ARCHIVE 2009

STUDIES AND EVALUATIONS OF ELECTRICAL CONTACTS

Test on Ball

Khaled Elmadbouly, Ila Pal, Cody Jacob, Dr. James Forster
—Antares Advanced Test Technologies

Contacting Pb-free Finishes - A Study of the Effects of Different Lead Finishes on the CRES and Reliability of a QFP Contact

Dr. James Forster, Kazumasa Sato—Antares Advanced Test Technologies
Don Hewer—ST-Microelectronics (Malta)

Current-Voltage Nonlinearities in Test Socket Contacts

Gert Hohenwarter—GateWave Northern, Inc.

Evaluation of Different Price-Point Spring Pin Contactors for an RF Application

James Migliaccio, John Capwell—RF Micro Devices

Test on Ball

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2009 BiTS Workshop
March 8 - 11, 2009

Advanced Test Technologies

Test on Ball

An inexpensive and practical solution for evaluating spring pin performance by testing on Pb-free solder balls

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Agenda

- Introduction to Spring Probe Validation
- Test using Device Simulator/Daisy Chain Packages
- Why Test on Ball is needed
- Test on Ball setup methodology
- Case Study:
  - SAC contamination on Spring Probe
  - The effect of High Current on Spring Probe
- Summary
- Key message

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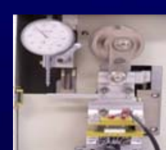
Introduction to Spring Probe Validation

The Pin Level Validation

- Visual and mechanical measurement verification, using smart scope, XRF, SEM, EDX and X Ray.
- Pin Lab Cycler /Kelvin Tester, 250K cycles to verify Cres against pin specification.
- FDR Test to verify Force, versus Deflection, versus Resistance.
- Current Carrying Capacity using IR Thermal Camera to verify Current versus temperature.
- Signal Integrity, using 2 probe VNA Agilent Network Analyzer with Giga Test Fixture.



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Introduction to Spring Probe Validation

The Socket Level Validation

- QC the socket 100% for visual and mechanical measurement, using Smart Scope and CMM to verify socket meets customer specification.
- Cycle the socket up to 100K, using the RFS or Evertech Handler at ambient, -50C and 150C.
- 100K socket validation, using Device Simulator, Cres Board and Antares TSE BOSS Tester.



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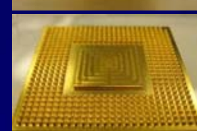
Test using Device Simulator Package

- BGA Device Simulator (DS) is a mechanical shorting device, similar to an IC Package.
- It is usually machined BeCu which is heat treated and plated with Au over Nickel.
- One DS will be used for cycling and another one is dedicated for Cres testing.
- Some Device Simulators are machined Silver.
- The Ag DS is used for spring probe life cycling and Cres measurement.
- These Device Simulators do not replicate the end user environment and it is difficult to asses the impact of **Contamination** or the effect of different **Power** levels when evaluating pins.

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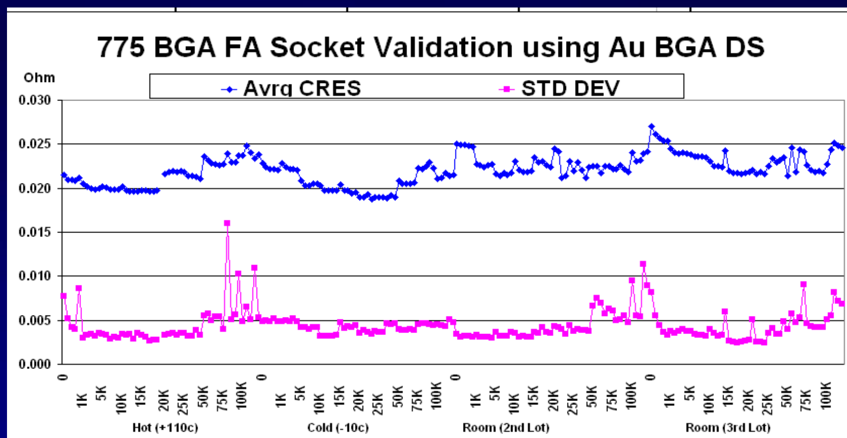
Test using Device Simulator Package

- A typical result using a Au plated BGA DS showing CRES variation during the life cycling of a spring



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Test using Daisy Chain Packages

- Daisy Chain BGA Package is a PCB shorting device simulator , or an actual electrical shorting package without the die.
- We have designed and purchased 10 thousands of those packages few years ago to validate the life and the Cres of many spring pins using the RFS Handler.
- The cost of these packages is very expensive and there is a long lead time.
- What would be the cost of 20K packages required for one validation (minimum of 100K of cycles, 5 hit per package)?
- Also, there will be an additional cost for every RFS Handler's Change Kit, complicated setup and longer validation time.

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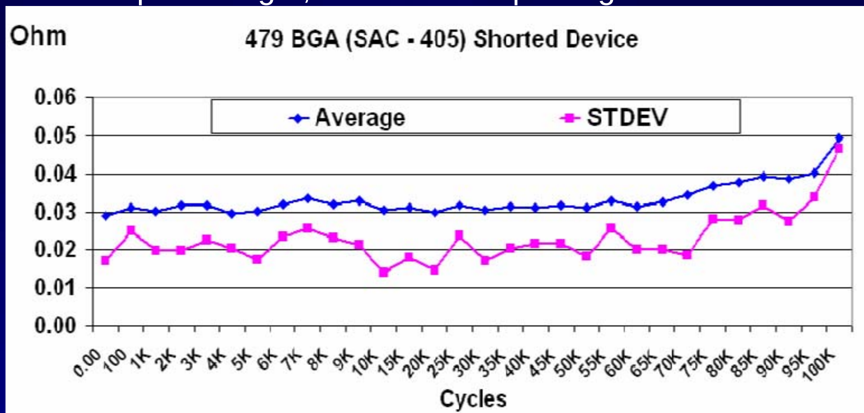
Test using Daisy Chain Packages

- The spring probe validation results shown below, using the RFS Handler with the TSE BOSS Tester was developed using 5,000 479 BGA packages with SAC



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Why Test on Ball is needed

Examples of some customer's complaints

- First pass yield is dropping rapidly
  - Appears to be due to contamination of spring probe.
- Devices tested at higher power (current) have lower yield than standard device.
- SAC105 devices appear to have lower yield than devices using other SAC alloy.

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Why Test on Ball is needed

The requirements for Test on Ball - new methodology:

- Inexpensive setup and universal design for any pin geometry.
- Accelerated test - 10K touchdowns in 5 hours, and complete validation of 100K in 50 hours.
- Testing at different input current during cycling.
- Measurement of Cres during cycling.
- Can do Hot and Cold testing, if needed, without complicated Handler Change Kit Setup.
- Precision alignment and live visual inspection with verification of current measurement at every cycle.

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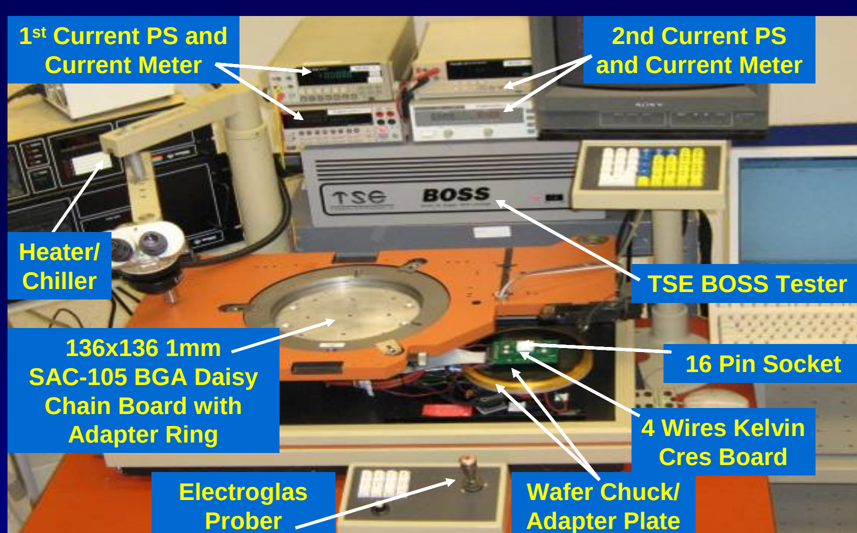
Test on Ball setup methodology



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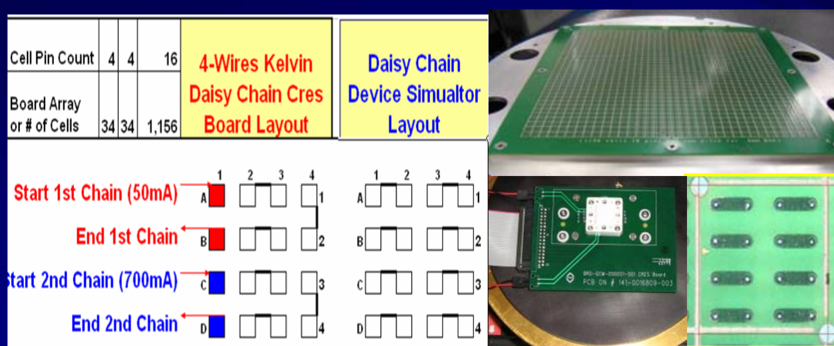
Test on Ball setup methodology

- Close up picture illustrates the wiring diagram for the 4-wires Kelvin Cres board and the large Daisy Chain Device Simulator.



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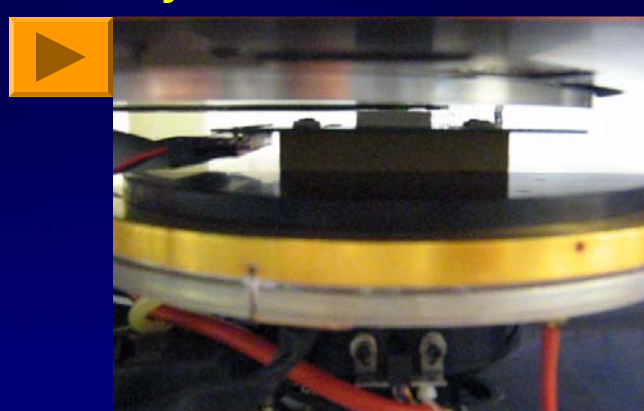
Test on Ball setup methodology

Click to Play Video



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Case Study

SAC contamination on Spring Probe

- Visual inspection of all customer returned/failed or low yield pins and examination of the surface contamination on the spring probe tips as well as on the packages using SEM and EDX Analysis
- Measurements (Cres) were taken for the returned pins, using the 4-wire Kelvin Lab Tester.
- The measurements were repeated on the Prober (new methodology) with the TSE BOSS Tester.

