

Australian Standard™

Environmental testing

**Part 2.81: Tests—Test Ei: Shock—Shock
response spectrum synthesis**



This Australian Standard was prepared by Committee EL-026, Protective Enclosures and Environmental Testing for Electrical/Electronic Equipment. It was approved on behalf of the Council of Standards Australia on 3 May 2004 and published on 1 June 2004.

The following are represented on Committee EL-026:

Australian Chamber of Commerce and Industry
Australian Electrical and Electronic Manufacturer's Association
Electrical Compliance Testing Association
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This Standard was issued in draft form for comment as DR 04140.

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First published as AS 60068.2.81—2004.

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Published by Standards Australia International Ltd
GPO Box 5420, Sydney, NSW 2001, Australia

ISBN 0 7337 6011 2

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PREFACE

This Standard was prepared by the Standards Australia Committee EL-026, Protective Enclosures and Environmental Testing for Electrical/Electronic Equipment

The objective of this Standard is to provide the electrotechnology industry with a complete set of environmental test procedures published as a series under AS 60068 *Environmental testing*. This Standard is Part 2.81 of that series.

This Standard is identical with, and has been reproduced from, IEC 60068-2-81:2003, *Environmental testing – Part 2-81: Tests—Test Ei: Shock—Shock response spectrum synthesis*.

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In this Standard, the following print types are used:

- requirements proper: in arial type;
- *test specifications: in italic type;*
- explanatory matter: in smaller arial type.

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INTRODUCTION

This part of IEC 60068, designed for testing with a synthesized shock response spectrum (SRS) is intended for general application for components, equipment and other products, hereinafter referred to as “specimens”, when simulation of transient responses of a complex nature is required. The test method centres on the use of SRS and techniques associated with SRS.

The purpose of the test is to demonstrate the adequacy of the test specimen to resist the specified transient excitation, without unacceptable degradation of its functional and/or structural performance. It is particularly useful for tailoring shock responses where measured data are available from the operational environment. However, the test is applicable to any transient excitation within the limits of the testing apparatus.

The test method is based primarily on the use of an electrodynamic or a servo-hydraulic vibration generator with an associated computer-based control system used as a shock testing system.

Other shock testing machines may be used, provided they fulfil the requirements of this standard.

It is emphasized that SRS synthesis testing always demands a certain degree of engineering judgement. Both supplier and purchaser should be fully aware of this fact. The writer of the relevant specification is expected to select the testing procedure and the values of severity appropriate to the specimen and its use.

STANDARDS AUSTRALIA

Australian Standard
Environmental testing

Part 2.81: Tests—Test Ei: Shock—Shock response spectrum synthesis

1 Scope

This part of IEC 60068 specifies tests using a synthesized shock response spectrum (SRS). It is intended for general application to specimens when simulation of transient excitation of a complex nature is required.

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.

IEC 60068-1:1988, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-6:1995, *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-27:1987, *Basic environmental testing procedures – Part 2: Tests – Test Ea and guidance: Shock*

IEC 60068-2-47:1999, *Environmental testing – Part 2-47: Test methods – Mounting of components, equipment and other articles for vibration, impact and similar dynamic tests*

IEC 60068-2-57:1999, *Environmental testing – Part 2-57: Tests – Test Ff: Vibration – Time-history method*

IEC 60068-2-64:1993, *Environmental testing – Part 2: Test methods – Test Fh: Vibration, broad-band random (digital control) and guidance*

ISO 266:1997, *Acoustics – Preferred frequencies*

ISO 2041:1990, *Vibration and shock – Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, IEC 60068-1, IEC 60068-2-6, IEC 60068-2-27, IEC 60068-2-57 and IEC 60068-2-64, together with the following definitions, apply.

3.1**–3 dB bandwidth**

frequency bandwidth between two points in a frequency response function which is 0,707 of the maximum response when associated with a single resonance peak

3.2**critical damping**

minimum viscous damping that will allow a displaced system to return to its initial position without oscillation in the shortest time possible

3.3**critical frequency**

frequencies at which

- malfunctioning and/or deterioration of performance of the specimen which are dependent on vibration are exhibited, and/or
- mechanical resonances and/or other response effects occur, for example chatter

3.4**damping**

generic term ascribed to the numerous energy dissipation mechanisms in a system. In practice, damping depends on many parameters, such as the structural system, mode of vibration, strain, applied forces, velocity, materials, joint slippage, etc.

