DIGITAL INDUSTRIES SOFTWARE

Using Simcenter to test the thermal performance of electronics

Performing nondestructive thermal characterization, reliability and quality testing from design to manufacturing

Solution benefits

- Achieve detailed thermal characterization
- Leverage a quick and easy-to-use method
- Achieve accurate thermal metrics
- Be ready for the future

In today's technological landscape, electronic components, designs and packages are becoming increasingly complex and compact. According to a study by the U.S. Air Force Avionics Integrity Program, over 50 percent of electronics failures are the result of high temperatures.[1] As a result, electronics manufacturers face challenges in developing more accurate and efficient thermal designs, conducting detailed thermal performance validations and gaining a better understanding of the thermal behavior and lifetime reliability of new designs and materials. However, accurately simulating the internal thermal structure and the behavior of new designs remains a complex task.

Addressing these challenges requires a combined test and simulation approach for designing electronics in a precise, detailed and time-efficient manner. Using Simcenter™ Micred™ hardware and software plays a vital role in measuring the thermal metrics and performance of electronic components under static and dynamic conditions. This information is crucial for creating accurate thermal simulation models at earlier stages of the design process.

1. Fortna, H.C., Avionics Integrity Issues Presented During NAECON 1984. U.S. Air Force Avionics Integrity Program. Technical report (1984).

SIEMENS

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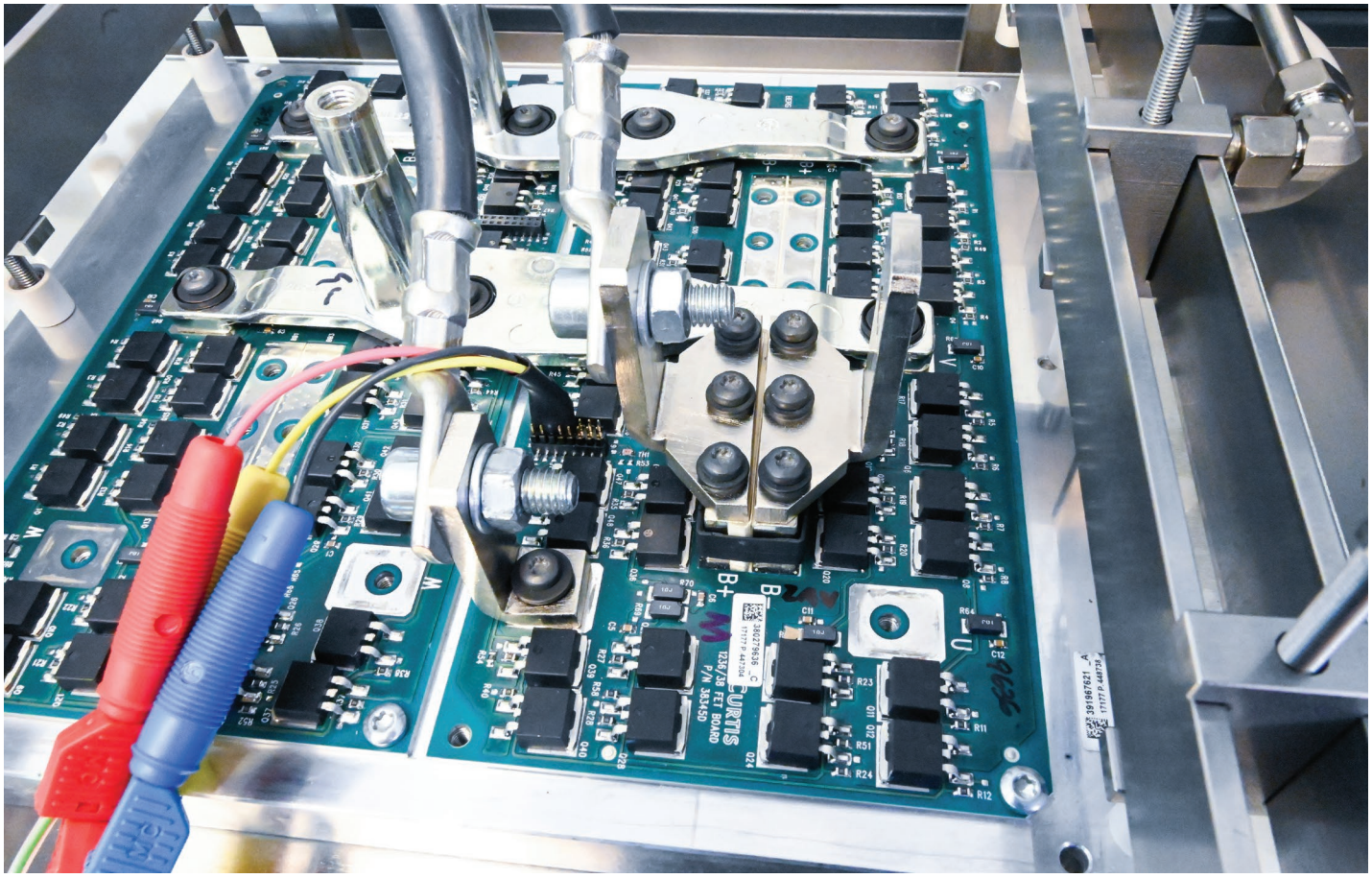
Using Simcenter to test the thermal performance of electronics

By gaining a detailed understanding of the heat flow path and internal mechanisms of electronic components, it is possible to study their lifetime, identify degradation and damage mechanisms, perform root cause analyses (RCA), conduct competitive benchmarking, optimize production processes and implement integrated end-of-line (EoL) testing systems for ensuring the thermal quality of final products. This results in faster design cycles, more high-performance and reliable electronics and reduced costs in terms of design, manufacturing and warranty.

