INTERNATIONAL STANDARD

# ISO 8041

Second edition
2005-04-01

# Human response to vibration — Measuring instrumentation

*Réponse des individus aux vibrations — Appareillage de mesure*



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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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 8041 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 second edition cancels and replaces the first edition (ISO 8041:1990), which has been technically revised, and incorporates its Amendment, ISO 8041:1990/Amd.1:1999, and Technical Corrigendum ISO 8041:1990/Cor.1:1993.



The reasons for the main changes introduced in this edition are as follows:

— to improve the specifications for human response to vibration measuring instrumentation;

— to incorporate into one document the specifications introduced by the 1999 amendment to ISO 8041:1990, which themselves were required following the introduction of new frequency weightings in ISO 2631-1:1997;

— to recognise changes in the frequency weighting specification introduced in ISO 5349-1:2001 that allows frequencies outside the one-third octaves from 6,3 Hz to 1250 Hz to be excluded from the weighted acceleration calculation (this is achieved by changing the frequencies at which the tolerance is extended to –100 % to be the lower boundary of the 6,3 Hz one-third-octave bands and the upper boundary of the 1 250 Hz one-third-octave band);

— to introduce allowances for the uncertainties of testing the conformance of the human vibration measuring instruments;

— to introduce a hierarchy of testing requirements (pattern evaluation, periodic verification and *in-situ* check) with tests defined according to the needs of this hierarchy;

— to recognise the needs for the specification and testing of new parameters such as maximum transient vibration value (MTVV) and vibration dose value (VDV);

— to recognise the need to test multi-axis instrumentation and to test combined results from these multi-axis inputs;

— to introduce informative tests for mounting methods.

# Human response to vibration — Measuring instrumentation

## 1 Scope

This International Standard specifies the performance specifications and tolerance limits for instruments designed to measure vibration values, for the purpose of assessing human response to vibration. It includes requirements for pattern evaluation, periodic verification and *in-situ* checks, and the specification of vibration calibrators for *in-situ* checks.

Vibration instruments specified in this International Standard can be single instruments, combinations of instrumentation or computer-based acquisition and analysis systems.

Vibration instruments specified in this International Standard are intended to measure vibrations for one or more applications, such as

— hand-transmitted vibration (see ISO 5349-1),

— whole-body vibration (see ISO 2631-1, ISO 2631-2, ISO 2631-4), and

— low-frequency whole-body vibration in the frequency range from 0,1 Hz to 0,5 Hz (see ISO 2631-1).



Vibration instruments can be designed for measurement according to one or more of the frequency weightings defined within each of these applications.



Three levels of performance testing are defined in this International Standard:

a) pattern evaluation, i.e. a full test of the instrument against the specifications defined in this International Standard;

b) periodic verification, i.e. an intermediate set of tests designed to ensure that an instrument remains within the required performance specification, and

c) *in-situ* checks, i.e. a minimum level of testing required to indicate that an instrument is likely to be functioning within the required performance specification.

## 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 2041, *Vibration and shock — Vocabulary*

ISO 2631-1, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*

ISO 2631-2, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 2: Vibration in buildings (1 Hz to 80 Hz)*

ISO 2631-4, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 4: Guidelines for the evaluation of the effects of vibration and rotational motion on passenger and crew comfort in fixed-guideway transport systems*

ISO 5347 (all parts), *Methods for the calibration of vibration and shock pick-ups*

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

ISO 5349-1:2001, *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 1: General requirements*

ISO 16063 (all parts), *Methods for the calibration of vibration and shock transducers*

IEC 61000-4-2:2001, *Electromagnetic compatibility (EMC) — Part 4-2: Testing and measurement techniques — Electrostatic discharge immunity test*

IEC 61000-4-3:2002, *Electromagnetic compatibility (EMC) — Part 4-3: Testing and measurement techniques —Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) — Part 4-6: Testing and measurement techniques — Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-6-2:1999, *Electromagnetic compatibility (EMC) — Part 6-2: Generic standards — Immunity for industrial environments*

CISPR 22:2003, *Information technology equipment — Radio disturbance characteristics — Limits and methods of measurement*

GUM, *Guide to the expression of uncertainty in measurement*. BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 1993

