INTERNATIONAL STANDARD

ISO 16063-44

First edition
2018-11

Methods for the calibration of vibration and shock transducers —

Part 44:
Calibration of field vibration calibrators

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

Partie 44: Étalonnage des calibreurs de vibrations pour usage in situ

Reference number
ISO 16063-44:2018(E)

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*.

A list of all the parts in the ISO 16063 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ISO 16063 comprises a series of documents dealing with methods for the calibration of vibration and shock transducers.

This document focuses on field vibration calibrators (FVCs). In this context, FVCs are mainly used for *in situ* checks of vibration and shock transducers providing sine wave vibration at known frequency and magnitude under field conditions. The FVC acts as a calibrated vibration source for *in situ* checks of transducer sensitivity that is specified or requested, for example, in ISO 8041-1 or in ISO 8042.

Operational frequency and acceleration RMS value of FVCs are usually 160 Hz or 159,2 Hz, and 3,16 m/s^2, 9,81 m/s^2 or 10 m/s^2, respectively, which are widely accepted as reference conditions. There are also FVCs with selectable acceleration magnitudes and frequencies. In comparison with stationary calibration systems, FVCs have limitations in shaker power and inertial mass. Therefore, they can be unsuitable for heavy test objects, high acceleration magnitudes and large displacements.

Using the calibration procedure described by this document, the acceleration generated by an FVC can be traceable, through chain of calibration, to a primary or national standard as defined by ISO/IEC Guide 99 ("the VIM") with associated uncertainty defined by ISO/IEC Guide 98-3 ("the GUM").

Methods for the calibration of vibration and shock transducers —

Part 44: Calibration of field vibration calibrators

1 Scope

This document specifies the instrumentation and procedure to be used for performing calibration of field vibration calibrators (FVCs).

It is not applicable to FVCs used for the calibration of transducers. These are covered by ISO 16063-21.

Procedures and requirements of *in situ* calibration by FVC are beyond the scope of this document.

Annex B provides more information on the application of FVC.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 16063-21, *Methods for the calibration of vibration and shock transducers — Part 21: Vibration calibration by comparison to a reference transducer*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

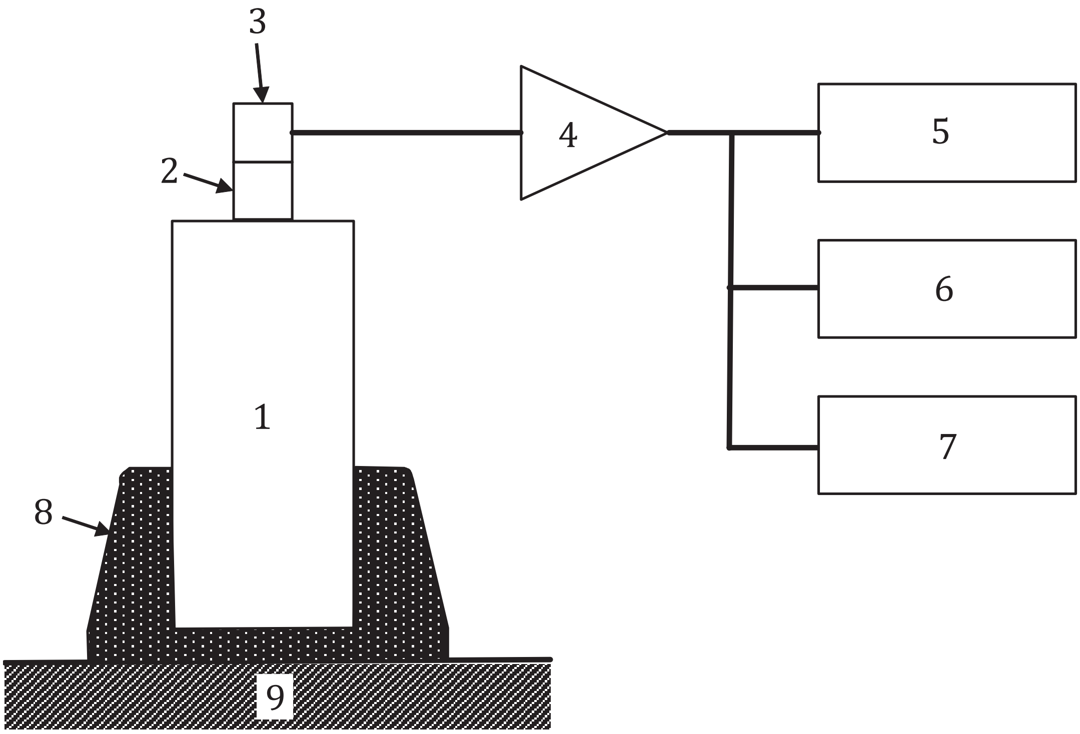
— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Requirements for apparatus and other conditions

