LAFAYETTE

Formula Electric Vehicle 2015
Final Presentation

May 11, 2015

FORMULA HYBRID THE FUTURE ON TRACK.

ECE 492: Senior Design II

Project Overview

1. SAE Formula Hybrid Competition Vehicle
    a. Electric Car
2. 4 year project senior spring semester
3. Spring 2013
    a. Prototype 3-cell battery
4. Spring 2014
    a. Full Spec 7-cell battery
    b. Purchased - Motor Controller and Dynamometer
5. Spring 2015
    a. 4 competition ready accumulator packs
    b. Fully integrated vehicle control and data acquisition
    c. Low voltage electrical system interfacing with DYNO
    d. Fully interfaced Dynamometer

ELECTRICAL & COMPUTER ENGINEERING

Rules and Requirements

1. Maximum operating voltage of 300 volts
2. UL Recognized insulation
3. Accumulator Isolation Relays
4. High and Low voltage must be galvanically isolated
5. Accumulators must not be able to be touched
6. Quick disconnect of the high voltage systems

LFEV Team Breakdown

Tractive System Voltage (TSV)

- High Voltage Battery Pack Design

Dynamometer (DYNO)

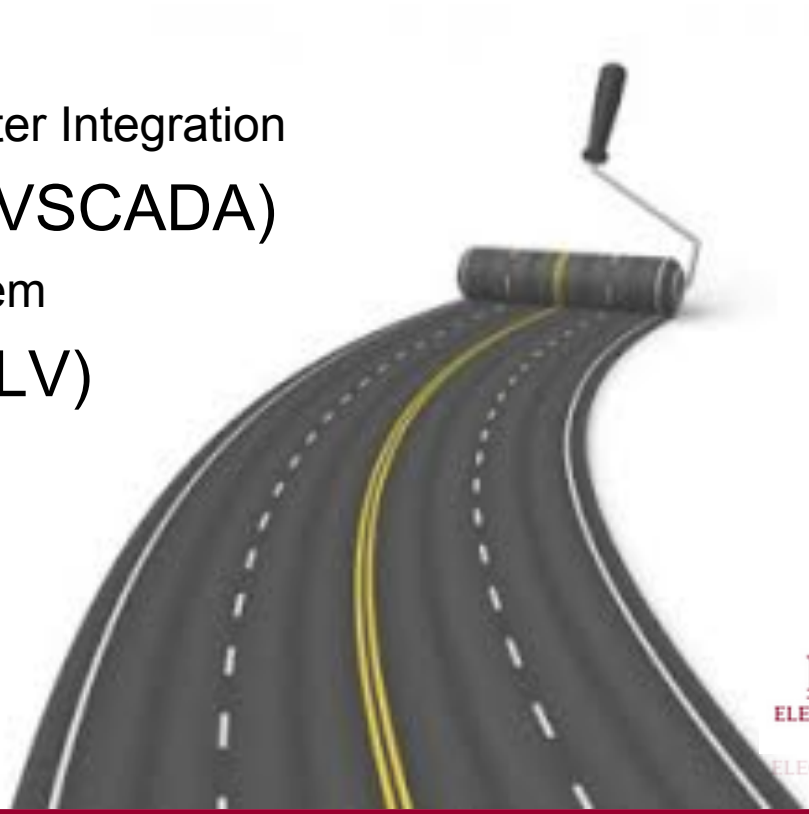
- Huff Technologies Dynamometer Integration

Vehicle Control Software (VSCADA)

- Vehicle Software Control System

Grounded Low Voltage (GLV)

- Low Voltage Power Supply
- Vehicle Safety Loop System

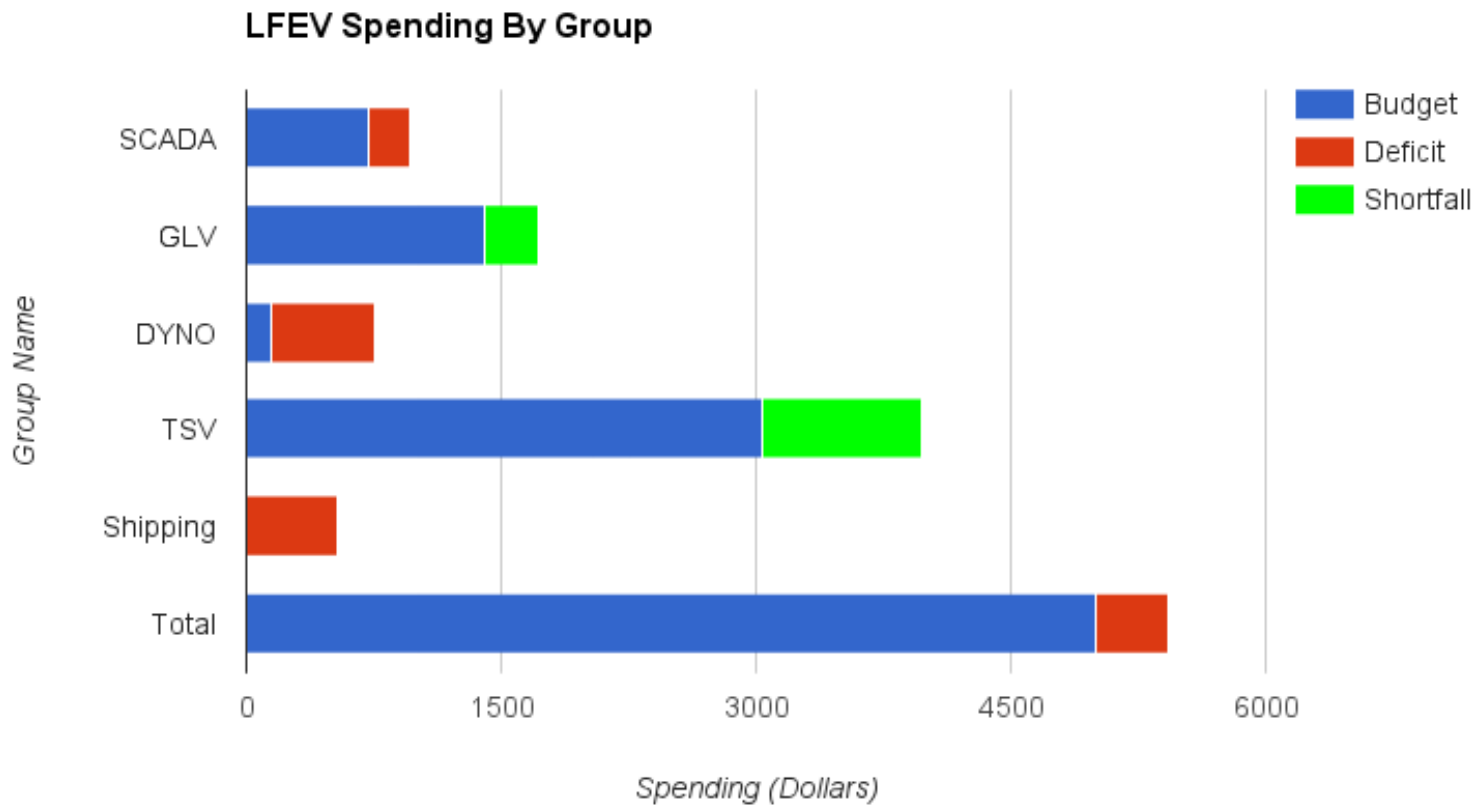


ELECTRICAL & COMPUTER ENGINEERING

Team Members

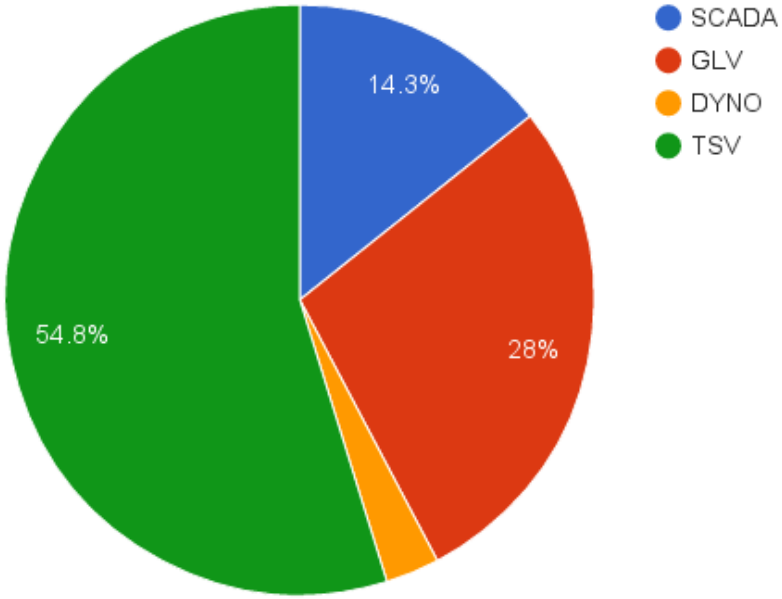
DYNO	TSV	VSCADA	GLV
Steve Mazich	William Stathis	Yiming Chen	Dan Zakzewski
Brendan Malone	Jordan Blake	Bikram Shrestha	Zach Helwig
Nate Hand	Hansen Liang	Rameel Sethi	Nick DiNino
Alex Hytha	Katie Nellis	Adam Cornwell	Jordan Frank
John Bloore		John Gehrig	Alo Posillico
		Sam Cesario	

Project Budget

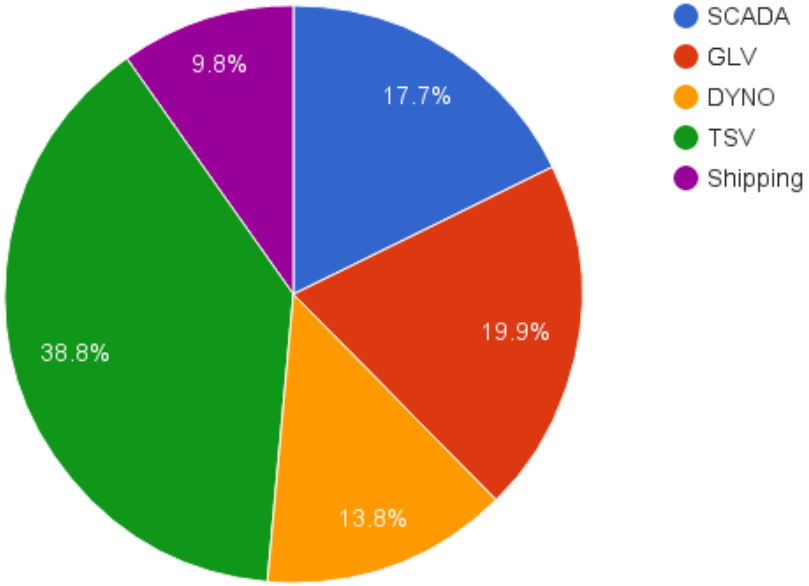


Project Budget

Requested Budget



Spending Breakdown



TSV Objectives

- Plug-and-forget charging
- Control and data acquisition
  - Overall Pack
  - Individual Cell
  - LCD/State of Charge
- Safe charging and discharging
  - Voltage
  - Temperature
  - Fusing
- Communicate with VSCADA
- Reduce Cost/Power consumption

TSV Requirements

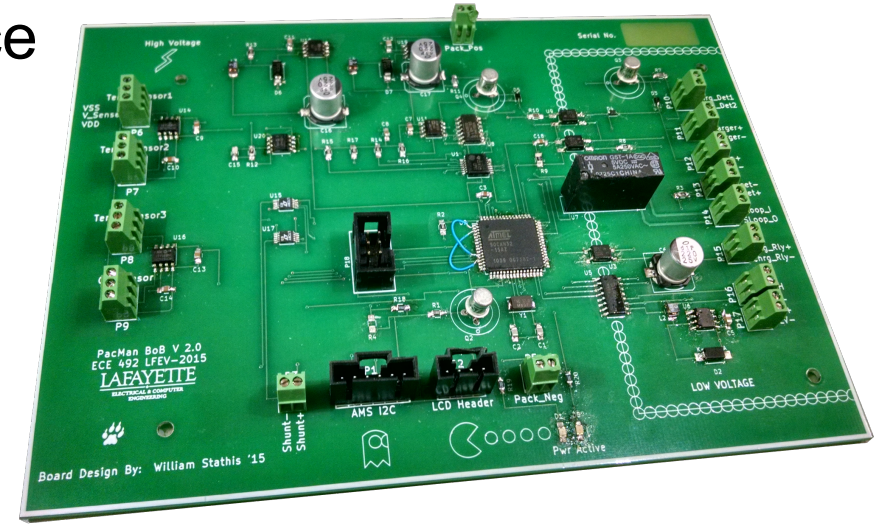
- Galvanic Isolation from GLV
- Accumulator must be separated into segment maintenance disconnects
- High voltage indicator light
- Individual cell voltages and temperatures must be monitored for error
- High Voltage Disconnect port
- Shutdown circuit carries AIR current

Physical Pack Design

- Secure components against forces created in racing
- Increase accessibility for pack maintenance
- Design pack to be mountable to a vehicle
- Ensure galvanic isolation (10mm)
- Divide pack into 33lb sections (FSAE rule)

What Changed?

