

IEEE Standard Specification Format Guide and Test Procedure for Linear, Single-Axis, Digital, Torque-Balance Accelerometer

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IEEE Standards Board

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Foreword

(This Foreword is not a part of IEEE Std 530-1978, Specification Format Guide and Test Procedure for Linear, Single-Axis, Digital, Torque-Balance Accelerometer.)

This standard is provided as a guide for the preparation of a digital accelerometer specification and test procedure. The accelerometer considered in this standard utilizes a linear, single-axis, nongyroscopic acceleration sensor with a permanent magnet torquer. The torquing electronics are considered part of the accelerometer. The format was prepared by the Gyro and Accelerometer Panel of the Aerospace and Electronics System Society of the Institute of Electrical and Electronics Engineers. It is intended to provide a common meeting ground of terminology and practice for manufacturers and users.

The user is cautioned not to *overspecify*; only those parameters that are required to guarantee proper performance in the specific application should be controlled. In general, the specification should contain only those requirements that can be verified by test or inspection. Parameters in addition to those given in this format are not precluded. Appendix A presents a typical block diagram for response of the accelerometer to aid in specifying dynamic environmental effects on the pendulum of the acceleration sensor.

Blank spaces permit the insertion of specific parameter values and their tolerances. Brackets are used to enclose alternate choices of dimensional units, signs, axes, etc. Boxed statements are included for information only and are not part of the specification format. The figures presented are to be used as a guide for the preparation of specific figures or drawings.

The terminology used conforms to ANSI/IEEE Std 100-1977, IEEE Standard Dictionary of Electrical and Electronics Terms; and the units used conform to ANSI/IEEE Std 268-1976, Metric Practice. In this standard, the symbol g is used to denote a unit of acceleration equal in magnitude to the local value of gravity at the test site or other specified value of gravity. This symbol is thus distinguished from g which is the standard symbol for gram.

The accelerometer is used to provide a digital output which is a measure of acceleration or velocity, or both. An acceleration applied along the input axis of the acceleration sensor causes its proof mass to deflect. The pickoff error signal caused by this motion is utilized in the electronics to produce a restoring torque (see Fig 1). When static equilibrium is reached, the reaction torque of the proof mass to the average acceleration is balanced by the mean value of the restoring torque. The pulse rate required to maintain this equilibrium condition, is proportional to the average acceleration and provides a digital output.

The major contributors to this standard were the following:

N. F. Sinnott (*Chairman, 1970*)
M. D. Mobley (*Chairman, 1971*)
K. W. Komb (*Chairman, 1972*)
A. T. Campbell (*Chairman, 1973*)
H. L. Gubbins (*Chairman, 1974*)
G. E. S. Morrison (*Chairman, 1975*)
G. E. S. Morrison (*Chairman, 1976*)
C. O. Swanson (*Chairman, 1977*)

C. E. Bosson
A. M. Brady
J. Claasen
J. F. Conroy
J. H. Crittenden
H. B. Diamond
H. A. Dinter
J. A. Divine

T. A. Fuhrman
K. N. Green
J. E. Hardie
J. G. Hawkins
C. A. Jones
K. J. Klarman
M. G. Koning
W. G. Lane

A. M. Leeking
J. J. Meehan
C. F. Morley
G. C. Murray
G. H. Neugebauer
R. B. Peters
T. M. Rankin
R. F. Rathcke

H. Rogall
B. Schwartz
C. W. Spencer

C. I. Thornburg
R. Van Alstine
M. M. Van Schoiack

C. W. Wellner
B. J. Wimber
H. M. Ziegler

In addition, there were more than 100 other individuals who attended meetings of the Gyro and Accelerometer Panel and who helped develop this standard.

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IEEE Standard Specification Format Guide and Test Procedure for Linear, Single-Axis, Digital, Torque-Balance Accelerometer

1. Scope

This specification defines the requirements and test procedures for a digital accelerometer which utilizes a linear, single-axis, nongyroscopic acceleration sensor with a permanent magnet torquer (forcer) operated in a [ternary pulse mode, pulse-width modulation mode, analog mode with voltage to frequency converter, ...]. The electronics are considered to be part of the accelerometer which produces a digital output proportional to sensed velocity changes. The digital accelerometer is hereafter referred to as the accelerometer. With appropriate modifications, this specification may also be applied to force balance nonpendulous accelerometers.

2. Applicable Documents

The following documents of the issue in effect, on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein. In the event of any conflict between the requirements of this specification and the listed documents, the requirements of this specification shall govern.

