THIRTEENTH ANNUAL
BiTS 2012
Burn-in & Test Strategies Workshop

Session 1

ARCHIVE 2012

THE TRICKS ARE IN THE TOOLING

What do today's burn-in process, power delivery efficiency, DUT temperature control, pin characterization and socket qualification all have in common? They're all being challenged by smaller geometries, increased power with localized densities and thermal conditions, all compounded with a need to produce solutions in less time at lower cost. Speakers in this session have come up with some innovative solutions such as a novel approach to addressing burn-in challenges with a thermal interface material, managing electrical, mechanical and thermal challenges for high current implementation in a temperature-humidity system, managing DUT temperature using LN2 injection and the development of a programmable tool to characterize socket pins.

Burn-in Process Thermal Challenges With High End Applications

Oswaldo Chacon, Alexandre Leblanc, Martin Laliberté, Benoît Foisy
—IBM Canada Ltd.

High Current Implementation in a Temperature-Humidity System

John Pioroda, Naveed Syed—Incal Technology

DUT Temperature Control Using LN2 Injection

Nolan Riley, Chad Turner, Joseph Mayfield—Texas Instruments

Sophisticated Tool for Pin Characterization & Socket Qualification

Praveen Kumar Ramamoorthy, K.W. Low—Intel Corporation

Burn-in Process Thermal Challenges With High End Applications

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IBM Canada Ltd.

2012 BiTS Workshop
March 4 - 7, 2012

Thermal Project Agenda

- **Project Introduction / Incentive / Goal**
- Evaluation Strategy
- Evaluation Results
- Conclusions

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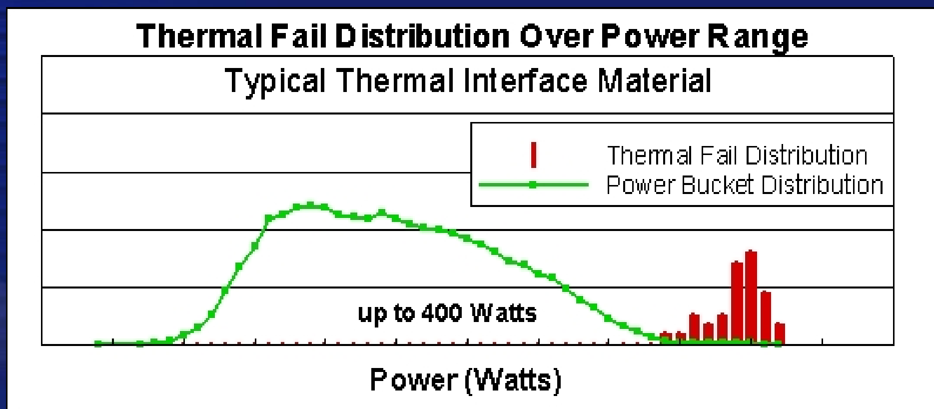
Project Introduction

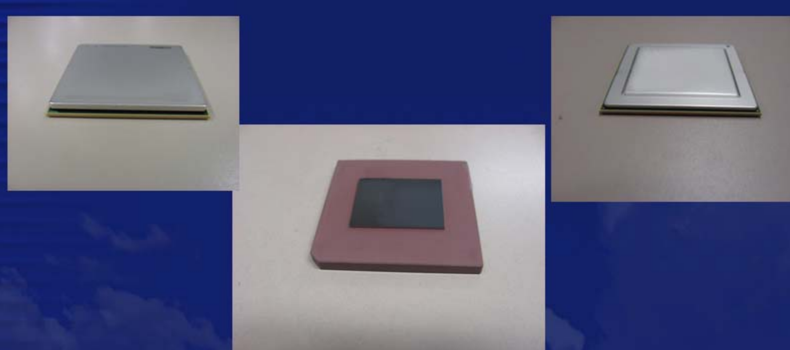
- Today's high end applications require more efficient thermal control during Test / BI.

For Burn-in:



Project Introduction

- Many different module configurations:
  - TIM's need to adapt to this diversity & perform well.



Project Incentives

- In a volume mfg environment, critical variables for new TIM's:
  - Need to be cost efficient (many ovens).
  - Thermal solutions need to meet present and future thermal requirements (minimize requal's).
  - No capital intensive tool retrofit / purchase .
  - Easy maintenance to minimize down time (minimum impact to production).
  - Use of common thermal solution for all configurations.
  - And, need to maximize thermal performance in temporary Burn-in heat-sink.

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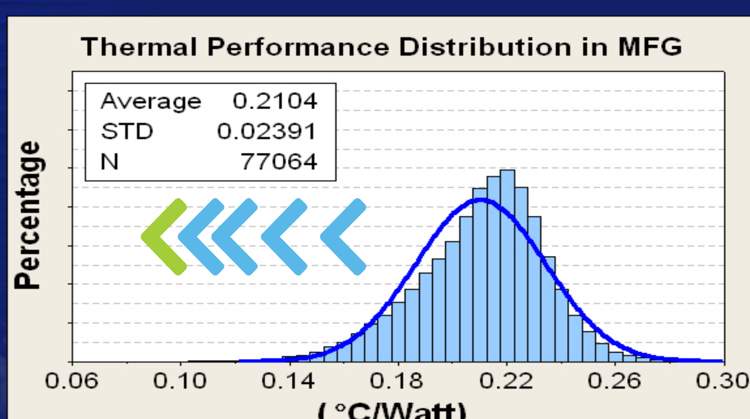
Project Incentives

- To evaluate alternate TIM's for our High end applications
  - Present production TIM performance = at it's max.
  - Need to improve thermal performance.



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Project Technical Goals:

	Goal importance
Improve thermal performance	√√√√
High temperature Cycling & Longevity	√√√√
Uniform heat sink pop. performance	√√√
Enable Burn-in parameter increase	√√√√
Ease of replacement	√√
No additional process needed & Cost	√√√

√ = Less
√√√√√ = Most

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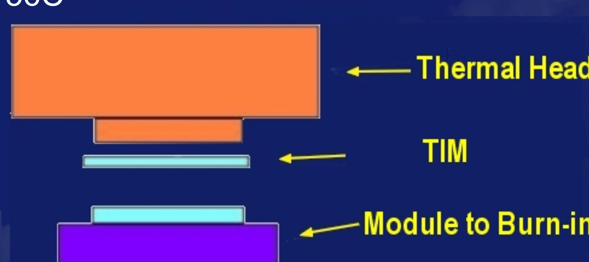
Material Choice & Characteristics:

- **Why Indium?**
  - Best fit for our mfg. environment and technical goals.
  - Minimal hardware changes to existing environment.
  - Looking for a different solution than what is available in the market.
- **Choice of Material → Indium pad**
  - Th. Conductivity: 81.8 W /m·K
  - Melt. temperature: 156C
  - Pure Indium
  - Malleable
  - Pad Cladding



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Thermal Project Agenda

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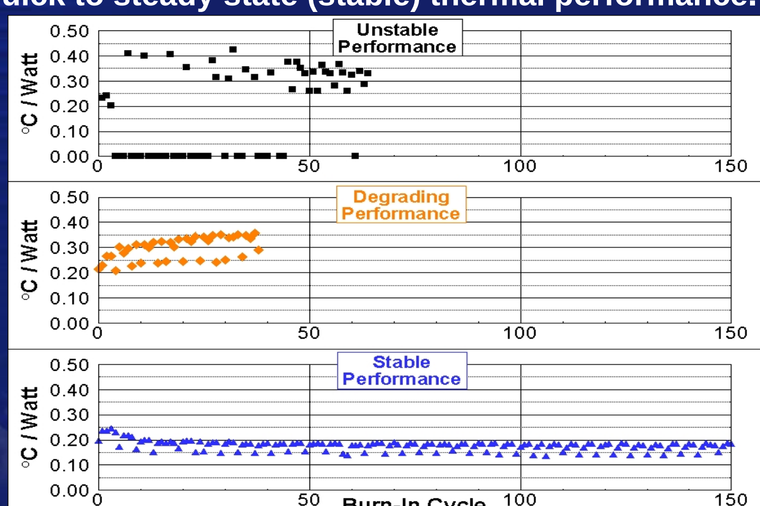
What to look for during TIM evaluation:

- Withstand mechanical cycling at higher temp.
- Quick to steady state (stable) thermal performance.



