



BSI Standards Publication

Methods for the calibration of vibration and shock transducers

Part 21: Vibration calibration by comparison to a reference transducer

National foreword

This British Standard is the UK implementation of ISO 16063-21:2003+A2:2024, incorporating corrigendum April 2009. It supersedes BS ISO 16063-21:2003+A1:2016, which is withdrawn.

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Methods for the calibration of vibration and shock transducers —

Part 21: Vibration calibration by comparison to a reference transducer

*Méthodes pour l'étalonnage des transducteurs de vibrations et de
chocs —*

*Partie 21: Étalonnage de vibrations par comparaison à un transducteur
de référence*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16063-21 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

This first edition of ISO 16063-21 cancels and replaces ISO 5347-3:1993, which has been technically revised.

ISO 16063 consists of the following parts, under the general title *Methods for the calibration of vibration and shock transducers*:

- *Part 1: Basic concepts*
- *Part 11: Primary vibration calibration by laser interferometry*
- *Part 12: Primary vibration calibration by the reciprocity method*
- *Part 13: Primary shock calibration using laser interferometry*
- *Part 21: Vibration calibration by comparison to a reference transducer*
- *Part 22: Shock calibration by comparison to an accelerometer, velocity or force transducer*

Introduction

The ISO 16063 series of standards is concerned with methods for the calibration of vibration and shock transducers under both standard laboratory conditions and in the field.

As such, the intended user group of this part of ISO 16063 is wide, ranging from metrologists in mechanical vibration to technicians evaluating the vibration characteristics of a machine or structure, or human exposure to vibration. The key to the application of this part of ISO 16063 is in the careful detailed specification and evaluation of measurement uncertainty, i.e. the error budget and computation of expanded uncertainty associated with the measurement of vibration.

This part of ISO 16063 is particularly intended for those engaged in vibration measurements requiring traceability to primary national or international standards through a secondary, reference, working or check standard (portable calibrator intended for field use) as defined in the *International vocabulary of basic and general terms in metrology* (VIM). The specifications for the instrumentation and the procedures given are intended to be used for calibration of rectilinear vibration transducers (with or without signal conditioning) to obtain the magnitude and (optionally) phase shift of the complex sensitivity at frequencies in the range of 0,4 Hz to 10 kHz.

 ISO 16063-21:2003/Amd 2 aims to explain better the use of reference transducers, different calibration set-ups and opens up the frequency limits for the applicable calibration range. 

Methods for the calibration of vibration and shock transducers —

Part 21:

Vibration calibration by comparison to a reference transducer

1 Scope

This part of ISO 16063 describes the calibration of rectilinear vibration transducers by comparison. Although it mainly describes calibration using direct comparison to a standard calibrated by primary methods, the methods described can be applied between other levels in the calibration hierarchy.

This part of ISO 16063 specifies procedures for performing calibrations of rectilinear vibration transducers by comparison in the frequency range from 0,4 Hz to 10 kHz. It is primarily intended for those who are required to meet ISO standardized methods for the measurement of vibration under laboratory conditions, where the uncertainty of measurement is relatively small. It can also be used under field conditions, where the uncertainty of measurement may be relatively large.

From knowledge of all significant sources of uncertainty affecting the calibration, the expanded uncertainty can be evaluated using the methods given in this part of ISO 16063. It also covers the assessment of uncertainties for calibrations performed using a check standard.

Comparison calibrations made in accordance with this part of ISO 16063 need to allow for the environmental conditions of the reference transducer calibration.

 This document is applicable to calibrations outside the frequency range from 0,4 Hz to 10 kHz, considering the additional facts described in 4.3. Systems have been demonstrated to cover the range from 0,01 Hz to 30 kHz. 

NOTE Transducer calibrations made under extreme environmental conditions are covered by other International Standards.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 266, *Acoustics — Preferred frequencies*

ISO 2041:1990, *Vibration and shock — Vocabulary*

ISO 16063-1:1998, *Methods for the calibration of vibration and shock transducers — Part 1: Basic concepts*

ISO 16063-11:1999, *Methods for the calibration of vibration and shock transducers — Part 11: Primary vibration calibration by laser interferometry*

Guide to the expression of uncertainty in measurement (GUM). BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 1993¹⁾

1) Corrected and reprinted in 1995.

