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# New Breed of Semiconductors Demands New Breed of Semi Characterization and Test Solutions

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*In response to the demand for more energy-efficient devices, semiconductor technology is evolving to create devices that can operate at much higher levels of voltage, current, power, and frequency. This new breed of semiconductors holds the promise of higher growth for device manufacturers, as silicon-based devices increasingly replace the electro-mechanical technology once so prevalent in energy generation and transmission applications. Power transistors are expected to be the largest and fastest growing segment of the discrete semiconductor industry, with much of this growth being driven by energy efficiency-related applications and technologies.*

High power semiconductor end applications are becoming increasingly demanding, requiring test instrumentation capable of characterizing significantly higher rated voltages and peak currents than ever before. Breakdown and leakage tests, which are typically performed at 2–3 times the level of the rated or operating voltage, also contribute to the need for instrumentation capable of sourcing and measuring ever-high voltages. When high power semiconductor devices are in the ON state, they have to pass through tens or hundreds of amps with minimal loss; when they are OFF, they have to block thousands of volts with minimal leakage currents.

New compound materials, including silicon carbide (SiC) and gallium nitride (GaN), are increasingly being used to create these high power semiconductor devices because they offer much higher power density, smaller size, better high temperature performance, higher frequency response, and lower ON resistance than silicon. All of these advantages add up to greater operating efficiency. These compound semiconductor devices are also far less leaky than silicon, so testing demands a combination of greater current measurement sensitivity and higher voltage sourcing. Characterizing these new devices at current levels barely above the noise floor typically requires special triaxial cabling.

From a processing standpoint, compound semiconductor materials are more difficult to work with and control than traditional silicon simply because the underlying technologies are less mature. The engineers responsible for designing and characterizing these devices, as well as those involved in quality assurance, failure analysis, and process monitoring, face significant and expensive technical challenges. These challenges make these devices more expensive than their silicon equivalents, which puts pressure on the cost of test, especially final test. However, given their end-user customers' reliability requirements, these manufacturers can't afford to skimp on testing.

More than ever before, power semiconductor manufacturers are being challenged to create devices that operate at both higher power levels and with less leakage and to do so quickly and profitably. Finding new approaches to testing these devices is increasingly urgent. When power semiconductors were typically manufactured using only silicon-based technologies, the measurement ranges involved were not nearly as challenging as they are today. The relatively slow rate of change in the power semiconductor industry for a number of years meant that existing equipment types largely met power semi manufacturers' test requirements, so instrument manufacturers had little motivation to innovate and develop new, more capable solutions. Some were even allowed to go obsolete.

Fortunately, the growing thirst for more energy-efficient, environmentally conscious, and "green" products is revitalizing the power semiconductor industry. Power semi device manufacturers are striving to squeeze every last drop of efficiency and performance from new devices and there's a new demand for technical innovation. However, after returning to growth after years of stagnation, semi power device manufacturers are realizing the test and measurement (T&M) equipment they've long depended on is no longer up to the task. Older solutions lack the power as well as the low current measurement range and accuracy required to characterize next-generation devices and materials.

The T&M industry is struggling to respond to these test needs, and many traditional vendors simply haven't caught up yet. Some new parameter analyzer products have been rushed to market to address R&D characterization applications, but these solutions are often well beyond the means of many of budget-conscious equipment buyers. Moreover, they can't address the broader application requirements for production test and quality assurance/failure analysis.

Another approach that some have pursued involves integrating a system that combines separate power supplies with low current measurement instruments. Frankly, this approach just doesn't make sense to me from a throughput standpoint. As single-quadrant devices, power supplies cannot sink power; therefore, they require several seconds for the capacitance charge to bleed off after testing, which slows the test process, which is particularly problematic in production applications. In addition, such custom-designed systems typically require large test engineering teams to develop and maintain them.

Although traditional curve tracers are suitable for some lower power R&D and QA/FA applications, they're no longer being manufactured (so they're only available through the second-hand market), and they typically lack ultra-low current measurement capabilities. Commercial ATE systems have long been used for power semi production test applications, but their cost, size, and lack of characterization and low current measurement capabilities make them impractical for R&D and QA/FA applications.

