Measuring Power MOSFET Electrical Characteristics using the B1505A
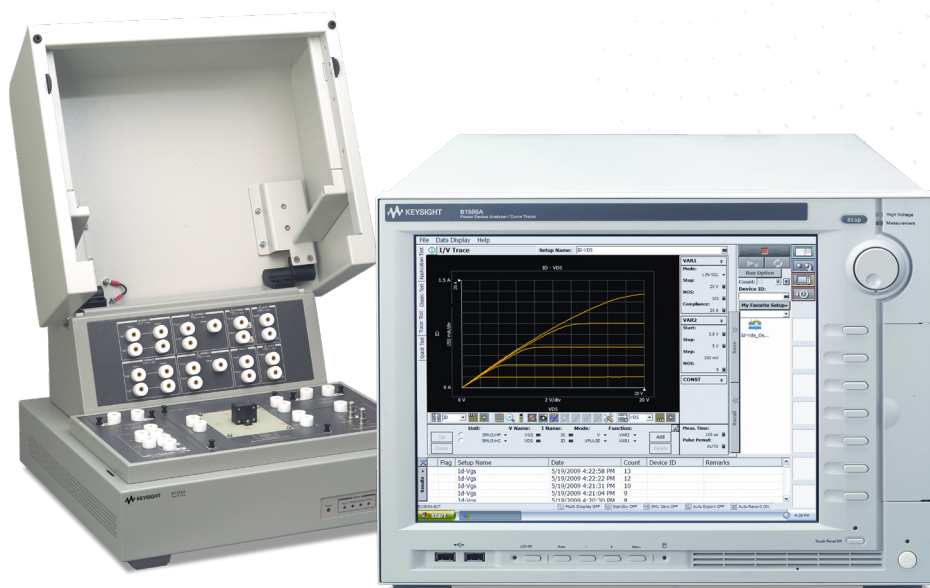
B1505A Power Device Analyzer/Curve Tracer

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Introduction

The Keysight Technologies, Inc. B1505A Power Device Analyzer/Curve Tracer is a powerful tool for measuring and characterizing power devices, with many advanced features that improve measurement efficiency and accuracy.

The B1505A employs Source/Measure Unit (SMU) technology and has 40 A and 3 kV sourcing capability. This makes it much easier to apply precise currents and voltages to a device and to perform fast and accurate parameter extraction than is possible with a traditional analog curve tracer.

The B1505A can perform accurate capacitance versus voltage (CV) measurement at up to 3 kV of DC bias. In addition, during high-voltage CV measurement you can use the B1505A's available SMUs to bias non-measurement terminals to facilitate the extraction of complex CV parameters. The B1505A makes it easy to directly measure MOSFET data sheet capacitance parameters such as Ciss, Coss and Crss.

EasyEXPERT, the GUI-based software resident on the B1505A, supports the automatic extraction of Power MOSFET parameters (including the auto-placement of lines and markers), eliminating the need for manual post-measurement adjustments. The B1505A is a powerful replacement for traditional curve-tracers that provides both improved test efficiency and measurement accuracy. This application note explains how to use the B1505A to measure the typical DC and capacitance parameters of power MOSFET devices.

Typical MOSFET Parameters

The DC and capacitance parameters listed in a typical power MOSFET data or specification sheet are summarized in table 1. The two right-most columns indicate whether or not the B1505A can measure a parameter and the B1505A's measurement range for that parameter.

Previously, these parameters were only measurable using either a DC test system or a collection of instruments that included a curve tracer, a CV meter and a DC bias source. However, with the introduction of the B1505A, all of these parameters can be measured by a single-box instrument solution.

Table 1. Typical DC and Capacitance parameters of power MOSFET and the compatibility of the B1505A.

