BiTS™ Burn-in & Test Socket Workshop **2008** **Session 6**

ARCHIVE 2008

KEY CHALLENGES AND TECHNOLOGY TRENDS IN SOCKET DESIGN

"Automated Topside and Bottomside Testing of POP Packages on a Robotic Handler"

Eric Pensa, Willie Jerrels
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"High Speed Contactor Interconnect"

David Mahoney
Xilinx, Inc.
Hongjun Yao
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"Particle Interconnect: Simple and Effective Socket Solution"

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Automated Topside and Bottomside Testing of POP Packages on a Robotic Handler

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Outline

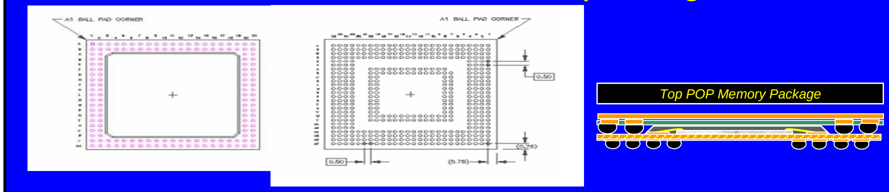
- Why is topside testing needed
- History of topside testing
- What is topside vs. bottom side testing
- Current status of topside testing
- Future requirements for topside testing

Why is Topside Testing Needed?

- Customer demand for POP packaging is strong and only expected to grow
- POP packages need to be contacted on both the bottom (BGA) *and* top side (Pads) simultaneously
- Current approach on existing robotic handlers is for bottom side testing only

Why is topside testing needed?

What is a POP package?



Top View *Bottom View* *Side view of stacked package*

- POP = Package on Package Technology
- A memory package is stacked directly onto the above POP package
- Customer chooses their own POP Package memory configurations/densities & preferred POP memory vendor

(Cont'd)

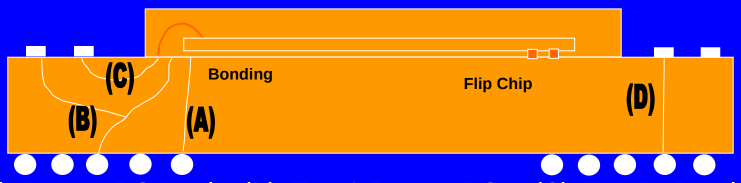
Why is topside testing needed?

- Offering a production worthy solution for testing POP packages that is not currently available. Without this test capability the large cost savings achievable with POP packages will not be realized.
- *"Top Test capability is expected to reduce TI costs on selected POP packages considerably. This is a direct result of not having to bring the full memory interface to the bottom BGA, thus decreasing ball count, decreasing substrate complexity, decreasing substrate layer count, and finally decreasing cost."* (Cont'd)

Why is topside testing needed?

Current POP design and test methods require 100% access to the memory device from the bottom BGA solder balls (paths A, B & D below). This practice increases the package pin count, reduces BGA pitch and in turn increases our customer's assembly complexity, adds to system PWB cost and lowers reliability. The goal is to eliminate path B and only have paths A, C & D. (Cont'd)

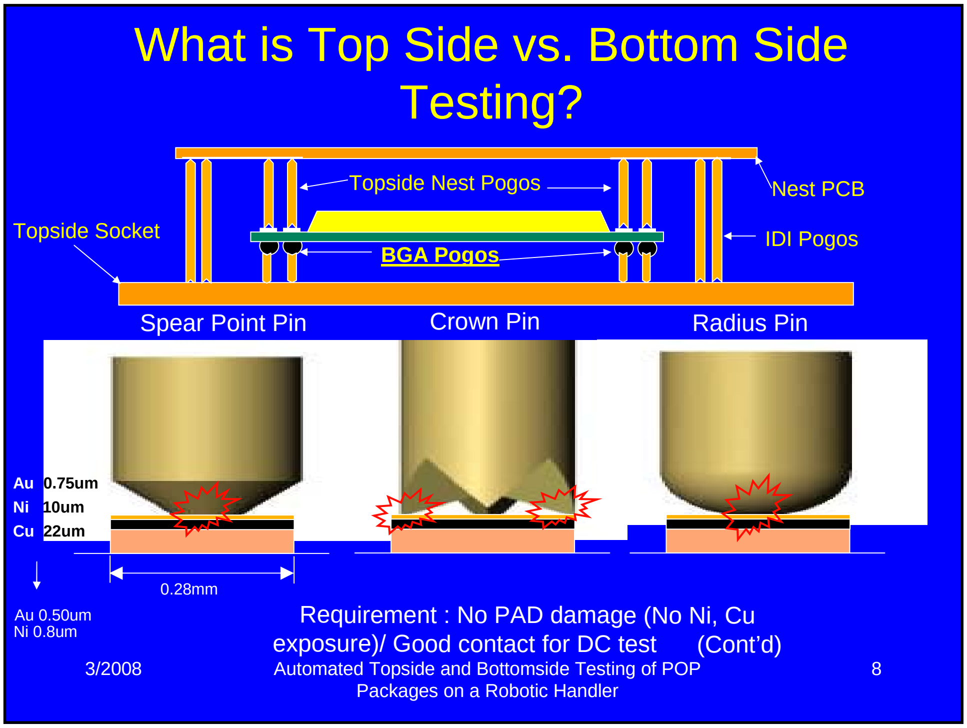
Bottom package cross section
(wire bond or flip chip)



(A): Bottom BGA only; (B): Top & Bottom BGA; (C): Top PAD only

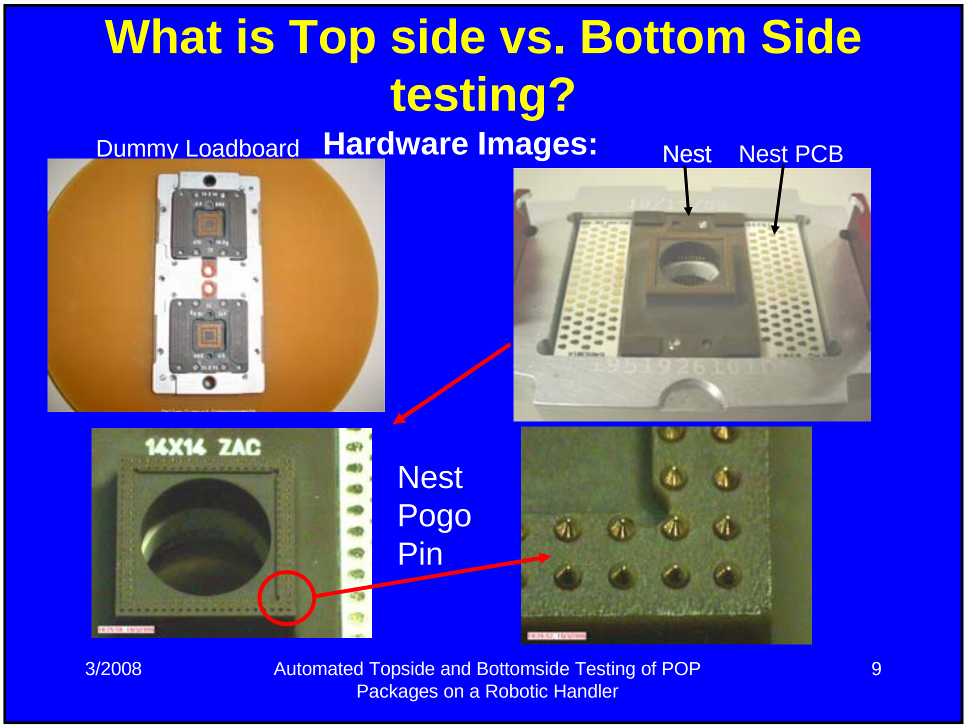
History of Topside Testing

- First customer request ~ 2.5 years ago for 14x14 POP package
- TI MAKE Test and Delta Contactor teams began development of topside test solution for 14x14 POP package
- Challenge was finding 2 pogopins for bringing signal up to topside
- Unexpected challenge was building non-flat nest PCB board - handler vendor declined!
- Kit and socket were verified Summer 2005 with O/S testing using daisy chains only due to device being cancelled - no production testing ever done w/ 14x14 POP



What is Top Side vs. Bottom Side Testing?

Requirement : No PAD damage (No Ni, Cu exposure)/ Good contact for DC test (Cont'd)



What is Top side vs. Bottom Side testing?

Hardware Images:

Current Status of Topside Testing

- Topside testing resurrected ~ 1 year ago for a 12x12 POP package by a TI customer
- To meet aggressive 3 month kit/socket request, decision was made to leverage off of 14x14 topside kit as much as possible
- Customer's 2 key requirements: 1) ***NO*** Ni or Cu exposure; 2) "gentle mark" to topside pad will only be accepted
- Topside pogopin from 14x14 kit was single point/spear type: SEM analysis of tested units showed failure to meet both requirements.
- Only 3 "drop-in replacement" pogopins were available for consideration: 2 w/ radiused tips & 1 w/ 3 point crown tip

(Cont'd)

Current Status of Topside Testing

- 14x14 units were run thru the handler with all 3 “drop-in” pogos: SEM testing showed all 3 would meet customer requirements with radiused tip markings being slightly more gentle than 3 point crowns. (Note: No electrical testing; same mechanical settings as used w/ 14x14 kit.)
- Topside Handler Kit, Socket, and O/S Testboards were ordered for the 12x12 POP package
- Both radiused and 3 point crown type pogos were ordered
- Customer preferred the radiused tip (Cont’d)

- SEM results from **Initial Mechanical Assessment of Probe Pins**:
  - Evaluation varied 1) Probe type 2) Force, 3) # of probe attempts
  - Radial pins exhibited minimal “marking” and no Ni detection
  - Alternate pin styles showed ~2x “mark size” over radial pin

Radial Pin Results – 20g Force:

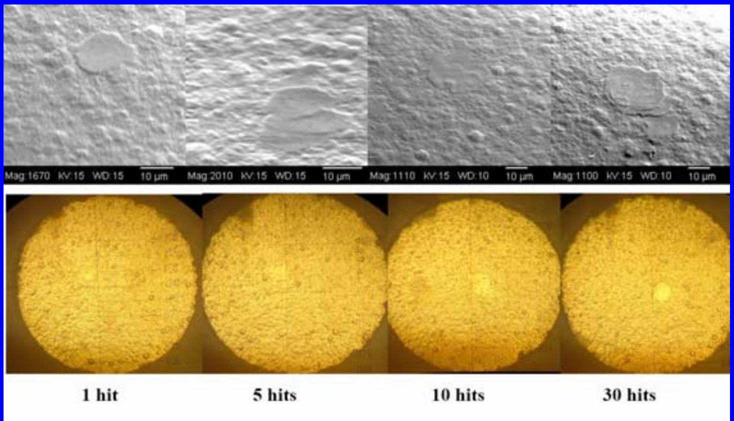
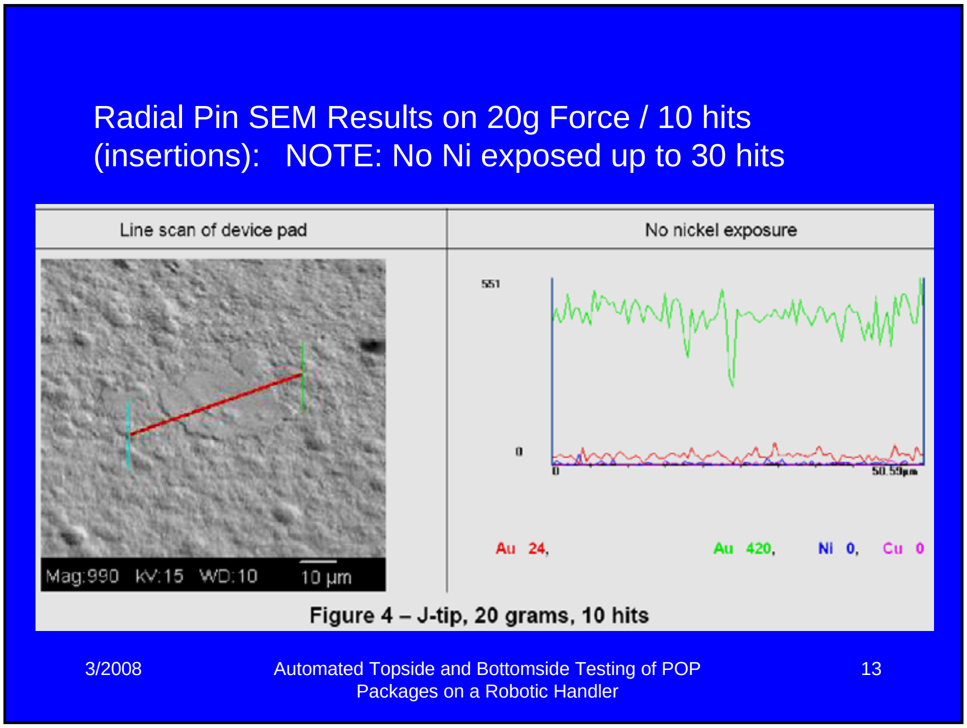
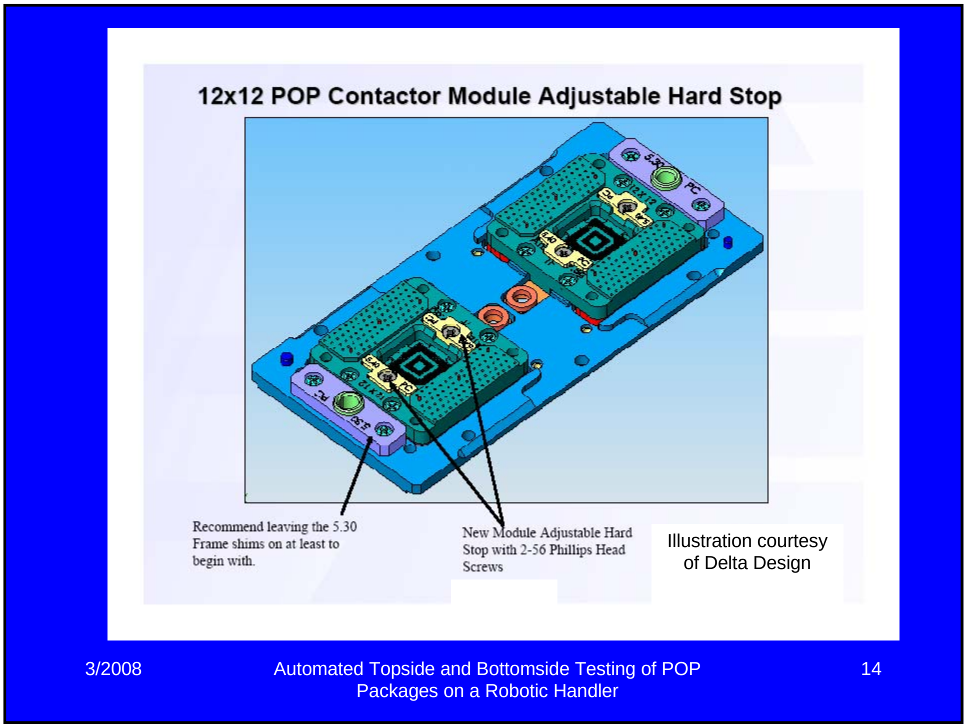


Figure 1 – J tip, 20 grams



Radial Pin SEM Results on 20g Force / 10 hits (insertions): NOTE: No Ni exposed up to 30 hits

Figure 4 – J-tip, 20 grams, 10 hits



12x12 POP Contactor Module Adjustable Hard Stop

Recommend leaving the 5.30 Frame shims on at least to begin with.

