A GREATER MEASURE OF CONFIDENCE

KEITHLEY
A Tektronix Company

Learn How to Overcome the Electrical Measurement Challenges *of High Brightness LEDs*

start

Overcome the Electrical Measurement Challenges of High Brightness LEDs

High Brightness Light Emitting Diodes (HBLEDs) are growing rapidly in popularity in today's devices because of their high-use efficiency, long life, and wide range of available colors. These characteristics are driving their use in applications such as architectural lighting, automotive lighting, medical equipment, military systems, and even general illumination. The demand for HBLEDs will continue to grow even faster as their price decreases and their efficiency increases; however, this achievement is contingent upon refined testing methodology and instrumentation.

Reliable and accurate electrical measurements are vital for the mass production of high brightness LEDs, and, therefore, a solid understanding of them is critical. Our e-guide provides access to application-based seminars, application notes and other materials. After viewing these materials, we expect that you will come away with an overview of the common electrical measurements performed on high brightness LEDs and how to overcome the challenges associated with those measurements. You will learn and understand:

- The effects of self-heating in LEDs and how to avoid it
- How to relate forward voltage to junction temperature
- The effects of noise in your forward voltage measurements
- The testing differences between DC and AC LEDs

High Value HBLED Testing

To take advantage of the new opportunities that HBLEDs bring, manufacturers are looking for ways to increase production volumes and reduce unit costs of existing HBLED designs. In R&D labs, new III-V materials and phosphors (for white light) are being investigated to find those that allow HBLEDs to be produced cheaply and with better performance. Major objectives include higher efficiency, more colors, higher current density and optical output, and better packaging with increased cooling capabilities. These aims are especially important for HBLEDs used in illumination, where incandescent and fluorescent lamps currently have a significant unit price advantage. View our two-part seminar series now:

- **Seminar: Overcoming the Electrical Measurement Challenges of High Brightness LEDs** (Part 1)
- **Seminar: Meeting the Electrical Measurement Demands of High Power High Brightness LEDs** (Part 2)

View the video:
How to Overcome Electrical Measurement Challenges of High Brightness LEDs

- Article – **Accurate, Cost-Effective High Brightness LED Testing Starts with Device Fundamentals**
- Application Overview – **Simplified I/V Characterization of LEDs**

Want assistance, a quote, or to place an order?
Contact us online.

- Join the discussion on our **application forum**.

Let's take a look at the three steps in the life cycle of LED manufacturing.

Step One: Wafer Acceptance Testing (WAT) or Die Sort

During the wafer acceptance testing or die sort cycle in production testing, every LED device on a wafer is tested to identify the good die from the bad die. This ensures that the LED device on the wafer meets the design specifications and prevents additional value-added process steps on bad die.

The Keithley **Series 2600B SourceMeter® SMU Instrument Family** is a great fit for automated test applications like WAT that demand the highest levels of automation and throughput. The Series 2600B's **Test Script Processor (TSP®)** technology delivers industry-best performance by fully embedding and then executing complete test programs from within the SMU instrument itself. This virtually eliminates all time-consuming bus communications to and from the PC controller and, thus, dramatically improves overall test times.

- Learn more about the Series 2600B SMU Instruments

Step Two: LED Device Testing

In the LED device testing cycle, parameters such as reverse breakdown voltage, leakage current, forward voltage, optical test, etc. are examined on each individual LED device. Keithley's **Series 2400 SourceMeter SMU Instructions** and, for high power requirements, **Model 2651A High Current SMU Instrument** streamline this process and provide reliable operation and superior throughput in non-stop production environments. Additionally, the **Model 2602B Dual-Channel SMU Instrument** enables parallel testing of LED devices when even greater production efficiency is required.

- Learn more about the Series 2400 Family of SMU Instruments
- Learn more about the Model 2651A High Current System SMU Instrument
- Learn more about the Model 2602B Dual-Channel SMU Instrument

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Let's take a look at the three steps in the life cycle of LED manufacturing. *continued.*

Step Three: Testing LED Modules

Once the LED devices are embedded in a complete module (for example, LED car headlights,) the entire LED module is tested for reverse breakdown voltage, leakage current, forward voltage, optical tests etc. Though it seems as though the same parameters are tested in this step as in the LED device testing done in step two, testing complete LED modules in this step is done at much higher power, voltage, and current levels than testing LED devices.

