Motorcycle Headlight Correction System

April 18, 2007

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Presentation Outline

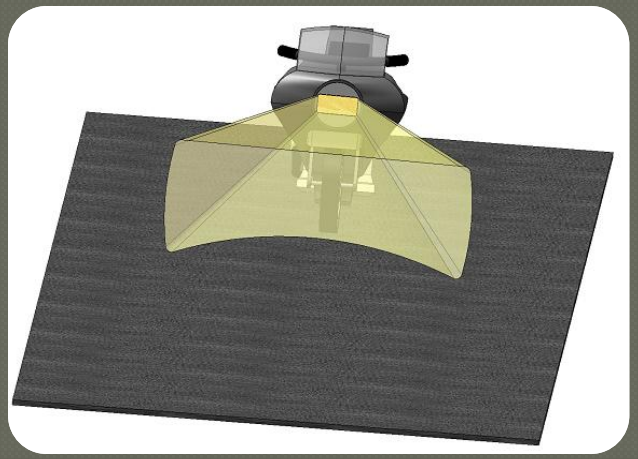
- Motivation
- Roles
- System Overview
- High Level System Design
- Mechanical Design
- Electrical Design
- Software Design
- Finance & Market
- Budget
- Timeline
- Teamwork
- What was Learnt
- Conclusion
- Information Sources
- Acknowledgements
- Questions

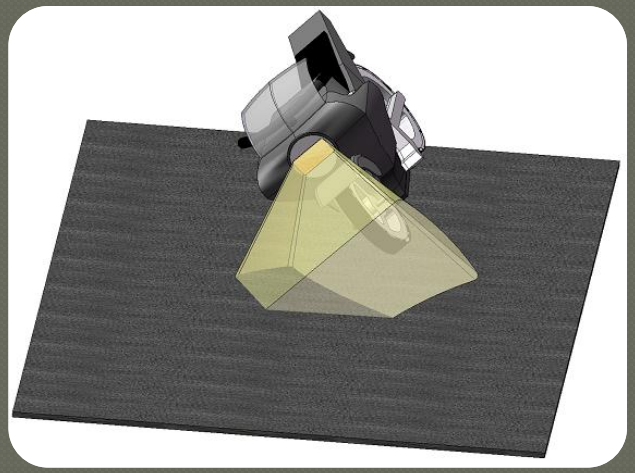
Motivation

- U.S. National Highway Traffic Safety Administration (NHTSA)
  - 50% of motorcycle fatalities are related to negotiating a curve prior to the crash
  - 60% of motorcycle fatalities occur at night

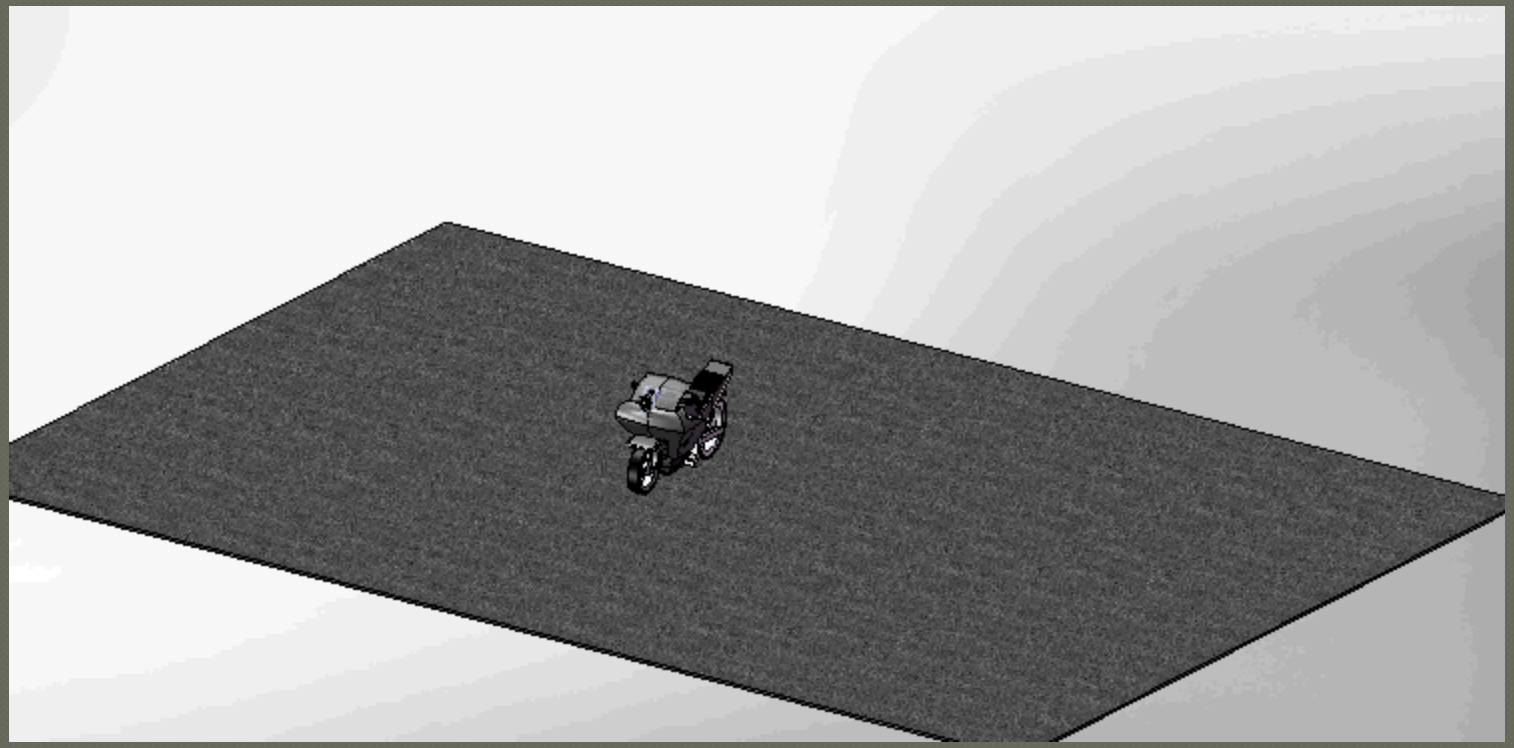
Problem

- Headlight remains pointing straight forward (rigid body)
  - limits portions of the road that can be seen, particularly around curves
  - inadequate light directed in the path of movement
  - glare towards other motorists





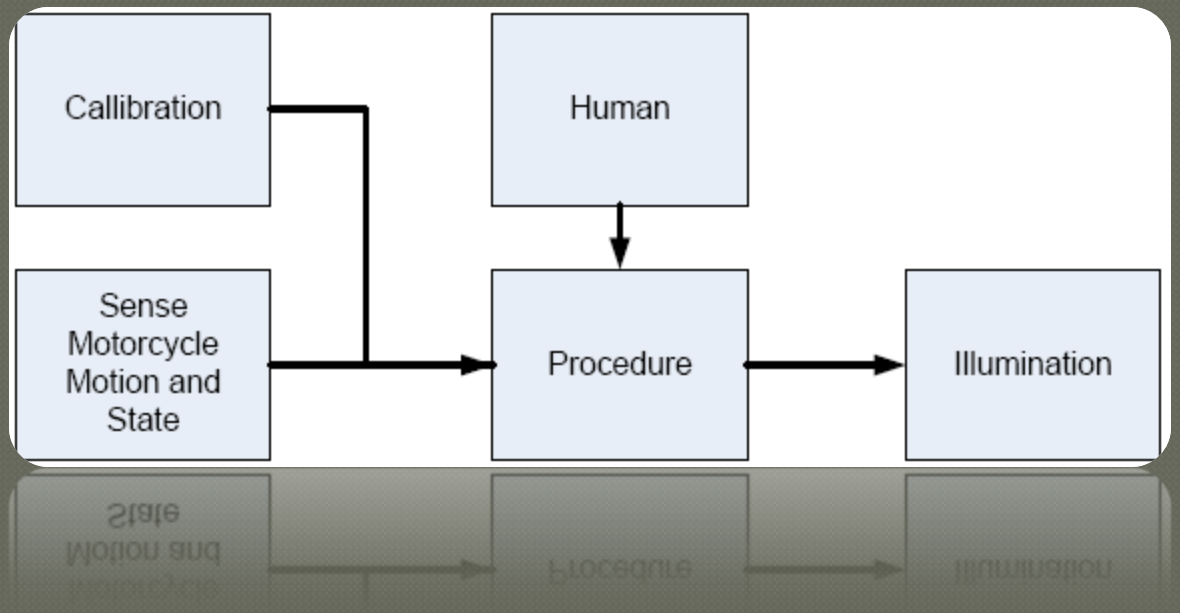
Proposed Solution



Benefits

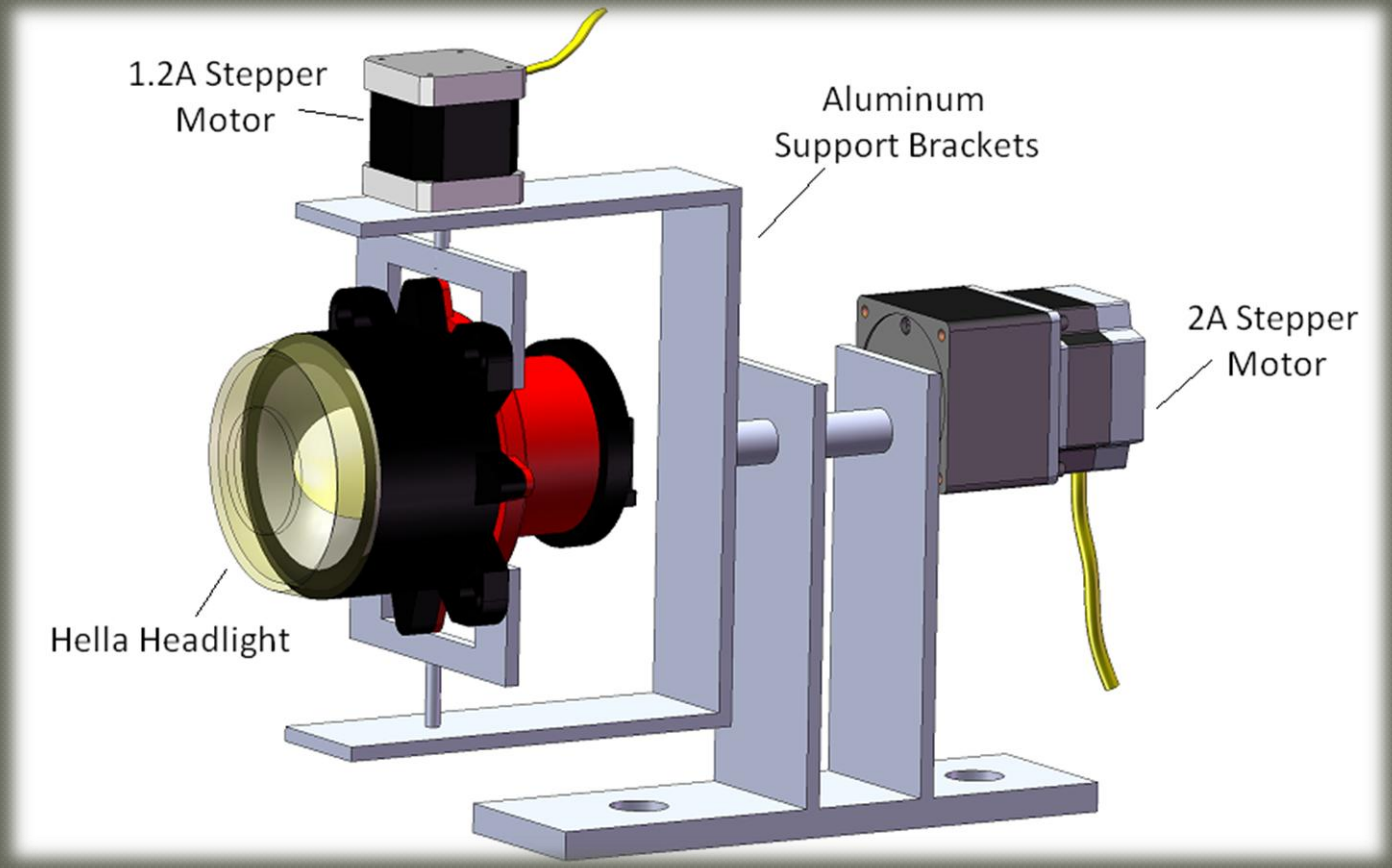
- Provide better visibility
  - reduce the risk of injuries and fatalities
    - Safer environment for rider, pedestrians, & other motorists
- Better lighting
  - Reduces glare into oncoming traffic