4.1 General

Figure 1 shows the apparatus for the calibration. In some cases, reference transducer and amplifier may be a single device as transducer chain.



Key

1 FVC
2 dummy mass
3 reference transducer
4 amplifier
5 distortion meter
6 voltmeter
7 frequency counter
8 fixing attachment (only for hand-held FVCs)
9 base

Figure 1 — Calibration apparatus

4.2 Reference transducer and amplifier

The reference transducer (preferably together with amplifier) shall be calibrated in accordance with the comparison method given in ISO 16063-21 or other known methods with expanded uncertainty of less than 2 % (magnitude). The uncertainty is the expanded uncertainty using a coverage factor of 2. When the FVC allows selectable acceleration magnitudes and frequencies, the reference transducer shall be calibrated at each magnitude and frequency in advance.

The reference transducer shall have a low transverse sensitivity of preferably less than 2 % to minimize the influence of the FVC's transverse vibration. The mass of the reference transducer shall be equal to, or smaller than the capability of the FVC to be tested. Additional mass (dummy mass) may be employed for evaluation of acceleration, distortion and other performances of the FVC.

4.3 Voltage measuring instrument for true RMS transducer chain output

A voltmeter measuring true RMS at the reference transducer chain output is used. Required expanded uncertainty of voltmeter is 0,3 % at the selected reference frequency (coverage factor of 2).

4.4 Frequency measuring instrument

A frequency counter at the reference transducer chain output is used. Required expanded uncertainty is 0,05 % at the selected reference frequency (coverage factor of 2).

4.5 Distortion measuring instrument

A distortion meter or an FFT analyser for total distortion evaluation (minimum up to 5th harmonic) at the reference transducer chain output is used. Required relative expanded uncertainty of the instrument is 10 % at the selected reference frequency (coverage factor of 2). When a narrowband FFT analyser is used to render the transducer chain output signal value, the observation time shall be at least three times the reciprocal of the FFT line window width and the levels of the FFT lines clustered about the calibration frequency shall be energy-summed into one result and reported.

4.6 Dummy mass

A set of different dummy masses may be employed as additional mass to the reference transducer in order to test stability at changing loads. The dummy masses shall have appropriate threads on both sides for the shaker and the reference transducer. The mounting surface of the dummy masses shall be appropriately finished by means of mechanical geometry. It shall be cylindrical to ensure symmetrical load of the FVC and be designed in a way that the reference transducer stays as close as possible to the FVC. If the distance becomes too wide, transverse vibrations of the FVC can affect the calibration due to leverage. Material, geometry and each mass of the dummy masses may be reported upon request.

4.7 Environmental conditions

These shall be as follows:

Room temperature:	(23 ± 10) °C
Relative humidity:	75 % max
Vibration noise:	Sufficiently isolated less than 0,1 m/s^2 (RMS value) at the base surface of the calibration apparatus in Figure 1.

