INTERNATIONAL STANDARD

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Methods for the calibration of vibration and shock transducers —

Part 31:
Testing of transverse vibration sensitivity

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

Partie 31: Essai de sensibilité aux vibrations transversales

Reference number
ISO 16063-31:2009(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.

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 16063-31 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

This first edition cancels and replaces ISO 5347-11:1993.

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 15: Primary angular vibration calibration by laser interferometry*

— *Part 21: Vibration calibration by comparison to a reference transducer*

— *Part 22: Shock calibration by comparison to a reference transducer*

— *Part 31: Testing of transverse vibration sensitivity*

— *Part 41: Calibration of laser vibrometers*

The following parts are planned:

— Part 23: Angular vibration calibration by comparison to reference transducers

— Part 32: Resonance testing[1)]

— Part 42: Calibration of seismometers

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1) Revision of ISO 5347-14:1993 and ISO 5347-22:1997.

Methods for the calibration of vibration and shock transducers —

Part 31:
Testing of transverse vibration sensitivity

1 Scope

This part of ISO 16063 specifies details of the instrumentation and methods to be used for transverse vibration sensitivity testing. It applies to rectilinear velocity and acceleration transducers.

The methods and procedures specified in this part of ISO 16063 allow the determination of the sensitivity of a transducer to vibration in the plane perpendicular to its geometric axis of sensitivity (see Annex A). Because the magnitude of this transverse sensitivity can vary with the direction of the applied vibration, the various methods determine the maximum value. Using that value, the ratio of the transverse sensitivity to the sensitivity on the geometric axis of the transducer can be calculated. In addition, the angle at which the maximum transverse sensitivity occurs can be determined.

The methods and techniques specified can be applied without re-mounting the transducer away from its mounting surface during the test, thus avoiding significant uncertainties often encountered in methods which require repeated mounting. The different methods specified use a single-axis vibration exciter, a two-axis vibration exciter or a tri-axial vibration exciter. Tri-axial vibration excitation allows the transverse sensitivity and the sensitivity on the geometric axis to be determined simultaneously, thus simulating application conditions where the transducer is exposed to multi-axial vibration.

NOTE In accelerometer designs using a bending beam, the transverse sensitivity measured without any vibration acting on the geometric axis of sensitivity of the accelerometer may considerably differ from the transverse sensitivity measured in the presence of a vibration acting on the geometric axis of sensitivity (i.e. when the bending beam is deflected by a vibration to be measured).

This part of ISO 16063 is applicable to a frequency range from 1 Hz to 5 kHz and for a dynamic range from 1 m/s^2 to 1 000 m/s^2 (frequency dependent) and from 1 mm/s to 1 m/s (frequency dependent). Although among all the systems specified it is possible to achieve these ranges, generally each has limitations permitting its use in much smaller ranges.

The methods specified are by comparison both to a reference transducer and to a laser interferometer.

The methods specified allow an expanded uncertainty of the transverse sensitivity (coverage factor $k = 2$) of 0,1 % or less to be achieved, if the expanded uncertainty is expressed as a percentage of the sensitivity of the test transducer in its sensitive axis.

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

3 Uncertainty considerations

An expanded uncertainty of 0,1 % (see Clause 1) means, for the example of a transverse sensitivity of 1 %, that the measured value lies within the interval of 0,9 % to 1,1 %.

All users of this part of ISO 16063 are expected to assess and report the uncertainty of measurement according to ISO 16063-1:1998, Annex A, to document their uncertainty expressed as expanded uncertainties for a coverage factor of 2 or a coverage probability of 95 %. It is the responsibility of the laboratory or end user to make sure that the reported values of expanded uncertainty are credible.

4 Determination of transverse sensitivity using a single-axis vibration generator

4.1 Apparatus

The single-axis test system of transverse sensitivity specified in this clause consists of a single-axis vibration exciter that is equipped with a specially designed fixture that enables the transducer under test to be mounted such that its geometric axis of sensitivity is perpendicular to the direction of motion of the vibration exciter table (where the direction of the motion of the vibration exciter table shown in Figure 1 is defined as the Z-direction). It shall be possible to mount the test transducer at different angles about its sensitive axis, preferably for continuous rotation over at least 180°. An example (Reference [5]) of an octahedral fixture is shown in Figure 1.

