PRODUCT SPECIFICATION

PRODUCT TYPE: AC-1

PRODUCT DESCRIPTION: QUARTZ ACCELEROMETER

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1. Introduction

AC-1 quartz flexible accelerometer series is a high-precision military inertial navigation class accelerometer with excellent long-term stability, repeatability, start-up performance, environmental adaptability and high reliability. It can be used for both static and dynamic testing, and it is also a standard vibration sensor and inclination sensor.

The output current of the product has a linear relationship with the force or acceleration received. Users can select the appropriate sampling resistance through calculation to achieve high precision output. And according to user needs built-in temperature sensor, used to offset value and scale factor compensation, reduce the impact of environmental temperature.

Applications: inertial measurement of military high-precision inertial navigation system and vibration isolation test of precision instruments and equipment in aerospace, aviation, ships, weapons and other fields.

2. Main parameter

Parameters	AC-1A	AC-1B	AC-1C	Unit
Range	±50 （10Ω）			g
Threshold /Resolution	1	2	3	μg
Bias k0/k1	≤±1	≤±3	≤±5	mg
Scale factor kl	1.05~1.30			mA/g
Class II nonlinearity coefficient k2/k1	≤±10	≤±15	≤±20	μg /g2
0g 4 hours short time stability	≤10	≤10	≤15	μg
1g 4 hours short time stability	≤10	≤10	≤15	ppm
Bias drift Sigma k0(1σ， one month)	≤10	≤20	≤30	μg
Repeatability of scale factor Sigma kl/kl（1σ, one month)	≤15	≤30	≤50	ppm
Class II nonlinearity Coefficient repeatability k2/k1 (1σ, one month)	≤±10	≤±20	≤±30	μg /g2
Bias thermal coefficient	≤±10	≤±30	≤±50	μg /℃
Scale factor thermal coefficient	≤±10	≤±30	≤±50	ppm /℃
Noise (sample resistance 840Ω)	≤5	≤8.4	≤8.4	mv
Natural Frequency	400~800			Hz
Bandwidth	800~2500			Hz
Vibration	6g			Hz
Shock	100g			8ms, 1/2s in
Temperature range (Operating)	-55~+85			℃
Temperature range (saved)	-60~+120			℃
Power	±12~±15			V
Consume current	≤±20			mA
Temp. sensor	PT1000/AD590			Optional
Size	Φ25.4X30			mm
Weight	≤80			g

