System Design Document - TSV

ECE 492 - Spring 2015

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Abstract

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 Lafayette Formula Electric Vehicle (LFEV)-2015 project design, including Grounded Low Voltage (GLV) and Vehicle Supervisory Control and Data Acquisition (VSCADA). 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.

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Introduction

Scope

The TSV division of the LFEV-2015 team has been tasked to produce one fully functioning and guideline suitable battery pack, 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 VSCADA. With the goal of assembling a working and usable system, we as a team have scoped specific modifications within both the firmware 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

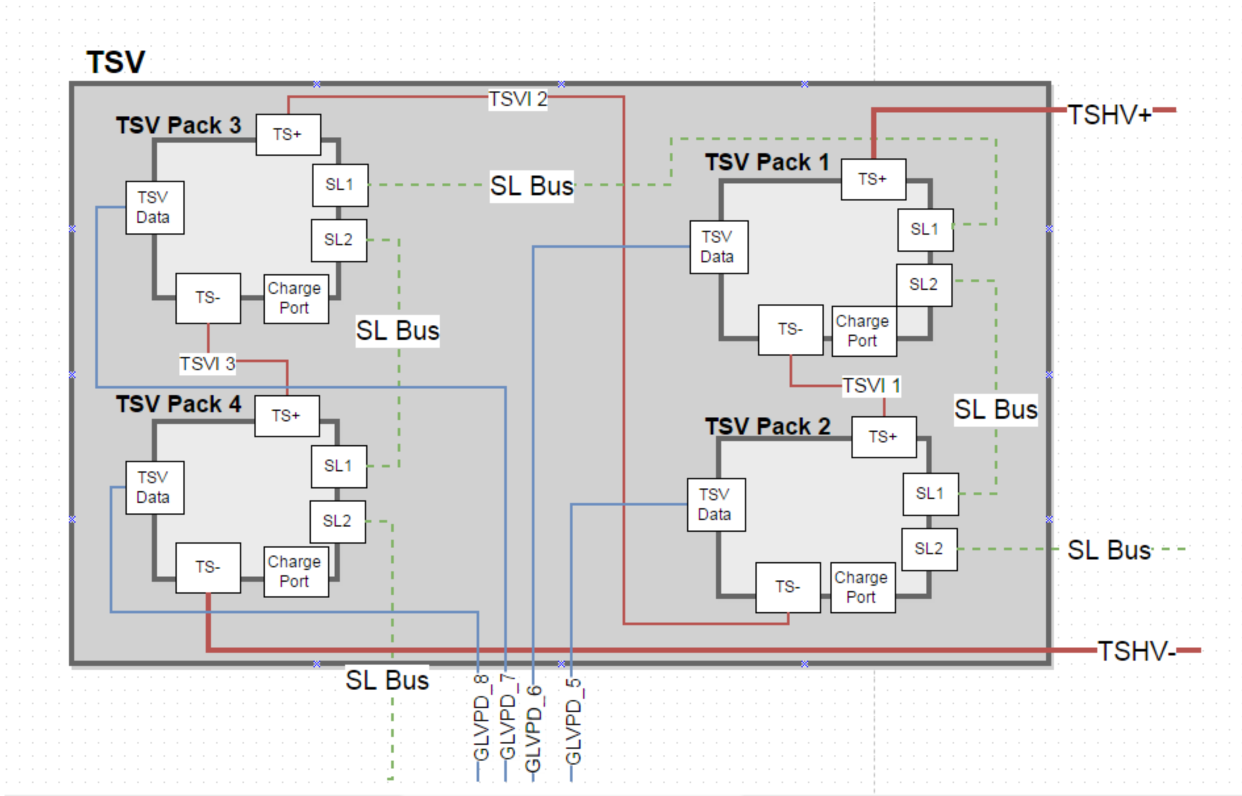
This report begins with a System Design/Architecture top level view of the LFEV-2015 system and can be easily visualized with the supporting block diagram, highlighting how each component is connected to the TSV System Interfaces, which details how our subsystem will communicate with the other parts of the project. Also depicted here is how the set-up of the individual packs and their connections within the full system will situated, assuming that our pack design becomes implemented into a total of four functioning packs. 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:
  - Users Manual
    - http://sites.lafayette.edu/ece492-sp14/files/2014/02/LFEV-ESCM-2014-UsersManual.pdf
  - PacMan Program Errata Memo
    - http://sites.lafayette.edu/ece492-sp14/files/2014/03/PacMan-Software-Errata-Memo.pdf
  - PacMan Breakout Board Errata Memo
    - http://sites.lafayette.edu/ece492-sp14/files/2014/03/PacManBoBErrataMemo.pdf
  - PacMan program file "i2c_controller.c"
- LFEV 2015 GLV Users Manual
  - http://sites.lafayette.edu/ece492-sp15/files/2015/02/GLVUserManual.pdf
- LFEV 2015 VSCADA User Manual
  - http://sites.lafayette.edu/ece492-sp15/files/2015/02/UserManual.pdf
- AT90CAN32 Datasheet
  - http://www.atmel.com/images/doc7679.pdf