Another example is the use of an electro-dynamic long-stroke vibration exciter operated in combination with a turntable driven by a stepper motor as specified in Clause 5. The amplitude of the transverse acceleration of the fixture due to transverse motion inherent in the vibration exciter shall be less than 1 % of the acceleration amplitude in the Z-direction at each of the test frequencies. For cases in which the measured transverse sensitivity is less than 2 % of the sensitivity measured on the geometric axis, the transverse motion of the vibration exciter shall meet even higher requirements (e.g. 0,2 % at the test frequencies). To ensure that the transverse motion of the vibration exciter is sufficiently small, measurements of the transverse motion of the total setup (vibration exciter with fixture) with a load close in shape and weight to the transducer being tested should be performed beforehand or the transverse motion could be monitored during the measurement of the transverse sensitivity. For the measurement of the input and output signal of the transducer to be tested, see Clause 8.

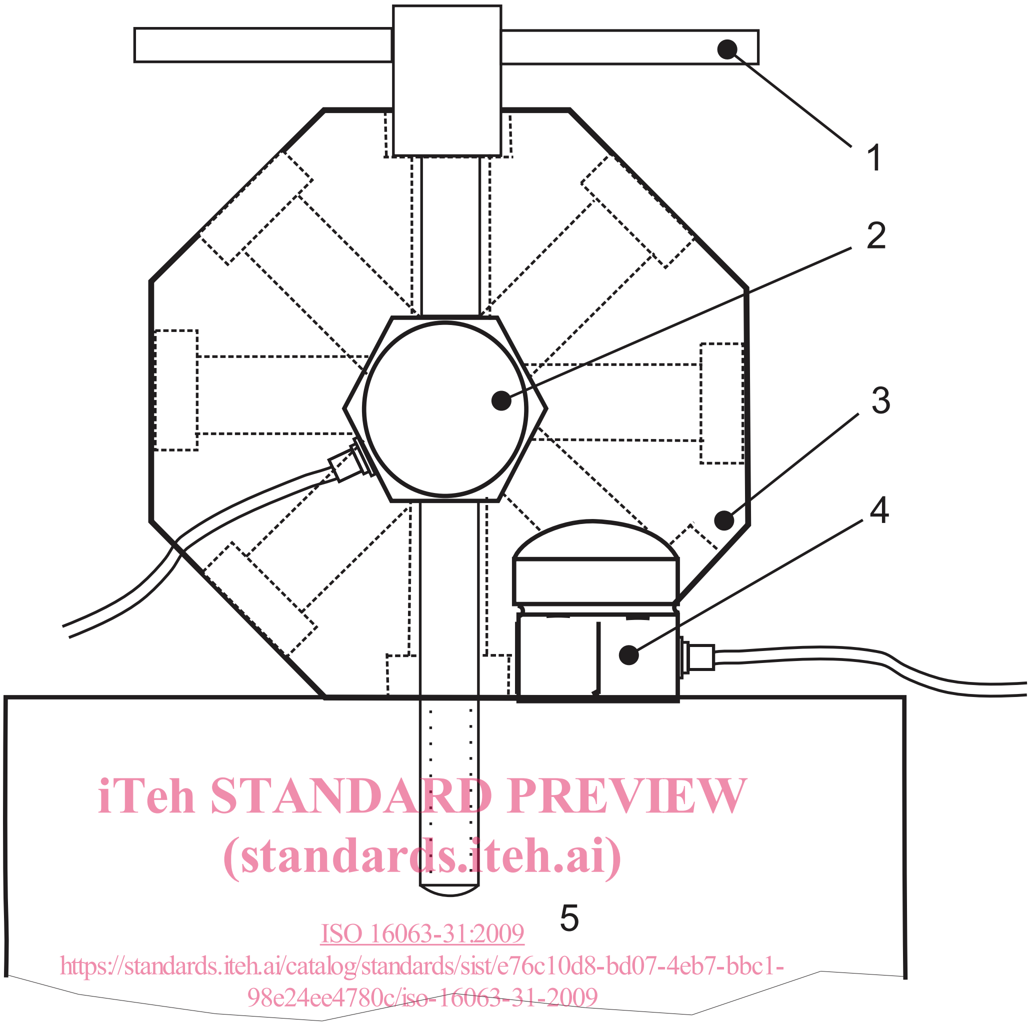
The frequency range of the transverse test system is generally 1 Hz to 5 kHz, depending on the working range of the vibration exciter, and on the mass of the fixtures and of the transducer tested. Acceleration amplitudes from 1 m/s^2 to 200 m/s^2 can be generated.

