SAE Baja Data Acquisition System

Team E#5

Milestone #7
Final Presentation

http://www.eng.fsu.edu/ece/senior_design/2015/team05/
https://github.com/hp09d/SAE-Baja-Data-Acquisition

April 21, 2015

The Design Team

Project Manager/Lead Programmer
Christopher Riker (CpE)
cdr11c@my.fsu.edu
Technical Contributions:

- *MSP430 Communication Interfaces*
- *MSP430 Sensor Development*
- *Mounting/Installation*

Data Coordinator
Tyler Dudley (EE)
dudleyt2004@my.fsu.edu
Contributions:

- Power System Development

Financial Manager/Webmaster
Dewey Williams (CpE)
dmw10g@my.fsu.edu
Technical Contributions:

- Hercules Development
- PCB Design & Soldering
- Raspberry Pi GUI Development
- Installation

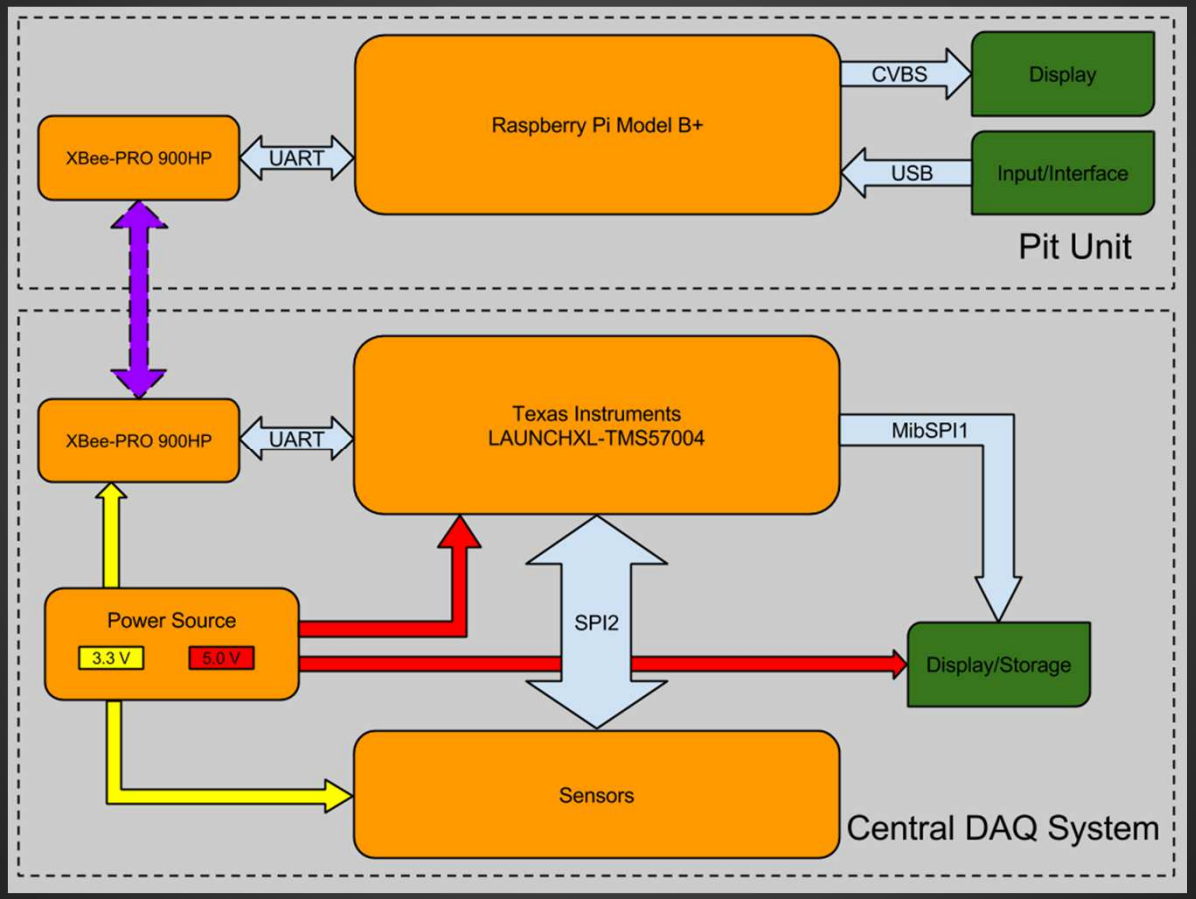
DAQ Leader
Hebe Perez (CpE)
hp09d@my.fsu.edu
Technical Contributions:

- Wireless Communication
- Mounting/Installation
- MSP430 Timer

Project Overview

- Goal: To develop a comprehensive and reliable data acquisition system for use in SAE's Baja Series off road competition
- Collects data such as:
  - Speed
  - Acceleration
- Stores data to a log file and transmits readings wirelessly to a remote display
- Applicant in Texas Instruments' North America Innovation Challenge contest
  - Received free ICs and a store voucher for development tools/components