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Evaluation Strategy:

	Range of change
Material Configuration	0µ – 500µ (with or without Oxidation barrier)
Temperature	Up to 150C
Indium Alloy	Pure – InAg - other
Applied force	10 – 45 pound F
Pad Surface finish	Pure – Aluminum - other
Heatsink surface finish	Pure Cu – Cu Ni plating

Thermal Project Agenda

- **Project Introduction / Incentive / Goal**
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- **Evaluation Results**
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Material Configuration & Alloy

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Test Results: Material Configuration and Alloy choice

- **Thinner material** configuration will perform better short term
  - Will not withstand numerous cycles (wear & tear).
  - Cosmetic degradation
    ➔ Staining on module.

  - Fast thermal degradation, on alloys with lower melting temps.

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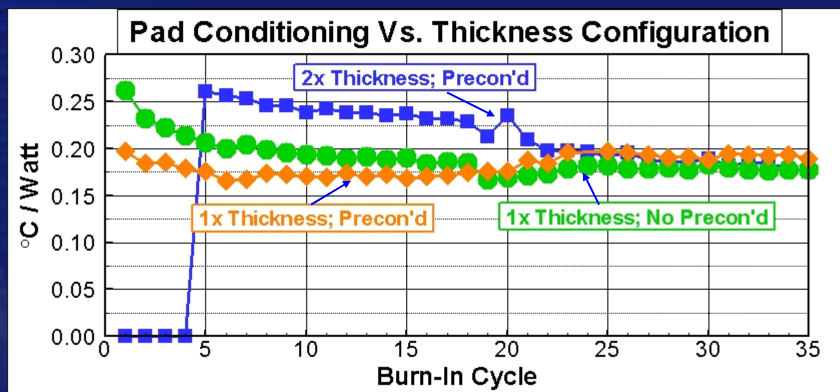
Test Results: Material Configuration and Alloy choice

- **Thicker pad** configuration needs to be conditioned to perform:
  - Withstands larger number of Burn-in cycles
  - Worse initial thermal performance
    - Longer to steady state performance
    - Yield impact



Test Results Summary:

- Material configuration and Alloy:

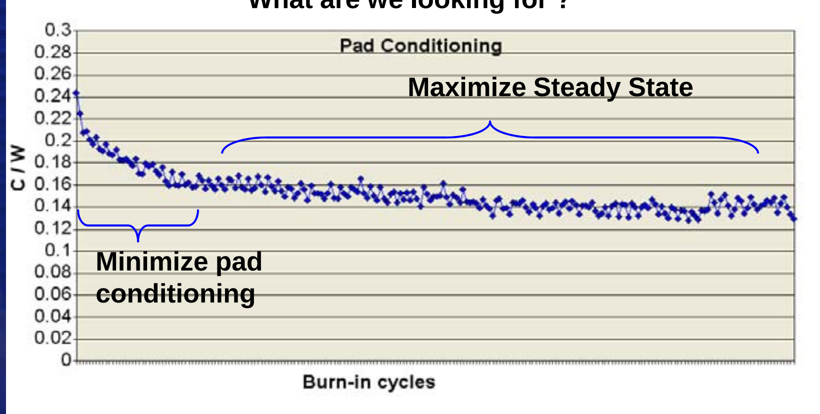
Results	Pro's	Con's
Material configuration	- Thinner material will perform better short term	- Will not withstand numerous cycles
	- Thicker material will withstand very large number of cycles	- Longer time to steady state performance
Alloy material Indium – InAg - Other	- Comparable performance on alloys	- Alloys will have a lower melting temp. ➔ rapid degradation.

Pad Surface, Applied Force, Heat sink Finish

From earlier learning on TIM:

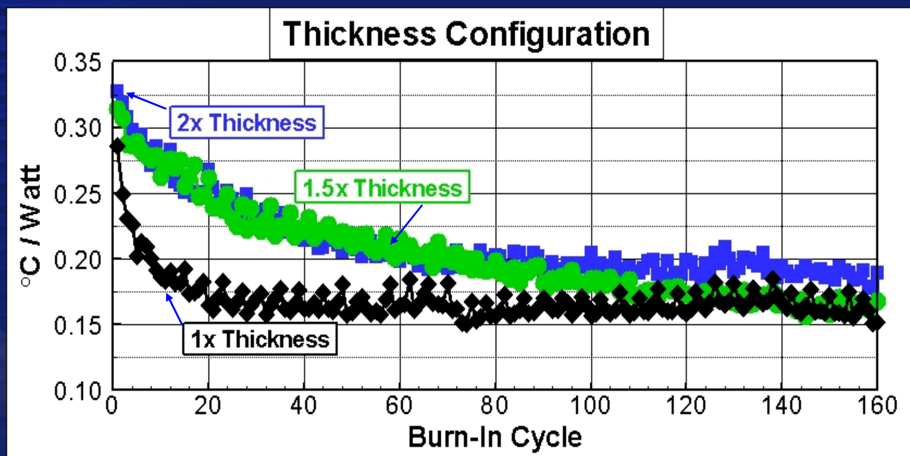
- **We need to get**:
  - **Fast Steady State performance (conditioning).**
  - **Stable long-term performance (no degradation).**

What are we looking for ?



Test Results Pad Clad Thickness:

- **2x Clad thickness** ➔ ~20% impact in thermal performance.
  ➔ Longer conditioning of pad to Steady State.



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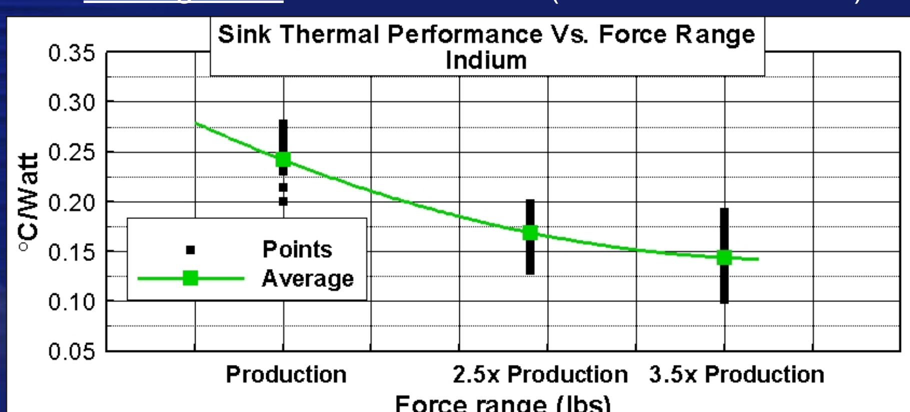
Applied Force Test Results:

- **Higher force is key factor using this TIM:**
  - Maximizes pad to module thermal contact.
  - Decreases conditioning time spent before Steady State.
  - Limiting factor = Tool mechanics (multi module Burn-in).



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Test Results:

• Heat sink surface finish impact:

• Normal Tin (Sn) HS surface finish with Indium pad:
  • Intermetallic formation causing damage to the HS
    - Need to find alternate surface finish to avoid condition

• Nickel surface finish barrier applied
  - Indium – works well with Ni barrier
  - Repeatable performance after pad replacement in production.

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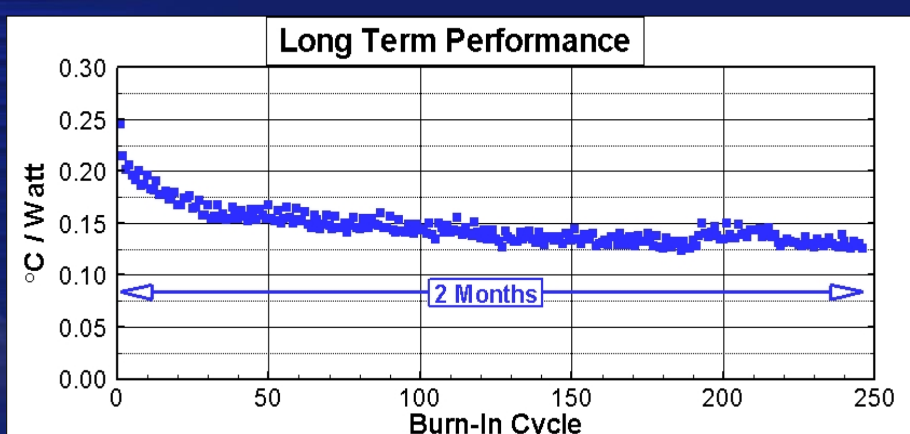
Test Results Pad Longevity:

- Good longevity with chosen TIM thickness, Cladding, Force & Heat sink surface finish configuration.



