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BSI Standards Publication

Test methods for electrical materials, printed boards and other interconnection structures and assemblies

Part 5-601: General test methods for materials and assemblies — Reflow soldering ability test for solder joint, and reflow heat resistance test for printed boards

bsi.

National foreword

This British Standard is the UK implementation of EN IEC 61189-5-601:2021. It is identical to IEC 61189-5-601:2021.

The UK participation in its preparation was entrusted to Technical Committee EPL/501, Electronic Assembly Technology.

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

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Date	Text affected

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EN IEC 61189-5-601

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English Version

Test methods for electrical materials, printed boards and other interconnection structures and assemblies - Part 5-601: General test methods for materials and assemblies - Reflow soldering ability test for solder joint, and reflow heat resistance test for printed boards (IEC 61189-5-601:2021)

Méthodes d'essai pour les matériaux électriques, les cartes imprimées et autres structures d'interconnexion et ensembles - Partie 5-601: Méthodes d'essai générales pour les matériaux et les assemblages - Essai d'aptitude au brasage par refusion pour un joint brasé, et essai de résistance à la chaleur de refusion pour les cartes imprimées
(IEC 61189-5-601:2021)

Prüfverfahren für Elektromaterialien, Leiterplatten und andere Verbindungsstrukturen und Baugruppen – Teil 5-601: Allgemeine Prüfverfahren für Materialien und Baugruppen – Prüfverfahren für die Aufschmelz-Lötfähigkeit für Lötverbindungen und die Aufschmelz-Lötwärmebeständigkeit von Leiterplatten
(IEC 61189-5-601:2021)

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The text of document 91/1601/CDV, future edition 1 of IEC 61189-5-601, prepared by IEC/TC 91 "Electronics assembly technology" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61189-5-601:2021.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2021-12-10
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2024-03-10

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Endorsement notice

The text of the International Standard IEC 61189-5-601:2021 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 60068-2-58	NOTE	Harmonized as EN 60068-2-58
IEC 60068-2-78	NOTE	Harmonized as EN 60068-2-78
IEC 61188-5-8	NOTE	Harmonized as EN 61188-5-8
IEC 61189-5-3	NOTE	Harmonized as EN 61189-5-3
IEC 61190-1-1	NOTE	Harmonized as EN 61190-1-1
IEC 61190-1-2	NOTE	Harmonized as EN 61190-1-2
IEC 61249 (series)	NOTE	Harmonized as EN 61249 (series)
IEC 61249-2-7	NOTE	Harmonized as EN 61249-2-7
IEC 61249-2-8	NOTE	Harmonized as EN 61249-2-8
IEC 61760-1:2006	NOTE	Harmonized as EN 61760-1:2006 (not modified)
IEC 62137-1-1	NOTE	Harmonized as EN 62137-1-1
IEC 62137-4:2014	NOTE	Harmonized as EN 62137-4:2014 (not modified)

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60068-2	series	Environmental testing	EN 60068-2	series
IEC 60068-2-14	-	Environmental testing - Part 2-14: Tests - Test N: Change of temperature	EN 60068-2-14	-
IEC 60191-6-2	-	Mechanical standardization of semiconductor devices - Part 6-2: General rules for the preparation of outline drawings of surface mounted semiconductor devices packages - Design guide for 1,50 mm, 1,27 mm and 1,00 mm pitch ball and column terminal packages	EN 60191-6-2	-
IEC 60191-6-5	-	Mechanical standardization of semiconductor devices - Part 6-5: General rules for the preparation of outline drawings of surface mounted semiconductor device packages - Design guide for fine-pitch ball grid array (FBGA)	-	-
IEC 60191-6-19	-	Mechanical standardization of semiconductor devices - Part 6-19: Measurement methods of the package warpage at elevated temperature and the maximum permissible warpage	EN 60191-6-19	-
IEC 60194-1[1]	-	Printed boards design, manufacture and assembly - Vocabulary - Part 1: Common usage in printed board and electronic assembly technologies	-	-

[1] Under preparation. Stage at the time of publication: IEC/FDIS 60194-1:2020.