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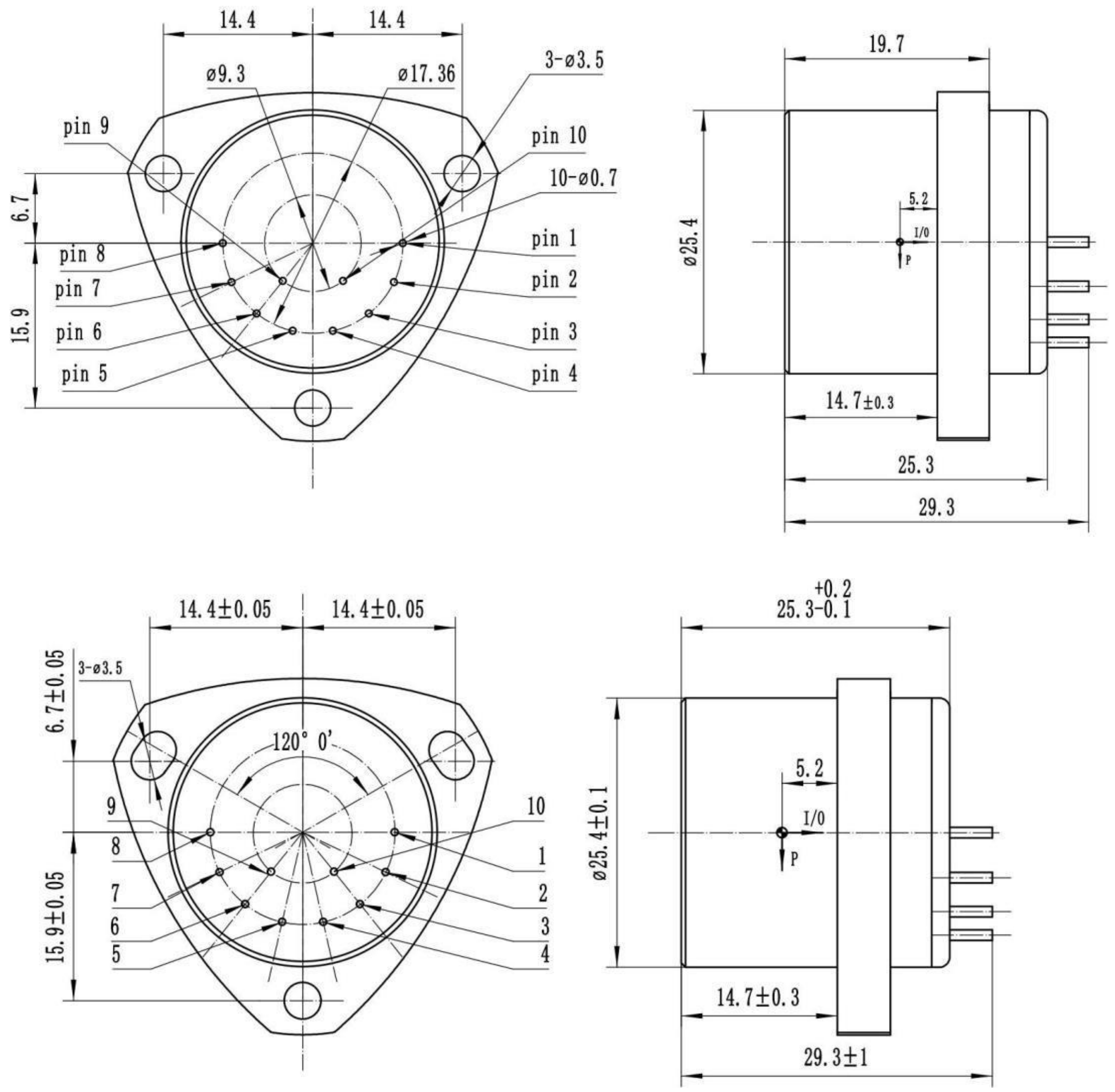
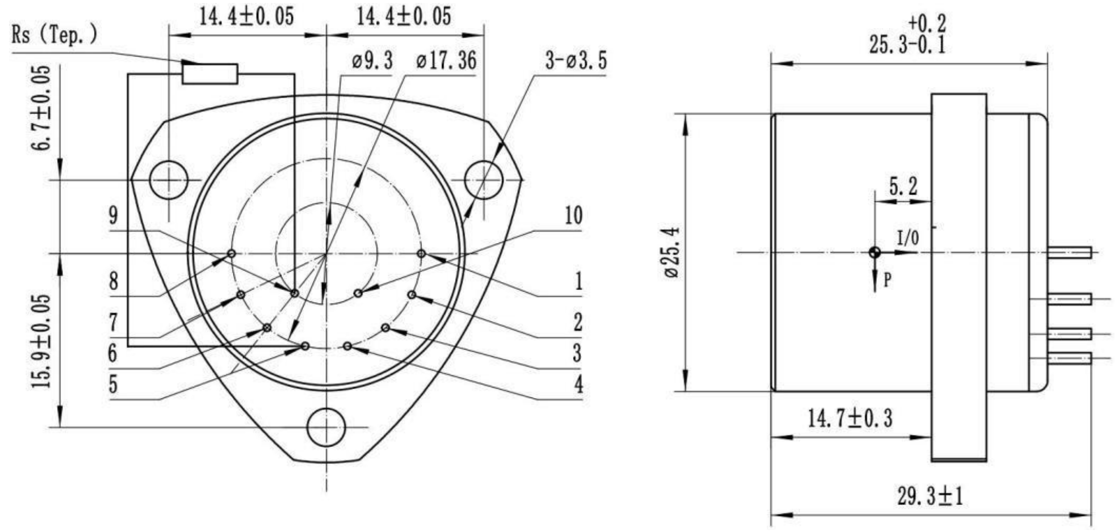
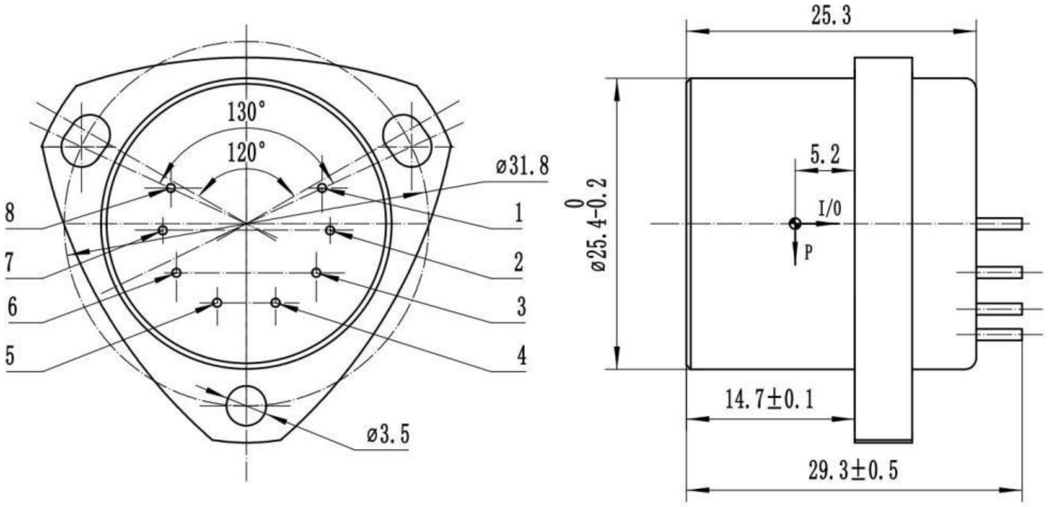
3. Configuration drawing and interface