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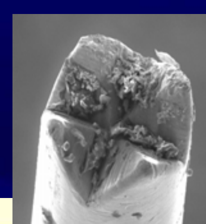
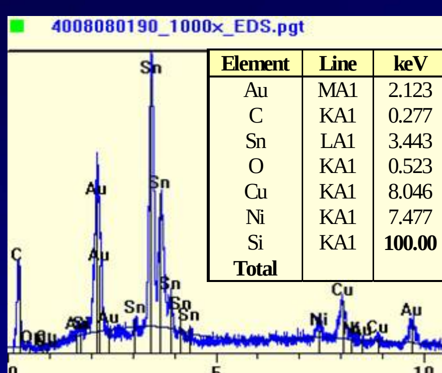
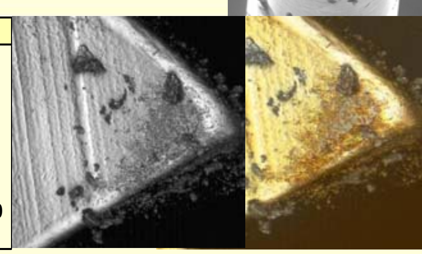
SAC Contamination on Spring Probes

Contamination on Spring Probes identified as Carbon, Tin Oxide, Tin Whisker and Organic compounds such as flux





Element	Line	keV
Au	MA1	2.123
C	KA1	0.277
Sn	LA1	3.443
O	KA1	0.523
Cu	KA1	8.046
Ni	KA1	7.477
Si	KA1	100.00
Total		



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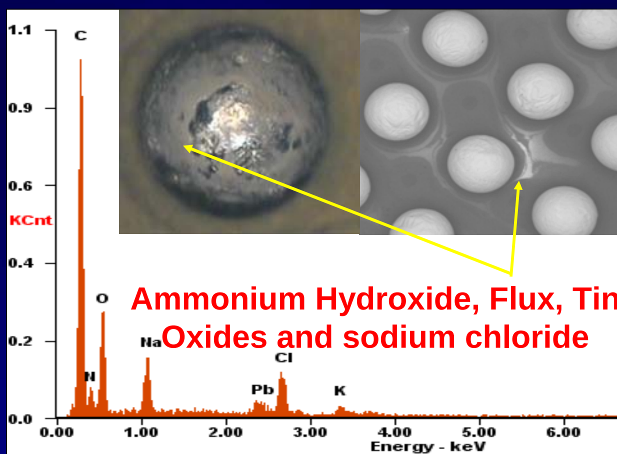
SAC contamination on Spring Probe

Analysis of Customer's SAC-105 Packages showed similar elements/contaminations



Element	Wt%	At%
C	73.91	86.51
O	07.25	06.37
Na	03.43	02.10
Al	00.56	00.29
Si	00.84	00.42
S	01.59	00.70
Cl	03.90	01.55
Pd	04.28	00.57
K	02.33	00.84
Ca	01.92	00.67

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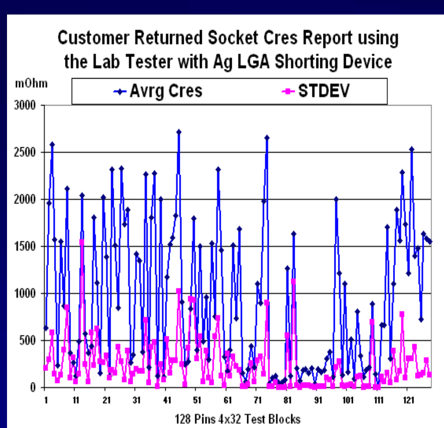
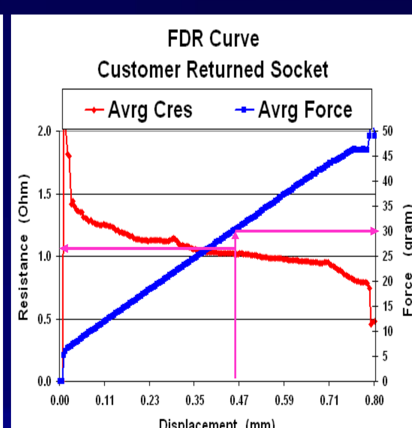
SAC contamination on Spring Probe

Testing of the returned, low yield socket, confirmed that the majority of the pins were above 1 ohm. Measured using our Lab Tester and the FDR Tester





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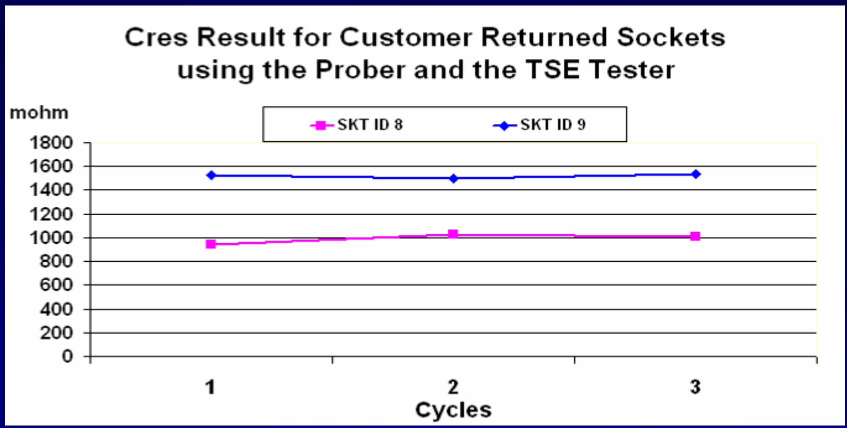
SAC contamination on Spring Probe

We confirmed using the prober that the Cres of all Customer Returned Pins was above 1 ohm.



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Case Study

The effect of High Current on Spring Probe

- Visual inspection - All the High Current Spring Probe tips were examined for solder contamination and ball melting.
- A setup was established to measure temperature at different current levels.
- The (Cres) for customer returned high current pins was measured using the Prober with the TSE BOSS Tester.
- The Current Carrying Capacity (CCC) for the “used” pins was developed in the lab using the Prober CCC setup.
- The results/data were compared with new pins.

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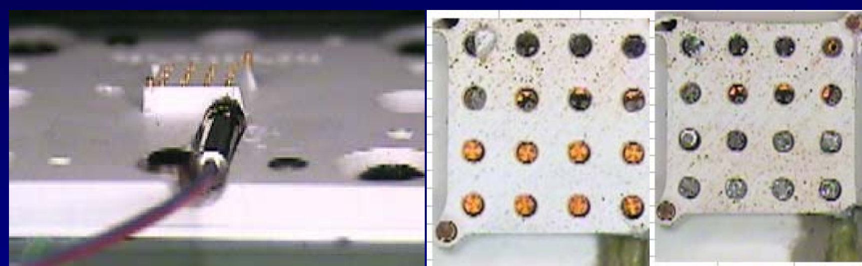
The effect of High Current on Spring Probe

- Installed spring loaded thermocouple to touch one of the spring probe which was exposed to different currents (5 minutes for every level).
- The Cres and Temperature for each current level (0.5, 1, 1.5, 2, 2.5 and 3Amp) were recorded.



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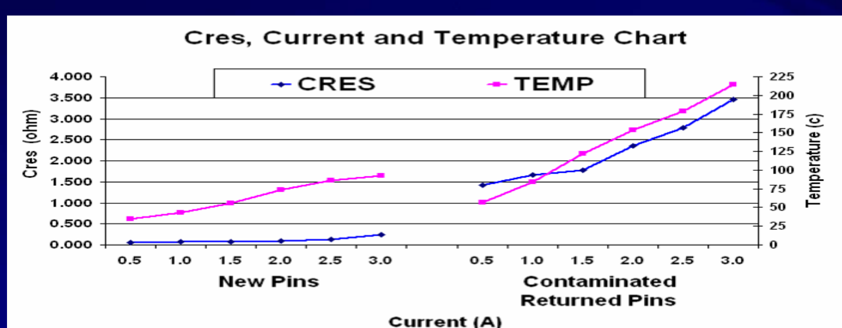
The effect of High Current on Spring Probe

- Brand New Pins using our Prober/ SAC-105 were able to carry 3A with the pin temperature remaining below 125C.
- The temperature of the customer retuned "Contaminated Pins" exceeded 125C at a current of 1.5 amps and the solder balls were melted over 2.5A.



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Summary

- We have developed a capability to evaluate the performance of a pin when contacting solder balls which reproduces the interaction between pins and real devices.
  - Pins showing low yield at customer site have high Cres measured on prober.
  - High current failures on contaminated pins have caused solder ball melting on pin tips on customers test floor.
  - We can reproduce solder melting issue using CCC set up on Prober.
- Our prober methodology emulates the physical contamination seen on customer returned pins.

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Key Message

For all the challenges related to Test on Ball problems, we developed a way to measure them and reproduce them which is much closer to customer environment.

This provides a cost effective tool which allows us to evaluate designs, materials, plating and cleaning systems to improve the performance of spring probes.

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Contacting Pb-free finishes

– A study of the effects of different lead finishes on the CRES and Reliability of a QFP contact.

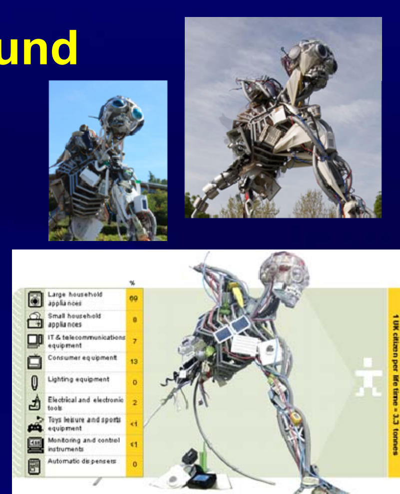
Dr James Forster*,
Kazumasa Sato*, and Don Hewer+
+ St-Micro Malta and *Antares-ATT USA

2009 BiTS Workshop
March 8 - 11, 2009

antares Advanced Test Technologies

Background

- **February 2003** European Union pass two directives
  - **RoHS R**estriction **o**f **H**azardous **S**ubstances
  - **WEEE W**aste **E**lectrical and **E**lectronic **E**quipment
- **Goal -** Reduce dumping of hazardous material in landfills.
- Pb materials must be eliminated – Alternates to eutectic Pb/Sn solder proposed.



WEEE man – A 7 meter statue in England representing the amount of electronic waste one person throws away in their life.
3.3 tonnes or 7300 lbs

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Background

- Semiconductor industry develop a series of Pb-Free solutions
- PbSn packages allowed for military and other uses.
- Pb-Free Solutions include:-
  - Matte Sn,
  - NiPdAu
  - New solder alloys including SAC alloys which are alloys of Tin (Sn) Silver (Ag) and Copper (Cu) Primarily used for BGA's
- Melting temperatures of 225+°C for new solders are approx 40°C higher than eutectic PbSn.
- Challenges for socket industry include
  - Interfacing with a harder materials
  - Reduced socket life due to contamination Different metallurgical interactions between contacts and package
- Previous presentations at BiTS have discussed some of these issues.

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Background

Previous presentations at BiTS:-

- 2003 Session titled: "Socketing Lead-Free Packages"
  - "Lead Free Area Array Module Test and Burn-in" Ethan Gallagher, Zenon Podpora, IBM
  - "Lead Free Contacting" Bert Brost, Johnstech International
  - "The Effects of No Lead Solder Balls on Burn-In Socket Design Decisions" Mike Noel, Don VanOverloop, Daniel Wilcox, K.Y. Yap – Motorola, Tom Lyzinski, Keith Callahan -Wells-CTI
- 2004 Session titled: "Socketing Lead-Free Packages"
  - "Effect of Compression Style Contactors on Lead Free Solder", Ila Pal, Ironwood.
  - "Pb-Free Leadframe Devices And Their Impact on Pogo Pin Socket Performance" Valts Treibergs, Everett Charles Technologies
- 2005
  - "Challenges Of Contacting Lead-Free Devices" Brian Sheposh, Johnstech
- 2006
  - "Socket Performance Over Time and Insertion Count With Pb-Free Applications" Jeff Sherry and Bert Brost, Johnstech International.
- 2008
  - "Keeping It Real: Simulating QFN and BGA Probe Performance in the Test Lab" Kevin Deford, Nick Argyros, Jon Diller, Synergetix

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Background
Contact contamination

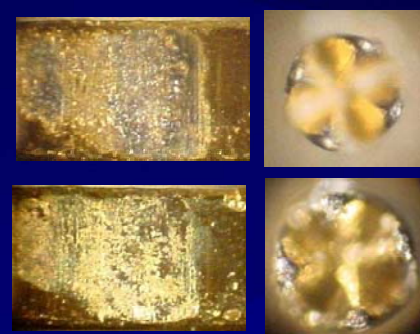
As parts transition to Pb-free a number of test floors and burn-in operations observed lower yields.

The same problems were observed in both test and burn-in sockets.

This was associated with pin contamination.