>99%	78%	+30%
Accuracy achieved with automated model calibration	Time and cost reduction in designing ECUs	Heat dissipation capacity and lifetime increase on their power electronics IGBT modules

Some customer return-on-investment (ROI) statements.

Simcenter is part of the Siemens Xcelerator business platform of software, hardware and services.



Solution benefits

Detailed characterization of internal thermal structure

Traditional thermal testing methods, such as thermocouples or infrared imaging, provide surface temperature data only or are difficult to install without damaging the device under test (DUT). Other techniques, like x-ray imaging, may offer more detail but primarily focus on geometrical information. In contrast, Simcenter Micred solutions employ a nondestructive electrical test method that complies with the JEDEC 51 standard. This approach not only gives accurate junction temperatures but also characterizes the internal thermal structure, heat flow path, performance and behavior of electronic components and packages. It provides valuable insights that are unavailable using conventional testing methods.

A quick and easy-to-use testing method

Simcenter Micred solutions employ a thermal transient testing method. The implemented test method uses the device itself as a temperature sensor based on a calibrated temperature-sensitive parameter (TSP). By applying a power step to the DUT, it induces a thermal transient response. It measures the transient change of junction temperature in a highly accurate manner, and with one click, it generates thermal impedance profiles and structure functions.

This makes it an extremely quick and easy-to-apply testing method, even for more complex designs. Additionally, companies can use this technique for high-volume testing or integrate it into the production line for EoL quality testing of each component, leading to zero defect production.

Accurate thermal metrics

Using test result data from Simcenter Micred gives you accurate values for junction temperatures (junction-to-case (RthJC), junction-to-ambient (RthJA)), which can serve as input to the technical specification sheets of your product. You also get accurate information about the internal thermal structure and heat flow path inside your electronic design. You can use this data to feed tasks in the various lifecycle stages of your product: during the early design in combination with thermal simulation, predicting the lifetime and reliability, helping you prepare a new product introduction (NPI), monitoring the final manufacturing process or determining the root cause of thermal damage.

Testing for future designs and materials

Industry trends, such as vehicle electrification, renewable energies, the internet of things (IoT) and artificial intelligence (AI), push electronics manufacturers to explore new designs and alternative materials to achieve more compact, energy-efficient and performant designs. Increasing power density and current levels of devices, as well as the higher density of components in one printed circuit board (PCB), necessitate the need for thermal transient testing and optimization of components. Leveraging Simcenter Micred solutions enables you to research, evaluate and design the electronics of the future with fewer prototypes in a shorter time. Testing can be done on power diodes, transistors and digital integrated circuits (ICs), power metal-oxide-semiconductor field-effect transistors (MOSFETs) and insulated-gate bipolar transistors (IGBTs). Simcenter Micred solutions offer you the flexibility to test and evaluate the thermal performance of devices based on these materials, such as silicon-carbide (SiC) MOSFETs and gallium nitride (GaN) high electron mobility transistors (HEMTs).

Testing can be done on individual components but also on assembled boards or packaged in the final product.

Industry applications

Automotive and transportation

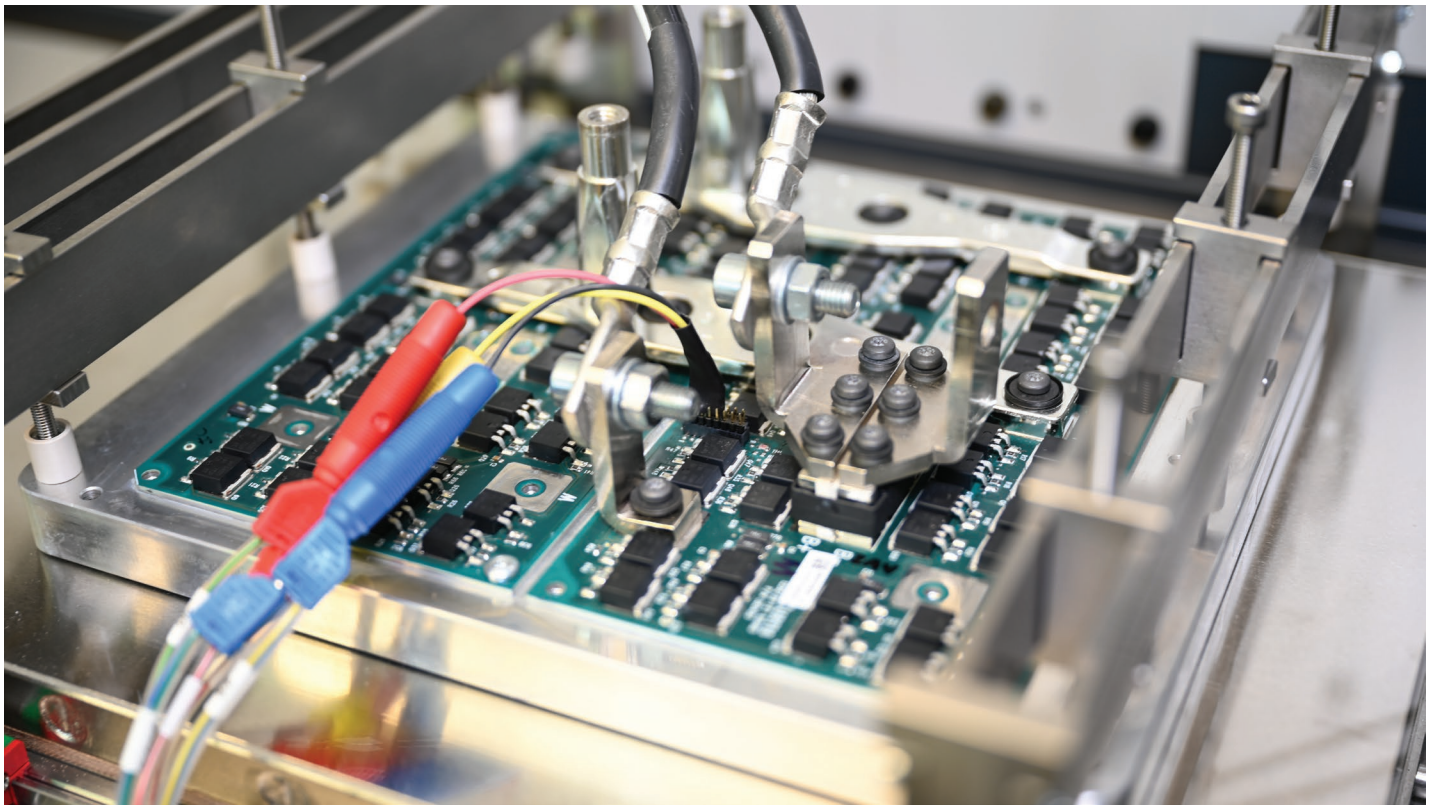
Transitioning to hybrid electric vehicles (HEVs) comes with stricter environmental regulations, increased competition and growing consumer demand. This puts higher demands on the onboard electronics, knowing that a modern car contains about 1,000 electronic components. Among these, power electronics play a crucial role in the reliability of the vehicle due to their high switching rate. For example, the powertrain inverter, battery charging and conversion systems, steering servo, engine cooling, starting motor and regenerative braking all require a deep understanding of their thermal behavior and lifetime. This understanding becomes even more critical as the need to reduce weight and cost pushes electronics development for higher power density, increased cooling requirements, the adoption of new designs like MOSFETs or IGBTs and new materials such as SiC and GaN.

