ARCHIVE 2011

TESTING THE TESTERS

Low Force Contact Technology for Electronic Package Backend Test
Jin Yang, Tim Swettlen—Intel Corporation

Contact Force Change As A Measure For Current Carrying Capability
Marcus Frey—Multitest

Testing the Socket - The Benefits of Verifying Socket Functionality
James Forster, David Weston, Marco Michi—Wells-CTI
Josef Magro, Silvio Spiteri — ST-Microelectronics

Monte Carlo Simulation and Design of Experiments for Improved Pin-Pad Alignment
John DeBauche—Johnstech International Corporation

Low Force Contact Technology for Electronic Package Backend Test

Jin Yang, Tim Swettlen
Sort, Test Technology Development (STTD)
Intel Corporation

2011 BiTS Workshop
March 6 - 9, 2011

Outline

- Problem Statement
- Why low force contact technology?
- What we have done in this area
- Make it a mature technology?
- Summary & Acknowledgments

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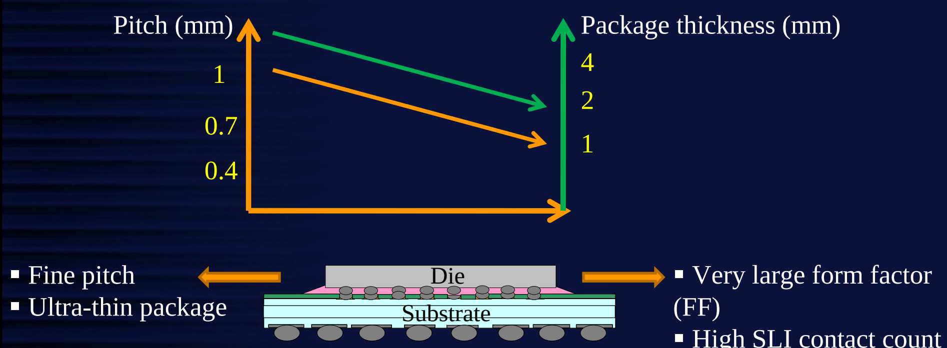
Problem Statement

- Emerging electronic packages bring up new requirements on second level interconnect (SLI) contact technology to meet product backend (BE) test targets
- How to minimize test-package interactions in product test for emerging electronic packages? - SLI contact force as one of key knobs?



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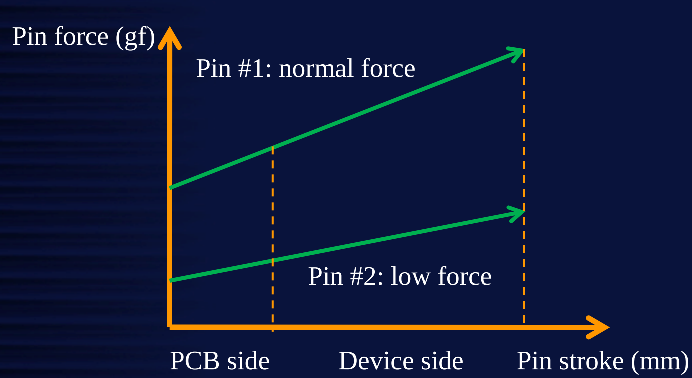
Lower Force to SLI Contact Technology



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Advantages of Low Force Contact Technology

- Would reduce potential test induced damages/impacts to packages, especially to ultra-thin packages
- Would reduce total reaction loading requirement of handler for parallel test
  — For high-parallel test, large reaction force normally required from handler
- Would help reduce incoming warpage of socket and help improve pin coplanarity, especially for large form factor (FF), high ball count packages
  — Pin preload would reduce correspondingly with pin force
- Would help reduce pin force variation and improve spring lifetime
- …

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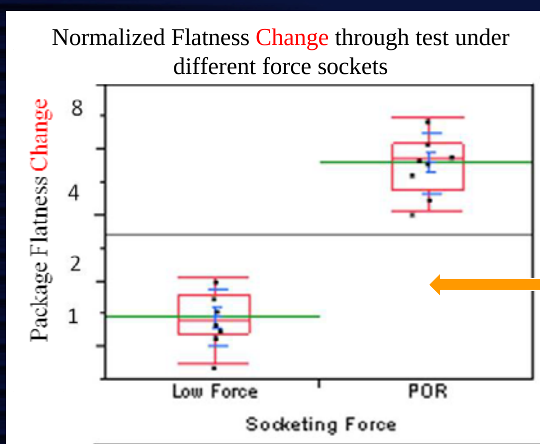
Low Force Socketing for Thin Packages



- Two sockets: process of record (POR) force vs. low force
- Flatness measured at land side of package on a number of points

Seven times reduction in test induced permanent flatness change

- Low force socketing reduced test induced permanent deformation risk to thin packages

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General Concerns about Lowering Contact Force

- **Higher path resistance and larger variation**
  - **Would affect contact stability**
  - **Might affect test performance and yield – from perspective of power delivery (PD)**
- **Pin sticking in socket in high volume manufacturing (HVM) environment**
  - **Might affect test yield**
  - **Might degrade pin lifetime**

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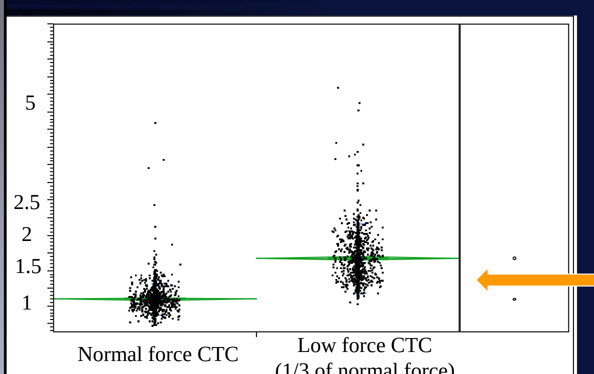
Path Resistance Comparison

- **Apple to apple path resistance comparison between normal force and low force class test contactor (CTC)**

Normalized Path Resistance Data



50% increase for medium

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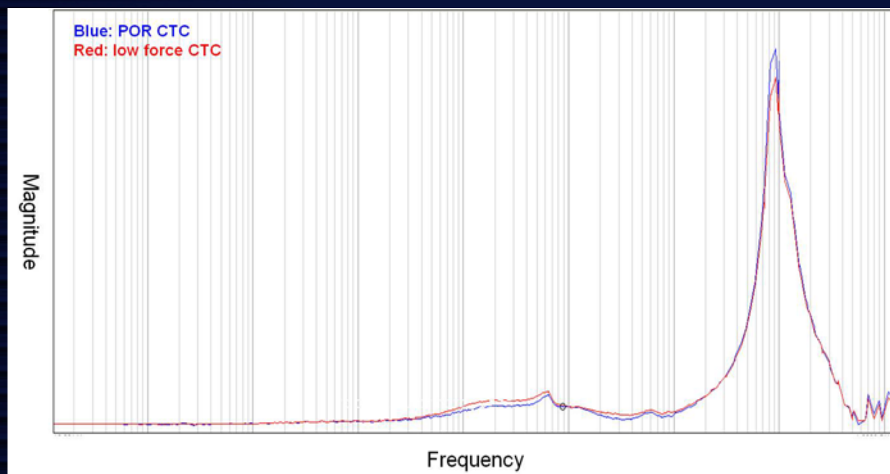
Impedance Comparison

