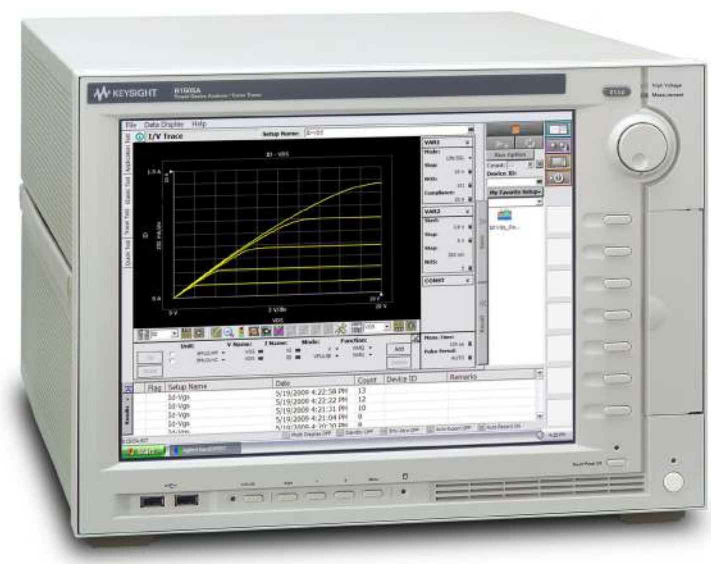
Keysight B1505A Power Device Analyzer/Curve Tracer

Application Note

Precision Power Device Evaluation at 40 Amps



KEYSIGHT TECHNOLOGIES

Introduction

Power devices play an important role in our modern world. They are used in a wide variety of applications from home electronics to industrial equipment, including such familiar items as TVs, refrigerators, PCs, FAXs, air conditioners, industrial robots, and electric vehicles. Stricter energy efficiency requirements are driving not only changes in electrical and electronics circuit design but also improvements to power devices such as power MOSFETs and IGBTs (Insulated Gate Bipolar Transistor). Specifically, it is desirable for power transistors to have lower power loss in their on-state and to possess a higher breakdown voltage in their off-state. The Keysight Technologies, Inc. B1505A Power Device Analyzer/Curve Tracer excels at evaluating and characterizing these types of power device properties.

The Keysight B1505A's HVSMU (High Voltage Source Monitor Unit) covers up to 3000 V and the B1505A's HCSMU (High Current Source Monitor Unit) outputs and measures up to 20 A. In addition, these modules can also perform very accurate current-voltage (IV) measurements in their high voltage and high current ranges. Keysight EasyEXPERT software also provides an easy-to-use user interface for both instrument control and data management and analysis. For all of these reasons, the B1505A is the best choice to evaluate and analyze modern state-of-the-art power devices.

This application note describes how you can combine the outputs from two HCSMUs together using optional adapters to expand the current range up to 40 A. EasyEXPERT software fully supports the adapters and allows you to treat the two HCSMUs as a single 40 A unit. The expanded 40 A current range improves the utility of the B1505A by allowing it to test more state-of-the-art, low power-loss transistors used in many consumer electronic products. In addition to showing how to combine two HCSMUs together to achieve 40 A, this application note also shows actual characterization examples of power MOSFETs.

Measurement Principles Using Two HCSMUs

SMUs can operate as either voltage or current sources in all four quadrants. They can force or sink current to a load device at a specified voltage. In other words, the SMU can function not only as a power supply but also as an active load (i.e. sinking current). The HCSMU can supply ±20 A at ±20 V in pulsed mode and ±1 A at ±40 V in both DC and pulsed modes.

Two HCSMUs can be configured in parallel to increase the maximum available current to 40 A in pulsed mode. Figure 1 shows a simplified circuit diagram for a power MOSFET measurement using this technique. As the adjacent graph in Figure 1 shows, the current range between the drain and source terminals is doubled.

