

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

Application Note B1500-2

## Agilent B1500A Semiconductor Device Analyzer

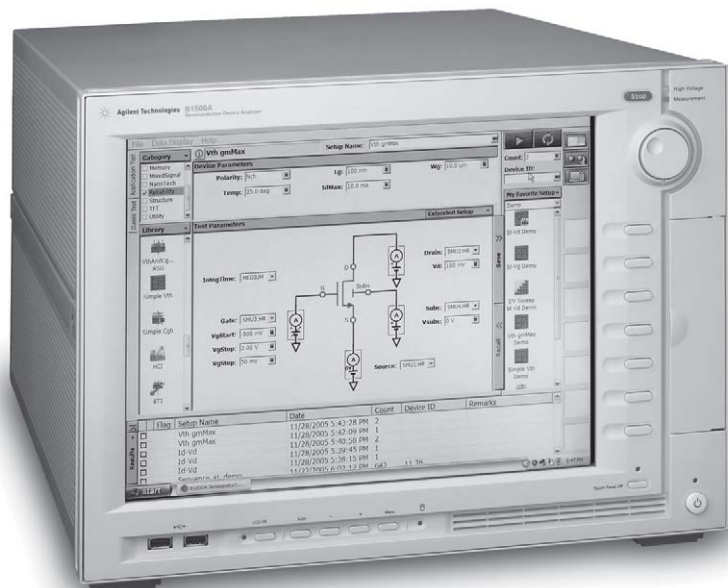
### Introduction

The International Technology Roadmap for Semiconductors (ITRS) shows that as the complexity of semiconductor devices increases, there is a corresponding increase in the development of advanced semiconductor process technology. Next generation 65-nanometer and 45-nanometer processes present significantly more parametric characterization challenges than do current processes. These challenges arise not only from shrinking feature sizes but also from other factors such as high-k gate insulators, metal gate structures, and low-k interconnect insulation materials.

The continuing changes in the advanced semiconductor technology development environment require increased human resources for process and device design, test chip production, and parametric characterization. In the area of parametric characterization, a major change in the traditional semiconductor parameter analyzer is required in order to improve user efficiency. Improvements require minimizing the time needed to learn analyzer

operation, make measurements, characterize the device, and to report the results. The Agilent B1500A represents the next generation of parameter analyzers and is designed specifically to provide improvements in user efficiency.

For many years the Agilent 4155C and 4156C have represented the de facto industry standard for semiconductor parameter analyzers. This application note presents the B1500A's major features and examines both the differences and similarities of the two product lines.



Agilent Technologies

## B1500A Major Features

The B1500A provides an extensive array of features that are aimed directly at improving user efficiency.

### Windows-based user interface

The B1500A comes standard with the Microsoft® Windows® XP Professional operating system. The familiar Windows graphical user interface reduces the learning curve and virtually eliminates the need for instrument training. The Windows platform also provides easy-to-use networking and linkage to already-familiar office tools.

### B1500A EasyEXPERT software

B1500A EasyEXPERT software uses 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. With EasyEXPERT software, a user can simply select one or more technology categories then choose the appropriate application test.

The B1500A comes with more than 100 application tests, which cover a wide variety of processes and device types to help users get up and running quickly. Once measurement parameters are entered, the user can simply push a button or click on an icon to begin measuring and analyzing device parameters.

### Desktop EasyEXPERT software

Desktop EasyEXPERT software installed on your Windows PC provides additional versatility for efficient use of the B1500A. It provides the capability for off-line analysis and manipulation of data measured by the B1500A, as well as efficient transfer of the processed data to your Windows applications. In addition, Desktop EasyEXPERT enables you to create your own application tests and to enhance the supplied library shown in

Figure 1 without using the B1500A. This yields the dual benefits of allowing multiple users to create application tests at the same time and allowing the B1500A measurement hardware to be utilized at maximum efficiency. Finally, if you have a GPIB interface and Agilent I/O libraries installed on the same PC running Desktop EasyEXPERT, then you can control the B1500A from the external PC via GPIB.

### 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 simple “drag-and-drop” and “fill-in-the-blank” processes. Each new or modified library can be shared with other members of the B1500A test group, or can be exported to other B1500A analyzers or Desktop EasyEXPERT software used within the group.

