Lab 3 Report

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October 2024

Rosbag Google Drive Link:
`https://drive.google.com/drive/folders/1lAlkXrp8wsSy8YKRbfoYOfePwz4mimio?usp=sharing`

1 Introduction

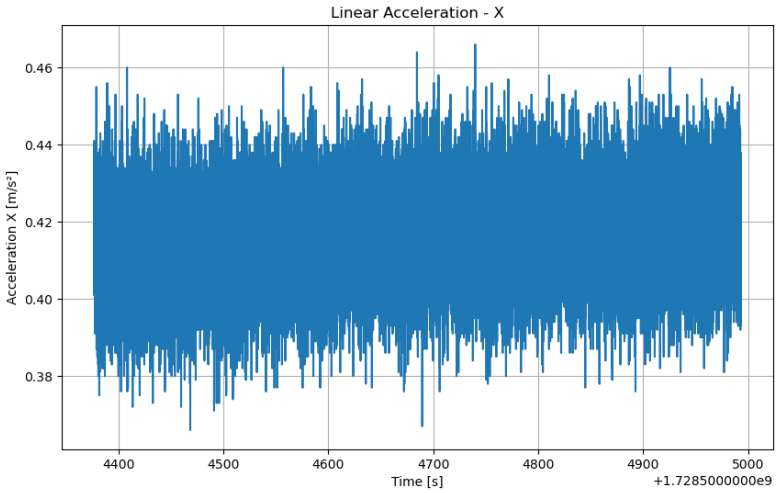
The purpose of this lab is to understand how to characterize and choose IMU sensors for different robotic applications. In order to do so, we wrote a ROS2 driver for the VectorNav VN-100 IMU and collected 5 hours of data with the IMU stationary.

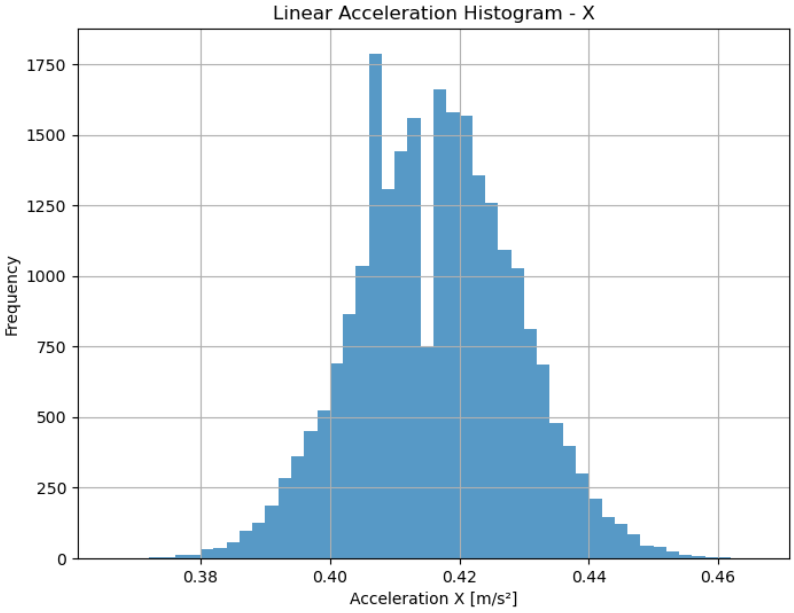
2 Time-series Readings on the 10 minute dataset

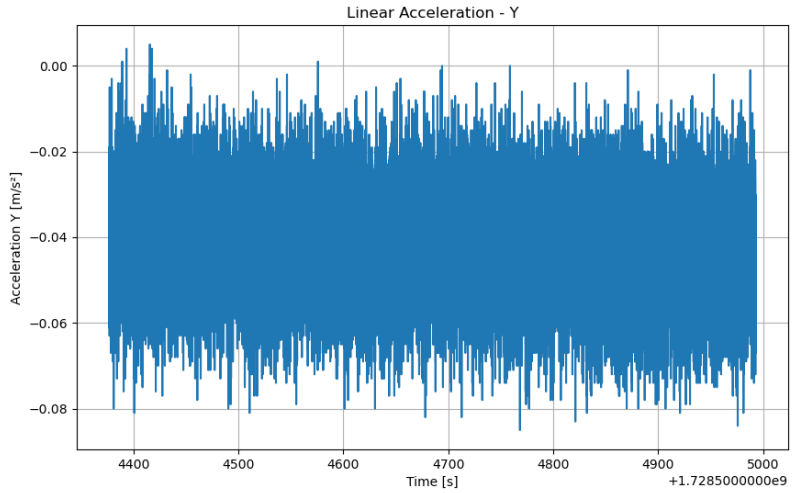
2.1 Accelerometer

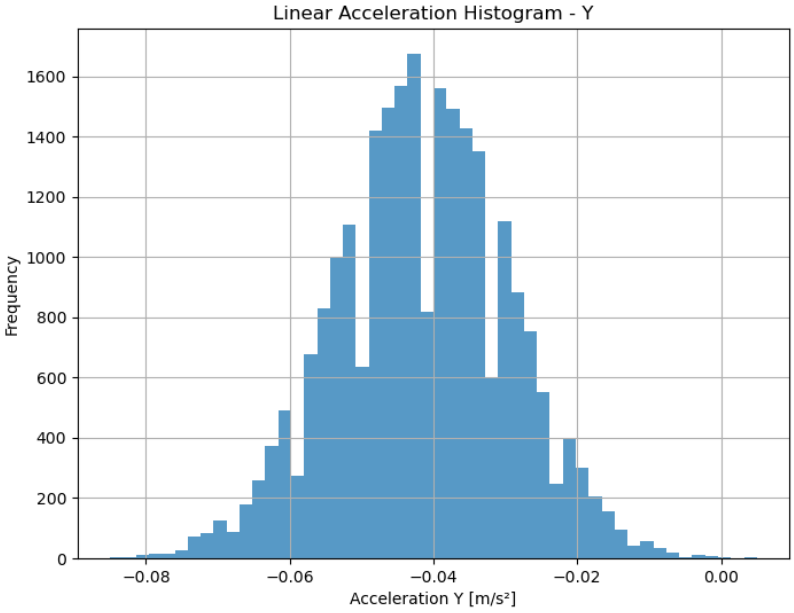
Mean: [0.41614433, -0.04168208, -9.71783585]
Std Dev: [0.01235747, 0.01204045, 0.01981698]

