# Imu 模型_allen 法分析噪声

## 1.Summary

（1）学习了 kalibr_allan，理解了 white-noise 和 bias 的含义和计算方法，也理解了 param.h 中的噪声系数的含义，可以从 allen 曲线上计算噪声系统，并且能够和 imu 器件的 datasheet 相对应；

（2）生成了 imu 的噪声数据，用 imu_utils 进行了分析，直接分析 allen 曲线，发现有的噪声系数可以和代码对应，有的似乎不能对应；时间局限，没有仔细寻找原因；

（3）问题：对 imu_utils 输出的结果，mytest_imu_param.yaml 中的数据不理解，.yaml 中的 unit 是" rad/s"和" m/s^2"，不是噪声系数的单位，不知道如何与代码 param.h 中的噪声系数相对应？

（4）学习 kalibr_allan 中，结合 imu 器件的 datasheet，有一些问题：

[a]datasheet 中的 In-Run Bias Stability 表示 $\sigma_{bg}$ and $\sigma_{ba}$ 的准确度吧？

[b]实际使用中如何将 allen 方差标定的 $\sigma_{bg}$ and $\sigma_{ba}$ 和 In-Run Bias Stability 相结合使用呢？

## 2.kalibr_allan 的学习

（1） datasheet 中的 gyr 的 Angular Random Walk 是 white-noise; 即 allen 曲线中计算的 $\sigma = 0.000141$ rad/s$^1$sqrt(Hz)；

datasheet 中为： 0.66 | °/√hr

转换单位，结果为：

$$0.66\,\frac{\frac{\pi}{180}}{\sqrt{3600}} = \frac{0.66\cdot\pi}{180\cdot 60} = 1.9e-4$$

$$= 0.00019\ \text{rad}/\sqrt{s}$$

基本上和 allen 曲线对应；

（2） datasheet 中的 acc 的 Velocity Random Walk 是 white-noise， 即 allen 曲线中计算的 $\sigma = 0.001694$ m/s$^2$sqrt(Hz)

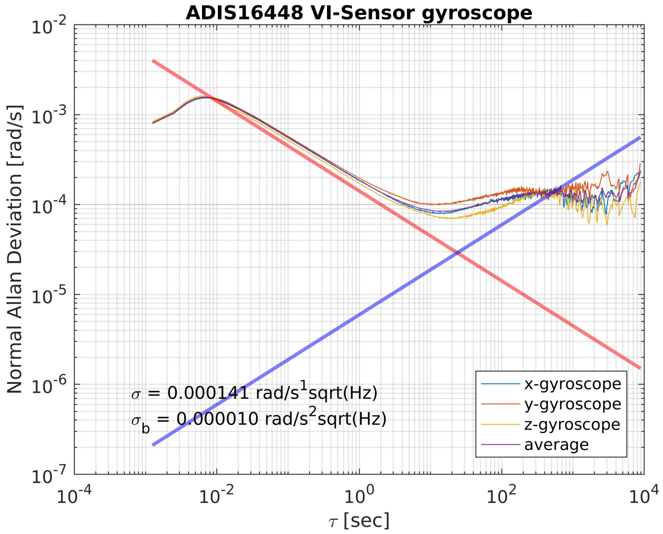
datasheet 中为： 0.11 | m/sec/√hr

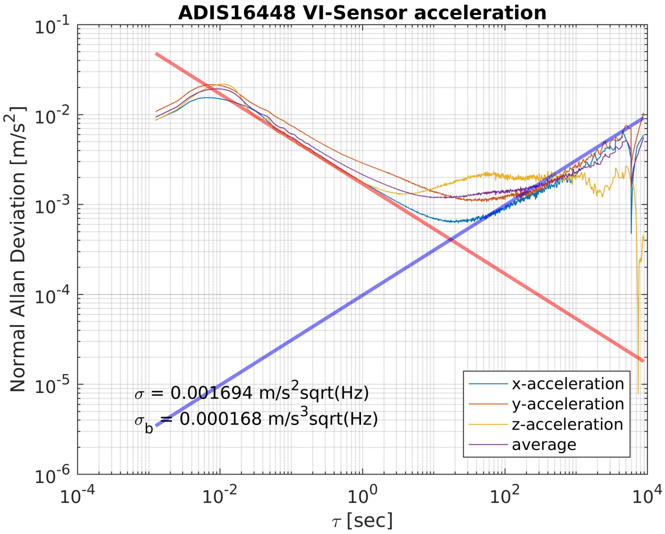
$$0.11\,\frac{1}{\sqrt{3600}} = \frac{0.11}{60} = 0.00183$$