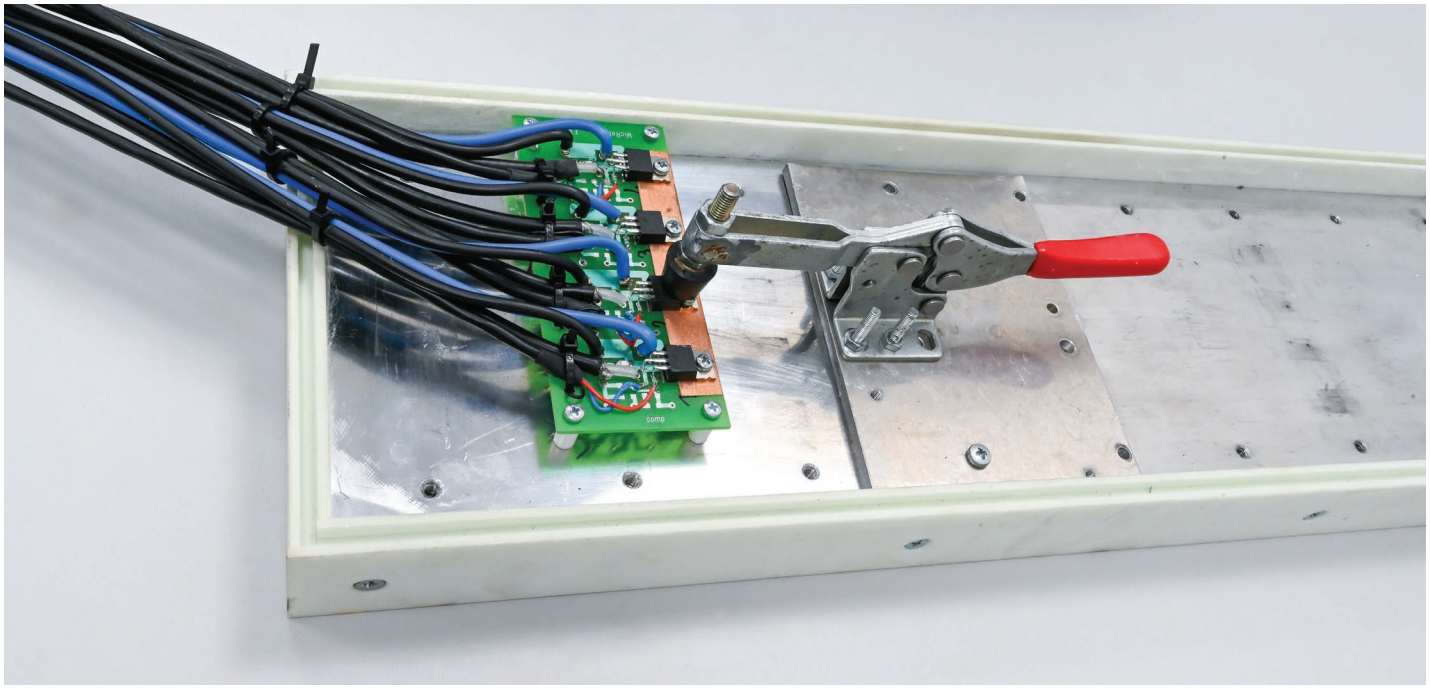
Other transportation industries that are transitioning to electric propulsion face similar challenges in terms of thermal management and reliability. The railway traction industry, electric scooters, hybrid marine propulsion systems and electric vertical take-off and landing (eVTOL) aircraft require efficient thermal design and reliable performance. Additionally, transport vehicles, such as military trucks, heavily rely on their communication systems, like radar radio. Similarly, airplanes and helicopters depend on the correct functioning of the onboard avionics. These systems play a vital role in navigation, communication and overall aircraft control.

Achieving a more refined design for these components can lower costs while maintaining full-lifetime reliability. By using Simcenter Micred products, you can build more accurate thermal simulation models in the early design phase, conduct power cycling tests that comply with the European Center for Power Electronics (ECPE) Automotive Qualification Guideline (AQG) 324 for reliability, monitor degradation mechanisms or perform EoL testing to guarantee delivering components with zero defects to your customers.

