BS EN 60749-40:2011

BSI Standards Publication

Semiconductor devices — Mechanical and climatic test methods

Part 40: Board level drop test method using a strain gauge

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The UK participation in its preparation was entrusted to Technical Committee EPL/47, Semiconductors.

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

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ISBN 978 0 580 64629 4

ICS 31.080.01

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2011.

Amendments issued since publication

Amd. No.	Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 60749-40

September 2011

ICS 31.080.01

English version

Semiconductor devices - Mechanical and climatic test methods - Part 40: Board level drop test method using a strain gauge (IEC 60749-40:2011)

Dispositifs à semiconducteurs -
Méthodes d'essais mécaniques et climatiques -
Partie 40: Méthode d'essai de chute au niveau de la carte avec utilisation d'une jauge de contrainte
(CEI 60749-40:2011)

Halbleiterbauelemente -
Mechanische und klimatische Prüfverfahren -
Teil 40: Prüfverfahren zum Fall einer Leiterplatte unter Verwendung von Dehnungsmessstreifen
(IEC 60749-40:2011)

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

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Foreword

The text of document 47/2094/FDIS, future edition 1 of IEC 60749-40, prepared by IEC TC 47, Semiconductor devices, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60749-40 on 2011-08-17.

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– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2012-05-17
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2014-08-17

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60749-40:2011 was approved by CENELEC as a European Standard without any modification.

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

Publication	Year	Title	EN/HD	Year
IEC 60749-37	-	Semiconductor devices - Mechanical and climatic test methods - Part 37: Board level drop test method using an accelerometer	EN 60749-37	-

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SEMICONDUCTOR DEVICES – MECHANICAL AND CLIMATIC TEST METHODS –

Part 40: Board level drop test method using a strain gauge

1 Scope

This part of IEC 60749 is intended to evaluate and compare drop performance of a surface mount semiconductor device for handheld electronic product applications in an accelerated test environment, where excessive flexure of a circuit board causes product failure. The purpose is to standardize test methodology to provide a reproducible assessment of the drop test performance of a surface mounted semiconductor devices while duplicating the failure modes normally observed during product level test.

This international standard uses a strain gauge to measure the strain and strain rate of a board in the vicinity of a component. Test method IEC 60749-37 uses an accelerometer to measure the mechanical shock duration and magnitude applied which is proportional to the stress on a given component mounted on a standard board. The detailed specification shall state which test method is to be used.

NOTE 1 Although this test can evaluate a structure where the mounting method and its conditions, the design of a printed wired board, solder material, the mounting capability of a semiconductor device, etc. are combined, it does not solely evaluate the mounting capability of a semiconductor device.

NOTE 2 The result of this test is strongly influenced by the differences between soldering conditions, the design of the land pattern of a printed wired board, solder material, etc. Therefore, in carrying out this test, it is necessary to recognize that this test cannot intrinsically guarantee the reliability of the solder joint of the semiconductor devices.

NOTE 3 When the mechanical stress which is generated by this test does not occur in the actual application of the device, implementation of this test is unnecessary.

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 60749-37, *Semiconductor devices – Mechanical and climatic test methods – Part 37: Board level drop test method using an accelerometer*

3 Terms and definitions

For purposes of this document, the following terms and definitions apply.

3.1
device
single electronic component to be surface mounted

3.2
drop impact strength
strength of the test substrate held by a jig that is dropped from a defined height, as represented by the number of cyclic drops that finally cause fracture on the joint between a device and a PWB copper land

3.3
strain
strain of surface of substrate
degree of stretching observed when the test substrate is distorted

NOTE The strain is a numeric dimensionless quantity.

3.4
maximum strain
tensile side (+) of the strain waveform

3.5
pulse duration
duration between the instant when the acceleration first reaches 10 % of its specified peak level and the instant when the acceleration first returns to 10 % of the specified peak level after having reached that peak level

3.6
momentary interruption detector
equipment which detects extremely short electrical discontinuity (momentary interruptions) in a daisy-chain circuit

4 Test equipment

The equipment shall be selected to satisfy the test conditions specified in Clause 6. Alternatively, the test method described in Annex A can be used.

5 Test procedure

5.1 Test specimen

Unless otherwise specified, specimen devices shall be of a structure that allows continuity to be checked (e.g., daisy chain). They shall be of a design based on the same specifications as devices in actual use.

The test specimens shall be on a daisy-chained substrate on the lead frame of a surface mounted device or on a substrate that is a carrier of a BGA, LGA, or SON, or the actual device shall be used.

NOTE When using daisy-chain connections, care should be taken not to cause any failure in wiring patterns on the test substrate. For example, the wiring patterns should be drawn in a crosswise direction on the test substrate, not in a longitudinal direction.

5.2 Test substrate

The test substrate shall be prepared in accordance with the relevant specification, preferably using a substrate of the same structures an actual electrical device.

Unless otherwise specified, a solder mask defined (SMD) land is desirable for a BGA and a non solder mask defined (NSMD) land for a QFP. For a BGA, it is desirable to match the land size of the test substrate with the land size of the package.

5.3 Solder paste

The solder paste shall be prepared in accordance with the relevant specification.

5.4 Mounting method

The mounting method shall prepared in accordance with the relevant specification. However, one test specimen shall be mounted in the centre of the test substrate.

5.5 Pre-conditionings

When specified in the relevant specification, carry out moisture soaking and soldering heat stress testing before the board level drop test.

5.6 Initial measurements

The initial measurement shall be carried out in accordance with the relevant specification.

5.7 Intermediate measurement

Intermediate measurement shall be carried out in accordance with the relevant specification.

