Team 23

Development of a Wheel Force/Torque Sensor for Autonomous Ground Vehicles

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Outline

- Background
- Problem Description
- Previous Work
- Testing
- Future Work
- Potential Challenges
- Budget

Background

- CISCOR focuses on intelligent systems, controls and robotics
- Gas Operated Land Intelligent All Terrain Hub
  - 2012 Polaris Sportsman 550

Goliath ATV

Problem Description

Need Statement

- In its current state, the GOLIATH cannot indicate wheel interaction with the ground without an actual driver on vehicle

Problem Statement

- Design, test, and implement a way to quantify the interaction between the wheel and the ground

Problem Description

Constraints

- Weather, vibration, corrosion resistant
- Sample and relay data at 1kHz
- Minimal effects to GOLIATH’s performance
- Operational for at least five hours
- Reliable sampling of data

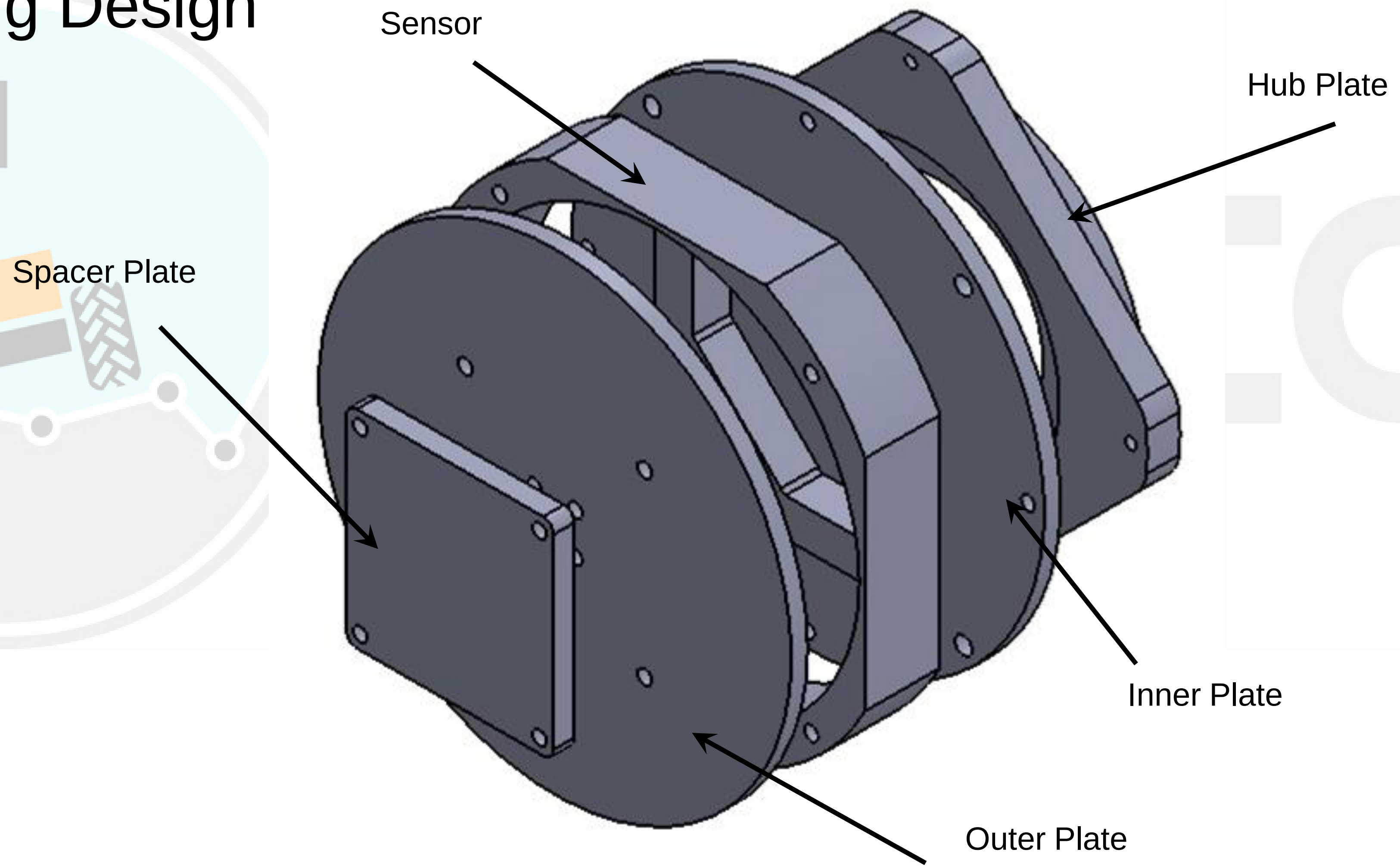
Purpose

- After market units already available
- Most units are specialized to only one purpose or setup
- Due to specialization, units typically start between $10,000 and $15,000, potentially more
  - Project budget: $5000