5 Calibration procedure

5.1 Preparation of calibration

The FVC to be calibrated should be placed on a rigid and stable base. The mounting method and direction of the FVC should be the same as its operation condition that is specified by the FVC manufacturer. If the FVC is operated by handheld, it shall be fixed by an appropriate attachment. The attachment shall hold the FVC tightly but shall not give mechanical stress to the FVC. Item 8 in Figure 1 shows an example of such a fixing attachment. The attachment has to be made of a soft and flexible material. A hard material can cause coupling resonances between the calibrator case and the fixture, which might interfere with the vibration output.

A proper power supply (battery) shall be provided during the calibration as specified by the FVC manufacturer. A mounting surface of the FVC should be checked to see whether there is any serious damage (scratch) on it. If there is, it shall be reported to the customer to confirm whether the calibration should be terminated or the scratches should be smoothened for calibration. The reference transducer shall be screw-mounted with an appropriate torque. Transducer mounting should be in accordance with ISO 5348. It can be necessary to calibrate the FVC in different directions referred to earth's gravity.

The reference transducer, voltmeter, distortion meter and frequency counter shall be connected as shown in Figure 1. Dummy mass is also fixed if needed.

Before the calibration, confirm there is no significant noise or hum from the reference transducer chain output.

5.2 Calibration

The output voltage of reference transducer, vibration frequency and distortion shall be recorded. If vibration frequency and acceleration magnitude are selectable, measurement shall be performed at each frequency and acceleration magnitude or frequency and acceleration magnitude sets indicated by the customer.

5.3 Other evaluation (optional)

It is advisable to monitor rocking and transverse motion by employing an appropriate angled fixture for the reference transducer or tri-axial transducer both with a symmetrical distribution of weight. If it is difficult to evaluate, technical information provided from the manufacturer may be employed as type B uncertainty components. However, when the FVC is mechanically damaged from its original condition, it usually presents larger distortion or rocking and transverse motion than designed.

If the FVC equips a measuring channel for the transducer chain output, electrical calibration of the channel may be performed by an appropriate procedure.

Power supply to the FVC during the calibration should satisfy the specification provided by the FVC manufacturer. If the FVC is battery operated, specification of the battery (e.g. alkaline type or rechargeable type, its open circuit voltage) should be reported. A minimum and nominal voltage test is also recommended.

6 Calculation and expression of the result

6.1 Calculation of the result

6.1.1 FVC provides sinusoidal vibration $a(t)=\hat{a}\sin\omega t$

where

$\hat{a}$ is the acceleration amplitude;

ω = $2\pi f$;

f is the sinusoidal vibration frequency measured by a frequency counter.

The target quantity of the calibration is the acceleration RMS value produced by the FVC.

Calibration results are given in 6.1.2 to 6.1.4.

6.1.2 Acceleration RMS value: a

$$a=\frac{V_a}{S_1}$$

where

V_a is the true RMS voltage at the reference transducer chain output;

S_1 is the sensitivity of the reference transducer chain.

6.1.3 Velocity RMS value: v

$$v = a/(2\pi f)$$

6.1.4 Displacement RMS value: s

$$s = a/(4\pi^2 f^2)$$

6.2 Expression of the result

a) Environmental conditions: temperature and humidity.

b) Description of how to place/hold the FVC, orientation: if fixing mount is used, its material, dimensions should be described.

c) Description of reference transducer:

   1) reference transducer and amplifier type, uncertainty;

   2) mass of the transducer, mounting condition (fixing torque);

   3) if additional dummy masses are used, each mass, material and dimension should be described.

d) Other equipment:

   1) voltmeter (type, uncertainty);

   2) distortion meter settings (if FFT is used, time window settings should be reported).

e) Calibration results and uncertainties: acceleration RMS value and frequency at each setting (nominal frequency and acceleration amplitude), distortion and uncertainty. Velocity and displacement RMS value may be also reported. Uncertainty of measurement shall be estimated in accordance with Annex A.

f) Other information:

   1) power supply (battery type, open circuit voltage);

   2) rocking and transverse motion (optional);

   3) if the mounting surface is damaged, it shall be reported.

