NINETEENTH ANNUAL

# BiTS

## Burn-in & Test Strategies Workshop™

**March 4 - 7, 2018**

**Hilton Phoenix / Mesa Hotel**
**Mesa, Arizona**

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# Life Cycles of Sockets; Specification vs Reality and Setting Standards

**Jiachun (Frank) Zhou**
**Smiths Interconnect**

**BiTS Workshop**
**March 4 - 7, 2018**

# Life Cycle Test Methodology

- Equipment
  - Custom fixture design
    - 32 pins for life Cycles test
    - 32 pins for FDR test
  - Customize Force/Measurement unit
    - Flexible to control the current density
  - Contact medium
    - Top plate silver - Life Testing & FDR
    - Bottom plate Cu/Gold plating - Life Testing
    - Bottom plate silver - FDR

**Cres Vs. Life Measurement**

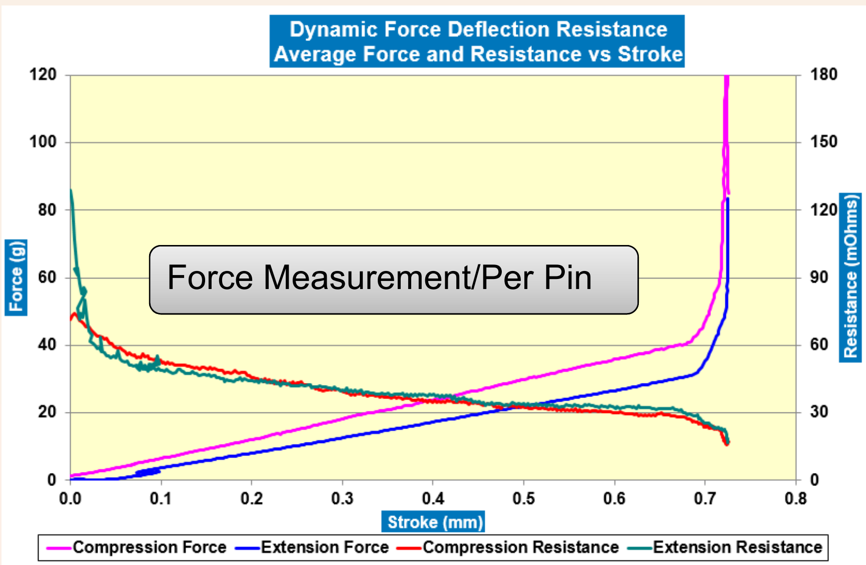

**Force Vs. Cres Vs. Displacement Measurement**

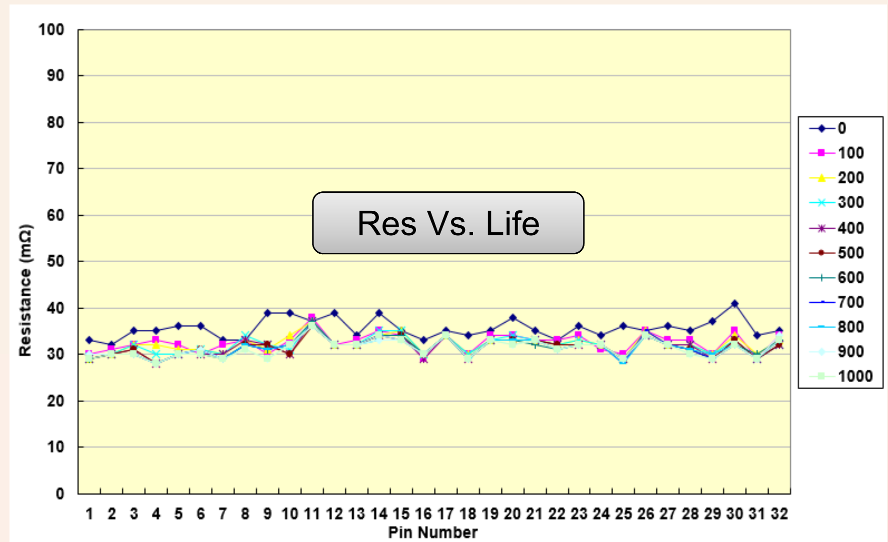
# Key Parameters/Assumption

- What defines End of Life in your method?
  - 5% over 200mOhms
  - Average Spec
  - Average + 2Std Spec
- Variables captured
  - Room Temperature
  - Normal Test 30mA/Customer Request maximum 1A.

# Example Data Internal vs. External

- FDR data
- Life cycle data



# Supplier Standards

- What are the major influences on socket life?
  - If "socket life" refers to spring probe, many factors, such as contaminations, spring force & stress, tip and surface wears, etc. can affect the life.
- How should life cycle be defined across the industry?
  - Really affected by usage environment and package
  - Actually, the life of spring probes from different suppliers is almost no differences if using same materials and plating specifications.

