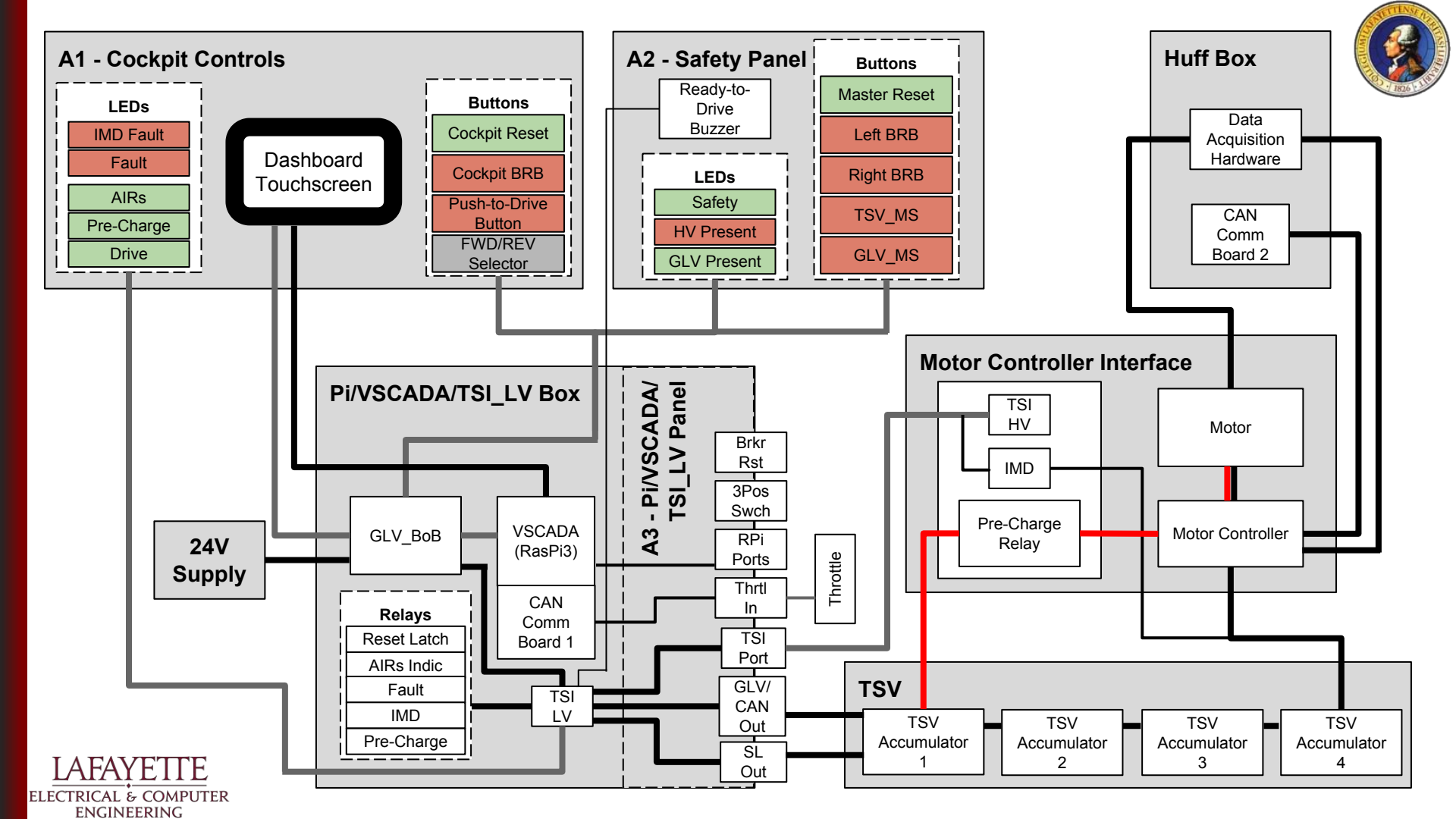
LFEV-Y4-2016

Lafayette Formula Electric Vehicle - Year 4
ECE 492 - Spring 2016

Final Presentation

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

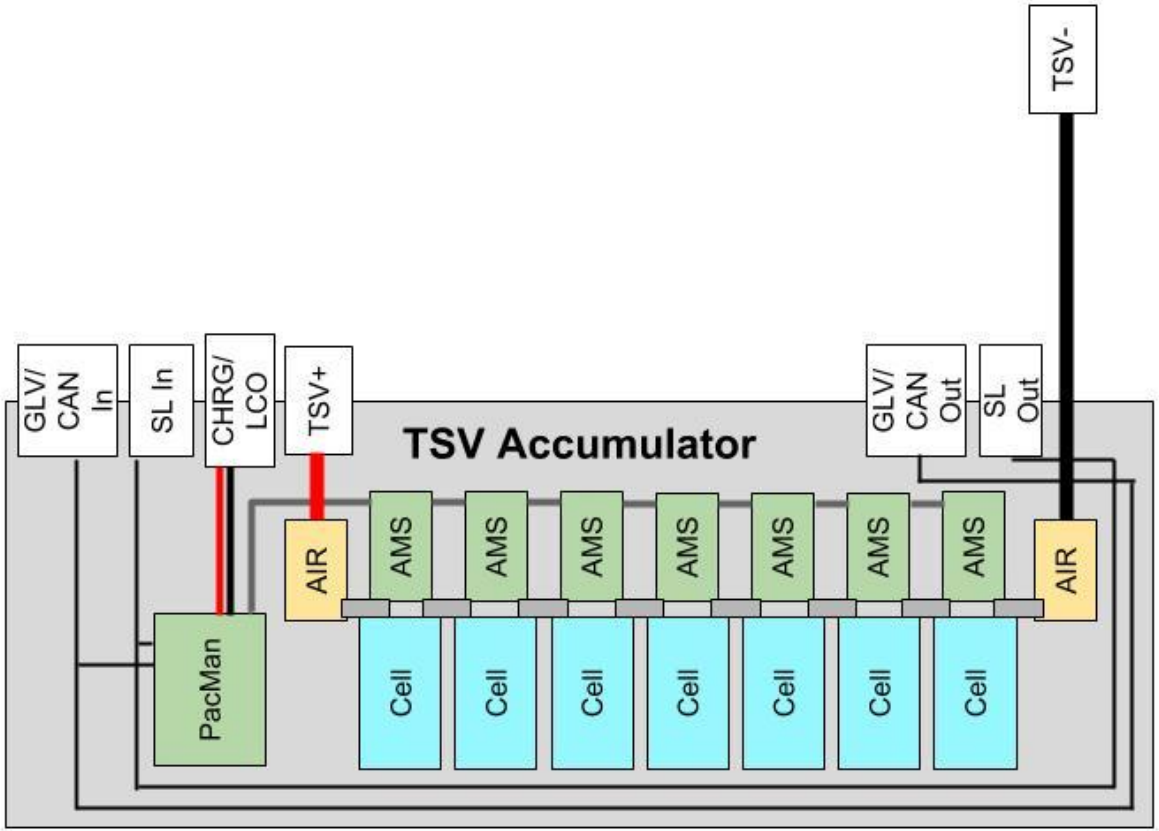
System Overview



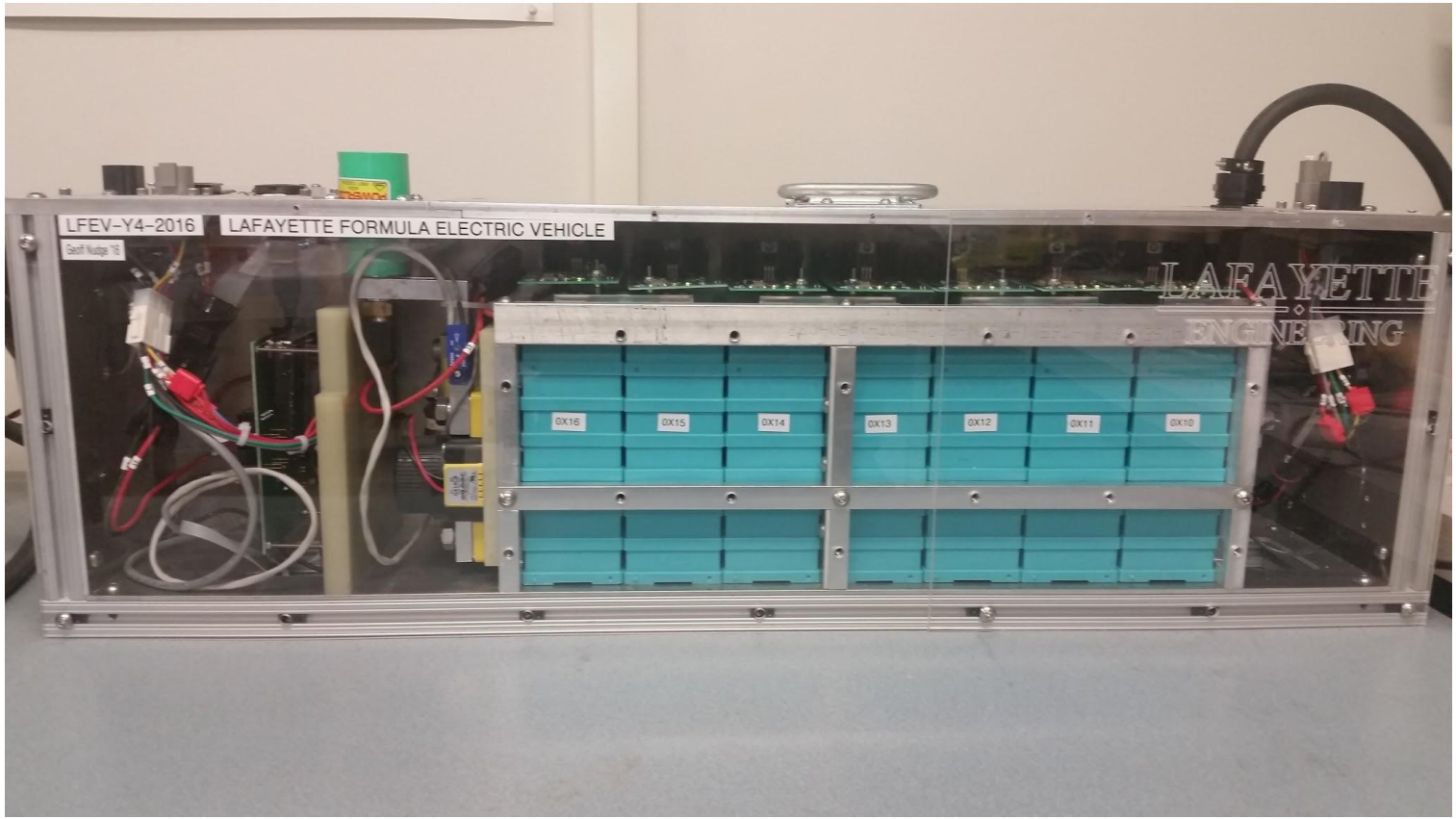
LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

TSV – Tractive System Voltage

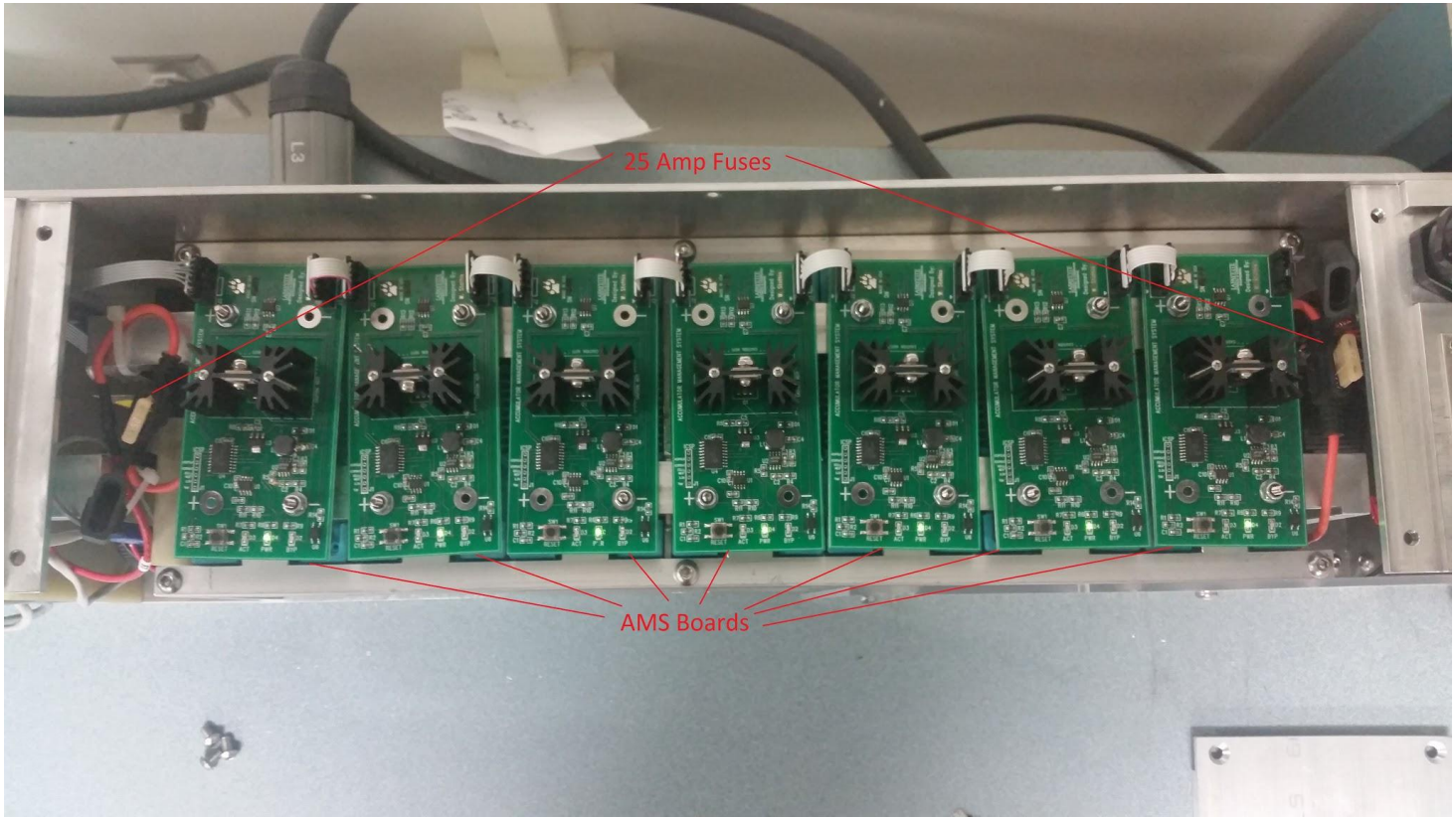
TSV


TSV-
GLV/ CAN In
SL In
CHRG/ LCO
TSV+
TSV Accumulator
GLV/ CAN Out
SL Out
AIR
AMS
AMS
AMS
AMS
AMS
AMS
AMS
AIR
PacMan
Cell
Cell
Cell
Cell
Cell
Cell
Cell

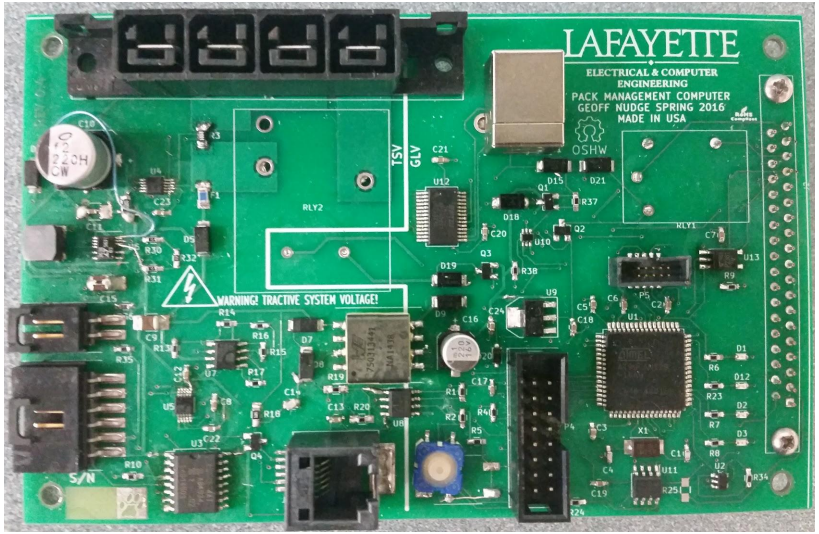
TSV

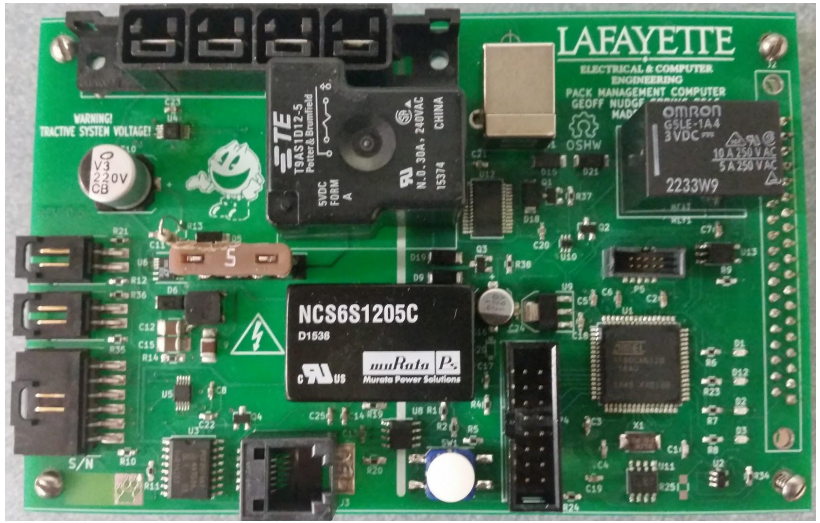

LFEV-Y4-2016
LAFAYETTE FORMULA ELECTRIC VEHICLE
LAFAYETTE
ENGINEERING
0X16
0X15
0X14
0X13
0X12
0X11
0X10

TSV



TSV


LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING
PACK MANAGEMENT COMPUTER
GEOFF NUDGE SPRING 2016
MADE IN USA
OSHW
TSV
GLV
RLY2
RLY1
WARNING! TRACTIVE SYSTEM VOLTAGE!
S/N


LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING
PACK MANAGEMENT COMPUTER
OSHW
WARNING!
TRACTIVE SYSTEM VOLTAGE!
TE
T9AS1D12-5
12VDC
FORM A
N.O. 30A, 240VAC
CHINA
15374
omron
G5LE-1A4
3VDC
10A 250VAC
5A 250VAC
2233W9
NCS6S1205C
D1536
muRata Power Solutions
S/N

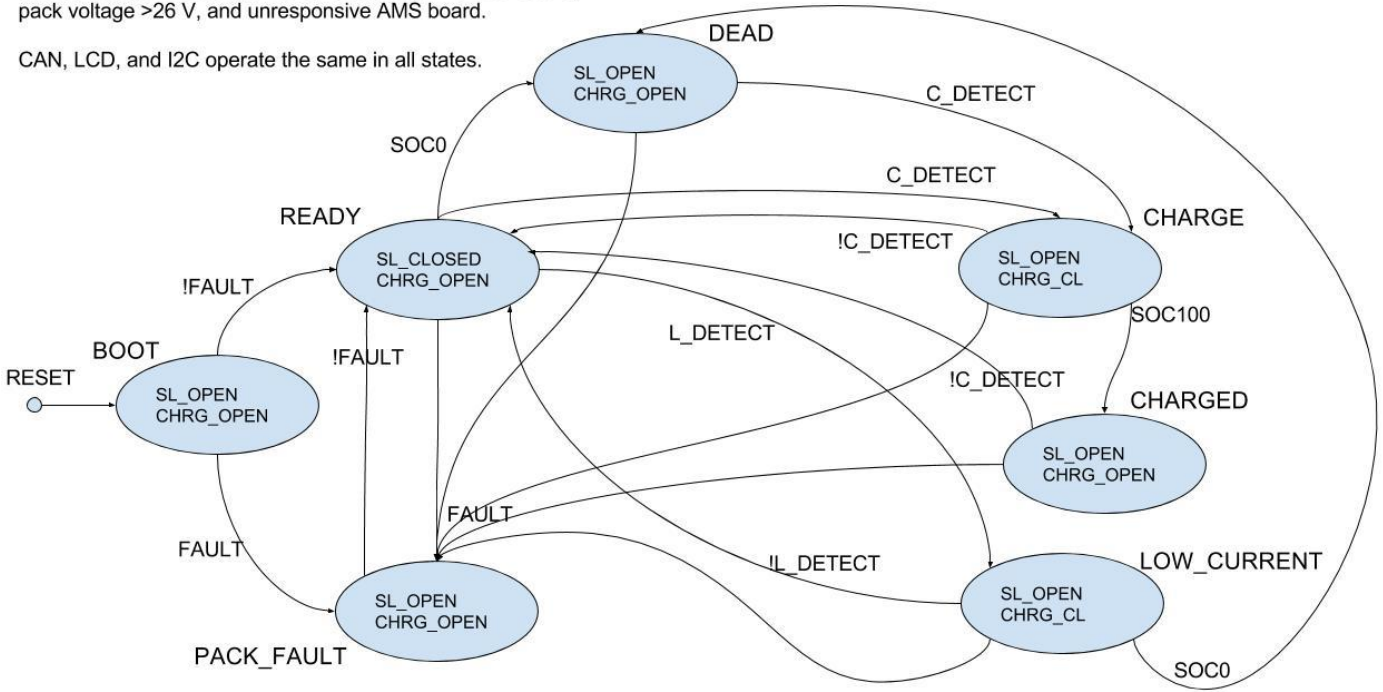
TSV

Transitions to LOW_CURRENT, CHARGE and CHARGED are locked when system is in DRIVE or DRIVE_TEST.

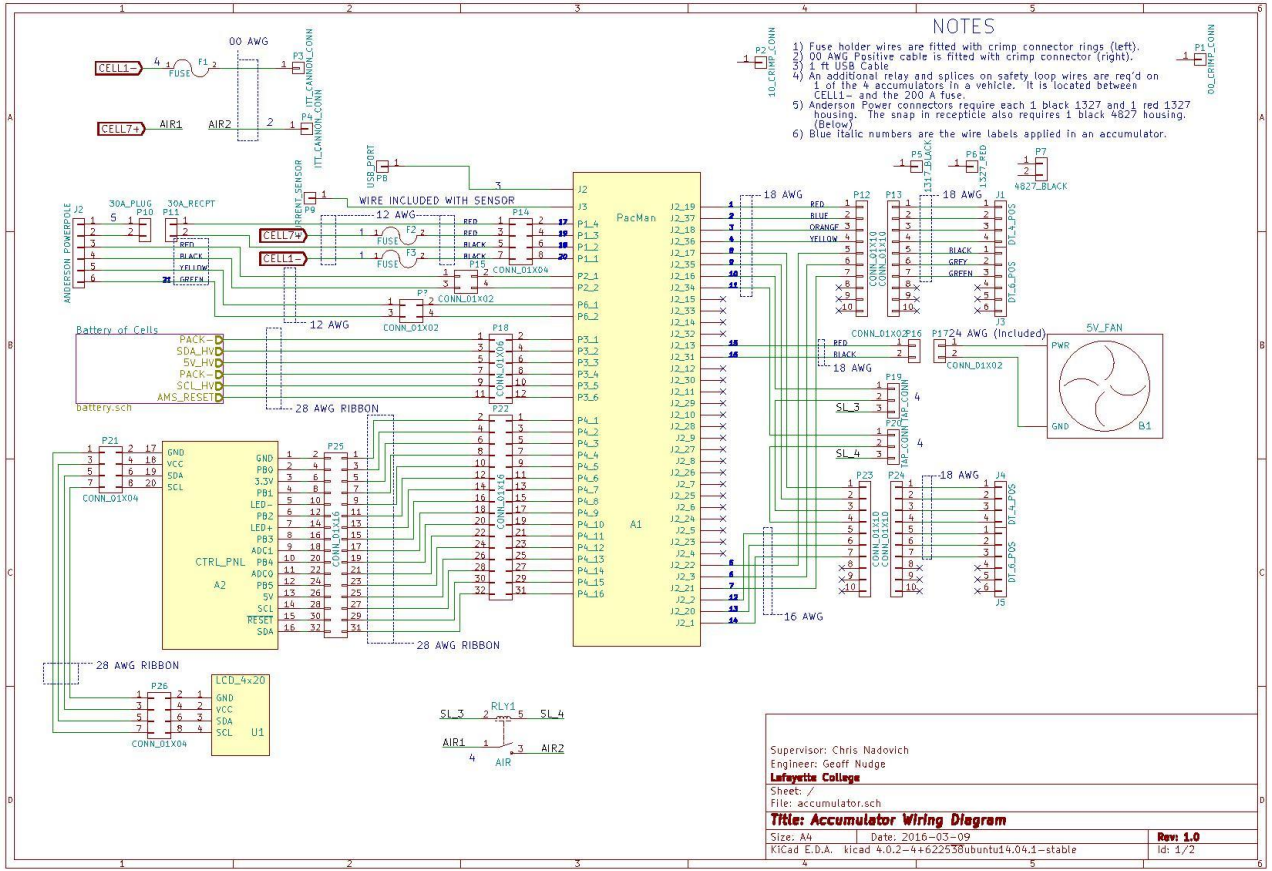
FAULT includes cell temp >60 C, cell voltage >4 V or <2.5 V, pack voltage >26 V, and unresponsive AMS board.