New Module Adjustable Hard Stop with 2-56 Phillips Head Screws

Illustration courtesy of Delta Design

Current Status of Topside Testing

- To reduce risk, handler vendor was requested to run kit continuity check at all 3 temp's w/ daisy chained 12x12 POP units: good results from both pogo types at all 3 temps!
- Kit arrives in TI Dallas: however live 12x12 POP units proved to be more sensitive than the daisy chained ones: Mis-contact(Bin 8) rates were significantly worse! Fortunately customer received required units throughout troubleshooting phase.
- A multi-month effort began to fine-tune the setup to eliminate mis-contact (Bin 8) with the nest being the focus:

(Cont'd)

Current Status of Topside Testing

a) "Retainers" were added to the handler nest for pogopin to pad alignment

b) Nest "ceiling" was lowered to counter any package warpage

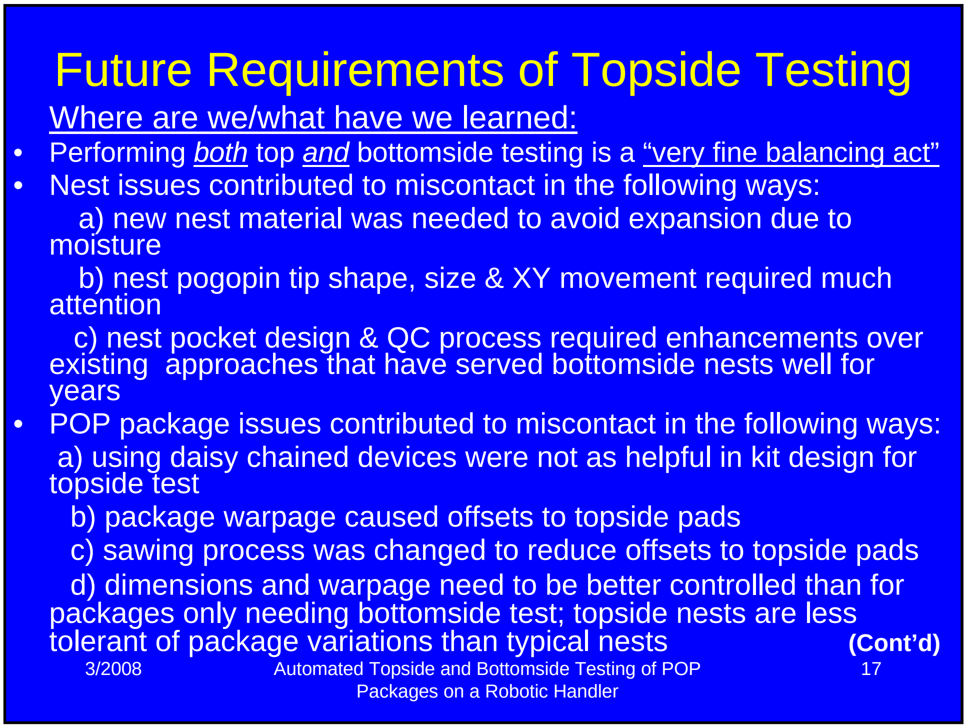
c) Single ended BGA pogopins replaced w/ double ended as used on 14x14 kit

d) Adding hardstop height with Kapton tape helped; therefore variable hardstops on the contactor were offered [5.30 thru 5.45mm in .05 steps] to deal with package thickness variances

e) Variable hardstops also added to the contactor modules to replicate the success of hand test lids *w/ hardstops closer to the POP unit under test* by reducing package flexing possibility – finally both chucks for the 1st time recorded 0% Bin 8 for 1st pass test!

f) Same chuck/nest assemblies were transferred to TI Asia; 0% Bin 8 was achieved with same units tested in Dallas

(Cont'd)



Future Requirements of Topside Testing

Where are we/what have we learned:

- Performing *both* top *and* bottomside testing is a "very fine balancing act"
- Nest issues contributed to miscontact in the following ways:
  - a) new nest material was needed to avoid expansion due to moisture
  - b) nest pogopin tip shape, size & XY movement required much attention
  - c) nest pocket design & QC process required enhancements over existing approaches that have served bottomside nests well for years
- POP package issues contributed to miscontact in the following ways:
  - a) using daisy chained devices were not as helpful in kit design for topside test
  - b) package warpage caused offsets to topside pads
  - c) sawing process was changed to reduce offsets to topside pads
  - d) dimensions and warpage need to be better controlled than for packages only needing bottomside test; topside nests are less tolerant of package variations than typical nests

(Cont'd)

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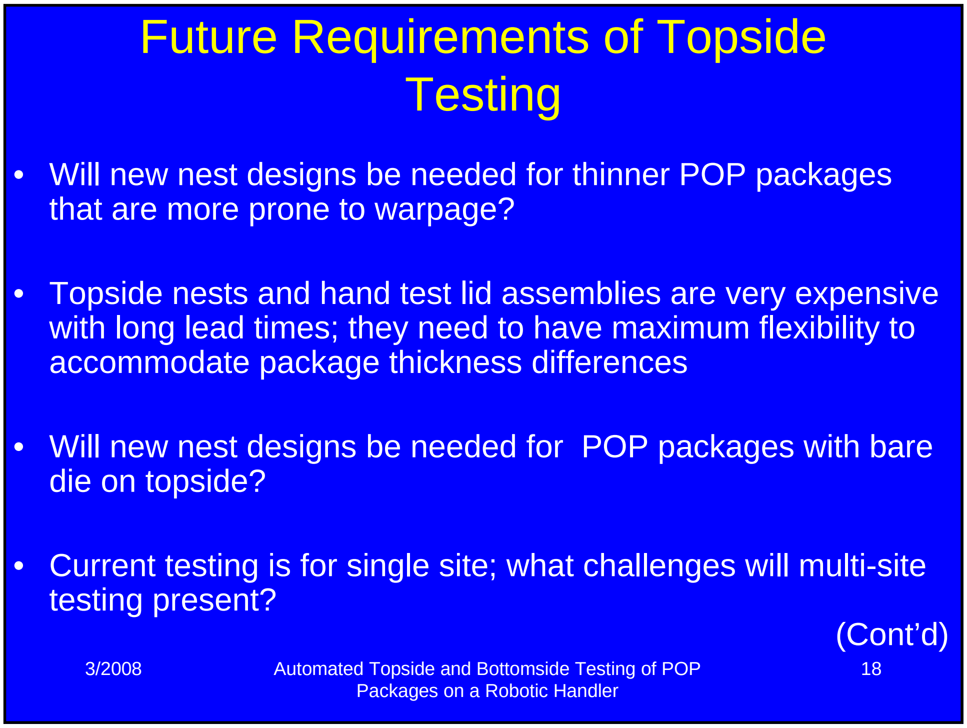

Future Requirements of Topside Testing

- Will new nest designs be needed for thinner POP packages that are more prone to warpage?
- Topside nests and hand test lid assemblies are very expensive with long lead times; they need to have maximum flexibility to accommodate package thickness differences
- Will new nest designs be needed for POP packages with bare die on topside?
- Current testing is for single site; what challenges will multi-site testing present?

(Cont'd)

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Future Requirements of Topside

- Having our strategic socket vendors producing turnkey topside sockets and hand test lids [nest PCB and new pogo designs will be needed]
- Developing topside testing solutions for other strategic handlers
- Current topside pogopins are very expensive with lead times up to 6 to 8 weeks; both need to be reduced

High Speed Contactor Interconnect

2008 Burn-in and Test Socket Workshop
March 9 - 12, 2008

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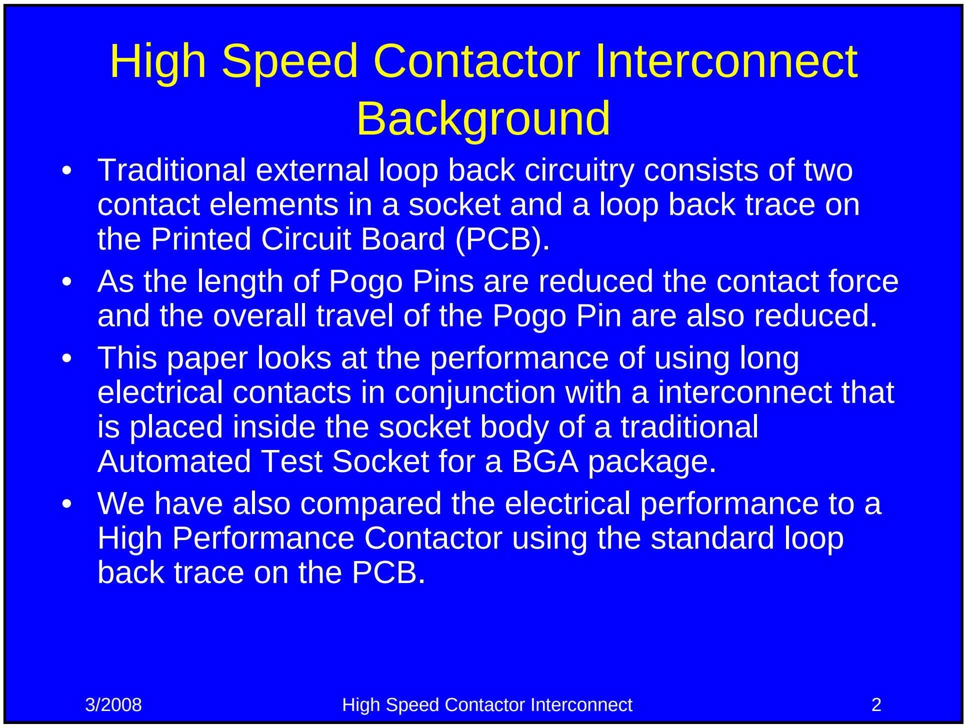
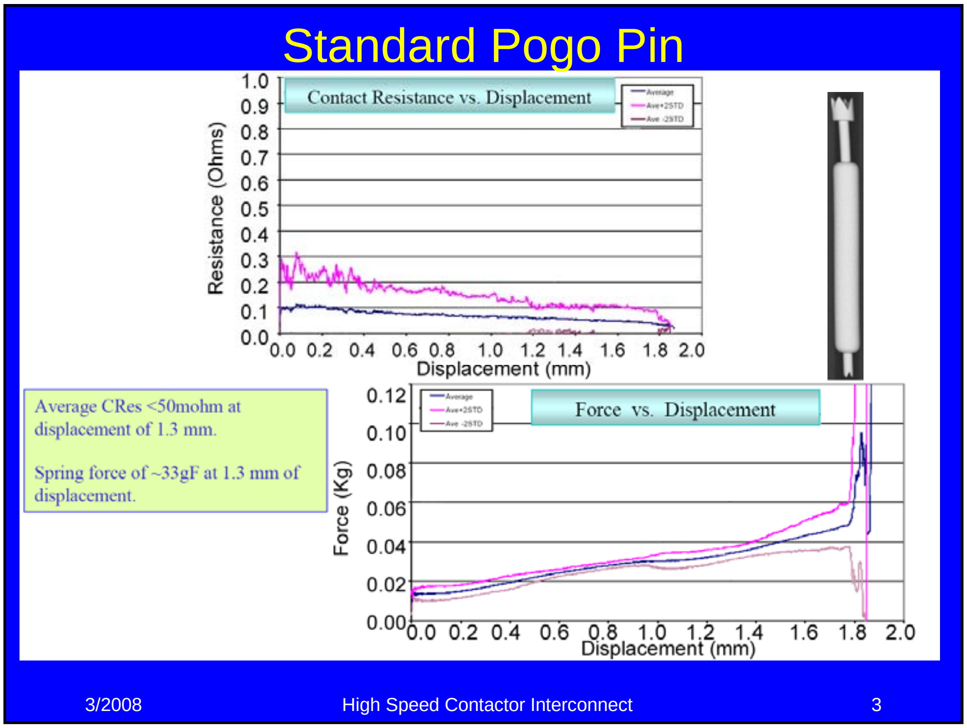


High Speed Contactor Interconnect Background

- Traditional external loop back circuitry consists of two contact elements in a socket and a loop back trace on the Printed Circuit Board (PCB).
- As the length of Pogo Pins are reduced the contact force and the overall travel of the Pogo Pin are also reduced.
- This paper looks at the performance of using long electrical contacts in conjunction with a interconnect that is placed inside the socket body of a traditional Automated Test Socket for a BGA package.
- We have also compared the electrical performance to a High Performance Contactor using the standard loop back trace on the PCB.



Standard Pogo Pin

Average CRes <50mohm at displacement of 1.3 mm.

Spring force of ~33gF at 1.3 mm of displacement.

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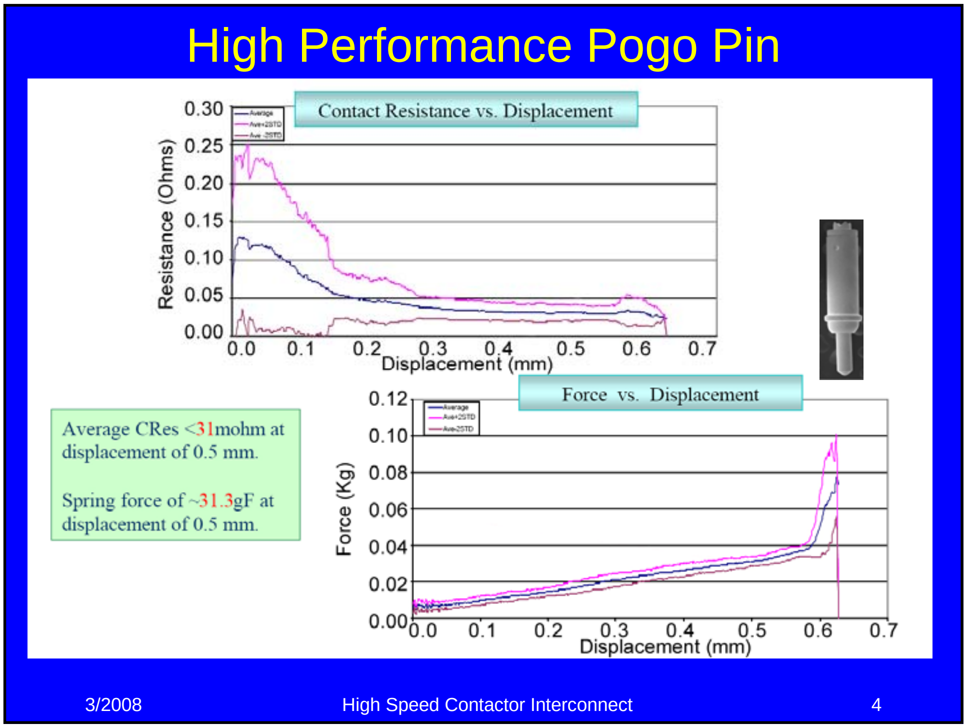
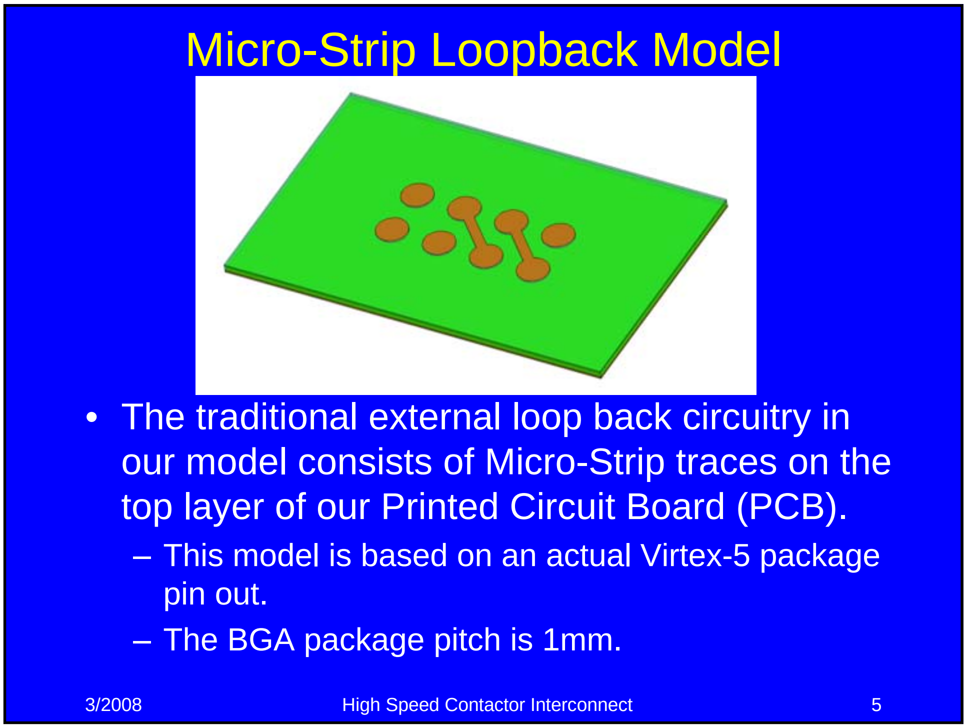


High Performance Pogo Pin

Average CRes <31mohm at displacement of 0.5 mm.

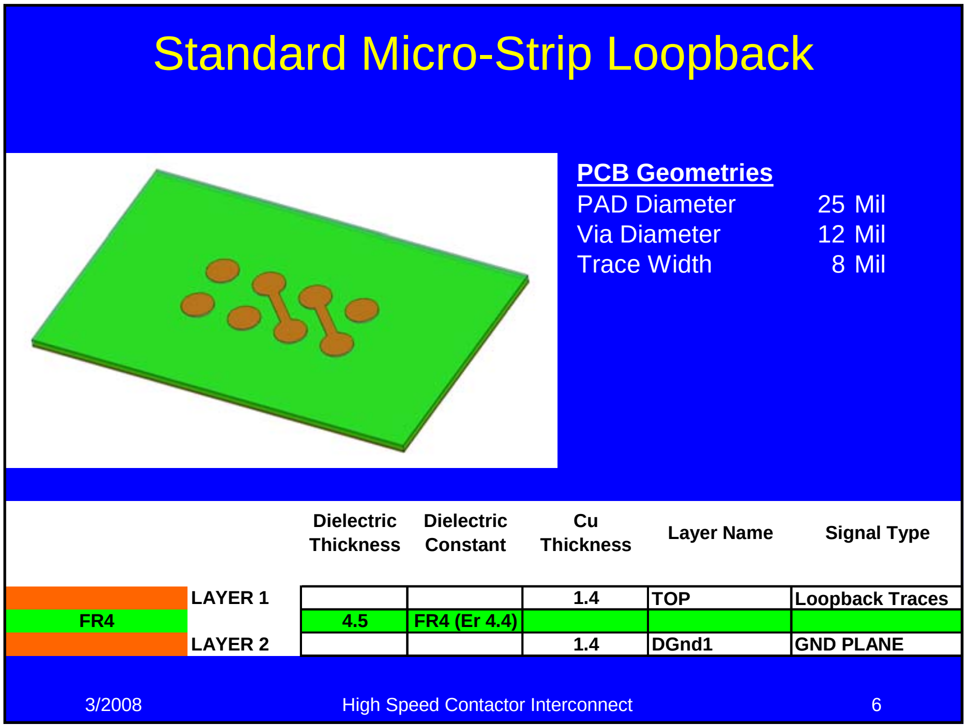
Spring force of ~31.3gF at displacement of 0.5 mm.

3/2008 High Speed Contactor Interconnect 4



Micro-Strip Loopback Model

- The traditional external loop back circuitry in our model consists of Micro-Strip traces on the top layer of our Printed Circuit Board (PCB).
  - This model is based on an actual Virtex-5 package pin out.
  - The BGA package pitch is 1mm.

