



SURFACE VEHICLE RECOMMENDED PRACTICE

J211™-1

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Instrumentation for Impact Test Part 1 - Electronic Instrumentation

RATIONALE

In an effort to improve overall accuracy of data collection, SAE J211 is being revised to add additional sensor types, improve the definition of the forces and to recommend that data collection move to 20K samples per a second and 16-bit resolution. Adding a definition for CFC20. Continued ongoing effort to harmonize with ISO 6487.

1. SCOPE

This SAE Recommended Practice outlines a series of performance recommendations, which concern the whole data channel. These recommendations are not subject to any variation and all of them shall be adhered to by any agency conducting tests to this practice. However, the method of demonstrating compliance with the recommendations is flexible and can be adapted to suit the needs of the particular equipment the agency is using.

It is not intended that each recommendation be taken in a literal sense, as necessitating a single test to demonstrate that the recommendation is met. Rather, it is intended that any agency proposing to conduct tests to this practice shall be able to demonstrate that if such a single test could be and were carried out, then their equipment would meet the recommendations. This demonstration shall be undertaken on the basis of reasonable deductions from evidence in their possession, such as the results of partial tests.

In some systems, it may be necessary to divide the whole channel into subsystems, for calibration and checking purposes. The recommendations have been written only for the whole channel, as this is the sole route by which subsystem performances affect the quality of the output. If it is difficult to measure the whole channel performance, which is usually the case, the test agency may treat the channel as two or more convenient subsystems. The whole channel performance could then be demonstrated on the basis of subsystem results, together with a rationale for combining the subsystem results together.

SAE J211-1 of this SAE Recommended Practice covers electronic instrumentation. SAE J211-2 covers photographic instrumentation.

1.1 Purpose

The purpose of this SAE Recommended Practice is to provide guidelines and recommendations for the techniques of measurement used in impact tests. The aim is to achieve uniformity in instrumentation practice and in reporting test results. Use of this SAE Recommended Practice will provide a basis for meaningful comparisons of test results from different sources.

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Documents

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1.2 Field of Application

The instrumentation as defined in this SAE Recommended Practice applies in particular to impact tests for road vehicles, including tests of their sub-assemblies, and occupant surrogates.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J670	Vehicle Dynamics Terminology
SAE J1727	Calculation Guidelines for Impact Testing
SAE J1733	Sign Convention for Vehicle Crash Testing
SAE J2570	Performance Specifications for Anthropomorphic Test Device Transducers

Chou, C., Lin, Y., and Lim, G., "An Evaluation of Various Viscous Criterion Computational Algorithms," SAE Technical Paper 930100, 1993, <https://doi.org/10.4271/930100>.

2.1.2 NHTSA Publications

Available from Department of Transportation, The Office of Crashworthiness Research, 408 7th Street SW, Washington, DC 20590.

NHTSA Version 5 Test Reference Guide: Volume 1 - Vehicle Tests, Volume 2 - Biomechanics, Volume 3 - Components, and Volume 4 - Signal Waveform Generator

3. DEFINITIONS

The definitions in 3.5 to 3.14 apply to the whole data channel, as defined in 3.1.

3.1 DATA CHANNEL

All of the instrumentation from and including a single transducer (or multiple transducers whose outputs are combined in some specified way) up to and including any analysis procedures that may alter the frequency content or the amplitude content or the timing of data. It also includes all cabling and interconnections.

3.2 TRANSDUCER

The 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. For transducer equivalency, see Appendix B.

3.3 FULL SCALE

The maximum usable linear range of a data channel. For ATD transducers, refer to SAE J2570.

3.4 DATA CHANNEL FULL SCALE

That value of a data channel determined by the component of the channel with the lowest full scale level. This is expressed in terms of the measured variable (input). For example, F.S. = 50 G, 1000 N, 1 m/s, etc.

