Probe Solutions
743 E. Goldenrod St.
Phoenix, AZ 85048
480.460.9179

http://www.ProbeSolutions.com

Effects of Z-Stage Motion control on Probe Contact Force

Martín Martínez
ESACORP - ProbeSolutions
Uday Nayak
Electroglas

ENGINEERING SCIENCE ANALYSIS CORPORATION

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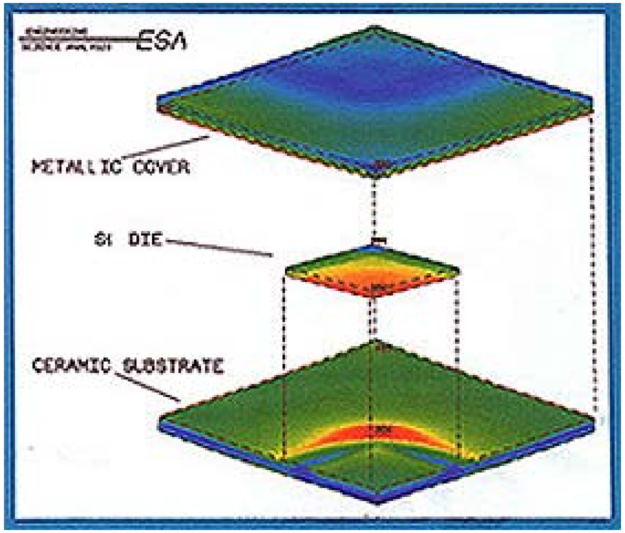
Outline

- Introduction to Engineering Science Analysis ProbeSolutions
  - Who we are
  - Why we're here
- Presentation Objectives
- Q & A
- Conclusion

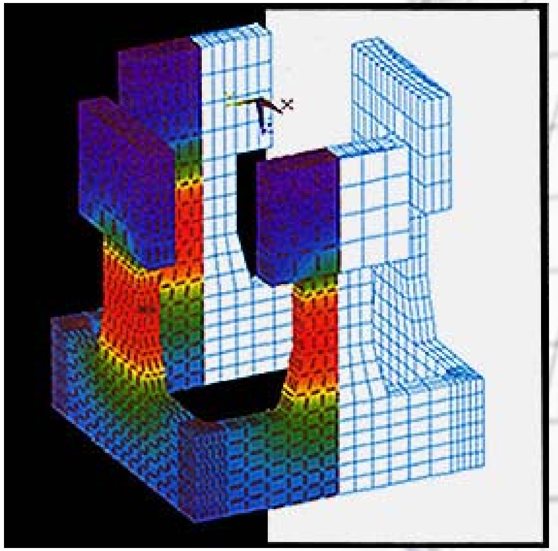
Introduction
ESA - ProbeSolutions

- ESA was founded in 1991 to help major Semiconductor manufacturers with their microprocessor packaging process.
  - Introduced analysis techniques that were predominantly used in the Aerospace industry.

CPU - Package



TAB - Thermode



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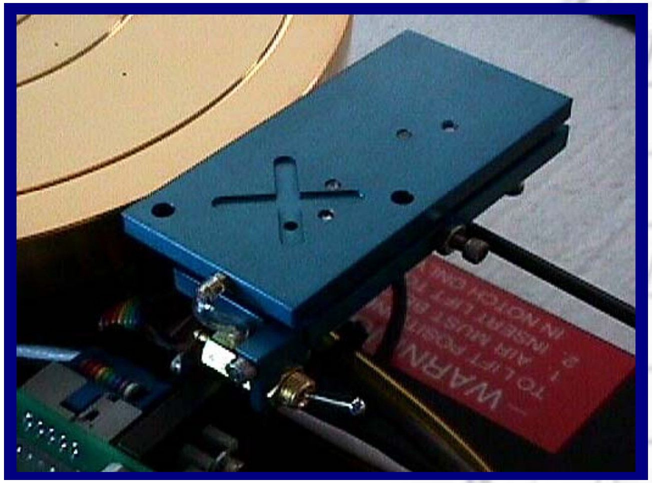
Introduction
ESA - ProbeSolutions

- ProbeSolutions - an extension of ESA into the Semiconductor test arena.
- Formed to help a major Semiconductor manufacturer solve a problem with their probe cleaning process.
  - Co-developed a bolt-on product to enhance prober capability.
- Our Charter - We are a premier one-stop shop specializing in cleaning materials and product/process enhancements for semiconductor test.

Introduction
ESA - ProbeSolutions

- Our main Product(s) and Services
  - Enhancements for the probing world.
  - Probe-Tip cleaning materials
  - BlueMax - Probe Tip cleaning platform



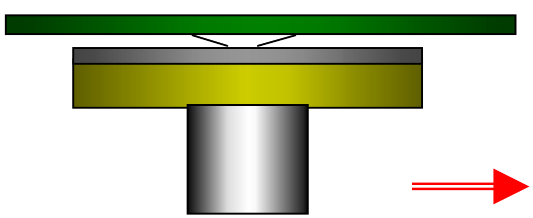
  - Concepts proven using ESA’s analytical techniques and expertise.