## 3 Terms, definitions and symbols



### 3.1 Terms and definitions

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



**3.1.1**
**vibration acceleration**
component of acceleration, where the axis of measurement is specified by application standards

**3.1.2**
**band-limiting frequency weighting**
component of a frequency weighting defined by the high and low pass band-limiting filters

**3.1.3**
**band-limited frequency range**
frequency range defined by the band-limited component of a frequency weighting

**3.1.4**
**nominal frequency range**
frequency range of interest, as defined in the relevant measurement standard

#### 3.1.5 Frequency-weighted values

**3.1.5.1**
**time-averaged weighted acceleration value**
frequency-weighted r.m.s. vibration acceleration value in a specified axis, $a_{\mathrm{w}}$, in metres per second squared or radians per second squared, as defined by the expression:

$$a_{\mathrm{w}} = \left( \frac{1}{T} \int_0^T a_{\mathrm{w}}^2 (\xi) \, \mathrm{d}\xi \right)^{1/2} \qquad (1)$$

where

$a_w(\xi)$ is the translational or rotational, weighted vibration acceleration in a specified axis as a function of the instantaneous time, $\xi$, in metres per second squared (m/s$^2$) or radians per second squared (rad/s$^2$), respectively;

$T$ is the duration of the measurement

**3.1.5.2**
**time-averaged weighted acceleration level**
frequency-weighted r.m.s. vibration acceleration level expressed in decibels, as defined by

$$L_w = 20 \lg \frac{a_w}{a_0} \text{ dB} \tag{2}$$

where

$a_w$ is defined in 3.1.5.1;

$a_0$ is the reference acceleration (defined as $10^{-6}$ m/s$^2$ in ISO 1683)

**3.1.5.3**
**running r.m.s. acceleration value**
frequency-weighted running r.m.s. vibration acceleration, in metres per second squared, defined by the expression



$$a_{w,\theta}(t) = \left( \frac{1}{\theta} \int_{t-\theta}^{t} a_w^2(\xi) \mathrm{d}\xi \right)^{1/2} \tag{3}$$



where

$a_w(\xi)$ is the frequency-weighted instantaneous vibration acceleration at time $\xi$, in metres per second squared;

$\theta$ is the integration time of the measurement;

$t$ is the instantaneous time

NOTE Exponential averaging may be used for the running r.m.s. method, as an approximation of the linear averaging. The exponential averaging is defined as follows:

$$a_{w,\tau}(t) = \left( \frac{1}{\tau} \int_{-\infty}^{t} a_w^2(\xi) \exp\left( \frac{\xi - t}{\tau} \right) \mathrm{d}\xi \right)^{1/2} \tag{4}$$

where $\tau$ is the time constant.

**3.1.5.4**
**maximum transient vibration value**
**MTVV**
maximum value of the running r.m.s. vibration acceleration value when the integration time is equal to 1 s

**3.1.5.5**
**motion sickness dose value**
**MSDV**
integral of the squared weighted instantaneous vibration acceleration $a_w(t)$ in m/s$^{1,5}$ as defined by the expression:

$$\mathrm{MSDV} = \left( \int_0^{\Phi} a_{\mathrm{w}}^2 (\xi) \mathrm{d}\xi \right)^{1/2} \tag{5}$$

where $\Phi$ is the total period during which motion could occur

NOTE 1 The motion sickness dose value may be obtained from the frequency weighted r.m.s. vibration acceleration through multiplication by $\Phi^{1/2}$.

NOTE 2 For measurement instrumentation, the exposure period $\Phi$ is likely to be assumed to be equal to the measurement period, $T$, unless otherwise indicated.

**3.1.5.6**
**vibration dose value**
**VDV**
integral of the fourth power of the weighted instantaneous vibration acceleration $a_{\mathrm{w}}(t)$ in m/s$^{1,75}$ as defined by the expression

$$\mathrm{VDV} = \left( \int_0^{\Phi} a_{\mathrm{w}}^4 (\xi) \mathrm{d}\xi \right)^{1/4} \tag{6}$$

where $\Phi$ is the total (daily) period for which exposure occurs



NOTE 1 The vibration dose value is more sensitive to peaks than is the r.m.s. value.