- LFEV 2015 TSV LCD Solution Proposal
  - http://sites.lafayette.edu/ece492-sp15/files/2015/02/NewLCDSolutionProposal1.pdf

System Architecture



TSV 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 (FEV rule EV 4.1.5), 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, the voltage from this system (TSHV+ & TSHV-) is fed into the TSI through high-current discharge connectors - specifically Newark part 44W4365 (source/blue) and Newark part 44W4361 (drain/grey). Along with the voltage, the Safety Loop bus connection is fed through each pack within TSV and passed into the TSI through 4-pin connectors, specifically Mouser part 571-14807030. This entire interface allows the TSV power to be safely connected to the other low voltage parts of the LFEV project. Each of these modules functions can be found fully detailed within the LFEV 2015 GLV team's design documents, which can be found under this document's Reference Materials.

VSCADA

As the central computer system of the LFEV, VSCADA 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 VSCADA to relay any data requested, such as voltage levels, temperatures, and state of charge values. Through collaboration between our team and the VSCADA, we have agreed that a physical connection such as a controller area network (CAN) bus would be more reliable, flexible, and applicable to what we hope to accomplish. The physical connector for this communication will be a standard DB9 surge protector. The process of how this communication works, as well as the user interface involved, is better detailed within the LFEV 2015 VSCADA team's design documentation, listed under this document's Reference Materials.

Pack Design

As seen in the provided block diagram, our TSV system consists of one complete and operational battery pack to create the main voltage source for our LFEV motor. The powerhouse behind this system is how the battery pack functions, and its design was developed largely from the LFEV-2014 team's accomplishments, with additions and modifications from this year's team.

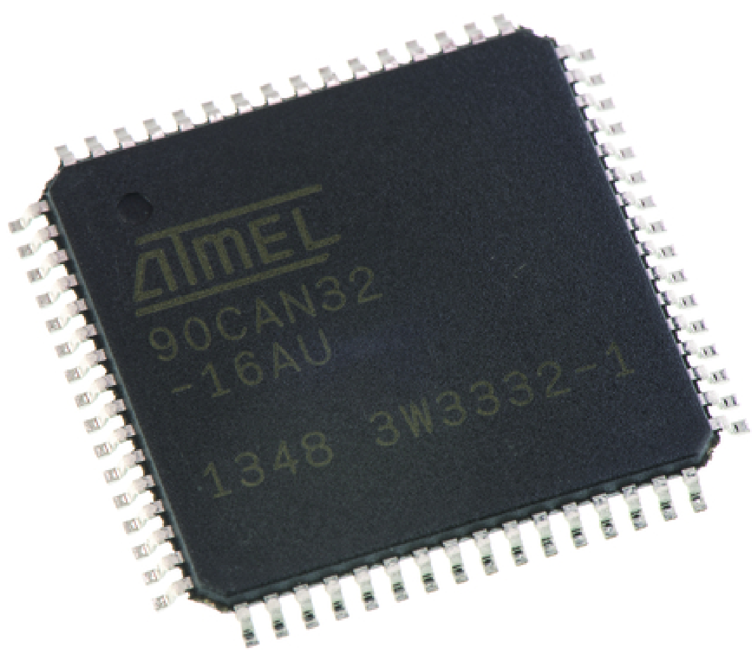
Pack Mechanical

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 address this, the Mechanical Engineers working with the LFEV 2015 team have redesigned the packaging of the packs to have the top plate easily removable, so that the inner pieces of the pack can be easily accessible. However, for convenience of the user/operator of the pack, we have implemented a system reset button on the outer casing of the pack so that no disassembly is needed in order to perform a manual reset of the AMS boards.

