BRITISH STANDARD

BS EN 60068-2-47:2005

Environmental testing —

Part 2-47: Tests — Mounting of specimens for vibration, impact and similar dynamic tests

The European Standard EN 60068-2-47:2005 has the status of a British Standard

ICS 19.040

British Standards

National foreword

This British Standard is the official English language version of EN 60068-2-47:2005. It is identical with IEC 60068-2-47:2005. It supersedes BS EN 60068-2-47:2000 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/104, Environmental conditions, classification and testing, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 36, an inside back cover and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 13 October 2005

ISBN 0 580 46448 2

Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD **EN 60068-2-47**

NORME EUROPÉENNE

EUROPÄISCHE NORM June 2005

ICS 19.040 Supersedes EN 60068-2-47:1999

English version

Environmental testing
Part 2-47: Tests - Mounting of specimens for vibration, impact and similar dynamic tests
(IEC 60068-2-47:2005)

Essais d'environnment
Partie 2-47: Essais –
Fixation de spécimens pour essais de vibrations, d'impacts et autres essais dynamiques
(CEI 60068-2-47:2005)

Umgebungseinflüsse
Teil 2-47: Prüfverfahren –
Befestigung von Prüflingen zur Schwing-, Stoß- und ähnlichen dynamischen Prüfungen
(IEC 60068-2-47:2005)

This European Standard was approved by CENELEC on 2005-05-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 60068-2-47:2005 E

Foreword

The text of document 104/359/FDIS, future edition 3 of IEC 60068-2-47, prepared by IEC TC 104, Environmental conditions, classification and methods of test, was submitted to the IEC/CENELEC parallel vote and was approved by CENELEC as EN 60068-2-47 on 2005-05-01.

This European Standard supersedes EN 60068-2-47:1999 + corrigendum June 2000.

The major technical changes with regard to EN 60068-2-47:1999 are related to specific guidance on the testing of packaged products.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2006-02-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2008-05-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60068-2-47:2005 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60068-2-6	NOTE	Harmonized as EN 60068-2-6:1995 (not modified).
IEC 60068-2-7	NOTE	Harmonized as EN 60068-2-7:1993 (not modified).
IEC 60068-2-21	NOTE	Harmonized as EN 60068-2-21:1999 (not modified).
IEC 60068-2-27	NOTE	Harmonized as EN 60068-2-27:1993 (not modified).
IEC 60068-2-29	NOTE	Harmonized as EN 60068-2-29:1993 (not modified).
IEC 60068-2-31	NOTE	Harmonized as EN 60068-2-31:1993 (not modified).
IEC 60068-2-32	NOTE	Harmonized as EN 60068-2-32:1993 (not modified).
IEC 60068-2-57	NOTE	Harmonized as EN 60068-2-57:2000 (not modified).
IEC 60068-2-59	NOTE	Harmonized as EN 60068-2-59:1993 (not modified).
IEC 60068-2-64	NOTE	Harmonized as EN 60068-2-64:1994 (not modified).
IEC 60068-2-65	NOTE	Harmonized as EN 60068-2-65:1994 (not modified).
IEC 60068-2-75	NOTE	Harmonized as EN 60068-2-75:1997 (not modified).
IEC 60068-2-81	NOTE	Harmonized as EN 60068-2-81:2003 (not modified).

CONTENTS

blank

ENVIRONMENTAL TESTING –

Part 2-47: Tests – Mounting of specimens for vibration, impact and similar dynamic tests

1 Scope

This part of IEC 60068 provides methods for mounting products, whether packaged or unpackaged, as well as mounting requirements for equipment and other articles, for the series of dynamic tests in IEC 60068-2, that is impact (Test E), vibration (Test F) and acceleration, steady-state (Test G). When they are fastened to the test apparatus and subjected to these tests, whether packaged or unpackaged, they are referred to as specimens.

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 60068-2-55:1987, *Environmental testing – Part 2-55: Tests – Test Ee and guidance: Bounce*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions used in ISO 2041 and IEC 60068-1 apply.

3.1
package
result of the packing operation, consisting of the packaging and its contents, for example, electronic devices prepared for transport

3.2
packaging
product made of any material of any nature to be used for the containment, protection, handling and delivery, for example, a corrugated fibreboard box

4 General

The relevant specification shall state whether the effect of gravitational force is important. If so, the specimen shall be mounted in such a way that the gravitational force acts in the same direction as it would in use. Where the effect of gravitational force is not important, the specimen may be mounted in any attitude.

If significant for the test results, the relevant specification shall also state

a) the temperature limits within which the specimen shall be tested,

b) the maximum level of magnetic interference which may be imposed on the specimen and/or the orientation of the specimen in relation to the direction of the magnetic field (for example, near an electrodynamic vibration generator),

c) the relative humidity limits within which the specimen shall be tested.

5 Mounting, where the specimen is a component

The mounting method to be used shall be as stated in the relevant specification.

Where the method of mounting is not specified but is obvious from the design, as in Figure 1, this method shall be used. Where it is not obvious, the mounting methods shall, whenever possible, be chosen in accordance with the principles shown in Figures 2, 3 or 4, bearing in mind whether the intention is to load dynamically the leads and/or the body or to determine the internal robustness.

When the specimen is to be tested with additional leads attached, these shall be so arranged that they impose similar restraint and mass to those when the specimen is used in its normal manner.

In all cases, components shall be fastened to a rigid test fixture or directly to the mounting surface of the test apparatus. The most common failure mode for electronic components as shown in Figures 1, 2 and 3 is not failure of the component itself but of the solder connection due to flexure of the printed circuit board. Testing of the complete printed circuit board is essential.

NOTE A "rigid test fixture" is one where there are no resonances within the test range or where the requirements of the test tolerances can be met at all fixing points.

6 Mounting, where the specimen is equipment and other articles

The specimen shall be mechanically connected to the mounting surface of the test apparatus either directly or by means of a rigid test fixture (see note above), as shown in Figure 5, or as stated in the relevant specification.

NOTE In the case of acoustically induced vibration, the mounting technique is quite different and reference should be made to IEC 60068-2-65.

In cases where the normal mounting structure for the equipment is available, the relevant specification shall state if it shall be used (see also Clause A.2).

Any additional stays or straps shall be avoided. Any connections to the specimen such as cables, pipes, etc. shall be so arranged that they impose similar restraint and mass to those when the specimen is installed in its operational position. In order to achieve this, it may be necessary to fasten the cables, pipes, etc., to the fixture.

The relevant specification shall specify the size, mounting torque and associated tolerance of the fixing bolts.

Specimens intended for use with isolators shall normally be tested with their isolators. If it is not practicable to carry out the test with the appropriate isolators, the specimen may be tested without the isolators at a different severity, as stated in the relevant specification.

The relevant specification may require an additional test on a specimen with the external isolators removed or blocked, in order to demonstrate that minimum acceptable structural resistance has been achieved. In this case, the severity to be applied shall be given in the relevant specification.

Where, operationally, any heating effect on the isolators is likely to be of significance, this shall be taken into account during testing.

7 Mounting, where the specimen is a packaged product

All the relevant requirements in Clauses 5 and 6 above shall be met.

Generally, in order to reproduce the effects of the transportation phase, a product, if normally packaged for that phase, shall be tested in its packaging. However, there are a number of situations to consider, as follows:

7.1 Packaging available (see also Clause B.2)

Unless otherwise stated in the relevant specification, the packaging, if available, shall be used during the testing.

If the method of fastening the packaged product to a transportation vehicle is known, that method shall, where practicable, be replicated and details of this shall be specified in the relevant specification and stated in the test report.

The relevant specification shall specify the size, mounting torque and associated tolerance of the fixing bolts.

If the specimen is capable of being fastened to a transportation vehicle in a number of known ways then, from engineering knowledge of the dynamic behaviour of the product, the worst case(s) shall be selected so that faults are most likely to be revealed.

Where the specimen is fastened to a transportation vehicle but the method varies in an unpredictable way, it shall be mechanically connected to the test apparatus as detailed in the relevant specification. This may be in a manner which only engineering judgement can decide and shall be based upon faults considered most likely to be revealed.

If the specimen is intended, or is likely, to be carried in a transportation vehicle without being fastened down, or with some degree of freedom, it shall be tested in accordance with IEC 60068-2-55. See also B.4.3.

If the packaged product is intended to be fastened to a transportation vehicle but it is considered likely that, in practice, it might not be fastened down, the relevant specification may require the test method stated in the previous paragraph to be applied. This may be in addition to the appropriate test where the product is fastened down.

7.2 Product normally packaged but packaging not available (see also Clause B.3)

If a product is normally packaged but the packaging is not available, it is generally not possible to mount the product on the test apparatus in a truly representative manner and the test becomes one of an empirical nature. However, it is possible to adjust the test severity in order to allow for an element of the protection provided when the packaging is otherwise present. Great care is needed in interpreting the results in this case and such a test should be considered as a development test, not an approval test. It is strongly recommended to test again with the specimen in the packaging.

Two situations exist; firstly, where the packaging performance is known and secondly, where it is not known. These are dealt with separately below.

7.2.1 Packaging performance known

If the packaging performance is known, or can be calculated, this will often enable the applied severity to be modified. Knowledge of the transfer function or transmissibility of the packaging provides the ability to adjust the vibration or shock test levels, see also Annex C.

Where the design of the packaging defines its attitude during transportation, then the attitude of the internal product is also known. It shall be fastened to the mounting surface of the test apparatus in a manner representative of that attitude. Unless otherwise stated by the relevant specification, the modified severity shall be applied (see previous paragraph).

