider of the pack that faces a segment of cells.
- 7) *What would happen if you dropped a pack off the top of Acopian?* It would break, don’t do this.
- 8) *What would happen if you drop something metal across a cell?* Joking aside, safety with regard to the packs is always a top priority. This would likely result in an arc flash. Only work on the packs utilizing the safety procedures outlined in the relevant documents linked in “Safety” section below. Note that there are two arrangements in which dropping something across the top of the pack. The following figures illustrate these arrangements.

Overview

This document will describe all the safety measures, interfaces, necessary functions and controls, and maintenance of the Tractive System Voltage. Figures are used for a visual aid on what to avoid or to describe a setup procedure.

The TSV subsystem delivers high voltage power to the Formula SAE hybrid electric vehicle. Each pack or accumulator container, numbered 1-2, supplies around 48V through fourteen LiFePO₄ battery cells. These cells are monitored by the accumulator management system which includes a pack manager (PacMan-computer of a pack), segment manager (SegMan - monitors 7 cells) and cell manager (CellMan - monitors a cell). The two accumulator containers are wired in series to provide ~96V in the assembled system. The TSV subsystem interacts with other subsystems via the CAN bus communication protocol.

All information regarding the TSV subsystem (schematics, wiring diagrams, memos, firmware/hardware, etc), some of which is linked in this document, can be found on the 2019 LFEV website on the TSV page. See: <https://sites.lafayette.edu/motorsports/tsv/>

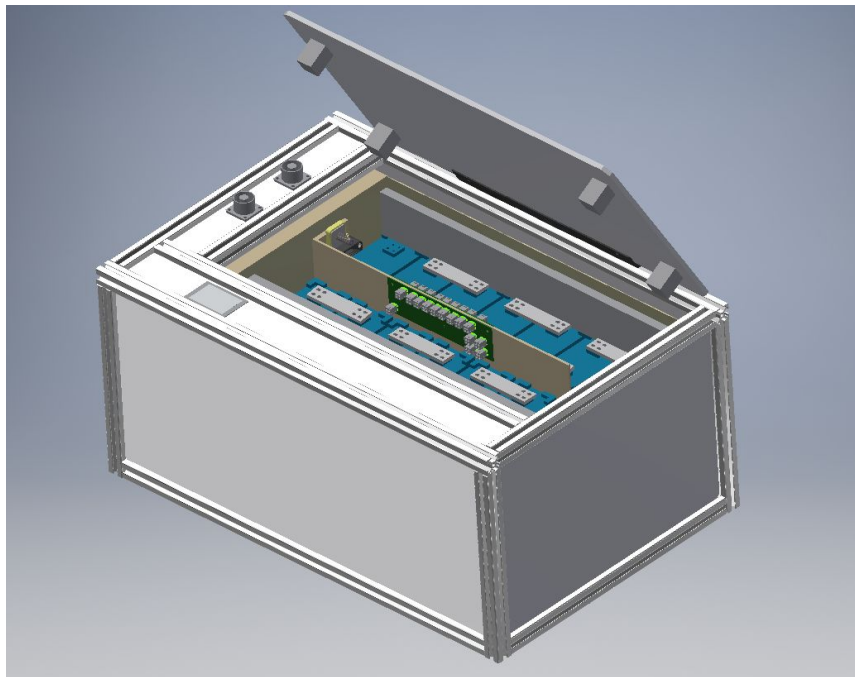


Figure 1: Mechanical rendering of the pack.

Safety

The 2019 LFEV teams took precautions and safety measures to reduce the risk involved with working on the packs. Some of these included wearing eye protection, cotton clothing, close-toed shoes and not having long conductive necklaces or bracelets.

