



*Intel Strain Measurement Methodology for  
Circuit Board Assembly – Board Flexure  
Initiative (BFI)*

Intel® Manufacturing Enabling Guide

March 2016



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## Board Flexure Control Methodology Overview

### Important Notice

The information in this document represents part of Intel's current strain measurement method for circuit board assembly.

This document is a reference. Adjustments may be required in order to meet user requirements and constraints.

This information is subject to change without prior notice.

### Problem Statement

With the transition to lead-free, SLI (Second Level Interconnect) failure risk due to manufacturing over-flexure has become an increasing concern, especially when combined with the process changes for lead-free manufacturing. Over-flexure may cause partial cracking of the SLI as well as PCB pad crater, resulting in customer field returns. These partial cracks cannot currently be detected by functional testing. Intel uses the IPC-9707 standard spherical bend test methodology (minimum strain rate of 5000 $\mu$ e/sec) to provide Intel BFI strain guidance. Intel's BFI methodology is in alignment with IPC-9704A and is outlined in this MAS so that customers can monitor and reduce SLI failure risk due to over-flexure in manufacturing.

### Board Flexure Overview

To compare monitored manufacturing strains to Intel strain guidance, a strain report should be generated.

- Prepare test boards by mounting strain gages in specified locations.
- Perform an audit to identify all assembly steps that may cause over-flexure.
- Measure the strain during these assembly steps that may cause over-flexure.
- Calculate maximum diagonal strain values.



## Board Flexure

- Make a formal strain report comparing maximum diagonal strain values with Intel BFI strain guidance values.

All of these steps are detailed in the following pages.

## Strain Methods

Intel board flexure guidance aligns to IPC-9704 and IPC-9707 standards.

**Metric:** In the applicable assembly steps, diagonal strain guidance should be compared to the maximum calculated diagonal strain (other metrics, such as principal strain should not be used).

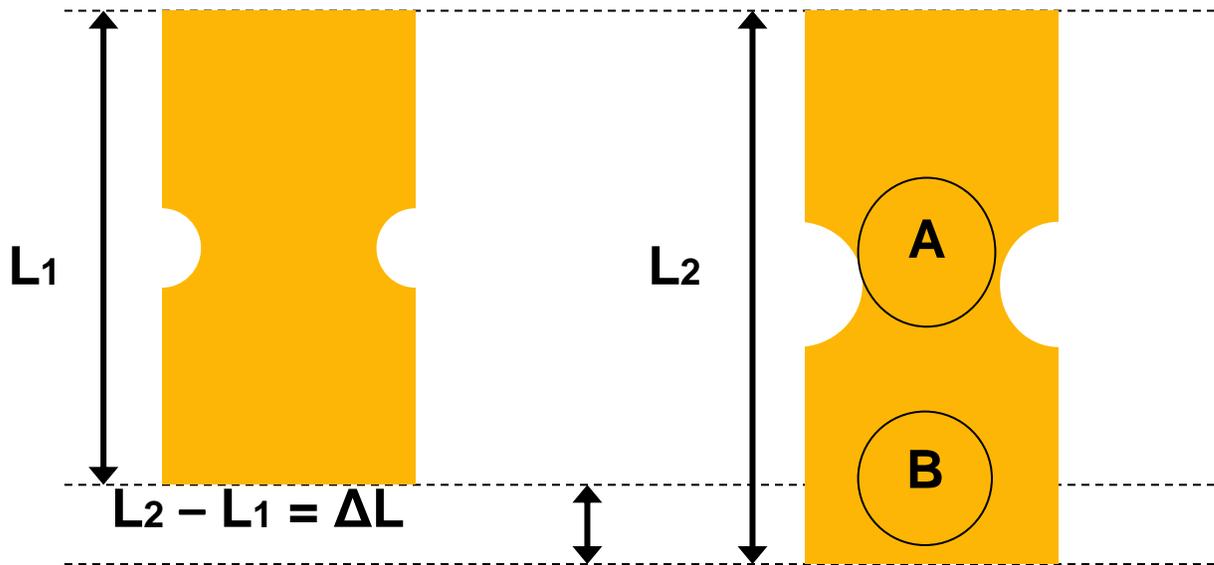
**Location:** Accurate strain gage rosette positioning is required to compare monitored manufacturing strain to Intel's BFI strain guidance.

Please contact Intel CQE for the location and BFI strain guidance for Intel products.

Intel recommends using Intel BFI strain guidance to monitor and reduce SLI failure risk due to over-flexure in manufacturing.

## Fundamentals of Strain Measurement

**Definition of Strain:** Strain is a measure of change in length - it is a relative number.



Strain can be calculated by:

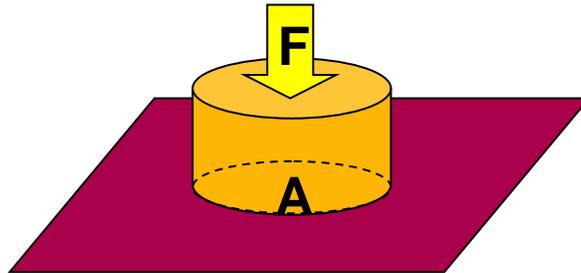
$$\epsilon = \Delta L / L1$$

This value is dimensionless (the units of length cancel out). When  $\epsilon = 0.000001$ , it is called 1 micro-strain ( $\mu\epsilon$  or  $ue$ ). Strain may depend on location. In the picture above, the strain at A will be different than the strain at B.

**Definition of Stress:**

Stress is defined as force divided by the area over which the force is acting. The equation is:

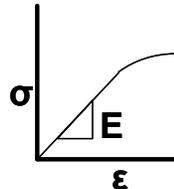
$$\sigma = F / A$$



Stress ( $\sigma$ ) causes strain ( $\epsilon$ ). The equation is

$$\sigma = E \times \epsilon$$

$$\sigma = F/A \Rightarrow \epsilon = F/AE$$



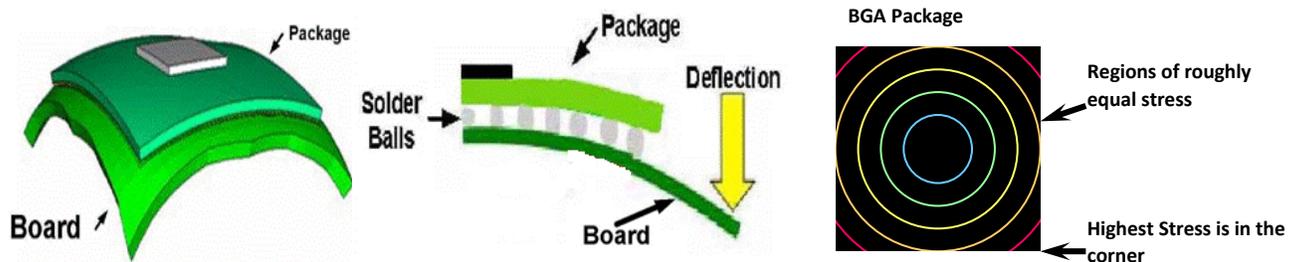
The "E" is the elastic modulus (stiffness) of the material. The



In the assembly and test environment, only displacement ( $\Delta L$ ) and force ( $F$ ) can be changed. Therefore, all flexure reduction comes down to limiting displacement and reducing forces.

### Definition of Board Flexure:

When a board is assembled, it is stressed—and therefore strained—in many directions. This “board flexure” puts stress on the solder joints and causes the package to flex, too. The corner solder balls are usually under the most stress.



