Re-inventing the connector industry.

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Novel Fine Pitch, Low Profile, Low Cost Connector Technology

David Light, VP Technology
Neoconix, Inc.
June 9, 2010

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Interconnect Overview

- Connectors & sockets are historically low performing elements of high performance systems
  - Can limit signal integrity and power distribution
  - Increases number of reliability risk sites
  - Price high relative to passive function
  - Design changes costly due to tooling: stamp/form, mold
  - Size vs. reliability trade-offs limit miniaturization
  - Manufacturing challenges limit pitch and contact count
  - EMI source
  - Compression force trade-offs vs. contact resistance, shock/vibe/drop performance, total force for large arrays

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Is a New Technology Needed?

- Development of connector technology has generally been slow and evolutionary
  - Variations on a theme
  - Occasionally novel technologies are introduced but rarely combine excellence in size, cost, mechanical performance, true position *and* electrical performance
  - Tooling costs high for most technologies and limit design flexibility and tailorability
  - Existing technologies in general inhibit miniaturization for hand-held electronics
    - No current interconnect equivalent of the CSP revolution

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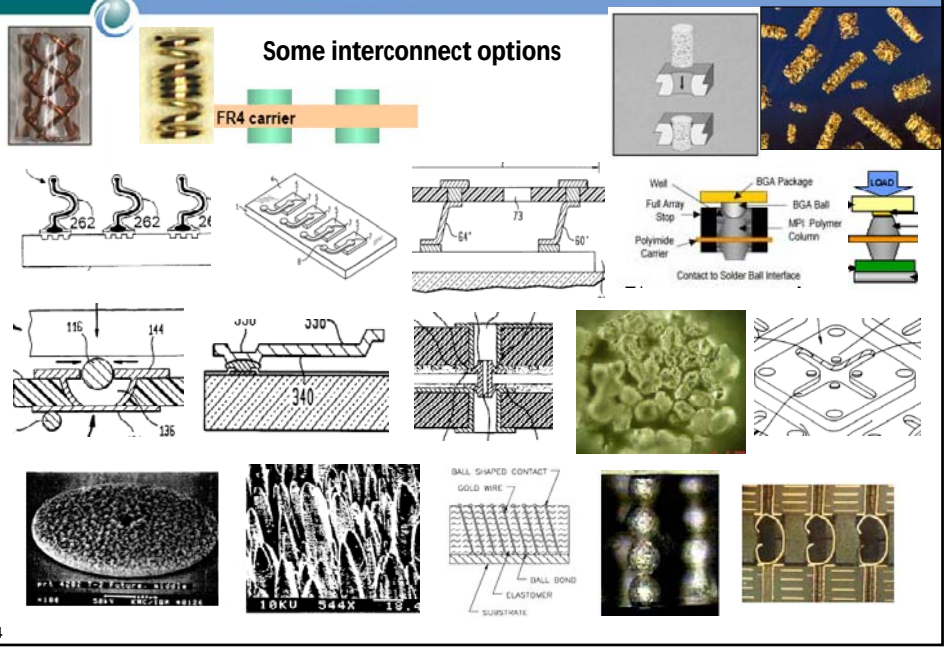
Some interconnect options



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Intent of PCBeam™ Technology

- Utilize batch processing and an existing infrastructure to speed adoption and reduce cost
- Lithographically define contact arrays to provide design flexibility and ability to tailor on the fly
- Provide enhancement of multiple properties in parallel, and ability to optimize quickly and at low cost through material and design choices
- Provide scalability to finer pitch and compatibility with miniaturization trends: footprint and profile
- Extension to embedded contacts: IC package, flex

Make a better connector, and ultimately eliminate the connector

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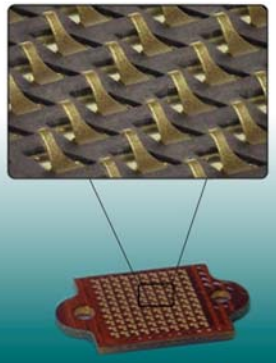
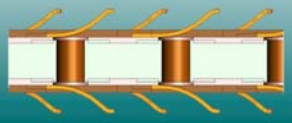
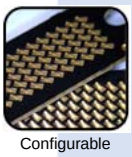
PCBeam™ Connectors

* Industry leading capabilities in pitch, mated height, signal integrity, and ruggedness
* Unparalleled design flexibility and low cost

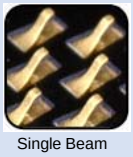




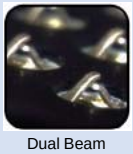
Board-to-Board Flex-to-Board Device-to-Board



Configurable Interposers

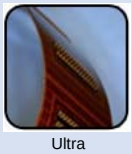


Single Beam



Dual Beam

SMT Option



Ultra Low Profile > > >

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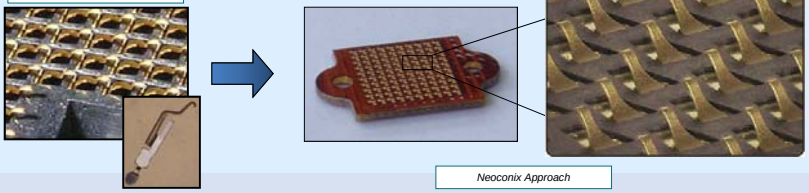
PCBeam™ Connector Technology

- PCB processing techniques to make monolithic electrical connectors
  - Replace *Stamp & Form & Stitch Insertion* with *Lithography & Etch*

Historical Approach



Neoconix Approach

- Neoconix Connector Products
  - → Contact pitch to 0.3 mm
  - → "Z" thickness from 0.20mm to 19mm
  - → Excellent signal integrity
  - → Design freedom – any configuration desired, tailorable properties
  - → Low cost batch processing

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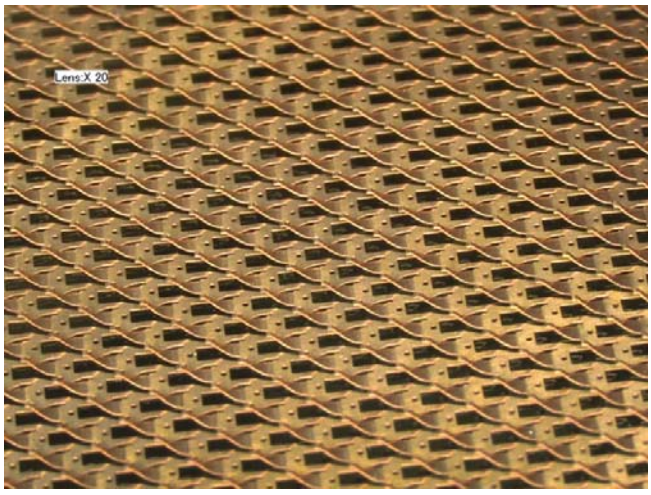
Portion of batch etched and formed Cu alloy foil for a high pin count array for a high performance processor socket

Sheet of batch formed contacts is integrated into interposer structure and contacts are later singulated using pattern etching.



