Investigation of acceleration of on-campus electric scooters using an accelerometer

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Objectives

- Investigate the acceleration patterns experienced by a lime electric scooter during safe riding through the use of an accelerometer.
- Visually represent the acceleration of safe turning and two dimensional acceleration and deceleration.
- What is the acceleration behavior as we approach maximum velocity?
- Analyze the recorded data, compare it to predicted data sets and identify any visible trends hidden under statistical noise.

Equipment

- Lime brand operated electric scooter (modified Xiaomi M365 electric scooter)
- Sparkfun ADXL 335 Triple Axis Accelerometer
- NI DAQ USB-6212 board
- 2 1kΩ resistors
- Banana, alligator, and jumper wires
- BNC connectors + cables
- Laptop with LabVIEW software
- Equipment Casing
    - Polypropylene Plastic Tote Milk Crate 24” x 16” x 12-¾”
    - Hose Tubes: Worm-Drive Clamps Steel Screw, 1/2" Band Width, 2-1/2" to 5-½”
    - Nylon Cable Tie, Standard, 14" Long, 70 lbs.

Setup

- Used as plastic crate as casing to carry and protect DAQ board and laptop during runs

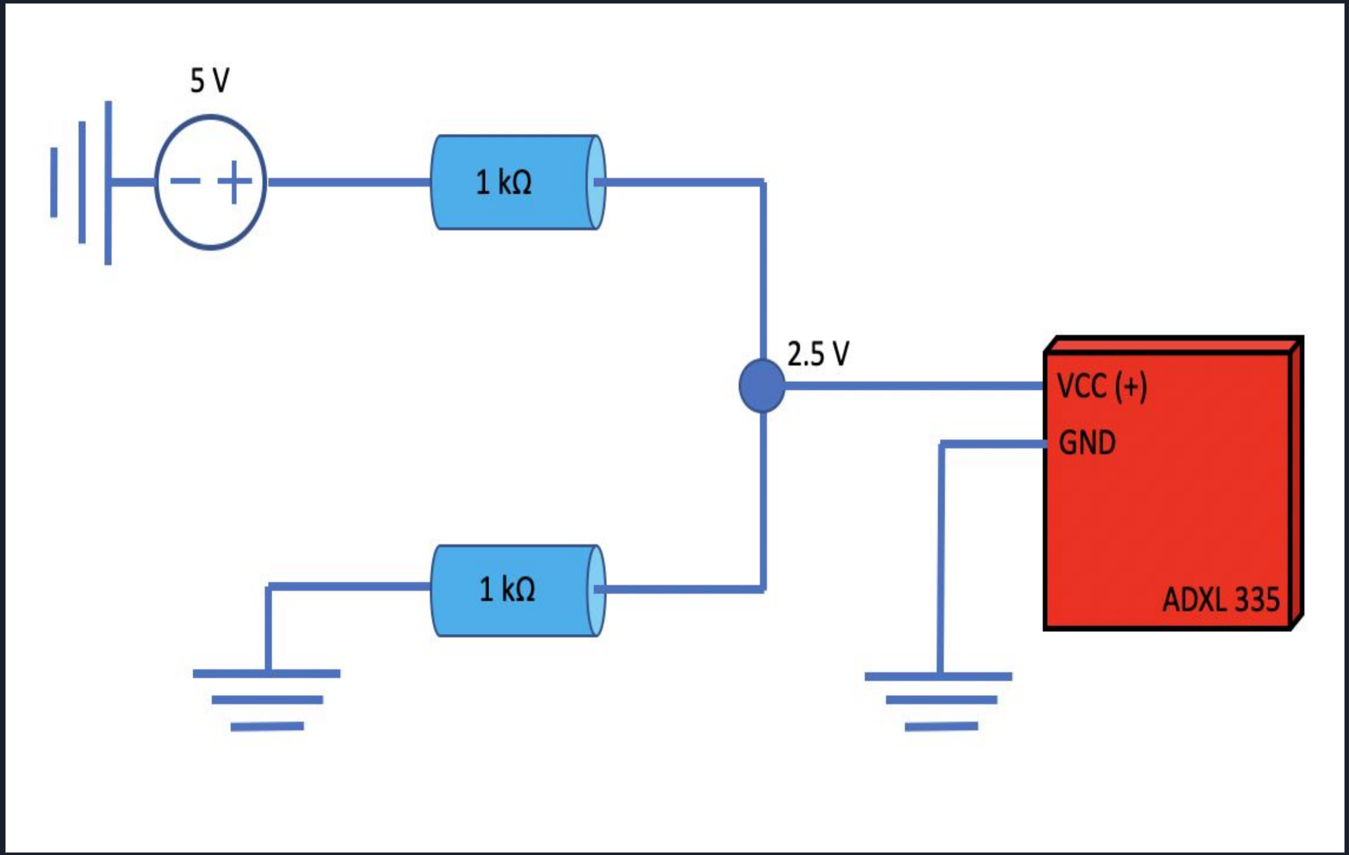
- Constructed circuit to power and read accelerator output voltages while maintaining the required amount of input voltage to the accelerometer and ensuring that the current flowing into the accelerometer is negligible as compared to the current flowing through the other branches of the circuit.

- LabVIEW vi written to convert voltage to acceleration by calibrating with respect to gravity (calibration methods)

- Triple-taped accelerometer to DAQ board to maximize security, DAQ zip-tied tightly to crate. The crate was then secured to the front of the scooter using clamps and zip ties.

- Recorded accelerometer readings at safe turning speeds.