3.5 CHANNEL AMPLITUDE CLASS (CAC)

The designation for a data channel that meets certain amplitude characteristics as specified by this SAE Recommended Practice. The CAC number is numerically equal to the upper limit of the measurement range (that is, equivalent to the data channel full scale).

3.6 CHARACTERISTIC FREQUENCIES (F_H , F_L , F_N)

These frequencies are defined in Figures 1 and 2.

3.7 CHANNEL FREQUENCY CLASS (CFC)

The channel frequency class is designated by a number indicating that the channel frequency response lies within limits specified by Figure 1 for CFCs of 1000 and 600, and by Figure 2 for CFCs of 60 and 180.

NOTE: Figure 1 has not changed in reference to SAE J211 March 1995 except to specify nodal points instead of slopes. This number and the value of the frequency F_H in hertz are numerically equal.

3.8 CALIBRATION VALUE

The value measured and read during the calibration of a data channel (see 4.6).

3.9 SENSITIVITY COEFFICIENT

The 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.

3.10 CALIBRATION FACTOR OF A DATA CHANNEL

The arithmetic mean of the sensitivity coefficients evaluated over frequencies which are evenly spaced on a logarithmic scale between F_L and $F_H/2.5$.

3.11 LINEARITY ERROR

The ratio, in percent, of the maximum difference between the calibration value and the corresponding value read on the straight line defined in 3.9 at the upper limit of the channel amplitude class (data channel full scale).

3.12 SENSITIVITY

The 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 gage accelerometer.) For ATD transducers, refer to SAE J2570.

3.13 PHASE DELAY TIME

The phase delay time of a data channel is equal to the phase delay (in radians) of a sinusoidal signal, divided by the angular frequency of that signal (in radians per second).

3.14 ENVIRONMENT

The aggregate, at a given moment, of all external conditions and influences to which the data channel is subjected.

3.15 TRANSVERSE SENSITIVITY (OF A RECTILINEAR TRANSDUCER)

The sensitivity to excitation in a nominal direction perpendicular to its sensitive axis.

NOTE: The transverse sensitivity is usually a function of the nominal direction of the axis chosen. For ATD transducers, refer to SAE J2570.

3.16 TRANSVERSE SENSITIVITY RATIO (OF A RECTILINEAR TRANSDUCER)

The ratio of the transverse sensitivity to its sensitivity along its sensitive axis.

3.17 FAST FOURIER TRANSFORM (FFT)

A mathematical function used to convert data from the time domain to the frequency domain. An FFT filter is a filter which operates in the frequency domain.

3.18 ANTHROPOMORPHIC TEST DEVICE (ATD)

Crash test dummy.

4. DATA CHANNEL PERFORMANCE REQUIREMENTS

4.1 Linearity Error

The absolute value of the linearity error of a data channel at any frequency in the CFC, shall be less than or equal to 2.5% of the value of the CAC, through the whole measurement range. In general a sufficient number of measurements shall be carried out in order to ensure the linearity in the range of interest, that is, between F_L and F_H .