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Test Results Summary:

- Most important variables for Burn-in oven:

Results	Pro's	Con's
Force	- High, maximizes contact surface - High, allows to maximize thermal performance	- Needs higher force setup in oven * Limited by oven hardware.
Heatsink configuration	- Ni surface finish, allows good thermal performance - Allows for easy pad replacement	- Needs an alternate HS surface finish
Pad Cladding	- Avoids Oxidation of In pad - Maximizes longevity - Less Residue / Cosmetic defects	- Small thermal performance impact

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Conclusions: Most important variables for Burn-in oven were successfully addressed.

- **Force:**
  - **<u>Higher force</u> =** major factor for solution Implementation → brings uniformity to heat sink / pad performance.
  - **Minimizes the conditioning time.**
  - **Combined with the optimal thickness of material, clad, brings best performance – longevity combination**
- **Expected durability:**
  - **Production data shows durability potential up to 6 months (may vary on application conditions).**
  - **No mechanical impact to Heat sinks (pad replacement only)**

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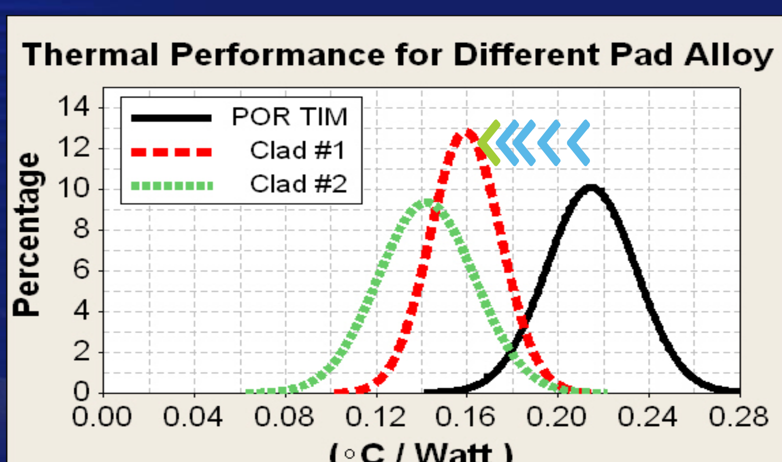
Conclusions:

- **Indium with Cladding**
  - Performs well in high end applications.
  - Clad #1 selected based on its overall benefits.



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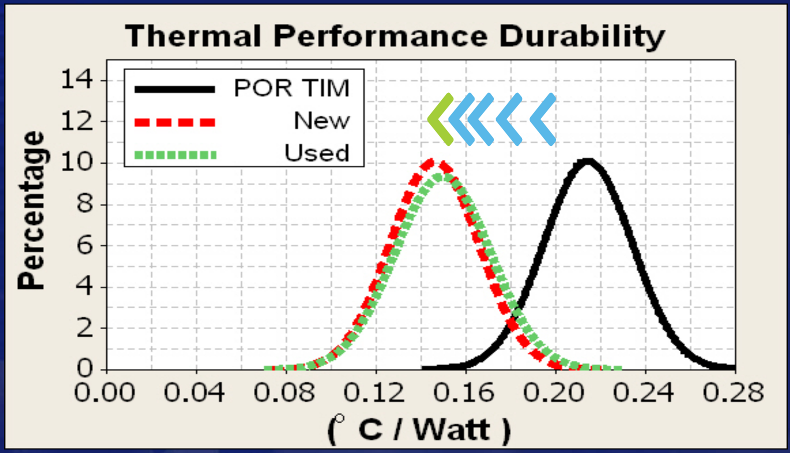
Conclusions:

- **Performance** improvement goal:
  - Based on test & qual results with the new TIM configuration
  - ➔ better thermal solution for high end applications.



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Final conclusions:

Process Items	Results
Thermal performance	↑ 30 %
Maximum power dissipation	↑ to 550 W
Yield	↑ 5% to 10%
Benefits for future family of high end products	to come

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What's next:

- **There is still room for optimization**
  - Additional Burn-in time reduction
  - Burn-in program flow improvement
  - Apply learning to other platforms of test & Burn-in.
- **Continue search for improved TIM alternatives to fit in our environment.**

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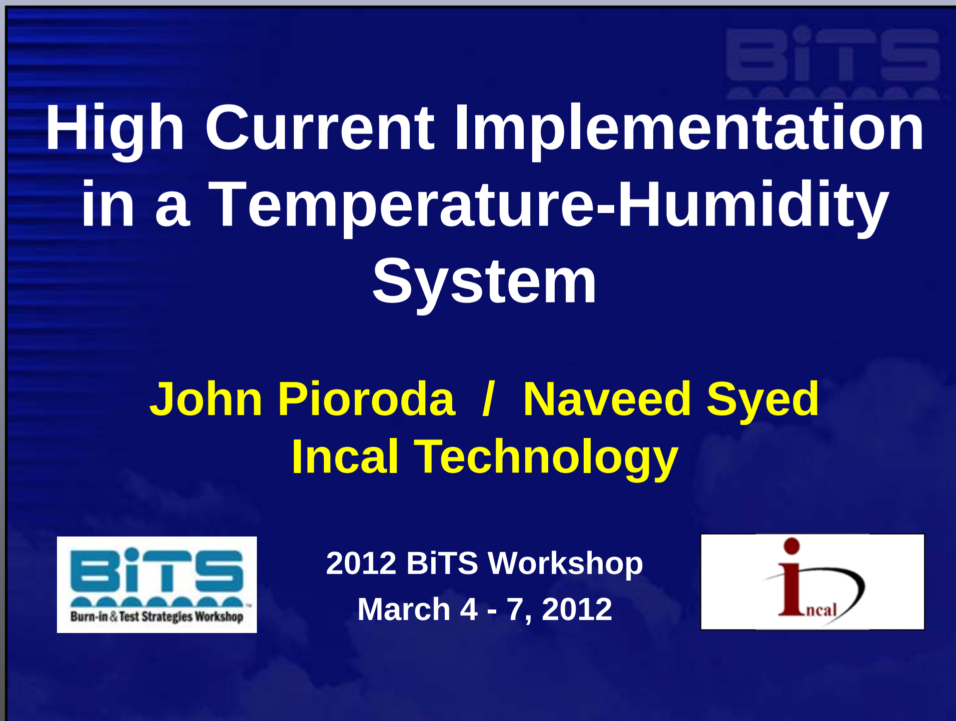
High Current Implementation in a Temperature-Humidity System
John Pioroda / Naveed Syed
Incal Technology
2012 BiTS Workshop
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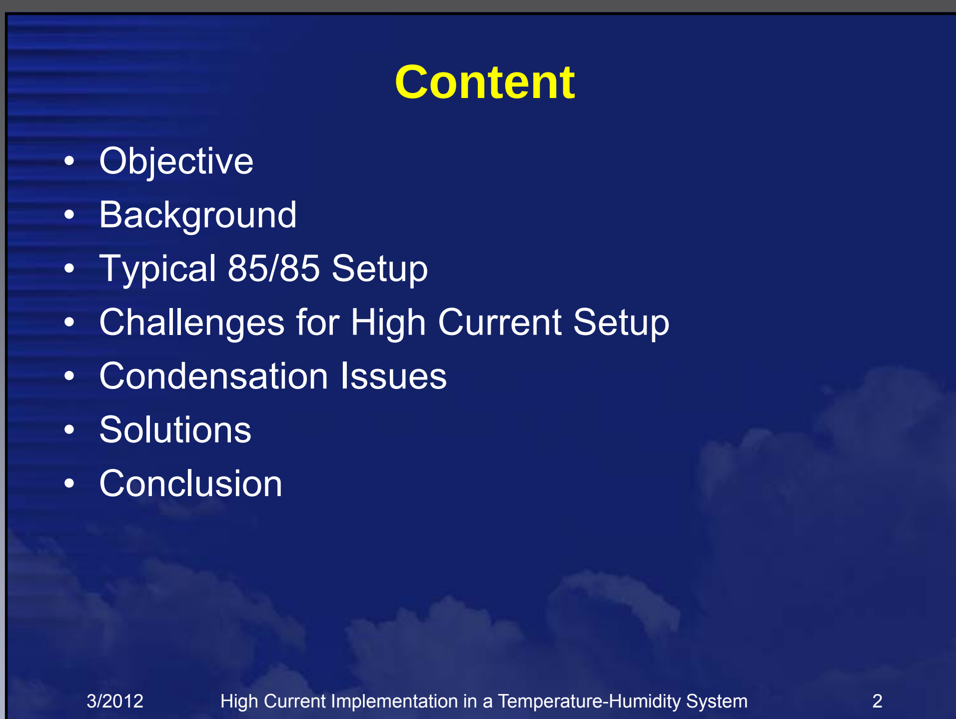
Content
• Objective
• Background
• Typical 85/85 Setup
• Challenges for High Current Setup
• Condensation Issues
• Solutions
• Conclusion
3/2012
High Current Implementation in a Temperature-Humidity System
2