For many applications, space is limited and/or the light must be directional. This demand for a lot of light in a small package has led to the development of high power LED modules, which consist of one or more large-die LEDs. When multiple LEDs are present, they're either wired in parallel or in series, depending on the application and the available power source. The die of these LEDs are much larger than the die of typical HBLEDs and can handle much larger currents as well. In fact, it's common for a single die to be required to withstand current levels as high as 10A. High current pulse width modulation is a common method of controlling the brightness of such LEDs. When using this technique, the current through the LED is pulsed at a constant frequency with a constant pulse level, but the width of the pulse is varied. Keithley's **Series 2600B SMU Instruments** and **Model 2651A High Current SMU** are powerful solutions that offer unmatched throughput in production applications.

KEITHLEY
Application Note Series

Testing High Brightness LEDs under Pulse Width Modulation Using the Model 2651A High Power System SourceMeter® Instrument

Introduction

The Demand for More Power

- **Application Note: High Brightness LEDs under Pulse Width Modulation Using the Model 2651A High Power System SourceMeter® Instrument**
- **Learn more about the Series 2600B SMU Instruments**
- **Learn more about the Model 2651A High Current System SMU Instrument**

Other LED Testing Requirements

In device testing, there is also a need for temperature profiling and environment stress screening. These applications involve batch testing of devices by sampling requiring the need for multiplexing to reduce costs. Keithley's **Model 3706A System Switch** with High Performance Digital Multimeter is a tightly integrated switch and measurement system that meets demanding precision and multiplexing requirements in an automated test system for device testing.

- **Learn more about the Model 3706A**

Want assistance, a quote, or to place an order?
Contact us online.

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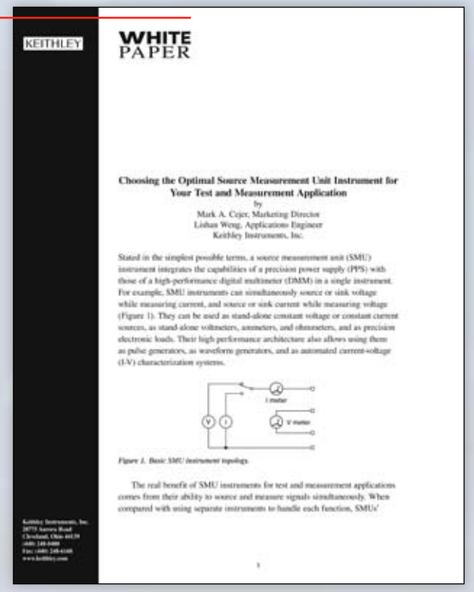
Learn How to Choose the Right SMU for Your Application

The popularity of SMU instruments has increased rapidly as more people discover that their tightly-integrated DMM and precision power supply capabilities can serve a wide variety of applications throughout the electronics and semiconductor industries. Learn how to evaluate instrument specifications carefully in order to choose the most appropriate SMU for a specific application. ***View our online webinar.***

- **Read the White Paper:**
  - Choosing the Optimal Source Measurement Unit Instrument for Your Test and Measurement Application


KEITHLEY

WHITE PAPER

Choosing the Optimal Source Measurement Unit Instrument for Your Test and Measurement Application

by

Mark A. Cejer, Marketing Director
Lishan Weng, Applications Engineer
Keithley Instruments, Inc.

Stated in the simplest possible terms, a source measurement unit (SMU) instrument integrates the capabilities of a precision power supply (PPS) with those of a high-performance digital multimeter (DMM) in a single instrument. For example, SMU instruments can simultaneously source or sink voltage while measuring current, and source or sink current while measuring voltage (Figure 1). They can be used as stand-alone constant voltage or constant current sources, as stand-alone voltmeters, ammeters, and ohmmeters, and as precision electronic loads. Their high performance architecture also allows using them as pulse generators, as waveform generators, and as automated current-voltage (I-V) characterization systems.

Figure 1. Basic SMU instrument topology.