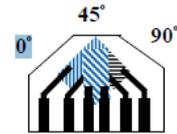
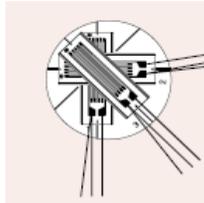
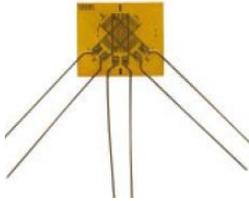
Intel does not have a way to directly measure the stress or strain on the solder balls, so we measure the strain on the PCB near the corner of the package.

### Strain Gages:

Intel measures strain using strain Gages. Strain gages work by measuring the resistance change that occurs when a metal is strained. A stack of three gages (a rosette) allows for measuring the strain in three directions and to calculate the strain in any direction. Some of the commonly available rectangular rosette strain gages are included below. Intel does not recommend the use of a specific strain gage manufacturer or brand.



## Board Flexure



Courtesy of Vishay

Micro-Measurements®  
NMB®

Courtesy of Kyowa®

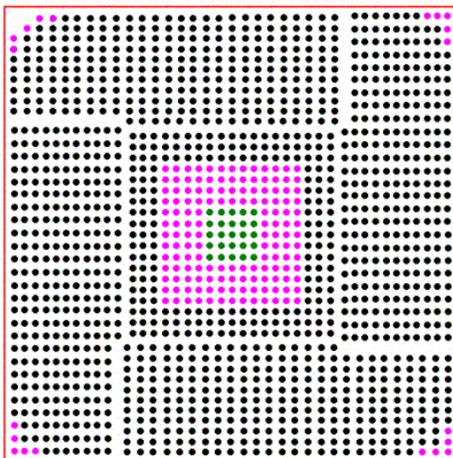
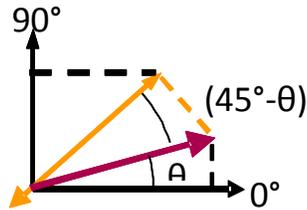
Courtesy of

Mounting a rosette on the PCB near the corner of the package allows for indirectly monitoring the risk at the corner solder joint due to board flexure in manufacturing.

### Intel BFI Strain Guidance Metrics

**Intel is using diagonal strain;  $\epsilon_d = \max(|\epsilon_2|, |\epsilon_4|)$**  as the metric to define the package strain guidance based on spherical bend mode for many of its BGA components.

Diagonal Strain is the transformation of Principal strain to 45°.



Max Principal Strain at

$$\cos(45 - \theta) = \frac{\epsilon_D}{\epsilon_p}$$

$$\epsilon_D = \epsilon_p \times \cos(45 - \theta)$$

Intel will continue to provide component strain guidance for its BGA and sockets in diagonal strain metric based on spherical bend mode.

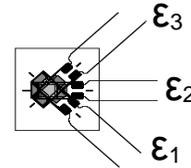
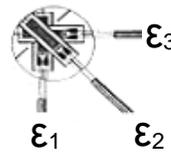
The strain values provided in Intel BFI strain guidance apply only to transient bend conditions seen in manufacturing assembly environment.

**Strain Metric - Diagonal Strain:**

Board Flexure

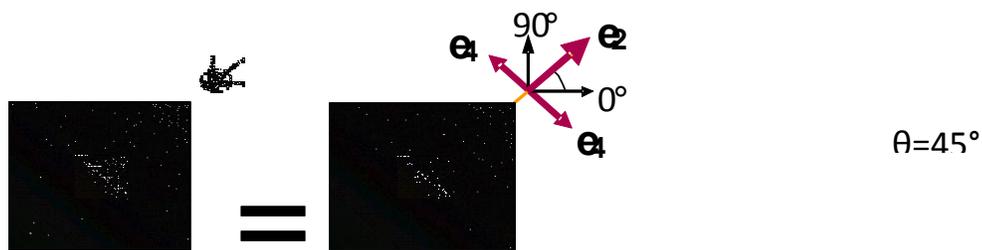
Intel uses a strain metric called diagonal strain which is a coordinate transformation of the Principal Strain to 45° to determine the strain guidance. The diagonal strain equation is:

$$\varepsilon_d = \max(|\underbrace{\varepsilon_2}_{\varepsilon_2}|, |\underbrace{\varepsilon_1 + \varepsilon_3 - \varepsilon_2}_{\varepsilon_4}|)$$



Drawings courtesy of Kyowa and Vishay Micro-

This picks out the strain vector that is concentrated on the corner solder joint.

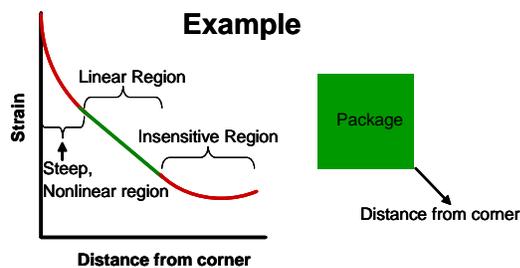


### Gage Placement:

The strain gradient at the package corner is very steep and nonlinear. Placing strain gages too close to the package corner causes measurements to be very sensitive to small errors in gage placement.

Placing strain gages too far from the package corner reduces sensitivity to the true bending at the corner.

Intel chose a strain gage location in the linear region between the two extremes.





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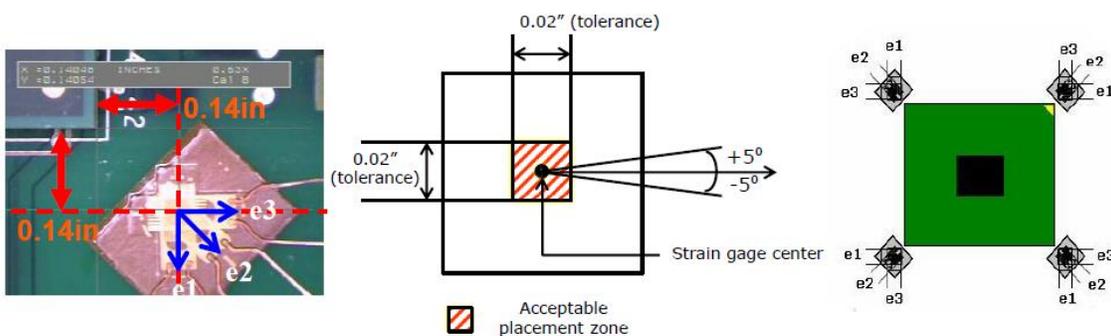
### Strain Gage Placement for Intel BGA components (Plan of Record Location and Alternate Gage Locations):

Since strain is relative to location, the same strain gage location must be used for testing as was used to get the strain guidance. Unless the gages are placed in the same location, strain numbers cannot be compared to the strain guidance.

For direct-attach BGA components, the center of the strain Gages must be at the intersection of lines 0.14" +/- 0.02" (3.6 +/- 0.5mm) from the edge of the substrate, with e1 and e3 parallel to the edges.

Monitoring of all FOUR corners is recommended.

Accurate positioning of strain gages is necessary to compare strain data to Intel strain guidance. Strain gage location accuracy should be +/- 0.02" (0.5mm) and +/- 5°.





