IPC Electronics Midwest 2010

Strategies for the Prevention of Board Strain and Cracked Chips in Automotive Electronics

Steve Davidson

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Biography:

Mr. Davidson is Delphi Electronic & Safety's Global Manufacturing Technology Team Leader for Board and Final Assembly. With 24+ years experience, Steve has used his extensive knowledge base to provide innovative technical solutions and strategic leadership for a vast array of board and final assembly tactical technologies such as fastener assembly, automated assembly, compliant pin and press fit assembly, friction stir welding, tooling & fixture design, and material handling. Product design issues, factory controls and material handling. In addition to his work at Delphi, Steve has consulted with numerous electronics suppliers and customers. He received a BSME from Rose-Hulman Institute of Technology before joining Delphi in 1986.

Executive Summary

BGA's, ceramic capacitors, and similar strain sensitive components are used extensively throughout the automotive and consumer electronics industries. Unfortunately these components can be easily damaged when exposed to excessive board strain and flex and induce microscopic defects within the components that typically are undetectable. Additional thermal and mechanical cycling can cause these defects to propagate over time and ultimately lead to component failure, product failure, and customer dissatisfaction. Since defect detection is ineffective, defect prevention is the key to success.

This paper will review in depth the various failure modes, identify high risk assembly processes, and outline the critical prevention strategies that need to be implemented to produce a defect-free quality product. Topics will cover product design, process design, and verification strategies.

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Delphi Automotive Systems, LLC

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Association Connecting Electronics Industries

CANON COMMUNICATIONS LLC

IPC

Distressing Phrases

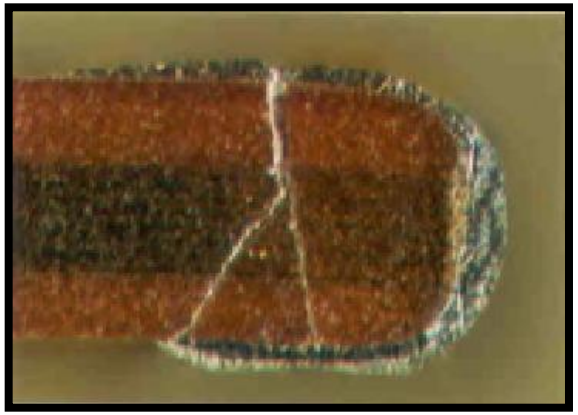
Defect

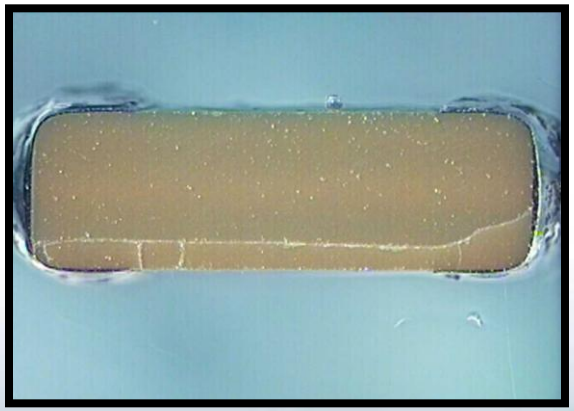
Recall

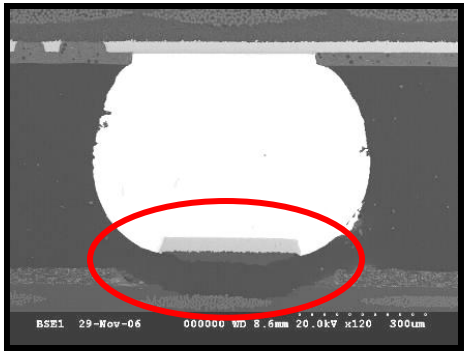
Scrap

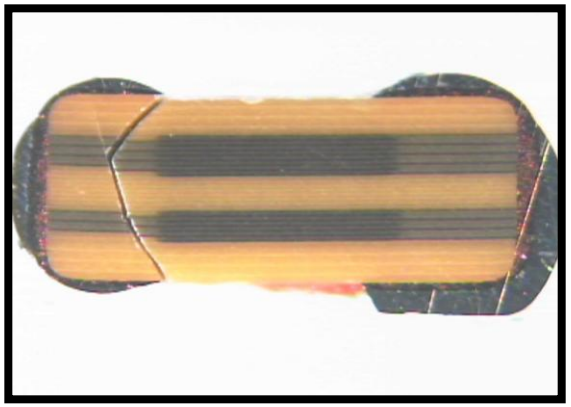
Warranty Return

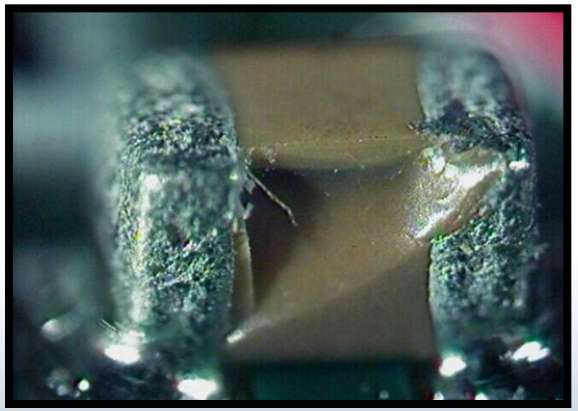
Examples of Component Damage











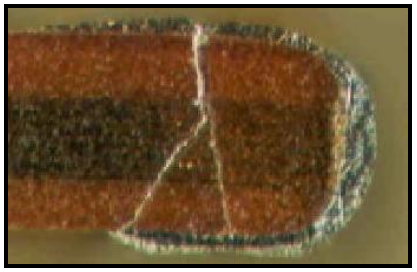
Component Damage Facts

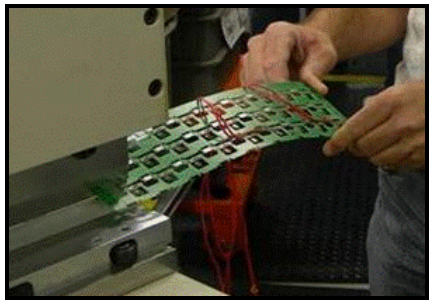
- Product testing does not always detect damaged components
- Damaged components may result in intermittent as opposed to a catastrophic product failure
- Thermal or mechanical loading may accelerate component damage and result in latent product failure