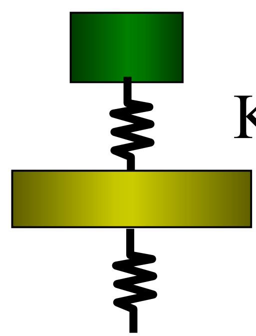
Presentation Objectives

- Create awareness of impact of Z-stage motion on probe performance
- Introduce new concepts
- Illustrate concepts using analytical techniques
- Discuss some of the benefits
  - How it can be used to increase
- Discuss some of the detriments
  - Pitfalls if not controlled

Background

- Probecards all use the same basic principle of overdriving a ‘spring’ to create a force (BCF)
- Differing styles with different probe materials & probe tip configuration
- Common denominator:





$K_p =$ Probe tips + PCB + Mount + etc.

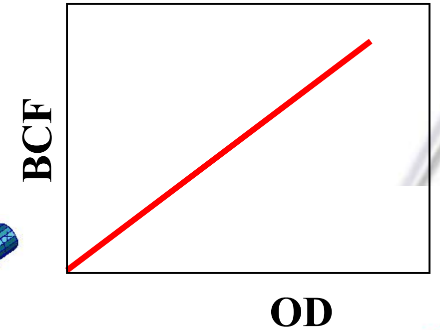
- It’s a spring-mass system

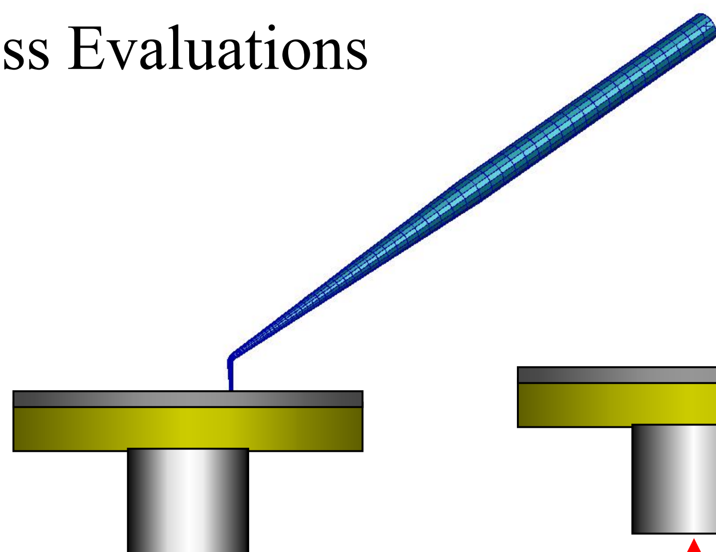
Background

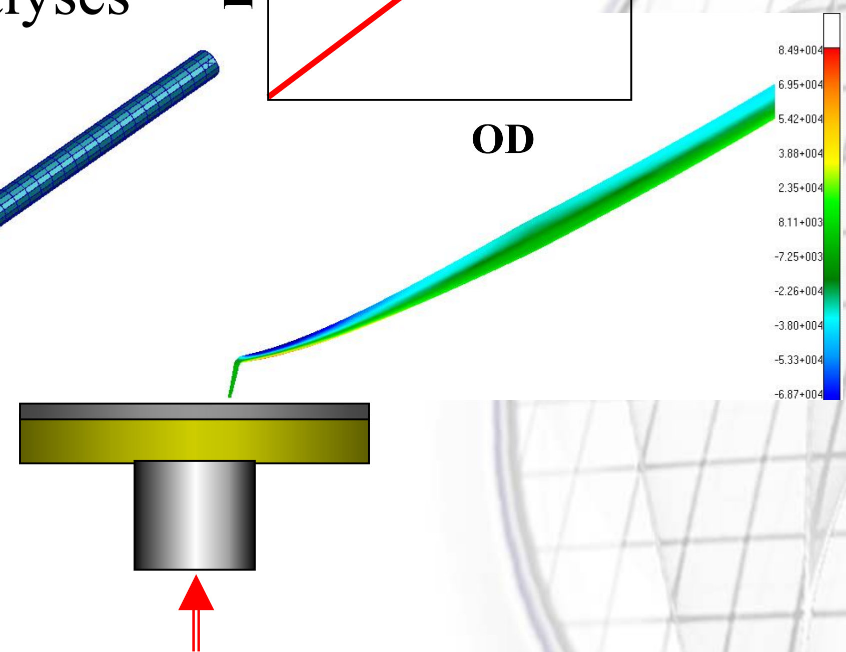
- Electroglas (EG) & ESACORP's ProbeSolutions (PS) understand that probecards designs have remained relatively 'constant' over the last few years
- Issue:
  - Devices and pads are continuously getting smaller and tighter
  - Pushing the limitations of the mechanical geometry of probecard and probecard manufacturing processes
- Solution:
  - EG and PS investigating the mechanics of the probe and prober system to enhance performance of existing probecard designs

Z-Stage Motion control on Probe Contact Force

- Probes sized using ‘static’ loading conditions
- Same assumptions used in:
  - QA Testing
  - Engineering studies / analyses
  - Process Evaluations