### **Alternate Gage Locations for BGA components (Background):**

Since strain gages cannot always be placed at the POR location in mobile systems due to spacing constraints, Intel has identified two alternate locations that can be used to monitor board flexure during manufacturing. The specific Intel BFI strain guidance's for alternate locations only would apply for mobile platforms (e.g. Laptops, Tablets, Smartphone, Ultrabooks, etc.)

The first alternate gage location is on the primary board side, and the second alternate gage location is on the secondary side of the board (henceforth referred to as ALT1 and ALT2 location, respectively). Intel recommends that customers use the POR location whenever possible before considering ALT1 and ALT2 locations.

The gage locations are consistent with the existing metrology. No changes to the test method are required. Intel will continue to provide component strain guidance at this reference location. Additionally Intel may provide strain value at the alternate location for certain Intel products using existing product BFI strain guidance sheet\* which is separate from this document or the BFI Manufacture Advantage Service (MAS) document.

\* This BFI strain guidance sheet does not supersede the Thermal Mechanical Design Guidance (TMDG) document provided by Intel for a product.

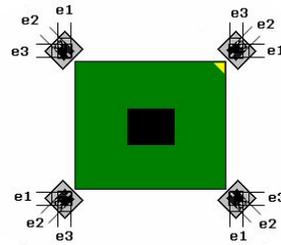
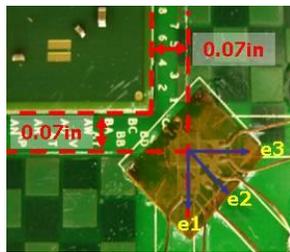
### **Alternate Gage Placement-ALT1 on Intel BGA (Closer on PRIMARY SIDE):**



For direct-attach BGA components, the center of the strain gages must be at the intersection of lines 0.07" +/- 0.02" (1.78mm +/- 0.5mm) from the edge of the substrate on the PRIMARY side, with e1 and e3 parallel to the edges.

Monitoring of all FOUR corners is recommended.

Strain gage location accuracy should be +/- 0.02" (0.5mm) and +/-5°.



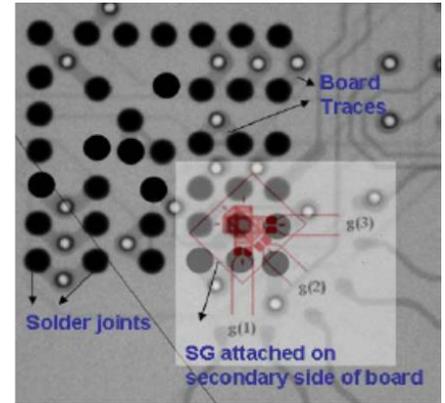
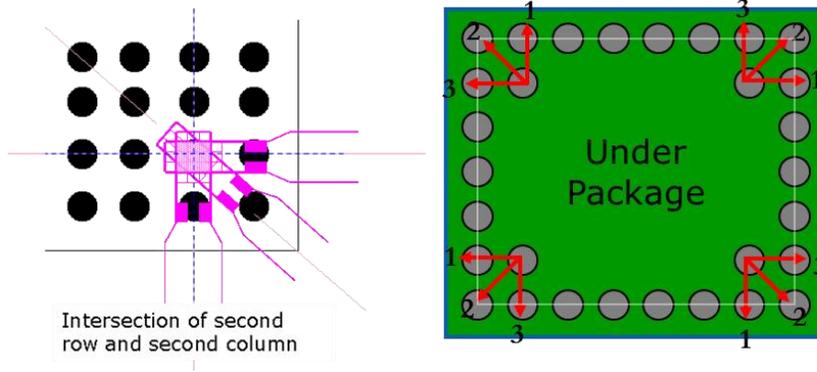
### **Alternate Gage Placement-ALT2 on Intel BGA (Under Package on SECONDARY SIDE):**

For direct-attach BGA components, the center of the strain gages must be at the intersection of the 2nd vertical and horizontal row from the package edge on the SECONDARY side, with e1 and e3 parallel to the footprint of the package edges.

Silk-screening an attach "line-up" is recommended to ensure accuracy.

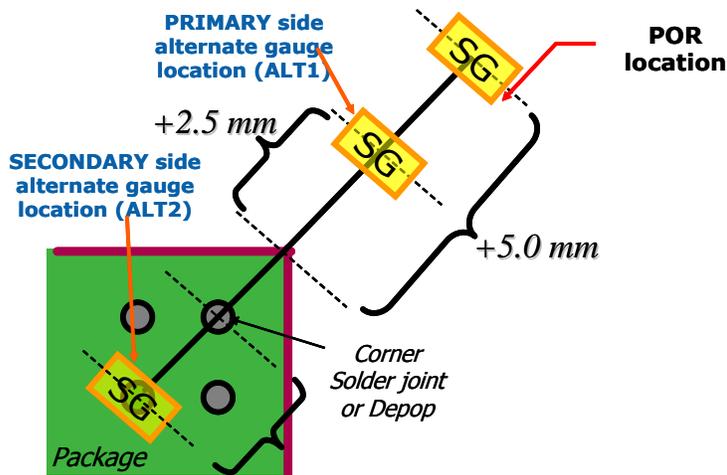
Monitoring of all FOUR corners is recommended. Strain gage location accuracy should be +/- 0.02" (0.5mm) and +/-5°.

Board Flexure



For packages with ball pitch  $0.5\text{mm} \leq x < 0.8\text{mm}$

**Alternate Gauge Location Summary for Intel BGA Components:**





*\* At the intersection of second*

**Gage Placement for Intel Socket LGA771/775 (Plans of Record Location):**

Intel has published BFI strain gage locations for sockets, starting with the LGA771/775 socket. The gage locations might vary from socket to socket and are different from BGA strain gage locations

The gage locations are consistent with the existing metrology. No changes to the test method are required.

Similar to BGA components, it is recommended that all four corners be monitored for sockets as well



**All subsequent Intel socket launches:**

Socket strain guidance and gage location will continue to be released using product BFI strain guidance sheet. The BFI strain guidance sheet does not supersede the Thermal Mechanical Design Guide (TMDG) document provided by Intel for a product.

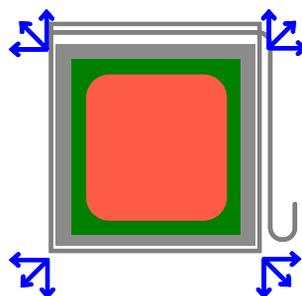
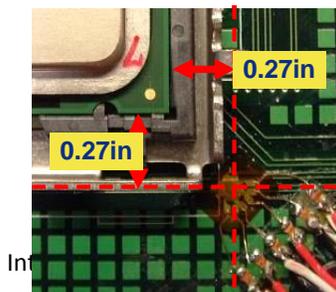
Customers need to be aware that strain gage locations may differ for different sockets.

**Gage Locations for Intel Socket LGA771/775 (Plan of Record Location):**

For LGA771 and LGA775 sockets, the center of the strain gages must be at the intersection of lines offset from the package edges 0.27" +/- 0.02" (6.9 +/- 0.5mm), with e1 and e3 parallel to the edges.

All four corners are recommended.

Strain Gage location accuracy should be +/- 0.02" (0.5mm) and +/-5°.



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## Intel Component Strain Guidance Determination

The BFI strain guidance is determined for each of Intel's major BGA components and Sockets. The BFI strain guidance will be provided in the component BFI strain guidance sheet.

Intel determines acceptable BFI strain guidance for its components through mechanical testing, component failure analysis, and finite element analysis modeling. The BFI strain guidance is based on the strain level at which solder joint cracking may begin, not on the level at which electrical open occurs.