System Overview



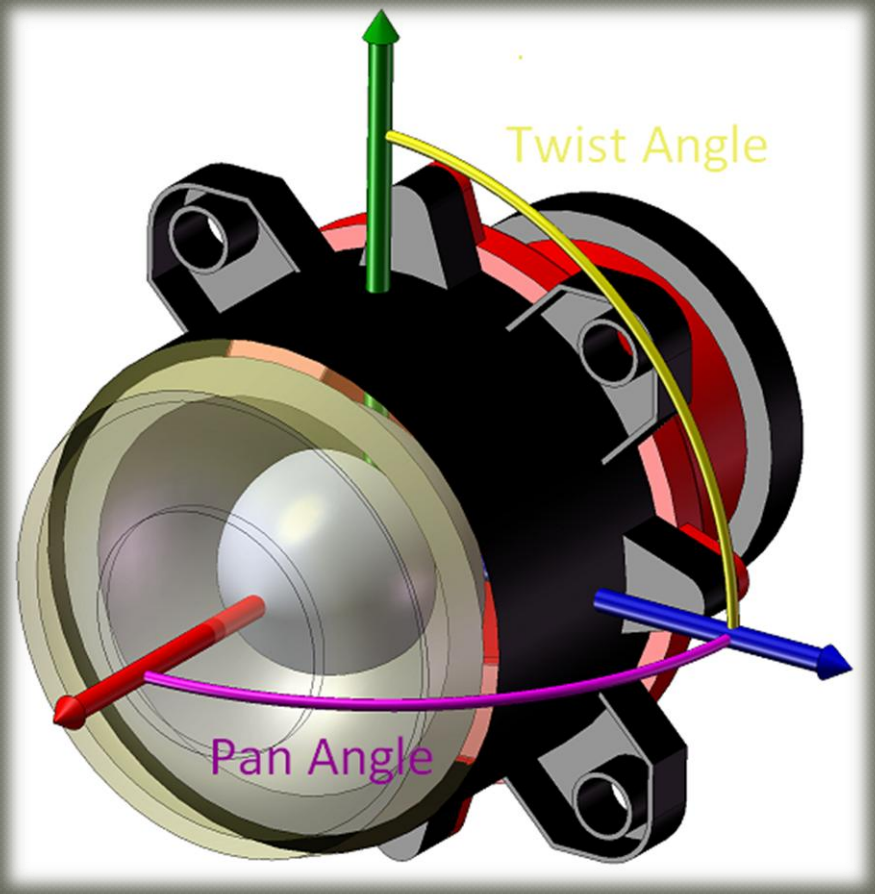
Mechanical Design

- SolidWorks model of system

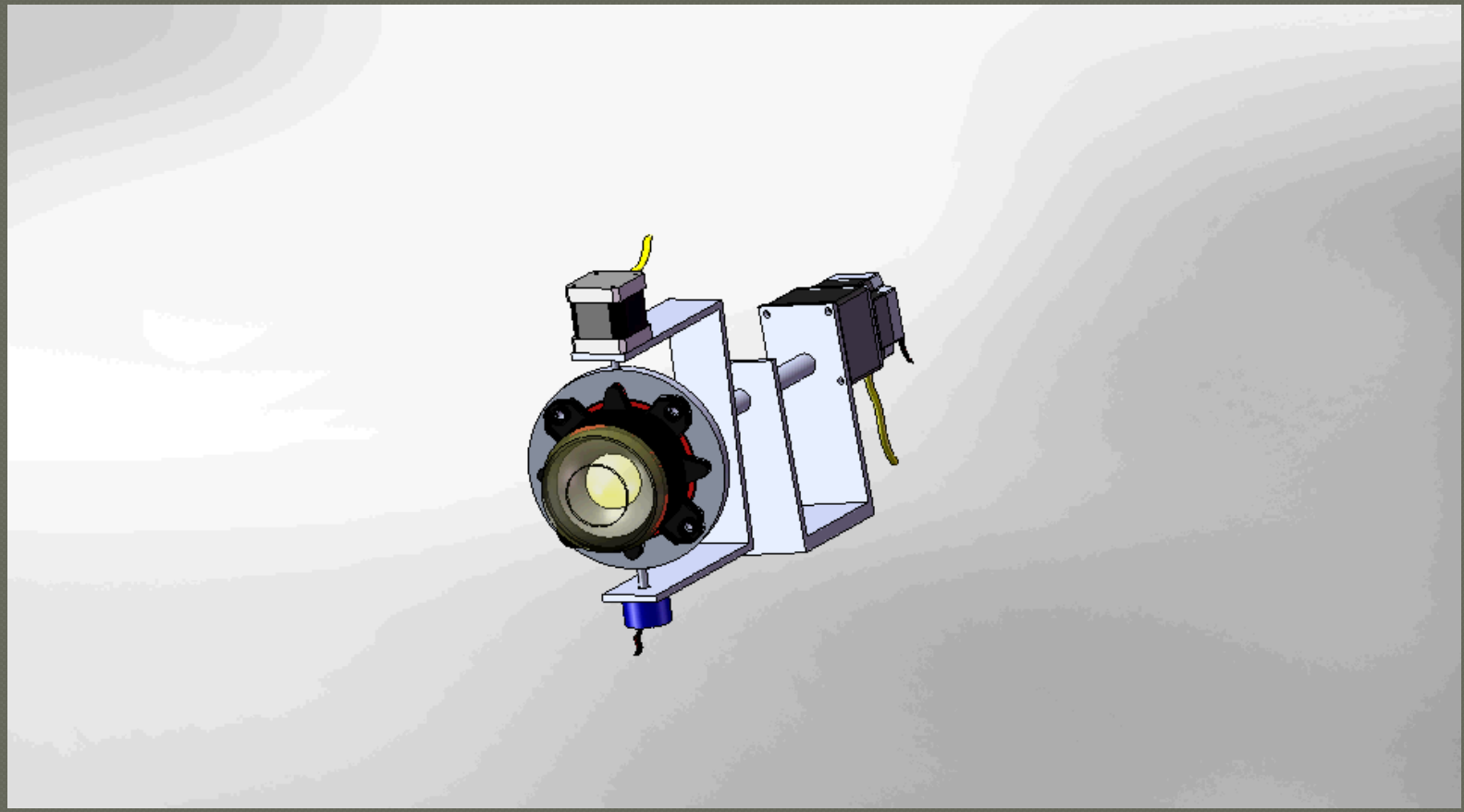


Mechanical Design

- Headlight motions:

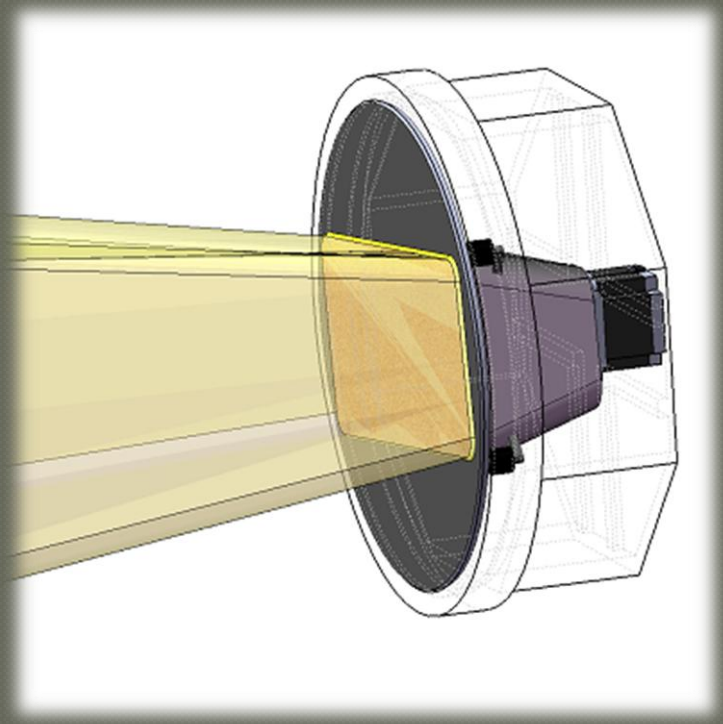


Mechanical Design

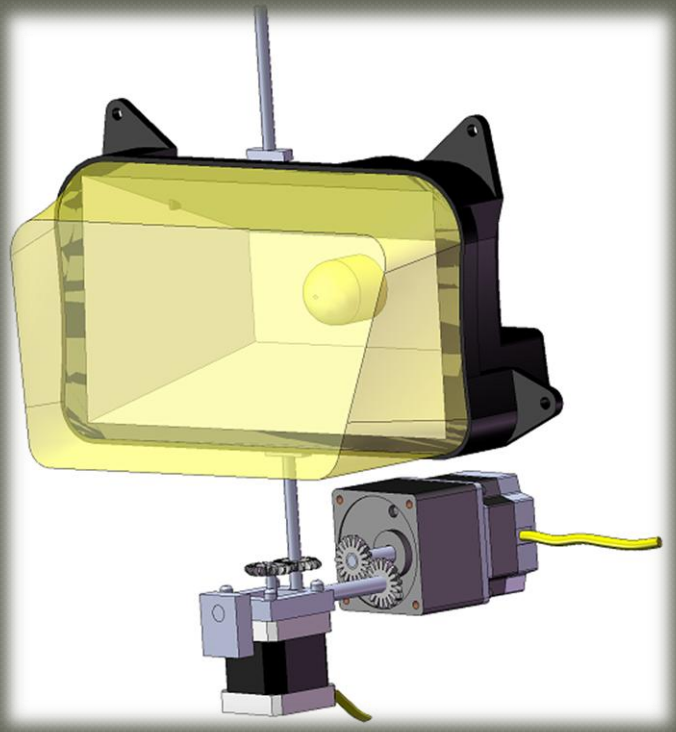


Mechanical Design

- Previously Considered Designs



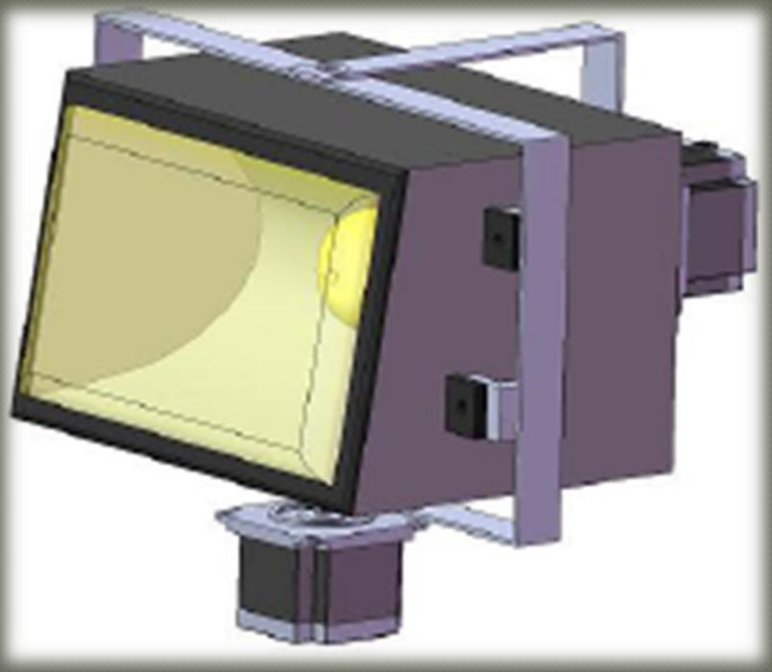
Initial Design



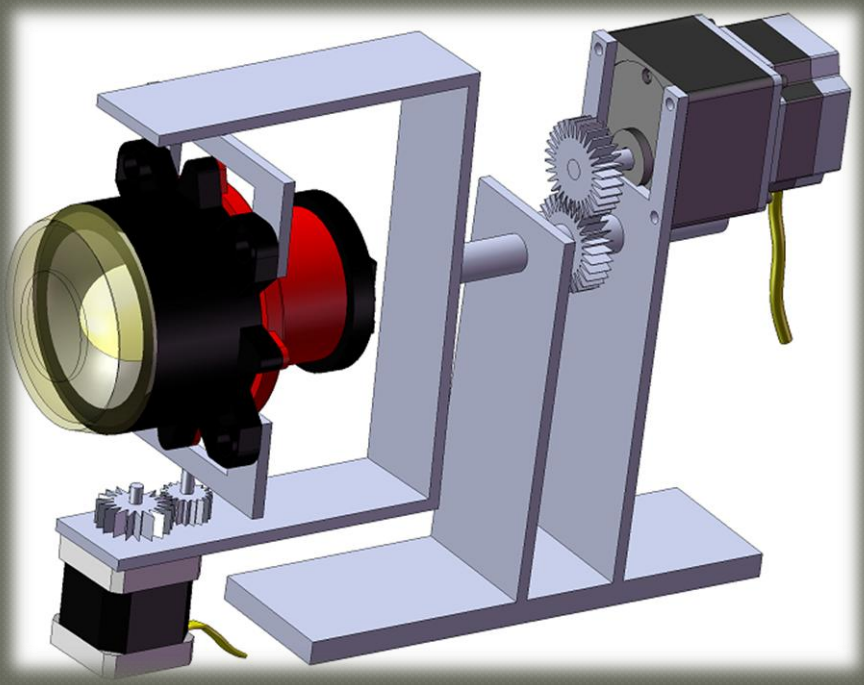
2nd Design

Mechanical Design

- Previously Considered Designs

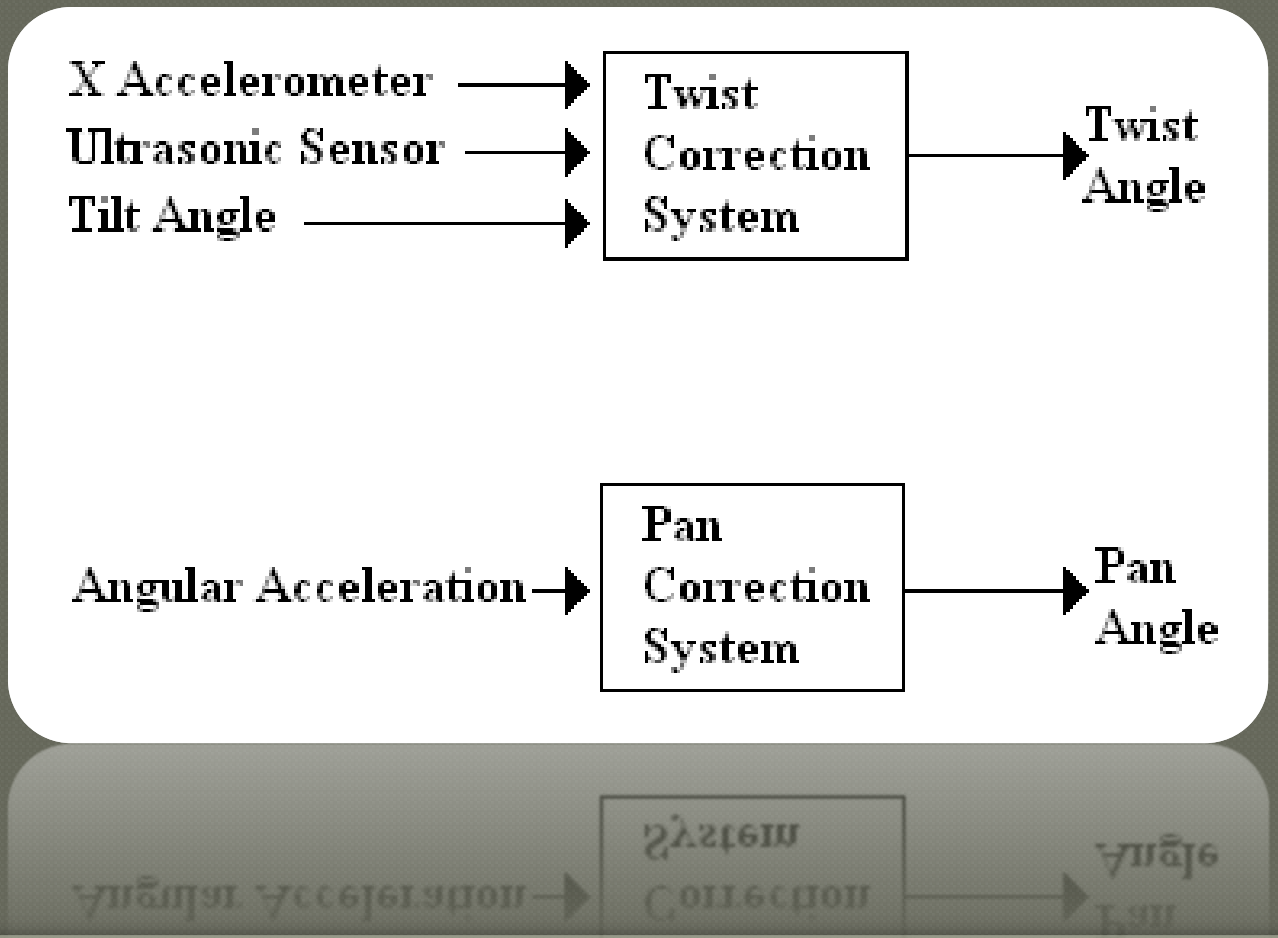


3rd Design



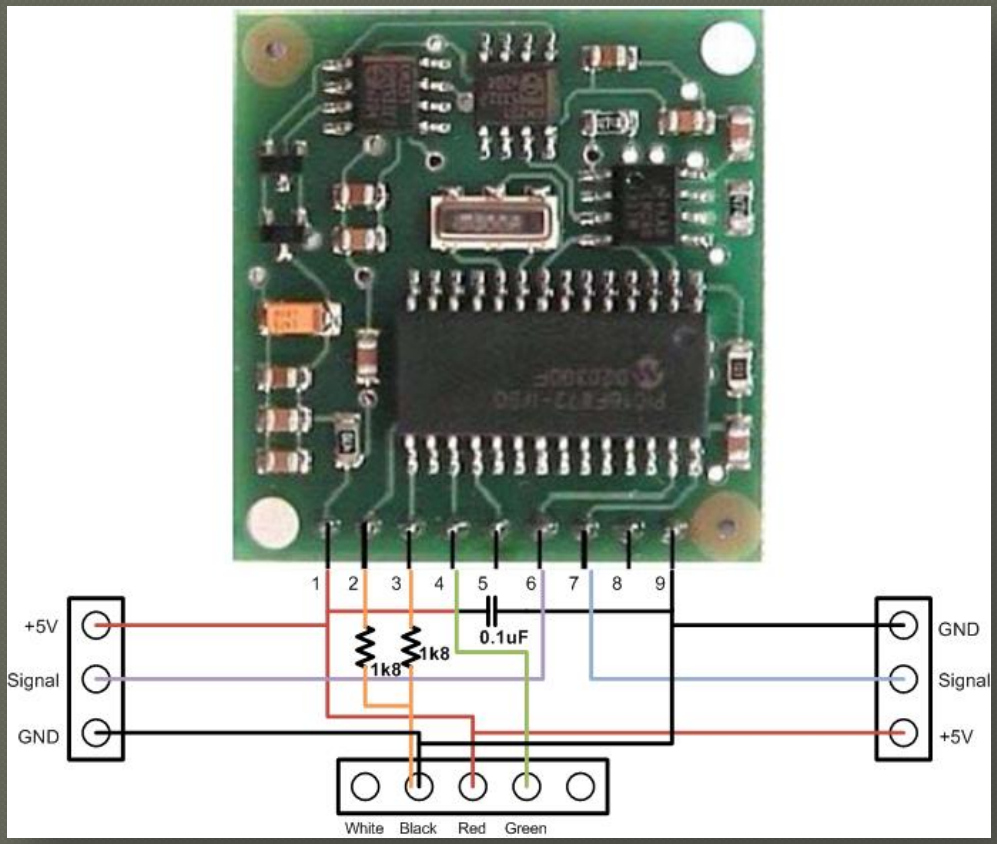
4th Design

High Level System Design



Electrical Design

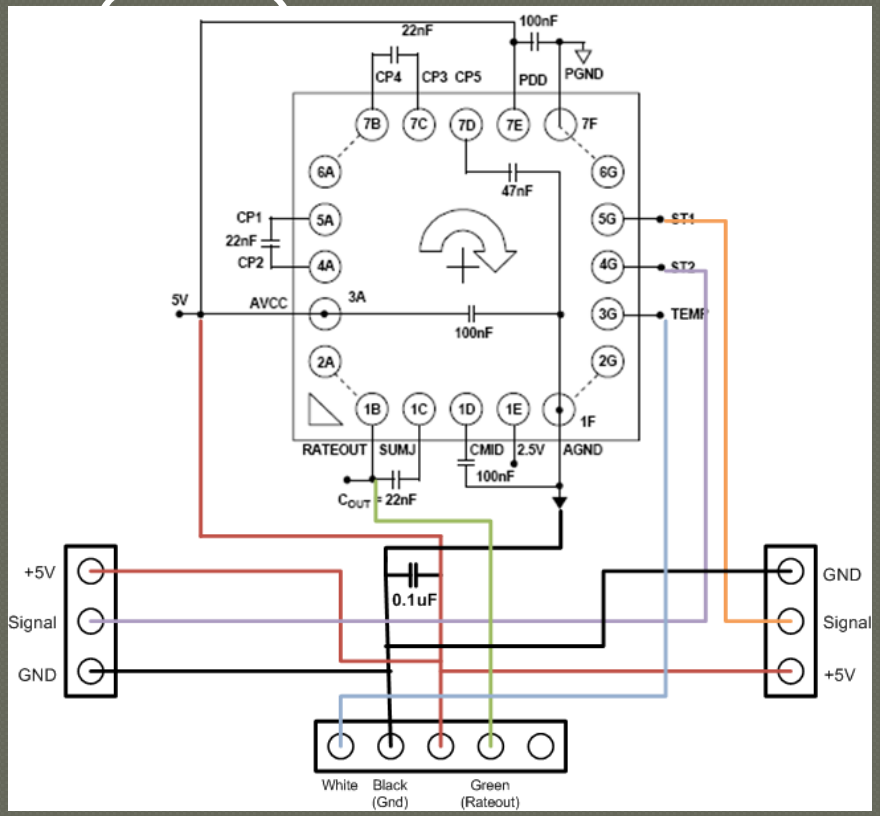
- Magnetic Compass (no longer used)



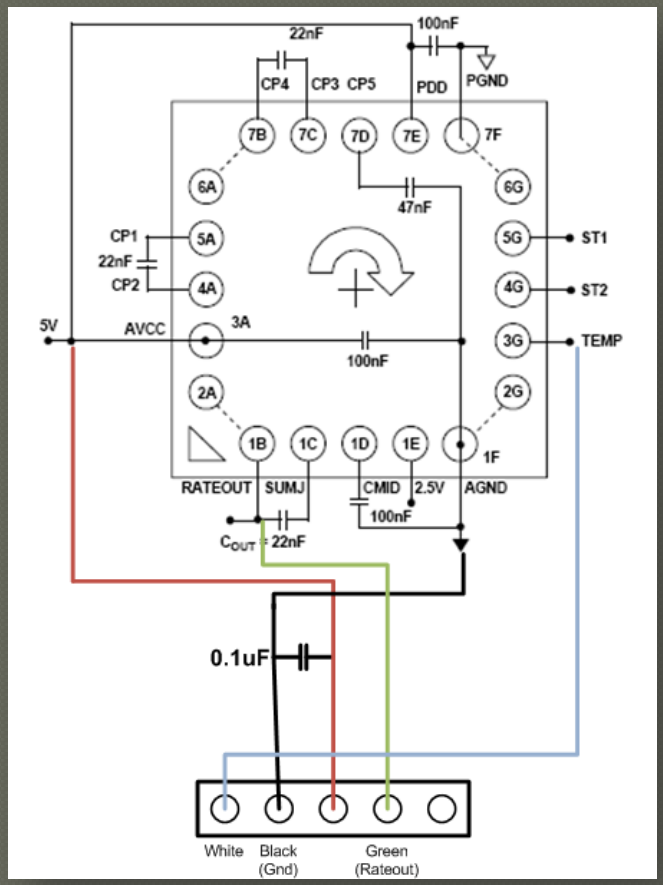
CMPS03

Electrical Design

- Gyroscope I (tilt)



Gyroscope II

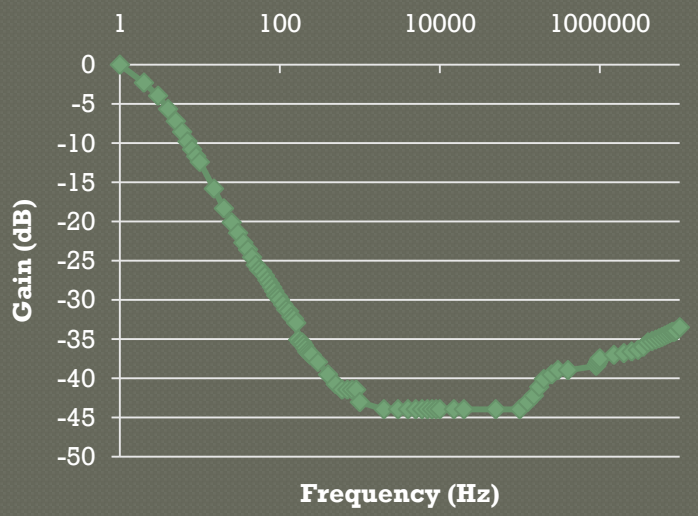


Electrical Design

- Gyroscope I (tilt) (pan)

Cutoff frequency at 1kHz

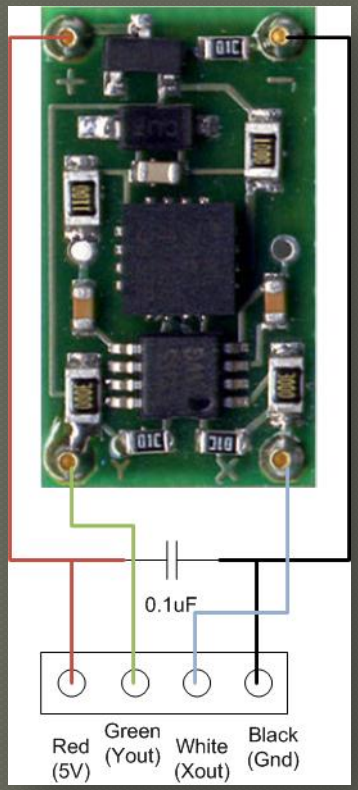
Gyroscope II

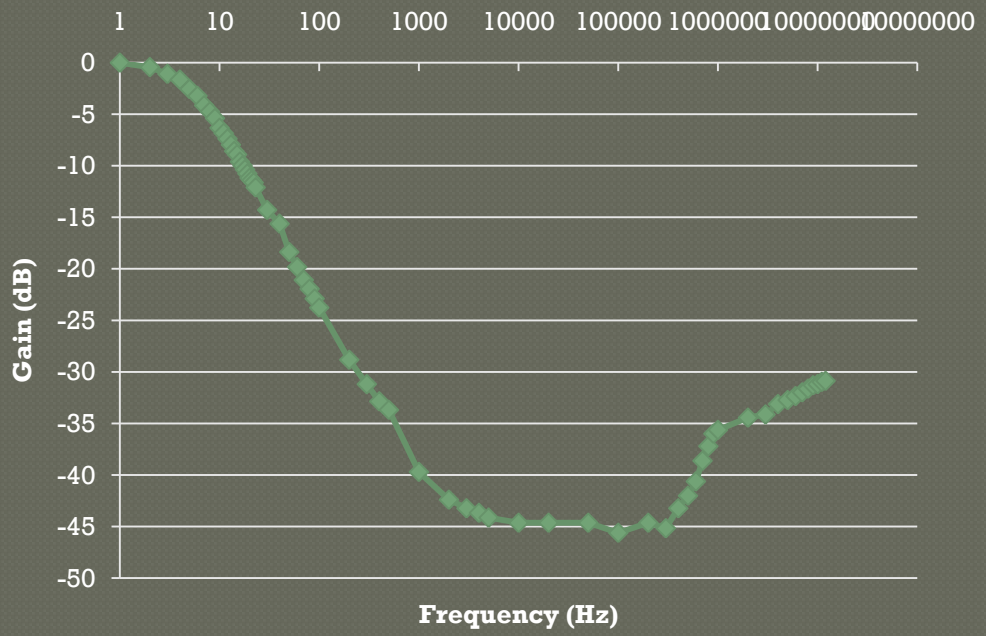


Cutoff frequency at ~6Hz

Electrical Design

- Accelerometer

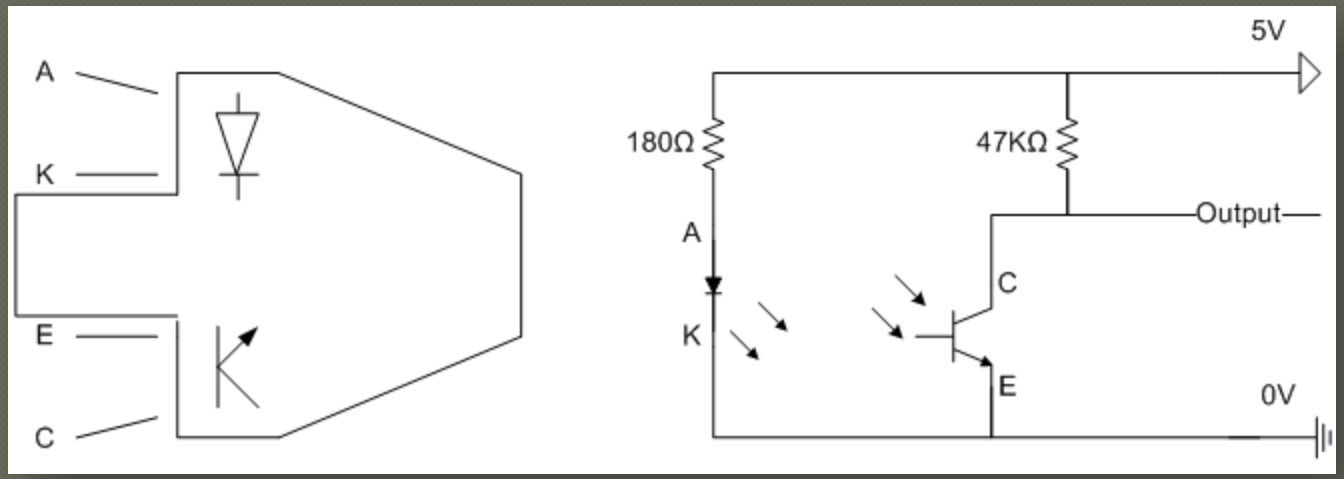




Cutoff frequency at ~1.2Hz

Electrical Design

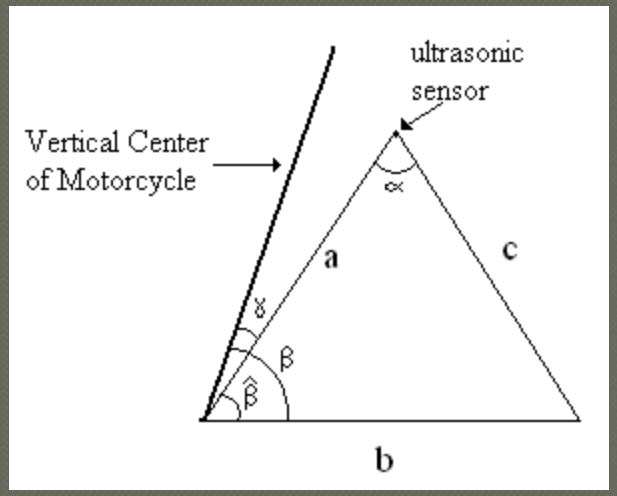
- Speedometer



Opto-Reflective Sensor

Electrical Design

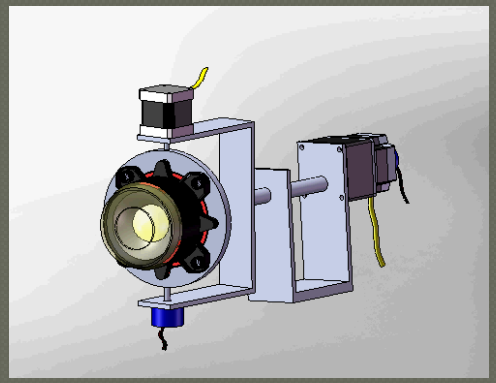
- Ultrasonic Sensor
  - Used to determine when motorcycle is vertical