Honeywell torque transducer

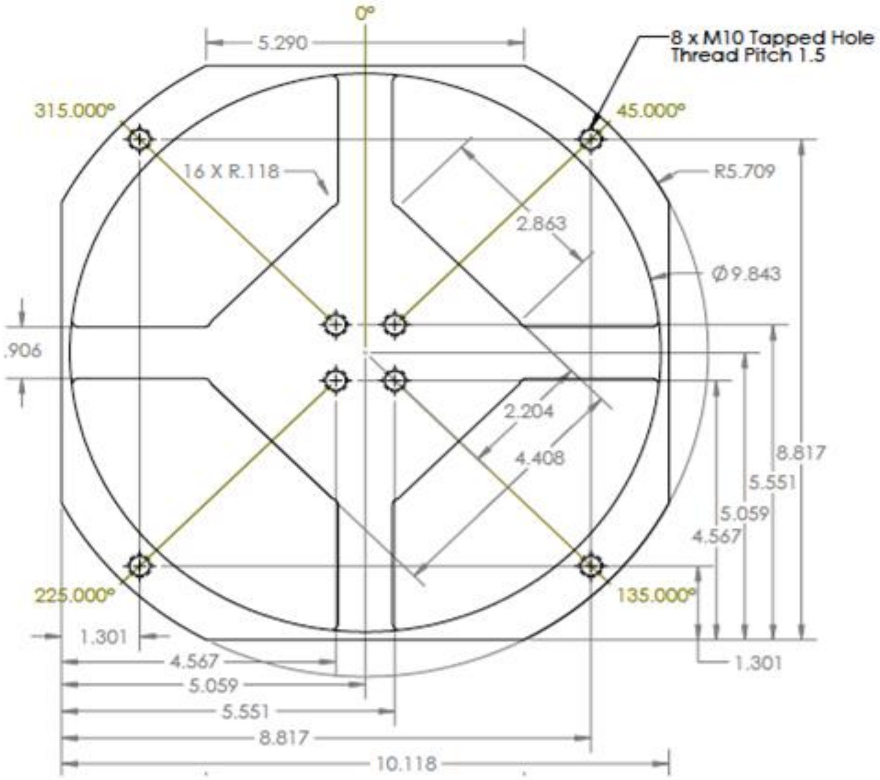
Previous Work

- Working Design

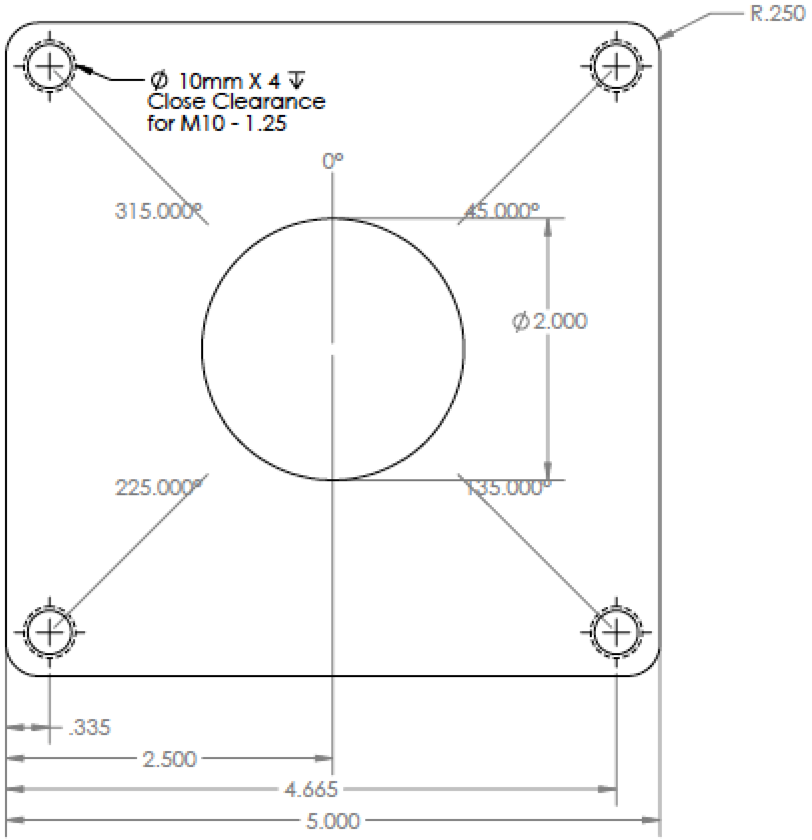


Design Revisions

- Spacer plates
- Revised cross
- Component attachments
- Overall Weight ~25lbs



Revised Cross



Spacer Plate

Working Circuit

Working Circuit Components

1: Precision Resistors (350 Ohm, .1%)

2: Strain Gauges (16)

3: Reference Voltage
(2 Resistors and Transistor)

4: Power (red) and Ground (black)