4.2 Method

4.2.1 Test procedure

Vibrate the transducer at the reference amplitude and frequency on the geometric axis of sensitivity to determine its sensitivity, S_N (briefly referred to as S). Determine the values of transverse sensitivity as a function of frequency, S_T, by vibrating perpendicularly to the sensitive axis of the transducer at different angles about its sensitive axis.

The directions and magnitudes of the maximum and minimum transverse sensitivity shall be reported at a designated test frequency or as a function of frequency.



Key

1 screw unit for re-mounting the octahedron in different positions (angle shifts of 45°)
2 transducer to be tested
3 octahedron
4 reference accelerometer
5 vibration exciter table

Figure 1 — Example of a fixture for mounting the test transducer with its sensitive axis perpendicular to the direction of the vibration generated by the vibration exciter

4.2.2 Expression of results

Calculate the transverse sensitivity, S_T, using Equation (1):

$$S_T = \frac{\hat{u}_{out}}{\hat{a}_T} \quad (1)$$

where

$\hat{u}_{out}$ is the amplitude of the output signal of the transducer vibrating perpendicularly to its sensitive axis;

$\hat{a}_T$ is the amplitude of the acceleration in the test direction.

Calculate the relative transverse sensitivity, S_T^*, expressed as a percentage, using Equation (2):

$$S_T^* = \frac{S_T}{S} \times 100\ \% \tag{2}$$

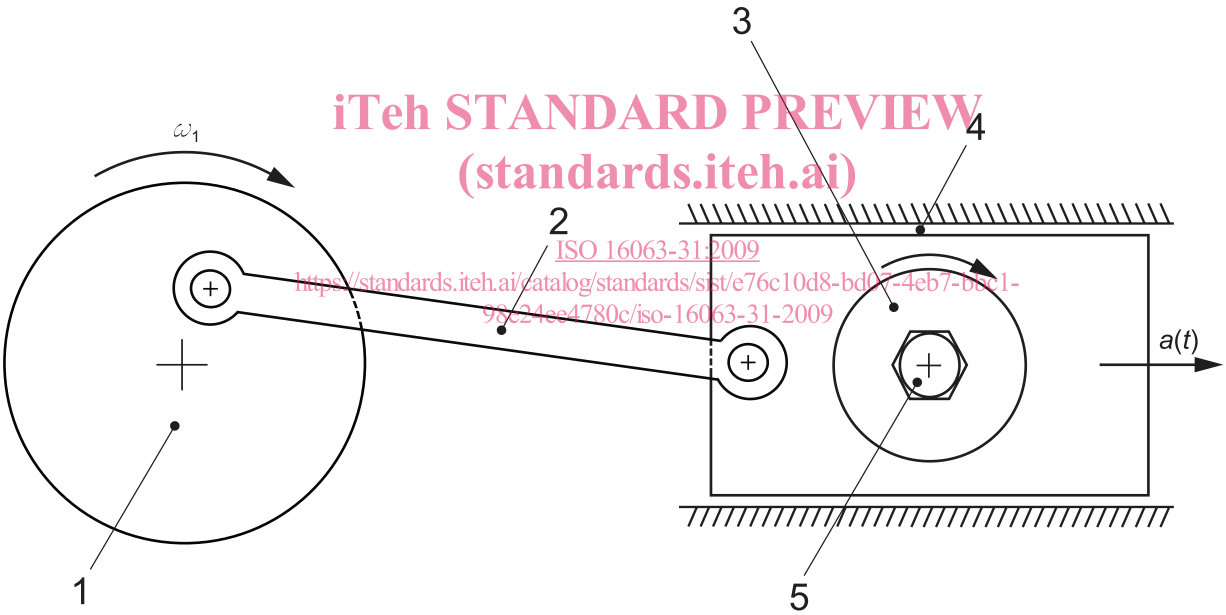
where S is the sensitivity of the transducer on the geometric axis of sensitivity.

5 Determination of the transverse sensitivity using a vibration generator with turntable

5.1 Apparatus

5.1.1 General. The single-axis test system of transverse sensitivity specified in this clause consists of a single-axis vibration exciter and a rotating table.