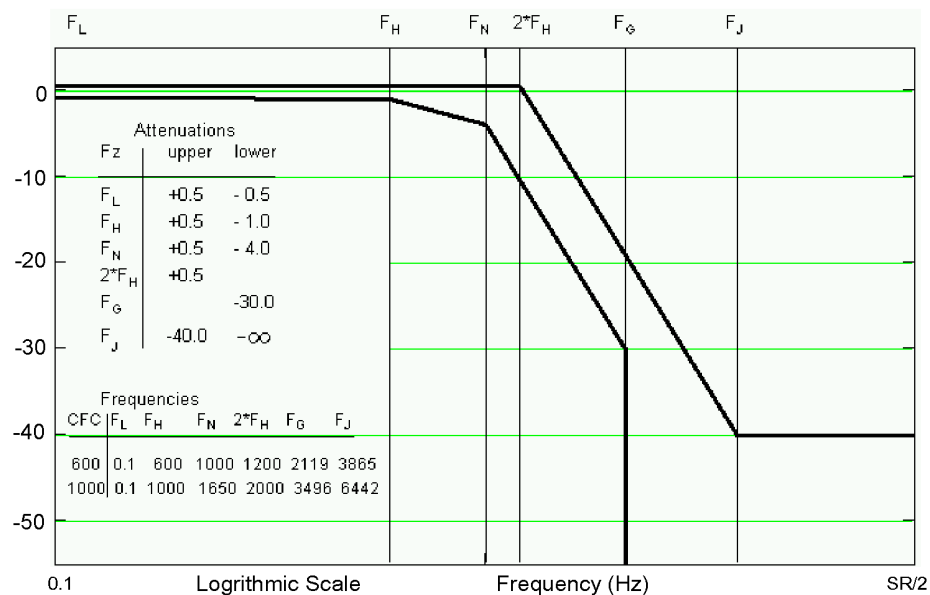


Figure 1 - Data channel dynamic accuracy, class 600 and 1000

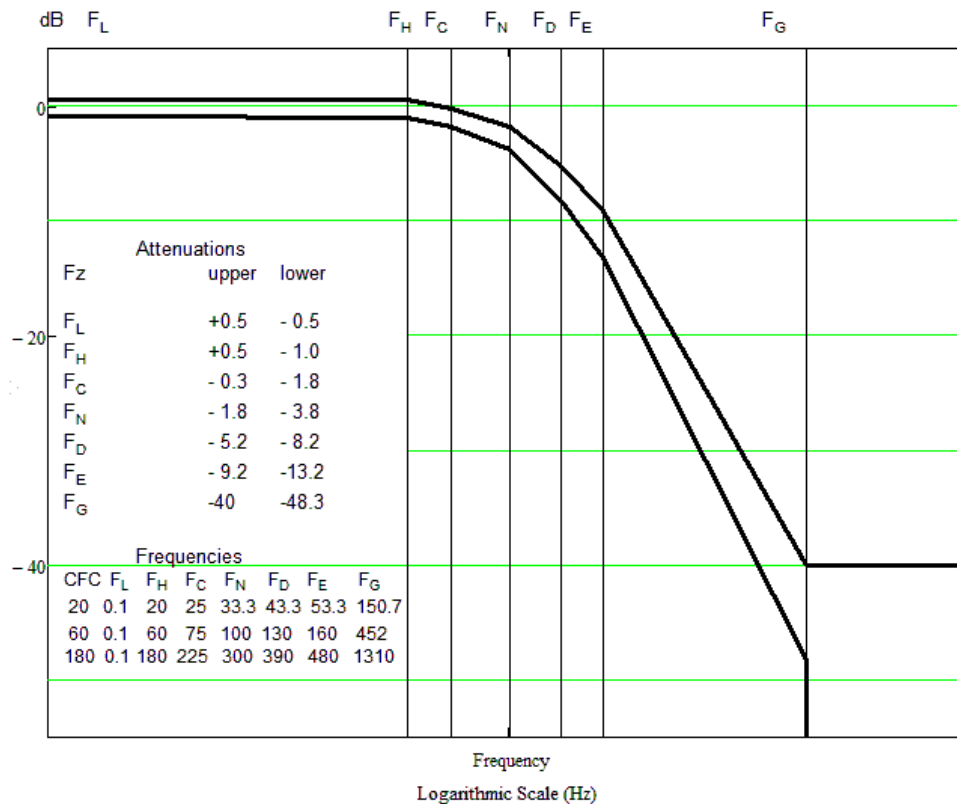


Figure 2 - Data channel dynamic accuracy, class 20, 60, and 180

4.2 Amplitude Against Frequency

The frequency response of a data channel shall lie within the limiting curves given in Figure 1 for CFCs of 1000 or 600. For CFCs of 180, 60, or 20 the frequency response of a data channel shall lie within the limiting curves given in Figure 2. The 0 dB line is defined by the calibration factor.