Top-Level Block Diagram



Christopher Riker

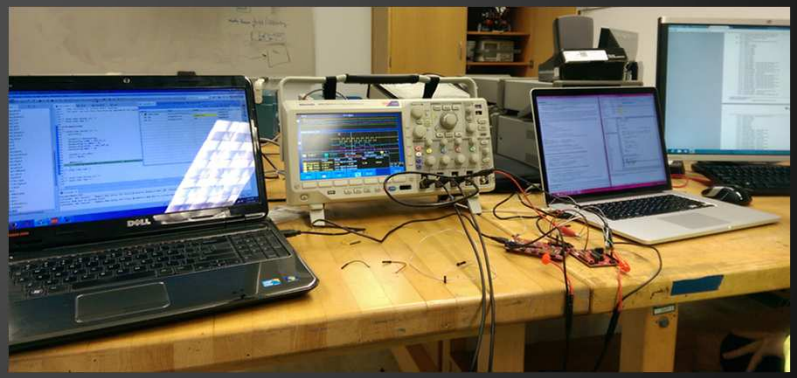
Design Process

Initial System Requirements

- Measurements:
  - Speed
  - Acceleration
  - Suspension Travel
  - Tire Pressure
  - Vibrations
- Voice Communication
- Driver-to-pit signal
  - Driver-enabled or based on sensor data
- Data logging

Final System Features

- Measurements:
  - Speed
  - Acceleration
- Driver-to-pit and Pit-to-driver signals
- Data logging



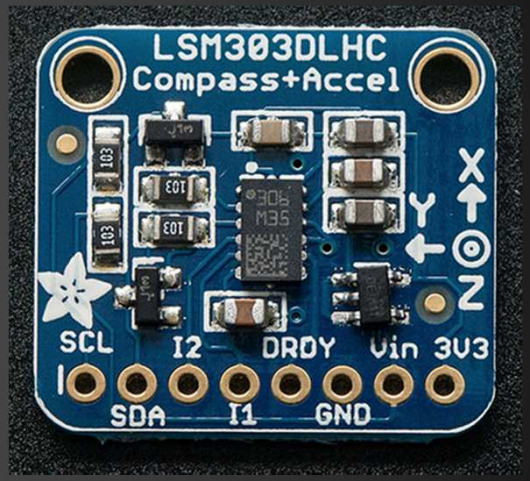
Design Changes

TI Innovation Challenge

- TL2575 Switching Regulators
- DRV5053 Bipolar Analog Hall Effect Sensor
- MSP430G2553

Accelerometer

- ADXL335 - Analog Accelerometer
  - +/- 3G range
  - MSP430G2553: 10-bit ADC
  - Not enough resolution given small acceleration of vehicle
- LSM303DLHC - Digital Accelerometer
  - +/- 2G range minimum
  - Built-in 16-bit ADC
  - Much higher resolution



Future Considerations

Operating Environment

- Paddocks were far away from the course
- Pit unit not very portable
- Removing the DAQ system took a long time

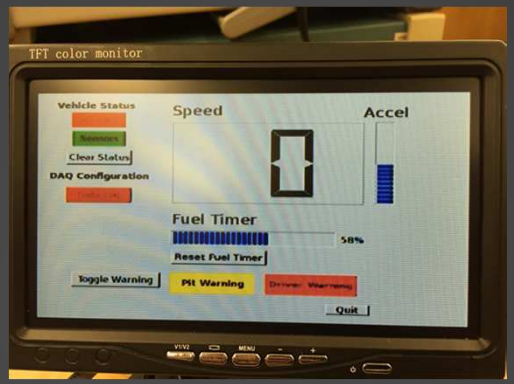
Tire Pressure Monitoring System

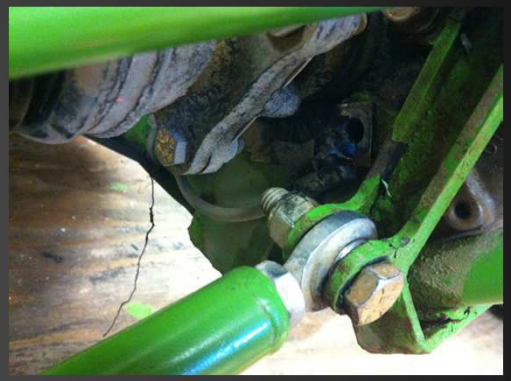
- Overall usefulness seemed minimal
- Difficult to get data framework from Schrader
- Indirect TPMS more viable

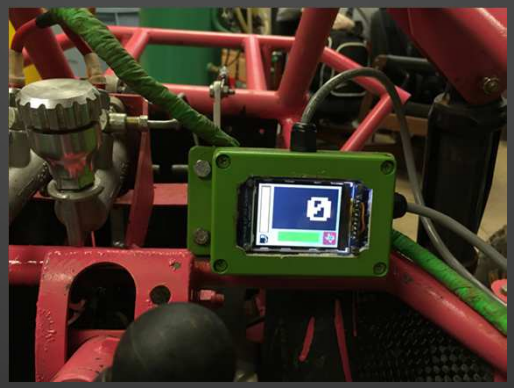
On-Vehicle Display

- Structural integrity was not good enough
- A more robust screen should be used in the future
  - Would require a new SD card slot
- Changing display may mean a less visually pleasing display

