Gyro Comparison

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Introduction

- There are many gyros one can choose from, so how do you pick one?

- This talk
  - Evaluates three different gyros
    - AD22425 from Analog Devices
    - BMX055 from Bosch Sensortec, Gmbh
    - MPU6000 from InvenSense
  - Points out parameters of interest
  - Shares references I find super helpful

Specification Comparison

Parameter	Units	AD22425	BMX055	MPU6000
Measurement range	(°/sec)	$\pm$ 2000	$\pm$ 125 to $\pm$ 2000	$\pm$ 250 to $\pm$ 2000
Temperature Drift	(%/°C)	$\pm$ 0.0625	$\pm$ 0.03	$\pm$0.0167
Linear acceleration effect	(°/sec/g)	0.1	0.1	0.1
Rate Noise Density	(°/sec/$\sqrt{Hz}$)	0.25	0.014 @ bandwidth = 47Hz	0.005 @ bandwidth = 10Hz
Bandwidth	(Hz)	up to 2000	12 to 230	5 to 256

- Missing
  - Bias instability (°/hr):
    - How stable the gyro is over a period of time; how much the bias will wander or walk over time due to flicker noise
    - Lower value means less errors in angular position
  - Angle random walk (°/$\sqrt{hr}$):
    - Average error that will occur when you integrate the gyro signal

Random Walk (Reference 5)

Figure 1

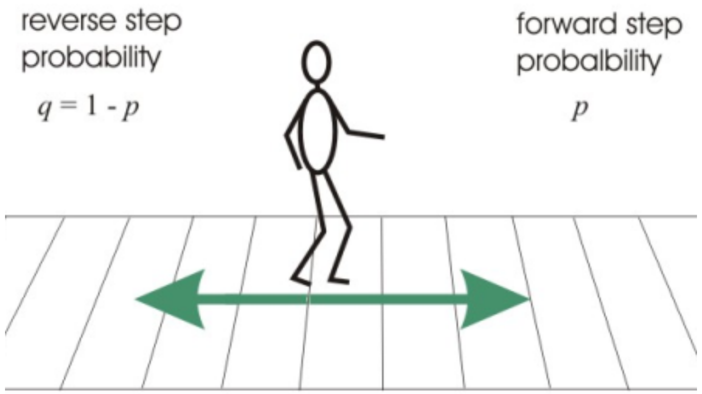
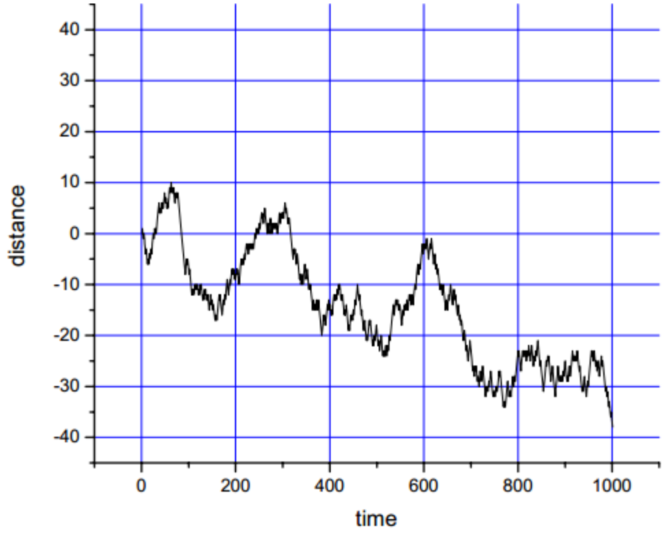


