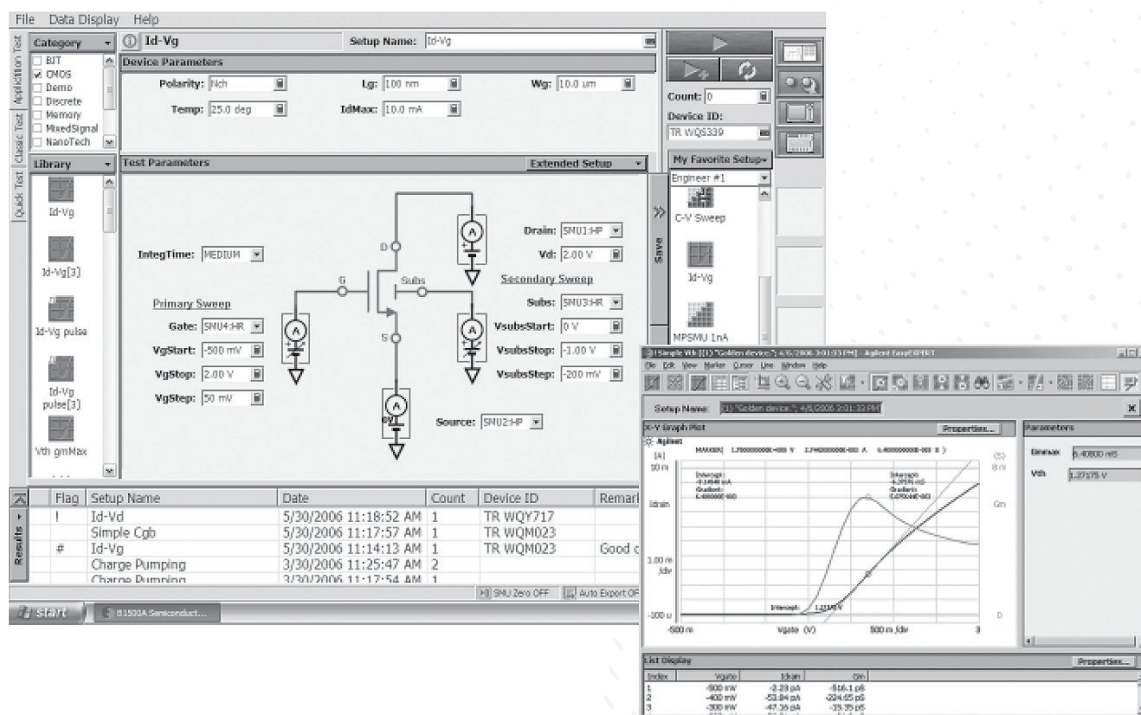


Creating a Test Sequence Using B1500A EasyEXPERT Software



Introduction

Keysight B1500A Semiconductor Device Analyzer

The Keysight Technologies, Inc. B1500A Semiconductor Device Analyzer with EasyEXPERT software comes with more than 150 categorized application tests, which greatly reduce the time required for characterizing new devices, processes and materials.

EasyEXPERT provides an easy-to-use, efficient user interface. Implementing a unique “top-down” approach allows users to immediately focus on making measurements without having to learn all the intricacies of the instrument hardware. With EasyEXPERT, users can start making measurements immediately in three easy steps, as shown in Figure 1.

The application tests provided in the EasyEXPERT software library are conveniently categorized by device type and application. Sample categories include bipolar junction transistors (BJT), complementary metal-oxidesemiconductor (CMOS) transistors, nanotechnology structures and reliability tests.

By creating a sequence of tests and by setting the measurement parameters at one location for each test in the sequence, a user can increase test efficiency and improve test quality. A good candidate for a test sequence would be a series of dc tests or a series of current versus voltage (IV) and capacitance versus voltage (CV) tests. The SMU CMU unify unit (SCUU) and attosense and switch unit (ASU) make it easy to switch automatically between CV and IV measurements.

This application note demonstrates how a test sequence can be created using tests from the CMOS category with the furnished EasyEXPERT “Id-Vd” and “Vth gmMax” application test definitions as an example.

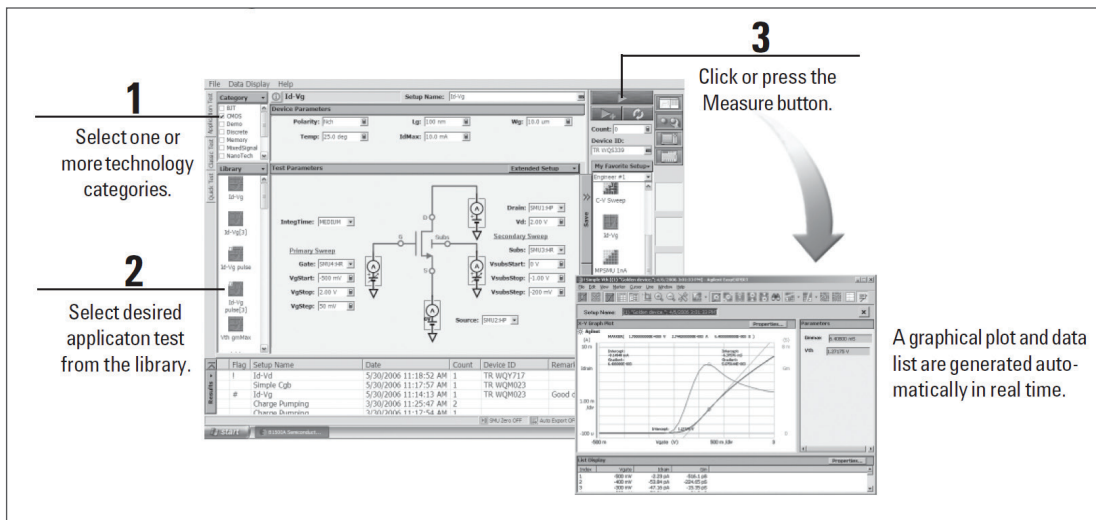


Figure 1. Easy three-step measurement using EasyEXPERT

Creating a test sequence definition

Two or more application test definitions can be executed at once by creating a test sequence definition. This is very useful for running frequently used test routines. A new test sequence definition can be created very easily using existing EasyEXPERT test definitions by taking the following steps:

- Open the New Test Definition window
- Set up the Test Specification tab
- Define the device parameters in the Test Specifications tab
- Define the test parameters in the Test Specification tab
- Set up the Test Contents tab
- Make measurements

The following sections in this application note provide information on how to create a new test sequence definition by using the existing EasyEXPERT Id-Vd and Vth gmMax application test definitions in the CMOS category. Figure 2 shows the user interface of the new test definition that will be created in this application note. In this case, a new bitmap background image file was created using other software to provide a visual reference. Note that the input parameters for both the Id-Vg and Vth GmMax application tests can be entered in a single window.

