Keysight Technologies
Measuring Power BJT Electrical Characteristics using the B1505A

B1505A Power Device Analyzer/Curve Tracer

Application Note

KEYSIGHT TECHNOLOGIES

Introduction

The Keysight Technologies, Inc. B1505A Power Device Analyzer/Curve Tracer is a powerful tool for measuring and characterizing power bipolar junction transistors (BJTs). The B1500A has many advanced features that greatly improve measurement efficiency. 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. The B1505A makes it easy to directly measure BJT data sheet capacitance parameters.

EasyEXPERT, the GUI-based software resident on the B1505A, supports the automatic extraction of Power BJT 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 the B1505A can measure the typical DC and capacitance parameters of power BJT devices.

Typical Power BJT Parameters

The DC and capacitance parameters listed in a typical power BJT data or specification sheet are summarized in table 1. The right-most column indicates 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 BJT and the measurement range of the B1505A.

Typical power BJT Parameter	Symbol	Unit	Measurement[1]	Typical Measurable Range of B1505A
Collector Current	Ic	A	Ic-Vce	–40 A to 40 A (Minimum 10 fA resolution)[2]
DC Current gain	hFE		Ic-Ib	1 ~ 10000[3]
Collector Emitter Sustaining Voltage	VCE(SUS)	V	Ic-Vceo	–3,000 V to 3,000 V (Minimum 200 µV resolution)[4]
Collector Emitter Breakdown Voltage	V(BR)CEO			
Collector-Emitter Cut-off Current	ICEO	A	Ic-Vceo	–8 mA to 8 mA (Minimum 10 fA resoluion)[4]
Collector-Base Voltage	VCBO	V	Ic-Vcbo	–3,000 V to 3,000 V (Minimum 200 µV resolution)[5]
Collector-Base Cut-off Current	ICBO	A	Ic-Vcbo	–8 mA to 8 mA (Minimum 10 fA resolution)[4]
Emitter-Base Voltage	VEBO	V	Ie-Vebo	–20 V to 20 V (Minimum 2 µV resolution)[6]
Emitter Cut-off Current	IEBO	A	Ie-Vebo	–1 A to 1 A (Minimum 10 fA resolution)[7]
Collector-Emitter Saturation Voltage	VCE(sat)	V	Vce(sat)-Ic	–20 V to 20 V (Minimum 2 µV resolution)[6]
Collector-Base Saturation Voltage	VBE(sat)	V	Vce(sat)-Ic	–20 V to 20 V (Minimum 2 µV resolution)[6]
Base Emitter ON Voltage	VBE(on)	V	Ic-Vbe	–20 V to 20 V (Minimum 2 µV resolution)[6]
Collector-Emitter Voltage (Base-Emitter short)	VCES	V	Ic-Vces	–3,000 V to 3,000 V (Minimum 200 µV resolution)[5]
Output Capacitance	Cob	pF	C-V	Better than 1% at C<10 nF[8]

1. Measurement used for extracting the parameter.
2. With two HCSMUs and requires Dual HCSMU Combination Adapter.
3. Rule of thumb (Example (Ic/Ib): 20 A/20 A ~ 1 A/100 µA).
4. HVSMU. Maximum 4 mA at 3 kV, 8 mA at 1,500 V.
5. HVSMU.
6. HPSMU and HCSMU. 2 µV resolution at 2 V range.
7. HPSMU at 20 V range.
8. Max. 3,000 V DC bias with High-voltage Bias T adapter.

Typical Power BJT Parameter Measurements

Typical power BJT parameters can be measured easily using the B1505A. The following section illustrates how to measure some of the power BJT 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 Ic-Vce 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.

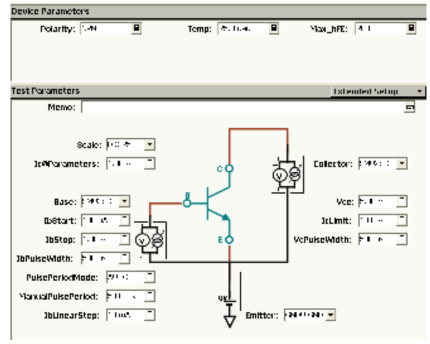
The following measurement examples illustrate power MOSFET parameter extraction using these different test modes.

1. DC Current gain: hFE

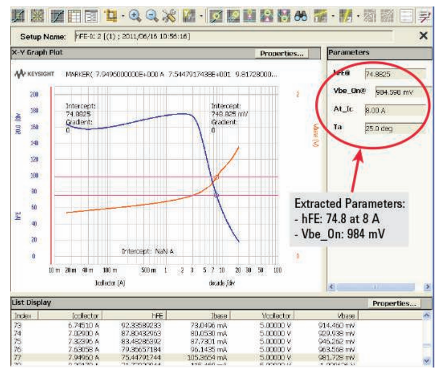
The hFE-Ic Application Test shown in figure 1 measures two parameters: hFE and Vbe. Figure 1(a) shows the GUI-based measurement parameter setup window that includes a schematic detailing the connections between the device terminals and the SMUs. You can begin measuring after specifying the SMU connections and modifying the default measurement parameters as necessary. Sample test results are shown in figure 1(b), with the automatically extracted parameters of 74.8 for hFE and 984 mV for Vbe_On at 8 A collector current shown in the parameters 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 BJT measurement 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. hFE-Ic and Vbe-Ic measurement example using new hFE-Ic Application Test.