NOTE 2 For measurement instrumentation, the exposure period $\Phi$ is likely to be assumed to be equal to the measurement period, $T$, unless otherwise indicated.



**3.1.5.7**
**vibration total value**
combined vibration from three axes of translational vibration, as defined by the expression

$$a_{\mathrm{w}v} = \sqrt{k_x a_{\mathrm{w}x}^2 + k_y a_{\mathrm{w}y}^2 + k_z a_{\mathrm{w}z}^2} \tag{7}$$

where

$a_{\mathrm{w}x}$, $a_{\mathrm{w}y}$ and $a_{\mathrm{w}z}$ are the vibration values in the three orthogonal axes $x$, $y$ and $z$;

$k_x$, $k_y$ and $k_z$ are multiplying constants whose values depend on the measurement application

**3.1.5.8**
**peak vibration value**
maximum modulus of the instantaneous (positive and negative) peak values of the frequency-weighted acceleration

**3.1.5.9**
**crest factor**
parameter for a measurement period, given by the peak vibration value divided by the r.m.s. acceleration value, with both values having the same frequency weighting

**3.1.6**
**linear operating range**
on each measurement range, the range between lower and upper boundaries over which the linearity errors are within the applicable tolerance limits specified in this International Standard

**3.1.7**
**overload**
condition that occurs when the upper boundary of the linear operating range is exceeded

**3.1.8**
**under-range**
condition that occurs when the vibration value is below the lower boundary of the linear operating range

**3.1.9**
**reference measurement range**
level range specified for testing the characteristics of the vibration instrumentation

NOTE This range is that used for measuring the reference vibration.

**3.1.10**
**reference vibration signal**
sinusoidal vibration signal, the magnitude and frequency of which is specified in this International Standard for testing the electromechanical performance of a human-vibration meter

NOTE Different reference vibration signals are specified according to the application of the instrumentation.

**3.1.11**
**calibration check frequency**
frequency specified for providing a check of the vibration sensitivity of the instrument

**3.1.12**
**tone burst**
one or more complete cycles of a sinusoidal signal that start and end at a zero crossing of the waveform



**3.1.13**
**signal burst**
one or more complete cycles of a periodic signal (such as saw-tooth) that start and end at a zero crossing of the waveform



**3.1.14**
**vibration measuring instrumentation**
combination of a vibration transducer, signal processor and display, being any single instrument, or a collection of instruments, which is capable of measuring parameters relating to human response to vibration

NOTE See Figure 1.

**3.1.15**
**instrument documentation**
instruction manual, operating procedure, or other documentation provided for the use of users of the vibration measurement instrument

## 3.2 Symbols

For the purposes of this document, the following symbols and abbreviated terms are used:

$a_w$ time-averaged frequency-weighted single-axis vibration acceleration

$a_w(t)$, $a_w(\xi)$ instantaneous frequency-weighted translational or rotational single-axis acceleration at time $t$, or time $\xi$