Final Product







MSP430 Communication Interfaces

Single-Byte SPI

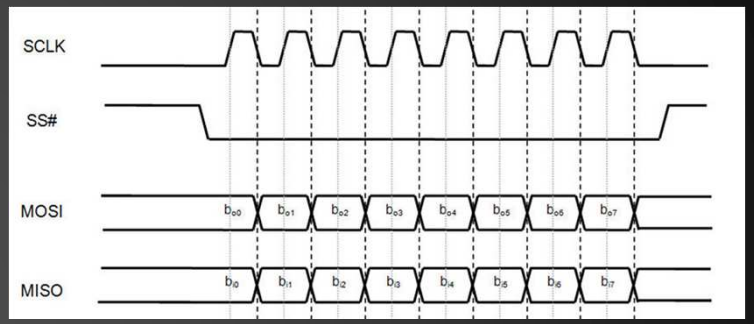
- Load transmit buffer whenever data is available
- Preload buffer
  - Data transmission begins as soon as master starts clocking

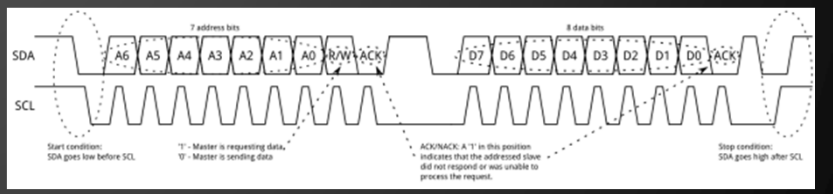
Multi-Byte SPI

- 2-byte preamble for byte alignment
  - 0xAE transmitted while data is being prepared
  - 0xBB indicates the start of a byte stream

I²C

- **Bit banging technique**
  - GPIO pins manipulated through software
  - Slower than hardware modules
  - Can use any GPIO pins





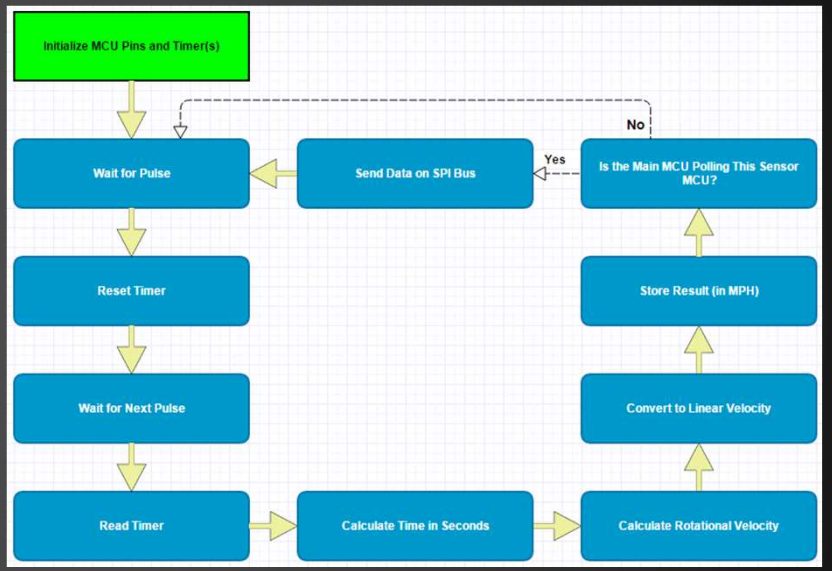
Hall Effect Sensor Module

TI DRV5053 Hall Effect sensor

- Output range 1V - 2V

MSP430 Software

- Detects edges correctly when magnet is very close to the sensor
  - Magnet was too far away on the vehicle
- Nyquist rate: 20 Hz
- Calculations done in floating point format
- Calculations stored in fixed-point format
  - UQ6.2
  - Max vehicle speed: 37 MPH
  - Max representable: 63.75
- Includes a time-out for speeds <5MPH



