BiTS 2011 Burn-in & Test Socket Workshop

Session 2

ARCHIVE 2011

SOCKETS: BETTER BY DESIGN

New Contactor for Pb-free Ball & NiPdAu Pad
Jiachun (Frank) Zhou, Kevin DeFord, Khaled Elmadbouly
— Interconnect Devices, Inc.

Air Gap Contactor
Tuck Hon Lam—Test Tooling Solutions Group

Improving Test Sockets and Test Boards Using Embedded Capacitance Material
Mike Giesler, Alexander Barr—3M Company
Yoshihisa Kawate, Yuichi Tsubaki—Sumitomo 3M

Improvement of Dual Core Power Delivery Performance Through Modulation of Socket-Mechanical Dimension
Suchismita Ghosh, Jeremy Littrell, Satish Prathaban—Intel Corporation

New Contactor for Pb-free Ball & NiPdAu Pad

Jiachun Zhou (Frank)
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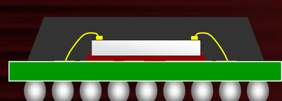
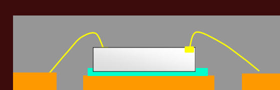
Interconnect Devices, Inc.

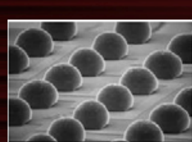
2011 BiTS Workshop
March 6 - 9, 2011

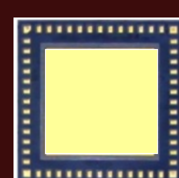


Content



- Background & Objective
- Fundamentals & Approaches
- HG Pin Basic
- HG Pin Test & Evaluation
  - Laboratory test
  - End user application
- Summary
- About Authors





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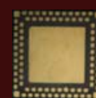
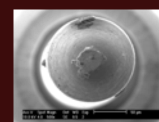
Background

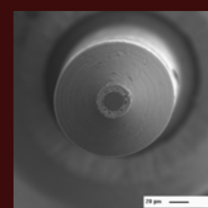
Pb free BGA package uses SAC alloys that produce more challenges to contactors due to more contamination, less cycling life, more cleanings for crown, etc.

NiPdAu pad on QFN package can cause more contactor tip wear and damage due to high hardness of pad.





Au plating contactor has exposed more weaknesses, such as quick tip wear and performance deterioration.



Hard plating, such as PdCo plating, may have problem of unstable Cres of contactor.

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Objective

Search and apply a homogeneous metal or alloy for spring probe top tip to replace conventional plating technology for Pb free BGA and NiPdAu pad QFN applications.

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Fundamental of Alloy Selection

Electrical conductivity:

Contact resistance, Cres, is related to electrical conductivity. Au plated spring probe has good Cres but deteriorates after Au is worn out on tip. Homogeneous alloy for spring probe tip needs good conductivity to keep low and stable Cres over contact cycles.

High hardness

Spring probe tip wear is a major failure mode. Currently, heat treated BeCu or C-steel are major alloys. BeCu has good conductivity but low hardness. C-steel has high hardness and wear-resistance but low electrical conductivity. Both these alloys need coating to keep good Cres.

Material	Conductivity % IACS	Hardness HV	Notes
BeCu, C17200	25	HV360	Surface corrosion
C-steel	~ 9%	HV620	High Cres & surface Oxidization

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Fundamental of Alloy Selection

Low friction at contacting Pb-free ball:

Package testing for BGA needs reliable contact and also less contaminates on crown tips. Low friction coefficient of contacting pair can reduce contact force and adhesion.

For pair of alloys contact, friction coefficient, μ_a, has function:

$$\mu_a \sim C_1 * C_2/H$$

Where:

C_1 ~ constant for geometry; H ~ hardness of alloy

C_2 ~ constant of pair alloys compatibility, affecting adhesion energy of contacting alloys. Low C_2, less adhesion energy.

Condition	C_2	Example
Identical	1.00	
Compatible	0.50	Au~Sn, Au~Cu
Limited compatibility	0.32	
Very limited compatibility	0.20	Au~Pb
Incompatible	0.125	

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Selected Homogeneous Alloy

IDI has applied one alloy for spring probe and done extensive internal and external tests. This alloy, called HG, has basic properties as in following table. Its electrical conductivity is better than C-steel and hardness is higher than BeCu.

Material	Conductivity % IACS	Hardness HV	Notes
BeCu, C17200	25	HV360	Surface corrosion
C-steel	~ 9%	HV620	High Cres & surface Oxidization
HG	15%	HV450	No concern on corrosion or oxidization

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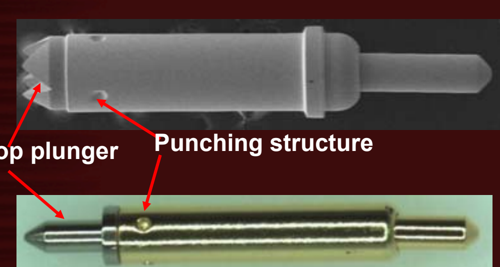
HG Pin Basic Structure

Spring probe using HG material, called HG pin, use punching assembly structure. The top plunger is made of HG material without any plating or coating. Shell and bottom plunger use same materials as other spring probes.

IDI has developed a series of HG pins on the base of existing Au plating & customer proved good performance pins, by changing Au plating top plunger to HG material. It keeps same general pin performance with improved contacting performance of crown tip.



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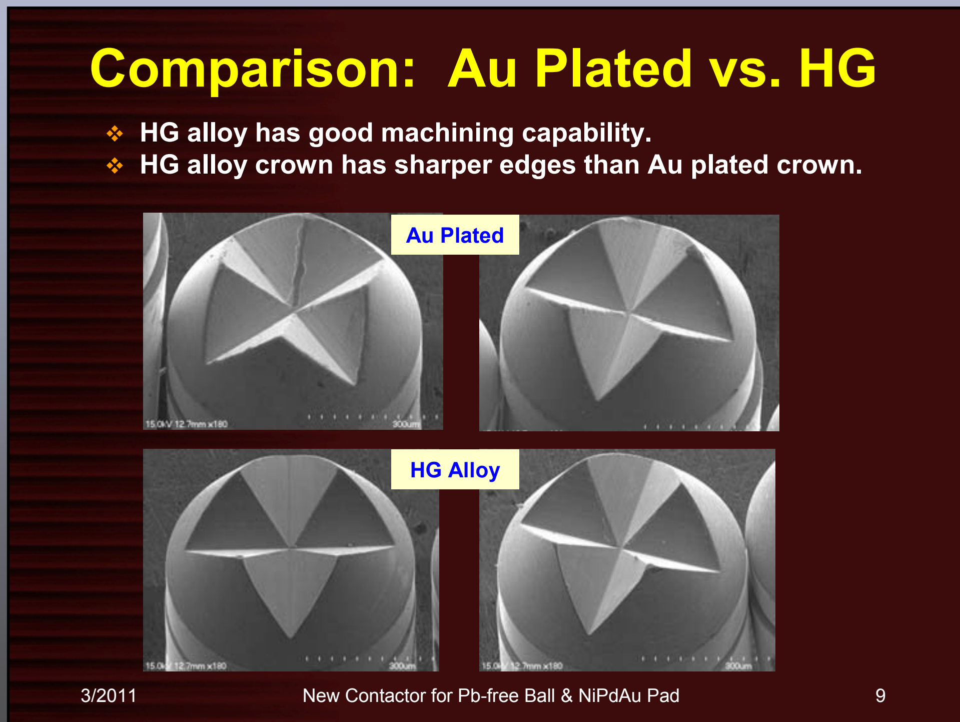
Comparison: Au Plated vs. HG
HG alloy has good machining capability.
HG alloy crown has sharper edges than Au plated crown.
Au Plated
HG Alloy
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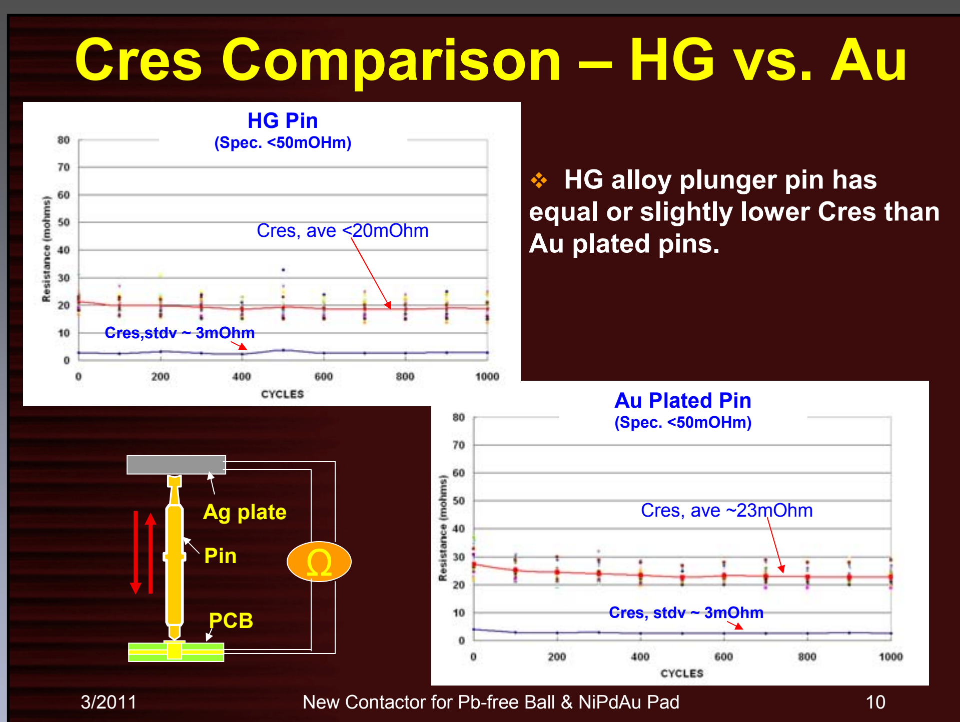
9