PREVENTION STRATEGIES

Presentation Topics

- Review
  - Typical circuit board component damage failure modes
  - Identify high risk areas for damage
- Outline strategies to prevent damage
  - Product Design
  - Process Design
  - Verification





Presentation Topics

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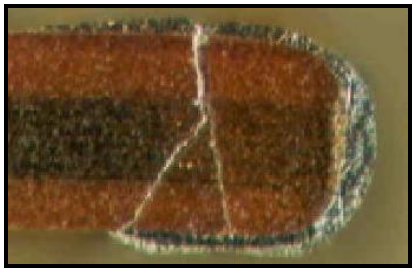
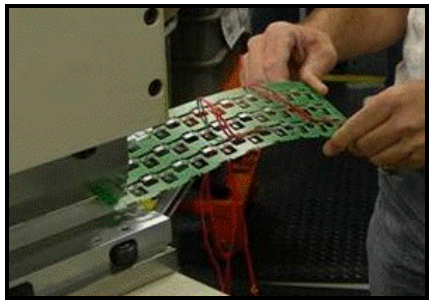
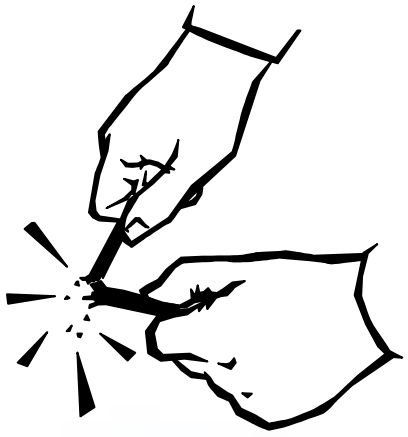




Component Damage

Mechanical Strain

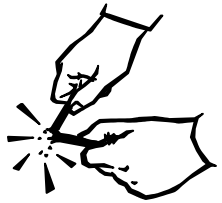


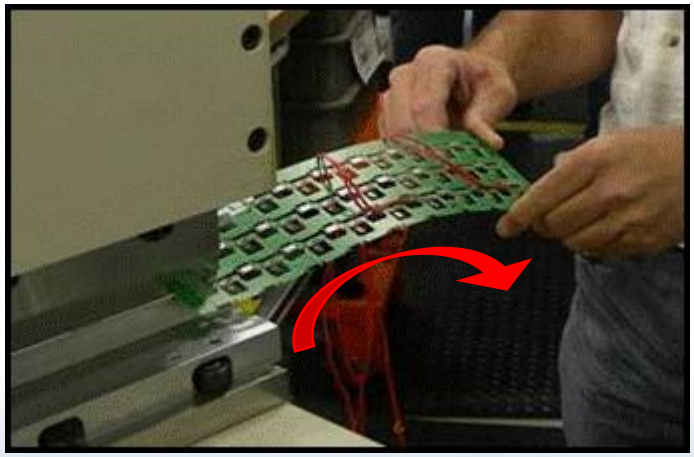
Impact

Thermal Strain

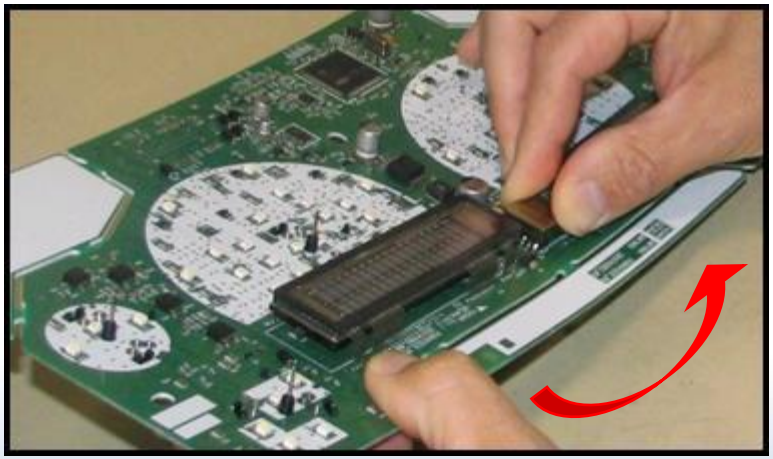
Mechanical Strain Generators

- Circuit board flexing generates board strain
- Excessive board strain can severely damage components





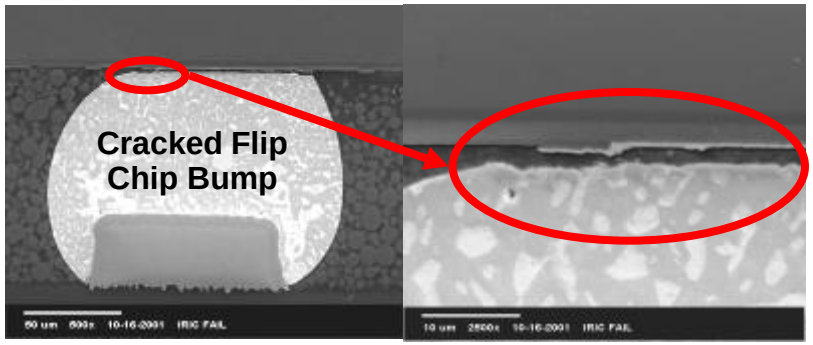
Significant board flex at singulation

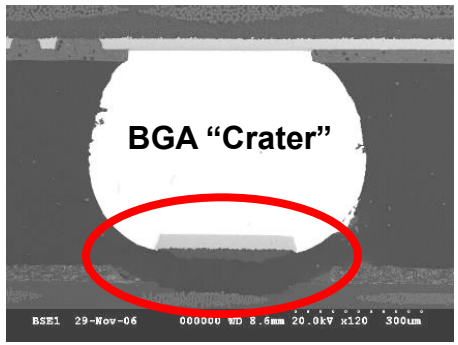


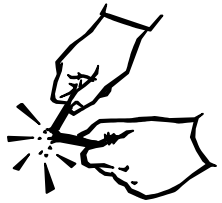
Excessive board flex during component assembly