Give identification number, title, date of issue, and revision letter of each listed document.
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2.1 Specifications

2.1.1 Government

2.1.2 Industry/Technical

2.1.3 Company

2.2 Standards

2.2.1 Government

2.2.2 Industry/Technical

2.2.2.1

ANSI/IEEE Std 100-1977, Dictionary of Electrical and Electronics Terms.

2.2.2.2

ANSI/IEEE Std 337-1972, Specification Format Guide and Test Procedure for Linear, Single-Axis, Pendulous, Analog Torque Balance Accelerometer.

2.2.3 Company

2.3 Drawings

2.3.1 Government

2.3.2 Industry/Technical

2.3.3 Company

2.4 Bulletins

2.4.1 Government

2.4.2 Industry/Technical

2.4.3 Company

2.5 Other Publications

Other applicable documents should listed under appropriate categories.
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3. Requirements

3.1 General

3.1.1 Precedence

In the event of conflict among the purchase agreement, this specification, and other documents referred to herein, the order of precedence shall be as follows:

- 1) Purchase agreement
- 2) This specification and its applicable drawings

3) Other applicable documents

List other applicable documents in order of precedence; see Section 2.

3.1.2 Other

List other applicable general requirements.

3.2 Design

The accelerometer shall consist of a single-axis acceleration sensor in accordance with IEEE Std 337-1972 and associated electronics, as shown in Fig 1.

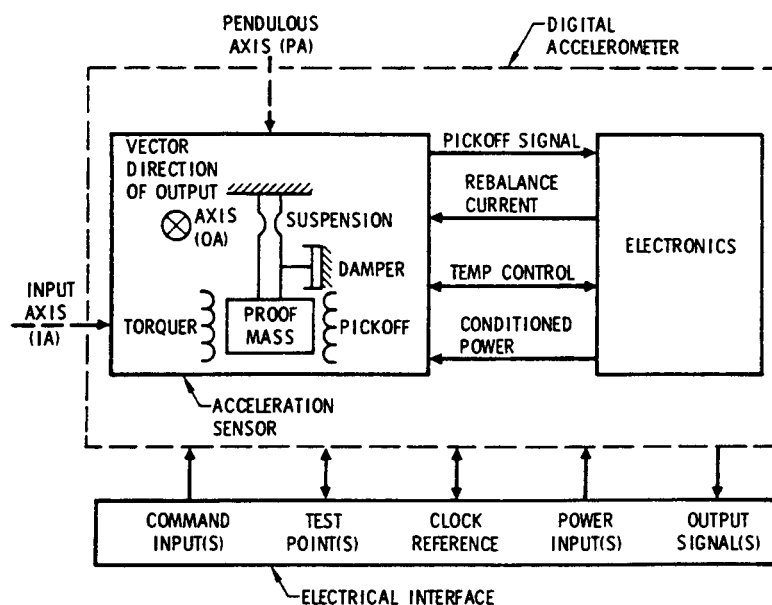


Figure 1—Digital Accelerometer Schematic

The associated electronics shall include the pulse torquing electronics or voltage to frequency converter, and may include such items as power conditioning, signal conditioning, temperature control, clock reference, and test points.

The method of pendulum torquing may be specified (for example, ternary pulse, binary pulse width modulation, analog).

3.2.1 Mechanical and Thermal Design

The following mechanical and thermal requirements apply to accelerometer package(s) to the extent specified:

The configuration should be specified to convey the user's limitations and specific needs. The accelerometer may consist of more than one package.

3.2.1.1 Exterior Surfaces

All exterior surfaces must withstand the environment specified herein and the handling expected in the normal course of operation, testing, and maintenance without deterioration which causes nonconformance to this specification.

Additional requirements controlling surface finish, protective treatment, metals, dissimilar metals, workmanship, etc, may be designated. Mounting surfaces which define the location of the input axis may require special consideration.

3.2.1.2 Dimensions

The outline and mounting dimensions shall conform to the outline drawing No ____.

The following may be specified with appropriate tolerances:

Center of gravity of each package
Center of gravity of proof mass
Effective center of mass

3.2.1.3 Identification of Product

The accelerometer shall be marked as specified on the outline drawing.

The specification may require: name of components, part number, serial number, contract number, and manufacturer's name or symbol.

3.2.1.4 Sensor Axes

The input, pendulous, and output reference axes and their positive directions shall be defined by external markings and by reference mounting surface(s) on the package which contains the acceleration sensor. The positive direction of the axes shall be such that the cross product of input and pendulous axes shall be along the output axis. (See Fig 1).