The real benefit of SMU instruments for test and measurement applications comes from their ability to source and measure signals simultaneously. When compared with using separate instruments to handle each function, SMUs'

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Click here for an online discussion on "What Is an SMU Instrument, and How Do You Decide Which One Is Right for Your Application?"

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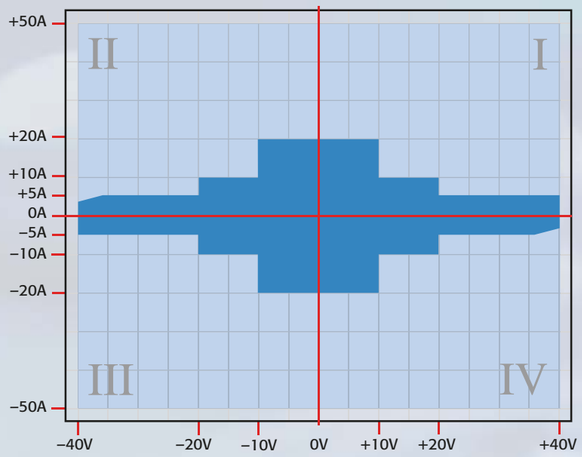
Get Unmatched Performance for Characterizing and Testing High Power, High Current Electronics

Our new ***Model 2651A High Power/High Current System SourceMeter® Instrument*** simplifies characterizing today's challenging high power electronics with unprecedented power, precision, speed, flexibility, and ease of use. It combines a highly flexible, four-quadrant voltage and current source/load with precision voltage and current meters.

- Source or sink 2,000W of pulsed power (±40V, ±50A), 200W of DC power (±10V@±20A, ±20V@±10A, ±40V@±5A)
- Easily connect two units (in series or parallel) to create solutions up to ±100A or ±80V
- 1pA resolution enables precise measurement of very low leakage currents
- 1μs per point (1MHz), continuous 18-bit sampling, accurately characterizes transient behavior

Choice of digitizing or integrating measurement modes

With the Model 2651A, you can choose from either digitizing or integrating measurement modes for precise characterization of both transient and steady-state behavior. Two independent ADCs define each mode—one for current and the other for voltage—which run simultaneously for accurate source readback without sacrificing test throughput. The digitizing measurement mode's 18-bit ADCs can support continuous one-microsecond-per-point sampling, making it ideal for waveform capture and measuring transient characteristics with high precision. The integrating measurement mode, based on 22-bit ADCs, supports applications that demand the highest possible measurement accuracy and resolution. This ensures precise measurements of the very low currents and voltages common in next-generation devices.

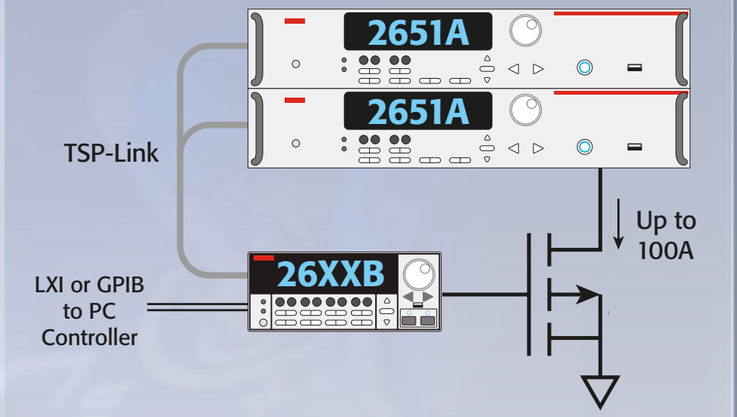


A single Model 2651A unit can source and sink up to ±40V and ±50A. Connect two units in parallel via the built-in TSP-Link expansion bus to extend the system's current range to 100A or connect them in series to expand the voltage range to 80V. The embedded Test Script Processor (TSP®) included simplifies testing by allowing you to address multiple units as a single instrument so that they act in concert. The built-in trigger controller can synchronize the operation of all linked channels to within 500 nanoseconds.