Accelerometer power supply set-up

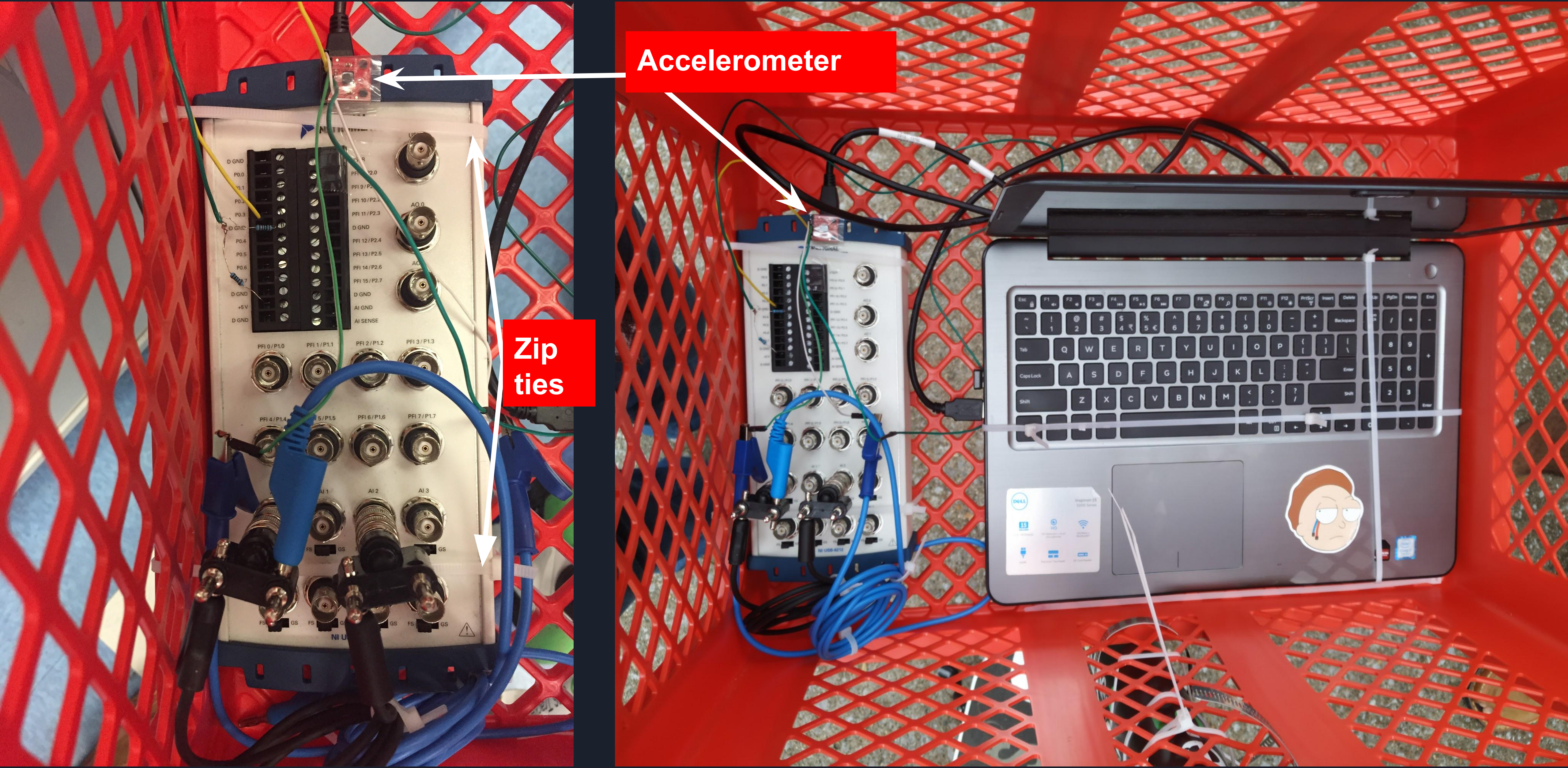


- Accelerometer VCC (input voltage) limits of 1.8-3.6 V
- Circuit constructed to provide power in range
- Kirchoff Current Law analysis at VCC

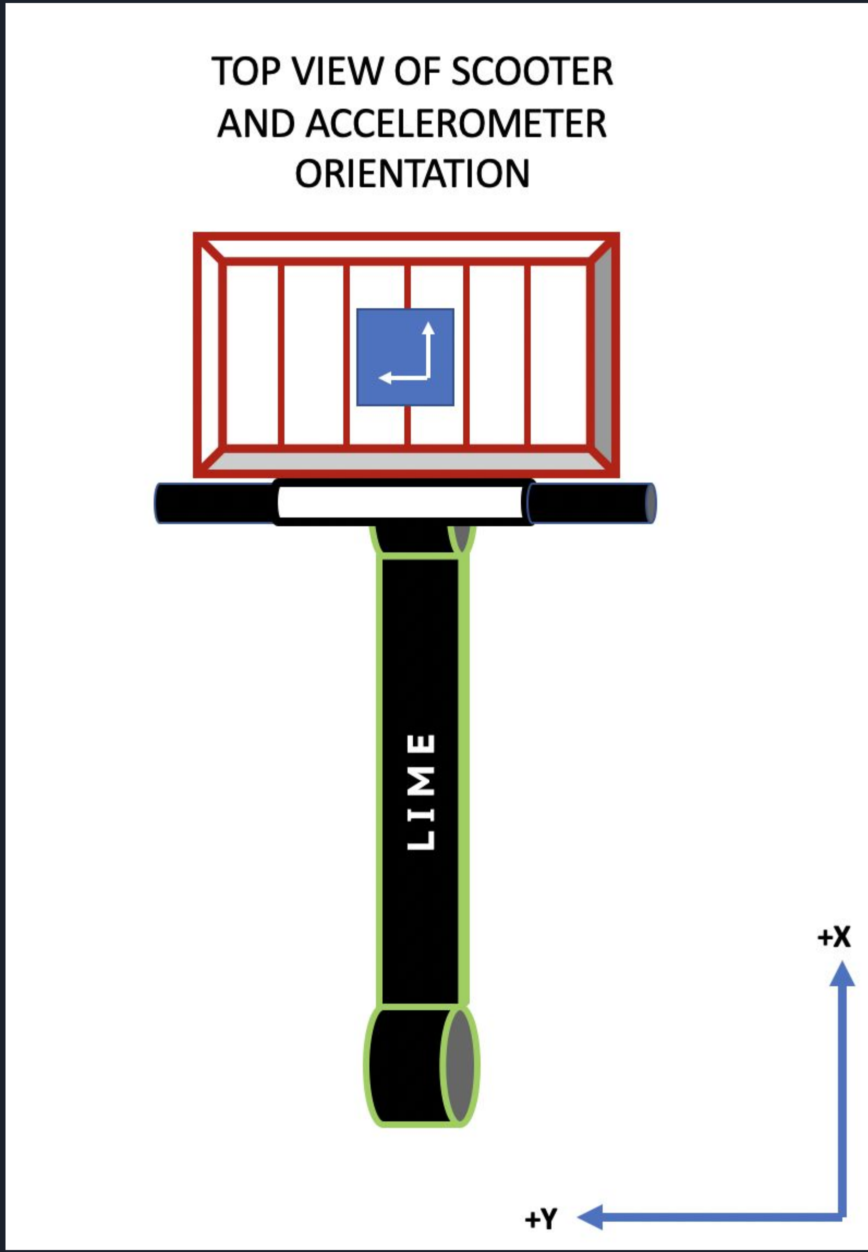
$$\frac{(VCC-5)\ V}{1k\Omega} + \frac{(VCC-0)\ V}{1k\Omega} = 0\ mA$$

