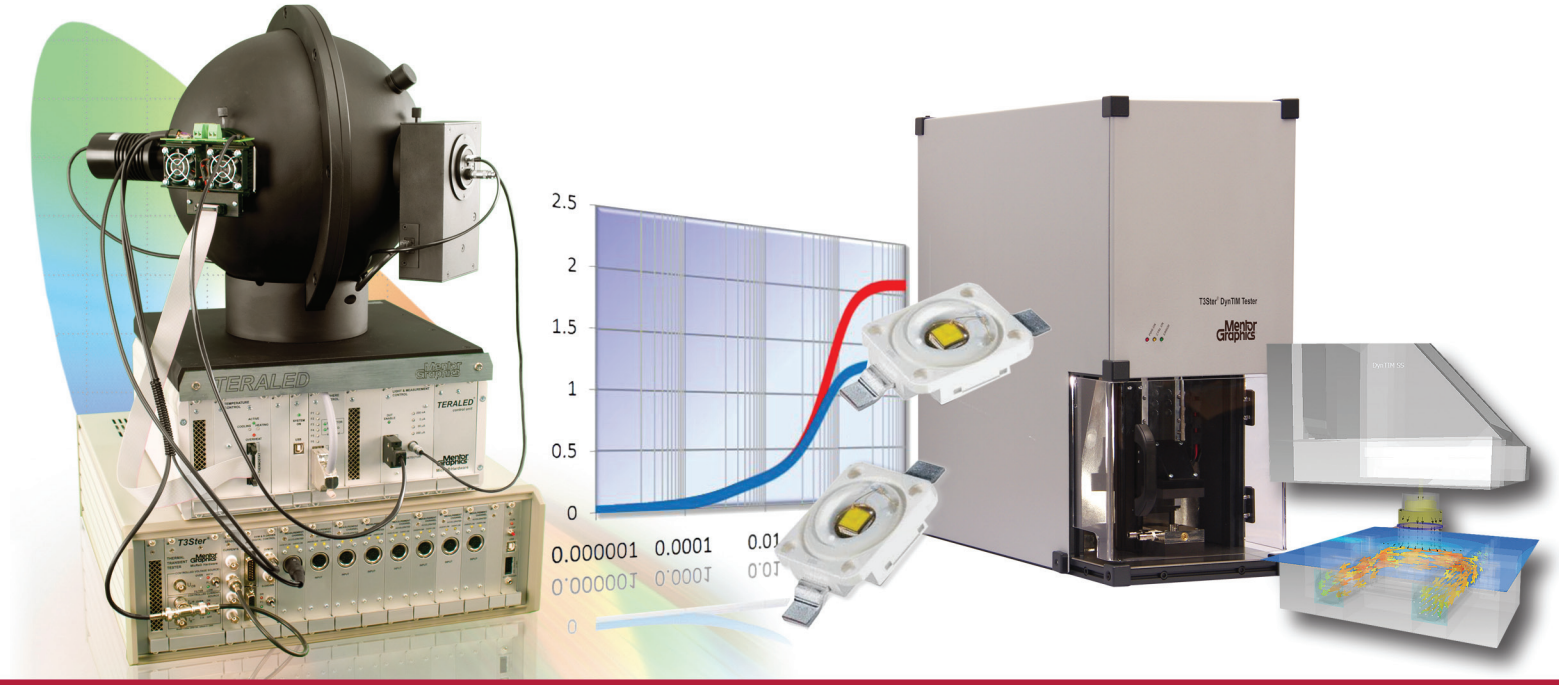
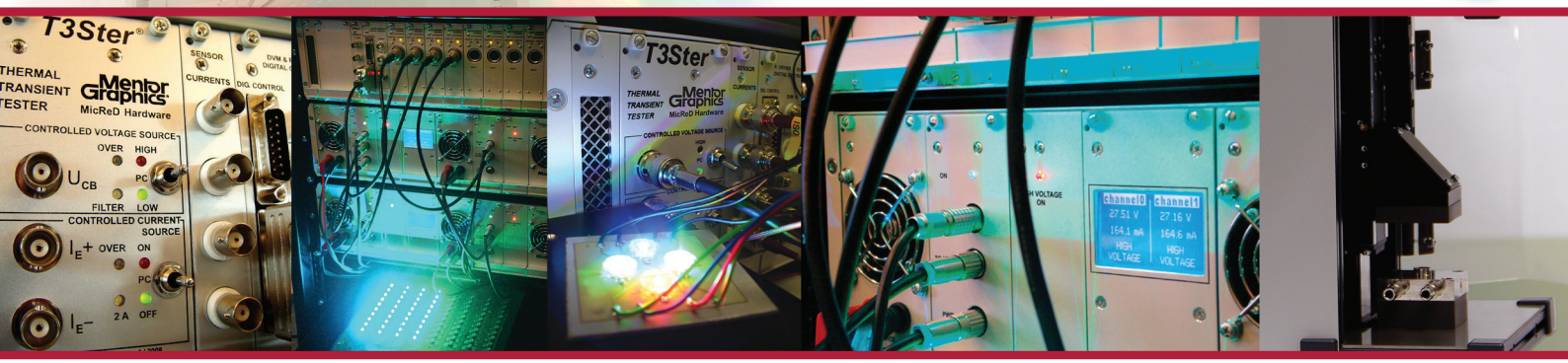
MicReD Hardware Products

Thermal Transient Test and Measurement





Mentor Graphics®

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

www.mentor.com

What our customers say about T3Ster

"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. Furthermore, for determining the properties of SOI materials, we also measure special test chips with T3Ster, yielding reliable data for thermal simulations of our own SOI chips. T3Ster is a highly versatile piece of equipment. I am sure that we will find other application areas in the near future."

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

package thermal characterization

thermal analysis

transient measurements

thermal transient testing

compact modeling

structure functions

model validation

"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

Intro to MicReD

MicReD® – Microelectronics Research & Development Ltd. was established in 1997 by four individuals (Vladimír Székely, Márta Rencz, András Poppe and Éva Nikodémusz) as a spin-off of the Department of Electron Devices of the Budapest University of Technology & Economics (BME). The creation of MicReD was motivated by the need to commercialize the results from various European funded research projects such as BARMINT and THERMINIC. The success of this technology transfer was then continued in further research projects such as the EU funded PROFIT project and some national projects such as INFOTERM. MicReD's present flagship product, T3Ster® ("the" thermal transient tester) was launched to the market in 2000. It was chosen as the standard test equipment for the PROFIT project.

The main focus of MicReD activity was the development of thermal simulation and modeling tools as well as the development, production and distribution of thermal measurement hardware (the T3Ster family of products and arrayable, intelligent thermal test chips), thermal measurement services and consulting. As a result of a national R&D and technology transfer project, the TeraLED® system (aimed at combined thermal and radiometric/photometric measurements of LEDs) was developed in cooperation with BME, University of Pannonia (Veszprém, Hungary) and the ancestor of LightingMetrics Ltd. (Pilisvörösvár, Hungary). The TeraLED system was launched to the market in 2005. The combined T3Ster and TeraLED setup established a de facto standard for the characterization of power LEDs.

MicReD's hardware portfolio covers the thermal characterization of all kinds of semiconductor devices. MicReD's testing technology is based on high precision thermal transient measurements completed by sophisticated post-processing which yields a detailed thermal capacitance / thermal resistance maps of the junction-to-ambient heat-flow path. This technology allows qualification of thermal interfaces such as die attach layers or TIM materials.