Electronics and semiconductors

When it comes to electronic components and IC packages, new technologies such as 5G and AI have increased the demand for higher, multicore computational power, reliable communication and miniaturization. This also creates new challenges and higher demands for thermal design for cooling, high performance and reliability. This requires new designs that are





fundamentally different or make use of new materials (like SiC and GaN), and your testing methods will need to adapt to them. Using Simcenter Micred can help in creating more accurate simulation models for cooling efficiency. With test results from Simcenter Micred, you can obtain accurate thermal metrics that go into your specification sheet, along with the ability to measure the lifetime and reliability of your components. In this mass production market, you can use Simcenter Micred to validate and optimize the manufacturing process and parameters. Furthermore, it serves as a high-volume or fully automated EoL testing system for failure-free production and binning into various quality levels.

Energy and utilities

The trend towards sustainable energy production and conversion pushes for reliable systems that contain critical electronic components. This includes multimegawatt wind turbines, where reliability is key, down to domestic solar panels with local battery storage, where price and safety are important. From your heat pump or heating, ventilation and air conditioning (HVAC) unit to public charging stations for electrical cars, this energy needs to be produced, converted, transported and stored in an efficient and reliable way. Power electronics play a vital role in controlling and managing these processes, demanding reliability, efficiency and cost-effectiveness.

Academics

To keep up with the growing demands and to understand the capabilities of new designs and materials requires a lot of research. The combined test and simulation approach helps you more accurately characterize the design of electronic components and packages, their interconnects and cooling requirements. This is especially true when dealing with new designs and materials. Building a realistic digital twin is only possible when it is calibrated and correlated with accurate thermal testing data, coming from Simcenter Micred products.

Other applications

Electronics are used in a wide range of consumer products. From laptops, battery chargers and phones to washing machines, microwave ovens, televisions, the motor unit in domestic air conditioning units and the medical devices in hospitals, each of those contains electronic components and systems that you need to optimize during the design, reliability testing and manufacturing phases of your product using Simcenter Micred solutions.

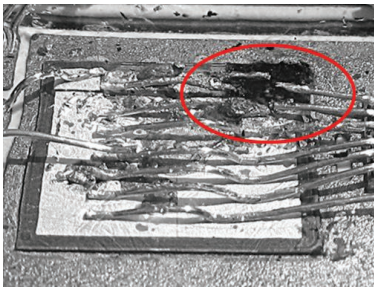
Simcenter thermal testing capabilities

Detect damage Evaluate design alternatives | **Generate JEDEC compliant thermal metrics** | **Guarantee thermal reliability via power cycling** | **Assure quality with end-of-line testing** | **Build accurate thermal simulation models**

Thermal testing is crucial in every step of the product design cycle, from the initial simulation to the first prototype, reliability testing and lifetime prediction up to the manufacturing phase.

Detect damage and evaluate design alternatives

An electronic component or IC package consists of various elements, from the chip to the die attach, the base, thermal interface material (TIM), the cold plate and ambient environment. In each of those, there can be imperfections from manufacturing, or degradation and damage can occur during the operational lifetime of the electronics. The imperfections then lead to device failure, leading to warranty costs and a loss of customer goodwill. Thus, it is critical to discover where imperfections exist in your design or which design alternatives lead to better thermal performance.



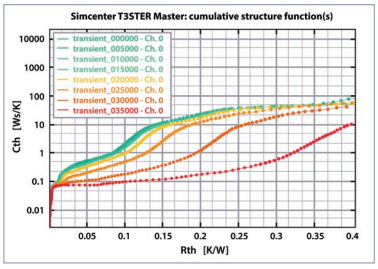
Generate JEDEC-compliant thermal metrics

Obtaining accurate values for junction temperature and RthJC, junction-to-pin (RthJP) or RthJA is difficult based on thermal simulation models only. The Simcenter Micred T3STER™ hardware uses an electrical testing method compliant with the JEDEC 51 standard.

THERMAL METRIC	
R_{thJA}	Junction-to-ambient thermal resistance
$R_{thJC\ (top)}$	Junction-to-case (top) thermal resistance
R_{thJB}	Junction-to-board thermal resistance
Ψ_{JT}	Junction-to-top characterization parameter
Ψ_{JB}	Junction-to-board characterization parameter

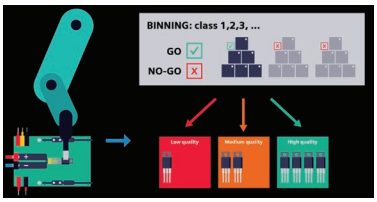
Guarantee thermal reliability using active power cycling

To experimentally verify the predicted lifetime of the electronics, manufacturers can perform active power cycling tests. Power electronics, experiencing frequent switching and temperature transients in a short period of time, are more prone to failure and reliability issues.



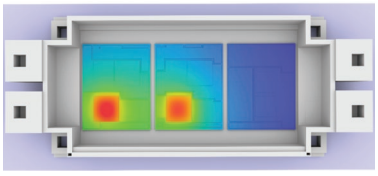
Assure quality with automated thermal testing

Once the electronics go into mass production, you need to make sure that what is coming off your production line meets the requirements. Automated thermal testing can help you find production defects before your customers, and it can guarantee a near zero percent defect production quality. EoL testing can help you detect assembly errors and change production parameters or materials so your team can make go/no-go decisions or sort the produced samples into quality ranges or bins.



Build accurate thermal simulation models

Thermal simulation models can evaluate a lot of design alternatives quickly without the need for building prototypes, but they are only helpful if the results accurately predict what is happening in the real world. Calibrating the thermal models based on thermal measurement data boosts the accuracy of your thermal simulation results.