- Some impedance increase observed for low force CTC compared to POR CTC



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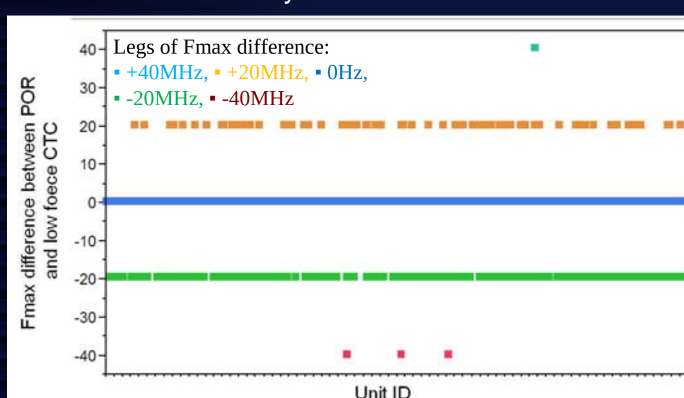
Maximum Frequency (Fmax) Comparison

- With 95% confidence, DO NOT reject hypothesis that Fmax using POR force = Fmax using low force CTC in terms of mean and variability

Fmax difference overlay at unit level: baseline=POR CTC



- Sample size: ~ 1K

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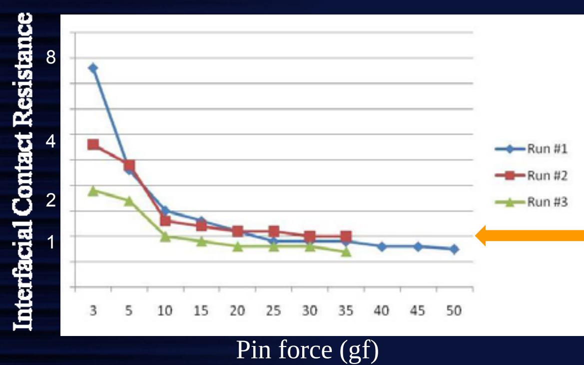
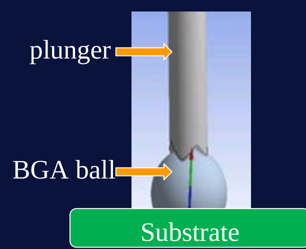
Test Pin – BGA Ball Interfacial Contact Characterization (1)

- **Interfacial contact between BGA ball and test pin piece characterized**

Normalized **interfacial** contact resistance





Ratio = ~10%
: Increase of interfacial contact resistance/total path resistance increase with a reduction of 20gf per pin

- Interfacial contact resistance between BGA ball/LGA pad and spring pin ≠ dominant contributor to overall path resistance

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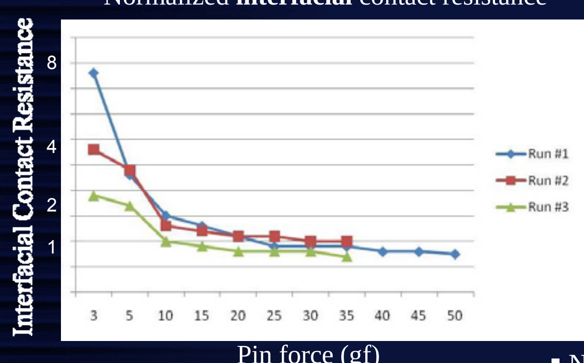
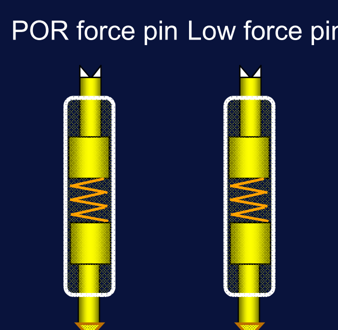
Test Pin – BGA Ball Interfacial Contact Characterization (2)

Normalized **interfacial** contact resistance





- No difference in geometry designs between pins
- Internal attributes contribute to large portion of path resistance increase

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Test Requirements for Low Force Contact Technology

- Low force contact technology to meet specs equivalent to those of normal force from technical and commercial perspectives:
  - Path resistance ← Low force pins first need to have equivalent path resistance as POR
  - Lifetime
  - Inductance
  - Stroke/coplanarity
  - Current carrying capability (CCC)
  - Cost
  - …

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Summary

- Contact force identified as one of knobs to minimize test-package interactions in product test for emerging electronic packages
- Low force contact technology with an acceptable contact performance expected to be achievable by improving internal pin design and other design parameters

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Acknowledgements

- Thanks to peers who have contributed and/or provided inputs to this project
- Thanks to support from Intel STTD group

Contact Force Change As A Measure For Current Carrying Capability

Marcus Frey
Multitest

2011 BiTS Workshop
March 6 - 9, 2011

Content

- Why is high current so important?
- Challenges
- Usual specification method
- New approach
- Results and comparison
- Future work

Introduction

Growing demand for high current semiconductors

High current test solutions are needed

How do we specify our test sockets?

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High current applications

Automotive electronics

- Motor drivers for comfort systems
- Electronic ignition and fuel injection
- Electric brakes, electric gearbox

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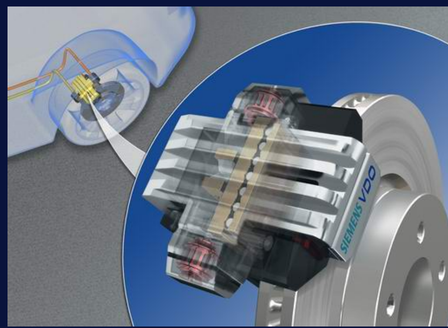
High current applications

Automotive electronics



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High current applications

Electric and hybrid cars

- Battery management
- Drive motor controller
- Brake energy recuperation

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High current applications

Electric and hybrid cars

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High current applications

Mobile electronics

- Charging controllers for Li-Ion cells
- Battery management
- Power saving

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High current applications

Mobile electronics

High current applications

High speed digital

- Fast switching in the GHz range
- Low voltage, high current
- Switching power supplies

High current applications

High speed digital

130 W thermal design power

75 A at 12 V

Challenges

- Small pitches: 0.4 mm and smaller
- Small packages: MLF…
- Short contacts

Less space available for heat dissipation

Determining the maximum current

Current flow leads to temperature rise

- **Place probe into fixture**
- **Apply constant or pulsed current**
- **Measure temperature change of the probe**
- **Usual specification limit: 20 K rise**