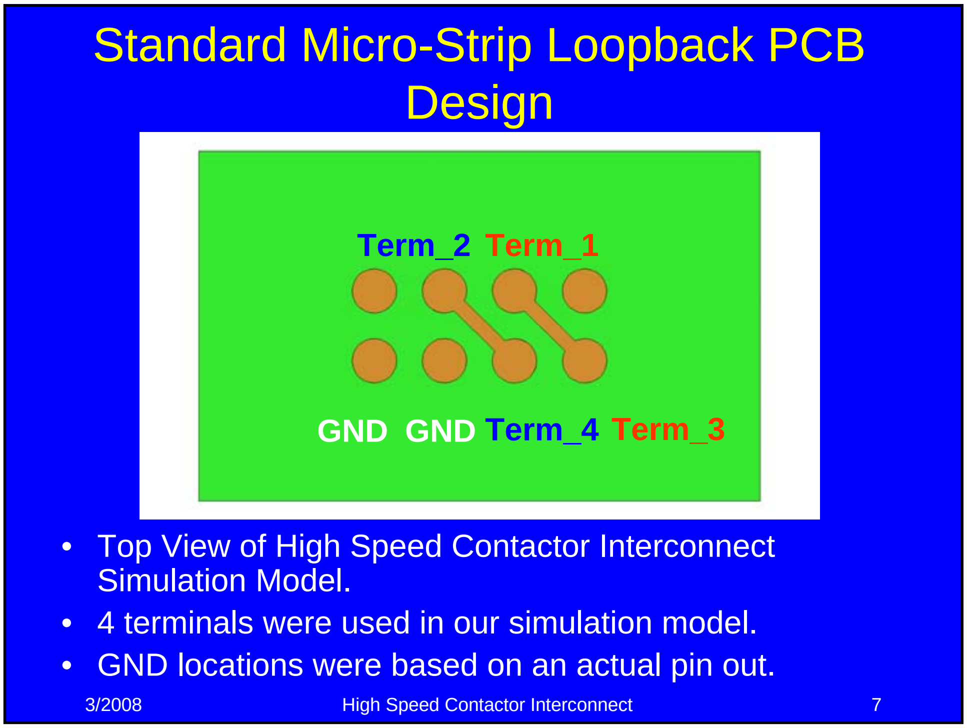


Standard Micro-Strip Loopback

PCB Geometries

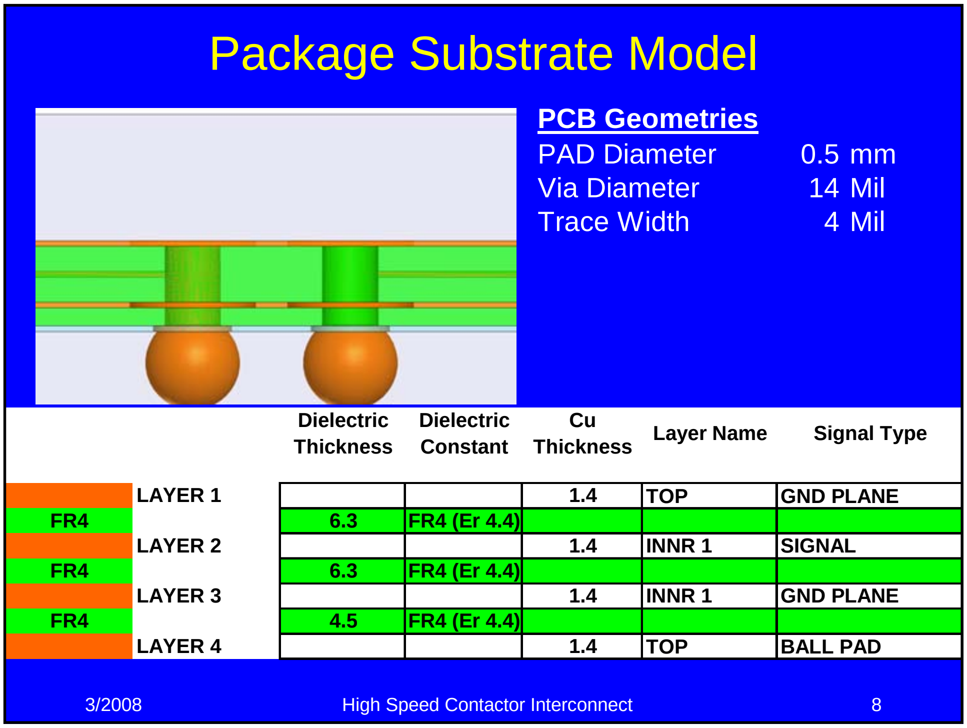
PAD Diameter	25 Mil
Via Diameter	12 Mil
Trace Width	8 Mil

		Dielectric Thickness	Dielectric Constant	Cu Thickness	Layer Name	Signal Type
	LAYER 1			1.4	TOP	Loopback Traces
FR4		4.5	FR4 (Er 4.4)			
	LAYER 2			1.4	DGnd1	GND PLANE



Standard Micro-Strip Loopback PCB Design

- Top View of High Speed Contactor Interconnect Simulation Model.
- 4 terminals were used in our simulation model.
- GND locations were based on an actual pin out.

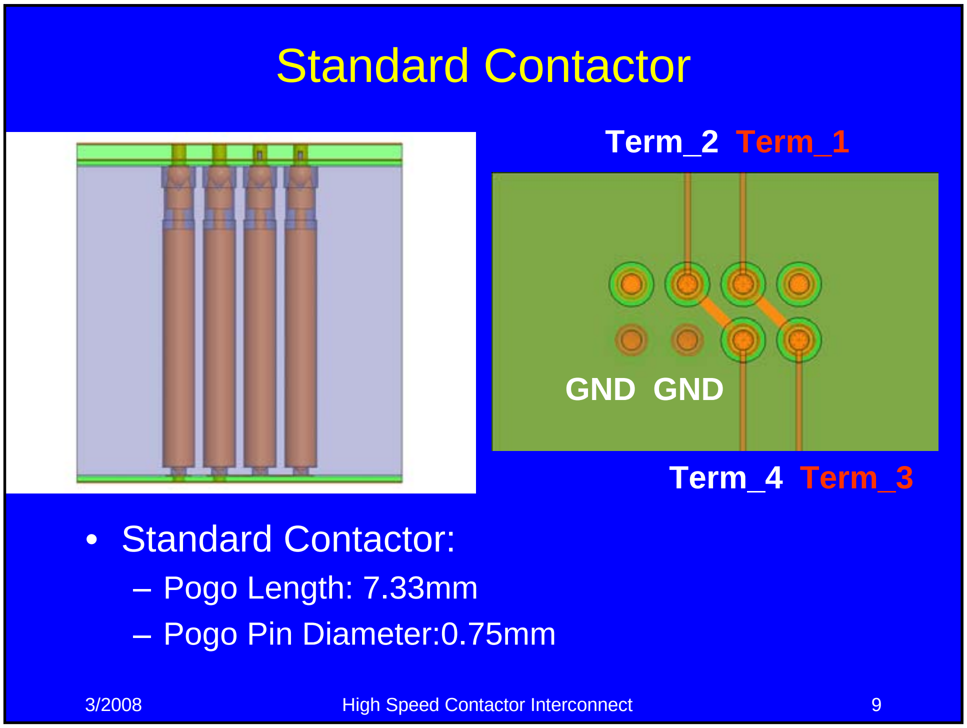


Package Substrate Model

PCB Geometries

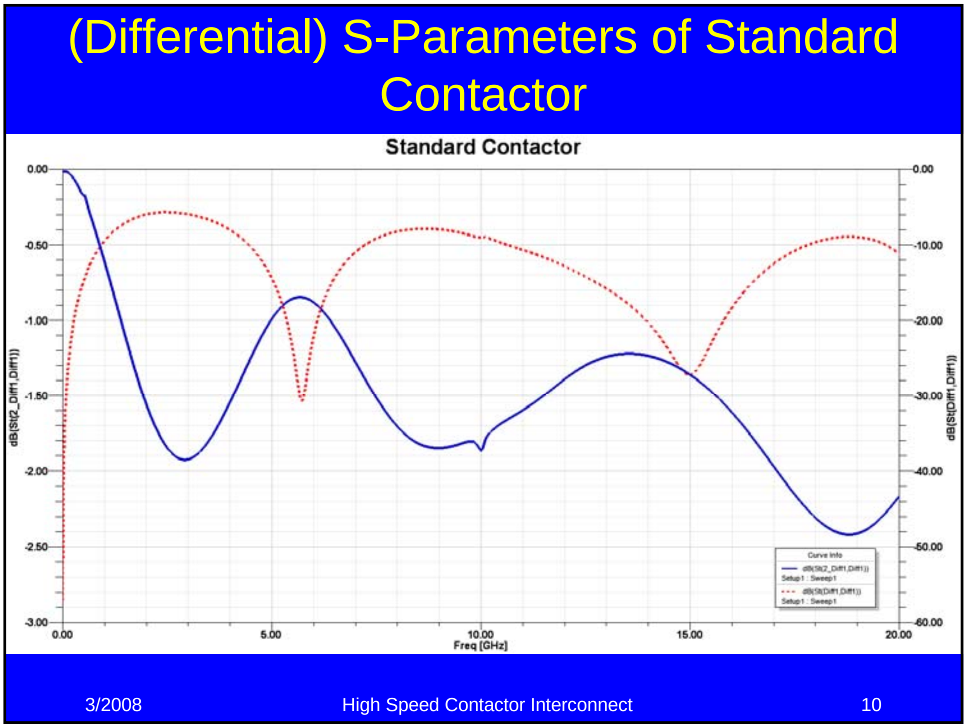
PAD Diameter	0.5 mm
Via Diameter	14 Mil
Trace Width	4 Mil

		Dielectric Thickness	Dielectric Constant	Cu Thickness	Layer Name	Signal Type
	LAYER 1			1.4	TOP	GND PLANE
FR4		6.3	FR4 (Er 4.4)			
	LAYER 2			1.4	INNR 1	SIGNAL
FR4		6.3	FR4 (Er 4.4)			
	LAYER 3			1.4	INNR 1	GND PLANE
FR4		4.5	FR4 (Er 4.4)			
	LAYER 4			1.4	TOP	BALL PAD



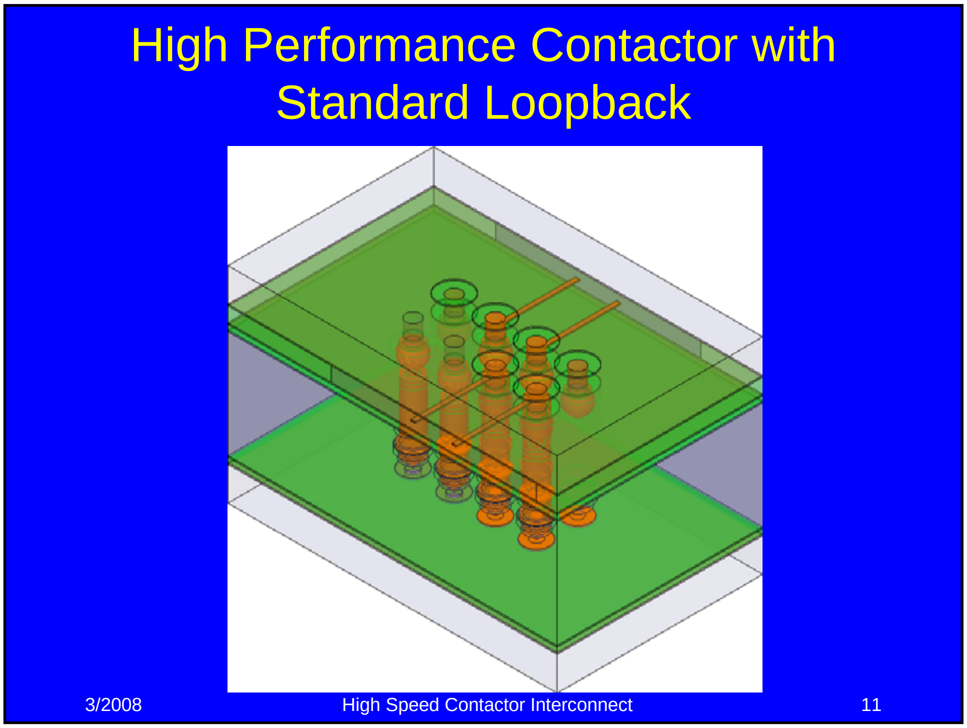
Standard Contactor

- Standard Contactor:
  - Pogo Length: 7.33mm
  - Pogo Pin Diameter:0.75mm

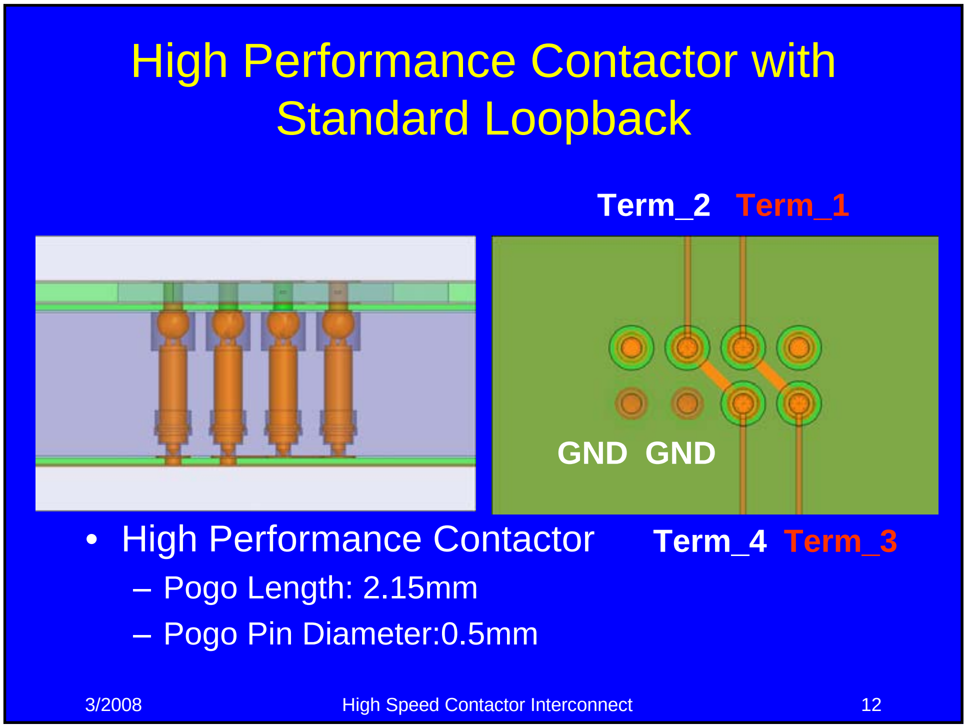


(Differential) S-Parameters of Standard Contactor

Standard Contactor



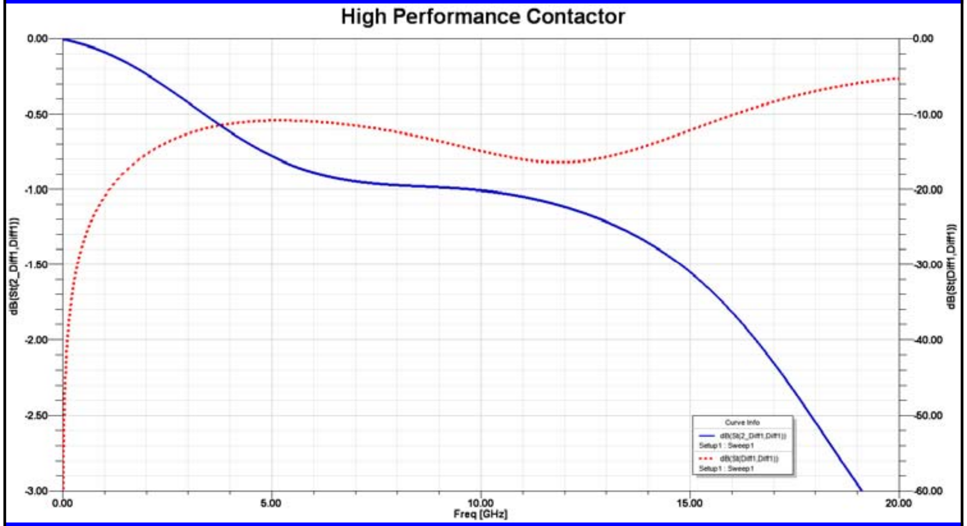
High Performance Contactor with Standard Loopback



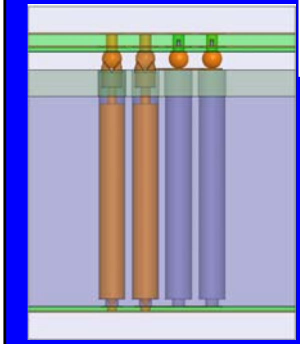
High Performance Contactor with Standard Loopback

- High Performance Contactor
  - Pogo Length: 2.15mm
  - Pogo Pin Diameter:0.5mm

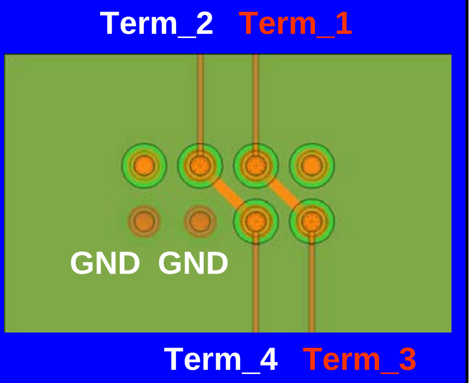
(Differential) S-Parameters of High Performance Contactor