NOTE When determining failure after a drop test, a failure can wrongly be considered as acceptable because of electrical contact of a disconnect. Therefore, when determining failure, checking the daisy-chain signal lines with a momentary interruption detector or other similar equipment is advised. When using this technique, the resolution of the momentary interruption detector shall be capable of detecting 100μs of momentary discontinuity.

5.8 Final measurement

The final measurement shall be carried in accordance with the relevant specification.

A sufficient number of failures from the test lot shall be subjected to failure analysis to determine the root cause and to identify the failure mechanism. Each failure site shall be clearly identified as “device failure”, “interconnect failure”, or “board failure”.

6 Test method

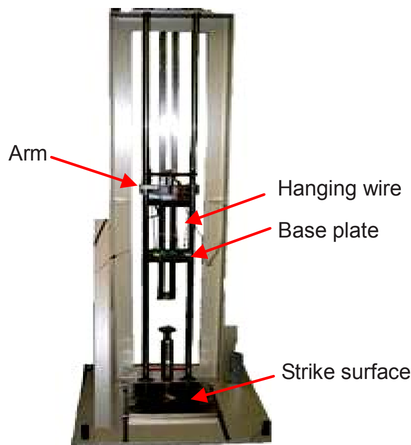
6.1 Purpose of test method

This test method specifies the drop test conducted with the fall height based on measured strain using a strain gauge set on the test substrate.

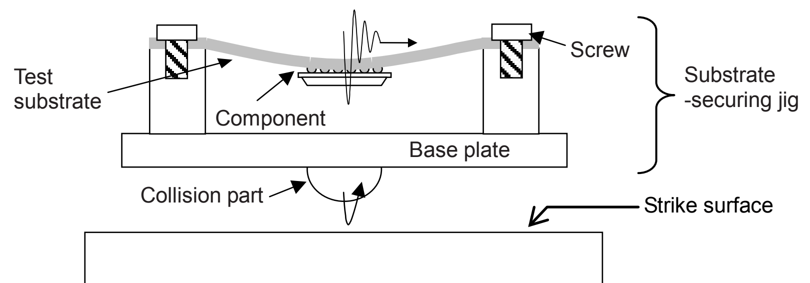
NOTE This test method uses drop test equipment, a substrate-securing jig and a strain measurement instrument. Because the test equipment is verified using the value of strain measured by a strain gauge attached to the surface of the test substrate, the test result does not depend on the drop test equipment or the substrate-securing jig. Accordingly, this standard does not prescribe the drop test equipment, the structure of the jig, or its form Correlation of a test result with the device and equipment type is straightforward since the test results are quantified in terms of the strain values. However, details of the device and equipment should be recorded.

6.2 Example of drop test equipment

The drop test equipment is designed to drop a substrate-securing jig with a protrusion on its base, from a specified height onto a collision plane to apply the impact that would result from a free fall or similar situation (Figure 1).



Example of test equipment



Example of substrate securing jig

IEC 1619/11

Figure 1 – Example of drop test equipment and substrate securing jig

6.3 Example of substrate-securing jig

Unless otherwise specified, the substrate-securing jig shall be constructed to allow the attachment of the test substrate with screws, and give a drop impact to the solder joints. The test substrate is fixed so that the device is in the centre of the substrate-securing jig. Unless otherwise specified, the colliding interface shall be a hemispherical protrusion as shown in Figure 1 in order to obtain the reproducibility of strain. However, this is not mandatory if appropriate repeatability can be obtained by another method.

6.4 Example of distance between supporting points

The distance between the supporting points shall be in accordance with the relevant specification. The recommended distance between supporting points is 50 mm to 80 mm for a mobile phone (see 6.9.4).

6.5 Example of impacting surface

Unless otherwise specified, the drop test shall be performed on a flat concrete or steel plate floor.

NOTE Since destruction of the concrete or deformation of the steel plate might be caused by repetitive impacts, it is desirable to check the surface of floor at each test. When a steel plate floor is used, hardened-steel plate is recommended in order to prevent deformation due to impact.

6.6 Strain gauge

Unless otherwise specified, the strain gauge shall satisfy following:

a) the gauge length shall be from 1 mm to 2 mm.

b) the strain gauge shall be a foil-type gauge.

c) the strain gauge shall be of a single-axis type.

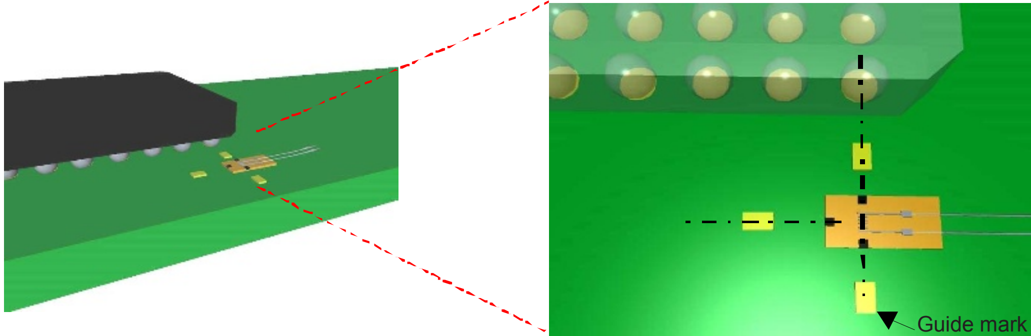
6.7 Strain gauge attachment

Attach the strain gauge to the test substrate as shown in Figure 2. The strain gauge is attached to the extension of a corner land central line in the vicinity of the device, taking care not to stick the gauge on the substrate wiring.

