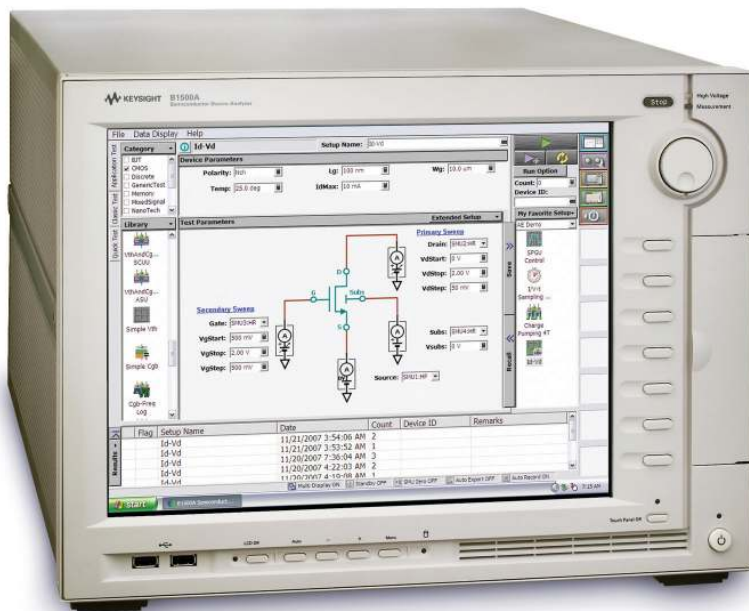


# Keysight Technologies

## Migrating from the 4155C and 4156C to the B1500A

### Application Note





## Introduction

Recent advances in device and process technology present new parametric characterization challenges. This includes both more precise measurement requirements of not only static but also dynamic device parameters as well as the ability to more efficiently measure and analyze large volumes of parametric data.

The Keysight Technologies, Inc. B1500A Semiconductor Device Analyzer is the next generation of parameter analyzers and it is capable of meeting these new challenges. For many years the Keysight 4155C and 4156C Semiconductor Parameter Analyzers have represented the de facto industry standard for semiconductor parameter analyzers. However, as this application note will show, the B1500A can both meet these new challenges as well as perform all of the functions found in 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 software
3. Convenient tools to ease migration from the 4155/4156 to the B1500A

## 1. Broader Measurement Coverage

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

### Module configuration

The 4155C/4156C are fixed configuration instruments, but they can be expanded 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).

In contrast, the B1500A has 10 slots into which SMUs and other types of modules can be inserted. The B1500A supports the same types of SMUs that are found in the 4155C and 4156C. However, since the B1500A is modular the user has the ability to select and configure the exact SMU combination that they need.

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

		Keysight B1500A	Keysight 4155C/56C	
Module configuration		1 – 10 SMUs	4 – 6 SMUs <sup>1</sup>	
		1 – 4 HPSMUs	1 HPSMU <sup>2</sup>	
		1 GDNU (4.2 A)	1 GDNU (1.6A) <sup>2</sup>	
		No VSVMUs <sup>3</sup>	2 VSUs and 2 VMUs	
		1 MFCMU	Not available	
		1 – 5 (1-10 channels) HV-SPGUs <sup>4</sup>	2 PGUs <sup>2</sup>	
		1 – 5 (1-10 channels) WGFMs <sup>4</sup>	Not available	
Measurement resolution	Current	1 fA (HRSMU) 0.1 fA (HRSMU + ASU)	1 fA (4156C)	
	Voltage	0.5 $\mu$ V (MPSMU & HRSMU)	2 $\mu$ V (SMU) 0.2 $\mu$ V (VMU)	
Measurement accuracy (Offset)	Current	15 fA (10 pA range HRSMU)	20 fA (10 pA range)	
	Voltage	120 $\mu$ V (0.5 V range MPSMU & HRSMU)	200 $\mu$ V (2 V range SMU) 10 $\mu$ V (0.2 V range VMU)	
Specialized measurement functions	Standby mode	Available	Available	
	Current off-set cancel	Available	Available	
	High speed sampling	Multi channel measurement	Multi channel measurement	Single channel measurement
		100 $\mu$ sec. minimum interval	100 $\mu$ sec. minimum interval	60 $\mu$ sec. minimum interval
		20,000 counts of full scale resolution (SMU)	20,000 counts of full scale resolution (SMU)	1,000 counts of full scale resolution (SMU)
		Multi channel measurement, 5 ns minimum interval (WGFMs)		
	Pulsed sweep	Multi channel measurement (SMU or WGFMs)	Single channel measurement	
QSCV	Available	Available		
IV knob sweep	Available	Available		
Pulse generator range	Frequency	1 Hz – 33 MHz (HV-SPGU)	0.1 Hz – 500 kHz (PGU)	
Switching between IV and measurements		SCUU, ASU or B2200A/B2201A/E5250A	E5250A	

