

# Combine High Power SMUs to Extend Component Testing to 100 A

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Today's focus on green technology has led to a significant increase in the amount of research and development being done to create semiconductor devices for power management. Their high current/high power operating levels, as well as their low On resistances, mean these devices demand test instruments that combine power with precision. Fortunately for device developers and manufacturers, the latest generation of Source-Measurement Units (SMUs) can provide this unique combination. The latest generation of high power SMUs is capable of sourcing up to 50 A pulsed and measuring down to picoamps or microvolts. For applications that require even higher power levels, two of these instruments can be combined to extend their operating range.

When two of these SMUs are connected in parallel, the current range is expanded from 50 A to 100 A (Figure 1). Some of the latest generation of SMU designs even come with software that simplifies testing by allowing two instruments to be addressed as a single instrument, creating a dynamic range from 100 A to just picoamps and making it possible to test a much wider range of devices, such as high brightness LEDs (HBLEDs), power semiconductors, DC-DC converters, and batteries, as well as other high power materials, components, modules, and subassemblies.

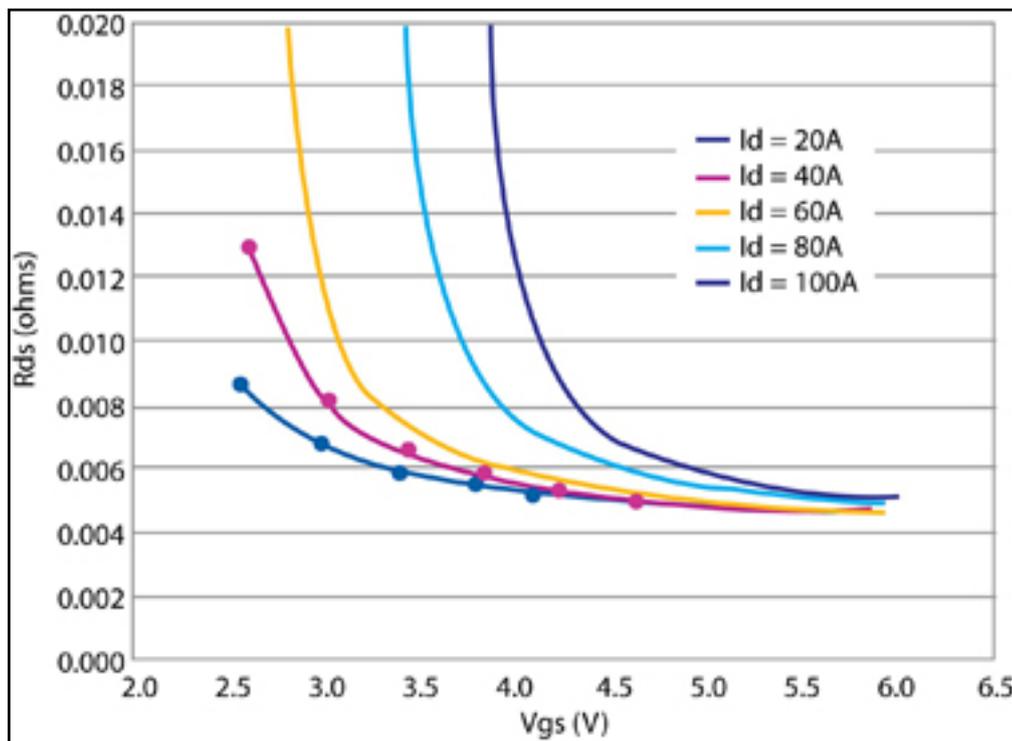
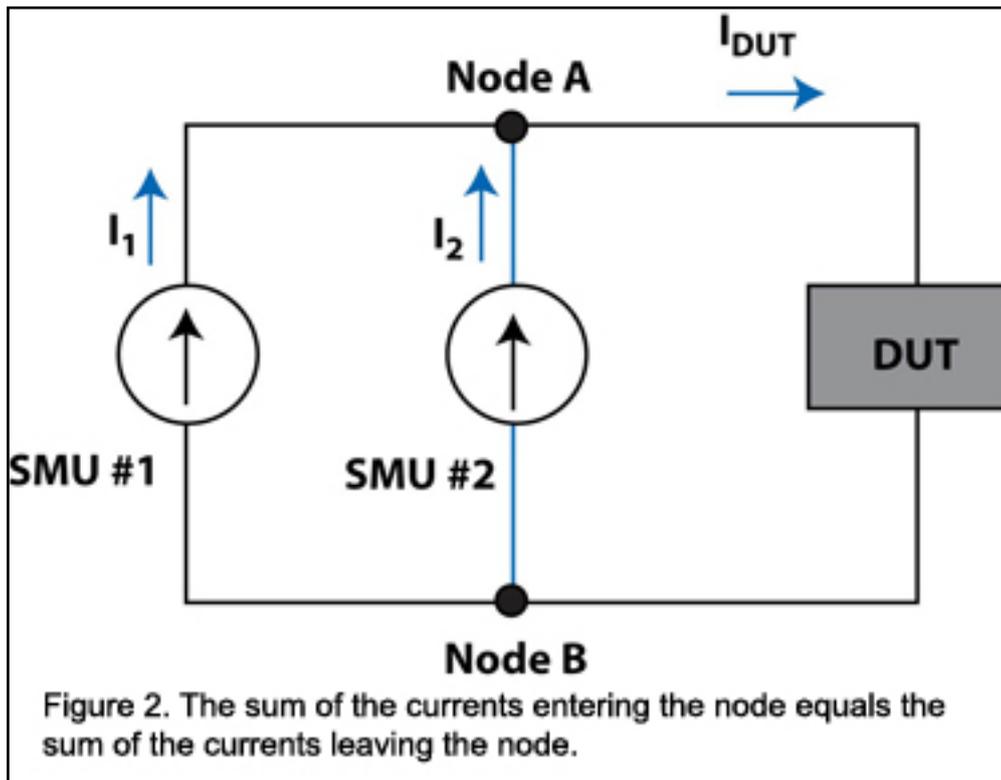


