

JEDEC STANDARD

Board Level Cyclic Bend Test Method for Interconnect Reliability Characterization of Components for Handheld Electronic Products

JESD22B113

MARCH 2006

JEDEC SOLID STATE TECHNOLOGY ASSOCIATION



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Background

Printed circuit board assemblies experience various mechanical loading conditions during assembly and use. The repeated flexing (cyclic bending) of board during various assembly and test operations and in actual use can cause electrical failures due to circuit board and trace cracks, solder interconnects cracks, and the component cracks. Although the number of repeated bend cycles are small during assembly (e.g., handling between various assembly operations, In-circuit Testing, final assembly in product casing), the magnitude of flexure can be very significant. On the other hand, the actual use conditions such as repeated key-presses in mobile phone can result in a large number of repeated bend cycles during the life of the product, albeit at a lower magnitude.

Since component manufacturers and suppliers cannot evaluate their package performance on actual final products, a board level test method is needed to evaluate the performance of mounted components due to repeated bending of board and compare their performance with other components.

Board Level Cyclic Bend Test Method for Interconnect Reliability Characterization of Components for Handheld Electronic Products

(From JEDEC board Ballot, JCB-06-20, formulated under the cognizance of the JC-14.1 Subcommittee on Reliability Test methods for Packaged devices.)

1 Scope

The Board Level Cyclic Bend Test Method is intended to evaluate and compare the performance of surface mount electronic components in an accelerated test environment for handheld electronic products applications. The purpose is to standardize the test methodology to provide a reproducible performance assessment of surface mounted components while duplicating the failure modes normally observed during product level test. This is not a component qualification test and is not meant to replace any product level test that may be needed to qualify a specific product and assembly.

Correlation between test and field conditions is not yet fully established. Consequently, the test procedure is presently more appropriate for relative component performance than for use as a pass/fail criterion. However, to do comparisons care must be taken to have the same test variables used, such as component configuration and size.

This publication assumes a surface mount device such as BGAs, LGAs (excluding sockets and connectors), TSOP, and CSPs. Discrete SMT devices, e.g., capacitors, resistors, etc., are outside the scope of this test method. Furthermore, this test method is only applicable for handheld products applications where cyclic bending due to repeated key-press operations is a concern. The size of surface mount device is limited to 15 mm x 15 mm maximum.

2 Apparatus

- Any cyclic bend test apparatus that can cause a repeated bending of printed wiring boards at 1 to 3 Hz cyclic frequency for up to 200,000 cycles with maximum cross-head displacement of 4 mm. The cross-head displacement accuracy shall be +/- 5% of the maximum displacement.
- Strain monitoring equipment with minimum sample rate of at least 10 times the cyclic bending frequency with simultaneous sampling of all channels. The specific requirements for data recording are described in section 10.3. The strain monitoring equipment shall be as per IPC/JEDEC-9704 guidelines.
- Resistance monitoring equipment able to detect electrical failures as per the criteria defined in this standard. The sample rate of resistance monitoring equipment shall be at least 10 times the cyclic bending frequency with simultaneous sampling of all channels.
- A system which monitors both PCB strain and electrical resistance of daisy chain nets at the same sampling rate is preferred, but not required.

3 Terms and definitions

For purposes of this standard, the following definitions shall apply

Component: A packaged semiconductor device.

Single-sided PCB assembly: A printed circuit board assembly with components mounted on only one side of the board

Handheld electronic product: A product that can conveniently be stored in a pocket (of sufficient size) and used when held in user's hand.

NOTE Included in handheld electronic products are cameras, calculators, cell phones, pagers, palm-size PCs (formerly called 'pocket organizers'), PCMCIA cards, smart cards, mobile phones, personal digital assistants (PDAs), and other communication devices.

Global PWB Strain: Four-point bending strain of uniform printed wiring board measured between the edge of the component and the anvil as described in Figure 4.

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

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

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

Strain Gage: Planar 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 active serpentine grid pattern.

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

Peak displacement: The maximum displacement applied at the printed wiring board by load anvils during cyclic bending

Cycle frequency: Number of times test vehicle undergoes complete loading and unloading sequences in one second.