- Redesigned PacMan system
  - Replaced computer with embedded microcontroller
  - More efficient power consumption & cost
  - All new software
  - Allows for future integration with VSCADA
  - Unified data interface to I2C



What Changed? - Cont'd

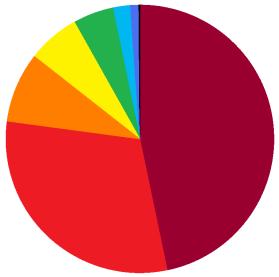
- Changed fusing, relays, and connections
- Ambient temperature measurement
- Full system remote reset
- RS-485 replaced with CAN
- Smaller heat sinks - more compact design

Power Consumption

- BoB - 0.624W in idle
- AMS - 0.46W for all of them
- Total Power Idle 0.884W
- ~66 Days before recharging needed
  - About double last year

Cost

- AMS - $38.68 each (down from $63.36)
  - Ordered 30 boards - enough for future 4 packs
- PacMan - $61.31 each (down $308+)
  - No separate Linux computer
- Pack Electrical
  - Only 1 AIR and 1 Charge Relay (down from 2 each)
  - Down $94.35 (AIR) and $54 (charge relay)
  - Other changes are minor



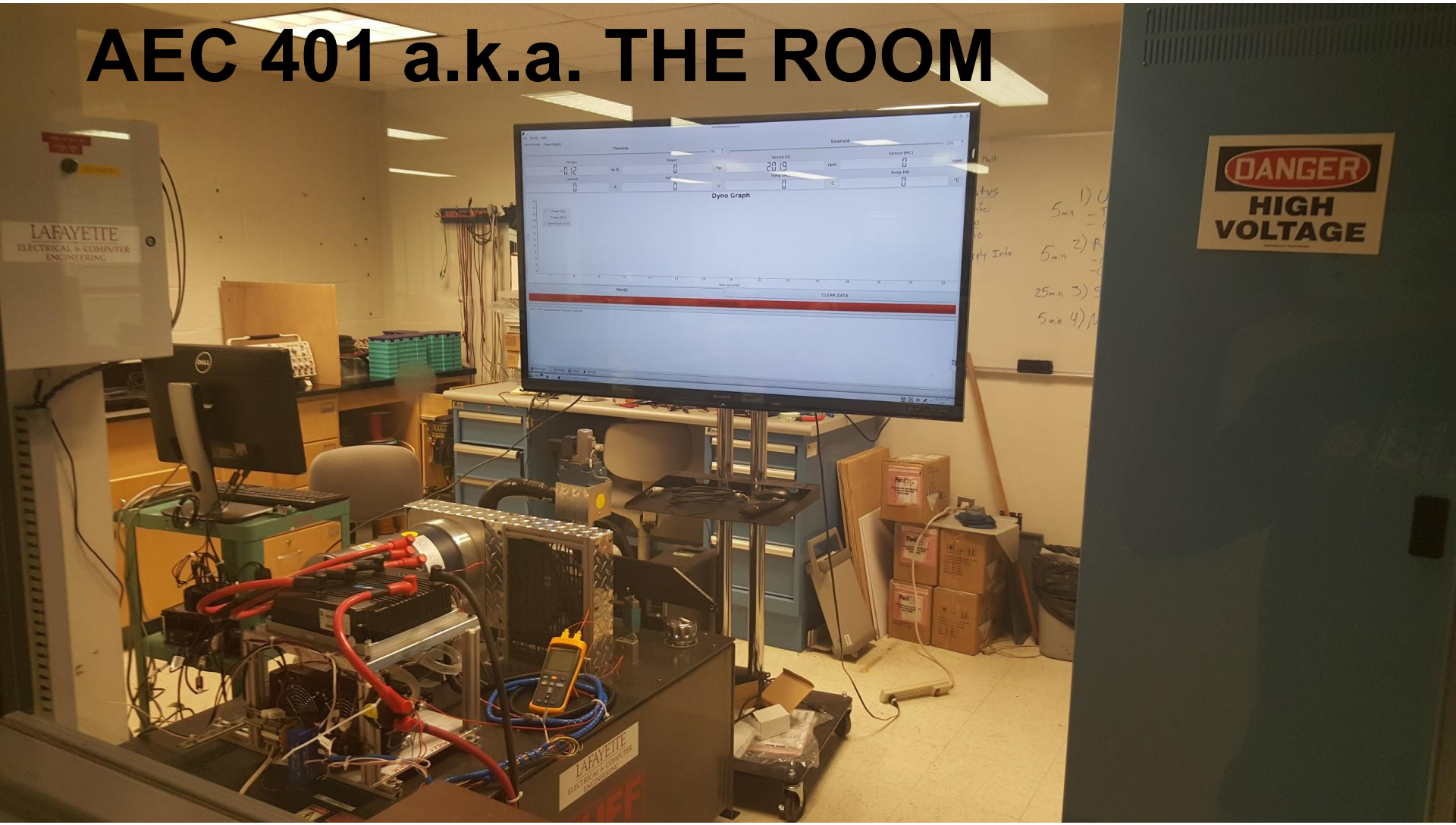
TSV Errata

- Correcting current measurement
- SOC algorithm correction
- LCD display utilization and low charge notification
- Plug-and-forget charging
- Anderson port can power low-current devices

TSV Items Descoped

- VSCADA fuse failure sensors
  - Not a necessary function
- Pack interface to VSCADA
  - TSI replaces this system

AEC 401 a.k.a. THE ROOM



DYNO Objectives

- Control the motor and motor controller
- Use software to acquire data from motor and motor controller
- Learn motor and motor controller characteristics
- Integrate Dyno control and data acquisition with VSCADA
- Integrate with GLV safety loop

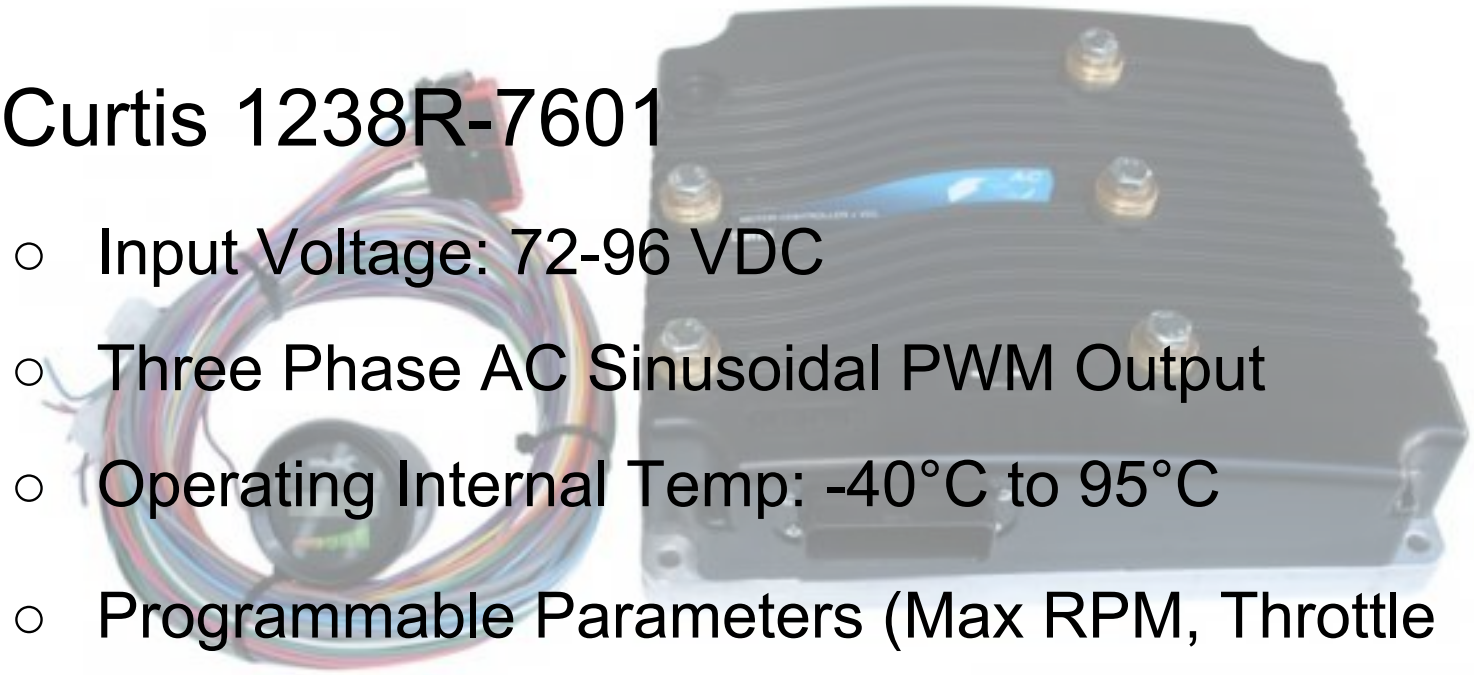
DYNO Requirements

- Galvanic Isolation
- Color Coded Wiring
- 300 Volt maximum
- Conductive surfaces must be covered
- Send sensor data to VSCADA
- Integrate with GLV Safety Loop
- Integrate with TSI

Motor Info

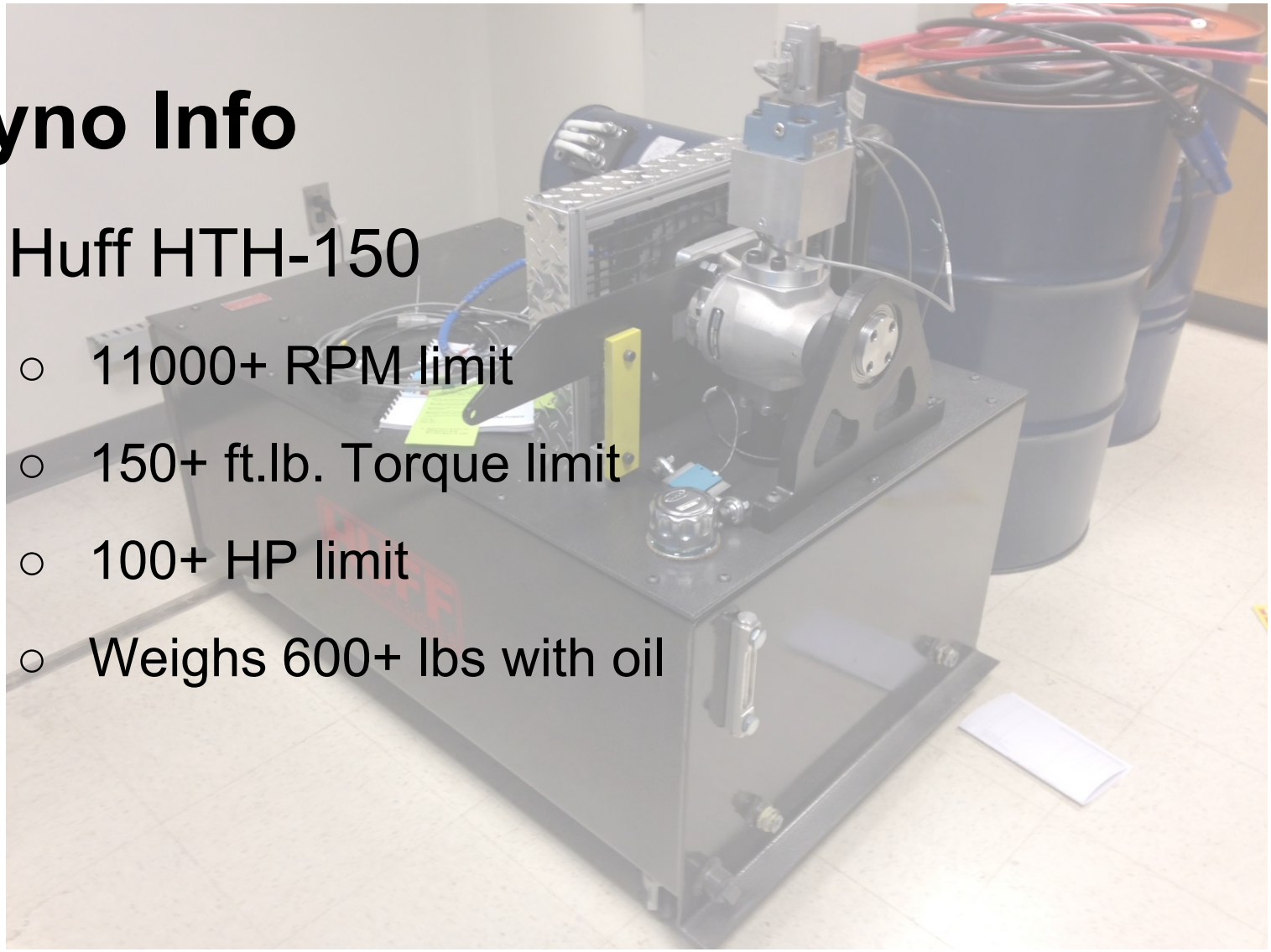
- HPEVS AC50
  - Air Cooled
  - 6500 Max RPM
  - 71 HP, 120 lb-ft torque w/ 96V and 650A
  - 18 HP, 48 lb-ft torque w/ 89.6V and 200A

Motor Controller Info



- Curtis 1238R-7601
  - Input Voltage: 72-96 VDC
  - Three Phase AC Sinusoidal PWM Output
  - Operating Internal Temp: -40°C to 95°C
  - Programmable Parameters (Max RPM, Throttle Type, Current Limits, etc.)