shows VCC is 2.5 V

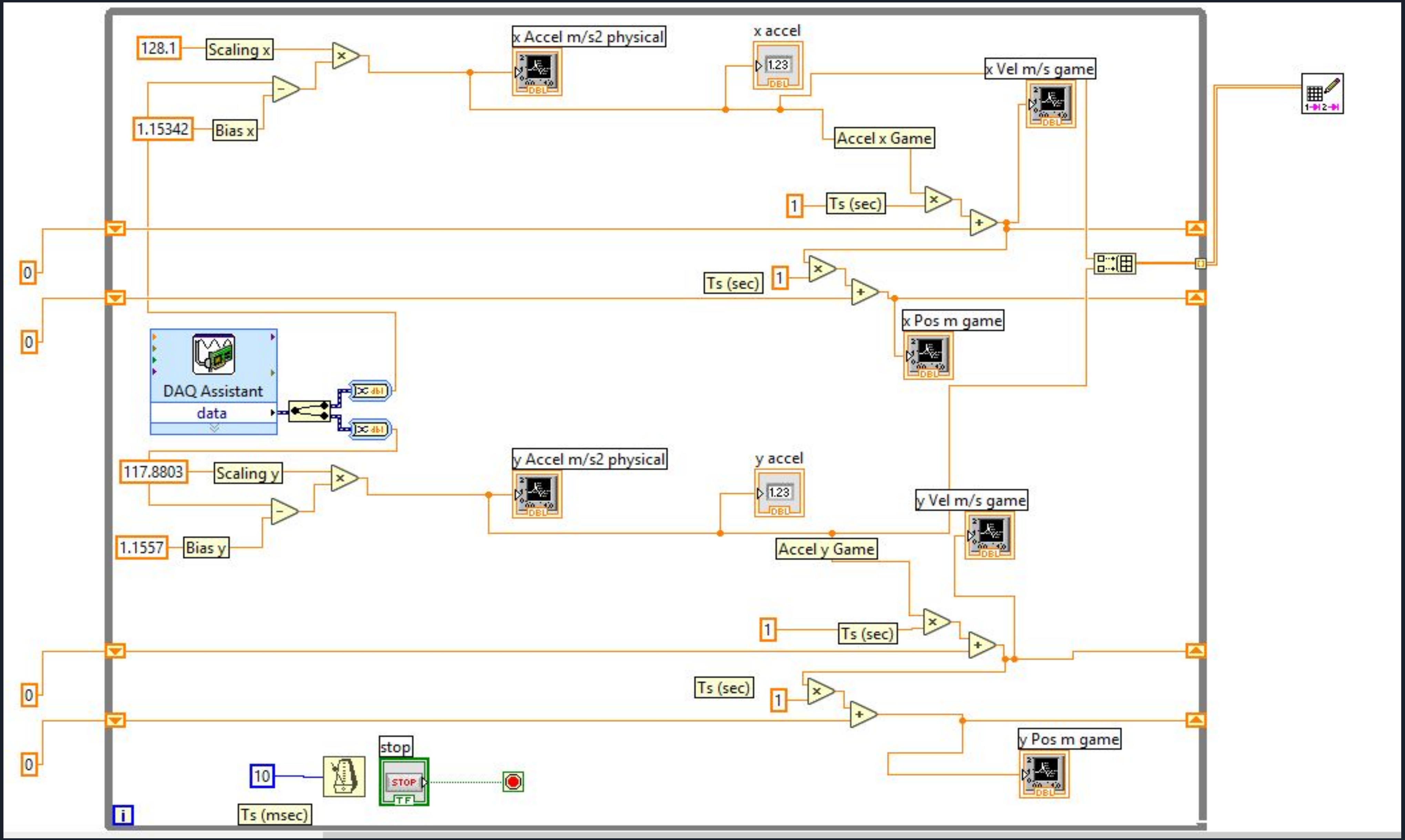
Experiment Set-up



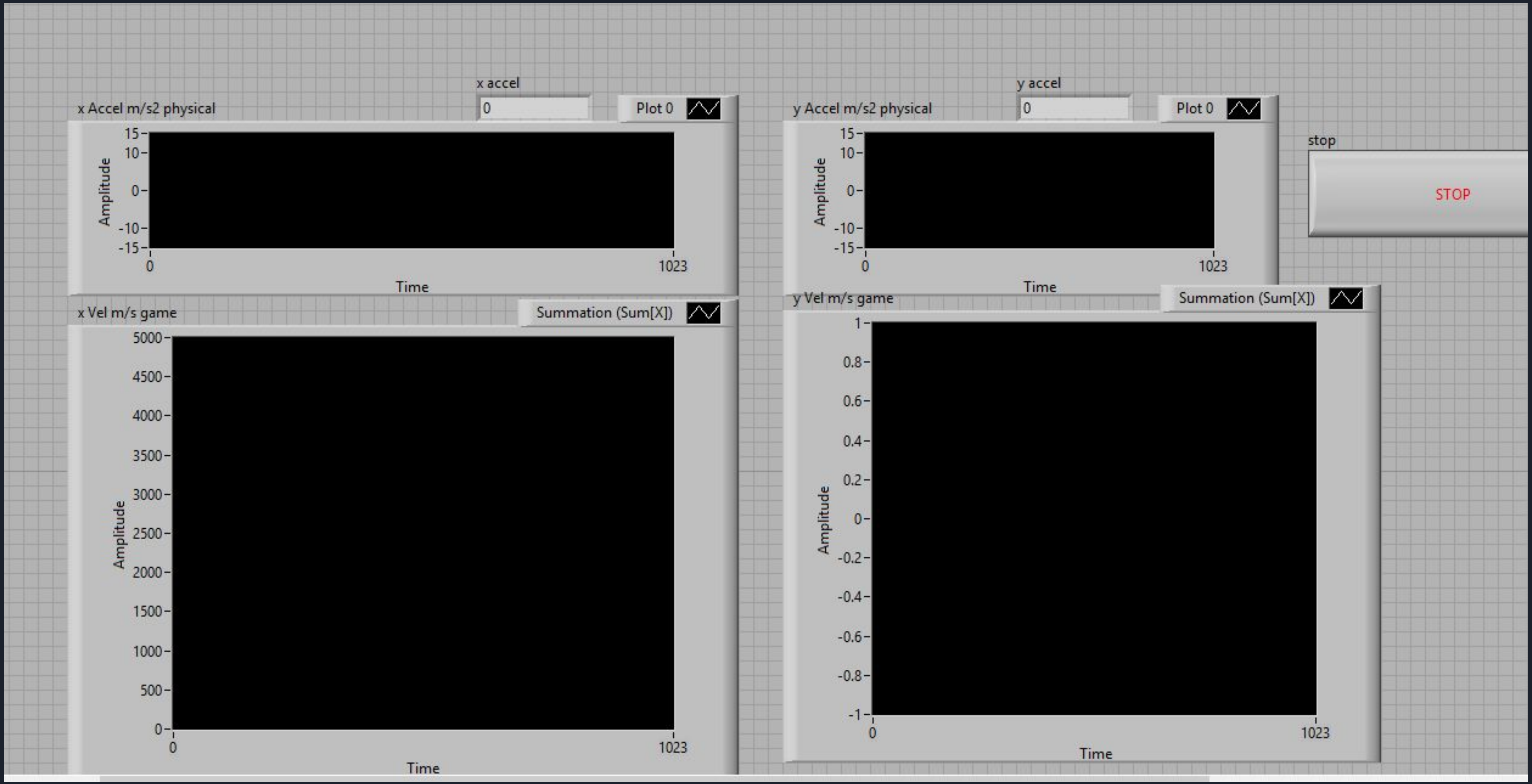
Setup of scooter and measurement devices