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.

3 Terms and definitions (cont'd)

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.

Threshold Resistance: 1000 ohms or 5 times the initial resistance of daisy chain net and associated wiring to the event detector/data logger, whichever is greater.

Event: An electrical discontinuity of resistance greater than the threshold resistance lasting for a period of 1 microsecond

Event detector: A continuity test instrument capable of detecting electrical discontinuity of resistance greater than the threshold resistance lasting for a period of 1 microsecond.

Data Logger: A high speed resistance measurement equipment capable of measuring resistance of up to 36 channels simultaneously at a sampling rate of at least 30Hz per channel.

4 Applicable documents

JESD22-B111	Subassembly Mechanical Shock
IPC-SMT-782	Surface Mount Design and Land Pattern Standard
J-STD-020	Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices
J-STD-033	Standard for Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices
IPC-9701	Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments
IPC/JEDEC-9702	Monotonic Bend Characterization of Board-Level Interconnects
IPC/JEDEC-9704	PWB Strain Gage Test Standard

5 Test method

This publication standardizes 4-point bend method for cyclic bend performance characterization of components. The cyclic bending is achieved by resting the printed wiring board assembly on two support anvils while deflecting the board in the downward direction by displacing the load anvils. This is schematically depicted in Figure 1. The 4-Point bend method is specified as it results in constant curvature of the board in between the two inner anvils if there are no components on the board. With components mounted, the local strain in the component region will be different from the global PWB strain.

5 Test method (cont'd)

Due to large number of cycles for this test, the board may move on the anvils in the plane of the board (right / left). It is recommended that this movement is controlled to 1 mm max in each direction from the absolute center position of the roller anvil by designing some constraining features in the test fixture.

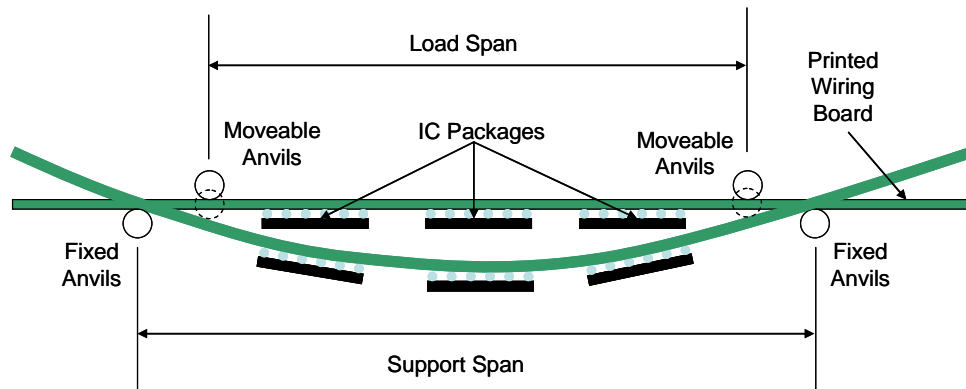


Figure 1 — Schematic showing 4-Point bend setup

Figure 1 describes the parameters needed to setup the cyclic bend test machine and the values of these parameters are specified in Table 1. The table lists the recommended value as well as optional values for some of the parameters. Wherever there is a choice, the optional parameters should only be used if an acceleration factor has already been established and proven between the recommended and optional setting of a parameter. The parameter values listed under optional setting should not be exceeded as it may result in a change of failure mechanism. For cyclic bend test, the primary failure mechanism is solder fatigue in bulk solder.