Accelerometer Module

The Sensor

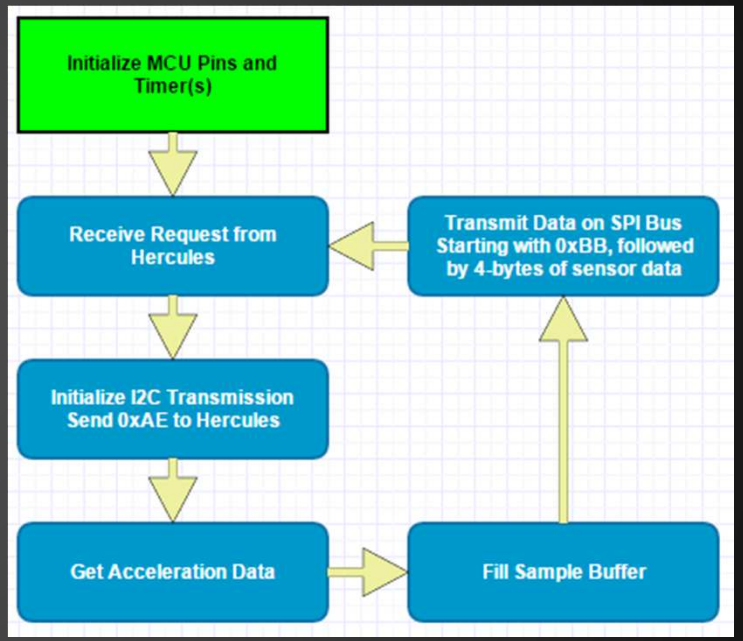
- LSM303 Communication - I^2C
- Read in “burst mode,” using auto-increment registers
- 16-bit built-in A/D converter
  - Outputs signed values

Communication

- Multi-byte SPI
  - Transmits 2 axes of acceleration
  - 2-bytes for each axis

Software

- Library developed for the LSM303
  - Uses Software I2C library functions to write config data to the accelerometer
  - Reads acceleration and magnetometer registers in burst mode
- Polls sensor and transmits data when the Hercules requests a transfer



Hercules MCU

Main features used in the DAQ:

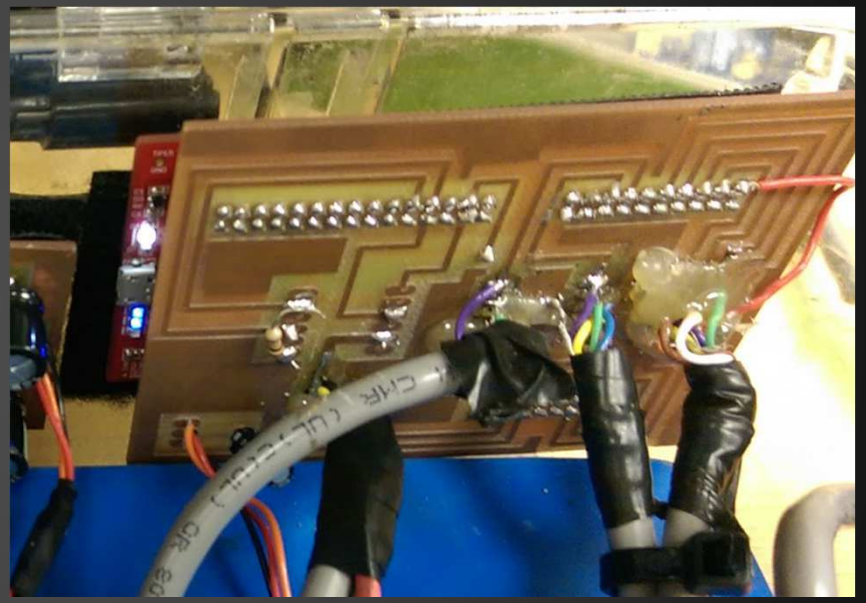
- SCI (UART)
- mibSPI and standard SPI interfaces
- GPIO
- Real time interrupts

Software Developed:

- SDHC Reading/Writing
- ILI9340 Display Library
- Driver code for MSP430 multi-byte transfers

PCB Designs:

- Breakout booster pack



Data Storage

- Data is logged every second when enabled
- Logged data:
  - Uptime
  - Samples recorded
  - X & Y acceleration
  - Speed
  - Fuel time remaining

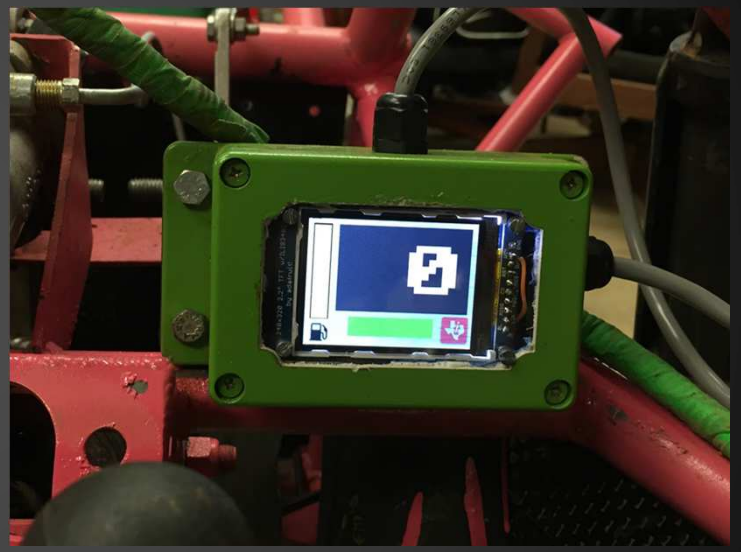
- Graphics are read from the card for display

- FatFS ported for SDHC cards using mibSPI
- FatFS provides high level file system traversal and file I/O
  - Low level drivers written for initializing the card and reading/writing 512B blocks