NOTE: The Figure 2 envelopes have been derived to center the frequency responses of the SAE J211 March 1995 Appendix C CFC 20, 60, and 180 filters in the corridors.

4.3 Phase Delay Time

The phase delay time between the input and the output of a data channel shall be determined, and shall not vary more than $1/(10 \cdot F_H)$ seconds between $0.03 \cdot F_H$ and F_H . This includes the transducer, that is, the input is the excitation to the transducer.

4.4 Time

4.4.1 Time Base

A time base shall give at least 1/100 second resolution with an error of less than 1/10000 second.

4.4.2 Relative Time Delay

The relative time delay between the signals of two or more data channels regardless of their frequency class, must not exceed 1 ms. Two or more data channels of which the signals are combined shall have the same frequency class and shall not have a relative time delay greater than $1/(10 \cdot F_H)$ seconds. This requirement applies to analog signals, as well as digital signals.

4.5 Transducer Transverse Sensitivity Ratio

The transverse sensitivity ratio of all transducers shall be less than 5% in any direction. For ATD transducers, refer to SAE J2570.

4.6 Calibration

Values in this section apply to reference equipment or standards against which a data channel is calibrated; that is, its performance is determined.

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 introduce an error greater than 1% of the CAC. The use of the reference equipment is limited to the range of frequencies for which they have been calibrated. Subsystems of a data channel may be evaluated individually and the results factored into the accuracy of the total data channel. This can be accomplished for example by an electrical signal of known amplitude simulating the output signal of the transducer which allows a check to be made on the gain of the data channel, except the transducer.

4.6.2 Accuracy of Reference Equipment for Calibration

The accuracy of the reference equipment shall be certified or endorsed by an approved metrology service (for example, traceable to the National Institute of Standards and Technology).

4.6.2.1 Static Calibration

4.6.2.1.1 Accelerations

The error shall be less than 1.5% of the channel amplitude class.

4.6.2.1.2 Forces

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

4.6.2.1.3 Displacements

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

4.6.2.2 Dynamic Calibration

4.6.2.2.1 Accelerations

The error in the reference accelerations expressed as a percentage of the channel amplitude class shall be less than 1.5% 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 utilized (see 4.6.4).

Use of a shock calibration device error as a percentage of channel amplitude class shall be less than 1.8%.

4.6.2.2.2 Forces, Moments, and Displacements

Refer to SAE J2570 for load cell specifications titled "Free Air Resonance" for force and moment info.

4.6.2.2.3 Angular Rate

The error in reference angular rate expressed as a percentage of the channel amplitude class shall be less than 0.5%.

4.6.2.3 Time

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

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 well-known input signal, for various values of this signal. (The input signal is referenced to well known physical data, which is, a load or acceleration, but not voltage.)

The calibration of the data channel shall cover the whole range of the amplitude class. (This is between F_L and $F_H/2.5$.)

For bi-directional channels, both the positive and negative values shall be evaluated. If the calibration equipment cannot produce the required input, due to 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 a spectrum of frequencies with its significant values comprised between F_L and $F_H/2.5$.

4.6.4 Calibration of the Frequency Response

The response curves of phase and amplitude against frequency for the data channel 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 3000 Hz, whichever is the lower value.

4.7 Environmental Effects

4.7.1 Data System Grounding and Sensor Cable Shielding

Electrostatic discharge (ESD), electromagnetic fields (EMF), and radio frequency interference (RFI) commonly encountered in the impact test environment can seriously degrade recorded data quality if proper grounding and shielding techniques are not implemented. ISO and NHTSA have published guidance documents with specific recommendations. These are contained in Appendix D along with more detailed information regarding grounding and cable shielding/routing methods.