Paper #2
1

Objective

To share the challenges and solutions in constructing a temperature/humidity bias system for high-current applications

Environment: 85ºC / 85% RH

Electrical: deliver up to 250A per board x 28

Mechanical: dissipate 2500W live load

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Background

- THB = Temperature Humidity Bias testing
- Environment: 85ºC / 85% RH
- Non-hermetic Package Qualification Test
- JESD22-A101C Steady State Temperature Humidity Bias Life Test standard
  - Alternate Pin Bias
  - Accelerate electro-chemical corrosion (Dendritic Growth and CAF)

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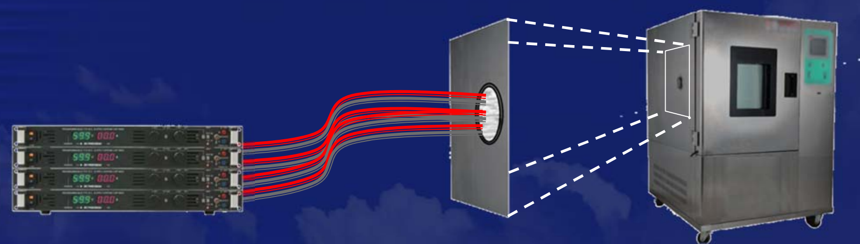
Typical 85/85 Equipment Setup

- Tabletop and Standalone Chambers
- External Power Supplies
- 4” or 6” Porthole Access
- For low power / low current DUTs



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Typical 85/85 Equipment Setup

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Limitations of the Typical System in High-Current Applications

- Delivery of up to 7000A into the chamber
  - Need 300 AWG#11 wires into a 10” port hole
- Voltage drop across 8 feet of 11 AWG wire
  - At 10 mΩ, 45A on AWG#11 = 0.45V drop
- No DUT current monitoring capability
- Chamber heat dissipation
  - Typical is less than 1000W

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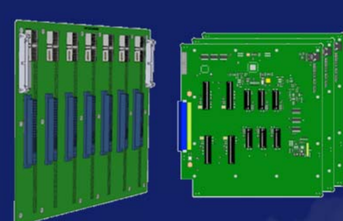
Customized High Current 85/85 System

- Deliver power thru a Backplane
- Programmable Power Supply Board
  - Remote sense back
  - DUT current measurement
- High dissipation THB chamber



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Improved Electrical Performance

	Traditional External Bulk Supplies	Custom Power Board thru Backplane Solution
Delivery Method	8 ft. of Cables	Custom Power Supply via Backplane
Cables required for 7000A	150 pairs of AWG #11	None
Port Hole Diameter	Min. 10 inches	None
Voltage drop from PS to DUT Board (45A)	Over 500mV end-to-end	160mV end-to-end
Voltage Compensation	Over 500mV	Under 200mV
Current Measurement / DUT	Not Available	Yes

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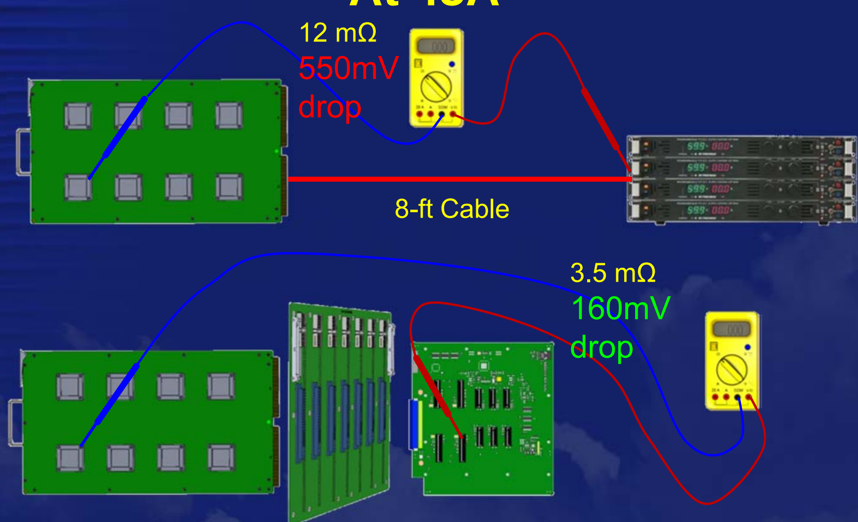
Improved Electrical Performance At 45A



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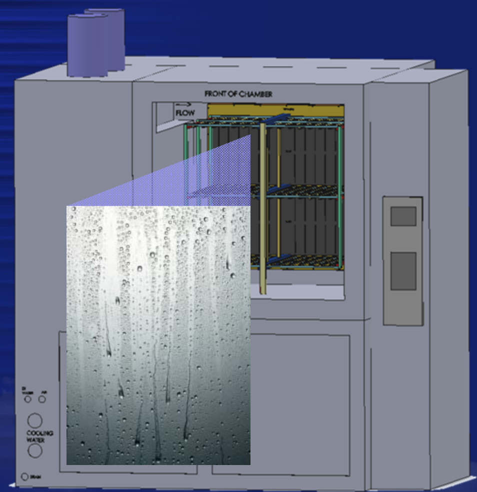
Backplane based 85/85 System Condensation Challenge



- Water droplets form on the back wall
  - Even at 3-hour ramp to 85/85
- Risk of electrical shorting on connectors and backplane

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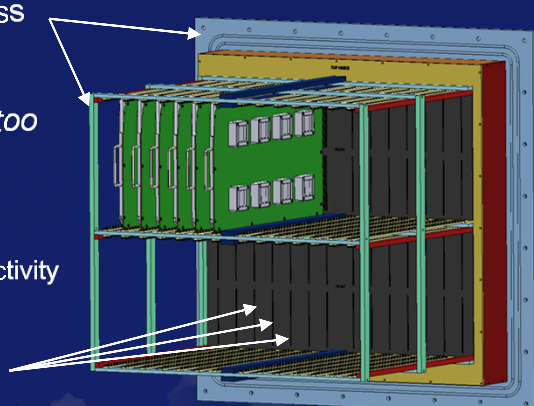
Causes of Condensation

- Too much metal mass right behind the wall
- 316 Stainless Steel *too cold!*
  - High density ($8\ g/cm^3$)
  - Low Thermal Conductivity (16.3 W/m.K)
- Leak to outside air
  - Through 56 openings behind the connectors



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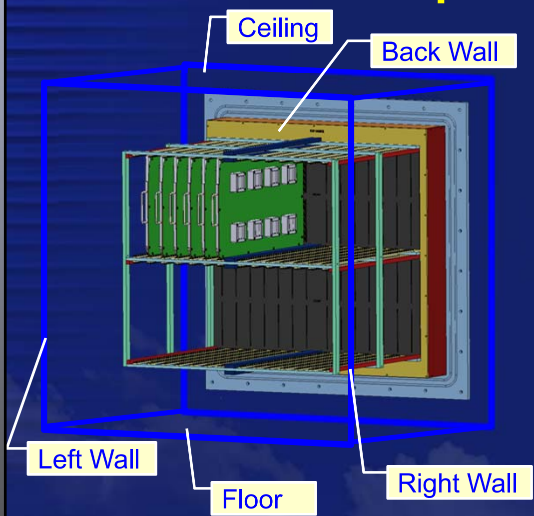
Chamber (internal) Temperature Spread



Simple Dew Point Estimation:

$$T_d = T - \frac{(100-RH)}{5}$$

Set Temp	85ºC
DewPoint	***82ºC (@ 85%RH)***
Back Wall	79.9
Ceiling	85.1
Floor	83.9
Left Wall	84.1
Right Wall	84.3