Table 1 — Recommended and Optional Parameters for Cyclic 4-Point Bend Test

Parameter	Recommended	Optional
Span for support Anvils (mm)	110	N/A
Span of Load Anvils (mm)	75	N/A
Load Anvil to Component Keep-out (the minimum distance from load anvil centerline to edge of closest components) (mm)	10	N/A
Minimum Anvil radius (mm)	3	N/A
Load Anvil vertical displacement (mm)	2	Up to 4 mm
Load profile	Sinusoidal	Triangular
Cyclic Frequency (Hz)	1	Up to 3

6 Components

This standard covers all area arrays and perimeter leaded surface mountable packaged semiconductor devices such as BGAs, LGAs (excluding connectors and sockets), CSPs, TSOPs, and QFNs or any surface mounted package. All components used for this testing must be daisy chained. The daisy chain should either be done at the die level or by providing daisy chain links at the lead-frame or substrate level. In case of non-daisy chain die (i.e., when daisy chain is done at the substrate level), a mechanical dummy die must be used inside the package to simulate the actual structure of the package. The die size and thickness should be similar to the functional die size to be used in application. The component materials, dimensions, and assembly processes shall be representative of typical production device.

7 Test Board and component locations

This standard recommends the use of drop test board as defined by JESD22-B111. The suggested board resembles the boards used in actual applications in material and construction. The board design and construction guidelines are detailed in JESD22-B111 and should be followed. If another board construction better represents a specific application or a mechanical equivalent board is used, the test board construction, dimensions and material should be documented and test results shall be correlated with those obtained by using standard board defined in JESD22-B111. Since this is primarily a component characterization test and since PWB trace failures are possible during bend and drop testing, the copper trace and ball pad should have sufficient strength to ensure that no open at the trace on the test board occurs before the onset of solder joint and package open failures. Trace failures can also be avoided by implementing fillet where trace enters the pad and also by routing the trace out from pad at an angle. This is depicted in Figure 2.

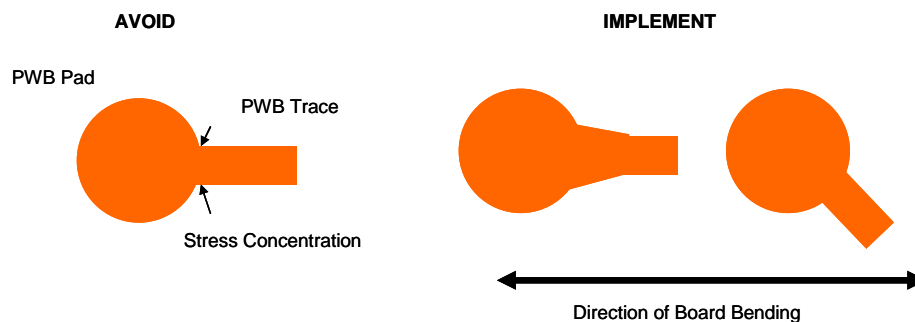


Figure 2 — PWB pad-trace interface design to avoid trace cracks.

The board specified in JESD22-B111 is 132 x 77 mm in size and allows placement of up to 15 components of same type in a 3 row X 5 column format. However, in order to accommodate anvils/rollers on the board to conduct 4-point bending test, this standard recommends that only 9 components of the same size should be mounted per board in 3 row x 3 column format for bend test purpose. It is important to maintain symmetry in the X-Y directions to minimize board to component interactions which can influence test results. This is shown in Figure 3 as the area enclosed by the dashed rectangle. The outer locations are crossed out, indicating non-populated sites. The maximum component size shall be 15 mm in length or width and there shall be at least 5 mm gap between the components. For rectangular components, the long axis of the component must be parallel to the long axis of the board.

7 Test Board and component locations (cont'd)

All components must be located within the 55 X 55 mm box (shown by the dashed line in Figure 3) defined by the outer edges of all outer components. The outer edges of out side components (U2, U4, U7, U9, U12, and U14) shall align with the boundary of this box, guaranteeing a fixed gap of 10mm between the center-line of the inner anvils and components edges closest to the inner anvils irrespective of component size. The x, y locations of the center of each component location are listed in Table 2, using lower left corner of the board as datum. No connectors should be mounted on the long edge of the board adjacent to components to minimize interactions with test components.

The area of the board in the length direction outside of components shall be restricted for labeling, connectors, and any other fixtures, such as anvils for board bending test. Plated through holes or edge fingers shall be provided on each end of the board for soldering wires or attaching connectors. It should also be ascertained that metal anvils of 4-point bend fixture do not make any contact with the traces on PWB. It is recommended that the traces in anvil contact area be moved to inner layers.

