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Semiconductor Wafer Test Workshop

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Kelvin Contactors for Wafer-Scale Test

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SEMICONDUCTOR TEST GROUP
A DOVER COMPANY

Agenda

- Two Growing Test Trends: Wafer-Scale & Kelvin
- Wafer-Scale has been Increasing in Popularity
- Wafer-Scale Contacting a Challenge
- Benefits of Spring Probes for Wafer-Scale Test
- Kelvin: Useful Tool for Final Test
- ECT's Gemini Kelvin
- Gemini Kelvin Examples for Wafer-Scale Test
- Most Wafer-Scale Devices 0.5 & 0.4 mm Pitch
- Finer-Pitch Version of Gemini Kelvin More Appropriate for Wafer-Scale Test
- Summary

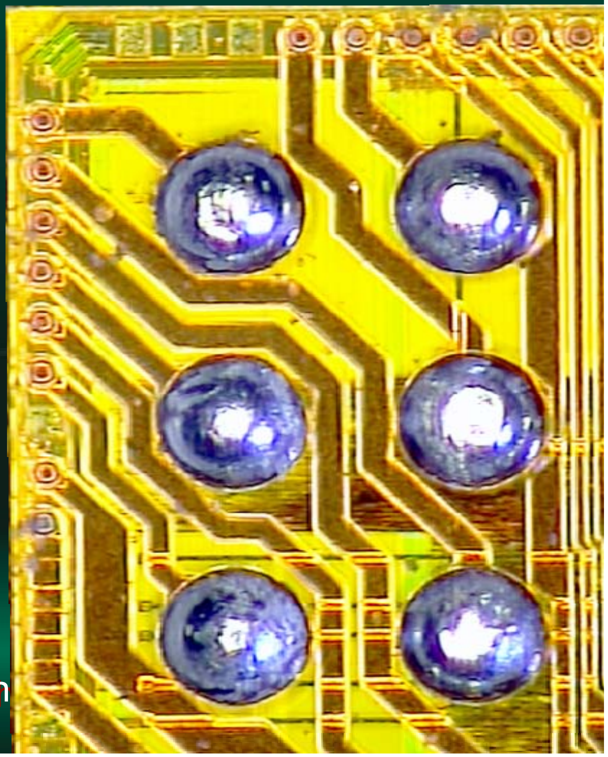
Two Growing Test Trends

Wafer-Scale and Kelvin Test

- **Each Presents Challenges**
- **Greater Challenge Together**
- **Spring Probes an Excellent Solution**

WST Increasingly Popular

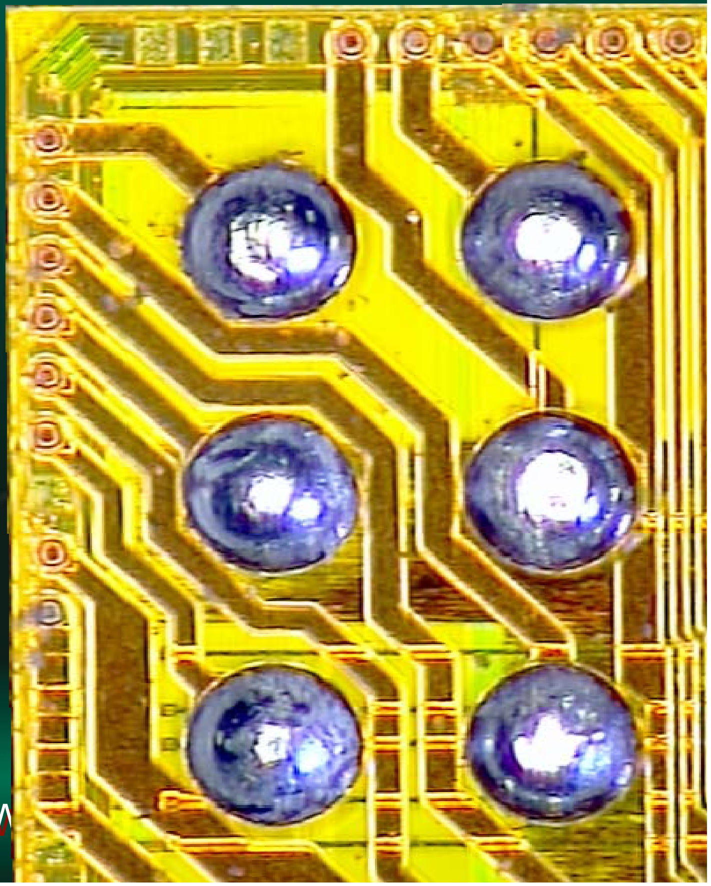
- Wafer-Scale Test is an Increasingly Popular Test Method
- WST is Made Possible by Adding a Redistribution Layer to Dice
- Redistribution Layer Effectively Packages the Die at the Wafer Level
- Allows Final Test at Wafer Level
- Wafer-Scale Test Presents Challenges for Contacting



Redistribution layer on WS device

WST a Contacting Challenge

- **Contact Must be Capable of Everything Required for Final Test**
  - High conductance for high-current tests
  - Low resistance for accurate voltage measurements
  - Low inductance for power and ground paths
  - High bandwidth for at-speed functional tests
- **Wafer-Scale Devices are Fine-Pitch BGA**