Click here to learn more

Model 2651A Applications

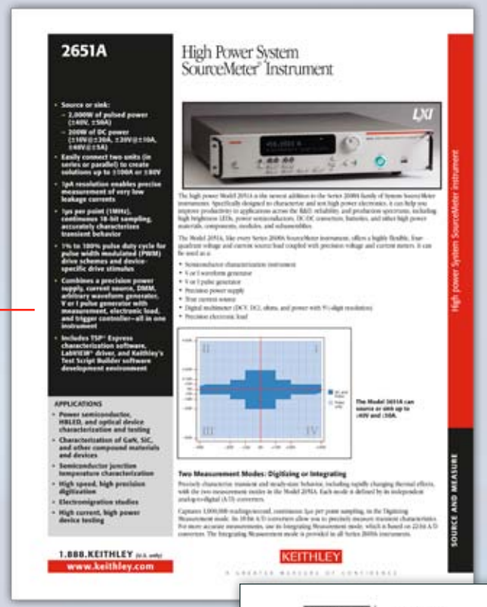
- Power semiconductor, high brightness LED (HBLED), and optical device characterization and testing
- Characterization of GaN, SiC, and other compound materials and devices
- Semiconductor junction temperature characterization
- Reliability testing
  - High speed, high precision digitization
  - Electromigration studies



Built for building systems. The embedded TSP controller and TSP-Link interface in each Series 2600B instrument make it easy to link multiple Model 2651As with Series 2600B instruments to create an integrated test system with up to 64 channels. Precision timing and tight channel synchronization are guaranteed with built-in 500ns trigger controllers. The fully isolated, independent channels of Series 2600B instruments allow true SMU-per-pin testing without the power and/or channel limitations of mainframe-based systems.

Ready to learn more?

- Download the Model 2651A datasheet.



- Read these Application Briefs:
  - Testing High Brightness LEDs under Pulse Width Modulation Using the Model 2651A High Power System SourceMeter® Instrument. Learn how to test high brightness LEDs properly with accuate, reliable and repeatable measurements by using complex drive schemes such as pulse width modulated waveforms, AC waveforms, and even arbitrary waveforms.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Application Note Series
Number 3129
Testing High Brightness LEDs under Pulse Width Modulation Using the Model 2651A High Power System SourceMeter® Instrument
Introduction
The Demand for More Power
Figure 1: Power envelope for the Model 2651A High Power System SourceMeter instrument.

Click on the video above to view our demo of how you can combine two Model 2651As to source currents as high as 100A!

Want assistance, a quote, or to place an order?
Contact us online.

- Join the discussion on our application forum.

Get Superior Ease-of-Use with Best-in-Class Value & Performance

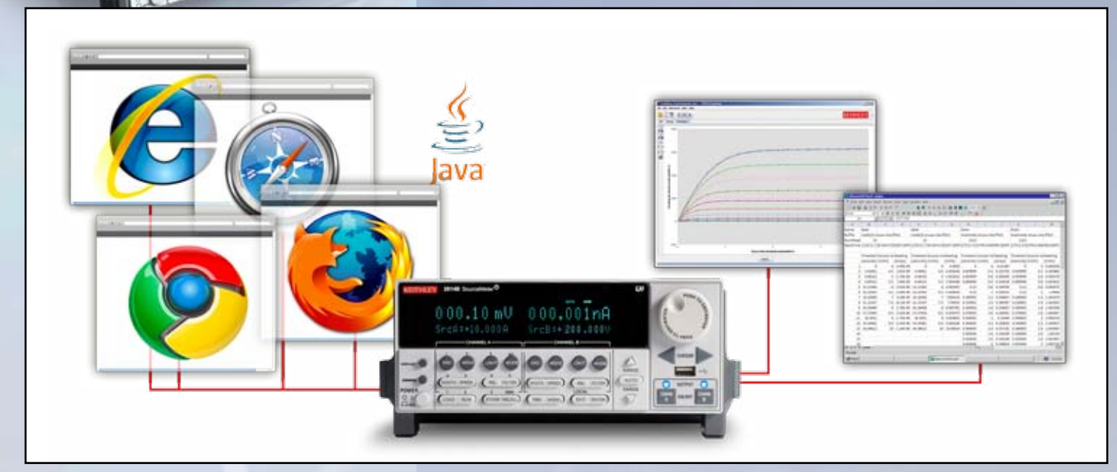
Like other SourceMeter® SMU Instruments, Series 2600B offers both single- and dual-channel models. Each combines the capabilities of a Precision Power Supply, true Current Source, 6½ digit DMM, Arbitrary Waveform Generator, Pulse Generator, and Electronic Load – all into one tightly-integrated, 4-quadrant voltage/current source and measure instrument.