The strong research background of the company is highlighted by the fact that MicReD's staff members are authors and co-authors of technical papers in top quality journals and conference proceedings.

MicReD is located on the ground floor of Building D, Infopark, Budapest.

Intro to T3Ster

INTRODUCTION

T3Ster (pronounced "tri-ster") – The thermal transient tester is an advanced thermal tester for thermal characterization of semiconductor device packages. Designed and launched to the market by MicReD in 2000, T3Ster already had more than a decade of R&D effort behind it. T3Ster has been designed to produce fast, repeatable and accurate thermal characteristics from a wide range of ICs, including stacked-die and system-in-package devices as well as other semiconductor components. Aside from measurement of existing packages, T3Ster results can be used to create thermal analysis models for further verification. The data can be used by the market leading electronics cooling software FloTHERM® to predict device performance in various applications. Together, T3Ster and FloTHERM, enable engineers and developers to take full advantage of a comprehensive thermal design solution.

THE T3Ster TECHNOLOGY

T3Ster technology comprises of a flexible range of hardware, including the thermal transient tester station itself and numerous accessories (thermostat, booster, thermocouple pre-amplifiers, JEDEC standard still-air chambers, test-boards and special fixtures e.g. for TIM measurements). The measurements are controlled through a USB port; the advanced results post-processing program enables easy viewing and comparison of the results. The connection to the world of lighting is the TeraLED system – aimed at testing power LEDs. Using a smart implementation of the JEDEC JESD51-1 static test method, the thermal tester forces a packaged semiconductor chip from a "cool" to a "hot" state using a single step change in input power, and uses the measured internal transient temperature response to generate a complete thermal characterization of the package. Following the latest testing standards such as the JEDEC JESD51-14 "transient dual interface method", measurements take just a few minutes. The equipment yields very accurate temperature vs. time trace for a packaged chip in a given environment. This information can then be used for various purposes, for example to obtain metrics like R_{thJC}, R_{thJB} or R_{thJA} directly from the measurements, to get information about the heat-flow path to find and locate failures like die attach delamination or to create a compact thermal model of the part. T3Ster can be used to characterize the heat-flow path from the heat source to the environment, it can also be used for characterizing complete systems or thermal management devices such as heat-sinks and heat pipes, and the resistance of thermal interfaces. What separates T3Ster from all other thermal characterization equipment on the market is its:

- speed and ease of use;
- wide applicability;
- accurate temperature measurements (0.01°C) ; and
- one micro-second measurement resolution in time.

This combination produces unrivaled accuracy and highly repeatable thermal impedance data.

APPLICATIONS INCLUDE:

- Heat-flow path reconstruction
- Die attach qualification
- Study of stacked die packages and other laminated structures
- Characterization of power LEDs
- Test based compact thermal model generation packages for CFD analysis
- In-situ, non-destructive failure analysis
- Material property identification (i.e., thermal conductivity of TIM)
- Thermal model verification
- In-situ thermal testing of parts in application environment, in live systems
- Test based multi-domain modeling of LEDs for hot lumen calculations

T3Ster's multi-channel architecture enables most package varieties (single or multi-die packages) to be characterized with the minimum number of measurements, including stacked-die packages, MCMs and RGB LED modules. Semiconductor manufacturers and packaging companies are the clear beneficiaries, but end-users of packages can also use T3Ster to produce their own highly accurate thermal models. As a result, system-builders can quickly create an in-house library of validated thermal models resulting in a significant competitive advantage in thermal design.

SCALABLE SYSTEM

The T3Ster system consists of a Main System Unit having an **interface** to the measurement control computer (any desktop or notebook PC with the Windows® operating system), a **power driving module** for heating up the components to be measured, **sensor current sources** and up to eight measurement channels. The equipment can be ordered in different configurations with any number of **measurement channels** between two and eight. Hardware add-on components provide further scaling options.

Intro to T3Ster

MAJOR CHARACTERISTICS OF T3Ster

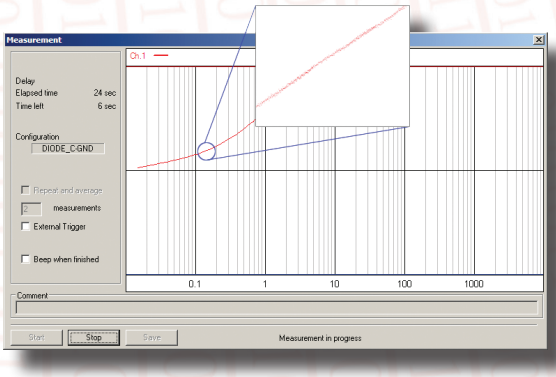
KEY FEATURES:

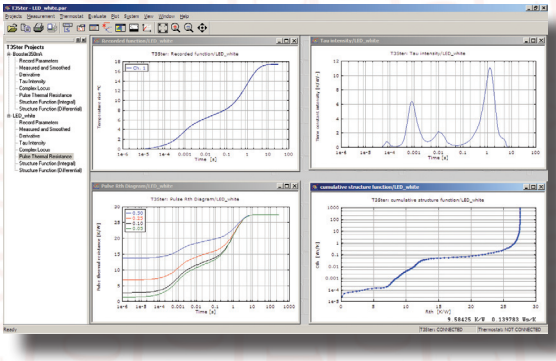
- Scalable equipment - rich set of hardware add-on options
- JEDEC compliant thermal resistance measurements
- Real-time measurement
- Continuous development, solid scientific background and worldwide consulting services
- Measurement control from any desktop or notebook computer
- T3Ster has the highest figure of merit among test appliances available on the market

ACCURACY, RELIABILITY, VERSATILITY, SCALABILITY

REAL-TIME MEASUREMENT

T3Ster carries out real-time measurements 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.** The JEDEC JESD51-1 dynamic test method is also available with T3Ster. T3Ster complies with the latest JEDEC thermal testing standards such as JESD51-14 "transient dual interface method" for the measurement of the junction-to-case thermal resistance of power semiconductor packages or the JESD51-5x series of LED thermal testing standards. Compliance to MIL standard 750E for testing transistors is also provided.





RESULTS POST-PROCESSING

The equipment comes with the T3Ster software. The standard software - besides measurement control - provides results post-processing options as well. With our unique evaluation technology the MicReD T3Ster software automatically derives:

- device response to pulsed periodic excitation (pulse thermal resistance);
- device responses to periodic excitation shown in frequency domain (complex loci);
- time constant spectra; and
- structure functions; all derived from the measured thermal impedance curves.

Structure functions are ideal means for the identification of:

- junction-to-ambient thermal resistance and other JEDEC standard thermal metrics such as junction-to-case thermal resistance (using the latest JEDEC standard JESD51-14);
- partial thermal resistances and related thermal capacitance values along the heat-flow path; and
- material properties and geometrical dimensions of the heat-flow path.

Hardware add-on options include :

- **additional measurement channels**
- **power boosters** to raise the power driving capability of the main system unit from 100 W to **multiple kilowatts**
- **extension** of the main system unit to provide additional power driving channels for simultaneous powering of multiple junctions
- **thermocouple pre-amplifiers** to interface J, K or T type thermocouples to the measurement channels of the main system unit
- a Peltier-based dry **thermostat** used as a device calibrator or as a cold-plate with an automated control from within the T3Ster measurement software
- test environments such as JEDEC standard 1ft^3 **still-air chamber** or dual cold-plates
- a special test environment called TeraLED for the combined thermal and radiometric measurement of power LEDs
- a special test environment called DynTIM for the characterization of various thermal interface materials

T3Ster Technical Overview

T3Ster MAIN SYSTEM UNIT: MAJOR SPECIFICATIONS

POWER DRIVER UNITS:

Controlled voltage source
U = ±10.24 V, LSB = 5 mV
Controlled current source
I = ±2 A, LSB = 1 mA
R-switch,
max. switched power 50 V, 2 A

A separate power booster (as an add-on option) can be used for 10 to 40 times higher driving capability.