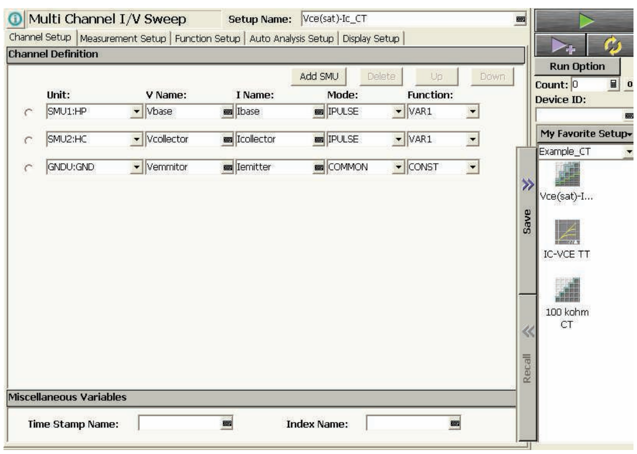
2. Collector-Emitter voltage: Vce(sat)

It is possible to measure the data sheet parameter Vce(sat) using Classic Test mode to sweep the collector current as shown in Figure 2. Figure 2(a) shows one of the Classic Test mode parameter setup windows, and figure 2(b) shows the measurement output. It shows automatically extracted Vce(sat) and Vbe(sat) parameters in the parameters field of the output.

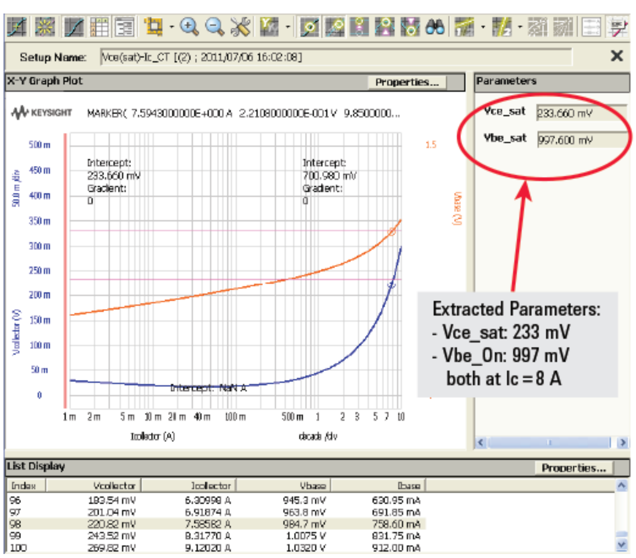
As can be seen, the output of Classic Test is the same as that of an application test. This is perfectly logical since all application tests ultimately use the Classic Test mode as their measurement engine. Using Classic Test mode you can perform the same measurements as you can using the Application 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.

Power device 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.



(a) Test parameter setup window of Classic Test



(b) Test result window of Classic Test

Figure 2. Vce_sat and Vbe_sat measurement example using Vce(sat)-Ic_CT Classic Test.

3. Collector characteristics: Ic-Vce

Figure 3 shows a measurement that uses the Tracer Test mode to measure Ic-Vce collector characteristics. 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.

Note that figure 3 measurement was made with the power compliance set at 230 W (limit shown in red line) so as to not exceed the maximum power rating of the example device.

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.

Step by Step Measurement Handbook

The detail of the test setup and the tips of the measurements with the B1505A for each test specifications listed in table 1 are available as "Step by Step Measurement Handbook for Power BJT by Keysight B1505A" with the new example application test definitions through Keysight web. Visit www.keysight.com/find/B1505A for downloading the measurement handbook.

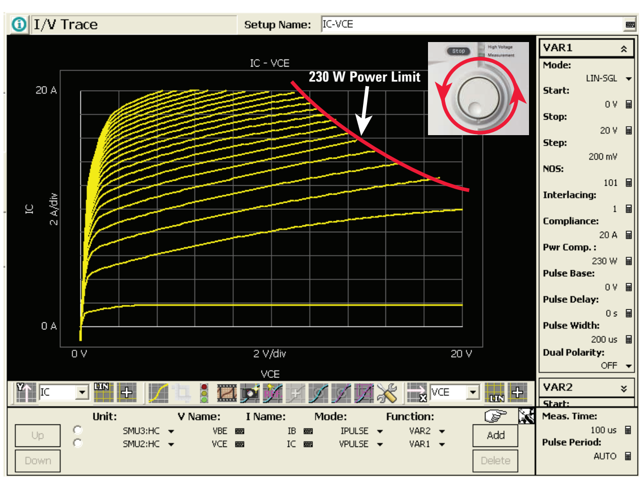


Figure 3. Ic Vce Tracer Test example.

Conclusion

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

The measurement range of the B1505A is up to 3 kV and 40A, 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 BJT 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 Tek 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 Agilent`s free Power BJT measurement handbook, including the test setup files and new sample application test definitions covered in this application note.

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Published in USA, August 1, 2014
5990-8988EN
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