Figure 2



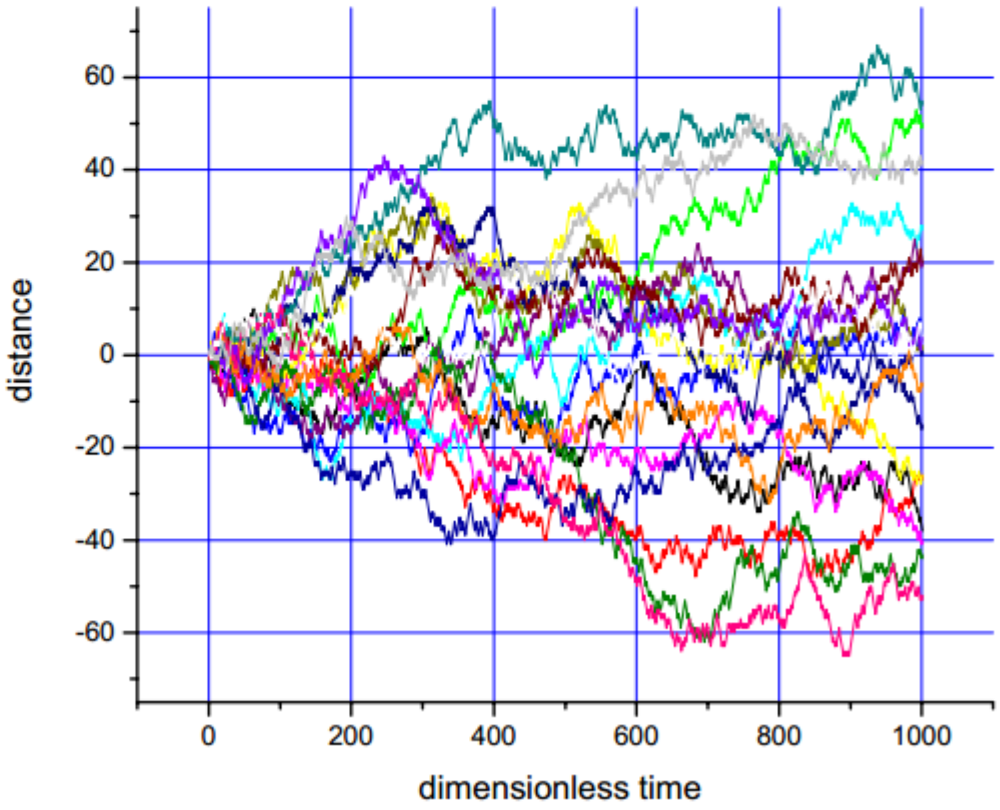


Figure 3

Allan Variance (Reference 2)

Allan Variance is a time domain analysis technique originally designed for characterising noise and stability in clock systems. The technique can be applied to any signal to determine the character of the underlying noise processes. The Allan Variance of a signal is a function of averaging time. For an averaging time t, the Allan Variance is computed as follows:

1. Take a long sequence of data and divide it into bins of length t. There must be enough data for at least 9 bins (otherwise the results obtained begin to lose their significance).

2. Average the data in each bin to obtain a list of averages $(a(t)_1, a(t)_2, ..., a(t)_n)$, where n is the number of bins.

3. The Allan Variance is then given by

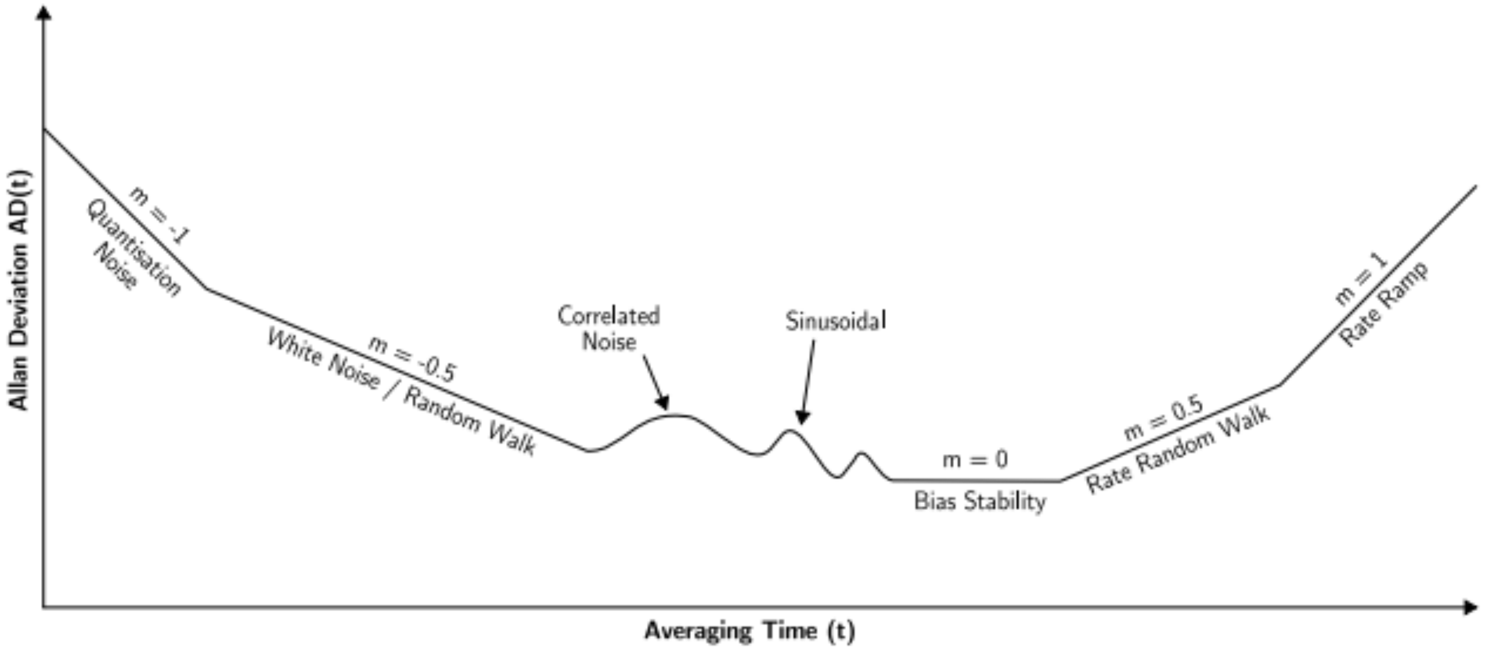
$$\mathrm{AVAR}(t) = \frac{1}{2 \cdot (n-1)} \sum_i \left(a(t)_{i+1} - a(t)_i\right)^2 \tag{19}$$