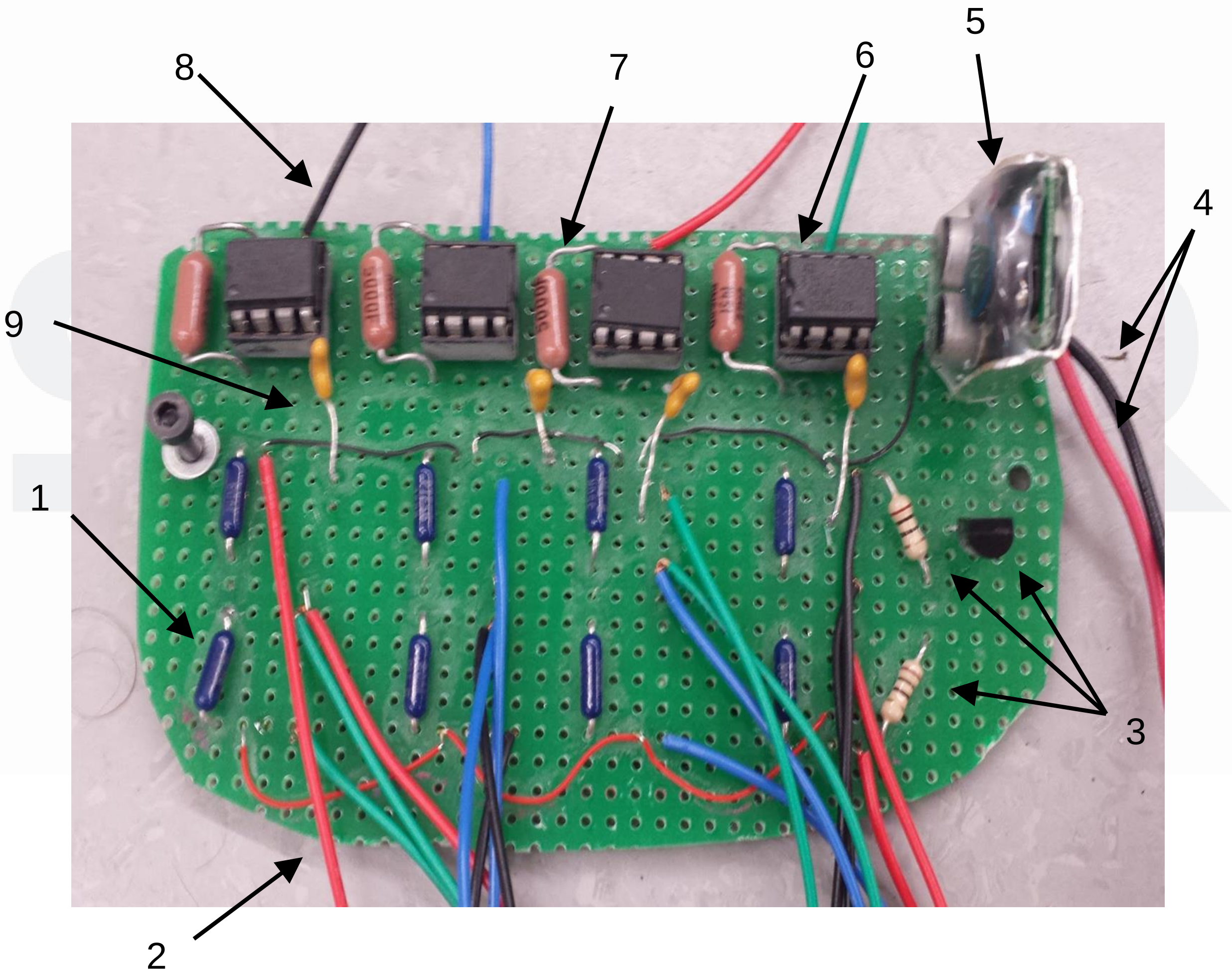
5: Switch Voltage Regulator

6: Amplifier

7: Gain Resistor

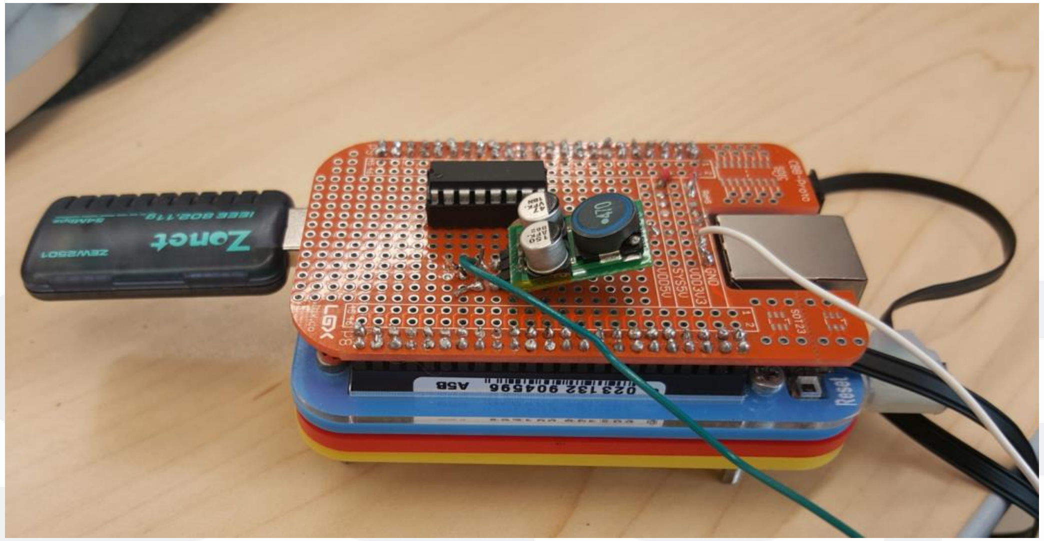
8: To Analog to Digital Converter

9: Capacitor



Design Revisions

- BeagleBone Protective Case
  - Allows access to all ports/pins
  - Secured into metal
- BeagleBone proto board with A2D converter and voltage regulator.
- Wi-Fi adapter
  - Auto connects



Programming

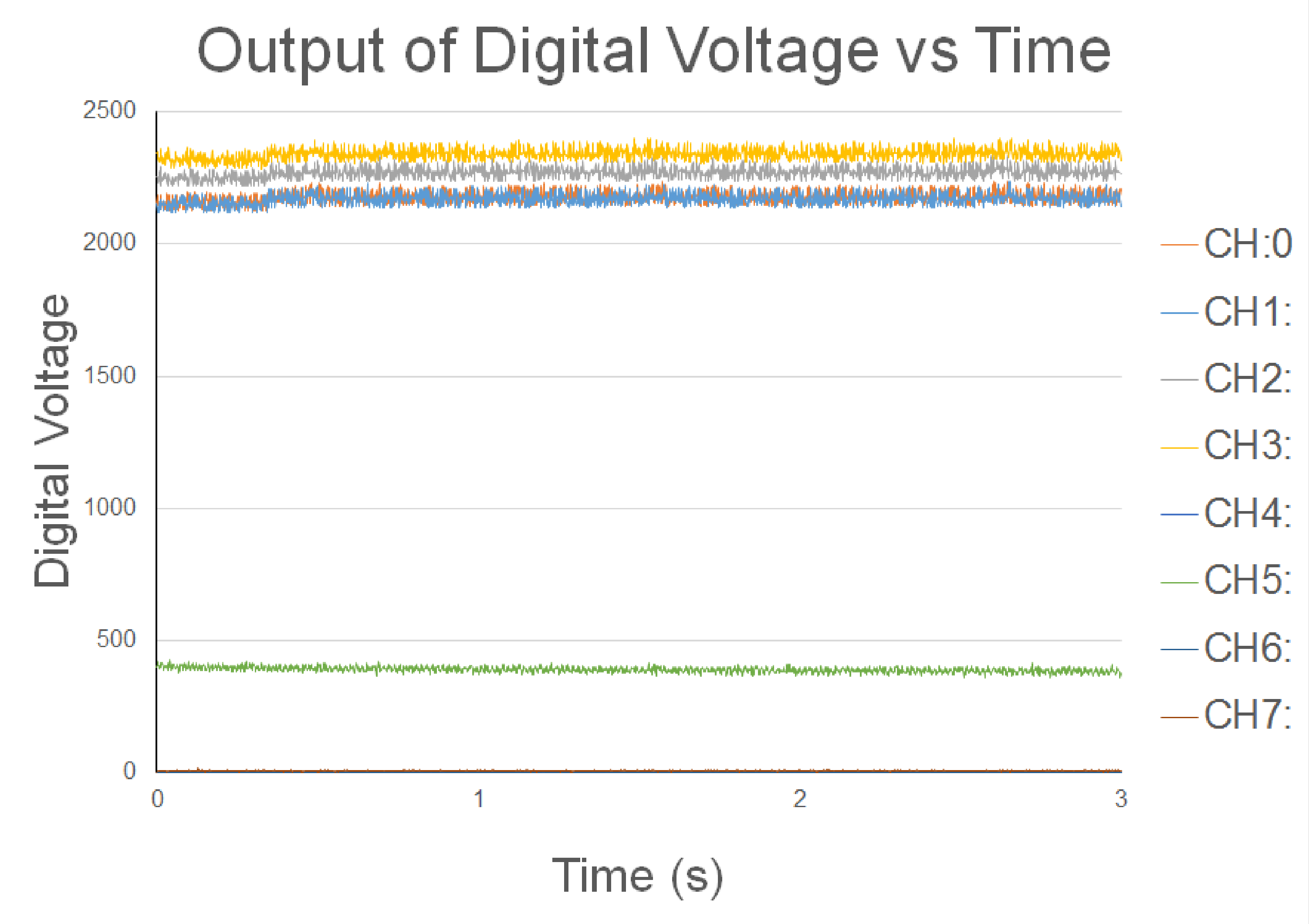
- In testing, max output rate of 700 samples/sec per channel
- 8 channels total
- Data outputted to .txt file

```
while(1)
{
    //CHANNEL 0 CONVERSION------------------------------------------------------------------------
    data0[0] = 0b00000110;  //  first byte transmitted -> 00000(STARTBIT = 1) (SGL/DIF = 1) (D2)
    data0[1] = 0b00000000; // second byte transmitted -> (D1)(D0)000000
    data0[2] = 0; // third byte transmitted....don't care
    a2d.spiWriteRead(data0, sizeof(data0));
    a2dVal0 = 0;
    a2dVal0 = (data0[1] << 8) & 0b111100000000; //merge data[1] & data[2] to get result
    a2dVal0 |=  (data0[2] & 0xff);
    //------------------------------------------------------------------------------------------

    //CHANNEL 1 CONVERSION------------------------------------------------------------------------
    data1[0] = 0b00000110;  //  first byte transmitted -> 00000(STARTBIT = 1) (SGL/DIF = 1) (D2)
    data1[1] = 0b01000000; // second byte transmitted -> (D1)(D0)000000
    data1[2] = 0; // third byte transmitted....don't care
    a2d.spiWriteRead(data1, sizeof(data1));
    a2dVal1 = 0;
    a2dVal1 = (data1[1] << 8) & 0b111100000000; //merge data[1] & data[2] to get result
    a2dVal1 |=  (data1[2] & 0xff);
    //------------------------------------------------------------------------------------------
```