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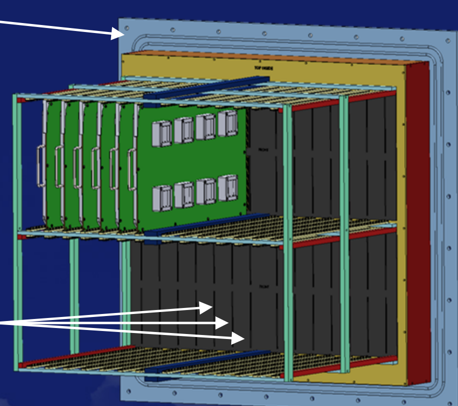
Controlling Condensation

- Increase Back Wall Temperature
  - Install 12W heater strips in 24 locations
  - Back wall & Feedthrus
- Plug the leak
  - Install insulation material on 56 openings behind the connectors
  - Change standoffs from metal to plastic



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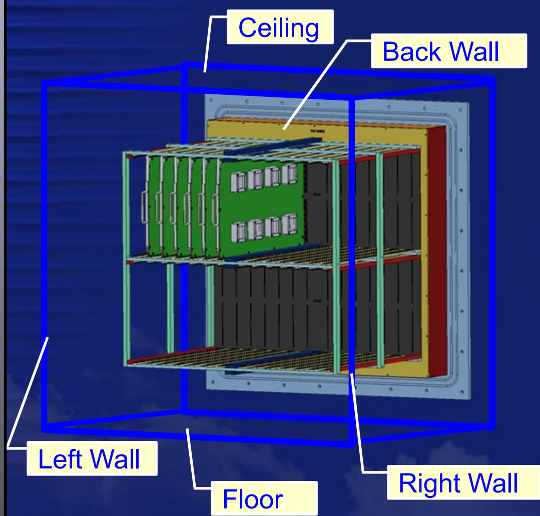
Chamber Temperature Spread after Condensation Control



Set Temp	85ºC
DewPoint	*82ºC*
Back Wall	83.5
Ceiling	85.1
Floor	83.9
Left Wall	84.1
Right Wall	84.3

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Final System

- Custom 85/85 system
- Backplane based design to deliver 250A per board (7000A per system)
- Power cycling per lot to comply with THB standards for high power devices
- Alternate lot power cycling to mitigate 2500W live load limit

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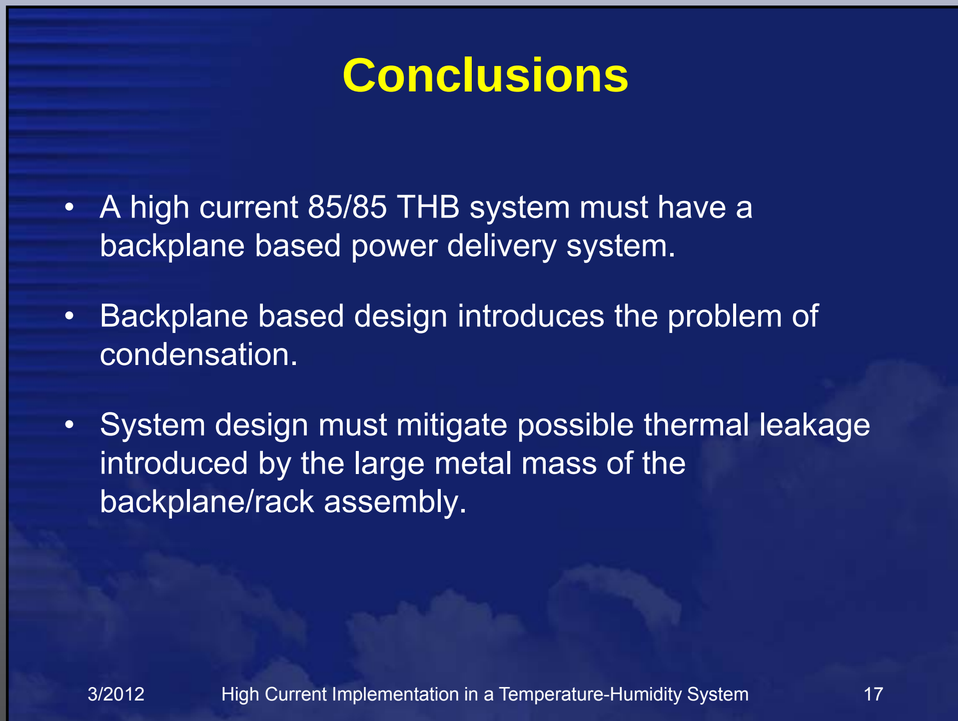
Conclusions
• A high current 85/85 THB system must have a backplane based power delivery system.
• Backplane based design introduces the problem of condensation.
• System design must mitigate possible thermal leakage introduced by the large metal mass of the backplane/rack assembly.
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17

DUT Temperature Control Using LN2 Injection

Nolan Riley, Chad Turner, Joseph Mayfield
Texas Instruments

2012 BiTS Workshop
March 4 - 7, 2012

Problem Statement

- High power devices experience unstable junction temperature during packaged test due to inaccurate handler temperature calibration and DUT self-heating
  - This leads to over/under testing, poor device modeling, and inhibits the ability to reproduce test results
- Cannot afford to upgrade existing handler fleet
- Cannot use 'program stall' tactics to manipulate junction temperature as this would make it impossible to achieve very low 'Cost Of Test' goals

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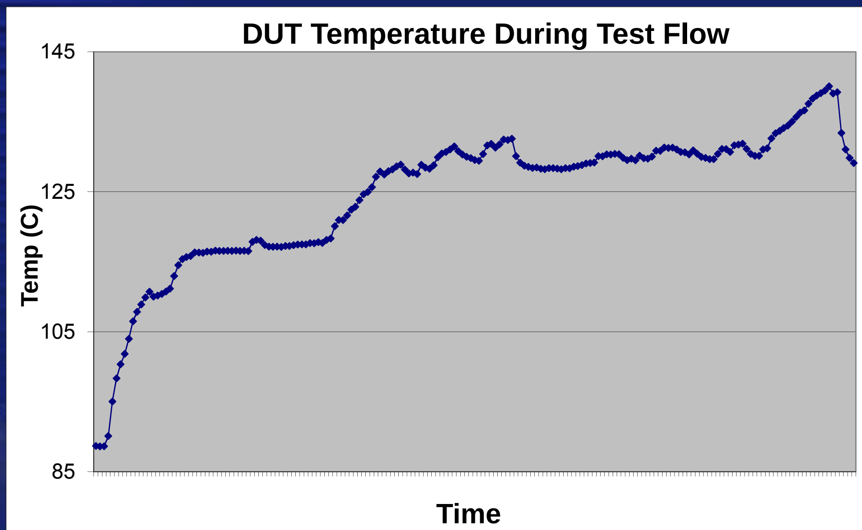
Runaway DUT



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Possible Solution

- Read device temperature directly from DUTs internal thermal diode and operate a valve controlling compressed air or liquid N_2
- Gas will target direct contact with device lid for maximum temperature impact
- Controller must be responsive and easily tunable

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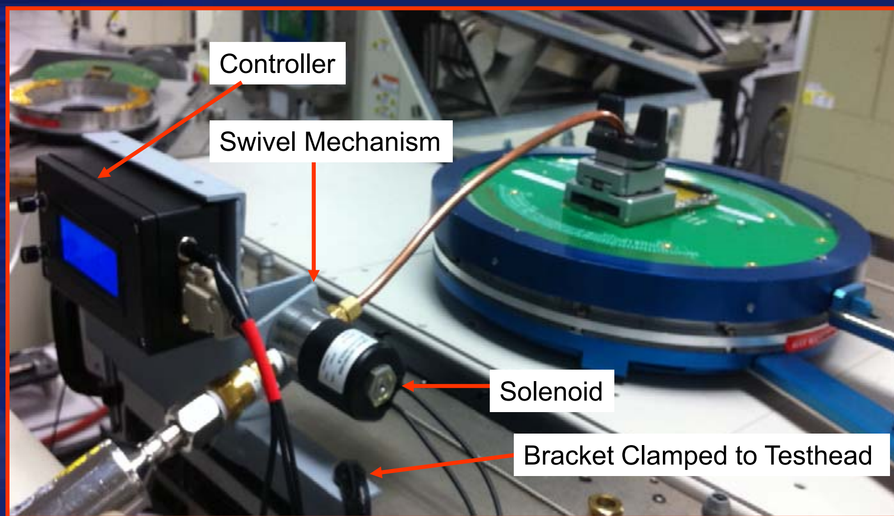
Initial Prototype