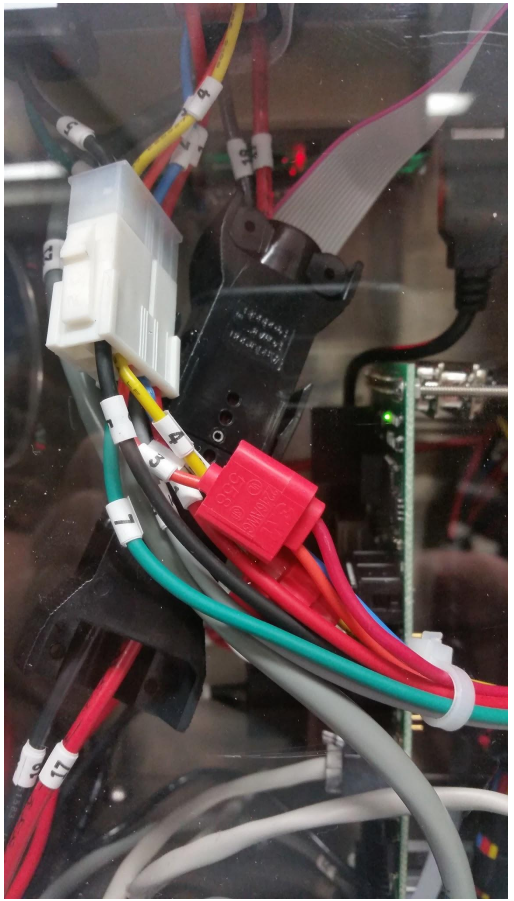
CAN, LCD, and I2C operate the same in all states.

PacMan State Diagram

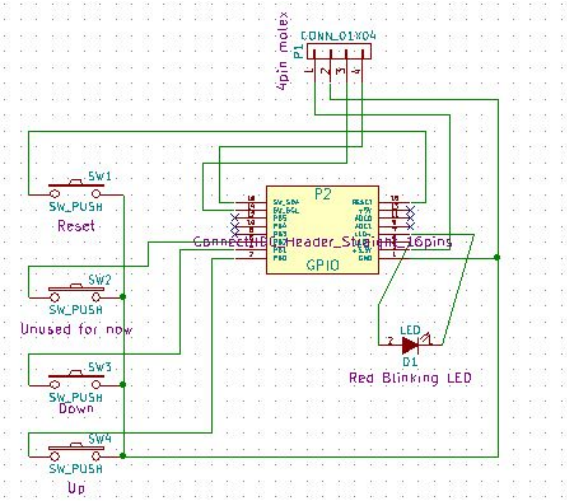


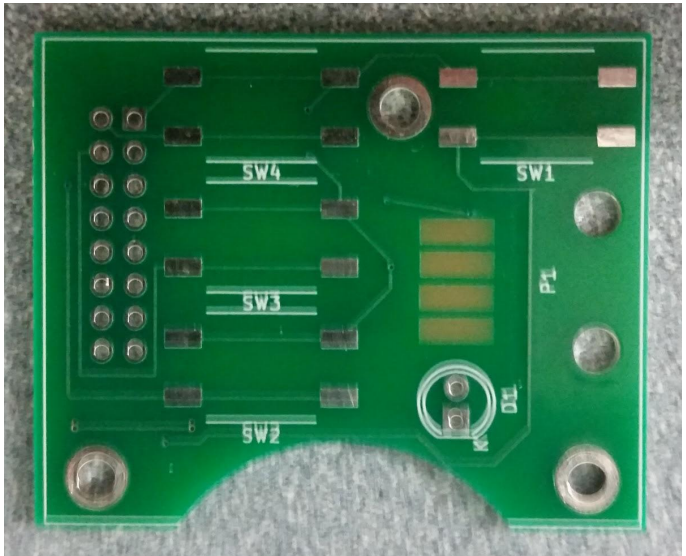
TSV

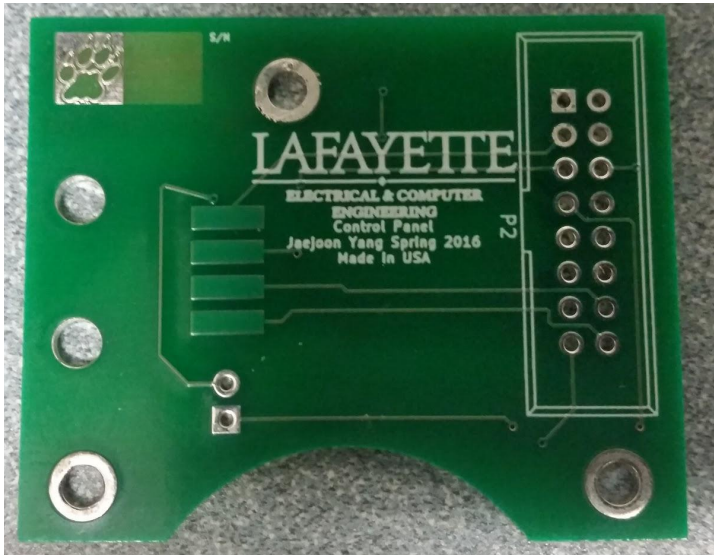

NOTES
1) Fuse holder wires are fitted with crimp connector rings (left).
2) 00 AWG Positive cable is fitted with crimp connector (right).
3) 1 ft USB Cable
4) An additional relay and splices on safety loop wires are req'd on 1 of the 4 accumulators in a vehicle. It is located between CELL1- and the 200 A fuse.
5) Anderson Power connectors require each 1 black 1327 and 1 red 1327 housing. The snap in receptacle also requires 1 black 4827 housing. (Below)
6) Blue italic numbers are the wire labels applied in an accumulator.
00 AWG
CELL1-
CELL7+
AIR1
AIR2
WIRE INCLUDED WITH SENSOR
12 AWG
18 AWG
16 AWG
28 AWG RIBBON
PacMan
A1
CTRL_PNL
A2
LCD_4x20
U1
Battery of Cells
battery.sch
5V_FAN
ANDERSON POWERPOLE
30A_PLUG
30A_RECPT
RLY1
AIR
Supervisor: Chris Nadovich
Engineer: Geoff Nudge
Lafayette College
Sheet: /
File: accumulator.sch
Title: Accumulator Wiring Diagram
Size. A4
Date. 2016-03-09
Rev: 1.0
KiCad E.D.A. kicad 4.0.2-4+622538ubuntu14.04.1-stable
Id: 1/2



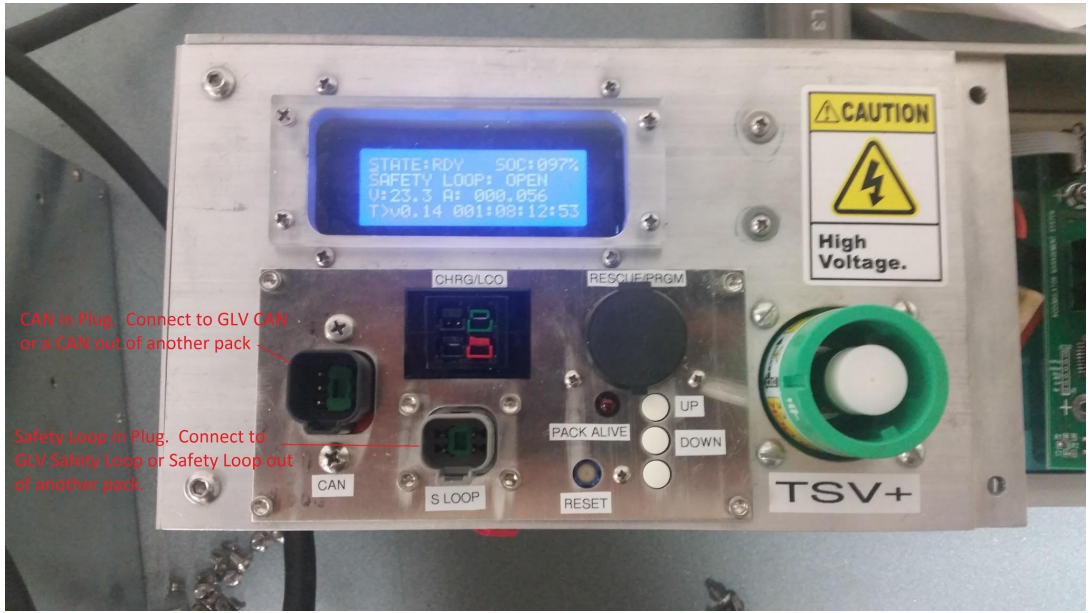
TSV

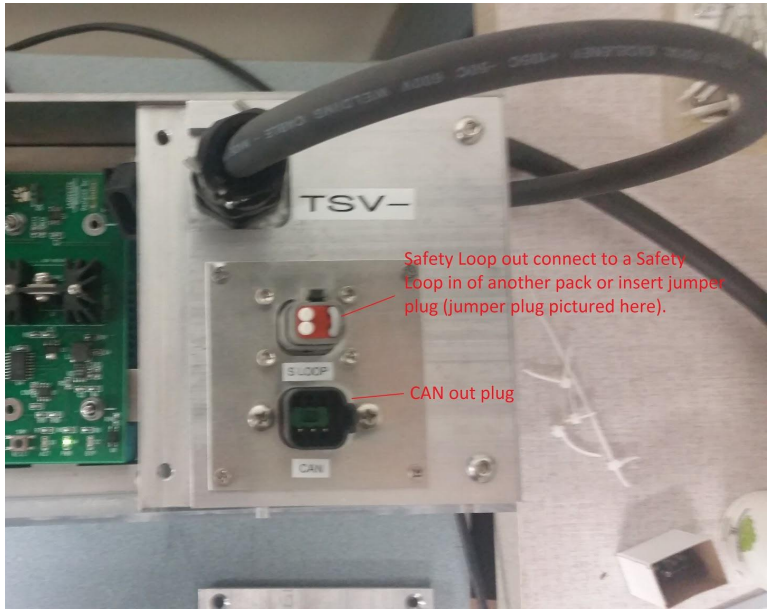

4pin molex
P1
CONN_01X04
SW1
SW_PUSH
Reset
SW2
SW_PUSH
Unused for now
SW3
SW_PUSH
Down
SW4
SW_PUSH
Up
P2
GPIO
LED
D1
Red Blinking LED


SW4
SW1
SW3
SW2
P1
D1


LAFAYETTE
ELECTRICAL & COMPUTER
ENGINEERING
Control Panel
JaeJoon Yang Spring 2016
Made in USA
P2

TSV


STATE:RDY SOC:097%
SAFETY LOOP: OPEN
V:23.3 A: 000.056
T>v0.14 001:08:12:53
CAUTION
High Voltage.
CHRG/LCO
RESCUE/PRGM
PACK ALIVE
UP
DOWN
RESET
CAN
S LOOP
TSV+
CAN in Plug. Connect to GLV CAN or a CAN out of another pack
Safety Loop in Plug. Connect to GLV Safety Loop or Safety Loop out of another pack.

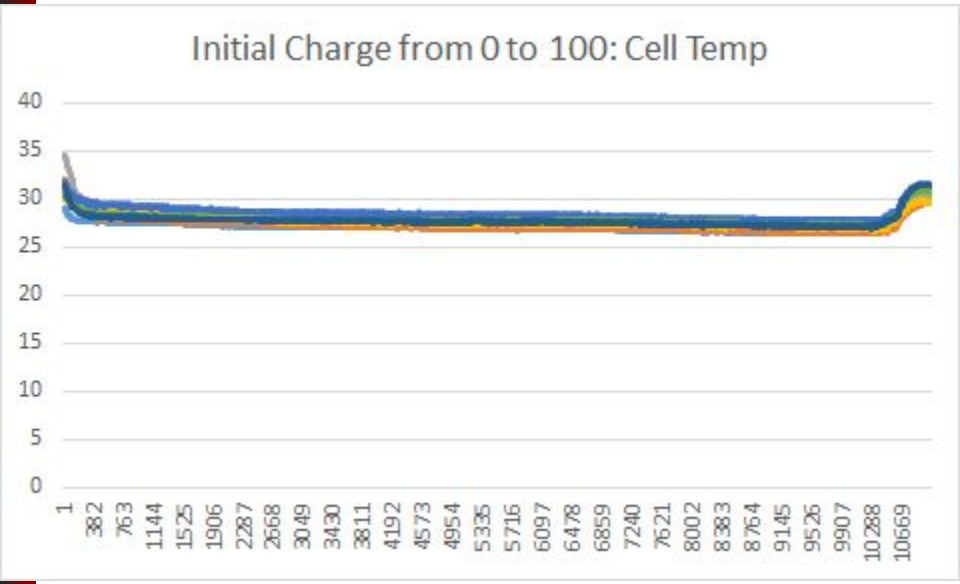

TSV–
S LOOP
CAN
Safety Loop out connect to a Safety Loop in of another pack or insert jumper plug (jumper plug pictured here).
CAN out plug

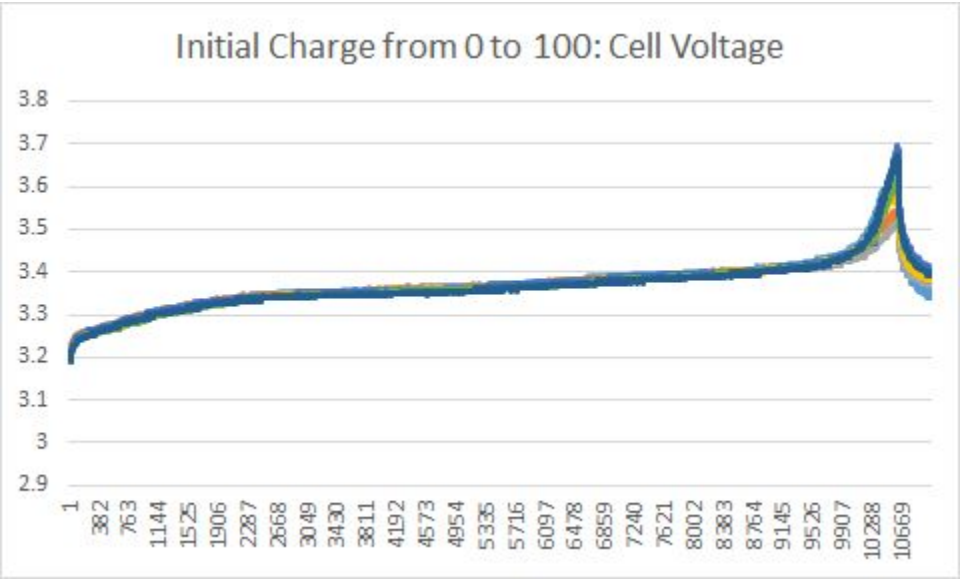
TSV


STATE:RDY SOC:100%
SAFETY LOOP: OPEN
V:23.4 A: 000.056
T>v0.14 000:02:47:02
CHRG/LCO
RES

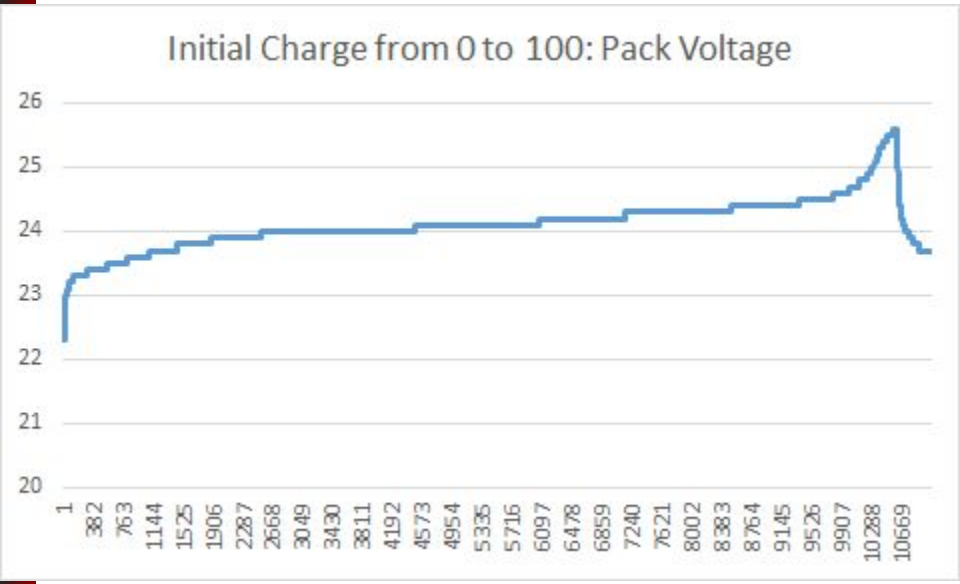

STATE:
C0_T:022.6
C0_V:3.342
T/C0>
CHRG/LCO
RESCUE

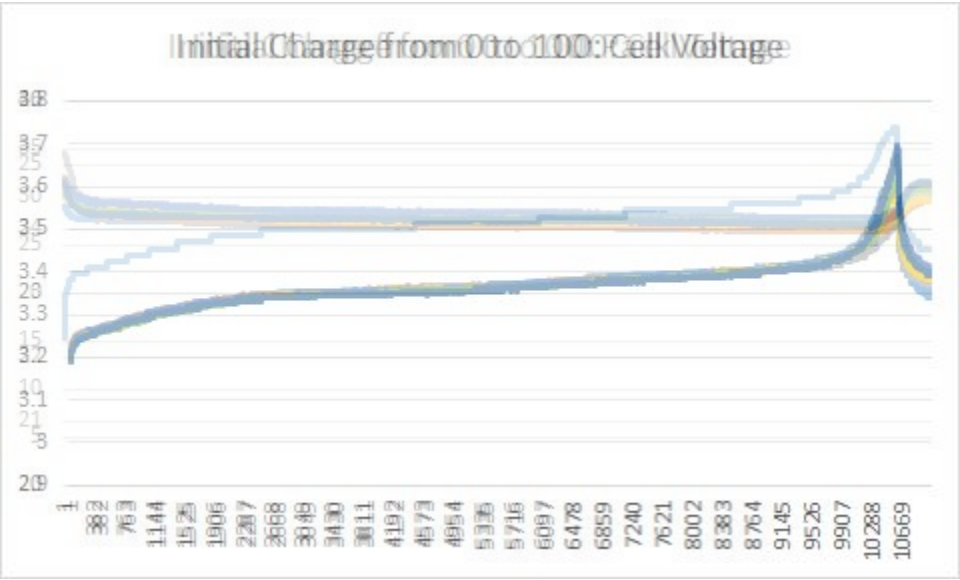
TSV


Initial Charge from 0 to 100: Cell Temp
40
35
30
25
20
15
10
5
0
1
382
763
1144
1525
1906
2287
2668
3049
3430
3811
4192
4573
4954
5335
5716
6097
6478
6859
7240
7621
8002
8383
8764
9145
9526
9907
10288
10669

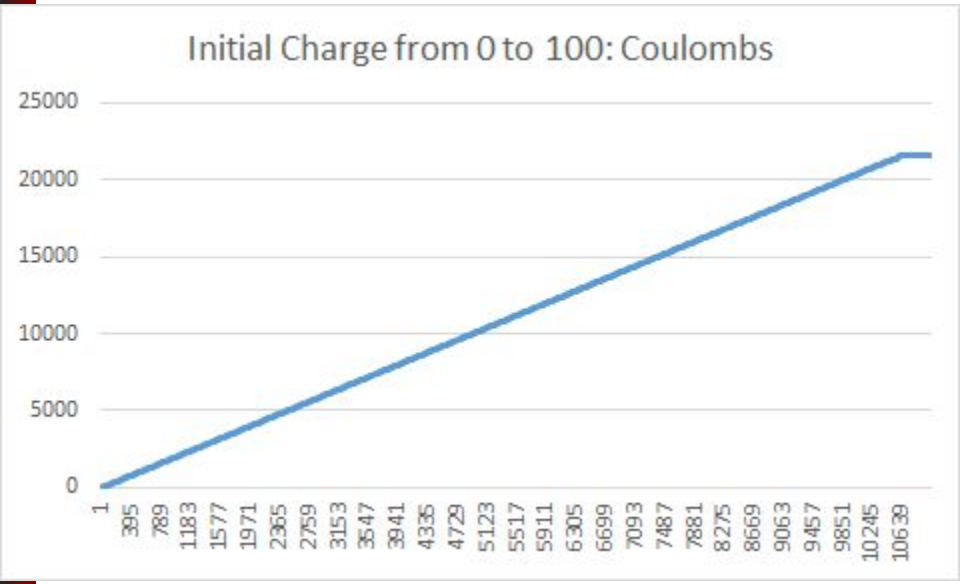

Initial Charge from 0 to 100: Cell Voltage
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
1
382
763
1144
1525
1906
2287
2668
3049
3430
3811
4192
4573
4954
5335
5716
6097
6478
6859
7240
7621
8002
8383
8764
9145
9526
9907
10288
10669

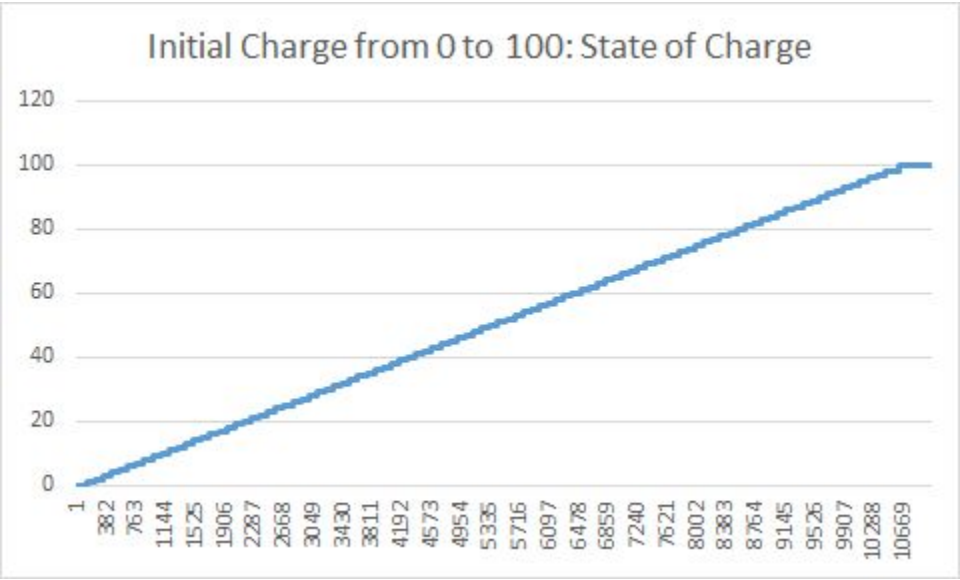
TSV


Initial Charge from 0 to 100: Pack Voltage
26
25
24
23
22
21
20
1
382
763
1144
1525
1906
2287
2668
3049
3430
3811
4192
4573
4954
5335
5716
6097
6478
6859
7240
7621
8002
8383
8764
9145
9526
9907
10288
10669

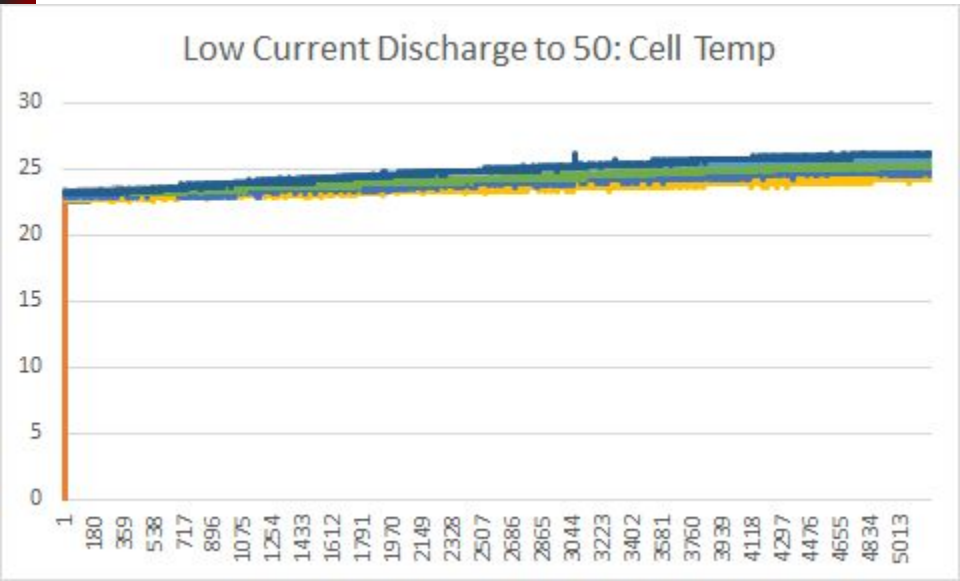

3.6
3.5
3.4
3.3
3.2
3.1
1
382
763
1144
1525
1906
2287
2668
3049
3430
3811
4192
4573
4954
5335
5716
6097
6478
6859
7240
7621
8002
8383
8764
9145
9526
9907
10288
10669