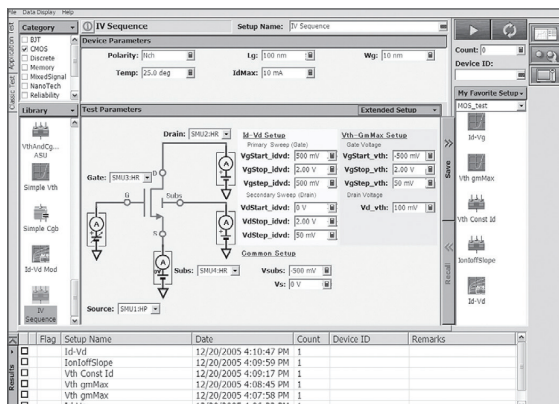


Figure 2. IV Sequence application test setup window

Opening the test definition window

The Test Definition window is used to define the test setup used in the application test definition. Figure 3 shows the two steps involved in opening the window:

1. Select the application test category that includes the application test definition to be opened (in this example the CMOS category).
2. In the Library pull-down menu, select "Define New Test." The test definition window appears, as shown in Figure 4.

The Test Definition window provides three tabs to define the test setup.

- The Test Specification tab defines the look and feel of the application test by specifying the test information, device parameter definitions, and test parameter definitions.
- The Test Contents tab contains the test execution flow - the essence of the test definition.
- The Test Output tab specifies the data output and is generally only needed for certain types of very complicated tests.

Note: The Test Specification tab and the Test Contents tab are used as examples in this application note.

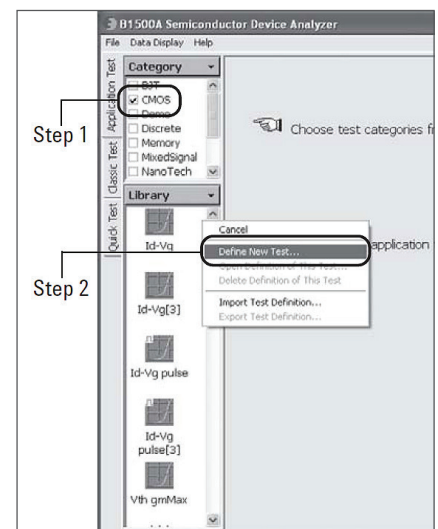


Figure 3. Steps required to open the Test Definition window

Setting up the Test Specifications tab

When the Test Definition window opens, the Test Specification Tab is the default. Figure 4 also shows the four main setup areas under the Test Specification Tab:

- Test Information
- Device Parameters Definition
- Test Parameters Definition
- Properties

The relationship between the Test Specification setup area and the main window is shown in Figures 5 and 6 below.

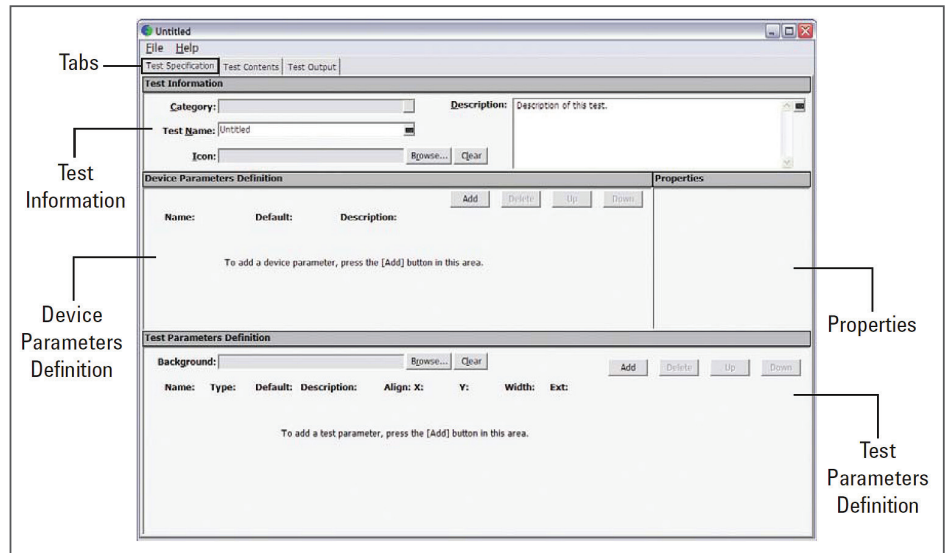


Figure 4. Test Definition Window showing the four main setup areas under the Test Specification Tab