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Initial Prototype Controller

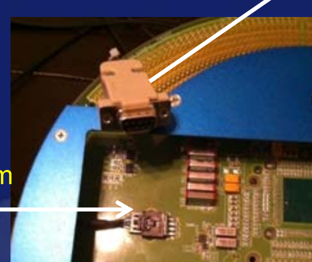
Set Point Control

USB to Power Controller & Serial Communication

Temperature Input & Solenoid Control

Solenoid Power

Connection to the DUTs thermal diode as well as the top and bottom side load board temperatures



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System Software – Valve Control Algorithm

- Valve is a GEMS S & C 24V cryogenic valve
  - Pure "digital" operation
  - Not quick enough to react to pulses shorter than ~25ms
- Algorithm uses very low frequency PWM scheme with software-based PID feedback control to set duty cycle
- PID is very adaptive, responsive, and easily tunable
  - **P**roportional – Increases PWM duty cycle proportional to the temperature offset (error)
  - **I**ntegral – Sum of instantaneous error over time. Eliminates any steady-state temperature offset
  - **D**erivative – Error's rate of change. Helps to control over-shoot and maintain system stability

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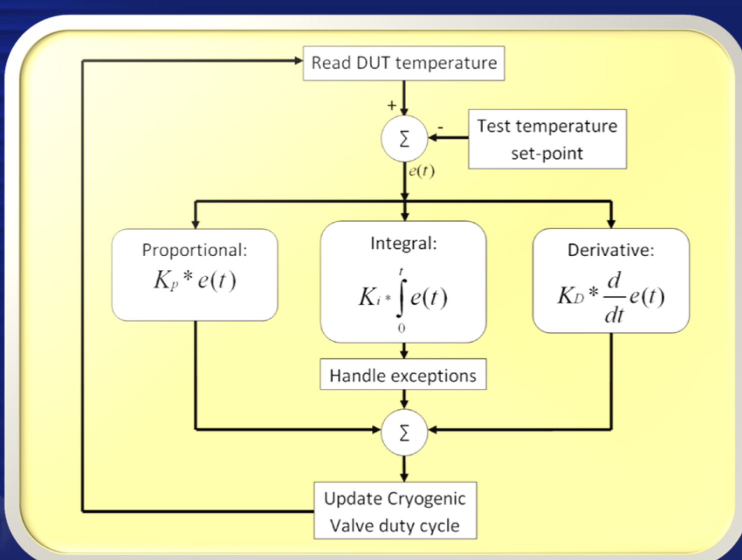
System Software – Valve Control Algorithm



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System Software – Valve Control Algorithm

- PID Exceptions
  - Integral term boundaries
    0 ≤ integral ≤ MAX_OUTPUT / Ki
    - Cannot allow integral term to become negative because the system cannot heat the DUT
    - Cannot allow integral term to accumulate with no bounds.
  - Overall Valve pulse width
    - Valve is too slow to react to narrow pulses
    - If desired response is less than 50ms, the result is accumulated until it will bring pulse over this threshold

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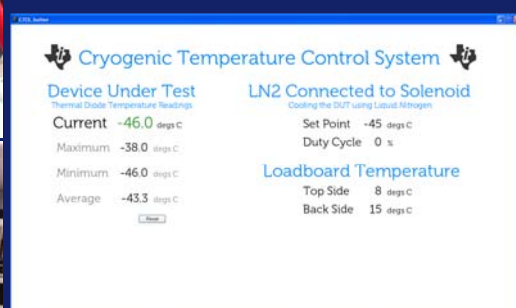
Initial Prototype Results



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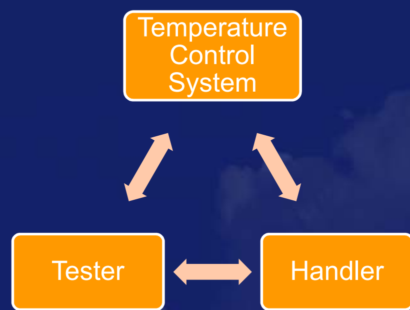
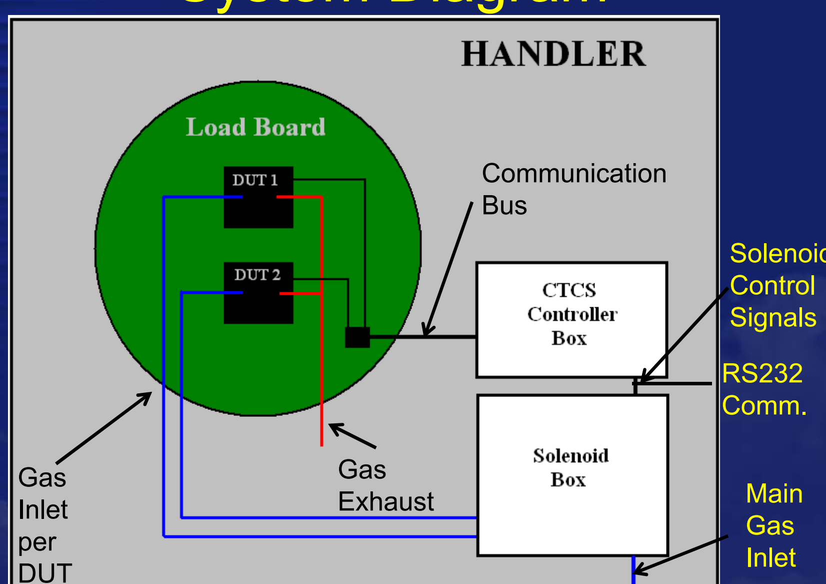
Production Solution

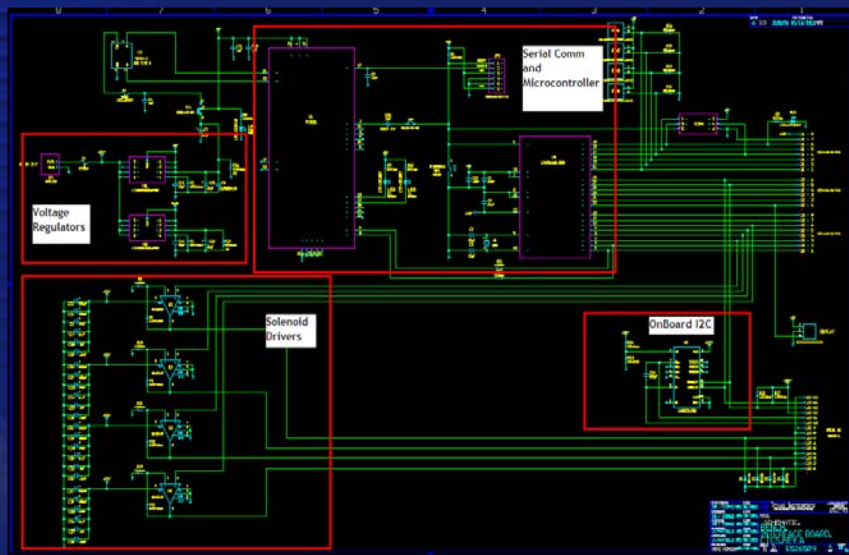
- Need to be able to control the temperature of DUTs when tested using existing production handlers.
- Must have up to Quad-site independent thermal control
- Need ability to collect and store thermal data
- Critical to have communication with tester and handler for setpoint control and sanity checks