LabVIEW Block Diagram



LabVIEW Front Panel

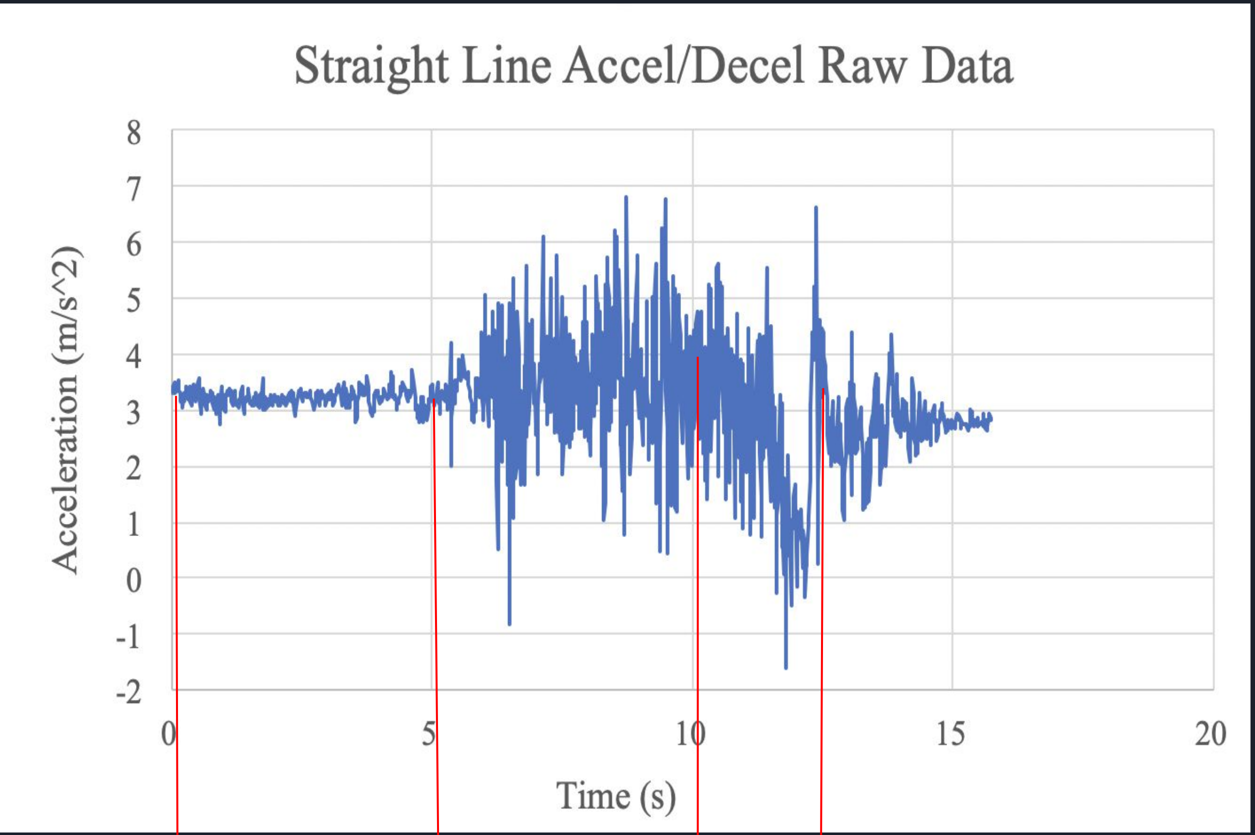


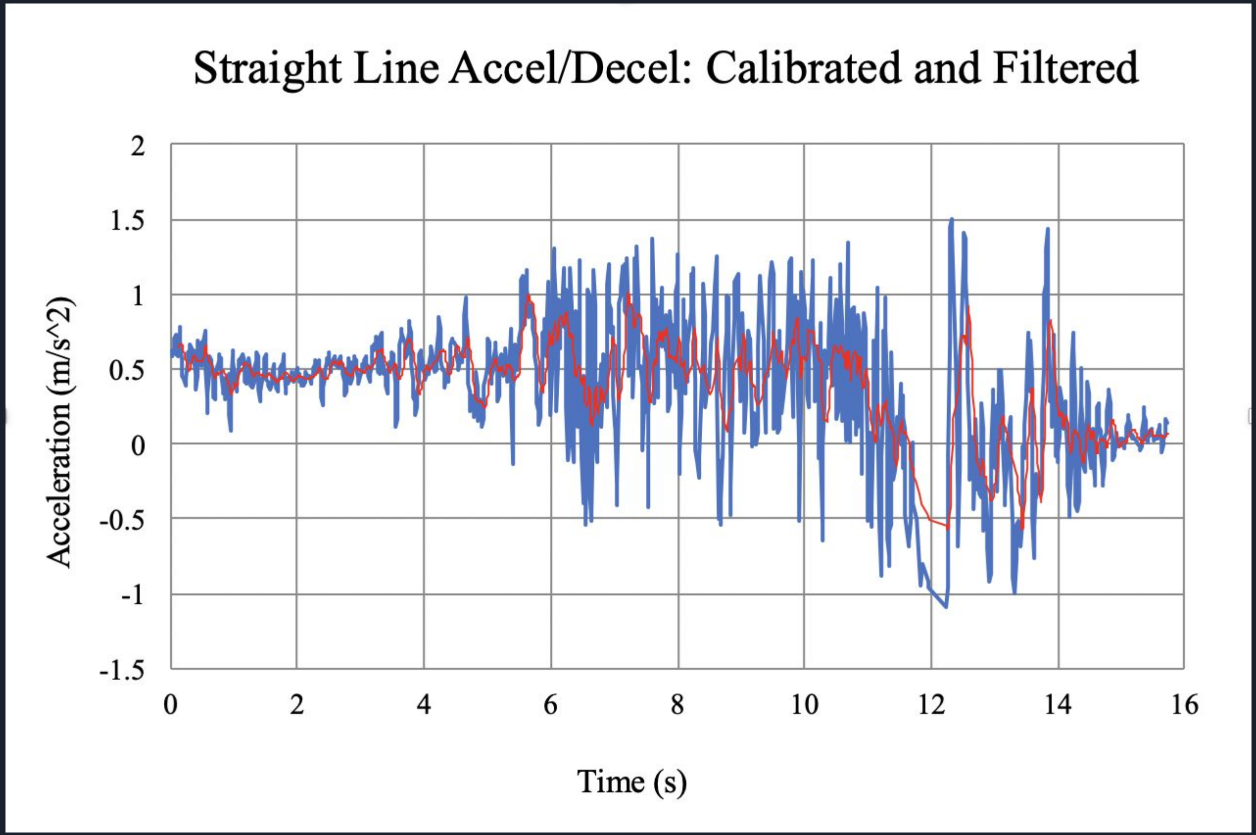
Methods to filter residual data due to vibration

- Data was severely obscured by statistical noise caused by vibration experienced scooter at riding speeds due to the uneven nature of the riding surface and small adjustments made by the rider.
- Methods were used in an attempt to calibrate and filter the data to reveal underlying patterns.
- Steps:
  1. Calibration: Data was aligned so that at moments of rest, acceleration was set to zero
  2. Outlier trimming: First and third quartiles of data set calculated, as well as interquartile range Q3-Q1. Let low and high limits to the accepted values, as we are not expecting extreme values of acceleration due to the overall body motion.
     a. Low Limit
        $L = Q1 - (Q3-Q1)*1.5$

     b. High Limit
        $H = Q3+(Q3-Q1)*1.5$
  3. Moving Average used to filter out noise and smooth out data
     a. Moving average value of a data point is calculated by taking the average between the current data point and the two data points before

Acceleration Data: Straight line Accel/Decel (X-Axis)





