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# IPC/JEDEC-9702

## Monotonic Bend Characterization of Board-Level Interconnects

**IPC/JEDEC-9702**

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A standard developed by IPC and JEDEC

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Developed by the SMT Attachment Reliability Test Methods Task Group (6-10d) of the Product Reliability Committee (6-10) of IPC and the JEDEC Reliability Test Methods for Packaged Devices Committee (JC-14.1)

Users of this publication are encouraged to participate in the development of future revisions.

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# Monotonic Bend Characterization of Board-Level Interconnects

## 1 FOREWORD

This publication on monotonic bend testing is intended to characterize the fracture strength of a component's board-level interconnects. The document is applicable to surface mount components attached to printed wiring boards using conventional solder reflow technologies. The monotonic bend characterization results provide a measure of fracture resistance to flexural loading that may occur during conventional non-cyclic board assembly and test operations, and supplements existing standards that address mechanical shock or impact during shipping, handling or field operation.

## 2 INTRODUCTION

Semiconductor devices are assembled in a variety of package configurations, and are used in a multitude of applications. Given the diversity of package constructions and end-use conditions, it is not feasible to establish a single qualification requirement relating to bend testing; however, definition of a uniform test methodology and a standard reliability characterization reporting process are increasingly necessary to ensure adequate product quality.

## 3 SCOPE

This publication specifies a common method of establishing the fracture resistance of board-level device interconnects to flexural loading during non-cyclic board assembly and test operations. Monotonic bend test qualification pass/fail requirements are typically specific to each device application and are *outside* the scope of this document.

## 4 TERMS AND DEFINITIONS

For the purposes of this standard, the selected terms and definitions listed below apply.

### General Terms

**Component:** Packaged semiconductor device

**Interconnect:** Conductive element used for electrical interconnection, e.g., solder ball, lead, etc.

**Monotonic Test:** Non-reversing, test to fail

### Strain Related Terms

**Global PWB Strain:** Four-point bending strain of uniform printed wiring board, ignoring any effects due to the package(s)

**Microstrain:** Dimensionless unit,  $10^6 \times (\text{change in length}) \div (\text{original length})$

**Strain:** Dimensionless unit,  $(\text{change in length}) \div (\text{original length})$

**Strain-Rate:** Change in strain divided by the time interval during which this change is measured

**Strain Gage:** Planar copper foil pattern that is adhered to an underlying surface and exhibits a change in resistance when subjected to a strain

**Strain Gage Element:** Sensing area of strain gage defined by the serpentine copper grid pattern

**Uniaxial Strain Gage:** Strain gage incorporating a single strain gage element, i.e., capable of detecting strain along a single axis

### Mechanical Test Equipment Terms

**Anvil:** Four-point assembly fixture support with a rounded contact surface

**Crosshead Assembly:** Clamping/attachment assembly of universal tester that moves relative to the base of the test equipment, and creates the forces necessary for specimen testing

**Four-Point Bending Fixture:** Test assembly that supports a specimen on two anvils or rollers, and symmetrically loads the specimen on the opposite surface with two anvils or rollers

**Load Span:** Distance between the two anvils or rollers that load the test specimen

**Roller:** Four-point assembly fixture support that incorporates a cylindrical bar as the contact surface

**Support Span:** Distance between the two anvils or rollers that support the test specimen

**Universal Tester:** Test equipment capable of tensile/compressive loading using controlled linear motion of a crosshead assembly

### Electrical Test Terms

**Daisy-Chain:** A conductive link that can be connected in series with other conductive links (like a chain of daisies) to form a continuous electrical net

**In-Situ Measurement:** Measurement conducted during a test, i.e., in place, rather than during an interruption of the test condition

### Failure Analysis Term

**Dye-and-Pry:** Dye exposure of package/board assembly followed by mechanical removal of the package

## 5 SYMBOLS AND ABBREVIATED TERMS

| Unit                               | Symbol                              |
|------------------------------------|-------------------------------------|
| board thickness                    | $t$                                 |
| crosshead travel distance          | $\delta$                            |
| crosshead speed                    | $\dot{\delta}$                      |
| degree Celsius                     | $^{\circ}\text{C}$                  |
| degree Fahrenheit                  | $^{\circ}\text{F}$                  |
| Hertz                              | Hz                                  |
| load span                          | $L_L$                               |
| microstrain                        | $\mu\epsilon$ or $\mu\text{Strain}$ |
| second (time)                      | s                                   |
| strain                             | $\epsilon$                          |
| strain-rate                        | $\dot{\epsilon}$                    |
| support span                       | $L_S$                               |
| Term                               | Abbreviation                        |
| ball grid array                    | BGA                                 |
| chip scale (size) package          | CSP                                 |
| intermetallic compound             | IMC                                 |
| organic solderability preservative | OSP                                 |
| printed wiring board               | PWB                                 |
| surface mount                      | SMT                                 |
| small outline package              | SOP                                 |

## 6 SAMPLING

A statistically relevant sample size is required. It is recommended that several manufacturing lots be sampled to evaluate lot-to-lot variability. Depending on failure distribution, desired sensitivity, confidence limits, etc., sample quantities such as 23, 30, 45, etc., may be appropriate.