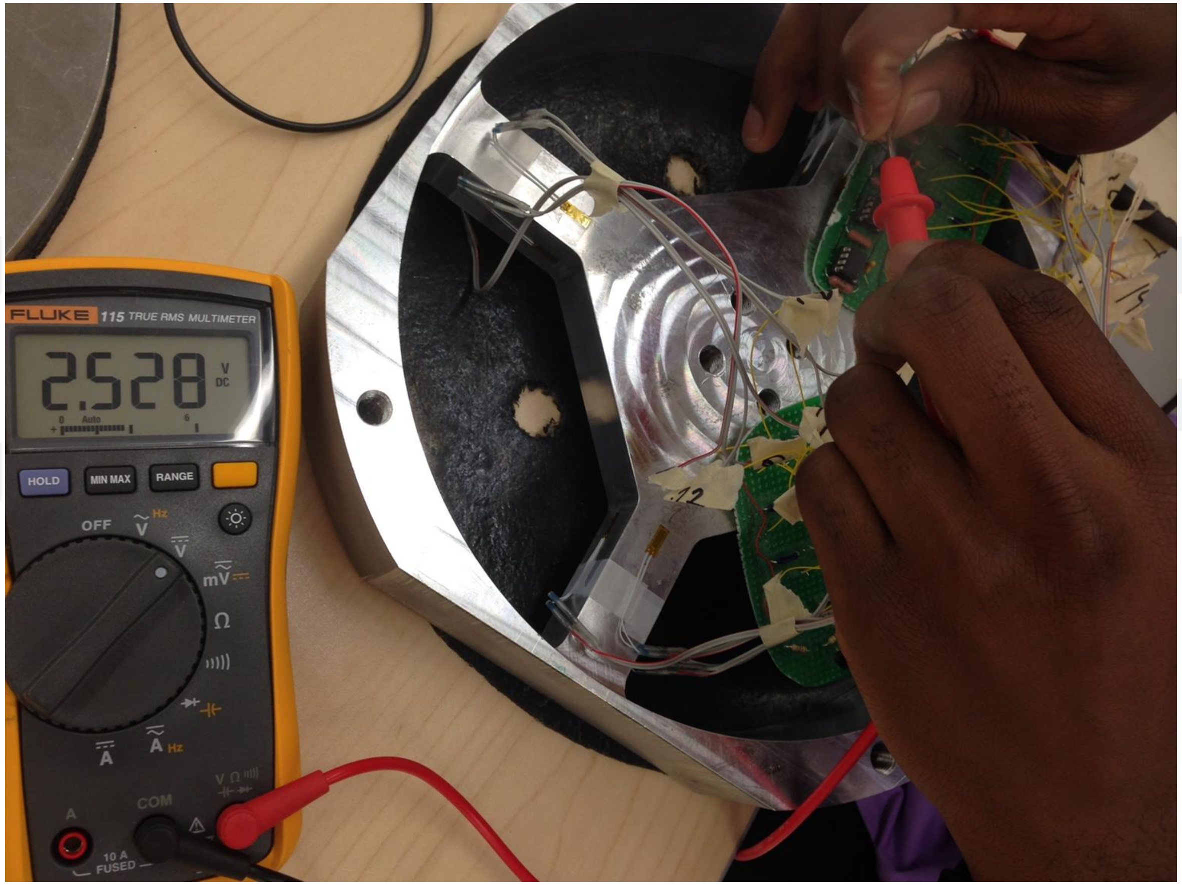
Code Test

- Wirelessly SSH into Beaglebone and run code
- Stop test after 3 seconds and analyze the .txt file
- During Conversion, Regulator, A2D, Wi-Fi adapter and BBB use approx. 340-360mA, at 7.2V.
  - Approx 2.52 ± .08 W



Circuit Test

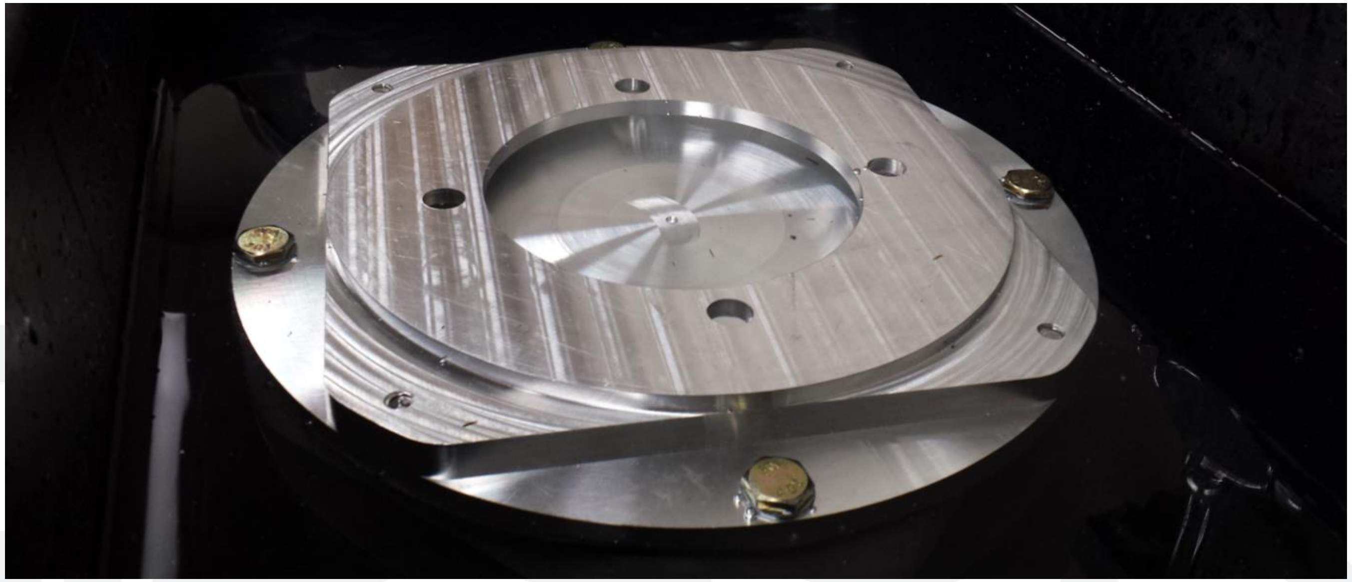
- Working circuit used
- 7.2 Volts in
- Output from each Wheatstone bridge was approx. 2.5 Volts