With our new Series 2600B SMU line, the most powerful, fastest, and highest resolution SMU instruments are now easier than ever to use, with:

- 6½ digit display with industry-best resolution up to 0.1fA
- Software emulation for Keithley's Model 2400 SourceMeter SMU Instruments
- Built-in, Java-based test software that enables true plug & play I/V characterization and test through any browser.
- USB 2.0, LXI-C, GPIB, RS-232, and digital I/O interfaces

With our **Series 2600B SourceMeter SMU Instruments**, we've added three new bench-top models and expanded the capabilities of six more instruments.

See our selector table on page 11 of this guide.



View our video demo and learn how to boost productivity using the built-in, Java-based test software runs directly from any web browser

Click here to learn more

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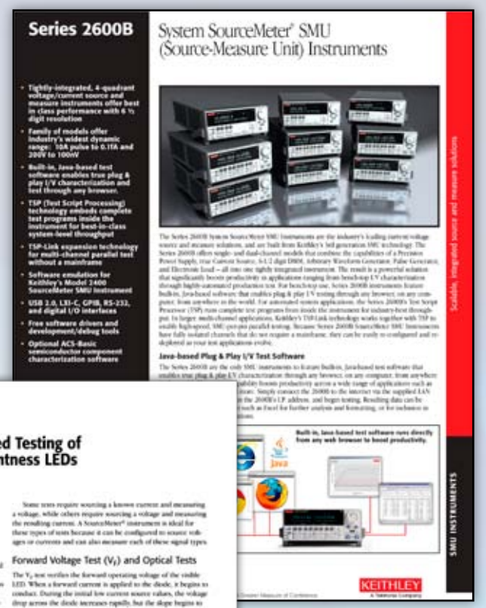
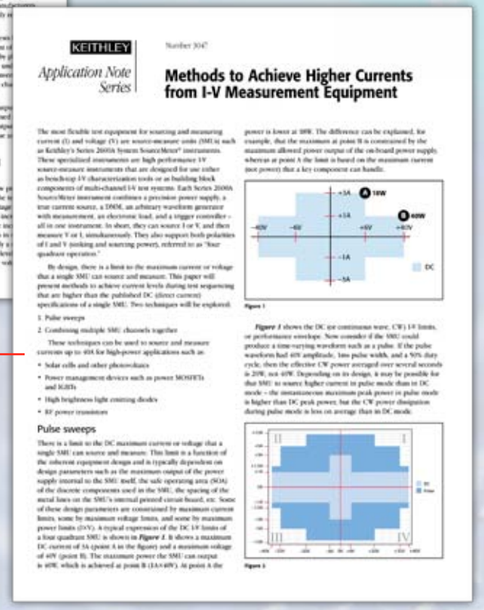
Ready to learn more?

- **Download the Series 2600B datasheet.**



- **Read an Application Note:**
  - **High Speed Testing of High Brightness LEDs –** Learn how to achieve throughput advantages and reduce the cost of test by using new test technologies, including instruments enabled with an embedded Test Script Processor.

  - **Methods to Achieve Higher Currents from I-V Measurement Equipment –** Discover how to achieve current levels during test sequencing that are higher than the published DC (direct current) specifications of a single SMU.



Click here to download our 2 page overview of simplified I/V characterization of LEDs.

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Contact us online.

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Explore the Series 2400 SourceMeter instrument family

Series 2400 SourceMeter instruments are designed specifically for testing devices that demand tightly coupled precision voltage and current sourcing as well as measurement capabilities. Each is a single-channel instrument that is both a highly stable DC power source and a true instrument-grade 6½-digit multimeter. The power source characteristics include low noise, precision, and readback. The multimeter capabilities include high repeatability and low noise. The result is a compact, single-channel, DC parametric tester.