3 Uncertainty of measurement

3.1 All users of this part of ISO 16063 are expected to make uncertainty budgets according to Annex A to document their level of uncertainty (see example in Annex D).

To help set up systems fulfilling different requirements two examples are given. System requirements for each are set up and the attainable uncertainty is given. Example 1 is typical for calibrations under well-controlled laboratory conditions with the requirement to obtain a high accuracy. Example 2 is typical for calibrations where less than the highest accuracy can be accepted or where calibration conditions are such that only less narrow tolerances can be maintained. These two examples will be used throughout this part of ISO 16063.

a) Example 1

The reference transducer is calibrated by primary means and documented uncertainty. The calibration may be transferred to a working standard for practical reasons. The temperature and other conditions are kept within narrow limits during the comparison calibration as indicated in the appropriate clauses.

b) Example 2

The reference transducer is not calibrated by primary means, but has a traceable calibration, as defined in VIM (see [2]), with the corresponding uncertainty documented. The calibration may be transferred to a working standard for practical reasons. The requirements on other parameters and instruments are indicated in the appropriate clauses.

3.2 For both examples, the minimum calibration requirement for the reference transducer is calibration under suitable reference conditions (i.e. frequency, amplitude and temperature). Normally the conditions will be chosen as indicated in ISO 16063-11.

It is applicable for the following parameters:

Frequency range:	20 Hz to 5 000 Hz, optionally 0,4 Hz to 10 000 Hz ($\square_{AC1}$ see Note $\square_{AC1}$)
Dynamic range:	10 m/s ² to 1 000 m/s ² r.m.s., optionally 0,1 m/s ² to 1 000 m/s ² (frequency dependent)

NOTE The indicated frequency ranges are not mandatory and single-point calibrations are also acceptable.

At any given frequency and amplitude of acceleration, velocity or displacement, the dynamic range will be limited by the noise floor and the amount of distortion produced by the excitation apparatus (if no filtering is used) or its maximum power. (Techniques are also used to counteract the inherent distortion at large displacements for spring-controlled exciters by changing the waveform of the input voltage.) Typical maximum values for electrodynamic vibration exciters designed for the frequency range from 10 Hz to 10 kHz are 200 m/s² to 1000 m/s² r.m.s. acceleration, 0,5 m/s to 1 m/s r.m.s. velocity and 5 mm peak displacement. The lower limits will be set by the noise in the two measurement channels, and by the bandwidth used. Typical values used for measurement are 50 m/s² to 100 m/s² r.m.s. acceleration or 0,1 m/s r.m.s. velocity. For calibrators, values between 1 m/s² and 10 m/s² r.m.s. are normally used. A graph similar to the one shown in Annex C is useful when considering the ranges covered.

When measurements are performed at the lowest frequencies, the limiting factor is normally displacement. At 1 Hz, typical values for long-stroke vibrators are 1 m/s² to 2 m/s² r.m.s. acceleration or 0,1 m/s to 0,3 m/s r.m.s. velocity.

3.3 The attainable uncertainties (expanded uncertainties calculated using a coverage factor of 2 in accordance with ISO 16063-1) for the two examples are given in Table 1. In practice, these limits may be exceeded depending on the uncertainty with which the reference transducer has been calibrated, the response characteristics of the reference transducer and the transducer to be calibrated, the vibratory characteristics of the exciter and the instrumentation used in the measurement apparatus. It is the responsibility of the laboratory or end user to make sure that the reported values of expanded uncertainty are credible.

Table 1 — Attainable uncertainties of magnitude and phase shift of the complex sensitivity

Parameter	Example 1	Example 2
Magnitude		
For accelerometers (0,4 Hz to 1 000 Hz)	1 %	3 %
For accelerometers (1 000 Hz to 2 000 Hz)	2 %	5 %
For accelerometers (2 kHz to 10 kHz)	3 %	10 %
For displacement and velocity transducers (20 Hz to 1 000 Hz)	4 %	6 %
Phase shift ^a		
At reference conditions ^b (i.e. the level and frequency at which the reference transducer was calibrated)	1°	3°
Outside reference conditions	2,5°	5°
^a Phase shift measurement is not mandatory. ^b Recommended reference conditions are as follows (from ISO 16063-11:1999, Clause 2): — frequency in hertz: 160, 80, 40, 16 or 8 (or angular frequency ω in radians per second: 1000, 500, 250, 100 or 50), — acceleration in metres per second squared (acceleration amplitude or r.m.s. value): 100, 50, 20, 10, 5, 2 or 1.		
NOTE The expanded uncertainties given as examples (e.g. 1 %) are based on concrete uncertainty budgets such as given in Annex D as an example (resulting expanded uncertainty 0,84 %).		