3.5**damping ratio**

ratio of actual damping to critical damping in a system with viscous damping

3.6**decibel****dB**

relation between magnitudes written in a logarithmic form:

$$L = 20 \log_{10} \left(\frac{X}{X_0} \right) \text{ (dB)}$$

where

L is the logarithmic value in dB;

X/X_0 is the relation between magnitudes X and X_0

3.7**fixing point**

part of the specimen in contact with the fixture or vibration table at a point where the specimen is normally fastened in service

NOTE If a part of the real mounting structure is used as the fixture, the fixing points are taken as those of the mounting structure and not of the specimen.

3.8 **g_n**

standard acceleration due to the earth's gravity, which itself varies with altitude and geographical latitude

NOTE For the purposes of this standard, the value of g_n is rounded up to the nearest whole number, that is, 10 m/s².

3.9**Hanning window**

weighting function for time-histories that forces the start and the end of the time-history to a zero value in the selected time window. It has the shape of a cosine bell

NOTE See ISO 18431-2 for a more detailed definition.

3.10

high-frequency asymptote

HFA

high-frequency asymptotic value of the SRS curve (see Figure 3)

NOTE 1 The SRS high-frequency asymptote is of practical significance as it represents the largest peak value of the excitation time-history. This is not to be confused with the peak value in the SRS.

NOTE 2 Another name of the SRS high-frequency asymptote is zero-period acceleration (ZPA).

3.11

measuring points

specific points at which data are gathered when conducting the test. These points are of three types, as defined below

3.11.1

check point

point located on the fixture, on the vibration table or on the specimen as close as possible to, or combined with, one of its fixing points, and in any case rigidly connected to it

NOTE 1 A number of check points are used as a means of ensuring that the test requirements are satisfied.

NOTE 2 If four or fewer fixing points exist, each is used as a check point. If more than four fixing points exist, four representative fixing points will be defined in the relevant specification to be used as check points.

NOTE 3 In special cases, for example, for large or complex specimens, the check points will be prescribed by the relevant specification if not close to the fixing points.

NOTE 4 Where a large number of small specimens are mounted on one fixture, or in the case of a small specimen where there are a number of fixing points, a single check point (that is the reference point) may be selected for the derivation of the control signal. This signal is then related to the fixture rather than to the fixing points of the specimen(s). This procedure is only valid when the lowest resonance frequency of the loaded fixture is well above the upper frequency of the test.

3.11.2

reference point

point, chosen from the check points, whose signal is used to control the test

3.11.3

response point

point on the specimen used for measurement of the response during vibration response investigation or during testing. This point is not a check or a reference point

NOTE More than one response point can be used.

3.12

natural frequency

frequency of damped or undamped free vibration of a structure depending only on its own physical characteristics (mass, stiffness and damping)

3.13

number of high peaks of the response time-history

measured number of peaks at the response point or number of peaks of the calculated response time-history of one single-degree-of-freedom system (oscillator), excited by a time-history, exceeding a specified threshold value (see Figure 1)

NOTE 1 In practice, reference is made to high peaks of the response time-history since it is difficult to identify complete response cycles due to a transient excitation.

NOTE 2 The peak is a positive or a negative maximum deviation from the zero-line between two consecutive zero-crossing points (see Figure 2).

NOTE 3 Calculated peaks instead of measured peaks are preferred in this standard, as it is not always possible to obtain measured peaks of response time-histories.

3.14

oscillator

single-degree-of-freedom system intended to produce, or be capable of maintaining, mechanical oscillations

3.15**pause**

interval between two consecutive time-histories

NOTE A pause should be such as to result in no significant superposition of the response motion of the specimen and can be obtained from

$$T > \frac{1}{f} \times \frac{100}{d}$$

where

T is the duration in seconds (s);

f is the lowest undamped natural frequency in hertz (Hz);

d is the damping ratio at the lowest natural frequency (in per cent).

3.16**preferred testing axes**

three orthogonal axes which correspond to the most vulnerable axes of the specimen

3.17 **Q -factor**

quantity, which is a measure of the sharpness of resonance, or frequency selectivity of a resonant oscillatory mechanical system having a single degree of freedom. The Q -factor is one-half the reciprocal of the damping ratio

3.18**required SRS**

SRS specified in the relevant specification (see Figure 3)

NOTE The relevant specification can contain more than one SRS with different Q -factors for a certain test case.

