Lafayette Electric Vehicle 2015

ECE 492: Senior Design II
Morning Critical Design Review
March 11, 2015
Hugel 100

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
    a. System Assemblies Layout/Interfaces (Car)
    b. System Assemblies Layout/Interfaces (Rack)
    c. Interconnects
    d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
    a. Safety Loop
    b. GLV Power
    c. VCI
    d. TSI
5. GLV BOM and Budget

Roadmap Cont.

6. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

Roadmap

1. **Meet the Morning Teams**
2. Introduction: Motivation
3. Interface Control
   a. System Assemblies Layout/Interfaces (Car)
   b. System Assemblies Layout/Interfaces (Rack)
   c. Interconnects
   d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
   a. Safety Loop
   b. GLV Power
   c. VCI
   d. TSI
5. GLV BOM and Budget

Meet the Morning Teams

- Grounded Low Voltage (GLV)
  1. Dan Zakzewski
  2. Alo Posillico
  3. Nick DiNino
  4. Jordan Frank
  5. Zach Helwig
- Tractive System Voltage (TSV)
  1. William Stathis
  2. Duhang “Hansen” Liang
  3. Katherine Nellis
  4. Jaejoon Yang
  5. Jordan Blake
- Mechanical Engineering Team
  1. Ben Prevoznak
  2. Kailan Ottaway
  3. A. Freddie Hess

Roadmap

1. Meet the Morning Teams
2. **Introduction: Motivation**
3. Interface Control
   a. System Assemblies Layout/Interfaces (Car)
   b. System Assemblies Layout/Interfaces (Rack)
   c. Interconnects
   d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
   a. Safety Loop
   b. GLV Power
   c. VCI
   d. TSI
5. GLV BOM and Budget

Introduction: Motivation

- Formula Hybrid Competition Vehicle
  - Electric Car
- Capable of Vehicle Integration
- Four Team Integration
- Integrate with Mechanical Engineering Department
- Provide next year's team with a well-structured Formula Hybrid Vehicle ready for integration

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. **Interface Control**
    a. System Assemblies Layout/Interfaces (Car)
    b. System Assemblies Layout/Interfaces (Rack)
    c. Interconnects
    d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
    a. Safety Loop
    b. GLV Power
    c. VCI
    d. TSI
5. GLV BOM and Budget

Interface Control

An Interface Control Document was created to accurately and completely define all (electrical, mechanical, semantic) aspects of top-level interfaces to allow different designers to coordinate with each other successfully.

Next, we will discuss these top-level interfaces.

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
   a. **System Assemblies Layout/Interfaces (Car)**
   b. System Assemblies Layout/Interfaces (Rack)
   c. Interconnects
   d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
   a. Safety Loop
   b. GLV Power
   c. VCI
   d. TSI
5. GLV BOM and Budget

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

System Assemblies Layout - Top View

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

System Assemblies Layout - Top View

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Layout Selection

- SAE Requirements:
  - Side Panels
  - Cockpit Panel
  - Warning Devices
- Mechanical:
  - TSV best placed adjacent to the driver
  - Motor located near rear axle
- Cabling
  - Orientation of TSV System Packs
  - TSI, Motor Controller, and Motor all adjacent
- Interfacing
  - VCI accessible by pit station crew

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Physical Interfaces Layout - Side View

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Physical Interfaces Layout - Top View

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

System Assemblies Layout - Top View

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Main Hoop Box
Right Side Panel
Cockpit
A8
SL1
GLV24
TSVP
SL2
Safety Loop Termination
GLV Hub 1
TSV Pack 1
TSV Data
SL1
Charge Port
SL2
A1
TS-
TSV Pack 2
TS-
A2
SL2
Charge Port
SL1
TSV Data
VCI
RTD/ TSAL
A7
SL2
SL1
GLVPD
Cockpit
GLVPD
A5
Side Panel
Safety Loop
Pedals
TSI
SL2
TSVP
A6
HV+
HV-
Load Power +
SL1
GLVPD
Motor Controller
HV+
HV-
A9
GLVPD
J0
J1
J2
Motor
J0
J1
A10
J2
GLV Hub 3
TSV Pack 3
TSV Data
SL1
Charge Port
SL2
A3
TS-
TSV Pack 2
TS-
A4
SL2
Charge Port
SL1
TSV Data
GLV Hub 2
Left Side Panel
TSVP
GLV24C
GLV24B
GLV Power
GLVPD
A0
Charge Port
GLV24B
Chassis Ground
LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Vehicle Layout

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
   a. System Assemblies Layout/Interfaces (Car)
   b. System Assemblies Layout/Interfaces (Rack)
   c. Interconnects
   d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
   a. Safety Loop
   b. GLV Power
   c. VCI
   d. TSI
5. GLV BOM and Budget

End-of-Term Integration Layout

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

End of Term Integration Layout

- Most Boxes Car Integratable
  - VCI
  - Cockpit Box
  - GLV Power Box
  - TSI
  - TSV Packs
- Cable Design
  - Same length as used in vehicle integration where possible (longer elsewhere)
  - Easy to test as parts are integrated into the system

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Semester Integration Physical Interfaces

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Physical Interfaces

- Side Panel
  - Contains Master Switches
  - Safety Loop Interface
  - Power Indicators

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Physical Interfaces

- VCI Display
  - 9 Inch Touchscreen
  - Direct VSCADA Maintenance
  - System Parameter Control

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Physical Interfaces

- Cockpit Panel
  - Driver Interface
  - E-Stop (BRB) and Reset (CPR)
  - Indicators
  - Key Start Switch

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Physical Interfaces

- GLV Power Panel
  - Low Voltage Battery Indicators
  - GLV Power Switch

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
   a. System Assemblies Layout/Interfaces (Car)
   b. System Assemblies Layout/Interfaces (Rack)
   c. **Interconnects**
   d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
   a. Safety Loop
   b. GLV Power
   c. VCI
   d. TSI
5. GLV BOM and Budget

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Power and Data Distribution

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Power and Data Distribution

- 12 Volt Power Supply
  - Needed for VSCADA Computer
  - Easily Regulated to 5V
- CAN Data Line
  - Industry Standard in Automotive Systems
  - Already Implemented inside the Motor Controller
- CAN Consequences
  - Single long bus line
  - Nodes connected via short (<1.0 m) stubs
  - GLV Hub Boxes

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Safety Loop Connections

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Safety Loop Connections

- SAE Requirement
  - Control of the Tractive System Accumulator Isolation Relays (AIRs)
- Two Ports Per System
  - Easily add additional systems
  - No required order of systems

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Tractive System High Voltage Path

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Tractive System High Voltage Path

- Internally Hardwired Connections
  - Less Cables
  - Less Interconnects
- Powerlock Connectors
  - SAE Requirements:
    - Easily Removable
    - Lockable

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Tractive System High Voltage Path

- Powerlock Connectors
- Bolt Terminals
  - Pre-existing

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Semester Integration Layout

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
   a. System Assemblies Layout/Interfaces (Car)
   b. System Assemblies Layout/Interfaces (Rack)
   c. Interconnects
   d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
   a. Safety Loop
   b. GLV Power
   c. VCI
   d. TSI
5. GLV BOM and Budget

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Side Controls Panel

- Designed for testing purposes

Materials list:

Panel will be aluminum 18"x7"x1/4"

PSHB	Push button
BRB1	Big Red Button
BRB2	Big Red Button
LED1	Green LED
LED2	Amber LED
MS1	Rotary Switch
MS2	Rotary Switch
J1	3-pin TE Connectivity Connectors
J2	3-pin TE Connectivity Connectors
J3	2-pin TE Connectivity Connectors
J4	4-pin TE Connectivity Connectors
J5	4-pin TE Connectivity Connectors

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Side Controls Panel Drawing

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Hub 1

- Connects to GLV Hub 2 and 3
- Dangly that connects to TSV Pack 1 data port
- Dangly that connects to TSV Pack 2 data port

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Hub 2

- Connects to GLV Hub 1
- Connects to TSI
- Dangly that connects to TSV Pack 3 data port
- Dangly that connects to TSV Pack 4 data port

LAFAYETTE
ELECTRICAL & COMPUTER
ENGINEERING

GLV Hub 1 & 2

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Hub 3

- Connects to GLV Hub 1
- Connects to Motor Controller Interface
- Dangly that connects to the VCI
- Dangly that connects to the Cockpit
- Dangly that connects to GLV Power

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Hub 3

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
   a. System Assemblies Layout/Interfaces (Car)
   b. System Assemblies Layout/Interfaces (Rack)
   c. Interconnects
   d. Panel Drawings and Hubs
4. **Grounded Low Voltage (GLV)**
   a. Safety Loop
   b. GLV Power
   c. VCI
   d. TSI
5. GLV BOM and Budget

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Grounded Low Voltage

- GLV system is responsible for supplying power to all non-tractive devices on the vehicle, interfacing other subsystems together, and operating the safety circuit in accordance to the EV requirements.

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
   a. System Assemblies Layout/Interfaces (Car)
   b. System Assemblies Layout/Interfaces (Rack)
   c. Interconnects
   d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
   a. **Safety Loop**
   b. GLV Power
   c. VCI
   d. TSI
5. GLV BOM and Budget

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Cockpit and the Safety Loop

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Cockpit Panel and Internals

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Cockpit Panel Drawing

Materials List:

Aluminum Panel 5"x5"x1/4"
CPR - Cockpit Reset Button
Cockpit BRB
Red 'Safety' LED
Amber 'Warning' LED
Green 'System OK' LED
Amber Indicator LED
RTD - Ready To Drive Key

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Safety Loop and Safety Circuit

- Keeps high level voltage system in a safe state
- Monitors status of the system and provides multiple shutdown options to both driver and surrounding personnel
- Interacts with each electrical subsystem

LAFAYETTE
ELECTRICAL & COMPUTER
ENGINEERING

Shutdown Priority Table

Controlled Systems

Shutdown Sources

	GLV Supply to: Instrumentation, Data Acquisition, Computers, Telemetry, Etc.	AIRs (TS Voltage)
TSMS		OFF
Cockpit BRB		OFF
AMS		OFF
IMD		OFF
Brake Over-Travel		OFF
Side-Mounted BRBs	OFF	OFF
GLVMS	OFF	OFF

Safety Loop Summary

- Safety Loop accounts for failures/faults in the 4-wire safety loop
- Any failure in the safety loop will be appropriately reacted to within the time constraints provided by the Formula Hybrid Rules
- Appropriate steps must be taken in order to make the car ready-to-drive in each scenario
- The Test Plan for the Safety Loop does not have a threshold for any test; whether it be button/switch functionality or the shutdown circuit itself. The loop will function to the specifications provided.