Where the attitude of the package during transportation is variable and hence the attitude of the product can vary, the test shall be conducted in the attitude considered to represent the worst case(s). If engineering judgement does not enable this choice to be made, a number of possible worst case attitudes shall be stated in the relevant specification. Unless otherwise stated in the relevant specification, the modified test severity (see above) shall be applied.

Although the packaging performance may be known and the package is, or might be, carried in an unfastened manner in a transportation vehicle, the absence of the packaging prevents a practicable test from being performed. See Clause B.3 and B.4.3.

7.2.2 Packaging performance not known

Where the packaging is not available and its performance is not known, generalized transmissibility curves are provided in Figure B.1 for use in modifying the applied vibration test severity. The relevant specification should state which transmissibility curve shall be used. Annex C provides a method for adjusting the half-sine shock severity.

8 Information to be given in the relevant specification

When this part of IEC 60068-2 is referred to in a relevant specification, the following details shall be given as far as they are applicable.

a) Mounting and attitude for testing, gravitational effect (Clause 4)
b) Maximum or minimum temperature (Clause 4)
c) Maximum magnetic interference (Clause 4)
d) Maximum or minimum relative humidity (Clause 4)
e) Mounting of specimens (components) (Clause 5)

f) Mounting of specimens (equipment and other articles) (Clause 6)

g) Mounting of package (stacking)

h) Transmissibility curve used to modify test severity (Clause 7)

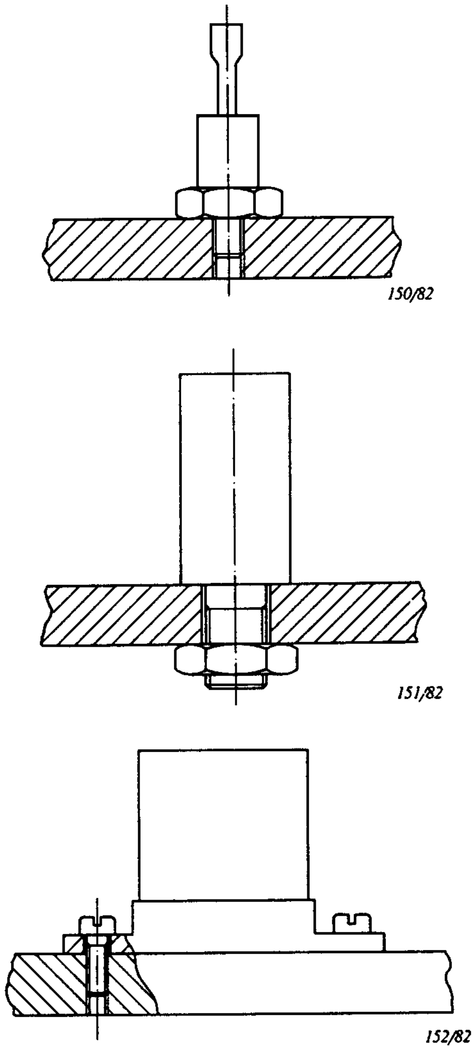
Methods of mounting	**Examples**
	Components provided with obvious means of mounting, for example diodes, electrolytic capacitors, rectifiers, switches, connectors, relays, transformers, power transistors

Figure 1 – Examples of obvious means of mounting components

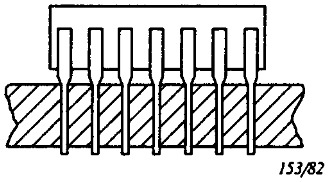
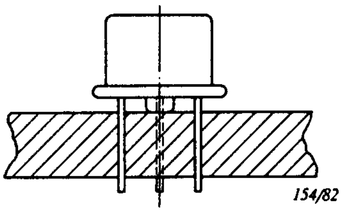
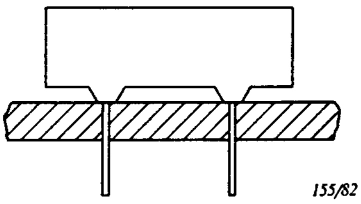
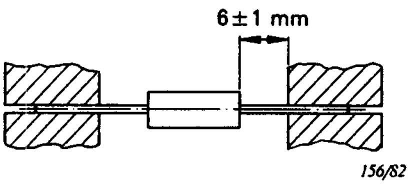
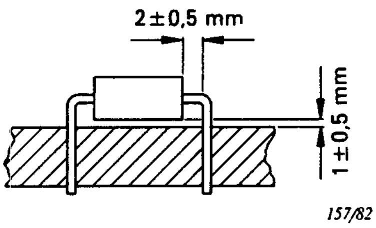
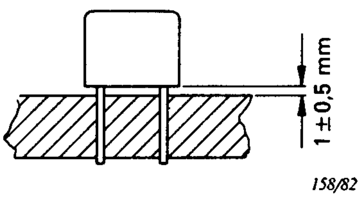
Methods of mounting	Examples
 	Components such as transistors, integrated circuits, relays and others where the distance to the fixture is limited by design
	Resistors, capacitors
	Resistors, capacitors, inductors, diodes
 	Resistors, capacitors, inductors, diodes, transistors NOTE It is important that the relevant specification states whether or not the component is in contact with the mounting surface.

Figure 2 – Examples of mounting of components by the leads only

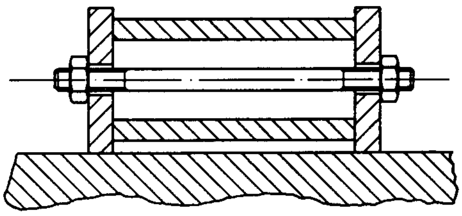
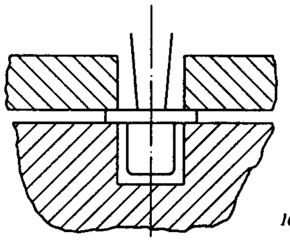
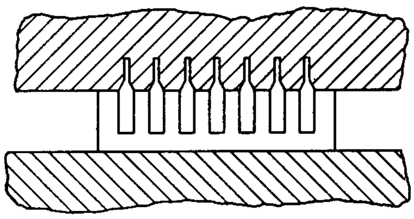
Methods of mounting	Examples
 159/82	Tubular components, the coating of which is fragile, such as high-power resistors
 160/82	Transistors, diodes
 161/82	Integrated circuits

Figure 3 – Examples of mounting of components by the body only

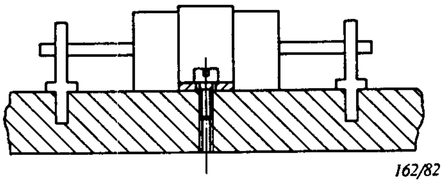
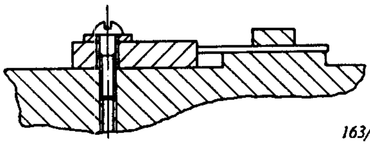
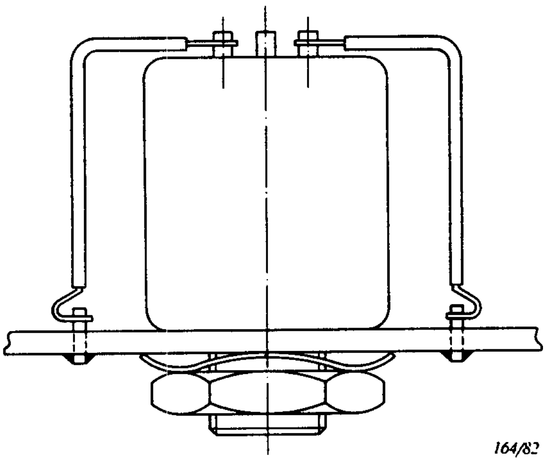
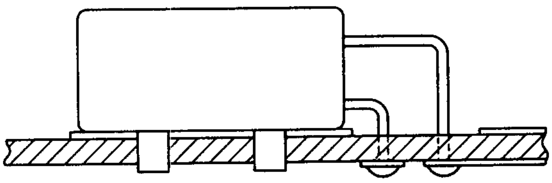
Methods of mounting	Examples
 162/82	Capacitors, relays. Additional body fastening, for example with extra bracket, necessary by reason of weight or severity
 163/82	Transistors mounted on a heat-sink
 164/82	Transformers, chokes
 165/82	Relays

