INTERNATIONAL STANDARD

ISO 6487

Fifth edition
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Road vehicles — Measurement techniques in impact tests — Instrumentation

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

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

This fifth edition cancels and replaces the fourth edition (ISO 6487:2002) and its Amendment 1:2008, subclauses 3.4, 3.9 and 3.13, 4.1, 4.2, 4.6.1, 4.6.2 and 4.6.3 of which have been technically revised.

Annexes A, B and C are for information only.

Introduction

This edition of ISO 6487 is the result of a willingness to harmonize the previous edition, ISO 6487:2002, and SAE International's Recommended Practice, SAE J211-1 (JUL2007).

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

These requirements may not be altered by the user and all are obligatory for any agency conducting tests according 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 according 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 measuring 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.

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 ensuring that the ISO 6487 requirements are met by their instrumentation system. The evidence on which they have based this proof assessment 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 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, *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 J211-1:2007, *Instrumentation for impact test — Part 1: Electronic instrumentation*

3 Terms and definitions

For the purposes of this document, 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 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 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

3.6
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 (CAC)

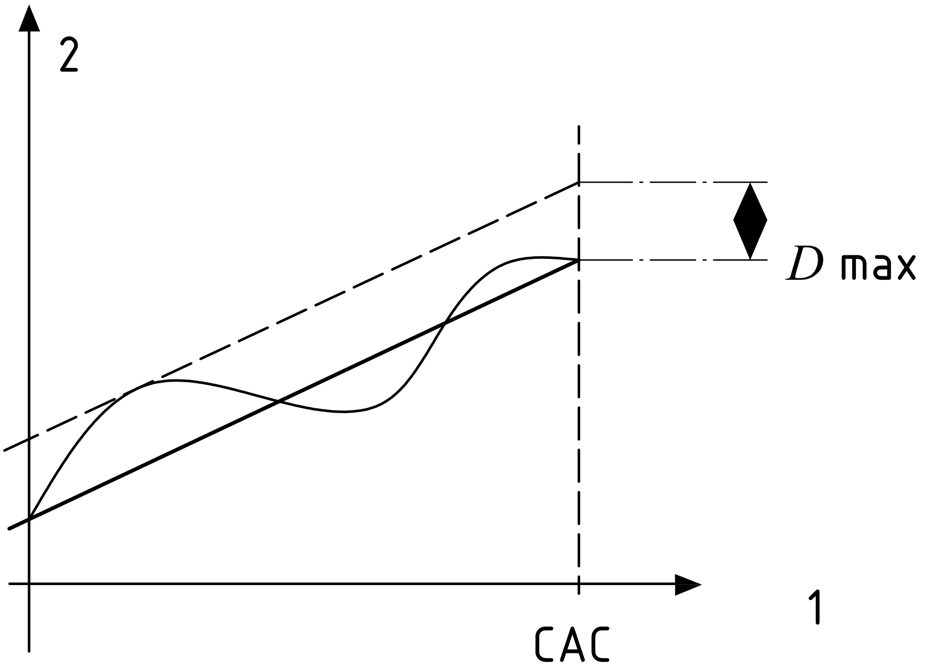
NOTE Specific sensors, such as seat belt sensors, torque sensors and multi-axial force sensors, may require a specific calibration procedure.

3.8
calibration factor of a data channel
arithmetic mean of the sensitivity coefficients evaluated over frequencies evenly spaced on a logarithmic scale between F_L and $F_{H/}2,5$

NOTE See Figures 2 and 3.

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

NOTE See Figure 1 and 4.5.4.



Key

1 input signal

2 output signal

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

Figure 1 — Non-linearity

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 are 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 are 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