$$m/s^2 sqrt(Hz)$$

转换单位，结果为：

基本上和 allen 曲线对应；




**ADIS16448** Data Sheet

## SPECIFICATIONS

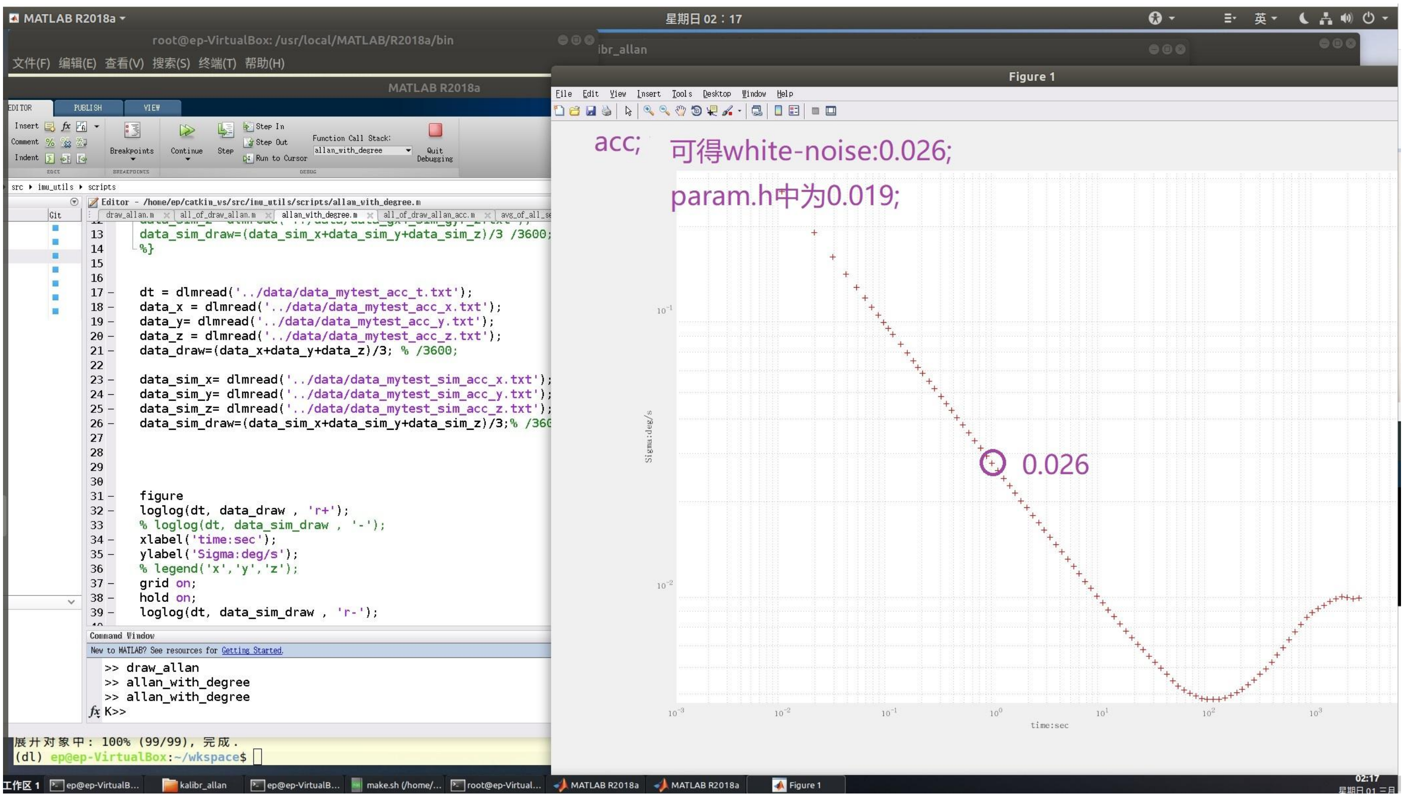
| Parameter | Test Conditions/Comments | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| GYROSCOPES | | | | | |
| Dynamic Range | | ±1000 | ±1200 | | °/sec |
| Initial Sensitivity | ±1000°/sec, see Table 12 | | 0.04 | | °/sec/LSB |
| | ±500°/sec, see Table 12 | | 0.02 | | °/sec/LSB |
| | ±250°/sec, see Table 12 | | 0.01 | | °/sec/LSB |
| Repeatability[1] | −40°C ≤ $T_A$ ≤ +85°C | | | 1 | % |
| Sensitivity Temperature Coefficient | −40°C ≤ $T_A$ ≤ +85°C | | ±40 | | ppm/°C |
| Misalignment | Axis to axis | | ±0.05 | | Degrees |
| | Axis to frame (package) | | ±0.5 | | Degrees |
| Nonlinearity | Best fit straight line | | ±0.1 | | % of FS |
| Bias Repeatability[1, 2] | −40°C ≤ $T_A$ ≤ +85°C, 1 σ | | 0.5 | | °/sec |