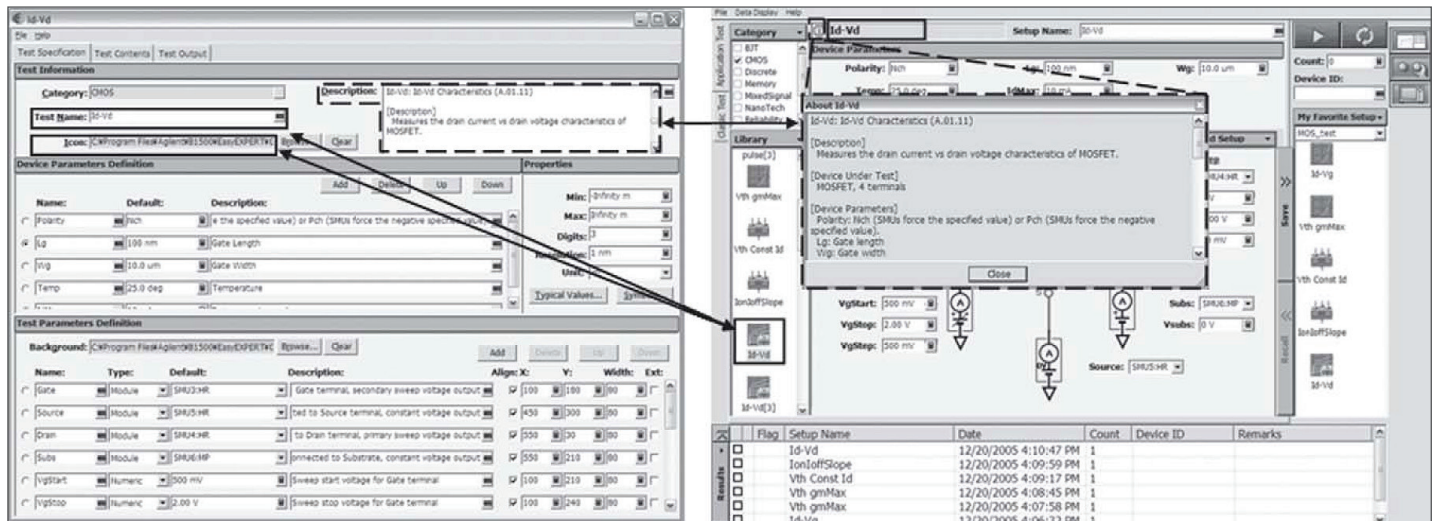


Figure 5. Relationship between the Test Specification window and the Main window with respect to Test Information

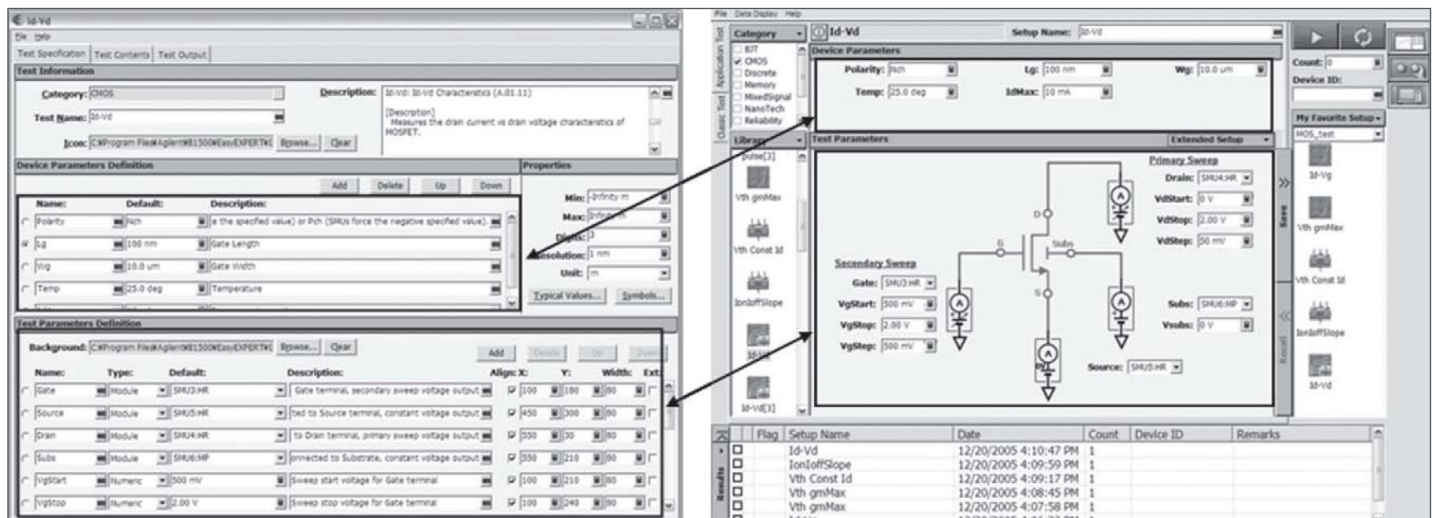


Figure 6. Relationship between the Test Specification window and the Main window with respect to the Device Parameters Definition and the Test Parameters Definition

Defining information in the Test Information area under the Test Specifications tab

The setup parameters for the Category, Test Name, Icon and Description fields are shown in Table 1.

Field Name	Value
Category	CMOS
Test Name	IV Sequence
Icon	C:\Program Files\Keysight\B1500\EasyEXPERT\Graphics\Icons\MOSFET.bmp
Description	This application test is a test sequence of Id-Vd and Vth gmMax measurements.

Table 1. Test information list.

The Category field is populated by using the softkey or by clicking the square button to the right of the field, and selecting from the list, as shown in Figure 7.

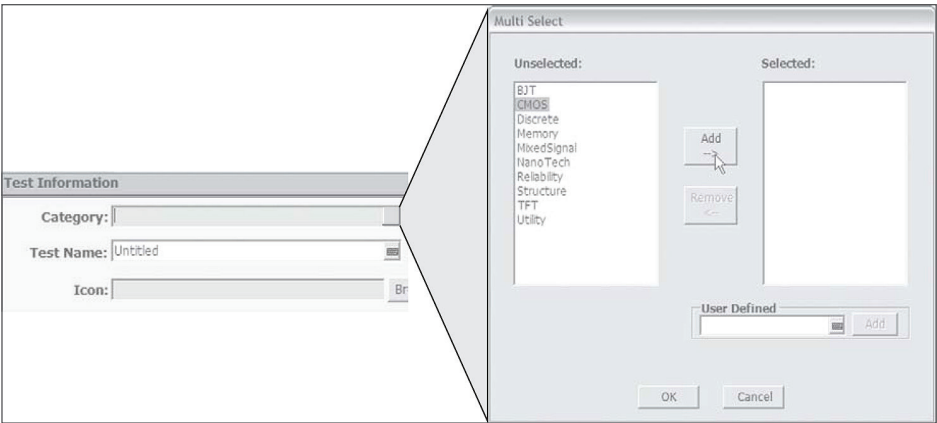


Figure 7. Selecting categories

The test name is a new application test definition name, which must be entered directly in the Test Name field. The name must be unique to the specified workspace.