Electrical Design

- Pan Stepper Motor

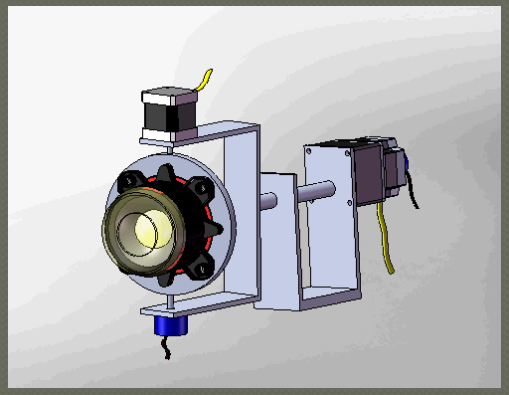
- Two-Phase 1.2 Ampere Motor
- Stepping Angle of 1.8º



Electrical Design

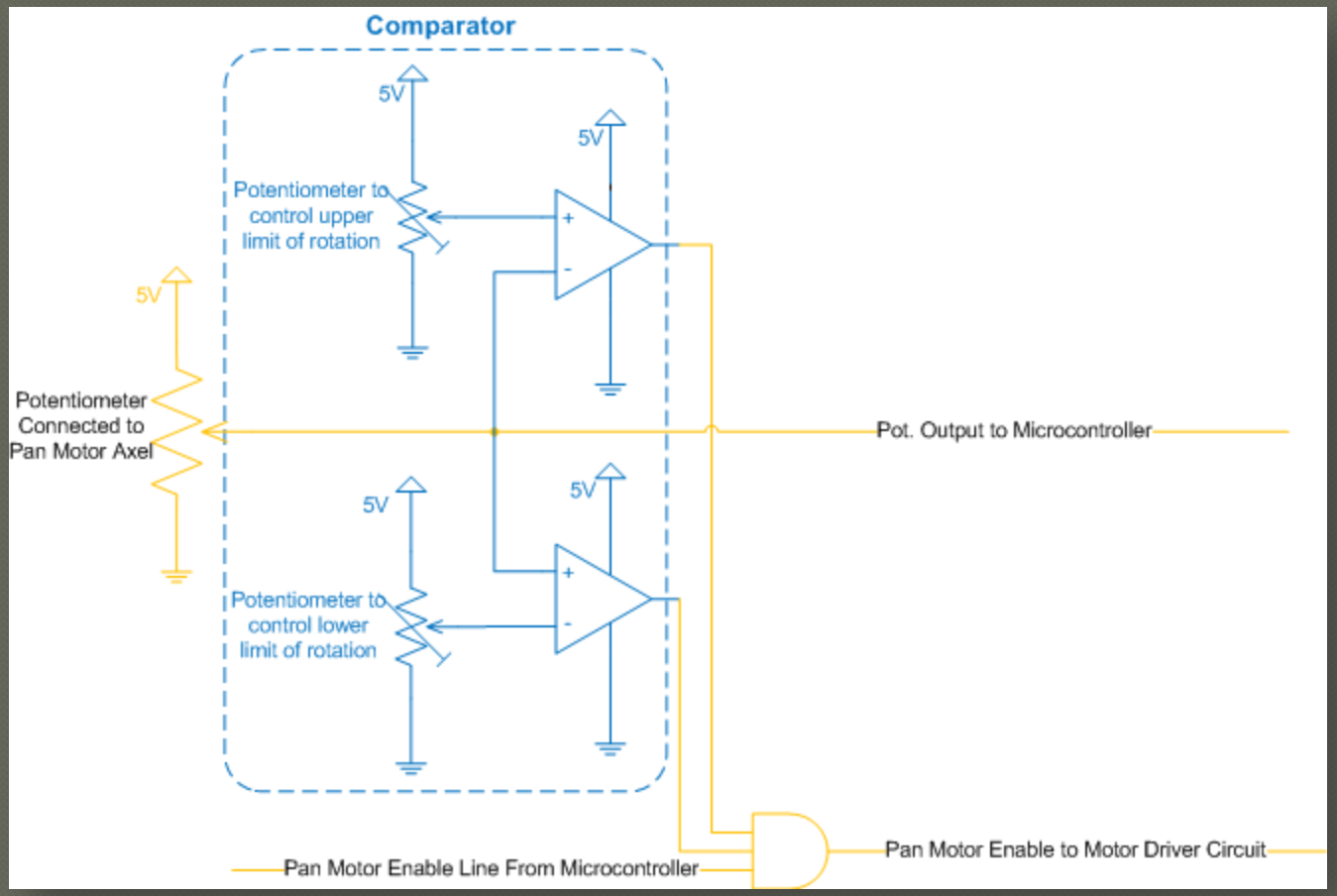
- Twist Stepper Motor

- Two-Phase 2 Ampere Motor
- Gearing Ratio 3.6 : 1
- Stepping Angle of 0.5°



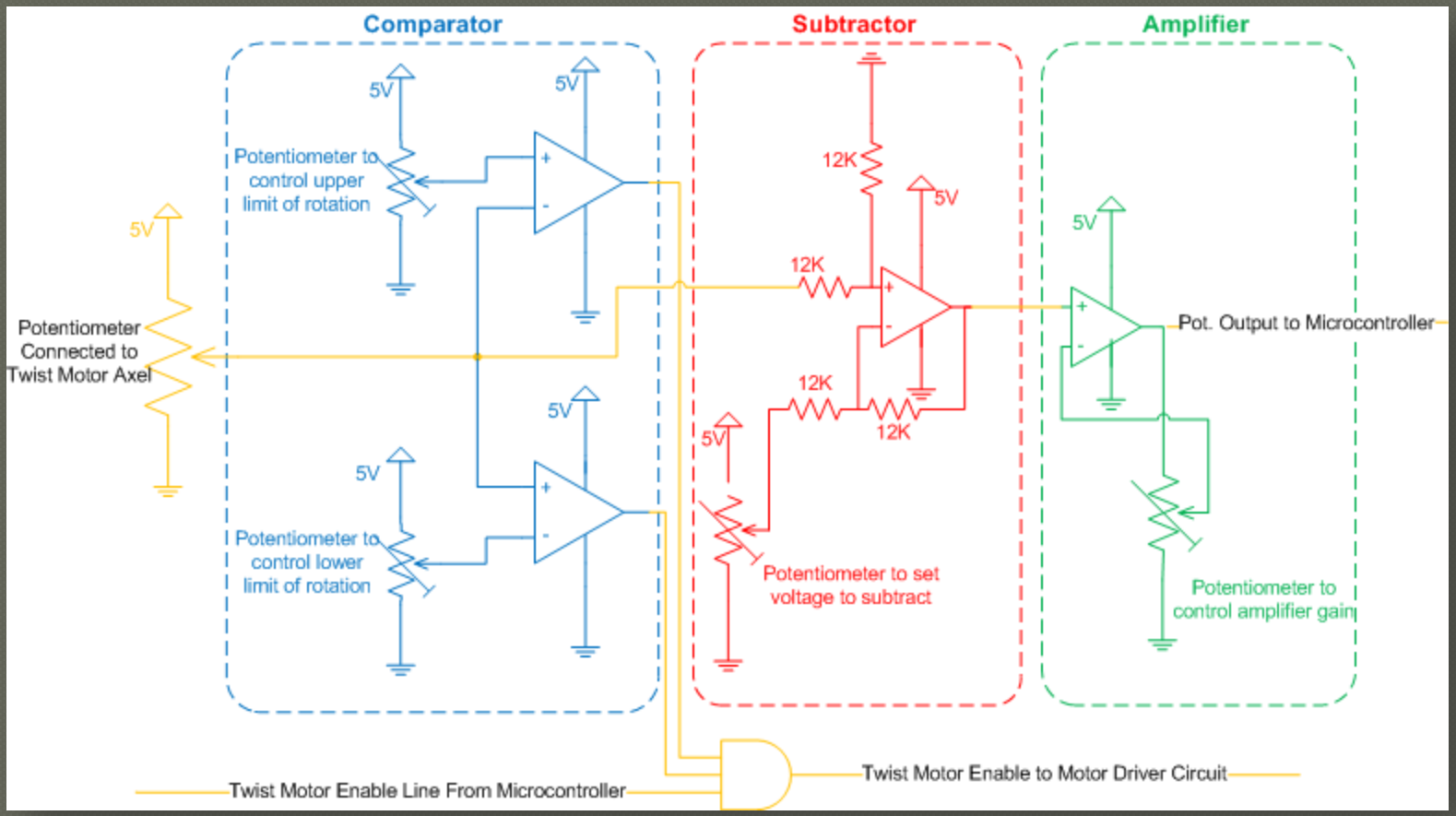
Electrical Design

- Pan Motor Feedback



Electrical Design

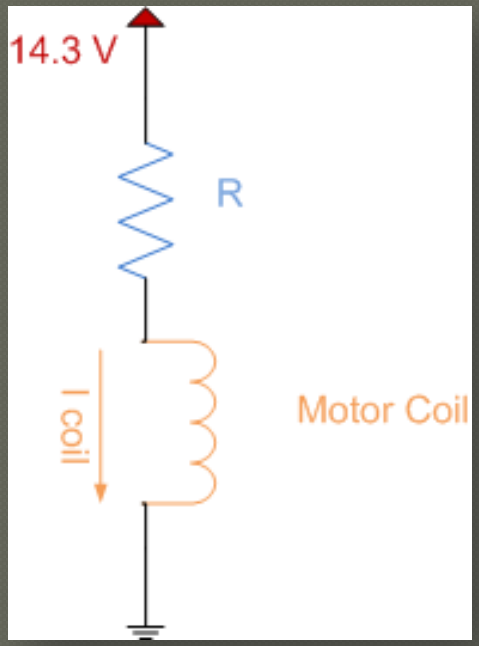
- Twist Motor Feedback



Electrical Design

- Resistive Motor Current Limiting

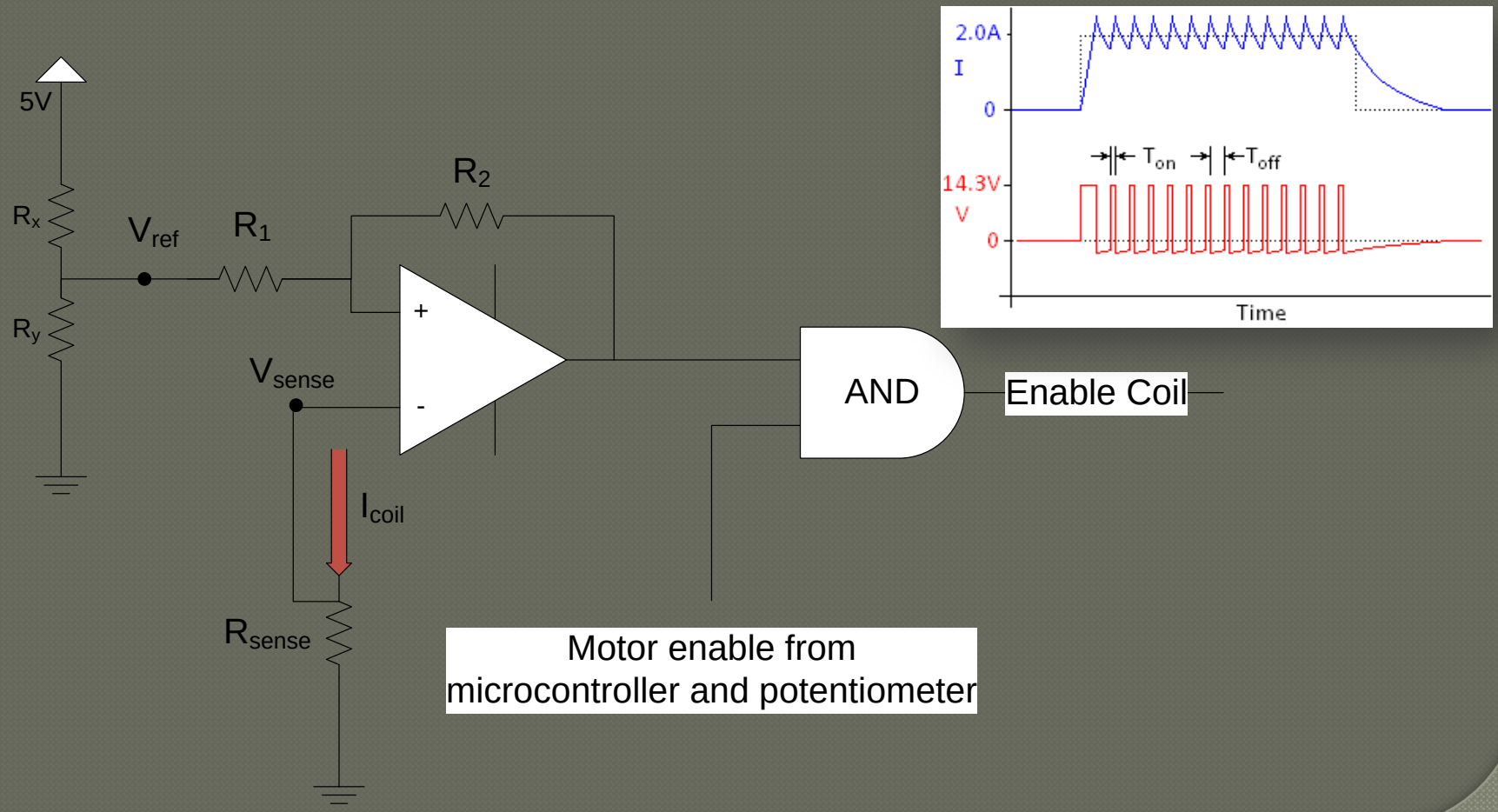
$$I = \frac{V}{R}$$



- Problem: Large Power Loss Via Resistor

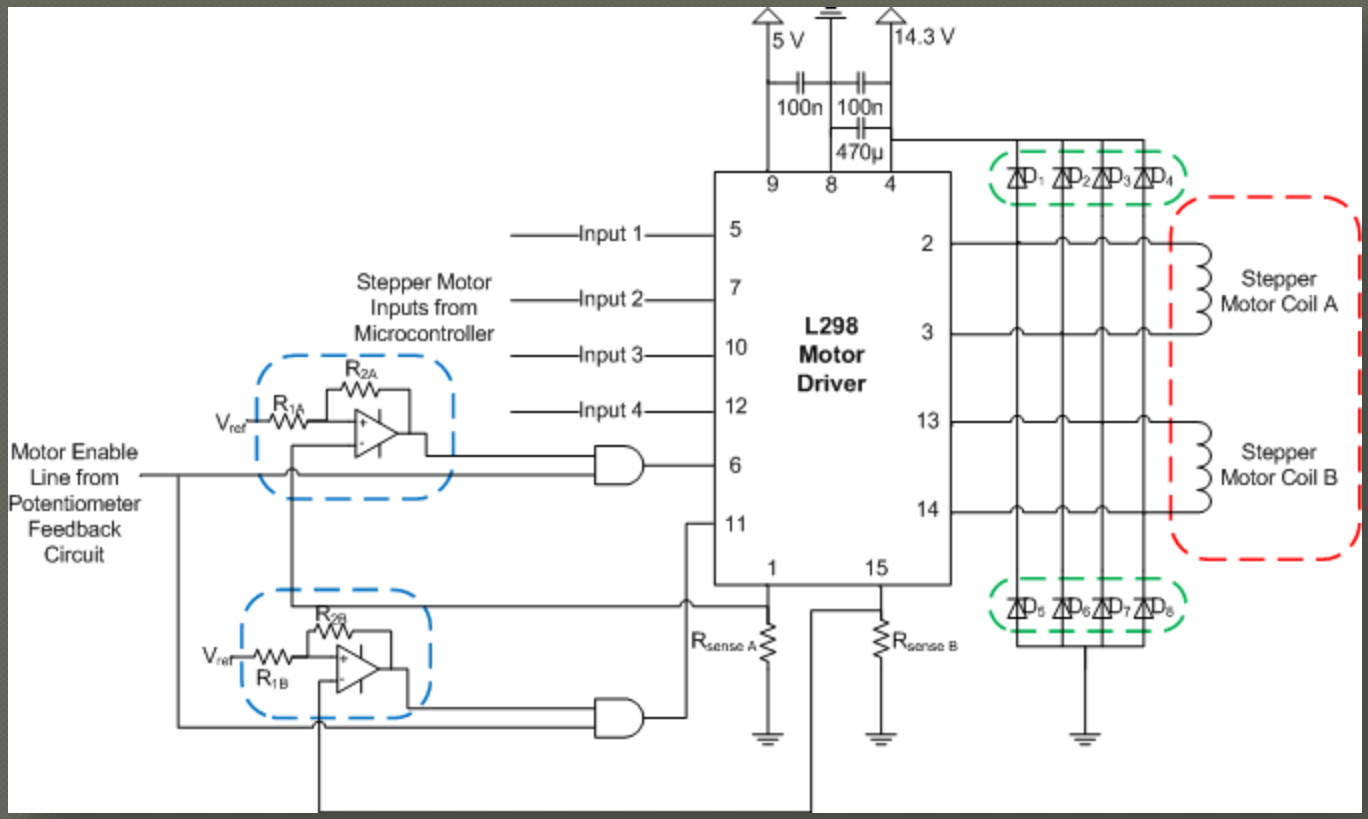
Electrical Design

- Chopper Motor Current Limiting



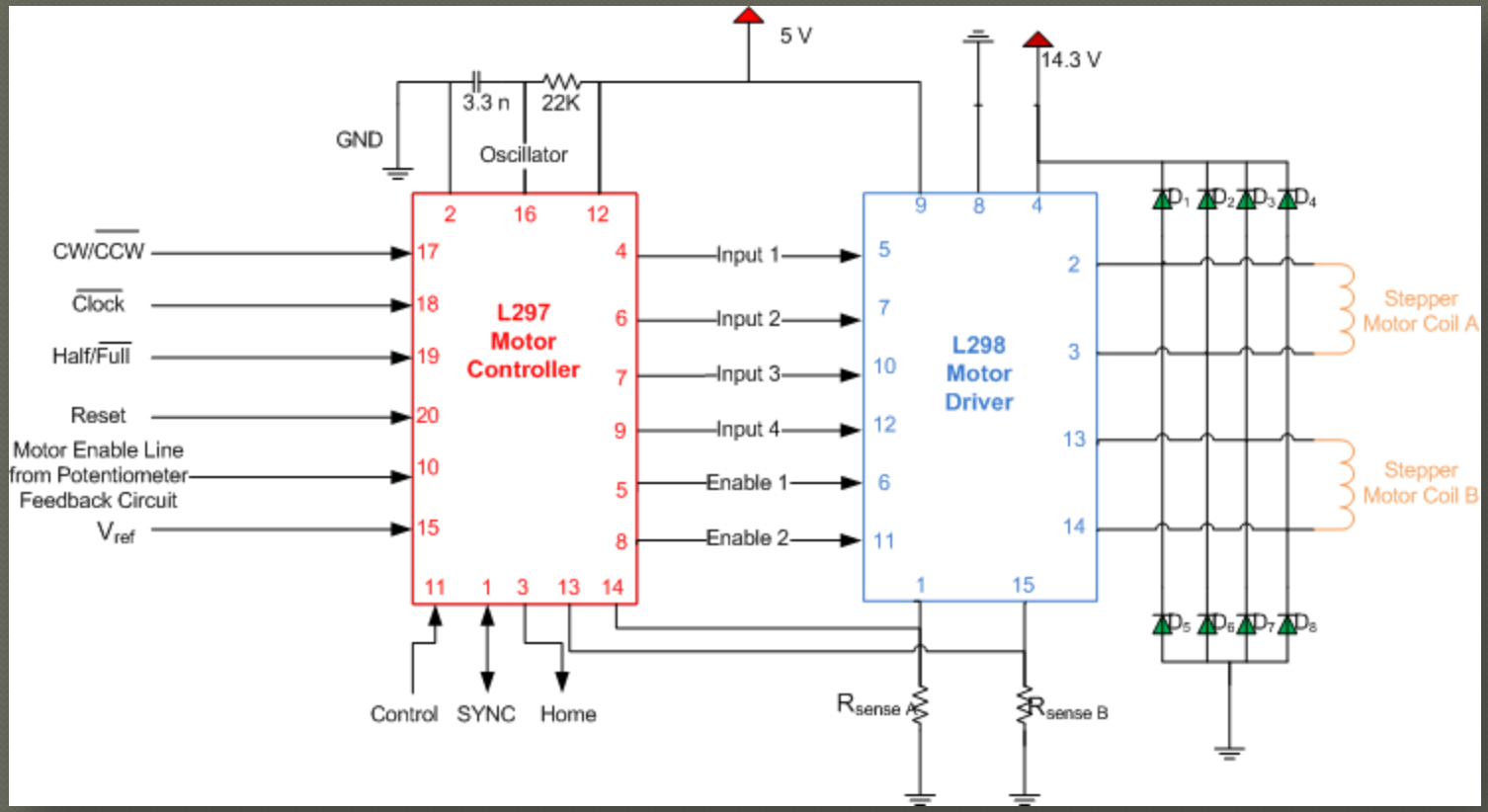
Electrical Design

- Initial Motor Driver Circuit



Electrical Design

- Motor Driver Employed