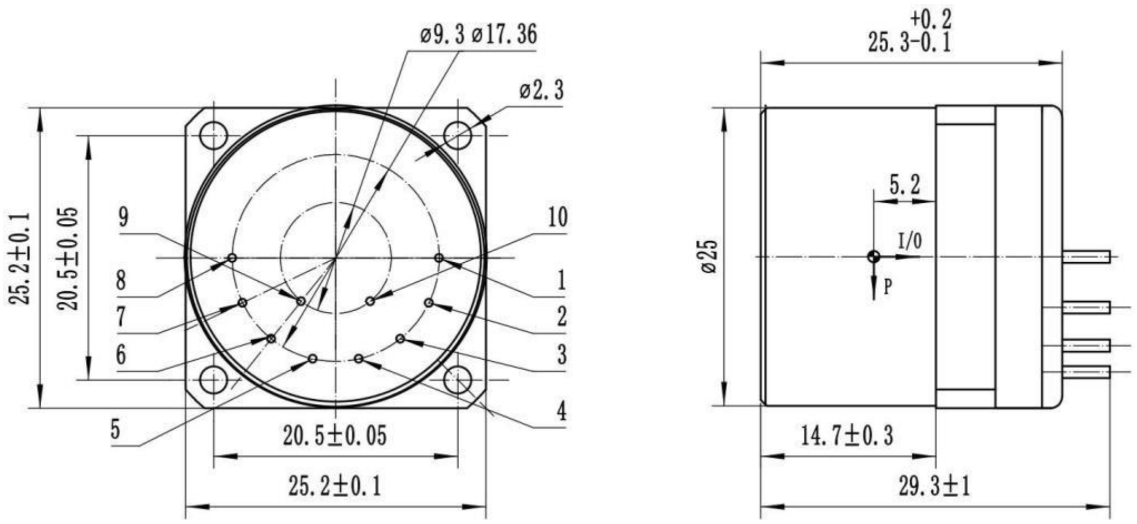
Mark: Default temperature sensor: PT1000 (AD590 Optional); Point 10 is the high power. The point 9 is the low power. The point 9 and power ground use one platinum resistance; the value is 1K, the thermal coefficient is less than 5ppm.



