BS EN 62137-4:2014

Incorporating corrigendum February 2015

BSI Standards Publication

Electronics assembly technology

Part 4: Endurance test methods for solder joint of area array type package surface mount devices

National foreword

This British Standard is the UK implementation of EN 62137-4:2014, incorporating corrigendum February 2015. It is identical to IEC 62137-4:2014. It supersedes BS EN 62137:2004, which is withdrawn.

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 secretary.

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Date	Text affected
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English Version

Electronics assembly technology - Part 4: Endurance test methods for solder joint of area array type package surface mount devices (IEC 62137-4:2014)

Technique d'assemblage des composants électroniques - Partie 4: Méthodes d'essais d'endurance des joints brasés des composants pour montage en surface à boîtiers de type matriciel
(CEI 62137-4:2014)

Montageverfahren für elektronische Baugruppen - Teil 4: Oberflächenmontierbare Bauteilgehäuse mit Flächenmatrix - (Lebens-)Dauerprüfungen für Lötverbindungen
(IEC 62137-4:2014)

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Foreword

The text of document 91/1188/FDIS, future edition 1 of IEC 62137-4, prepared by IEC/TC 91 "Electronics assembly technology" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62137-4:2014.

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)	2015-08-13
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-11-13

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 62137:2004.

Endorsement notice

The text of the International Standard IEC 62137-4:2014 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 60068-1:1988+A1:1992	NOTE	Harmonized as EN 60068-1:1994 (not modified).
IEC 60068-2-2	NOTE	Harmonized as EN 60068-2-2.
IEC 60068-2-6	NOTE	Harmonized as EN 60068-2-6.
IEC 60068-2-21:2006	NOTE	Harmonized as EN 60068-2-21:2006 (not modified).
IEC 60068-2-27	NOTE	Harmonized as EN 60068-2-27.
IEC 60068-2-44:1995	NOTE	Harmonized as EN 60068-2-44:1995 (not modified).
IEC 60068-2-58:2004	NOTE	Harmonized as EN 60068-2-58:2004 (not modified).
IEC 60068-2-78:2001	NOTE	Harmonized as EN 60068-2-78:2001 [1)] (not modified).
IEC 60749-1:2002	NOTE	Harmonized as EN 60749-1:2003 (not modified).
IEC 60749-20:2008	NOTE	Harmonized as EN 60749-20:2009 (not modified).
IEC 60749-20-1:2009	NOTE	Harmonized as EN 60749-20-1:2009 (not modified).
IEC 61188-5-8	NOTE	Harmonized as EN 61188-5-8.
IEC 61189-3:2007	NOTE	Harmonized as EN 61189-3:2008 (not modified).
IEC 61189-5	NOTE	Harmonized as EN 61189-5.
IEC 61190-1-1	NOTE	Harmonized as EN 61190-1-1.
IEC 61190-1-2	NOTE	Harmonized as EN 61190-1-2.
IEC 61760-1:2006	NOTE	Harmonized as EN 61760-1:2006 (not modified).
IEC 62137-1-3	NOTE	Harmonized as EN 62137-1-3.
IEC 62137-1-4:2009	NOTE	Harmonized as EN 62137-1-4:2009 (not modified).

[1)] Superseded by EN 60068-2-78:2013 (IEC 60068-2-78:2012): DOW = 2015-12-03.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When 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 60068-2-14	-	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 device 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)	EN 60191-6-5	-
IEC 60194	-	Printed board design, manufacture and assembly - Terms and definitions	EN 60194	-
IEC 61190-1-3	-	Attachment materials for electronic assembly - Part 1-3: Requirements for electronic grade solder alloys and fluxed and non-fluxed solid solders for electronic soldering applications	EN 61190-1-3	-
IEC 61249-2-7	-	Materials for printed boards and other interconnecting structures - Part 2-7: Reinforced base materials, clad and unclad - Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad	EN 61249-2-7	-
IEC 61249-2-8	-	Materials for printed boards and other interconnecting structures - Part 2-8: Reinforced base materials, clad and unclad - Modified brominated epoxide woven fibreglass reinforced laminated sheets of defined flammability (vertical burning test), copper-clad	EN 61249-2-8	-

Publication	Year	Title	EN/HD	Year
IEC 62137-3	2011	Electronics assembly technology - Part 3: Selection guidance of environmental and endurance test methods for solder joints	EN 62137-3	2012

CONTENTS

ELECTRONICS ASSEMBLY TECHNOLOGY –

Part 4: Endurance test methods for solder joint of area array type package surface mount devices

1 Scope

This part of IEC 62137 specifies the test method for the solder joints of area array type packages mounted on the printed wiring board to evaluate solder joint durability against thermo-mechanical stress.

This part of IEC 62137 applies to the surface mounting semiconductor devices with area array type packages (FBGA, BGA, FLGA and LGA) including peripheral termination type packages (SON and QFN) that are intended to be used in industrial and consumer electrical or electronic equipment.

An acceleration factor for the degradation of the solder joints of the packages by the temperature cycling test due to the thermal stress when mounted, is described Annex A.

Annex H provides some explanations concerning various types of mechanical stress when mounted.

The test method specified in this standard is not intended to evaluate semiconductor devices themselves.

NOTE 1 Mounting conditions, printed wiring boards, soldering materials, and so on, significantly affect the result of the test specified in this standard. Therefore, the test specified in this standard is not regarded as the one to be used to guarantee the mounting reliability of the packages.

NOTE 2 The test method is not necessary, if there is no stress (mechanical or other) to solder joints in field use and handling after mounting.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-14, *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 device 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 60194, *Printed board design, manufacture and assembly – Terms and definitions*

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

IEC 61249-2-7, *Materials for printed boards and other interconnecting structures – Part 2-7: Reinforced base materials clad and unclad – Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad*

IEC 61249-2-8, *Materials for printed boards and other interconnecting structures – Part 2-8: Reinforced base materials clad and unclad – Modified brominated epoxide woven fibreglass reinforced laminated sheets of defined flammability (vertical burning test), copper-clad*

IEC 62137-3:2011, *Electronics assembly technology – Part 3: Selection guidance of environmental and endurance test methods for solder joints*

3 Terms definitions and abbreviations

3.1 Terms and definitions

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

3.1.1
temperature cycling life
period of time to reach a lost performance state as agreed between the trading partners during the temperature cycling test

3.1.2
momentary interruption detector
instrument capable to detect an electrical discontinuity in the daisy chain circuits

Note 1 to entry: See Annex B for the electrical continuity test of solder joint.

3.2 Abbreviations

FBGA Fine-pitch ball grid array

BGA Ball grid array

FLGA Fine-pitch land grid array

LGA Land grid array

SON Small outline non-leaded package

QFN Quad flat-pack non-leaded package

SMD Surface mounting device

OSP Organic solderability preservative

FR-4 Flame retardant type 4

FEA Finite element method analysis

CGA Column grid array

4 General

The regions of the solder joints to be evaluated are shown in Figure 1. The test method in this standard is applicable to evaluate the durability of the solder joints against thermal stress to the package mounted on substrate but not to test the mechanical strength of the package itself.

Therefore, the conditions for accelerated stress conditioning by a temperature cycling test may exceed the maximum allowable temperature range for the package.

The test method specified in this standard is mainly applicable to the solder joint between substrates of printed wiring board and the package as an evaluation target. However, the test results depend on conditions such as the mounting method and the condition, materials and the printed wiring board, etc. See Annex C to Annex G.

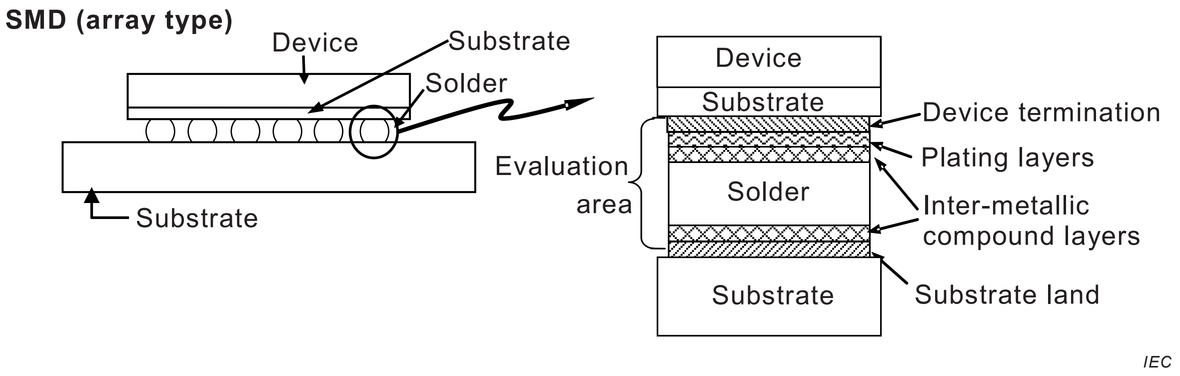


Figure 1 – Region for evaluation of the endurance test

5 Test apparatus and materials

5.1 Specimen

Specimen is the package mounted on the test substrate (refer to Clause 6 for preparation).

5.2 Reflow soldering equipment

The reflow soldering equipment shall be able to realize the reflow soldering temperature profile specified in Clause 6. Examples of temperature profile are shown in Figure 2 and Figure 3.

NOTE A standard mounting process for the package is shown in Annex G.