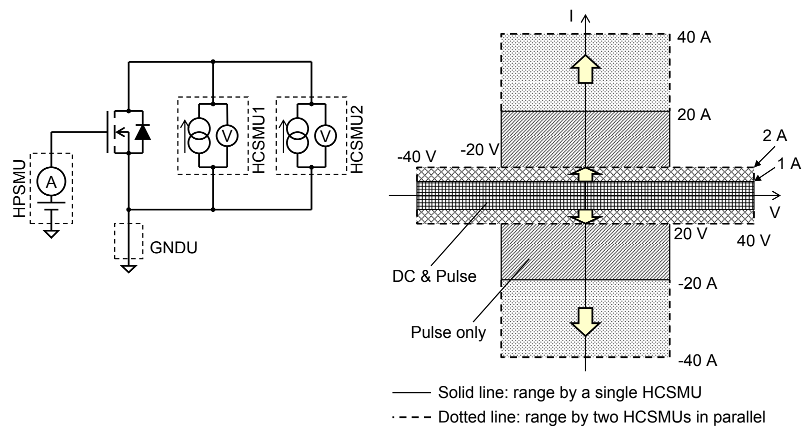


Figure 1.Two HCSMUs can be combined in parallel to expand the current range

The HCSMU has high-force, high-sense, low-force and low-sense terminals that support a Kelvin environment to cancel residual resistance in the measurement paths. The GNDU (Ground Unit) must be connected to the low terminal to provide zero potential to the low side because the HCSMU does not have an internal ground connection. The HCSMU supports both voltage force (VF) and current force (IF) modes.

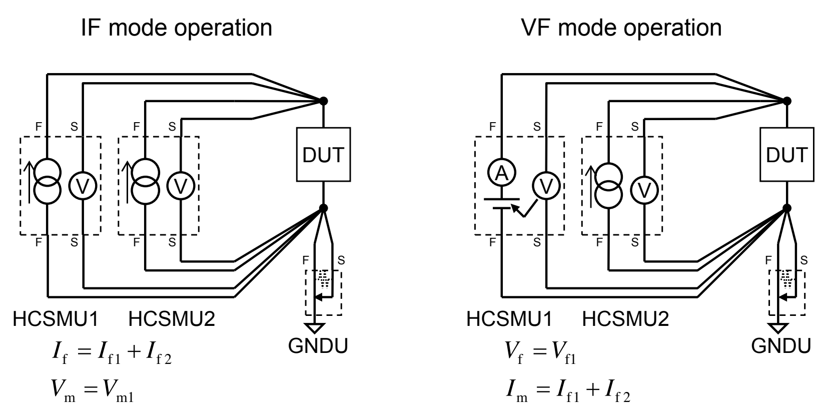


Figure 2.Block diagram of current force (IF) and voltage force (VF) modes using two HCSMUs in parallel.

Two HCSMUs connected in parallel can operate in two different ways: the first is both units in IF mode and the other is with one unit in VF mode and the other unit in IF mode. When both HCSMUs are in IF mode, both HCSMUs are supplying current to the device under test (DUT) and the voltage can be measured by either HCSMU. When the HCSMUs are in VF plus IF mode, one HCSMU forces current so that the sensed voltage matches that specified for the VF mode HCSMU and the other HCSMU supplies additional current to the DUT to make up for the current shortfall from the VF mode HCSMU. The first case is equivalent to IF mode operation and the second case is equivalent to the VF mode operation for a single HCSMU.

Figure 3 shows a measurement example for a diode in VF mode. HCSMU1 forces a constant current of I_1*force* and HCSMU2 forces a voltage of V_2*force* with a current compliance of I_2*comp*. When the output voltage V_2*force* is lower than the diode on-state voltage (case 1 in Figure 3), almost no current flows through the diode and HCSMU2 sinks the current I_1*force* from HCSMU1. When the output voltage V_2*force* increases enough so that the diode can conduct current (case 2 in Figure 3), HCSMU1 and HCSMU2 force currents I_1*force* and I_2*comp* (respectively). In both of these cases, all of the current from one HCSMU can flow into the other HCSMU without any problems since both modules can force and sink 20 A.

