T3Ster®

Thermal
Transient Tester
General Overview

Mentor Graphics®

M E C H A N I C A L A N A L Y S I S

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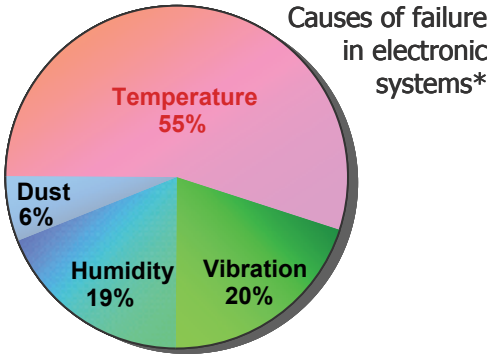
SAFEGUARDING AGAINST TEMPERATURE RELATED PERFORMANCE PROBLEMS

The relationship between high temperature and poor performance in electronics is well documented. When junction temperatures reach and exceed critical levels, reliability decreases exponentially, performance degrades and physical defects can occur.

Safeguard against excess heat by using *T3Ster* – the world's leading thermal transient testing solution. *T3Ster* produces fast, repeatable and accurate thermal characteristics from a wide range of semiconductor devices, including stacked-die ICs and system-in-package devices as well as different kinds of discrete semiconductor components like power transistors, IGBTs, power LEDs – just to mention a few. Accurate thermal measurement with *T3Ster* can help you:

- Reduce chances of premature product failure
- Comply with emerging industry standards
- Publish accurate, verifiable product data
- Obtain real input for thermal simulation

Offering unrivaled accuracy and highly repeatable thermal impedance data, *T3Ster*'s multi-channel architecture enables almost all package varieties to be characterized with the minimum number of measurements. It offers extremely accurate temperature measurements (0.01°C)[1] and one micro-second measurement resolution in time and unlike other systems, *T3Ster* directly measures the actual thermal impedance curves – the thermal transient response of packaged semiconductor devices rather than artificially composing them from individual responses.

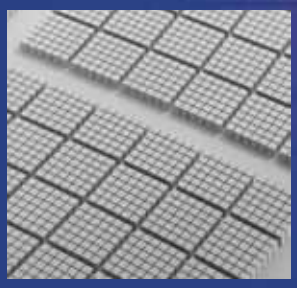


* 1997 IEEE, Zhang, Jovanovic and Lee

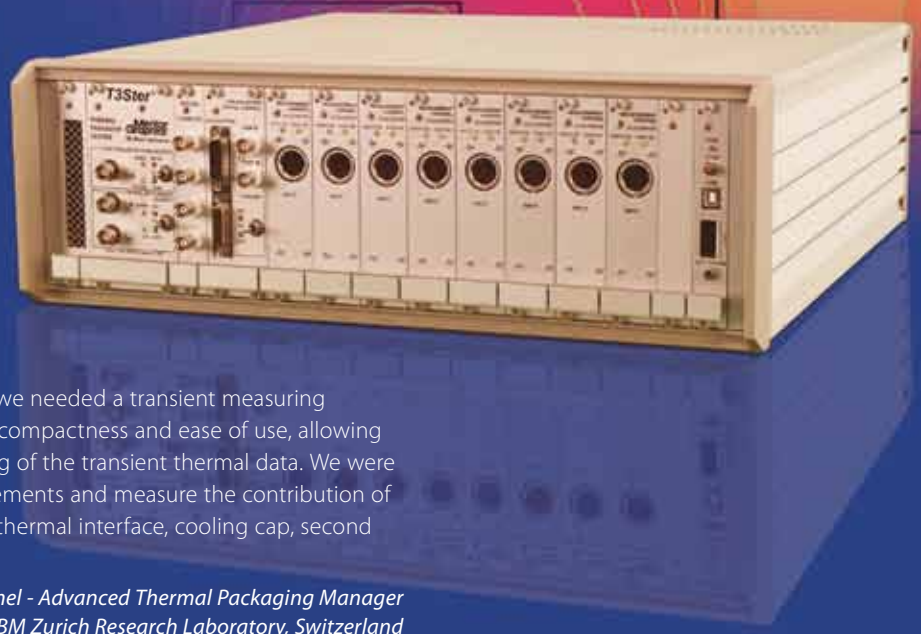
T3Ster can be used for:

- Heat-flow path reconstruction
- Die attach qualification
- Testing of stacked die packages
- Characterization of power LEDs
- Material property identification
- Thermal model verification and validation
- In-situ, non-destructive failure analysis
- Reliability testing with power cycling and subsequent structure function analysis
- Thermal testing of parts in application environment, in live systems

[1] *Using a diode type sensor with -2mV/°C sensitivity and assuming 50mV temperature induced change of forward voltage.*



IBM's Hierarchically Nested Channels prevent voiding in the thermal interface material during temperature cycling. T3Ster measurements have been used to verify this.



"To reliably measure the interface resistance we needed a transient measuring method. We chose the ***T3Ster*** because of its compactness and ease of use, allowing us to improve data acquisition and processing of the transient thermal data. We were able to improve the accuracy of TIM measurements and measure the contribution of the different components – the heater chip, thermal interface, cooling cap, second interface, and heat-sink."

Dr. Bruno Michel - Advanced Thermal Packaging Manager
IBM Zurich Research Laboratory, Switzerland

"As LEDs become more powerful, more attention should be paid to thermal management, which is essential to ensure stable LED performance and long lifetime. This is why OSRAM is devoting considerable attention to thermal design. ***T3Ster***'s accuracy and repeatability enable us to verify our thermal designs and confirm the stability and reliability of our products. By testing in bulk we get increased statistical confidence in the measurement results. The structure functions built into the ***T3Ster*** software are extremely powerful for identifying different thermal attach issues during our extensive reliability testing."

Dr. Thomas Zahner, Quality Manager
Osram Opto Semiconductors GmbH, Regensburg, Germany

High brightness LEDs and LED modules of OSRAM have been characterized by T3Ster. The T3Ster measurements were used in large scale reliability analysis of power LEDs.

A SOLID INVESTMENT IN YOUR COMPANY'S FUTURE

SEMICONDUCTOR MANUFACTURERS

Semiconductor and IC package manufacturers are constantly trying to fit more components into smaller and tighter spaces. An unfortunate consequence is the increasing heat dissipation density. At the same time, with higher speed and more functions, IC power dissipation continues to rise due to increasing bandwidths and transistor densities. As a result, the chip temperature increases. This excess temperature modifies and eventually destroys the operation of the circuit if the heat is not correctly led away from the device. Increasing junction temperatures can reduce IC performance, and the reliability of components can decrease exponentially due to thermal problems. Increased temperatures can also result in physical warping and cracking of components, potentially delaminating material layers and causing defects such as die attach voiding. Sufficient heat dissipation often comes down to the IC package design and the materials used.

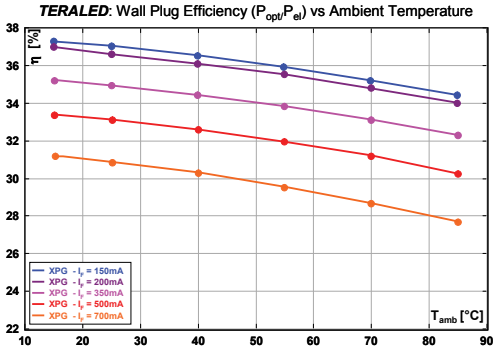
By using a thermal tester during the design and quality assurance processes, manufacturers can design products with superior thermal performance and publish reliable thermal data for downstream applications. *T3Ster* is used by engineers during the design and product development phase to predict the chip temperature correctly. In addition it can verify the thermal path of an assembly and provide thermal data for the physical design during the post layout stage of design verification. In manufacturing it helps uncover hidden failures and can perform production testing in a suitably configured production line. And QA departments can use *T3Ster* to identify mechanical failures such as die-attach delamination quickly and easily in a non-destructive way.

Case study: A prominent semiconductor manufacturer for the automotive market can produce up to 1,000,000 semiconductor chips a day. If the sale price of a single chip is $5, a stoppage in production of 2 days due to a die attach problem would cost the company $10,000,000 in potential lost revenue. With a very reasonable list price, avoiding even a 2 hour stoppage will pay for the cost of *T3Ster*.

LED MANUFACTURERS

LED manufacturers have several compelling reasons why they should invest in thermal characterization and testing.