4 Requirements for apparatus and environmental conditions

4.1 General

The examples referred to in this clause are those described in Clause 3.

If the recommended specifications listed below are met for each item, the uncertainties given in Clause 3 should be obtainable over the applicable frequency range depending on the uncertainty with which the reference transducer has been calibrated, and the response characteristics of the reference transducer and transducer to be calibrated. Other combinations of requirements can, however, lead to the same uncertainty. Special instrumentation may be required in order to meet the expanded uncertainties given in Clause 3 at frequencies less than 1 Hz. It is mandatory to document the expanded uncertainty using the methods of Annex A.

4.2 Environmental conditions

These shall be the following.

	Example 1	Example 2
Room temperature	(23 ± 5) °C	(23 ± 10) °C
Relative humidity	75 % max.	90 % max.

4.3 Reference transducer

This should preferably be calibrated together with the amplifier.

a) Example 1

The transducer shall be calibrated in accordance with suitable primary methods or by comparison against a transducer calibrated in accordance with suitable primary methods (see ISO 16063-11 or other parts) with an expanded uncertainty of 0,5 % (magnitude) and 0,5° (phase shift) at selected reference frequency

and acceleration (the uncertainties are those obtained when calculating expanded uncertainties using a coverage factor of 2). Higher uncertainty values are accepted at high and low frequencies.

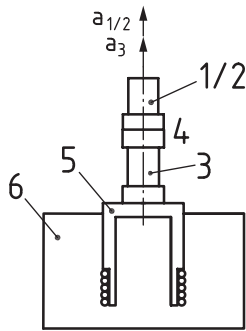
b) **Example 2**

The transducer shall be calibrated by suitable and known methods with traceability to a primary reference transducer and an uncertainty of less than 2 % (magnitude) and 2° (phase shift) at selected reference frequency and acceleration (the uncertainties are those obtained when calculating expanded uncertainties using a coverage factor of 2). Higher uncertainty values are accepted at high and low frequencies.

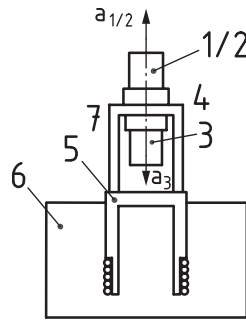
A2 The reference transducer may be of the back-to-back type meant for direct mounting of the transducer to be calibrated on top of it, in a back-to-back configuration, see Figure 1 a). It may also be a transducer used in a fixture, see Figure 1 b), or underneath the exciter mounting platform (built-in reference transducer), see Figure 1 c), always in line with the transducer to be calibrated. In the setup shown in Figure 1 c) the reference might even be an integral part of the exciter (which means it cannot be detached). To reduce the influence of rocking motions, the centres of the seismic elements of both transducers should be superimposed on one axis coinciding with the axis of vibration. It is not recommended to mount the two transducers side by side as rocking motions will often be present, causing large errors in many circumstances.

For low frequency calibrations requiring measurements below a few Hz, long stroke exciters are used giving displacements of 100 mm or more. The setups are normally like the one shown schematically in Figure 2. The principle is the same as Figure 1 b) but the armature is a sledge driven by an electromagnetic system or otherwise. The sledge configuration permits heavy transducers to be calibrated. Some transducers (e.g. seismometers) are sensitive in the transverse direction with respect to their mounting surface. They can then be mounted directly on the sledge without the fixture 7 in Figure 2.