Publication	Year	Title	EN/HD	Year
IEC 60194-2	-	Printed boards design, manufacture and assembly - Vocabulary - Part 2: Common usage in electronic technologies as well as printed board and electronic assembly technologies	-	-
IEC 61190-1-3	-	Attachment materials for electronic assembly - Part 1-3: Requirements for electronic grade solder alloys and fluxed and non-fluxed solid solder for electronic soldering applications	EN IEC 61190-1-3	-
IEC 62137-3	-	Electronics assembly technology - Part 3: Selection guidance of environmental and endurance test methods for solder joints	EN 62137-3	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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TEST METHODS FOR ELECTRICAL MATERIALS, PRINTED BOARDS AND OTHER INTERCONNECTION STRUCTURES AND ASSEMBLIES –

Part 5-601: General test methods for materials and assemblies – Reflow soldering ability test for solder joint, and reflow heat resistance test for printed boards

FOREWORD

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IEC 61189-5-601 has been prepared by IEC technical committee 91: Electronics assembly technology. It is an International Standard.

The text of this International Standard is based on the following documents:

Draft	Report on voting
91/1601/CDV	91/1674/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 61189 series, published under the general title *Test methods for electrical materials, printed boards and other interconnection structures and assemblies*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

TEST METHODS FOR ELECTRICAL MATERIALS, PRINTED BOARDS AND OTHER INTERCONNECTION STRUCTURES AND ASSEMBLIES –

Part 5-601: General test methods for materials and assemblies – Reflow soldering ability test for solder joint, and reflow heat resistance test for printed boards

1 Scope

This part of IEC 61189 specifies the reflow soldering ability test method for components mounted on organic rigid printed boards, the reflow heat resistance test method for organic rigid printed boards, and the reflow soldering ability test method for the lands of organic rigid printed boards in applications using solder alloys, which are eutectic or near-eutectic tin-lead (Pb), or lead-free alloys.

The printed boards materials for this organic rigid printed boards are epoxide woven E-glass laminated sheets that are specified in IEC 61249-2 (all parts).

The objective of this document is to ensure the soldering ability of the solder joint and of the lands of the printed boards. In addition, test methods are provided to ensure that the printed boards can resist the heat load to which they are exposed during soldering.

This document covers tests Tg_1, Tg_2, Tg_3, Tg_4, Tg_5, and Tg_6 listed in Table 1:

Table 1 – Test items defined in this document

Number of test method	Test	Method
Tg_1	Solder joint initial quality after reflow	Reflow
Tg_2	Warpage of component and printed boards in reflow process	
Tg_3	Resistance to soldering heat of printed boards	
Tg_4	Wetting and dewetting of printed board land	
Tg_5	Resistance to dissolution of printed board land	
Tg_6	Pull strength of the test substrate land	

NOTE The test methods do not apply to the solder bath method.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60068-2 (all parts), *Environmental testing*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60191-6-2, *Mechanical standardization of semiconductor devices – Part 6-2: General rules for the preparation of outline drawings of surface mounted semiconductor devices packages – Design guide for 1,50 mm, 1,27 mm and 1,00 mm pitch ball and column terminal packages*

IEC 60191-6-5, *Mechanical standardization of semiconductor devices – Part 6-5: General rules for the preparation of outline drawings of surface mounted semiconductor device packages – Design guide for fine-pitch ball grid array (FBGA)*

IEC 60191-6-19, *Mechanical standardization of semiconductor devices – Part 6-19: Measurement methods of the package warpage at elevated temperature and the maximum permissible warpage*

IEC 60194-1 [1], *Printed boards design, manufacture and assembly – Vocabulary – Part 1: Common usage in printed board and electronic assembly technologies*

IEC 60194-2, *Printed boards design, manufacture and assembly – Vocabulary – Part 2: Common usage in electronic technologies as well as printed board and electronic assembly technologies*

IEC 61190-1-3, *Attachment materials for electronic assembly – Part 1-3: Requirements for electronic grade solder alloys and fluxed and non-fluxed solid solder for electronic soldering applications*

IEC 62137-3, *Electronics assembly technology – Part 3: Selection guidance of environmental and endurance test methods for solder joints*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60191-6-2, IEC 60191-6-5, IEC 60194-1 and IEC 60194-2, as well as the following, apply.