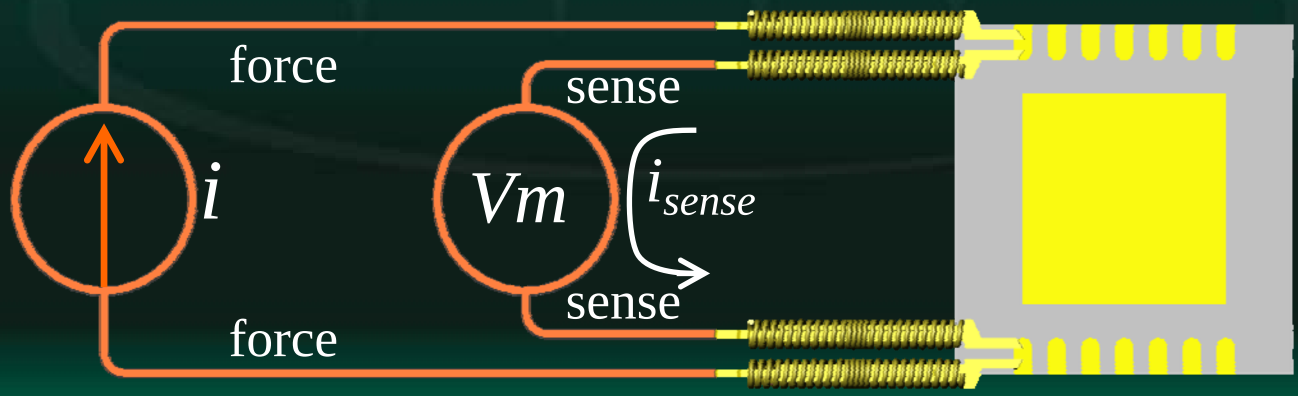
Redistribution layer on WS device

Benefits of Spring Probes for Wafer-Scale Test

- **Final-Test Capable for Best Yields**
  - High current for DC tests and power delivery
  - High bandwidth for RF tests
  - Low inductance for power delivery
- **Lowest Cost of Ownership**
  - Lower initial price than Cantilever, buckling beam, membrane
  - Field repairable / rebuildable in the field without special tools

Kelvin: Very Useful in Final Test

- Concept of Four-Wire Measurement Developed by Lord Kelvin over 100 Years Ago!
- Eliminates Contact Resistance from DC Measurements
- Essential for Accurate Voltage Force or Measure
- Useful for R_{DSON} and V_{DO}, for Example



Kelvin circuit diagram

Recognizing the Need for Kelvin

- **Low Resistance Specifications. Examples:**
  - RDSON (common low-R parameter):

		switching		
Output Stage MOSFETs				
$R_{DSON,LS}$	Drain-to-source resistance, low side	T_J = 25°C, LDMOS only	40	mΩ
$R_{DSON,HS}$	Drain-to-source resistance, high side	T_J = 25°C, LDMOS only	40	mΩ
I/O Protection				

  - Calculation required
  - Implied R=280 mΩ (280 mV / 1 A):

I_{STDBY}	Standby current	CE = High, V_{IN} = 5.0V	65	95	µA
INPUT TO OUTPUT CHARACTERISTICS					
VDO	Drop-out voltage IN to OUT	$\overline{CE}$ = Low, V_{IN} = 5V, I_{OUT} = 1A	170	280	mV
INPUT OVERVOLTAGE PROTECTION					

- **High Maintenance Requirements**
  - Frequent probe cleaning
  - Short probe life
  - Indicate R_C sensitivity – should be investigated

Kelvin Test at Wafer-Scale

A Growing Need

WLP 004-018 I/O Forecast

	2007	2008	2009	2010	2011	2012	CAGR
Analog:			Units (M)				(%)
Amps & Comp	1838	2054	2243	2517	2743	2990	10.2
Regulators	3142	3756	4375	5361	6561	8295	21.4
Data Conv.	11	12	14	17	21	25	18.0
Consumer	483	597	732	842	960	1089	17.6
Comm.	38	40	43	48	54	61	9.8
Computer	24	27	30	35	39	43	13
Other	324	362	395	435	478	526	10.2

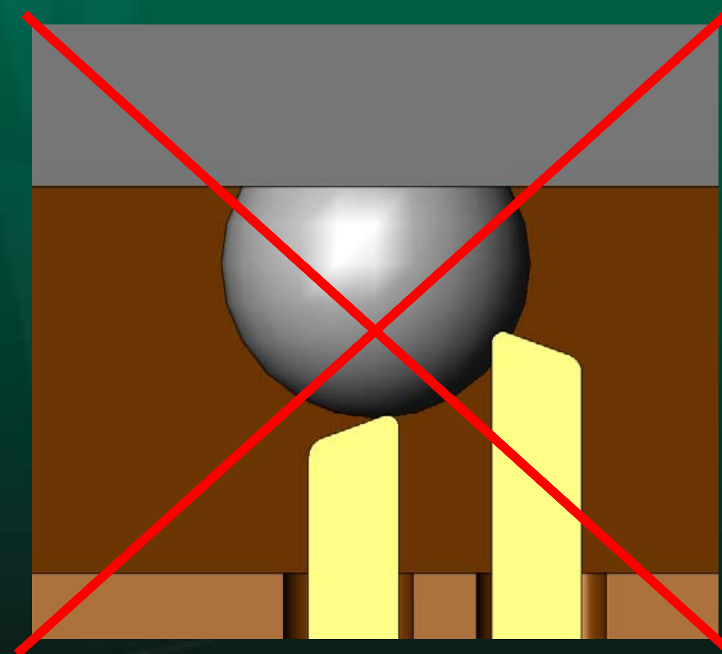
Data courtesy Electronic Trend Publications

BGAs Present Challenges for Kelvin contact

Probe pairs on 0.65 mm BGA

Accuracy is Critical

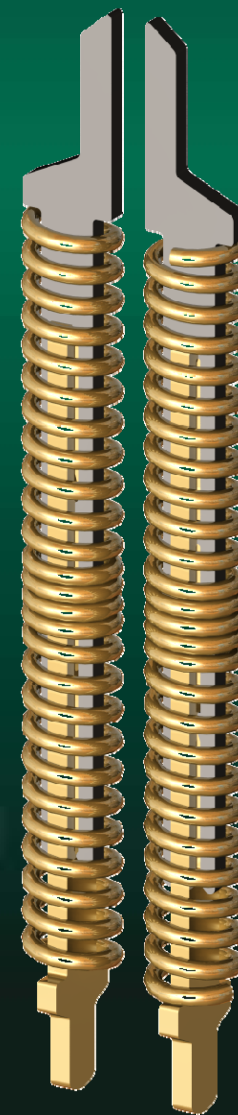
- Leaving Mark in Ball Apex Can Negatively Affect Solderability
- Landing a Probe Too Close to Edge Can Cause Ball Shear
- Decreasing Pitch Exacerbates Issues



