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Individual Device Temperature Control at Burn-In - Thermal Considerations

Rich Karr
Texas Instruments

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Contents

Motivation

Today's medium (2 - 20 W) and higher powered devices generally require Individual Temperature Control (ITC) during Qualification and/or Production Burn-In due to device-to-device power variation.

A lack of standardized ITC solutions has led to high cost custom solutions for any particular device and/or Burn-in platform.

The challenge of incorporating ITC, especially in high volume Production Burn-in solutions, results in a call to action for simplification, standardization, and cost reduction.

Background

The goal of an Engineer generating hardware and software for a Qualification Stress Test (HTOL, HTRB, PTC, etc.) and/or Production Burn-In solution is to minimize fixed, recurring, and operating costs while also achieving all Stress requirements and Production metrics.

Costs

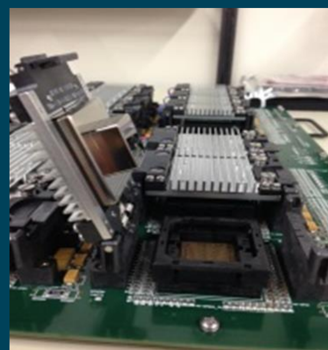
Fixed	Recurring	Operating
Floor Space	Oven PM	Load/Unload
Grid Tie	BIB Repair	People
Chamber(s)	OS Updates	Facilities
Environment		BIBs

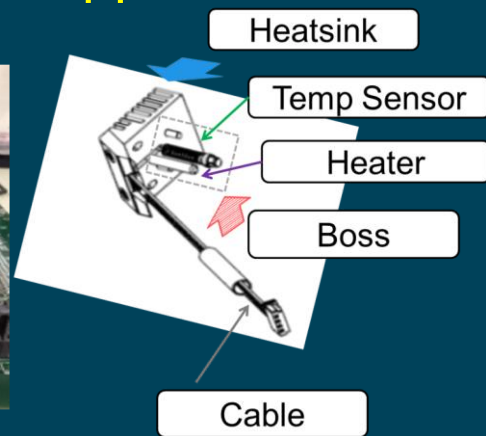
Individual Device Temperature Control at Burn-In - Thermal Considerations

Background: ITC Costs

- The typical engineer response to large varying device power during Stress is to develop a custom ITC solution that maximizes BIB device density for a given chamber type.
- The engineer then pursues minimizing cost of the custom ITC solution during piece part acquisition.

Custom ITC Solution Thermal Apparatus





Individual Device Temperature Control at Burn-In - Thermal Considerations

Objectives

Simplification and standardization of the ITC solution requires defining both fixed boundaries and variables associated with the solution. This paper is based on a case study which fixes the oven, oven volume air flow, and desired device junction temperature.

An objective then becomes determining the ITC solution variables and their effect on thermal performance given the fixed boundary conditions.

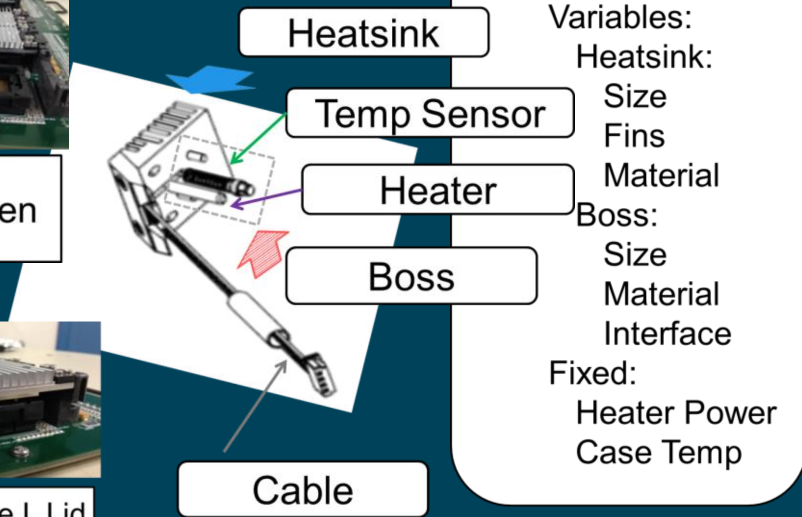
Additional objectives include standardization of both Burn-in sockets and ITC associated Thermal Apparatus.