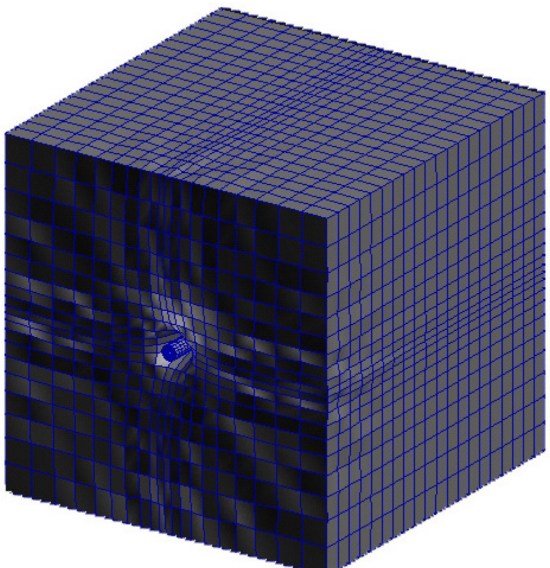




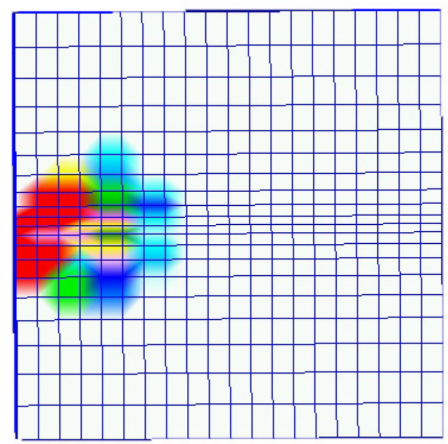


Why is understanding the motion so important?

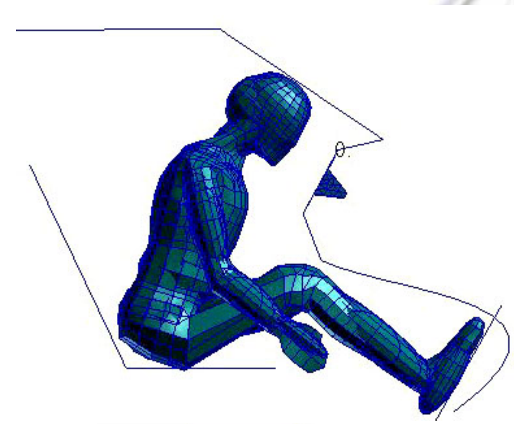
- In the real world, there is impulse loading.

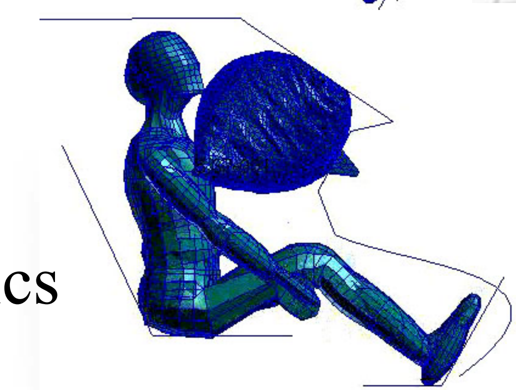


Projectile Impacting Fluid Filled Vessel



Sectional View of Fluid - Initial Shock

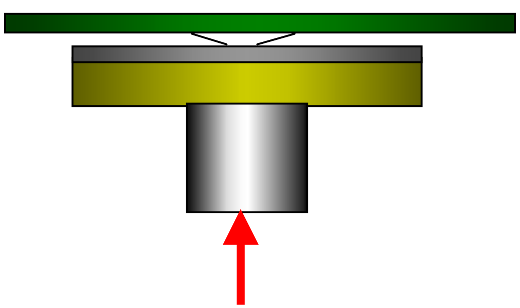


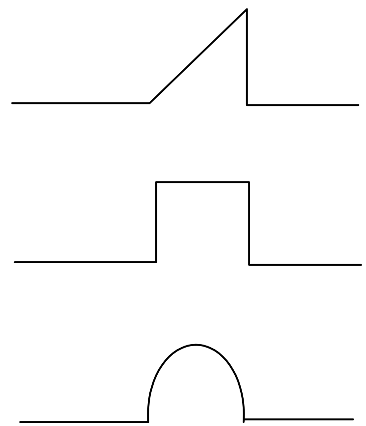


- Extensively used in penetration mechanics
- Crash-worthiness
- Software used - MSC.DYTRAN

How does this apply to Semiconductor Probe?

- In actuality, chuck moves up according to a motion curve.