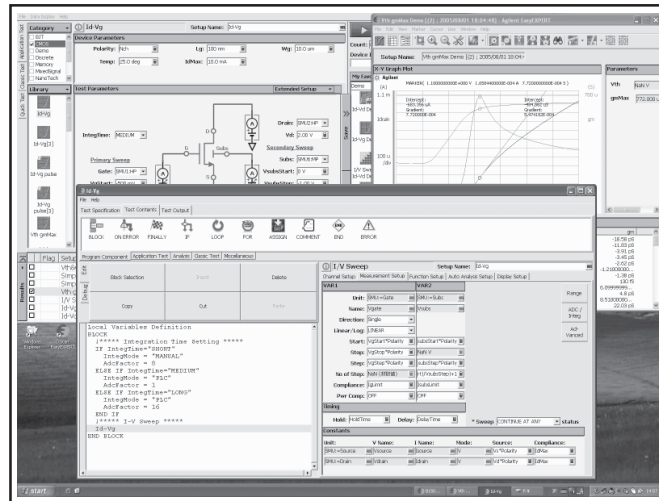


Figure 1. Desktop EasyEXPERT provides a convenient offline analysis and development environment.

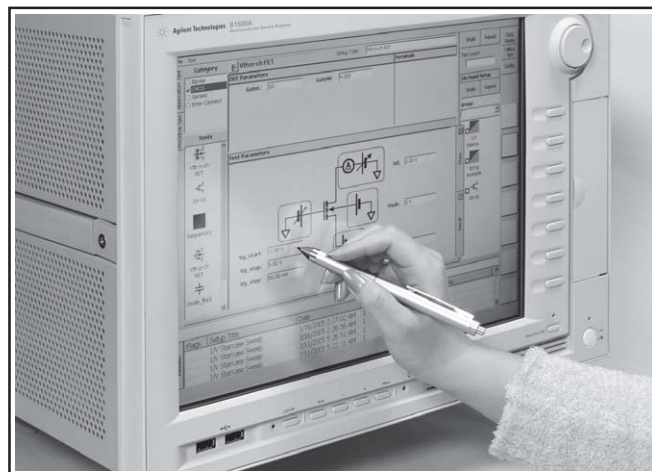


Figure 2. B1500A LCD touch-screen display

### Easy-to-use touch-screen operation

The B1500A has a large LCD touch-screen display, shown in Figure 2. This feature eliminates the need to use a keyboard and mouse, which are required to operate some Windows-based semiconductor analyzers. Selecting the application test and inputting test conditions can all be done through the touch-screen, which enhances the user-

friendly interface of the B1500A. Of course, a keyboard and mouse can always be used in situations where that interface is more convenient.

### Versatile data transfer capabilities

The data management capability of any parameter analyzer is of great interest to users. The B1500A offers several choices for handling measurement data such as saving data to the

default EasyEXPERT database, or exporting it to a user-specified folder. The user has the option of filtering the data selection using several criteria before export.

The B1500A 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.

## B1500A Measurement Function Advantages

### Sequencing test algorithms

Prior to the introduction of the B1500A, running a complicated test sequence or multiple test sequences required the user to write a test program. In the case of the 4155C and 4156C, Instrument Basic (IBASIC) provides a handy, built-in programming tool. However, IBASIC does require a certain level of programming expertise.

In contrast, the B1500A provides two methods for performing sequence testing. Using the Quick Test feature of the EasyEXPERT software, test definitions stored in the pre-set group of My Favorite Setup can be tested sequentially without any programming. The other method is via the drag-and-drop, fill-in-the-blank, graphical application development environment. The B1500A software environment allows the user to easily create an application test that performs both data analysis and test sequencing. The B1500A is supplied with more than 100 application tests, which can be used as is or customized into a unique library for a specific application.

### Making measurements using a semi-automatic prober

A single test or sequential tests can be performed using a semi-automatic prober. The EasyEXPERT software's Quick Test feature provides an efficient automatic test environment that allows you to synchronize sequences of

tests with the wafermap resident on your semi-automatic wafer prober. You need only to specify the order in which you want the tests executed. You can specify sequences of tests for

dies and subdies (modules), and you can also combine the testing with either the Agilent B2200A or B2201A switching matrices to automate the DUT selection within a module.