Given the limitations of the other test solutions available, power semi device manufacturers are being forced to explore new options for material and device characterization and testing. Recently, T&M vendors have begun applying the integrated sourcing and measurement capabilities of SMU (source measurement unit) instruments to this challenge. Essentially, SMUs integrate fast-response, readback voltage and current sources with high accuracy measurement capabilities in a single enclosure. At one time, these instruments offered relatively limited sourcing and measurement ranges, so they couldn't deliver the power levels required to characterize high power semi devices accurately. Today, however, SMUs with more expansive power envelopes are increasingly available.

For example, Keithley introduced the Model 2651A High Power System SourceMeter® instrument in 2011, which was specifically designed for high current characterization, with 2000W (40V@50A) of pulsed power capability and 200W of continuous DC power for the industry's widest current range. A single unit can source and measure currents from 1pA to 50A; the top end of the current pulsing range can be expanded to 100A by linking two units together.

In response to the need for higher voltage testing of compound semiconductor materials and devices, Keithley developed a complementary product optimized for applications that demand a combination of high voltage sourcing, fast response, and precise voltage and current measurements, the Model 2657A High Power System SourceMeter instrument (***Figure 1***). The Model 2657A is capable of sourcing up to 180 watts of either continuous DC or pulsed power, which means it offers the highest power level available at such a high


***Figure 1. Model 2657A High Power System SourceMeter instrument is designed for high voltage/low current sourcing and measurement in high power semiconductor characterization.***

voltage (3,000V). Both the Model 2651A and Model 2657A combine the capabilities of a semiconductor parametric analyzer, precision power supply, true current source, DMM, low-frequency ARB, pulse generator, electronic load, and trigger controller – all in one full-rack, four-quadrant instrument.

Together, the Model 2651A and Model 2657A address the needs of many of today's power semiconductor applications and can be used across multiple departments within a single organization. This broad applicability offers the added advantage of greater measurement correlation at various stages throughout the commercialization process, which helps resolve problems faster and gets products to the marketplace faster.

Although some other SMU solutions on the market offer up to 3kV sourcing and measurement capabilities, their applications are relatively limited because they have just 12 watts of power, which is insufficient to characterize today's power semi devices. The Model 2657A's combination of high voltage at high power levels allows capturing important parametric data that other SMU solutions can't. Modern power semiconductor device designs also require the use of high speed pulsing during testing. The Model 2657A offers the speed necessary to source high voltage pulses quickly, like a 3000V pulse in less than 15 milliseconds or a 500V pulse in less than 2 milliseconds.

The new breed of power semiconductors also demands the use of test instrumentation that can characterize transient and steady-state behavior precisely, including rapidly changing thermal effects. The ability to measure the extremely low levels of leakage common in next-generation devices is also critical. To address both of these needs in a single instrument, the newest high power test solutions offer a choice of measurement modes, each of which is defined by an independent pair of analog-to-digital (A/D) converters. The high speed digitizing mode, which uses 18-bit A/D converters, allows one-microsecond per point sampling for characterizing signal transients. To handle low-level current leakage measurements, which require exceptional precision, these solutions offer a high accuracy integrating mode, based on 22-bit integrating A/D converters. Two A/D converters are used with each measurement mode (one for current and the other for voltage), which run simultaneously to provide accurate source readback without sacrificing test throughput.

Once these power semiconductor devices move into actual full-scale production, still other test system requirements, including ease of system integration and cost containment, become increasingly important. To minimize the time needed to integrate new instrumentation into their test setups, power semi device designers and manufacturers need hardware options that speed and simplify the system integration process. For example, the TSP-Link® virtual backplane common to all Keithley Series 2600A SMUs simplifies creating high speed, scalable integrated systems with up to 32 nodes. This allows system builders to create powerful multi-channel power semi test systems that rival the speed of large ATE systems that cost tens of thousands of dollars more. Optional protection and interconnect modules simplify connecting multiple instruments to a prober, handler, or custom fixture while helping to enhance operator safety.

The new breed of power semiconductor devices is making greater technical demands on their developers and manufacturers than ever before. They, in turn, must demand more from their T&M vendors in order to support their own efforts to innovate, control costs, and bring new products to market faster than their competition. It's only by seeking out the most capable test solutions that these manufacturers can hope to keep pace in this fast-changing market. ■

## About the Author

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