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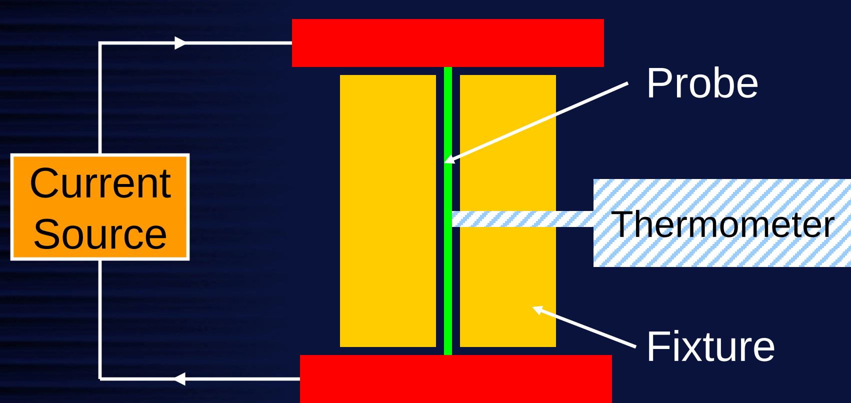
Determining the maximum current

Experiment setup



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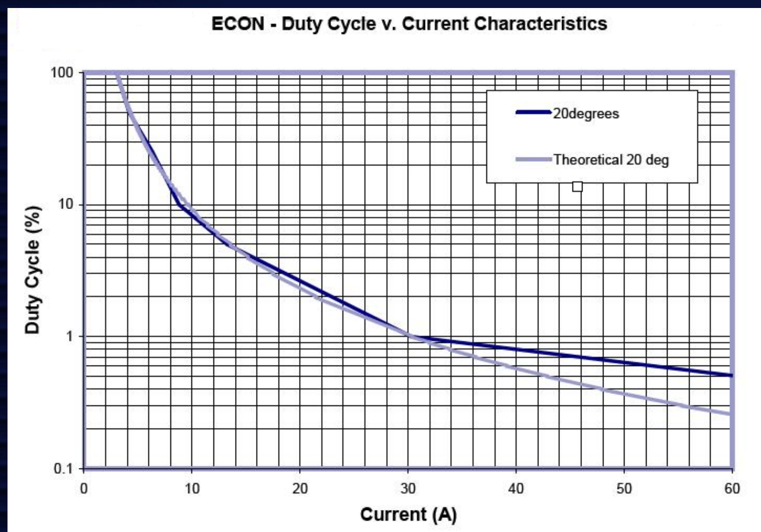
Example result: ECON probe



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Drawbacks

- Not the same environment as in the "real" test socket
- Little space for sensor placement at tiny probes
- Temperature sensor can draw away heat
- Are you sure you are measuring at the hot spot?

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New measurement principle

- Using the influence of temperature on mechanical properties of the spring
- CuBe alloy is hardened at 315 °C (600 °F) and loses its hardness at high temperatures
- Contact force changes when the probe is exposed to high current

Experiment setup

Experiment setup

- High precision 3-axis gantry system
- Solid state force sensor up to 2.5 N
- HP/Agilent 3457A multimeter
- Custom tester with 277 A maximum pulsed current
- Probes are held in original production ledges

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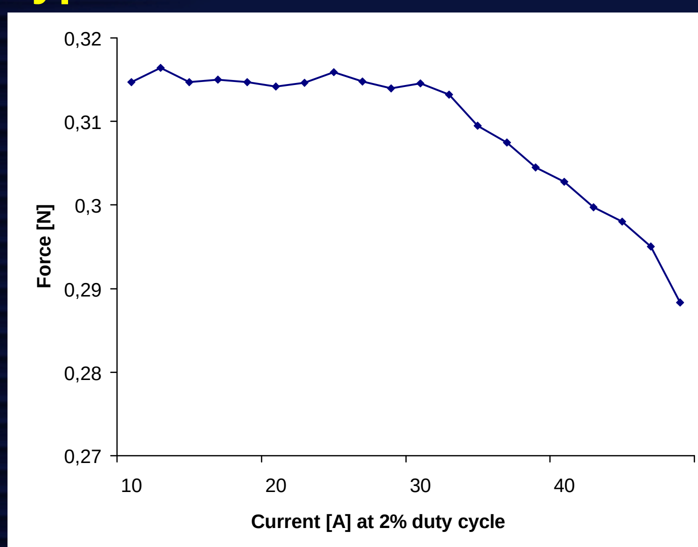
Typical current / force behavior



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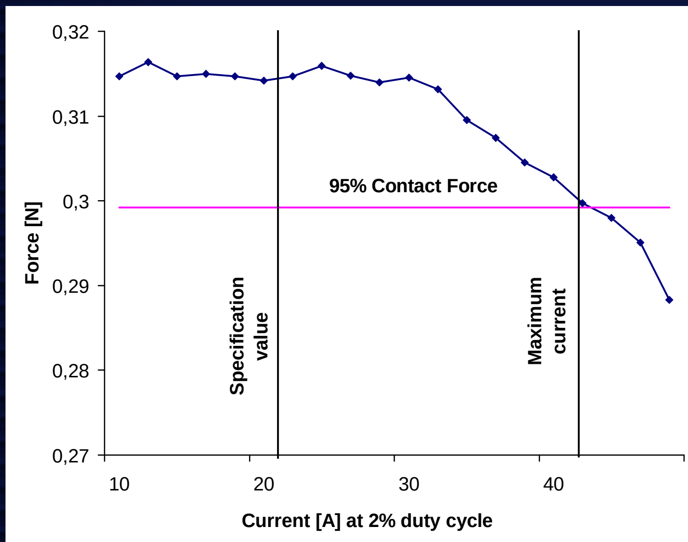
Determining specification current



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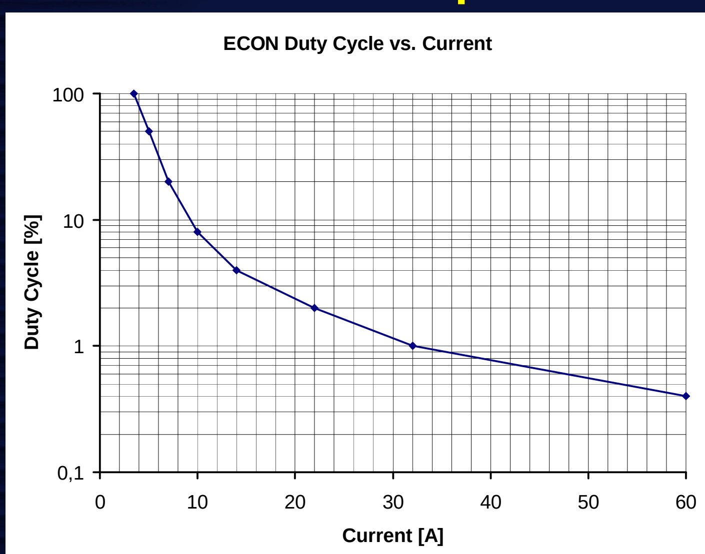
Result: ECON probe