Annex A
(normative)

Expression of uncertainty of measurement in calibration

The expanded uncertainty of the acceleration amplitude is typically 3 % of the calibration reported at laboratory conditions by applying the procedure in this document.

Table A.1 shows the traceability hierarchy and example of attainable expanded uncertainty in terms of the ISO 16063 series.

Table A.1 — Traceability hierarchy and example of expanded uncertainty

Description	Application	Attainable expanded uncertainty at reference frequency (example, typical)
Transducer: Primary calibration	ISO 16063-11 *Primary vibration calibration by laser interferometry* Measurand: Sensitivity	0,5 %
Transducer: Comparison calibration	ISO 16063-21 *Vibration calibration by comparison to a reference transducer* Measurand: Sensitivity	1 %
Shaker: Comparison calibration	This document *Calibration of field vibration calibrators* Measurand: Acceleration (velocity, displacement) amplitude	3 %[a]

[a] The expanded uncertainty obtained here cannot be directly applied under the field conditions. It depends heavily on the condition of the field (temperature, humidity, mechanical and electrical background noise).

Components of uncertainty that contribute to the uncertainty of the measurement are listed in Table A.2. As there is no significant correlation, the combined standard uncertainty u_c can be expressed by Formula (A.1):

$$u_c = \sqrt{\sum_{i=1}^{6} {u_i}^2} \qquad \text{(A.1)}$$

where u_i is the uncertainty contribution in line i in Table A.2.

The expanded uncertainty U shall be determined by multiplying u_c by the coverage factor k with a value of $k = 2$.

Table A.2 — Source of uncertainty list

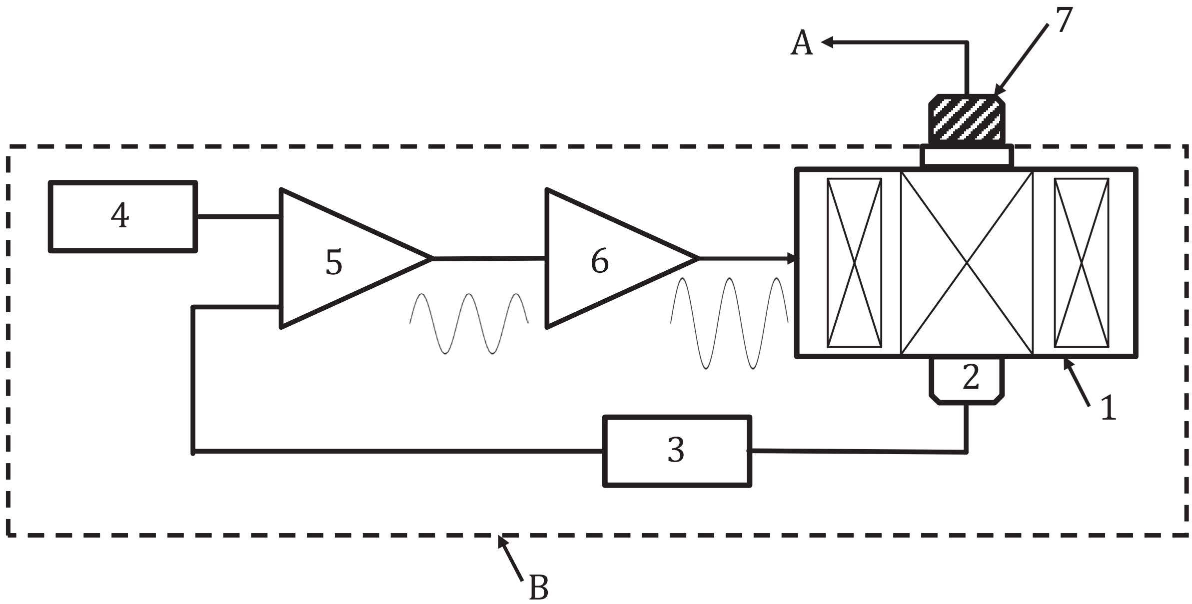
i	Standard uncertainty component	Source of uncertainty	Uncertainty contribution $u_i(y)$
1	$u(S_a)$	The combined standard uncertainty of the reference transducer and amplifier combination at specified conditions.	$u_1(y)$
2	$u(a_D)$	Effect of total distortion on the voltage measurement to be regarded as rectangular distribution.	$u_2(y) = u(a_D)/\sqrt{3}$
3	$u(S_T a_T)$	Effect of transverse, rocking and bending vibration on output voltage associated with the effect of transverse sensitivity of the reference transducer. If such information cannot be obtained, it may be included in row 6, residual effects.	$u_3(y)$
4	$u(V_{VM})$	The standard uncertainty of the voltmeter.	$u_4(y)$
5	$u(V_{HN})$	Effect of hum and noise on the voltage measurement.	$u_5(y)$
6	$u(U_{residuals})$	Residual effects (e.g. temperature coefficient of the internal acceleration transducer).	$u_6(y)$