Adhering to the Intel BFI strain guidance throughout your entire process will ensure that components will not be damaged during manufacturing. Exceeding Intel BFI strain guidance may result in BGA solder joint cracks and failure analysis is recommended to fully assess risk to product quality

Intel's assembly strain guidance applies to "transient bend" conditions. The Spherical bend mode is the most destructive bending mode.

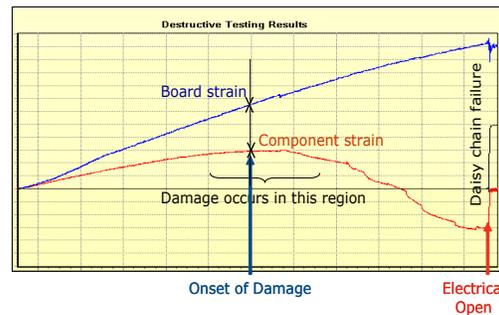
Rosette strain gages are placed on the surface of the component substrate and on the PCB.

## Board Flexure

The board is tested to daisy chain failure. The testing will identify the displacement level at the onset of mechanical damage (peak substrate strain level).



Strain gauge at component  
Strain gauge at board

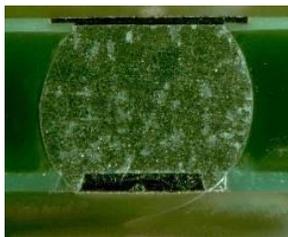


### Strain Guidance Validation Failure Analysis:

Additional boards are tested at lower strain levels. Final data-turn testing is only to one strain level, either determined through modeling, or through testing.

Cross section and dye penetration are used to look for damage.

The guidance is set where no damage is detected.



X-section



Dye & Pry

### **Transient Bend (Spherical Bend) Test:**

Intel's BFI strain guidance applies to "transient bend" conditions.

The guidance is for use in the assembly environment. They are not for use in reliability testing.

The guidance is a function of component design, solder type, and board thickness. If a different board thickness is used, the strain value for the thicker board should be used.



**Spherical Bend Test Setup**



**Eight reaction pins attached to support plate**

### **Intel Reference Hardware**

This section provides hardware performance references for accurate use of Intel's strain measurement method.



## Board Flexure

Customers are responsible for selecting their own hardware, and for verifying the performance of hardware with the supplier.

Customers are responsible for all supplier interactions related to tool upgrades and purchases.

Customers are also responsible for understanding and operating their hardware.

Intel may make changes to these references at any time, without prior notice.

### Reference System Capability:

<b>Component</b>	<b>Reference</b>
<b>Data Acquisition</b>	Capable of 2000 samples per second (2kHz) sampling rate for each channel. Low strain rates may miss significant peak strains (see backup)
	Capable of sampling all strain gage channels at the same time (simultaneous) at 2kHz. Individual Gage measurement (sequential) may cause miscalculations (see backup).
<b>Channels</b>	At least 12 channels per Intel component. Quarter bridge capability.
<b>Filter</b>	Low pass analog filter. Should be set to less than half the sampling rate to prevent aliasing.
<b>Power</b>	Free of irregularities, such as voltage spikes and grounding faults.



<b>supply</b>	
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## Test Board Preparation Procedure

### 4.2.1 Strain Gages Attachment Reference Process

#### Introduction:

Strain Gages are attached to printed circuit boards in order to relate strain near Ball Grid Array (BGA) components and socket to solder ball strain conditions in the manufacturing environment.

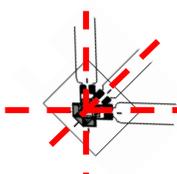
Intel BGA and socket strain guidance is determined based on a combination of lab testing and FEA modeling.

Application of Intel strain guidance requires careful positioning of strain gages relative to BGA components as well as for socket. Improper positioning or application of strain gages may result in incorrect data and may not be applicable for comparing against Intel BFI strain guidance.

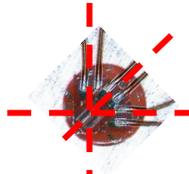
#### 4.2.2 Strain Gages Types

Strain Gage (Rosette) Center: There are many brands and types of strain gages with different shapes and sizes.

The center of a strain gage rosette is the center of the overlaid active grids and is marked with grid indicators that are used to orient the gages when gluing to circuit boards.



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Drawing courtesy of Vishay Micro-Measurements®



Courtesy of NMB®

March 2016 Drawing courtesy of Vishay Micro-Measurements®



## Test Board Setup

### **General Information:**

Proper strain gage attach is critical to the accuracy of the measurement.

In order to ensure proper strain gage attachment, here are some of the general recommendations:

- Strain gage preparers need to have working knowledge on attaching strain gages or must be trained
- Use only vendor related and listed materials to attach gages. Follow the manufacturer's recommended bonding process
- Clean any portion of the tools that will be in contact with the strain gage to avoid spreading any type of contamination to the gage, board, or bondable terminal
- Ensure that strain gages are completely bonded to the surface. Any bubbles / air trapped between gage grid and board surface will result in inaccurate measurement result

## Board Flexure

- The exact location for strain gage attachment is dependent upon the data analysis required for a particular project. The location accuracy will greatly impact data collection accuracy

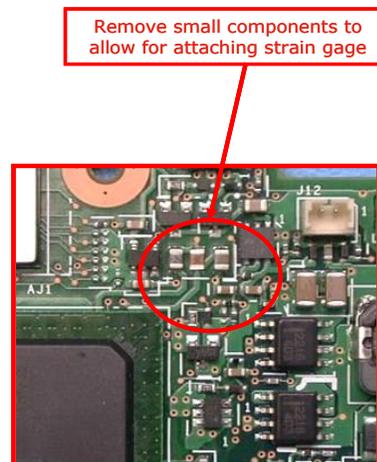
## Board Preparation

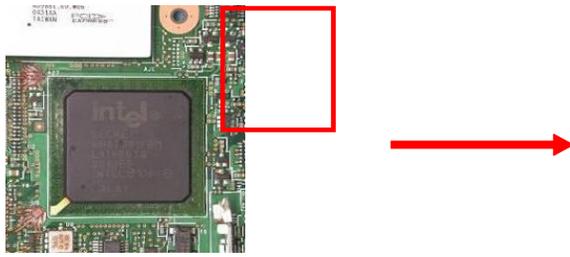
### **Board Preparation for Strain Gage Attachment:**

Small surface mount components should be removed by de-soldering and smoothed by solder wicking to allow proper strain gage attach. Large caps and leaded components can be cut off.

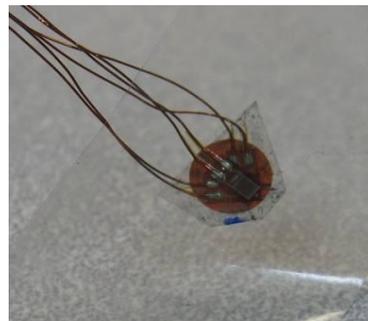
Very large connectors must be left in place, and if a gage cannot be placed in the required location, record a note in the test log.

Do not use sanding paper as it will remove the solder mask and damage the board surface and the resulting strain results could not be applicable/comparable with the Intel BFI strain guidance.





