Why Migrate from the 4155C and 4156C to the B1500A?
Introduction

Recent advancements in device and process technology present new parametric characterization challenges. This includes both more precise measurement requirements of static and dynamic device parameters and the ability to measure and analyze large volumes of parametric data more efficiently.

For many years, the Keysight 4155C and 4156C Semiconductor Parameter Analyzers have been the de facto industry standard for semiconductor parameter analyzers. However, they are now obsolete.

The Keysight B1500A Semiconductor Device Analyzer is the next generation of parameter analyzers. It is capable of meeting these new challenges instead of the 4155C/4156C.

This application note details the top 3 reasons to migrate from the 4155C/4156C to the B1500A:

1. Broader Measurement Coverage
2. Easy-to-Use and Intuitive EasyEXPERT group+ Software
3. Convenient Tools to Ease Migration from the 4155/4156 to the B1500A
1. Broader Measurement Coverage

Table 1 shows a comparison of the B1500A and the 4155C/4156C measurement capabilities.

**Module configuration**

The 4155C/4156C are fixed-configuration instruments, but it is expandable via the Keysight 41501B SMU and Pulse Generator Expander unit. The 41501B allows users to add either a High Power SMU (HPSMU) or two additional Medium Power SMUs (MPSMUs). It also allows the addition of two Pulse Generator Units (PGUs).

Table 1. Comparison of B1500A and 4155C/4156C measurement capabilities

<table>
<thead>
<tr>
<th></th>
<th>B1500A</th>
<th>4155C/4156C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Module configuration</strong></td>
<td>1 to 10 SMUs</td>
<td>4 to 6 SMUs 1</td>
</tr>
<tr>
<td></td>
<td>1 to 4 HPSMUs</td>
<td>1 HPSMU 2</td>
</tr>
<tr>
<td></td>
<td>1 GNDU (4.2 A)</td>
<td>1 GNDU (1.6 A) 2</td>
</tr>
<tr>
<td></td>
<td>No VSU/VMUs 3</td>
<td>2 VSUs and 2 VMUs</td>
</tr>
<tr>
<td></td>
<td>1 MFCMU</td>
<td>Not Available</td>
</tr>
<tr>
<td></td>
<td>1 to 5 (1 to 10 Ch) HV-SPGUs 4</td>
<td>2 PGUs 2</td>
</tr>
<tr>
<td></td>
<td>1 to 5 (1 to 10 Ch) WGFMU 4</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Measurement resolution</strong></td>
<td>Current</td>
<td>Voltage</td>
</tr>
<tr>
<td></td>
<td>1 fA (HRSMU)</td>
<td>0.1 fA (HRS MU or MPS MU + ASU)</td>
</tr>
<tr>
<td></td>
<td>0.1 fA (HRSMU or MPSMU + ASU)</td>
<td>15 fA (10 pA range HRSMU)</td>
</tr>
<tr>
<td></td>
<td>120 μV (0.5 V range MP/HRSMU)</td>
<td>200 μV (2 V range SMU)</td>
</tr>
<tr>
<td><strong>Measurement accuracy (offset)</strong></td>
<td>Standby mode</td>
<td>Available</td>
</tr>
<tr>
<td></td>
<td>Available</td>
<td>Available</td>
</tr>
<tr>
<td></td>
<td>Current offset cancel</td>
<td>Multi-channel meas.</td>
</tr>
<tr>
<td></td>
<td>Available</td>
<td>100 μs min. interval</td>
</tr>
<tr>
<td></td>
<td>Multi-channel meas., 5 ns min. interval</td>
<td>20,000 counts of full-scale resolution (SMU)</td>
</tr>
<tr>
<td><strong>Specialized measurement functions</strong></td>
<td>High-speed sampling</td>
<td>Multi-channel meas. (SMU or WGFMU)</td>
</tr>
<tr>
<td></td>
<td>Multi-channel meas. (SMU or WGF MU)</td>
<td>Single-channel meas.</td>
</tr>
<tr>
<td></td>
<td>100 μs min. interval</td>
<td>60 μs min. interval</td>
</tr>
<tr>
<td></td>
<td>20,000 counts of full-scale resolution (SMU)</td>
<td>1,000 counts of full-scale resolution (SMU)</td>
</tr>
<tr>
<td></td>
<td>Multi-channel meas. (SMU or WGF MU)</td>
<td></td>
</tr>
<tr>
<td><strong>Pulse generator</strong></td>
<td>Pulsed sweep</td>
<td>Available</td>
</tr>
<tr>
<td></td>
<td>Available</td>
<td>Available</td>
</tr>
<tr>
<td></td>
<td>Single-channel meas.</td>
<td>Available</td>
</tr>
<tr>
<td></td>
<td>I/V knob sweep</td>
<td>Available</td>
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<tr>
<td></td>
<td>Frequency range</td>
<td>1 Hz to 33 MHz (HV-SPGU)</td>
</tr>
<tr>
<td></td>
<td>SCU, ASU or B2200/01A, E5250A</td>
<td>E5250A</td>
</tr>
</tbody>
</table>