Cres Comparison – HG vs. Au
HG Pin
(Spec. <50mOHm)
Cres, ave <20mOhm
Cres,stdv ~ 3mOhm
Resistance (mohms)
CYCLES
HG alloy plunger pin has equal or slightly lower Cres than Au plated pins.
Ag plate
Pin
PCB
Ω
Au Plated Pin
(Spec. <50mOHm)
Cres, ave ~23mOhm
Cres, stdv ~ 3mOhm
Resistance (mohms)
CYCLES
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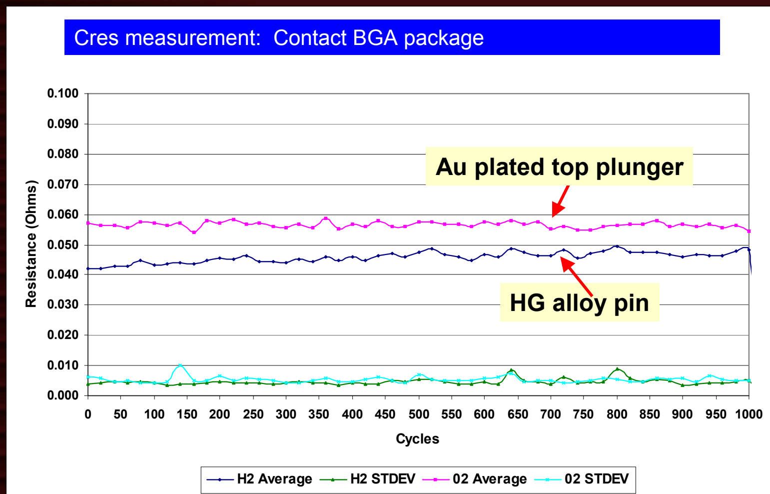
10

Cres Comparison – BGA

- Tests using BGA packages show HG alloy plunger pin has lower Cres than Au plated pins.



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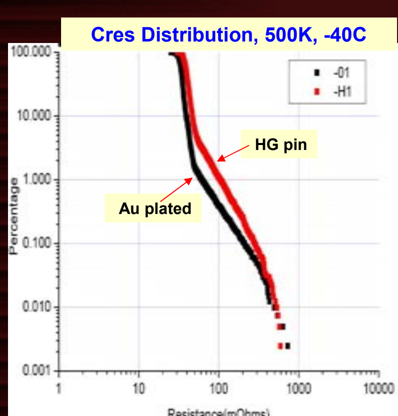
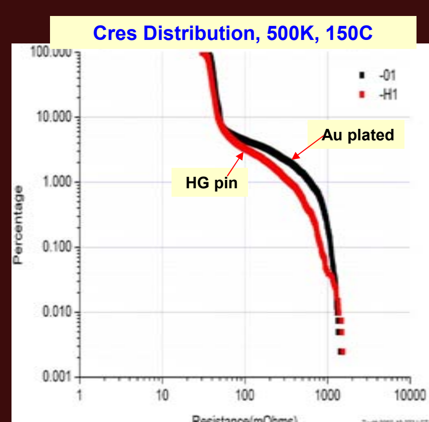
Cres Comparison – QFN Pin

- Cres of HG & Au plated pins is verified at contacting QFN pad, NiPdAu & Matte Tin.
- HG & Au plated pins have similar Cres distributions at QFN contacts over 500K cycles.





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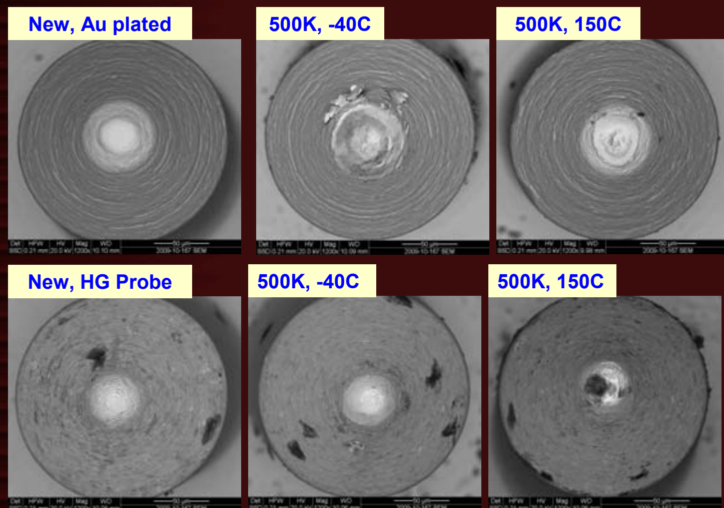
Tip Wear Comparison

- HG probe tip keeps sharp over 500K contacts on NiPdAu pad, less tip wear than Au plated pins.



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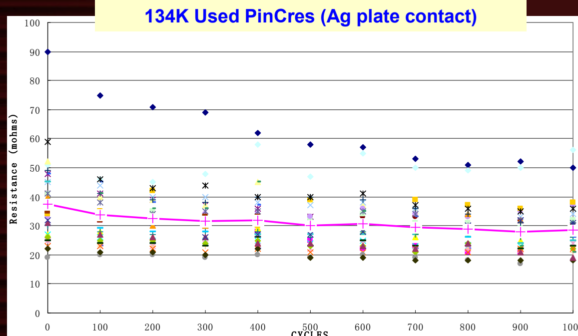
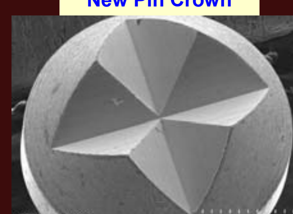
Customer Usage Example 1

- Used 623-0195-H2 pin after 134K was inspected for crown wear and Cres.
- Crown of used pin is still sharp with almost no contamination on tip.
- Cres of used pins < 30mOhm, closing to new pin Cres.

134K Used PinCres (Ag plate contact)



New Pin Crown



134K Cycled Pin Crown

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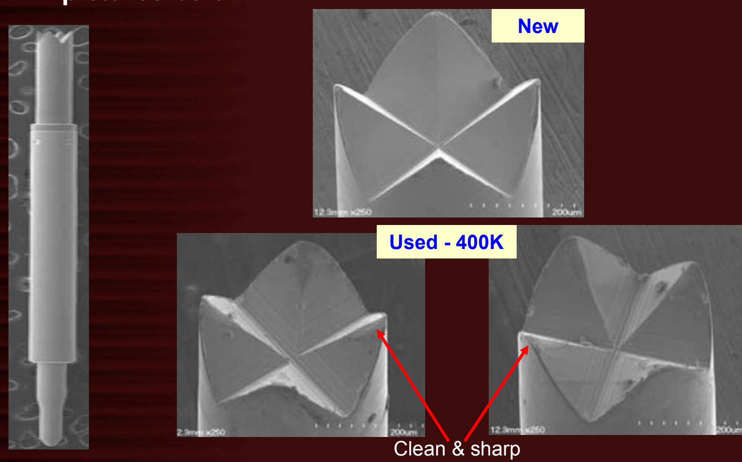
Customer Usage Example 2

- 623-0047-H7 was used at customer over 400K with better yield than new Au plated pin.
- After various cleanings during 400K cycles, crown keeps sharp, as shown in pictures below.



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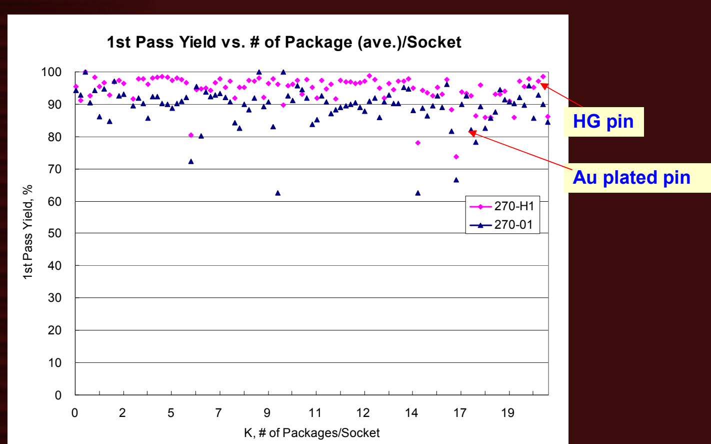
Customer Usage Example 3

- 623-0270-H1 pin was used and compared with Au plated pins.
- HG pin has better 1st pass yield (~5% higher yield) than Au pin.
- HG pin has more insertions while Au pin is replaced with new pin.