Pair of misaligned probes on 0.4 mm solder ball

ECT's Gemini Kelvin

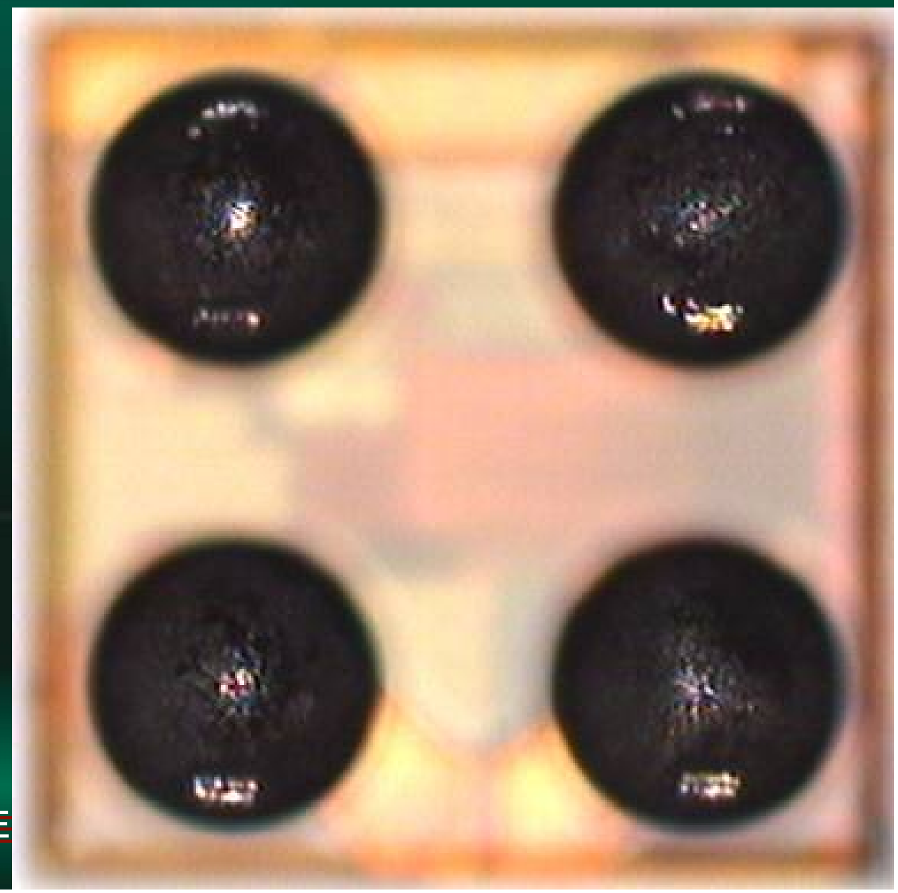
- Gemini Kelvin in Use Since 2007
- Over 150 Designs, Over 700 Contactors Shipped
- Mostly In-Line (QFN/MLF) Designs
- Hundreds of Thousands of Insertions per Contactor



Gemini Kelvin probe pair

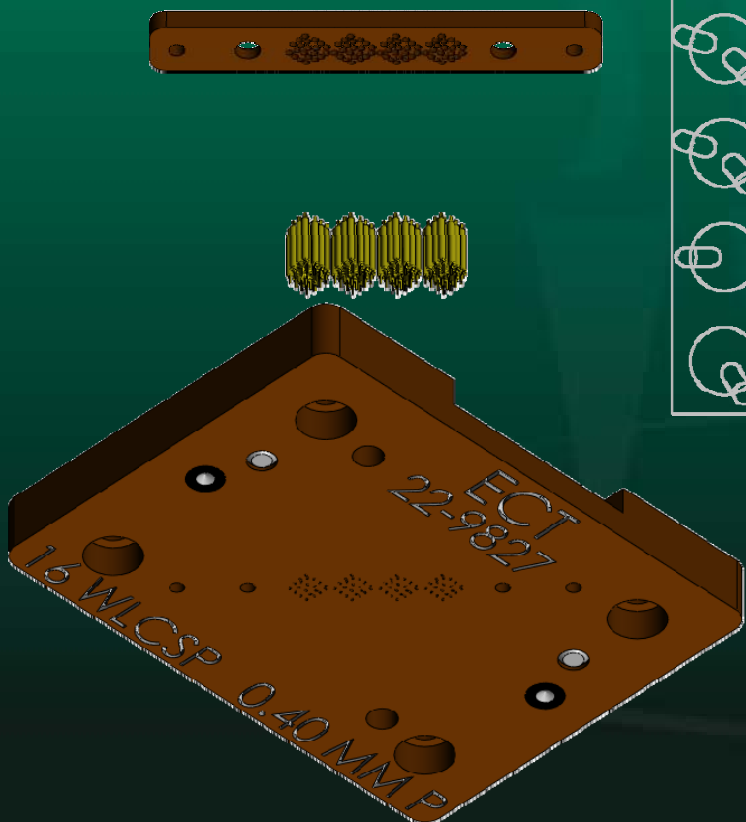
Gemini Kelvin Probes Used for Wafer-Scale Contact

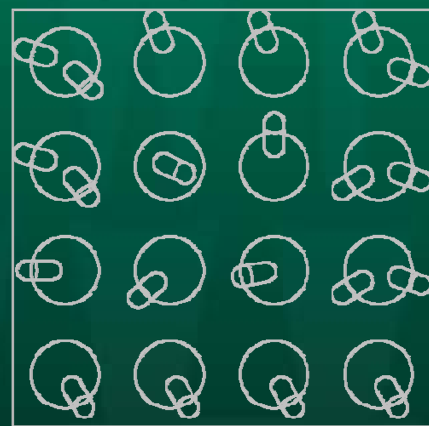
- Actively Being Used in High-Volume Production Test Environments
- Capable of Partial Arrays at 0.5 mm Pitch
- Partial Arrays Around Perimeter at 0.4 mm Pitch