5.3 Temperature cycling chamber

The temperature cycling chamber shall be able to realize the temperature cycling profile specified in Figure 4. The general requirements for the temperature cycling chamber are specified in IEC 60068-2-14.

5.4 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 of 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.

5.5 Test substrate

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 wiring 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.

NOTE 1 Heat resistance to reflow soldering for the test substrate is described in Annex E.

b) Test substrate dimensions

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

c) Land shape and land dimensions

Land shape and land dimensions should be as specified in IEC 61188-5-8 or as recommended by the package manufacturer.

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.

NOTE 2 Annex D provides a test substrate design guide.

NOTE 3 Annex C provides a solderability test for the substrate land. And Annex F provides a strength test for the substrate land.

d) Surface finish of land pattern

If specified in the product specification, a solderable region (land pattern of the test substrate) shall be treated suitably against oxidization, for example, by means of an organic solderability preservative (OSP) layer. The surface protection shall not interfere with the solderability of the land pattern being soldered by using the reflow soldering equipment specified in 5.2.

5.6 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 on 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.

6 Specimen preparation

The package shall be mounted on the test substrate using the following reflow soldering process. The package for the specimen shall be modified as for test dummy package to form a daisy chain circuit with a land pattern of the test substrate after reflow soldering.

NOTE The solderability test to confirm the termination of the package and the test substrate land which affects the solder joint strength is described in Annex C.

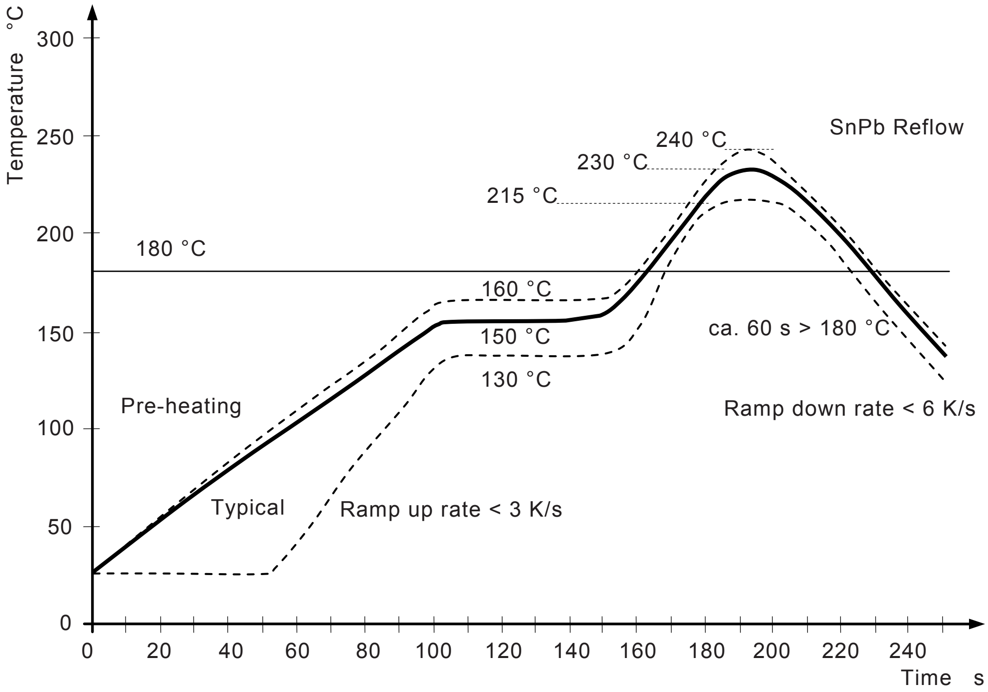
The specimen preparation process and the conditions are as follows.

a) Unless otherwise specified in the product specification, the solder paste specified in 5.6 shall be printed on the test substrate land specified in 5.5, using a stencil made of stainless steel being 120 μm to 150 μm thick, and that have the same aperture dimensions as the dimensions, shape and arrangement of the test substrate land.
b) The package shall be placed onto the printed solder paste.

c) The reflow soldering equipment specified in 5.2 shall be used for soldering the package terminals under the conditions shown in Figure 2 or Figure 3. The measuring point of the temperature shall be on the land portion.

Figure 2 shows an example of a typical reflow soldering profile using Sn63Pb37 solder alloy, as stated in IEC 61760-1:2006, Figure 13.

Figure 3 shows an example of a typical reflow soldering profile using Sn96,5Ag3Cu,5 solder alloy, as stated in IEC 61760-1:2006, Figure 14.

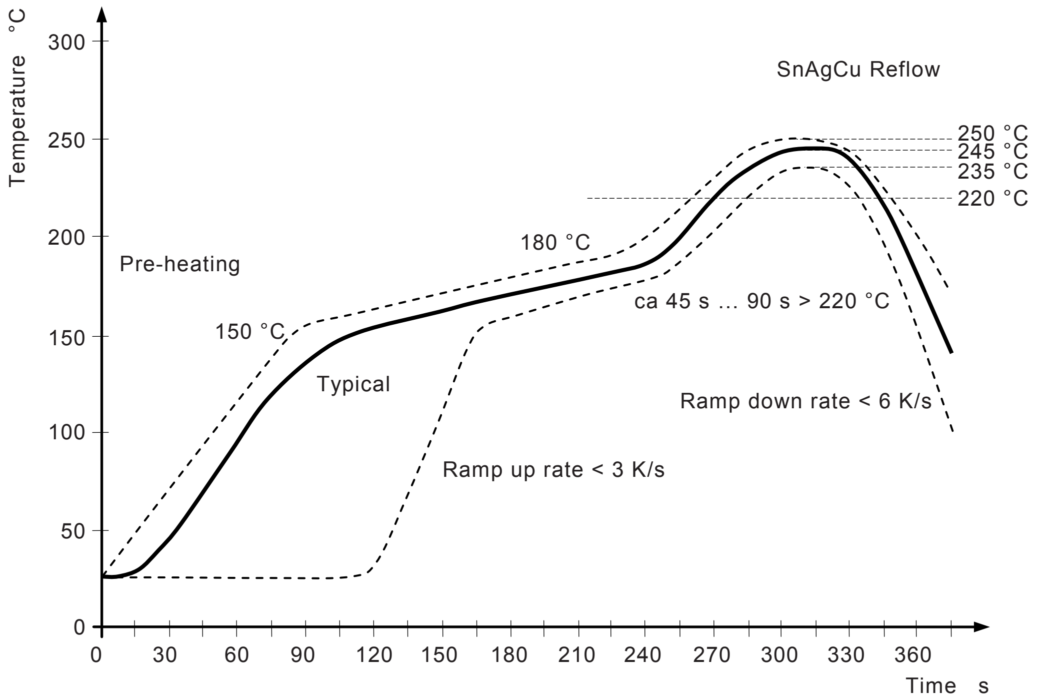


Continous line: typical process (terminal temperature)

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

IEC

Figure 2 – Typical reflow soldering profile for Sn63Pb37 solder alloy



Continous line: typical process (terminal temperature)

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

IEC

Figure 3 – Typical reflow soldering profile for Sn96,5Ag3Cu,5 solder alloy

7 Temperature cycling test

7.1 Pre-conditioning

If the specimen needs to be cleaned, the product specification should specify the cleaning method.

7.2 Initial measurement

The specimen shall be subjected to visual examination. There shall be no defect, which may impair the validity of the test.

Electrical resistance as electrical continuity of the specimen (daisy chain circuit) shall be confirmed using the momentary interruption detector specified in 5.4.

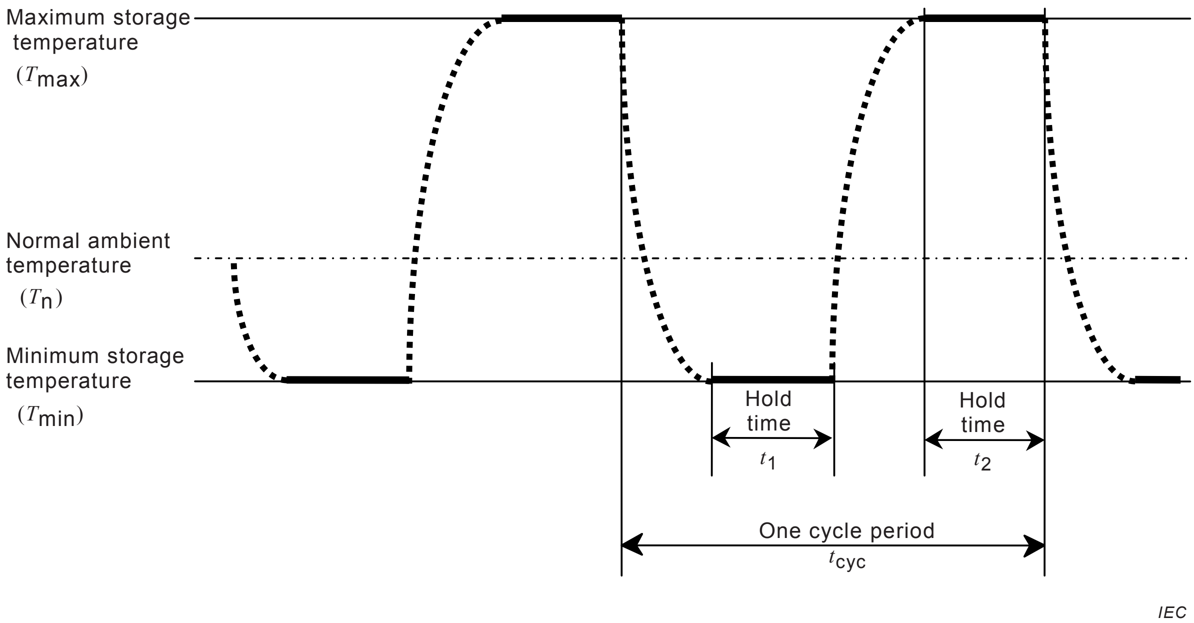
7.3 Test procedure

The temperature cycling test is according to test Na (rapid change of temperature within the prescribed time of transfer) specified in IEC 60068-2-14 with the following details.