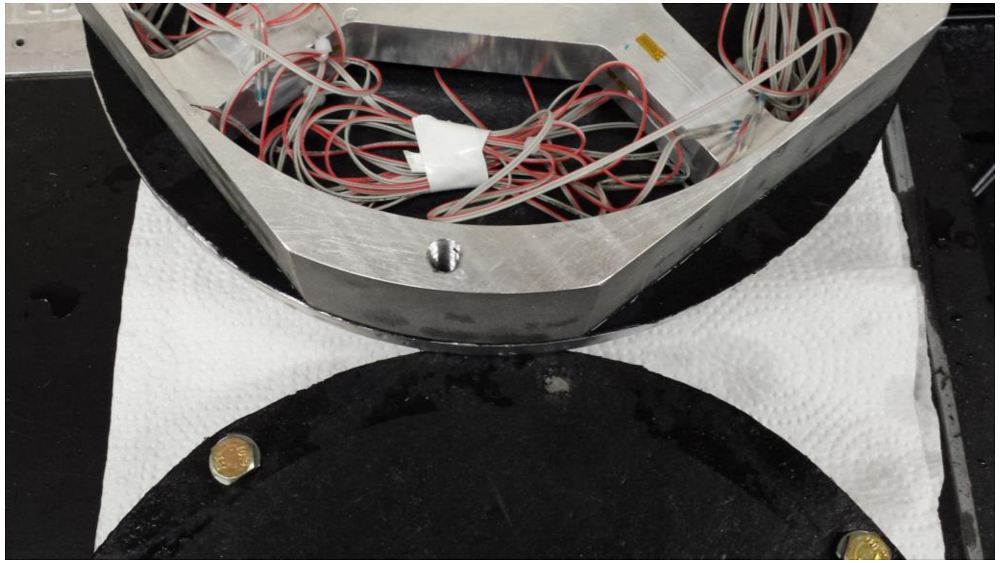


Drive Testing

Weatherproof Testing

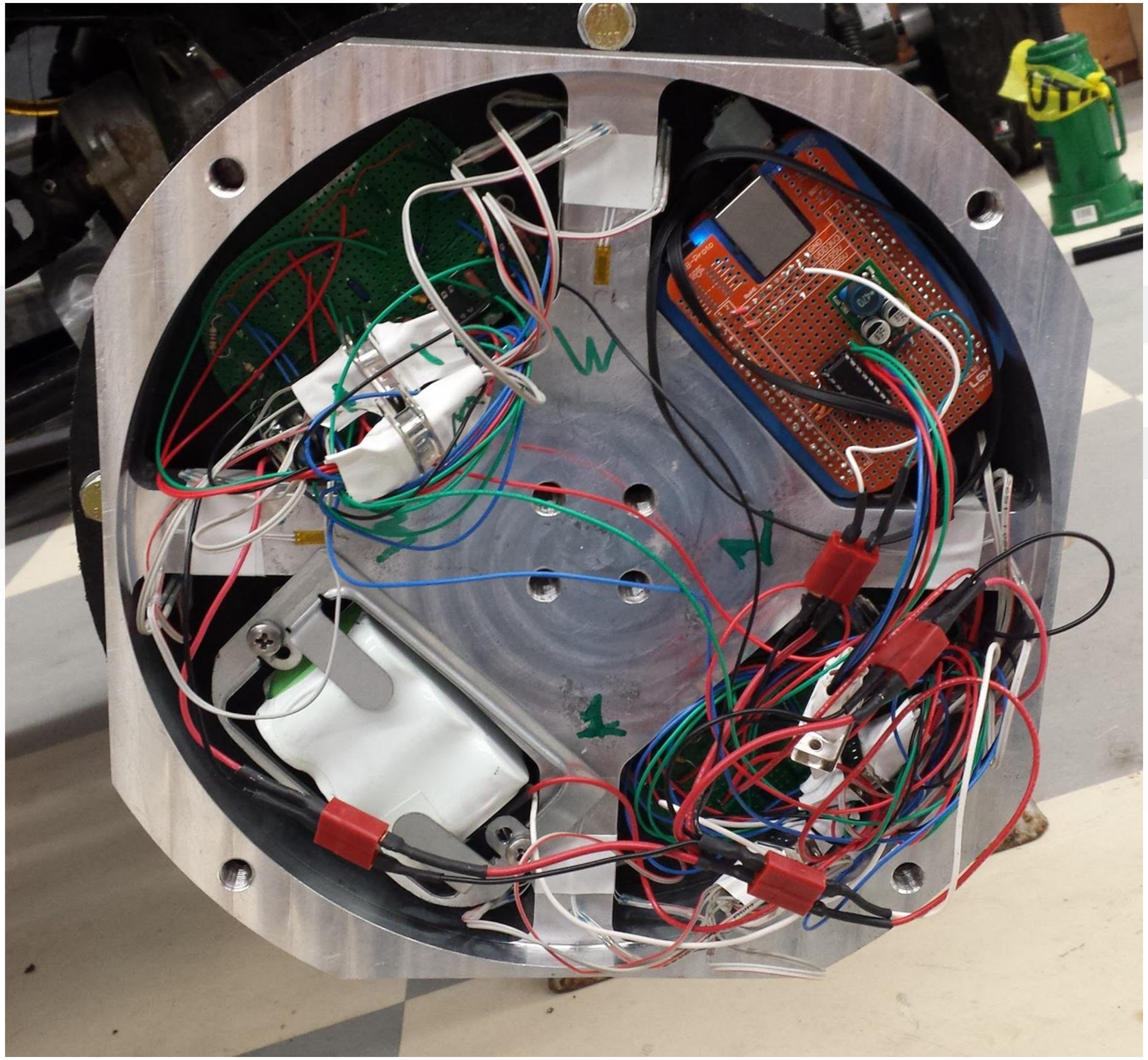
- Unit assembled with seals and fully submerged for five minutes





FinalTests

- Entire assembly mounted in hub and on ATV
- Data transmitted from all eight channels wirelessly to computer