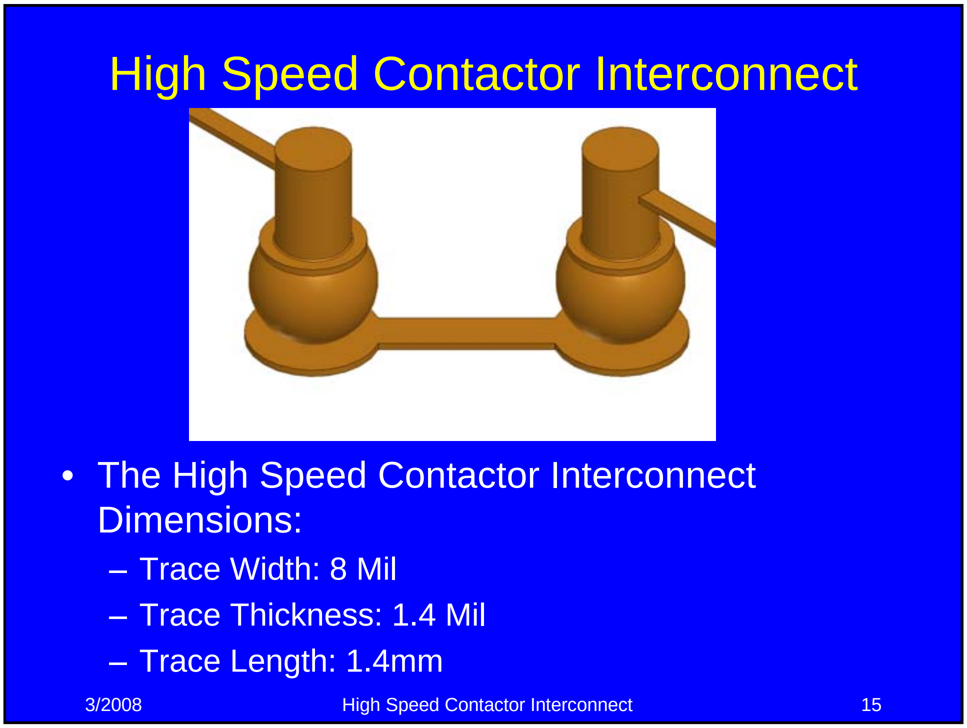
High Speed Contactor Interconnect



Non Conductive Elastomer

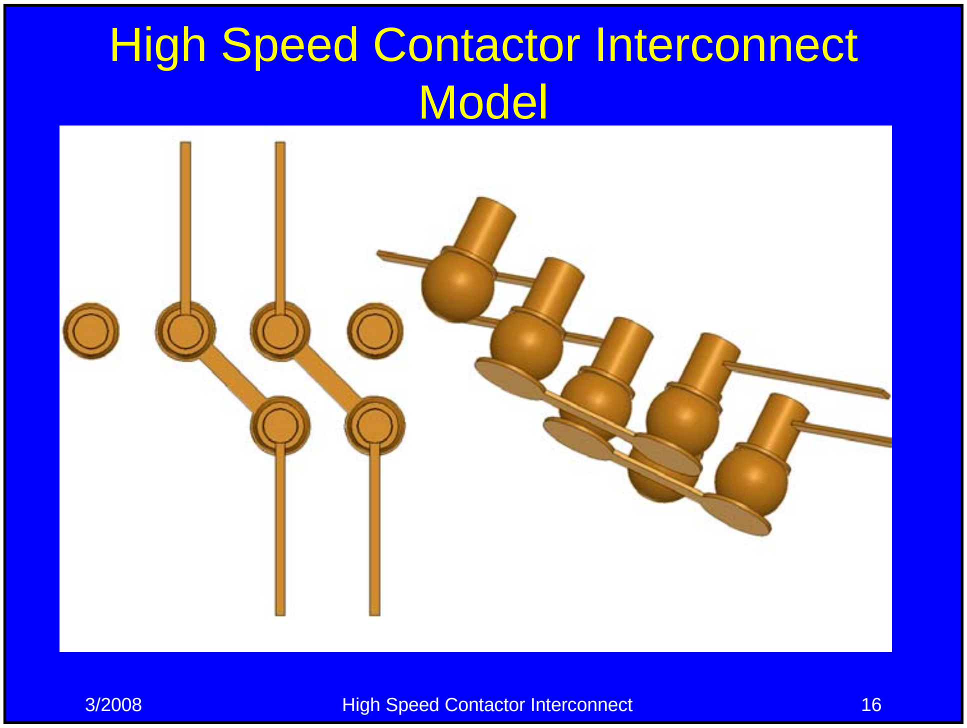


- High Speed Contactor Interconnect
  - GND Pogo Length: 7.33mm
  - GND Pogo Pin Diameter: 0.75mm
  - Interconnect above non conductive Elastomer.



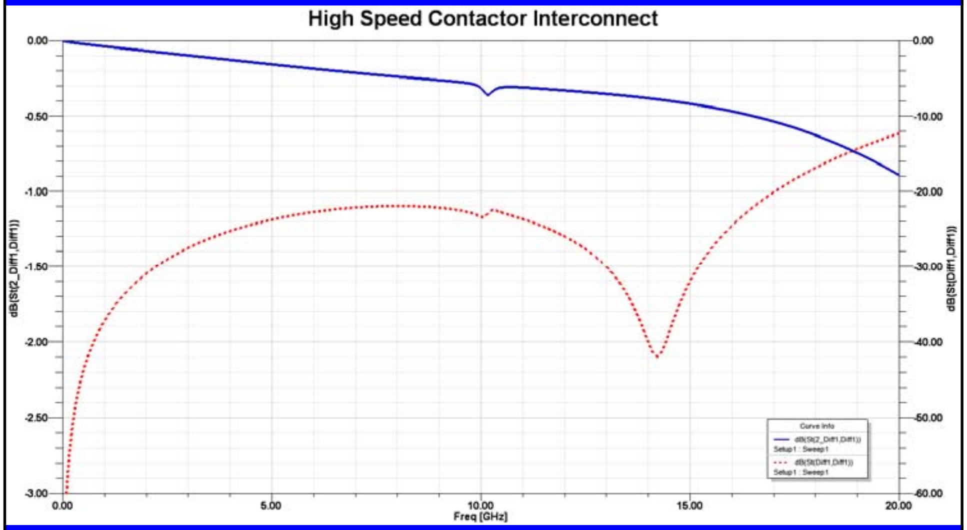
High Speed Contactor Interconnect

- The High Speed Contactor Interconnect Dimensions:
  - Trace Width: 8 Mil
  - Trace Thickness: 1.4 Mil
  - Trace Length: 1.4mm



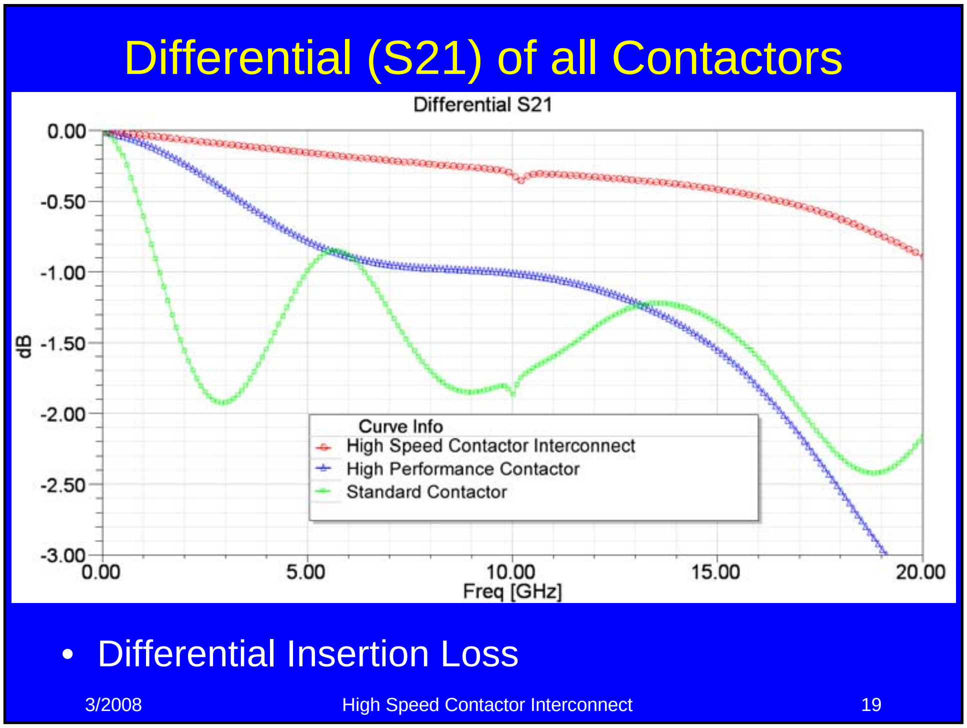
High Speed Contactor Interconnect Model

(Differential) S-Parameters of High Speed Contactor Interconnect



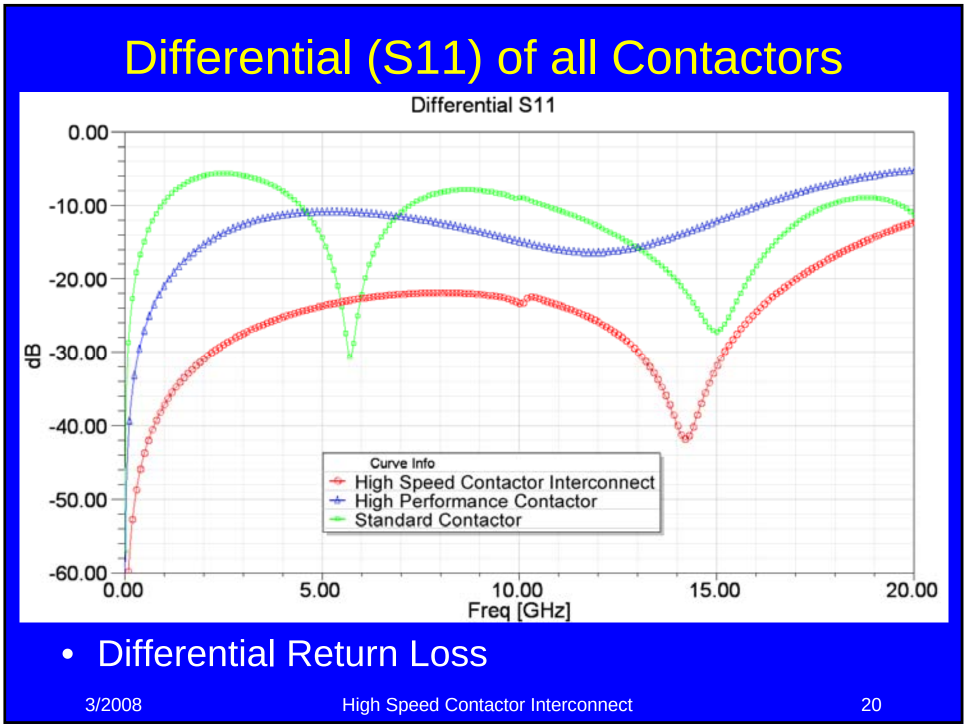
Contactor Comparisons

- Differential Insertion Loss
- Differential Return Loss
- Differential TDR



Differential (S21) of all Contactors

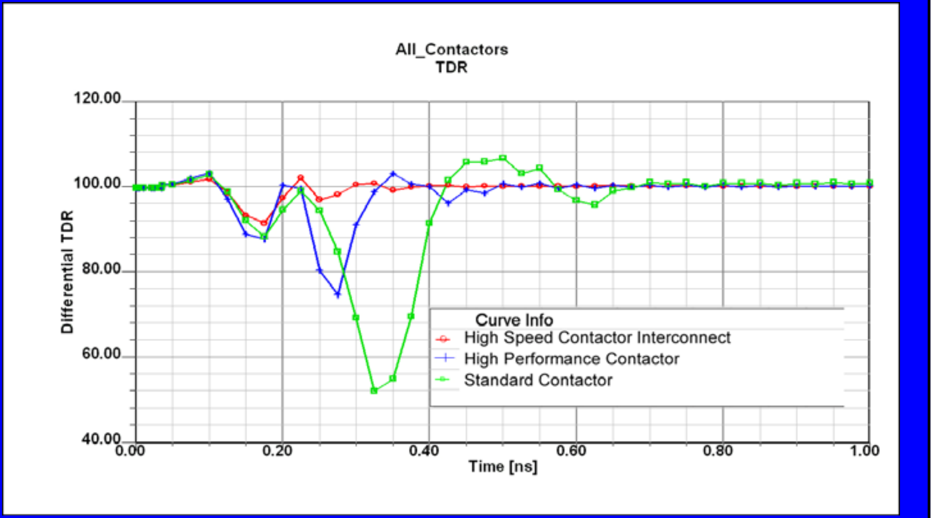
- Differential Insertion Loss



Differential (S11) of all Contactors

- Differential Return Loss

Differential TDR of All Contactors

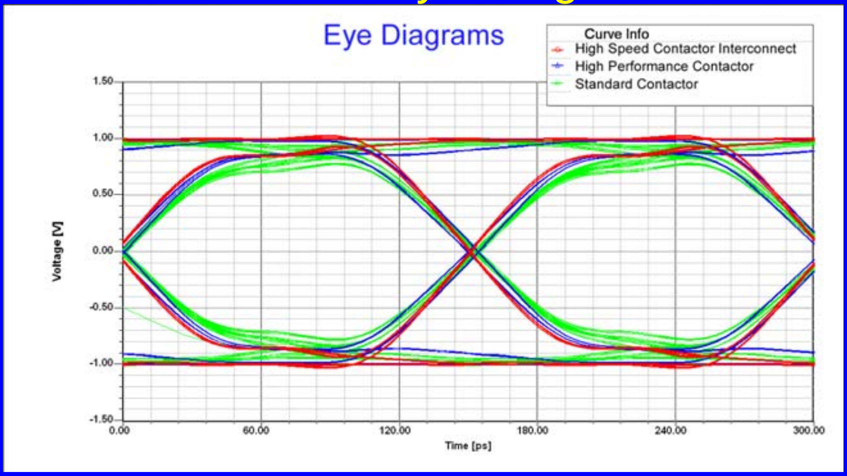


- Differential TDR

Eye Diagrams

- PRBS Parameters:
  - 80pS rise time
  - 80pS fall time
  - 6.5Gbps

Combined Eye Diagrams

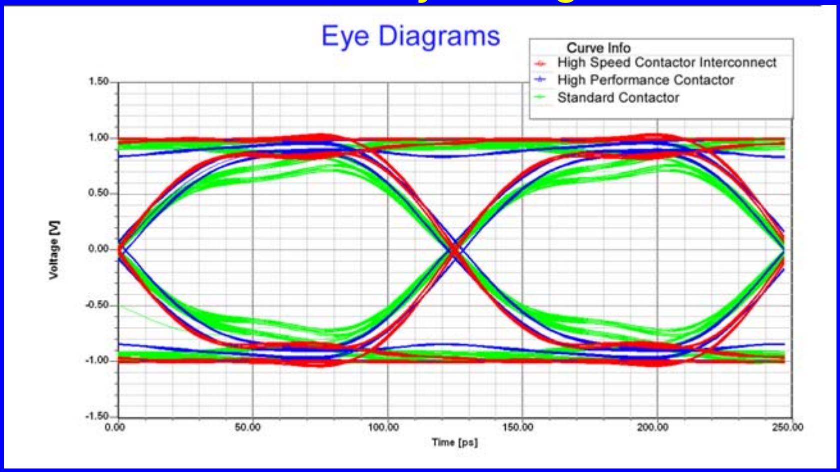


- Although the Eye Diagram results are based on ideal elements the High Speed Contactor Interconnect provided greater bandwidth for external Loopback testing.

Eye Diagrams

- PRBS Parameters:
  - 60pS rise time
  - 60pS fall time
  - 8Gbps

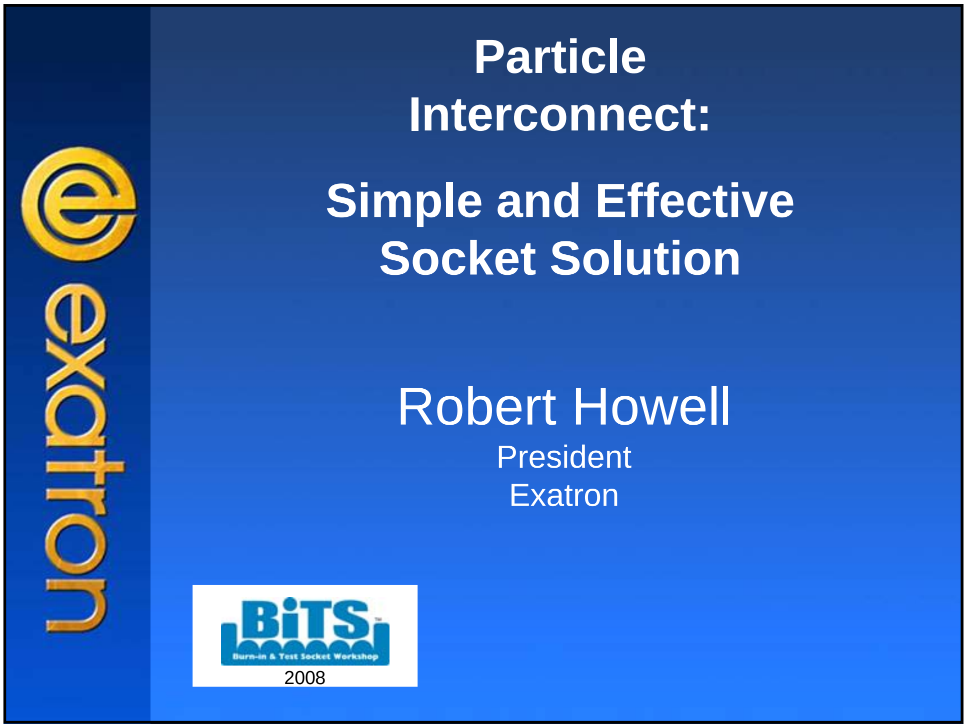
Combined Eye Diagrams



- Although the Eye Diagram results are based on ideal elements the High Speed Contactor Interconnect provided greater bandwidth for external Loopback testing.

High Speed Contactor Interconnect Summary

- The High Speed Contactor Interconnect demonstrated greater Bandwidth than a High Performance Contactor with standard loopback traces on the PCB.
- The High Speed Contactor Interconnect maintained both greater working range and higher bandwidth than the High Performance Pogo Pin Contactor.
- The addition of an interconnect in the socket provides greater bandwidth for loop back testing purposes without having to change the entire socket to high performance pogo pins.