# Life Cycles of Sockets; Specification vs Reality and Setting Standards

**Rahima Mohammed**
**Senior Principal Engineer**
**Intel Corporation**

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# Agenda

- End of Life Requirements
  - scenarios in Validation and Test
- Socket Evaluation Methodology
- Factory feedback
- Need Standards

# End of Life Requirements

| Validation Disciplines | Validation Coverage |
|---|---|
| Power Thermal and Performance Validation | Validates thermal design power (TDP), thermal sensor accuracy, thermal throttling algorithm and power delivery |
| Analog and electrical Validation | Validates electrical performance and IO design |
| Functional validation | Validates logical functionality of the device |

**Validation → Find Logical Bugs**

**Validation uses validation boards or reference boards**

**Socket and thermal system uses quick release retention designs or simple loading mechanisms**

**Socket EOL > 200 cycles**

| Test | Coverage |
|---|---|
| Burn-in | Accelerates latent defects to meet time zero reliability |
| Class | Continuity tests, power measurements, dynamic frequency/voltage, test of all logic, arrays, I/O testing and SKU calculations |
| Circuit Marginality Validation (CMV) | Validates the safety margins of circuits |
| System Level Validation (SLT) | Uses a product specific tester interface unit based on the reference motherboard SLT insures shipping quality parts and for measuring outgoing Quality |
| Quality and Reliability | Extended life test |

**Test → Transforms design into competitive products.**

**Test→ Remove the defects introduced by Si fabrication process**

**Class and SLT utilizes robotic handlers**

**Socket EOL > 500K cycles**

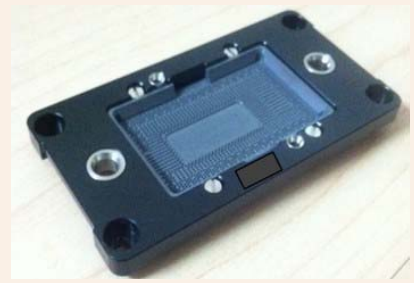
**Socket Electrical, Mechanical, Thermal Performance, Lifecycle and Cost are critical vectors**

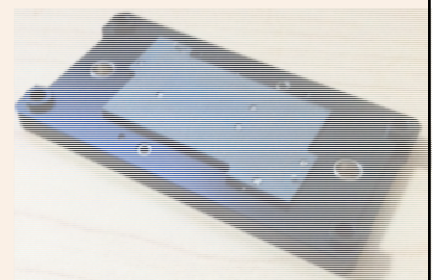
# Additional Socket Evaluation Methodology

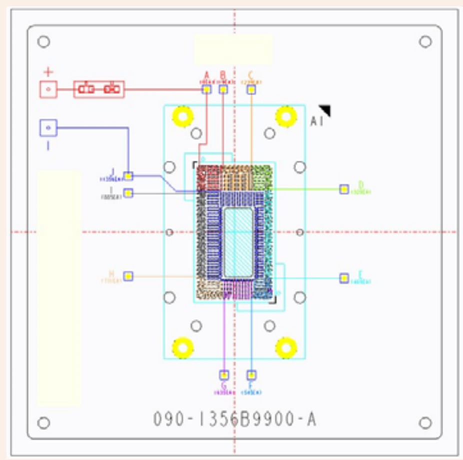
- Equipment
  - Tester/Handler with actual devices
  - Socket and test fixture
  - Cres measurement equipment
- Process
  - Maintenance Cleaning intervals
  - Insertion/extraction tracking
- Other
  - Evaluation are done per technology
  - Then done for every families
  - Per device, only tested for opens/shorts, mechanical fit check

# Socket Evaluation Methodology

- Electrical
  - Daisy Chained Test Boards are used to evaluate the force/pin and contact resistance per pin and variations between sockets of same or alternate technology
  - Insertion loss and return loss
- Mechanical
  - Force/pin, socket tip wear on the DUT side and PCB side, marks on the package
  - Checking for contamination on the pins under the microscope
- The socket is then run for 1000 mechanical cycles in the system level testing setup, then through actual system level testing.
  - Passed the short test and passed the long test content except for a specific content for 1000 cycles. Cres tests were repeated using the daisy chained test boards.
  - Similar exercise were done for 2000, 3000 and 5000 cycles. At 5000 cycles, failed short and long test content for SLT.