3.2.1.5 Weight

The weight shall be _____ $\pm$ _____ [g, kg, oz, lb].

If appropriate, maximum weight only need be specified. When accessories such as cable and connector are to be included in the weight requirement, the specification shall so state. When the accelerometer consists of more than one package, the weight may be specified for each package.

3.2.1.6 Seal

The accelerometer package shall meet the following seal requirements:

Specify either (1) or (2), below, as appropriate. If required, specify the appropriate seal requirements for the other package(s).

- 1) *Fluid Filled.* The accelerometer shall be sealed such that no fluid leakage is detected under _____ power magnification after being subjected to an external vacuum at _____ $\pm$ _____ Pa and a temperature of _____ $\pm$ _____ °C for a minimum period of _____ minutes.

In some cases, other procedures may be more appropriate, such as the use of fluorescent tracers in the fluid to facilitate leak detection.

- 2) *Gas Filled.* The accelerometer shall be sealed such that the maximum gas leakage rate shall not exceed _____ cm³/s of _____ gas, measured at standard conditions for a minimum period of _____ min while being subjected to a vacuum of _____ $\pm$ _____ Pa at a temperature of _____ $\pm$ _____ °C.

Tracer gases may be added to the fill gas in order to facilitate leak detection.

3.2.1.7 Operating Temperature

The operating temperature, as indicated by a temperature sensor [on, within] the accelerometer shall be _____ $\pm$ _____ °C.

This requirement is applicable only to an accelerometer with its own temperature control. If electronics and the acceleration sensor are separately controlled, specify operating temperature for each.

In some applications, consideration should be given to the magnitude of the thermal gradients existing across the accelerometer.

3.2.2 Electrical and Magnetic Design

The accelerometer's electrical and magnetic design requirements shall be as specified below. The accelerometer shall meet the performance criteria of 3.3 during all permissible variations of the inputs of 3.2.2.1.

3.2.2.1 Electrical Interface

The electrical interface for the accelerometer consists of the signals, power, and test points listed below and illustrated in Fig 1.

3.2.2.1.1 Power Input(s)

Specify the characteristics of the power input(s). For example:

Source impedance _____ $\pm$ _____ [$+$, $-$]j _____ $\pm$ _____ Ω
 Load impedance _____ $\pm$ _____ [$+$, $-$]j _____ $\pm$ _____ Ω
 Voltage _____ $\pm$ _____ [V ac, V dc]
 Frequency _____ $\pm$ _____ Hz
 Nominal current _____ A for _____ [s, min]
 Peak current _____ A for _____ [s, min]
 Harmonic content _____ %

3.2.2.1.2 Output Signal(s)

Specify the type and characteristics of output signal(s) required. For example:

Type:

Pulses indicating positive velocity increments on one signal line and pulses indicating negative velocity on a second line.

Characteristics:

Source impedance _____ $\pm$ _____ $[+, -]j$ _____ $\pm$ _____ Ω

Load impedance _____ $\pm$ _____ $[+, -]j$ _____ $\pm$ _____ Ω

Phasing with respect to clock reference $[+, -]$ _____ $\pm$ _____ s

Polarity of output signal with +1 *g* along the input reference axis

Wave shape (see Fig 2)

Repetition rate _____ pulses per second (p/s)

3.2.2.1.3 Command Input(s)

Specify the type and characteristics of command input(s). For example:

Type:

ON/OFF

Self Test

Characteristics:

Source input impedance _____ $\pm$ _____ $[+, -]j$ _____ $\pm$ _____ Ω

Load impedance _____ $\pm$ _____ $[+, -]j$ _____ $\pm$ _____ Ω

Input voltage _____ $\pm$ _____ [V dc, V ac]

3.2.2.1.4 Clock Reference

Specify the characteristics of the clock reference. For example:

Source Impedance _____ $\pm$ _____ $[+, -]j$ _____ $\pm$ _____ Ω

Load impedance _____ $\pm$ _____ $[+, -]j$ _____ $\pm$ _____ Ω

Repetition rate _____ $\pm$ _____ p/s

Wave shape (see Fig 2)

Stability $\pm$ _____ % per _____ [hours (h), days (d)]

3.2.2.1.5 Test Points

Specify the test points required for monitoring and testing of the accelerometer. These may include excitation voltages pick-off output signal, torquer signal, other control signals, or temperature sensor resistance. Any special buffering or scaling requirements should be specified.