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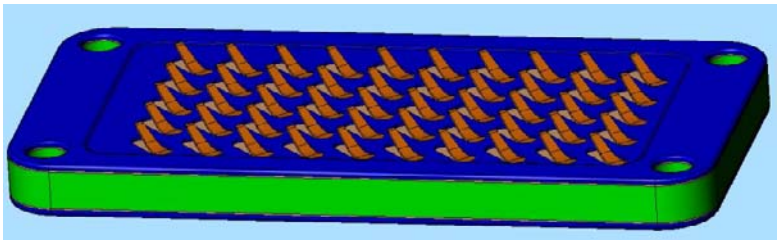
Schematic of Typical Neoconix Connector



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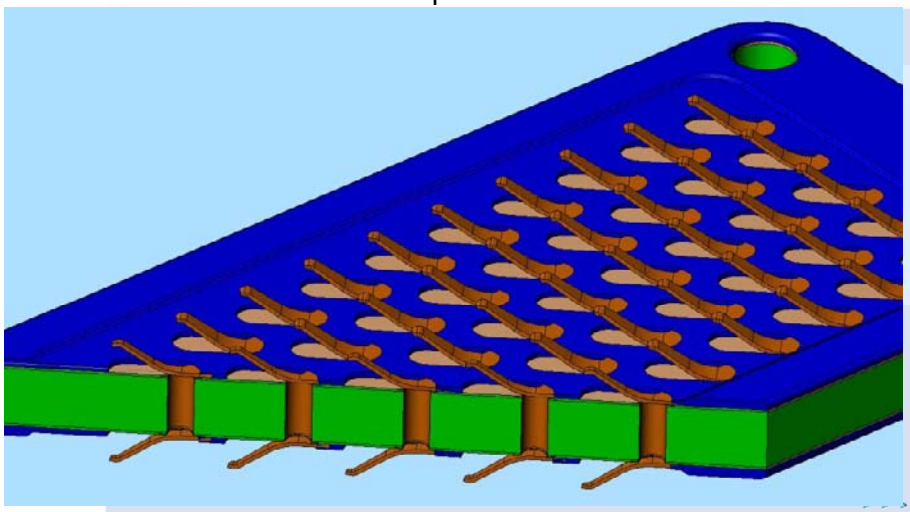
Schematic cut-away of two-sided spring contact array, in un-compressed state



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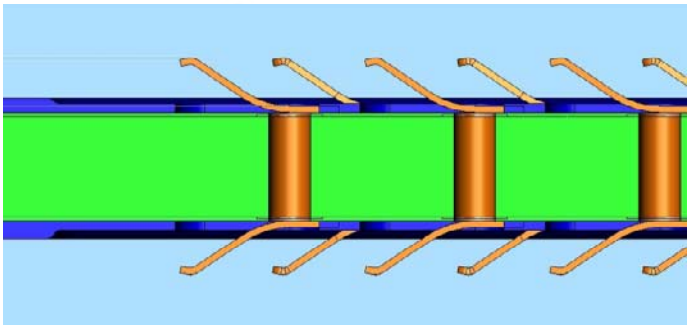
Schematic cross section of two-sided contact array, in un-compressed state



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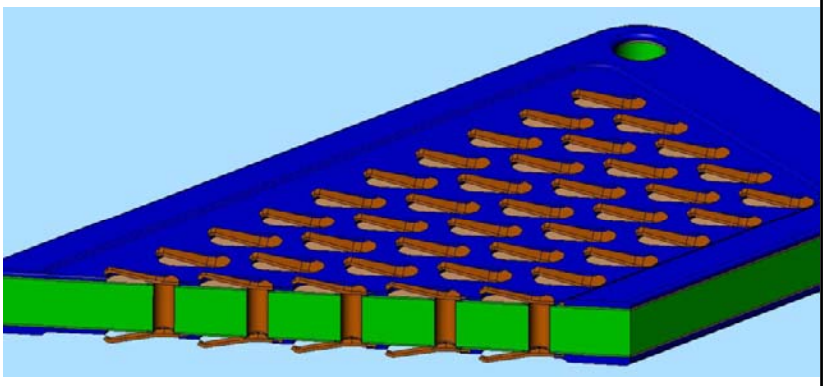
Schematic cut-away of two-sided contact array, in compressed state



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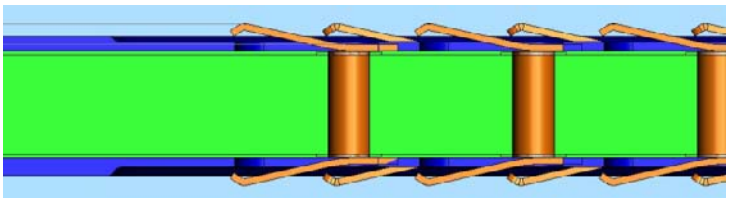
Schematic cross section of two-sided contact array, in compressed state



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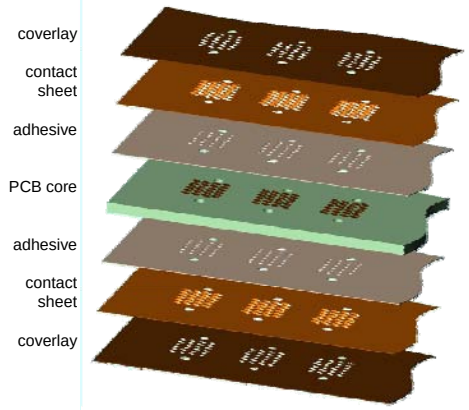
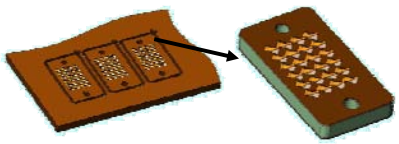
Process Overview



PCB Infrastructure



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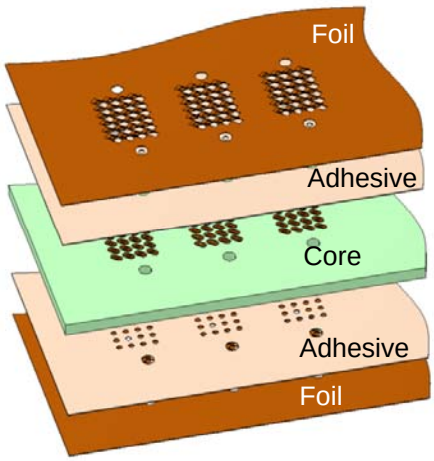
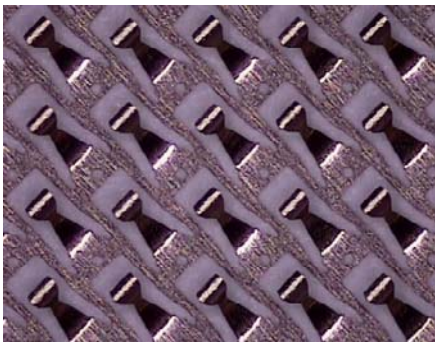
Lamination and Plating Enables Precise Mechanical and Electrical Integration of Contact Array into Interposer Structure

Schematic of lamination stack-up





Etched and formed sheet of contacts prior to lamination

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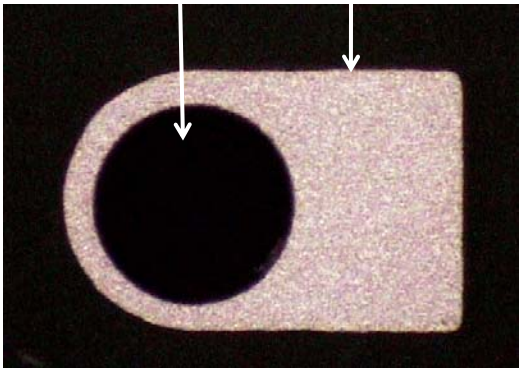
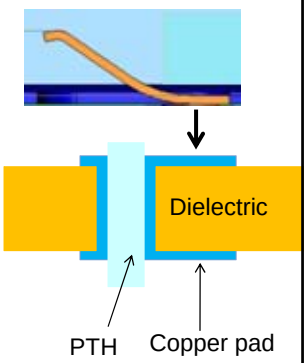
'Core' is a simple 2 layer PCB (or flex circuit) with arrays of plated through holes (PTHs) and oblong 'dogbone' pads

Core PTH and 'Dogbone'



Base of PCBeam™ contact is aligned and laminated to 'dogbone' pad.