Figure 4 – Examples of mounting of components by the body and the leads

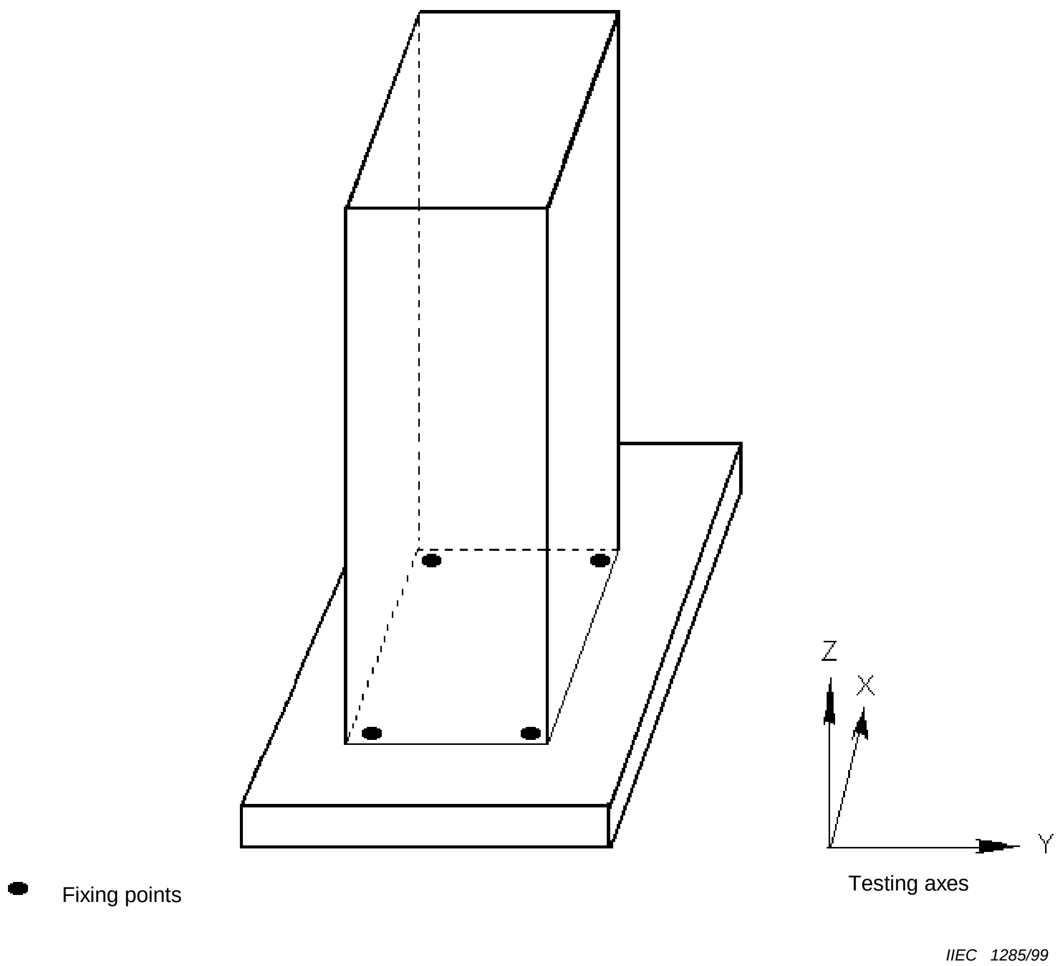


Figure 5 – Examples of mounting of electronic cabinets

Annex A
(informative)

General guidance

A.1 Mounting, where the specimen is a component

When the test is to determine the suitability of a component for its operational environment, the relevant specification should ensure that the component is held in a manner that simulates that used in service. It cannot be emphasized too strongly that components above a certain mass, which should be given in the relevant specification, will also require the body to be supported both for the test and for the operational environment.

It is important that the method of mounting is in accordance with the requirements of the manufacturer. The detailed information given in Figures 1 to 4 should be used only when such requirements are not available.

Some components having special geometrical shapes, for instance discs, spheres, bulbs, and those requiring special fastening devices are not shown in the figures. For these, it is essential that the relevant specification gives detailed information.

If a specimen is designed for a number of methods of mounting, all of these should be considered. It is recommended that new components should be used for each test.

Whichever method is specified or chosen it is important that the fastening to the test fixture or apparatus be rigid. This can be achieved by clamping, soldering, embedding or bonding the component body and/or its leads, as appropriate. A normal size printed wiring board to which components are fastened does not, generally, give sufficient rigidity, and it may not be possible to achieve the requirements of the test in this manner. In addition, reproducibility will probably be impaired. Small portions of a board may prove to be satisfactory, provided that attention is paid to their dynamic characteristics.

When an internal robustness test is to be performed, it is important to note that the mounting method is rarely that which will be used in the operational environment. It is then essential that the dynamic stress be transmitted to the internal structure. This is generally obtained by mounting the component both by its body and by its leads.

Should it be necessary to subject a component to a ‘robustness of terminations test’ (see IEC 60068-2-21), after the dynamic tests, the leads should not be bent for the dynamic tests, nor should they be displaced relative to the body of the components. If, however, this cannot be avoided, the relevant specification should specify that separate components are to be used for each test.

In addition, it may be necessary for the velocity of sound in the fixture material to be considered. Care should be taken to ensure, as far as is practicable, that the propagation path is well below a quarter wavelength. Test fixtures for large components or for the simultaneous testing of several components will need special consideration and the general principles given for equipment fixtures are applicable (see Clause A.3).

For guidance related to packaged products, see Annex B.

A.2 Mounting, where the specimen is equipment and other articles

It is important that the specimen is mounted in a manner representative of that used in its operational position. For example, a specimen normally held by its front panel alone should be so mounted for the test (see Figure 5).

If it is practical to use part of the real mounting structure as the fixture, it should be utilized as this represents operational conditions. The fixing points are then taken as those of the mounting structure and not of the specimen. The relevant specification should state whether to use the mounting structure and which fixing points to use as control points for controlling the test.

If the normal mounting structure is not available or, in special cases even when it is available but where it is known that it does not influence the behaviour of the equipment, the test fixture, designed so that the appropriate test requirements can be met, should be used.

Specimens intended for use with isolators may sometimes have to be tested without them, for example if the specimen is mounted with others on a common mounting system, or if the dynamic characteristics of the isolators are very variable (for example if they are temperature dependent). As a result, the test level will then need to be modified. For vibration testing, this new level should be determined by considering the envelope of the transmissibility curve of the isolator system in each axis. Where the severity is known to vary with the direction of the applied test/excitation, this should be taken into account.

If no transmissibility characteristics are available, the new severity will need to be chosen arbitrarily but preferably after discussion between the supplier and the purchaser.

NOTE In the case of the sinusoidal vibration test (see IEC 60068-2-6), some general transmissibility curves are given in A.5.1 of Annex A of that standard. These general curves may also be appropriate for other IEC 60068-2 vibration tests.

It should be noted that, for a steady-state acceleration test, there may, under certain circumstances, be a safety hazard if the specimen is tested with its isolators. The use of stays or straps may then be unavoidable. It is particularly important for this test that the stresses to be experienced by the attachment bolts be calculated in order to avoid a safety hazard.

For guidance related to packaged products see Annex B.

A.3 Test fixture

A test fixture will invariably be required for mounting and for orientation purposes. Therefore, it is considered desirable to highlight possible problem areas associated with the fixture design that could prevent the achievement of the test requirements and thus affect reproducibility. However, it should be noted that it is not the function of this annex to offer solutions; these can usually be found in the technical literature.

The fundamental purpose of the test fixture is to transmit faithfully the mechanical stimulation from the test apparatus to the specimen, and to ensure that the specification requirements can be met at the fixing points of the specimen.

The physical shape and mass of the specimen, the severity of the test requirements and the capabilities of the test apparatus will govern the design of the test fixture. These last two parameters are dependent on the test under consideration. In addition, for the impact and steady-state acceleration tests, the design may be further complicated by the need to test in the "plus" and "minus" directions of each test axis.

Additionally some of the parameters, which need to be considered in the fixture design, are given in A.3.5 and in Clause A.4.

A.3.1 Shock and bump

The manufacturer will normally specify the total mass and maximum severity permitted for the test apparatus. For a given specimen mass, the design of the test fixture will generally be easier if the capability of the test apparatus is significantly greater than that strictly necessary, since the fixture can then be heavier and less complex.

It is still important to consider the effect of stiffness and dimensions (see A.3.5).

A.3.2 Vibration

The main parameter limiting the total mass of the specimen and its test fixture is the thrust capability of the vibration generator. The manufacturer normally specifies this. In terms of severity, the most important features are the frequency range and displacement and/or acceleration required. However, in terms of the test apparatus performance, large thrust and a wide frequency range are normally incompatible. Thus, unlike the shock and bump situation, it may not be appropriate to use the largest vibration generator available. As a result, test fixtures are normally more complex than those required for other tests, and extensive experience is needed in order to achieve satisfactory results. Also, the frequency response may well be affected when the fixture and specimen are fastened to the vibration generator. It needs to be remembered that the dynamic mass may well be of greater significance than the static mass.

A.3.3 Vibration, acoustically induced

The type and design of test fixtures to mount specimens for vibration tests that are acoustically induced depend very much on the size and mass of the test specimens. In the simplest case of an electronic box to be tested in a reverberation chamber, the specimen should be elastically suspended so that it becomes located in the central area of the chamber.

The suspension device, such as rubber cords, should be attached to the fixing points of the electronic box. Larger test specimens such as reflectors or solar arrays should, wherever practicable, use the same fixing mechanisms as in the operational case.

Generally the test fixtures should be as transparent as possible, with respect to the acoustic environment. However, in special cases it may be desirable to simulate the shielding or reflecting conditions to which the specimen is subjected in its operational environment. Such cases include solar arrays for satellites that are often mounted on a satellite sidewall simulator for acoustic tests. Very large specimens, such as complete satellites, generally use their real payload attachment fitting as a test fixture.

In all cases, the total assembly should be isolated against vibration from the floor or ceiling of the reverberation chamber. The suspension frequency should be less than 25 Hz or 25 % of the lowest frequency of interest of the specimen.

A.3.4 Acceleration, steady-state

The fixture design is simplest for this case since the acceleration is applied progressively and the dynamic behaviour of the fixture and the specimen can be ignored. Thus the fixture need only be rigid enough to withstand the static forces involved and sufficiently versatile to accommodate the orientation of the specimen. It should be remembered, however, that normally a maximum force for the test apparatus would be specified by the manufacturer. It should not be overlooked that the ratio of specimen to centrifuge radius is important because of the acceleration gradient across the specimen.

Attention is drawn to the difficulties which may arise when testing components at very high values of acceleration, particularly those above 10 000 ms^{-2}.

A.3.5 Choice of material

When designing a test fixture, the choice of material will primarily be governed by mass and stiffness considerations. Some problems associated with mass limitations were dealt with above as appropriate to each type of test. Stiffness, which is only of significance where dynamic considerations are involved, can impose severe restrictions on the design of the fixture.