Place the specimen in the temperature cycling chamber where the best airflow is obtained and where there is sufficient airflow around the specimen.

The test condition shall be selected from Figure 4 and Table 1, and the test shall be performed to the specified cycles in the product specification.

The electrical resistance of the daisy chain circuit shall be monitored continuously during the test using the momentary interruption detector specified in 5.4.



Key

T_{max}	Maximum storage temperature	t_1	Hold time at T_{min}
T_n	Normal ambient temperature	t_2	Hold time at T_{max}
T_{min}	Minimum storage temperature	t_{cyc}	One temperature cycle

Figure 4 – Test conditions of temperature cycling test

Table 1 – Test conditions of temperature cycling test

Step	Test condition A	Test condition B	Test condition C	Test condition D
Minimum storage temperature: T_{min} °C	−40 ± 5	−25 ± 5	−30 ± 5	$T_{op,\ min}$ ± 5
Maximum storage temperature: T_{max} °C	125 ± 5	125 ± 5	80 ± 5	$T_{op,\ max}$ ± 5
Hold time: t_1, t_2	$t_1 = t_2 \geq 7$ min for Sn63Pb37 solder alloy $t_1 \leq 30$ min, $t_2 \geq 15$ min for Sn96,5Ag3Cu,5 solder alloy			
For Sn96,5Ag3Cu,5 solder alloy, the dwell time in the temperature cycling chamber shall be set to 30 min at maximum storage temperature, including the hold time t_2; 15 min for stress relaxation and 15 min for stable temperature. Refer to IEC 62137-3:2011, Annex A. At minimum storage temperature, it may not be necessary that the stress relaxation be 15 min. It is acceptable to set the hold time: t_1 to equal or less than 30 min. Maximum period of transfer time from one chamber to another shall not be more than 3 min as described in IEC 60068-2-14. The condition setting of the temperature cycling test should be adopted in the product specification as listed below. – The test condition can be reproduced, the defect mode is supposed in the field condition. – The test condition can be correlated to linear acceleration to the field condition. – The test condition can be correlated to a nearby conventional specification. – The test condition can be a shortened test period.				
NOTE $T_{op,\ min}$ is the minimum operating temperature of the specimen. $T_{op,\ max}$ is the maximum operating temperature of the specimen. The hold time starts when the temperature of the specimen reaches the specified value. The transition time from maximum storage temperature to minimum storage temperature and vice versa is included in the one cycle period.				

7.4 End of test criteria

The test shall continue until the electrical resistance of the daisy chain circuit within all or a specified number of specimens increases, caused by a solder joint break, or because the number of test cycles has been reached, as specified.

The criteria of the increased electrical resistance value shall be specified in the product specification. The threshold value of the increased electrical resistance should be defined as percentage of the typical resistance of the daisy chain circuit within the specimen at maximum storage temperature, or the fixed value of the higher electrical resistance, 1 000 Ω.

7.5 Recovery

If it is necessary to arrange the measurement condition, the specimen shall be placed, after the test, under the final measurement conditions, as specified in the product specification.

The product specification may prescribe a specific recovery period such as cooling down and a stabilized temperature for the specimen.

7.6 Final measurement

The specimen shall be subjected to visual inspection. There shall be no defect, which may impair the test result.

The electrical resistance of the daisy chain circuit shall be confirmed using the momentary interruption detector as electrical resistance measuring instrument specified in 5.4.

8 Temperature cycling life

When the electrical resistance of the daisy chain circuit increases caused by the solder joint break, the number of test cycles at that moment is the number of failure cycles of the specimen.

Statistically, the temperature cycling life should be determined as mean life or characteristic life of the Weibull distribution resulting from the failure cycles data of the specimens. Similarly, the life time shall be calculated from the test result of the specimens specified by the number of samples as indicated in the product specification.

Using the test result and acceleration factor, the life time in the field can be estimated. However, the acceleration factor depends on the conditions such as package dimensions, materials and the printed wiring board, etc. The acceleration factor shall be estimated individually between the field condition and the accelerated temperature cycling condition. See Annex A.

9 Items to be specified in the relevant product specification

The following items shall be specified in the product specification.

a) Specification of the test substrate (see 5.5)
b) Solder paste (see 5.6)
c) Specimen preparation (see Clause 6)
d) Pre-treatment conditions (if necessary) (see 7.1)
e) Items and conditions of initial measurement (see 7.2)
f) Test conditions (see 7.3)

g) Hold time, transition time and transfer time at low and high temperatures and at normal ambient temperature (if different from 7.3) (see 7.3).

h) Whether or not to continuously monitor the electrical resistance (see 7.3)

i) End of test criteria (number of repetitive cycles) (see 7.4)

j) Recovery (see 7.5)

k) Items and conditions of final measurement (see 7.6)

l) Temperature cycling life and the condition of calculation (see Clause 8)

Annex A
(informative)

Acceleration of the temperature cycling test for solder joints

A.1 General

This annex describes the acceleration characteristic to evaluate durability in the field from the temperature cycling test results of solder joints.

A.2 Acceleration of the temperature cycling test for an Sn-Pb solder joint

The temperature cycling test specified in the standard is mainly applied when obtaining the temperature cycling life at the solder joint between the device and the substrate. A modified Coffin-Manson's law is conventionally used to obtain thermal fatigue life as the temperature cycling life of the solder joint. It can conveniently be expressed as shown in Equation (A.1).

$$NF = C \times f^{m} \times (\Delta\varepsilon_{\mathrm{in}})^{-n} \times \exp\left(\frac{H}{kT_{\mathrm{max}}}\right) \quad \text{(A.1)}$$

where

- NF is the number of failure cycles (thermal fatigue life)
- C is the material constant
- f is the On/Off frequency (cycles/day)
- m is the frequency parameter
- $\Delta\varepsilon_{\mathrm{in}}$ is the inelastic strain range of thermal fatigue
- n is the material constant (inverse of fatigue elongation exponent)
  It is known that the soldering life is inversely proportional to the inelastic strain range of thermal fatigue.
- k is the Boltzmann constant: 8,617 385 × 10^{-5} (eV/K)
- H is the activation energy of solder (eV)
  The temperature dependence is expressed by exponential law
- T_{max} is the maximum test temperature (K)

An acceleration factor: AF of the temperature cycling test under test and in field conditions is given as shown in Equation (A.2).

$$AF = \left[\frac{f_{\mathrm{f}}}{f_{\mathrm{t}}}\right]^{m} \times \left[\frac{\Delta T_{\mathrm{f}}}{\Delta T_{\mathrm{t}}}\right]^{-n} \times \exp\left[\frac{H}{k} \times \left(\frac{1}{T_{\mathrm{max}-f}} - \frac{1}{T_{\mathrm{max}-t}}\right)\right] \quad \text{(A.2)}$$

where

- f_{f} is the number of On/Off cycles in the field (cycles/day)
- f_{t} is the number of On/Off cycles under the test condition (cycles/day)
- ΔT_{f} is the temperature variation in the field (°C)
- ΔT_{t} is the temperature variation under test condition (°C)
- $T_{\mathrm{max}\text{-}f}$ is the maximum temperature in the field (K)
- $T_{\mathrm{max}\text{-}t}$ is the maximum temperature under test condition (K)

In the case of Sn-Pb solder joint, H is the activation energy of the solder which is 0,123 eV, k is a Boltzmann constant, m is 1/3, and n is 1,9 in general.

Table A.1 shows an example of temperature cycling test results of the acceleration factor in specific field conditions related to the temperature cycling test conditions.

Table A.1 – Example of test results of the acceleration factor (Sn63Pb37 solder alloy)

Conditions	T_{min}	T_{max}	ΔT	Temperature cycling frequency (cycles per day) [a]	Number of temperature cycles		Test result (acceleration factor in the field condition) [b]
	°C	°C	°C		5 years	10 years	
Field	25	70	45	1	1 825	3 650	–
A	−40	125	165	72	365	730	5,0
B	−25	125	150	72	435	869	4,2
C	−30	80	110	72	1 217	2 433	1,5

[a] Calculation was made assuming the hold time at maximum and minimum storage temperatures set to 7 min and the transition time from maximum storage temperature to minimum storage temperature and vice versa set to 3 min.

[b] These calculation results are, for example, an estimation of the number of test cycles according to Equation (A.2).

NOTE The acceleration factors in Table A.1 are only applicable to the specified conditions.

Currently, it is possible that a computer simulation output using as finite element method can solve an equivalent inelastic strain range $\Delta\varepsilon_{in}$. The activation energy of solder, the fatigue elongation exponent and the acceleration factor can be obtained. The acceleration factor can be calculated from the obtained inelastic strain range instead of the temperature range ΔT of the accelerated test condition.