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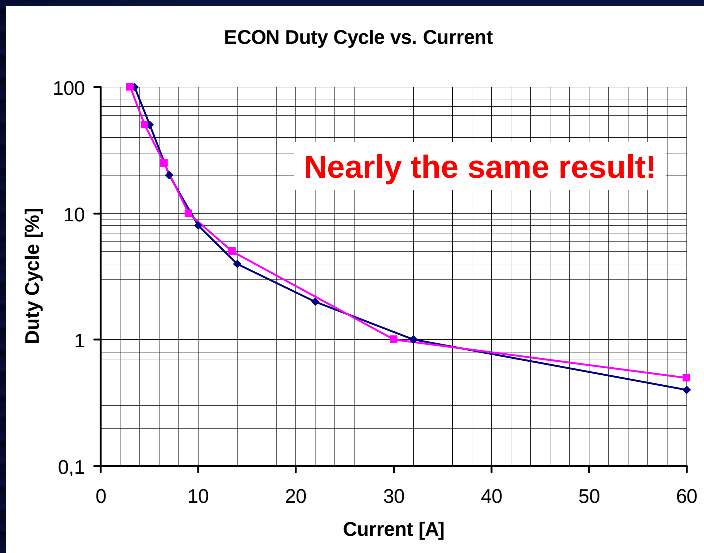
Comparison



Summary

- A new method for determining current carrying capacity has been presented
- The results are comparable to the well-established measurement principle
- No special fixture or temperature sensor attachment needed
- No limit on the size of the probe

Future works

- Influence of contamination and wearout
- Characterization of different probe geometries
- Applicability on Pogo style probes

Acknowledgements

Thanks to Antonio Peterson and Aaron Magnuson for their temperature measurements on the ECON probes

Testing the Socket

– The Benefits of Verifying Socket Functionality.

Josef Magro*, Silvio Spiteri*, Marco Michi+,
David Weston+ and James Forster+
*St Micro + WELLS-CTI

2011 BiTS Workshop
March 6 - 9, 2011

Agenda

- Introduction and background
- Review Contact Resistance and it's importance.
- Describe the CRES Tester
- Experience at ST Micro
- Closing comments

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Introduction

- For test or burn-in the contact resistance is one of the most important characteristics of a pin.
- If the contact is the heart of a socket then contact resistance is pulse of the socket.
  - When it is low and stable the contact is healthy and in good shape.
  - When it is high and variable there is a problem.
- What is contact resistance?
  - How do we measure it?
  - How do we monitor it?
- This presentation will attempt to answer these questions.

3/2011 Testing the Socket 3

Introduction

- What is a test socket?

  The single interface between a device being tested and a > $100K ATE
- An assembly of electrical conductors in a non-conductive body.
- How do you know the test socket is “good”?

3/2011 Testing the Socket 4

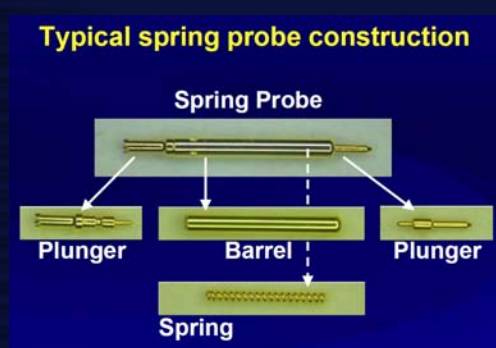
Introduction

- There are many kinds of "contacts" or pins.
- Fit into 3 broad categories
  - Stamped and formed.
  - Assembled springs and contact tips – e.g. spring or pogo pins
  - Others, elastomers and …

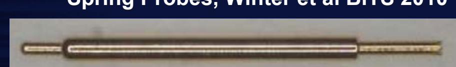
Pictures of different contacts from past BiTS Presentations

Introduction

– Assembled springs and contact tips – e.g. spring or pogo pins



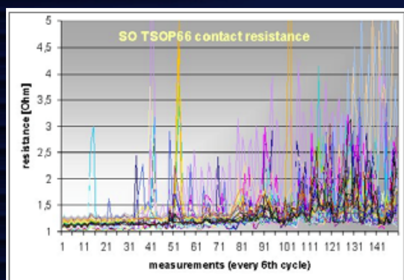
From New Development in High Temperature Spring Probes, Winter et al BiTS 2010



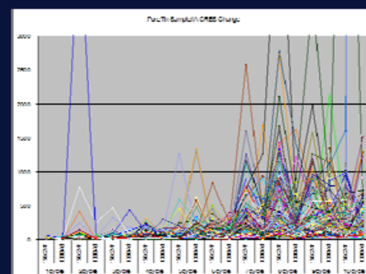
Pictures of different pins from past BiTS Presentations

Introduction

- Key electrical characteristic is contact resistance.
- Contact resistance can be inconsistent and "messy".
- It can be effected by lead finish, plating, temperature, number of cycles



From "Automated Burn-in Socket Testing and Evaluation," Hoppe, BiTS Workshop 2003



From "Contacting Pb-free finishes – A study of the effects of different lead finishes on the CRES and Reliability of a QFP contact", Forster et al, BiTS Workshop 2009

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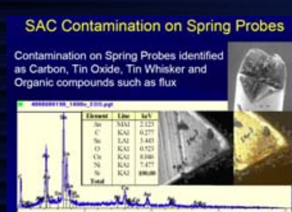
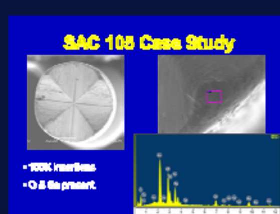
Introduction

- The causes of variation ….. contamination, wear and plating failures have been documented by many….



From "Test on Ball," Elmadbouly, BiTS Workshop 2009



From "An Examination of the Causes of C_{res} Degradation …..," Langston, BiTS Workshop 2008

From "Application of Socket Cleaning …," Orwoll, BiTS Workshop 2005

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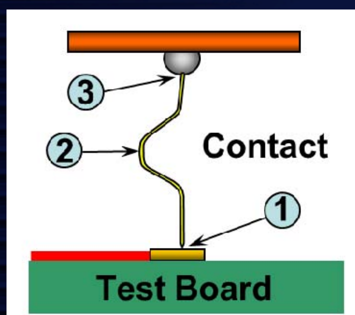
What is Contact Resistance?

- **The sum of all the resistances associated with interfaces and the bulk resistance of a contact.**
- **The "Contact Resistance" of a contact is shown in the schematic for a BGA and includes:**



1. The "*constriction resistance*" of the interface between the pad on the test board and the contact
2. The bulk resistance of the contact
3. The "*constriction resistance*" of the interface between the solder ball on the package and the contact.

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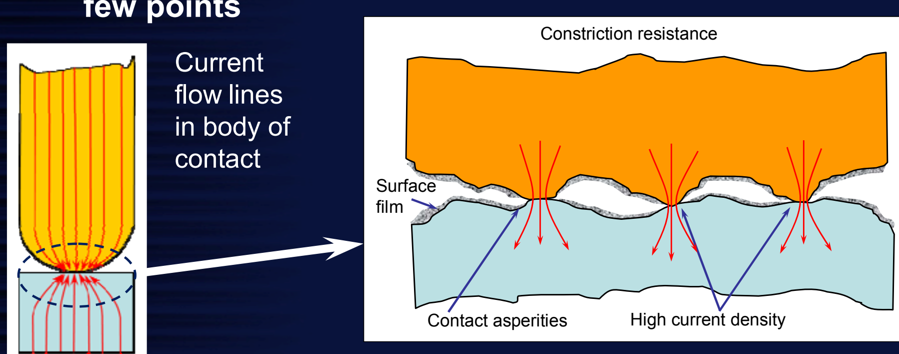
What is Constriction Resistance?