From Erik Orwoll "Application of Socket Cleaning and Contact Restoration to Reduce Burn-In Test Device Programming Cost". BiTS 2005

From Burd "Development of a Production Worthy Kelvin Contact Test Socket" BiTS 2005



From Erik Orwoll "Minimizing Spring Probe Operational Cost Using Optimized Maintenance Techniques". BiTS 2006

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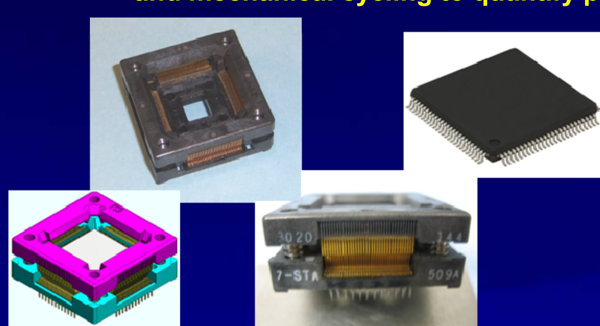
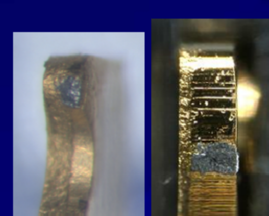
Objective - Focus of this Effort

Objective of this study

- Evaluate performance of QFP burn-in sockets for different Pb-free lead options
- Identify differences associated with contact design.
- Examine contact witness marks on QFP leads.
- Compare contact resistance (Cres) over time, temperature and mechanical cycling to quantify performance.





Solder contamination of contact tip

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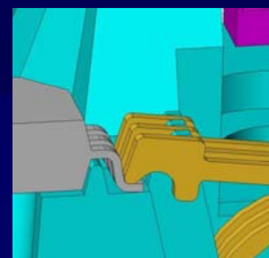
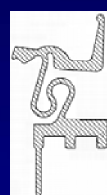
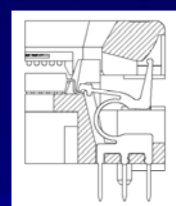
The Single Beam Contact

- Details of the Single Beam contact

Normal Force	21 grams
Contact Shape	0.13mm radius
Edge Condition	Stamped / sheared edge
Force-Deflection Rate	131 g/mm
Actuation Force	15 g/pin
Contact Retention	> 2500 grams







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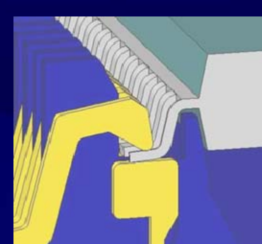
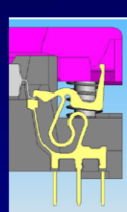
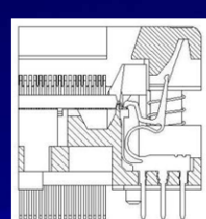
The Dual Beam Contact

- Details of the Dual Beam contact

Normal Force	35 grams
Contact Shape	0.1 mm radius
Edge Condition	Stamped / sheared edge
Force-Deflection Rate	128 g/mm
Actuation Force	18 g/pin
Contact Retention	> 800 grams







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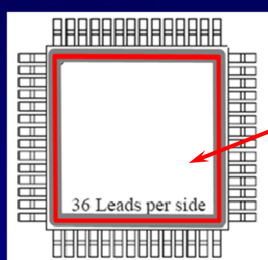
Approach

Use production packages with:-

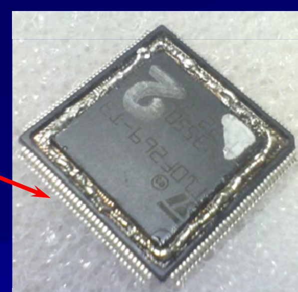
- Matte Sn
- NiPdAu
- PbSn – for comparison with historical performance and reliability.

Daisy chain packages for Cres measurements not available.

Modify production packages by machining and shorting lead frame.



Slot machined in lid and leads shorted



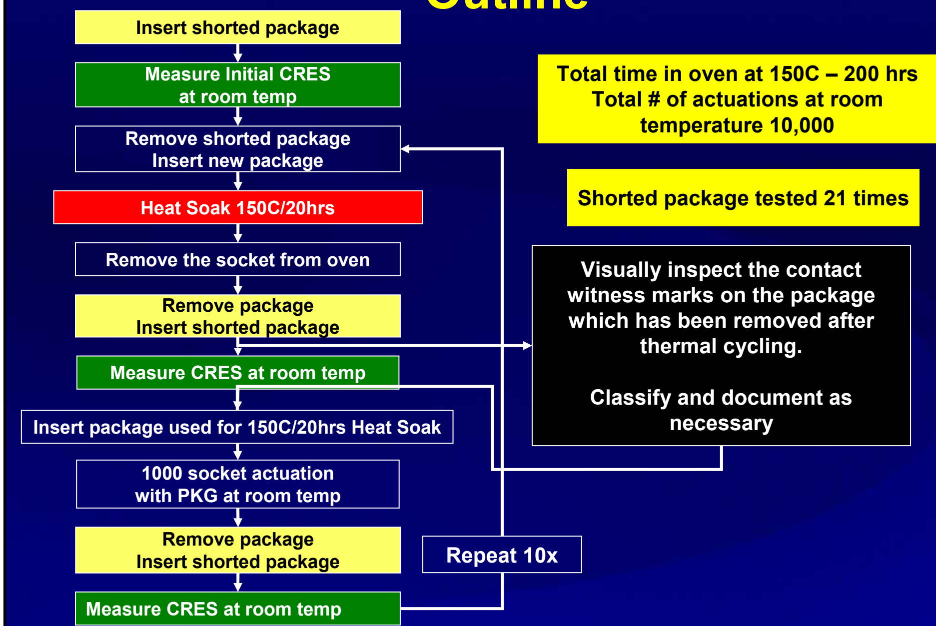
Test Details

The testing involved a series of actuations and thermal exposures.

1) Insert shorted package.
2) Measure initial CRES at room temperature.
3) Remove shorted package. Insert new package.
    - 3.1 Heat soak for 20 hours at 150° C.
    - 3.2 Remove socket from oven, cool to room temperature.
        - 3.2.1 Remove package and photograph witness marks.
            - 3.2.1.1Classify and document as necessary.
    - 3.3 Insert shorted package.
        - 3.3.1 Measure CRES at room temperature.
    - 3.4 Remove shorted package.
        - 3.4.1 Insert package from previous heat soak.
        - 3.4.2 Actuate socket one thousand (1000) times at room temperature.
    - 3.5 Remove package. Insert shorted package.
        - 3.5.1 Measure CRES at room temperature.
4) Repeat step 3.0 ten (10) times.

Schematically …….

Outline



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Validating Different Test Sites

- To ensure that the measurement technique was identical in Japan and the USA we created a test board with known resistors.
- The average resistance was measured by both labs.
- The results of the measurements were not shared between the laboratories until all testing was completed.
- Some of the results are shown below. The correlation was excellent validating the different test labs

Pin Number	CRES Data (Milli-Ohms)			
	Avg Japan	Avg Phoenix	Delta	Delta %
31-50	33.17	33.04	0.13	0.4%
31-51	24.97	24.93	0.0p4	0.1%
25-56	16.33	16.26	0.07	0.4%
25-57	11.83	11.80	0.03	0.3%

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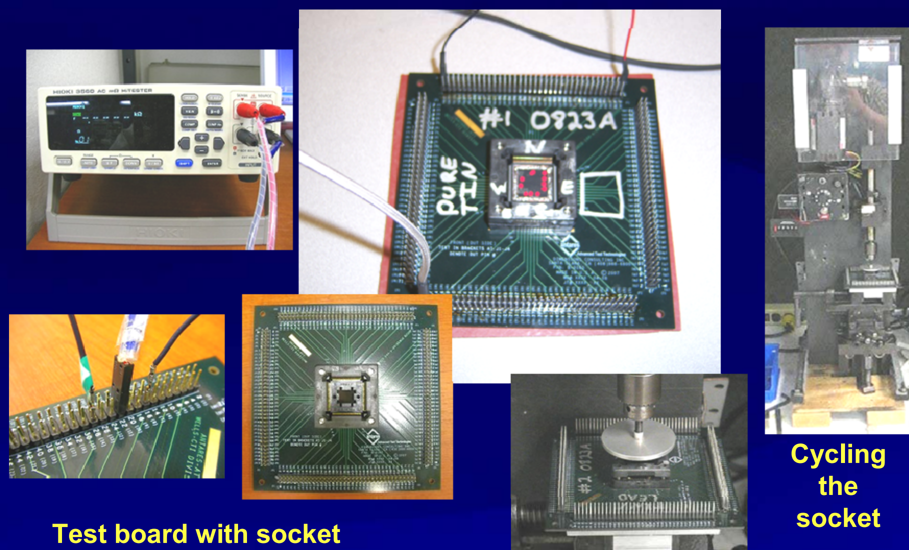
Testing

Some images of the test set-up

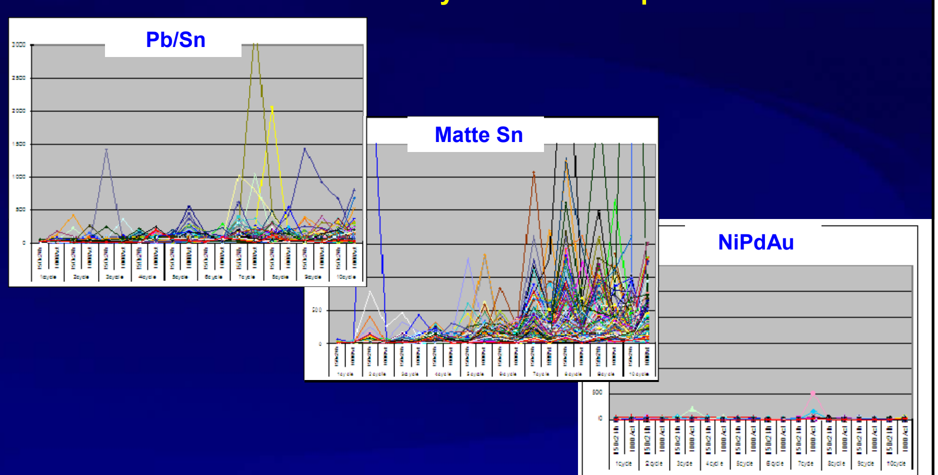


Test board with socket

Cycling the socket

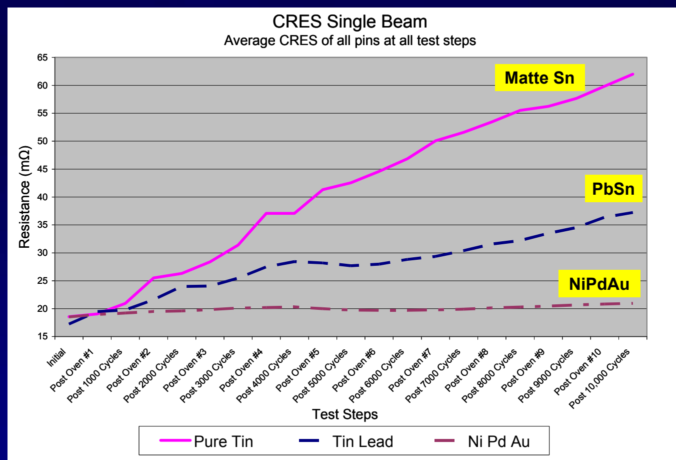
Cres Results – The Data

- 144 data points at each measurement
- Initial data plot showed a lot of "noise".
- BUT - Basic differences clearly visible in first pass look at data.