	Agilent B1500A	Agilent 4155C and 4156C
<b>Furnished applications</b>	More than 100 application tests	4 default setups and sample IBASIC program
<b>Off-line data analysis and library creation</b>	EasyEXPERT desktop software	Not available
<b>User interface options</b>	Touch screen, clickable knob, softkeys, USB keyboard and mouse	Knob, buttons, softkeys and keyboard
<b>Data transfer</b>	CD-RW, LAN, USB	Floppy disk, LAN
<b>Test algorithm sequencing</b>	Quick Test GUI and sequence test library	IBASIC
<b>Prober control</b>	Semi-automatic prober driver	Not applicable
<b>AC capacitance</b>	1-slot MFCMU	Agilent 4284A (external)
<b>IV-CV switching</b>	SCUU, ASU or B2200A/B2201A	E5250A

Figure 3. Comparison of 4155C/4156C and B1500A features

## Multi-Frequency Capacitance Measurement Unit

Figure 4 illustrates an IV and CV measurement setup using two SMUs, the MFCMU, and the SCUU. The one-slot MFCMU (multi-frequency capacitance measurement unit) can make frequency sweep or spot CV measurements at frequencies from 1 KHz to 5 MHz. The MFCMU and SMU outputs can be switched using the SMU CMU unify unit (SCUU), as illustrated in Figure 5. 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.



Figure 4. Accurate IV and CV measurement setup using SMU, MFCMU and SCUU.

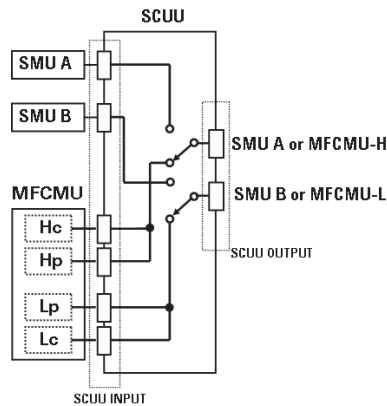


Figure 5. SCUU switches between SMUs and MFCMU.

## Similarities and differences in the 4155C /4156C and B1500A product families

Figure 6 illustrates the similarities and differences in the 4155C/4156C and B1500A product lines.

### Hardware configuration

The 4155C and 4156C are fixed-configuration instruments, but can be expanded via the Agilent 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).

By contrast, the B1500A has 10 slots into which SMUs and other types of modules can be inserted. The B1500A SMUs are available in the same types as those available for the 4155C and 4156C. However, the modularity of the B1500A allows the user

more flexibility to configure the SMU combinations. Although the B1500A does not support VSUs and VMUs, the B1500A MPSMUs and HRSMUs can provide similar or better voltage measurement performance. The B1500A's 10 module slots provide the flexibility required to duplicate the measurement functionality of the 4155C's and 4156C's SMUs, VSUs and VMUs. PGUs, which are available for the 4155C and 4156C via the 41501B, can be replaced with the Agilent 81110A pulse generator, whose driver is supported by the EasyEXPERT library. Agilent is also considering future support for a B1500A PGU module in order to cover 40 V applications that are covered by 4155C and 4156C.

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

B1500A SMUs have wider voltage/current output and measurement ranges, and better accuracy, than do the 4155C and 4156C SMUs.

### Voltage measurement accuracy

Since the 4155C and 4156C contain VSUs and VMUs, and since these measurement modules are not available for the B1500A, it is important to understand the impact of this on voltage measurement situations.

The offset voltage accuracy of the B1500A's MPSMU and HRSMU is 120  $\mu$ V, compared to 10  $\mu$ V for the VMU of the 4155C and 4156C. For the vast majority of measurement situations, the difference in accuracy between these measurement resources does not matter since the voltage measurement

resolution of these measurement resources is so close that they can be considered equivalent. As always, for situations requiring extremely stable measurements taken over a long time period, a separate external DVM is always superior to SMUs or VMUs. Using the B1500A's EasyEXPERT software environment, it is very easy to create an application test to control the Agilent 3458A Digital Multimeter (DMM) via GPIB. The 3458A provides very precise levels of voltage measurement accuracy.

### Minimum current resolution

The current measurement resolution provided by the B1500A's Atto Sense and Switch Unit (ASU), shown in Figure 6, is approximately 10 times better than that provided by the 4156C. When the ASU is used in conjunction with the HRSMU, the minimum current resolution of the B1500A is 100 aA (or 0.1 fA) as shown in Figure 7. Resolution of 100 aA is useful when measuring a very low leakage current such as that found in memory cells.