NOTE 1 If attachment is difficult, the substrate can be made smooth with the emery paper etc. It is better to apply adhesives thinly so that cracking and peeling of the interfaces do not occur in during the drop test.

NOTE 2 Test results can differ depending upon the strain gauge attachment method. Refer to Annex B (example of strain gauge attachment procedure).

NOTE 3 Strain can differ depending upon the strain gauge attachment position on the test board. Therefore, it is necessary to adjust the position on the board to that of the actual electronic device.



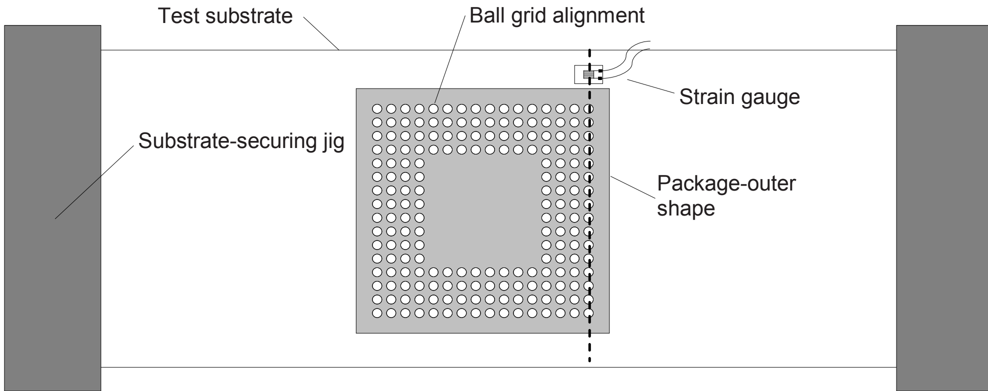


Figure 2 – Position of strain gauge attachment

6.8 Strain measurement instrument

The strain measurement instrument used during the drop test shall have sampling rate that is higher than 150 kHz. When the sampling rate of an instrument is low, strain values and strain wave patterns are not shown correctly because the peak value of the maximum strain sometimes cannot be picked up. Therefore, an instrument that has higher sampling rate than 150 kHz is desirable (Figure 3 and Figure 4). However, a sampling rate that is lower than 150 kHz is acceptable if the measuring result is otherwise correctly assured.

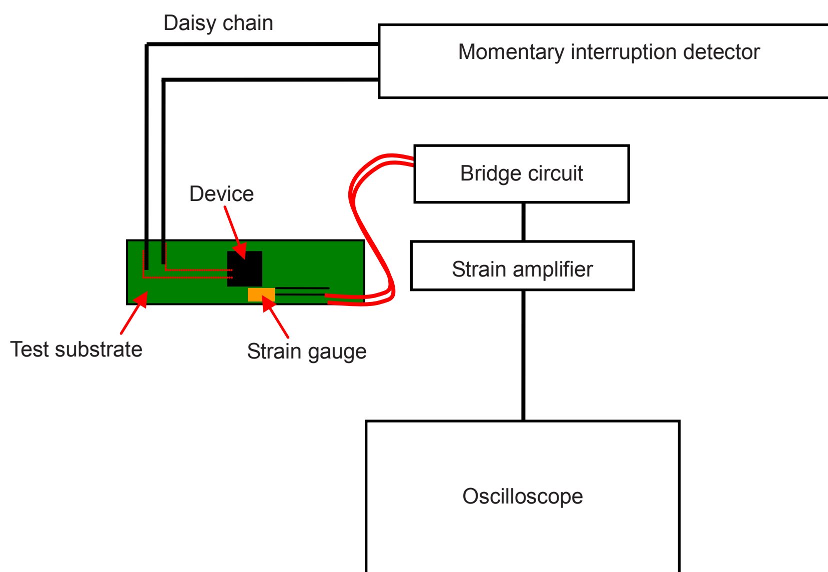


Figure 3 – Strain measurement instrument

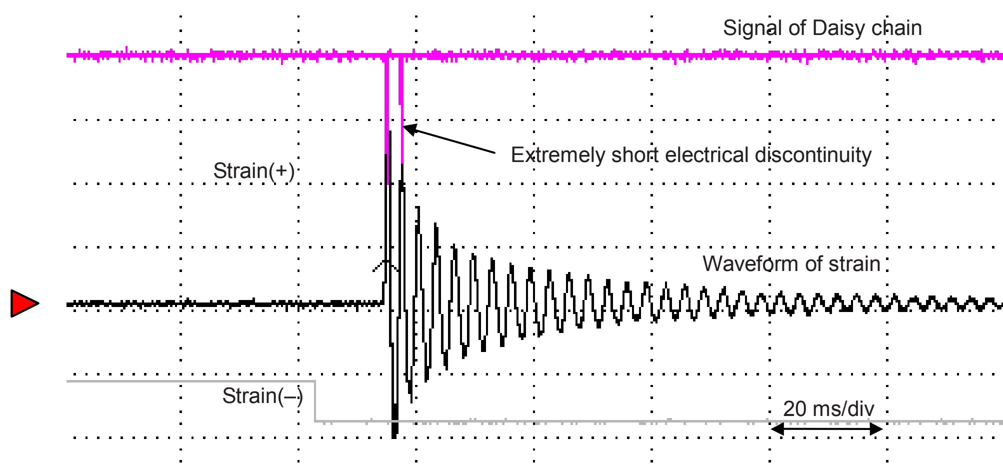


Figure 4 – Waveform of strain and electrical conductivity of daisy chain

6.9 Test condition

6.9.1 Drop test conditions

The method and conditions of the drop test shall be specified in the relevant specification.

6.9.2 Test procedure

The drop test method shall be natural free fall.