NOTE An apparatus similar to Figure 2 is used by several manufacturers of accelerometers in order to comply with criteria contained in ISA-RP 37.2 [6]. For details of the apparatus specified as an example in the following, see Reference [7].



Key

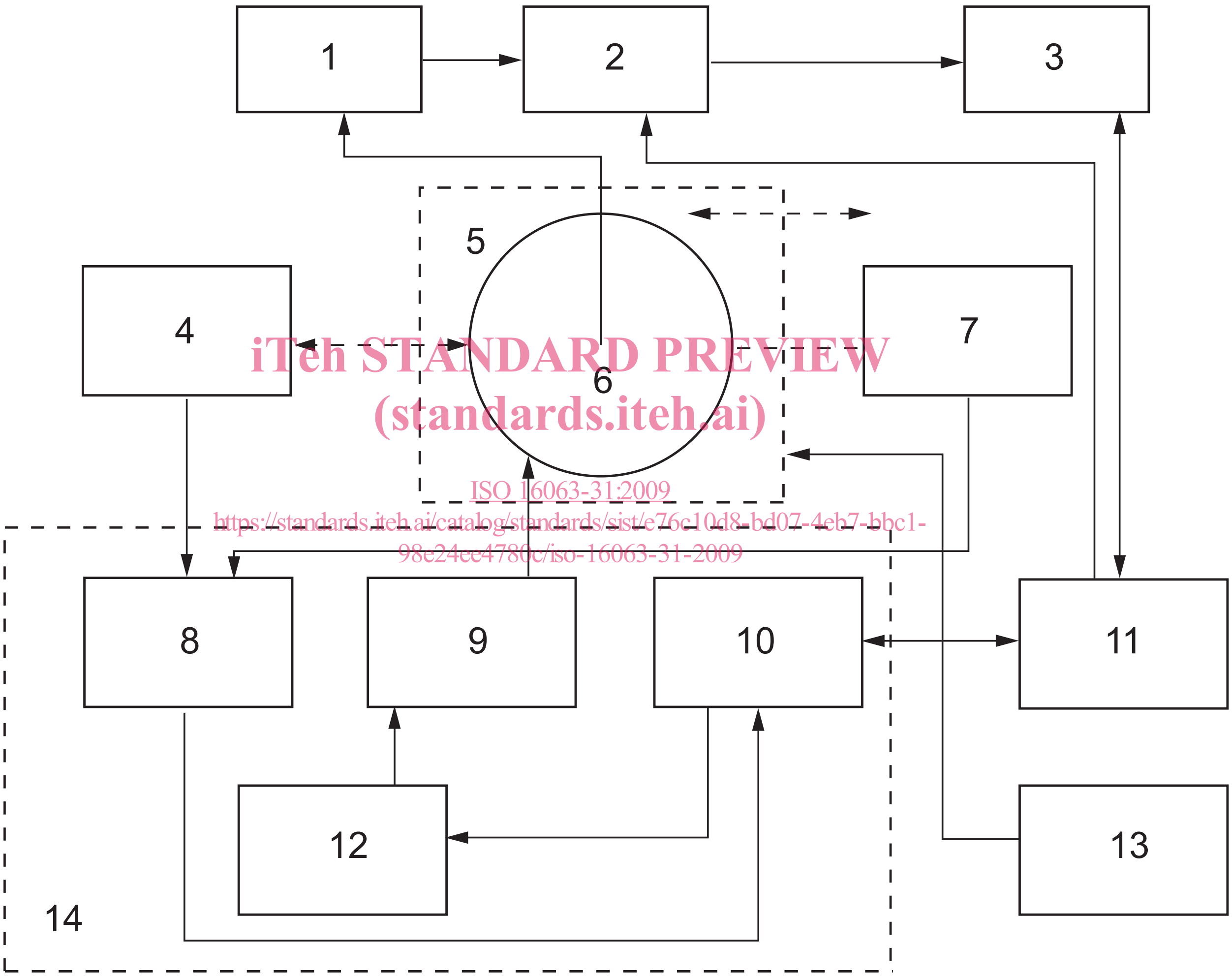
1 rotating disk
2 drive rod
3 turntable controlled by a stepper motor
4 slide or air bearing
5 transducer to be tested
$a(t)$ acceleration
ω_1 angular frequency ("speed")

Figure 2 — Example of a mechanical vibration exciter with turntable used for the measurement of the transverse sensitivity

The crank is driven at a constant speed, ω_1, by an electric motor via a toothed belt. The slider, in turn, drives a carriage, the motion of which is constrained by two bars with bronze sockets. On the carriage, there is a turntable whose motion is controlled by a stepper motor. The carriage is made to oscillate at approximately

12 Hz with a 25,4 mm peak-to-peak amplitude, which corresponds to a root mean square (r.m.s.) acceleration value of 51 m/s^2.