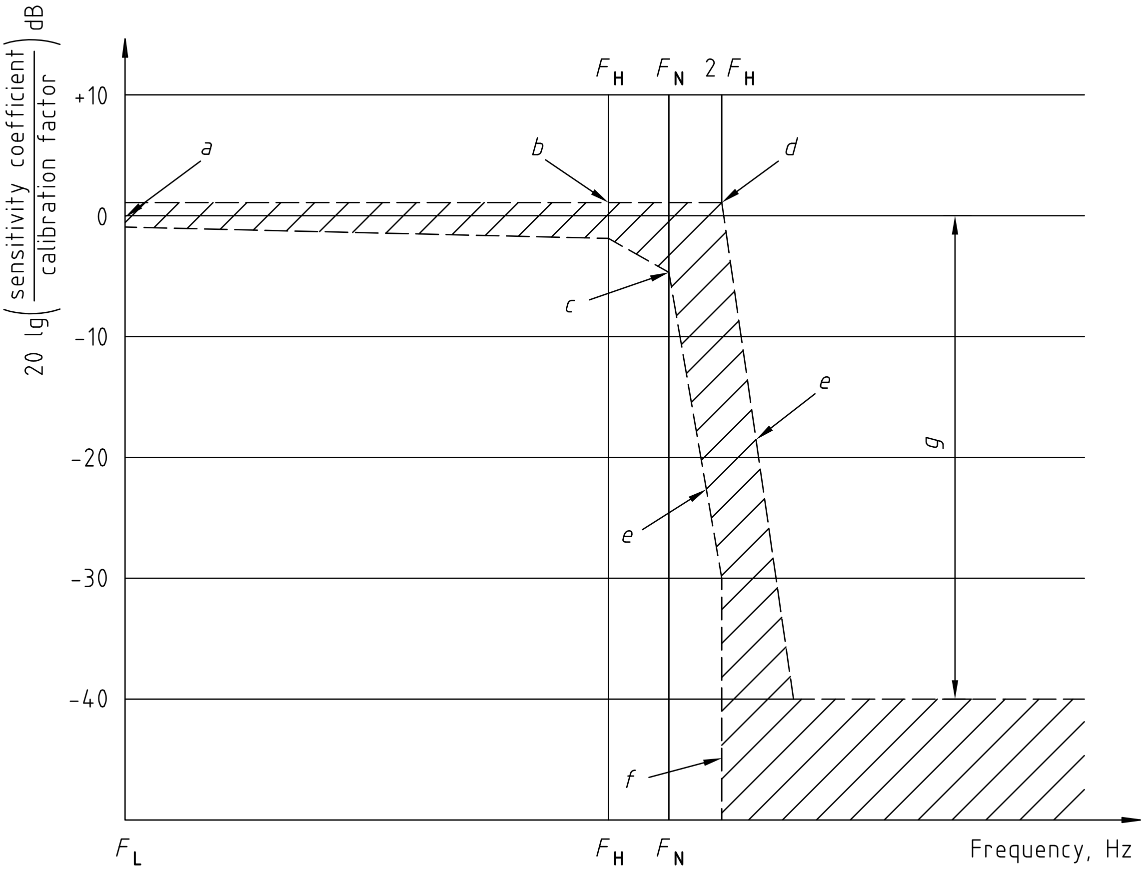
4 Performance requirements

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 CFC (channel frequency class) 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 Figure 2 for CFCs 1 000 and 600. For CFCs 180 and 60, the frequency response of a data channel shall lie within the limiting curves given in Figure 3. The zero decibels line is defined by the calibration factor.

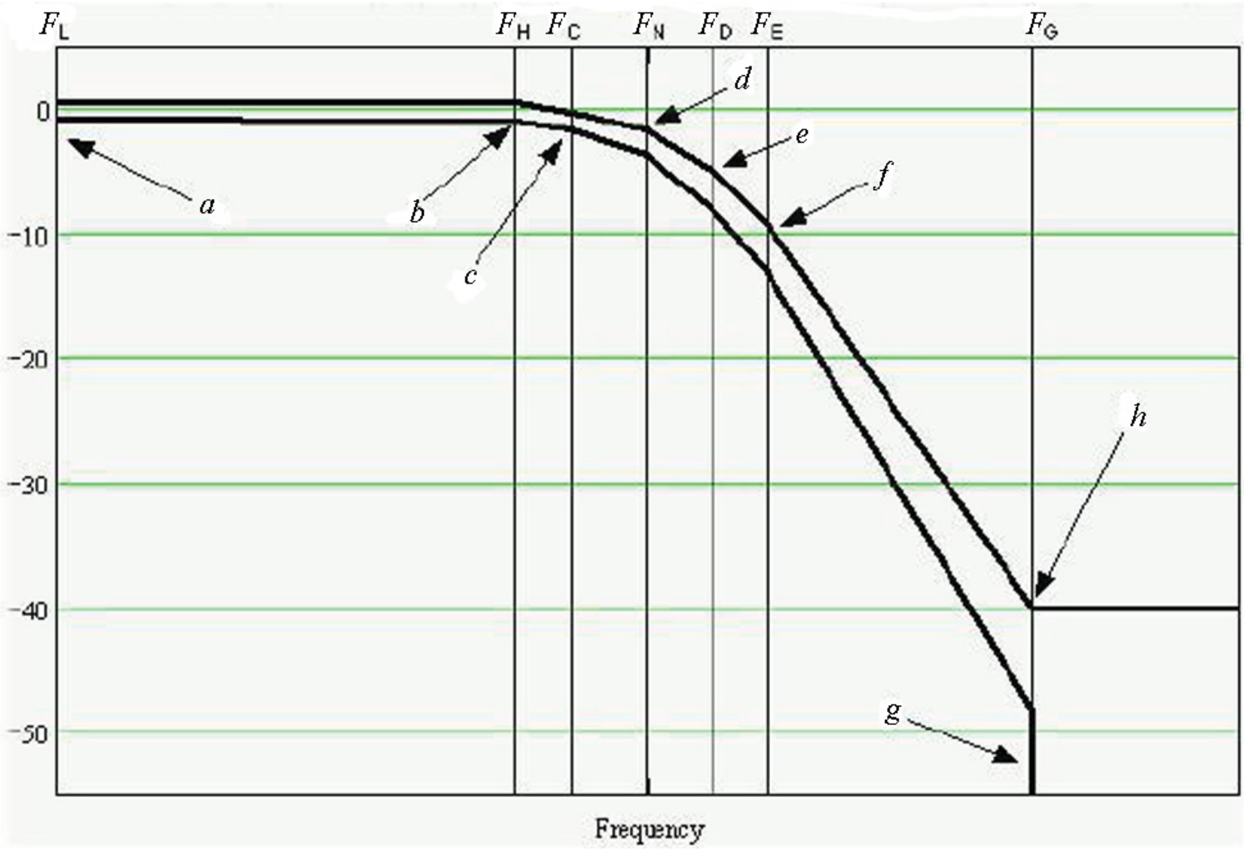
NOTE For CFCs 180 and 60 the filtering algorithm given in Annex A addresses this requirement.