Defining Thermal Apparatus Variables

- The heater wattage is based on socket density and oven power capability – 25 W in this case study.
- The heatsink and boss may be one, two, or three piece construction.
- The thermal apparatus may or may not be integrated into the socket design. The example shows a non-integrated socket solution.
- The example Thermal Apparatus is controlled via package case temperature measurements. Alternatives include DUT die thermal diode measurements.

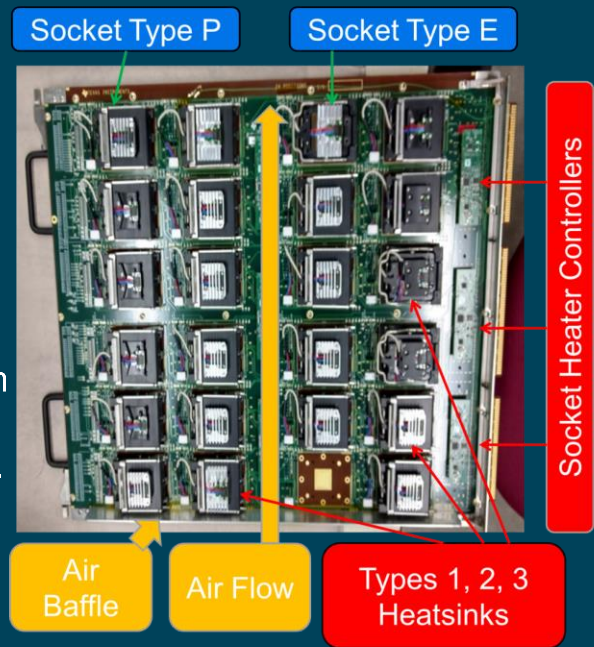
Lid Open

Socket Type L Lid Closed



Defining Burn-In Board (BIB) Variables

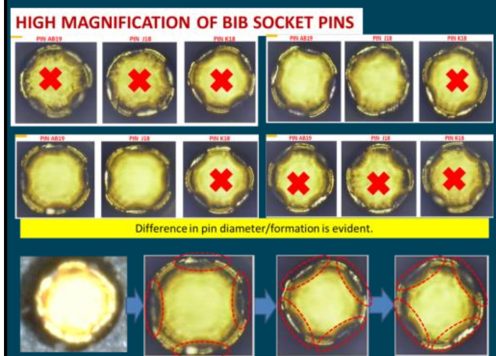
- There were 2 BIB designs utilized during the case study. The baseline with type "L" socket, and the other at right with a standard socket footprint.
- Both BIB designs have 24 sockets arranged in the same 4 x 6 grid and are inserted in the same chamber.
- The baffle type at right is straight across with the height coincident with the top of the heatsink fins. Other baffle shapes were also investigated.
- At right is a BIB top view with the oven wall electrical connector towards the right side.
- Oven temp = 70C, Oven airflow = 3000 CFM, Max DUT Current = 10 A

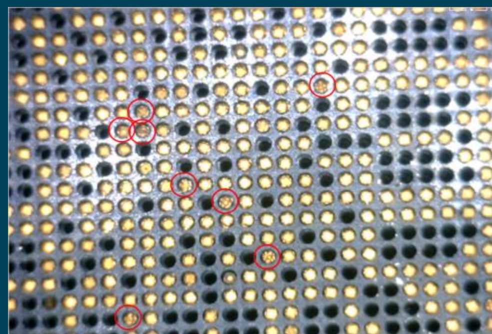


Burn-In Board (BIB) Variables:
- Socket Type
- Socket Position
- Air Baffle
- Oven Temp
- PS Layout
- Heater Duty Cycle
- DUT Power

Fixed:
- Oven Temp
- Oven Output Airflow
- Max DUT Current

Defining Boundary Conditions





- Minimum DUT power limited by available Heater Power.
  - Max Heater Power per BIB is ~600 W for Chamber Type A.
  - Heaters on all 24 position BIBs for Type A set to 600 W / 24 = 25 W.