- 6 SMUs by using the 41501B with 4155C or 4156C.
- Using the 41501B either with the 4155C or 4156C.
- SMUs can be used for the VSU and VMU.
- 2 channels per 1 module.

## SMU output/measurement range and accuracy/resolution

The B1500A SMUs have wider voltage/current outputs, broader measurement ranges and better accuracy than do 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 HRSMU. When the ASU is used in conjunction with the high resolution SMU (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 such as that 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 software has application tests available to control the 3458A via GPIB.

## Multi-frequency capacitance measurement unit

Figure 3 illustrates an IV 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 at frequencies from 1 kHz to 5 MHz.



Figure 2. The ASU provides 100 aA current measurement resolution.



Figure 3. Accurate IV and CV measurement setup using SMU, MFCMU and SCUU.

## Multi-frequency capacitance measurement unit (continued)

The MFCMU and SMU outputs can be switched using the SCUU, as illustrated in Figure 4. The SCUU enables the user to make IV 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 return path current 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  $\pm 100$  V, which is well beyond the inherent  $\pm 25$  V capability of the MFCMU.

## High voltage semiconductor pulse generator unit

The high-voltage semiconductor pulse generator unit (HV-SPGU) is specifically designed to meet the challenges posed by advanced flash memory testing needs such as a multi-bit or multi level cell (MLC) and charge trap flash memory. The HV-SPGU possesses both a  $\pm 40$  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 as compared with the 4155C/4156C's PGU-based solutions.

## Waveform generator/fast measurement unit

The Waveform Generator/Fast Measurement Unit (WGFMU) is a new type of measurement resource developed to accurately characterize dynamic device characteristics. 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 types of measurement solutions have had difficulty producing stable and consistent measurement results. In contrast, the WGFMU has both ALWG capability and high-speed IV measurement capability in an integrated module with guaranteed specifications. This 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 IV measurement (5 ns sampling rate) synchronized with the applied waveforms
- Fast and accurate low current measurement (1 nA measurement resolution)

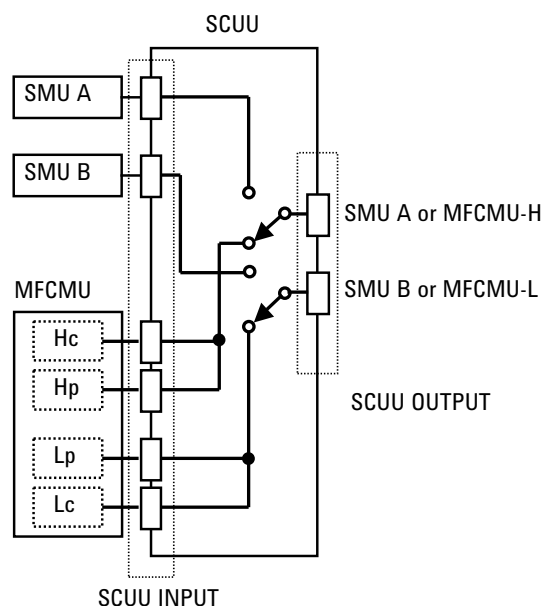


Figure 4. SCUU switches between SMUs and MFCMU.

## 2. Easy-to-Use and Intuitive EasyEXPERT Software

EasyEXPERT software, which is resident on the B1500A, is a Microsoft Windows based application program for semiconductor device evaluation. EasyEXPERT on the B1500A provides an easy and effective measurement and analysis environment, and its intuitive graphical user interface (GUI) can be accessed either 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 also simplifies networking and data transfer into familiar MS Office tools such as Excel and PowerPoint.

