TESTING HIGH POWER SEMICONDUCTOR DEVICES FROM INCEPTION TO MARKET

Methods for Efficient, Flexible Test and Characterization Throughout the Life Cycle of a Power Semi Device
Introduction

This e-guide examines the life cycle of a power semiconductor device and the tremendous variety of test and characterization activities and measurement challenges faced by the engineers involved in each stage throughout the cycle. From the early stages of designing a new power device to the point where it’s ready for market. Keithley’s flexible set of high power characterization tools are ideal for testing across the entire life cycle of a power device.

- For basic curve tracing measurements, perhaps a single source measure unit (SMU) instrument with Android-based curve tracer app is sufficient.
- When more meticulous curve tracing is required, a SMU instrument with semiconductor I-V characterization software may be the solution.
- For detailed on-state, off-state, or capacitance-voltage characterization, a full parametric curve tracer (PCT) allows both easy data acquisition and detailed parameter extraction.
- The flexible instrumentation used for curve tracing can also be configured in a racked system for simple functional test, process monitoring, or other higher volume characterization.
Evaluating Existing Devices and Designs for New Application Requirements

Applications engineers work with customers who are constantly stressing, testing, or stretching a design to maximize efficiency. These customers need detail beyond what is noted in the device specification. Requirements are continually changing, so what needs to be measured can vary on a daily basis. How can measurements be made quickly and easily without time being wasted to relearn software or instrumentation?

The IVy Android App works with Series 2600B SourceMeter® SMU Instruments to perform I-V characterization. Pinch and zoom for deeper insight into device performance.
Keithley offers a wide range of test capabilities, including pulse, DC, and C-V. Our ACS Basic Software uses device-specific – not instrument-specific – vocabulary to simplify measurements. It also simplifies the interaction between multiple source measurement unit (SMU) instruments, so users can focus on the device rather than the instrumentation. The IVy Android App works with Series 2600B SourceMeter® SMU Instruments to perform I-V characterization, including two- and three-terminal device testing and trend monitoring, and enables interactive analysis and insight into your device without programming! Or, use the Model 2450 Interactive SourceMeter SMU Instruments with KickStart I-V Characterization Software to perform current versus voltage (I-V) testing on a variety of materials, two terminal and multi-terminal semiconductor devices, solar cells, embedded systems, and much more.
Designing New Devices to Meet Evolving Needs

To effectively design devices to meet their customer’s latest requirements, power device design engineers and process engineers must understand how to tweak the process to produce the desired device performance. There must be confidence that the device models are fairly accurate, and changing a particular process step must produce the necessary change in the device measurement parameter. Therefore, the device engineer must perform preliminary verification of key device parameters.

With its trace mode, ACS Basic Edition Software allows quick verification of key device parameters, including family of curves, bias voltage, etc. In addition to being intuitive, it’s designed from the device perspective and includes scores of device libraries and a built-in formulator to quickly relate measurement to device parameters. Parametric Curve Tracer (PCT) Configurations and the Model 8020 Probe Station Interface simplify a wide range of tests that must be performed on-wafer for DC, CV, and pulsed test.

Trace Mode supports interactive testing of a device.
Characterizing Full Performance of New Device Design

A characterization engineer provides the necessary measurement expertise and understanding of how measurement anomalies can impact non-targeted areas of device performance. It’s imperative to get results fast to enable multiple iterations with device or process engineers and quickly convert measurements to device parameters.

For on-wafer characterization, the Model 8020 High Power Interface Panel minimizes connection changes between major measurement types. I-V and C-V measurements can be made through bias tees without connection changes. ACS Basic Edition Software allows users to quickly calculate desired parameters.
Preparing the Device for Production

To properly prepare a device for production, the production test engineers must prove if the device can be produced reliably. Measurements must be gathered for statistical setting of device specifications, and test times must be optimized to meet required production throughput.

Multi-functional instruments offer the best way to obtain measurements quickly with minimal connection changes and switching.

Source measure unit (SMU) instruments are multi-functional instruments that are proven for use in semiconductor applications. SMU instruments with Test Script Processor (TSP®) technology are primed for throughput because of their tight synchronization, built-in processors for complex operations, and decision-making performed within the instrument, thus minimizing communication times. These SMUs instruments are used in PCT configurations for interactive testing and also in S500 Parametric Test Systems for automated production testing. Automated Characterization Suite (ACS) Software combines advanced semiconductor test capabilities along with prober control, data reporting, and statistics.

ACS maps devices and tests to sites and subsites, eliminating the need to duplicate each test for each subsite and reducing test development time.

Maximize Speed and Throughput for Semiconductor Measurements Using Source Measure Unit (SMU) Instruments
Meeting Reliability Standards for Commercial Use

To conclude that a device meets reliability standards for commercial use, reliability test engineers have several responsibilities:

- Determining if a device will survive environmental stresses and continue to meet specifications
- Answering customer questions about device lifetime (MTBF, MTTF)
- Providing key insight into device fit for certain high reliability applications (mil/aero, automotive, etc.)