  Maximum DUT power limited to Socket pin capability or Chamber PS capability.
  - Each DUT power domain evaluated for max current at Stress conditions.
  - Max DUT current = DUT power domain / # DUT pins * Socket pin current capability at Stress temp for Hi current domains.
  - Max DUT current = 10 A for case study

Individual Device Temperature Control at Burn-In - Thermal Considerations

Defining Boundary Conditions – Case Study

Flower Fail Pattern - Heat Map

	H	J	K	L	M	N	P	R	T	U	V	W	Y	AA	AB	AC	AD			
29																				
28																				
27																				
26						1								2						
25																				
24			1		1													1		
23														2				5		
22								1					2	7	1			4		
21						1				2					2	7				
20			1		1	1		1	3						1	5		1		
19					15	12	2	3				2			17	2	1	2	1	
18		6	16	1													9			
17																				
16						4								2						
15		5	4											1	1					
14		7		2	2						1				1					
13					2	2	1		1		1	1								
12								2						1						
11																				

PIN	PIN NAME
AB19	vdd_mm
K18	Vdd_mpu
N19	vss
AA22	vss
AD18	cap_vbb_ldo_mm
M19	vdd_mpu

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Individual Device Temperature Control at Burn-In - Thermal Considerations

Methods: Evaluation Controls

- Medium powered high volume Production Burn-in devices with a large spread between min and max power dissipation at Stress conditions, that share existing ITC solution hardware (BIBs and chambers).
- The existing Control BIBs used through-hole mounted Type “L” sockets.
- The exact same Devices at the power corners of the process range were used through-out the evaluation.
- The original device Production Burn-In program was used during Evaluation Control experiments.

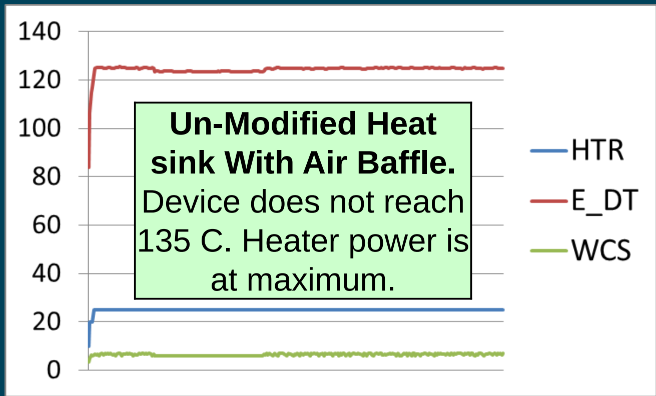
Individual Device Temperature Control at Burn-In - Thermal Considerations

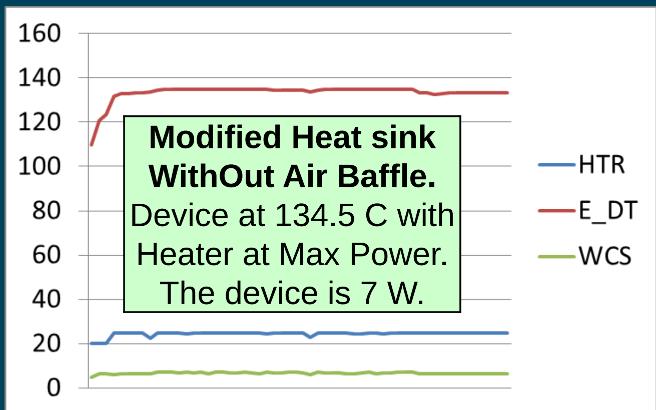
Methods: Evaluation Development

- A new compression mount standard Socket footprint was developed for the subject device(s) from which 2 different Sockets were developed and evaluated.
- A new BIB was developed utilizing the new Burn-In Socket footprint as well as various ITC control circuit options.
- Multiple Air Baffles were generated and utilized in different configurations.
- A Solidworks model of the BIB was developed for airflow and thermodynamic simulation analysis.
- A highly configurable device Burn-In program was developed to easily enable hardware changes.

Methods: Evaluation

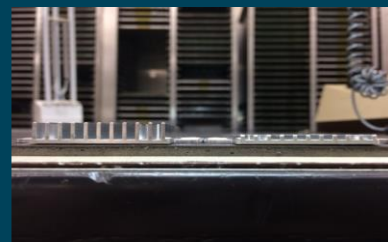
- The new BIB was populated with multiple vendor Burn-in Sockets at multiple DUT positions including both leading and trailing airflow positions for each vendor’s sockets.
- Minimum and Maximum powered control devices were then run on both the Control hardware and the new compression mount hardware across all available variables including Socket type, Socket position, Baffle designs, Oven temperature, Oven slot position, Power Supply layout/voltage, Heater Duty Cycle, and Heatsink/Boss designs.