Figure 1. Results after performing a pulsed drain-to-source resistance  $R_{DS(ON)}$  current sweep (500 microsecond pulse width and 0.01 NPLC) to test a power MOSFET device at up to 100 A using two SMUs connected in parallel.

## Theory

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



In this figure, note that two currents ( $I_1$  and  $I_2$ ) are entering Node A and a single current ( $I_{DUT}$ ) is leaving Node A. In accordance with Kirchhoff's Current Law:

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

Therefore, the current delivered to the DUT is equal to the sum of the currents flowing from each SMU. With two SMUs connected in parallel, it's possible to deliver twice the current to the DUT as would be possible using a single SMU. With the latest high power SMU designs, a two-SMU system can deliver up to 100A pulsed.

## Implementation

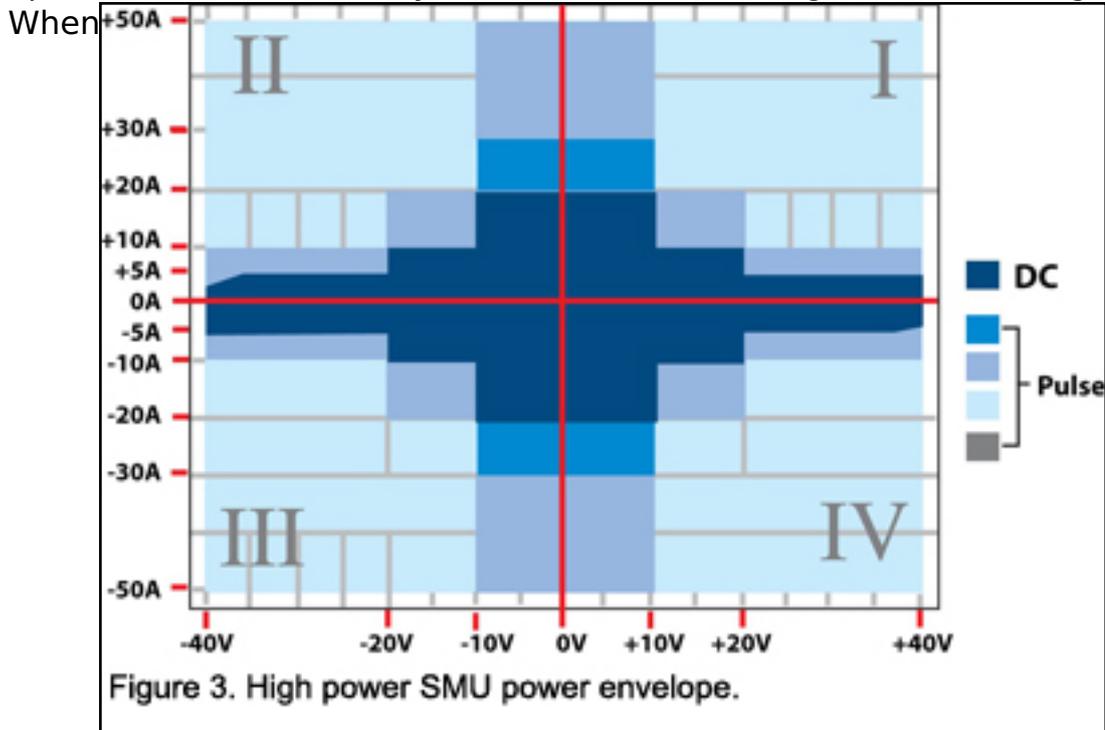
Creating a current source capable of delivering higher currents than can a single SMU requires using two SMUs, both configured as current sources, in parallel. Here's how to combine SMUs successfully so that together they can source up to 100 A pulsed.