Driver Interface

- Driver developed to interface the ILI9340 display using mibSPI
- Incorporates a 9x8 console font
- Can draw “565” images from SD card

- Interface designed in GIMP and stored on SD card in raw “565” image format
  - Could also potentially be stored in program space to remove dependency
- Includes fuel timer, speed, and notification area
- Driver button controls the driver notification, and can reset the fuel timer

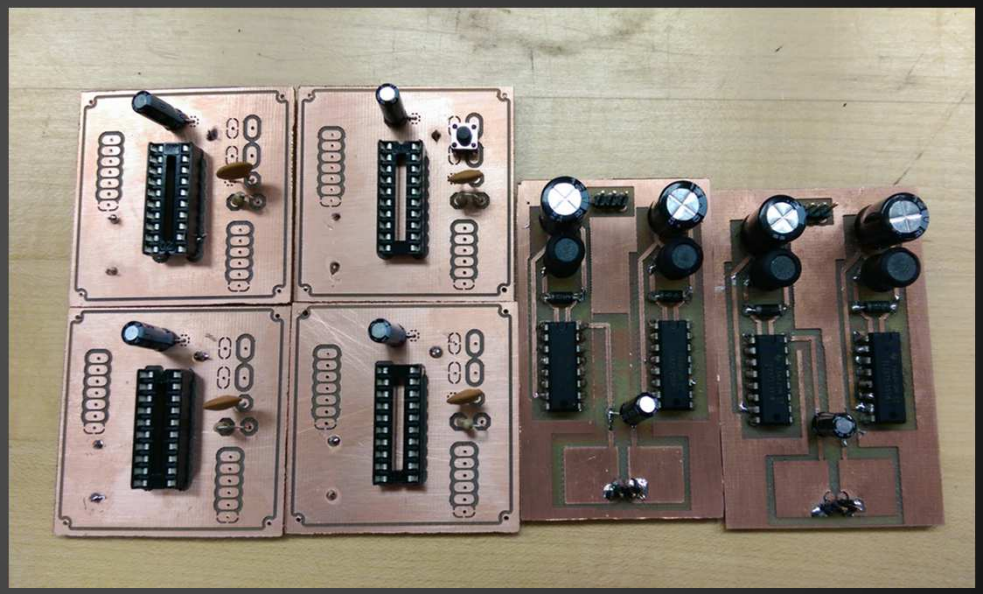


PCB Design

- PCBs designed in CadSoft EAGLE
- Milled in-house at the CoE

Boards designed for:

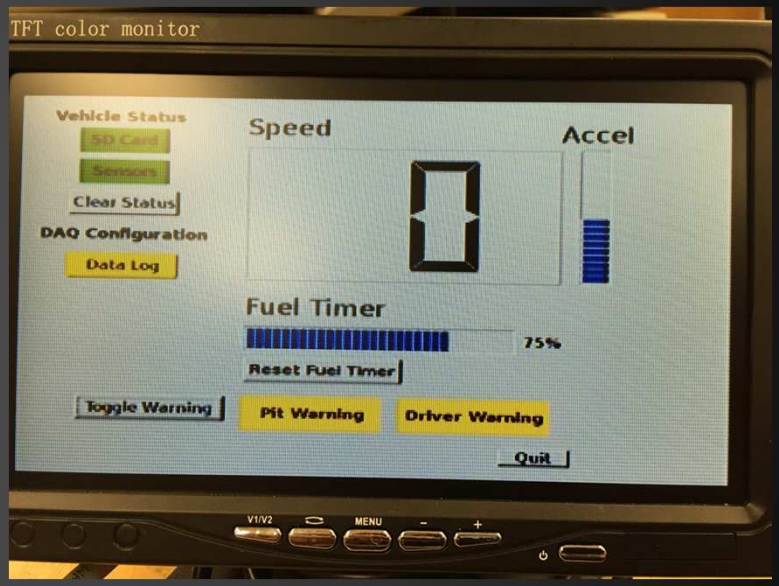
- MSP430 sensors
  - RST stabilization
  - Dual USCI breakout
  - Reset button
- Power regulation
  - 5 and 3.3 V rails
  - Using TI TL2575 switching regulators
- Hercules breakout
  - Power input
  - Headers for 4 sensors, XBee, and display



Pit Unit

- GUI application developed on the Raspberry Pi in C++ using Qt Creator
- Qt tools used to implement timing functions

- System receives a 3 byte preamble from the DAQ and 4 data bytes:
  - 1 status byte
    - Status of subsystems such as sensors, SD card, data logging, and notifications
  - 1 byte for X acceleration
  - 1 byte for speed
  - 1 byte for fuel time
- Transmissions every 500ms