**Board and Gage Preparation:**

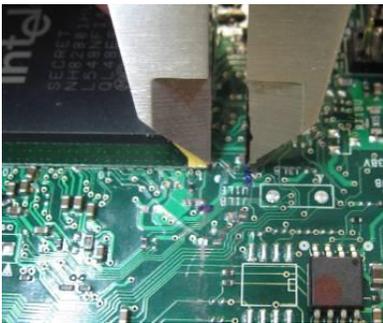


## Board Flexure

1. Small parts removed in the gage mounting area by de-soldering and

2. Gage attached to cellophane tape, do not

## Locating Gage on the board



5. Align the gage to the pen mark making sure the gage is

6. Glue gage using



3. Using a caliper or ruler, mark 2 lines at 0.14 in. from the all



4. Attach gage to cellophane



Board Flexure

### **Strain Gage placement tool:**

Intel designed this tool to help customers be consistent and quick during the strain gage placement process at the Plan of Record recommended gage location - 5mm diagonally, or 3.6mm in the X and Y direction.

This tool is used for Intel BGA packages only and is not for sockets. The Intel strain gage placement tool is not available for alternate locations: ALT-1 and ALT-2.



**Tool used for  
Rectangular  
Vishay® Strain  
Gage**



**Tool used for  
Circular  
Kyowa® Strain  
Gage**



**Tool used for  
Half Hexagon  
NMB® Strain  
Gage**

### **Attaching the Gage using Intel Strain Gage placement tool:**

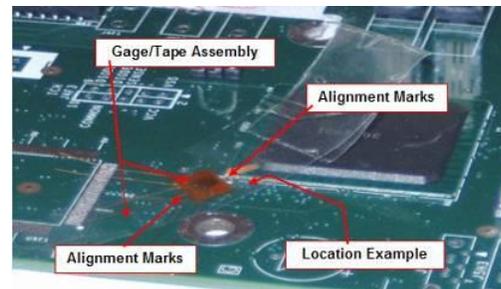
1. Place gage on cellophane tape, bonding side exposed, with half of the gage not covered by the tape.



2. Place the tool at the corner of the component to be tested.
3. Position and align the tape with gage attached to the Intel template directly over the required location.
4. Remove the Intel template, now attach an additional piece of the cellophane tape over the bonding side that is exposed, thus covering and securing the gage completely.
5. Holding the tape carefully, pulling back the side of the tape toward the gage wires revealing the bottom side of the gage to apply glue under. Then apply glue over the board surface that would cover gage dimension. Then carefully fold the tape back down to attach the gage to the board
6. Apply pressure and hold over the top of the gage with your index finger for approximately 1 minute to release bubbles/air trapped between gage grid and the board surface
7. After 1 minute, CAREFULLY remove the cellophane tape from the tape side that is holding the gage wires toward to the BGA corner. Note: Ensure to hold the wires of the gage during this step



Place the strain gage template at the corner of the



Aligning the gage on the sample location



## Final Preparation

### **Inspect The Entire Gage Assembly:**

Inspect the entire gage assembly area under the microscope.

Correct any of the following problems:

- Detached strain gage leads - remove and replace the gage, taking care not to break the leads
- Any bubbles trapped between gage grid and board surface - remove and replace gage
- Remaining debris / other contaminants - clean with isopropyl alcohol, taking care not to damage leads
- Coat with sealant to protect gage during testing



## Video – Strain Gages procedure

Intel developed videos to provide customers the strain gage attachment procedure / guidelines for Intel (BGA) components on motherboard using various strain gage types: Vishay®, Kyowa® and NMB®. Go to <http://bcove.me/7gf5awo7> and <http://bcove.me/gcv1udqf>

## Motherboard Assembly Line Strain Measurement

### Introduction

A careful and methodical approach to strain testing will improve your chances of getting good and accurate results.

A test plan is the best way to ensure accurate data collection. A good plan will save time, reduce confusion and mistakes, and help avoid having to test again or, worse, making conclusions based on bad data.

This document gives a reference plan and testing procedure that you may need to adapt to your needs and assembly processes.

It is recommended to audit the production line and every assembly process to identify where over-flexure may occur.

Gage placement is different for different types of Intel Components (Sockets and BGAs). Use caution to use the correct strain guidance for appropriate component type.

The test board and fixtures must match those that will be used in production for the testing to be representative.

## Test Planning

The first step in data collection is to make a plan.

1. Start by listing all assembly steps, identify if they may cause over flexure, and people and parts needed.
2. Write down a testing plan.
3. Gather all parts and people needed for test and assembly.
4. Ensure that the test board with the gages attached and the hardware/software (for data acquisition) are ready prior to the test so as to minimize downtime in the production line.

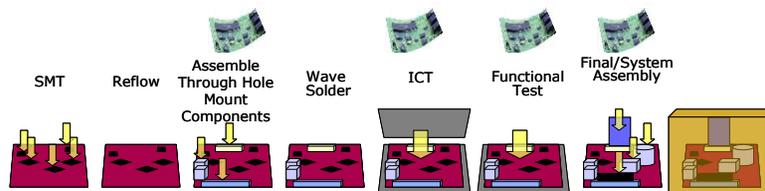
This section gives references for each of these steps.

## Identify Assembly Steps

Damage can occur at any assembly step, so strain measurements should be taken anywhere on the line where flexure may occur.

This includes all board assembly steps, all ICT fixtures, all functional test fixtures, and all system assembly steps.

### **Common Motherboard Assembly Steps**





Intel recommends that strain measurements be taken after new product introduction, product line change over, after any fixture maintenance or change of fixture, and on a regular schedule.

### **Manufacturing Line Flexure:**

In the manufacturing environment, there are several procedures which typically flex the board enough to cause damage:



- Manual board assembly, where many through hole components and others such as battery, z-clips, BGA heat sink, etc., are inserted in the board by hand before being permanently soldered in place.
- In-circuit test (ICT) or Manufacturing Defects Analysis (MDA) — an automated process which tests electrical connections.
- Final/System assembly— where many large components are put in place by hand. Example, Independent Loading Mechanism (ILM) and heat sink installation.
- Functional test—a test which simulates system boot: CPU insertion, CPU temporary fan, DIMM insertion and peripherals attachments.
- System Integration – where motherboard is assembled in chassis, followed by CPU Insertion, CPU heat sink and fan assembly, DIMM insertion and peripheral attach.

### Sample Test Plan

### **File Naming Plan:**



## Board Flexure

It is a good practice to create a naming system and plan the names for the data files in advance. Also, be sure to name the files appropriately as soon as they are created so there is not confusion.

Here are some things you may want to include in the file name:

1. Customer name
2. Segment (Notebook, Desktop, Server etc..)
3. Product Board name
4. Date
5. Intel component name
6. Manufacturing step (System assembly, ICT or MDA, Functional test or System integration).
7. Test fixture name – ID number
8. Test Cycle number



Example: Intel Desktop Pike-ton 01-24-11 LGA1156 ICT-106 #3

**Sample Test Plan:**

After performing an audit in the production line, take care to write down each assembly step for the board or assembly line, identify if it may cause over-flexure, write down the people and the parts required to assembled the board.

Use the list of assembly steps and file naming system to plan your tests. Include the manufacturing step, number of repetitions, people and parts needed, and file name.

Measurements should be taken in order from the beginning to the end of the assembly process of the particular product so that the combined strains are recorded.