| In-Run Bias Stability | 1 σ, SMPL_PRD = 0x0001 | | 14.5 | | °/hr |
| Angular Random Walk | 1 σ, SMPL_PRD = 0x0001 | | 0.66 | | °/√hr |
| ACCELEROMETERS | Each axis | | | | |
| Dynamic Range | | ±18 | | | *g* |
| Sensitivity | See Table 16 for data format | | 0.833 | | m*g*/LSB |
| Repeatability[1] | −40°C ≤ $T_A$ ≤ +85°C | | | 1 | % |
| Sensitivity Temperature Coefficient | −40°C ≤ $T_A$ ≤ +85°C | | ±40 | | ppm/°C |
| Misalignment | Axis to axis | | 0.2 | | Degrees |
| | Axis to frame (package) | | ±0.5 | | Degrees |
| Nonlinearity | Best fit straight line | | 0.2 | | % of FS |
| Bias Repeatability[1, 2, 3] | −40°C ≤ $T_A$ ≤ +85°C, 1 σ | | 20 | | m*g* |
| In-Run Bias Stability | 1 σ, SMPL_PRD = 0x0001 | | 0.25 | | m*g* |
| Velocity Random Walk | 1 σ, SMPL_PRD = 0x0001 | | 0.11 | | m/sec/√hr |