The stiffness of a material is a function of its physical properties. It therefore varies over the wide range of metals and plastics available for use. For any given material, the stiffness varies with the dimensions, its means of support (for example single or double encastre beams) and, to a lesser extent, the method of construction. Certain materials have more advantageous stiffness-to-mass ratios, and this enables a fixture to be stiffer for the same mass, which is usually desirable.

Another characteristic of a material is its internal damping, which is also a function of its fundamental properties. As an example, the internal damping of aluminium is approximately four times greater than that for steel. Damping has some influence, mainly on the behaviour of vibration fixtures.

The fundamental aim of the design of the test fixture is to permit no resonances to exist within the frequency range specified for the test. If this is impracticable, then the fidelity of the transmission of vibration from the test apparatus to the specimen is affected. The degree to which it is affected is directly related to the damping. It should be borne in mind that the internal damping of most common metals, whilst varying one to another, has a relatively small effect on the overall behaviour of the test fixture, but under certain circumstances it may need to be utilized.

A further feature that needs to be considered, particularly in the case of a shock test requiring a fast rise time or a vibration test with a high upper frequency, is the velocity of sound in the material to be chosen.

The distance along the propagation path between any fixture point and the vibration generator table should be, whenever possible, well below a quarter of the wavelength in the fixing material.

For calculating the wavelength λ it is necessary to take into account the vibratory mode associated with the lowest velocity of sound. Usually, it is the mode in the transverse direction.

Example: aluminium test fixture for use up to 2 000 Hz.

The approximate velocity of sound in aluminium is

v_1 = 5 100 ms^{-1} for the longitudinal wave,

v_2 = 3 200 ms^{-1} for the transverse wave.

The wavelength to be considered is therefore

$$\lambda = \frac{v_2}{f} = \frac{3\ 200}{2\ 000} = 1{,}6 \text{ m}$$

The maximum length, *l,* of the propagation path is consequently

$$l = \frac{\lambda}{4} = 0{,}4 \text{ m}$$

Test fixtures need not be made of the same material throughout. It may be necessary, for various reasons, for example, electrical or thermal insulation, or increased damping, to use fixtures made of a combination of materials such as metal and plastics, or even metal and ceramic.

A.4 General recommendations for fixture design

There are various methods of construction available. These include bolting, riveting, welding, casting, the use of adhesives and so on. The choice will depend on the difficulties anticipated in meeting the test requirements, the material used, etc. The test fixture should be as simple as possible; for example, a solid block is often all that is necessary. It should be noted that bolted structures will not normally achieve the stiffness obtained with the other forms of construction, and that a riveted structure would be worse than that of the use of a bolted structure. This factor becomes important when dealing with large structures and/or high frequencies.

For cheapness, ease of manufacture and due to its relatively high internal damping properties, aluminium alloy is often used.

All interfaces should be as square and flat as is necessary to achieve good mechanical contact, especially when conducting frequency tests above, e.g. 500 Hz. In addition, the maximum number of fixing holes on the mounting surface of the test apparatus should be utilized, consistent with the size of the fixture.

It is often advantageous to design a fixture which can be used a number of times for different specimens. If threaded holes are used and the material is such that undue wear might occur, the use of steel inserts is recommended. Care should be taken, however, that their fit is adequate and that no deterioration takes place. If bolts are used, they may need to be of the high-tensile type. It is good practice to remove material at the centre of a bolted connection to ensure that the contact surface is well defined and at a large radius (for high rotational stiffness) even if the mating surfaces are not completely flat.

It is important that, when fastening the specimen to the fixture, no deformation of either should occur. If it does, this probably indicates that the fixture is insufficiently stiff and might prevent the required test severity from being applied to the fixing points of the specimen. The stiffness of a fixture can be greatly reduced by insufficient pre-load in fasteners or bolt strength.

As far as is practicable, all bolts should be tightened to their maximum permitted torque. This value is determined by the weakest link in the system, for example, insert strength, compressive strength of fixture materials or bolt strength.

On fabricated fixtures joints should be welded. If possible, bolted or spot welded connections should be avoided. If this is not possible, the joint line should be filled with suitable adhesive. However, if damping is likely to be of real significance, it should be noted that the damping of a bolted or riveted structure is greater than that of one that has been welded.

Where it is difficult to build a fixture whose natural frequency is outside the vibration specification, as much damping as possible needs to be introduced into the design since, above the natural frequency of the fixture, the drop-off rate of transmissibility is significantly reduced. In addition, at the natural frequency, the damping reduces the speed of power decrease to maintain a constant acceleration level and, therefore, the control system and power amplifier responses reduce proportionally.

A.5 Balancing

Balancing is generally only a problem in the case of vibration and steady-state acceleration tests but may need to be considered for the shock and bump tests.

A.5.1 Vibration

In the case of vibration, it is necessary to ensure that the centre of gravity of the fixture, when loaded with the specimen, is always kept as low as possible, is nominally on a line which passes through the centre of gravity of the moving element of the vibration generator and is also perpendicular to the surface of the element. In some instances, it may not be possible to ensure that the centre of gravity of the fixture and specimen is in line with the thrust axis of the vibration generator. This can result in flexural modes, standing wave patterns due to the length of the propagation path, and rocking, all of which restrict the usable frequency range and prevent the test requirements being met at the fixing points of the specimen. Thus, it may be necessary to use counter-balancing techniques, although these should be avoided unless found to be essential. As the frequency increases, the specimen, and possibly the fixture, may resonate and, if so, will cause relative movement of the "dynamic centre of gravity" which will continue to move. This situation can be aggravated if counter-balancing techniques have been used and a position is created which currently has no practical solution. This effect can usually be tolerated, but, if not, it may be alleviated by the use of a larger or more powerful vibration generator, provided the test specification requirements can still be met.

Very often, slip-tables are used in conjunction with vibration generators, in particular where the specimen is sensitive to gravity and where complex test fixture design might otherwise be necessary. None the less, problems similar to those mentioned above may be encountered.

A.5.2 Acceleration, steady-state

For steady-state acceleration testing, a centrifuge is normally used, and it is essential to balance the fixture and specimen statically and dynamically in relation to the test apparatus, in order to prevent damage to its bearings. The centrifuge manufacturer will normally state the degree of unbalance permissible. It is preferable to keep the centre of gravity of the specimen in the same place for all test orientations in order to avoid re-balancing.

A.6 Positioning of accelerometers

The design of the test fixture should allow for the attachment of accelerometers at the positions required for the appropriate tests. Attachment can be made in a number of ways, usually recommended by the manufacturer of the accelerometer, and include screwing, the use of special adhesives, etc. It may, on occasion, be advantageous in the case of a vibration test, to allow for the attachment of additional accelerometers in order to explore the dynamic behaviour of the fixture, although this is not normally a requirement of the test specification (see also ISO 5348).

A.7 Performance check of test fixture

Before performing a vibration test, it may also be useful to check that the test requirements can be achieved at the specified points when the fixture is either unloaded, loaded with a dynamically representative specimen or loaded with the real specimen. In this latter case, it would usually be advisable to carry out the check at a lower vibration amplitude than that required subsequently.

It may be appropriate to carry out this check in the case of the other dynamic tests covered by this standard.

A.8 Large and/or complex specimens

The terms "large" and "complex" are difficult to define. A fixture designed for an item of equipment may be large for a test laboratory normally involved in testing components. This is not the case in this standard. "Large" is intended to describe a specimen/fixture combination which an equipment testing laboratory would normally have difficulty in handling and which, because of its mass, physical size, complexity of attachment or the frequency range specified, requires a solution which is currently beyond the engineering state of the art.

There are inevitably occasions when such a fixture is required, and it will be found that the test requirements cannot be fully met by conventional means, because the resonance behaviour of the fixture and the specimen is beyond control. After having explored other techniques, possibly including the use of parallel operation of vibration generators, reference will ultimately need to be made to the text of the test to ascertain what actions need to be taken. Usually the test procedure in such cases requires that the various parameter values achieved are noted and subsequently agreed between the purchaser and the supplier.

Annex B
(informative)

Guidance on packaged products

B.1 General

During the life-cycle sequence of events, from design to delivery and operation at a customer's premises, a product is subjected to many different environments of varying severity, depending on the particular phase of the life cycle. Where the product is destined for installation in a benign environment, such as a computer room, where the dynamic environmental conditions are of a low level, the transportation environment is often the most severe part of the product’s life. This may not be obvious to the specification writers or test engineers.

To reproduce the effects of the transportation phase of a product’s life cycle presents a number of difficulties. The packaging designed to protect the product during transportation may not be available. The methods by which the package may be fastened to the transportation vehicle are often unknown and may not be controllable. The means by which a package is fixed to the testing apparatus also presents problems. The rigidity of a packaging is usually low when compared to the product it contains and can often deform easily. Also, repeatability and reproducibility of test conditions are of major significance and the writing of specifications to achieve these two requirements is extremely difficult.

The purpose of this annex is to outline the problems and to offer suggestions and a consistent philosophy that can be adopted to overcome them. It should be appreciated that a high level of engineering judgement is required both by the specification writer and the test engineer. Consequently, more experienced individuals would best exercise such judgement in this area of dynamic environmental engineering.

Annex B should to be read in conjunction with Annex A.

B.2 Mounting – Packaging available

The rigidity of the outer container presents a fundamental problem for test methods that require the package to be fastened to the test apparatus. If the packaging is reasonably rigid, for example, made of metal or wood resulting in insignificant deformation of the mounting interface, then to fasten it to the test apparatus is not too difficult. This assumes that the method of carrying the package in the transportation vehicle is known and that this specified fastening method in the vehicle will be used in the test.