The icon file for an application test definition must be entered in the Icon field. EasyEXPERT stores icon files in the folder C:\Program\Files\Keysight\B1500\EasyEXPERT\Graphics\Icons. Although the icon files furnished with EasyEXPERT can be used, unique icon files can also be created.

The Description field is where a detailed description of the application test definition is entered. It is displayed by clicking the Information button at the left side of the Test Name in the main window as shown in Figure 5 on page 4. The first line of the description is displayed when a user clicks the test definition icon in the main window as shown in Figure 8.

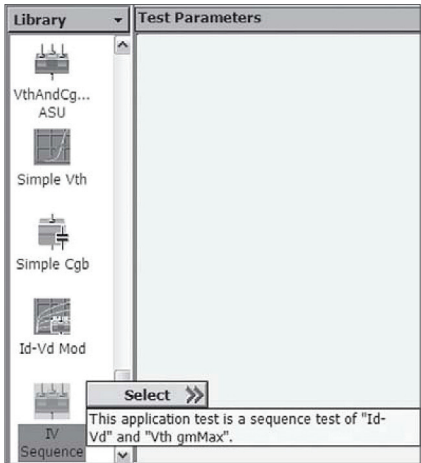


Figure 8. Single line description of the application test

Defining parameters in the Device Parameters Definition area under the Test Specifications tab

The Device Parameters Definition area is used to input device-related parameters, as illustrated in Figure 10, and then to input physical device parameters such as gate length, gate width, temperature, etc. These parameters are generally optional but some application tests require them in order to calculate certain device parameters in conjunction with measured values. In this example, neither of the application tests called by the new application test requires any device parameters to execute. The details of the parameters used as an example in Figure 9 are shown in Table 2 and Table 3.

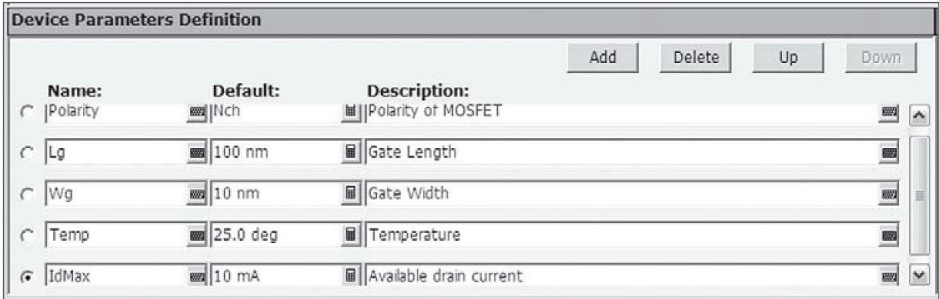


Figure 9. Device Parameters Definition area

Name	Default	Description
Polarity	1 (Nch)	MOSFET polarity
Lg	100 nm	Gate length
Wg	10 nm	Gate width
Temp	25° C	Temperature
IdMax	10 mA	Available drain current

Table 2. Device parameters

Name	Min	Max	Digits	Resolution	Unit	Typical	Symbol
Polarity	- 1	1	1	1	m	Value	Nch, - 1: Pch
Lg	Infinity	Infinity	3	1 nm	m	1, - 1 ¹	
Wg	Infinity	Infinity	3	1 nm	deg		
Temp	- 50	200	4	100 m deg	A		
IdMax	1 μ	100 m	2	1 μA			

1. Although these are initially input as numerical values, they are displayed as Nch and Pch when the Define Typical Values window is opened.

Table 3. Properties of device parameters

There are three steps involved in setting up the device parameter definitions:

- Adding the device parameters and defining the name
- Setting the properties of the device parameters
- Setting the default values and descriptions

A new parameter can be added in the Device Parameter Definition area by clicking the Add button. A definition line will appear with the default name “Param1” Here a user can define the parameter name used in the application test. Since these parameters are numeric values, the Properties window appears, as shown in Figure 10. It is important to specify in the Properties window the maximum number of significant digits and the resolution allowed for the numeric input. Any digits entered beyond the specified maximum number or values below those of the specified resolution are automatically reduced to zero. The Digits, Resolution and Unit values can be set by selecting them with the softkey or by inputting them directly. In addition to the minimum and maximum values, typical values can be assigned to the parameter, and the user can choose from the selection menu rather than entering the value from the keyboard.

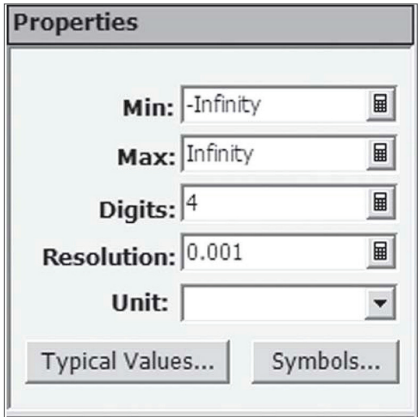


Figure 10. Properties window for numeric parameters

Defining parameters in the Device Parameters Definition area under the Test Specifications tab (continued)

To define typical values,

1. Click Typical Values in the first Properties window, shown in Figure 11. The Define Typical Values window appears
2. 2. Click Add, then input a value.

It is also possible to specify numeric device parameter values using symbols that have predefined numeric values. For example, symbol "Pch" can be assigned the value - 1 and symbol "Nch" can be assigned the value +1 for the polarity input variable.

This allows mnemonic names to be created for numeric input parameters and to have numeric values automatically associated with them. To define symbols,

1. Click Symbols in the first Properties window, shown in Figure 11. The Define Symbols window appears.
2. 2. Click Add, then input a value and the alphabetic symbol name assigned to the value.