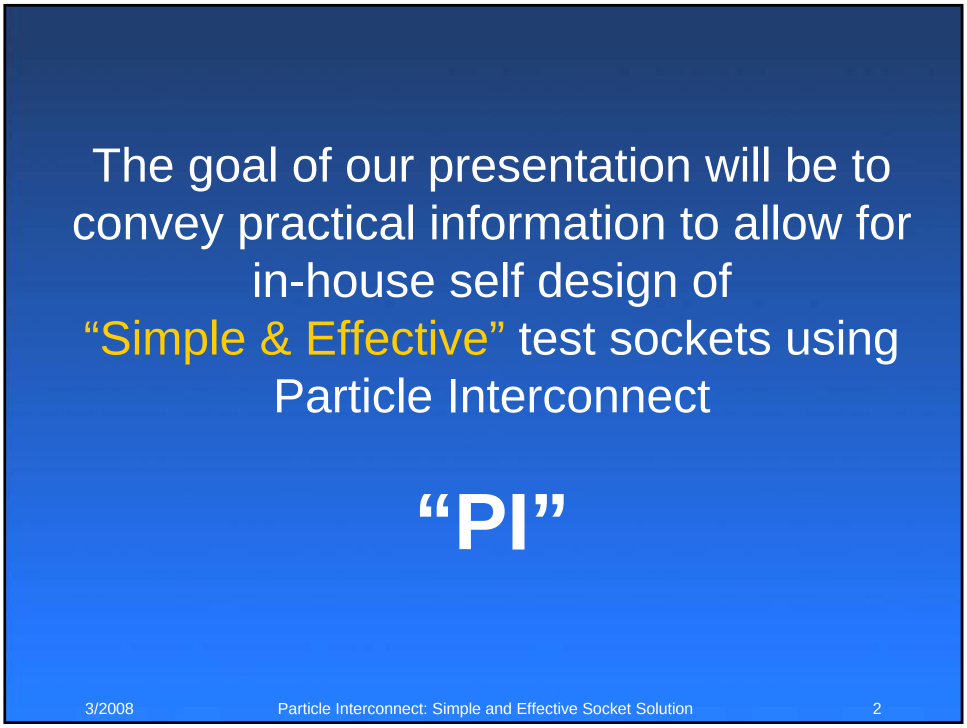


Particle Interconnect:

Simple and Effective Socket Solution

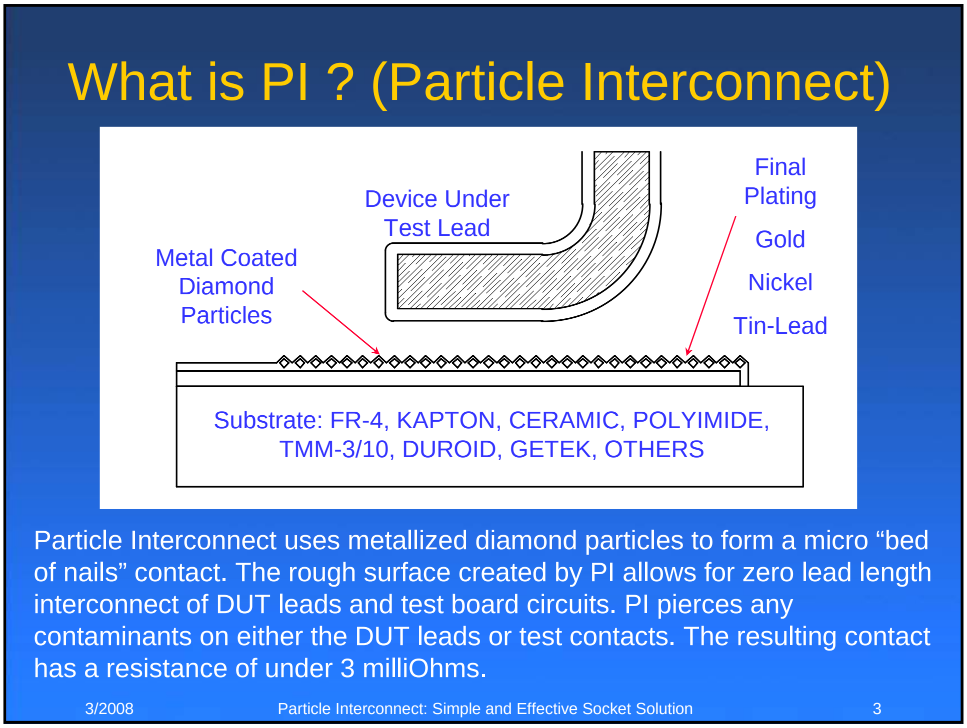
Robert Howell
President
Exatron

2008



The goal of our presentation will be to convey practical information to allow for in-house self design of “Simple & Effective” test sockets using Particle Interconnect

“PI”



What is PI ? (Particle Interconnect)

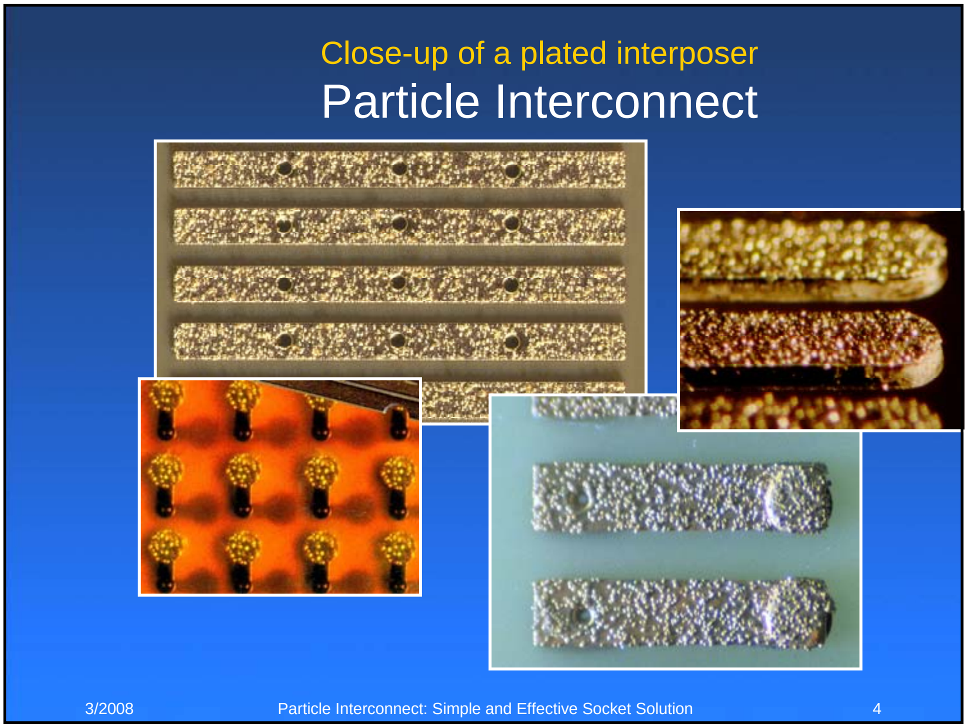
Device Under Test Lead

Metal Coated Diamond Particles

Final Plating
Gold
Nickel
Tin-Lead

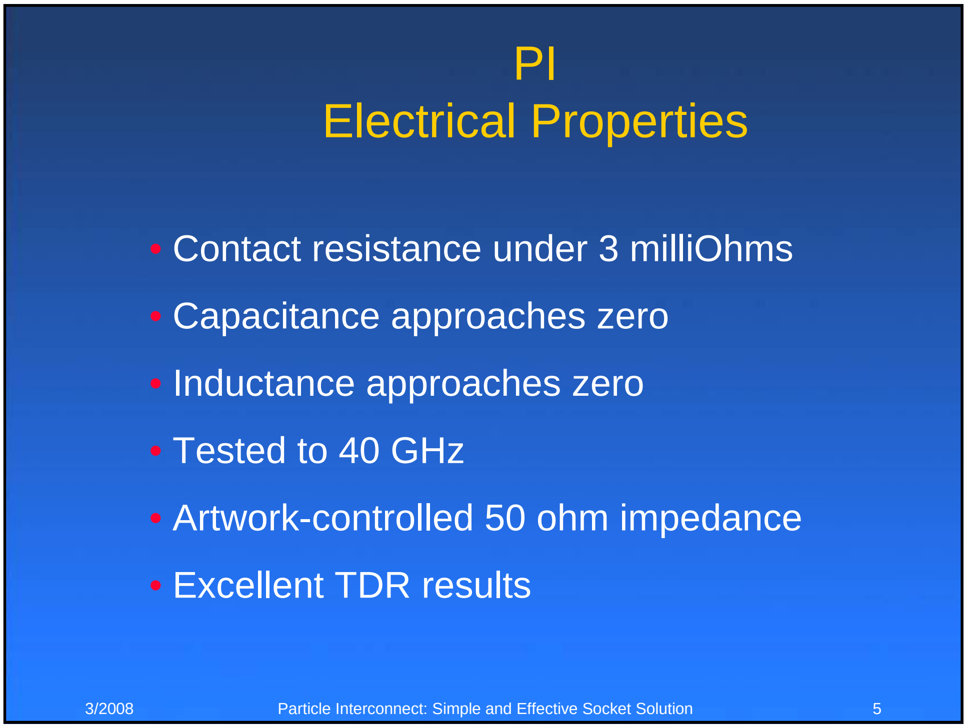
Substrate: FR-4, KAPTON, CERAMIC, POLYIMIDE, TMM-3/10, DUROID, GETEK, OTHERS

Particle Interconnect uses metallized diamond particles to form a micro “bed of nails” contact. The rough surface created by PI allows for zero lead length interconnect of DUT leads and test board circuits. PI pierces any contaminants on either the DUT leads or test contacts. The resulting contact has a resistance of under 3 milliOhms.



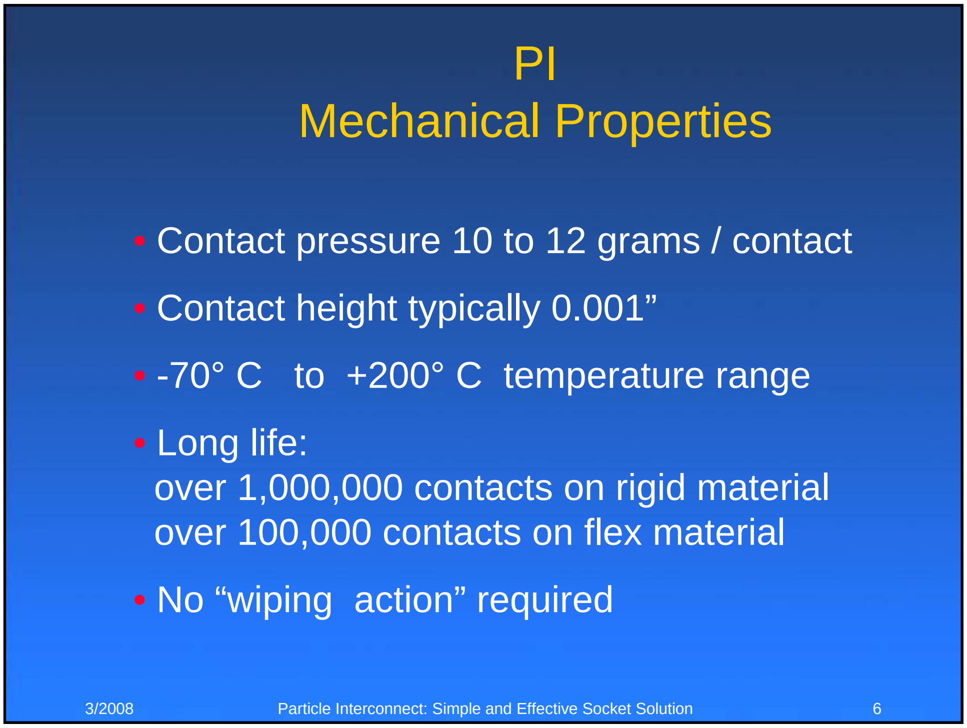
Close-up of a plated interposer

Particle Interconnect



PI
Electrical Properties

- Contact resistance under 3 milliOhms
- Capacitance approaches zero
- Inductance approaches zero
- Tested to 40 GHz
- Artwork-controlled 50 ohm impedance
- Excellent TDR results



PI
Mechanical Properties

- Contact pressure 10 to 12 grams / contact
- Contact height typically 0.001”
- -70° C to +200° C temperature range
- Long life:
  over 1,000,000 contacts on rigid material
  over 100,000 contacts on flex material
- No “wiping action” required

All Particle Interconnect Test Sockets
are
RoHS Compliant

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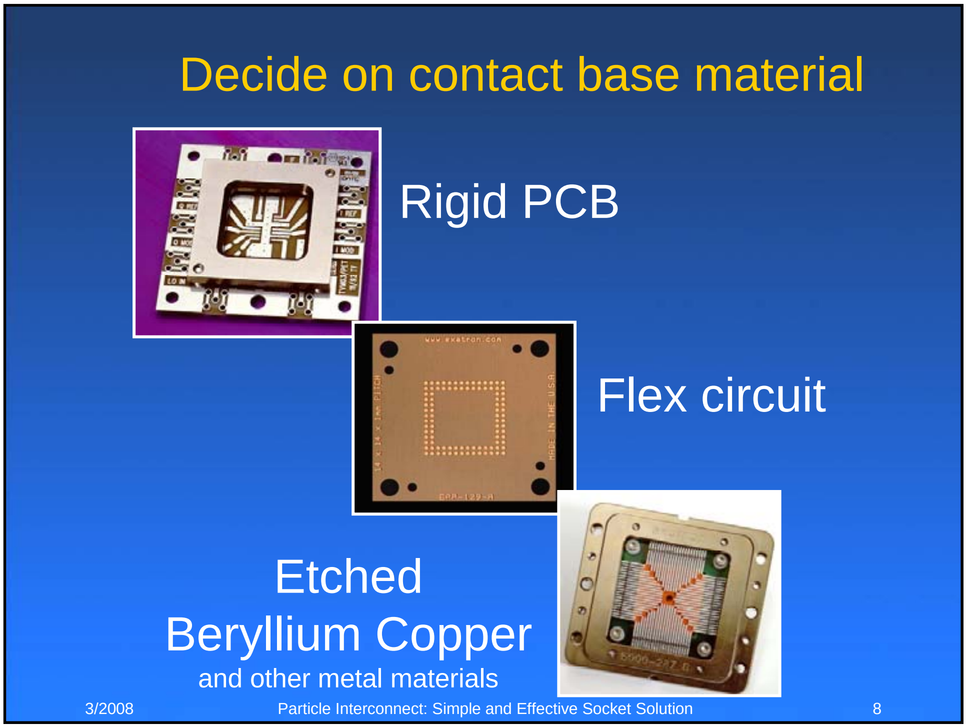

Decide on contact base material

Rigid PCB

Flex circuit

Etched
Beryllium Copper
and other metal materials

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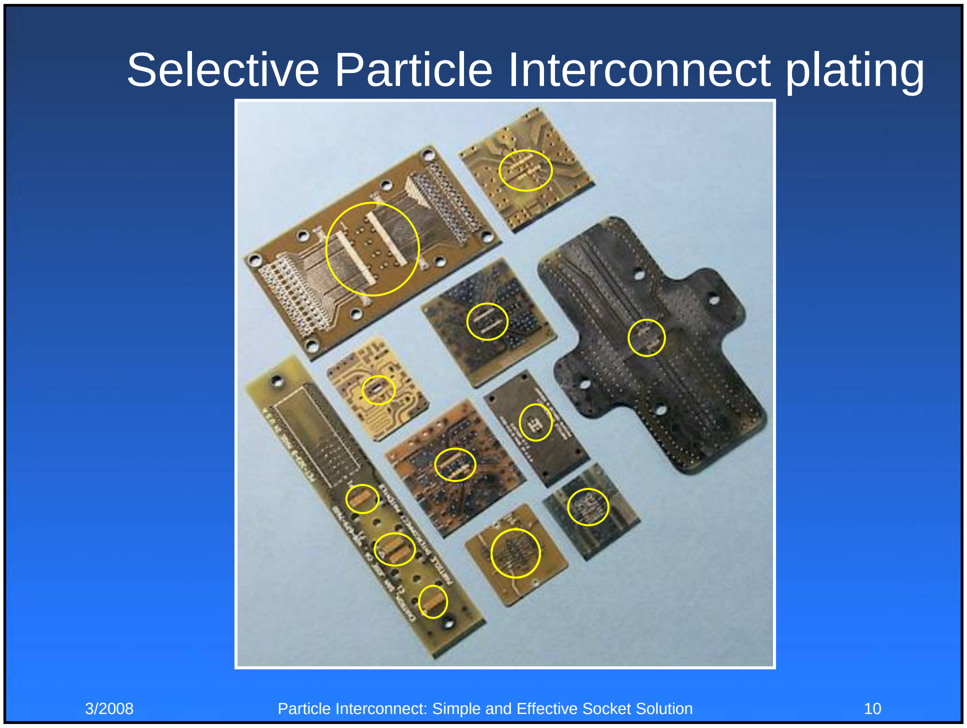
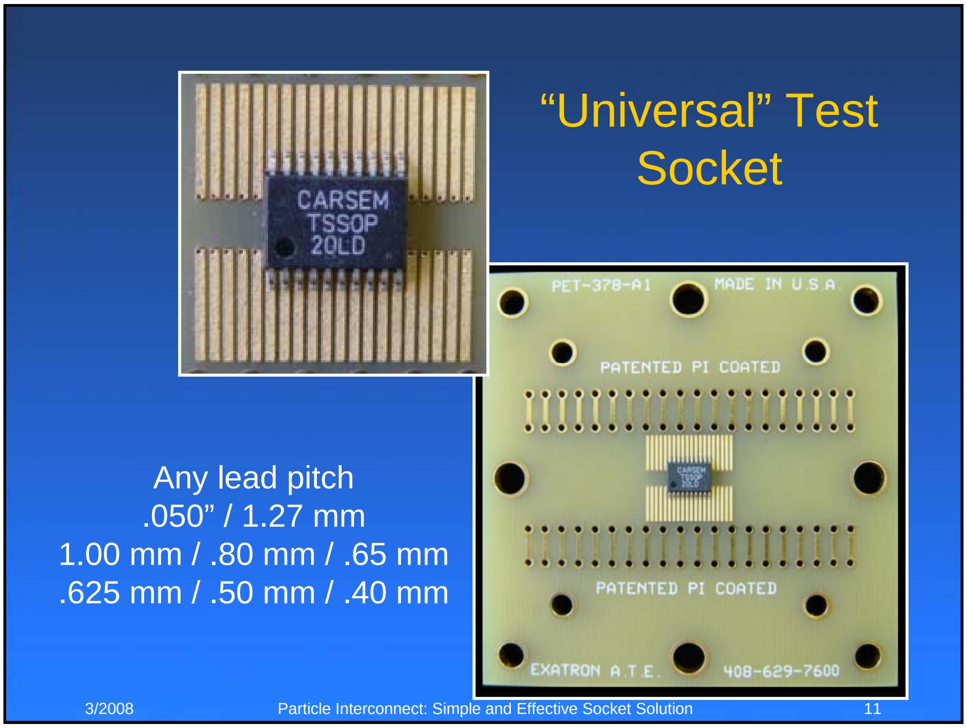
Rigid PCB Applications