1. 6 SMUs by using the 41501B with 4155C or 4156C.
2. Using the 41501B either with the 4155C or 4156C.
3. SMUs can be used for the VSU and VMU.
4. 2 channels / module.
In contrast, the B1500A has 10 slots that enable you to install SMUs and other types of modules. The B1500A supports the same types of SMUs found in the 4155C and 4156C. However, since the B1500A is modular, the user can select and configure the exact SMU combination that they need.

**SMU output/measurement range and accuracy/resolution**

The B1500A SMUs have wider voltage/current outputs, broader measurement ranges, and better accuracy than the 4155C/4156C SMUs.

**Minimum current resolution**

The current measurement resolution provided by the B1500A’s atto-sense and switch unit (ASU) is approximately 10 times better than that provided by the 4156C’s High-Resolution SMU (HRSMU). When we use the ASU in conjunction with the MPSMU or HRSMU, the minimum current resolution of the B1500A is 100 aA (or 0.1 fA). A measurement resolution of 100 aA is useful when measuring a very low-level leakage current found in memory cells.

**Voltage measurement accuracy**

Although the B1500A does not support a voltage source unit (VSU) or voltage monitor unit (VMU), the B1500A MPSMUs and HRSMUs can provide similar or better voltage measurement performance. In addition, for more exacting measurements, it is preferable to use an external DVM such as the Keysight 3458A Digital Multimeter, which provides very precise levels of voltage measurement accuracy. The B1500A’s EasyEXPERT group+ software has application tests available to control the 3458A via GPIB.

*Figure 1.* The ASU provides 100 aA current measurement resolution.
Multi-frequency capacitance measurement unit

Figure 2 shows an I/V and CV measurement setup using two SMUs, the multi-frequency capacitance measurement unit (MFCMU) and the SMU CMU unify unit (SCUU). The one-slot MFCMU can make frequency sweeps or spot CV measurements from 1 kHz to 5 MHz.

![Figure 2](image)

**Figure 2.** Accurate I/V and CV measurement setup using SMU, MFCMU and SCUU.

You can switch the MFCMU and SMU outputs using the SCUU, as illustrated in Figure 3. The SCUU enables the user to make I/V and CV measurements without sacrificing any measurement accuracy. Besides taking care of switching and accuracy issues, the combination of the B1500A software with the SCUU hardware also solves CV measurement compensation and current return path issues. All of this is done automatically, without requiring the user to have a detailed understanding of the measurement theory involved.

In addition, using the SCUU, the CV measurement DC bias voltage can be extended to ±100 V, which is well beyond the inherent ±25 V capability of the MFCMU.

![Figure 3](image)

**Figure 3.** SCUU switches between SMUs and MFCMU.
High voltage semiconductor pulse generator unit

We specifically designed the high-voltage semiconductor pulse generator unit (HV-SPGU) to meet the challenges posed by advanced flash memory testing needs such as a multibit or multi-level cell (MLC) and charge trap flash memory. The HV-SPGU possesses both a ±40 V output capability and an arbitrary linear waveform generation (ALWG) function that permits the creation of complex waveforms for characterizing novel new flash cell technologies. The ultra-fast switching speeds of the semiconductor switches in the HV-SPGU outputs dramatically reduce flash endurance testing write and erase cycle times compared with the 4155C/4156C’s PGU-based solutions.