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
   a. System Assemblies Layout/Interfaces (Car)
   b. System Assemblies Layout/Interfaces (Rack)
   c. Interconnects
   d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
   a. Safety Loop
   b. GLV Power
   c. VCI
   d. TSI
5. GLV BOM and Budget

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Power

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Power Box and Dependents

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Power Box

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Power Box - End Goal (JGB)

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Battery Cell

3.3V LiFePO4 10Ah

GLV Battery

Eight cells
24V
10Ah

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Battery Connection

Crimped Terminal
(Open Barrel)

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Battery Mounting

EV3.7.1- All GLV batteries must be attached securely to the frame.

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Battery Capacity Calculation

R006-1 The GLV system shall contain a rechargeable battery of sufficient capacity to run the car GLV systems for at least three hours.

GLV Relays	(2.04W x 2) = 4.08W + 1W (for microcontrollers, relays)		
AIRS	(2.04W x 2) = 8.16W + ~100mW (CAN transceivers)		
VSCADA	2.64W computer + 2W screen		
Total	17.88W / 24V = 0.745A x 1.5 =	1.1175Ah	1hr
		2.235Ah	2hr
		3.3525Ah	3hr
		4.47Ah	4hr
		5.5875Ah	5hr

Utilizes the measured power consumption of the VSCADA computer and a reasonable ceiling estimation for the screen.

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Battery Capacity Calculation

R006-1 The GLV system shall contain a rechargeable battery of sufficient capacity to run the car GLV systems for at least three hours.

GLV Relays	(2.04W x 2) = 4.08W + 1W (for microcontrollers, relays)		
AIRS	(2.04W x 2) = 8.16W + ~100mW (CAN transceivers)		
VSCADA	5.28W computer + 4W screen		
Total	25.52W / 24V = 1.06A x 1.5 =	1.595Ah	1hr
		3.19Ah	2hr
		4.785Ah	3hr
		6.38Ah	4hr
		9.57Ah	5hr

Utilizes the peak power consumption of the VSCADA computer and a higher ceiling estimation for the screen.

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Power and Battery Duration Test

R006-0 The GLV system shall provide DC supply voltage with sufficient current to supply all the power needs of the GLV systems and other non-tractive systems.
R006-1 The GLV system shall contain a rechargeable battery of sufficient capacity to run the car GLV systems for at least three hours.

Simplified Procedure:

1. Fully charge the battery.
2. Attach the Power Box to the adjustable load and set the current to simulate appropriate power consumption.
3. Record voltage at timing intervals.
4. Voltage must remain above designated value (21V) for three hours.

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Charging Circuit

Charging Circuit - Charging

R006-2ii The charging system shall be capable of powering the GLV system indefinitely as it simultaneously charges the GLV battery in a *plug and forget* functionality.

LAFAYETTE
ELECTRICAL & COMPUTER
ENGINEERING

Charging Circuit - Discharging

GLV Power - Charger

R006-2i The GLV system shall be rechargeable by means of a UL listed charging device that plugs into the 120 VAC mains.

www.trcelectronics.com

www.powergatellc.com

Battery Protection

R006-2iii It shall be possible to charge a fully discharged GLV battery without disassembly or special actions.
R006-2v The GLV battery shall be protected from full discharge, overcharge, overcurrent, and overvoltage.

Full Discharge:

- The 24-24 DC-to-DC Converter has an under voltage shutdown of 15.7 VDC.
- The solid-state relay controlling the charge circuit will be the normally closed type.

Overcharge:

- Discussed on previous slides.

Overcurrent:

- The 24-24 DC-to-DC Converter has a current limitation of 110% its typical, which is 2.5A for this device.
- 2.5A x 1.1 = 2.75A… Well above the expected range and below battery capabilities.

Overvoltage:

- The 24-24 DC-to-DC Converter has an overvoltage protection trigger point of <42V.

uk.farnell.com

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Voltage Sensing

R006- The GLV battery shall be protected from overcharge.
GLV voltage shall be measured by VSCADA.

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Power Software

R006- GLV voltage, current, temperature, and SOC shall be measured by VSCADA.

GLV Power Arduino

Maintainability:

- Code will be written in C which is not going extinct in the near future.
- Files will be uploaded to the website containing the source code and Arduino ID.

www.arduino.cc

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
   a. System Assemblies Layout/Interfaces (Car)
   b. System Assemblies Layout/Interfaces (Rack)
   c. Interconnects
   d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
   a. Safety Loop
   b. GLV Power
   c. **VCI**
   d. TSI
5. GLV BOM and Budget

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Vehicle Computer Interface

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

VCI

- Contains:
  - VSCADA Computer
  - Maintenance Panel Display
  - Safety Loop Control and Monitors
  - TSAL Circuit
  - RTD Sound Control

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

VCI

- Contains:
  - VSCADA Compu
  - Maintenance Pa
  - Safety Loop Con
  - TSAL Circuit
  - RTD Sound Con

VCI

- TSAL
  - 555 Timer in astable configuration
  - Active whenever the AIRs is open
  - Set for a frequency of 3.2 Hz
- Physical TSAL Lamp not included
  - Tested using DDM
  - Expected output:
    - 12V
    - 50% duty cycle
    - 0.3125 second period

VCI

- Safety Loop Monitoring
  - Interfaced to the CAN Controller board
  - Safety Loop Monitor
  - AIRs State Monitor
- Safety Loop Control
  - Controlled by VSCADA digital I/O
  - Gives Safety Loop control to system software

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
   a. System Assemblies Layout/Interfaces (Car)
   b. System Assemblies Layout/Interfaces (Rack)
   c. Interconnects
   d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
   a. Safety Loop
   b. GLV Power
   c. VCI
   d. TSI
5. GLV BOM and Budget

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Tractive System Interface (TSI)

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

TSI - Overview

- High Voltage Relay Control
- Precharge Protection
- Tractive System Voltage Present Light (TSVP)
- Insulation Monitoring Device (IMD)
- GLV PD 24 to 12 stepdown
- TSMP

TSI

LAFAYETTE
ELECTRICAL & COMPUTER
ENGINEERING

TSI - Pre-Charge/Relay Control

- Precharge circuit prevents inrush current and damage to relay contacts
- This configuration will take about 4 seconds for the motor controller to reach 96V

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

TSI - TSVP

- Must be powered by TSV and grounded to GLV ground
- Use a DC DC converter to satisfy this requirement and maintain isolation

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

TSI - IMD

- Pin 8 - Status Output High
- Feeds directly to a relay on Safety Loop
- Pin 8 output change opens Safety Loop (High → Low)

TSI - Other Components

- GLV Power
  - 24V to 12V DC-DC converter steps down the voltage from GLV24 to power the GLVPD at 12 Volts
- TSMP
  - TSMP+ is a direct contact to the HV+ terminal
  - TSMP- is a direct contact to the HV- terminal
  - GLV GMP provides a reference to GLV ground

TSI - QA Configuration

- Connect high voltage terminals to a high voltage power source
- Connect the high voltage load terminals to the motor controller
- Connect the GLV24 terminal to a low voltage power supply
-

TSI - QA Test Plan

- TSVP Test
  - Apply 30 volts to high voltage power supply and check the TSVP output with a multimeter
- Pre-charge/Relay Test
  - Put start signal high and measure time it takes relays to close
- IMD Test
  - Using a multimeter, check for connection across the relay after shorting the ground

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
   a. System Assemblies Layout/Interfaces (Car)
   b. System Assemblies Layout/Interfaces (Rack)
   c. Interconnects
   d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
   a. Safety Loop
   b. GLV Power
   c. VCI
   d. TSI
5. **GLV BOM and Budget**

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Bill of Materials

Description	Vendor Part Name	Quantity	Unit Price	Total Price
Te-Connectivity 2 pin/1 row parallel	1-480699-0	4	$0.28	$1.12
Te-Connectivity 2 pin/1 row free	1-480698-0	4	$0.28	$1.12
Te-Connectivity 3 pin/1 row parallel	1-480701-0	6	$0.28	$1.68
Te-Connectivity 3 pin/1 row free	1-480700-0	6	$0.27	$1.62
Te-Connectivity 8 pin/2 row parallel	794954-8	4	$0.25	$1
Te-Connectivity 8 pin/2 row parallel	794953-8	4	$0.25	$1
Te-Connectivity pin	350561-3	10	$0.14	$1.38
Te-Connectivity socket	350570-3	10	$0.13	$1.32
24V DIN Rail DC/DC Converter	TCL 060-124 DC	1	$80.62	$80.62
DIN Rail DC/DC Converter	STMGFS152405-N2	1	$69.05	$69.05
36vdc PFC Power Supply	HRP-200-36	1	$64.80	$64.80
DIN Rail	277-2064-ND	1	$9.82	$9.82
DIN Rail Terminal Blocks	APC1281-ND	50	$1.33	$66.63
SWITCH PUSH SPST-NO	CWI282-ND	1	$4.12	$4.12
SWITCH KEYLOCK SP3T	KO129B606-ND	1	$9.80	$9.80
DIODE SCHOTTKY 45V 7A	SB15H45-E3/73GITB-ND	5	$0.81	$4.05
LED RED 1/4" HOLE 5V	L10021-ND	5	$2.17	$10.85
Relay 5A 5V	Z2774-ND	10	$1.18	$11.78
			Grand Total	$341.76

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV Budget

Total Allocated Funds - $1397.90

LAFAYETTE
ELECTRICAL & COMPUTER
ENGINEERING

Roadmap Cont.

5. **Tractive System Voltage (TSV)**
   a. **Overview**
   b. Safety
   c. Mechanical
   d. PacMan System
   e. Charging
   f. AMS
   g. BoB
   h. Acceptance Testing
   i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

Tractive System Voltage

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Main subsystems

- Accumulator Managment System (AMS)
- Breakout Board (BoB)
- Pack Manager (PacMan)
- 7 3.2V 60A-hr LiFePO4 Cells

LAFAYETTE
ECTRICAL & COMPUTER
ENGINEERING

Roadmap Cont.