### Revolutionary task-oriented approach to parametric test

EasyEXPERT employs a unique “top-down” approach to device characterization that allows users to immediately focus on making measurements without having to learn all the intricacies of the instrument hardware. EasyEXPERT comes standard with more than 230 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. 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 simply 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. These tasks can be accomplished through a simple “drag-and-drop” and “fill-in-the-blank” processes.

**1** Select one or more technology categories

**2** Select desired application test from the library

**3** Click or press the measure button

A graphical plot and data list are generated automatically in real time

Flag	Setup Name	Date	Count	Dev
	Simple Vth	4/26/2007 1:27:23 PM	2	
	Cgb with Parameters	4/25/2007 2:27:36 PM	1	
	Simple Cgb	4/25/2007 2:27:01 PM	2	
	Id-Vd	4/25/2007 2:25:48 PM	1	
	Generic Vth	4/25/2007 3:24:56 PM	7	

Figure 5. EasyEXPERT 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 not only maintains the look, feel, and terminology of the 4155C/4156C interface, but it also enhances user interaction by taking full advantage of Microsoft Windows GUI features.

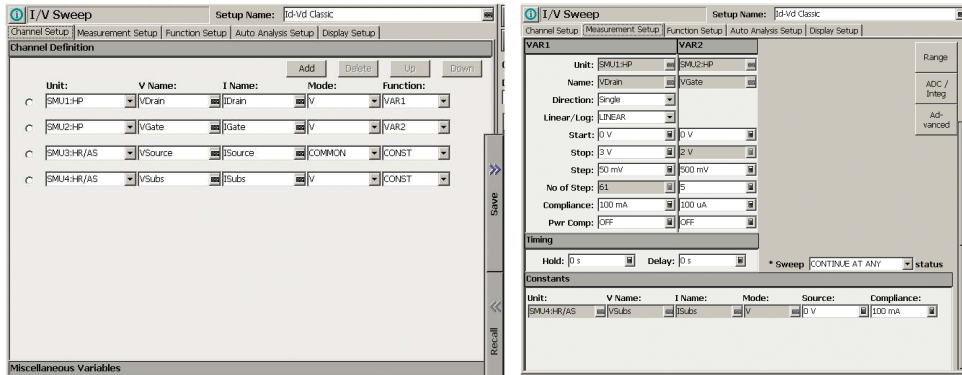


Figure 6. Classic Test mode

## Tracer Test

The 4155C/4156C has a knob sweep function which allows you to perform interactive sweeps by simply rotating the knob just like on a traditional curve tracer. However, the B1500A's Tracer Test mode offers far more features and capabilities than the 4155C/4156C's knob sweep function or a traditional curve tracer by incorporating the convenience and flexibility of a modern PC-based GUI as shown in Figure 7.

- 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.

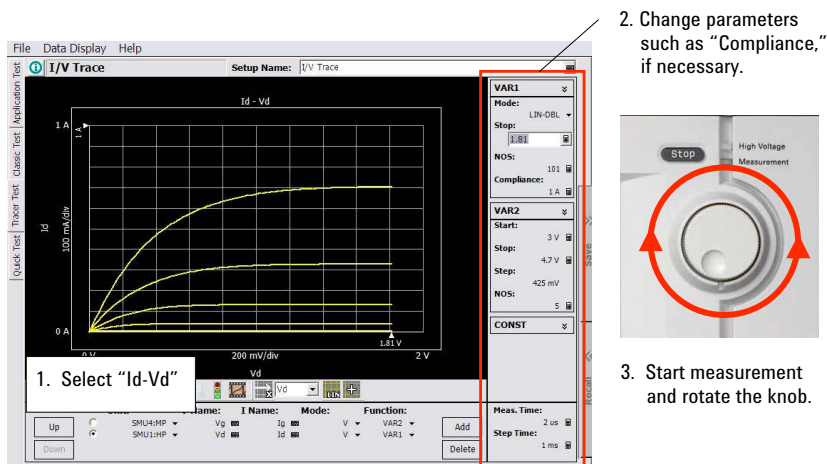


Figure 7. The Tracer Test mode supports quick and easy device characterization..