Every form of electric lighting produces an unwanted by-product -- heat -- and LED lights are no exception. Today high power LEDs are generating on the average 60-65% heat versus 35-40% light. Heat build-up can reduce an LED's light output, cause a color shift and at the same time shorten the component's useful life. Therefore, thermal management is by far the most critical aspect of LED system design. An LED's thermal resistance must be characterized to ensure a safe, reliable design and satisfactory performance. Also, there may be multiple thermal interfaces such as glue layers in the heat flow path, and their thickness and resistance can be difficult to control in manufacturing. As such, thermal resistance must be understood as early as possible. Complete understanding of temperature dependence of light output characteristics is also a key issue both for LED vendors and LED users.



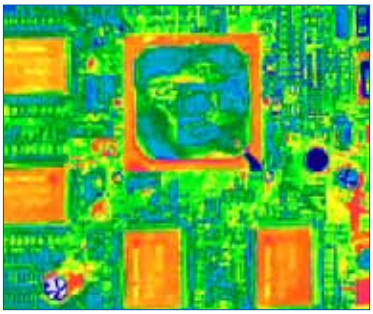
New rules and requirements are necessitating further improvements – both in cost and in resource usage. The US Department of Energy (DOE) forecasts an increase of LED efficiency by more than 1.5x and reduction of LED production costs by about 10x by 2015 and by about 25- to 30x by 2025. Considering that manufacturing efficiency improvements have led to a 20x cost reduction per decade, to maintain the same curve, further cost reductions need to come from yield, productivity and cost improvement. Using thermal measurements, an engineer can determine the best and most cost effective materials to serve this purpose. This way an engineer can select from a vast range of materials, components and interface compounds to fine tune each element to best fulfill system design goals. Thermal transient measurements with subsequent structure function analysis support QA and reliability departments locate problems and this way improve production yield.

Case study: According to a DOE presentation in 2009, the costs associated with LED manufacturing are as follows: 50% in packaging, 25% in chip processing, and 25% in EPI processing. The front-end processing leverages the backend costs such as binning. Therefore, by improving the front-end manufacturing costs, companies will be able to leverage back-end costs and reduce lighting costs.

SYSTEM MANUFACTURERS

For system manufacturers it is important to know how certain critical IC chips would operate in their real life thermal environment such as a GPU in a high performance graphics card inside an HD TV set or RAM chips on RAM modules inside a computer enclosure. Therefore in-situ thermal transient testing of such chips is a must for them: thermal transients taken inside the operational environment is characteristic for the actual working conditions of these IC devices. In the case of such tasks, powering of the chip to be tested is provided by the system itself. The sudden change in power is triggered by T3Ster. Such a change could be the sudden reduction of the clock speed of a digital IC. For measuring the junction temperature some temperature sensitive elements inside the chip to be tested are used. The chip may contain a dedicated thermal test diode, but other diodes – if electrically deactivated – can be used for temperature sensing. This way TV sets, computer mother boards and RAM modules can be tested under real operating conditions. In the case of RAM module testing, structure functions obtained from in-situ testing of such devices in a computer enclosure can help assess the heat transfer properties of the RAM module's FR4 assembly.

In a real life example, structure function analysis helped identify a costly element (a heat-spreader) in the thermal management solution of a compact notebook RAM module design which did not add much value to the cooling properties. Removing this part saved several dollars per unit in material costs alone, and lowered manufacturing costs in production. Using an improved TIM material, the properties of which were verified in-situ, allowed the design target for thermal resistance target to be achieved, and the cost of the TIM material minimized. Here again, significant material and production cost savings can be achieved and end product quality assessment is possible – something which, by any other means, would not be available to system architects.

