NINETEENTH ANNUAL

BiTS™

Burn-in & Test Strategies Workshop

March 4 - 7, 2018

Hilton Phoenix / Mesa Hotel
Mesa, Arizona

Archive

An Improved Method to Measure Junction-to-Case thermal characterization parameter ψ_{jc}

Bernard Tam, Manish Saini
Intel Corporation

INTRODUCTION

•Thermal characterization parameter ψ_{jc} is used to set test conditions, "bin splits" and thermal set points for integrated heat spreader (IHS) processor products. It is given as $\frac{T_j - T_{case}}{Total\ Package\ Power}$.

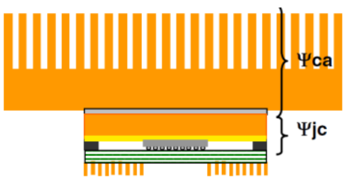


Fig 1. Thermal characterization parameter ψ_{jc}

•Digital thermal sensors (DTS) are usually located at the proximity of the cores and are used to measure junction temperature approximately. DTS temperature is derived with a slope equation from two calibration temperature data points. T_{case} is measured with a T-type thermocouple installed in a groove engraved on the IHS lid.

•System dynamic ψ_{jc} data is used to roughly correlate with tester ψ_{jc}. A correlation of within 10% will be sufficient for this purpose but previous measured results shown run-to-run errors up to 40%.

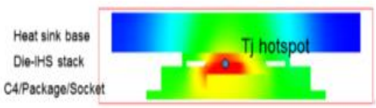
The two main goals are to

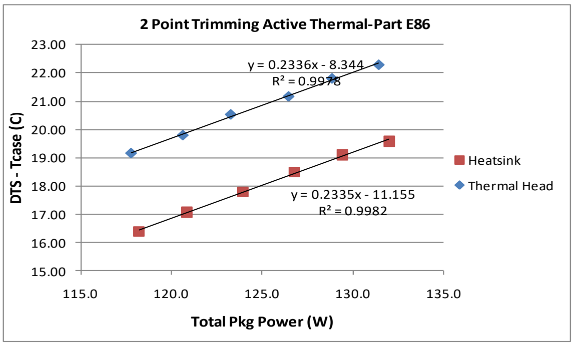
1. **Improve precision in ψ_{jc} data**
   - DTS measurements can be improve by using multiple calibration temperature points instead of only two.
   - Accuracy of T_{case} measurement can be substantially increased if it is calibrated to a better known standard.
2. **Explore better measurement setup**
   - An active thermal control device is typically used to regulate T_{case} but this is significantly different thermal boundary condition than a fan based heat sink. The differences in the resulting ψ_{jc} need to be investigated.

Steps of improvement

•Heatsink Vs Active Thermal Tool

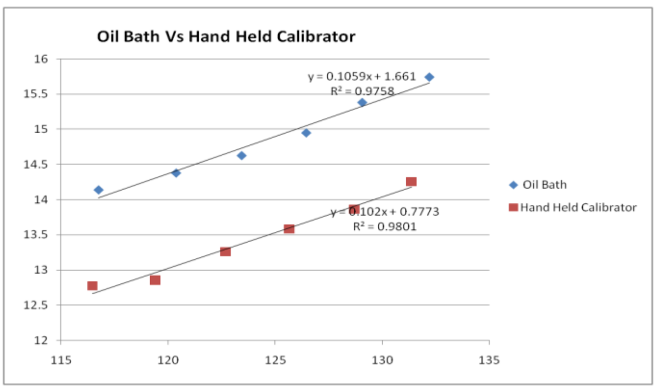
- When ψ_{jc} was previously measured in the lab, T_{case} was regulated using an active thermal tool but secondary effects such as bi-directional heat flows on the IHS edges may affect the T_{case} temperature. The result below shows that by keeping DTS at near throttle temperature with the active thermal tool, some reverse heat flow from locations away from hotspot affects the T_{case} temperature.





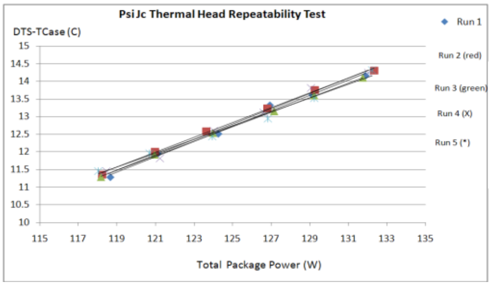
•Thermocouple calibration

- A thermocouple is usually calibrated with an Omega CL25 calibrator but it's accuracy can be improved by calibrating with an oil bath. Our result shows a difference of 1.5 °C of a thermocouple calibrated between an oil bath and a calibrator. The error is caused by the intrinsic tolerance of the calibrator,



Repeatability of measuring dynamic ψ_{jc}

- Dynamic ψ_{jc} can be approximately evaluated with leakage held constant by maintaining supply voltage and temperature the same while varying speed to change dynamic power. The run-to-run errors in collecting dynamic ψ_{jc} data is caused by the imprecisions when varying the narrow range of the system The solution is to vary the core ratio and uncore ratio in a synchronous manner



Dynamic ψ_{jc} Repeatability Test				
Run 1	Run 2	Run 3	Run 4	Run 5
0.228	0.226	0.228	0.225	0.227

Summary

- thermocouple calibration in oil bath provided better accuracy than a handheld calibrator.
- It is better to use a passive heatsink for T_{j-max} prediction when measuring static ψ_{jc} if higher accuracy and repeatability is needed.
- Changing core/uncore ratios instead of varying clock frequency allow wider ranges for power and T_{case} and are less susceptible to minor adjustment errors.
- The new method can be used to reduce guard bands and increase bin splits.