Detect damage and evaluate design alternatives

An electronic component or IC package consists of various elements, from the chip to the die attach, the base, TIM, the cold plate and the ambient environment. In each of those, there can be imperfections from manufacturing, or degradation and damage can occur during the operational lifetime of the electronics. The imperfections then lead to device failure, leading to warranty costs and a loss of customer goodwill. Thus, it is critical to discover where imperfections exist in your design or which design alternatives lead to better thermal performance.

Using Simcenter Micred T3STER helps you investigate those imperfections, damage locations and weak spots. Additionally, with Simcenter Micred T3STER, you can identify and visualize the thermal resistance and capacitance steps corresponding to each of the elements in the heat flow path, from junction to ambient. This helps you find the weak spots where you can improve the design, such as by changing the die attach material or thickness. It can also help you identify potential thermal issues, such as thermal path degradation or changes in the thermal resistance of specific components. Leveraging Simcenter Micred T3STER gives an accurate "fingerprint" of the internal structure and thermal behavior, which is especially insightful when using new designs or materials.

Challenges

- Detect small imperfections and their location
- Identify weak spots in the design
- Characterize new designs and materials

Solutions

- Use the structure function to show the complete heat flow path and internal thermal structure

Results

- Described the link between elements and their thermal behavior
- Identified initial imperfections and weak spots
- Quantified thermal degradation
- Achieved A to B comparison
- Reached a detailed understanding of new materials and designs

Detect damage and evaluate design alternatives

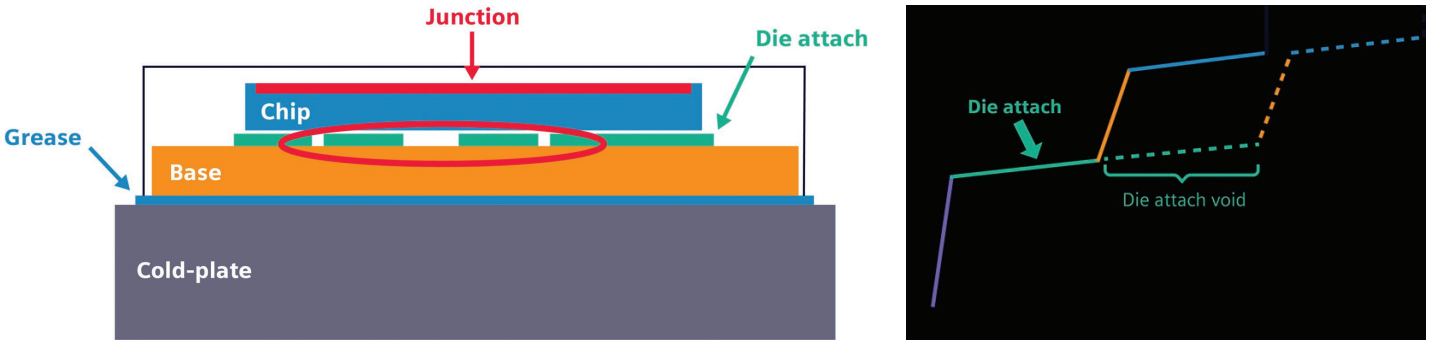
Thermal characterization of packaged semiconductor devices' internal structure with advanced, nondestructive testing hardware by employing highly accurate and repeatable thermal transient test technology along with structure function analysis.

Key features

- Nondestructive, repeatable and reproducible testing allows samples to remain operational after testing
- Easy setup and measurement process, with software guidance for simple learning and use
- Provides valuable diagnostic tools, converting temperature/time traces into structure functions for detailed thermal characterization
- Enables in-situ tests for various thermal environments without disturbing thermal boundary conditions
- Supports a wide range of semiconductor types, including diodes, MOSFETs, IGBTs and digital VLSI ICs

Simcenter Micred T3STER SI for characterizing semiconductor packages
Product
Simcenter Micred T3STER SI hardware
Simcenter Micred T3STER SI control software
Simcenter Micred T3STER master postprocessing tool

Options
Product
Simcenter Micred T3STER boosters



Internal damage in the die attach shows up as a shift in the structure function.

Generate JEDEC-compliant thermal metrics

Obtaining accurate values for junction temperature and RthJC, RthJP or RthJA is difficult based on thermal simulation models only. The Simcenter Micred T3STER uses an electrical testing method compliant with the JEDEC 51 standard. Although infrared or thermocouple-based testing methods can be inaccurate or difficult to install and only measure the surface temperature, using Simcenter Micred T3STER is highly accurate within a 1/100th of a degree accuracy while providing full insight into the internal structure and heat flow path from junction to ambient. In addition to accuracy, Simcenter Micred T3STER only requires a single test. With a quick, easy and repeatable setup method, you can speed up your electronics testing processes.

Challenges

- Get accurate thermal metrics
- Comply with standards
- Conduct nondestructive testing

Solutions

- Use an electrical testing method
- Comply with JEDEC 51
- Use existing electrical connections

Results

- Enabled quick and easy setup
- Created a highly repeatable process
- Achieved highly accurate results
- Found additional insights

Generate JEDEC-compliant thermal metrics

JEDED compliant characterization of junction temperatures for thermal metrics specification sheet.