- Typically 0.010” or thicker
- Standard FR-4 is the most popular material
- Ceramic, Teflon, G-10 and other special base materials are available
- Works best for devices with flexible leads

SOIC, SSOIC, TSOP, SOT, PLCC,
Power Transistors



Selective Particle Interconnect plating



“Universal” Test Socket

Any lead pitch
.050” / 1.27 mm
1.00 mm / .80 mm / .65 mm
.625 mm / .50 mm / .40 mm

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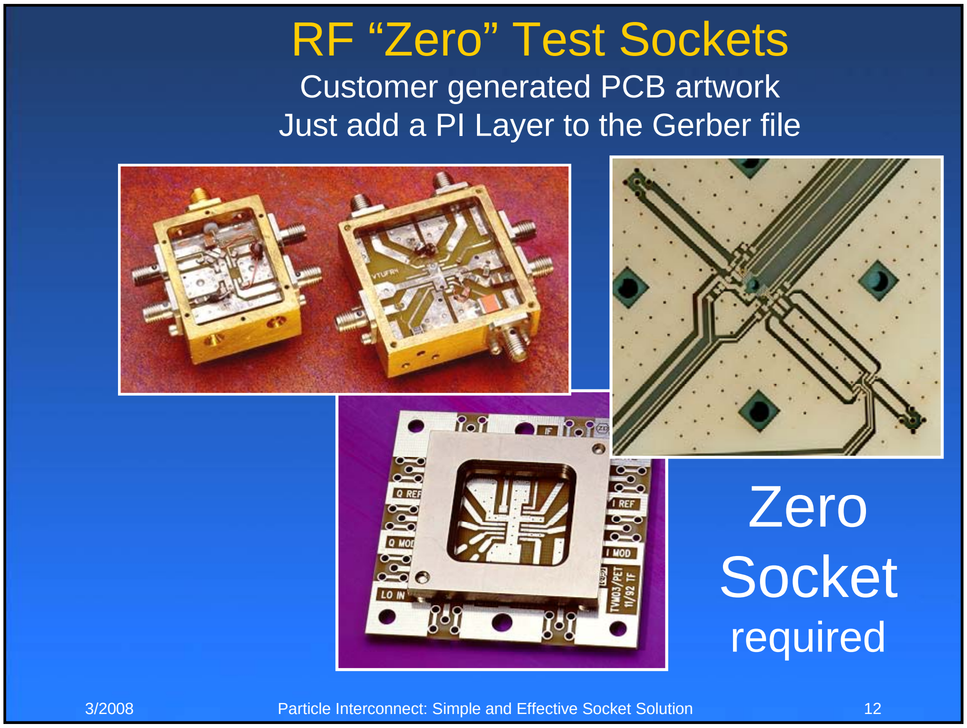

RF “Zero” Test Sockets

Customer generated PCB artwork
Just add a PI Layer to the Gerber file

Zero
Socket
required

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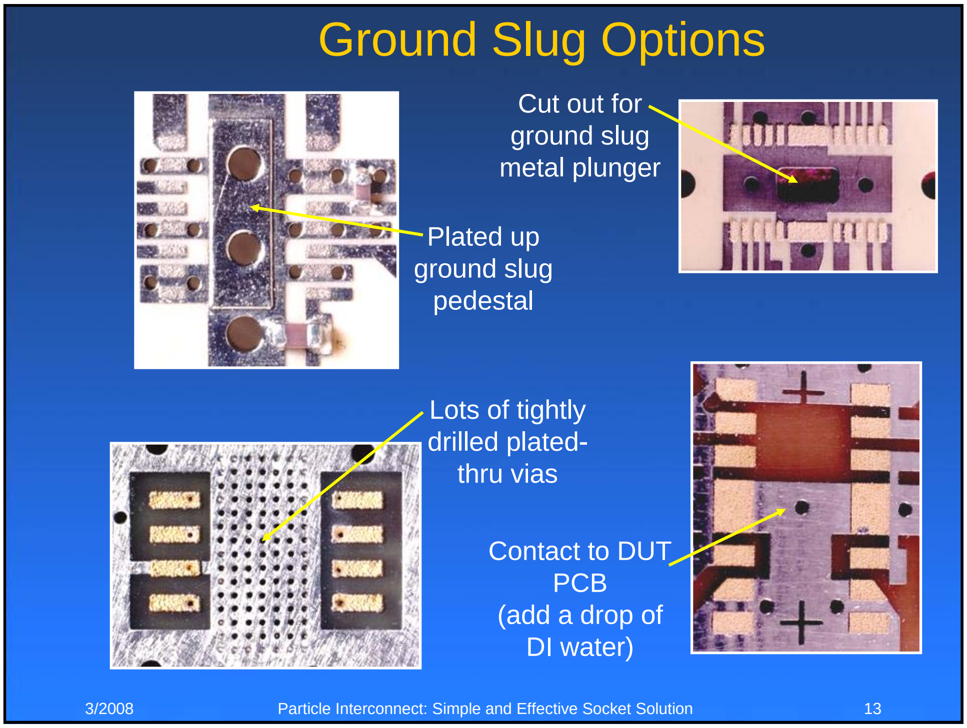


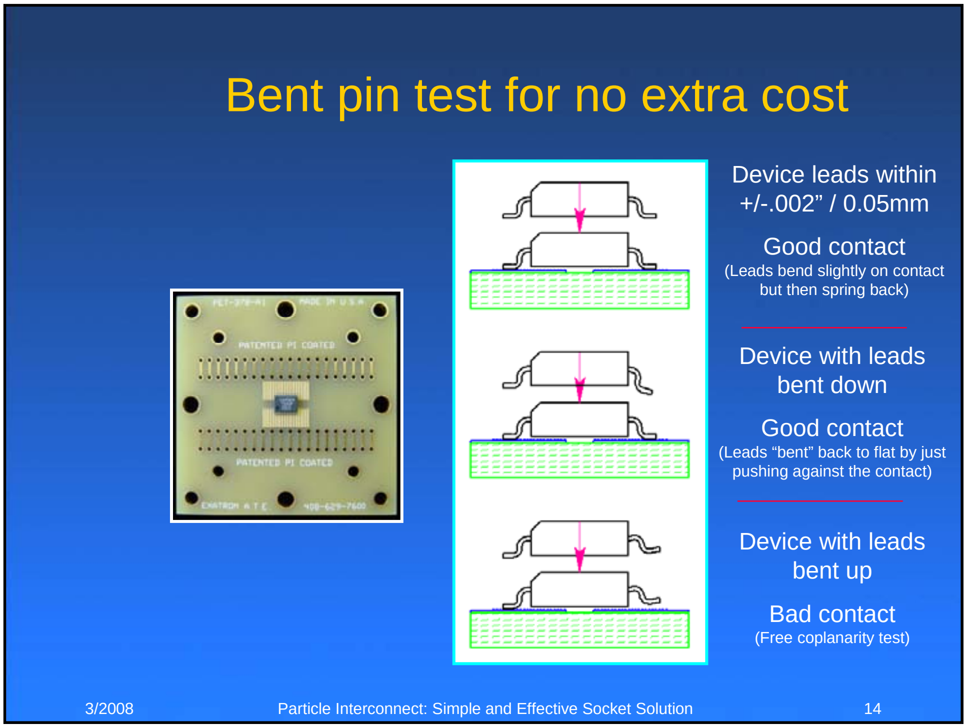
Ground Slug Options

Cut out for ground slug metal plunger

Plated up ground slug pedestal

Lots of tightly drilled plated-thru vias

Contact to DUT PCB (add a drop of DI water)



Bent pin test for no extra cost

Device leads within +/-.002” / 0.05mm

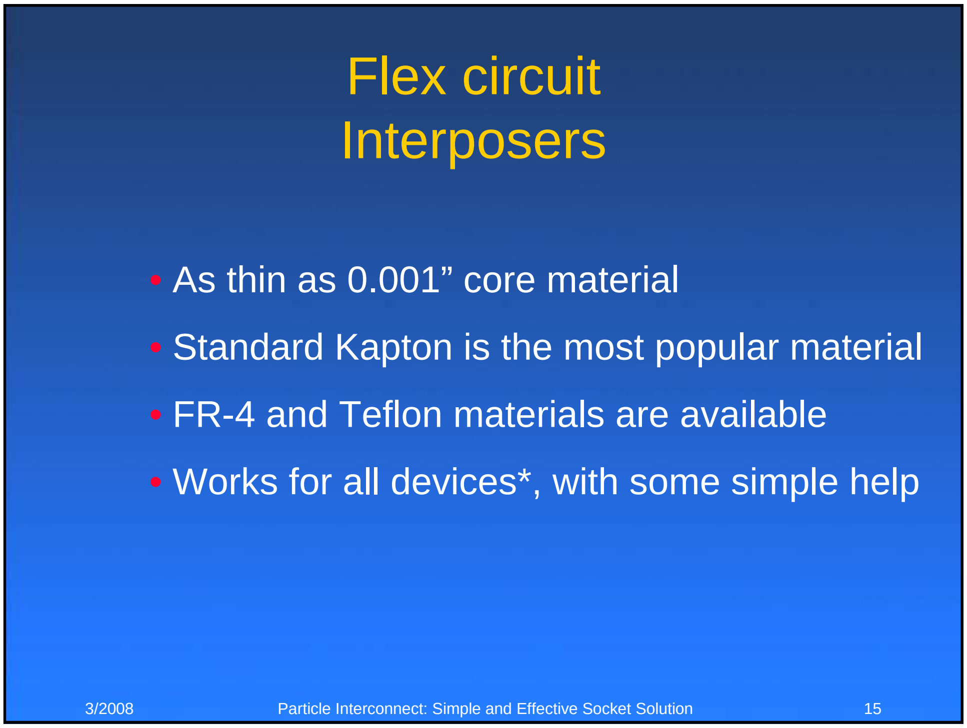
Good contact
(Leads bend slightly on contact but then spring back)

Device with leads bent down

Good contact
(Leads “bent” back to flat by just pushing against the contact)

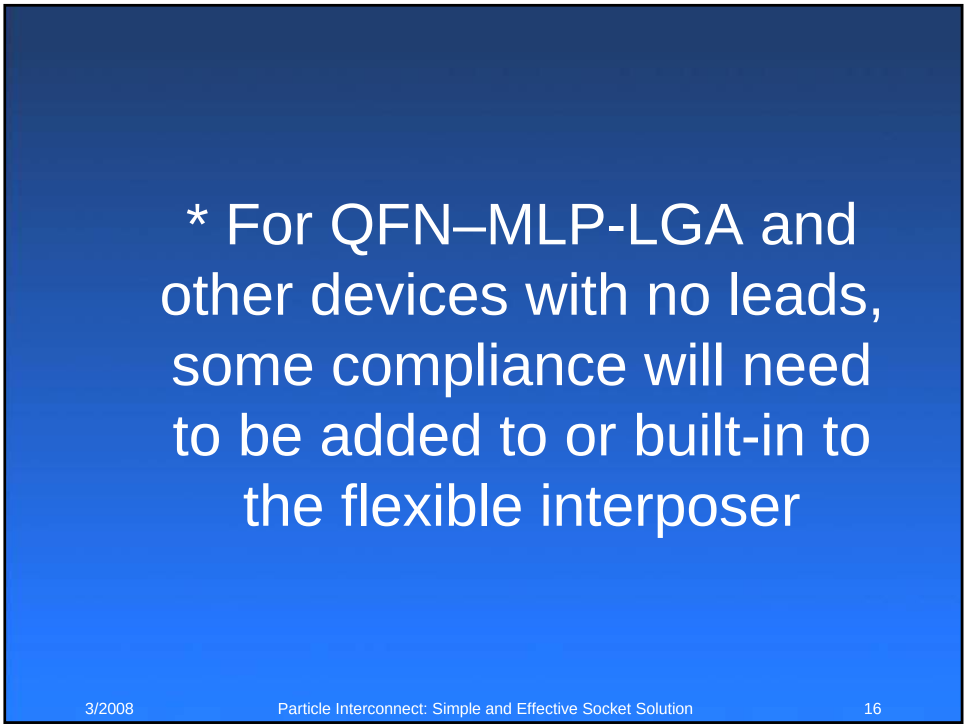
Device with leads bent up

Bad contact
(Free coplanarity test)



Flex circuit Interposers

- As thin as 0.001” core material
- Standard Kapton is the most popular material
- FR-4 and Teflon materials are available
- Works for all devices*, with some simple help



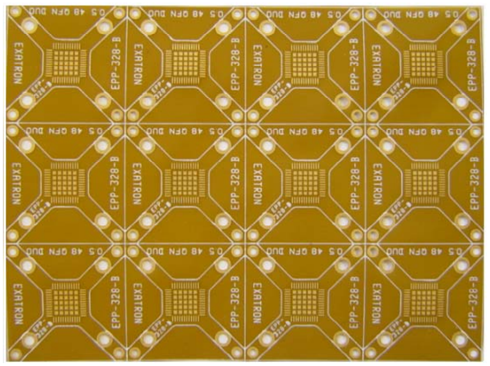
* For QFN–MLP-LGA and other devices with no leads, some compliance will need to be added to or built-in to the flexible interposer

Which materials?

Teflon: Best electrical properties (best for RF / 40 GHz)
Most flexible
Shortest mechanical life

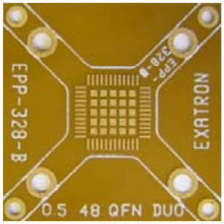
Kapton: Good electrical properties (includes most RF)
Most popular to date
100K contacts minimum mechanical life

FR-4: Basic electrical properties
Allows for best mechanical compliance
100K contacts minimum mechanical life

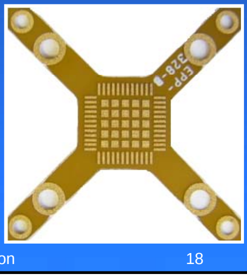


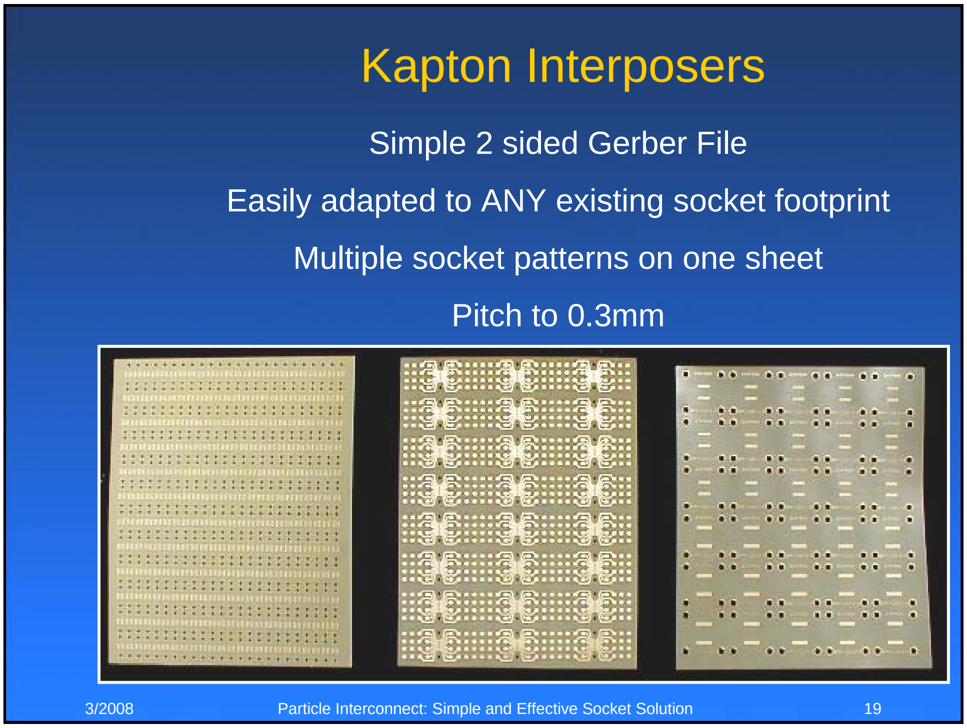
Interposers are manufactured in sheet form