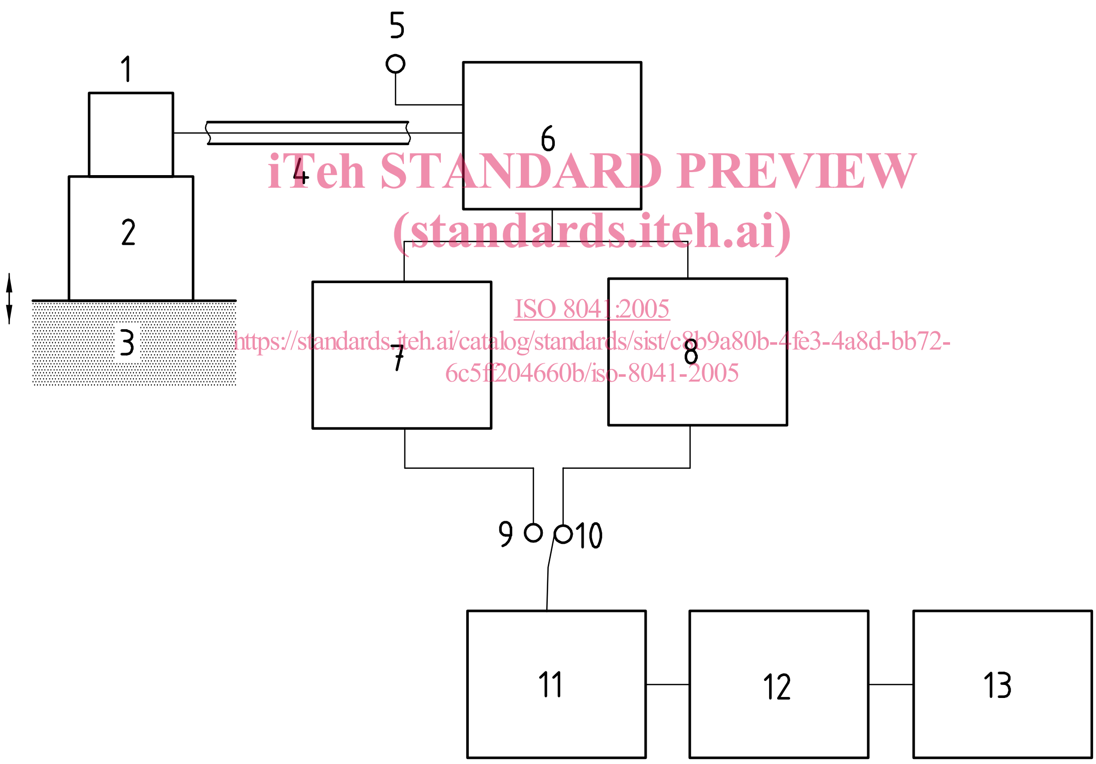
$f$ frequency

$H$ overall frequency weighting function

$k_i$ multiplying constants applied to the whole-body frequency-weighted acceleration value for axis $i$

$n$ one-third-octave band number

| | |
|---|---|
| $t$ or $\xi$ | instantaneous time |
| $T$ | measurement duration |
| $s$ | variable of the Laplace transform |
| $W_x$ | frequency weighting $x$ |
| $\Phi$ | exposure duration |
| $\Delta\varphi$ | phase error |
| $\tau$ | exponential averaging time constant |
| $\theta$ | linear averaging time |
| MTVV | maximum transient vibration value |
| MSDV | motion sickness dose value |
| VDV | vibration dose value |



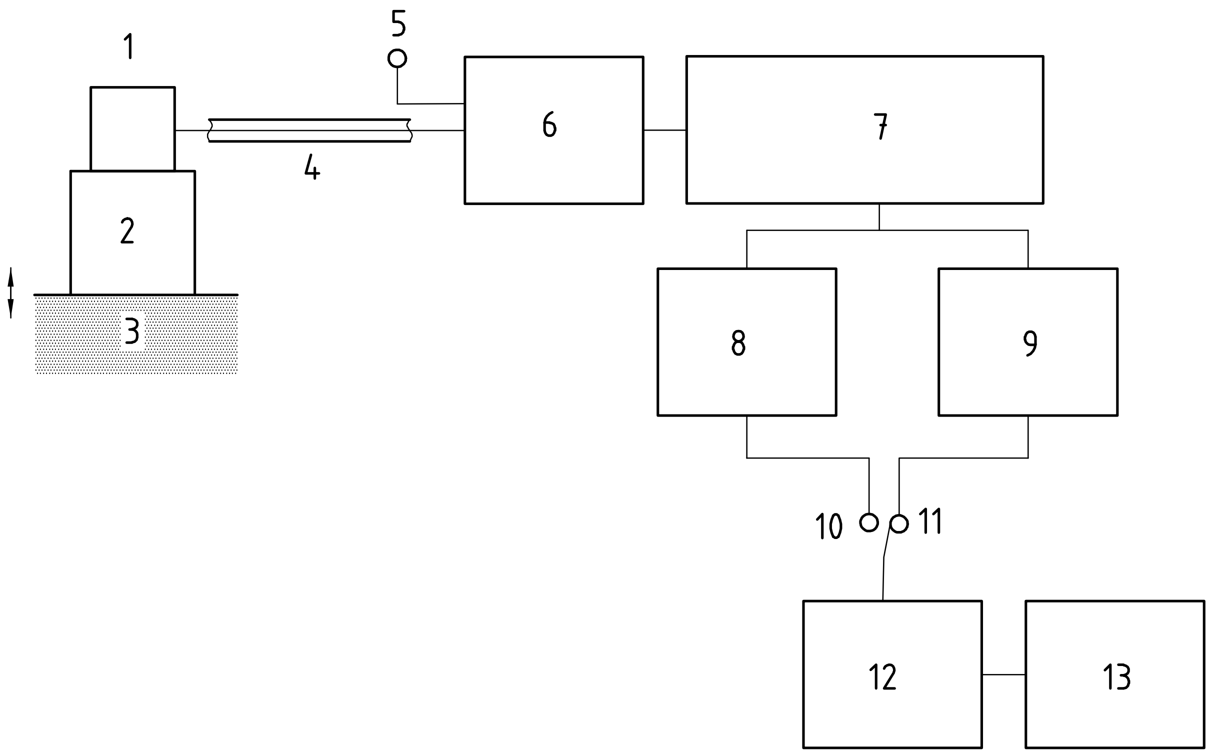



**Key**

1 transducer
2 mounting system
3 vibrating surface
4 cable
5 electrical input
6 signal conditioning
7 band limiting
8 frequency weighting (including band-limiting)
9 band-limited output
10 frequency-weighted output
11 time weighting
12 additional processing
13 display

**a) Time-domain signal processing**

**Figure 1 — Overview of the basic functional path output of a vibration measurement instrument or measurement system**




**Key**

1 transducer
2 mounting system
3 vibrating surface
4 cable
5 electrical input
6 signal conditioning
7 frequency analysis
time weighting
time averaging
8 band limiting (calculation)
9 frequency weighting — including band limiting (calculation)
10 band-limited output
11 frequency-weighted output
12 accumulation of frequency bands
13 display



b) **Frequency-domain signal processing** (not applicable to VDV processing)

**Figure 1** (*continued*)

## 4 Reference environmental conditions

Reference environmental conditions for specifying the performance of a vibration meter are

— air temperature: 23 °C;

— relative humidity: 50 %.

## 5 Performance specifications

### 5.1 General characteristics

The performance specifications of this clause apply under the reference environmental conditions.

As a minimum, human-vibration measuring instrumentation shall provide a means of displaying

— time-averaged weighted vibration acceleration value over the measurement duration,

— band-limited time-averaged vibration acceleration value over the measurement duration, and

— measurement duration.

The human-vibration measuring instrument shall also provide a means of indicating whether an overload occurred at any time within the measurement duration.

The human-vibration measuring instrument shall provide a method for setting and adjusting the vibration sensitivity.

Human-vibration measuring instruments may contain any or all of the design features for which performance specifications are given in this International Standard. An instrument shall conform to the applicable performance specifications for those design features that are provided.

If the instrument has more than one measurement range, the instrument documentation shall describe the measurement ranges that are included and the operation of the measurement range control. The instrument documentation shall also identify which is the reference measurement range.

The reference vibration signal frequencies and values are given in Table 1.

If the instrument is capable of measuring the maximum (e.g. MTVV) and peak vibration values, a “hold" function shall be provided. The instrument documentation shall describe the operation of the hold feature and the method for clearing a display that is held.

Many of the specifications and tests in this International Standard require the application of electrical signals substituting for the signal from the vibration transducer. The instrument documentation shall specify a means for substituting an electrical signal, equivalent to the signal from the vibration transducer, for performing electrical tests on the complete instrument without the vibration transducer. If appropriate, the instrument documentation may describe alternative methods to test the specified operations of the human vibration meter.



NOTE The manufacturer of the human-vibration meter may provide an input test point, or a dummy vibration transducer of specified electrical impedance, or an equivalent input adapter (electrical or non-electrical) to perform electrical tests on the instrument.



The instrument documentation shall specify the maximum peak vibration at the vibration transducer and the maximum peak-to-peak signal (e.g. charge or voltage) that can be applied at the electrical input facility. The maximum vibration value and the maximum peak-to-peak voltage shall not cause damage to the instrument.

**Table 1 — Reference vibration values and frequencies**

| **Application** | **Frequency weighting** | **Table in annex** *(informative)* | **Nominal frequency range** Hz | **Reference** Frequency | **Reference** r.m.s. acceleration value m/s$^2$ | **Weighting factor at reference frequency** | **Weighted acceleration at reference frequency and r.m.s. acceleration value** m/s$^2$ |
|---|---|---|---|---|---|---|---|
| Hand-transmitted | $W_h$ | B.6 | 8 to 1 000 | 500 rad/s (79,58 Hz) | 10 | 0,202 0 | 2,020 |
| Whole-body | $W_b$ | B.1 | 0,5 to 80 | 100 rad/s (15,915 Hz) | 1 | 0,812 6 | 0,812 6 |
| | $W_c$ | B.2 | | | | 0,514 5 | 0,514 5 |
| | $W_d$ | B.3 | | | | 0,126 1 | 0,126 1 |
| | $W_e$ | B.4 | | | | 0,062 87 | 0,062 87 |
| | $W_j$ | B.7 | | | | 1,019 | 1,019 |
| | $W_k$ | B.8 | | | | 0,771 8 | 0,771 8 |
| | $W_m$ | B.9 | 1 to 80 | | | 0,336 2 | 0,336 2 |
| Low-frequency whole-body | $W_f$ | B.5 | 0,1 to 0,5 | 2,5 rad/s (0,397 9 Hz) | 0,1 | 0,388 8 | 0,038 88 |

The tolerance limits given in this International Standard include the associated expanded uncertainties of measurement, calculated for a coverage factor of 2, corresponding to a level of confidence of approximately 95 %, in accordance with guidance given in the GUM.

## 5.2 Display of signal magnitude

### 5.2.1 General

For instruments that can display more than one measurement quantity, a means shall be provided to ascertain clearly the measurement quantity that is being displayed, preferably indicated by standard abbreviations or letter symbols.

The quantities that can be displayed by the human-vibration meter shall be described in the instrument documentation, along with a description of the corresponding indications on each display device.

The instrument shall display the frequency-weighted acceleration values. Optionally, it may also display the frequency-weighted acceleration value multiplied by a factor $k$, as defined in ISO 2631-1. Where the multiplying factors are used, this shall be clearly indicated on the instrument and the instrument shall be capable of displaying the multiplying factors.

Where a combined axis output is displayed [e.g. vibration total value, Equation (7)], the instrument shall be capable of displaying the values of the multiplying factors used.

When results of a measurement are provided at a digital output, the instrument documentation shall describe the method for transferring or downloading the digital data to an external data-storage or display device. The instrument documentation shall identify the computer software as well as the hardware for the interface.



Internationally standardized interface bus compatibility is recommended.



Each alternative device for displaying the signal value, stated in the instrument documentation as conforming to the specifications of this International Standard, is considered an integral part of the instrument. Each such alternative device shall be included as part of the components required for conformance to the performance specifications in this clause and the applicable environmental specifications of Clause 7. Examples of alternative display devices include level recorders or computers with monitor screens.

For an instrument that uses a display device with a range less than the linear operating range specified in 5.7, the instrument documentation shall describe a means to test the linearity beyond the limits of the indicator range.

### 5.2.2 Resolution and refresh rate

The display device(s) specified in the instrument documentation shall permit measurements with a resolution of 1 % of the indicated value, or better.

If an instrument only has an analog, or simulated analog, display device that provides a continuous indication, the display shall be a logarithmic display of the vibration value. The range of the analog display device shall include a display of at least 2 decades, with each decade being at least 10 mm wide. Where the display range does not encompass the whole of the linearity range of the instrument, then the display range shall be switchable to allow for the whole of the linearity range to be viewed.

If a digital indicator is provided, and the measurement quantity displayed is a vibration parameter, the display shall be updated at regular time intervals. The time interval between updates shall be appropriate to the measurement being displayed. The extent of the range of a digital display shall be at least sufficient to cover the linear operating range.

For instruments with digital display devices updated at periodic intervals, the indication at each display update shall be the value of the user-selected quantity at the time of the display update. Other modes of indication at the time of the display update may be identified in the instrument documentation and, if so, the operation of