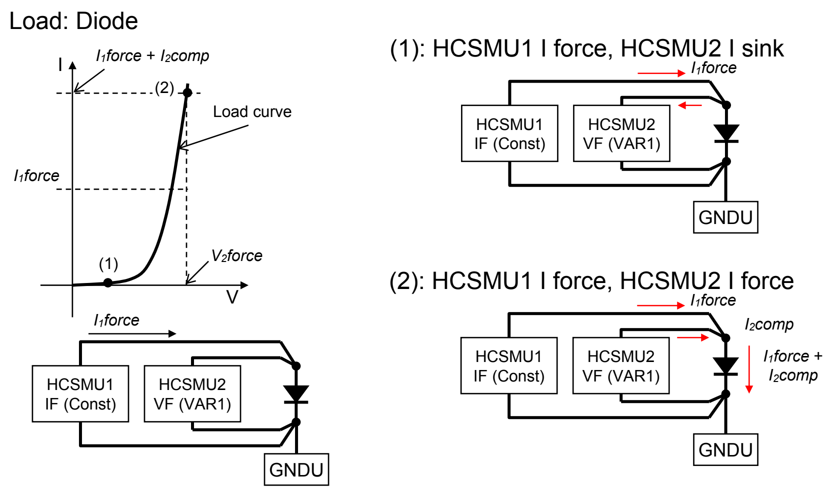


Figure 3. VF mode operation example using two HCSMUs in parallel

In the past many schemes have been proposed to increase the maximum available current using more than two SMUs – for example by combining four single channel SMUs in parallel. However, this technique is difficult to implement when making voltage sweep measurements. Because a single SMU cannot sink all of the current coming from all of the other SMUs in a worst-case scenario, it is possible for serious SMU damage to occur. This damage can be prevented by inserting a diode to prevent current from entering the force terminal of the VF mode SMU; however this technique requires careful programmatic control of the SMUs since the VF mode SMU then loses its ability to sink current. Developing such complex control programs takes too many resources for most users. Conversely, using two B1505A HCSMUs to source 40 A cannot cause any SMU damage and it is easy to control.

Practical High Current Measurements Considerations

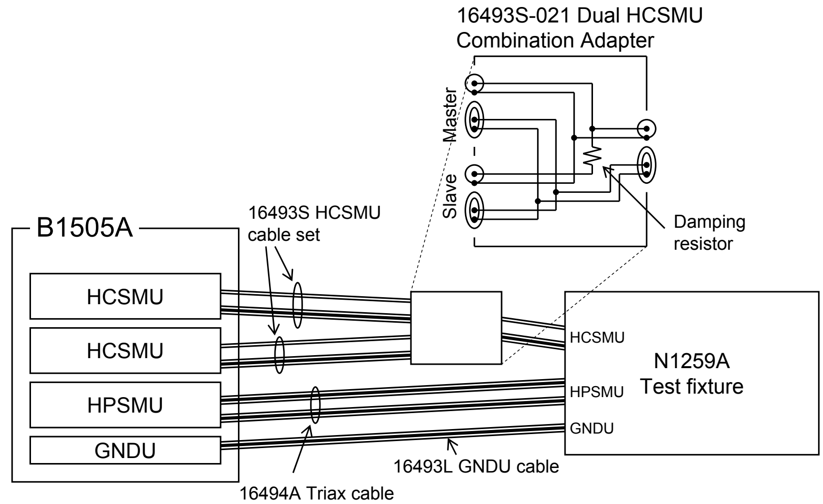


Figure 4. Block diagram showing two HCSMUs connected in parallel to the N1259A packaged device test fixture.

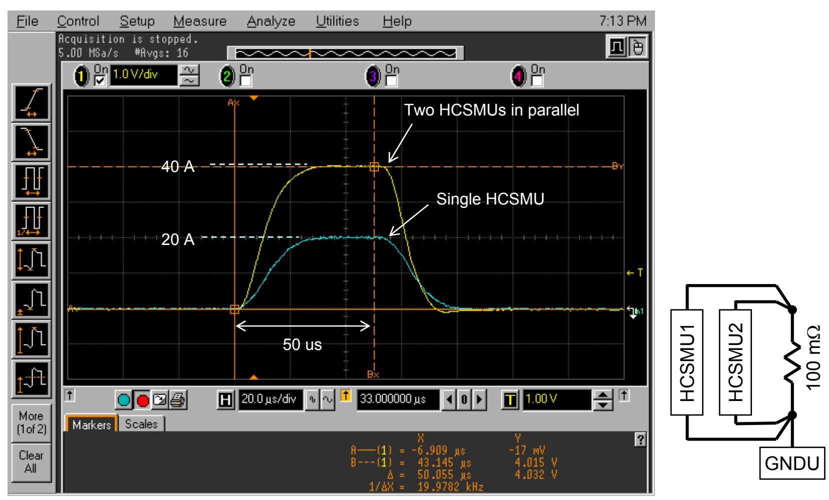


Figure 5. Waveforms comparing the output of a single HCSMU with two HCSMUs in parallel. The load is a 100 mΩ resistor.