Electrical Design

- Driver Chip Power Loss
  - Power Loss In Driver Circuit:

$$P_{\text{Resistor Loss}} = I_{\text{coil}}{}^2 R_{\text{Sense}} = (2A)^2(0.5\Omega) = 2W$$

$$P_{\text{Driver Chip Loss}} = V_{\text{Drop Across Chip}} I_{\text{coil}} = (1.67V)(2A) = 3.4W$$

$$P_{\text{Total Loss}} = 2W + 3.4W = 5.4W$$

  - Power Supplied From Battery:

$$P_{\text{Total Supplied}} = V_{\text{Supplied}} I_{\text{Coil}} = (14.3V)(2A) = 28.6W$$

Electrical Design

- Comparison of Driver Efficiency
  - Chopper Current Limiting

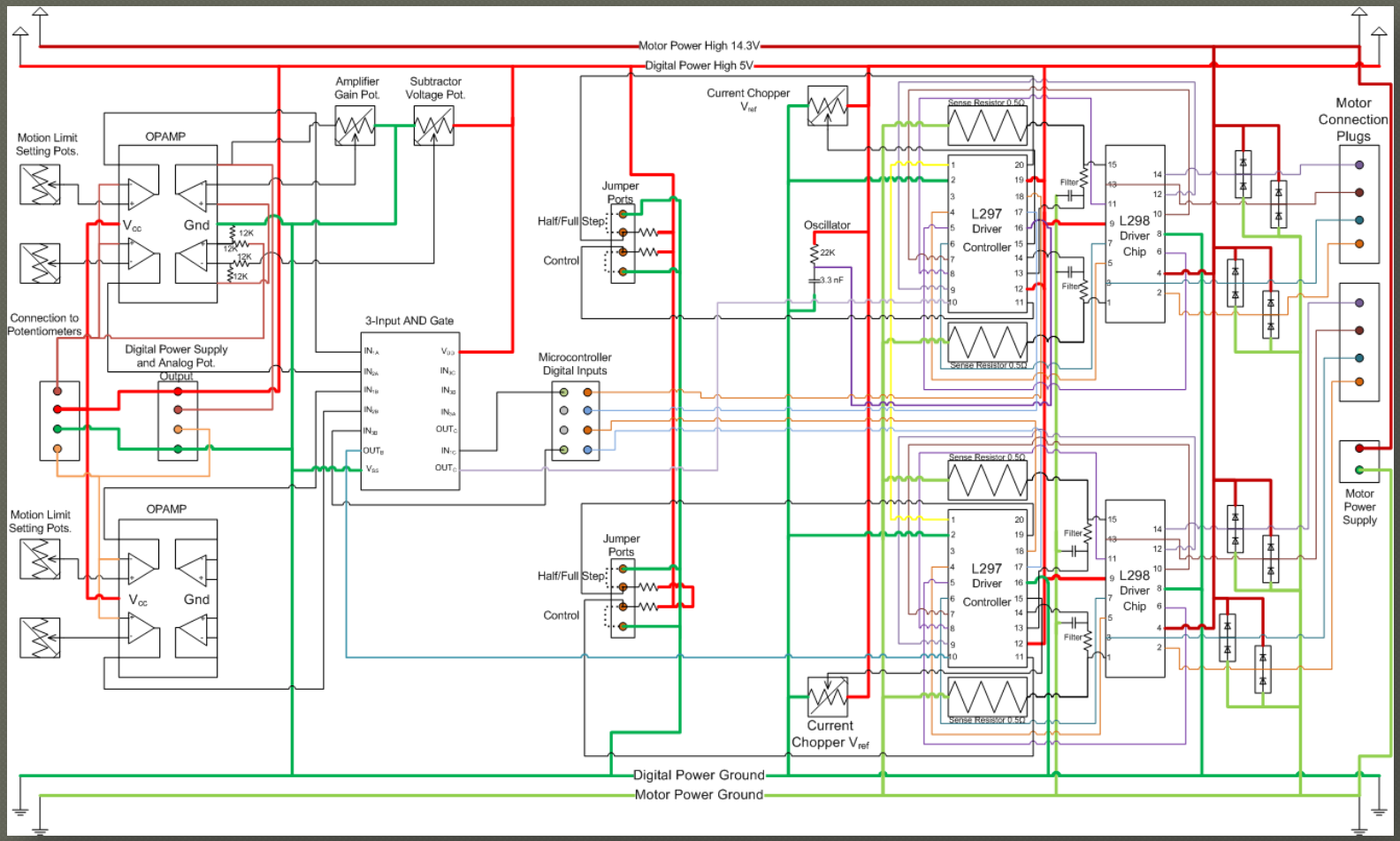
$$Efficiency = \frac{P_{Supplied} - P_{Loss}}{P_{Supplied}} = \frac{28.6W - 5.4W}{28.6W} = 81\%$$

  - Resistive Current Limiting Model

$$Efficiency = \frac{P_{\text{supplied}} - I_{coil}{}^{2} R_{limiting}}{P_{\text{supplied}}} = \frac{28.6W - (2A)^{2}(5\Omega)}{28.6W} = 16\%$$