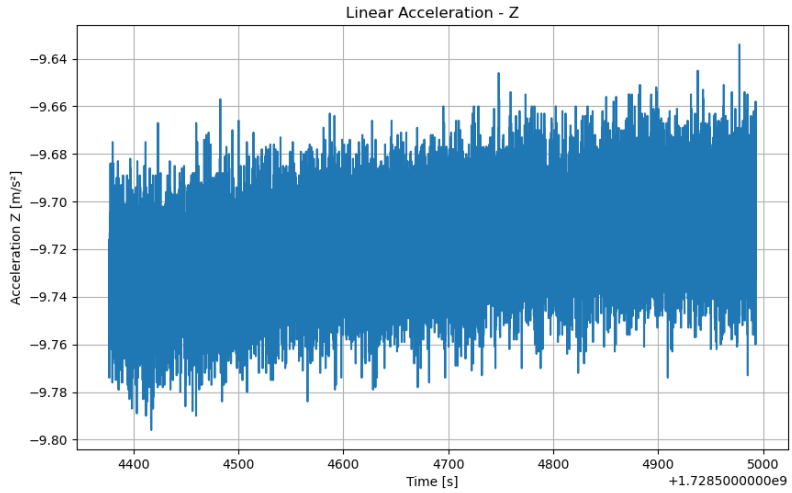
The distribution of the Accelerometer Readings is normal, with constant accelerations in both the +X and -Z directions, and no acceleration in the Y direction. The +X acceleration is likely due to the rotation of the earth, while the -Z acceleration is due to gravity.

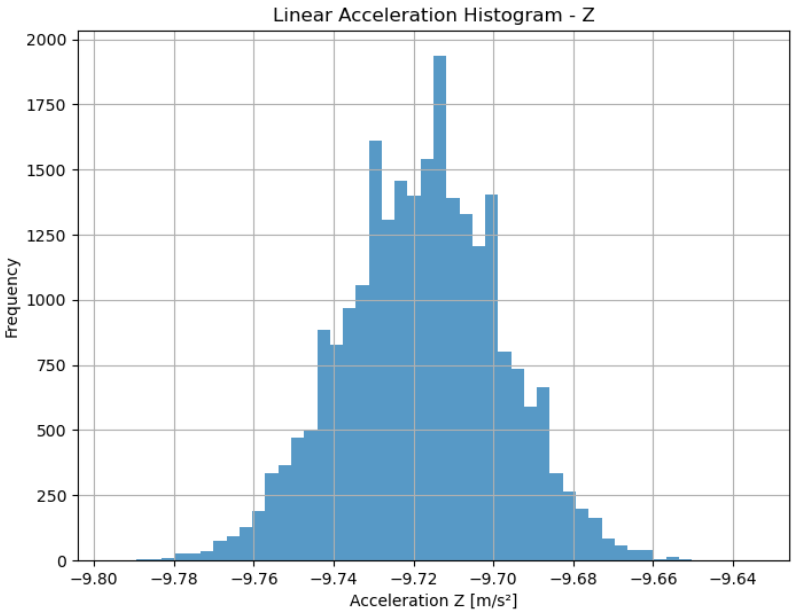

Linear Acceleration - X
Acceleration X [m/s²]
0.46
0.44
0.42
0.40
0.38
4400
4500
4600
4700
4800
4900
5000
Time [s]
+1.7285000000e9


Linear Acceleration Histogram - X
Frequency
1750
1500
1250
1000
750
500
250
0
0.38
0.40
0.42
0.44
0.46
Acceleration X [m/s²]


Linear Acceleration - Y
Acceleration Y [m/s²]
0.00
−0.02
−0.04
−0.06
−0.08
4400
4500
4600
4700
4800
4900
5000
Time [s]
+1.7285000000e9


Linear Acceleration Histogram - Y
Frequency
1600
1400
1200
1000
800
600
400
200
0
−0.08
−0.06
−0.04
−0.02
0.00
Acceleration Y [m/s²]