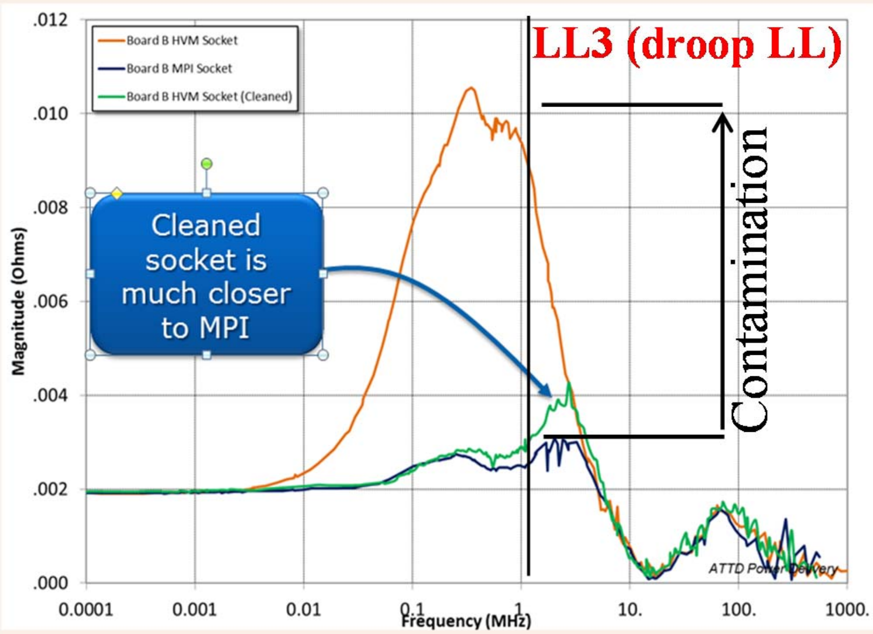




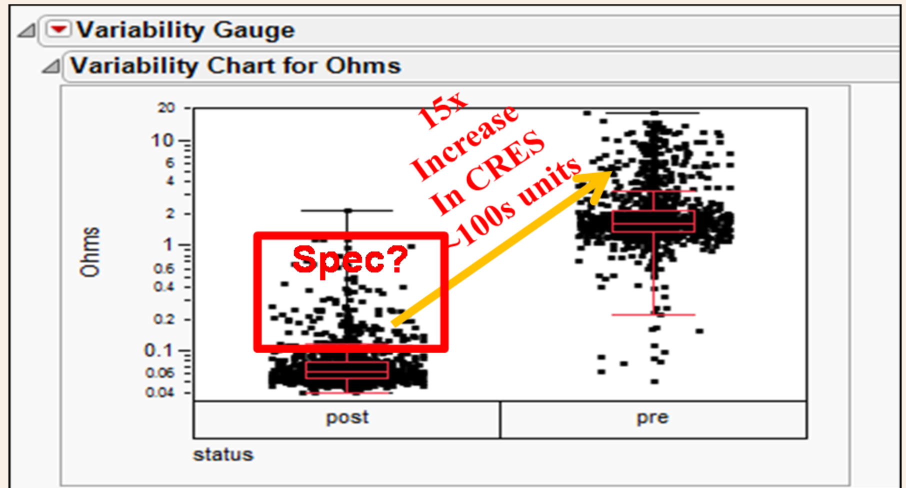


**Clear disconnect between socket vendor data of 100K cycles vs > 3K and < 5K cycles**

# Factory Feedback




Impedance vs Frequency Measurements




Variability Summary for Ohms

| | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| Ohms | 1.26698 | 2.10801 | 0.039287 | 1.189946 | 1.344014 |
| status[post] | 0.089859 | 0.111249 | 0.002932 | 0.084108 | 0.095609 |
| status[pre] | 2.44492 | 2.470863 | 0.065136 | 2.317149 | 2.572691 |

Contact Resistance between Pre and Post cleaning

**Manual reject validation shows ~50% of the SLT rejected failures actually pass with the validation sockets → Direct impact on Yield**

## Need Standards

- What are the major influences on socket life?
  - Temperature cycling, power cycling, current carrying capability, how long the current is applied for, force distribution, electrical performance specially high speed data rates, package size, pitch, number of pins, routing of the signal, power and ground pins.

- How should life cycle be defined across the industry?
  - What is critical?
    - Socket Electrical, Mechanical, Thermal Performance, Lifecycle and Cost are critical vectors
    - Socket specs has to be defined for that socket rather than the technology itself. It's all the other interaction that actually determines the performance of the socket in the specific application
  - What is controversial?
    - Disconnect between the socketing technology and the whole socket performance itself
  - What is unnecessary?
    - One size fits all for the technology will not work

# Life Cycles of Sockets; Specification vs Reality and Setting Standards

Yoinjun Shi Twinsolution

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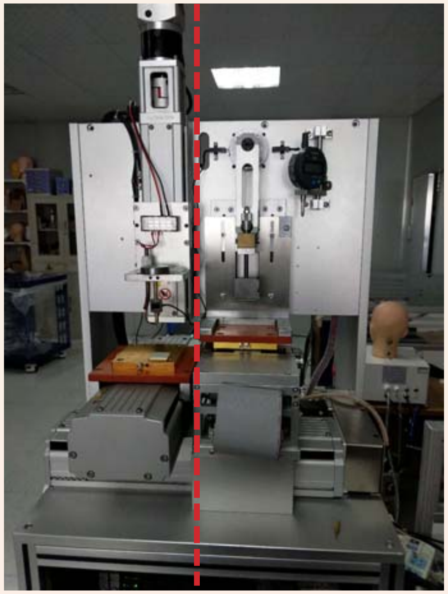
# Life Cycle Test Methodology