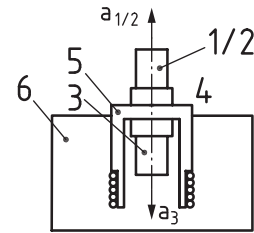
For these low frequency setups, the influence of rocking motion typically is very low, so side by side measurements can be performed with low uncertainty.



a) Calibration set-up with back-to-back reference transducer



b) Calibration set-up with mounting fixture (contains single ended transfer reference transducer)

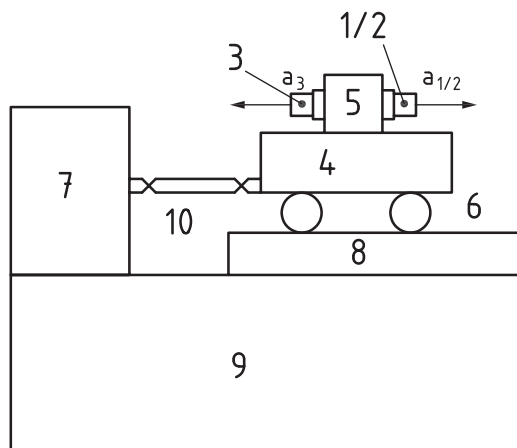


c) Calibration set-up with vibration exciter internal reference transducer

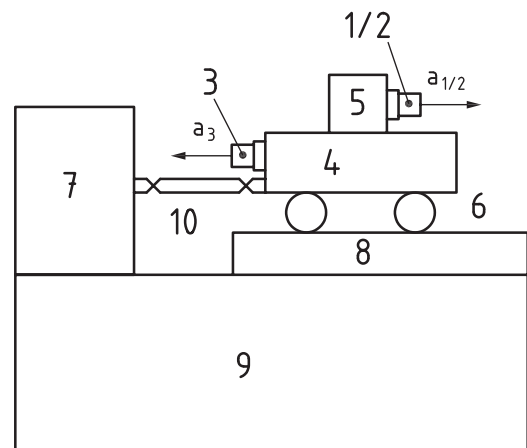
Key

- 1 transducer to be calibrated (see Note 1)
- 2 transfer standard, used for transfer calibration of transducer 3 (see Note 1 and ISO 16063-21:2003/Amd 1:2016, Annex E)
- 3 reference transducer (see Note 1)
- 4 top surface of back-to-back transducer (subfigure a)), mounting surface of mounting fixture (subfigure b)) or mounting surface of vibration exciter (subfigure c))
- 5 vibration exciter armature
- 6 vibration exciter body
- 7 mounting fixture (providing back-to-back configuration)
- $a_{1/2}$ nominal sensitivity axis of transducer 2/1 (standard set-up: transducer to be calibrated)
- a_3 nominal sensitivity axis of transducer 3 (standard set-up: reference transducer)

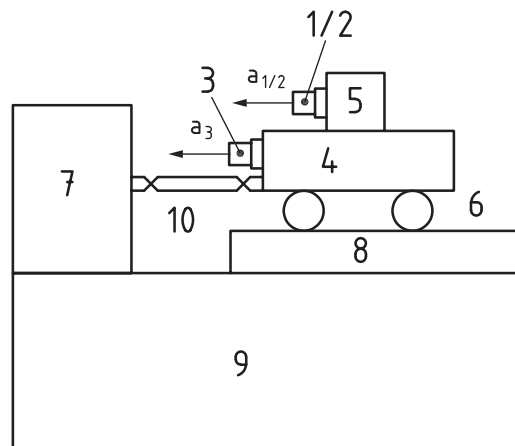
Figure 1 — Permitted calibration set-ups for a standard calibration and transfer calibration



a) Calibration set-up with back-to-back reference transducer



b) Calibration set-up with mounting fixture (contains single ended transfer reference transducer)



c) Calibration set-up with vibration exciter internal reference transducer

Key

- 1 transducer to be calibrated (see Note 1)
- 2 transfer standard (see Note 1 and ISO 16063-21:2003/Amd 1:2016, Annex E)
- 3 reference transducer (see Note 1)
- 4 vibration exciter armature
- 5 mounting fixture
- 6 armature bearing (air or solid)
- 7 driving force unit
- 8 bearing fixed part
- 9 heavy seismic mounting block
- 10 connecting drive element
- $a_{1/2}$ nominal sensitivity axis of transducer 2/1 (standard set-up: transducer to be calibrated)
- a_3 nominal sensitivity axis of transducer 3 (standard set-up: reference transducer)

Figure 2 — Permitted calibration set-ups for a standard calibration and transfer calibration