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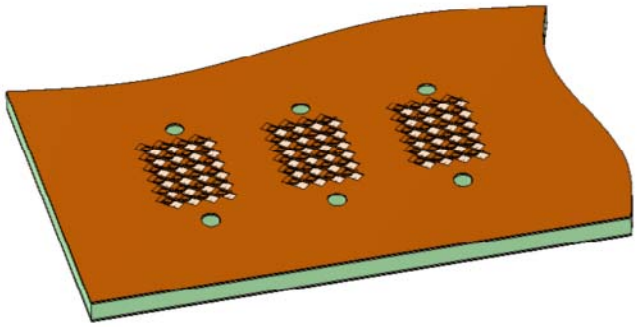
Foil containing formed contact arrays integrated into interposer structure (core PCB) by lamination, prior to plating for interconnection and surface finishing.



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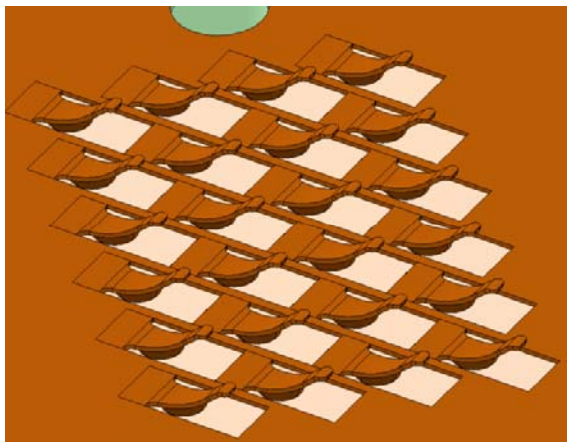
Laminated structure is processed through standard PCB direct metallization, followed by acid copper and nickel electroplating.
Hard gold is subsequently pattern plated on the contacts.



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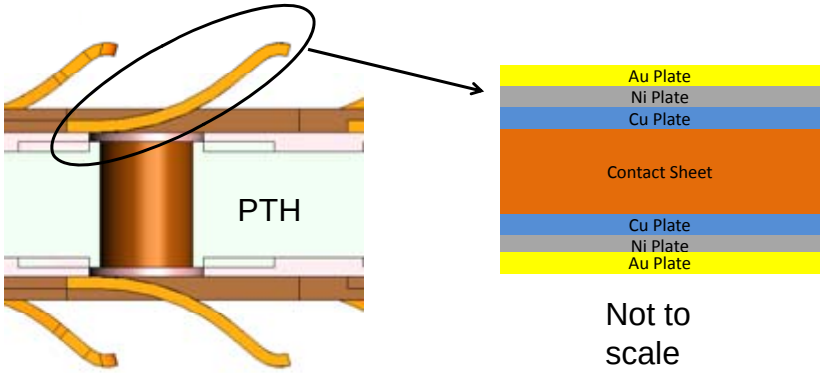
Beam (flange) Cross Section Schematic



Not to scale

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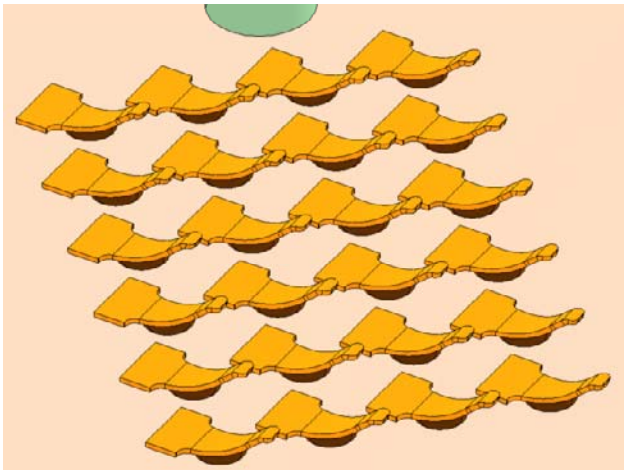
Contacts are singulated by etching following surface finish plating.



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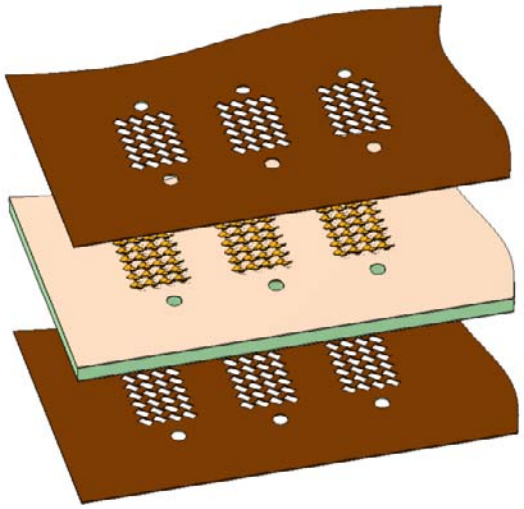
Coverlay lamination seals contact base, enhances spring properties and provides hard compression stop.



Beam travel can be controlled by coverlay thickness.

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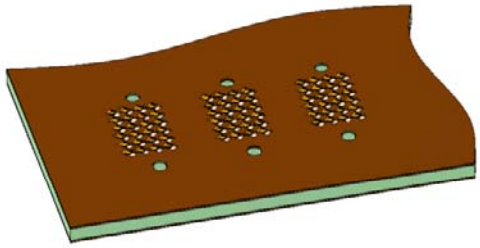
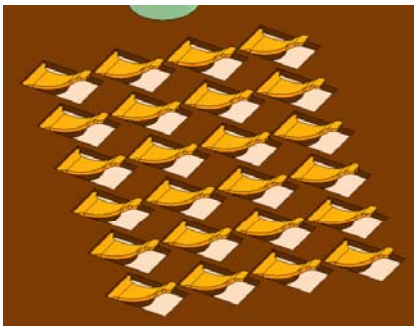
Structure after coverlay lamination





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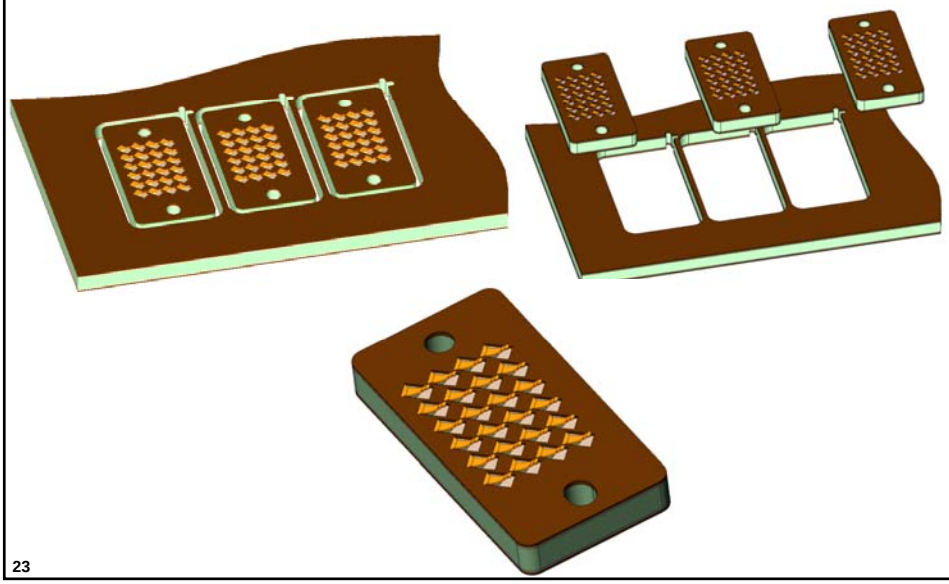
Finished units can be routed or diced from panel.