\* Use two identical high power SMUs capable of sourcing currents up to  $\pm 50A$  pulsed, employing the same current range for both instruments. The use of identical SMUs ensures that, if they are forced into a condition in which one SMU must sink all of the current from the other SMU, the first SMU is capable of sinking all the current. Setting both SMUs to the same source current range is equally crucial. The manner in which a SMU responds to a change in current level can vary according to the current range on which it is being sourced. Configuring both SMUs to source on the same current range ensures that both SMUs will respond similarly to changes in current levels. This reduces the chance of overshoots, ringing, and other undesired SMU-to- SMU interactions.

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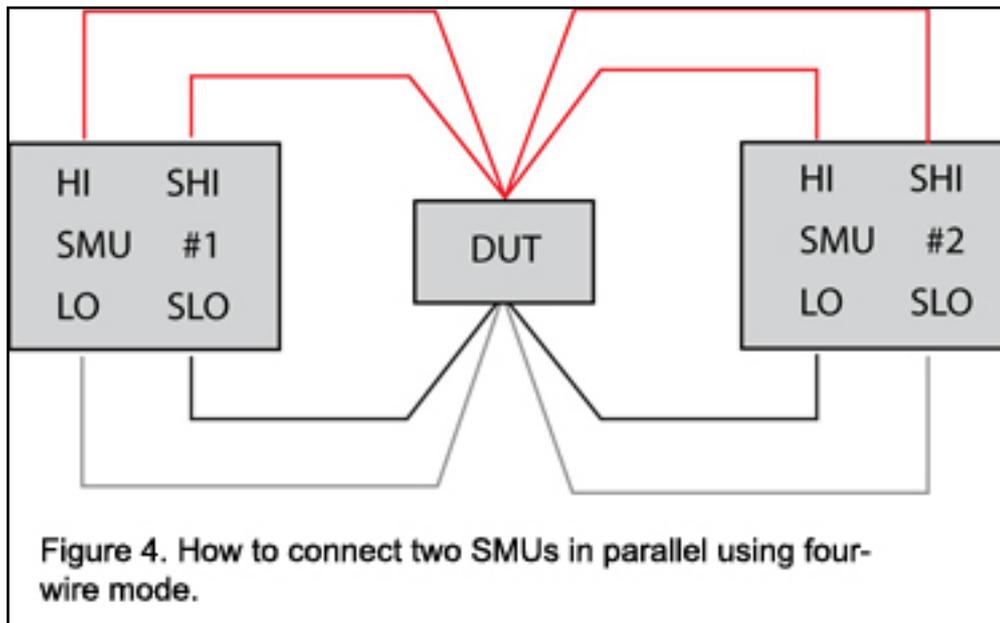
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\* Restrict both SMUs to the same region of the power envelope. In order for one SMU to sink all the current sourced by the other SMU, the sinking SMU must operate in a region of the power envelope that is equivalent to that of the sourcing SMU. When configured as a current source, the power envelope region in which the SMU operates is determined by the source current range and the voltage limit value.



combining SMUs in parallel, each SMU should be set to the same source current range so that the final determining factor for the region is the voltage limit. The high power SMU power envelope shown in Figure 3 has three ranges of voltage limit values that determine the operating region:  $>0V$  to  $?10V$ ,  $>10V$  to  $?20V$ , and  $>20V$  to  $?40V$ . For example, if one SMU's voltage limit is set to 20 V, then the other SMU's voltage limit should be set to a value that is less than 20 V and greater than 10 V in order to keep both SMUs in the same operating region.