5. Tractive System Voltage (TSV)
    a. Overview
    b. **Safety**
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

TSV - Safety

- Fusing
  - 2 fuses for BoB
  - 1 fuse for voltage present LED
  - 1 large fuse for pack main current path
  - 2 fuses for charge relay
- Voltage present LED
  - turns on when voltage > 20V DC present at poles
  - can sustain voltage up to 96V
  - works even when a cell fails with all other packs connected
- Safety protocols

Pack Safety Loop

- One port at each end of the pack
- Each contains safety loop and SL 24V/GND
  - SL 24V/GND used to power AIR
- Safety path:

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

High Voltage Interfaces

- 4 “Danglies” one per pack
  - 400A rated Newark 44W4352
  - Source Hangs off of pack with cable to + terminal
- 4 Panel mount female connectors
  - 400A rated Newark 44W4361
  - Connected to - terminal bus bar

http://www.newark.com/itt-cannon/nls-3-gy-s120-m40a/line-source-line-3-grey-400a/dp/44W4352

http://www.newark.com/itt-cannon/npdft-3-gy-l-t4/panel-drain-line-3-grey-400a/dp/44W4361

Roadmap Cont.

5. Tractive System Voltage (TSV)
   a. Overview
   b. Safety
   c. Mechanical
   d. PacMan System
   e. Charging
   f. AMS
   g. BoB
   h. Acceptance Testing
   i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

Mechanical Objectives

- acceleration requirements
- splash proof
- internal wall
- vibration
- galvanic isolation

Mechanical- Frame/External Casing

- Rigid 8020 Aluminum External Frame

Mechanical- Frame/External Casing

-Removable Top For Quick Battery/BMS Access

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Mechanical- Frame/External Casing

-Splash Resistant Ventilation

LAFAYETTE
ELECTRICAL & COMPUTER
ENGINEERING

Cell Restraint

Top Bars

Side Bars

End Plates

Integration with Container

BMS Restraint

BMS Removal

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Added Components

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Free Terminal

Mechanical - Conductor Bars

- Carries large current
- Low resistance

Mechanical - Current Measuring Shunt

- Special conductor used to measure current
- 118μΩ at STP

Roadmap Cont.

5. Tractive System Voltage (TSV)
   a. Overview
   b. Safety
   c. Mechanical
   d. PacMan System
   e. Charging
   f. AMS
   g. BoB
   h. Acceptance Testing
   i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

PacMan System

- Receives and processes data from AMS
- Receives and processes pack sensor data
- Opens BoB safety loop
- CAN communication with VSCADA and LCD
- Implement charge and forget charging

PacMan Computer

https://www.embeddedarm.com/products/board-pictures.php?product=TS-7400-V2

Technologic Systems TS-7400-V2

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

PacMan Computer Hardware Specs

- 1.2W Typical power usage
  - 6.67 Weeks for each pack
- 10mW sleep mode
  - 15.35 years for each pack
- I2C bus for AMS and LCD communication
- CAN bus for VSCADA interface
- 4 ADC inputs for pack sensors
- 39 DIO ports for logic functions

PacMan Computer - Connections

https://www.embeddedarm.com/products/board-pictures.php?product=TS-7400-V2

PacMan Computer - Connections

https://www.embeddedarm.com/products/board-pictures.php?product=TS-7400-V2

PacMan Computer - Connections

https://www.embeddedarm.com/products/board-pictures.php?product=TS-7400-V2

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

PacMan Software

- Debian 'Wheezy' Linux (Kernel 2.6.36)
- Updates from 2014 team's code
  - Correct State of Charge algorithm
  - Reboot should not invalidate state of charge
  - Temperature adjustment for current-measuring shunt
- CAN communication with VSCADA

PacMan Safety Loop Control

- Safety loop opened in 3 different ways
  - Charger plugged
  - Watchdog timeout
  - CPU DIO02 pin for software control
- Watchdog fed by CPU DIO03 pin

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

VSCADA CAN Interface

- No longer RS-485, new isolated chip
- All 4 packs on the same main CAN line
- When address prompted, will return all relevant data to VSCADA

http://www.mouser.com/ProductDetail/TE-Connectivity-AMP/1-480705-0/?qs=OSEowtgdlxJxrUuPTLeZpA%3D%3D

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Roadmap Cont.

5. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

Charger-GENESYS 750W Half-Rack

http://www.testoon.com/images_produit/009789-full.jpg

http://sites.lafayette.edu/ece492-sp14/files/2014/02/LFEV-ESCM-2014-UsersManual.pdf

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Charging

- Anderson PowerPole connector used
  - Charge Detect
    - Charge Detect goes to BoB ends at PacMan
  - Charge +/-
    - Charge +/- go to charge relays
  - Safety Loop
    - Open when charging plug is plugged in
    - Closed when dummy plug is in charge port

Pack State Diagram

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Charge Detect

- Charger creates electrical connection between CHRG_DET1 and CHRG_DET2
  - Pulls CPU DIO06 pin high through optoisolator

Cooling

- When bypassing cells, they get HOT
- When charger is plugged, fan switches on
  - Fan powered by charger to not deplete batteries
- Reducing heat sink to half height
  - Thermal resistance now 3.7 ℃/W @ 200 LFM
  - With 10.2W power, 37.74 ℃ rise

http://www.mouser.com/ProductDetail/ebm-papst/4414F/?qs=sGAEpiMZZMt8mcbdCMUjUxEnE1a%2fhD2SdPrUzYqJg8M%3d

http://www.digikey.com/product-detail/en/657-20ABP/345-1035-ND/340333?WT.z_cid=ref_octopart_dkc_buynow&site=us

Charge Relays

- We will be using a normally closed charge relay
  - This fixes previous error where pack was unchargeable when depleted
- Charging is finished when all AMS bypass
  - CPU DIO00 pin signals CHRG_TRIG to optoisolator for charge relays to open when charging is finished
- Using relay - OMRON MGN1C-DC24
  - SPDT - can wire to be NO or NC
  - 24V DC 30A

Roadmap Cont.

5. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Accumulators and AMS

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Accumulator Management System Board

- Boards monitor attributes of each assigned cell
  - Voltage levels
  - Current levels
- Ability to bypass cell during charging
- Reports back to PacMan through I^2C
- Board Reset
  - Software
  - Remote/Manual

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

AMS Command List

Command #	Description	#Bytes Returned
0x 10	Gets the cell voltage	2
0x 11	Gets the cell temperature	2
0x 12	Gets the pack charging current	2
0x 13	Gets the pack discharging current	2
0x 14	Gets the bypass resistor switch state	2
0x 15	Gets the slave/board address	2
0x 16	Gets the software version	2
0x 17	Gets 0x0042(test command)	2
0x 18	Gets the bypass time in minutes	2
0x 19	Gets charging coulomb count as well as the number of times the charging current was summed	8*
0x 1A	Gets discharging coulomb count, as well as the number of times the discharging current was summed	8*
0x 1B	Gets cell voltage and temperature	4
0x1C	Gets the voltage, temperature and charging current of the cell	6
0x 1D	Gets the voltage, temperature and discharging current of the cell	6
0x 1E	Gets the time elapsed since the bypass switch has been set	6**
0x00	Sets the bypass switch state	n/a
0x 01	Sets the board address	n/a
0x 02	Sets the bypass time in minutes	n/a
0x 03	Calls the function to test the watchdog timer	n/a

Designed by 2013 Team.

AMS Software Bug

- Bugs documented by LFEV-2013
  1. No constraint to force PacMan to wait until the AMS board has processed a request
     - Results: incorrect data readings on the first response
  2. Concurrency issues in memory: read/write collisions
     - Results: possible retrieval of unwanted data

- LFEV-2015 Goals
  1. Manipulate clocks so that no additional requests could be sent by PacMan until original request is processed.
  2. Implement constraints so that data cannot be read and written at the same time

AMS Software Reset

- Initialization: PacMan will attempt to communicate with each board
  - Failed attempt → reset of that board
  - Error & Reset will display on Pack LCD

AMS Remote Reset

- LFEV 2014's Design → LFEV 2015 utilizing it
- Asserted by manual reset button through PacMan BoB

Roadmap Cont.

5. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

PacMan Breakout Board

- Acts as connector between TS-7400-V2 and the AMS boards and proper sensor relays
- Contains circuitry used for current, temperature, and pack voltage measurements
- Includes isolation chips to provide galvanic isolation between low and high voltage circuits

PacMan BoB Manual Reset

- MB2000 series switch pushbutton (NKK Switches)
  - RESET_POS
  - RESET_NEG
  - J22

- 6N135 high-speed optocoupler (Vishay Semiconductors)
  - U16

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

PacMan BoB Layout Errata

LAFAYETTE
ELECTRICAL & COMPUTER
ENGINEERING

Roadmap Cont.

5. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Acceptance Testing

- Overview
  - Designed around requirements
  - Minimizing time and charge cycles needed
  - Repeatable for individual packs
- Focus
  - Safety
  - Plug-and-forget charging
  - Accuracy of measurands
  - New SoC algorithm

Acceptance Testing Cont.

- Test configuration A

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Acceptance Testing Cont.

- Test configuration B

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Acceptance Testing Cont.

- T000: Pack Display and Safety Qualification
  - Prerequisite for all other tests
  - Configuration A
  - No active load
  - Measurement accuracy verification
  - Safety checks (isolation, sensor readings)
  - Controls/reset tests

Acceptance Testing Cont.

- T001: Low Current Discharge Test
  - Discharge cycle
  - Configuration A
  - Safety features tested (safety loop, low-voltage protection, temp/voltage sensors)
  - Un-balances cells for subsequent tests
  - Measurement accuracy verification
  - SoC tested

Acceptance Testing Cont.

- T002: Charge Cycle Test
  - Complete charge cycle
  - Configuration B
  - Charges at two different rates to test SoC
  - Safety loop tested
  - Measurement accuracy verification
  - Cell-balancing tested
  - Plug-and-forget feature tested

Acceptance Testing Cont.

- T003: High/low Current Discharge Test
  - Discharge cycle
  - Configuration A
  - Discharge at 3 different rates (high/low/paused)
  - Max current performance tested
  - Measurement accuracy verification
  - Safety features tested
  - SoC tested
  - Simulates real-life use case

Roadmap Cont.

5. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

Maintainability

- Hardware
  - MTTR = 1 day for most parts when spare parts on hand
  - MTTR < 8 days for most parts when no spare parts available
  - Full analysis in maintainability plan

Maintainability Cont.