Examples of Mechanical Strain Component Damage

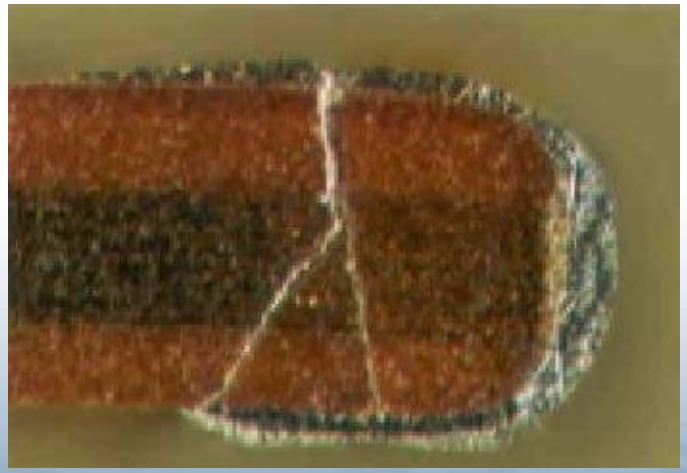
BGAs & Flip Chips

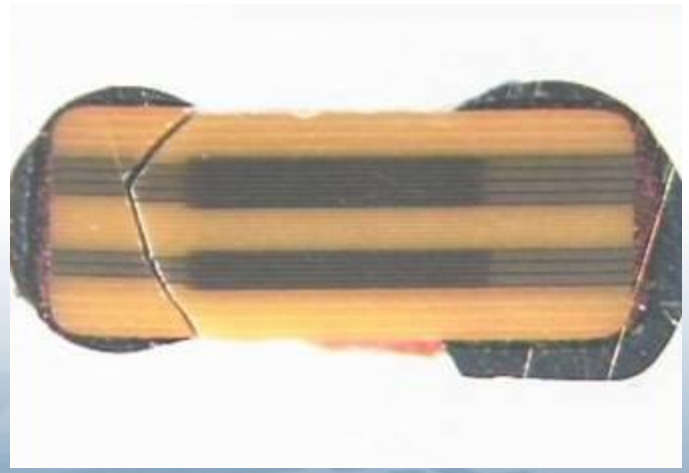




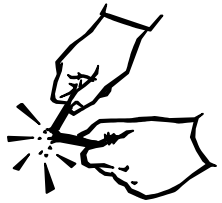


Ceramic Capacitors

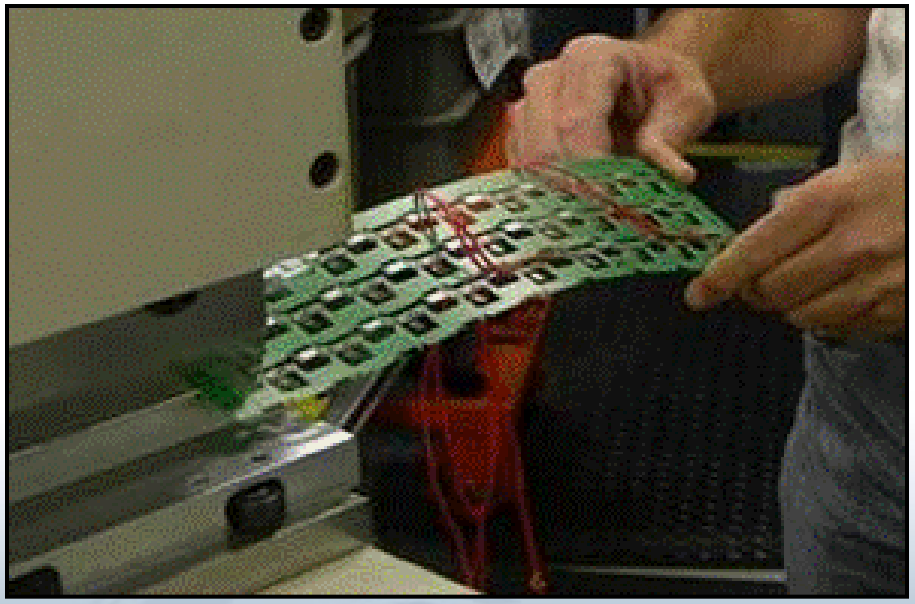




Typical High Risk Areas



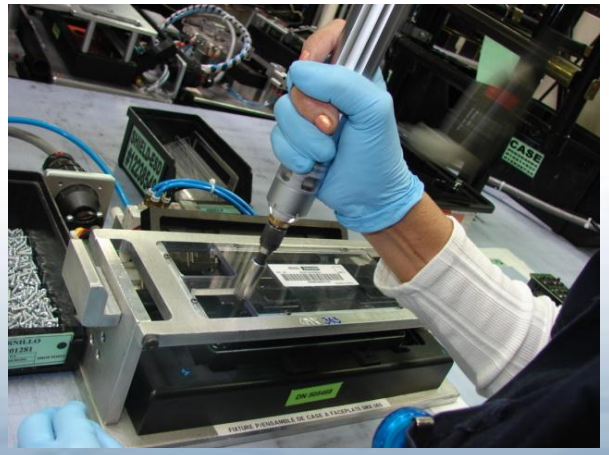
- General product nesting
  - Excessive board flex during load / unload
  - Inadequate or poor board support
- Test and assembly processes
  - In-circuit test
  - Fastener assembly
  - Press fit assembly
  - Manual thru-hole assembly
  - Singulation