Example Device Type "J"

Boss: Change X-Y from 20.9mm to 18.5mm, and Z from 10.1mm to 11.7mm.



Heat Sink: Fins are milled down from 6.2mm to 1.7mm

Air Baffle: Shape and location

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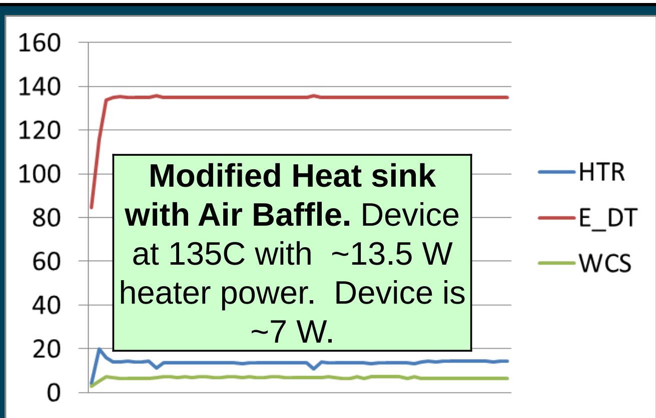
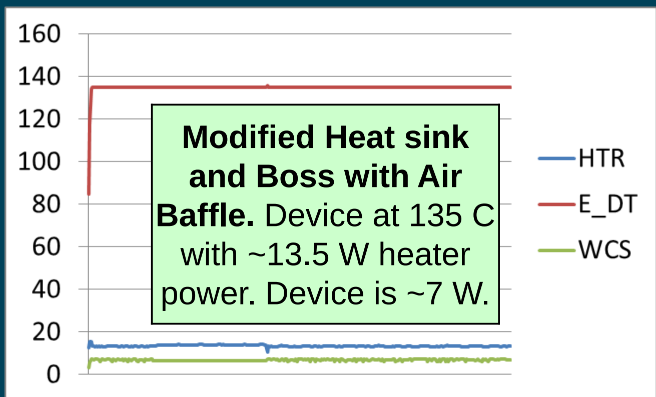
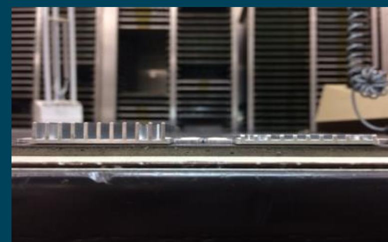
Example Device Type "J"





Boss: Change X-Y from 20.9 mm to 18.5 mm, and Z from 10.1 mm to 11.7 mm.



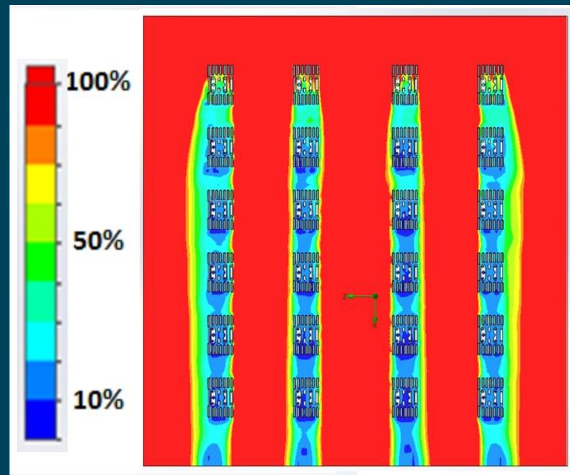
Heat Sink: Fins are milled down from 6.2 mm to 1.7 mm