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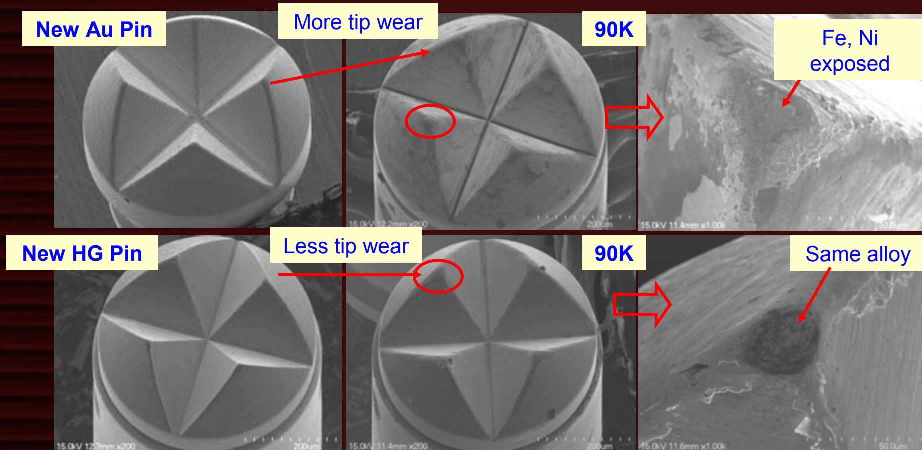
Customer Usage Example 3

- HG pin has less tip wear than Au plated pin and keep same alloy.
- At this application, Au pin life is much shorter than HG pin.



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Cleaning Method

- Generally, existing cleaning methods at customer sites for Au plated pins can be used at IDI HG probe cleaning.

Cleaning probes in socket:
- Brush + air (IPA cleaning brush)

Cleaning probes off socket:
- Ultrasonic cleaner with chemicals, Acetone, Alcohol, IPA, or other chemicals.


Ultrasonic Cleaner


Acetone/ Alcohol/ IPA

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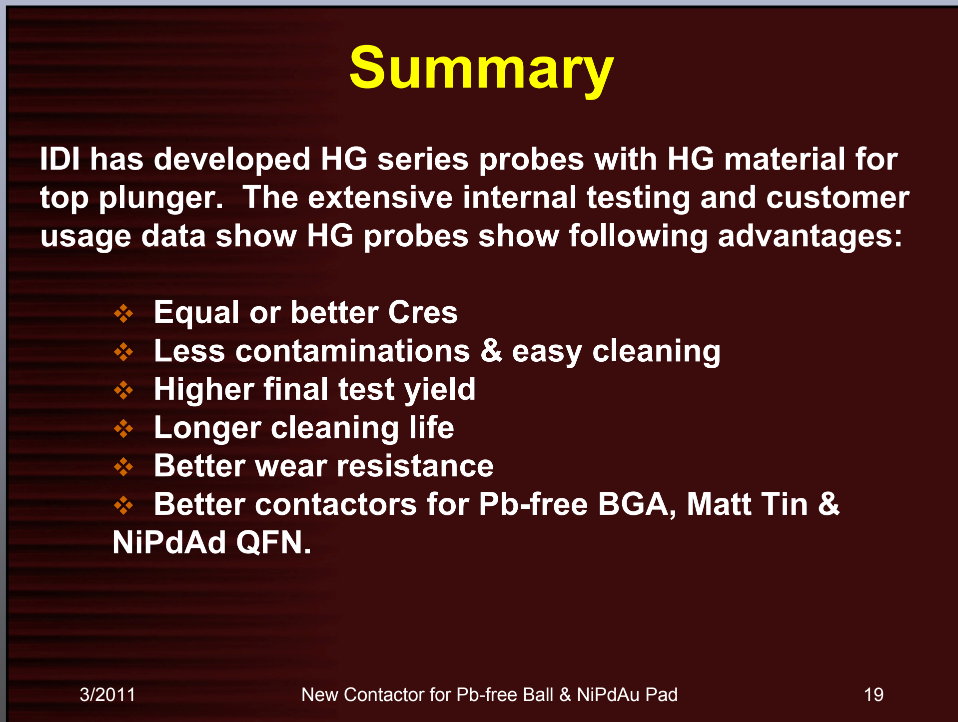
Summary
IDI has developed HG series probes with HG material for top plunger. The extensive internal testing and customer usage data show HG probes show following advantages:
Equal or better Cres
Less contaminations & easy cleaning
Higher final test yield
Longer cleaning life
Better wear resistance
Better contactors for Pb-free BGA, Matt Tin & NiPdAd QFN.
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19

Air Gap Contactor

Lam Tuck Hon
Test Tooling Solutions Group

2011 BiTS Workshop
March 6 - 9, 2011

Topics

- Introduction
- Basic Requirement
- Normal Conventional Contactor
- Technical Challenge
- Air Gap Contactor
- Summary

3/2011 Air Gap Contactor 2

Introduction

- The Signal Integrity performance of a Test Contactor is defined as the speed and quality of the signal transmitted and received via Probe Pins in the Test Contactor.
- These probe pins are further separated as Power, Ground and Signal pins.
- There are multiple variables that contribute to the electrical performance of the Test Contactors.
- Enhancing the multiple variables achieves an optimized Electrical Performance.

3/2011 Air Gap Contactor 3

Basic Requirements

- The (Signal Integrity) electrical performance of the Socket/Contactor will depend on :-
  - Pitch
  - Number of GND Probe Pin
  - Number of Signal Probe Pin

  Assign by Customer

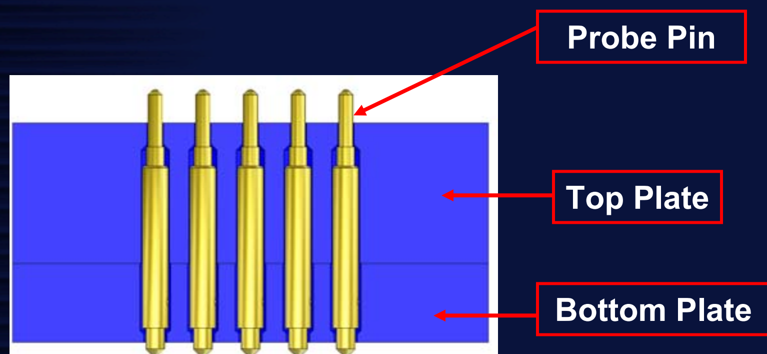
  - Diameter of Probe Pin
  - Length of Probe Pin
  - Material of the Socket

  Advise By Socket/Pin Maker

3/2011 Air Gap Contactor 4

Normal Conventional Contactor

- Consists of two plates (Top Plate & Bottom Plate) made of Engineered Plastic materials



3/2011 Air Gap Contactor 5

Normal Conventional Contactor

Technical Challenge

- The main challenge in optimizing the electrical performance/SI of a Test Contactor is to have good control of the Signal Path Impedance
- The major parts that affect the impedance:-
  - ❖ Pitch to Pitch
  - ❖ Diameter of Probe Pin
  - ❖ Dielectric Constant of the Material

3/2011 Air Gap Contactor 6

Normal Conventional Contactor

Technical Challenge

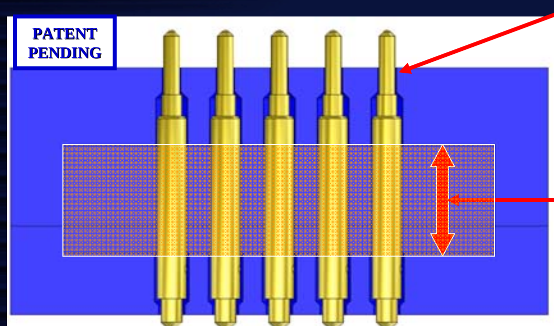
- **Pitch to Pitch**
    - ❖ **Assigned By Customer**
- **Diameter of the Probe Pin**
    - ❖ **Machining limitation**
    - ❖ **Limited choices for fine pitch pins**
- **Material**
    - ❖ **Looking for Low Dielectric Constant material**

3/2011 Air Gap Contactor 7

Air Gap Contactor

- **A new feature known as an Internal Air Gap to further improve the control over impedance.**

Probe Pin



Internal Air Gap on Top and Bottom Plate Solid

3/2011 Air Gap Contactor 8

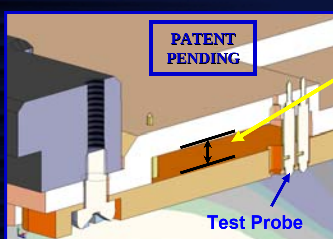
Air Gap Contactor

- By providing an air gap internally in the Test Contactor the Effective Dielectric Constant is further improved.
- This is because the Air Gap created provides the lowest Dielectric Constant possible and the best Dielectric Loss Tangent value achievable.
- By reducing the Dielectric Constant this helps in increasing the impedance of the Probe Pin as the impedance is inversely proportional to the Dielectric Constant.
- Dielectric Constant of Air = 1
- Dielectric Loss Tangent of Air = 0

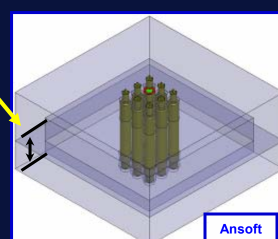
Could not be achieved in any known materials.

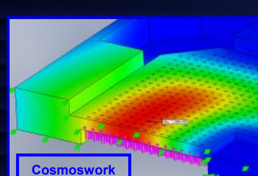
3/2011 Air Gap Contactor 9

Air Gap Contactor



Air Gap Thickness





- Due to some of the contactor materials being removed, it will make the contactor's body structure become weak.
- Cosmoswork software will be used to analyze the Air Gap Contactor structure.