- **The bulk resistance of the contact is dependent on material resistivity. Copper is better than steel**
- **The constriction resistance is the resistance between two surfaces because they only touch at a few points**



From "Electric Contacts" by Holm

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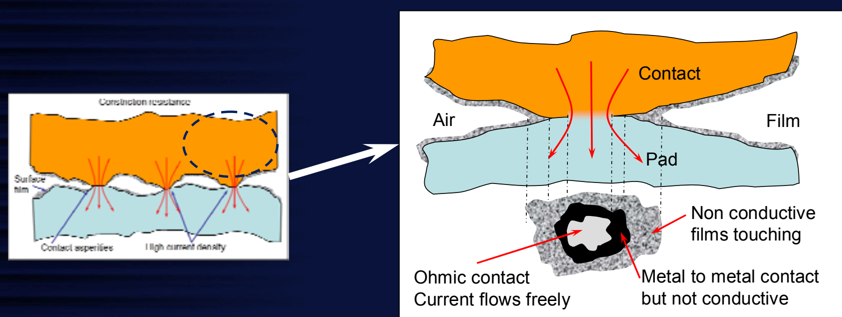
What is Constriction Resistance?

- When 2 surfaces touch the surface film is disrupted and with sufficient force or wiping the metal surfaces come into contact and a small area of intimate metal-to-metal contact is formed.
- It is important to differentiate between two surfaces touching and an "Ohmic contact".
- An Ohmic contact is one where the current and voltage follow a linear relationship i.e Ohm's law holds V=IR



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Problems at Test

- When a new device gets to production there is an expected yield but when that yield drops what are the causes?
- Possible causes of poor yield
  - Defective devices
    - Issues on the silicon from manufacturing
  - Package problems
    - Missing balls
    - Package size
  - Handler issues
    - Jams
    - Worn out or broken parts
  - Socket reliability
    - Contact CRES
    - Contact force

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So What and Who Cares?

- Contacts touch → Current flows
- Major property controlling this is contact resistance CRES
- Why should I care about the CRES?

  ……..Because in the end it's all about costs

- Since I care about costs I care about the CRES – but how can I measure it?

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The Impact of CRES

- **First Pass Yield.**
  - A good set-up would:-
    - Reliably and definitively identify good devices.
    - There would be no miss-tests or marginal fails.
- **First Pass Yield is often used as an indicator of socket performance.**
  - There is an expected yield, when that drops the performance and reliability of the socket is suspect
  - Monitoring first pass yield can be used to compare performance of suppliers, contacts or contact technology

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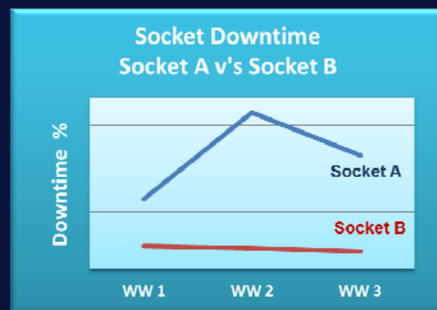
The Impact of CRES

- **Unstable/Inconsistent CRES or pin performance results in downtime and lost productivity due to:-**
  - Retest
  - Troubleshooting
  - Maintenance
  - Cleaning
  - Identification of "bad" pins
  - Pin replacement
- **Reliable pin performance, even at significantly higher prices, pays dividends in:-**
  - Capacity improvements
  - Availability of staff to concentrate on production.



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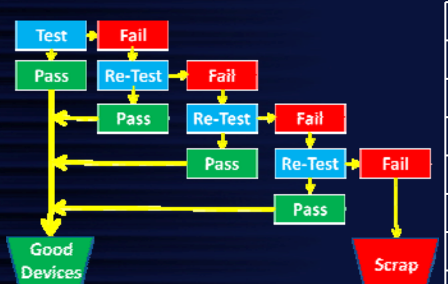
The Impact of CRES

- **Lets take a look at the two sockets shown in the previous slide.**
  - A good set-up would **reliably and definitively** identify good devices.
  - Customer evaluated 2 sockets
  - Number of devices tested approx. 300K/socket



	Socket A	Socket B
1st Pass Yield	X%	X+5%
Final	Y%	Y%
Socket Cost ($)	1X	3X
Pin Cost ($)	1X	2.5X
Retest Costs ($)	3X	X
Downtime (hrs)	More	–
Pin Life (Cycles)	Less	–

Total cost savings over life of project using socket B estimated >$250K

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Benefits of a Reliable Socket

- **Receive full entitlement for the investment**
  - Reduced operational costs
  - Delay capital investments by eliminating the hidden factory
    - Capacity used in rework/retest
    - Lost time due to downtime associated with socket cleaning and replacement
- **Socket purchase decisions based on cost of ownership, not acquisition cost**
- **But how can you evaluate the life/health of a socket?**

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Monitoring the Health of a Socket

- **The "Operational Approach"**
  - Any problems …. It's the socket, examine, remove, clean, rework, replace pins.
  - Monitor
    - First pass yields
    - Downtime/cleaning frequency
    - Cost of replacement pins
- **The "Proactive Approach"**
  - Monitor the health of the socket by measuring the CRES of each contact
  - Verify socket functionality before replacing in service
  - Know how the socket health changes with time/number of cycles.

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Socket Contact Resistance Tester

- **The CR-2600 tester is:-**
  - portable,
  - easy to use
- **Validates socket integrity by measuring contact resistance.**
- **Identifies the locations of open or high resistance pins within a socket array.**
- **User interface is displayed on a Windows computer via USB connection.**
- **No standard maintenance is required.**
- **Self calibrates before each measurement using 8 internal precision resistors for reference.**
- **Makes a Kelvin measurement.**

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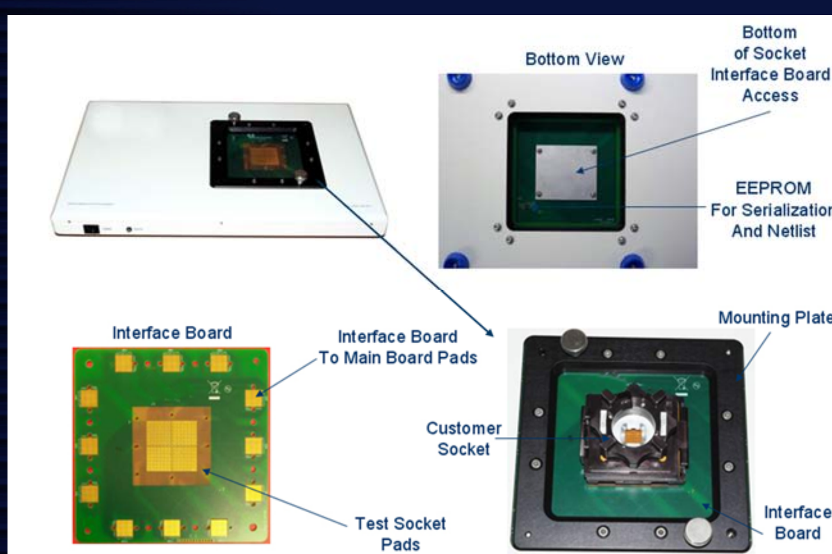
Key Components