## 7 APPARATUS

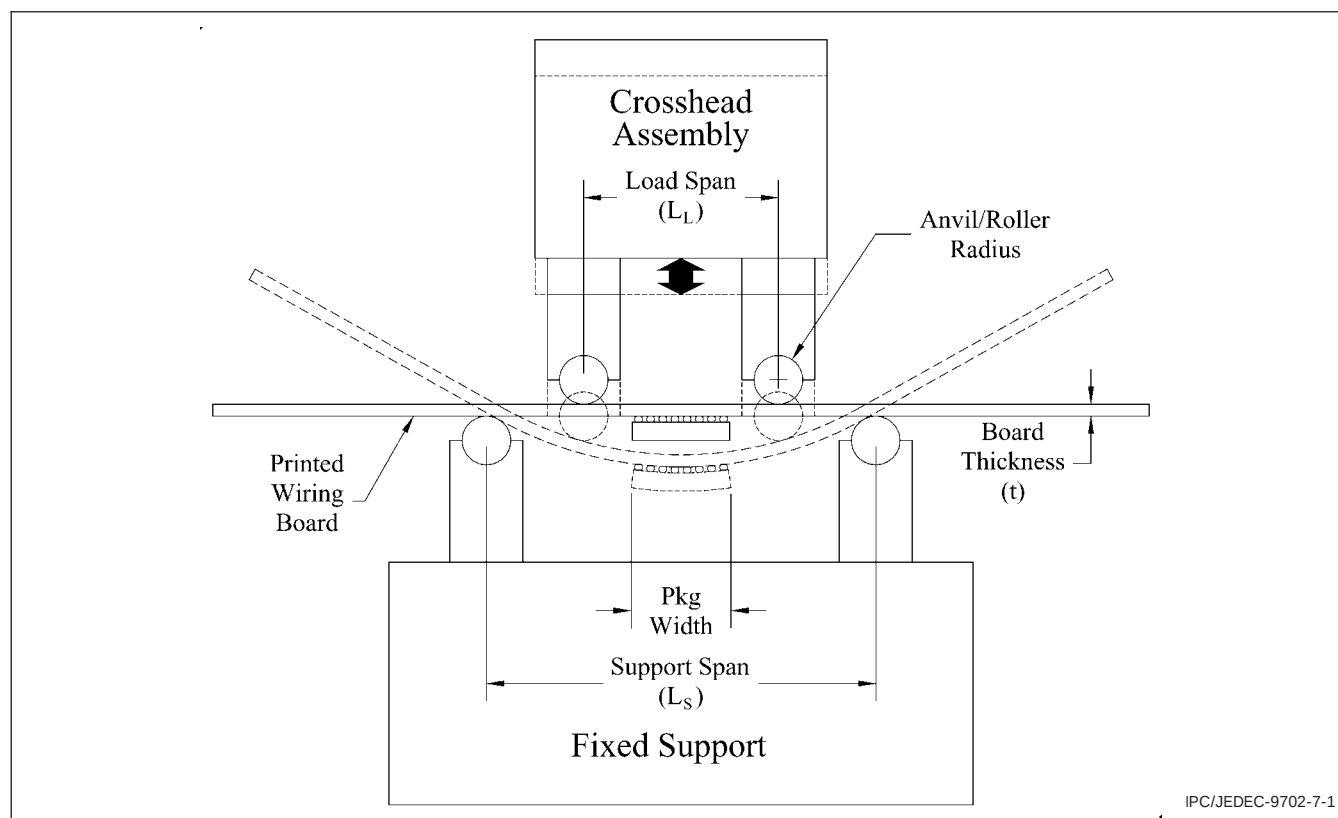
**7.1 Universal Tester** A universal tensile tester incorporating a deflection measuring device shall be used to generate a controlled board deflection rate. The tester shall include a four-point bending fixture (see Figure 7-1) to apply a theoretically uniform bending moment across the load span.

Table 7-1 lists dimensional and operational requirements for the universal tester.