The value is assigned to the alphabetic symbol and can be used as an indirect variable in the test definition. Since the variables Pch (p-channel MOSFET) and Nch (n-channel MOSFET) have associated numeric values, it is easy to use these variables within the application test to change various settings automatically for these two different types of devices. Using symbols helps create an easy-to-use user interface.

After defining the Properties area, set up the default values and descriptions. When data are entered into the application test main window, the descriptions (if defined) will appear automatically when an input variable is selected. The device parameters will be displayed in the Device Parameter area of the main window in the same order as they are arranged in the Device Parameter Definition area.

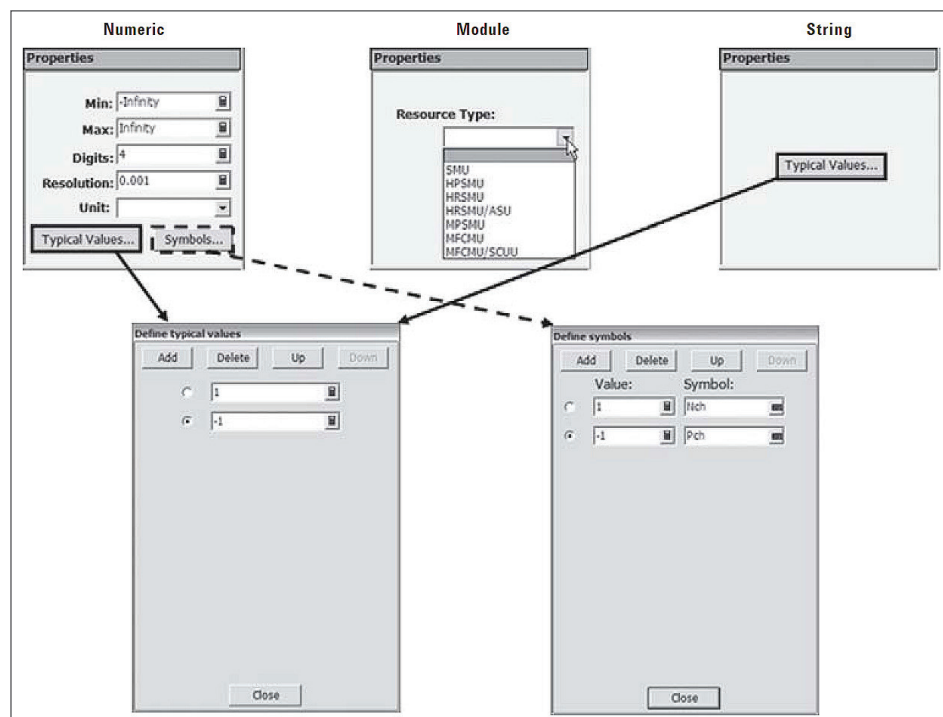


Figure 11. Numeric, Module and String Properties windows

Defining parameters in the Test Parameters Definition area under the Test Specifications tab (continued)

The completed Test Parameters Definition area is shown in Figure 12, and details of the parameters are shown in Tables 4 and 5.

Five basic steps are necessary for setting parameters in the Test Parameters Definition area.

1. Define the device connection image of the background.
2. Add the parameters and define the name.
3. Select the parameter type and set up the properties.
4. Set the default values and the descriptions.
5. Set the X-Y positions of the input field.

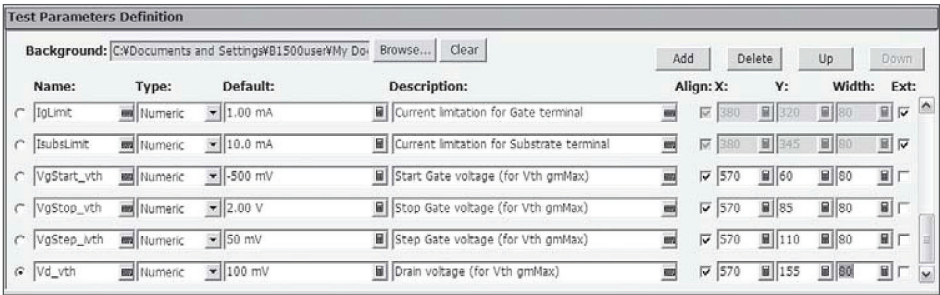


Figure 12. Example of completed Test Parameters Definition area

In Step 1, the device connection diagram or any bitmap image can be used as a background for the graphical user interface in the Test Parameters area of the main window. All the images used by the EasyEXPERT software can be found at the following location within the B1500A's directory structure: C:\ProgramFiles\ Keysight\B1500\EasyEXPERT\Graphics\Backgrounds.

These image files are organized into separate folders based on application test categories so they can be used to minimize the development time of new test definitions.

There also is another option for the user to create a unique background image by using paint tools. For the example used in this application note, none of the standard images in the EasyEXPERT image libraries are usable. Therefore a new image was created. The new image file, named "IV_sequence.png," can be downloaded from the Keysight Web site (www.keysight.com/go/semiconductor). Enter the full path for the file or select the file name by using the "Browse..." button in the Background entry field. For example, C:\Documents and Settings\B1500user\MyDocuments\image\IV_sequence.png.

In Step 2, test parameters can be added by clicking the Add button. When the new definition line Param1 appears, change it to the appropriate name.

In Step 3, three types are listed under Test Parameters. These three types can be selected from the pull-down menu of the Type entry field, and can be chosen from Numeric, Module or String. Each property type uses a different method for setting the properties as shown in Figure 14. In the case of the Numeric type, it uses the same method as the entry of the Device Parameters. In the case of the Module type, the Resource Type is selected from the pull-down menu of the Properties entry field, also shown in Figure 14. For the String type, only a Typical Values button is available. The entry uses the same method as the entry of the Device Parameters.

Defining parameters in the Test Parameters Definition area under the Test Specifications tab (continued)

In Step 4, The default values and descriptions are set. The descriptions are displayed by pointing the cursor to the parameter's entry field in the main window.