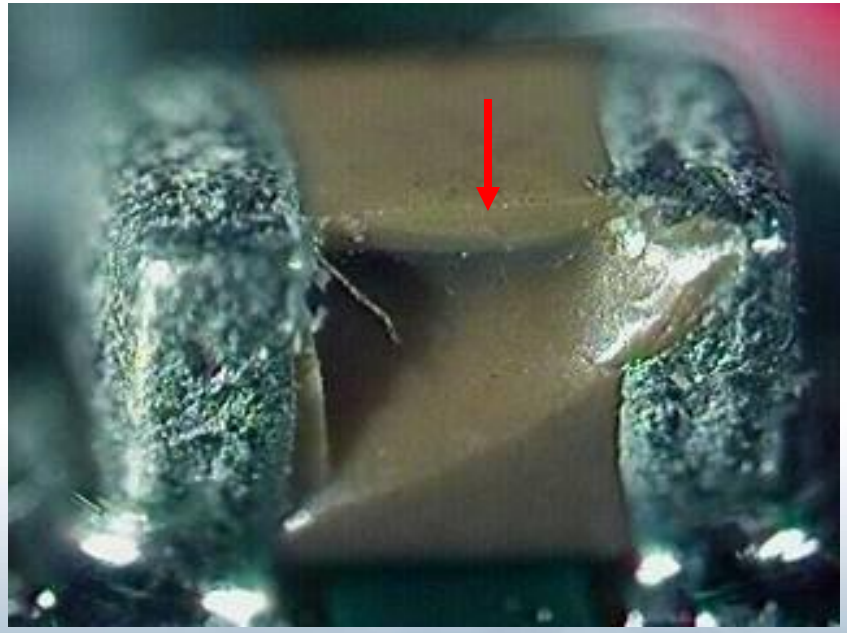
Impact Damage Generators

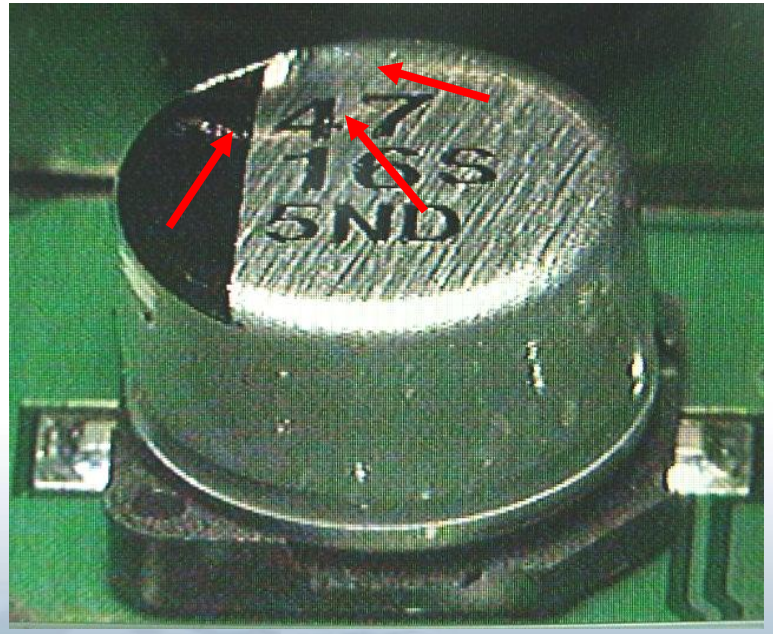
- General assembly processes, test processes, and board handling expose components to the risk of impact damage

Assembly	Test	Handling



Examples of Impact Damage



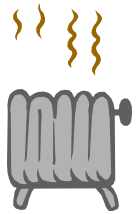


Typical High Risk Areas

- Typical assembly & test processes
  - General component assembly
  - In-circuit-test
  - Screw driving
- Material handling
  - Mis-handled / dropped boards during manual transfer/transportation
  - Conveyors
    - Mis-adjusted pallet stops
    - Mis-aligned conveyor interfaces
  - Tall objects, protrusions, sharp corners or similar objects in the part path
  - Stacking boards or placing boards in unusual locations

Thermal Strain Generators

- Excessive thermal gradients can produce thermal strain component damage

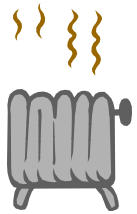


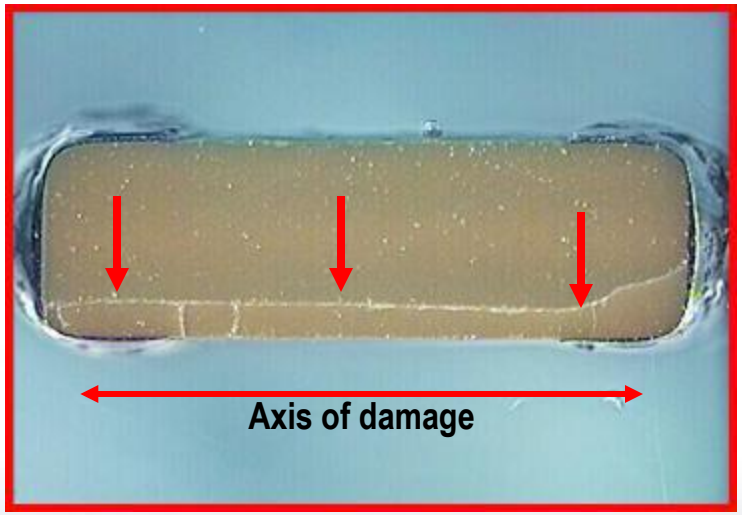
Wave Solder

Manual Solder

Reflow

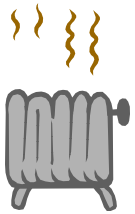
Thermal Strain Damage





Typical High Risk Areas

- Improper pre-heat ramp prior to wave solder or reflow process
- Improper heat ramp in cure ovens or at hot test
- Rework
  - Improper soldering iron temperatures
  - Touching the iron directly to the component rather than only touching the pad and terminal or lead