3.2.2.1.6 Grounding

Specify electrical grounding design requirements (for example, requirements for isolation between input, output, and power returns and the grounding requirements for shields, chassis, and critical components).

3.2.2.2 Dielectric Strength

The leakage current shall not exceed _____ nA when _____ $\pm$ _____ V rms, at _____ Hz, are applied between isolated interface circuits, and between the case(s) and circuits isolated from the case(s), for _____ $\pm$ _____ s.

Different voltages may be specified for different circuits. In some instances, lower voltages may be specified for subsequent tests.

3.2.2.3 Insulation Resistance

The insulation resistance between isolated interface circuits and between the case(s) and circuits isolated from the case(s) shall not be less than _____ M Ω measured at _____ $\pm$ _____ V dc, applied for _____ $\pm$ _____ s.

Different voltages may be specified for different circuits.

3.2.2.4 Electromagnetic Interference

The maximum electromagnetic interference from the accelerometer package(s) shall conform to _____.

Describe the requirements. In the United States, a common standard is MIL-STD-461.

3.2.2.5 Electromagnetic Compatibility

Describe the requirements. In the United States, a common standard is MIL-STD-461.

3.2.2.6 Magnetic Leakage

The magnetic leakage shall not exceed _____ mT at a distance of _____ m from the accelerometer package(s), in any direction.

3.2.3 Maintainability

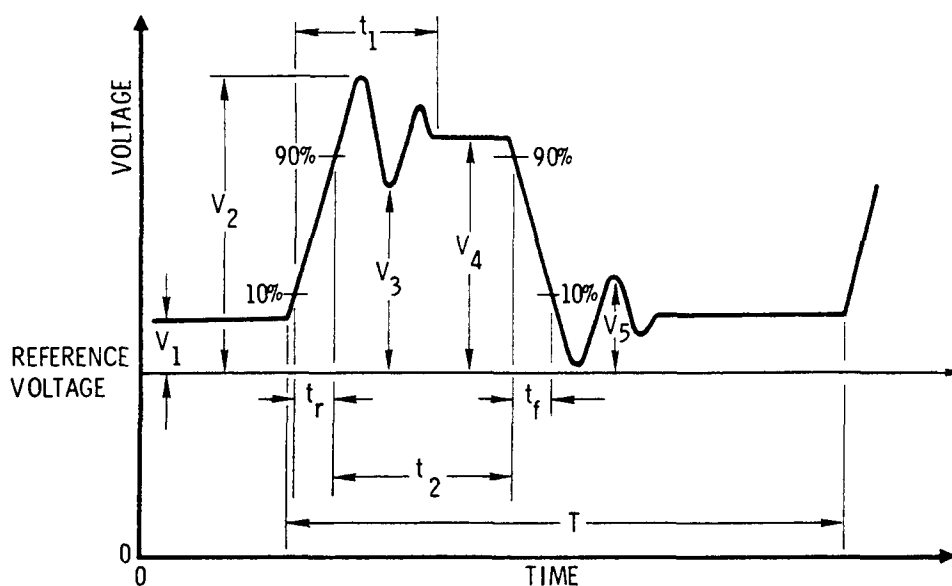
Maintenance for operational accelerometers shall utilize fault isolation to a line replaceable unit (LRU) by use of [built in test equipment, special test equipment, or commonly available test equipment].

3.2.3.1 LRU Interchangeability

Each LRU shall be interchangeable with like units, with the same part number, without calibration or adjustment.

3.2.3.2 LRU Maintenance

LRU maintenance is generally limited to depot or manufacturers level facilities.



	Units	Maximum	Minimum	Remarks
V_1	volts			steady-state low voltage
V_2	volts		N/A	overshoot voltage
V_3	volts	N/A		undershoot voltage
V_4	volts			steady-state high voltage
V_5	volts		N/A	maximum low voltage transient
t_r	seconds			rise time
t_f	seconds			fall time
t_1/t_2	—		N/A	ratio of the TURN-ON transient time to required ON time
t_2	seconds			duration of high voltage ON time
t_2/T	—			$(t_2/T) (100) = \% \text{ duty cycle}$
T	seconds			waveform period

N/A — not applicable

Figure 2—Wave Shape Requirements for Direct Coupled Pulse-Type Signals

3.3 Performance

3.3.1 General

The accelerometer shall comply with the performance requirements of this specification before, during (if applicable), and after exposures to any compatible combination of the environments specified in 3.4.

3.3.2 Input Range

The minimum input range shall be from minus _____ g to plus _____ g .