- Software
  - PacMan software and AMS firmware
  - Source control
  - Backup/restore
  - Instructions for programming
  - Compatibility with VSCADA

TSV BOM & Budget

Total TSV Budget Required				
AMS	PacMan	BOB Parts	Pack Electrical Parts	Grand Total Budget
$430.38	$674.15	$223.75	$1,263	$2,590.95

Total Given Budget:	$2,739.10
Spent So Far:	$1,026.03
Remaining Budget:	$1,713.07

AMS

AMS (Accumulator Management System)				
Vendor Part# / Order#	Description	Unit Price	QTY	Total Price
~~1048778~~	~~Advanced Circuits PCB 30 AMS Boards~~	~~$8.32~~	~~30~~	~~$249.46~~
Mouser				
538-70543-0040	6-PIN SL Locking Header, tin-plate (J2, J3)	$0.74	20	$14.80
538-50-57-9706	6-PIN SL Locking Plug w/TPA (for J2, J3)	$0.75	20	$15.00
538-73838-0006	6-PIN SL TPA Piece (for J2, J3)	$0.26	20	$5.20
538-16-02-0096	SL Socket 24-30 AWG	$0.06	100	$6.00
567-657-15ABPN	TO-220 Vertical Board Mount Heatsink	$1.31	10	$13.10
652-PWR220T-20-R750F	TO-220 Resistor 20watt 0.75ohms 1% (RPOW)	$4.00	10	$40.00
567-173-7-220P	Thermal Interface Pad TO-220 .007" GRAY (for Q1, RPOW)	$0.42	17	$7.14
532-7721-7PPS	Insul Shoulder Washer (for No. 4 screw)	$0.18	15	$2.70
579-PIC16LF1827-I/SO	PIC16LF1827 8-bit Microcontroller (U4)	$1.72	8	$13.76
652-SRN8040-100M	SMD Inductor 10uH 20% (L1)	$0.39	20	$7.80
859-LTV-357T	Transistor Output Isolator (U6)	$0.19	20	$3.80
634-SI8600AB-B-IS	Silicon Labs Dual I2C Isolator Interface (U7)	$3.18	8	$25.44
579-MCP1825S-3302EDB	LDO Voltage Regulators 500 mA 3.3V (U3)	$0.51	9	$4.59
Digikey				
LT1307BCS8#PBF-ND	LT1307B	$2.75	4	$11.00
TIP102TU-ND	TRANS NPN DARL 100V 8A TO-220 (U2)	$0.73	1	$0.73
MCP9700AT-E/TTCT-ND	IC Sensor Thermal 2.3V SOT-23-3 (U5A, U5B)	$0.25	11	$2.75
MBR0520LCT-ND	Diode Schottky 20V 500MA SOD123 (D1)	$0.23	2	$0.46
MCP6242-E/SN	IC Opamp GP 550KHz PRO 8SOIC (U1)	$0.30	5	$1.50
655K-ND	Banana Plug	$1.72	3	$5.16
RMCF0805FT20K0CT-ND	20K 0805 SMD Resistor 1% 1/8W	$0.016	50	$0.81

AMS Total:	$430.38

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

PacMan & BOB

PacMan (Pack Manager)				
Vendor Part# / Order#	Description	Unit Price	QTY	Total Price
~~TS-1400-v2-256-2048F-I-Dev~~	~~MicroComputer TS-7400-V2~~	~~$158~~	~~4~~	~~$632.00~~
908-MSD04GC54P-1TM	Micro SD Card 4GB Class 10 Industrial	$10.54	4	$42.15

PacMan Total:	$674.15

BOB (Breakout Board)				
Vendor Part# / Order#	Description	Unit Price	QTY	Total Price
N/A	PCB for BOB boards	$10	6	$60
998-MIC4680-5.0YM	Switching Regulators 1.3A SuperSwitcher in SO-8 (Lead Free)	$4.23	3	$12.69
LTC4151CS-2#PBF-ND	IC CURRENT MONITOR(12BIT) 16SOIC	$5.55	4	$22.20
MCP6242-E/SN	Switching Regulators 1.3A SuperSwitcher in SO-8 (Lead Free) (also in AMS)	$4.23	5	$21.15
859-LTV-357T	Transistor Output Optocouplers (also in AMS)	$0.19	2	$0.38
584-ADM1232ARN	ADM1232 Watchdog Timer SOIC-8	$2.53	2	$5.06
849-LDA210S	LDA210 Dual Optoisolator/Darlington Pair SIP-8	$1.83	2	$3.66
771-HCT4002D118	Single 4 Input NOR/OR Gate SOIC-8	$0.50	2	$1.00
653-G6B-1114P-DC5	SPST 5V PCB Relay	$5.16	2	$10.32
ADM2483BRWZ	Half Duplex RS-485 Isolator	$6.84	2	$13.68
511-74LCX07YMTR	M74HC07 Hex Open-Drain Buffer SOIC-14	$0.52	2	$1.04
652-SRU1028-680Y	SMD Inductor 68uH 30%	$0.75	2	$1.50
P2N2222AGOS-ND	P2N2222A NPN BJT Transistor 600ma	$0.50	2	$1.00
621-B260A-F	B260A Schottky Diodes	$0.47	2	$0.94
512-1N4148	D1N4148 Diode Through Hole	$0.10	6	$0.60
810-C3216X5R1V226M	22uF SM Ceramic Capacitor 1206	$1.26	2	$2.52
598-AVE227M16X16T-F	220uF Electrolytic Capacitor Surface Mount 16V	$0.51	2	$1.02
538-70543-0013	Headers & Wire Housings 14 POS SHROUD HDR	$3.50	5	$17.50
538-50-57-9414	Headers & Wire Housings HSG 14P SINGLE ROW POSITIVE LATCH	$0.87	10	$8.70
517-D3408-6202-AR	16-PIN Shrouded Header	$1.99	3	$5.97
517-3452-6000	16-PIN Plug	$3.23	6	$19.38
517-D3793-6202-AR	10-PIN Shrouded Header	$1.44	2	$2.88
517-3473-6000	10-Pin Plug	$2.64	4	$10.56

BOB Total:	$223.75

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Pack Electrical Parts (page 1)

Pack Electrical Parts				
Vendor Part# / Order#	Description	Unit Price	QTY	Total Price
G3475534	Fuse, 200A, Class T, A3A, 300VAC/160VDC	$28.34	2	$56.68
G1878003	Fuse Holder, 200A AC, 300V, 1 Pole, Molded	$68.99	2	$137.98
504-BK/HKP-R	Cooper Bussmann AGC 30A/250V Fuse Holder	$4.72	6	$28.32
504-C10G0.5	Fuse, Bussman .5A/500V	$13.26	6	$79.56
5912-4414F	Fans 119x25 24DC 100CFM 5W 2900RPM 43dBA BB	$33.58	2	$67.16
562-0945030	Fan Accessories BLK FLTR ASSM 4.65"	$2.08	2	$4.16
562-09123-G	Fan Accessories PLASTIC GUARD 120MM	$1.21	3	$3.63
GX14CB	AIR - 350A Contractor, 24VDC coil, 24-in flying leads, no auxiliary contact	$94.35	1	$94.35
Waytek 124-903 124-11411	POWER RELAY CONTACTOR 24V 100A SPNO WHITE-RODGERS 124-903	$34.96	3	$104.88
Newark 44W4342	Panel Drain, Line 3, Grey	$74.10	2	$148.20
Newark 44W4365	Panel Source, Neutral, Blue	$50.62	2	$101.24
~~DFR0184~~	~~LCD Character Display Module STN Y/G~~	~~$23.00~~	~~4~~	~~$92.00~~
571-14807030	Pin & Socket Connectors CAP HOUSE 4 POS	$0.20	50	$10.00
571-14807050	Pin & Socket Connectors CAP HOUSE 6 POS	$0.32	50	$16.00
571-32950	Insul. Ring Terminal, 18 AWG, #6/M3 stud	$0.29	25	$7.25
538-19070-0121	Insul. Ring Terminal, 10-12 AWG, #8/M4 stud	$0.20	25	$5.00
571-35492	Insul. Ring Terminal, 12-10 AWG #1/4 /M6 stud	$0.56	10	$5.60
579-MCP9700A-E/TO-ND	Board Mount Temperature Sensors Lin Active Therm	$0.37	4	$1.48
517-9602207102AR	Headers & Wire Housings 20P SIDE ENT DR SKT	$3.18	3	$9.54
517-9602406303AR	Headers & Wire Housings 40P STR SR BDMNT SKT 3.5MM TAIL/8.5MM BODY	$4.85	3	$14.55
879-1470G1	Heavy Duty Power Connectors PP PAK 2-4P HSG SNAP-IN RECEPT	$2.10	4	$8.40
879-1327FP	Heavy Duty Power Connectors PP15/45 FINGERPROOF HOUSING ONLY, RED	$0.85	3	$2.55
879-1327G6FP	Heavy Duty Power Connectors PP15/45 FINGERPROOF HOUSING ONLY, BLACK	$0.82	3	$2.46
879-269G1-LPBK	Heavy Duty Power Connectors PP30 HD LOOSE CONT #12-16 AWG	$0.70	3	$2.10
879-4827G6	Heavy Duty Power Connectors PPMX 2-PIECE BLACK HOUSING ONLY	$0.80	3	$2.40
879-261G2	Heavy Duty Power Connectors PP45 REELED CONTACT #10-14 AWG, TIN	$0.16	25	$4.00

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Pack Electrical Parts (page 2)