Future Work

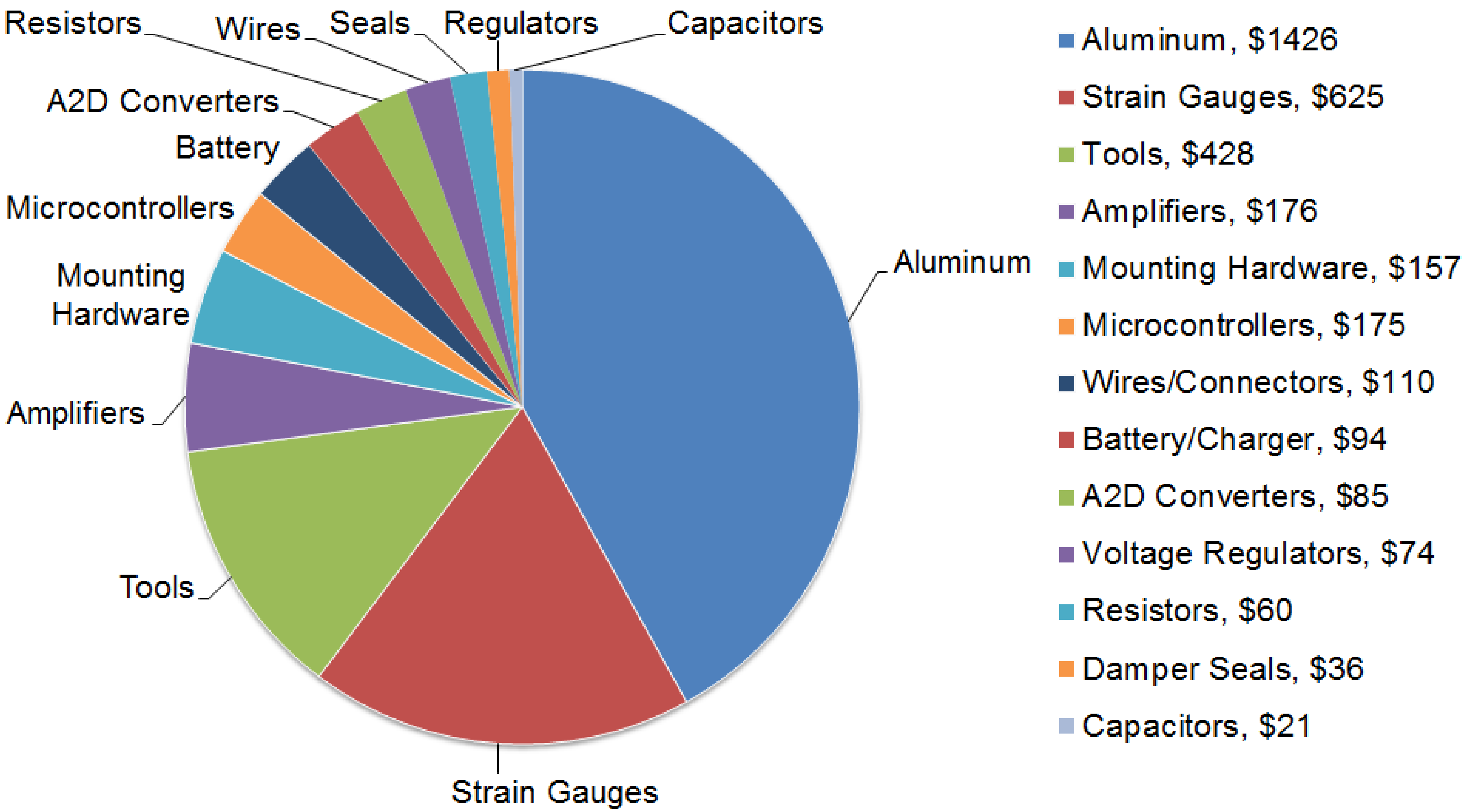
- Dynamic wheel balancing
- Printed circuit boards (PCB)
- Adding bigger and higher capacity battery
  - Battery bank that outputs regulated 5V
  - Possibility of 10000mAh+
- Wireless transmission
  - Smaller USB adapter to mount on microcontroller
- Miniaturization
  - Smaller Sensor (by volume)

Problems Faced

- Proper Sized wireless adapter to fit inside sensor
- Proper Circuit Signal
  - Printed Circuit Board
- Securing All Components into the sensor
- Proper means of calibration
- Compiling the assembly onto the wheel

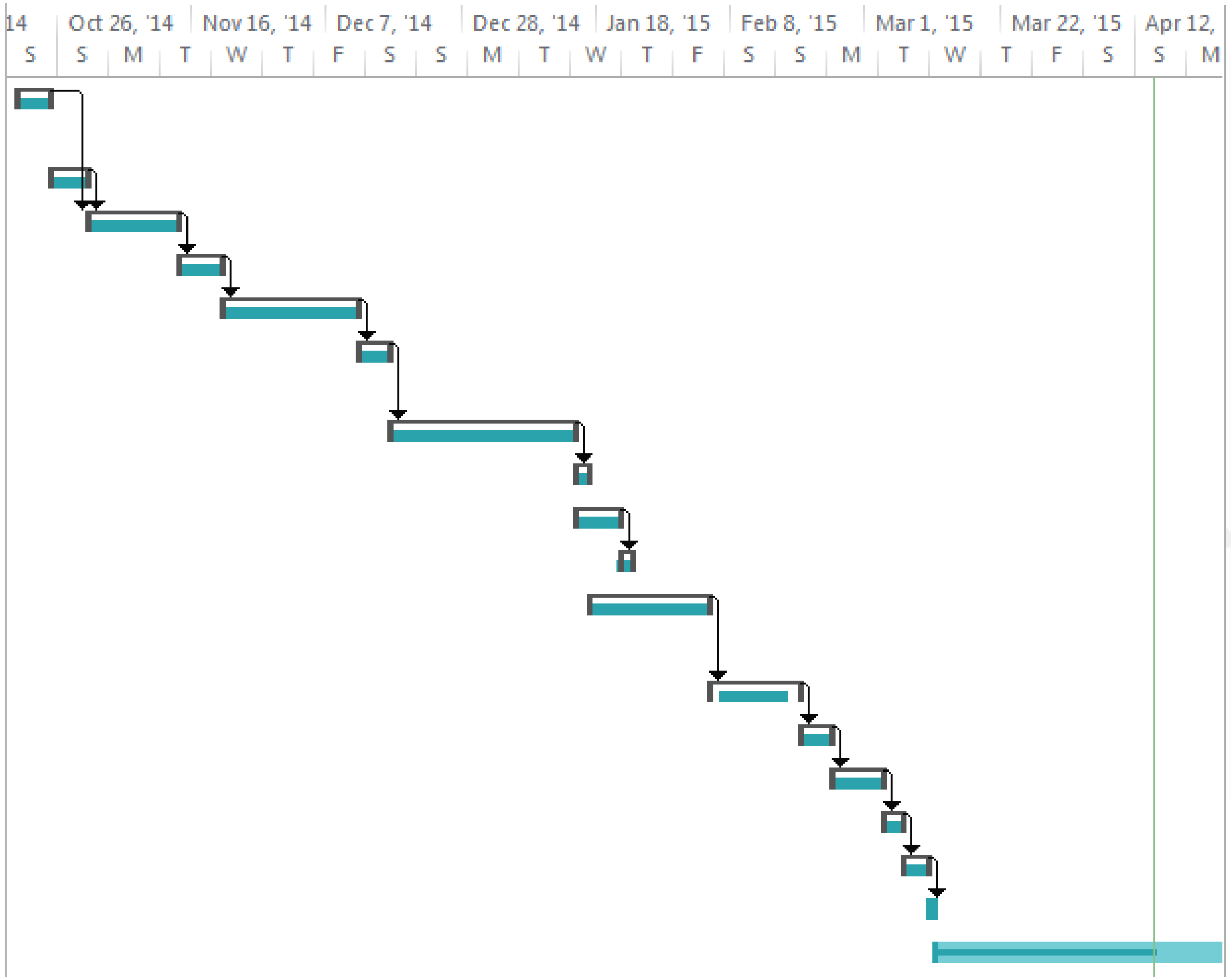
Current Budget

- $3402 of $5000 allocated has been spent.