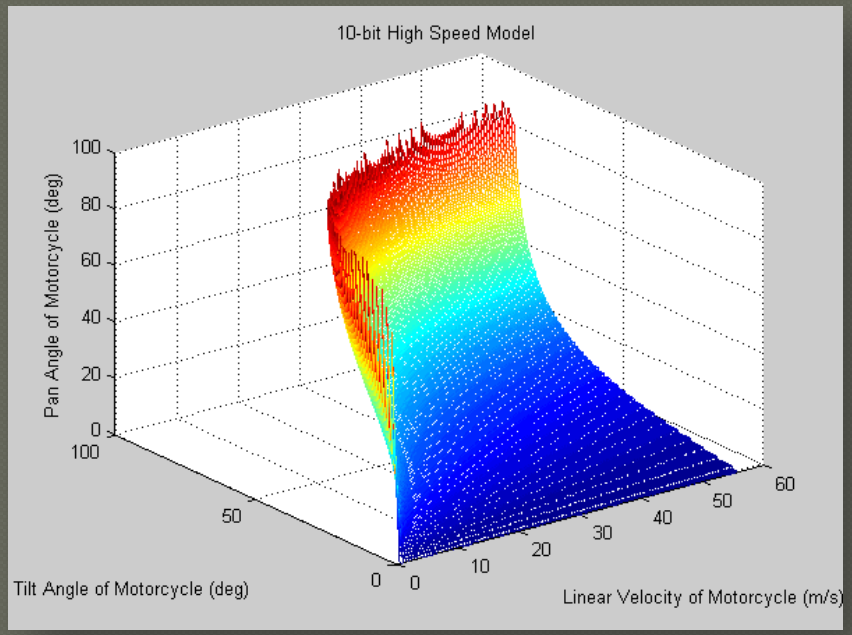
Electrical Design

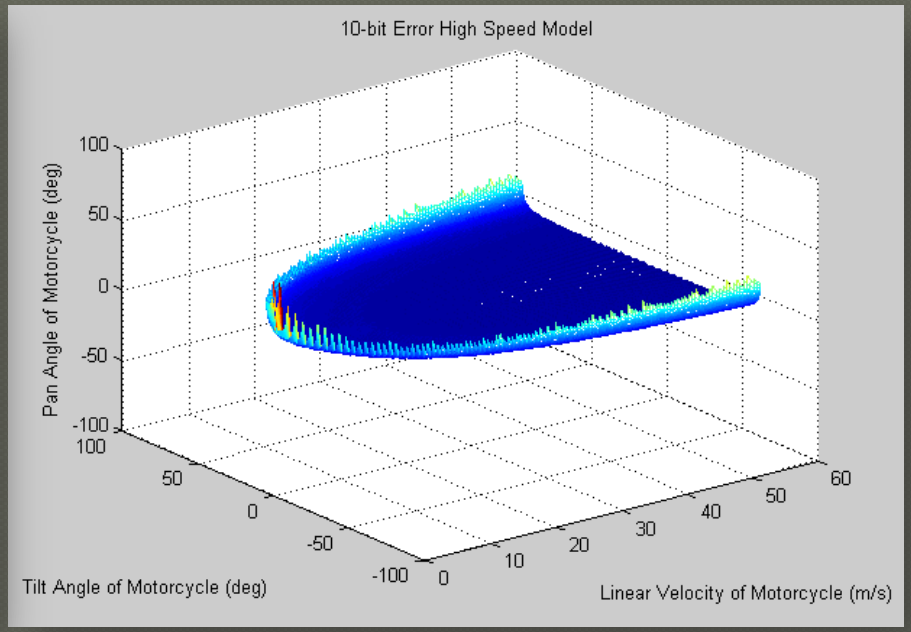
- Driver Board Connected



Look-up Tables

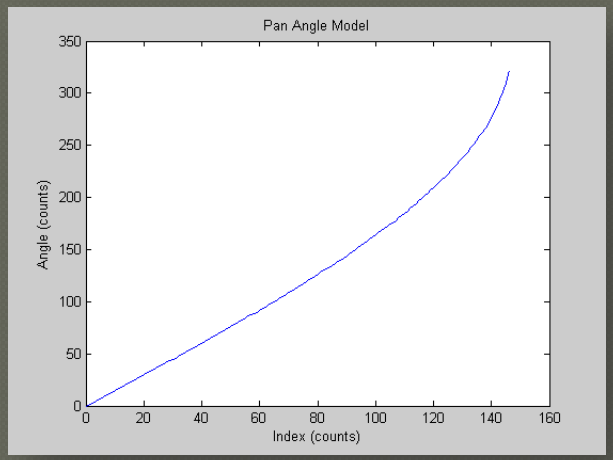
- High Speed Pan Angle Look-up Table

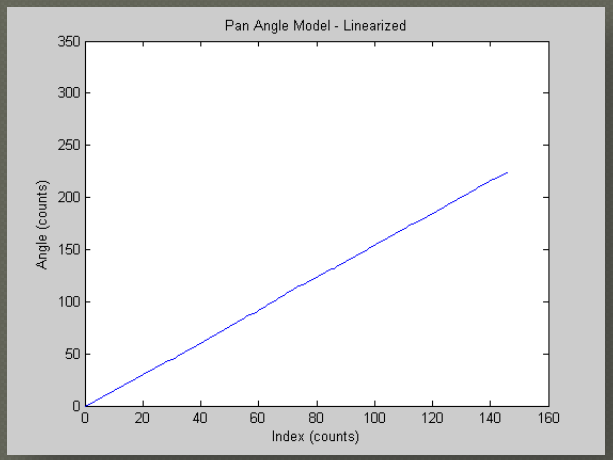


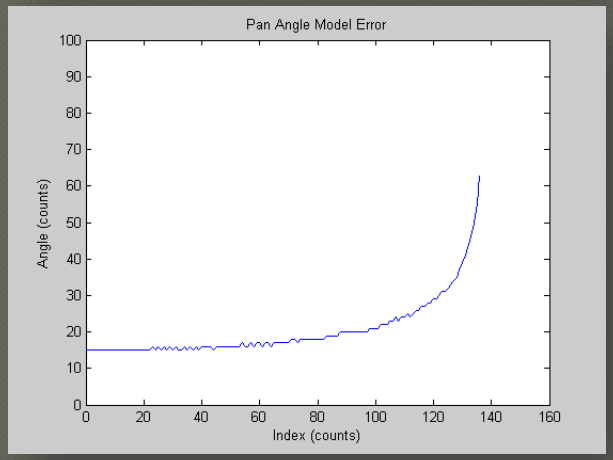


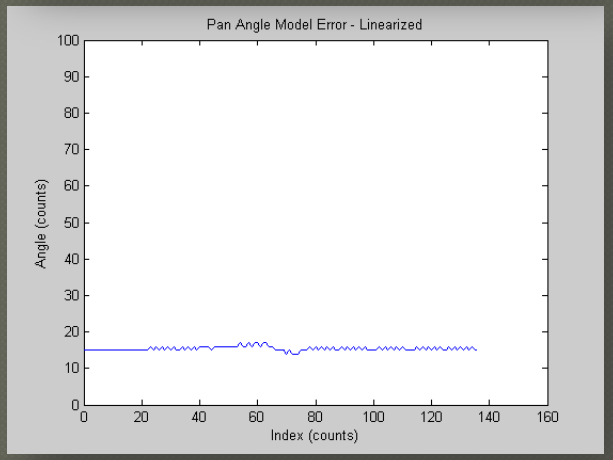
Look-up Tables

- All Speed Pan Angle Look-up Table



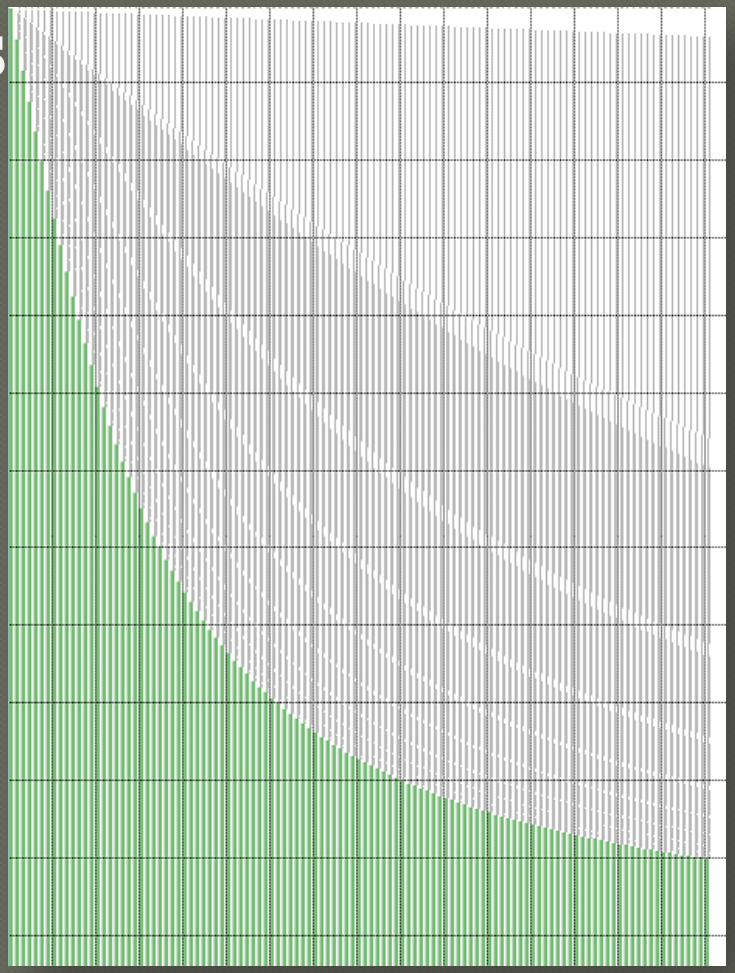






Look-up Tables

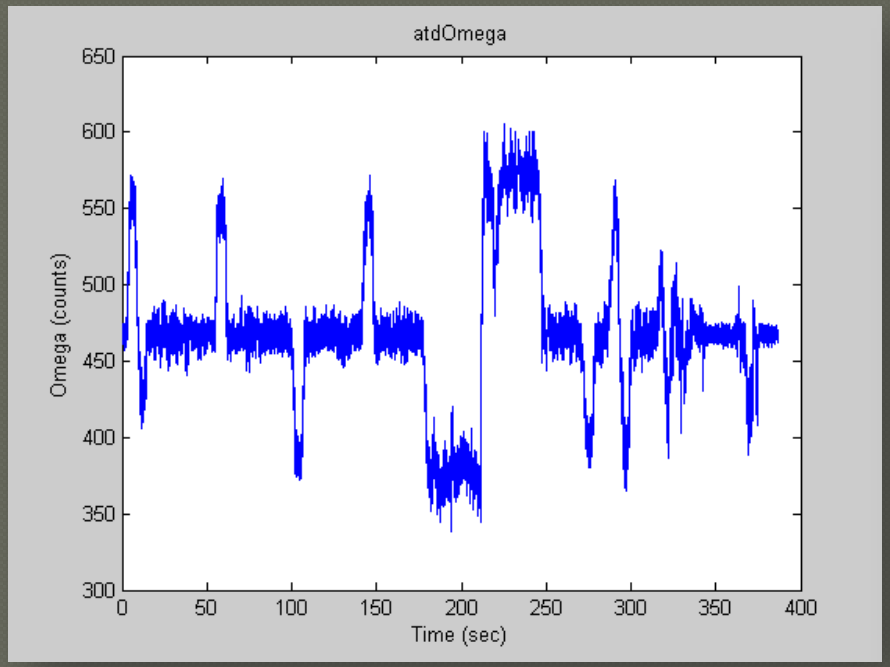
- Bike Velocity-Tilt Limits

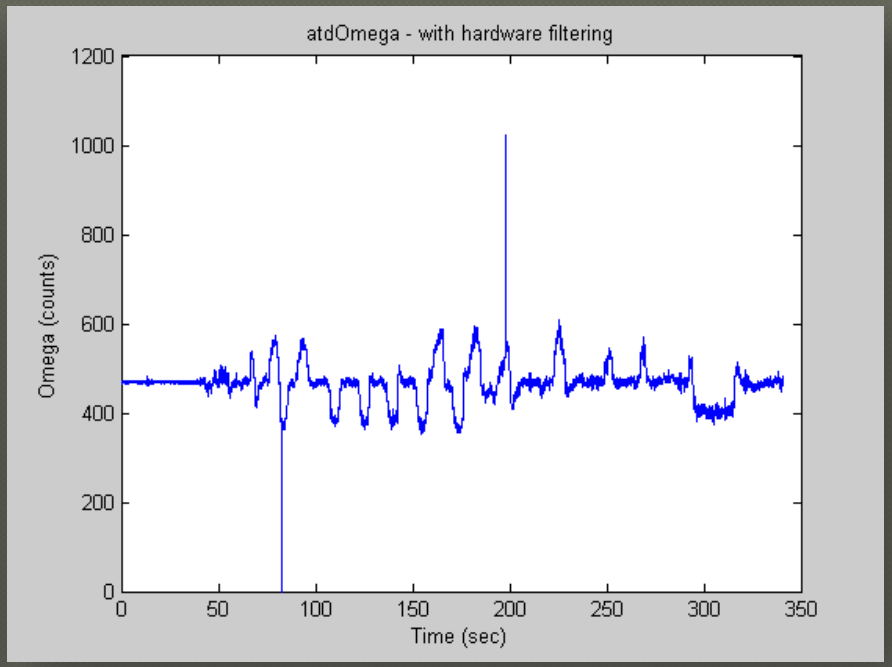


  - X-axis: velocity
  - Y-axis: tilt angle
  - Green: not computable

Sensor Ouputs

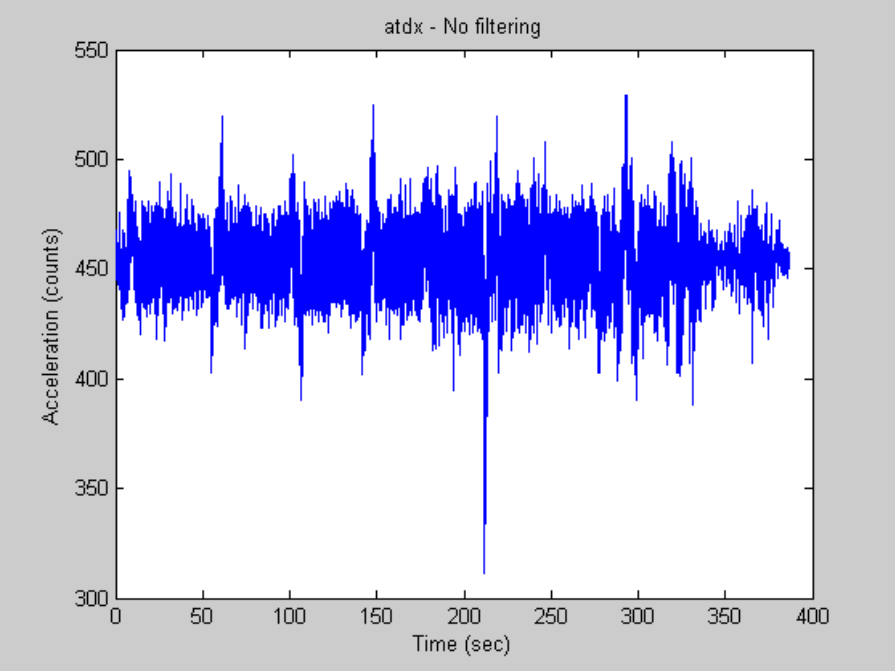
- Angular Velocity Around Curve:
  - unfiltered vs. filtered

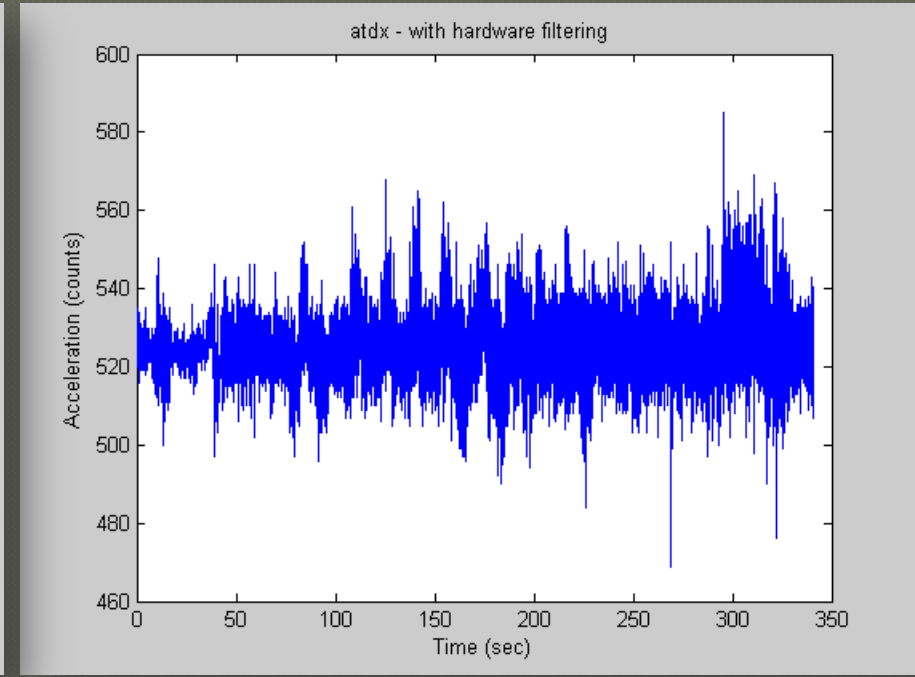




Sensor Outputs

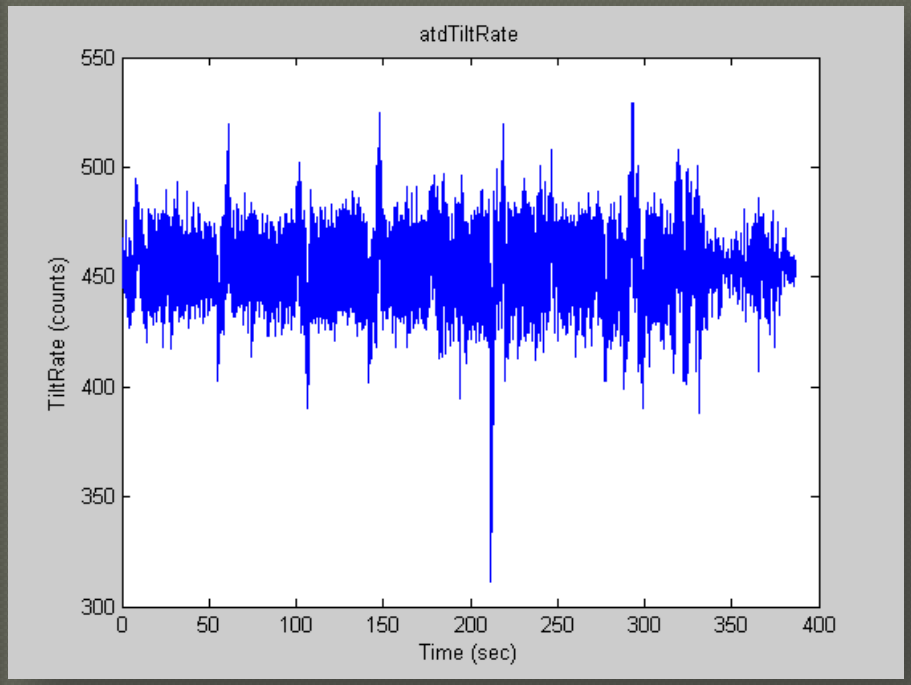
- X-Acceleration:
  - unfiltered vs. filtered