Cres Results – Single Beam

- NiPdAu is most stable
- Matte Sn increases as contact is contaminated
- PbSn performance between NiPdAu and Matte tin (Sn)



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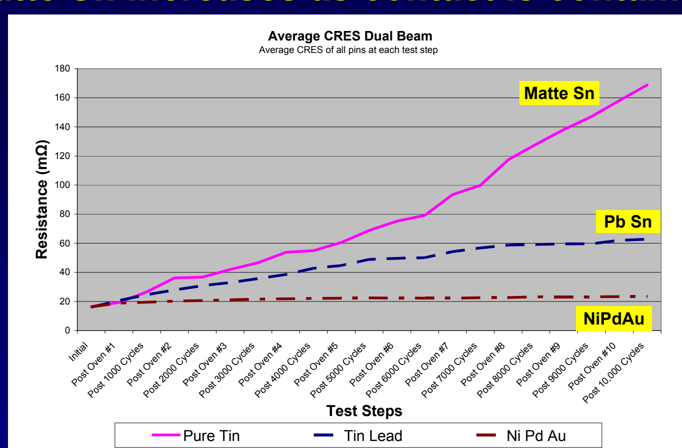
Cres Results – Dual Beam

- NiPdAu is most stable
- Matte Sn increases as contact is contaminated



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Cres Results – Summary

Lead Plating	Start of test		After 10 thermal cycles and 10,000 actuations	
	Single Beam	Dual Beam	Single Beam	Dual Beam
Matte Sn	19	17	105	221
PbSn	17	16	54	90
NiPdAu	19	16	24	25

- **The Cres increases with thermal cycles and mechanical actuations.**
- **This is associated with contamination of the contact tip.**
- **The harder NiPdAu has the most consistent Cres over time and temperature exposure.**
- **Matte Sn increases as contact is contaminated**
- **The single beam contact appears to have a lower Cres than the dual beam.**

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Contact Witness Marks

- **When the contact touches the package lead it will leave a “witness mark”.**
- **A key element of the testing was to evaluate the witness marks on the QFP leads.**
- **Experience has shown that a clear witness mark is indicative of good mechanical contact between the package and the contact**
- **For softer materials, such as PbSn, the witness marks become more visible after thermal cycles.**
- **Harder materials such as NiPdAu can “wear” the contact tip.**
- **The soft material will transfer to the contact and can impact contact resistance over time as shown in previous slides.**
- **The interaction between the plating and the contact can be assessed by visually examining:-**
  - **The witness marks on the package lead**
  - **The wear/contamination on the contact tip.**
- **The next slides examine this for the three package lead materials and the two contact types.**

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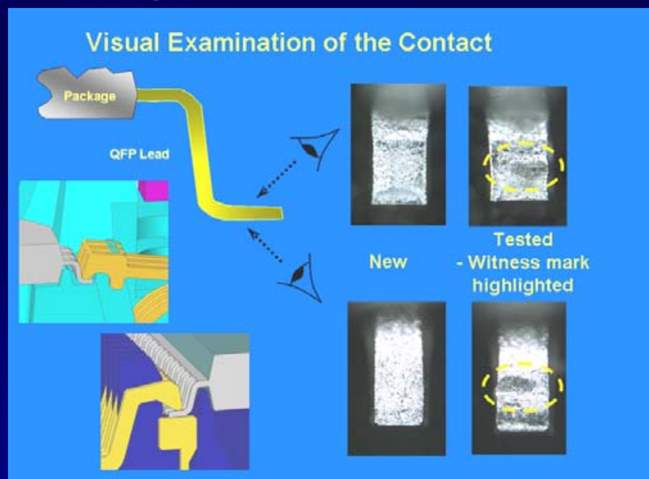
Evaluating Contact Witness Marks

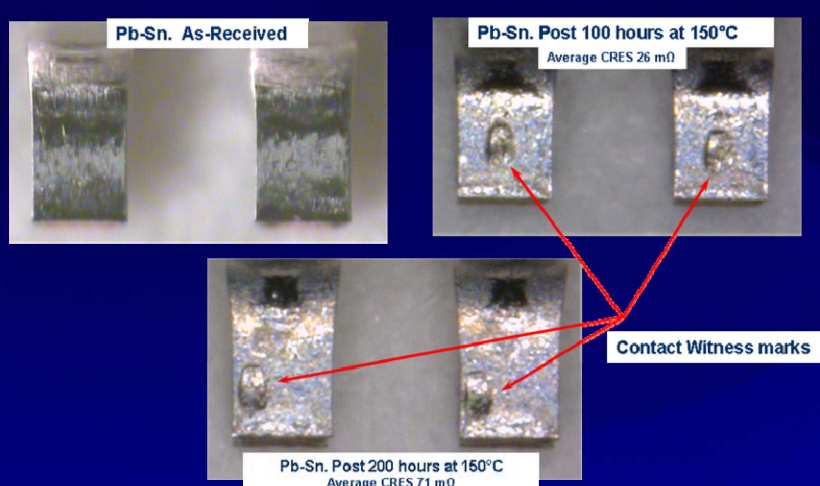
- **A key element of the testing was to evaluate the witness marks on the QFP leads and the condition of the contact tip**



3/2009 Contacting Pb-free finishes 19

Contact Witness Marks
– Single Beam PbSn

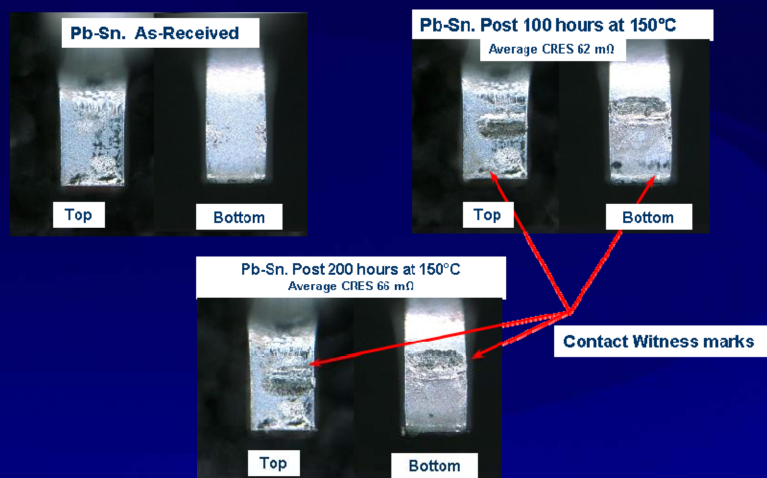
- Initial CRES 17 mΩ



3/2009 Contacting Pb-free finishes 20

Contact Witness Marks – Dual Beam PbSn

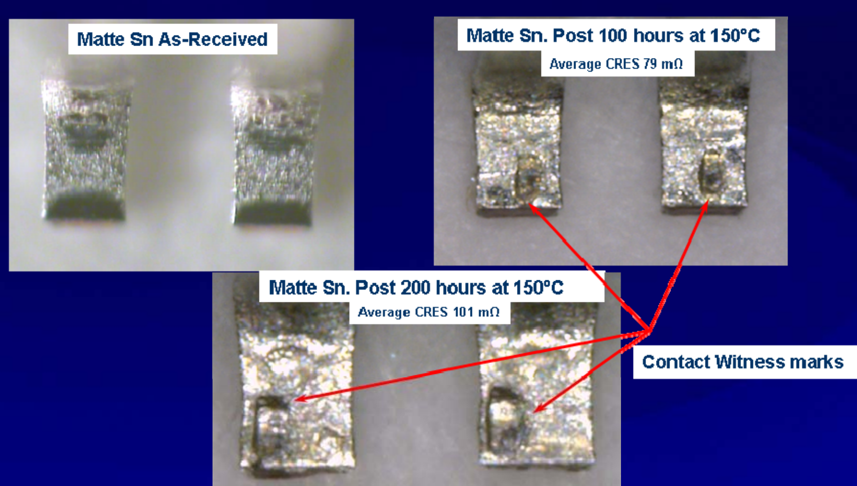
- Initial CRES 16 mΩ



3/2009 Contacting Pb-free finishes 21

Contact Witness Marks – Single Beam Matte Sn

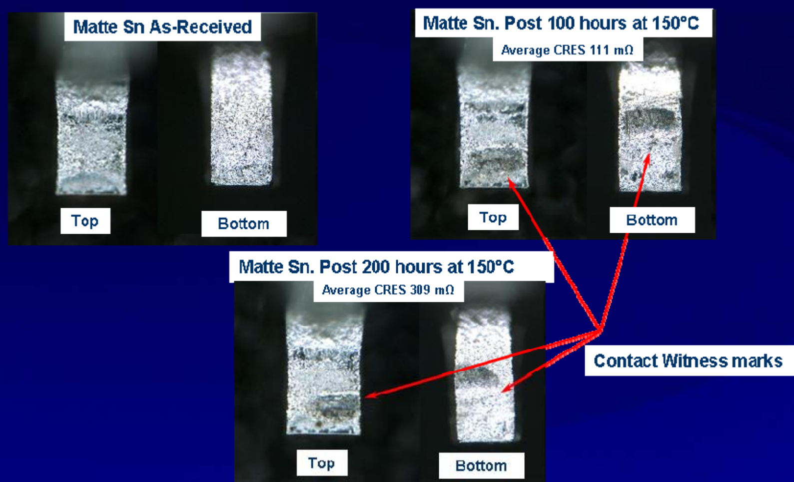
- Initial CRES 19 mΩ



3/2009 Contacting Pb-free finishes 22

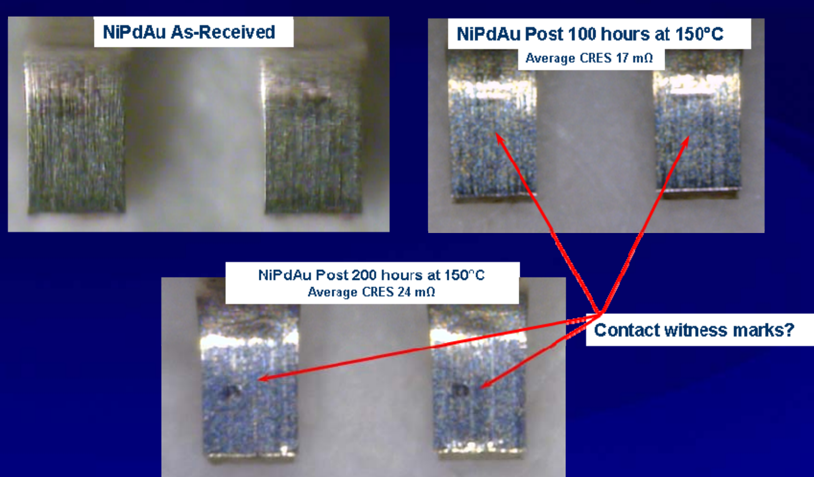
Contact Witness Marks
– Dual Beam Matte Sn

- Initial CRES 17 mΩ



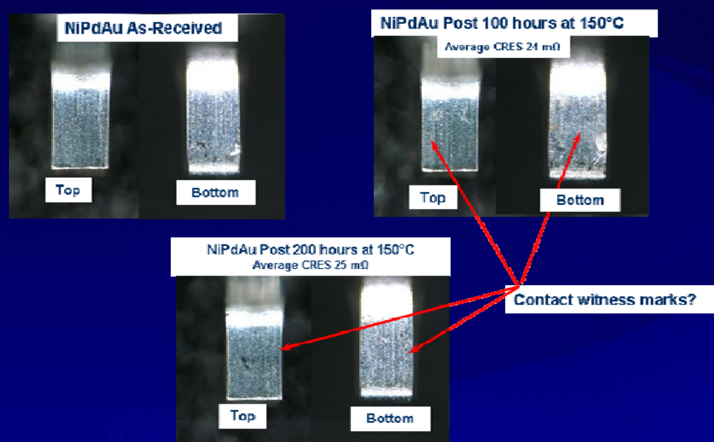
Contact Witness Marks
– Single Beam NiPdAu

- Initial CRES 19 mΩ



Contact Witness Marks
– Dual Beam NiPdAu

- Initial CRES 16 mΩ
- Because of the hardness of the NiPdAu the witness marks are not easily identified



3/2009 Contacting Pb-free finishes 25

Contact Contamination

- During cycling and thermal exposure the contact tip can become contaminated.
- This contamination builds up, oxidizes and leads to the increase in the contact resistance.
- As burn-in times, temperatures and currents increase, the transfer of material to the contact becomes a more significant problem and impacts the reliability and life of the sockets.
- Contacts can be chemically cleaned to remove accumulated solder.