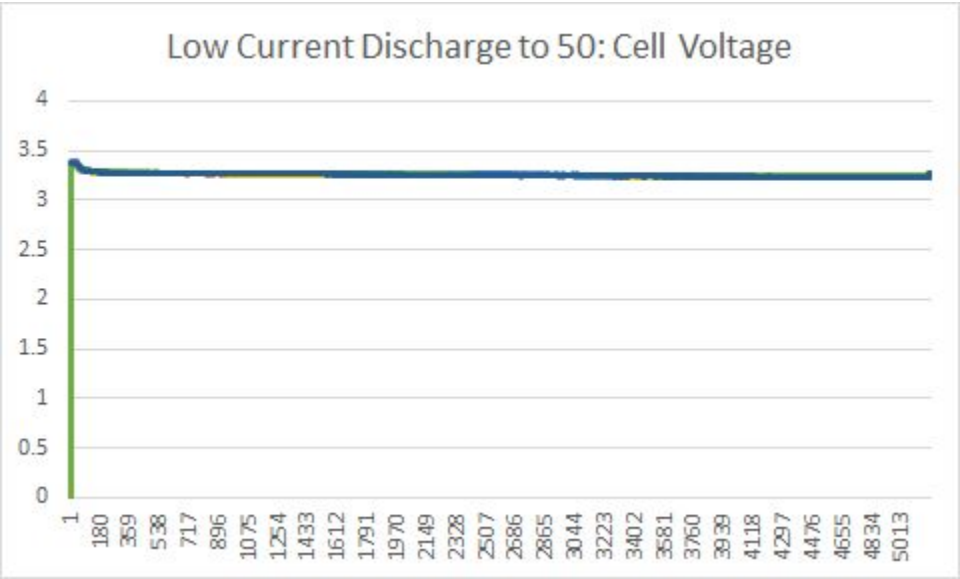
TSV


Initial Charge from 0 to 100: Coulombs
25000
20000
15000
10000
5000
0
1
395
789
1183
1577
1971
2365
2759
3153
3547
3941
4335
4729
5123
5517
5911
6305
6699
7093
7487
7881
8275
8669
9063
9457
9851
10245
10639

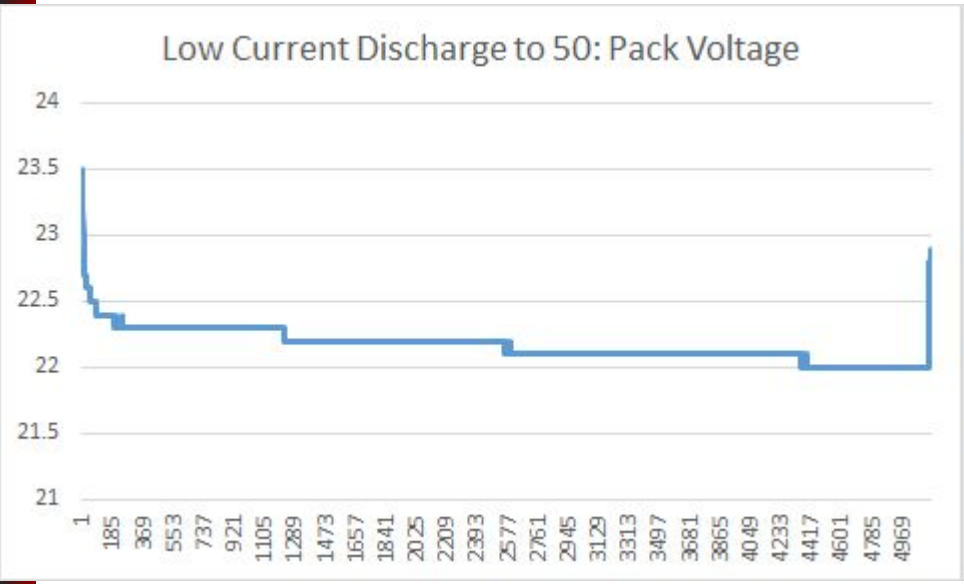

Initial Charge from 0 to 100: State of Charge
120
100
80
60
40
20
0
1
382
763
1144
1525
1906
2287
2668
3049
3430
3811
4192
4573
4954
5335
5716
6097
6478
6859
7240
7621
8002
8383
8764
9145
9526
9907
10288
10669

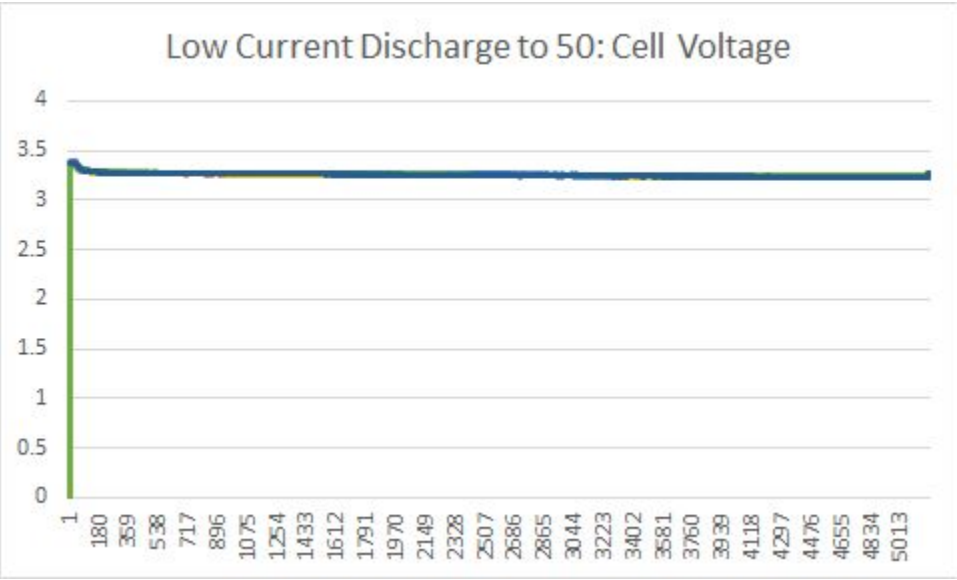
TSV


Low Current Discharge to 50: Cell Temp
30
25
20
15
10
5
0
1
180
359
538
717
896
1075
1254
1433
1612
1791
1970
2149
2328
2507
2686
2865
3044
3223
3402
3581
3760
3939
4118
4297
4476
4655
4834
5013

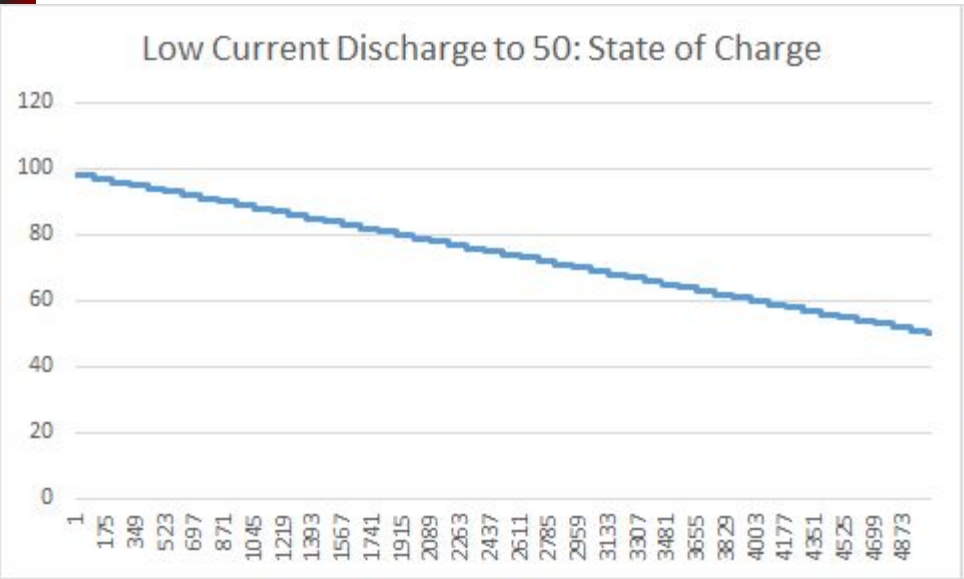

Low Current Discharge to 50: Cell Voltage
4
3.5
3
2.5
2
1.5
1
0.5
0
1
180
359
538
717
896
1075
1254
1433
1612
1791
1970
2149
2328
2507
2686
2865
3044
3223
3402
3581
3760
3939
4118
4297
4476
4655
4834
5013

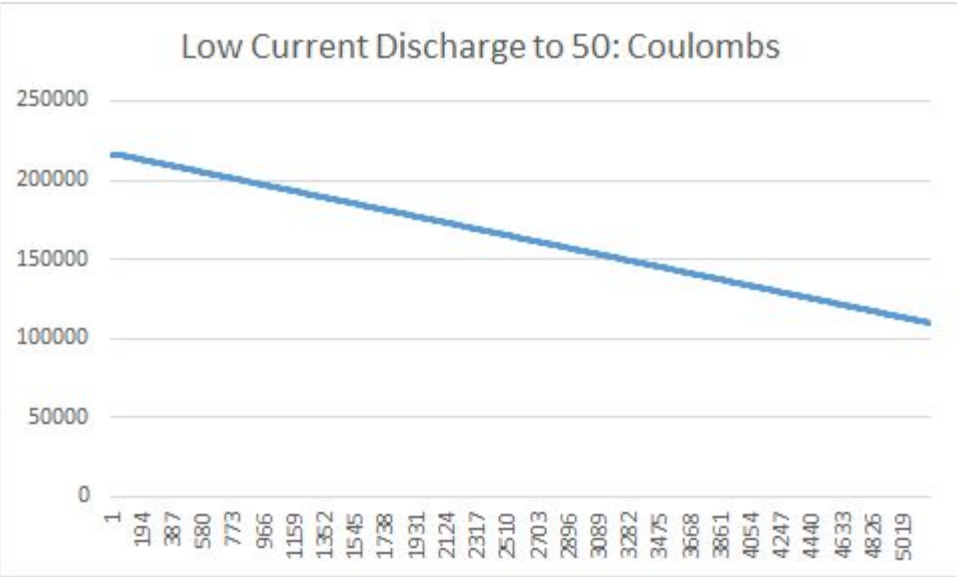
TSV


Low Current Discharge to 50: Pack Voltage
24
23.5
23
22.5
22
21.5
21
1
185
369
553
737
921
1105
1289
1473
1657
1841
2025
2209
2393
2577
2761
2945
3129
3313
3497
3681
3865
4049
4233
4417
4601
4785
4969

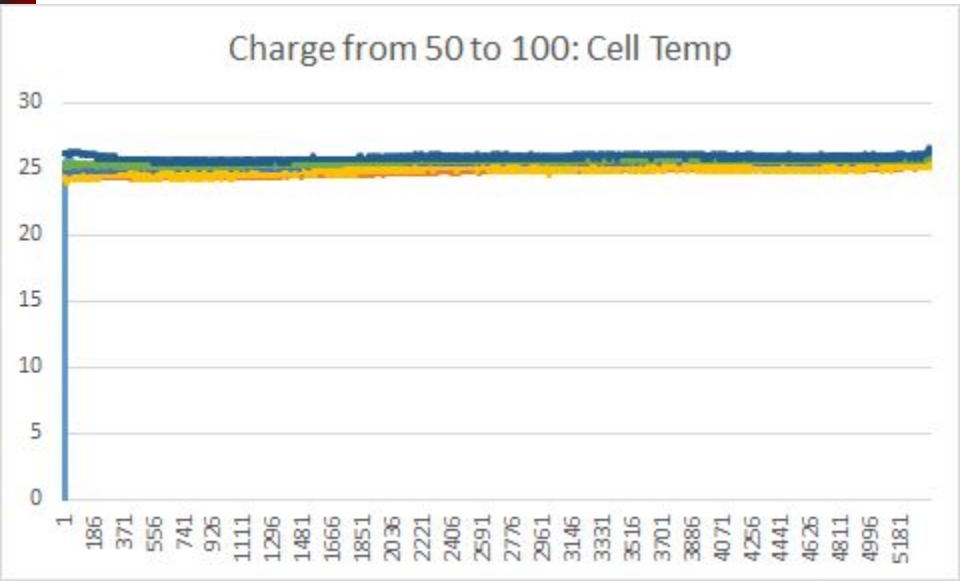

Low Current Discharge to 50: Cell Voltage
4
3.5
3
2.5
2
1.5
1
0.5
0
1
180
359
538
717
896
1075
1254
1433
1612
1791
1970
2149
2328
2507
2686
2865
3044
3223
3402
3581
3760
3939
4118
4297
4476
4655
4834
5013

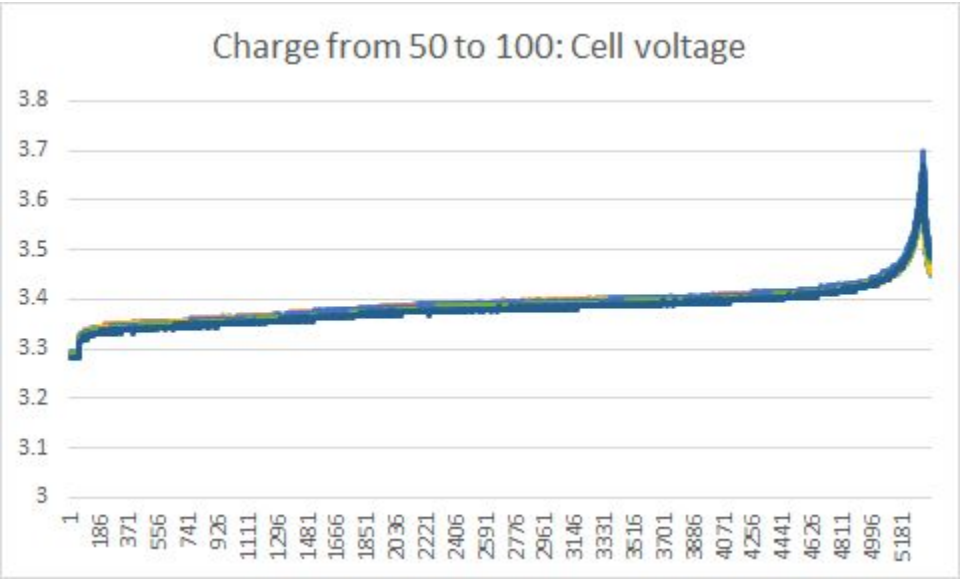
TSV


Low Current Discharge to 50: State of Charge
120
100
80
60
40
20
0
1
175
349
523
697
871
1045
1219
1393
1567
1741
1915
2089
2263
2437
2611
2785
2959
3133
3307
3481
3655
3829
4003
4177
4351
4525
4699
4873

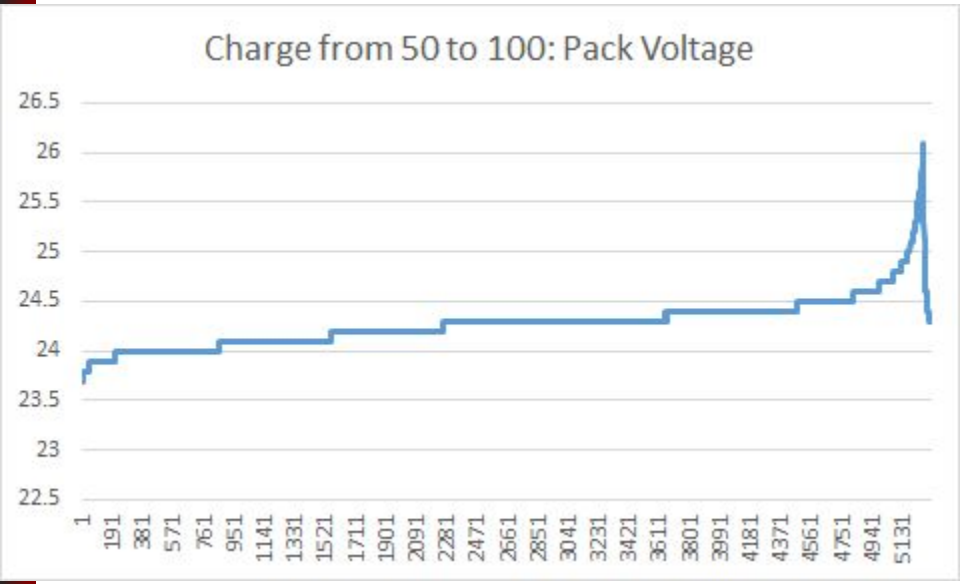

Low Current Discharge to 50: Coulombs
250000
200000
150000
100000
50000
0
1
194
387
580
773
966
1159
1352
1545
1738
1931
2124
2317
2510
2703
2896
3089
3282
3475
3668
3861
4054
4247
4440
4633
4826
5019

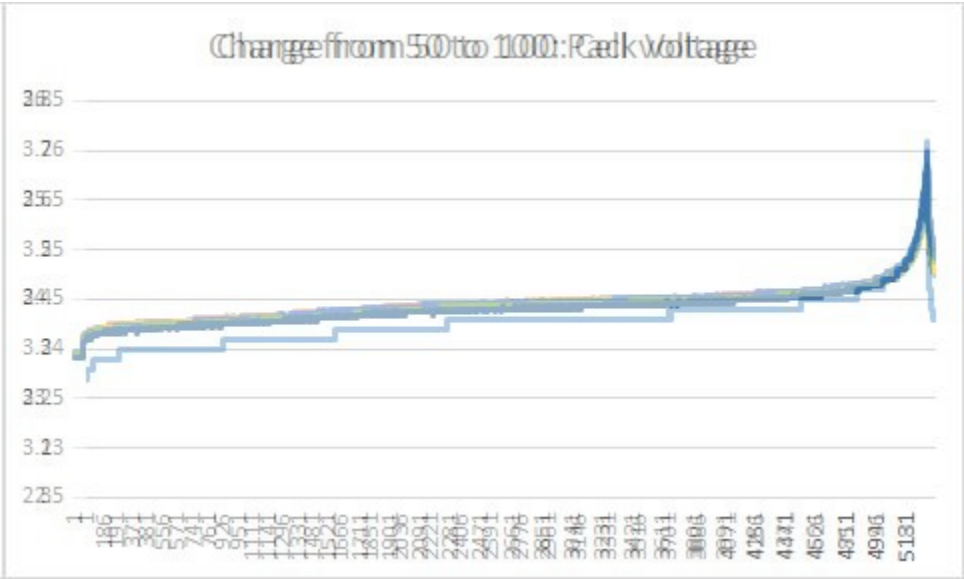
TSV


Charge from 50 to 100: Cell Temp
30
25
20
15
10
5
0
1
186
371
556
741
926
1111
1296
1481
1666
1851
2036
2221
2406
2591
2776
2961
3146
3331
3516
3701
3886
4071
4256
4441
4626
4811
4996
5181

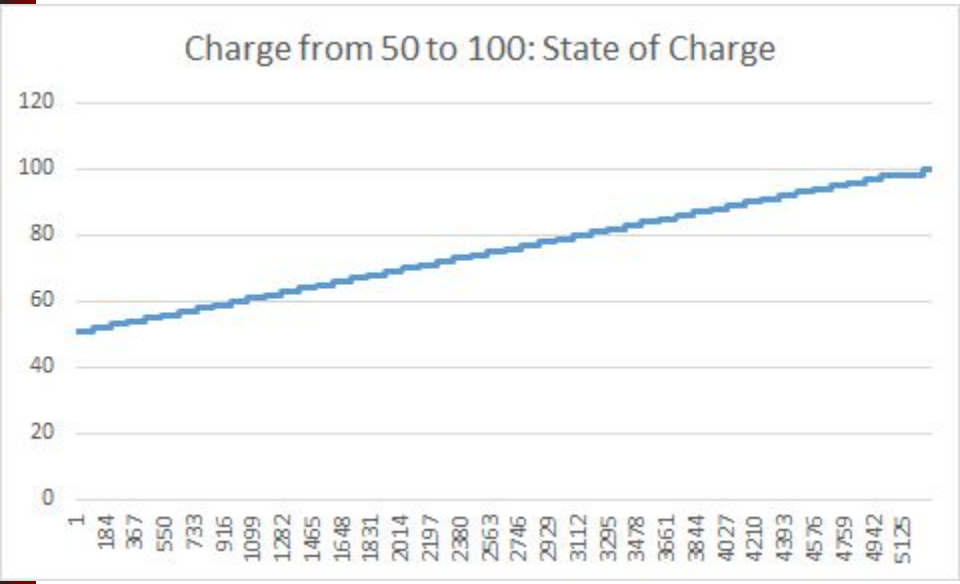

Charge from 50 to 100: Cell voltage
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
1
186
371
556
741
926
1111
1296
1481
1666
1851
2036
2221
2406
2591
2776
2961
3146
3331
3516
3701
3886
4071
4256
4441
4626
4811
4996
5181

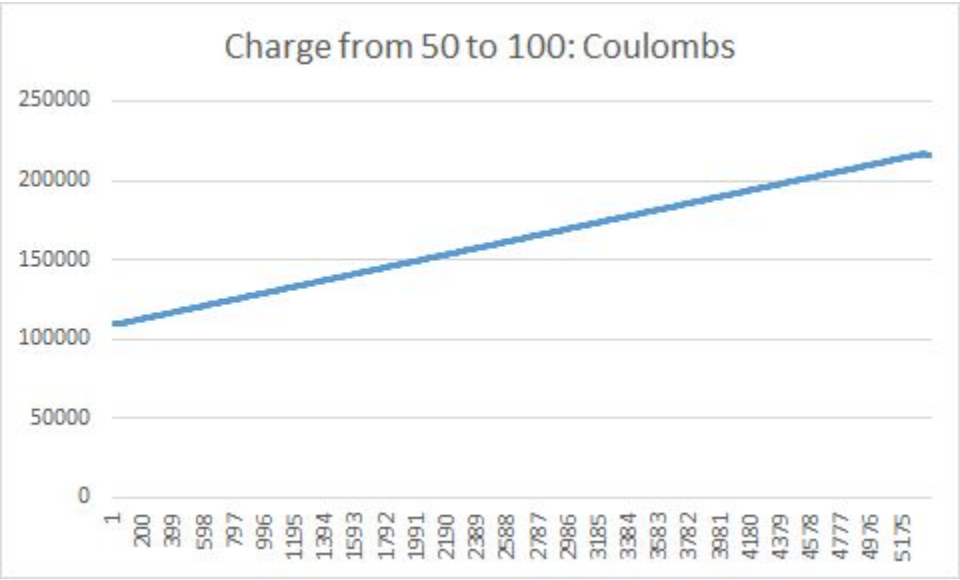
TSV


Charge from 50 to 100: Pack Voltage
26.5
26
25.5
25
24.5
24
23.5
23
22.5
1
191
381
571
761
951
1141
1331
1521
1711
1901
2091
2281
2471
2661
2851
3041
3231
3421
3611
3801
3991
4181
4371
4561
4751
4941
5131

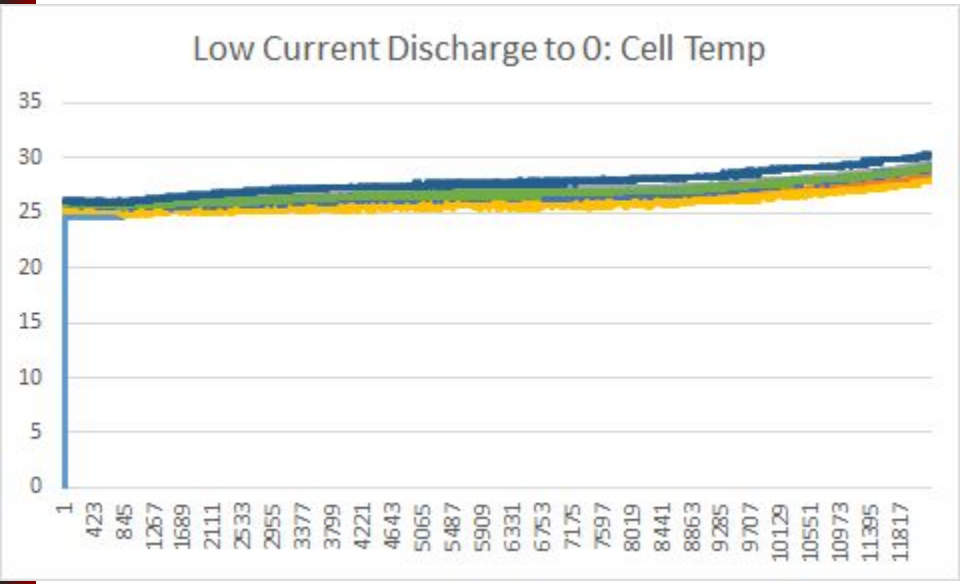

Charge from 50 to 100: Pack Voltage

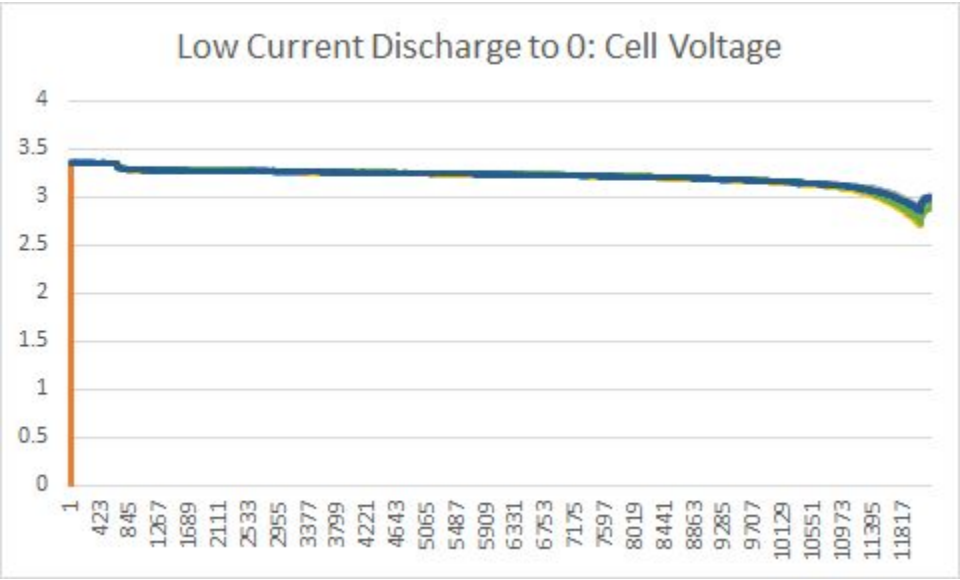
TSV


Charge from 50 to 100: State of Charge
120
100
80
60
40
20
0
1
184
367
550
733
916
1099
1282
1465
1648
1831
2014
2197
2380
2563
2746
2929
3112
3295
3478
3661
3844
4027
4210
4393
4576
4759
4942
5125