The accelerometer to be tested is held in place on the turntable of the carriage through, for instance, a ¼-28 UNF hole drilled in the centre of the turntable. Normally the accelerometer is placed such that the geometric axis is perpendicular to the direction of acceleration. However, by using specially designed adaptors, the geometric axis of the accelerometer can be aligned with the direction of motion of the carriage. Then, the sensitivity on the geometric axis of the accelerometer can be determined at the same excitation frequency as its transverse sensitivity. The accelerometer then can be mounted with its geometric axis perpendicular to the direction of motion of the carriage to determine transverse sensitivity as a function of the orientation angle, as illustrated in Figure 3. The time to complete one revolution can be between 30 s and 120 s, depending on the resolution, especially for the direction of least cross-axis sensitivity.



Key

1 power supply/coupler (or) charge amplifier
2 filter
3 digital voltmeter (DVM)
4 angular position detector part A
5 carriage
6 transducer under test mounted on turntable
7 angular position detector part B
8 angular position controller for items 4 and 7
9 stepper motor
10 controller
11 computer
12 driver
13 a.c. motor
14 turntable control panel

Figure 3 — Example of block diagram of complete signal conditioning and data acquisition system

It is recommended that an accelerometer be permanently or periodically placed in the direction of the slider motion to monitor the condition of the exciter. By double integration, the value of amplitude of displacement can be computed from the acceleration experienced in the excitation axis and hence a comparison drawn between the observed value and the expected value (25,4 mm).

The transverse test system is generally operated at a fixed frequency between 5 Hz and 15 Hz and a fixed displacement amplitude (25,4 mm peak-to-peak amplitude is widely preferred, see Note).

5.1.2 Vibration exciter assembly. In the example introduced in 5.1.1, the vibration exciter consists essentially of a three-phase synchronous a.c. motor and a mechanical excitation unit. The excitation unit itself is composed of a crank-slider mechanism driving the carriage with the turntable, controlled by a stepper motor, on to which the transducer under test is mounted. With a power line frequency of 50 Hz, the synchronous speed, n, is 1 500 r/min for the 4-pole motor in use.

NOTE The use of a 3-phase, 4-pole synchronous motor is not mandatory. To simplify the setup, a special series-wound single-phase motor can be used working in a synchronous way with the power line frequency.

5.1.3 Signal conditioning and data acquisition system. In general, the output of the unit under test requires signal conditioning, including filtering and amplification. The signal conditioning unit may be comprised of a power supply, voltage or charge amplifier, and a 24 dB/octave narrow analogue band-pass filter which can be a combination of a high-pass and a low-pass filter. The filtered signal is connected to the input of the DVM which is in turn connected to a computer via a suitable digital interface. Figure 3 shows a block diagram of an example of a complete signal conditioning and data acquisition system.

5.2 Method

Mount the transducer in a test arrangement such that the known vibratory motion in a plane perpendicular to the sensitive axis is at least 100 times the motion in the direction of the sensitive axis. The frequency and amplitude of the motion shall be stated and shall lie within the rated frequency and amplitude ranges of the transducer. Determine the amplitude of maximum transverse sensitivity and the direction of the maximum and minimum sensitivity by rotating the transducer about its geometric axis of sensitivity.

NOTE Generally, the most interesting parameters are the maximum transverse sensitivity and the direction of the minimum transverse sensitivity.