Key features

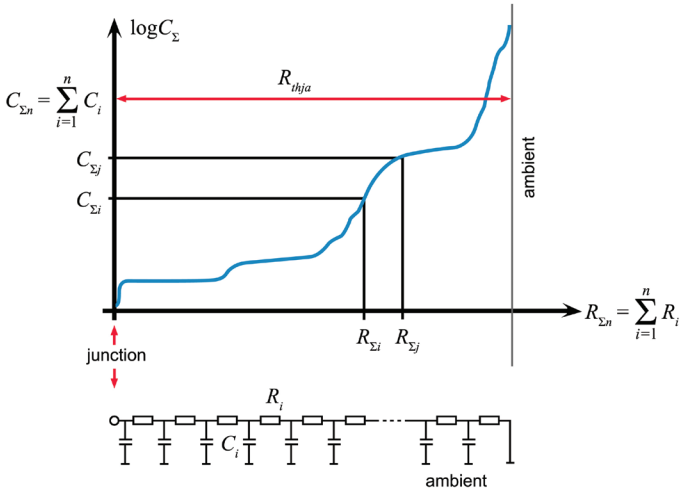
- Compliant with JEDEC JESD 51-1 for nondestructive, repeatable and reproducible testing, allowing samples to remain operational after testing
- Dedicated software to process, visualize and analyze measurement results in full detail
- High accuracy and resolution for measuring semiconductor junction temperatures over temperature and time scales
- Easy setup and measurement process, with software guidance for simple learning and use.
- Enables in-situ tests in various thermal environments without disturbing thermal boundary conditions
- Supporting a wide range of semiconductor types, including diodes, MOSFETs, IGBTs, digital VLSI ICs and SiC and GaN devices

Base system for measuring thermal metrics
Product
Simcenter Micred T3STER SI hardware
Simcenter Micred T3STER SI control software
Simcenter Micred T3STER master post processing tool

Options
Product
Simcenter Micred T3STER boosters
Simcenter Micred cooling plate
Simcenter Micred T3STER dual cold plate
Simcenter Micred T3STER still air environment

THERMAL METRIC	
$R_{\theta JA}$	Junction-to-ambient thermal resistance
$R_{\theta JC\ (top)}$	Junction-to-case (top) thermal resistance
$R_{\theta JB}$	Junction-to-board thermal resistance
Ψ_{JT}	Junction-to-top characterization parameter
Ψ_{JB}	Junction-to-board characterization parameter

An example of a thermal metric in the technical specification sheet.



Structure function showing thermal capacity versus thermal resistance.

Guarantee thermal reliability using active power cycling

To experimentally verify the predicted lifetime of the electronics, manufacturers can perform active power cycling tests. Power electronics, experiencing frequent switching and temperature transients in a short period of time, are more prone to failure and reliability issues.

Traditionally, components are tested until failure and then brought into the laboratory to investigate the reason and location of the failure using, for example, visual or x-ray techniques. However, these methods are either destructive or they provide inaccurate and difficult to interpret images. Additionally, you cannot always separate the cause and effect of the failure mechanisms and understand how they interact with each other.

The Simcenter Micred Power Tester hardware and software combine active power cycling with monitoring of thermal and electrical degradation. This process is fully automated, eliminating the need to go back and forth to the laboratory. It clearly separates the damage mechanisms (delamination, tear off, etc.) and pinpoints which interfaces (die attach, solder joints, etc.) are the weak spots that need to be redesigned. It also allows you to design finer and save material costs in certain areas while guaranteeing the expected lifetime of the design.

Challenges

- Identify the primary cause of failure and weak spots in the design
- Understand the cause and effect of various failure mechanisms

Solutions

- Combine the power cycling test with thermal degradation monitoring

Results

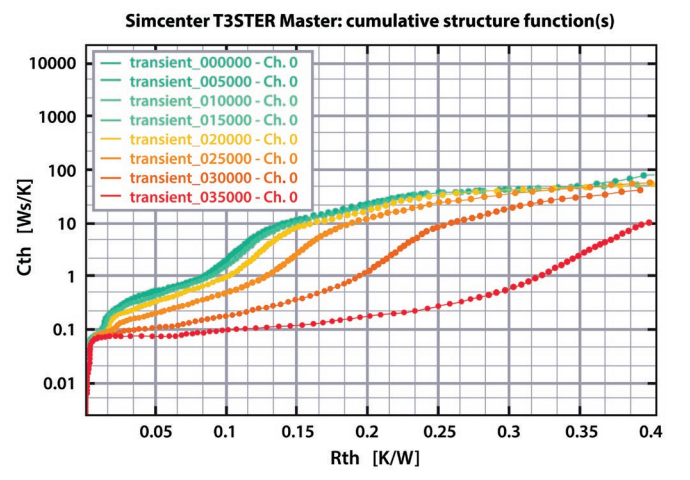
- Achieved faster testing
- Increased insights
- Achieved a real-time failure diagnosis

Guarantee thermal reliability using active power cycling

Assess power semiconductor thermal reliability and lifetime using test hardware that combines active power cycling with thermal structure degradation monitoring.

Key features

- Supports various industry and application powering requirements
- Test up to 12 units in parallel
- Perform short- and long-duration tests (PCSEC and PCMIN), which can run over weeks or months
- A wide range of power cycling strategies (recommended in AQG-324)
- Operator user interface (UI) with recommended workflow and remote monitoring
- Combined with understanding damage mechanism cause and effect
- Requires minimum user interaction
- Built-in safety features and high reliability

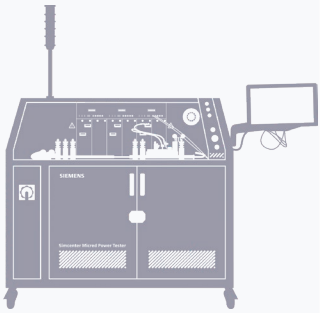


Evolution of the structure function showing degradation during the active power cycling.