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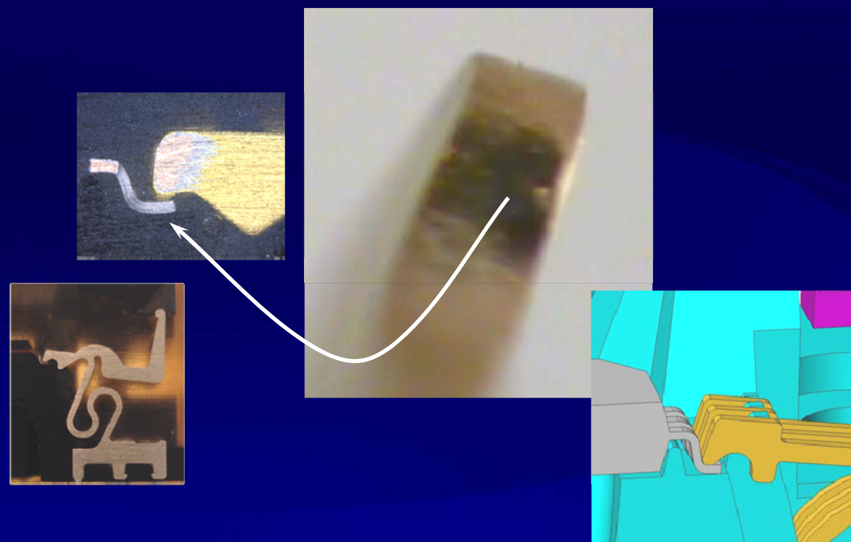
Single Beam Contact Tip

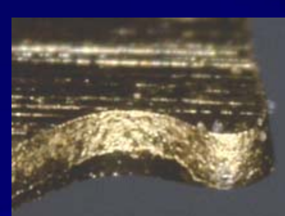


Single Beam Contact Contamination

- Photographs were recorded after 10 test cycles. Accumulated time, temperature and cycles is
  - 200 hrs @ 150°C
  - 10,000 socket actuations at room temperature
- No contamination by the NiPdAu

Matte Sn

Pb-Sn



NiPdAu

Dual Beam Contact Contamination

- The next slides document the contact tip after testing.
- **No cleaning**, by brushing or blowing air was performed during the course of these trials.
- The images show the contamination on the top and bottom contact tip for each type of lead finish.
- Accumulation of the softer PbSn and Matte Sn can be seen on the tip.
- The harder NiPdAu abrades or polishes the tip.
- All the photographs were recorded after 10 test cycles. Accumulated time at temperature and cycles is
  - 200 hrs @ 150°C
  - 10,000 socket actuations at room temperature

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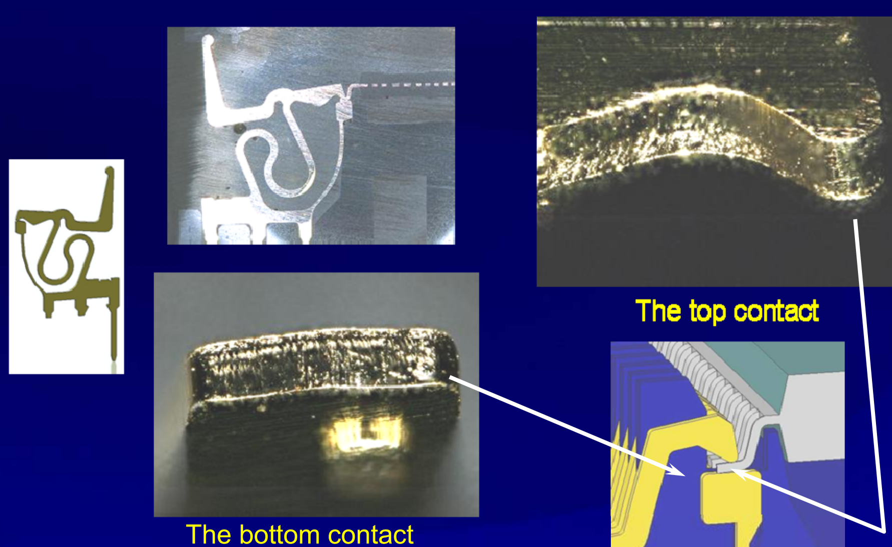
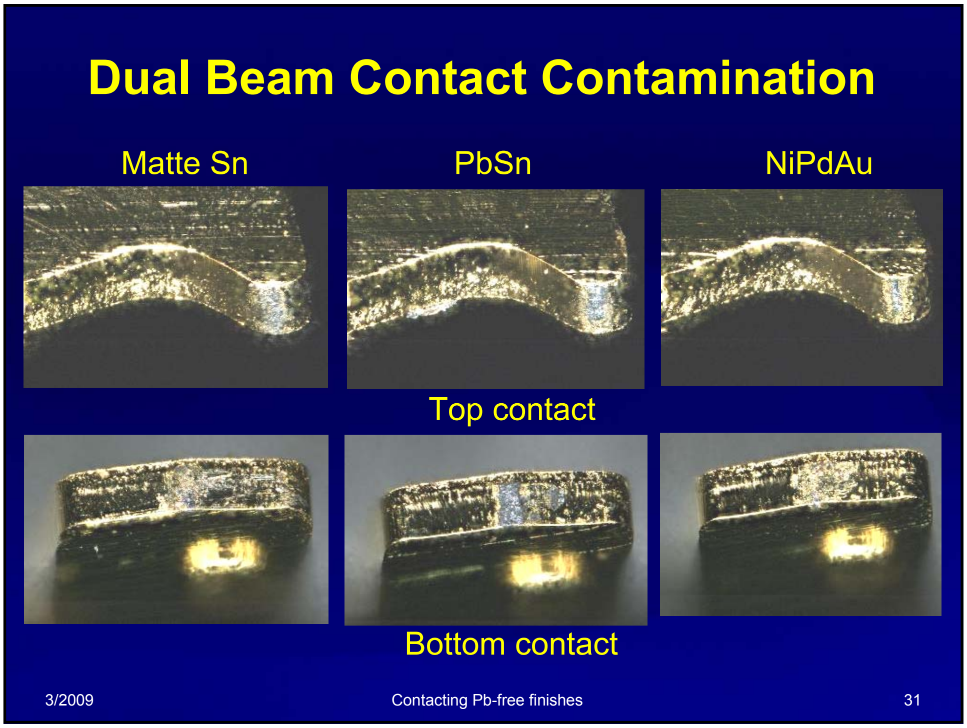
Dual Beam Contact Tip



3/2009 Contacting Pb-free finishes 30


Dual Beam Contact Contamination
Matte Sn
PbSn
NiPdAu
Top contact
Bottom contact
3/2009
Contacting Pb-free finishes
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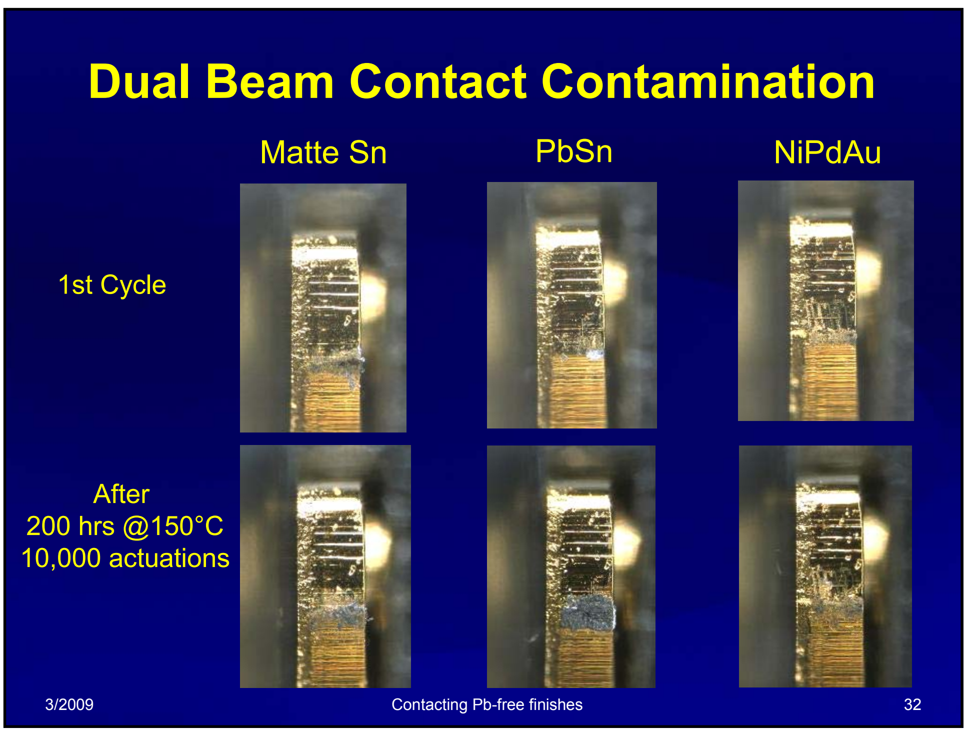
Dual Beam Contact Contamination
Matte Sn
PbSn
NiPdAu
1st Cycle
After
200 hrs @150°C
10,000 actuations
3/2009
Contacting Pb-free finishes
32

Conclusions

The results show:-

- The QFP lead plating has a significant effect on the increase in the CRES over multiple cycles
- The most reliable method to evaluate consistent and reliable interconnection is to measure the contact resistance over time with multiple thermal and mechanical cycles
- The visual appearance of a witness mark on the QFP lead does not indicate a “reliable” interconnect.
- Packages with Matte Sn and Pb-Sn leads had very clear “witness marks” however the CRES increased over time.
- There was no association between the appearance of a witness mark and the value of CRES. The witness mark only indicates that the contact was in mechanical contact with and “touched” the package lead.
- Packages with the harder NiPdAu showed virtually no evidence of a mechanical contact yet provided the most consistent CRES over the 10 thermal and 10,000 mechanical cycles

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Summary

The move to Pb-free has created reliability and contact life issues.

The NiPdAu system is significantly better than matte tin (Sn) but contact wear, due to the hardness has been reported.

Broad adoption of NiPdAu in packages for consumer applications is unlikely due to the costs of this lead finish.

Additional work is required to evaluate alternate contact finishes which might improve the reliability of the contact regardless of device lead finish.

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Acknowledgments

- The work reported here is the result of much diligent work by the Antares global team especially by the following:
  - Phoenix
    - Scott Condor
    - Paul Kennedy
  - Japan
    - Yoshinori Harada
    - Kenji Sotowa
  - Europe
    - Marco Michi
    - Trevor Beard

Current-Voltage Nonlinearities in Test Socket Contacts

Gert Hohenwarter
GateWave Northern, Inc.

2009 BiTS Workshop
March 8 - 11, 2009

GateWave Northern, Inc.