3.3.3 Warm-Up Time

The output of the accelerometer shall be within _____ pulses per second (p/s) of its steady state value in no more than _____ min after starting up from _____ °C.

The orientation of the input axis with respect to the gravity vector should be specified in the test method.

3.3.4 Scale Factor

3.3.4.1 Absolute Value

The scale factor K_1 shall be _____ $\pm$ _____ (p/s)/g.

The scale factor K_1 may also be utilized to obtain velocity quantization:

$$\text{velocity quantization} = \frac{\text{local value of gravity (m/s}^2\text{)}/g}{K_1 \text{ (p/s)}/g}$$

(that is, (m/s)/p)

3.3.4.2 Asymmetry

The difference between the scale factor measured with positive applied acceleration and negative applied acceleration shall not exceed $\pm$ _____ % of the nominal absolute scale factor.

3.3.4.3 Short Term Stability

The rms deviation of the scale factor from its mean value, over a period of _____ [h, d] of continuous operation, shall be less than _____ %.

Alternate means of specifying stability may be utilized, such as standard deviation, curve fitting for trend determination, or computer analysis to determine the auto-correlation time.

3.3.4.4 Long Term Stability

The best fit slope of the scale factor, over a period of _____ days of continuous operation, shall be less than _____ %/d. The rms deviation of the scale factor data points, from the best fit line, shall be less than _____ %.

Other criteria for establishing stability may be utilized such as standard deviation, curve fitting for trend determinations or computer analyses to determine the auto-correlation times.

3.3.4.5 Repeatability

The rms deviation of the scale factor from the mean of _____ measurements shall be less than _____ %. Between successive measurements, the accelerometer shall be cooled to _____ °C for at least _____ h.

Other environmental exposures may be substituted or added to the temperature environment specified. In addition, combinations of various successive environments, for example, vibration, shock, temperature, etc, may also be specified. Alternate means of specifying repeatability may be used, for example, rms deviation about the first day mean or peak-to-peak deviation.

The cool-down time should be sufficient to attain thermal equilibrium. Other conditions for repeatability may be specified, such as turn off with the accelerometer maintained at operating temperature.

3.3.4.6 Sensitivity

The absolute value of the sensitivity coefficient of the scale factor to variations from the standard test conditions of 4.5 shall not exceed the limits listed below:

Input voltage(s)	_____ %/V
Power input frequency(ies)	_____ %/Hz
Operating temperature	_____ %/°C
External magnetic fields [dc or ac, or both]	_____ %/mT per axis
Pressure	_____ %/Pa

3.3.5 Bias

3.3.5.1 Absolute Value

The absolute value of the bias K_0 shall not exceed _____ g .

3.3.5.2 Short Term Stability

The rms deviation of the bias, from its mean value, over a period of _____ [h, d] of continuous operation, shall be less than _____ g .

Alternate means of specifying stability may be utilized such as standard deviation, curve fitting for trend determination, or computer analysis to determine the auto-correlation time.

3.3.5.3 Long Term Stability

The best fit slope of the bias, over a period of _____ days of continuous operation, shall be less than _____ g/d . The rms deviation of the bias data points from the best fit line shall be less than _____ g .

The unbiased estimate of the standard deviation may be substituted for the rms deviation. Alternate means of specifying long term bias stability may be used, for example, rms deviation about the first day mean or peak-to-peak deviation.

3.3.5.4 Repeatability

The rms deviation of the bias from the mean of _____ measurement shall be less than _____ g . Between successive measurements, the accelerometer shall be cooled to _____ $^{\circ}\text{C}$ for at least _____ h.

Other environmental exposures may be substituted or added to the temperature environment specified. In addition, combinations of various successive environments, for example, vibration, shock, temperature, etc, may also be specified. Alternate means of specifying repeatability may be used, for example, rms deviation about the first day mean or peak-to-peak deviation. The cool-down time should be sufficient to attain thermal equilibrium. Other conditions for repeatability may be specified, such as turn off with the accelerometer maintained at operating temperature.

3.3.5.5 Sensitivity

The absolute value of the sensitivity coefficients of the bias to variations from the standard test conditions of 4.5 shall not exceed the limits listed below:

Input voltage(s)	_____ g/V
Power input frequency(ies)	_____ g/Hz
Operating temperature	_____ $g/^{\circ}\text{C}$
External magnetic fields	
[dc or ac, or both]	_____ g/mT
Pressure	_____ g/Pa

In some applications the sensitivity of accelerometer bias to angular rate or acceleration, or both, may be significant and should be specified.