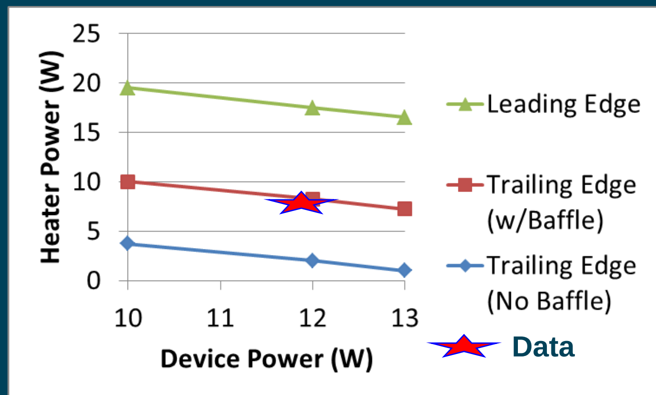
Air Baffle: Shape and location

Individual Device Temperature Control at Burn-In - Thermal Considerations

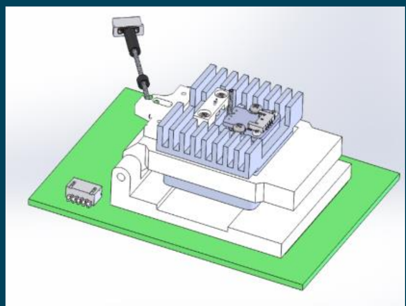
Methods: Airflow Simulation Results

- Solidworks used for modeling airflow at socket positions with and without air baffles.
- Simulation at upper right shows effects of air baffle “B2”.
- Up to 2X increase of airflow at BIB trailing edge with appropriate air baffle as compared with no air baffle (lower right).