4.7.2 Quantifying Environment Effects.

The presence of environmental effects should periodically be checked (that is, electric or magnetic flux, electrostatic discharge, cable velocity, etc.). This can be done for example by recording the output of spare channels equipped with a known input (such as simulated transducers, shorting plug, etc.). If such an output signal is greater than 2% of the expected data peak value, corrective action shall be taken such as relocation or replacement of cables.

5. DATA CHANNEL SELECTION

The selection of a frequency response class is dependent upon many considerations, some of which may be unique to a particular test. The ultimate usage of the data and good engineering judgment will determine what portions of the frequency spectrum are significant or useful. The various classes of frequency response in Figures 1 and 2 are intended to permit appropriate choices for different engineering requirements.

It is important to note that valid comparisons using different frequency response classes may be difficult to make. It is useful to establish specific frequency response classes when comparing test results from different sources. The frequency response classes in Table 1 are recommended for that purpose. These recommendations reflect current practices and equipment. However, it is recognized that other considerations (for example, biomechanics) may impose special instrumentation requirements.

The channel class recommendations for a particular application shall not be considered to imply that all the frequencies passed by that channel are significant for the application. In several cases, such as occupant head accelerations, headform accelerations, and femur force, the recommendation may be higher than necessary, but current biomechanical knowledge will not permit a closer specification. All data are to be gathered at CFC 1000 or higher, for any purpose.

Table 1 - Frequency response classes

Typical Test Measurements	Channel Frequency Class (CFC) ⁽¹⁰⁾
Vehicle structural	
Acceleration	
Total vehicle comparison	60 ⁽¹⁾
Collision simulation input	60
Component analysis	600
Integration for velocity or displacement	180
Angular Rate	
Vehicle Control Modules	180
Integration for rotational displacement	180
Barrier face force	60
Belt restraint system loads	60
Anthropomorphic Test Device	
Angular Rate	60
Integration for rotational displacement	180 ⁽⁸⁾
Differentiation for Angular Acceleration	180 ⁽⁹⁾
Head	
Accelerations (linear and angular)	1000
Neck	
Forces	1000 ^(2,3,7)
Moments	600 ^(2,3)
Arm	
Forces	600 ⁽⁵⁾
Moments	600 ⁽⁵⁾
Accelerations	600 ⁽⁵⁾
Thorax	
Spine accelerations	180
Rib accelerations	1000 ⁽²⁾
Sternum accelerations	1000 ⁽²⁾
Deflections	600 ^(2,4)
Lumbar	
Forces	600 ⁽⁶⁾
Moments	600 ⁽⁶⁾
Pelvis	
Accelerations	1000 ⁽²⁾
Forces	600 ⁽⁶⁾
Moments	600 ⁽⁶⁾
Femur/Knee/Tibia/Ankle	
Accelerations	1000
Forces	600
Moments	600 ⁽²⁾
Displacements	180 ⁽²⁾
Sled acceleration	60
Steering column loads	600
Headform acceleration	1000

(1) When overall acceleration of the frame or body in a given direction is desired and a higher frequency response class is used, readability of the data may be improved by averaging outputs of two or more transducers at different locations.

(2) UMTRI-86-32 and ISO/TC22/SC12/WG3 N194.

(3) These classifications are needed to calculate head impact forces based on neck forces and head accelerations when using an ATD.

(4) SAE paper 930100.

(5) SAE paper 2002-01-0806 or ISO/TC22/SC12/WG6 N557.

(6) See Appendix B.

(7) When force channels are multiplied by a moment arm, a CFC 600 filter shall be used.

(8) MVSS202a S5.3.9 Low Speed Rear Impact specifies CFC 600 for head rotation.

(9) SAE Paper 2010-01-1017.

(10) Specific testing protocols may require filters that are different than listed in Table 1.



