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

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**Normalisation mécanique des dispositifs à semiconducteurs –
Partie 6-19: Méthodes de mesure du gauchissement des boîtiers à température élevée et du gauchissement maximum admissible**

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MECHANICAL STANDARDIZATION OF SEMICONDUCTOR DEVICES –

Part 6-19: Measurement methods of the package warpage at elevated temperature and the maximum permissible warpage

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International Standard IEC 60191-6-19 has been prepared by subcommittee 47D: Mechanical standardization for semiconductor devices, of IEC technical committee 47: Semiconductor devices.

This standard cancels and replaces IEC/PAS 60191-6-19 published in 2008. This first edition constitutes a technical revision.

The text of this standard is based on the following documents:

FDIS	Report on voting
47D/757/FDIS	47D/764/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all the parts in the IEC 60191 series, under the general title *Mechanical standardization of semiconductor devices*, can be found on the IEC website.

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

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MECHANICAL STANDARDIZATION OF SEMICONDUCTOR DEVICES –

Part 6-19: Measurement methods of the package warpage at elevated temperature and the maximum permissible warpage

1 Scope

This part of IEC 60191 specifies measurement methods of the package warpage at elevated temperature and the maximum permissible warpages for Ball Grid Array(BGA), Fine-pitch Ball Grid Array (FBGA), and Fine-pitch Land Grid Array (FLGA).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies.

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*

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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)*[1]

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IEC 60749-20, *Semiconductor devices – Mechanical and climatic test methods – Part 20: Resistance of plastic-encapsulated SMDs to the combined effect of moisture and soldering heat*

3 Terms and definitions

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

3.1
measuring area
area for measurement of package warpage, composed of either

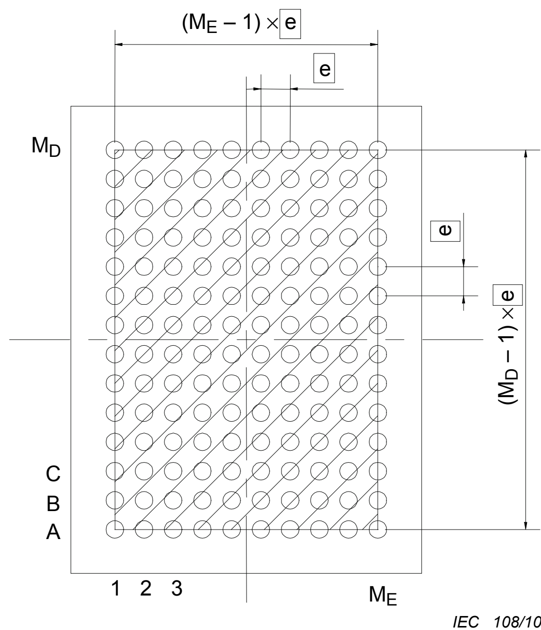
- terminal-existing area bordered by the lines connecting the centres of the outermost neighbouring solder balls for the packages with the standoff height more than 0,1 mm, including BGA and FBGA

  NOTE Examples of measurement area is shown in Figure 1 and Figure 2. If there are balls at the package centre, their area is also considered as a part of measuring areas.

- substrate surface except certain edge margin for the packages with the standoff height of 0,1 mm or less, including FLGA

  NOTE Examples of measurement area is shown in Figure 3. The width of this margin *L* depends on the capability of each measuring instrument (*L* = 0,2 mm recommended).

1 hereinafter referred as "FBGA design guide".



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NOTE 1) The hatched area indicates the measuring area.

2) Symbols in this figure are specified to FBGA design guide (IEC 60191-6-5).