A.3 Temperature cycling life prediction method for an Sn-Ag-Cu solder joint

In the case of an Sn96,5Ag3Cu,5 solder alloy, a state of the art of fatigue life prediction model for lead-free solder is proposed that considers the microstructural characteristics of the Sn96,5Ag3Cu,5 solder joint.

This new fatigue life prediction model is a solution of the result of the physical analysis of the Coffin-Manson's law that examined the consideration of the material scientific factors related to microstructural variety involving thermo-mechanical fatigue characteristics of the lead-free Sn96,5Ag3Cu,5 solder alloy.

On reflection, basically the Coffin-Manson's empirical law is shown in Equation (A.3).

$$\Delta\varepsilon_{in} \cdot NF^{\alpha} = C \qquad \text{(A.3)}$$

where

NF is the number of failure cycles (thermal fatigue life)

C is the fatigue ductility coefficient

$\Delta\varepsilon_{in}$ is the inelastic strain range of thermal fatigue

α is the fatigue ductility exponent (inverse of material constant n)

In the case of Sn96,5Ag3Cu,5 solder alloy, the fatigue ductility exponent α is obtained from Equations (A.4) and (A.5). And the fatigue ductility coefficient C is derived from Equation (A.6), theoretically and experimentally.

$$\alpha = 0{,}6/(n'+1) \tag{A.4}$$

where n' is cyclic strain hardening exponent which is determined by the following equation.

$$n' = A_1 \exp\left(\frac{Q}{RT}\right)\sqrt{\frac{1}{r}} \tag{A.5}$$

where

T is the maximum temperature

A_1 and Q are material constants for the cyclic strain hardening exponent

r is radius of intermetallic compound during fatigue deformation which is determined by the thermal diffusion growth and the strain-enhanced growth due to cyclic deformation during the temperature cycling.

$$C = A_2 \cdot T - A_3 \tag{A.6}$$

where A_2 and A_3 are material constants regarding the fatigue ductility coefficient.

The material constants are applied to become a function of the temperature and the microstructural factor during fatigue deformation resulting from the Equations (A.4), (A.5) and (A.6). It is possible to predict the fatigue life of the Sn96,5Ag3Cu,5 solder alloy given the temperature, time and microstructural change during the temperature cycling test by substituting the applied material constants to the Coffin-Manson's Equation (A.3).

This new fatigue life prediction model can calculate the acceleration factor AF using Equation (A.7).

$$AF = \frac{N_{\text{field}}}{N_{\text{test}}} = \frac{(C_{\text{field}}/\Delta\varepsilon_{\text{field}})^{1/\alpha_{\text{field}}}}{(C_{\text{test}}/\Delta\varepsilon_{\text{test}})^{1/\alpha_{\text{test}}}} = \left(\frac{C_{\text{field}}}{\Delta\varepsilon_{\text{field}}}\right)^{1/\alpha_{\text{field}}}\left(\frac{\Delta\varepsilon_{\text{test-max}}}{C_{\text{test-max}}}\right)^{1/\alpha_{\text{test}}} \tag{A.7}$$

where

N_{field} is the number of failure cycles in the field condition (cycles)

N_{test} is the number of failure cycles under test condition (cycles)

C_{field} is the material constant in the field condition

C_{test} is the material constant under test condition

$\Delta\varepsilon_{\text{field}}$ is the inelastic strain range of thermal fatigue in the field

$\Delta\varepsilon_{\text{test}}$ is the inelastic strain range of thermal fatigue under test condition

α_{field} is the fatigue elongation exponent in the field

α_{test} is the fatigue elongation exponent under test condition

NOTE The temperatures T in the field and test condition are each maximum temperatures.

Table A.2 shows an example of temperature cycling test results of the acceleration factor in specific field conditions related to the temperature cycling test conditions.

Table A.2 – Example test results of the acceleration factor (Sn96,5Ag3Cu,5 solder alloy)

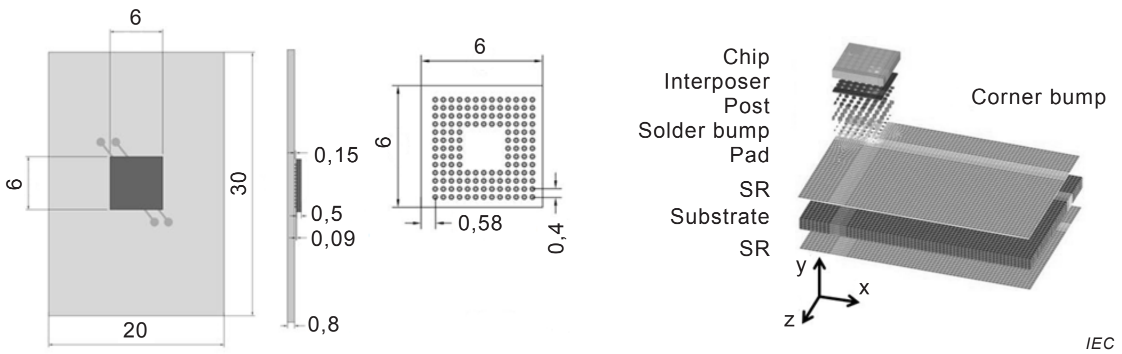
Conditions	T_{min}	T_{max}	ΔT	Temperature cycling frequency (cycles per day) [a]	Number of temperature cycles		Test result (acceleration factor in the field condition) [b]
	°C	°C	°C		5 years	10 years	
Field	25	70	45	1	1 825	3 650	–
A	–40	125	165	40	119	239	15,3
B	–25	125	150	40	135	270	13,5
C	–30	80	110	40	493	986	3,7

[a] The calculation was made assuming that the hold time at maximum and minimum storage temperatures is set to 15 min and the transition time from maximum storage temperature to minimum storage temperature and vice versa is set to 3 min.

[b] These calculation results are, for example, an estimation of the number of test cycles using FBGA package devise mounting on the FR-4 test substrate based on Equation (A.7).

NOTE The acceleration factors in Table A.2 are only applicable in the specified conditions.

The acceleration factors AF are calculated by a finite element analysis about the FBGA package device using this fatigue life model. An example is shown in Figure A.2. The acceleration factors AF are different for each test temperature range caused by two different mount substrate materials, between FR-4 and alumina, as shown in Figure A.1.



Units are in millimetres.

Figure A.1 – FBGA package device and FEA model for calculation of acceleration factors AF

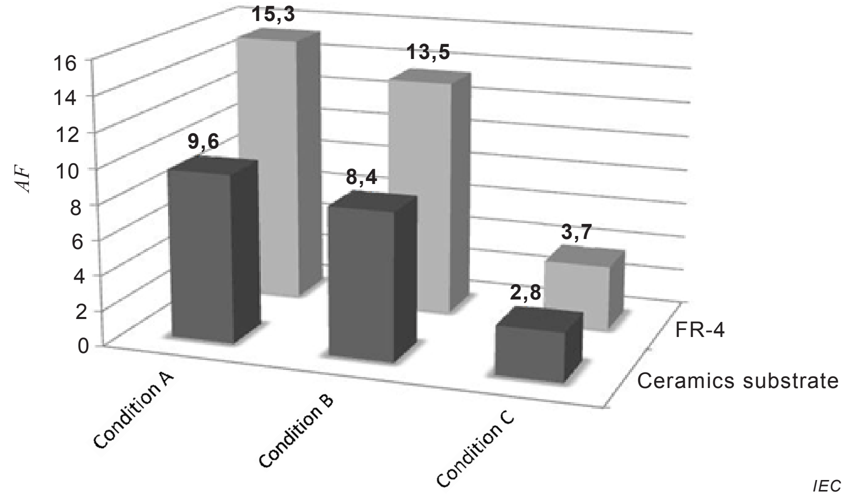


Figure A.2 – Example of acceleration factors AF with an FBGA package device using Sn96,5Ag3Cu,5 solder alloy

The fatigue life prediction model mentioned above is derived to consider a physical meaning of fatigue fracture behaviour from the fatigue test data of the Sn96,5Ag3Cu,5 solder joint, under the various temperature and the stress conditions. The fatigue characteristics reveal a state of alloy microstructure within the micro solder joint, using the fatigue test results of a single solder ball joint specimen such as BGA. They are shown in Figure A.3. The material constant of Equation (A.7) and the inelastic strain range of solder are listed in Table A.3. The material constant was determined according to Equations (A.4), (A.5) and (A.6) using experimental data as shown in Figure A.3.