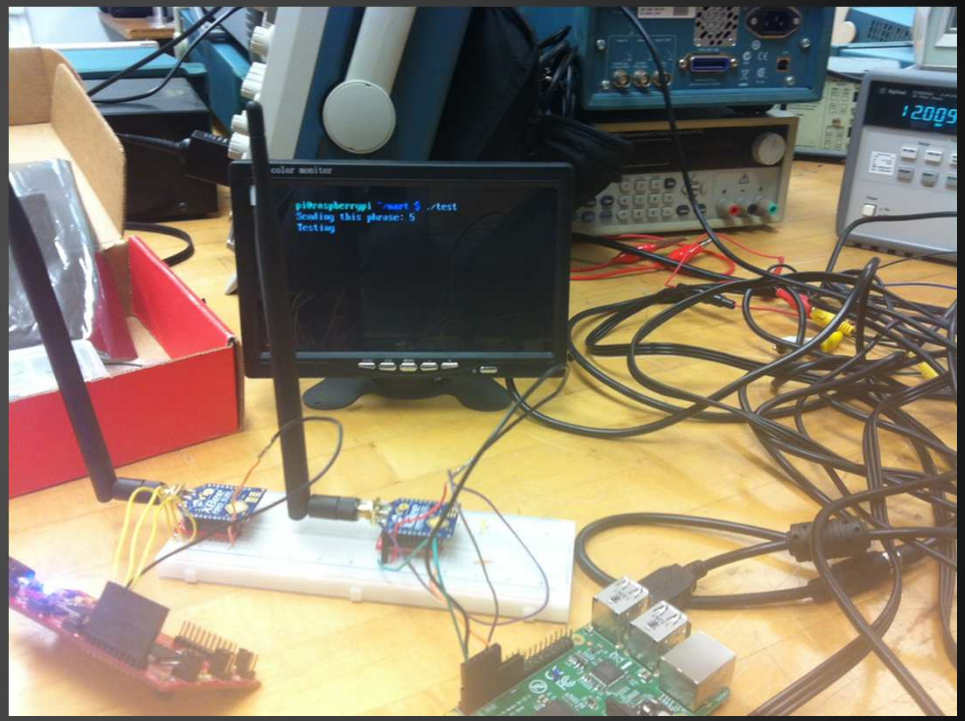
Wireless Transmission

Raspberry Pi

- Setup
  - Raspbian
- UART Initialization
  - Default: serial console
- UART Transmit and Receive Programming

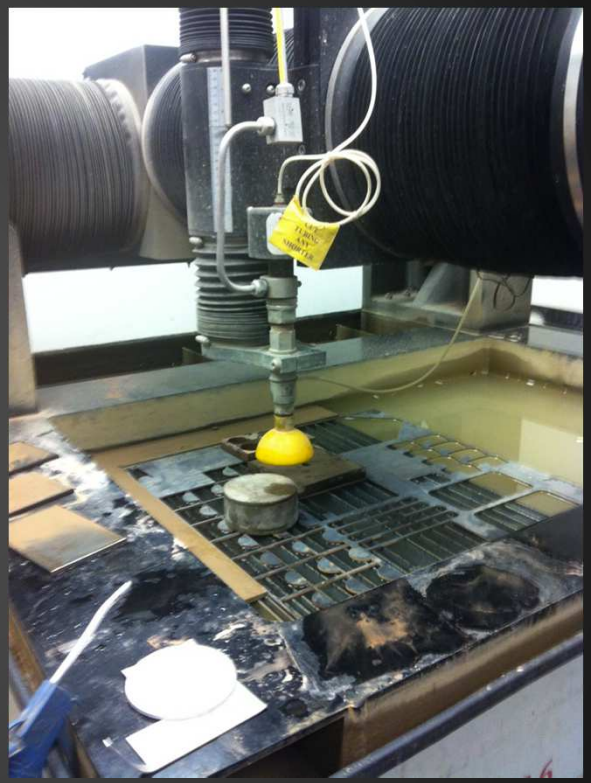
Hercules

- HALCoGen to create SCI initialization code
- Transmit and Receive programming for the Hercules



Installation

- Collaboration with Baja Team
  - Component box placements
  - Vehicle modifications
- Metal Manufacturing
  - Steel tabs
  - Aluminum plates
- Mounting
  - Waterjet enclosure and plexiglass
  - Brackets
- Testing for rigidness