Another mechanical consideration for our team was that although each AMS 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. The final design proposed by the MechE team members is to attach a long piece of Flame-Retardant Garolite (G-10/FR4) to the inner side of the top plate of the pack. With the pack fully assembled, this piece will run along the lengths of each of the cells, and the specific spacing will allow the G-10/FR4 to act as a secure buffer, preventing the boards from jostling out of place. Since our team is expected to deliver a fully operational pack fit for competition, it is necessary that all mechanical packaging of our pack should be compliant with all of the FEV rules. It should be noted that in order to optimize the use of manpower and time, the mechanical designs of the pack are being handled by the supporting Mechanical Engineering students within the LFEV 2015 project, as their knowledge and expertise in this area is most valuable.

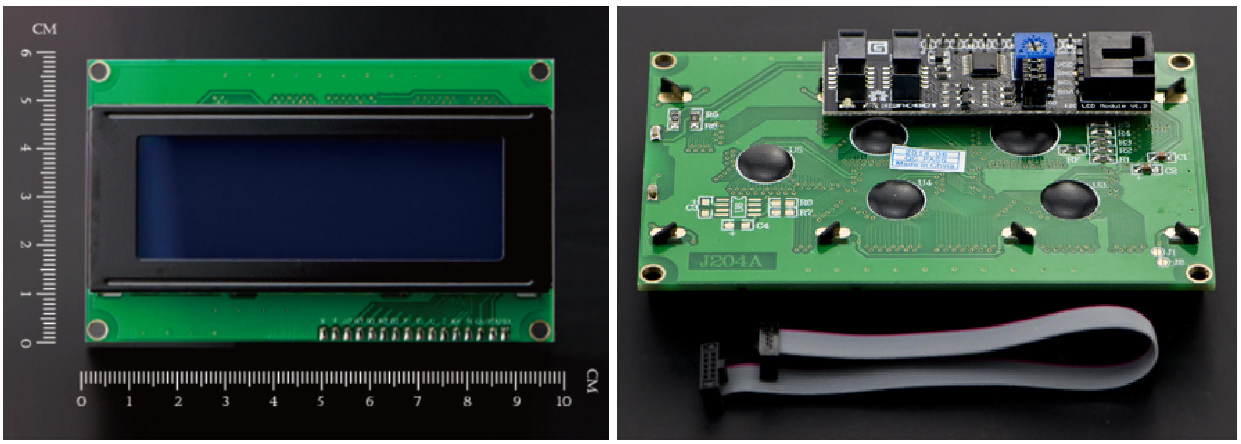
PacMan Program

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. For conservation of power and budgetary reasons, the LFEV 2015 TSV team has opted to replace the main computer with a microcontroller (Atmel AT90CAN32) that will carry out similar functionality as last year's PacMan program, which is pictured below and whose manual can be found under the Reference Materials.



http://au.rs-online.com/web/p/microcontrollers/7153748/

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 AMS boards, pass on the compiled data to the VSCADA interface, and to act as central control over the charging process of the battery pack. One design change our team has finalized is the use of a different LCD display, that better fits our needs in size, cost, and most importantly, communication with our new computer. The display we have chosen to use is the I2C/TWI LCD2004 Module (pictured below) and the research and reasoning behind this decision can be found detailed in Hansen Liang's proposal which is listed under Reference Materials.



Pictures obtained from the listing of the I2C/TWI LCD2004 Module on www.dfrobot.com.

Upon initialization, the PacMan program will check that it can communicate with each BMS board within its pack. Should this process not be successful, it will output to the display that a reset is taking place, and reset the corresponding board.

Accumulator Management System (AMS) Board

For each of the seven cells within the pack, 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 microcontroller using I2C.

While most of the functionality detailed here is a product of last year's design, there are a couple integral flaws to the firmware that our team has been tasked to address. 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. It is also very applicable to have a manual reset for the user to be able to take advantage of should an error arise. LFEV 2014 was able to design a remote reset included on each AMS board: if the

RST_POS pin of J3/J2 is asserted with 3.3 V, the boards are reset through a resistor and optoisolator circuit. This year's team utilized this functionality by including a manual reset to create this assertion, through the PacMan Breakout Board.