Install hole is U type



Install hole is U type, 8 Pin



The outline is square

4. Methodology

4.1 Scope

The technical requirements for Accelerometer are defined in Section 3.

4.2 Applicable documents

IEEE 1293-1998:	IEEE Standard Specification Format Guide and Test Procedure for Linear, Single-Axis, Nongyroscopic Accelerometers
IEEE 337-1972:	IEEE Standard Specification Format Guide and Test Procedure for Linear, Single-Axis, Pendulous, Analog, Torque Balance Accelerometers
IEEE 530-1978:	IEEE Standard Specification Format Guide and Test Procedure for Linear, Single-Axis, Digital, Torque Balance Accelerometers
IEEE 836-2001:	IEEE Recommended Practice for Precision Centrifuge Testing of Linear Accelerometers
EEE 836-2001:	IIEEE Recommended Practice for Inertial Sensor Test Equipment, Instrumentation, Data Acquisition and Analysis
IEEE 528-2001:	IEEE Standard Inertial Sensor Terminology

4.3 Requirements

The Accelerometer requirements not specified in this document shall conform to the documents mentioned in 2.

4.3.1 Type

The Accelerometer shall be linear, single-axis, torque-balance and non-gyroscopic.

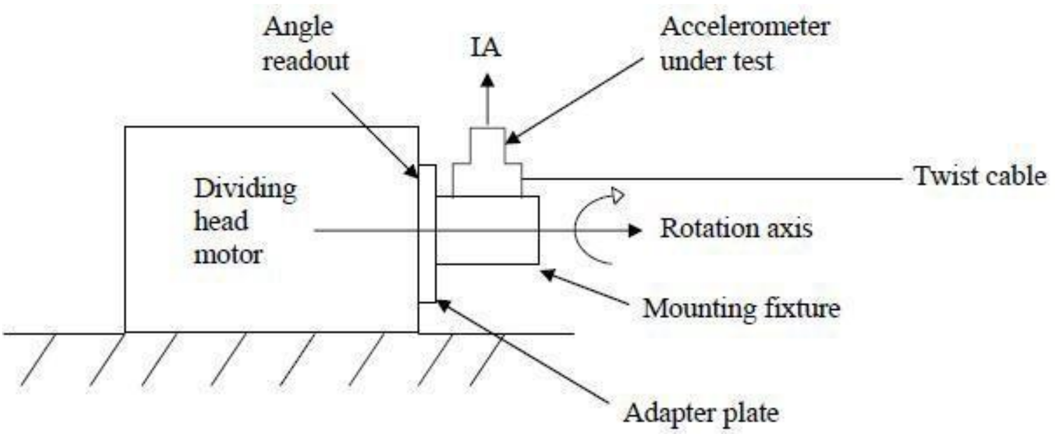
4.3.2 Application

The Accelerometer shall be used in inertial navigation and control systems of aerospace vehicles.

4.3.3 Scale factor parameters

The required instrumentation for bias /scale factor/ second order nonlinearity repeatability measurements is given below:

- Mult-tooth index head for rotating the Accelerometer
- Rotating fixture for fixing the Accelerometer
- Environmental test cabin for changing the measurement temperature
- Electronics for reading and storing the Accelerometer measurements



Repeatability test equipment

Figure 1: The Layout of Accelerometer Rotation Test Setup

4.3.4 Scale factor

The scale factor of the Accelerometer shall be 1±0.15 or 0.8±0.2mA/g. The calculation of the scale factor shall be as follows:

$$K_1 = \frac{I_0 + I_{180}}{2} \quad (1)$$

$K_1 = Scale\ factor$

$I_0 = The\ output\ of\ the\ Accelerometer\ at\ 0^o\ \vec{TA}\ antiparallel\ to\ \vec{g}$