3/2011 Air Gap Contactor 10

Air Gap Contactor

Simulation Results

Probe Pin	S05556CR			
Contactor Material	TECA PEEK	TECA PEEK	TECA PEEK	TECA PEEK
Air Gap Thickness (mm)	N/A	1.0	1.5	2.0
Pitch (mm)	0.80	0.80	0.80	0.80
Self Inductance (nH)	1.16	1.15	1.14	1.14
Bandwidth (Frequency)	5GHz	5GHz	5GHz	5GHz
Return Loss	-11.16dB	-15.87dB	-17.33dB	-17.69dB
Insertion Loss	-0.48dB	-0.21dB	-0.15dB	-0.13dB
Near-End-Cross-Talk	-17.42dB	-17.93dB	-18.28dB	-18.51dB
Far-End-Cross-Talk	-27.88dB	-33.26dB	-36.01dB	-36.98dB
Impedance	40.02Ω	44.23Ω	45.10Ω	46.03Ω

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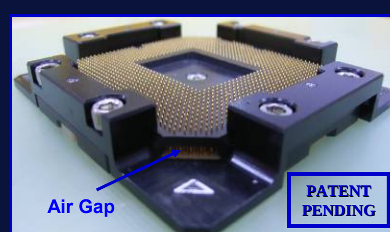
Air Gap Contactor

The technical reviews are as below:-

- Solving Impedance mismatch issues especially when the impedance is lower than required impedance
- The Electrical Properties of Air provides the best electrical value - could not be achieved in any materials
- Signal Pin
  - ❖ Improve Insertion Loss
  - ❖ Improve Return Loss



3/2011 Air Gap Contactor 12

Summary

- Easily improve the Electrical Performance for current socket by adding the internal Air Gap, significantly save cost and time.
- To maximize the electrical performance of the AG Contactors, one must find out the correct height required to obtain the necessary impedance and thus maximizing the Signal Integrity of the Contactors.

3/2011 Air Gap Contactor 13

Improving Test Sockets and Test Boards Using Embedded Capacitance Material

Michael Giesler – 3M
Yoshihisa Kawate – Sumitomo 3M
Alexander Barr – 3M
Yuichi Tsubaki – Sumitomo 3M

2011 BiTS Workshop
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Agenda

- Issues at High Speed Testing
- Embedded Capacitance Material (ECM)
- Simulation Modeling Analysis of Socket
  - Power Distribution
  - High Speed Signal Transmission
- Customer Measured Results
- Test Board with ECM
  - Future Work

3/2011 Improving Test Sockets and Test Boards Using Embedded Capacitance Material 2

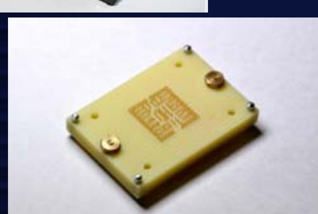
Issues for High Speed Testing

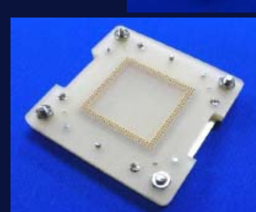
- Mechanical Performance
  - Mechanical Cycle Life
  - Low, Reliable Mating Force
- Electrical Performance
  - Power Integrity
    - Self Impedance
  - Signal Integrity
    - Insertion Loss
    - Crosstalk

3/2011 Improving Test Sockets and Test Boards Using Embedded Capacitance Material 3

The Anatomy of the 3M FAST Test Socket …

The Interposer Cartridge, its construction and its impact on performance will be the focus this presentation.





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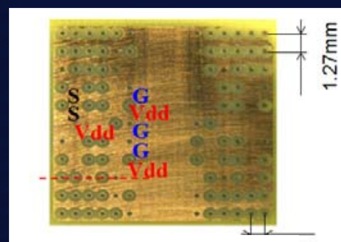
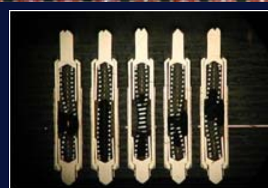
Cartridge Construction Variables



Pattern of Inner Layer

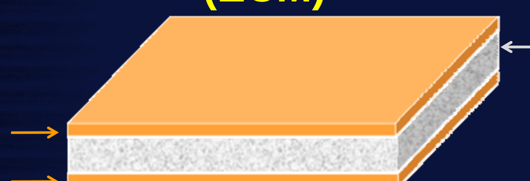
Cartridge
* Non-PCB
* PCB
  - Power Planes
  - Ground Planes
  - ECM

Contact Pin Length



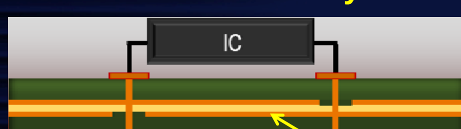
Coaxial Construct

3M™ Embedded Capacitance Material (ECM)

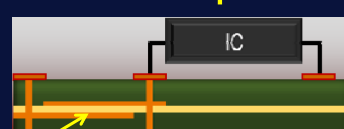


(Not to scale)

Power/Ground Layer



Discrete Capacitor



3M™ ECM

Copper clad laminate that can function as both a power/ground layer or a discrete capacitor.

Embedded Capacitance Material Key Properties

Attribute	Value
Capacitance /Area	6.4 nF/in² (1.0 nF/cm²) (14 µm) 8.1 nF/in2 (1.25 nF/cm²) (11 µm)
Dielectric Constant	16
Dielectric Thickness	0.55 mil (14 µm); 0.43 mil (11 µm)
Dielectric loss @ 1GHz	0.03
Resin system	Epoxy, ceramic filler
Temperature (TCC)	Meets X7R
Dielectric Strength	~3300 V/mil (130 V/µm)
Breakdown Voltage	>100 V
Copper Thickness	1.4 mil (35 µm)
Flammability Rating	94V-0

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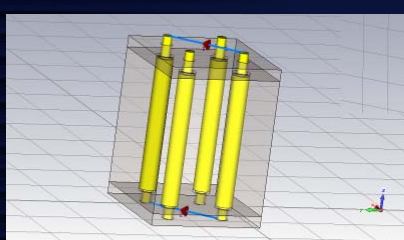
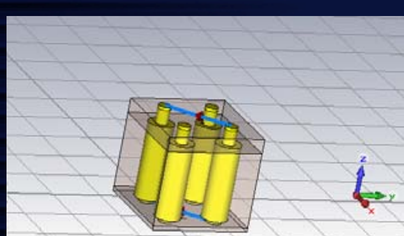
Power Distribution Simulation Model



- Existing (Long)
  - Spring probe
    - Sleeve Diameter = 0.3mm
    - Sleeve Length = 2.3mm
    - Total Length ~ 2.7mm



- Short Pin
  - Spring probe
    - Sleeve Diameter = 0.53mm
    - Sleeve Length = 1.53mm
    - Total Length ~ 1.98mm

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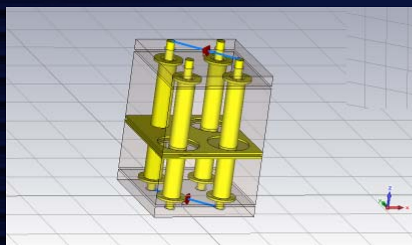
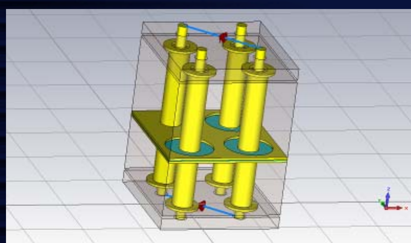
Power Distribution Simulation Model



- FAST with P-G Planes
  - Spring probe
    - Same as long pins
  - 0.05mm FR-4 between P and G planes for not only connecting ground & power, but also for capacitive effects



- FAST with P-G and ECM
  - Spring probe
    - Same as long pins
  - 14 µm ECM (k = 16) between ground plane and power plane

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Power Distribution Simulation Model

- 4 pins are modeled
  - Power and ground are assigned as follows for power-ground characteristics.

S	P
G	S

- Simulation
  - Transient simulation for 0-10 GHz by CST MWS.
  - Periodic boundary condition in x-y directions.
  - Open conditions in z direction.
  - Spring probe model is from solid cylinder not including coil spring.
  - Power-Ground impedance(Z11) is converted from S-Parameter.