Waveform generator/fast measurement unit

The Waveform Generator/Fast Measurement Unit (WGFMU) is a new measurement resource developed to characterize dynamic device characteristics accurately. Previously, dynamic device measurement solutions have consisted of user-configured instrument setups, usually consisting of a pulse or function generator, a current to voltage converter, and an oscilloscope (or voltage sampler). However, these measurement solutions have had difficulty producing stable and consistent measurement results. In contrast, the WGFMU has both ALWG and high-speed I/V measurement capability in an integrated module with guaranteed specifications. It makes the WGFMU a powerful solution for characterizing a wide range of transient and time-domain phenomenon, and it does not require any external equipment or complex cabling.

Key features:

- Fast and flexible waveform generation up to 10 V with 10 ns programmable resolution
- Fast I/V measurement (5 ns sampling rate) synchronized with the applied waveforms
- Fast and accurate low current measurement (1 nA measurement resolution)

2. Easy-to-Use and Intuitive EasyEXPERT group+ Software

EasyEXPERT group+ software, which resides on the B1500A, is a Microsoft Windows-based application program for semiconductor device evaluation. EasyEXPERT group+ on the B1500A provides an easy and effective measurement and analysis environment. The user can access its intuitive graphical interface (GUI) through the LCD touch screen panel or by using an optional USB keyboard and mouse. The familiar Windows-based GUI reduces the learning curve and simplifies networking and data transfer into familiar MS Office tools such as Excel and PowerPoint.
Revolutionary task-oriented approach to parametric test

EasyEXPERT group+ employs a unique “top-down” approach to device characterization that allows users to immediately focus on making measurements without learning all the intricacies of the instrument hardware. EasyEXPERT group+ comes standard with more than 300 application tests that cover a wide variety of processes and device types to help users get up and running quickly. The user simply has to select one or more technology categories and choose the appropriate application test, and then a GUI with a picture of the DUT and simple fill-in-the-blanks menus is then displayed. After modifying the measurement setup conditions, the user can push a button or click on an icon to begin measuring devices and collecting measurement data.

Flexible application tests

In certain instances, a user may want to create a new application test from scratch or modify an existing application test to meet a specific test requirement. The user can accomplish these tasks through simple “drag-and-drop” and “fill-in-the-blank” processes.

Figure 4. EasyEXPERT group+ makes parametric test as easy as 1-2-3.
**Classic test**

The EasyEXPERT Classic Test mode duplicates the familiar 4155C/4156C user interface. This mode maintains the look, feel, and terminology of the 4155C/4156C interface and enhances user interaction by taking full advantage of Microsoft Windows GUI features.

![Figure 5. Classic test mode](image)

**Tracer test**

The 4155C/4156C has a knob sweep function that allows you to perform interactive sweeps by simply rotating the knob just like a traditional curve tracer. However, the B1500A Tracer Test mode offers far more features and capabilities than the 4155C/4156C knob sweep function or a traditional curve tracer by incorporating the convenience and flexibility of a modern PC-based GUI, as shown in Figure 6.

![Figure 6. The Tracer Test mode supports quick and easy device characterization.](image)

1. Select “Id-Vd”
2. Change parameters such as “Compliance”
3. Start measurement and rotate the knob
• Snapshot
A snapshot feature allows you to save and display multiple data traces so that you can easily compare them with data from the current measurement.
• Stoplight
A stoplight feature allows you to graphically define forbidden regions (either voltage or current based) such that the measurement immediately ceases if the trace enters the forbidden area.
• Auto-record
An auto-record feature keeps a running record of the most recent trace changes so that you can replay and save measurement trace data even if your device is inadvertently damaged or destroyed. These features significantly reduce device characterization cycle times.

Versatile data transfer capabilities

A parameter analyzer's data management capabilities often define its real value to the user. EasyEXPERT group+ offers several choices for handling measurement data, such as saving data to the default EasyEXPERT group+ database or exporting it to a user-specified folder. A user can filter the data selection using several criteria before export. EasyEXPERT group+ also offers three options for data transfer: over a network via an Ethernet port; transfer to USB memory devices; and a DVD/CD-ROM/CD-RW drive.

