# IEEE Standard Specification Format Guide and Test Procedure for Linear Single-Axis, Nongyroscopic Accelerometers

IEEE Aerospace and Electronic Systems Society

Sponsored by the
Gyro and Accelerometer Panel

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IEEE Std 1293™-2018
(Revision of
IEEE Std 1293-1998)

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# IEEE Standard Specification Format Guide and Test Procedure for Linear Single-Axis, Nongyroscopic Accelerometers

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Approved 23 October 2018

**IEEE-SA Standards Board**

**Abstract:** The specification and test requirements for a linear, single-axis, nongyroscopic accelerometer for use in inertial navigation, guidance, and leveling systems are defined. A standard specification guide and a compilation of recommended test procedures for such accelerometers are provided. Informative annexes are given on the various types of such accelerometers (force or pendulous torque rebalance with analog or digital output, vibrating beam, and micromechanical) and error effects, on filtering, noise, and transient analysis techniques, and on calibration and modeling techniques (multipoint tumble analysis, vibration and shock test analyses, and geophysical effects in inertial instrument testing).

**Keywords:** accelerometer, geophysical effects, IEEE 1293™, inertial instrument, inertial sensor, micromechanical accelerometer, pendulous accelerometer, power spectral density, specification, testing, vibrating beam accelerometer, vibration and shock

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PDF: ISBN 978-1-5044-5524-4 STD23537
Print: ISBN 978-1-5044-5525-1 STDPD23537

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David J. Winkel
Bruce R. Youmans

*Past Chair

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Steve F. Becka
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Timothy Buck
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Randall Curey
Harry Davis
Rayna DeMaster-Smith
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The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

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Jean-Francois Kieffer
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When the IEEE-SA Standards Board approved this standard on 23 October 2018, it had the following membership:

## Introduction

This introduction is not part of IEEE Std 1293-2018, IEEE Standard Specification Format Guide and Test Procedure for Linear Single-Axis, Nongyroscopic Accelerometers.

This standard is provided as a guide for the preparation of an accelerometer specification (Part I) and an accelerometer test procedure (Part II). The accelerometer considered in this standard uses a linear, single-axis, nongyroscopic acceleration sensor. The capture-loop, pickoff, oscillator, and readout electronics, when used, can be considered either as a part of the accelerometer or as separately provided by the user. The format was prepared by the Gyro and Accelerometer Panel of the Aerospace and Electronic Systems Society of the Institute of Electrical and Electronics Engineers (IEEE). 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.

Blank spaces permit the insertion of specific parameter values and their tolerances. Brackets are used to enclose alternate choices of dimensional units, sign, axes, and so on. Boxed statements are included for information only and are not part of the specification format nor test procedure. The figures presented are to be used as a guide for the preparation of specific figures or drawings.

The annexes are informative and cover

- Typical block diagrams for accelerometer response
- The various types of accelerometers considered (including pendulous torque rebalance, vibrating beam, and micromechanical)
- Error effects
- Filtering, noise, and transient analysis techniques
- Calibration and modeling techniques (multipoint tumble analysis, vibration and shock test analyses, and geophysical effects in inertial instrument testing)

The following documents were used in the development of this standard:

IEEE/ASTM SI 10™-1997, Standard for Use of the International System of Units (SI): The Modem Metric System.

IEEE Std 260.1™-1993, American National Standard Letter Symbols for Units of Measurement.

IEEE Std 280™, IEEE Standard Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering.

IEEE Std 315™-1975, IEEE Standard, American National Standard, Canadian Standard Graphic Symbols for Electrical and Electronics Diagrams (Including Reference Designation Letters).

IEEE Std 315A™, Supplement to IEEE Std 315.

IEEE Std 528™-1994, IEEE Standard for Inertial Sensor Terminology.

IEEE 100™, *The Authoritative Dictionary of IEEE Standards Terms*.

In this standard, the symbol *g* (italic) is used to denote an acceleration equal in magnitude to the local value of gravity at the test site. This symbol is thus distinguished from g (nonitalic), which is the standard symbol for gram. The standard value of gravity $g_o$ is 9.806 65 m/s$^2$.

The accelerometer is used to provide an analog, digital, or frequency output that is a measure of acceleration or velocity increment, or both. An acceleration applied along the input axis of the acceleration sensor causes its proof mass to deflect. For open-loop accelerometers, the pickoff error signal caused by this motion is the measure of acceleration.

For force-rebalance accelerometers, the pickoff error signal is used in the electronics to produce a restoring force or torque. When static equilibrium is reached, the reaction force or torque of the proof mass to the average acceleration is balanced by the mean value of the restoring force or torque. The average rebalance current or pulse rate required to maintain this equilibrium condition is proportional to the average acceleration and provides the analog or digital output signal.

For vibrating beam accelerometers (VBAs), acceleration causes one resonator to increase in frequency ($f_1$) and the other resonator to decrease in frequency ($f_2$). The difference ($f_1 - f_2$) is a measure of the applied acceleration. The VBA difference frequency scale factor is the sum of the individual resonator scale factors. Thus, using the difference frequency observable in a dual-resonator VBA doubles the scale factor as well as rejects many common mode error effects.

In this standard, no distinction is made between input axis (IA) and input reference axis (IRA) [similarly between output axis (OA) and output reference axis (ORA) and pendulous axis (PA) and pendulous reference axis (PRA)]. When dealing with the accelerometer, sensor physics IA, OA, and PA would typically be used. When orienting the accelerometer, package IRA, ORA, and PRA would typically be used. In some cases, it may be desirable to attempt to orient the IA, OA, and/or PA by observing a signal (such as the output or a reference voltage). Even in these cases, the IRA, ORA, and/or PRA can be used as a check if the approximate orientation between IA, OA, and PA and the IRA, ORA, and PRA is known. In all cases, users should determine which set of axes is appropriate for their application.

# Contents

# IEEE Standard Specification Format Guide and Test Procedure for Linear Single-Axis, Nongyroscopic Accelerometers

## 1. Overview

### 1.1 Scope

The specification and test requirements for a linear, single-axis, nongyroscopic accelerometer for use in inertial navigation, guidance, and leveling systems are defined. A standard specification format guide and a compilation of recommended test procedures for such accelerometers are provided. Informative annexes are given on the various types of such accelerometers (force or pendulous torque rebalance with analog or digital output, vibrating beam, and micromechanical) and error effects, on filtering, noise, and transient analysis techniques, and on calibration and modeling techniques (multipoint tumble analysis, vibration and shock test analyses, and geophysical effects in inertial instrument testing).

### 1.2 Purpose

A standard specification format guide is provided, along with a compilation of recommended test procedures for the preparation of a linear, single-axis, nongyroscopic accelerometer specification. These test procedures are derived from those currently in use in the industry.

### 1.3 Document structure

This standard consists of five parts: The first two parts are in the normative portion of the standard, and the other three are in the informative portion. Part I is a specification format guide for the preparation of a linear single-axis, nongyroscopic accelerometer specification. Part II is a compilation of recommended procedures for testing a linear single-axis, nongyroscopic accelerometer. Part III contains descriptions of various types of accelerometers. Part IV discusses filtering, noise, and transient analysis. Part V contains calibration and modeling techniques.