Acceleration from rest

High vibration speeds

Brake

Figure: X- acceleration vs Time while doing a Right Turn

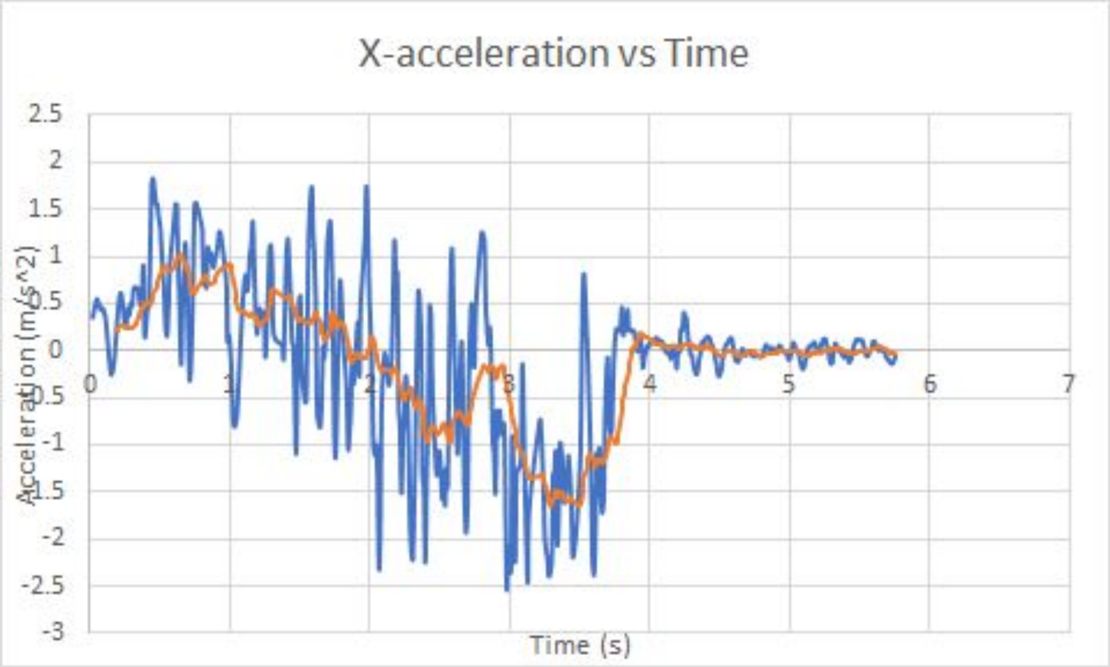
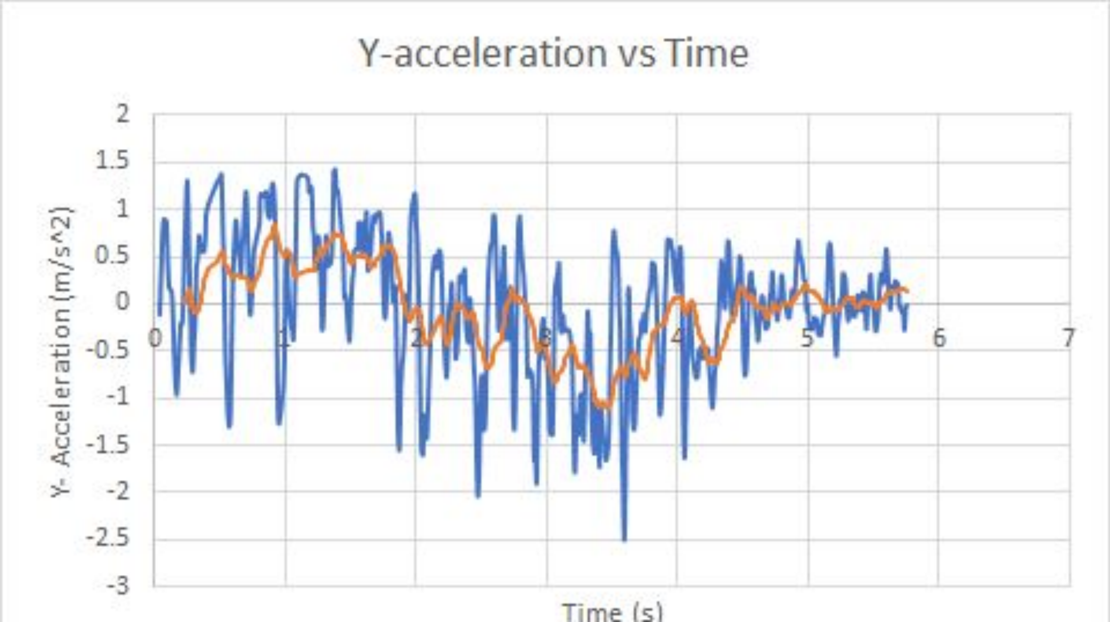
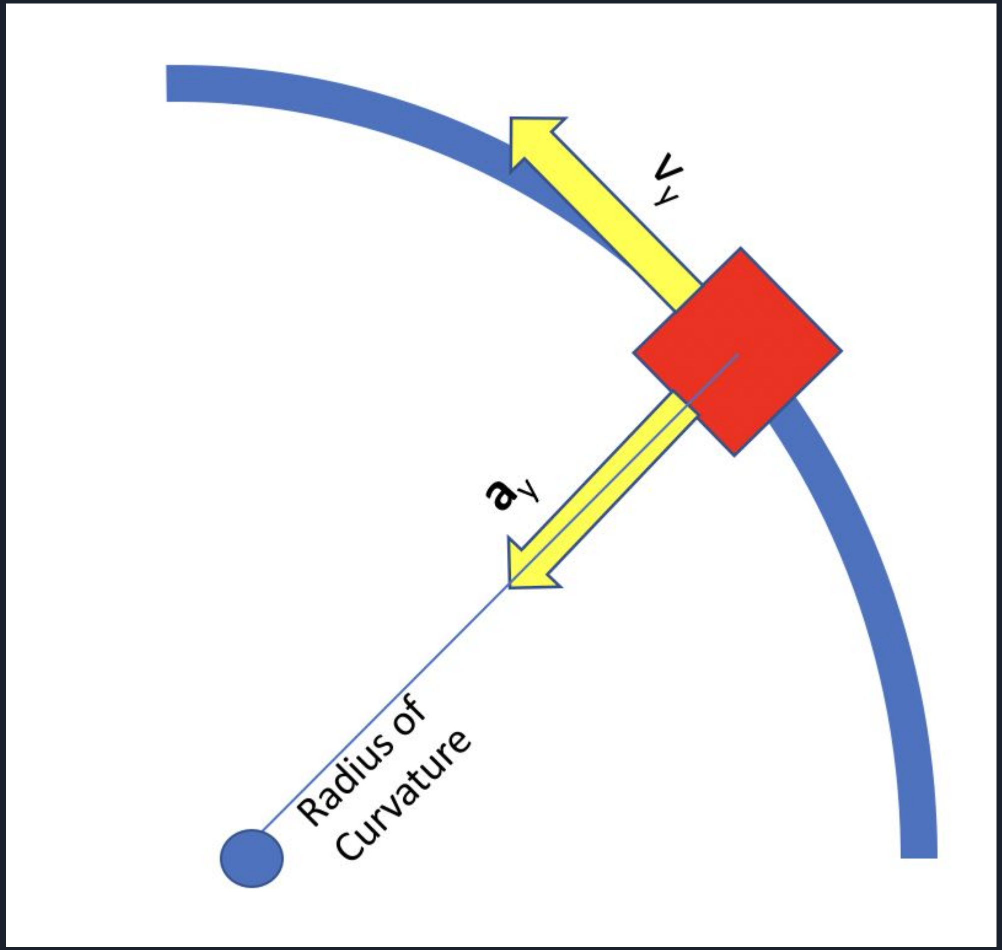


Figure: Y acceleration vs Time while doing a Right Turn



Acceleration data for right turn

We expected to see centripetal acceleration reflected in Y-axis direction, our data did not necessarily reflect