Sequencing test algorithms

Prior to the introduction of EasyEXPERT group+, running a complicated test sequence or multiple test sequences required a user to write a test program. In the case of the 4155C/4156C, Instrument Basic (IBASIC) provides a handy, built-in programming tool. However, IBASIC requires a certain level of programming expertise, and its line-based coding can quickly become rather tedious. In contrast, EasyEXPERT group+ provides two methods for performing sequenced testing. The Quick Test mode enables you to sequentially test the test definitions stored in a My Favorite Setup group without any programming. The other method is via the EasyEXPERT group+ drag-and-drop, fill-in-the-blank, graphical application development environment. The EasyEXPERT group+ application test editor allows a user to easily create an application test that performs both data analysis and test sequencing.
EasyEXPERT group+ for PC

Keysight EasyEXPERT group+ for PC software provides the same functionality as EasyEXPERT running on the B1500A, except that it runs on a standalone PC. Figure 7 shows an overview of the EasyEXPERT group+ and EasyEXPERT group+ for PC software environments.

![Figure 7. Overview of the EasyEXPERT group+ and EasyEXPERT group+ for PC software environments.](image)

EasyEXPERT group+ for PC software installed on an external PC provides additional versatility for efficient use of the B1500A. It provides the capability of offline analysis and manipulation of B1500A measurement data, and it facilitates the efficient transfer of processed data to Windows applications. In addition, EasyEXPERT group+ for PC enables you to create and edit application tests without using the B1500A. This yields the dual benefits of allowing multiple users to simultaneously create application tests and enabling the B1500A measurement hardware to be utilized for its intended purpose of making measurements. Finally, suppose you have a supported GPIB interface and Keysight I/O libraries software installed on the same PC running EasyEXPERT group+ for PC. In that case, you can control the B1500A from the external PC via GPIB.
Making measurements using a semi-automatic prober and switching matrix

You can perform a single test or a sequenced test in conjunction with a semi-automatic wafer prober. Quick Test provides an efficient automatic test environment that allows you to synchronize sequences of tests with the wafer map resident on your semi-automatic wafer prober. You only need to specify the order in which you want the tests executed. You can specify sequences of tests for both dies and sub-dies (modules), and you can also use the Keysight B2200A, B2201A, or E5250A switching matrices to automate DUT selection within a module.

3. Convenient Tools to Ease Migration From the 4155/4156 to the B1500A

Setup file converter

The Setup File Converter is a program that converts Keysight 4155B/C, 4156B/C setup files (extension: DAT or MES) * into equivalent EasyEXPERT group+ setup files as shown in Figure 8. You can download the setup file converter for free from www.keysight.com.

Figure 8. Converting 4155/4156 setup files to B1500A test setup files using the Setup File Converter.
Conclusion

The B1500A represents a new paradigm in semiconductor parametric measurement. It is designed to meet the challenges of the current and emerging technologies in addition to replacing the 4155C and 4156C, which have been the de-facto industry standards for semiconductor parameter analyzers for many years.

The B1500A has 10 slots into which the user can install any of the following modules: HRSMU, MPSMU, HPSMU, MFCMU, HV-SPGU, and WGFMU. These modules cover a wide range of measurement requirements, from DC I/V measurements to accurate CV measurements to very fast time-domain measurements.

EasyEXPERT group+ software provides an easy-to-use measurement environment that enables you to focus on your real goal: parametric measurement and analysis.

EasyEXPERT group+ for PC software allows you to maximize the use of your B1500A by enabling you to analyze measurement data on an external Windows-based PC.

The Setup File Converter saves you effort and time when migrating 4155/4156 test setups to the B1500A.

Trading in Your Analyzer Model

After more than 20 years on the market, the 4155/4156 series has been outdated. Keysight offers its Precision Current-Voltage Analyzer Series that provides a range of I/V analyzers at competitive prices, is suitable for your specific measurement needs, and is capable of supporting cutting-edge applications.

To support the move to the new analyzer series for a limited time, Keysight is offering money off the cost of a new analyzer when you trade in your old model. For further details about this promotion, visit the Keysight Trade-In web page.