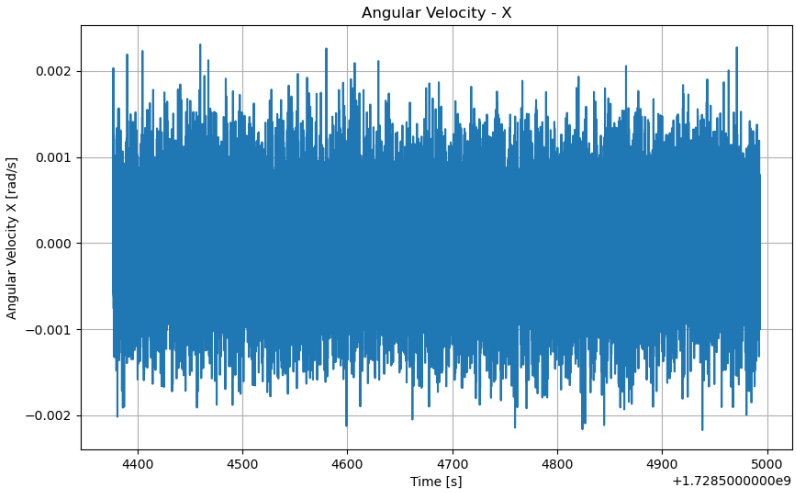


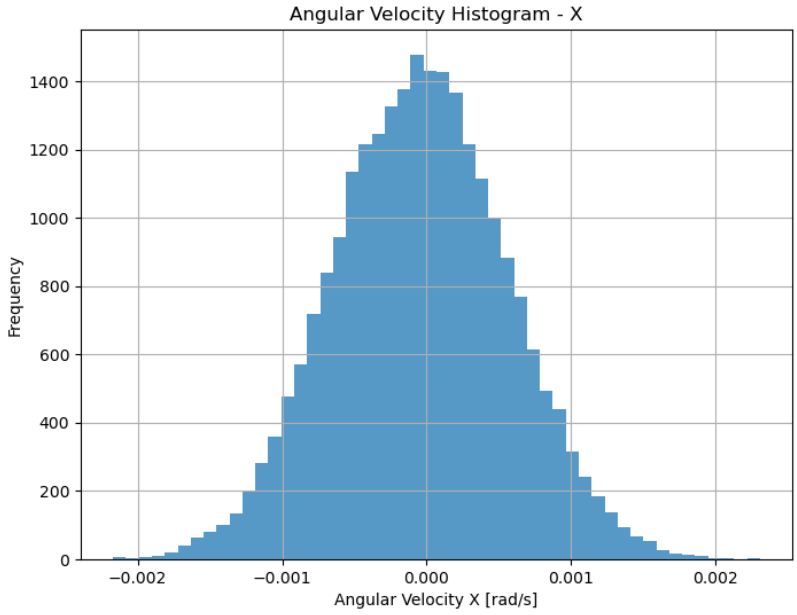


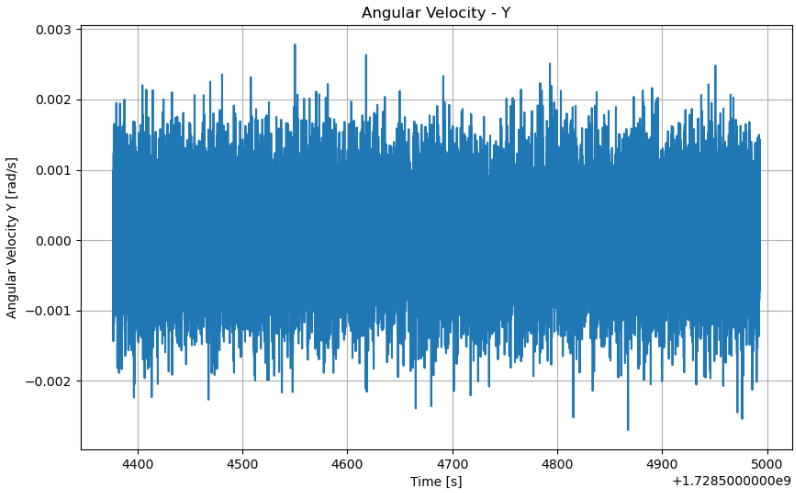
2.2 Angular Rate Gyros

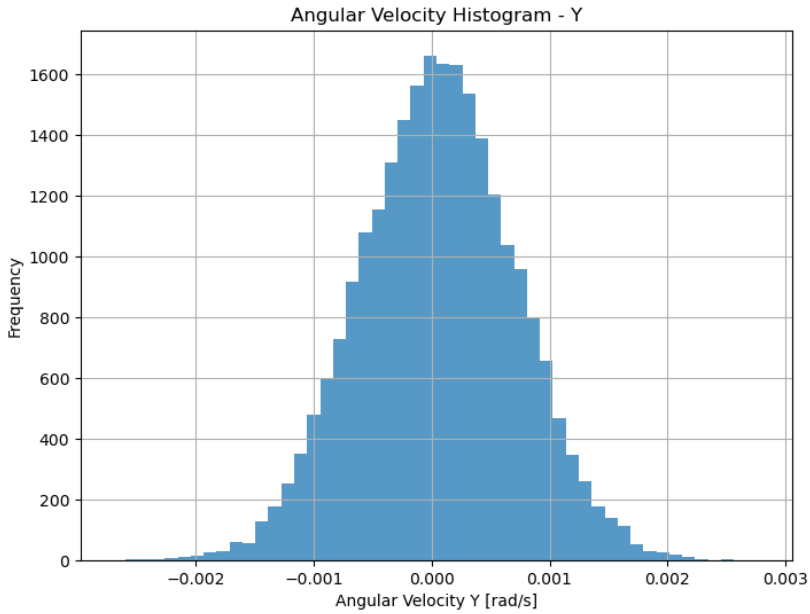
Mean: [-4.17073141e-5, 5.28862795e-5, -1.9370589e-5]
Std Dev: [0.00060263, 0.00065851, 0.00066114]

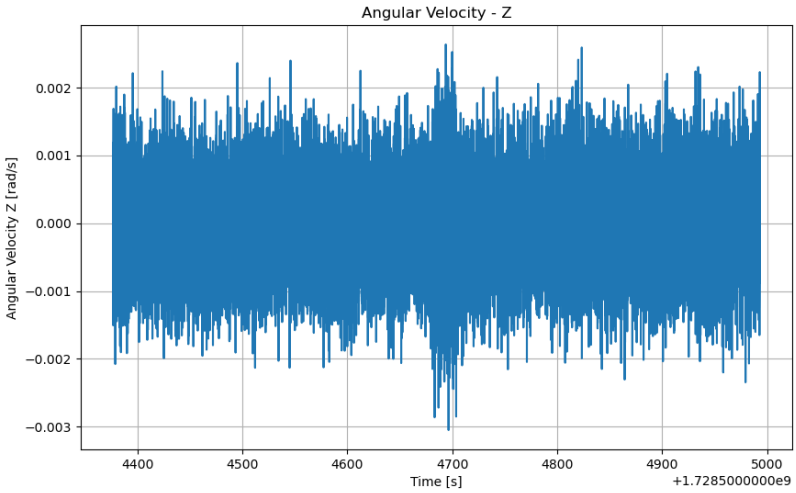
The distribution of data for the angular rate gyros is normal, all with means near 0.

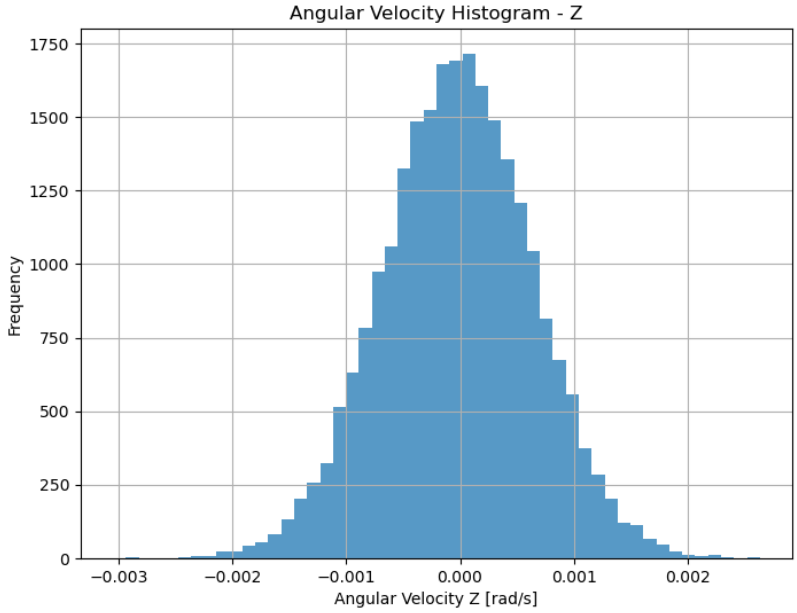





Angular Velocity - Y
Angular Velocity Y [rad/s]
0.003
0.002
0.001
0.000
−0.001
−0.002
4400
4500
4600
4700
4800
4900
5000
Time [s]
+1.7285000000e9