System Diagram



System Hardware – PCB Schematic



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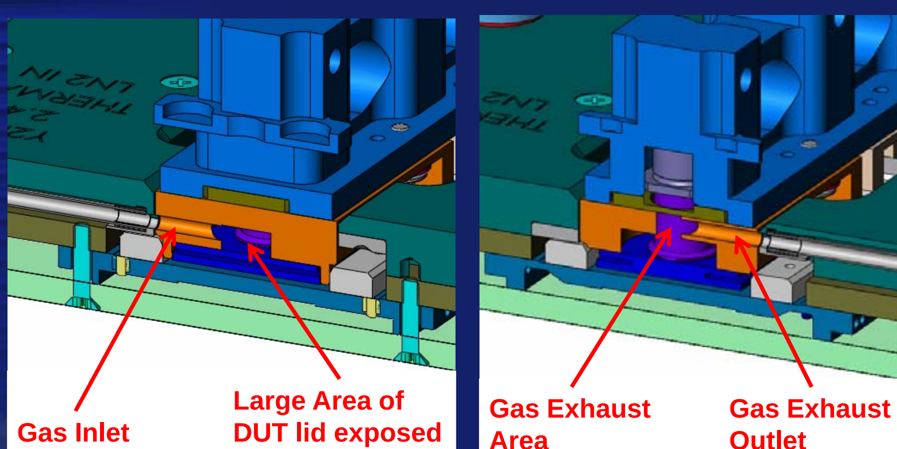
Handler Manifold Design



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Handler Adaption

Controller and Solenoid Boxes

Dual-Site Gas Inlet

Gas Exhaust

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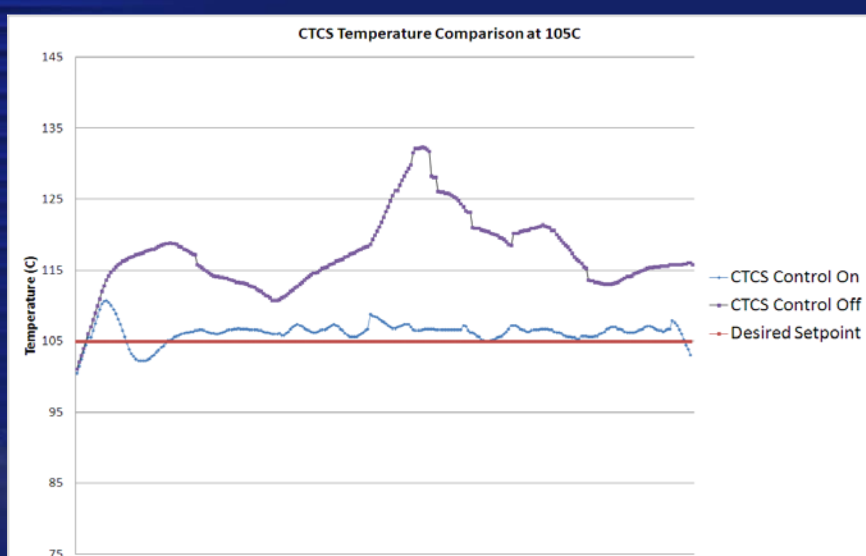
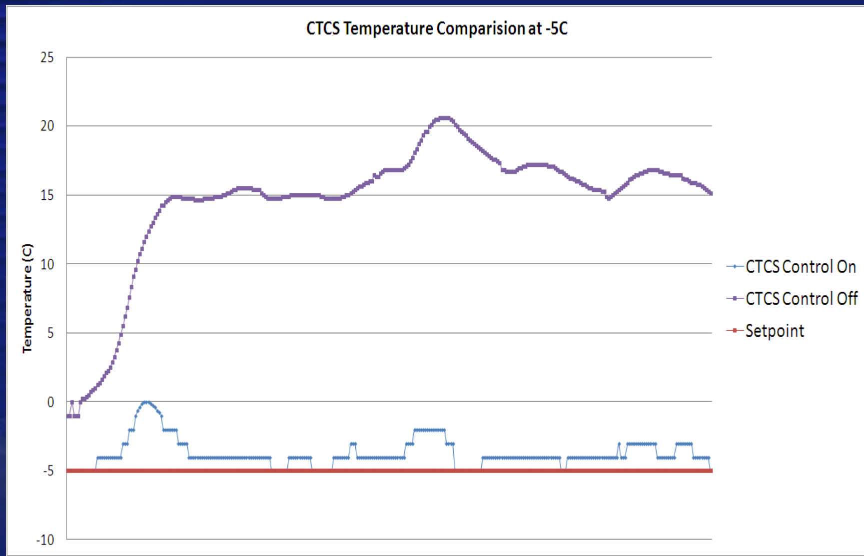
Results



3/2012 DUT Temperature Control Using LN2 Injection 16

Results



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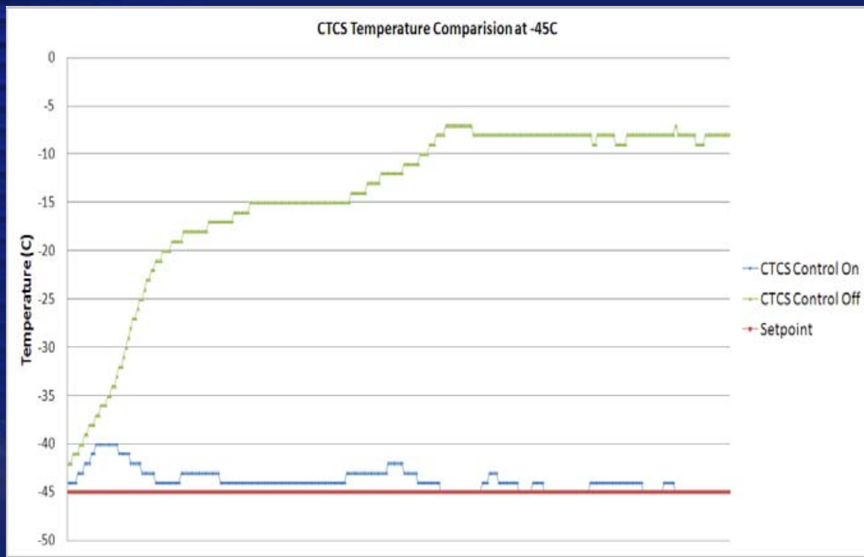
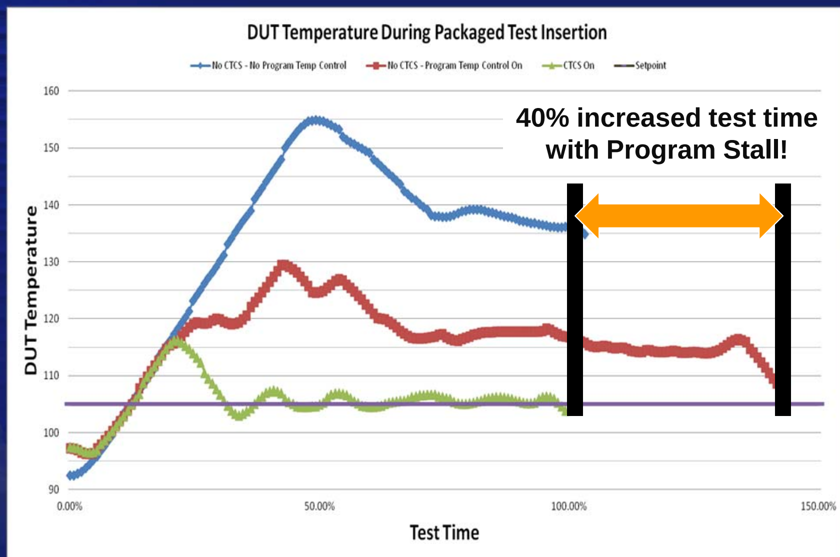
Results



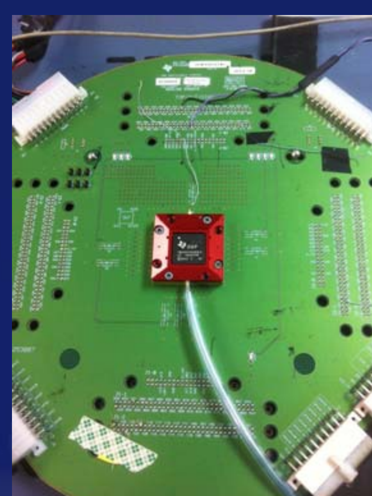
3/2012 DUT Temperature Control Using LN2 Injection 18

Results



3/2012 DUT Temperature Control Using LN2 Injection 19

Additional Applications



3/2012 DUT Temperature Control Using LN2 Injection 20

Sophisticated Tool for Pin Characterization & Socket Qualification

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KW Low
Intel Corporation

2012 BiTS Workshop
March 4 - 7, 2012

Agenda

- IC packaging trends
- Backend test socket
- Socket pin
- Drawback of current pin measurements
- Characterizing socket pins on-the-fly
- Experimental results
- Conclusion