Where a reasonably rigid package can be fastened to the transportation vehicle in a number of known or unknown ways, the problem is one of choice and judgement. It is assumed that the structural behaviour of the product is known by the time a transportation dynamic test is conducted. This information should have been gained either by design and development tests, extrapolation from similar designs, or specific environmental tests performed to establish the protection needed from the packaging against the transportation environment. The absence of this data significantly reduces the subsequent confidence level and the judgement of an experienced environmental test engineer is required.

When there are a number of ways in which a package can be fastened, a selection of the most vulnerable ones needs to be made which is fundamentally dependent on the behaviour of the product (known or estimated). If this is not known and cannot be judged by a suitably qualified individual, the value of transportation dynamic testing becomes questionable.

The previous statements also apply in the case of a soft package; that is, one where the outer container is of a much lower rigidity than that of the product. In this case, where the outer container is of such low rigidity, say, paper based, the means by which the package is fastened to the test apparatus is of fundamental importance.

Again, as far as is practicable, this should attempt to simulate the means by which the package is fastened within the transportation vehicle providing the test method requirements can be met. Where straps are used, their material, placement and stressing should be similar to that used in practice. In addition, the strapping should keep the package-mounting surface in contact with the test apparatus at all times. It is important that bounce is not present unless a bounce test is being performed, and it may be necessary to use instrumentation in order to confirm this. The signal from the control transducer may be adequate or a transducer mounted on the package may be required, particularly where the mass of the specimen is high compared to the mass of the moving element of the test apparatus.

If the package bounces during testing and increasing the strap tension is likely to deform the packaging, it becomes virtually impossible to meet the requirements of an IEC 60068-2 dynamic test, particularly vibration. The situation may improve if either the upper frequency of a vibration test is reduced or the level is decreased until bouncing ceases. The degree to which this becomes necessary will influence the validity of the test and the information should to be recorded in the test report.

It may become necessary to investigate whether packaging deformation occurs in real life. If so, making the package more rigid may be the most practicable solution for both testing and real life cases.

A dynamically representative dummy product in a package may be used, particularly where the real product is delicate or expensive. This can be a useful method of exploring the performance of the packaging but should be considered, primarily, as a packaging development test.

Sometimes, a package, regardless of whether the outer container is soft or rigid, is carried loose within a vehicle. In such a case, and depending upon the severity of the vibration, that is specifically above or below $1g_n$, an additional bounce test may be necessary if stated in the relevant specification. See also B.4.3.

Where a package may be carried in a fastened or a loose manner, the relevant specification should state if tests are to be performed for both conditions, see 7.1. Knowledge of the dynamic behaviour of the product may enable a worst case to be predicted, for example, when fastened securely, vibration is likely to be the most severe dynamic environment. When loose, impacting may cause most damage. This knowledge may remove the need to perform both fastened and loose tests.

B.3 Mounting – Packaging not available

If the packaging is not available there are then several possibilities. Although not available, the performance of the packaging may be known or can be evaluated. The converse may also apply, that is, the performance of the packaging is not known and therefore cannot be evaluated. A third possibility may be the use of packaging not specifically designed for the product but extrapolated from similar designs. Great care is needed in interpreting the results in this case and such a test should be considered as a development test, not an approval test. It is strongly recommended to test again with the specimen in the packaging.

In the first two situations mentioned above, the product would need to be tested without its packaging. The way in which the package would be carried in the transportation vehicle still needs to be considered, as far as test axes and directions for the product test are concerned.

The method of fastening the product to the test apparatus is, of necessity, fundamentally different to the way in which it is fastened within the packaging. Therefore, the vibration or impact from the test apparatus should be transmitted to the product at the same point(s) as it would be transmitted by the packaging. Control of the test should be performed using these new input points. If the product merely rests on packaging material, then this will need to be taken into account, as far as is practicable, as should any other packaging and internal support or strengthening devices to which the product is in contact.

Where the packaging is not available, the test severities will require adjustment (see below).

If the packaging is not available and it is normally carried loose within the transportation vehicle, a meaningful test cannot be performed. Some experts believe that a bump test performed in accordance with IEC 60068-2-29 on a product rigidly mounted can be considered as equivalent, for similar velocity changes, to a bounce test (IEC 60068-2-55) on the same packaged product. More evidence is needed but, as a means of boosting confidence, it is often worthwhile performing such a test. A confirmatory test should be performed when all relevant hardware is available.

On occasions, although a product is intended, ultimately, to be packaged, the original manufacturer does not know the packaging performance and insufficient information is available for it to be calculated. This is particularly the case where a product is being supplied to a second manufacturer, is built into a larger assembly which is itself packaged and transported. Under these circumstances, engineering judgement should be exercised. In the absence of better and more realistic information, generalized transmissibility curves are offered which may be used to modify the test severity (see Figure B.1). The relevant specification should state which of the transmissibility curves are appropriate. Transmissibility is the ratio of vibration levels, for example, in terms of displacement, velocity or acceleration amplitude, between the product response within the packaging and that of the input at the external surface(s) of the package, expressed in the same units and in the same direction of vibration. The methods of mounting are the same as those discussed above.

Figure B.1 gives four curves, each representing the transmissibility for a different stiffness of packaging material, the stiffer material producing the higher resonance frequency. An estimation needs to be made of which curve is the most appropriate. If using the sinusoidal vibration test method of IEC 60068-2-6 (Test Fc), the specified vibration level should be multiplied, for each frequency, by values taken from this curve.

Where the broad-band random vibration test method of IEC 60068-2-64 (Test Fh) is being used, having selected the appropriate transmissibility curve from Figure B.1, the specified acceleration spectral density level should be multiplied, for each frequency, by the square of the value taken from this curve.

For both the above conditions, the product of the values may lead to test levels which may be impossible to reproduce in some test laboratories. In this case, if stated in the relevant specification, it may necessary for the levels to be adjusted in such a way that the maximum possible values are achieved at all times throughout the frequency range. It is of the utmost importance that the actual values used are stated in the test report.

Annex C gives guidance in relation to the response of a single degree of freedom system to a half-sine shock pulse. If using the shock test method (Test Ea) or the bump tests (Test Eb), this enables an adjustment to be made to the test severity.

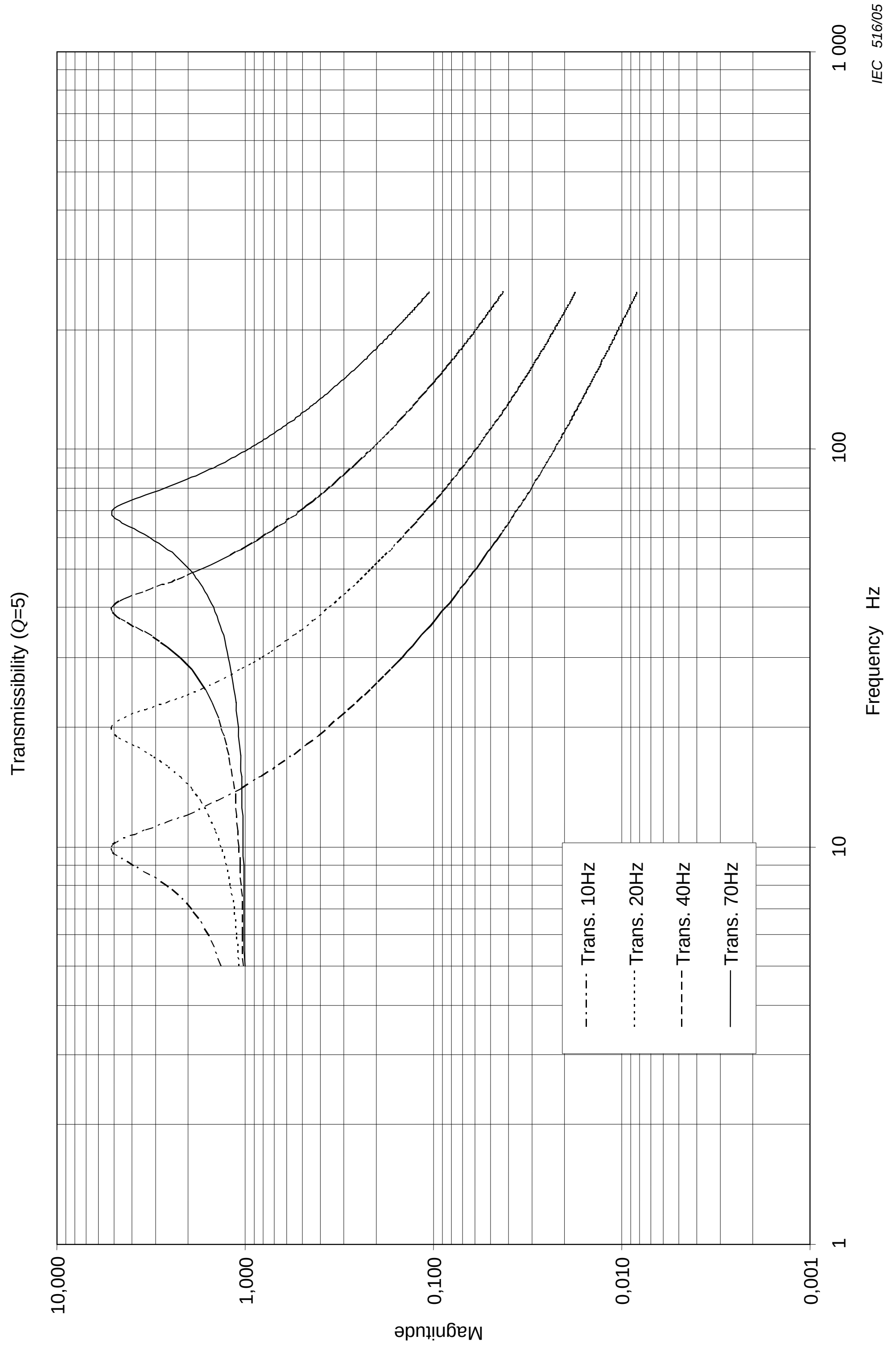


Figure B.1 – Generalized transmissibility factors for packaging materials

B.4 Dynamic conditions

B.4.1 Impact

The shock test (Test Ea) simulates the effects of non-repetitive shocks likely to be encountered by specimens during transportation or operation. Where the shock spectrum of the transportation environment is known, a selection of one of the three pulse shapes given in the shock test which most nearly conforms should be made. Where the shock response spectrum is not known, reference should be made to guidance within the shock test itself. However, in the case of packaged products, it is considered that the shocks encountered during handling and transportation are usually of a simple nature which makes it possible to use a half-sine pulse, often derived from the observed velocity change.

