INTERNATIONAL STANDARD

ISO 6487

Fourth edition
2002-10-01

Road vehicles — Measurement techniques in impact tests — Instrumentation

Véhicules routiers — Techniques de mesurage lors des essais de choc — Instrumentation

Reference number
ISO 6487:2002(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 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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 6487 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 12, *Passive safety crash protection systems*.

This fourth edition cancels and replaces the third edition (ISO 6487:2000), which has been technically revised.

Annex A forms a normative part of this International Standard. Annex B is for information only.

Introduction

This edition of ISO 6487 is the result of a willingness to harmonize the previous edition, ISO 6487:2000, and the American Society of Automotive Engineers' standard, SAE J211:1995.

It presents a series of performance requirements concerning the whole measurement sequence of impact shocks.

These requirements may not be altered by the user and all are obligatory for any agency conducting tests to this International Standard. However, the method of demonstrating compliance with them is flexible and can be adapted to suit the needs of the particular equipment used by a testing agency.

This approach affects the interpretation of requirements. For example, there is a requirement to calibrate within the working range of the channel, i.e. between F_L and $F_H/2,5$. This cannot be interpreted literally, as low-frequency calibration of accelerometers requires large displacement inputs beyond the capacity of virtually any laboratory.

It is not intended that each requirement be taken as necessitating proof by a single test. Rather, it is intended that any agency proposing to conduct tests to this International Standard certify that if a particular test could be and were to be carried out then their equipment would meet the requirements. This certification would be based on reasonable deductions from existing data, such as the results of partial tests. The agency would normally be expected to make the basis of their certification available to users of their test results.

The basis of certification of some subjects can be very direct, in that a single test can demonstrate compliance. For others, a less direct form of certification will be necessary. To continue with the above example, the agency could have obtained similar calibrations with direct current at a medium frequency and, from knowledge of the transducer, might infer that calibrations at intermediate frequencies would have been the same.

Similar considerations apply to the practical need to divide the whole channel into subsystems, for calibration and checking purposes. The requirements are valid only for the whole channel, as this is the sole route by which subsystem performance affects the output quality. If it is difficult to measure the whole channel performance, which is often the case, the test agency may treat the channel as two or more convenient subsystems. The whole channel will be certified on the basis of subsystem results, together with a rationale for combining them.

To summarize, this International Standard enables users of impact test results to call up a set of relevant instrumentation requirements by merely specifying ISO 6487. Their test agency then has the primary responsibility for certifying that the ISO 6487 requirements are met by their instrumentation system. The evidence on which they have based this certification will be available to the user on request. In this way, fixed requirements, guaranteeing the suitability of the instrumentation for impact testing, can be combined with flexible methods of demonstrating compliance with those requirements.

Road vehicles — Measurement techniques in impact tests — Instrumentation

1 Scope

This International Standard gives requirements and recommendations for measurement techniques involving the instrumentation used in impact tests carried out on road vehicles. Its requirements are aimed at facilitating comparisons between results obtained by different testing laboratories, while its recommendations will assist such laboratories in meeting those requirements. It is applicable to instrumentation including that used in the impact testing of vehicle subassemblies. It does not include optical methods, which are the subject of ISO 8721.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard 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 2041:1990, *Vibration and shock — Vocabulary*

ISO 3784, *Road vehicles — Measurement of impact velocity in collision tests*

ISO 4130, *Road vehicles — Three-dimensional reference system and fiducial marks — Definitions*

SAE J211/1, *Instrumentation for impact test — Part 1: Electronic instrumentation*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 2041 and the following apply.

3.1
data channel
all the instrumentation from, and including, a single transducer (or multiple transducers, the outputs of which are combined in some specified way) to, and including, any analysis procedures that may alter the frequency content or the amplitude content of data

3.2
transducer
first device in a data channel used to convert a physical quantity to be measured into a second quantity (such as an electrical voltage), which can be processed by the remainder of the channel

3.3
channel amplitude class
CAC
designation for a data channel that meets certain amplitude characteristics as specified by this International Standard

NOTE The CAC number is numerically equal to the upper limit of the measurement range.

3.4
channel frequency class
CFC
frequency class designated by a number indicating that the channel frequency response lies within limits specified by Figure 1 for CFCs 1 000 and 600, or is filtered using the algorithm given in annex A

NOTE This number and the value of the frequency F_H (see Figure 1), in hertz, are numerically equal.

3.5
calibration value
mean value measured and read during calibration of a data channel

3.6
sensitivity
ratio of the output signal (in equivalent physical units) to the input signal (physical excitation) when an excitation is applied to the transducer

EXAMPLE 10,24 mV:g/V for a strain gauge accelerometer.

3.7
sensitivity coefficient
slope of the straight line representing the best fit to the calibration values, determined by the method of least squares within the channel amplitude class

3.8
calibration factor of a data channel
mean value of the sensitivity coefficients evaluated over frequencies evenly spaced on a logarithmic scale between F_L and $F_H/2,5$

3.9
linearity error
ratio of the maximum difference between the calibration value and the corresponding value read on the straight line at the upper limit of the channel amplitude class

NOTE It is expressed as a percentage.

See 4.6.

3.10
transverse sensitivity of a rectilinear transducer
sensitivity to excitation in a nominal direction perpendicular to its sensitive axis

NOTE 1 The transverse sensitivity of a rectilinear transducer is usually a function of the nominal direction of the axis chosen.

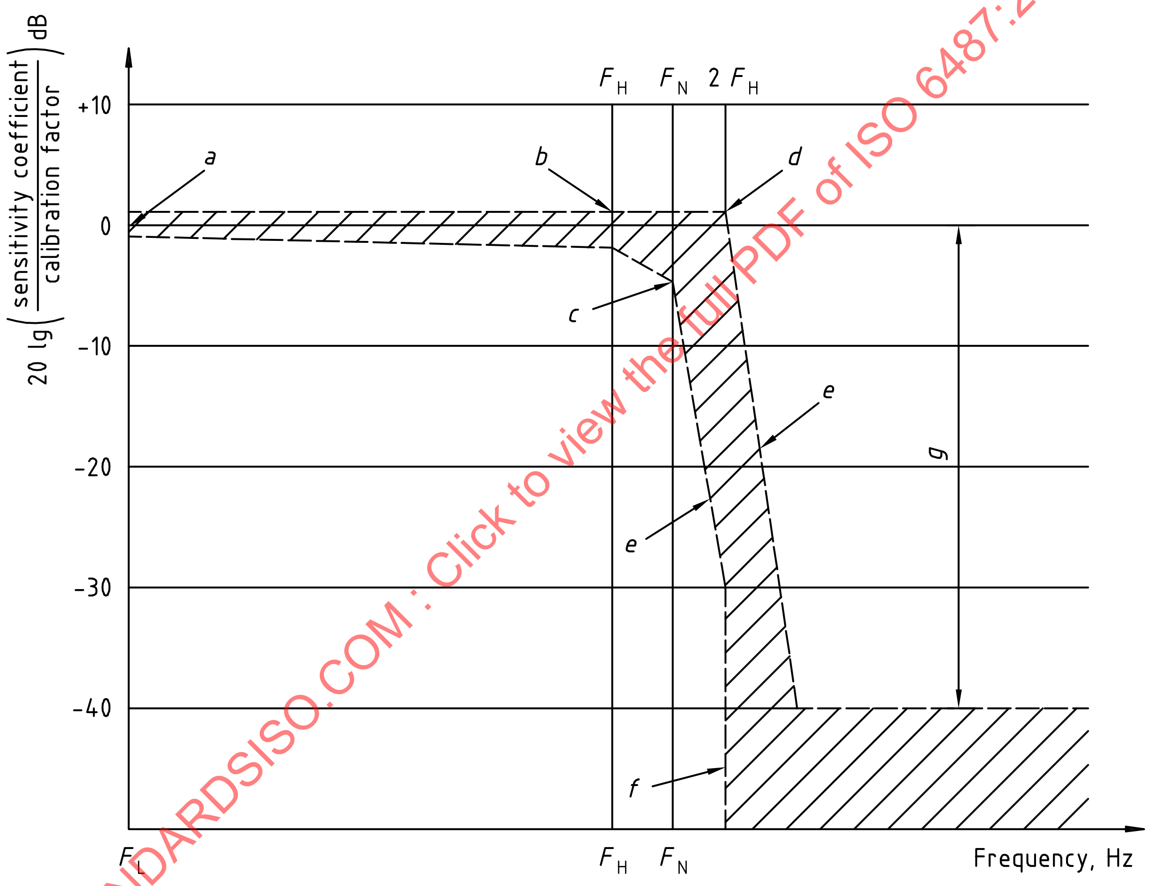
NOTE 2 The cross sensitivity of force and bending moment transducers is complicated by the complexity of loading cases. At time of publication, this situation had yet to be resolved.

3.11
transverse sensitivity ratio of a rectilinear transducer
ratio of the transverse sensitivity of a rectilinear transducer to its sensitivity along its sensitive axis

NOTE The cross sensitivity of force and bending moment transducers is complicated by the complexity of loading cases. At time of publication, this situation had yet to be resolved.

3.12
phase delay time of a data channel
time equal to the phase delay, expressed in radians, of a sinusoidal signal, divided by the angular frequency of that signal, and expressed in radians per second

3.13
environment
aggregate, at a given moment, of all external conditions and influences to which the data channel is subject



Logarithmic scale	
a	± 0,5 dB
b	+ 0,5; – 1 dB
c	+ 0,5; – 4 dB
d	+ 0,5 dB
e	– 24 dB/octave
f	– ∞
g	– 40 dB

CFC	F_L Hz	F_H Hz	F_N Hz
1 000	⩽ 0,1	1 000	1 650
600	⩽ 0,1	600	1 000

Figure 1 — Frequency response limits — CFC 1000 and CFC 600

4 Performance requirements

4.1 Linearity error

The absolute value of the linearity error of a data channel at any frequency in the CFC (channel frequency class) shall be less than or equal to 2,5 % of the value of the CAC over the whole measurement range.

4.2 Amplitude against frequency

The frequency response of a data channel shall lie within the limiting curves given in Figure 1 for CFCs 1 000 and 600. For CFCs 180 and 60, the frequency response of the channel is determined by the filter algorithm given in annex A. The zero decibels line is defined by the calibration factor. For CFCs 180 and 60, the frequency response of the data channel shall remain within 0,5 dB of the zero decibel line at frequencies ranging from 0,1 Hz to the CFC, before the digital filter is applied.

See 4.6.2.3.2.

4.3 Phase delay time of a data channel

The phase delay time of a data channel between its input and output shall be determined; it shall not vary by more than $1/10 F_H$ s between 0,03 F_H and F_H.

4.4 Time

4.4.1 Timebase

A timebase shall be recorded that shall give at least 0,01 s with an accuracy of 1 %.

4.4.2 Relative time delay

The relative time delay between the signals of two or more data channels, regardless of their frequency class, shall not exceed 1 ms, excluding phase delay caused by phase shift. Two or more data channels whose signals are combined shall have the same frequency class and shall have a relative time delay not greater than $1/10 F_H$ s.

This requirement is applicable to analog signals, synchronization pulses and digital signals.

4.5 Transducer transverse sensitivity ratio of a rectilinear transducer

The transducer transverse sensitivity ratio of a rectilinear transducer shall be less than 5 % in any direction.

4.6 Calibration

4.6.1 General

A data channel shall be calibrated at least once a year against reference equipment traceable to known standards. The methods used to carry out a comparison with reference equipment shall not cause an error greater than 1 % of the CAC. The use of reference equipment is limited to the range of frequencies for which it has been calibrated.

Data channel subsystems may be evaluated individually and the results factored into the accuracy of the total data channel. This can be made, for example, by an electrical signal of known amplitude simulating the output signal of the transducer, allowing a check to be made on the gain of the data channel, excluding the transducer.

4.6.2 Accuracy of reference equipment for calibration

4.6.2.1 General

The accuracy of the reference equipment shall be certified or endorsed by an approved metrology service.

4.6.2.2 Static calibration

4.6.2.2.1 Acceleration

The error shall be less than 1,5% of the channel amplitude class.

4.6.2.2.2 Force and displacement

The error shall be less than 1 % of the channel amplitude class.

4.6.2.3 Dynamic calibration

4.6.2.3.1 Acceleration

The error in the reference accelerations expressed as a percentage of the channel amplitude class shall be less than 1,5 % at below 400 Hz, less than 2 % between 400 Hz and 900 Hz, and less than 2,5 % between 900 Hz and the maximum frequency at which the reference acceleration is used (see 4.6.4).

4.6.2.3.2 Forces and displacements

A method for the evaluation of the dynamic response during the calibration of data channels for forces and displacements has not been included in this International Standard, since no satisfactory method is known at present. The problem is to be reconsidered at a later date.

4.6.2.4 Time

The relative error in the reference time shall be less than 10^{-5}.

4.6.3 Sensitivity coefficient and linearity error

The sensitivity coefficient and the linearity error shall be determined by measuring the output signal of the data channel against a known input signal, for various values of this signal.

The calibration of the data channel shall cover the whole range of the amplitude class.

For bi-directional channels, both the positive and negative values shall be used.

If the calibration equipment cannot produce the required input, due to the excessively high values of the quantity to be measured, calibrations shall be carried out within the limits of these calibration standards, and these limits shall be recorded in the report.

A total data channel shall be calibrated at a frequency or at spectrum of frequencies, with its significant value being between F_L and $F_H/2{,}5$.

4.6.4 Calibration of frequency response

The response curves of phase and amplitude against frequency shall be determined by measuring the output signals of the data channel in terms of phase and amplitude against a known input signal, for various values of this signal varying between F_L and ten times the CFC or 3 000 Hz, whichever is the lower.

4.7 Environmental effects

The existence or nonexistence of an influence of environmental effects shall be checked regularly (i.e. electric or magnetic flux, cable velocity, etc.). This can be done, for example, by recording the output of spare channels equipped with dummy transducers.

If significant output signals are obtained, corrective action shall be taken — for example, the re-allocation or replacement of cables.

4.8 Choice and designation of data channel

The CAC and CFC define the data channel, and their values are chosen for a given application by the party requiring the application.

A data channel in accordance with this International Standard shall be designated as follows.

ISO 6487-CAC XXX-CFC XXX

Reference to this International Standard
Channel amplitude class
Channel frequency class

The type of filter used, phaseless or phase shifting, shall be declared for each channel.

For CFCs 180 and 60, the Butterworth four-pole phaseless filter, as specified in annex A, shall be used.

If the calibration of the amplitude or frequency response does not cover the complete CAC or CFC, owing to limited properties of the calibration equipment, then the CAC or CFC shall be marked with an asterisk.

EXAMPLE A measurement carried out in accordance with this International Standard, where the channel amplitude class is 200 m/s^2, the channel frequency class 1 000, and the calibration of the amplitude response did not cover the complete CAC, is designated as follows:

ISO 6487 – CAC* 200 m/s^2 – CFC 1 000

The test report shall indicate the calibration limits.

4.9 Choice of reference coordinate system

The following coordinate systems shall be used.

— For the dummy measurements: SAE J211/1.

— For the vehicle measurements: ISO 4130 or SAE J211/1.

The coordinate reference system used shall be clearly defined for each measurement.

4.10 Impact velocity measurement

Impact velocity measurement shall be in accordance with ISO 3784.

Annex A
(normative)

Butterworth four-pole phaseless digital filter (including initial-condition treatment) algorithm

The following algorithm is unsuitable for filter frequencies above CFC 180, since, at high frequencies, the frequency response of this digital filter varies as a function of the sampling rate used.

```
/*  ----------------------------------------------------------------------------------------  */
/*                            Butterworth phaseless filter                                    */
/*  ----------------------------------------------------------------------------------------  */
```

// Author : NHTSA
// for CFC 60 : **F-3db** = 100
// for CFC 180 : **F-3db** = 300

```
/*  ----------------------------------------------------------------------------------------  */
/*                                 Variables used                                             */
/*  ----------------------------------------------------------------------------------------  */
```

F-3db = cutoff frequency at -3dB
F-6db = cutoff frequency at -6dB = 1,25 * F-3db

SampleRate = sampling interval in seconds
Pi = 3,141592654
a1, **a2**, **b0**, **b1**, **b2** filter coefficients
Samples = initial table of samples
NumberOfSamples = length of **Samples** table ***(! note ! : the index of a table is between zero and length of table -1)***
FilterTab = table of filtering samples
IndexLastPoint + 1 = length of **FilterTab** table
NumberOfAddPoints = number of points to be added to **NumberOfSamples**


```
/*  ----------------------------------------------------------------------------------------  */
/*                                Initial condition                                           */
/*  ----------------------------------------------------------------------------------------  */
```

//The table **Samples** is completed with anti-symmetry around t = 0. Gives table **FilterTab**

/*compute the number of points to be added to the table **Samples** */
NumberOfAddpoints = 0,01 / **SampleRate**
NumberOfAddPoints = min (max(**NumberOfAddPoints**,100), **NumberOfSamples**-1)
IndexLastPoint = **NumberOfSamples** + 2 * **NumberOfAddPoints** - 1

```
/* Generation of table to be filtered FilterTab */
for i = NumberOfAddPoints to NumberOfAddPoints + NumberOfSamples -1 by step 1
            FilterTab[i] = Samples[i - NumberOfAddPoints]
endfor

for i = 0 to NumberOfAddPoints - 1 by step 1
      FilterTab[NumberOfAddPoints - i - 1] = 2 * Samples[0] - Samples[i+1];
      FilterTab[NumberOfSamples + NumberOfAddPoints + i] =
            2 * Samples[NumberOfSamples - 1] - Samples[NumberOfSamples - i - 2]
endfor

/*    ----------------------------------------------------------------------------------------------------------    */
/*                              compute filter coefficients                                                          */
/*    ----------------------------------------------------------------------------------------------------------    */

Wd = 2. * Pi * F-6db
Wa = sin( Wd * SampleRate / 2,0) / cos( Wd * SampleRate / 2,0)
b0 = Wa² / (1 + √2 * Wa + Wa²)
b1 = 2. * b0
b2 = b0
a1 = -2 * (Wa² - 1 ) / ( 1 + √2 * Wa + Wa² )
a2 = ( -1 + √2 * Wa - Wa² ) / ( 1 + √2 * Wa + Wa²)

/*    ----------------------------------------------------------------------------------------------------------    */
/*                              Filter forward                                                                       */
/*    ----------------------------------------------------------------------------------------------------------    */

y1 = 0
for i = 0 to i = 9 by step 1
         y1 = y 1 + FilterTab[i]
endfor

y1 = y1 / 10,0
x2 = 0.
x1 = FilterTab[0]
x0 = FilterTab[1]
FilterTab[0] = y1
FilterTab[1] = y1
for i = 2 to i = IndexLastPoint by step 1
         x2 = x1
         x1 = x0
         x0 = FilterTab[i]
         FilterTab[i] = b0 * x0 + b1 * x1 + b2 * x2 +a1 * FilterTab[i-1] +a2 * FilterTab[i-2]
endfor

/*    ----------------------------------------------------------------------------------------------------------    */
/*                              Filter backward                                                                      */
/*    ----------------------------------------------------------------------------------------------------------    */

y1 = 0
for i = IndexLastPoint to IndexLastPoint - 9 by step -1
         y1 = y1 + FilterTab[i]
endfor
```

```
y1 = y1/10,0
x2 = 0.
x1 = FilterTab[IndexLastPoint]
x0 = FilterTab[IndexLastPoint - 1]
FilterTab[IndexLastPoint] = y1
FilterTab[IndexLastPoint - 1] = y1
for i = IndexLastPoint - 2 to i = 0 by step -1
        x2 = x1
        x1 = x0
        x0 = FilterTab[i]
        FilterTab[i] = b0 * x0 +b1 * x1 +b2 * x2 + a1 * FilterTab[i+1] + a2 * FilterTab[i+2]
endfor

/*   -----------------------------------------------------------------------------------------------   */
/*                                 Filtering of samples                                                */

/*   -----------------------------------------------------------------------------------------------   */


for i = NumberOfAddPoints to i = NumberOfAddPoints + NumberOfSamples -1 by step 1
    Samples[i - NumberOfAddPoints] = FilterTab[i]
endfor
```

Annex B
(informative)

Recommendations for enabling requirements to be met

B.1 Mounting of transducers

Transducers should be rigidly mounted so that their recordings are affected as little as possible by vibration. Any transducer mounting component assembly having a lowest resonance frequency equal to at least five times the frequency F_{H} of the given data channel should be considered valid.

Acceleration transducers, excluding transducers in dummies, should be mounted such that the initial angle of the actual measurement axis to the corresponding axis of the reference axis system is not greater than 5°, unless analytical or experimental assessment of the effect of the mounting on the collected data is made. When multi-axial accelerations at a point are to be measured, each acceleration transducer axis should pass within 10 mm, and the centre of seismic mass of each accelerometer within 30 mm, of that point.

Transducers should be mounted on the dummies using a support specially provided for that purpose.

B.2 Data processing

B.2.1 Filtering

Filtering corresponding to the frequencies of the data channel class may be carried out either during recording or processing of data.

However, before recording, analog filtering at a level greater than or equal to CFC 1 000 should take place in order to use at least 50 % of the dynamic range of the recorder and reduce the risk of high frequencies saturating the recorder or of aliasing error in the digitizing process.

If no pre-impact event data is recorded, then the initial conditions algorithm defined in annex A or an alternative procedure should be used.

If filtering is to be performed, it should precede all non-linear operations, such as calculation of resultant vectors or injury indices.

B.2.2 Digitizing

B.2.2.1 Sampling frequencies

The sampling frequency should be at least 10 F_{H}.

The analog anti-aliasing filters should have an attenuation of at least 30dB at half the sampling rate.

In the case of analog recording, when the recording and reading speeds are different, the sampling frequency can be divided by the speed ratio.

B.2.2.2 Amplitude resolution

The length of digital words should permit a resolution of at least 0,2 % of CAC.