6.9.3 Drop height

The drop shall be defined in accordance with 6.9.4 by using a strain gauge set on the test substrate.

6.9.4 Pre-test characterization

6.9.4.1 Strain gauge attachment

Attach the strain gauge to the test substrate as shown in Figure 2 and Annex B. The gauge shall be attached to test surface on which the specimen device is mounted, at a location in the vicinity of the device.

6.9.4.2 Test substrate attachment

The test substrate shall be attached to the substrate-securing jig with its device side facing downward.

6.9.4.3 Adjustment of drop height

The substrate-securing jig shall then be raised to the height specified in the relevant specification and dropped on to the strike surface while measuring the strain level and pulse duration. Multiple drops maybe required while adjusting the drop height to achieve the specified strain level and pulse duration. The amount of strain level specified in the relevant specification shall be consistent with the value measured by the actual application. The peak value of pull-strain (+ strain) of the wave pattern is considered as the maximum strain. If there are several kinds of test sample, a drop height is determined by measuring each test sample. However, if the test samples are the same, it is not necessary to measure all samples.

6.9.4.4 Adjustment of pulse duration

There is a correlation between the drop test life time and the pulse duration of the strain as shown in Figure 5. There is also a correlation between the distance between the supporting points and the pulse duration of the strain as shown in Figure 6. It is therefore necessary to adjust the pulse duration to be consistent with such correlation, and to that of an actual electronic device pulse duration.

NOTE The pulse duration of a mobile phone is seen to be 0,5 ms to 1,7 ms. Therefore the recommended pulse duration is set to 1,0 (± 0,5) ms for a mobile phone it is also desirable to adjust the pulse duration so that the distance between supporting points is 50 mm to 80 mm.

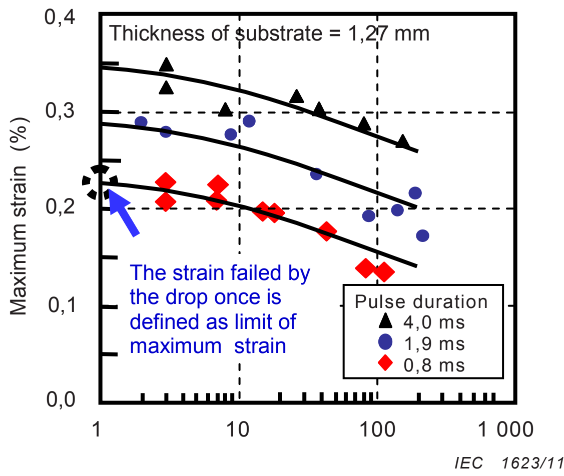


Figure 5a – Number of times of drop to failure

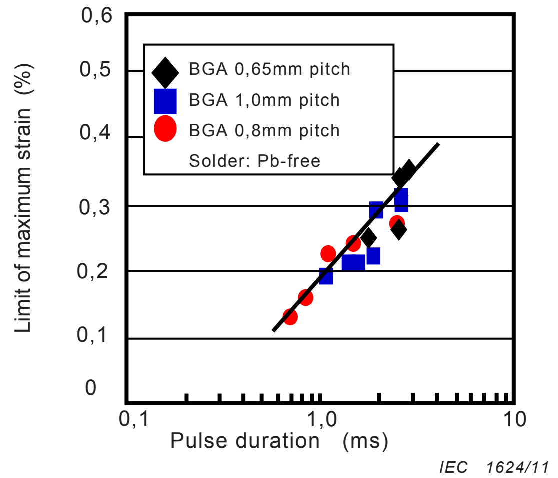
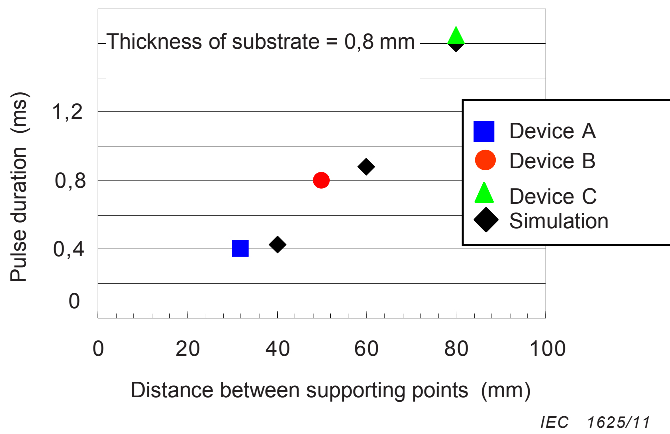


Figure 5b – Pulse duration

Figure 5 – Correlation strain and number of failures and strain and pulse duration



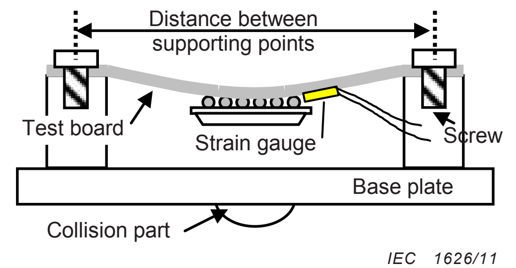


Figure 6 – Correlation between pulse duration and distance between supporting points

6.9.4.5 Drop test

The drop test shall be carried out after adjusting drop height.

NOTE 1 There is a correlation between the number of times to failure and the maximum strain. The number of times to failure can be presumed to be the arbitrary maximum strain (Figure 7).