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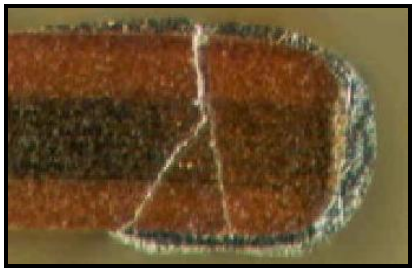
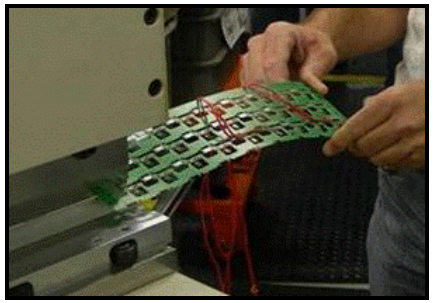
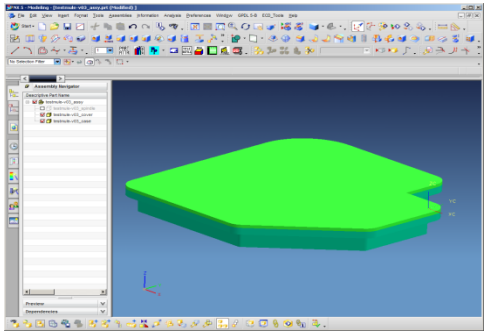




Strategies to Prevent Damage

Product Design

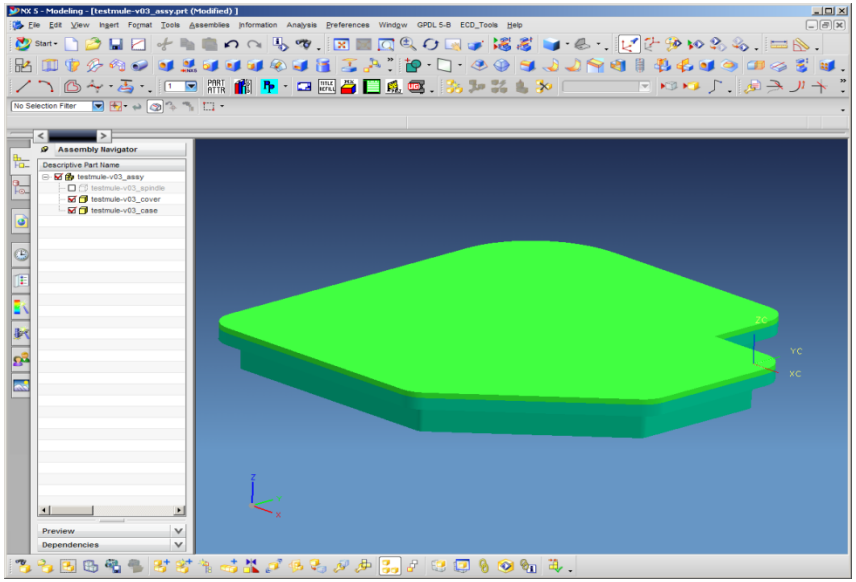


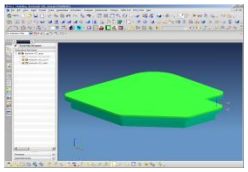
Process Design

Verification

Product Design

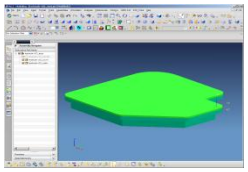
- There are many areas within product design that, when optimized, will positively impact your ability to minimize component damage and cracked chips
- Products need to be designed to minimize:
  - Induced strain
  - Risk of impact damage
- Some examples include:
  - Component location
  - Component orientation
  - Component selection
  - Circuit board array design
  - Mechanical assembly design and tolerancing





Product Design
Clearance and Keepout Zones

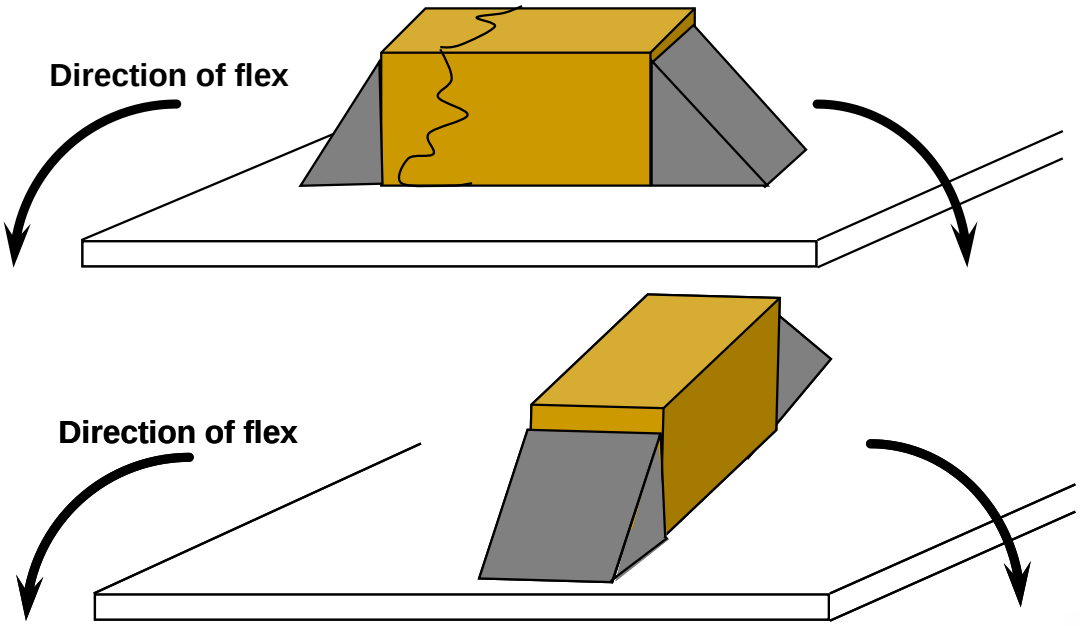
- High risk processes
  - Board singulation
  - Board handling
    - Conveyors
    - Containers
    - Tooling & fixtures
  - Fastener / screw assembly
  - Press fit assembly
    - Connectors
    - Compliant pins
  - Repair / rework
  - Test processes
    - In-circuit test
    - Final test