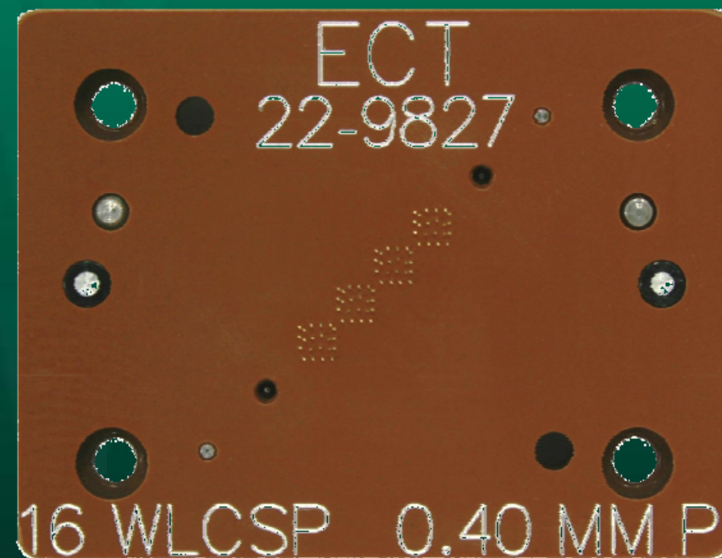


0.4 mm pitch BGA with Kelvin probe marks on two solder balls

Example: Gemini Kelvin Contactor

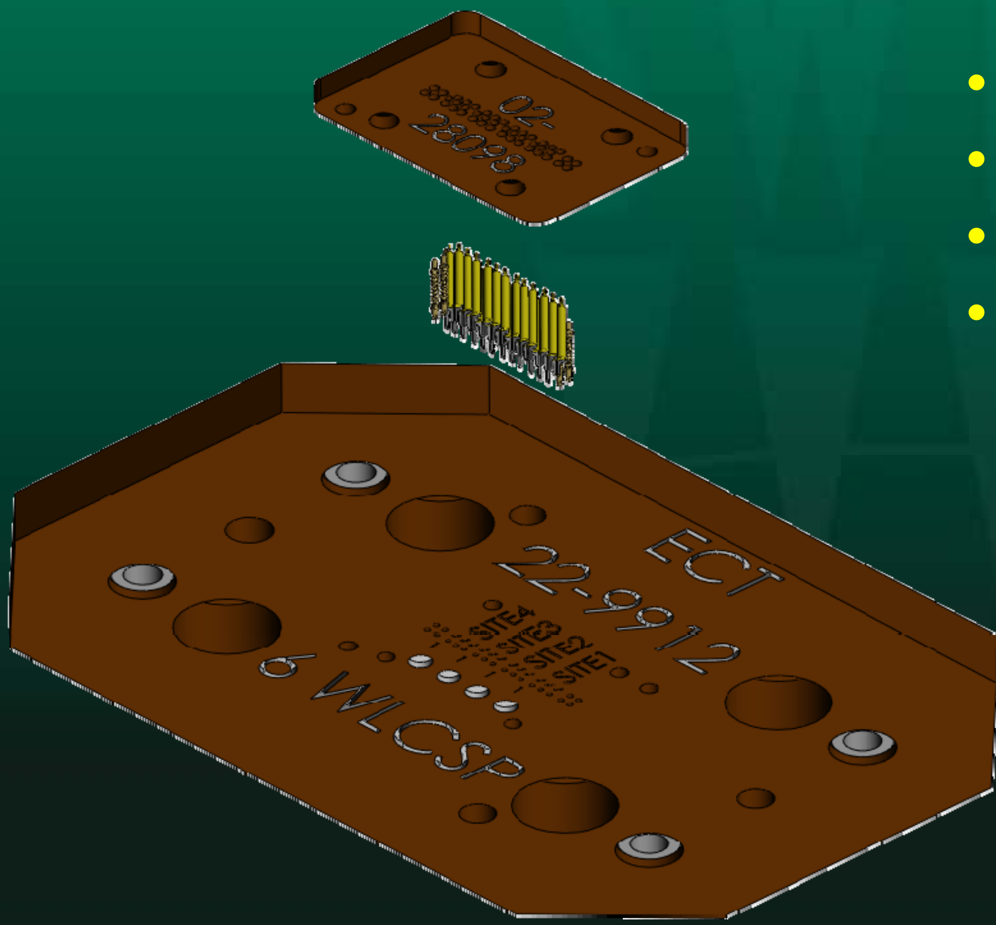






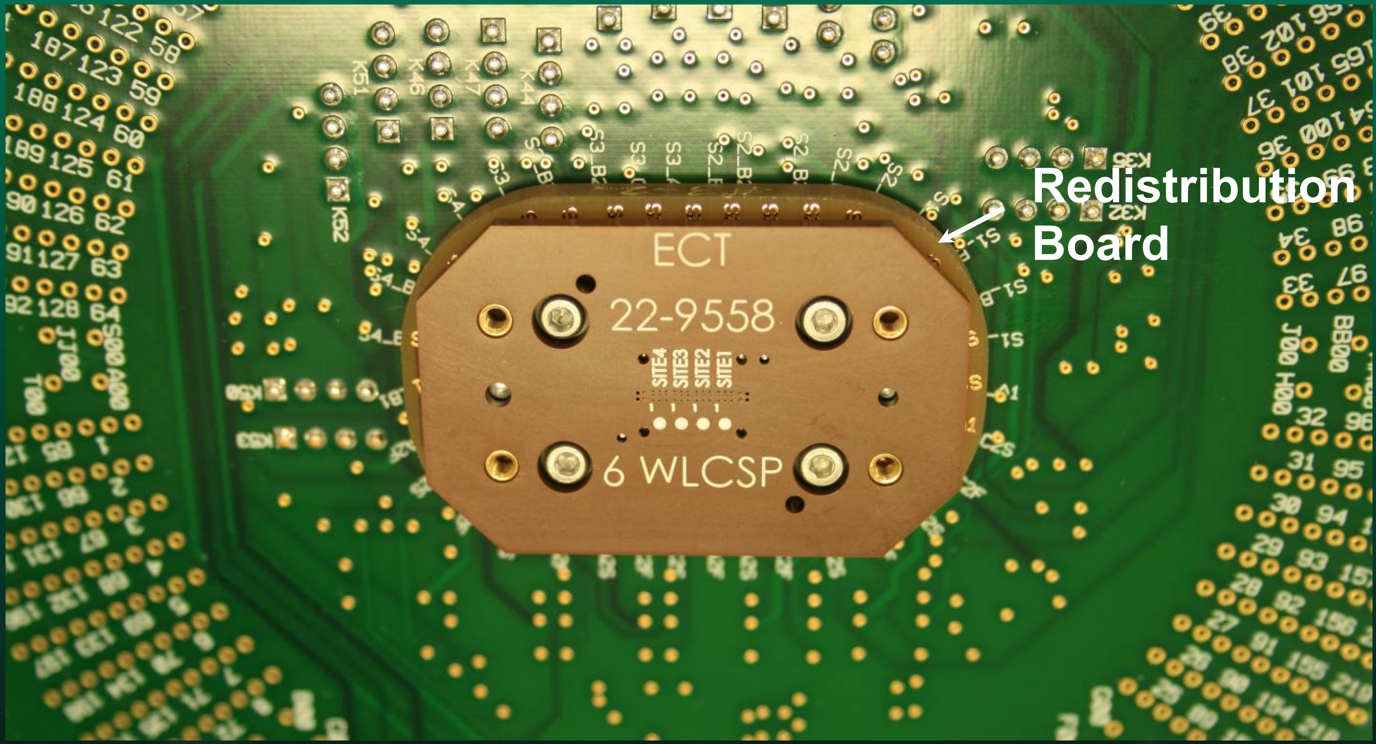
- Quad Site
- 16 BGA - 0.4 mm Pitch
- Diagonal Sites
- Optical Fiducials
- Partial Kelvin – 5 of 16 balls