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Neoconix Reliability Testing Summary

Test	Conditions	Criteria	Result	Reference Spec.
Insulation Resistance	IR→T&H[1] Cycle→IR; 100V	>1 E +11 Ω	PASS	EIA 364-21C
Dielectric Breakdown	DWV→T&H[1] Cycle→DWV	>1 E +11 Ω @ >100V	PASS	EIA 364-20C
Temperature Life	2,500 hours @ 105°C	< 10mΩ ↑ / contact	PASS	EIA 364-17B TC 4F
Temperature Life	1,000 hours @ 125°C	< 10mΩ ↑ / contact	PASS	EIA 364-17B TC 5D
Accel. Thermal Cycling	2,000 cycles 0-105°C	< 10mΩ ↑ / contact	PASS	Customer Specification
Temperature & Humidity	500 hrs 80°C, 80% RH	< 10mΩ ↑ / contact	PASS	Customer Specification
Cyclic Humidity	See reference specifications	< 10mΩ ↑ / contact	PASS	EIA 364-28E, TC 1
Operating Temperature	-80°C to +125°C	< 15% Ω change vs. RT	PASS	Customer Specification
Shock & Vibration	50G 3 axis, 11.3 ft/s; 7.3G, 50-2K Hz	< 10mΩ ↑ & <10 ns interrupt	PASS	EIA 364-27B TC A, 364-28E TC A&B
Salt Spray Testing	96 hr, 5% NaCl, 35°C after Precon.[2]	< 10mΩ ↑ / contact; <15mΩ	PASS	Precon[2], EIA 364-26B TC A
Mixed Flowing Gas	10 days mated,10 days unmated	< 10mΩ ↑ / contact	PASS	EIA364 TP 65
High Cycle Durability	12,000 cycles full compression	< 10mΩ ↑ / contact; <25mΩ; < 15% ↓ in force/deflection	PASS	EIA 364-09C. Test stopped at 12K cycles with no failures.

Notes:
1. -40 to 70°C, 10 to 95% RH
2. Salt Spray Precondition:
   a. Vibration per EIA 364-28E, TC 1
   b. Cyclic Humidity per EIA 364-31B, TC A, Method IV 96 hours

- Neoconix interposers pass standard EIA & rugged military reliability testing > > >

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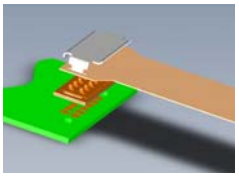
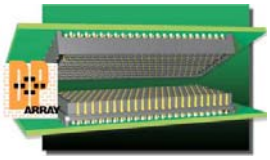
Diverse Application Space for Area Array Connectors Drives Design Flexibility

Computing
Courtesy: Wikipedia

ATE
Courtesy: www.xandex.com



Flex-to-Board



High Speed
Courtesy: www.samtec.com

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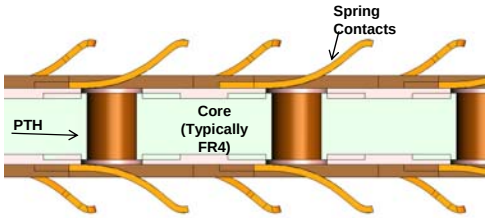
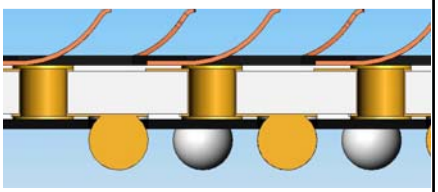
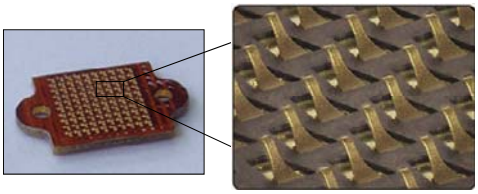
Cross-Section Options: 2 sided spring contacts or surface mount

LGA-LGA

LGA-BGA







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From Matsubayashi, Maynard et al, SMTA, 8/2009

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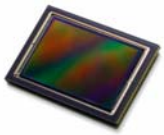
Mechanical characteristics can be easily customized

- Shock and vibration (high force)
- Low contact resistance (high current, high performance) (high force)
- Limited space for compression stiffeners ; or large arrays (low force)
- Low distortion of mating surface (low force)
  - Connectors behind CMOS sensors



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From Matsubayashi, Maynard et al, SMTA, 8/2009

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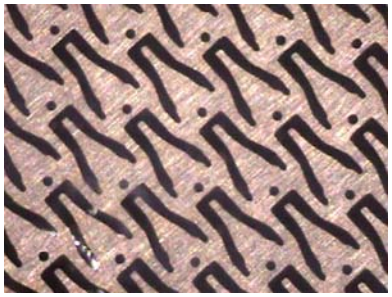
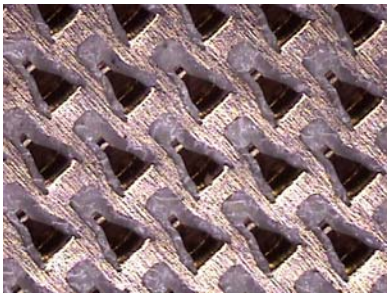
Lithographically Defined Contacts allow Tailored Beam Properties



Etched Contact
Sheet: 2D



Formed Contact
Sheet: 3D

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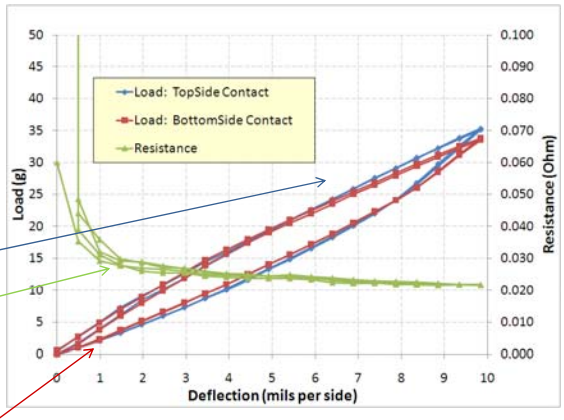
Force-Deflection-Resistance Basics



Top Load Cell
Blue Curve

4 wire CRes
Green Curve

Bottom Load Cell
Red Curve

Z-Axis Motion Control

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From Matsubayashi, Maynard et al, SMTA, 8/2009

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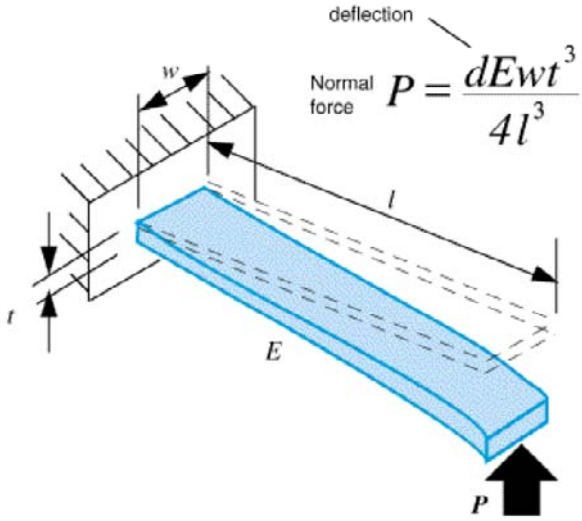
Basics of How to Control Force of a Spring



Variables

Thickness

Length

Width

Modules

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From Matsubayashi, Maynard et al, SMTA, 8/2009