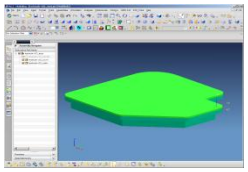


Product Design

Orientation for High Strain Areas

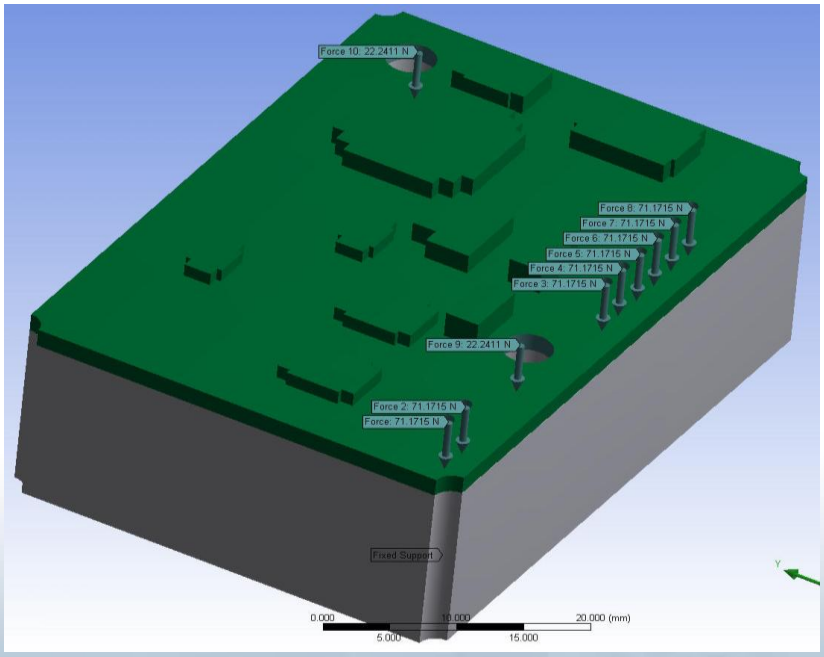
- Proper component orientation in areas of known board flex can also prevent damage
- High risk processes
  - Board singulation
  - Fastener / screw Assembly
  - Test processes
    - In-circuit
    - Connector engagement

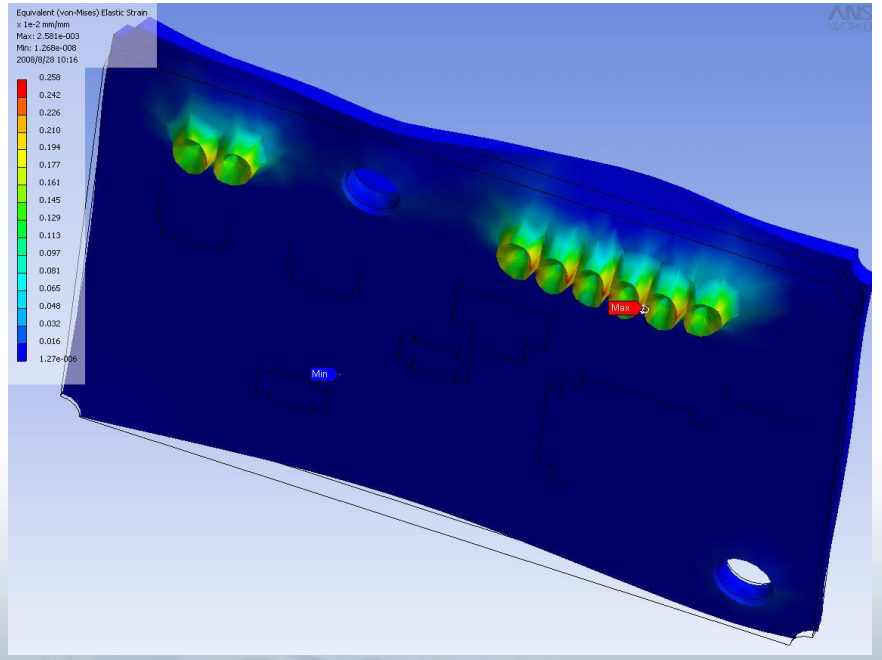




Product Design Modeling

- Modeling can be used to predict potential high strain
- Designs can be optimized to minimize board strain in critical areas



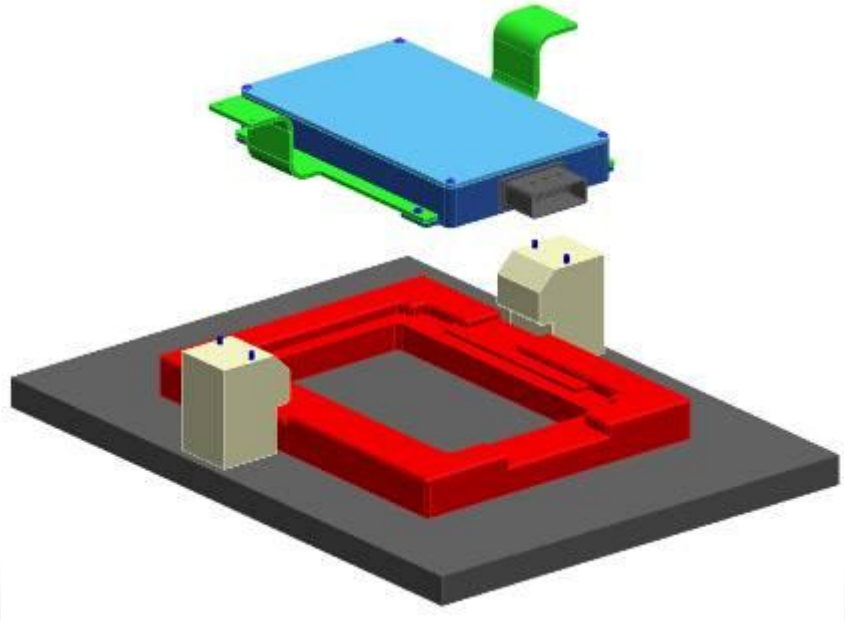


Process Design

- High-quality process designs are extremely important to the prevention of component damage
- A superior process design will fully support and protect the product from damage throughout the value stream
- Critical process design areas include
  - Tooling & Fixture Design
  - Handling
  - Containerization
  - Product Movement

Process Design
Tooling & Fixtures

- Fixtures, tooling and pallets play a critical role in manufacturing quality products
- They are enablers to:
  - Properly locate the product for position-sensitive operations
  - Provide adequate product support during part placement, assembly and test
  - Protect the product from damage, debris, and excessive heat