6. MOUNTING OF TRANSDUCERS

6.1 Transducer Mounting Considerations

Mechanical resonance associated with transducer mounting shall not distort readout data. Transducers shall be mounted on dummies using a support specially provided for this purpose. In cases where properties of non-mechanical test subjects preclude rigid transducer mounting, an analytical or experimental evaluation of mounting effects on the data shall be provided. Acceleration transducers, in particular, shall be mounted in such a way that the initial angle of the actual measurement axis to the corresponding axis of the reference axis system is not greater than 5 degrees 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 shall pass within 10 mm of that point, and the center of seismic mass of each accelerometer shall be within 30 mm of that point.

6.2 Transducer Resonance

Many transducers have resonant frequencies well above CFC 1000 that may distort recorded data. Care must be exercised to ensure that typical transducer resonance signatures do not cause signal distortion such as unexpected channel saturation, DC offsets, or aliasing. Additional information and recommendations for minimizing effects of transducer resonance are contained in Appendix E.

7. SIGN CONVENTION

In order to compare test results obtained from different crash test facilities, standardized coordinate systems need to be defined for crash test dummies, vehicle structures and laboratory fixtures. In addition, recorded polarities for various transducer outputs need to be defined relative to positive directions of the appropriate coordinate systems. This section describes the standardized sign convention.

7.1 Right-Handed Coordinate System

To assure consistent vector directions of moments and angular velocities and accelerations produced by vector multiplications all coordinate systems used in vehicle testing will be "right-handed."

Right-handed coordinate system consists of an ordered set of three mutually perpendicular axes (x, y, z) which have a common origin and whose positive directions point in the same directions as the ordered set of the thumb, forefinger and middle finger of the right hand when positioned as shown in Figure 3. Note that one can choose the positive x-axis to point in the direction of either the thumb, forefinger or middle finger as shown in the orientations 1, 2, and 3 of Figure 3. However, once this decision is made then the positive directions of the y- and z-axes must be as indicated by corresponding orientation shown in Figure 3.

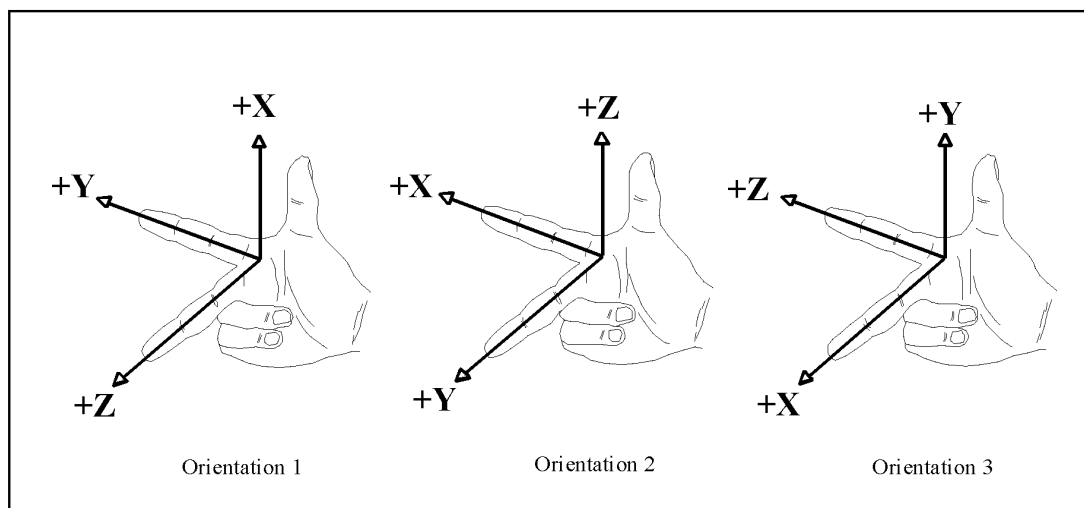


Figure 3 - The three possible orientations of a right-handed coordinate system relative to the thumb, forefinger, and middle finger of the right hand