### Available functions

Most of the functionality available in the 4155C/4156C product line has been covered in the second release of the EasyEXPERT software for the B1500A, as shown in Figure 7. QSCV measurement capability is planned in a future release of the B1500A software.

### 4155C and 4156C setup data

The second release of EasyEXPERT provides a tool that allows .MES measurement setup files created on the 4155 or 4156 to be imported into the B1500A. The 4155 and 4156 setup files are then available from the EasyEXPERT classic test measurement mode, which duplicates the familiar 4155 and 4156 user interface. When importing files, some modification may be required due to differences in the system architecture of the two product lines.

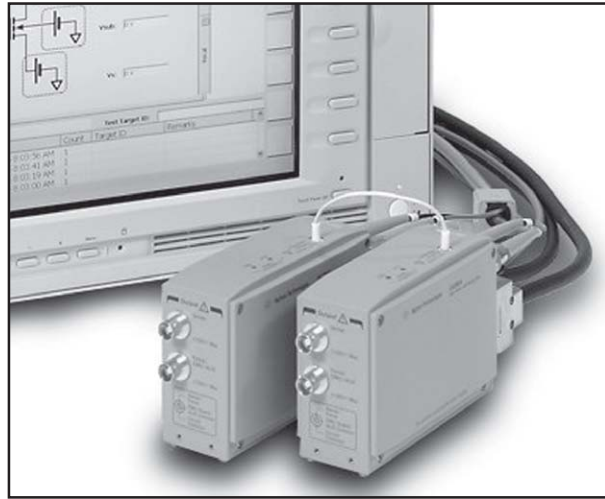


Figure 6. ASU provides 100 aA current measurement resolution.

Figure 7. Key product differences

		Agilent B1500A	Agilent 4155C and 4156C
<b>Hardware Configurations</b>		1 - 10 MPSMUs	4 - 6 MPSMUs <sup>1</sup>
		1 - 4 HPSMUs	1 HPSMU <sup>2</sup>
		4.2 A GNDU	1.6 A GNDU <sup>2</sup>
		No VSUs or VMUs <sup>3</sup>	2 VSUs and 2 VMUs
<b>Measurement Resolution</b>	<b>Current</b>	0.1 fA (HRSMU + ASU) 1 fA (HRSMU)	1 fA (4156C)
	<b>Voltage</b>	0.5 μV (MPSMU & HRSMU)	2 μV (SMU) 0.2 μV (VMU)
<b>Measurement Accuracy (Offset)</b>	<b>Current</b>	15 fA @ 10 pA range (HRSMU)	20 fA (10 pA range)
	<b>Voltage</b>	120 μV (0.5 V range - MPSMU & HRSMU)	200 μV (2 V range - SMU) 10 μV (2 V range - VMU)
<b>Specialized Measurement Functions</b>	<b>Continuous Output<sup>5</sup></b>	Available in Applications Test Mode	Standby Mode
	<b>Current Offset Cancel</b>	Available	Available
	<b>High-speed Sampling</b>	100 μ sec. minimum interval	60 μ sec. minimum interval
	<b>Logarithmic Time Sampling</b>	Available	Available
	<b>QSCV</b>	Available in future software release	Available
	<b>IV Knob Sweep</b>	Not available	Available
<b>Remote Control Command Sets</b>		Agilent FLEX VXIplug&play driver	Agilent FLEX VXIplug&play driver 4145 syntax, SCPI

<sup>1</sup> 6 SMUs by using the 41501B with the 4155C or the 4156C .

<sup>2</sup> Using the 41501B with either the 4155C or 4156C.

<sup>3</sup> SMUs can be used for the VSU and VMU.

<sup>4</sup> Can be controlled from EasyEXPERT.

<sup>5</sup> Keeping SMU output on between measurements

## Similarities and differences (continued)

While the file converter is a useful tool for re-using 4155C and 4156C setups, 4155C and 4156C measurement data cannot be imported into the B1500A.

### Internal and external PC control modes

The B1500A offers two PC control modes. Figure 8 illustrates the internal mode where the B1500A's built-in PC functions as the system controller for analyzer measurement resources as well as external GPIB instruments. This is also true for the Agilent B2200A and B2201A switches, the Agilent 81110A pulse generator, and the Agilent 3458A DVM, and semi-automatic probers.