**Table 7-1 Universal Tester Requirements**

| Description         | Requirement                                                                                         |
|---------------------|-----------------------------------------------------------------------------------------------------|
| Anvil/roller radius | 3 mm<br>[0.12 in.], min.                                                                            |
| Anvil/roller length | > board width                                                                                       |
| Ambient temperature | 23 $^{\circ}\text{C} \pm 2$ $^{\circ}\text{C}$<br>[73 $^{\circ}\text{F} \pm 4$ $^{\circ}\text{F}$ ] |

Non-standardized bend test methods in practice today often specify an applied load, span and/or crosshead travel distance to characterize mechanical resistance to failure of board-level device interconnects. Unfortunately, these parameters are not readily transferable to differing board thicknesses, package configurations or board layouts. The dimensionless unit of strain,  $\epsilon$ , however, can be applied more broadly to differing board/package geometries and relates more directly to analytical and computational failure models.



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**Figure 7-1 Universal Tester**

The crosshead travel distance ( $\delta$ ) and crosshead speed ( $\dot{\delta}$ ) of a universal tester are approximately proportional to the test board assembly strain ( $\epsilon$ ) and strain-rate ( $\dot{\epsilon}$ ), respectively. The relationship between these variables can be determined empirically by testing a mechanically representative package/board assembly (set-up test board); however, these relationships may prove non-constant or non-determinant, depending on universal tester capability and board/ package configuration.

This test method specifies use of the following simplified analytical relationships (see Equations 1 & 2) to establish the universal tester control settings for crosshead travel distance and crosshead speed, based upon global PWB strain and strain-rate input variables, respectively. These equations are derived from classic beam theory and ignore any effects due to the package(s), or to the Poisson's ratio effect of a plate in bending.

#### Equation 1

$$\delta = \frac{\epsilon (L_S - L_L) (L_S + 2L_L)}{6t}$$

where

$\delta$  = crosshead travel distance

$\epsilon$  = global PWB strain

$L_S$  = support span

$L_L$  = load span (centered within support span)

$t$  = PWB thickness

#### Equation 2

$$\dot{\delta} = \frac{\dot{\epsilon} (L_S - L_L) (L_S + 2L_L)}{6t}$$

where

$\dot{\delta}$  = crosshead speed

$\dot{\epsilon}$  = global PWB strain-rate

$L_S$  = support span

$L_L$  = load span (centered within support span)

$t$  = PWB thickness

**7.2 Strain Measurement Equipment** A strain measurement equipment scan frequency of 500 Hz (min.), and a data signal resolution of 16 bits (min.) are preferred for the short duration (<5 seconds, typ.) monotonic bend test.

**7.3 Continuity Monitoring Equipment** Continuity monitoring is preferably performed by the same high scan frequency equipment used for strain measurements, allowing simultaneous recording of net resistance and strain.

## 8 PROCEDURE

**8.1 Component Sample** This standard assumes a surface mount device; BGA, SOP and CSP are typical device

examples. Discrete SMT devices, e.g., capacitors, resistors, etc., are outside the scope of this test method. The test component must contain daisy-chain connections to allow in-situ continuity monitoring of the device board-level interconnects during the bend test. It is likely that the same daisy-chain package construction may be used for both bend testing and thermal cycle testing. For bend testing of array-based packages; however, only the outermost package daisy-chain links need to be connected to a corresponding PWB daisy-chain link and electrically monitored.

The daisy-chain package materials, dimensions, and construction must be representative of a typical production device. The layout of solder balls or leads for the daisy-chain package should represent a typical leadcount configuration expected for a production device of that package body size. As indicated previously, the monitored daisy-chain links on the package consist of the outer component interconnects. Each package daisy-chain link should consist of a pair of adjacent solder joints or leads.

Functional devices may be used in lieu of a daisy-chain package if the electrical continuity monitoring requirements defined in this publication can be met.

**8.2 Test Board Material** The test board material should match the composition of the actual end-use PWB, typically FR4 epoxy/glass laminate.

**8.3 Test Board Thickness and Metal Layer Count** The test board thickness and metal layer count should match the actual end-use PWB. Definition of a "typical" printed wiring board is problematic given the expanding usage of alternative board constructions and materials, and the widening form-factor gap between handheld electronic devices and other application types. Table 8-1 provides a minimum recommended test board thickness and metal layer count if the device will be used in a variety of end-use applications, or if the actual PWB configuration is unknown. Finite element modelling suggests that the ratio between package/ solder interfacial strain and global PWB strain increases with increased board thickness and copper layer count. Consequently, use of a thicker test board or higher metal layer count than listed in Table 8-1 will typically lead to more conservative bend test results.

**Table 8-1 Recommended Test Board Thickness & Layer Count**

| Max. Package Body Dimension, X (mm) [in.] | PWB Thickness, min. (mm) [in.] | Copper Layers, min. |
|-------------------------------------------|--------------------------------|---------------------|
| Small: X ≤15 [0.59]                       | 1.00 [0.039]                   | 4                   |
| Medium: 15 [0.59] < X <40 [1.58]          | 1.55 [0.062]                   | 6                   |
| Large: X ≥40 [1.58]                       | 2.35 [0.093]                   | 8                   |



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