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IC packaging trends

- Packages have converged towards mobility
  - More Moore's Law in FCBGA small form factors platform
  - Differentiated by power, price and performance

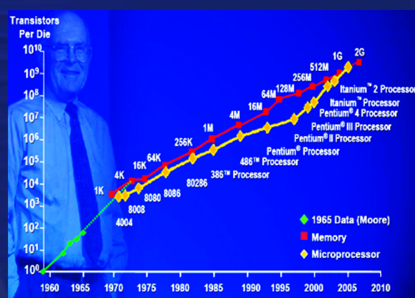


Fig 1. Moore's law in practice

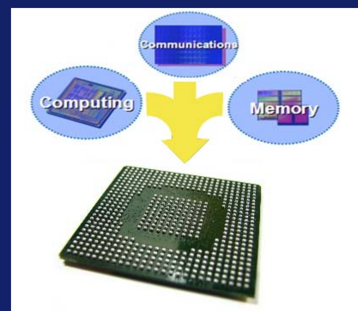


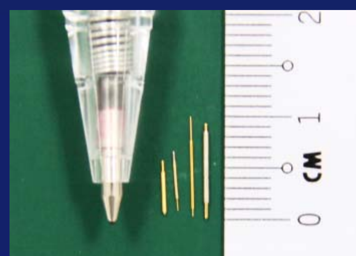
Fig 2. Packaging Direction

Backend Test socket

- Increasing socket design challenges
  - Applications drive requirements
  - Finer pitch, non-grid ball anywhere matrix
  - Topside interposer and bottom substrate contact

Socket Pin

- Increasing socket pin challenges
  - Pin getting smaller with tighter dimensional tolerances
  - Pin height difference coupled with IC package warpage affects contact force, Cres resulting in open failure



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Drawback of current pin measurements

- What, how and where to measure
  - Back to basics: Force, Compression, Resistance
  - Manual or semi-automated tool set-up
  - Results are human dependent- not precise
  - Not accurate, no pin profile, time consuming, need dedicated headcount and cannot probe <0.4mm

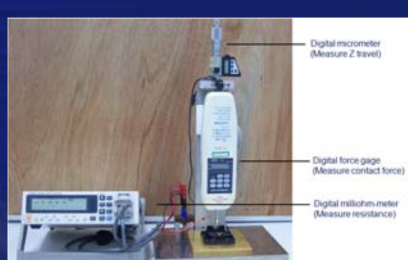

Fig 1. Manual FDR

Fig 2. Semi-Automated FDR

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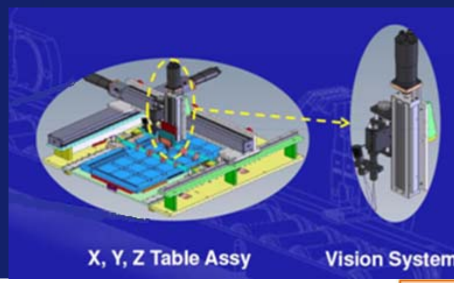
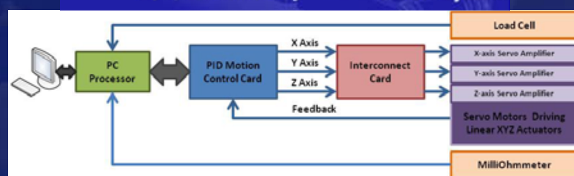
Characterizing Socket Pins On-The-Fly (1)

- Auto-FDR has several features
  - Closed loop, PID controlled system
  - Precise, programmable to read socket pin-map





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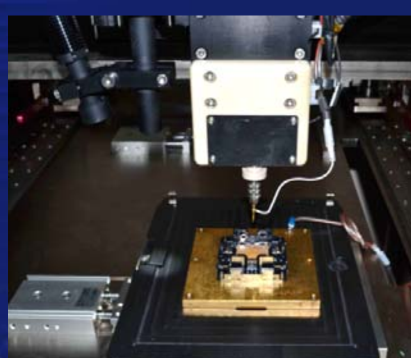
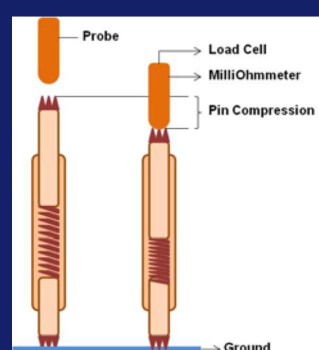
Characterizing Socket Pins On-The-Fly (2)

- Automatically measures pins in array or selective pin
- Tracks force and resistance during pin compression





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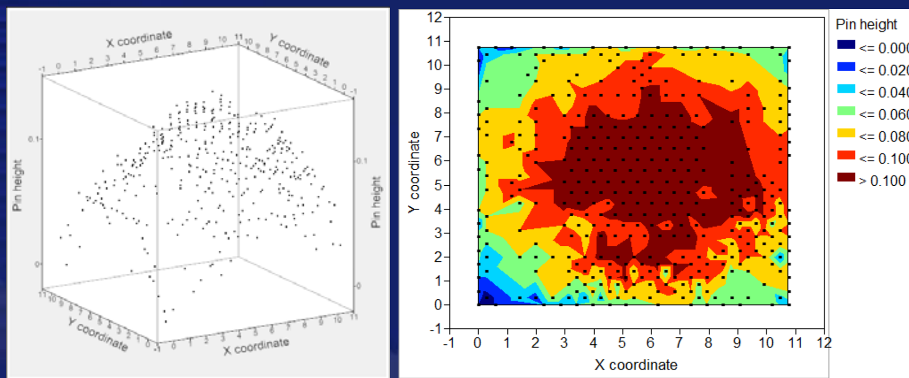
Experimental Results (1)

- Pin array height profile for BGA 392 pin socket
  - In a socket there are short and tall pins
  - Dome shaped, cluster of pins higher at socket center



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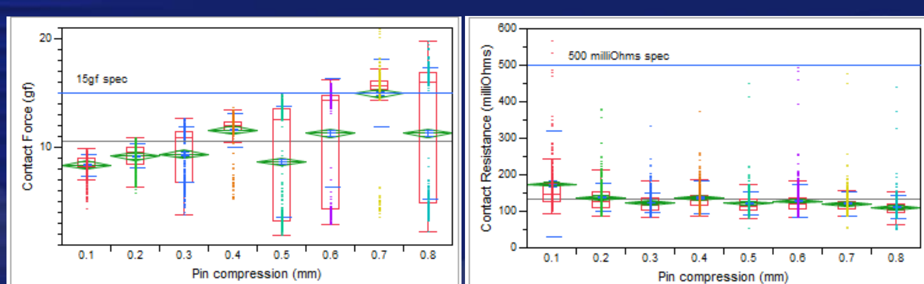
Experimental Results (2)

- Contact force and contact resistance at different compression setting
  - How did the supplier set recommended compression?
  - Contact force shows bimodal distribution behavior
  - New pins without stress test operate below Cres spec



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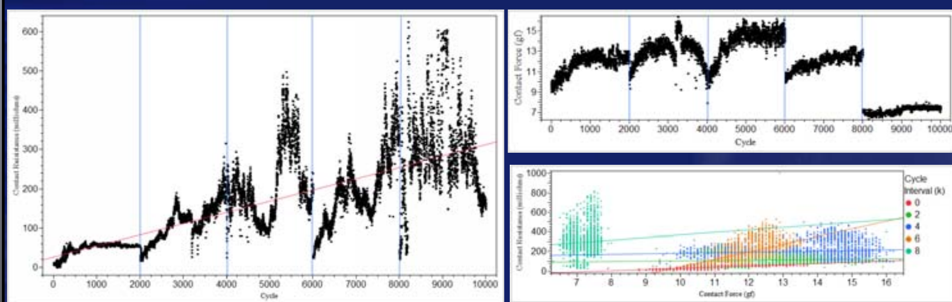
Experimental Results (3)

- Contact force and contact resistance changes over 10K cycle lifespan
  - New information needs further investigation
  - Pin wear and contamination cause Cres wide spread



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Conclusion

- Precise, accurate and 3x reduction in time and resources.
- Data acquired can be used to validate
  - Modeling and simulations.
  - Predict pin effective lifespan.
- Better visibility on socket pin behavior
  - To study the pin profile for the first time.
  - To study pin contact bounce and settling time.
- Only workable tool for 0.3mm pitch and non-grid array.
- Gives insight to re-define socket design rules.

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