## Versatile data transfer capabilities

A parameter analyzer's data management capabilities often ultimately define its real value to the user. EasyEXPERT offers several choices for handling measurement data such as saving data to the default EasyEXPERT database, or exporting it to a user-specified folder. A user has the option of filtering the data selection using several criteria before export.

EasyEXPERT 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, 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 provides two methods for performing sequenced testing. Using the Quick Test mode, test definitions stored in a My Favorite Setup group can be tested sequentially without any programming. The other method is via the EasyEXPERT drag-and-drop, fill-in-the-blank, graphical application development environment. The EasyEXPERT application test editor allows a user to easily create an application test that performs both data analysis and test sequencing.

## Desktop EasyEXPERT

Keysight Desktop EasyEXPERT software provides the same functionality as EasyEXPERT running on the B1500A, except that it runs on a standalone PC. Figure 8 shows an overview of the EasyEXPERT and Desktop EasyEXPERT software environments.

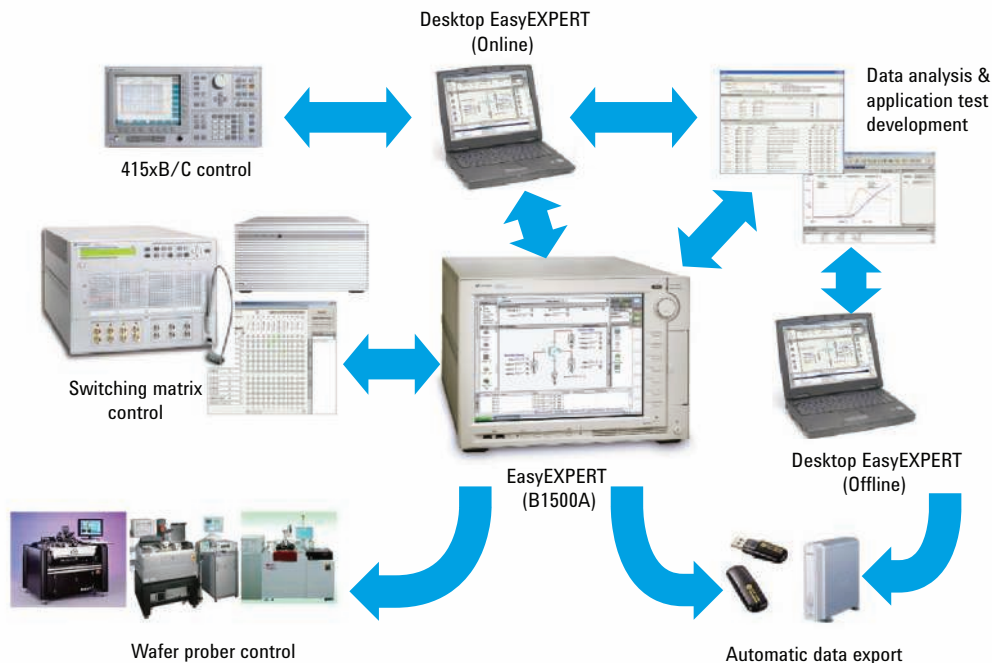


Figure 8. Overview of the EasyEXPERT and Desktop EasyEXPERT software environments.



## Desktop EasyEXPERT (continued)

Desktop EasyEXPERT 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 efficient transfer of processed data to Windows applications. In addition, Desktop EasyEXPERT 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, if you have a supported GPIB interface and Keysight I/O libraries software installed on the same PC running Desktop EasyEXPERT, then you can control the B1500A from the external PC via GPIB.

## Making measurements using a semi-automatic prober and switching matrix

A single test or sequenced tests can be performed in conjunction with a semiautomatic 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 semiautomatic wafer prober. You need only to specify the order in which you want the tests executed. You can specify sequences of tests for both dies and subdies (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

### Desktop EasyEXPERT 4155B/4156B/4155C/4156C support

Desktop EasyEXPERT supports not only the B1500A but also a subset of the 4155B/4156B/4155C/4156C\* functions as shown in Figure 8. Desktop EasyEXPERT is available for download free of charge from [www.keysight.com](http://www.keysight.com). Desktop EasyEXPERT support for the 4155B/4155C/4156B/4156C gives users of these products many of the benefits of EasyEXPERT, such as being able to use over 80 of the furnished application tests, exporting and importing data without having to go through a FDD, to name just a few. Since Desktop EasyEXPERT test setups created for the 4155B/4156B/4155C/4156C can also be used on the B1500A, transition from the 4155B/4156B/ 4155C/4156C to the B1500A is greatly simplified.