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
solderability
ability of the lead or termination of a component or electrode of a component or printed board to be wetted by solder at the temperature of the lead, termination or electrode, which is assumed to be the lowest temperature in the soldering process, within the applicable temperature range of the solder alloy

Note 1 to entry: The term "solderability" is often used in combination with the term "test", indicating a specific method to evaluate the wettability or ability to be soldered of a surface under worst case conditions (soldering temperature and contact time with solder). It is not to be confused with the concepts "soldering ability" (see 3.3).

3.2
wettability
intrinsic property of the termination material to form an alloy with the solder

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[1] Under preparation. Stage at the time of publication: IEC/FDIS 60194-1:2020.

Note 1 to entry: Wettability depends on the base metal used to produce the termination or, in the case of a plated termination, the condition and material used to plate the base metal.

3.3
soldering ability
ability of a specific combination of components to facilitate the formation of a proper solder joint

Note 1 to entry: See 3.2, wettability.

3.4
resistance to soldering heat
ability of the component to withstand the highest temperature in terms of temperature gradient, peak temperature and duration of the soldering process, within the applicable temperature range of the solder alloy

3.5
reflow soldering
joining of surfaces that have been tinned and/or have solder between them, placing them together, heating them until the solder flows, and allowing the surface and the solder to cool in the joined position

3.6
wetting
formation of an adherent coating of solder on a surface indicated by a small contact angle

3.7
dewetting
retraction of molten solder on a solid area that it has initially wetted

Note 1 to entry: In some cases, an extremely thin film of solder may remain. As the solder retracts, the contact angle increases.

3.8
non-wetting
inability to form an adherent coating of solder on a surface indicated by a contact angle greater than 90°

3.9
dissolution of printed-board land
process of dissolving metal, usually by introduction of chemicals

4 Grouping of soldering processes and related test severities

The melting temperatures of lead-free solder alloys selected for industrial processes are significantly different from those for Sn-Pb solder alloy. Moreover, the melting temperatures of lead-free solder alloys are different from each other but can be clustered in groups.

The groups of soldering processes indicated in Table 2 are given as a guideline to select the severities for the wetting and resistance tests at a specified soldering heat.

Table 2 – Grouping of soldering processes and typical test severities – Overview

<table>
<tr><th colspan="3">Process temperature group [a]</th><th>1</th><th>2</th></tr>
<tr><th colspan="3">Typical solder alloy group</th><th>Sn-Pb</th><th>Sn-Ag-Cu</th></tr>
<tr><td>Typical process temperature</td><td colspan="2">Reflow peak temperature</td><td>210 °C to 240 °C</td><td>235 °C to 250 °C</td></tr>
<tr><td>Test method</td><td colspan="2">Test property</td><td colspan="2">Reflow peak temperature/Duration</td></tr>
<tr><td rowspan="7">Reflow [b]</td><td rowspan="2">Solder joint initial quality "Soldering ability"</td><td>Maximum profile temperature</td><td>235 °C / 20 s or more</td><td>245 °C / 30 s or more</td></tr>
<tr><td>Minimum profile temperature</td><td>215 °C / 10 s or less</td><td>235 °C / 10 s or less</td></tr>
<tr><td colspan="2">Warpage</td><td>235 °C / 20 s or more</td><td>245 °C / 30 s or more</td></tr>
<tr><td colspan="2">Resistance to soldering heat</td><td>235 °C / 20 s or more</td><td>245 °C / 30 s or more</td></tr>
<tr><td colspan="2">Wetting and dewetting</td><td>215 °C / 10 s or less</td><td>235 °C / 10 s or less</td></tr>
<tr><td colspan="2">Resistance to dissolution</td><td>235 °C / 20 s or more</td><td>245 °C / 30 s or more</td></tr>
<tr><td colspan="2">Pull strength</td><td>235 °C / 20 s or more</td><td>245 °C / 30 s or more</td></tr>
<tr><td colspan="5">Typical process temperatures for reflow soldering are the land temperatures in device area on printed boards.
The Sn-Ag-Cu alloy listed in this table represents compositions that are currently preferred for lead-free soldering processes. However, other solder alloys when matching with the specified group should not be excluded.
[a] Refer to each appropriate subclauses for the detailed test conditions.
[b] Measured at the solder joint or land of printed boards.</td></tr>
</table>