The outputs from two HCSMUs can be combined using the 16493S-021 Dual HCSMU Combination Adapter, and the outputs of the adapter can be connected to the HCSMU input terminal of the N1259A test fixture as shown in the Figure 4. For the two HCSMUs connected using the dual HCSMU combination adapter one is designated as the *master* and the other is designated as the *slave*. The master HCSMU can be used in either IF or VF mode; the slave HCSMU then supplies any additional current that cannot be supplied by the master HCSMU. Note that even though a damping resistor (~0.4 Ω) is in the slave unit's high-force path to help stabilize measurements, the Kelvin configuration ensures that the presence of the damping resistor does not affect the accuracy of the IV measurements. Once the master and slave HCSMUs have been assigned on the B1505A's EasyEXPERT software configuration page, you can force and measure current as if a single 40 A HCSMU were installed in the B15050A.

The test fixture's module selector (N1259A option 300) allows you to switch between high current and high voltage measurements without having to change any cables. The outputs of the dual HCSMU combination adapter can be connected to the module selector HCSMU inputs on the N1259A test fixture. However, you can only force currents of 30 A when using the module selector. Currents greater than 30 A can damage the module selector.

The dual HCSMU combination adapter maintains the same pulse quality as that of a single HCSMU. Figure 5 shows sample output waveforms at the minimum pulse width of 50 µs into a resistor load of 100 mΩ. The lower waveform shows the output from a single HCSMU, with a peak voltage of 2.0 V across the 100 mΩ resistor (equivalent to a current of 20 A). The upper waveform shows the output from two HCSMUs in parallel, with a peak voltage of 4.0 V across the 100 mΩ resistor (equivalent to a current of 40 A). Both waveforms reach their peak voltages in about 30 µs, showing that the two parallel HCSMUs are well synchronized due to the HCSMU's advanced design. In addition, you can increase the pulse width by 1 ms increments (with 2 µs resolution) to refine the measurement timing, which is sometimes necessary because the rising edge characteristics of the pulse depend not only on the SMU but also on the characteristics of the DUT. The ability to vary the pulse width represents a major improvement over the fixed pulse width of conventional curve tracers.

When performing on-wafer measurements with a wafer prober, the 16493S-020 Dual HCSMU Kelvin Combination Adapter should be used (please refer to Figure 6). The two HCSMUs connect to the master and slave terminals of the dual HCSMU Kelvin combination adapter using 16493S HCSMU cable sets, and the GNDU connects to the GNDU terminal using a 16493L GNDU cable. The separate sense and force terminals of the adapter's high and low outputs are connected to the prober positioners and wafer chuck, which in-turn enable connectivity to a power MOSFET on the wafer. In this particular case an HPSMU (High Power Source Monitor Unit) is also connected to the MOSFET's gate terminal through a protection adapter (PA), which prevents the HPSMU from getting inadvertently damaged by high currents coming from the HCSMUs. Note that in some other cases the PA is not necessary and can be omitted. As this example shows, the dual HCSMU Kelvin combination makes it easy to combine two HCSMUs together when making on-wafer measurements.

You can also use the N1258A Module Selector for automatic switching between high current and high voltage measurements when making measurements on-wafer using a wafer prober. The outputs of the dual HCSMU combination adapter connect to the HCSMU inputs of the module selector unit exactly the same as in the test fixture case.