Table A.3 – Material constant and inelastic strain range calculated by FEA for FBGA package devices as shown in Figure A.1 (Sn96,5Ag3Cu,5 solder alloy)

Conditions	Fatigue ductility exponent α	Fatigue ductility coefficient C	Inelastic strain range of solder	
			FR-4	Ceramics
Field	0,54	0,33	0,005	0,001 5
Condition A	0,53	0,44	0,03	0,007 1
Condition B	0,53	0,44	0,028	0,006 6
Condition C	0,51	0,35	0,013	0,003 6

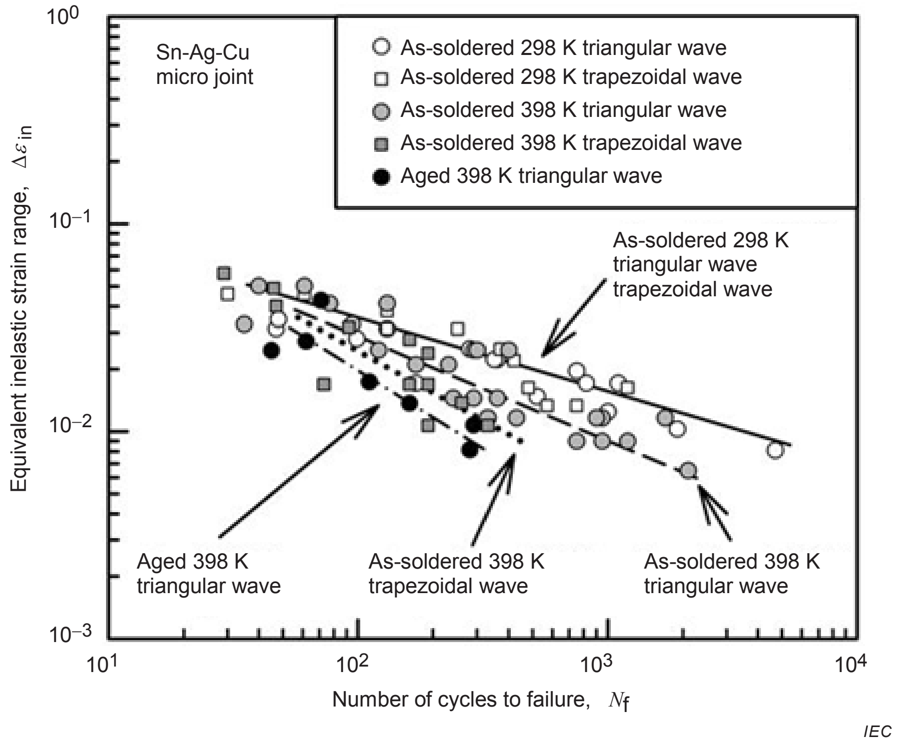


Figure A.3 – Fatigue characteristics of Sn96,5Ag3Cu,5 an alloy micro solder joint (N_f = 20 % load drop from initial load)

A.4 Factor that affects the temperature cycling life of the solder joint

To analyse the test data so as to predict the acceleration characteristic in the field use, it is desirable to carry out the statistical process in the Weibull distribution, log normal distribution, etc.

Solder, both the thickness and the layer configuration of the substrate, as well as the packaging density on the substrate, significantly affect the temperature cycling life of the solder joint with the package being mounted on the substrate. It is well known that the temperature cycling life becomes about half, especially when the area array type packages are mounted on the same area of both sides of the substrate.

When the packages subject to the evaluation test can be mounted on a double sided substrate, it is recommended to evaluate the life of the solder joint with the packages mounted on the same area of both sides of the substrate.

Annex B
(informative)

Electrical continuity test for solder joints of the package

B.1 General

This annex describes a test that allows to evaluate the solder joint durability of the package using electrical continuity.

B.2 Package and daisy chain circuit

The package for this test is a dummy package within which terminations are connected as shown in Figure B.1. All the terminations of the specimen and of the test substrate are connected alternately to form a daisy chain circuit after reflow soldering.

It is highly recommended that the structure of the package for this test has the same structure as that of the actual package to be evaluated.

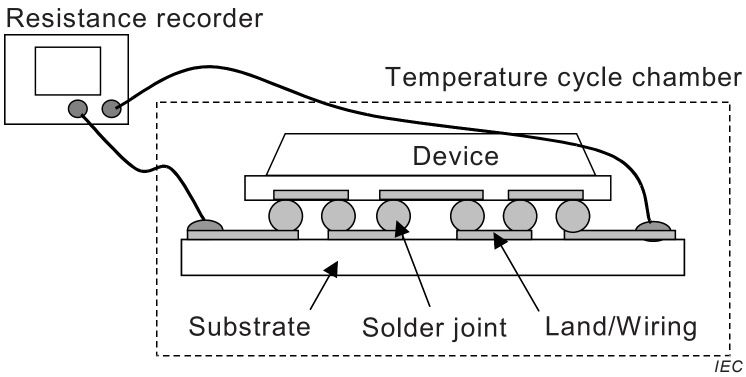


Figure B.1 – Example of a test circuit for the electrical continuity test of a solder joint

B.3 Mounting condition and materials

The specimen should be made according to the procedure specified in Clause 6 using test apparatus and the materials specified in Clause 5.

B.4 Test method

Measure the electrical resistance of the daisy chain before and after the accelerated stress conditioning specified in Clause 7 to evaluate the presence of a solder joint break. The resistance value of the daisy chain should be continuously monitored to find the degree of degradation of solder joints. It is desirable to continue the resistance measurement until a solder joint break is detected.

B.5 Temperature cycling test using the continuous electric resistance monitoring system

When evaluating the life of the solder joint on the substrate, conventionally, a failure such as the development of a crack was presumed by measuring the contact electrical resistance of the specimen outside the temperature cycling chamber, in normal ambient temperature at certain moments. However, for the area array type packages subject to the evaluation of this standard, as shown in Figure B.2, a failure occurs at high temperatures as "open" indicated by infinite electrical resistance, but it recovers to normal resistance at normal ambient temperature.

Therefore, it is desirable during the temperature cycling test to monitor the electrical resistance continuously.

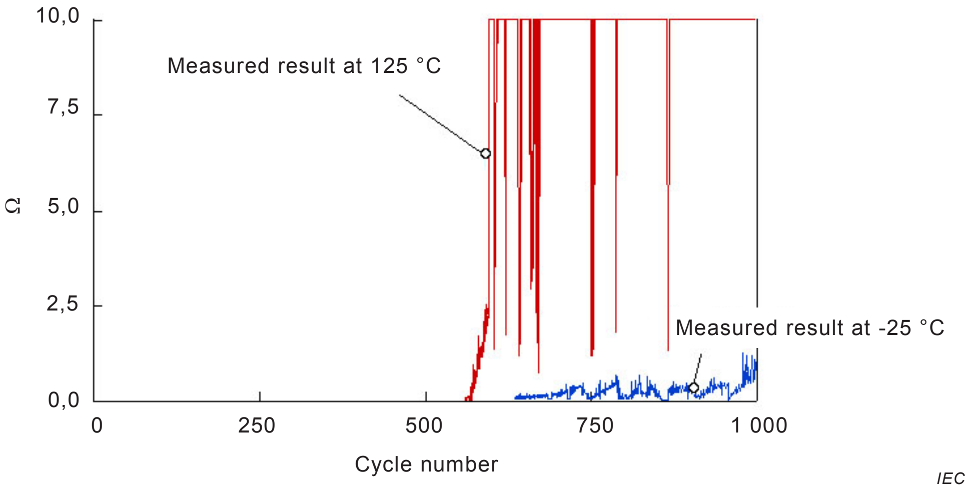


Figure B.2 – Measurement example of continuously monitored resistance in the temperature cycling test

Annex C
(informative)

Reflow solderability test method for package and test substrate land

C.1 General

This annex gives an explanation to the test method for the reflow solderability of packages.

C.2 Test equipment

C.2.1 Test substrate

The test substrate should be as specified in 5.5.

C.2.2 Pre-conditioning oven

The pre-conditioning oven can maintain the conditions specified in the product specification for a long time.

The humidifier should maintain the temperature and humidity as specified in the product specification for a long time. The material of the oven at high temperature should not react. The water used for the test should be purified water or de-ionized water, with resistivity of 5 000 Ωm (0,5 MΩ·cm) or higher (conductivity of 2 μS/cm or less). The equipment should performed test according to IEC 60068-2-78.

C.2.3 Solder paste

The solder paste should be as specified in 5.6.

C.2.4 Metal mask for screen printing

The metal mask for screen printing should be as described in G.2.3.

C.2.5 Screen printing equipment

The screen printing equipment should be capable of solder printing as described in G.2.4.

C.2.6 Package mounting equipment

The package mounting equipment should be capable of mounting the packages as described in G.3.3.

C.2.7 Reflow soldering equipment

The reflow soldering equipment should meet the heating process conditions specified in Figure 2 or Figure 3. The temperature of the specimen should be measured at thermocouple measuring point A (the centre on the top of the package) and thermocouple measuring point B (the soldered inner part of the terminal), shown in Figure C.1.

Each thermocouple wire should be routed in such a way that there is no interference and no influence to the temperature measurement.

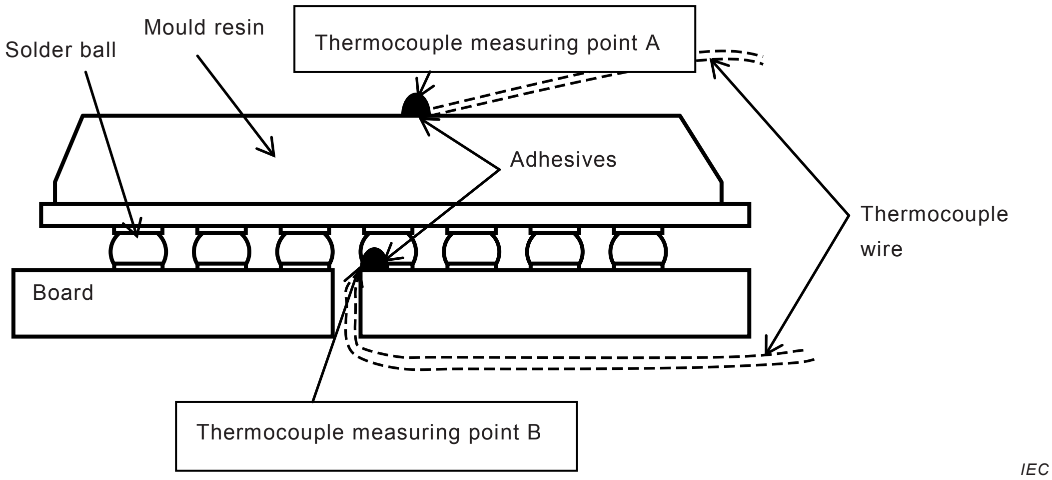


Figure C.1 – Temperature measurement of specimen using thermocouples

C.2.8 X-ray inspection equipment

The X-ray inspection equipment should be able to transparently observe the area array type packages being mounted on the test substrate.