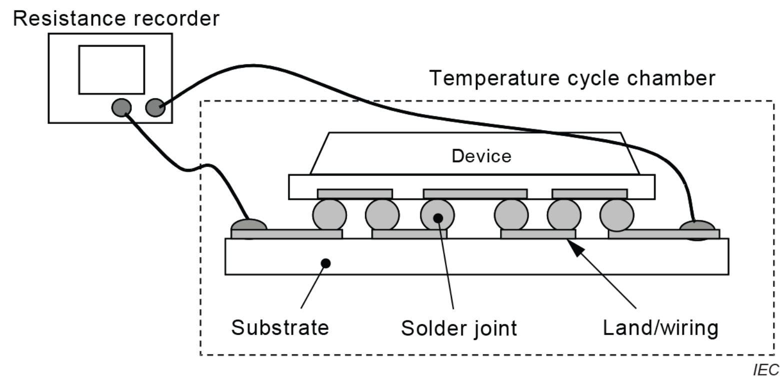
5 Specimens

5.1 Devices

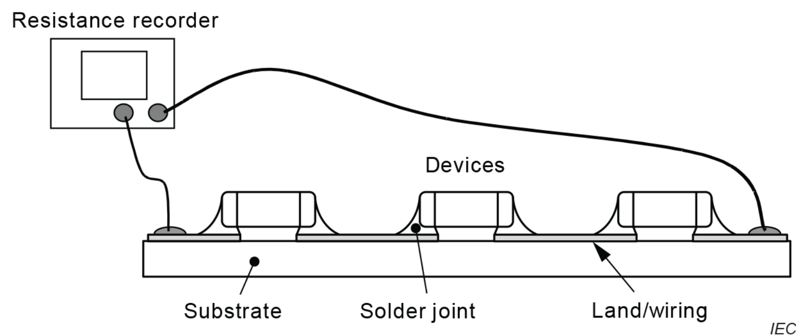
Device specimens for this test are specified in IEC 62137-3.

When the evaluation needs to be conducted, the device used for this test is a dummy device within which the terminations are connected as shown in Figure 1.

When the evaluation for leadless termination type devices needs to be conducted on the resistance device, the device resistance for the test is a low-resistance device [as shown in Figure 1 b)]. The resistance of the low-resistance device should be 50 mΩ or less.



a) Example of area array type packages



b) Example of leadless termination type devices

Figure 1 – Example of a test circuit for the electrical continuity test of a solder joint

The following Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6 show the typical appearance of each package type.

