Kelvin Contactors for Wafer-Level Test

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Multitest - Xcerra
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Kelvin Method over 150 Years Old

• Created by William Thompson (Lord Kelvin)
• Also Calculated Absolute Zero
• Kelvin temperature scale named for him
Industry Standard

- Kelvin is recognized as the best way to perform $R_C$-sensitive measurements
- Without a Kelvin connection:
  - Yields suffer
  - Probes require frequent cleaning
  - Probes require frequent replacement
Kelvin is a Mechanical Challenge

- Electrical contact points are small
- Landing a single probe tip is a challenge
- Landing two doubles the challenge
  - Especially in area arrays (BGAs, e.g.)
- Challenge increases as pitches shrink
0.4 mm Pitch Kelvin

- Introduced in 2008 - Very successful
  - Hundreds of designs
  - Thousands of contactors
  - Millions of probes
- Main limitation has been pitch
  - Capable of 0.4 mm pitch in-line
  - Capable of full arrays at 0.65 mm pitch
  - Capable of partial arrays at 0.5 mm pitch
  - Capable of partial arrays (peripheral) at 0.4 mm pitch
Need for Kelvin at WL Test

- Wafer-Level test has always been an important application for Kelvin
  - Many devices include power management
- Mainline pitch has been 0.4 mm
  - 0.4 mm probe used despite array limitations at 0.4

Contactor for WL test using 0.4 mm pitch probe
Spring Probes for WL Test

- Spring probes good choice for WL test
- WL test is final test
- More capability required than wafer probe

<table>
<thead>
<tr>
<th>Technology</th>
<th>Pogo™ Probe</th>
<th>Spring Probe</th>
<th>Spring Probe</th>
<th>Membrane</th>
<th>Vertical 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>CSP050</td>
<td>0.4 Kelvin</td>
<td>0.3 Kelvin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inductance</td>
<td>1.22 nH</td>
<td>1.1 nH</td>
<td>1.8 nH</td>
<td>0.2 nH**</td>
<td>N/A</td>
</tr>
<tr>
<td>DC Current</td>
<td>1.7 A</td>
<td>1.8 A</td>
<td>1.5 A</td>
<td>200 mA***</td>
<td>0.5 A</td>
</tr>
<tr>
<td>Resistance</td>
<td>100 mΩ typ.</td>
<td>75 mΩ typ.</td>
<td>100 mΩ typ.</td>
<td>&lt; 200 mΩ</td>
<td>&lt; 2 Ω</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>5.7 GHz</td>
<td>16 GHz</td>
<td>17 GHz</td>
<td>20 - 33 GHz</td>
<td>1.3 GHz</td>
</tr>
</tbody>
</table>

** Tip Only  *** On Solder

Membrane and Vertical Probe specifications from internet
First Attempt at 0.3 mm Probe Failed

- First Attempt at finer pitch simple shrink of 0.4 mm Kelvin probe
- QuadTech architecture results in geometries that are too fragile
- Development shelved for several years
More-Recent Release of 0.3 mm Probe

- Development restarted in 2012
- Different approach taken
- Internal contact simple flat-on-flat
- Latching mechanism is different
- A patent has been applied for, based on the latch feature
### 0.3 mm Probe Basic Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductance @ 20° C rise</td>
<td>1.5 A</td>
</tr>
<tr>
<td>Maximum Resistance (New Probe)</td>
<td>150 mΩ</td>
</tr>
<tr>
<td>Bandwidth @ -1dB (Dual-Probe, GSG)</td>
<td>17 GHz</td>
</tr>
<tr>
<td>Inductance (Loop, Dual-Probe, GSG)</td>
<td>1.01 nH</td>
</tr>
<tr>
<td>Tip Options</td>
<td>K &amp; D now, B later</td>
</tr>
<tr>
<td>Minimum Kelvin Tip Spacing</td>
<td>83 μm</td>
</tr>
<tr>
<td>Test Height</td>
<td>3.46 mm</td>
</tr>
<tr>
<td>Total Compliance</td>
<td>552 μm</td>
</tr>
<tr>
<td>DUT-Side Compliance</td>
<td>412 μm</td>
</tr>
<tr>
<td>Force at test height</td>
<td>15 g</td>
</tr>
<tr>
<td>Material</td>
<td>H.P. Alloy</td>
</tr>
<tr>
<td>Plating (Board Side Only)</td>
<td>Hard Gold</td>
</tr>
</tbody>
</table>
GMK030 Characterization: Life Test
0.3 mm probe Characterization: High Current Test