Objective

- *Measure representative samples that exhibit nonlinear resistance*
- *Establish range of contact resistance variations under applied current*
- *Identify ways to model variations*
- *Examine impact of nonlinear resistance variations on socket performance*

Approach

- *Perform 4-terminal (Kelvin) DC measurements*
- *Examine reproducibility and dependence on test cycle as well as mechanical cycle number*
- *Compare SPICE model I-V with measured sample*
- *Evaluate impact of nonlinearities in representative application environments*

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Tools Used

- *Standard DC test for I-V and R measurements*
- *SPICE circuit analysis (predicts currents, voltage waveforms and S-parameters)*
- *Fourier transform of SPICE output for harmonic content examination*
- *GateWave LI-1000A low impedance RF probe*

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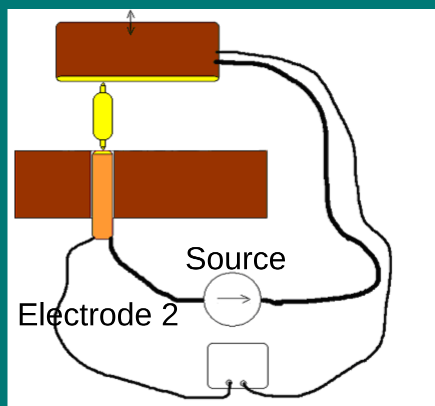
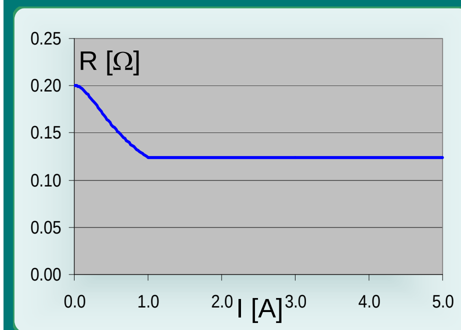
DC test setup

Electrode 1

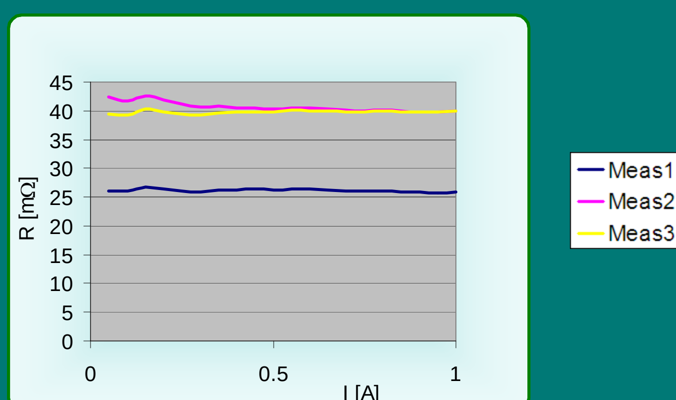


DVM



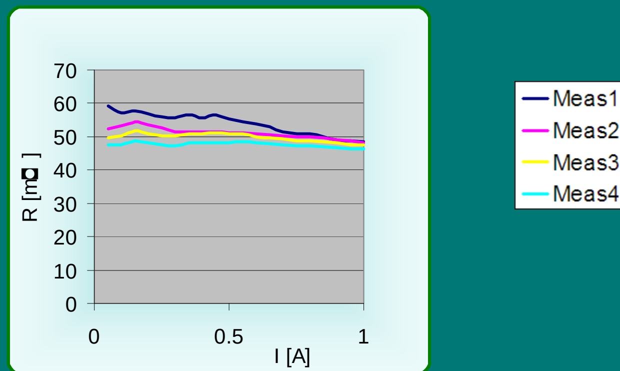
Resistance – current relationship example

R as a function of drive current Au contact surface



Meas2, 3 same contact, without additional actuation

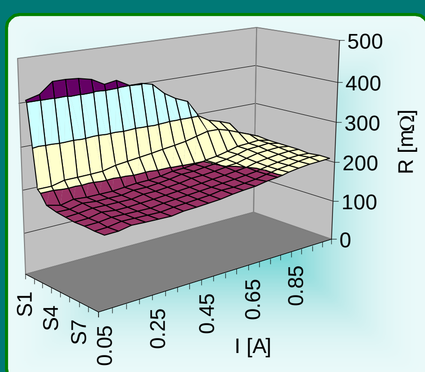
R as a function of drive current Cu contact surface



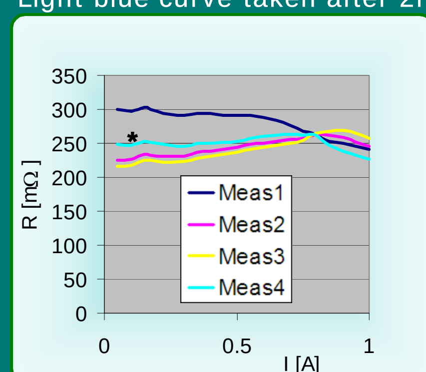
Successive measurements without additional actuation

R as a function of drive current Al contact surface

*Light blue curve taken after 2h



First touch

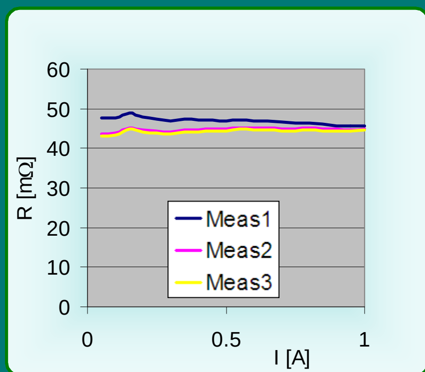


Actuated

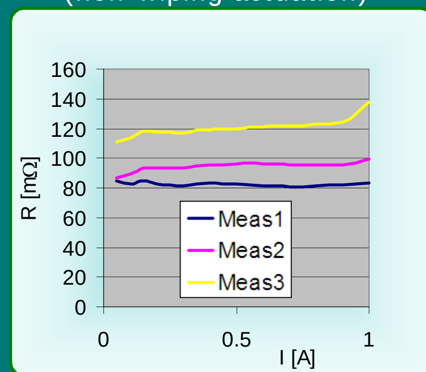
Each graph: Successive measurements without additional actuation

R as a function of drive current SAC105 contact surface

(non-wiping actuation)



First touch



Actuated

Each graph: Successive measurements without additional actuation

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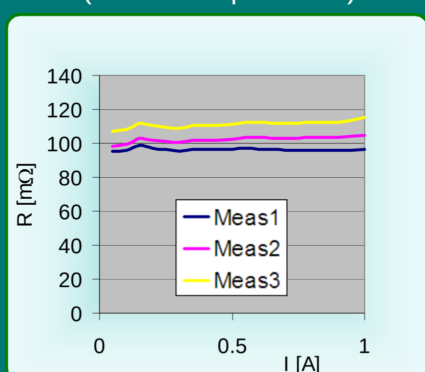
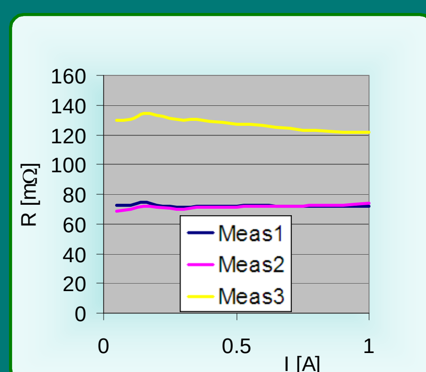
R as a function of drive current SAC105 contact surface

(increased pressure)



3rd actuation



4th actuation

Each graph: Successive measurements without additional actuation

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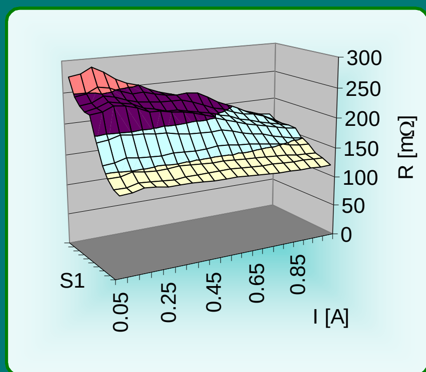
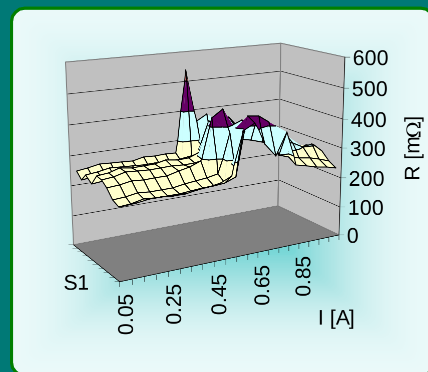
R as a function of drive current
SAC105 contact surface



1000 cycles



3500 cycles

Each graph: Successive measurements without additional actuation

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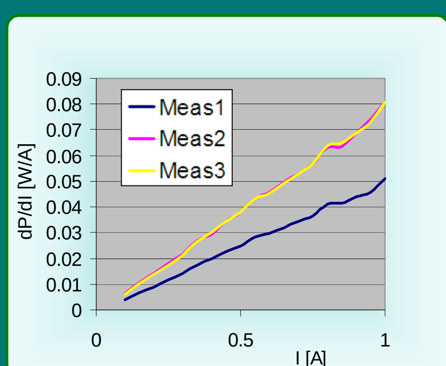
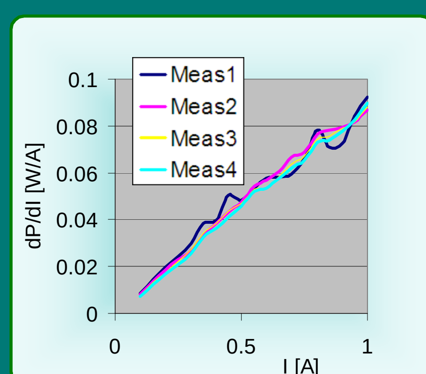
dP/di as a function of drive current
Au and Cu contact surfaces



Au



Cu

Each graph: Successive measurements without additional actuation

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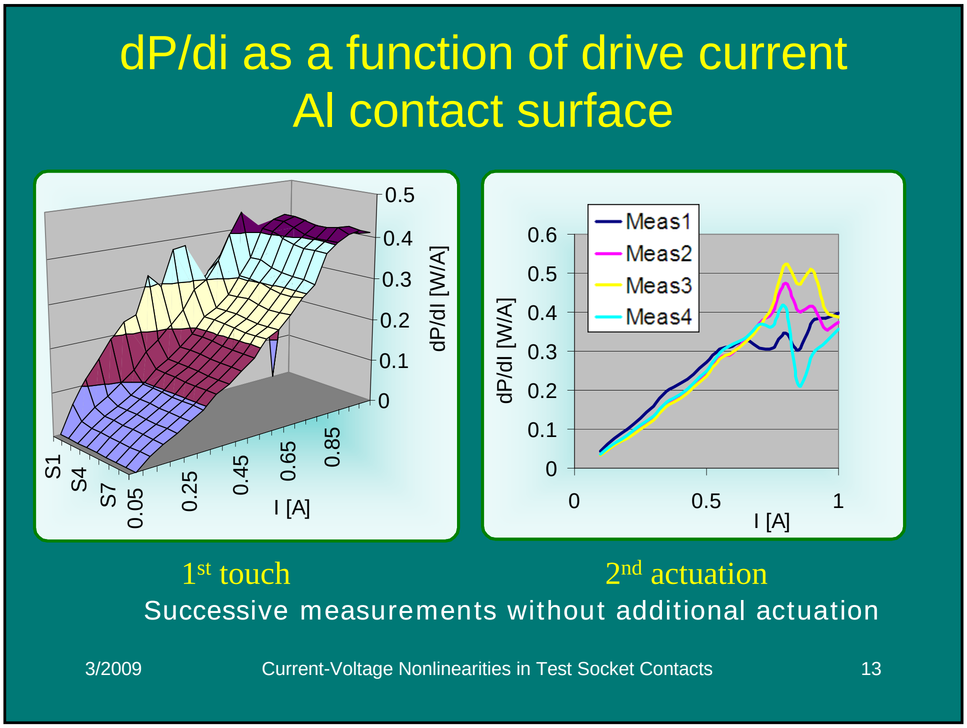
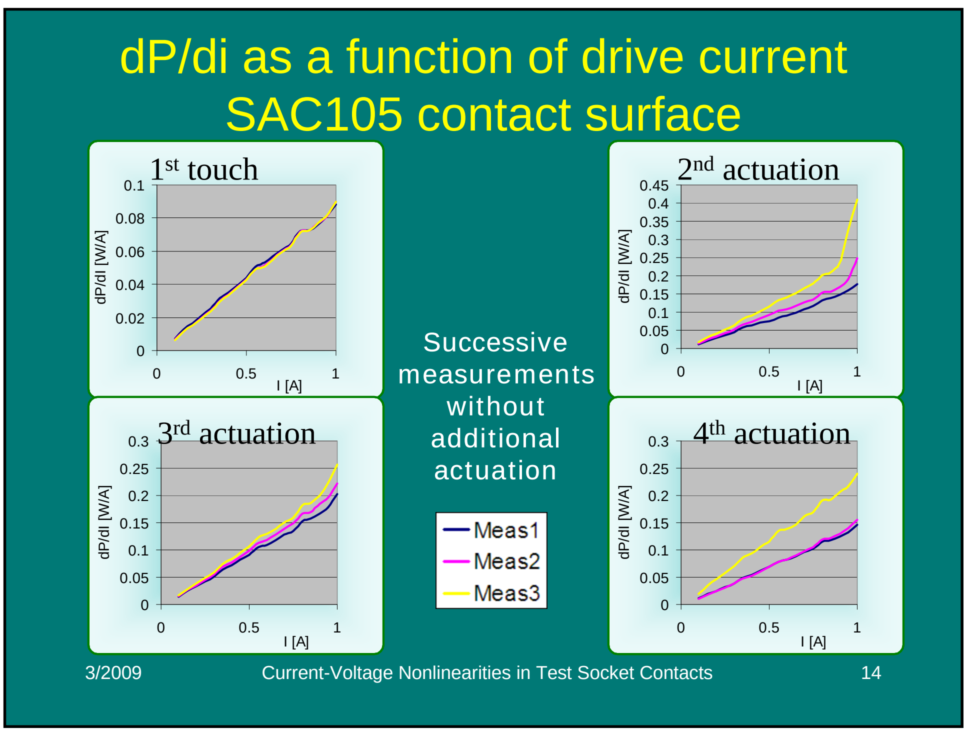
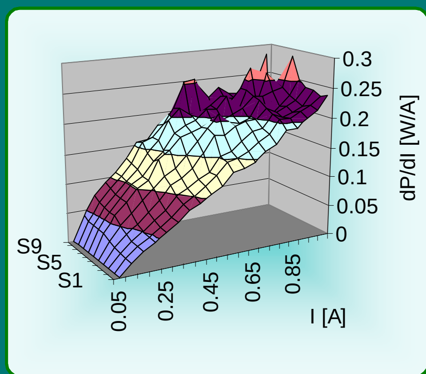
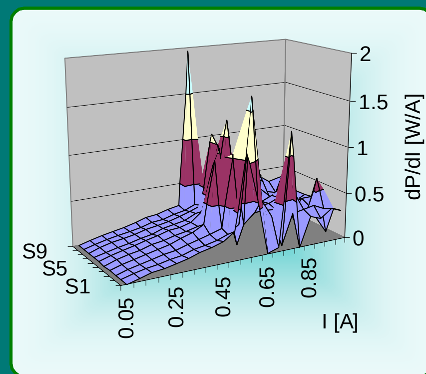