Angular Velocity Histogram - Y
Frequency
1600
1400
1200
1000
800
600
400
200
0
−0.002
−0.001
0.000
0.001
0.002
0.003
Angular Velocity Y [rad/s]

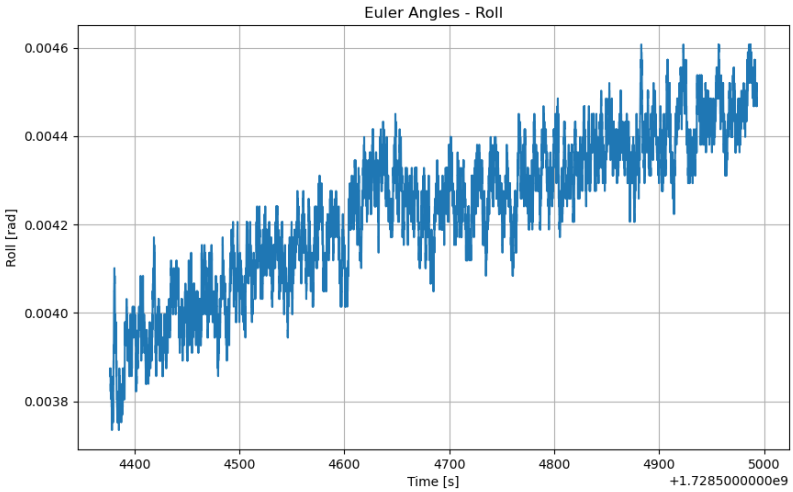


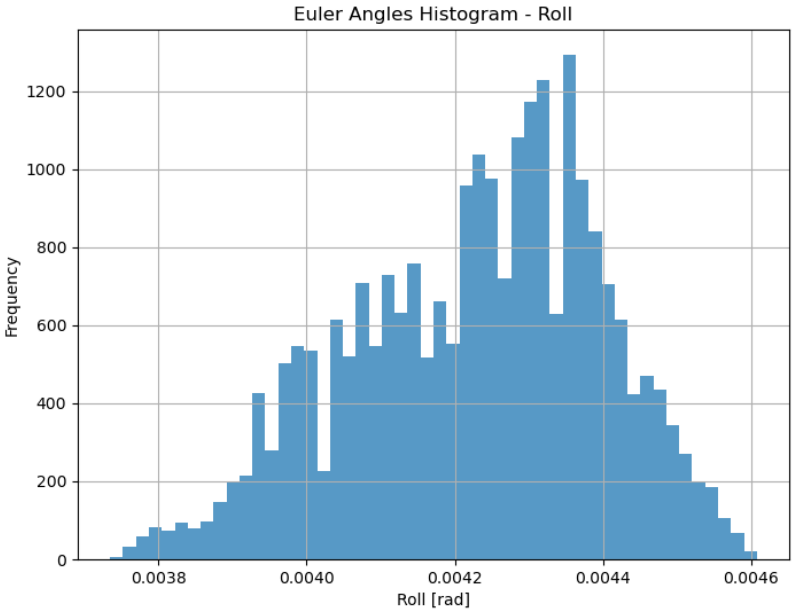


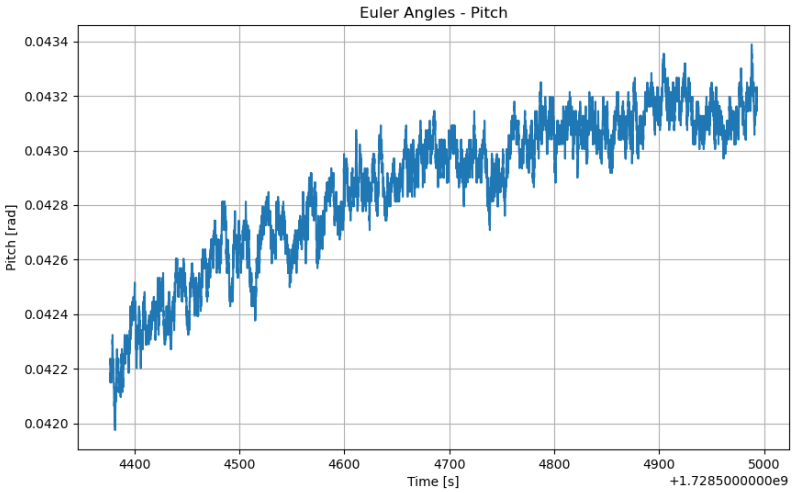
2.3 Orientation

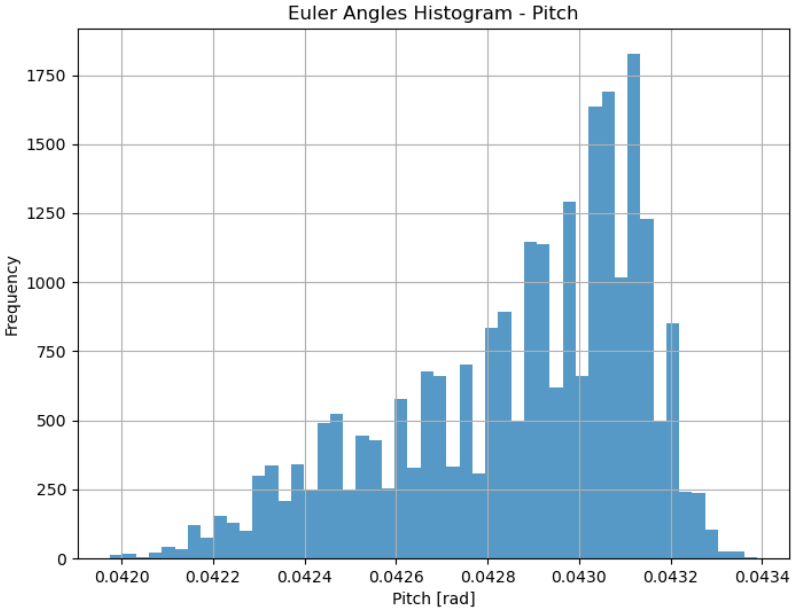
Mean: [0.00423002, 0.04286492, 0.44842187]
Std Dev: [0.00017211, 0.00027105, 0.00072557]