	Testing Locations		Schedule		Execution					Notes
	Mfg. Step	Flexure?	Planned	Actual	Board(s)	Reps	People	Parts	File(s)	
1	Board inspection at SMT	Yes	WW04	WW05	A	6	2 SMT inspectors	None	Dolphin 2006-01 22 LGA771 THMT Station1 Operator1-John	
2	Board transportation from SMT to Wave	No	WW04	WW05						Conveyor does not flex board
3	Board handling and THMT component assembly	Yes	WW04	WW05	A	6	6 assembly operators	All THMT parts	Dolphin 2006-01 22 LGA771 THMT Station1 Operator1-John	
4					B,C,D					If board B is <70% of limit, don't build or test boards C and D.
5										



### Zeroing the Strain Gages:

All assembly steps should be tested in order from the start until the end of the assembly or test process.

It is recommend to zero the strain gages before each motherboard assembly steps (ICT, Functional test, System assembly etc) with the board at rest.

It is recommend during manual functional test process to split the strain measurements (record strain activity) in two sections:

1. Insertion process (DIMM, CPU, I/O cables, CPU fan, keyboard, mouse etc)
2. Removal process (DIMM, CPU, I/O cables, CPU fan, keyboard, mouse etc)

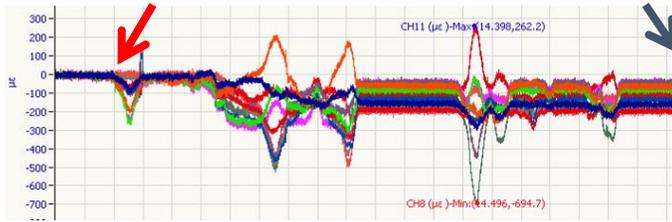
Example of correct procedure during manual functional step

Strain gage should be zeroed before attachment of devices that leaves residual strain after installation. In the example shown below, the insertion steps in order are as follows: install CPU, close the socket, install CPU heat sink, insert power cable and Keyboard, DIMMs insertion.





Board Flexure



Install

Clos

Inst  
all

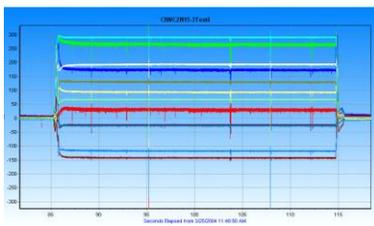
Keyb  
card

### Checking the Data:

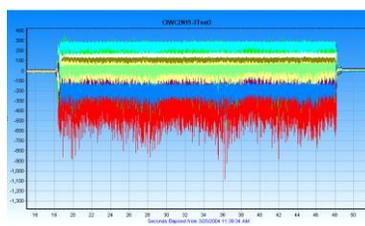
After recording the first test cycle, it is recommend to always check the strain data for problems. This prevents the user from wasting time collecting bad strain data from an assembly step or an entire assembly line.

Example: During the ICT or MDA testing if the data has strange spikes, ensure that test probes or pushdown are not touching the gages.

In general, if the data has noise, ensure the board is supported properly (with no vibration or shaking) and that there are no grounding faults or voltage fluctuation in power supply connection.



Data set with spikes



Data set with noise



## Testing Areas

### **Assembling Through Hole Mounts:**

Prior to performing the strain measurement, ensure that the test board with the gages attached and the hardware/software (for data acquisition) are ready prior to the test so as to minimize downtime in the production line.

Identify all of the components that are required to be assembled. Get 6 samples of each component.

Go to each manufacturing step on the list prepared earlier. If there are many people who do that step, pick two or three for the test that represent the worst case scenario in the production line. Request each person to do their normal operation on the test board while measuring the BFI strain induced by board flexure.

Support the test board in the same way as in normal assembly and record the strain during the assembly step.

Stop the recording after each assembly step, remove the components for that step, and get new components.

Repeat the assembly step and record the strain a total of 6 times (manual process).



### **In Circuit Test (ICT):**

- Prior to performing the strain measurement, ensure that the test board with the gages attached and the hardware/software (for data acquisition) are ready prior to the test so as to minimize downtime in the production line.
- Place the test board in the ICT fixture. Slowly close the fixture and move the strain gage lead wires so that nothing presses on them. Use tape to hold the strain gage lead wires.
- If necessary, remove anything that presses or touch the strain gage. Make a note in the report if anything is removed, or if something presses or touch strain gages during the test.
- Place the board in the fixture, start recording the strain, close the fixture, operate or activate the test fixture and wait for ~ 10 sec, then release the test fixture, open the fixture and stop recording.
- Repeat the test 3 times.
- Repeat this test for every ICT fixture. Different fixtures may give very different results, and may change over time.
- Testing must be done on the real production test head. In addition to test board variability and changes due to damage during shipping, test heads at fixture manufacturer's sites may give very different results due to vacuum supply differences.

### **Functional Test (FT) – Manual or Automated:**

- Prior to performing the strain measurement, ensure that the test board with the gages attached and the hardware/software (for data acquisition) are ready prior to the test so as to minimize downtime in the production line.
- Place the test board in the functional test fixture. If applicable, slowly close the fixture and move the strain gage lead wires so that nothing presses on them. If components are assembled onto the board for the



## Board Flexure

test, move the strain gage lead wires so that the components do not press on the wires. Use tape to hold the strain gage lead wires.

- If necessary, remove anything that presses or touches the strain gage. Make a note in the report if anything is removed, or if something presses or touches strain gages during the test.
- Place the board in the fixture, start recording the strain, do the normal functional test insertion/removal and stop recording.
- Repeat the test 3 times for a fully automated test. If the test is partially automated, there is operator interaction that would place it into the "manual assembly" category and require 6 repetitions.
- Repeat this test for every functional test fixture. Different fixtures may give very different results, and may change over time.

### **Final or System Assembly:**

- Prior to performing the strain measurement, ensure that the test board with the gages attached and the hardware/software (for data acquisition) are ready prior to the test so as to minimize downtime in the production line.
- Identify all of the components that are required to be assembled. Get 6 samples of each component.
- Go to each manufacturing step on the list. If there are many people who do that step, pick two or three for the test that represent the worst case scenario in the production line. Tell each person to do their normal operation on the test board while measuring the BFI strain induced by board flexure.
- Support the test board in the same way as in normal assembly and record the strain during the assembly step.
- Stop the recording after each assembly step and remove the components for the step.
- Repeat the assembly step and record the strain a total of 6 times.



### **Original Equipment Manufacture (OEM) or Original Design Manufacture System Integration Line:**

- Prior to performing the strain measurement, ensure that the test board with the gages attached and the hardware/software (for data acquisition) are ready prior to the test so as to minimize downtime in the production line.
- Identify all of the components that need to be assembled. Get 1 sample of each component.
- Identify the assembly step for each of the component – CPU insertion, CPU heat sink and fan installation etc.
- Go to each manufacturing step on the list. If there are many people who do that step, pick two or three for the test that represent the worst case scenario in the production line. Tell each person to do their normal operation on the test board while measuring the BFI strain induced by board flexure.
- Support the test board in the same way as in normal assembly and record the strain during the assembly step.
- Stop the recording after each assembly step and remove the components for the step.
- Repeat the assembly step and record the strain a total of 6 times.

### **General Tips**

Ensure that there is a robust preventive maintenance program in place in the manufacturing assembly environment (recommended ~ 2 time per day).

1. Always keep the fixture in good condition by cleaning it daily.
2. Always remove any debris from the fixture as they can get trapped in plate reliefs and prevent the fixture from moving smoothly and can induce additional strain.