Annex B
(informative)

Configuration and application of field vibration calibrators

B.1 Configuration of FVC

Figure B.1 shows the typical configuration of an FVC. Here, the power supply (normally a DC battery) is omitted. It also omits additional functions such as operation timer, limiter, etc.



Key

A output
B FVC to be calibrated by this document
1 shaker
2 monitor transducer
3 conditioning amplifier
4 frequency generator
5 comparator
6 amplifier for shaker
7 transducer to be tested by the FVC

Figure B.1 — Configuration of FVC

An internal monitor transducer attached to the armature of the electromagnetic shaker (or other actuator e.g. piezo actuator) measures the level of generated vibration acceleration. The output from the monitor transducer which may be processed and rectified by a signal conditioner leads to a comparator which compares generated and intended acceleration level (feedback loop). According to the output from the comparator, the shaker is driven by an amplifier at an appropriate level. Vibration frequency is kept at the frequency generated by the frequency generator. In the market, there are some FVCs which can select acceleration levels and frequencies.

There are commercial FVCs which equip signal conditioner/amplifier for transducers under test. But such a component of conditioner/amplifier calibration is not specified in this procedure.

B.2 Guidance of usage

As noted in the introduction, the uncertainty of acceleration level generated by the FVC is usually larger than the one generated by a stationary calibration shaker. It shall not be applied for transducer calibration in accordance with the uncertainty achieved at laboratory conditions. It is well used for periodical check of transducers in testing. For those purposes, good or no-good decision of the transducer may be obtained by Formula (B.1) and (B.2).

Good for application:

$$\frac{\left|a - a_{\text{output}}\right|}{\sqrt{U_{\text{MPE}}^2 + U^2}} \leq 1 \qquad \text{(B.1)}$$

No-good for application:

$$\frac{\left|a - a_{\text{output}}\right|}{\sqrt{U_{\text{MPE}}^2 + U^2}} > 1 \qquad \text{(B.2)}$$

where

a	is the generated acceleration RMS value by the FVC;
a_{output}	is the measured acceleration obtained from the output voltage of the transducer under test;
U_{MPE}	is the acceptable expanded uncertainty of the FVC for the user;
U	is the expanded uncertainty of the transducer under test.

B.3 Calibration interval

The FVC should be re-calibrated at intervals determined to be appropriate by the end user. Calibration intervals should be determined based on periodic examinations of the operational condition of the FVC. If the FVC is used under field conditions, the calibration interval should probably be decreased as the FVC can be damaged by use under more severe field conditions.

Bibliography

[1] ISO 5348, *Mechanical vibration and shock — Mechanical mounting of accelerometers*

[2] ISO 8041-1, *Human response to vibration — Measuring instrumentation — Part 1: General purpose vibration meters*

[3] ISO 8042, *Shock and vibration measurements — Characteristics to be specified for seismic pick-ups*

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

[5] ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM)*

[6] ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

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