Charge from 50 to 100: Coulombs
250000
200000
150000
100000
50000
0
1
200
399
598
797
996
1195
1394
1593
1792
1991
2190
2389
2588
2787
2986
3185
3384
3583
3782
3981
4180
4379
4578
4777
4976
5175

TSV


Low Current Discharge to 0: Cell Temp
35
30
25
20
15
10
5
0
1
423
845
1267
1689
2111
2533
2955
3377
3799
4221
4643
5065
5487
5909
6331
6753
7175
7597
8019
8441
8863
9285
9707
10129
10551
10973
11395
11817


Low Current Discharge to 0: Cell Voltage
4
3.5
3
2.5
2
1.5
1
0.5
0
1
423
845
1267
1689
2111
2533
2955
3377
3799
4221
4643
5065
5487
5909
6331
6753
7175
7597
8019
8441
8863
9285
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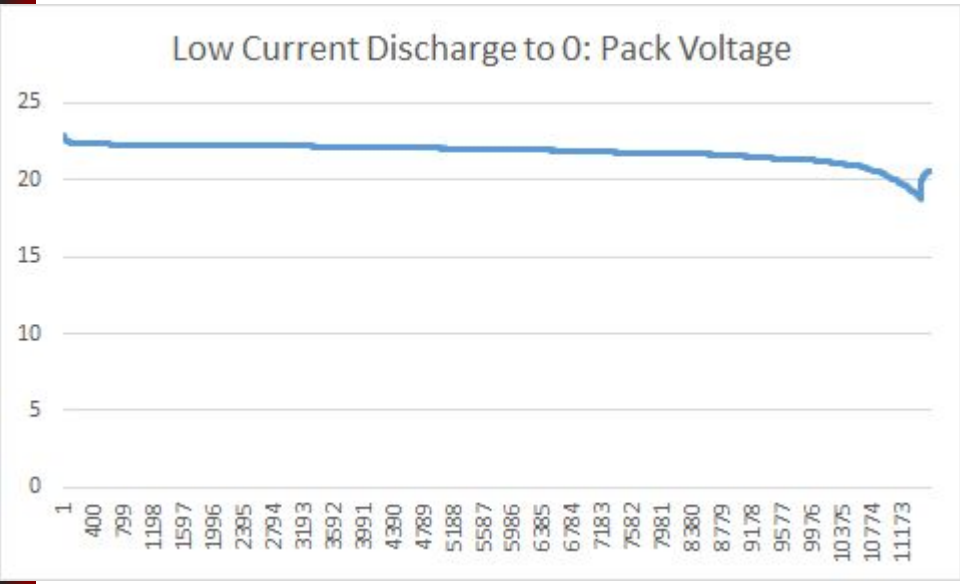
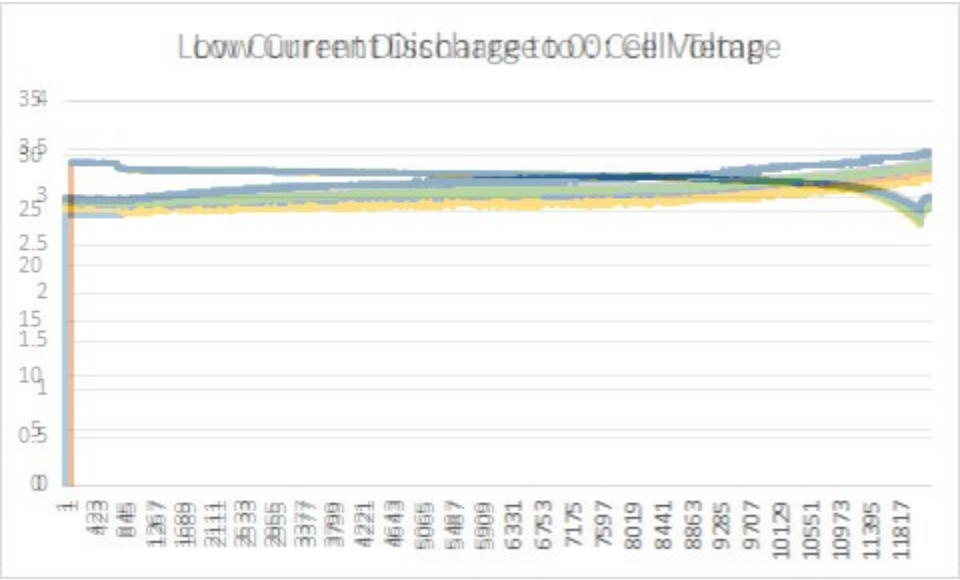
10129
10551
10973
11395
11817

TSV


Low Current Discharge to 0: Pack Voltage
25
20
15
10
5
0
1
400
799
1198
1597
1996
2395
2794
3193
3592
3991
4390
4789
5188
5587
5986
6385
6784
7183
7582
7981
8380
8779
9178
9577
9976
10375
10774
11173


Low Current Discharge to 0: Cell Voltage
1
423
845
1267
1689
2111
2533
2955
3377
3799
4221
4643
5065
5487
5909
6331
6753
7175
7597
8019
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8863
9285
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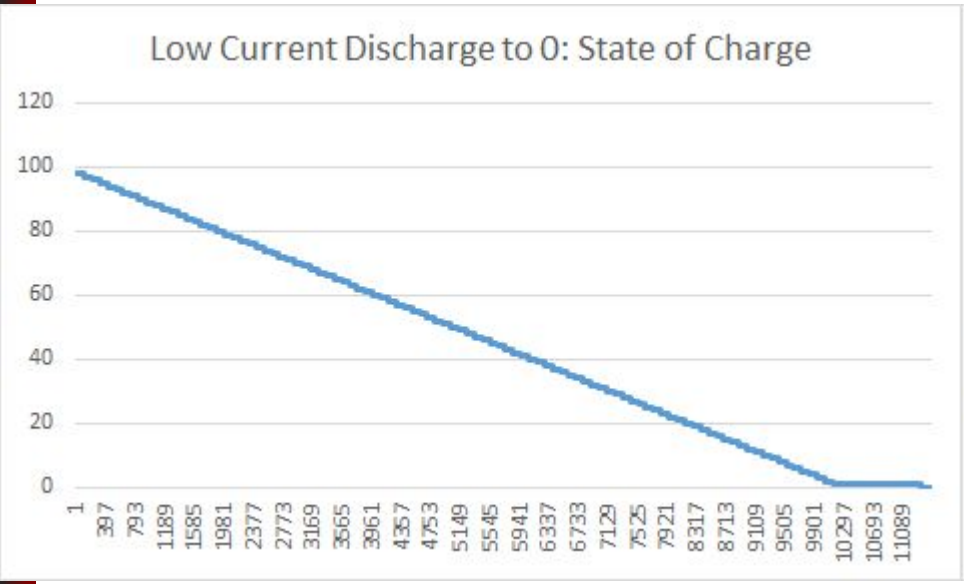
10129
10551
10973
11395
11817

TSV


Low Current Discharge to 0: State of Charge
120
100
80
60
40
20
0
1
397
793
1189
1585
1981
2377
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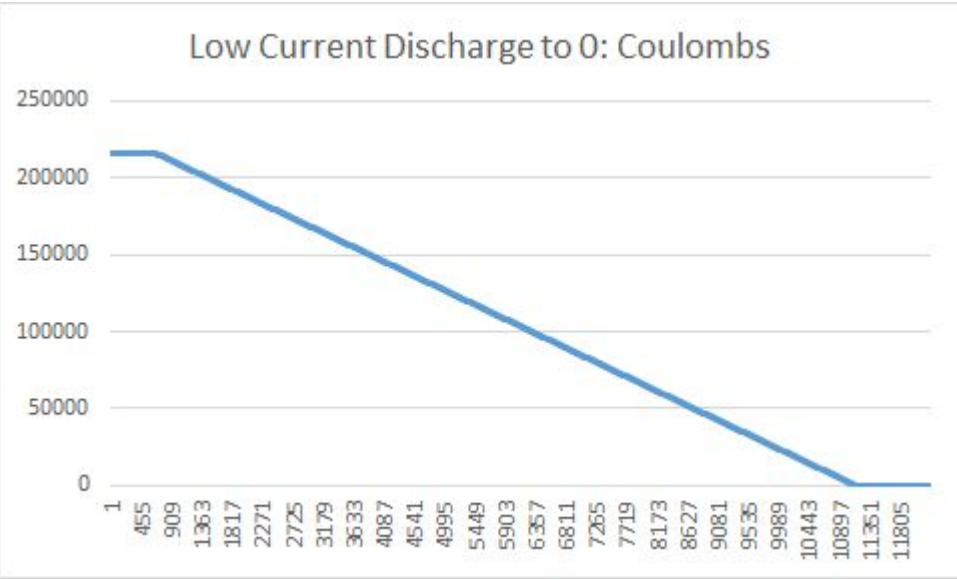
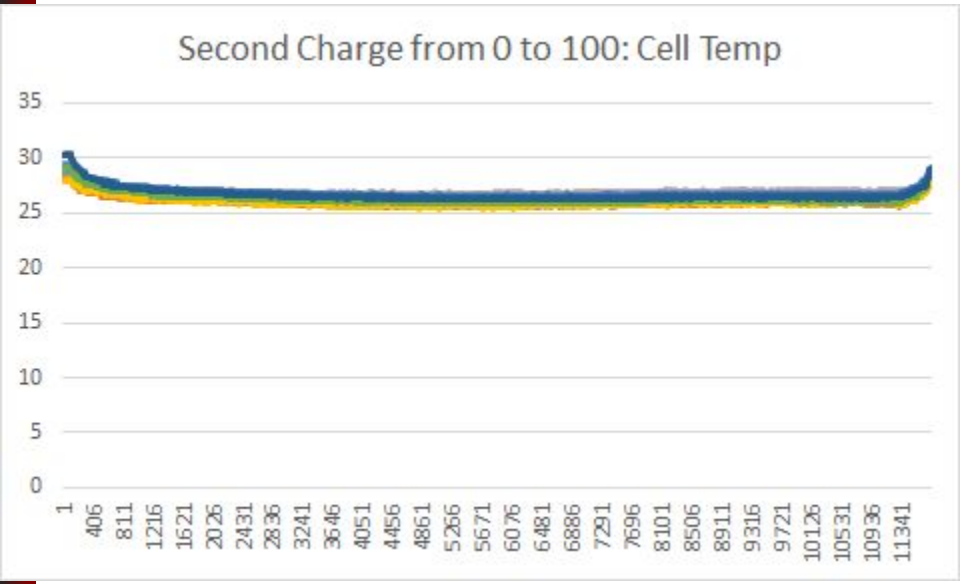
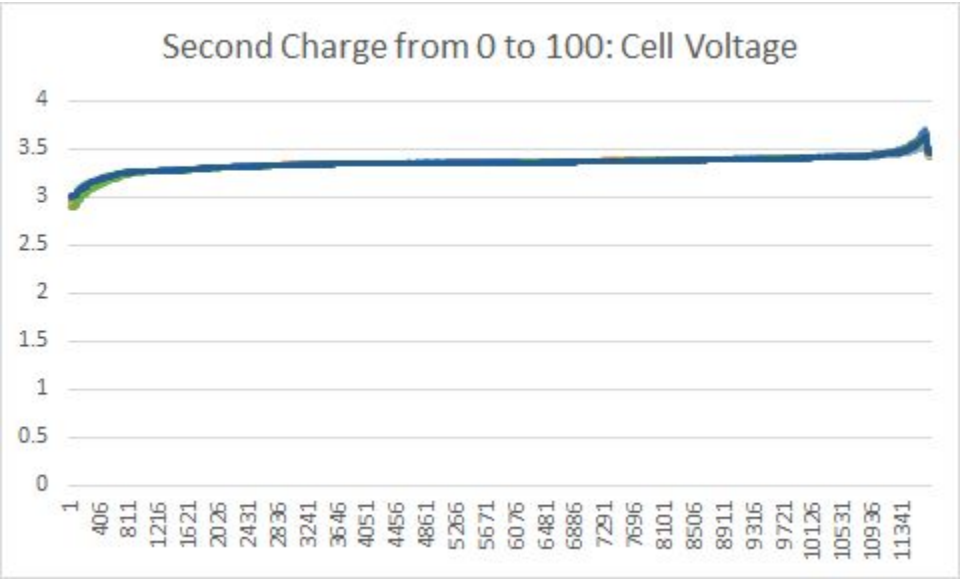
3169
3565
3961
4357
4753
5149
5545
5941
6337
6733
7129
7525
7921
8317
8713
9109
9505
9901
10297
10693
11089

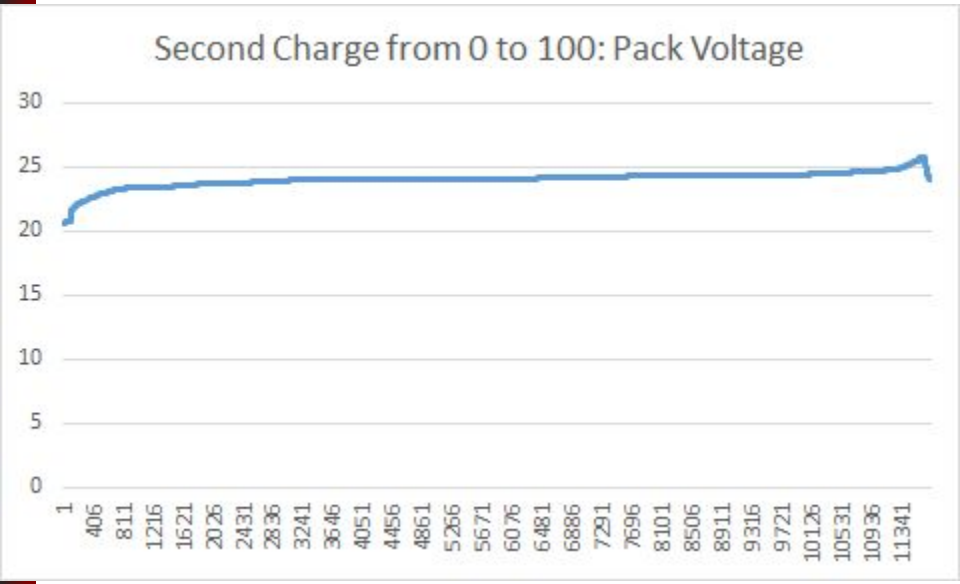

Low Current Discharge to 0: Coulombs
250000
200000
150000
100000
50000
0
1
455
909
1363
1817
2271
2725
3179
3633
4087
4541
4995
5449
5903
6357
6811
7265
7719
8173
8627
9081
9535
9989
10443
10897
11351
11805

TSV


Second Charge from 0 to 100: Cell Temp
35
30
25
20
15
10
5
0
1
406
811
1216
1621
2026
2431
2836
3241
3646
4051
4456
4861
5266
5671
6076
6481
6886
7291
7696
8101
8506
8911
9316
9721
10126
10531
10936
11341


Second Charge from 0 to 100: Cell Voltage
4
3.5
3
2.5
2
1.5
1
0.5
0
1
406
811
1216
1621
2026
2431
2836
3241
3646
4051
4456
4861
5266
5671
6076
6481
6886
7291
7696
8101
8506
8911
9316
9721
10126
10531
10936
11341

TSV


Second Charge from 0 to 100: Pack Voltage
30
25
20
15
10
5
0
1
406
811
1216
1621
2026
2431
2836
3241
3646
4051
4456
4861
5266
5671
6076
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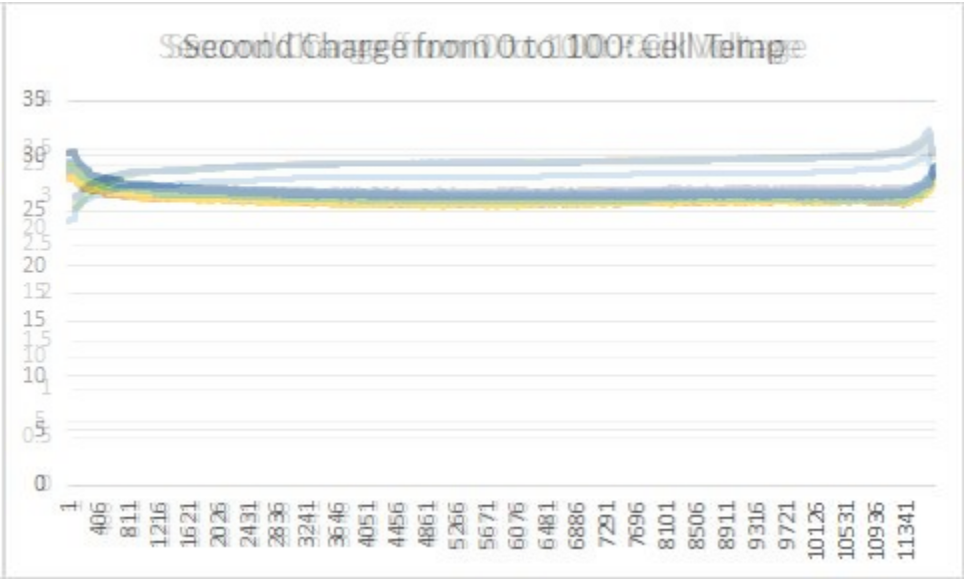
6886
7291
7696
8101
8506
8911
9316
9721
10126
10531
10936
11341


Second Charge from 0 to 100: Cell Temp
35
30
25
20
15
10
5
0
1
406
811
1216
1621
2026
2431
2836
3241
3646
4051
4456
4861
5266
5671
6076
6481
6886
7291
7696
8101
8506
8911
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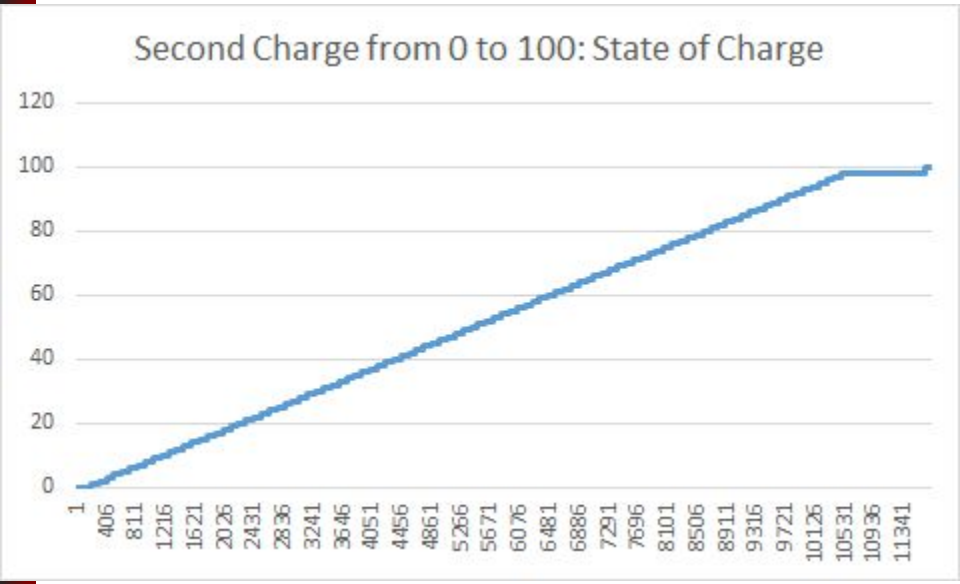
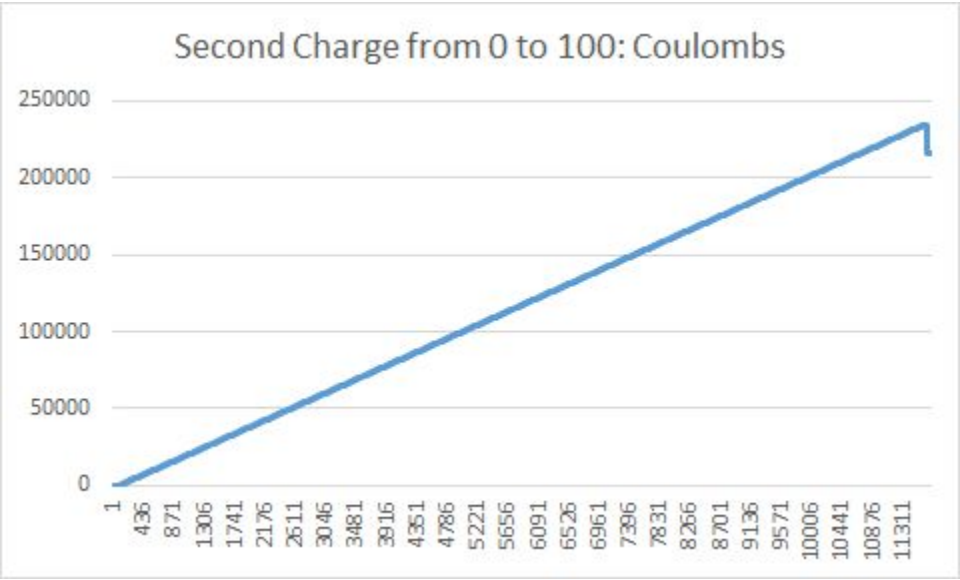
9721
10126
10531
10936
11341

TSV


Second Charge from 0 to 100: State of Charge
120
100
80
60
40
20
0
1
406
811
1216
1621
2026
2431
2836
3241
3646
4051
4456
4861
5266
5671
6076
6481
6886
7291
7696
8101
8506
8911
9316
9721
10126
10531
10936
11341