Figure 9 illustrates the case where an external PC controls B1500A measurement resources and external GPIB instruments. When controlled by an external PC, the B1500A's built-in PC controller and its GUI are disabled. In external mode, the B1500A's measurement resources are controlled using the FLEX command set or the high-level *VXIplug&play* instrument driver.

FLEX is a common GPIB language set for controlling measurement modules. Programs written for the 4155C and 4156C using the FLEX command set can be converted easily to control B1500A SMUs with minor modification. If the PC controller is running on a Windows 2000 or XP Professional operating system, 4155C and 4156C programs written using the *VXIplug&play* driver can be converted easily to control B1500A measurement resources. The 4155C's and 4156C's SCPI command mode is not available on the B1500A.



Figure 8. B1500A using built-in internal PC to control analyzer measurement resources and external GPIB instruments.



Figure 9. B1500A using an external PC to control analyzer measurement resources and external GPIB instruments. The built-in PC controller, touch-screen and GUI are disabled.

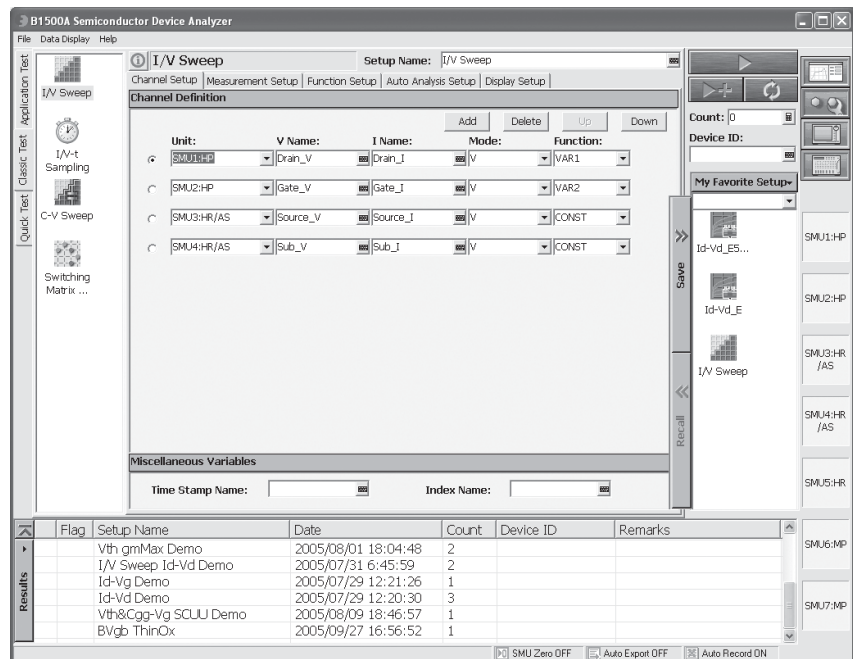


Figure 10. Classic test mode

## Conclusion

The Agilent B1500A Semiconductor Device Analyzer represents a new paradigm in semiconductor parameter measurement. It is designed to meet the challenges of current 65-nanometer and future sub 45-nanometer process technologies. The Agilent 4145, 4155 and 4156 series of instruments has been the de facto industry standard for semiconductor parameter analyzers for more than 20 years. These instruments all employed a similar measurement concept, in that the user was required to have an intimate understanding of the SMU hardware in order to make even a simple measurement.

The B1500A with EasyEXPERT software employs a completely different task-oriented measurement approach using application tests. It does not require the user to learn the instrument hardware in order to make productive measurements, which makes the B1500A a better choice for new or occasional users. In addition, EasyEXPERT provides a Classic Test mode (shown in Figure 10) that duplicates the familiar 4155 and 4156 interface, and measurement setups created in the 4155 and 4156 can be imported into the B1500A classic test mode. Of course, users already familiar with the 4155 and 4156 user interface can use the B1500A entirely from the classic test mode if they choose.

Desktop EasyEXPERT software provides additional versatility for efficient use of the B1500A and allows the analysis of measurement data analysis on an external Windows-based PC.

At this time a majority of the 4155 and 4156 measurement solutions can be performed more efficiently on the B1500A. A few measurements such as quasi-static capacitance versus voltage (QSCV) measurement are not yet supported on the B1500A, but there are plans to support this in future software releases.

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