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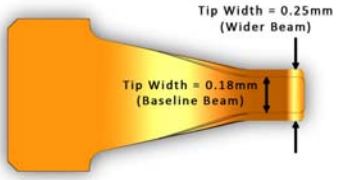
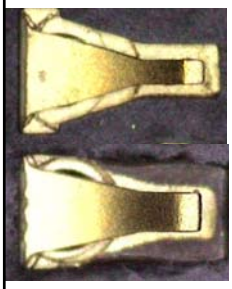
Contact Geometry (Beam Width)





Baseline Beam

Wide Beam

Individual Contact Force (g/spring per side)

Sample	Baseline Beam	Wider Beam
1	42.9	52.3
2	44.0	53.3
3	44.0	50.4
4	41.8	50.9
Average	43.2	51.7
Impact	**20%**	

An infinite number of variations in flange geometry can be achieved with lithographic techniques

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From Matsubayashi, Maynard et al, SMTA, 8/2009

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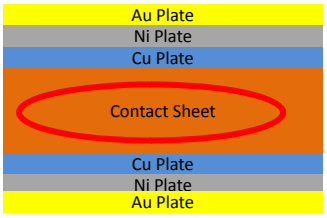

Flange X-Section

Individual Contact Force (g/spring per side)

Sample	Baseline (50 µm) Base Thickness	Reduced (38 µm) Base Thickness
1	42.9	22.1
2	44.0	21.5
3	44.0	21.8
4	41.8	21.9
Average	43.2	21.8
Impact	**-49%**	

Copper alloy sheets now available down to 0.0011" thickness

Force is modulated by increasing contact sheet thickness F is proportional to thickness^3

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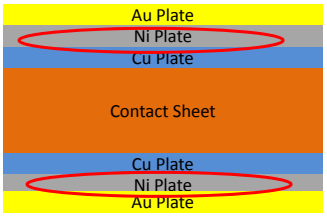
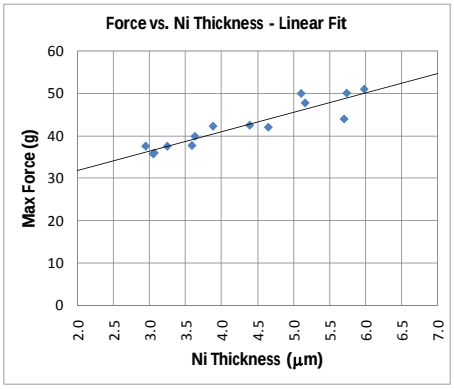
Ni Plating Thickness



Flange X-Section



- **More subtle changes in force can be introduced by varying plating thickness.**
- **Controlled variability within a single connector can be achieved by plating control**
- **Plating thickness also impacts amount of compression set upon first compression cycle**

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Customization of DC Electrical Characteristics (Resistance)

- Minimize electrical DC resistance
  - Higher current carrying capacity (Low T_{rise})
    - Improved reliability, higher operating temperatures
  - Improved electrical performance
  - Enhanced reliability

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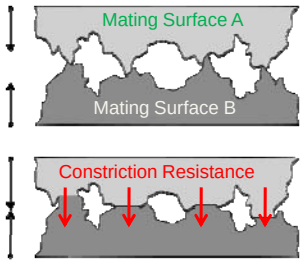
Customization of DC Electrical Characteristics (Resistance)

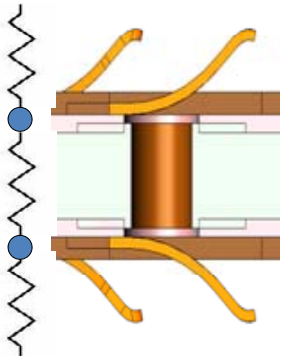


+

R1: Top contact

R2: Core (PTH, etc.)

R3: Bottom contact



Contact Resistance: increased force can help overcome constriction resistance and break through oxides/contaminants

Bulk Path Resistance = R1+R2+R3

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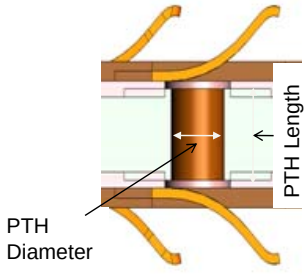
PTH Diameter and Length affect bulk resistance in core

$R = (\rho)(L)/(A)$

R = DC Resistance
ρ = Resistivity (Cu)
L = Length of Path
A = X-Sectional Area of Path



Path Resistance (mOhms)		PTH Outer Diameter (mm)									
PTH Length (mm)		0.15	0.20	0.25	0.30	0.36	0.41	0.46	0.51	0.56	0.61
	0.3	1.5	1.1	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.4
	0.8	4.4	3.3	2.6	2.2	1.8	1.6	1.4	1.3	1.2	1.1
	1.3	7.3	5.4	4.3	3.6	3.1	2.7	2.4	2.1	1.9	1.8
	1.8	10.3	7.6	6.0	5.0	4.3	3.7	3.3	3.0	2.7	2.5
	2.3	13.2	9.8	7.8	6.5	5.5	4.8	4.3	3.8	3.5	3.2
	2.8	16.1	12.0	9.5	7.9	6.7	5.9	5.2	4.7	4.3	3.9
	3.3	19.0	14.1	11.2	9.3	8.0	7.0	6.2	5.5	5.0	4.6
	3.8	22.0	16.3	13.0	10.8	9.2	8.0	7.1	6.4	5.8	5.3
	4.3	24.9	18.5	14.7	12.2	10.4	9.1	8.1	7.2	6.6	6.0
	4.8	27.8	20.6	16.4	13.6	11.6	10.2	9.0	8.1	7.4	6.7
	5.3	30.8	22.8	18.1	15.1	12.9	11.2	10.0	9.0	8.1	7.4
	5.8	33.7	25.0	19.9	16.5	14.1	12.3	10.9	9.8	8.9	8.2
	6.4	36.6	27.2	21.6	17.9	15.3	13.4	11.9	10.7	9.7	8.9
	6.9	39.5	29.3	23.3	19.4	16.5	14.4	12.8	11.5	10.5	9.6
	7.4	42.5	31.5	25.0	20.8	17.8	15.5	13.8	12.4	11.2	10.3
	7.9	45.4	33.7	26.8	22.2	19.0	16.6	14.7	13.2	12.0	11.0

Increased bulk resistance for thick interposers can be mitigated by larger diameter PTHs and thicker copper plating

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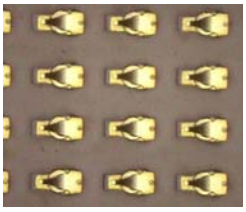
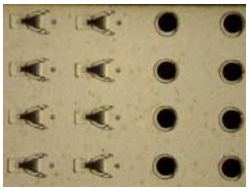
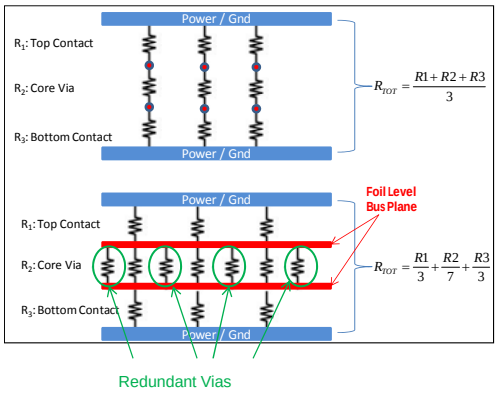
Bus Plane in Core – Redundant PTH to reduce bulk resistance



Singulated Contacts



Bussed Contacts with Redundant PTH



Contribution of the core to total path resistance can be driven to near negligible values with redundant PTH