dP/di as a function of drive current
Al contact surface
0.5
0.4
0.3
0.2
0.1
0
dP/dI [W/A]
S1
S4
S7
0.05
0.25
0.45
0.65
0.85
I [A]
Meas1
Meas2
Meas3
Meas4
0.6
0.5
0.4
0.3
0.2
0.1
0
dP/dI [W/A]
0
0.5
1
I [A]
1st touch
2nd actuation
Successive measurements without additional actuation
3/2009
Current-Voltage Nonlinearities in Test Socket Contacts
13


dP/di as a function of drive current
SAC105 contact surface
1st touch
0.1
0.08
0.06
0.04
0.02
0
dP/dI [W/A]
0
0.5
1
I [A]
2nd actuation
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
dP/dI [W/A]
0
0.5
1
I [A]
Successive measurements without additional actuation
3rd actuation
0.3
0.25
0.2
0.15
0.1
0.05
0
dP/dI [W/A]
0
0.5
1
I [A]
Meas1
Meas2
Meas3
4th actuation
0.3
0.25
0.2
0.15
0.1
0.05
0
dP/dI [W/A]
0
0.5
1
I [A]
3/2009
Current-Voltage Nonlinearities in Test Socket Contacts
14

dP/di as a function of drive current
SAC105 contact surface





1000 cycles 3500 cycles

Successive measurements without additional actuation

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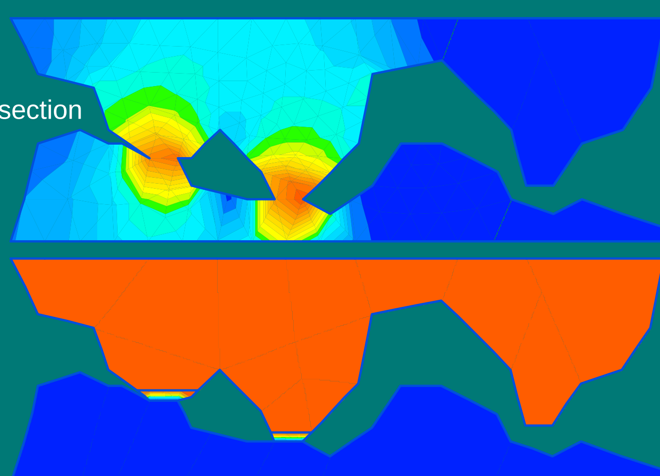
Potential causes

Asperities:
Reduced cross-section

Interface layers:
High resistance



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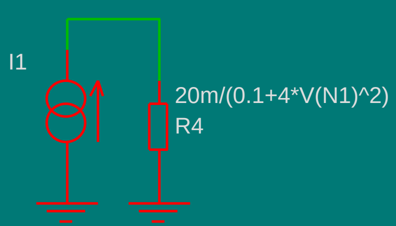
Potential causes

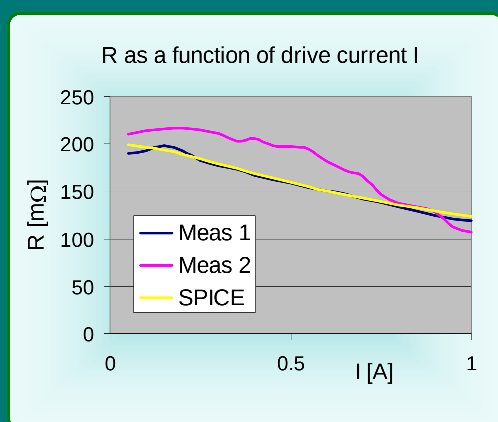
Type	*Change due to*	*Effect*	*Reversible*	*Speed*
Asperities				
(metal to metal)	Heating	Shape change	no	µs
		R(T)	yes	µs
Interface layers				
(MOM,Schottky)	Barrier	Nonlinear R	yes	GHz
	Heating	R(T)	yes	µs
Combination	-"-	-"-		µs, GHz
Modification	Chemistry	e.g. oxidation	no	µs

3/2009 Current-Voltage Nonlinearities in Test Socket Contacts 17

Nonlinear circuit model



SPICE engine allows for nonlinear R as a function of voltage at a node in the circuit



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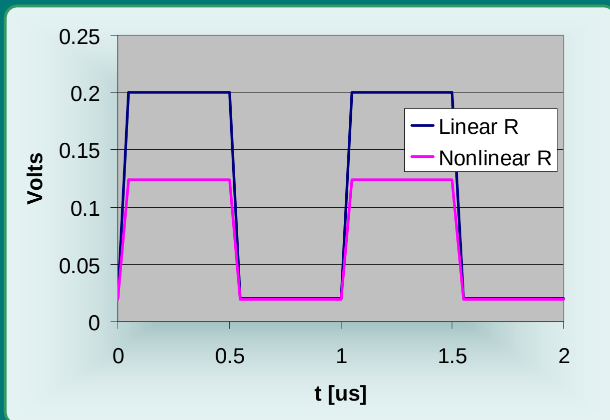
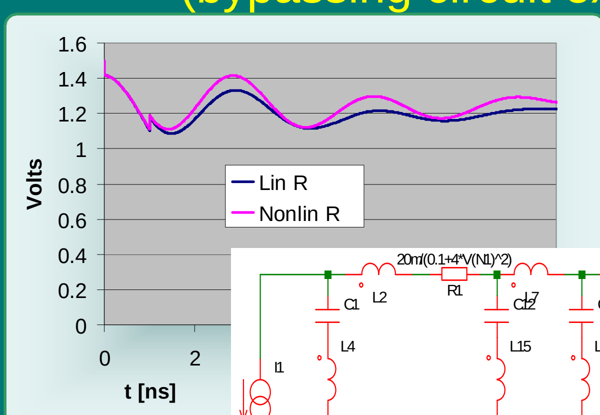
Effect of nonlinearity in digital circuit

Example: Current draw varies linearly between 100 mA and 1 A



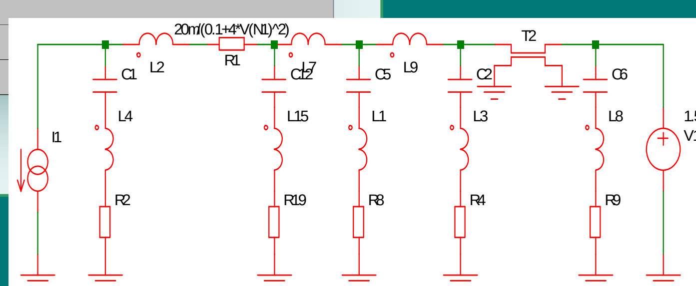
The resistance decrease with increasing current results in a lower voltage drop across the contact for the nonlinear resistance case

Digital signal nonlinear response (bypassing circuit example)

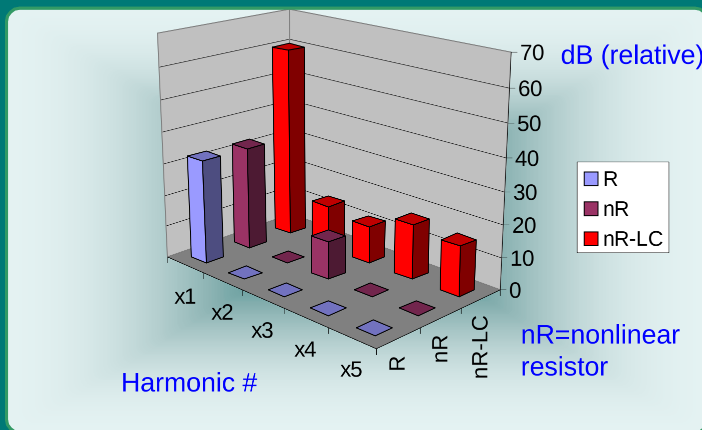


The nonlinear resistance results in increased ringing of the supply voltage after a current step of 750 mA/1ns.