- Equipment
  - Custom fixture design
    - 32 pins~96 pins for life test
    - 36pins ~ 2000pins for F/Res test
  - Cam mechanism for life cycling
  - Customize Force/Measurement unit
    - Flexible to control the current density
  - Contact medium
    - Top plate silver-Life Testing
    - Top Plate BeCu/Gold plating-FDR
    - Bottom plate BeCu/Gold plating

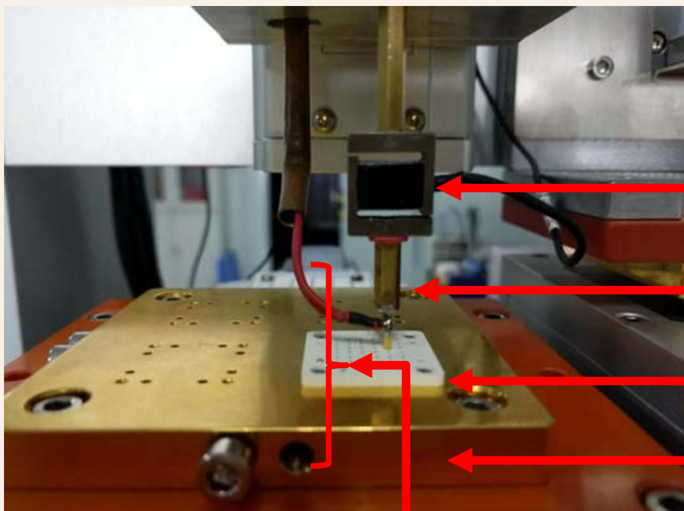
F/Res Vs. Displacement Measurement



Res Vs. Life Measurement

# Life Cycle Test Methodology-Continue

F/Res Vs. Displacement Measurement Unit



Compress force measurement unit (500gf)

Top Contact Plate

Customize Fixture

Bottom Contact Plate

Res(Force/Measurement Unit)

# Key Parameters/Assumption

- Why was this method chosen
  - Contact method is more life the IC ATE testing, it's a steadily contact, no movement after the handler compressed.
  - Silver and gold plated plate provide a good contact for top plunger and bottom plunger tip, to minimize the impact of contact point impact.
  - CAM design more precise compare with cylinder piston, comparable wear acceleration with handler.
  - CAM design is also easy to control the running speed of the life testing.
- What defines End of Life in your method?
  - 5% over 200mOhms
  - Average Spec
  - Average + 2Std Spec
- Variables captured
  - Room Temperature
  - Normal Test 30mA/Customer Request maximum 1A.

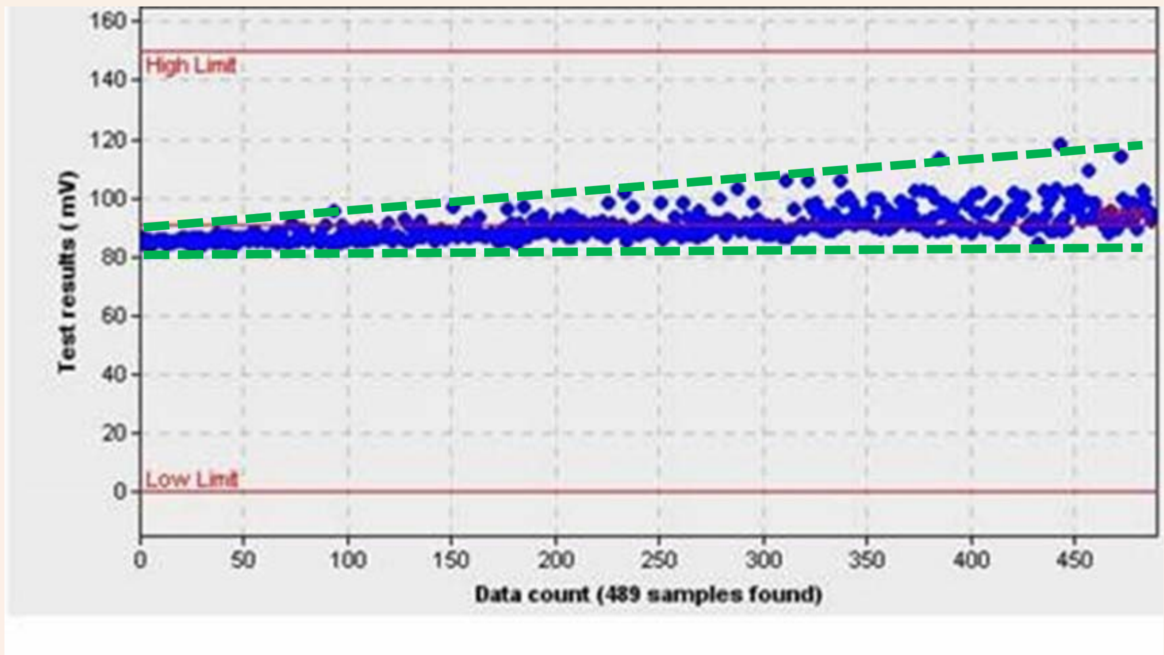
# Example Data Internal vs. External

- IDM Data-Example3 (Switch Voltage)

Test Type: Parametric
Low L. 0mV
High L. 152mV

Mean: 91mV
Min: 84mV
Max: 119mV

Samples:500



## Supplier Standards

- How should life cycle be defined across the industry?
  - Res/Contact force
  - Top plate material normally is solder or matt tin, which is quite different from device, and this play a big role of life span.
  - Current density and on time is also another important factor to impact the life span of pin.
  - Sampling data of measurement is good enough to test the life span, we do not have to measure the pin by each cycle.