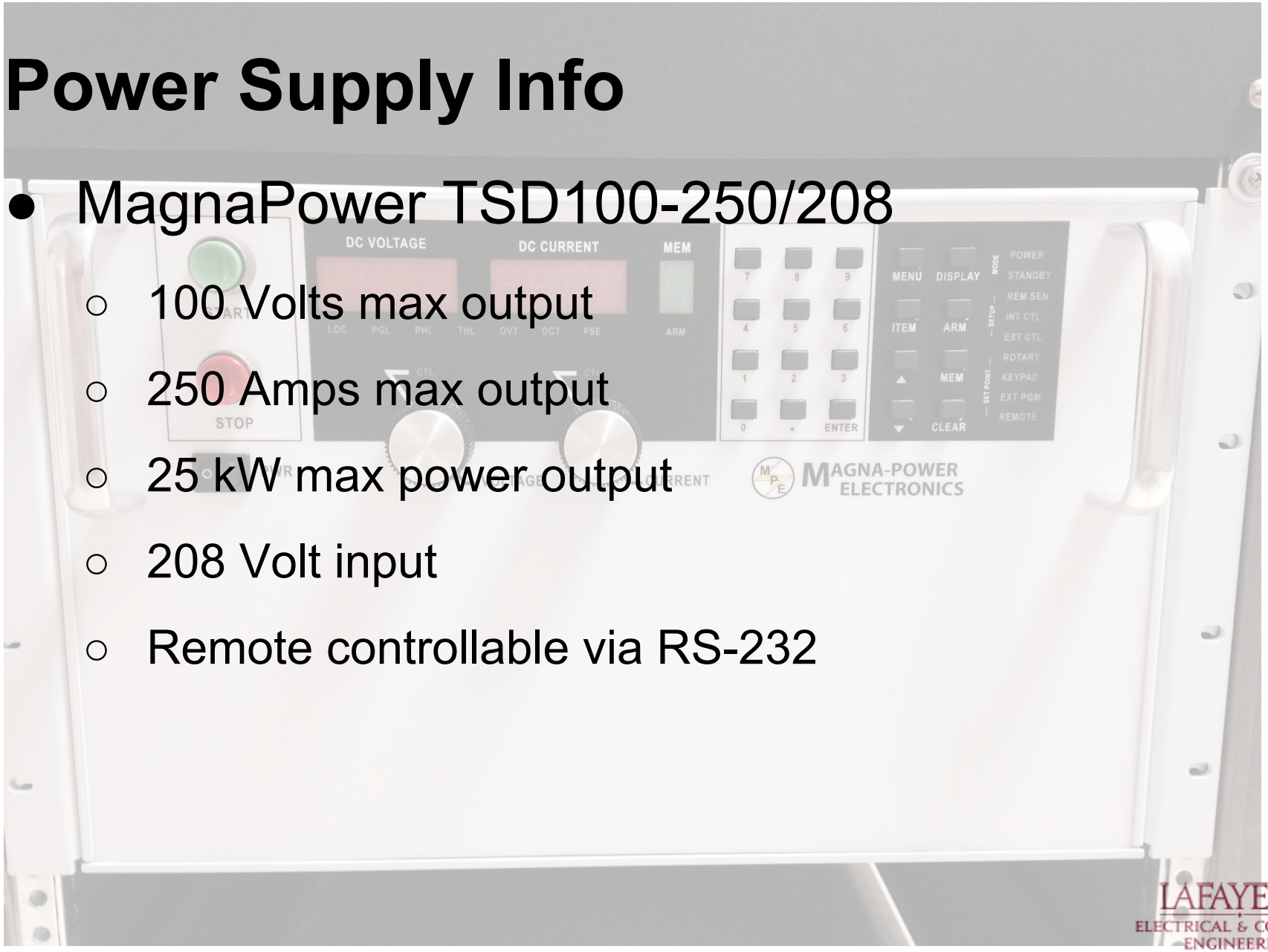
Dyno Info



- Huff HTH-150
  - 11000+ RPM limit
  - 150+ ft.lb. Torque limit
  - 100+ HP limit
  - Weighs 600+ lbs with oil

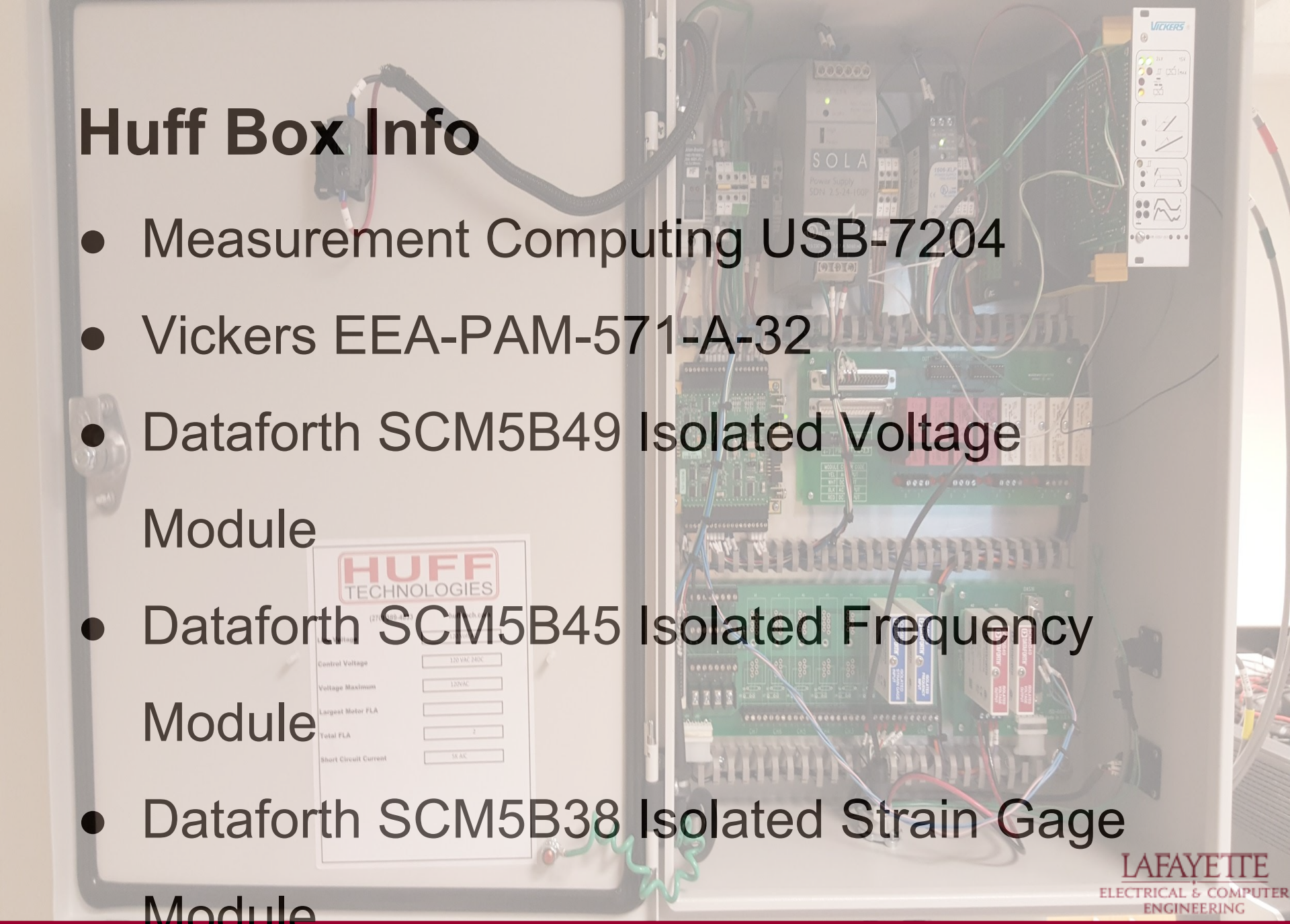
Power Supply Info

- MagnaPower TSD100-250/208
  - 100 Volts max output
  - 250 Amps max output
  - 25 kW max power output
  - 208 Volt input
  - Remote controllable via RS-232

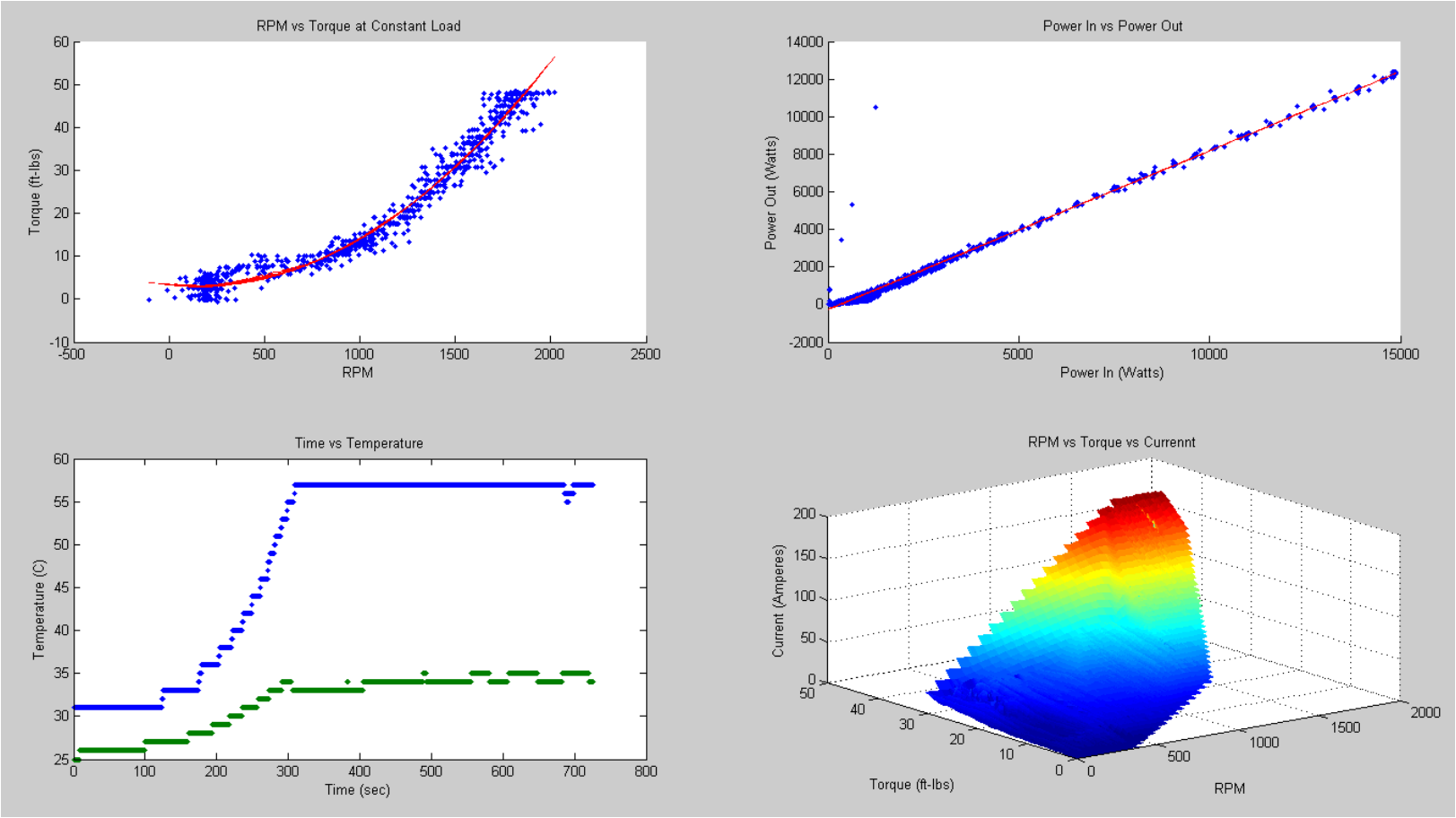


Huff Box Info

- Measurement Computing USB-7204
- Vickers EEA-PAM-571-A-32
- Dataforth SCM5B49 Isolated Voltage Module
- Dataforth SCM5B45 Isolated Frequency Module
- Dataforth SCM5B38 Isolated Strain Gage Module