Figure 1 – Measuring area of BGA and FBGA in full grid layout

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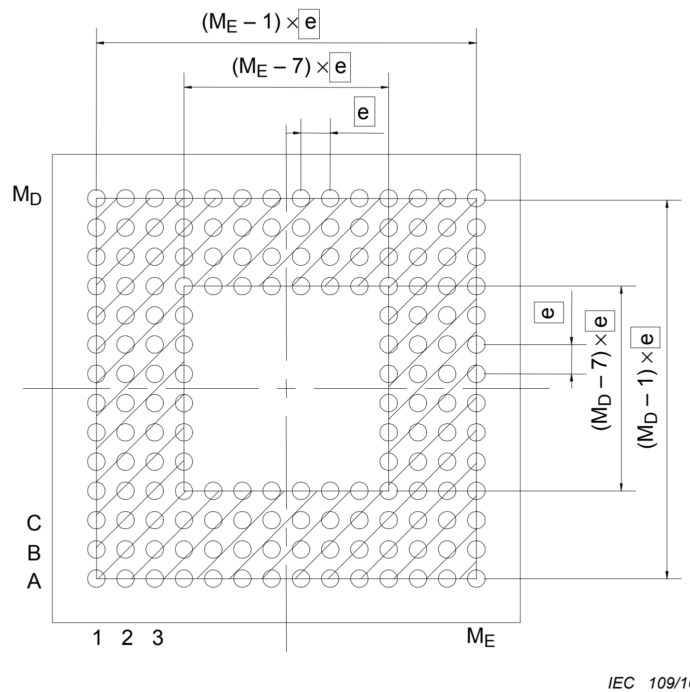
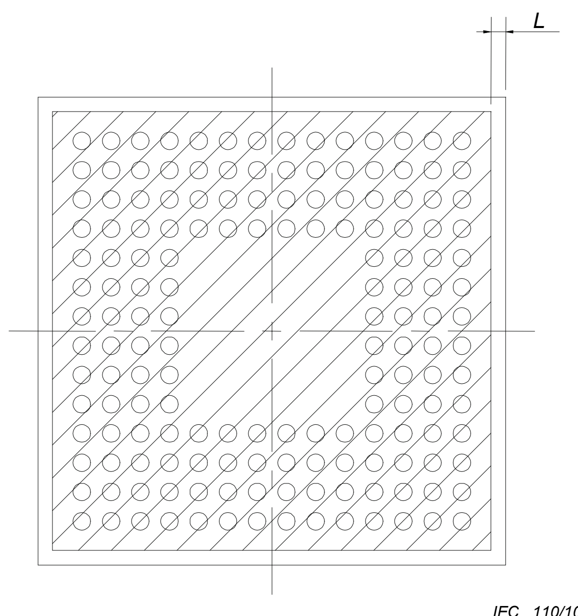


NOTE Symbols in this figure are specified to FBGA design guide (IEC 60191-6-5).

Figure 2 – Measuring area of BGA and FBGA perimeter layout with 4 rows and 4 columns



NOTE The edge margin *L* indicates the exempt area from measurement to avoid measurement noise depending on the instrument capability. Recommended edge margin *L* = 0,2 mm.

Figure 3 – Measuring area of FLGA perimeter layout with 4 rows and 4 columns

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3.2
convex warpage
arched top surface (not interconnect side) of package being mounted on PWB, wherein the sign of the convex warpage is defined as plus

3.3
concave warpage
inward-curving top surface (not interconnect side) of package being mounted on PWB, wherein the sign of the concave warpage is defined as minus

3.4
package warpage sign
plus or minus sign of package warpage determined by the sign of the sum of the largest positive displacement and the largest negative displacement of the package profile on both measurement area diagonals, which are regarded as base lines connecting the outermost opposite corners of the measuring area, thus resulting to be the sign of

$$(AB_{MAX}+AB_{MIN}+CD_{MAX}+CD_{MIN})$$

where

AB_{MAX} is the largest positive displacement;

AB_{MIN} is the largest negative displacement of the package profile on the diagonal AB;

CD_{MAX} is the largest positive displacement; and

CD_{MIN} is the largest negative displacement of the package profile on the diagonal CD.