Example Device Type "M" Airflow Effects

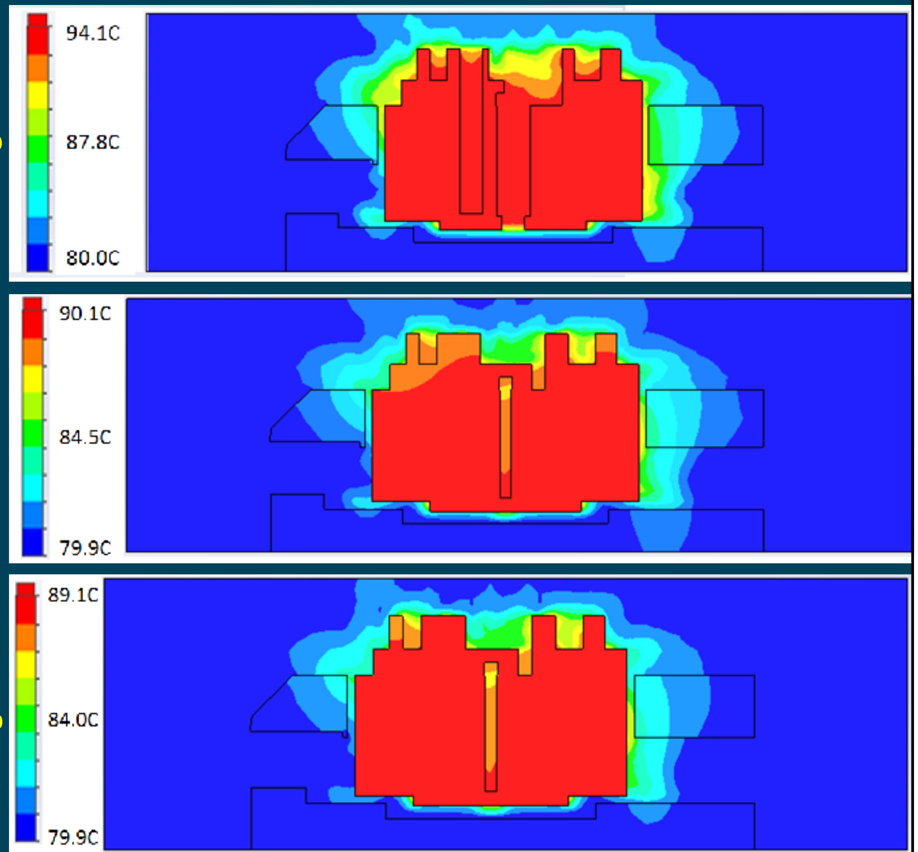


Socket + Thermal Apparatus

Source – 50%
Tcase = 94C

Source
Tcase = 90C

Source + 25%
Tcase = 89C



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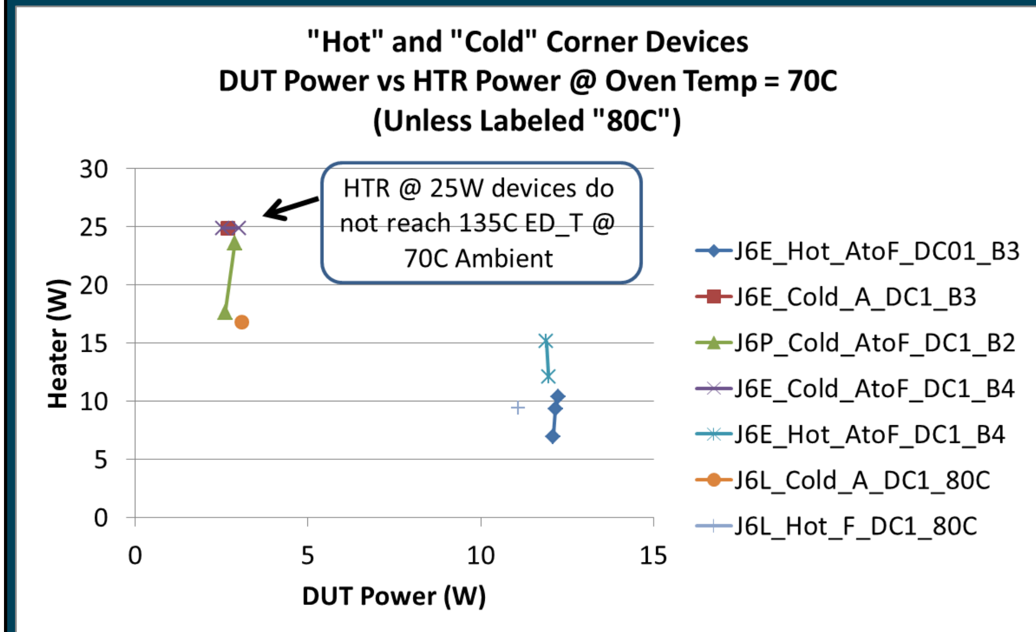
Methods: Evaluation Results



J6:	= DUT Type
E/P/L:	= Socket Type
L:	= Different BIB/PS Layout & No Baffle
Hot/Cold :	= DUT Corner Devices
A/F :	= Socket Postion (“A” Near Baffle)
DC0/1:	= Oven Position (“1” Near Air Flow)
B2/B3/B4/” “:	= Air Baffle type

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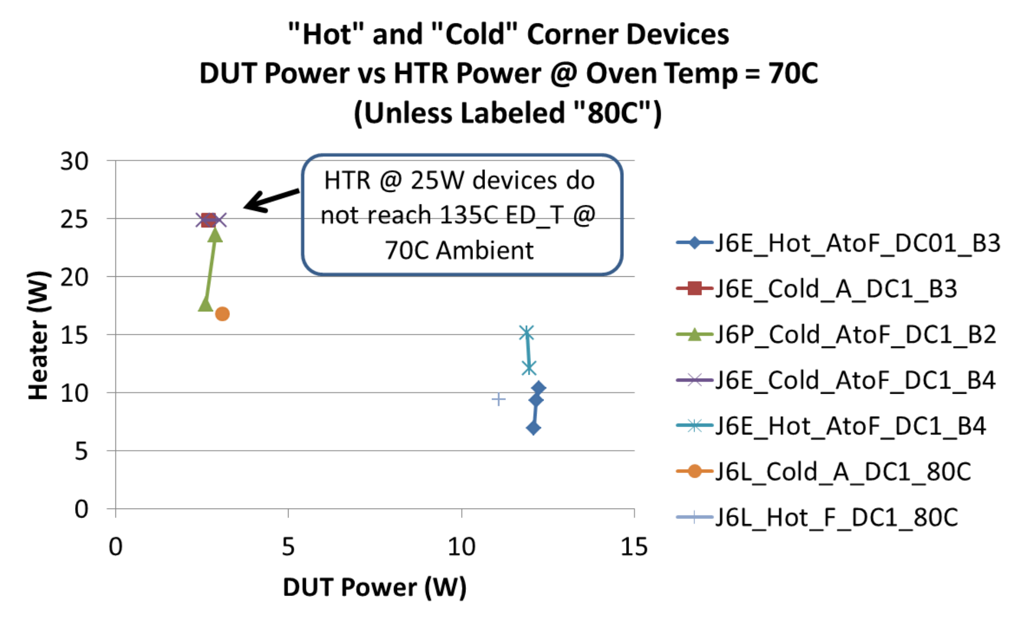
Findings