Example: Gemini Kelvin Contactor



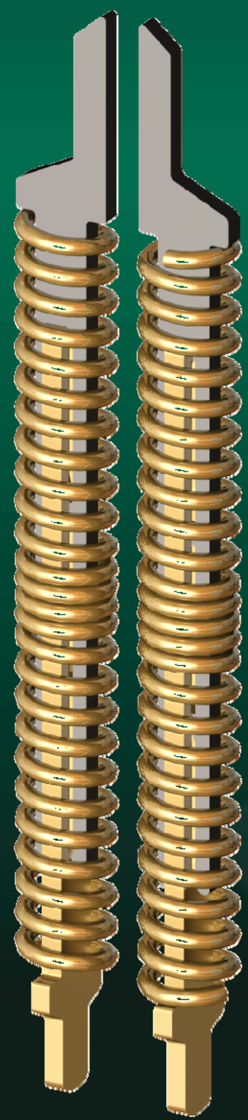
- Quad Site
- 6 BGA - 0.5 mm pitch
- Optical Fiducials
- Partial Kelvin – 3 of 6 balls

Example: Gemini Kelvin Contactor



- Turnkey with Probe Card and Redistribution Board
- Redistribution Board:
  - Allowed Existing Probe Card Design to be used
  - Achieved Customer-Required Minimum Test Height