- Six models: 20–100W DC, 1000W pulsed, 1100V to 1μV, 10A to 10pA
- Source and sink (4-quadrant) operation, plus 2-, 4-, and 6-wire ohms functions
- 0.012% basic DCV measure accuracy with 6½-digit resolution
- Available high speed sense lead contact check function
- Programmable DIO port for automation/handler/prober control
- Up to 1700 readings/second at 4½ digits via the GPIB bus
- 5000 6½-digit readings can be stored in the non-volatile buffer memory

Built-In Test Sequencer

The Series 2400 Source Memory list provides faster and easier testing by allowing you to set up and execute up to 100 different test setups that can run without PC intervention.

- Stores up to 100 individual test configurations, each containing unique source settings, measurement settings, pass/fail criteria, etc., linked together to form a complete test suite
- Pass/fail limit test as fast as 500μs per point with onboard comparator that eliminates the delay caused when sending data to the computer for analysis
- Built-in, user definable math functions to calculate derived parameters

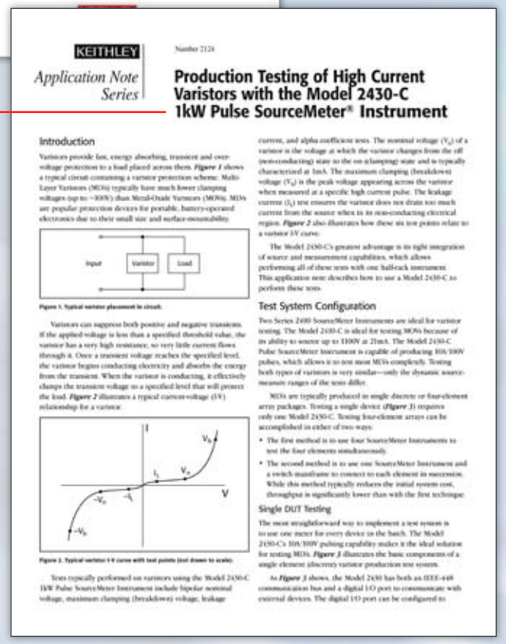
Click here to learn more

Series 2400 SourceMeter instruments are easy to set up and use, providing convenient DMM-like operation, while eliminating many of the connection, compatibility, and synchronization problems that occur when multiple instruments are used. You can source voltage or current while making measurements without changing connections. This not only makes it easier to use, it saves test time.

Ready to learn more?

- Download the Series 2400 datasheet.

- Read an Application Note:
  - Production Testing of High Current Varistors with the 2430C 1kW Pulse SourceMeter Instrument – Learn about the methods and issues related to creating production test system solutions that verify the performance of single and multiple (array) LED devices.


KEITHLEY
Application Note Series

Production Testing of High Current Varistors with the Model 2430-C 1kW Pulse SourceMeter® Instrument

Introduction

Varistors provide fast, energy absorbing, transient and over-voltage protection to a load placed across them. *Figure 1* shows a typical circuit containing a varistor protection scheme. Multi-Layer Varistors (MLVs) typically have much lower clamping voltages (up to ~100X) than Metal-Oxide Varistors (MOVs). MLVs are popular protection devices for portable, battery-operated electronics due to their small size and surface-mountability.

Figure 1. Typical varistor placement in circuit.

Varistors can suppress both positive and negative transients. If the applied voltage is less than a specified threshold value, the varistor has a very high resistance, so very little current flows through it. Once a transient voltage reaches the specified level, the varistor begins conducting electricity and absorbs the energy from the transient. When the varistor is conducting, it effectively clamps the transient voltage to a specified level that will protect the load. *Figure 2* illustrates a typical current-voltage (I-V) relationship for a varistor.

Figure 2. Typical varistor I-V curve with test points (not drawn to scale).

Tests typically performed on varistors using the Model 2430-C 1kW Pulse SourceMeter Instrument include bipolar nominal voltage, maximum clamping (breakdown) voltage, leakage current, and alpha coefficient tests. The nominal voltage (V_N) of a varistor is the voltage at which the varistor changes from the off (non-conducting) state to the on (clamping) state and is typically characterized at 1mA. The maximum clamping (breakdown) voltage (V_B) is the peak voltage appearing across the varistor when measured at a specific high current pulse. The leakage current (I_L) test ensures the varistor does not drain too much current from the source when in its non-conducting electrical region. *Figure 2* also illustrates how these six test points relate to a varistor I-V curve.