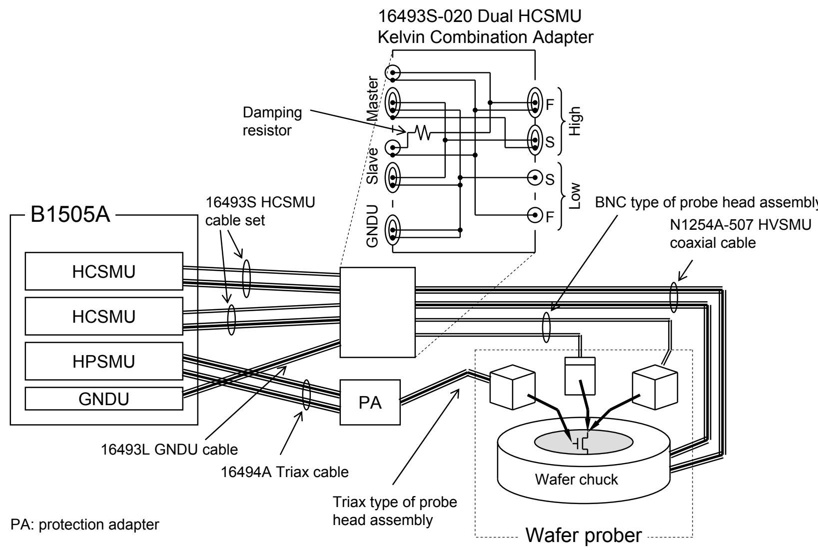
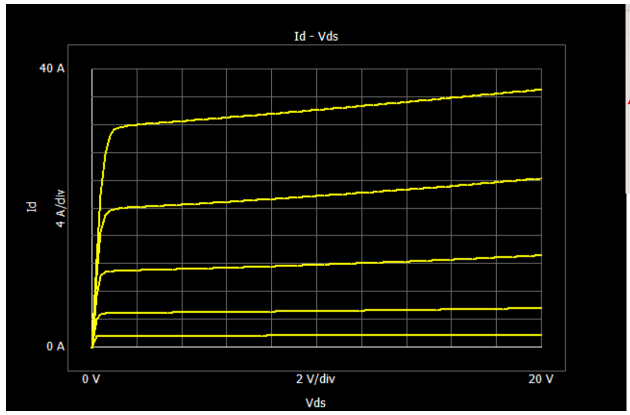


Figure 6. Block diagram of an on-wafer measurement using the 16493S-020 Dual HCSMU Kelvin Combination Adapter to place two HCSMUs in parallel (vertical MOSFET).

High Current Measurement Examples at 40 A

The EasyEXPERT software environment allows you to treat two HCSMUs combined using the 16493S dual combination adapter as a single 40 A HCSMU. Once the HCSMU information is properly entered onto the EasyEXPERT configuration page, a single HCSMU resource with 40 A at 20 V sourcing capability appears on the Tracer Test and Classic Test pages.

The Tracer Test mode allows you to measure IV characteristics at 40 A quickly and easily, just like on a conventional curve tracer. Figure 7 shows an example of Id-Vds characteristics for a packaged power MOSFET in which the maximum current is close to 40 A at 20 V. The Tracer Test mode makes it easy to change setup parameters by rotating the knob or by entering numbers from the keyboard even as the IV sweep measurements are being continuously executed.



Rotary Knob

Figure 7. Example Id-Vds characteristics of a packaged power MOSFET measured in Tracer Test mode. Vds is swept from 0 V to 40 V, and Vgs is stepped from 2.0 V to 2.8 V in 0.2 V steps.

The Classic Test mode has a lot of features that make it convenient for power device evaluation at 40 A. Figure 8 shows some sample device characteristics for a packaged power MOSFET with an Rds(on) resistance of 8 mΩ. The top-left graph shows the Id-Vds characteristics with the maximum Id close to 40 A. The top-right graph shows the Rds-Vgs characteristics at Id of 20 A and 40 A. The Rds (=Vds/Id) is automatically calculated via a user function and is plotted on a log scale of the Y-axis. This graph indicates values for Rds of about 10 mΩ and 7 mΩ for Vgs values of 4 V and 10 V (respectively). Note how the user function enables Rds to be plotted in real time and how the log scale plotting capability makes it easy to show data across many orders of magnitude, which represents a great improvement over conventional curve tracers that do not possess these capabilities. The bottom-left graph shows Rds-Id characteristics at Vgs of 10 V, and the Rds value is about 7 mΩ as Id is varied from 0.2 A to 40 A. The stability and repeatability of this Rds measurement demonstrates that the HCSMU can perform accurate millivolt measurements in pulsed mode. The bottom-right graph shows the parasitic diode (Is-Vsd) characteristics under forward bias condition at up to 40 A, which is measured by having the HCSMUs apply a negative pulsed bias. All of these pulse mode measurements are performed with a pulse period of 1 ms and a pulse duty cycle of 0.1 %.