Acceleration Data for going Downhill

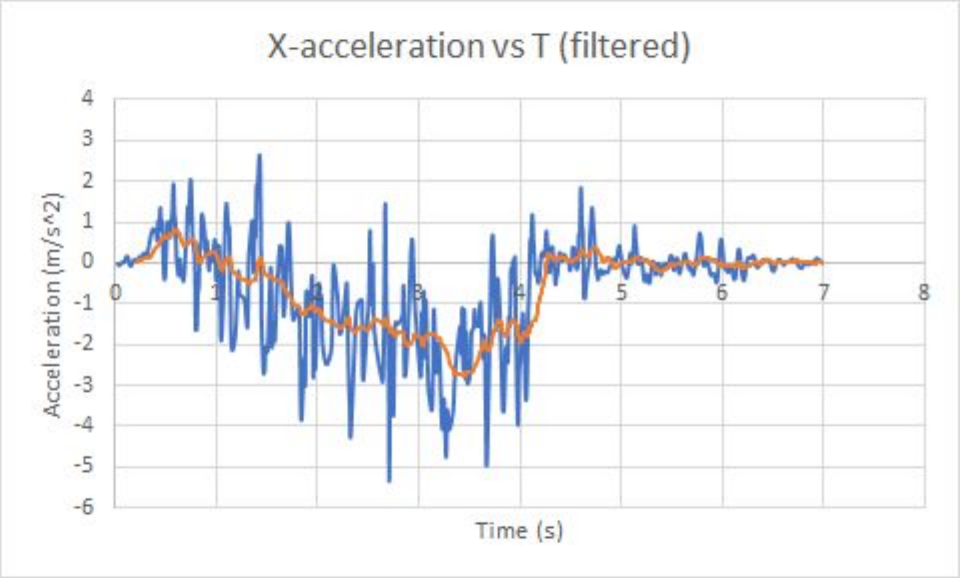


Fig: Acceleration vs Time for x-axis while going downhill

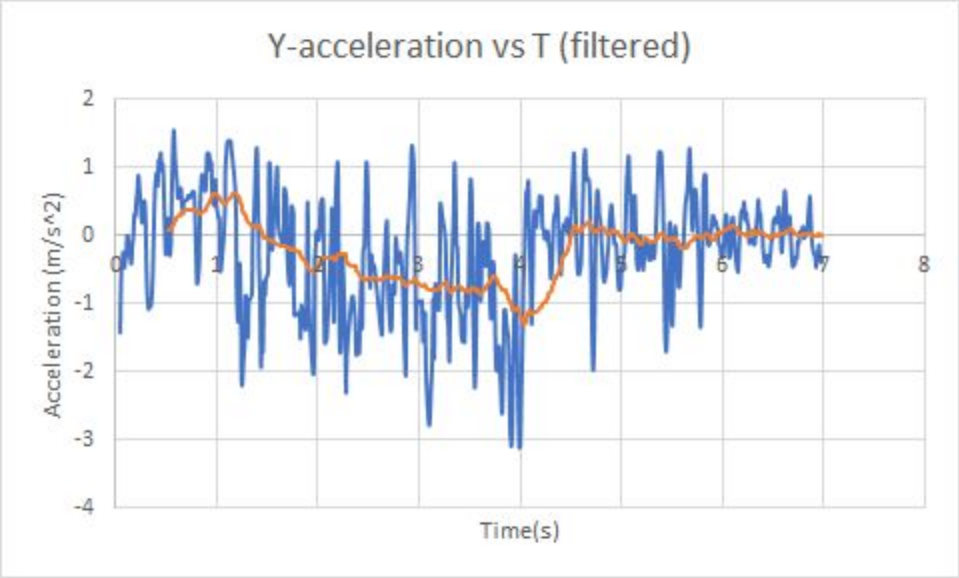


Fig: Acceleration vs Time for y-axis while going downhill

Acceleration Data for going Uphill

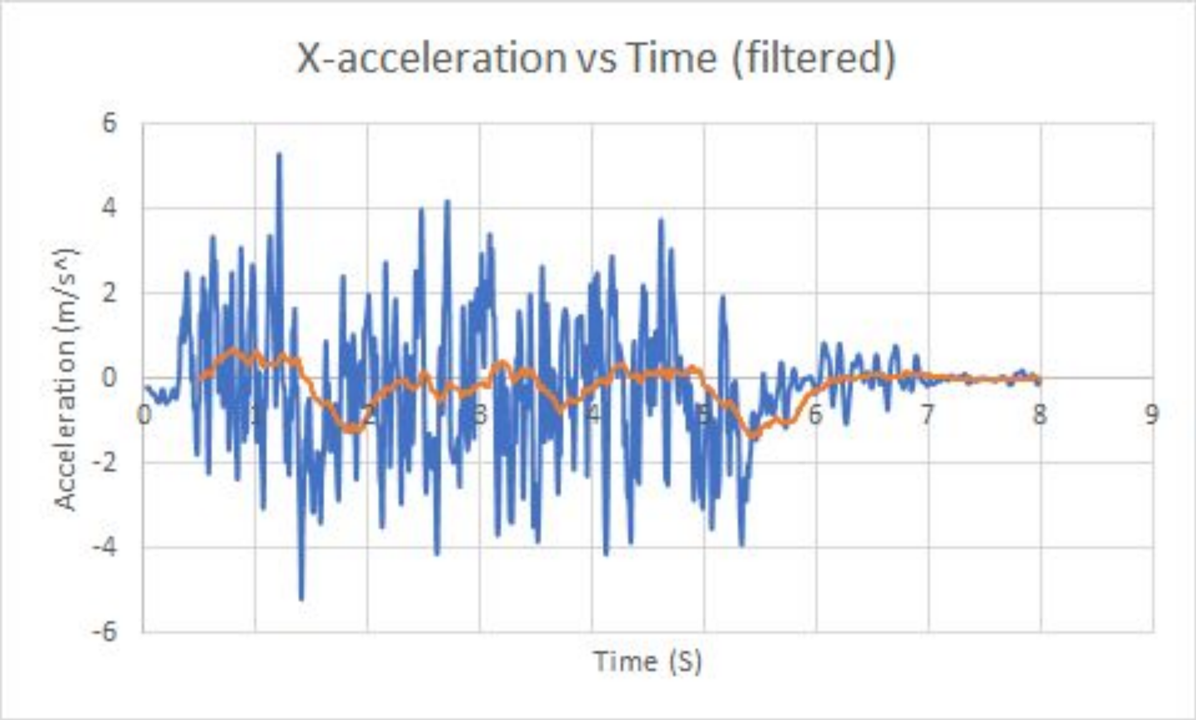


Figure: Acceleration vs Time for X axis while going Uphill

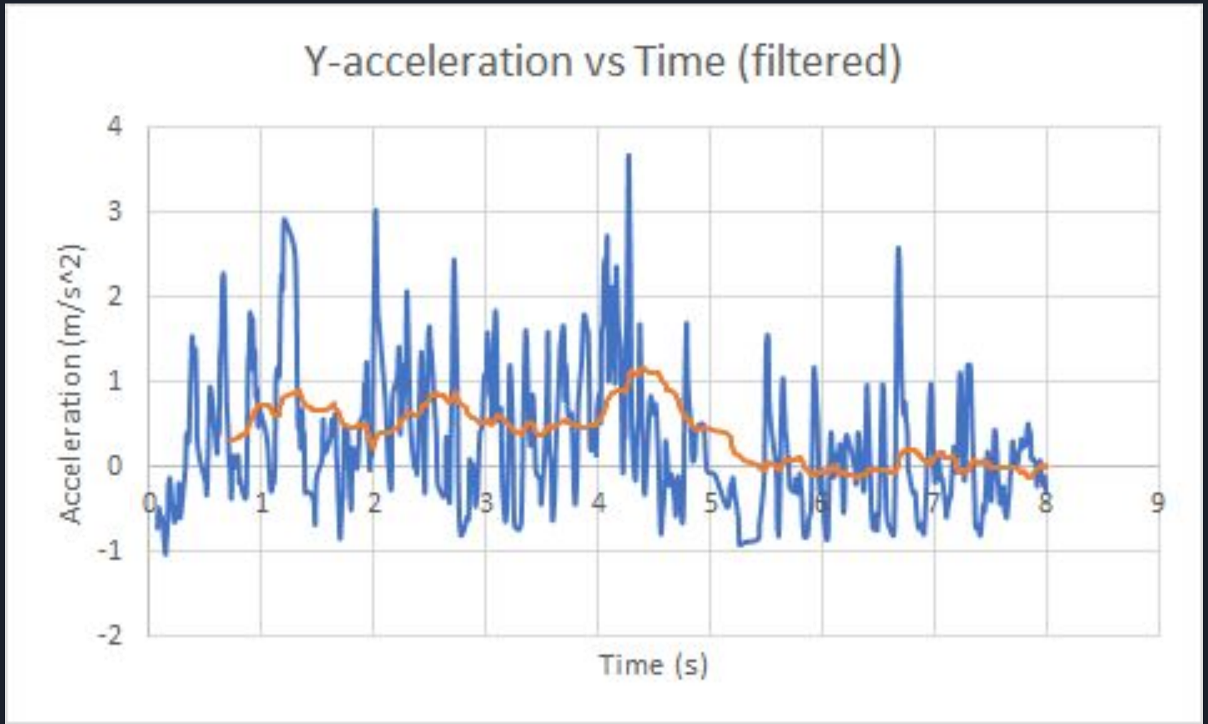
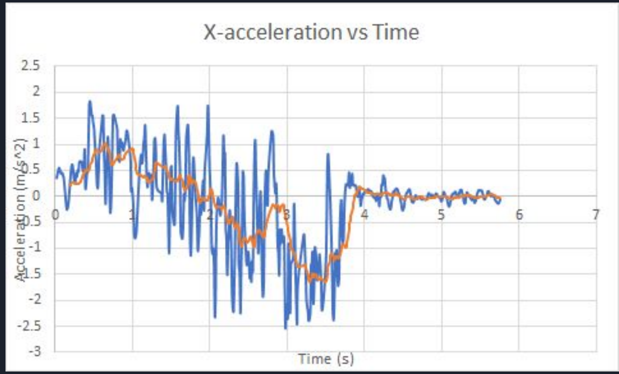


Figure: Acceleration vs Time for Y axis while going Uphill

Data and Error analysis

- As we accelerated to higher speeds on the scooter from rest, statistical noise of acceleration increased with the increased speed and rate we experienced uneven ground.
- Concrete was not smooth enough to prevent vibrations from obscuring data.
- The magnitude of the acceleration felt by the scooter due to overall motion was much smaller than the fluctuations of the magnitude of acceleration due to the uneven riding when travelling at slower speeds. Better data sets were obtained when the scooter decelerated quickly from a high speed or accelerated to a high speed in a very short amount of time after rest.

Plastic cargo hold and imbalance



The data collected for the turns accounts for the deceleration of the scooter while approaching it and acceleration immediately after the turn is complete. We believe the high center of gravity and increased rotational inertia caused by the crate at the front of the scooter affected our ability to balance as steadily during the ride. The average weight of a lime scooter is 45 pounds. The crate and equipment setup weighed 16 pounds. It was experimentally observed that there was less control of motion with the crate, which contributed to the factors that imbalanced our accelerometer data.

Possible Improvements to our experimental setup:

- The accelerometer can be sufficiently cushioned using styrofoam to minimize the impact of jolts caused by surface irregularities on the acceleration data.

- The experiment can be repeated on much smoother surfaces such as hardwood/tile

- The setup could be lighter if we used a lighter casing for the instruments, and perhaps kept the instruments off the scooter connected by wire. That would ascertain that the scooter would be easier to keep balance and the rotational inertia of the crate would not affect the y readings of the acceleration data. In this experiment we dealt with the scooter's overall imbalance by subtracting the calculated offset from our calculations.

Conclusions

- Accelerometer was not an effective instrument to track the overall body acceleration felt by the scooter due to vibration noise
- How to increase effectiveness:
  - More suspension and cushioning to provide damping and insulation
  - Test ride on very smooth surface
- Small tires, poor suspension, and instability of two wheel vehicle contributed to inconclusive data.
- The sensitivity of the instrument that resulted in the statistical noise may serve as a limitation in this project, but has benefits if frequent minute acceleration measurements must be collected (such as vibrations felt by a body).