Torque Curve (and other graphs)



DYNO Errata

- Water Cooling System
- Twist lock connector - wrong colors
- Integration with GLV safety loop
- Oil Temperature shutdown
- Integrate with TSI

VSCADA Objectives

Vehicle

Supervisory

Control

And

Data

Acquisition

- Collect, Graph, Store Data
  - Modularity of Current Sensors/Outputs
  - Expandability for Future Sensors/Outputs
  - Flexible, Robust Data Storage
  - Vehicle Fault Logging
  - Verbose Data Output

- Control Vehicle Subsystems
  - Interface with all Present and Future Systems
  - Make Vehicle Control Decisions
  - Monitor Vehicle Safety
  - Aid System Development
  - System Debugging/Testing

VSCADA Requirements

- Interface with all subsystems (GLV, TSV, Dyno)
  - integrated with Dyno team
- On-car and off-car (remote) control
  - is accessible locally
- Unified API; SDK; common data format and protocols
  - Installation and tool chain will be documented and provided; Use .csv format and CAN protocol

VSCADA Requirements

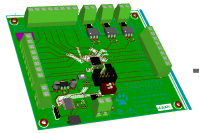
- Three modes: Demo, Drive, Maintenance
  - maintenance mode is provided
- Measuring, calibrating, logging, plotting and storing data; high level control over the subsystems
  - Is able to talk with Dynamometer and motor controller; manual control to throttle
- Shall be configurable, maintainable, user-friendly
  - Configuration control over database; source code hosted on bitbucket and lfev website

System Overview

HUFF TECHNOLOGIES

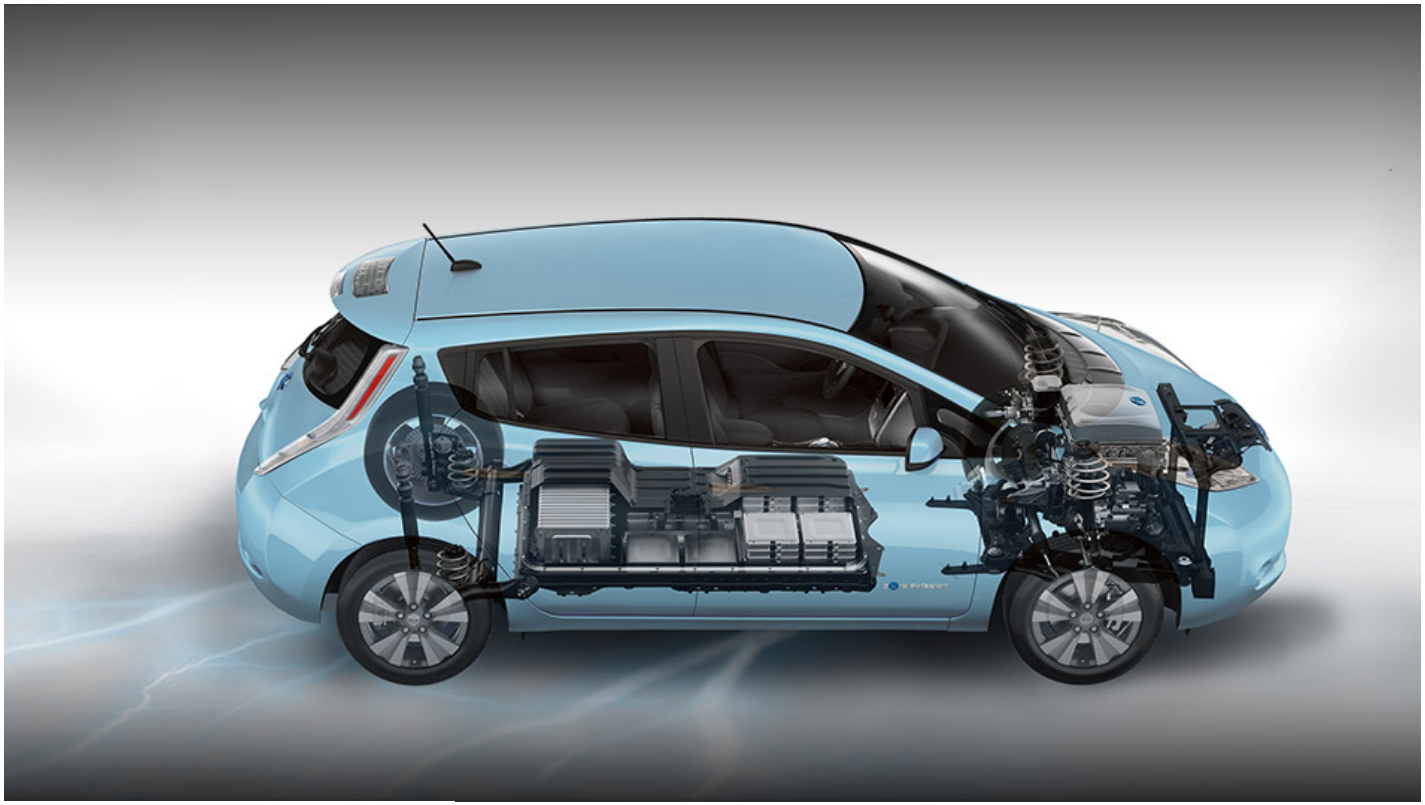
USB

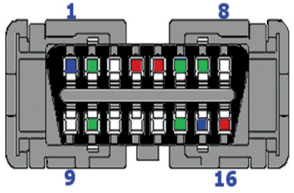
CAN

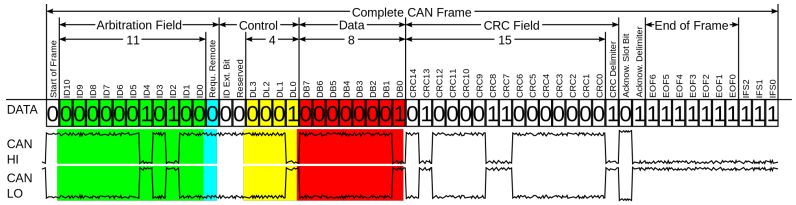


RS-232

CAN BUS







Network Model (7-Layer)

OSI (Open Source Interconnection) 7 Layer Model

Layer	Application/Example		Central Device/ Protocols		DOD4 Model
Application (7) Serves as the window for users and application processes to access the network services.	**End User layer** Program that opens what was sent or creates what is to be sent Resource sharing • Remote file access • Remote printer access • Directory services • Network management		**User Applications** SMTP	GATEWAY	Process
Presentation (6) Formats the data to be presented to the Application layer. It can be viewed as the "Translator" for the network.	**Syntax layer** encrypt & decrypt (if needed) Character code translation • Data conversion • Data compression • Data encryption • **Character Set Translation**		JPEG/ASCII EBDIC/TIFF/GIF PICT		
Session (5) Allows session establishment between processes running on different stations.	**Synch & send to ports** (logical ports) Session establishment, maintenance and termination • Session support - perform security, name recognition, logging, etc.		**Logical Ports** RPC/SQL/NFS NetBIOS names		
Transport (4) Ensures that messages are delivered error-free, in sequence, and with no losses or duplications.	**TCP** Host to Host, Flow Control Message segmentation • Message acknowledgement • Message traffic control • Session multiplexing	PACKET FILTERING	TCP/SPX/UDP		Host to Host
Network (3) Controls the operations of the subnet, deciding which physical path the data takes.	**Packets** ("letter", contains IP address) Routing • Subnet traffic control • Frame fragmentation • Logical-physical address mapping • Subnet usage accounting		**Routers** IP/IPX/ICMP		Internet
Data Link (2) Provides error-free transfer of data frames from one node to another over the Physical layer.	**Frames** ("envelopes", contains MAC address) [NIC card — Switch — NIC card] (end to end) Establishes & terminates the logical link between nodes • Frame traffic control • Frame sequencing • Frame acknowledgment • Frame delimiting • Frame error checking • Media access control		**Switch Bridge WAP** PPP/SLIP	Land Based Layers	Network
Physical (1) Concerned with the transmission and reception of the unstructured raw bit stream over the physical medium.	**Physical structure** Cables, hubs, etc. Data Encoding • Physical medium attachment • Transmission technique - Baseband or Broadband • Physical medium transmission Bits & Volts		**Hub**		