Timeline

% Comp	Task Name	Duration	Start	Finish
100%	Calculate force and compliance calculations for ATV	5 days	Mon 10/20/14	Fri 10/24/14
100%	Run Calculations for Electrical Circuit	5 days	Sat 10/25/14	Thu 10/30/14
100%	Develop Prototype sensor	10 days	Fri 10/31/14	Thu 11/13/14
100%	Develop Electrical Prototype	5 days	Fri 11/14/14	Thu 11/20/14
100%	Create CAD drawings	15 days	Fri 11/21/14	Thu 12/11/14
100%	Perform Finite Element Analysis on Prototype	3 days	Fri 12/12/14	Tue 12/16/14
100%	Order Parts	21 days	Wed 12/17/14	Wed 1/14/15
100%	Finalize CAD Model	2 days	Thu 1/15/15	Fri 1/16/15
100%	Order Additional Parts	5 days	Thu 1/15/15	Wed 1/21/15
100%	Testing Specimens	2 days	Wed 1/21/15	Fri 1/23/15
100%	Fabricate Prototype	14 days	Sat 1/17/15	Wed 2/4/15
100%	Program Microcontroller	0 days	Wed 2/4/15	Wed 2/4/15
100%	Compile components in hub of ATV	10 days	Thu 2/5/15	Wed 2/18/15
88%	Trouble shoot hardware	3 days	Thu 2/19/15	Mon 2/23/15
83%	Intergrate hardware & Software	6 days	Tue 2/24/15	Tue 3/3/15
92%	Assemble unit and mount to ATV	3 days	Wed 3/4/15	Fri 3/6/15
63%	Test Prototype	3 days	Sat 3/7/15	Tue 3/10/15
75%	Trouble shoot as needed	1 day	Wed 3/11/15	Wed 3/11/15
72%	Buffer	34 days	Thu 3/12/15	Tue 4/28/15



Summary

- Design, fabricate, and test a wheel torque sensor for CISCOR's GOLIATH ATV
  - More feasible approach to units currently on market
- Testing shows that sensor works reads and transmits data
- Still substantially under budget

References

- Akbar, Marc, Merrick Salisbury, Michael Brazeau, Lester Kendrick, Omesh Dalchand, Jeremy Hammond, and Nahush Kulkarni. "Gas Operated Land Intelligent All Terrain Hub." FAMU FSU COE, 17 Apr. 2014. Web. 26 Sept. 2014
- "Polaris." *ATV RANGER RZR Snowmobile Official Website*. N.p., n.d. Web. 10 Oct. 2014
- "How to Pick the Right Electronics Board for Your DIY Project." *Lifehacker*. N.p., n.d. Web. 09 Oct. 2014
- *Discount Steel*. N.p., n.d. Web. 06 Nov. 2014
- Brier, Hyman. Strain Gauge Load Indicator. Ohio Commw Eng Co, assignee. Patent US 2813709 A. 19 Nov. 1957. Print
- “Honeywell Sensing and Control.” N.p., n.d. Web 29 Jan. 2015

http://eng.fsu.edu/me/senior_design/2015/team23/

Questions?

Calculations

ATV

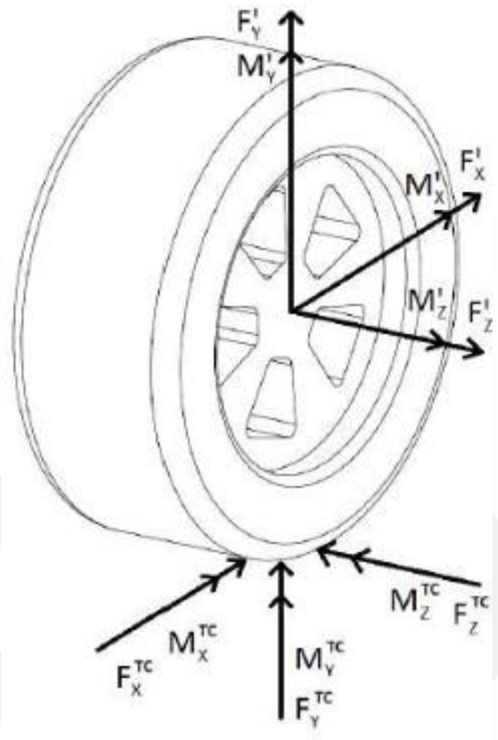
Dry Weight : 733 lbs ➔ 3260 N

Max Payload : 575 lbs ➔ 2558 N

Gross Weight : 1308 lbs ➔ 5818 N

Wheel and Tire Radius : 8 inches ➔ 0.203 m

Factor of Safety: 1.5



Wheel Forces

$$F_x = F_y = \frac{W_G}{2} * FS = 4364N$$

$$F_z = 2000\ N$$

Wheel Torques

$$T_{max\ x} = T_{max\ y} = 4364\ N * 0.203\ m = 1663\ N*m$$

$$T_{max\ z} = 2000\ N * 0.203\ m = 763\ N*m$$

Randall Veliky

Strain Gauge Calibration

$$C = \begin{bmatrix} C_{11} & C_{12} & C_{13} & 0 & 0 & 0 \\ C_{12} & C_{11} & C_{13} & 0 & 0 & 0 \\ C_{13} & C_{13} & C_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{44} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{2}(C_{11} - C_{12}) \end{bmatrix}$$

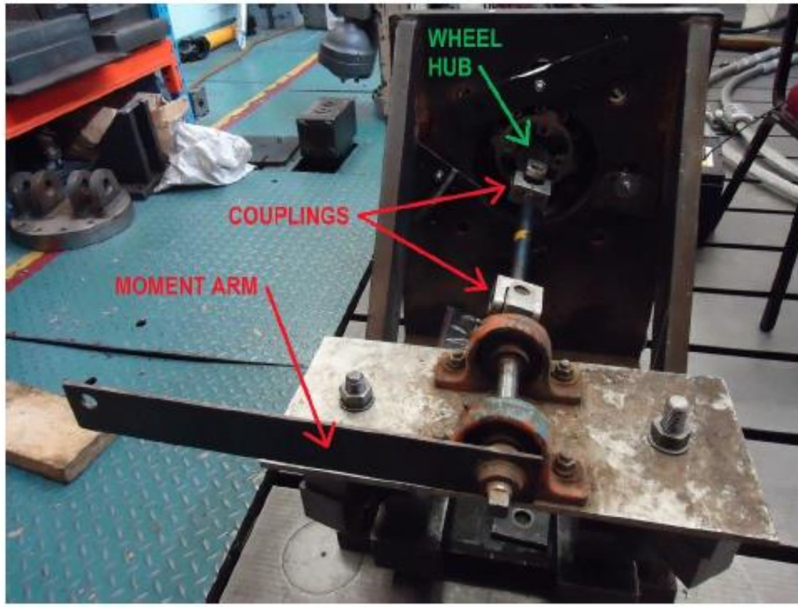
$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \end{pmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & 0 & 0 & 0 \\ C_{12} & C_{11} & C_{13} & 0 & 0 & 0 \\ C_{13} & C_{13} & C_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{44} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{2}(C_{11} - C_{12}) \end{bmatrix} \cdot \begin{pmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{pmatrix}$$