In Step 5, the X-Y placement of the test parameters is specified in the Test Parameters Definition section. If the input parameters only need to be modified occasionally, then they can be placed in the Extended Setup window. This is done by checking the Ext box. The Align check box is used to specify the X origin of the entry field in the Test Parameters area of the main window. As shown in Figure 18, checking this box sets the left edge of the entry field to the specified X-Y coordinate. Unchecking it aligns the left edge of the parameter's name. For the example used in this application note, Id-Vd and Vth gmMax test definitions are used. In order to change the input parameters to either of these tests, parameters must be defined in the new application test. Figure 16 on page 7 clearly illustrates the importance of being able to modify many of the parameters for these application tests. Also, since the B1500A is modular, many different SMU configurations are possible. The default SMU assignments for the Gate, Source, Drain and Substrate terminals can be set up to match a user's default configuration.

Name	Type	Default	Description	Align	X	Y	Width	Ext
Gate	Module	SMU3:HR	Gate terminal SMU	OFF	0	100	80	OFF
Drain	Module	SMU2:HR	Drain terminal SMU	OFF	140	20	80	OFF
Source	Module	SMU1:HR	Source terminal SMU	OFF	0	340	80	OFF
Subs	Module	SMU4:HR	Substrate terminal SMU	OFF	160	270	80	OFF
VgStart_idvd	Numeric	500 mV	Start Gate voltage ¹	ON	390	60	80	OFF
VgStop_idvd	Numeric	2 V	Stop Gate voltage ¹	ON	390	85	80	OFF
VgStep_idvd	Numeric	500 mV	Step Gate voltage ¹	ON	390	110	80	OFF
VdStart_idvd	Numeric	0 V	Start Gate voltage ²	ON	390	155	80	OFF
VdStop_idvd	Numeric	2 V	Stop Gate voltage ²	ON	390	180	80	OFF
VdStep_idvd	Numeric	50 mV	Step Gate voltage ²	ON	390	205	80	OFF
Vsubs	Numeric	0 V	Substrate voltage	ON	380	270	80	OFF
Vs	Numeric	0 V	Substrate voltage (0 V)	ON	380	295	80	ON
IgLimit	Numeric	1 mA	Current limitation for gate terminal	ON	380	320	80	ON
IsLimit	Numeric	10 mA	Current limitation for substrate terminal	ON	380	345	80	ON
VgStart_vth	Numeric	- 500 mV	Start gate voltage ³	ON	570	60	80	OFF
VgStop_vth	Numeric	2 V	Stop gate voltage	ON	570	85	80	OFF
VgStep_vth	Numeric	50 mV	Step gate voltage	ON	570	110	80	OFF
Vd_vth	Numeric	500 mV	Drain gate voltage	ON	570	155	80	OFF

1. Primary sweep for Id-Vd
2. Secondary sweep for Id-Vd
3. For Vth gmMax

Table 4. Test parameters

Defining parameters in the Test Parameters Definition area under the Test Specifications tab (continued)

Name	Min	Max	Digits	Resolution	Unit	Resolution
Gate						SMU
Drain						SMU
Source						SMU
Subs						SMU
VgStart_idvd	0	5	3	10 m	V	
VgStop_idvd	0	5	3	10 m	V	
VgStep_idvd	0	1	3	1 m	V	
VdStart_idvd	0	5	3	10 m	V	
VdStop_idvd	0	5	3	10 m	V	
VdStep_idvd	10 m	1	3	1 m	V	
Vsubs	– 5	500 m	3	10 m	V	
Vs	0	0	3	10 m	V	
IgLimit	1 n	100 m	3	1 n	A	
IsubsLimit	1 n	100 m	3	1 n	A	
VgStart_vth	– 1	1	3	10 m	V	
VgStop_vth	0	5	3	10 m	V	
VgStep_vth	1 m	1	3	1 m	V	
Vd_vth	10 m	5	3	1 m	V	

Table 5. Properties of test parameters

At this point, all of the parameters in the Test Specification tab and the user interface shown in Figure 2 on page 2 will appear in the main window after the test definition has been saved within EasyEXPERT.

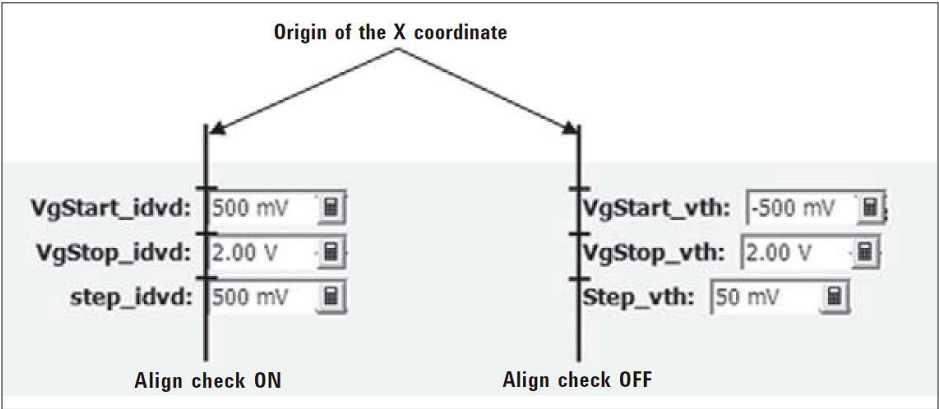


Figure 13. Operation of the Align check box.

Setting up the Test Contents tab

The next important task is to specify the actual application tests to be executed in the Test Contents tab, as shown in Figure 19. The application test program is created in the Test Contents tab window. The test and analysis parameters defined in the previous section are passed down to these application tests automatically during test execution. The test content consists of the following functions:

- Program Component - a list of the components for controlling the test flow of the program
- Application Test - a list of the existing application test definitions available for the test
- Analysis - the analysis functions available for the test
- Classic Test - the classic test objects, IV Sweep, IV Sampling and CV Sweep
- Miscellaneous - the miscellaneous functions available for the test

These functions appear in the five sub-menu tabs, as shown in Figure 15.