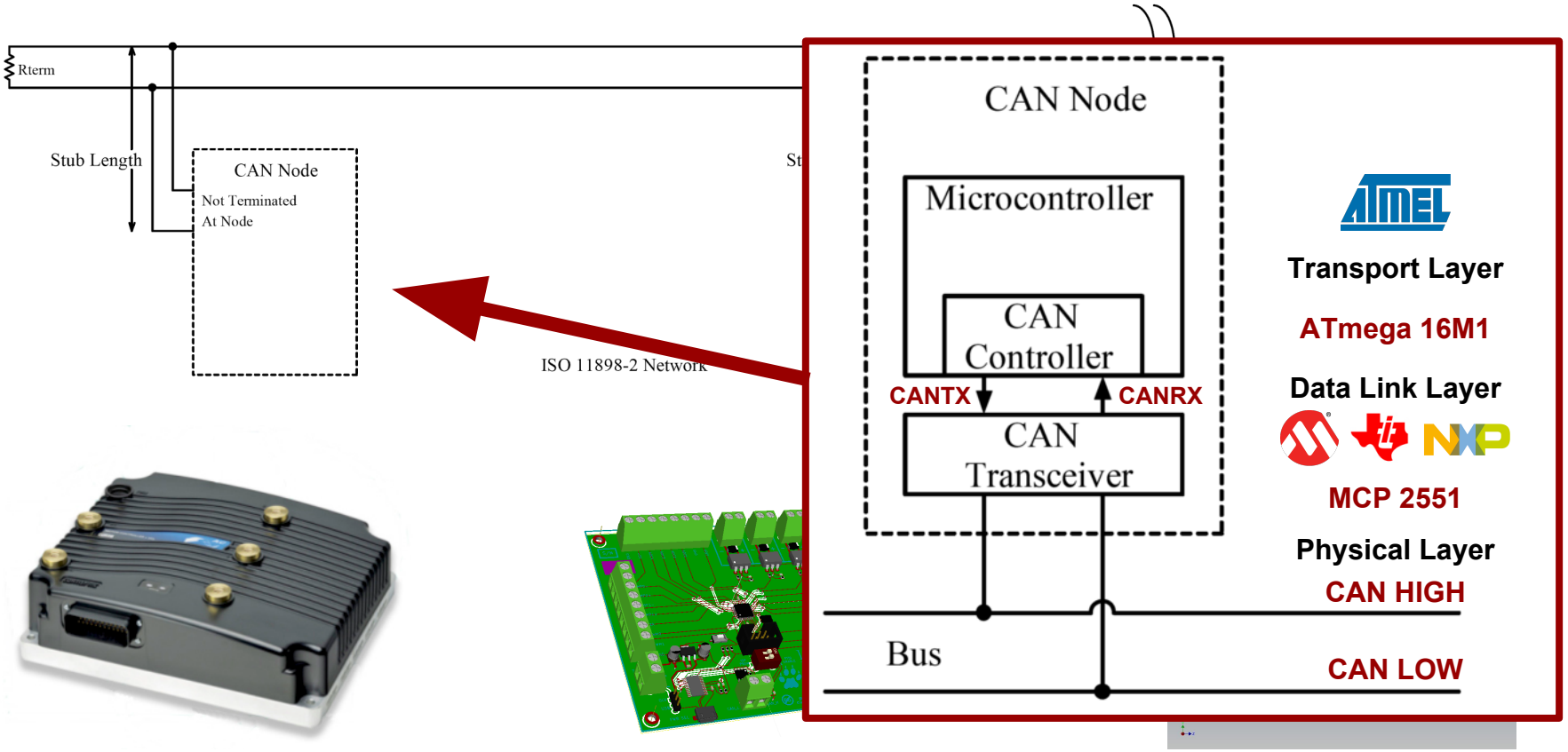
GATEWAY: Can be used on all layers

ISO International Organization for Standardization

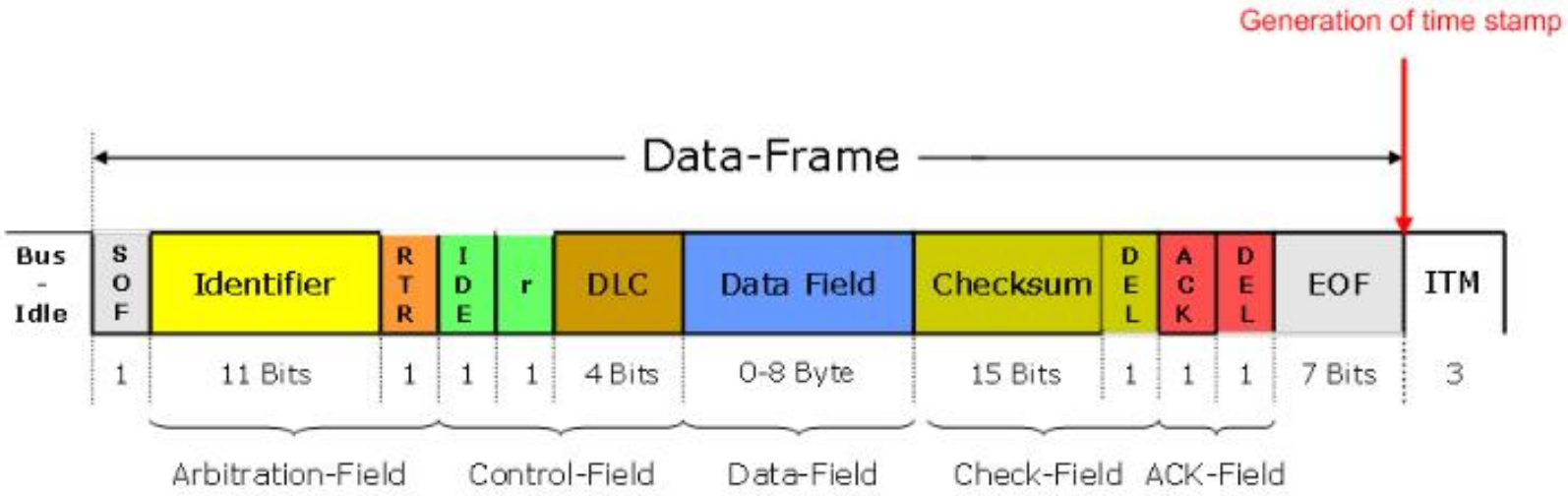
ISO 7498-1

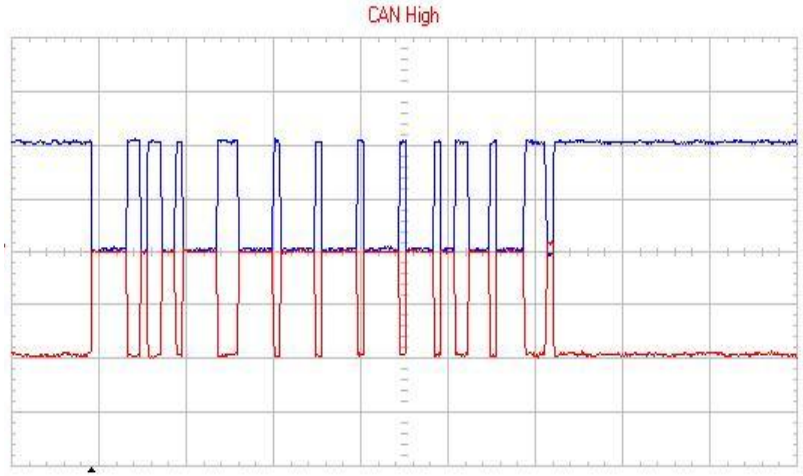
LAFAYETTE ELECTRICAL & COMPUTER ENGINEERING

CAN Physical Layer



CAN Frames Overview





RTR - Remote Transmit Request

IDE - Extended Identifier

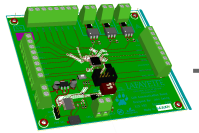
DLC - Data Length Code

System Overview

HUFF TECHNOLOGIES

USB

CAN



RS-232

Motor Controller Frame

Generic CAN Messages from Controller							
	ADDRESS ID						
	CAN ADDRESS 0x601	Units	Scale		CAN ADDRESS 0x602	Units	Scale
Byte0	Motor RPM high byte	RPM	1		Stator Frequency high byte	Hz	1
Byte1	Motor RPM low byte				Stator Frequency low byte		
Byte2	Motor Temp	Deg C	-40 to 200		Controller Fault Primary		
Byte3	Controller Temp				Controller Fault Secondary		
Byte4	RMS Current high byte	Amps	0.1		Throttle Input	%	1
Byte5	RMS Current low byte				Brake Input		
Byte6	Capacitor Voltage high byte	Volts	0.1		System Bits*		
Byte7	Capacitor Voltage low byte				Not used		

* System bits configuration	
Bit	Logic
0	Econo bit
1	Regen bit
2	Reverse bit
3	Brake Light Bit

Huff Box Data Acquisition

MEASUREMENT COMPUTING

http://www.mccdaq.com/PDFs/manuals/DAQFlex%20Software.pdf

python

https://github.com/torfbolt/PyDAQFlex

```
import daqflex

def _send_cmd(dev, cmd, regex):
    try:
        resp = dev.send_message(cmd)
        m = re.findall(regex, resp)
        if m:
              return m
    except:
        print('ERR: Message "' + cmd + '" not recognized!')
    return None

def get_cal_date(self):
        cmd = '?DEV:MFGCAL'
        regex = '''DEV:MFGCAL=
              (\d+)-(\d+)-(\d+)\s(\d+):(\d+):(\d+)'''
        resp = _send_cmd(self.dev, cmd, regex)

 year = int(resp[0][0])
        month = int(resp[0][1])
        day =  int(resp[0][2])
        hour = int(resp[0][3])
        minute = int(resp[0][4])
        second = int(resp[0][5])
        date = datetime.datetime(
              year, month, day, hour, minute, second)

return date
```

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

DAQFlex SCPI Commands

AI

Gets the analog input properties of a device.

Properties

CJC, CHANNELS, CHMODES, FACCAL, INPUTS, MAXCOUNT, MAXRATE, RANGES, SELFCAL, SENSORS, SENSORCONFIG, TCTYPES

CJC

- Get the CJC channel number associated with an analog input channel.

  Message "@AI{*ch*}:CJC"

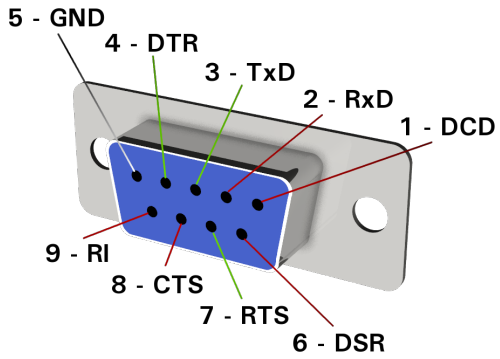
  Response "AI{*ch*}:CJC=*implementation*>*value*"

ch	Channel number.
implementation	FIXED%, PROG% (programmable), HWSEL% (hardware selectable), or not specified if value is NOT_SUPPORTED
value	Channel number for the CJC associated with the specified channel, or returns NOT_SUPPORTED if the device doesn't support CJCs or the value of {ch} is not valid for the device.

  Example "AI{0}:CJC=FIXED%0"

Power Supply Control

MAGNA-POWER




```
ser = serial.Serial('/dev/ttyUSB0', 19200, timeout=0.5)

def _send_cmd(cmd, read=True):
        '''
        Private Method: Send SCPI commad
        cmd: string containing SCPI command
        returns: response message
        '''
        ser.flushInput()
        ser.flushOutput()
        ser.write(cmd.encode('ascii') + b'\r\n')
        time.sleep(.05)
        if(read):
        resp = ser.read()
        while ser.inWaiting():
                resp+= ser.read()
                return resp
        else:
                return None

def get_voltage():
        '''
        Get PSU Voltage
        returns: floating point voltage value
        '''
        cmd = "MEAS:VOLT?"
        resp = _send_cmd(cmd)
        return float(resp)
```

Power Supply SCPI Commands

5.1.7.3. OUTP:START

Description

This command closes the power supply's input contactor and initiates either normal or auto sequence mode. Auto sequence mode will be initiated if the **ARM** option is enabled. Normal mode energizes the power supply with the current parameters for voltage set point, current set point, over voltage trip, and over current trip. Auto sequence mode will sequentially step through memory locations until the stop is commanded, **OUTP:STOP**, or a terminating condition is reached (see **PER**, **OUTP:STOP**).

Command Syntax

OUTP:START

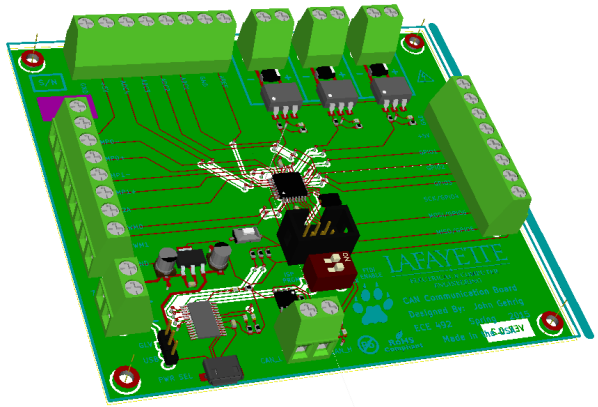
Examples

OUTP:START
OUTPUT:START

CAN Communication Board (JGB)