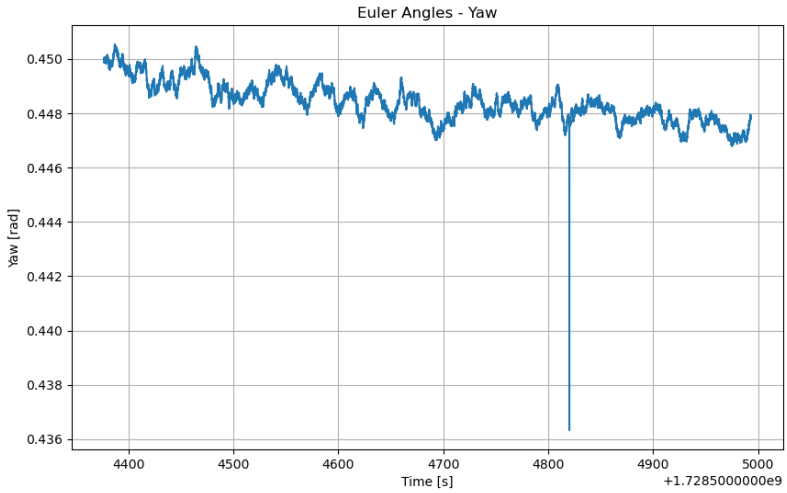
The orienation angle readings are all oscillatory, but also skewed, likely because the IMU took a small amount of time to determine the correct approximate angle readings with oscillatory behavior.

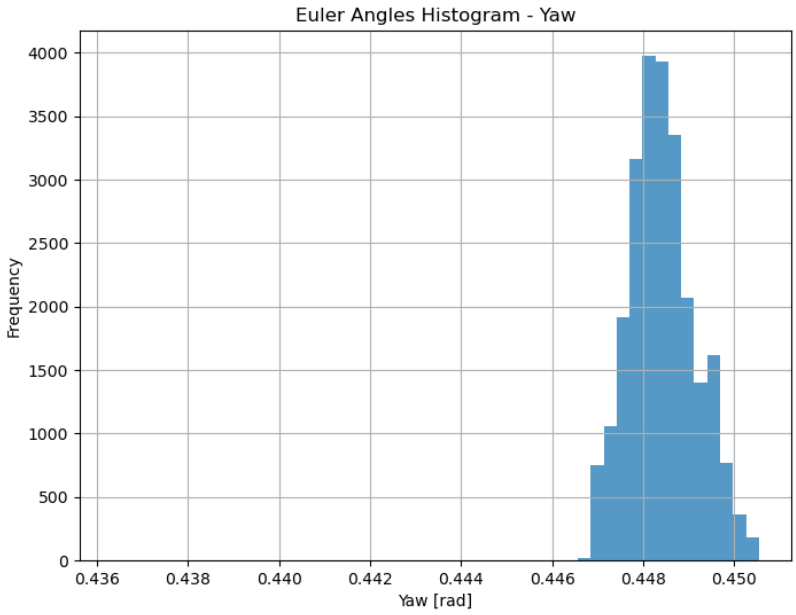





Euler Angles - Pitch
Pitch [rad]
0.0434
0.0432
0.0430
0.0428
0.0426
0.0424
0.0422
0.0420
4400
4500
4600
4700
4800
4900
5000
Time [s]
+1.7285000000e9

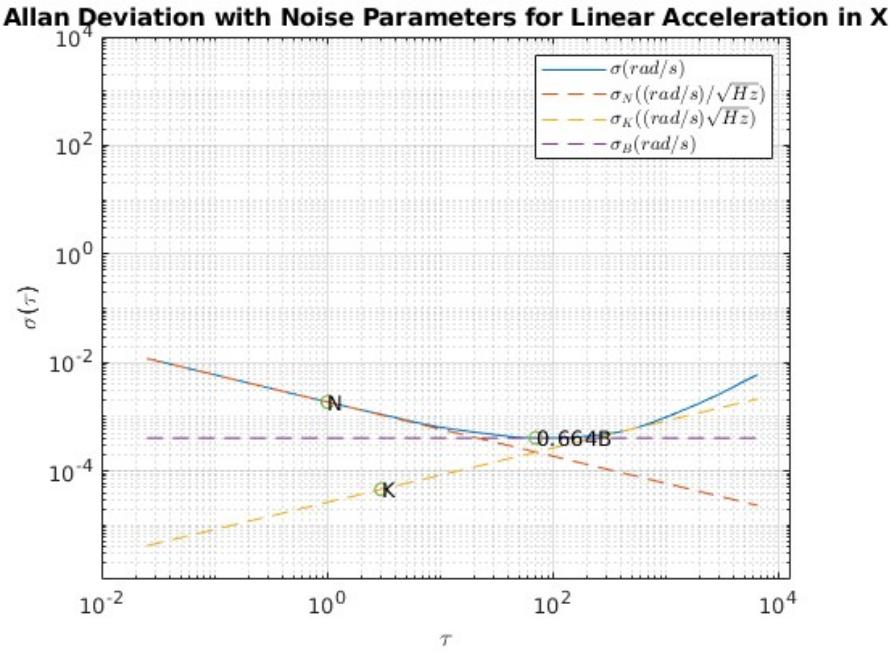

Euler Angles Histogram - Pitch
Frequency
1750
1500
1250
1000
750
500
250
0
0.0420
0.0422
0.0424
0.0426
0.0428
0.0430
0.0432
0.0434
Pitch [rad]