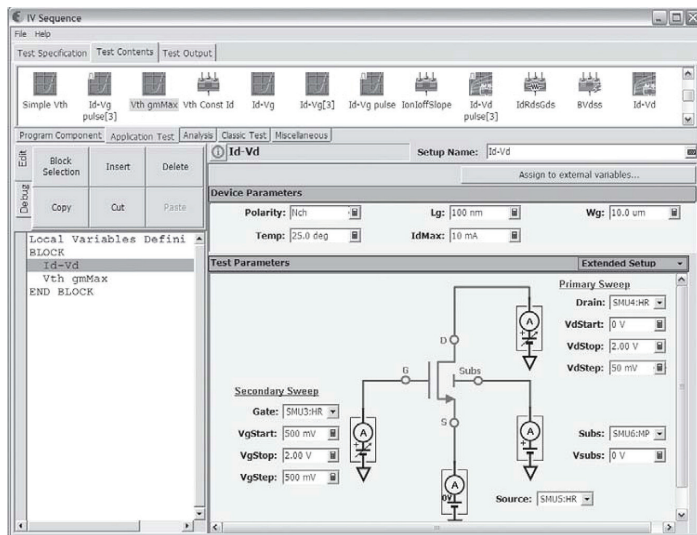


Figure 14. Shows the two application tests that have been inserted into this application test.

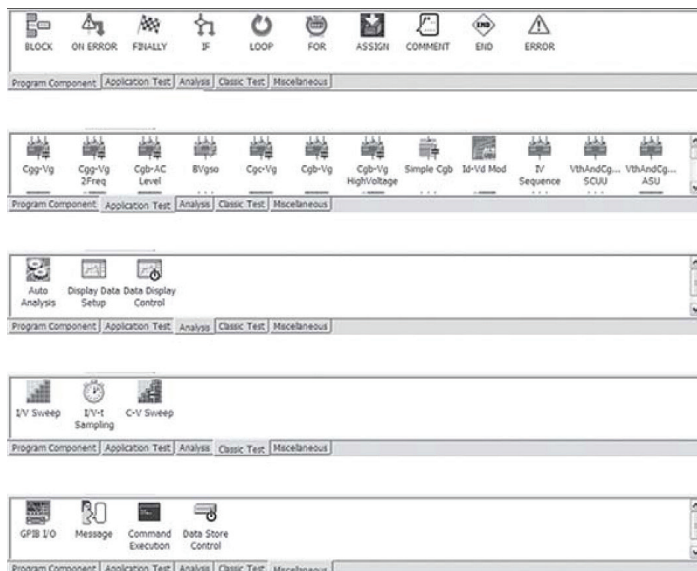


Figure 15. Five component tabs in Test Contents Window.

Setting up the Test Contents tab (continued)

The test flow can be defined by repeating the following three steps in the Test Contents tab:

- Highlight the line below which a component will be inserted (for example, the Id-Vd line highlighted in Figure 16).
- Select a component from those located in the window above the test component tabs.
- Add a component to the application test program by clicking the Insert button.

In this example, the Id-Vd and Vth gmMax application test definitions are used and the components appear in the Application Test tab. The components are inserted between BLOCK and END BLOCK statements, as shown in Figure 16.

The final action is to create the link that assigns the input parameters entered in the main window of the application test that is called in the example test sequence definition. This is done by entering the test parameter name (which was defined in the Test Specification tab) into the corresponding input parameter entry field of the application tests appearing in the Test Contents tab. Thus, when the value is entered in the main window it is passed down to the called application tests as a variable.

Figure 16 shows the finished application test window and Table 6 shows the correspondence between the variable names of the called application tests and the variable names used in the new application test that calls the Id-Vd and Vth gmMax application tests.

Finally, the test definition is saved and closed in order to run the test. At this point, the IV Sequence application test setup appears in the main window.

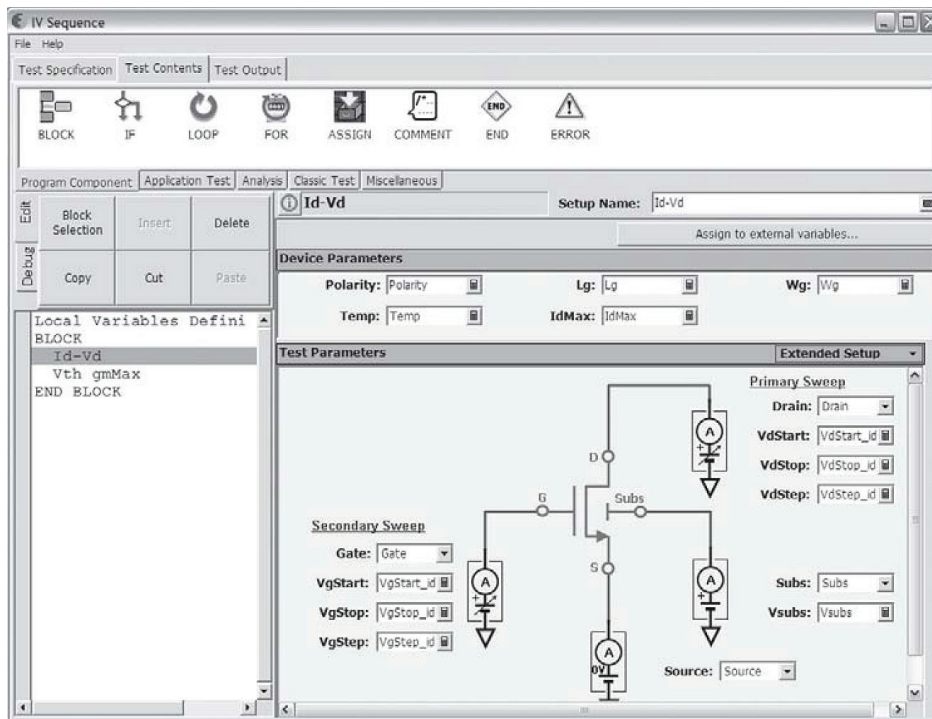


Figure 16. Test Component tab after the variable names from the main window have been inserted into the called application test.