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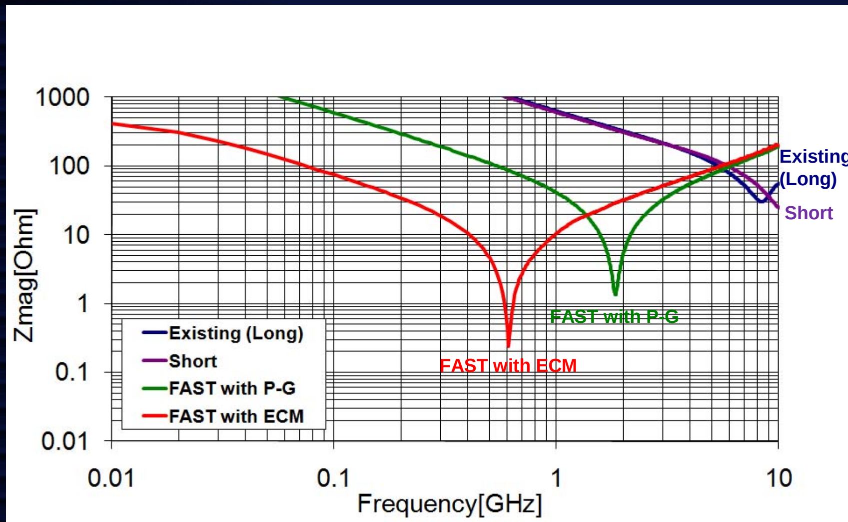
Power Distribution Simulation Self-Impedance of Socket



Power Distribution Simulation Conclusions

- **Short Contact pins have the lowest impedance above the resonance frequency.**
- **Sockets having power and ground planes decrease impedance in lower frequency region.**
- **ECM based sockets have the lowest impedance below the resonance frequency.**
- **FAST Socket with P-G Only and P-G with ECM**
  - **Show much lower input impedance than Short Contact Pins**
  - **Show much lower input impedance than Long Contact Pins**
- **FAST Socket with P-G and ECM**
  - **Shows significant improvement over FAST with P-G Only**

This is conceptual simulation. The actual impedance is design dependent. Actual performance may vary from modeled simulation.

Signal Transmission Simulation Model

- 4 pins are modeled
  - Signal and ground are assigned as follows for signal transmission.

S	G
G	S

- Simulation
  - Transient simulation for 0-12 GHz by CST MWS.
  - Periodic boundary condition in x-y directions.
  - Open conditions in z direction.
  - Spring probe model is from solid cylinder not including coil spring.

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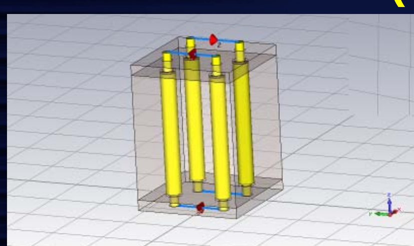
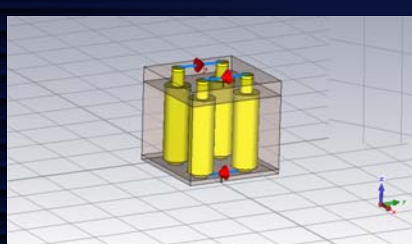
Signal Transmission Simulation Model (1mm pitch)



- Existing (Long)
  - Spring probe
    - Sleeve Diameter = 0.3mm
    - Sleeve Length = 2.3mm
    - Total Length ~ 2.7mm



- Short
  - Spring probe
    - Sleeve Diameter = 0.53mm
    - Sleeve Length = 1.53mm
    - Total Length ~ 1.98mm

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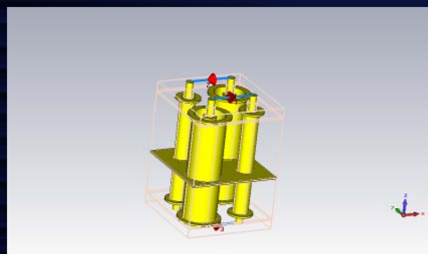
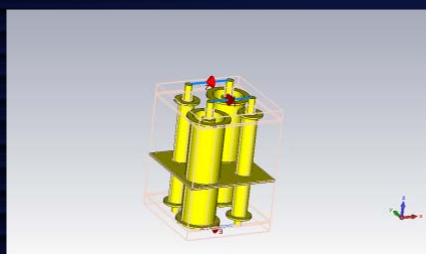
Signal Transmission Simulation Model (1mm pitch)

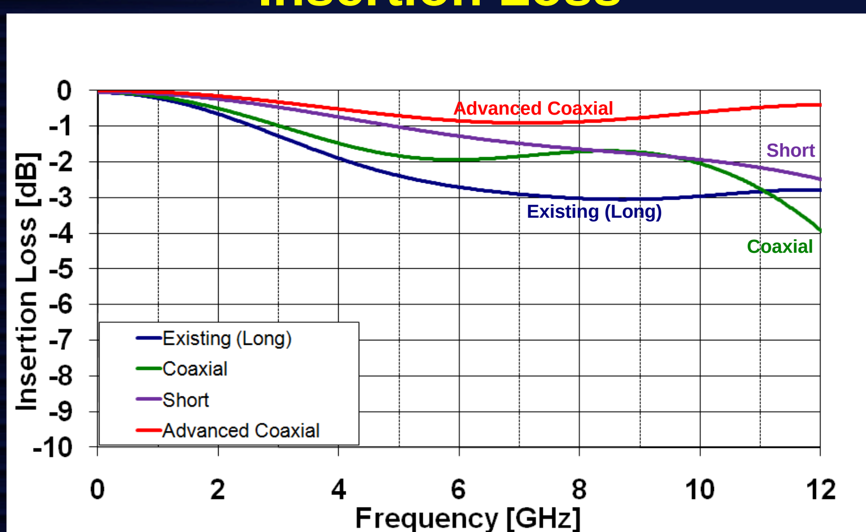


- **Coaxial**
  - **Spring probe**
    - **Same as long pins**
  - Coaxial structure around sleeve area

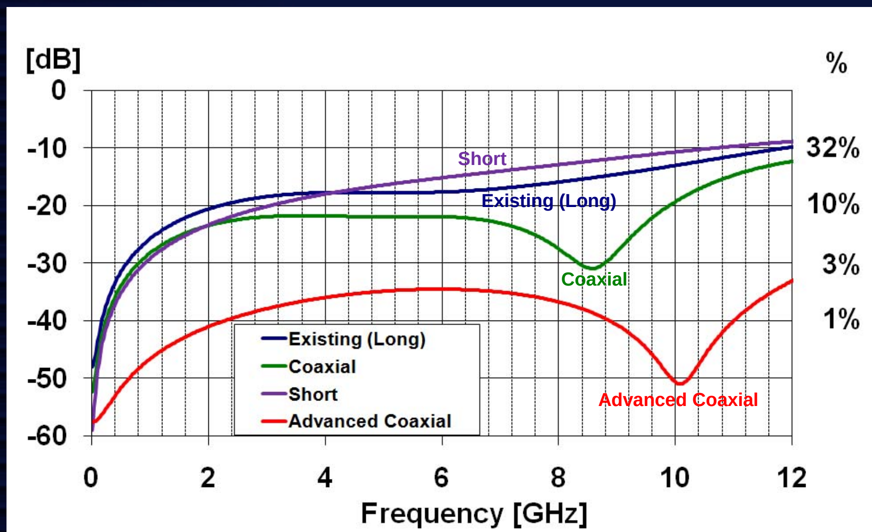


- **Advanced Coaxial**
  - Spring probe
    - Same as long pins
  - Advanced Coaxial Construct

Signal Transmission Simulation Insertion Loss



Signal Transmission Simulation Near End Crosstalk



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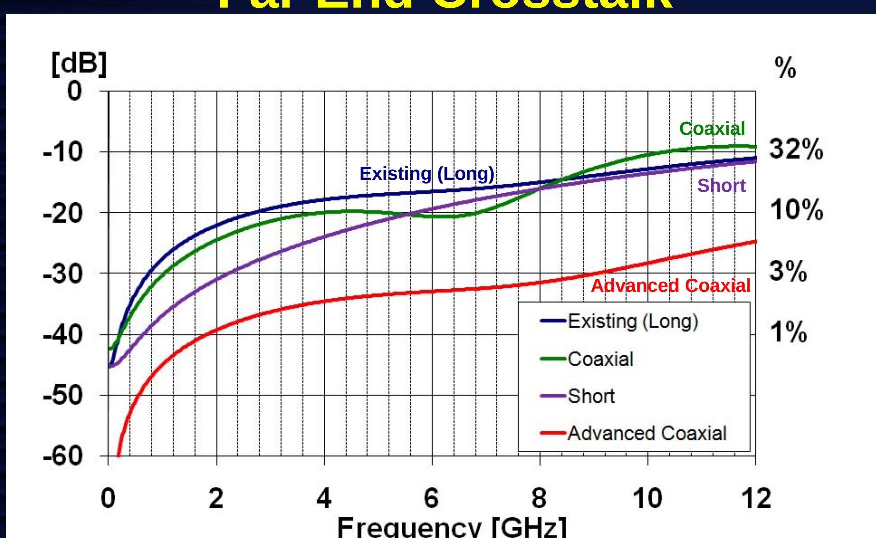
Signal Transmission Simulation Far End Crosstalk



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High Speed Simulation Conclusions

- Insertion Loss and Crosstalk can be reduced by Coax and Advanced Coax Construct.
- Coax Constructs enable the option to use a Longer Pin Length for Mechanical Stability.
- Advanced Coax Construct further improves the Electrical Performance. Based on the parameters of this modeling, it shows the potential of 12 GHz performance with less than 1 dB insertion loss and less than 7% crosstalk.
- FAST Coax Sockets enable a High Speed option for Testing.