8 Test board assembly

Prior to board assembly, all devices shall be inspected for missing balls or bent leads. Board thickness, warpage, and pad sizes shall also be measured using a sampling plan. A visual inspection shall be performed on all boards for solder mask registration, contamination, and daisy chain connection. One board shall also be used to measure the mechanical properties (modulus, and Tg) of the board at the component location using DMA and TMA method. It is highly recommended that the CTE of the board be also measured in X, Y, and Z direction. The mechanical property measurements are not required for every board lot, unless the fab process, material, or vendor is changed from lot to lot.

The components shall be baked according to J-STD-020 and J-STD-033 prior to board assembly.

The test boards shall be assembled using assembly process representative of production methods. At least one board shall be used to adjust board mounting process such as paste printing, placement, and reflow profile.

All assemblies shall be single side only.

A 100% X-ray inspection shall be conducted on assembled units to check for voids (some voiding is expected with micro-via-in-pad), shorts, and other abnormalities. Electrical continuity test shall also be performed on all mounted units to detect any opens or shorts.

To minimize the effect of storage conditions (temperature and humidity) on assembled boards and solder joints, it is recommended that the cyclic bend test should complete within 3 weeks of completing the board assemblies. This 3 week window is based on maximum of 200,000 cycles of testing per board at 1 Hz frequency and a sample size of 4 boards.

9 Test procedure

9.1 Board & component sample size

Table 3 provides the minimum sample size (number of components and boards) required to characterize the cyclic bend performance of components mounted on boards. As handheld electronic products use fine pitch components, Via in Pad (ViP) design is required for most boards. However, ViP design sometimes result in via failures as opposed to solder joint or intermetallic failures. As the purpose of this standard is component characterization, this standard specifies the use of NViP design only. However, ViP design can be used if it is absolutely required due to ball pitch requirements. If ViP design is used, the failure analysis shall be done to identify both solder joint and via failures and the failure data shall be segregated per failure mode, wherever possible. The use of ViP board design is also allowed if this test method is being used to characterize via integrity. It should be noted that the possibility of PWB trace cracking at trace-pad interface exists if NViP design is used. This can be avoided, however, by implementing design features as discussed in Section 8.

In order to limit the sample size and the amount of testing, this standard recommends a sample size of 36 for components mounted on NViP boards. However, the sample size can be reduced to 18 (or 2 boards) for additional comparison, such as cross-head deflection, cyclic frequency, and ViP vs NViP board design. Although the reduced sample size for additional testing does not provide the same number of failures, it is valid for mean life comparison purposes.

Table 3 — Recommended Sample Size for Cyclic 4-Point Bend Test

Configuration	# of boards	# of components
NViP board design	4	36
Other variations (e.g., cross-head deflection, cyclic frequency)	2	18

9.2 Strain measurement

Although the test method standardized here uses cross-head deflection and cyclic frequency as the main parameters, a better comparison of component performance due to bending can be achieved by comparing the in-plane strain and strain rate at the board level. The magnitude of strain and strain rate at the board is directly related to the amount of board curvature and strain in the solder joints and other interconnects. For this reason, this standard specifies the use of strain gages to quantify the bending or in-plane strain for every lot of test board assemblies. The strain characterization shall be done at least on one board from this lot with components mounted on board and test parameters as per Table 1. It should be emphasized, however, that this is a displacement controlled test method, not strain controlled. The requirement for strain measurement is for characterization purposes only.

For the test configuration defined in this standard, finite element modeling indicates that the PWB principal strain angle is essentially coincident with the longitudinal board axis at all board locations. Therefore, the use of uniaxial strain gages for monitoring board strain and strain-rate is acceptable. A nominal strain gage element size of 1.5 mm x 1.5 mm [0.059 in. x 0.059 in.] is recommended. The sensing direction of the uniaxial strain gage must be aligned with the longitudinal board direction. The strain gages should be mounted to the test board using the procedures specified by IPC-9704 method.

