FIFTEENTH ANNUAL BiTS 2014 Burn-in & Test Strategies Workshop

Session 2

Monday 3/10/14 3:30pm

DOING THE HEAVY LIFTING

Within burn-in and test strategies the heavy lifting that falls to the technologies within test systems is this session's focus. The first paper outlines the issues related to Kelvin contacting for wafer-scale test and presents a solution to these obstacles. The second paper discusses a temperature study of high power switching regulators with thermal shutdown to develop an accurate method of determining junction temperature rise. The final paper introduces using MEMS in place of traditional electro-mechanical technologies.

Kelvin Contactors for Wafer-Level Test
Jim Brandes—Multitest - LTXC

This Paper

Temperature Characterization of High Power Switching Regulators
Paolo F. Rodriguez—Analog Devices, Inc.

LIGA Precision Microfabrication for Electromechanical Applications
Frank Schonig—Innovative Micro Design

Temperature Characterization of High Power Switching Regulators

Paolo F. Rodriguez
Analog Devices

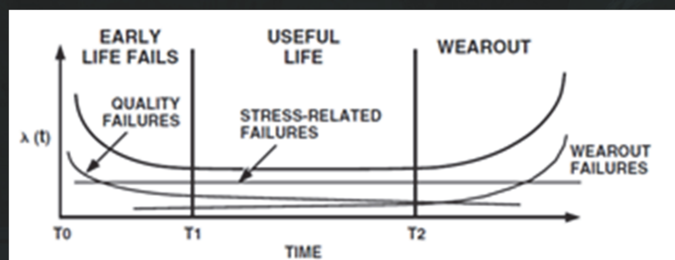
2014 BiTS Workshop
March 9 - 12, 2014

Industry Trends

- Integrated Circuits…
  - More functions packed in smaller dimensions
  - High power dissipation
- HTOL…
  - Moving to true application simulation

Introduction

- **Reliability of Integrated Circuits…**
  - **Dependent on environmental conditions**
  - **Thermal stress is most significant**
  - **Die temperature is critical**



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Introduction

- **Temperature Acceleration (Arrhenius)…**

$$A_f = e^{\left(\frac{E_a}{k}\left\{\frac{1}{T_{USE}} - \frac{1}{T_{STRESS}}\right\}\right)}$$

T_{USE}	T_{STRESS}	E_a	A_f
55	85	0.7	8
55	100	0.7	20
55	120	0.7	60
55	125	0.7	78

  - **↑ $\text{Temp}_{\text{STRESS/Ambient}}$ ↑ Acceleration Factor**
  - **For Reliability, the higher the Stress Temp the better**

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Introduction

- High Temperature Operating Life…
  - JESD22-A108D
  - Simulates product use at high temperature to achieve acceleration
  - Usually between 100°C to 150°C

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The Challenge

- Accurate Junction Temperature Rise During Life Testing
  - Thermal impedance values specified in product datasheets are inappropriate for life test
  - Availability of a digital input pin for ESD diode characterization during life test is uncertain

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Presentation Objective

- Present a Solution to Accurately Measure the Junction Temperature Rise Over Ambient
  - On high power switching regulators
  - Taking advantage of built-in thermal shutdown feature
  - Using standard life test hardware and bias equipment

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Limitation w/ Datasheet Θ_{JA}

- Junction-to-ambient Thermal Impedance is Measured Using Natural Convection on a JEDEC 4-Layer Board; the Exposed Pad is Soldered to the Printed Circuit Board

Leads	Std/ Special	Body Size	Power	Θja (0 Airflow)	Θja (200 LFM)	Θja (400 LFM)	Power	Θjc	Test Device	Die Size	Pad/ Cavity Size	PCB Type	Comments
32	LFCSP	5 x 5 mm		32.5				32.71		.100 x .100	.059 x .059 Optipad	JEDEC 2S2P	Paddle soldered to board, 9 thermal vias in pad. Report ANA-082

- Life test board uses sockets; exposed pad is not soldered
- Chamber utilizes high volume circulation fan

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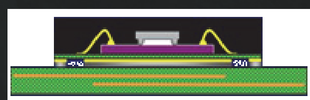
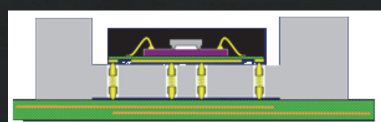
Limitation w/ Datasheet Θ_{JA}