$I_{180} = The\ output\ of\ the\ Accelerometer\ at\ 180^o\ \vec{TA}\ parallel\ to\ \vec{g}$

4.3.5 Scale factor temperature coefficient

Temperature coefficient value test equipment

The scale factor temperature coefficient of the Accelerometer shall be smaller than 50ppm/°C. The calculation of the scale factor temperature coefficient shall be as follows:

$$\zeta_{K_1}(T_1 \ldots T_2) = \frac{K_1(T_2) - K_1(T_1)}{T_2 - T_1} \qquad (2)$$

$\zeta_{K_1}(T_1 \ldots T_2)$: *Scale factor temperature coefficient between* T_1 *and* T_2

T_1: *Initial temperature*

T_2: *Final Temperature*

$K_1(T_1)$: *Scale factor at* T_1

$K_1(T_2)$: *Scale factor at* T_2

We will test it from -55℃~+85℃, the temperature point from -55℃, -35℃, -15℃, 5℃, 25℃, 45℃, 65℃, 85℃

Temperature coefficient δk1(-55 ～+85℃)= 【 δ(-55 ～-35℃)+ δ(-35 ～-15℃)+

δ(-15 ～+5℃)+ δ(+5 ～+25℃)+ δ(+25 ～+45℃)+ δ(+45 ～+65℃)+ δ(+65 ～+85℃)】/7

4.3.6 Scale factor repeatability (1/3months)

The scale factor repeatability (1/3months) of the Accelerometer shall be 30ppm or 50ppm. The calculation of the scale factor repeatability (1/3months) shall be as follows (the Accelerometer shall be turned off after the initial measurement):

The scale factor repeatability (1/3months) of the Accelerometer shall be smaller than 50ppm. The calculation of the scale factor repeatability (1/3months) shall be as follows (the Accelerometer shall be turned off after the initial measurement): we will test it 10 times（10 days one time), we will get 10 data K1(0), K1(1), K1(2), K1(3), K1(4), K1(5), K1(6), K1(7), K1(8), K1(9)

$$\overline{k_1} = \frac{\sum_{i=0}^{9} k_1(i)}{10}$$

$$\sigma k_1 / \overline{k_1} = \sqrt{\frac{\sum_{i=0}^{9}\left(k_1(i) - \bar{k}_1\right)^2}{10-1}} \Big/ \overline{k_1}$$

4.4 Bias parameters

The required instrumentation for bias measurements is the same as scale factor measurements.

4.4.1 Bias

The bias of the Accelerometer shall be smaller than 4 mg. The calculation of the bias shall be as follows:

$$K_0 = \frac{I_{270} - I_{90}}{2 \times K_1} \qquad (4)$$

$$K_0 = Bias$$

$$I_{270} = The\ output\ of\ the\ Accelerometer\ at\ 270^o$$

$$I_{90} = The\ output\ of\ the\ Accelerometer\ at\ 90^{\circ}$$

4.4.2 Bias temperature coefficient

The test equipment is same as scale factor

The bias temperature coefficient of the Accelerometer shall be 50μg/°C. The calculation of the bias temperature coefficient shall be as follows:

$$\zeta_{K_0}(T_1 \ldots T_2) = \frac{K_0(T_2) - K_0(T_1)}{T_2 - T_1} \qquad (5)$$

$\zeta_{K_0}(T_1 \ldots T_2)$: *Bias temperature coefficient between T_1 and T_2*

T_1: *Initial temperature*

T_2: *Final Temperature*

$K_0(T_1)$: *Bias at T_1*

$K_0(T_2)$: *Bias at T_2*

We will test it from -55℃~+85℃, the temperature point from -55℃, -35℃, -15℃, 5℃, 25℃, 45℃, 65℃, 85℃

Temperature coefficient δk0(-55 ～ +85℃)= 【 δ(-55 ～ -35℃)+ δ(-35 ～ -15℃)+ δ(-15～+5℃)+ δ(+5～+25℃)+ δ(+25～+45℃)+ δ(+45～+65℃)+ δ(+65～

4.4.3 Bias repeatability (1/3months)

Bias repeatability (1 months) of the Accelerometer shall be smaller than 20μg or 40μg.