# BiTS Contactor Life Cycle Panel Session

James Migliaccio
Qorvo

BiTS Workshop March 4 - 7, 2018

# Qorvo

Formed from the merger of TriQuint Semiconductor and RF Micro Devices →January 2015

We test a broad portfolio of RF devices: from low volume custom products to high volume general market devices at package and die level

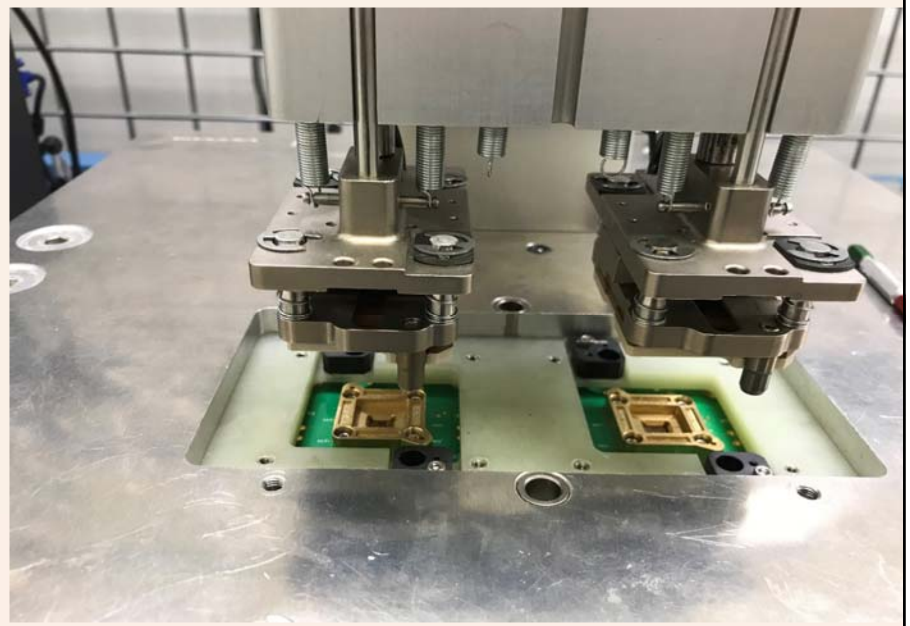
Correspondingly need a variety of contactor solutions to satisfy divergent families of products with different needs

# End of Useful Life Requirements

- Yield (electrical) or # of cycles (planned mechanical)
  - Poor performance (low yield), customized by product as each device is unique
  - Contact Performance Maintence System (CPMS) used to set standard maintenance and replacement intervals based on similar products initially
  - Factory adjusts intervals based on testing
- Typically will run a contact to failure (fatigue) if possible
  - Replace all pins at once
  - Do not mix new and old contacts in same socket

# Socket Evaluation Methodology

- Life Tester
  - Socket designed around product
  - Uses handler plunge assembly to cycle devices
  - Socket mounted on test fixture
- Process
  - Plunge actual devices, mimic test time
  - Periodic read points to inspect/measure
- Other
  - Use force gauge to determine displacement versus normal force to get average normal force per pin



# Purpose of Internal Data

- Our data is to estimate the expected life of a socket/contact as used in production setting
- Use data to set cleaning and replacement intervals (CPMS)
- Use actual devices rather than surrogates to determine wear rate of contacts and damage to pads
- Observe changes in contact surface (plating), shape (wear), and damage

# IDM Standards

- What are the major influences on socket life?
  - Real world use → contamination, temp, current
- How should life cycle be defined across the industry?
  - Change in contact resistance is basically a default standard (20%?)
  - Measured at nominal current and max current along with defined duty cycle and recommended/max stroke
  - Common surrogate device design
  - Need a significant sample to determine population