NOTE In Figure 4, the signs of AB_{MAX}, AB_{MIN}, CD_{MAX} and CD_{MIN} are plus, zero, plus and minus, respectively. The concave or convex impression of the package warpage can differ from the above defined sign, in critical case.

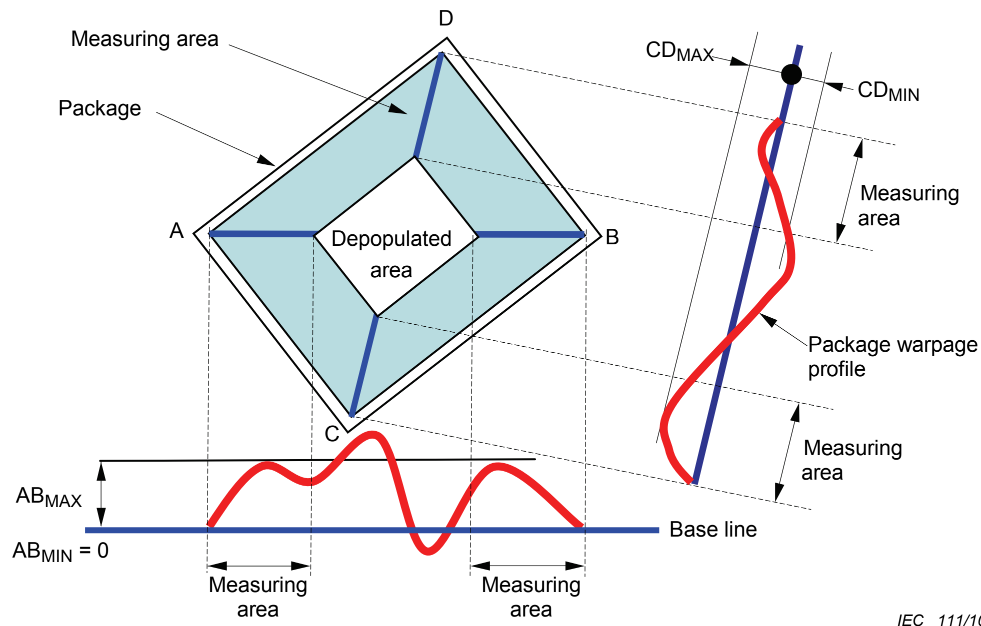

Figure 4 – Calculation of the sign of package warpage

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3.5
package warpage
difference of the largest positive and the largest negative displacements of the package warpage in the measuring area with respect to the reference plane, preceded by package warpage sign, where reference plane is derived using the least square method with the measuring area data

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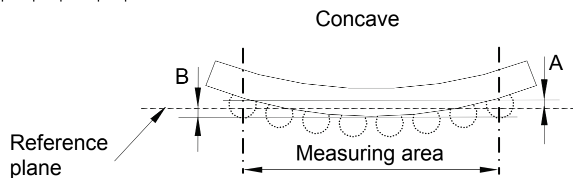
NOTE For example, the absolute value of the package warpage $|C|$ is obtained by the sum of the absolute value of the largest positive displacement $|A|$ and that of the largest negative displacement $|B|$. This is in respect to the reference plane which is derived by using the least square method, as shown in Figure 5. Package warpage sign precedes $|C|$.

$|C| = |A| + |B|$



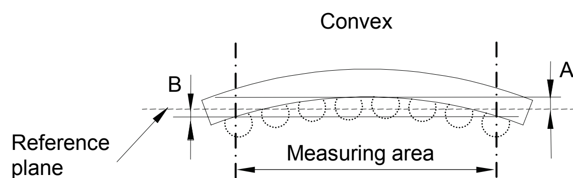


Figure 5 – Package warpage

4 Sample

4.1 Sample size

At least three samples are required for each measurement condition.