3.3.6 Input Axis Misalignment

3.3.6.1 Pendulous Reference Axis

The absolute value of the input axis misalignment about the pendulous reference axis δ_p shall be less than _____ rad.

3.3.6.2 Output Reference Axis

The absolute value of the input axis misalignment about the output reference axis δ_o shall be less than _____ rad.

In some applications it may be desirable to specify the input axis misalignment stability, sensitivity to temperature, etc.

3.3.7 Nonlinearity

The absolute values of the second order nonlinearity coefficient K_2 and the third-order nonlinearity coefficient K_3 shall be less than _____ g/g^2 and _____ g/g^3 , respectively.

3.3.8 Cross Coupling

The absolute values of the cross coupling coefficients K_{ip} and K_{io} shall be less than _____ $(g/g)/\text{cross } g$.

3.3.9 Acceleration Threshold

The threshold shall be less than _____ g .

3.3.10 Acceleration Resolution

The resolution shall be less than _____ g .

3.3.11 Acceleration Dead Zone

The dead zone at zero indicated output, shall be less than _____ g .

Dead zone at zero g input, or other input values may be specified if desired.

3.3.12 Turn-On Hysteresis

The absolute value of the turn-on hysteresis shall be less than _____ g .

3.3.13 Velocity Storage

The velocity stored in an accelerometer is a function of its design and is sometimes verified by analysis rather than actual test.

3.3.13.1 Normal Operation

The maximum velocity stored in the accelerometer shall not exceed _____ [$g \cdot s$, m/s].

3.3.13.2 Overrange Operation

The minimum velocity storage for an overrange acceleration pulse shall exceed _____ [$g \cdot s$, m/s].

In some cases the overrange condition may be specified as a shock pulse defined in terms of peak amplitude, waveform duration, or spectrum.

3.3.14 Frequency Response

Linear system frequency response specifications may be useful in some applications. When stated in these terms, the describing function interpretation is implied. Caution must be exercised, when this technique is applied to a nonlinear system, that a solution exists. Frequency response may be verified by analysis rather than actual test.

3.3.15 Vibration Induced Errors

The rectification error shall not exceed _____ g while the accelerometer is subjected to the vibration environment of 3.4.2.2 along any combination of axes.

Vibropendulous and anisoelastic effects are two examples of rectification errors. Vibropendulous error shall be specified for vibration acceleration applied in a plane normal to the output axis and at 45° to the input reference axis.

3.3.16 Self Test Scale Factor

The accelerometer self test scale factor shall be _____ $\pm$ _____ (p/s)/mA.

In some cases, the self test scale factor may be specified in units of (p/s)/V or as a response to a logic or fixed input.

3.4 Environmental Requirements

The environmental conditions listed in this paragraph are those to which the accelerometer may be subjected during storage, transportation, handling or operation, or both. The equipment shall be designed to survive these environments and to successfully complete the environmental tests specified in Section 4..

3.4.1 Nonoperative Environment

The following conditions, occurring separately, or in combination, may be encountered during transportation, handling or storage, or both. The accelerometer shall conform to all the requirements of 3.3 after exposure to any reasonable combinations of the specified service conditions.

Where appropriate, the environment specified must be adjusted for the protection afforded by packaging.

3.4.1.1 Temperature and Thermal Radiation

Ambient temperature may vary from a minimum of _____ °C to a maximum of _____ °C under unsheltered ground conditions. Areas exposed to direct sunlight shall be considered as unsheltered conditions.

3.4.1.2 Thermal Shock

_____ °C to _____ °C. The heating and cooling rates of the ambient environment shall be _____ $\pm$ _____ °C/s.

For cyclic conditions, specify temperature limits for each level, dwell times, and sequence.

3.4.1.3 Vibration

Describe the vibration environment. For sinusoidal vibration, include the specific vibration amplitude versus frequency, duration, or sweep rate and axes of application. For random vibration, specify power spectral density (provide figure if complex), tolerance, bandwidth, peak acceleration level, total rms acceleration, duration, and axes of application.

3.4.1.4 Mechanical Shock

Specify the shock wave shape or shock spectrum, tolerances, number of shocks and axes of application.

3.4.1.5 Pressure

_____ [Pa, lbf/in²] to _____ [Pa, lbf/in²]. The rate of change of pressure shall be nominally _____ [Pa/s, (lbf/in²)/s].

If desired, pressure may be expressed in terms of altitude during transportation and rate of climb.