

# Testing to 100A by Combining Keithley Model 2651A High Power SourceMeter® Instruments

## Introduction

Source-measure units (SMUs), such as the Keithley Model 2651A High Power System SourceMeter instrument, are the most flexible and most precise equipment for sourcing and measuring current and voltage. Because of this, they are widely used to test semiconductor devices such as MOSFETs, IGBTs, diodes, high brightness LEDs, and more.

With today's focus on green technology, the amount of research and development being done to create semiconductor devices for power management has increased significantly. These devices, with their high current/high power operating levels, as well as their low On resistances, require a unique combination of power and precision to be tested properly. A single Keithley Model 2651A is capable of sourcing up to 50A pulsed and measuring down to 1pA or 1 $\mu$ V. For applications requiring even higher currents, the Model 2651As are capable of being combined to extend their operating range to 100A pulsed.

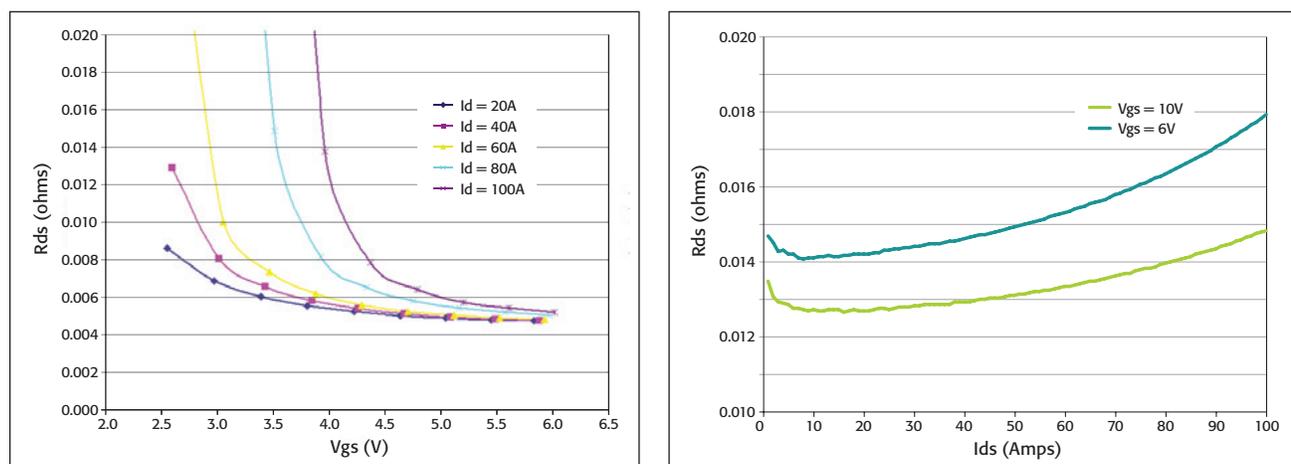
The high power Model 2651A is the newest addition to the Series 2600A family of System SourceMeter instruments. Specifically designed to characterize and test high power

electronics, it can help you improve productivity in applications across the R&D, reliability, and production spectrums, including high brightness LEDs, power semiconductors, DC-DC converters, batteries, and other high power materials, components, modules, and subassemblies.

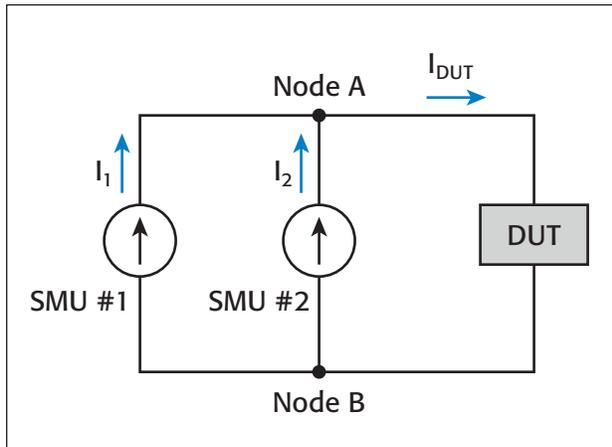
When two Model 2651As are connected in parallel with Keithley's TSP-Link® technology, the current range is expanded from 50A to 100A. When two units are connected in series, the voltage range is expanded from 40V to 80V. The built-in intelligence simplifies testing by enabling the units to be addressed as a single instrument, thus creating an industry-best dynamic range (100A to 1pA). This capability enables you to test a much wider range of power semiconductors and other devices. (See example in **Figure 1**.)

## Theory

Kirchhoff's Current Law says that the sum of the currents entering a node is equal to the sum of the currents leaving the node. In **Figure 2** two current sources representing SMUs and a device under test (DUT) are connected in parallel.