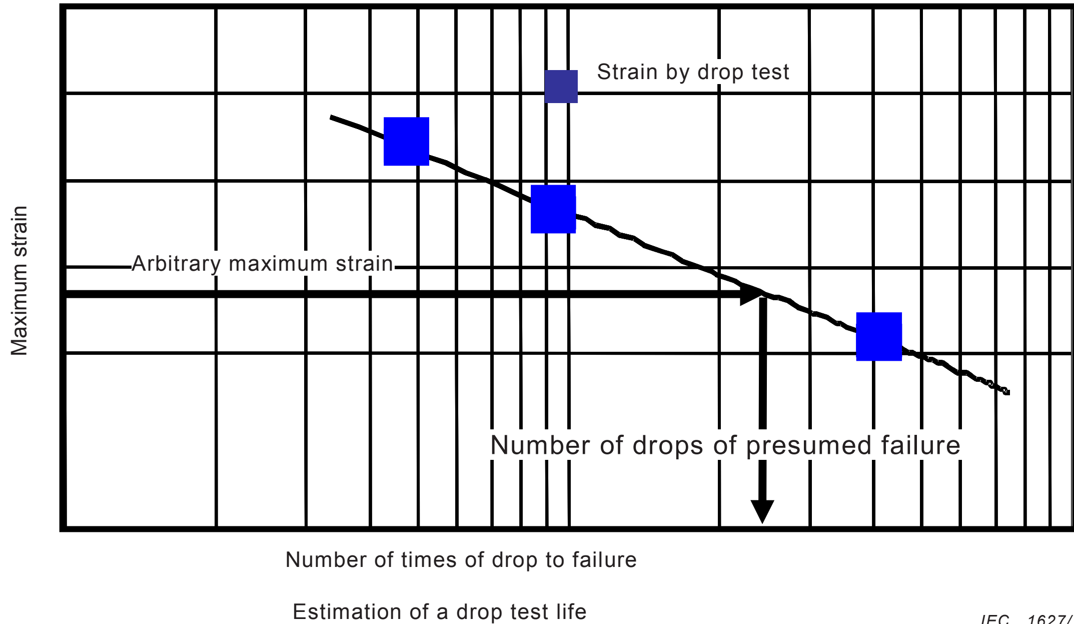


Figure 7 – Correlation between the number of times of failure and the maximum strain

NOTE 2 As an alternative method of deriving strain, the method shown in Annex A (dropping a test rod) may be used.

6.9.5 Direction

The test substrate shall be attached to the substrate-securing jig with its device side facing downwards as shown in Figure 8.

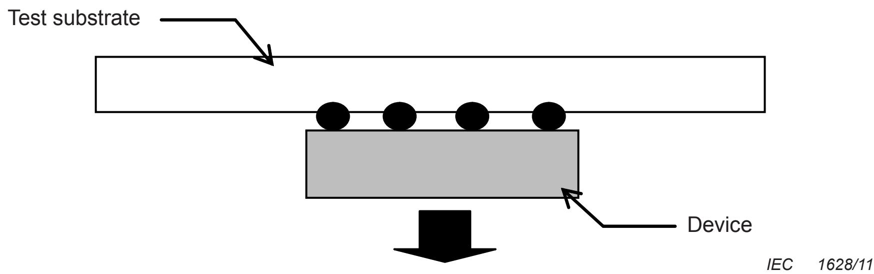


Figure 8 – Direction of dropping

6.9.6 Number of drops

The board shall be dropped to destruction or 20 times, whichever is earlier.

7 Summary

The following shall be detailed in the relevant specification:

a) Specification of test substrate (see 5.2)
b) Specification of solder paste (see 5.3)
c) Mounting method and conditions (see 5.4)
d) Specification of pre-conditioning, if required. (see 5.5)

e) Specification of initial measurement (see 5.6)

f) Test method. The test method shall be selected from this test method (Clause 6) or the test method in Annex A (see Clause 6 or Annex A)

g) Final measurement (see 5.8)

h) Distance between supporting points (see 6.4 or A.2)

i) Drop height by adjustment (see 6.9.4 or A.3.4)

j) Pre-test characterisation, strain level and pulse duration (see 6.9.4 or A.3.4)

Annex A
(normative)

Drop impact test method using test rod

A.1 Equipment

The drop impact test equipment is equipped with a mechanism that is able to drop a test rod (e.g., metal rod), from a specified height onto the back surface of test substrate in order to apply the impact that would result from a free fall or similar situation. An outline of the test apparatus is shown in figure A.1

The test equipment consists of:

a) a substrate securing-jig
b) the mechanism for measuring the substrate surface strain measurement at the time of a rod fall
c) the mechanism to stabilize the rod fall position
d) the mechanism for eliminating ‘bounce’ so that the rod only strikes once per drop

NOTE A method of fixing the rod in its horizontal plane is recommended.

A.2 Substrate securing-jig

The test substrate shall be fixed to the substrate-securing jig (by bolts or other method) as follows:

a) the distance between supporting points shall be variable in order to adjust the strain pulse duration.
b) the test substrate shall be attached with bolts (direct attachment or indirect attachment using plates) or other method that produces reproducibility of strain.
c) The tip of a rod shall be processed into the shape of a hemisphere (e.g., R = 3 mm) so that the angling at the tip of the rod does not make contact when the test board bends.

