

Methods for the calibration of vibration and shock transducers —

Part 12: Primary vibration calibration by the reciprocity method

ICS 17.160

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National foreword

This British Standard reproduces verbatim ISO 16063-12:2002 and implements it as the UK national standard. It supersedes BS 6955-20:1997 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GME/21, Mechanical vibration and shock, to Subcommittee GME/21/2, Vibration and shock measuring instruments and testing equipment, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

This British Standard, having been prepared under the direction of the Engineering Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 29 July 2002

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Part 12: Primary vibration calibration by the reciprocity method

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Partie 12: Étalonnage primaire de vibrations par méthode réciproque



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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 3.

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 part of ISO 16063 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16063-12 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

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: Secondary shock calibration*

Annex A forms a normative part of this part of ISO 16063. Annex B is for information only.

Methods for the calibration of vibration and shock transducers —

Part 12:

Primary vibration calibration by the reciprocity method

1 Scope

This part of ISO 16063 specifies the instrumentation and procedures to be used for primary calibration of accelerometers using the reciprocity method and the SI system of units.

It is applicable to the calibration of rectilinear accelerometers over a frequency range of 40 Hz to 5 kHz and a frequency-dependent amplitude range of 10 m/s² to 100 m/s² and is based on the use of the coil of an electrodynamic vibrator as the reciprocal transducer.

Calibration of the sensitivity of a transducer can be obtained using this part of ISO 16063 provided that the signal conditioner or amplifier used with the transducer during calibration has been adequately characterized. In order to achieve the uncertainties of measurement given in clause 3, it has been assumed that the transducer has been calibrated in combination with its signal conditioner or amplifier (the combination of which in this part of ISO 16063 is referred to as the “accelerometer”).

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 16063. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 16063 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 266, *Acoustics — Preferred frequencies*

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

3 Uncertainty of measurement

At a reference frequency of 160 Hz and a reference amplitude of 100 m/s², 50 m/s², 20 m/s² or 10 m/s², the applicable limits of uncertainty are 0,5 % of the modulus (magnitude) of complex sensitivity and 1° of the argument (phase shift) of complex sensitivity. Over the full range of amplitudes and frequencies, the limits of uncertainty in the measured magnitude and phase shift of sensitivity are 1 % and 2°, respectively.

All users of this part of ISO 16063 are expected to make uncertainty budgets according to annex A to document the uncertainty of measurement.

The uncertainty of measurement is expressed as the expanded measurement uncertainty in accordance with ISO 16063-1 (referred to here as “uncertainty”).

4 Symbols

A general list of symbols used in this part of ISO 16063 is contained in Table 1. Specific symbols used in formulae are defined following the formulae in which they appear.

Table 1 — General symbols

Symbol	Definition	Unit
f	frequency of vibration	Hz
n	indices of test masses ($n = 0$ indicates no test mass)	
m_n	mass of the test mass number n	kg
u	complex voltage	V
U	complex voltage ratio	
Y	complex electrical admittance	S
R	electrical resistance	Ω
α	complex intercept of least-squares fit	kg· Ω
β	complex slope of least-squares fit	Ω
S_a	complex sensitivity of the calibrated accelerometer	V/(ms ⁻²)
$ S_a $	modulus (magnitude) of S_a	V/(ms ⁻²)
φ_a	argument (phase shift) of S_a	degree
Re	real part of a complex quantity	
Im	imaginary part of a complex quantity	
$ $	modulus or absolute value of a complex quantity	
arg	argument of a complex quantity	

5 Requirements for apparatus

5.1 General

The case of the transducer shall be structurally rigid over the frequency range of interest. The sensitivity to base strain and transverse motion and the stability of the accelerometer (transducer in combination with the signal conditioner or amplifier) shall be included in the calculation of the expanded uncertainties in determining the modulus and argument of complex sensitivity (see annex A).

5.2 Frequency generator and indicator or counter

Use equipment having the following characteristics:

- a) maximum uncertainty in frequency: 0,01 %;
- b) change in frequency: less than 0,01 % over each measurement period;
- c) change in amplitude: less than 0,01 % over each measurement period.

5.3 Power amplifier/vibrator combination

Use equipment having the following characteristics for all measurement conditions:

- a) maximum total harmonic distortion: 2 %;
- b) transverse, bending and rocking acceleration: commensurate with the uncertainty of the measured sensitivity (typically <10 % of the acceleration in the intended direction over the frequency range of interest);
- c) minimum ratio of signal to noise at the output of the accelerometer: 30 dB;
- d) change in acceleration amplitude: less than 0,05 % over each measurement period.

5.4 Seismic block for vibrator

The vibrator shall be mounted on a massive rigid seismic block so as to minimize the reaction of the vibrator support structure to the motion of the vibrator from significantly affecting the uncertainty in the calibration results. The mass of the seismic block should be at least 2 000 times that of the moving element of the vibrator. Examples of seismic blocks suitable for this use include granite blocks or steel honeycomb optical tables. The seismic block should be vibration isolated with vertical and horizontal suspension resonances of less than 2 Hz if significant seismic vibration exists in the calibration environment.

5.5 Instrumentation for complex voltage ratio measurements

Use equipment having the following characteristics:

- a) frequency range: 40 Hz to 5 kHz;
- b) maximum uncertainty in the modulus (magnitude) of complex voltage ratio: 0,1 %;
- c) maximum uncertainty in the argument of complex voltage ratio: 0,1°.

5.6 Resistor

The resistor shall have a maximum uncertainty in the determination of its resistance of 0,05 % over the calibration frequency range and the range of power dissipated.

Ensure that the value of the impedance of the standard resistor used to determine current does not vary appreciably due to inductive and thermal effects.

5.7 Set of test masses

The test masses shall

- a) cover a range of at least five approximately equal intervals, with the largest test mass between approximately 0,5 to 1 times the mass of the moving element of the vibrator, and
- b) have a maximum uncertainty in the determination of mass of 0,05 %.

It is recommended that the shape of the test masses be similar to that of a cube or cylinder with a length-to-width ratio of approximately one. The maximum frequency at which the test mass behaves as a rigid body can then be estimated by use of the formula: $c/(2L)$ where c is the speed of sound in the material of the test mass and L is its length. The surface finish specifications and the machining tolerances of the mounting hardware of the test masses should meet or exceed the requirements specified for mounting the transducer being calibrated. This is particularly critical if calibrations are performed at high frequencies. The test masses should be machined from a relatively stiff material such as tungsten carbide to maximize the frequencies of the natural resonances occurring in them.

In practice, the number and size of the test masses selected will be a compromise between reducing the statistical uncertainty versus increasing the measurement uncertainty due to thermal effects occurring in the drive coil as a result of making a relatively large number of measurements with large differences in measured electrical admittance.

5.8 Distortion-measuring instrumentation

Use equipment capable of measuring a total harmonic distortion of 0,01 % to 5 % and having the following characteristics:

- a) frequency range: 40 Hz to 5 kHz;
- b) maximum uncertainty: 10 % of the measured value of distortion.