The calculation of the bias repeatability (1 months) shall be as follows (the Accelerometer shall be turned off after the initial measurement):

(According to the requirements of technical indicators to decide whether to use 1 month or 3 months standard)

$$\Delta_{K_0}(0 \ldots 3M) = \frac{K_0(3M) - K_0(0)}{2} \qquad (6)$$

$\Delta_{K_0}(0 \dots 3M)$: *Bias repeatability for 3 months*

$K_0(3M)$: *Bias measurement after 3 months*

$K_0(0)$: *Initial bias measurement*

Bias repeatability (1/3months) of the Accelerometer shall be smaller than 20μg or 40μg. The calculation of the bias repeatability (1/3months) shall be as follows (the Accelerometer shall be turned off after the initial measurement): we will test it 10 times (10 days one time) ,we will get 10 data K0(0), K0(1), K0(2), K0(3), K0(4), K0(5), K0(6), K0(7), K0(8), K0(9)

$$\overline{k_0} = \frac{\sum_{i=0}^{9} k_0(i)}{10}$$

$$\sigma k_0 = \sqrt{\frac{\sum_{i=0}^{9}\left(k_0(i) - \bar{k}_0\right)^2}{10-1}}$$

4.4.4 Bias drift

Bias drift of the Accelerometer shall be smaller than 100μg. The calculation of the bias drift shall be as follows:

Take and record 30 Accelerometer measurements, each averaged over 30 seconds. The bias drift is the standard deviation of those 30 measurements.

BIAS DRIFT VARIATION UNDER RANDOM VIBRATION

Bias drift variations of the Accelerometer before, during and after the random vibration shall be 50μg. The calculation of the bias drift variation shall be as follows:

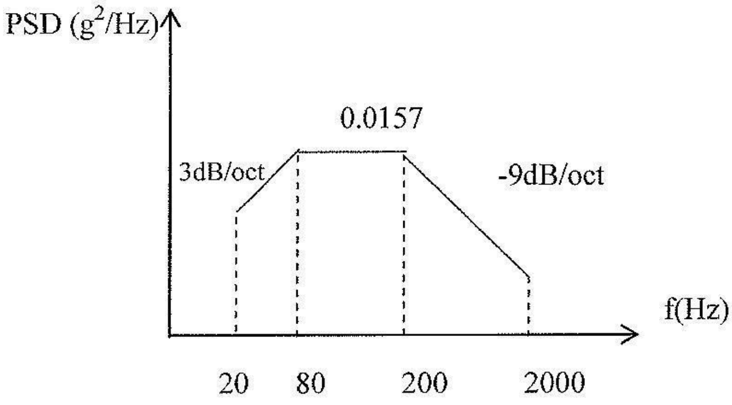


Figure 1: Random Vibration Profile

$$\Delta K_0(i \rightarrow v) = K_0(v) - K_0(i) \quad (7)$$

$$\Delta K_0(v \rightarrow f) = K_0(f) - K_0(v) \quad (8)$$

$\Delta K_0(i \rightarrow v)$: *The variation between the averages of bias drift during and before the random vibration, respectively*

$K_0(v)$: *The average of the bias drift during the random vibration*

$K_0(i)$: *The average of the bias drift before the random vibration*

$\Delta K_0(v \rightarrow f)$: *The variation between the averages of bias drift after and during the random vibration, respectively*

$K_0(f)$: *The average of the bias drift after the random vibration*

4.4.4 Bias instability

Bias instability of the Accelerometer shall be smaller than 10μg. Bias instability shall be determined from the value of Allan Variance curve where the slope is 0.