Sawtooth - Triangular

Square - Trapezoidal

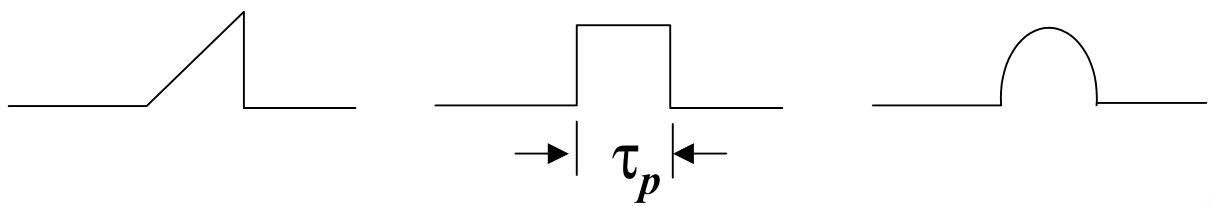
1/2 Sine Pulse

- Depending on the mechanical aspects of the system, the load at the probe tip can be ***magnified***.
  - Could be beneficial - penetrate oxides, short scrub
  - Could be detrimental - pad strike-through, probe damage

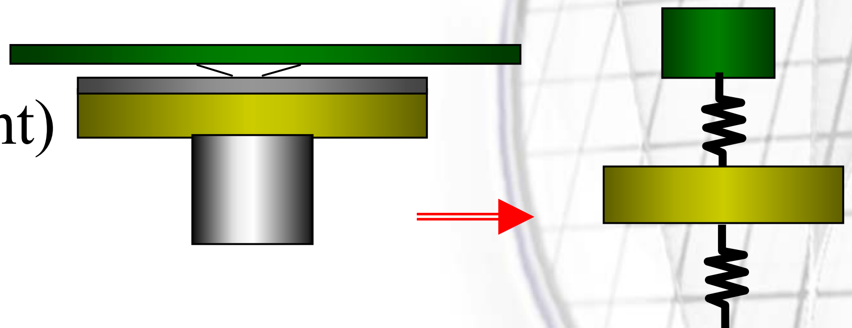
Probe Solutions

What Factors Govern Impulse?

- Impulsive Response Dependent on:
  - Time (period) of overdrive pulse (τ_p)



- Mechanical Natural Frequency (f_n) of ***System***
  - Probes + PCB + Stiffeners + Probecard Tray + etc.
  - Component stiffness
  - Component Mass (weight)



Why Control Z-Stage Motion?

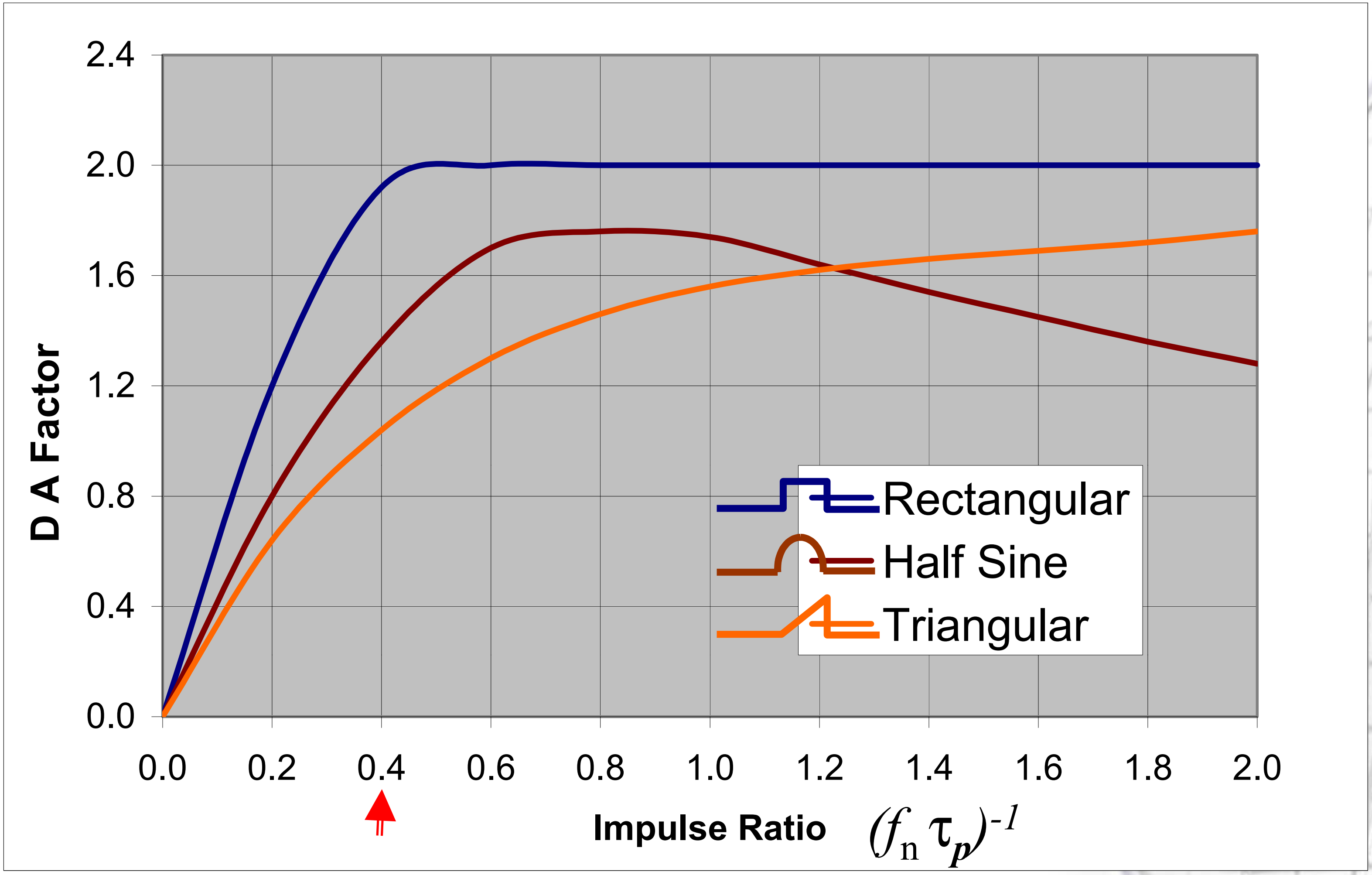
- Effect of Z-Stage Motion control on Probe Contact Force
  - Impulse Ratio inversely proportional to Probe system frequency (f_n) x Overdrive pulse period (τ_p)