571-5550521	Ethernet Connectors 8 COUPLER IN-LINE	$7.02	2	$14.04
651-5602099	15mm DIN Rail Perf	$9.64	1	$9.64
651-3100305	MT1.5 Feed-Thru DIN Rail Terminal Block	$2.62	20	$52.40
651-3001682	MT1.5 Twin DIN Rail Terminal Block	$4.62	3	$13.86
651-3100318	MT1.5 PE Ground Din Rail Terminal Block	$8.42	1	$8.42
651-3100321	MT1.5 End Plate	$0.78	3	$2.34
651-3002979	MT1.5 Twin End Plate	$1.34	3	$4.02
651-1402940	MBK5/EZ Feed-Thru DIN Rail Terminal Block	$3.15	6	$18.90
651-1415021	MBK5/EZ End Plate	$0.97	2	$1.94
651-1421659	DIN 15 End Clamp	$1.28	4	$5.12
298-G75X75LG72-ND	Wire Ducting TYPE G .75 X .75 6-FOOT SECTION	$28.56	1	$28.56
651-1725711	Fixed Terminal Blocks 8P 2.54mm 90DEG	$5.40	2	$10.80
651-1725656	Fixed Terminal Blocks 2P 2.54mm 90DEG	$1.42	3	$4.26
651-1725669	Fixed Terminal Blocks 3P 2.54mm 90DEG	$2.16	4	$8.64
571-3506891	Pin & Socket Connectors SOCKET 24-18 AWG	$0.085	100	$8.50
571-3506901	Pin & Socket Connectors PIN 24-18 AWG	$0.088	100	$8.80
538-16-02-0096	SL Socket 24-30 AWG	$0.10	100	$10.00
651-3001624	FBRN 10-4 N Fixed Bridge (10 Position)	$7.90	1	$7.90
298-C75LG72-ND	Wire Ducting COVER 3/4" 6-FOOT SECTION	$8.46	1	$8.46
651-0203250	FBI10-6 Fixed Bridge for 6.2mm DIN blocks	$9.86	1	$9.86
782-ILD755-1X017	Transistor Output Optocouplers Photodarlington	$2.77	4	$11.08
156-1409-E	D-SUB CRIMP FEMALE 9P	$0.56	2	$1.12
156-1401-E	D-SUB CRIMP PIN FM	$0.10	20	$2.00
164-9007-E	IDC SOCKET 14 PIN W/STRAIN RELIEF	$0.65	2	$1.30
164-9008-E	IDC SOCKET 16 PIN W/STRAIN RELIEF	$0.61	2	$1.22
Pack Electrical Total:	**$1,262.67**			

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Budget

- Initially allocated money:
  - Dyno - $148
  - SCADA - $715
  - GLV - $1397.90
  - TSV - $2739.10

Budget

- Money Spent so far
  - Dyno - $362
  - TSV - $1026.03
  - SCADA - $304.26
  - GLV - $10.24

Budget

Current status of money:

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Roadmap Cont.

5. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. **Out of Scope: LFEV-2016**
7. Conclusion

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Out of Scope: LFEV-2016

- GLV
  1. Implement AIR failure sensors
  2.

Out of Scope: LFEV-2016 Cont.

- TSV
  1. Implement AIR failure sensors
  2. Low voltage indicator light
  3. Building 4 complete packs

Roadmap

6. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. Out of Scope: LFEV-2016
7. **Conclusion**

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Lafayette Electric Vehicle 2015

ECE 492: Senior Design II
Afternoon Critical Design Review
March 11, 2015
Hugel 100

Roadmap

8. Meet the Afternoon Teams
9. Interface Control Review
10. Vehicle Supervisory Control and Data Acquisition (VSCADA)
    a. Daemon
    b. Interfacing
    c. User Applications
    d. Data Storage
11. Dynamometer (DYNO)
    a. Decomposition and Definition
    b. Integration and Recomposition

Roadmap

8. **Meet the Afternoon Teams**
9. Interface Control Review
10. Vehicle Supervisory Control and Data Acquisition (VSCADA)
    a. Daemon
    b. Interfacing
    c. User Applications
    d. Data Storage
11. Dynamometer (DYNO)
    a. Decomposition and Definition
    b. Integration and Recomposition

Meet the Afternoon Teams

- Vehicle Supervisory Control and Data Acquisition (VSCADA)
  1. Yiming Chen
  2. Bikram Shrestha
  3. Rameel Sethi
  4. John Gehrig
  5. Sam Cesario
  6. Adam Cornwell
- Dynamometer (DYNO)
  1. Steve Mazich
  2. Brendan Malone
  3. John Bloore
  4. Nate Hand
  5. Alex Hytha

Roadmap

8. Meet the Afternoon Teams
9. **Interface Control Review**
10. Vehicle Supervisory Control and Data Acquisition (VSCADA)
    a. Daemon
    b. Interfacing
    c. User Applications
    d. Data Storage
11. Dynamometer (DYNO)
    a. Decomposition and Definition
    b. Integration and Recomposition

Interface Control

An Interface Control Document was created to accurately and completely define all (electrical, mechanical, semantic) aspects of top-level interfaces to allow different designers to coordinate with each other successfully.

Next, we will discuss these top-level interfaces.

System Assemblies Layout - Top View

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Physical Interfaces Layout - Side View

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Physical Interfaces Layout - Top View

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

System Assemblies Layout

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Roadmap

8. Meet the Afternoon Teams
9. Interface Control Review
10. **Vehicle Supervisory Control and Data Acquisition (VSCADA)**
    a. Daemon
    b. Interfacing
    c. User Applications
    d. Data Storage
11. Dynamometer (DYNO)
    a. Decomposition and Definition
    b. Integration and Recomposition

VCI

Daniel Zakzweski, Class of 2015

LAFAYETTE
ELECTRICAL & COMPUTER
ENGINEERING

Embedded Computer: VAB-820

VSCADA

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Roadmap

8. Meet the Afternoon Teams
9. Interface Control Review
10. Vehicle Supervisory Control and Data Acquisition (VSCADA)
    a. **Daemon**
    b. Interfacing
    c. User Applications
    d. Data Storage
11. Dynamometer (DYNO)
    a. Decomposition and Definition
    b. Integration and Recomposition

Logging/Daemons - Main Program

- VSCADA uses systemd to initially launch the main program
  - systemd has most major linux distributions support
- The main program will run in the background as the server with PID registered
- The main program will start by doing system startup procedures

Logging/Daemons - Startup

- VSCADA uses systemd to initially launch the main program
  - systemd has most major linux distributions support
- The main program will run in the background as the server with PID registered
- The main program will start by doing system startup procedures

System Startup

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

System States and Exceptions

Startup Stage

- **When system boots up and will goto one of the following stages**

Good to Go Stage

- **No error or warning and is ready to be driven**

Driving Stage

- **The car is drving**

Vehicle Boot Up Error Stage

- **VSCADA is functional but other subsystems are not**

VSCADA Boot Up Error Stage

- **VSCADA is not functional**

Failed Stage

- **VSCADA failed to boot up**

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

System States and Exceptions

System Errors:

Snytax error

- ➔ **Failed Stage**

VehicleStartupConfigLoadException

- ➔ **Other Boot Up Error Stage**

DatabaseLoadException

- ➔ **VSCADA Boot Up Error Stage**

RRDFileNotFoundException

- ➔ **VSCADA Boot Up Error Stage**

VehicleStartupTimeoutException

- ➔ **Other Boot Up Error Stage**

SensorCheckingTimeoutException

- ➔ **Other Boot Up Error Stage**

SystemFailureError

- ➔ **Failed Stage**

OtherCommunicationException

- ➔ **Vehicle Boot Up Error Stage**

OtherSystemException

- ➔ **VSCADA Boot Up Error Stage**

Sensor Errors:

Logic:

Errors are configurable and specific

If happens before driving, then the car is disabled from driving;

else take actions according to sensor configuration

Possible Errors:

OverHeating

UnderCharged

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Logging/Daemons - Logging

- Have 5 levels, in their respective order:
  - Debug: detailed information, mainly used for debugging
  - Info: general information, should contain important data
  - Warning: Need user's attention
  - Error: Need user to check the source of the error
  - Critical: Opps.
- Logs are stored in syslog of Linux
  - syslog handles storage, update, filter, etc.
  - Python and other library support for syslog
- Can be viewed by clients over the TCP protocol
- Levels can be set by configuration. Info level by default

Roadmap

8. Meet the Afternoon Teams
9. Interface Control Review
10. Vehicle Supervisory Control and Data Acquisition (VSCADA)
    a. Daemon
    b. **Interfacing**
    c. User Applications
    d. Data Storage
11. Dynamometer (DYNO)
    a. Decomposition and Definition
    b. Integration and Recomposition

Interfaces

- TSV Communication
  - Send/Receive Packets of data from the four PACMAN via CAN
  - will follow API
- GLV Communication
  - JGB act as a hub for groups of sensors via CAN
- DYNO Communication
  - Control Throttle via JGB board
  - Motor Controller CAN
  - Dynamometer - USB interface to read RPM and torque, set valve

CAN Interface

- SocketCAN -Linux Drivers

```
sam@bull3:~/Desktop/vscada/can-lib$ cansend vcan0 123#11.02.fe.fe.ee.ee.95.33
```

```
sam@bull3:~/Desktop/vscada/can-lib$ candump vcan0
  vcan0  123   [8]  11 22 33 44 55 66 77 88
  vcan0  123   [8]  11 22 33 44 55 66 77 88
  vcan0  001   [3]  11 12 13
```

- Python-CAN

```
sam@bull3:~/Desktop/vscada/can-lib$ python3 CANexample.py vcan0
Received: can id=123, can dlc=8, data=b'\x01\x02\xff\xff\xee\xee\x952'
```

TSV Pack LevelCAN Frame

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7

Byte 0 - 1,Pack#(1-4)

Byte 1 - Voltage (High)

Byte 2 - Voltage (Low)

Byte 3 - Current (High)

Byte 4 - Current (Low)

Byte 5 - SOC (High)

Byte 6 - SOC (Low)

Byte 7 - Fuse Temp

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

TSV(1) AMS Level CAN Frame

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7

Byte 0 - x1,Pack#(1-4)

Byte 1 - AMS#(1-7)

Byte 2 - Voltage (High)

Byte 3 - Voltage (Low)

Byte 4 - Current (High)

Byte 5 - Current (Low)

Byte 6 - Temperature (High)

Byte 7 - Temperature (Low)

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV(2) Cockpit CAN Frame

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7

Byte 0 - x21 (Cockpit)

Byte 1 - Ambient_temp (High)

Byte 2 - Ambient_temp (Low)

Byte 3 - Failure_LED (High)

Byte 4 - Failure_LED (High)

Byte 5 - Warning_LED(High)

Byte 6 - Ok_LED (High)

Byte 7 - Ok_LED (Low)

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV(2) TSI CAN Frame

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7

Byte 0 - x22 (TSI)

Byte 1 - Temperature (High)

Byte 2 - Temperature (Low)

Byte 3 - x00

Byte 4 - x00

Byte 5 - x00

Byte 6 - x00

Byte 7 - x00

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV(3) GLV_Power CAN Frame

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7

Byte 0 - x13

Byte 1 - Voltage (High)

Byte 2 - Voltage (Low)

Byte 3 - Current (High)

Byte 4 - Current (Low)

Byte 5 - Temperature (High)

Byte 6 - Temperature (Low)

Byte 7 - SOC

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Motor Controller CAN Frames (1 / 2)

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7

Byte 0 - RPM (High)

Byte 1 - RPM (Low)

Byte 2 - Motor Temp

Byte 3 - Controller Temp

Byte 4 - RMS Current (High)