Typical power levels with the base unit:
Transistor (3 pole device) measurement
Voltage step mode:
U_{CB}=10 V, I_E=2 A 20 W
Current step mode:
U_{CB}=50 V, I_E=2 A 100 W
Diode (2 pole device) measurement
Current step mode:
U_{diode}~ 1 V, I=2 A ~2 W
Generic resistive heater
R-switch mode:
U_{max}=50 V, I_{max}=2 A 100 W

With power boosters multiple kWatts of switched power can be achieved.

THE MEASUREMENT METHOD

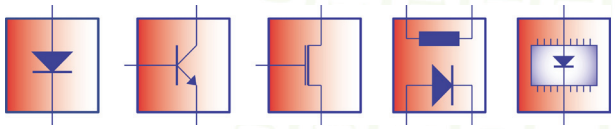
In accordance with the JEDEC standard static test method (JESD51-1), T3Ster forces a semiconductor package change between "cool" and "hot" states, using a single step change in input power, and while waiting for the new steady-state it continuously measures the internal transient temperature response of the device under test. The temperature change of the packaged semiconductor chip is measured by the electrical test method: a temperature sensitive parameter (TSP) of the semiconductor chip (e.g. forward voltage of a PN junction or the threshold voltage of a MOSFET) is used as a temperature indicator.

BASIC CONFIGURATION (PN: 240172)

The measurement requires **power driving units** that can switch the power abruptly, and **measurement channels** that capture the temperature transient very accurately with a time resolution as high as one micro-second. The T3Ster Main System Unit hosts these components together with the necessary **control circuitry** and **computer interface**. The main system unit can be equipped with up to eight measurement channels. The *T3Ster* hardware is completed with a **measurement control & results evaluation software** which runs on Windows® platforms. The USB interface allows using desktop or notebook computers for measurement control. With three different types of power driving options, T3Ster is suitable for measuring many different chip structures, such as:

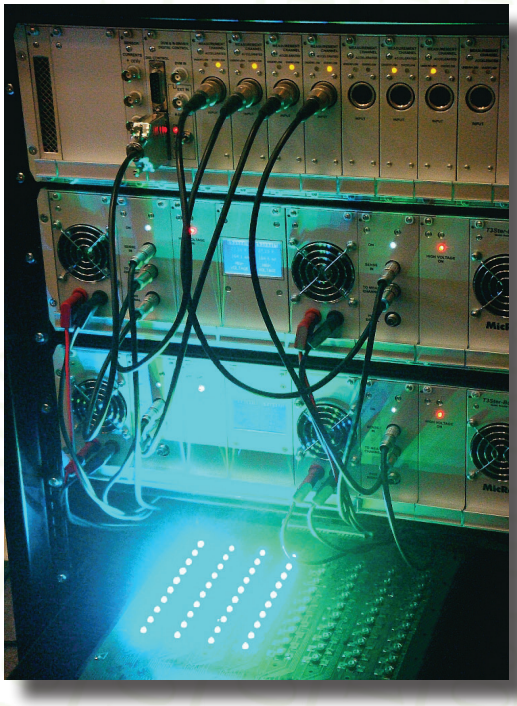
- discrete or integrated bipolar transistors, power MOSFETs, IGBTs, HEMTs, all kinds of diodes, power LEDs and live integrated circuits of any complexity; and
- dedicated thermal test chips with separate heater and temperature sensors.

Live IC chips can be typically measured through their substrate diodes. In a given measurement configuration one of three power driving options is available.



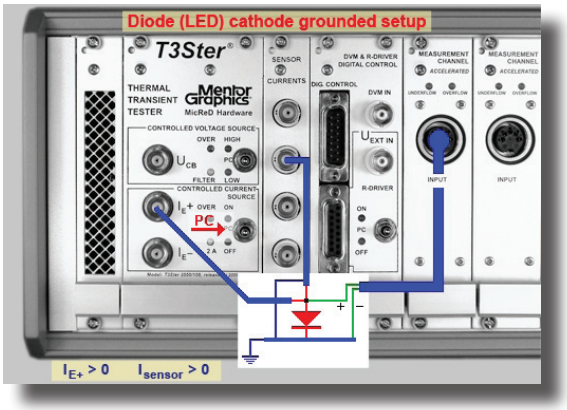
The power step can be created in different modes:

- Current step mode: programmed current step at fixed voltages
- Voltage step mode: programmed voltage step at fixed current
- R-switch mode: voltage and current is changed and measured



T3Ster Technical Overview

For the type of device under test (DUT) chosen, the measurement software suggests the appropriate measurement mode using graphical help to show the user how to connect the DUT to the main system unit. Simple device adaptors are provided as standard accessories to facilitate easy connection of the various types of devices.



MEASUREMENT CHANNELS (PN: 239868)

Voltage ranges: 400 mV / 200 mV / 100 mV / 50 mV

Resolution: 12 bit (i.e. least significant bit equals to 25 µV in the 100 mV range)

Noise: ±1 bit (prior to software filtering)

With a diode sensor having a sensitivity of 2 mV/K the 100 mV range corresponds to a temperature change of about 50 °C, the temperature resolution is Δ_{temp} = 0.01 °C. Eight measuring channels can be installed. On the parallel channels measurement and data acquisition takes place simultaneously.

Thermocouple and infrared sensors need an external pre-amplifier (available as an add-on option). With these typical LSB corresponds to 0.025 °C.

Minimum figure of merit: ~ 10000 W/°C
(diode measurement, without booster)

HIGH FIGURE OF MERIT

High precision, differential input amplifiers are the key elements of the measurement channels. Their high signal-to-noise ratio allows very sensitive measurements. This way one does not need to apply high heating power to be able to measure the temperature elevation of the junction. The quality of thermal test equipment can be well described by the figure of merit - a number independent of the equipment. T3Ster provides the highest figure of merit of all thermal test equipment available on the market.

FIGURE OF MERIT

The major sensitivity and accuracy parameters of thermal test equipment can be lumped into a single characteristic value, the figure of merit. It is defined as

$FM = P_{max} / \Delta_{temp} = SNR / R_{thJA}$

where P_{max} is the maximal power driving capability of the equipment, Δ_{temp} is the temperature resolution of the measurement, SNR is the signal-to-noise ratio and R_{thJA} is the total junction-to-ambient thermal resistance.

WHY USE T3Ster?

The sophisticated mathematics of the NID-method (network identification by deconvolution) embedded in the T3Ster software can only be fully exploited when applied to highly accurate and continuous real thermal transients, like the ones provided by the T3Ster hardware. Moreover, the equipment with hardware and software add-ons provides a complete thermal testing station, a single tool that allows a wide range of thermal measurements. Besides standard package characterization the structure function concept helps locate failures and irregularities in the heat-flow path such as die attach voids in single chip and stacked die packages, soldering failures, mechanical problems in cooling assemblies in a cost-effective, non-destructive way and provides alternative means of identification of material properties as well. T3Ster with its software provides input data directly from measurements for compact thermal models of packages. The models can be used in industry standard simulation tools such as FloTHERM.