Typical power MOSFET Parameter	Symbol	Unit	Measurement[1]	Measureable by B1505A	Typical Measurable Range of B1505A
Drain-to-Source Breakdown Voltage	V(BR)DSS	V	Id-Vd	YES	–3,000 V to 3,000 V (Minimum 200 µV resolution)[2]
Gate-to-Source Voltage	VGSS	V	Ig-Vg	YES	–200 V to 200 V (Minimum 2 µV resolution)[3]
Drain Current (DC)	ID	A	Id-Vd	YES	–2 A to 2 A (Minimum 10 pA resolution)[4]
Drain Current (Pulse)	IDP, IDM	A	Id-Vd	YES	–40 A to 40 A (Minimum 10 pA resolution)[4]
Drain-to-Source Leakage Current	IDSS	A	Id-Vd	YES	–8 mA to 8 mA (Minimum 10 fA resoluion, ≤ 1,500 V)[5]
Gate-to-Source Leakage Current	IGSS	A	Ig-Vg	YES	–1 A to 1 A (Minimum 10 fA resolution)[3]
Gate threshold Voltage, or Cutoff Voltage	VGS(th) VGS(off)	V	Id-Vg	YES	-200 V to 200 V (Minimum 2 µV resolution)[3]
Forward Transfer Admittance, or Forward Transconductance	|yfs| Gfs	S	Vd-Id @Vds	YES	1 mS ~ 1000 S[6]
Static Drain-to-Source On-State Resistance	RDS(on)	ohm	Vd-Vg @Id	YES	Better than 100 µΩ[7]
Diode Forward Voltage	VSD	V	Is-Vs	YES	–40 A to 40 A (Minimum 10 pA resolution)[4]
Reverse Drain Current	ISD	A	Is-Vs	YES	–40 A to 40 A (Minimum 10 pA resolution)[4]
Input Capacitance	Ciss	pF	C-V	YES	Better than 1% at C<10 nF[8]
Output Capacitance	Coss	pF	C-V	YES	Better than 1% at C<10 nF[8]
Reverse Transfer Capacitance	Crss	pF	C-V	YES	Better than 1% at C<10 nF[8]

1. Measurement used for extracting the parameter.
2. HVSMU
3. HPSMU
4. With two HCSMUs and requires Dual HCSMU Combination Adapter.
5. Maximum 4 mA at 3,000 V.
6. Rule of thumb (Example: 1mA/1V ~ 1A/1mV)
7. Rule of thumb (Example: 1 mV/10 A)
8. Max. 3,000V DC bias with High-voltage Bias T adapter.

Typical Power MOSFET Parameter Measurements

Typical power MOSFET parameters can be measured easily using the B1505A. The following section illustrates how to measure some of the power MOSFET parameters listed in table 1.

Multiple test modes available

The B1505A has three available test modes: Application Test, Classic Test and Tracer Test. Each of these test modes has unique capabilities, and the choice of which one to use in a given situation depends upon a variety of factors (including personal preference). The following descriptions briefly highlight the features of each test mode.

The Application Test mode includes a library of pre-defined tests that eliminate the need to manually specify most of the instrument parameters for common tests (such as Id-Vd measurements). The user can perform a measurement through an intuitive "fill in the blanks" procedure. Measurements are performed and parameters are automatically extracted with just the simple click of the measurement button.

The Classic Test mode resembles the user interface of the Keysight 4155/4156 Semiconductor Parameter Analyzers, and users familiar with these popular instruments can easily use Classic Test mode to create measurement setups. Any application not furnished in the Application Test mode library can be performed using Classic Test mode. In fact, Classic Test mode represents the fundamental method of instrument control, and all of the pre-defined application tests included in the Application Test mode libraries internally use the Classic Test mode.

The Tracer Test mode emulates an analog curve tracer, allowing parameters to be modified in real time during a measurement using the knob on the B1505A's front panel. This ability to get real-time feedback on device parameters (such as breakdown voltage) while varying a voltage or current input can be invaluable when characterizing or performing a quick check on new or unknown devices. The following measurement examples illustrate power MOSFET parameter extraction using these different test modes.

## 1. Drain-to-Source Breakdown Voltage: V(BR)DSS

The Id(off)-Vds application test shown in figure 1 extracts two parameters: V(BR)DSS and IDSS. Figure 1(a) shows the GUI-based measurement parameter setup window that includes a schematic detailing the connections between the device terminals and the SMUs. You can begin measuring after specifying the SMU connections and modifying the default measurement parameters as necessary. Sample test results are shown in figure 1(b), with the automatically extracted parameters of 1.64 kV for VBDSS and 102 nA for IDSS shown in the parameter field of the output.

As this example shows, the Application Test mode makes performing a complex parameter extraction straightforward and simple. This allows the user to focus on their real objective of making the measurement, and it also eliminates many of the errors associated with creating a test setup from scratch.