\* Desktop EasyEXPERT does not support the 4155A/4156A.

## Setup file converter

The Setup File Converter is a program that converts Keysight 4155A/4156A/4155B/4156B/4155C/4156C setup files (extension: DAT or MES)\*\* into equivalent EasyEXPERT setup files as shown in Figure 9. The Setup File Converter is included with the Desktop EasyEXPERT installation package and it can be downloaded for free from [www.keysight.com](http://www.keysight.com).

\*\* Note: The Setup File Converter does not convert the measurement data included in a DAT setup file.

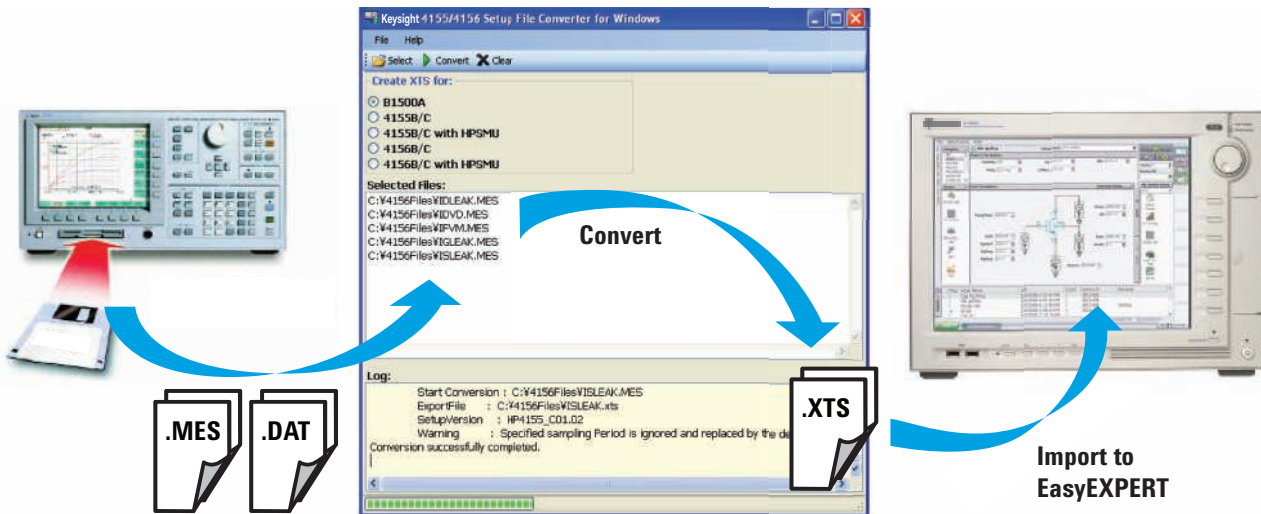


Figure 9. Converting 4155/4156 setup files to B1500A test setup files using the Setup File Converter.

## Conclusion

The B1500A represents a new paradigm in semiconductor parametric measurement. It is designed to meet the challenges of 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 IV measurements to accurate CV measurements to very fast time domain measurements.

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

Desktop EasyEXPERT software allows you to maximize the use of your B1500A by enabling you to analyze measurement data on an external Windows-based PC. Desktop EasyEXPERT also supports control of the 4155B/4155C/4156B/4156C via GPIB using a PC. This makes the transition from these older legacy instruments to the B1500A easier by providing a common software platform, and it also makes it simpler to support a mixed instrument environment in your laboratory.

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

## Learn more

- *Keysight B1500A Semiconductor Device Analyzer Technical Overview*  
<http://literature.cdn.keysight.com/litweb/pdf/5989-2785EN.pdf>
- *Improving Flash Memory Cell Characterization Using the Keysight B1500A (Application Note B1500-9)*  
<http://literature.cdn.keysight.com/litweb/pdf/5989-8654EN.pdf>
- *Pulse/Waveform Generation with Integrated Measurement Capability (Product Note B1500A-1)*  
<http://literature.cdn.keysight.com/litweb/pdf/5990-4567EN.pdf>

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