# 3．imu_utils 的学习

（1）　安装了 imu_utils，运行生成了 imu 噪声，用 imu_utils 进行了处理，生成了.txt 和 mytest_imu_param.yaml；

（2）　用 matlab 程序查看 allen 曲线，根据曲线计算噪声系数；

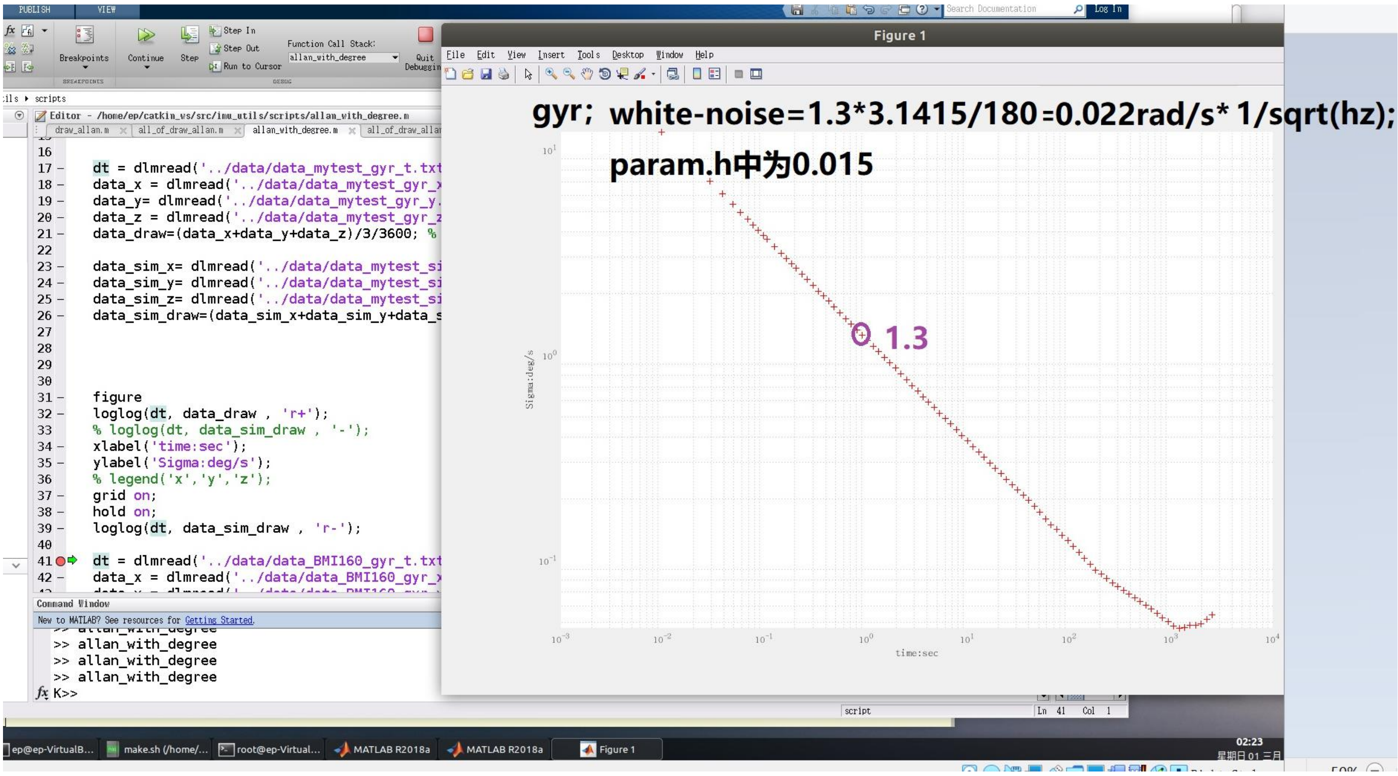
[a] acc 的 white-noise 计算如下图；基本上和 code 的 param.h 对应；




[b] gyr 的 white-noise 如下图：

如果 imu_utils 的分析程序保存的.txt 文件中的单位是 deg/sec，那么 allen 曲线中的值基本上能和 code 的 param.h 对应；

如果保存的单位是 rad/sec，那么则无法对应，**时间局限，没有仔细研究“单位”问题**；




[c]时间局限，没有计算 bias；

（3） 查看 mytest_imu_param.yaml，其中应该是计算得到的噪声系数；

问题：**对 imu_utils 输出的结果，mytest_imu_param.yaml 中的数据不理解，.yaml 中的 unit 是" rad/s"和" m/s^2"，不是噪声系数的单位，不知道如何与代码 param.h 中的噪声系数相对应**？

以下为 mytest_imu_param.yaml 的内容：

---

type: IMU

```yaml
name: mytest
Gyr:
  unit: " rad/s"
  avg-axis:
    gyr_n: 2.1179373392200354e-01
    gyr_w: 7.7286413876991717e-04
  x-axis:
    gyr_n: 2.1336982205731223e-01
    gyr_w: 1.1139183174148734e-03
  y-axis:
    gyr_n: 2.1326625525377810e-01
    gyr_w: 7.3339197827198676e-04
  z-axis:
    gyr_n: 2.0874512445492033e-01
    gyr_w: 4.7128212062289102e-04
Acc:
  unit: " m/s^2"
  avg-axis:
    acc_n: 2.6920222386658110e-01
    acc_w: 3.7094606309429883e-03
  x-axis:
    acc_n: 2.6325107920953139e-01
    acc_w: 3.6588656216941778e-03
  y-axis:
    acc_n: 2.7384195872049905e-01
    acc_w: 3.6158494895211584e-03
  z-axis:
    acc_n: 2.7051363366971282e-01
    acc_w: 3.8536667816136279e-03
```