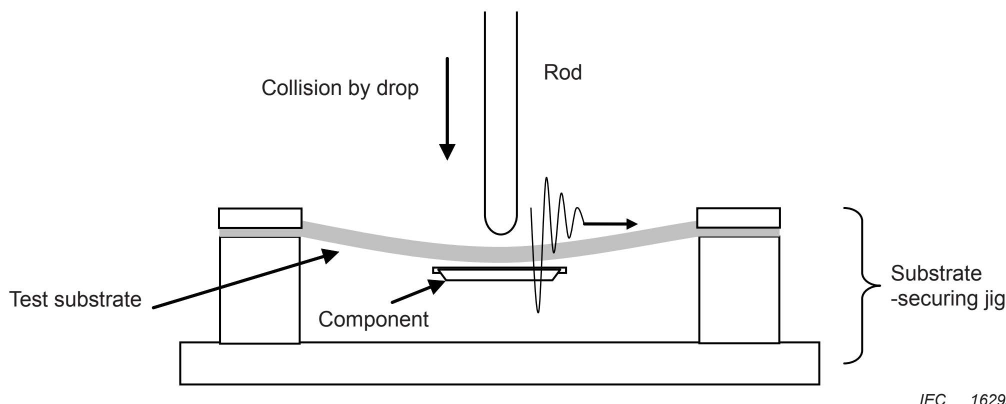


Figure A.1 – Outline of test apparatus

A.3 Test condition

A.3.1 Test condition requirements

The test shall be carried out in accordance with the relevant specification.

A.3.2 Fall method

The rod shall fall naturally and the set up shall be determined by using the strain measurement pre-test of A.3.4

A.3.3 Drop height of the rod

The fall height is determined using the strain gauge attached to the substrate during the pre-test of A.3.4.

A.3.4 Adjustment requirements to the fall height of the rod

A.3.4.1 Strain gauge attachment

Attach the strain gauge to the test substrate. The gauge shall be attached to the surface on which the specimen component is mounted, at the location shown in Figure A.2.

A.3.4.2 Test substrate attachment

The test substrate shall be attached to the substrate-securing jig with its component side facing downward.

A.3.4.3 Characterization

Using a reserve sample, the fall height of the rod and the distance between supporting points are adjusted so that they may meet the target substrate surface strain and strain pulse duration. The test level, with respect to strain, is defined in the individual specification. The strain defined by the individual specification needs to be in accordance with the value measured by actual products.

NOTE A pulse duration of 1,0ms or less is recommended (refer to 6.9.4).

If there are several kinds of test sample, a drop height is determined by measuring each test sample. However, if the test samples are the same, it is not necessary to measure all samples

A.3.4.4 Test

The rod is repeatedly dropped after the preliminary test for strain measurement of A.3.4.1 to A.3.4.3 above from the height adjusted by repeating A.3.4.3.

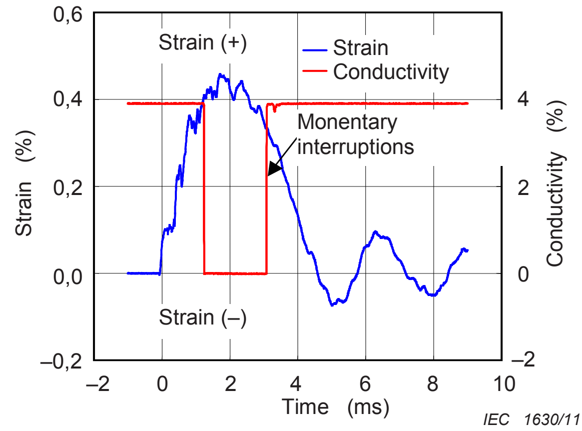


Figure A.2 – Waveform of strain and electrical conductivity of a daisy chain

Annex B
(informative)

An example of strain gauge attachment procedure

B.1 Object

This annex provides an example of strain gauge attachment to ensure the correct measurement of the value of the strain is generated when the samples are subject to drop impact.

B.2 Equipment and materials

The equipment and materials for strain gauge attachment are shown in Figure B.1. The adhesive type indicated below must be used to attach the strain gauge. When any other type of adhesive is used, separate evaluation work is required.