T3Ster MAIN SYSTEM UNIT, DEVICE CALIBRATION

MEASUREMENT FEATURES

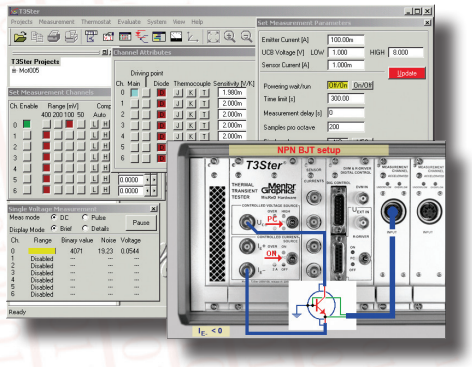
Smart device calibration, fast transient measurement:

- K-factor is identified either at measurement current or at operating current, depending on the test method chosen; and
- measurement takes place in real-time, "on the fly".

Flexible sampling rate: The sampling rate is controlled by the measurement software. The hardware supports individual programming of sampling intervals between 1µs and 8s. Typically 200-300 data points are collected in an octave with a quasi-logarithmic variable sampling rate.

STANDARD SOFTWARE

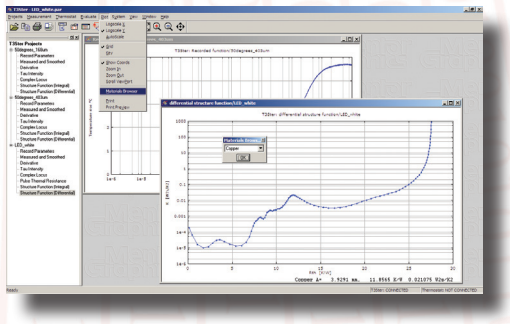
The T3Ster Measurement Control Tool is a mandatory component of any T3Ster configuration. The program runs under the Windows® operating system. Using a USB interface, any notebook computer can be used to control the measurements: after completing the measurements, the results can be taken back to the office on the notebook computer.



All equipment parameter settings such as voltage ranges, current levels, heating on/off state are controlled from appropriate dialog boxes in the software. The proper connection of the DUT to the Main System Unit is supported by graphics. During measurement the actual thermal transient is displayed in a window as it is captured.

In addition to the measurement control, results evaluation (based on the NID method) is also provided in the **T3Ster Master** transient measurement results post processing tool. Evaluation of the results takes place within a couple of seconds. The calculated results are the descriptive functions of the device tested.

A built-in materials browser can be used to facilitate the identification of geometrical data (e.g. cross-sectional area of the heat-flow path) from the structure functions.



EXTENDING THE POWERING OPTIONS OF T3Ster

MULTI-CHANNEL POWERING

The T3Ster Multi-channel Power Driving units (or T3Ster extension boxes in short) were designed to multiply the power driver channels of the T3Ster equipment. Extension boxes provide additional power switching modules and sensor current sources housed in the same type of enclosure as the Main System Unit.

PROPERTIES OF EXTENSION BOXES

Switching modes:
current step mode
voltage step mode

Number of power driving channels:
Max. 3 / extension box

Number of sensor current sources:
Max. 12 / extension box

Current load of a power driver unit:
Max. 2 A

Total allowed current:
Max. 5 A / extension box

Interface:
2 SPI ports: to the Main System Unit and/or another extension box

Up to two extension boxes can be installed.

THE T3Ster BOOSTER FAMILY

T3Ster-Boosters are add-on options of T3Ster. They are used to raise the switched power driving capability of T3Ster. They are external devices which follow the multi-channel architecture of T3Ster. The baseline model of the booster family provides switched power in the order of magnitude of kWatts. Two kinds of boosters are available: low voltage / high current or high voltage / low current, depending on the required application such as IGBT measurements or testing long LED chains.

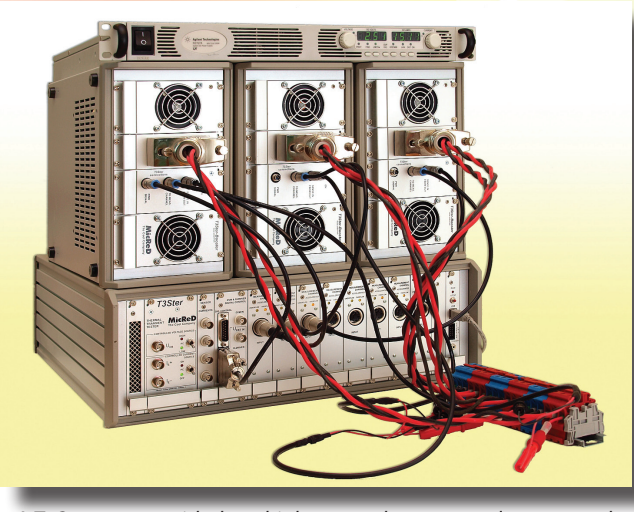
EXAMPLES OF BOOSTED POWER

IGBT measurement in current step mode
V_{CB} = 4V, I_{heat} = 400 A 1600 W

LED-line measurement in current step mode
V_{LED} = 100 V, I_{heat} = 2 A 200 W

VLSI IC
V_{core} = 1 V. I_{heat} = 200 A 200 W

Add-on Options



A T3Ster system with three high current boosters and an external Agilent power supply aimed at high current applications such as IGBT measurements.

Typical applications of T3Ster Boosters include:

- measurement of power devices such as thyristors or IGBTs;
- measurement of power LED assemblies such as LED lines; and
- measurement of large area VLSI chips through the substrate diode.

A single channel high current booster PNs: 239874, 239875

A single channel high voltage booster PN: 245899

BOOSTER CONFIGURATIONS

Dual channel high current booster PNs: 245935, 245936

Dual channel high voltage booster PN: 245938

Dual channel 280V booster extension box PN: 245900

200 A booster for T3Ster (PN: 250196). Up to three such units can be connected parallel to achieve 600 A of heating current (PN: 250195).

Add-on Options

THERMOSTAT FOR T3STER (PN: 239869)

This Peltier-cell cooled, dry thermostat is designed mainly for the calibration of temperature sensing semiconductor structures in the devices under test. It is directly controlled by the measurement software and can be used as a single-sided cold-plate as well.

The thermostat module of the measurement control software provides automatic temperature excursion and calculation of the sensitivity parameter of diode or resistance sensors. Thus the calibration diagrams are automatically generated within a few minutes. In manual mode the thermostat control module of the T3Ster software can treat the thermostat as a cold-plate during the measurements. This way the thermostat may serve as a "hard thermal boundary".

MAIN PROPERTIES

Temperature range:	5...90 °C
Accuracy:	±0.2 °C
Power sinking capability:	min. 8 W (above 30 °C)
Overheating protection	above 95 °C

DUAL COLD-PLATE (PN: 239886)

Third party, liquid based thermostats can also be used for calibration and measurement. Dual cold-plates are available from Mentor Graphics for that purpose.

In addition to the control of Mentor Graphics' own thermostat, manual and automatic control of third party liquid cooled thermostats (models from JULABO©, Cole-Parmer©, Lauda©, Haake©, Hart Scientific© or Arroyo Instruments©) is also included in the T3Ster software.

Each power booster includes an internal power supply and sensor current source. To achieve the highest rated power, external power supplies are needed. Selected models from Agilent© are supported through the T3Ster-Booster plug-in module of the T3Ster measurement control software.