Byte 5 - RMS Current (Low)

Byte 6 - Capacitor V (High)

Byte 7 - Capacitor V (Low)

Motor Controller CAN Frames (2 / 2)

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7

Byte 0 - Stator Freq (High)

Byte 1 - Stator Freq (Low)

Byte 2 - Controller Fault P

Byte 3 - Controller Fault S

Byte 4 - Throttle Input

Byte 5 - Brake Input

Byte 6 - System Bits

Byte 7 - (UNUSED)

CAN Microcontroller Board (JGB)

Automotive AVR

- CAN Bus
- LIN
- UART (RS-232)

Board Inputs/Outputs

- Internal Temperature
- 5 ADC Channels
- 3 PWM Channels
- 1 DAC Channel
- 6 GPIO/SPI
- 2 Differential ADC
- USB - UART

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Microcontroller Firmware Design

UART

Send/Receive
Test/Debugging Information

CAN

SCADA Communication

TIMER

PWM, Sensor Timing

WATCHDOG TIMER

Crash Prevention

I/O

System Control Interface

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Microcontroller Prototype Hardware

WORKING:

- ADC
- D2A
- PWM
- GPIO

NOT WORKING:

- CAN
- UART

Microcontroller CAN Frames

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7

Byte 0 -

Byte 1 -

Byte 2 -

Byte 3 -

Byte 4 -

Byte 5 -

Byte 6 -

Byte 7 -

POWER CONNECTIONS
J1
PWR
V_GLV
GND
V_GLV
JUMPER3
JP1
V_USB
V_USER
U1
NCP1117ST50T3G
V_USER
VCC
C2
47u
C4
47u
C5
0.1
PWR_FLAG
AREF
GND
V_USER
POWER LED
R1
220
D1
PWR
ATMEGA 16M1 MICROCONTROLLER
IC1
VCC
AVCC
AREF(ISRC)
AGND
GND
C6
0.1u
C7
0.1u
(PCINT0/MISO/PSCOUT2A)PB0
(PCINT1/MOSI/PSCOUT2B)PB1
(PCINT2/ADC5/INT1/ACMPN0)PB2
(PCINT3/AMP0−)PB3
(PCINT4/AMP0+)PB4
(PCINT5/ADC6/INT2/ACMPN1/AMP2−)PB5
(PCINT6/ADC7/PSCOUT1B)PB6
(PCINT7/ADC4/SCK/PSCOUT0B)PB7
(PCINT8/INT3/PSCOUT1A)PC0
(PCINT9/PSCIN1/OC1B/SS_A)PC1
(PCINT10/T0/TXCAN)PC2
(PCINT11/T1/ICP1B/RXCAN)PC3
(PCINT12/ADC8/ACMPN3/AMP1−)PC4
(PCINT13/ADC9/ACMP3/AMP1+)PC5
(PCINT14/ADC10/ACMP1)PC6
(PCINT15/D2A/AMP2+)PC7
TQFP32
(PCINT16/PSCOUT0A)PD0
(PCINT17/CLKO/PSCIN0)PD1
(PCINT18/PSCIN2/OC1A/MISO_A)PD2
(PCINT19/TXD/TXLIN/OC0A/SS/MOSI_A)PD3
(PCINT20/ADC1/RXD/RXLIN/ICP1A/SCK_A)PD4
(PCINT21/ADC2/ACMP2)PD5
(PCINT22/ADC3/INT0/ACMPN2)PD6
(PCINT23/ACMP0)PD7
(PCINT24/OCD/RESET)PE0
(PCINT25/OC0B/XTAL1)PE1
(PCINT26/ADC0/XTAL2)PE2
ATMEGA16M1-A
MISO
MOSI
ADC5
AMP0−
AMP0+
GPIO0
ADC4
SCK
GPIO2
PWM1
CANTX
CANRX
AMP1−
AMP1+
SSR0
D2A
SSR1
SSR2
PWM0
TXD
RXD
ADC2
ADC3
GPIO1
RESET
X1
16MHz
C8
C9
AC/DC Relay
SSR0
U3
RELAY_VO14642AT
SSR_0A
SSR_0B
SSR1
U4
RELAY_VO14642AT
SSR_1A
SSR_1B
SSR2
U5
RELAY_VO14642AT
SSR_2A
SSR_2B
I/O HEADERS
SSR_0A
SSR_0B
J3
RELAY
SSR_1A
SSR_1B
J4
RELAY
SSR_2A
SSR_2B
J5
RELAY
GPIO0
GPIO1
GPIO2
MISO
MOSI
SCK
VCC
GND
J6
GPIO
AMP0+
AMP0−
AMP1+
AMP1−
D2A
PWM0
PWM1
J7
AMP/D2A
ADC1
ADC2
ADC3
ADC4
ADC5
AREF
VCC
GND
J8
ADC
CAN_H
CAN_L
J9
CAN
J2
USB
V_USB
GND
GND
USBD+
USBD−
GND
U2
VCCIO
VCC
USBD−
USBD+
RESET
OSCI
OSCO
3V30UT
TXD
RXD
RTS
CTS
DTR
DCR
DCD
RI
CBUS0
CBUS1
CBUS2
CBUS3
CBUS4
AGND
GND
GND
GND
TEST
FT232RL
FTDI_TX
FTDI_RX
RTS
CBUS0
CBUS1
C1
PROGRAMMING PORT
MISO_A
SCK_A
RESET
ISP0
ISP1
VCC
MOSI_A
GND
SCK_A
MISO_A
MOSI_A
ADC1
PWM0
TXD
RESET SW
R9
10k
SW1
SW_PUSH
RESET
CAN TRANCEIVER
IC2
CANRX
CANTX
RXD
TXD
Vref
Rs
VDD
SO8
VSS
CANH
CANL
MCP2551-I/SN
CAN_H
CAN_L
R10
10k
FTDI <-> AVR
FTDI_TX
R2
1k
TXD
FTDI_RX
R3
1k
RXD
GND
R4
1k
RTS
RESET
0.1u
C
RTS
CBUS0
CBUS1
CANTX
CANRX
D2
D3
D4
D5
RX?
TX?
CANTX
CANRX
R5
1k
R6
1k
R7
1k
R8
1k
ATMEGA 16M1 Automotive AVR
Engineer: John Gehrig
Lafayette College
File: ATMEGA16M1.sch
Sheet: /
Title: LFEF CAN Communication Board
Size: USLetter
Date: 10 mar 2015
Rev: 0
KiCad E.D.A.
Id: 1/1

Microcontroller Code/Toolchain

{INSERT CODE HERE/TOOLCHAIN IMAGES}

Client - Server Architecture

Request - Response Model

- Client Initiates Request
- Server Responds to Request
- JSON Object Passing

Unix-Style Commands

- Modular, Flexible, Expandable

Server Command Architecture

Server Command Syntax:

CMD NAME	FLAGS	OPTIONS	ARGUMENTS

CMD NAME -

Unique command name, identifies specific server task to carry out.

FLAGS -

Enables or disables specific command functionality or output.

OPTIONS -

Utilized to pass data from the client to server.

ARGUMENTS -

End objects affected by the server command.

Syntax Notes:

All command Options, Flags, Arguments space separated.
Flags begin with the “-” character.
Options are followed by a string containing no spaces.

Server - Client Demonstration

{INSERT VM/Host Images Here}

Server - Client Code Review

{INSERT PYTHON TCP SERVER CODE HERE}

Roadmap

8. Meet the Afternoon Teams
9. Interface Control Review
10. Vehicle Supervisory Control and Data Acquisition (VSCADA)
    a. Daemon
    b. Interfacing
    c. **User Applications**
    d. Data Storage
11. Dynamometer (DYNO)
    a. Decomposition and Definition
    b. Integration and Recomposition

Front-End User Application

- VSCADA Maintenance Application
  - Contains all required user functionality in one program
  - Runs on remote PC (pit station PC) and vehicle embedded computer with touchscreen
  - Demo mode can be selected in the maintenance application
  - Password is used to protect maintenance mode from unauthorized access

Maintenance App - Measurands/Input

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Maintenance App - Add/Edit Sensor Window

Maintenance App - Measurand Graph Window

Maintenance App - Hardware/Output

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Maintenance App - Rules

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Maintenance App - Settings

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Roadmap

8. Meet the Afternoon Teams
9. Interface Control Review
10. Vehicle Supervisory Control and Data Acquisition (VSCADA)
    a. Daemon
    b. Interfacing
    c. User Applications
    d. Data Storage
11. Dynamometer (DYNO)
    a. Decomposition and Definition
    b. Integration and Recomposition

Round Robin Database (RRD)

- High performance data logging and graphing system for time series data

- Uses circular buffer to store data
  - Data size does not expand with time.
  - Overwrite the data once it reach the starting point

- Framework for storing measurement averages, min,max and derivative

- Graphical presentation for both stored and archived data.

RRD Creation

- Size of the database can be determined at creation time.
- Specify the step time (rate at which the database update the data)
- Specify the step time for archives too. For different archives, different time step can be applied.

Round Robin Archives (RRA)

- Average
- Minimum
- Maximum
- Last

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

RRD for this project

- Monitor the time series data.
- Take care of time and space complexity.
- Very simple in structure.
- Manipulate the stored data and archived the data.
- Graphing tools.