**Figure 1: Example results after performing a pulsed  $R_{ds}(on)$  current sweep (500 $\mu$ s pulse width and 0.01 NPLC) to test up to 100A on a power MOSFET device using two Model 2651A SourceMeter instruments connected in parallel.**



**Figure 2: The sum of the currents entering the node equals the sum of the currents leaving the node.**

In **Figure 2**, we can see that two currents,  $I_1$  and  $I_2$ , are entering Node A and a single current,  $I_{DUT}$ , is leaving Node A. Based on Kirchhoff's Current Law we know that:

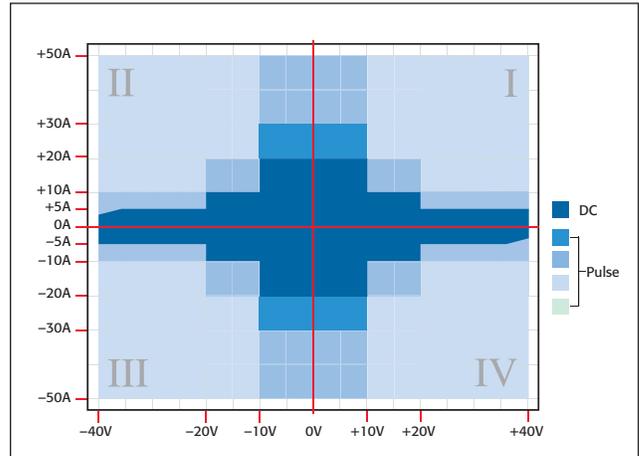
$$I_{DUT} = I_1 + I_2$$

This means that the current delivered to the DUT is equal to the sum of the currents flowing from each SMU. With two SMUs connected in parallel, we can deliver to the DUT twice the amount of current that can be delivered by a single SMU. Using this method with two Model 2651As, we can deliver up to 100A pulsed.

### Implementation

To create a current source capable of delivering more current than a single SMU can provide, we put two SMUs, both configured as current sources, in parallel. Below is a quick overview of what needs to be done to successfully combine two Model 2651As so that together they can source up to 100A pulsed.

1. Use two Model 2651As.
2. Use the same current range for both SMUs.
3. Use the same regions of the power envelope (**Figure 3**) for both SMUs.
4. Use 4-wire mode on both SMUs with Kelvin connections placed as close to the DUT as possible.
5. Use the Keithley supplied cables. If this is not possible, be sure your cabling matches the specifications of the Keithley supplied cable.



**Figure 3: Power envelope for a single Model 2651A.**

6. Set the voltage limit of both SMUs. (When the output of an SMU reaches its voltage limit, it goes into compliance.) The voltage limit of one SMU should be set 10% lower than the other SMU.
7. Select the output off-mode of each SMU. This determines whether an SMU will function as a voltage source set to 0V or as a current source set to 0A when the output is turned off. When two SMUs are functioning in parallel as current sources:
  - The SMU with the lower voltage limit should have its output off-mode set to NORMAL with the off function set to voltage, and
  - The SMU with the higher voltage limit should have its output off-mode set to NORMAL with the off function set to current.

### Example Test System Configuration

The test system in this example is designed to collect  $R_{ds(on)}$  measurement data for a power MOSFET device, however, it can easily be modified for use in other applications. This application was selected to demonstrate how to gather data using a pulsed current sweep to test up to 100A. (See **Figure 4**.)

### Required Equipment

The following equipment is needed:

- Two Model 2651A High Power System SourceMeter instruments that will be connected in parallel to source up to 100A pulsed through the drain of the DUT.

- One Model 26xxA System SourceMeter Instrument to control the gate of the DUT. The 26xxA can be a Model 2601A, 2602A, 2611A, 2612A, 2635A, or 2636A.
- Two TSP-Link cables for communications and precision timing between instruments.
- One GPIB cable or one Ethernet cable to connect the instruments to a computer.

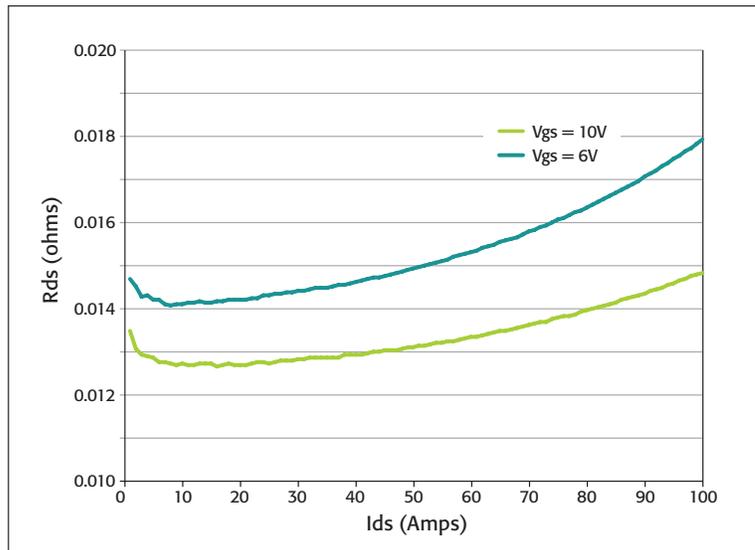
### Communications Setup

The communication setup is illustrated in **Figure 5**. GPIB is used in this example to communicate with the PC, but this application can be run using any of the supported communication interfaces for the instruments. The TSP-Link connection enables communication between the instruments, precision timing, and tight channel synchronization to within <500ns.