Base system for active power cycling reliability tests

Solution with integrated measurement cavity and cold plates

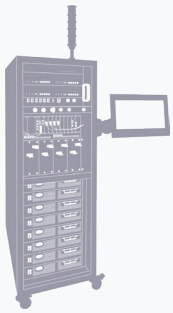
- Built-in cold plates and measurement chamber
- Available options up to 3600A



Product
Simcenter Micred Power Tester hardware
Simcenter Micred Power Tester control software
Simcenter Micred T3STER master postprocessing tool

Solution without integrated measurement cavity and cold plates

- For integration with measurement environments
- Available options up to 2400A



Product
Simcenter Micred Power Tester hardware
Simcenter Micred Power Tester control software
Simcenter Micred T3STER master postprocessing tool

Options

Product
Simcenter Micred cooling plate

Assure quality with automated thermal testing

Once the electronics go into mass production, you need to make sure that what is coming off your production line meets the requirements. High throughput automatic thermal testing or EoL testing can help you find production defects before your customers, and it can guarantee a near-zero percent defect production quality. We offer high flexibility and customization options of a Quality Tester that fits the customer need, whether it is a pushbutton T3STER operated by personnel or patch testing automized by a robotic handler or even EoL that is fully atomized and integrated to the production line. EoL testing can help you detect assembly errors and alarm on changing production parameters or materials so your team can make go/no-go decisions or sort the produced samples into quality ranges or bins. Given high production rates, EoL testing must be quick, fully automated and integrated with the production line.

The Simcenter Micred Quality Tester hardware and software picks and places every produced item from the production line, applies a short power pulse to verify the junction-to-case thermal resistance and qualifies each sample into a predefined set of quality bins. You can integrate the Simcenter Micred Quality Tester on an existing production line, or it can be useful for NPI when you are defining and optimizing the manufacturing parameters between the prototype and mass production phase.

Using Simcenter Micred Quality Tester enables packaged power semiconductor manufacturers to elevate their quality assurance practices, advancing from basic quality to consistent quality. The Simcenter Micred Quality Tester software is customizable to support various communication protocols, including SECS/GEM, OPC UA and Modbus.

Challenges

- Guarantee zero-defect production
- Test all produced samples at high production rates
- Detect deviations in material quality and production parameters

Solutions

- Test thermal quality quickly
- Integrate with the production line via a robot handler

Results

- Tested 100 percent of the produced samples quickly and accurately
- Automized go/no-go or quality binning
- Detected changes in production parameters

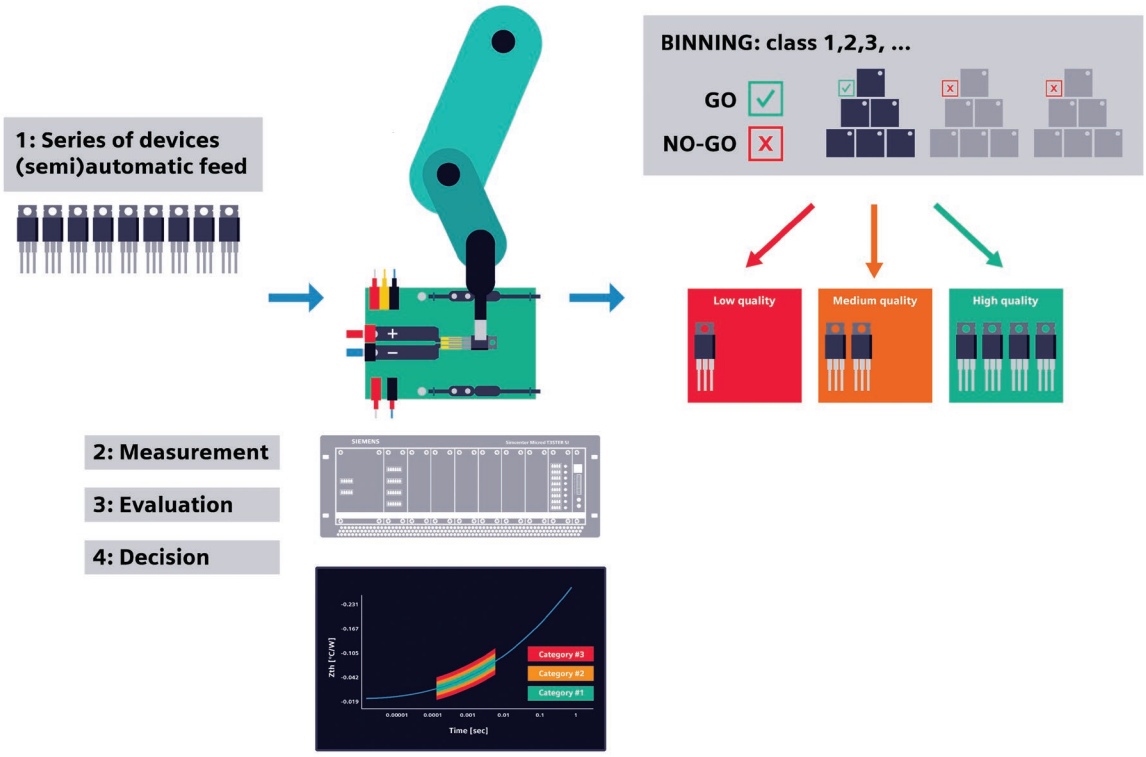
Assure quality with automated thermal testing

Enhance semiconductor package thermal quality assurance with a test solution combining precise thermal impedance measurement with high-throughput automatic binning.

Base system for end of line thermal quality testing
Simcenter Micred Quality Tester hardware
Simcenter Micred Quality Tester control software

Key features

- High throughput rate
- Quality boundary settings based on simulation models
- Automatic accept/reject or quality binning
- Integrates with the test bench or handler



Build accurate thermal simulation models

Thermal simulation models can evaluate a lot of design alternatives quickly without the need for building prototypes, but they are only helpful if the results accurately predict what is happening in the real world. Improving the accuracy of the thermal models based on thermal measurement data boosts the accuracy of your thermal simulation results.