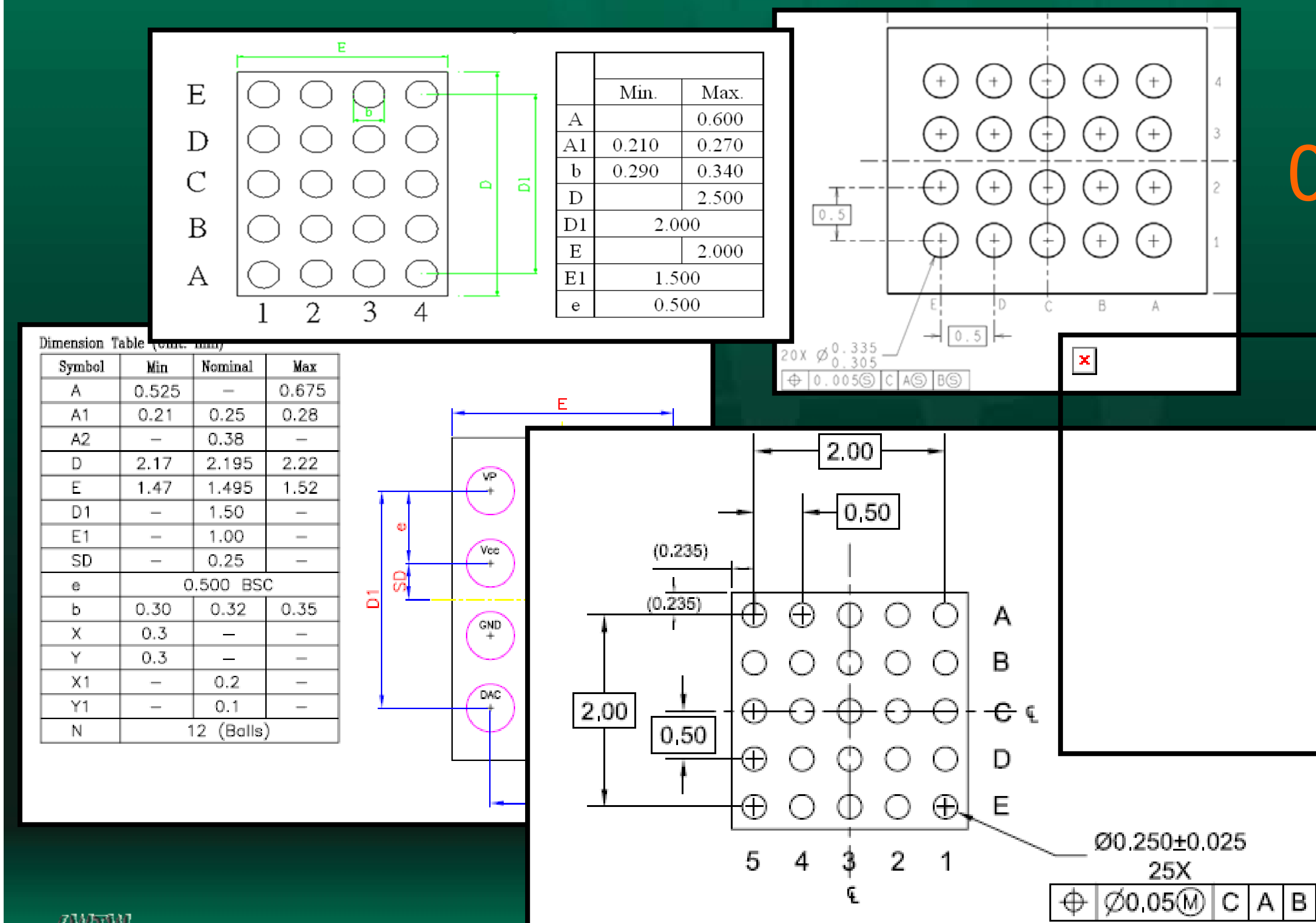
Gemini Kelvin Specifications


Gemini Kelvin probe pair

Probe Pitch	0.4 mm and up (inline) 0.65 and up full array; 0.4, 0.5 partial array
Kelvin Tip Spacing	0.1 mm minimum
Board-side spacing	0.4 mm minimum
Test Height	3.22 mm
Probe Compliance	0.44 mm total (0.26 mm DUT-side)
Force at Test Height	25 – 30 g
Loop Inductance	1.05 nH (single probe) 0.65 nH (dual probe)
Bandwidth	-1dB @ 22 GHz (single probe @ 0.5 mm Pitch) -1dB @ 16 GHz (dual probe @ 0.5 mm Pitch)
Contact Resistance	<150 mΩ (new probe)
Tip Styles	R 0.015 mm (DUT), R 0.125 mm (board)
Probe Finish	Hard Gold, PG2 for Sn, PG3 for NiPd
Current Carrying Capacity	1.6 A Continuous (20º C rise) 6 A maximum @ 1% duty cycle

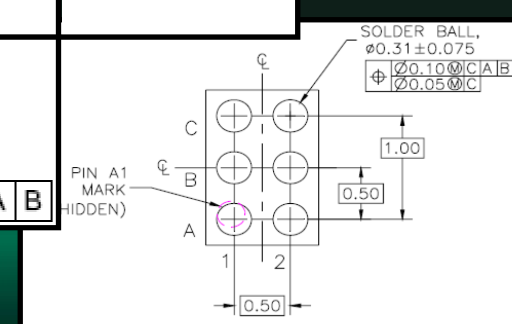
Need for Finer-Pitch Kelvin

0.5 mm Pitch

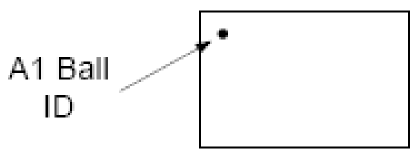


	Min.	Max.
A		0.600
A1	0.210	0.270
b	0.290	0.340
D		2.500
D1	2.000	
E		2.000
E1	1.500	
e	0.500	

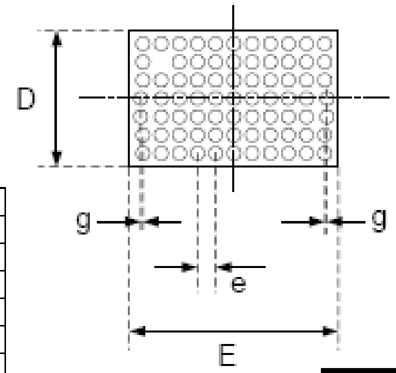
Symbol	Min	Nominal	Max
A	0.525	–	0.675
A1	0.21	0.25	0.28
A2	–	0.38	–
D	2.17	2.195	2.22
E	1.47	1.495	1.52
D1	–	1.50	–
E1	–	1.00	–
SD	–	0.25	–
e	0.500 BSC		
b	0.30	0.32	0.35
X	0.3	–	–
Y	0.3	–	–
X1	–	0.2	–
Y1	–	0.1	–
N	12 (Balls)		

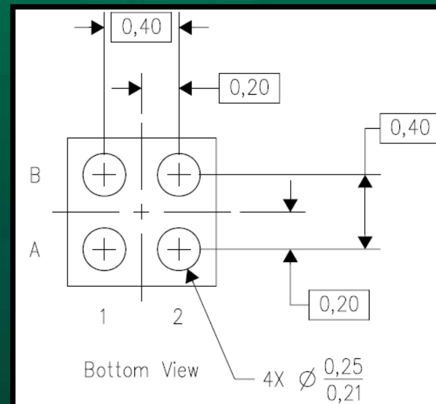


Need for Finer-Pitch Kelvin

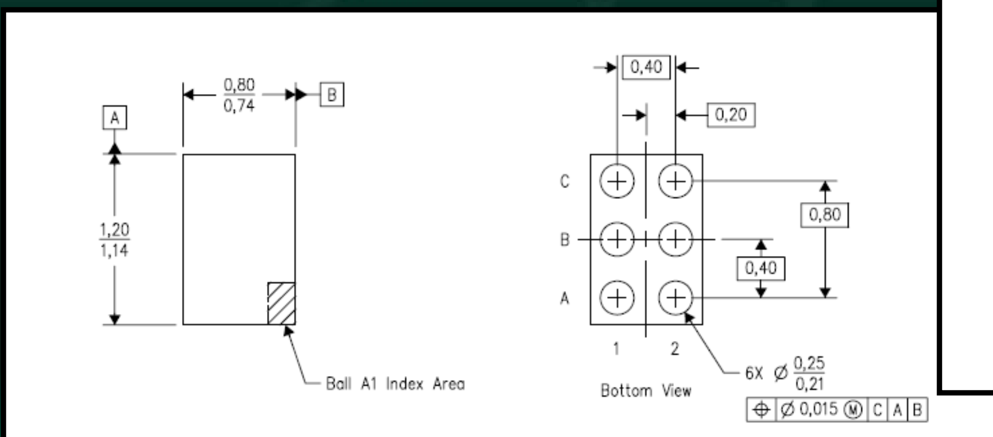


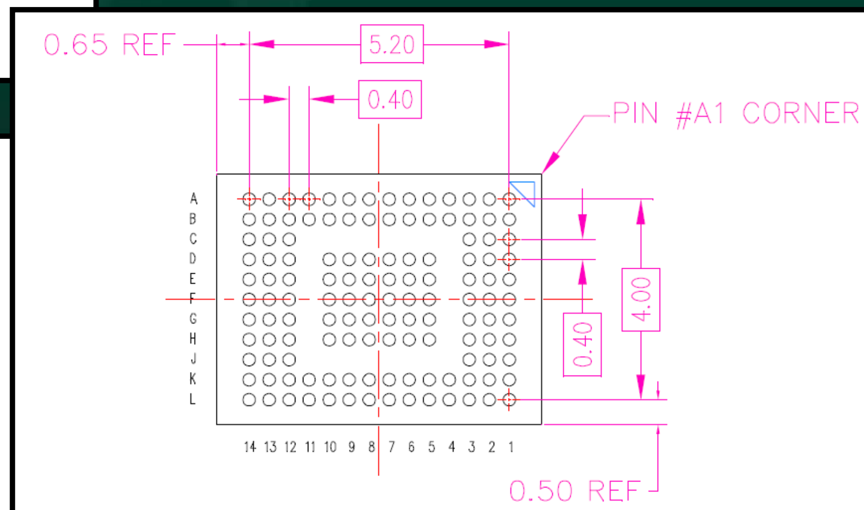
Dimension	Minimum	Nominal	Maximum
D		4.550	
E		2.950	
b		0.25	
e		0.40	
g		0.05	
A		0.68	
A1		0.18	
A2		0.50	