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3. Always inspect the testing probes daily for wear and tear, especially on Lead Free solders.
- 4.

Measure fixtures using base testers and avoid vacuum table simulators since they often don't represent the real conditions.

Re-measure fixtures when conditions change, when probes are replaced, or when there is a major SKU change.

## Flexure Reduction

Test operations can apply excessive force, causing boards to exceed the Intel component strain guidance. Some of the main factors that can lead to the application of excessive force are:

- Pushdown and testing probes near to the corners or around the edges of the components.
- Lack of maintenance on fixture – strain could change overtime.
- Brand New Fixture Validation process – difference strain results between tester and simulator

Performance of a test fixture can change with time and when used with different testers.

It is important to measure the strain on all test fixtures on a regular schedule. If a fixture exceeds the Intel BFI strain guidance, contact the fixture supplier for adjustment.

Human operators may also apply excessive force during their assembly process. It is important to train each operator to ensure that they are aware of board flexure risks. Intel recommends that multiple operators are used when measuring BFI strain on automated and manual processes.



## Reporting Procedure

### Overview

A strain report is the final step and the most important process to determine the risks after strain measurements.

A good strain report will compare the maximum measured strain values against the Intel BFI strain guidance, and includes important test and assembly use condition information.



There are several methods for calculating the principal strain and diagonal strain metrics, including the data acquisition system software and the Intel BFI reporting tool.

Most of the data acquisition software available in the market have the capability to calculate Principal Strain metric only. Intel BFI Reporting Tool allows the user to automatically calculate "Diagonal Strain" metric for those DAQ (data acquisition) strain measurement equipment that DO NOT have this capability.

## Report Format

A good report must have:

- Customer name
- Segment name (Notebook, Desktop, Server etc.)
- Product Board name
- Date
- Intel Components tested
- Manufacturing steps tested (System assembly, ICT or MDA, Functional test or System integration).
- Test fixture name – ID number
- Test Cycle number (1, 2, 3, ...6)
- Maximum strain metric value for each component and assembly step
- Pass or fail indicator



A completed strain report must consist of:

- Data summary with the Intel Strain Guidance information
- Pictures of boards with Intel components and the strain gages attached
- Diagonal Strain graphs
- Raw Data files

**Sample Report Format:**

Information		Data Acquisition System	
Company	Intel Corporation	Machine Make / Model	Vishay 6200
Site	HF1 Campus - Hillsboro, OR	Machine Software / Version	Strainsmart / 4.31
Product Name	DT Sugar Bay Lunas MTB1	Sampling Rate / Filter	500 / 100 H
Customer	CME	<b>Strain Gage</b>	
Manufacturing Line	BDL Lab System Assembly Workstation	Gage Part Number	VMM B -00629-B
Date of Report	12-Jan-11	Gage Vendor	Vishay Measurement Group
Inspector	Ruben Torres	Gage Description	120 ohms

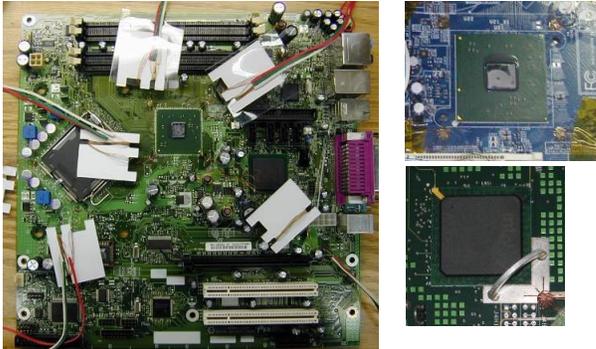
Maximum Component Strain				Values at Maximum Diagonal Strain				Intel Strain Guidance
Assembly Step	Product - Component - Solder type - Board Thickness	Segment / Rep.	Strain Gage	Grid 1	Grid 2	Grid 3	Diagonal Strain	
				microstrain	microstrain	microstrain	microstrain	microstrain
System Assembly - Man CPU Installation wLGA115X tool on ATXcase	Intel DT Sugar Bay Lunas - BGA CPT- OSP HF - 062"	4	A	-342	239	-16	-597	500uE

Summary of Strain Data				Values at Maximum Diagonal Strain				Intel Strain Guidance
Assembly Step	Product - Component - Solder type - Board Thickness	Segment / Rep.	Strain Gage	Grid 1	Grid 2	Grid 3	Diagonal Strain	
				microstrain	microstrain	microstrain	microstrain	microstrain
System Assembly - Man CPU Installation wLGA115X tool on	Intel DT Sugar Bay Lunas - BGA CPT- OSP HF - 062"	1	A	-377	282	63	-596	500uE
			B	-81	-167	-102	-167	
			C	39	142	97	142	
			D	65	-127	-211	-127	
System Assembly - Man CPU Installation wLGA115X tool on	Intel DT Sugar Bay Lunas - BGA CPT- OSP HF - 062"	2	A	-287	218	38	-467	500uE
			B	-62	-135	-92	-135	
			C	31	107	73	107	
			D	52	-90	-159	-90	

**Sample Board / Components Photographs:**

## Board Flexure

Include a picture of the strain gage locations that verifies the gages were placed in the correct locations.



Close up  
pictures  
should be

## Sample Graph of Diagonal Strain Results:

Include a graph of the diagonal strain results that verifies the strain report and shows the relative strain intensity.





## Intel Strain Guidance Information

### Access for Strain Guidance for Intel Components (BGAs and LGA Sockets):

In order to obtain the "Strain Guidance" information for individual Intel components (BGAs and LGA Sockets) customers should contact any Intel representative below by region (AMER, APAC, EUR, IJCK and LAR):

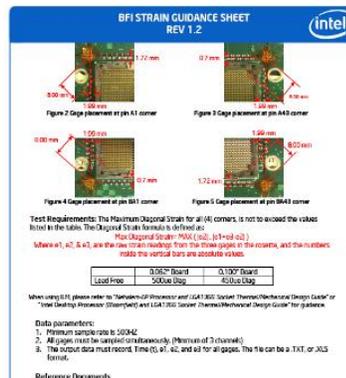
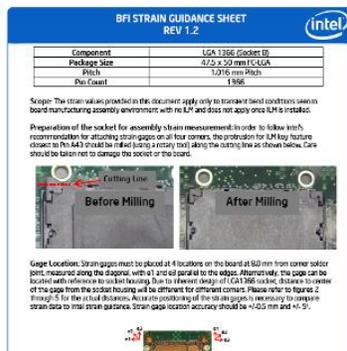
- Intel Sales Representative
- Intel Technical Marketing Engineer
- Intel Field Application Engineer
- Intel Product Application Engineer
- Intel Customer Quality Engineer

The Intel representative would be the person responsible to download the strain guidance sheet information for individual Intel components (BGAs or LGA Socket) and share with customers externally.

#### Note:

There is not a link available today in order to customers download the strain guidance information from Intel website.

### Example: Intel Strain Guidance for Intel Components (LGA1366 Socket):





## Summary

The goal of this training is to enable customers to create strain reports that compare measured BFI strain against the Intel BFI Strain Guidance for Intel components.

Strain is a dimensionless number and is relative to location. Strain values from different methodologies can NOT be compared.

Gage location and diagonal strain metric are the critical factors in making the comparison between lab data and field testing. Strain measurement has many significant variables, and must be done with care and consistency.

The right equipment set is important for the accuracy of the strain measurements.