Purpose

- Interface SCADA with all other systems



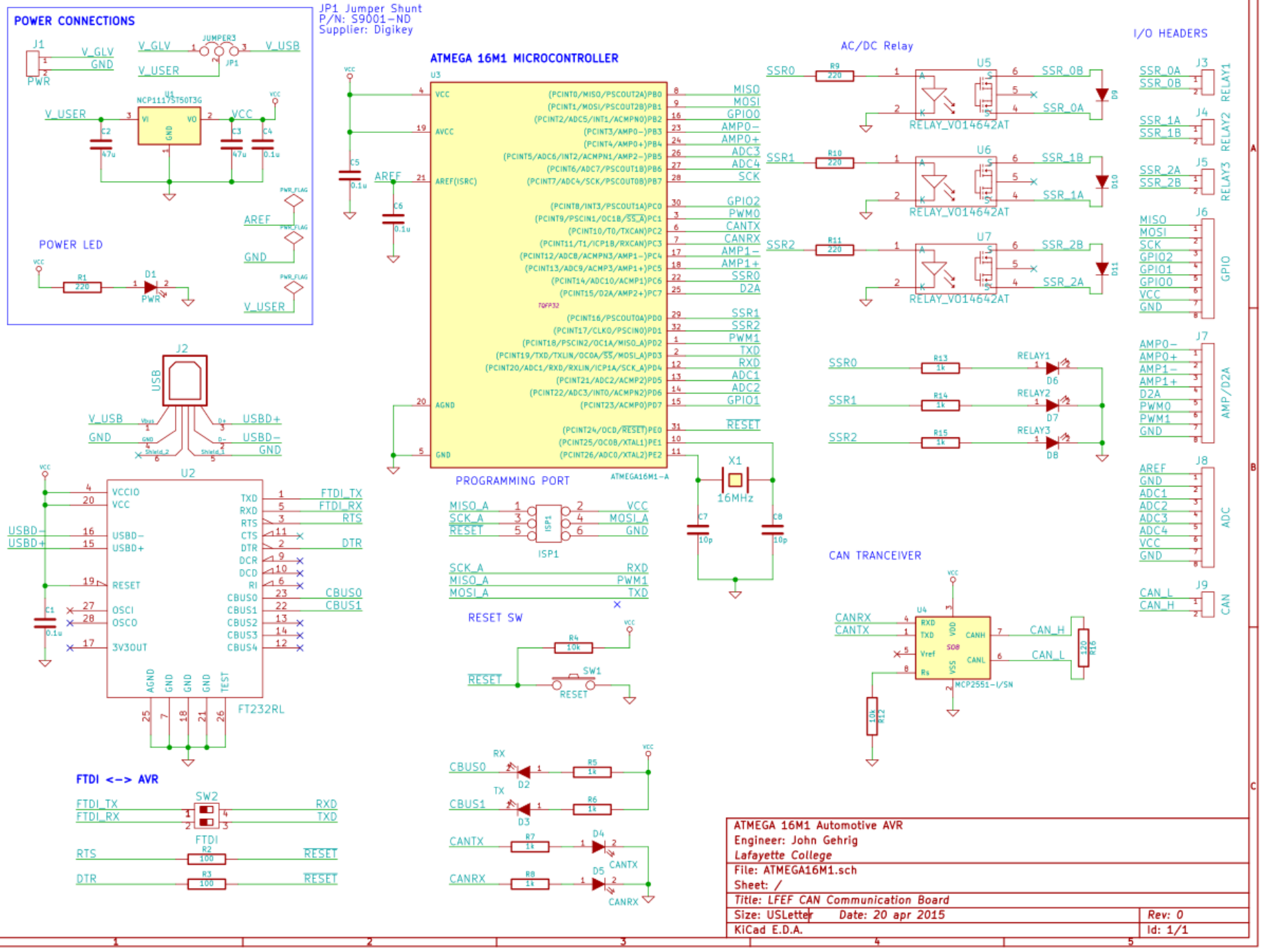
Capabilities

ATmega 16M1 Automotive AVR

- Supports CAN 2.0 A/B
- Support LIN

Capabilities

- Analog to Digital Conversion
- Digital to Analog Conversion
- Pulse Width Modulation
- Isolated Relays
- Digital Inputs
- Digital Outputs
- RS-232 Debugging/Configuration


POWER CONNECTIONS
JP1 Jumper Shunt
P/N: S9001-ND
Supplier: Digikey
ATMEGA 16M1 MICROCONTROLLER
I/O HEADERS
AC/DC Relay
PROGRAMMING PORT
RESET SW
FTDI <-> AVR
CAN TRANCEIVER
POWER LED
ATMEGA 16M1 Automotive AVR
Engineer: John Gehrig
Lafayette College
File: ATMEGA16M1.sch
Sheet: /
Title: LFEF CAN Communication Board
Size: USLetter Date: 20 apr 2015
KiCad E.D.A.
Rev: 0
Id: 1/1

Program Structure (1/2)

GlobalParameters

_time
_motorRPM
_motorTemp
_controllerTemp
_rmsCurrent
_capVoltage
_motorThrottle
_psu_voltage
_psu_current
_strain_guage
_tachometer
_dyno_power
_throttle_value
_load_value
_slopeTorque = 0.366
_offsetTorque = -641.906
_slopeRPM = -4.499
_offsetRPM = 9402.315

_HuffBox(*HuffBox*)
_psu_control
(*PowerSupplyControl*)

Window

-spinBoxPSUVoltageChanged(int)
-spinBoxPSUCurrenteChanged
(int)
-initPSUButtons()
-initGraph()
-updateGraph()
-actionSaveTriggered()
-guiUpdate()
-buttonEmergencyClicked()
-buttonPauseDataClicked()
-buttonPSUOnClicked()
-buttonPSUOffClicked()

GUIUpdateThread

-run()

CANMonitorThread

can_dev (*CANDataHandler*)

-run()

CAN Frame Descriptor

id *(int)*
name *(str)*
offset *(int)*
length *(int)*
single-bit *(bool)*
bit *(int)*

Program Structure (2/2)

PowerSupplyControl

get_voltage()
get_current()
get_state()
set_voltage()
set_current()
set_state()
turn_on()
turn_off()

HuffBox

dev (*DataDevice*)

-set_throttle (int)
-set_load_value (int)
-get_strain_guage *()*
-get_tachometer *()*

DataDevice

device (*_DeviceCmd*)
anaolog_in (*_AnalogInCmd*)
analog_out (*_AnalogOutCmd*)

CANDataHandler

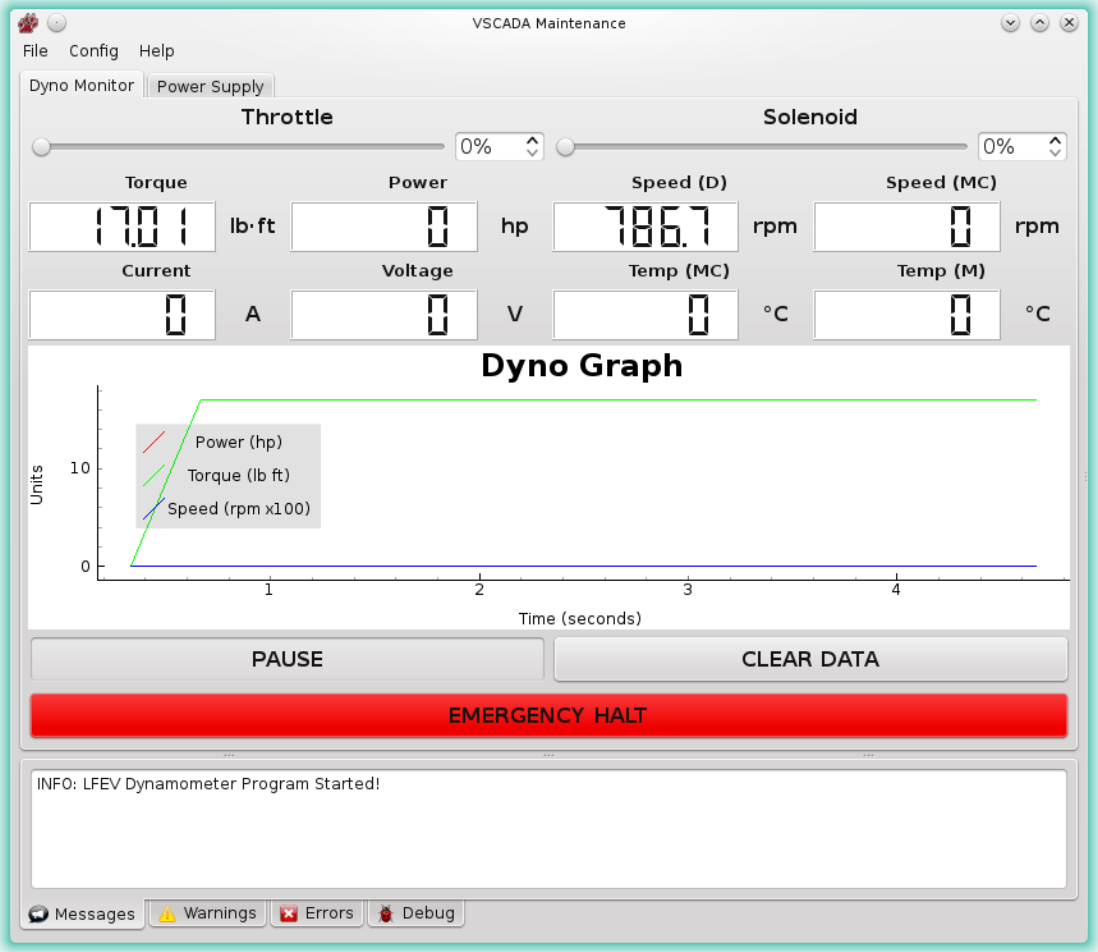
can_handler (*SocketCANHandler*)

request_data (*int*)
recv_data_frame (*int, frame*)
recv_frame ()
frame_available ()

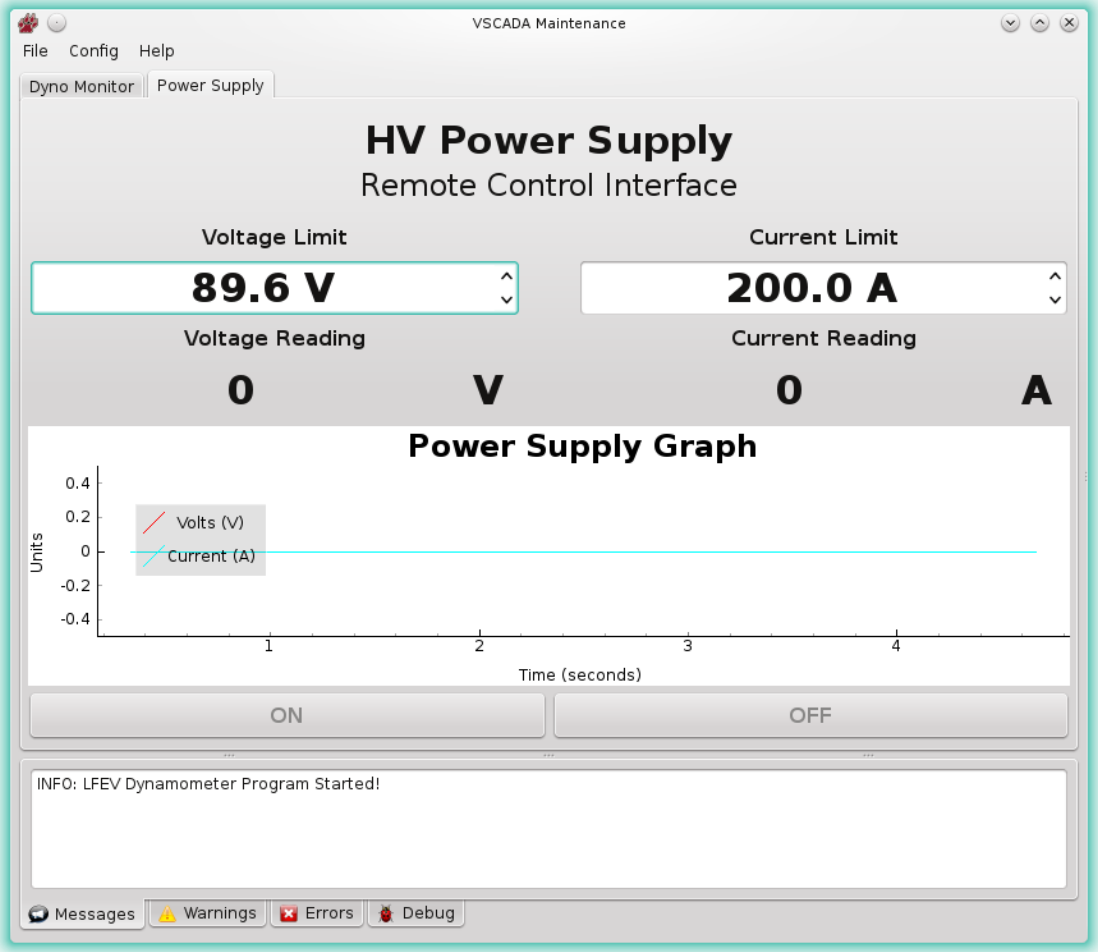
SocketCANHandler

build_frame (*int, bool, list*)
send_frame (*frame*)
send_rtr (*int*)
send_payload (*list*)
recv_frame ()
recv_frame_blk ()

GUI Data Acquisition



GUI Power Supply Control



GLV Objectives

1. GLV Power
2. Tractive System Interface
3. Vehicle Computer Integration/Interface
4. High Voltage Safety Loop
5. System Interconnect