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Temperature Rise</th>
<th>Current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20° C Temperature Rise</td>
<td>1.5 A</td>
<td></td>
</tr>
<tr>
<td>40° C Temperature Rise</td>
<td>1.6 A</td>
<td></td>
</tr>
<tr>
<td>60° C Temperature Rise</td>
<td>1.7 A</td>
<td></td>
</tr>
<tr>
<td>1% duty cycle</td>
<td>5.0 A</td>
<td></td>
</tr>
</tbody>
</table>
### 0.3 mm Probe Characterization: RF Simulation

<table>
<thead>
<tr>
<th>GS (Single Pin)</th>
<th>GSG (Single Pin)</th>
<th>GS (Dual Pin)</th>
<th>GSG (Dual Pin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Probe GS</td>
<td>2.1 GHz</td>
<td>Single Probe</td>
<td>1.77 nH</td>
</tr>
<tr>
<td>Dual-Probe GS</td>
<td>5.2 GHz</td>
<td>Dual Probe</td>
<td>1.01 nH</td>
</tr>
<tr>
<td>Single-Probe GSG</td>
<td>3.9 GHz</td>
<td></td>
<td>inductance values are GSG</td>
</tr>
<tr>
<td>Dual-Probe GSG</td>
<td>16.7 GHz</td>
<td></td>
<td>all values at 0.3 mm pitch</td>
</tr>
</tbody>
</table>

Jim Brandes  
June 8-11, 2014  
IEEE Workshop
Equally distributing the probes to make contact to a 0.4 mm pitch device results in a probe pitch of 283 μm and a probe tip spacing of 83 μm.
Board Fabrication Challenging

• **Space Transformer Board**
  - May be used for full Kelvin @ 0.4 mm
  - Fans 283 μm pitch to something larger

• **Full Performance Board**
  - Full Kelvin may be possible @ 0.4 mm
  - Depending on probe and site count

• **Few Shops are Capable**
Beta Site History #1

• First beta-site contactors shipped Feb 2013
  • 25-ball device
  • WL test and manual test contactors
  • Only used for engineering work
• Each contactor has only a few thousand uses
  • Insufficient to conclude beta site
• User excited – has acquired several more
  • Six quad-site (25-ball device)
  • Six quad-site (12-ball device)
First Beta-Site Contactors

Quad-site HVP contactor

Drawing of single-site hand-test contactor

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June 8-11, 2014

IEEE Workshop
Contactors for Singulated Devices

- Probe designed to support a FAP
- Necessary for singulated devices
- Wafer-level or other packaging

*DUT pocket of contactor for singulated 25 BGA*
Beta Site History #2

• Second beta-site contactor shipped March 2013
  • “Universal” WL contactor – 0.5 mm pitch
  • 12 X 12 array, partially populated
• It took a visit in July to get them to start using
• After first 100 k touchdowns
  • Life and yield far exceeded incumbent
  • Insufficient to conclude beta site
• User excited enough to acquire more
Second Beta-Site Contactor

Close-up of probes in the populated area of the “universal” contactor
Beta Site History #2

• Additional Shipments:
  • One “universal” (12 X 12), 0.4 mm pitch
    • August 2013
  • Second universal 0.5 mm pitch
    • August 2013
  • Eight quad-site HVP contactors, 46-ball, 0.4 mm pitch
    • Three in December 2013, five in May 2014
  • Spare probes
• One contactor has reached 850 k touchdowns
  • Almost enough high-volume production data to conclude beta site
Beta Site History #3

• After browbeating, 0.3 mm pitch probe offered to a third user, on an evaluation basis
• Two contactors for singulated devices
  • 32-ball device – July 2013
• Two 20-site HVP contactors
  • 6-ball device – October 2013
• Five quad-site HVP contactors
  • 12-ball device – February 2014
• Spare probes
• Still not enough high-volume production data
Summary

• Sixteen months later . . .
• With 41 contactors in the field . . .
• Of fifteen separate designs . . .
• The beta site stage is *almost* complete
• (That’s the way it goes sometimes)

• Questions?