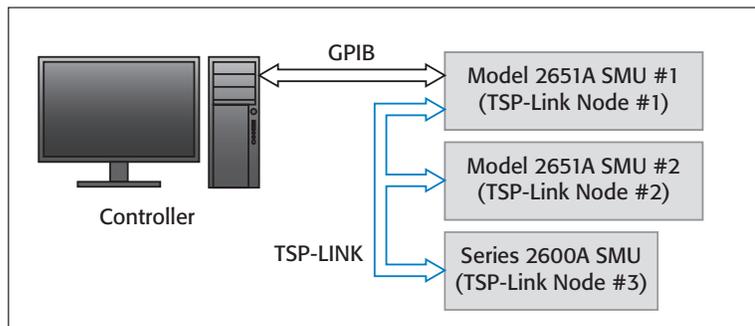
### Device Connections

Connections from the SourceMeter instruments to the DUT can be seen in **Figure 6**. Proper care should be taken to ensure good contact through all connections. For best results, all connections should be left floating and no connections should be tied to ground. Also, all connections should be made as close to the device as possible to minimize errors caused by voltage drops between the DUT and the points in which the test leads are connected.

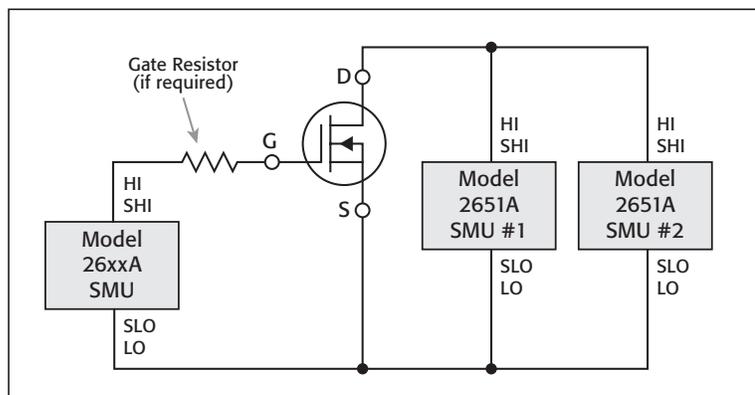
Note: During high current pulsing, the gate of your DUT may begin to oscillate, creating an unstable voltage on the gate and thus unstable current through the drain. To dampen these oscillations and stabilize the gate, a resistor can be inserted between the gate of the device and the Force and Sense Hi leads of the Model 26xxA. If the gate remains unstable after inserting a dampening resistor, enable High-C mode on the Model 26xxA (leaving the dampening resistor in place.)



**Figure 4: Example Rds(on) measurement data on a power MOSFET device using two Model 2651As connected in parallel.**



**Figure 5: Communications setup for example application.**



**Figure 6: Connections for a dual SMU Rds(on) sweep.**

## Test

The Test Script Processor (TSP®) script for this example should include:

- Initializing the TSP-Link connection
- Configuring all SMUs
- Configuring the trigger models of the two Model 2651As
- Preparing the readings buffers
- Initializing the sweep
- Processing and returning the collected data in a format that can be copied and pasted directly into Microsoft Excel®

## Conclusion

Keithley's Model 2651A High Power System SourceMeter® Instrument lets you characterize and test today's challenging high power electronics with unprecedented power, precision, speed, flexibility, ease of use, and:

- 1 $\mu$ V measurement resolution and current sourcing up to 50A (100A with two units)—enable low-level Rds measurements to support next-generation devices
- TSP-Link—tightly synchronizes the operations between channels and/or other Series 2600A instruments to within <500ns
- 1 $\mu$ s per point (1MHz) 18-bit sampling—accurately characterizes fast transient behavior
- True SMU-per-pin testing—prevents the distortion of measurement and load signals

For complete details about configuring the test system and the trigger models as well as all the code necessary to perform a pulsed Rds(on) sweep up to 100A using two Model 2651A High Power System SourceMeter instruments and a Model 26xxA System SourceMeter instrument, see the application note titled "Combining Keithley Model 2651A High Power SourceMeter Instruments for 100A Operation."

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