To determine the characteristics of the underlying noise processes, Allan Deviation

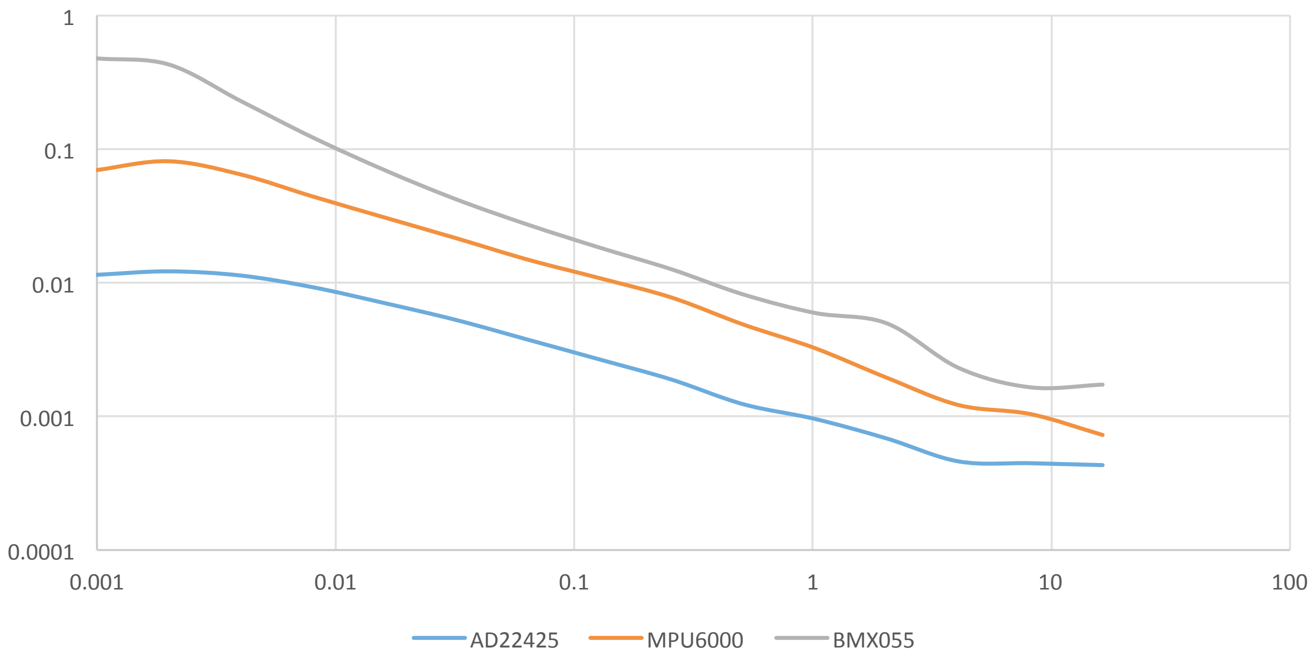
$$\mathrm{AD}(t) = \sqrt{\mathrm{AVAR}(t)} \tag{20}$$

is plotted as a function of t on a log-log scale. Different types of random process cause slopes with different gradients to appear on the plot, as shown in Figure 10. Furthermore different processes usually appear in different regions of t, allowing their presence to be easily identified.