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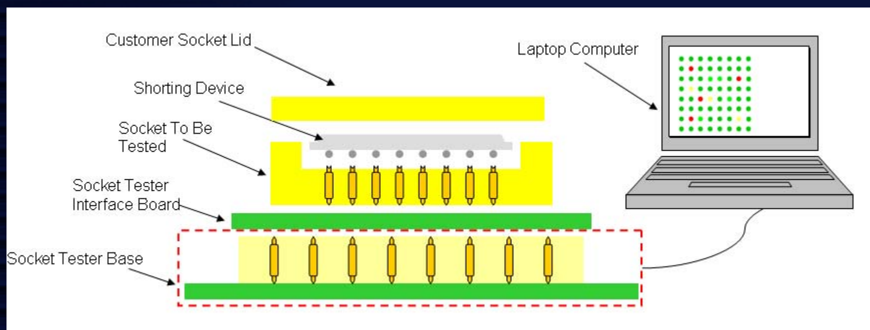
Tester - Overview



- **Shorting Device:** Shorting/Daisy chain package
- **Socket and Lid:** Spring Probe Socket to be tested
- **Interface Board:** Footprint specific, socket interface card.
- **Socket Tester Base:** Electronic circuitry to perform tester function
- **Host Computer:** Runs software to configure tester and report results

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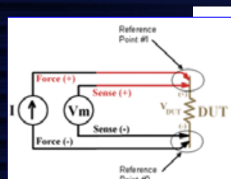
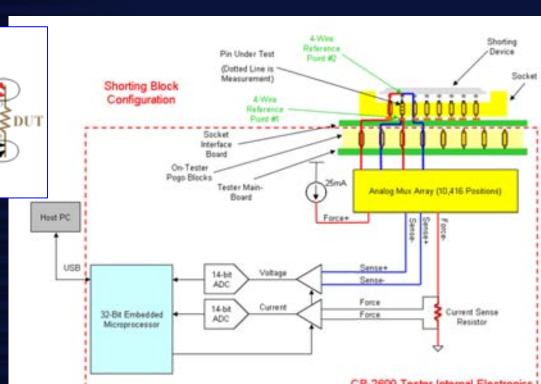
Resistance Measurement Methodology

- **4-Wire (Kelvin) Approach**
  - **Eliminates PCB and Cabling From Measurement**
  - **Requires Separate Current & Voltage Path**
  - **Accurately measures low-valued resistors**
  - **Allows single pin measurement**





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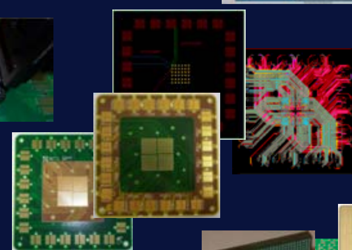
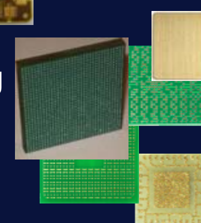
Overview CR-2600 Tester

- Solution includes
  - Software interface for ease of operation
  - Test probe pen
  - Interface boards
  - Custom built daisy chain and shorting packages





Applications

- Incoming inspection
  Validate/accept sockets before use.
- Socket maintenance
  Sockets tested before and after use.
- Root cause resolution
  Verify socket performance is within specification when a problem is discovered and engineering suspects a hardware problem.
- Preventive maintenance increases tester uptime.
  Based on history of DUT fails and monitoring of socket performance a max allowable CRES is establish. If pin exceeds that limit it is changed.
- Cost savings
  Keep good pins during socket rebuilding. One customer saved 12,800 pins/month valued at $24,298/month

ST Micro - Experience

- PROBLEM: Test Contact Issues.
  - Downtime due to test contact issues.
  - No verification of the socket refurbishing process effectiveness.
  - Typical device 35x35mmPBGA with 680 balls
- ACTION:
  - Introduced the use of a socket tester to check pogo pin resistance after cleaning

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ST Micro - Experience

- Introduced the use of a socket tester

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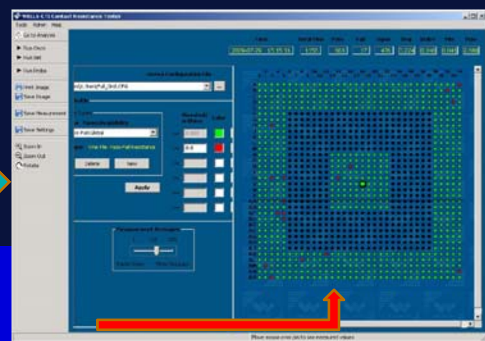
ST Micro - Experience

- The socket tester helps the technician identify failing pins more easily and quickly.
  - Improves the OEE, Overall Equipment Efficiency
  - Reduces the pogo pin consumption

User-friendly software highlighting the failing pin.



Green: Resistance < 0.8 Ohms
Red: Resistance > 0.8 Ohms
Black: No contact.
The threshold (0.8)can be changed.

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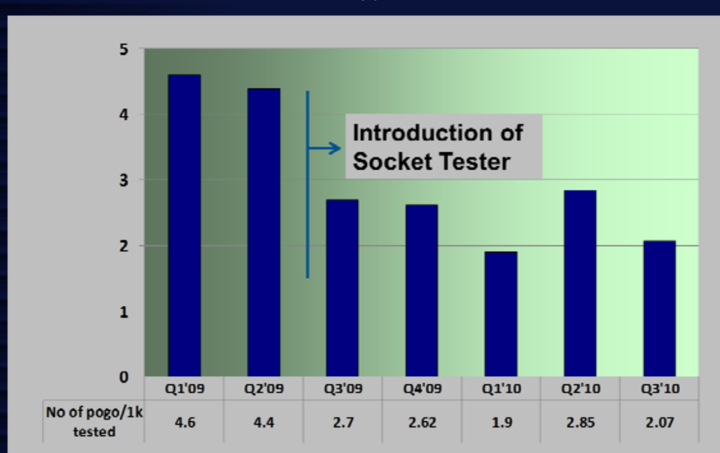
ST Micro - Experience

- Pogo Pin Consumption.
  - Reduced more than 35%



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ST Micro - Experience

- Socket Tester Enabled:
  - Faulty Pogo Pins to be easily identified
  - Faster repair
  - Reduced socket maintenance costs
  - Reduced pogo pins consumption, only replaced those pins with high CRES
- Production Benefit
  - Only good sockets are supplied to the production test floor
  - Reduced setup time
  - Reduced re-tests
  - More tester up-time

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Closing Comments

- We are learning more about the pin.
- Simplified identification of pin failures.
- Being able to easily and efficiently measure the pin CRES has led to improvements in the understanding of pin reliability, appropriate cleaning intervals and the effectiveness of cleaning
- Overall costs have been reduced by reducing downtime and expenditures for pins; the overall test floor equipment efficiency has been increased.