3.19**shock response spectrum****SRS**

plot of the maximum response (displacement, velocity or acceleration) of a base-excited series of single-degree-of-freedom systems to a defined input motion as a function of their undamped natural frequencies and at a specified Q -factor

NOTE 1 For calculation purposes, linear fixed-base single-degree-of-freedom systems and viscous damping are assumed, if not otherwise defined.

NOTE 2 The relevant specification can contain several SRS with different Q -factors for a given test case, from which the required SRS shall be selected depending on the Q -factor of the test specimen.

3.20**sampling frequency**

number of discrete magnitude values taken per second to record or represent a time-history in digital form

3.21**signal tolerance**

signal tolerance S_t in per cent is defined as

$$S_t = \left(\frac{NF}{F} - 1 \right) \times 100 \text{ (per cent)}$$

where

NF is the r.m.s. value of the unfiltered signal;

F is the r.m.s. value of the filtered signal

NOTE 1 This parameter applies to whichever signal, i.e. acceleration, velocity or displacement, is being used to control the test.

NOTE 2 This parameter applies only to excitation with sinusoidal vibration.

3.22**strong part of the time-history**

part of the time-history from the time when the plot first reaches 25 % of the maximum value to the time when it falls for the last time to the 25 % level (see Figure 4)

3.23**synthesized time-history**

artificially generated time-history such that its SRS envelops the required SRS

3.24**test frequency range**

frequency range chosen for testing depending on the synthesizing of the required SRS and on the capabilities of the test apparatus with the test specimen attached. It has a lower (f_1) and an upper (f_2) frequency limit, corresponding to the lowest and highest wavelet frequency that may be used

NOTE The frequency range of the SRS is larger than the test frequency range and extends to infinite frequency (see definition 3.10).

3.25**test SRS**

SRS derived from the real motion of the reference point on the vibration generator table, either analytically or by using SRS analysis equipment (see Figure 3)

3.26**time-history**

recording, as a function of time, of acceleration, velocity or displacement

NOTE A definition of the mathematical term "time-history" is given in ISO 2041 and relates to the magnitude of a quantity expressed as a function of time.

3.27**time window**

duration of synthesis of the test time-history in which all the wavelets are contained

NOTE In some test control systems, this time window is doubled in duration and the synthesized time-history centred in the middle of the new time frame.

3.28**wavelet**

time-history with a single frequency that is a component of the synthesized time-history for SRS testing

NOTE The term 'wavelet' as used in this standard should not be mixed up with wavelet as used in wavelet theory and wavelet analysis.

4 Requirements for test apparatus

The required characteristics apply to the complete test apparatus, which for an electrodynamic testing system includes the control system, power amplifier, vibrator, test fixture and specimen when loaded for testing. The components are similar for a servo-hydraulic testing system.

The requirements for the test apparatus according to 4.1 to 4.3 shall be verified by means of sinusoidal vibration excitation.

4.1 Basic motion

The basic motion during verification shall be a sinusoidal function of time and such that the fixing points of the specimen move substantially in phase and straight parallel lines, subject to the limitation of 4.2 and 4.3.

4.2 Cross-motion

The maximum vibration amplitude of acceleration or displacement at the check points in any axis perpendicular to the specified axis shall not exceed 50 % of the vibration amplitude of the basic motion up to 1 000 Hz and is allowed to go up to 100 % above 1 000 Hz. The measurements need only cover the specified test frequency range. In special cases, for example small specimens, the maximum permissible cross-motion may be limited to 25 % if required by the relevant specification.

Where rotational motion of the vibration table is likely to be important, a tolerable level shall be prescribed by the relevant specification and then be stated in the test report.

In some cases, for example with large-size or high-mass specimens or at certain frequencies, it may be difficult to achieve the figures quoted above. In such cases the relevant specification shall state which of the following requirements applies:

- a) cross-motion in excess of that specified above shall be stated in the test report; or
- b) cross-motion which is known to offer no hazard to the specimen need not be monitored.

4.3 Signal tolerance

Unless otherwise stated in the relevant specification, acceleration signal tolerance measurements shall be performed. They shall be carried out at the reference point and shall cover the frequencies up to 5 000 Hz, or five times the upper test frequency (f_2), whichever is the lesser value. However, this maximum analysing frequency may be extended to the upper test frequency, or beyond if specified by the relevant specification. Unless otherwise stated in the relevant specification, the signal tolerance shall not exceed 5 %.