Hebe Perez

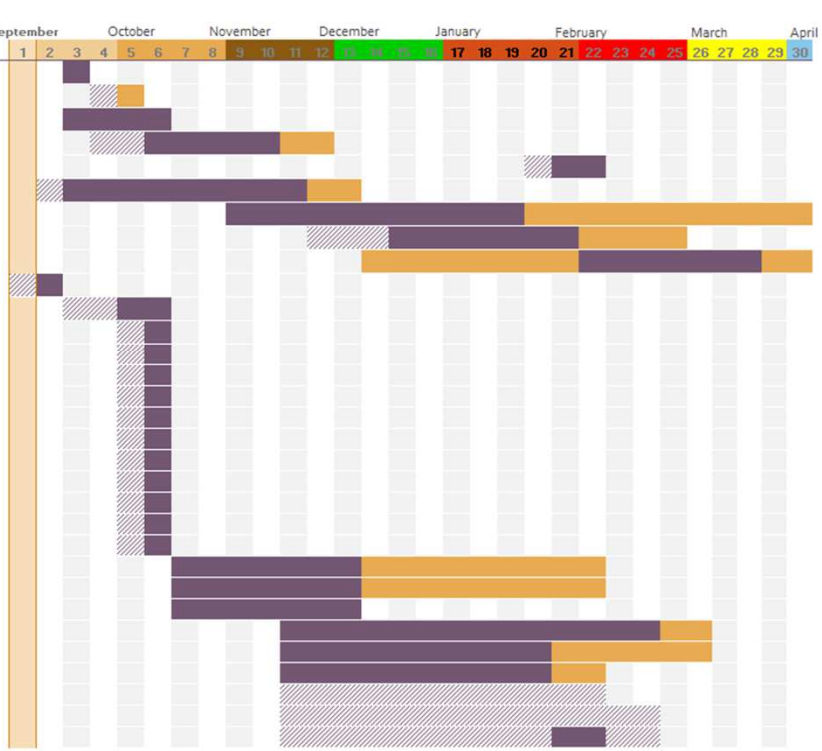

BRIGGS & STRATTON

Schedule

Project Planner

Period Highlight: 1 | Plan | Actual | % Complete | Actual (beyond plan)

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Needs Analysis Report	3	1	3	1	100%
Needs Analysis Presentation	4	1	5	1	100%
Project Research	3	4	3	4	100%
Project Proposal	4	7	6	7	100%
Design Review	20	3	21	2	100%
Design	2	10	3	11	100%
Parts Purchasing	9	11	9	22	100%
Subsystem Implementation	12	10	15	11	100%
Testing	22	7	14	20	100%
Task 1: Project Management	1	2	2	1	100%
Task 2: Concept Generation	3	4	5	2	100%
Subtask 2.1: Main Microcontroller Selection	5	2	6	1	100%
Subtask 2.2: Wireless Transceiver Selection	5	2	6	1	100%
Subtask 2.3: Sensor Microcontroller Selection	5	2	6	1	100%
Subtask 2.4: Sensor Network/Data Bus Selection	5	2	6	1	100%
Subtask 2.5: Data Logging Filetype Selection	5	2	6	1	100%
Subtask 2.6: Battery Selection	5	2	6	1	100%
Subtask 2.7: Accelerometer Selection	5	2	6	1	100%
Subtask 2.8: Fuel Sensor Selection	5	2	6	1	100%
Subtask 2.9: Suspension Sensor Selection	5	2	6	1	100%
Subtask 2.10: Hall Effect Sensor Selection	5	2	6	1	100%
Subtask 2.11: Display Panel Selection	5	2	6	1	100%
Task 3: Circuit Design	7	7	7	16	100%
Subtask 3.1: Regulator Circuit Design	7	7	7	16	100%
Subtask 3.2: Sensor MCU Circuit Design	7	7	7	7	100%
Task 4: Programming	11	14	11	16	100%
Subtask 4.1: Hall Effect Sensor Programming	11	10	11	16	100%
Subtask 4.2: Accelerometer Programming	11	10	11	12	100%
Subtask 4.3: Suspension Travel Programming	11	12			0%
Subtask 4.4: Tire Pressure Sensor Programming	11	14			0%
Subtask 4.5: Fuel Level Sensor Programming*	11	14	21	2	100%



*Fuel Timer

Preliminary Budget

Item	Quantity	Price Per Unit	Total Price
Hercules LaunchPad	1	$19.99	$19.99
MSP430G2332IN20	10	$1.86	$18.60
SD BoosterPack	1	$9.99	$9.99
ADXL335 Accelerometer	1	$14.95	$14.95
Fuel Sender	1	$25.00	$25.00
Xbee-PRO 900HP	2	$39.00	$78.00
LiFePO4 Battery	2	$40.99	$81.98
LiFePO4 Battery Charger	1	$19.95	$19.95
Magnets (30 pk)	1	$6.88	$6.88
Hall Effect sensor (5 pk)	1	$4.49	$4.49
Blank PCB	3	$3.95	$11.85
2.2" TFT SPI Display	1	$20.00	$20.00
Raspberry Pi (Model B)	1	$35.00	$35.00
	Extra Parts		$50.00
	Shipping		$150.00
	Total		**$546.68**