Size of sheet determined by smallest pitch feature on the sheet



And then cut out as needed by your application





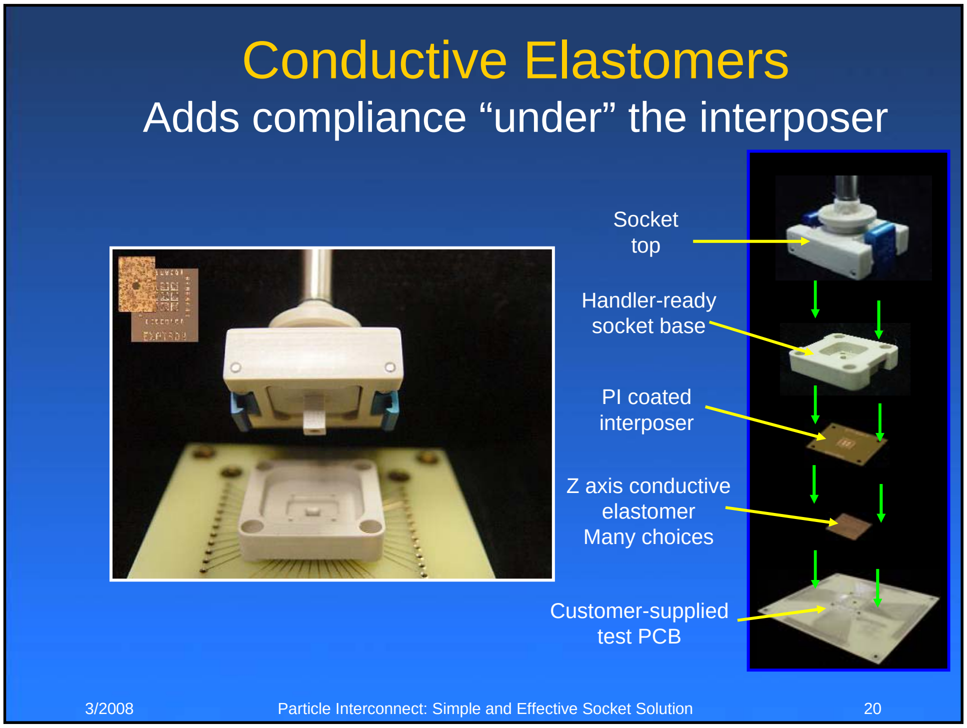
Kapton Interposers

Simple 2 sided Gerber File

Easily adapted to ANY existing socket footprint

Multiple socket patterns on one sheet

Pitch to 0.3mm



Conductive Elastomers

Adds compliance “under” the interposer

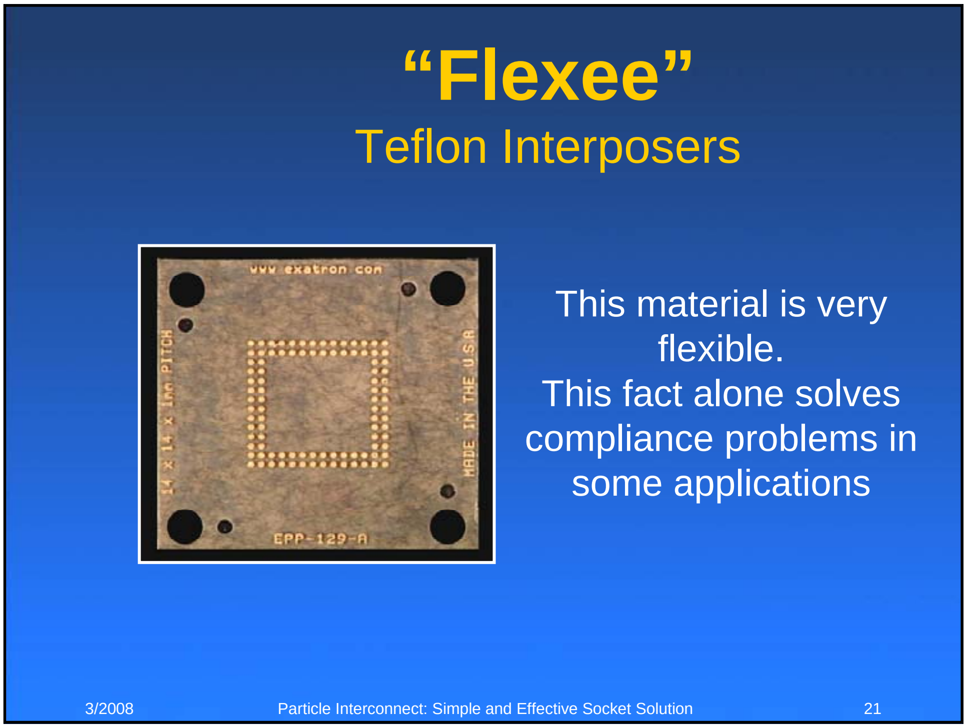
Socket top

Handler-ready socket base

PI coated interposer

Z axis conductive elastomer
Many choices

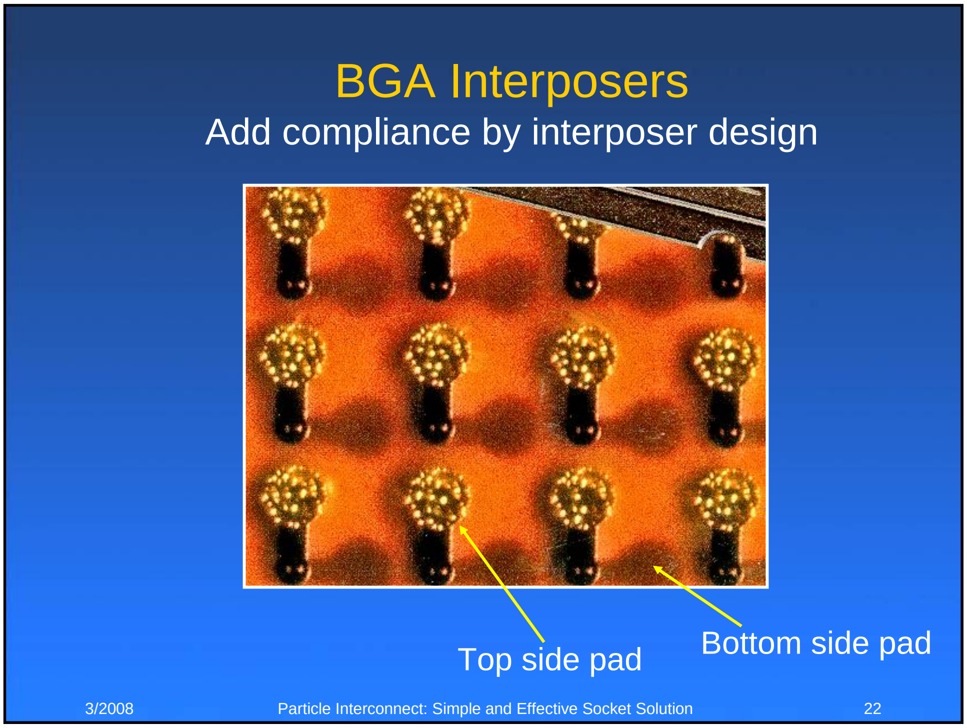
Customer-supplied test PCB



“Flexee”

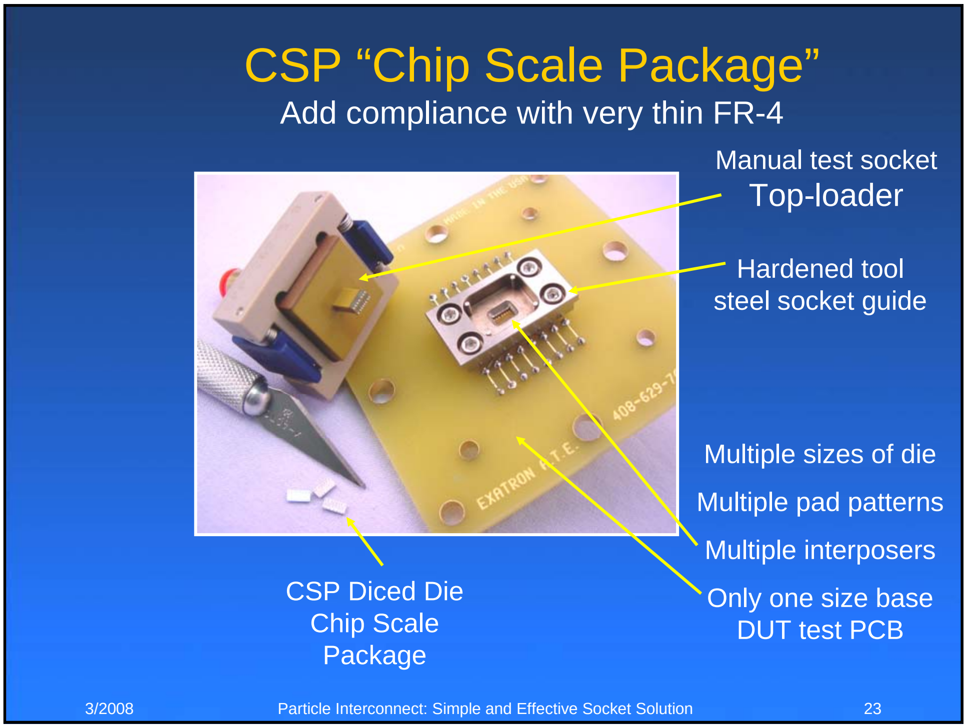
Teflon Interposers

This material is very flexible.
This fact alone solves compliance problems in some applications



BGA Interposers

Add compliance by interposer design



CSP “Chip Scale Package”

Add compliance with very thin FR-4

Manual test socket
Top-loader

Hardened tool
steel socket guide

Multiple sizes of die

Multiple pad patterns

Multiple interposers

Only one size base
DUT test PCB

CSP Diced Die
Chip Scale
Package

CSP “Chip Scale Package”
Interposer Close-up

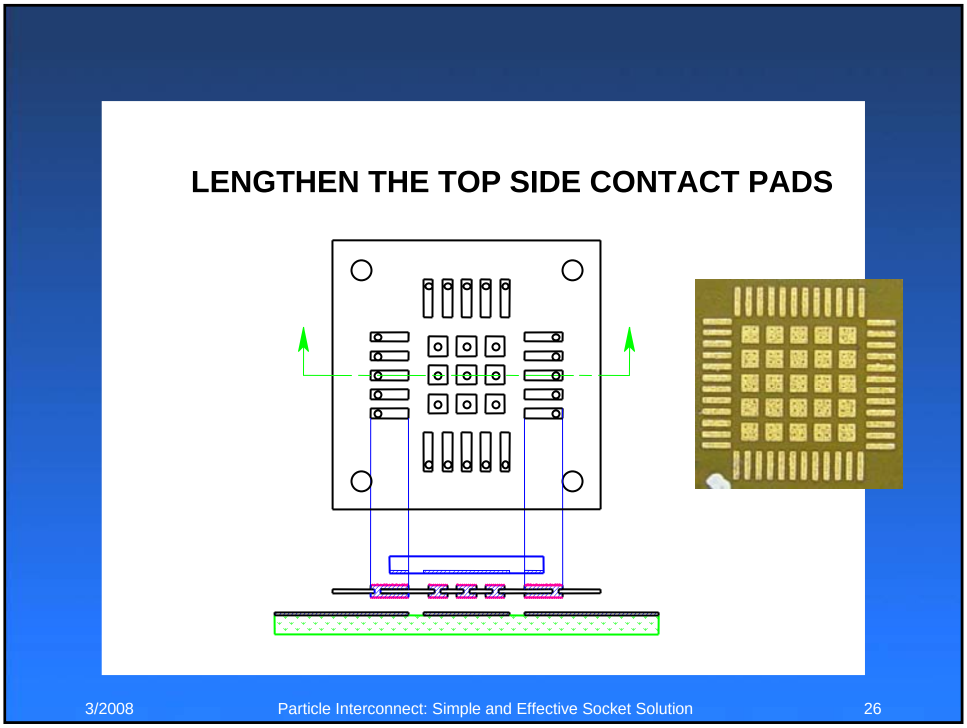
Mini
Diving
Boards

Scale in 0.01 inches

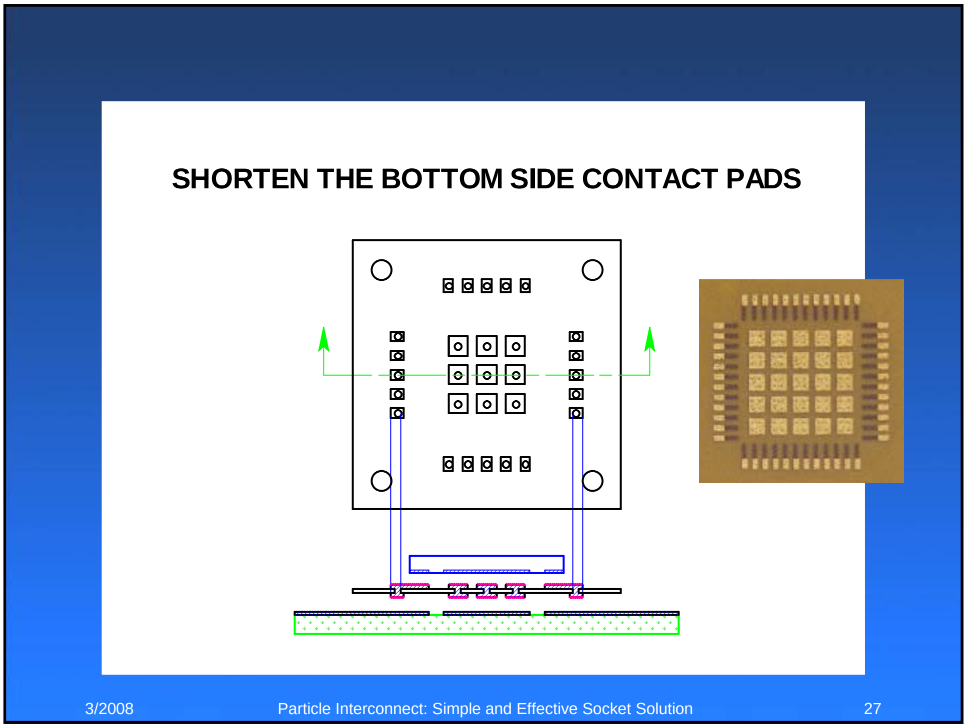
DUO-Compliant Interposers

Adds compliance "within" the interposer

- Allows up to 0.004"/0.1mm of compliance
- Brings otherwise ruined DUT test boards back to life!
- There are additional ways to add compliance "in the works"



LENGTHEN THE TOP SIDE CONTACT PADS



SHORTEN THE BOTTOM SIDE CONTACT PADS

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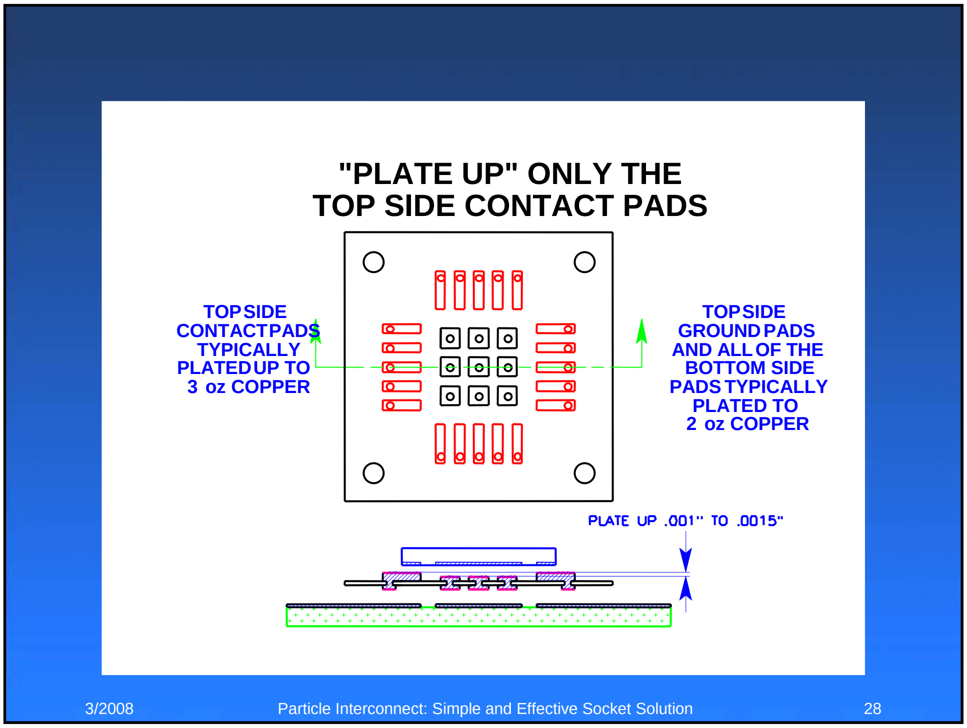

"PLATE UP" ONLY THE TOP SIDE CONTACT PADS

TOP SIDE CONTACT PADS TYPICALLY PLATED UP TO 3 oz COPPER

TOP SIDE GROUND PADS AND ALL OF THE BOTTOM SIDE PADS TYPICALLY PLATED TO 2 oz COPPER

PLATE UP .001" TO .0015"

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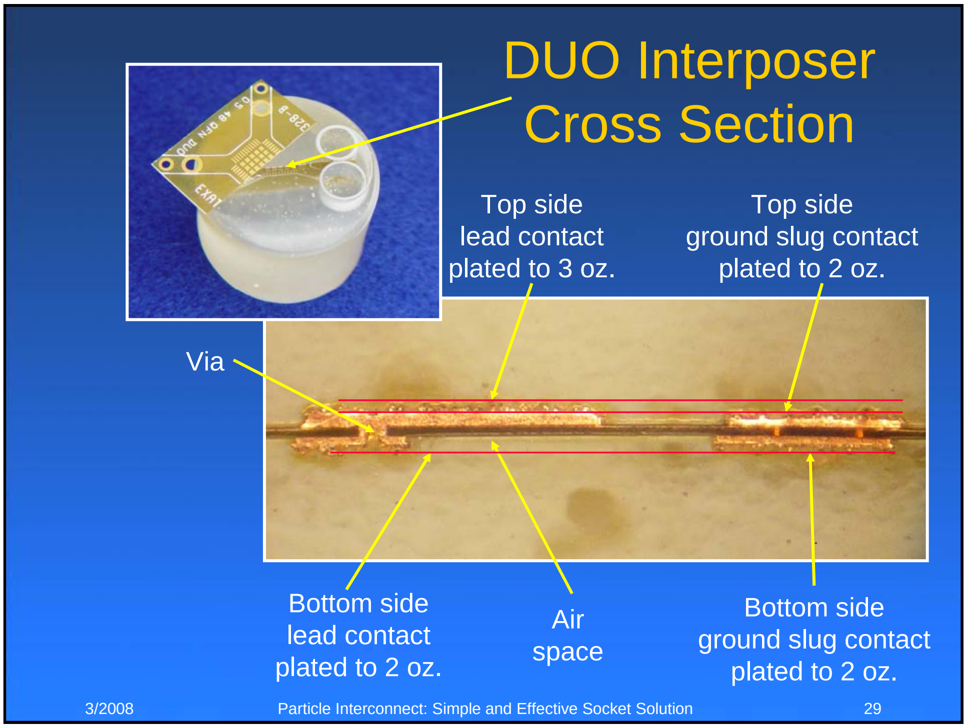


DUO Interposer Cross Section

Top side
lead contact
plated to 3 oz.