Second Charge from 0 to 100: Coulombs
250000
200000
150000
100000
50000
0
1
436
871
1306
1741
2176
2611
3046
3481
3916
4351
4786
5221
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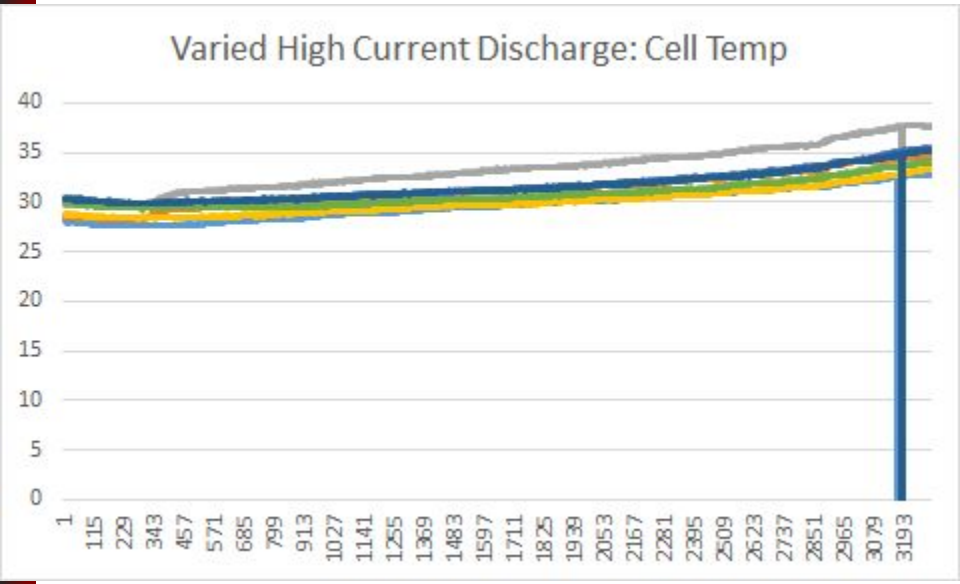
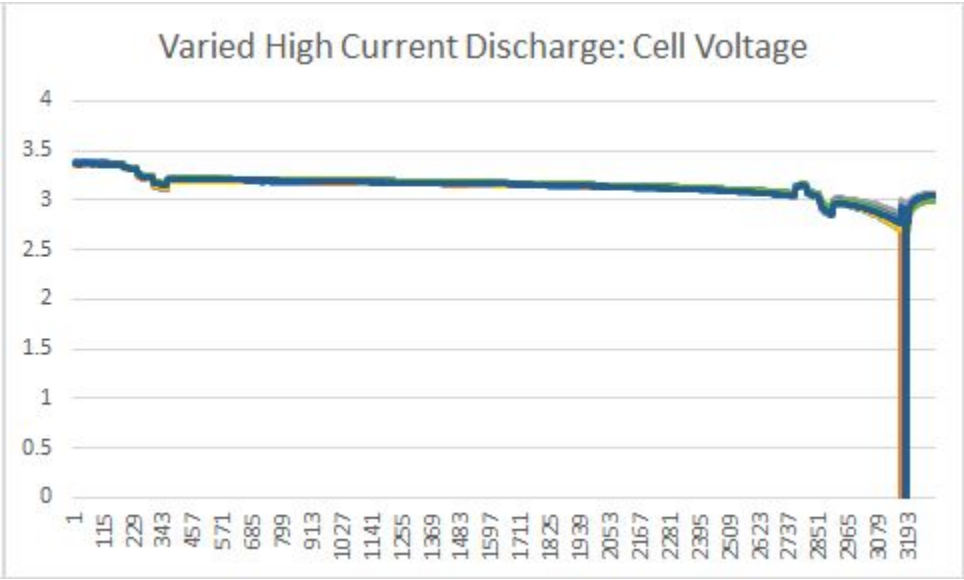
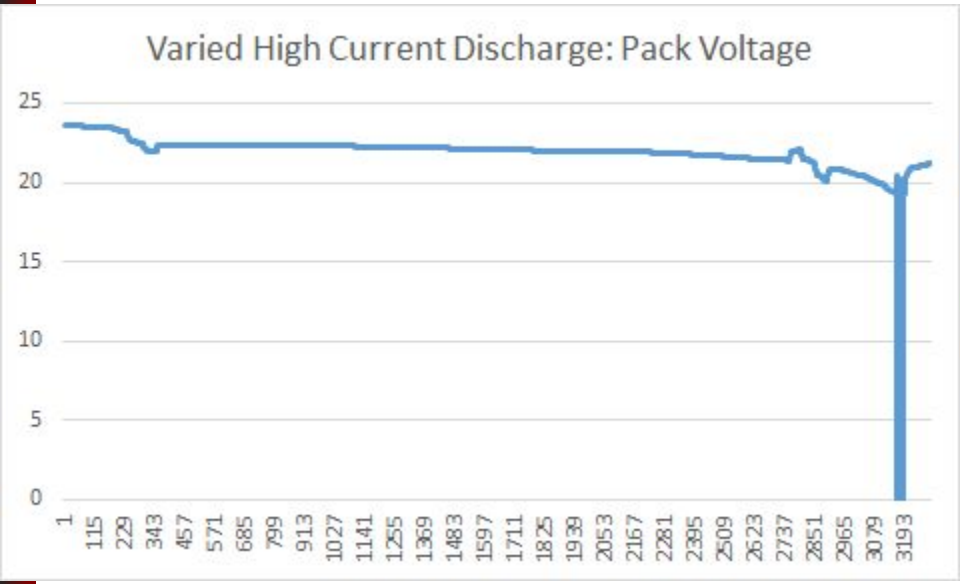
8701
9136
9571
10006
10441
10876
11311

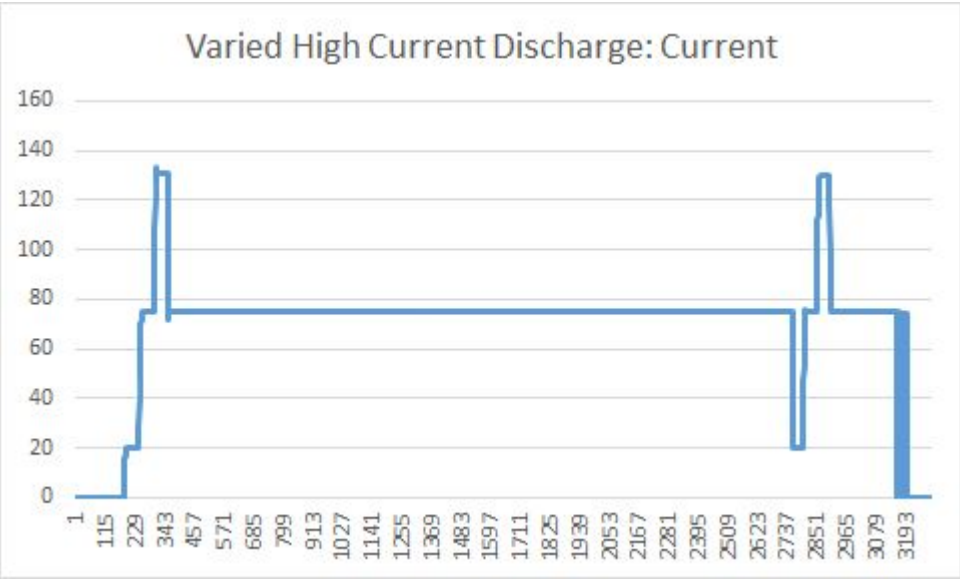
TSV


Varied High Current Discharge: Cell Temp
40
35
30
25
20
15
10
5
0
1
115
229
343
457
571
685
799
913
1027
1141
1255
1369
1483
1597
1711
1825
1939
2053
2167
2281
2395
2509
2623
2737
2851
2965
3079
3193

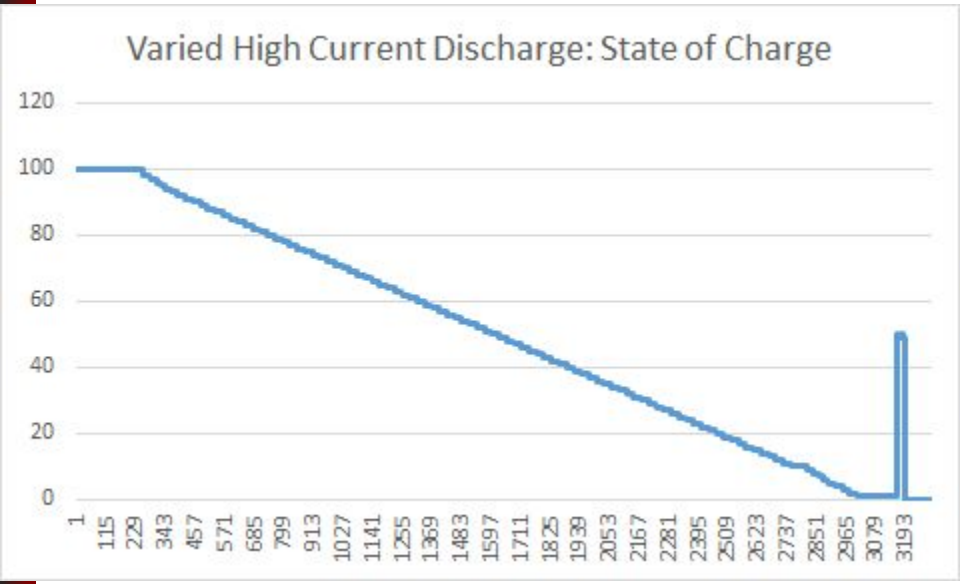

Varied High Current Discharge: Cell Voltage
4
3.5
3
2.5
2
1.5
1
0.5
0
1
115
229
343
457
571
685
799
913
1027
1141
1255
1369
1483
1597
1711
1825
1939
2053
2167
2281
2395
2509
2623
2737
2851
2965
3079
3193

TSV


Varied High Current Discharge: Pack Voltage
25
20
15
10
5
0
1
115
229
343
457
571
685
799
913
1027
1141
1255
1369
1483
1597
1711
1825
1939
2053
2167
2281
2395
2509
2623
2737
2851
2965
3079
3193


Varied High Current Discharge: Current
160
140
120
100
80
60
40
20
0
1
115
229
343
457
571
685
799
913
1027
1141
1255
1369
1483
1597
1711
1825
1939
2053
2167
2281
2395
2509
2623
2737
2851
2965
3079
3193

TSV


Varied High Current Discharge: State of Charge
120
100
80
60
40
20
0
1
115
229
343
457
571
685
799
913
1027
1141
1255
1369
1483
1597
1711
1825
1939
2053
2167
2281
2395
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2623
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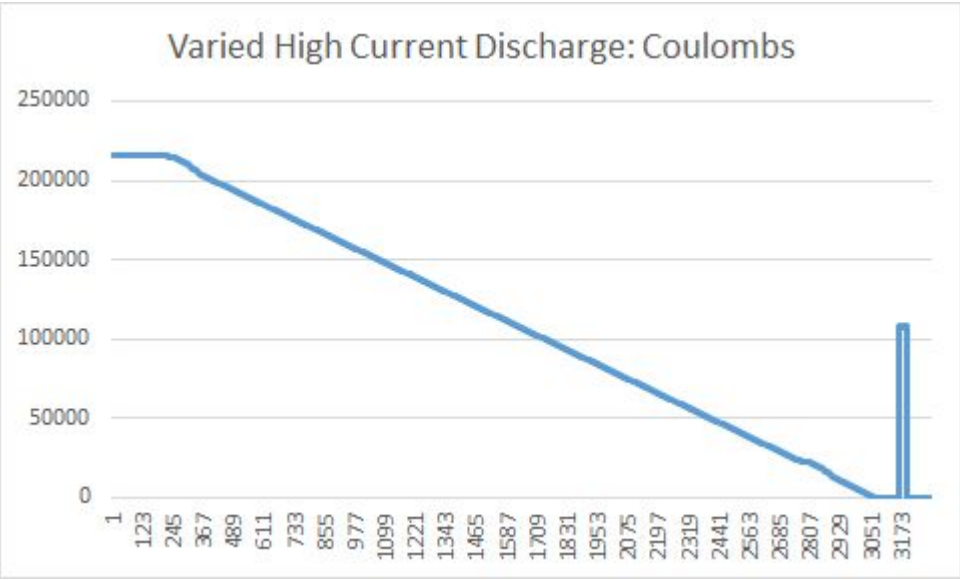
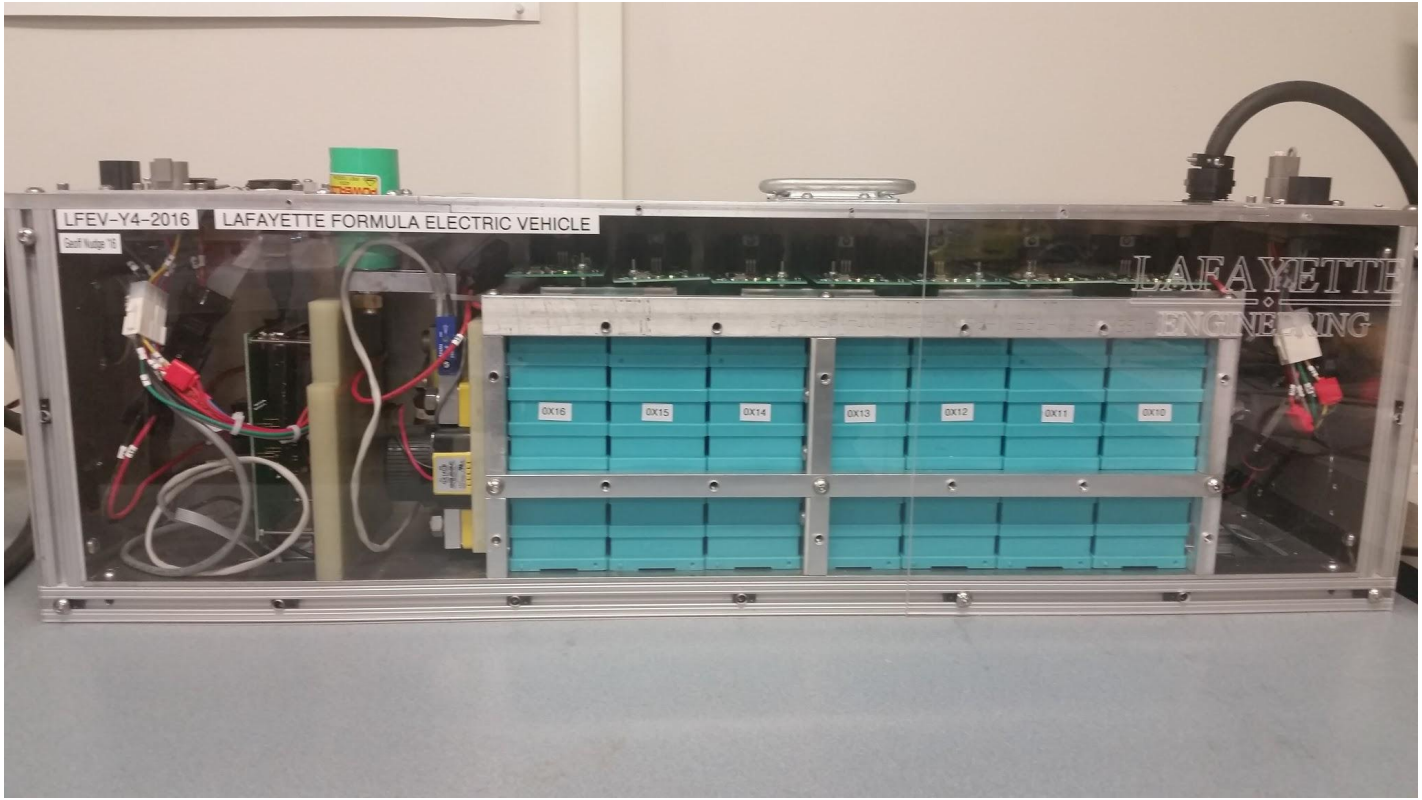
2851
2965
3079
3193


Varied High Current Discharge: Coulombs
250000
200000
150000
100000
50000
0
1
123
245
367
489
611
733
855
977
1099
1221
1343
1465
1587
1709
1831
1953
2075
2197
2319
2441
2563
2685
2807
2929
3051
3173

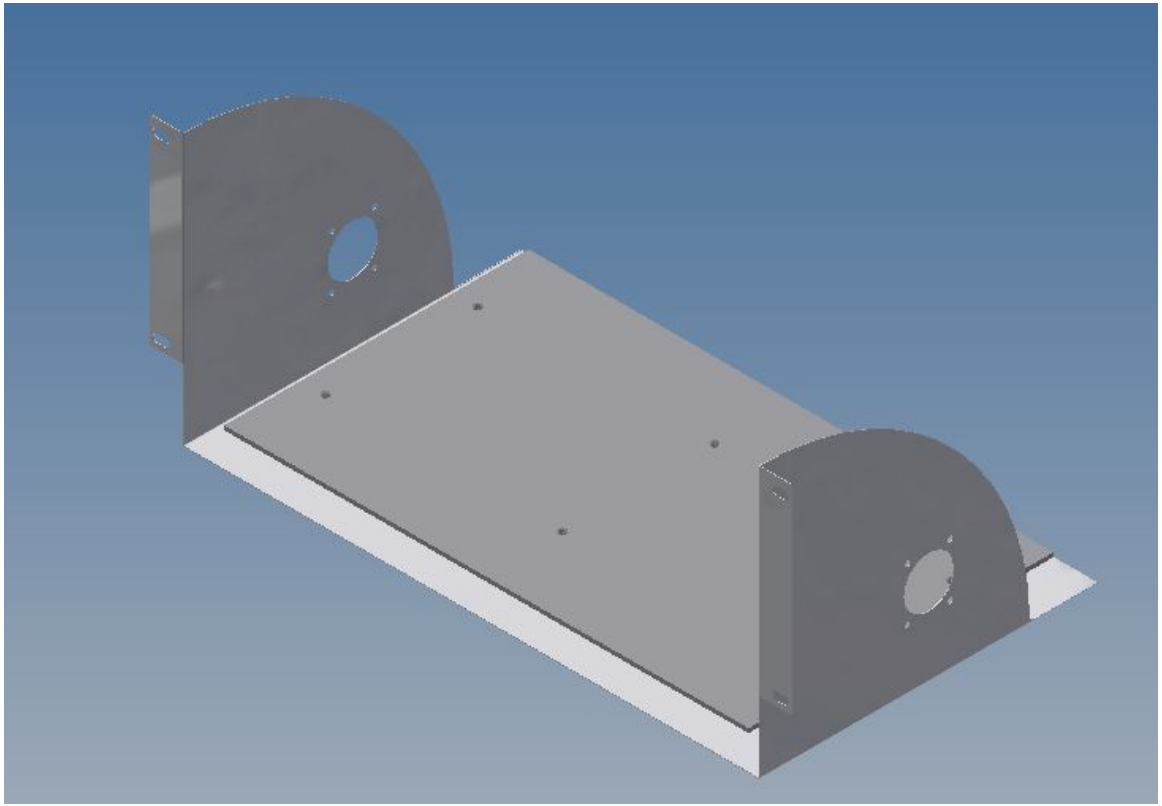
Mech E – Goals

1. Create continuity between years
    a. Part numbers
    b. Consolidation of 3D model
2. Physically make one battery pack
    a. Changes minimized compared to 2015, mostly just electrical accommodations
3. Gathering data for future mechanical work
    a. Dynamometer
    b. Research current FSAE vehicle
4. Construction

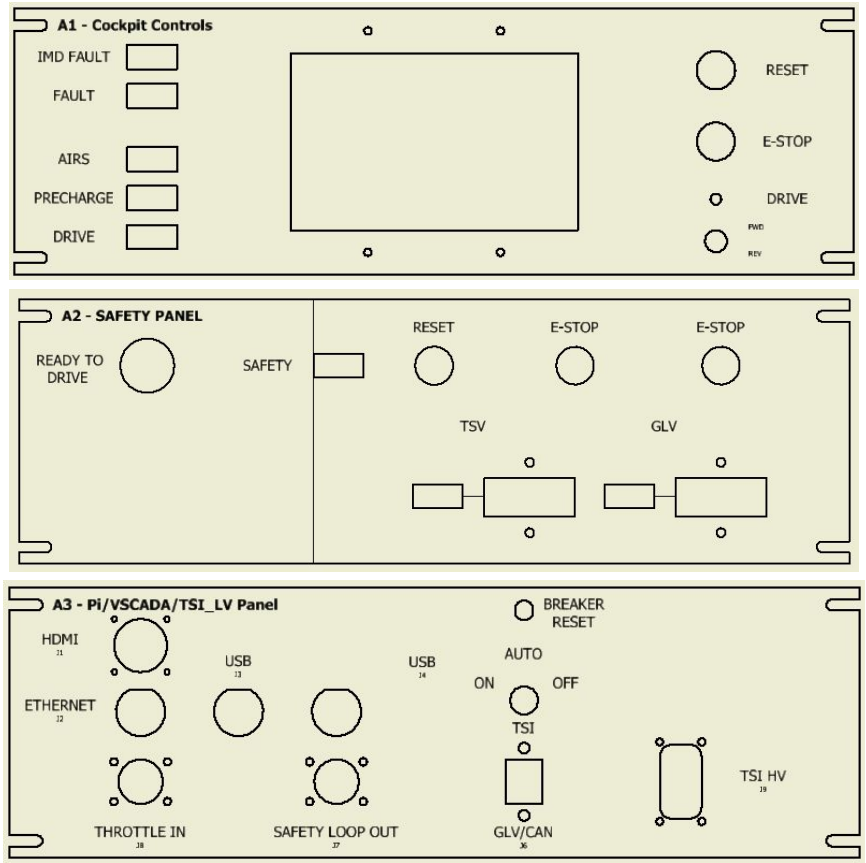
Mech E - Battery Pack



Mech E – Rack

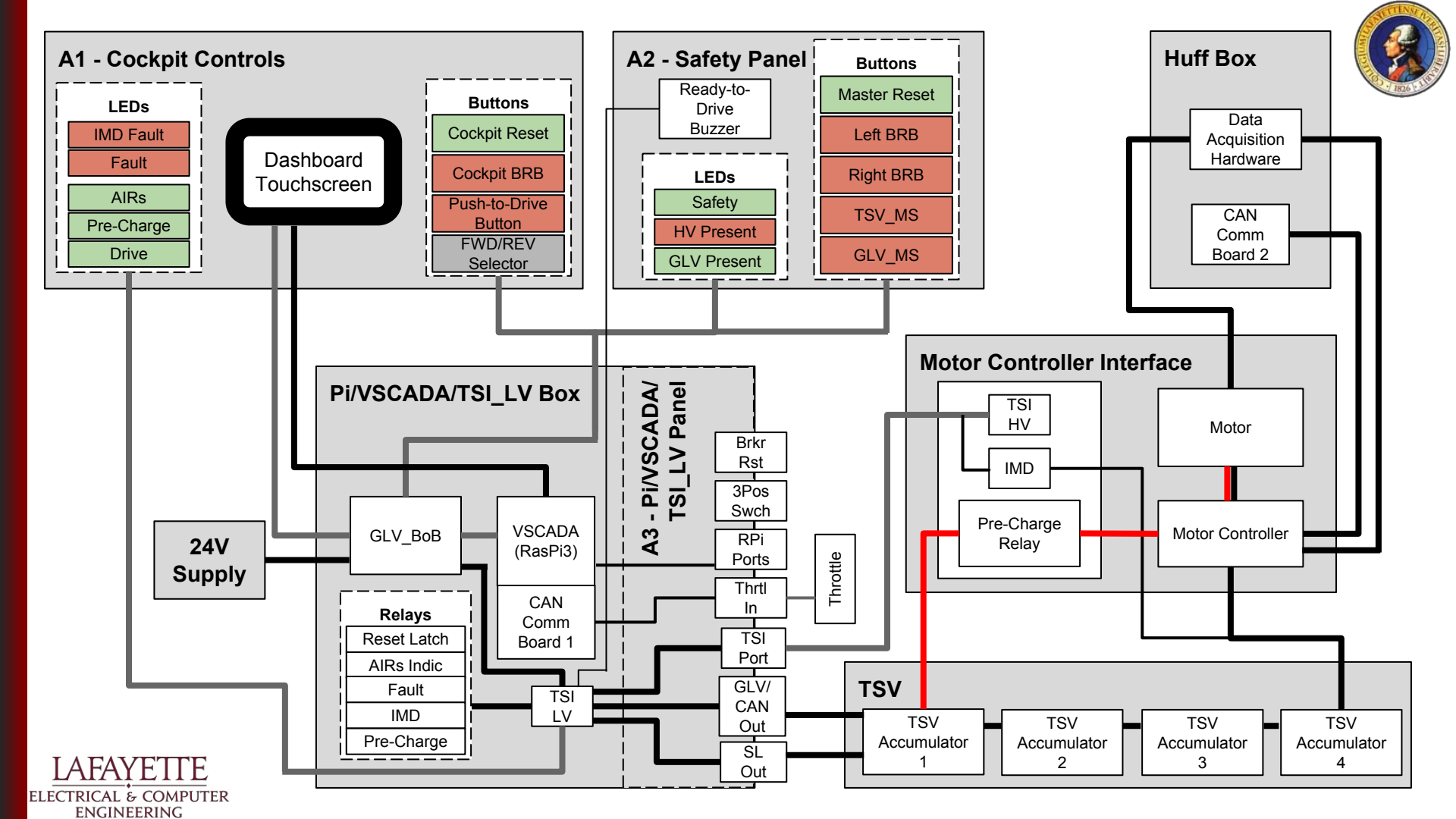


Mech E - Rack



LAFAYETTE ENGINEERING

GLV – Grounded Low Voltage

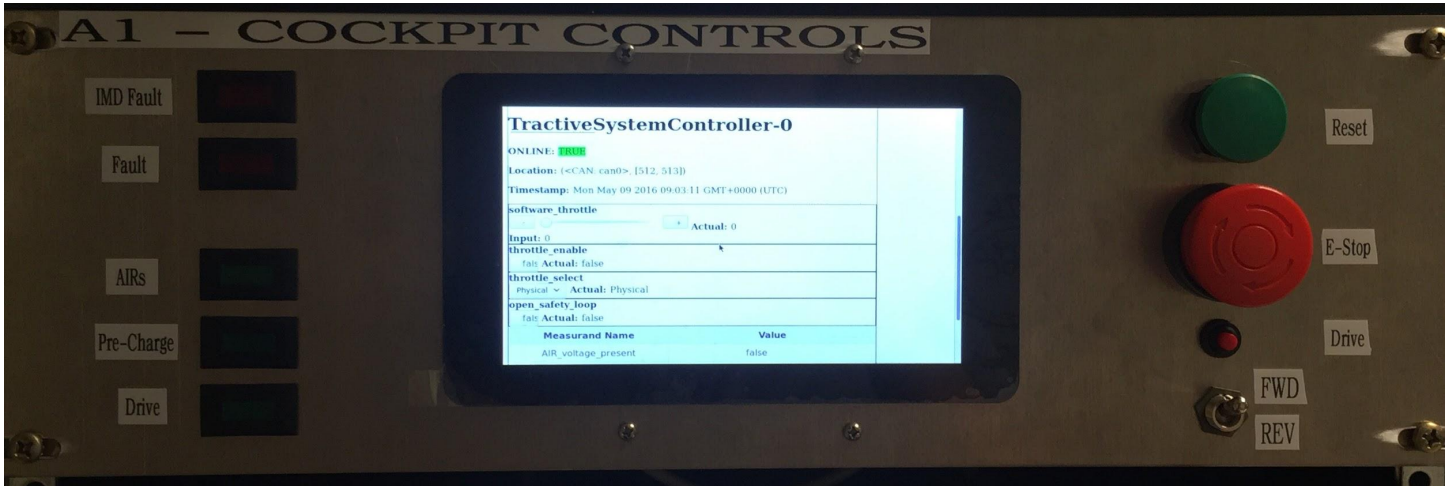


LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

GLV - Purpose

- Provide DC voltage to power non-TSV systems
  - VSCADA, safety loop, insulation monitoring device, etc.
- Safety loop - allows VSCADA or the driver to disable the vehicle in case of emergency
  - Prevents AIRs from closing if there is any sort of fault present
- Indicators, switches, buttons, and cable interconnections that can be used both in the dynamometer test stand and the car
- Tractive System Interface (TSI) - monitors the TSV and GLV sections to ensure they remain isolated; if they are, it allows power to flow between the accumulator packs and the Curtis motor controller and, if not, it opens the safety loop
- Provide connections to allow throttle control and CAN communications between systems