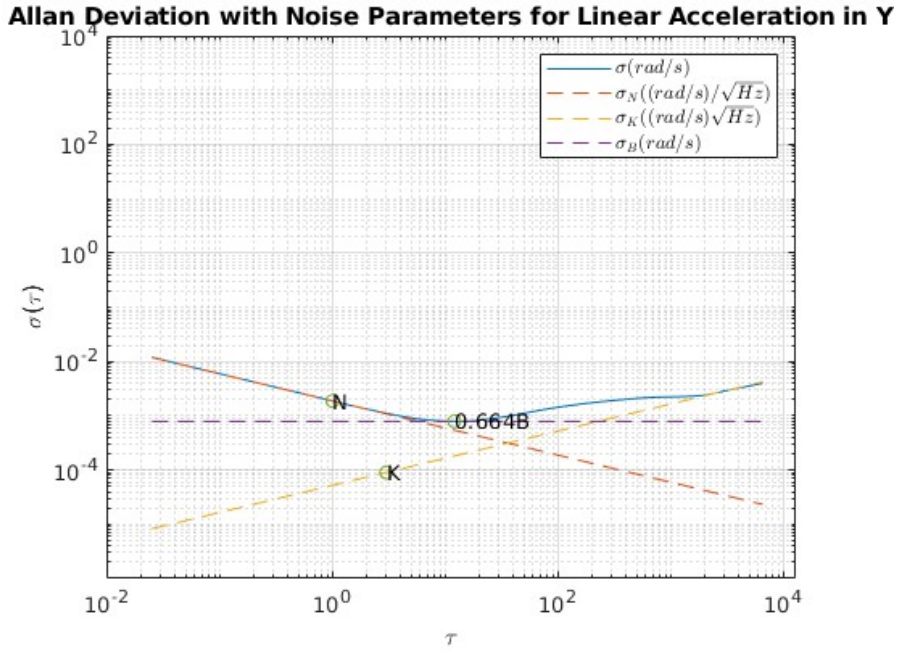

Euler Angles - Yaw
Yaw [rad]
0.450
0.448
0.446
0.444
0.442
0.440
0.438
0.436
4400
4500
4600
4700
4800
4900
5000
Time [s]
+1.7285000000e9

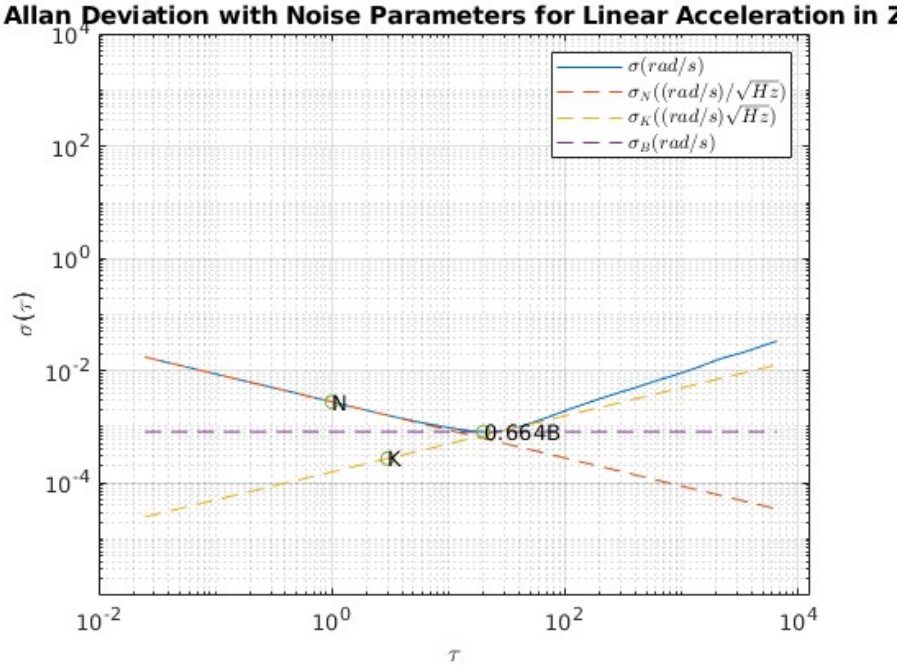

Euler Angles Histogram - Yaw
Frequency
4000
3500
3000
2500
2000
1500
1000
500
0
0.436
0.438
0.440
0.442
0.444
0.446
0.448
0.450
Yaw [rad]