5.3 Expression of results

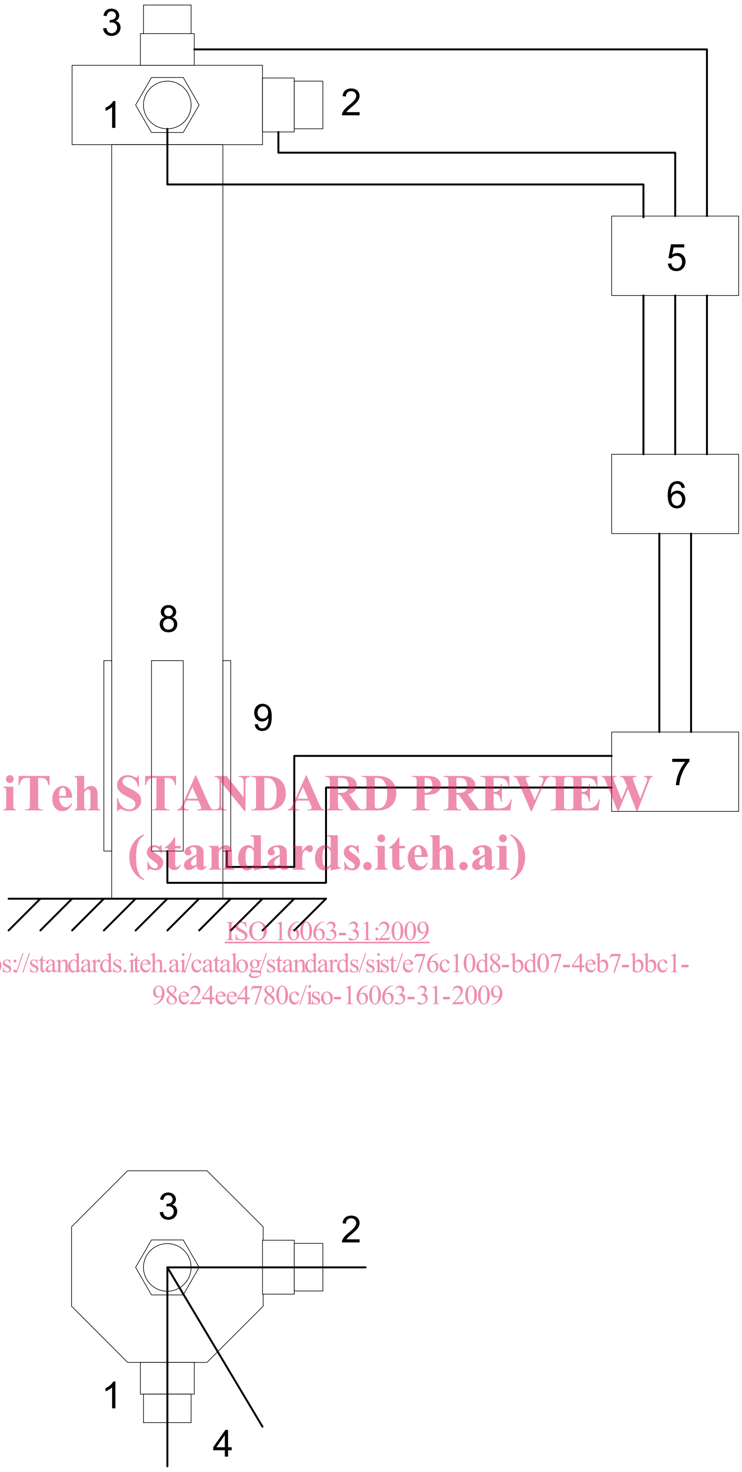
Express the output at the maximum transverse sensitivity as a percentage of the output which would be obtained if the known motion were applied in the direction of the geometric axis (Reference [7]).

For further details, see 4.2.2 and Annex A.

6 Determination of transverse sensitivity using a test system with X- and Y-vibration generators

6.1 Apparatus

The transverse test system consists of at least two vibration exciters in the X–Y plane, X- and Y-axis reference accelerometers, a power amplifier and a computer-based acquisition and control system. In Figure 4 and Figure 5, two versions of transverse vibration exciters are shown (see Reference [8] for Figure 4 and Reference [9] for Figure 5). Both are designed to generate vibration in all possible directions in the X–Y plane, yet keeping a fixed angular position of the transducer. This is in contrast with the methods specified in Clause 4, in which the motion is in a single direction and the transducer is turned through all angles to find the direction of maximum transverse sensitivity.



Key

1 X-axis reference accelerometer
2 Y-axis reference accelerometer
3 transducer to be tested
4 direction of transverse acceleration
5 signal conditioner
6 computer, data acquisition, analogue output
7 power amplifier
8 X-axis actuator
9 Y-axis actuator

Figure 4 — Example 1 of a test system with X–Y plate