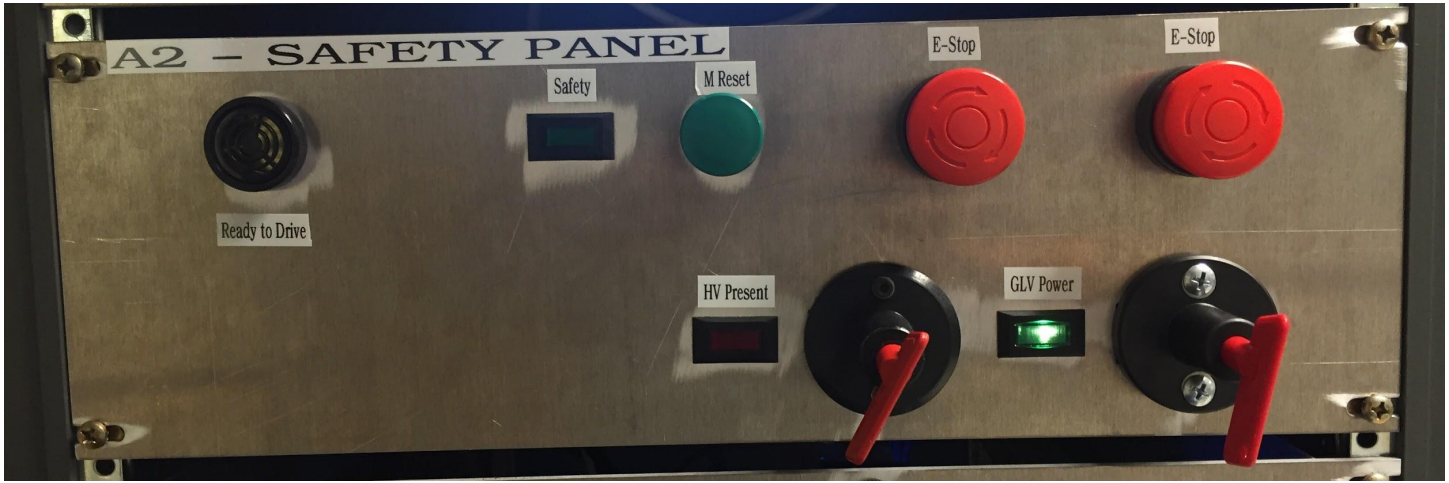
GLV-Cockpit Controls



- IMD FAULT*- Triggered by ground fault
- FAULT*- General system fault
- AIRs - AIRs Voltage Present
- Pre-Charge - Precharge Voltage Present
- FWD/REV
- Drive - Car enters drive state
- Reset - Driver Reset
- E-STOP
- Drive - Enter Drive mode

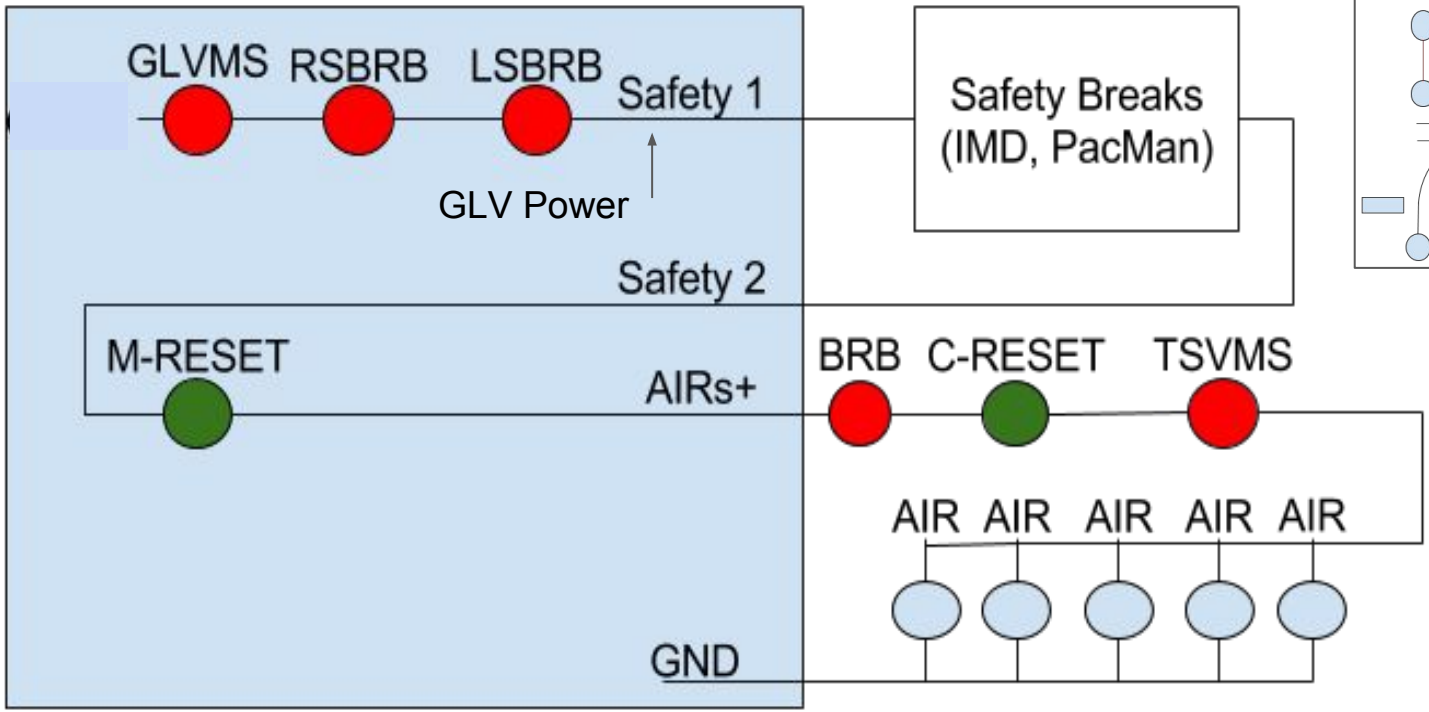
*non-driver resettable

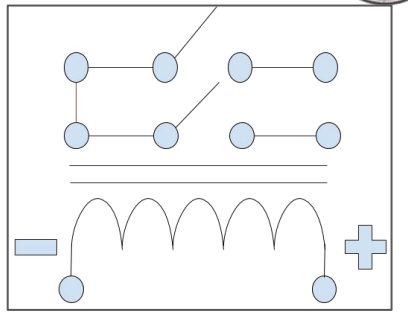
GLV-Safety Controls



- Ready to Drive- Sound indicating drive mode has been entered
- Safety- Safety loop voltage present
- M_Reset- Required reset for all faults
- HV Present- When HV is present at Motor Contr.
- GLV Master SW- Required for GLV Power
- GLV Power - 24 Volts
- E-STOP (Right)
- E-STOP (LEFT)
- TSV Master SW - Required for AIRs voltage to be present

GLV-Safety Loop





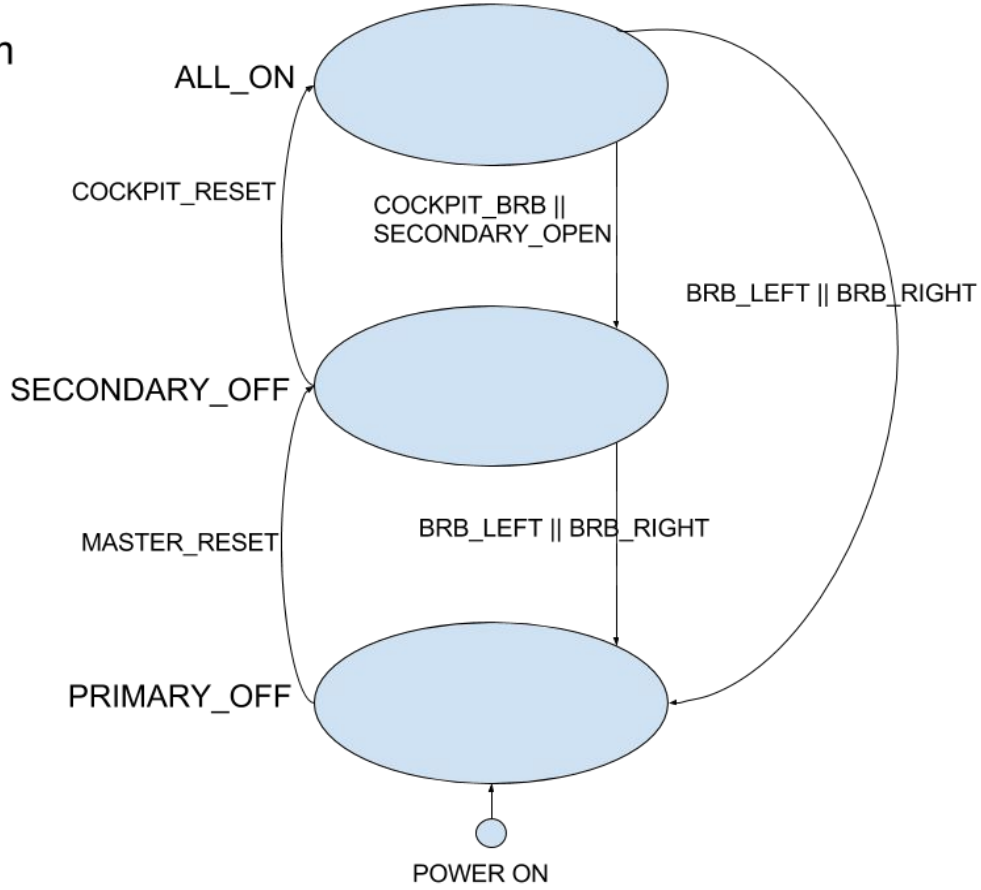
GLV-Safety Loop Cont.

Safety Loop State Diagram

In ALL_ON, the START button requests SCADA allow physical throttle.

Reset buttonw will only cause transition if corresponding BRBs are closed.

These states are stored by the physical position of BRBs and Reset buttons.



GLV - VSCADA/TSI LV

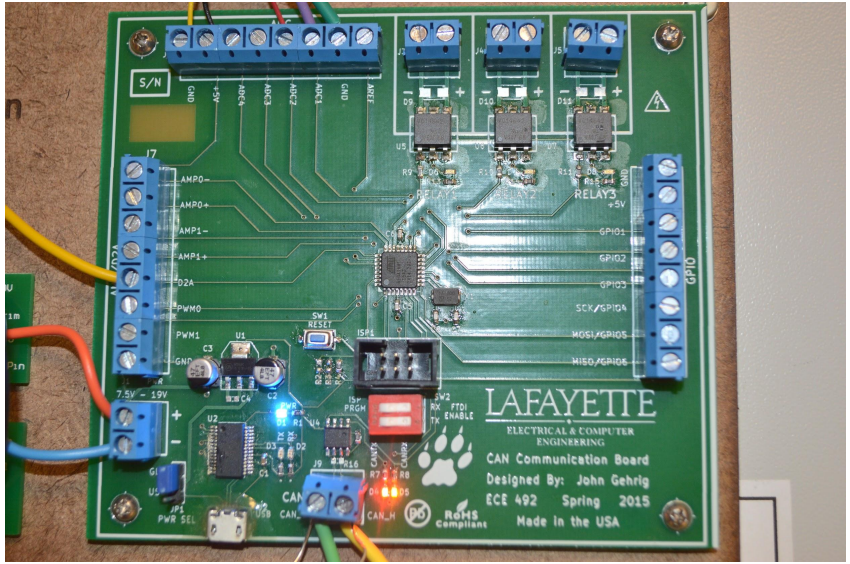
- HDMI/USB 1/USB2/Ethernet - These are for using a mouse and keyboard with the Raspberry Pi, internet and an external monitor
- Throttle IN- External throttle connection (POT)
- Safety Loop Out
- GLV/CAN
- TSI Selector SW- ON (on when precharge is present) OFF (always off) AUTO (software defined)
- TSI-HV - Cable for connecting TSI-LV to TSI-HV

GLV-TSI (HV/LV) /VCI

- The GLV system is intended to run off of a 24V+ battery that is independent of the TSV battery
- GLV distributes +5V, +12V, +24V, CAN_H and CAN_L, and the four wire safety loop
- Safety Loop Safety1, Safety2, AIRs+, and GND
- GLV interfaces with the scada computer (Raspberry Pi 3)
- 2x USB, 1x Ethernet, 1xHDMI, and I2C from the Raspberry Pi 7” touch screen and CAN
- The traditional Tractive System Interface have been split into two sections TSI_LV and TSI_HV
- The TSI_LV contains a JGB, DIN rail relays and TSI prototype board
- The TSI_LV contains all of the logic for the TSI_HV
- The TSI_HV contains the HV voltage measuring point, the precharge relay, the current sensor, IMD, (Insulation monitoring device), the CAN bus isolator, and an Isolation board to isolate relevant signals living inside HV Land

GLV - JGB

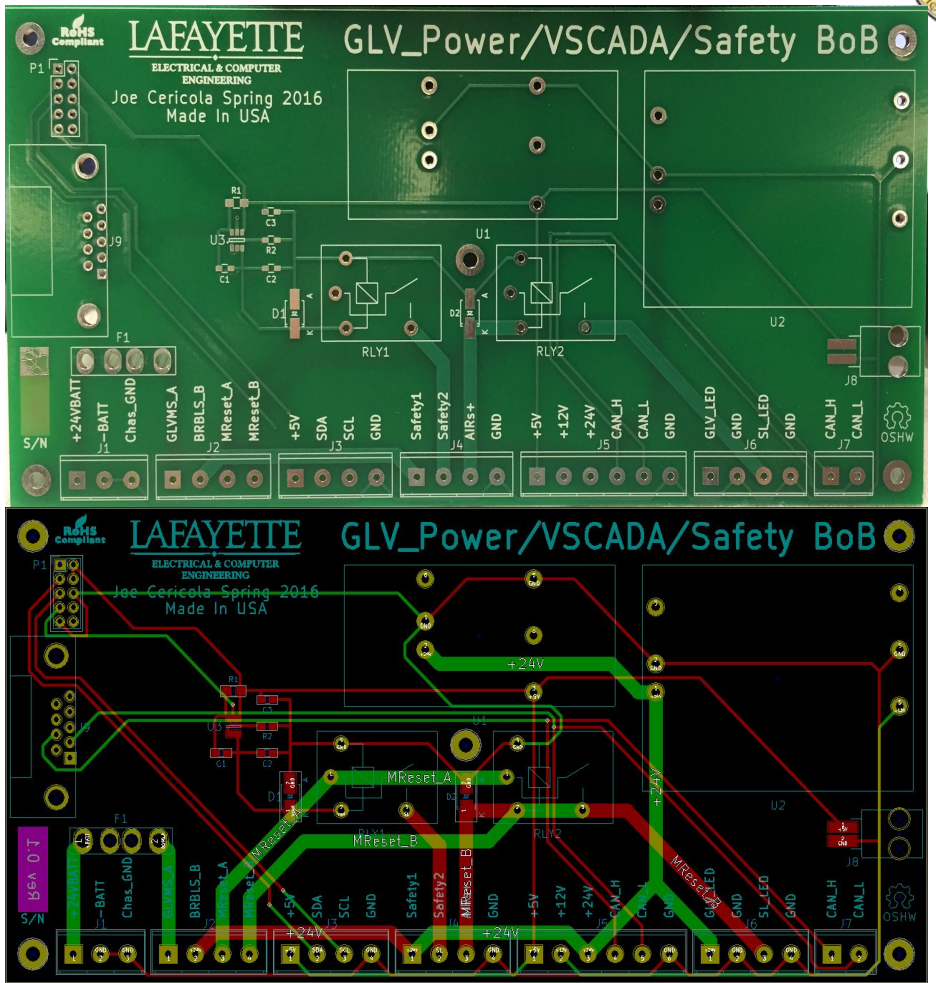
- Multi-mode board capable of analog-to-digital conversions, digital-to-analog conversions, GPIO, controlling onboard relays, and CAN communication with SCADA
- Mode is selectable based on voltage present on 4th ADC
  - Tractive System Controller - 0V present
    - Reads in drive button, physical throttle voltage, current meter output voltage, and AIR voltage
    - Controls relays for safety loop, precharge relay, and drive mode light
    - Outputs throttle voltages based on state of safety loop, SCADA controls, and input values
  - Huff Box DAQ - 5V present
    - Reads in torque valve voltage and oil temperature sensor voltage
    - Outputs load valve voltage based on values sent from SCADA



LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

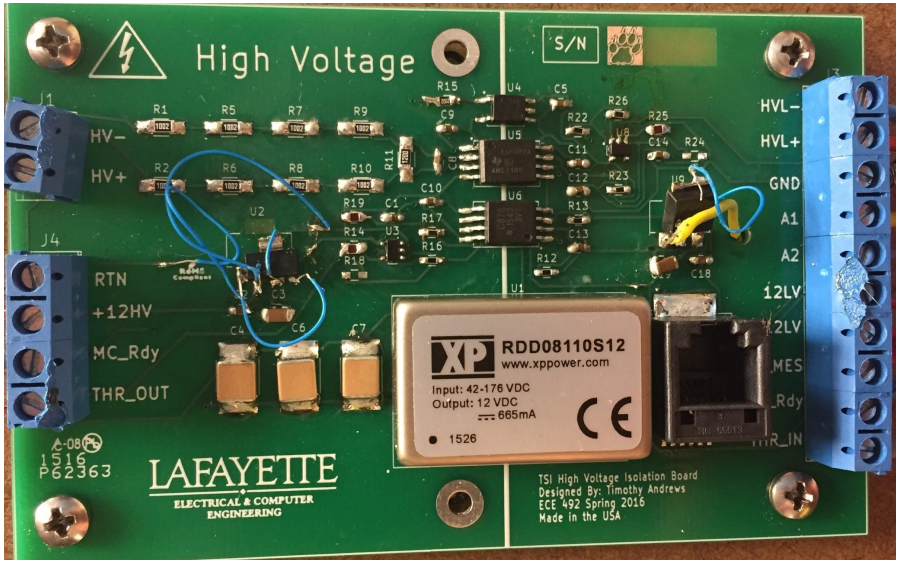
GLV_Power/VSCADA/ Safety BoB

- Handles safety loop routing
- Handles GLV power routing
- Handles SCADA interfacing with the rest of the system
- Includes 1x Safety Loop break
- Includes Routing to the Raspberry Pi Touch Screen
- Two DC to DC converters for 12V and 5V for additional systems, Lights, and Relays



GLV-TSI HV Isolation Board

- The TSI_HV contains the HV voltage measuring point and isolation
- The precharge relay for the motor controller is routed through this board; the signal is isolated
- The current sensor plugs into the RJ-12 jack
- HV voltage light is bucked down and provides power to the HV voltage present light
- The throttle input from the SCADA computer or the driver is passed through and isolated

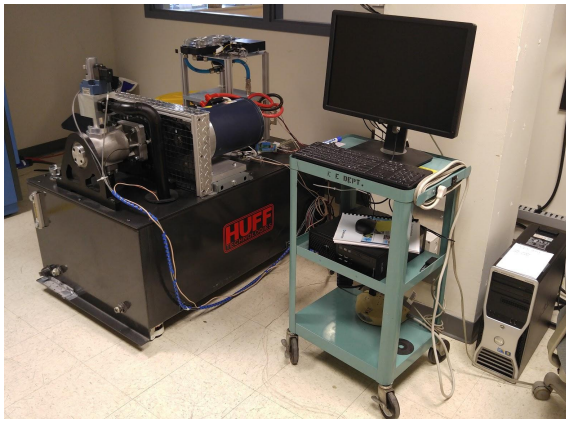


GLV - Errata

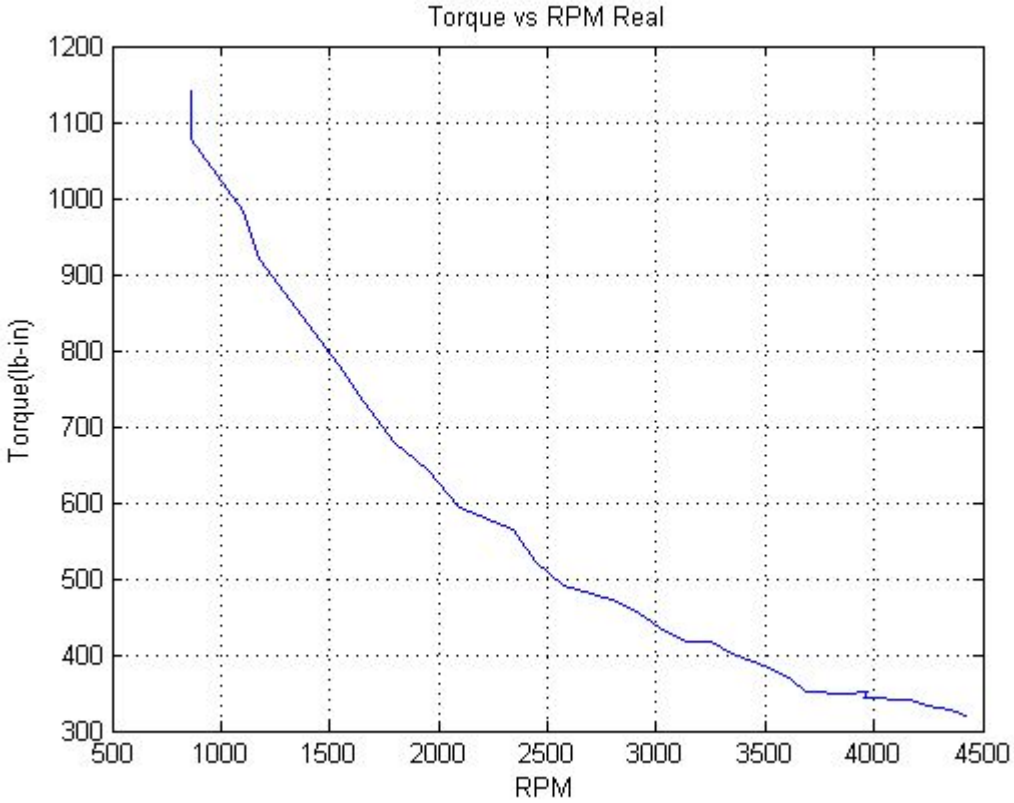
- Safety Loop
  - Refabricating revised TSI-HV board
  - Motor controller isolation and IMD
- Power
  - Migrate from power supply to battery system
- Miscellaneous
  - Precharge return line behavior
  - Forward and reverse switch wiring and safety mechanisms preventing its use in undesirable conditions such as when motor is spinning
  - HV measurement at TSI-HV untested/uncalibrated
  - Current measurement at TSI-HV untested/uncalibrated

MCM – Purpose

- Static Characterization
  - Full Power curve Torque vs RPM
  - Determine the motors limits and best Gear ratio for use in the vehicle
- Dynamic Characterization
  - What is the max acceleration for the fully integrated car?
- Efficiency
  - What is the most efficient speed we can run the vehicle?
- Cooling
  - Does the car benefit from having cooling? Does it improve efficiency?

