MEMS Gyroscope Metrics

1. Scale Factor : S

def : The ratio of change in output to a change in input

$[S] = mV/°/s$

→ evaluated as the slope of the least squares straight line fit to the input-output data

a. Scale Factor Errors

① Linearity Error – linear deviation from the least squares straight line fit

② Nonlinearity Error – nonlinear deviation from the least squares straight line fit

③ Scale Factor Temperature Sensitivity

④ Scale Factor Acceleration Sensitivity

⑤ Asymmetry Error – the difference in the scale factor between a $+\Omega$ input and a $-\Omega$ input

⑥ Scale Factor Stability – how the scale factor varies over time of continuous gyro operation

2. Bias

def : the average gyro output voltage with zero input

ex: 2.5V is a common bias

$\therefore V_{OUT} > 2.5V$ for $\Omega > 0$ °/s

$V_{OUT} < 2.5V$ for $\Omega < 0$ °/s

a. <u>Bias Error</u> : ε

Typically expressed in °/hr

∴ Resulting angular error : $\theta_\varepsilon(t) = \varepsilon t$ → for zero input

b. <u>Noise on Bias</u>

The gyro's output is perturbed by zero-mean thermomechanical noise, which has an effect on the output signal

① <u>Angle Random Walk</u>

- The angular error buildup with time that is due to white noise in angular rate.

  Typically expressed in $°/\sqrt{hr}$ or $°/s/\sqrt{hr}$

* remember : $\dot{\theta}_{meas}$ is produced, while $\theta(t)$ is desired :

$$\theta(t) = \int_0^t \dot{\theta}_{meas}\, dt, \text{ and } \dot{\theta}_{meas} \text{ is noisy}$$

② <u>Bias Stability</u>

- The random variation in bias as computed over a specified finite time, and averaging time intervals

  Typically expressed in °/hr

③ <u>Rate Random Walk</u>

- The drift rate error buildup with time due to white noise in angular acceleration

  Typically expressed in $°/hr/\sqrt{hr}$

④ <u>Other Related Bias Error Metrics</u>

i. <u>Power Spectral Density</u> (PSD) : $(°/hr)^2/Hz$

ii. <u>FFT Noise Density</u> : $(°/hr)/\sqrt{Hz}$

iii. <u>Noise Density</u> (or rate noise density)

$°/s/\sqrt{Hz}$ → note : $\sqrt{Hz} = \sqrt{BW}$

⑤ Bias Offset Calibration Error

- If the bias has a fixed DC offset → then the measurement of Ω will be off a fixed amount at all times
- An easy error to measure and correct for

⑥ Temperature Induced Bias Offset

- temperature can be measured on chip and used to null this error

3. Operating Characteristics

a. Resolution

- The nominal minimum detectable change in input

b. Bandwidth

- The (typically 3dB) range in frequency of the angular rate input that can be detected

c. Turn-On Time

- time from power on to useful output

d. Linear and Angular Vibration Sensitivity

e. Mechanical Shock Resistance

f. Power Supply Sensitivity

① max/min voltages

② PSRR

③ Effect of supply voltage on output:

→ °/s/V