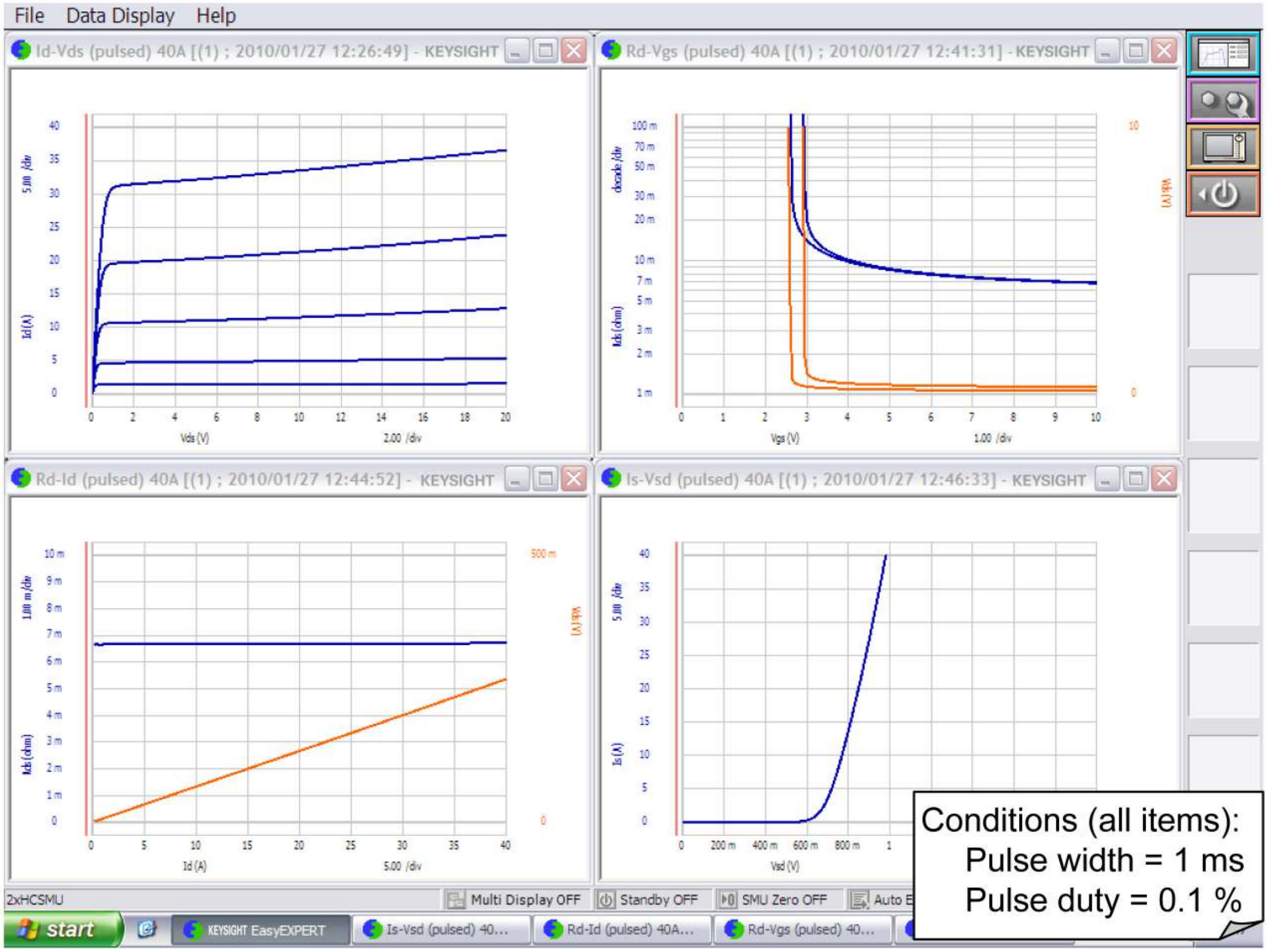


Figure 8. Sample Rds(on) measurements of a packaged power MOSFET (Rds(on) ≈ 8 mΩ). Plots show the Id-Vds, Rds-Vgs, Rds-Id, and Is-Vsd characteristics.

Conclusion

The Keysight B1505A supports the B1512A HCSMU that can source 20 A at 20 V in pulsed mode. This application note has described how two HCSMUs can be combined in parallel using the Dual HCSMU Combination Adapter to expand the B1505A's current range up to 40 A at 20 V. Keysight EasyEXPERT software allows you to control the two HCSMUs as if a single 40 A HCSMU resource were installed in the B1505A. These features not only extend the power device current measurement range, but also free the user from complex programming tasks and from having to worry about possible hardware damage.

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