Boosters can be upgraded. For example, up to 280 V of voltage is available through a voltage shift and safety switch - ideal for testing AC mains driven LED modules.

MIL-STD 750E INTERFACE

When connected to high current T3Ster-Booster, this unit serves as constant V_{CB} generator for measurement of BJT-s according to MIL-STD 750E. By using this connected to the T3Ster main system unit and the high current T3Ster-Booster, all current and voltage sources are available according to the requirements of the classical MIL-STD E750 while providing the superior transient measurement capabilities of the latest T3Ster technology of Mentor Graphics.

MIL-STD 750E interface PN: 251496

MEASUREMENT CHANNEL OPTIONS

THERMOCOUPLE PRE-AMPLIFIERS

Thermocouple pre-amplifiers are provided for easy interfacing of J (PN: 239882), K (PN: 239883) or T (PN: 239884) type thermocouples to the Main System Unit. They assure simultaneous measurement of external package or PCB temperatures along with the junction temperature measured directly through a T3Ster measurement channel. The amplifiers provide an output voltage range matched to the measurement channels of T3Ster.

Add-on Options

MEASUREMENT CHANNELS (PN: 245945)

T3Ster's fast thermal measurements are made possible through an advanced realization of the first stage of the measurement channel that minimizes the parasitic electrical transients superimposed on the thermal signal. Typically the data samples in the first few micro-seconds belong to the parasitic electrical transient inherently present in the measurements. Data points belonging to the junction temperature transients are captured from about 10 microseconds after the time instance of switching the power. Capturing thermal transients from as early time as possible results in a more detailed image of the package internals in the junction-to-ambient heat conduction path shown by the structure functions. Such details are very important in die attach failure analysis applications and characterization of power LEDs.

The base T3Ster model is equipped with two measurement channels. Up to six further channels can be added to the system in a plug & play manner: the measurement control software will automatically recognize the new channels added.

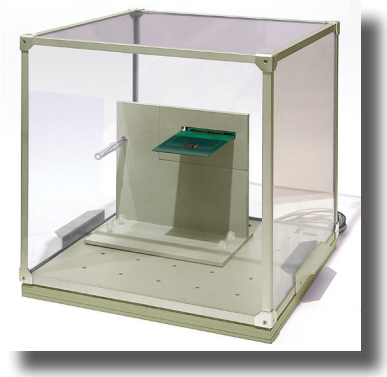
LED STRING TAPPER (PN: 250664)

T3Ster's multi-channel architecture can be exploited when measuring chains of serially connected single junction LEDs. When the complete string of LEDs is powered, forward voltages of individual LEDs can be taped with this device, allowing the measurement of their cooling curves individually. With a single LED string tapper device up to four LEDs can be connected to T3Ster. Two such devices can be connected in series, allowing the simultaneous measurement of up to eight LEDs of a string.

TEST ENVIRONMENTS

JEDEC STANDARD STILL-AIR CHAMBER (PN: 239885)

Mentor Graphics offers a still-air chamber (1 ft^3) to assure JEDEC JESD51-2A compliant setup for thermal transient measurements in a natural convection environment. The chamber can be easily adjusted to any JEDEC standard thermal test board size and to any edge connector type.



DUAL COLD-PLATE (PN: 239886)

Cold plates are not only used for device calibration but are also used as test environment. Both plates are identical and provide high heat transfer coefficient for the packages under test. The plates can be detached and can be used separately as well. They can be used as test environment for junction-to-case thermal resistance measurements based on the JEDEC JESD51-14 standard. The dual-cold plates can be used with any third party liquid-based thermostat. In addition to the control of Mentor Graphics' own thermostat, manual and automatic control of third party liquid cooled thermostats (models from JULABO®, Cole-Parmer®, Lauda®, Haake®, Hart Scientific® or Arroyo Instruments®) is also included in the T3Ster software.

THE TeraLED SETUP FOR POWER LEDS

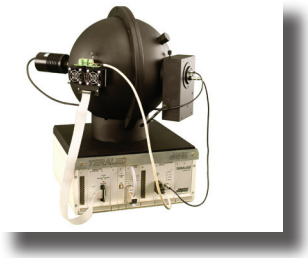
WHAT IS TeraLED?

In power LEDs, a significant amount of the supplied electrical energy is converted to light. Thus, when thermal characterization of LEDs is performed by the electrical test method, the emitted energy also has to be measured. The TeraLED system provides combined thermal and radiometric/ photometric characterization of high-power LEDs in an automated way. Thermal metrics as well as other properties such as luminous flux or efficiency can also be measured as a function of temperature and operating current.

TeraLED is designed to be used as an add-on to the MicReD T3Ster equipment to allow comprehensive testing of LEDs. The optical measurements are performed in thermal steady-state and once they are completed, the LED under test is switched off and its cooling transient is measured by the T3Ster equipment. TeraLED can be used with any combination of power boosters and the T3Ster Main System Unit.

TeraLED HARDWARE (PNS: 23988, 253162)

TeraLED hardware contains a total flux measurement system to allow photometric and radiometric measurements, using a high precision detector system with revolving filters and a reference light source, complete with control electronics.



TeraLED with a 30 cm diameter integrating sphere

Temperature controlled LED fixture

An integrating sphere hosts the temperature stabilized DUT fixture, the reference LED and a detector with different filters. A fiber optics port allows attachment of external devices such as a spectrometer. TeraLED is available either with a 30cm diameter integrating sphere (PN: 23988) or with a 50cm diameter integrating sphere (PN:253162).

The TeraLED control electronics interfaces all devices attached to the sphere with the measurement control computer. Through biasing the LED under test it allows a stand-alone operation. Combined thermal and radiometric measurements are possible when the biasing of the LED under test is provided by the T3Ster equipment or the power booster.

Temperature controlled LED fixtures are provided for both the 30 cm and the 50 cm diameter integrating spheres. For the 30 cm system a fast, Peltier-based device is provided with a 55 mm inner diameter providing a 40x400 mm2 mounting area and a heat sinking capability of 10 W in the temperature range of +10..+90 °C. For the 50cm sphere a liquid cooled cold plate is provided with 120 mm inner diameter with a heat sinking capability of about 50 W. (Available temperature range and the actual heat sinking capability depends on the type liquid used.) With a mechanical adaptor the same Peltier-based cold-plate is also provided with the larger sphere as with the 30 cm system. For using the liquid cooled TeraLED cold-plate the TeraLED measurement control software supports the same third party thermostats as the T3Ster measurement control tool (e.g. models from JULABO®, Cole-Parmer®, Lauda®, Haake®, Hart Scientific® or Arroyo Instruments®).

TeraLED with a 50 cm diameter integrating sphere

MEASUREMENT OPTIONS WITH T3STER TERALED SYSTEM:

- *K-factor calibration of the LED under test*
- *Photometric and/or radiometric measurements in thermal steady-state*

The LED under test is measured in a stabilized state at a programmed current and at a programmed temperature. Depending on the filter in use:

- **total radiant flux,**
- **total luminous flux (filter matched to the CIE V(λ) function within 1.5%) and scotopic flux, and**
- **X, Y, Z tristimulus values**

can be measured.