The mounting problems associated with a package needing to be subjected to a shock test are, essentially, the same as those for a vibration test, although there is the added difficulty that the test requires the application of the shock in two directions of each of three axes. The selection of directions of test and methods of fixing require the same engineering considerations as given earlier.

A factor which is more specific to shock than vibration is that concerning the mass of the specimen in relation to that of the moving element of the test apparatus. In the case of a shock test, with a highly reactive specimen, it may be necessary to limit the mass that can be tested in order that the tolerance requirements of the test can be met.

Where it is appropriate to carry out a shock test on a packaged product, but the packaging is not available, it is possible, based upon certain known or assumed parameters, to predict the response of a single degree of freedom system excited at its foundations by a shock pulse and to use this information to modify the applied shock test severity. A method of doing this is given in Annex C for a half-sine pulse.

The bump test (Test Eb) simulates the effects of repetitive shocks likely to be experienced during transportation or when installed. The transportation environment is frequently more severe than the operational environment and, for this reason, the test severity chosen may need to be related to the former.

The bump test is basically a robustness test conducted in order to give a measure of confidence in the ability of the specimen to survive transportation. As with the shock test, the bump test should always be performed with the package rigidly attached to the fixture or the table of the bump test machine. Whilst it has been known for bump tests to be performed on a package which is not fastened to the test apparatus, this is not the intention of the bump test and the more appropriate environmental test method to use for a situation where the package is carried loose, or with some degree of freedom, within the transportation vehicle, is that of the bounce test (Test Ec). See Clause B.3 and B.4.3.

The axes and directions chosen for the tests should be representative, as far as is practicable, of those in which the specimen will receive such impacts during transportation. Specimens which are always transported on their normal base need only be subjected to bump when mounted on that base, since bumps are, generally, most severe in a vertical direction relative to the road surface. If, during transportation, it is likely to be placed on more than one of its faces, each of the axes and directions defined in the relevant specification will need to be tested. However, bearing in mind the nature of the test, three mutually perpendicular directions would normally be adequate under those circumstances.

Since the bump test applies a half-sine pulse, Annex C could be used to allow for the absence of the packaging.

It should be noted that shock and bump tests on products in their packaging present difficulties. There will be a tendency for specimens to leave the surface of the test apparatus, or fixture, on impact, see also Clause B.2. In addition, the high frequency content of the impact pulse and the level of tolerancing and control specified in the IEC 60068-2 tests may make the requirements difficult to meet. Knowledge and experience will be needed and it is vital that the eventual conditions under which the tests are performed are recorded in the test report.

A revision of a number of other IEC 60068-2 impact tests can be foreseen in order to enable those tests to be used for products in their packaging.

B.4.2 Vibration

For a product destined to reside in a benign environment, the transportation vibration test simulates the effects of probably the most dominant dynamic environment encountered. When a product is large, expensive, delicate, rare or particularly when some combination of these features exists, the manufacturer will normally feel it necessary to specify strong packaging having unique mounting methods. Care will also be taken to ensure that, as far as it is in the manufacturer’s direct control, his specified transportation requirements and conditions are met. Under these circumstances, the situation is relatively straightforward and as long as the design of product and packaging is satisfactory for the environment, few problems should be encountered.

Much of the time, however, the manufacturer may have little control over the manner in which his package is actually fastened to the transportation vehicle and carried to its ultimate destination.

In order to limit the possibility of vibration failure during transportation, certain fundamental actions need to be taken by the manufacturer. He needs to be aware of the range and level of vibration that his product will encounter during its life. He will need to explore sources of reliable vibration data and, in certain circumstances, perform his own measurements. The design and development testing of the product should be carried out based on the best environmental information he can obtain, in order to establish that it can meet the requirements of such safety factors as may be appropriate. If it is considered that package protection is needed for the transportation vibration environment, this should be provided at an early stage. Subsequent testing of the product in its packaging is essential for greater confidence.

The specification writer, whether it be the manufacturer or the customer, needs to provide requirements data which should enable a cost-effective solution to be found for the ultimate product. The design/development team should have sufficient data and experience on which to base the design, making use, whenever practicable, of extrapolation techniques. The environmental test engineer, whose experience should be used from the early design stages, is normally responsible for proving the environmental performance of the product and of the product in its packaging.

As has been stated earlier, in practice the manufacturer may have little control over the conditions in which his packaged product is transported. Thus, the test engineer’s task to reproduce the effects of these conditions in order to establish whether or not the product can survive the transportation is a most difficult one, as is the production of a test specification for this purpose.

Ultimately, however, decisions have to be made. The vulnerable axes of the product should be known from the design/development tests. If such tests were limited or not carried out, then these axes will need to be a matter of judgement. Also, the method of fastening the package to the test apparatus, and the tensioning of straps or cables, are important factors that, too often, are unquantifiable in relation to the real transportation situation. However, when the inertial force of the specimen becomes greater than the restraining force, the specimen will bounce on the machine. Again, due to the size or mass of the specimen, and even the way in which it is attached to the test apparatus, it is often necessary, depending on the inertial forces present, to either limit the upper frequency of the test or reduce the test level in order to meet test method fixing point requirements.

These decisions, and others necessary for the testing phase, require experience together with a considerable amount of knowledge. In such circumstances, it is vital that the eventual conditions under which the tests are performed are recorded in the test report.

B.4.3 Bounce

The bounce test (Test Ee) is intended to simulate the random shock conditions experienced by packaged products that may be carried as loose cargo in wheeled vehicles travelling over irregular surfaces.

Such packages, carried by overland transport, can be subjected to severe and repetitive shock from impacting, rebounding and scuffing on the floor of the transportation vehicle or from colliding with the side walls of the vehicle or other cargo. Even when tied to the vehicle platform they may be subjected to similar impacts if the constraints allow freedom of movement.

The bounce test fulfils a similar function to the bump test but, since the specimen is not fastened to the test platform, it more closely simulates the stress resulting from impact to which it would be subjected when carried loose, or with some degree of freedom, in a transportation vehicle. The axes and directions of bounce chosen for the test should be representative of its attitudes during transportation. Packages, specifically transported on a dedicated base, need only be subjected to the bounce test when resting on that base. For a package that can be carried resting on more than one of its faces, testing should be carried out on each face prescribed by the relevant specification.

The effect of impacting on walls of the vehicle platform or other cargo, and the effect of stacking packages in a vehicle where there can be a significant difference between the environment experienced by the top and bottom layers, may also need to be considered.

The bounce test machine can be of two types with either a synchronous or a non-synchronous circular motion. In either case, the only variation achievable, in terms of severity, is to alter the duration of the test. This is not considered sufficient to modify the test in order to allow for the absence of the packaging and, therefore, the bounce test is only relevant for products in their packaging.

It should be noted that the applicability of the bounce test is currently limited to road transportation conditions.

Annex C
(informative)

Response of a single degree of freedom (SDOF) system to a half-sine shock pulse

C.1 General

In situations where the transportation impact environment needs to be simulated, but the packaging is not available and its performance is unknown, it is still possible to allow for this in a generalized way.

NOTE A specimen and packaging in combination may not respond as a simple single degree of freedom system. Therefore, caution should be exercised when employing this technique and it should not be used as a final qualification of the specimen. It is recommended that a final test be conducted with a specimen in its packaging.

C.2 Specimen response

To predict the shock response of a product within its packaging, the dynamic characteristics of the packaging may be assumed to be those of a single degree of freedom (SDOF) system. If such a system is excited by a half-sine shock pulse at its foundation, its computed response can be considered as that of the product. In order to compute the product's responses, four items of information are required, as follows:

1) amplitude of the applied half-sine shock pulse, as illustrated in Figure C.1;
2) duration τ (s) of the applied half-sine shock pulse, as illustrated in Figure C.1;
3) damped resonance frequency f_n (Hz) of the transmissibility characteristic, as illustrated in Figure C.2;
4) dynamic magnification (Q) of the transmissibility characteristic, as illustrated in Figure C.2

C.3 Peak amplitudes

Figure C.3 is used to establish the peak amplitude of the first half cycle of the response. Information from Figure C.4 can be used to determine whether the amplitude of subsequent half cycles, as defined in Figure C.5, are significant.

C.4 Calculation of initial peak amplitude

The procedure for establishing the peak amplitude of the first half cycle of the response using Figure C.3 is as follows:

(i) Compute the parameter ($\tau \times f_n$) that is the product of the half-sine pulse duration (s) and the SDOF resonance frequency (Hz).

(ii) From Figure C.3 obtain the appropriate peak acceleration response due to a unity amplitude pulse for the parameter ($\tau \times f_n$). The value obtained from Figure C.3 is for a Q value of 5. However, the value obtained from Figure C.3 will not, for practical purposes, be different for other values of Q, provided Q has a value greater than 2.

(iii) The required response amplitude is computed from the product of the value obtained from Figure C.3 (which is for unity amplitude) and the amplitude of the applied half-sine shock pulse. The units of the required response amplitude are the same as those of the applied half-sine shock pulse.