3 Allan Variance Graphs on 5 hour dataset

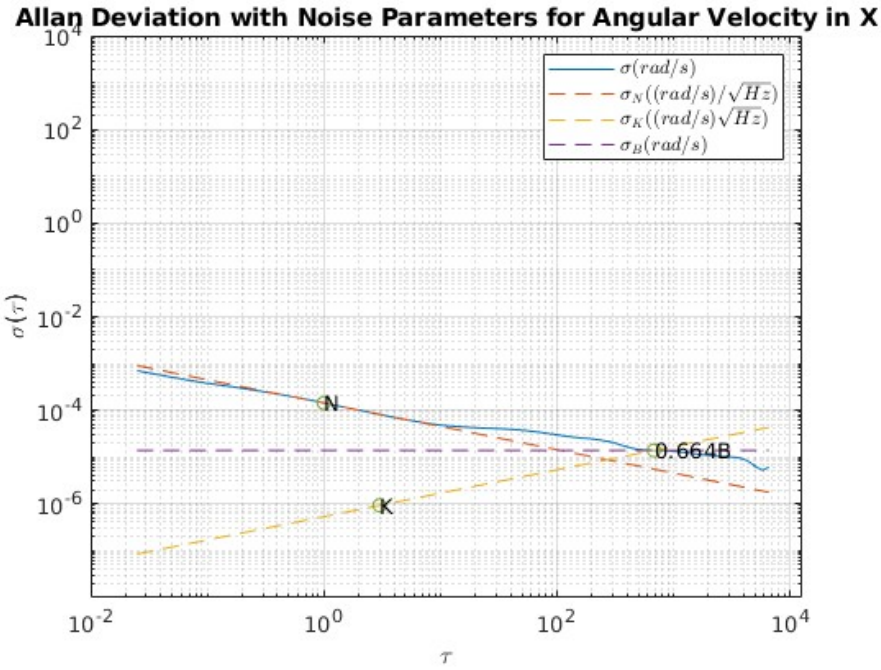
3.1 Linear Acceleration

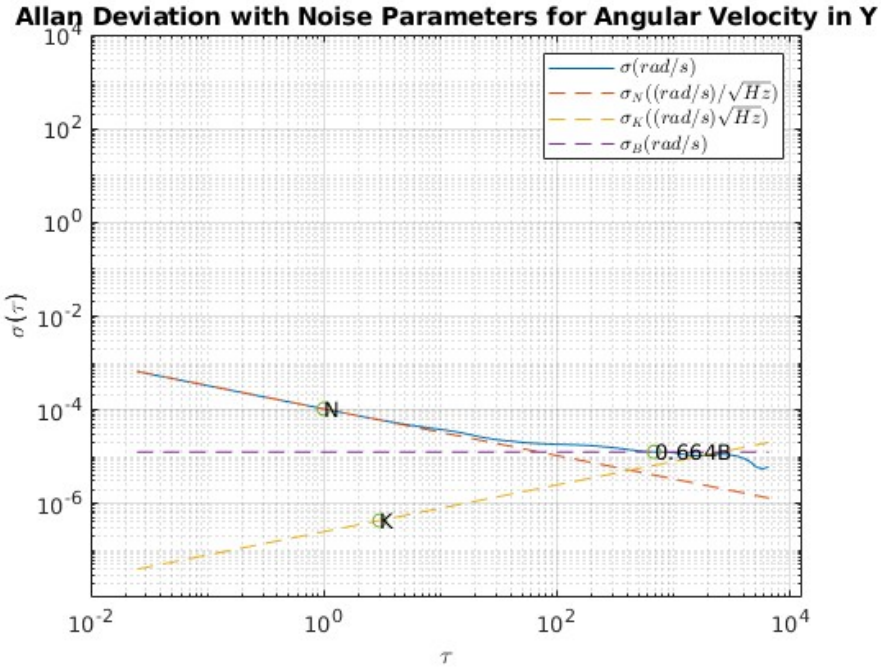


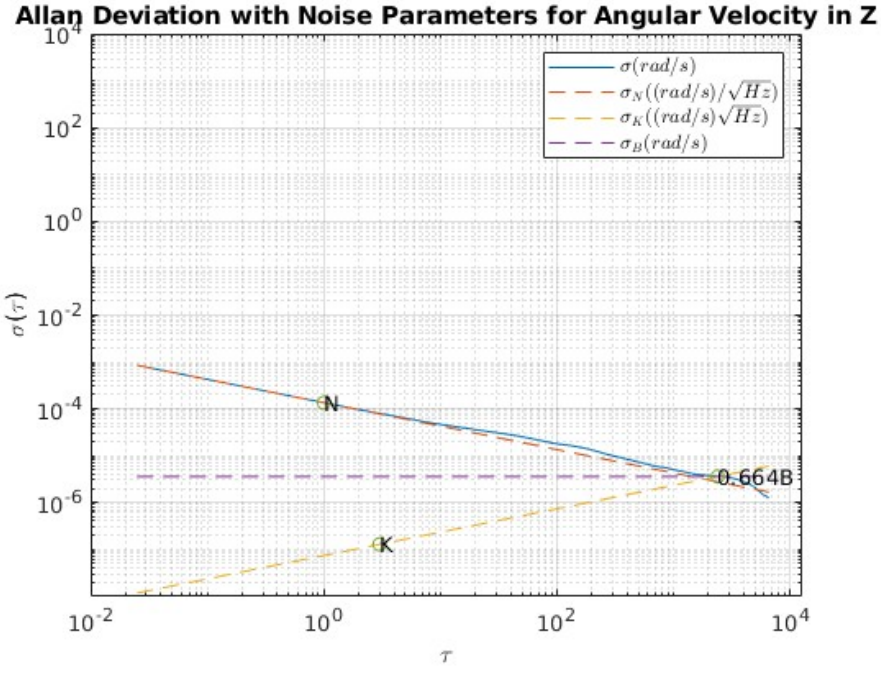

Allan Deviation with Noise Parameters for Linear Acceleration in Y
$\sigma(rad/s)$
$\sigma_N((rad/s)/\sqrt{Hz})$
$\sigma_K((rad/s)\sqrt{Hz})$
$\sigma_B(rad/s)$
N
0.664B
K
$\sigma(\tau)$
τ


Allan Deviation with Noise Parameters for Linear Acceleration in Z
$\sigma(rad/s)$
$\sigma_N((rad/s)/\sqrt{Hz})$
$\sigma_K((rad/s)\sqrt{Hz})$
$\sigma_B(rad/s)$
N
0.664B
K
$\sigma(\tau)$
τ