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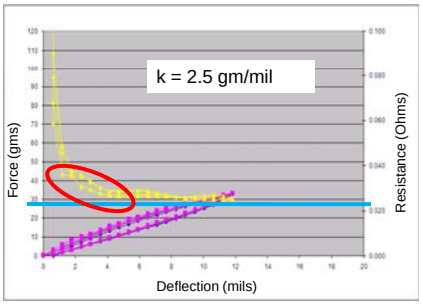
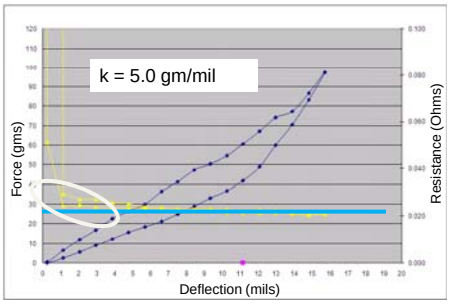
Spring Force vs. Contact Resistance

Low Force Spring



(Contact) Resistance decreases with increased deflection

High Force Spring



(Contact) Resistance reaches minimum early in compression cycle

High force (stress) deforms asperities and pierces contaminants to achieve stable resistance with less deflection. Also reduces transients due to shock/vibe/drop.

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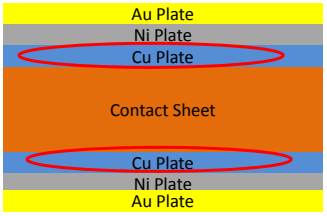
Resistance vs. Beam and Core Cu Plating



Flange X-Section

Individual I/O Path Resistance (mΩ)

Sample	Cu Plating Time (Normalized) = 1	Cu Plating Time (Normalized) = 1.2
1	16.1	10.4
2	13.7	10.3
3	16.5	10.6
4	17.0	10.0
5	15.6	10.2
Average	15.8	10.3
Impact	**-35%**	

Increasing Cu plating time 20% reduced path resistance by 35%

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Summary: Design Flexibility vs. Performance

	Input	Primary Influence	Force (Mech)	Resistance (DC Elec)	Current Capacity (DC Elec)
Contact Design	↑ Beam Thickness	Force	⇧	⇩	⇧
	↑ Beam Width	Force	⇧	⇩	⇧
	↑ Ni Thickness	Force	⇧	⇩	⇧
Core Design	↑ Interposer Thickness	DC Resistance	0	⇧	⇩
	↑ PTH Diameter	Bandwidth	0	⇩	⇧
	↑ Redundant Via	DC Resistance	0	⇩	⇧
Both	↑ Cu Thickness	DC Resistance	⇧	⇩	⇧

Interconnect performance can be easily tailored, at low cost, on an application by application basis

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Design Flexibility

- Enabled by lithography
- Enabled by low cost and modular forming dies
- Enabled by use of standard, off the shelf materials
  - PCB laminate materials instead of custom, injection molded housings. Many thicknesses and properties available.
  - Various copper alloy sheet thicknesses and material properties available
  - Multiple coverlay material thicknesses control beam deflection
- Enabled by process flexibility
  - Plating thicknesses, PTH drill diameters, cross sectional thickness, formed beam height can be tailored
- Lithography and HDI PCB infrastructure enable scaling to finer pitches
  - *Working range decreases as pitch decreases

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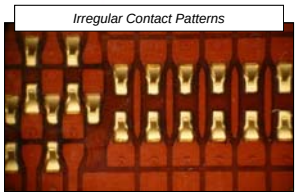
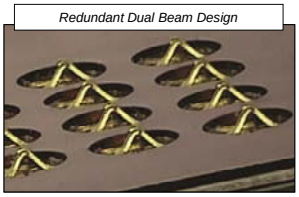
Design Flexibility Examples

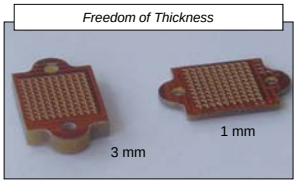
Irregular Contact Patterns



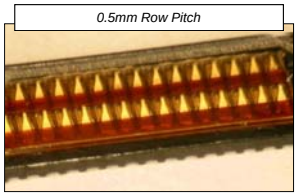
Redundant Dual Beam Design



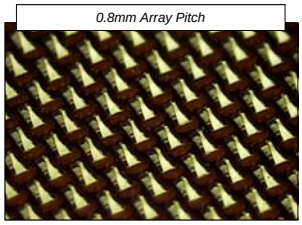
Freedom of Thickness



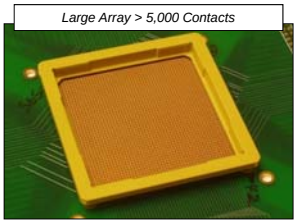
0.5mm Row Pitch



0.8mm Array Pitch



Large Array > 5,000 Contacts



- Flexible design without large tooling costs

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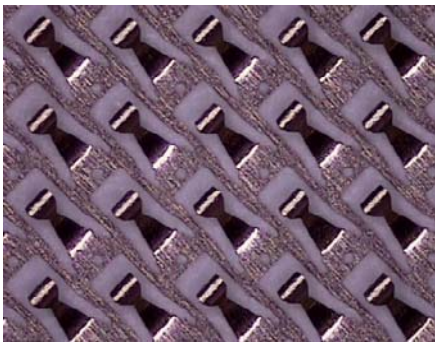
Design Flexibility Enabled by Lithography

Standard straight-beam contact tip enables smaller mating pad.



Widened 'hammerhead' contact tip enables mating to via–in–pad constructions

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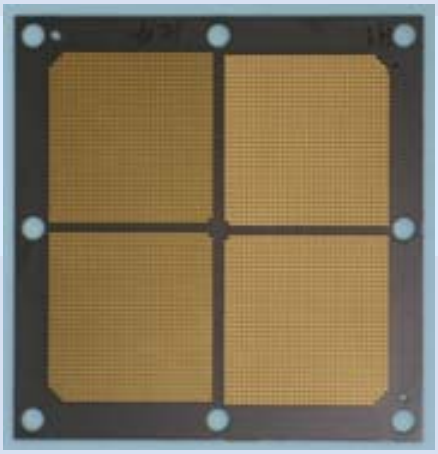
PCBeam Socket for >5,000 Pin LGA Processor Package

>10K contacts on 2 sides



PCBeam technology enables redistribution and pitch translation within the connector or socket interposer

"Core" can be a multilayer, circuitized substrate

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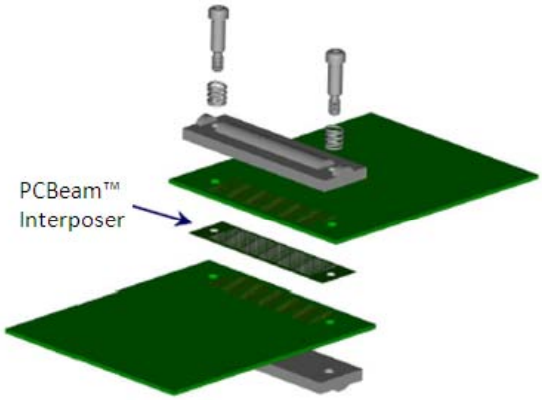
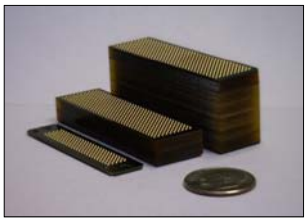
Board to Board Interconnection with Thin, Tailorable Profile

Flexibility enabled by PCB material choice and board construction methods



PCBeam interposer thickness is easily tailored to accommodate modifications in board to board spacing, e.g. as other components shrink in profile



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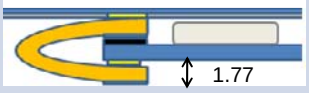
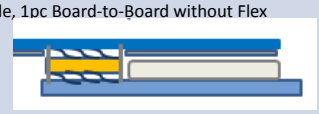
60 Pin Smart Phone Board to Board Interconnect: Neoconix Proposal

Item	Current Interconnect	Neoconix Interconnect
Design	Double, 2pc Board-to-Board with Flex Jumper 	Single, 1pc Board-to-Board without Flex  *Thickness tailored to accommodate any gap, and can scale with other components' height:* 
Footprint	52 mm^2 (occupies *both sides* of mother board)	44 mm^2 or less
Thickness	3.86 mm	Eliminate 1.77 mm on back of MB. Interposer can be any thickness.
Cost	Two 2 pc. connectors; 2 layer flex; flex SMT process; stiffeners and elastomer pad.	Eliminates many components, simplifies assembly, improves yield. Eliminating flex may reduce # ground pins required.