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Monte Carlo Simulation and Design of Experiments for Improved Pin-Pad Alignment

John DeBauche
Johnstech International

2011 BiTS Workshop
March 6 - 9, 2011

Agenda

- What is Pin to Pad Alignment?
- History
- Why Monte Carlo?
- How Does it Work?
- Introduction to Design of Experiments
- Case Studies

Pin-Pad Alignment

- Goal: improve pin-pad alignment to prevent false failures (resulting in less retest and lower cost of test)
- Misregistration of socket pin to ball/lead/pad is source of false reject
- At right is view of BGA through clear contactor, balls should align with contact mark
- Industry is pursuing tighter pitch and smaller lead frame features
- Back-end test equipment challenged to maintain high yield

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History

- 1946: Scientists working on radiation shielding gained access to a computer and code named their work Monte Carlo
- 2006: Ultra Fine Pitch Socket Development Challenges, Wei-ming Chi, Ken Kassa, Chak Fung Kong
- 2007: Monte Carlo Based Package to Socket Alignment Assessment Methodology, David Shia, Wei-ming Chi
- New: This presentation couples DOE with Monte Carlo for pin-pad alignment

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The Alternatives

- Worst case analysis based on extreme values is pessimistic (process capability-Cpk too low)
- Root sum squared considers typical variation but makes too many assumptions (process capability-Cpk too high)
- Monte Carlo is preferred for asymmetric distribution and non-linear boundary conditions

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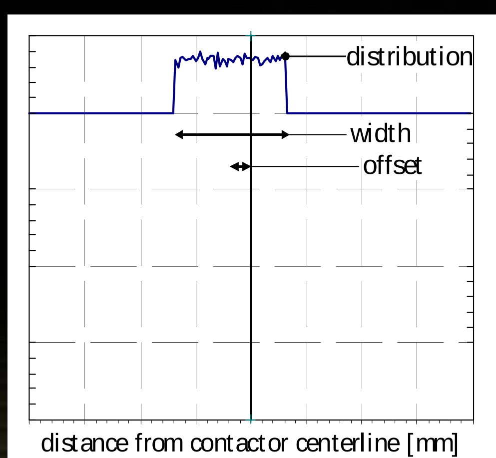
Model Strategy



- Distribution of retrieved package
- Data input:
  - Good: Measure input shuttle pocket, track width or precisor features (width only)
  - Better: Measure worn out alignment plate (width and offset)
  - Best: Video of packages presented to clear contactor (width, offset, distribution)

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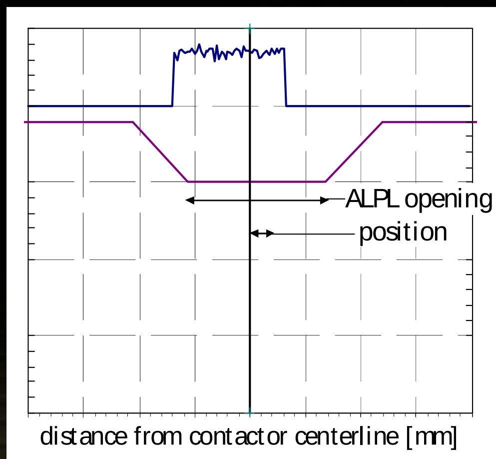
Model Strategy



- Alignment plate features
- Data input:
  - Good: Measure window with caliper
  - Better: Use optical equipment for width and position
  - Best: Repeat simulation for a range of window width and position

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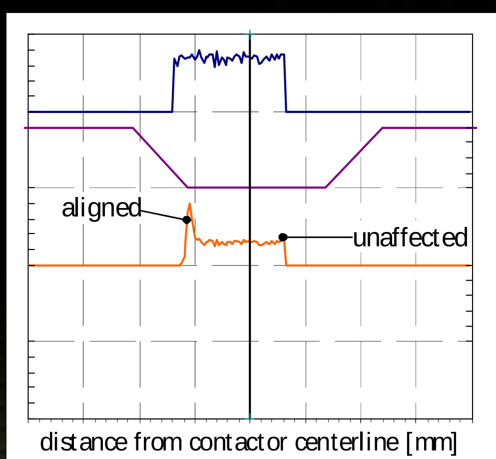
Model Strategy



- Aligned package is result of pickup and alignment plate plus body size and lead frame offset
- Package data:
  - Good: Measure virgin parts (rejects may be biased)
  - Better: Statistics from 100% visual inspection
  - Best: Summary data for consecutive lots over time

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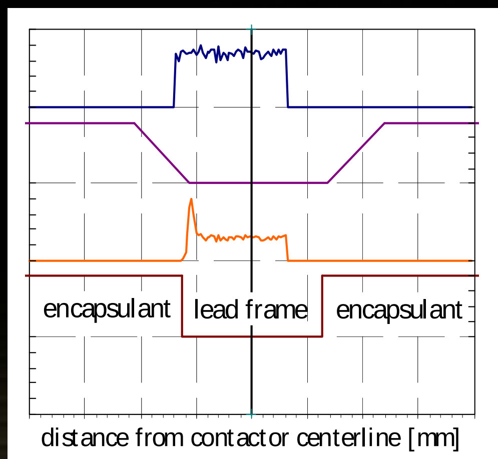
Model Strategy



- Pin-pad limits
- Contactor data
  - Different features for each technology
- Pad data
  - Recessed/exposed, width, length data
  - Data same as package
- Full engagement may not be required

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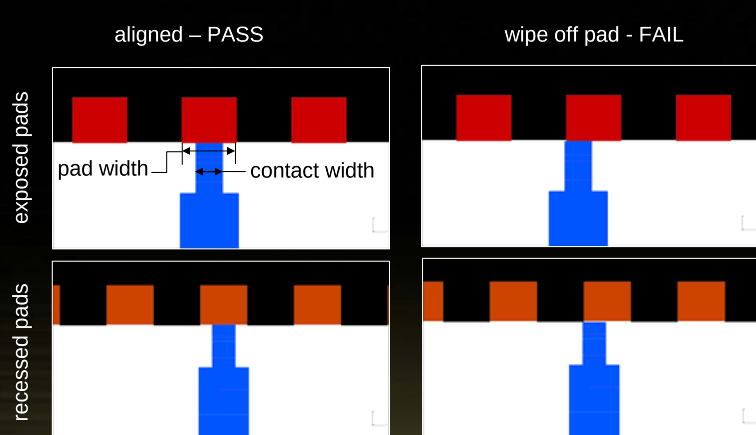
Pin-pad limits