$$(f_n \tau_p)^{-1}$$

  - Dynamic Amplification Factor (DAF) = Increase in actual probing force due to impulsive loading
- Dynamic motion of Z-Stage can affect actual probe force on pad

Actual Probe Force = Predicted Static Force x DAF

Impulse Ratio may amplify expected Probe Force



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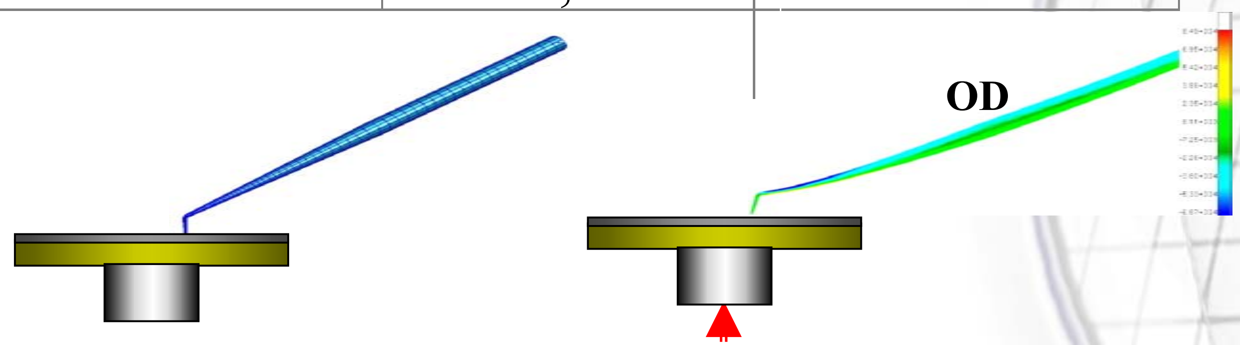
What controls Natural Frequency of components?

- Springrate dependent on system mechanical aspects
- Component factors affecting Natural Frequency
  - Materials
    - Tungsten probes have higher mass and stiffness than Be probes
    - PCB / Stiffening Layers / Stiffeners
  - Geometry
    - PCB Diameter / Thickness (Diaphragm effects)
    - Probe Diameter / Length / Style / Interposers
  - Support mechanisms
    - Probecard Tray

Geometric Contributions Probe

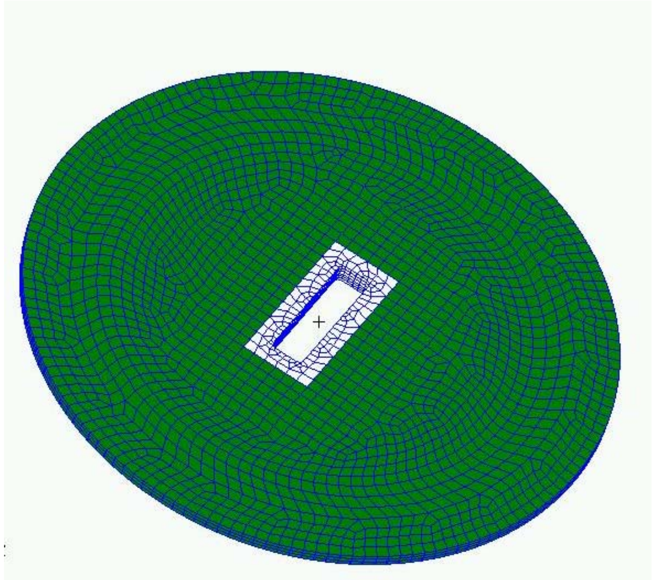
- Tungsten Probe
  - 5 mil diameter wire vs. 7 mil diameter wire - 100 mil etch
  - Smaller diameter reduces stiffness and almost doubles critical overdrive pulse period.