0.4 mm Pitch





Fine-Pitch Gemini Kelvin in Development

- **New, Finer-Pitch Probe has Capability to Accommodate Finer-Pitch BGAs**
  - GMK is a scalable technology
  - Full BGA arrays at 0.4 mm pitch
  - Can be used in-line down to 0.3 mm pitch
  - DUT-side tips 0.08 mm spacing
  - Board-side tips 0.27 mm spacing

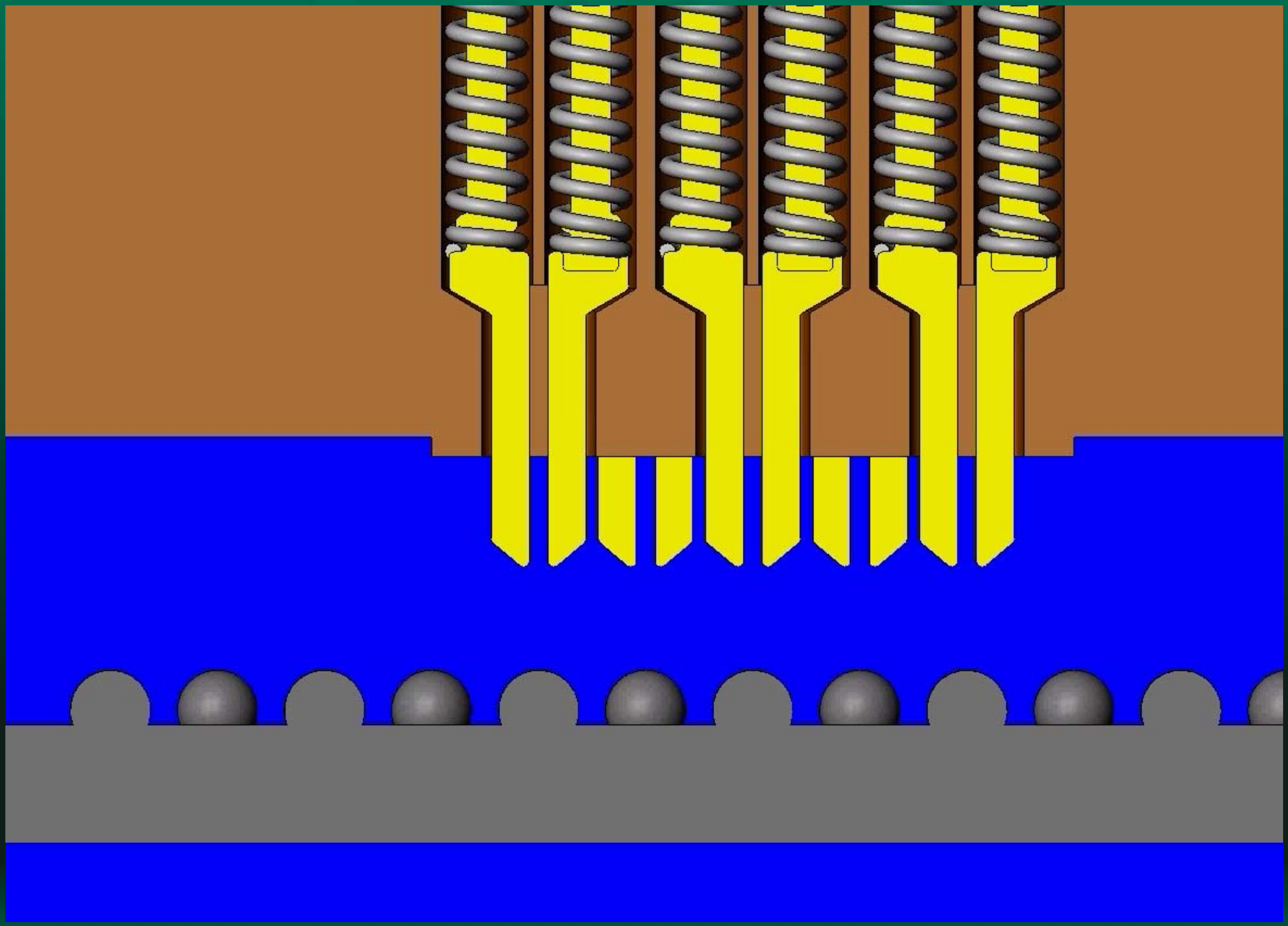
Fine-Pitch Gemini Kelvin

Fine-Pitch Gemini Kelvin in Development

- **Capable of Being Used With a Floating Alignment Plate (FAP)**
  – Wafer-scale testing does not use FAP
  – Optical alignment eliminates the need for this mechanical alignment
  – FAP useful for contacting singulated packages
  – Packages can be tested in same contactor for consistency

Fine-Pitch Gemini Kelvin

GMK030 in Wafer Scale Test



Issues to Overcome at Fine Pitch

- **Contactor Body Machining**
  - Small, closely-spaced holes challenging:
  - Wall thickness
  - Aspect ratio
  - Might affect material choice