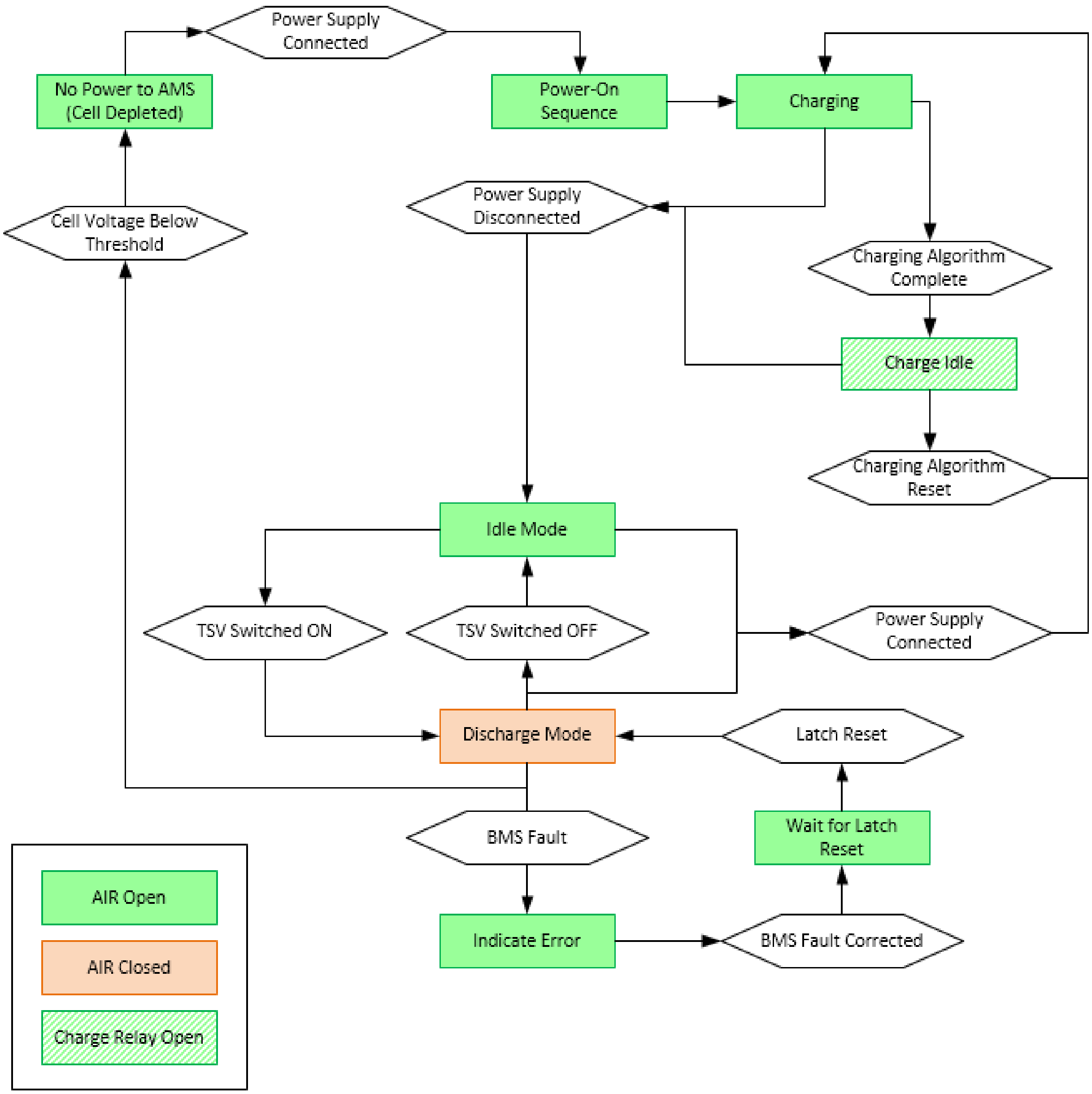
PacMan Breakout Board

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 improved the layout of this board, there is however a more crucial circuitry design error that we addressed. 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. To address this, we have opted to include 'normally - closed' relays in place of the 'normally - open' relays. 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 present. To meet this constraint, we have decided to implement individual 20 V DC indicators on the BoB within each pack. This threshold is a more accurate indicator of the voltage because each pack supplies at most around 23 V DC.

Appendix

A. PacMan State Transition Diagram



Glossary

AIR → Accumulator Isolation Relay
AMS → Accumulator Management System
BoB → Breakout Board
CAN → Controller Area Network
Dyno → Dynamometer
GLV → Grounded Low Voltage
LCD → Liquid Crystal Display
LFEV → Lafayette Formula Electric Vehicle
PacMan → Pack Manager
SAE → Society of Automotive Engineers
SL → Safety Loop
SOC → State of Charge
SOP → State of Pack
TSI → Tractive System Interface
TSV → Tractive System Voltage
VSCADA → Vehicle Supervisory Control and Data Acquisition