# 4. datasheet 参数和 bias 的关系

学习 kalibr_allan 中，结合 imu 器件的 datasheet，有一些问题：

[a]datasheet 中的 In-Run Bias Stability 表示 $\sigma_{bg}$ and $\sigma_{ba}$ 的准确度吧？而不是 $\sigma_{bg}$ and $\sigma_{ba}$ 吧？

[b]实际使用中如何将 allen 方差标定的 $\sigma_{bg}$ and $\sigma_{ba}$ 和 In-Run Bias Stability 相结合使用呢？

https://github.com/ethz-asl/kalibr/wiki/IMU-Noise-Model#from-the-allan-standard-deviation-ad

Bias Terms In contrast to the "white noise sigmas", $\sigma_{bg}$ and $\sigma_{ba}$ are rarely directly specified in the datasheet. The reason is that in practice, the bias does not truly behave like a "random walk" for longer integration times. Often, the so-called in-run bias (in)stability is specified instead. This sensor parameter indicates (approximately) the accuracy with which the bias can be determined (if a random process is the sum of "white noise" and a "random walk" bias, the bias can not be estimated with arbitrarily low uncertainty at any point in time). In combination with the strength of the "white noise", however, one can often use the in-run bias stability (the lowest point in the Allan standard deviation, see below) to determine reasonable values for $\sigma_{bg}$ and $\sigma_{ba}$ (assuming that the noise is dominated by "white noise" and a "random walk").

adis16448.pdf



| | | | | | |
|---|---|---|---|---|---|
| GYROSCOPES | | | | | |
| Dynamic Range | | ±1000 | ±1200 | | °/sec |
| Initial Sensitivity | ±1000°/sec, see Table 12 | | 0.04 | | °/sec/LSB |
| | ±500°/sec, see Table 12 | | 0.02 | | °/sec/LSB |
| | ±250°/sec, see Table 12 | | 0.01 | | °/sec/LSB |
| Repeatability[1] | −40°C ≤ $T_A$ ≤ +85°C | | | 1 | % |
| Sensitivity Temperature Coefficient | −40°C ≤ $T_A$ ≤ +85°C | | ±40 | | ppm/°C |
| Misalignment | Axis to axis | | ±0.05 | | Degrees |
| | Axis to frame (package) | | ±0.5 | | Degrees |
| Nonlinearity | Best fit straight line | | ±0.1 | | % of FS |
| Bias Repeatability[1, 2] | −40°C ≤ $T_A$ ≤ +85°C, 1 σ | | 0.5 | | °/sec |
| In-Run Bias Stability | 1 σ, SMPL_PRD = 0x0001 | | 14.5 | | °/hr |
| Angular Random Walk | 1 σ, SMPL_PRD = 0x0001 | | 0.66 | | °/√hr |
| Bias Temperature Coefficient | −40°C ≤ $T_A$ ≤ +85°C | | 0.005 | | °/sec/°C |
| Linear Acceleration Effect on Bias | Any axis, 1 σ | | 0.015 | | °/sec/*g* |
| Bias Supply Sensitivity | −40°C ≤ $T_A$ ≤ +85°C | | 0.2 | | °/sec/V |
| Output Noise | ±1000°/sec range, no filtering | | 0.27 | | °/sec rms |
| Rate Noise Density | f = 25 Hz, ±1000°/sec range, no filtering | | 0.0135 | | °/sec/√Hz rm |
| −3 dB Bandwidth | | | 330 | | Hz |
| Sensor Resonant Frequency | | | 17.5 | | kHz |
| ACCELEROMETERS | Each axis | | | | |
| Dynamic Range | | ±18 | | | *g* |
| Sensitivity | See Table 16 for data format | | 0.833 | | m*g*/LSB |
| Repeatability[1] | −40°C ≤ $T_A$ ≤ +85°C | | | 1 | % |
| Sensitivity Temperature Coefficient | −40°C ≤ $T_A$ ≤ +85°C | | ±40 | | ppm/°C |
| Misalignment | Axis to axis | | 0.2 | | Degrees |
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| Bias Repeatability[1, 2, 3] | −40°C ≤ $T_A$ ≤ +85°C, 1 σ | | 20 | | m*g* |
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