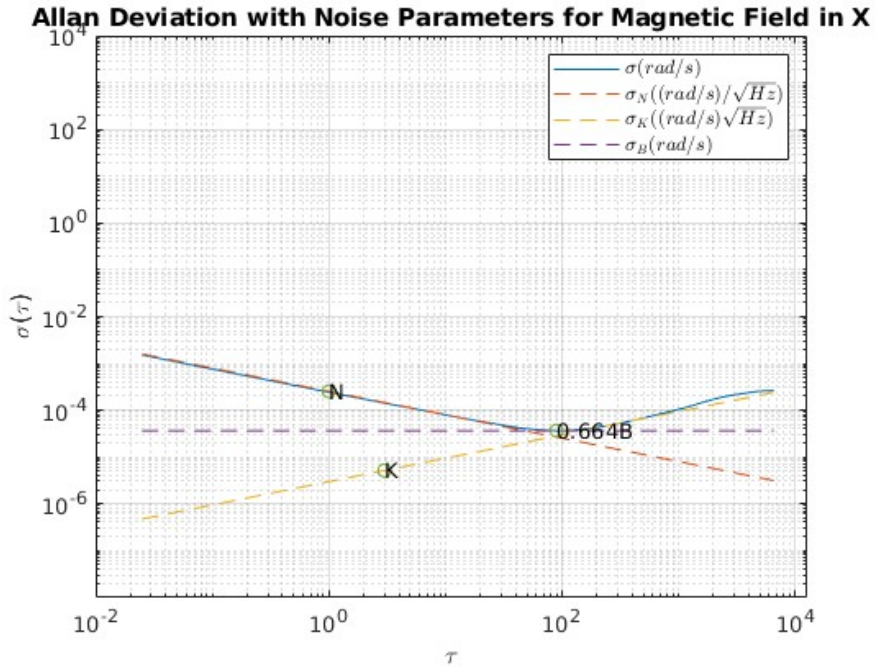
3.2 Angular Velocity

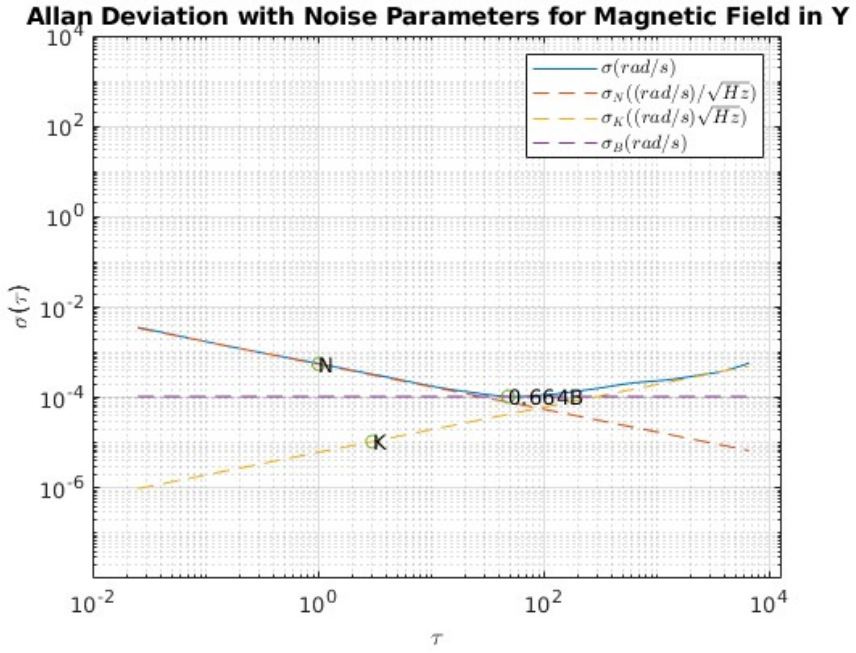


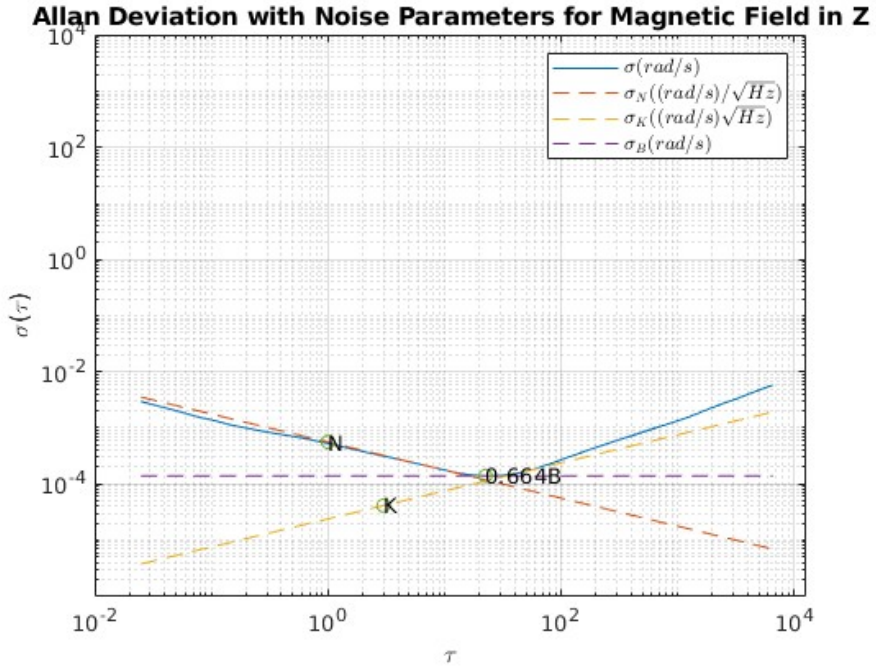

Allan Deviation with Noise Parameters for Angular Velocity in Y
$\sigma(rad/s)$
$\sigma_N((rad/s)/\sqrt{Hz})$
$\sigma_K((rad/s)\sqrt{Hz})$
$\sigma_B(rad/s)$
N
0.664B
K
$\sigma(\tau)$
τ


Allan Deviation with Noise Parameters for Angular Velocity in Z
$\sigma(rad/s)$
$\sigma_N((rad/s)/\sqrt{Hz})$
$\sigma_K((rad/s)\sqrt{Hz})$
$\sigma_B(rad/s)$
N
0.664B
K
$\sigma(\tau)$
τ

3.3 Magnetic Field




Allan Deviation with Noise Parameters for Magnetic Field in Y
$\sigma(rad/s)$
$\sigma_N((rad/s)/\sqrt{Hz})$
$\sigma_K((rad/s)\sqrt{Hz})$
$\sigma_B(rad/s)$
N
0.664B
K
$\sigma(\tau)$
τ


Allan Deviation with Noise Parameters for Magnetic Field in Z
$\sigma(rad/s)$
$\sigma_N((rad/s)/\sqrt{Hz})$
$\sigma_K((rad/s)\sqrt{Hz})$
$\sigma_B(rad/s)$
N
0.664B
K
$\sigma(\tau)$
τ

4 Analysis

4.1 What kinds of errors/sources of noise are present?

The sources of noise that are present are Angle Random Walk (aka Noise Density) and the In-Run Bias Stability.

4.2 How do we model them? Where do we measure them? Can you relate your measurements to the datasheet for the VN100?

We can model the Angle Random Walk and In-Run Bias Stability with an Allan Deviation Plot for each directional measurement. As shown in the previous Allan Deviation plots, Angle Random Walk is the slope of the σ_N line, defined by the parameter N. Additionally, the In-Run Bias Stability is defined by the parameter B which is the altitude of the zero-slope line represented by σ_B.

Relating to the datasheet for the VN-100:
Accelerometer: $B < 0.04mg$, $N = 0.14mg/\sqrt{Hz}$
Gyro: $B < 10\,\mathrm{deg}/hr$, $N = 0.003\,\mathrm{deg}/s/\sqrt{Hz}$

These values align with the B and N parameters derived in each Allan Variation test.