Intel has developed a thorough method for using strain gages to measure board flexure during manufacturing assembly and publishes Intel BFI Strain Guidance for each of its components.

Intel components that exceed Intel BFI strain guidance is at risk and may have partial solder joint cracks, depending on unique assembly use conditions or applications. Efforts must be made to reduce board flexure by either supporting the board properly or by reducing the forces that are applied.

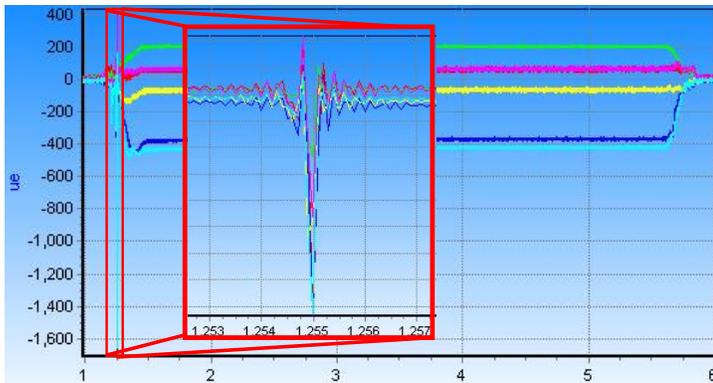


## Backup / Reference

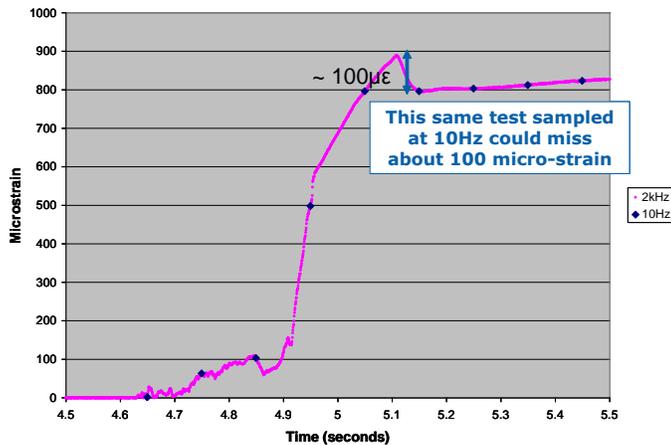
This section provides customer information and guidelines that Intel uses.

### **Sampling Rate Error:**

Using a low sampling rate decreases the chances of detecting problems. This ICT fixture was out of alignment and caused strains that lasted about 0.0004 seconds, and broke the boards.



## Board Flexure

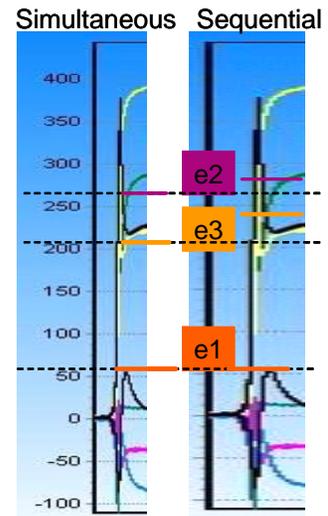


*ICT strain profile is a typical sample from Intel's industry database*

### Sequential vs. Simultaneous Sampling:

Using sequential sampling during a high strain rate operation (such as ICT) will capture the three grid strains at different instants in time, potentially causing the diagonal strain to be miscalculated.

In this example, e1 is captured at the same instant in both graphs, but in sequential sampling, e2 would be captured slightly later, and e3 later still.

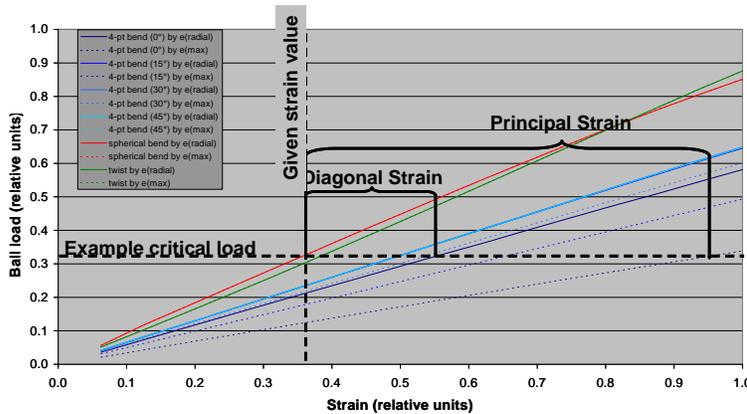


Since the diagonal strain calculation assumes that



all three grid strain values are recorded at the same instant in time, sequential sampling would cause a miscalculation. The extent of the error depends on the strain rate, the sampling rate, and the order of sampling.

### Comparison of Strain Metrics:



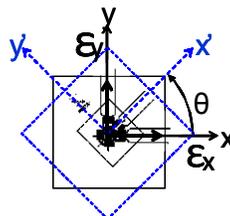
### Key Findings:

- Diagonal strain is less sensitive to bend mode.
- Spherical bend is a worst case bend mode for manufacturing.

### Diagonal Strain Equation:

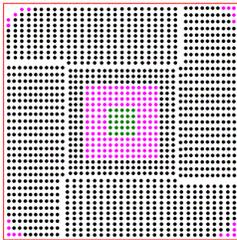
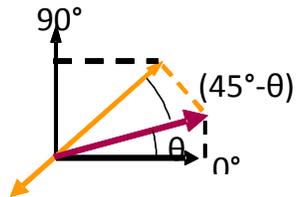
The diagonal strain equation comes from a coordinate system transformation:

$$\begin{aligned} \epsilon_{x'} &= \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2} \cos 2\theta + \epsilon_{xy} \sin 2\theta \\ \epsilon_{y'} &= \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2} \cos 2\theta - \epsilon_{xy} \sin 2\theta \\ &= \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2} \cos 2\theta - \\ 56 \quad \epsilon_{x'} &+ \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2} \cos 2\theta \\ &= (\epsilon_x + \epsilon_y) (1 + \cos 2\theta) - \epsilon_{x'} \\ &= \epsilon_x + \epsilon_y - \epsilon_{x'} \end{aligned}$$



$$\begin{aligned} \text{for } \theta &= 45^\circ \\ \epsilon_{x'} &= \epsilon_2 \quad \text{and} \quad \epsilon_{y'} = \epsilon_4 \\ \text{so} \quad \epsilon_4 &= \epsilon_1 - \epsilon_2 + \epsilon_3 \end{aligned}$$

**Diagonal Strain is the transformation of Principal strain to 45°:**



Max Principal Strain at 45° is

$$\cos(45 - \theta) = \frac{\epsilon_D}{\epsilon_p}$$

$$\epsilon_D = \epsilon_p \times \cos(45 - \theta)$$



Currently Intel publishes strain guidance based on diagonal strain.

**Industry Standard Strain Method:**

Intel participated in the publication of the IPC/JEDEC 9704 standard, and agrees with the emphasis this document places on using board strain measurements to monitor and control board flexure.

We are a component supplier, Intel provides component-specific strain guidance to aid customers in risk assessments of their manufacturing board handling processes. Intel publishes the BFI MAS to provide customers with greater clarity on Intel's guidelines for board flexure measurements and application of Intel component-specific strain guidance.



Board Flexure

## Revision Summary

May 2010: Original publication

Mar 2016: Updated and align references to Board Flexure Manufacturing Advantage Services (MAS) collateral.