Creating statistically relevant results requires sufficient sample sizes of the test devices. The nature of stress-measure cycling over many devices necessitates multi-channel parallel test with automated data evaluation.
Methods for Efficient, Flexible Test and Characterization Throughout the Entire Life Cycle of a Power Semi Device

Optimizing Reliability Testing of Power Semiconductor Devices and Modules with Keithley SMU Instruments and Switch Systems

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Figure 1. Typical breakdown voltage measurement of a high voltage diode. In qualifying breakdown voltage, measurements are typically performed on high voltage diodes with appropriately-rated accessories that the test system designer has chosen. The Series 2290 Power Supply is the ideal platform for performing this test, as it includes a Series 2290 High Voltage Power Supply. Note that the 2290 is a unipolar supply, while the Series 2600B System is a bipolar power supply that can not be used for this purpose. Figure 2. Keithley Series 3700A and 707B Series Switch Systems.

Learn More from these Application Resources

Breakdown and Leakage Current Measurements on High Voltage Semiconductor Devices

Vs Ramp and HTRB Reliability Testing of High Power Semiconductor Devices with Automated Characterization Suite (ACS) Software

In addition, since WBG devices exhibit failure mechanisms that are different from those of silicon (Si) for power device applications, enabling some big challenges associated with designing and characterizing power devices based on these materials to withstand high voltages and greater current density, and faster switching [1]. These emerging devices, as well as process monitoring and reliability requirements.

Typical reliability tests involve stressing a batch or batches of devices. In a VDS ramp test, as the drain-source voltage is stepped from a low voltage to a voltage that's higher than the rated operation, the devices undergo both electrical and thermal stress: degradation effects in the field depletion structures at the device point in the system is closed to ensure that operators cannot de-grade device reliability if it is not dissipated efficiently [1].

With integrated decision making, Keithley also provides a wide range of power supply and SMU instrument solutions to permit simultaneous power cycling with integrated decision making. The models 2290-5 and 2290 Power Supplies are unipolar supplies and therefore less mature than silicon technology. This creates some big challenges associated with designing and characterizing power devices based on these materials to withstand high voltages and greater current density, and faster switching [1]. These emerging devices, as well as process monitoring and reliability requirements.

For example, opening the lid of the test fixture should open the switch/relay that disengages the interlock of the Series 2290 Power Supply. Note that the 2290 is a unipolar supply, while the Series 2600B System is a bipolar power supply that can not be used for this purpose.

The leakage current measurements in a typical power conversion application, the semiconductor device is used as a switch. Leakage current measurements indicate how closely the semiconductor performs to an ideal device. In other words, leakage current measurements reflect the extent to which the semiconductor's performance is ideal. In a typical power conversion application, the semiconductor device is used as a switch. Leakage current measurements indicate how closely the semiconductor performs to an ideal device. In other words, leakage current measurements reflect the extent to which the semiconductor's performance is ideal. The models 2290-5 and 2290 Power Supplies are unipolar supplies and therefore less mature than silicon technology. This creates some big challenges associated with designing and characterizing power devices based on these materials to withstand high voltages and greater current density, and faster switching [1].

Figure 1. Automated Characterization Suite (ACS) graphical user interface.

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Reliability tests typically involve high voltages, long test times, and often multiple devices under test (wafer level testing). As a result, well-designed test systems and measurement plans are essential to avoid breaking devices, damaging equipment, and degrade device reliability if it is not dissipated efficiently [1].

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Optimizing Reliability Testing

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Implementing the Device in Actual Designs

Once a device is validated, it’s ready for commercial use. Those who purchase devices must verify that the device is within tolerance for a particular application to ensure that the expected power efficiency gains will be achieved in the end product. As the device matures and becomes available from multiple suppliers, power device consumers want to quickly inspect incoming devices in order to identify and eliminate counterfeit devices to avoid potential failures in the end product.

Tektronix and Keithley offer a wide variety of power supply solutions to power basic circuit boards. Additionally, Tektronix’s power analyzers can quickly and accurately assess overall end product performance. Keithley’s Parametric Curve Tracer (PCT) Configurations and ACS Basic Edition Software include a large library of power device tests so individual device performance can be quickly verify. Oscilloscopes with optional power analysis modules enable quick and accurate analysis of switching loss, harmonics, and safe operating area. Choose from a wide variety of high voltage, current, and differential probes to partner with an oscilloscope.
Implementing the Device in Actual Designs

Failure analysis engineers must determine whether a failure has been caused by end-product use or by a design flaw that was previously overlooked. Once this determination has been made, design and process engineering must be made aware of the cause of the failure, so that either process or design changes can be implemented to prevent future failures.

It’s important that basic device specifications, both static and dynamic, can be measured quickly. The end use application is mimicked in an effort to reproduce the failure.

Parametric Curve Tracer Configurations feature trace mode, which provides quick device analysis. Additionally, Keithley’s Automated Characterization Suite (ACS) has several built-in stress-measure tests that can be used until a device reaches the desired level of degradation.
Want to learn more?

CONTACT US BY PHONE, FAX, MAIL, OR EMAIL:
Within the USA: 1-888-534-8453
Outside the USA: + 1-440-248-0400
Email: applications@keithley.com

Additional contact information at www.keithley.com

Keithley Instruments hosts an online applications forum to encourage idea exchange, discussions among users. Join the discussion today.