In the case of large or complex specimens, where the specified signal tolerance values cannot be satisfied at some parts of the frequency range the signal tolerance shall be stated in the test report.

4.4 Measuring system

The characteristics of the measuring system shall be such that it can be determined that the true value of the time-history, as measured in the intended axis at the reference point, is within the tolerances required for the test.

The frequency response of the overall measuring system, which includes the transducer, the signal conditioner and the data acquisition and processing device, has a significant effect on the accuracy of the measurements.

The frequency range of the measuring system shall extend from at least 0,67 times the lowest wavelet frequency (f_1) to 1,5 times the highest wavelet frequency (f_2) of the test frequency range. (See also 4.2 in IEC 60068-2-27.) The frequency response of the measuring system shall be flat within ± 5 % in this frequency range.

5 Requirements for testing

5.1 Test control

The test time-history shall be a synthesized time-history composed of wavelets included within the specified time window. This time-history is obtained from the specified SRS in the relevant specification as shown in 9.3.

A value of the damping ratio of 5 % (Q -factor of 10) shall be used unless otherwise specified in the relevant specification. Alternative values can be obtained from a vibration response investigation (see 9.2). A vibration response investigation can also show which Q -factor to use if several SRS (with different Q -factors) have been specified in the relevant specification.

The spacing of the wavelets by frequency shall be selected depending on the specified Q -factor for the test as follows:

- in 1/3 octave bands if the Q -factor is lower than, or equal to, 5;
- in 1/6 octave bands if the Q -factor lies between 5 and 25;
- in 1/12 octave bands if the Q -factor is higher than, or equal to, 25.

NOTE Preferred frequencies for octave bands are given in ISO 266.

5.2 Tolerances on SRS

The test SRS, measured at the reference point, shall be within $\pm 1,5$ dB of the required SRS (see Figure 3).

If a small portion of the test SRS, in less than 20 % of the frequency range, lies within the tolerance band ± 3 dB, the test may still be acceptable provided such points do not coincide with the critical resonance frequencies of the specimen in the test frequency range. The deviation from the required SRS shall be stated in the test report.

At a minimum, the test SRS shall be checked with the same frequency spacing as stated in 5.1 – selection depending on the Q -factor.

5.3 Calculation of test SRS

In order to keep errors to a minimum when calculating the test SRS, special consideration shall be given to sampling and filtering of the signal from the reference point.

It is recommended that the sampling frequency of the time-history be at least a factor of 10 or higher than the upper frequency (f_2) for the response calculation if an interpolation algorithm is not used in the subsequent SRS calculation.

NOTE 1 In this way the response time-history for the highest f_2 oscillator will be calculated with a magnitude error of less than 5 %. If a sampling frequency of $2,56 f_2$ is used, as is common for frequency analysis, an error exceeding 60 % can be obtained in the maximum response of the highest f_2 oscillator.

If an interpolation algorithm is used in the subsequent SRS calculation, the sampling frequency can be as low as four times the upper frequency (f_2).

A low-pass filter shall always be used prior to digitizing the time-history under evaluation to avoid aliasing errors. It is recommended that the half-power point cut-off frequency of the anti-aliasing filter is $1,5 f_2$. The cut-off rate shall be at least -60 dB/octave. Use of these recommended values ensures that a full response is obtained for the highest f_2 oscillator. Errors at the highest oscillators, due to phase modifications induced by anti-aliasing filters, are also suppressed. Filters shall have a linear relation between phase and frequency.

A high-pass filter shall be used if low-frequency errors or d.c. offset influence the test. It is recommended that the half-power cut-off frequency of such a filter is not higher than $0,1$ of the lower frequency (f_1) for the response calculation, or 2 Hz, whichever is higher.

Truncation errors can be obtained if the time-history under evaluation or the response time-histories of the oscillators do not decay within the time frame for the calculation. This is particularly critical when calculations are performed for oscillators with low damping. Truncation errors shall be avoided by using a long time frame.

NOTE 2 A rationale of the problem is reported in Appendix B of IEC 60068-2-27 which gives the definitions of "initial" and "residual" SRS. For the evaluation of the test SRS, a maximax SRS should be calculated.