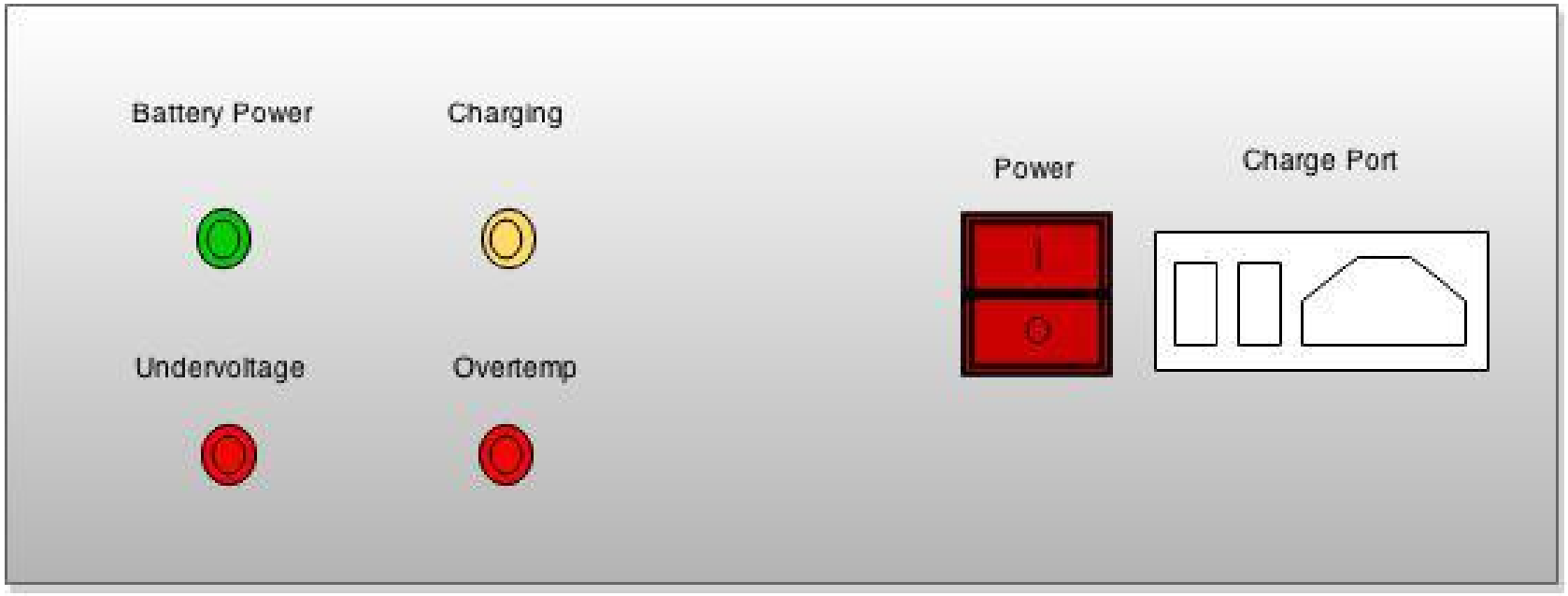
http://connectmedia.co.za/tips-for-creating-marketing-objectives/

GLV Objective 1: GLV Power

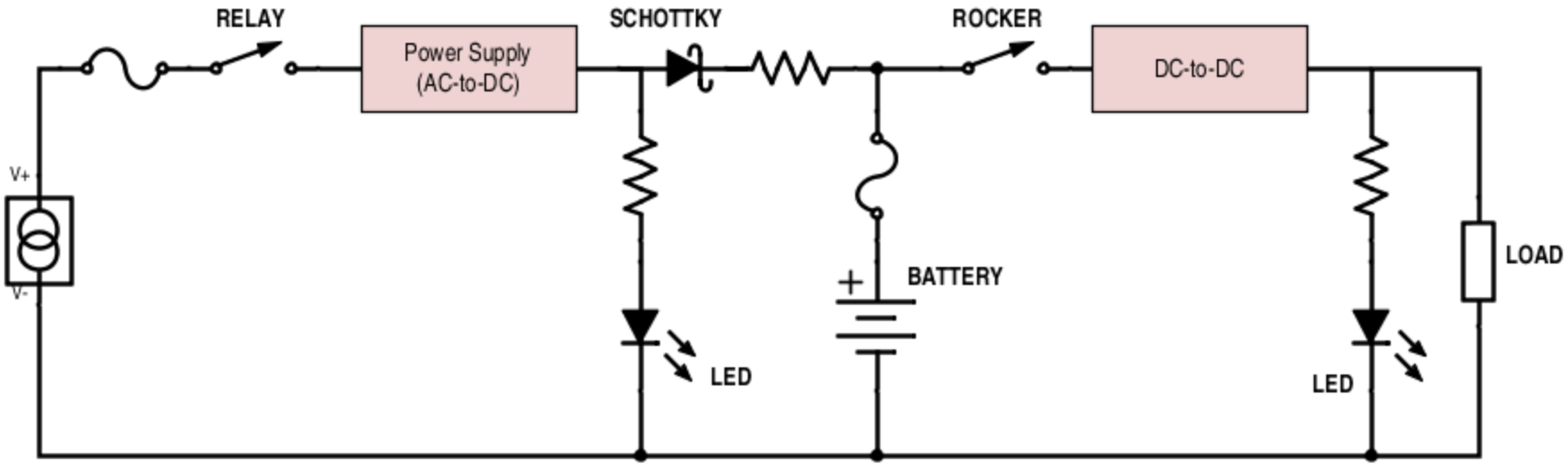
- Power all Low Voltage Systems
  - power non-tractive systems for three hours
  - charging system must have *plug-and-forget* functionality- simultaneous charging + load current
  - battery protection from full discharge, overcharge, overcurrent, and overvoltage
  - voltage, current, temperature, and SOC measured by VSCADA
  - battery is secu[illegible]he frame

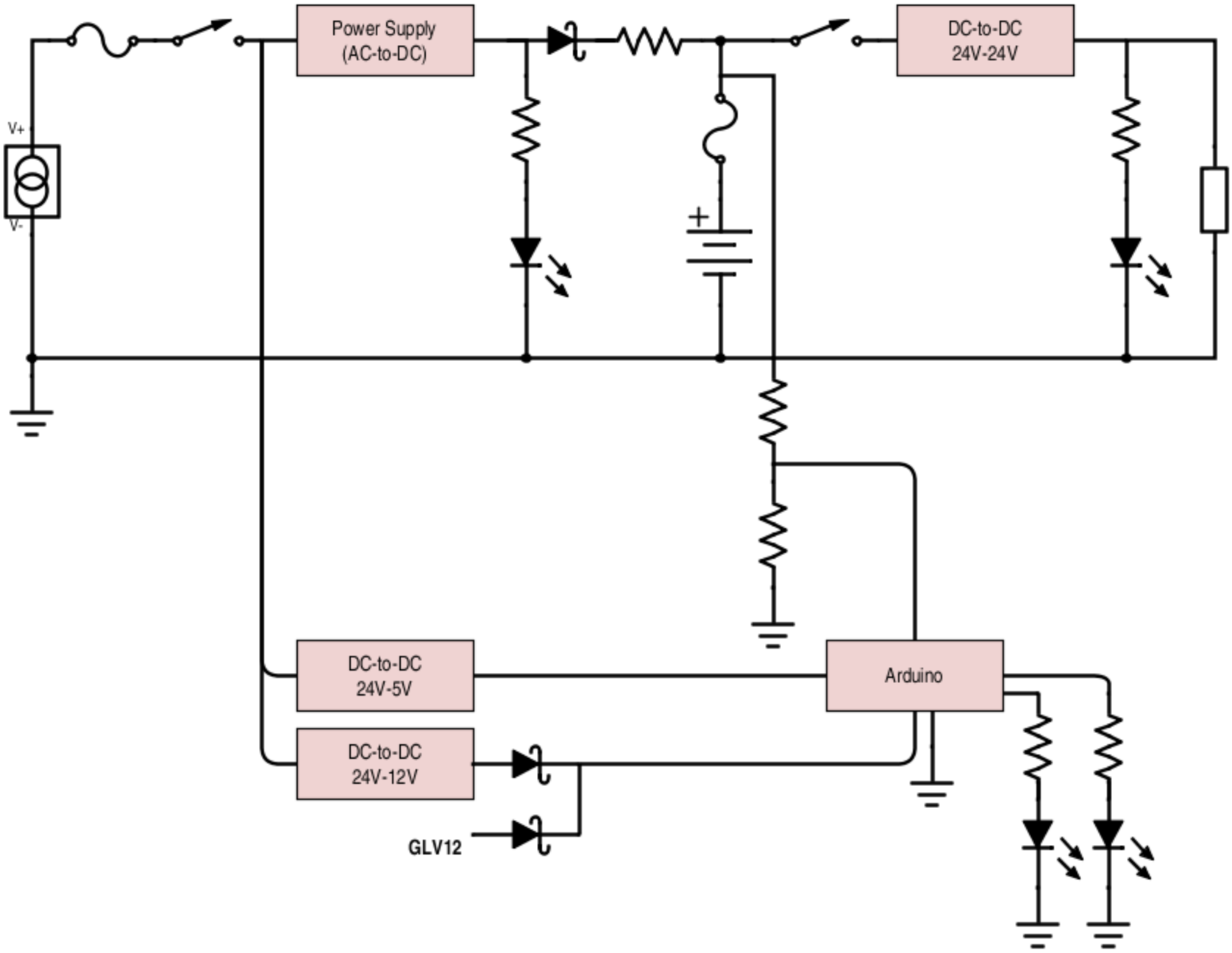
http://www.breslev.co.il/articles/breslev/rebbe_nachmans_wisdom/we_have_the_power.aspx?id=25453&language=english

Power Panel


Battery Power
Charging
Undervoltage
Overtemp
Power
Charge Port

GLV Charging Circuit

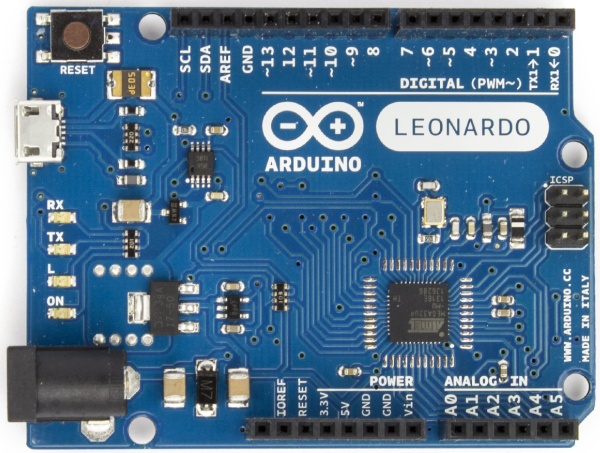



Power Supply
(AC-to-DC)
DC-to-DC
24V-24V
V+
V-
DC-to-DC
24V-5V
DC-to-DC
24V-12V
Arduino
GLV12

Power Software

plug-and-forget functionality

- wait for voltage at Charge Port
- hold relay closed until battery voltage reaches 28.5V
- close relay when battery voltage drops below 22.5V



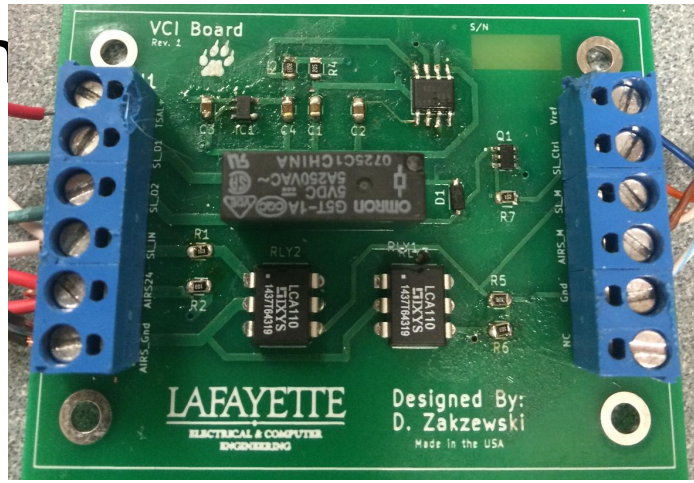
http://www.arduino.cc/en/uploads/Main/ArduinoLeonardoFront_2.jpg