C.3 Standard mounting process

C.3.1 Initial measurement

The initial measurement of the electrical characteristics of the specimen should be carried out according to the items and conditions specified in the product specification. Also, a visual inspection of the specimen, magnified 10×, should be carried out.

C.3.2 Pre-conditioning

When the product specification specifies the pre-conditioning as a moisture treatment, this pre-conditioning should be carried out under the specified conditions.

In the case where multiple reflow heating is specified in the product specification, the moisture treatment of the specimen should be repeated under the following specified conditions.

The multiple reflow heating methods are as follows.

a) The multiple reflow heating is repeated after the moisture treatment.
b) The moisture treatment and the reflow heating are performed one after the other.

C.3.3 Package mounting on test substrate

The package mounted on the test substrate becomes the specimen according to the standard mounting process described in Annex G. For Sn63Pb37 solder alloy, apply the reflow heating process that meets the reflow temperature profile in Figure 2. For Sn96,5Ag3Cu,5 solder alloy, apply the reflow temperature profile in Figure 3.

When the specimen is subjected to the multiple reflow heating process, apply the same reflow heating process as above.

C.3.4 Recovery

At the end of the test, and if necessary, the recovery process specified in the product specification should be carried out on the specimen.

C.3.5 Final measurement

Measure the electrical characteristics of the specimen according to the product specification. Also, a visual inspection of the specimen, magnified 10×, should be carried out.

The following items should then be checked:

- insufficient solder wetting;
- repelled solder;
- solder ball drop out;
- solder dissolution.

Then, using X-ray inspection equipment, check the soldered condition. If necessary, observe the cross-sectional view after the casting process in a resin.

C.4 Examples of faulty soldering of area array type packages

C.4.1 Repelled solder by contamination on the ball surface of the BGA package

Figure C.2 shows an example of a cross-sectional view of repelled solder caused by contamination on the solder ball surface. The solder ball surface was examined and the contamination was found to be organic material.

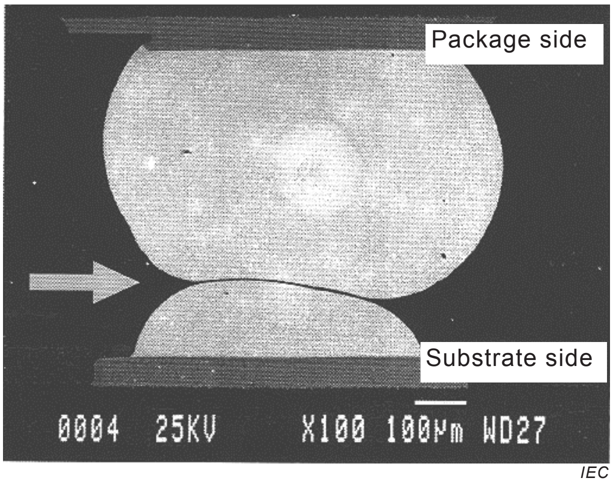
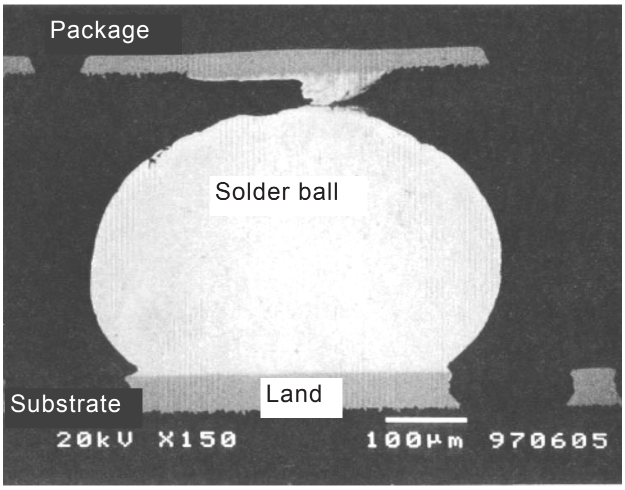


Figure C.2 – Repelled solder caused by contamination on the solder ball surface

C.4.2 Defective solder ball wetting caused by a crack in the package

Figure C.3 shows a defective soldering as a result of the solder ball drop caused by the moistening of the package.



IEC

Figure C.3 – Defective soldering as a result of a solder ball drop

C.5 Items to be given in the product specification

The following items should be specified in the product specification.

a) Solder paste printing conditions (if different from C.2.3).

b) Metal mask specifications (if different from C.2.4).

c) Items and conditions of initial measurement (see C.3.1).

d) Pre-conditioning conditions (if necessary) (see C.3.2).

e) Reflow heating process conditions (if different from C.3.3).

f) Multiple reflow was done or not, and moisture treatment conditions (see C.3.3).

g) Recovery conditions (if necessary) (see C.3.4).

h) Items and conditions of final measurement (see C.3.5).

Annex D
(informative)

Test substrate design guideline

D.1 General

This annex gives an explanation to the test substrate design guideline. It applies to the design guideline of the printed wiring board to be used to evaluate the durability of packages.

In the case of the substrate, both of thickness and the layer configuration, as well as the mount congestion on the substrate, significantly affect the temperature cycling durability of the solder joint with the package being mounted on the substrate. It is well known that the durability of solder joint becomes about half particularly when the area array type packages are mounted on the same area of both sides of the substrate.

When the packages subject to the evaluation test are mounted on a double side of the printed wiring board, it is recommended to evaluate the life of the soldering with the components mounted on both sides of the substrate.

D.2 Design standard

D.2.1 General

The items listed below shall be taken into account for the design standard of the test substrate.

a) Classification of the substrate specification (see D.2.2 and D.2.4).
b) Test substrate thickness, number of layers, copper foil thickness.
c) Material of the test substrate (see D.2.3).
d) Land shape, land size and the surface finish (see D.2.5 and D.2.6).

D.2.2 Classification of substrate specifications

D.2.2.1 Types of classification of the test substrate

Both the substrate thickness and the number of layers of the test substrate applicable to the area array type packages are to be determined by selecting the appropriate type in Table D.1, according to the usage of the evaluation package subject to the test.

Table D.1 – Types classification of the test substrate

Types		Type A	Type B	Type C	Type D	Type E
Example of application		Cell phones, video cameras, recorders, etc.	Notebook type PCs, etc.	Desktop type PCs, etc.	Server, Telecommunications equipment, etc.	Pre-test, General
Substrate thickness		0,6 mm to 0,8 mm	1,0 mm to 1,2 mm	1,6 mm	2,4 mm	Not specified
Number of layers		4 layers or more	4 layers or more	4 layers or more	6 layers or more	1 layer or more
Terminal pitch	1,27 mm		X	X	X	X
	1,00 mm		X	X	X	X
	0,80 mm	X	X			X
	0,75 mm	X	X			X
	0,65 mm	X	X			X
	0,50 mm	X	X			X
	≤ 0,40 mm	X				X
Standard copper foil thickness (outer layer/ inner layer)[a]	18 μm/12 μm	X	X			X
	35 μm/18 μm		X	X	X	X

NOTE 1 Because the thickness and the number of layers of the substrates affect the solder joint reliability, the substrate types have been classified as types A through E.

NOTE 2 The substrate design significantly depends on the terminal pitch of the component to be mounted. Therefore, the table shows the example of applications and the terminal pitch which corresponds to the application. The checked mark "X" indicates the major applications.

NOTE 3 The copper foil thickness significantly depends on the terminal pitch of the component to be mounted. It also significantly depends on the method of the substrate manufacturing process. For this reason, this table gives two kinds of copper foil thicknesses for type B.

[a] Nominal dimensions.

D.2.2.2 General comment

In general, thicker test substrates result in the degradation of the durability of the solder joint in the temperature cycling test. In view of the mechanical strength, the stress of the solder joint tends to decrease with the increase of the substrate thickness. It is therefore recommended to select the test substrate type according to the intended application and by paying attention to the requirements for test quality.

The copper foil thickness significantly depends on the pattern layout of the substrate, and also on the methods of the substrate manufacturing process. In order to increase the reliability of the solder joint, it is better to make the copper foil thicker. If this is the case, the terminal pitch becomes shorter, and it becomes difficult to print fine patterns. For the standard copper foil thickness, if the line to space ratio (line/space) of the printed pattern on the substrate needs to be set to 100/100 μm or less, it becomes necessary to produce thinner copper foil. It is assumed that such a process may be applied to the terminal pitch of an area array type of 0,8 mm pitch or less. In case of the terminal pitch which is more than 0,8 mm, the copper foil thickness will be more or less 18 μm when a build-up substrate is used. The copper foil thickness, when the thickness of the copper plating at the through-hole section is added, will be about 35 μm for the substrate in the conventional subtractive process. The substrates of Types A and B may have a build-up substrate. Therefore, a standard copper foil thickness of 18 μm is also included as a standard for them.