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Simulation Modeling Summary

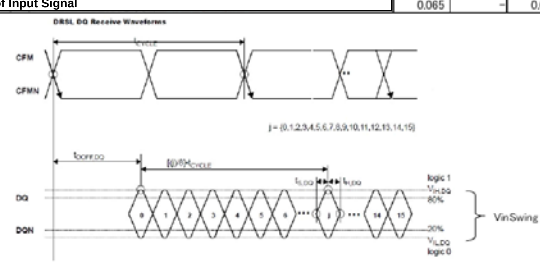
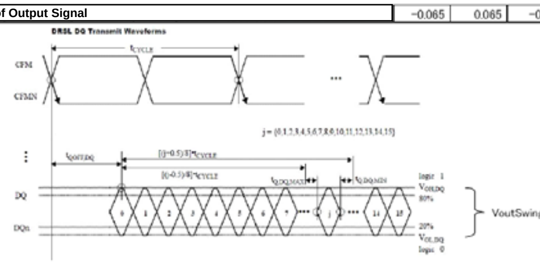
- Power Distribution
  - Sockets with ECM Show better Performance than existing sockets without ECM.
- High Speed Signal Transmission
  - Advanced FAST coaxial socket Shows Better Performance than long or short contact type sockets.

3/2011 Improving Test Sockets and Test Boards Using Embedded Capacitance Material 20

Customer Measured Constructs Evaluated
(ECM used on Samples 04 and 06)

	03	04	05	06
Pin Length	3.8mm	3.8mm	2.4mm	2.4mm
Plunger Travel/Stroke	0.65mm	0.65mm	0.4mm	0.4mm
Spring Force	25gf	25gf	25gf	25gf
Mech. Cycle Life	> 100K Cycles	> 100K Cycles	> 100K Cycles	> 100K Cycles
Operating Temp.			-40 ～ +120	-40 ～ +120
CD Resistance			＜100mΩ	＜100mΩ
Self Inductance			＜1.0nH	＜1.0nH
Contact				
Socket				

Signal Sensitivity Evaluation

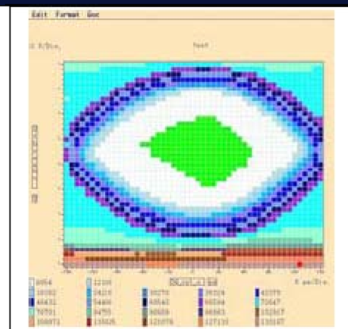
項目		概要	SPEC値 3.2GHz Min	SPEC値 3.2GHz Max	SPEC値 4.8GHz Min	SPEC値 4.8GHz Max	unit
DQ	tS.tH	Sensitivity of Input Signal	0.065	-	0.055	-	ns
							
	tQ	Sensitivity of Output Signal	-0.065	0.065	-0.055	0.055	ns
							

Shmoo Plot

Shmoo Plot

Parameters:
1) Source Voltage
2) Signal Input/Output Timing
3) Input/Output Voltage of Signal

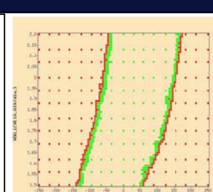
X-Axis is Output Signal Timing
Y-Axis is Output Voltage

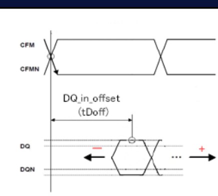


Signal Pass Tolerance vs. VDD/Signal in(out) Timing

tSH_DQ

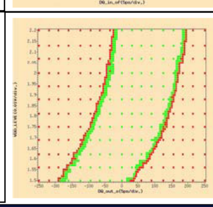
tSH_DQ is timing of input signal.
VDD is source voltage.
X-Axis is tSH_DQ. Center of x-axis is +/- 0 msec of input signal timing.
Y-Axis is source voltage.

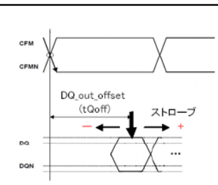




tQ_DQ

tQ_DQ is timing out of output signal.
VDD is source voltage.
X-Axis is tQ_DQ. Center of x-axis is +/- 0 msec of output signal timing.
Y-Axis is source voltage.





Sensitivity of Signal Transmission @ 4.8 Gbps Signal Transmission Speed

	03	04	05	06
Pin Length	3.8mm	3.8mm	2.4mm	2.4mm
Plunger Travel/Stroke	0.65mm	0.65mm	0.4mm	0.4mm
Spring Force	25gf	25gf	25gf	25gf
Mech. Cycle Life	> 100K Cycles	> 100K Cycles	> 100K Cycles	> 100K Cycles
Operating Temp.			-40 ~ +120	-40 ~ +120
CD Resistance			< 100mΩ	< 100mΩ
Self Inductance			< 1.0nH	< 1.0nH
Contact				

			03	04	05	06
	1.75V		90.2	90.8	93.1	65.7
tSH	1.85V		67.2	68.5	61.5	54.7
	1.95V		59.5	59.2	54.0	48.5
	1.75V		98.2	97.6	93.3	74.5
tQ	1.85V		75.6	75.5	68.3	62.4
	1.95V		65.3	64.7	59.7	55.8

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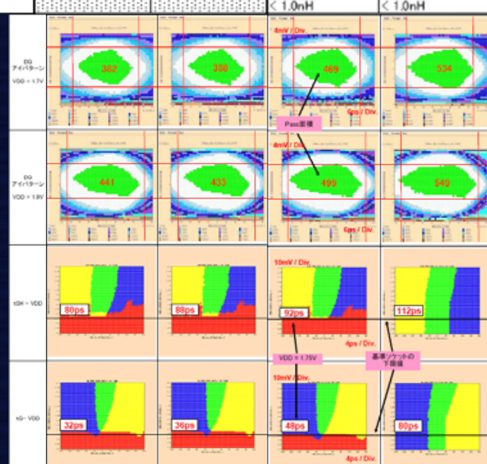
Shmoo Plot and Signal Timing Results

	03	04	05	06
Pin Length	3.8mm	3.8mm	2.4mm	2.4mm
Plunger Travel/Stroke	0.65mm	0.65mm	0.4mm	0.4mm
Spring Force	25gf	25gf	25gf	25gf
Mech. Cycle Life	> 100K Cycles	> 100K Cycles	> 100K Cycles	> 100K Cycles
Operating Temp.			-40 ~ +120	-40 ~ +120
CD Resistance			< 100mΩ	< 100mΩ
Self Inductance			< 1.0nH	< 1.0nH



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Customer Measured Results Conclusions

- A short contact pin length will show the best performance relative to speed, but the tradeoff is typically reduced mechanical stability.
  - Mechanical Cycle Life
  - Higher Spring Force.
- With ECM added to the short contact length, significant improvement is achieved in order to meet requirements.
- With ECM, a longer pin with a lower spring force may be used to achieve similar electrical performance as a shorter pin without ECM while not compromising the mechanical cycle life of the contact.

3/2011 Improving Test Sockets and Test Boards Using Embedded Capacitance Material 27

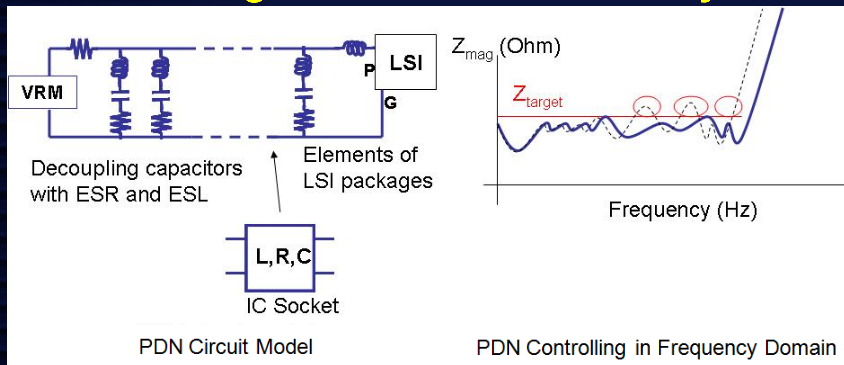
Value of ECM in Test Socket

- Impedance of power delivery network circuit (known as PDN) can be designed and controlled.
  - Especially needed for High Performance LSI Devices.
  - Some LSI suppliers propose Target Impedance and recommend Control of it.
- Spring probe of socket has excess Inductance and increases socket Impedance.
- Sockets having ECM will contribute to reducing the Impedance because of the additional Capacitance.
- Sockets having ECM will contribute to minimizing and controlling the PDN Impedance.

ECM is a potential solution, but other methods may exist as well to address the Issues facing a Test Socket.