Database and Configuration

- Database for sensor list and most of the configurations
- Text files for logic related (startup procedures, logic switches, etc)

Database

- SQL is used for the followings:
  - Table 1: restoring sensor information
    - sensor hierarchy
    - CAN id
    - sampling rate
    - rrd file reference
      - This means, all data is going to be stored in RRD, but a reference is kept in SQL as a cleaner solution
  - Table 2: type of sensor
    - analog in, analog out, digital in, digital out
    - need to know this for sending out data on CAN

Database

- Table 3: warning/error threshold
  - High and low values for warnings, errors and failures
  - Reaching these values will trigger some certain actions, which is referred in the next table
- Table 4: warning/error actions
  - Each of the actions here is generic and configurable
- Table 5: calibration
  - have slop and offsets

SQL DB: ‘Sensor_Table’

Name	id_CAN	id_Sensor	Type	Sample_Rate

Overwrite_Period	Units	Factor	Offset	RRD_DB

SQL DB: ‘Sensor_Type’

id	Description	Type	Direction

SQL DB: ‘Sensor_Levels’

id	Warning_Low	Warning_High	Error_Low	Error_High	Fail_Low	Fail_High

SQL DB: ‘Sensor_Actions’

id	Action_Name	Priority_Level	Effector_Name	Effector_State

id	Name	id_CAN	id_Sensor	Type	Sample_Rate	Overwrite_Period	Units	Factor	Offset	RRD_DB
1	TSV/Pack1/Voltage	0	1	Analog	20	24	V	1	0	/data/TSV/pack1/voltage.rrd
2	TSV/Pack1/Current	1	2	Analog	21	25	A	1	0	/data/TSV/pack1/current.rrd
3	TSV/Pack1/SOC	2	3	Analog	22	26	%	1	0	/data/TSV/pack1/SOC.rrd
4	TSV/Pack1/Fuse_Temperature	3	4	Analog	23	27	°C	1	0	/data/TSV/pack1/fuse_temperature.rrd
5	TSV/Pack1/AMS1/Temperature	4	5	Analog	24	28	°C	1	0	/data/TSV/pack1/AMS1/temperature.rrd
6	TSV/Pack1/AMS1/Voltage	5	6	Analog	25	29	V	1	0	/data/TSV/pack1/AMS1/voltage.rrd
7	TSV/Pack1/AMS1/Current	6	7	Analog	26	30	A	1	0	/data/TSV/pack1/AMS1/current.rrd
8	TSV/Pack1/AMS2/Temperature	7	8	Analog	27	31	°C	1	0	/data/TSV/pack1/AMS2/temperature.rrd
9	TSV/Pack1/AMS2/Voltage	8	9	Analog	28	32	V	1	0	/data/TSV/pack1/AMS2/voltage.rrd
10	TSV/Pack1/AMS2/Current	9	10	Analog	29	33	A	1	0	/data/TSV/pack1/AMS2/current.rrd
11	TSV/Pack1/AMS3/Temperature	10	11	Analog	30	34	°C	1	0	/data/TSV/pack1/AMS3/temperature.rrd
12	TSV/Pack1/AMS3/Voltage	11	12	Analog	31	35	V	1	0	/data/TSV/pack1/AMS3/voltage.rrd
13	TSV/Pack1/AMS3/Current	12	13	Analog	32	36	A	1	0	/data/TSV/pack1/AMS3/current.rrd
14	TSV/Pack1/AMS4/Temperature	13	14	Analog	33	37	°C	1	0	/data/TSV/pack1/AMS4/temperature.rrd
15	TSV/Pack1/AMS4/Voltage	14	15	Anal	34	38	V	1	0	/data/TSV/pack1/AMS4/voltage.rrd

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Configuration

- Bash style
- Read during startup, and bad syntax will raise exceptions and the car will be disabled from driving
- Switches can be updated and modified by maintenance app
- Will be stored under same directory and database in a separate folder
- Is accessible from debug port

http://img.talkandroid.com/uploads/2011/08/seal-of-approval.jpg

Acceptance Testing

- Show that VSCADA meets all requirements as both:
  - part of integrated LFEV system
  - standalone software system
- Strive for maximum amount of test automation/avoid recompiling software
- Main criteria:
  - Exception handling
  - Automated hardware detection/configuration
  - Logging, plotting and storing of measurands
  - Controlling system state

Acceptance Testing (cont.)

Test configurations:

- Config A: VSCADA powered by 12 V power source
- Config B: VSCADA interfaced with GLV
- Config C: VSCADA interfaced with GLV and TSV
- Config D: VSCADA interfaced with GLV, TSV and DYNO

Acceptance Testing (cont.)

T000 - System Startup/Shutdown and GLV Data Logging

- Config B
- Tests:
  - Automatic startup without user interaction once GLV power is provided
  - Logging of GLV measurands
  - Keeping of backup in case of unexpected shutdown

Acceptance Testing (cont.)

T001 - Safety Checking/Exception Handling

- Config D
- Tests:
  - Lighting of Ready LED on cockpit if all subsystems are in a safe state when Ready-to-Drive buttton pressed
  - Lighting of warning LEDs to warn user and prevent drive mode being activated by Ready-to-Drive button if unsafe condition occurs (exception handling)
  - Examples are open safety loop, voltage threshold exceeded, temperature threshold exceeded, missing config file for sensors

Acceptance Testing (cont.)

T002 - Maintenance App Operation

- Config D
- Tests:
  - Requirement of proper user credentials to login to maintenance mode
  - Logging and storing of all subsystem measurands (TSV pack/cell voltages, currents, temperatures, GLV voltage, current, Dyno torque, RPM)
  - Allowing user to control all aspects of VSCADA such as disabling safety checks, disabling data logging, and programming individual shutdown rules

Acceptance Testing (cont.)

T003 - Drive Mode Operation

- Config D, then repeat with Config A (simulated throttle)
- Tests:
  - Accurate reporting of measurands while driving
  - Logging of exceptions should unsafe condition occur while driving
  - Demo operation of vehicle through software throttle if other subsystems not available

Acceptance Testing (cont.)

T004 - Pack Charging/Discharging

- Config C
- Tests:
  - Displaying that accumulator is charging
  - Displaying that accumulator is discharging

Acceptance Testing (cont.)

T005 - Reliability Test

- Config D
- Tests:
  - System can run through series of drive modes/simulations and maintenance configuration changes over period of 24 hours without failure

Acceptance Testing (cont.)

T006 - Maintainability Test

- Config D
- Tests:
  - Novice user can solve frequently occurring problem
  - Expert maintenance individual can solve unexpected problem
  - New sensors can be added to system without software recompilation
  - VSCADA software can be installed easily using “make/install” on different computer

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Schedule

Week 9

Demonstration System Integration & Debugging

System parts designed in the past six weeks will be integrated into a cohesive system demonstration for CDR, and for displaying system capabilities to other groups.

CAN Communication PCB Fabrication

The General Sensor CAN Communication PCB GERBER files will be ready for fabrication and sent out for production.

Week 10

Preliminary Demonstration System

A primitive scada system will be functioning, and ready for demonstration to other groups. This system should be capable of allowing groups to test communications between themselves and the SCADA system in the future.

Week 11

SCADA Server Maintenance Mode

The main system server will be capable of performing all 'Maintenance Mode' tasks, and interfacing with all 'Maintenance Mode' client interfaces.

QA Report Submitted

Deliverable **D006** (QA Report) will be submitted.

Schedule cont'd

Week 12

System Integration & Debugging

Any remaining components not added to the SCADA system will be added at this time. Debugging and integration into other vehicle sub-systems.

SCADA Server Demo **Mode**

The main system server will be capable of performing 'Demo Mode' tasks.

Week 13

Final ATR Report Submitted

Deliverable **D005** (ATR Report) will be submitted.

System Integration & Debugging

Any remaining components not added to the SCADA system will be added at this time. Debugging and integration into other vehicle sub-systems.

Dynamometer Communication Library

The main system is capable of sending messages to the Huff Box over serial ports.

Schedule cont'd

Week 14

System Integration & Debugging

Any remaining components not added to the SCADA system will be added at this time. Debugging and integration into other vehicle sub-systems.

System Documentation

All project documentation will be finalized and completed.

Completed Maintenance **Manual Submitted**

A VSCADA Maintenance Manual Working Draft will be submitted.

Week 15

Final Report & Maintenance Manual Submitted

Deliverable **D003** (Final Report) will be submitted.

System Errata Documentation

Any known bugs, and system errata will be documented for use by future students.

Budget

Item/Group	Total
SCADA	
Embedden Computer System	270
Dashboard LCD display and controller	80
Wireless Radio	50
Slave Sensor Micro Controller Hardware	100
Debugger	80
Programmer	10
Total	590
Budget:	715

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Roadmap

8. Meet the Afternoon Teams
9. Interface Control Review
10. Vehicle Supervisory Control and Data Acquisition (VSCADA)
    a. Daemon
    b. Interfacing
    c. User Applications
    d. Data Storage
11. **Dynamometer (DYNO)**
    a. Decomposition and Definition
    b. Integration and Recomposition

http://ops.fhwa.dot.gov/publications/seitsguide/images/image068.jpg

Roadmap

8. Meet the Afternoon Teams
9. Interface Control Review
10. Vehicle Supervisory Control and Data Acquisition (VSCADA)
    a. Daemon
    b. Interfacing
    c. User Applications
    d. Data Storage
11. Dynamometer (DYNO)
    a. **Decomposition and Definition**
    b. Integration and Recomposition

Concepts of Operation

- Generate a torque curve
- Develop a software simulation of the car
- Develop a hardware simulation of the car
- Determine the car gear ratio

System Requirements

- Motor/Dyno Selection
- Motor Controller
- Software
  - Data Acquisition
  - Throttle Control
- Interfaces
  - VSCADA
  - GLV
  - TSV
- Safety

Motor Selection

- HPEVS AC 50-27.28

Photo: HPEVS

Dynamometer Selection

- Huff HTH-100

Motor Controller

- Curtis 1238R-7601

Photo: evwest.com

Interfaces

- VSCADA - Interface for data acquisition and throttle control
- GLV - Interface for power and data transmission
- TSV - Interface to power supply

Software

VSCADA - Dyno

- Data Acquisition
  - RPM
  - Torque
  - Temp - Motor and Controller
  - RMS Current
  - Voltage
- Throttle Control

Safety

- Emergency Shutoff
  - Must be have an emergency stop
  - Must be shut down when GLV is down
- Oil Temperature Shutoff
  - Must shut down when temperature limit is exceeded
- Galvanic Isolation
  - Must separate high and low voltage subsystems
- Motor Controller Contact Shield
  - Prevents accidental contact with terminals

High-Level Design

- ICD Layouts
- Safety Shutoff
- Throttle
- HUFF - VSCADA Interface
- Motor Controller
  - Cooling
  - Safety
- Galvanic Isolation

ICD Layout

- Two configurations
  - Dyno Testing Configuration:

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

ICD Layout

- Two configurations
  - Integrated Design Configuration:

Safety Shutoff

- Requirements -
  - Must include emergency stop
  - Must include temperature shutoff
- Design -
  - Use the power supply control inputs. These control mechan contactors.