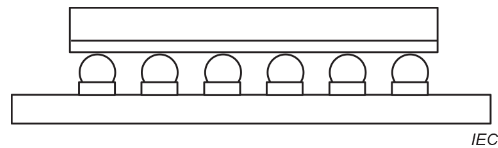


Figure 2 – Example of area array type packages

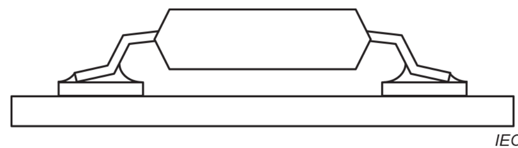


Figure 3 – Example of leaded type devices

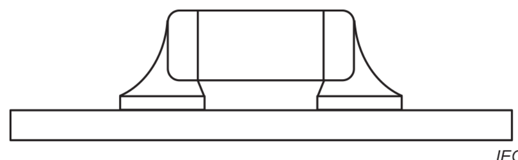


Figure 4 – Example of leadless termination type devices

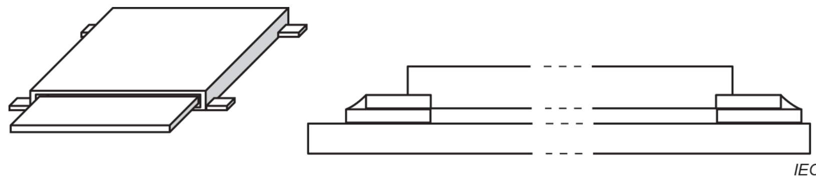


Figure 5 – Example of connector for card type devices

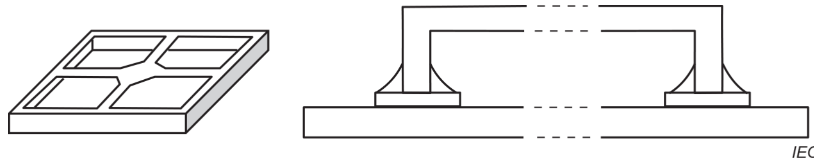


Figure 6 – Example of shielding metal components

5.2 Test substrate

The test substrate material shall be single or double-sided mounting with single-layer, double-layer or multilayer printed boards for material structure used with product. Unless otherwise specified in the product specification, the test substrate shall be as follows.

a) Test substrate material

Test substrate material shall be a single-sided printed board for general use, for example, copper-clad epoxide woven fiberglass reinforced laminated sheets as specified in IEC 61249-2-7 or IEC 61249-2-8. The thickness shall be (1,6 ± 0,2) mm including copper foil. The copper foil thickness shall be (35 ± 10) µm.

b) Test substrate dimensions

The test substrate dimensions depend on the mounted package size and shape. However, the test substrate dimensions shall be able to be fixed on the pull strength test equipment.

c) Land shape and land dimensions

Land shape and land dimensions should be the same specification as used for product design. Land shape and land dimensions should be as specified in IEC 61188-5-8.

Moreover, the test substrate and the test package shall be designed in such a way that their land pattern forms a daisy chain circuit after mounting for the electrical continuity measurement.

d) Surface finish of land pattern

If specified in the product specification, the surface finish treatment (for land pattern of the printed board) shall be the same as specified in the product specification.

EXAMPLE: organic solderability preservative (OSP) or electroless nickel immersion gold (ENIG) plating layer.

5.3 Solder paste

Solder paste is made of flux, finely divided particles of solder, and additives to promote wetting and to control viscosity, tackiness, slumping, drying rate, etc. Unless otherwise specified in the product specification, one of the solder alloys listed below (as specified in IEC 61190-1-3) shall be used. The product specification shall specify details of the solder paste.

The major composition of the solder alloys are as follows:

a) 63 % mass fraction of Sn (tin) and 37 % mass fraction of Pb (lead);

b) from 3,0 % to 4,0 % mass fraction of Ag (silver), from 0,5 % to 1,0 % mass fraction of Cu (copper) and the remainder of Sn (tin).

EXAMPLE: Sn-Ag-Cu ternary alloy such as Sn96,5Ag3Cu,5 alloy is used.

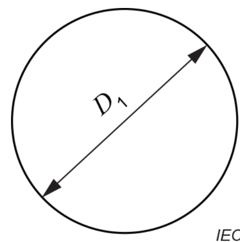
Solder paste shall be properly stored in accordance with the product's specification.

5.4 Solder ball

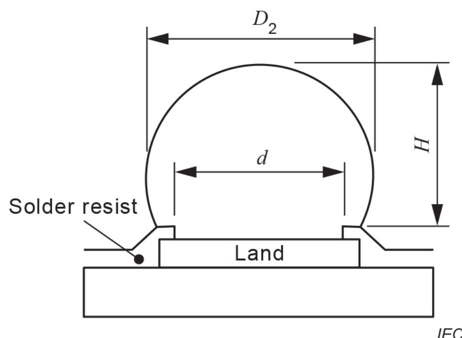
The diameter and height of the solder ball used should be the following size a) and b) and the shape should be as shown in Figure 7. The composition should be equivalent to the one indicated in IEC 61190-1-3.