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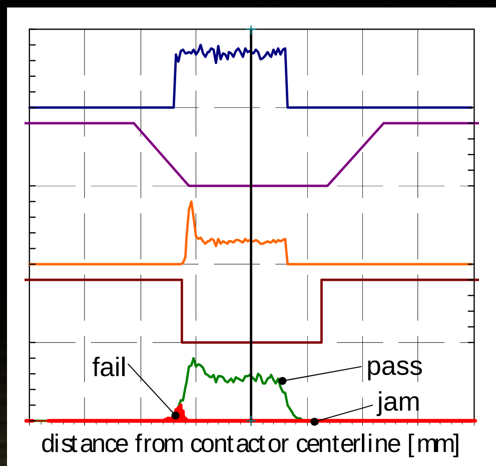
Model Strategy



- Bin results to
  - pass-green
  - fail-red
  - jam-black
- Fail is partial or no engagement and can be pad length or pad width

Design of Experiments

- Create matrix high and low states for all factors
- Randomize order
- Repeat Monte Carlo at prescribed conditions
- Fit quadratic polynomial to results of FPY from Monte Carlo
- Improve model fit by ignoring insignificant terms

	A	B	C	D	E	F	G	H	J	K	L	M	N	O
1	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	+	+	+	+	+	+	+	+	+	+	+	+	+	-
3	+	+	+	+	+	+	+	+	+	+	+	+	-	-
4	+	+	+	+	+	+	+	+	+	+	+	-	-	-
5	+	+	+	+	+	+	+	+	+	+	-	-	-	-
6	+	+	+	+	+	+	+	+	+	-	-	-	-	-
7	+	+	+	+	+	+	+	+	-	-	-	-	-	-
8	+	+	+	+	+	+	+	-	-	-	-	-	-	-
9	+	+	+	+	+	+	-	-	-	-	-	-	-	-
10	+	+	+	+	+	-	-	-	-	-	-	-	-	-
11	+	+	+	+	-	-	-	-	-	-	-	-	-	-
12	+	+	+	-	-	-	-	-	-	-	-	-	-	-
13	+	+	-	-	-	-	-	-	-	-	-	-	-	-
14	+	-	-	-	-	-	-	-	-	-	-	-	-	-
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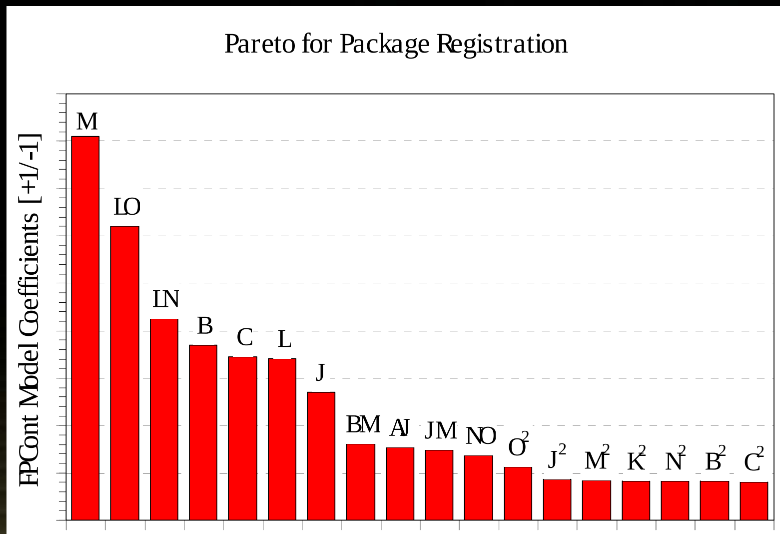
Pareto for First Pass Continuity



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Case Study 1

- Customer with 0.40mm pitch 88 lead QFN was concerned with retest rate and alignment plate life
- Performed MC for handler and package variables
- Pareto indicates alignment plate clearance is top contributor to retest rate
- Alignment plate material changed to ceramic, window nominal dimension and service limit reduced to compliment package assembly

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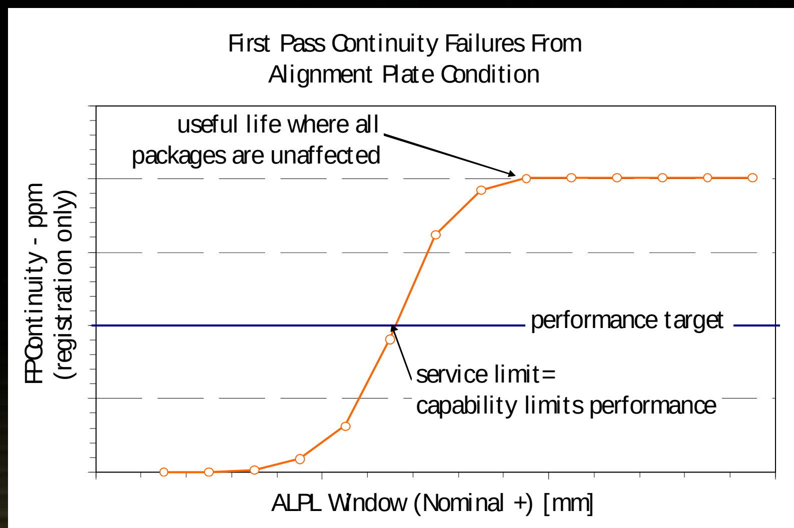
Case Study 1



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Case Study 2

- Customer with 0.50mm pitch 40 lead QFN is concerned about contactor contribution to retest
- Customer provided package assembly SPC data
- Johnstech characterized handler presentation
- Housing and contact measurements retrieved
- Performed Monte Carlo for all of the relevant contactor features plus handler and package details
- Monte Carlo indicates that all contactor features combined rank # 7 and just 1/3 the magnitude of top contributing factor on pareto

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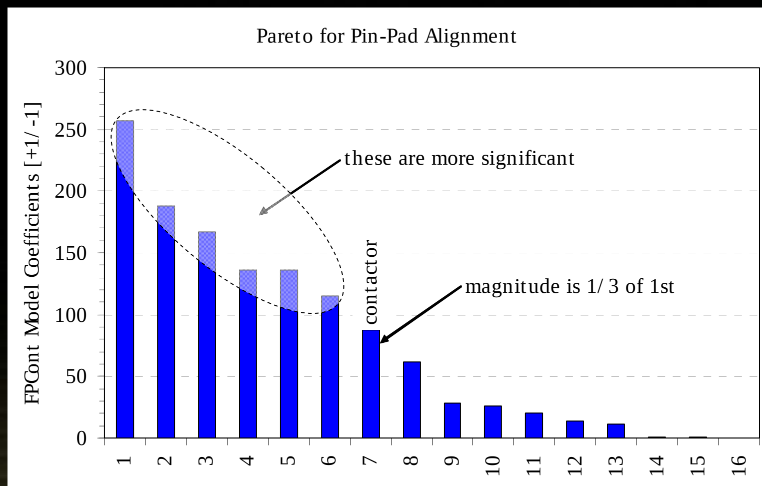
Case Study 2



Conclusion

- Monte Carlo is appropriate statistical tool for pin-pad alignment
- Monte Carlo can identify issues and yield
- Design of experiments is a powerful tool to identify interactions and rank factors
- Complexity of analysis increases with smaller pitch due to more significant factors