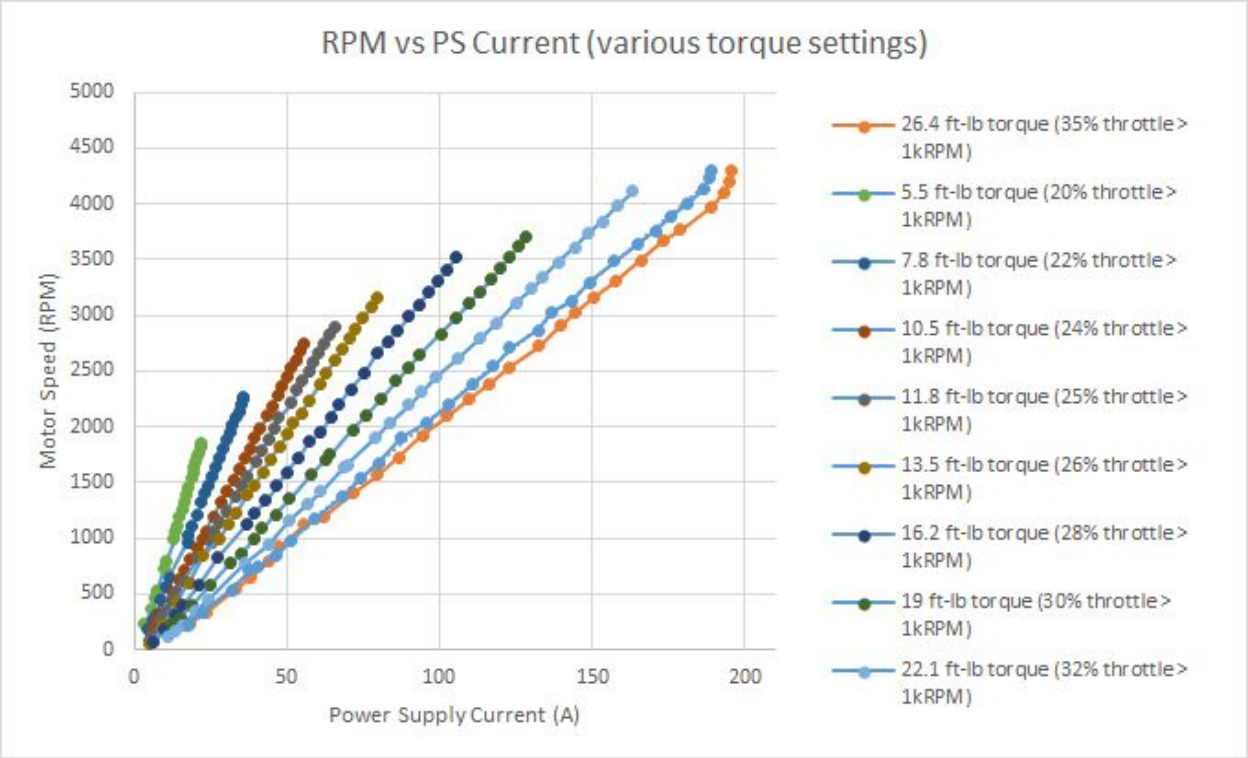


MCM- Static Characterization



MCM- Static Characterization

- Relationships determined between system inputs and measurable outputs
  - Controller corresponds throttle input with torque values
  - load only varies speed



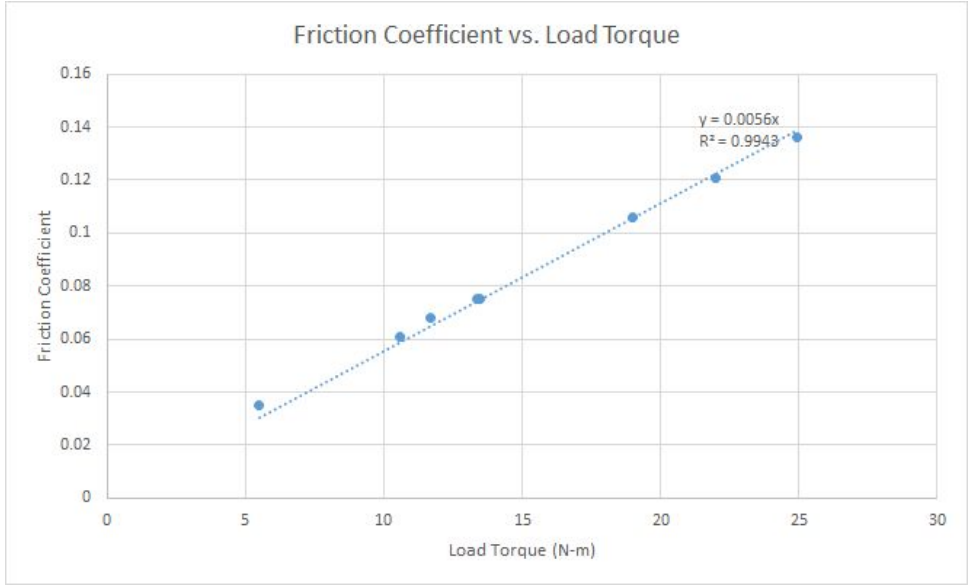
MCM- Static Characterization

Comparing the equation we produced

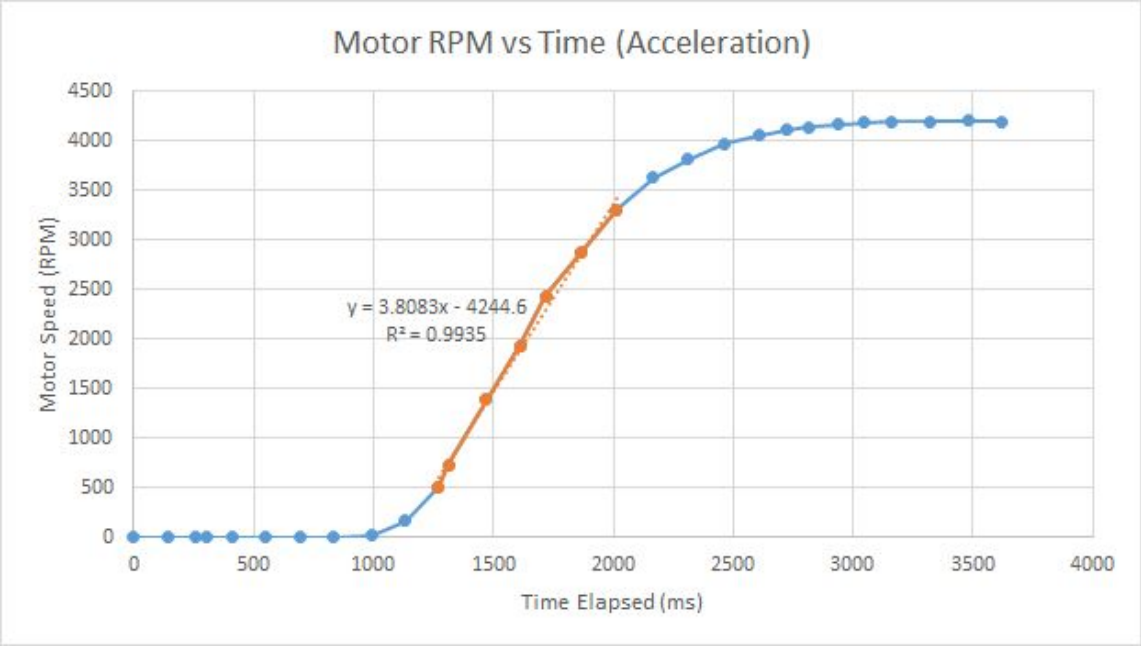
$$.0056T_L = \frac{4.305i}{w} - \frac{T_L}{w}$$

$$w = \frac{768.75i}{TL} - 178.57$$

With multiple experiments, within the operating range of 1000-4500 RPM there is a +/- 5.7% accuracy in our equations ability to predict motor RPMs

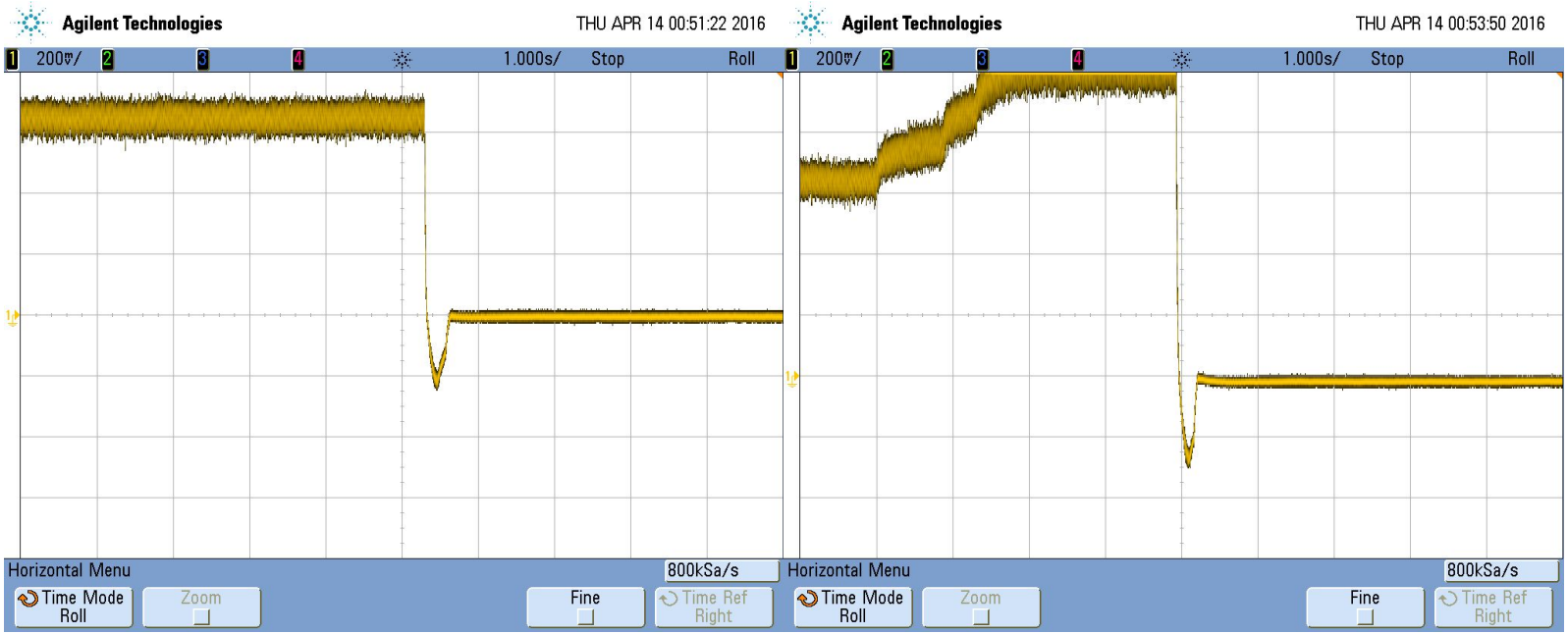


MCM- Dynamic Characterization



MCM- Dynamic Characterization

Regenerative Braking



MCM- Dynamic Characterization

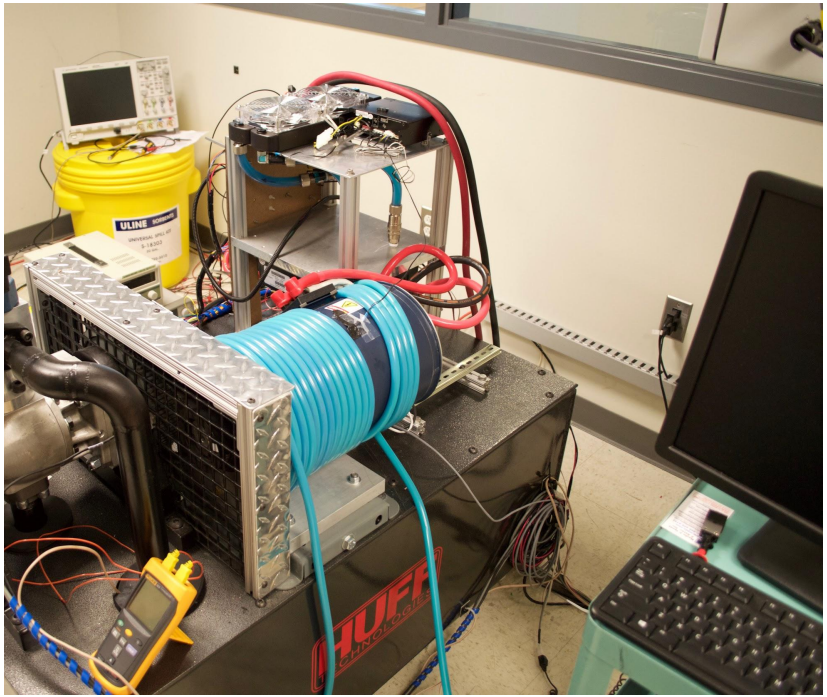
$$w = \frac{768.75i}{TL} - 178.57$$

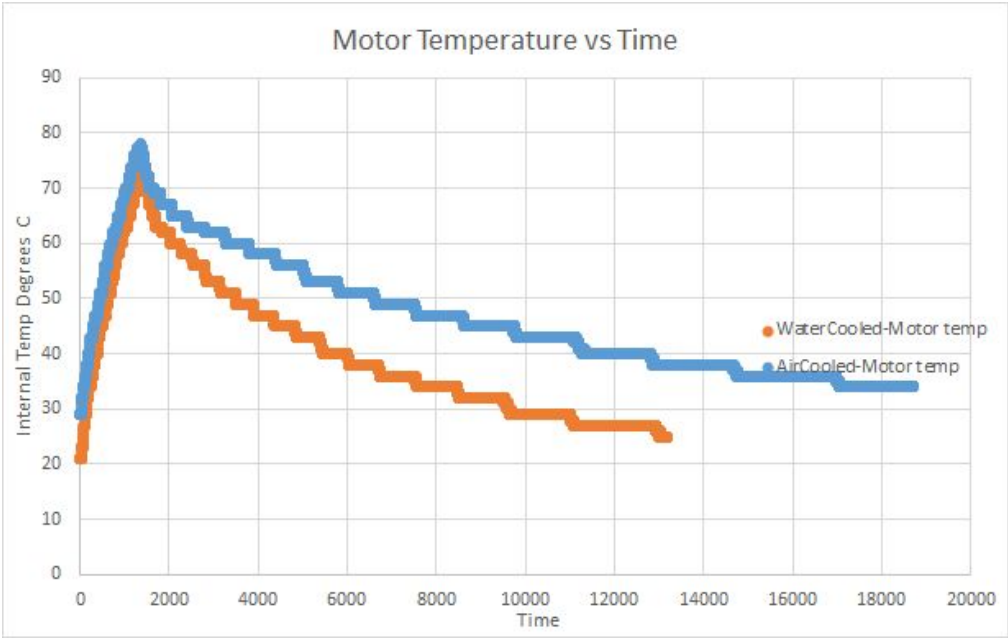
$$\downarrow$$

$$J\frac{dw}{dt} = K_T i - fw - T_L$$

- Calculations made using slope from acceleration vs RPM graphs
- Find that J is proportional to steady state torque of motor operation

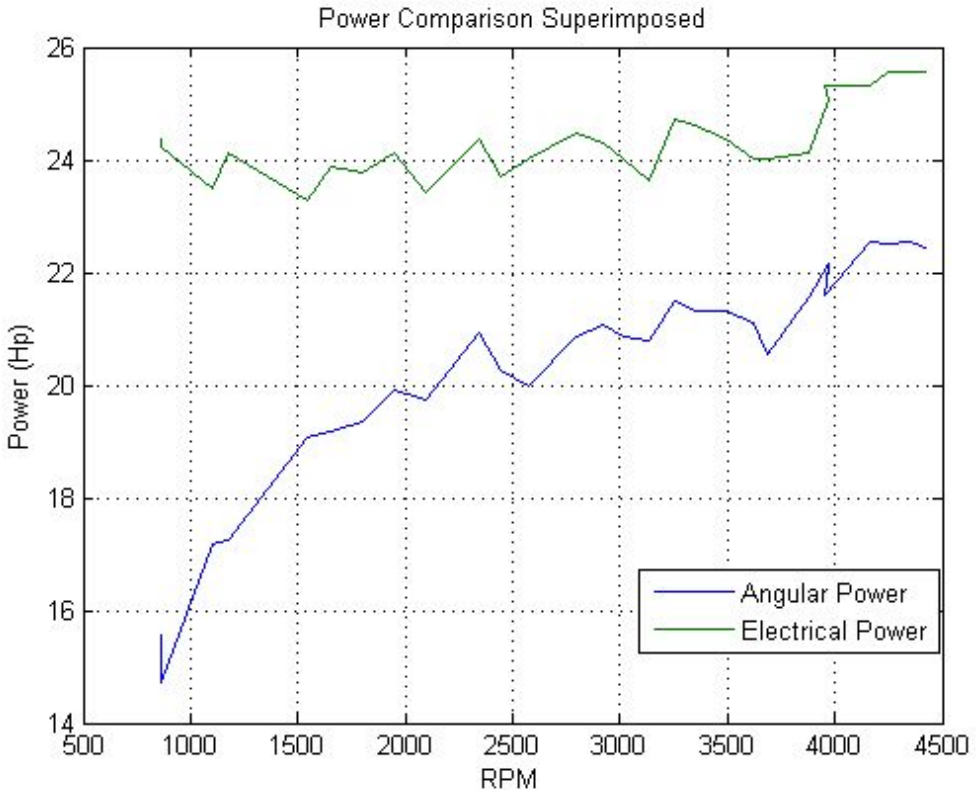
MCM – Cooling & Efficiency





- 70 to 35 degC half life:
  - Air Cooled: 15430 s
  - Water Cooled: 6074 s
- 60.6% improvement in half life, 8% -> 18% duty cycle

MCM – Cooling & Efficiency

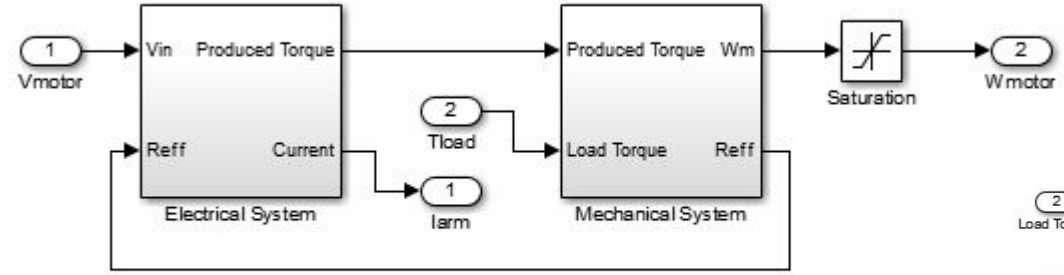


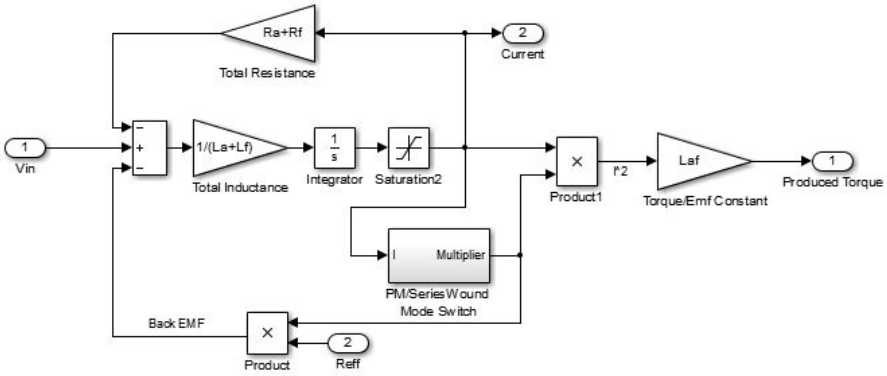
Power Loss = 9777 - 8306 = 1471 Watts

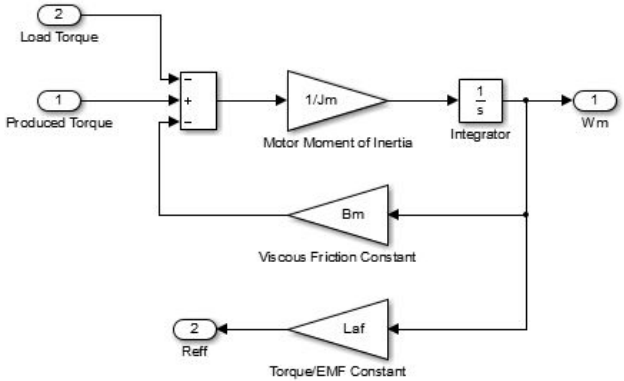
Heat	Watts
Oil	409.8625
Motor	767.7091
Controller	77.43279
Room Air	136.894
Total	1391.903

Heat	Watts
Mtr Cool	105.4501
Ctrlr Cool	103.082
Ht oil	348.689
Ht motor	784.8966
Ht Ctrl	86.54253
Hr Room	4.277938
Total HtPower	1432.938

MCM – Modeling

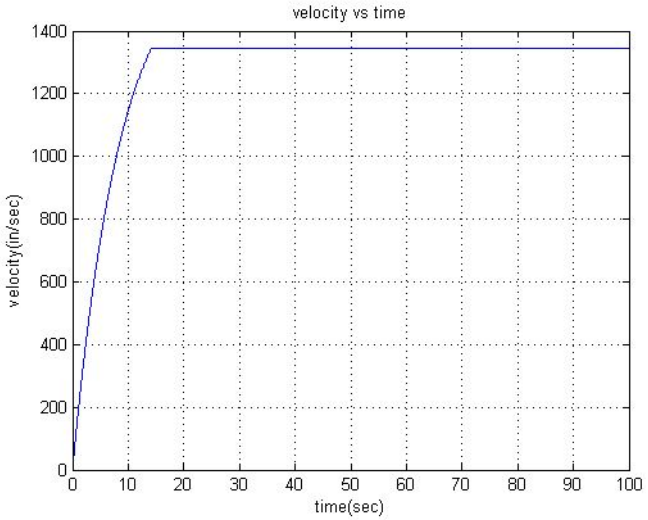


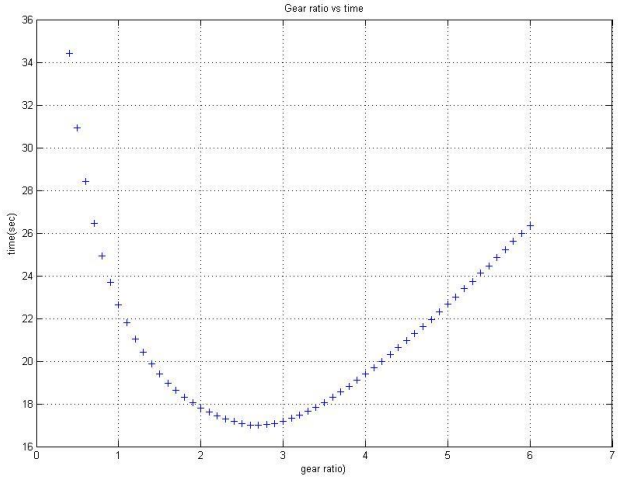




MCM – Results

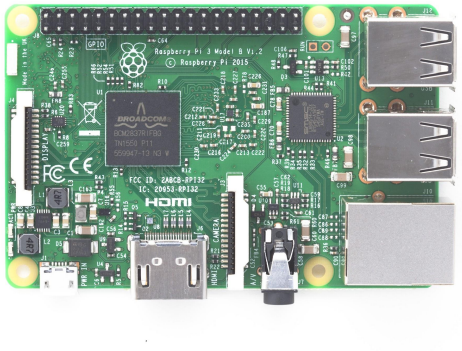
- Full Range of Speeds for the Car:
  - 0-4500 RPM for the motor corresponds with 0-1500 RPM at the wheels. Given 8 inch radius wheels, **max speed for car is about 76 mph**
- Speed for max Efficiency:
  - Determined that motor is electrically efficiency at and above 2500 RPM. At a motor speed of 2500 RPM, **the car is running at about 42 mph.**
- Time to dissipate battery:
  - Running at the efficient speed of 2500 RPM with steady state torque 15 ft-lb gives 71A current draw -> **51 minutes**
- Gear Ratio:
  - for straight line acceleration test **gear ratio determined to be 2.8**
- Max Acceleration:
  - Assuming car weight of 800lbs, **car max acceleration pulling max power is 0.27 Gs over 13 seconds**





VSCADA - Hardware

- Raspberry Pi 3
- CANbus communication via usb2can adaptor
- 7” display screen
    - Connected via hdmi



VSCADA - SCADAd

- Python-3.5 backend
- Does the heavy lifting
  - CAN communications
    i. Receive data for logging
    ii. Send data to JGB for controlling motor and dyno
  - Event logging
    i. Event logs can be parsed by slog_parser and be turned into csv files
- Serves up the front end scada-ui which is react-js
- Designed with extendability in mind. It is straightforward to add subsystems with any knowledge of python
  - Includes useful pre-built components such as plot for making new subsystems

VSCADA - System Topology

```
"physical":
 "vcan0":
          "[0x601, 0x602]": "MotorController"
          "[0x500, 0x0501, 0x0502]": "BatteryPack"
          "[0x510, 0x0511, 0x0512]": "BatteryPack"
          "[0x520, 0x0521, 0x0522]": "BatteryPack"
          "[0x530, 0x0531, 0x0532]": "BatteryPack"
          "[0x200, 0x201]": "TractiveSystemController"
          "[0x250, 0x251]": "DynomometerController"



 "fake0": "GPS"

"virtual":
          - ["Dashboard"]
          - ["BatteryManager"]
```