- *Measurement of optical properties as function of temperature & operating current*
- *Measurement of efficiency*
- *Combined with the T3Ster equipment* JEDEC compliant *thermal metrics* of the LED are identified, considering the actual emitted optical power. After having measured R_{thJA} of the LED under test temperature dependence of *optical parameters* is provided *as functions of the exact junction temperature.* The T3Ster TeraLED system is in compliance with the latest JEDEC LED thermal testing standards JESD51-51 and 51-52.
- *Derating curves*
- *Pulsed thermal resistance diagrams*

TeraLED SOFTWARE SUITE

The easy-to-use TeraLED software automates procedures like measurement of emitted flux (photometric or radiometric), efficiency or color coordinates as function of temperature and/or operating current. The LEDs' electrical characteristics as well as thermal calibration diagrams are also measured. Results are presented in form of plots, similarly to the T3Ster software. The TeraLED software automatically cooperates with the T3Ster and the T3Ster-Booster control software; thus even high voltage LED devices (110 V or 230 V) mounted on metal core printed circuit board (MCPCB) can be measured.

WHY CHOOSE TeraLED?

TeraLED has been developed specifically in response to demand from leading LED manufacturers, and provides a unique, complete solution for LED testing. This integrated system is scalable with low initial investment. You can start with just a stand-alone TeraLED system to measure the total radiometric flux as well as luminous flux and chromaticity coordinates. Combining TeraLED and T3Ster, thermal transient measurements produce real thermal metrics considering the emitted light as well as highly accurate structure functions which provide detailed internal information for power LED packages revealing die attach failures and other structural integrity problems.

ADVANCED RESULTS POST-PROCESSING TOOLS

THE TERALED VIEW UTILITY

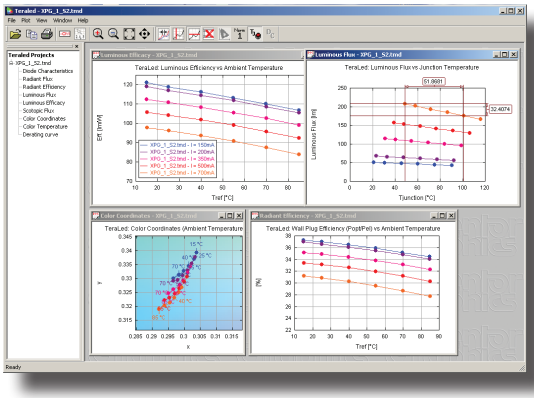
The TeraLEDView utility depicts the measurement results obtained with the TeraLED hardware as diagrams. The results can be plotted as a function of current and temperature (either ambient or junction), thus enabling you to examine the characteristics of the tested LED.

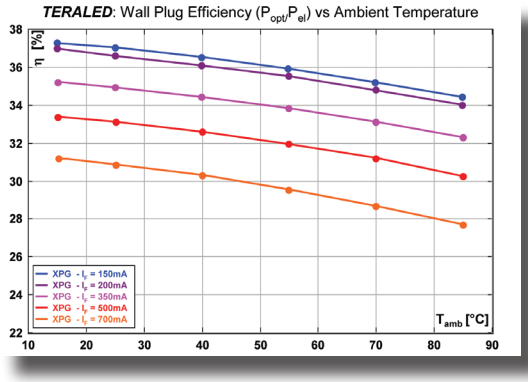
FUNCTION DIAGRAMS

You can view the following as function plots:

- Diode characteristics
- K-factor
- Absolute or relative total radiant flux
- Absolute or relative total luminous flux
- Luminous efficacy
- Energy conversion efficiency
- CIE x-y color coordinates
- Correlated color temperature,
- And furthermore, the utility calculates the derating curve.

A detailed test report in tabulated format is also available, including real thermal resistance. For further details, please contact your local Mechanical Analysis office .

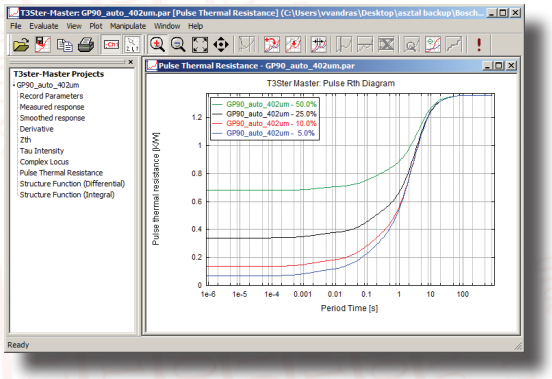




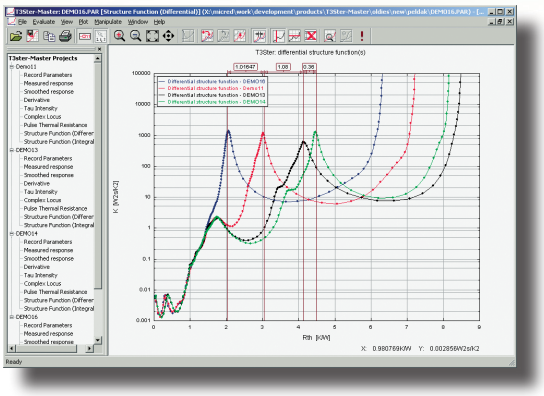
Links to CFD tools

THE T3Ster-MASTER PROGRAM: ADVANCED RESULTS EVALUATION

T3Ster-Master is an optional software tool (available on all types of Windows® operating systems) primarily aimed at post-processing measurement results obtained by the T3Ster equipment. Thanks to its import wizard, thermal transient curves from almost any source can also be post-processed with this tool: simulated thermal transient (and all the descriptive functions derived from it) can be easily compared with measured ones (and with the descriptive functions identified from the measured data).