Simcenter includes thermal testing and simulation tools to help you correlate your electronics' thermal models more easily. Using tools like Simcenter FLOEFD™ software and Simcenter Flotherm™ software provides automatic calibration procedures based on the data measured with Simcenter Micred. With a unique combination of Simcenter tools, you can find the best design of electronic components and packages accurately and efficiently.

Challenges

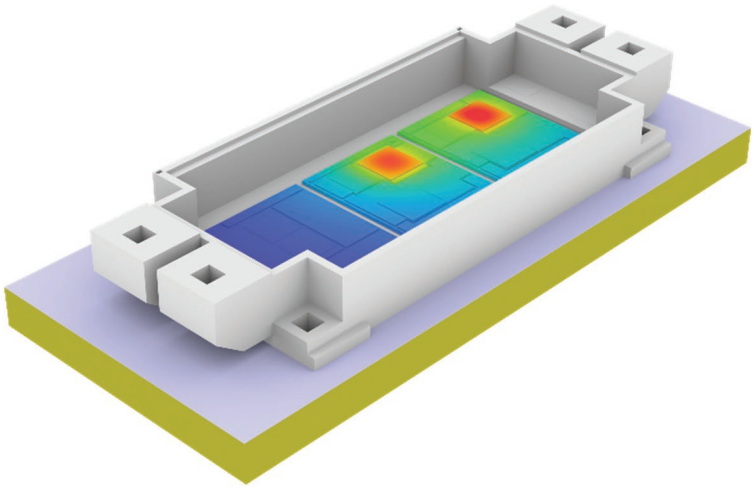
- Optimize material designs and geometry thickness
- Optimize the internal heat flow and cooling correctly
- Decide which properties to use for new materials

Solutions

- Combine thermal testing and simulation tools for higher accuracy
- Calibrate simulation models in Simcenter Flotherm and Simcenter FLOEFD automatically

Results

- Achieved over 99 percent accuracy of temperatures in space and time, creating a true digital twin
- Validated the thermal model for any operating point
- Validated thermal model for static and time transient conditions
- Achieved accurate thermal model behavior for every component in the design
- Enabled boundary condition independent reduced order model (BCI-ROM) sharing of models safeguarding intellectual property (IP)
- Maximized the computational fluid dynamics (CFD) simulation models' accuracy



Build accurate thermal simulation models

Facilitates creating a true digital twin, enhancing the simulation accuracy of Simcenter Flotherm and Simcenter FLOEFD using calibrated models based on Simcenter Micred T3STER measurements.

Key features

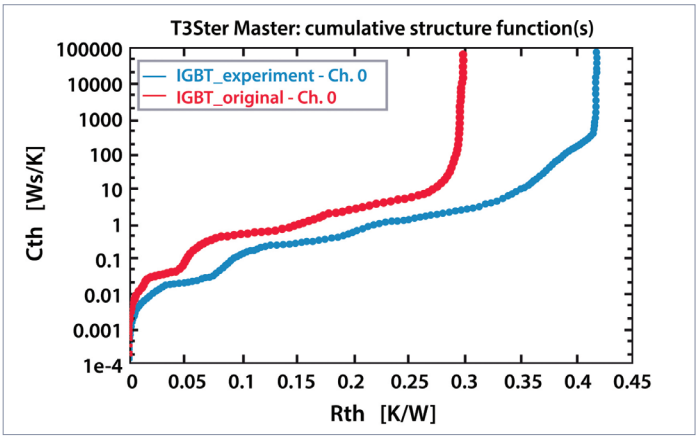
- Generates detailed thermal resistance-thermal capacity R-C network models for accurate 1D thermal behavior analysis and 3D CFD simulation integration
- Supports a wide range of semiconductor types and materials, including diodes, MOSFETs, IGBTs, digital very large-scale integration (VLSI) ICs and SiC and GaN devices
- Easily import structure functions into Simcenter FLOEFD and Simcenter Flotherm
- Automates design exploration to find the optimal parameters, making the model match the thermal testing structure function results
- Creates BCI-ROMs for steady-state and transient applications, supporting multiple dies and cores and hiding the IP

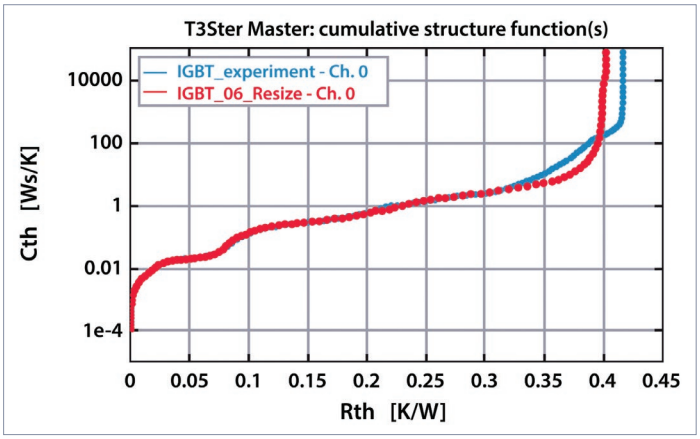
Simcenter Micred T3STER SI for accurate thermal simulation models
Product
Simcenter Micred T3STER SI
Simcenter Micred T3STER SI control software
Simcenter Micred T3STER master postprocessing tool

Options
Product
Simcenter Micred T3STER boosters

Simcenter Flotherm for thermal simulation models
Product name/description
Simcenter Flotherm parallel application software
Simcenter T3STER auto calibration option

Simcenter FLOEFD for thermal simulation models
Product name/description
Simcenter FLOEFD standalone application software
Simcenter FLOEFD electronics option





Automatic calibration: non-calibrated (left) and calibrated (right).

Siemens Digital Industries Software

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