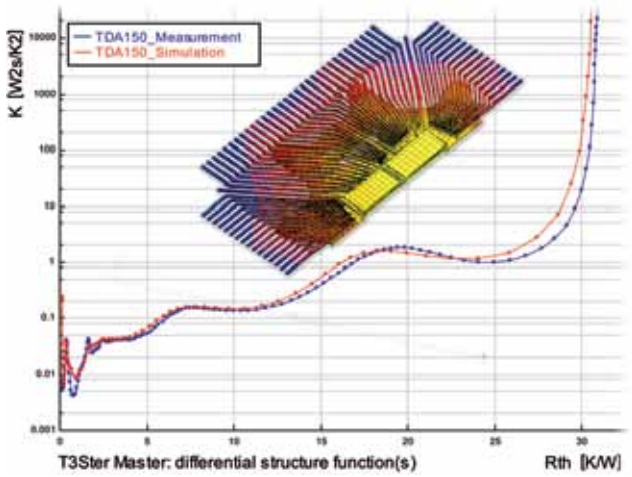


7 REASONS WHY *T3Ster* IS THE BEST CHOICE?

As the leading thermal transient test solution, *T3Ster* offers:

1. Accurate results: *T3Ster* offers extremely accurate temperature measurements, a superior signal to noise ratio and 1 micro-second measurement resolution in time. This high level of precision in measurement enables you to identify the true behavior of your design instead of having to settle for results that are just not good enough.
2. Fully scalable system: *T3Ster* can be fully tailored to meet your needs today and in the future. It can be extended to support large scale tests and can measure systems and components from ~100mW up to the kW range. And with a wide range of hardware add-on accessories available, you can be assured that your investment is safe:
    a. Automated device calibration with our dry thermostat and supported liquid-cooled thermostats
    b. Easy connection of any type of thermocouple through the appropriate preamplifiers
    c. Increased level of switched power with different booster options
    d. Addition of the ***TERALED*** unit for high-power LED measurement
3. Real-time measurement: *T3Ster* carries out measurements in real-time in conformance with the static test method described in the JEDEC JESD51-1 standard. This continuous measurement technique combined with precision hardware results in capturing very accurate, noise free, real thermal transient curves at high time resolution.
4. Powerful results post-processing: Use the additional *T3Ster*-Master software to visualize a wide range of device responses as well as the structure functions. *T3Ster*'s heat-conduction path structural analysis is an ideal solution for final prototype testing. It can help designers verify the quality of their final product quickly, accurately and cost-effectively.
5. Real Data for Simulation: Advanced thermal analysis software such as FloTHERM or FloTHERM PCB are used to predict thermal behavior of electronic equipment but they are dependent upon the availability of accurate thermal models of the components. *T3Ster* can provide accurate data which can be used as validated input for simulation purposes.
6. Technical support and testing & modeling services in Mentor Graphics Mechanical Analysis Division's global thermal testing facility network. Our application engineers help properly configure a *T3Ster* system and later on they also provide advice on further scaling and extensions. Technical advice regarding new applications is also available. Thermal testing hardware products are backward compatible assuring long term protection of your investment.
7. Mentor Graphics' MicReD product line is based on solid R&D. The MicReD team is actively involved in large scale industrial R&D with leading edge partners like Thales and IBM – key members of the NANOPACK research consortium of the EU. Also, our R&D engineers are actively involved in international standardization work (e.g. in JEDEC and CIE) which assures that our thermal testing solutions comply with the latest industrial standards such as JEDEC JESD51-14 transient method for measuring junction-to-case thermal resistance of power semiconductor packages

For a complete and up to date accessories list please consult with http://www.mentor.com/products/mechanical/products/t3ster/options-accessories



"In our lab today the *T3Ster* is mainly used to measure the thermal resistance of our packages in customer-specific environments. Thanks to the *T3Ster*, these measurements are very quick and easy to perform. With the help of the *T3Ster*-Master software we are not only able to give customers strong confidence that our compact thermal models are correct, but also give them insights into how the heat can be dissipated to the environment and the impact of possible faults that may occur during board assembly."

ir John H.J. Janssen, Manager Virtual Prototyping, Senior Principal, NXP-Semiconductors, Nijmegen, The Netherlands

Heat-sinks and other types of cooling assemblies can be characterized by T3Ster.

VLSI chips, live processors, discrete semiconductor devices from simple diodes, bipolar transistors through MOSFETs and JFETs up to IGBTs and thyristors can be measured by *T3Ster.*

Parts in their live environment can also be studied. Structure functions help distinguish the thermal response of the part being measured by *T3Ster* from the effects of the environment.

The structure functions derived from the very accurate, noise-free temperature transients measured by *T3Ster* clearly show details of the power transistor chip – heat slug – TIM – heat-sink heat-conduction path providing insights into the system's behavior.

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