3/2011 Improving Test Sockets and Test Boards Using Embedded Capacitance Material 28

Controlling Power Distribution System



- PDN (Power distribution network) should be designed and controlled below target impedance (Ztarget) for newer LSI devices.
- Long spring probes exhibit high inductance.
- Now what about the Test Board …

ECM Benefits Relative to the Test Board

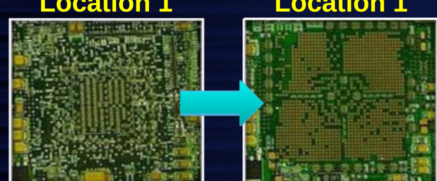
Miniaturization	Performance	Component Reduction

Telecom Example: Base Station

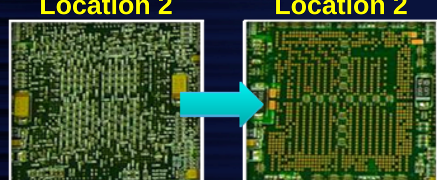
Backside of BGA

Without 3M ECM — With 3M ECM

Location 1 — Location 1



Location 2 — Location 2



Need

Reduction in Number of Components
Better Power Distribution Management

Solution

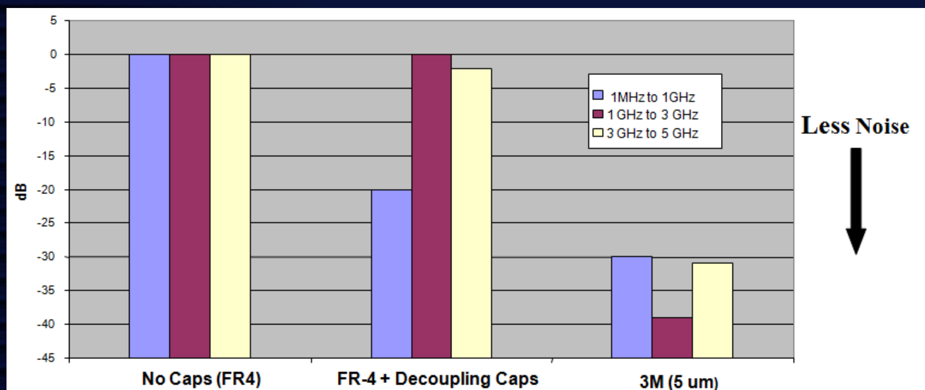
ECM

Results

50% Reduction in Discrete Component Count

Power Distribution Significantly Improved

Power Bus Noise on Test Vehicle (EDC TV1)



Source: Data from NCMS Embedded Decoupling Capacitance Project Report - 12/00

* Traditional decoupling capacitors are not effective at frequencies above 500 MHz

* 3M has excellent performance to 5 GHz (and beyond)

Why ECM for the Test Board?

(Future Evaluation Work for Test Board Environment)

- ECM in the Test Board will likely enable not only Higher Frequency Performance, but also help eliminate capacitors on the PCB surface.
  - Help control the Test Board Impedance of the PDN
  - Elimination of Capacitors …
    - May make it possible to increase the number of test sockets per board
      - Improving Throughput
    - May make it possible to shrink the PCB
      - Reducing Total PCB Cost

Conclusions

- With ECM and FAST Socket platform, you have more options relative to the tradeoffs between Mechanical and Electrical Performance.
- ECM can also be applied to the Test Board, to potentially improve electrical performance, increase throughput and reduce the total cost.

Improvement of Dual Core Power Delivery Performance Through Modulation of Socket-Mechanical Dimension

Suchismita Ghosh, Jeremy Littrell,
Satish Prathaban

2011 BiTS Workshop
March 6 - 9, 2011

Agenda

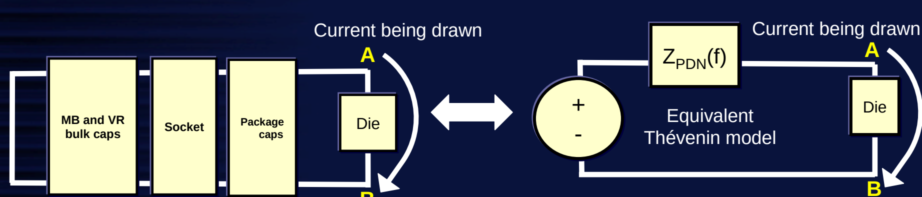
- Power Delivery Basics
- Power Delivery Network Analysis
- Problem Statement
- IFDIM Measurements
- Socket Pin Specifications
- Simulations using 3d EM Solver
- Conclusions

Power Delivery Basics

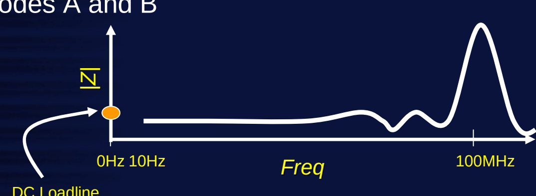
- The purpose of a power delivery network (PDN) is to distribute power and return current to the CPU under test.
- With higher activity and lower operating voltages, the power delivery impedance needs to decrease over a wider bandwidth. This calls for improved packages, efficient voltage regulators and more decoupling.
- The test socket's impedance must reduce at the same pace to keep the overall test platform operational.
  - even more critical in BGA packages

Power Delivery Impedance

All PDN analysis tools are generally based on a lumped equivalent model representation of the power delivery network topology

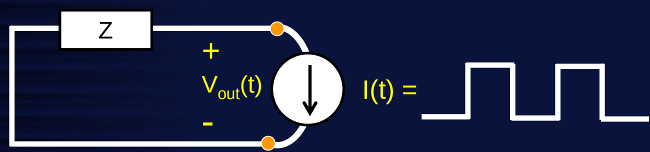


The impedance profile describes the effective PDN impedance seen looking into two PDN nodes A and B

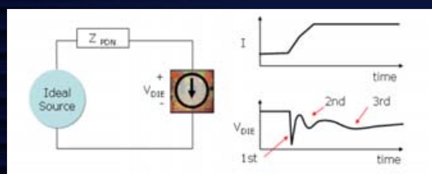


Integrated Frequency Domain Impedance Meter (IFDIM)

The Z(f) tool utilizes a square wave current draw



Resonances in Z_{PDN} coupled with di/dt cause voltage droops



Z(f) = F[V(t)]/F[I(t)]

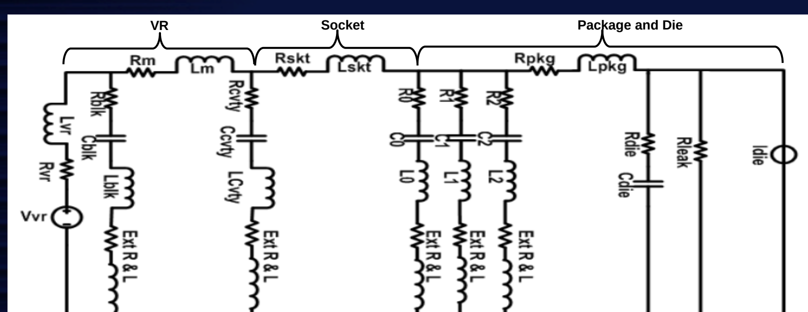
F=Fourier transform

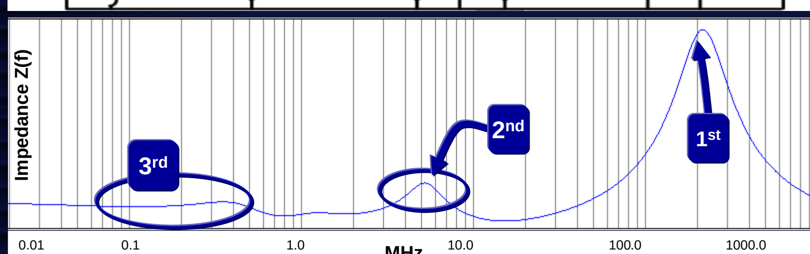
1. Alex Waizman, "Integrated Power Supply Frequency Domain Impedance Meter (IFDIM)", Electrical Performance of Electronic Packaging, 2004. IEEE 13th Topical Meeting

2. H-S. Jung and M. Pedram, Proc. of Design Automation and Test in Europe, Mar. 2010, pp. 351-356.

3/2011 Improvement of Dual Core Power Delivery Performance Through Modulation of Socket-Mechanical Dimension 5

Impedance Profile Peaks





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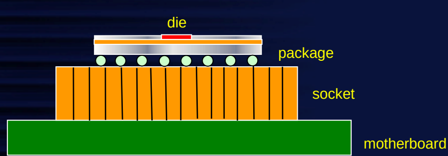
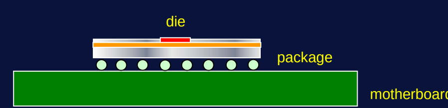
Power Delivery Impedance in Product Platform Validation

- In system level test environment, IFDIM measurement on a test board helps to understand how the test socket affects the PDN beyond the effect of direct attach BGA
- Results are used to tune the voltage regulator to meet the load line specification through the platform- test-module sockets

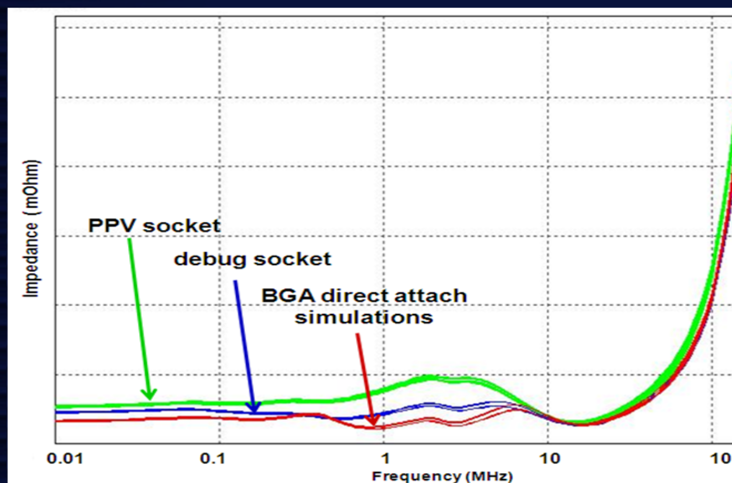




Problem Statement

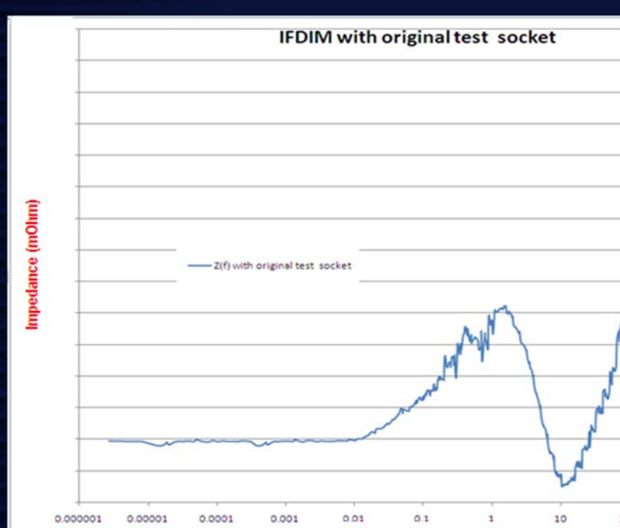
- In the mid-frequency range, the PDN excursion of the test platform was significantly worse than the customer reference board (CRB)
- Excursion in low frequency range – compensated through VR
- In a similar but different platform, addition of caps fixed the problem, but there was not enough space on this platform to do so