The Model 2430-C's greatest advantage is its tight integration of source and measurement capabilities, which allows performing all of these tests with one half-rack instrument. This application note describes how to use a Model 2430-C to perform these tests.

Test System Configuration

Two Series 2400 SourceMeter Instruments are ideal for varistor testing. The Model 2430-C is ideal for testing MOVs because of its ability to source up to 1100V at 21mA. The Model 2430-C Pulse SourceMeter Instrument is capable of producing 10A/100V pulses, which allows it to test most MLVs completely. Testing both types of varistors is very similar—only the dynamic source-measure ranges of the tests differ.

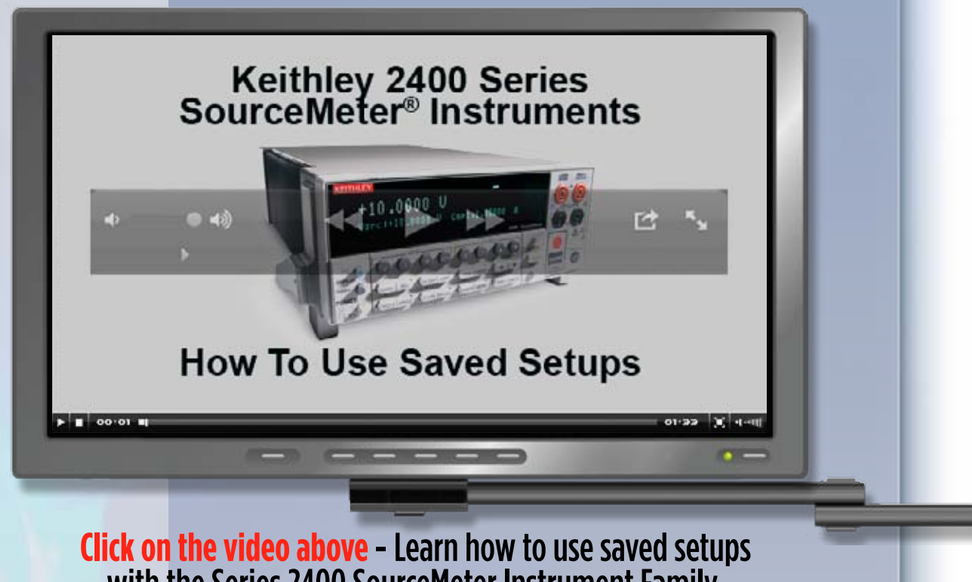
MLVs are typically produced in single discrete or four-element array packages. Testing a single device (*Figure 2*) requires only one Model 2430-C. Testing four-element arrays can be accomplished in either of two ways:

- The first method is to use four SourceMeter Instruments to test the four elements simultaneously.
- The second method is to use one SourceMeter Instrument and a switch mainframe to connect to each element in succession. While this method typically reduces the initial system cost, throughput is significantly lower than with the first technique.

Single DUT Testing

The most straightforward way to implement a test system is to use one meter for every device in the batch. The Model 2430-C's 10A/100V pulsing capability makes it the ideal solution for testing MLVs. *Figure 3* illustrates the basic components of a single element (discrete) varistor production test system.

As *Figure 3* shows, the Model 2430 has both an IEEE-488 communication bus and a digital I/O port to communicate with external devices. The digital I/O port can be configured to



Click on the video above – Learn how to use saved setups with the Series 2400 SourceMeter Instrument Family.

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Discover how you benefit from our legacy of innovation in Source-Measure Unit engineering

Our latest generation of System SourceMeter® instruments offers the T&M industry's best combination of precision, throughput, and functionality. When used individually, they bring together everything we've learned about engineering instruments that deliver unparalleled performance. They're also flexible, efficient, I-V source-and-measure building blocks for creating fast, powerful, and cost-effective test and measurement systems for electronic devices. Keithley has been a leading provider of integrated sourcing and measurement solutions since the late 1980s, when we introduced our first generation of source-measure units (SMUs).