VSCADA - Event Logger Raw

{"calibrated": 472.0, "uncalibrated": 4720, "unit": "Volts", "location": ["BatteryPack-0", "pack_voltage"], "type": "measurand", "timestamp": 1462653402.564536}
{"calibrated": 4573.39, "uncalibrated": 457339, "unit": "s", "location": ["BatteryPack-0", "uptime"], "type": "measurand", "timestamp": 1462653402.567994}
{"calibrated": 14.895, "uncalibrated": 14895, "unit": "Coulombs", "location": ["BatteryPack-0", "total_coulombs"], "type": "measurand", "timestamp": 1462653402.567994}
{"calibrated": 0.798, "uncalibrated": 798, "unit": "Volts", "location": ["BatteryPack-0", "cells", 0, "voltage"], "type": "measurand", "timestamp": 1462653402.5692666}
{"calibrated": 4407.7, "uncalibrated": 44077, "unit": "Celcius", "location": ["BatteryPack-0", "cells", 0, "temperature"], "type": "measurand", "timestamp": 1462653402.5692666}
{"calibrated": 27.274, "uncalibrated": 27274, "unit": "Volts", "location": ["BatteryPack-0", "cells", 1, "voltage"], "type": "measurand", "timestamp": 1462653402.5705724}
{"calibrated": 4847.6, "uncalibrated": 48476, "unit": "Celcius", "location": ["BatteryPack-0", "cells", 1, "temperature"], "type": "measurand", "timestamp": 1462653402.5705724}
{"calibrated": 4.11, "uncalibrated": 4110, "unit": "Volts", "location": ["BatteryPack-0", "cells", 2, "voltage"], "type": "measurand", "timestamp": 1462653402.571856}
{"calibrated": 6078.5, "uncalibrated": 60785, "unit": "Celcius", "location": ["BatteryPack-0", "cells", 2, "temperature"], "type": "measurand", "timestamp": 1462653402.571856}
{"calibrated": 6.941, "uncalibrated": 6941, "unit": "Volts", "location": ["BatteryPack-0", "cells", 3, "voltage"], "type": "measurand", "timestamp": 1462653402.5731318}
{"calibrated": 3234.5, "uncalibrated": 32345, "unit": "Celcius", "location": ["BatteryPack-0", "cells", 3, "temperature"], "type": "measurand", "timestamp": 1462653402.5731318}
{"calibrated": 20.819, "uncalibrated": 20819, "unit": "Volts", "location": ["BatteryPack-0", "cells", 4, "voltage"], "type": "measurand", "timestamp": 1462653402.5746467}
{"calibrated": 3240.5, "uncalibrated": 32405, "unit": "Celcius", "location": ["BatteryPack-0", "cells", 4, "temperature"], "type": "measurand", "timestamp": 1462653402.5746467}
{"calibrated": 14.102, "uncalibrated": 14102, "unit": "Volts", "location": ["BatteryPack-0", "cells", 5, "voltage"], "type": "measurand", "timestamp": 1462653402.5759284}
{"calibrated": 6478.7, "uncalibrated": 64787, "unit": "Celcius", "location": ["BatteryPack-0", "cells", 5, "temperature"], "type": "measurand", "timestamp": 1462653402.5759284}
{"calibrated": 54.491, "uncalibrated": 54491, "unit": "Volts", "location": ["BatteryPack-0", "cells", 6, "voltage"], "type": "measurand", "timestamp": 1462653402.5772016}
{"calibrated": 1674.8, "uncalibrated": 16748, "unit": "Celcius", "location": ["BatteryPack-0", "cells", 6, "temperature"], "type": "measurand", "timestamp": 1462653402.5772016}
{"calibrated": 1458332.385, "uncalibrated": 1458332385, "unit": "Amperes", "location": ["BatteryPack-0", "pack_current"], "type": "measurand", "timestamp": 1462653402.7655206}
{"calibrated": 2988.2, "uncalibrated": 29882, "unit": "Volts", "location": ["BatteryPack-0", "pack_voltage"], "type": "measurand", "timestamp": 1462653402.7655206}
{"calibrated": 4573.59, "uncalibrated": 457359, "unit": "s", "location": ["BatteryPack-0", "uptime"], "type": "measurand", "timestamp": 1462653402.7689815}
{"calibrated": 7.713, "uncalibrated": 7713, "unit": "Coulombs", "location": ["BatteryPack-0", "total_coulombs"], "type": "measurand", "timestamp": 1462653402.7689815}
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{"calibrated": 2333.7, "uncalibrated": 23337, "unit": "Celcius", "location": ["BatteryPack-0", "cells", 0, "temperature"], "type": "measurand", "timestamp": 1462653402.7702641}
{"calibrated": 43.314, "uncalibrated": 43314, "unit": "Volts", "location": ["BatteryPack-0", "cells", 1, "voltage"], "type": "measurand", "timestamp": 1462653402.7715514}

VSCADA – CSV Log after parsing

time	BatteryPack-0.cells-0.status	BatteryPack-0.cells-0.temperature	BatteryPack-0.cells-0.voltage	BatteryPack-0.cells-1.status	BatteryPack-0.cells-1.temperature	BatteryPack-0.cells-1.voltage	BatteryPack-0.cells-2.status	BatteryPack-0.cells-2.temperature
0.1	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.291	n/a	n/a
0.2	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.291	n/a	n/a
0.3	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.291	NOT BYPASS	22.6
0.4	NOT BYPASS	21.9	3.294	NOT BYPASS	22.2	3.291	NOT BYPASS	22.6
0.5	NOT BYPASS	21.9	3.294	NOT BYPASS	22.3	3.291	NOT BYPASS	22.6
0.6	NOT BYPASS	21.9	3.294	NOT BYPASS	22.3	3.291	NOT BYPASS	22.6
0.7	NOT BYPASS	21.9	3.294	NOT BYPASS	22.2	3.297	NOT BYPASS	22.5
0.8	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6
0.9	NOT BYPASS	21.9	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6
1	NOT BYPASS	21.9	3.294	NOT BYPASS	22.2	3.297	NOT BYPASS	22.6
1.1	NOT BYPASS	21.9	3.3	NOT BYPASS	22.2	3.291	NOT BYPASS	22.6
1.2	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6
1.3	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6
1.4	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6
1.5	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.291	NOT BYPASS	22.6
1.6	NOT BYPASS	21.9	3.294	NOT BYPASS	22.3	3.291	NOT BYPASS	22.6
1.7	NOT BYPASS	21.9	3.294	NOT BYPASS	22.3	3.291	NOT BYPASS	22.5
1.8	NOT BYPASS	21.9	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.5
1.9	NOT BYPASS	21.9	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6
2	NOT BYPASS	22	3.294	NOT BYPASS	22.2	3.297	NOT BYPASS	22.6
2.1	NOT BYPASS	22	3.294	NOT BYPASS	22.2	3.297	NOT BYPASS	22.6
2.2	NOT BYPASS	22	3.294	NOT BYPASS	22.2	3.297	NOT BYPASS	22.6
2.3	NOT BYPASS	22	3.294	NOT BYPASS	22.2	3.297	NOT BYPASS	22.6
2.4	NOT BYPASS	22	3.294	NOT BYPASS	22.2	3.297	NOT BYPASS	22.6
2.5	NOT BYPASS	22	3.294	NOT BYPASS	22.2	3.297	NOT BYPASS	22.5
2.6	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.5
2.7	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6
2.8	NOT BYPASS	21.9	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.5
2.9	NOT BYPASS	21.9	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.5
3	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6
3.1	NOT BYPASS	21.9	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6
3.2	NOT BYPASS	21.9	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6
3.3	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6
3.4	NOT BYPASS	22	3.294	NOT BYPASS	22.3	3.297	NOT BYPASS	22.6

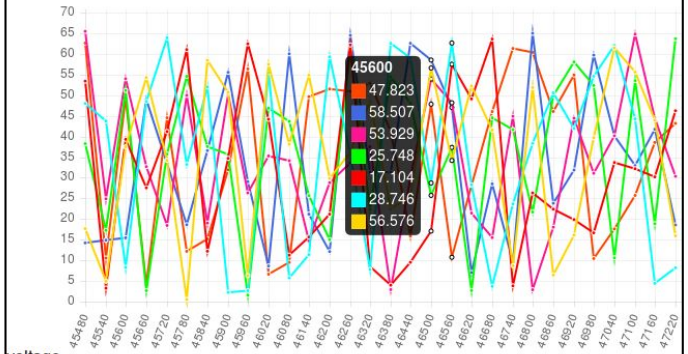
VSCADA - SCADA-ui

- Serves as the main user interface and is opened up in a web browser
- Replicates system state on client in Javascript
- Renders view of state using React-JS
- Can be accessed by any device on campus network with a web browser
- The dashboard screen auto-navigates to the ui on boot-up
- Designed with extendability in mind. It is straightforward to add subsystem views.
    - Includes useful pre-built components such as plot for making new subsystems displays

- MotorController-0
- TSC-0

total_coulombs	15.448000 Coulombs (15448)
uptime	1:07:33:18.780 (11359878)

BatteryPack-0cell_voltage



Play/Pause Graph

BatteryPack-0cells0voltage
BatteryPack-0cells1voltage
BatteryPack-0cells2voltage
BatteryPack-0cells3voltage
BatteryPack-0cells4voltage
BatteryPack-0cells5voltage
BatteryPack-0cells6voltage

true **Actual:** true

ID	Voltage	Temperature	Status
0	58.999000 Volts (58999)	4.475700 KCelcius (44757)	NOT BYPASS Status (0)
1	12.140000 Volts (12140)	1.167900 KCelcius (11679)	NOT BYPASS Status (0)
2	4.173000 Volts (4173)	5.718200 KCelcius (57182)	NOT BYPASS Status (0)
3	53.198000 Volts (53198)	2.474000 KCelcius (24740)	NOT BYPASS Status (0)
4	54.626000 Volts (54626)	3.160300 KCelcius (31603)	NOT BYPASS Status (0)
5	60.223000 Volts (60223)	1.185800 KCelcius (11858)	NOT BYPASS Status (0)
6	34.064000 Volts (34064)	147.600000 Celcius (1476)	NOT BYPASS Status (0)

Tom Anderson & Sons

Soul-Machine

Virtual

- BatteryManager-0
- Dashboard-0
- SafetyManager-0
- TSM-0

Physical

- BatteryPack-0
- BatteryPack-1
- BatteryPack-2
- BatteryPack-3
- DC-0
- GPS-0
- MotorController-0
- TSC-0

TractiveSystemController-0

ONLINE: TRUE

Location: (<CAN: can0>, [512, 513])

Timestamp: Sun May 08 2016 22:55:30 GMT-0400 (EDT)

software_throttle

\- + **Actual:** 127

Input: 127

throttle_enable

true **Actual:** true

throttle_select

Physical **Actual:** Physical

open_safety_loop

false **Actual:** false

Measurand Name	Value
AIR_voltage_present	true (true)
current	4.882813 mAmperes (64)
drive_button	false (false)
mc_voltage_present	true (true)
physical_throttle	0 (0)
voltage	991.210938 mVolts (12992)

Soul-Machine

Virtual

- BatteryManager-0
- SafetyManager-0
- TSM-0

Physical

- BatteryPack-0
- BatteryPack-1
- BatteryPack-2
- BatteryPack-3
- DC-0
- GPS-0
- MotorController-0
- TSC-0

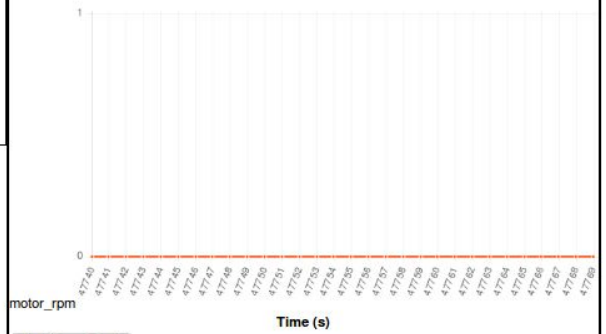
MotorController-0

ONLINE: FALSE

Location: (<CAN: vcan0>, [1537, 1538])

Timestamp: Not contacted.

MotorController-0motor_rpm_plot



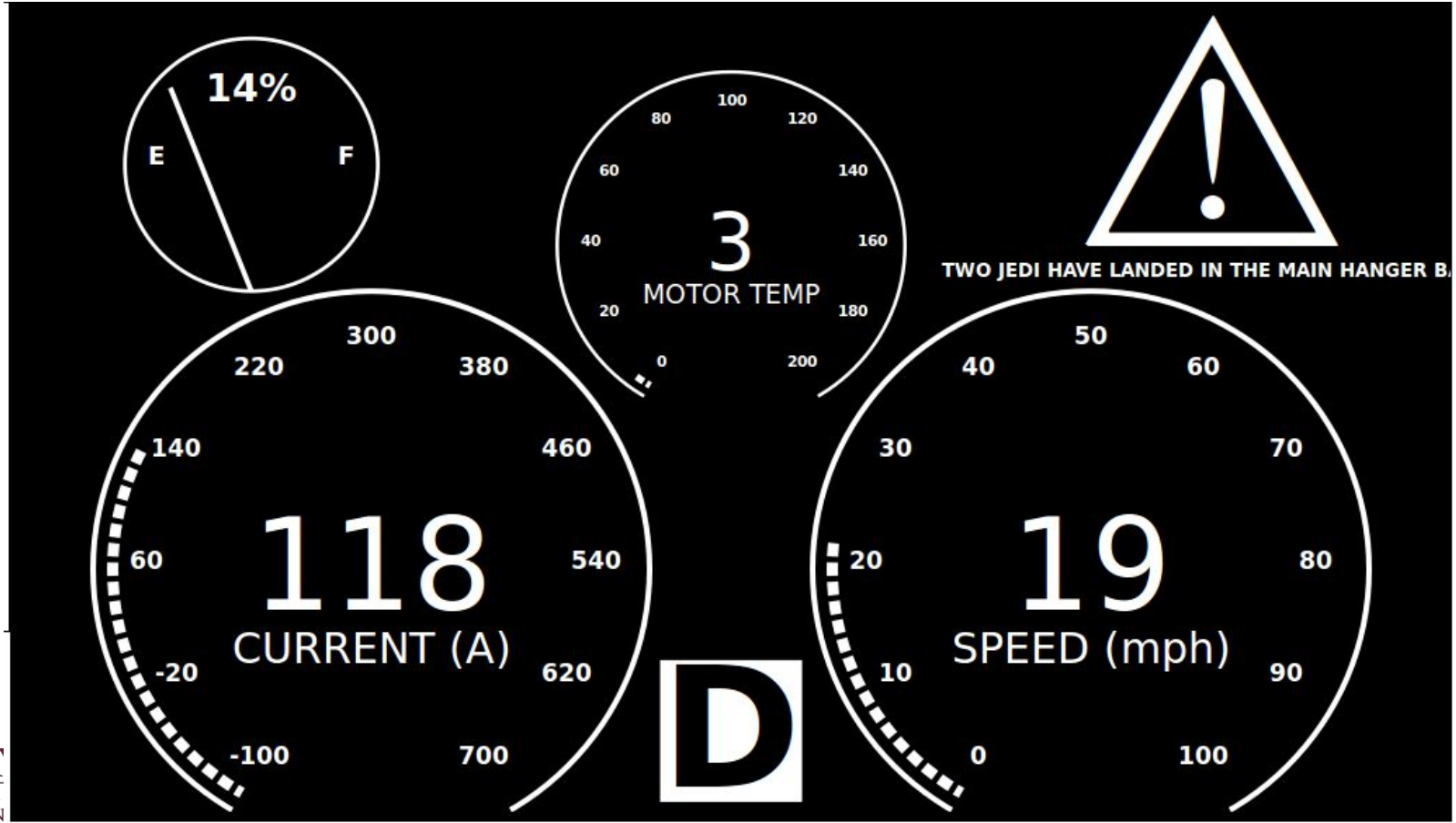
Play/Pause Graph

MotorController-0motor_rpm

true **Actual:** true

Measurand Name	Value
brake_input	no-data % (no-data)
brake_light	no-data Boolean (no-data)
cap_voltage	no-data Volts (no-data)
controller_fault1	no-data Fault (no-data)
controller_fault2	no-data Fault (no-data)
controller_temperature	no-data Celcius (no-data)
econo	no-data Boolean (no-data)
motor_rpm	no-data RPM (no-data)
motor_temperature	no-data Celcius (no-data)
regen	no-data Boolean (no-data)
reverse	no-data Boolean (no-data)
rms_current	no-data Amperes (no-data)
stator_frequency	no-data Hz (no-data)
throttle_input	no-data % (no-data)

Vscada – Dashboard



VSCADA – Safety Manager (Part of SCADAd)

- Safety parameters are user defined and very simple to make
  - Chose parameter, set warning threshold, set failure threshold and you're done
- Communicates with Safetyd to keep safety loop closed.

VSCADA - Safetyd

- Serves as an intermediary between the Scada-daemon and the raspberry pi GPIO pins
- Listens for UDP traffic on localhost. Reading 1 bytes messages
- A 0x01 means close the safety loop. If it goes 200ms without receiving this message, the loop opens
- A 0x00 means open the loop immediately.
- If SCADAd goes down, the loop opens after a timeout. If the SafetyManager subsystem detects a fault it signals to open the loop immediately.

VSCADA - Safety-Dict

```
SAFETY_DICT = {
        'pack_voltage' :        {'location': ['BatteryPack-0', 'voltage'],
                'warning' : '>3.7',
                'failure' : '>4.0',
                'units'   : 'Volts'
                },
        'motor_temperature':        {'location': ['MotorController-0', 'temperature'],
                'failure' : '>80',
                'units'   : 'Celcius'
                },
        'cell_one_voltage' :    {'location': ['BatteryPack-0', 'cells', 0, 'voltage'],
                'warning' : '>50',
                'failure' : '>65',
                'units'   : 'Volts'
                },
}
```

Soul-Machine

Virtual

- BatteryManager-0
- SafetyManager-0
- TSM-0

Physical

- BatteryPack-0
- BatteryPack-1
- BatteryPack-2
- BatteryPack-3
- DC-0
- GPS-0
- MotorController-0
- TSC-0

SafetyManager-0

ONLINE: FALSE

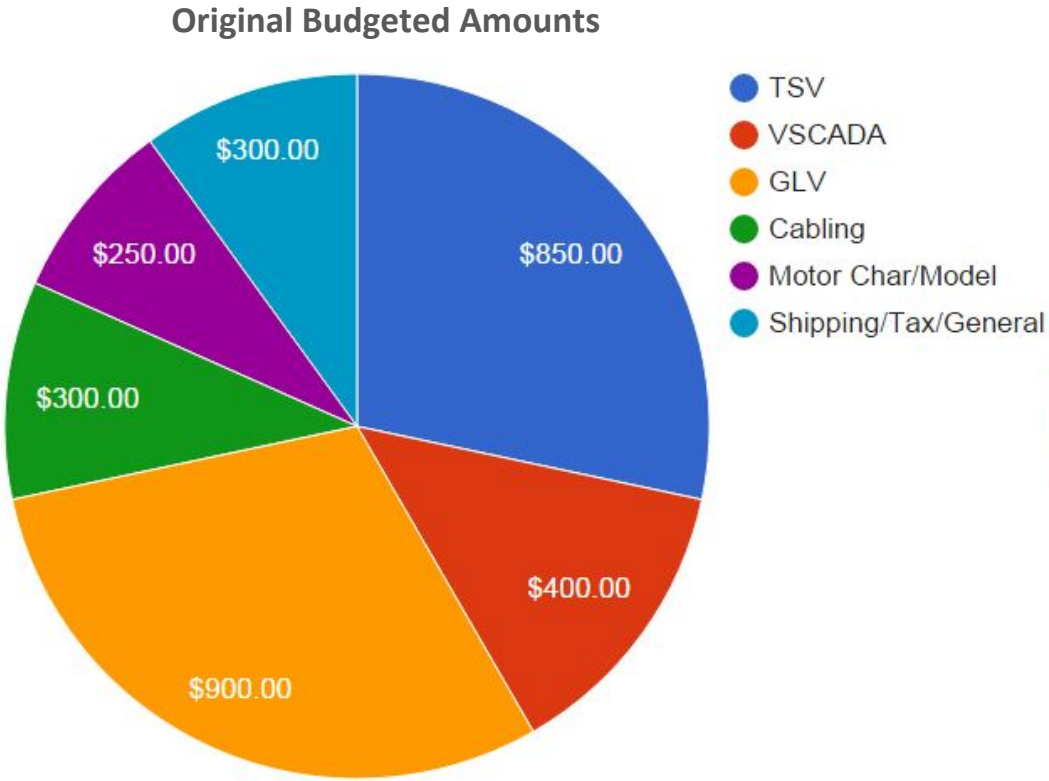
Location: virtual

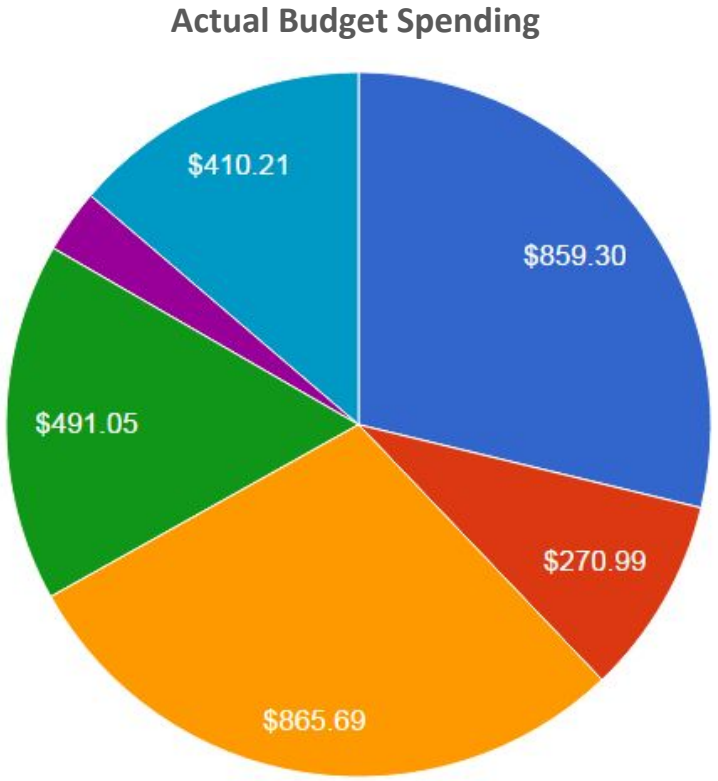
Timestamp: Not contacted.

Measurand Name	Value	Warning	Warning Enabled	Failure	Failure Enabled	Reset Failure
cell one voltage	20.023000 Volts (20.023)	>50 false	true **Actual:** true	>65 true	true **Actual:** true	false **Actual:** false
motor temperature	no-data Celcius (no-data)			>80 false	true **Actual:** true	false **Actual:** false
pack voltage	no-data Volts (no-data)	>3.7 false	true **Actual:** true	>4.0 false	true **Actual:** true	false **Actual:** false

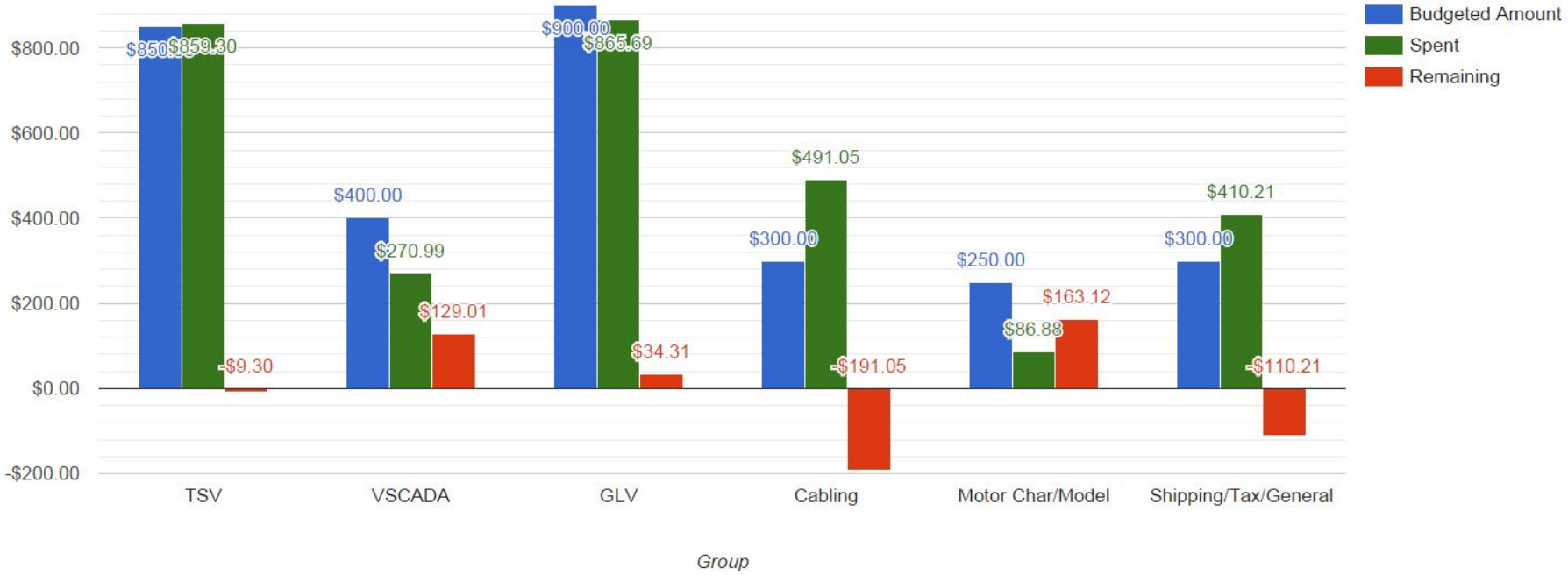
soulmachine.lafayette.edu:1428/index.html

Budget


Original Budgeted Amounts
$850.00
$400.00
$900.00
$300.00
$250.00
$300.00
TSV
VSCADA
GLV
Cabling
Motor Char/Model
Shipping/Tax/General


Actual Budget Spending
$859.30
$270.99
$865.69
$491.05
$410.21

Budget – Category Breakdowns



Budget – Overall Budgeted v. Spent Comparison

Budget – Weekly Spending

Budget – Table View

Group	TSV	VSCADA	GLV	Cabling	Motor Char/Model	Shipping/Tax/General	Project Total	Extra-Budgetary
Budgeted Amount	$850.00	$400.00	$900.00	$300.00	$250.00	$300.00	**$3,000.00**	
Spent	$859.30	$270.99	$865.69	$491.05	$86.88	$410.21	**$2,984.12**	$1,336.47
Remaining	-$9.30	$129.01	$34.31	-$191.05	$163.12	-$110.21	**$15.88**	

Questions