4.2 Solder ball removal

If the measurement method of the package warpage requires the elimination of the solder balls from a package, it is recommended to use mechanical removal rather than hot reflow. If the samples are prepared without solder balls for the convenience of the measurement, the package shall be subjected to the thermal history of the solder ball attachment process.

4.3 Pretreatment conditions

The bake and moisture soak conditions shall conform to the moisture sensitivity level specified in IEC 60749-20. The peak temperature of the package warpage measurement shall meet the specification of the product.

4.4 Maximum time after pretreatment until measurement

It is recommended to measure the warpage no longer than 5 h after the pretreatment.

4.5 Repetition of the reflow cycles for the sample

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The same sample shall not be subjected to the repetition of the reflow cycles. The sample can only be subjected to more than one cycle of reflow for remeasurement, if reproducibility of test data was evaluated prior to the test.

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5 Measurement

5.1 General description

The package warpage is measured by “shadow moiré method” or “laser reflection method”.

Samples are subjected to heating and cooling while measuring the package warpage at the temperatures specified in 5.2. The measurement points shall not be on the crown of solder balls but on the substrate surface of the package. Only when the behaviour of the top surface of the package (mostly marking surface) is verified to coincide with that of the substrate surface, the measurement on the top surface is allowed.

5.2 Temperature profile and the temperatures for measurements

5.2.1 The temperature profile for the warpage measurement does not necessarily simulate that for production. Higher priorities are placed on

- maintaining the temperature constant during the measurement,
- never exposing the samples more than necessary duration at high temperature. Samples shall be proceeded to the next measurement as soon as possible,
- avoiding a temperature surge to prevent the overshoot, and
- minimizing the temperature difference between the top and bottom surfaces.

5.2.2 The temperatures for measurements are

- room temperature,
- melting point,
- peak temperature,

– solidification point, and
– room temperature after cool down.

The melting point and the solidification point are 220 °C for Sn-3,0Ag-0,5Cu solder as a reference. Other solder composites may take different temperatures. The peak temperature basically conforms to the package classifications specified in IEC 60749-20, but to be exact, it shall follow the supplier's recommended max temperature.

5.2.3 It is recommended that a thermocouple of gauge 30 (ϕ0,25 mm) or flat tip type be used.

5.2.4 The thermocouple is attached on the center of the package body using either thermally conductive epoxy or heat-resistant polyimide tape. When polyimide tape is used, thermally conductive sheet shall be applied between the thermocouple bead and the package surface to enhance thermal conductivity as a thermal interface material.

5.2.5 When a measuring instrument is being set up, the temperature of the molded side of the package facing a heater is also measured. The temperature difference from the substrate surface shall preferably be less than 10 °C by adjusting the heating mechanism and the temperature profile.

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Figure 6 – Thermocouple placement

5.3 Measurement method

5.3.1 Shadow moiré method

Solder balls shall be removed prior to the measurement on the substrate surface. Measurements are conducted by placing the grating [low coefficient of thermal expansion (CTE) glass with transparent and opaque stripes] parallel to the sample. Then, the projection of light beam at an angle of approximately 45 ° through the grating produces the stripe pattern on the sample. Observation of the stripe pattern through the grating results in the moiré fringe pattern (geometric interference pattern). Image processing and the analysis of the patterns provide the displacement from planarity over the substrate surface. The instrument is capable of setting the measuring area and measuring the warpage at elevated temperatures including the peak temperature.

5.3.2 Laser reflection method

Solder balls shall be removed when the solder ball pitch is not large enough for laser beam to measure the warpage on the substrate surface. Samples are placed on the measurement table. The displacement from the flatness is measured by the laser displacement sensor. The warpage is generally measured by scanning the laser beam over the terminal lands or between balls throughout the measuring area. The grid pitch of the measurement points is preferably less than the solder ball pitch. The instrument is capable of setting the measuring area and measuring the warpage at elevated temperatures including the peak temperature.