- Heat Dissipation Path is Different in a Socket…



- Die - Case - Ambient
- Die - IC Pads - Board - Ambient



- Die - Case - Socket - Ambient
- Die - IC Pads - Socket - Board - Ambient

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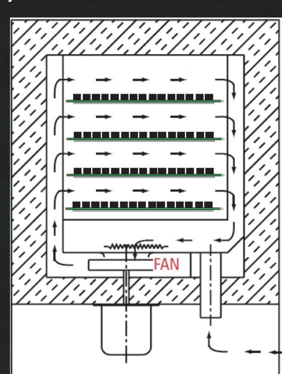
Limitation w/ Datasheet Θ_{JA}

- Printed Circuit Board and Chamber Air Flow Affect Thermal Impedance
  - PCB (Material, Cu Volume, Cu Thickness, Trace Width, No. of Layers, Size)
  - Chamber Air flow



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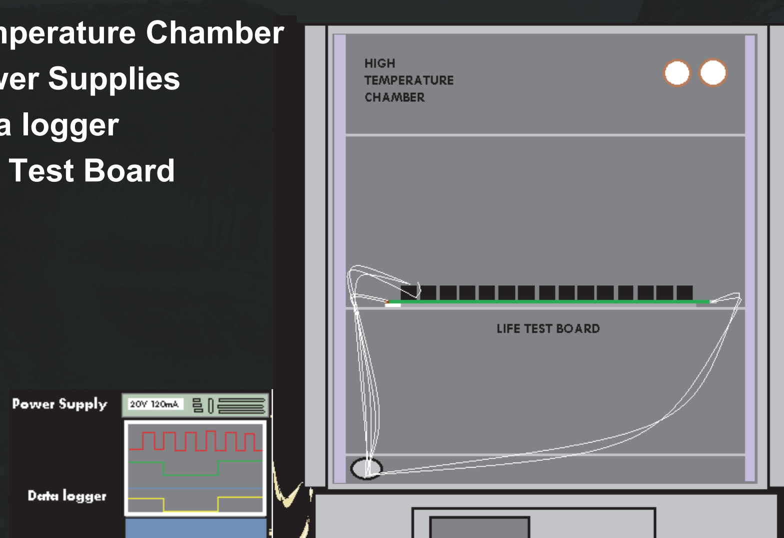
Thermal Shutdown (TS)

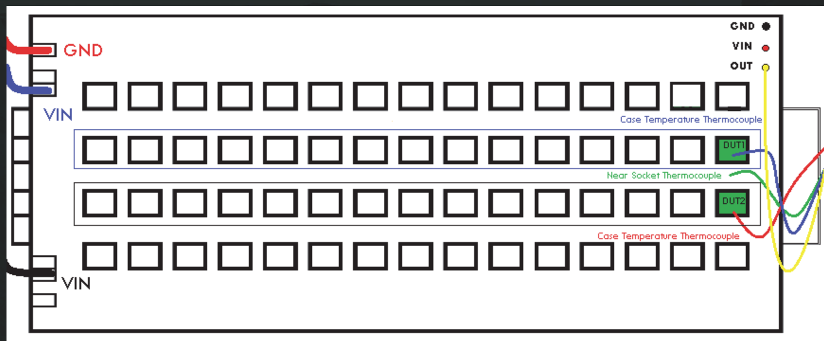
- Utilized on integrated circuits operating with high power dissipation at elevated temperature
- Senses the die temperature and turns off the regulator when the die temperature rises to a predefined threshold
- Thermal Shutdown Threshold = $150^{o}C$
- Thermal Shutdown Hysteresis = $15^{o}C$

Characterization Set-up

- Temperature Chamber
- Power Supplies
- Data logger
- Life Test Board



Characterization Set-up



- **Case Temperature Thermocouple**
- **Near Socket Thermocouple**
- **Output Voltage Test Point**