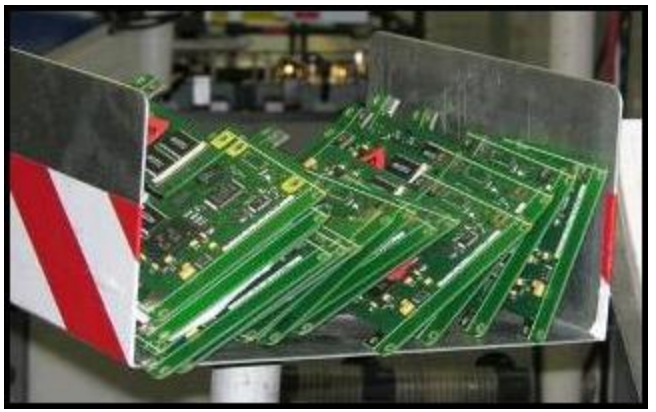
Process Design
Tooling & Fixtures Guidelines

- Design in appropriate clearances and tolerances to:
  - Minimize board flex
  - Eliminate potential for impact damage
- Eliminate sharp edges, protrusions, and similar that may damage the product or components
- Protect components and circuitry from high risk operations such as screw driving and lead clenching
- Protect product from debris and stray components intrusion such as screws

Process Design

Manual Product Handling Guidelines

- Boards should only be handled by the edges
  - Many products have high risk/fragile areas that should never be handled:
    - Wire bonded components
    - Locations with grease or adhesives
- Large, heavy circuit boards must be handled by locations that do not induce strain
- Product or circuit board stacking is never allowed

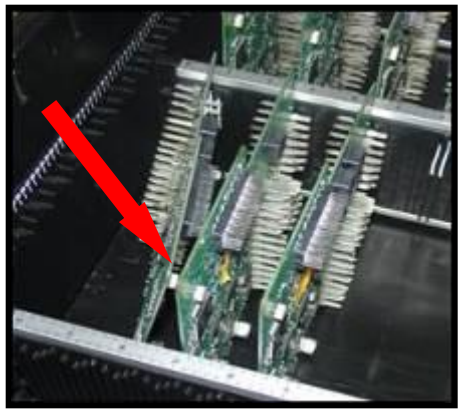


Stacking of boards can cause component damage

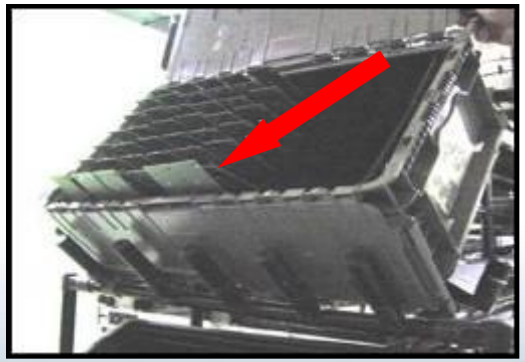
- Only one board should be handled by the operator at a time
- Optimizing ergonomics can improve the probability that the operator will handle the product properly

Process Design
Containerization Guidelines

- Product containers should be designed
  - Specifically for the product
  - To prohibit product-to-product contact
  - To fully contain and protect the product
  - From static dissipative or conductive material
  - From durable materials to minimize wear, debris generation, and sharp edges



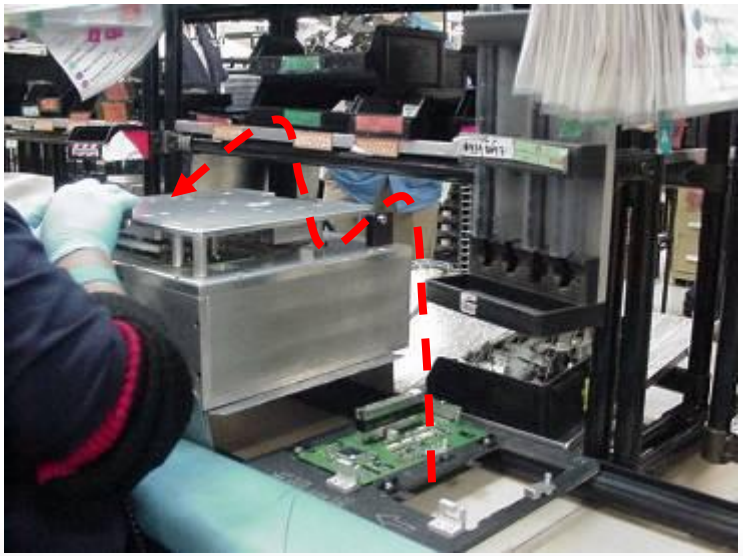
Board to Board Contact



Container Does Not Fully Contain Board

Process Design
Material Movement Guidelines

- Work cells should be designed
  - To minimize elevation changes as the product passes through the value stream
  - To minimize sharp edges, protrusions and obstacles that may impact the product
  - So that the product is not placed on any surface that is not a dedicated work surface
  - To ensure that products are not stacked or impact one another between assembly stations



Extreme elevation changes in part path

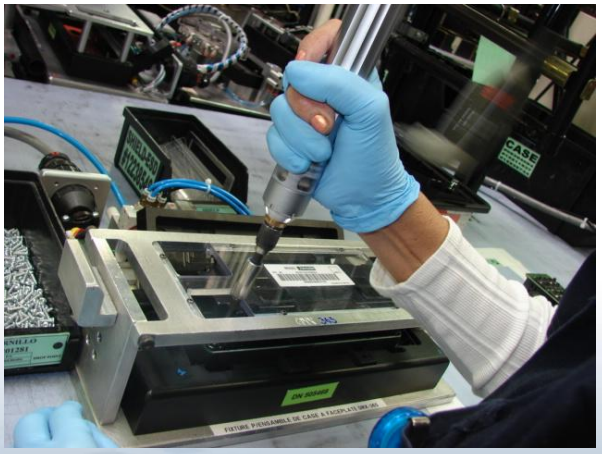
Verification

- Verification is critical to ensure that the product and process designs have met their objectives