Logarithmic scale	
a	± 0,5 dB
b	+ 0,5; – 1 dB
c	+ 0,5; – 4 dB
d	+ 0,5 dB
e	– 30 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 2 — Frequency response limits — CFC 1 000 and CFC 600



Logarithmic scale	
a	± 0,5 dB
b	+ 0,5; – 1 dB
c	+ 0,3; – 1,8 dB
d	– 1,8; – 3,8 dB
e	– 5,2; – 8,2 dB
f	– 9,2; – 13,2 dB
g	– ∞
h	– 40; – 48,3 dB

CFC	F_L Hz	F_H Hz	F_C Hz	F_N Hz	F_D Hz	F_E Hz	F_G Hz
180	≤ 0,1	180	225	300	390	480	1310
60	≤ 0,1	60	75	100	130	160	452

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

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 DAS shall ensure that timebase is a minimum of 0,01s 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 may 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 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.

4.5.2 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

Table 1 presents the relevant procedures.

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

Table 1 — 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 (CAC)
Accelerometer Shock calibration (pendulum)	< 1,8 %
Accelerometer Sinusoidal calibration (Shaker)	< 1,5 % below 400 Hz <2 % from 400 Hz to 2 kHz < 2,5 % from 2 kHz to 5 kHz
Force sensor – static calibration	< 1 %
Displacement	< 1,5 %
Angle	< 1,5 %
Angular rate	TBD
Pressure	1%
Temperature	< 1 % or 0,2 K
Tork	< 2 %

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 x sample rate).

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

4.5.4 Sensitivity coefficient and non-linearity

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 ten times the CFC or 3 500 Hz, whichever is lower.

4.6 Environmental effects

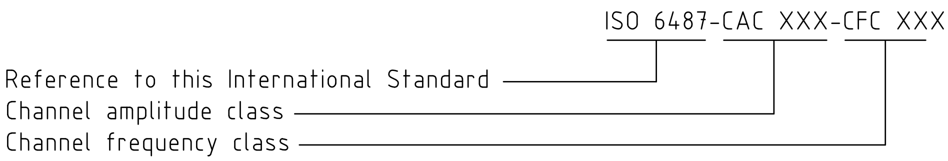
The existence or non-existence of an influence of environmental effects shall be checked regularly (i.e. electric or magnetic flux, electric, magnetic, electrostatic effects due to the violent displacement or friction of electric cables during tests, etc.). This can be done, for example, by recording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



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 J211-1:2007.

— For the vehicle measurements: ISO 4130 or SAE J211-1:2007.

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)

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-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 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 must verify their combined performance to establish equivalence.

The compatibility of the channel is affected by potential sources of error from transducer characteristics (the transducer can act unfavourably with the rest of the measurement data channel), e.g. influences resonance/damping. Other sources of error 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 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.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 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.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 measurement 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

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[9] ASTM E879-01, *Standard specification for thermistor sensors for clinical laboratory temperature measurements*

[10] ASTM E1137/E1137M-04, *Standard specification for industrial platinum resistance thermometers*

[11] JCGM 100:2008 (E), *Evaluation of measurement data — Guide to the expression of uncertainty in measurement*

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