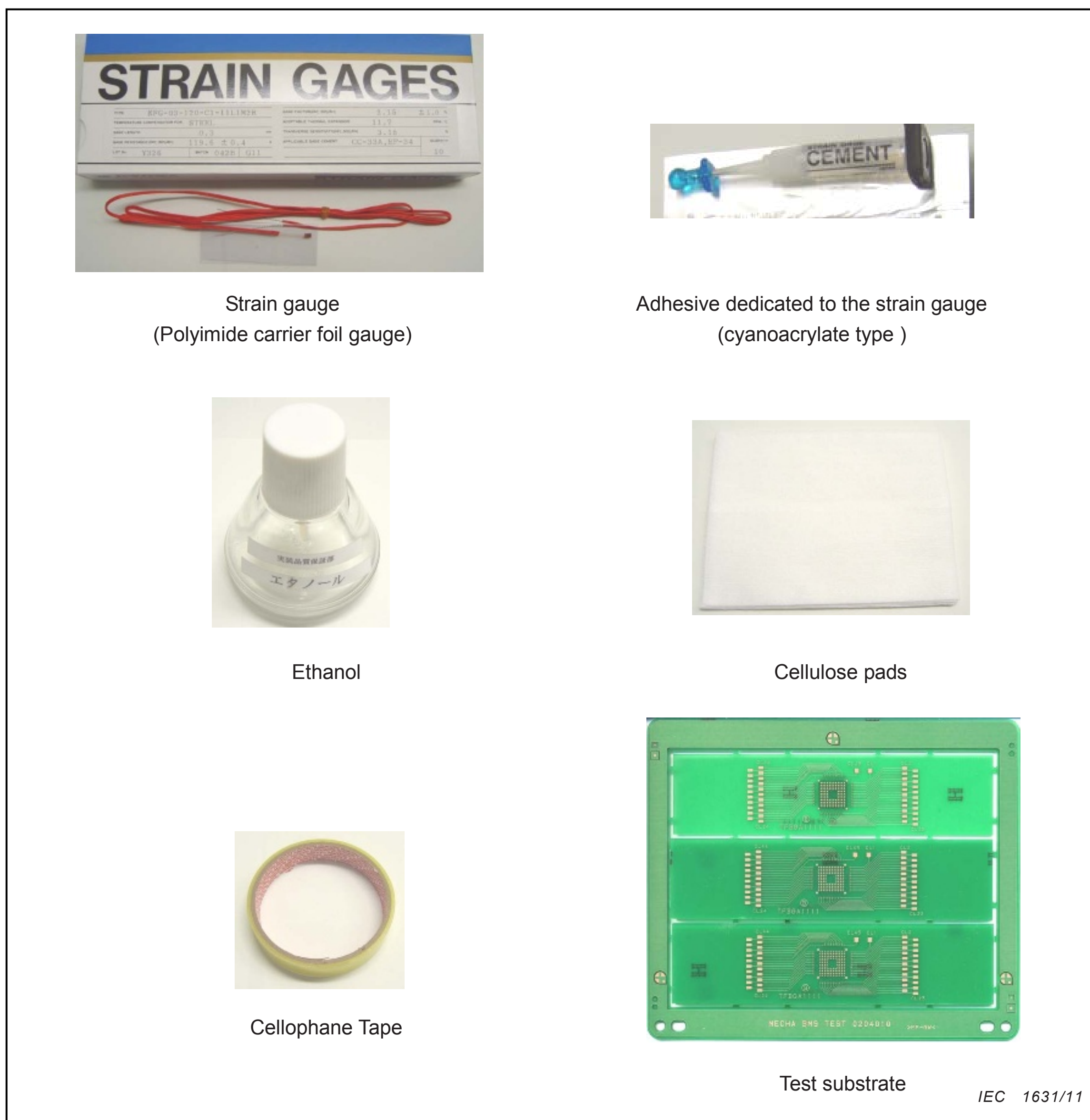


Figure B.1 – Equipment and materials

B.3 Strain gauge guide marks

Attach a strain gauge to the side on which the component under test is mounted. The position at which it is attached shall be 3,25 mm from the centre of the land at a package corner. To ensure attachment position precision, it is recommended that strain gauge guide marks be placed. Figure B.2 below shows an example of attaching the strain gauge. For reference, the dimensions of the guide marks are given.

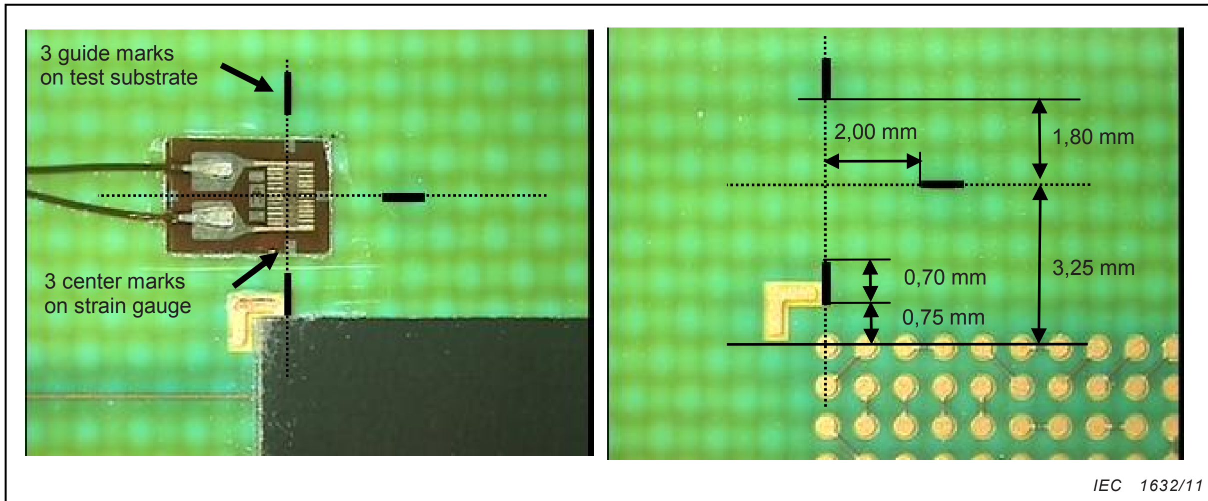
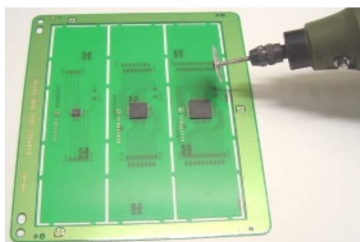


Figure B.2 – Example of Attaching Strain Gauge and Guide Mark Dimensions

B.4 Strain gauge attachment procedure

The strain gauge attachment procedure is described below in Figure B.3 and Figure B.4.

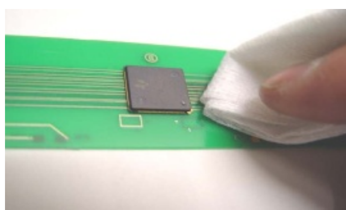
Step 1 Dividing the substrate



Using a router, divide the substrate into sections whilst ensuring no stress is applied to the substrate.

IEC 1633/11

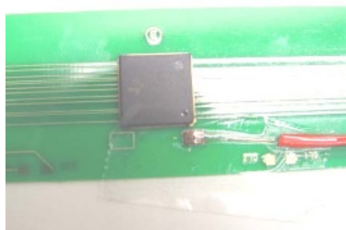
Step 2 Cleaning the board surface



Using the cellulose pads moistened with ethanol, clean the location where the strain gauge is to be attached (on the side where mounting takes place), ensuring no stress is applied to the attachment location.