Safety documents detailing procedures, expectations, and guidelines produced by previous LFEV teams and to which reflects the 2019 LFEV team's precautions and safety measures are:

<http://sites.lafayette.edu/ece492-sp15/files/2015/02/SafetyPlan.pdf>

<https://sites.lafayette.edu/ece492-sp16/files/2016/03/2016SafetyPlan.pdf>

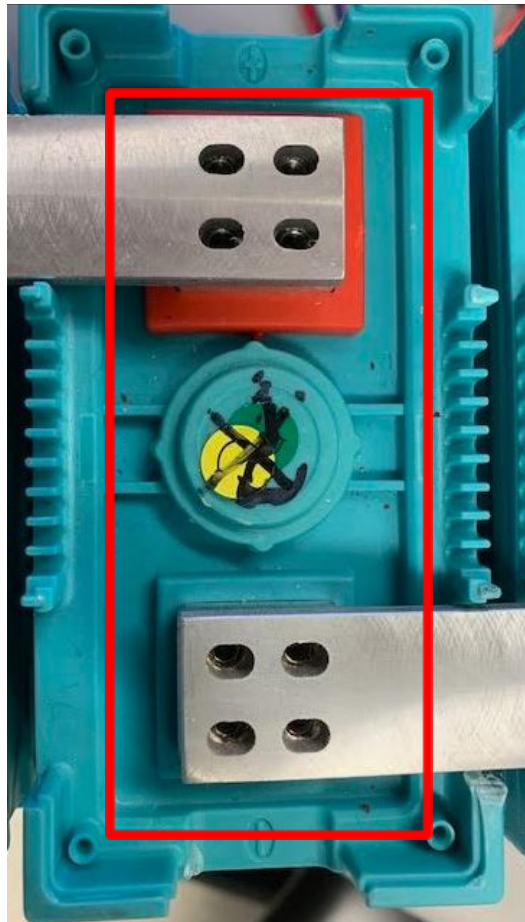


Figure 2:

WARNING DO NOT DO THIS Short across one cell. Dropping something across the + and - terminals of a single cell, as shown with the red rectangle would short a cell.

Electrical System Components

The TSV system contains two accumulator containers which are connected in series to provide high voltage power (~96V) for the vehicle. Each pack contains fourteen cells to provide approximately 48 V (each cell is ~3.3V). The PacMan board acts as the computer of the pack, controlling pack state, charging, pack/cell monitoring, safety loop, and CAN communication. The SegMan will monitor a segment of cells as an intermediate board between CellMan and PacMan. It will send data about a segment of cells to the PacMan. The CellMan will measure each cell's temperature and voltage and send it to SegMan.

PacMan

General

PacMan determines the cell state of charge parameters, cell faults, under voltage, etc. These parameters can be configured using the pushbuttons and the LCD screen on the packs. The PacMan will utilize an Isolated Serial Peripheral Interface (ISO-SPI) to communicate with the SegMan, more details in the SegMan section, to actively balance the cells in each segment. To achieve this, it will extract parameters from the SegMan such as cell voltage, discharge rate, and cell temperature. Using this information, the PacMan can determine when to continue charging a cell or when to stop charging a cell.

PacMan will be able to trip the safety loop as a safety measure when the cell voltage is too high or too low, or the cell temperature is too high. Furthermore, it will use a CAN interface to communicate with other subsystems in the car.

Connectors

- J1 - handles the 24V+ PacMan power connection and the can line
- J2 - connects the safety loop and airs to PacMan
- J3 - handles the 24V+ PacMan power connection and the can line
- J5 - handles the ISO-SPI communication interface
- J6 - the interface between the LCD display and PacMan