a) $$\frac{D_1}{d} \leq 1{,}5$$

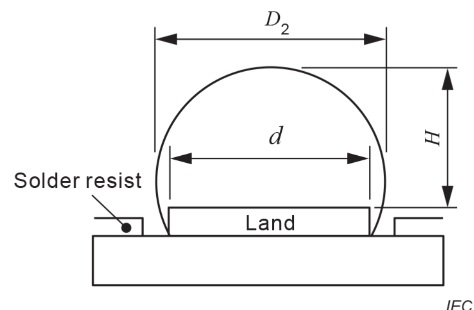
b) $$1{,}1 \leq \frac{D_2}{H} \leq 2{,}2$$



a) Solder ball



b) Solder mask defined (SMD) type land



c) Non solder mask defined (NSMD) type land

Key

d Land opening diameter

D_1 Solder ball diameter

D_2 Solder ball diameter after solder ball assembling

H Solder ball height after solder ball assembling

Figure 7 – Recommended solder ball shape

6 Apparatus and equipment

6.1 Constant temperature and humidity testing equipment

The pre-conditioning oven shall be able to maintain the evaluation conditions specified in the specimen’s product specification. The general requirements for the pre-conditioning oven are specified in IEC 60068-2 (all parts).

The humidifier shall be able to maintain the evaluation temperature and humidity as specified in the specimen’s product specification. The material of the oven should not react at high

temperature. The water used for the test should be purified or de-ionized water, with a resistivity of 5 000 MΩm (0,5 MΩcm) or higher (conductivity of 2 µS/cm or less). The equipment should perform the test in accordance with IEC 60068-2-78.

6.2 Device-mounting equipment

a) Stencil for screen printing

The stencil shall be suitable for permitting the application of solder paste for the device types and sizes to be mounted.

Unless otherwise specified in the product specification, the stencil used should conform to the design standard shown in Table 3.

Table 3 – Stencil design standard for devices

Terminal type	Stencil thickness	Aperture diameter
For device	80 µm to 150 µm	Match with the land size specified for device

There are three processing methods for the stencil: the etching method, the additive method, and the laser processing method. It is recommended to use the stencil made by the additive method or by the laser processing method, whose solder paste printing characteristic is superior as it allows for finer pitches to be created.

b) Solder paste applying equipment

1) Screen printing equipment

The screen-printing equipment shall be capable of solder printing as described in 7.4.1.

2) Other equipment

If a dispenser, inkjet printing equipment or solder transfer apparatus are used to apply solder paste, they shall be able to apply the amount defined by the product specification.

c) Device-mounting equipment

The device-mounting equipment shall be capable of mounting the devices described in 7.4.2.

d) Reflow soldering equipment

The reflow soldering equipment shall be able to realize the reflow soldering temperature profile specified in Clause 4. Examples of temperature profiles are shown in Figure 10, Figure 11, Figure 12, Table 4 and Table 5.

6.3 X-ray transmission equipment

The X-ray transmission equipment shall be able to transparently observe the device being mounted on the test substrate.

6.4 Electrical resistance recorder

The electrical resistance recorder shall be able to detect electrical continuity interruption in the daisy chain circuit. If there is no doubt in the measuring result, an electrical resistance measuring instrument featured with a momentary interruption detector and/or a continuous electrical resistance data logger should be used.

The interruption detector should be sufficiently sensitive to detect a 100 µs momentary interruption. Furthermore, the electrical resistance measuring instrument should be able to measure a resistance exceeding 1 000 Ω.

6.5 Warpage measurement equipment

The warpage measurement equipment shall be able to realize the reflow soldering peak temperature specified in Clause 4. The general requirements for the warpage measurement equipment are specified in IEC 60191-6-19.

6.6 Temperature cycling chamber

The general requirements for the temperature cycling chamber are specified in IEC 60068-2-14.

6.7 Pull strength test equipment

The pull strength measuring equipment should meet the conditions of measurement described in IEC 62137-1-1 and IEC 62137-4.

7 Tg_1 Solder joint initial quality after reflow

7.1 General

Test Tg_1 provides the test method for the reflow soldering ability of solder joint as shown in Figure 8.