D.2.3 Material of the test substrate

The standard material of the test substrate is defined by IEC 61249-2-7 or IEC 61249-2-8 or in other standards related to material of the printed wiring board called FR-4.

D.2.4 Configuration of layers of the test substrate

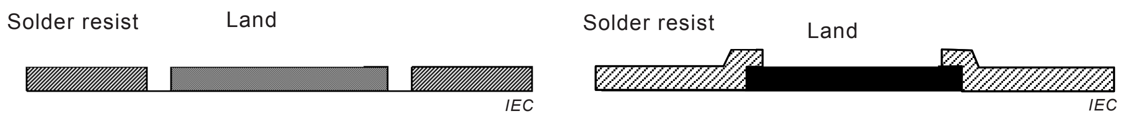
Table D.2 shows the standard layers' configuration of the test substrates.

Table D.2 – Standard layers' configuration of test substrates

<table>
<tr><th colspan="2">Types A, B, and C</th><th colspan="2">Type D</th><th colspan="2">Type E</th></tr>
<tr><td>1st layer</td><td>Signal path layer</td><td>1st layer</td><td>Signal path layer</td><td>1st layer</td><td>Signal path layer</td></tr>
<tr><td rowspan="2">2nd layer</td><td rowspan="2">Plane layer or mesh layer</td><td>2nd layer</td><td>Plane layer or mesh layer</td><td rowspan="2">2nd layer</td><td rowspan="2">Plane layer or mesh layer (optional)</td></tr>
<tr><td>3rd layer</td><td>Plane layer or mesh layer</td></tr>
<tr><td rowspan="2">3rd layer</td><td rowspan="2">Plane layer or mesh layer</td><td>4th layer</td><td>Plane layer or mesh layer</td><td rowspan="3" colspan="2"></td></tr>
<tr><td>5th layer</td><td>Plane layer or mesh layer</td></tr>
<tr><td>4th layer</td><td>Signal path layer</td><td>6th layer</td><td>Signal path layer</td></tr>
<tr><td colspan="4">If a signal path cannot be made in the 1st, 4th and/or 6th layer, use the internal plane layer or increase the number of layers.</td><td colspan="2">It is recommended to include surface plating on the 1st layer added to the starting copper foil.</td></tr>
</table>

D.2.5 Land shape of test substrate

Figure D.1 shows the standard land shapes.



NSMD (No solder mask defined) SMD (Solder mask defined)

Figure D.1 – Standard land shapes of the test substrate

The standard surface finish of the land should be copper plating covered with heat-resistant pre-flux called organic solderability preservative (OSP).

The land of the test substrate should satisfy the quality evaluation methods of both Clause C.3 and Annex F.

D.2.6 Land dimensions of the test substrate

The land dimensions of the test substrate should be defined in the product specification.

The design guidelines for the land size of the area array type packages as BGA, FBGA, LGA, and FLGA are in accordance with IEC 61188-5-8.

The relationship between the package land diameter and the test substrate land diameter should be specified for the durability of the solder joint as follows.

a) The durability of the solder joint will be increased with similar size of land diameter between the package and the test substrate.

b) The durability of the solder joint will be increased when the test substrate land diameter is slightly larger than the land diameter of the package.

D.3 Items to be given in the product specification

The following items should be specified in the product specification.

a) Type classification of the test substrate (see D.2.2).
b) Test substrate size
c) Substrate thickness (if different from D.2.2)
d) Number of substrate layers (if necessary) (see D.2.2).
e) Substrate layers configuration (if necessary) (see D.2.4).
f) Copper foil thickness (if necessary) (see D.2.2).
g) Test substrate materials (if necessary) (see D.2.2).
h) Land shape (if necessary) (see D.2.5).
i) Surface finish of land (if necessary) (see D.2.5).
j) Land dimensions (if necessary) (see D.2.6).

Annex E
(informative)

Heat resistance to reflow soldering for test substrate

E.1 General

This annex gives an explanation concering the heat resistance with respect to reflow soldering of the test substrate.

When the test substrate has not sufficient thermal stability, the test substrate may get warpage during the reflow heating process, so that the temperature cycling test cannot sufficiently evaluate the durability of the solder joints.

E.2 Test apparatus

E.2.1 Pre-conditioning oven

The pre-conditioning oven can maintain the conditions specified in the product specification for a long time.

The humidifier should maintain the temperature and humidity as specified in the product specification for a long time. 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 Ωm (0,5 MΩ· cm) or higher (conductivity of 2 μS/cm or less). The equipment should perform the test according to IEC 60068-2-78.

E.2.2 Reflow soldering equipment

The reflow soldering equipment should meet the heating process conditions specified in Figure 2 or Figure 3. Otherwise the conditions specified in the product specification should be met.

E.3 Test procedure

E.3.1 General

Soaking in moisture is not to be a major problem for the printed wiring board materials with respect to resin materials of the package. A suitable moisture treatment is therefore recommended as pre-conditioning against humidity of the test substrate to obtain moisture sensitive material only. For example, a polyimide material is moisture sensitive.

E.3.2 Pre-conditioning

When the product specification indicates that the pre-conditioning be a moisture treatment, this pre-conditioning should be carried out in accordance with the specified conditions.

E.3.3 Initial measurement

The initial measurement should be carried out by visual inspection of the test substrate specimen, magnified 10×. The following checks should be carried out.

- Substrate curving or warping.
- Solder resist stripping.

E.3.4 Moistening process (1)

The test substrate specimen should be moistened using the pre-conditioning oven specified in E.2.1 under the conditions as specified in the product specification.

E.3.5 Reflow heating (1)

Using the reflow soldering equipment specified in E.2.2, heat up the test substrate in the condition specified in the product specification. Then, the surface temperature should be measured in the centre on the test substrate.

E.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.

E.3.7 Reflow heating process (2)

Unless otherwise specified in the product specification, heat the specimen once again as indicated in E.3.4.

E.3.8 Final measurement

The final measurement should be carried out by visual inspection of the test substrate, magnifying 10×. The following items should be checked.

- Substrate curving or warping/bending.
- Substrate or solder resist stripping.
- Substrate cracking.
- Substrate swelling.

E.4 Items to be given in the product specification

The following items should be specified in the product specification.

a) Pre-conditioning conditions (if it is necessary to specify them) (see E.3.2).
b) Moistening conditions (if it is necessary to specify them) (see E.3.4 and E.3.6).
c) Reflow heating profile (if it is necessary to specify it) (see E.3.5 and E.3.7).
d) Items for final measurement (see E.3.8).

Annex F
(informative)

Pull strength measurement method for the test substrate land

F.1 General

This annex gives an explanation to the pull strength measurement method for the test substrate land.

When the test substrate has poor land pull strength, the temperature cycling test cannot sufficiently evaluate the durability of the solder joints. The following parameters have a large impact on the result.

- Pull speed.
- Temperature of attached pull strength test probe (probe heat bond method, see Figure F.1).
- Probe temperature during pull strength test (probe heat bond method, see Figure F.1).

F.2 Test apparatus and materials

F.2.1 Pull strength measuring equipment

The pull strength measuring equipment should meet the conditions of measurement described in F.3.2.

F.2.2 Reflow soldering equipment

The reflow soldering equipment should be capable of keeping the temperature as specified Clause 6. The temperature of the specimen should be measured around the land to be evaluated.

F.2.3 Test substrate

Unless otherwise specified in the product specification, the test substrate should be as indicated in 5.5, except for the daisy chain requirement.

F.2.4 Solder ball

The diameter of the solder ball used should be 60 % of the terminal pitch of the test substrate land. The composition should be equivalent to the one indicated in IEC 61190-1-3.

F.2.5 Solder paste

The solder paste should be as specified in 5.6.

F.2.6 Flux

The flux should be equivalent to the flux quality classification specified in IEC 61190-1-1.

F.3 Measurement procedure

F.3.1 Pre-conditioning

Unless otherwise specified in the product specification, the reflow heating process as specified in Clause 6 should be applied twice to the test substrate.

F.3.2 Solder paste printing

The solder paste should be printed on the test substrate land according to G.3.2.

F.3.3 Solder ball placement

The solder ball should be placed on the solder paste printed land.

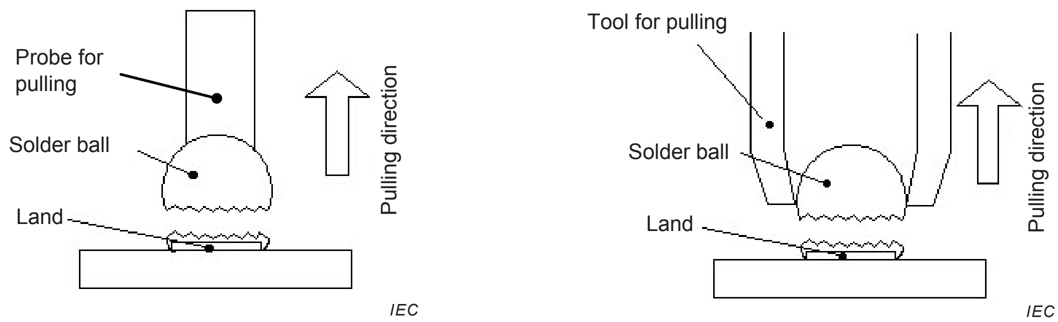
F.3.4 Reflow heating process

The solder ball on the test substrate should be melted and bonded securely on the test substrate land used by the reflow heating process, as specified in Clause 6.