Huff - VSCADA interface

- USB interface
- Utilizes serial communication
- Based on a call and response system
- Used to acquire data and set values
- Protocol is defined by the chip on data acquisition board

Motor Controller Cooling

- Must regulate MC temperature
  - Storage ambient temperature range:-40°C to 95°C
  - Operating ambient temperature range:-40°C to 50°C
  - Internal heatsink operating temperature range:-40°C to 95°C
- Utilize a Water Cooling system
  - Pump→ MC→ Radiator→ Pump
  - Mounted Cooling Housing
  - Effectiveness to be determined upon delivery of parts

Motor Controller Safety

- Must prevent conductive injury from MC ports
  - High Voltage
- Cover all electrical hazards to prevent accidental contact
  - Use non-conductive plastic cover

Throttle

- Must control the throttle input of the MC
  - Throttle input is 0 to +5 volts
  - VSCADA must be connected
  - Must be scriptable for testing
- Use two systems:
  - Use a VSCADA CANbus node with an analog output for the integrated system
  - Use an Arduino connected over USB to control an analog output

Galvanic Isolation

- High/Low voltage CAN must be separated
- High/Low Voltage Throttle must be separated

Layout Review:

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Detailed Design

- Simulations
  - Motor
  - Car
  - Track
- Safety
  - Independent shutoff
  - Insulating covers
- Throttle
  - Independant solution
  - VSCADA solution
- Motor Controller
  - Isolation
  - Parameters
  - Wiring Diagram
  - Cooling
  - Safety
- Room Wiring
  - Testing config
  - Integrated config

Simulations - Motor

Using IEEE circuit equivalent model developed the following torque curve

Induction Motor
2.5
2
1.5
1
0.5
0
N-m
0
1000
2000
3000
4000
5000
6000
7000
RPM

Simulations - Car/Track

Car will be reduced down to a singular body in order to simplify the static and dynamic equations required.

The track will be simulated by an array of values that will dictate the curvature and incline of the track based on position.

Simulations Layout

Safety - Independent Shutoff

- Use the input control lines
  - Directly linked to mechanical contactors
- Interface is a 37-pin D-Sub connector
  - Need only the start and stop inputs

Figure 3.26. Digital input control lines

Safety - Independent Shutoff

- Solution: simple rack mounted unit

Safety - Insulating Covers

- Plastic Cover
  - Non-conductive
  - Transition temperature higher than cutoff temp
- Aluminum connecting rods

Throttle - Independent Solution

- Need to control throttle from a computer
  - Arduino with USB connection
- No analog outputs
  - Low pass filter on a PWM
- Scripting
  - Write values in a python script

http://arduino.cc/en/uploads/Main/ArduinoMega2560_R3_Fronte.jpg

https://www.python.org/static/community_logos/python-logo.png

Throttle - Independent Solution

Python script writes PWM values, which are filtered to analog voltages

Throttle - VSCADA Solution

- USB connection from VSCADA to Huff Box
- Serial communication
- Call and response
- Protocol dictated by DAQ chip
- Generate PWM signal
  - Relates RPM to voltage
  - PWM is low pass filtered

Motor controller - Isolation

- Isolates motor controller from GLV systems
  - Isolate CANbus
    - Using TI ISO1050DUBR
    - Voltage step down using LM7805
  - Isolate throttle
    - Using 6N135 optocoupler
    - low pass filter PWM signal

Motor Controller - Parameters

Program		
User Settings		
Speed Settings		
Forward Speed	6500	rpm
Reverse Speed	6500	rpm
Econo Speed	6500	rpm
Accel Rates		
Normal Accel Rate	0.4	Seconds
Econo Accel Rate	1.0	Seconds
Throttle Settings		
Throttle Type	2	
Deadband	0	Volt
Throttle Max	5	Volt
Mapped Throttle	50	%
Brake Pedal Settings		
Brake Type	0	
Brake Deadband	0.30	Volt
Brake Max	3.50	Volt
Regen Brake Light Th...	50	Ampere
Current Limits		
Normal Neutral Braking	15	%
Econo Neutral Braking	25	%
Shift Neutral Braking	7	%
Normal Drive Current...	100	%
Econo Drive Current ...	60	%
Brake Current Limit	10	%
Idle Setup		
Idle Enable	Off	
Clutch Start Enable	Off	
Idle Speed	600	rpm
Idle Torque	50	%
Creep Torque	0	%

Motor Tuning		
Motor Type	50	
Base Speed	3000	rpm
Field Weakening	50	%
Econo Field Weakening	20	%
Weakening Rate	60	%
Main Contactor		
Main Contactor Voltage	48	Volt
Main Holding %	80	%
Display Menu Items		
Auto Scroll	On	
Scroll Delay Time	10	Seconds
Display SOC	Off	
Display Motor RPM	On	
Display Battery Amps	On	
Display Voltage	On	
Display Motor Temp	On	
Display Controller Temp	On	
Display Minimum Volt...	On	
Display Maximum Cur...	On	
BMS		
BMS Installed	Off	
BMS Address	768	
User Undervoltage	80	%
Low Cell Begin Cutback	2.800	Volt
Low Cell Full Cutback	2.300	Volt
Max Current at Full C...	50	%
Maximum Cell Voltage	3.700	Volt
Low SOC Cutback	20	%
Max Current at Low ...	30	%
Dual Drive		
Dual Drive Mode	Off	
Response Timeout	200	ms

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Motor Controller - Wiring

Testing w/ Power Supply

Motor Controller - Wiring

Testing w/ TSV Packs

Motor Controller - Wiring

Suggested in-vehicle wiring

Motor Controller - Cooling

Room Wiring - Testing Config

Room Wiring - Integrated Config

System Integration

- Two configurations
  - Dyno Testing Configuration
  - Integrated Design Configuration

Dynamometer

- Dyno Testing Configuration
  - Utilizes Windows PC with software
  - Records RPM and Torque
  - Controls dynamometer
- Integrated Design Configuration
  - Utilizes VSCADA computer
  - Records RPM and Torque
  - Controls dynamometer

System Wide

- VSCADA
  - CAN data acquisition
  - Dyno data acquisition and control
  - Throttle
- TSI
  - Galvanic isolation from TSV packs
- TSV
  - Supplies power

Budget

- Wires/Tubing: $203.92
  - Water cooling tubes - $15.30
  - Power supply cables - $188.62
- Transistor/Electrical Parts - $43.22
  - Button switches - $15.76
  - Transistors - $27.46
- Connectors - $108.52
  - Panels - $107.37
  - Pin Connector - $1.15
- Total - $362.19

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Roadmap

8. Meet the Afternoon Teams
9. Interface Control Review
10. Vehicle Supervisory Control and Data Acquisition (VSCADA)
    a. Daemon
    b. Interfacing
    c. User Applications
    d. Data Storage
11. Dynamometer (DYNO)
    a. Decomposition and Definition
    b. Integration and Recomposition

Unit/Device Testing

- Throttle Testing
- Safety Shutoff
- Galvanic Isolation

Throttle Testing

- Independant Solution - T001-2
  - Using Arduino system
  - Sweep the throttle in increments of 100 RPM
  - Value must be within 5 RPM with 90% confidence

if complete:

- VSCADA Solution - T002-3
  - Using VSCADA system
  - Sweep the throttle in increments of 100 RPM
  - Value must be within 5 RPM with 90% confidence

Safety Shutoff

- Emergency Stop - T000-1
  - Press the stop, check that the system powers down
- Oil Temp. Shutoff - T000-3
  - Heat up sensor, check that the system powers down

Subsystem Verification

- Data Acquisition
  - Verification tests for:
    - Torque
    - Velocity
    - Current
    - Voltage
    - Temperature
    - Load control
- Simulation Results Comparison

Data Acquisition

- Verify sensor accuracy - T001-1
  - Torque - verified with first principles
    - Calibrate with weights on the arm
    - Verify calibration with different weights

Data Acquisition

- Verify sensor accuracy - T001-2
  - Motor Velocity - redundant measurements
    - Dynamometer encoder
    - Motor encoder
    - Handheld tachometer
  - Verified statistically

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

http://www.abqindustrial.net/store/images//products/ET-2109LSR/main_small.jpg

Data Acquisition

- Verify sensor accuracy - T001-3
  - Motor Current - redundant measurements
    - Motor controller output
    - Clamp sensor
  - Verified statistically

http://www.hiokiusa.com/images/products/m9709.gif

Data Acquisition

- Verify sensor accuracy - T001-4
  - Motor Voltage - redundant measurements
    - Motor controller output
    - Power supply reading
  - Verified statistically

http://www.magna-power.com/products/programmable-dc-power-supplies/ts-series

Data Acquisition

- Verify sensor accuracy - T001-5
  - System Temperature - redundant measurements
    - Motor controller output (Motor/Controller temp.)
    - Handheld sensor
  - Verified statistically

http://www.chinoamerica.com/products/sensors/mc1000/img/sensor_mc1000.jpg

Data Acquisition

- Verify sensor accuracy - T001-6
  - Load Variance - check torque response
    - Use steady motor RPM
    - Vary load and check that torque varies

http://curriculum.vexrobotics.com/sites/default/files/7.7.1%20Torque%20vs.%20Speed.PNG

Simulation Results Comparison

Create scripts to mimic the MATLAB simulations in hardware. This will be done in automatically controlling the valve opening in the dynamometer.

System Verification

- VSCADA Tests
  - Data acquisition
  - Throttle control
- TSI Tests
  - Checks for galvanic isolation
- TSV Pack Tests
  - With 4 packs
  - With 1 pack

VSCADA Tests

- VSCADA data acquisition via CAN
- VSCADA data acquisition from Huff Box
- VSCADA throttle control
  - Uses data from CAN and Huff Box
  - Control Dynamometer valve via Huff Box

TSI Tests

- Run the dynamometer with the TSI attached
  - T002-4 (assumes the TSI works properly)
  - If the system powers down:
    - It is not galvanically isolated
  - If the system runs:
    - It is properly isolated

TSV Tests

- Run the dynamometer with TSV power
  - If 4 packs have been completed:
    - Connect the packs to the TSI
  - If only 1 pack has been completed:
    - Connect the pack in series with the power supply
    - Power supply will make up voltage difference

System Validation

- Gear Ratio
- Torque Curve
- Final Demonstration

Gear Ratio

Knowing the maximum rpm and our desired maximum velocity we can solve for the gear ratio

Torque Curve

- At minimum:
  - Must show velocity vs. torque at an estimated load
- Goal:
  - Will show velocity vs. torque at several load points
  - Will show power consumption
- Ideal:
  - 3D graph of velocity, torque, and load

Budget

- Initially allocated money:
  - Dyno - $148
  - SCADA - $715
  - GLV - $1397.90
  - TSV - $2739.10

Budget

- Money Spent so far
  - Dyno - $362
  - TSV - $1026.03
  - SCADA - $304.26
  - GLV - $10.24

Budget

Current status of money:

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING