BSI Standards Publication

Road vehicles — Measurement techniques in impact tests — Instrumentation

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National foreword

This British Standard is the UK implementation of ISO 6487:2015. It supersedes BS ISO 6487:2012 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AUE/7, Automobile occupant restraint systems.

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

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INTERNATIONAL STANDARD

**ISO
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Sixth edition
2015-08-01

Road vehicles — Measurement techniques in impact tests — Instrumentation

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

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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 document 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).

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

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 36, *Safety aspects and impact testing*.

This sixth edition cancels and replaces the fifth edition (ISO 6487:2012), which has been technically revised.

Introduction

This International Standard is the result of a willingness to harmonize the previous edition, ISO 6487:2012, and SAE International's Recommended Practice, SAE J211-1.

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 guarantee that if a particular test could be and were to be carried out, then their equipment would meet the requirements. This proof would be based on reasonable deductions from existing data such as the results of partial tests.

On the basis of studies carried out by technical experts, no significant difference has been identified between the characteristics of the load transducer when using static as opposed to dynamic calibration methods. This new edition helps to define the dynamic calibration method for force and moment data channels in accordance with the current knowledge base and studies available.

The temperature of the anthropomorphic test device (ATD) used in a collision test needs to be monitored to confirm that it has been used within the acceptable temperature range prescribed for the whole ATD or body segment. The objective is to prevent temperature from being a variable that will influence the ATD response. The actual ATD temperature can be influenced by various factors including ambient air, high-speed photography lighting, sunshine, heat dissipation from transducers, and ATD in-board data acquisition systems. In order to respond to these objectives, the new edition specifies the performance requirements for the ATD temperature measurement.

This International Standard defines the requirements of an impact test for which the measurement uncertainties can only be partially calculated.

To summarize, this International Standard enables users of impact test results to call up a set of relevant instrumentation requirements by merely specifying this International Standard. Their test agency then has the primary responsibility for ensuring that the requirements of this International Standard are met by their instrumentation system. The evidence on which they have based this proof assessment will be available to the user upon 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 documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 3784, *Road vehicles — Measurement of impact velocity in collision tests*

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

ISO/TR 27957, *Road vehicles — Temperature measurement in anthropomorphic test devices — Definition of the temperature sensor locations*

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

3 Terms and definitions

For the purposes of this document, the following 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* (3.1) 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* (3.1) that meets certain amplitude characteristics as specified by this International Standard

Note 1 to entry: The CAC number is numerically equal to the upper limit of the measurement range which is equivalent to data channel full scale.

3.4
channel frequency class
CFC
frequency class designated by a number indicating that the channel frequency response lies within certain limits

Note 1 to entry: CFC XXX defines the frequency class with XXX = Frequency, F_H, in hertz.

3.5
calibration value
mean value measured and read during calibration of a *data channel* (3.1)

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* (3.2)

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* (3.5) determined by the method of least squares within the *channel amplitude class (CAC)* (3.3)

Note 1 to entry: Specific sensors such as seat belt sensors, torque sensors, and multi-axial force sensors may require a specific calibration procedure.

3.8
calibration factor of a data channel
arithmetic mean of the *sensitivity coefficients* (3.7) evaluated over frequencies evenly spaced on a logarithmic scale between F_L and $F_H/2,5$

Note 1 to entry: See Figure 2 and Figure 3.

3.9
non-linearity
ratio of the maximum difference (D_{max}) between the *calibration value* (3.5) and the value read from the best approximation of *calibration values* (3.5) expressed as a percentage of the *channel amplitude class (CAC)* (3.3)

Note 1 to entry: See Figure 1 and 4.5.4.
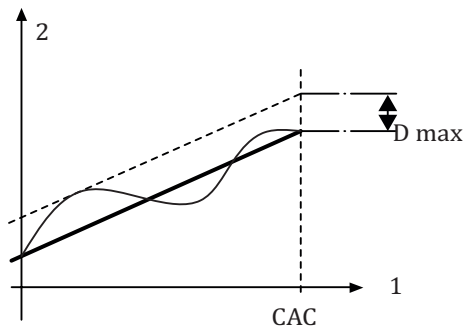
Key

1   input signal

2   output signal

NOTE   Non-linearity = D_{max}/CAC * 100.

Figure 1 — Non-linearity

3.10
transverse sensitivity of a rectilinear transducer
sensitivity (3.6) to excitation in a nominal direction perpendicular to its sensitive axis

Note 1 to entry: The transverse sensitivity of a rectilinear transducer is usually a function of the nominal direction of the axis chosen.

Note 2 to entry: 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* (3.10) to its sensitivity along its sensitive axis

Note 1 to entry: 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* (3.1) is subject

4   Performance requirements

4.1   CFC specifications and performance requirements

The absolute value of the non-linearity of a data channel at any frequency (except if data channel is calibrated against only one point) in the channel frequency class (CFC) shall be less than or equal to 2,5 % of the value of the CAC over the whole measurement range.

The frequency response of a data channel shall lie within the limiting curves given in Table 1 and Figure 2 for CFC 1 000 and CFC 600. For CFC 60 and CFC 180, the frequency response of a data channel

shall lie within the limiting curves given in Table 2 and Figure 3. The zero decibels line is defined by the calibration factor.

NOTE   For CFC 180 and CFC 60, the filtering algorithm given in Annex A addresses this requirement.

Table 1 — Logarithmic scales for CFC 1 000 and CFC 600

F_Z	Attenuations (dB)		Frequency (Hz)	
	Upper	Lower	CFC 600	CFC 1000
F_L	+0,5	−0,5	0,1	0,1
F_H	+0,5	−1,0	600	1 000
F_N	+0,5	−4,0	1 000	1 650
$2*F_H$	+0,5		1 200	2 000
F_G		−30,0	2 119	3 496
F_J	−40,0	-∞	3 865	6 442

Key
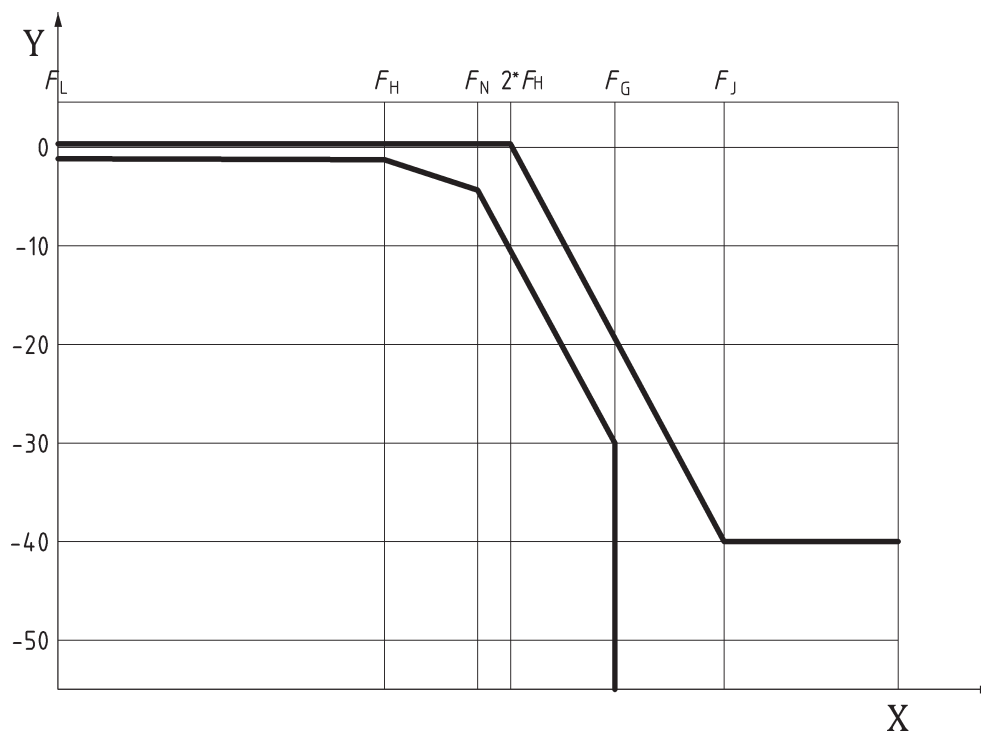
X   in Hertz

Y   in dB

Figure 2 — Frequency response limits — CFC 1 000 and CFC 600

Table 2 — Logarithmic scales for CFC 60 and CFC 180

F_Z	Attenuations (dB)		Frequency (Hz)	
	Upper	Lower	CFC 60	CFC 180
F_L	+0,5	−0,5	0,1	0,1
F_H	+0,5	−1,0	60	180
F_C	−0,3	−1,8	75	225
F_N	−1,8	−3,8	100	300
F_D	−5,2	−8,2	130	390
F_E	−9,2	−13,2	160	480
F_G	−40	−48,3	452	1 310

Key
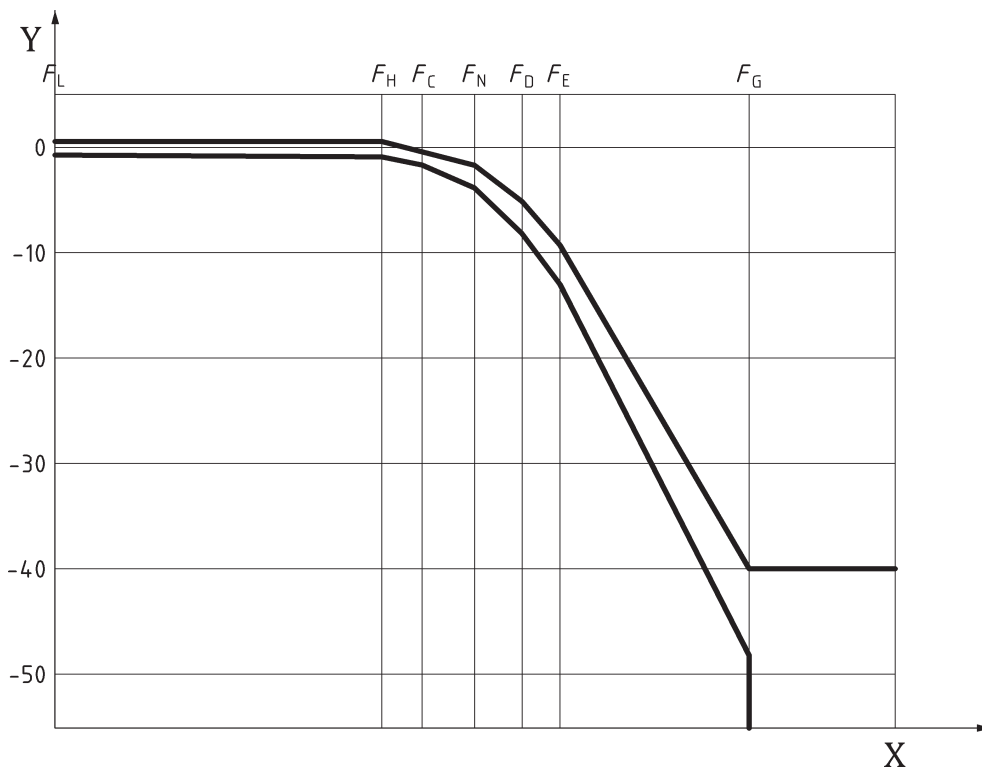
X   in Hertz

Y   in dB

Figure 3 — Frequency response limits — CFC 60 and CFC 180

4.2   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.

4.3 Time

4.3.1 Timebase

Time reference system of data acquisition system (DAS) shall ensure that time base is a minimum of 0,01 s with an accuracy equal or better than 1 %.

4.3.2 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.

4.4 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.

4.5 Calibration

4.5.1 General

As a general rule, a data channel should be calibrated once a year. Other intervals can be defined in accordance with standards, regulations, or requirement specific to the application to ensure that the measuring equipment meets the requirements of this International Standard and corresponds to the intended use. The calibration shall be done against reference equipments traceable to known National or International Standards through an unbroken chain. The use of reference equipment is limited to the range of frequencies for which it has been calibrated.

Data channel subsystems can 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.

4.5.2 Accuracy of reference equipment for calibration

The accuracy of the reference equipment for calibration shall be confirmed by an accredited metrology organization.

4.5.3 Calibration procedures and uncertainties

The stated uncertainty should be the product of the standard deviation and coverage factor k = 2, which for a normal distribution, corresponds to a coverage probability of approximately 95 %.

Table 3 presents the relevant procedures.

The result of a calibration can be recorded in a document sometimes called a calibration certificate or a calibration report.

Table 3 — Calibration procedures and uncertainties

Calibration procedures	Uncertainties
	Relative expanded measurement uncertainty for transducer types used in crash testing specific to the maximum value of the calibration range
Accelerometer Shock calibration (pendulum)	<1,8 %
Accelerometer Sinusoidal calibration (Shaker)	<2 % below 400 Hz <2,5 % from 400 Hz to 2 kHz <3,5 % from 2 kHz to 5 kHz
Acceleration static calibration (centrifuge)	<1,5 %
Force sensor – static calibration	<1 %
Displacement	<1 %
Angle	<1,5 %
Angular rate	<3 %
Pressure	1%
Temperature	<1 % or 0,2 K
Torque	<2 %
NOTE Calculation of uncertainties according to JCGM 100:2008.	

4.5.3.1   Forces and moments

Static calibration is a sufficient method for the calibration of force and moment data channels and can therefore be used to determine transducer sensitivity.

4.5.3.2   Displacements

A method for the evaluation of the dynamic response during the calibration of data channels for displacement 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.

4.5.3.3   Time

The error in the reference time shall be less than $1/(10 \times \text{sample rate})$.

NOTE   The reference time is the timebase of the reference system used for calibration.

4.5.4   Sensitivity coefficient and nonlinearity

The sensitivity coefficient and the non-linearity 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 $F_H/2,5$.

4.5.5 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 10 times the CFC or 3 000 Hz, whichever is lower.

4.6 Environmental effects

The existence or non-existence of an influence of environmental effects shall be checked regularly (i.e. electric or magnetic flux, electric, magnetic, electrostatic effects due to the violent displacement or friction of electric cables during tests, etc.). This can be done, for example, by recording the output of spare channels equipped with dummy transducers.

If significant output signals (typically greater than 2 % of the expected data peak value) are obtained, corrective action shall be taken, for example, the relocation or replacement of cables.

4.7 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.

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.

4.8 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.

4.9 Impact velocity measurement

Impact velocity measurement shall be in accordance with ISO 3784.

4.10 ATD temperature measurement

Measurements shall be recorded at a rate of one reading per minute. The minimum measurement range shall be from 10 °C to 40 °C. The location of the measurement probe shall be in accordance with ISO/TR 27957.

The accuracy tolerance of the complete measurement chain shall be three times narrower than the temperature tolerance specified for the ATD.

EXAMPLE   For a Hybrid III, the specified temperature span is from 20,6 °C to 22,2 °C which corresponds to a tolerance of ±0,8 °C. The accuracy tolerance for the temperature measurement would then be ±0,26 °C.

The error contribution of the transducer, extension wire (if applicable), and data acquisition equipment shall be taken into account.

Dynamic response: After a temperature step, the transducer shall indicate 90 % of the new value within one minute.

The measurements shall be carried out in accordance with recognized standards (see Annex C).

Annex A
(informative)

Example of Butterworth four-pole phaseless digital filter (including initial conditions 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 – 3 dB = 100
//    for CFC 180:     F – 3 dB = 300

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

F – 3 dB = cutoff frequency at −3 dB

F – 6 dB = cutoff frequency at −6 dB = 1,25 * F – 3 dB

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


```
/*      ------------------------------------------------------------      */
/*                      computer filter coefficients                     */
/*      ------------------------------------------------------------      */
```

Wd = 2. * **Pi * F – 6 dB**

Wa = sin(Wd * **SampleRate**/2,0)/cos(Wd * **SampleRate**/2,0)

b0 = $Wa^2/(1 + \sqrt{2} * Wa + Wa^2)$

b1 = 2. *** b0**

b2 = **b0**

a1 = $-2 * (Wa^2 - 1)/(1 + \sqrt{2} * Wa + Wa^2)$

a2 = $(-1 + \sqrt{2} * Wa - Wa^2)/(1 + \sqrt{2} * Wa + Wa^2)$

```
/*      ------------------------------------------------------------      */
/*                          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 = y 1 + **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 of this International Standard to be met

B.1   Equivalence of transducers

The selection of transducers is a major concern in the process of choosing a data channel configuration. In addition, the variety of transducers in a category, e.g. acceleration, pressure, force, displacement, etc., grow continuously increasing concern about the equivalence of correlation of various sensors for any specific application.

As the transducer is part of the measurement data channel, the contribution to error factors will be included in considering the performance requirements of the complete measuring chain as described in Clause 4.

The aim of this International Standard is to recommend "the measurement techniques used in crash tests" to provide a basis for comparison between tests resulting from different sources. The aim is also to establish the equivalence of performance for various types of transducers. Such a goal down to a class of transducer requires thorough knowledge of the objective measurement and its environment. It is not necessarily constrained by the technology of manufacture of transducer or their designs, but is undoubtedly related to changing conditions during an impact test.

The static and dynamic responses of the transducers depend on the combined performance characteristics of sensors and their specifications. The interaction characteristics of the transducers can generate significant differences in both static and dynamic between sensors with similar specifications. The user shall verify their combined performance to establish equivalence.

The compatibility of the channel is affected by potential sources of error from transducers characteristics (the transducer can act unfavourably with the rest of the measurement data channel), e.g. influences resonance/damping. Other sources of errors are related to environmental compatibility, that is to say, influences which include temperature drift, magnetic effects of electric fields, etc., as well as the transducer size, its weight, the location of the seismic mass, the transverse sensitivity, etc.

To establish the equivalence of the complete measuring data channel, it is the responsibility of the user to perform the necessary tests to ensure that the sensors give similar results consistent with the error tolerances recommended by this International Standard.

To verify the equivalence, if feasible, the transducers can be used back to back or side by side in a real test for a given measurement application. A statistically significant number of tests will be performed to validate the results. This method can also be used if there is no calibration method for validating the dynamic response of the transducer type in question.

B.2   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.3 Data processing

B.3.1 Filtering

Filtering corresponding to the frequencies of the data channel class can 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.3.2 Digitizing

B.3.2.1 Sampling frequencies

The sampling frequency should be at least 10 F_H.

The analog anti-aliasing filters should have an attenuation of at least 30 dB 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.3.2.2 Amplitude resolution

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

B.4 Presentation of results

The measurements may be recorded at various locations on the vehicle. These locations shall be stated in the test report.

Results presented as diagrams should have axes scaled with one measurement unit corresponding to a suitable multiple of the chosen unit (for example 1 mm, 2 mm, 5 mm, 10 mm, 20 mm).

SI units shall be used. For vehicle velocity, kilometres per hour may be used and for accelerations due to an impact, g may be used (where g = 9,81 m/s^2).

Annex C
(informative)

Temperature measurements systems

Notes and references on most common temperature measurement systems are as described below.

— **Thermocouples**: Accuracy tolerances of the various thermocouple types are specified in IEC 60584, ISA MC 96.1-1982, or equivalent standards. Tolerances are specified for the thermocouple element as well as for any extension wire used. Thermocouples and extension wires having a better accuracy tolerance than the "standard" products are available from manufacturers. Calibration within a limited temperature range which results in narrower tolerances is also available. The accuracy of the whole measurement chain should be verified before use. Periodic calibration should be done as it will change with time and use.

— **Thermistors**: Thermistors are sensitive to small temperature changes and can be made in small sizes. The most common type is the negative temperature coefficient (NTC) thermistor. This type of sensor will dissipate a small amount of heat. The user should verify that this self-heating characteristic does not produce errors depending on the sensor location. Temperature/resistance characteristics are provided by each supplier.

NOTE   ASTM E879–01 provides specifications even though it is directed to clinical applications.

— **Platinum resistance thermometers**: These are part of the resistance temperature detector (RTD) family. The sensitivity of these sensors is generally stable with time. Since the resistance value of the sensor is low, the contribution of the wires to the total resistance value should be compensated. This type of sensor will dissipate a small amount of heat. The user should verify that this self-heating characteristic does not produce errors depending on the sensor location. Main specifications, as well as temperature/resistance relations, are provided in IEC 60751, ASTM E1137/E1137M-04, or equivalent standards.

Bibliography

[1]   ISO 8721, *Road vehicles — Measurement techniques in impact tests — Optical instrumentation*

[2]   IEC 60584 (all parts), *Thermocouples*

[3]   IEC 60751, *Industrial platinum resistance thermometer and platinum temperature sensors*

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