Probe Diameter	f_n (Hz)	Critical Pulse Period
5 mil	5,700	0.07 ms
7 mil	10,500	0.04 ms

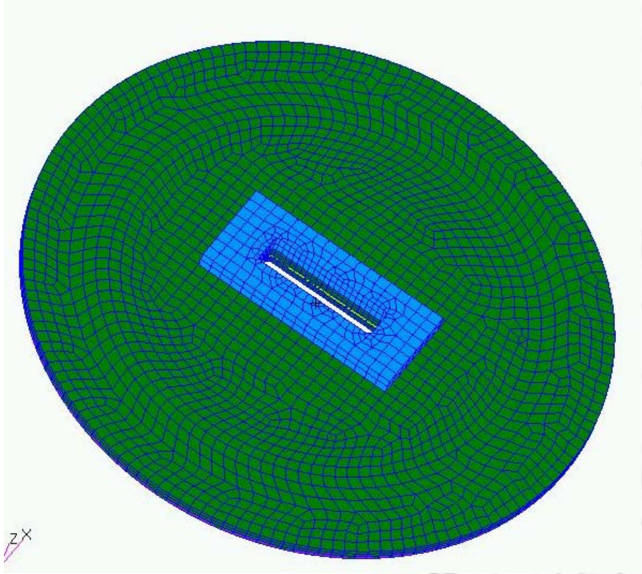


Geometric Contributions PCB

- Probecard - PCB effects on overdrive pulse
  - J996 - Style
  - Critical frequencies examined -> Overdrive Pulse



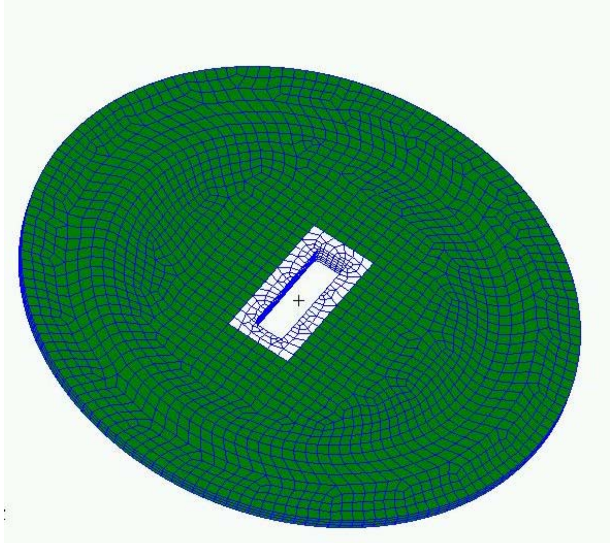
Board without stiffener



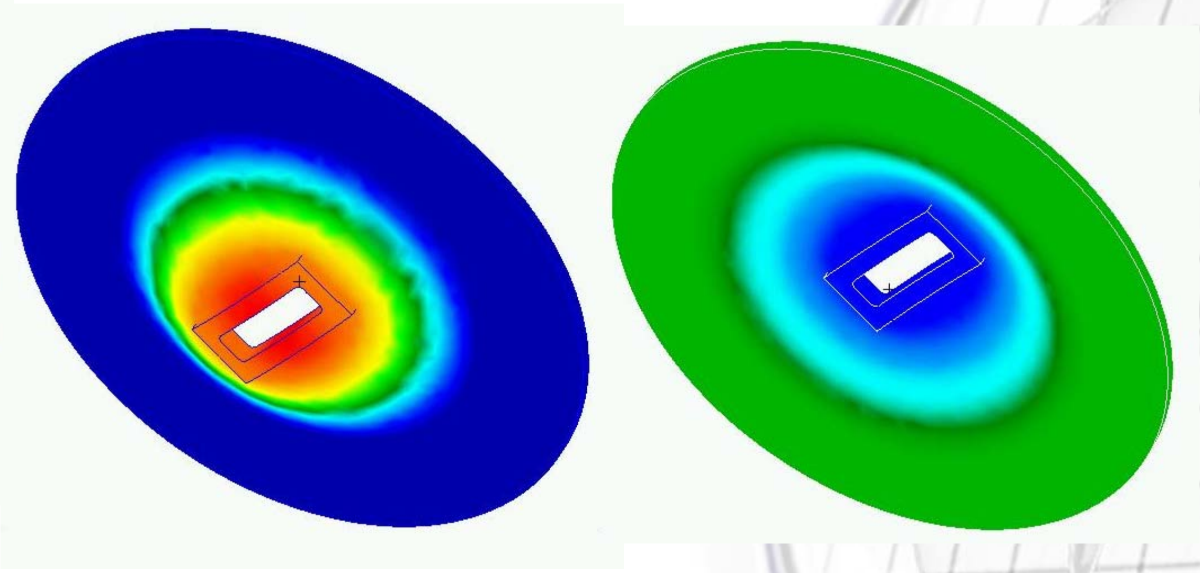
Board with stiffener

Geometric Contributions PCB

- J996 Board without stiffener - Note 'Diaphragm' mode
  - Natural Frequency = 500 Hz
  - Critical overdrive pulse period = 0.8 ms