Keysight has a Power MOSFET application handbook available that explains how to use the B1505A's new and furnished application tests to measure all of the parameters shown in table 1.
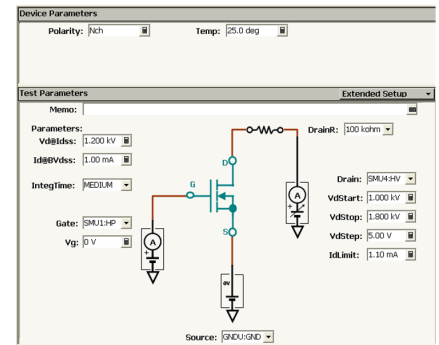
(a) Test parameter setup window
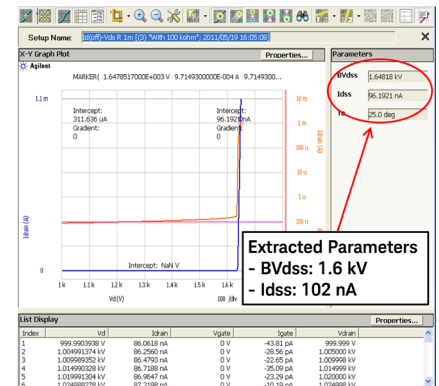
(b) Test result window

Figure 1. V(BR)DSS measurement example using new Id(off)-Vds R Application Test.

2. Drain Current: Id-Vd

Drain current is usually evaluated by measuring the Id-Vd characteristics. Figure 2 shows how these can be measured using the Id-Vds application test.

Power device drain current characterization is typically performed using pulsed inputs with short pulse widths to eliminate self heating effects. The B1505A's minimum pulse width of 50 µs effectively minimizes self-heating effects and enables the achievement of accurate and stable test results.
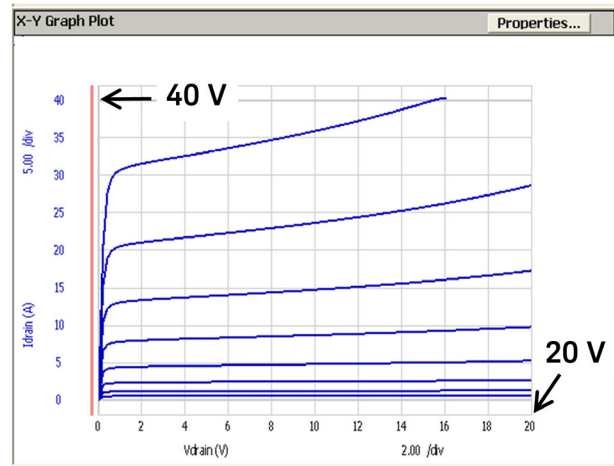

Figure 2. 40A pulsed Id-Vd plot using Id-Vd application test. Note: Two HCSMUs are combined in parallel.

3. Static Drain-to-Source On-State Resistance: RDS(on)

It is possible to measure the data sheet parameter RDS(on) using Classic Test mode to sweep the gate voltage as shown in Figure 3. Figure 3(a) shows one of the Classic Test mode parameter setup windows, and figure 3(b) shows the measurement output. As can be seen, the output of Classic Test is the same as that of an application test. This is perfectly logical since all application tests ultimately use the Classic Test mode as their measurement engine. Using Classic Test mode you can perform the same measurements as you can using the Application Test mode, except that in Classic Test mode there is no elaborate GUI like that shown in figure 1(a).

Of course, using the EasyEXPERT application test editor you can create a GUI interface for any Classic Test and thereby convert it into a new application test.
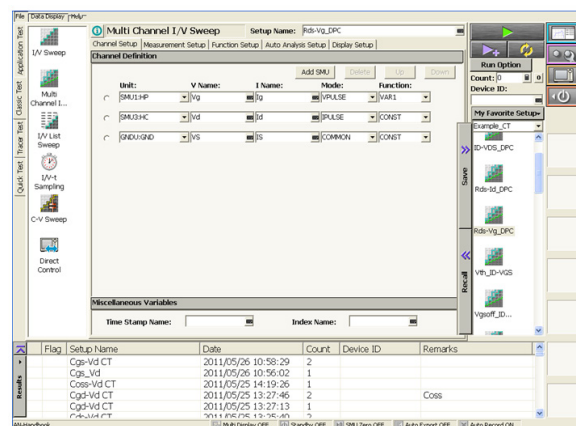
(a) Test parameter setup window of Classic Test
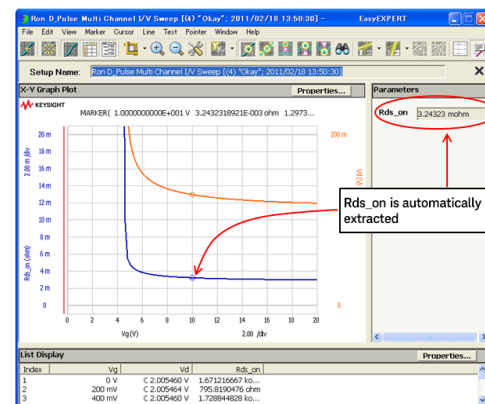
(b) Test result window Classic Test