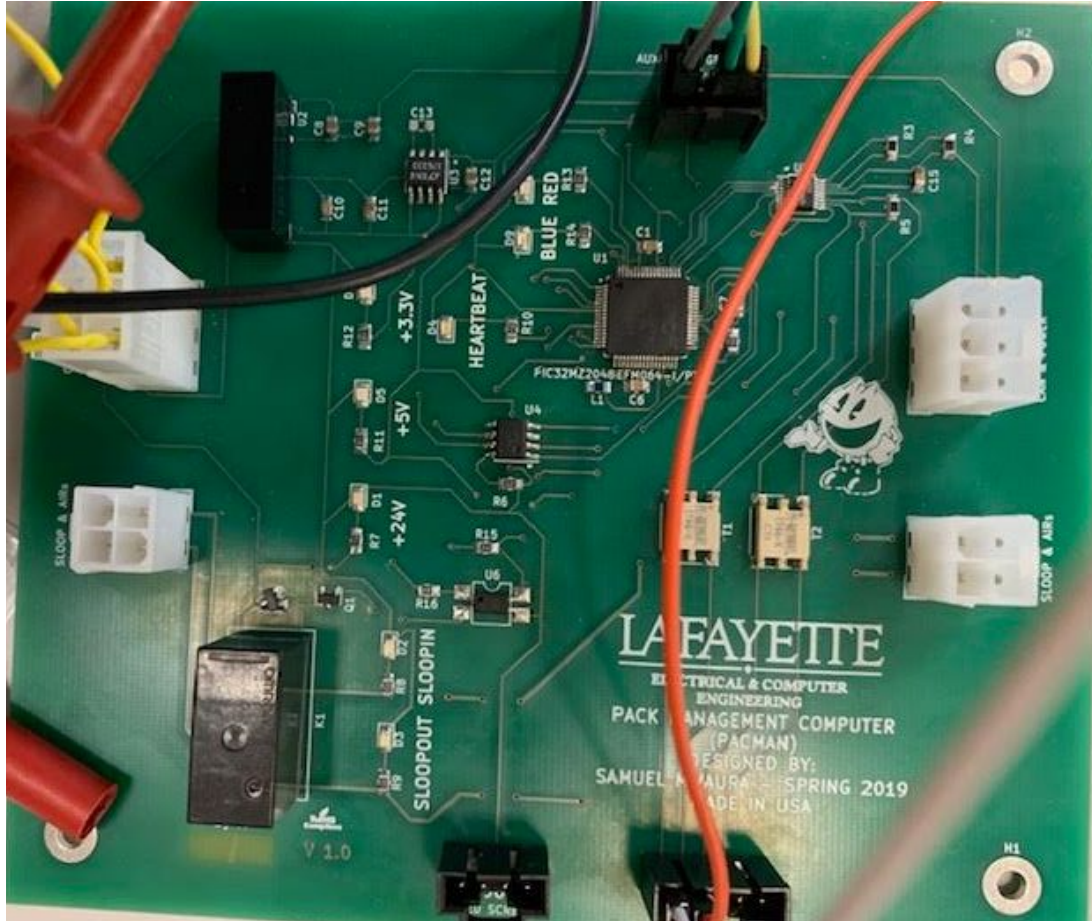


Figure 3: PacMan Printed Circuit Board (PCB)

SegMan

General

The SegMan uses ISO-SPI protocol to communicate with the PacMan. The SegMan itself does not have a processor but does have digital logic through the LTC6804-1. This digital logic will allow the SegMan to store relevant information about the expected cell performance (provided by the PacMan) in memory. Then, the SegMan will use the pin Sn to transmit a signal to enable/disable discharging to CellMan.

Connectors

- J1 - 24 pin connector that is connected to all the cells in a segment (7 cells) (it can support up to 12 cells)
- J2 - 2 pin connector that receives the discharge current from the cells
- J3 - 2 pin connector that supplies power to the LTC6804-2 chip
- J4 - 2 pin connector that detects if the charger is plugged in or not
- J5 - 2 pin connector that connects to the charger
- J6 - 2 pin connector that handles the ISO-SPI communication



Figure 4: SegMan Printed Circuit Board (PCB) (rev 1)