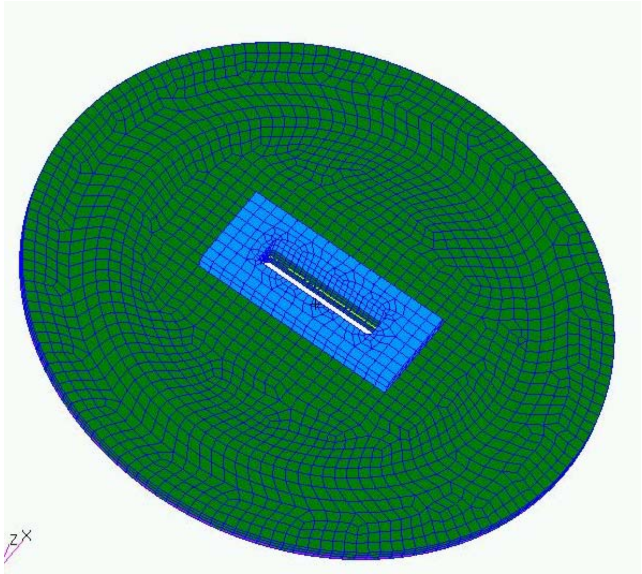
Undeformed



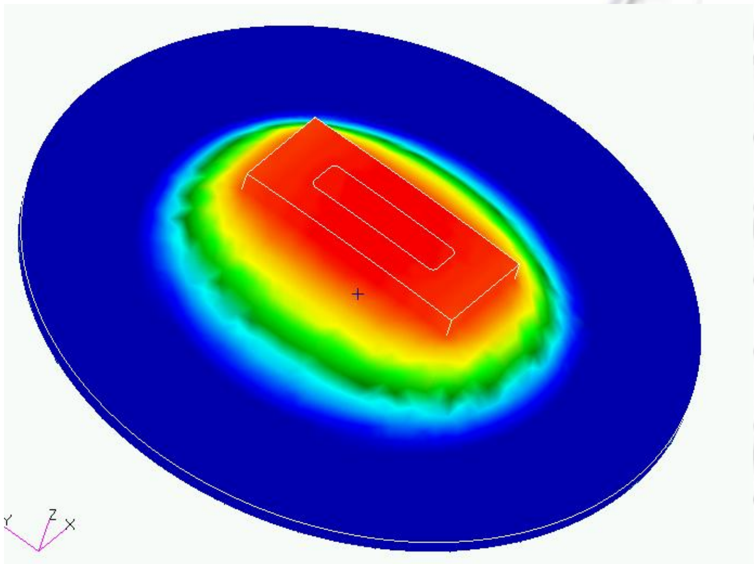
Frequency mode shapes

Geometric Contributions PCB

- J996 Board with stiffener - 'Diaphragm' mode
  - Natural Frequency = 375 Hz
  - Critical overdrive pulse period = 1.1 ms



Undeformed



Mode shape

Geometric Contributions PCB

- J996 Board
  - Adding ‘stiffener’ actually adds weight to the probecard
  - Reduces natural frequency
  - Increases critical pulse period by 37%
  - Design is more susceptible to impulse loading

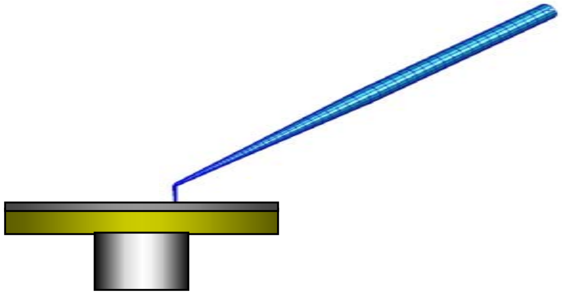
PCB Stiffener	f_n (Hz)	Critical Pulse Period
No	500	0.8 ms
Yes	375	1.1 ms

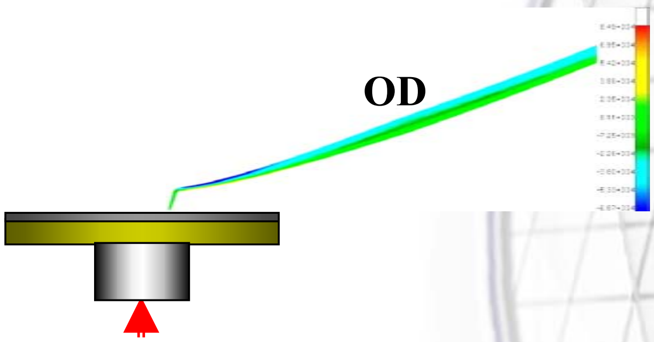
Other Contributors

- Other factors that affect critical overdrive pulse period:
  - PCB thickness
  - Elevated or reduced temperatures
  - Probecard support features
    - Clamping around edges
    - Stiffeners