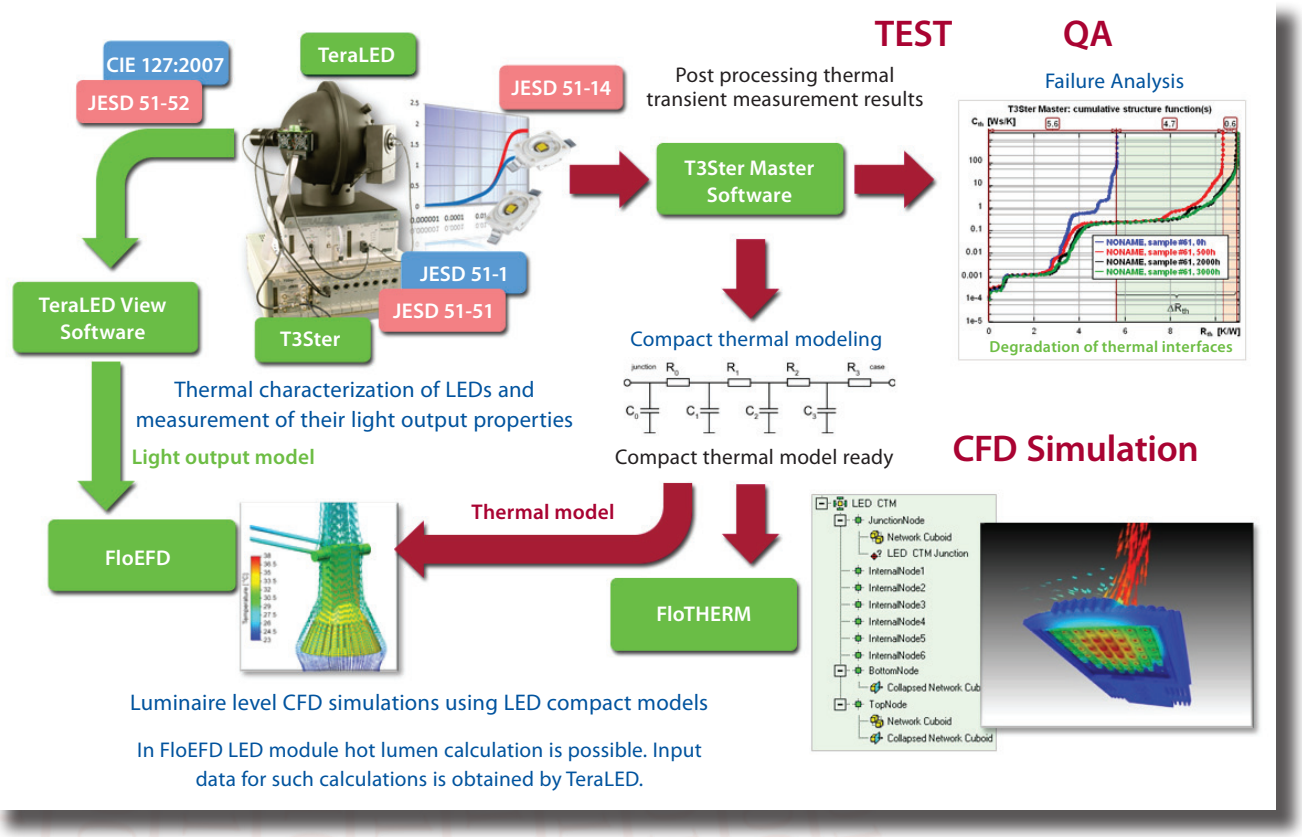


This way one can validate detailed simulation models with test results of packages. By comparing "measured" and "simulated" structure functions it is possible to identify where in the package the simulation model fails to match reality.



Results of multiple T3Ster measurement "projects" can be displayed in one single plot allowing one to quantify differences in structure functions e.g. failures in the heat-conduction path or identify junction-to-case thermal resistance according to the JEDEC JESD51-14 standard.

Besides advanced results presentation options, the latest version of T3Ster-Master provides dynamic compact models in the form of Cauer-ladders which can be used directly in FloTHERM.



DynTIM

DynTIM is a high precision test environment designed to measure the bulk thermal conductivity of thermal interface materials, in connection with T3Ster, our leading thermal transient testing solution. The system is mainly designed for the measurement of soft materials, such as thermal greases and compressible pads, however with some additional considerations, the test of adhesives and solid samples is also possible.

OVERVIEW OF OPERATION

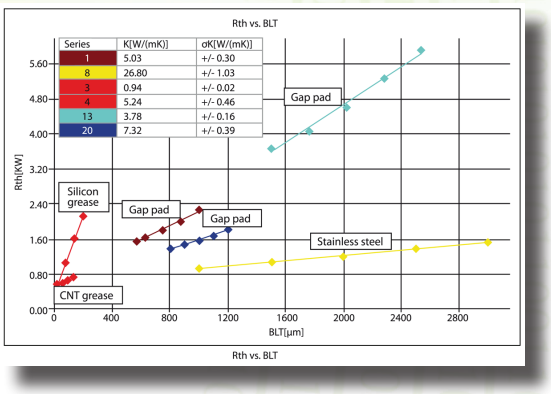
Using DynTIM the material to be tested is placed to a realistic thermal environment, between a real diode package and a nickel plated copper cold-plate. The system can set up the distance of the two surfaces with a resolution of one micrometer in an automated way. This way the system can accurately control the BLT (BondLine Thickness) of the material under test.

The thermal conductivity of samples is calculated based on the change of the thermal resistance of the TIM as a function of its thickness. This idea resembles the ASTM D5470 standard, however the measurement of the temperature is carried out at semiconductor diode in the top grip. This fine temperature measurement (0.01°C temperature resolution) and the calculation of the applied power based on accurate electrical parameters is responsible for the high repeatability of the testing solution.

DynTIM takes advantage of T3Ster's high temperature measurement accuracy, therefore it always requires one for its operation. The control of T3Ster is realized from DynTIM's own measurement control tool, in a simple and automated way.

The bottom grip's temperature is maintained constant using a liquid circulator thermostat. DynTIM software can control major brands. Supported third party thermostat models are the same as in the T3Ster measurement control tool and include models from JULABO®, Cole-Parmer®, Lauda®, Haake®, Hart Scientific® or Arroyo Instruments®

MEASUREMENT OF DIFFERENT MATERIAL TYPES



Measurement examples on all the 3 ASTM material types

DynTIM can handle the test of all three material types in the following way:

For Type I materials, such as greases and pastes, DynTIM realizes strict bond line thickness control, without maintaining any pressure on the sample, assuming that due to its low viscosity, the excess material leaves the space between the grips as the BLT decreases during the test.

For Type II materials, viscoelastic solids, such as gap pads and gap fillers, bond line thickness control with pressure limit is used, making sure that the material is kept at the target thickness. Beside BLT controlled operation, pressure controlled operation is also an option.

For Type III materials, non-compressible solids, pressure control is used. This way the measurement of different samples at different thicknesses is possible.

All these measurement modes are directly supported by DynTIM's measurement control software tool, all you need to do is to select the proper material type prior to the tests.

In addition, by testing a wide range of TIMs, users can choose a narrowed selection of the best performing materials. Use in combination with T3Ster thermal characterization hardware to test the materials in-situ and in their target environment, for the best possible design decision.

Thermal conductivity data measured by DynTIM can also be applied to add thermal properties to simulation models in our CFD solutions, such as FloTHERM or FloEFD.

Power Tester 1500A—Accelerated Testing and Failure Diagnosis of High-Power Semiconductors

Change of the junction temperature during one cycle as the function of cycles (using different control strategies).

The MicReD Power Tester 1500A supports automatic testing and diagnosis of possible failure causes of power components on the manufacturing floor. The energy demands of both consumer and industrial electronic systems are increasing, and power electronics component suppliers as well as OEMs are faced with the challenge of providing the highly reliable systems needed for aviation, electric vehicles, trains, power generation, and reusable energy production. The Power Tester 1500A can power the modules through tens of thousands, potentially millions, of cycles while simultaneously providing real-time failure-in-progress diagnosis.

REAL-TIME FAILURE DIAGNOSIS

The Mentor Graphics MicReD Power Tester 1500A is the only machine built for manufacturing as well as laboratory environments that does automated power cycling while producing analytical data for real-time failure-in-progress diagnosis. It's designed to perform lifetime testing to test the reliability of applications that use power electronic modules.

The Power Tester 1500A is the industrial implementation of the MicReD T3Ster® thermal measurement and characterization technology to enhance the capabilities from electronic parts, LEDs, and systems to high power electronics. The Power Tester 1500A is unique in that it provides fully automated power testing and cycling at the same time, on the same machine, without having to remove the device under test during the process. A simple touch-screen interface allows a technician to use it on the manufacturing floor and/or failure analysis engineer to use it in the lab.

Mentor Graphics®

The Power Tester 1500A senses current, voltage, and die temperature while it uses structure function analysis to record changes or failures in the package structure. The machine can be used to enhance and speed up package development, reliability testing, and batch checking of incoming parts before production.

While running power cycles, the real-time structure function analysis shows the failure in progress, the number of cycles, and the cause of the failure, eliminating the need for a lab post-mortem. Conducting lengthy cycling measurements on multiple samples to estimate the cycle count range corresponding to degradation is no longer necessary. Also there's no need for an excess number of thermal measurements in this range to ensure degradation is captured. The device under test only has to be mounted and connected once; cycling and configuration are defined at the start.