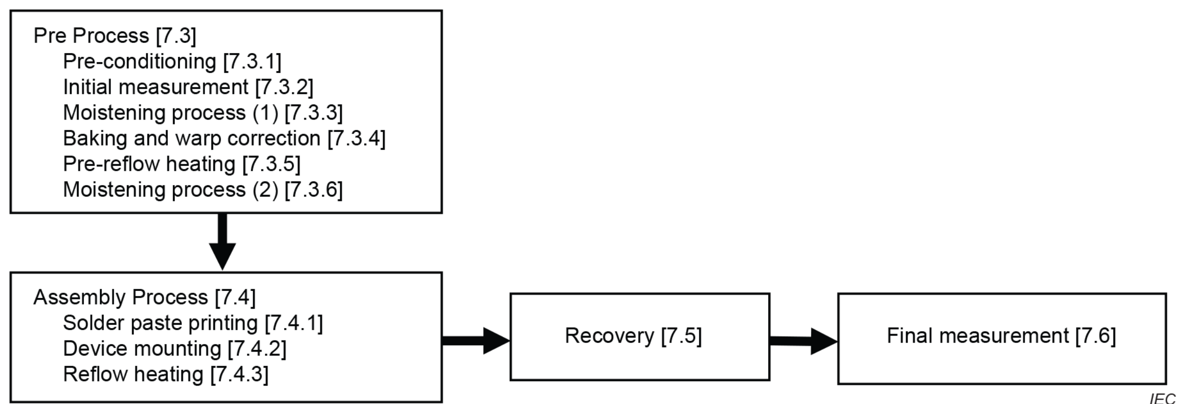


Figure 8 – Test procedure for Tg_1

7.2 Specimen preparation

The surface to be tested shall be in the "as received" condition and needs to be shielded from any kind of contamination, and the specimen shall not be subsequently touched by fingers.

If required by the product specification, the device specimen may be degreased by immersion in a neutral organic solvent at room temperature.

7.3 Pre-process

7.3.1 Pre-conditioning

The process to which the printed boards and devices are subjected to results in equivalent degradation and moisture absorption that they would be subjected to between the component's manufacture and the assembly process.

7.3.2 Initial measurement

a) Visual inspection

The initial visual inspection shall be carried out on the package to verify that there is no apparent damage, by magnifying it 10×:

- substrate curving or warping (out of product specifications);
- substrate cracking or delamination;
- solder resist stripping;

- land is lacking or stripping;
- adhesion of a foreign object

b) Electrical measurement

If the devices are daisy chain type, the initial electrical measurement of the package should be carried out according to the product specification.

7.3.3 Moistening process (1)

The test substrate specimen should be moistened using the pre-conditioning equipment specified in 6.1 under the conditions as specified in the product specification.

7.3.4 Baking and warp correction

The test substrate specimen should be baked using the pre-conditioning equipment specified in 6.1 under the conditions as specified in the product specification.

If specified in the product specification, weight shall be put on test substrate specimen for correction of warp.

The weight shall be specified in the product specification.

7.3.5 Pre-reflow heating

Using the reflow soldering equipment specified in 6.2 d), heat up the test substrate in the condition specified in the product specification. Then, the surface temperature of the printed board should be measured in the centre of the device mounting area on the test substrate.

The test substrate shall be heated up to the maximum temperature and for the time of reflow soldering profile in Figure 10, Figure 11, Figure 12 and Table 4.

7.3.6 Moistening process (2)

When the test substrate is subjected to the reflow process twice, the test substrate should be moistened once again under the conditions as specified in the product specification.

7.4 Assembly process

7.4.1 Solder paste printing

The solder paste shall be applied to the test substrate by screen or stencil printing, dispensing or pin transfer.

The area (size) to be printed, and thus the amount of solder paste deposit, shall be specified in the product specification. When solder paste is applied by dispensing or pin transfer, the volume shall be adjusted so that a comparable solder volume can be achieved.

NOTE The thickness of the solder deposit will be in the range from 60 μm to 250 μm.

Using the stencil described in 6.2 b) 1), print the solder paste as described in 5.3 so that there is no lacking, exuding or bridging that occurs on the test substrate.

Solder paste should be printed under print conditions set up in such a way as to avoid the defects listed below in Figure 9 and as shown in IEC 62137-4:2014, Annex G.

- Paste icicle produced when the stencil is removed.
- Recess in the middle section of the paste.
- Paste sagging.