Problem Statement continued…



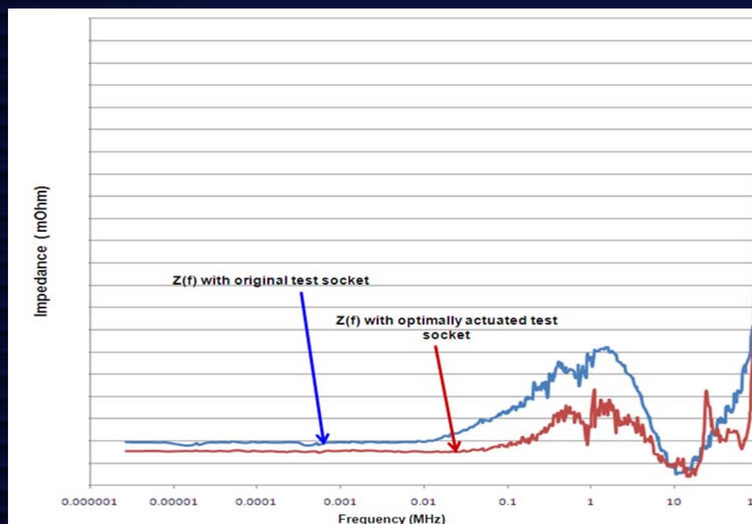
Initial simulation results on Customer Reference Board - platform using test socket, debug socket and BGA direct attach

Problem Statement continued…



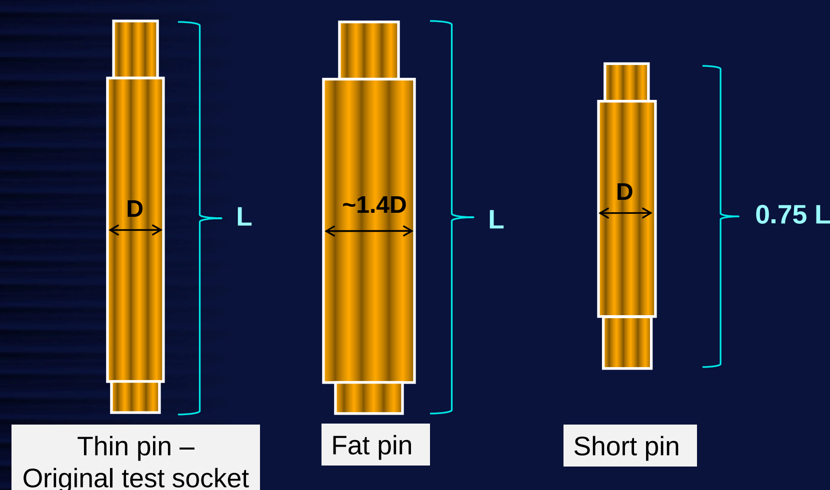
On running IFDIM on the test board, we realized the measurement was marginally worse than the simulation results.

Optimal Actuation affects IFDIM Peak



3/2011 Improvement of Dual Core Power Delivery Performance Through Modulation of Socket-Mechanical Dimension 11

Socket Pin Specifications



Self and mutual inductance of thin pin and fat pin are almost comparable.
In case of short pin, each inductance value was ~0.6 times that of thin pin.

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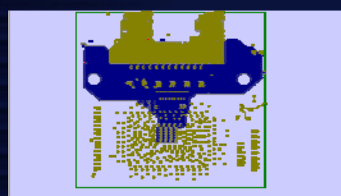
Simulation using 3d EM solver

- The PDN analysis, in this case, was attributed to the socket-pin dimensions.
- Main aim was to reduce loop inductance - key contributor to this problem.
- Both electrical and mechanical specifications of the various socket-pins were taken into consideration.



Board

Modeling the socket

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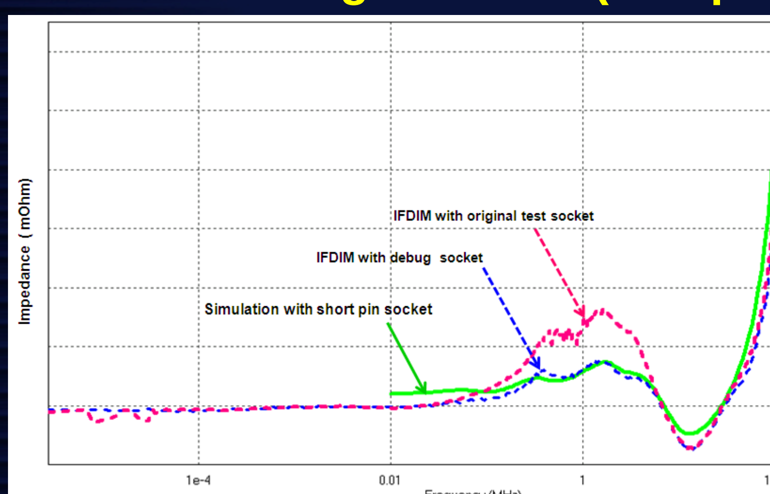
Comparison between Simulations, and IFDIM with Debug and Test (thin pin)



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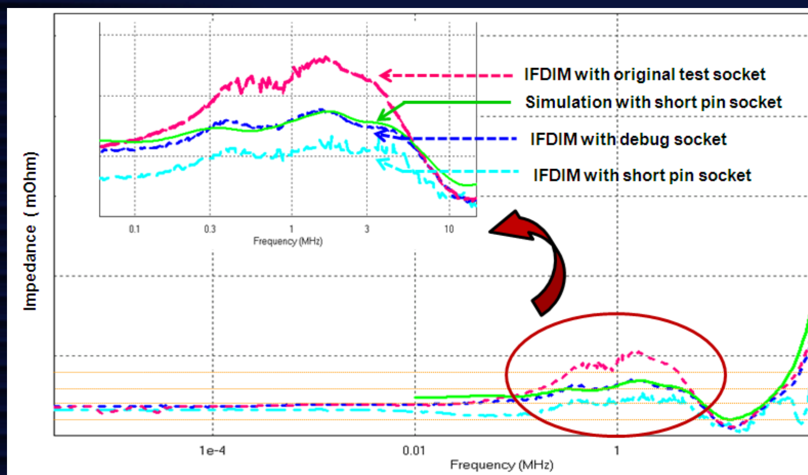
Comparison between Test (thin pin), Debug and Short Pin Sockets



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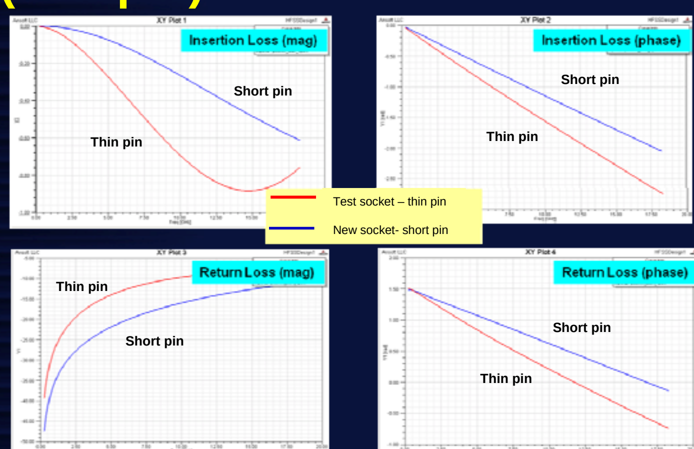
Signal Integrity Analysis of Test Socket (thin pin) and Short Pin Socket



From signal integrity view point the short pin socket provided better performance

Data Courtesy: Se-Jung Moon

3/2011 Improvement of Dual Core Power Delivery Performance Through Modulation of Socket-Mechanical Dimension 16

Conclusions

- The excursion in the PDN impedance profile around mid-frequency range was brought down to a value close to the load line spec with the short-pin socket. This new reduced value was ~ 1/3 of the initial excursion.
- The inductance of the socket pin was a key contributor to the problem. A decrease in length is better than an increase in diameter.
- The short pin has been predicted to be equal to or better than the thin pin from signal integrity view point.
- The socket design and manufacturing groups need to consider ways of reducing the inductance or compensating for it, since socket has started becoming an important aspect of PD.

3/2011 Improvement of Dual Core Power Delivery Performance Through Modulation of Socket-Mechanical Dimension 17

Acknowledgements

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3/2011 Improvement of Dual Core Power Delivery Performance Through Modulation of Socket-Mechanical Dimension 18