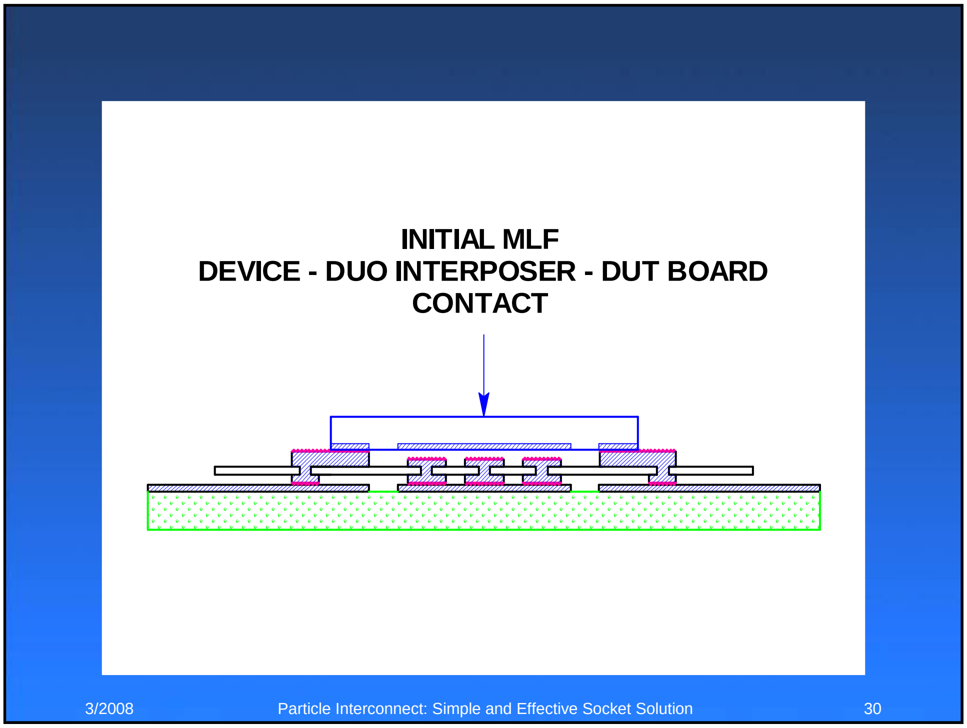
Top side
ground slug contact
plated to 2 oz.

Via

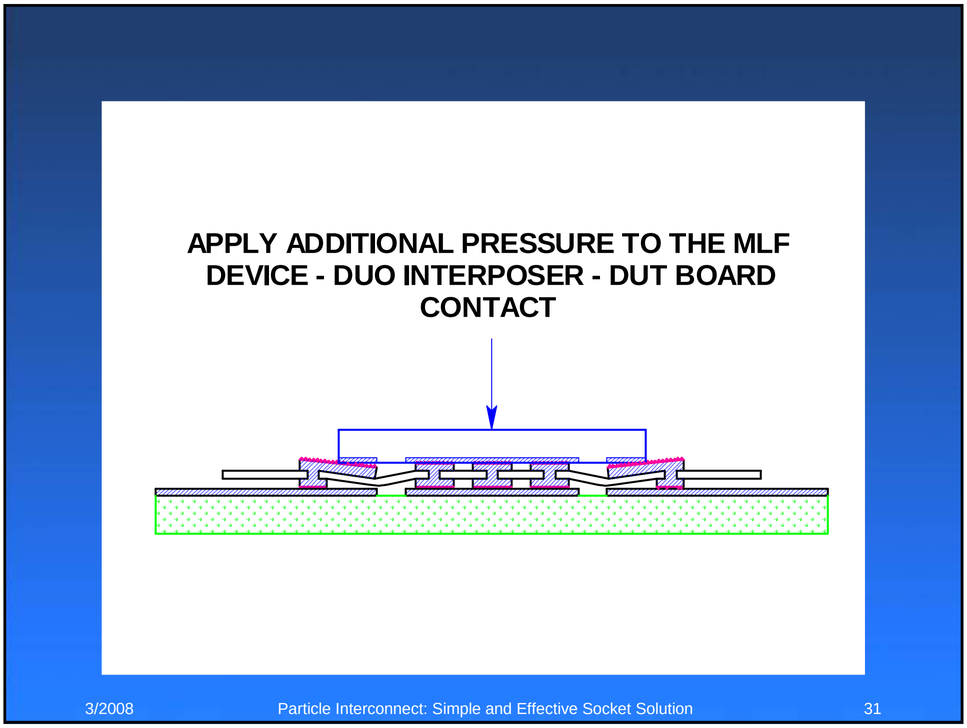
Bottom side
lead contact
plated to 2 oz.

Air
space

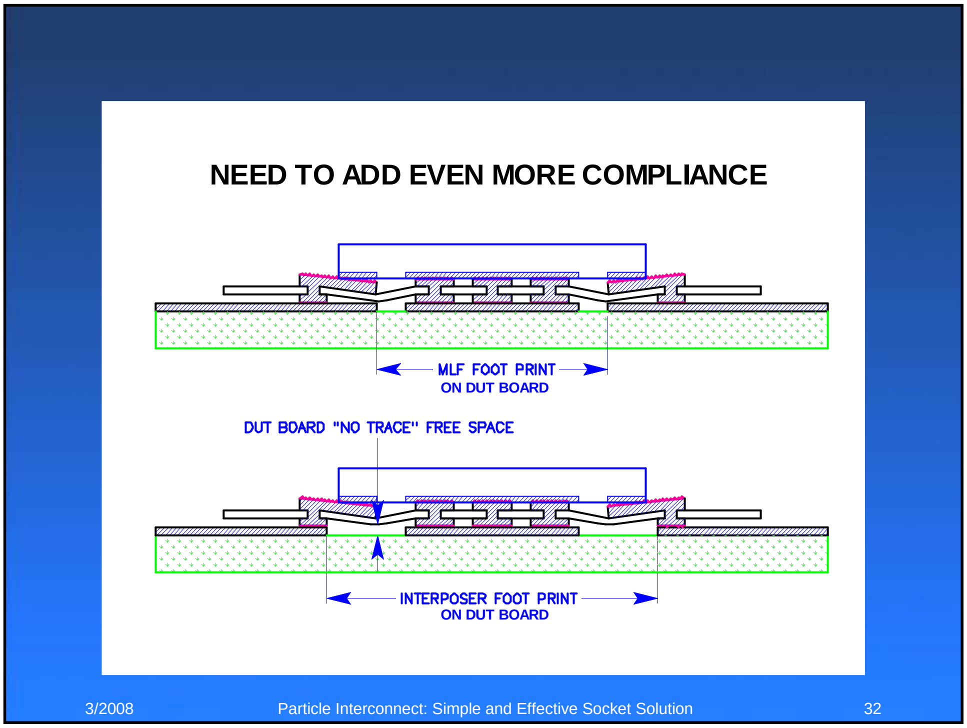
Bottom side
ground slug contact
plated to 2 oz.



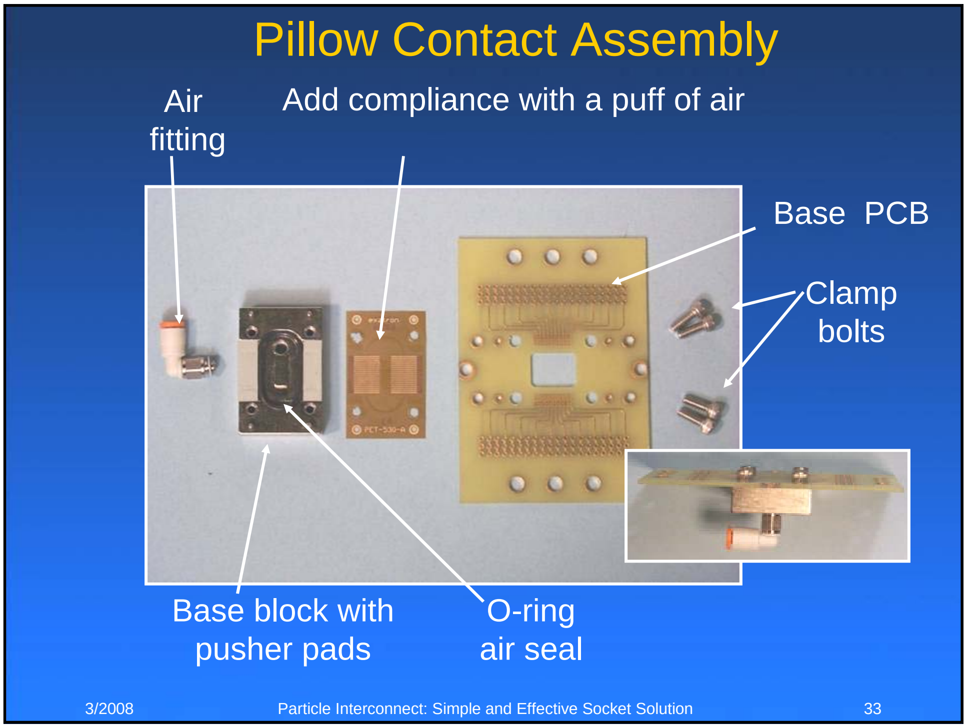
INITIAL MLF
DEVICE - DUO INTERPOSER - DUT BOARD
CONTACT



APPLY ADDITIONAL PRESSURE TO THE MLF DEVICE - DUO INTERPOSER - DUT BOARD CONTACT



NEED TO ADD EVEN MORE COMPLIANCE



Pillow Contact Assembly

Air fitting

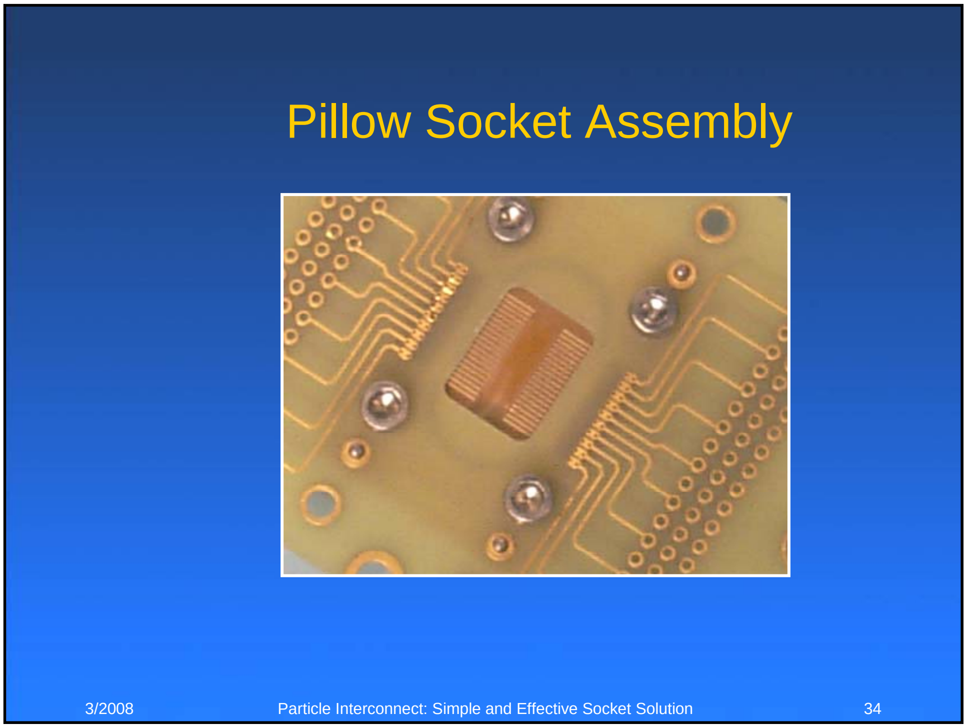
Add compliance with a puff of air

Base PCB

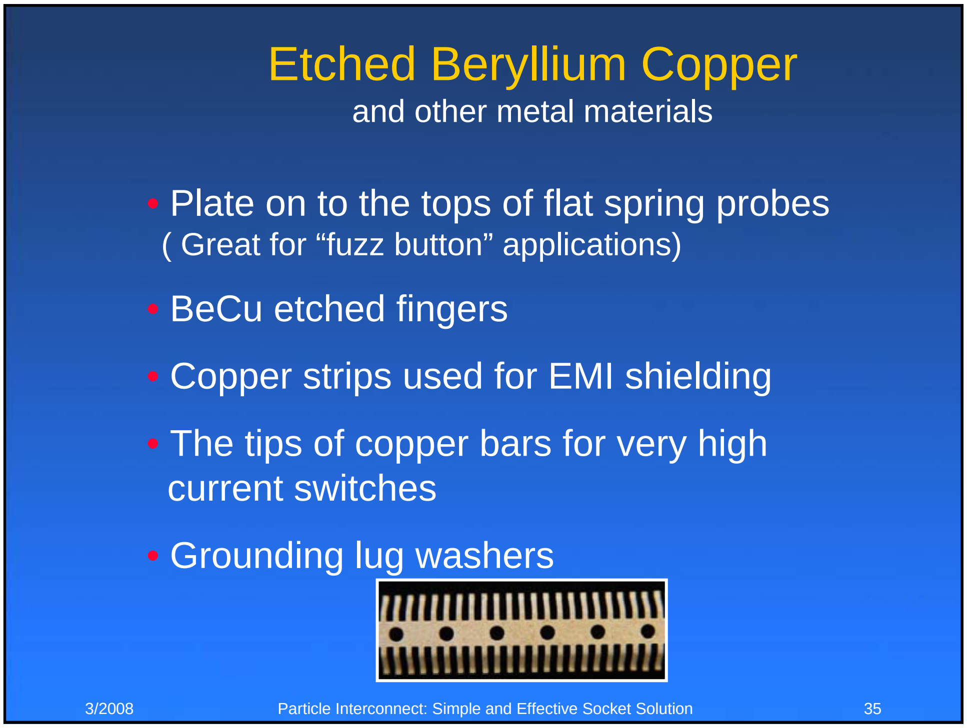
Clamp bolts

Base block with pusher pads

O-ring air seal

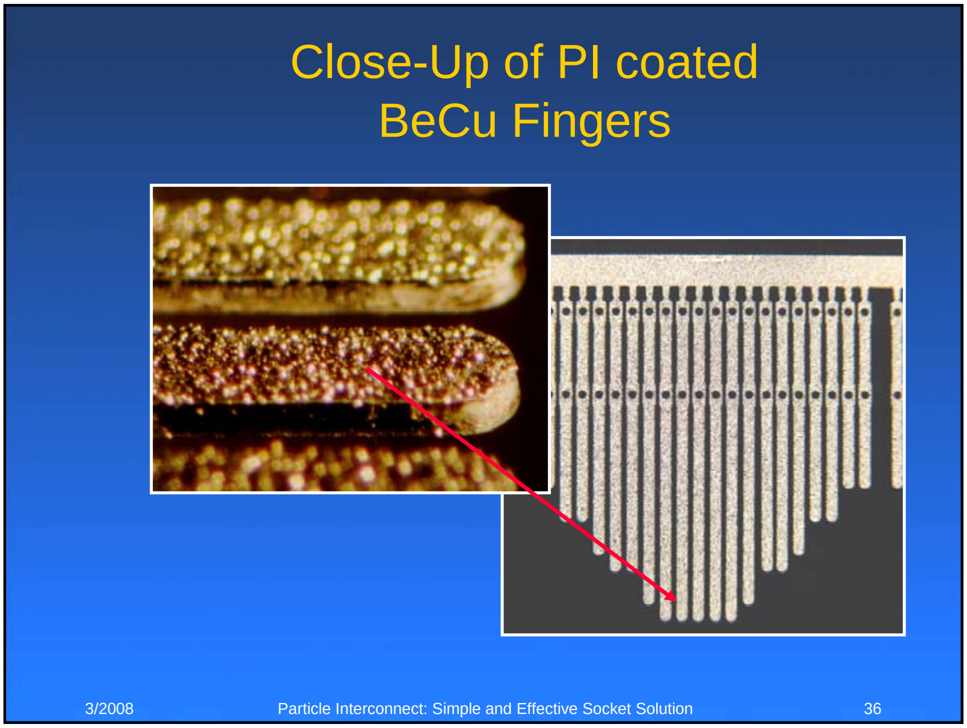


Pillow Socket Assembly

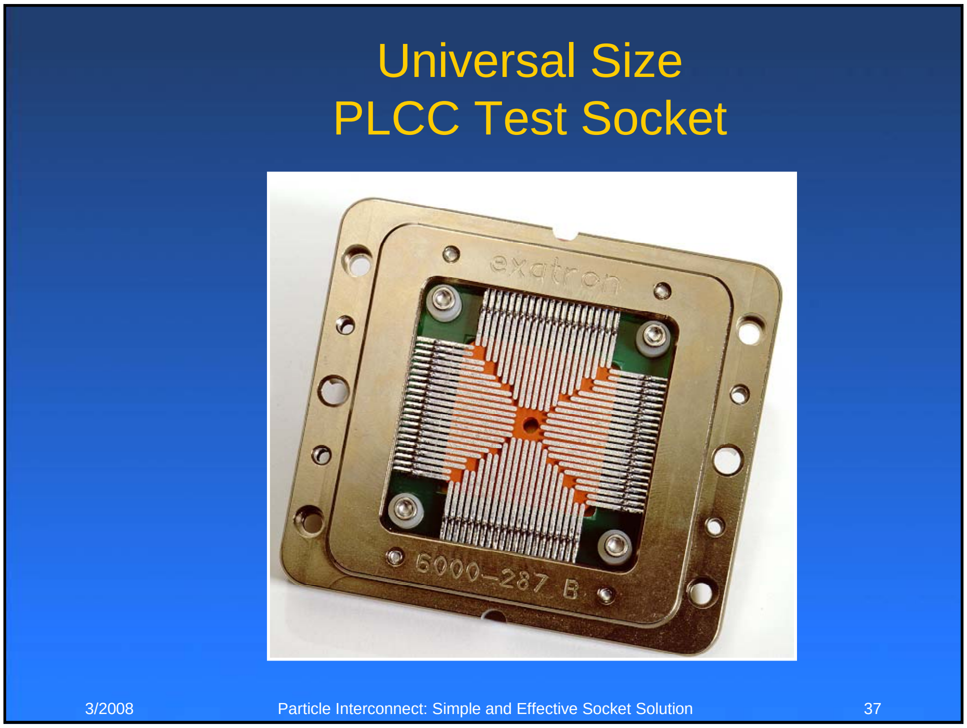


Etched Beryllium Copper
and other metal materials

- Plate on to the tops of flat spring probes
(Great for “fuzz button” applications)
- BeCu etched fingers
- Copper strips used for EMI shielding
- The tips of copper bars for very high current switches
- Grounding lug washers



Close-Up of PI coated BeCu Fingers



Universal Size
PLCC Test Socket

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Thank You

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