*From the Project Proposal & Statement of Work

Final Expenses

Item	Quantity	Price	Item Total
XBee-PRO 900HP, P-MP, RPSMA	2	$39.00	$78.00
2.1dB 900MHz Articulating Dipole Antenna	2	$9.00	$18.00
XBee Explorer USB	1	$24.95	$24.95
Xbee Breakout Board	2	$2.95	$5.90
Breakaway Headers - 2.54mm	3	$1.50	$4.50
10 pin Headers - 2mm	4	$1.00	$4.00
Raspberry Pi Model B+	1	$39.95	$39.95
ADXL335 Accelerometer Breakout	1	$14.95	$14.95
Dual Female USB Type A Connector	1	$1.39	$1.39
ROHM 5V LDO Voltage Regulator	2	$1.76	$3.52
ROHM 3.3V LDO Voltage Regulator	2	$2.17	$4.34
3M 20 pin DIP socket	8	$0.42	$3.36
8GB Micro SD Card	2	$6.49	$12.98
MSP430G2553 Chips	5	$2.80	$14.00
Tenergy 3.2V 24Ah LiFePO4 Battery	2	$39.99	$79.98
Tenergy 6.4V 1A 2-cell Charger	1	$9.99	$9.99
Neodymium Magnets, 10pk	1	$5.99	$5.99
2.5mm to RCA A/V Cable	1	$4.59	$4.59
12V 7" TFT Display	1	$26.20	$26.20
Cable Grommets, 30pk	1	$9.28	$9.28
Plano Large Waterproof Case	1	$50.12	$50.12
Estone Waterproof Enclosure	6	$3.79	$22.74
LSM303 Accelerometer+Magnetometer	1	$14.95	$14.95
2.2" 18-bit color TFT LDC display w/ MicroSD	1	$24.95	$24.95
30-pin Male Header	3	$1.47	$4.41
30-pin Female Header	3	$2.13	$6.39
20-pin Female Header	2	$1.53	$3.06
3M 20-pin DIP Socket	3	$0.58	$1.74
47k Resistor	10	$0.05	$0.54
2.2 nF Ceramic Capacitor	10	$0.08	$0.80
100 uF Capacitor	10	$0.12	$1.20
330 uF Capacitor	5	$0.18	$0.90
150 uH Inductor	5	$0.42	$2.10
1N5819 Schottky Diode	5	$0.13	$0.65
50 ft Cable - 9 conductor 24AWG	1	$54.04	$54.04
6x6 Blank Copper Clad PCB	2	$9.49	$18.98
2"x4" Industrial Velcro Strips	4	$2.97	$11.88
Black Zip Ties	1	$6.47	$6.47
8"x10" Polycarbonate Lexan Sheet	1	$3.98	$3.98
2 Oz Gorilla Glue	1	$4.97	$4.97
#6x3/8 Sheet Metal Screws	1	$1.18	$1.18
M6 Lock Washers	3	$0.75	$2.25
6mm Hex Nuts	3	$0.58	$1.74
M6 Cap Screws	3	$0.90	$2.70
36" ZMAX Steel Strap	3	$2.98	$8.94
M2.5x20mm Machine Screws	4	$0.37	$1.48
M2.5 Hex Nuts	4	$0.23	$0.92
M2.5 Washers	4	$0.17	$0.68
Shipping & Handling + Tax			$134.33
Discounts			-$3.99
Total			**$750.97**

Testing

Title	Test Type	Attempt 1	Tester	Result
Accelerometer Calibration Test	Component	1/9/2015	Chris	Pass
Hall Effect Sensor Test	Component	2/15/2015	Chris	Pass
Xbee Baseline Test	Component	12/5/2014	Chris/Dewey	Pass
Xbee Short Range Test	Component	12/5/2014	Chris/Dewey	Pass
Xbee Long Range Test	Component			
Xbee Raspberry Pi - Communication Test	Component	1/16/2015	Hebe	Fail
Hercules SD Card Test	Component		Dewey	Pass
Hercules Display Test	Component	1/14/2015	Dewey	Pass
LSM303 Calibration test	Component	2/20/2015	Chris	Pass
MSP430 ADC10 Test	Integration	1/25/2015	Chris	Pass
3.3V Switching Regulator Circuit Test	Integration	2/1/2015	Dewey	Fail
5V Switching Regulator Circuit Test	Integration	2/1/2015	Dewey	Fail
Hercules SPI Test	Integration	1/12/2015	Dewey	Pass
MSP430 SPI Slave Test	Integration	1/21/2015	Chris	Pass
MSP SPI Slave Mode with ADC10 Test	Integration	1/15/2015	Chris/Dewey	Pass*
MSP430 I2C	Integration	2/20/2015	Chris	Pass
I2C and SPI MSP430 Test	Integration	3/1/2015	Chris/Dewey	Pass
Battery Life Test	Integration			
Project Box Waterproof Seal Test	Integration	3/5/2015	Chris	Pass
Plano Waterproof Seal Test	Integration	3/20/2015	Chris	Pass
MSP430 PCB Test	Integration	3/15/2015	Dewey	Pass
Xbee between Hercules and RPi Test	Integration	1/30/2015	Dewey	Pass
Hall Effect Sensor Accuracy Test	Integration	3/20/2015	Chris	Pass
Hall Effect Sensor Project Box Test	Integration	3/16/2015	Chris	Pass
Full System Test	Integration	4/4/2015	Chris/Dewey	Pass
Xbee Raspberry Pi - Communication Test 2	Component	1/23/2015	Dewey	Pass
3.3V Switching Regulator Circuit Test 2	Integration	3/5/2015	Hebe/Dewey/Chris	Pass
5V Switching Regulator Circuit Test 2	Integration	3/6/2015	Hebe/Dewey/Chris	Pass