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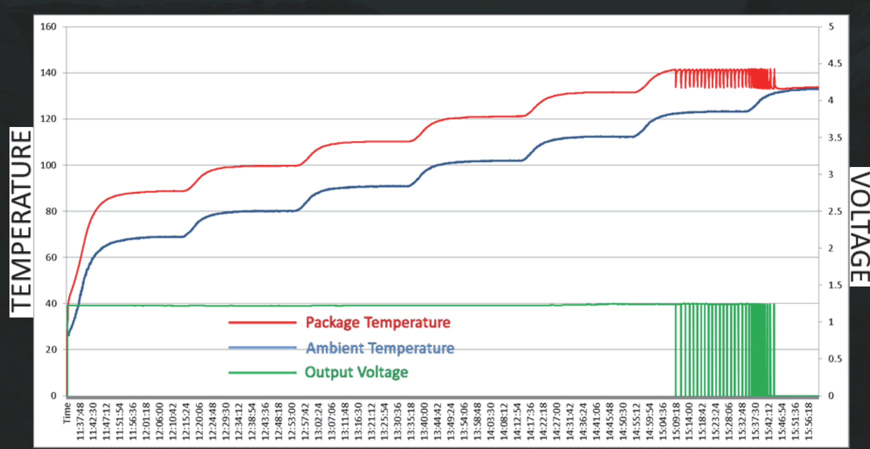
Characterization Results



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Characterization Results

Time	OUT 2	Ambient	Package
HH:MM:SS	V	°C	°C
15:09:00	1.239	122.4	141.3
15:09:02	1.239	122.4	141.4
15:09:04	1.239	122.4	141.4
15:09:06	1.239	122.4	141.4
15:09:08	1.239	122.4	141.4
15:09:10	1.239	**122.4**	**141.5**
15:09:12	1.239	122.4	141.5
15:09:14	0.000	122.4	139.4
15:09:16	0.000	122.4	136.6
15:09:18	**0.000**	**122.4**	134.8
15:09:20	0.000	122.4	133.7
15:09:22	1.240	122.4	134.9
15:09:24	1.240	122.4	137.1

19.1 *Delta between case & ambient temperature during DUT operation.*

27.6 *Delta between thermal shutdown threshold & near socket ambient during initial DUT shutdown.*

- IC heats up significantly (19°C above ambient)
- <u>27.6°C</u> = 150°C (TS Threshold) - 122.4° C

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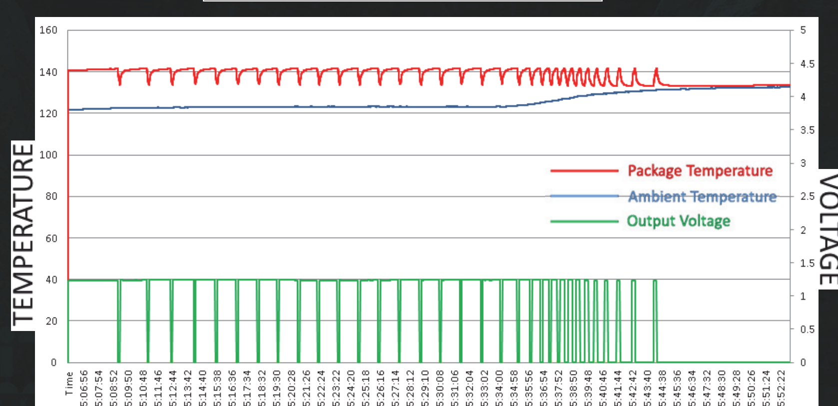
Characterization Results

Near Socket Ambient Temperature	Duty Cycle (% of operation per minute)
119°C	100%
123°C	83.33%
127°C	50%
131°C	16.67%
135°C	0%



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Compute vs. Characterize

- 65.40°C **computed** junction temperature rise over ambient

$Temp_{ambient}$, °C	0.00
Θ_{ja}, °C/watt	32.70
Supply	VIN
Current rating, A	0.100000
Voltage supply, V	20.00
$T_{junction}$, °C	65.40
PD_{TOTAL}	2.0000000
Rise over Ambient	65.40

$$T_J = T_A + \Theta_{JA} (P_D)$$

T_J = Junction Temperature
T_A = Ambient Temperature
Θ_{JA} = Thermal Impedance, junction to ambient
P_D = Power Dissipation, Current x Voltage

- 27.60°C junction temperature rise over ambient by using the “Thermal Shutdown Technique”
- **137%** Percentage Error

= (Approximate Value – Exact Value) / Exact Value x 100

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Compute vs. Characterize

- By Addressing the Over Estimation of the Junction Temperature Rise…
  - HTOL was performed at a higher ambient temperature
  - Higher Acceleration is Achieved

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Conclusion

- Junction temperature rise over ambient can be more accurately determined by utilizing the IC's built in temperature shutdown circuit

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Recommendations

- Ensure that disabling the thermal shutdown bit does not affect other functional IC blocks
- Always be aware of the product's absolute maximum junction temperature

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