Figure 3. RDS(on) measurement using the Classic Test mode.

4. Diode Forward Voltage and Reverse Drain Current: VSD, ISD

Figure 4 shows a measurement that uses the Tracer Test mode to measure VSD and ISD using the dual polarity sweep function. This example shows how Tracer Test mode's interactive knob sweep capability allows the user to interactively control the maximum voltage in the sweep in real time as the measurement is being made. Knob sweep is especially useful for failure analysis, since the voltages and currents that need to be applied are usually not known before the user begins to make a measurement.

Tracer Test mode supports unique capabilities that are not available in traditional curve tracers, such as the ability to add markers and lines exactly on the curve and to capture the screen image in a PC-compatible format. In Tracer Test mode the B1505A also supports a real time data capture feature that saves recent measurement data into a memory buffer. Even if your device is inadvertently damaged or destroyed, this feature allows you to display recorded measurement data right up to the point where the damage occurred. None of the features listed above are available in traditional analog curve tracers, and the combination of them with the B1505A's precision measurement capabilities create a powerful and unique solution for characterizing power devices.

Keysight recognizes that one major barrier when switching to a new test system is the cost of the test fixtures. Therefore, the Keysight N1259A High Power Test Fixture for the B1505A supports a test adapter socket module that enables you to use legacy interfaces designed for the Tektronix 370B and 371B curve tracers.

Figure 4. VSD and ISD quadrant sweep using the Tracer Test mode.

5. Step by Step Measurement Handbook

The detail of the test setup to make the measurements with the B1505A for each test specifications listed in table 1 are available in the "Step by Step Measurement Handbook for Power MOSFET by Keysight B1505A", including the setup files and sample application test definitions. This handbook can be downloaded from the Keysight B1505A website at: www.keysight.com/find/B1505a.
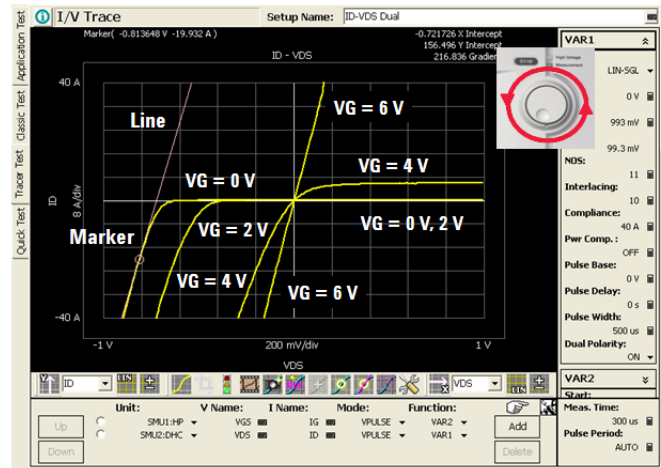
Conclusion

This application note explains how the B1505A can measure the typical DC and capacitance parameters specified on a commercial power MOSFET data sheet.

The measurement range of the B1505A is up to 3 kV and 40 A, and it also supports high-voltage CV measurement with up to 3 kV of DC bias (using the high-voltage bias-T). These capabilities combine with the B1505A's many other data analysis features to create a state-of-the-art tool for power MOSFET measurement that far surpasses the abilities of a traditional curve tracer.

The B1505A's three modes of operation (Application Test mode, Classic Test mode and Tracer Test mode) provide the user with different options for device evaluation for maximum measurement flexibility. The B1505A's N1259A test fixture supports a socket adapter that permits the use of legacy Tektronix curve tracer test fixtures.More detail on the test setups as well as tips for making measurements with the B1505A for each of the test specifications listed in table 1 are available in Keysight's free Power MOSFET Test Handbook, including the test setup files and new sample application test definitions covered in this application note.

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