# Life Cycles of Sockets; Specification vs Reality and Setting Standards – Contact Resistance

**Valts Treibergs**
**R&D Engineering Manager**
**Xcerra**

**BiTS Workshop**
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# Xcerra Cycling for $C_{res}$ Characterization

**OFF-LINE CYCLING**

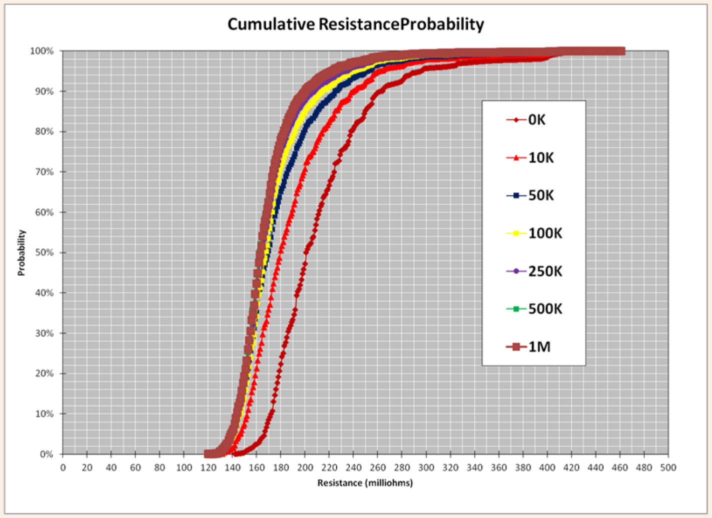
- Mainly used for spring probe qualification
- 256 pin socket **(LARGE SAMPLE SIZE)**
- Hardstop to set probe overdrive
- Gold / Gold cycling surfaces – checked often for wear
- Force – Resistance – Deflection evaluated at prescribed cycle intervals: 0, 10k, 50k, 100k, 250k, 500k, 1M, +
  - MAP – Cres and Force at contact nominal test height
  - FReD – Contact consistency over entire stroke – window of consistency, hysteresis

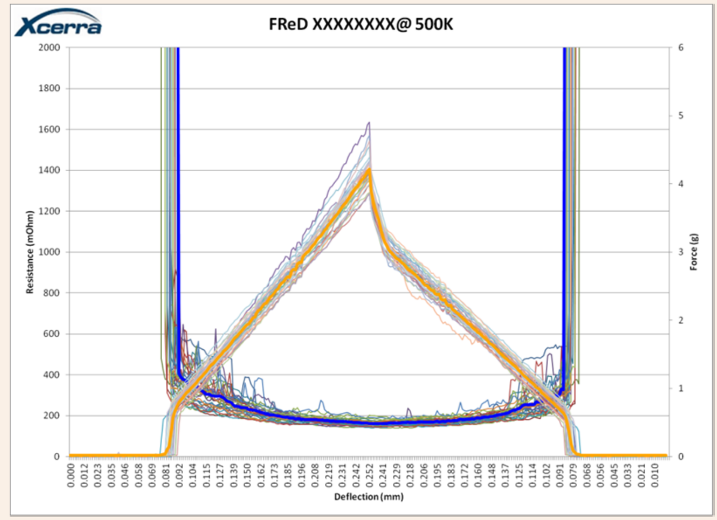
**DYNAMIC CYCLING**

- Used primarily for elastomer and cantilever contact qualification
- 28-56 contact points in socket configuration
- Hardstop to set probe overdrive
- Gold / Gold cycling surfaces – checked often for wear
- Automated $C_{res}$ data collection in programmable tri-temp chamber
- Off-line Force / Resistance / Deflection test also done at 250k intervals

## Xcerra Off-Line Cycling Data

MAP test shows statistical trends in performance – probability plots – statistical trends in force and resistance




| Cycle Count | 0 | 10,000 | 50,000 | 100,000 | 250,000 | 500,000 | 1,000,000 |
|---|---|---|---|---|---|---|---|
| Average Resistance (milliohms): | 89.3 | 90.0 | 92.1 | 105.5 | 96.1 | 106.4 | 106.9 |
| Std Dev Resistance (milliohms): | 8.9 | 8.2 | 9.6 | 14.7 | 12.5 | 18.0 | 21.4 |
| Max Resistance (milliohms): | 118.1 | 107.2 | 132.9 | 144.7 | 153.1 | 189.9 | 217.4 |
| Min Resistance (milliohms): | 73.1 | 71.9 | 75.0 | 80.2 | 75.8 | 82.1 | 76.5 |
| Average Force (g): | 13.6 | 14.0 | 14.0 | 13.8 | 13.8 | 13.7 | 13.6 |
| Std Dev Force (g): | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Max Force (g): | 14.4 | 14.7 | 15.4 | 14.4 | 14.6 | 14.8 | 14.7 |
| Min Force (g): | 12.9 | 13.3 | 13.1 | 13.0 | 13.3 | 13.0 | 13.0 |

FReD plots display internal frictional/Cres effects over time – hysteresis and potential mechanical and plating problems