C.5 Secondary responses

A SDOF system, when excited with a half-sine shock pulse, will exhibit decaying responses following those of the first half cycle. Such secondary responses are illustrated in Figure C.5. Secondary responses are normally considered of little significance and are suppressed in the classical uni-directional pulse shock test. They can only be included if alternative test procedures, such as the time history test method, are adopted. Whether the half cycles occurring after the first half cycle are significant, will depend upon their amplitude and the sensitivity to them of the specimen under test. If the parameter ($\tau \times f_n$) is equal to or greater than 1,5, then secondary amplitudes are within the tolerance bands of the classical uni-directional pulse test and can generally be ignored. If the parameter ($\tau \times f_n$) is less than 1,5, the secondary responses may require consideration and their amplitude can be derived from Figure C.4. The value of the secondary peaks is sensitive to the value of Q, which is 5 in this case.

C.6 Pulse duration

If the parameter ($\tau \times f_n$) is less than 0,5, the duration of the first half cycle of the response is 1 /(2 f_n). If the parameter ($\tau \times f_n$) is greater than or equal to 0,5, the duration of the first half cycle of the response is τ, that is, the duration of the first positive half cycle which is also the duration of the excitation pulse, see also Figure C.3.

C.7 Worked example

Example: Assume the following:

Half-sine pulse amplitude = 10 g

Half-sine pulse duration = 10 ms, that is, 0,010 s

SDOF resonance frequency = 20 Hz

SDOF dynamic magnification = 5

Then, from Clause C.4 (i), the product value = 0,010 x 20 = 0,2

from C.4 (ii), the value obtained from Figure C.3 is, say, 0,70

from C.4 (iii), the actual response amplitude = 0,70 x 10 g = 7,0 g

from C.6, the duration is 1 / (2 x 20) = 25 ms, that is, 0,025 s

Thus, the 10 g, 10 ms pulse, has become a 7 g, 25 ms pulse (approximately).

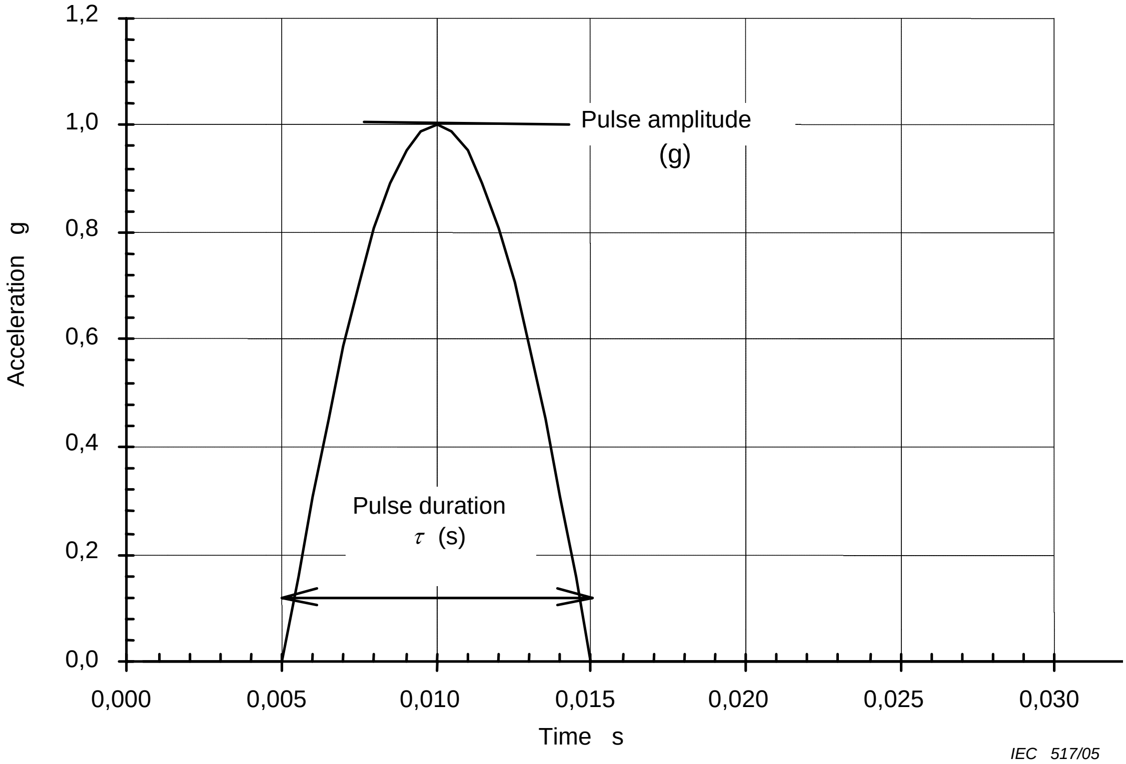


Figure C.1 – Typical characteristics of half sine pulse

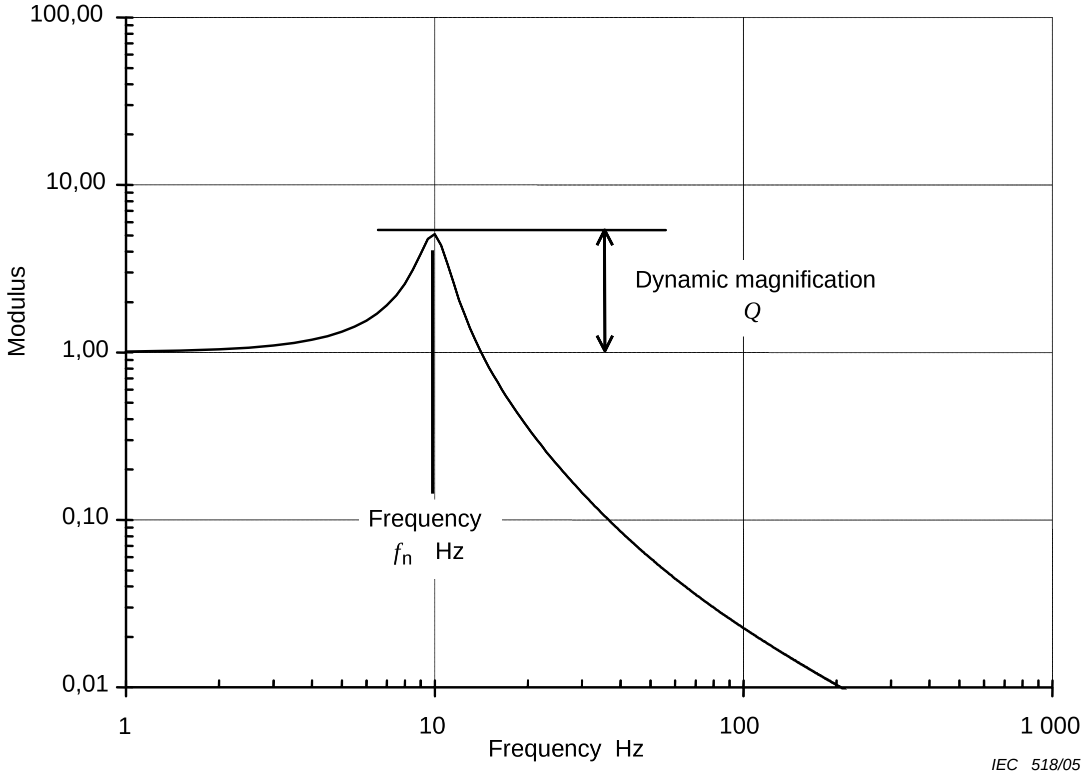


Figure C.2 – Typical single degree of freedom (SDOF) transmissibility characteristics