Allan Variance (Reference 2)



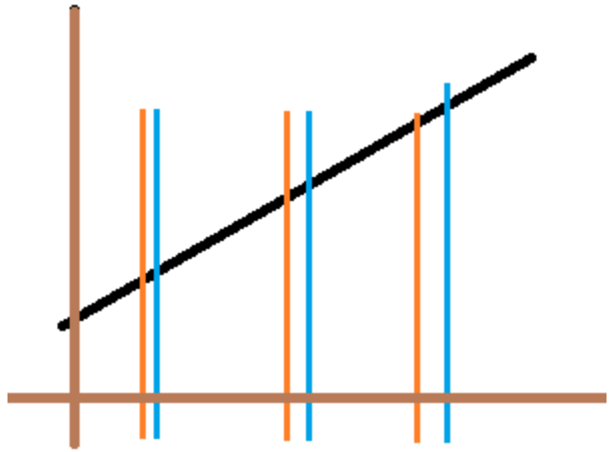
Allan Variance Comparison



Parameter	Units	AD22425	BMX055	MPU6000
Bias Instability	(°/hr)	1.6 (@ 16 sec)	8.3 (@ 4 sec)	2.6 (@ 16 sec)
Angle Random Walk	$(°/\sqrt{hr})$	0.06	0.36	0.20

Digital Gyro Considerations

- On digital sensors, you get an asynchronous sample because the internal sample rate is not synchronized to your servo rate
  - Gyro value is the black line
  - Servo runs on the orange lines
  - Gyro is sampled on the blue lines



  - Why does it matter?
    - Value used is different than the actual value when the servo ran
    - Delay between gyro reading and usage in the servo code is changing and this affects the phase delay
    - Due to clock frequency difference between the servo rate and the gyro conversion rate, you can miss data
      - When you read the gyro, it may return 0 or MAX value or a stale value

Digital Gyro Considerations (cont.)

- Since gyros are noisy, if every servo interrupt, you add the gyro output to the previous gyro position, you'll get very noisy results

- I compute the standard deviation of the data I gather for the Alan variance calculation to create a deadband that is 3 * the standard deviation
  - Only if the absolute value of the gyro output is outside the deadband, I add the gyro output to the previous gyro position, otherwise, I do nothing
    - This seems to be less noisy
    - You can easily model this in Excel

Characterizing Your Gyro / Accelerometer

- The steps are:
  - At the sample rate you intend to use, record one minute of data
  - Run the data through AlaVar[3] to get the Allan Variance on your data set
  - Compare the results to what the vendor publishes and what others have measured
- Slide I showed used data Peter Harrison and I captured:
  - 60,000 samples @ 1kHz for each of the gyros and ran the information through AlaVar Analysis Software (reference 4)

Analyze Data Using AlaVar

- To analyze data from your mouse with AlaVar, do the following:
  1. Grab data with the mouse sitting still and format it as shown below
  2. Convert gyro reading degrees per second units
  3. Compute the average for the data from step #2
  4. Format the data as shown below and then load it into AlaVar
  5. Take the average from step #3 and type that into the PreProcess “Add a Constant a =” cell
  6. Check the “Add a Constant a =” box
  7. Click the “PreProcess” button
  8. Set Tau to the sample rate
     In this analysis, we entered 0.001 since the data was grabbed every millisecond
  9. Turn off all graphs except ADEV
  10. Click the “Process” button
  11. Turn on Fixed Slope (which should be set to -0.5)
  12. Click the “Fit” button

- The flat part at the bottom of the ADEV graph is the Bias Instability in °/sec. To convert to °/hr, multiply by 3600
- The Angle Random Walk is ADEV(tau=1) value in $°/\sqrt{sec}$ To convert to $°/\sqrt{hr}$, multiply by 60

AlaVar Data File Format

- To use your data with AlaVar, format it as follows:
- First four lines can be any text. I use them the describe the data
- Starting with line five, the first column is the sampling time and the second column is the gyro data in degrees per second

NOTE: I’ve found that AlaVar wants the time to be in exponent format; I don’t know why

First Few Lines Of Data From The File Used For The AD22425 Analysis

Average

60 seconds capture

Blank

Time	AD22425 (deg/s)
0.00E+00	-0.013413173
1.00E-03	-0.005809973
2.00E-03	0.023335627
3.00E-03	0.043610827
4.00E-03	0.001793227
5.00E-03	-0.009611573

<rest of data deleted>

References

1. Evaluating inertial measurement units, Ramon Chow, Epson Electronics America
   http://www.edn.com/design/test-and-measurement/4389260/Evaluating-inertial-measurement-units

2. An introduction to inertial navigation, Oliver Woodman, University of Cambridge
   http://www.cl.cam.ac.uk/techreports/UCAM-CL-TR-696.pdf

3. Gyroscope information
   http://www.vectornav.com/support/library/gyroscope

4. AlaVar Analysis Software
   http://www.alamath.com/alavar/

5. Random Drift In The MemSense Product Line, Samuel French, MemSense