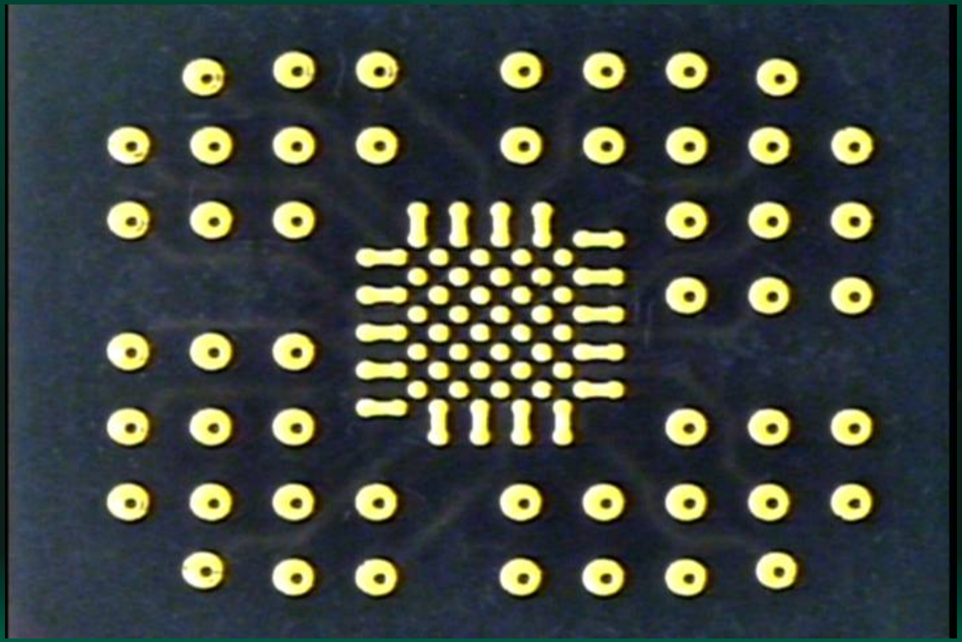
Board-side tip
Spacing 0.275 mm

DUT-side tip
Spacing 0.08 mm

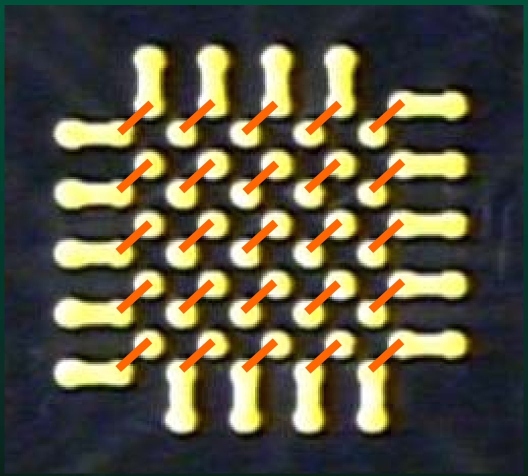
Fine-pitch Gemini Kelvin working height 2.45 mm

Issues to Overcome at Fine Pitch

- **Board Fabrication**
  - Probes placed at 45° to increase pitch
  - Results in 0.275 mm pitch
  - May require space transformer



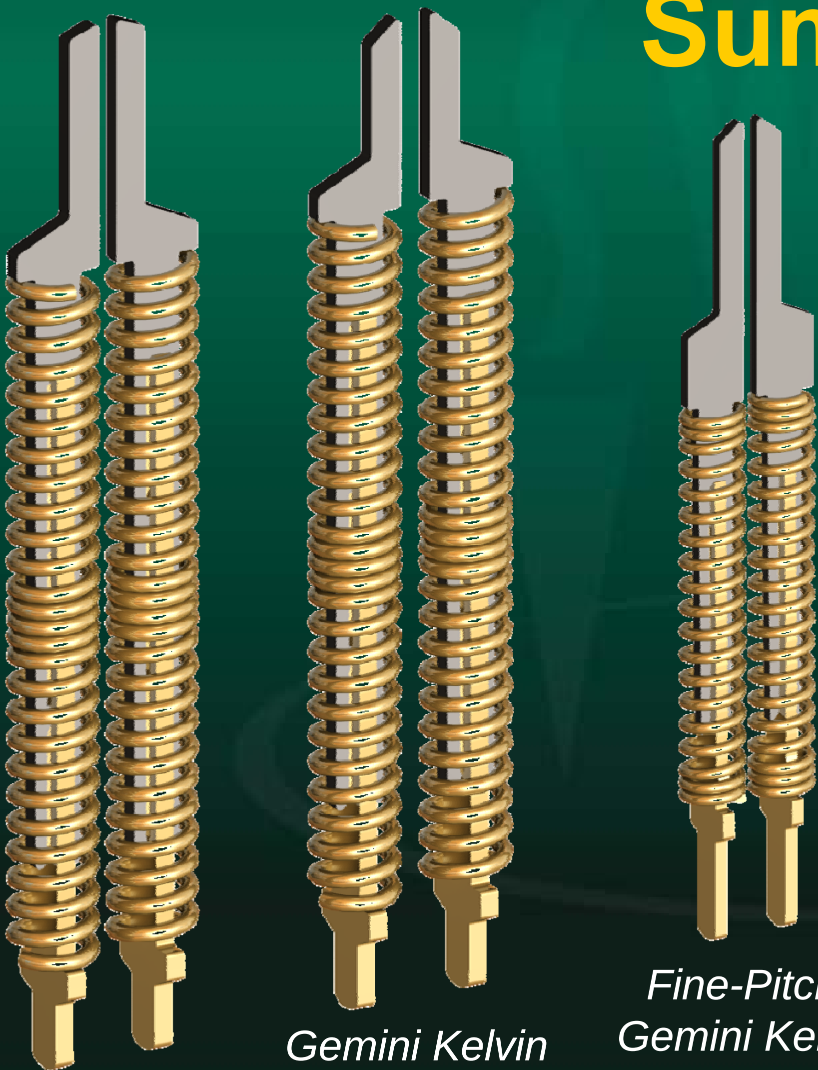
0.4 mm pitch Gemini Kelvin Pattern, fanned out to 0.8 mm



Kelvin pad pairs

Summary

- **Kelvin Test at Wafer-Scale is a Growing Requirement**
- **Kelvin at Wafer-Scale Presents Contacting Challenges**
- **Spring Probes are Available to Meet the Current Need**
- **Further Spring Probe Development is Focused on Full Kelvin for Fine-Pitch Wafer-Scale Test**



Gemini Kelvin for BGA

Gemini Kelvin

Fine-Pitch Gemini Kelvin