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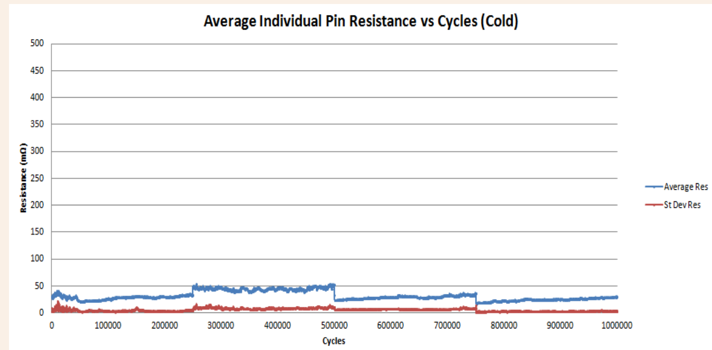
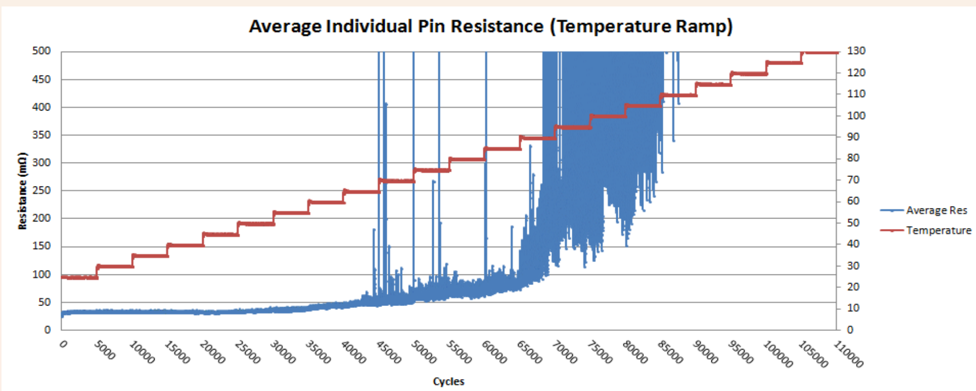
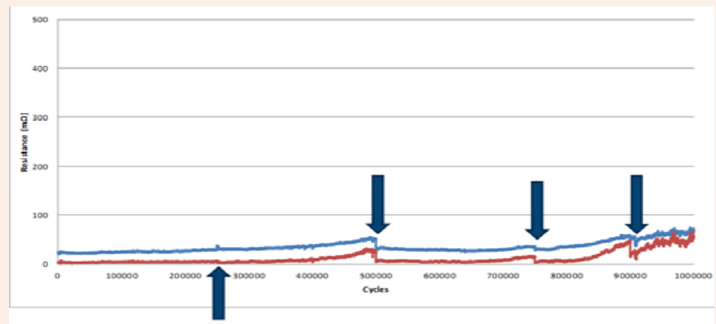
# Xcerra Dynamic Cycling Data

Dynamic cycle plots show statistical trends in $C_{res}$ performance over various conditions

| Pin State | Cycles | Ravg (mΩ) | Rstdev (mΩ) | Favg (g) | Fstdev (g) | % Force Reduction |
|---|---|---|---|---|---|---|
| Initial | 0 | 24.6 | 2.5 | 29.3 | 2.8 | - |
| Pre-Clean | 250,000 | 36.2 | 9.4 | 28.0 | 2.8 | 4.5 |
| Post-Clean | 250,000 | 34.0 | 7.2 | 27.6 | 2.7 | 5.8 |
| Pre-Clean | 500,000 | 38.1 | 6.1 | 27.8 | 2.7 | 5.2 |
| Post-Clean | 500,000 | 33.3 | 5.7 | 27.6 | 2.7 | 6.0 |
| Pre-Clean | 750,000 | 42.3 | 4.7 | 26.9 | 2.5 | 8.4 |
| Post-Clean | 750,000 | 36.5 | 6.1 | 27.0 | 2.3 | 7.8 |
| Pre-Clean | 1,000,000 | 41.1 | 10.8 | 27.4 | 2.3 | 6.5 |
| Post-Clean | 1,000,000 | 35.3 | 11.2 | 27.0 | 2.2 | 8.0 |




•250k – Mipox cleaning only
•500k – Mipox cleaning and elastomer replacement
•750k – Mipox cleaning only
•900k – Mipox cleaning and elastom replacement

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# Key Parameters & Assumption

- Off-line Cycling
  - Very defined procedure – automated data collection – relatively quick
  - Large sample size – can keep retains for post-mortem analysis (SEM/other)
  - Best for spring probe applications
  - **END OF LIFE:** any mechanical failures (breakage or sticking), $C_{res}$ standard deviation exceeds 20% of average Cres value
- Dynamic Cycling
  - Best for elastomer/cantilever contacts, because elastomer performance is very specific to environment. Scrub amount influences lifetime/performance
  - **END OF LIFE:** any mechanical failures (breakage or sticking), $C_{res}$ standard deviation exceeds 20% of average Cres value
- Variables captured
  - Forcing current during $C_{res}$ measurement, contact interface metallurgy conditions, temperature

## Lab vs. Real Test-Floor Performance Data

- Lab data is only useful to define a data-sheet baseline set of performance parameters **– <u>The best case scenario – ignoring everything else</u>**
- Socket suppliers interact with hundreds of customers, DUT types, handlers/probers, and test conditions. **This makes it impossible to test for every possible combination and scenario**
- How does production yield data relate to contact resistance? It depends. The onion must be peeled back carefully to rule out environment, device or setup related problems