Analysis Example

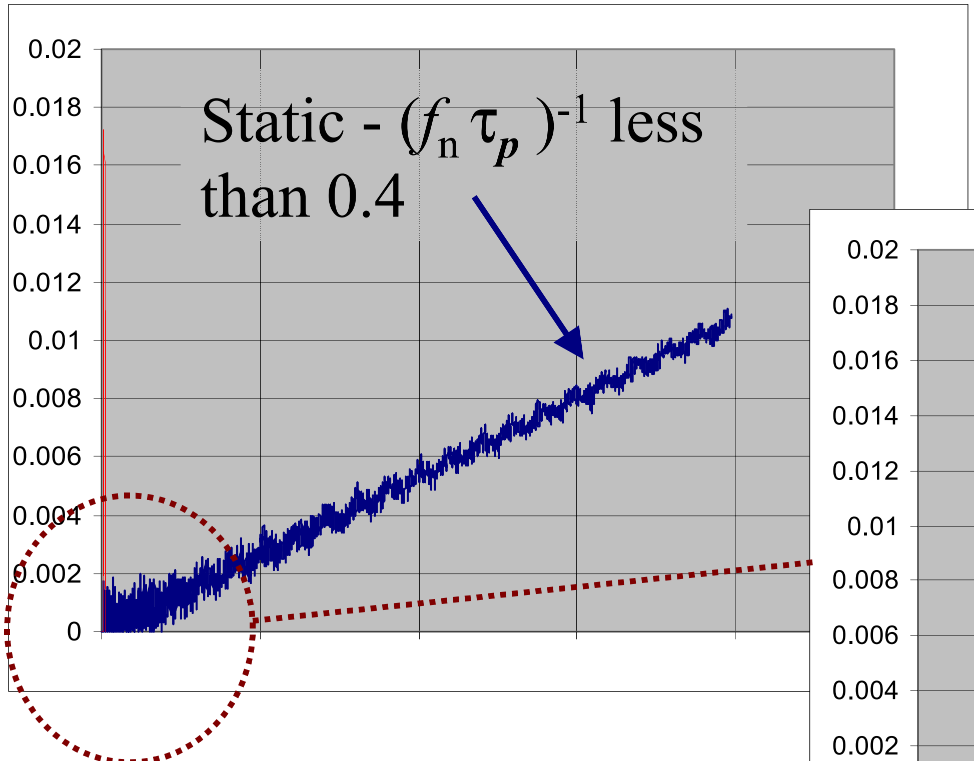
- Analyze Probe using DYTRAN software
- Probe subjected to input pulse that produces:
  - An impulsive ratio $(f_n \tau_p)^{-1}$ less than 0.4
  - An impulsive ratio greater than 0.4



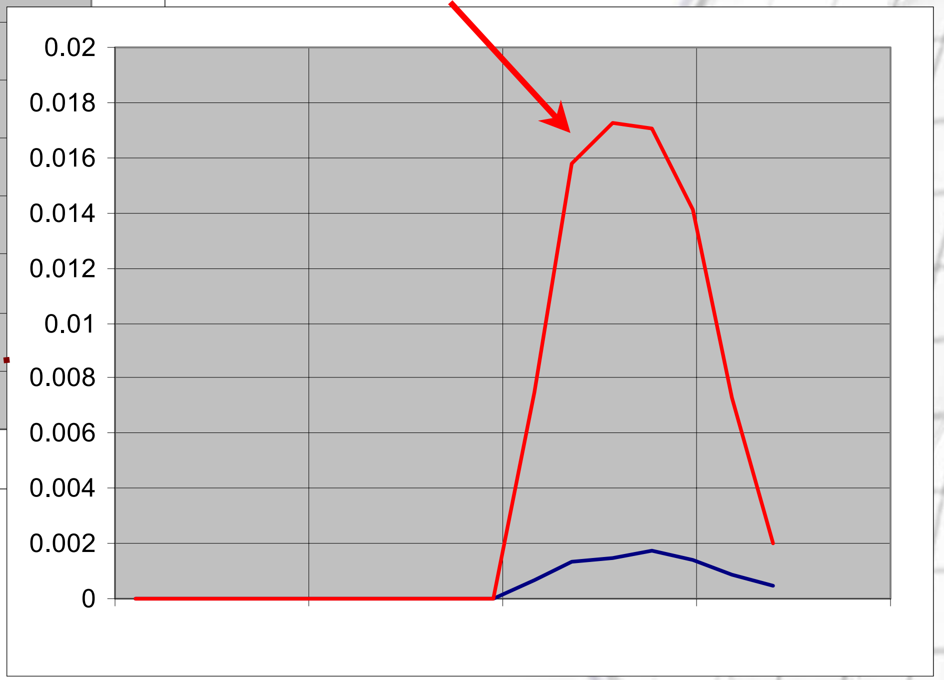


Analysis Example

- Resulting BCF - Time curve:



Dynamic Probe Force - 150% x Static under ***less overdrive***



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Z-Stage Motion control Summary

- Z-Stage Motion:
  - Plays a role in probe performance
  - Can dramatically affect the probe contact force
  - Depending on pulse, can increase force to 200% of static levels at low overdrives
- Controlling factors:
  - Materials - Probe - Tungsten - BeCu - Ni
    - PCB / Stiffening Layers / Stiffeners
  - Geometry - PCB Diameter / Thickness (Diaphragm effects)
    - Probe Diameter / Length / Style / Interposers
  - Support mechanisms - Probecard Tray

Z-Stage Motion control Summary

- Benefits - Increased forces - Break Oxides
  - Provides ability to use smaller probe diameters
    - Reduce probe layers
    - Tighter pitch
  - Exploits Kinetic Energy - less overdrive - reduced scrub
  - Good for small pad applications
  - Expands ability to use existing probecard technologies in future applications

Z-Stage Motion control Summary

- Detriments - if not controlled
  - Can create too high a force that can penetrate underlying pad circuitry
    - Strike-through
  - Reduce probecard life
  - Damage probes

Z-Stage Motion control

- Acknowledgements:
  - Electroglas for working in collaboration with ProbeSolutions
  - ESACorp Engineers for analysis support
  - MSC.Software Corporation - DYTRAN support
  - IEEE - SWTW

- More about us:

http://www.ProbeSolutions.com
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