CellMan

General

The CellMan is a small board that receives its power from the cell it is monitoring. It has a chip LTC8584 which receives information from the SegMan on whether to discharge a cell or not. When discharging, the CellMan will intercept the incoming current and divert it back to the rest of the cells (refer to the high-level wiring diagram) to actively balance the cells. It also transmits the cell's voltage and temperature to SegMan through a custom serial interface. The custom serial interface is a communication protocol developed between the compatible LTC6804 and LTC8584

Connectors

(Figure 5)

J3 - pin 1 (top left pin) VSEG-, pin 2 (top right pin) VSEG+, pin 3 (bottom left pin) Sn (Rx), pin 4 (bottom right pin) Cn (Tx)



Figure 5: CellMan Printed Circuit Board (PCB)

Maintenance

Charging with SegMan:

SegMan has a charging circuit that is directly connected to a segment of cells. You may charge the segment by connecting to the Anderson port, which is directly routed to SegMan. Also, SegMan combined with PacMan and CellMan will send a discharge signal to make sure that the cell are actively balanced during charging.

Charging without SegMan:

If the charging circuit of SegMan is not functioning properly, then you can charge the pack by connecting the SKD Lambda Power Supply to a segment. In this case, the CellMan and SegMan should be disconnected from the cells. The voltage should be set to $3.7 * n + V_{\text{cable}}$ where n is the number of cells being charged and V_{cable} is the voltage drop over the cable (usually around 0.64 V). The current limit should be set to about 15 A. Turn on the power supply, then plug the positive output of the power supply into SEG+ and the negative output into SEG-. Cells should be individually monitored with a voltmeter. When a cell reaches 3.7 V, charging should be stopped on that cell. Turn off the power supply and then unplug the leads. Keep charging the remaining cells until all are measured to be 3.7 V. The volt measurement of the cells will fluctuate for a few hours after charging, this is normal. Do not leave charging cells unattended and always have a safety watch present.

Charging Individual Cells:

This involves a 3.5V power supply and appropriate cables (See Figures below). Completely charge each cell to ensure they are now at the same amount of charge. This is useful for “precharging” cells before they are installed within a pack.

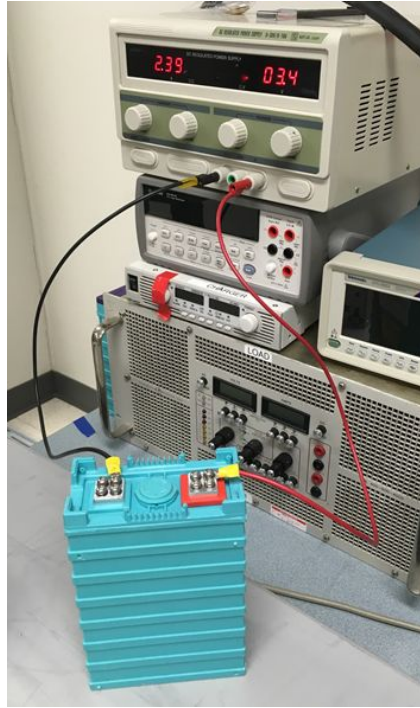


Figure 6: Charging setup for individual cell

Thermal Analysis

	<i>Diam</i>	<i>Area (in²)</i>	<i>Area (m²)</i>	<i>Volume m³/ft</i>	<i>Perimeter Area (m²/ft)</i>	<i>Resistance Ohms/ft</i>	<i>Mass (lb/ft)</i>	<i>Cost (\$/ft)</i>	<i>Ampacity (A)</i>
0.2x3.65		7.30E-01	4.71E-04	1.44E-04	2.32E-02	1.81E-05	8.55E-01	\$0.90	1012.6

Fusing Analysis

The maximum current we expect in the packs 300 A. Thus the first fuse that exists between the segments is rated to reflect this max current.

The maximum current expected through the circuit containing the segment manager is 20 A. The fuse between the positive segment voltage and the segment manager is sized to reflect the 20 A max current. It is fused on both ends.