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## Supplier Standards

- **What is Critical:** Define a standard force and Cres baseline (at what current and under what conditions)
- **What I want to see:**
  - From Customers: What statistics and under what conditions shall we provide data? How do you want this data presented? A standard template would be quite nice!
  - From Xcerra and other Socket Suppliers: **Complete test reports** that include equipment, test conditions, methods, results with complete statistics

DATA SHEETS ARE WORTHLESS

(unless supported by test methods & statistics)

# Life Cycles of Sockets; Specification vs Reality and Setting Standards

**Texas Instruments**
**James Tong**

**BiTS Workshop**
**March 4 - 7, 2018**

## TI Contactor Strategy

Pass/Fail Criteria: $\geq$ Life of **1M insertions**,1 pins for **all pitch** by **package type**

**Pin life performance base on actual production evaluation data along with typical production variables**

### Electrical

- Mis-contact reliability
  - DC (Open/Shorts) –
    - First Pass conti%
    - Yield recovery from Conti test
- Frist Pass yield
  - Func-Para failures
    - RF or speed related test

### Others

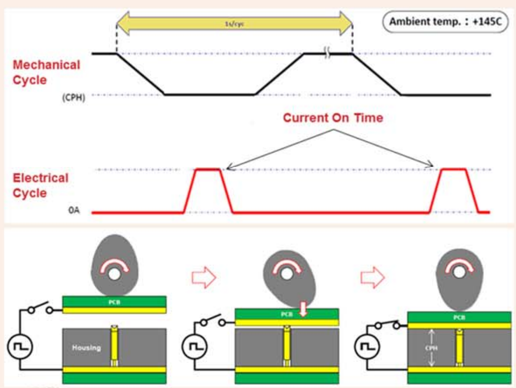
- Temperature performance

### Mechanical

- Force? – Do we care if it performs the test
- Tip wear? – Do we care if it does not affects the yield (electrical and mechanical)
- Package witness marks – No physical damage to DUT pad or ball
- Alignment features - alignment of contact affecting potential VM rejects/electrical performance

# Supplier Socket Self-Evaluation Methodology

- Equipment for **METS Test**
  - Standard contactor vendor test equipment
    - FReD tester, Contactor cycler, Power suppliers, offline measurement tools, Infrared camera, network analyzer and contactor checker or OQC tools
  - Tester/Handler with actual devices




Emulating test application as best as possible

**Vendor Self Qualification**

- Pin specification
- Cost → Pin and contactor
- METS test
- 1M Cres test at temp
- Mechanical test: scrub wear test, Cu expose test

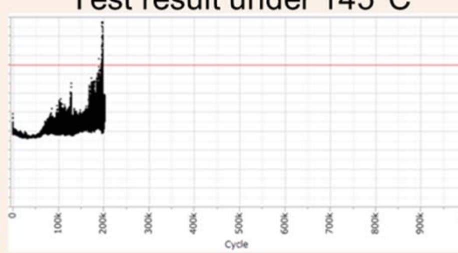
**Prototype Checkout**

- Build prototype contactor/s for engineering evaluation
- Prove RF/Speed characteristic of solution
- Small sample run to reduce risk at production qualification phase

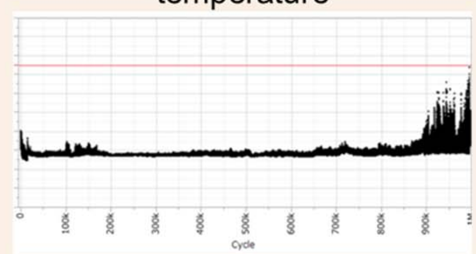
**Production Qualification**

- Multiple samples of contactor to prove lifetime (Cres) and other spec envelop →Temperature, Current, Speed/RF test performance
- Maintenance learning

Test result under 145°C




Test result under room temperature

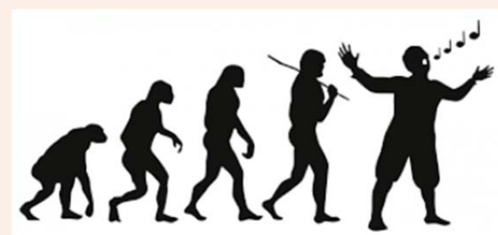


# Santa's List

- The "Not-Me-Too" Supplier

  Product distinction
  - Cres stability
    - Pin structure design, Plunger material and hardness, Spring material and characteristic
  - Temperature, current, plating of plunger and barrel if applicable

  Support distinction
  - Application support from supplier
    - Hot switching, Residual electrical charge handling, Current load sharing and distribution
- Standardization
  - Current carrying capability using METS
  - Insertions life expectancy base on test application
  - Compress pin height
  - Common test guide line of specifying solution for high speed broadband and/or RF test needs

Contactor Live Cycles Panel Session – Texas Instruments 4