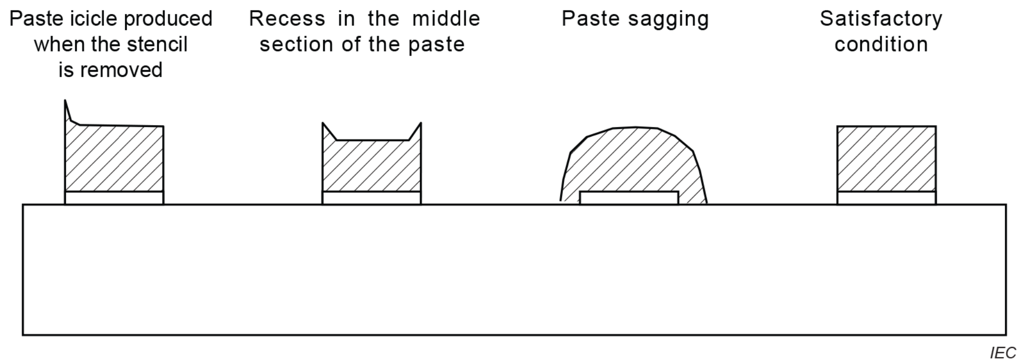


Figure 9 – Example of printed conditions of solder paste

7.4.2 Device mounting

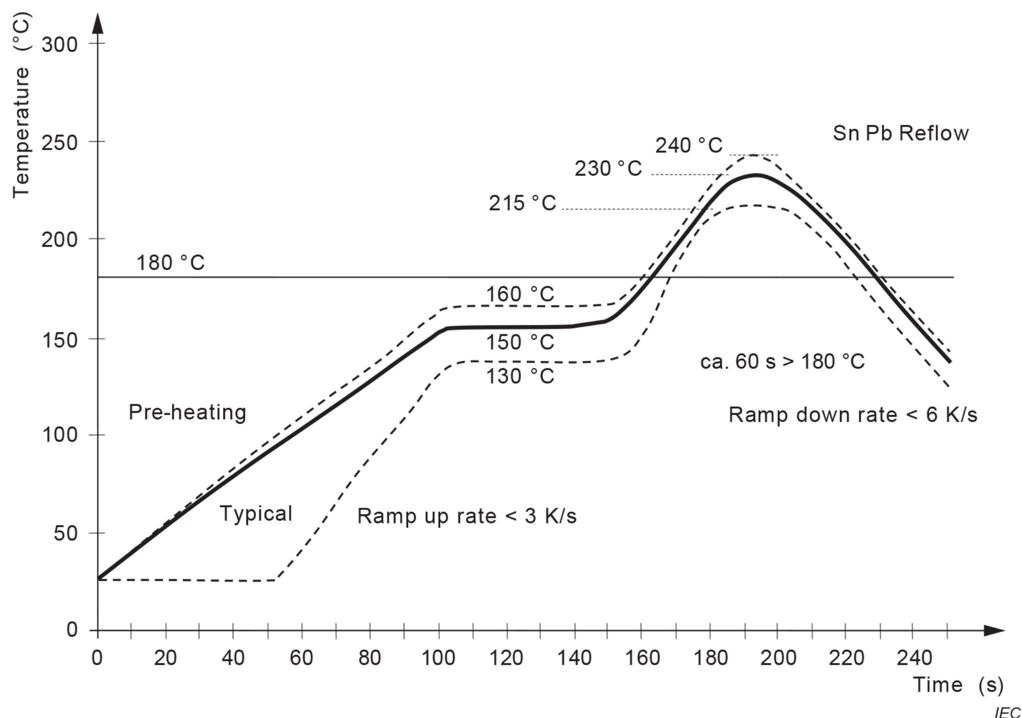
Mount the device on the test substrate, on which solder paste has been printed as described in 5.3.

Figure 10 shows an example of a typical reflow soldering profile using Sn63Pb37 solder alloy, as stated in IEC 61760-1:2006, Figure 13.

Figure 11 shows an example of a typical reflow soldering profile using Sn96,5Ag3Cu,5 solder alloy, as stated in IEC 61760-1:2006, Figure 14.

The test substrate shall be heated up to the minimum temperature and for the time of reflow soldering profile in Figure 10 or Figure 11.

As a minimum, the following parameters shown in Figure 10 shall be specified for the reflow temperature profile.



Continuous line: typical process (terminal temperature)

Dotted line: process limits. Bottom process limit (terminal temperature). Upper process limit (top surface temperature)

Figure 10 – Typical reflow soldering profile for Sn63Pb37 solder alloy

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