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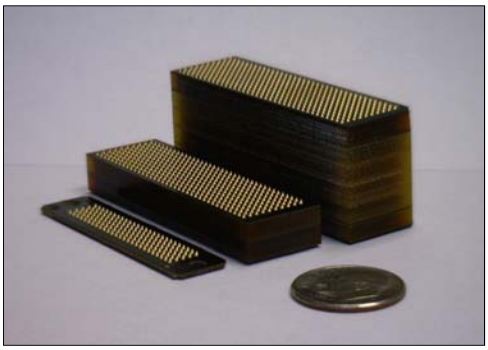
Interposers have been fabricated
from 0.5 mm (0.020”) to 19 mm (0.75”)



PCBeam connector interposers at various thicknesses

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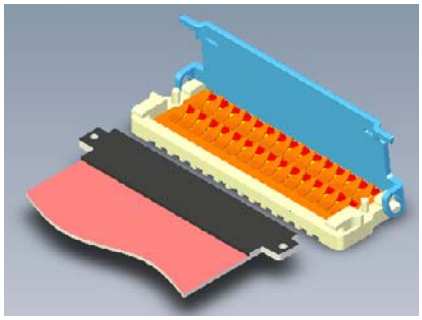
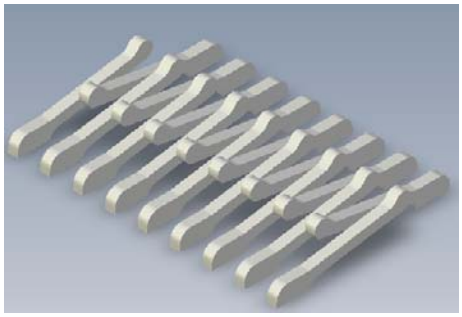
Flex Interconnect Options:

Neoconix designs offer substantially reduced footprint and profile



Small footprint, low profile Neoconix PCBeam ZIF connector for flex to board or flex to flex. 2 sided spring contact or SMT. No solder tails.



Competing stamp and form alternative, showing schematic of contacts and solder tails. Increased footprint and profile. SMT only.

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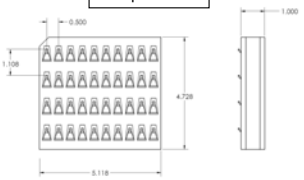
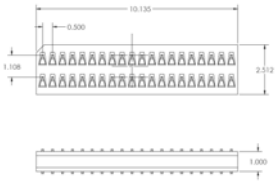
Smaller Flex Connectors for Smart Phone Application

Freedom of Design - Any Pattern, Any Pitch, Any Thickness, Always Smaller

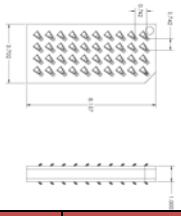
Neoconix Option 1



Neoconix Option 2



Neoconix Option 3



Parameter	Option 1	Option 2	Option 3	Current
Row x Columns	4 x 10	2 x 20	4 x 10	2 x 20
Pitch	0.5 x 1.1 mm	0.5 x 1.1 mm	0.74 x 0.74 mm	0.4 x 2.0 mm
Footprint	4.7 x 5.1 (24.2 mm^2)	2.5 x 10.1 (25.5 mm^2)	3.7 x 8.2 (29.7 mm^2)	3.75 x 9.5 (36 mm^2) Stiffener: 94mm^2
Thickness	0.8 to 3.0 mm (customer choice)	0.8 to 3.0 mm (customer choice)	0.6 mm or greater (customer choice)	1.7 mm

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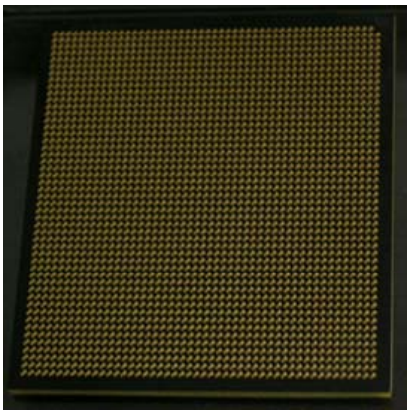
Eliminate the connector:

Contacts Embedded In Integrated Circuit Package



Photograph of ceramic IC package substrate with >2,300 embedded PCBeam contacts

Flip chip device side of same package

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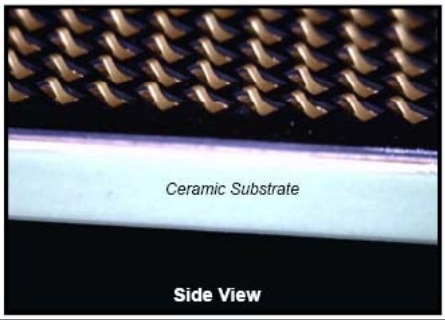
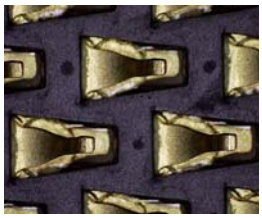
Contacts Embedded In IC Package

- Demonstrated on ceramic substrate for flip chip device, high performance application
  - >2,300 positions, 1 mm pitch
  - 100% electrically good samples produced using standard processing
  - Replacement for BGA direct attach and LGA / Socket constructions
  - Potential to eliminate test, burn-in, and production sockets
  - Compatible with organic as well as ceramic substrates



Eliminate the connector!



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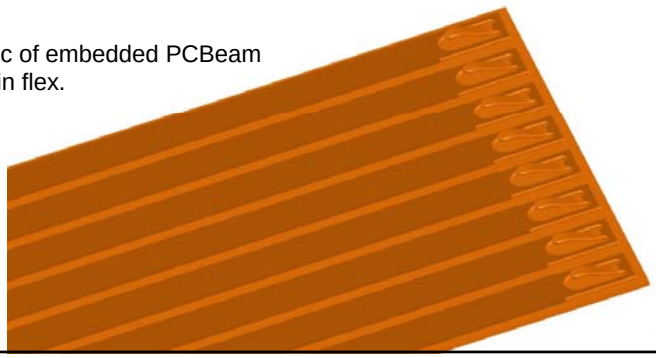
Eliminate the Connector!
PCBeam contacts embedded in flex cable

- Eliminate separate connector, reduce BOM.
- Reduce interfaces.
- Improved SI.
- Eliminate flex SMT assembly operations.

Schematic of embedded PCBeam contacts in flex.