Setting up the Test Contents tab (continued)

Parameter Category	Id-Vd Application Test	Test Specification
Device Parameters	Polarity	Polarity
	Lg	Lg
	Wg	Wg
	Temp	Temp
	IdMax	IdMax
Test Parameters	Gate	Gate
	VgStart	VgStart_idvd
	VgStop	VgStop_idvd
	VgStep	VgStep_idvd
	Drain	Drain
	VdStart	VdStart_idvd
	VdStop	VdStop_idvd
	VdStep	VdStep_idvd
	Subs	Subs
	Vsubs	Vsubs
	Source	Source
Extended Test Parameters ¹	Vs	Vs
	IgLimit	IgLimit
	IsubsLimit	IsubsLimit

1. Can be set up in the window opened by clicking the Extended Setup button.

Table 6. Correspondence of the Test Specification tab and the Id-Vd and Vth gmMax application test parameters.

Parameter Category	Vth gmMax Application Test	Test Specification
Device Parameters	Polarity	Polarity
	Lg	Lg
	Wg	Wg
	Temp	Temp
	IdMax	IdMax
Test Parameters	Gate	Gate
	VgStart	VgStart_vth
	VgStop	VgStop_vth
	VgStep	VgStep_vth
	Drain	Drain
	Vd	Vd_vth
	Subs	Subs
	Vsubs	Vsubs
	Source	Source
Extended Test Parameters ¹	Vs	Vs
	IgLimit	IgLimit
	IsubsLimit	IsubsLimit

1. Can be set up in the window opened by clicking the Extended Setup button.

Table 7. Correspondence of the Test Specification tab and the Id-Vd and Vth gmMax application test parameters.

Making measurements

The IV Sequence application test setup can be selected from the Library area of the CMOS category. As was shown in Figure 2 on page 3, the IV Sequence application test resides in the CMOS category of the application tests.

Before starting the measurements, make sure the device connections and the SMU module assignments for the Gate, Drain, Subs and Source are matched and that the measurement parameters do not exceed the configured SMUs. To start the measurements, click the green triangle icon in the Measurement button in the top right of the main window, shown in Figure 2 on page 3. The Id-Vd and Vth gmMax graphs will be plotted sequentially, as shown in Figures 17 and 18.

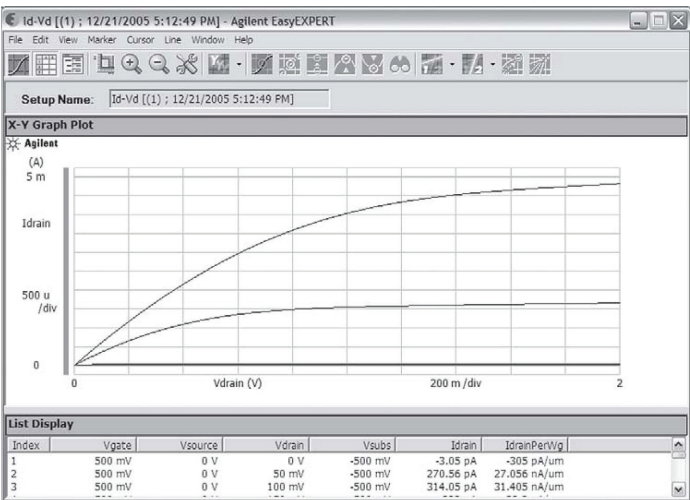


Figure 17. Results of Id-Vd application test.

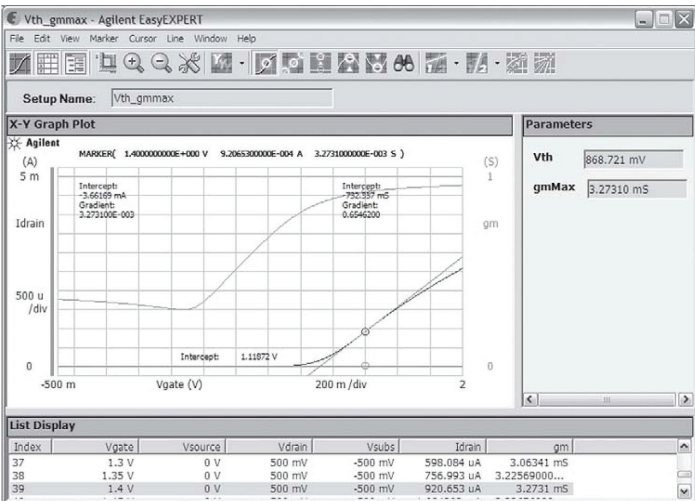


Figure 18. Results of Vth gmMax application test.

Conclusion

This application note describes how to create an application test that runs a sequence of other application tests. The example shows how the input parameters for both of the called application tests (Id-Vd and Vth gmMax) can all be placed in the same main window. Since some of the input parameters (such as SMU assignments) are shared by both application tests, this is a very convenient approach when running multiple tests. As a result, the parameters only need to be assigned once for both tests. Obviously, this approach could be expanded beyond just two tests, resulting in an even greater improvement in efficiency.

This measurement approach would be especially beneficial when combined with a B1500A equipped with a MFCMU and either an SCUU or two ASUs. An application test could then be created that performed both CV and IV measurements in sequence without requiring any physical change in cables.

Laboratory environments, in which new devices or processes are being developed, frequently need to run the same sets of application tests on different devices repeatedly. Moreover, most of these environments use positioner-based wafer probing systems where the SMUs associated with the device inputs change frequently. Creating an application test that can run a series of tests in sequence and that can allow certain common variable settings (such as SMU assignments) to pass down to all of the sequenced application tests greatly reduces the amount of time required to make all of these measurements. The methodology described in this application note enables the achievement of this goal.

The application test definition “IV_sequence” created in this application note can be downloaded from the B1500A Web site, www.keysight.com/see/B1500A.

For more information about the B1500A Semiconductor Device Analyzer and EasyEXPERT software, please call one of the centers listed to the right and ask to speak with a Keysight sales representative (formerly known as Application Note B1500-5).

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