- ***Simulation results are close approximations to actual data.***
- ***PS Layout moves DUT and Heater Power in relation to trace resistance for non-Kelvin connections.***
- ***Heater Duty Cycle affects system stability.***
- ***All other variables move heater power Up/Down in relation to DUT Airflow or Ambient Temp effects.***

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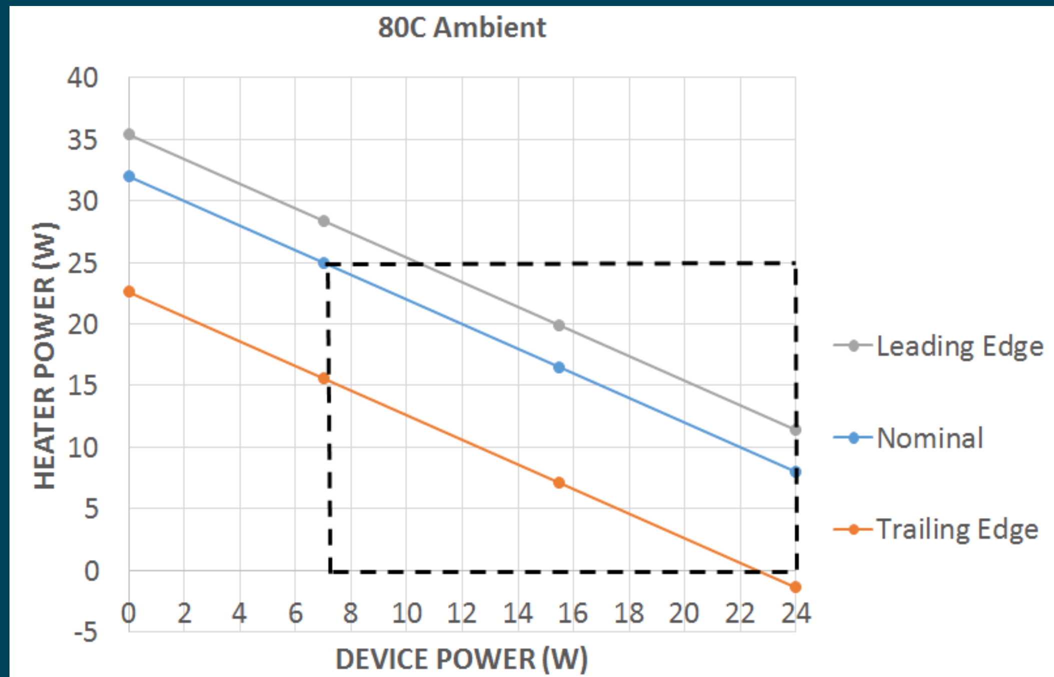
Example Device Type “M”

Device "M" requirements	
Oven Make	Type "A"
Package	23 x 23mm
BGA count	784
Pitch	0.8mm
Sockets per BIB	24
Rows / Columns	4 Row 6 Col
Socket Used	Type "E23"
Max Heater Size	25W

Device "M"	Min	Nom	Max
Oven Air Flow Leading Edge	Source-50%	Source	Source+25%
Oven Ambient Set point (°C)	80	80	80
Device Power (W)	7	15.5	24
Device Case Set Point Temp (°C)	125C	125C	125C
Device ØJC (°C/W)	0.5	0.5	0.5



Conclusions

Evaluation results were provided to Socket and Thermal Apparatus vendors to refine thermal and airflow models. The refined models are now in use to predict Thermal Apparatus performance for follow-on devices.

Air Baffles can be used to extend the device power range for a given Thermal Apparatus and BIB solution.

Standardized Thermal Apparatus including heatsinks are now in definition, based on Standard BIB Airflow profiles, that will serve multiple medium powered devices for at least 2 oven platforms utilizing proprietary ITC systems.

Additionally, a standardized compression mount Burn-in Socket footprint was demonstrated across multiple socket vendors.

Acronyms Addendum

BIB : Burn-In Board
CFM : Cubic Feet per Minute
DUT : Device Under Test
ED_T : Estimated Die Temperature
HTOL : High Temperature Operating Life stress test
HTR : Heater
HTRB : High Temperature Reverse Bias stress test
ITC : Individual Temperature Control
LFM : Linear Feet per Minute
OS : Operating System
PM : Preventative Maintenance
PS : Power Supply
PTC : Power Temperature Cycle stress test
WCS : Watt Current Sense