\* Follow the simple connection diagram for combining two SMUs in parallel to achieve higher current shown in Figure 4. Because the latest generation of high power SMUs can produce such high currents, test leads (even those with very little resistance) can produce significant voltage drops and add significant error to the voltage measurements. To eliminate these errors, use four-wire connections on both SMUs. With this configuration, the test current is forced through one set of test leads, while the voltage across the DUT is measured through a second set of leads called the sense leads. Because the input resistance of the voltage measurement circuitry to which the sense leads are connected is extremely high, only a negligible amount of current can flow through them. Therefore, there is no voltage drop across them, so the voltage measured by the SMU will be the same as the voltage across the device. In the two-wire sense method, the same leads that are used to source the current are used to measure the voltage. Consequently, not only will the voltage across the device be measured, the measurement will also include the voltage drop across the test leads. Note that the voltage-sensing leads should be as closely connected to the DUT as possible to avoid the inclusion test lead resistance in the measurement.

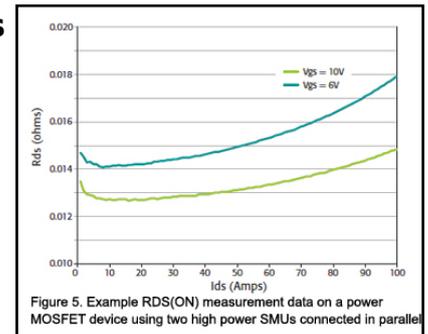


\* Always use cabling capable of supporting the high levels of current that high power SMUs can produce. The cable used must be designed for both low resistance and low inductance. When combining SMUs for higher currents such as a 40 A DC signal or 100 A pulse, 10 AWG or thicker wire should be used. Following these guidelines is critical; wiring that's not rated for the current being sourced can affect the performance of the SMU and could also create a potential fire hazard.

\* Set the appropriate compliance levels. In parallel configurations, the voltage limit of one SMU should be set 10 percent lower than the voltage limit of the other SMU. This allows only one SMU to go into compliance and become a voltage source. A SMU (or, in fact, any real current source) is limited in terms of how much voltage it can output in order to deliver the desired current. When a SMU's voltage limit is reached, the SMU goes into compliance and becomes a voltage source set to that voltage limit. When the compliance on one SMU is set lower than the compliance on the other, the voltage limit can only be reached by one of the SMUs. In other words, when the SMU with the lower voltage limit goes into compliance, it becomes a voltage source with low impedance and begins to sink the current from the other SMU, which can then source its programmed current level without needing to raise its output voltage any further and therefore will never achieve compliance. If both SMUs were to achieve compliance and become voltage sources, the system would have two voltage sources in parallel, which could allow an uncontrolled amount of current to flow between the SMUs, possibly leading to unexpected results and/or damage to the DUT. Such circumstances can also arise if the DUT becomes disconnected from the test circuit. Fortunately, this can easily be avoided simply by setting the compliance for one of the SMUs lower than that of the other SMU.

\* Select the output off-mode of each SMU. This mode determines whether a 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 whose voltage compliance is 10% less should be configured as a voltage source when its output is off. The SMU that has its voltage compliance set higher should be configured as a current source when its output is turned off.

## Test System Configuration for $R_{DS(ON)}$ Measurements



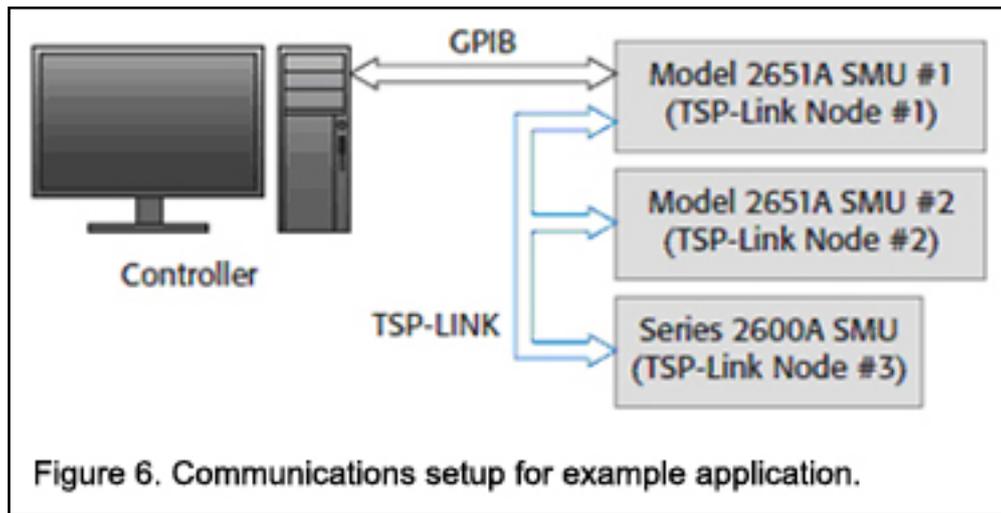
Although the test system outlined here is configured to collect  $R_{DS(ON)}$  measurement data for a power MOSFET device using a pulsed current sweep, it's easily modified for other applications. Keithley's Model 2651A High Power System SourceMeter instrument and another Series 2600A SMU are employed in this example. The following equipment is required to create the test configuration used to obtain the data plotted in Figure 5:

- \* Two Model 2651A High Power System SourceMeter instruments, which are connected in parallel to source up to 100A pulsed through the drain of the DUT.
- \* One Series 2600A System SourceMeter Instrument to control the gate of the DUT.
- \* Two TSP-Link cables for communications and precision timing between instruments.
- \* One GPIB cable or one Ethernet cable to connect the instruments to an external controller.

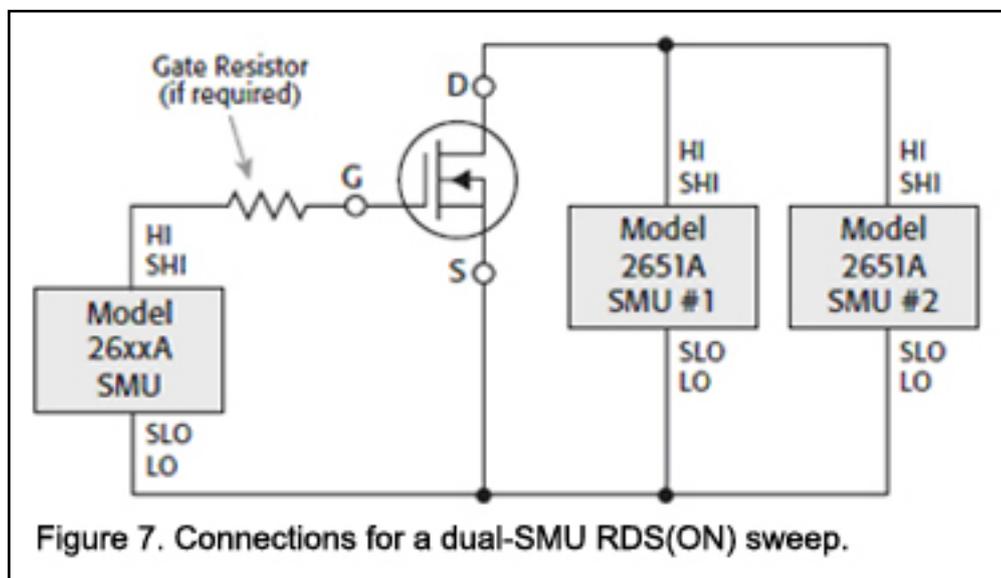
The communication setup is illustrated in Figure 6. Although the instrument in this example employs the GPIB interface to communicate with the PC, the system can be controlled using any of the other communication interfaces that the instruments support. In addition, the TSP-Link connection supports communication between the instruments, precision timing, and tight inter-unit synchronization. Figure 7 illustrates the required connections from the SMUs to the DUT. Ensuring good contact through all connections is essential. 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 at which the test leads are connected.

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Note: During high current pulsing, the gate of the DUT may begin to oscillate, creating an unstable voltage on the gate and, therefore, 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 SMU controlling the DUT's gate. If the gate remains unstable after the insertion of a dampening resistor, the SMU's high-capacitance mode should be turned on and the dampening resistor should be left in place.



## Conclusion

For in-depth information on configuring a test system, including the trigger models involved and all the code necessary to perform a pulsed RDS(ON) sweep up to 100 A, download Keithley's Application Note #3115: "[Combining Keithley Model 2651A High Power SourceMeter Instruments for 100A Operation](#) [1]."

## Biographical Note

David Wyban is an applications engineer with Keithley Instruments, Inc., Cleveland, Ohio, which is part of the Tektronix test and measurement portfolio. He joined the company in 2006, working on the team that developed Keithley's line of System SourceMeter instruments. He holds a bachelor's degree in electrical and computer engineering from The Ohio State University. He can be reached at [dwyban@keithley.com](mailto:dwyban@keithley.com) [2].

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[1] <http://www.keithley.com/data?asset=55819>

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