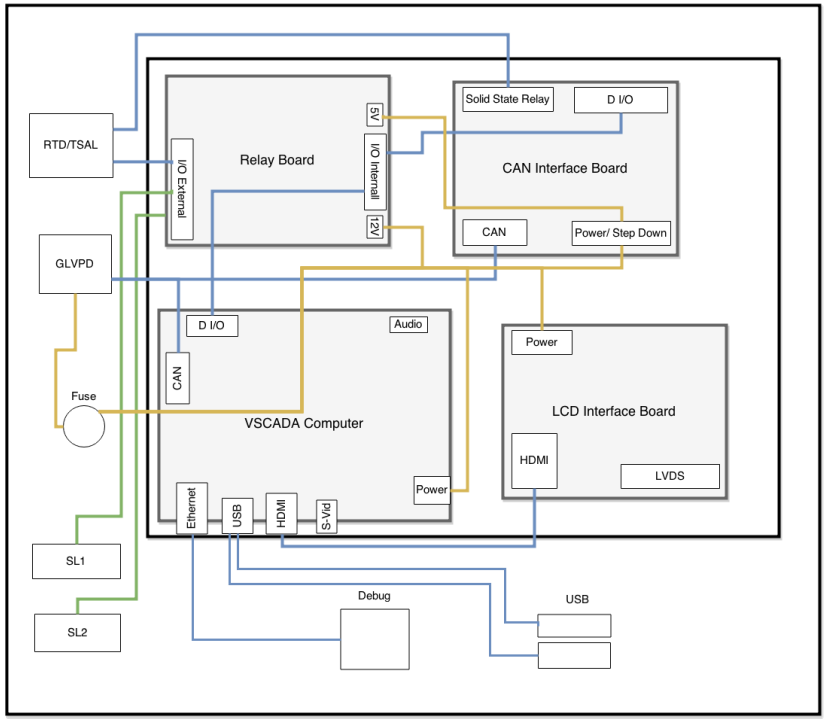
GLV Objective 2: Tractive System Interface

- Final high voltage relay before motor controller
  - Precharge circuit protects motor controller form inrush current
- Tractive System Voltage Present Light
- High Voltage Measurement
- IMD Safety Loop Control
- Provides measurement points for high voltage system
- GLVPD power

GLV Objective 3: Vehicle Computer Integration

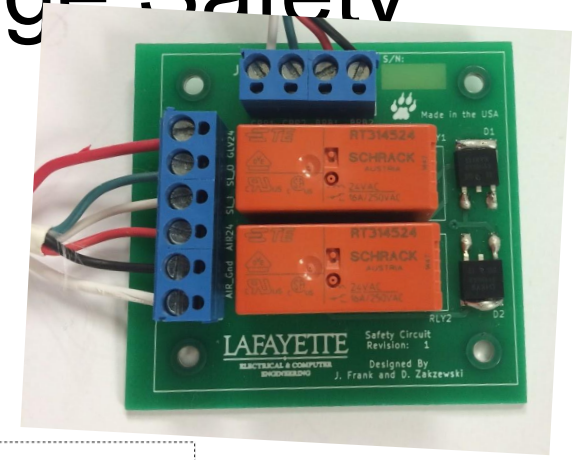
- Vehicle/Computer Integration
  - Hardware elements of VSCADA
  - Interfacing to Safety Loop.

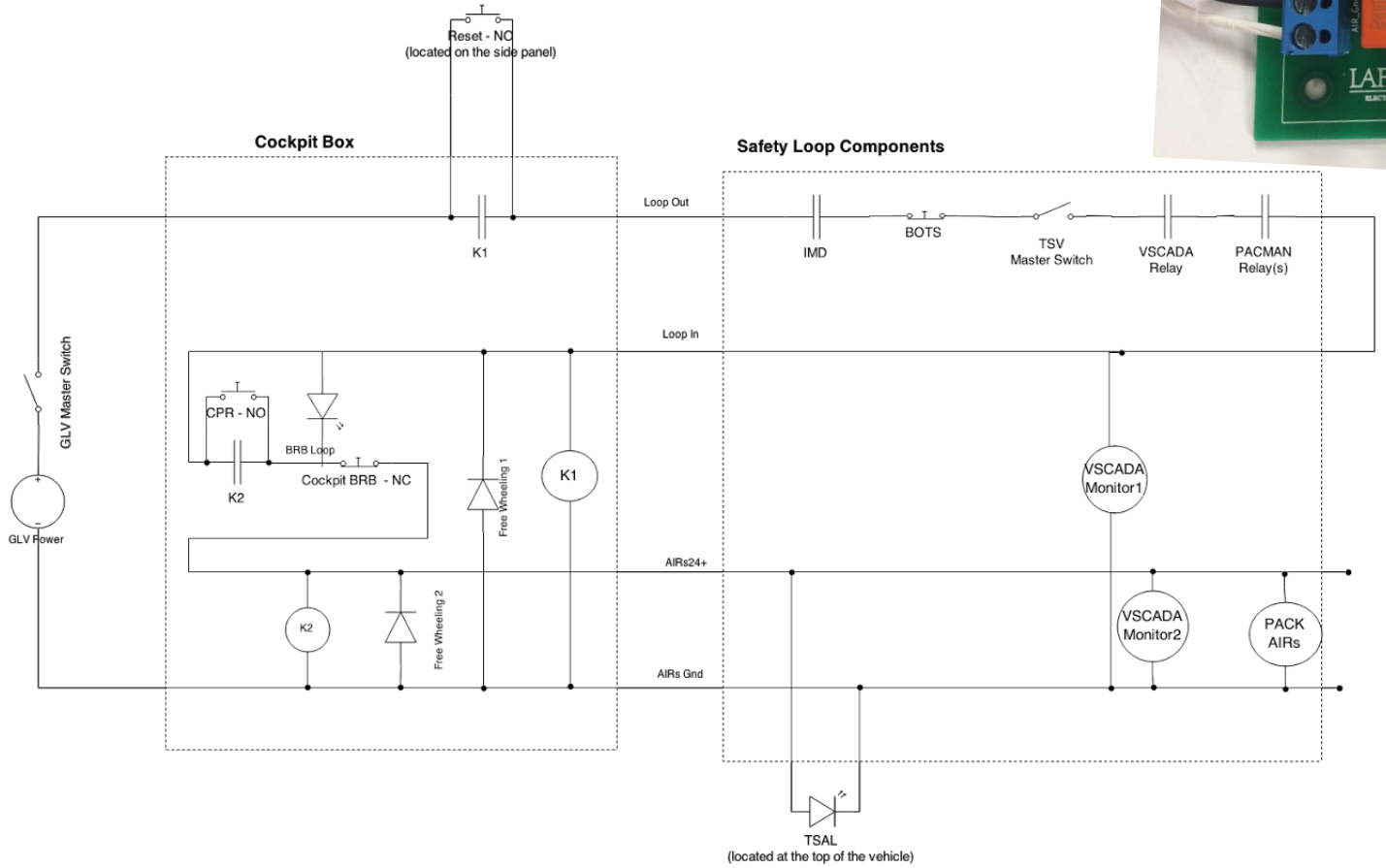




GLV Objective 4: High Voltage Safety

- Safety / Shutdown Circuit
  - Disable HV if issue found

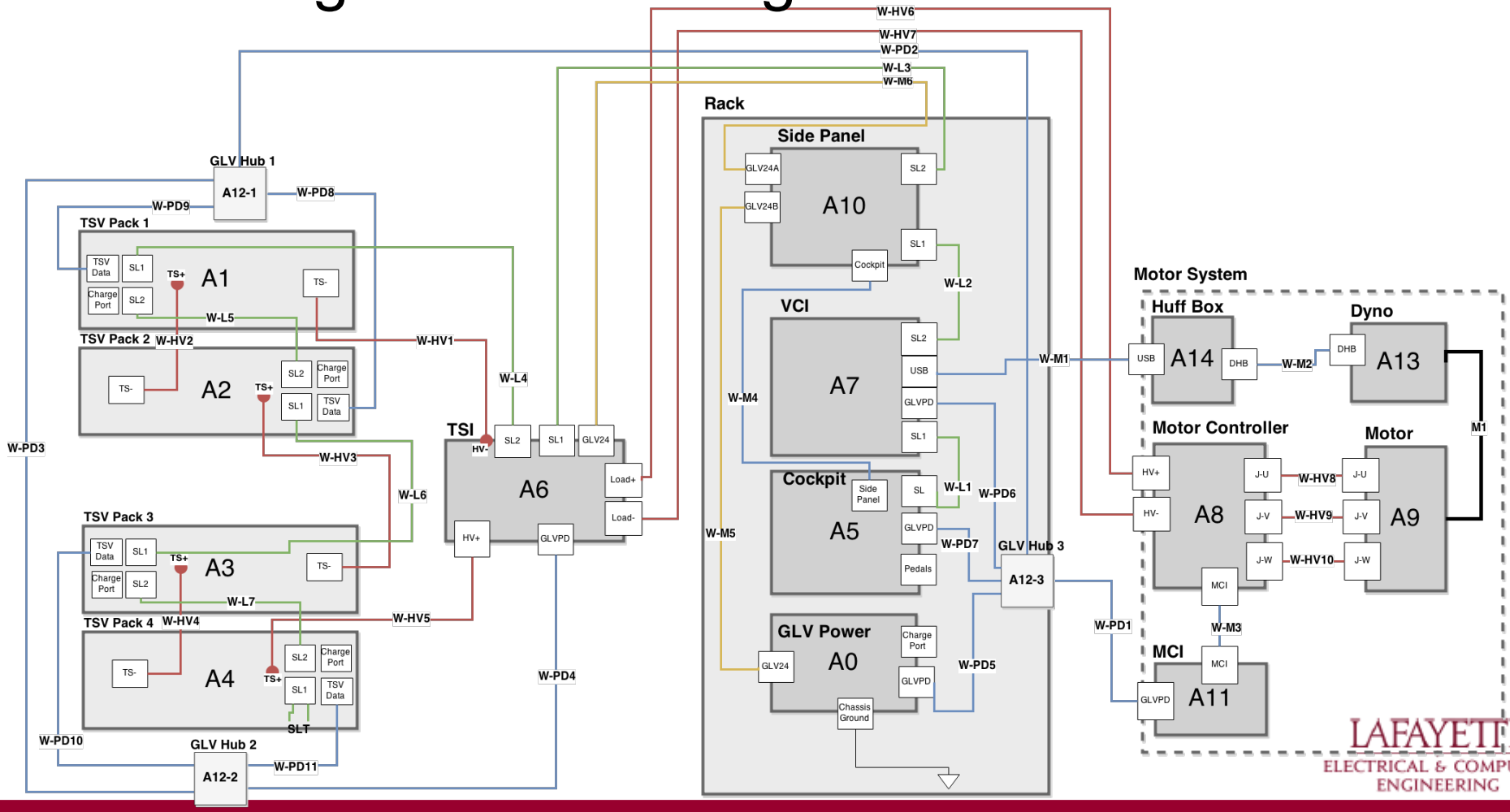




LAFAYETTE
ELECTRICAL & COMPUTER
ENGINEERING

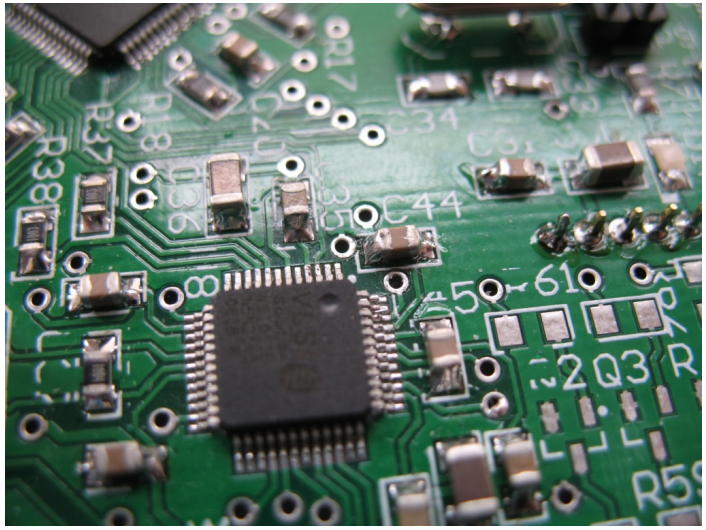
GLV Objective 5: System Interconnect

- Wiring and Interfacing



GLV Errata

1. GLV Power
   a. Replace the Arduino with a JGB to speak CAN
   b. Add current and temperature sensing technology
   c. Stabilize the battery vertically
   d. Fusing
2. Tractive System Interface
   a. Motor Controller Connections
   b. PCB errors/redesigns



http://www.sphere.ws/blog/?attachment_id=50

GLV Errata

3. Vehicle Computer Integration/Interface
    a. Large/ hardware intensive touchscreen
4. High Voltage Safety Loop
    a. LED displays
5. System Interconnect
    a. Assemble two more HUBs
    b. Cable length

http://www.techandinnovationdaily.com/2013/02/27/uni-pixel-touchscreen-technology/

Moving Forward Next Year...

TSV

- Break Out Board Firmware

GLV

- Mechanical Integration

VSCADA

- General System Expansion
- Control System

DYNO

- Data Analysis

MECH

- Gearbox
- Chassis

Demonstration Time!

For further information, check us out at:

sites.lafayette.edu/ece492-sp15/