F.3.5 Pull strength measurement

F.3.5.1 General

The pull strength of the test substrate land should be measured using the probe heat bond method or ball pinch method shown in Figure F.1.



a) Method A – Probe heat bond method **b) Method B – Ball pinch method**

Figure F.1 – Measuring methods for pull strength

F.3.5.2 Pull strength measuring method A – Probe heat bond method

F.3.5.2.1 Probe heat bond

Transfer the flux to the tip of the probe for the pull strength test, to which solder plating or other finish is applied. Then bond the probe to the solder ball by heating up the probe to (220 ± 20) °C.

F.3.5.2.2 Measurement

Cool down the probe to (25 ± 5) °C, then pull it out at a speed of (0,3 ± 0,05) mm/s while test substrate is fixed. See Figure F.1 a).

Record the force as pull strength after breaking.

F.3.5.3 Pull strength measuring method B – Ball pinch method

Using the tool, pinch the solder ball, then pull it out at a speed of (0,3 ± 0,05) mm/s while the test substrate is fixed. See Figure F.1 b).

Record the force as pull strength after breaking.

F.3.6 Final measurement

After measuring the pull strength, observe the shape of the stripped surface and then note the breaking mode listed below.

- Mode A: breaking in the solder ball.
- Mode B: stripping between the solder ball and the land on the substrate.
- Mode C: stripping between the land on the substrate and the substrate material.

The pull strength should not be significantly weakened. If many breakings in Mode C have been observed, the test substrate may have some adhesion problems.

F.4 Items to be given in the product specification

The following items should be specified in the product specification.

a) Pre-conditioning conditions (if it is necessary to specify them) (see F.3.1).

b) Solder ball usage (see F.3.3).

c) Method of pull strength measurement (see F.3.5).

d) Conditions of pull strength measurement (see F.3.5).

e) Measured value of pull strength (see F.3.6).

f) Breaking mode (see F.3.6).

Annex G
(informative)

Standard mounting process for the packages

G.1 General

This annex gives an explanation to the standard mounting process for the packages.

G.2 Test apparatus and materials

G.2.1 Test substrate

The test substrate should be as specified in 5.5.

NOTE The required items concerning the test substrate are described in Annex C to Annex F to confirm the quality of the test substrate.

G.2.2 Solder paste

The solder paste should be as specified in 5.6.

G.2.3 Metal mask for screen printing

The stencil used should conform to the design standard shown in Table G.1.

Table G.1 – Stencil design standard for packages

Terminal type	Stencil thickness	Aperture diameter
Area array	120 μm to 150 μm	Match with the land size specified in 5.5 c)

There are three processing methods of the metal mask, 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 because of a fine pitch process.

G.2.4 Screen printing equipment

The screen printing equipment should be capable of solder printing as described in G.3.2.

G.2.5 Package mounting equipment

The package mounting equipment should be capable of mounting the package described in G.3.3.

G.2.6 Reflow soldering equipment

The reflow soldering equipment should be capable of maintaining the temperature as specified in G.3.4.

G.3 Standard mounting process

G.3.1 Initial measurement

The initial electrical measurement of the package should be carried out according to the product specification. In addition, a visual inspection shall be carried out on the package to verify that there is no apparent damage, by magnifying it 10×.

G.3.2 Solder paste printing

Using the stencil mask described in G.2.3, print the solder paste as described in G.2.2 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 and as shown in Figure G.1.

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

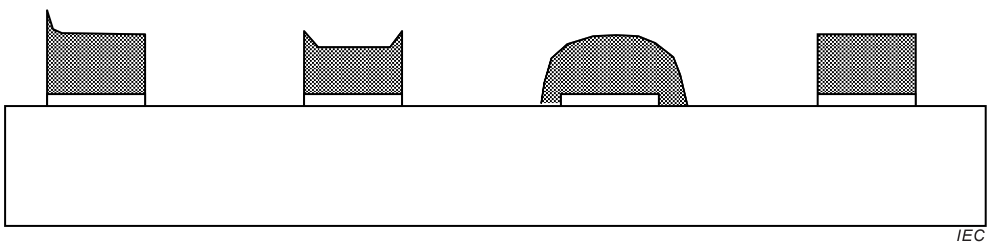


Figure G.1 – Example of printed conditions of solder paste

It is also important to select print conditions that can avoid misaligned and faint prints.

G.3.3 Package mounting

Mount the package on the test substrate, on which solder paste has been printed as described in G.2.2.

G.3.4 Reflow heating process

Heat up the specimen as the package mounted on the test substrate using the reflow temperature profile shown in Figure 2 or Figure 3, and the soldering that has been processed.

The temperature of the specimen should be measured at the thermocouple measuring point A (the centre on the top of the package) and thermocouple measuring point B (the soldered inner part of the terminal), as shown in Figure G.2.

Each thermocouple wire should be routed in such a way that there is no interference and no influence to the temperature measurement.

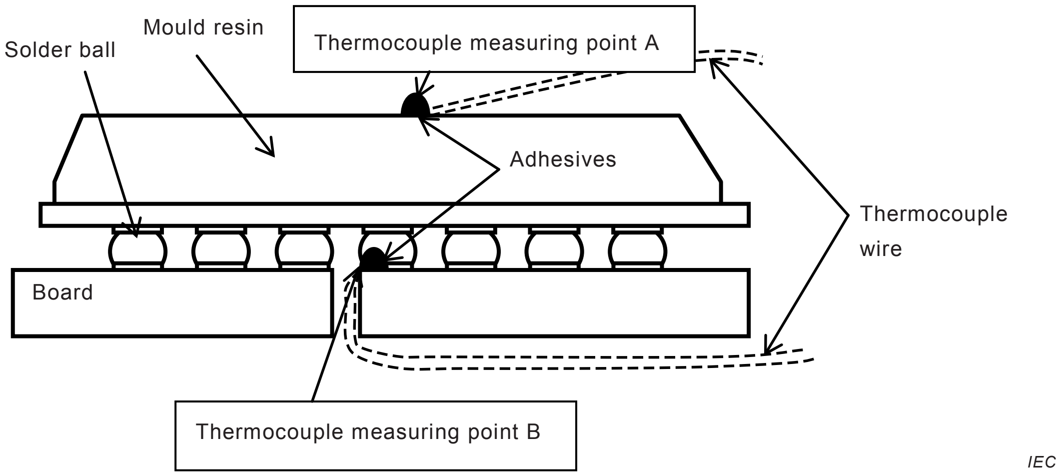


Figure G.2 – Temperature measurement of the specimen using thermocouples

G.3.5 Recovery

After completion of the test, if necessary, leave the specimen under the standard condition for the time specified in the product specification.

G.3.6 Final measurement

The final electrical measurement of the specimen should be carried out according to the product specification. In addition, a visual inspection should be carried out on the specimen to verify that there is no apparent damage, by magnifying it 10×. The following checks should be carried out.

- Insufficient solder wetting.
- Repelled solder.
- Solder ball drop out.
- Solder dissolution.

G.4 Items to be given in the product specification

The following items should be specified in the product specification.

a) Solder paste (if different from G.2.2).
b) Metal mask specification (if different from G.2.3).
c) Items and conditions of initial measurement (see G.3.1).
d) Solder paste printing conditions (if different from G.3.2).
e) Reflow heating process conditions (if different from G.3.4).
f) Recovery conditions (if necessary) (see G.3.5).
g) Items and conditions of final measurement (see G.3.6).

Annex H
(informative)

Mechanical stresses to the packages

H.1 General

This annex gives an explanation to the mechanical stress after mounting of the packages on the printed wiring board.

When the mechanical stresses are loaded to the mounted package, the temperature cycling test may be subjected to any effects with respect to the durability of the solder joints.

H.2 Mechanical stresses

For the durability test concerning the mechanical stresses for the mounted packages, the test should be selected and carried out by taking into account the relationship between the type of mechanical stresses and the actual use conditions.

The type of the mechanical stresses and the example of the quality requirement presume a fault mechanism. A supposed example of factors and the evaluation methods are shown in Table H.1.

Table H.1 – Mechanical stresses to mounted area array type packages

Types of stress	Example of quality requirements	Presumed fault mechanism	Example of evaluation methods
Transient bending	No break at bending displacement X mm	Over stress fracture occurs to joint caused by the substrate bending	Monotonic bending test described in IEC 62137-3:2011, Annex D
Cyclic bending	No break at key typing X times	Fatigue fracture occurs to joint caused by the cyclic bending of the substrate	Cyclic bending strength test specified in IEC 62137-1-4
Shock	No break during drop Y times from drop height X m	Drop shock stress fracture occurs to the joint caused by transient bending to the substrate in an piece of equipment	Cyclic drop test specified in IEC 62137-1-3 or IEC 60068-2-27
Permanent bending	No break during Y h at bending displacement X mm	Creep fracture occurs to the joint caused by a substrate bending stress	Creep test specified in IEC 60068-2-21:2006, 8.5.1
Vibration	No break during X Hz/Y g/Z h	Fatigue fracture occurs to the joint caused by the substrate cyclic bending stress or transient bending stress from the vibration	IEC 60068-2-6 or IEC 60068-2-21:2006, 8.5.1 specified

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