- Critical verification elements include
  - Board Strain Studies
  - Verification Build & Inspection

Verification
Board Strain Studies

- **Where** should strain studies be conducted?
  - All assembly and test process that may induce board strain
  - Typical high strain processes include
    - In-circuit test
    - Board singulation
    - Fastener assembly
    - Press fit assembly
    - Connector engagement

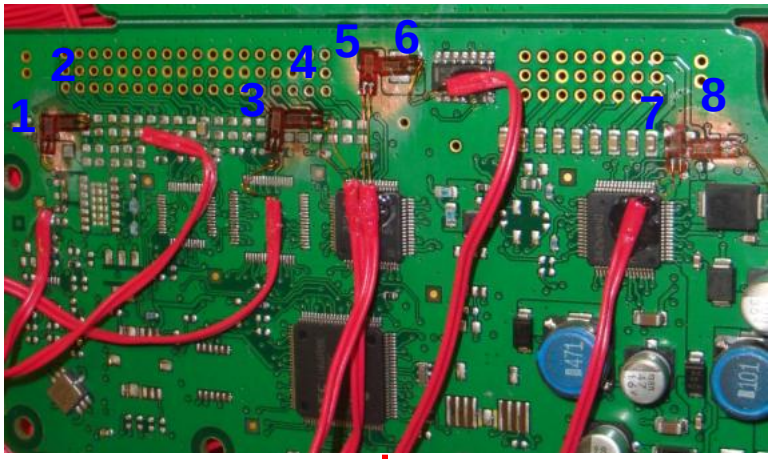


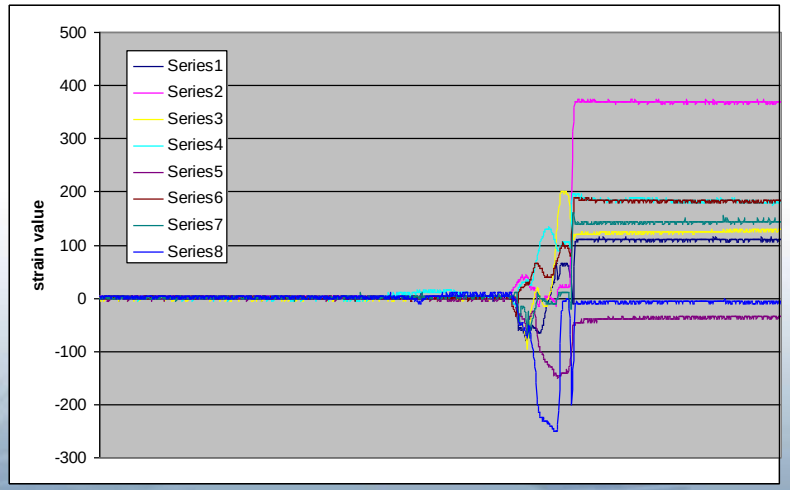
Verification
Board Strain Studies

- **When** should strain studies be conducted?
  - Before process is released to production
  - When equipment modifications have been made that could impact board strain
  - When significant product design changes have incurred

Verification
Board Strain Studies

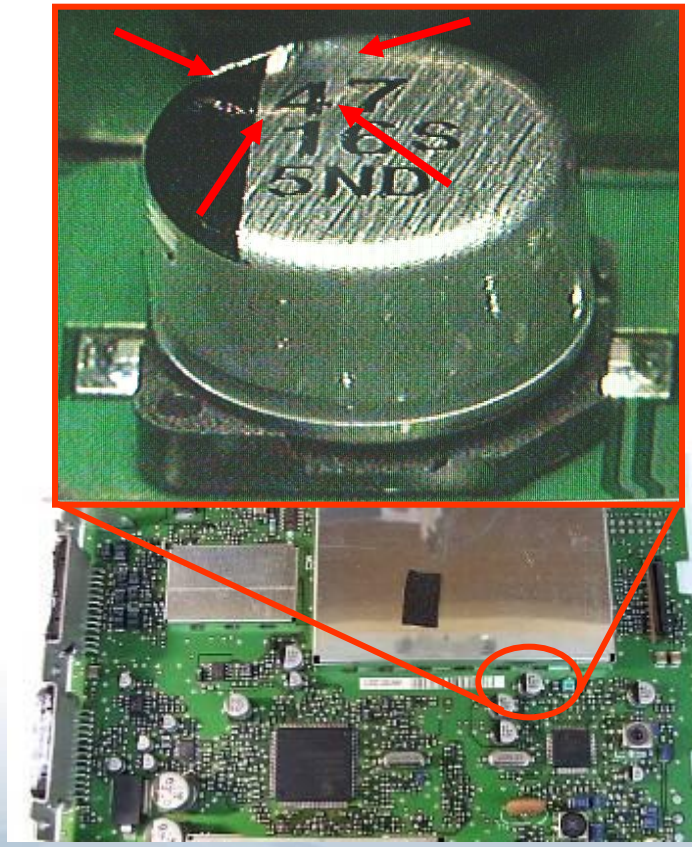
- **Where** should strain gages be located?
  - When there is a known problem or product design standard violation:
    - Remove component
    - Attach strain gage
    - Measure strain at suspect processes
  - When evaluating new equipment, processes or tooling more evaluation is required
    - Evaluate potential board flex locations > 1mm
    - Identify typical high risk areas
      - Singulation zones
      - Screw holes
      - Hinge zones
      - Connector engagement





Verification
Verification Build & Inspection

- A verification build should be conducted to ensure that the product and process designs
  - Perform as expected
  - Do not damage the product
- The verification build
  - Must utilize the production intent processes, tools, and fixtures
  - Must utilize fully populated production intent parts
  - Must include a sample size that is large enough to encompass normal production variation



Verification

Verification Build & Inspection

- The following areas should be inspected for signs of damage or wear
  - Product
    - Verify that the product meets Fit, Form, and Function requirements
    - Look for impact or wear damage
    - Inspect cosmetically critical surfaces for defects
  - Fixtures, tooling, and containers
    - Look for impact or wear indicators
    - Look for debris in fixtures, containers or on floor