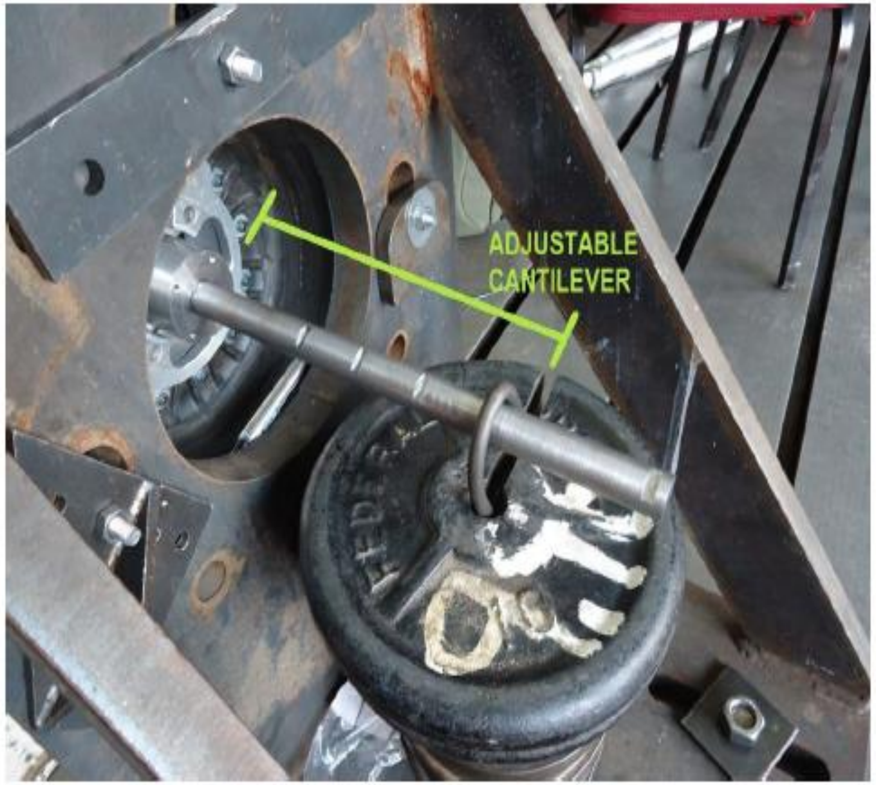
$$C^{-1}\varepsilon_s = B \cdot \varepsilon_s = \vec{F}$$

Sample (Raw)Output Data

108179	CH0: 3481	CH1: 809	CH2: 2241	CH3: 778	CH4: 2142	CH5: 692	CH6: 2116	CH7: 2272
108180	CH0: 3479	CH1: 838	CH2: 2207	CH3: 776	CH4: 2144	CH5: 710	CH6: 2150	CH7: 2233
108181	CH0: 3500	CH1: 836	CH2: 2257	CH3: 720	CH4: 2127	CH5: 690	CH6: 2163	CH7: 2234
108182	CH0: 3477	CH1: 831	CH2: 2222	CH3: 745	CH4: 2138	CH5: 672	CH6: 2130	CH7: 2211
108183	CH0: 3481	CH1: 827	CH2: 2237	CH3: 732	CH4: 2144	CH5: 732	CH6: 2147	CH7: 2272
108184	CH0: 3503	CH1: 815	CH2: 2230	CH3: 779	CH4: 2151	CH5: 721	CH6: 2154	CH7: 2218
108185	CH0: 3491	CH1: 804	CH2: 2213	CH3: 717	CH4: 2125	CH5: 691	CH6: 2144	CH7: 2234
108186	CH0: 3477	CH1: 791	CH2: 2217	CH3: 724	CH4: 2138	CH5: 693	CH6: 2104	CH7: 2223
108187	CH0: 3518	CH1: 834	CH2: 2213	CH3: 741	CH4: 2137	CH5: 684	CH6: 2113	CH7: 2232
108188	CH0: 3483	CH1: 832	CH2: 2176	CH3: 740	CH4: 2144	CH5: 707	CH6: 2114	CH7: 2240
108189	CH0: 3482	CH1: 810	CH2: 2175	CH3: 716	CH4: 2140	CH5: 684	CH6: 2135	CH7: 2242
108190	CH0: 3476	CH1: 853	CH2: 2246	CH3: 772	CH4: 2133	CH5: 696	CH6: 2132	CH7: 2279
108191	CH0: 3484	CH1: 819	CH2: 2184	CH3: 727	CH4: 2132	CH5: 690	CH6: 2178	CH7: 2278
108192	CH0: 3476	CH1: 799	CH2: 2258	CH3: 770	CH4: 2150	CH5: 709	CH6: 2151	CH7: 2204
108193	CH0: 3513	CH1: 814	CH2: 2212	CH3: 737	CH4: 2125	CH5: 671	CH6: 2147	CH7: 2235
108194	CH0: 3474	CH1: 809	CH2: 2200	CH3: 727	CH4: 2140	CH5: 706	CH6: 2163	CH7: 2282
108195	CH0: 3477	CH1: 853	CH2: 2212	CH3: 744	CH4: 2128	CH5: 696	CH6: 2155	CH7: 2277
108196	CH0: 3480	CH1: 852	CH2: 2248	CH3: 745	CH4: 2135	CH5: 688	CH6: 2161	CH7: 2244
108197	CH0: 3524	CH1: 826	CH2: 2226	CH3: 767	CH4: 2128	CH5: 701	CH6: 2163	CH7: 2268
108198	CH0: 3469	CH1: 804	CH2: 2178	CH3: 734	CH4: 2141	CH5: 691	CH6: 2104	CH7: 2236
108199	CH0: 3510	CH1: 810	CH2: 2191	CH3: 721	CH4: 2128	CH5: 691	CH6: 2160	CH7: 2235
108200	CH0: 3510	CH1: 836	CH2: 2185	CH3: 744	CH4: 2142	CH5: 687	CH6: 2156	CH7: 2207
108201	CH0: 3494	CH1: 843	CH2: 2182	CH3: 738	CH4: 2128	CH5: 731	CH6: 2196	CH7: 2246
108202	CH0: 3507	CH1: 829	CH2: 2201	CH3: 720	CH4: 2126	CH5: 694	CH6: 2151	CH7: 2255
108203	CH0: 3529	CH1: 815	CH2: 2209	CH3: 740	CH4: 2124	CH5: 705	CH6: 2144	CH7: 2229
108204	CH0: 3479	CH1: 848	CH2: 2222	CH3: 771	CH4: 2136	CH5: 712	CH6: 2204	CH7: 2248


APPLIED
WEIGHTS


WHEEL
HUB
COUPLINGS
MOMENT ARM


ADJUSTABLE
CANTILEVER