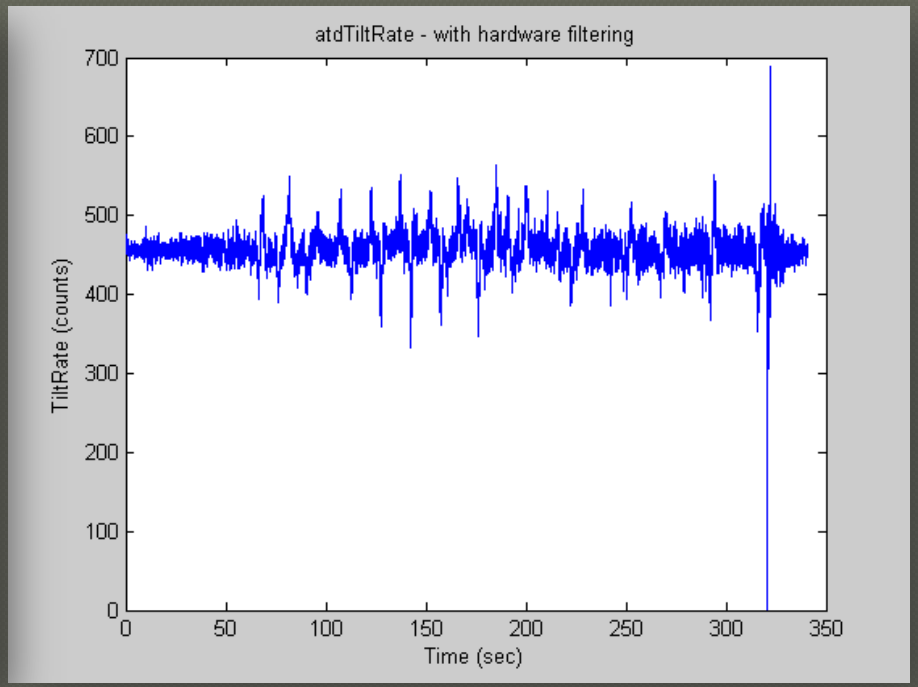




Sensor Outputs

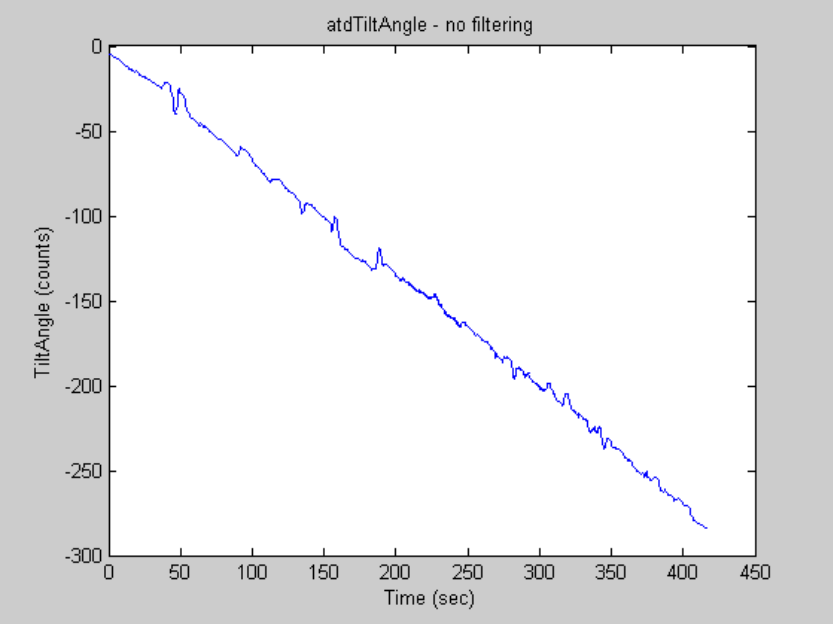
- Bike Tilt Rate:
  - unfiltered vs. filtered





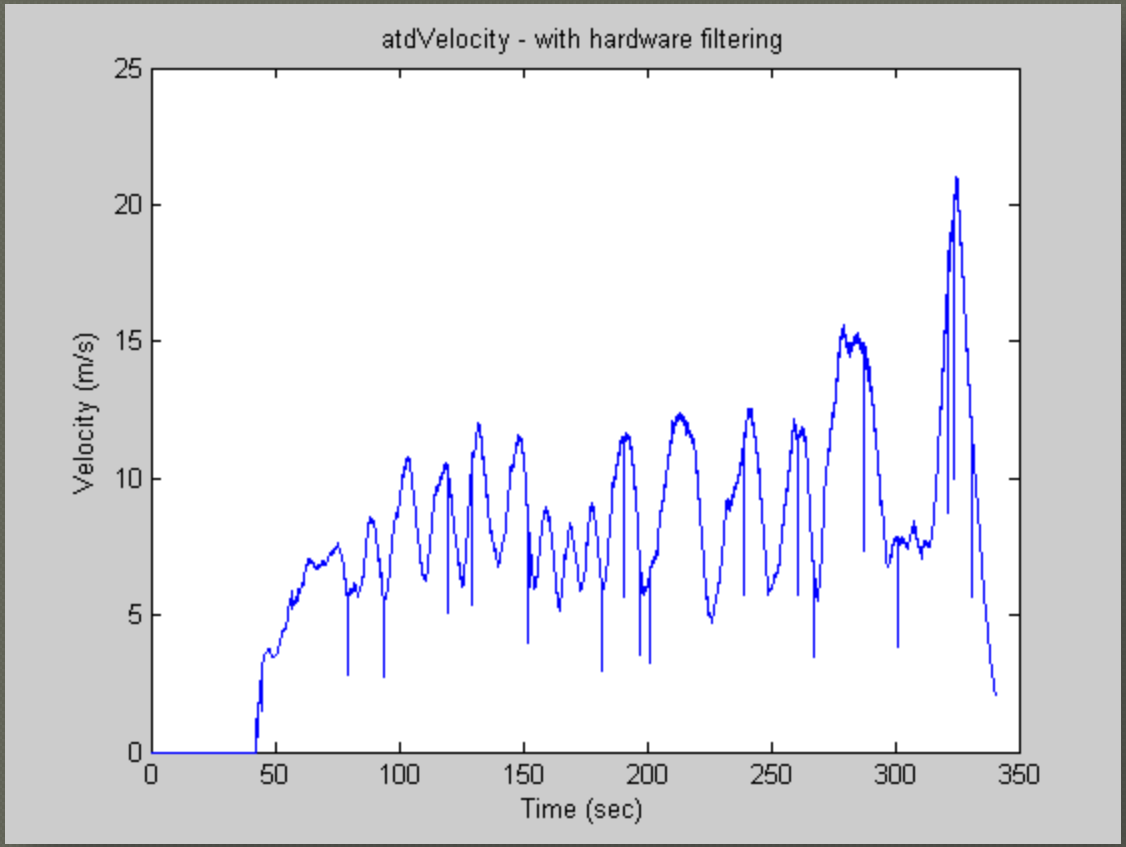
Sensor Outputs

- Bike Tilt Angle
  - Integrating tilt rate



Sensor Outputs

- Velocity:

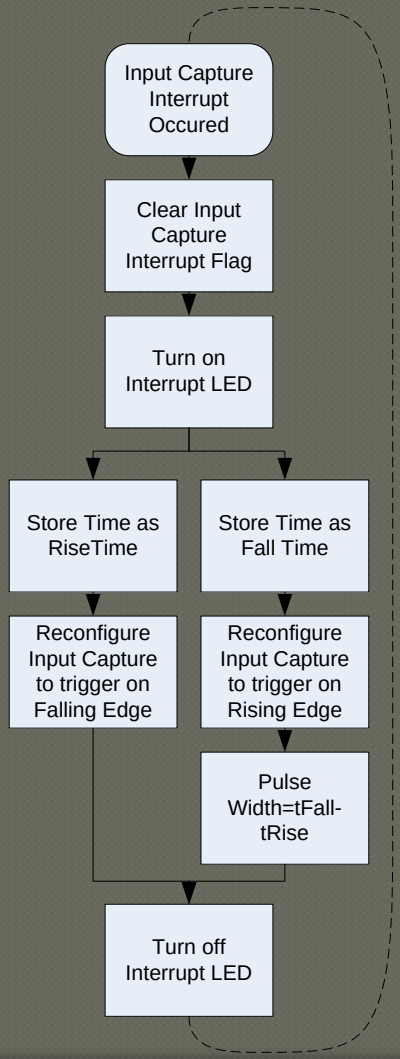


Firmware Design

- Interrupt Handling
- Processing Loops
- I/O Systems
- Dealing with Complex transfer functions

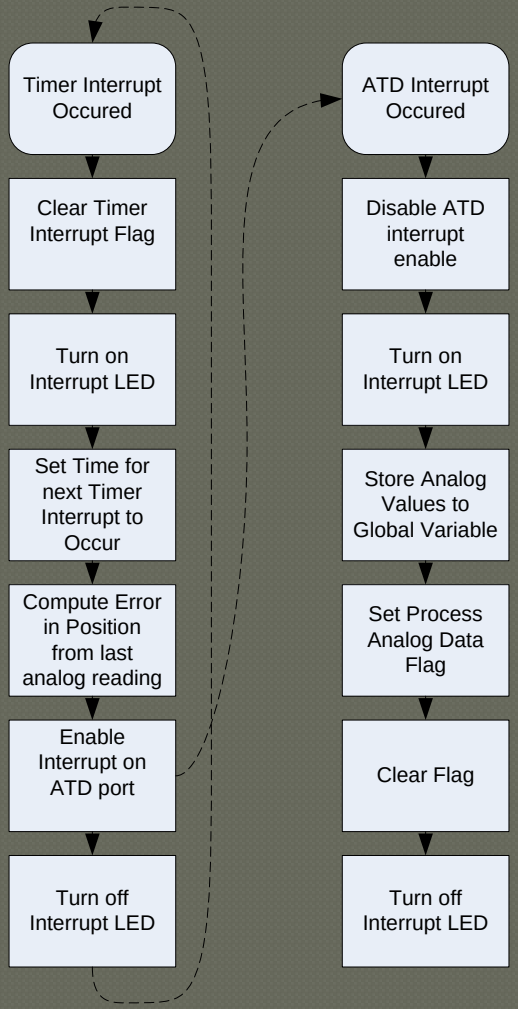
Firmware Design

- Input Capture Timer Interrupt Service Routine



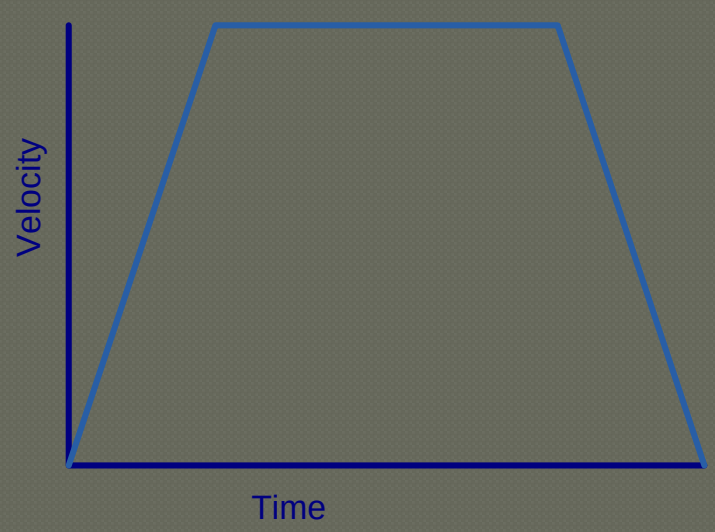
Firmware Design

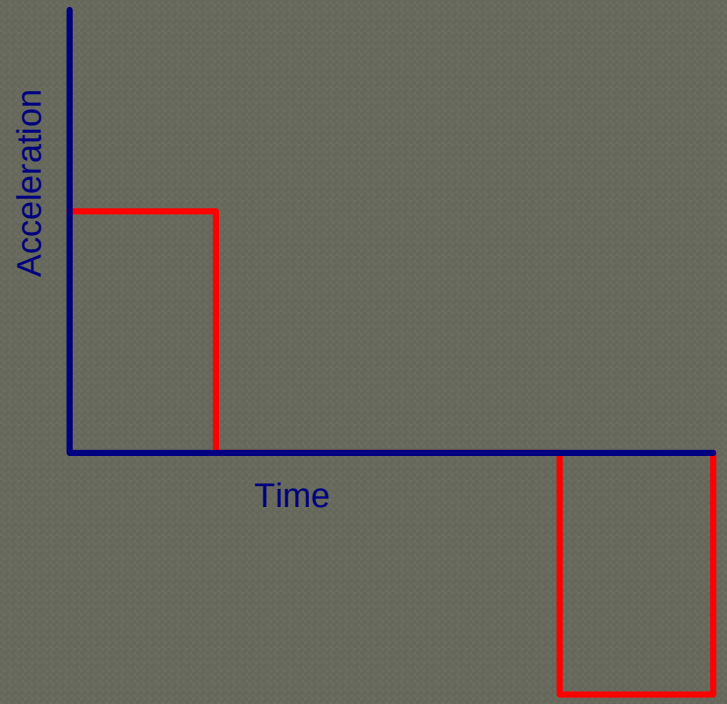
- 1kHz Time and Analog Interrupt Service Routine