With the Power Tester 1500A, power electronics suppliers will be able to design a more reliable power electronics package and supply reliability specifications to their customers.

The testing and characterization data produced by the Power Tester 1500A can be used to calibrate and validate detailed models in FloTHERM and FloEFD thermal simulation software.

TECHNICAL HIGHLIGHTS

Field-Tested Technology: Based on the T3Ster advanced thermal testing hardware solution used in industries worldwide for accurate thermal characterization.

Test a Wide Range of Power Electronics: Includes metal-oxide semiconductor field-effect transistors (MOSFETs), insulated-gate bipolar transistors (IGBTs), and power diodes.

Conduct Continuous Power Cycling until Failure: Save time because the component doesn't need to be removed, taken for lab testing, then back to tester for more cycles.

User-Friendly Touch-Screen Interface: Can record a broad range of information during test, such as current, voltage, and die temperature sensing; and detailed structure function analysis to record changes in the package's thermal structure.

Apply Different Powering Strategies during Operation: Constant power on/off time, constant case temperature swing, constant junction temperature rise, and constant applied power.

"Real-Time" Structure Function Diagnostics: Obtain results such as failure in progress, number of cycles, and failure cause quickly.

No Lab Post-Mortem or Destructive Failure Analysis: Eliminate the need for x-ray, ultrasonic, or visual and costly destructive failure analysis.

Easy to Operate: Can be used by both specialists and production personnel.

Enhanced Safety Features: Over-temperature, smoke, and coolant leakage detection ensure safe operation of the system even if it is left standalone.

Concurrent Testing: Up to three samples (maximum 500 A each).

Remote Monitoring during Operation: Follow progress on a tablet or computer.

Maximum load current	3 x 500 A / 1 x 1,500 A
Pulse current duration	0.5 s onward
Automated k-factor calibration for thermal testing	As many as 3 samples in parallel
Automated failure detection based on	UCE, ΔT_j, T_{jmax}, R_{th} increase
Data recording	UCE before and after switching, ΔT_j, T_{jmax}, T_{jmin}, ΔP, $\Delta T_j/\Delta P$, structure functions, Igate
Gate current measurement range and resolution	200 pA –100 µA , 25 pA resolution
Voltage measurement time base	1 µs

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1500A Power Cycling Test Station – Hardware and Software specification

The 1500A Power Cycling Test Station has been designed for thermal transient testing and power cycling of IGBT, MOSFET and diode devices at elevated current levels. Listed below are the electric and mechanical specifications, the safety features and a functional description.

Electrical specifications

- Powering capabilities
  - 0 – 1500 A current driving capability, 500 mA resolution, accuracy 0.5%
    - 3-phase architecture, equivalent to 3 individual 500A sources
    - 50 ms switch-on time
    - 100 µs switch-off time
  - 0 – 8 V V_{CE} voltage
  - V_{GS} voltage 0 – 30 V, 0.1 V resolution, accuracy 0.5%
- Sensing capabilities
  - Measurement current: 3x ±1000mA/8 V, 0.5 mA resolution, accuracy 0.5%
  - 7 system temperature measurement locations
    - 1 PT 100 outlet temperature sensor/cold-plate, 0.1°C resolution, accuracy 0.5°C
    - 1 PT 100 temperature sensor/cold-plate to measure case-temperature, 0.1°C resolution, accuracy 0.5°C
    - 3 temperature sensor inputs to measure temperatures on the DUT package, either embedded NTC or thermocouple. Accuracy depends on sensor. Transient measurement capability
  - Gate current measurement: 200 pA -100 µA , 25 pA resolution

The equipment can test a single device up to 1500A or maximum three individual devices up to 3x500A each based on its three-phase architecture. The timing parameters of the individual tests in case of 3-phase mode must be the same for each phase, the system runs in synchronous mode.

- Measurement capabilites
  - 3 input channels for transient capturing
  - ±10V input range
  - Maximum 12 µV resolution
  - 1µs time resolution
  - Continuous sampling ensures the on-line monitoring of the DUT voltage and the gate current as a function of the cycle number and/or time
- External power requirements
  - Three-phase, 440V, 45A inlet
  - The presence of each phase is monitored by the equipment

Mechanical specifications

- Dimensions: (L x W x H, without the tower light): 1400mm x 900mm x 1300mm
- Weight: approx. 500kg uncrated, 540kg crated as shipped
- Two cold-plate (400x300 mm), one for calibration, one for measurement
  - For the calibration an external Julabo thermostat is required
  - For the measurement process-water is advised
  - The thermostat and the process-water can be connected externally, connectors on the back-side of the equipment
  - Fixtures enabling the quick and simple mechanical mounting of the sample on the DUT
  - The DUT size and location can be varied in a flexible way
- The measurement area is covered by a thermally insulated Lexan door to make sure that the long-term measurements can run uninterrupted
- The system has an embedded 15" touch-screen PC on a flexible and ergonomic mounting arm

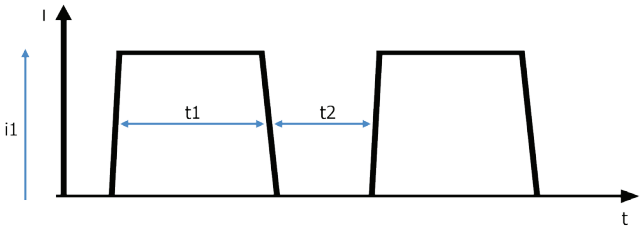
Safety specifications

- The system is equipped with a standard four-color tower light to indicate the status of the operation
- The measurement area is equipped with safety sensors/features which immediately shut off the high power output if activated:
  - Smoke alarm
  - Over temperature alarm
  - Cold-plate leakage sensor
  - Water flow sensor on the measurement cold-plate using process water
  - Manual stop button

- The high current output is only enabled if the Lexan door is closed and the measurement area is not accessible to personnel

Operation specifications

- Computer control
  - The control of the equipment is through dedicated device control and measurement evaluation software running on the built-in PC
  - The user interface is touch-screen based and user friendly
  - Select between engineer and operator modes
  - Earlier test results can be viewed and downloaded via USB or Ethernet interface
- Measurement modes
  - Rth measurement mode
    - Thermal transient measurement for junction temperature and Rth characterization following the JEDEC JESD 51-1 static test method
    - Structure functions can be generated based on the test results
    - Support of JEDEC JESD 51-14 dual interface method for RthJC measurements
  - Combined power cycling + Rth measurement mode
    - The system creates stress on the device using power cycles and performs Rth measurements periodically to monitor possible die-attach degradation or the evolution of other structural failures
    - The system monitors the evolution of the device voltage, gate current and the output of selected temperature sensors as a function of the cycle number and/or time
    - The frequency of the Rth measurement can be defined by the user and it can be automatically increased if the system detects gate current or device voltage increase
  - The system will support different power control strategies:



Current cycling vs. time

- Constant t_{on} and t_{off}, degradation has immediate impact on resulting temperature swing, no compensation
- Constant ΔT_C, adjusts the load current following fixed case temperature swing.
- Constant t_{on} and t_{off}, degradation has immediate impact on resulting temperature swing, no compensation with the possibility to adjust the water flow in the cold-plates during the cycling using electrically controlled valves
- Constant ΔT_J, by control of the load current to have a less constant severe strategy ensuring a larger number of possible cycles
- Constant ΔP, keeps the power level constant by adjusting the load current.

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