9 Test procedure (cont'd)

9.2 Strain measurement (cont'd)

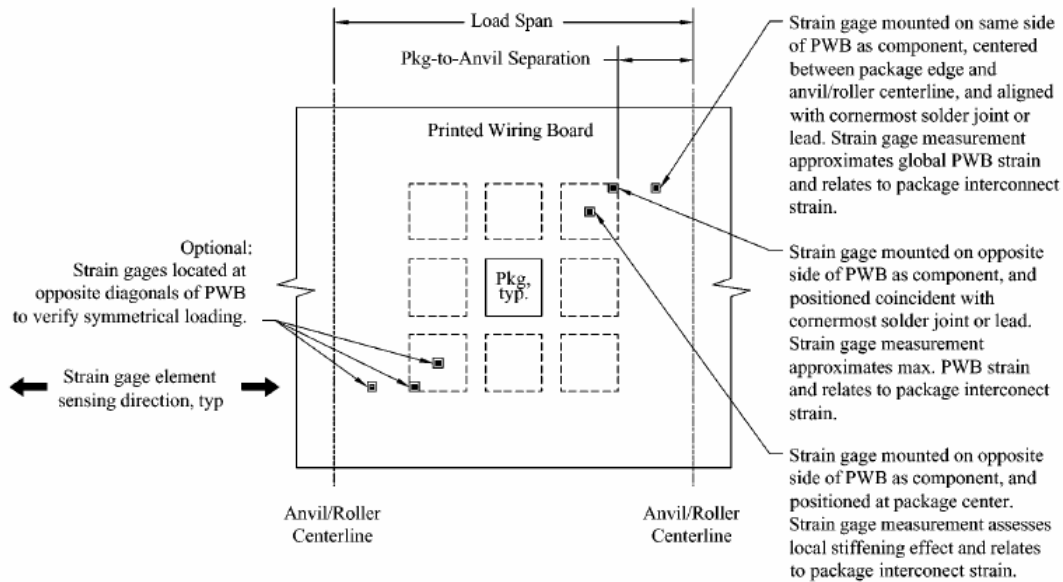


Figure 4 — Recommended Strain Gage Locations

This standard recommends that the strain is measured on at least three locations, as described by IPC/JEDEC-9702 method and shown in Figure 4. The PWB strain readings at these locations provide enhanced characterization to make the comparison between components as well as with actual use conditions meaningful. The three locations recommended provide a measure of component stiffening effect, global PWB strain, and maximum PWB strain which can be correlated with solder joint strain using finite element analysis. For X-Y symmetric test configurations meeting the specific requirements of this test method, the PWB strain values are generally uniform from one package location to another, allowing for the requirement of only 3 strain gages per test board. Finite Element Analysis on the bending behavior of populated board shows that the sensing element of strain gage for global board strain measurement (between anvil and component edge) should be located at least 5 mm away from component edge. The strain values at these three locations on one board shall be recorded for the duration of the test to determine any shift due to permanent deformation of board with cycling. The magnitude of this change in strain value over the duration of test should not exceed 15%. The history of measured strain on one board during the test should be reported along with the minimum, maximum, and average values of strain recorded.

9 Test procedure (cont'd)

9.3 4-Point bend test procedure

The following procedure shall be adopted to conduct the cyclic bend test using 4-point bend method.

1. Attach strain gages and wires for strain monitoring and cables for daisy chain resistance monitoring to test boards. Attach the other end of these wires and cables to the strain and resistance monitoring equipment. Strain gage readings should be calibrated and set to zero in the initial undeflected condition.
2. Move the cross-head up to create enough gap between support and load anvils to slide test board(s) on support anvils without any restrictions. If multiple boards are tested at the same time, allow at least 10 mm gap between the boards by using spacers fixed to anvils or some other features.
3. Place test board (s) on support anvil with component facing down. The test board shall be aligned on the support anvils to achieve a consistent clearance between anvils and closet edge of the components for the two support anvils. If necessary, scribe marks on boards to achieve this alignment. Also, constraining fixtures are recommended to limit the horizontal movement of the board during the test to 1 mm max in each direction.
4. With board aligned on the support anvils, bring the cross-head down until the load anvils touch board surface. If there is visible gap between the anvils and the board, this gap should be minimized by the use of feeler gauges.
5. Program the bend tester according the parameters defined in Table 1.
6. Start in-situ electrical monitoring using event detector or data logger as specified in section 11.
7. Conduct the test until test duration criteria, as specified in next section, is achieved. The test board strains should be monitored at a recommended scan frequency of no less than 10 times the cyclic bending frequency of the test. To limit the file size of measured strain values, the data acquisition system should be programmed to record strain for up to 10 seconds of every 5000 cycle interval.
8. The test board assembly should be returned to an unloaded condition immediately upon conclusion of the test.