4.5 Axis misalignment parameters

The required instrumentation for axis misalignment measurements is the same as scale factor measurements.

4.5.1 Axis misalignment

Axis misalignment of the Accelerometer shall be smaller than 2000 μ rad. The calculation of axis misalignment shall be as follows:

$$\Omega\uparrow = \frac{(I_{270}\uparrow) - (I_{90}\uparrow)}{2 * K_1} \tag{9}$$

$$\Omega\rightarrow = \frac{(I_{270}\rightarrow) - (I_{90}\rightarrow)}{2 * K_1} \tag{10}$$

$\Omega\uparrow$= *Axis misalignment corresponding to original measurement position*

$I_{270}\uparrow$: *The output of the Accelerometer at 270° for original measurement position*

$I_{90}\uparrow$: *The output of the Accelerometer at 90° for original measurement position*

$\Omega\rightarrow$: *Axis misalignment corresponding to the measurement position, where the Accelerometer is rotated 90° clockwise*

$I_{270}\rightarrow$: *The output of the Accelerometer at 270° for the measurement position, where the Accelerometer is rotated 90° clockwise*

$I_{90}\rightarrow$: *The output of the Accelerometer at 90° for the measurement position, where the Accelerometer is rotated 90° clockwise*

4.5.2 Axis misalignment repeatability

Axis misalignment repeatability of the Accelerometer shall be smaller than 500μrad. The calculation of axis misalignment repeatability shall be as follows (the Accelerometer shall be turned off after the initial measurement):

$$\Delta\Omega\uparrow=\frac{(\Omega\uparrow_f)-(\Omega\uparrow_i)}{2} \tag{11}$$

$$\Delta\Omega\rightarrow=\frac{(\Omega\rightarrow_f)-(\Omega\rightarrow_i)}{2} \tag{12}$$

$\Delta\Omega\uparrow$: *Axis misalignment repeatability for original measurement position*

$\Omega\uparrow_f$: *Final axis misalignment for original measurement position*

$\Omega\uparrow_i$: *Initial axis misalignment for original measurement position*

$\Delta\Omega\rightarrow$: *Axis misalignment repeatability for rotated measurement position*

$\Omega\rightarrow_f$: *Final axis misalignment for rotated measurement position*

$\Omega_{\to i}$: *Initial axis misalignment for rotated measurement position*

4.6 Nonlinearity parameters

The required instrumentation for nonlinearity parameters is the same as scale factor measurements.

4.6.1 Second order nonlinearity

The second order nonlinearity of the Accelerometer shall be smaller than 20μg/g2. The measurement and calculation of second order nonlinearity of the Accelerometer shall be as follows:

At each dividing head angle θ = 0°, θn, 2θn, ···, kθn ···, (n-1) θn take and record m Accelerometer measurements (E_0) for each individual position averaged over a time t, where θn = 360/n, n, m and k are integers, and 0 ≤ k ≤ n-1.

1. Take average of m measurements for each individual position.

2. Calculate the component of gravitational acceleration parallel to the measurement axis of the Accelerometer for each position

$$a = -\frac{\cos(k \times \theta_n) \times \pi}{180} \tag{13}$$

3. Make a second order equation fit of the values between Accelerometer measurements calculated in 2 and gravitational acceleration components calculated in 3:

$$E_0 = K_0 + K_1 \times a + K_2 \times a \tag{14}$$

K_2: *Second order nonlinearity*

4.6.2 Second order nonlinearity repeatability (1/3months)

The second order nonlinearity repeatability (1/3months) of the Accelerometer shall be smaller than 20μg/g2. The calculation of the second order nonlinearity repeatability (1/3months) shall be as follows (the Accelerometer shall be turned off after the initial measurement):