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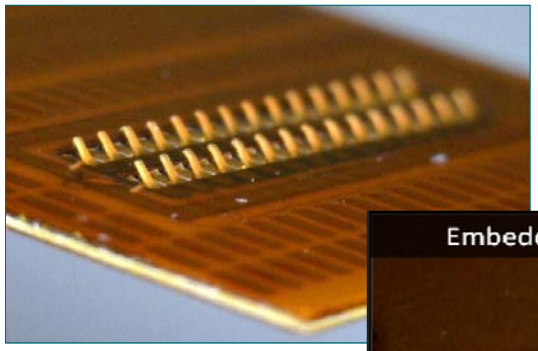

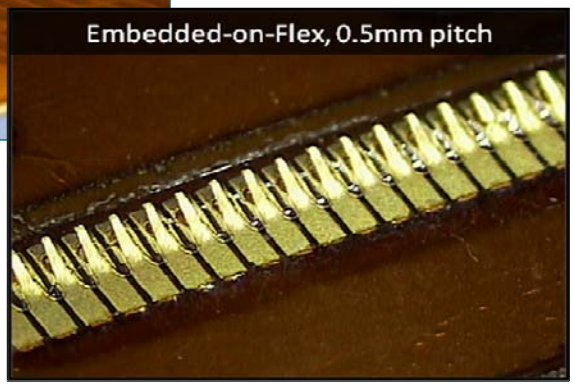

Examples of embedded PCBeam contacts in flex cable

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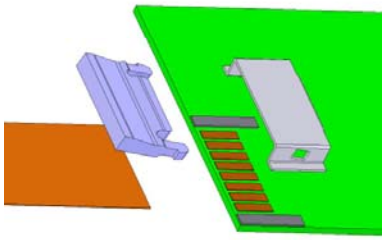
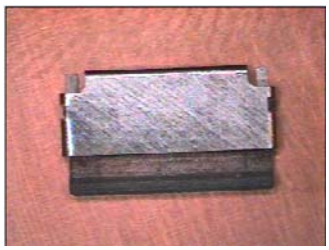
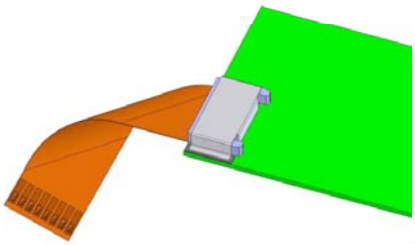
One example of integration options for embedded PCBeam contacts in flex interconnect.







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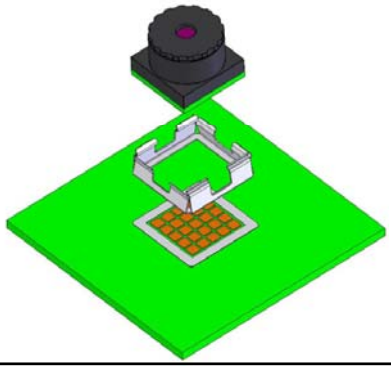
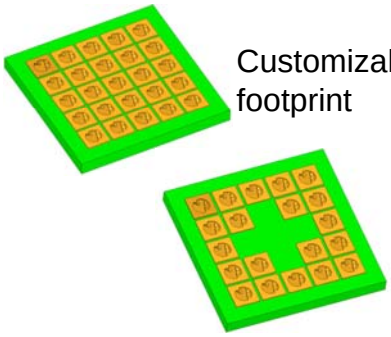
Re-inventing the connector industry.

Integration alternatives for camera module in hand-held electronics

- Simplified 'socket' provides mechanical alignment and hold-down only
- Separable contacts embedded in module substrate, motherboard, or keyboard PCB





Customizable I/O footprint

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Re-inventing the connector industry.

Camera module integration on flex allows increased freedom in locating camera module in phone

- Contacts can be embedded in flex, or on interposer between camera module and flex
  - 2 sided contact or SMT

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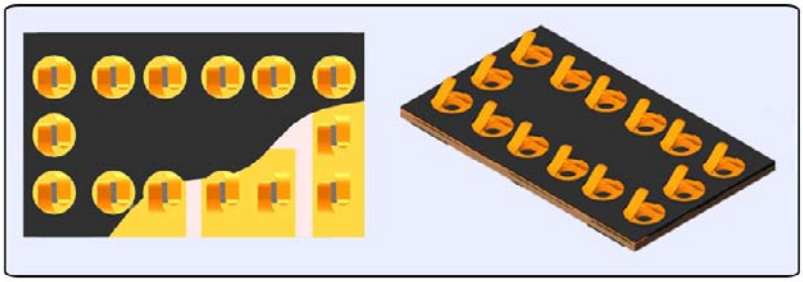
Bussed contacts can provide redundancy or enhanced power distribution and shielding



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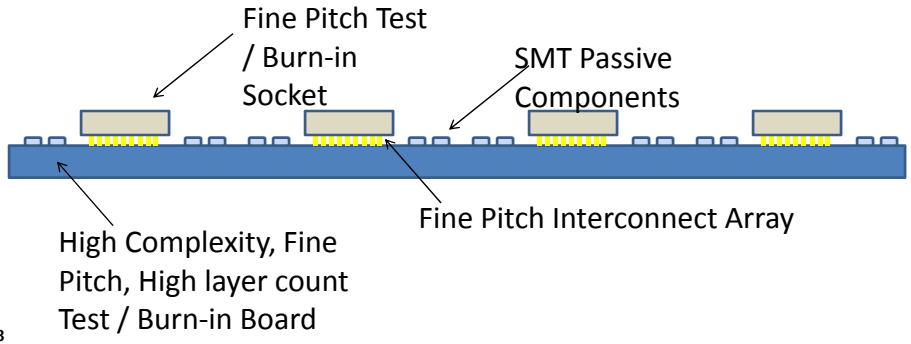
Pitch Translation Interposers:
Burn-In and Test Application Example

- High board cost for fine pitch arrays, particularly where parallelism is high (multiple DUTS per board; 200 or more DUTS/board common in burn-in)
  - 0.4 mm pitch, high pin count designs in production, 0.3 mm pitch is coming.
- Difficult to fabricate, repair / rework boards, and lost production time for maintenance



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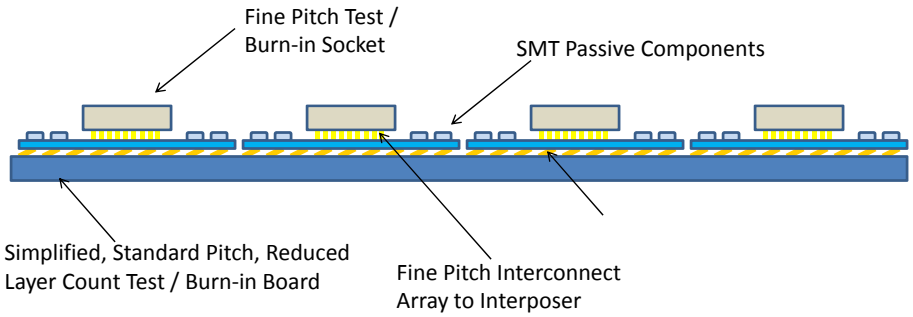
Field-Replaceable, Pitch translation interposers with PCBeam contacts

- Simplifies board design and construction.
- Reduces cost.
- Complex redistribution pulled into small format interposer.
- PCBeam contacts enable field replacement with minimal down time.



Potential for zero reduction of parallelism (DUTs per board) when bring SMT passive components from main board to interposer

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Re-inventing the connector industry.

Summary: Novel interconnect technology providing:

- Lithographically defined contacts
- Ultimate in design flexibility, surpassing incumbent and evolving technologies
- Substantial improvements in performance
- Fine pitch, small footprint and low profile supports miniaturization for handheld electronics
- Ability to tailor combined mechanical and electrical characteristics
- PCB infrastructure and batch processing for low cost

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