Firmware Design

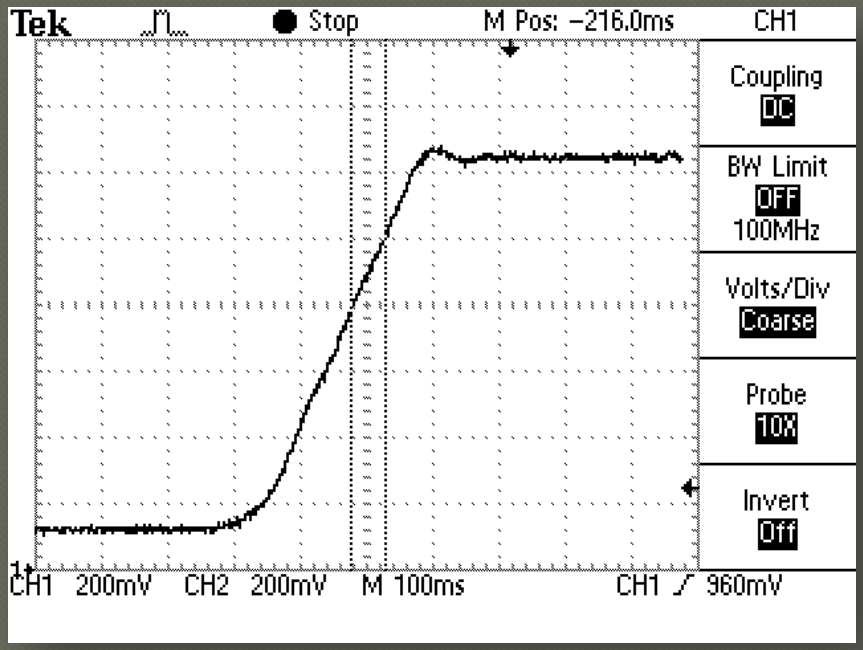
- Velocity and Acceleration Profiles

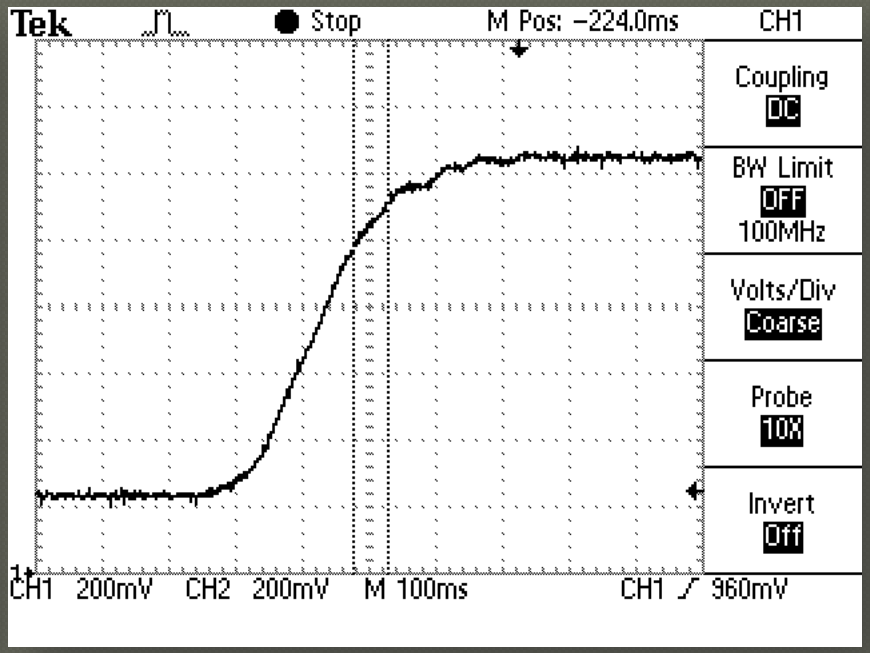




Firmware Design

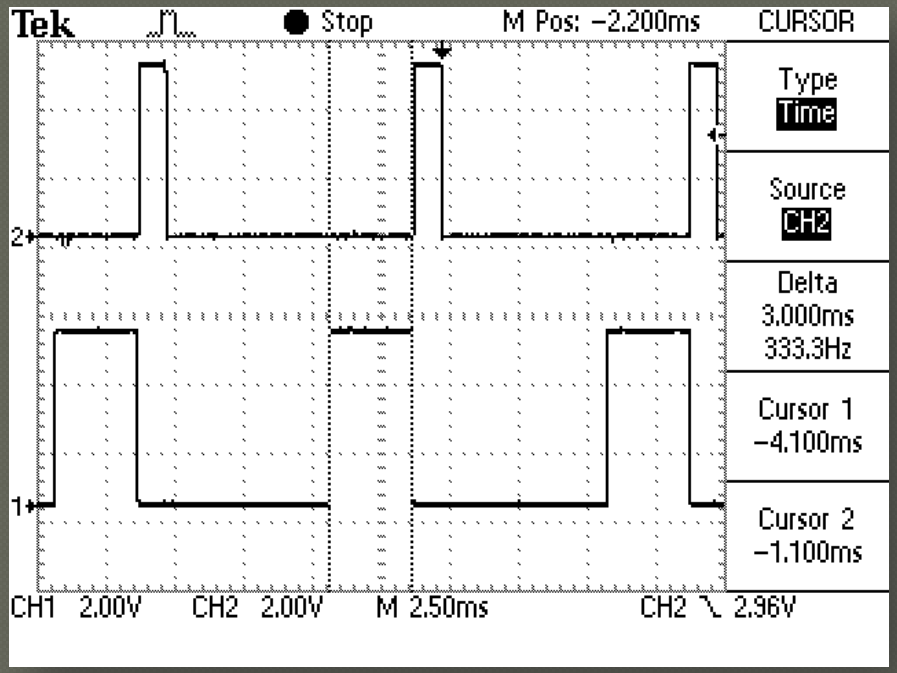
- Motor Driver Profile

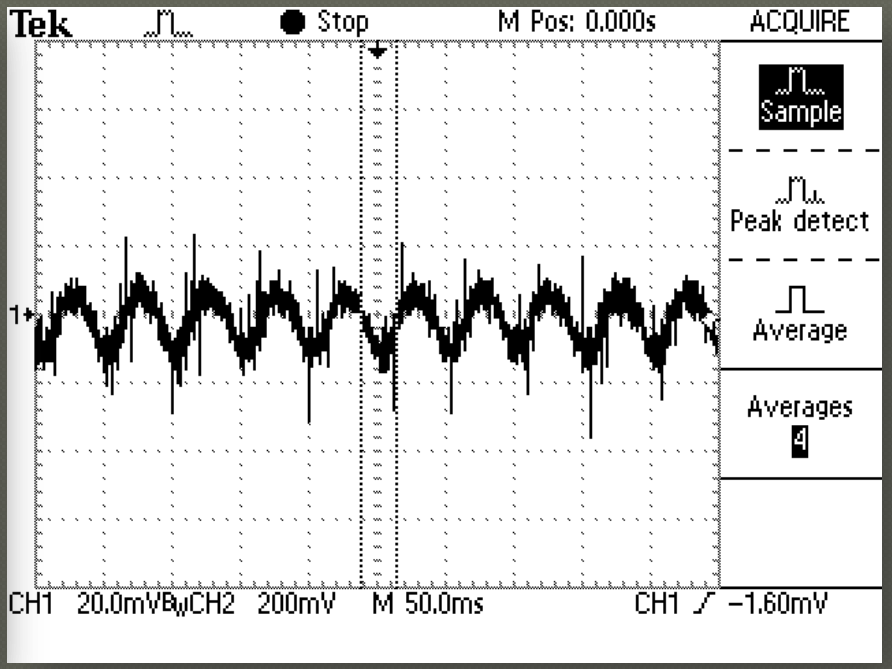




Firmware Design

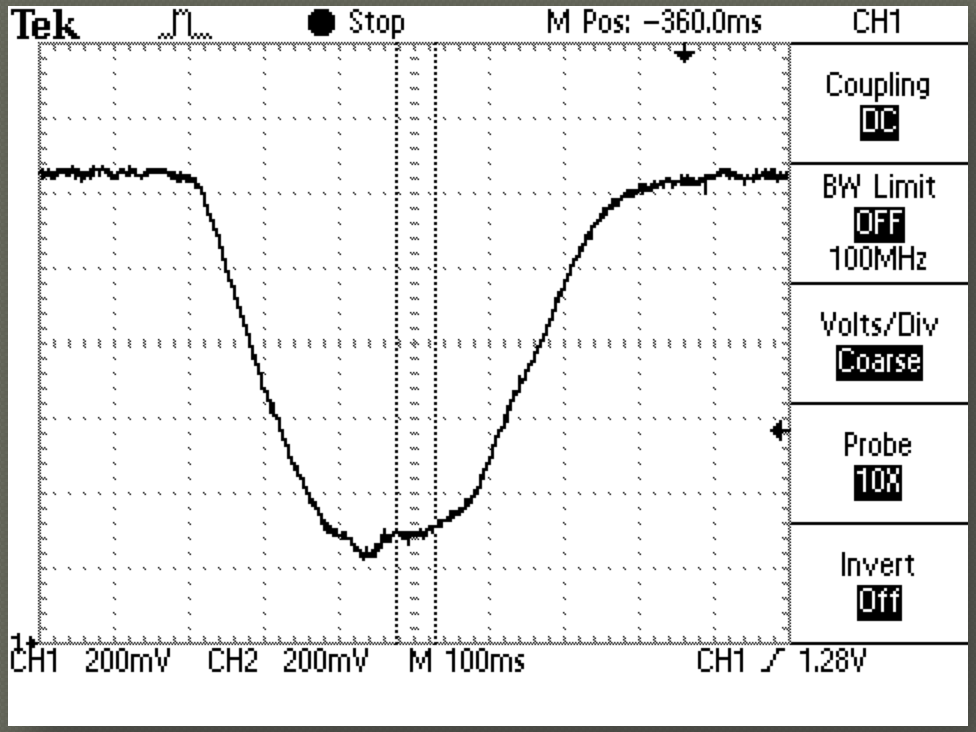
- Position based Power-Savings
  - Switching duty 20% Twist, 40% Pan @ 200Hz





Firmware Design

- Motor Disturbance, Detection & Recovery
  - Divergent Error detection
    - If Error(t=now) is less than Error(t=now-10)



Firmware Design

- Processing time < Inputs
- Interrupt handling Anti-Chaos technique
  - Spy on your neighbors, and push them out of your way!
  - Only let others interrupt you when needed
- Transfer functions committed to memory

Future Improvements

- Pitch stabilization and levelling
- Human factors
- ‘Out of turn’ improvements
- Driving pattern recognition
- Full Inertial Measure Unit

Finance

- Engineering Science Student Endowment Fund (ESSEF)
  - Awarded $340
- School of Engineering Science
  - $50 per group
- Sponsorship
  - Kodak
  - BCIT
  - Kawasaki Burnaby

Budget

- Initial Estimate:
  - Chris owns Kawasaki motorcycle
    - For testing and demo
  - 15% contingency for mechanical & electrical
  - Components and costs for project:

Model	Component	Part#	Cost(CAD)
Headlight Unit	Headlight	Kawasaki ZZR 250	$40.00
	Stepper Motor	Jameco 57BYGH801	$100.00
	Encoder	Potentiometer	$30.00
	Mechanical hardware		$100.00
	Housings / Bearings		$50.00
Control, Sensors, Connectors	Microcontroller development kit	Adapt9S12C128	$104.00
	Accelerometer / Gyroscope kit	Sense-5DOF	$110.00
	Cables / Interconnect		$15.00
	Safety Button		$10.00
Unforeseen Charges	May include repair, shipping, insurance and other unforeseen events		$83.85
Total (CAD)			**$642.85**

Budget

- Actual Costs:

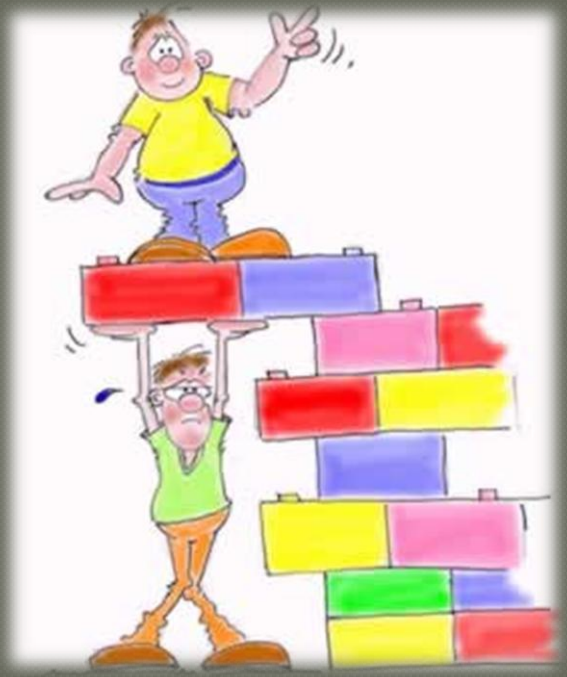
Mechanical	
Stepper Motor 2-Phase 1.2A (PK245-01AA)	$80.48
Stepper Motor 2-Phase 2A (PK264A2A-SG3.6)	$189.38
Headlight (Kawasaki)	$40.00
Headlight (Hella HL68137)	$79.01
Set of screws, washers, nuts for headlight	$4.25
Box of screws for mounting motor	$2.25
Electrical	
Potentiometer	$35.17
Accelerometer/Gyroscope (Sense-5DOF)	$157.72
2nd Gyroscope and Accelerometer	$113.49
Diodes	$17.00
Additional Diodes and Heatsinks	$4.36
Microcontroller (Lionel-HC912D60A)	$150.00
Safety Button	$2.00
Driver Board Misc Components	$7.00
Driver Chip Controller	$22.58
4 resistors & 1 vector board	$18.49
Total	**$923.18**

Teamwork

- Great group dynamics
- Able to communicate ideas
- 'Floater' position

"It is amazing how much you can accomplish when it doesn't matter who gets the credit."

- unknown

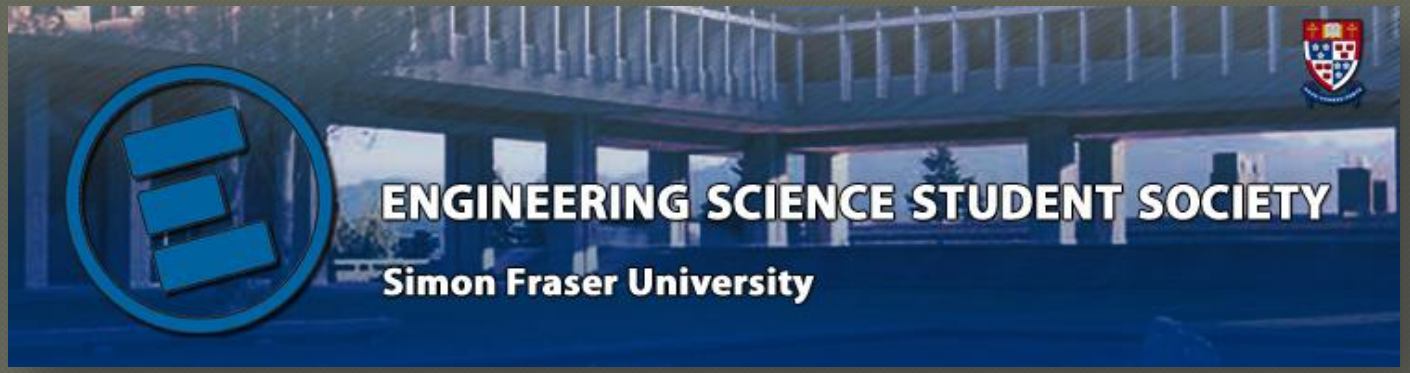


What We Learnt

Acknowledgements

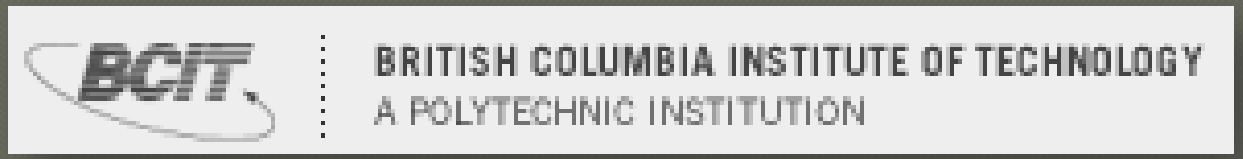
- Microcontroller
- Motors
- Use of facilities
- Printing

Acknowledgements



- ESSEF Endowment Fund: $340

Acknowledgements



- Machining Of Mechanical Hardware

Acknowledgements

- Motorcycle Headlight

Questions?

Demo Videos