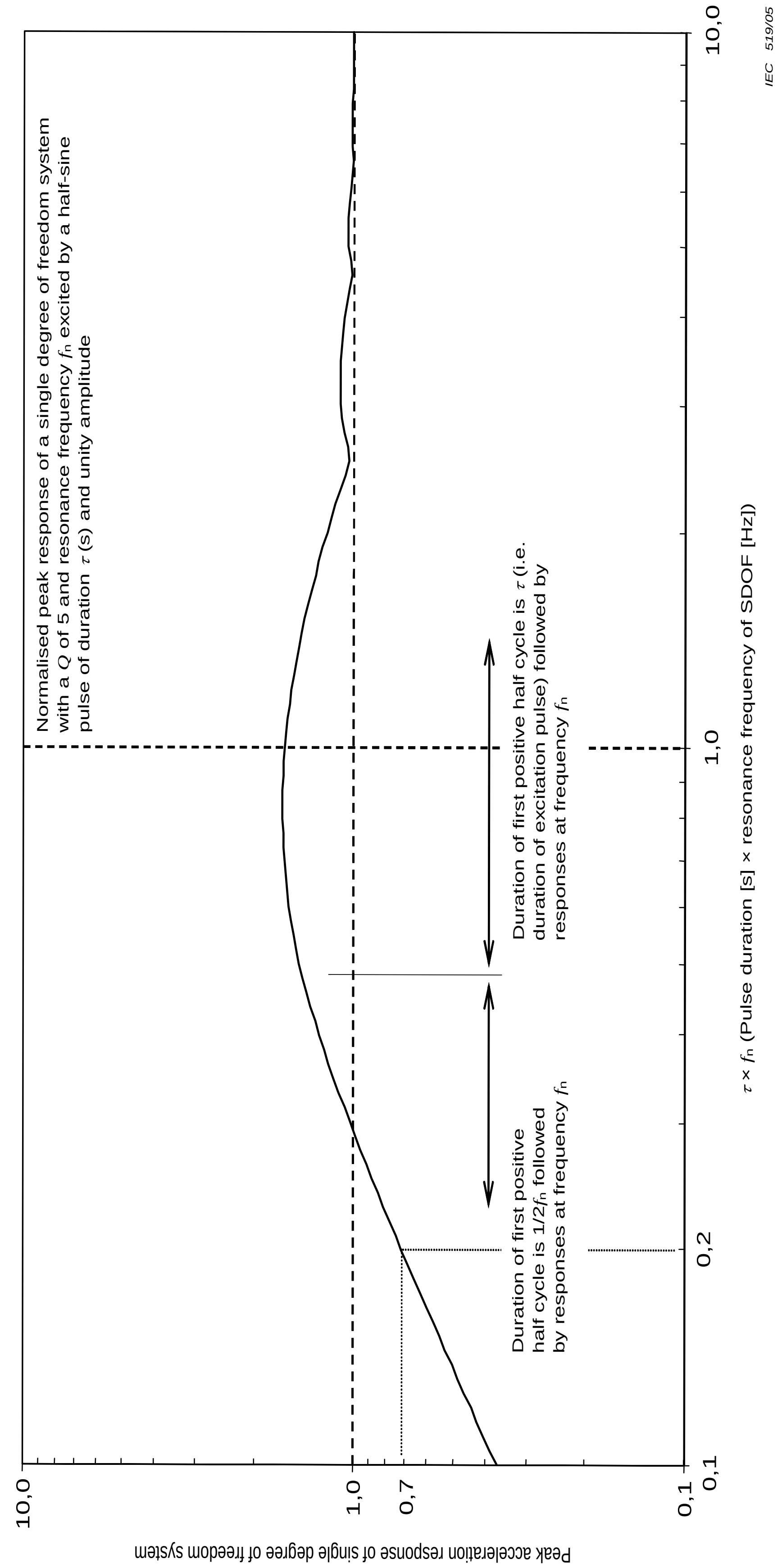


Figure C.3 – Peak Acceleration Responses SRS

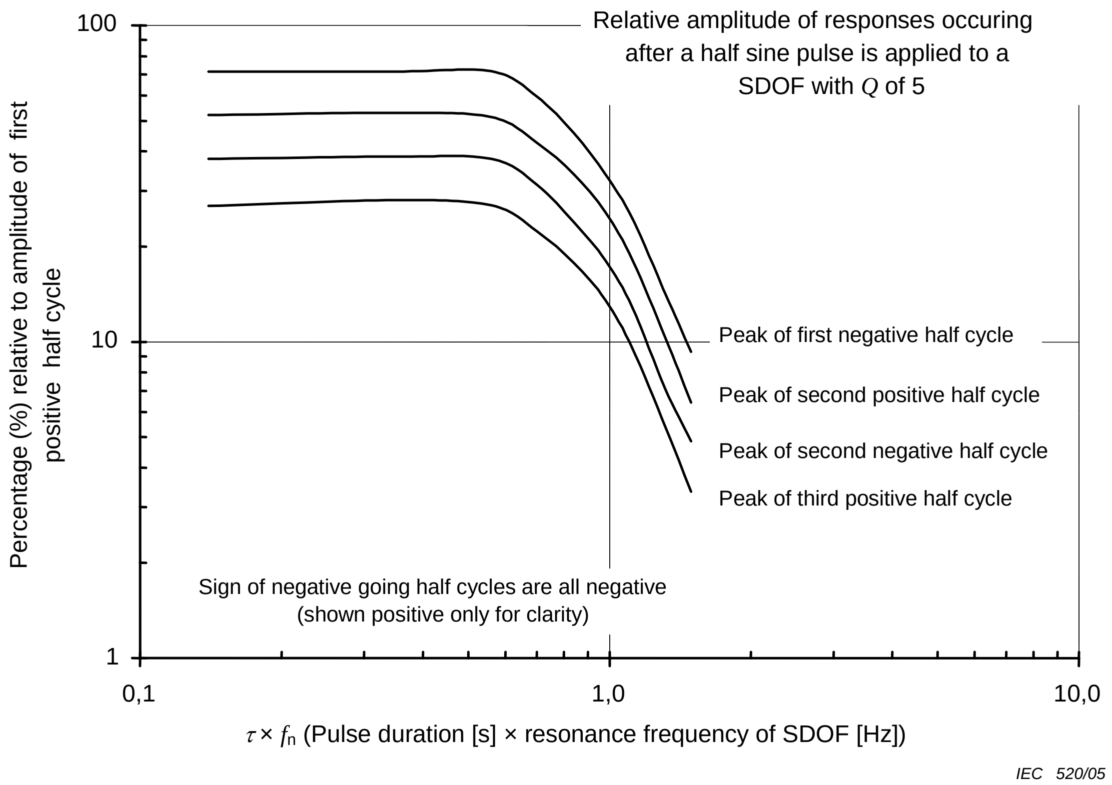


Figure C.4 – Relative Amplitude of Secondary Response Peaks

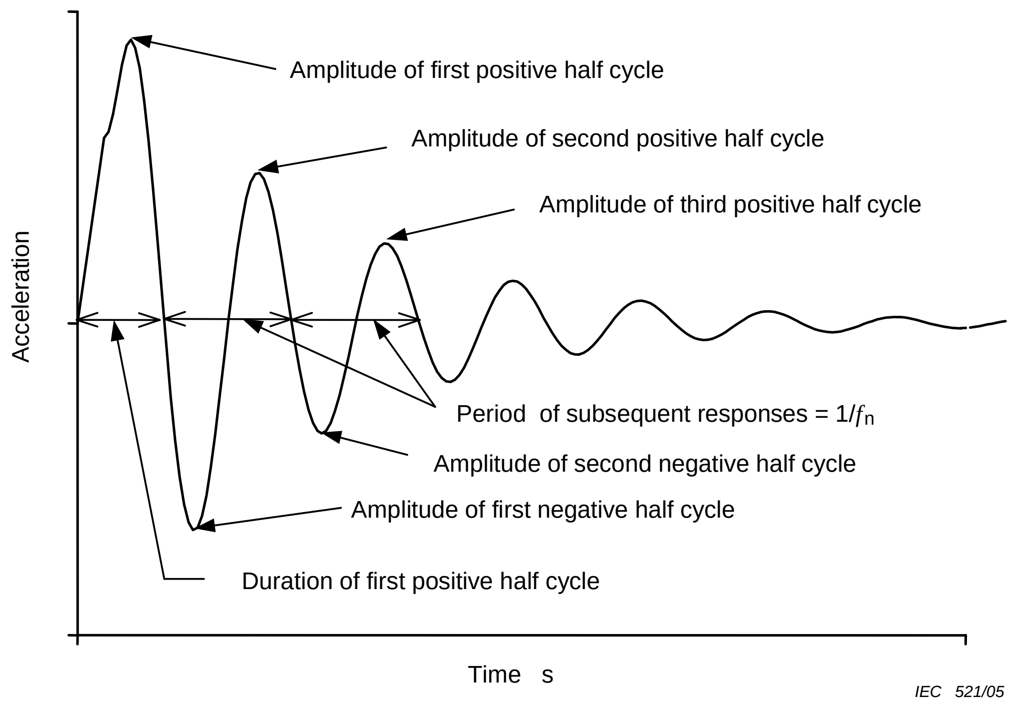


Figure C.5 – Notation of Response Characteristics

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE Where an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60068-1	1988	Environmental testing Part 1: General and guidance	EN 60068-1 [1)]	1994
IEC 60068-2-55	1987	Part 2: Tests - Test Ee and guidance: Bounce	EN 60068-2-55	1993
ISO 2041	1990	Vibration and shock - Vocabulary	-	-

[1)] EN 60068-1 includes corrigendum October 1988 + A1:1992 to IEC 60068-1.

Bibliography

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

IEC 60068-2-7:1983, *Environmental testing – Part 2-7: Tests – Test Ga and guidance: Acceleration, steady state*

IEC 60068-2-21:1999, *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-27:1987, *Environmental testing – Part 2-7: Tests – Test Ea and guidance: Shock*

IEC 60068-2-29:1987, *Environmental testing – Part 2-29: Tests – Test Eb and guidance: Bump*

IEC 60068-2-31:1969, *Environmental testing – Part 2-31: Tests – Test Ec: Drop and topple, primarily for equipment-type specimens*

IEC 60068-2-32:1975, *Environmental testing – Part 2-32: Tests – Test Ed: Free fall*

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

IEC 60068-2-59:1990, *Environmental testing – Part 2-57: Tests – Test Fe: Vibration – Sine-beat method*

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

IEC 60068-2-65:1993, *Environmental testing – Part 2-65: Tests – Test Fg: Vibration*, *acoustically induced*

IEC 60068-2-75:1997, *Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests*

IEC 60068-2-81:2003, *Environmental testing – Part 2-81: Tests – Test Ei: Shock – Shock response spectrum synthesis*

ISO 5348:1998, *Mechanical vibration and shock – Mechanical mounting of accelerometers*

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: +44 (0)20 8996 9000. Fax: +44 (0)20 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: +44 (0)20 8996 9001. Fax: +44 (0)20 8996 7001. Email: orders@bsi-global.com. Standards are also available from the BSI website at http://www.bsi-global.com.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre. Tel: +44 (0)20 8996 7111. Fax: +44 (0)20 8996 7048. Email: info@bsi-global.com.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: +44 (0)20 8996 7002. Fax: +44 (0)20 8996 7001. Email: membership@bsi-global.com.

Information regarding online access to British Standards via British Standards Online can be found at http://www.bsi-global.com/bsonline.

Further information about BSI is available on the BSI website at http://www.bsi-global.com.

Copyright

BSI
389 Chiswick High Road
London
W4 4AL