The second order nonlinearity repeatability (1/3months) of the Accelerometer shall be smaller than 20μg/g2. The calculation of the bias repeatability (1/3months) shall be as follows (the Accelerometer shall be turned off after the initial measurement): we will test it 10 times (10 days one time), we will get 10 data K2(0), K2(1), K2(2), K2(3), K2(4), K2(5), K2(6), K2(7), K2(8), K2(9)

$$\overline{k_2} = \frac{\sum_{i=0}^{9} k_2(i)}{10}$$

$$\sigma k_2 = \sqrt{\frac{\sum_{i=0}^{9}\left(k_2(i) - \bar{k}_2\right)^2}{10-1}}$$

4.6.3 Asymmetry

Asymmetry of the Accelerometer shall be smaller than 50ppm. The calculation of asymmetry shall be as follows:

$$\Delta K_1 = \frac{K_1(+) - K_1(-)}{K_1} \tag{16}$$

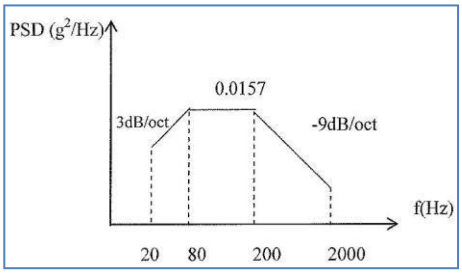
ΔK_1: *Asymmetry*

$K_1(-)$: *Scale factor coefficient for positive accelerations*

$K_1(-)$: *Scale factor coefficient for negative accelerations*

4.7 Bandwidth

Bandwidth of the Accelerometer shall be greater than 60Hz. The measurement shall be done on a digitally controlled vibrational platform. The bandwidth is defined as the frequency corresponding to a phase shift of 90°.



4.8 Angular random walk

Angular random walk of the Accelerometer shall be smaller than 50µg/ √ Hz. Angular random walk shall be determined from the value of Allan Variance curve where the slope is 1.

4.9 Acceleration range

The measurement range of the Accelerometer shall be bigger than ± 50g. The measurement shall be done on a centrifugal platform. The Accelerometer shall make meaningful maximum acceleration measurements of at least 50g.

Vibration: The Accelerometer shall be resistant to vibrations of 15g amplitude between 20-2000Hz. The measurement shall be done on a digitally controlled vibration platform. The Accelerometer shall make meaningful acceleration measurements under vibrations of 5g amplitude sweeping from 20Hz to 2000Hz.

Shock: The Accelerometer shall be resistant to half-sine wave shocks of 100g amplitude of 11 ms duration. The measurement shall be done on a digitally controlled mechanical shock platform. The Accelerometer shall make meaningful acceleration measurements under half-sine wave mechanical shocks of 100g amplitude of 11 ms duration.

Operating temperature: The Accelerometer shall be able to operate between -55°C and 125°C. The measurement shall be done in an environmental control chamber. The Accelerometer shall make meaningful acceleration measurements between -55°C and 125°C.

Resolution: The resolution of the electronic reading device for Accelerometer measurements shall be smaller than 5µg.

Weight: The Accelerometer shall be lighter than 80gr.

4.9 EMI/EMC requirements

Seller shall provide information about their quality standards, the design procedures used for EMI/EMC compliance, standards used for EMI/EMC compliance together with exceptional frequencies and their levels if any.

4.10 Calibration requirements

Seller shall define and propose the related equipment, tools and their specifications together with the related training for the user level calibration of the Accelerometer in the Proposal.

Periodical performance checks and self-tests of the Accelerometer shall be defined by Seller in the Proposal.

5. Quality assurance provision

The product provided shall meet the salient characteristics of this specification; conform to the Seller's drawings, specifications, standards and quality assurance practices. Quality conformance inspection shall be applied to the Accelerometer prior to being offered for acceptance under the contract. Failure of the Accelerometer to pass the examination, test or inspection shall be cause for rejection. The buyer reserves the right to require proof of such conformance.

No less than two operational tests shall be performed by operating the Accelerometer with pre-described processes decided by the Buyer. After these tests the Accelerometer shall be accepted.