PDS approximation



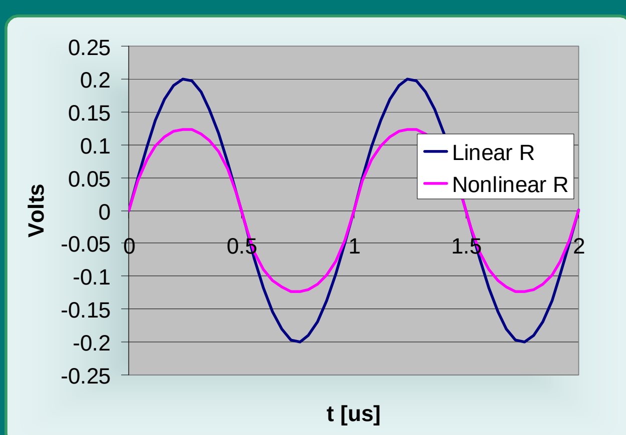
Harmonic strength in bypassing application



Presence of a bypassing network plus inductance on socket causes additional components and stronger harmonic response (red)

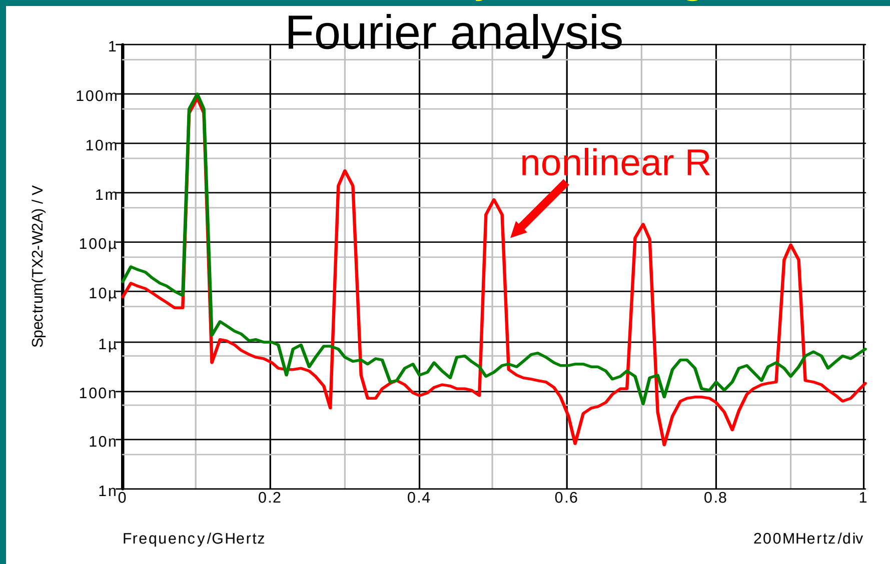
Effect of nonlinearity in analog circuit

Example: Current varies by 1 A



The lower voltage drop in the nonlinear case results in a distorted and non-sinusoidal waveform

Effect of nonlinearity in analog circuit



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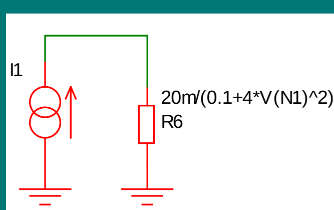
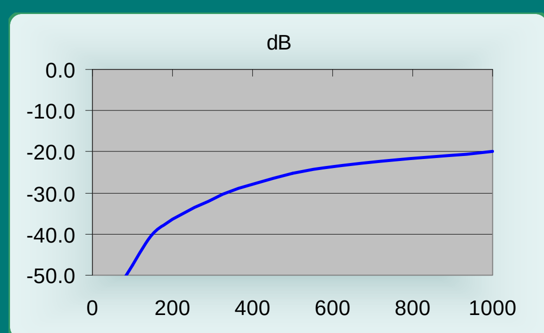
Harmonic content in dB

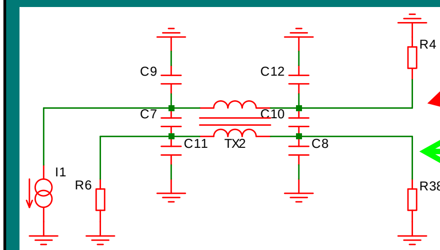




Sinusoidal current applied to nonlinear contact, curve shows strength of 3rd harmonic as current amplitude is increased

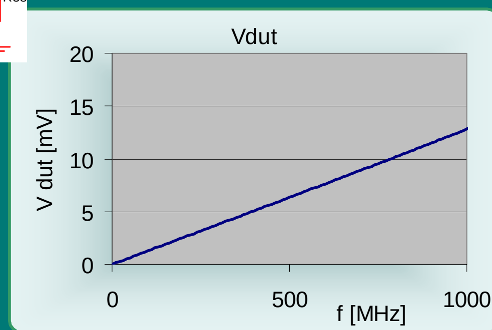
3/2009 Current-Voltage Nonlinearities in Test Socket Contacts 24

Harmonic signal level example



GND return path

Signal path to DUT



Impact of a 5 mA GND return current component at frequency f [MHz] on the level of crosstalk into the signal input of the DUT

Conclusion

- Examples show non-linear resistance observed during DC testing
- Lead-free SAC105 compound very sensitive to cycling with the particular contact chosen here
- Harmonic frequency content can become significant in applications like mixed signal environments, A/D converters, power amplifiers etc.
- Impact of non-linear I-V curve on performance must be individually assessed
- Future work will include RF measurements and examination of increased noise generation in contact

Evaluation of Different Price-Point Spring Pin Contactors for an RF Application

James Migliaccio & John Capwell
RFMD

2009 BiTS Workshop
March 8 - 11, 2009

Overview

This paper will review several spring pins from different pricing tiers for:

- RF Integrity – S-parameter analysis to extract equivalent circuit parameters and measured bandwidth
- Robustness - Mechanical or production life testing
- Variance by segment - Affect of cost on performance

3/2009 Evaluation of Different Price-Point Spring Pin Contactors for an RF Application 2

Spring Pins

Pins chosen for analysis are marketed for RF applications and designed to work on 0.5 mm pitch or smaller.

Pins selected from three different price tiers:

- Low price [1 pin, A]
- Mid price [3 pins, B, C, D, E]
- Premium price [1 pin, F]

3/2009 Evaluation of Different Price-Point Spring Pin Contactors for an RF Application 3

Process

Pin holders were fabricated for a ground-signal-ground (GSG) configuration on 500um pitch. The holders were designed to hold the pins at their working height for measurement.

All holders used the same material and mounting geometry.

Holders and pins were mounted on a small substrate for measurement in order to capture the pin to board transition.

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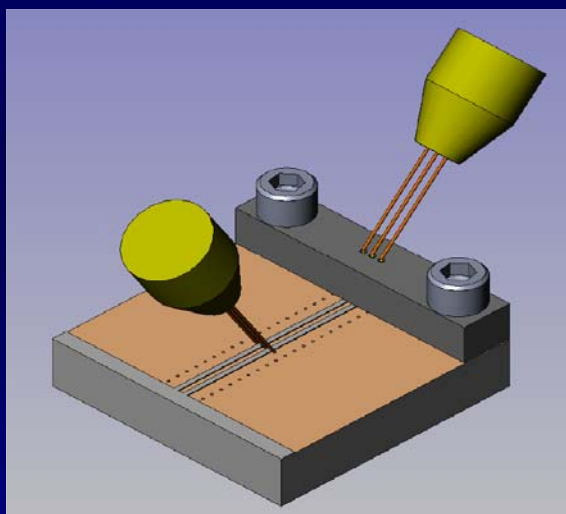
Process (cont)

- Utilized same PCB for each pin holder
- Cascade probe station
- Pins were probed using GGB probes on 0.5mm centers
- 40 GHz Agilent VNA
- S-Parameters collected for each Pin setup
- S-Parameters measured on PCB – moved reference plane to edge of pins (for de-embedding)

Measurement Setup



Extracting Circuit Parameters

- Probes calibrated using standards – 20 GHz validity range
- PCBs designed for short, open, load and thru in order to de-embed board
- Series inductance, resistance, and shunt capacitance extracted from S-Parameters
- De-embedding performed using ADS software
- ADS used to fit measurements to circuit parameters
- Direct measurement of bandwidth

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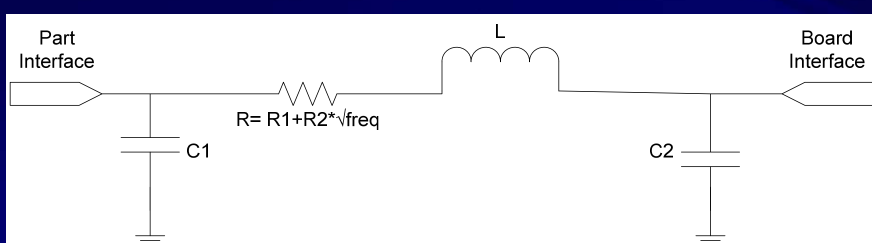
Equivalent Circuit Model

S-parameter data is matched to a circuit model which has a frequency range of validity



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Electrical Properties

Pin	L1 (nH)	R 1GHz (Ω)	C1 (pF)	C2 (pF)	1dB BW	Model Fit
A	0.88	2.10	0.11	0.18	>10 GHz	<10 GHz
B	0.59	0.43	0.12	0.18	>10 GHz	<10 GHz
C	0.64	0.50	0.06	0.14	>10 GHz	<10 GHz
D	1.23	0.83	0.06	0.32	>6 GHz	<6 GHz
E	1.00	0.89	0.14	0.27	>10 GHz	<10 GHz
F	1.05	1.14	0.12	0.12	>6 GHz	<6 GHz

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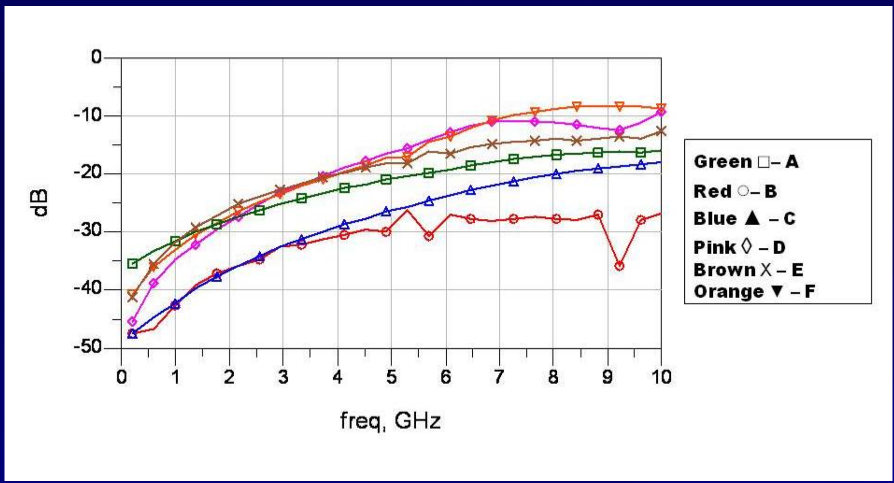
Return Loss



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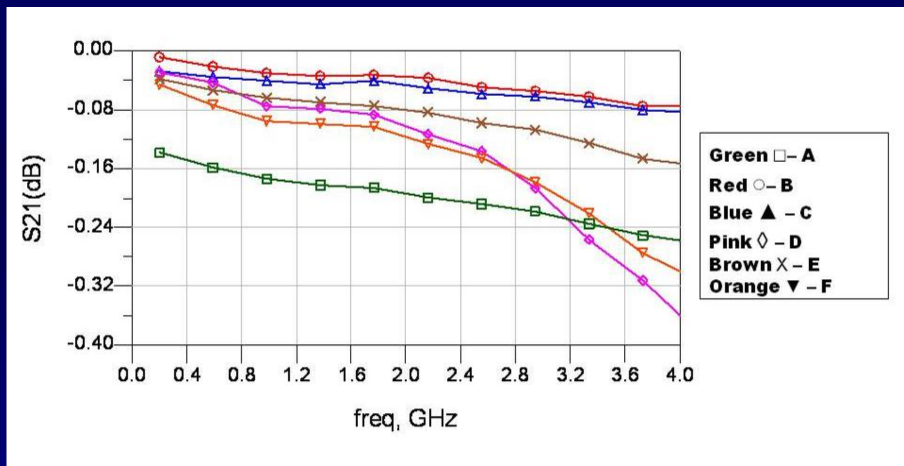
Insertion Loss



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Mechanical Review

- In our application, most pins tend to have mechanical failures (fatigue) before electrical issues
- For life testing - fully populated sockets mounted to PCB and tested to failure
- Mechanically cycled, tested, cycled, … to failure
- Good life testing results are not a guarantee of production life
- Production data if available is preferred

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Mechanical Properties

Pin	Working Height (mils)	Cycle Life (K)	Lab or Prod
A	101	600+	Lab
B	85	300+	Lab
C	75	175+	Lab
D	104	250	Prod
E	130	Not Started	-
F	61	300+	Prod

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Conclusions

- All pins exhibit good return loss for cellular frequencies
- Equivalent circuit parameters are similar in magnitude for most pins
- Initial results looking at new pins may not indicate long term performance
- Price does not appear to correlate to mechanical lifetime
- Issues with pin holders skewed some results – Pins D&F

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Next Steps

- Refinements of pin holders for better constraint of pins
- Use thin core substrate interface between probe and pin tips
- Implement on PCB calibration – to get better pin to board transition information
- Measure pins after fixed number of cycles to understand variation during lifetime
- Use impedance analyzer in addition to VNA – improve resistance values

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