10 Electrical monitoring requirements and failure criteria

In-situ electrical monitoring of daisy chain nets for failure is required during cyclic bend test. The electrical continuity of all nets should either be detected by an event detector or by a data logger. Before the start of the test, the initial resistance of daisy chain nets and associated wiring to the event detector/data logger shall be measured. A threshold resistance of 1000 ohms or 5 times the initial resistance, whichever is greater, should be set for failure determination. Preferably, the event detector should be able to detect an intermittent discontinuity of resistance greater than the threshold resistance value lasting for a period as short as 1 microsecond. Optionally, event detector transient detect capability may be relaxed to 5 microseconds maximum. If data logger is being used, it should be able to measure resistance with a sampling rate of at least 10 times the cyclic bending frequency of the test, allowing at least 10 measurements within a cycle. However, to limit the file size, the data logger can be programmed to record only when resistance value exceeds the threshold resistance. It is recommended that at least 100 such recordings are saved to check if the failure criteria specified below is satisfied.

10 Electrical monitoring requirements and failure criteria (cont'd)

Depending on the monitoring system used, the failure is defined as follows:

- Event Detector: The first event of intermittent discontinuity with resistance peak greater than the threshold value followed by at least 9 additional confirmation events within 10% of the cycles to first event.
- Data Acquisition: The first indication of resistance greater than the threshold value followed by at least 9 additional confirmation indications within 10% of the cycles of first event.

11 Test duration requirements

Since this is a characterization test method, no qualification requirements are imposed in this standard. However, to limit the duration of the test, it is recommended that the test be continued for 200,000 cycles OR until at least 60% of all units have failed from the initial samples, whichever occurs first. If the test is conducted one board at a time, at least 6 of the 9 components should fail per board (or 200,000 cycles) before stopping the test. The test duration of 200,000 cycles should not be construed as an expectation of reliability; it is only a recommendation to get enough component failures to generate a valid probability failure plot or to limit the duration of testing. The reliability requirements should be separately determined between the supplier and customer.

12 Reporting

All test reports shall include the following information:

- Package geometrical details including body size, I/O, ball size, layer thickness, and die size
- Board geometry, material, and material properties such as thickness, pad size, and modulus.
- Board assembly details including stencil thickness, apertures, stencil material, solder alloy & paste, reflow profile, and other board assembly process details.
- Test details: load and support spans, cross-head deflection, and cycle frequency
- Board response: Maximum strain and strain rate at three locations during the first 10-100 cycles of every 5000 cycle interval
- Initial resistance of daisy chain nets
- Failure detection equipment and failure criteria
- Test results including the number of cycles to failure for each location on each test board, all observed failure mechanisms, and representative pictures.
- Data analysis showing Weibull plots, Weibull slope and characteristic life, 1st failure and mean life. Lognormal analysis of failure data is also acceptable, in addition to Weibull analysis.

Annex A

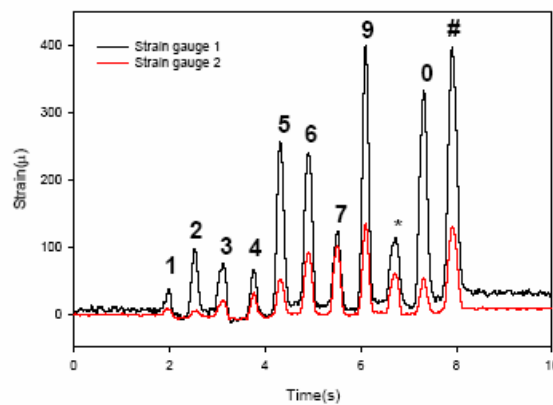
The parameters specified in this test method are based on the work performed by various members of JEDEC task group for board level cyclic bend test standardization. The task group comprised of following companies in alphabetical order:

Amkor Technology, Cisco Systems, Ericsson Mobile Platforms, Flextronics Internation, IBM Corporation, Infineon Technologies, Institute of Microelectronics, Intel Corporation, Nokia Mobile Phones, Research in Motion, SonyEricsson Mobile Communication, ST Microelectronics, Sun Microsystems, and Texas Instruments.