IEC 1634/11

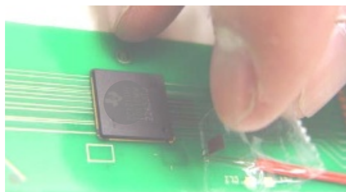
Step 3 Attachment using cellophane tape (1)



Attach a strain gauge to cellophane tape, then position and attach the strain gauge onto the substrate temporarily, ensuring that the tape is not too 'sticky' so as to prevent its removal.

IEC 1635/11

Step 4 Attachment using cellophane tape (2)



Tear back the strain gauge together with cellophane tape until the back of the strain gauge is visible.

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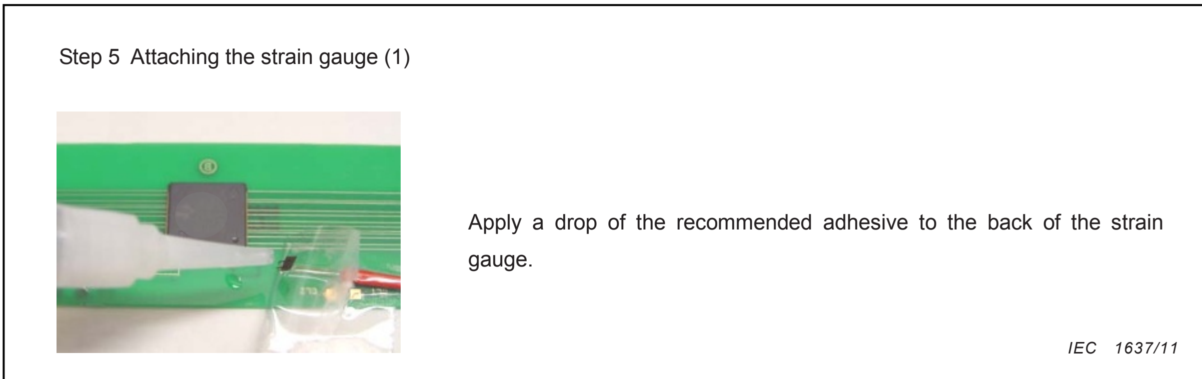
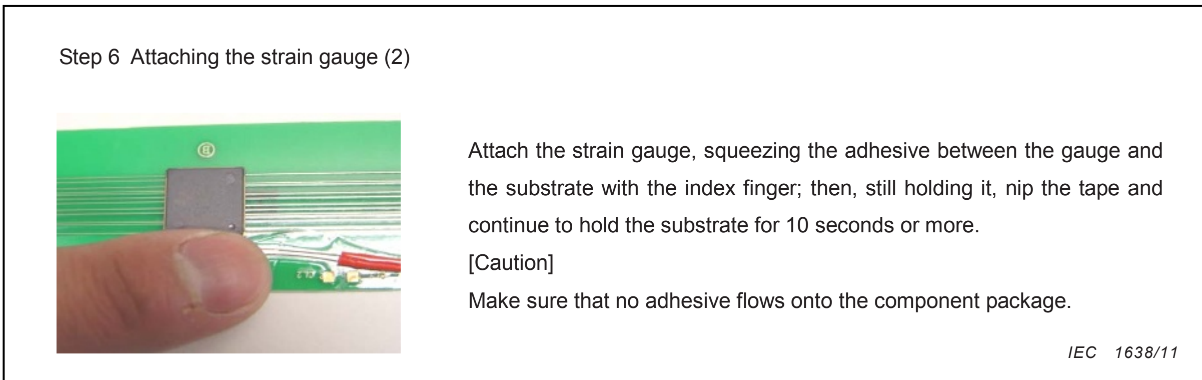
Figure B.3 – Strain gauge attachment procedure, part 1





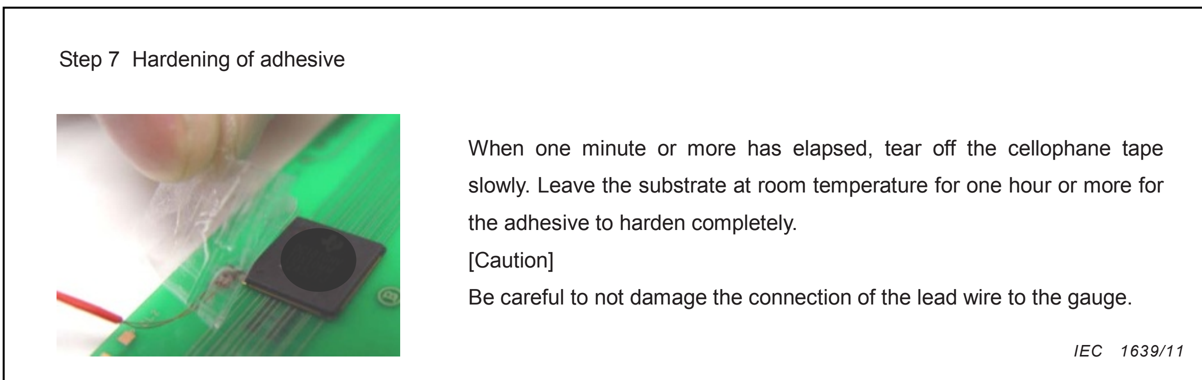


Figure B.4 – Strain gauge attachment procedure, part 2

Each strain gauge has its specific gauge factor. A true strain value can be obtained by compensating the reading with the gauge factor. Usually, a strain value can be compensated by entering the gauge factor into the measuring instrument.

The following is the compensation expression:

$$\text{True strain value} = \left(\frac{2{,}00}{\text{Gauge factor of the strain}} \right) \times \text{Reading} \tag{B.1}$$

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