1989

First instrument-based SMU (Series 23X)

First 1000V SMU instrument (Model 237)

First half-rack, DMM-like SMU instrument (Model 2400)

1995

First one-kilowatt pulsed SMU instrument (Model 2430)

2000

First sub-femtoamp SMU instrument (Model 6430)

First two-channel, half-rack SMU instrument (Model 2602)
First script-based SMU instrument (Models 2601/2602)

2005

First one-microsecond per point digitizing SMU instrument (Model 2651A)
First 200W DC, 2000W pulsed SMU instrument (Model 2651A)
First 3,000V, 180W SMU with 1fA current measurement resolution (Model 2657A)

Series 2600B SourceMeter® SMU Instruments

First SMU instrument with parallel test expansion capability (Series 2600A)

today

System SourceMeter® SMU Instruments

Feature	2651A / 2657A High Current / High Voltage	2634B / 2635B / 2636B Low Current	2602B / 2612B Dual Channel	2601B / 2611B Single Channel	2604B / 2614B Dual Channel Benchtop
# of Channels	1 (optional expansion to 32)	1 – 2 (optional expansion to 64 via TSP Link for 2635B/2363B)	2 (optional expansion to 64 via TSP-Link)	1 (optional expansion to 32 via TSP-Link)	2
Current Max / Min	1 (optional expansion to 32 via TSP-Link®)	2634B: 10A pulse/1fA 2636B, 2635B: 10A pulse/0.1fA	10A pulse/100fA	10A pulse/100fA	10A pulse/100 fA
Voltage Max / Min	2651A: 50A pulse/100fA 2657A: 120mA/1fA	200V/100nV	40V/100nV for 2602B 200V/100nV for 2612B	40V/100nV for 2601B 200V/100nV for 2611B	40V/100nV for 2604B 200V/100nV for 2614B
System-Level Automation	Digital I/O, TSP-Link, Contact Check	Digital I/O, TSP-Link, Contact Check (not available on 2634B)	Digital I/O, TSP-Link, Contact Check	Digital I/O, TSP-Link, Contact Check	N/A
Max readings / sec	38,500 1µSec/pt.,18-bit digitizer	20,000	20,000	20,000	20,000
ComputerInterface	GPIB, LAN (LXI), RS-232	GPIB, LAN (LXI), RS-232, USB	GPIB, LAN (LXI), RS-232, USB	GPIB, LAN (LXI), RS-232, USB	GPIB, LAN (LXI), RS-232, USB
Connectors/Cabling	2651A: Screw terminal, adaptors for banana 2657A: HV triax, SHV	Triax	Screw terminal, adaptors for banana or triax	Screw terminal, adaptors for banana or triax	Screw terminal, adaptors for banana or triax

Feature	6430 Low I SourceMeter	2430 High Power SourceMeter Instrument	2410 High V SourceMeter Instrument	2420 / 2425 / 2440 High I SourceMeter Instruments	2400 / 2401 Low Power SourceMeter Instruments
Current Max / Min	105mA / 10aA	10.5A pulse / 100pA	1.05A / 10pA	5.25A/ 100pA	1.05A / 10pA
Voltage Max / Min	200V / 1uV	200V / 1uV	1100V / 1uV	100V / 1uV	200V / 1uV
Power	2W	1100W	22W	110W	22W
Max readings / sec	256	2,000	2,000	2,000	2,000
Interface	GPIB, RS-232, Digital I/O, Trigger Link Trigger Bus	GPIB, RS-232, Digital I/O, Trigger Link Trigger Bus	GPIB, RS-232, Digital I/O, Trigger Link Trigger Bus	GPIB, RS-232, Digital I/O, Trigger Link Trigger Bus	GPIB, RS-232, Digital I/O, Trigger Link Trigger Bus
Connectors	Triax	Banana (front / rear)	Banana (front / rear)	Banana (front / rear)	Banana (front / rear)

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

To learn more about how Keithley's family of SMUs can enhance the productivity of your test and measurement applications, contact your local Keithley representative or **ask us a question online**.

Want to learn more?

Contact us by phone, fax, mail, or email:

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A Greater Measure of Confidence

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