Special test boards were fabricated and assembled and various companies in the task group conducted tests to study the effect of different parameters. Some of the represented data is shown here to show the validity of parameters specified in the standard.

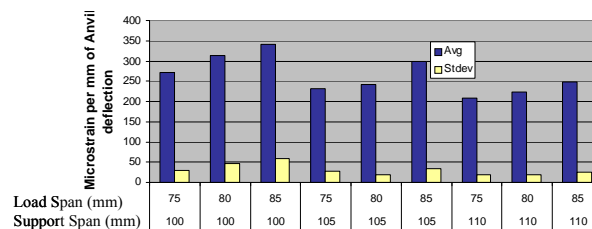
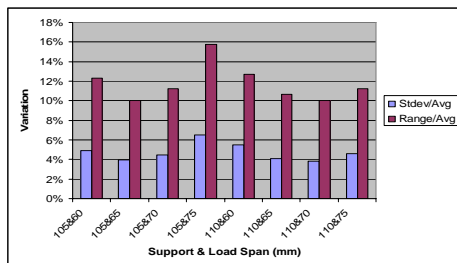
A.1 Mobile phone use condition

An example of strain amplitude and typical key-press duration during normal operation of mobile phone is shown below. The Longitudinal and transverse strains were measured on printed wiring board underneath key “9” and key “8”. Figure below shows maximum strain of about 400 microstrain and a duration of about 0.2 second for each key-press.



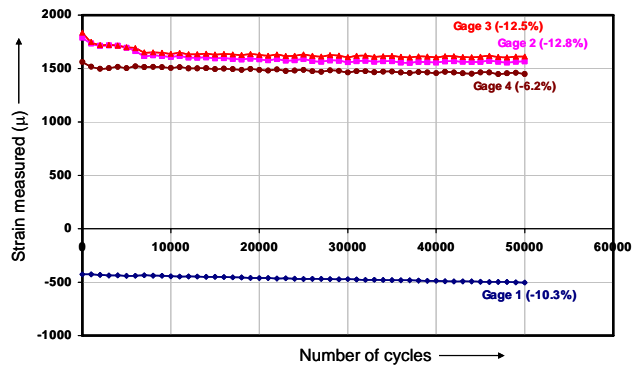
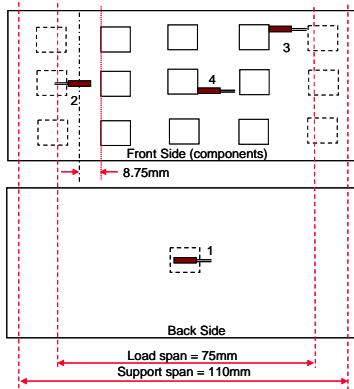
A.2 Effect of support and load span

The smallest variation was found for load span of 75 mm and support span of 110 mm.



A.3 Strain variation as a function of test duration

Figure below shows that the strain amplitude varies with cycle duration and most of the variation is during the first 10000 cycles. The test method allows up to 15% reduction in strain from the initial value for the duration of test.





Standard Improvement Form**JEDEC JESD22B113**

The purpose of this form is to provide the Technical Committees of JEDEC with input from the industry regarding usage of the subject standard. Individuals or companies are invited to submit comments to JEDEC. All comments will be collected and dispersed to the appropriate committee(s).

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1. I recommend changes to the following:

Requirement, clause number _____

Test method number _____ Clause number _____

The referenced clause number has proven to be:

Unclear Too Rigid In Error

Other _____

2. Recommendations for correction:

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